STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office, 3190 - 160th Ave S.E. • Bellevue, Washington 98008-5452 • (425) 649-7000

July 31, 2000

Mr. Chip Hilardes
Georgia-Pacific West
300 West Laurel Street
Bellingham WA 98225-5593

Dear Mr. Hilardes:

Re: Remedial Investigation/Feasibility Study, Whatcom Waterway Site

The purpose of this letter is to approve the Final Remedial Investigation /Feasibility Study (RI/FS) for the Whatcom Waterway Site, prepared by Georgia-Pacific under Agreed Order No. DE 95TC-N399.

The Department of Ecology (Ecology) solicited public comment on the Draft Final RI/FS for the Whatcom Waterway Site from July 19, 1999 to September 20, 1999 and held a public meeting on August 26, 1999. The Port of Bellingham was the only entity that submitted comments, these are attached as well as a response from Ecology.

The changes articulated in the enclosed Responsiveness Summary have been incorporated into the document and Ecology hereby approves the Final RI/FS for the Whatcom Waterway Site dated July 25, 2000.

If you have any questions feel free to contact me at 425-649-7272.

Sincerely,

Lucille T. Pebles
Site Manager

LTP:lp
Enclosure

cc: Clay Patmont, Anchor Environmental L.L.C.

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Responsiveness Summary

Whatcom Waterway Site

Bellingham

Final Remedial Investigation/Feasibility Study

July 2000

Response to Comments

The Port of Bellingham provided the only comments on the Draft Final Remedial Investigation/Feasibility Study for the Whatcom Waterway Site. A copy of their comment letter is attached and Ecology's response follows:

General Response (to comments contained in the Port's letter):

Comments noted.

Specific Responses (to comments provided in the Attachment to the Port's letter):

1. The Port is correct that the Pilot's "no comprehensive strategy" alternative is not equivalent or comparable to the "No Action" Alternative A presented in the Draft Final RI/FS. Changes have been made to Section 13.3 and to Table 13-1 to remove the reference to the Pilot's "no comprehensive strategy" alternative.

2. Comment noted. The RI/FS describes that the "No Action" Alternative A is not protective. However, inclusion of "No Action" Alternative A, along with "Natural Recovery/Capping" Alternative B in the detailed evaluation of cleanup alternatives is consistent with MTCA guidelines.

3. Comment noted.

4. Any cap designed and constructed as a remedial action, including within the Whatcom Waterway navigation channel, must be able to resist erosion from waves, currents, and propeller wash. As discussed in the RI/FS, a preliminary assessment of caps to be used as part of the Whatcom Waterway cleanup was performed using existing data and past Puget Sound experience. For example, detailed remedial design evaluations of propeller wash recently completed for sediment cleanup sites in Commencement Bay and Elliott Bay/Duwamish River have demonstrated that sand caps constructed to thicknesses ranging from approximately 1 to 3 feet will provide protection from worst-case propeller wash in similar navigation channels. The RI/FS analysis is consistent with this regional experience. As part of final design, each of the key cap stability factors including propeller wash will be evaluated in greater detail, using additional site-specific data and refined engineering analyses.

5. Comment noted. See response to comment #2 above.

6. Data presented in the RI/FS reveal that within I & J Waterway, surface sediments comply with State Sediment Quality Standards (SQS) criteria. Further, the existing channel depth is consistent with the authorized navigation depth and current and projected uses of the channel are not likely to expose subsurface sediments. For these reasons, I & J Waterway has not been identified as an area requiring active remediation.

In addition, screening-level PSDDA suitability sampling data reported in the RI/FS suggest that both surface and subsurface sediments within the I & J Waterway would likely comply with PSDDA open-water disposal requirements, should they be dredged for channel maintenance purposes.

The Dredged Material Management Program (DMMP), which includes Ecology, EPA, Corps, and DNR representatives, makes the final decision on material suitability for open-water PSDDA disposal or beneficial reuse. The DMMP suitability determination is based upon a review of specific dredge management proposals and requirements in effect at the time of the project application. While Ecology cannot presuppose such future requirements and conditions, it is important to note that the 1.2 mg/kg bioaccumulation screening level (BSL) developed in the RI/FS was intended to be used as a conservative screening criterion to identify those sediments for which mercury bioaccumulation protection can be assured. Should a dredged material beneficial reuse proposal be presented to the DMMP that would comply with BSL, SQS, PSDDA, and other relevant DMMP criteria, then prospective acceptance of such a proposal is indicated. Conversely, should any of these screening criteria be exceeded, it may also be appropriate to consider more detailed risk assessment methods or engineering designs to develop protective reuse plans, consistent with DMMP and SMS requirements in effect at the time.

7. Ecology's preference is to expedite and enhance the natural capping process by isolating contaminants outside of navigational areas with clean sediments rather than relying solely on more time consuming natural processes. However, Ecology has not yet selected a remedy for the site. A draft cleanup action plan articulating Ecology's selected remedy for public review is expected in the fall of 2000. See also response to comment #4 above.

8. Comment noted. Section 8.3.2 acknowledges historical pulping process wastewaters as a possible source of 4-methylphenol to subsurface sediments.

9. Comments noted. See previous responses.

10. Comments noted. Upland dewatering and disposal costs were estimated based on several projects performed in other areas of Puget Sound. However, uncertainties in total costs are acknowledged, and are reflected in the 30 percent contingency included in the total cost estimate.

11. Comment noted. Information on subsurface contamination would be used as appropriate during remedial design. The estimated extent of subsurface SQS exceedances is presented in the Bellingham Bay Demonstration Pilot Sediment Site and Source Control Documentation Report.

PORT OF BELLINGHAM
Washington State

September 17, 1999

Lucy Pebles, Site Manager
Department of Ecology
3190 – 160th Ave. SE
Bellevue, WA 98008

Re: Whatcom Waterway Draft RI/FS

Dear Lucy:

The Port of Bellingham has reviewed the July 1999 draft Remedial Investigation/ Feasibility Study (RI/FS) for the Whatcom Waterway Site and is pleased to provide comments below and in attachment.

The RI/FS was prepared by Georgia-Pacific and issued by Ecology for public review and comment concurrent with Ecology's July 1999 Draft Environmental Impact Statement on the Bellingham Bay Comprehensive Strategy. Port comments on the DEIS have been transmitted to Ecology under separate cover.

First, we would like to acknowledge our appreciation for Georgia-Pacific's contribution to the Bellingham Bay Demonstration Pilot. Their active participation in the Pilot has been instrumental in the Pilot Team's effort to develop and publish a proposed Comprehensive Strategy for Bellingham Bay, as described in the DEIS. In addition, the Whatcom Waterway Site has been consistently recognized by Ecology and the Pilot Team as the top priority sediment site in Bellingham Bay, because it includes over 90% of the areal extent of aquatic land with contaminant levels exceeding the State Sediment Management Standards. It also includes two heavily-used federal channels and the estuarine portion of Whatcom Creek. The data and analysis presented in the Whatcom Waterway RI/FS have been critical to the success of the Bellingham Bay Demonstration Pilot.

The following comments are therefore provided with the intention of clarifying certain key issues described in the Whatcom Waterway Site RI/FS in order to ensure that the selection of a remedy by Ecology is consistent with the requirements of MTCA and the goals of the Demonstration Pilot.

Our comments on the July 1999 draft RI/FS are very similar to comments provided last year on September 21, 1998. In summary, alternatives that leave extensive contamination in the federal channels (i.e., Alternatives A-F) are simply not compliant with MTCA, because they are not sufficiently protective over the long-term. However, the RI/FS confirms that environmentally safe, cost-effective,

1801 Roeder Avenue / P.O. Box 1677 / Bellingham, WA 98227-1677

readily implementable alternatives for sediment remediation exist. Based on sound science, reliable engineering, and extensive proven success in Puget Sound, they rely on in-water containment. In contrast, alternatives which require upland disposal of very large volumes of contaminated marine sediment are substantially and disproportionately higher in cost than in-water alternatives without providing any greater level of protectiveness.

The Port strongly recommends, therefore, the selection of draft RI/FS Alternative G, as the preferred alternative for the Whatcom Waterway Site. Alternative G is consistent with Alternative 2C "Full Removal from Navigation Areas with Confined Aquatic Disposal", as described in the DEIS for Bellingham Bay. The Board of Commissioners of the Port of Bellingham has recommended selection of DEIS Alternative 2C under Resolution No. 1113, because it provides a cost-effective means of addressing environmental liability, it provides for the full and unencumbered use of our federal channels, and it provides a substantial increase in higher functioning habitat within the working waterfront.

Additonal comments are provided in attachment. We look forward to working with you through the decision-making phase of the Whatcom Waterway Site and implementation of the selected remedy. Please feel free to call me, or Mike Stoner, should you have any questions.

Sincerely,

James S. Darling
Executive Director

Attachment

Attachment: **Port comments on draft Whatcom Waterway RI/FS (9/20/99)**

1. Comparison between the Whatcom Waterway FS and Pilot DEIS:

The WW FS has a total of 9 remedial alternatives (Alternatives A through I). The Pilot DEIS has five "near term remedial action" alternatives (2A through 2E) under the Comprehensive Strategy (Alternative 2) and a contrasting "No-comprehensive Action" alternative (Alternative 1). This somewhat confusing nomenclature appears to warrant some clarification.

For example, the WW FS states that the Pilot's Alternative 1 is the same as the FS's Alternative A. This is not an accurate comparison. The FS Alternative A is a "no action" alternative which relies upon natural recovery to address all contaminated sediments. In contrast, the Pilot's Alternative 1 is a "no comprehensive action" alternative. As referenced in the FS, Alternative A does not meet the threshold requirements of MTCA of the SMS. Ecology has repeatedly clarified that in the absence of the comprehensive action under the Pilot, all contaminated sites would be cleaned up under Alternative 1pursuant to MTCA and SMS regulations. The FS Alternative A is therefore not the same as the Pilot's Alternative 1.

In addition, since the Pilot process has resulted in the publication of a DEIS under SEPA which considers actions for the WW site, it is expected that the final remedy will be determined consistent with MTCA and SMS regulations and other ARARs. A SEPA evaluation of alternatives in the DEIS has been performed, considering land use, permitting and habitat issues. Selection of any WW alternative presented in the FS, but not included in the DEIS would not be compliant with MTCA or SEPA.

If a final FS is published, Table 13-1 and related text referencing the Pilot process should be revised to correctly explain the relationship between the FS and the Pilot DEIS, and to confirm that Alternative 1 of the DEIS is not equivalent to Alternative A in the WW FS.

2. Threshold requirements for cleanup remedies:

Under MTCA, cleanup technologies and alternatives that are not capable of meeting cleanup levels may not be considered as final remedies. Compliance with cleanup levels and ARARs is a threshold requirement for final cleanup actions.

Because Alternative A is truly a "no action", it does not meet this threshold requirement of MTCA. It is inappropriate, therefore, for it to be compared to other alternatives, which do meet those requirements. The FS implies a false baseline for comparison when it describes Alternative A as ranking "high" under the short-term effectiveness criteria, "easiest" under the implementability criteria, and "least expensive" under the cost-effectiveness criteria. Such descriptions imply that Alternative A is a viable alternative and are particularly misleading in comparison to the other alternatives. The effectivenss, implementability and cost of Alternative A are not relevant and should not be included in the detailed evaluation of alternatives.

The use of Alternative B as a benchmark for comparison in the detailed analysis of alternatives presents similar problems. Alternative B uses on-site containment and institutional controls in areas which present an unacceptable risk of re-exposure (i.e., federal navigation channels). Since Alternative B does not meet the MTCA threshold requirements for protectiveness, it too should be screened out prior to a detailed evaluation of alternatives.

3. Long-term effectiveness of in-water containment technologies:

The WW FS provides an excellent description and evaluation of containment technologies as they may be applied to contaminated marine sediments. It is clear that capping sediments in place is a safe, cost-effective and readily implementable remedy for low-level contamination that can be applied in circumstances that do not have depth requirements for navigation and commerce, and in areas where the cap can be designed to be stable over the long term. Furthermore, the FS confirms that capping materials can provide appropriate substrate for benthic organisms and therefore support important marine habitat functions.

The WW FS confirms that dredging with confined aquatic disposal can be applied to meet navigation and commerce needs in the dredging area and habitat requirements in the disposal area. The use of low-level sediment contamination as building material for shallow sub-tidal habitat along the shoreline where this important habitat is limited provides a benefit that is compatible with local salmon recovery plans. Furthermore, the WW FS indicates that for Bellingham Bay sediments, contaminant leachate is more limited and much more easily controlled in a CAD facility than in an upland facility. The cost of material transport, disposal and long-term leachate control is substantially and disproportionately higher for contaminated sediment disposal in an upland landfill than in a confined aquatic disposal facility.

4. Long-term effectiveness concerns regarding capping in navigation areas:

Several of the alternatives presented in the WW FS include capping of contaminated sediments within navigation areas, including the federal channels. The long-term effectiveness of this approach has not been demonstrated. Propeller wash from the large vessels and support tugs that frequent Bellingham Bay are capable of sudden and substantial erosion of bottom sediments. These vessels often operate with minimal draft between the hull/propellers and the bottom. There is some discussion of armoring to prevent such erosion in the feasibility study, however the costs and implementability of the capping proposals do not reflect the types of protection likely to be required. For example, under Alternatives B and C, the FS describes capping material as 2 to 3 feet of sand. No justification has been presented as to why armor stone would not be required to prevent cap erosion. If an armored bottom is considered or required, the habitat impacts, cost of construction, and cost impacts for maintenance dredging need to be included in the evaluation.

Without a proper analysis of the effects of prop-wash and potential ship grounding, it is not clear that alternatives B through F are capable of complying with MTCA cleanup levels or ARARs or that the costs presented for these alternatives are realistic. As noted above, Alternative A should be excluded from the FS analysis of alternatives because it does not meet cleanup levels or ARARs as required for final cleanup actions.

For a balanced comparison of Alternatives B-F with the other alternatives, it is necessary to provide the following information in the RI/FS:

- Type of armoring to be required to protect caps or recovering areas in each site unit,
- Habitat impacts of armored bottom sediment near Whatcom Creek,
- Impacts on routine maintenance dredging over an armored bottom,
- Effects on costs, cap thickness and overall implementability for each alternative, and
- For non-armored areas, a demonstration that prop-wash erosive effects do not result in long-term or short-term exceedences of MTCA and SMS cleanup levels and other ARARs is needed (e.g., effects of resuspended sediments on surface water quality).

While the final design for caps may be appropriately conducted during the remedial design process, the basis for the assumptions used in the FS must be stated and uncertainties with respect to costs, effectiveness and implementability clarified. In the absence of this information, the FS does not provide the information necessary to appropriately evaluate FS Alternatives B-F against the other alternatives.

For example, in the analysis of CAD sites for the Port of Long Beach, it was determined that between ½ and 3 feet of net cobble armoring would be required to counter potential cap disturbance from propeller wash from ocean-going vessels (please reference 1996 "Assessment of Confined Disposal Capping Needs" by SAIC). This is substantially different from the FS Alternatives B-F as presented.

As presented in previous comments (9/21/98), the Port is very concerned about the effects of in-channel capping of contaminated sediment on navigation and commerce within the Whatcom Waterway. Such capping should only be considered when there is an over-riding technical constraint (e.g., buried pipeline), or important habitat functions to be preserved (e.g., site unit 3C). Alternative 2C in the Pilot DEIS appropriately addresses these constraints. Other alternatives in the WW FS do not.

5. Analysis of cost-effectiveness under MTCA:

Under MTCA, remedies must be evaluated for effectiveness, implementability and cost. Further, MTCA includes a stated preference for permanent remedies. The analysis of remedy permanence must be considered as part of the cost analysis using the preference hierarchy described in WAC 173-340-360(4) and (5) and the cost effectiveness must be analyzed consistent with WAC 173-340-360(5)(d)(vi).

The FS uses Alternatives A and B as the benchmarks against which to compare the cost-effectiveness of all other cleanup alternatives. This is inappropriate, because neither alternative provides an adequate level of long-term protectiveness. Alternative A does not meet the threshold requirements for a final remedy under MTCA. Alternative B uses on-site containment and institutional controls in areas which present an unacceptable risk of re-exposure. These are the least permanent and the lowest preference alternatives under MTCA and it is therefore not appropriate to give alternatives a moderate or low rating under cost-effectiveness simply due to higher costs than Alternative B. Such ratings are appropriate only where the alternatives share the same protectiveness. For example, it is appropriate to compare the consolidation and disposal of sediments in a CAD site to the upland disposal of those same materials. Because both alternatives include disposal in engineered facilities, the costs can be directly compared. It is appropriate in this instance to give the CAD site disposal a higher cost-effectiveness rating, because it is substantially less expensive than the upland disposal site.

While it is true that dredging and CAD site disposal is more expensive than capping, the analysis of cost-effectiveness under MTCA must also take into account the preferences under MTCA for permanent solutions. The cost-effectiveness rating for Alternative C and D should be shown as "medium", not "medium to high".

6. Clarification of Ecology position on beneficial uses for I&J Waterway sediments:

In the analysis of the I&J waterway sediments, it is stated that the sediments are likely suitable for PSDDA open-water disposal and/or beneficial reuse. The Port agrees with this characterization, but seeks confirmation of several issues from Ecology.

First, the characterization that was performed on the sediment from the I&J Waterway demonstrated that, though the sediments contain elevated levels of mercury, they are capable of passing both the PSDDA bioassays and the PSDDA bioaccumulation testing using standard PSDDA criteria. This is true of two of the samples tested (HC-VC-94-C1/C2) that contained mercury concentrations in excess of the 1.2 mg/kg human health screening level used in the RI/FS as part of site cleanup levels. As the samples have passed bioaccumulation testing, the Port agrees that the materials do not have a significant bioaccumulation risk. However, in its review of the RI/FS, the Port requests that Ecology confirm that the empirical testing will supercede the 1.2 mg/kg screening level. Thus, for example, a mercury concentration of 1.8 mg/kg in sediments from the I&J that have passed bioassay and bioaccumulation testing would not be restricted from potential PSDDA disposal or in-water beneficial re-use options for those sediments.

Second, while the Port supports PSDDA disposal and beneficial re-use options (upland and in-water) for the I&J Waterway sediments, the Port seeks confirmation that Ecology would not oppose such re-use. If the re-use of these materials will be significantly limited by Ecology under MTCA or SMS regulations, then the Port requests that those limitations be clearly defined at this time, so that planning efforts and implementation agreements with other parties may incorporate realistic projections of re-use alternatives.

7. Natural recovery analysis predictions:

The natural recovery analysis presented in the feasibility study overstates the certainty of the natural recovery predictions. While the basic processes of natural recovery have been demonstrated to occur within the project area, there are several sources of uncertainty regarding the extent of natural recovery to occur, particularly within the navigation areas. As a result of these uncertainties, the long-term effectiveness of the alternatives incorporating natural recovery is reduced:

- Natural recovery cores were placed solely in areas outside of the Whatcom Waterway and shipping areas. The effects of periodic disturbances have not been taken into account.
- The elevated concentrations of 4-methylphenol present in the sediment traps are two orders of magnitude higher than those measured in storm drain sediments, yet these are attributed to the storm drains. The basis for this conclusion is not convincing. Disturbance and resuspension of the much higher concentrations of 4-methylphenol known to be present in subsurface sediments is a possibility of equal or greater probability.
- The natural recovery models are simplistic. In contrast, the sedimentation patterns present in the waterway are much more complex as demonstrated in the RI/FS by differences in net sedimentation rates throughout the waterway.

- For those samples repeated in 1998 sampling interval, average mercury concentrations were higher (over 20 percent) in comparison to 1996. This highlights the uncertainty associated with natural recovery measurements in a complex environment. The FS should clarify that natural recovery predictions are subject to significant uncertainty, particularly in heavily used federal channels and berthing areas.

8. Former pulping wastewaters as a potential source of 4-methylphenol:

There are substantial deposits of surface and subsurface sediments at the head of the waterway containing 4-methylphenol concentrations several orders of magnitude above the current SQS. Wood waste is discussed as the primary source of these contaminants. It should also be referenced in the document that high-BOD wastewaters from the pulping process were discharged by G.P. at the head of the waterway prior to upgrades in wastewater treatment system and construction of the ASB and diffuser in the late 1970s. Given the prior discharge of pulping wastewaters in this area, the RI/FS should specifically note the former outfall as a likely contributing source of this contamination. In addition, the potential impact of the outfall on 4-methylphenol concentrations in other areas of the site should be discussed. Given the demonstrated deposition of mercury in other site areas, the high resuspension rate for site sediments and the demonstrated presence of elevated 4-methylphenol in suspended particulate matter, such impacts may be significant.

9. Clarification of Port Concerns:

The RI/FS document repeatedly states that the Port's concerns regarding the contamination present in the subsurface sediments within Whatcom Waterway are based on future development considerations and potential future dredging of the channel. While the Port is concerned about future encumbrances to navigation and commerce if large quantities of contamination were to be left in the federal channels, it is important to recognize in the FS that these concerns are not mere speculation. Alternatives which leave contaminated material in the federal channel would impose immediate and significant encumbrance to navigation and commerce in the Whatcom Waterway. They also impose environmental and regulatory concerns that have been raised by the Port during the Pilot process and in our previously submitted comments on the draft RI/FS, including:

- Potential for recontamination of capped or recovered areas within the channel, resulting in increases in contaminated material volumes should dredging become necessary;
- Concerns about the long-term effectiveness of several of the proposed alternatives due to potential cap erosion and/or damage, and resultant spreading of contamination;

- Current non-compliance with waterway navigation depths due to obstructions caused by the presence of the contamination in the waterways;
- Demonstrated inability to restore permitted water depths due to the presence of contamination (e.g., recent PSDDA failures at BST area);
- Potential for damage to shipping vessels due to shoaling. Such damage can result in substantial costs and/or environmental harm in the event that a ship's hull is compromised. In the past four years, multiple groundings at the BST have been recorded (see attached 1996 memo of urgent safety concerns from Gearbulk Shipping). In most instances, underwater inspections were required to determine if the hulls of the ships had been damaged. It has been fortuitious that no environmental harm, such as fuel spillage, has resulted from such groundings.

10. Estimate of upland disposal costs:

The cost estimates included in the FS for upland disposal alternatives appear to underestimate the costs associated with sediment staging and dewatering as required to support upland disposal. While the need for staging and dewatering is discussed in the FS, the unit costs do not seem to include a significant line item to cover these costs. Given the low solids content of much of the contaminated sediments, the potential need for sediment dewatering stockpiles or staging areas, or the need for addition of solidification reagents to the sediments prior to truck/rail transport is significant. The ability to off-load, dewater, stage, transport and dispose of very large volumes of marine sediment for the unit cost of $45/cy should be verified prior to any agency consideration of this option.

11. Presentation of subsurface SQS/MCUL exceedences:

The presentation of data in the RI/FS document downplays the significance of subsurface sediment contamination. The presence of high mercury levels in subsurface sediments has been clearly demonstrated. However, the RI/FS presents the subsurface impacted areas in a very limited manner. The RI/FS figures should show areas where suburface mercury contamination above the current SQS/MCUL/human health criteria are known to exist. While these data appear to have been used in the calculation of sediment volumes for specific remedial alternatives, they are not clearly presented. Where subsurface contamination is graphically presented, the presentation is somewhat misleading. For example, in Figure 11-1, subsurface mercury contamination is presented on the figure only where such contamination is present within 2 feet of the waterway permit depth. This 2-foot criterion is based on dredging permit criteria, but disregards potential effects of prop-wash and other significant risk factors. In addition, in a routine dredging operation it is not unusual for the operator to inadvertantly excavate significantly deeper than the 2-foot over-dredge allowance, thus potentially exposing contaminated material in these area.

Under MTCA, the RI/FS should clearly document the location of contaminated materials which are being left on-site as part of a proposed cleanup action. The need to clarify where subsurface contamination is known or suspected to exist is critical in order to properly evaluate the adequacy of proposed containment measures and institutional controls associated with each of the remedial alternatives.

GEARBULK SHIPPING CANADA LTD.
Suite 1410, 555 W. Hastings Street
P.O. Box 12140
Vancouver, B.C. V6B 4N6
Canada

FAX

Fax No: (604) 669-1824
Tel No: (604) 689-7194
Telex: 04-55294 GEARCAN VCR

TO:PORT OF BELLINGHAM-WARREN BAILEY
CC:INTALCO ALUMINUM CORPORATION-BOB MERRIFIELD
CC:GEARBULK UK
CC:GEARBULK SHIPPING (CANADA) LTD

FM:KEITH MOGER

REF:AVAILABLE DRAFT AT PORT OF BELLINGHAM

WE ARE EXTREMELY CONCERNED AT RECENT DEPTH SOUNDINGS OBTAINED FROM MASTER M.V. MOZU ARROW SECURED AT THE PORT OF BELLINGHAM ON 18TH JUNE 1996 AT ZERO TIDE

THE REPORTED SOUNDINGS ARE 27FT 03INS IN WAY OF THE FORWARD LOADING DOOR AGAINST AN ANTICIPATED ALLOWABLE WORKING DRAFT OF 30FT 00INS.

AS YOU ARE AWARE, THE SHALLOWNESS OF THE WATER NECESSITATED CARGO OPERATIONS BEING SUSPENDED FOR APPROXIMATELY 9 GANG HOURS AND SUBSTANTIALLY INCREASED LABOUR COSTS FOR BOTH OURSELVES AND OUR CUSTOMERS.

WE MUST INSIST THAT THE PORT TAKE APPROPRIATE ACTION TO ENSURE THAT A SAFE OPERATING DRAFT OF 30FT IS AVAILABLE TO OUR VESSELS IN ORDER THAT WE MAY EXECUTE OUR BUSINESS IN A SAFE AND EFFICIENT MANNER.

SINCERELY

K.MOGER
SR.OPERATIONS MANAGER
GEARBULK SHIPPING (CANADA) LTD

CONTENTS

Page

VOLUME I

CONTENTS for Volume I (Continued)

TABLES

CONTENTS for Volume I (Continued) Page

TABLES (Continued)

CONTENTS for Volume I (Continued) Page

FIGURES

CONTENTS **Page**

VOLUME II

LIST OF TABLES

LIST OF FIGURES

CONTENTS for Volume II (Continued) Page

FIGURES (Continued)

CONTENTS **Page**

Volume III

APPENDIX A FIELD ACTIVITIES AND METHODS

TABLES

FIGURES

APPENDIX B
RESULTS OF CHEMICAL ANALYSES

TABLES

APPENDIX C
DATA QUALITY REVIEW FOR CHEMICAL ANALYSES

TABLES

Attachment C-1
Data Validation Report
EcoChem, Inc.

Attachment C-2
Data Validation Report
Phenol Analysis
Sediment Trap Particulate Matter

APPENDIX D
PHYSICAL TESTING

TABLES

FIGURES

APPENDIX E
SEDIMENT BIOASSAY DATA QUALITY REVIEW AND LABORATORY AUDITS AND MARINE SEDIMENT BIOASSAY REPORT
EVS ENVIRONMENTAL CONSULTANTS

Checklists

10-Day Amphipod Bioassay
20-Day Juvenile Polychaete Bioassay

Attachment E-1
Quality Assurance Evaluation
of the Mussel (Mytilus edulis) Larval Bioassays
Dinnel Marine Research

Attachment E-2
Marine Sediment Testing
EVS Environment Consultants

Attachment E-3
Toxicity Profile and
Analysis for 4-Methyl Phenol
EVS Environment Consultants

CONTENTS

Page

Volume IV

APPENDIX F
FISH AND SHELLFISH CONCENTRATION DATA
INNER BELLINGHAM BAY

TABLE

APPENDIX G
EFFLUENT MONITORING DATA
GEORGIA-PACIFIC OUTFALL

APPENDIX H
WASP INPUT/OUTPUT FILES
GEORGIA-PACIFIC OUTFALL

TABLES

APPENDIX I
ADDENDUM NO. 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
WHATCOM WATERWAY
BELLINGHAM, WASHINGTON

FIGURES

CONTENTS for Volume IV (Continued) **Page**

TABLES

APPENDIX J
SUPPLEMENTARY INVESTIGATION OF SURFACE SEDIMENT
BOULEVARD PARK/STARR ROCK AREA
BELLINGHAM, WASHINGTON

CONTENTS for Volume IV (Continued) **Page**

FIGURES

TABLES

Attachment J-A
Chemistry Data Validation Report

Attachment J-B
Bioassay Data Validation Report

Attachment J-C
Bioassay Data Report

APPENDIX K
NATURAL RECOVERY REMODELING

TABLES

CONTENTS for Volume IV (Continued) **Page**

APPENDIX L
SCREENING-LEVEL PUGET SOUND DREDGED DISPOSAL ANALYSIS SEDIMENT QUALITY EVALUATION

TABLES

FIGURES

APPENDIX M
ASSESSMENT OF CONTAMINANT MOBILITY SEQUENTIAL BATCH LEACHING TESTS

TABLES

FIGURES

APPENDIX N
ENGINEERING COST ESTIMATE
WHATCOM WATERWAY AREA

TABLES

FINAL REMEDIAL INVESTIGATION/FEASIBILITY STUDY
WHATCOM WATERWAY SITE
BELLINGHAM, WASHINGTON

1.0 EXECUTIVE SUMMARY

The Whatcom Waterway Area (WW Area) consists of intertidal and subtidal aquatic lands within and adjacent to the Whatcom and I&J Street Waterways in Bellingham, Washington (Figures 1-1 and 1-2). Mercury has historically been detected in sediment samples collected within this area at concentrations that exceed state Sediment Management Standards (SMS) chemical criteria.

The Bellingham Bay Demonstration Pilot Project (Pilot Project), which encompasses the WW Area as well as other sediment cleanup sites in Bellingham, is an initiative of the Cooperative Sediment Management Program. The Pilot Team is made up of 15 federal, state, and local entities addressing and coordinating contaminated sediment cleanup needs with other key management issues in Puget Sound. The Pilot Project was designed to expand opportunities for achieving multiple goals in Bellingham Bay, including source control, sediment cleanup, sediment disposal, habitat restoration, and aquatic land use elements.

Working under the oversight of the Washington Department of Ecology (Ecology) and other Pilot Project participants, Georgia-Pacific West, Inc. (G-P) performed a detailed remedial investigation/feasibility study (RI/FS) of the site. The study provided data, analysis, and engineering evaluations to develop and evaluate a set of feasible cleanup alternatives for the WW Area. This WW Area RI/FS, coupled with the Bellingham Bay Comprehensive Strategy Environmental Impact Statement (EIS), will be used by the Pilot Team to select a preferred alternative. As a member of the Pilot Team, Ecology will make a regulatory selection consistent with the consensus opinion of the Pilot Team.

Ecology approved G-P's cleanup study plan in August 1996. The Draft Remedial Investigation (RI) Report containing the results of physical, chemical, and biological testing was submitted to Ecology in May 1997. In June 1997 and again in October 1998, additional sediment sampling and analysis was added to the RI/FS. The draft final RI/FS Report was issued in July 1999 for public comment, concurrent with the Comprehensive Strategy EIS. This final RI/FS Report presents the integrated results of all sampling and analysis, along with evaluations of sediment site units, cleanup technologies, and detailed evaluations of remediation alternatives. The report presents information relevant to the weighing of alternative actions considering net environmental benefits, permanence, implementability, cost, and other SMS and Model Toxics Control Act (MTCA) criteria.

This RI/FS Report is intended to facilitate agency, landowner, and public review, and to enable Ecology and the Pilot Project to select an appropriate cleanup action alternative for the WW Area. The Pilot Project has developed a Comprehensive Strategy that integrates bay-wide source control, sediment cleanup, sediment disposal, habitat restoration, and aquatic land use elements into a coordinated approach. In the EIS, the environmental consequences of implementing the Comprehensive Strategy, including the sediment remediation alternatives presented herein, are analyzed. This RI/FS is a companion document to the EIS.

1.1 Summary of Existing Conditions

Major findings of the study are summarized below:

- **Sediment Thickness**. The typical thickness of non-native sediments (i.e., those deposited after initial channel dredging, and which contained detectable chemical constituents), ranged from two feet below the mudline within inner Bellingham Bay (including the outer Whatcom Waterway federal navigation channel), to more than 10 feet near the head of the Waterway.

- **Sediment Quality.** Of the more than 50 chemicals analyzed, only three were regularly detected at concentrations that exceeded current state Sediment Quality Standard (SQS) chemical criteria. These chemicals of potential concern included mercury, 4-methylphenol, and phenol. Accumulations of wood material exceeding 50 percent by volume were also identified within the WW Area, and were often associated with elevated 4-methylphenol and phenol concentrations.

  Surface sediment concentrations of mercury, 4-methylphenol, and wood material in the WW Area were significantly lower than concentrations detected several feet below the mudline. These patterns correspond to decreasing surface sediment concentrations over the past 25 years, which in turn is attributed to source controls implemented at the G-P facility and in other areas of inner Bellingham Bay beginning in the early 1970s. This process, referred to as natural recovery, is also driven by the gradual incorporation of clean sediments deposited in the area, primarily from the Nooksack River. Continuing wood material degradation processes appear to affect the distribution of 4-methylphenol and phenol concentrations at the site.

- **Sediment Toxicity.** Over the 1996 to 1998 period, sediment samples from 40 site locations were submitted for confirmatory biological testing to verify or refute sediment toxicity predicted on the basis of sediment chemical concentrations. Sixty percent of these samples (collected from 24 locations) were determined to be non-toxic (i.e., did not exceed SQS minor biological effects criteria). The remaining 40 percent of the locations exceeded SQS no minor adverse biological effects criteria. Fifteen percent (6 locations) exceeded Ecology's minimum cleanup level (MCUL) based on more than minor adverse biological effects. Sediment toxicity was not correlated with mercury or with other chemical parameters.

Most of the surface sediments located within the Whatcom Waterway navigation channel did not exceed SQS biological effects criteria, even though underlying subsurface sediments within the channel contained some of the highest concentrations of mercury, 4-methylphenol, and wood material detected at the site. These data confirm the protectiveness of the natural sediment cap that has formed in the channel as the result of source controls and natural recovery, and concurrent with active navigation use of the channel.

Sediments exceeding SQS biological effects criteria were restricted to a small portion of the Whatcom Waterway near the head of the navigation channel, along with nearshore areas adjacent to the navigation channel, and the former Starr Rock sediment disposal site. Sediments exceeding MCUL biological effects criteria were more localized, restricted to several nearshore areas immediately adjacent to G-P's Aerated Stabilization Basin (ASB), and to one sample near Starr Rock. The areal extent of biological effects was significantly smaller than that represented by sediment chemistry.

- **Bioaccumulation.** In addition to ecological risks, bioaccumulation of mercury in certain fish and shellfish populations within inner Bellingham Bay (e.g., Dungeness crab caught within the Whatcom Waterway) may also have potential human health implications. Tissue mercury concentrations within the WW Area are currently elevated as much as ? ? three times above regional background levels. However, even the maximum tissue concentrations reported in this area are below conservative benchmark concentrations calculated to protect tribal fishers and sensitive wildlife that may consume relatively large amounts of seafood.

  In order to address the potential for localized exposures, a sediment screening level was developed for mercury that is conservatively protective of potential bioaccumulation risks to human health and to high trophic level wildlife receptors. The screening level utilized the observed relationship between tissue concentrations and surface sediment concentrations within the sampled species' home range. Using screening-level risk assessment methods, a conservative tissue benchmark mercury level was calculated to protect tribal fishers and wildlife that may consume relatively large amounts of seafood from Bellingham Bay. The sediment screening level determined using these methods was 1.2 milligrams per kilogram (mg/kg; dry weight basis). For the WW Area, sediments exceeding this health-based screening level generally corresponded to those areas of the site also targeted for cleanup to address sediment toxicity concerns.

- **Source Control.** Detailed sampling and analysis of more than ten potential contaminant sources in inner Bellingham Bay was undertaken as a part of this RI/FS. No ongoing, significant sources of mercury were identified within the WW Area that have the potential to recontaminate sediments. Although ongoing urban stormwater inputs of 4-methylphenol and phenol have been documented in the area, these sources appear to affect only a relatively small area surrounding two stormwater outfalls in the WW Area. Moreover, the available data suggest that sediment concentrations of phenol and 4-methylphenol are more closely associated with the degradation of historical wood material deposits. Cleanup of WW Areas to address sediment toxicity concerns would likely alleviate this "internal" source of 4-methylphenol and phenol.

  Low-level mercury concentrations have been detected in shallow groundwater adjacent to the G-P Log Pond. Shoreline seepage may contain similar or lower concentrations due to tidal mixing and chemical attenuation. Although the low rate of groundwater mercury loading to the Log Pond does not appear sufficient to result in sediment recontamination, control of potential seepage releases to the G-P Log Pond is nevertheless being addressed as a component of this RI/FS. G-P is also planning further mercury controls as part of forthcoming chlor-alkali facility closure actions.

1.2 Development of Remedial Action Alternatives

For the purpose of developing and evaluating appropriate remedial action alternatives, the WW Area was differentiated into site sediment units with unique physical, chemical, biological, and site use characteristics. For example, site units with water depths that are compliant with the federally authorized channel depths were differentiated from units that have shoaled to less than the authorized depths. Comparisons with authorized channel depths and future maintenance dredging projects considered a typical overdredge allowance of two feet.

As part of initial development of sediment remediation alternatives for the WW Area, general response actions were identified and screened, cleanup technologies were assessed, and various process options incorporated to develop a reasonable range of remedial alternatives, consistent with SMS guidance. The identification, screening, and assembly of cleanup technologies into bay-wide alternatives followed direction provided by the Pilot Project, and included additional site-specific remedial alternatives developed by G-P.

Three response action categories were evaluated in this RI/FS: source control/natural recovery; containment; and treatment. Although several existing treatment technologies are feasible, the potential implementability and effectiveness on various types of contaminants and volumes of sediment is uncertain. Specifically, the high sediment volumes and low contaminant concentrations characteristic of the WW Area may be difficult to address using available treatment technologies. In addition, many of the available "treatment" technologies do not remove, concentrate or recover mercury, but rather alter the sediment containing the mercury. Studies are underway by various state and federal agencies to assess production, cost and effectiveness aspects of the more promising treatment technologies. These studies should provide a more refined determination of the practicability of sediment treatment for WW Area sediments. Nevertheless, because of current implementability and effectiveness uncertainties, treatment of sediments was not carried forward into the detailed RI/FS analysis of remediation alternatives.

Consistent with SMS guidance, remedial technologies including source control/natural recovery, *in situ* containment (capping) and *ex situ* containment (removal and disposal) were assessed for possible application to the WW Area. All of these technologies are capable of addressing the volumes and contaminant levels observed at the WW Area, and were therefore carried forward into the detailed analysis of remediation alternatives.

Source controls and natural recovery of sediments in the WW Area have been well documented by the historical record of declining surface concentrations of mercury over the past 25 years. These declines were corroborated with detailed mathematical modeling of natural recovery processes performed for this RI/FS. The RI/FS analyses indicated that most (more than 80 percent) of those WW areas that currently exceed SQS criteria will recover to below prospective SQS criteria (incorporating confirmatory biological monitoring as appropriate) by the year 2005.

However, based on conservative modeling assumptions, three sediment site units may not recover within the next 10 years to below SQS criteria. These areas are: 1) the G-P Log Pond; 2) nearshore areas located adjacent to the Whatcom Waterway, immediately offshore of the G-P Aerated Stabilization Basin (ASB); and 3) the former Starr Rock sediment disposal site. All three of these areas contained the highest mercury and wood material concentrations reported within inner Bellingham Bay, and also encompass most of the areas that currently (1996 to 1998 sampling) exceed Ecology's MCUL based on biological effects.

With the exception of the no action (baseline) alternative, all of the cleanup alternatives carried forward for detailed analysis in this RI/FS included either *in situ* containment (capping) and/or removal of these three priority sediment cleanup areas. Removal process options evaluated in this FS include mechanical and hydraulic dredging. Mechanical methods were found to be more practicable for the WW Area.

The disposal options evaluated include upland, nearshore, and contained aquatic disposal (CAD), incorporating the "short list" of high priority disposal sites identified by the Pilot Project (BBWG, 1998b). A review of key technical considerations relevant to application of these technologies and process options within the WW Area is included in this RI/FS. This review includes considerations for short- and long-term water quality impacts, disposal site stability, habitat considerations, and navigation dredging requirements. Key technical considerations identified from this review were incorporated into the development of the site-specific remedial alternatives.

For the purpose of this RI/FS, a total of 9 sediment remediation alternatives were evaluated that represent a wide range of potentially appropriate remedial technologies and process options. These alternatives include different combinations of natural recovery, capping, removal, and disposal. The majority of the alternatives were developed by the Pilot Project, with the balance being developed independently by G-P. When viewed together, the alternatives present the broad range of potential remediation, habitat enhancement, and land use options available within the WW Area, and highlight tradeoffs associated with implementation of different alternatives, consistent with SMS and Pilot Project objectives.

1.3 Identification of a Preferred Alternative

Through the MTCA Cleanup Action Plan and EIS processes, a preferred bay-wide sediment remediation alternative will be identified. It is important to note that, in the absence of the Pilot Project effort, the preferred sediment remediation alternative for the WW Area would necessarily focus only on statutory selection criteria set forth in the SMS. In consideration of the statutory criteria comparisons, as summarized in this RI/FS, the likely recommendations for WW Area sediment remediation would include elements of further source controls, short-term natural recovery, capping, and limited dredging. The site-specific alternatives incorporating these technologies and process options are consistent with SMS selection factors and comply with statutory requirements. However, as discussed above, the Pilot Project will identify a preferred sediment remediation alternative that will achieve multiple goals including habitat restoration and land use actions in an effective, cost-efficient way. It is Georgia-Pacific's belief that the best course of action is to not identify a preferred alternative and defer to the Pilot Project. From a regulatory standpoint, Ecology will ultimately select the remedy for the Whatcom Waterway Site.

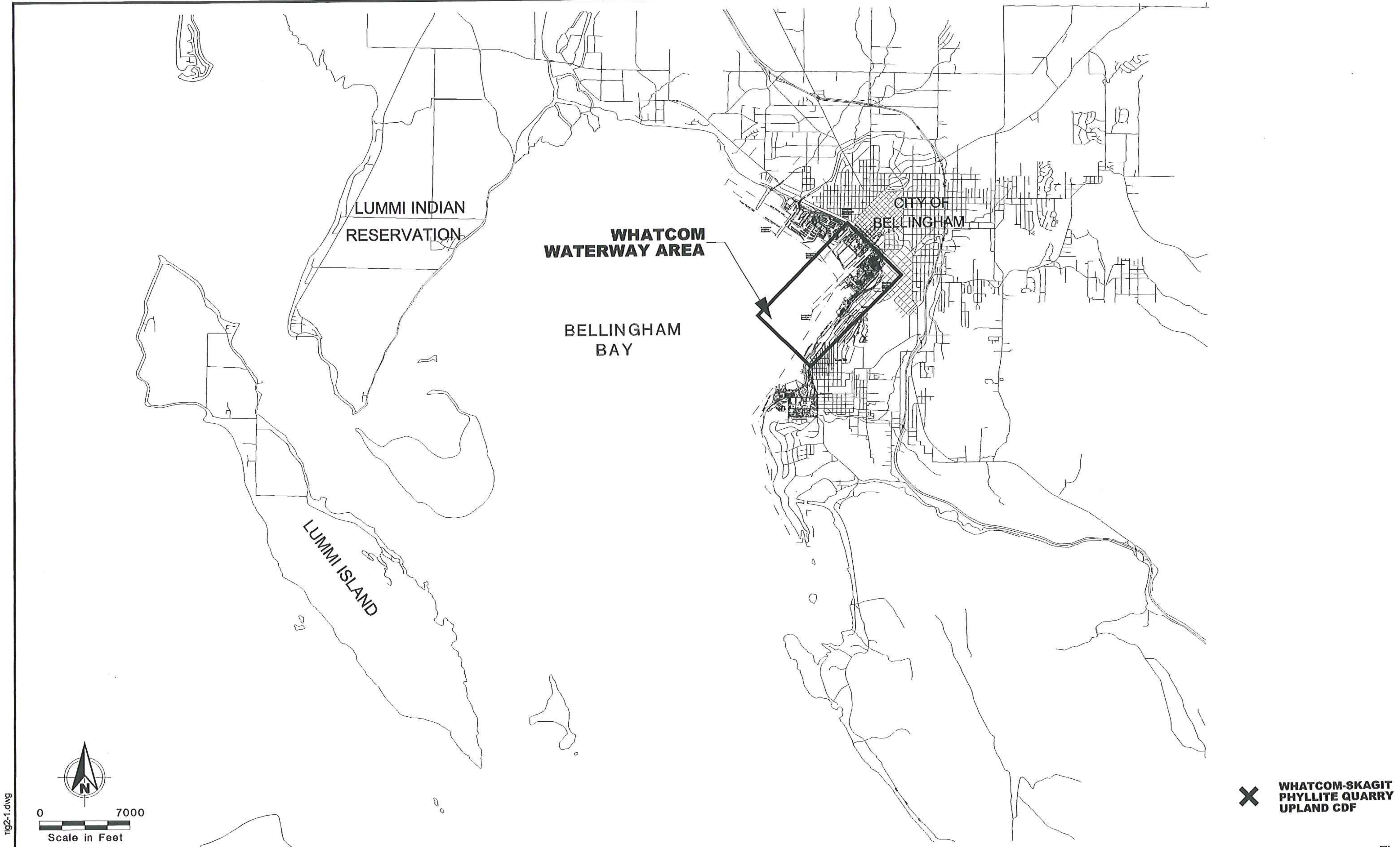
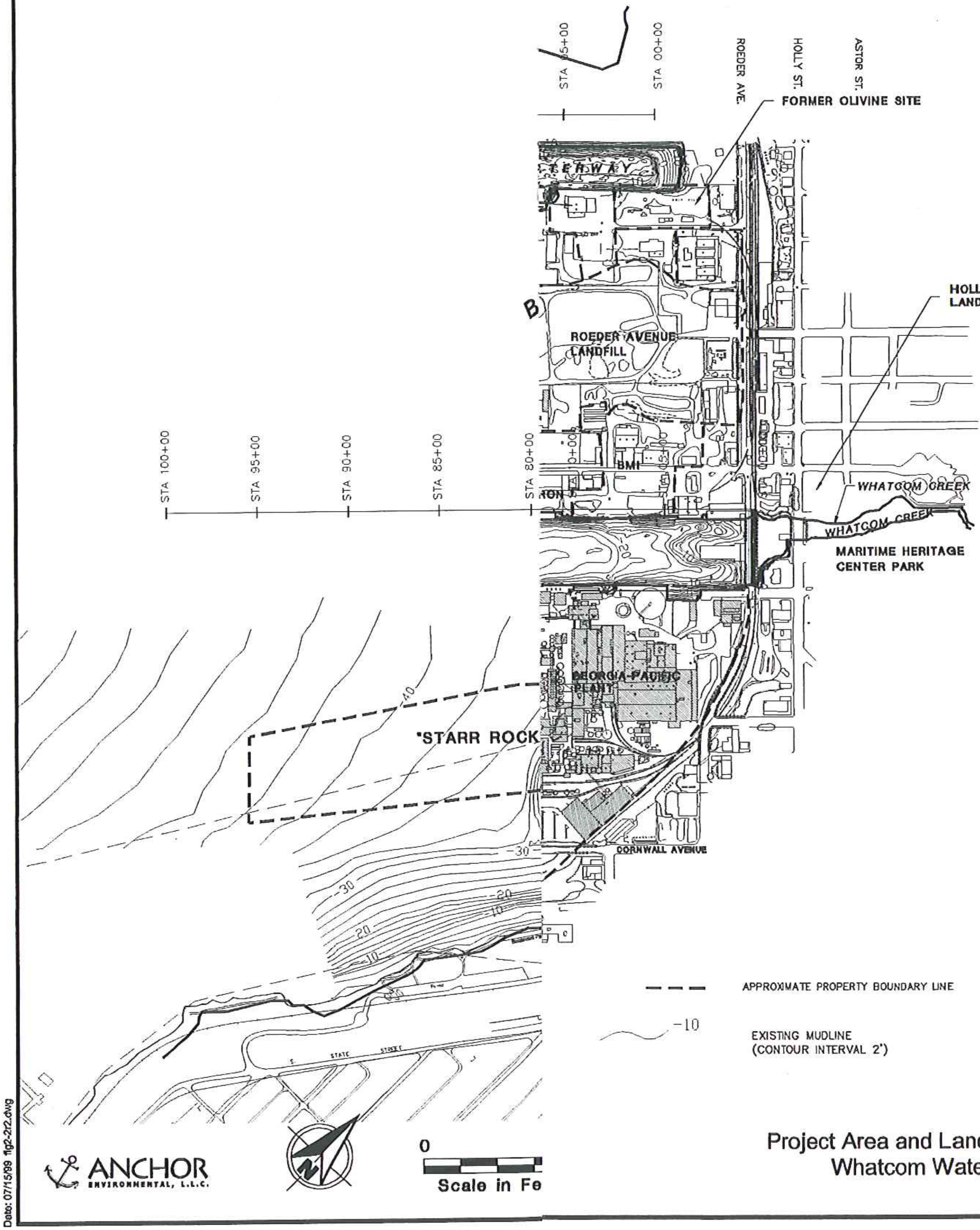


Figure 1-1
Vicinity Map
Whatcom Waterway Area

Date: 07/15/99 fig2-1.dwg

ANCHOR
ENVIRONMENTAL, L.L.C.



ANCHOR ENVIRONMENTAL, L.L.C.

Figure 1-2
Project Area and Land Use Plan
Whatcom Waterway Area

Date: 07/15/99 fig2-2r2.dwg

2.0 INTRODUCTION

The Whatcom Waterway Area (WW Area) consists of intertidal and subtidal aquatic lands within and adjacent to the Whatcom and I&J Street Waterways in Bellingham, Washington (Figure 1-1). Mercury concentrations detected in some sediment samples collected within the WW Area have exceeded Sediment Quality Standards as defined in the Washington State Sediment Management Standards (SMS; Chapter 173-204 WAC).

Since the 1960s, the Georgia-Pacific Corporation (G-P) has owned and operated a pulp and paper mill located directly adjacent to the WW Area. Beginning in 1965, wastewaters containing mercury were discharged to the Whatcom Waterway from the mill's chlor/alkali plant. Mercury discharges from the mill have been controlled for more than 20 years through process changes and wastewater treatment controls. The direct discharge of wastewater to the Whatcom Waterway was discontinued in 1979.

In January 1996, G-P and the Washington State Department of Ecology (Ecology) entered into an Agreed Order to perform a Remedial Investigation/Feasibility Study (RI/FS) of the WW Area sediments, pursuant to the Washington State Model Toxics Control Act (MTCA; Chapter 173-340 WAC; RCW 70.105D.050[1]). The RI/FS is intended to provide sufficient data, analysis, and engineering evaluations to enable Ecology to select a preferred sediment cleanup action alternative that is protective of human health and the environment and considers local site development plans.

Ecology approved the RI/FS Project Plans (Hart Crowser, 1996b) for the WW Area on August 27, 1996. The Project Plans specified those tasks and management strategies necessary to support and complete the RI/FS, and set forth project objectives and decision criteria. Sampling and analysis activities were initiated by G-P shortly after Ecology's approval—including sampling of surface and subsurface sediments, suspended particulate matter, seep and outfall discharges, and physical surveys of the waterways and inner bay. In November 1996, additional water quality sampling was added to the RI program, as detailed in Addenda Nos. 1 and 2 to the Project Plans (Hart Crowser, 1997a). As discussed above, in August 1998, collocated samples were collected in the WW Area to confirm the findings of the 1996 study. These samples (Addendum No. 3) and additional samples in the Starr Rock area were collected in accordance with the approved work plans (Anchor, 1998a and 1998b).

2.1 Report Organization

The WW Area includes the Whatcom and I&J Street Waterways, the mouth of Whatcom Creek, the G-P Log Pond, and subtidal areas around the G-P biotreatment lagoon and the Cornwall Avenue Landfill.

Volume I of this final RI Report presents the results of the sampling and analysis program as set forth in the approved RI/FS Work Plan and addenda. This report is organized as follows:

- Section 1.0 - Executive Summary;
- Section 2.0 - Introduction;
- Section 3.0 - Inner Bellingham Bay Physical Characteristics;
- Section 4.0 - Sediment Chemical Determinations;
- Section 5.0 - Confirmatory Bioassay Determinations;
- Section 6.0 - Assessment of Mercury Bioaccumulation;
- Section 7.0 - Natural Resources in Bellingham Bay;
- Section 8.0 - Source Control and Recontamination Evaluation; and
- Section 9.0 - Sediment Natural Recovery Evaluation

Tables and figures compiling and illustrating the data are numbered to correspond to and are presented at the end of their respective sections.

Volume II of this report presents the Feasibility Study (FS), and provides analyses and engineering evaluations of remediation alternatives to protect human health and the environment. Appendices, presented in Volumes III and IV, provide supporting project documentation and are organized as follows:

- Appendix A - Field Activities and Methods;
- Appendix B - Results of Chemical Analyses;
- Appendix C - Data Quality Review for Chemical Analyses;
- Appendix D - Physical Testing;
- Appendix E - Sediment Bioassay Data Quality Review and Marine Sediment Bioassay Report;
- Appendix F - Fish and Shellfish Concentration Data;
- Appendix G - Effluent Monitoring Data;
- Appendix H - WASP Input/Output Files;
- Appendix I - Data Report Addendum 3. Remedial Investigation/Feasibility Study, Whatcom Waterway. Bellingham, WA;
- Appendix J - Supplementary Investigations of Surface Sediments, Boulevard Park/Starr Rock Area. Bellingham, WA;
- Appendix K – Natural Recovery Modeling;
- Appendix L – Screening-Level Puget Sound Dredged Disposal Analysis Sediment Quality Evaluation;
- Appendix M – Assessment of Contaminant Mobility Sequential Batch Leaching Tests; and
- Appendix N – Engineering Cost Estimate, Whatcom Waterway Area.

2.2 Remedial Investigation Objectives

The specific objectives of the RI, and the attendant data collection and analysis efforts required to support these objectives, included the following:

- Delineation of the spatial extent of sediments exceeding the ecological criteria (SQS and MCUL) set forth in the State Sediment Management Standards using chemical testing and, in selected locations, synoptic biological testing of surface sediments in the active biological zone;
- Delineation of the depth of contamination based on chemical testing of subsurface cores, and geologic mapping of the depth to native (prehistoric) deltaic sediments, in areas that may require dredging for remediation, navigation, or development;
- Characterization of the physical condition of the waterways and inner bay, including bathymetry, habitat, natural resources, shoreline structures, and sediment physical properties (wood material; grain size, density, etc.);
- Evaluation of contaminant bioaccumulation in fish and shellfish of Bellingham Bay, and potential risks to human health through review of local fish and shellfish tissue concentrations, seafood consumption rates, and human health risk assessment;
- Evaluation of the potential for on-going recontamination of the waterways and inner bay, and the status of present-day source controls, through sampling of creeks, seeps, outfalls, and bay water; deployment of sediment traps; and contaminant transport modeling of the G-P outfall; and
- Evaluation of natural recovery as a possible component of a cleanup alternative for the site using dated cores, detailed chemical stratigraphy, and reconstruction of pollutant load reductions over time (this objective is pursued further in the FS).

A summary of sampling locations, analytical parameters, and sampling objectives is provided in Table 2-1. In total, 82 locations were sampled for surface sediment chemistry (40 of which were submitted for bioassay testing); 27 locations for subsurface sediment chemistry (including 3 dated cores for natural recovery analysis); 2 sediment trap deployment locations for suspended particulate matter (SPM); and 14 locations for water quality (including samples of seeps, creeks, outfalls, and Bellingham Bay).

2.3 Summary of Field Activities

Water, surface sediment, underpier sediment, and subsurface sediment quality sampling was performed in the WW Area between February 1996 and October 1998. The majority of field work was conducted from August 29 through October 19, 1996, including collection of sediment samples. Supplemental surface sediment sampling was conducted in October 1998 to further delineate cleanup boundaries identified in the earlier sampling efforts. Sediment sampling locations within the WW Area are depicted on Figure 2-1.

In addition, a physical survey of waterway shoreline and structures was conducted on February 13, 1996, and wet season seep/outfall sampling was conducted on April 23, 1996. The wet season seep/outfall sampling event was expedited to take advantage of high spring runoff conditions by obtaining Ecology's advance approval of the pertinent sections of the RI/FS Work Plan. Sediment traps were deployed on October 8, 1996; January 30, 1997; and May 16, 1997; providing coverage of nearly a full year in the three deployments.

Hart Crowser and subcontractor personnel performed the sampling. Field activities included the following:

- Initial shoreline inventory and habitat assessment;
- Bathymetry surveys;
- Structures surveys;
- van Veen grab sampling of surface sediments;
- Underpier diver core sediment sampling;
- Subsurface sediment core sampling;
- Natural recovery sediment core profiling;
- Sediment trap deployment and suspended particulate matter sampling;
- Water column sampling; and
- Potentially significant source sampling (seeps, creeks, outfalls) during wet and dry seasons.

A chronology of field sampling activities is summarized in Table 2-2.

2.4 Summary of Deviations from Project Plans

A summary of deviations from the approved Project Plans (Hart Crowser, 1996b), Addendum No. 1 to the Project Plans (Hart Crowser, 1996g), and Addendum No. 3 to the Project Plans (Anchor, 1998a) is presented below. (Addendum No. 2 addressed FS data gaps, and is discussed in Volume II). These deviations were required because of unexpected field or laboratory conditions. However, the deviations did not compromise the integrity of the data or the ability of the data to meet the specified objectives of the Remedial Investigation in any significant way.

Deviations from the approved Project Plans included the following:

- Surface sediment sampling and coring was performed by Marine Sampling Systems (MSS) aboard the *R/V Nancy Anne*; vibracoring technology was used instead of impact coring, and sample nomenclature was changed from HC-IC-## to HC-VC-## to reflect this change;

- Whatcom Creek surface samples (HC-SS-38 and HC-SS-39) were not accessible by foot or by the MSS sampling vessel; these samples were collected from a small skiff using a ponar sampler which required multiple deployments to retrieve sufficient sample volumes, and which resulted in 8-cm depth samples rather than the specified 10-cm depth samples;

- Samples HC-SS-36, HC-SS-42, and HC-SS-45 were moved from 50 to 75 feet from proposed locations based on field conditions (i.e., vessel obstructions, recovery problems, etc.); other samples were collected within 50 feet of proposed locations;

- Surface water sampling locations HC-SW-03, HC-SW-05, HC-SW-08, and HC-SW-09 could not be sampled during either wet weather or dry weather events because of insufficient or no flow; location HC-SW-06 could not be sampled during the dry weather event;

- Bioassay larval tests in 1996 were problematic because of an unusually cool and early fall. After two unsuccessful attempts at spawning *Dendraster*, the laboratory organism was switched to *Mytilus edulis*. In the first two experiments using *Mytilus*, the control sediment results did not meet performance criteria, but the third experiment was successful. However, the repeated unsuccessful larval tests caused some of the sediment holding times to be exceeded by a few days. No quality control concerns occurred during the 1998 supplemental sample bioassays;

- Sediment traps were deployed for three periods, rather than two, each for approximately four-month durations, to provide year-round coverage of SPM quality. However, the sediment trap at location HC-ST-101 overturned during the second deployment period, and a sample could not be recovered. Particulate matter was analyzed for phenols, in addition to mercury, because of observed phenol enrichments in WW Area sediments and in municipal storm drains; and

- The background water sample from the Nooksack River (HC-BC-100) was collected upstream from the river mouth, rather than over the delta area, because shallow water precluded access by boat from the bay.

Table 2-1 - Sampling Locations, Test Parameters, and Objectives

Sheet 1 of 5

Station	Matrix	Initial Depth in feet	Final Depth in feet	No. of Samples	Mercury	SMS Metals	SVOAs	PCBs	Radio-nuclides	TOC	Grain Size	Bio-assays	Primary Objective/Rationale
Surface Sediment - 1996 Data													
HC-SS-01	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-02	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-03	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences
HC-SS-04	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-05	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-06	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences
HC-SS-07	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-08	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences
HC-SS-09	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-10	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-11	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-12	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-13	Sed	0	0.3	1	X					X	X	X	Surface Sediment SMS Exceedences
HC-SS-14	Sed	0	0.3	1	X					X	X	X	Surface Sediment SMS Exceedences
HC-SS-15	Sed	0	0.3	1	X					X	X	X	Surface Sediment SMS Exceedences
HC-SS-16	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-17	Sed	0	0.3	1	X					X	X	X	Surface Sediment SMS Exceedences
HC-SS-18	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-19	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-20	Sed	0	0.3	1		X				X	X		Surface Sediment SMS Exceedences
HC-SS-21	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-22	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-23	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-24	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-25	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-26	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-27	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-28	Sed	0	0.3	1		X				X	X		Surface Sediment SMS Exceedences
HC-SS-29	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences

Table 2-1 - Sampling Locations, Test Parameters, and Objectives

Station	Matrix	Initial Depth in feet	Final Depth in feet	No. of Samples	Mercury	SMS Metals	SVOAs	PCBs	Radio-nuclides	TOC	Grain Size	Bio-assays	Primary Objective/Rationale
HC-SS-30	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences
HC-SS-31	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-32	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-33	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences
HC-SS-34	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences
HC-SS-35	Sed	0	0.3	1		X	X	X		X	X	X	Surface Sediment SMS Exceedences
HC-SS-36	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SS-37	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SS-38	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SS-39	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SS-40	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-41	Sed	0	0.3	1		X				X	X	X	Surface Sediment SMS Exceedences
HC-SS-42	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-43	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-44	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-45	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SS-46	Sed	0	0.3	1	X					X	X		Surface Sediment SMS Exceedences
HC-SS-47	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SS-48	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
Surface Sediment - 1998 Data													
AN-SS-36	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SS-37	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SS-301	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SS-302	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SS-303	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SS-304	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SS-305	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SS-306	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
Collocated Surface Sediment - 1996 Data													
HC-SC-70	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences

Table 2-1 - Sampling Locations, Test Parameters, and Objectives

Sheet 3 of 5

Station	Matrix	Initial Depth in feet	Final Depth in feet	No. of Samples	Mercury	SMS Metals	SVOAs	PCBs	Radio-nuclides	TOC	Grain Size	Bio-assays	Primary Objective/Rationale
HC-SC-71	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-72	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-73	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-74	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-75	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-76	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-77	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-78	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-79	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-80	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-81	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-82	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-83	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-84	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
HC-SC-85	Sed	0	0.3	1		X	X	X		X	X		Surface Sediment SMS Exceedences
Collocated Surface Sediment - 1998 Data													
AN-SC-70	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-71	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-72	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-73	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-77	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-78	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-80	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-81	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-82	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
AN-SC-84	Sed	0	0.3	1	X	X	X			X	X	X	Surface Sediment SMS Exceedences
Subsurface Cores													
HC-VC-70	Sed	0	5.8	3	X		X	X		X	X		Depth of Contamination
HC-VC-71	Sed	0	14.9	7		X	X	X		X	X		Depth of Contamination
HC-VC-72	Sed	0	13.1	7		X	X	X		X	X		Depth of Contamination

447806/Whatcom Waterway RI/Whatcom.xls-Table 2-1

Table 2-1 - Sampling Locations, Test Parameters, and Objectives

Station	Matrix	Initial Depth in feet	Final Depth in feet	No. of Samples	Mercury	SMS Metals	SVOAs	PCBs	Radio-nuclides	TOC	Grain Size	Bio-assays	Primary Objective/Rationale
HC-VC-73	Sed	0	9.7	4	X		X	X		X	X		Depth of Contamination
HC-VC-74	Sed	0	11.5	4	X		X	X		X	X		Depth of Contamination
HC-VC-75	Sed	0	9	3		X	X	X		X	X		Depth of Contamination
HC-VC-76	Sed	0	15.5	4	X		X	X		X	X		Depth of Contamination
HC-VC-77	Sed	0	18.9	7		X	X	X		X	X		Depth of Contamination
HC-VC-78	Sed	0	7	3		X	X	X		X	X		Depth of Contamination
HC-VC-79	Sed	0	21	6		X	X	X		X	X		Depth of Contamination
HC-VC-80	Sed	0	9	3	X		X	X		X	X		Depth of Contamination
HC-VC-81	Sed	0	8	4	X		X	X		X	X		Depth of Contamination
HC-VC-82	Sed	0	10.1	4	X		X	X		X	X		Depth of Contamination
HC-VC-83	Sed	0	7.9	3	X		X	X		X	X		Depth of Contamination
HC-VC-84	Sed	0	9.6	4	X		X	X		X	X		Depth of Contamination
HC-VC-85	Sed	0	9.7	3		X	X	X		X	X		Depth of Contamination
Underpier/slope Cores													
HC-DC-86	Sed	0	3.8	2		X	X	X		X	X		Depth of Contamination
HC-DC-87	Sed	0	3.8	2		X	X	X		X	X		Depth of Contamination
HC-DC-88	Sed	0	3.8	2		X	X	X		X	X		Depth of Contamination
HC-DC-89	Sed	0	3.8	2		X	X	X		X	X		Depth of Contamination
HC-DC-90	Sed	0	3.8	2		X	X	X		X	X		Depth of Contamination
HC-DC-91	Sed	0	3	2		X	X	X		X	X		Depth of Contamination
HC-DC-92	Sed	0	2.8	2		X	X	X		X	X		Depth of Contamination
HC-DC-93	Sed	0	2	1		X	X	X		X	X		Depth of Contamination
Natural Recovery Cores													
HC-NR-100	Sed	0	3.7	23	X				X				Natural Recovery Evaluation
HC-NR-101	Sed	0	3.8	22	X				X				Natural Recovery Evaluation
HC-NR-102	Sed	0	3.5	18	X				X				Natural Recovery Evaluation
Sediment Traps													
HC-ST-100	Sed Trap	n/a		3	X		X (1)			X	X		Natural Recovery/Recontamination
HC-ST-101	Sed Trap	n/a		2	X		X (1)			X	X		Natural Recovery/Recontamination

Table 2-1 - Sampling Locations, Test Parameters, and Objectives

Sheet 5 of 5

Station	Matrix	Initial Depth in feet	Final Depth in feet	No. of Samples	Mercury	SMS Metals	SVOAs	PCBs	Radio-nuclides	TOC	Grain Size	Bio-assays	Primary Objective/Rationale
Seeps, Creeks, Outfalls, Bay													
HC-SW-01	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-02	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-04	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-04A	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-04B	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-06	Water		n/a	1		X (2)	X (3)						Recontamination Evaluation
HC-SW-07	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-10	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-11	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-12	Water		n/a	2		X (2)	X (3)						Recontamination Evaluation
HC-SW-99	Water		n/a	1	X (4)								Recontamination Evaluation
HC-SW-100	Water		n/a	1	X (4)								Recontamination Evaluation
HC-SW-101	Water		n/a	1	X (4)								Recontamination Evaluation
HC-BC-100	Water		n/a	1	X (4)								Recontamination Evaluation
HC-BC-101	Water		n/a	1	X (4)								Recontamination Evaluation

Notes:

SS = Surface Sediment
SC = Surface Sediment - Collocated with Core
VC = Vibracore
DC = Diver Core

NR = Natural Recovery Core
ST = Sediment Trap
SW = Surface Water
n/a = not applicable

(1) Includes phenolic compounds only
(2) Includes total and dissolved metals
(3) Includes PAHs only
(4) Includes dissolved and particulate mercury

Table 2-2 - RI Field Sampling Chronology

Dates	Activity	Sampling Location
February 13, 1996	Site Reconnaissance and Shoreline/Structures Survey	See Figure 3-6
April 23, 1996	Wet Season Water Sampling	HC-SW-01-W, HC-SW-02-W, HC-SW-04A-W/04B-W, HC-SW-06-W, HC-SW-07-W, HC-SW-10-W through HC-SW-12-W
August 29 through September 10, 1996	Surface Sediment Grab Sampling	HC-SS-01 through HC-SS-48; HC-SC-70 through HC-SC-85
September 10 through 13, 1996	Subsurface Sediment Coring	HC-VC-70 through HC-VC-85
September 13, 1996	Natural Recovery Core Collection	HC-NR-100, HC-NR-101, and HC-NR-102
September 18, 1996	Underpier Diver Coring	HC-DC-86 through HC-DC-93
September 26, 1996	Dry Season Water Sampling	HC-SW-01-D, HC-SW-02-D, HC-SW-04A-D/04B-D, HC-SW-07-D, HC-SW-10-D through HC-SW-12-D
October 7, 1996	Underpier Bathymetry Survey	See Figure A-29
October 8, 1996	Sediment Trap Deployment (First Round)	HC-ST-100 and HC-ST-101
October 9 and 10, 1996	Open-Water Bathymetry Survey	See Figure A-29
January 27 and 28, 1997	Low-Level Mercury Water Column Sampling	HC-SW-99, HC-SW-100, HC-SW-101, HC-BC-100, and HC-BC-101
January 30, 1997	Sediment Trap Retrieval and Re-Deployment (Second Round)	HC-ST-100 and HC-ST-101
May 16, 1997	Sediment Trap Retrieval and Re-Deployment (Third Round)	HC-ST-100 and HC-ST-101
September 16, 1997	Final Sediment Trap Retrieval	HC-ST-100 and HC-ST-101
July 1997	Screening-Level PSDDA Disposal and Leachability Analysis	See Appendices K and L
October 26, 1998	Surface Sediment Grab Sampling (performed separately by Port of Bellingham and Ecology; Anchor Environmental [1999])	AN-SS-301 through AN-SS-306
October 27 through 29, 1998	Surface Sediment Grab Sampling	AN-SS-36, AN-SS-37, AN-SC-70 through AN-SC-73, AN-SC-77, AN-SC-78, AN-SC-80 through AN-SC-82, and AN-SC-84

Sampling Location Plan
Whatcom Waterway Area

SEDIMENT SAMPLE LOCATION AND NUMBER

■ HC-VC-70/ HC/AN-SC-70	SUBSURFACE SEDIMENT VIBRACORE AND COLLOCATED SURFACE SEDIMENT SAMPLE
▲ HC/AN-SS-01	SURFACE SEDIMENT SAMPLE
● HC-DC-86	UNDER PIER/SLOPE DIVER CORE
◆ HC-NR-101	NATURAL RECOVERY CORE
⊙ HC-ST-101	SEDIMENT TRAP DEPLOYMENT
——	MUDLINE BATHYMETRY IN FEET

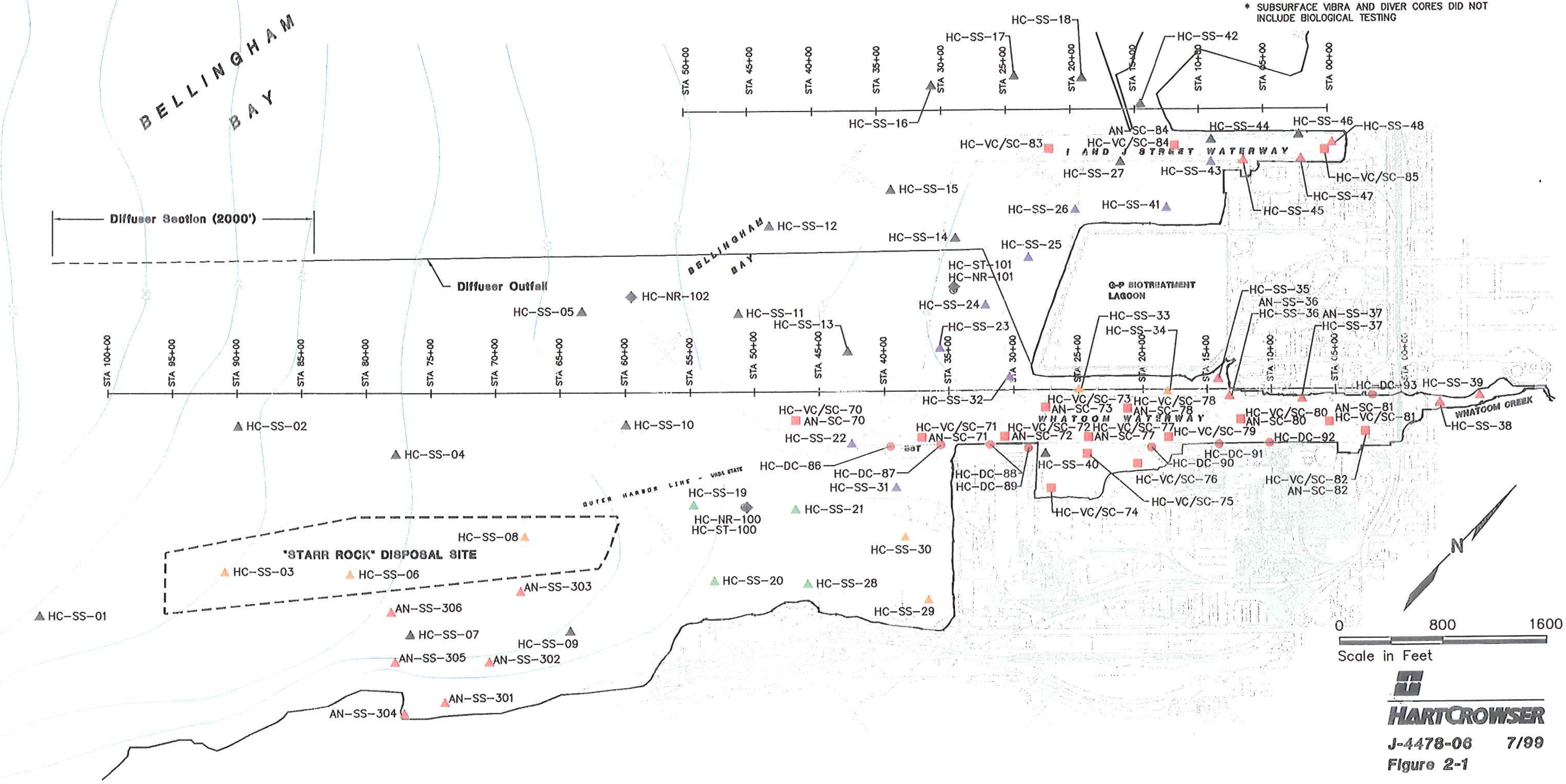
NOTE: SEE COLOR CODES TO RIGHT FOR ANALYSIS TYPE

TEST PARAMETER LIST	SYMBOL COLOR DESIGNATION	ANALYSES AT EACH SAMPLE LOCATION
1	▲	TOTAL MERCURY, TOTAL SOLIDS, TOC, GRAIN SIZE; CONTINGENT SMS BIOLOGICAL TESTING
2	▲	SMS METALS, TOTAL SOLIDS, TOC, AND GRAIN SIZE CONTINGENT SMS BIOLOGICAL TESTING
3	■ ▲ ●	SMS CHEMICALS, TOTAL SOLIDS, TOC, AND GRAIN SIZE CONTINGENT SMS BIOLOGICAL TESTING*
4	▲	SMS CONFIRMATORY BIOLOGICAL TESTING IN ADDITION TO TEST PARAMETER LIST 1
5	▲	SMS CONFIRMATORY BIOLOGICAL TESTING IN ADDITION TO TEST PARAMETER LIST 3
6	◆	RADIOCHEMISTRY, TOTAL SOLIDS, AND TOTAL MERCURY
7	⊙	TOTAL MERCURY, TOTAL SOLIDS, TOC, AND GRAIN SIZE

* SUBSURFACE VIBRA AND DIVER CORES DID NOT INCLUDE BIOLOGICAL TESTING

NOTES:
1. BASE MAP GENERATED FROM "BELLINGHAM MILLSITE PLOT PLAN" BY CASCADE AERIAL MAPS AND SURVEYS, INC. DATED JULY 1990, SUPPLIED BY GEORGIA-PACIFIC CORPORATION.

2. WHATCOM WATERWAY BATHYMETRY DATA FROM DRAFT AUGUST 1994 SURVEY BY U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT, AND U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) NATIONAL SURVEY 19TH EDITION CHART 18423, DATED FEBRUARY 24, 1979.



HARTCROWSER

J-4478-06 7/99

Figure 2-1

07/16/99 1=800

44780646

3.0 INNER BELLINGHAM BAY PHYSICAL CHARACTERISTICS

The physical properties of the Whatcom and I&J Street Waterways were characterized as part of the RI/FS field activities for use in describing local habitat and to provide information needed for the development and evaluation of remedial options in the forthcoming feasibility study. The physical surveys performed for this RI/FS included the following elements:

- Hydrographic surveys;
- Shoreline reconnaissance and structure surveys; and
- Sediment grain size determinations and analyses of Atterberg limits, specific gravity, total organic carbon (TOC), and sediment density on selected samples.

Regional geology, hydrology, and oceanography elements were also reviewed to describe the physical setting of the WW Area relative to Bellingham Bay and the adjacent upland areas. WW Area sediments were compared to regional geologic conditions and grouped into three major sediment units.

3.1 Objectives

The purpose of the RI/FS physical surveys and analyses was to describe the physical dynamics of the waterways, to assess sediment physical properties, and to summarize engineered structures (e.g., piers, bulkheads, etc.) and other physical features. These data are used in the RI/FS for contaminant transport evaluations, habitat assessments, and feasibility study analyses of cleanup alternatives.

3.2 Regional Geology, Hydrology, and Oceanography

3.2.1 Regional Geology

The WW Area is located in the northern Puget Sound lowlands and is underlain by a series of Late Pleistocene sedimentary glacial deposits. These sediments were deposited on the Eocene-aged bedrock of the Chuckanut Formation. Glacial activity during the Pleistocene Epoch produced the major natural landforms in the region. The geology of the region has been compiled by Easterbrook (1976) and is summarized below.

The Chuckanut Formation is a 10,000-foot-thick sequence of arkosic sandstone interbedded with conglomerate, shale, and coal which formed between 55 to 43 million years ago. This formation originated as an alluvial floodplain deposit. Subsequent deformation of the Chuckanut Formation resulted in a series of northwest-southeast trending ridges and valleys. Following this episode of folding and faulting, deposition of sandstone and shale resumed, and the Huntingdon Formation was formed, similar in composition to the Chuckanut Formation.

Unconsolidated glacial and fluvial sediments overlie the Chuckanut and Huntingdon Formations. These deposits are the result of the cycle of continental glaciation that impacted the Puget Lowlands at least four times during the Late Pleistocene. During these glacial cycles, thick sequences of gravel, sand, silt, and clay were deposited.

In the WW Area, only deposits from the Frasier glaciation are present. The advance and subsequent retreat of this glaciation occurred between 10,000 and 20,000 years ago. The resulting glacial sediments cover a broad area along the northeast shore of Bellingham Bay and are known collectively as the Bellingham Drift. This deposit, dated as 11,000 to 12,000 years old, is characterized by 15 to 25 feet of poorly sorted, unstratified, pebbly/sandy silt, and pebbly clay, with occasional boulders that can be up to ten feet in diameter. These sediments were deposited beneath and peripheral to the glacier, and in a marine basin below the ice sheet. The glacial retreat resulted in the release of large amounts of debris through glacial meltwater rivers, and deposition of outwash sand and gravel known as the Kulshan glaciomarine drift. The total thickness of the glacial sedimentary sequence is at least 50 feet in the vicinity of the waterway.

Approximately 5 to 40 feet of well-sorted, stratified fluvial and deltaic sands known as the Deming Sands and rare peat bogs were deposited on top of the glaciomarine drift. Over the last 10,000 years, fine-grained materials carried by the Nooksack River have been the primary source of fluvial and deltaic deposits in the region. Dredging in the Whatcom and I & J STREET Waterways has created a discontinuity at the surface of the deltaic sequence. The thickness of the recent, surficial post-dredge deposits ranges from about 10 feet in inner Whatcom Waterway, to about 2 or 3 feet in inner Bellingham Bay adjacent to the waterway.

3.2.2 Surface Water and Groundwater Hydrology

The WW Area lies principally within the Whatcom Creek Watershed, near the Whatcom Creek mouth. Here, a salt water wedge migrates upstream with the progression of high tides. Both the creek and tides in Bellingham Bay affect local groundwater movement. Generally, the surface water and shallow groundwater flow directions are directly influenced by local topography. However, constructed fill areas, depending on their composition, may cause groundwater to flow in unpredictable directions or to perch over dense fill horizons. Regionally, along the northeast shore of Bellingham Bay, groundwater and surface water generally flow in a west to southwest direction to the bay.

The inner Bellingham Bay area is primarily influenced by the drainage from three watersheds. The largest is the Nooksack River Watershed, which drains approximately 1,500 km^2. All of the Nooksack flow does not, however, reach Bellingham Bay. Part of it enters Lummi Bay by way of the Lummi River. The Nooksack River is also the primary source of sediments to the bay, with an annual discharge of 650,000 m^3. The Nooksack River is influenced by anthropogenic factors that include agriculture and logging.

The Whatcom Creek Watershed drains an area of approximately 26 km^2. Whatcom Creek flows from Lake Whatcom through the City of Bellingham to the bay. The City occupies much of the watershed. Presently, Whatcom Creek is influenced by channelization, vegetation removal, and urban storm water runoff.

The Squalicum Creek Watershed drains an area of 65 km^2 via Squalicum Creek; this creek originates at Squalicum Lake and also flows through the City. The creek is influenced by channelization, vegetation removal, and urban storm water runoff. Five other smaller watersheds also contribute fresh water to Bellingham Bay.

3.2.3 Oceanography

Bellingham Bay is part of a system of interconnected bays that exchange water with the Rosario Strait and ultimately the Pacific Ocean through a complex network of channels and passages (Figure 3-1). Collias et al. (1966), Shea et al. (1981), and Broad et al. (1984) have previously described the physical oceanography of Bellingham Bay. In addition, a recent study of inner Bellingham Bay currents was performed by Colyer (1998).

Regional Bottom Currents. Most oceanic waters enter Bellingham Bay at depth through the northern end of Rosario Strait between Lummi and Vendovi Islands. Some water also enters through Bellingham Channel. Exchange of water to the west through Hale Passage is limited by a shallow sill. The residence time for water in Bellingham Bay is typically four to five days, but varies between one and eleven days.

The available data indicate that there is a net southward flow throughout Bellingham Bay at depth, largely resulting from the lateral and vertical spreading of the Nooksack River discharge. Overall, bottom currents are relatively consistent throughout the year and typically range from 0.2 to 0.3 m/sec. As described by Colyer (1998), deep current velocities typically range from 0.04 to 0.18 m/sec in the inner bay and can be as high as 0.40 m/sec (Figure 3-2). Based on generalized relationships between bottom current velocities and sediment resuspension thresholds, bottom velocities above approximately 0.3 to 0.4 m/sec may be capable of resuspending fine-grained sediments (i.e., silt and clay particles). Accordingly, inner Bellingham Bay appears to be primarily a net depositional environment, though periodic resuspension of sediments in the inner bay is possible. This interpretation is consistent with the predominance of fine-grained sediment textures throughout the inner bay (see Section 3.4 below).

Relative to the inner Bellingham Bay area, bottom and near-bottom currents within the more protected Whatcom Waterway are slower, and typically range between 0.04 and 0.10 m/sec (Figure 3-3). The maximum bottom velocity reported by Colyer (1998) in this area is 0.16 m/sec. Thus, the Whatcom Waterway is also predominantly a depositional environment, with even less resuspension of bottom sediments by ambient oceanographic currents.

Regional Surface Currents. Surface currents throughout Bellingham Bay vary primarily in response to wind stress (Shea et al., 1981). Winds over the bay are from the south or southwest during much of the year, typical of foul-weather low-pressure systems in winter months, resulting in the forcing of surface water toward the northern part of the bay with return flow along the shorelines of the Lummi Peninsula, Portage Island, and Lummi Island. Fair-weather winds from the west or northwest cause surface flow to the east and south along the eastern shoreline.

In response to seasonal wind forcing, both clockwise and counter-clockwise circulation patterns are set up in Bellingham Bay (see Figure 3-3). The salinity distribution maps of Collias et al. (1966) summarized on Figure 3-4 delineate freshwater discharges from the Nooksack River. The brackish river plume sometimes exits the bay along the western shoreline near Lummi Peninsula and Lummi Island (counter-clockwise circulation), but at other times exits primarily along the eastern shoreline near the City of Bellingham and Post Point, where it is then directed southwestward across the bay toward the southern tip of Lummi Island (clockwise circulation). In both configurations, surface water enters Rosario Strait mainly near the southern tip of Lummi Island and Vendovi Island. The compensating inflow of seawater to the Bellingham Bay occurs partly via surface waters along the opposite shoreline from the brackish river plume, and partly via bottom waters.

Typical surface currents range between 0.02 to 0.06 m/sec in the inner bay, reaching maximum velocities of 0.36 m/sec (Figure 3-2). Within the Whatcom Waterway, currents typically range from 0.04 to 0.06 m/sec (Figure 3-3). Maximum surface velocities exceeded 0.4 m/sec (Colyer, 1998).

Currents in the Whatcom Waterway Area. Surface water and deep water circulation patterns in the vicinity of the Whatcom Waterway site are shown on Figure 3-3, as interpreted from the data of Colyer (1998). Circulation patterns are very transient, changing quickly over the tidal cycle, and further complicated by the influence of discharge from Whatcom Creek. Nevertheless, some consistent patterns can be discerned.

The circulation within Whatcom Waterway appears to be typical of a two-layer estuary, with discharge to the bay of brackish, riverine water at the surface, and recharge into the waterway of saline marine water at depth. Thus, the surface water layer is dominated by seaward flow out of the waterway, and the deep water layer is dominated by landward flow into the waterway, although tidal currents (Figure 3-3) may overwhelm this general pattern. The currents in the inner bay, both shallow and deep, are dominated by east-southeasterly, along-shore flow. However, the influence of freshwater discharge or ebbing tidal currents from the Whatcom Waterway creates transient and complex counter-currents, eddies, and shear zones in the inner bay, and displaces the southeasterly ambient flow field farther into the bay.

Tides. The mean tidal range within Bellingham Bay is 5.2 feet. The diurnal tidal range is about 8.6 feet.

Salinity, Temperature, and Total Suspended Solids. In the top 30 feet of the water column, salinity varies with depth and over time. Representative distribution maps of surface salinity in greater Bellingham Bay, as reported by Collias et al. (1966), are presented on Figure 3-4. The observed variability is primarily the result of fresh water input, wind-induced circulation, and wind-induced mixing. Because most fresh water comes from the Nooksack River, brackish water (salinity less than about 26 parts per thousand [ppt]) is most extensively distributed in the upper part of Bellingham Bay, but a lower salinity surface layer has been observed to extend throughout the bay and south of Post Point. This surface layer is typically less than 6 feet thick, but high winds may occasionally deepen the surface layer to 12 feet. The deepest waters in Bellingham Bay are similar in character to those of Rosario Strait. Bottom water salinities typically range from 29 to 31 ppt, and are relatively stable throughout the year.

Colyer (1998) recorded surface salinities in inner Bellingham Bay ranging from approximately 10 to 25 ppt. Colyer also observed higher surface salinities during the incoming tide, and recorded deep water salinities in the inner Bellingham Bay area in the range of 26 to 30 ppt.

Water temperatures in Bellingham Bay vary with depth and over time primarily as the result of seasonal air temperature changes. Water temperatures range from 8 to 13°C and are warmest in the summer and early fall and coldest during winter and spring.

The concentration of total suspended solids (TSS) within the inner Bellingham Bay area was recently measured by Colyer (1998). Surface water TSS concentrations ranged from 3 to 25 mg/L. Deep water TSS concentrations were similar, and ranged from 1 to 32 mg/L. TSS concentrations averaged about 10 mg/L in both surface and deep waters.

3.3 Physical Characteristics of the Waterways

A bathymetric contour map of the project area is presented on Figure 3-5. This map incorporates bathymetric soundings collected as part of this RI/FS, with recent surveys conducted by the Army Corps of Engineers (Corps) in the Whatcom Waterway and I&J Street Waterway navigation channels. A summary of the shoreline structures survey is presented in Table 3-1 and on Figure 3-6.

3.3.1 Bathymetry Survey

The main shipping channels of the Whatcom and I&J Street Waterways were mapped in 1992 and 1996, respectively, by the Corps as part of its periodic soundings conditions assessment of navigation channels (Corps, 1992 and 1996). The supplemental RI/FS bathymetric survey conducted by Blue Water Engineering included non-channel areas of the WW Area (i.e., the G-P Log Pond and underpier areas of the WIST, G-P, and Citizens' Docks), subtidal areas near Cornwall Avenue Landfill, and subtidal areas west and north of the G-P Biotreatment Lagoon, not included in the previous Corps survey areas. Mudline elevations were referenced in feet to the MLLW datum. A map of the transect lines included in the 1996 survey is included on Figure A-29. This survey accomplished the following:

- Identified surface bottom conditions of previously non-surveyed areas of the project area;
- Located physical obstructions which could hinder remediation; and
- Established the condition of waterway slopes.

The 1996 RI bathymetry correlated reasonably well with Corps bathymetry (Corps, 1992 and 1996) where they overlapped. Base maps presented in this report have been updated with the new bathymetric and shoreline data.

In general, subtidal mudline elevations within the WW Area ranged from -2 to -35 feet MLLW. Mudline soundings in the main channel of the Whatcom Waterway ranged from elevation -7 feet at the head of the waterway to -35 feet near the mouth. In the main channel of the I&J Street Waterway, soundings ranged from elevation -5 feet at the head of the waterway to -18 feet near the mouth. Mudline elevations in the G-P Log Pond ranged from -4 to -15 feet with an average elevation of -10 feet MLLW. The non-channel area near the Cornwall Avenue Landfill can be described as a gently sloping mudline that dips toward the northwest to a maximum depth at elevation -26 feet MLLW. The non-channel area immediately northwest of the G-P

Biotreatment Lagoon, supporting a local eelgrass meadow (see Figure 3-6), had an average mudline elevation of -2 to -6 feet MLLW.

3.3.2 Slopes

The shoreline slopes of the Whatcom and I&J Street Waterways were included in the visual shoreline reconnaissance conducted from sea level (MLLW) to the top of bank. This information will be used in assessments of slope stability (e.g., during potential future dredging activities) and to support the design of appropriate remediation options where banks may be involved. Information regarding slopes was also used during generation of mudline profiles and cross sections. The shoreline survey was recorded in video and may be requested from the Hart Crowser project files.

The substrate of the Whatcom and I&J Street Waterways slope sections included vertical bulkheads, riprap, poured concrete, slag, wooden pilings, concrete and asphalt rubble, and various construction debris. The remaining shoreline areas consisted of gravelly sand or very soft, mud beaches. The WW Area shorelines have been divided into 22 segments of similar substrates and/or physical features (Figure 3-6 and Table 3-1).

The steepest slopes were measured near locations with bulkheads and/or steep riprap slopes. Bulkheads were usually located near marinas and boat moorings. Steep riprap slopes were located near the lee slope of the WIST pier, the north side of the I&J Street Waterway, and the three sides of the G-P Biotreatment Lagoon. Slope inclination (rise over run) ranged from vertical to 1.5H:1V. Moderately steep slopes with inclinations up to 1H:1V were partially covered with sediment. These slopes were usually engineered and included areas such as the Cornwall Avenue Landfill shoreline. Gently sloping banks with inclinations of 3H:1V to 5H:1V were largely limited to the head of the Whatcom and I&J Street Waterways.

3.3.3 Structures and Shoreline Survey

Over-water, nearshore, and shoreline structures, shoreline matrices, and slopes were inventoried during the 1996 RI/FS sampling activities. These activities included observations made during the shoreline video reconnaissance, site walks, bathymetry survey, boat tours, water sampling, and sediment sampling. Specific features documented for use during the evaluation of remedial options included features such as piling size, construction, dimensions, and spacing; bent spacing; slope integrity; slope construction; and substrate. These structures are summarized in Table 3-1.

As summarized on Figure 3-6, the shoreline areas were divided into one of five categories depending on the features listed above. The shoreline categories described in this report are defined as follows:

- Category A - Soft, silt substrate;
- Category B - Sand and small gravel substrate, shallow slope;
- Category C - Moderately steep gravel and riprap armored beaches (<3 ft
- diameter);
- Category D - Steep riprap and concrete debris slope (>3 ft diameter); and
- Category E - Vertical bulkhead.

These categories are valid only for conditions observed at the time of the survey. Shoreline conditions may change and may require re-evaluation.

3.4 Sediment Grain Size and Other Physical Properties

Physical testing of WW Area sediment samples included grain size distribution, total organic carbon (TOC), specific gravity, Atterberg limits, wet density, water content, and visual estimation of wood debris. Wood material distribution in sediments is discussed in Section 3.5, and TOC results are discussed in Section 3.6. A description of physical testing methods and supporting data plots are presented in Appendix D.

3.4.1 Grain Size Distribution

Visual descriptions and grain size analysis information from RI/FS sampling locations (Figure 2-2) were compiled to describe generalized sediment distribution patterns. Two figures were prepared to illustrate the distribution of sediment textures within the waterways. Figure 3-7 illustrates the general distribution of fine-grained sediment (percent by weight less than No. U.S. 230 sieve size) from RI/FS data. Figure 3-8 is a facies map of sediment textures as described using ASTM classification methods.

Grain size results for RI/FS samples are compiled in Table 3-2 as a percentage of gravel, sand, silt, and clay size fraction by weight (PSEP classification). Visual sediment descriptions are presented in Table A-4B (Appendix A) and include other field observations in addition to grain size such as presence of wood chips, bark, lumber, metal/plastic debris, plant fragments, odor and sheen, and eelgrass.

In general, the surface (0 to 10 cm) sediment grain size distribution in the Whatcom Waterway grades from coarser material at the head of the waterway to finer grained material near the mouth of the waterway. This pattern is likely a function of water depth, with higher wave energies impinging on the bottom in shallow water and winnowing out the finer sediments. The grain size distribution in the I&J Street Waterway is similar and grades from coarser at the head of the waterway to finer near the mouth. Surface sediment samples outside of the main waterway channels generally consisted of clayey silt to slightly sandy, very clayey silt with sandier material located near the intertidal banks.

The average sediment composition in the surface samples from subtidal areas of the waterways may be inferred by considering the mean values in each of the grain size classes. The average composition for RI/FS samples includes 2 percent gravel, 22 percent sand, 52 percent silt, and 24 percent clay, and the mean sediment type is a sandy, clayey SILT with trace gravel.

In core samples collected between depths of 0 and 20 feet below mudline, the average composition includes 1 percent gravel, 30 percent sand, 42 percent silt, and 27 percent clay. The mean sediment type is clayey, very sandy SILT. Note that this average composition includes not only recent sediments but also underlying native deposits of fluvial or glacial origin. The average sediment composition for diver core samples collected from underpier areas is 10 percent gravel, 52 percent sand, 26 percent silt, and 13 percent clay. The mean sediment type for underpier sediments is a slightly gravelly, slightly clayey, silty SAND. The distribution of subsurface sediment textures and geologic units is discussed in more detail in Section 4.8.

3.4.2 Atterberg Limit Results

Atterberg limit analyses were completed on ten selected cohesive core samples representing a variety of depths and locations. Atterberg limits, which include the liquid limit, plastic limit, and the plasticity index, were used to define plasticity characteristics of clays and other cohesive sediments. These results help define dredgability and compression properties of fine-grained sediments. The majority of cohesive samples were classified as a medium to high elastic silt or clay. Two samples (HC-VC-72-S4 and HC-VC-79-S4, Figures 3-10 and 3-11) were classified as clay with low plasticity. These samples are from the compact Glacial Marine Outwash unit. The liquid and plastic limits test reports for the ten selected samples are presented on Figures D-151 and D-152 in Appendix D.

3.5 Wood Material Distribution

The spatial distribution of wood material in surface sediments of the WW Area was developed based on visual observations in van Veen surface grab samples from 0- to 1-foot depths. The distribution is described as percent wood by volume. Percent wood ranged from zero to locally greater than 50 percent, as shown on Figure 3-9. As discussed by Kendall and Michelsen (1997), wood materials present at greater than 50 percent by volume may be addressed as an other deleterious substance under SMS.

The surface sediment samples with the largest percentage of wood materials (>50%) can be grouped into four areas: the G-P Log Pond (HC-SS-40, HC-SC-74, and HC-SC-75); the southern corner of the G-P Biotreatment Lagoon (HC-SS-32 and HC-SS-33); a small area in inner Bellingham Bay near Station 78+00 (HC-SS-04); and a small area inshore of the Starr Rock disposal site (AN-SS-305).

Surface sediment samples with greater than 20 percent (by volume) wood fragments and chips were also observed near the east end of the Cornwall Avenue Landfill and in the main channel of the Whatcom Waterway between the Log Pond and the G-P Biotreatment Lagoon (Figure 3-9). The type of wood materials observed in the surface samples included the following descriptions in descending order of frequency: wood chips up to 2-foot long; wood bark; twigs; pulp or fibrous material; wood lumber; and wood timbers. All wood materials were observed in various states of decomposition.

Wood fragments and chips were present in subsurface sediments at depths of up to 9 feet. Within the Whatcom Waterway, trace to substantial amounts of wood materials were present within the recent sediments (Recent Deposits on Figure 3-11). Maximum thicknesses and percentages of woody material were found in sediments from the log pond, including a 9-foot-thick layer of up to 70 percent wood fragments in HC-VC-76. Within the I&J Street Waterway, traces of wood fragments were present within recent sediments (Recent and Post-Dredge Deposits on Figure 3-12) at subsurface depths of up to 9 feet.

3.6 Sediment Total Organic Carbon (TOC)

3.6.1 Surface Sediment Samples

The distribution of TOC concentrations in surface sediment samples is presented on Figure 3-7. Surface (0 to 10 cm) sediment TOC concentrations in the WW Area ranged from 0.82 percent (HC-SS-48) to 13.0 percent (AN-SS-305) in 82 samples. Seventy-nine percent of these samples contained TOC concentrations between 2 and 4 percent, with an average concentration of 3.2 percent. The four highest concentrations (8.3, 8.8, 9.2, and 13.0 percent, measured in surface samples HC-SC-74, AN-SS-301, AN-SS-304, and AN-SS-305, respectively) were collected from the G-P Log Pond and Starr Rock/Boulevard Park areas. The elevated TOC concentrations are likely the result of the high percentage (moderate to >50%) of wood fragments in these samples.

Other surface sediment samples which contained TOC concentrations above 4 percent included HC-SC-75 (6.9%), HC-SS-40 (6.0%), AN-SC-82 (4.8%), HC-SC-76 (4.6%), HC-SS-29 (4.4%), AN-SC-78 (4.3%), HC-SC-79 (4.2%), HC-SC-81 (4.2%), HC-SC-82 (4.2%), AN-SS-303 (4.1%), and HC-SS-25 (4.1%), which were concentrated near the head of the Whatcom Waterway and the corner of Cornwall Avenue. Substantial to moderate wood fragments were present in AN-SC-82, HC-SS-29, AN-SS-78, and HC-SC-79. However, only trace wood fragments were present in the other samples with TOC concentrations above 4 percent, indicating that elevated TOC values at these locations are likely comprised of fine organic matter derived from Whatcom Creek or possibly decayed vegetation.

3.6.2 Subsurface Sediment Samples

Subsurface (0 to 20 feet) sediment TOC concentrations in the WW Area ranged from a low of 0.16 percent to a maximum of 49 percent (HC-VC-77-S2; 2.1 to 3.9 feet depth). The average TOC concentration in fifty-five subsurface sediment samples was 5.6 percent. In general, elevated TOC concentrations correlated with the presence of wood materials in the subsurface.

3.7 Sediment Density

Profiles of sediment density were determined for the natural recovery cores HC-NR-100, HC-NR-101, and HC-NR-102 (see Figure 2-2 for their locations). A summary of average sediment wet and dry densities is presented in Table 3-3. Profiles of sediment wet density are presented on Figure D-154 in Appendix D.

Sediment wet density was calculated using an empirical formula derived by Battelle (1995) for sediment compositions typical of Puget Sound. This formula relates the percent dry weight of sediments to the wet density through the following equation:

$$\text{Wet density} = 0.1737(5.0245 + e^{0.0238 \times \%\text{dry weight}})$$

Sediment wet density calculations were volumetrically corrected for compaction compression which occurred during coring. A detailed description of this volumetric correction is presented in Appendix D. Field estimates of sediment compaction during coring are presented in Appendix A.

Average surface (0 to 2 cm) wet density in inner Bellingham Bay ranged from approximately 1.23 to 1.30 g/cm^3 (Figure D-154). Wet density increased with depth in the cores to a maximum of approximately 1.32 to 1.42 g/cm^3 at a depth of 1 meter below the mudline.

3.8 Sediment Geologic Units

The subsurface geology of the Whatcom and I&J Street Waterways was interpreted from core profiles, sediment grain size distributions, presence of wood debris, chemical concentration data (Section 4.0), historical and current bathymetry maps, dredging history, and upland borings and reports. One profile and one cross section of the Whatcom Waterway (A-A' and C-C'), one profile of the I&J Street Waterway (B-B'), and one cross section through the Cornwall Avenue Landfill (D-D') were developed to identify the depth to native (pre-dredge) sediments and to provide information necessary for evaluation of remedial design options. Geologic profiles and cross sections are presented on Figures 3-11 through 3-14. Figure 3-10 shows the profile/cross section locations.

3.8.1 Sediment Geology Overview

The sedimentary sequence within the WW Area is a function of fluvial sediment loads, deltaic growth rate, and the local depositional environment. A rapidly advancing delta front is characterized by an abundance of sands. Slower growth periods are characterized by finer grained sediments, principally silts, being deposited in lower energy environments. The distributary channels within a delta also meander and shift, resulting in erosion and channel backfilling. Discharges from the Nooksack River, Whatcom Creek, and Squalicum Creek all contribute to the WW Area sediment profiles, which commonly display sediment stratigraphy consisting of interlayered sands, gravelly sands, silty sands, and sandy silts.

The natural depositional environment of the waterway has been altered by dredging, including excavation of the original waterway, maintenance dredging, and fill replacement during nearshore construction.

3.8.2 Sediment Stratigraphy

The waterway sediments were vertically divided into three distinct sediment units, as depicted on Figures 3-11 through 3-14. Variations within these units may exist and when applicable, these variations were described as subunits (a, b, c).

- **Unit 1—Post-Dredge Recent Deposits.** Unit 1 consists primarily of very soft, brown-black, slightly sandy, clayey silt with shell fragments and varying amounts of wood debris overlying a soft, dark gray silt with trace wood fragments. Physical events that may have resulted in disturbed sequences include previous trenching and backfilling of the G-P pipeline installation in 1979 (Unit 1a).

  Unit 1 is fine-grained sediment recently deposited since the last dredging events of 1974 and 1992 (see below). This unit contains most of the chemicals detected in RI/FS sediment samples. The vertical extent of contamination is discussed in more detail in Section 4.0.

  The thickness of Unit 1 varies widely across the waterways from 1 foot thick at the mouth to 7 feet thick at the head of the Whatcom Waterway. The thickest sequence was observed in core HC-VC-76 (9 feet thick) located in the Log Pond. In localized areas, Unit 1 also contains varying amounts of wood debris (Unit 1b in the Log Pond), and coarser grained material (Unit 1c near head of the waterways).

- **Unit 2—Post-Glacial (Pre-Dredge) Fluvial Deposits.** Unit 2 consists of medium dense, gray, non-silty to silty, fine to medium sand with multi-colored grains, shell fragments, and occasional gravel and silt lenses grading to gray silt with clay. Deposits are coarser near the head of the waterway, described as slightly gravelly sand with shell fragments (Unit 2a). An upland variation of this unit is a greenish olive-gray, silty clay with varying amounts of sand, sawdust, and wood fragments (Unit 2b). This unit represents fine-grained material characteristic of the old upland mudflat before placement of construction fill.

  Unit 2 represents native fluvial sediments, primarily from Whatcom Creek, deposited prior to the deepest dredging event and prior to industrialization of the area. The base of this sand unit is gradational in nature but generally occurs at an elevation of approximately -22 feet MLLW near the head of the Whatcom Waterway and deepens to an elevation of -36 feet near the mouth of the Whatcom Waterway. In the I&J Street Waterway, the base of the sand unit ranges from elevation -22 to -25 feet MLLW. The base of the sand unit is at elevation -40 feet MLLW near the 1979 pipeline trench.

- **Unit 3—Glacial Outwash Deposits.** Unit 3 is a stiff to very stiff, damp to moist, gray, silty clay to clay with scattered gravels and occasional fine to medium sand layers.

  Unit 3 was encountered at elevations ranging from -28 feet MLLW near the head of both waterways to -50 to -60 feet MLLW near the mouth of the waterways. This glacial outwash unit was confirmed by adjacent upland borings advanced through fill, lagoon silts, alluvial sands, and then into glacial sequences.

Native Horizon. The waterway dredging history (Hart Crowser, 1996b), adjacent upland boring profiles, vertical extent of chemical contamination, and our interpreted contacts based upon sediment descriptions were used to characterize the contact with the native pre-dredge horizon. The elevation of the interpreted contact with native sediments ranged from -22 feet MLLW at the head of the Whatcom Waterway to -48 feet MLLW near the mouth of the Whatcom Waterway. On average, an 8-foot-thick deposit of recent sediments overlies the native horizon. By comparison, the average thickness of recent deposits in the I&J Street Waterway is approximately 6 feet. The thickest recent sediment sequences were observed in the G-P Log Pond with the native horizon calculated at elevation -17 feet MLLW under a 9-foot-thick deposit of recent sediments.

As shown on the subsurface profiles/cross sections, several apparent construction anomalies have occurred which have altered the configuration of the native sediment contact. These events include:

- Filling the Cornwall Avenue shoreline with municipal waste (1953 to 1965);
- Construction of a containment dike and filling upland portions of the G-P Log Pond behind the dike (1970s); and
- Construction of the G-P biotreatment lagoon and underground pipeline crossing in the Whatcom Waterway (1979).

Historical Dredging. The upstream and downstream limits of the last dredging event (1974) in the Whatcom Waterway ranged from Station 3+00 to 32+00, respectively, excluding the areas beneath the piers, Citizens Dock, and southeast of the Citizens Dock. In the Whatcom Waterway, the area between Station 0+00 to 3+00 was last dredged in 1960 to a reported project elevation of -18 feet MLLW. The area from Station 32+00 to deep water was last dredged in 1969 to a reported project elevation of -35 feet MLLW. Dredging in the Whatcom Waterway for the pipe crossing from the G-P plant to the biotreatment lagoon occurred in 1979 (exact station is unknown) and totaled 50,000 cubic yards, half of which was returned as pipe trench backfill. A more detailed description of dredging history in the Whatcom and I&J Street Waterways is included in the Whatcom Waterway Site RI/FS Work Plan (Hart Crowser, 1996b).

The last recorded maintenance dredging in the I&J Street Waterway occurred in 1992 totaling approximately 31,000 cubic yards (for I&J Street and Squalicum Waterways combined). At that time, the waterway was dredged to elevation -18 feet (MLLW) from Station 0+00 to Station 12+80. Prior to the partial 1992 dredging, the last dredge event in the I&J Street Waterway occurred in 1966 from Station 0+00 to deep water, totaling approximately 148,000 cubic yards.

3.8.3 Correlation of Geologic Units with Sediment Contamination

As discussed in Section 4.5, the vertical extent of chemical contamination (e.g., mercury concentrations detected above the 0.41 mg/kg sediment quality standard [SQS]) was generally restricted to non-native sediments deposited after initial channel dredging. These sediments consist of very soft, brown-black, clayey silt deposits with varying amounts of wood material, corresponding to the marine variant of Unit 1 on Figures 3-11 through 3-14. Waterway profiles/cross sections illustrate the vertical extent of contamination for each core. Refer to tables and core logs in Appendix A for actual depth and elevation values, and Section 4.0 for constituents of concern and chemical concentrations at each sampling depth.

The depth of chemical contamination below mudline ranged from less than 1 foot at the mouth of the Whatcom Waterway to 9 feet in the G-P Log Pond. However, the vertical extent of contamination was significantly greater (i.e., deeper) than the reported historical dredge prism elevation. Generally, the observed contact with native pre-dredge sediments (i.e., between Units 1 and 2) in the waterway areas was at least several feet deeper than the reported maximum historical dredging depth. This observation suggests possible overdredging (beyond typical allowances) during previous channel maintenance projects. The typical thickness of recent Unit 1 sediments observed within the WW Area is summarized as follows:

- Deep water to Whatcom Waterway Station 32+00: 1 to 2 feet below mudline;
- Whatcom Waterway Station 32+00 to 10+00: 4 to 6 feet below mudline;
- Whatcom Waterway Station 10+00 to 0+00: 5 to 8 feet below mudline;
- Log Pond: 6 to 9 feet below mudline; and
- I&J Street Waterway: 5 to 6 feet below mudline.

Table 3-1 Summary of Shoreline Structures and Habitat Survey

Sheet 1 of 3

Shore-line Area No.	Area Description	Lower Intertidal Bank approx. -2 to 5 ft MLLW Elevation	Shore-line Category (Lower)	Upper Intertidal Bank approx. 5 to 12 ft MLLW Elevation	Shore-line Category (Upper)
1	Cornwall Avenue	Low angle coarse beach sand. 1:1 slope. Cobbles near base.	B	Riprap slope (<5 ft diam.). No sediment. 2:1 slope	C, D
2	Cornwall Avenue	Low angle sandy beach with coarse sand gravel (< 3 inch diam.). Miscellaneous refuse debris (i.e., glass, metal). 0.5:1 slope. Occasional logs and pilings offshore.	B	Scattered logs and gravel lying over large broken concrete debris (<4 ft diam.) protected bank. Soil bank above the riprap. 1:1 slope.	C, D
3	Cornwall Avenue	Low angle sandy beach. Occasional logs and larger rocks.	B	Low angle sandy beach. Many logs lying on the beach. Soil bank above the logs.	B
4	POB	Steep slope with concrete rubble, gravel, and cable debris (0.5 to 3 ft diam.) 1:1 slope.	C	Large concrete rubble (<6 ft diam.) protected slope with logs, timbers, and wire coil debris. Steep 2.5:1 to 1:1 slope.	D
5	POB	Wood pier decking over riprap (<4 ft diam.) slope. Over 4 ft of fine-grained sediment on lower reaches near pierface.	A	Wood pier decking over riprap slope and concrete bulkhead. Broken concrete (<4 ft diam.). Steel 36 INCH piles with 10 ft spacing. Bents 15- to 20-foot spacing. Wooden fender piles. 1:1 slope. Section of older steel pilings with wooden headers.	C
5a	POB	Wood pier decking over shallow sloped, fine-grained substrate. Over 4 ft of accumulated sand and silt with substantial shell fragments.	A	Wood pier decking over fine-grained substrate. Wooden batter and fender piles. Difficult access - 80% cross beams.	A, B
6	G-P Log Pond	Low angle slope of fine-grained sediment accumulated around bulkhead. Scattered pilings.	A	Bulkhead of wooden lagging and piling. Partially eroded with gravel matrix filled-in behind lagging.	E
7	G-P Log Pond	Large concrete block and riprap. No fine-grained sediment except small intertstitial and corner accumulations. 0.5:1 slope. Pea gravel on shallow sloped lower beach. Scattered logs.	D	Large concrete block and riprap. High angle concrete slabs (<6 ft diam.). 2:1 slope. Logs and wood debris. Scattered pilings and dolphins.	D
8	G-P Log Pond	Medium gravel and concrete armored bank. Scattered logs.	C	Medium gravel and riprap armored bank (<1 ft diam.). Large concrete blocks above rock armoring. 2:1 slope.	C, D

Table 3-1 Summary of Shoreline Structures and Habitat Survey

Sheet 2 of 3

Shore-line Area No.	Area Description	Lower Intertidal Bank approx. -2 to 5 ft MLLW Elevation	Shore-line Category (Lower)	Upper Intertidal Bank approx. 5 to 12 ft MLLW Elevation	Shore-line Category (Upper)
9	G-P Pier	Wood pier decking over riprap protected slope and concrete bulkhead. Same pilings as upper bank. Over 4 ft of accumulated fine-grained sediment on the lower reaches of the slope near the pierface.	A	Wood pier decking over riprap protected slope (<2 ft diam.) and concrete bulkhead. Wooden 24-inch timber pilings at 4 ft spacing. 10 ft spacing between bents. Wooden fender piles and no batter piles(cross beams) until station 15+00. 3:1 slope.	C
10	G-P Pier	Wooden tongue and groove bulkhead. Scattered pilings offshore. One area of eroding shallow gravel beach bank with 0.5:1 slope.	E	Wooden tongue and groove bulkhead.	E
11	Whatcom Creek	Low angle mud slope. Occasional pilings offshore. Concrete columns supporting roadway.	A	Steep soil bank covered with grasses. Pilings offshore. Miscellaneous concrete debris and large rocks. Concrete walls, piles, and concrete columns supporting roadway and structures.	B
12	North Whatcom Waterway	Wood pier decking over steep riprap slope. 2:1 slope.	C, D	Wood pier decking over steep riprap slope. 2:1 slope. Moderate size riprap.	C, D
13	North Whatcom Waterway	Intact and partially eroded concrete bulkhead with concrete slab debris, wire coils, and timbers. Low angle gravelly, coarse sand beach exposed in eroded corner section. Scattered offshore pilings and dolphins.	E	Intact and partially eroded concrete bulkhead.	E
14	End of C-Street	Low angle sandy beach with miscellaneous concrete debris and logs.	B	"Platey" concrete slab debris armored slope with occasional logs. Slope ranges from 2:1 to 1:1 slope.	D
15	Bio-Treatment Lagoon	Steep riprap protected slope (<5 ft diam.). 2:1 slope.	D	Steep riprap protected slope (<5 ft diam.). 2:1 slope.	D
16	Corner of Bio-Treatment Lagoon	Low angle sandy beach with miscellaneous concrete debris and logs.	B	Low angle sandy beach with riprap armoring soil bank covered with grasses.	B, C
17	Hawleys Marina/ I & J Street Waterway	Metal sheet piling wall.	E	Metal sheet piling wall.	E

447806/Whatcom Waterway Ri/Whatcom.xls - Table 3-1

Table 3-1 Summary of Shoreline Structures and Habitat Survey

Shoreline Area No.	Area Description	Lower Intertidal Bank approx. -2 to 5 ft MLLW Elevation	Shoreline Category (Lower)	Upper Intertidal Bank approx. 5 to 12 ft MLLW Elevation	Shoreline Category (Upper)
17a	Hawleys Marina	Low angle gravel armoring (<10-inch diam.), riprap, and concrete slab beach with miscellaneous debris and logs. 1.5:1 slope.	B, C	Rock and concrete debris armoring with occasional logs.	B, C
18	Bornstein's Seafood/ I & J Street Waterway	Wood decking pier over moderate riprap (< 2 ft diam.) slope and wooden lagging bulkhead. Wood 10-inch-diameter piles with 6 ft spacing. Bents are 12 ft spacing. Wooden 14-inch fender piles.	C	Same as lower bank.	C
19	Former Olivine Site/ I & J Street Waterway	Wooden bulkhead with steel tiebacks supported by 12-inch pilings. Treated wood. One eroding bank area with gravel armor, broken concrete and discarded debris (<2 ft diam.). Debris in water (appliances, tires, concrete, metal).	E	Wooden bulkhead with steel tiebacks supported by 12-inch pilings.	E
20	Head of I & J Street Waterway	Low angle, sand and gravel beach with miscellaneous concrete debris (<3 ft diam.) and logs. Submerged timber pile heads.	B	Logs lying on riprap and large broken concrete debris protected bank. Soil bank above the riprap.	B, C
21	North I & J Street Waterway	Small riprap and gravel armor protected bank (<1 ft diam.). Moderate 1:1 slope. Small armor exposed near waterline.	C	Small riprap and armor protected bank. Slight bench at high tide mark. Moderate 1:1 to 2:1 slope. Short soil bank covered with grasses.	C, D
22	North I & J Street Waterway	Riprap protected bank (<3 ft diam to 4 ft diam.) with pockets of exposed gravel armor. 1:1 to 1.5:1 slope. Scattered logs and debris.	D	Large riprap protected bank. Evidence of sloughing near upper bank.	D

Shoreline Category:

A = Soft silt substrate
B = Sand plus small gravel substrate
C = Moderately steep gravel and riprap armored beach (<3 feet diameter)
D = Steep riprap plus concrete debris slope (>3 feet diameter)
E = Vertical bulkhead

Note: Elevations indicate approximate boundaries between substrate and shoreline conditions. Actual conditions may vary in the field.

Table 3-2 - Summary of Grain Size Results

Sample ID		Sample Depth in Feet	Sample Elev. in Feet	Gravel	Sand	Silt	Clay
Surface Samples (0 - 10 cm) - 1996 Data							
HC-SS-01		0 to .3	-43.6 to -43.9	0	5	79	16
HC-SS-01B	GS DUP	0 to .3	-43.6 to -43.9	0	4	78	18
HC-SS-01C	GS DUP	0 to .3	-43.6 to -43.9	0	3	81	16
HC-SS-02		0 to .3	-44.2 to -44.5	0	7	78	15
HC-SS-03		0 to .3	-42.4 to -42.7	0	7	64	29
HC-SS-04		0 to .3	-36.2 to -36.5	0	7	76	17
HC-SS-05		0 to .3	-28.3 to -28.6	0	3	80	17
HC-SS-06		0 to .3	-34 to -34.3	0	4	58	38
HC-SS-07		0 to .3	-29.5 to -29.8	0	3	55	42
HC-SS-08		0 to .3	-28.5 to -28.8	0	8	60	32
HC-SS-09		0 to .3	-23 to -23.3	0	2	81	17
HC-SS-10		0 to .3	-36 to -36.3	0	2	80	18
HC-SS-11		0 to .3	-23.3 to -23.6	0	2	78	20
HC-SS-12		0 to .3	-21 to -21.3	0	14	54	32
HC-SS-13		0 to .3	-19.8 to -20.1	0	4	75	21
HC-SS-14		0 to .3	-18 to -18.3	0	3	71	26
HC-SS-15		0 to .3	-17.8 to -18.1	0	4	79	17
HC-SS-16		0 to .3	-16 to -16.3	0	2	73	25
HC-SS-17		0 to .3	-14 to -14.3	0	3	76	21
HC-SS-18		0 to .3	-10.3 to -10.6	0	6	59	35
HC-SS-19		0 to .3	-25 to -25.3	0	4	70	26
HC-SS-20		0 to .3	-19.4 to -19.7	1	6	69	24
HC-SS-21		0 to .3	-21 to -21.3	0	11	60	29
HC-SS-22		0 to .3	-31 to -31.3	0	7	60	33
HC-SS-22B	GS DUP	0 to .3	-31 to -31.3	0	6	61	33
HC-SS-22C	GS DUP	0 to .3	-31 to -31.3	0	6	63	31
HC-SS-23		0 to .3	-16 to -16.3	0	16	69	15
HC-SS-24		0 to .3	-15.3 to -15.6	0	18	55	27
HC-SS-25		0 to .3	-9.6 to -9.9	0	15	56	29
HC-SS-202	Dup of HC-SS-25	0 to .3		0	14	59	27
HC-SS-26		0 to .3	-6.9 to -7.2	0	60	20	20
HC-SS-27		0 to .3	-8.6 to -8.9	0	83	10	7
HC-SS-28		0 to .3	-15.8 to -16.1	0	5	65	30
HC-SS-29		0 to .3	-11.3 to -11.6	0	18	59	23
HC-SS-30		0 to .3	-25.6 to -25.9	0	3	71	26
HC-SS-203	Dup of HC-SS-30	0 to .3		0	8	65	27
HC-SS-31		0 to .3	-29.5 to -29.8	0	6	61	33
HC-SS-32		0 to .3	-9 to -9.3	2	71	17	10
HC-SS-33		0 to .3	-7.5 to -7.8	9	70	17	4
HC-SS-34		0 to .3	-12.9 to -13.2	11	66	17	6
HC-SS-35		0 to .3	-10.5 to -10.8	0	10	64	26
HC-SS-36		0 to .3	-16 to -16.3	0	53	31	16
HC-SS-37		0 to .3	-14.5 to -14.8	0	32	52	16

Table 3-2 - Summary of Grain Size Results

Sample ID		Sample Depth in Feet	Sample Elev. in Feet	Gravel	Sand	Silt	Clay
Surface Samples (0 - 10 cm) - 1996 Data							
HC-SS-38		0 to .3	-.2 to -.5	0	66	26	8
HC-SS-39		0 to .3	-2.6 to -2.9	18	61	19	2
HC-SS-40		0 to .3	-8.4 to -8.7	0	48	33	19
HC-SS-41		0 to .3	-3.3 to -3.6	1	93	4	2
HC-SS-204	Dup of HC-SS-41	0 to .3		0	94	3	3
HC-SS-42		0 to .3	-11.6 to -11.9	0	19	47	34
HC-SS-43		0 to .3	-3.9 to -4.2	0	83	13	4
HC-SS-44		0 to .3	-10.1 to -10.4	0	5	69	26
HC-SS-45		0 to .3	-13.1 to -13.4	0	10	66	24
HC-SS-45B	GS DUP	0 to .3	-13.1 to -13.4	0	10	65	25
HC-SS-45C	GS DUP	0 to .3	-13.1 to -13.4	0	11	66	23
HC-SS-46		0 to .3	-7 to -7.3	35	23	27	15
HC-SS-47		0 to .3	-7.1 to -7.4	5	49	37	9
HC-SS-48		0 to .3	-2.3 to -2.6	6	88	5	1
HC-SC-70		0 to .3	-35.2 to -35.5	1	9	55	35
HC-SC-71		0 to .3	-34.1 to -34.4	0	8	47	45
HC-SC-72		0 to .3	-37.1 to -37.4	0	15	57	28
HC-SC-73		0 to .3	-27.4 to -27.7	0	10	66	24
HC-SC-73B	GS DUP	0 to .3	-27.4 to -27.7	0	10	65	25
HC-SC-73C	GS DUP	0 to .3	-27.4 to -27.7	0	11	66	23
HC-SC-74		0 to .3	-4.2 to -4.5	0	24	59	17
HC-SC-75		0 to .3	-12.2 to -12.5	0	21	61	18
HC-SC-76		0 to .3	-9.65 to -9.95	0	14	69	17
HC-SC-77		0 to .3	-30.7 to -31	0	6	54	40
HC-SC-78		0 to .3	-28 to -28.3	0	10	71	19
HC-SC-79		0 to .3	-33.8 to -34.1	2	14	47	37
HC-SC-205	Dup of HC-SC-79	0 to .3		0	14	69	17
HC-SC-80		0 to .3	-25 to -25.3	0	11	62	27
HC-SC-81		0 to .3	-19.2 to -19.5	0	28	64	8
HC-SC-82		0 to .3	-15.6 to -15.9	0	14	66	20
HC-SC-83		0 to .3	-17.7 to -18	0	8	59	33
HC-SC-84		0 to .3	-17.8 to -18.1	0	9	51	40
HC-SC-85		0 to .3	-16.6 to -16.9	0	13	71	16
Surface Samples (0 - 10 cm) - 1998 Data							
AN-SS-301		0 to .3	-5.4 to-5.7	2.3	39.0	32.0	26.8
AN-SS-302		0 to .3	-22.8 to -23.1	0.0	3.8	58.3	37.9
AN-SS-303		0 to .3	-20.7 to -21.0	4.3	15.3	43.9	36.4
AN-SS-304		0 to .3	0.1 to -0.2	5.6	88.8	2.4	3.2
AN-SS-305		0 to .3	-12.9 to -13.2	1.5	37.6	31.6	29.4
AN-SS-306		0 to .3	-18.7 to -19.0	2.7	29.8	39.0	28.5
AN-SS-36		0 to .3	-10.0 to -10.3	17.4	65.6	9.3	7.8
AN-SS-37		0 to .3	-11.8 to -12.1	40.1	22.3	24.1	13.5

Table 3-2 - Summary of Grain Size Results

Sample ID	Sample Depth in Feet	Sample Elev. in Feet	Gravel	Sand	Silt	Clay
Surface Samples (0 - 10 cm) - 1998 Data						
AN-SC-70	0 to .3	-34.5 to -34.8	0.9	7.4	51.5	40.3
AN-SC-71	0 to .3	-34.0 to 34.3	0.2	13.3	44.7	41.8
AN-SC-72	0 to .3	-36.1 to 36.4	0.0	16.6	45.3	38.0
AN-SC-73	0 to .3	-28.1 to -28.4	0.0	10.5	46.8	42.7
AN-SC-77	0 to .3	-29.7 to -30.0	0.1	9.1	47.2	43.6
AN-SC-78	0 to .3	-26.1 to -26.4	1.2	11.6	54.2	33.0
AN-SC-80	0 to .3	-24.8 to -25.1	1.2	14.9	45.3	38.7
AN-SC-81	0 to .3	-17.6 to -17.9	0.0	26.0	46.0	28.0
AN-SC-82	0 to .3	-14.4 to 14.7	0.1	17.2	50.8	31.8
AN-SC-84	0 to .3	-17.7 to -18.0	2.1	6.1	47.7	44.0
Subsurface Core Samples						
HC-VC-70-S1	0 to 1.5	-35.1 to -36.6	0	6	51	43
HC-VC-70-S2	3.7 to 5.8	-38.8 to -40.9	0	3	45	52
HC-VC-70-S2B GS DUP	3.7 to 5.8	-38.8 to -40.9	0	3	46	51
HC-VC-70-S2C GS DUP	3.7 to 5.8	-38.8 to -40.9	0	2	46	52
HC-VC-71-S1	0 to 1.6	-32 to -33.6	0	17	64	19
HC-VC-71-S2	1.6 to 4.8	-33.6 to -36.8	0	15	47	38
HC-VC-71-S3	6 to 7.6	-38 to -39.6	2	81	14	3
HC-VC-71-S4	9.8 to 11.4	-41.8 to -43.4	0	70	23	7
HC-VC-71-S7	13.1 to 14.9	-45.1 to -46.9	0	59	35	6
HC-VC-72-S1	0 to 3.2	-36 to -39.2	0	11	65	24
HC-VC-72-S2	3.2 to 4	-39.2 to -40	0	53	32	15
HC-VC-72-S3	4 to 7	-40 to -43	0	86	10	4
HC-VC-72-S4	8.4 to 10	-44.4 to -46	0	1	50	49
HC-VC-72-S7	12 to 13.1	-48 to -49.1	0	2	39	59
HC-VC-73-S1	0 to 1.9	-28 to -29.9	0	15	69	16
HC-VC-73-S2	1.9 to 4.6	-29.9 to -32.6	0	11	46	43
HC-VC-74-S1	0 to 2.4	-4.2 to -6.6	1	36	38	25
HC-VC-74-S3	4.5 to 6.9	-8.7 to -11.1	0	7	47	46
HC-VC-74-S3B GS DUP	4.5 to 6.9	-8.7 to -11.1	0	7	49	44
HC-VC-74-S3C GS DUP	4.5 to 6.9	-8.7 to -11.1	0	7	47	46
HC-VC-75-S1	0 to 3.3	-12 to -15.3	3	18	22	57
HC-VC-75-S2	3.6 to 5.8	-15.6 to -17.8	3	91	4	2
HC-VC-76-S1	0 to 3.5	-11.7 to -15.2	1	33	47	19
HC-VC-76-S2	3.5 to 7.9	-15.2 to -19.6	1	43	38	18
HC-VC-77-S1	0 to 2.1	-30.7 to -32.8	1	21	51	27
HC-VC-77-S2	2.1 to 3.9	-32.8 to -34.6	2	26	41	31
HC-VC-77-S3	3.9 to 5.4	-34.6 to -36.1	0	62	24	14
HC-VC-77-S4	5.4 to 8.6	-36.1 to -39.3	0	22	45	33
HC-VC-78-S1	0 to 2.4	-28.1 to -30.5	1	12	60	27
HC-VC-78-S2	2.7 to 4	-30.8 to -32.1	0	76	15	9
HC-VC-79-S1	0 to 2	-35 to -37	5	17	52	26
HC-VC-79-S2	2 to 3.8	-37 to -38.8	0	23	37	40

Table 3-2 - Summary of Grain Size Results

Sheet 4 of 4

Sample ID		Sample Depth in Feet	Sample Elev. in Feet	Gravel	Sand	Silt	Clay
HC-VC-79-S3		4 to 4.9	-39 to -39.9	3	30	37	30
HC-VC-79-S4		4.9 to 7	-39.9 to -42	0	21	47	32
HC-VC-80-S1		0 to 1.7	-28 to -29.7	0	23	53	24
HC-VC-80-S2		1.9 to 5.3	-29.9 to -33.3	0	31	44	25
HC-VC-206	Dup of HC-VC-80-S2	1.9 to 5.3		0	35	44	21
HC-VC-81-S1		0 to 1.6	-20 to -21.6	0	35	52	13
HC-VC-207	Dup of HC-VC-81-S1	0 to 1.6		0	36	54	10
HC-VC-81-S2		1.6 to 3.2	-21.6 to -23.2	0	28	49	23
HC-VC-82-S1		0 to 2.3	-16 to -18.3	0	20	52	28
HC-VC-82-S2		2.6 to 5.2	-18.6 to -21.2	0	19	50	31
HC-VC-82-S2B	GS DUP	2.6 to 5.2		0	18	51	31
HC-VC-82-S2C	GS DUP	2.6 to 5.2		0	19	49	32
HC-VC-83-S1		0 to 2.6	-17.8 to -20.4	0	4	60	36
HC-VC-83-S2		5.9 to 7.9	-23.7 to -25.7	0	4	51	45
HC-VC-84-S1		0 to 1.4	-17.6 to -19	1	18	46	35
HC-VC-84-S2		2 to 4.9	-19.6 to -22.5	0	13	48	39
HC-VC-85-S1		0 to 4.5	-16.3 to -20.8	0	10	65	25
HC-VC-85-S2		4.7 to 7.1	-21 to -23.4	0	69	22	9
Diver Core Samples							
HC-DC-86-S1		0 to 1.9	-16 to -17.9	5	53	36	6
HC-DC-86-S2		1.9 to 3.8	-17.9 to -19.8	4	51	40	5
HC-DC-87-S1		0 to 2.3	-15 to -17.3	3	47	36	14
HC-DC-208	Dup of HC-DC-87-S1	0 to 2.3	-15 to -17.3	4	47	31	18
HC-DC-87-S2		2.3 to 3.8	-17.3 to -18.8	0	12	55	33
HC-DC-88-S1		0 to 1.6	-4.5 to -6.1	10	70	13	7
HC-DC-88-S2		1.6 to 3.8	-6.1 to -8.3	12	39	30	19
HC-DC-89-S1		0 to 1.6	-4 to -5.6	21	59	13	7
HC-DC-89-S2		1.6 to 3.8	-5.6 to -7.8	10	43	32	15
HC-DC-90-S1		0 to 1.6	-2 to -3.6	2	24	49	25
HC-DC-90-S2		1.6 to 3.8	-3.6 to -5.8	0	29	45	26
HC-DC-91-S1		0 to 1.6	-3 to -4.6	13	68	13	6
HC-DC-91-S2		1.6 to 3	-4.6 to -6	3	65	11	21
HC-DC-92-S1		0 to 1.4	-5 to -6.4	19	74	6	1
HC-DC-92-S2		1.4 to 2.8	-6.4 to -7.8	16	75	5	4
HC-DC-93-S1		0 to 2	-5 to -7	25	64	9	2
Reference Samples							
CR-02		0 to .3	-15.4 to -15.7	0	14	78	8
CR-22		0 to .3	-16.5 to -16.8	0	85	12	3
CR-24		0 to .3	-14 to -14.3	0	30	62	8
Sediment Trap Samples							
HC-ST-100 (A)				0	1	53	46
HC-ST-100 (B)	GS DUP			0	2	51	47
HC-ST-100 (C)	GS DUP			0	2	50	48
HC-ST-101			-14	0	3	53	44

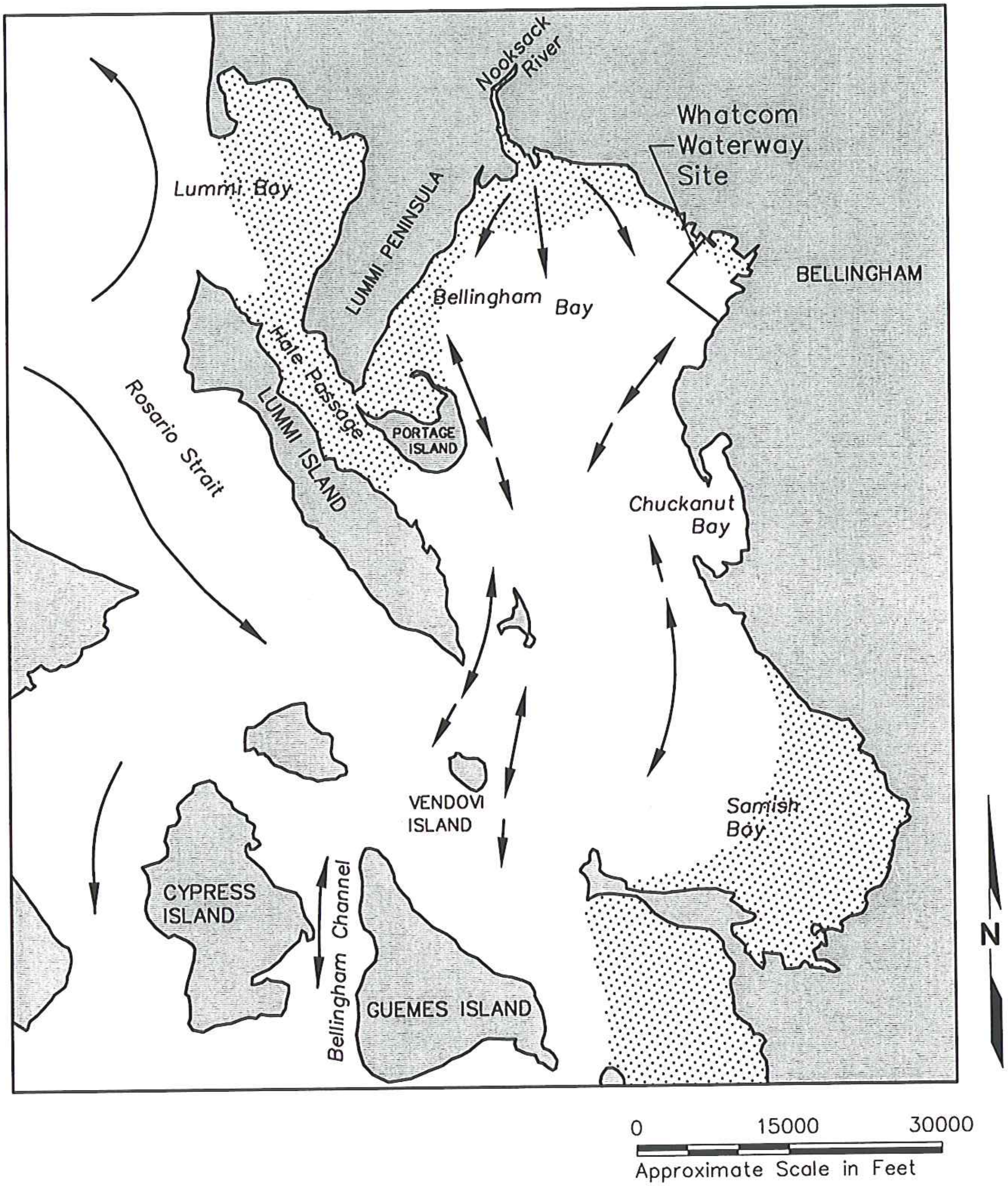
447806/Whatcom Waterway RI/Whatcom.xls - Table 3-2

Table 3-3 - Summary of Average Sediment Densities in Selected Short Cores

Natural Recovery Core Number	Average Sediment Wet Density in g/cm^3		Average Sediment Dry[1] Density in g/cm^3	
	Surface (0 to -10 cm)	Subsurface (-10 to -115 cm)	Surface (0 to -10 cm)	Subsurface (-10 to -115 cm)
HC-NR-100	1.32	1.32	0.47	0.52
HC-NR-101	1.26	1.30	0.42	0.49
HC-NR-102	1.33	1.36	0.54	0.59

Notes:
1. Sediment Dry Density = Wet Density·(%Solids/100)

Net Current Directions in Greater Bellingham Bay



▨ Shoal Areas
(< 20 Feet MLLW)

→ Net Current Drift Directions
Inferred from Puget Sound
Environmental Atlas (1987)
and Collias (1966)

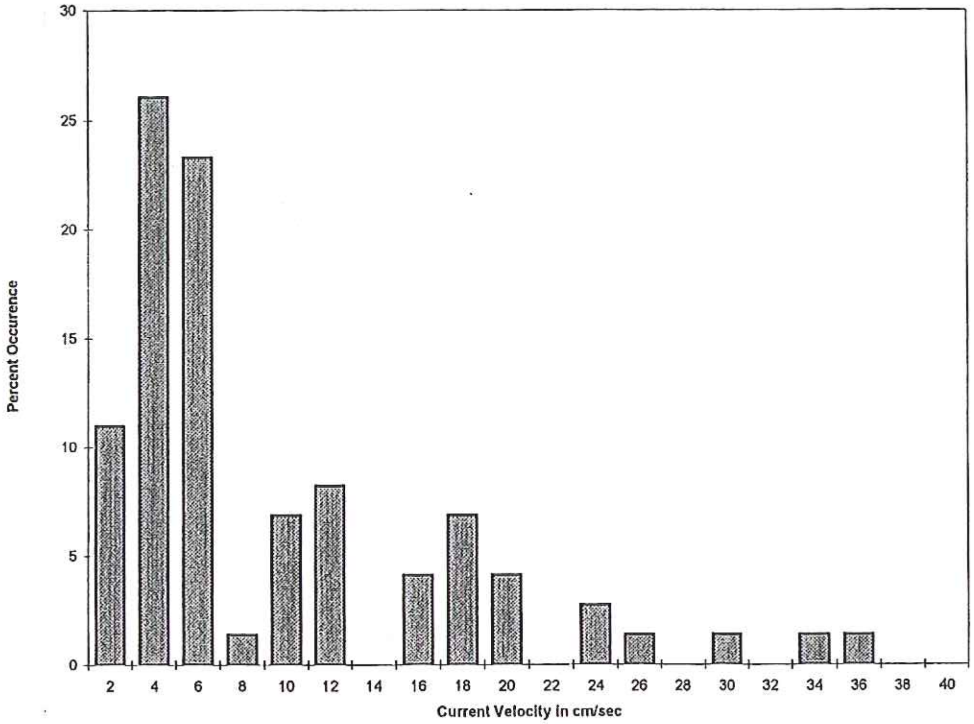
HARTCROWSER
J-4478-06 6/98
Figure 3-1

jch 6/29/98 1=15000 ..stk.pcp
44780645

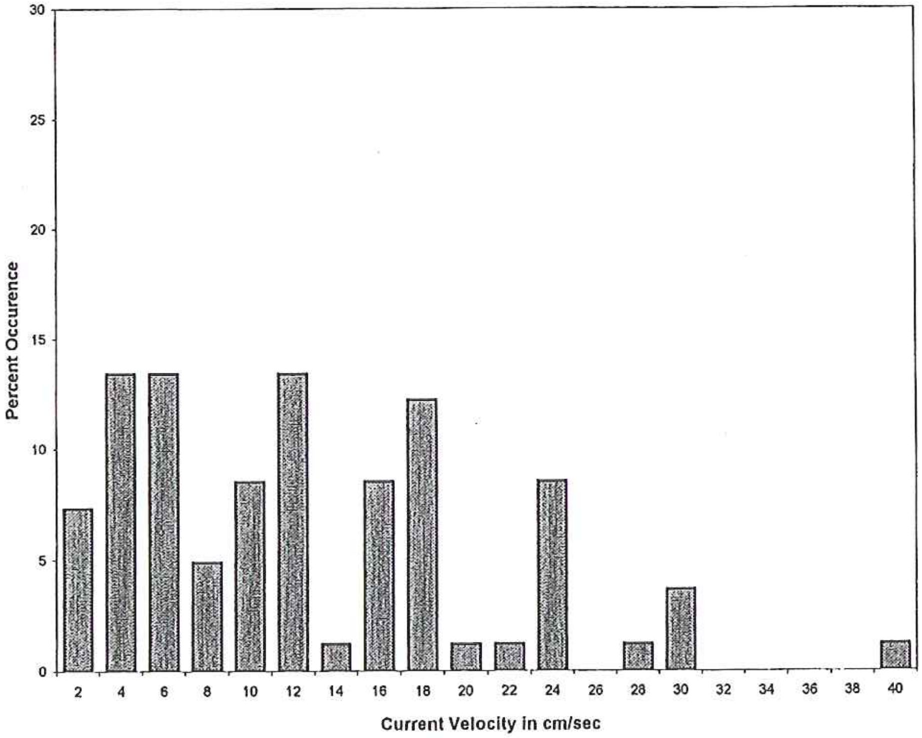
Distribution of Current Velocities

Inner Bellingham Bay

Shallow Current Velocities



Deep Current Velocities



Note: Shallow velocities from less than 2 meter depth below water surface.
Deep velocities from greater than 2 meter depth below water surface.

Data from Colyer (1998)

HARTCROWSER

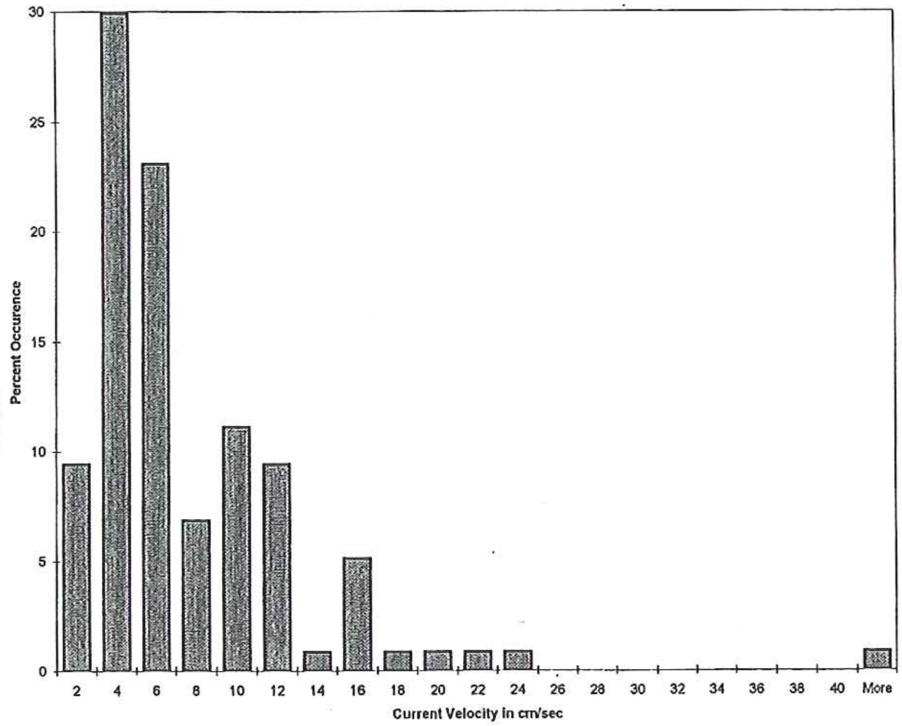
J-4478-06 6/98

Figure 3-2 1 of 2

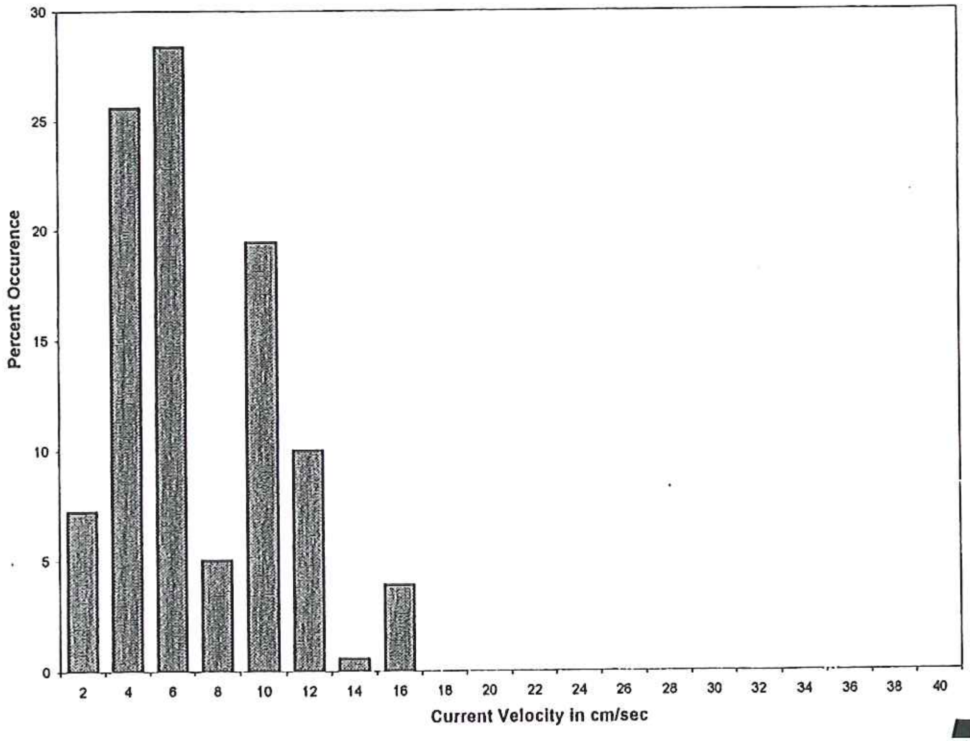
Distribution of Current Velocities

Whatcom Waterway

Shallow Current Velocities



Deep Current Velocities



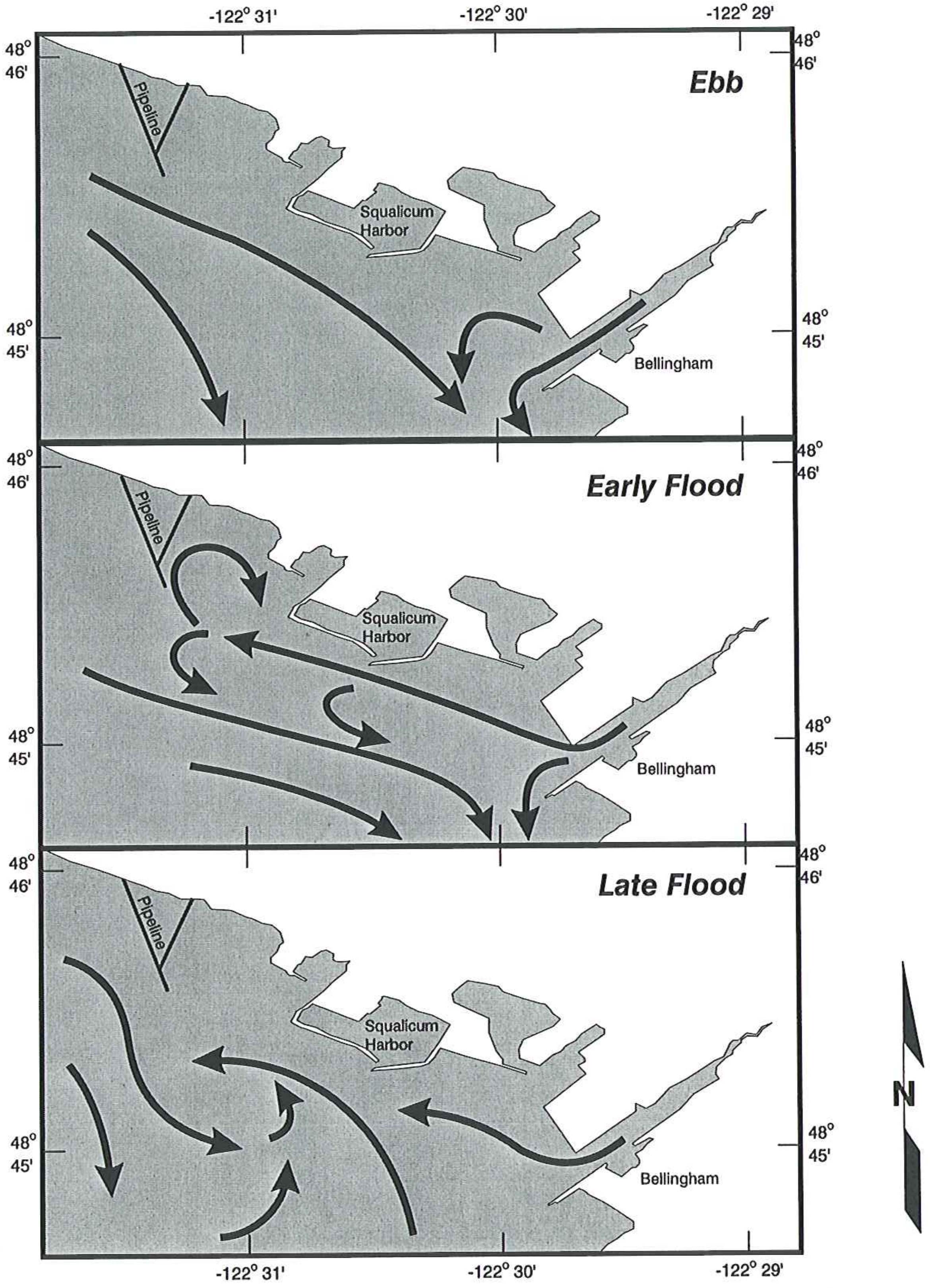
Note: Shallow velocities from less than 2 meter depth below water surface.
Deep velocities from greater than 2 meter depth below water surface.

Data from Colyer (1998)

HARTCROWSER

J-4478-06 **6/98**
Figure 3-2 **2 of 2**

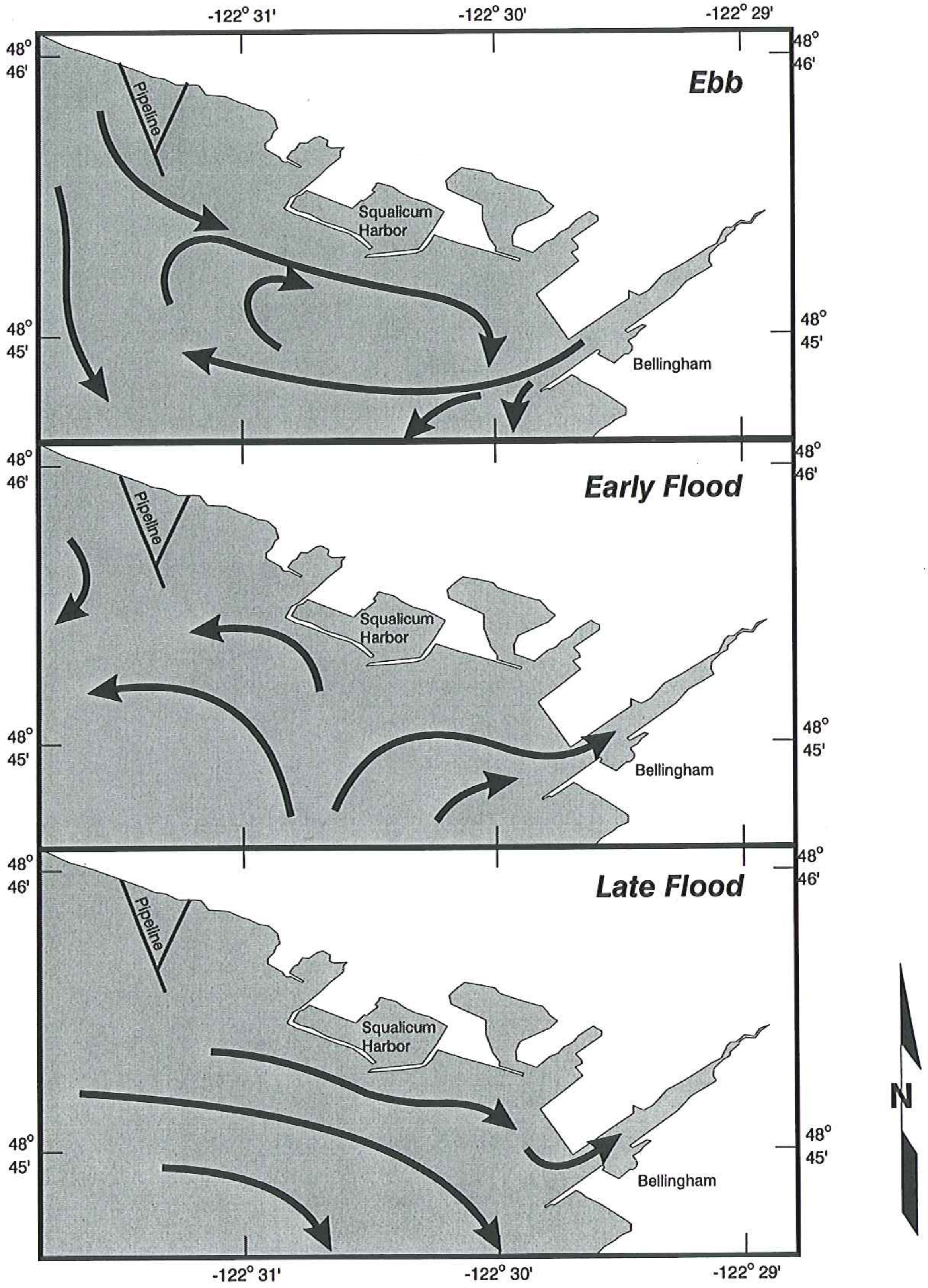
Inferred Shallow-Water Circulation Patterns
Whatcom Waterway Site



core\jobs. ..d\SCurrent

HARTCROWSER
J-4478-08 6/98
Figure 3-3 1 of 2

Inferred Deep-Water Circulation Patterns
Whatcom Waterway Site



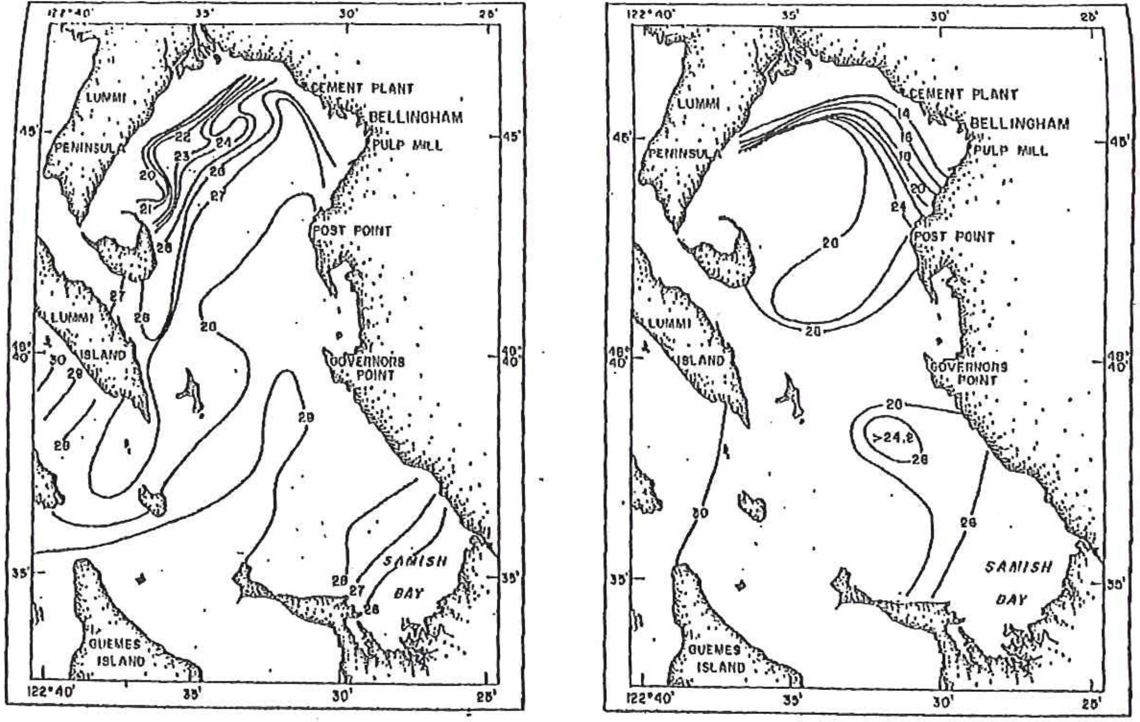
core\jobs\4478[illegible]current

HARTCROWSER

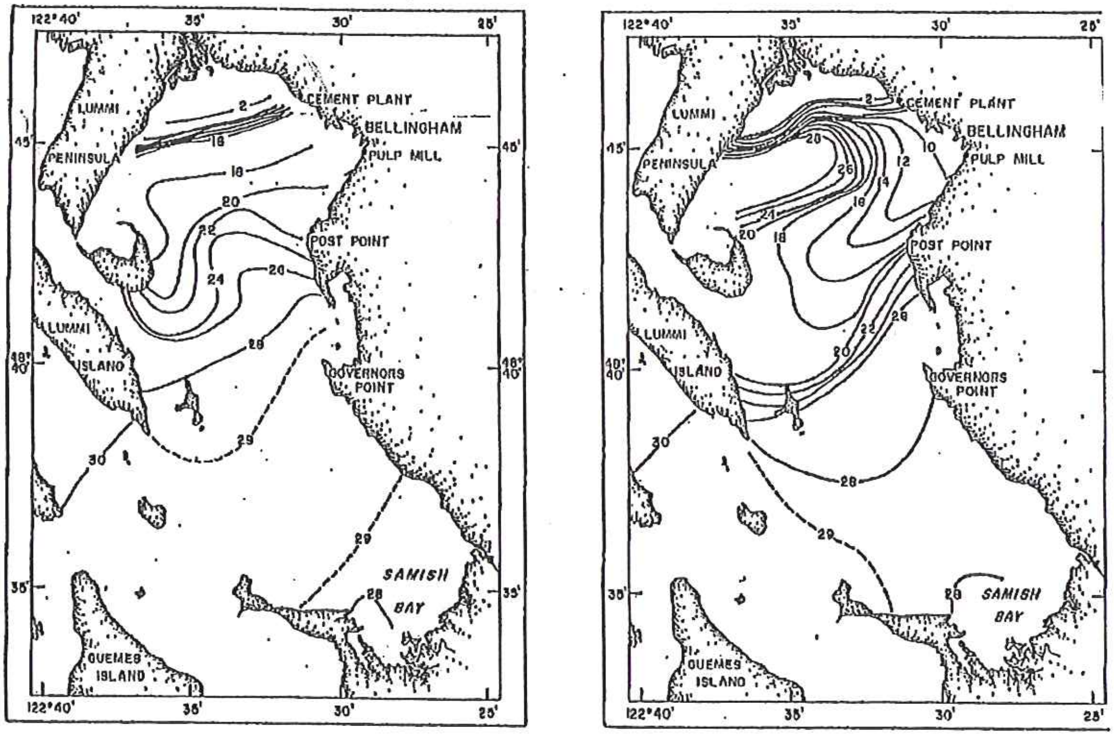
J-4478-08 6/98

Figure 3-3 2 of 2

Surface Salinity Distributions in Bellingham Bay



November 1959 **April 1960**



May 1960 **June 1960**

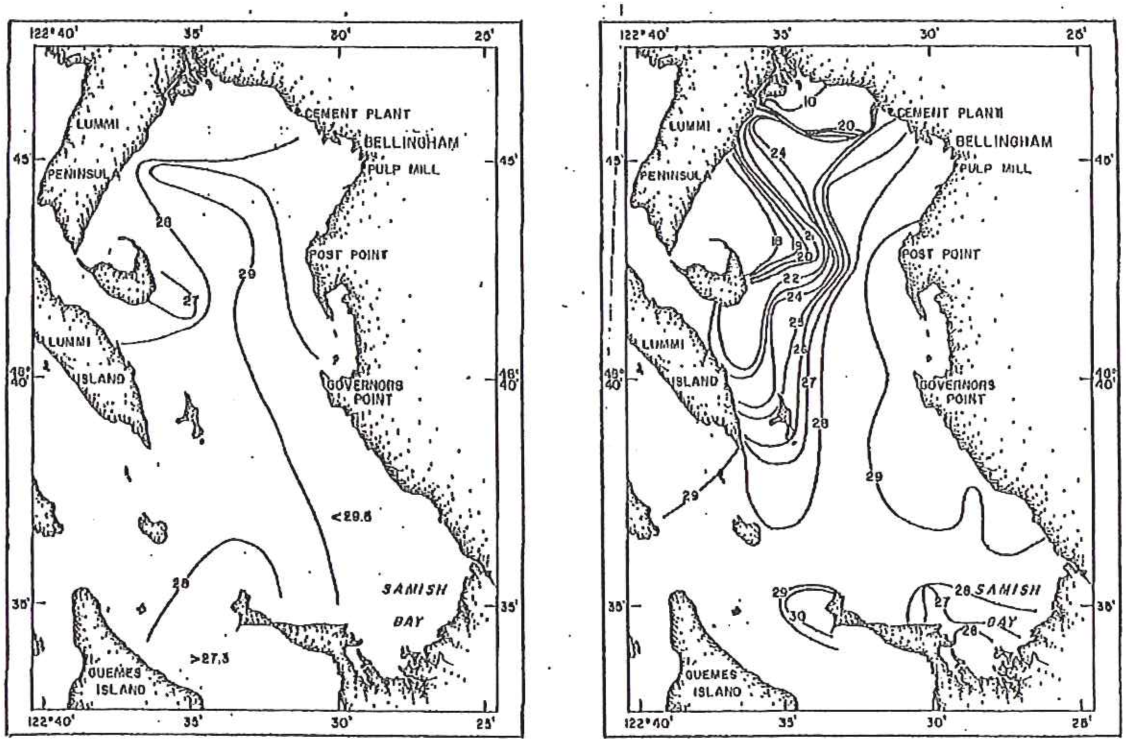
From Collias et al. 1966

HARTCROWSER

J-4478-06 6/98

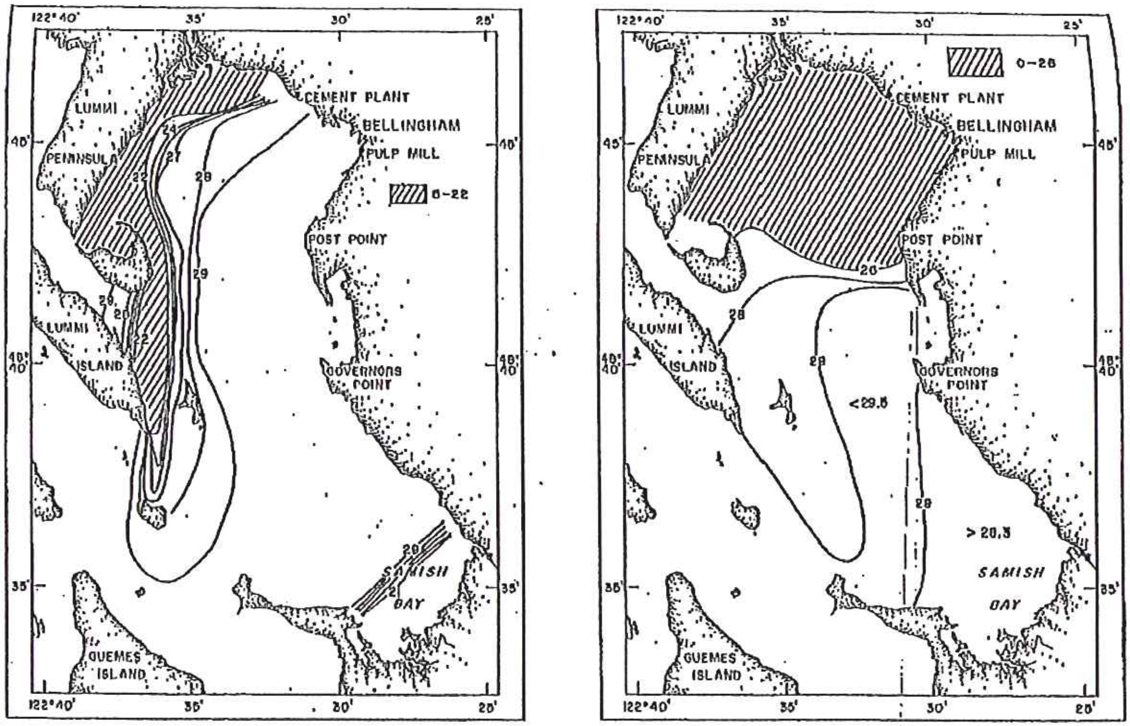
Figure 3-4 1 of 2

Surface Salinity Distributions in Bellingham Bay



September 1960

November 1960



December 1960

February 1961

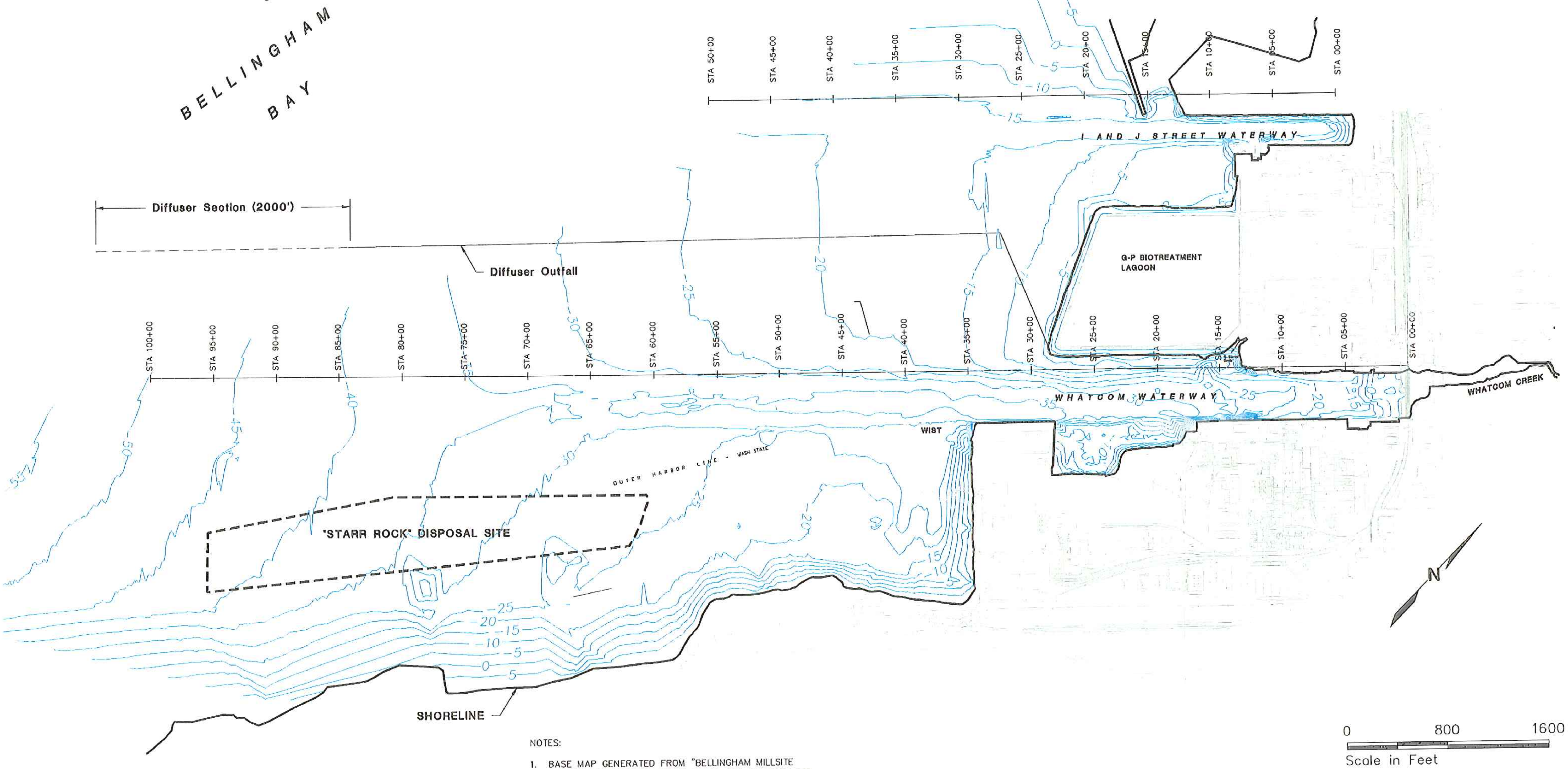
From Collias et al. 1966

HARTCROWSER

J-4478-06 6/98

Figure 3-4 2 of 2

Bathymetric Contour Map
Whatcom Waterway Area



NOTES:

1. BASE MAP GENERATED FROM "BELLINGHAM MILLSITE PLOT PLAN" BY CASCADE AERIAL MAPS AND SURVEYS, INC. DATED JULY 1990, SUPPLIED BY GEORGIA-PACIFIC CORPORATION.

2. WHATCOM WATERWAY BATHYMETRY DATA FROM DRAFT AUGUST 1994 SURVEY BY U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT. I & J STREET WATERWAY BATHYMETRY DATA FROM 1992 SURVEY BY U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT.

3. WW AREA BATHYMETRY DATA FOR NON-MAINTAINED CHANNEL AREAS OBTAINED FROM SEPTEMBER 1996 BLUE WATER ENGINEERING (BWE) SURVEY AS PART OF RI/FS WORK PLAN STUDY.

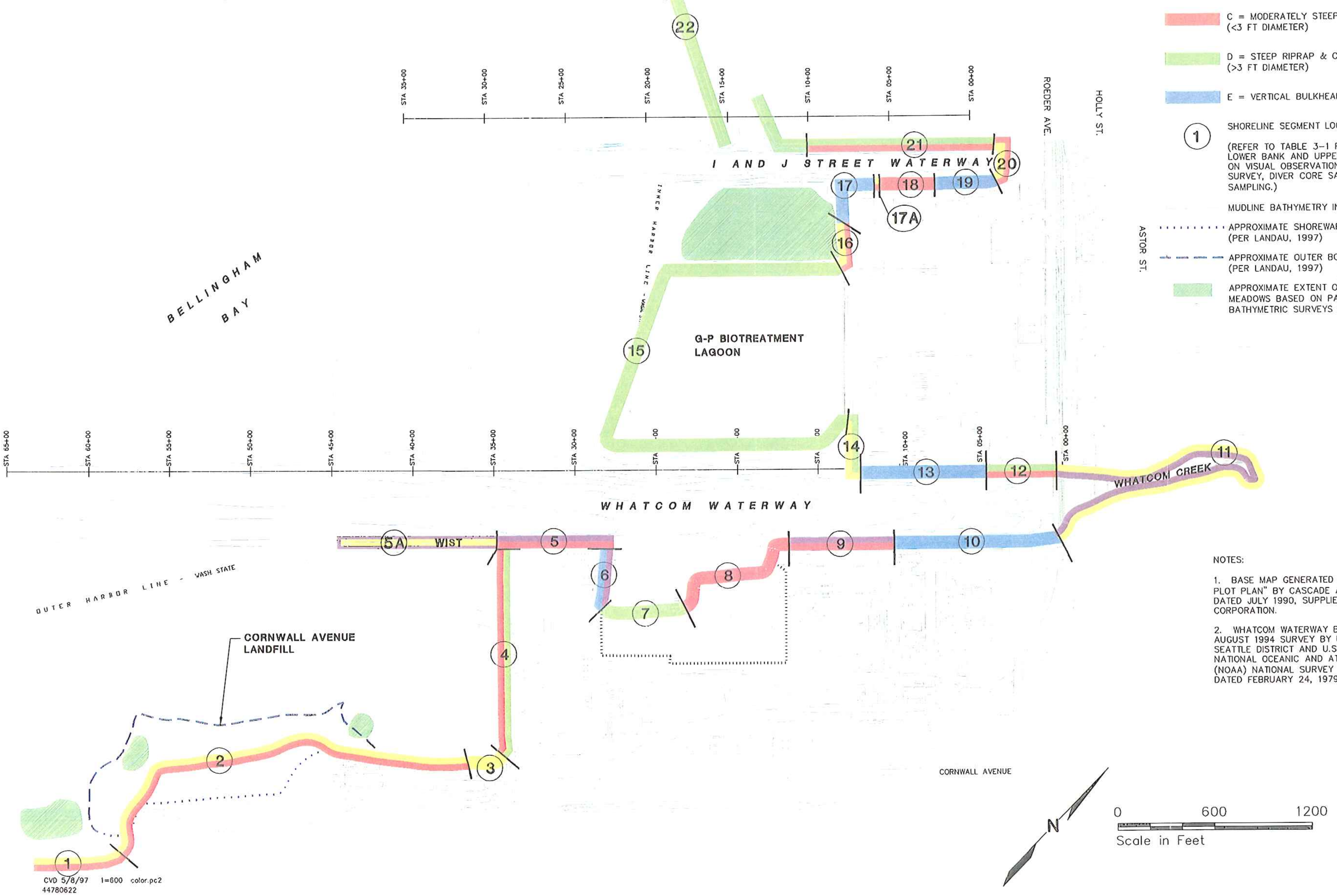
—— 5 —— MUDLINE BATHYMETRY IN FEET
CONTOUR INTERVAL = 5 FEET

jch 6/24/98 1=800 color.pc2
44780621

HARTCROWSER
J-4478-06 6/98
Figure 3-5

Site Plan Showing Shoreline Structures and Habitats

Whatcom Waterway Area



SHORELINE CATEGORY

🟪 A = SOFT SILT SUBSTRATE

🟨 B = SAND & SMALL GRAVEL SUBSTRATE

🟥 C = MODERATELY STEEP GRAVEL AND RIPRAP ARMORED BEACH (<3 FT DIAMETER)

🟩 D = STEEP RIPRAP & CONCRETE DEBRIS SLOPE (>3 FT DIAMETER)

🟦 E = VERTICAL BULKHEAD

① SHORELINE SEGMENT LOCATION AND NUMBER

(REFER TO TABLE 3-1 FOR DETAILED INFORMATION REGARDING LOWER BANK AND UPPER BANK SUBSTRATES. CATEGORIES BASED ON VISUAL OBSERVATIONS CONDUCTED DURING SHORELINE VIDEO SURVEY, DIVER CORE SAMPLING, BATHYMETRY SURVEY, AND WATER SAMPLING.)

MUDLINE BATHYMETRY IN FEET (MLLW)

⋯⋯ APPROXIMATE SHOREWARD BOUNDARY OF LANDFILL (PER LANDAU, 1997)

– – – APPROXIMATE OUTER BOUNDARY OF SURFACE DEBRIS (PER LANDAU, 1997)

🟩 APPROXIMATE EXTENT OF EXISTING EEL GRASS PATCHES AND MEADOWS BASED ON PALM (1995), LANDAU (1997), AND RI BATHYMETRIC SURVEYS (HART CROWSER, RI STUDY)

NOTES:

1. BASE MAP GENERATED FROM "BELLINGHAM MILLSITE PLOT PLAN" BY CASCADE AERIAL MAPS AND SURVEYS, INC. DATED JULY 1990, SUPPLIED BY GEORGIA-PACIFIC CORPORATION.

2. WHATCOM WATERWAY BATHYMETRY DATA FROM DRAFT AUGUST 1994 SURVEY BY U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT AND U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) NATIONAL SURVEY 19TH EDITION CHART 18423, DATED FEBRUARY 24, 1979.

CVD 5/8/97 1=600 color.pc2
44780622

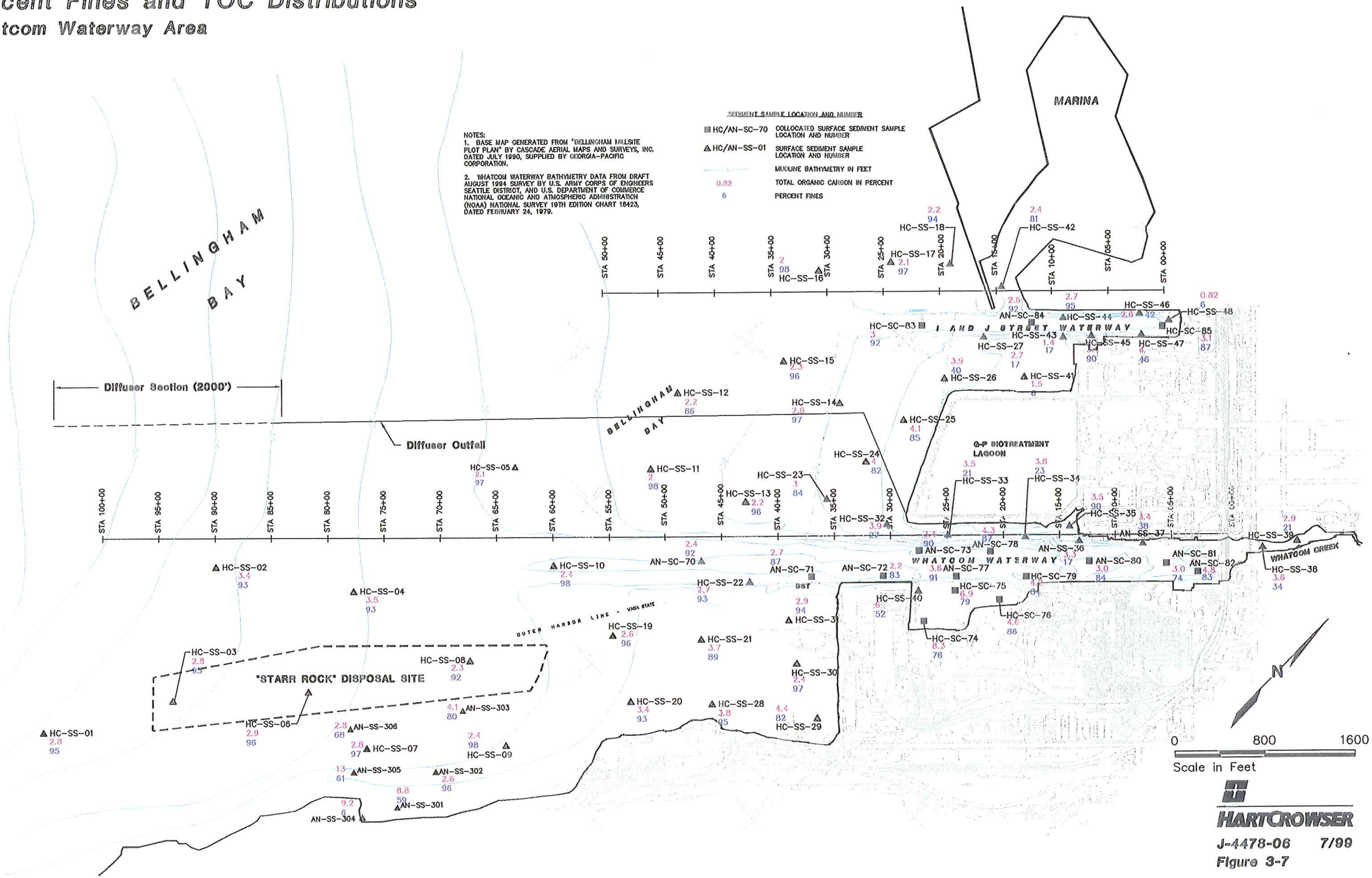
HARTCROWSER

J-4478-06 *5/97*

Figure 3-6

Percent Fines and TOC Distributions

Whatcom Waterway Area



NOTES:
1. BASE MAP GENERATED FROM "BELLINGHAM MILLSITE PLOT PLAN" BY CASCADE AERIAL MAPS AND SURVEYS, INC. DATED JULY 1990, SUPPLIED BY GEORGIA-PACIFIC CORPORATION.

2. WHATCOM WATERWAY BATHYMETRY DATA FROM DRAFT AUGUST 1994 SURVEY BY U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT, AND U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) NATIONAL SURVEY 19TH EDITION CHART 18423, DATED FEBRUARY 24, 1979.

SEDIMENT SAMPLE LOCATION AND NUMBER

■ HC/AN-SC-70	COLLOCATED SURFACE SEDIMENT SAMPLE LOCATION AND NUMBER
△ HC/AN-SS-01	SURFACE SEDIMENT SAMPLE LOCATION AND NUMBER
—5—	MUDLINE BATHYMETRY IN FEET
0.82	TOTAL ORGANIC CARBON IN PERCENT
6	PERCENT FINES

HARTCROWSER

J-4478-06 7/99

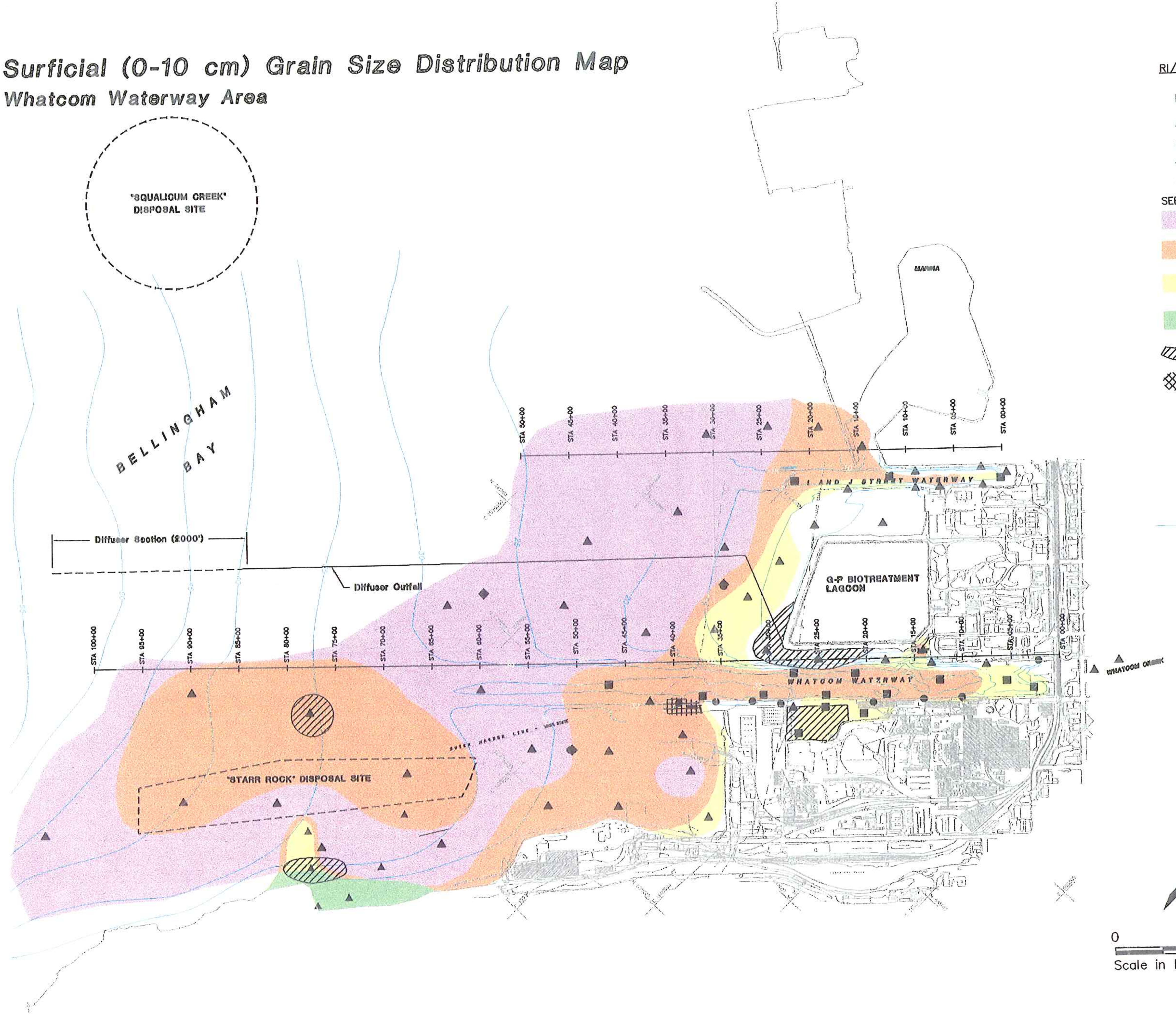
Figure 3-7

07/15/99 1=800 color.pc2

44780644

Surficial (0-10 cm) Grain Size Distribution Map

Whatcom Waterway Area



RI/FS SEDIMENT SAMPLE LOCATIONS

■ SUBSURFACE SEDIMENT VIBRACORE AND COLLOCATED SURFACE SEDIMENT SAMPLE

▲ SURFACE SEDIMENT SAMPLE

● UNDERPIER/SLOPE DIVER CORE

◆ NATURAL RECOVERY CORE

◎ SEDIMENT TRAP DEPLOYMENT

SEE FIGURES 3-2 AND 3-3 FOR SAMPLE NUMBERS

🟪 CLAYEY SILT

🟧 SLIGHTLY SANDY, CLAYEY TO VERY CLAYEY SILT

🟨 SANDY TO VERY SANDY SILT WITH VARYING AMOUNTS OF CLAY

🟩 SLIGHTLY CLAYEY, SILTY SAND WITH VARYING AMOUNTS OF GRAVEL

▨ >50% WOOD

▦ >50% SHELL FRAGMENTS

—5— MUDLINE BATHYMETRY IN FEET (MLLW)

NOTES:

1. BASE MAP GENERATED FROM "BELLINGHAM MILLSITE PLOT PLAN" BY CASCADE AERIAL MAPS AND SURVEYS, INC. DATED JULY 1990, SUPPLIED BY GEORGIA-PACIFIC CORPORATION.

2. WHATCOM WATERWAY BATHYMETRY DATA FROM DRAFT AUGUST 1994 SURVEY BY U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT AND U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) NATIONAL SURVEY 19TH EDITION CHART 18423, DATED FEBRUARY 24, 1979.

N

0 1000 2000
Scale in Feet

HARTCROWSER
J-4478-06 7/99
Figure 3-8

07/16/99 1=1000
88Y039-02.dwg

Site Plan Showing Wood Distribution In Nearshore Sediments
Whatcom Waterway Area

HARTCROWSER
J-4478-06 7/99
Figure 3-9

Site Plan Showing Profile and Cross Section Locations

Whatcom Waterway Area

NOTES:

1. BASE MAP GENERATED FROM "BELLINGHAM MILLSITE PLOT PLAN" BY CASCADE AERIAL MAPS AND SURVEYS, INC. DATED JULY 1990, SUPPLIED BY GEORGIA-PACIFIC CORPORATION.

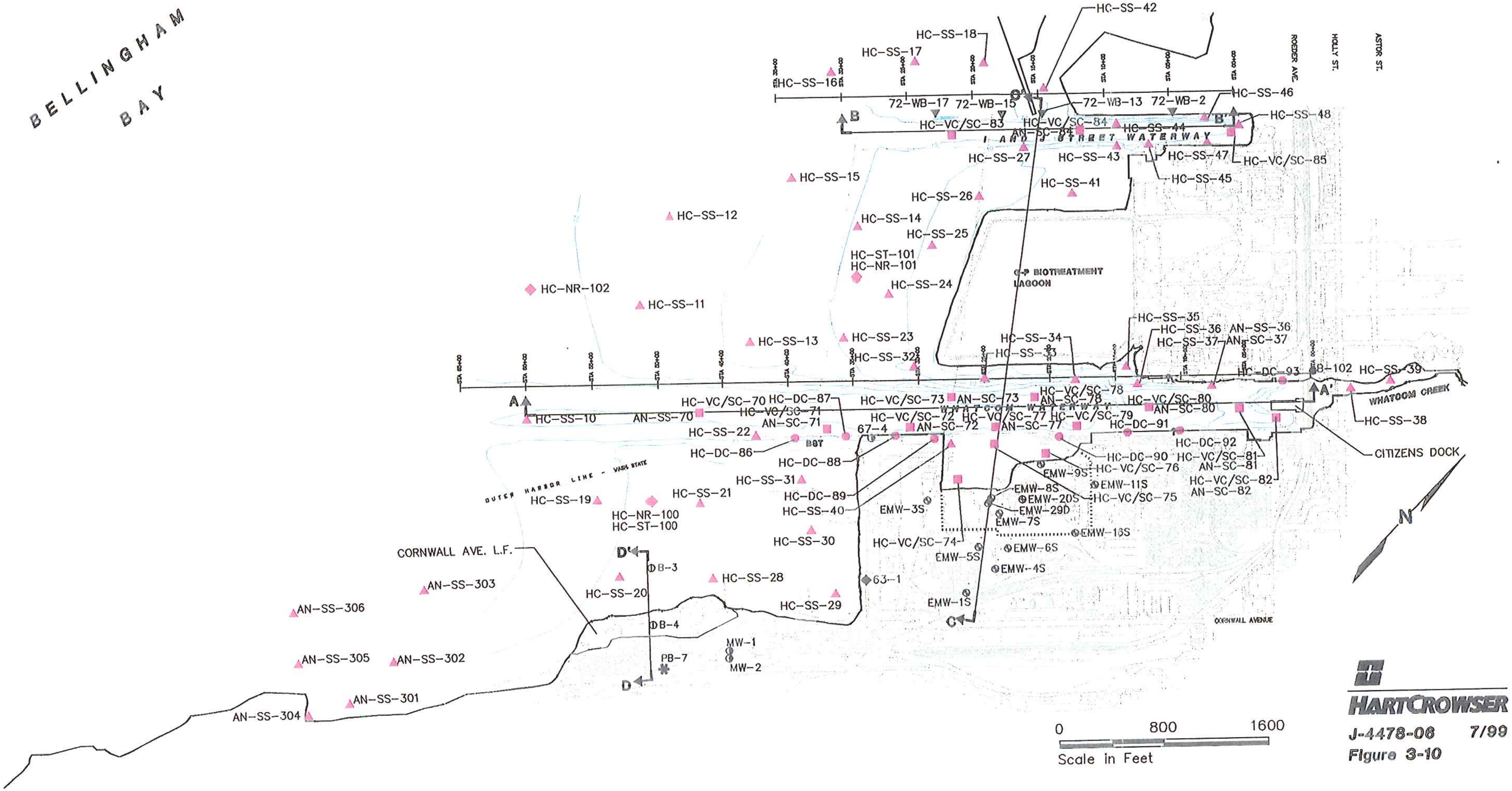
2. WHATCOM WATERWAY BATHYMETRY DATA FROM DRAFT AUGUST 1994 SURVEY BY U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT, AND U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) NATIONAL SURVEY 19TH EDITION CHART 18423, DATED FEBRUARY 24, 1979.

RI/FS SEDIMENT SAMPLE LOCATION AND NUMBER

■ HC-VC-70/SC-70	SUBSURFACE SEDIMENT SAMPLE
▲ HC/AN-SS-01	SURFACE SEDIMENT SAMPLE
● HC-DC-86	UNDERPIER/SLOPE DIVER CORE
◆ HC-NR-101	NATURAL RECOVERY CORE
◎ HC-ST-101	SEDIMENT TRAP DEPLOYMENT
AA'	PROFILE/CROSS SECTION LOCATION AND DESIGNATION

EXISTING BORING LOCATION AND NUMBER

✱ PB-7	PORT OF BELLINGHAM
● B-102	CONVERSE CONSULTANTS NW, JUNE 1989. GEOTECH BORING FOR PROPOSED ROEDER AVE. BRIDGE REHAB PROJECT
⦶ 67-4	DAMES AND MOORE BORING , OCTOBER 1967. GEOTECH BORING NORTH TERMINAL PROJECT.
⦶ B-3	DAMES AND MOORE BORING, 1960
▼ 72-WB-13	CORPS, 1971. GEOTECHNICAL WASH. BORINGS FOR SMALL BOAT BASIN FOUNDATION FILE #E-9-7-39
⦶ EMW-9S	ENSR, 1994. RI/FS SHALLOW MONITORING WELLS FOR G-P PLANT.
⦶ MW-1	E & E, 1986. R.G. HALEY INTERNATIONAL CORP. MONITORING WELL.
◆ 63-1	DAMES AND MOORE BORING, 1963



07/15/99 1=800
4478O647

HARTCROWSER

J-4478-06 7/99

Figure 3-10

4.0 SEDIMENT CHEMICAL DETERMINATIONS

This section discusses chemical testing results for surface and subsurface sediment samples collected during the Remedial Investigation (RI) of the Whatcom Waterway site. Approximately 179 sediment samples were collected during the RI and subsequent field efforts, at locations depicted on Figure 2-2. Samples were obtained using standard field procedures outlined in Appendix A. Validated chemical analytical results for these samples are presented in Appendix B. A brief review of laboratory data quality, a comparison of sample results to the Washington State Sediment Management Standards (SMS) regulatory criteria, and descriptions of the spatial distributions of key site contaminants are discussed below.

4.1 Sediment Sampling Objectives

A primary objective of the RI sediment sampling and chemical analysis was to characterize the horizontal and vertical extent of sediments which exceed the Sediment Quality Standards (SQSs) and Minimum Cleanup Levels (MCULs) chemical criteria set forth in the SMS. Along with the results of confirmatory biological testing discussed in Section 5.0 and human health evaluations discussed in Section 6.0, these data define the extent of sediments that may require remediation. In addition, the surface sediment chemistry data identify chemicals of potential concern targeted for upland source evaluations discussed in Section 8.0.

The SMS set forth a cleanup decision process for identifying contaminated sediment areas and determining appropriate remedial responses. The SMS establish two sets of numerical chemical criteria against which surface sediment chemical concentrations are evaluated.

The more conservative Sediment Quality Standard (SQS) provides a regulatory goal by identifying surface sediments that are predicted to have no adverse effects on biological resources. The higher Minimum Cleanup Level (MCUL) identifies sediments which may represent minor adverse effects to some sensitive species. Ecology selects a site-specific cleanup standard between these two levels, as close as practicable to the SQS but no higher than the MCUL, taking into consideration environmental benefit, cost, and technical feasibility.

For this RI/FS, bioassay testing, including two acute toxicity tests and one chronic toxicity test, was performed at several locations to confirm or refute predictions of adverse effects based on sediment chemistry (see Section 5. 0). In addition, a conservative bioaccumulation assessment was performed to evaluate protection of human health and the environment (see Section 6.0).

included in the summary statistics. In addition, exceedance frequencies presented in Table 4-2 represent the number of exceedences out of the total number of sample results with acceptable reporting limits. Listings of individual surface sample results that exceeded the SQS and MCUL chemical criteria are presented in Tables 4-3 and 4-4, respectively.

Of the more than 100 chemicals analyzed, only seven were detected in surface sediments at concentrations exceeding SQS chemical criteria. In order of descending frequency of exceedance relative to SQS chemical criteria, the following analytes were elevated in surface sediments within the WW Area at concentrations above SQS chemical criteria:

- Mercury (76% exceeding SQS);
- Phenol (33% exceeding SQS);
- 4-Methylphenol (14% exceeding SQS);
- Bis(2-ethylhexyl) phthalate (4% exceeding SQS; two samples only);
- Benzoic Acid (2% exceeding SQS; one sample only);
- Acenaphthene (2% exceeding SQS; one sample only); and
- Hexachlorobenzene (2% exceeding SQS; one sample only).

4.3.2 Subsurface Sediment Exceedences of SMS Criteria

Statistical summaries of subsurface sediment chemical results, including vibracore samples and underpier samples collected by diver, are presented in Table 4-5. Listings of individual subsurface sample results that exceeded the SQS and MCUL chemical criteria are presented in Tables 4-6 and 4-7, respectively. The following analytes were elevated in subsurface sediments at concentrations above SMS chemical criteria:

- Mercury (70% exceeding SQS);
- 4-Methylphenol (42% exceeding SQS);
- 2,4-Dimethylphenol (13% exceeding SQS);
- Acenaphthene (11% exceeding SQS);
- Hexachlorobenzene (11% exceeding SQS);
- Dibenz(a,h)anthracene (7% exceeding SQS);
- Butyl benzyl phthalate (7% exceeding SQS);
- Zinc (5% exceeding SQS);
- Dibenzofuran(5% exceeding SQS);
- Fluoranthene (5% exceeding SQS);
- Chrysene (5% exceeding SQS);
- Phenol (4% exceeding SQS);
- Pentachlorophenol (4% exceeding SQS);
- Total Benzofluoranthenes (4% exceeding SQS);
- Fluorene (4% exceeding SQS);
- Cadmium (2% exceeding SQS, one sample only);
- 2-Methylphenol (2% exceeding SQS, one sample only

- Benz(a)anthracene (2% exceeding SQS, one sample only);
- Indeno(1,2,3-c,d)pyrene (2% exceeding SQS, one sample only);
- Pyrene (2% exceeding SQS, one sample only);
- Phenanthrene (2% exceeding SQS, one sample only);
- Bis(2-ethylhexyl) phthalate (2% exceeding SQS; one samples only);
- Benzoic Acid (2% exceeding SQS; one sample only).

4.4 Identification of Key Constituents

The constituents, which exceeded the SMS chemical criteria in surface and subsurface sediments, were reduced to a list of key constituents of concern using MCUL exceedance statistics. Constituents were ranked independently on the basis of exceedance frequency (number of samples exceeding MCUL per number of samples analyzed with detection limits at or below MCUL) and maximum enrichment ratio (ratio of maximum sample concentration to MCUL concentration). The ranking scores based on these two statistics were added to produce a combined ranking score, and the combined ranking score was sorted to produce the ordered list of constituents in Table 4-8. Constituents with highest combined ranking scores exhibit the highest percentage of MCUL exceedences and also the most elevated concentrations relative to MCULs.

This ranking scheme provides a means of prioritizing waterway pollutants to focus investigation and remedial engineering efforts. However, other factors—in particular human health risks—may need to be considered in the prioritization of waterway pollutants and selection of a cleanup action.

4.4.1 Key Constituents in Surface Sediments

Based on the MCUL exceedance statistics in Table 4-8, the following chemicals were selected as key constituents of concern in the surface sediments of the WW Area:

- Mercury;
- 4-Methylphenol; and
- Phenol.

These constituents are intended to serve as indicator chemicals or surrogates for the major groups of contaminants in waterway sediments. In particular, the distribution and magnitude of MCUL exceedences of these key constituents should encompass SQS exceedences of other lesser priority chemicals, and thus help to circumscribe and delineate remedial action areas.

Acenaphthene, benzoic acid, hexachlorobenzene, and bis(2-ethylhexyl)phthalate exceeded their SQS chemical criteria but exceedences were rare. One sample result (HC-SC-76) exceeded the SQS and MCUL criteria for benzoic acid (650 μg/kg for both criteria). Concentrations of acenaphthene and hexachlorobenzene exceeded the SQS in one sample each (HC-SS-47 and HC-SS-34, respectively); however, the concentrations of these compounds did not exceed the MCUL. Bis(2-ethylhexyl)phthalate exceeded the SQS criteria in 2 of 49 samples. Only one of these samples (HC-SS-47 in the I&J Street Waterway) exceeded the MCUL of 78 mg/kg-OC; however, this sample had a high enrichment ratio (15 times the SQS and 9 times the MCUL).

4.4.2 Key Constituents in Subsurface Sediments

A similar ranking of constituents was performed using a data set of subsurface core samples, and is presented in Table 4-8. The following chemicals were selected as key constituents of concern in the subsurface sediments of the WW Area:

- Mercury;
- 4-Methylphenol; and
- 2,4-Dimethylphenol.

Mercury and 4-methylphenol have similar ranks in subsurface sediments compared to surface sediments. However, 2,4-dimethylphenol did not exceed its SQS/MCUL criteria in any surface sediments within the WW Area.

Three subsurface sediment sample results for zinc and one sample result for cadmium marginally exceeded the SQS criteria for these metals (maximum exceedences of 1.4 and 1.1 times the SQS, respectively). None of these metal concentrations exceeded their respective MCUL. The sample locations of mercury MCUL exceedences encompass these SQS exceedences, with the following exception. One sample near the head of Whatcom Waterway (HC-DC-93-S1) had concentrations of zinc above the SQS, but mercury concentrations were not detected.

Unusual enrichments of several semivolatile constituents appear in subsurface sediments that are evidently not present at the surface. Concentrations of seven high molecular weight polycyclic aromatic hydrocarbons (HPAHs) and four low molecular weight polycyclic aromatic hydrocarbons (LPAHs) exceeded their SQS criteria in at least one subsurface sediment sample. Only one HPAH—flouranthene—was present at concentrations above the MCUL (sample HC-DC-87-S1). Two LPAHS—fluorene and phenanthrene—as well as total LPAHs were also present at concentrations above the MCUL in sample HC-DC-87-S1. Benzoic acid exceeded its MCUL in HC-DC-90-S2. These MCUL exceedences are associated with samples collected from underpier areas and could be derived from treated pilings. Isolated MCUL exceedences of these semivolatile compounds are all constrained by higher enrichments of the key constituents.

Concentrations of several other semivolatile organics exceeded the SQS, but were below the MCUL (see Section 4.3).

4.5 Spatial and Vertical Distribution of Key Constituents

The areal distributions of SQS and MCUL exceedences for the surface sediment constituents of potential concern—mercury, phenol, and 4-methylphenol—are presented on Figures 4-1 and 4-2. The distributions of SQS and MCUL exceedences for the key constituents in subsurface sediments are presented in cross sections through the Whatcom Waterway on Figures 4-3 and 4-4 and through the I&J Street Waterway on Figures 4-5 and 4-6. The following presents a summary of these distributions by analyte.

4.5.1 Total Mercury

Mercury exceeded the SQS criteria of 0.41 mg/kg in 62 of 82 surface samples; 39 of these samples also exceeded the MCUL of 0.59 mg/kg. As shown on Figure 4-1, concentrations of mercury were highest in the G-P Log Pond. Exceedences of the MCUL criteria for mercury were constrained to an area in outer Bellingham Bay near the diffuser section, the outer half of the Whatcom Waterway extending into inner Bellingham Bay, and near the Starr Rock Disposal Site. Concentrations of mercury above the SQS but below the MCUL were present in outer Bellingham Bay near the G-P outfall, at the head of Whatcom Waterway, within the I&J Street Waterway, and near the Starr Rock Disposal Site.

In general, mercury concentrations in surface sediments were significantly less than concentrations detected at depth (Figures 4-3 and 4-5), reflecting the implementation of source controls by G-P beginning in the early 1970s, and associated natural recovery of sediments in response to these source reductions (see Section 9.0). The maximum subsurface concentrations were detected near the G-P Log Pond, at depths of up to 10 feet below the sediment surface. The maximum concentration (69 mg/kg) was detected in HC-VC-74-S2, located at the 2- to 4-foot-depth interval. The vertical extent of contamination for mercury as well as other contaminants was generally contained within recent sediments consisting of very soft, organic-rich, clayey silt deposits which overlie the dredging horizon and native fluvial sediments.

4.5.2 Phenols

In general, concentrations of phenols appear to be correlated primarily with accumulations of wood or organic debris (Figure 3-9) and to some extent storm drains. Phenol can be derived from the natural degradation of plant matter. In addition, these compounds are fairly ubiquitous in storm drains near the site, based on data collected during Ecology's Drainage Basin Tracing Study (Cubbage, 1994). Phenolic compounds were detected in catch basin sediments at concentrations ranging from 510 to 2100 µg/kg for phenol, and 560 to 7,000 µg/kg for 4-methylphenol.

The highest concentrations of phenolic compounds were detected in the upper half of Whatcom Waterway. Phenolic compound concentrations generally increased with depth until contact with native (pre-dredge) sediments. A brief description of the distribution of three phenols identified as key constituents (4-methylphenol, phenol, and 2,4-dimethylphenol) is presented below.

4-Methylphenol. Concentrations of 4-methylphenol exceeded the SQS and MCUL criteria (both criteria are equivalent at 670 µg/kg) in 7 of the 49 surface sediment samples. The areal distribution of 4-methylphenol is presented on Figure 4-2. Maximum concentrations of 4-methylphenol were highest near the Starr Rock Disposal Site. Exceedences of both the SQS and MCUL criteria for 4-methylphenol in surface sediments were located in isolated hot spots within the Whatcom and I&J Street Waterways, and in the log storage area south of the WIST Pier.

In subsurface sediments, 23 of 55 sample results for 4-methylphenol exceeded the SQS/MCUL. The vertical distribution of 4-methylphenol in the Whatcom and I&J Waterways is presented on Figures 4-4 and 4-6. Similar to the vertical distribution of mercury, 4-methylphenol concentrations at the surface were also significantly less than concentrations detected at depth. This distribution may be indicative of reduced concentrations in discharges to the waterway over time or, alternatively, diagenic production of 4-methylphenol in buried sediments as a result of subsurface decomposition of organic matter. Maximum subsurface concentrations were detected in the center of Whatcom Waterway (HC-VC-80-S2) at the 2- to 5-foot-depth interval and at the head of Whatcom Waterway (HC-VC-82-S2) at a similar depth.

Phenol. Phenol exceeded the SQS criteria of 420 µg/kg in 16 of 49 surface samples. Five of these samples also exceeded the MCUL of 1,200 µg/kg. Maximum concentrations of phenol (2,200 µg/kg at HC-SS-06) were detected near the Starr Rock Disposal Site, as shown on Figure 4-2. Exceedences of the MCUL criteria for phenol were also located in isolated hot spots within the G-P Log Pond (HC-SC-74), near storm water outfalls (e.g., HC-SS-35), in the log storage area south of the WIST pier (HC-SS-30), and within the I&J Street Waterway (HC-SC-84). Concentrations of phenol were above the SQS but below the MCUL criteria in those same areas as well as at the head of the Whatcom Waterway.

Concentrations of phenol exceeding the SQS criteria were present near the head of Whatcom Waterway in only two (HC-VC-82-S2, HC-VC-82-S2) of 55 subsurface samples at depths ranging from 1.9 to 5.3 feet below the sediment surface. Neither of these samples exceeded the MCUL, suggesting that phenol may be degraded in the subsurface.

2,4-Dimethylphenol. Concentrations of 2,4-dimethylphenol were less than the SQS/MCUL criteria in all surface sediment samples located within the WW Area. Of the 55 subsurface sample results, seven samples exceeded the SQS/MCUL criterion for 2,4-dimethylphenol (29 μg/kg). The most elevated concentrations were detected in samples collected under the WIST pier (HC-DC-86 and HC-DC-89) and in the I&J Street Waterway (HC-VC-85, S2).

Data Qualifier Definitions

The following data qualifiers have been used in the following tables and figures based on a quality assurance review of the laboratory procedures and results:

U - Indicates the compound or analyte was analyzed for and not detected. The value reported is the sample quantitation limit corrected for sample dilution and moisture content by the laboratory.

UE - Indicates the compound or analyte was analyzed for and not detected. Due to quality control deficiencies identified during data validation the value reported may not accurately reflect the sample quantitation limit.

E - Indicates the compound or analyte was analyzed for and detected. The associated value is estimated but the data are usable for decision-making processes.

B - Analyte detected in samples and in associated method blank.

C - Combined with unresolved substances due to coelution.

G - Value greater than minimum shown.

Blanks in the following tables indicate samples were not analyzed for specific analyte.

Exceedance of SQS criteria

☐ Exceedance of MCUL criteria

Notes for Tables 4-1C and 4-1D

(1) Total benzofluoranthene criterion represents the sum of the concentrations of the b and k isomers. For those with concentrations that were not detected, the detection limit was used in the calculation. The "E" qualifier was attached to the Total benzofluoranthenes value if any of the contributing concentrations were denoted with that qualifier.

(2) Total LPAHs and HPAHs are sum of all contaminants within the subheading. For those with concentrations that were not detected, the detection limit was used in the calculation. The "E" qualifier was attached to the Total LPAHs or HPAHs value if any of the contributing concentrations were denoted with that qualifier.

Table 4-1A - Analytical Results for Surface Sediment Samples

Lab-ID	9609011-1	9609011-2	9609024-4	9609011-3	9609011-4	9609024-5	9609011-5	9609024-6
Sample-ID	HC-SS-01	HC-SS-02	HC-SS-03	HC-SS-04	HC-SS-05	HC-SS-06	HC-SS-07	HC-SS-08
Depth	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft
Sampling Date	9/03/96	9/03/96	9/06/96	9/03/96	9/03/96	9/06/96	9/03/96	9/06/96
Conventionals in pct. (dry)								
Moisture	70	70	67	66	63	68	62	61
Total Organic Carbon	2.8	3.4	2.8	3.5	2.1	2.9	2.8	2.3
Metals in mg/kg (dry)								
Arsenic			8.6			12		9.5
Cadmium			1.5 U			1.6 U		1.3 U
Chromium			55			65		57
Copper			37			45		43
Lead			9 U			11		11
Mercury	0.32 U	0.47	0.32	0.35	0.32	0.39	0.47	0.53
Silver			1.5 U			1.6 U		1.3 U
Zinc			72			81		78

Lab-ID	9609011-6	9609011-7	9609011-8	9609011-9	9609011-10	9609011-11	9609011-12	9609011-13
Sample-ID	HC-SS-09	HC-SS-10	HC-SS-11	HC-SS-12	HC-SS-13	HC-SS-14	HC-SS-15	HC-SS-16
Depth	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft
Sampling Date	9/03/96	9/03/96	9/03/96	9/03/96	9/04/96	9/04/96	9/04/96	9/04/96
Conventionals in pct. (dry)								
Moisture	64	66	61	56	60	70	60	58
Total Organic Carbon	2.4	2.4	2	2.2	2.2	2.6	2.3	2
Metals in mg/kg (dry)								
Arsenic								
Cadmium								
Chromium								
Copper								
Lead								
Mercury	0.5	0.44	0.47	0.23 U	1	0.77	0.67	0.47
Silver								
Zinc								

Table 4-1A - Analytical Results for Surface Sediment Samples

Lab-ID	9609011-20	9609012-4	9609012-5		
Sample-ID	HC-SS-46	HC-SS-47	HC-SS-48		
Depth	0 to .3 ft	0 to .3 ft	0 to .3 ft	SQS	
Sampling Date	9/05/96	9/04/96	9/05/96	Criteria	MCUL
Conventionals in pct. (dry)					
Moisture	55	50	23		
Total Organic Carbon	2.6	4	0.82		
Metals in mg/kg (dry)					
Arsenic		9.2 E	3.2 E	57	93
Cadmium		1.3	0.59 U	5.1	6.7
Chromium		49	17	260	270
Copper		51	16	390	390
Lead		24	11	450	530
Mercury	0.36	0.29	0.13 U	0.41	0.59
Silver		1 U	0.59 U	6.1	6.1
Zinc		190	51	410	960

Table 4-1B - Analytical Results for Surface Sediment Samples

Sheet 1 of 4

Lab-ID	9609024-4	9609024-5	9609024-6	9609024-2	9609024-1	9609024-3	9609024-7	9609024-8
Sample-ID	HC-SS-03	HC-SS-06	HC-SS-08	HC-SS-29	HC-SS-30	HC-SS-203	HC-SS-33	HC-SS-34
Depth	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft
Sampling Date	9/06/96	9/06/96	9/06/96	9/06/96	9/06/96	9/06/96	9/09/96	9/09/96
HPAHs in mg/kg (OC)								
Benz(a)anthracene	2.36 UE	0.93 E	2.43 UE	5.45 E	6.25 E	3.85 E	2.26	4.47
Benzo(a)pyrene	0.68 E	1.03 E	2.43 E	5.00 E	3.42 E	2.42 E	1.46	2.89
Benzo(b)fluoranthene	1.32 EC	1.07 E	2.65 E	5.00 E	4.58 E	3.85 E	4.57 C	3.95
Benzo(ghi)perylene	3.32 UE	1.10 E	4.04 E	5.45 E	2.83 E	2.00 E	1.11 E	2.53
Benzo(k)fluoranthene	1.32 EC	0.79 E	2.35 E	5.23 E	4.58 E	2.85 E	4.57 C	2.47
Chrysene	1.00 E	1.48 E	3.17 E	9.32 E	10.00 E	8.08 E	5.71	5.26
Dibenz(a,h)anthracene	3.32 UE	3.31 UE	3.43 UE	2.00 E	3.46 UE	3.31 UE	2.20 U	0.92 E
Fluoranthene	2.61 E	3.03 E	8.70 E	14.32 E	12.50 E	10.00 E	9.14	11.32
Indeno(1,2,3-cd)pyrene	3.21 UE	3.21 UE	2.57 E	4.55 E	2.42 E	1.77 E	1.03 E	1.97
Pyrene	2.79 E	3.38 E	10.00 E	21.59 E	13.33 E	10.38 E	9.71	15.79
Total benzofluoranthenes	1.32	1.86	5.00	10.23	9.17	6.69	4.57	6.42
Total HPAHs	8.39	12.83	35.91	77.91	59.92	45.19	35.00	51.58
LPAHs in mg/kg (OC)								
2-Methylnaphthalene	1.79 UE	1.79 UE	1.78 E	2.73 E	0.63 E	1.77 UE	0.29 E	2.45
Acenaphthene	1.82 UE	1.83 UE	1.87 UE	1.41 E	1.92 UE	1.81 UE	1.20 U	1.29
Acenaphthylene	1.64 UE	1.66 UE	1.91 E	0.91 E	1.71 UE	1.62 UE	1.09 U	0.53 E
Anthracene	1.93 UE	1.93 UE	1.61 E	2.95 E	2.08 E	1.50 E	0.74 E	2.89
Fluorene	2.11 UE	2.10 UE	0.91 E	2.11 E	1.00 E	1.04 E	0.43 E	2.42
Naphthalene	5.36 E	4.83 E	13.91 E	9.32 E	1.75 E	1.81 UE	1.23 U	5.26
Phenanthrene	2.89 E	3.03 E	9.57 E	10.68 E	5.83 E	5.77 E	2.06	8.16
Total LPAHs	8.25	7.86	27.91	27.39	10.67	8.31	3.23	20.55
Semivolatiles in µg/kg (dry)								
Benzoic Acid	220 EB	340 EB	250 EB	230 EB	260 EB	240 EB	180 EB	160 EB
Benzyl Alcohol	4.4 E	5.1 E	7.1 E	12 E	49 E	31 E	4.6 E	4.2 E
Semivolatiles in mg/kg (OC)								
1,2,4-Trichlorobenzene	1.68 UE	1.66 UE	1.70 UE	0.93 UE	1.75 UE	1.65 UE	1.11 U	0.23 E
1,2-Dichlorobenzene	1.96 UE	1.97 UE	2.04 UE	1.09 UE	2.04 UE	1.96 UE	1.31 U	0.61 E
1,4-Dichlorobenzene	1.79 UE	1.79 UE	1.83 UE	1.00 UE	1.88 UE	1.77 UE	1.17 U	0.53 E
Dibenzofuran	0.75 E	0.72 E	2.74 E	1.80 E	0.83 E	0.73 E	0.34 E	2.18
Hexachlorobenzene	0.18 U	0.18 U	0.19 U	0.10 U	0.19 U	0.18 U	0.12 U	0.53
Hexachlorobutadiene	0.18 U	0.18 U	0.19 U	0.10 U	0.19 U	0.18 U	0.12 U	0.09 U
N-Nitroso diphenylamine	2.21 UE	2.21 UE	2.30 UE	1.23 UE	2.29 UE	2.19 UE	1.46 U	1.13 U

447806/Whatcom Waterway RI/Whatcom.xls - Table 4-1B

Table 4-1B - Analytical Results for Surface Sediment Samples

Sheet 2 of 4

Lab-ID	9609024-4	9609024-5	9609024-6	9609024-2	9609024-1	9609024-3	9609024-7	9609024-8
Sample-ID	HC-SS-03	HC-SS-06	HC-SS-08	HC-SS-29	HC-SS-30	HC-SS-203	HC-SS-33	HC-SS-34
Depth	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft
Sampling Date	9/06/96	9/06/96	9/06/96	9/06/96	9/06/96	9/06/96	9/09/96	9/09/96
Phthalates in mg/kg (OC)								
Bis(2-ethylhexyl)phthalate	7.50 B	2.86 B	6.96 B	5.23 B	4.17 B	4.23 B	2.11 B	34.21 B
Butyl benzyl phthalate	3.32 UE	3.31 UE	1.00 E	1.84 UE	0.75 E	3.27 UE	2.20 U	1.68 U
Di-n-butyl phthalate	2.57 UE	2.55 UE	1.04 E	0.55 E	1.08 E	2.54 UE	1.69 U	1.29 U
Di-n-octyl phthalate	3.11 UE	3.07 UE	3.17 UE	1.70 UE	3.21 UE	3.04 UE	2.06 U	1.58 U
Diethyl phthalate	4.29 UE	4.48 UE	4.35 UE	2.50 UE	4.58 UE	4.23 UE	2.86 U	2.21 U
Dimethyl phthalate	3.57 UE	3.79 UE	3.83 UE	2.05 UE	3.83 UE	3.65 UE	2.46 U	1.87 U
PCBs in mg/kg (OC)								
PCB-1016	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.63 U
PCB-1221	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.63 U
PCB-1232	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.63 U
PCB-1242	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.63 U
PCB-1248	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.63 U
PCB-1254	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.11 E
PCB-1260	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.63 U
Total PCBs	5.36 U	5.52 U	5.65 U	2.95 U	5.83 U	5.38 U	3.71 U	2.11 E
Phenols in µg/kg (dry)								
2,4-Dimethylphenol	23 UE	24 UE	2.3 E	6.3 E	2.1 E	42 UE	2.3 E	4.2 E
2-Methylphenol	9.1 E	13 E	3 E	8 E	3.9 E	17 E	3.2 E	7.4 E
4-Methylphenol	1600 E	1900 E	870 E	410 E	680 E	1100 E	200	870
Pentachlorophenol	6.5 E	4.7 E	8.2 E	100 E	24 E	19 E	5.9 E	14 E
Phenol	900 E	2200 E	1000 E	1000 E	1300 E	1500 E	270	230
Total Phenols(detects only)	2516	4118	1884	1524	2010	2636	481.4	1126

Table 4-1B - Analytical Results for Surface Sediment Samples

Lab-ID	9609012-1	9609012-6	9609012-2	9609012-7	9609012-8	9609012-3	9609012-4	9609012-5		
Sample-ID	HC-SS-35	HC-SS-36	HC-SS-37	HC-SS-38	HC-SS-39	HC-SS-45	HC-SS-47	HC-SS-48	SQS	
Depth	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	Criteria	MCUL
Sampling Date	9/03/96	9/05/96	9/03/96	9/09/96	9/09/96	9/04/96	9/04/96	9/05/96		
HPAHs in mg/kg (OC)										
Benz(a)anthracene	3.71	5.56	8.57	11.67	8.28	5.29	42.50	18.29	110	270
Benzo(a)pyrene	2.80	3.94	6.29	12.22	9.66	3.24	13.50	20.73	99	210
Benzo(b)fluoranthene	7.14 C	9.44 C	14.57 C	23.89 C	20.00 C	8.53 C	35.00 C	20.73		
Benzo(ghi)perylene	3.14	3.78	6.29	11.11	11.03	2.24 E	5.75	19.51	31	78
Benzo(k)fluoranthene	7.14 C	9.44 C	14.57 C	23.89 C	20.00 C	8.53 C	35.00 C	19.51		
Chrysene	6.00	8.33	13.71	17.50	11.72	8.82	47.50	29.27	110	460
Dibenz(a,h)anthracene	1.57 E	2.72	2.63	5.00	4.48	1.32 E	3.75	9.27	12	33
Fluoranthene	7.43	10.56	16.57	25.28	20.69	10.29	125.00	47.56	160	1200
Indeno(1,2,3-cd)pyrene	2.71	3.33	5.43	10.00	9.31	2.24	5.75	18.29	34	88
Pyrene	7.71	13.33	19.43	26.67	24.14	10.00	117.50	47.56	1000	1400
Total benzofluoranthenes	7.14	9.44	14.57	23.89	20.00	8.53	35.00	40.24	230	450
Total HPAHs	42.23	61.00	93.49	143.33	119.31	51.97	396.25	250.73	960	5300
LPAHs in mg/kg (OC)										
2-Methylnaphthalene	0.83 E	1.39 E	8.00	0.83 E	2.34	0.94 E	4.00	6.83	38	64
Acenaphthene	1.46 U	1.11 E	2.06	1.14	1.00 E	0.47 E	40.00	2.07 E	16	57
Acenaphthylene	1.31 U	1.72 U	0.49 E	0.26 E	1.07 U	1.12 U	2.15	1.16 E	66	66
Anthracene	1.43 E	2.11	6.86	3.89	3.28	1.56	35.00	5.98	220	1200
Fluorene	0.69 E	1.50 E	4.00	1.83	1.38	0.94 E	7.50	4.02	23	79
Naphthalene	1.49 U	3.39	6.86	1.42	2.48	1.53	3.75	7.44	99	170
Phenanthrene	4.57	6.67	12.86	15.28	13.45	4.41	30.00	24.39	100	480
Total LPAHs	6.69	14.78	33.11	23.82	21.59	8.91	118.40	45.06	370	780
Semivolatiles in µg/kg (dry)										
Benzoic Acid	390 B	180 EB	340 B	350 B	59 EB	230 EB	290 B	89 EB	650	650
Benzyl Alcohol	19 E	9.5 E	30 E	55	23 E	5.7 E	7.7 E	34 U	57	73
Semivolatiles in mg/kg (OC)										
1,2,4-Trichlorobenzene	1.34 U	1.72 U	1.00 U	0.83 U	1.07 U	1.15 U	0.78 U	2.44 U	0.81	1.8
1,2-Dichlorobenzene	1.57 U	2.06 U	1.17 U	0.97 U	1.24 U	1.35 U	0.90 U	2.93 U	2.3	2.3
1,4-Dichlorobenzene	1.43 U	1.89 U	1.09 U	0.89 U	1.14 U	1.21 U	0.83 U	2.56 U	3.1	9
Dibenzofuran	0.63 E	1.22 E	3.43	1.03	1.03 E	0.91 E	4.50	4.88	15	58
Hexachlorobenzene	0.31	0.19 U	0.11 U	0.09 U	0.11 U	0.12 U	0.08 U	0.27 U	0.38	2.3
Hexachlorobutadiene	0.15 U	0.19 U	0.11 U	0.09 U	0.11 U	0.12 U	0.08 U	0.27 U	3.9	6.2
N-Nitroso diphenylamine	1.77 U	2.33 U	1.34 U	1.08 U	1.41 U	1.50 U	1.03 U	3.29 U	11	11

Table 4-1B - Analytical Results for Surface Sediment Samples

Sheet 4 of 4

Lab-ID	9609012-1	9609012-6	9609012-2	9609012-7	9609012-8	9609012-3	9609012-4	9609012-5		
Sample-ID	HC-SS-35	HC-SS-36	HC-SS-37	HC-SS-38	HC-SS-39	HC-SS-45	HC-SS-47	HC-SS-48		
Depth	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	0 to .3 ft	SQS	
Sampling Date	9/03/96	9/05/96	9/03/96	9/09/96	9/09/96	9/04/96	9/04/96	9/05/96	Criteria	MCUL
Phthalates in mg/kg (OC)										
Bis(2-ethylhexyl)phthalate	9.71 B	8.33 B	16.86 B	38.89 B	33.59 B	13.24 B	700.00 B	25.61 B	47	78
Butyl benzyl phthalate	0.91 E	0.83 E	1.31 E	1.72	2.59	0.59 E	1.53 U	1.83 E	4.9	64
Di-n-butyl phthalate	2.06 U	2.67 U	1.54 U	0.94 E	1.34 E	1.74 U	1.18 U	1.34 E	220	1700
Di-n-octyl phthalate	2.49 U	3.22 U	1.86 U	2.78	1.97 U	2.12 U	1.43 U	4.51 U	58	4500
Diethyl phthalate	3.43 U	4.56 U	2.60 U	2.14 U	1.62 E	2.94 U	2.00 U	6.34 U	61	110
Dimethyl phthalate	0.86 E	0.61 E	2.14 E	1.83 U	0.55 E	2.53 U	0.73 E	5.37 U	53	53
PCBs in mg/kg (OC)										
PCB-1016	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	2.50 U	7.93 U		
PCB-1221	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	2.50 U	7.93 U		
PCB-1232	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	2.50 U	7.93 U		
PCB-1242	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	2.50 U	7.93 U		
PCB-1248	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	2.50 U	7.93 U		
PCB-1254	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	2.50 U	7.93 U		
PCB-1260	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	3.25	7.93 U		
Total PCBs	4.29 U	5.56 U	3.14 U	2.67 U	3.45 U	3.82 U	3.25	7.93 U	12	65
Phenols in µg/kg (dry)										
2,4-Dimethylphenol	23 U	1.7 E	10 E	29 U	2.1 E	14 E	16 E	10 E	29	29
2-Methylphenol	4.1 E	2.1 E	7.1 E	6.7 E	3.3 E	9 E	11 E	5.9 E	63	63
4-Methylphenol	340	320	630	95	55	220	210	42	670	670
Pentachlorophenol	38 E	20 E	35 E	35 E	19 E	15 E	18 E	10 E	360	690
Phenol	1500	880	900	29 U	24 E	1500	460	72	420	1200
Total Phenols(detects only)	1882	1224	1582	136.7	103.4	1758	715	139.9		

Table 4-1C - Analytical Results for Surface Sediment Samples - WW Area - 1998

Parameter	Chemical Criteria SQS	Chemical Criteria MCUL	Survey Date Sample ID	Z063 98-030-01 10/28/98 AN-SS-36	Z063 98-030-01 10/29/98 AN-SS-37	Z037 98-030-01 10/27/98 AN-SC-70
Metals in mg/kg (dry)						
Cadmium	5.1	6.7		0.9 J	0.9 J	0.9 J
Mercury	0.41	0.59		0.61	0.50	0.85
Zinc	410	960		92	148	100
Conventional Parameters in %						
Gravel				17.4	40.1	0.9
Sand				65.6	22.3	7.4
Silt				9.3	24.1	51.5
Clay				7.8	13.5	40.3
Fines				17.1	37.5	91.8
Total solids				72.8	58.0	37.8
Total organic carbon				3.3	3.4	2.4
pH in pH units				7.8	8.1	7.4
LPAHs in mg/kg (TOC)						
Naphthalene	99	170		1.9	5.9	6.7
Acenaphthylene	66	66		0.58 U	0.88	0.83
Acenaphthene	16	57		0.91	2.8	0.79 U
Flourene	23	79		1.3	3.8	1.1
Phenanthrene	100	480		5.5	14	7.1
Anthracene	220	1200		2.1	5.0	1.7
2-Methylnaphthalene	38	64		1.7	5.0	1.3
Total LPAHs[2]	370	780		14	37	19
HPAHs in mg/kg (TOC)						
Fluoranthene	160	1200		9.1	18	8.8
Pyrene	1000	1400		33	41	11
Benzo(a)anthracene	110	270		4.2	11	2.0
Chrysene	110	460		5.5	15	3.1
Benzo(b)fluoranthene				7.6	14	2.0
Benzo(k)fluoranthene				5.8	10	3.2
Total benzofluoranthenes[1]	230	450		13	24	5.2

Table 4-1C - Analytical Results for Surface Sediment Samples - WW Area - 1998

Parameter	Chemical Criteria SQS	Chemical Criteria MCUL		Z063	Z063	Z037
			Survey	98-030-01	98-030-01	98-030-01
			Date	10/28/98	10/29/98	10/27/98
			Sample ID	AN-SS-36	AN-SS-37	AN-SC-70
Benzo(a)pyrene	99	210		5.5	10	2.0
Indeno(1,2,3-cd)pyrene	34	88		2.4	5.0	1.3
Dibenz(a,h)anthracene	12	33		1.3	1.7	0.79 U
Benzo(g,h,i)perylene	31	78		2.1	3.5	1.3
Total HPAHs[2]	960	5300		77	131	35
Phthalates in mg/kg (TOC)						
Dimethylphthalate	53	53		0.58 U	1.2	0.79 U
Diethylphthalate	61	110		0.58 U	0.56 U	0.79 U
Di-n-Butylphthalate	220	1700		0.58 U	1.0	1.8
Butylbenzylphthalate	4.9	64		0.58 U	1.6	0.79 U
Bis(2-ethylhexyl)phthalate	47	78		28	25 EB	6.3
Di-n-Octyl phthalate	58	4500		0.58 U	0.56 U	0.79 U
Semivolatiles in mg/kg (TOC)						
1,2-Dichlorobenzene	2.3	2.3		0.58 U	0.56 U	0.79 U
1,4-Dichlorobenzene	3.1	9.0		3.0	0.56 U	0.79 U
1,2,4-Trichlorobenzene	0.81	1.80		0.58 U	0.56 U	0.79 U
Hexachlorobenzene	0.38	2.30		0.58 U	0.56 U	0.79 U
Dibenzofuran	15	58		1.4	4.1	2.0
Hexachlorobutadiene	3.9	6.2		0.58 U	0.56 U	0.79 U
N-Nitrosodiphenylamine	11	11		0.58 U	0.56 U	0.79 U
Semivolatiles in ug/kg (dry)						
Phenol	420	1200		36	19 U	19 U
2-Methylphenol	63	63		19 U	19 U	19 U
4-Methylphenol	670	670		300	200	240
2,4-Dimethylphenol	29	29		19 U	19 U	19 U
Pentachlorophenol	360	690		97 U	95 U	96 U
Benzyl Alcohol	57	73		180	19 U	19 U
Benzoic Acid	650	650		190 U	190 U	190 U

Table 4-1C - Analytical Results for Surface Sediment Samples - WW Area - 1998

Parameter	Z063 98-030-01 10/27/98 AN-SC-71	Z063 98-030-01 10/28/98 AN-SC-72	Z063 98-030-01 10/28/98 AN-SC-73	Z063 98-030-01 10/28/98 AN-SC-77	Z063 98-030-01 10/28/98 AN-SC-78	Z063 98-030-01 10/28/98 AN-SC-80
Metals in mg/kg (dry)						
Cadmium	0.9 J	0.8 J	0.9 J	1	2	1
Mercury	1.2	0.90	0.81	1.2	1.0	0.71
Zinc	109	102	129	116	121	145
Conventional Parameters in %						
Gravel	0.2	0.0	0.0	0.1	1.2	1.2
Sand	13.3	16.6	10.5	9.1	11.6	14.9
Silt	44.7	45.3	46.8	47.2	54.2	45.3
Clay	41.8	38.0	42.7	43.6	33.0	38.7
Fines	86.5	83.3	89.5	90.8	87.2	83.9
Total solids	35.7	37.5	35.1	36.3	37.3	33.8
Total organic carbon	2.7	2.2	3.4	3.6	4.3	3.0
pH in pH units	7.6	7.8	7.5	7.6	8.1	7.6
LPAHs in mg/kg (TOC)						
Naphthalene	6.3	5.9	2.6	2.8	2.8	3.0
Acenaphthylene	0.85	1.0	0.59 U	0.56 U	0.47	1.3 U
Acenaphthene	4.4	2.4	1.3	1.1	0.65	1.7
Flourene	5.6	5.0	2.2	2.0	1.3	2.8
Phenanthrene	22	18	8.8	6.4	6.0	13
Anthracene	6.7	12	3.8	3.3	3.0	6.0
2-Methylnaphthalene	2.4	2.6	1.3	1.4	1.3	1.9
Total LPAHs[2]	48	47	21	18	16	29
HPAHs in mg/kg (TOC)						
Fluoranthene	32	31	18	20	11	33
Pyrene	44	50	20	26	19	40 G
Benzo(a)anthracene	14	18	7.4	7.8	4.9	16
Chrysene	19	27	9.4	11	6.5	18
Benzo(b)fluoranthene	11	13	6.5	6.1	5.8	15
Benzo(k)fluoranthene	10	10	5.3	6.4	4.4	13
Total benzofluoranthenes[1]	21	23	12	13	10	27

Table 4-1C - Analytical Results for Surface Sediment Samples - WW Area - 1998

Parameter	Z063 98-030-01 10/27/98 AN-SC-71	Z063 98-030-01 10/28/98 AN-SC-72	Z063 98-030-01 10/28/98 AN-SC-73	Z063 98-030-01 10/28/98 AN-SC-77	Z063 98-030-01 10/28/98 AN-SC-78	Z063 98-030-01 10/28/98 AN-SC-80
Benzo(a)pyrene	8.5	9.1	5.0	5.3	3.5	9.3
Indeno(1,2,3-cd)pyrene	3.4	4.0	2.2	2.6	2.0	4.7
Dibenz(a,h)anthracene	1.2	1.6	0.82	0.97	0.56	2.2
Benzo(g,h,i)perylene	2.2	2.5	1.6	1.6	1.9	3.7
Total HPAHs[(2)]	147	166	76	88	59	154
Phthalates in mg/kg (TOC)						
Dimethylphthalate	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
Diethylphthalate	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
Di-n-Butylphthalate	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
Butylbenzylphthalate	0.74 U	0.91 U	0.59 U	0.56 U	1.0 M	2.1 M
Bis(2-ethylhexyl)phthalate	4.4 E	6.4 E	5.3 E	5.3 E	8.4	26
Di-n-Octyl phthalate	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
Semivolatiles in mg/kg (TOC)						
1,2-Dichlorobenzene	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
1,4-Dichlorobenzene	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
1,2,4-Trichlorobenzene	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
Hexachlorobenzene	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
Dibenzofuran	5.6	4.5	2.3	2.3	1.5	3.2
Hexachlorobutadiene	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
N-Nitrosodiphenylamine	0.74 U	0.91 U	0.59 U	0.56 U	0.47 U	1.3 U
Semivolatiles in ug/kg (dry)						
Phenol	20 U	20 U	20 U	20 U	20 U	39 U
2-Methylphenol	20 U	20 U	20 U	20 U	20 U	39 U
4-Methylphenol	290	240	170	140	160	140
2,4-Dimethylphenol	20 U	20 U	20 U	20 U	20 U	39 U
Pentachlorophenol	99 U	99 U	99 U	99 U	98 U	190 U
Benzyl Alcohol	20 U	20 U	20 U	20 U	20 U	39 U
Benzoic Acid	200 U	200 U	200 U	200 U	200 U	390 U

Table 4-1C - Analytical Results for Surface Sediment Samples - WW Area - 1998

Parameter	Z063 98-030-01 10/29/98 AN-SC-81	Z063 98-030-01 10/29/98 AN-SC-82	Z037 98-030-01 10/27/98 AN-SC-84
Metals in mg/kg (dry)			
Cadmium	1	1	1 U
Mercury	0.62	0.52	0.45
Zinc	183	166	106
Conventional Parameters in %			
Gravel	0.0	0.1	2.1
Sand	26.0	17.2	6.1
Silt	46.0	50.8	47.7
Clay	28.0	31.8	44.0
Fines	74.0	82.6	91.8
Total solids	51.4	32.6	43.3
Total organic carbon	3.0	4.8	2.6
pH in pH units	7.9	8.0	7.5
LPAHs in mg/kg (TOC)			
Naphthalene	3.1	1.7	2.0
Acenaphthylene	0.67	0.42	0.77 U
Acenaphthene	2.1	0.98	0.77 U
Flourene	3.1	3.8	0.96
Phenanthrene	17	18	3.8
Anthracene	7.3	12	1.6
2-Methylnaphthalene	1.8	1.2	1.4
Total LPAHs(2)	35	38	11
HPAHs in mg/kg (TOC)			
Fluoranthene	29	14	8.5
Pyrene	57	25	9.2
Benzo(a)anthracene	17	15	2.4
Chrysene	29	46	3.8
Benzo(b)fluoranthene	28	16	2.5
Benzo(k)fluoranthene	15	7.5	3.0
Total benzofluoranthenes(1)	43	24	5.5

Table 4-1C - Analytical Results for Surface Sediment Samples - WW Area - 1998

Parameter	Z063 98-030-01 10/29/98 AN-SC-81	Z063 98-030-01 10/29/98 AN-SC-82	Z037 98-030-01 10/27/98 AN-SC-84
Benzo(a)pyrene	19	9.2	1.9
Indeno(1,2,3-cd)pyrene	9.7 L	4.6 L	1.1
Dibenz(a,h)anthracene	3.7 L	1.6 L	0.77 U
Benzo(g,h,i)perylene	7.0 L	2.9 L	1.3
Total HPAHs[(2)]	214	142	35
Phthalates in mg/kg (TOC)			
Dimethylphthalate	0.83	0.42 U	0.77 U
Diethylphthalate	0.67 U	0.42 U	0.77 U
Di-n-Butylphthalate	0.67 U	0.42 U	1.3
Butylbenzylphthalate	5.3 M	2.3 M	0.88
Bis(2-ethylhexyl)phthalate	47 EB	27 EB	4.6
Di-n-Octyl phthalate	0.67 U	1.2 E	0.77 U
Semivolatiles in mg/kg (TOC)			
1,2-Dichlorobenzene	0.67 U	0.42 U	0.77 U
1,4-Dichlorobenzene	0.67 U	0.42 U	0.77 U
1,2,4-Trichlorobenzene	0.67 U	0.42 U	0.77 U
Hexachlorobenzene	0.67 U	0.42 U	0.77 U
Dibenzofuran	3.0	1.9	1.4
Hexachlorobutadiene	0.67 U	0.42 U	0.77 U
N-Nitrosodiphenylamine	0.67 U	0.42 U	0.77 U
Semivolatiles in ug/kg (dry)			
Phenol	20 U	20 U	34
2-Methylphenol	20 U	20 U	20 U
4-Methylphenol	89	84	62
2,4-Dimethylphenol	20 U	20 U	20 U
Pentachlorophenol	98 U	98 U	99 U
Benzyl Alcohol	20 U	20 U	20 U
Benzoic Acid	200 U	200 U	200 U

Table 4-1D - Analytical Results for Surface Sediment Samples - Starr Rock - 1998

Sheet 1 of 6

	Chemical Criteria						
				Z036	Z036	Z036	Z036
			Survey	98-007-03	98-007-03	98-007-03	98-007-03
			Date	10/26/98	10/26/98	10/26/98	10/26/98
			Sample ID	AN-SS-301	AN-SS-302	AN-SS-303	AN-SS-304
Parameter	SQS	CSL					
Metals in mg/kg (dry)							
Arsenic	57	93		12	8	12	3
Cadmium	5.1	6.7		0.9 J	1.0 U	0.6 J	1.0 U
Chromium	260	270		67	79	79	16
Copper	390	390		51	54	52	22
Lead	450	530		29	20 U	25	29
Mercury	0.41	0.59		1.0	0.45	2.9	0.062 J
Silver	6.1	6.1		2.0 U	2.0 U	2.0 U	2.0 U
Zinc	410	960		90	106	108	72
Conventional Parameters in %							
Gravel				2.3	0.0	4.3	5.6
Sand				39.0	3.8	15.3	88.8
Silt				32.0	58.3	43.9	2.4
Clay				26.8	37.9	36.4	3.2
Fines				58.8	96.2	80.3	5.6
Total solids				33.2	38.0	36.7	55.8
Total organic carbon				8.8	2.6	4.1	9.2
pH in pH units				7.6	7.5	7.6	8.1
LPAHs in mg/kg (TOC)							
Naphthalene	99	170		16	9.2	2.0	7.7
Acenaphthylene	66	66		8.0	3.8	0.49 U	2.4
Acenaphthene	16	57		2.6	1.3	0.49 U	1.1
Flourene	23	79		4.9	2.5	0.49 U	2.4
Phenanthrene	100	480		27	12	2.2	21 E
Anthracene	220	1200		16	6.9	0.61	5.2
2-Methylnaphthalene	38	64		6.5	2.6	0.61	1.7
Total LPAHs[2]	370	780		81	39	6.9	42
HPAHs in mg/kg (TOC)							

Table 4-1D - Analytical Results for Surface Sediment Samples - Starr Rock - 1998

Sheet 2 of 6

	Chemical Criteria			Z036	Z036	Z036	Z036
			Survey	98-007-03	98-007-03	98-007-03	98-007-03
			Date	10/26/98	10/26/98	10/26/98	10/26/98
			Sample ID	AN-SS-301	AN-SS-302	AN-SS-303	AN-SS-304
Parameter	SQS	CSL					
Fluoranthene	160	1200		63 E	33	2.9	37 E
Pyrene	1000	1400		108 E	46	4.9	33 E
Benzo(a)anthracene	110	270		57 E	21	1.0	15
Chrysene	110	460		56	23	1.5	15
Benzo(b)fluoranthene				60 E	19	1.8	16
Benzo(k)fluoranthene				30	20	0.98	13
Total benzofluoranthenes[1]	230	450		90 E	39	2.8	29
Benzo(a)pyrene	99	210		68 E	28	1.3	20 E
Indeno(1,2,3-cd)pyrene	34	88		42 E	15	0.83	13
Dibenz(a,h)anthracene	12	33		15	3.8	0.49 U	3.3
Benzo(g,h,i)perylene	31	78		35	8.5	0.73	11
Total HPAHs[2]	960	5300		534 E	219	16	177 E
Phthalates in mg/kg (TOC)							
Dimethylphthalate	53	53		0.45 U	0.77 U	0.49 U	0.21 U
Diethylphthalate	61	110		0.45 U	0.77 U	0.49 U	0.21 U
Di-n-Butylphthalate	220	1700		0.45 U	0.77 U	0.49 U	0.21 U
Butylbenzylphthalate	4.9	64		0.45 U	0.77 U	0.49 U	0.21 U
Bis(2-ethylhexyl)phthalate	47	78		0.65	2.2	1.6	0.83
Di-n-Octyl phthalate	58	4500		0.45 U	0.77 U	0.49 U	0.21 U
Semivolatiles in mg/kg (TOC)							
1,2-Dichlorobenzene	2.3	2.3		0.45 U	0.77 U	0.49 U	0.21 U
1,4-Dichlorobenzene	3.1	9.0		0.45 UG	0.77 UG	0.49 UG	0.21 UG
1,2,4-Trichlorobenzene	0.81	1.80		0.45 UG	0.77 UG	0.49 UG	0.21 UG
Hexachlorobenzene	0.38	2.30		0.45 U	0.77 U	0.49 U	0.21 U
Dibenzofuran	15	58		2.7	2.5	0.54	1.3
Hexachlorobutadiene	3.9	6.2		0.45 U	0.77 U	0.49 U	0.21 U
N-Nitrosodiphenylamine	11	11		0.45 U	0.77 U	0.49 U	0.21 U
Semivolatiles in ug/kg (dry)							

Table 4-1D - Analytical Results for Surface Sediment Samples - Starr Rock - 1998

	Chemical Criteria			Z036	Z036	Z036	Z036
			Survey	98-007-03	98-007-03	98-007-03	98-007-03
			Date	10/26/98	10/26/98	10/26/98	10/26/98
			Sample ID	AN-SS-301	AN-SS-302	AN-SS-303	AN-SS-304
Parameter	SQS	CSL					
Phenol	420	1200		40 UG	24 G	33 G	36 G
2-Methylphenol	63	63		40 U	20 U	20 U	19 U
4-Methylphenol	670	670		86	190	70	120
2,4-Dimethylphenol	29	29		40 U	20 U	20 U	19 U
Pentachlorophenol	360	690		200 UG	98 UG	99 UG	95 UG
Benzyl Alcohol	57	73		40 U	20 U	20 U	19 U
Benzoic Acid	650	650		400 U	200 U	200 U	190 U

Table 4-1D - Analytical Results for Surface Sediment Samples - Starr Rock - 1998

Parameter	Z036 98-007-03 10/26/98 AN-SS-305	Z036 98-007-03 10/26/98 AN-SS-306
Metals in mg/kg (dry)		
Arsenic	14	12
Cadmium	0.8 J	0.8 J
Chromium	52	56
Copper	47	41
Lead	44	20 U
Mercury	1.5	0.74
Silver	2.0 U	2.0 U
Zinc	83	92
Conventional Parameters in %		
Gravel	1.5	2.7
Sand	37.6	29.8
Silt	31.6	39.0
Clay	29.4	28.5
Fines	61.0	67.5
Total solids	28.2	45.9
Total organic carbon	13	2.8
pH in pH units	7.5	7.7
LPAHs in mg/kg (TOC)		
Naphthalene	7.7	1.8
Acenaphthylene	0.85	0.68 U
Acenaphthene	0.58	0.68 U
Flourene	1.2	0.68 U
Phenanthrene	6.2	3.9
Anthracene	2.2	0.89
2-Methylnaphthalene	1.4	0.68 U
Total LPAHs[(2)]	20	9.4
HPAHs in mg/kg (TOC)		

Table 4-1D - Analytical Results for Surface Sediment Samples - Starr Rock - 1998

Parameter	Z036 98-007-03 10/26/98 AN-SS-305	Z036 98-007-03 10/26/98 AN-SS-306
Fluoranthene	8.5	7.1
Pyrene	13	7.5
Benzo(a)anthracene	4.8	3.1
Chrysene	4.8	3.6
Benzo(b)fluoranthene	4.7	6.1
Benzo(k)fluoranthene	3.9	3.9
Total benzofluoranthenes(1)	8.6	10
Benzo(a)pyrene	6.0	4.3
Indeno(1,2,3-cd)pyrene	3.7	3.5
Dibenz(a,h)anthracene	1.3	1.1
Benzo(g,h,i)perylene	2.8	2.3
Total HPAHs(2)	53	43
Phthalates in mg/kg (TOC)		
Dimethylphthalate	0.17 U	0.68 U
Diethylphthalate	0.17 U	0.68 U
Di-n-Butylphthalate	0.17 U	0.68 U
Butylbenzylphthalate	0.17 U	0.68 U
Bis(2-ethylhexyl)phthalate	0.49	1.2
Di-n-Octyl phthalate	0.17 U	0.68 U
Semivolatiles in mg/kg (TOC)		
1,2-Dichlorobenzene	0.17 U	0.68 U
1,4-Dichlorobenzene	0.17 UG	0.68 UG
1,2,4-Trichlorobenzene	0.17 UG	0.68 UG
Hexachlorobenzene	0.17 U	0.68 U
Dibenzofuran	1.0	0.68 U
Hexachlorobutadiene	0.17 U	0.68 U
N-Nitrosodiphenylamine	0.17 U	0.68 U
Semivolatiles in ug/kg (dry)		

Table 4-1D - Analytical Results for Surface Sediment Samples - Starr Rock - 1998

	Z036	Z036
	98-007-03	98-007-03
	10/26/98	10/26/98
Parameter	AN-SS-305	AN-SS-306
Phenol	52 G	58 G
2-Methylphenol	22 U	19 U
4-Methylphenol	190	36
2,4-Dimethylphenol	22 U	19 U
Pentachlorophenol	110 UG	97 UG
Benzyl Alcohol	22 U	19 U
Benzoic Acid	220 U	190 U

Table 4-2 - Sediment Quality Screening Assessment for Surface Samples

Sheet 1 of 2

Analyte	Detection Frequency	Range	Maximum Detection	Location of Max. Detect.	SQS	Exceedence Frequency	Maximum Enrichment Ratio	MCUL	Exceedence Frequency	Maximum Enrichment Ratio
Total Metals in mg/kg										
Arsenic	49/49	3 to 17 E	17 E	HC-SC-70	57	0/49		93	0/49	
Cadmium	31/61	0.59 U to 2.4	2.4	HC-SC-79	5.1	0/61		6.7	0/61	
Chromium	49/49	10 E to 84 E	84 E	HC-SS-28	260	0/49		270	0/49	
Copper	49/49	10 to 110	110	HC-SS-37	390	0/49		390	0/49	
Lead	45/49	4.2 U to 74	74	HC-SC-79	450	0/49		530	0/49	
Mercury	75/82	0.13 U to 11.8	11.8	HC-SS-40	0.41	62/82	28.78	0.59	39/82	20
Silver	3/49	0.59 U to 2.9	2.9	HC-SS-39	6.1	0/49		6.1	0/49	
Zinc	61/61	20 to 190	190	HC-SC-79; HC-SS-47	410	0/61		960	0/61	
Phenols in ug/kg dry										
2,4-Dimethylphenol	27/49	1.5 E to 40 U	16 E	HC-SC-84	29	0/49		29	0/49	
2,4-Dimethylphenol	27/49	1.5 E to 40 U	16 E	HC-SS-47	29	0/49		29	0/49	
2-Methylphenol	31/49	2 E to 19 E	19 E	HC-SC-76	63	0/49		63	0/49	
4-Methylphenol	31/49	42 to 1900 E	1900 E	HC-SS-06	670	7/49	2.84	670	7/49	2.84
Pentachlorophenol	31/49	4 E to 100 E	100 E	HC-SS-29	360	0/49		690	0/49	
Phenol	37/49	19 U to 2200 E	2200 E	HC-SS-06	420	16/49	5.24	1200	5/49	1.83
HPAHs in mg/kg oc										
Benz(a)anthracene	47/49	0.4 E to 42.5	42.5	HC-SS-47	110	0/49		270	0/49	
Benzo(a)pyrene	49/49	0.47 E to 20.73	20.73	HC-SS-48	99	0/49		210	0/49	
Benzo(ghi)perylene	47/49	0.73 to 35	35	AN-SS-301	31	1/49	1.13	78	0/49	
Chrysene	49/49	0.83 E to 56	56	AN-SS-301	110	0/49		460	0/49	
Dibenz(a,h)anthracene	38/49	0.49 E to 15	15	AN-SS-301	12	1/49	1.25	33	0/49	
Fluoranthene	49/49	0.7 E to 125	125	HC-SS-47	160	0/49		1200	0/49	
Indeno(1,2,3-cd)pyrene	46/49	0.83 to 42 E	42 E	AN-SS-301	34	1/49	1.24	88	0/49	
Pyrene	49/49	0.87 E to 117.5	117.5	HC-SS-47	1000	0/49		1400	0/49	
Total HPAHs	49/49	3.27 to 534 E	534 E	AN-SS-301	960	0/49		5300	0/49	
Total benzofluoranthenes	48/49	1.32 to 90 E	90 E	AN-SS-301	230	0/49		450	0/49	

Table 4-2 - Sediment Quality Screening Assessment for Surface Samples

Sheet 2 of 2

Analyte	Detection Frequency	Range	Maximum Detection	Location of Max. Detect.	SQS	Exceedence Frequency	Maximum Enrichment Ratio	MCUL	Exceedence Frequency	Maximum Enrichment Ratio
LPAHs in mg/kg oc										
2-Methylnaphthalene	43/49	0.29 E to 8	8	HC-SS-37	38	0/49		64	0/49	
Acenaphthene	34/49	0.47 E to 40	40	HC-SS-47	16	1/49	2.5	57	0/49	
Acenaphthylene	23/49	0.26 E to 8.0	8	AN-SS-301	66	0/49		66	0/49	
Anthracene	46/49	0.61 to 35	35	HC-SS-47	220	0/49		1200	0/49	
Fluorene	44/49	0.43 E to 7.5	7.5	HC-SS-47	23	0/49		79	0/49	
Naphthalene	45/49	0.74 E to 16	16	AN-SS-301	99	0/49		170	0/49	
Phenanthrene	49/49	0.5 E to 30	30	HC-SS-47	100	0/49		480	0/49	
Total LPAHs	49/49	0.5 to 118.4	118.4	HC-SS-47	370	0/49		780	0/49	
PCBs in mg/kg oc										
Total PCBs	3/31	2.11 E to 7.93 U	5.48	HC-SC-79	12	0/31		65	0/31	
Phthalates in mg/kg oc										
Bis(2-ethylhexyl)phthalate	48/49	1.67 U to 700	700	HC-SS-47	47	1/49	14.89	78	1/49	8.97
Butyl benzyl phthalate	23/49	0.44 E to 5.3 M	5.3 M	AN-SC-81	4.9	0/49		64	0/49	
Di-n-butyl phthalate	18/49	0.55 E to 2.72 E	2.72 E	HC-SC-71	220	0/49		1700	0/49	
Di-n-octyl phthalate	3/49	0.47 U to 4.51 U	4.19	HC-SC-85	58	0/49		4500	0/49	
Diethyl phthalate	1/49	0.17 U to 6.34 U	1.62 E	HC-SS-39	61	0/49		110	0/49	
Dimethyl phthalate	8/49	0.17 U to 5.37 U	2.14 E	HC-SS-37	53	0/49		53	0/49	
Semivolatiles in mg/kg oc										
1,2,4-Trichlorobenzene	1/49	0.17 UG to 2.44	0.23 E	HC-SS-34	0.81	0/22		1.8	0/38	
1,2-Dichlorobenzene	1/49	0.17 U to 2.93 U	0.61 E	HC-SS-34	2.3	0/48		2.3	0/38	
1,4-Dichlorobenzene	2/49	0.17 UE to 3.0	3	AN-SS-301	3.1	0/49		9	0/49	
Dibenzofuran	46/49	0.34 E to 5.6	5.6	AN-SC-71	15	0/49		58	0/49	
Hexachlorobenzene	2/49	0.07 U to 0.53	0.53	HC-SS-34	0.38	1/49	1.39	2.3	0/49	
Hexachlorobutadiene	0/49	0.07 U to 1.3 U			3.9	0/49		6.2	0/49	
N-Nitroso diphenylamine	0/49	0.17 U to 3.29 U			11	0/49		11	0/49	
Semivolatiles in ug/kg										
Benzoic Acid	6/49	59 UE to 770	770	HC-SC-76	650	1/49	1.18	650	1/49	1.18
Benzyl Alcohol	31/49	2.5 E to 180	180	AN-SS-36	57	0/49		73	0/49	

Table 4-3 - Detected SQS Exceedences in Surface Sediment Samples

Sample ID	Analyte	Result	Unit	SQS	E-Ratio
1996 Data					
HC-SC-79	4-Methylphenol	1600	µg/kg (dry wt.)	670	2.39
HC-SC-84	4-Methylphenol	1200	µg/kg (dry wt.)	670	1.79
HC-SS-03	4-Methylphenol	1600 E	µg/kg (dry wt.)	670	2.39
HC-SS-06	4-Methylphenol	1900 E	µg/kg (dry wt.)	670	2.84
HC-SS-08	4-Methylphenol	870 E	µg/kg (dry wt.)	670	1.30
HC-SS-30	4-Methylphenol	680 E	µg/kg (dry wt.)	670	1.01
HC-SS-34	4-Methylphenol	870	µg/kg (dry wt.)	670	1.30
HC-SC-74	Phenol	1800	µg/kg (dry wt.)	420	4.29
HC-SC-75	Phenol	960	µg/kg (dry wt.)	420	2.29
HC-SC-76	Phenol	1100	µg/kg (dry wt.)	420	2.62
HC-SC-81	Phenol	960	µg/kg (dry wt.)	420	2.29
HC-SC-82	Phenol	1100	µg/kg (dry wt.)	420	2.62
HC-SC-84	Phenol	720	µg/kg (dry wt.)	420	1.71
HC-SS-03	Phenol	900 E	µg/kg (dry wt.)	420	2.14
HC-SS-06	Phenol	2200 E	µg/kg (dry wt.)	420	5.24
HC-SS-08	Phenol	1000 E	µg/kg (dry wt.)	420	2.38
HC-SS-29	Phenol	1000 E	µg/kg (dry wt.)	420	2.38
HC-SS-30	Phenol	1300 E	µg/kg (dry wt.)	420	3.10
HC-SS-35	Phenol	1500	µg/kg (dry wt.)	420	3.57
HC-SS-36	Phenol	880	µg/kg (dry wt.)	420	2.10
HC-SS-37	Phenol	900	µg/kg (dry wt.)	420	2.14
HC-SS-45	Phenol	1500	µg/kg (dry wt.)	420	3.57
HC-SS-47	Phenol	460	µg/kg (dry wt.)	420	1.10
HC-SS-47	Acenaphthene	40	mg/kg OC	16	2.50
HC-SC-76	Benzoic Acid	770	µg/kg (dry wt.)	650	1.18
HC-SC-81	Bis(2-ethylhexyl)phthalate	54.76	mg/kg OC	47	1.17
HC-SS-47	Bis(2-ethylhexyl)phthalate	700	mg/kg OC	47	14.89
HC-SS-34	Hexachlorobenzene	0.53	mg/kg OC	0.38	1.39
HC-SC-70	Mercury	0.88	mg/kg (dry wt.)	0.41	2.15
HC-SC-71	Mercury	0.62	mg/kg (dry wt.)	0.41	1.51
HC-SC-72	Mercury	1	mg/kg (dry wt.)	0.41	2.44
HC-SC-73	Mercury	0.84	mg/kg (dry wt.)	0.41	2.05
HC-SC-74	Mercury	4.9	mg/kg (dry wt.)	0.41	11.95
HC-SC-75	Mercury	1.7	mg/kg (dry wt.)	0.41	4.15
HC-SC-76	Mercury	1.1	mg/kg (dry wt.)	0.41	2.68
HC-SC-77	Mercury	0.7	mg/kg (dry wt.)	0.41	1.71
HC-SC-78	Mercury	0.96	mg/kg (dry wt.)	0.41	2.34
HC-SC-79	Mercury	1.8	mg/kg (dry wt.)	0.41	4.39
HC-SC-80	Mercury	0.56	mg/kg (dry wt.)	0.41	1.37
HC-SC-81	Mercury	0.42	mg/kg (dry wt.)	0.41	1.02
HC-SC-83	Mercury	0.72	mg/kg (dry wt.)	0.41	1.76
HC-SC-84	Mercury	0.5	mg/kg (dry wt.)	0.41	1.22

Table 4-3 - Detected SQS Exceedences in Surface Sediment Samples

Sheet 2 of 3

Sample ID	Analyte	Result	Unit	SQS	E-Ratio
HC-SC-85	Mercury	0.45	mg/kg (dry wt.)	0.41	1.10
HC-SS-02	Mercury	0.47	mg/kg (dry wt.)	0.41	1.15
HC-SS-07	Mercury	0.47	mg/kg (dry wt.)	0.41	1.15
HC-SS-08	Mercury	0.53	mg/kg (dry wt.)	0.41	1.29
HC-SS-09	Mercury	0.5	mg/kg (dry wt.)	0.41	1.22
HC-SS-10	Mercury	0.44	mg/kg (dry wt.)	0.41	1.07
HC-SS-11	Mercury	0.47	mg/kg (dry wt.)	0.41	1.15
HC-SS-13	Mercury	1	mg/kg (dry wt.)	0.41	2.44
HC-SS-14	Mercury	0.77	mg/kg (dry wt.)	0.41	1.88
HC-SS-15	Mercury	0.67	mg/kg (dry wt.)	0.41	1.63
HC-SS-16	Mercury	0.47	mg/kg (dry wt.)	0.41	1.15
HC-SS-17	Mercury	0.58	mg/kg (dry wt.)	0.41	1.41
HC-SS-19	Mercury	0.62	mg/kg (dry wt.)	0.41	1.51
HC-SS-20	Mercury	0.44	mg/kg (dry wt.)	0.41	1.07
HC-SS-21	Mercury	1.2	mg/kg (dry wt.)	0.41	2.93
HC-SS-22	Mercury	0.93	mg/kg (dry wt.)	0.41	2.27
HC-SS-23	Mercury	2	mg/kg (dry wt.)	0.41	4.88
HC-SS-24	Mercury	1.9	mg/kg (dry wt.)	0.41	4.63
HC-SS-25	Mercury	1	mg/kg (dry wt.)	0.41	2.44
HC-SS-28	Mercury	0.47	mg/kg (dry wt.)	0.41	1.15
HC-SS-29	Mercury	0.7	mg/kg (dry wt.)	0.41	1.71
HC-SS-30	Mercury	0.49	mg/kg (dry wt.)	0.41	1.20
HC-SS-32	Mercury	0.73	mg/kg (dry wt.)	0.41	1.78
HC-SS-33	Mercury	0.89	mg/kg (dry wt.)	0.41	2.17
HC-SS-34	Mercury	1.5	mg/kg (dry wt.)	0.41	3.66
HC-SS-35	Mercury	0.73	mg/kg (dry wt.)	0.41	1.78
HC-SS-36	Mercury	0.5	mg/kg (dry wt.)	0.41	1.22
HC-SS-37	Mercury	0.43	mg/kg (dry wt.)	0.41	1.05
HC-SS-40	Mercury	11.8	mg/kg (dry wt.)	0.41	28.78
HC-SS-42	Mercury	0.42	mg/kg (dry wt.)	0.41	1.02
HC-SS-44	Mercury	0.59	mg/kg (dry wt.)	0.41	1.44
1998 Data					
AN-SS-301	Mercury	1.0	mg/kg (dry wt.)	0.41	2.44
AN-SS-301	Indeno(1,2,3-cd)pyrene	42 E	mg/kg OC	34	1.24
AN-SS-301	Dibenz(a,h)anthracene	15	mg/kg OC	12	1.25
AN-SS-301	Benzo(g,h,I)perylene	35	mg/kg OC	31	1.13
AN-SS-302	Mercury	0.45	mg/kg (dry wt.)	0.41	1.10
AN-SS-303	Mercury	2.9	mg/kg (dry wt.)	0.41	7.07
AN-SS-305	Mercury	1.5	mg/kg (dry wt.)	0.41	3.66
AN-SS-306	Mercury	0.74	mg/kg (dry wt.)	0.41	1.80
AN-SS-36	Mercury	0.61	mg/kg (dry wt.)	0.41	1.49
AN-SS-36	Benzyl Alcohol	180	µg/kg (dry wt.)	57	3.16
AN-SS-37	Mercury	0.50	mg/kg (dry wt.)	0.41	1.22

447806/Whatcom Waterway RI/Whatcom.xls - Table 4-3

Table 4-3 - Detected SQS Exceedences in Surface Sediment Samples

Sheet 3 of 3

Sample ID	Analyte	Result	Unit	SQS	E-Ratio
AN-SC-70	Mercury	0.85	mg/kg (dry wt.)	0.41	2.07
AN-SC-71	Mercury	1.2	mg/kg (dry wt.)	0.41	2.93
AN-SC-72	Mercury	0.9	mg/kg (dry wt.)	0.41	2.20
AN-SC-73	Mercury	0.81	mg/kg (dry wt.)	0.41	1.98
AN-SC-77	Mercury	1.2	mg/kg (dry wt.)	0.41	2.93
AN-SC-78	Mercury	1.0	mg/kg (dry wt.)	0.41	2.44
AN-SC-80	Mercury	0.71	mg/kg (dry wt.)	0.41	1.73
AN-SC-81	Mercury	0.62	mg/kg (dry wt.)	0.41	1.51
AN-SC-82	Mercury	0.52	mg/kg (dry wt.)	0.41	1.27
AN-SC-84	Mercury	0.45	mg/kg (dry wt.)	0.41	1.10
AN-SC-81	Butylbenzylphthalate	5.3 M	mg/kg OC	4.9	1.08

447806/Whatcom Waterway RI/Whatcom.xls - Table 4-3

Table 4-4 - Detected MCUL Exceedences in Surface Sediment Samples

Sheet 1 of 2

Sample ID	Analyte	Result	Unit	MCUL	E-Ratio
1996 Data					
HC-SC-79	4-Methylphenol	1600	µg/kg (dry wt.)	670	2.39
HC-SC-84	4-Methylphenol	1200	µg/kg (dry wt.)	670	1.79
HC-SS-03	4-Methylphenol	1600 E	µg/kg (dry wt.)	670	2.39
HC-SS-06	4-Methylphenol	1900 E	µg/kg (dry wt.)	670	2.84
HC-SS-08	4-Methylphenol	870 E	µg/kg (dry wt.)	670	1.30
HC-SS-30	4-Methylphenol	680 E	µg/kg (dry wt.)	670	1.01
HC-SS-34	4-Methylphenol	870	µg/kg (dry wt.)	670	1.30
HC-SS-06	Phenol	2200 E	µg/kg (dry wt.)	1200	1.83
HC-SS-30	Phenol	1300 E	µg/kg (dry wt.)	1200	1.08
HC-SS-35	Phenol	1500	µg/kg (dry wt.)	1200	1.25
HC-SS-45	Phenol	1500	µg/kg (dry wt.)	1200	1.25
HC-SC-74	Phenol	1800	µg/kg (dry wt.)	1200	1.50
HC-SC-76	Benzoic Acid	770	µg/kg (dry wt.)	650	1.18
HC-SS-47	Bis(2-ethylhexyl)phthalate	700	mg/kg OC	78	8.97
HC-SC-70	Mercury	0.88	mg/kg (dry wt.)	0.59	1.49
HC-SC-71	Mercury	0.62	mg/kg (dry wt.)	0.59	1.05
HC-SC-72	Mercury	1	mg/kg (dry wt.)	0.59	1.69
HC-SC-73	Mercury	0.84	mg/kg (dry wt.)	0.59	1.42
HC-SC-74	Mercury	4.9	mg/kg (dry wt.)	0.59	8.31
HC-SC-75	Mercury	1.7	mg/kg (dry wt.)	0.59	2.88
HC-SC-76	Mercury	1.1	mg/kg (dry wt.)	0.59	1.86
HC-SC-77	Mercury	0.7	mg/kg (dry wt.)	0.59	1.19
HC-SC-78	Mercury	0.96	mg/kg (dry wt.)	0.59	1.63
HC-SC-79	Mercury	1.8	mg/kg (dry wt.)	0.59	3.05
HC-SC-83	Mercury	0.72	mg/kg (dry wt.)	0.59	1.22
HC-SS-13	Mercury	1	mg/kg (dry wt.)	0.59	1.69
HC-SS-14	Mercury	0.77	mg/kg (dry wt.)	0.59	1.31
HC-SS-15	Mercury	0.67	mg/kg (dry wt.)	0.59	1.14
HC-SS-19	Mercury	0.62	mg/kg (dry wt.)	0.59	1.05
HC-SS-21	Mercury	1.2	mg/kg (dry wt.)	0.59	2.03
HC-SS-22	Mercury	0.93	mg/kg (dry wt.)	0.59	1.58
HC-SS-23	Mercury	2	mg/kg (dry wt.)	0.59	3.39
HC-SS-24	Mercury	1.9	mg/kg (dry wt.)	0.59	3.22
HC-SS-25	Mercury	1	mg/kg (dry wt.)	0.59	1.69
HC-SS-29	Mercury	0.7	mg/kg (dry wt.)	0.59	1.19
HC-SS-32	Mercury	0.73	mg/kg (dry wt.)	0.59	1.24
HC-SS-33	Mercury	0.89	mg/kg (dry wt.)	0.59	1.51
HC-SS-34	Mercury	1.5	mg/kg (dry wt.)	0.59	2.54
HC-SS-35	Mercury	0.73	mg/kg (dry wt.)	0.59	1.24
HC-SS-40	Mercury	11.8	mg/kg (dry wt.)	0.59	20.00

Table 4-4 - Detected MCUL Exceedences in Surface Sediment Samples

Sample ID	Analyte	Result	Unit	MCUL	E-Ratio
1998 Data					
AN-SS-36	Benzyl Alcohol	180	ug/kg	57	3.16
AN-SC-71	Mercury	1.2	mg/kg	0.59	2.03
AN-SC-72	Mercury	0.9	mg/kg	0.59	1.53
AN-SC-73	Mercury	0.81	mg/kg	0.59	1.37
AN-SC-77	Mercury	1.2	mg/kg	0.59	2.03
AN-SC-78	Mercury	1.0	mg/kg	0.59	1.69
AN-SC-80	Mercury	0.71	mg/kg	0.59	1.20
AN-SC-81	Mercury	0.62	mg/kg	0.59	1.05
AN-SS-301	Mercury	1.0	mg/kg	0.59	1.69
AN-SS-303	Mercury	2.9	mg/kg	0.59	4.92
AN-SS-305	Mercury	1.5	mg/kg	0.59	2.54
AN-SS-306	Mercury	0.74	mg/kg	0.59	1.25
AN-SS-36	Mercury	0.61	mg/kg	0.59	1.03
AN-SS-70	Mercury	0.85	mg/kg	0.59	1.44

Table 4-5 - Sediment Quality Screening Assessment for Subsurface Samples

Sheet 1 of 2

Analyte	Detection Frequency	Range	Maximum Detection	Location of Max. Detect.	SQS	Exceedence Frequency	Maximum Enrichment Ratio	MCUL	Exceedence Frequency	Maximum Enrichment Ratio
Total Metals in mg/kg										
Arsenic	55/55	3 to 24	24	HC-DC-92-S1	57	0/55		93	0/55	
Cadmium	42/55	0.57 U to 5.6	5.6	HC-VC-80-S2	5.1	1/55	1.10	6.7	0/55	
Chromium	55/55	14 to 140 E	140 E	HC-VC-80-S2	260	0/55		270	0/55	
Copper	55/55	8.6 to 360 E	360 E	HC-VC-82-S2	390	0/55		390	0/55	
Lead	46/55	3.4 U to 270	270	HC-VC-79-S1	450	0/55		530	0/55	
Mercury	48/70	0.11 U to 69	69	HC-VC-74-S2	0.41	45/70	168.29	0.59	40/70	116.95
Silver	1/55	0.57 U to 1.8 U	1.5	HC-VC-82-S2	6.1	0/55		6.1	0/55	
Zinc	55/55	19 to 570	570	HC-VC-79-S2	410	3/55	1.39	960	0/55	
Phenols in ug/kg dry										
2,4-Dimethylphenol	43/55	2.7 E to 610 E	610 E	HC-VC-85-S2	29	7/53	21.03	29	7/53	21.03
2-Methylphenol	43/55	2.3 E to 400 E	400 E	HC-VC-85-S2	63	1/55	6.35	63	1/55	6.35
4-Methylphenol	50/55	3 E to 21000	21000	HC-VC-80-S2	670	23/55	31.34	670	23/55	31.34
Pentachlorophenol	42/55	3.9 E to 460 E	460 E	HC-DC-88-S1	360	2/55	1.28	690	0/55	
Phenol	33/55	3.1 UE to 680	680	HC-VC-82-S2	420	2/55	1.62	1200	0/55	
HPAHs in mg/kg oc										
Benz(a)anthracene	45/55	0.76 to 217.65	217.65	HC-DC-87-S1	110	1/55	1.98	270	0/55	
Benzo(a)pyrene	47/55	0.53 to 91.18	91.18	HC-DC-87-S1	99	0/55		210	0/55	
Benzo(ghi)perylene	46/55	0.57 to 26.76	26.76	HC-DC-87-S1	31	0/55		78	0/55	
Chrysene	50/55	1.1 to 411.76	411.76	HC-DC-87-S1	110	3/55	3.74	460	0/55	
Dibenz(a,h)anthracene	39/55	0.2 to 18.53	18.53	HC-DC-87-S1	12	4/55	1.54	33	0/55	
Fluoranthene	49/55	1.78 to 1441.18	1441.18	HC-DC-87-S1	160	3/55	9.01	1200	1/55	1.20
Indeno(1,2,3-cd)pyrene	45/55	0.43 to 35.29	35.29	HC-DC-87-S1	34	1/55	1.04	88	0/55	
Pyrene	50/55	0.84 U to 1205.88	1205.88	HC-DC-87-S1	1000	1/55	1.21	1400	0/55	
Total HPAHs	51/55	4.83 U to 3771.76	3771.76	HC-DC-87-S1	960	1/55	3.93	5300	0/55	
Total benzofluoranthene	50/55	1.1 to 323.53	323.53	HC-DC-87-S1	230	2/55	1.41	450	0/55	

Table 4-5 - Sediment Quality Screening Assessment for Subsurface Samples

Sheet 2 of 2

Analyte	Detection Frequency	Range	Maximum Detection	Location of Max. Detect.	SQS	Exceedence Frequency	Maximum Enrichment Ratio	MCUL	Exceedence Frequency	Maximum Enrichment Ratio
LPAHs in mg/kg oc										
2-Methylnaphthalene	51/55	0.27 to 17.02	17.02	HC-DC-89-S2	38	0/55		64	0/55	
Acenaphthene	45/55	0.27 to 41.18	41.18	HC-DC-87-S1	16	6/55	2.57	57	0/55	
Acenaphthylene	44/55	0.15 to 22.81	22.81	HC-DC-92-S2	66	0/55		66	0/55	
Anthracene	47/55	0.41 to 95.24	95.24	HC-DC-87-S2	220	0/55		1200	0/55	
Fluorene	48/55	0.39 to 82.35	82.35	HC-DC-87-S1	23	2/55	3.58	79	1/55	1.04
Naphthalene	50/55	1.18 to 50.88	50.88	HC-DC-92-S2	99	0/55		170	0/55	
Phenanthrene	52/55	1.27 to 1235.29	1235.29	HC-DC-87-S1	100	1/55	12.35	480	1/55	2.57
Total LPAHs	52/55	3.08 U to 1469.71	1469.71	HC-DC-87-S1	370	1/55	3.97	780	1/55	1.88
PCBs in mg/kg oc										
Total PCBs	26/55	0.12 E to 11.43 U	7.58	HC-DC-90-S2	12	0/55		65	0/55	
Phthalates in mg/kg oc										
Bis(2-ethylhexyl)phthalat	31/55	0.43 U to 50 E	50 E	HC-VC-85-S1	47	1/55	1.06	78	0/55	
Butyl benzyl phthalate	26/55	0.13 U to 6.76	6.76	HC-DC-89-S1	4.9	4/55	1.38	64	0/55	
Di-n-butyl phthalate	15/55	0.1 U to 18.82	18.82	HC-DC-89-S1	220	0/55		1700	0/55	
Di-n-octyl phthalate	8/55	0.12 U to 21.88 U	2.62 E	HC-VC-85-S1	58	0/55		4500	0/55	
Diethyl phthalate	4/55	0.12 E to 31.25 U	0.27 E	HC-VC-80-S1	61	0/55		110	0/55	
Dimethyl phthalate	10/55	0.14 U to 26.25 U	1.23 E	HC-DC-92-S1	53	0/55		53	0/55	
Semivolatiles in mg/kg oc										
1,2,4-Trichlorobenzene	3/55	0.06 U to 2.42 U	0.56 E	HC-DC-89-S1	0.81	0/27		1.8	0/52	
1,2-Dichlorobenzene	12/55	0.02 E to 2.83 U	1.67	HC-VC-81-S2	2.3	0/52		2.3	0/52	
1,4-Dichlorobenzene	22/55	0.02 E to 2.58 U	1.14	HC-VC-80-S2	3.1	0/55		9	0/55	
Dibenzofuran	46/55	0.31 to 38.24	38.24	HC-DC-87-S1	15	3/55	2.55	58	0/55	
Hexachlorobenzene	32/55	0.02 to 1.04	1.04	HC-DC-90-S1	0.38	6/55	2.74	2.3	0/55	
Hexachlorobutadiene	0/55	0.01 U to 0.38 U			3.9	0/55		6.2	0/55	
N-Nitroso diphenylamin	8/55	0.09 U to 7.88 UE	4.8 E	HC-VC-78-S2	11	0/55		11	0/55	
Semivolatiles in ug/kg										
Benzoic Acid	13/55	35 UE to 680	680	HC-DC-90-S2	650	1/55	1.05	650	1/55	1.05
Benzyl Alcohol	40/55	1.6 E to 57 U	46 E	HC-VC-81-S2	57	0/55		73	0/55	

447806/Whatcom Waterway RI/Whatcom.xls - Table 4-5

Table 4-6 - Detected SQS Exceedences in Subsurface Sediment Samples

Sample ID	Analyte	Result	Unit	SQS	E-Ratio
HC-DC-89-S2	2,4-Dimethylphenol	35	µg/kg	29	1.21
HC-VC-74-S3	2,4-Dimethylphenol	36 E	µg/kg	29	1.24
HC-VC-80-S2	2,4-Dimethylphenol	31 E	µg/kg	29	1.07
HC-VC-82-S2	2,4-Dimethylphenol	43	µg/kg	29	1.48
HC-VC-84-S2	2,4-Dimethylphenol	74 E	µg/kg	29	2.55
HC-VC-85-S1	2,4-Dimethylphenol	38 E	µg/kg	29	1.31
HC-VC-85-S2	2,4-Dimethylphenol	610 E	µg/kg	29	21.03
HC-VC-85-S2	2-Methylphenol	400 E	µg/kg	63	6.35
HC-DC-87-S2	4-Methylphenol	880	µg/kg	670	1.31
HC-DC-88-S2	4-Methylphenol	690	µg/kg	670	1.03
HC-DC-89-S2	4-Methylphenol	4600	µg/kg	670	6.87
HC-DC-90-S1	4-Methylphenol	1200	µg/kg	670	1.79
HC-DC-90-S2	4-Methylphenol	2900	µg/kg	670	4.33
HC-DC-91-S2	4-Methylphenol	1000	µg/kg	670	1.49
HC-DC-92-S2	4-Methylphenol	1200	µg/kg	670	1.79
HC-VC-73-S2	4-Methylphenol	1500	µg/kg	670	2.24
HC-VC-74-S3	4-Methylphenol	1900	µg/kg	670	2.84
HC-VC-75-S1	4-Methylphenol	830 E	µg/kg	670	1.24
HC-VC-76-S2	4-Methylphenol	1500	µg/kg	670	2.24
HC-VC-77-S1	4-Methylphenol	1000	µg/kg	670	1.49
HC-VC-77-S2	4-Methylphenol	1200	µg/kg	670	1.79
HC-VC-78-S2	4-Methylphenol	810 E	µg/kg	670	1.21
HC-VC-79-S1	4-Methylphenol	3200 E	µg/kg	670	4.78
HC-VC-79-S2	4-Methylphenol	3400 E	µg/kg	670	5.07
HC-VC-80-S1	4-Methylphenol	3200	µg/kg	670	4.78
HC-VC-80-S2	4-Methylphenol	21000	µg/kg	670	31.34
HC-VC-81-S1	4-Methylphenol	1100	µg/kg	670	1.64
HC-VC-81-S2	4-Methylphenol	5600	µg/kg	670	8.36
HC-VC-82-S1	4-Methylphenol	3100	µg/kg	670	4.63
HC-VC-82-S2	4-Methylphenol	18000	µg/kg	670	26.87
HC-VC-85-S2	4-Methylphenol	1500 E	µg/kg	670	2.24
HC-DC-88-S1	Pentachlorophenol	460 E	µg/kg	360	1.28
HC-DC-93-S1	Pentachlorophenol	380	µg/kg	360	1.06
HC-VC-80-S2	Phenol	440	µg/kg	420	1.05
HC-VC-82-S2	Phenol	680	µg/kg	420	1.62
HC-DC-87-S1	Acenaphthene	41.18	mg/kg OC	16	2.57
HC-DC-89-S1	Acenaphthene	17.35	mg/kg OC	16	1.08
HC-DC-89-S2	Acenaphthene	36.17	mg/kg OC	16	2.26
HC-DC-90-S2	Acenaphthene	22.5	mg/kg OC	16	1.41
HC-DC-92-S1	Acenaphthene	22.33	mg/kg OC	16	1.40
HC-VC-71-S2	Acenaphthene	28.08	mg/kg OC	16	1.75
HC-DC-87-S1	Benz(a)anthracene	217.65	mg/kg OC	110	1.98
HC-DC-90-S2	Benzoic Acid	680	µg/kg	650	1.05
HC-VC-85-S1	Bis(2-ethylhexyl)phthalate	50 E	mg/kg OC	47	1.06

Table 4-6 - Detected SQS Exceedences in Subsurface Sediment Samples

Sample ID	Analyte	Result	Unit	SQS	E-Ratio
HC-DC-89-S1	Butyl benzyl phthalate	6.76	mg/kg OC	4.9	1.38
HC-VC-79-S4	Butyl benzyl phthalate	5.45 E	mg/kg OC	4.9	1.11
HC-VC-80-S1	Butyl benzyl phthalate	5.11	mg/kg OC	4.9	1.04
HC-VC-81-S2	Butyl benzyl phthalate	5.09	mg/kg OC	4.9	1.04
HC-DC-86-S1	Chrysene	121.74	mg/kg OC	110	1.11
HC-DC-87-S1	Chrysene	411.76	mg/kg OC	110	3.74
HC-DC-88-S1	Chrysene	132.43	mg/kg OC	110	1.20
HC-DC-86-S1	Dibenz(a,h)anthracene	13.04	mg/kg OC	12	1.09
HC-DC-86-S2	Dibenz(a,h)anthracene	12.61	mg/kg OC	12	1.05
HC-DC-87-S1	Dibenz(a,h)anthracene	18.53	mg/kg OC	12	1.54
HC-DC-89-S1	Dibenz(a,h)anthracene	14.41	mg/kg OC	12	1.20
HC-DC-87-S1	Dibenzofuran	38.24	mg/kg OC	15	2.55
HC-DC-89-S2	Dibenzofuran	22.34	mg/kg OC	15	1.49
HC-DC-92-S1	Dibenzofuran	24.33	mg/kg OC	15	1.62
HC-DC-87-S1	Fluoranthene	1441.18	mg/kg OC	160	9.01
HC-DC-88-S1	Fluoranthene	167.57	mg/kg OC	160	1.05
HC-DC-92-S1	Fluoranthene	203.33	mg/kg OC	160	1.27
HC-DC-87-S1	Fluorene	82.35	mg/kg OC	23	3.58
HC-DC-89-S2	Fluorene	30.85	mg/kg OC	23	1.34
HC-DC-89-S2	Hexachlorobenzene	0.65	mg/kg OC	0.38	1.71
HC-DC-90-S1	Hexachlorobenzene	1.04	mg/kg OC	0.38	2.73
HC-DC-90-S2	Hexachlorobenzene	0.48	mg/kg OC	0.38	1.25
HC-DC-91-S2	Hexachlorobenzene	0.47	mg/kg OC	0.38	1.24
HC-DC-92-S1	Hexachlorobenzene	0.53	mg/kg OC	0.38	1.40
HC-VC-80-S2	Hexachlorobenzene	0.79	mg/kg OC	0.38	2.07
HC-DC-87-S1	Indeno(1,2,3-cd)pyrene	35.29	mg/kg OC	34	1.04
HC-DC-87-S1	Phenanthrene	1235.29	mg/kg OC	100	12.35
HC-DC-87-S1	Pyrene	1205.88	mg/kg OC	1000	1.21
HC-DC-87-S1	Total benzofluoranthenes	323.53	mg/kg OC	230	1.41
HC-DC-89-S1	Total benzofluoranthenes	252.94	mg/kg OC	230	1.10
HC-VC-80-S2	Cadmium	5.6	mg/kg	5.1	1.10
HC-DC-86-S2	Mercury	0.51	mg/kg	0.41	1.24
HC-DC-87-S1	Mercury	1.2	mg/kg	0.41	2.93
HC-DC-87-S2	Mercury	7.5	mg/kg	0.41	18.29
HC-DC-88-S1	Mercury	0.67	mg/kg	0.41	1.63
HC-DC-88-S2	Mercury	2.2	mg/kg	0.41	5.37
HC-DC-89-S1	Mercury	6.4	mg/kg	0.41	15.61
HC-DC-89-S2	Mercury	43	mg/kg	0.41	104.88
HC-DC-90-S1	Mercury	3.8	mg/kg	0.41	9.27
HC-DC-90-S2	Mercury	12	mg/kg	0.41	29.27

Table 4-6 - Detected SQS Exceedences in Subsurface Sediment Samples

Sample ID	Analyte	Result	Unit	SQS	E-Ratio
HC-DC-91-S1	Mercury	0.93	mg/kg	0.41	2.27
HC-DC-91-S2	Mercury	1.6	mg/kg	0.41	3.90
HC-DC-92-S2	Mercury	0.5	mg/kg	0.41	1.22
HC-VC-70-S1	Mercury	2.3	mg/kg	0.41	5.61
HC-VC-71-S1	Mercury	4.3	mg/kg	0.41	10.49
HC-VC-71-S2	Mercury	4.5	mg/kg	0.41	10.98
HC-VC-72-S1	Mercury	2.6	mg/kg	0.41	6.34
HC-VC-73-S1	Mercury	2	mg/kg	0.41	4.88
HC-VC-73-S2	Mercury	3.9	mg/kg	0.41	9.51
HC-VC-73-S3	Mercury	0.56	mg/kg	0.41	1.37
HC-VC-73-S4	Mercury	0.5	mg/kg	0.41	1.22
HC-VC-74-S1	Mercury	10.5	mg/kg	0.41	25.61
HC-VC-74-S2	Mercury	69	mg/kg	0.41	168.29
HC-VC-74-S3	Mercury	8.4	mg/kg	0.41	20.49
HC-VC-75-S1	Mercury	6.4	mg/kg	0.41	15.61
HC-VC-76-S1	Mercury	1.3	mg/kg	0.41	3.17
HC-VC-76-S2	Mercury	0.96	mg/kg	0.41	2.34
HC-VC-77-S1	Mercury	11	mg/kg	0.41	26.83
HC-VC-77-S2	Mercury	7	mg/kg	0.41	17.07
HC-VC-78-S1	Mercury	2.1	mg/kg	0.41	5.12
HC-VC-78-S2	Mercury	0.42	mg/kg	0.41	1.02
HC-VC-79-S1	Mercury	8.1	mg/kg	0.41	19.76
HC-VC-79-S2	Mercury	2.2	mg/kg	0.41	5.37
HC-VC-80-S1	Mercury	1	mg/kg	0.41	2.44
HC-VC-80-S2	Mercury	12	mg/kg	0.41	29.27
HC-VC-81-S1	Mercury	0.93	mg/kg	0.41	2.27
HC-VC-81-S2	Mercury	1.2	mg/kg	0.41	2.93
HC-VC-82-S1	Mercury	1.4	mg/kg	0.41	3.41
HC-VC-82-S2	Mercury	2	mg/kg	0.41	4.88
HC-VC-82-S3	Mercury	1.3	mg/kg	0.41	3.17
HC-VC-83-S1	Mercury	1.4	mg/kg	0.41	3.41
HC-VC-83-S3	Mercury	3.6	mg/kg	0.41	8.78
HC-VC-84-S1	Mercury	0.65	mg/kg	0.41	1.59
HC-VC-84-S2	Mercury	2.2	mg/kg	0.41	5.37
HC-VC-84-S3	Mercury	6.7	mg/kg	0.41	16.34
HC-VC-85-S1	Mercury	0.88	mg/kg	0.41	2.15
HC-DC-93-S1	Zinc	440	mg/kg	410	1.07
HC-VC-79-S1	Zinc	460	mg/kg	410	1.12
HC-VC-79-S2	Zinc	570	mg/kg	410	1.39

Table 4-7 - Detected MCUL Exceedences in Subsurface Samples

Sheet 1 of 2

Sample ID	Analyte	Result	Unit	MCUL	E-Ratio
HC-DC-89-S2	2,4-Dimethylphenol	35	µg/kg (dry wt.)	29	1.21
HC-VC-74-S3	2,4-Dimethylphenol	36 E	µg/kg (dry wt.)	29	1.24
HC-VC-80-S2	2,4-Dimethylphenol	31 E	µg/kg (dry wt.)	29	1.07
HC-VC-82-S2	2,4-Dimethylphenol	43	µg/kg (dry wt.)	29	1.48
HC-VC-84-S2	2,4-Dimethylphenol	74 E	µg/kg (dry wt.)	29	2.55
HC-VC-85-S1	2,4-Dimethylphenol	38 E	µg/kg (dry wt.)	29	1.31
HC-VC-85-S2	2,4-Dimethylphenol	610 E	µg/kg (dry wt.)	29	21.03
HC-VC-85-S2	2-Methylphenol	400 E	µg/kg (dry wt.)	63	6.35
HC-DC-87-S2	4-Methylphenol	880	µg/kg (dry wt.)	670	1.31
HC-DC-88-S2	4-Methylphenol	690	µg/kg (dry wt.)	670	1.03
HC-DC-89-S2	4-Methylphenol	4600	µg/kg (dry wt.)	670	6.87
HC-DC-90-S1	4-Methylphenol	1200	µg/kg (dry wt.)	670	1.79
HC-DC-90-S2	4-Methylphenol	2900	µg/kg (dry wt.)	670	4.33
HC-DC-91-S2	4-Methylphenol	1000	µg/kg (dry wt.)	670	1.49
HC-DC-92-S2	4-Methylphenol	1200	µg/kg (dry wt.)	670	1.79
HC-VC-73-S2	4-Methylphenol	1500	µg/kg (dry wt.)	670	2.24
HC-VC-74-S3	4-Methylphenol	1900	µg/kg (dry wt.)	670	2.84
HC-VC-75-S1	4-Methylphenol	830 E	µg/kg (dry wt.)	670	1.24
HC-VC-76-S2	4-Methylphenol	1500	µg/kg (dry wt.)	670	2.24
HC-VC-77-S1	4-Methylphenol	1000	µg/kg (dry wt.)	670	1.49
HC-VC-77-S2	4-Methylphenol	1200	µg/kg (dry wt.)	670	1.79
HC-VC-78-S2	4-Methylphenol	810 E	µg/kg (dry wt.)	670	1.21
HC-VC-79-S1	4-Methylphenol	3200 E	µg/kg (dry wt.)	670	4.78
HC-VC-79-S2	4-Methylphenol	3400 E	µg/kg (dry wt.)	670	5.07
HC-VC-80-S1	4-Methylphenol	3200	µg/kg (dry wt.)	670	4.78
HC-VC-80-S2	4-Methylphenol	21000	µg/kg (dry wt.)	670	31.34
HC-VC-81-S1	4-Methylphenol	1100	µg/kg (dry wt.)	670	1.64
HC-VC-81-S2	4-Methylphenol	5600	µg/kg (dry wt.)	670	8.36
HC-VC-82-S1	4-Methylphenol	3100	µg/kg (dry wt.)	670	4.63
HC-VC-82-S2	4-Methylphenol	18000	µg/kg (dry wt.)	670	26.87
HC-VC-85-S2	4-Methylphenol	1500 E	µg/kg (dry wt.)	670	2.24
HC-DC-87-S1	Phenanthrene	1235.29	mg/kg OC	480	2.57
HC-DC-90-S2	Benzoic Acid	680	µg/kg (dry wt.)	650	1.05
HC-DC-87-S1	Fluoranthene	1441.18	mg/kg OC	1200	1.20
HC-DC-87-S1	Mercury	1.2	mg/kg (dry wt.)	0.59	2.03
HC-DC-87-S2	Mercury	7.5	mg/kg (dry wt.)	0.59	12.71
HC-DC-88-S1	Mercury	0.67	mg/kg (dry wt.)	0.59	1.14
HC-DC-88-S2	Mercury	2.2	mg/kg (dry wt.)	0.59	3.73
HC-DC-89-S1	Mercury	6.4	mg/kg (dry wt.)	0.59	10.85
HC-DC-89-S2	Mercury	43	mg/kg (dry wt.)	0.59	72.88
HC-DC-90-S1	Mercury	3.8	mg/kg (dry wt.)	0.59	6.44
HC-DC-90-S2	Mercury	12	mg/kg (dry wt.)	0.59	20.34
HC-DC-91-S1	Mercury	0.93	mg/kg (dry wt.)	0.59	1.58
HC-DC-91-S2	Mercury	1.6	mg/kg (dry wt.)	0.59	2.71

Table 4-7 - Detected MCUL Exceedences in Subsurface Samples

Sheet 2 of 2

Sample ID	Analyte	Result	Unit	MCUL	E-Ratio
HC-VC-207	Mercury	0.84	mg/kg (dry wt.)	0.59	1.42
HC-VC-70-S1	Mercury	2.3	mg/kg (dry wt.)	0.59	3.90
HC-VC-71-S1	Mercury	4.3	mg/kg (dry wt.)	0.59	7.29
HC-VC-71-S2	Mercury	4.5	mg/kg (dry wt.)	0.59	7.63
HC-VC-72-S1	Mercury	2.6	mg/kg (dry wt.)	0.59	4.41
HC-VC-73-S1	Mercury	2	mg/kg (dry wt.)	0.59	3.39
HC-VC-73-S2	Mercury	3.9	mg/kg (dry wt.)	0.59	6.61
HC-VC-74-S1	Mercury	10.5	mg/kg (dry wt.)	0.59	17.80
HC-VC-74-S2	Mercury	69	mg/kg (dry wt.)	0.59	116.95
HC-VC-74-S3	Mercury	8.4	mg/kg (dry wt.)	0.59	14.24
HC-VC-75-S1	Mercury	6.4	mg/kg (dry wt.)	0.59	10.85
HC-VC-76-S1	Mercury	1.3	mg/kg (dry wt.)	0.59	2.20
HC-VC-76-S2	Mercury	0.96	mg/kg (dry wt.)	0.59	1.63
HC-VC-77-S1	Mercury	11	mg/kg (dry wt.)	0.59	18.64
HC-VC-77-S2	Mercury	7	mg/kg (dry wt.)	0.59	11.86
HC-VC-78-S1	Mercury	2.1	mg/kg (dry wt.)	0.59	3.56
HC-VC-79-S1	Mercury	8.1	mg/kg (dry wt.)	0.59	13.73
HC-VC-79-S2	Mercury	2.2	mg/kg (dry wt.)	0.59	3.73
HC-VC-80-S1	Mercury	1	mg/kg (dry wt.)	0.59	1.69
HC-VC-80-S2	Mercury	12	mg/kg (dry wt.)	0.59	20.34
HC-VC-81-S1	Mercury	0.93	mg/kg (dry wt.)	0.59	1.58
HC-VC-81-S2	Mercury	1.2	mg/kg (dry wt.)	0.59	2.03
HC-VC-82-S1	Mercury	1.4	mg/kg (dry wt.)	0.59	2.37
HC-VC-82-S2	Mercury	2	mg/kg (dry wt.)	0.59	3.39
HC-VC-82-S3	Mercury	1.3	mg/kg (dry wt.)	0.59	2.20
HC-VC-83-S1	Mercury	1.4	mg/kg (dry wt.)	0.59	2.37
HC-VC-83-S3	Mercury	3.6	mg/kg (dry wt.)	0.59	6.10
HC-VC-84-S1	Mercury	0.65	mg/kg (dry wt.)	0.59	1.10
HC-VC-84-S2	Mercury	2.2	mg/kg (dry wt.)	0.59	3.73
HC-VC-84-S3	Mercury	6.7	mg/kg (dry wt.)	0.59	11.36
HC-VC-85-S1	Mercury	0.88	mg/kg (dry wt.)	0.59	1.49

Table 4-8 - Ranking of Chemical Constituents in Sediment Samples

Surface Samples

Combined Score	Percent Exceedence	Maximum Enrichment	Analyte	MCUL	Exceedence Ratio	Percent Exceedence	Maximum Enrichment
2	1	1	Mercury	0.59	39/82	47.56	20.00
4	2	2	4-Methylphenol	670	7/49	14.29	2.84
6	3	3	Phenol	1200	1/49	2.04	8.97
8	4	4	Bis(2-ethylhexyl)phthalate	78	5/49	10.20	1.83
9	4	5	Benzoic Acid	650	1/49	2.04	1.18

Subsurface Samples

Combined Score	Percent Exceedence	Maximum Enrichment	Analyte	MCUL	Exceedence Ratio	Percent Exceedence	Maximum Enrichment
2	1	1	Mercury	0.59	41/71	57.75	116.95
4	2	2	4-Methylphenol	670	24/56	42.86	31.34
6	3	3	2,4-Dimethylphenol	29	7/54	12.96	21.03
9	5	4	2-Methylphenol	63	1/56	1.79	6.35
9	4	5	Phenanthrene	480	1/55	1.82	2.57
10	4	6	Total LPAHs	780	1/55	1.82	1.88
11	4	7	Fluoranthene	1200	1/55	1.82	1.20
13	5	8	Benzoic Acid	650	1/56	1.79	1.05
13	4	9	Fluorene	79	1/55	1.82	1.04

447806/Whatcom Waterway RI/Whatcom.xls - Table 4-8

Surface (0 to 10 cm) S

Whatcom Waterway Sit

n in mg/kg (dry wt.)

ncentration > Bioaccumulation
ng/kg)

ncentration > MCUL

ncentration > SQS

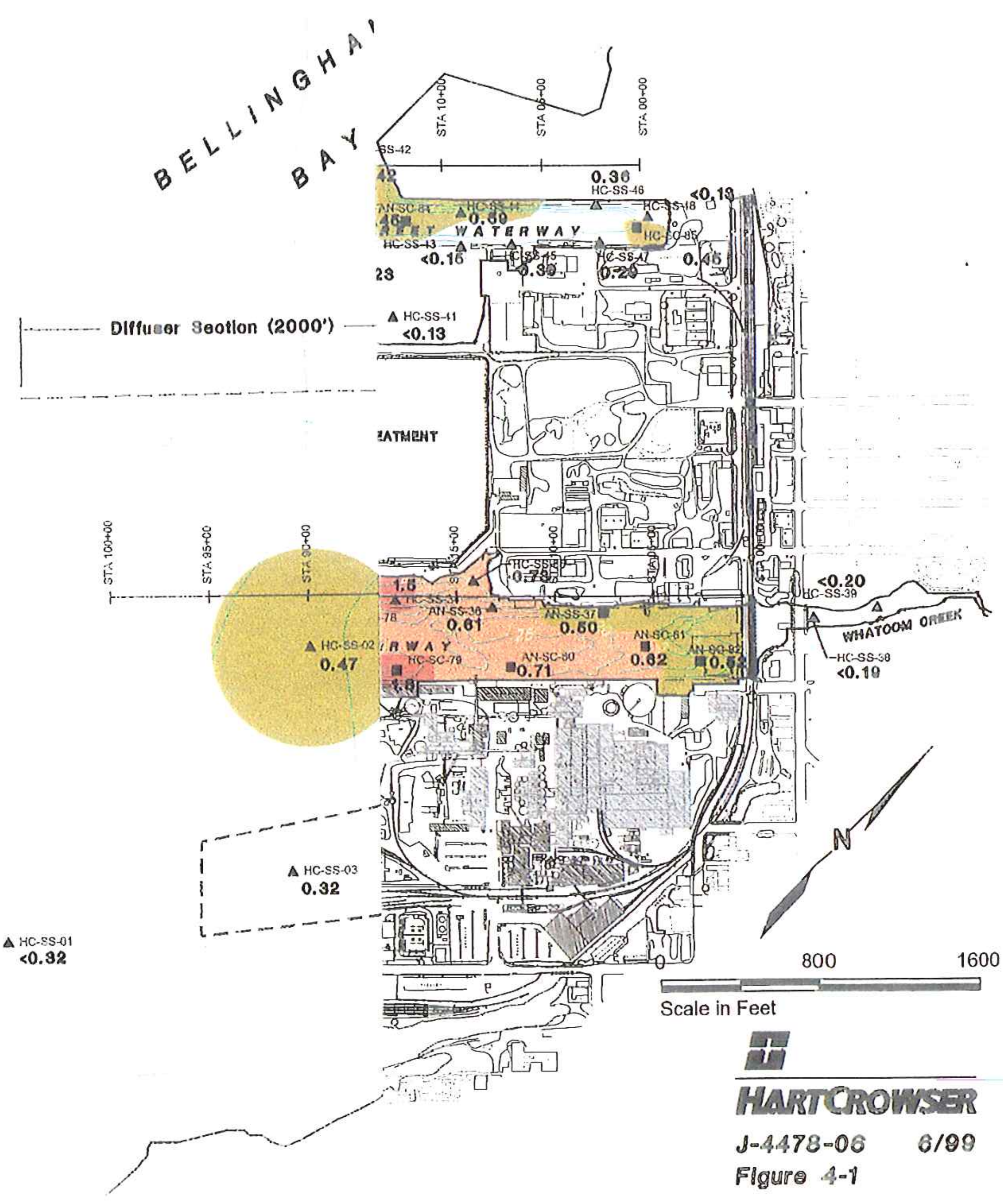
'BELLINGHAM MILLSITE PLOT
S AND SURVEYS, INC. DATED JULY
CIFIC CORPORATION.

METRY DATA FROM DRAFT
RMY CORPS OF ENGINEERS
PARTMENT OF COMMERCE
PHERIC ADMINISTRATION (NOAA)
I CHART 18423, DATED FEBRUARY

RI/FS SEDIMENT SAMPLE LOCATION

■ HC-SC-70	SUBSURFACE SEDIMENT VIBRACORE AND COLLOCATED SURFACE SEDIMENT SAMPLE
▲ HC-SS-01	SURFACE SEDIMENT SAMPLE
◆ HC-NR-101	NATURAL RECOVERY CORE
△ BELL50	SURFACE SEDIMENT SAMPLE FROM PRIOR STUDIES (PRIOR TO 1995)
— — —	MUDLINE BATHYMETRY IN FEET

△D
0.15



HARTCROWSER

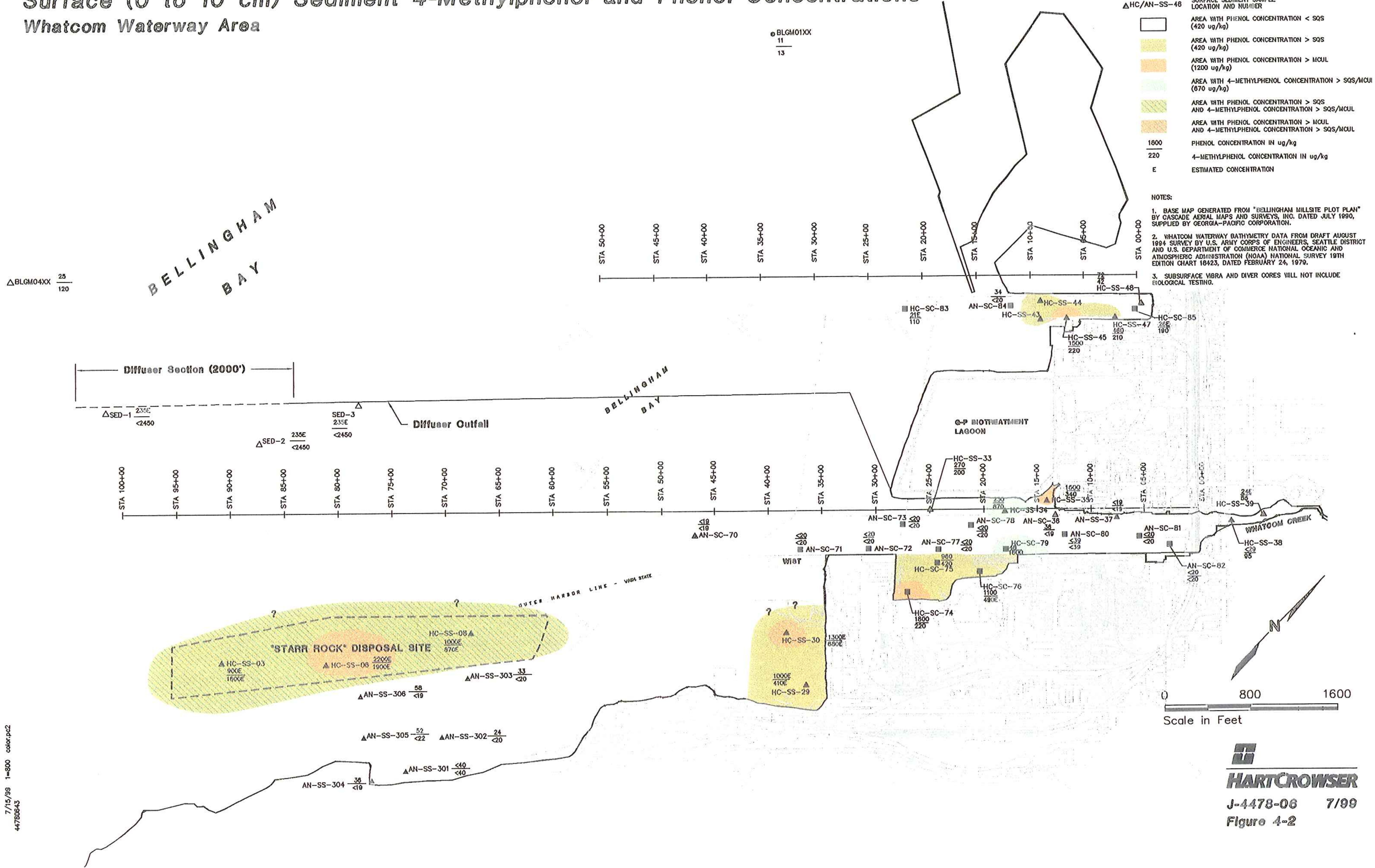
J-4478-06 6/99

Figure 4-1

05/21/99 1=400 99-007-04
BBy025-01.dwg

Surface (0 to 10 cm) Sediment 4-Methylphenol and Phenol Concentrations

Whatcom Waterway Area



■ HC/AN-SC-85	SURFACE SEDIMENT SAMPLE CO-LOCATED WITH CORE SAMPLE LOCATION AND NUMBER
△HC/AN-SS-46	SURFACE SEDIMENT SAMPLE LOCATION AND NUMBER
☐	AREA WITH PHENOL CONCENTRATION < SQS (420 ug/kg)
🟨	AREA WITH PHENOL CONCENTRATION > SQS (420 ug/kg)
🟧	AREA WITH PHENOL CONCENTRATION > MCUL (1200 ug/kg)
🟩	AREA WITH 4-METHYLPHENOL CONCENTRATION > SQS/MCUL (670 ug/kg)
▨	AREA WITH PHENOL CONCENTRATION > SQS AND 4-METHYLPHENOL CONCENTRATION > SQS/MCUL
▨	AREA WITH PHENOL CONCENTRATION > MCUL AND 4-METHYLPHENOL CONCENTRATION > SQS/MCUL
1800	PHENOL CONCENTRATION IN ug/kg
220	4-METHYLPHENOL CONCENTRATION IN ug/kg
E	ESTIMATED CONCENTRATION

NOTES:

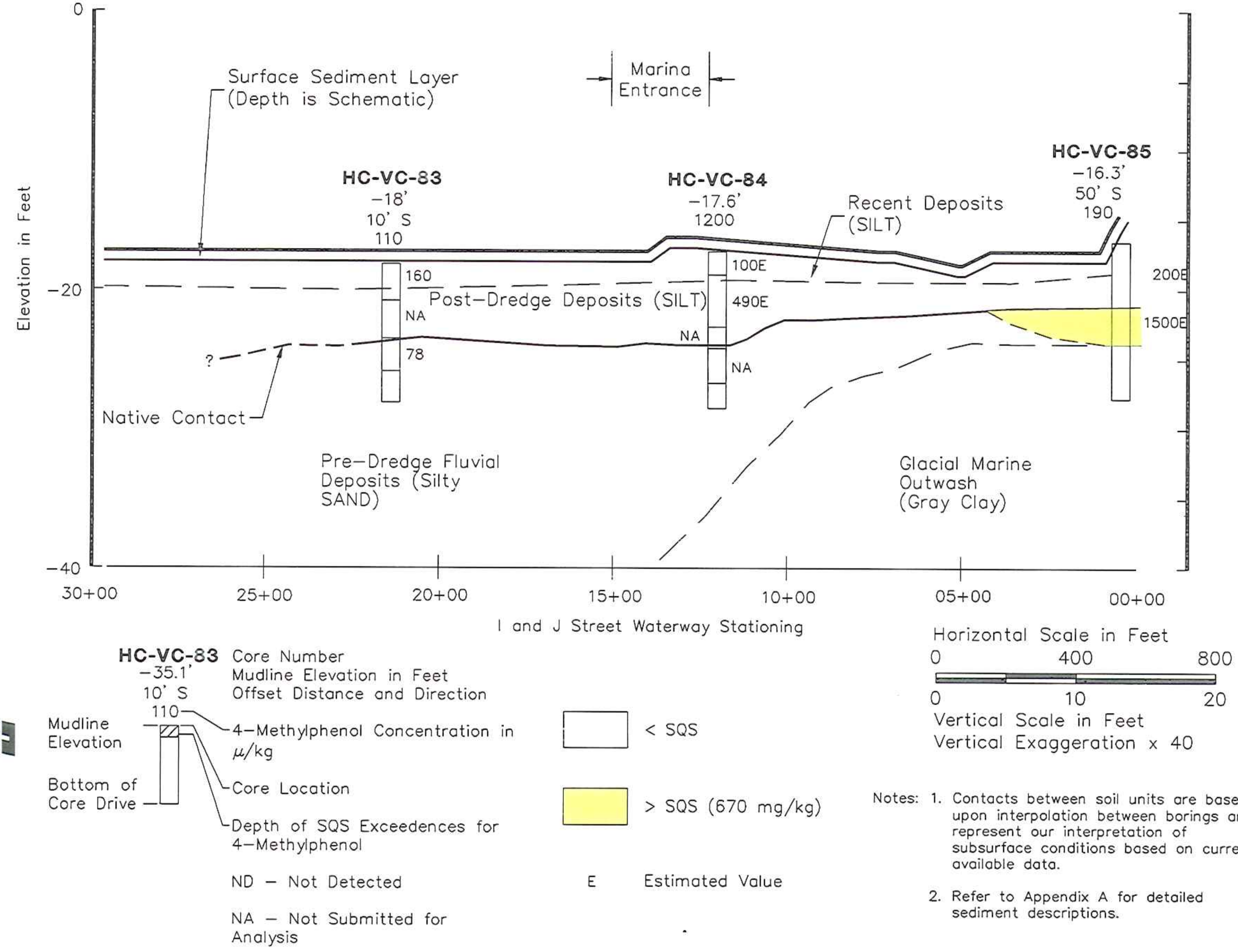
1. BASE MAP GENERATED FROM "BELLINGHAM MILLSITE PLOT PLAN" BY CASCADE AERIAL MAPS AND SURVEYS, INC. DATED JULY 1990, SUPPLIED BY GEORGIA-PACIFIC CORPORATION.
2. WHATCOM WATERWAY BATHYMETRY DATA FROM DRAFT AUGUST 1994 SURVEY BY U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT AND U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) NATIONAL SURVEY 19TH EDITION CHART 18423, DATED FEBRUARY 24, 1979.
3. SUBSURFACE VIBRA AND DIVER CORES WILL NOT INCLUDE BIOLOGICAL TESTING.

7/15/99 1=800 color.pc2
44780643

HARTCROWSER
J-4478-06 7/99
Figure 4-2

jch 6/29/98 1= Jlor.pc2 44780640

Subsurface Sediment 4-Methylphenol Concentrations
I and J Street Waterway



Notes:
1. Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.
2. Refer to Appendix A for detailed sediment descriptions.

HARTCROWSER

J-4478-06 5/98

Figure 4-6

5.0 CONFIRMATORY BIOASSAY DETERMINATIONS

This section summarizes the investigation of biological effects using confirmatory bioassay testing of sediments collected in three separate studies: 1) within the WW Area in 1996; 2) within the WW Area in 1998; and 3) in the Boulevard Park/Starr Rock Area in 1998. For each study, three bioassays were conducted on sediments collected during the sampling event:

- 10 day amphipod mortality test using *Euhaustorius estuarius*;
- 20-day juvenile polychaete growth test using *Neanthes arenaceodentata*; and
- 48-hour bivalve larval development test using *Mytilus* spp.

The mussel *M. edulis* was used in the larval development testing of sediments collected from the WW Area in 1996. *M. galloprovincialis* was used in the larval development testing of sediments collected from the WW Area and the Boulevard Park/Starr Rock Area in 1998.

This section also provides a brief description of the testing methods, a presentation of the results and comparisons with the Sediment Management Standards (SMS) interpretive criteria, and an interpretation of the data.

5.1 Methods

In the three studies, forty test sediment samples were submitted for toxicity testing. This included:

- 22 samples collected from the WW Area in 1996 (August 29 through September 10);
- 12 samples collected from the WW Area in 1998 (October 27 through 29); and
- 6 samples collected from the Boulevard Park/Starr Rock Area in 1998 (October 26).

In each study, three reference sediment samples from Carr Inlet were included in each test series, as were the required controls. Because the 1998 sampling of the WW and Boulevard Park/Starr Rock Areas was conducted as part of one effort, the toxicity testing for both studies used the same reference sediment samples from Carr Inlet for comparisons to SMS criteria.

5.1.1 WW Area - 1996

Sediments collected in the WW Area in 1996 and submitted for toxicity testing were received by the laboratory between September 4 and 13, 1996, and stored at 4° C in the dark until testing was initiated. If there was headspace in the jars, nitrogen was added prior to storage (PSDDA, 1989). The amphipod bioassays were initiated on September 27, 1996. The juvenile polychaete bioassays were initiated on October 4, 1996. The bivalve larval development bioassays were initiated on October 30, 1996.

Bioassays were conducted in accordance with protocols outlined in the project QAPP (Hart Crowser, 1996d) with two exceptions. First, the test organism *M. edulis* was used in place of *Dendraster excentricus* for the larval development bioassay (Johns et al., personal comm., 1996a). The laboratory obtained bivalve specimens for testing after the gametes obtained from two separate batches of echinoderm species failed to meet quality control criteria. Bivalves were entering their natural spawning cycle and were expected to provide better quality gametes to conduct testing (Johns personal comm., 1996b). Second, the bivalve test using *M. edulis* was initiated on October 30, one day beyond the holding time (56 days) for one of the sediment samples. Ecology provided verbal approval to proceed with both the test animal substitution for the larval bioassay, and with the slight exceedance of holding time for the one bivalve test sample. Otherwise, testing followed protocols recommended by PSEP (1995).

5.1.2 WW and Boulevard Park/Starr Rock Areas - 1998

Sediment samples collected in the WW and Boulevard Park/Starr Rock Areas and submitted for toxicity testing were received by the laboratory between October 28 and 30, 1998, and stored in the dark at 4°C until testing was initiated. The amphipod toxicity tests were initiated on November 6 and 9, 1998. The bivalve larval development toxicity tests were initiated on November 15, 1998. The juvenile polychaete toxicity tests were initiated on December 8, 1998.

Bioassays were conducted in accordance with protocols outlined in the project Work Plans (Anchor, 1998a and 1998b). Testing followed protocols recommended by PSEP (1995) and subsequent Sediment Management Annual Review Meeting (SMARM) updates (PSDDA, 1996).

Prior to test initiation, the pore water ammonia measurements from one test sample (AN-SC-78 at 21.4 mg-N/L), and two reference samples (CR-22 at 23.2 mg-N/L and CR-23W at 22.8 mg-N/L), exceeded the target value of 15 mg-N/L, prompting the initiation of the ammonia purging protocol. A separate test series was initiated for these samples that included ammonia purging. Sample CR-10 and a negative control sample were also included in the ammonia purging test series. The results of this testing series are discussed in Appendices I and J as they relate to the WW Area and Boulevard Park/Starr Rock Area samples, respectively.

Toxicity data resulting from the bioassays were used to calculated test statistics. As set forth in the SMS, the determination of whether adverse effects are observed in a test sediment is established in part by a pairwise statistical comparison of test sediment with that collected from an appropriate reference site. Prior to statistical analysis, data expressed as percentages were transformed using the arcsine-square root transformation. The 1996 WW Area sample replicates were first tested for normality and homogeneity of variances against reference replicate data using Quantile-Quantile plots and boxplots, respectively, to guide the use of subsequent statistical analysis. In separate analyses for each study, the 1998 WW Area sample replicates and the Boulevard Park/Starr Rock Area sample replicates were tested for normality and homogeneity of variance against reference replicate data using Wilk-Shapiro test (W test) and Cochran's test (F test for variances), respectively. For test locations demonstrating normal distribution and homogeneity of variance, one-tailed pairwise t-tests were used to investigate whether respective sample means were statistically different from the mean of the replicates of the appropriate reference sites. For test locations demonstrating skewed (non-normal) distributions, a nonparametric test (one-sided Mann-Whitney U test) was used to determine statistical difference from appropriate reference sites. Sample means then provided the basis for comparison with biological effects interpretive criteria to yield pass/fail evaluations for each sample.

Test statistics were interpreted according to the SMS interpretive criteria for biological effects as promulgated in the State of Washington Administrative Code (WAC) established for sediment quality standards (SQS) (WAC 173-204-320) and for minimum cleanup levels (MCUL) (WAC 173-204-520). Table 5-1 summarizes the biological effects interpretive criteria. A sediment sample from a given location is considered to fail in comparison to the overall MCUL biological criteria if:

- Two of the biological tests exceed the SQS biological criteria presented in Table 5-1; or

- One of the biological tests exceeds the MCUL biological criteria presented in Table 5-1.

Sediments that pass these confirmatory biological testing criteria are deemed to be in compliance with WAC 173-204-520.

5.2 Data Quality Review

The bioassay results were deemed acceptable for use as outlined in the QAPP (Hart Crowser, 1996d) and Work Plans (Anchor, 1998a and 1998b). For the 1996 WW Area study, Appendix E describes the general procedures used to conduct the bioassays, discusses the specific deviations from environmental test parameters for each type of bioassay, and presents an evaluation of the effects of these deviations. Similar descriptions of the toxicity testing conducted for the WW Area in 1998 and the Boulevard Park/Starr Rock Area are contained in Appendices I and J, respectively.

5.3 Comparison of Bioassay Results with SQS/MCUL Criteria

The individual replicate results for the amphipod, bivalve larvae, and juvenile polychaete bioassays are presented in Tables 5-2, 5-3, and 5-4, respectively. The comparative grain size data, biological effects data, and the results of comparisons with biological effects interpretive criteria are summarized in Tables 5-5 through 5-9. Laboratory data reports for *E. estuarius*, *M. edulis*, and *N. arenaceodentata* bioassays conducted for the WW Area in 1996 are provided in Appendix E. Similar descriptions of the toxicity testing conducted for the WW Area in 1998 and the Boulevard Park/Starr Rock Area are contained in appendices associated with Appendices I and J, respectively.

Selection of appropriate reference sites for comparison with test sediments was based upon the percent fines fraction (Table 5-5).

The percent fines for reference sites collected for the 1996 WW Area sampling were 15% (HC-CR-22), 70% (HC-CR-24), and 86% (HC-CR-02). The median values of the percent fines between reference sites were used to determine the appropriate locations to use for statistical comparison. Therefore, the determinations for the 1996 WW Area sampling were based on the following ranges:

- Test sediments with % fines < 43% were compared to HC-CR-22;
- Test sediments with % fines > 43% and < 78% were compared to HC-CR-24; and
- Test sediments with % fines > 78% were compared to HC-CR-02.

The percent fines for test sediments ranged from 6 to 97 percent. Five test sediments contained percent fines less than 43 percent and were compared to HC-CR-22. Seventeen test sediments contained percent fines greater than 78 percent and were compared to HC-CR-02. No locations had percent fines within the range for comparison to HC-CR-24.

The percent fines for reference sites collected for the 1998 WW and Boulevard Park/Starr Rock Area sampling ranged from 13.5 to 88.9 percent. The WW Area sediment samples ranged from 17.1 to 91.8 percent fines. For the 1998 WW Area samples, the percent fines of the reference samples match the test samples within 20 percent. The Boulevard Park/Starr Rock sediment samples ranged from 5.6 to 96.1 percent fines. For three test samples (AN-SS-301, AN-SS-305, and AN-SS-306), the closest matching reference sediment sample had more than 20 percent difference in percent fines. Nevertheless, appropriate SMS reference site comparisons were supported by the available data.

Results for the negative control and reference sediments for the three bioassays met the requirements of the SMS performance standards. The bioassay results for negative control and reference sediments are presented in Table 5-6.

Tables 5-7, 5-8, and 5-9 show the results of the toxicity tests using *E. estuarius*, *M. galloprovincialis (M. edulis* for 1996 WW Area study), and *N. arenaceodentata*, respectively. These tables list the locations tested, the corresponding reference site (based upon similar grain size), the test endpoint, results of the one-tailed t-test or Mann-Whitney Test comparison with the reference sediment, and whether the results passed or failed the SQS and MCUL biological effects interpretive criteria.

For the three studies, the mean percent mortality for the 10-day amphipod test *(E. estuarius)* ranged from 1 to 24 percent. The test sediments passed both the SQS and MCUL criteria for amphipod mortality (Table 5-7).

The mean percent normal survival for the 48-hour bivalve larval test using *M.* spp. ranged from 46 to 99 percent. Six of the forty test sediments (HC-SS-08, HC-SS-25, HC-SS-30, HC-SS-31, HC-SS-34, and HC-SS-35) failed the MCUL criteria. Twelve test sediments (i.e., the six sediments having MCUL failures, and sediments from HC-SS-26, HC-SS-29, HC-SS-32, HC-SS-33, AN-SC-80, and AN-SC-81) failed the SQS criteria (Table 5-8).

The mean individual growth rate for the 20-day juvenile polychaete test *(N. arenaceodentata)* ranged from 0.38 to 0.67 milligrams/individual/day (mg/ind-day) (dry weight basis) (Table 5-9). The survival in the control replicates for the 1998 WW Area and Boulevard Park/Starr Rock Area sampling was 60 percent, attributable to two of the replicates becoming anoxic. The survival in the three replicates that did not become anoxic was 93 percent. The mean individual growth across the *N. arenaceodentata* control replicates was 0.43 mg/ind-day; the growth in the three replicates that did not become anoxic was 0.53 mg/ind-day. The mean individual growth of *N. arenaceodentata* in the test sediment ranged from 0.41 to 0.59 mg/ind-day. Regardless of the control comparison, the eighteen sediments from the two 1998 studies tested with

N. arenaceodentata passed SQS biological criteria. Four (HC-SS-03, HC-SS-13, HC-SS-22, and HC-SS-23) of the twenty-two test locations sampled in the WW Area in 1996 failed the SQS criteria. None of the forty test sediments failed the MCUL criteria.

5.4 Interpretation of Biological Effects Data

Table 5-10 provides a summary of the pass/fail comparisons between sediment toxicity tests and biological effects interpretive criteria. Sixteen locations failed the SMS SQS biological criteria. Locations HC-SS-08, HC-SS-25, HC-SS-30, HC-SS-31, HC-SS-34, and HC-SS-35 failed the MCUL biological criteria for the bivalve larval test *(M. edulis)*. No sample locations demonstrated toxicity in multiple bioassay tests.

The spatial distribution of the locations failing the MCUL criteria for the bivalve larval test are shown on Figure 5-1. The six locations are disbursed throughout the study area and do not appear to form a significant spatial pattern in toxicity (e.g., locations that are toxic are not clustered). One location, HC-SS-08 is located at the Starr Rock Disposal Site, three are located along the perimeter of the G-P Biotreatment Lagoon, with HC-SS-25 on the west side and HC-SS-34 and HC-SS-35 to the east of the lagoon. The final two locations, HC-SS-30 and HC-SS-31, are located adjacent to Port of Bellingham property.

The sediment toxicity was not significantly correlated with mercury, phenol, or 4-methylphenol concentrations, or with other factors such as ammonia. Concentrations of total mercury (the primary contaminant of concern) were not correlated with toxicity, i.e., locations exhibiting toxicity contained mercury concentrations lower than the highest concentrations observed in locations that were not toxic (Figure 5-1). The MCUL chemical criteria for 4-methylphenol (670 μg/kg) was exceeded at three locations where toxicity tests were conducted. However, at the location having the highest concentration of 4-methylphenol (HC-SS-06), no biological effects were observed in the three toxicity tests conducted. The probable absence of significant 4-methylphenol toxicity is also indicated by a literature review of the toxic effects of this chemical (see Appendix E). A similar lack of correlated effects was observed for the phenol data. Additionally, there were no obvious relationships between sediment toxicity and non-contaminant factors (e.g., grain size, total organic carbon, ammonia, and total sulfides).

5.5 Comparison of Biological & Chemical Exceedance Areas

Bioassay SQS exceedences and chemical MCUL exceedences in areas not tested with bioassays as shown in Figure 5-1.

Enrichment ratios relative to MCUL chemical criteria indicate exceedences in the central and outer portions of Whatcom Waterway, in the Boulevard Park/Starr Rock Area, and in inner Bellingham Bay extending from the Cornwall landfill to the mouth of the I & J Street Waterway. Biological exceedences of SQS and MCUL criteria were spatially clustered, covering limited areas along the northern margin of Whatcom Waterway, some of the Starr Rock Disposal Site, and the inner bay. Sample locations along the federal navigation channel in Whatcom Waterway passed toxicity testing. Thirteen locations (HC-SS-14, HC-SS-15, HC-SS-17, HC-SS-19, HC-SS-21, HC-SS-24, AN-SS-36, AN-SC-70, AN-SC-71, AN-SC-72, AN-SC-73, AN-SC-77, and AN-SC-78) with MCUL chemical exceedences in Whatcom Waterway and the inner bay were overridden by passing bioassays.

As discussed above, sediments exhibiting bioassay toxicity were not clearly associated with any single chemical, but may have been caused by the compound effects of a mixture of chemicals (primarily mercury and phenolics), and possibly other constituents (e.g., decaying organic matter).

Table 5-1 - Sediment Standards Biological Criteria

SQS BIOLOGICAL CRITERIA	MCUL BIOLOGICAL CRITERIA
Sediments are determined to have adverse effects on biological resources when any one of the confirmatory marine sediment biological tests of WAC 173-204-315(1) demonstrates the following results:	The MCUL is exceeded when any two of the biological tests exceed the SQS biological criteria, or one of the following test determinations is made:
1)**Amphipod.** The test sediment has a higher[a] mean mortality than the reference sediment, and the test sediment mean mortality exceeds 25%, on an absolute basis.	1)**Amphipod.** The test sediment has a higher[a] mean mortality than the reference sediment, and the test sediment mean mortality is more than 30% higher than the reference sediment mean mortality, on an absolute basis.
2)**Larval.** The test sediment has a mean survivorship of normal larvae that is less[a] than the mean normal survivorship in the reference sediment, and the test sediment mean normal survivorship is less than 85% of the mean normal survivorship in the reference sediment (i.e., the test sediment has a mean combined abnormality and mortality that is greater[a] than 15% relative to time-final in the reference sediment).	2)**Larval.** The test sediment has a mean survivorship of normal larvae that is less[a] than the mean normal survivorship in the reference sediment, and the test sediment mean normal survivorship is less than 70% of the mean normal survivorship in the reference sediment (i.e., the test sediment has a mean combined abnormality and mortality that is greater[a] than 30% relative to time-final in the reference sediment).
3)**Juvenile Polychaete.** The test sediment has a mean individual growth rate that is statistically different[a] from the reference sediment mean individual growth rate, and the test sediment has a mean individual growth rate of less than 70% of the reference sediment mean individual growth rate.	3)**Juvenile Polychaete.** The test sediment has a mean individual growth rate that is statistically different[a] from the reference sediment mean individual growth rate, and the test sediment has a mean individual growth rate of less than 50% of the reference sediment mean individual growth rate.

NOTE: MCUL- Minimum Cleanup Level
SQS - Sediment Quality Standards

[a] Statistical significance for amphipod and juvenile polychaete tests is defined using a t-test, p£ 0.05; for larval tests p£ 0.10.

447806/Whatcom Waterway RI/Whatcom.doc

Table 5-2 - 10-day Amphipod (*E. estuarius*) Mortality Sediment Bioassay

Sheet 1 of 2

	Replicate (mortality)					
	A	B	C	D	E	Mean
Whatcom Waterway Area in 1996						
Reference ID						
CR-02	0.05	0.00	0.00	0.05	0.10	0.04
CR-22	0.20	0.10	0.00	0.00	0.15	0.09
CR-24	0.05	0.20	0.05	0.00	0.00	0.06
Negative Control	0.00	0.00	0.00	0.00	0.00	0.00
Sample ID						
HC-SS-03	0.15	0.05	0.25	0.20	0.05	0.14
HC-SS-06	0.05	0.10	0.10	0.05	0.00	0.06
HC-SS-08	0.15	0.05	0.05	0.40	0.00	0.13
HC-SS-13	0.05	0.00	0.10	0.05	0.05	0.05
HC-SS-14	0.05	0.00	0.00	0.00	0.00	0.01
HC-SS-15	0.10	0.00	0.00	0.00	0.00	0.02
HC-SS-17	0.10	0.15	0.15	0.10	0.05	0.11
HC-SS-19	0.05	0.00	0.00	0.00	0.00	0.01
HC-SS-21	0.10	0.05	0.00	0.10	0.05	0.06
HC-SS-22	0.20	0.00	0.05	0.05	0.10	0.08
HC-SS-23	0.00	0.10	0.10	0.10	0.00	0.06
HC-SS-24	0.05	0.00	0.10	0.15	0.10	0.08
HC-SS-25	0.05	0.00	0.00	0.00	0.00	0.01
HC-SS-26	0.05	0.05	0.05	0.05	0.05	0.05
HC-SS-29	0.15	0.15	0.05	0.05	0.10	0.10
HC-SS-30	0.05	0.05	0.05	0.05	0.00	0.04
HC-SS-31	0.10	0.10	0.25	0.00	0.05	0.10
HC-SS-32	0.05	0.05	0.15	0.10	0.10	0.09
HC-SS-33	0.20	0.20	0.05	0.10	0.10	0.13
HC-SS-34	0.05	0.15	0.15	0.10	0.15	0.12
HC-SS-35	0.10	0.00	0.10	0.05	0.05	0.06
HC-SS-41	0.05	0.00	0.00	0.00	0.00	0.01
Whatcom Waterway Area in 1998						
Reference ID -- Non-purged						
CR-10	0.05	0.05	0.10	0.15	0.10	0.09
CR-22	0.00	0.05	0.00	0.00	0.10	0.03
CR-23W	0.05	0.05	0.00	0.05	0.05	0.04
Negative Control	0.00	0.00	0.05	0.00	0.05	0.02
Reference ID -- Purged						
CR-10	0.10	0.00	0.00	0.00	0.10	0.04
CR-22	0.00	0.00	0.00	0.00	0.00	0.00
CR-23W	0.00	0.00	0.00	0.00	0.00	0.00
Negative Control	0.00	0.00	0.00	0.00	0.10	0.02

447806/Whatcom Waterway RI/Whatcom2.xls - Table 5-2

Table 5-2 - 10-day Amphipod (*E. estuarius*) Mortality Sediment Bioassay

	Replicate (mortality)					
	A	B	C	D	E	Mean
Whatcom Waterway Area in 1998 (continued)						
Sample ID – Non-purged						
AN-SS-36	0.15	0.05	0.25	0.05	0.05	0.11
AN-SS-37	0.10	0.10	0.05	0.05	0.05	0.07
AN-SC-70	0.00	0.10	0.05	0.05	0.10	0.06
AN-SC-71	0.05	0.10	0.15	0.10	0.05	0.09
AN-SC-72	0.20	0.10	0.00	0.05	0.00	0.07
AN-SC-73	0.00	0.20	0.05	0.05	0.10	0.08
AN-SC-77	0.10	0.00	0.05	0.05	0.10	0.06
AN-SC-78	0.00	0.00	0.00	0.00	0.15	0.03
AN-SC-80	0.00	0.00	0.10	0.00	0.00	0.02
AN-SC-81	0.00	0.15	0.05	0.30	0.15	0.13
AN-SC-82	0.05	0.00	0.05	0.00	0.05	0.03
AN-SC-84	0.10	0.00	0.00	0.05	0.10	0.05
Sample ID – Purged						
AN-SC-78	0.20	0.00	0.10	0.05	0.00	0.07
Boulevard Park/Starr Rock Area in 1998						
Reference ID – Same as Non-purged Reference for Whatcom Waterway Area in 1998						
Sample ID						
AN-SS-301	0.25	0.20	0.10	0.10	0.20	0.17
AN-SS-302	0.00	0.20	0.25	0.30	0.40	0.23
AN-SS-303	0.20	0.15	0.10	0.00	0.30	0.15
AN-SS-304	0.00	0.00	0.00	0.05	0.10	0.03
AN-SS-305	0.05	0.10	0.10	0.05	0.15	0.09
AN-SS-306	0.00	0.15	0.45	0.10	0.50	0.24

447806/Whatcom Waterway RI/Whatcom2.xls - Table 5-2

Table 5-3 - 48-Hour Bivalve Larval (*M. edulis* or *M. galloprovincialis*) Sediment Bioassay

	Replicate (Normal Survival)					
	A	B	C	D	E	Mean
Whatcom Waterway Area in 1996 (*M. edulis*)						
Reference ID						
CR-02	0.66	0.62	0.64	0.63	0.70	0.65
CR-22	0.62	0.46	0.51	0.65	0.56	0.56
CR-24	0.53	0.47	0.64	0.61	0.60	0.57
Negative Control	0.75	0.74	0.69	0.82	0.73	0.74
Sample ID						
HC-SS-03	0.60	0.65	0.58	0.57	0.60	0.60
HC-SS-06	0.61	0.62	0.62	0.58	0.74	0.63
HC-SS-08	0.12	0.13	0.52	0.64	0.37	0.35
HC-SS-13	0.50	0.45	0.65	0.60	0.57	0.56
HC-SS-14	0.66	0.55	0.56	0.54	0.58	0.58
HC-SS-15	0.58	0.74	0.60	0.54	0.68	0.63
HC-SS-17	0.60	0.79	0.76	0.82	0.71	0.74
HC-SS-19	0.56	0.63	0.62	0.54	0.68	0.61
HC-SS-21	0.68	0.59	0.68	0.67	0.60	0.64
HC-SS-22	0.63	0.81	0.86	0.71	0.56	0.71
HC-SS-23	0.71	0.63	0.53	0.47	0.59	0.59
HC-SS-24	0.68	0.61	0.63	0.46	0.11	0.50
HC-SS-25	0.43	0.43	0.51	0.49	0.26	0.42
HC-SS-26	0.54	0.46	0.40	0.30	0.41	0.42
HC-SS-29	0.37	0.34	0.71	0.71	0.43	0.51
HC-SS-30	0.18	0.49	0.55	0.44	0.51	0.43
HC-SS-31	0.37	0.55	0.17	0.38	0.23	0.34
HC-SS-32	0.51	0.45	0.33	0.38	0.36	0.41
HC-SS-33	0.37	0.42	0.49	0.37	0.34	0.40
HC-SS-34	0.31	0.46	0.44	0.35	0.38	0.39
HC-SS-35	0.16	0.28	0.60	0.25	0.54	0.37
HC-SS-41	0.42	0.55	0.56	0.44	0.65	0.52
Whatcom Waterway Area in 1998 (*M. galloprovincialis*)						
Reference ID						
CR-10	0.67	0.70	0.64	0.83	0.68	0.70
CR-22	0.67	0.68	0.73	0.60	0.74	0.69
CR-23W	0.67	0.74	0.65	0.71	0.66	0.69
Negative Control	0.94	0.99	0.93	0.86	0.88	0.92
Sample ID						
AN-SS-36	0.58	0.63	0.62	0.55	0.67	0.61
AN-SS-37	0.63	0.68	0.62	0.60	0.65	0.63
AN-SC-70	0.77	0.70	0.78	0.66	0.73	0.73
AN-SC-71	0.66	0.72	0.63	0.71	0.70	0.68

447806/Whatcom Waterway RI/Whatcom2.xls - Table 5-3

Table 5-3 - 48-Hour Bivalve Larval (*M. edulis* or *M. galloprovincialis*) Sediment Bioassay

	Replicate (Normal Survival)					
	A	B	C	D	E	Mean
Whatcom Waterway Area in 1998 (*M. galloprovincialis*)						
Sample ID						
AN-SC-72	0.69	0.72	0.62	0.66	0.75	0.69
AN-SC-73	0.71	0.66	0.68	0.72	0.63	0.68
AN-SC-77	0.77	0.73	0.69	0.73	0.74	0.73
AN-SC-78	0.55	0.70	0.67	0.63	0.70	0.65
AN-SC-80	0.45	0.47	0.52	0.63	0.66	0.55
AN-SC-81	0.58	0.60	0.56	0.59	0.61	0.59
AN-SC-82	0.61	0.78	0.49	0.52	0.59	0.60
AN-SC-84	0.77	0.80	0.77	0.81	0.79	0.79
Boulevard Park/Starr Rock Area in 1998 (*M. galloprovincialis*)						
Reference ID - Same as Whatcom Waterway Area in 1998						
Sample ID						
AN-SS-301	0.71	0.76	0.74	0.69	0.77	0.73
AN-SS-302	0.73	0.63	0.71	0.67	0.70	0.69
AN-SS-303	0.69	0.72	0.66	0.75	0.73	0.71
AN-SS-304	0.60	0.53	0.57	0.63	0.60	0.59
AN-SS-305	0.66	0.71	0.68	0.65	0.72	0.68
AN-SS-306	0.59	0.65	0.67	0.63	0.67	0.64

Table 5-4 - 20-day Juvenile Polychaete (*N. arenaceodentata*) Growth Sediment Bioassay

	Replicate (individual growth rate)					
	A	B	C	D	E	Mean
<u>Whatcom Waterway Area in 1996</u>						
Reference ID						
CR-02	0.53	0.57	0.68	0.56	0.49	0.56
CR-22	0.48	0.67	0.52	0.61	0.63	0.58
CR-24	0.41	0.58	0.33	0.53	0.53	0.48
Negative Control	0.50	0.47	0.40	0.62	0.67	0.53
Sample ID						
HC-SS-03	0.55	0.00	0.40	0.49	0.46	0.38
HC-SS-06	0.60	0.30	0.34	0.62	0.64	0.50
HC-SS-08	0.54	0.41	0.63	0.54	0.53	0.53
HC-SS-13	0.49	0.38	0.39	0.23	0.44	0.38
HC-SS-14	0.52	0.54	0.48	0.53	0.46	0.50
HC-SS-15	0.51	0.45	0.49	0.44	0.53	0.48
HC-SS-17	0.58	0.43	0.27	0.38	0.49	0.43
HC-SS-19	0.51	0.33	0.67	0.32	0.33	0.43
HC-SS-21	0.34	0.50	0.39	0.59	0.42	0.44
HC-SS-22	0.43	0.36	0.38	0.40	0.32	0.38
HC-SS-23	0.49	0.37	0.32	0.30	0.47	0.39
HC-SS-24	0.63	0.63	0.63	0.54	0.64	0.61
HC-SS-25	0.64	0.42	0.32	0.52	0.42	0.46
HC-SS-26	0.56	0.56	0.72	0.41	0.63	0.57
HC-SS-29	0.68	0.43	0.42	0.42	0.40	0.47
HC-SS-30	0.43	0.51	0.60	0.78	0.42	0.55
HC-SS-31	0.42	0.48	0.45	0.59	0.58	0.50
HC-SS-32	0.41	0.46	0.53	0.69	0.29	0.47
HC-SS-33	0.54	0.54	0.52	0.67	0.51	0.55
HC-SS-34	0.42	0.75	0.55	0.65	0.54	0.58
HC-SS-35	0.35	0.38	0.47	0.43	0.54	0.43
HC-SS-41	0.67	0.57	0.41	0.48	0.60	0.54
<u>Whatcom Waterway Area in 1998</u>						
Reference ID						
CR-10	0.44	0.44	0.50	0.17	0.62	0.43
CR-22	0.54	0.60	0.64	0.56	0.51	0.57
CR-23W	0.32	0.66	0.53	0.89	0.54	0.59
Negative Control	0.48	0.59	0.12	0.53	0.00[a]	0.43
Sample ID						
AN-SS-36	0.43	0.42	0.76	0.46	0.56	0.53
AN-SS-37	0.55	0.40	0.50	0.58	0.00[a]	0.51
AN-SC-70	0.41	0.32	0.39	0.79	0.49	0.48
AN-SC-71	0.58	0.41	0.42	0.52	0.46	0.48

Table 5-4 - 20-day Juvenile Polychaete (*N. arenaceodentata*) Growth Sediment Bioassay

	Replicate (individual growth rate)					
	A	B	C	D	E	Mean
Whatcom Waterway Area in 1998						
Sample ID						
AN-SC-72	0.63	0.44	0.67	0.38	0.21	0.47
AN-SC-73	0.41	0.28	0.82	0.28	0.51	0.46
AN-SC-77	0.55	0.62	0.50	0.68	0.50	0.57
AN-SC-78	0.54	0.42	0.99	0.42	0.60	0.59
AN-SC-80	0.55	0.45	0.43	0.37	0.64	0.48
AN-SC-81	0.29	0.47	0.60	0.54	0.24	0.43
AN-SC-82	0.45	0.59	0.42	0.43	0.57	0.49
AN-SC-84	0.45	0.39	0.59	0.39	0.25	0.41
Boulevard Park/Starr Rock Area in 1998						
Reference ID - Same as Whatcom Waterway Area in 1998						
Sample ID						
AN-SS-301	0.87	0.49	0.51	1.01	0.48	0.67
AN-SS-302	0.39	0.75	0.33	0.23	0.73	0.49
AN-SS-303	0.74	0.59	0.47	0.47	0.31	0.52
AN-SS-304	0.43	0.58	0.82	0.51	0.31	0.53
AN-SS-305	0.50	0.61	0.74	0.57	0.56	0.60
AN-SS-306	0.67	0.59	0.45	0.54	0.72	0.59

447806/Whatcom Waterway RI/Whatcom2.xls - Table 5-4

Table 5-5 - Comparative Grain Size Data for Reference and Test Sediments

Sheet 1 of 2

	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	PERCENT FINES (SILT + CLAY)	COMPARATIVE REFERENCE SITE
Whatcom Waterway Area in 1996						
Sample ID						
HC-CR-02	0	14	78	8	86	N/A
HC-CR-22	0	85	12	3	15	N/A
HC-CR-24	0	30	62	8	70	N/A
HC-SS-03	0	7	64	29	93	HC-CR-02
HC-SS-06	0	4	58	38	96	HC-CR-02
HC-SS-08	0	8	60	32	92	HC-CR-02
HC-SS-13	0	4	75	21	96	HC-CR-02
HC-SS-14	0	3	71	26	97	HC-CR-02
HC-SS-15	0	4	79	17	96	HC-CR-02
HC-SS-17	0	3	76	21	97	HC-CR-02
HC-SS-19	0	4	70	26	96	HC-CR-02
HC-SS-21	0	11	60	29	89	HC-CR-02
HC-SS-22	0	6	61	33	94	HC-CR-02
HC-SS-23	0	16	69	15	84	HC-CR-02
HC-SS-24	0	18	55	27	82	HC-CR-02
HC-SS-25	0	15	56	29	85	HC-CR-02
HC-SS-26	0	60	20	20	40	HC-CR-22
HC-SS-29	0	18	59	23	82	HC-CR-02
HC-SS-30	0	3	71	26	97	HC-CR-02
HC-SS-31	0	6	61	33	94	HC-CR-02
HC-SS-32	2	71	17	10	27	HC-CR-22
HC-SS-33	9	70	17	4	21	HC-CR-22
HC-SS-34	11	66	17	6	23	HC-CR-22
HC-SS-35	0	10	64	26	90	HC-CR-02
HC-SS-41	1	93	4	2	6	HC-CR-22

Table 5-5 (continued) - Comparative Grain Size Data for Reference and Test Sediments

Sheet 2 of 2

	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	PERCENT FINES (SILT + CLAY)	COMPARATIVE REFERENCE SITE
Whatcom Waterway Area in 1998						
Sample ID						
AN-SS-36	17	66	9	8	17	AN-CR-22
AN-SS-37	40	22	24	14	38	AN-CR-23W
AN-SC-70	1	7	52	40	92	AN-CR-10
AN-SC-71	0	13	45	42	87	AN-CR-10
AN-SC-72	0	17	45	38	83	AN-CR-10
AN-SC-73	0	11	47	43	90	AN-CR-10
AN-SC-77	0	9	47	44	91	AN-CR-10
AN-SC-78	1	12	54	33	87	AN-CR-10
AN-SC-80	1	15	45	39	84	AN-CR-10
AN-SC-81	0	26	46	28	74	AN-CR-10
AN-SC-82	0	17	51	32	83	AN-CR-10
AN-SC-84	2	6	48	44	92	AN-CR-10
Boulevard Park/Starr Rock Area in 1998						
Sample ID						
AN-SS-301	2	39	32	27	59	AN-CR-23W
AN-SS-302	0	4	58	38	96	AN-CR-10
AN-SS-303	4	15	44	36	80	AN-CR-10
AN-SS-304	6	89	2	3	6	AN-CR-22
AN-SS-305	2	38	32	29	61	AN-CR-23W
AN-SS-306	3	30	39	29	68	AN-CR-10

Table 5-6 - Summary of Control and Reference Site Bioassay Performance

	Eohaustorius estuarius **Mean Percent Mortality**[b]	***Mytilus*** **spp.**[a] **Mean Percent Normal Survival**[b] **(Seawater Normalized)**	***Neanthes arenaceodentata*** **Mean Individual Growth (MIG) Rate in mg/ind-day (dry weight)**[b]
Whatcom Waterway Area in 1996			
Negative Control Performance Criteria	< 10% mortality	> 70% normal survival	< 10% mortality MIG ^{3} 0.72 mg/ind/day[c]
Negative Control	0 ± 0	74 ± 5	0.53 ± 0.11
Reference Sediment Performance Criteria	< 25 % mortality	>0.65*(control) = 48.1	> 0.8*(MIG control) = 0.42
HC-CR-02	4 ± 4	87 ± 4	0.56 ± 0.07
HC-CR-22	9 ± 9	75 ± 10	0.58 ± 0.08
HC-CR-24	6 ± 8	76 ± 9	0.48 ± 0.10
Whatcom Waterway Area and Boulevard Park/Starr Rock Area in 1998			
Negative Control Performance Criteria	< 10% mortality	> 70% normal survival	< 10% mortality 6.7% mortality[d]
Negative Control	2 (non-purged) 2 (purged)	92 ± 5	0.43 ± 0.16
Reference Sediment Performance Criteria	< 25 % mortality	>0.65*(control)	> 0.8*(MIG control)
AN-CR-10	9 ± 4 (non-purged) 4 (purged)	70 ± 8	0.43 ± 0.16
AN-CR-22	3 ± 5 (non-purged) 0 (purged)	69 ± 6	0.57 ± 0.05
AN-CR-23W	4 ± 2 (non-purged) 0 (purged)	69 ± 4	0.59 ± 0.21

[a] *Mytilus edulis* was used in the 1996 Whatcom Waterway Area sediment toxicity testing. *M. galloprovincialis* was used in the 1998 Whatcom Waterway Area and Boulevard Park/Starr Rock Area sediment toxicity testing.

[b] Mean and standard deviation for five replicate samples.

[c] The performance criteria of 0.72 mg/ind/day has been established as a target. Control growth rates below 0.38 mg/ind/day will be considered a QA/QC failure. The lower limit reflects adjustments to the PSDDA/SMS control performance guideline accounting for the observed variability exhibited by the laboratories performing the test (0.72 - 0.34 = 0.38), where the lower limit of observed control growth (≥ 0.38 mg/ind/day) expresses one standard deviation of the mean (PSDDA, 1996).

[d] Two of the *N. arenaceodentata* control replicates became anoxic resulting in complete mortality in one and 80% mortality in the other. The data presented are calculated from the remaining three replicates.

Table 5-7 - Summary of the Results of the *Eohaustorius estuarius* Bioassays

Sheet 1 of 2

	Reference Site[a]	Mean Percent Mortality[b]	Statistical Significance[c]		SQS	MCUL
			Significant	Test used	> 25%	> reference + 30%
Whatcom Waterway Area in 1996						
Sample ID						
HC-SS-03	HC-CR-02	14 ± 9	Yes	t-Test	No Hit (< 25%)	No Hit (< 34%)
HC-SS-06	HC-CR-02	6 ± 4	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-08	HC-CR-02	13 ± 16	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-13	HC-CR-02	5 ± 4	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-14	HC-CR-02	1 ± 2	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-15	HC-CR-02	2 ± 4	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-17	HC-CR-02	11 ± 4	Yes	t-Test	No Hit (< 25%)	No Hit (< 34%)
HC-SS-19	HC-CR-02	1 ± 2	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-21	HC-CR-02	6 ± 4	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-22	HC-CR-02	8 ± 8	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-23	HC-CR-02	6 ± 5	No	t-Test	No Hit (< 25%)	No Hit (< 34%)
HC-SS-24	HC-CR-02	8 ± 6	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-25	HC-CR-02	1 ± 2	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-26	HC-CR-22	5 ± 0	No	t-Test	No Hit (< 25%)	No Hit (< 39%)
HC-SS-29	HC-CR-02	10 ± 5	Yes	t-Test	No Hit (< 25%)	No Hit (< 34%)
HC-SS-30	HC-CR-02	4 ± 2	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-31	HC-CR-02	10 ± 9	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-32	HC-CR-22	9 ± 4	No	t-Test	No Hit (< 25%)	No Hit (< 39%)
HC-SS-33	HC-CR-22	13 ± 7	No	t-Test	No Hit (< 25%)	No Hit (< 39%)
HC-SS-34	HC-CR-22	12 ± 4	No	t-Test	No Hit (< 25%)	No Hit (< 39%)
HC-SS-35	HC-CR-02	6 ± 4	No	M-W	No Hit (< 25%)	No Hit (< 34%)
HC-SS-41	HC-CR-22	1 ± 2	No	M-W	No Hit (< 25%)	No Hit (< 39%)

Table 5-7 (cont.) - Summary of the Results of the *Eohaustorius estuarius* Bioassays
Sheet 2 of 2

	Reference Site[a]	Mean Percent Mortality[b]	Statistical Significance[c]		SQS	MCUL
			Significant	Test used	> 25%	> reference + 30%
Whatcom Waterway Area in 1998						
Sample ID						
AN-SS-36	AN-CR-22	89 ± 9	No		No Hit (< 25%)	No Hit (< 33%)
AN-SS-37	AN-CR-23W	93 ± 3	No		No Hit (< 25%)	No Hit (< 34%)
AN-SC-70	AN-CR-10	94 ± 4	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-71	AN-CR-10	91 ± 4	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-72	AN-CR-10	93 ± 8	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-73	AN-CR-10	92 ± 8	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-77	AN-CR-10	94 ± 4	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-78	AN-CR-10	97 ± 7	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-78 (purged)	AN-CR-10	93	No		No Hit (< 25%)	No Hit (< 34%)
AN-SC-80	AN-CR-10	98 ± 5	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-81	AN-CR-10	87 ± 12	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-82	AN-CR-10	97 ± 3	No		No Hit (< 25%)	No Hit (< 39%)
AN-SC-84	AN-CR-10	95 ± 5	No		No Hit (< 25%)	No Hit (< 39%)
Boulevard Park/Starr Rock Area in 1998						
Sample ID						
AN-SS-301	AN-CR-23W	17 ± 7	Yes		No Hit (< 25%)	No Hit (< 34%)
AN-SS-302	AN-CR-10	23 ± 15	No		No Hit (< 25%)	No Hit (< 39%)
AN-SS-303	AN-CR-10	15 ± 11	No		No Hit (< 25%)	No Hit (< 39%)
AN-SS-304	AN-CR-22	3 ± 5	No		No Hit (< 25%)	No Hit (< 33%)
AN-SS-305	AN-CR-23W	9 ± 4	Yes		No Hit (< 25%)	No Hit (< 34%)
AN-SS-306	AN-CR-10	24 ± 22	No		No Hit (< 25%)	No Hit (< 39%)

NOTE: SQS - Sediment Quality Standard; MCUL - Minimum Cleanup Level

a: Corresponding reference station with similar grain size; b: Mean and standard deviation for five replicate samples.

c: Statistically significant increases in percent mortality compared to reference as determined by a t-Test (normally distributed data); or Mann-Whitney Test (M-W: nonparametric data) at the a = 0.05 level.

Table 5-8 - Summary of the Results of the *Mytilus* spp. Bioassays (Seawater Normalized)
Sheet 1 of 2

	Reference Site[a]	Mean Percent Normal survival[b]	Statistical Significance[c]		SQS	MCUL
			Significant	Test used	<85%*reference	<70%*reference
Whatcom Waterway Area in 1996 (*Mytilus edulis*)						
Sample ID						
HC-SS-03	HC-CR-02	81 ± 4	Yes	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-06	HC-CR-02	85 ± 8	No	M-W	No Hit (> 74)	No Hit (> 61)
HC-SS-08	HC-CR-02	47 ± 31	Yes	t-Test	Hit (< 74)	Hit (< 61)
HC-SS-13	HC-CR-02	75 ± 11	Yes	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-14	HC-CR-02	77 ± 6	Yes	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-15	HC-CR-02	85 ± 11	No	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-17	HC-CR-02	99 ± 11	No	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-19	HC-CR-02	81 ± 8	Yes	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-21	HC-CR-02	86 ± 6	No	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-22	HC-CR-02	96 ± 17	No	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-23	HC-CR-02	79 ± 12	No	t-Test	No Hit (> 74)	No Hit (> 61)
HC-SS-24	HC-CR-02	67 ± 31	No	M-W	No Hit (< 74)	No Hit (> 61)
HC-SS-25	HC-CR-02	57 ± 13	Yes	M-W	Hit (< 74)	Hit (< 61)
HC-SS-26	HC-CR-22	57 ± 11	Yes	M-W	Hit (< 64)	No Hit (>53)
HC-SS-29	HC-CR-02	69 ± 25	Yes	t-Test	Hit (< 74)	No Hit (> 61)
HC-SS-30	HC-CR-02	58 ± 19	Yes	M-W	Hit (< 74)	Hit (< 61)
HC-SS-31	HC-CR-02	46 ± 20	Yes	t-Test	Hit (< 74)	Hit (< 61)
HC-SS-32	HC-CR-22	55 ± 10	Yes	t-Test	Hit (< 64)	No Hit (>53)
HC-SS-33	HC-CR-22	53 ± 8	Yes	t-Test	Hit (< 64)	No Hit (>53)
HC-SS-34	HC-CR-22	52 ± 9	Yes	t-Test	Hit (< 64)	Hit (< 53)
HC-SS-35	HC-CR-02	49 ± 26	Yes	t-Test	Hit (< 74)	Hit (< 61)
HC-SS-41	HC-CR-22	70 ± 13	No	t-Test	No Hit (> 64)	No Hit (>53)

Table 5-8 (continued) - Summary of the Results of the *Mytilus* spp. Bioassays (Seawater Normalized)

Sheet 2 of 2

	REFERENCE SITE[a]	MEAN PERCENT NORMAL SURVIVAL[b]	STATISTICAL SIGNIFICANCE[c]		SQS	MCUL
			Significant	Test used	<85%*reference	<70%*reference
Whatcom Waterway Area in 1998 (*Mytilus galloprovincialis*)						
Sample ID						
AN-SS-36	AN-CR-22	61 ± 4	Yes		No Hit (< 59)	No Hit (< 48)
AN-SS-37	AN-CR-23W	63 ± 3	Yes		No Hit (< 59)	No Hit (< 48)
AN-SC-70	AN-CR-10	73 ± 5	No		No Hit (< 60)	No Hit (< 49)
AN-SC-71	AN-CR-10	68 ± 4	No		No Hit (< 60)	No Hit (< 49)
AN-SC-72	AN-CR-10	69 ± 5	No		No Hit (< 60)	No Hit (< 49)
AN-SC-73	AN-CR-10	68 ± 4	No		No Hit (< 60)	No Hit (< 49)
AN-SC-77	AN-CR-10	73 ± 3	No		No Hit (< 60)	No Hit (< 49)
AN-SC-78	AN-CR-10	65 ± 6	No		No Hit (< 60)	No Hit (< 49)
AN-SC-80	AN-CR-10	55 ± 9	Yes		Hit (< 60)	No Hit (< 49)
AN-SC-81	AN-CR-10	59 ± 2	Yes		Hit (< 60)	No Hit (< 49)
AN-SC-82	AN-CR-10	60 ± 11	Yes		No Hit (< 60)	No Hit (< 49)
AN-SC-84	AN-CR-10	79 ± 2	No		No Hit (< 60)	No Hit (< 49)
Boulevard Park/Starr Rock Area in 1998 (*Mytilus galloprovincialis*)						
Sample ID						
AN-SS-301	AN-CR-23W	73 ± 3	No		No Hit (< 59)	No Hit (< 48)
AN-SS-302	AN-CR-10	69 ± 4	No		No Hit (< 60)	No Hit (< 49)
AN-SS-303	AN-CR-10	71 ± 3	No		No Hit (< 60)	No Hit (< 49)
AN-SS-304	AN-CR-22	59 ± 3	Yes		No Hit (< 59)	No Hit (< 48)
AN-SS-305	AN-CR-23W	68 ± 3	No		No Hit (< 59)	No Hit (< 48)
AN-SS-306	AN-CR-10	64 ± 3	Yes		No Hit (< 60)	No Hit (< 49)

NOTE: SQS - Sediment Quality Standards; MCUL - Minimum Cleanup Level

a: Corresponding reference station with similar grain size.

b: Mean and standard deviation for five replicate samples.

c: Statistically significant decreases in percent normal survival compared to reference as determined by a t-test (normally distributed data) or Mann-Whitney Test (M-W: nonparametric data) at the a = 0.05 level.

Table 5-9 - Summary of the Results of the *Neanthes arenaceodentata* Bioassays

Sheet 1 of 2

	Reference Site[a]	Mean Individual Growth Rate in mg/ind-day (dry wt)[b]	Statistical Significance[c]		SQS	MCUL
			Significant	Test used	<70%*reference	<50%*reference
Whatcom Waterway Area in 1996						
Sample ID						
HC-SS-03	HC-CR-02	0.38 ± 0.22	Yes	M-W	Hit (<0.39)	No Hit (>0.28)
HC-SS-06	HC-CR-02	0.50 ± 0.17	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-08	HC-CR-02	0.53 ± 0.08	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-13	HC-CR-02	0.38 ± 0.10	Yes	M-W	Hit (<0.39)	No Hit (>0.28)
HC-SS-14	HC-CR-02	0.50 ± 0.03	Yes	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-15	HC-CR-02	0.48 ± 0.04	Yes	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-17	HC-CR-02	0.43 ± 0.11	Yes	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-19	HC-CR-02	0.43 ± 0.15	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-21	HC-CR-02	0.44 ± 0.10	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-22	HC-CR-02	0.38 ± 0.04	Yes	M-W	Hit (<0.39)	No Hit (>0.28)
HC-SS-23	HC-CR-02	0.39 ± 0.09	Yes	M-W	Hit (<0.39)	No Hit (>0.28)
HC-SS-24	HC-CR-02	0.61 ± 0.04	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-25	HC-CR-02	0.46 ± 0.12	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-26	HC-CR-02	0.57 ± 0.12	No	M-W	No Hit (>0.41)	No Hit (>0.29)
HC-SS-29	HC-CR-02	0.47 ± 0.12	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-30	HC-CR-02	0.55 ± 0.15	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-31	HC-CR-02	0.50 ± 0.08	No	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-32	HC-CR-02	0.47 ± 0.15	No	t-Test	No Hit (>0.41)	No Hit (>0.29)
HC-SS-33	HC-CR-02	0.55 ± 0.06	No	M-W	No Hit (>0.41)	No Hit (>0.29)
HC-SS-34	HC-CR-02	0.58 ± 0.12	No	t-Test	No Hit (>0.41)	No Hit (>0.29)
HC-SS-35	HC-CR-02	0.43 ± 0.08	Yes	M-W	No Hit (>0.39)	No Hit (>0.28)
HC-SS-41	HC-CR-02	0.54 ± 0.10	No	t-Test	No Hit (>0.41)	No Hit (>0.29)

Table 5-9 (cont.)-Summary of the Results of the *Neanthes arenaceodentata* Bioassays
Sheet 2 of 2

	REFERENCE SITE[a]	MEAN INDIVIDUAL GROWTH RATE IN mg/ind-day (dry wt)[b]	STATISTICAL SIGNIFICANCE[c]		SQS	MCUL
			Significant	Test used	<70%*reference	<50%*reference
Whatcom Waterway Area in 1998						
Sample ID						
AN-SS-36	AN-CR-22	0.53 ± 0.14	No		No Hit (>0.40)	No Hit (>0.29)
AN-SS-37	AN-CR-23W	0.51 ± 0.08	No		No Hit (>0.41)	No Hit (>0.30)
AN-SC-70	AN-CR-10	0.48 ± 0.18	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-71	AN-CR-10	0.48 ± 0.07	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-72	AN-CR-10	0.47 ± 0.19	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-73	AN-CR-10	0.46 ± 0.22	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-77	AN-CR-10	0.57 ± 0.08	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-78	AN-CR-10	0.59 ± 0.24	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-80	AN-CR-10	0.48 ± 0.11	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-81	AN-CR-10	0.43 ± 0.16	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-82	AN-CR-10	0.49 ± 0.08	No		No Hit (>0.30)	No Hit (>0.22)
AN-SC-84	AN-CR-10	0.41 ± 0.12	No		No Hit (>0.30)	No Hit (>0.22)
Boulevard Park/Starr Rock Area in 1998						
Sample ID						
AN-SS-301	AN-CR-23W	0.67 ± 0.25	No		No Hit (>0.41)	No Hit (>0.30)
AN-SS-302	AN-CR-10	0.49 ± 0.24	No		No Hit (>0.30)	No Hit (>0.22)
AN-SS-303	AN-CR-10	0.52 ± 0.16	No		No Hit (>0.30)	No Hit (>0.22)
AN-SS-304	AN-CR-22	0.53 ± 0.19	No		No Hit (>0.40)	No Hit (>0.29)
AN-SS-305	AN-CR-23W	0.60 ± 0.09	No		No Hit (>0.41)	No Hit (>0.30)
AN-SS-306	AN-CR-10	0.60 ± 0.11	No		No Hit (>0.30)	No Hit (>0.22)

NOTE: SQS - Sediment Quality Standards MCUL - Minimum Cleanup Level

a: Corresponding reference station with similar grain size.

b: Mean and standard deviation for five replicate samples.

c: Statistically significant decreases in growth relative to reference as determined by a t-test (normally distributed data) or Mann-Whitney Test (M-W: nonparametric data) at the a = 0.05 level.

Table 5-10 - Comparison of Bioassay Results and Sediment Biological Effects Interpretive Criteria

Sheet 1 of 2

	E. estuarius		*M.* spp		*N. arenaceodentata*		SQS Biological Criteria	MCUL Biological Criteria
	SQS	MCUL	SQS	MCUL	SQS	MCUL		
Whatcom Waterway Area in 1996 (*M. edulis*)								
Sample ID								
HC-SS-03	no hit	no hit	no hit	no hit	hit	no hit	Fail	Pass
HC-SS-06	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
HC-SS-08	no hit	no hit	hit	hit	no hit	no hit	Fail	Fail
HC-SS-13	no hit	no hit	no hit	no hit	hit	no hit	Fail	Pass
HC-SS-14	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
HC-SS-15	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
HC-SS-17	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
HC-SS-19	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
HC-SS-21	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
HC-SS-22	no hit	no hit	no hit	no hit	hit	no hit	Fail	Pass
HC-SS-23	no hit	no hit	no hit	no hit	hit	no hit	Fail	Pass
HC-SS-24	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
HC-SS-25	no hit	no hit	hit	hit	no hit	no hit	Fail	Fail
HC-SS-26	no hit	no hit	hit	no hit	no hit	no hit	Fail	Pass
HC-SS-29	no hit	no hit	hit	no hit	no hit	no hit	Fail	Pass
HC-SS-30	no hit	no hit	hit	hit	no hit	no hit	Fail	Fail
HC-SS-31	no hit	no hit	hit	hit	no hit	no hit	Fail	Fail
HC-SS-32	no hit	no hit	hit	no hit	no hit	no hit	Fail	Pass
HC-SS-33	no hit	no hit	hit	no hit	no hit	no hit	Fail	Pass
HC-SS-34	no hit	no hit	hit	hit	no hit	no hit	Fail	Fail
HC-SS-35	no hit	no hit	hit	hit	no hit	no hit	Fail	Fail
HC-SS-41	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass

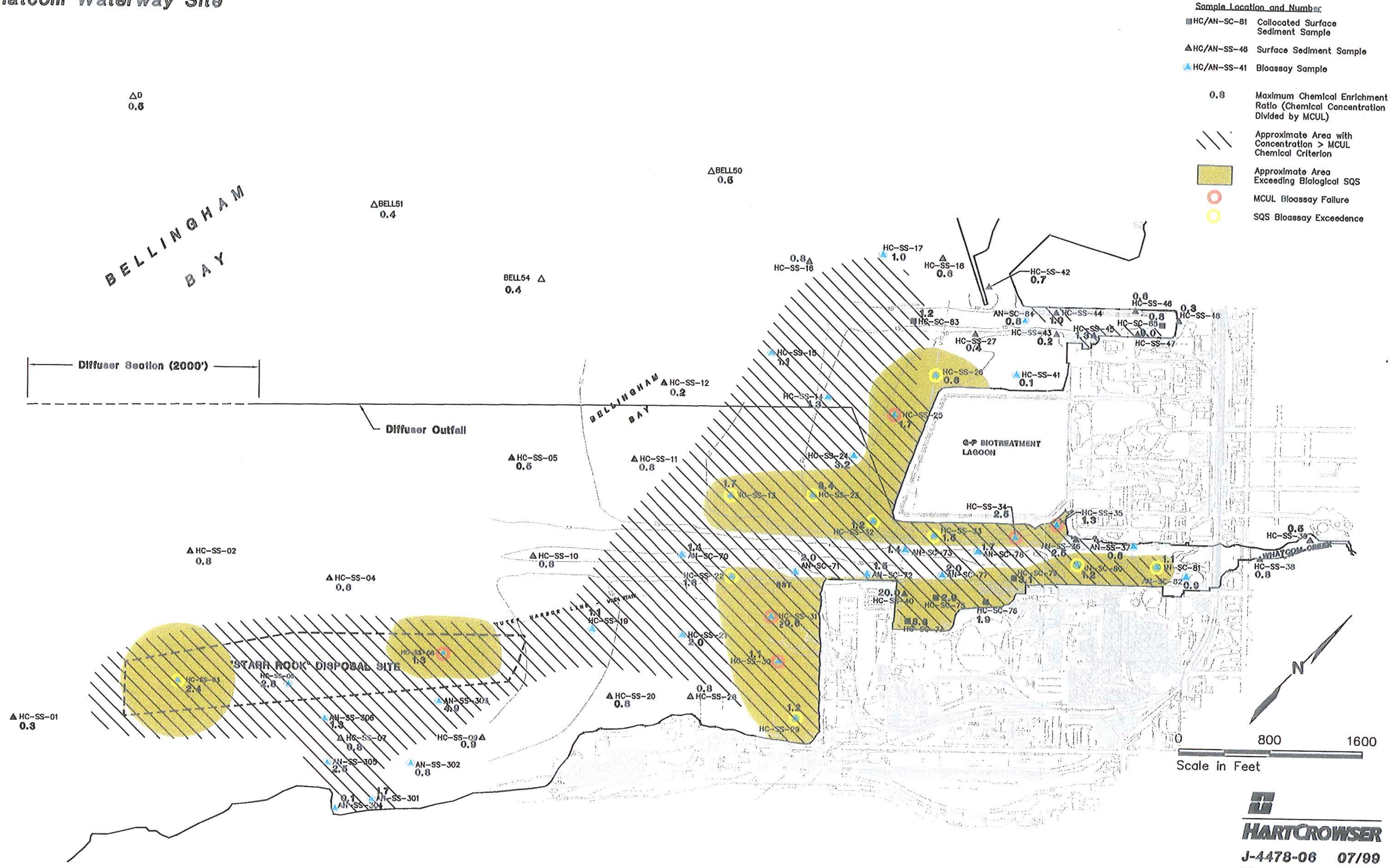
Table 5-10 (continued) - Comparison of Bioassay Results and Sediment Biological Effects Interpretive Criteria

Sheet 2 of 2

	E. estuarius		*M. spp*		*N. arenaceodentata*		SQS Biological Criteria	MCUL Biological Criteria
	SQS	MCUL	SQS	MCUL	SQS	MCUL		
Whatcom Waterway Area in 1998 (*M. galloprovincialis*)								
Sample ID								
AN-SS-36	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SS-37	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-70	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-71	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-72	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-73	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-77	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-78	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-80	no hit	no hit	hit	no hit	no hit	no hit	Fail	Pass
AN-SC-81	no hit	no hit	hit	no hit	no hit	no hit	Fail	Pass
AN-SC-82	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SC-84	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
Boulevard Park/Starr Rock Area in 1998 (*M. galloprovincialis*)								
Sample ID								
AN-SS-301	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SS-302	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SS-303	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SS-304	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SS-305	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass
AN-SS-306	no hit	no hit	no hit	no hit	no hit	no hit	Pass	Pass

NOTE: SQS - Sediment Quality Standards MCUL - Minimum Cleanup Level

Surface (0 to 10 cm) Sediment Bioassay Results
Whatcom Waterway Site



07/15/99 1=800 98-007-04
BBY024-01.DWG

HARTCROWSER
J-4478-06 07/99
Figure 5-1