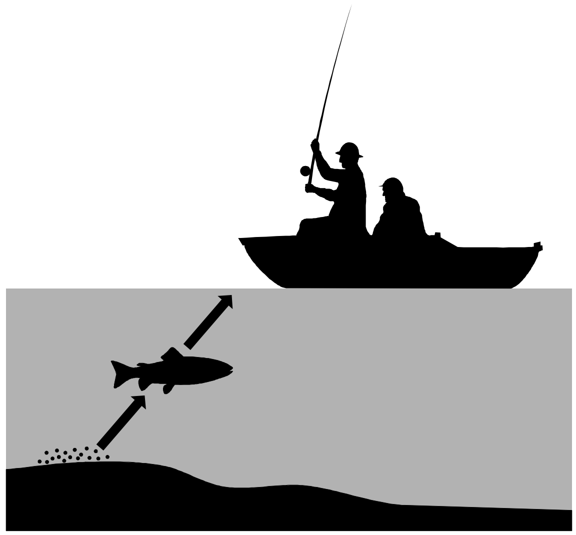

Developing Health-Based Sediment Quality Criteria for Cleanup Sites: A Case Study Report

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Abstract

The Washington Department of Ecology is planning to amend the state Sediment Management Standards to include criteria for protecting human health. These criteria could affect the extent of cleanup required at contaminated sites. This report evaluates Ecology's proposed criteria through four case studies from the Puget Sound region**.** For each case study the report evaluates the approach currently being used on a case-by-case basis to protect human health, and shows how the proposed criteria would have impacted the cleanup site in terms of area and/or volume affected. The report includes recommendations on rule design and implementation strategies.

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Executive Summary

Scientific studies show that sediments in many urban bays and estuaries of Puget Sound contain elevated levels of pollutants. Sediment contamination has been associated with impacts on animals living in the sediments and bottom-feeding organisms. In addition, many commonly found pollutants accumulate in fish and shellfish, which are then consumed by people. As a result, there is concern that contaminated sediments pose a health threat to humans through the consumption of seafood.

In response to this concern, the State of Washington has taken action to prevent future contamination of sediments and to clean up sites where contamination is unacceptably high. In March 1991, the Department of Ecology (Ecology) adopted the Sediment Management Standards, Chapter 173-204 WAC. The rule contains specific procedures for identifying sediments that pose unacceptable environmental risks. However, the rule does not contain similar procedures for evaluating human health impacts.

Ecology is now taking steps to develop and adopt human health sediment quality criteria (HHSQC). Ecology's goal is to amend the sediment standards rule to provide more consistent protection of human health from contaminated sediments in a cost-effective, workable manner. Without these criteria, Ecology must make case-by-case decisions about how to protect people from exposure to sediment contamination. This approach is resource-intensive and can lead to unpredictable results.

With input from an advisory committee, Ecology has developed draft health-based criteria and a proposed strategy for implementing the criteria (see Appendix B). This "Preliminary Implementation Strategy" relies on a tiered approach, with "Tier I" representing an initial evaluation to determine if sediment chemical concentrations pose a significant human health risk via seafood consumption. Additional, site-specific analysis ("Tier II") could occur and be used as an "override" of the Tier I criteria.

Some advisory committee members expressed concerns about how HHSQC might affect cleanup costs and liability. To address these concerns, Ecology conducted the "case studies" described in this report. These case studies allow Ecology and the public to take a closer look at how the proposed health-based criteria might impact cleanup sites in terms of area and/or volume affected. The information collected for the case studies will also be used during the development of the cost/benefit analysis for rule adoption as required by the Administrative Procedures Act and to comply with the State Environmental Policy Act.

[Note: This report focuses on impacts of the rule on cleanup decisions; Ecology expects to address how the rule will affect source control and dredging issues in a separate document. Nonetheless, the information contained in this report is pertinent to all three issues.]

Goals and Objectives

The case studies were selected to address three primary questions:

1. What approaches and methods are currently being used to make case-by-case decisions to protect human health at sediment cleanup sites?

2. What are the key policy and methodological problems and issues encountered during case-by-case decisions?

3. What incremental impacts would the Preliminary Implementation Strategy for HHSQC have in terms of areas of concern for cleanup relative to existing ecological criteria and case-by-case decisions?

Summary of Findings and Conclusions

Current Approaches and Methods

The case studies show that Ecology and EPA are currently making case-by-case decisions at cleanup sites to account for human health risks. More specifically:

- **At each case study site, the area slated for active remediation was smaller than the overall area of concern as defined by the cleanup level.** Especially at larger sites, areas requiring active remediation are generally smaller than the entire area of concern, as defined by human health and ecological concerns. This difference illustrates how risk assessment and risk management are applied at cleanup sites.

- **A combination of active remediation, natural recovery, institutional controls and monitoring are being used fairly regularly to meet cleanup levels.** Agencies have used the flexibility inherent in the selection of the cleanup action process to address the real-world constraints associated with cost and technical feasibility. As a result, most cleanups include a combination of actions with higher sediment concentrations being actively remediated via dredging and capping and less contaminated areas being addressed via natural recovery, institutional controls and sometimes monitoring.

- **Agencies are generally using site-specific risk assessments to establish cleanup requirements based upon human health protection**. Specifically, cleanup standards at most sites are based on (1) reasonable maximum exposure estimates which take into account recreational and subsistence fishing, (2) toxicity information (i.e. slope factors and reference doses) developed and published by EPA, and (3) risk levels for carcinogens ranging from 10^{-4} to 10^{-6}.

- **Agencies are generally modifying risk-based cleanup levels when they are found to be less than sediment quality values reported in non-urban areas of Puget Sound**. This is an issue primarily for chemicals such as PCBs and HPAHs. Agencies have generally used the 90th percentile of non-urban sediment levels as an estimate of background levels.

Key Policy and Methodological Issues

- **On-going tissue or sediment monitoring to verify compliance with cleanup standards is applied only in some cases**. When the remedial action alternative chosen results in the potential for residual concentrations that exceed health-based levels, some sites are requiring ongoing tissue and/or sediment monitoring to ensure long-term human health protection, while others have not instituted such requirements.

- **Establishing the quantitative link between sediments and the fish/shellfish species of interest is the most technically challenging aspect of determining a cleanup level for protection of human health**. Ecology's use of biota-sediment accumulation factors (BSAFs) to calculate Tier I HHSQC provides a mechanism to reduce some of the difficulties that site managers face when attempting to make that link.

- **There is some variability in the cancer risk levels being used to establish cleanup standards for individual sites**. This variability reflects the (1) different regulatory risk ranges found in EPA's National Contingency Plan and the MTCA Cleanup Regulations and (2) different approaches for addressing cumulative/additive risks.

- **Historically, the data collected at individual sites are generally not sufficient to support a tissue-based approach that could be used to make decisions about cleanup actions**. Sufficient tissue data were collected for only some of the case study sites. Where tissue measurements were taken, the data was most often used to develop a site-specific BSAF.

Impacts Associated with the Preliminary Implementation Strategy for HHSQC

In general, the case studies indicate that Ecology's Preliminary Implementation Strategy for human health criteria would lead to some changes in cleanup levels, but the areas subject to active remediation may not significantly change, because the SMS rule requires Ecology to consider cost and technical feasibility when selecting cleanup actions.

- **Site-specific cleanup levels are generally slightly higher than Ecology's preliminary Tier I criteria for human health chemicals of concern**. The table below summarizes the cleanup levels identified for each case study site in comparison to the preliminary Tier I criteria. With the exception of dioxin, the preliminary Tier I criteria are lower than the

Case Study-Specific Cleanup Levels, by a factor of 1.3 to 12. The largest difference seen was for HPAHs at Eagle Harbor, with a ratio of 12, while the smallest difference was for dioxins at Cascade Pole, where the ratio is just below 1.

Comparison of Preliminary Tier I Human Health Cleanup Screening Levels (HHCSLs) to Case Study-Specific Cleanup Levels

Site	Chemical of Concern	Preliminary Tier I HHCSL	Cleanup Level Chosen at Case Study Site	Ratio of Case Study Cleanup Level to Tier I HHCSL
Hylebos Waterway	PCBs	1.2 ppm	8.8 ppm	7.3
Manchester Annex	PCBs	31 ppb *	40 ppb *	1.3
Cascade Pole	HPAHs	3.3 ppm	11.5 ppm	3.5
	Dioxins	60 ppt	54 ppt	0.9
Eagle Harbor	HPAHs	3.3 ppm	40 ppm	12
	Mercury	NA	0.59 ppm	NA

** The PCB levels for Manchester Annex are presented as a dry weight concentration so as to make the comparison between the Preliminary Tier I HHCSL and the dry weight cleanup level for Manchester Annex, where very low organic carbon levels make it inappropriate to organic carbon normalize. All other concentrations in this table are in terms of total organic carbon.*

- **Many of the site-specific cleanup levels reviewed in the Case Studies are similar to levels that would have been established under Ecology's Tier II approach**. Tier II is a site-specific analysis which can be used to override default Tier I criteria values. Ecology used data collected at each Case Study site to develop Tier II values. In several cases, these values were similar to the site-specific cleanup levels derived for the site.

- **It is difficult to evaluate the full implications of the HHSQC in terms of areas subject to active remediation.** The cleanup levels listed in the table above did not define the areas subject to active remediation (i.e.: capping or dredging) at each case study site. Instead, higher remedial action levels were developed at the sites to define the active remediation area. Since neither the Sediment Management Standards nor the Preliminary Implementation Strategy for HHSQC directly include the concept of remedial action levels, areas that might have been subject to active remediation under Ecology's Preliminary Implementation Strategy could not be defined.

Recommendations

Overall, Ecology believes that adoption of HHSQC will increase certainty and consistency in the decision-making process, while still allowing for enough flexibility to account for site-specific differences. In addition, Ecology recommends the following:

- **The use of area-wide averaging to determine compliance with a cleanup level provides a useful approach for making human health cleanup decisions, especially at large sites**. The use of an area-wide averaging methodology generally results in a smaller area subject to active remediation. Use of this approach raises several key implementation issues, such as definition of the site, definition of fish home range, geometric vs arithmetic averaging, etc., that will need to be resolved.

- **For health-based cleanup actions, the Sediment Management Standards do not clearly define how to identify the sediment cleanup concentration that triggers active remediation**. Under the Sediment Management Standards, cleanup actions may include a combination of actions including dredging, capping, source control, natural recovery, institutional controls and monitoring. For implementation of HHSQC, the level at which active remediation is required will have a significant impact on the cost and feasibility of a cleanup action. Ecology recommends that further public discussion will be necessary to resolve this important issue.

- **To effectively implement the HHSQC, Ecology will need to provide clear guidance on the more complex implementation issues such as use of area-wide averaging, remedial action levels and use of institutional controls**. This guidance will also help to increase consistency among sites undergoing Tier II analysis.

Acronyms and Abbreviations

BSAF	Biota-Sediment Accumulation Factor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Corps	U.S. Army Corps of Engineers
CPF	Cancer Potency Factor
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
FS	Feasibility Study
HHSQC	Human Health Sediment Quality Criteria
HHCSL	Human Health Cleanup Screening Level
HHMCUL	Human Health Minimum Cleanup Level
HHSQS	Human Health Sediment Quality Standard
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
MTCA	Model Toxics Control Act
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PSDDA	Puget Sound Dredge Disposal Analysis
RfD	Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SEDQUAL	Ecology's Sediment Quality Database
SMS	Sediment Management Standards
SQO	Sediment Quality Objective
SQS	Sediment Quality Standards
TOC	Total Organic Carbon
UCL	Upper Confidence Limit
WAC	Washington Administrative Code
ppb	parts per billion, which is equivalent to micrograms per kilogram (µg/kg)
ppm	parts per million, which is equivalent to milligrams per kilogram (mg/kg)

Report Overview

1.0 Introduction

Several studies have shown that sediments in Puget Sound contain elevated levels of pollutants, especially in urban bays and estuaries. Sediment contamination has been associated with impacts on animals living in the sediments and bottom-feeding organisms. In addition, many commonly found pollutants accumulate in fish and shellfish. As a result, there is concern that contaminated sediments pose a health threat to humans through the consumption of seafood which has bioaccumulated chemicals directly or indirectly from sediments.

In response to this concern, the Department of Ecology's Sediment Management Unit has been conducting and managing the technical and policy development work needed to propose human health sediment quality criteria (HHSQC)[1] for marine sediments, primarily in Puget Sound. Since 1991, a number of technical studies designed to investigate relevant issues such as background concentrations, bioaccumulation, fish consumption and distributional analysis have been completed (DOH, 1995; DOH, 1996; PTI, 1995; PTI, 1995b; PTI, 1995c; Male, 1994; Male, 1994a). In addition, Ecology has engaged its sediment advisory committee in discussions regarding the policy and science/policy issues surrounding development and implementation of HHSQC.

Ecology's goal is to amend the sediment standards rule to provide more consistent protection of human health from contaminated sediments in a cost-effective, workable manner. Without these criteria, Ecology must make case-by-case decisions about how to protect people from exposure to sediment contamination. This approach is resource-intensive and can lead to unpredictable results.

While much of the technical work for criteria development has been completed, there are still many questions and concerns about how implementation of health-based criteria will affect sediment cleanup decisions. To address some of these concerns, Ecology chose to conduct the cleanup case studies described in this report. The case studies will allow Ecology and the public to take a closer look at how HHSQC could have impacted specific cleanup sites in Puget Sound in terms of area and/or volume affected.

The case studies are intended to provide insight on the future implementation of HHSQC by:

- Documenting the approaches currently being used on a case-by-case basis to protect human health. These case-by-case decisions provide an opportunity to "field test"

[1] The term "HHSQC" is used throughout this report to indicate either the lower health-based Sediment Quality Standard (HHSQS) or the higher health-based Cleanup Screening Level/Minimum Cleanup Level (HHCSL/HHMCUL).

Ecology's Preliminary Implementation Strategy for HHSQC and learn from previous experiences at cleanup sites.

- Evaluating current approaches used on a case-by-case basis for their utility, relevance and effectiveness in developing HHSQC rule language and guidance.

- Evaluating impacts and implications of several alternative approaches for implementing HHSQC. This includes comparing chemical concentrations at the site with the Preliminary Implementation Strategy for HHSQC to determine how HHSQC would have impacted the cleanup process and decisions at the site.

- Developing recommendations on rule design and specific implementation requirements based on the case studies.

In addition, the information collected for the case studies will be used during the development of the cost/benefit analysis for rule adoption as required by the Administrative Procedures Act and to comply with the State Environmental Policy Act. While this report is limited to cleanup decision-making, Ecology expects that it will be informative for people concerned about issues related to source control and dredging. Nonetheless, Ecology expects to address these issues separately, at a later date. This analysis focuses on cleanup due to some stakeholder concerns regarding cleanup costs and liability.

The case studies are designed to build upon previous efforts to evaluate the implications of HHSQC. For example, Ecology distributed a Puget Sound-wide implications analysis which compares sediment concentrations throughout Puget Sound to preliminary health-based criteria values (see PTI , 1995a). That analysis indicated that for a few of the chemicals of concern, concentrations found in both urban and non-urban areas of Puget Sound are above preliminary health-based criteria. The case studies described here will allow for a more detailed assessment of the implications of the criteria on a site-specific basis.

2.0 Case Study Goals and Objectives

As previously stated, the overall goal of this effort is to develop a rule that provides more consistent protection of human health in a cost-effective, workable manner. The case studies are designed to answer the following three primary questions regarding rule implications, rule design and methods:

- What approaches and methods are currently being used to make case-by-case decisions to protect human health at sediment cleanup sites?

- What are the key policy and methodological problems and issues encountered during case-by-case decisions?

- What incremental impacts would the Preliminary Implementation Strategy for HHSQC have in terms of cleanup areas/requirements relative to existing ecological criteria and case-by-case decisions?

Within these overall goals are several, more specific objectives. These are to:

- Describe the approach that was used to make cleanup decisions at the site.
- Identify key technical and implementation issues which may need to be considered for incorporation into rule or guidance.
- Refine proposed methodologies for rule implementation based on experiences in the field.
- Quantify the potential impact of the Preliminary Implementation Strategy in terms of area designated as requiring cleanup.
- Compare the area requiring cleanup as a result of the Preliminary Implementation Strategy versus case-by-case decision-making.
- Recommend an approach for implementation of human health criteria, particularly for implementation of Tier II.

3.0 Case Study Methods

Ecology followed the steps outlined below in conducting this case study report:

3.1 Site Selection

Ecology evaluated four case study sites. In selecting the sites, Ecology considered the following factors:

- data availability
- chemicals of concern
- geographical diversity
- stage in the cleanup process

Ecology identified four cleanup sites which could demonstrate a range of issues for consideration. These sites are Hylebos Waterway, Manchester Annex, Cascade Pole, and Eagle Harbor. A brief summary of these sites is provided in Section 4.0.

3.2 Site Document Review and Site Manager Discussions

A review of relevant site documents and discussions with site managers were conducted in order to gain a full understanding of the cleanup decisions and the rationale used to reach those decisions. Documents reviewed include Records of Decision, Remedial Investigation/Feasibility Studies and Human Health Risk Assessments.

3.3 Site Methodology Characterization

At each site, Ecology characterized the approaches being implemented, focusing on how human health protection was factored into the cleanup decision, what assumptions were used to calculate risks to human health, what data were collected to support health-based decision-making, and how the data were used to support cleanup decisions.

Some of the key questions identified include:

- how were fish tissue data used to make decisions?
- what species of fish and/or shellfish were chosen?
- how were caged fish/shellfish used (if at all)?
- how were reference area/background concentrations used in decision-making?
- how was natural recovery taken into account?
- were institutional controls used as a remedy?
- how were current vs. future exposures taken into account?

The answers to these questions are included in each of the case studies, where applicable.

3.4 Alternative Approaches Selection and Documentation

There are multiple options for implementation of HHSQC. Therefore, an evaluation of at least two alternative approaches was conducted for each case study. The Preliminary Implementation Strategy provides a point of comparison to evaluate the potential impacts of the Tier I HHSQC in relation to case-by-case approaches.

3.5 Alternative Approach Impact Evaluation

For each approach described above, Ecology determined its relative impact in terms of the physical area potentially requiring cleanup.

4.0 Case Study Summary

Ecology prepared case studies for four cleanup sites in Puget Sound. These are summarized below. For each case study, several approaches were evaluated. The amount and type of data available for each site influenced the range of options that were evaluated. For instance, enough tissue data had been collected for the Eagle Harbor site to allow for a full analysis of a site-specific biota-sediment accumulation factor (BSAF), whereas very little tissue data was collected for the Cascade Pole site, which limited Ecology's ability to analyze potential BSAFs for that case study.

In selecting these sites as case studies, Ecology was interested in sites where cleanup decisions had already been made. It is **not** Ecology's intent to "second guess" decisions or implement changes to cleanup decisions based on any findings in this report.

A Preliminary Implementation Strategy is included at the end of this report (Appendix B). This strategy provides the reader with some background on how the criteria might be implemented. It also provided Ecology with a point of reference when developing this case study report.

Case Study #1 - Hylebos Waterway

In 1983, EPA placed the Commencement Bay Nearshore/Tideflats Site on the National Priorities List of sites requiring investigation and cleanup under the Superfund Program. The nearshore/tideflats area was shown to be contaminated with a large number of hazardous substances at concentrations greatly exceeding those found in Puget Sound reference areas. At Hylebos Waterway, one of the nine problem areas in Commencement Bay, PCBs were identified as the primary chemical of concern.

In 1989, EPA issued a Record of Decision (ROD) which established Sediment Quality Objectives (SQO's) for a wide range of hazardous substances, as well as a strategy for meeting those values over a ten year period using a combination of sediment cleanup, source controls and natural recovery. The SQO for PCBs was based on protection of human health. In July 1997, EPA issued an Explanation of Significant Difference (ESD) in order to modify the PCB SQO from 150 to 300 ppb, dry weight.

For this case study, Ecology evaluated and compared the following approaches for establishing cleanup standards and/or sediment quality objectives based on human health protection:

- <u>EPA 1989 Approach (ROD)</u>: A site-specific BSAF was calculated based on available tissue and sediment data and was used to establish the SQO for PCBs of 150 ppb, based on protection of human health from consumption of fish. For the case study, this value was converted to a TOC-normalized value of 4.4 ppm, TOC.

- <u>EPA 1997 Approach (ESD)</u>: Using the same BSAF and revised input parameters for fish consumption rates and the toxicity factor for PCBs, EPA revised the SQO to 300 ppb (which is equivalent to 8.8 ppm, TOC).

- <u>Tier I Approach (point-by-point compliance)</u>: Based on Puget Sound-wide background levels of PCBs, a human health cleanup screening level (HHCSL) of 1.2 ppm, TOC was applied to the site to determine the area that exceeded that value.

- Tier II Approach (area weighting): Using the same background value of 1.2 ppm, TOC, an area-weighting approach was used to determine the area impacted. The primary difference between Ecology Approaches #1 and #2 is that Approach #2 measures compliance based on the ***post-remedial average*** sediment concentration versus relying on active remediation of all stations that exceed the HHCSL.

Comparison of Alternatives – Hylebos Waterway: PCBs

Alternative	Cleanup Standard (ppm, TOC)	Remedial Action Level (ppm, TOC)	Volume of Concern (yds^3)	Active Remediation Volume (yds^3)
EPA 1989 (ROD)	4.4	8.8	1,100,000	560,000
EPA 1997 (ESD)	8.8	13.2	560,000	246,000
Tier I Approach (point-by-point)	1.2	1.2	1,600,000	1,600,000
Tier II Approach (area-weighted)	1.2	~ 8.8	1,600,000	560,000

Case Study #2 – Manchester Annex Site

The old Navy Dump/Manchester Annex Site, located near Manchester, WA was historically owned and operated by the U.S. Navy for submarine net maintenance, fire training and waste disposal activities. These activities resulted in soil, water and sediment contamination. The site was listed on the National Priority List in May 1994. The Environmental Protection Agency (EPA) and the Corps of Engineers (Corps) completed a Remedial Investigation/Feasibility Study in November 1996. The final Record of Decision documenting cleanup standards and remedial actions was issued in September 1997.

For this case study, Ecology evaluated the following approaches for the cleanup of PCBs in sediments at the site:

- Record of Decision Approach: EPA and the Corps used a two-step process to establish a PCB cleanup goal of 40 ppb, dry weight for marine sediments. In the first step, a preliminary shellfish tissue criterion 42 ppb, wet weight was calculated. Then the average sediment concentration that would result in an average PCB tissue concentration of 42 ppb, wet weight in edible clam species was estimated using site-specific clam data and regression analysis techniques.

- Ecological Standards Approach: The current SMS rule contains a Sediment Quality Standard and a Minimum Cleanup Level for PCBs roughly equivalent to 130 ppb, dry weight and 700 ppb, dry weight, respectively.

- Tier I Approach: Tier I of the Preliminary Implementation Strategy includes risk-based chemical criteria that are derived using standard risk assessment techniques and default exposure parameters. Under this approach, however, the minimum cleanup level is based on the 90th percentile Puget Sound reference area concentration of 31 ppb, dry weight. The 90th percentile PCB concentration is higher than the risk-based value calculated using the risk assessment parameters described in this report.

- Tier II Approach: Tier II of the Preliminary Implementation Strategy provides the flexibility to use site-specific information to modify the default risk assessment parameters used to establish the Tier I values. Ecology used the site-specific information presented in the Remedial Investigation Report to calculate a Tier II value for PCBs of 40 ppb, dry weight.

Comparison of Alternatives – Manchester Annex: PCBs

Approach	Cleanup Standard (ppb, dry weight)	Remedial Action Level (ppb, dry weight)	Area of Concern (acres)	Active Remediation Area
Record of Decision Approach	40	130	13	5
Ecological Criteria	130	130	5	5
Tier I Approach	31	??	~ 13	??
Tier II Approach	40	??	13	??

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

Case Study #3 - Cascade Pole

The Cascade Pole Site is located in Budd Inlet in Olympia WA. The site is the location of a former wood treatment facility that operated from the early 1940's to 1986. The site and adjacent sediments are contaminated with several hazardous substances including polycyclic aromatic hydrocarbons, dioxins/furans, pentachlorophenol and other chlorinated compounds. The Department of Ecology is overseeing the investigation and cleanup of the site which is being performed under the Model Toxics Control Act and the Sediment Management Standards. A Remedial Investigation/Feasibility Study has been prepared for the site and

Ecology has established preliminary cleanup standards and action levels for the hazardous substances found at the site.

Ecology evaluated and compared the following approaches for establishing human health sediment quality criteria:

- Cascade Pole Approach: Ecology established both "Cleanup Standards" and "Action Levels" at this site:

  ***Cleanup Standards*:** Cleanup standards for the site were based on risks to human health and the environment. Human health risks were based on exposure via clam ingestion, sediment ingestion and dermal exposure to sediments.

  Preliminary Action Levels: Action levels define the areas that will be actively remediated. The areas that fall below the action levels but exceed the cleanup standards will be addressed via natural recovery and institutional controls.

- Ecology Tier I Approach: Tier I human health criteria are based on default input parameters that are designed to provide an acceptable level of protection for a reasonably maximum exposed individual consuming fish from Puget Sound. These values are risk-based and may be used to define areas of concern.

- Fish-Shellfish Tissue Approach: Clam tissue data collected at the site were evaluated in relation to target tissue levels calculated for development of HHSQC. The tissue chemistry results suggest that it may be possible to use tissue chemistry from non-mobile species such as clams to help define the boundaries of the cleanup area. However, it was not possible to use the limited data to develop a cleanup standard or a cleanup area.

Comparison of Alternatives – Cascade Pole: HPAHs

	Cleanup Level (ppm, TOC)	Action Level (ppm, TOC)	Area of Concern (acres)	Active Remediation Area (acres)
Cascade Pole Approach	11.5	166	22	4
Tier I Approach	3.3	??	> 22	??

Comparison of Alternatives – Cascade Pole: Dioxins/Furans

	Cleanup Level (ppm, TOC)	Action Level (ppm, TOC)	Area of Concern (acres)	Active Remediation Area (acres)
Cascade Pole Approach	54	3077	NA	6.5
Tier I Approach	60	??	??	??

In the tables above, "??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

Case Study #4 - Eagle Harbor/Wyckoff

The Wyckoff/Eagle Harbor Superfund Site is located on the east side of Bainbridge Island. In order to facilitate sediment cleanup, EPA divided the site into two "Operable Units" (East and West). With respect to the West Operable unit, mercury and other heavy metals were found in intertidal sediments at concentrations that exceeded background concentrations, with the highest levels concentrated near the former shipyard on the north shore. EPA completed a Remedial Investigation/Feasibility Study in 1991 and issued the West Harbor Record of Decision in 1992.

With respect to the East Operable Unit, polycyclic aromatic hydrocarbons (PAHs), mercury and other heavy metals were found near the former wood-treating facility on the southern shore. EPA completed a Remedial Investigation/Feasibility Study in 1991 and issued the East Harbor Record of Decision in 1994.

For this case study, Ecology evaluated the following approaches for establishing cleanup standards and/or sediment quality objectives based upon human health protection:

- <u>EPA Approach</u>: EPA established cleanup levels and chose remedies for mercury and HPAHs based on risks to human health and the environment.

- Ecology Tier I Approach: Based on default input parameters and an analysis of the literature for determining a BSAF for methylmercury, Tier I values for mercury and HPAHs were compared to EPA's cleanup levels.

- Ecology Tier II (BSAF) Approach: A site-specific, Tier II assessment was completed using the fish and shellfish tissue data that was collected in Eagle Harbor in combination with the available sediment data to calculate a site-specific BSAF.

- Ecology Tier II (Tissue) Approach: Instead of using the tissue data to calculate a site-specific BSAF, Ecology compared the tissue chemistry data directly to target tissue levels and compared this approach to the approaches that relied more heavily on sediment chemistry data.

Comparison of Alternatives – Eagle Harbor: Mercury

	Cleanup Standard (ppm, dry weight)	Remedial Action Level (ppm, dry weight)	Area of Concern (acres)	Active Remediation Area (acres)
EPA Approach	0.59	2.1	78	9
Tier I Approach	0.84 – 1.4	??	7 - 40	??
Tier II (BSAF) Approach	0.61	??	~ 78	??
Tier II (Tissue-only) Approach	??	??	??	??

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

Comparison of Alternatives – Eagle Harbor: HPAHs

	Cleanup Standard (ppm, TOC)	Remedial Action Level (ppm, TOC)	Area of Concern (acres)	Active Remediation Area (acres)
EPA Approach	40	>40	13.6	none
Tier I Approach	3.3	??	27	??
Tier II (BSAF) Approach	2.7	??	27	??
Tier II (Tissue-only) Approach	??	??	~ 27	??

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

5.0 Preliminary Approach Overview

Ecology's "Preliminary Implementation Strategy for Human Health Sediment Criteria," (see Appendix B) represents the initial proposal for both the preliminary criteria values and their implementation.

The strategy describes Ecology's preliminary approach for implementing these criteria under the Sediment Management Standards (SMS). Ecology's proposed construct for implementation of the SMS human health criteria relies on a tiered approach. "Tier I" represents an initial evaluation to determine if sediment chemical concentrations pose a significant human health risk. Additional, site-specific analysis would then be available ("Tier II") to verify the results of the Tier I analysis.

The criteria values in Appendix B represent Ecology's preferred approach at this time and should be considered more up-to-date than values listed in the DOH Tier I Report. Criteria have not been formally proposed; Ecology is interested in receiving comments from the public on the preferred criteria values and the implementation strategy included in this draft.

6.0 Major Findings

The Case Studies illustrate a myriad of important methodological and policy issues associated with establishing cleanup levels that are protective of human health. Some of those key issues include.

- Use of Area-Wide Averaging to Determine Compliance
- Definition of Fish Home Range
- Use of Remedial Action Levels
- Compliance Time Frames
- Use of Fish Tissue Data
- BSAF Calculations/Site-Specific Analysis
- Scope of Site-Specific Evaluations
- Cancer Risk Levels
- Cumulative Risks
- Protection of Special Population Groups

Current Approaches and Methods

These case studies show that Ecology and EPA are currently making case-by-case decisions at cleanup sites to account for human health risks. More specifically:

- **At each case study site, the area slated for active remediation was smaller than the overall area of concern as defined by the cleanup level.** Especially at larger sites, areas requiring active remediation are generally smaller than the entire area of concern, as defined by ecological and human health concerns. This difference illustrates an important distinction between risk assessment and risk management.

- **A combination of active remediation, natural recovery, institutional controls and monitoring are being used fairly regularly to meet cleanup levels.** Agencies have used the flexibility inherent in the selection of the cleanup action process to address the real-world constraints associated with cost and technical feasibility. As a result, most cleanup actions include a combination of actions with higher sediment concentrations being actively remediated via dredging and capping and less contaminated areas being addressed via natural recovery, institutional controls and sometimes monitoring as remedial alternatives.

- **Agencies are generally using site-specific risk assessments to establish cleanup requirements based upon human health protection**. Specifically, cleanup standards at most sites are based on (1) reasonable maximum exposure estimates which take into account recreational and subsistence fishing, (2) toxicity information (i.e. slope factors and reference doses) developed and published by EPA, and (3) risk levels for carcinogens ranging from 10^{-4} to 10^{-6}.

- **Agencies are generally modifying risk-based cleanup levels when they are found to be less than sediment quality values reported in non-urban areas of Puget Sound**. This is an issue primarily for chemicals such as PCBs and HPAHs. Agencies have generally used the 90th percentile of non-urban sediment levels as an estimate of background levels.

Key Policy and Methodological Issues

- **On-going tissue or sediment monitoring to verify compliance with cleanup standards is applied only in some cases**. When the remedial action alternative chosen results in the potential for residual concentrations that exceed health-based levels, some sites are requiring ongoing tissue and/or sediment monitoring to ensure long-term human health protection, while others have not instituted such requirements.

- **Establishing the quantitative link between sediments and the fish/shellfish species of interest is the most technically challenging aspect of determining a cleanup level for protection of human health**. Ecology's use of BSAFs to calculate Tier I HHSQC provides a mechanism to reduce some of the difficulties that site managers face when attempting to make that link.

- **There is some variability in the cancer risk levels being used to establish cleanup standards for individual sites**. This variability reflects the (1) different regulatory risk ranges found in EPA's National Contingency Plan and the MTCA Cleanup Regulations and (2) different approaches for addressing cumulative/additive risks.

- **Historically, the data collected at individual sites are generally not sufficient to support a tissue-based approach that could be used to make decisions about cleanup actions**. Sufficient tissue data were collected for only some of the case study sites. Where tissue measurements were taken, the data was most often used to develop a site-specific BSAF.

Impacts Associated with the Preliminary Implementation Strategy for HHSQC

In general, the case studies indicate that Ecology's Preliminary Implementation Strategy for human health criteria would lead to some changes in cleanup levels, but the areas subject to active remediation may not significantly change, because the SMS rule requires Ecology to consider cost and technical feasibility when selecting cleanup actions.

- **Site-specific cleanup levels are generally slightly higher than Ecology's preliminary Tier I criteria for human health chemicals of concern**. The table below summarizes the cleanup levels identified for each Case Study site in comparison to the preliminary Tier I criteria. With the exception of dioxin, the preliminary Tier I criteria are lower than the Case Study-Specific Cleanup Levels by a factor of 1.3 to 12. The largest difference seen was for HPAHs at Eagle Harbor, with a ratio of 12, while the smallest difference was for dioxins at Cascade Pole, where the ratio is just below 1.

Comparison of Preliminary Tier I HHCSLs to Case Study-Specific Cleanup Levels

Site	Chemical of Concern	Preliminary Tier I HHCSL	Cleanup Level Chosen at Case Study Site	Ratio of Case Study Cleanup Level to Tier I HHCSL
Hylebos	PCBs	1.2 ppm	8.8 ppm	7.3
Manchester Annex	PCBs	31 ppb *	40 ppb	1.3
Cascade Pole	HPAHs	3.3 ppm	11.5 ppm	3.5
	Dioxins	60 ppt	54 ppt	0.9
Eagle Harbor	HPAHs	3.3 ppm	40 ppm	12
	Mercury	NA	0.59 ppm	NA

**The PCB levels for Manchester Annex are presented as a dry weight concentration so as to make the comparison between the Prelim. Tier I HHCSL and the dry weight cleanup level for Manchester Annex, where very low organic carbon levels make it inappropriate to organic carbon normalize. Al other concentrations in this table are in terms of total organic carbon.*

- **Many of the site-specific cleanup levels reviewed in the Case Studies are similar to levels that would have been established under Ecology's Tier II approach**. Tier II is a site-specific analysis which can be used to override default Tier I criteria values. Ecology used data collected at each Case Study site to develop Tier II values. In several cases, these values were similar to the site-specific cleanup levels derived for the site.

- **It is difficult to evaluate the full implications of the HHSQC in terms of areas subject to active remediation.** The cleanup levels listed in the table above did not define the areas subject to active remediation (i.e.: capping or dredging) at each case study site. Instead, higher remedial action levels were developed at the sites to define the active remediation area. Since neither the Sediment Management Standards nor the Preliminary Implementation Strategy for HHSQC directly include the concept of remedial action levels, areas that might have been subject to active remediation under Ecology's Preliminary Implementation Strategy could not be defined.

7.0 Recommendations

Overall, Ecology believes that adoption of HHSQC will increase certainty and consistency in the decision-making process, while still allowing for enough flexibility to account for site-specific differences. In addition, Ecology recommends the following:

- **The use of area-wide averaging to determine compliance with a cleanup level provides a useful approach for making human health cleanup decisions, especially at large sites**. The use of an area-wide averaging methodology generally results in a smaller area subject to active remediation. Use of this approach raises several key implementation issues, such as definition of the site, definition of fish home range, geometric vs. arithmetic averaging, etc., which will need to be resolved.

- **For health-based cleanup actions, the Sediment Management Standards do not clearly define how one identifies the sediment cleanup concentration that triggers active remediation**. Under the Sediment Management Standards, cleanup actions may include a combination of actions including dredging, capping, source control, natural recovery, institutional controls and monitoring. For implementation of HHSQC, the level at which active remediation is required will have a significant impact on the cost and feasibility of a cleanup action. Ecology recommends that further public discussion will be necessary to resolve this important issue.

- **To effectively implement the HHSQC, Ecology will need to provide clear guidance on the more complex implementation issues such as use of area-weighting averaging, remedial action levels and use of institutional controls**. This guidance will also help to increase consistency among sites undergoing Tier II analysis.

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Cleanup Case Study #1 - Hylebos Waterway

1.0 Background

The Hylebos Waterway is a highly industrialized waterway in Commencement Bay, Tacoma (Figure 1.1). Commencement Bay was listed as a Superfund site in 1983. In late 1988, a Remedial Investigation/Feasibility Study (RI/FS) was completed for the nearshore/tideflats portion of the Superfund site. Several chemicals of concern were identified at the site, but the compound that was identified as the most significant threat to human health was PCBs. EPA is the lead agency for sediment remediation at this site.

In 1989, a Record of Decision (ROD) was signed, establishing Sediment Quality Objectives (SQO) for a number of contaminants present in the waterway. The SQO for PCBs of 150 ppb, dry weight, is the only SQO based on the protection of human health; all others were based on protection of biological resources. The ROD predicted that if sediments with PCB concentrations greater than a Sediment Remedial Action Level (SRAL) of 240-300 ppb were removed, the SQO of 150 ppb would be met in 10 years via natural recovery processes. That is, after 10 years, all sediments remaining on site were expected to contain PCBs at less than 150 ppb.

In September 1995, the Hylebos Cleanup Committee (HCC), an organization representing several large companies identified as potentially responsible parties on the Hylebos Waterway, submitted a revised risk assessment to EPA, based on new sediment data and revised assumptions. The HCC asserted that the target cleanup level of 150 ppb was unnecessarily stringent and too costly. EPA disagreed with the HCC's risk assessment, but agreed to undertake its own re-evaluation of the PCB cleanup level. In July 1997, EPA issued an Explanation of Significant Difference (ESD) to modify the PCB cleanup level for remediation of sediments in Commencement Bay (EPA, 1997). In the final ESD, EPA decided to change the PCB SQO to 300 ppb, with a new SRAL set at 450 ppb, to be met immediately following cleanup.

This site was chosen as a case study because: (1) PCBs are a class of compounds of human health concern, (2) EPA's cleanup decision is based on risks to human health from consumption of PCB-contaminated fish, and (3) detailed analyses of the site and post-remediation residual risks have been conducted by EPA, providing Ecology with valuable data for the case study analysis.

Figure 1.1 Commencement Bay site map

1.1 Human Health Concerns

Concerns about bioaccumulation of contaminants led to the measurement of chemical concentrations in English sole and crab muscle tissue in Commencement Bay. Tissue levels in Commencement Bay biota were compared to those found in Carr Inlet (the reference area). After tissue levels were measured, the relationships between sediment chemistry and tissue levels were examined to "identify the sediment contaminants that are available for bioaccumulation in indigenous organisms and to determine sediment contaminant levels above which significant bioaccumulation occurs." (Tetra Tech, 1985).

Of all the chemicals examined, PCBs displayed the most marked accumulation in both sediments and biota. The RI reported that "... increasing tissue PCB levels generally corresponded with increasing sediment contamination," and that PCB concentrations in muscle tissue from Commencement Bay were up to 10 times higher than reference levels. A statistical analysis also showed that PCB levels in muscle tissue were significantly correlated ($r = 0.82$, $p < 0.05$) with sediment concentrations. As a result, EPA used an equilibrium partitioning, or BSAF-based approach to estimate a PCB sediment concentration corresponding to a target fish tissue concentration (based on tissue levels measured in Carr Inlet). The site-specific BSAF calculated for PCBs in Commencement Bay was 1.72.

In the ROD, EPA selected a PCB cleanup level (or SQO) of 150 ppb, dry weight based on the determination that this cleanup objective would result in an ***average post-remediation*** concentration at the site of 30 ppb, dry weight. The cleanup level was calculated based on a target tissue level of 36 ppb of PCBs in fish tissue, the average tissue level found in the reference area at Carr Inlet. The lifetime cancer risk associated with consumption of 12.3 grams of fish per day (approximately one pound per month) at this level was estimated to be 4×10^{-5}. EPA's goal for Superfund cleanups is to reduce human health risks to within a range of 10^{-4} to 10^{-6} (or 1 in 10,000 to 1 in 1,000,000) (EPA, 1997).

In 1996, EPA decided to reevaluate the SQO in response to the request by the HCC. In conducting the reevaluation, EPA calculated the post-remediation cancer risk to human consumers of fish from exposure to Commencement Bay sediments. In its re-analysis, EPA estimated the mean concentration of PCBs remaining after cleanup for a series of potential cleanup levels ranging from 50 to 900 ppb, dry weight (Weston, 1996).

For each potential cleanup level, EPA estimated the residual human health cancer risks based on the post-remediation mean sediment PCB concentrations. A slightly higher arithmetic mean residual (37 ppb as opposed to the earlier value of 30 ppb) was calculated to result from the original SQO of 150 ppb for Hylebos Waterway only. EPA also estimated the volume of sediments that would require remediation to achieve each of the potential cleanup levels (Weston, 1996; Weston, 1997).

In July, 1997, EPA issued an Explanation of Significant Differences, in which the agency described the revised cleanup levels and the rationale. EPA changed the SQO to 300 ppb, dry weight, and revised the SRAL to 450 ppb, dry weight, to be met immediately following cleanup. EPA's analysis showed that active remediation of all sediments exceeding 450 ppb would result in a post-cleanup average sediment PCB concentration in the Hylebos of 124 ppb, dry weight (EPA, 1997). The cancer risks associated with these cleanup levels were estimated to be 1.6 x 10^{-4} for high-end tribal fishers in the Hylebos Waterway. EPA also reported a Hazard Quotient of 9 (based on the non-cancer risks from PCBs) from the Hylebos Waterway alone for the same population of concern.

1.2 HHSQC for PCBs

PCBs are a class of compounds that is known to cause cancer in animals and is considered a "probable human carcinogen" by EPA. EPA recently revised the cancer slope factor (also known as the cancer potency factor or CPF) for PCBs. The former CPF was 7.7 $(mg/kg\text{-}day)^{-1}$; the up-dated CPF for exposure via the food chain is 2.0 $(mg/kg\text{-}day)^{-1}$ (EPA, 1996). EPA has also verified an oral reference dose (RfD) for the non-cancer effects of Aroclor 1254 of 2 x 10^{-5} mg/kg-day (EPA, 1996).

Ecology has calculated a risk-based, human health cleanup screening level (HHCSL) for PCBs based on the formula and input parameters presented in Appendix A. The risk-based PCB HHCSL is 260 ppb, TOC, based on a cancer risk of 1 in 100,000 (10^{-5}). For non-cancer risks, the HHCSL is 427 ppm, TOC, based on a Hazard Quotient of 1.0. Since the HHCSL based on cancer risk is lower, that value is considered to be protective of non-cancer risks.

However, Ecology recognizes that the ubiquitous nature of PCBs in the environment has led to "background" levels in sediments in relatively clean areas of Puget Sound which can be higher than these risk-based values. In light of this, Ecology's Preliminary Implementation Strategy allows cleanup decisions to be based on the Puget Sound-wide background level instead of the lower risk-based value. As described in Appendix A of this report, the Puget Sound-wide background concentration is 1.2 ppm, TOC, and will be used as the default, Tier I PCB HHCSL.

2.0 Potential Impacts of Alternative Approaches for Cleanup Standards

In order to compare EPA's cleanup levels with Ecology's preliminary Tier I HHSQC values, the dry weight concentrations had to be converted to TOC-normalized PCB concentrations. Table 1.1 below lists dry weight values and the equivalent TOC-normalized concentrations for PCBs in Hylebos Waterway for a series of sediment values.

Table 1.1 Sediment Concentrations, Dry Weight and TOC-Normalized Equivalents for Hylebos Waterway

	Dry Weight Concentration (ppb)	**Equivalent TOC-normalized concentration (ppm) (@ 3.4% TOC)**
Ecology Risk-based Value	8.8	0.26
Ecology Default HHCSL	31	1.2*
EPA Original SQO	150	4.4
EPA Revised SQO	300	8.8
EPA Revised SRAL	450	13.2

** The default HHCSL of 1.2 ppm, TOC, based on Puget Sound background levels, was calculated using sample-specific TOC levels; the dry weight equivalent was also determined directly from the background data set.*

Table 1.1 shows that Ecology's preliminary background-based HHCSL of 31 ppb, dry weight (or 1.2 ppm, TOC) is approximately five times lower than EPA's original SQO of 150 ppb, dry weight.

However, a comparison of criteria values alone is not necessarily adequate or appropriate to determine the impact on cleanup. The strategy for implementation of these values can have a significant impact on the resulting cleanup area. For example, since fish are mobile, it is reasonable to assume that if the ***average*** chemical concentration in the sediments is at or below an acceptable level, then the chemical concentrations in fish should also be at acceptable levels, even if some of the sediments exceed these levels.

Based on the fish mobility premise, EPA relied on an area-wide averaging approach at the Hylebos Waterway. In the ESD, EPA determined that a PCB SQO of 150 ppb would result in an ***average*** residual PCB concentration in sediments of 37 ppb. This is consistent with Ecology's preliminary HHCSL of 31 ppb.

Accordingly, Ecology evaluated the implications of two alternative implementation approaches: (1) a point-by-point approach and (2) an area-wide averaging approach. Both approaches are based on a HHMCUL/CSL for PCBs of 31 ppb, dry weight. In addition, this evaluation focuses only on PCB-contaminated sediments; remediation of areas with other chemicals of concern is not included in these estimates.

2.1 EPA's Revised Approach

EPA's current estimate of cleanup volume (for PCB-contaminated sediments only) for the Hylebos Waterway that would result from the original SQO is just under 600,000 cubic yards of contaminated sediments (EPA, 1997). EPA estimates a sediment volume of approximately 246,000 cubic yards requiring cleanup (for PCB-contaminated sediments only) at the SRAL of

450 ppb, dry weight. The post-remediation average of 124 ppb, dry weight associated with this SRAL is about four times higher than the preliminary HHCSL.

2.2 Alternative #1: Tier I Point-by-Point Approach

If the HHCSL of 1.2 ppm, TOC were applied on a point-by-point basis, then the area of concern would increase as compared to EPA's approach. In the Hylebos Waterway, of the 200 data points for which sediment chemistry is reported, only about 40 data points (20%) are lower than 1.2 ppm, TOC (Weston, 1996). EPA estimated that all areas exceeding a PCB concentration of 1.2 ppm, TOC resulted in an area of concern of approximately 1.6 million cubic yards (EPA, 1997).

2.3 Alternative #2: Tier II Area Wide Approach

Ecology is also considering an implementation strategy similar to the one described by EPA in the ROD. That is, the HHCSL would represent a cleanup value that can be met on an area-weighted average basis, not point-by-point (i.e: station-by-station). This approach is based on the concept that human health can be protected as long as the **average** sediment concentration to which fish are exposed does not exceed the HHCSL.

This approach allows for exceedences in some areas as long as the overall average concentration at the site remains at or below the HHCSL. For the Hylebos Waterway, EPA estimated that the post-remediation average PCB concentration would be 37 ppb, dry weight as a result of a SQO of 150 ppb. Ecology's preliminary HHCSL of 31 ppb, dry weight would therefore translate into a very similar cleanup area.

Table 1.2 Comparison of Cleanup Levels and Related Areas of Concern for PCBs

	Cleanup Level (SQO)	Remedial Action Level (SRAL)	Volume of Concern (yds^3)	Active Remediation Volume (yds^3)
EPA Approach (ROD)	150	300	1,100,000	560,000
EPA Approach (ESD)	300	450	560,000	246,000
Ecology Alternative #1 (point-by-point)	31	31	1,600,000	1,600,000
Ecology Alternative #2 (area-wide averaging)	31	240-300	1,600,000	560,000

(All concentrations in ppb, dry weight)

As can be seen from Table 1.2, there is a notable difference in active remediation volumes when comparing Ecology's point-by-point approach to an area-wide approach. There is little difference, however, in volume between Ecology's Alternative #2 Approach and that outlined by EPA in the original ROD. The primary difference in these two approaches involves how one calculates and measures compliance with the cleanup level. EPA used risk assessment to calculate a cleanup level (or SQO) that was to be met via a combination of active remediation and natural recovery within 10 years. In contrast, Ecology's Preliminary Implementation Strategy proposes to measure compliance according to an area-wide post-remedial average concentration. Nonetheless, the area subject to active remediation is essentially the same under both approaches.

However, EPA's changes to the ROD as outlined in the ESD result in a higher cleanup level and about half the volume of sediment requiring remediation as compared to the ROD and Ecology's approach.

3.0 Conclusions

The Hylebos Case Study is instructive in demonstrating the major differences that an implementation strategy can have on cleanup volume. It is also useful to illustrate how background concentrations relate to risk-based values for PCBs.

A significant finding of this case study is that EPA's original cleanup level is consistent with Ecology's preliminary approach for development and implementation of HHSQC. Therefore, if the HHSQC had been applied at this site, the results, in terms of cleanup level and area, would have been approximately comparable. However, EPA's proposal to raise the cleanup level and reduce the cleanup area will result in a smaller volume as compared to the preliminary HHSQC and would not be consistent with Ecology's Preliminary Implementation Strategy.

Some additional issues are discussed in more detail below.

3.1 Surface Area Weighting Approach Allows Greater Flexibility

This case study demonstrates how different implementation strategies for human health sediment quality criteria can affect cleanup area. Implementation of the criteria via a surface area weighting strategy under Tier II will provide more flexibility and may allow for a smaller area requiring remediation than an approach that requires remediation on a point-by-point basis. An area averaging approach was applied by EPA (although it was not done on an area-weighted basis; an arithmetic mean was calculated for the site without consideration of area). More specifically, EPA established a post-remediation average sediment concentration and then determined an "sediment remedial action level" that would result in the desired level following cleanup.

A point-by-point approach is the more protective approach, as it assumes that any sediment concentration which exceeds the HHSQC presents a risk to human health on its own. The area-wide approach, on the other hand, assumes that since fish tend to be mobile, protection of human health can be achieved as long as the ***average*** sediment concentration falls below the HHSQC. This approach also allows for more flexibility when making cleanup decisions, particularly when cost and technical feasibility make it more difficult to meet the criteria on a point-by-point basis. However, the averaging approach assumes that fish are exposed uniformly to all sediments within their home range, an assumption that due the uncertainties regarding fish behavior, could lead to either an under- or over- estimate of risk.

The Sediment Management Standards currently requires that all sediment concentrations be at or below the MCUL/CSL ten years after completion of the active cleanup action. For implementation of the HHSQC, Ecology is considering an approach under Tier II that allows for use of area-wide averaging for determining compliance with the MCUL/CSL. That is, the average sediment concentration remaining on-site after ten years following completion of active remediation must be at or below the HHCSL. Several issues must be considered when implementing this approach :

- An approach that relies on meeting the HHMCUL/CSL at all stations is more protective of human health and the environment and provides for a margin of safety given all the uncertainties associated with human exposure and fish mobility.

- To ensure that the appropriate tissue levels are being met, long-term fish tissue sampling and testing may be necessary. (i.e.: compliance monitoring).

- It is necessary to define the averaging area that will be used. This might be defined by the home range of the relevant species of fish or shellfish and/or by the site boundaries or other relevant physical characteristics at the site (e.g: water depth, distribution of chemical contamination, etc.).

- Is it necessary to define a minimum remedial action level to address the potential risk from sediment hot spots, (for example, requiring that all areas 10 times the HHCSL or greater be actively remediated)?

- To protect shellfish from contamination (and in case of potential dermal contact by humans), no stations in intertidal areas should be permitted to exceed the HHMCUL/CSL.

3.2 Approach for Evaluating Compliance: Affect on Areal Extent of Active Remediation

It was clear from this case study that there are at least three potential approaches for determining compliance with a human health cleanup level (HHCSL). The three approaches involve:

- active remediation of all sediments exceeding the HHCSL;
- active remediation of sediments so that no sediments exceed the HHCSL after 10 years (based on natural recovery predictions); or
- remedial actions that ensure that the post-remedial **average** concentration of remaining sediments is less than or equal to the HHCSL.

EPA relied on a variation of numbers 2 and 3 above to select the area requiring active remediation. That is, the agency selected a cleanup goal (SQO of 150 ppb in the ROD) and then determined the areal extent of active remediation required to achieve that cleanup level afer 10 years based on predictions about natural recovery. In addition, the agency calculated an average sediment concentration needed to achieve a target tissue level after 10 years to protect human health.

Currently, the Sediment Management Standards (SMS) incorporates the concept behind approach #2 above. Section 570 (3) of the SMS states that the "minimum cleanup level is the maximum allowed chemical concentration ... permissible at the cleanup site to be achieved by year ten after completion of the active cleanup action." In addition, Section 590 describes the requirement that a Sediment Recovery Zone (SRZ) be authorized whenever selected actions, such as natural recovery, leave in place sediments that exceed the Sediment Quality Standards.

To maintain as much consistency as possible with the SMS, the Preliminary Implementation Strategy for HHSQC also allows for a combination of active remediation and natural recovery to achieve the MCUL after 10 years. In addition, the Strategy includes a provision for meeting the HHMCUL based on area-wide averaging, under certain conditions. The Hylebos Waterway case study demonstrates how this approach could be implemented, particularly at larger sites, such as Commencement Bay.

3.3 Use of Background Concentrations

PCBs are bioaccumulative compounds that are ubiquitous in the environment. As a result, the chemical can be found in sediments (and other media such as tissue) in even relatively pristine environments. While this does not negate the need to address the much higher concentrations that are found in industrially-impacted area, it imposes a practical limitation on achieving and/or maintaining cleanup levels that are lower than background levels.

As identified in the Tier I Report (DOH, 1995), when risk-based HHSQC are lower than background concentrations, Ecology intends to use the background level as the default cleanup level. While this approach is not as protective as a risk-based approach, it is considered necessary to avoid requiring cleanup to an unrealistic level (i.e: below background) and also to avoid a situation where a relatively "clean" bay could become a cleanup site.

As described in Appendix A, PTI calculated a background concentration for PCBs in Puget Sound, based on data that were available in SEDQUAL. This calculation resulted in a 90th percentile background level of 1.2 ppm, TOC, or 31 ppb, dry weight. Ecology recognizes that this is not the level of human health protection that the agency generally strives to achieve. However, since the Tier I risk-based concentration is about 4.5 times lower than concentrations found in relatively clean areas of Puget Sound, Ecology considers it necessary to set its HHCSL at the background level.

3.4 Site-Specific BSAF is Consistent with Ecology's Approach for HHSQC

For the ROD, EPA calculated a site-specific BSAF for Commencement Bay based on available tissue and sediment data from the Bay. This BSAF of 1.72 was used by EPA in its evaluation of residual risks associated with a range of cleanup levels (Weston, 1996).

The use of a BSAF to quantify the relationship between sediments and fish tissue is consistent with the approach being proposed by Ecology for development of HHSQC. Ecology currently favors using a default BSAF of 2.6 for PCBs for Tier I criteria, which is only slightly higher than the site-specific BSAF of 1.7 calculated for Commencement Bay. Nonetheless, the Preliminary Implementation Strategy allows for determination of a site-specific BSAF under Tier II in essentially the same manner as was done at Commencement Bay.

3.5 Differences in Risk Assessment Assumptions and Risk Levels

EPA updated the human health risk evaluation and used it as a basis to evaluate the risks associated with a variety of potential PCB cleanup levels. Although EPA's risk assessment methodology has not been modified substantially since the original risk assessment was performed in 1988, some of the exposure and toxicity assumptions have been changed based on new information and Superfund guidance (EPA, 1997).

In its Explanation of Significant Differences (EPA, 1997), EPA calculated the health risks associated with the post-cleanup concentrations of PCBs in the sediments using up-dated exposure assumptions. Tribal fish consumption rates were used to estimate both average and upper-bound risks and were based on data from the Tulalip and Squaxin Island Tribal Consumption Survey (Toy, et. al., 1996). EPA calculated risks based on the upper bound fish consumption rate from the Toy study, while Ecology's preliminary HHSQC are based on the average fish consumption rate reported in that study.

EPA's risk assumptions for this site were generally consistent with the assumptions Ecology is using to develop preliminary HHSQC. However, EPA and Ecology rely on different cancer risk ranges to make cleanup decisions. EPA regulations state that cleanup decisions can be made in the range of 10^{-4} to 10^{-6}, while Ecology's cleanups must be at or below a risk of 10^{-5} (MTCA, 1993). This difference can result in a 10-fold difference in cleanup levels, all other input parameters being equal.

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Cleanup Case Study #2 - Manchester Annex

1.0 Background

The old Navy Dump/Manchester Annex Site is located near Manchester, WA (Figure 2.1). The site was historically owned and operated by the U.S. Navy for submarine net maintenance, fire training and waste disposal activities. These activities resulted in soil, water and sediment contamination. The site was listed on the National Priority List in May 1994. The Environmental Protection Agency (EPA) and the Corps of Engineers (Corps) completed a Remedial Investigation/Feasibility Study in November 1996. The Corps and EPA (labeled throughout this case study as "the Agencies") cooperated closely in accomplishing this work, with the Corps taking the technical lead. The final Record of Decision (ROD) documenting cleanup standards and remedial actions was issued in September 1997.

This case study is based on information contained in the Remedial Investigation/ Feasibility Study (RI/FS) (Hart Crowser, 1996). This information was supplemented with information obtained via personal communication with Marian Abbett (Ecology Toxics Cleanup Program) and John Wakeman (U.S. Army Corps of Engineers).

1.1 Human Health Concerns

The RI/FS (Hart Crowser, 1996) includes a baseline human health risk assessment. Key findings relevant to this case study include the following:

- Range of Chemicals: The baseline risk assessment identified 12 primary substances or groups of substances present at the site at concentrations which exceed risk-based remediation goals or criteria (i.e.: cumulative pathway Hazard Index greater than 1 or cancer risk exceeding 10^{-6}). These include several metals (arsenic, cadmium, lead, silver), PCBs (primarily Aroclor 1260), dioxins/furans and asbestos. With respect to human health impacts associated with contaminated sediments, PCBs were identified as the main chemical of concern.

- PCB Contamination Levels: The Agencies focused on PCBs when defining cleanup standards and remedial action requirements for marine sediments. PCBs were detected in 68/93 sediment samples with a maximum concentration of 6,470 ppb, dry weight. Twenty-three samples (primarily near the landfill) contained PCB concentrations that exceeded the preliminary sediment cleanup level (based on ecological concerns) of 130 ppb, dry weight. PCBs were also found in shellfish with 13/13 samples containing levels which exceeded the background-based screening level of 14 ppb, wet weight. The maximum reported shellfish concentration was 656 ppb, wet weight.

Figure 2.1 Manchester Annex site map

- Exposure Pathways: The Agencies evaluated the potential for exposure to PCBs via direct contact with contaminated sediments, incidental ingestion of contaminated sediments and consumption of contaminated fish and shellfish. With respect to the latter pathway, the Agencies evaluated potential exposures associated with both recreational and subsistence level fishing. Exposure parameters (e.g.: shellfish consumption rates, duration of exposure, etc.) used in the baseline risk assessment were based on a combination of sources including EPA Risk Assessment Guidance, the Model Toxics Control Act Cleanup Regulation and site-specific information.

- Health Risks: The Agencies estimated that subsistence level shellfish consumption would result in cancer risks of 2×10^{-5} (average exposure) and 6×10^{-5} (reasonable maximum exposure or RME). In addition, cumulative Hazard Indices of 0.7 and 3 for the average and RME subsistence shellfishers, respectively, were calculated.

The Agencies concluded that the potential long-term risks associated with sediment contamination in Clam Bay are above acceptable levels defined under state and federal cleanup regulations.

1.2 Cleanup Standards

PCBs, metals and dioxins were the primary chemicals identified in marine sediments at the site. Tissue analysis showed elevated levels in shellfish of the same contaminants, as well as PAHs. The Agencies established the following overall risk management goals:

- A cumulative cancer risk goal under future RME scenarios of 1×10^{-5} (MTCA requirement) considering combined seafood ingestion, sediment contact and incidental sediment ingestion pathways;

- A cumulative hazard index under future RME conditions of 1, also based upon a cumulative pathway analysis;

- No identifiable risk to aquatic biota and other wildlife; and

- Compliance with applicable or relevant and appropriate requirements including State of Washington's Water Quality Standards (Chapter 173-201A WAC) and Sediment Management Standards (SMS) (Chapter 173-204 WAC).

With respect to cleanup requirements for PCBs in sediments, the Agencies established two cleanup standards - "cleanup goals" and "cleanup levels," defined as follows:

- "**Cleanup goals**" were defined as conceptual targets for additional site-specific cleanup of two key contaminants (total petroleum hydrocarbons in soils and PCBs in sediments and shellfish). The Agencies used a two-step process to establish a PCB cleanup goal of 40 ppb, dry weight for marine sediments. In the first step, they developed a preliminary shellfish tissue criterion of 42 ppb, wet weight. This criterion was based on the RME subsistence shellfish consumption rates and an acceptable cancer risk of 1×10^{-5}. The Agencies then estimated the average sediment concentration that would result in an average PCB tissue concentration of 42 ppb, wet weight in edible clam species, using site-specific clam tissue data and regression analysis techniques (see Figure 2.2).

- "**Cleanup levels**" were defined as specific concentration limits to protect human health and the environment, as defined by the site-specific risk assessment and in applicable or relevant and appropriate requirements (ARARs). Remedial actions were designed to attain these cleanup levels. For PCBs, the cleanup level was defined as 130 ppb, dry weight. This dry weight value is roughly equivalent to the Sediment Quality Standard (SQS) value of 12 ppm, TOC for PCBs that is presented in the SMS as an organic-carbon normalized value. This level was also calculated to be protective of recreational consumers of fish.

1.3 Remedy Selection

The final cleanup remedy for the Manchester Annex site includes several components. To address sediment contamination problems, the Agency's selected remedy includes the following elements:

- Thick cap in the existing inter-tidal depression (approximately 2,700 sq ft).

- Thin layer capping in the inter-tidal sediment areas where the PCB sediment concentrations exceed 130 ppb, dry weight (approximately 210,000 sq. ft., or just under 5 acres).

- Institutional controls to limit subsistence fishing during the 10 year recovery time period (the Suquamish Tribe agreed to warn their members about the hazards and avoid any shellfish bed improvements).

- Monitoring of sediments and shellfish in areas where the PCB sediment concentrations exceed the cleanup goal of 40 ppb, dry weight, until compliance with sediment and tissue cleanup goals is established, or until the Washington State Department of Health and the Tribe determine that the shellfish are safe for subsistence-level harvesting, whichever comes first.

2.0 Potential Impacts of Alternative Approaches for Cleanup Standards

2.1 Description of Alternatives for Establishing Cleanup Standards

Section 570 of the SMS (WAC 173-204) establishes a framework and an overall process to determine site-specific cleanup standards. Using this process, sediment cleanup standards are established as close as practicable to the sediment quality standards (cleanup objective) taking into account net environmental impacts, cost and engineering feasibility of different cleanup alternatives. Site-specific cleanup standards may not exceed the minimum cleanup levels specified in WAC 173-204-520.

For this case study, Ecology evaluated three approaches for establishing site-specific cleanup standards and compared the resulting values with the cleanup levels/cleanup goals established at the Manchester Annex Site. These include the following:

- Tier I Approach: Tier I of the Preliminary Implementation Strategy includes risk-based chemical criteria that are derived using standard risk assessment techniques and default exposure parameters. Under this approach, the minimum cleanup level is established at the higher of either: (1) the risk-based value, or (2) Puget Sound reference area concentrations. The Tier I value for PCBs is 1.2 ppm, TOC, based on the 90th percentile PCB concentration in Puget Sound reference areas (PTI, 1995) (which is higher than the risk-based value). The comparable background dry weight concentration is 31 ppb.

- Tier II Approach: Tier II of the Preliminary Implementation Strategy provides the flexibility to use site-specific information to modify the default risk assessment parameters used to establish the Tier I values. Ecology used the site-specific information presented in the RI/FS (Hart Crowser, 1996) to establish a Tier II PCB cleanup level of 40 ppb, dry weight.

- Ecological Standards Approach: The current SMS rule contains a Sediment Quality Standard (cleanup objective) and a Minimum Cleanup Level for PCBs roughly equivalent to 130 ppb, dry weight and 700 ppb, dry weight, respectively.

- Record of Decision Approach: The Agencies used a two-step process to establish a PCB cleanup goal of 40 ppb, dry weight for marine sediments. In the first step, they developed a preliminary shellfish tissue criterion 42 ppb, wet weight. This criterion was developed using the following risk assessment parameters: (1) subsistence shellfish consumption rate of 128 g/day; (2) shellfish diet fraction of 0.5; (3) exposure frequency of 140 days/year, (4) exposure duration of 30 years; (5) 70 kg body weight, (6) cancer slope factor of 2.0 $(mg/kg/day)^{-1}$ and (7) an acceptable cancer risk of 10^{-5}. The Agencies then estimated the average sediment concentration that would result in an average PCB tissue concentration of 42 ppb, wet weight in edible clam species, using site-specific clam data and regression analysis techniques (Figure 2.2).

2.2 Impacts of Alternative Approaches on Cleanup Standards and Selection of Cleanup Actions

Table 2.1 summarizes the cleanup standards and remedial action levels established under the various approaches, with the associated area estimates defined by each of the cleanup levels.

Table 2.1 Comparison of Cleanup Levels and Related Areas of Concern for PCBs

Approach	Cleanup Standard* (ppb, dry weight)	Remedial Action Level* (ppb, dry weight)	Area of Concern (acres)	Active Remediation Area (acres)
ROD Approach	40	130	13	5
Tier I Approach	31	??	~ 13	??
Tier II Approach	40	??	13	??
Ecological Standards Approach	130	130	5	5

In this table, the term "cleanup goal" was replaced with "cleanup standard" and "cleanup level" was replaced with "Remedial Action Level."

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

This summary of the PCB concentrations triggering active remediation and the associated estimated areas shows that the cleanup standards (aka "cleanup goals") selected by the Agencies are generally consistent with the cleanup levels in the Preliminary Implementation Strategy for HHSQC.

The area defined by the ROD that is subject to active remediation (i.e.: capping) is about 1/3 the area exceeding the cleanup standard (or "goal"). Under the Sediment Management Standards, cleanup actions may include a combination of actions including dredging, capping, source control, natural recovery, institutional controls and monitoring. It is not possible for Ecology to predict if a different active remediation area would have been selected under the current Preliminary Implementation Strategy for HHSQC. Neither the rule nor the Preliminary Implementation Strategy specify how to identify areas that must be actively remediated vs. those that would be subject to more “passive” remedial actions such as natural recovery or institutional controls.

3.0 Conclusions

3.1 Selection of Cleanup Actions

For purposes of understanding the impacts of human health sediment criteria values, it is important to distinguish between cleanup standards and selection of cleanup actions. Agencies have used the flexibility inherent in the selection of the cleanup action process to address the real-world constraints associated with costs, disposal capacity, etc. Specifically, cleanup actions often include a combination of actions with higher sediment concentrations being actively handled through dredging and capping and less contaminated areas being addressed through source control, natural recovery and monitoring. This approach was applied at Manchester Annex, where the “cleanup level” defined the area to be actively remediated and the “cleanup goal” delineated the area subject to more passive actions, such as institutional controls and monitoring.

The site-specific standards for Manchester Annex were selected having considered the distribution of contamination, risks to human health, and balancing the implementability, practicability and costs associated with several remedial alternatives. For example, areas with the highest concentrations were subject to the most aggressive cleanup actions while less contaminated areas received less aggressive remedial actions.

WAC 173-204-570 establishes a framework and an overall process to determine site-specific cleanup standards. Using this process, sediment cleanup standards are established as close as practicable to the sediment quality standards (cleanup objective) taking into account net environmental impacts, cost and engineering feasibility of different cleanup alternatives. Site-specific cleanup standards may not exceed the minimum cleanup levels specified in WAC 173-204-520.

However, for health-based cleanup actions, the Sediment Management Standards do not clearly define how one identifies the sediment cleanup concentration that triggers active remediation. It is clear, however, that these levels will significantly impact the total cost and feasibility of a cleanup action. Ecology expects additional public discussion will be necessary to resolve this issue.

3.2 Terminology

In defining cleanup requirements, several terms (e.g. cleanup standards, cleanup levels, cleanup goals, remedial action levels) are sometimes used interchangeably. This can lead to some confusion. Adoption of HHSQC and the related implementation strategy should help to reduce some of this confusion by the establishment of some common terms.

3.3 Use of Site-specific Tissue Data

Although no standard, agency-approved fish or shellfish criteria exist, standard risk assessment parameters were used at the site to develop a shellfish tissue criteria. Since most of the bioaccumulation related risks at the site were attributable to PCBs in edible intertidal shellfish and the tissue PCB concentrations were shown to be highly correlated with sediment concentrations, site managers were able to develop a risk-based cleanup level using tissue measurements from the site and linear regression (see Figure 2.2).

This approach is consistent with Ecology's Preliminary Implementation Strategy. The use of site-specific tissue and sediment data offers the most reliable approach for establishing a site-specific cleanup standard. When enough data is available to use regression analysis techniques to quantify the relationship between tissue and sediment levels, then it is a useful tool for this purpose, as is seen in this case study.

3.4 Exposure Assumptions and Risk-based Cleanup Levels

For this case study, Ecology compared the Manchester Annex cleanup level of 40 ppb, dry weight to the Tier I HHSQC of 31 ppb, dry weight. While these two values are nearly the same, their derivation is quite different. In developing the cleanup goal of 40 ppb, the Agencies calculated a risk-based level based on consumption of shellfish from the site. In contrast, Ecology's Tier I values are based on Puget Sound-wide background concentrations, as the risk-based levels calculated by Ecology are lower than the background levels.

Nonetheless, it is interesting to compare the input parameters used to calculate the risk-based Tier I HHSQC and the Manchester Annex cleanup goal. For example, Tier I criteria values in the Preliminary Implementation Strategy are based on average fish consumption rates reported for members of Puget Sound tribes (Toy, 1996). At Manchester Annex, the Agencies used the data from the Toy study and worked closely with the Tribes and other stakeholders to develop the input parameters used to calculate the cleanup goals and cleanup levels.

The two sets of exposure factors are outlined in Table 2.2 below.

Table 2.2 Input Parameters Used to Calculate Cleanup Levels for Manchester Annex and Tier I HHSQC

Exposure Factor	**Manchester Annex ROD Assumptions**	**Ecology Tier I Assumptions**	**Units**
Risk Level	10^{-5}	10^{-5}	unitless
Shellfish Consumption Rate	128	19	grams/day
Shellfish Diet Fraction	0.5	1	unitless
Exposure Frequency	140	365	days/yr
Exposure Duration	30	30	yrs
Averaging Time	70	75	yrs
Body Weight	81	70	kg

Three exposure assumptions differ significantly: (1) consumption rate, (2) diet fraction and (3) exposure frequency. At Manchester Annex, the site-specific exposure factors were developed in close coordination with the Suquamish Tribe and the State of Washington fisheries and health managers. The modifying factors of diet fraction and exposure frequency were used because the site was not expected to support a full subsistence fish consumption scenario.

In comparison, Ecology's default exposure assumptions are not intended to be site-specific. As a result, parameters such as diet fraction and exposure frequency are not included as modifying factors (e.g: when diet fraction is equal to 1, it is essentially excluded from the equation). However, under the Tier II framework, the Manchester Annex approach seems to be consistent with Ecology's Preliminary Implementation Strategy, given that sufficient data is collected to support the site-specific exposure parameters. Issues related to selection of Tier II exposure parameters are expected to require additional discussion between Ecology and the public.

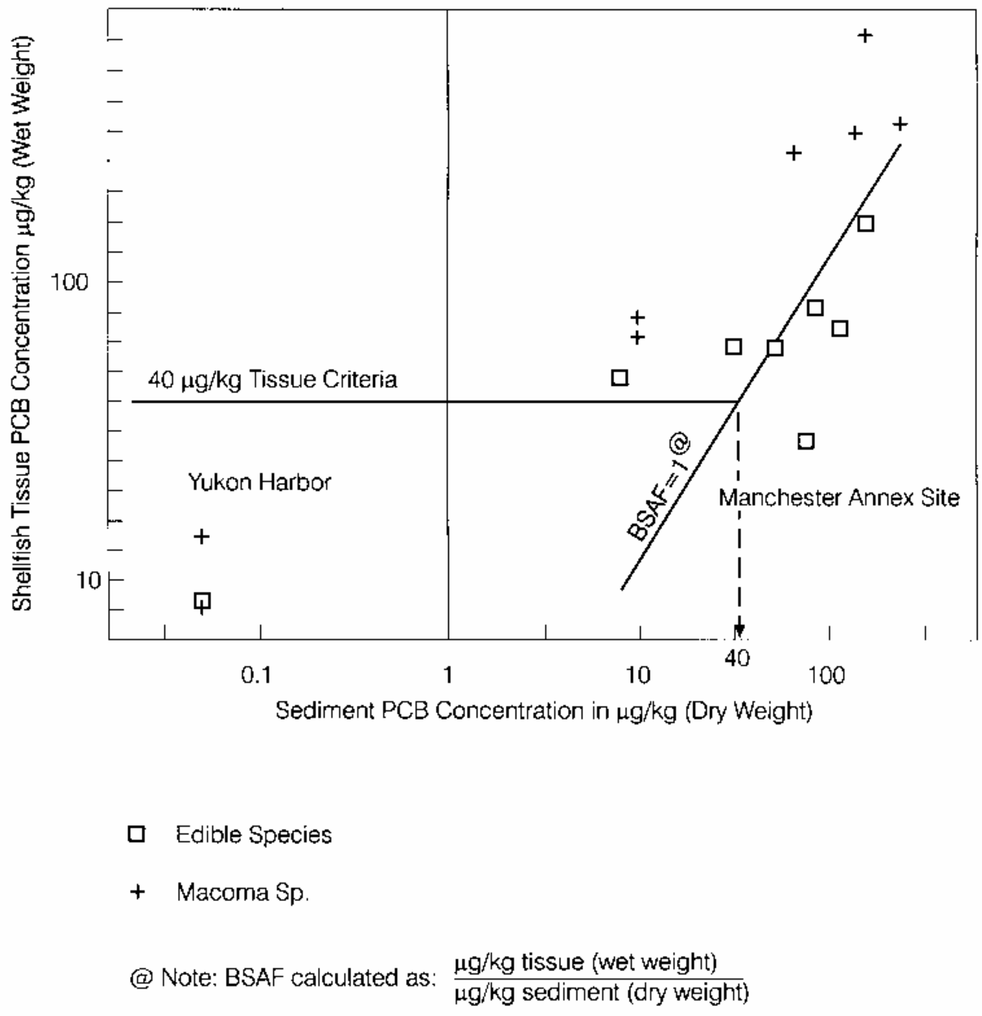

Figure 2.2 Sediment to tissue correlation - PCBs (Manchester Annex RI/FS), Hart Crowser, 1996.

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Cleanup Case Study #3 - Cascade Pole

1.0 Background

The Cascade Pole Site is located in Budd Inlet in Olympia, WA at a former wood-treatment facility that operated from the early 1940's to 1986 (Figure 3.1). The site is being managed by the Department of Ecology under the Model Toxics Control Act (MTCA) and the Sediment Management Standards (SMS). A Remedial Investigation and Feasibility Study have been completed for the site (Landau Associates, 1993 and 1993a). Physical cleanup work onshore is occurring in 1997 and 1998, while the offshore remediation is expected to begin in 1999.

This site was chosen as a case study because it involves two key human health chemicals of concern -- dioxins and high molecular weight polycyclic aromatic hydrocarbons (HPAHs). In addition, this site has progressed far enough through the cleanup process to allow for a comparison to potential human health sediment quality criteria (HHSQC), uninfluenced by the criteria development process.

This case study is based on information contained in the Risk Assessment (Landau Associates, 1992), the Remedial Investigation (Landau Associates, 1993a), the Feasibility Study (Landau Associates, 1993) and via personal communication with Charles Pitz, the site manager and Russ McMillan, sediment specialist, at Ecology's Southwest Regional Office, Toxics Cleanup Program.

1.1 Human Health Concerns

Human health concerns were identified at Cascade Pole due to the presence of HPAHs, pentachlorophenol and dioxins and furans. In addition, the area is a "usual and accustomed fishing area" under the Treaty of Medicine Creek, principally for the Squaxin Island Tribe, which has a net fishery in Budd Inlet. The State Department of Health has closed Budd Inlet to all shellfishing on a year round basis (due largely to nearby sewer outfalls).

A human health risk assessment (HHRA) was conducted to evaluate the potential human health risks associated with current and future occupational and recreational exposure to sediment, surface water, seeps and clam tissue (Landau Associates, 1992). The results of the baseline risk assessment showed that noncarcinogenic chemical effects were not of concern, but that risk from cancer-causing chemicals was a problem at the site. Total excess cancer risk from the modeled recreational exposures was calculated to be approximately 1 in 100 (10^{-2}). These risks far exceed MTCA's maximum allowable risk level of 1 in 100,000 (10^{-5}).

Figure 3.1 Cascade Pole site map

Human health-based cleanup standards were developed at Cascade Pole using a risk assessment approach. Cleanup levels were calculated that individually did not result in excess cancer risks greater that 10^{-6} and cumulatively did not result in excess cancer risk greater than 10^{-5}, as required by MTCA. Potential "Action Levels" were also proposed in the HHRA and Feasibility Study to allow for cleanup of a smaller area, taking into account costs and benefits of active remediation.

1.2 Risk Assessment Assumptions and Results

The HHRA evaluated two exposure scenarios, recreational and occupational (a subsistence exposure scenario was not included in the primary risk evaluation). The recreational scenario yielded the highest risks. The recreational exposure scenario included several routes of exposure, including sediment ingestion, dermal exposure and ingestion of clams from the site. Dermal exposure to contaminated sediments and water yielded the highest risk estimates.

For evaluating risks from shellfish consumption using a recreational scenario, the following exposure and toxicity assumptions were used:

Body weight = 70 kg
Exposure frequency = 48 meals/yr [2]
Ingestion rate = 54 g/meal
Diet fraction = 0.75
Exposure duration = 30 years
Cancer Potency Factor for chlorinated dibenzo-p-dioxins and furans = 1.5E05 $(mg/kg/day)^{-1}$ (TEF)
Cancer Potency Factor for individual carcinogenic HPAHs = 7.3 $(mg/kg/day)^{-1}$

Using these exposure assumptions, and the clam concentrations measured at the site, a risk of 2.4×10^{-4} from ingestion of clams was calculated. This risk was reported to be due primarily to the presence of carcinogenic PAH compounds (79 %) and chlorinated dibenzo-p-dioxins and dibenzofurans. Risk from carcinogenic HPAHs was calculated assuming all compounds were equi-potent to benzo(a)pyrene.

1.3 Sediment and Clam Tissue Measurements

Clams collected from within the Sediments Operable Unit showed elevated levels of wood-treating chemicals when compared to reference sample clams collected from nearby Eld Inlet. Each tissue sample was composed of 40-60 clams. The clam concentrations were higher than the health-based target tissue levels calculated in the HHRA and seemed to correlate well with the sediment concentrations at the site. Higher PAH levels were detected in the clams collected from close to the shoreline with the higher sediment levels as compared to clams collected from much further away (about 600 feet) from the shoreline, with much lower sediment levels.

[2] The exposure frequency of 48 meals/year was assumed based on professional judgement, according to Leslie Connor of Landau and Associates.

1.3.1 Dioxins/Furans

Dioxins and furans were detected in all 30 of the onsite sediment samples (this includes samples taken at several depths) taken from 12 sediment stations from within about 500 feet of the shoreline. These compounds were also found in all three clam samples, including the reference sample from Eld Inlet (however, most congeners from the reference clam sample were below the level of detection). The clam sample with the highest concentration was from an area identified as having elevated levels of organic chemicals in sediments. In addition, the RI reported that "[a]ll Site and Budd Inlet background water samples contained dioxin and furan concentrations that exceed the EPA water quality criteria based upon consumption of fish."

Exposure point concentrations for dioxins and furans were expressed as a toxicity equivalent to that amount of the 2,3,7,8-tetrachlorodibenzodioxin congener (Landau Associates, 1992).

1.3.2 HPAHs

Most of the calculated risk from consumption of shellfish was due to carcinogenic HPAHs. One clam sample had a total HPAH concentration as high as 3,900 ppb (in a place where high concentrations of HPAH were found in sediments). Exposure point concentrations[3] for HPAHs were developed for the sum of carcinogenic HPAH compounds. These HPAHs were assumed to be equi-potent to benzo(a)pyrene. For this case study, however, Ecology calculated TEF concentrations for HPAHs. See Appendix A for a more detailed description of TEFs.

1.3.3 Pentachlorophenol

Risk from pentachlorophenol was assessed based on the chemical's developmental toxicity. The HHRA concluded that the maximum single-event exposure to pentachlorophenol from shellfish consumption was less than the RfD, indicating the potential developmental toxicity from this compound is not of concern at this site.

1.4 Assessment of Tribal Fish Consumption

For finfish, a special assessment was conducted to estimate risk to tribal members who consume finfish *(see Landau, 1992, Appendix B).* Since no finfish were collected for tissue analysis, the exposure point concentrations from the shellfish samples were used as default concentrations for finfish tissue. A fish consumption rate of 31 grams/day for 365 days/year was used to calculate risk.

The results of this risk characterization showed high risks (3.3×10^{-3}) for Native American tribal members who eat finfish at a rate of 31 grams/day, assuming that all of the fish consumed contained contaminant levels equivalent to the shellfish analyzed at the site, an

[3] Exposure point concentration refers to a chemical concentration that is used to estimate an individual's exposure to a chemical contaminant. In the Cascade Pole Risk Assessment, the exposure point concentrations used to calculate risks were derived by calculating the upper 95 percent confidence interval on the mean.

assumption that was presumed to lead to an overestimate of risk. Eighty-two percent of the calculated risk was due to the presence of carcinogenic PAHs. However, the calculated risk from exposure to only dioxins/furans was also relatively high at 6.4×10^{-4}.

1.5 Identification of Remedial Actions

The objectives identified for selecting a remedial action included protection of the public from exposures to sediment or shellfish that pose an unacceptable risk to human health (as defined by MTCA). To meet the remedial action objectives, site cleanup standards were developed by integrating a human health risk approach with the ecological criteria in the SMS.

In addition, "Action Levels" were calculated based on modified risk parameters (Landau Associates, 1993). These Action Levels define the concentrations above which active remediation is required. Action Levels take into account costs, benefits and engineering feasibility. According to the site manager, the risks posed by the contaminated sediment not addressed by active cleanup will be addressed in some other "passive" manner, such as warning signs, or legal institutional controls (e.g. restrictive covenants that disallow shellfish harvesting or access), as well as via natural recovery.

2.0 Potential Impact of Alternative Approaches for Cleanup Standards

One of the primary goals of this case study effort is to determine the potential impact of the Preliminary Implementation Strategy for HHSQC. For this case study, Ecology compared the proposed cleanup decision at Cascade Pole to two approaches:

- Tier I HHSQC: Tier I human health criteria are based on default input parameters that are designed to provide an acceptable level of protection for a reasonably maximum exposed individual consuming fish from Puget Sound. These values are risk-based and may be used to define areas of concern. The preliminary Tier I HHSQC, based on a cancer risk level of 1 in 100,000, are compared to sediment cleanup levels calculated at Cascade Pole.

- Tier II, Tissue-Based Approach: Clam tissue concentrations measured at the site were compared to target tissue levels calculated for development of HHSQC. Although the data were insufficient for making cleanup decisions, the results suggested that additional tissue data might have been useful.

An approach that incorporates a site-specific BSAF is not included because a lack of sufficient tissue data precluded calculation of a site-specific BSAF.

2.1 Tier I/Sediment Criteria

In order to develop the health-based cleanup standards at Cascade Pole, an equilibrium partitioning model was used to relate sediment concentrations to surface water, pore water and clams. Using this model, in conjuction with risk-based concentrations, cleanup levels were calculated. These cleanup levels were calculated based on cumulative risk from all exposure pathways, as required by MTCA.

Table 3.1 shows the risk-based cleanup levels and the proposed action levels for the four primary chemicals of concern. The action levels are labeled "proposed" because Ecology had not made a final decision at the time this report was written.

Table 3.1. Calculated Health-based Cleanup Levels and Action Levels

Chemical of Concern	Sediment Cleanup Level (ppb, dry weight)	Proposed Action Level (ppb, dry weight)
HPAHs (sum)	300	4,300
Dioxins/furans	0.0014	0.08 *
Pentachlorophenol	1,770	4,570
2,4,6-Trichlorophenol	720	720

** The dioxin action level was determined based on risks to wildlife, not human health.*

Before comparing these values to preliminary Tier I HHCSLs, they were converted to TOC-normalized concentrations using 2.6% TOC, the average organic carbon level at the site (personal communication, Russ McMillan). Table 3.2 presents the TOC-normalized values in relation to the preliminary HHCSLs.

The HHCSLs were based on the following assumptions: a risk level of 10^{-5}, body weight of 70 kg, averaging time of 75 years, exposure duration of 30 years, toxicity based on TEF values recommended by EPA, a BSAF of 1.0 for dioxins/furans and a BSAF of 0.38 for HPAHs, ingestion rate of 19 grams/day for shellfish, and a lipid level of 1%.

Table 3.2 TOC-normalized Cleanup Levels, Action Levels and Preliminary HHCSLs (based on ingestion of shellfish only)

Chemical of Concern	Sediment Cleanup Level	Proposed Action Level	Preliminary HHCSL
HPAHs (sum)	11.5 ppm	166 ppm	3.3 ppm
Dioxins/furans	54 ppt	3077 ppt	60 ppt
Pentachlorophenol	68 ppm	176 ppm	NA
2,4,6-Trichlorophenol	28 ppm	28 ppm	NA

HHCSL values are not presented for pentachlorophenol or 2,4,6-trichlorophenol because Ecology does not currently have a reliable BSAF for these compounds on which to base a criteria value

Table 3.2 shows that:

- For dioxin, the Cascade Pole cleanup level is about the same as the preliminary HHCSL.
- For HPAHs, the Cascade Pole cleanup level is about 3.5 times higher than the preliminary HHCSL.
- The Action Levels are substantially higher than both the Cascade Pole cleanup level and the preliminary HHCSL for both dioxins and HPAHs.

2.1.1 Comparing Areas

The attached maps (Figures 3.2 – 3.4) show the areas that were estimated to exceed the health-based cleanup level and action level for carcinogenic HPAHs and the action level for dioxins/furans. The areas were mapped using a concentration contouring approach. The area exceeding the HPAH cleanup level of 300 ppb, dry, is approximately 22 acres, whereas the area exceeding the action level is approximately 4 acres (personal communication with Charles Pitz, September, 1997). The area that exceeds the dioxin/furan action level of 80 ppt (TEQ), dry weight is approximately 6.5 acres.

For the HPAHs, virtually every sediment station that was sampled exceeds the health-based cleanup level. As a result, it is not possible to determine how much more of the site would exceed the lower preliminary HHCSL. For dioxins/furans, since the preliminary HHCSL is slightly higher than the cleanup level for the site, the area exceeding the HHCSL would be slightly smaller than (if not the same as) the area exceeding the health-based cleanup level. However, the extent of the area exceeding these values is unknown because only 12 samples were taken from within about 500 feet of the shoreline and all of them exceed the cleanup level of 1.4 ppt, dry weight.

Table 3.3. Comparison of Cleanup Levels and Related Areas of Concern for HPAHs

	Cleanup Level (ppm, TOC)	**Action Level (ppm, TOC)**	**Area of Concern (acres)**	**Active Remediation Area (acres)**
Cascade Pole Approach	11.5	166	22	4
Tier I Approach	3.3	??	> 22	??

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

Table 3.4. Comparison of Cleanup Levels and Related Areas of Concern for Dioxins/Furans

	Cleanup Level	**Action Level (ppt, TOC)**	**Area of Concern**	**Active Remediation Area**

	(ppt, TOC)		(acres)	(acres)
Cascade Pole Approach	54	3077	NA	6.5
Tier I Approach	60	??	??	??

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

2.2 Tier II/Fish-Shellfish Tissue Approach

Chemical concentrations in clams corresponding to an "acceptable" tissue level were calculated in the HHRA. Table 3.5 shows these tissue levels as compared to target tissue levels calculated for development of preliminary HHCSL and the average tissue concentration of two samples taken in Budd Inlet.

Table 3.5. Comparison of Target Tissue Levels for Dioxins and Carcinogenic HPAHs (based on clam ingestion)

	Dioxins/Furans	HPAHs
Average Tissue Concentration Measured in Budd Inlet (n=2)	5.5 ppt	250 ppb *
Cascade Pole Target Tissue Level	0.037 ppt	1.3 ppb
Ecology Target Tissue Level	0.59 ppt	13 ppb

** The HPAH tissue concentration of 250 ppb represents a total carcinogenic PAH concentration based on a TEF calculation and exposure point concentrations reported in the HHRA.*

These results show that the tissue levels used in the HHRA are lower than Ecology's target tissue levels. The most likely reason for this difference is the consideration of cumulative/additive risk in the Cascade Pole HHRA, as required under MTCA. That is, other exposure pathways (such as dermal exposure to sediments) were taken into account at the site when calculating total risk, and therefore had an influence on the target tissue level calculation. In addition, all of the target tissue levels are lower than the measured tissue concentrations from the site.

The RI tissue chemistry results show significant differences in the HPAHs levels between the two sites where clams were collected. Higher PAH levels were detected in the clams collected from close to the shoreline where higher sediment levels exist as compared to clams collected from much further away (about 600 feet) from the shoreline, where sediment levels are much lower. Although it is not possible to make decisions based on only two samples, the results suggest that it may be possible to use tissue chemistry to help define the boundaries of the cleanup area (although this would only work for non-mobile species like clams).

3.0 Conclusions

The focus of this case study was on Tier I values, as there were insufficient fish tissue data collected to allow for the development of site-specific BSAFs or site-specific, Tier II criteria values. In addition, the results show that the health-based cleanup levels being used for the site are about the same for dioxins/furans as compared to preliminary HHCSL. For HPAHs, cleanup levels are slightly higher than preliminary HHCSL.

3.1 Use of Action Levels to Define Active Remediation Areas

The use of action levels for determining areas slated for active remediation raises interesting and challenging policy and technical issues. The action levels, which account for cost and engineering feasibility, designated a smaller area to be actively remediated than the area exceeding the risk-based cleanup levels.

Neither the Sediment Management Standards nor Ecology's Preliminary Implementation Strategy for HHSQC currently include the concept of action levels, per se, particularly not in the manner in which they were used at Cascade Pole. However, current revisions to the Model Toxics Control Act include provisions for establishing "remediation levels" (which are synonymous with action levels).

As previously mentioned, the site manager predicts that risks posed by the contaminated sediment beyond the action area will be managed by the use of institutional controls, such as signs, or legal institutional controls (e.g. restrictive covenants that disallow shellfish harvesting or access). Ecology found that at some case study sites, the decision to allow some level of contamination was coupled with a tissue monitoring requirement, to ensure a reduction of bioaccumulative risks. Post remedial monitoring at Cascade Pole may include sediment and/or tissue monitoring, but a final decision had not been made at the time this report was completed.

The SMS includes language that provides for some flexibility when evaluating cleanup action alternatives (e.g.: dredging vs. institutional controls). The rule states that in evaluating cleanup action alternatives, the department shall consider:

- the net environmental effects of the alternatives
- the cost of the alternatives
- the technical/engineering feasibility of the alternatives.

However, it is generally also necessary to consider treaty rights, protection of a fishery and environmental justice issues when considering use of institutional controls. The decision as to whether to allow the use of institutional controls where there are human health risks will depend on the factors listed above and will be based on site-specific considerations.

3.2 Bioaccumulation Assumptions and BSAFs

Managers at this site relied on the equilibrium partitioning theory to translate fish data into sediment concentrations. It was recognized that concentrations in biota were the result of exposure to contaminated sediments. The FS stated "[t]he concentrations of the chemicals of concern in harvested shellfish and surface water are primarily the result of exposure of these media to contaminated sediment or other uncontrolled sources. Implementing source controls at the site, remediating the sediment, and placing institutional controls on shellfish harvesting are expected to effectively address these other media."

The site managers were faced with a great deal of uncertainty when they were seeking to quantitatively relate the concentrations in sediments to those in tissue. This difficulty would be overcome by the application of a BSAF. While BSAFs have their own set of uncertainties, the use of BSAFs provides a tool to reduce some of the larger uncertainties and increase the efficiency of predicting potential risks to human health from sediment contamination.

3.3 Use of a TEF Approach for PAHs

EPA has recommended toxicity equivalence factors (TEFs) for seven HPAHs (including benzo(a)pyrene) (Sweeney, 1993; EPA, 1993). Each carcinogenic PAH is assigned a TEF that relates its toxicity to benzo(a)pyrene.

At Cascade Pole, the cleanup levels and risk calculations for PAHs were not based on the use of TEFs for PAHs. This differs from the proposed approach for HHSQC, which does rely on TEFs to determine compliance with the Tier I HHSQC for seven carcinogenic HPAHs. Everything else being equal, the use of TEFs results in a cleanup level that is less stringent than if the TEFs were not applied.

There is still debate about how to incorporate many other PAHs. As new scientific data becomes available, Ecology will incorporate that information as appropriate. Ecology's Risk Assessment Forum (RAF) has been reviewing the existing methods and issues surrounding TEFs for PAHs and is developing a position paper that is currently undergoing internal review (Delistraty, 1996). In that paper, Ecology is considering recommending the application of California's approach for TEFs for PAHs, which provides TEFs for 25 HPAHs. In the interim, Ecology will rely on EPA's approach and focus on the seven HPAHs identified by EPA.

3.4 Cumulative/Additive Risk

Under MTCA, risks from individual chemicals must be summed when calculating cleanup levels, so that the total site risk does not exceed 1 in 100,000. This approach leads to more stringent cleanup levels than considering risk of each chemical separately. To simplify the process for sediments, Ecology is proposing that Tier I HHSQC be based on risk from individual chemicals.

While Tier I criteria are based on exposure via consumption of fish and/or shellfish, other exposure routes will be taken into account in the Tier II process. Since Tier II is intended to be more site-specific and detailed, such an analysis should account for cumulative risks from all exposure routes (e.g.: dermal exposure). If there is reason to believe that multiple chemicals or pathways are of concern, then these should trigger a Tier II assessment.

3.5 Use of Background Concentrations

Background concentrations did not play a significant role in the decision-making process at this site. Three samples were collected in Budd Inlet for dioxins and furans outside of the site boundaries, but an area background level was not developed because a sufficient number of samples were not taken to meet the requirements of MTCA. In addition, there were questions about the proximity of the "background" stations to the site.

This raises issues regarding the application of ***area*** background levels vs. Puget Sound-wide background levels. In the development of HHSQC, Ecology relied on calculations by WDOH and PTI for Puget Sound-wide background levels. The preliminary HHSQC were compared to chemical-specific reference area background levels for some chemicals (background levels are not available for certain chemicals, such as dioxins/furans). The only compound that was found in reference areas above the risk-based value was PCBs (see Appendix A). In contrast, at Cascade Pole, a small number of sediment samples were taken in Budd Inlet to help characterize background levels in the Inlet (i.e: "area background").

The SMS and MTCA both address the issue of defining "background." In the SMS, reference sediment samples are intended to "represent the nonanthropogenically affected background surface sediment quality of the sediment sample." (WAC 173-204-200). In MTCA, ***area*** background and ***natural*** background are defined as follows:

> ***"Area background"*** *means the concentrations of hazardous substances that are consistently present in the environment in the vicinity of a site which are the result of human activities unrelated to releases from that site.*
>
> ***"Natural background"*** *means the concentrations of hazardous substances that are consistently present in the environment which has not been influenced by localized human activities.*

Application of background for determining compliance is also addressed. In MTCA, ***area*** background can only be used to establish a Method C cleanup level (WAC 173-340-706). In addition, area background can be a consideration in the development of a cleanup action plan:

> *When area background concentrations would result in recontamination of the site to levels which exceed cleanup levels, that portion of the cleanup action which addresses cleanup below area background concentrations may be delayed until the off-site sources of hazardous substances are controlled. In these cases, the remedial action shall be considered an interim action until cleanup levels are attained (WAC 173-340-360).*

The concern has been raised that if the HHSQC for a particular chemical is lower than the area background, measuring compliance with the criterion is problematic. While there is currently no provision for use of area background in determining a cleanup level in the SMS, the concept and definition provided in MTCA may prove useful at certain sediment cleanup sites.

3.6 Use of Fish Tissue Measurements to Make Cleanup Decisions

Measuring chemical concentrations in edible tissue provides a more direct indication of the potential human health risks posed at a site as compared to the default BSAFs used to develop Tier I HHSQC. However, fish tissue measurements alone do not provide enough information for decision-makers to define cleanup boundaries and/or choose remedial actions. Using tissue chemistry data in combination with sediment chemistry data is an approach that provides the most data. At Cascade Pole, insufficient samples were collected to make any decisions based on tissue data. However, the tissue samples that were available suggested a good correlation between HPAH levels in clams and the surrounding sediment levels.

In order to use tissue data, several questions need to be adequately addressed. For example, how do tissue and sediment chemistry data interrelate in the decision-making process? Does tissue override sediment? Ecology expects these types of questions to be addressed via on-going discussions with stakeholders and members of the interested public.

Figure 3.2 Cascade Pole human health standard area

Figure 3.3 Cascade Pole human health action area

Figure 3.4 Cascade Pole dioxin action area

References

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Cleanup Case Study #4 - Wyckoff/Eagle Harbor

1.0 Background

The Wyckoff/Eagle Harbor Superfund site is located on the east side of Bainbridge Island, in Central Puget Sound (Figure 4.1). Eagle Harbor was divided into two "Operable Units," the East Harbor Operable Unit and the West Harbor Operable Unit, to facilitate the administration of cleanup. The principal contaminant of concern in the West Harbor is mercury and the principal contaminants of concern in the East Harbor are polycyclic aromatic hydrocarbons (PAHs).

This site was chosen as a case study because it involves two human health chemicals of concern (mercury and HPAHs), fish tissue data are available and the site has progressed far enough through the cleanup process to allow for a comparison to potential human health sediment quality criteria (HHSQC), uninfluenced by the HHSQC development process.

This case study is based on information contained in the Risk Assessment (CH2M Hill, 1991), the Remedial Investigation (CH2M Hill, 1989), the Feasibility Study (CH2M Hill, 1991a), the West Harbor Record of Decision (EPA, 1992), the East Harbor Record of Decision (EPA, 1994) and via personal communication with the EPA Site Manager, Ellen Hale.

1.1 Legal Requirements

Under CERCLA, EPA's primary responsibility is to undertake remedial actions that assure adequate protection of human health, welfare and the environment. In addition, the selected remedial action must comply with all applicable or relevant and appropriate requirements (ARARs) established under state and federal environmental law. For this cleanup action, the Sediment Management Standards (SMS) (WAC 173-204) were identified as a significant ARAR.

1.2 Human Health Concerns

Human health concerns were identified at Eagle Harbor due to the presence of mercury and carcinogenic PAHs. Methylmercury is a developmental toxin and a neurotoxin and certain high molecular weight PAHs are considered probable human carcinogens (EPA, 1995). Both compounds bioaccumulate in the food chain; hence human exposure to these chemicals is primarily via consumption of fish and/or shellfish. The harbor supports salmon, several flatfish species, crab, shrimp and other species and is within the usual and accustomed fishing area of the Suquamish Tribe.

Figure 4.1 Wyckoff/Eagle Harbor site map

As a result of these concerns, a Human Health Risk Assessment (HHRA) for all of Eagle Harbor was conducted in 1989 as part of the Remedial Investigation (RI) and was revised in 1991 (CH2M Hill, 1991). The revised HHRA provides details on the assumptions used to calculate human health risks at the site.

The HHRA assessed the potential hazard to people exposed to site contaminants via ingestion of shellfish and fish and dermal exposure to intertidal sediments. Both cancer and non-cancer risks were calculated. The highest cancer risks calculated in the revised HHRA were for the ingestion of PAHs in shellfish. The highest non-cancer risks were associated with the ingestion of methylmercury in fish.

The HHRA considered risks to recreational consumers, but did not specifically include subsistence consumers, such as Native Americans. However, the consumption rates used would likely be protective of a large percentage of Native American fishers, based on current data from the Tulalip/Squaxin Consumption Survey (Toy, 1996). The consumption rates used as RMEs (the "reasonable maximum exposure" scenario) were 95 grams/day for fish consumption and 21.5 grams/day for shellfish consumption. Ecology's current default consumption rates are 42 grams/day for finfish and 19 grams/day for shellfish.

To calculate an RME chemical concentration for exposure assessment, EPA used the 95 percent upper confidence limit (UCL) on the mean. If the number of samples was insufficient to calculate a UCL, the mean was used instead.

2.0 West Harbor Operable Unit

Mercury and other heavy metals were found in intertidal sediments at concentrations that exceeded background concentrations, with the highest levels concentrated near the former shipyard on the north shore. Subtidal mercury concentrations exceeded maximum background values throughout the harbor and were particularly high near the former shipyard.

2.1 Remedy Selection

The cleanup remedy selected for the West Harbor Operable Unit focused on mercury and included the following elements:

- Thin layer capping in areas of moderate concern (sediment concentrations between 0.59 and 2.1 ppm mercury (unless the sediment of concern passed all 3 biological tests, then cleanup was not required).

- 1-meter cap for areas between 2.1 and 5 ppm mercury.

- Removal and disposal of sediments with greater than 5 ppm mercury.

- Natural recovery and monitoring in areas of lower concern.

- Continued fish tissue monitoring

- Institutional controls to protect human health from exposure to contaminated fish/shellfish.

The above remedy was designed primarily to address ecological risks. The 1991 HHRA conducted for both East and West Harbor concluded that, based on a 1990 data set, non-cancer risks from consumption of mercury-contaminated seafood were below a level of concern. However, due to conflicting results from previous data sets that showed higher risks, EPA required continued monitoring of fish tissue in the area (as well as institutional controls) to ensure protection of human health.

Consistent with the SMS, the ROD allowed for biological testing as a means of reducing the size of the cleanup area defined based on sediment chemistry. The area estimated by EPA to exceed the Minimum Cleanup Level/Cleanup Screening Level (MCUL/CSL) chemical criteria for mercury in the entire harbor was 78 acres (Schmitt, 1995). Based on the results of biological testing, the area requiring active remediation was reduced about nine-fold, to about 8.5 acres.

2.2 Mercury in Tissue

Since mercury has the potential to bioaccumulate in marine biota, it was recognized as a potential risk to human health. EPA calculated the following tissue screening level concentrations for methylmercury (the form of mercury that is of human health concern) to compare to measured tissue concentrations at the site. The screening levels correspond to a hazard quotient of one, and are based on a mercury RfD of 0.003 mg/kg/day and ingestion rates of 95.1 grams/day for finfish and 21.5 grams/day for shellfish:

- 0.22 mg/kg in fish
- 0.98 mg/kg in shellfish

Ecology also calculated tissue screening levels for mercury (and other compounds of human health concern) based on the same input parameters as the Tier I HHSQC, such as a fish consumption rate of 42 grams/day and a cancer risk level of 1 in 100,000 (10^{-5}) for carcinogens and a Hazard Quotient of 1 for non-carcinogens. Based on these parameters, Ecology's level of concern for methylmercury in fish is 0.17 ppm, which is just below EPA's screening level of 0.22 ppm.

EPA sampled clams in 1988-1990 and finfish in 1989-1990. These data were used to calculate human non-cancer risks from consumption of these organisms. Results from that sampling effort (as reported in Technical Memorandum 13 of the RI/FS (Marine Biota Tissue Sampling and Analysis Report)) are shown in Table 4.1.

Table 4.1 Methyl Mercury Concentrations in Fish and Shellfish Tissue (ppm, wet weight)

	Average	Min	Max
English sole/1989 (n=1)	---	---	**0.53**
English sole/1990 (n = 13)	0.09	0.056	0.16
Perch/1989 (n=9)	**0.57**	0.03	**1.6**
Perch/1990 (n=11)	0.14	0.055	**0.37**
Crab muscle (n=13)	0.089	0.025	0.26
Clams (n=17)	0.02	0.007	0.075

Notes: The Perch data represent results from Striped seaperch and Pile perch analysis. ***The numbers in bold exceed EPA's screening levels.***

Table 4.1 shows that consumption of finfish is likely to be more of a human health risk as compared to shellfish, since the concentrations in shellfish are well below EPA's screening level and some of the finfish concentrations approach or exceed the EPA screening level of 0.22 ppm. However, the only data set where the *average* tissue concentration exceeds the EPA screening level is the perch data collected in 1989 (with the exception of the one English sole data point from 1989). As identified in the ROD, the risks from the 1990 data were lower than those calculated from the 1989 data and were below a hazard quotient of 1. As a result of the apparent declining mercury tissue concentrations, EPA did not calculate a mercury cleanup level in sediments based directly on human health concerns. In addition, EPA had a higher level of confidence in the 1990 tissue data set. EPA expected that reductions in tissue concentrations would result from source control and cleanup to ecological standards.

3.0 East Harbor Operable Unit

For the East Harbor Operable Unit, the chemicals of primary concern were high molecular weight polycyclic aromatic hydrocarbons (HPAHs), as well as metals, primarily mercury. Initial cleanup actions were completed in early 1994. A clean sediment cap was placed over 54 acres of heavily contaminated subtidal sediments in the East Harbor in 1993 at a cost of approximately $1.5 million (see Figure 4.1). Additional capping may be conducted in the future, depending on future sediment test results.

3.1 Remedy Selection

The remedy chosen for the East Harbor Operable Unit is as follows:

- Capping (with limited sediment recovery zones) in the subtidal cleanup areas,
- Natural recovery in intertidal cleanup areas,
- Institutional controls in both areas.

Human health concerns were identified as a driver for cleanup of HPAHs in intertidal areas. The risk assessment indicated that the primary cancer risks from the harbor were associated with ingestion of PAH-contaminated shellfish. In the East Harbor, high cancer risks in the 10^{-3} (1 in a 1,000) range were associated with clams from beaches adjacent to the Wyckoff Facility. Because shellfish consumption was identified as the primary exposure pathway, EPA's cleanup decisions for human health protection were focused in the intertidal areas. In the subtidal areas, EPA relied on the MCUL from the SMS to make cleanup decisions.

An HPAH cleanup level of 1,200 ppb, dry weight was identified for the intertidal sediments to address human health risks from consumption of contaminated shellfish. This value was chosen because it corresponds to the 90th percentile of Puget Sound subtidal background concentrations for HPAHs available at the time of the RI/FS (PTI, 1989)[4]. EPA supported this cleanup level by linking sediment concentrations with clam tissue levels. In areas where intertidal sediments were above 1,200 ppb HPAHs, HPAH levels in clams exceeded EPA's level of concern of 60 ppb HPAHs in shellfish (at a 10^{-4} cancer risk level).

While the ROD concluded that sediment cleanup would result in reductions of contaminant levels in fish and shellfish, specific reductions in risk were not quantified. As described in the SMS, 10 years were allowed for intertidal sediments to meet the cleanup level.

The ROD concluded that because HPAHs are rapidly degraded by exposure to light, natural recovery was considered an appropriate remediation alternative in the contaminated intertidal areas. In addition, institutional controls were chosen as a remedy for addressing human health concerns in the interim. Bremerton-Kitsap County Health District issued a health advisory in 1985 to address bacterial and chemical contamination of seafood in Eagle Harbor. To supplement the Health District's efforts, EPA required posting additional warning signs on publicly accessible beach areas and piers to make the warning visible to recreational boats and to people on the affected beaches.

EPA recognized that the selected remedy would result in hazardous substances remaining on site above health-based and environmentally-based cleanup levels. Therefore, in addition to institutional controls, the ROD required continued monitoring until target tissue levels were achieved to assess future human health risks from consumption of contaminated seafood.

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[4] In September 1991, the Puget Sound Estuary Program (PSEP) published a final report on Reference Area Performance Standards for Puget Sound. The report recommended a new set of reference area performance standards based on a refined analysis of the data. The proposed performance standard recommended for HPAHs was 330 ppb, dry weight (PSEP, 1991), which is equivalent to about 10 ppm, TOC.

Ecology also developed reference area sediment concentrations for development of HHSQC (see Appendix A). The 90th percentile reference area concentration for benzo(a)pyrene, the most toxic HPAH, is 2.9 ppm, TOC. This is lower than the performance standard calculated in 1991 by PSEP due to the different approaches and purposes associated with the two values.

3.2 HPAHs in Tissue

Clams collected in 1988 in the East Harbor yielded risk estimates from 4 x 10^{-4} to 9 x 10^{-4} based on exposure to HPAHs. Use of 1990 tissue data resulted in risks as high as 1 x 10^{-3} from clams collected at transect 19, near the ferry dock. Background clam tissues collected near the mouth of the harbor produced risks from 1 x 10^{-4} to 5 x 10^{-4}. These risk values were calculated based on a benzo(a)pyrene cancer slope factor for all HPAHs, which is more conservative (ie: health protective) as compared to application of the toxicity equivalence factor (TEF) approach (see Appendix A for a description of the TEF approach).

4.0 Potential Impact of Alternative Approaches for Cleanup Standards

4.1 Comparing Outcomes

One of the primary goals of this case study is to determine the potential impact of the Preliminary Implementation Strategy for HHSQC. Ecology considered several alternative approaches for implementation of the HHSQC and compared the results to the decisions made by EPA at this site. The alternatives reviewed include Tier I criteria alone, site-specific, Tier II criteria, and a tissue-based approach. Sections 4.4 and 4.5 describe these approaches and the resulting areas of concern. The two chemicals of human health concern, mercury and HPAHs, are analyzed separately.

4.2 Data Analysis

Ecology obtained sediment and tissue data from EPA. These data were sorted and analyzed to determine the areas potentially requiring cleanup under the preliminary HHSQC.

4.2.1 Calculating a Toxicity Equivalent Concentration for HPAHs

For the HPAH data, the following procedure was used to determine the area potentially affected, based on a TEF approach:

1. The data was sorted by station. Where more than one concentration was reported for one station, all but the highest value was deleted. In addition, where one station was sampled in both March and June of 1988, the March data was deleted (this is consistent with EPA's approach -- the analytical method used in the June sampling was believed to be more accurate than the method used in March).
2. A TEF-based concentration was calculated for each carcinogenic HPAH.
3. A total TEF-based concentration was calculated by summing the individual HPAHs at each station to determine one PAH concentration per station.
4. Each TEF-based total was TOC normalized after an average TOC value was calculated for each station.

5. The TOC-normalized, TEF value from each station was compared to the preliminary HHCSL.

4.2.2 Treatment of sediment and tissue data for Tier II BSAF calculation

For Tier II, a site-specific BSAF was calculated by determining a surface area weighted average chemical concentration for the sediments, and an average fish tissue concentration. The site-specific BSAF was then used to determine a site-specific human health chemical criteria.

To determine a weighted average sediment chemical concentration, the chemical concentration at a station is multiplied by the area of that station. The products are then summed and divided by the total area for the site. Ecology determined area using a GIS thiessen polygon function which draws a station's polygon boundaries equi-distant from neighboring station boundaries. The maximum area for a station is about 786,000 square feet, with a maximum radius of 500 feet.

For fish tissue, the fish tissue concentrations of all the fish sampled at the site are averaged since fish are mobile and people's consumption of fish is expected to result in an overall exposure that will tend toward the average. Two sets of tissue concentrations were calculated for the two species analyzed by EPA , English sole and Perch. The average fish tissue concentration (lipid-normalized for lipophilic compounds) is divided by the area weighted average for sediments (TOC-normalized for organic compounds) to determine a site-specific BSAF.

4.3 Key Differences in Approach and Input Parameters Between Ecology and EPA

In addition to the differences in approach such as the use of TEFs for PAHs, other input parameters differed between Ecology's and EPA's assessment. As previously mentioned, EPA used a risk level of 1×10^{-4} as the upper limit for acceptable cancer risk and Ecology is using 1×10^{-5}. In addition, the HHRA used a slope factor of 11.53 $(mg/kg\text{-}day)^{-1}$ for all carcinogenic PAHs. Since the slope factor has since been updated by EPA since then, Ecology is basing the preliminary HHSQC on the more recent slope factor of 7.3 $(mg/kg\text{-}day)^{-1}$ for benzo(a)pyrene and is using a TEF approach for six other carcinogenic HPAHS.

In addition, EPA used 0.003 mg/kg/day as the oral RfD for methylmercury. EPA has since revised the RfD for methylmercury. Ecology is using the revised RfD of 0.0001 mg/kg/day.

4.4 Alternatives Assessment for Mercury

Making quantitative predictions about the relationship between sediment and tissue mercury concentrations involves a number of uncertainties. Unlike the extensive work that has been done to quantify the relationship between concentrations in sediments and tissue for PCBs, for example, relatively few studies have been published describing that relationship for mercury.

Nonetheless, mercury is of human health concern and its presence in sediments requires an assessment of potential subsequent risk to fish and shellfish consumers.

For the purposes of this case study, Ecology has presented a number of approaches for calculating a sediment concentration that would be expected to be protective of human health. Ecology recognizes the uncertainties inherent in these approaches and expects that as more information becomes available, methods for reducing these uncertainties will be employed.

4.4.1 Background

Table 4.2 includes estimates of areas exceeding sediment concentrations for three mercury sediment concentrations, corresponding to: (1) 2 x the local background level of 0.1 ppm, (2) the current ecologically-based SMS Sediment Quality Standard (0.41 ppm), and (3) the current SMS Minimum Cleanup Level/Cleanup Screening Level (MCUL/CSL) (0.59 ppm). These estimates were used to assess areal impacts in the analyses that follow.

Table 4.2 Areas Exceeding Selected Sediment Concentrations for Mercury

	Mercury in sediment (ppm, dry wt)	**Area Exceeding Sediment Concentration (acres)**	
		West Harbor	East Harbor
2 x background	0.2	92	188
Eco SQS	0.41	69	126
Eco CSL	0.59	42.6	78

Source: Schmitt, 1995

As allowed by the ROD, bioassays were conducted during remedial design to assess areas above the mercury MCUL of 0.59 (but less than the HAET for mercury of 2.1 ppm). Based on bioassay results and sediment samples collected during the remedial design phase, the following areas required remediation :

- Thick cap on 0.7 acres that are between 2.1 and 5 ppm mercury
- Thin cap on 7 acres -- between 0.59 and 2.1 ppm and did not pass bioassays
- Dredging for a little less than 1 acre for sediments above 5 ppm

Thus, in the West Harbor, active cleanup was required for about 8.5 acres of mostly subtidal areas to address biological effects and the most contaminated sediments .

4.4.2 Tier I Sediment Criteria

The relationship between the concentration of mercury in sediment and the concentration in fish/shellfish tissue has not been well-defined. Development of a default biota-sediment accumulation factor (BSAF) [5] for mercury is made difficult by the lack of literature values reported for this compound. However, a few researchers have reported mercury BSAFs (or data that can be used to calculate a BSAF). The three literature sources that were used to develop a default BSAF for this case study are:

- Mikac, et.al. (1985)
- Thomann, et.al. (1995)
- O'Neill, et.al. (1997).

In addition, an empirically-based approach from another site in Puget Sound, Whatcom Waterway, was applied. At that site, a site-specific BSAF was calculated for the Whatcom Waterway cleanup Section 6 of this case study.

Ecology is not proposing to use any of these approaches to develop a Tier I HHSQC for mercury. At sites where mercury is a chemical of concern, Tier II will be used to develop a site-specific mercury cleanup level.

4.4.3 Tier II, BSAF Approach

Using tissue and sediment data collected at the site, a site-specific HHCSL can be calculated based on a site-specific BSAF and a target tissue level. This approach is applicable for any bioaccumulative chemical of concern. Although there are uncertainties associated with the approach described below, a site-specific BSAF is likely to be more reliable than the literature-based approaches described in Section 6 of this chapter.

Based on data provided by EPA, a surface area weighted average mercury concentration in Eagle Harbor sediment (based on the 1988 data) was calculated. The surface area weighting approach was used to represent the fish's exposure to sediment throughout its home range. The surface area weighted mercury concentration is 0.555 ppm, dry weight.

Estimating home range for bottomfish is a highly uncertain exercise. For the purposes of this case study, the home range for English sole and Striped seaperch, [6] the two species with mercury concentrations reported by EPA, was assumed to be the entire harbor. Since the mean seaperch levels were slightly higher than the English sole concentrations, the seaperch levels were used to represent the worst case or reasonable maximum exposure scenario. The mean methylmercury concentrations in Striped seaperch is 0.156 ppm, based on the 1990 data set (CH2M Hill, 1991b).

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[5] "BSAF" is generally defined as the ratio of a lipid-normalized tissue level to an organic carbon-normalized sediment concentration. However, the term is used loosely in this section to mean the ratio between a tissue concentration and a sediment concentration, not normalized to lipid or organic carbon.

[6] The home range for the Striped seaperch was assumed to be the entire harbor, based on personal communication with Dr. Karl Brookins of Grays Harbor Community College, who estimated that given the size of the harbor, it is likely that the perch would be moving in and out of the Harbor on a daily basis.

Using the above sediment and tissue values, a BSAF is calculated as follows:

$$\text{BSAF} = \frac{\text{0.156 ppm Hg in tissue}}{\text{0.555 ppm Hg in sediment.}} = 0.28$$

Using this BSAF and a target tissue level for methylmercury of 0.17 ppm, the HHCSL is:

$$\text{HHCSL} = \frac{\text{0.17 ppm Hg in tissue}}{0.28} = \text{0.61 ppm Hg in sediments}$$

This value would represent a site-specific cleanup level and would be used in conjuction with ecological criteria to make cleanup decisions. As discussed in the Hylebos Waterway Case Study, it is possible to measure compliance with this HHCSL by applying it on an area-wide averaging basis. That is, not all sediments with concentrations above 0.61 ppm Hg would require active remediation as long as the area-wide average concentration could be shown to meet that value within the 10 year time frame.

4.4.4 Tier II, Tissue-based Approach

Using tissue measurements to assess human health risks and for making cleanup decisions has been suggested as a more direct approach for protecting human health from bioaccumulative contaminants in sediments. This approach relies on a comparison of measured tissue levels to tissue screening levels. When fish and/or shellfish tissue levels from the site are below screening levels, then one might be able to conclude that there is no human health risk of concern and therefore cleanup decisions can be based on ecological concerns. Where tissue screening levels are exceeded, however, cleanup options include:

a) Using the tissue data to calculate a site-specific BSAF to determine a health-based sediment cleanup level (as shown above); or
b) Requiring cleanup based on ecological criteria and monitoring to ensure that tissue levels are dropping over time (it is debatable whether use of the biological override is appropriate in this situation). This option would also preserve the option of requiring additional cleanup if tissue levels weren't met within the designated timeframe, or
c) Calculating the percent reduction needed based on the tissue data and selecting the cleanup area that reduces exposure proportionately

This approach requires the measurement of tissue concentrations and a comparison of these levels to tissue screening levels. The benefit of this approach is that it allows for the use of site-specific tissue data. However, application of a tissue level alone causes some difficulties when making decisions about sediment remediation and compliance monitoring, since it does not allow for the identification of a sediment concentration of concern.

Applying this approach to Eagle Harbor, the results would depend heavily on which tissue data set were used. The Risk Assessment conducted for this site determined both average exposure and reasonable maximum exposure (RME) scenarios. The RME is defined as the maximum exposure that is reasonably expected to occur at the site (CH2M Hill, 1991). For the tissue concentration, this was generally defined as the 95 percent upper confidence limit on the arithmetic mean.

The RME tissue concentrations reported in the risk assessment are listed in Table 4.3. These values can be compared to Ecology's level of concern in fish of 0.17 ppm methylmercury.

Table 4.3. Mercury Concentrations in Finfish

1989 RME Concentrations	1990 RME Concentrations
0.96 ppm (Seaperch)	0.24 ppm (Perch)
0.53 ppm (E. sole)	0.10 ppm (E. sole)

Only the English sole average from 1990 is below Ecology's target tissue level of 0.17 ppm Hg. Both the 1989 and 1990 Pile perch concentrations are above the target tissue level. Given the elevated perch concentrations, it is likely that Ecology would have used the tissue data to calculate a site-specific BSAF to determine a health-based sediment cleanup level or alternately, require cleanup based on ecological criteria and require monitoring to ensure that tissue levels are dropping over time, as EPA chose to do.

4.4.5 Summary of Findings for Mercury HHCSLs

Table 4.4 provides a summary of the approaches evaluated for mercury. The potential cleanup levels range from 0.61 ppm to 1.4 ppm, with most values centered around 0.85 ppm. It is interesting to note that the results from both the Thomann and O'Neill analysis are virtually the same. The area estimates are based on EPA's estimates (Schmitt, 1995) and rough calculations by Ecology staff using EPA's maps and a plenimeter.

Table 4.4 Summary of Areas of Concern for Various Approaches for Mercury

Alternative Approaches	Cleanup Level (ppm, dry wt)	Remedial Action Level (ppm, dry wt.)	Area of Concern (acres) **	Active Remediation Area (acres)
EPA Approach	0.59 *	*	78	9
Tier I Approaches: • Mikac, et. al. (1985)	1.4	??	7	??
• Thomann, et. al. (1995)	0.85	??	40	??
• O'Neill, et.al. (1997)	0.84	??	40	??
• Whatcom Waterway Approach	1.06	??	< 40	??
Tier II Approaches: • Site-Specific BSAF	0.61	??	78	??
• Tissue-Based Approach	??	??	??	??

** This level (and the area of concern defined by this concentration) represents the chemical criteria; as allowed in the SMS, EPA used bioassays as an override of the chemical criteria to develop the remediation area shown.*

*** Area estimates are for the entire harbor.*

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

Table 4.4 shows that, depending on the approach used, a range of HHCSLs could be calculated for mercury at Eagle Harbor. While the range of cleanup levels is relatively small (only about a factor of 2), the resulting areas of concern vary by about an order of magnitude. A mercury cleanup level of 1.4 ppm would fall within the area identified by EPA as requiring a thin cap, which was determined to be about 7 - 9 acres (see section 4.4.1 above). The other potential HHCSLs result in larger areas of concern, most of which, however, are smaller than EPA's area of concern. The areas subject to active remediation under each approach cannot be determined.

In addition, since exceedences of the ecological criteria are not factored in and some portion of this area also exceeds EPA's criteria for HPAHs, *the above area estimates should be considered overestimates due to mercury exceedences alone.* For example, EPA has already required the active remediation of 54 acres of subtidal sediments in the East Harbor due to high levels of HPAHs. Some of that 54 acres overlaps the areas identified in Table 4.4 above.

4.5 Alternatives Assessment for HPAHs

Estimating areas for PAH exceedences is more straight-forward, as EPA used only one value to make cleanup decisions. EPA calculated an area of 13.6 acres (55,000 sq. meters) in the *intertidal* areas that exceeded their cleanup level for human health protection of 1,200 ppb dry for HPAHs and selected natural recovery as the remedial action alternative for that area. EPA did not require cleanup in subtidal areas due to PAH risks to human health, based on the determination that there would be no human exposure to PAHs in subtidal areas. However, 54 acres of heavily contaminated subtidal sediments in the East Harbor were actively remediated in 1993 due to environmental risks. According to EPA, additional capping may be conducted in the future, depending on future sediment test results.

For HPAHs, several approaches were evaluated for this case study. Under Tier I, sediment concentrations in intertidal areas were compared to a preliminary HHCSL (based on shellfish consumption). For a Tier II analysis, several approaches were evaluated, including a tissue-based approach and calculation of a site-specific BSAF for shellfish. A finfish BSAF is not presented here based on the assumption that since finfish quickly metabolize HPAHs, the risk to human consumers of those fish is not of concern.

4.5.1 Tier I: Comparison to Preliminary HHCSL

The preliminary Tier I HHCSL for carcinogenic HPAHs is 3.3 ppm, TOC (based on consumption of 19 grams/day of shellfish). Sediment concentrations measured in the field were compared to these criteria after being converted to a TEF-based concentration and then summed.

For comparison purposes, Ecology normalized EPA's 1,200 ppb dry weight cleanup level assuming 3% organic carbon (based on the TOC data for the intertidal sediments with the higher PAH concentrations in Eagle Harbor). Using this TOC, the level of 1,200 ppb dry corresponds to a TOC-normalized concentration of 40 ppm TOC. This is about 11 times higher than the preliminary Tier I HHCSL value of 3.3 ppm, TOC. The current ecological SQS and CSL for HPAHs are 960 and 5300 ppm, TOC, respectively.

EPA sampled intertidal sediments for PAHs at 16 stations in and around Eagle Harbor (Figure 4.2). At each station, three sediment concentrations were reported, corresponding to three tide levels. Both the highest concentration and the mean concentration at each of the 16 stations are summarized in Table 4.5.

Table 4.5 Maximum and Mean Concentrations of HPAHs in Intertidal Sediments

Station	Maximum Sediment Concentration (ppm, TOC)	Mean Sediment Concentration (ppm, TOC)
1	1.76	0.88
2	***13.0***	***4.45***
3	1.67	1.13
4	***10.7***	***5.98***
5	***50.4 ****	***30.4***
6	***186 ****	***70.2 ****
7	***576 ****	***210 ****
8	***10***	***9.30***
9	***5.1***	***4.37***
10	***44 ****	***26.0***
11	***59 ****	***35.0***
12	***362 ****	***175 ****
13	***6.5***	***3.34***
14	***13.7***	***5.61***
15	***3.4***	1.5
16	***5.5***	***3.58***

Notes: See Figure 4.2 for station locations. All concentrations that exceed the HHCSL of 3.3 ppm are in ***bold, italic****. * An asterisk indicates values that exceed EPA's cleanup level of 40 ppm, TOC.*

EPA identified stations 5, 6, 7, 10, 11, 12 and part of 13 as exceeding the cleanup level. With the exception of station 13, the highest concentration at each of these stations exceeds 40 ppm, TOC. Using Ecology's preliminary Tier I value of 3.3 ppm, TOC, an additional 7 stations would exceed the cleanup level (stations 2, 4, 8, 9, 13, 14, and 16).

Based on the number of stations only, Ecology estimated that the area of concern could have doubled (from 13.6 acres to 27 acres) if the cleanup level had been lowered from 40 ppm to 3.3 ppm. However, some of the areas that exceed the 3.3 ppm value also exceed the mercury cleanup level, so those areas would be remediated anyway. In addition, it is not possible to accurately predict what method Ecology would have chosen to define an area of concern given the available data.

Figure 4.2 Eagle Harbor intertidal sample locations, June 1988

4.5.2 Tier II: Calculating a Site-specific BSAF for Shellfish

Using the sediment chemistry data and the tissue data, a site-specific BSAF for HPAHs can be calculated. To calculate site-specific BSAFs, each of the clam tissue concentrations listed in Table 4.7 is divided by the synoptic sediment concentration. For example:

At the T6 transect, the (non-lipid normalized) clam concentration is 0.03 ppm. To lipid normalize the clam tissue concentration, EPA's reported lipid content of 0.5% lipid for clams was used (EPA, 1995) as follows:

$$\frac{0.03}{0.005} = 6 \text{ ppm}$$

The average sediment concentration for the station in that area is 70 ppm, TOC. Using these two values, the BSAF is calculated as follows:

$$\frac{6 \text{ ppm, lipid}}{70 \text{ ppm, TOC}} = 0.086$$

Applying this BSAF, a site-specific cleanup level (HHCSL) is:

$$\text{HHCSL} = \frac{\text{target tissue level of 0.013 ppm}}{\text{BSAF of 0.086 x 0.5 \% lipid}} = 30 \text{ ppm, TOC}$$

This value is about 10 times higher than 3.3 ppm, TOC, the level determined using the Tier I Approach. However, it is fairly close to EPA's cleanup level of about 40 ppm, TOC.

The above calculation was done for each of the clam transects. The results are listed below in Table 4.6.

Table 4. 6 Summary of BSAFs and HHCSLs for Clam Tissue Data

Transect Number	BSAF	Corresponding HHCSL
T-1	0.638	4.1
T-2	0.263	10
T-3	3.542	0.73
T-14	0.553	4.7
T-15	1.734	1.5
T-16	0.525	5.0
T-4	0.522	5.0
T-5	0.145	18
T-6	0.085	30
T-7	0.011	247
T-8	1.291	2.0
T-9	0.337	7.7
T-10	1.328	2.0
T-12	0.067	39
T-13	2.253	1.2

These results show a range in HHCSL values from 0.73 ppm to 39 ppm, TOC (with the exception of the one outlier at Transect 7, which was excluded from the analysis). There are many factors that could cause the differences in BSAFs seen in this table, such as variability in clam lipid levels and/or sediment concentrations, or differences in clam age, sex or their steady-state levels. Unfortunately, lipid levels were not collected with the tissue chemistry, so one default lipid level was used to calculate each BSAF. This alone could account for the variability in the BSAFs seen here.

The mean BSAF from these data (after excluding T-7) is 0.95, which yields a cleanup level of 2.7 ppm, TOC. This value is very close to the Tier I value of 3.3 ppm, TOC.

Another potentially useful tool for analyzing this data set is regression analysis. Sediment and clam tissue concentrations were plotted to determine if a linear relationship could be seen. In general, regression methods can be applied to any data set that consists of paired observations of contaminant concentrations in sediment and tissue. However, in this case, no statistically significant relationship was seen to relate the clam tissue levels to the sediment concentrations. The same factors listed above in relation to the BSAF could cause the lack of significant relationship in the clam and sediment data. For example, if the clam concentrations vary due to variations in lipid levels, lack of lipid data could have a significant impact on the results of the regression analysis.

If the data showed a statistically significant linear relationship between the sediment and tissue levels, then the regression analysis could have been used to develop a sediment cleanup level.

4.5.3 Tier II: Comparison of Measured Clam Tissue Levels to Target Tissue Levels

Since the primary route of exposure to HPAHs is via ingestion of contaminated shellfish, Ecology evaluated an approach that relies on tissue levels measured at the site to make cleanup decisions.

In the ROD, EPA reported the following total HPAH tissue concentrations corresponding to an estimated excess cancer risk of 10^{-4} (which is the highest risk level EPA allows before requiring remedial action under Superfund):

- 15 ppb in fish, and
- 60 ppb in shellfish.

Using different input parameters (such as a risk level of 10^{-5} and average Tribal consumption rates from Toy, et. al. (1996)) the target tissue levels calculated by Ecology for development of HHCSL are slightly lower than EPA's:

- 6.0 ppb in fish
- 13 ppb in shellfish.

This value of 13 ppb for shellfish was compared to EPA clam tissue data, converted to TEF concentrations. Table 4.7 lists concentrations of carcinogenic HPAHs in clams calculated according to the TEF approach.

Table 4.7 Average Carcinogenic HPAHs in Clam Tissue from Intertidal Areas of Eagle Harbor

Transect	**TEF Concentration (ppb, wet weight)**
T-1 (background)	2.8
T-2 (background)	5.86
T-3 (background)	**20**
T-14 (background)	**15.5**
T-15 (background)	13
T-16 (background)	9.4
Background Average	11
T-4	**15.6**
T-5	**22**
T-6	**30**
T-7	11
T-8	**60 ***
T-9	7.36
T-10	**172.6 ***
T-11	NC
T-12	**58.6**
T-13	**37.6**
Average TEF	46.1

Based on 1988 data, calculated from Table 4-6 of HHRA

NOTE: *The numbers in* ***bold*** *exceed Ecology's target tissue level of 13 ppb. The values marked with an asterisk (*) are the ones that are at or above EPA's target tissue level of 60 ppb for shellfish. There is some question as to whether these "background" concentrations are truly representative of concentrations from an uncontaminated area, given their proximity to the site.*

When these values are compared to EPA's shellfish tissue screening level of 60 ppb, only two of the transect results are at or above this level (see *). However, using Ecology's lower value of 0.013 ppm, Transects 3, 4, 5, 6, 8, 10, 12, 13 and 14 would exceed the target tissue level. These stations correspond to sediment stations where the sediment chemistry exceeds HHCSL, with the exception of transect 5.

Figure 4.2 shows the location of these clam transects (the clam transects correspond to the sediment sampling locations). A comparison of the clam exceedence areas to the sediment exceedence areas for PAHs shows that generally, the clams exceed the target tissue level in areas where the intertidal sediments exceed the HHCSL of 3.3 ppm, TOC. Given this finding, one approach for use of these clam data for cleanup decision-making is to require that the sediments represented by the transects that exceed the target tissue level be included in the cleanup area.

Under this scenario, the area of concern would be approximately the same as the area previously defined as exceeding the CSL for PAHs in the intertidal areas (about 27 acres).

4.5.4 Summary of Findings for HPAH HHCSLs

Ecology evaluated four approaches for calculating a HHCSL for HPAHs at Eagle Harbor and compared these to EPA's approach. These results are summarized in Table 4.8 below.

Table 4.8 Areas of Concern for Various Approaches for HPAHs (intertidal areas only)

Approach	Cleanup Level (ppm, TOC)	Remedial Action Level (ppm, TOC)	Area of Concern* (acres)	Active Remediation Area (acres)
EPA Approach	40	none	13.6	none
Tier I	3.3	??	27	??
Tier II Approaches: • BSAF approach (range)	0.73 - 39	??	13 - 30	??
• BSAF approach (mean)	2.9	??	~27	??
• Tissue-based approach	??	??	~27	??

Area estimates are for the entire harbor.

"??" indicates that an action level and/or an area could not be determined given the available data and due to all the variables that affect the determination of Remedial Action Levels and related areas.

The results of these analyses show that there is a relatively small difference (a factor of 2) in the area of concern between the four approaches described above. All of Ecology's approaches result in areas of concern that exceed the area identified by EPA. However, it is worth noting that the area defined by EPA is close to the area defined by the highest HHCSL in the Tier II approach. In addition, the area estimates are expected to be overestimates because they do not account for areas that also exceed the mercury cleanup level.

5.0 Conclusions

The Eagle Harbor case study provided an opportunity to demonstrate options for Tier II, using tissue chemistry to calculate site-specific BSAFs. The site is large and fairly complex and involves two human health chemicals of concern. Several technical and policy issues were identified and are described in more detail below.

5.1 Mercury Bioaccumulation

Mercury bioaccumulation presents a potential risk to human health at several sites in Puget Sound. Since mercury is of human health concern, there is a need to quantify the relationship between tissue and sediment concentrations so that health-protective cleanup decisions can be made. This case study illustrates some options for developing cleanup levels for compounds such as mercury for which no default Tier I HHSQC can currently be determined.

Ecology reviewed the available literature for sources of data on tissue and sediment mercury concentrations from both within and outside Puget Sound that could be used to estimate a default BSAF. Data from four sources were used to calculate BSAFs, which were then used to calculate HHCSLs. The results showed a fairly small range of HHCSL values -- from 0.84 to 1.4 ppm, dry weight.

In addition, Ecology used data collected at Eagle Harbor to calculate a site-specific BSAF. The mercury HHCSL that resulted with this BSAF was 0.61 ppm, slightly lower than the range of HHCSLs calculated from the literature data.

EPA chose its cleanup levels at Eagle Harbor without attempting to quantify the relationship between sediment and tissue concentrations. Instead, they relied on tissue data from the site to show that the human health risk from consumption of mercury-contaminated fish was below a level of concern. However, due to conflicting results from other EPA data sets that showed higher risks, EPA is requiring institutional controls and continued monitoring of tissue in the area to ensure protection of human health.

5.2 Use of Tissue Data to Make Cleanup Decisions

As previously described, Ecology's proposed construct for human health criteria relies on a tiered approach, with "Tier I" representing an initial evaluation to determine if sediment chemical concentrations pose a significant human health risk. Additional, site-specific analysis would then be available ("Tier II") to verify the results of the Tier I analysis. Tier I criteria values are calculated by determining an "acceptable" level in fish consumed by people and then dividing that value by a BSAF to "back-calculate" a sediment concentration that will ensure that fish tissue level is not exceeded.

Tissue data may be useful in a Tier II assessment, to further refine the assumptions about the bioaccumulation potential of the chemicals of concern. Tissue chemistry data can be used in conjunction with sediment chemistry data to develop a site-specific BSAF, which can then be used to develop a site-specific, health-based cleanup level. Tissue and sediment data from other sites in Puget Sound may also be useful for calculating a site-specific cleanup level, particularly when the physical, biological and chemical characteristics of the sites are similar.

In order to calculate a site-specific BSAF, there are certain data requirements that site managers need to consider when planning a sampling effort. For example, at Eagle Harbor, no lipid data was collected for the clams that were collected and analyzed for HPAHs and mercury. The lack of lipid data complicated efforts to calculate an accurate site-specific BSAF.

Tissue data may also be used in a more direct manner to make cleanup decisions. For example, when shellfish are the species of concern, tissue data may be used to identify which intertidal areas to target for active remediation. In most cases, however, it will be necessary to use the tissue data to calculate a health-based sediment concentration so that decisions can be made about the extent of sediment remediation.

5.3 HPAHs in Fish vs. Shellfish

It is generally assumed that finfish can metabolize PAHs and therefore do not need to be considered when assessing human health risk from PAH contaminated sediments. Using this assumption, Ecology's preliminary Tier I HHSQC for HPAHs is based on shellfish consumption only. However, at Eagle Harbor, measurable levels of HPAHs were found in finfish at the site, indicating that consideration of finfish may be necessary in some cases where HPAHs are of concern.

One potential explanation for these high levels in finfish could be the presence of free-phase petroleum continually seeping out of the site at the time the finfish tissue levels were measured, and that once that source is controlled, the PAH levels in the fish would drop off significantly (personal communication with Teresa Michelsen, 1996).

EPA applied the human health-based cleanup standard for PAHs only in the intertidal areas where shellfish are harvested. For Tier I HHSQC for PAHs, it may be reasonable to use a shellfish consumption rate in most situations; however, if there is a potential for finfish contamination due to ongoing sources, for example, Ecology will need to consider that exposure pathway in setting cleanup levels.

5.4 The TEF Approach for PAHs

EPA's approach at Eagle Harbor was to assume that all PAHs were as carcinogenic as benzo(a)pyrene. Since several PAHs have been shown to be less carcinogenic than benzo(a)pyrene in animal studies, that approach has the potential to overestimate human health risk. Use of the toxicity equivalence factors (TEF) approach would result in fewer stations exceeding HHSQC than the approach used by EPA (all else being equal).

Ecology's draft approach relies on TEFs to calculate exceedences of HHSQC for seven carcinogenic HPAHs. Each carcinogenic PAH is assigned a TEF that relates its toxicity to benzo(a)pyrene. EPA has recommended TEFs for these seven HPAHs (including benzo(a)pyrene) (EPA, 1993). There is still debate about how to incorporate toxicity data for many other PAHs. As new scientific data becomes available on this front, Ecology will incorporate that information as appropriate.

Ecology's Risk Assessment Forum (RAF) has been reviewing the existing methods and issues surrounding TEFs for PAHs and is developing a position paper that is currently undergoing internal review (Delistraty, 1996). In the interim, the Sediment Management Unit will rely on EPA's approach and focus on the seven HPAHs identified by EPA.

5.5 Use of Background/Reference Areas

In the HHRA, EPA compared shellfish and intertidal sediment concentrations for several chemicals of concern to Puget Sound background concentrations (as defined by PTI, 1989). EPA also relied on those reference area concentrations in selecting the cleanup level for intertidal HPAHs. As a result, EPA selected the 90th percentile reference area performance standard-based HPAH concentration of 1,200 ppb, dry weight as the cleanup level. The reference area performance standards were later refined and the revised standard for HPAHs was reduced to 330 ppb, dry weight (PSEP, 1991).

Instead of relying on reference area performance standards to make decisions about human health, Ecology calculated Puget Sound wide background concentrations for the chemicals of concern that are detected in reference areas (PTI, 1995; DOH 1995). The background levels are based strictly on chemistry results, unlike the previously calculated performance standards, which were based on effects on benthic communities.

For HPAHs, the 90th percentile reference area concentrations are generally lower than the preliminary HHCSL of 3.3 ppm, TOC (PTI, 1995). Therefore Ecology is basing its HHCSL on the risk-based value.

5.6 Institutional Controls and Natural Recovery

In the intertidal areas that exceeded the health-based cleanup level for HPAHs, EPA selected natural recovery and institutional controls as the remedy. However, they also included a requirement for contingency actions to deal with future problems if predictions about natural recovery turn out to be incorrect.

The SMS rule allows the use of institutional controls as a cleanup action alternative. The rule states that in evaluating cleanup action alternatives, the department shall consider:

- the net environmental effects of the alternatives,
- the relative cost of the alternatives, and
- the technical feasibility of the alternatives.

In addition, it is also necessary to consider treaty rights, protection of a fishery and environmental justice issues when considering use of institutional controls. The decision as to whether, when or how to allow the use of institutional controls where there are human health risks will depend on the factors listed above and will be based on site-specific considerations.

At Eagle Harbor, EPA relied on institutional controls and natural recovery for portions of the cleanup. However, these were interim measures and compliance was contingent on the demonstration that cleanup levels would be met after 10 years. EPA retained the right to require additional remedial actions if future sediment test results show levels of concern. This approach is reasonable and is included in Ecology's Preliminary Implementation Strategy for HHSQC.

6.0 Technical Appendix: Literature-based Default BSAF Approach for Mercury

Three studies from the literature and another site-specific approach are described below. They are described in order of increasing confidence in the applicability of the data to the Eagle Harbor site. **It should be noted that these calculations are subject to a high degree of uncertainty and are not expected to be used to develop a HHSQC for adoption in the Sediment Management Standards. The calculations are presented here for this case study as a point of comparison with the other approaches being considered and to show the potential range of HHCSLs for mercury.**

In the aquatic environment, bacteria and some algae methylate inorganic mercury. In fish tissue, a very high percentage of mercury is in the toxic form of methylmercury (Windom and Kendall, 1979; Bloom, 1992). Due to the difficulty of distinguishing methylmercury from total mercury, and the high percentage of methylmercury, the BSAF calculations shown below are based on concentrations of total mercury in the sediment and in tissue.

The term "BSAF" is generally defined as the ratio of the tissue contaminant concentration (normalized to lipid content) to the sediment contaminant concentration (normalized to organic carbon). However, due to a lack of a better term, "BSAF" is used herein even though it does not conform with the definition, as the mercury BSAF is not based on TOC-or lipid - normalized data. Ecology is interested in receiving input on an alternative term that can be used to describe the ratio of tissue contaminant concentration to sediment contaminant concentration for polar compounds that do not partition heavily in the lipid and/or organic carbon fraction of tissue and sediment, respectively.

Mikac, et. al. (1985)

Mikac, et. al (1985) reported mercury and methylmercury levels in sediments, mussels and a variety of finfish species from the Adriatic Sea. Using the mercury data reported by Mikac, et. al., Ecology calculated a mean BSAF of 0.124 (in units of mg of mercury per kg of finfish tissue (wet weight)/mg of mercury per kg of sediment (dry weight)).[7]

Using this BSAF of 0.124 and a target tissue level of 0.17 ppm (based on the most recent EPA RfD of 0.0001 mg/kg-day and a consumption rate of 42 grams/day), the HHCSL is calculated as follows:

[7] Mikac, et. al. reported sediment concentrations in terms of wet weight. In order to convert these data to a dry weight basis, Ecology calculated a dry/wet ratio for the data so that the HHCSL would be reported on a dry weight basis.

$$HHCSL = \frac{\text{0.17 mg mercury/kg tissue, wet weight}}{0.124} = 1.4 \text{ ppm Hg}$$

Thomann, et. al. (1995)

Thomann, et.al. (1995) calculated BSAFs for metals in two species of bivalves, using NOAA Mussel Watch data. The mean BSAFs for mercury ranged from 1.39 to 2.9 (measured as ug bivalve metal/g (dry)/ug sediment metal/g (dry)). The median BSAFs reported were 1.6 and 0.74.

Using Thomann's data set, a default mercury HHCSL can be calculated. The authors report that the mercury BSAF is about 1.0. However, this value is reported in terms of a dry tissue weight and must be converted to a wet weight basis to correspond to the TTL, which is in units of wet weight. EPA reports that blue mussels are about 80% moisture (and therefore, 20% dry weight) (EPA, 1996).

Using these values, and a target tissue level of 0.17 ppm, the HHCSL is calculated as follows:

$$HHCSL = \frac{\text{0.17 mg mercury/kg tissue, wet weight}}{1.0 \times 0.20} = 0.85 \text{ ppm Hg}$$

Whatcom Waterway Approach (1997)

A site-specific HHCSL for mercury was calculated for the Whatcom Waterway site in Bellingham Bay. Tissue levels measured in: (1) Dungeness crabs, (2) English sole and (3) clams and mussels from Bellingham Bay and other locations in Puget Sound were plotted against area-weighted sediment levels, yielding three regression equations for each of the above species. The regression for male Dungeness crabs (n = 12), all of which were collected in Bellingham Bay, was the most significant and was the driver for establishing a cleanup level.

The form and terms of the regression equation calculated for the crabs in Bellingham Bay was as follows:

$$T = (m)(S) + b$$

where:

T = target tissue level

m = slope of regression line (0.116)
S = sediment concentration
b = y-intercept (0.047)

Solving for S and using a target tissue level of 0.17 ppm:

$$S = \frac{0.17 - 0.047}{0.116} = 1.06 \text{ mg/kg Hg}$$

O'Neill, et. al. (1997)

The Puget Sound Ambient Monitoring Program (PSAMP) has collected fish tissue in urban and non-urban bays throughout Puget Sound and analyzed for a number of chemicals, including mercury. PSAMP analyzed the tissue concentrations in conjunction with sediment concentrations and other variables, such as fish age, to determine how these factors were related (O'Neill, et. al., 1997).

Using multiple regression analysis, O'Neill, et. al. (1997) determined that mercury in English sole liver tissue was positively correlated with mercury concentration in sediment and with fish age. They also found very little difference between mercury levels in liver tissue as compared to muscle tissue.

The following formula was reported to represent the relationship of these three variables:

$$[Hg] = 0.0131\,(MCA) + 0.0958([HgSed]) - 0.0155$$

where:

[Hg] = mercury concentration in English sole liver (mg/kg wet wt.)
MCA = mean composite fish age (yrs)
HgSed = mean concentration of mercury in nearby sediments (mg/kg, dry wt)

This formula can be re-arranged as follows to solve for a mercury sediment concentration:

$$[HgSed] = \frac{[Hg] - 0.0131(MCA) + 0.0155}{0.0958}$$

Using this formula, one can solve for a target mercury concentration given a target tissue concentration and mean fish age. Using the target tissue level of 0.17 ppm and a mean fish age of 8 years, the resulting sediment concentration is:

$$HHCSL = \frac{0.17 - 0.1048 + 0.0155}{0.0958} = 0.84 \text{ ppm Hg}$$

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Appendix A: Basis for Human Health Sediment Quality Criteria

1.0 Introduction

Human health sediment quality criteria (HHSQC) are based on standard risk assessment methodologies in conjunction with empirically-derived biota-sediment accumulation factors (BSAFs). The formulas and assumptions used to calculate the criteria are outlined below. Technical development of the criteria is described in more detail in the Department of Health's Tier I Report (DOH, 1995).

Ecology's proposed construct for human health criteria relies on a tiered approach, with "Tier I" representing an initial evaluation to determine if sediment chemical concentrations pose a significant human health risk. Additional, site-specific analysis would then be available to develop "Tier II" criteria values based on site-specific information. The Department of Health has also completed a report describing the technical considerations for Tier II analysis (DOH, 1996). This two-tiered approach is conceptually similar to the current framework in the SMS rule and the DMMP/PSDDA Guidelines.

In addition to the tiered approach for decision-making, the SMS establishes two levels of criteria for protection of benthic organisms -- a "no effects" level that serves as the long-term goal for contaminant levels in sediments (the "Sediment Quality Standard"), and a "minor effects" level that is the maximum allowable level for sediment contamination (informally termed the "Regulatory Level"). Similarly, the Preliminary Implementation Strategy for HHSQC contains two sets of criteria, with the long-term goal (or "SQS") corresponding to a cancer risk of 1 in a million and the Regulatory Level ("RL") based on a risk of 1 in 100,000. For non-carcinogens, a Hazard Quotient of 1.0 is being used for both the SQS and RL.

2.0 Chemicals of Concern

In the Tier I Report, DOH grouped about 200 chemicals of concern into three categories, Groups 1, 2 and 3 (DOH, 1995). Ecology is focusing on Group 1 chemicals, which have all been detected in Puget Sound sediments, have a log K_{ow} greater than 3.5 (and therefore are considered bioaccumulative) and have a toxicity value defined by EPA. Of the 47 chemicals identified as Group 1 chemicals, Ecology has developed technically-defensible HHSQC for the following 14 organic compounds:

DDD	benzo(a)pyrene
DDE	benzo(a)anthracene
DDT	benzo(b)fluoranthene
hexachlorobenzene	benzo(k)fluoranthene
hexachlorobutadiene	chrysene
PCBs	dibenzo(a,h)anthracene
dioxins/furans	indeno(1,2,3-cd)pyrene

Ecology is currently focusing its efforts on developing HHSQC for this group of compounds because: (1) they are generally persistent, bioaccumulative and toxic chemicals of highest concern in sediments, and (2) these are the chemicals for which our confidence in the toxicity values and bioaccumulation factors is the highest. After grouping DDT and its metabolites and all seven HPAHs (listed in the right-hand column above) into two separate chemical groups, there are six organic chemicals or chemical groups for which the agency has developed HHSQC.

For two chemical groups (PAHs and dioxins/furans), sediment chemistry results are compared to the sediment criteria by summing chemicals within each group. The use of toxicity equivalence factors (TEFs) for these two chemical groups allows scientific evidence about the cancer potency of individual compounds to be taken into account in the calculation of human health risk (see discussion below for more details on the use of TEFs). For PCBs, criterion is being calculated for total PCBs, based primarily on the most toxic and bioaccumulative aroclor (Aroclor 1260).

Ecology compared preliminary HHSQC to ecological criteria currently in the SMS for all of the Group 1 chemicals of concern and found that existing ecological criteria tend to be lower than the human health values for the non-carcinogenic compounds evaluated. This is consistent with findings by others (Parkerton, et. al., 1993). Therefore, Ecology is not proposing to develop criteria for these compounds, as it is assumed that human health will be protected by implementation of existing ecological criteria.

There are several Group 1 chemicals of concern for which chemical-specific BSAFs could not be calculated given the current state of the knowledge. Nonetheless, these compounds tend to be of human health concern at levels lower than existing ecological criteria (Parkerton, 1993; PTI, 1995b) and are therefore of concern to Ecology when making decisions about contaminated sediments. These compounds include:

aldrin	arsenic
bis(2-ethylhexyl)phthalate	cadmium
pentachlorophenol	chromium (VI)
	mercury
	tributyltin

These and other compounds that may pose a human health risk will continue to be evaluated on a case-by-case basis to ensure protection of human health.

3.0 Key Assumptions for Criteria Development

HHSQC[8] for carcinogenic compounds are calculated according to the following formula:

$$HHSQC = \frac{R * BW * AT * UCF}{CPF * ED * IR * BSAF * FL}$$

For non-carcinogens, the formula is:

$$HHSQC = \frac{RfD * BW * UCF}{IR * BSAF * FL}$$

where:

R = risk level of 10^{-6} for SQS (and 10^{-5} risk level for RL)
BW = adult body weight of 70 kg
AT = averaging time of 75 years
UCF = unit conversion factor of 1,000 grams/kg
CPF = chemical-specific cancer potency factor as defined by EPA (IRIS)
RfD = chemical-specific reference dose as defined by EPA (IRIS)
ED = exposure duration of 30 years
IR = fish ingestion rate of 42 grams/day or shellfish ingestion rate of 19 grams/day
BSAF = chemical-specific biota-sediment accumulation factor
FL = fish lipid of 3% or shellfish lipid of 1%

Each of the above input parameters is discussed below. They are also discussed in more detail in the DOH Tier I and Tier II reports (DOH, 1995; DOH 1996).

3.1 Risk Level

Consistent with other Ecology rules, preliminary HHSQC are based on risk levels of 10^{-6} (1 in a million) and 10^{-5} (1 in a 100,000). The lower SQS value is based on the lower risk level of 10^{-6} and the Regulatory Limit (RL) is based on the higher risk level of 10^{-5}. The RLs for cleanup decision-making are known as the cleanup screening level (CSL) and the minimum cleanup level (MCULs). The terms CSL and MCUL are used interchangeably in the case studies.

Choice of a risk level is a policy decision. Most regulatory programs in the U.S. regulate carcinogens at risk levels that range from 10^{-4} to 10^{-6}. For example, the National Contingency Plan (40 CFR Part 300) directs EPA to select cleanup levels within a cancer risk range of 10^{-4} to 10^{-6}. The Department of Ecology implements several rules that are designed to protect

[8] The term "HHSQC" is used throughout this report to indicate either the lower health-based Sediment Quality Standard (HHSQS) or the higher health-based Cleanup Screening Level/Minimum Cleanup Level (HHCSL/HHMCUL).

humans from unacceptable cancer risk from pollutants. The Model Toxics Control Act (MTCA) sets cleanup standards for contaminated sites that range from 10^{-5} to 10^{-6} (Chapter 173-240 WAC). The Water Quality Program implements the National Toxics Rule (EPA, 1992b) which sets water quality criteria for the protection of human health at a risk level of 10^{-6}. In addition, the Puget Sound Dredged Disposal Analysis (PSDDA) Program uses a 10^{-5} risk level to calculate their target tissue levels (PSDDA, 1988).

3.2 Body Weight

A standard adult body weight of 70 kg (about 150 lbs) is used. This is consistent with other Ecology programs and EPA guidance (EPA, 1989a).

3.3 Averaging Time

Averaging time represents average life expectancy. This is set at 75 years and is consistent with MTCA. EPA guidance currently uses a 70 year averaging time (EPA, 1989a).

3.4 Exposure Duration

Exposure duration represents the amount of time an individual is likely to be exposed to a contaminant. In the case of an individual fisher, the exposure duration is the time interval over which he or she catches and consumes fish. To be consistent with MTCA, the draft approach is based on a 30 year exposure duration for carcinogens (for non-carcinogens, exposure duration is set equal to averaging time). This value represents the upper bound (90^{th} percentile) estimate of the number of years spent by an individual at a single residence and is consistent with EPA guidance on the issue (EPA, 1989a).

3.5 Cancer potency factors and reference doses

USEPA publishes cancer potency factors (CPFs) and Reference Doses (RfDs) on the Integrated Risk Information System (IRIS). A Reference Dose is the dose of a given contaminant below which no adverse noncancer health effects are expected to occur. A Cancer Potency Factor represents a dose-response relationship and is defined as “a plausible upper bound estimate of the probability of a response per unit intake of a chemical over a lifetime” (EPA, 1989) Ecology relies on IRIS (and sometimes HEAST) for these toxicity factors. The proposed HHSQC are based primarily on toxicity values from IRIS.

3.6 Fish Consumption Rate

Ecology’s Risk Assessment Forum (RAF) has reviewed fish consumption studies relevant to Washington State and is developing a final recommendation on a fish consumption rate for use by Ecology’s regulatory programs (Keill, et. al., 1997). For the purposes of the case studies, Ecology used the mean fish ingestion rate of 42 grams/day (and 19 grams/day for shellfish consumption), based on a survey of fish consumption among members of two Puget Sound tribes (Toy, et.al., 1996) Currently, MTCA uses a fish consumption rate of 54 grams/day in conjunction with a diet fraction of 0.5. These values are expected to change somewhat as a result of the RAF recommendations.

3.7 Biota-Sediment Accumulation Factor (BSAF)

BSAFs quantitatively measure the transfer of bioaccumulative compounds from sediments to fish and/or shellfish. By definition, a BSAF is the ratio of the tissue contaminant concentration (normalized to lipid content) to the sediment contaminant concentration (normalized to organic carbon). From a regulatory perspective, BSAFs are the least well-established of all the input parameters used to calculate HHSQC. As a result, Ecology has put the greatest effort into ensuring that default BSAF values are technically sound.

DOH compiled and analyzed BSAFs from several sources to develop recommended BSAFs for the Department of Ecology (DOE) to use in its development of HHSQC (DOH, 1995). Several large databases were identified in the peer-reviewed and gray literature (i.e: non-peer-reviewed), including BSAF values from Parkerton (1991), Corps of Engineers (COBIAA, 1992) and EPA's Great Lakes Water Quality Initiative (EPA, 1994a) (as cited in DOH, 1995).

After collating the data, DOH organized a combined database to allow for data analysis and querying. Over 1,200 data points were identified for fish from several trophic levels, with a focus on forage and piscivorous fish species (DOH, 1995). Most of the BSAF data points are from the field (as opposed to laboratory-derived) and are based primarily on data collected for resident fish, both bottom-feeders and predators (most data points for finfish are for saltwater "flounder" and freshwater "pike"). The chemicals were primarily non-polar organic chemicals, such as PCBs, dioxins and furans and a variety of other compounds.

The outcome of this data compilation and analysis was a set of recommended BSAFs categorized by chemical class and log K_{ow}.[9] DOH recommended the use of the 75th percentile BSAF value. The same data set collected and analyzed by DOH was subject to additional analysis by PTI Environmental Services for Ecology (PTI, 1995). PTI used linear and non-linear multiple regression analysis to investigate the effects of chemical-specific and species-specific characteristics on BSAF values and to estimate BSAF values.

Based on the results of the overall model, PTI developed separate BSAF calculation equations for different chemical classes, feeding types and taxonomic groups. A variety of upper confidence limits were calculated for these prediction equations. Regressions were found to be statistically significant for PCBs and dioxins in finfish and for PAHs and PCBs in shellfish. The R^2 values ranged from 0.70 for dioxins to 0.058 for PAHs.

Ecology is using the BSAF values in Table 1 to calculate preliminary HHSQC. These BSAFs are reported in PTI's 1995 report entitled "*Analysis of BSAF Values for Nonpolar Organic*

[9] K_{ow} represents the octanol/water partition coefficient. It is the ratio, at equilibrium, of the concentration of a substance in the octanol phase to its concentration in the aqueous phase in a 2-phase n-octanol/water system. The partition coefficient (log K_{ow}) is the log ratio of a chemicals concentration in the two solvents at equilibrium. Octanol, a non-polar molecule, is used as a surrogate for lipids or organic carbon.

Compounds in Finfish and Shellfish." For dioxins/furans, PCBs and HPAHs, a K_{ow} that best represents the chemical or chemical class was defined (for PCBs, Aroclor 1260 was used to define the K_{ow} range). Within that K_{ow} range, the BSAF value corresponding to the 90th upper confidence limit on the mean was chosen. Use of an upper confidence limit on a mean value is consistent with the approach used by other Ecology programs (e.g: Toxics Cleanup Program) and with EPA guidance (EPA, 1992).

Table 1. Biota-Sediment Accumulation Factors used to Calculate Preliminary HHSQC

Chemical or Chemical Class	BSAF
DDT and metabolites	13.5
Dioxins/furans	1.0
Hexachlorobenzene	0.057
Hexachlorobutadiene	0.16
HPAHs	0.38
PCBs	2.6

3.8 Fish lipid

DOH calculated a weighted average lipid concentration of 3.5% based on fish species most commonly consumed (as reported by Landolt, et. al., 1985). In addition, Ecology reviewed the species of fish reported eaten in the Tulalip and Squaxin Island Tribes Fish Consumption Survey (Toy, 1996) and calculated an average lipid of 3% for finfish. Since the fish consumption rates are based on the Squaxin/Tulalip Survey, a lipid concentration of 3% is proposed. For criteria values based on shellfish consumption, a lipid of 1% is used (EPA, 1996).

4.0 Use of Background Concentrations to Set Cleanup Levels

The Sediment Management Standards includes the consideration of reference area background concentrations in determining cleanup levels for ecological protection. The Preliminary Implementation Strategy for HHSQC incorporates a similar approach. The DOH and Ecology have established background levels for some human health chemicals of concern, such as PCBs and PAHs. For other chemicals, such as dioxins and DDT (and metabolites), no background level is established since these compounds are rarely detected in sediments in Puget Sound reference areas (DOH, 1995).

Of the six chemicals or chemical classes listed in Table 1, there are only two (PCBs and HPAHs) for which detectable levels in reference areas allow for a determination of a Puget Sound-wide background level. DOH calculated background concentrations based on data from nine locations throughout Puget Sound, for compounds that were detected 10 or more times. The results are reported in the Tier I Report (DOH, 1995), and include levels primarily for PAHs. PTI also calculated reference area background concentrations for Ecology using data from five locations (Carr Inlet, Dabob Bay, Holmes Harbor, Samish Bay and Sequim Bay).

PTI's values were lower than those calculated by DOH in the Tier I Report (DOH, 1995). The difference in the PTI vs. DOH reference area concentrations was driven by the inclusion of Navy Manchester site data by DOH, which was excluded by PTI. Since the Navy data show significantly elevated levels of PAHs as compared to other background levels, and sediments sampled near a potentially contaminanted site do not meet the definition of "background," Ecology judged the Manchester data as inappropriate for inclusion in the data set. The following table shows the results from PTI's analysis:

Table 2. Puget Sound Reference Area Concentrations (ppm, TOC)

Chemical	**Minimum**	**Maximum**	**Median**	**90^{th} percentile**
Total PCBs	0.19	1.8	1.1	1.2
Benzo(a)pyrene	0.2	46	0.75	2.9
Benzo(a)anthracene	0.3	43	1.2	5.6
Chrysene	0.5	64	1.7	7.0
Dibenzo(a,h)anthracene	0.08	0.7	0.36	0.58
Indeno(1,2,3-cd)pyrene	0.5	2.3	0.83	1.5

The PCB concentrations are based on a total of 60 PCB measurements in Puget Sound reference areas. However, only six of these data points include a PCB level that is above the limit of detection, with accompanying sample-specific TOC data. PTI analyzed the data using six different statistical approaches. Their recommended approach included a statistical analysis of 26 data points (a combination of detected and undetected data). The 90th percentile PCB concentration for those 26 values is 1.2 ppm, TOC.

The Preliminary Implementation Strategy uses the 90^{th} percentile reference area background level of 1.2 ppm, TOC as the HHCSL for PCBs since the risk-based criteria is lower than background and would therefore pose difficult implementation problems. However, Ecology is proposing to retain the lower, risk-based value of 260 ppb, TOC as the SQS for PCBs, since the goal for cleanup is based on no significant risk to human health. Using the exposure parameters listed above (Section 3.0), the background level corresponds to a risk level of approximately 4.5 in 100,000.

For HPAHs, the 90^{th} percentile levels calculated by PTI are below the preliminary HHSQC for HPAHs, so it is not necessary to default to the background levels for setting criteria.

5.0 Toxicity Equivalency Factor Approach: Description and Rationale

Ecology is proposing to use toxicity equivalency factor (TEF) approach to develop and implement HHSQC for high molecular weight polycyclic aromatic hydrocarbons (HPAHs) and polychlorinated dibenzodioxins and furans (dioxins/furans). By using this approach, the cancer potency of a chemical can be estimated based on its relative potency to a reference compound within the same class of compounds. TEFs have been developed by U.S. EPA for both of these chemical classes and are generally used to assess human health risks associated with exposures to complex mixtures (Sweeney, 1993; EPA, 1994).

There are currently seven HPAHs for which EPA has recommended TEF values (Sweeney, 1993). EPA and Ecology have often assumed that all carcinogenic PAHs are equally as potent as benzo(a)pyrene (B(a)P). This can lead to an overestimation of toxicity, as some PAHs have been shown to be less carcinogenic in animal studies than B(a)P (EPA, 1993).

Ecology's Risk Assessment Forum (RAF) has been reviewing the existing methods and issues surrounding TEFs for PAHs and is developing a position paper that is currently undergoing internal review (Delistraty, 1996). In that paper, Ecology is considering recommending the application of California's approach for TEFs for PAHs, which provides TEFs for 25 HPAHs. If this approach is adopted, it is likely to affect the number of analytes tested for in sediment samples. In the interim, the Preliminary Implementation Strategy will rely on EPA's approach and focus on the seven HPAHs identified by EPA.

For dioxins/furans, EPA has adopted a set of TEFs as an interim procedure for assessing the risks associated with exposures to complex mixtures of dioxins and furans (EPA, 1994). Ecology has used this method in previous analyses (Johnson, et. al., 1991) and proposes its use for implementation of HHSQC. In addition, if PCB congeners are collected in a Tier II analysis, TEFs for dioxin-like PCBs may be used.

6.0 Consideration of Tissue Data in Tier II Analysis

The attached Preliminary Implementation Strategy includes provisions for tissue testing as part of a Tier II analysis. Since HHSQC are based on human exposure to bioaccumulative chemical contaminants via consumption of fish or shellfish, it is necessary to calculate an "acceptable" contaminant level in tissue, in order to derive a health-based sediment criteria. In fact, tissue data played an important role in the decision-making process in several of the Case Studies.

Tissue data can provide valuable information at a cleanup site. The data can be used in conjunction with sediment data to calculate a site-specific BSAF, which allows for determination of a site-specific cleanup standard. In addition, tissue data can be used to confirm human health risks associated with certain sediments. Tissue data has its limitations, however. It is not useful, by itself, for establishing a sediment cleanup level or defining a cleanup area. In addition, there are uncertainties associated with factors such as fish movement and home range that need to be managed appropriately.

Ecology has studied this issue previously. For a more thorough examination of the issues related to use of fish tissue data, see "Regulatory Options: Use of Fish Tissue Criteria" by James Male (Male, 1994). Additional discussion of how to best incorporate tissue data into the cleanup decision-making process may be warranted.

7.0 Accounting for Cumulative and/or Additive risks

Cleanups conducted under MTCA are required to account for exposure to multiple contaminants and/or exposure resulting from more than one pathway of exposure. While Ecology strives for consistency between MTCA and the SMS wherever possible, Ecology preliminary Tier I criteria are based on risk due to individual chemicals and from exposure via fish/shellfish consumption only (i.e.: dermal exposures are not quantified and added as a route of exposure in the calculation of Tier I criteria). For Tier I, this approach is simpler and is not likely to result in significant underestimates of risk since the number of human health chemicals of concern at any given sediment site is generally limited. However, site-specific, Tier II decisions may be based on risk analyses that account for multiple chemical exposures and/or multiple pathways of exposure.

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Appendix B: Preliminary Implementation Strategy for Human Health Sediment Criteria

1.0 Marine Sediment Human Health Criteria

The chemical concentrations in Table I establish the Tier I marine sediment quality standards human health chemical criteria (HHSQS) for designation of sediments. Tier I human health criteria are based on default input parameters that are designed to provide an acceptable level of protection for a reasonably maximum exposed individual consuming fish from Puget Sound. More specifically, the criteria correspond to sediment quality that will result in no significant health risk (cancer risk = 1 in a million and non-cancer risk determined by a hazard quotient less than or equal to one) to humans who eat an average of 42 grams of finfish/day (or 19 grams/day of shellfish for HPAH criteria).

1.1 Confirmatory Designation

Monitoring the accumulation of toxic substances in tissues of fish and/or shellfish consumed by humans is useful for confirming assumptions about bioaccumulation and risk to human health. Any person or the department may confirm the designation of sediments which have either passed or failed initial designation procedures by using the applicable fish tissue testing procedure outlined below. Tissue data may be used to calculate a site-specific BSAF, as described below. Sediments that pass these confirmatory tests are designated as passing the applicable human health sediment management standards.

1.2 Calculation of Site-Specific HHSQC

A site-specific biota-sediment accumulation factor (BSAF) may be calculated using sediment and tissue data collected at the site. A site-specific BSAF should be based on synoptic sediment chemistry and fish tissue data (e.g.: data sets sampled within 5 years of each other). The temporal relationship between the sediment and fish/shellfish tissue depends on the persistence and half-life of the chemical(s) of interest and the type of fish and/or shellfish.

More specifically, the site-specific HHSQC is calculated based on determination of a site-specific BSAF using the following procedure:

(a) For non-polar, organic compounds, the site-specific BSAF is the ratio of the average concentration of the chemical in the lipid fraction of the fish to the average concentration of the chemical in the organic carbon fraction of the sediment. For certain compounds, such as mercury, that do not partition in the lipid of the fish or the organic carbon fraction of the sediment, the BSAF is the ratio of the average concentration of the chemical in the edible portion of the fish (wet weight) to the average concentration of the chemical in the sediment (on a dry weight basis).

(b) A site-specific HHSQC may also be calculated using regression analysis. Regression methods may demonstrate a relationship between contaminant concentrations in tissue and sediment in a more robust manner than the BSAF based on a ratio (as described in section (a) above).

(c) To calculate a site-specific BSAF for compounds that pose a risk to humans via consumption of finfish, a surface area weighted average may be used to determine an average sediment concentration. The sediment area included in the calculation may be defined according to physical conditions or habitat features of the species of interest (such as grain size, water depth, etc) and/or based on the expected home range of the species of interest.

To calculate a surface area weighted average concentration in sediments, sum the products of each sediment concentration multiplied by the area represented by that concentration and divide the total by the total area of the site or operable unit, according to the following equation:

$$WC = \Sigma (SC_i * A_i) / TA$$

where:

WC= surface area weighted average sediment concentration

SC_i = Sediment concentration in an individual area

A_i = Area associated with each individual sediment concentration

TA = Total area of interest

A site-specific HHSQC is calculated by applying the site-specific BSAF to either Formulas (1) or (2), below, depending on the toxic endpoint of the chemical of concern, in conjunction with the default input parameters listed with the each formula.

For compounds that do not partition to fish lipid, the BSAF is defined in terms of fish tissue (not fish lipid), so the "% fish lipid" parameter is removed from the equation. In addition, if compounds do not partition in the organic carbon fraction of the sediment, then the BSAF may be defined according to the chemical concentration in the sediment on a dry weight basis.

At sites where shellfish are the species of interest, a site-specific BSAF should be calculated for the shellfish of interest. Surface area weighting should not be used for shellfish, since shellfish tend to be relatively stationary. Instead, synoptic sediment and tissue data should be used to generate a BSAF.

Formula (1): For carcinogenic chemicals

$$\text{HHSQC} = \frac{R * BW * AT * UCF}{CPF * ED * IR * BSAF * FL}$$

where:

HHSQC = Human Health Sediment Quality Criteria (mg chemical/kilogram sediment, TOC)

R = risk level of 1 in 1,000,000 for SQS or 1 in 100,000 for SIZ_{max}/HHCSL/HHMCUL

BW = 70 kg body weight

AT = averaging time of 75 years

UCF = unit conversion factor of 1,000 grams/kg

CPF = chemical specific cancer potency factor from IRIS

ED = exposure duration of 30 years

IR = ingestion rate of 42 grams/day for finfish and 19 grams/day for shellfish

FL = fish lipid of 3% for finfish and 1% for shellfish

BSAF = chemical-specific BSAF from Table I or based on a site-specific calculation

Formula (2): ***For non-carcinogenic chemicals***

$$\text{HHSQC} = \frac{RfD * BW * UCF}{IR * BSAF * FL}$$

where:

HHSQC = Human Health Sediment Quality Criteria (mg chemical/kilogram sediment, TOC)

RfD = chemical-specific reference dose as defined by EPA (IRIS)

BW= 70 kg body weight

UCF = unit conversion factor of 1,000 mg/kg

IR = ingestion rate of 42 grams/day for finfish and 19 grams/day for shellfish

FL = fish lipid of 3% for finfish and 1% for shellfish

BSAF = chemical-specific BSAF from Table I or based on a site-specific calculation

1.3 Fish Tissue Testing

Fish and/or shellfish tissue may be used to make regulatory decisions as described above. The decision about which fish is the appropriate species to use should be based on the following criteria:

- capable of accumulating toxic substances representative of the study area,
- abundant enough over time and space to allow adequate sampling,
- relevance to human uses (e.g: recreational, commercial, tribal and/or subsistence fishing),
- residence period,
- association with sediments,
- ability or inability to metabolize contaminants of concern,
- exposure to contaminants (i.e: feeding habits),
- size of home range relative to size of contaminated areas.

Tissue may be sampled specifically for the site or previously collected tissue may be used if the species meets the criteria above and is of adequate quality. In general, bottom-feeding fish (such as English sole) and/or shellfish should be used. Bottom-feeding fish with a limited range and/or shellfish will provide a more direct measure of exposure to contaminated sediments at the site of interest as compared to more migratory fish such as salmon which spend a smaller percentage of their life in one area. When both finfish and shellfish are sampled, a HHSQC should be calculated for each species separately.

Ecology will also consider the use of caged mussels or other caged species, or laboratory bioaccumulation tests to assess bioaccumulation potential when appropriate. Anadromous fish may be the appropriate target species where those types of fish represent a significant portion of anglers' diets. More than one species of fish may be used, if appropriate.

The target species should be collected from an area that is deemed by Ecology to be representative of the area of concern. Fish should be sampled taking into consideration such factors as:

- the size of the area of concern,
- sediment chemistry results,
- the approximate home range of the fish,
- fish life cycle (including reproductive cycle),
- fish lipid levels
- knowledge of local fishing practices (ie: where and when people fish).

When conducting tissue testing, tissue should be analyzed for contaminants of concern identified through sediment chemistry results. As determined necessary, the department may also require testing for other chemicals of potential human health concern.

To determine the number of replicate samples or the number of samples per composite, consult the PSEP Protocols. Fish shall be tested as fillets with the skin on to be representative of human exposures, unless information exists indicating that different portions of the fish are likely to be consumed by the population of interest.

Proposed Source Control Strategy: Human Health Sediment Criteria

(For source control, the human health criteria will be implemented much the same way the ecological criteria are implemented. The specific strategy is described in the next few paragraphs.)

2.0 Sediment Impact Zone Maximum Criteria

Just as minor adverse ecological effects have been selected as the upper limit of sediment impact zones for protection of biological resources, maximum human health risks would establish the upper limit of sediment impact zones for protection of human health. Risk to human health within an authorized sediment impact zone shall not exceed 1 in a 100,000 for carcinogenic compounds or a hazard quotient of one for non-carcinogenic compounds. The maximum chemical concentration levels that may be allowed within an authorized sediment impact zone due to a permitted or otherwise authorized discharge shall be at or below the chemical levels stipulated in Table II, HHSIZmax, except as provided for by Sections 2.1 and 2.2 below.

2.1 Calculating Site-Specific Sediment Impact Zone Maximum Level ("Tier II")

A site-specific ("Tier II") assessment may be conducted.

To calculate a site-specific SIZmax level, apply one or both of Formulas (1) or (2), depending on the toxic effect of the chemical of concern. With the exception of risk level, each of the default input parameters listed may be modified based on site-specific data, given sufficient data are available to justify making such modifications. Ecology will use CPFs and RfDs established by USEPA through the "integrated risk information system (IRIS) unless the department determines there is clear and convincing scientific evidence which demonstrates that the use of a particular CPF or RfD is inappropriate. Ecology will apply the procedures outlined in MTCA (Chapter 173-340 WAC), Section 708, Human Health Risk Assessment Procedures; Subsections (7) and (8).

2.2 Confirmatory Tissue Testing

As determined by Ecology, fish/shellfish tissue testing may be used to confirm human health sediment criteria compliance for existing point sources. If average tissue concentrations exceed levels of concern, Ecology will develop a source control strategy on an area-wide basis so as to reduce tissue concentrations in an area to acceptable levels. This will be done by calculating the total load to an area and requiring appropriate reductions for all sources through the NPDES permit process (under the authority of section 303(d) of the Clean Water Act).

Average fish tissue concentrations may also be used in conjunction with average sediment concentrations at the site to calculate a site-specific BSAF. If average fish tissue concentrations are found not to exceed a level of concern where sediment chemistry is shown to exceed HHSQS, the discharger shall continue to monitor fish tissue in the area of concern to ensure that levels do not exceed a level of concern over time (under section 301(h) of the Clean Water Act, periodic assessment of bioaccumulation in marine organisms is specified as part of the biological monitoring program [40 CFR Part 125.62(b)(ii)]).

For human health chemicals of concern with no pre-determined BSAF, a site-specific criteria value will be calculated so as to lower fish or shellfish tissue concentrations to a level that corresponds to a cancer risk at or below 1 in 100,000 or a hazard quotient at or below one. This will be based on the agency's best information on the bioaccumulation potential of the chemical(s) of concern. If no information is available to indicate otherwise, Ecology will assume a linear relationship between tissue concentration and sediment concentration.

Proposed Cleanup Strategy: Human Health Sediment Criteria

(As already required in Part V of the SMS, human health protection is a consideration in every part of the cleanup decision process, from screening sediment station clusters of potential concern to determining the site-specific cleanup standard. This preliminary implementation strategy outlines in more detail how Ecology will achieve the appropriate level of human health protection throughout the cleanup decision-making process.)

3.0 Marine Sediment Cleanup Screening Levels and Minimum Cleanup Levels Human Health Criteria

Just as minor adverse ecological effects have been selected as the cleanup screening level for protection of biological resources, an maximum acceptable level of risk would establish the cleanup screening level for protection of human health. Risk to human health would not exceed 1 in a 100,000 for carcinogenic compounds or a hazard quotient of one for non-carcinogenic compounds. The chemical levels stipulated in Table II, CSL, except as provided for by Sections 3.1 and 3.2 below, establish the human health cleanup screening level (HHCSL) for making cleanup decisions under WAC 173-204-520.

3.1 Site-Specific Marine Sediment Cleanup Screening Levels and Minimum Cleanup Levels Human Health Criteria ("Tier II")

A site-specific assessment may be conducted.

To calculate a site-specific HHCSL, apply one or both of Formulas (1) or (2), depending on the toxic effect of the chemical of concern. With the exception of risk level, each of the default input parameters may be modified based on site-specific data, given sufficient data is available to justify making such modifications. Ecology will use CPFs and RfDs established by USEPA in the "integrated risk information system" (IRIS) unless the department determines there is clear and convincing scientific evidence which demonstrates that the use of a particular CPF or RfD is inappropriate. Ecology will apply the procedures outlined in MTCA (Chapter 173-340 WAC), Section 708, Human Health Risk Assessment Procedures; Subsections (7) and (8).

Sediments with chemical concentrations that are higher than the chemical criteria calculated using Formulas (1) or (2) shall be determined to exceed the minimum cleanup level, except as provided below. At sites where dermal exposure (or other route of exposure) is determined to pose a human health risk, Ecology may require sediment cleanup levels to be calculated on a site-specific basis that are protective of human health from all potential routes of exposure.

Exceptions:
For PCBs, a Puget Sound-wide background concentration of 1.2 ppm TOC may be used as the HHCSL in place of the value listed in Table II.

For those human health chemicals of concern with no BSAF, a site-specific cleanup standard shall be calculated so as to lower fish tissue concentrations to a level that corresponds to a cancer risk between 1 in 100,000 and 1 in 1,000,000 or a hazard quotient of one. This will be based on the agency's best information on the bioaccumulation potential of the chemical(s) of concern. If no information is available to indicate otherwise, Ecology will assume a linear relationship between fish concentration and sediment concentration.

3.2 Measuring Compliance with Human Health Criteria

Where any of the human health chemical criteria are below the method detection limit for that chemical, compliance with the requirements of this section shall be based upon the method detection limit.

In cases where a minimum cleanup level is less than the method detection limit, the department may also require one or more of the following:

- Use of surrogate measures of hazardous substance contamination, including but not limited to improved analytical techniques;
- Use or development of specialized sample collection or analysis techniques to improve the method detection limit

- Monitoring to assure that the concentration of a contaminant of concern does not exceed detectable levels

The Sediment Management Standards currently requires that all sediment concentrations be at or below the MCUL/CSL ten years after completion of the active cleanup action. For implementation of the HHSQC, Ecology is considering an approach under Tier II that allows for use of area-wide averaging for determining compliance with the MCUL/CSL. That is, the average sediment concentration remaining on-site after ten years following completion of active remediation must be at or below the HHCSL. Several issues must be considered when implementing this approach :

- An approach that relies on meeting the HHMCUL/CSL at all stations is more protective of human health and the environment and provides for a margin of safety given all the uncertainties associated with human exposure and fish movement.

- To ensure that the appropriate tissue levels are being met, long-term fish tissue sampling and testing may be necessary. (i.e.: compliance monitoring).

- It is necessary to define the averaging area that will be used. This might be defined by the home range of the relevant species of fish or shellfish and/or by the site boundaries or other relevant physical characteristics at the site (e.g: water depth, distribution of chemical contamination, etc.).

- It may be necessary to define a minimum remedial action level to address the potential risk from sediment hot spots, (e.g.: requiring that all areas 10 times the HHCSL or greater be actively remediated).

- To protect shellfish from contamination (and in case of potential dermal contact by humans), no station in intertidal areas should be permitted to exceed the HHMCUL/CSL.

When institutional controls or natural recovery are the selected remedial actions, monitoring of sediment and tissue will be required to ensure that sediment and tissue levels meet defined sgoals over time. Additional remedial actions may be required if future sediment test results show levels of concern.

Preliminary Tier I Human Health Sediment Quality Criteria

Table I: Tier I Human Health Sediment Quality Standards (HHSQS)

Chemical	HHSQS (ppm, TOC*)
DDT (sum of DDD, DDE and DDT) [1]	0.03
hexachlorobenzene	1.5
hexachlorobutadiene	11
HPAHs [2]	0.33
PCBs (total)	0.26
Polychlorinated dibenzodioxins and furans (TEQ) [3]	9.0E-07

Table II: Tier I Human Health Cleanup Screening Levels (HHCSL)/Human Health Sediment Impact Zones Maximum Criteria (HHSIZmax)

Chemical	HHCSL/HHSIZmax (ppm, TOC*)
DDT (sum of DDD, DDE and DDT) [1]	0.30
hexachlorobenzene	15
hexachlorobutadiene	110
HPAHs [2]	3.3
PCBs (total)	0.26 **
Polychlorinated dibenzodioxins and furans (TEQ) [3]	9.0E-06

** TOC = normalized to Total Organic Carbon*

*** For PCBs, a Puget Sound-wide background concentration of 1.2 ppm TOC may be used as the HHCSL in place of the value listed in Table II.*

Footnotes

[1] For DDT and its derivatives, EPA recommends that the total concentration of the 2,4'- and 4,4'-isomer of DDT and its metabolites, DDE and DDD be evaluated as a group using the cancer potency factor of 0.34 per mg/kg-day (EPA, 1995).

[2] Compliance with the HPAH criteria is determined by summing the TEQs of each of the following HPAHs and comparing to the table value. A TEQ is calculated by multiplying the chemical concentration by its TEF. The following TEFs recommended by EPA, Region X, should be used to convert each of the following carcinogenic HPAHs to a TEQ:

Compound	TEF
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(a,h)anthracene	1.0
Indeno(1,2,3-cd)pyrene	0.1

[3] Compliance with the polychlorinated dibenzodioxins and furans criteria is determined by summing the TEQs of each of the following dioxins and furans and comparing to the table value. A TEQ is calculated by multiplying the chemical concentration by its TEF. The following TEFs recommended by EPA, should be used to convert each of the following carcinogenic dioxins and furans to a TEQ:

Compound	TEF
2,3,7,8-TCDD	1.0
2,3,7,8-PeCDDs	0.5
2,3,7,8-HxCDDs	0.1
2,3,7,8-HpCDDs	0.01
OCDD	.001
2,3,7,8-TCDF	.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
2,3,7,8-HxCDFs	0.1
2,3,7,8-HpCDFs	0.01
OCDF	0.001

Biota-Sediment Accumulation Factors used to Calculate Preliminary HHSQC

Chemical or Chemical Class	BSAF
DDT and metabolites	13.5
Dioxins/furans	1.0
Hexachlorobenzene	0.057
Hexachlorobutadiene	0.16
HPAHs	0.38
PCBs	2.6