EVALUATION OF CONTAMINATION STUDIES FOR SEDIMENT CRITERIA DEVELOPMENT IN PUGET SOUND

FINAL REPORT

Submitted to the
Environmental Protection Agency

envirosphere company
A Division of EBASCO SERVICES INCORPORATED

EVALUATION OF ONGOING CONTAMINANT STUDIES FOR APPLICABILITY TO SEDIMENT CRITERIA DEVELOPMENT IN PUGET SOUND

FINAL REPORT

September 28, 1984

prepared for:

U.S. Environmental Protection Agency
Criteria and Standards Division
401 M Street S.W.
Washington, D.C. 20460

and

U.S. Environmental Protection Agency, Region X
Water Division
1211 Sixth Avenue
Seattle, Washington 98117

prepared by:

S.P. Pavlou and G.G. Mattson
Envirosphere Company
400 112TH Avenue N.E.
Bellevue, Washington 98004

5641A

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 BACKGROUND AND RATIONALE

Upon completion of the initial evaluation of alternatives for the development of sediment criteria (Pavlou and Weston 1983; Pavlou and Weston 1984), a series of activities were identified as the logical sequence to the initial study. These were separated into management and technical needs which reflected both regional and national programatic priorities as expressed by the EPA Criteria and Standards Branch and the EPA Region X project staff. These activities are summarized in Appendix A. Regionally, EPA intends to develop a coherent approach in the management of contaminanted sediments and in the control of toxic discharges in Puget Sound. Nationally, EPA intends to develop a methodology for establishing sediment criteria in a variety of marine sites throughout the country to define toxic levels of contaminants in sediments and determine what should be considered a safe level. Control, compliance, and enforcement decisions would be based on these numerical values.

1.2 OBJECTIVES

In response to these needs, and as a first step to performing the tasks presented in Appendix A, it was deemed appropriate to: (1) review all current investigations being performed in Puget Sound which address sediment quality aspects of relevance to sediment criteria development, and (2) to develop an interactive information-use framework which would eventually lead to the development of defensible numerical criteria.

The main focus of this short term effort was to stimulate common interest among the various agencies and to develop an informational feedback on methods, procedures, and interpretive techniques for deriving defensible and enforceable regulatory sediment criteria.

1.3 SUMMARY OF APPROACH

To achieve these objectives, the following tasks were performed:

- Current studies underway in Puget Sound which would contribute to the refinement of the "first cut" sediment criteria were identified through interviews with key agency staff and contractors.

- The general approach of each of these studies was clarified and verified by the parties performing the work.

- The specific work components for each study were detailed in an interactive information flow diagram. The projected results of each of these investigations were defined, together with an expected completion date. The interrelationships among components of the different studies and the comparative progress of each were also shown.

- A decision process chart was generated showing how the data developed by the different investigations could be incorporated into the regulatory process.

The studies evaluated were:

- EPA/NERC/R. Swartz - Dose/Response Studies
- WDOE/Tetra Tech - Burden-Effect Study, Commencement Bay
- NOAA/E. Long - Triad Evaluations in Puget Sound (Sediment Chemistry/Toxicology/Bioeffects)
- EPA/Battelle Northwest - Recruitment Studies in Puget Sound Embayments
- EPA/Envirosphere/S. Pavlou - Equilibrium Partitioning Analyses
- Miscellaneous Regional Efforts

In addition to the above tasks, an attempt was made to obtain an estimate of burden/effect levels from the principal investigators of those studies in which bioassay and residue level measurements were taken.

The ensuing sections of this report present the results of this short project, together with recommendations for follow-up activities.

2.0 REVIEW AND SUMMARY OF RELEVANT STUDIES

The studies identified in Section 1.0 of this report were reviewed and outlined in terms of an interactive activity and information flow scheme. These schematic diagrams are included in Appendix B as Figures B-1 through B-5. In addition to the flow schematics, the Figures include descriptive information consisting of: (1) the entity performing the study, (2) the approach, (3) the objectives of the study, (4) location, (5) expected results, (6) implementation and use of results, and (7) an outline of the advantages and disadvantages of the study. Provided below is a summary of the contents of each figure in Appendix B.

Figure B-1 EPA/NERC, Rick Swartz - Dose/Response Studies

This diagram was developed exclusively from two phone interviews with Dr. Swartz. The right half of the schematic represents an iterative process that is repeated for each contaminant of concern. A report describing the applicability of this bioassay to sediment quality determinations should be available in October 1984. Subsequent reports will follow containing data on additional contaminants as they are evaluated, such as the cadmium toxicity study which was completed this summer.

This approach shows promise for developing burden/effect relationships that could be used to generate threshold limits or be incorporated into the equilibrium partitioning approach for verifying the "first cut" criteria values.

Figure B-2 WDOE/Tetra Tech - Burden/Effect Study, Commencement Bay

The diagram was developed from Tetra Tech's draft report R-3752, May 1984 "A Decision-Making Approach" and then modified with information from the "Sampling and Analysis Plan Task 3 Report" February 1984, and two interviews with the project manager, Mr. Tom Ginn.

This investigation incorporates most of the bioassays and field biological surveys developed or used by NOAA/NWAFC, but modified to obtain specific results (a "no effect" level) required for remedial action decision making. Together with EPA's dose/response studies this project should provide the most coherent data base for establishing burden/effect relationships in Commencement Bay as well as a test case for the whole Puget Sound.

Figure B-3 NOAA/Edward Long - Triad Evaluations in Puget Sound (Sediment Chemistry/Toxicity/Bioeffects)

The diagram was developed from "A Multidisciplinary Approach to Assessing Pollution in Coastal Waters" (Long 1983), NOAA OMPA-2 (Malins et al. 1980), NOAA OMPA-19 (Malins, et al. 1982), the correspondence between NOAA and EPA concerning sediment criteria development, and two interviews with Mr. Long. Due to the complexity of the NOAA approach which is relatively broad topically and multidisciplinary, this diagram was greatly simplified to allow incorporation of the major study components which constitute the basic framework of these investigations. Other components such as oceanographic field studies, transport modeling, sedimentation studies and water chemistry studies were not included.

The box "Interim Reports on Results and Co-Occurrence" represents a series of annual update reports by several different subcontractors for NOAA. These documents have been published since 1980 and several more will be available in 1984 and 1985.

Step 6 consists of iterative components, as was the case with Figure B-1, in order to identify the specific effects of a contaminant or group of contaminants at the concentrations previously found in Puget Sound.

Step 7 is a proposed effort for incorporating all the data and previous reports generated up to 1986 into an overall program report. Through this step areas which are adversely affected by contaminants determined to be toxic at the concentrations currently found in the sound could be delineated. Several reports will probably be published in 1986 with different areas of emphasis and from different subcontractors.

Figure B-4 EPA/Battelle Northwest - Recruitment Studies in Puget Sound Embayments

This diagram was developed from two phone interviews with Dr. Eric Crecelius. The amphipod bioassays are being performed by EPA's Manchester Laboratory. The oyster larvae deformation bioassays are performed in Sequim along with the recruitment Phase 2 study. Phase 3 has yet to be funded by EPA/DOE but is considered a critical component by Battelle in verifying the validity of recruitment approach and expanding the usefulness of the data collected in Phase 2.

These Battelle studies will provide another useful data base of chemical, benthic infaunal and toxicological information for identifying possible correlations between combined contaminant levels and adverse biological effects, and ranking contaminated sediments. However, the results of their unique recruitment study will probably not be directly applicable in identifying burden/effect threshold limits for specific contaminants that can be compared with the "first cut" criteria derived from the equilibrium partitioning approach.

A standard method for the current recruitment experiments has yet to be published. The initial experiments demonstrating the proof of principle for contaminated sediment were conducted by J.W. Anderson of Battelle (Anderson et al. 1978). Subsequently, J.R. Vanderhorst further developed the techniques. The results of Vanderhorst's work are available (Vanderhorst et al. 1978, 1980, 1981). The procedures applied in the current EPA-sponsored recruitment experiment are extensions of a line of research conducted at Battelle's Marine Research Laboratory over the last eight years.

Two additional advantages of the Battelle approach not included in Figure B-4 are 1) the time course for recovery can be assessed experimentally, and 2) through evaluations of the variances, statements concerning statistical sensitivity are possible. Given such statements the cost to detect a given level of change can be determined.

Figure B-5 EPA/Envirosphere/S. Pavlou - Equilibrium Partitioning Approach

This method has been discussed in detail in previous reports (Pavlou and Weston, 1983; Pavlou and Weston, 1984). The diagram is a simplified representation of the method. The activities identified past April 1984 are projections pending further funding. Field verification, and comparison of refined criteria values with threshold limits determined from the burden/effect studies described above are considered high priority prior to adoption of this approach as the optimum method for sediment criteria development.

MISCELLANEOUS REGIONAL EFFORTS

In addition to the above studies, two activities addressing aspects related to sediment quality but of no direct applicability to sediment criteria were evaluated. These were: EPA/Versar Endangerment Assessment in Commencement Bay and the Seattle District Corps of Engineers dredge/disposal related studies. A brief summary of these two efforts is provided below.

EPA/Versar - Endangerment Assessment, Commencement Bay

This short project was an attempt to provide an assessment of the aquatic fate of contaminants, their toxicity to aquatic life and the risk to human health in Commencement Bay. The evaluations were focused on seven contaminants of toxic significance for which Toxic Significance Factors (TSF) were estimated. This study was of limited utility due to the lack of supporting data necessary to verify the TSF calculations. Although this study was primarily a generic assessment,

the methods provided in estimating bioavailability, population exposure and human health effects could be incorporated into WDOE/Tetra Tech's Commencement Bay assessment to supplement the burden/effect evaluations.

Seattle District Corps of Engineers Studies

The summary presented below reflects Envirosphere's interview discussions with Keith Phillips and Pat Storm of the Seattle District Corps of Engineers, June 28, 1984.

The Corps currently does not have any research projects underway that would provide information or data for direct use in sediment criteria development for Puget Sound. However, the following projects, reports and data generated in a variety of projects may be useful as indirect references, especially in clarifying the future use of sediment criteria for dredged material disposal.

- Since 1975, the Corps dredging office has kept records of the basic sediment chemistry analyses required for dredged material disposal. However, the data is inconsistent and is not research oriented. Sediment quality data exists for Everett, Bellingham, Duwamish, and Commencement Bay.

- Grays Harbor, Evaluation of Sediments for Ocean Disposal. The research report on field studies and bioassays being performed by NOAA will be available in August 1984. Data will include: Suspended and solid phase bioassays for worms, clams, amphipods, and salmon; newly developed procedures for testing sediments; and bioaccumulation analyses of tissues for contaminants.

- Commencement Bay, Final Report on Disposal Options for DOE, being prepared by Waterways Experiment Station. The Report will include summary tables of worldwide sediment chemistry data and disposal "criteria"; suites of tests to determine biological effects; prediction of problems with leaching and runoff from upland

disposal; and decision making guidelines. A workshop between WES and DOE scheduled in September 1984 will discuss the draft report. The final report should be available in November 1984.

- The capping project in Duwamish, scheduled in September 1984, will provide information on the percentage loss of contaminated sediments and percentage loss of contaminants through the cap layer.

3.0 BURDEN-EFFECT LEVELS AND STANDARD METHODS

As mentioned earlier (Section 1.0), in addition to the review of the studies addressing sediment quality impacts, available documentation for each study was reviewed for information on possible ranges of burden-effect threshold limits and for specific references to the standard methods that were used. In areas where studies were completed or interim results were available, the data was usually presented in charts and tables with discussions on comparisons among regions sampled and statistical correlations between bioeffects and contaminant concentrations in the sediments. Unfortunately, no conclusions or determinations of threshold limits were presented.

The only study that addresses this aspect explicitly is the superfund investigation in Commencement Bay performed by WDOE/Tetra Tech. In this case, it is anticipated that "no effect" levels for several categories of bioeffects will be determined and used to formulate remedial action plans; this information will not be available until November 1984.

Since it became apparent that available documentation could not provide immediate estimates of burden-effect limits without a coherent analysis of the data, the key scientists involved in the studies discussed in section 2.0 were asked if they could provide a "first cut" estimate of ranges (low, medium, high) of burden-effect levels, together with the latest reference for the standard methods used in their study. Summaries of their comments follow and their standard methods are referenced in Table 3-1 with the complete citation appearing in Section 6.0, References.

Rick Swartz - EPA/NERC Newport

The amphipod bioassay, which he developed and is being widely used by NOAA, WDOE/Tetra Tech, and EPA/Battelle Northwest, is used as an indication of lethality or acute toxicity with the results usually being presented as percent survival. A toxic effect is indicated if

TABLE 3-1

FIELD BIOLOGICAL SURVEYS

Category/Specific Analysis	Parameter Quantified	Standard Method
FIELD BIOLOGICAL SURVEYS:		
NOAA		
Fish Pathology		
Type and number of parasitic infections	Number of infections	
Type and number of all lesions	Number of lesions	Malins et al. 1980; 1982
Hematology and blood chemistry	Concentrations of contaminant	
Invertebrate Pathology		
Type and number of parasitic infections	Number of infections	Malins et al. 1980; 1982
Type and number of all lesions	Number of lesions	
Fish Ecology		
Seasonal and annual catch rates	(CPUE) Catch per unit effort	
Species richness	(S) number of species	Malins et al. 1980; 1982
Species diversity	(H) Shannon-Weaver Diversity Index	
Sex, age and size	Comparative percentages	
Invertebrate Ecology		
Community structure	(IBD) Index of benthic degradation	O'Conner and Swanson 1982
Total abundance	(ITI) infaunal trophic index	Word 1978
Taxon richness	(TA) number of organisms	
	(S) number of taxon	

TABLE 3-1 (Continued)

Category/Specific Analysis	Parameter Quantified	Standard Method
Bioaccumulation		
Fish livers	µg contaminant/g dry weight	Malins et al. 1980; 1982
Invertebrate edible tissues	µg contaminant/g dry weight	
Limited edible tissue analyses of fish	µg contaminant/g dry weight	
Harbor seal blubber	µg contaminant/g dry weight	Calambokidis 1984
Marine bird muscle and organs	µg contaminant/g dry weight	Riley 1983
Effect Studies		
Invertebrate exposure	Comparative survival	Malins et al. 1982
Recolonization	Comparative abundance and richness	
Tetra-Tech		
Bioaccumulation		
Crab and fish edible tissue and fish livers	Concentration (ppb) and $BI_i = C_{si}/C_{ri}$ (i = contaminant group)	Malins et al. 1982
Fish Pathology		
Type and number of liver lesions Malins et al. 1982	Percent prevalance and $PI_i = P_{Si}/P_{Ri}$ (i = type of lesion)	
Benthic Community Structure		
Total abundance		
Amphipod abundance		

TABLE 3-1 (Continued)

Category/Specific Analysis	Parameter Quantified	Standard Method
NOAA (Continued)		
Benthic Community Structure (Continued)		
Molluscan abundance Total taxa Amphipod taxa Molluscan taxa Species richness Species dominance	BCI = BC_{Ri}/BC_{Si} (i = structure variable)	Swartz 1978
Battelle		
Effect Studies	Number of species Number of organisms	
Recruitment	Number of species in a taxon Number of species in a trophic level	Vanderhorst et al. 1978
BIOASSAYS:		
NOAA		
Oyster Larvae		
Abnormal development Mortality	Comparative percent sublethal Comparative percent survival	Chapman and Morgan 1983
Surf Smelt Eggs and Larvae		
Abnormal development Hatching success Larval survival	Comparative percent sublethal Comparative percent survival Comparative percent survival	Chapman, et al. 1983

TABLE 3-1 (Continued)

Category/Specific Analysis	Parameter Quantified	Standard Method
NOAA (Continued)		
Polychaete Life Cycles		
Survival at all stages	Comparative percent survival	Chapman and Fink 1984
Growth rate	mm/day	
Timing to reproduction	Number of days	
Cell Reproduction		
Inhibition of cell proliferation	No. of cells/96 hours	Chapman et al. 1983
Cytotoxicity	µg/ml	Chapman et al. 1982
Anaphase aberration	Comparative percent occurrence	Landolt and Kocan 1984
Amphipod Toxicity		
Lethality	Comparative percent survival	Swartz et al. 1984
Oligochaete Response		
Respiration rate	Comparative µl O_2	Chapman 1984
Tetra-Tech		
Acute/Lethal		
Amphipod survival	Percent mortality and $TI_M = M_S/M_R$	Swartz et al. 1984

TABLE 3-1 (Continued)

Category/Specific Analysis	Parameter Quantified	Standard Method
Tetra-Tech (Continued)		
Sublethal		
Oyster larvae deformation	Percent abnormality and $TI_A=A_S/A_R$	Chapman and Morgan 1983

Definitions of Tetra-Tech Symbols

C_{Si} = tissue concentration of contaminant group i at a study area.
C_{Ri} = tissue concentration of contaminant group i at reference areas(s).
P_{Si} = percent of fish with liver lesion i at a study area.
P_{Ri} = percent of fish with liver lesion i at reference area(s).
BC_{Ri} = the value of a selected benthic community structure variable at reference area(s).
BC_{Si} = the value of the same benthic community structure variable at the study area.
M_S = mortality rate at a study area.
M_R = mortality rate of reference area(s).
A_S = abnormality rate at a study area.
A_R = abnormality rate at reference area(s).

mean survival is less than 85 percent (less than 17 out of 20 individuals surviving). This method has been used by EPA to evaluate the toxicity of sediments in the interim dredged material disposal decision process. It represents the point at which one can reliably detect a significant difference from background based on statistical analyses of numerous bioassay tests. The interpretive use of this method is summarized below.

In the control bioassays the number of surviving amphipods can range from 20/20 down to approximately 17/20 or 85 percent survival. Therefore, in the bioassays of contaminated sediments, if the mean survival rate is less than 85 percent then one could reasonably assume that a causative agent in the sediment induces a toxic effect on the amphipods. Dr. Swartz has not analyzed data from these amphipod bioassays to the extent required to develop burden-effect ranges. However, he suggested that 0 to 8 survival/20 might be considered highly toxic, 9 to 17 survival/20 moderately toxic and 17 to 20/20 normal background. He emphasized that the results of these bioassays are very site specific in that the survival of the amphipod also varies with sediment characteristics (i.e., grain size and organic content). He believes that a better understanding by researchers of how these burden-effect levels would be used by regulatory agencies is necessary in order to improve the utility of this method. Right now, all that can be reliably determined is a yes or no answer regarding the occurrence of an effect.

The benthic community structure indices (Swartz 1978) which WDOE/Tetra Tech is using in Commencement Bay are indicators of a "real world" change in a portion of the marine environment. These indices are used to detect a change in the structure of the community (i.e., change in number of species, taxon abundance, or disappearance of sensitive species). This change could be due not only to changes in contaminant concentrations, but also to variations in organic enrichment, sediment characteristics, and/or other covariates. Dr. Swartz believes that

these indices can only be used to compare similar communities in similar environments or follow the community behavior over a period of time. Therefore, benthic community indices by themselves are not conclusive enough to be used as a single "criterion" or grouped into ranges of burden-effect levels.

Peter Chapman - EVS Consultants

Dr. Chapman has developed and/or modified four bioassays which are being used in studies of Puget Sound sediment contamination. The oyster larvae bioassay is used to detect sublethal effects by recording abnormal larvae development and lethal effects by egg survival. The fish cell reproduction bioassay is used to determine lethal effects, cytotoxicity, by measuring the inhibition of cell proliferation and sublethal effects by calculating the percent occurrence of anaphase aberrations. The polychaete life-cycle bioassays also measure both levels of effects, lethal - survival at all stages, and sublethal - changes in growth rate and timing of reproduction. Sublethal effects of sediment contamination can also be detected with the oligochaete response bioassay which compares changes in respiration rates. Dr. Chapman indicated that with further research and statistical analyses, some components of these bioassays could be used to develop a "criterion" but cautioned that they would have to be applied very carefully due to the inherent site specific limitations and the difficulty in obtaining enough reliable data to perform adequate statistical analyses. He felt that there was not enough data yet to begin a meaningful evaluation of burden-effect levels and cautioned the regulatory agencies not to hurry into the sediment criteria development process.

Eric Crecelius and Walt Pearson - Battelle Northwest

The benthic community recruitment studies on sediments from eight embayments in Puget Sound are based on methods developed over the last eight years at Battelle's Marine Research Laboratory by Dr. J.V.

Anderson and J.R. Vanderhorst to predict the effects of oil spills on intertidal populations. Data obtained from these studies will include the number of species, number of individuals, number of species in a taxon and number of species in a trophic level. The data will be used to rank the eight embayments according to the comparative bioeffects on recruitment. Because these studies were designed to test the integrated effect of all the contaminants in a series of sediment samples and experimentally assess the impact of the whole sediment rather than individual components, both Drs. Crecelius and Pearson believe that the data will not be suitable for developing specific numerical sediment criteria. Limiting factors, such as the effects of grain size on species preference and the bioavailability of contaminants may preclude this benthic community structure test from being used in the development of sediment criteria for specific contaminants or groups of contaminants. These current studies can only show indications of contamination and to what relative degree they occur. Specific burden-effect relationships or ranges cannot be estimated. This technique, though, is not inherently incapable of determining such relationships. Experimental manipulation of oil-contaminated sediments have yielded quantitative relationships between the level of oil contamination and the rate of benthic recovery.

Jack Word - University of Washington

The infaunal trophic index (ITI) was developed by Jack Word to improve the reliability of comparing other benthic community structure indices. The ITI essentially is used to describe the community; it characterizes the community structure by taking into account the interrelationships between the four major trophic groups, food availability, and key sediment characteristics. Therefore, when benthic samples from different embayments with similar ITI values are compared, the effects of natural variables affecting the structure indices are minimized and the effects of contamination can more reliably be assessed.

From his experience, Dr. Word felt that a change in the number of species was a more sensitive indicator of contamination than the number of individuals because the sensitive and marginal species would disappear first due to toxic contaminants. Dr. Word said that a 30 percent change in the number of species versus background would be indicative of contamination, while a 50 percent change in the number of individuals would be required to conclude that the area was contaminated. However, the use of the ITI method in evaluating toxicant effects is still a controversial issue and is not being supported by other quantitative benthic biologists.

His opinion on the use of benthic community structure indices for sediment criteria concurs with those of Dr. Swartz and Dr. Pearson; the data and indices developed for purposes of comparison are not appropriate for establishing burden-effect relationships for specific contaminants.

Don Malins - NOAA/NWAFC

Numerous field biological survey techniques have been developed and/or modified by NWAFC for assessments of Puget Sound sediments. These surveys fall into the following five categories: fish pathology, invertebrate pathology, fish ecology, invertebrate ecology, and bioaccumulation. According to Dr. Malins, of all these surveys, only the incidence of liver lesions has been correlated with the presence of contaminants in the sediments. In a nonurban or pristine environment, the incidence of liver lesions is essentially zero in the five species of fish usually surveyed. Therefore, even a 1 to 2 percent incidence of liver lesions is an indication of contamination. No attempt has been made to group the percent incidence data into low, medium, or high levels of effect. All other types of lesions and parasitic infections commonly occur in fish and invertebrates even in pristine environments; to-date no correlations between their percent incidence and contaminant levels have been documented.

Similarly, statistical correlations required to establish burden-effect relationships have not yet been found in the data from fish ecology and invertebrate ecology surveys. Bioaccumulation studies are as yet inconclusive, as they are still in the developmental stages and much data has to be gathered and analyzed to first improve the scientists' understanding of bioaccumulation before attempts at identifying burden-effect relationships can be initiated.

4.0 DECISION SCHEME FOR REGULATORY USE OF SEDIMENT CRITERIA

Based on the evaluation of the most relevent ongoing studies in Puget Sound and discussions with EPA Region X staff, a decision process chart was generated showing how the data developed by the different investigations (approaches) could be incorporated into the regulatory process. The process scheme is shown in Figure 4-1. At this stage of the sediment criteria development program, this interactive chart is intended only as an example of the type of decision considerations that may have to be incorporated in the regulatory process for implementing an effective control/compliance/enforcement plan for toxic contaminants. This decision scheme is designed for a chemical-by-chemical assessment. It utilizes the criteria graph concept developed in the preliminary evaluation study in conjunction with supplemental information anticipated to be obtained from the burden-effect analyses and bioassay testing. The authors recognize the preliminary nature of this decision scheme and intend to refine and/or modify it as more evaluations are performed and additional feedback from the regulatory and scientific community is acquired.

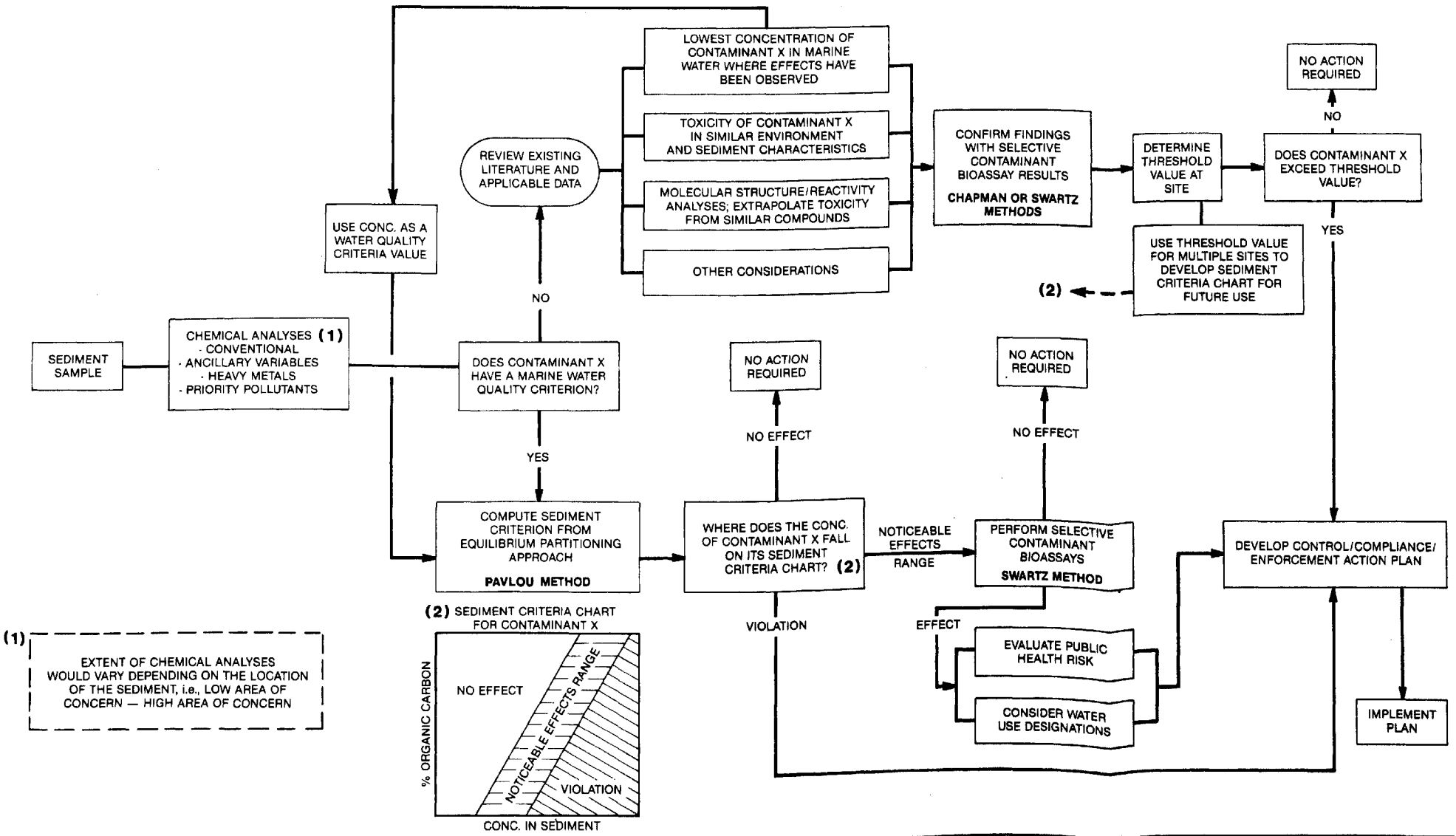
The following discussion summarizes the scheme and provides a brief description of the elements shown.

- A sample is obtained in the active sediment layer of a marine site under regulatory consideration. The statistical criteria for the number of samples obtained, the spatial configuration of the sampling grid, and sampling techniques are not discussed in this report.

- The sediment sample undergoes a range of analyses to quantify various parameters including:
    (1) Conventional parameters (e.g., nutrients, sulfides, oil and grease, total solids, BOD, COD, and other variables);

EXAMPLE OF REGULATORY DECISION PROCESS FOR USE OF SEDIMENT CRITERIA

Figure 4-1



(2) Ancillary variables which are important in determining bioavailability and burden-effect relationships. These, for example may include: grain size, percent organic carbon, oxidation and reduction potential, and interstitial water chemistry (salinity, DOM);

(3) heavy metals of ecological significance (priority list); and

(4) priority organic components including any other anthropogenic chemicals of known ecological significance and/or specific to the site of interest originating from land based sources.

- Each contaminant found in the sediment sample will be assessed on an individual basis. If a marine water quality criterion has been established by EPA for that contaminant, then the decision can follow the lower pathway involving use of the equilibrium partitioning approach. If no criterion are available a literature review and use of relevant information could be pursued as shown in the upper pathway.

Lower Pathway

- From the water quality criteria a range of sediment criteria can be computed from a predicted partition coefficient as described by Pavlou and Weston (1984).

- The next step on the path is determined by where the measured contaminant concentration falls on its sediment criteria chart. If the coordinates of the contaminant concentration and percent organic carbon fall within the "no effect" portion of the chart, no regulatory action is required. If the measured concentration falls within the "violation" portion, this sediment sample exceeds criterion for that specific contaminant and regulatory action is required.

- Instead of just having a line of values separating the "no effects" and "violation" portions, there is a range which encompasses the uncertainty associated with the derivation of the criterion value. If a concentration falls within this "noticable effects" range, additional evaluations of possible biological effects are required. Selective contaminant bioassays such as those developed by EPA (Swartz et al. 1984) could be used to determine the toxicity of a specific contaminant concentration associated with a given percent organic carbon.

- The results of these bioassays could be further evaluated in light of possible public health risks and actual water usage. Can this contaminant be bioconcentrated in edible tissues and would organisms that come in contact with this contaminated sediment or intermediate trophic levels be consumed by humans? Is the location of contaminated sediments used extensively by the public for recreation or fishing, or is it a critical habitat? Appropriate regulatory action could then be developed based on this evaluation.

Upper Pathway

- The first step involves a review of existing literature and applicable data to find possible correlations between concentrations of the contaminant (or chemically similar compounds) with biological effects.

- If detrimental biological effects have been observed for that contaminant in marine waters, the lowest concentration associated with effects could be used to develop a water quality criterion (Stephan et al. 1983). This derived criterion could then be used in the lower portion of the decision process just as those criteria which have been established.

- If only indirect information is available, then selective contaminant bioassays such as those developed by Swartz or Chapman as presented in Table 3-1 could be used to confirm the toxicity of this contaminant. From these results, tentative contaminant threshold values can be determined for these sediment characteristics.

- If the measured contaminant concentration exceeds this determined threshold value, then regulatory action is required. If there is no exceedence, no action would be necessary.

- The threshold values determined from these selective contaminant bioassays for multiple sites can be used to develop a sediment criteria chart for future applications.

5.0 RECOMMENDATIONS

Upon completion of this short project, it is apparent that prior to launching a full-fledged effort in sediment criteria development, EPA must determine whether (1) establishing sediment criteria is an effective method to protect the marine environment from present and future contaminant insults and (2) if the different approaches currently pursued by various environmental agencies and scientific groups will generate sufficiently reliable information which could render the derived numerical values defensible against scientific scrutiny as well as in a court of law. It is also apparent that, although there is a tacit agreement on the basic concepts currently considered by the various approaches, there are differences of opinion in the way these approaches are interpreted and the way the data should be applied in the development of sediment criteria.

Based on the above considerations, the following recommendations are made as logical steps for addressing both the regulatory and technical concerns addressed above.

- A technical workshop should be planned as soon as possible to evaluate the methodology and interpretive procedures currently used in the various approaches presented in this report and reach a technical concurrence on the applicability of state-of-the-art technology in the development of sediment criteria.

  Examples of State-of-the-Art Technology

  Bioassays - Made-up mixtures or fractionated suites
  - Spiked sediments
  - Polychaete lifecycles

  Bioaccumulation in edible tissues

  Recruitment in benthic communities

Concurrent to this activity should be an attempt (based on best current knowledge) by scientists and environmental managers to identify alternative decision methods for establishing acceptable levels. The workshop should include key individuals who are actively involved in the use and testing of relevent technology. A desirable output from the workshop should be a consensus document delineating applicable methods, procedures, and data which can be used to evaluate sediment criteria or related burden-effect threshold limits.

- A regulatory workshop should be organized to perform the following recommended tasks in order to address immediate and long term regional decision/regulatory needs:

  1. Identify estuarine/coastal decision and regulatory needs which may require the application of sediment criteria.

  2. Identify existing criteria upon which decisions/actions, (i.e., control, compliance, enforcement) are presently based.

  3. Describe regulatory decision making processes to which sediment criteria can be applied and/or existing water quality criteria can be confirmed by incorporating sediment quality parameters.

  4. Determine how sediment criteria can be incorporated in the permitting process (i.e., 301 (h) waivers, NPDES permits, dredge/disposal permits) by developing a conceptual process/procedural scheme which enhances end point of regulatory decision/need. (What do we need to protect?)

  5. Determine how the sediment criteria can be converted (and the process by which one goes about converting) from an ambient value to a source control limit. Determine transport and fate

process of contaminants from an input source or sources to ambient concentration. Develop general model relating input loading to ambient burden which can be tailored to a given specific need.

6. Based on 4 and 5, develop and recommend the type and form of sediment criteria needed to meet the regulatory/decision end point. (e.g., Type--biological, chemical, integrated; Form--criteria graph, threshold limits, index.) Look at regulatory instruments and how we would make these permits the most effective means for solving sediment problem by using sediment criteria.

7. Develop conceptual framework for incorporating sediment criteria into EPA's use-attainability analysis scheme.

o Implement recommendations 1A through 1E under Technical Tasks, Task 1, as presented in Appendix A. Recommendations 1A and 1B can be performed together.

6.0 REFERENCES

Anderson, J.W., R.G. Riley and R.M. Bean. 1978. Recruitment of benthic animals as a function of petroleum hydrocarbon concentrations in the sediment. J. Fish Bd. of Can. 35(5):776-790.

Calambokidis, J., J. Peard, G.H. Steiger, H.C. Cubbage, R.L De Long. 1984. Chemical contaminants in marine mammals from Washington State. NOAA Technical Memorandum NOS OMS-6. National Ocean Services, Rockville, MD. 167 pp.

Chapman, P.M. 1984. Oligochaete respiration as a measure of sediment toxicity in Puget Sound, Washington. Water Research.

Chapman, P.M. and R. Fink. 1984. Effects of Puget Sound sediments and their elutriate on the life cycles of Capitella capitata. Bulletin of Environmental Contaminants and Toxicology.

Chapman, P.M. and J.D. Morgan. 1983. Sediment bioassays with oyster larvae. Bulletin of Environmental Contaminants and Toxicology, Vol. 31. Pages 438-444.

Chapman, P.M., R.N. Dexter, R. Fink, R.M. Kocan, M.L. Landolt, J. Morgan, D.R. Munday. 1983. Survey of biological effects of toxicants upon Puget Sound biota, II-Test of Reproductive Impairment. NOAA Technical Report NOS-2, OMS-1, Rockville, MD, 58 pp.

Chapman, P.M., G.A. Vigers, M.A. Farrell, R.N. Dexter, E.A. Quinlan, R.M. Kocan, M.L. Landolt. 1982. Survey of biological effects of toxicants upon Puget Sound biota, I-Broad Scale Toxicity Survey. NOAA Technical Bulletin, OMPA-25. Office of Marine Pollution Assessment, Boulder, CO. 98 pp.

Landolt, M.L. and R.M. Kocan. 1984. Lethal and sublethal effects of marine sediment extracts on fish cells and chromasomes. Helgolander Meesunters. Vol. 38.

Long, E.R. 1983. A multidisciplinary approach to assessing pollution in coastal waters. In: Proceedings of the Third Symposium on Coastal and Ocean Management, ASCE/San Diego, CA. June 1-4, 1983. Pages 163-178.

Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, H.O. Hodgins, and S. Chan. 1982. Chemical contaminants and abnormalities in fish and invertebrates from Puget Sound. NOAA Technical Memorandum OMPA-19.

Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, and H.O. Hodgins. 1980. Chemical contaminants and biological abnormalities in central and southern Puget Sound. NOAA Technical Memorandum OMPA-2.

O'Connor, J.S. and R.L. Swanson. 1982. Unreasonable degradation of the marine environment - what is it?. In: Proceedings from Oceans 82, Marine Pollution Papers, Marine Technology Society, September 20-22, 1982, Washington, D.C. Pages 1125-1132.

Pavlou, S.P. and D.P. Weston. 1983. Initial Evaluation of Alternatives For Development of Sediment Related Criteria for Toxic Contaminants in Marine Waters (Puget Sound). Phase I: Development of Conceptual Framework.

Pavlou, S.P. and D.P. Weston. 1984. Initial Evaluation of Alternatives For Development of Sediment Related Criteria for Toxic Contaminants in Marine Waters (Puget Sound). Phase II: Development and Testing of the Sediment-Water Equilibrium Partitioning Approach. EPA Report 910/9-83-117.

Riley, R.G., E.A. Crecelius, R.E. Fitzner, B.L. Thomas, J.M. Gurtisen, N.S. Bloom. 1983. Organic and inorganic toxicants in sediment and marine biota from Puget Sound. NOAA Technical Memorandum NOS OMS-1. National Ocean Services, Rockville, MD. 125 pp.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman, W.A. Brungs. 1983. Guidelines for deriving numerical National Water Quality Criteria for the protection of aquatic life and its uses. Draft, EPA. July 5, 1983.

Swartz, R.C., W.A. Debend, J.K.P. Jones, J.O. Lamberson, and F.A. Cole. 1984. Amphipod bioassay for marine sediment toxicity. In: Proceedings of the 7th Symposium of Aquatic Toxicology, ASTM.

Swartz, R.C. 1978. Techniques of sampling and analyses of the marine benthos. EPA Ecological Research Series, EPA-600/3-78-030.

Vanderhorst, J.R., J.W. Anderson, P. Wilkinson, and D. Woodruff. 1978. Estimation of effects from oil on intertidal populations: experimental pertubations versus natural variation. In: Proceedings of Conference on Assessment of Ecological Impacts of Oil Spills, held in Keystone, Colorado on 14-17 June. Pages 807-820.

Vanderhorst, J.R., J.W. Blaylock, P. Wilkinson, M. Wilkinson and G. Fellingham. 1980. Recovery of Strait of Juan de Fuca intertidal habitat following experimental contamination with oil. DOC/EPA Interagency Energy/Environment R&D Program Report EPA-600/7-80-140, U.S. Environmental Protection Agency, Washington, D.C. 73 pp.

Vanderhorst, J.R., J.W. Blaylock, P. Wilkinson, M. Wilkinson and G. Fellingham. 1981. Effects of experimental oiling on recovery of Strait of Juan de Fuca intertidal habitats. DOC/EPA Interagency Energy/Environment R&D Program Final Report EPA-600/7/81/088. U.S. Environmental Protection Agency, Washington, D.C. 129 pp.

Word, J.Q. 1978. The infaunal trophic index. Coastal Water Research Project (W. Bascom, ed.). Annual Report, 19-37.

APPENDIX A

MANAGEMENT AND TECHNICAL NEEDS IN SEDIMENT CRITERIA DEVELOPMENT

APPENDIX A

MANAGEMENT AND TECHNICAL NEEDS IN SEDIMENT CRITERIA DEVELOPMENT

INTRODUCTION

Based on the initial evaluation of alternatives for development of sediment criteria for toxic contaminants in marine waters (Pavlou and Weston, 1983; Pavlou and Weston 1984) two types of follow-up activities were identified. One reflects the regional EPA needs and the other the national programatic priorities as expressed by the project staff of the EPA/Criteria and Standards Division. EPA Region X is pursuing the development of a coherent approach in the management of contaminated sediments and the implementation of a realistic contaminant control/compliance/enforcement plan for Puget Sound. The EPA's Criteria and Standards Division is interested in developing methodology for establishing sediment criteria for a variety of marine sites throughout the country to define toxic levels of contaminants in sediments and determine what should be considered a safe level so that effective regulation of contaminants can be implemented.

Envirosphere, in consultation with both management and technical staff from the EPA Region X Office, has developed a list of activities which, from the Agency's perspective, would strengthen the effort of developing defensible criteria. These activities include management and technical tasks applicable to the regional and national needs presented above. A short summary of these tasks is presented below.

OBJECTIVES AND ASSUMPTIONS

Although the objectives of the sediment criteria development continuation studies reflect primarily regional needs, they are applicable to any marine region. The objectives are summarized below:

- Develop best available interim criteria for Puget Sound.

- o Develop and manage a coordinated and coherent approach to upgrade criteria to legally defensible regulatory status consistent with EPA Headquarters needs.

- o Develop regional and national numerical defensible (scientifically sound) sediment criteria.

In performing the proposed tasks the assumption is made that Puget Sound is identified as the lead marine region where sediment criteria will be developed and will provide a test case for the national effort.

MANAGEMENT TASKS

Task 1 Preparation of Management Framework for the Sediment Criteria Development Program

- o Compile and document interim criteria values generated by all existing approaches and ongoing efforts by various agencies in Puget Sound. The list to be prepared following consensus among all concerned parties involved and confirmation by all regulatory agencies.

- o Perform comparative analyses of data generated by each approach and determine consistency of results produced by different approaches.

- o Develop theoretical projection of each approach, i.e., extend evaluations and analyses to a degree of rigor necessary to ensure that the derived criteria are technically and scientifically defensible numerical values.

- o Develop an interactive diagram of activities and CPM scheme to reach defensible numerical criteria values integrating the results of various approaches.

- o Perform coherent evaluations:

  - Interrelate and integrate approaches for Puget Sound; define common elements resulting in defensible numerical values.

  - Expand evaluations to include national needs and approaches.

- o Define existing/ongoing approaches and research efforts; relate to approaches identified in the initial evaluation reports. Define list through examination of ongoing activities (field surveys) in Puget Sound.

Task 2 Management of Interim Sediment Criteria Use

- o Project regulatory decision points (milestones) where interim sediment criteria will be required. Relate to interactive diagram and activities developed under Task 1 above.

- o Develop sediment criteria for open water dredge disposal of contaminated sediments. Obtain concensus by all regulatory agencies.

- o Propose field studies and laboratory research to provide cost effective improvement of numerical values.

- o Analyze projected use of interim Puget Sound numerical criteria.

  - Evaluate when numbers need to be upgraded with respect to data and regulatory decision points.

- Analyze data and recommend changes.

- Revise projected data needs and apply to interactive diagram/CPM scheme.

Task 3 Coordination of Interagency Communications and Information Exchange

o Document activities under Task 1 and disseminate information to participating agencies in easily understandable documents. Focus on visual methods, oral presentations, and workshops.

Task 4 Develop Interagency Information Exchange Program

These activities will focus on:

o Obtaining concurrence on the Interactive Diagram/CPM Scheme.

o Improving the understanding of the sediment criteria development effort by technical and management staff of all agencies.

o Assuring effective use of management framework, i.e., how each agency can apply ID/CPM scheme to meet their needs and how their work would relate to other agency needs.

o Providing rapid feedback on ongoing activities as it relates to criteria development, i.e., field surveys, laboratory studies, data synthesis, and interpretive evaluations.

- Assuring effective information transfer and that communications are maintained in formulating decisions for future field studies and research objectives as related to overall coordinated interagency approach to criteria development.

TECHNICAL TASKS

Task 1 Refinement and Confirmation Studies of the Equilibrium Partitioning Approach.

The proposed tasks comprise the follow-up activities to the preliminary assessment of sediment criteria development performed for Puget Sound and encompass the key aspects of the recommendations made by Pavlou and Weston (1984).

Task 1A Compilation and Analysis of Ancillary Information.

- Compile all available organic carbon/sediment texture data and develop master regression equation for fine-tuning preliminary criteria values. Examine the existence of subregional differences and adjust criteria accordingly. Products from this effort should include a master equation for Puget Sound sediments (estuary wide and subregional) with associated numerical uncertainty and computerized output (tabular and graphic).

Task 1B Sediment Criteria Data Base (SCDB) Development.

- This task should be performed in two phases for cost effectiveness. Each phase would consist of sequential evaluations leading to a modular final product for each phase.

Phase I - Feasibility Assessment

- Evaluate existing regional data base systems as to their compatibility with the sediment criteria program needs, accessibility by EPA and other users, and ease of data processing (reduction and statistical analyses).

- Identify immediate SCDB needs for the equilibrium partitioning approach to: (1) allow ease of quantitative analysis of existing data, (2) inclusion of addition contaminant residue and ancillary parameter information, (3) refinement and fine tuning of preliminary numerical values, and (4) expansion to additional geographical areas nationwide.

- Identify long term SCDB needs to include incorporation of other computational methods for generating numerical criteria. Establish interagency consensus on unified approach.

- Update progress status of ongoing regional water quality data management efforts, estimated completion schedules, and time of systems availability to outside users.

Phase II - SCDB Systems Development

- Develop a centralized sediment quality data management system (SQDMS) to meet EPA's regulatory short and long term needs.

Task 1C Verification Studies of Equilibrium Partitioning Approach

This task should be a field oriented activity and could consist of two phases:

- Phase I - Develop Technical Basis of Survey and Approach
  - This phase is to include developing the technical basis of survey and aprroach for site locations, sampling frequency, chemical and ancillary variables to be measured, and protocol development for interstitial water sampling and analysis.
  - This phase could provide an updated review on the state of knowledge in sampling and analysis of interstitial water and recommendations for optimum methodology to be used in a sediment criteria development program based on equilibrium partitioning approach.
- Phase II - Perform Survey and Analyses
  - Synthesize and interpret information resulting in modification and/or refinement of preliminary criteria values.

Task 1D Biological Confirmation of the Equilibrium Partitioning Approach.

This task should be implemented in two phases.

- o Phase I - Develop Work Plan

  - This work plan would be designed to determine if sediment criteria values derived by the equilibrium partitioning approach are below concentrations causing adverse biological effects. Examine and evaluate existing data. Perform preliminary analyses afforded by the data, identify data needs for field and/or laboratory studies, define products of the study.

- o Phase II - Perform Experimental and/or Field Survey, Synthesize Results, and Perform Evaluations

  - Recommend additional field work, criteria modifications, and/or specific protocol development to enhance equilibrium partitioning approach by specific bioassay tests. Refine numerical values as appropriate. It is recommended that this task be performed in conjunction with Task 1C to improve coherency of evaluations and cost effectiveness by consolidation of the sampling activities.

Task 1E Chemical/Biological Comparisons from Existing Data

- o This task, although specific to Puget Sound, is applicable to any estuarine and/or coastal system where sufficient information is available. The intent of this task would be to perform initial evaluations based on existing data to relate the occurrence of violations of established "first cut" numerical criteria values to the occurrence of biological effects. This task could be the preliminary assessment required to better define the

scope of the verification studies outlined in Tasks 1C and 1D above. Based on this initial assessment, develop study scenarios that could be implemented to quantify this relationship. Develop detailed work plan for performing these evaluations. Recommend field and/or laboratory studies.

Task 2 Application of Equilibrium Partitioning Approach to Other Marine Environments

The proposed tasks are intended to test the application of the equilibrium partitioning approach at different marine regions and sites of the U.S. consistent with the programmatic requirements (desires) of the EPA Criteria and Standard Division regarding the development of acceptable methodology nationwide for establishing sediment criteria. It is recommended that these tasks be performed after the technical assessments described in Task 1 are completed.

Task 2A Feasibility Testing of Derived Preliminary Criteria in the New York Bight

- This task would apply the procedures developed by Pavlou and Weston (1984) as verified and/or modified to the New York Bight area. Specific activities would include: compilation of contaminant residue data and appropriate ancillary sediment variables (emphasis should be placed on organic carbon/sediment texture data), the development of criteria-graphs for New York Bight, and an evaluation of the magnitude and spatial extent of violations. Comparisons could be made with the results obtained in Puget Sound and the relative magnitude, severity, and significance of the contamination in these tests sites could be assessed.

Task 2B Feasibility Testing of Derived Criteria in Dredge Disposal Sites

- This task would apply the procedures followed in Task 2A above, to the evaluation of the magnitude, severity, and significance of contamination at a test open water dredge disposal site selected by EPA. This assessment should provide EPA with: (1) an initial data base for redesignation of disposal sites, and (2) a realistic framework to base a coordinated effort with the Army Corps of Engineers to develop alternative disposal methods and site control practices.

APPENDIX B

INTERACTIVE ACTIVITY AND INFORMATION FLOW DIAGRAMS FOR STUDIES RELEVANT TO CRITERIA DEVELOPMENT IN PUGET SOUND

PAGE NOT

AVAILABLE

DIGITALLY

PAGE NOT

AVAILABLE

DIGITALLY

PAGE NOT

AVAILABLE

DIGITALLY

PAGE NOT

AVAILABLE

DIGITALLY

PAGE NOT

AVAILABLE

DIGITALLY