APPENDIX C

DREDGE MATERIAL EVALUATION AND DISPOSAL PROCEDURES, USERS MANUAL

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Dredged Material Evaluation and Disposal Procedures

USER MANUAL

July 2013

Dredged Material Management Program

Corps of Engineers, Seattle District
Environmental Protection Agency, Region 10
Washington State Department of Natural Resources
Washington State Department of Ecology

Prepared by:

Dredged Material Management Office
US Army Corps of Engineers
Seattle District

US Army Corps of Engineers

Washington State Department of Natural Resources

Department of Ecology State of Washington

EPA United States Environmental Protection Agency

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DEFINITIONS

Acute toxicity: Short-term toxicity to organism(s) that have been affected by the properties of a substance, such as contaminated sediment. The acute toxicity of a sediment is generally determined by quantifying the mortality of appropriately sensitive organisms that are exposed to the sediment, under either field or laboratory conditions, for a specified period.

Advanced Dredging/Advanced Maintenance. Advanced maintenance is dredging to a specified depth and/or width beyond the authorized channel dimensions in critical and fast shoaling areas to avoid frequent re-dredging, and to ensure the reliability and least overall cost of operating and maintaining the project authorized dimensions.

Antidegradation: Policy that seeks to manage "sediment quality so as to protect existing beneficial uses and move towards attainment of designated beneficial uses" of the new surface sediment that would be exposed following dredging (Ecology, 1995). The exposed sediment must meet the SMS antidegradation policy (WAC 173-204-120).

Apparent Effects Threshold (AET): The sediment concentration of various chemicals of concern above which statistically significant adverse biological effects (relative to an appropriate reference condition) are always expected. Theoretically, an AET can be calculated for any chemical and biological indicator.

Aquatic disposal: Placement of dredged material in rivers, lakes, estuaries, or oceans via pipeline or surface release from hopper dredges or barges.

Aquatic environment: The geochemical environment in which dredged material is submerged under water and remains water-saturated after disposal is completed.

Aquatic ecosystem: Bodies of water, including wetlands, which serve as the habitat for interrelated and interacting communities and populations of plants and animals.

Beneficial use: Placement or use of dredged material for some productive purpose.

Bioaccumulation: The accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, or dredged material.

Bioaccumulation Trigger (BT): For bioaccumulative chemicals of concern, the sediment concentration that constitutes a "reason to believe" level that the chemical would accumulate in the tissues of target organisms. Sediments with chemical concentrations above the calculated BT require bioaccumulation testing before suitability for open-water disposal can be determined.

Bioassay: A bioassay is a test using a biological system. It involves exposing an organism to a test material and determining a response. There are two major types of bioassays differentiated by response: toxicity tests which measure an effect (e.g., acute toxicity, sublethal/chronic toxicity) and bioaccumulation tests which measure a phenomenon (e.g., the uptake of contaminants into tissues).

Biomagnification: Bioaccumulation up the food chain. Organisms at higher trophic levels will have higher body burdens than those at lower trophic levels.

Capping: The controlled, accurate placement of a covering or cap of clean material over contaminated material to isolate the contamination from the aquatic environment.

Chemical of concern: A chemical present in a given sediment thought to have the potential for unacceptable adverse environmental impact due to a proposed discharge.

Chronic: Involving a stimulus that is lingering or which continues for a long time.

Clay: Soil particle having a grain size of less than 3.9 micrometers.

Coastal zone: Includes coastal waters and the adjacent shorelands designated by a State as being included within its approved coastal zone management program. The coastal zone may include open waters, estuaries, bays, inlets, lagoons, marshes, swamps, mangroves, beaches, dunes, bluffs, and coastal uplands. Coastal-zone uses can include housing, recreation, wildlife habitat, resource extraction, fishing, aquaculture, transportation, energy generation, commercial development, and waste disposal.

Comparability: The confidence with which one data set can be compared to others and the expression of results consistent with other organizations reporting similar data. Comparability of procedures also implies using methodologies that produce results comparable in terms of precision and bias.

Confined disposal: A disposal method that isolates the dredged material from the environment.

Confined disposal facility (CDF): An engineered structure for containment of dredged material consisting of dikes or other structures that enclose a disposal area above any adjacent water surface, isolating the dredged material from water during placement. Other terms used for CDFs that appear in the literature include confined disposal area, confined disposal site, and dredged material containment area.

Constituents: Chemical substances, solids, liquids, organic matter, and organisms associated with or contained in or on dredged material.

Confined aquatic disposal: Form of capping which includes the added provision of some form of lateral containment (for example, placement of the contaminated and capping materials in bottom depressions or behind subaqueous berms) to minimize spread of the materials on the bottom.

Contaminant: Chemical or biological substance in a form that can be incorporated into, onto, or be ingested by and is harmful to aquatic organisms, consumers of aquatic organisms, or users of the aquatic environment.

Contaminated sediment: Sediment that has been demonstrated to cause an unacceptable adverse effect on human health or the environment.

Control sediment: A sediment essentially free of contaminants and which is used routinely to assess the acceptability of a test. Control sediment is typically the sediment from which the test organisms are collected. Test procedures are conducted with the control sediment in the same way as the reference sediment and dredged material. The purpose of the control sediment is to confirm the biological acceptability of the test conditions and to help verify the health of the organisms during the test. Excessive mortality in the control sediment indicates a problem with the test conditions or organisms, and can invalidate the results of the corresponding dredged material test.

Data quality indicators: Quantitative statistics and qualitative descriptors which are used to interpret the degree of acceptability or utility of data to the user;

include bias (systematic error), precision, accuracy, comparability, completeness, representativeness and statistical confidence.

Disposal site: That portion of the waters of the United States where specific disposal activities are permitted and consist of a bottom surface area and any overlying volume of water.

Dredged material: Material excavated from freshwater, estuarine or marine waters.

Dredged Material Management Unit (DMMU): A manageable, dredgeable unit of sediment which can be differentiated by sampling and which can be separately dredged within a larger dredging area.

EC_{50}: The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the organisms tested in a laboratory toxicity test of specified duration.

Ecosystem: A system made up of a community of animals, plants, and bacteria and its interrelated physical and chemical environment.

Effluent: Water that is discharged from a confined disposal facility during and as a result of the filling or placement of dredged material.

Elutriate: Material prepared from the sediment dilution water and used for chemical analyses and toxicity testing.

Emergency: In the context of dredging operations, emergency is defined in 33 CFR Part 335.7 as a "situation which would result in an unacceptable hazard to life or navigation, a significant loss of property, or an immediate and unforeseen significant economic hardship if corrective action is not taken within a time period of less than the normal time needed under standard procedures."

Evaluation: The process of judging data in order to reach a decision.

Frequency: The repeated dredging of a given area within a specified period of time without the need for further sampling and testing.

Grain-size effects: Mortality or other effects in laboratory toxicity tests due to sediment granulometry, not chemical toxicity.

Gravel: A loose mixture of pebbles and rock fragments coarser than sand. Specifically, a soil particle having a grain size of greater than 2,000 micrometers.

Habitat: The specific area or environment in which a particular type of plant or animal lives. An organism's habitat provides all of the basic requirements for the maintenance of life. Typical coastal habitats include beaches, marshes, rocky shores, bottom sediments, mudflats, and the water itself.

Heterogeneous Sediment: Sediment layers that have potentially different characteristics or levels of chemicals of concern. Heterogeneous sediments are typically sampled with a coring device that allows for separate sampling and analysis for surface and subsurface sediment layers.

Homogeneous Sediment: Sediment that is well-mixed and deposited over a short time-frame. Homogenous sediments are often found in settling basins or some navigation channels where river flow slows down abruptly. A dredge prism made up of homogenous sediment can be represented with grab samples.

K_{OW}: The octanol-water partition coefficient (K_{ow}) is a measure of the equilibrium concentration of a compound between octanol and water that indicates the potential for partitioning into soil organic matter (i.e., a high K_{ow} indicates a compound which will preferentially partition into soil organic matter rather than water). K_{ow} is inversely related to the solubility of a compound in water.

LC_{50}: The median lethal concentration. The concentration of a substance that kills 50% of the organisms tested in a laboratory toxicity test of specified duration.

Leachate: Water or any other liquid that may contain dissolved (leached) soluble materials, such as organic salts and mineral salts, derived from a solid material. For example, rainwater that percolates through a confined disposal facility and picks up dissolved contaminants is considered leachate.

Loading density: The ratio of organism biomass or numbers to the volume of test solution in an exposure chamber.

Management actions: Those actions considered necessary to rapidly render harmless the material proposed for discharge (e.g., non-toxic, non-bioaccumulative) and which may include containment in or out of the waters of the US (see 40 CFR Subpart H). Management actions are employed to reduce adverse impacts of proposed discharges of dredged material.

Maximum Level (ML): A guideline value derived for each chemical of concern which represents the highest Apparent Effects Threshold (AET) – a chemical concentration at which biological indicators show significant effects.

Method detection limit (MDL): The minimum concentration of a substance which can be identified, measured, and reported with 99% confidence that the analyte concentration is greater than zero.

Overdepth: Paid allowable overdepth dredging (depth and/or width) is a construction design method for dredging that occurs outside the required authorized dredge prism. Paid overdepth is designed to compensate for physical conditions and inaccuracies in the dredging process and to allow for efficient dredging practices.

Pathway: In the case of bioavailable contaminants, the route of exposure (e.g., water, food).

Porewater: The water that fills the area between grains of sediment.

Practicable: Available and capable of being done after taking into consideration cost, existing-technology, and logistics in light of overall project purposes.

QA: Quality assurance; the total integrated program for assuring the reliability of data. A system for integrating the quality planning, quality control, quality assessment, and quality improvement efforts to meet user requirements and defined standards of quality with a stated level of confidence.

QC: Quality control, the overall system of technical activities for obtaining prescribed standards of performance in the monitoring and measurement process to meet user requirements.

Reason to believe: Subpart G of the CWA 404(b) (1) guidelines requires the use of available information to make a preliminary determination concerning the need for testing of the material proposed for dredging. This principle is commonly known as "reason to believe" and is used in Tier I evaluations to determine acceptability of the material for discharge without testing. The decision to not perform additional testing based on prior information must be documented, in order to provide a reasonable assurance that the proposed discharge material is not a carrier of contaminants.

Recency: The duration of time for which chemical and biological characterization of a given dredge prism remains adequate and valid for decision making without further testing.

Reference sediment: A whole sediment used to assess sediment conditions exclusive of the material(s) of interest that is as similar as practicable to the grain size of the dredged material. The reference sediment serves as a point of comparison to identify potential effects of contaminants in the dredged material.

Reference site: The location from which reference sediment is obtained.

Representativeness: The degree to which sample data depict an existing environmental condition; a measure of the total variability associated with sampling and measuring that includes the two major error components: systematic error (bias) and random error. Sampling representativeness is accomplished through proper selection of sampling locations and sampling techniques, collection of sufficient number of samples, and use of appropriate subsampling and handling techniques.

Salinity: Salt content, usually expressed in grams of salt per kilogram of water.

Sand: Soil particles having a grain size ranging between 62.5 micrometers and 2,000 micrometers.

Screening Level (SL): A guideline value defined for each DMMP chemical of concern that identifies concentrations at or below which there is no reason to believe that dredged material disposal would result in unacceptable adverse effects.

Sediment: Material, such as sand, silt, or clay, suspended in or settled on the bottom of a water body. Sediment input to a body of water comes from natural sources, such as erosion of soils and weathering of rock, or as the result of anthropogenic activities such as forest or agricultural practices, or construction activities. The term dredged material refers to material which has been dredged from a water body, while the term sediment refers to material in a water body prior to the dredging process.

Silt: soil having a grain size ranging between 3.9 micrometers and 62.5 micrometers.

Sublethal (chronic) toxicity: Biological tests which use such factors as abnormal development, growth and reproduction, rather than solely lethality, as end-points. These tests involve all or at least an important, sensitive portion of an organism's life-history. A sublethal endpoint may result either from short-term or long-term (chronic) exposures.

Suspended solids: Organic or inorganic particles that are suspended in water. The term includes sand, silt, and clay particles as well as other solids, such as biological material, suspended in the water column.

Tiered approach: A structured, hierarchical procedure for determining data needs relative to decision-making, which involves a series of tiers or levels of intensity of investigation. Typically, tiered testing involves decreased uncertainty and increased available information with increasing tiers. This approach is intended to ensure the maintenance and protection of environmental quality, as well as the optimal use of resources. Specifically, least effort is required in situations where clear determinations can be made of whether (or not) unacceptable adverse impacts are likely to occur based on available information. Most effort is required where clear determinations cannot be made with available information.

Toxicity: Level of mortality or other end point demonstrated by a group of organisms that have been affected by the properties of a substance, such as contaminated water, sediment, or dredged material.

Toxicity test: A bioassay which measures an effect (e.g., acute toxicity, sublethal/chronic toxicity). Not a bioaccumulation test (see definition of bioassay).

Turbidity: An optical measure of the amount of material suspended in the water. Increasing the turbidity of the water decreases the amount of light that penetrates the water column. Very high levels of turbidity can be harmful to aquatic life.

Upland environment: The geochemical environment in which dredged material may become unsaturated, dried out, and oxidized.

Water quality certification: A state certification, pursuant to Section 401 of the Clean Water Act, which states that the proposed discharge of dredged material will comply with the applicable provisions of the Clean Water Act and relevant State laws. Typically this certification is provided by the affected State. In instances where the State lacks jurisdiction (e.g., Tribal Lands), such certification is provided by EPA or the Tribe.

Waters of the US: In general, all waters landward of the baseline of the territorial sea and the territorial sea. Specifically, all waters defined in the CWA 404(b)(1) guidelines.

Whole sediment: The sediment and interstitial waters of the proposed dredged material or reference sediment that have had minimal manipulation. For purposes of this manual, press-sieving to remove organisms from test sediments, homogenization of test sediments, compositing of sediment samples, and additions of small amounts of water to facilitate homogenizing or compositing sediments may be necessary to conducting bioassay tests. These procedures are considered unlikely to substantially alter chemical or toxicological properties of the respective whole sediments except in the case of AVS (acid volatile sulfide) measurements (EPA, 1991a) which are not presently required. Alternatively, wet sieving, elutriation, or freezing and thawing of sediments may alter chemical and/or toxicological properties, and sediment so processed should not be considered as whole sediment for bioassay purposes.

Z-sample: A sample from the first two feet below the dredging overdepth, which must be collected during sampling of heterogeneous sediments, to characterize the surface exposed after dredging.

LIST OF ACRONYMS

AET Apparent Effects Threshold
ANOVA Analysis of Variance
ASTM American Society for Testing and Materials
BT Bioaccumulation Trigger
CAS Chemical Abstract Service
CERCLA Comprehensive Environmental Response, Compensation, and Liability Act (aka "Superfund")
CFR Code of Federal Regulations
COC Chemical of Concern
CSL Cleanup Screening Level
CSO Combined Sewer Overflow
CWA Clean Water Act
CY Cubic Yard
DAIS Dredged Analysis Information System
WDFW Washington Department of Fish and Wildlife
DMMO Dredged Material Management Office
DMMP Dredged Material Management Program
DMMU Dredged Material Management Unit
DNR Department of Natural Resources
DY Dredging Year
EC_{50} Effective Concentration (affecting 50% of test organisms)
EIM Environmental Information Management (Ecology database)
EPA Environmental Protection Agency
EPTA Evaluation Procedures Technical Appendix
ESA Endangered Species Act
FC Full Characterization
FDA Food and Drug Administration
GIS Geographic Information System
GPS Global Positioning System
HPA Hydraulic Project Approval
HPAH High-molecular-weight PAH
JARPA Joint Aquatic Resource Permits Application
K_{OW} Octanol-water partition coefficient
LC_{50} Lethal Concentration (affecting 50% of test organisms)
LPAH Low-molecular-weight PAH
ML Maximum Level
MLLW Mean Lower Low Water
MPR Management Plan Report
MTCA Model Toxics Control Act
NAD North American Datum
NPDES National Pollution Discharge Elimination System
PAH Polynuclear Aromatic Hydrocarbon
PC Partial Characterization
PCBs Polychlorinated Biphenyls
PCDDs Polychlorinated Dibenzodioxins
PCDFs Polychlorinated Dibenzofurans
PSDDA Puget Sound Dredged Disposal Analysis
PSEP Puget Sound Estuary Program
QA/QC Quality Assurance/Quality Control
SAP Sampling and Analysis Plan
SEDQUAL Sediment Quality Database
SMS Sediment Management Standards
SL Screening Level
TBT Tributyltin
TEC Toxic Equivalent Concentration
TEF Toxicity Equivalency Factor
TEQ Toxicity Equivalent
TOC Total Organic Carbon
TVS Total Volatile Solids
USCG United States Coast Guard
VTS Vessel Traffic Service
WGS World Geodetic System

1 INTRODUCTION

The Dredged Material Management Program (DMMP) is an interagency approach to the management of dredged material in Washington State. Two federal and two state agencies, all with roles in the oversight of dredging and disposal, cooperate to streamline dredged material evaluation and regulation. The Seattle District of the U.S. Army Corps of Engineers (Corps) acts as the lead agency. Cooperating agencies are Region 10 of the U.S. Environmental Protection Agency (EPA), the Washington Department of Ecology (Ecology), and the Washington Department of Natural Resources (DNR).

1.1 HISTORY OF THE DMMP

The interagency approach to dredged material management began in 1985 after studies surfaced concerns about environmentally degraded sediment and water quality in Puget Sound. Plunging public confidence in agency management of dredged material led to the loss of shoreline permits for the Elliott Bay disposal site and a halt to much local dredging. This crisis led to the Puget Sound Dredged Disposal Analysis (PSDDA) study, a 4.5 year initiative meant to restore confidence in agency regulation of unconfined open-water dredged material disposal. PSDDA was implemented in two phases, first in June 1988 for central Puget Sound and second in September 1989 for north and south Puget Sound.

The PSDDA program provided publicly acceptable and environmentally safe regulation of unconfined open-water dredged material disposal, but only for Puget Sound. In 1995 a long-term interagency management strategy was developed and implemented for the coastal estuaries of Grays Harbor and Willapa Bay. In 1998, a long-term interagency dredged material management strategy was also developed and implemented for the lower Columbia River. With the expansion of PSDDA oversight into Washington water bodies beyond Puget Sound, the program name changed from PSDDA to DMMP.

1.2 USER MANUAL

The procedures in this User Manual replace guidance in all previous versions of the DMMP User Manual; the 2000 PSDDA Users Manual; the Evaluation Procedures Technical Appendix - Phase I (PSDDA, 1988); the Management Plan Report - Phase II (PSDDA, 1989); and the Grays Harbor/Willapa Bay Users Manual (Dredged Material Evaluation Procedures and Disposal Site Management Manual: Grays Harbor and Willapa Bay, Washington, 1995). The updated procedures should be used for all projects in Puget Sound, on the Washington Coast, the north side of the Columbia River, and all other water bodies within the State of Washington.

Guidance described in this edition of the DMMP User Manual reflects technical and policy updates that have occurred through the sediment management annual review meeting process and public workshops. The User Manual is considered to be a living document and is revised periodically as needed to reflect changes made through the public review process.

1.3 THE DREDGED MATERIAL MANAGEMENT OFFICE (DMMO)

The Corps' Dredged Material Management Office (DMMO) provides a "one-stop" location for dredged material evaluations. The DMMO interfaces with the Corps' Regulatory Branch on dredging portions of the permit process, and provides assistance on sediment quality and dredged material management issues. DMMO staff is available to answer questions, assist in the development of sampling and analysis plans and help troubleshoot during sediment sampling and testing (see DMMO on Figures 2-1, 2-2, and 2-3). The DMMO coordinates SAP and data reviews with the other DMMP agencies, prepares the SAP approval letter and drafts suitability determinations. **Any questions, problems or issues related to dredged material management should be directed to the DMMO:**

	Department of Army Seattle District, CENWS-OD-ME
Physical Address:	4735 East Marginal Way South Seattle, WA 98134-2385
Mailing Address:	P.O. Box 3755 Seattle, WA 98124-3755
E-mail:	DMMOteam@usace.army.mil
Phones:	206-764-3768 206-764-6083 206-764-6945 206-764-6550

2 DREDGING PROJECT PERMITTING

Dredging and disposal in the waters of the U.S. require Department of the Army permits issued by the U.S. Army Corps of Engineers. Evaluation of the proposed dredged material by the DMMP is an integral part of the permitting process. This chapter describes the process of obtaining the appropriate permits and getting the necessary sediment evaluation performed.

See the Seattle District Regulatory Branch for complete information on applying for permits, getting extensions on existing permits, or other permitting questions.

There are three categories of dredging that require three different permitting approaches:

New dredging—dredging of areas that have not previously been dredged—will always require new permits.

Maintenance dredging—dredging to keep existing channels, harbor basins, ports etc. at the required depth by removing siltation—must also have a permit in effect to cover the planned work. If there are existing permits, the dredging proponent needs to check the expiration date. Unless all projected dredging can be completed before the permit expires, new permits (or extensions on existing permits) are required. DMMP coordination is required for every dredging cycle to insure that all relevant dredged material characterization guidelines are met.

Federal navigation project maintenance dredging—maintenance dredging done by the Corps of Engineers to keep existing federal channels open to authorized depths—is not issued a Corps permit. Public Notices are issued, however, and other state guidelines are always complied with.

Whenever dredging takes place, the dredging proponent must have both:

- Current Department of the Army permit
- Current DMMP Suitability Determination or other Decision Document

These are two separate, but interdependent, processes. The dredging proponent needs to coordinate with both the Regulatory Section for a permit, and the Dredged Material Management Office for a Suitability Determination.

2.1 REGULATORY PROCESS OVERVIEW

The regulatory permitting process consists of the following steps and is illustrated in **Figure 2-1** and **Figure 2-2**:

1. Project proponent submits a complete permit application (joint aquatic resource permit application or JARPA) to the appropriate agencies, including the Regulatory Branch of the Corps of Engineers. The permit application cannot be considered complete without a current DMMP Suitability Determination or other Decision Document.
2. The Corps (Regulatory) prepares and distributes a Public Notice with a 30-day comment period.
3. The Corps (Regulatory) reviews and incorporates comments from other agencies and the public.

4. The Corps (Regulatory) completes Endangered Species Act Section 7 consultation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service.
5. The State of Washington issues a Water Quality Certification (or Modification) and Hydraulic Project Approval.
6. The Corps (Regulatory) makes a permit decision.
7. Project proponent obtains a DNR Site Use Authorization (Section 2.2)
8. Project proponent submits a dredging and disposal quality control plan to the Corps (Regulatory) (Chapter 13).
9. The Corps (Regulatory) conducts a pre-dredge conference (Chapter 13).

If a new permit is not required, the dredging proponent should still contact the DMMO to determine any testing needs for the upcoming cycle of dredging.

For all dredging proposed to occur on State-Owned Aquatic Land managed by DNR, the dredging proponent should check with DNR prior to beginning work. This process should be initiated at the same time that coordination with the Corps begins.

Applicants considering beneficial-use projects are encouraged to coordinate with the DMMO and with other resource agencies early in the dredged material evaluation process. For more information on beneficial uses of dredged material, see EPA's Beneficial Use of Dredged Material page, and the Corps/EPA technical website Beneficial Uses of Dredged Material.

2.2 DNR DISPOSAL SITE USE AUTHORIZATION

A disposal site use authorization (SUA) must be obtained from Washington State Department of Natural Resources (DNR) prior to disposal of dredged material in any Puget Sound, Grays Harbor or Willapa Bay disposal site. Some Columbia River sites may also be managed under Washington DNR; the DNR agency representative should be consulted to determine appropriate jurisdiction early in the planning process.

Before DNR will begin processing an SUA application, the applicant must provide a COMPLETE application package. A typical application package includes a completed Site Use Application, and copies of all other agency permits required for dredging and dredged material disposal. DNR will not process an incomplete application package.

Typical dredging projects require the following permits:

- U.S. Army Corps of Engineers Permit
- Washington Department of Ecology Water Quality Certification
- Washington Department of Fish and Wildlife Hydraulic Project Approval
- Shoreline Substantial Development Permit or Exemption Letter

Application packages must be mailed to DNR's DMMP office at:

Department of Natural Resources, Aquatic Resources Division
ATTN: DMMP Manager
1111 Washington Street SE
P.O. Box 47027
Olympia, WA 98504-7027

Once DNR's DMMP office receives a completed Site Use Application and all required permits, it will take approximately two to three weeks to process the application and produce an unsigned SUA. Dredging proponents are encouraged to contact DNR well in advance of dredging (3+ weeks recommended) to avoid delays. DNR maintains updated information on all SUA requirements, including application forms, on its DMMP office web page.

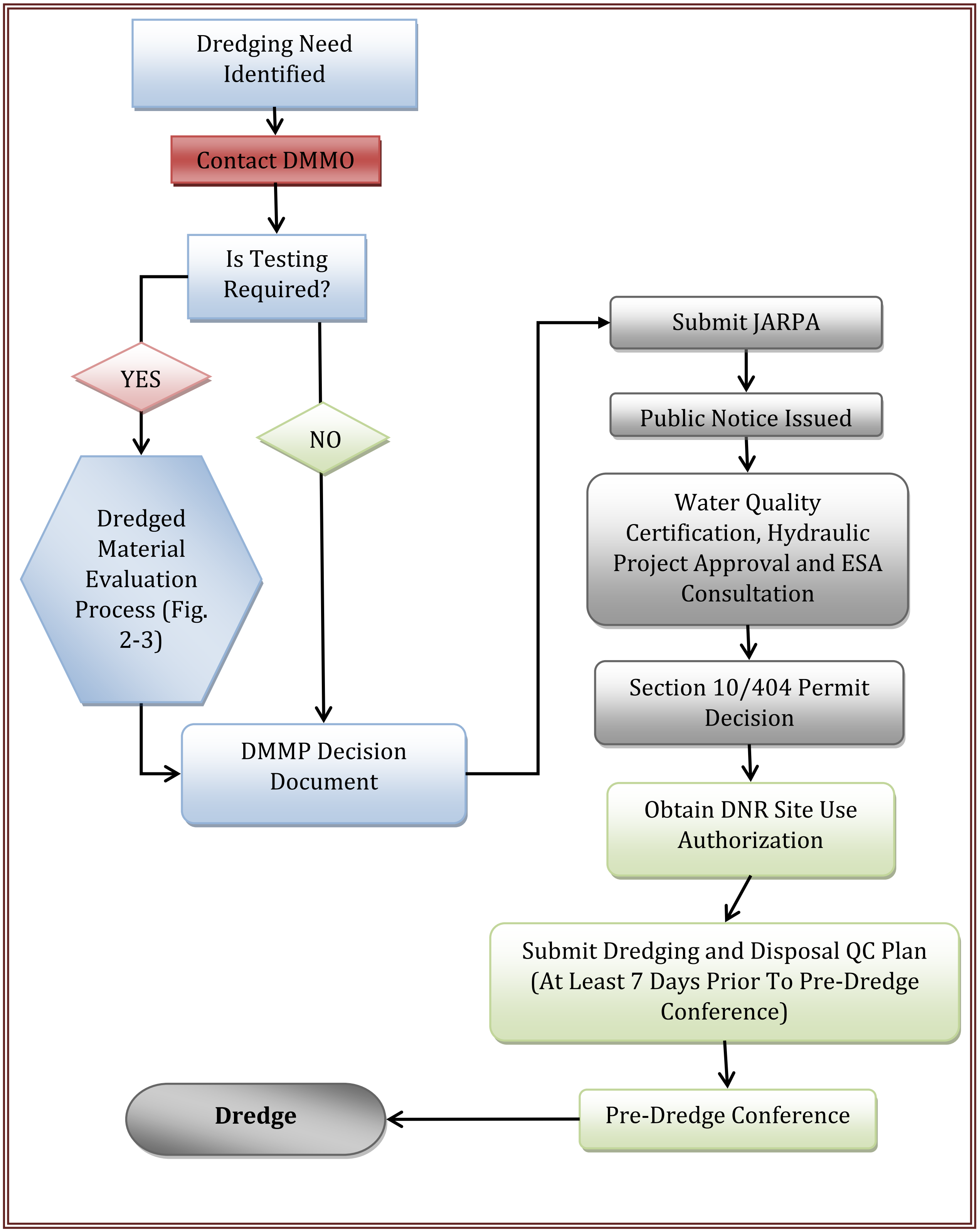

Figure 2-1. DMMP/Regulatory Process (new permit required)

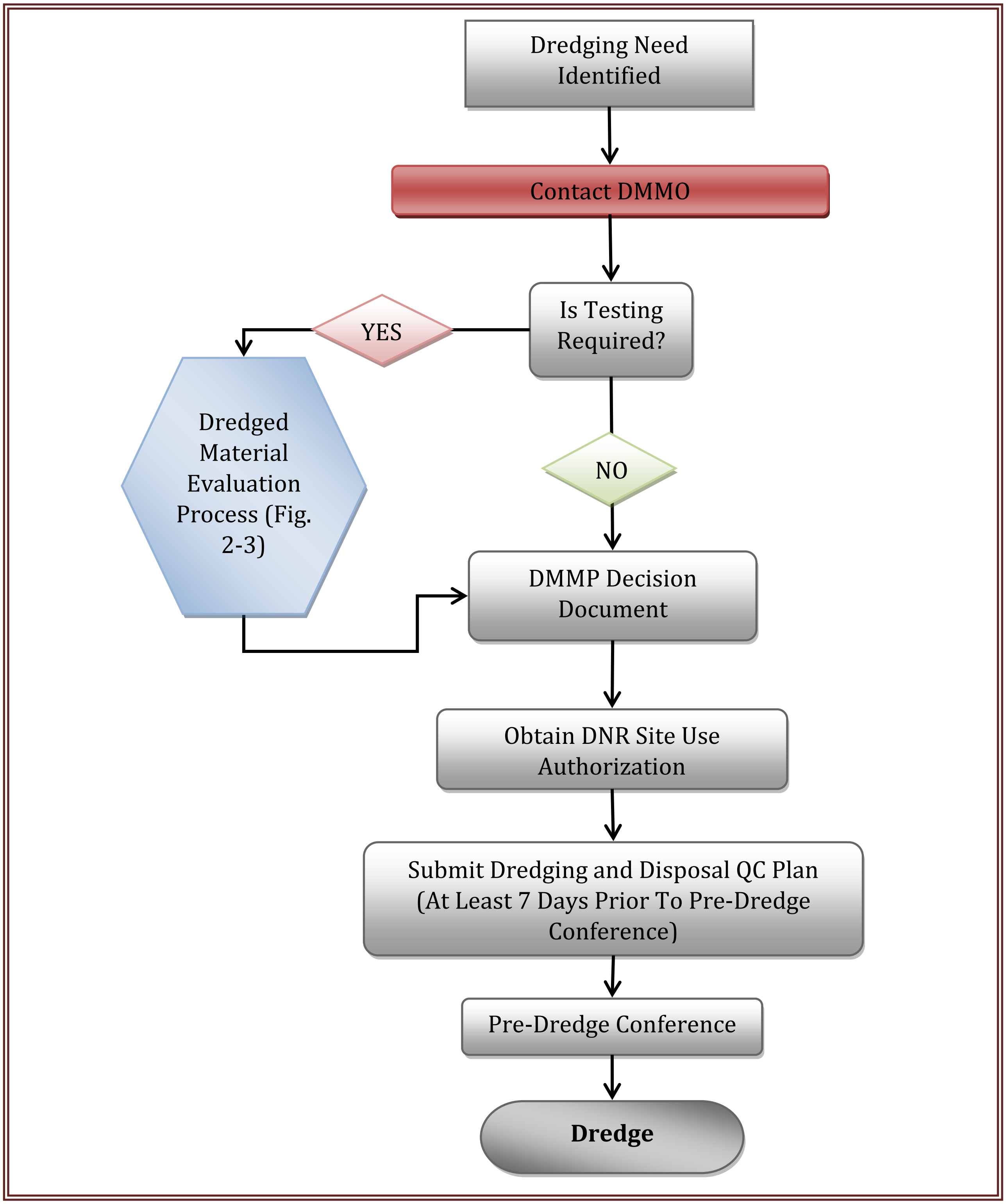

Figure 2-2. Regulatory Process (new permit not required e.g. dredging under an existing multi-year permit)

3 DREDGED MATERIAL EVALUATION PROCESS

The main questions that the DMMP evaluates are:

1. Is proposed dredged material suitable for disposal in open water? Open water disposal can be at one of the designated DMMP sites or in some cases in flowlane disposal areas.
2. Is proposed dredged material suitable for in-water beneficial use? In general, material proposed for beneficial use needs to not only meet DMMP guidelines for open water disposal, but must also meet Washington State Sediment Management Standards requirements as well.
3. Will the post-dredge surface meet Washington State anti-degradation standards when the project is finished? In other words, will the sediment surface left behind after dredging be degraded relative to the sediment surface that existed prior to dredging? This question is often the only applicable question for DMMP consideration if the proposed disposal site is upland with no return water.

To answer these questions, the DMMP uses a tiered approach to sediment characterization (**Figure 3-2**).

There are four tiers of evaluation:

Tier 1: Site Evaluation and History

Tier 2: Chemical Testing

Tier 3: Biological Testing (bioassay and or bioaccumulation testing)

Tier 4: Special Studies

Every project is subject to a Tier 1 evaluation, which is a review of historical and ongoing sources of contamination, land use, and any previously collected data (Chapter 4). Occasionally a suitability determination can be made using only Tier 1 information. For other projects, Tier 1 informs the characterization required in subsequent tiers. Tier 3 biological testing is invoked if chemicals of concern are present at concentrations that are of potential concern for human health or the environment. Time can be saved by compressing Tiers 2 and 3-- that is, by conducting concurrent chemical and biological testing. Tier 4 testing is rarely required by the agencies or pursued by dredging proponents. If Tier 4 testing is needed, it is specially designed in coordination with the DMMP agencies. **It is always the project proponent's decision whether to proceed to the next tier for further testing; the option of disposing of material upland rather than pursuing further testing is always available.**

The dredged material evaluation process is required for every dredging cycle. In some cases this will be as simple as checking to see if an existing suitability determination covers the proposed dredging, as might be the case for frequent, routine maintenance dredging. In other cases, it will require Tier 2 and 3 testing. Regardless of the project, DMMP coordination needs to be conducted and a decision for that dredging cycle documented.

The dredged material evaluation process consists of the following steps (**Figure 3-1**):

1. Dredging proponent (with consultant assistance as needed) determines project-specific sampling and analysis requirements, as stipulated in this Users Manual. DMMO may be contacted for assistance.

2. Dredging proponent develops a sampling and analysis plan (SAP) for sediment evaluation (Chapters 5 & 6).
3. Dredging proponent submits SAP to the DMMO.
4. DMMO coordinates review of the SAP by the other DMMP agencies.
5. DMMO sends a SAP approval letter or email message to the dredging proponent.
6. Dredging proponent conducts field sampling and laboratory testing.
7. Dredging proponent submits a final sediment characterization report to the DMMO for distribution to all DMMP agencies.
8. DMMO coordinates review of the testing data with the DMMP agencies.
9. DMMO drafts and the agencies review and sign a suitability determination for disposal.

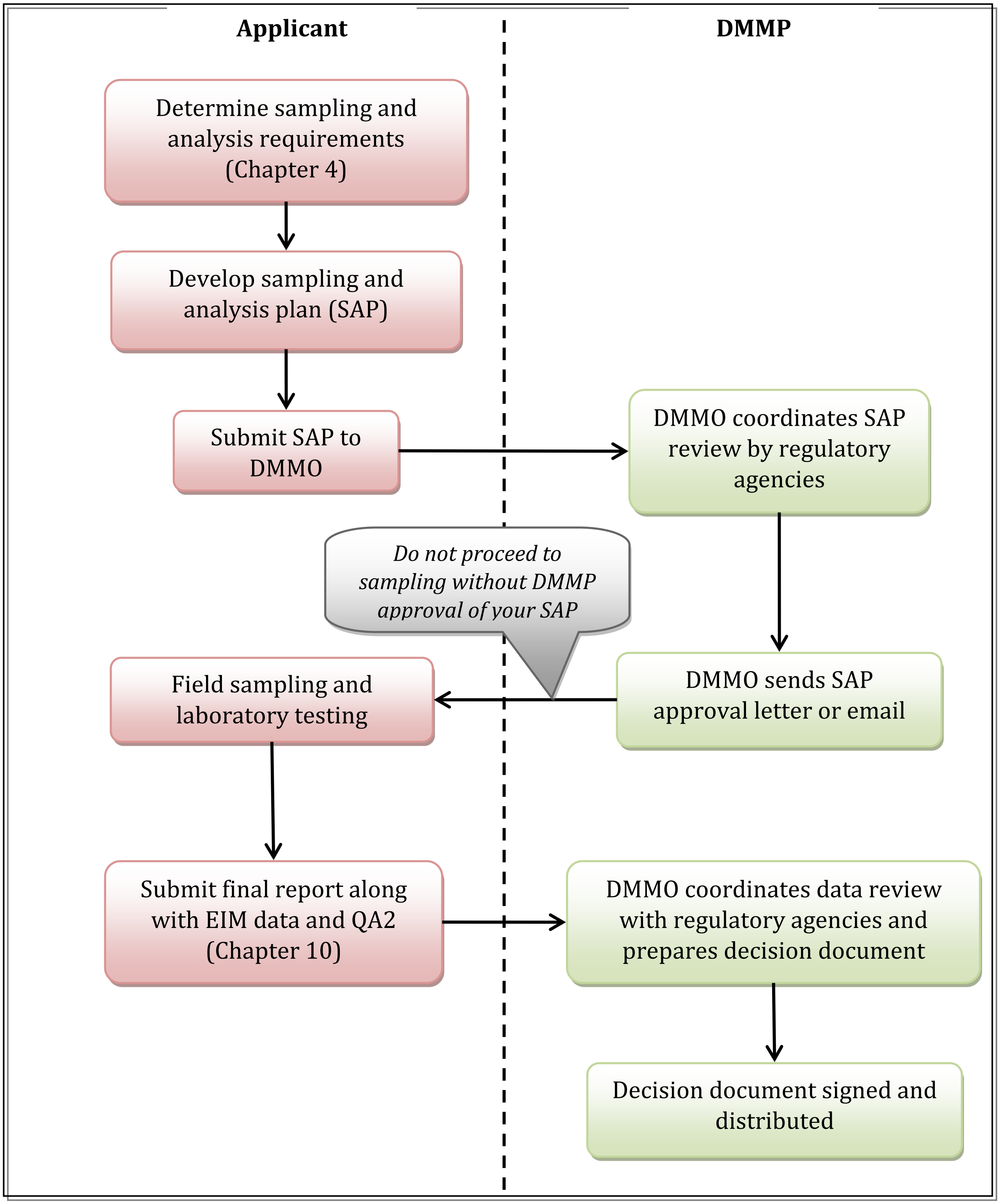

Figure 3-1. Dredged Material Evaluation Process

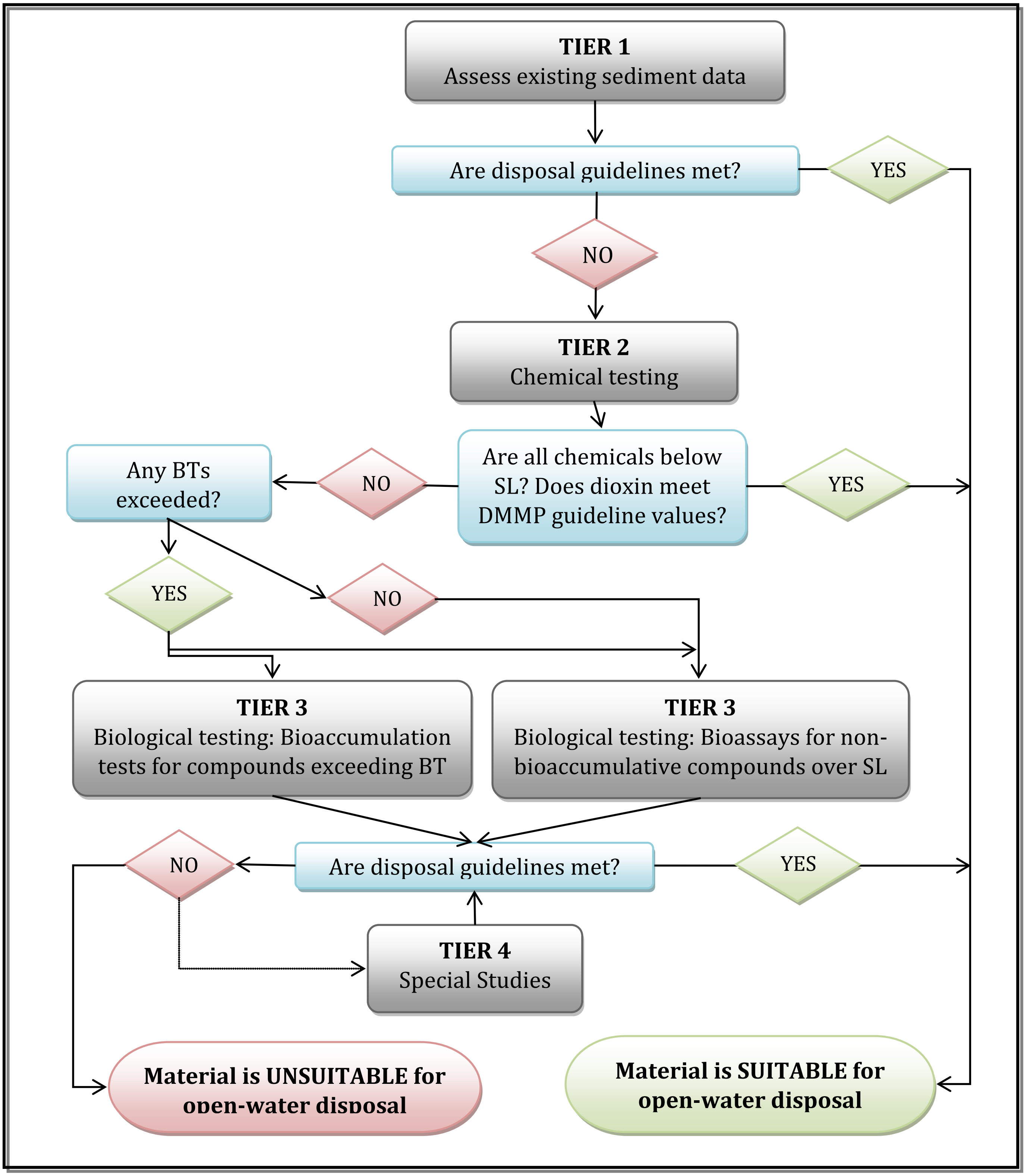

Figure 3-2. Tiered Testing Decision Diagram

4 TIER 1: EVALUATION/SITE HISTORY

Tier I is a comprehensive analysis of all readily available existing information on the proposed dredging project, including a site history and all previously collected physical, chemical and biological data. The type and amount of information required for a Tier I evaluation will vary according to the size and complexity of the project and the history of the dredging site.

A Tier 1 evaluation is necessary to inform the entire sediment evaluation process. It's not necessarily a long or complex process, but it is vital to determining all further steps for a given sediment evaluation. The Tier 1 evaluation needs to be included in the project Sampling and Analysis Plan (SAP).

4.1 SITE HISTORIES

The history of a project area plays a pivotal role in project evaluation and sampling plan development. The purpose of the site history is to document potential past and present sources of contamination to dredged material proposed for open-water disposal. A site history characterizes known activity at the dredging site, in near-shore areas, and on adjacent properties. It identifies past activities and describes the type of contamination that may have resulted from those activities.

The following outline identifies the type of information that may be necessary in a site history for a large, complicated site. Smaller projects in areas of lower concern will require less information. For most projects, site histories do not need to extend beyond two to three pages. A reasonable effort should be made to obtain relevant data. It is recognized that certain types of data may not be readily available but the effort to obtain it should be documented. Previous characterization and dredging in the area should be referenced and summarized to the extent possible. Emphasis should be placed on activities that have occurred since the last dredging cycle. Identify whether the proposed dredging project is within, or adjacent to, an EPA or Ecology-listed CERCLA, RCRA or MTCA site, and the appropriate site manager (if known). This should include upland sites in parcels adjacent to the in-water work area.

The site history should include all the following information that is applicable to the specific project:

1. A map showing the site's location, layout, storm drainage, outfalls, and special aquatic sites such as eelgrass or wetlands.
2. Current site use.
3. Industrial processes at or near the site (and hazardous substances used/generated).
4. Outfall information, such as type, volume, NPDES data.
5. MTCA-, CERCLA- or site information (including site manager if known), including those on adjacent upland areas.
6. Spill events.
7. History of site ownership and land uses.
8. Adjacent property use, especially those up-gradient or up-current/upstream.
9. Site characteristics that could affect movement of contaminants (e.g. prop wash, ferry traffic).
10. Results of any previous sampling and testing on and around the project site.

4.2 SOURCES OF INFORMATION

There are a wide variety of information sources for site histories. Potential sources include:

1. current and previous property owners
2. aerial photographs (past and present)
3. real estate and Sanborn fire insurance maps
4. zoning, topographic, water resource, and soil maps
5. agency records, such as NPDES permit files, contaminated site lists (state and federal), CERCLA construction completion and long-term monitoring reports, aquatic leases, previous permits, databases, etc.
6. land use records
7. knowledgeable persons at or near the site (managers, employees, adjacent property owners)
8. city atlases (Kroll and Metsker)
9. cleanup databases (http://www.ecy.wa.gov/cleanup.html, http://www.ecy.wa.gov/fs/index.html)
10. spills databases (http://www.ecy.wa.gov/programs/spills/incidents/main.html)

Not all sources are needed for all projects, and the type and extent of sources consulted will vary. Smaller projects and those with less complicated source histories will generally require less documentation but should always include enough information to enable the agencies to adequately address sampling and testing issues. Dredging proponents can contact the Dredged Material Management Office to determine the level of effort required for their specific project. The DMMO will coordinate with the other agencies as necessary to determine project-specific requirements.

4.3 TESTING EXCLUSIONS BASED ON TIER 1 ANALYSIS

Section 404 of the Clean Water Act (CWA) includes provisions for exclusion from testing based on Tier 1 evaluations, as does the Inland Testing Manual guidance document. Exclusions can be made if a Tier 1 evaluation indicates that the dredged material is not considered to be a "carrier of contaminants" (40 CFR 230.60 (b)). Potential exclusion situations occur most commonly "if the dredged material is composed primarily of sand, gravel and/or inert materials; the sediments are from locations far removed from sources of contaminants, or if the sediments are from depths deposited in preindustrial times and have not been exposed to modern sources of pollution" (ITM 1998). Testing may also not be necessary "where the discharge site is adjacent to the excavation site and subject to the same sources of contaminants, and materials at the two sites are substantially similar "(40 CFR 230.60(c)).

4.4 TIER 1 SUITABILITY DETERMINATIONS

Given the provisions in Section 4.3, the DMMP may issue suitability determinations based on a Tier 1 evaluation alone, or on limited additional testing (see DMMP 2004b). In these situations enough information is available to make a suitability determination call based on Tier 1 (sections 4.1 and 4.2 above) alone, and no additional testing is required.

5 DEVELOPING SAMPLING AND ANALYSIS REQUIREMENTS

Once a Tier 1 evaluation is completed, the following steps are followed to determine the requirements for the full characterization of project sediments:

1. determine the rank for the project
2. review recency & frequency guidelines
3. develop a conceptual dredging plan
4. determine the volume of material to be dredged
5. determine required number of dredged material management units (DMMUs) and field samples
6. develop a sampling plan which distributes the DMMUs to reflect the conceptual dredging plan, allocates the required number and depths of field samples, presents a compositing plan, and chemical and biological testing plans

These steps must be documented in the sampling and analysis plan developed for review by the agencies.

5.1 DETERMINE PROJECT RANK

A dredging area, or a specific project, is typically assigned to one of four possible ranks: *high*, *moderate*, *low-moderate*, or *low*. These ranks represent a best professional judgment of concern or potential risk *by the agencies*, typically based on a scale of potential for adverse biological effects or elevated concentrations of chemicals of concern. The lower the rank, the less the concern, and the less intense the sampling and testing requirements needed to adequately characterize the dredged material. The ranking system is based on two factors:

1. The available information on chemical and biological-response characteristics of the sediments.
2. The number, kinds, and proximity of chemical sources (existing and historical).

For those dredging projects with sufficient historical data, the assigned ranking is based on the available chemical and biological data for project sediments. For those projects lacking sufficient historical data, the number, kinds and proximity of chemical sources are the major factors driving the assigned rank. **Table 5-1** defines the ranking guidelines.

5.1.1 General Rankings

Certain geographic areas and use activities are assigned a general rank based upon the nature and extent of possible sources of chemicals of concern that could impact sediments needing to be dredged. In the absence of sediment quality data to the contrary, urban and industrialized areas are initially ranked ***high***. Marinas, ferry terminals, fueling and ship berthing facilities, construction facilities, and sediments located close to moderate-sized sewer outfalls are initially ranked ***moderate***. Areas that are geographically removed from potential sources of chemicals of concern are ranked ***low-moderate*** or ***low***.

Table 5-1. Dredged Material Ranking Guidelines

RANK	GUIDELINES
Low	Few or no sources of chemicals of concern. Data are available to verify low chemical concentrations (below DMMP screening levels) and no significant response in biological tests.
Low-Moderate	Available information indicates a "low" rank, but there are insufficient data to confirm the ranking.
Moderate	Sources exist in the vicinity of the project, or there are present or historical uses of the project site, with the potential for producing chemical concentrations within a range associated historically with some potential for causing adverse biological impacts.
High	Many known chemical sources, high concentrations of chemicals of concern, and/or biological testing failures in one or both of the two most recent cycles of testing.

5.1.2 Area-Specific and Project-Specific Rankings

To further facilitate the determination of sampling requirements, rankings for dredging projects in specific geographic areas or with adequate historical testing data were determined using the ranking guidelines in **Table 5-1**. Current rankings for the Puget Sound area are shown in **Table 5-2** and for Grays Harbor and Willapa Bay in **Table 5-4**.

5.1.3 Integration of Dioxin Data into Ranking Determinations in Puget Sound

In December 2010 the DMMP agencies implemented new interim dioxin guidelines for Puget Sound, which set a site management objective of 4 pptr TEQ for all disposal sites. In order to meet this goal, no DMMU with a TEQ of over 4 pptr can be disposed at dispersive sites. For disposal at non-dispersive sites, projects must have a volume weighted average of 4 pptr TEQ or less, with no single DMMU having a concentration greater than 10 pptr TEQ. Disposal of material with more than 10 pptr TEQ or not meeting the volume weighted average of 4 pptr TEQ is subject to DMMP Best Professional Judgment (BPJ) based on such things as the frequency of disposal site use and sequencing of dredged material disposal. The interim dioxin guidelines also include updated reason-to-believe guidance; in urban areas, there must be existing dioxin data that supports exclusion of dioxins as a chemical of concern (COC).

The DMMP uses BPJ to determine ranking relative to dioxin rather than including dioxin in the standardized ranking approach used with other COCs. Where dioxins are either known or suspected to be present, existing sediment dioxin data from the project and vicinity as well as source information will be used to design a sampling density appropriate for the project. This approach is used if elevated dioxin concentrations have limited distribution in a given area; there are demonstrated cases where the higher sampling density required for one portion of a project is not appropriate over the entire area to be characterized.

Table 5-2. Current general, area and project-specific rankings for Puget Sound

GENERAL RANKINGS	
All existing fueling and ship berthing or construction facilities	Moderate
All existing marinas except those listed individually	Moderate
All ferry terminals with the exception of Keystone	Moderate
All other unidentified areas	Low-Mod

Table 5-3. Current Area and Project-Specific Ranking for Puget Sound

AREA AND PROJECT-SPECIFIC RANKINGS		
AREA	**DETAILS**	**RANK**
Blaine	Except marina	Low
Bellingham	Bellingham waterfront, including Inner & Outer Squalicum Boat Harbor and the head of Squalicum Waterway	High
	Squalicum Waterway (except the head)	Moderate
	Bellingham Cold Storage	Moderate
Anacortes	Cap Sante Boat Haven	High
	Former Scott Paper Mill	High
	Cap Sante Waterway	Moderate
	Anacortes waterways, marinas and Guemes Channel	Moderate
Swinomish Channel	Federal Navigation Channel and La Conner Marina	Low
Whidbey Island	Coupeville (Keystone) Ferry Terminal	Low-Mod
	NAS Whidbey Island Fuel Pier	Moderate
Port Susan	West Port Susan, near Cavelero Beach	Moderate
Port Angeles	inside the harbor	High
Port Townsend	South side of point and south of PT Marina	High
	Port Townsend Marina	Moderate
	Oak Bay Channel	Low
Everett/ Snohomish River	East Waterway	High
	Snohomish River: Intertidal areas upstream to the upper turning basin	High
	Subtidal areas of the Snohomish River (through the upper settling basin)	Tier1/Low/ Low-Mod
	10th Street Boat Launch & Settling Basin Realignment	Low
	Everett Marina	Low-Mod/ Moderate
Mukilteo	All projects	High
Edmonds	All projects	High
Ship Canal/ Lake Washington	Salmon Bay	High
	Lake Washington Ship Canal	High
	Lake Union	High
	Kenmore (north end of Lake Washington)	High
	Lake Washington (except for Kenmore)	Moderate

AREA AND PROJECT-SPECIFIC RANKINGS		
AREA	**DETAILS**	**RANK**
Elliott Bay	Seattle Waterfront, West Waterway, East Waterway	High
Duwamish River	Navigation Channel, downstream of station 254+00	High
	Navigation Channel, upstream of station 254+00	Low-Mod
	Delta Marine	Low-Mod
	All other projects downstream of the settling basin	High
Bainbridge Island	Port Madison	Moderate
	Immediately adjacent to Wyckoff	High
	Inner Eagle Harbor (west of Wyckoff west beach)	Low-Mod
Bremerton	Sinclair Inlet	High
	Dyes Inlet	Moderate
Port Orchard	All projects	Low-Mod
Vashon Island	Upper portion Quartermaster Harbor	Moderate
	Outer Quartermaster Harbor	Low-Mod
Gig Harbor	All projects	Moderate
Tacoma	Commencement Bay except as specifically mentioned	High
	Blair Waterway (Commencement Bay) – navigation channel only; rank of cutback areas dependent on source review	Low
	Sitcum Waterway (Commencement Bay)	Low
Shelton	All projects	High
Olympia	Olympia Harbor (except parts of the federal navigation channel)	High
	Lower Budd Inlet, including East Bay and West Bay	High

Table 5-4. Current rankings for Grays Harbor and Willapa Bay

RANK	GRAYS HARBOR	WILLAPA BAY
High	Urban and Industrialized Areas	Urban and Industrialized Areas
Moderate	Marinas Fueling and Berthing Facilities Construction Facilities Located near moderate-sized sewer outfalls	Other Marinas Fueling and Berthing Facilities Construction Facilities Located near moderate-sized sewer outfalls
Low-Moderate	Rayonier Dock Port of Grays Harbor Terminals 2, 3, 4 Citifor Dock Weyerhaeuser Bay City Dock	None

RANK	GRAYS HARBOR	WILLAPA BAY
Low	Port of Grays Harbor Terminal 1 Crossover Reach North Reach Hoquiam Reach Cow Point Reach Aberdeen Reach South Aberdeen Reach	Bay Center Toke Point Channel
Tier 1 Exclusionary	Bar Reach Entrance Reach South Reach	Willapa Bar Bay Center Entrance Channel Bay Center Entrance Channel Bar

Table 5-5. Current rankings for projects on the Columbia River and other waterbodies

RANK	COLUMBIA RIVER	OTHER WATERBODIES
High	Typical locations include large urban areas and shoreline areas with major industrial development.	
Moderate	Typical locations include urban marinas, fueling, and ship berthing facilities; areas downstream of major sewer or stormwater outfalls; and medium-sized urban areas with limited shoreline industrial development. • Millennium Bulk Terminals – Longview • Georgia-Pacific Camas Slough	
Low-Moderate	Level 1 available data indicate a "low" rank may be warranted, but data are not sufficient to validate the low ranking. • Weyerhaeuser - Longview	• Port of Clarkston • Port of Lewiston
Low	Typical locations include areas adjacent to entrance channels, rural marinas, navigable side sloughs, and small community berthing facilities.	Snake/Clearwater federal navigation channel
Very Low (incl. in SEF)	Typical locations include gravel bars, mainstem channels such as the lower Columbia River or coastal inlets.	

5.1.4 Re-Ranking of Areas/Projects/Project Reaches

Modifications of the initial rankings can occur as the result of additional testing. A project area can be ranked higher (e.g., from low-moderate to moderate) based on the results of a single testing period. However, consistent results from two testing periods are required before a ranking can be lowered (e.g., from high to moderate). Projects may be ranked lower for a one-time dredging event based on the results of a partial characterization (see Section 5.7). However, two testing cycles will be required to lower the rank on a longer-term basis.

5.2 RECENCY & FREQUENCY GUIDELINES

Recency guidelines apply to material that has been sampled and tested for open-water disposal but not yet dredged. A key consideration in determining whether available data are still representative is the recency of the information. "Recency" guidelines for existing information refer to the duration of time for which chemical and biological characterization of project-specific sediment remains adequate and valid for decision making without further testing. These guidelines are based on the number and operating status of chemical sources near the area to be dredged, on whether the sediment is close to the sediment-water interface or could be disturbed, and on how well previous samples describe the current conditions at the project site. With older data there is increased potential for a "changed condition" that could alter its validity. Data must be sufficiently recent to be considered representative of the material to be dredged.

The ranking system for dredging projects takes into consideration both the sources of contamination and historical chemical and biological testing data (which are considered an integrated reflection of the effects of sources on the project area). Therefore, the recency guidelines are based on the project rank. For high-ranked projects, the recency guidelines allow characterization data to be valid for a period of 2 years. The recency guideline for moderate, low-moderate and low-ranked projects is a period of 5, 6 and 7 years respectively.

When other permitting requirements prevent a project from being dredged during the recency period, extension of the recency period will be considered on a case-by-case basis. When considering whether existing data continue to adequately characterize sediment from a specific project, the agencies will review previous characterization data, any new data from the dredge site or vicinity, and site use and character. Based on this review, the agencies may extend the recency determination, typically for one year. This extension may be allowed with no additional testing, or may require some level of additional testing, from confirmatory to full characterization.

The recency guidelines never apply when a known "changed" condition (e.g., accidental spills or new discharges) has occurred since the most recent samples were obtained. For subsurface sediments, the potential for contamination from groundwater sources must be considered.

Project proponents must request a recency extension from the DMMO if recency guidelines are likely to be exceeded at their project site prior to dredging. The recency extension request should thoroughly evaluate the above variables and suggest a course of action. The DMMP will respond in writing to the request, and provide a recency determination after the request has been evaluated.

For high-ranked areas with upland disposal, DMMP will use BPJ regarding recency.

For further clarification on recency extensions and guidelines, see the DMMP program-level updates entitled, *Recency Guidelines: Program Considerations* (2002b) and *Recency Guideline Exceedances: Guidelines for Retesting in High Ranked Areas* (2003b).

Frequency guidelines refer to the extent of time a given dredging project can be maintained with repeated dredging without further testing. Once the sampled and tested material has been dredged, frequency guidelines apply. Time durations for the frequency guidelines are the same as for the recency guidelines: two years for high-ranked areas; and 5, 6 and 7 years for moderate, low-moderate, and low-ranked areas respectively. Sediment dredged within the frequency guidelines will not generally require testing, unless there have been changed conditions in the project area (e.g. contaminant spill). However, two cycles of sampling and testing for a project are required before the frequency guidelines take effect. A biological testing failure--or opting out of biological testing during any testing cycle--will negate the applicability of the frequency guidelines and automatically result in a need to conduct testing every dredging cycle.

5.3 DEVELOPING A CONCEPTUAL DREDGING PLAN

Prior to determining a sampling plan, a project-specific conceptual dredging plan needs to be prepared. This plan takes into consideration the depth and physical characteristics of the sediment, side slopes, practicable dredge cut widths and depths, dredging along pier faces, other physical and logistical constraints, available dredging methods and equipment, and conventional construction practices at similar dredging projects.

While construction-level detail is not required at this point in the process, a realistic conceptual dredging plan will aid in the delineation of DMMUs and avoid the situation in which a regulatory determination could negatively impact the ability to dredge the project and properly dispose of the material.

5.4 DETERMINING VOLUME OF MATERIAL TO BE DREDGED

Where possible, the physical geometry and volume of sediments proposed for dredging should be determined from a pre-sampling bathymetric survey. The dredging volume calculation should include side slopes, overdepth and sediments anticipated to slough from under piers and wharves. For dredging projects with cuts deeper than 4 ft and that occur infrequently, the dredging prism should be divided between a "surface" layer (generally four feet in depth) and a "subsurface" layer consisting of everything below the surface layer. The volumes comprising each of these layers should be calculated.

Dredging contracts routinely include "overdepth" material that is often one to two feet below the required dredging depth (except for very small projects where it may be decided to minimize overdepth volume for cost control). Overdepth volume will be included in the calculation of the requirements for sampling and analysis.

Volume estimates, including overdepth material, are incorporated into the project permit, water quality certification and site use authorization. Exceedances of permitted volumes may result in fines or work stoppages. Thus it is important to develop an accurate volume estimate of material to be dredged. To reduce the incidence of permit violations, the following guidelines should be followed:

1. Pre-sampling surveys should be taken as close in time as possible to the sampling event to get the best possible bathymetric data for volume estimates.
2. Pre-sampling volume estimates must include allowable overdepth for the entire dredging prism, including sideslopes. Technical justification for the selected angle of repose for the sideslopes must be included in the sampling and analysis plan.
3. When a box cut is proposed along a pier face, it is recommended that sloughing from under the pier be anticipated in all cases. Technical justification for the selected angle of repose for sideslopes under piers must be included in the sampling and analysis plan. The dredging proponent should ensure that all necessary geotechnical or under-pier survey data be provided to the contractor estimating the dredged material volume.
4. It is highly recommended that presampling estimates of in-situ volume be increased by an uncertainty factor to account for the error inherent in the estimation process. Sampling and

testing requirements will be based on this adjusted volume. The uncertainty factor must be identified in the sampling and analysis plan along with a technical justification for its selection. It should be noted that the uncertainty factor applies only to estimates of in-situ volume and is not meant to address bulking of sediments during dredging.

Some areas, particularly channels and settling basins, are characterized by rapid shoaling during winter storm events. Since sampling and testing are required prior to dredging, not all of the sediments to be dredged will have been deposited at the time of sampling. In such instances, pre-sampling bathymetric surveys, records from previous dredging events and best professional judgment will be used to estimate the volume of sediments likely to be dredged. Sampling and testing requirements will be based on this estimated volume.

5.5 DETERMINING THE NUMBER OF DMMUS AND FIELD SAMPLES

The number of field samples to be taken and the number of laboratory analyses conducted to fully characterize the sediments for any given project must be sufficient to allow for an adequate assessment. The following guidelines specify a maximum volume of dredged material that can be represented by a single field sample and by a single laboratory analysis. They are considered "minimum" requirements in that the dredger may opt, or regulatory agencies may require, additional samples or analyses if warranted.

5.5.1 Dredged Material Management Units

A "dredged material management unit" (DMMU) is the smallest volume of dredged material that is truly dredgeable (i.e., capable of being dredged independently from adjacent sediments) and also for which a separate disposal decision can be made by the agencies. Thus, a given volume of sediment can only be considered a DMMU if it is capable of being dredged, evaluated and managed separately from all other sediment in the project.

The DMMO can provide any assistance necessary in the development of a sampling approach.

All of the field samples taken within a DMMU are composited to provide a single sediment sample for laboratory analysis that is representative of that DMMU. Therefore, the selection of sampling locations and the development of a compositing scheme must provide an accurate representation of the condition of each DMMU. In general, samples should be distributed across the dredging prism so as to target the bulk of the dredge volume. However, special circumstances, such as the presence of sources of contamination, may dictate otherwise. The location of point sources in the vicinity of the project must be taken into consideration when locating field samples, but "worst-case" sampling should *not* be the goal of full characterization (it *is* the goal of partial characterization sampling; see Section 5.7). Tier I information, including the location of point sources, should be included in the sampling and analysis plan and should support the sampling locations selected to ensure representative sampling of the proposed dredged sediments.

5.5.2 How Many DMMUs?

Sediment in any given project is considered either “heterogeneous” or “homogeneous.” Heterogeneous sediment is presumed, or known, to have different contamination levels in the surface and subsurface sediments. Most projects fall into this category. Heterogeneous sediments are sampled with a core sampling device in order to sample the entire depth of the dredge prism.

To characterize heterogeneous sediments, different sampling intensities are used for the surface and subsurface portions of the dredge prism (**Table 5-6**). Heterogeneous sediment is divided into "surface" (0 to 4 feet of the dredging prism) and "subsurface" (greater than 4 feet below the sediment surface. Using Table 5-5, in a moderate-ranked area with 32,000 cubic yards (CY) of surface material (0- 4-foot cut depth) and 24,000 CY of subsurface material (at 4-foot cut depth or deeper), a total of three DMMUs are required (two from the surface volume and one from the subsurface volume).

This approach assumes that the surface material is more contaminated than the underlying material. If it is known, or suspected, that this scenario does not hold for a particular dredging project, then best professional judgment must be applied in determining volume limits for DMMUs.

For projects which are dredged frequently due to rapid or routine shoaling, the sediments are expected to be relatively homogeneous and the distinction between surface and subsurface sediments becomes less important. In this case, DMMU volumes may be based on the average of surface and subsurface maximum allowable volumes. The proposed dredging volume may be divided by this average volume to determine the number of DMMUs. Grab samples are usually considered adequate to characterize homogeneous sediments.

The DMMO must be consulted before categorizing a project as "homogenous" as there are only a small number of cases in which this designation applies. These include--but are not limited to--the Duwamish turning basin and adjacent federal navigation project, Snohomish River federal navigation project, Swinomish Channel federal navigation project and the Grays Harbor federal navigation project.

Table 5-6. Maximum sediment volume represented by each DMMU

PROJECT RANK	HETEROGENEOUS SEDIMENT (contamination level decreases with depth)		HOMOGENEOUS SEDIMENT (well mixed)
	SURFACE	SUBSURFACE	
Low	48,000 CY	72,000 CY	60,000 CY
Low-moderate	32,000 CY	48,000 CY	40,000 CY
Moderate	16,000 CY	24,000 CY	20,000 CY
High	4,000 CY	12,000 CY	8,000 CY

5.5.3 Sampling Intensity

The maximum volume of sediment that may be represented by a single field sample (typically a 4-foot core section) varies with project rank and is presented in **Table 5-7**. For projects in areas ranked low or low-moderate, a single sediment sample should be taken for every 8,000 CY of material to be dredged. For projects in areas ranked high or moderate, a single sediment sample should be taken for every 4,000 CY. Unlike the maximum volume represented by each DMMU, the maximum volume represented by each field sample does not vary with sediment depth. Continuing with the example presented in the previous section, a moderate-ranked project with 32,000 CY of surface sediment and 24,000 CY of subsurface sediment would require a total of 14 field samples:

eight from the surface volume and six from the subsurface volume, which would be composited respectively to generate two analyses/DMMUs for the surface material and a single analysis/DMMU for the subsurface material.

Table 5-7. Maximum sediment volume represented by a single field sample

PROJECT RANK	SURFACE	SUBSURFACE
Low	8,000	8,000
Low-moderate	8,000	8,000
Moderate	4,000	4,000
High	4,000	4,000

5.6 SPECIAL PROJECT CONSIDERATIONS

5.6.1 Reduced Sampling and Testing for Small Projects

For small projects, the cost of testing must be balanced against the environmental risks posed by disposal of a very small volume of dredged material. Small projects in low, low-moderate and moderate ranked areas represent low potential risk that unacceptable adverse effects will result at the disposal site from the discharge of project material. As a result, with the exception of high-ranked areas, a small volume of sediment to be removed at a dredging site may require no testing or reduced testing.

To clearly define what constitutes a small project, there are two key qualifiers. First, intentional partitioning of a dredging project to reduce or avoid testing requirements is not acceptable. Second, recognizing that multiple small discharges can cumulatively affect the disposal site, project volumes are defined in as large a context as possible. One example of this latter qualifier is recurring maintenance dredging of a small marina where "project volume" will be the projected dredging volume over 5 years. Another example is multiple-project dredging contracts where a single dredging contractor conducts dredging for several projects under a single contract or contract effort. Again, the "project volume" will be summed across all projects (as will any sampling and compositing efforts prior to testing).

5.6.2 "No-Test" Volumes for Small Projects

For projects in low, low-moderate, or moderate-ranked areas, volumes for which no testing need be conducted are shown in **Table 5-8**. For low-ranked areas, the "no test" volume is equal to the maximum volume represented by a single field sample (i.e., 8,000 CY). For low-moderate and moderate rankings, the "no test" volume of 1,000 CY is representative of the capacity of medium-sized barges. For high-ranked areas there is not a "no test" volume and some testing is always required.

Table 5-8. "No Test" volumes for small projects

PROJECT RANK	"NO-TEST" VOLUME
Low	Less than 8,000 CY
Low-moderate and Moderate	Less than 1,000 CY
High	Some testing is always required

Some small dredging projects consist of the removal of sediment discharged from an outfall, or located directly adjacent to an outfall, yet fall within a general geographic area ranked low, low-moderate or moderate. However, it is possible that these sediments contain chemicals at a level of concern far greater than the area in general. Therefore, such dredging projects may be given a "high" rank by the agencies regardless of the rank of the general area. This decision will be made on a case-by-case basis, with consideration given to the type and size of the outfall, the shoaling pattern relative to the outfall, and any other relevant information available to the project proponent, such as catch basin and particulate data associated with the outfall.

5.6.3 Reduced Testing for Small Projects Exceeding the "No-Test" Volume

The original PSDDA documents outlined reduced testing requirements for some small projects that exceed the no-test volume (PSDDA 1988). These guidelines have been rarely used during the life of the program. For more information please contact the DMMO office.

5.6.4 Reduced Sampling and Testing for Native Material

Projects that involve dredging of native material that has not been exposed to contaminated groundwater may require less sampling and testing than the requirements identified in **Table 5-6** and **Table 5-7**. The agencies will make this determination using best professional judgment on a case-by-case basis using site-specific information.

5.7 PARTIAL CHARACTERIZATION FOR DOWN-RANKING

A dredging proponent may choose to do a partial characterization (PC) of project sediments. A PC is most frequently done on larger projects and is based on the chemical analysis of a limited number of samples. If the PC data indicate that the project has been over-ranked, then down-ranking may be permitted for a subsequent full characterization (FC). Down-ranking may substantially reduce the overall cost of sampling and testing for a large project.

A PC is designed to be simple and economical. A PC is not a substitute for a full characterization, but is only a means for establishing a "reason to believe" that a lower ranking is appropriate. A PC must provide sufficient information to support a decision to re-rank a project. PC results are used to down-rank a project on a one-time basis only. Two cycles of testing are required for longer-term down-ranking.

5.7.1 Development of a PC Sampling and Analysis Plan

A sampling and analysis plan must be developed for a PC. The PC plan must be submitted to the DMMO, who in turn will coordinate agency review with EPA, Ecology and DNR representatives.

The following PC guidelines are appropriate for most dredging projects. However, because anomalies may exist for a given project, the agencies reserve the right to depart from these guidelines if conditions so warrant (e.g. complex chemical source environment, ambiguous and/or highly variable characterization data, etc.). As with all aspects of the dredged material evaluation process, professional judgment will be an important factor in the decision-making process. The dredger should coordinate with the DMMO in the development of an adequate PC plan.

5.7.2 Sampling Requirements for Down-Ranking

The number of samples required for down-ranking is based on a percentage of the number of samples that would be required for a full characterization. A dredger may elect to down-rank up to two levels by increasing the sampling intensity. No compositing of samples for a PC is allowed. PC sampling station delineation must be approved in advance by the agencies and should represent "worst-case" sampling relative to the location of local point sources.

For the option of lowering a rank one level, ten percent of the FC minimum surface sample requirement must be analyzed for a PC. A minimum of two samples must be analyzed for this option. For the option of lowering a ranking two levels, 20 percent of the FC minimum surface sample requirement must be analyzed for a PC. At least three samples must be analyzed for this option. A dredger has the option of performing a PC on subareas of a dredging project. Subareas must be selected with the approval of the agencies. A minimum of two samples is required for each subarea. Although a PC is most frequently done on surface sediments, a dredger may be required to perform subsurface sampling and analysis during a PC if there is reason to believe that subsurface sediments are contaminated relative to sediments in the upper four feet of the dredging prism.

Partial characterization data for a given sampling station may also be used, in some limited cases, in partial fulfillment of FC requirements. The strategy for doing so must be clearly stated in the PC sampling and analysis plan and approved by the agencies.

5.7.3 Ranking Guidelines Based on PC Data

The down-ranking of a project (or subarea) will be based on the results of the sample having the highest level of chemicals of concern (see also Section 8.4, which discusses special COCs). Ranking guidelines based on PC data are shown in Table 5-9.

PC samples must be analyzed for the full list of chemicals of concern (see **Table 8-2**) and sediment conventionals. PC data may also be used as a "reason to believe" test to screen out certain chemicals of concern. If a chemical is not found in the PC and is not available from nearby sources, it may be deleted from the full characterization.

Table 5-9. Ranking Guidelines Based On Partial Characterization Data

RANK	PC GUIDELINE
High	At least one chemical > ML
Moderate	At least one chemical > (SL +ML)/2 and < ML
Low-moderate	At least one chemical > SL and < (SL + ML)/2
Low	All chemicals < SL

5.8 SAFETY-NET BIOLOGICAL TESTING

To avoid a situation where a COC not on the standard list is present at a concentration high enough to cause biological effects, "safety-net" biological testing may be required of a limited number of DMMUs for low-ranked areas. Biological testing will consist of the 10-day amphipod test and one other bioassay from the standard suite. Twenty percent of project DMMUs, representing the finest-grained material, should be tested (minimum of one DMMU). If there are exceedances of the screening levels for any DMMUs, triggering biological testing, these DMMUs will fulfill the requirement for safety-net testing as long as the twenty-percent guideline is followed. The frequency of safety-net testing for low-ranked projects is 6 years.

If all chemicals-of-concern are below the screening level, yet the safety-net biological testing indicates a potential for adverse biological effects, best professional judgment will need to be applied in resolving the apparent conflict between the chemical and biological testing data. Additional chemical or biological testing may be needed to determine the nature of the problem.

5.9 NEW SEDIMENT EXPOSED BY DREDGING (Z-SAMPLES)

Dredging alters environmental conditions in the dredging area by exposing new sediments to direct contact with biota and the water column. The sediment exposed by dredging must meet the antidegradation policy (WAC 173-204-120) under the State of Washington Sediment Management Standards (SMS). The “Z-sample” represents the sediment that will be exposed by dredging. Z-samples are collected from the **first two feet** below the dredging overdepth and must be collected during sampling for all projects requiring core sampling. Z-sample collection and analysis guidance is as follows:

- Z-samples will be collected and archived for every core sampling location for all projects, regardless of rank. Archived sediment must be maintained at -18° C.
- If TBT testing is required for the dredge prism samples, interstitial water from unfrozen Z-samples must be extracted within seven days of field collection. The porewater extract must be archived at -18°C.
- It is likely that the holding time for mercury will be exceeded prior to any testing of archived Z-sample sediment. If the Z-sample is eventually tested for mercury, the results should be flagged as having exceeded the holding time.
- If an immediately overlying DMMU is found to be contaminated (e.g., unsuitable for unconfined-open-water disposal), the associated underlying Z-sample must be analyzed to verify the sediment quality of the Z-horizon.
- If there is reason-to-believe that concentrations of chemicals of concern increase with depth, the DMMP agencies may require Z-samples to be analyzed concurrently with analysis of the DMMUs.
- Z-sample analyses will initially consist of sediment conventional and chemical analyses. If the results of these analyses indicate that the sediment to be exposed by dredging will be degraded relative to the existing sediment surface, the dredging applicant may be required to remobilize and resample locations with degraded Z-samples in order to perform required biological testing (bioassays and/or bioaccumulation testing).
- For the majority of projects, a decision about Z-sample analysis will be made after review of the chemistry/bioassay data associated with the dredged material.

For further discussion of Z-sample testing and antidegradation evaluations, see Chapter 12.

6 PREPARING THE SAMPLING AND ANALYSIS PLAN (SAP)

Once the required numbers of DMMUs and field samples have been calculated and a dredging plan conceived, a sampling plan must be developed. The DMMUs and field samples must be distributed within the actual dredging prism in a manner consistent with the definition of a DMMU and any project-specific constraints. It is not necessary or always desirable to restrict the volumes characterized by each individual sample or DMMU in the field to the maximums from **Table 5-6** and **Table 5-7**. Best professional judgment is necessary in the allocation of DMMUs and the development of a sampling and compositing plan.

In dividing the proposed dredging volume into DMMUs, it is important to ensure that the DMMUs be fully reflective of the dredging plan, i.e., *that the management units be truly "dredgeable."* If an individual DMMU (represented by one or more field samples) is found unsuitable for unconfined open-water disposal, then that DMMU must be capable of being dredged independently from adjacent sediment. Additional DMMUs--beyond the minimum number--may be required to achieve an appropriate dredging plan (e.g., where different sediment types or physically separated areas warrant separate DMMUs).

Steps followed in developing characterization requirements in Chapter 5 must be documented in the sampling and analysis plan developed for review by the agencies.

6.1 FULL CHARACTERIZATION SAMPLING PLAN DEVELOPMENT

A well-designed sampling and analysis plan (SAP) is essential when evaluating the potential impact of dredged material discharge upon the aquatic environment. The SAP is submitted to the DMMO for coordinated review and approval by regulatory agencies before any sampling is initiated, as shown in **Figure 3-1**. This coordination, including full and open disclosure of information, reduces the chance of having to repeat costly procedures and assists in keeping projects on schedule.

The SAP should contain the information outlined in the following sections in enough detail to allow the agencies to determine the adequacy of the sampling and analysis program.

6.2 PROJECT OVERVIEW

1. maps of vicinity and project area and plan view of site
2. project description, recent bathymetric survey data, one or more cross-sections of the dredging prism, dredging depth (MLLW) including overdepth, side-slope ratios, and proposed disposal site
3. project volume, including sideslopes and overdepth, and contingency factor used in volume calculations
4. site history, including past characterization data, past and current site use, identification of potential sources of contamination, and past permitting (including NPDES permits as well as dredging)
5. project schedule
6. personnel involved with the project and their respective responsibilities, including project planning and coordination, field sampling, chemical and biological testing labs, QA management, data validation and final report preparation
7. signature page for subcontractors

6.3 CHARACTERIZATION PLAN

1. project rank and justification
2. computation of DMMP sampling and analysis requirements based on surface (0-4 feet) and subsurface (> 4 feet) volumes,
3. conceptual dredging plan, if necessary, to justify the design of the DMMUs
4. map/s of project area with DMMU outlines(including sideslopes) and target sampling locations; cross sections if necessary
5. table with DMMU identification, DMMU volume, designation as surface or subsurface DMMU, and number of samples for each DMMU
6. compositing plan, including sampling depths relative to both mudline and MLLW
7. Z-sample plan

6.4 SAMPLING

1. sampling equipment and capability
2. table of sampling locations including coordinates, mudline elevation (MLLW), design depth, overdepth, Z-depth, and preliminary determination of required core lengths to be assigned to DMMUs and Z-samples
3. horizontal datum – NAD83, HPGN83, HARN83 or WGS84
4. anticipated mudline elevations at the target sampling stations
5. horizontal positioning system and accuracy of sampling stations (must be <± 3 meters)
6. method for determining real-time water depths at sampling stations
7. method for real-time determination of tide levels (e.g. Hazen gauge or tide board), including procedure for establishing or verifying vertical control
8. sample acceptance criteria (e.g. penetration and recovery criteria for cores)
9. description of the use of water depths, tide elevations, penetration and recovery data to determine the actual core lengths to be assigned to DMMUs and Z-samples
10. location where sample processing will occur (i.e. on-board vessel, onshore, laboratory)
11. decontamination procedures
12. table of analytical groups (e.g. semivolatiles, metals, bioassays) with planned sample volumes, container sizes and type, holding times and conditions; this table should also include archived samples
13. sulfides sampling procedure
14. description of entries that will be made in field/sampling logs
15. description of core logging
16. chain-of-custody procedures
17. proposed sampling schedule

6.5 CHEMICAL ANALYSIS

1. plans for physical and chemical laboratory testing, including grain-size analysis, sediment conventionals and chemicals-of-concern
2. table(s) of current chemicals of concern, with relevant regulatory limits (DMMP and SMS, marine and/or freshwater) clearly indicated (with correct units of measure), including extraction/digestion methods, analytical methods, method reporting limits and method detection limits for all COCs
3. table(s) of QA parameters, frequency of analysis, and acceptance guidelines
4. use of the Puget Sound Sediment Reference Material for dioxin and PCBs; including PS-SRM request procedure and acceptance ranges for Aroclors and congeners (as needed)
5. identification of SRMs to be used for semivolatiles, pesticides and metals, including the SRM certificates and the acceptance ranges the lab plans to use for quality control
6. dioxin quality assurance and interpretation guidelines, if necessary
7. validation stage for each analytical group
8. statement indicating that reporting limits or sample reporting limits must be at or below SLs to avoid bioassays
9. chemistry lab reporting requirements, including case narrative describing analytical problems

6.6 BIOLOGICAL ANALYSIS

1. selection of tiered or concurrent bioassays
2. bioassays to be used, species-selection rationale and a brief description of the protocols
3. decision-making process for determining amphipod species vis a vis grain size and clay content (i.e. if clay content is greater than 20%, use *Ampelisca abdita*)
4. decision-making process for determining whether to purge for ammonia or sulfides and/or run an LC_{50} test for ammonia
5. decision-making process for determining whether to use the larval resuspension protocol
6. statement that larval test will be aerated
7. water quality monitoring parameters, schedule and acceptance limits
8. proposed collection location of reference sediments and how reference sediments will be matched to test sediments; the wet-sieving protocol should be included
9. table with bioassay interpretation and reference/control performance standards
10. list of data to be provided to DMMO in the event that bioassays are needed: grain-size and sediment conventional data (especially ammonia and sulfides) for DMMUs to be tested
11. bioassay lab reporting requirements

6.7 REPORTING REQUIREMENTS

All of the following are required elements of a sediment characterization report and should be listed in the SAP:

1. explanations of any deviations from approved SAP
2. sampling equipment and protocols used
3. methods used to locate sampling positions
4. table with coordinates of actual sampling locations, measured water depth at each location, tidal stage at the time of sampling each station, and mudline elevations (tide-corrected to MLLW)
5. figure showing target and actual sampling locations with DMMU outlines
6. penetration and recovery data
7. compositing scheme with actual core lengths and depths (referenced to both MLLW and the mudline)
8. table of analyzed concentrations for all DMMP COCs, lab and validation qualifiers, method reporting limits and method detection limits, with DMMP guideline exceedances highlighted
9. table of analyzed concentrations for all SMS COCs, lab and validation qualifiers, method reporting limits and method detection limits, with SMS guideline exceedances highlighted
10. chemistry QA review and validation results
11. summary table/s of bioassay results, QA data and interpretation
12. sampling/field log as an appendix
13. core logs as an appendix, including any relevant photos
14. chemistry data report (including a case narrative) as an appendix
15. bioassay report as an appendix
16. validation report as an appendix
17. EIM-ready data to be submitted to the Corps for QA review (electronic submittal only)
18. QA2 data for Ecology (electronic submittal only)
19. chain-of-custody forms as an appendix

7 SAMPLING

7.1 TIMING OF SAMPLING

Sampling must be conducted using a SAP that has been approved by the DMMP agencies and accomplished well in advance of dredging to allow time for testing, data review and permitting.

Areas that receive large volumes of material due to shoaling during winter storm events also need to be sampled prior to dredging. Because these projects are typically dredged within a short time after deposition by winter storms, insufficient time is available to completely characterize all the material that will eventually be dredged. Instead, material that is already in place prior to the winter storm season is sampled and tested. This sampling strategy assumes that sediments deposited annually by winter storms will have a chemical composition very similar to the sediments that are in place at the time sampling and testing is conducted. This strategy is a compromise that includes consideration of the need to provide representative sampling and the need to provide an evaluation process adaptable to the fast shoaling pattern found in these areas. This compromise will also help avoid reliance on "emergency dredging" whereby sediment sampling and testing is not possible prior to dredging. Accordingly, the number of DMMUs and field samples will be based on pre-sampling bathymetric surveys, records from previous dredging events and best professional judgment.

7.2 SAMPLING APPROACH

If full characterization sampling and analysis is required for a project, the applicant will be required to sample the sediment for chemical and, if necessary, biological analyses. There are three sampling approaches that the dredging proponent may take:

1. **Concurrent Testing:** Collect sufficient sediment for all chemical and biological tests potentially required. Run these tests concurrently.
2. **Tiered Testing:** Collect sufficient sediment as above, but archive adequate sediment for biological testing pending the results of the chemical analysis.
3. **Tiered Testing/Resampling:** Collect only enough sediment to conduct the chemical analyses and, if biological testing is required, re-sample the site.

The proposed sampling approach should be clearly documented in the sampling and analysis plan. The selection of either option 1 or 2 is encouraged because these alternatives provide chemical and biological data on sub-samples of a single homogenized sediment sample. These alternatives are also advantageous because they both preclude the cost involved with collection of additional sediment. Concurrent testing is the least time consuming, and is likely the most economical when the need for biological testing is expected. For tiered testing, the biological samples must be stored in the dark at 4 degrees C with zero headspace (or with headspace purged with nitrogen) while chemical tests are completed. **Maximum holding time for biological testing is 56 days. Holding time starts the day the first cores or grabs representing a DMMU are collected.**

Tiered testing with re-sampling should only be considered if biological testing is not expected. If it does occur, biological analysis can proceed without re-analysis of sediment chemistry, unless bioaccumulation testing will also be conducted. Biological samples must be taken from the same stations as the previous sediment chemistry samples.

In general, seven (7) liters of composited and homogenized sediment will be needed to provide adequate volume for physical, chemical and standard biological analysis. Bioassay analysis requires a minimum of five (5) liters while physical and chemical analysis requires approximately one (1) liter of sediment. The additional liter should be archived for possible chemical retesting.

Bioaccumulation testing requires a minimum of 15-20 liters of sediment beyond the 6 liters needed for standard testing. Because of the large volume required for bioaccumulation testing, most dredging proponents do not collect this additional material during the initial sampling event, but wait to see if any bioaccumulation triggers are exceeded. In the event that bioaccumulation testing is triggered, a second round of sampling would become necessary, along with physical and chemical re-testing of the DMMU(s) in question. For all projects where samples are taken with coring devices, sediment that will be exposed by dredging must also be sampled. Please refer to Section 5.9 (Z samples).

7.3 POSITIONING METHODS

A precision navigation system should be used to navigate to and record all sediment sampling locations to a geodetic accuracy of ± 3 meters. In most cases, samples should be obtained as near as possible to the target locations provided in the project sampling plan. Such accuracy can be obtained with a range of positioning hardware, such as microwave transponders, differential GPS, electronic measuring devices, etc. The exact positioning system to be used and associated QA/QC procedures should be documented in the sampling and analysis plan.

Sampling location data will be entered into Ecology's Environmental Information Management (EIM) system referenced to North American Datum of 1983 (NAD 83) or the World Geodetic System 1984 (WGS 84). If sampling locations are referenced to a local coordinate grid, the local grid should be tied to NAD 83 or WGS 84 to allow conversion to latitudes and longitudes. The North American Datum of 1927 (NAD 27) is outdated and should not be used. **Table 7-1** outlines the required level of accuracy.

Table 7-1. Required accuracy for sample positioning

COORDINATES IN:	LEVEL OF ACCURACY
Degrees Minutes Seconds	2 decimal places
Degrees Minutes	4 decimal places
Decimal Degrees	6 decimal places
State Plane	Nearest foot
UTM	meters, with 1 decimal place

7.4 SAMPLING METHODS

The goal of sediment sampling for characterization of each individual DMMU is to collect a sample (or a number of composited samples) which will be representative of the DMMU. The accuracy of this representation can be increased vertically by taking core samples from the sediment/water interface down to the maximum proposed depth of dredging (including overdepth) and horizontally by increasing the number of samples taken. The DMMP agencies have established minimum sampling requirements (see Chapter 5) based on volumetric measurements. The type of sampling required, however, depends on the type of project. The sampling methodology to be used should be presented in the sampling and analysis plan along with the rationale for its use.

7.4.1 Core Sampling

For projects with heterogeneous sediment and for new-work dredging, the proponent will be required to take core samples from the sediment/water interface down to the maximum depth of dredging, including overdepth and Z-samples.

There are numerous gear options available for obtaining core samples. These include impact corers, hydraulic push corers, vibracorers, augers with split spoons or Shelby tubes, etc. The methodology chosen will depend on availability, cost, efficacy, type of sediment, and anticipated sediment recoveries.

7.4.2 Grab Sampling

Sediments in frequently dredged areas (e.g. Grays Harbor navigation channel) are assumed to be relatively homogeneous. Therefore, for homogenous projects not in high-ranked areas, grab samples will be considered adequate to represent the dredged material, even if shoaling results in sediment accumulation greater than four feet. The minimum number of grab samples required can be calculated from the tables in Chapter 5.

7.5 SAMPLE COLLECTION AND HANDLING PROCEDURES

Proper sample collection and handling procedures are vital for maintaining the integrity of the sample. If the integrity of the sample is compromised, the analysis results may be skewed or otherwise unacceptable. Procedures for decontamination, sampler deployment, sample logging, sample extrusion, compositing, sample transport, chain of custody, archiving and storage all need to be discussed in the sampling and analysis plan.

The remainder of this chapter provides general guidance on sample handling procedures. For further guidance please refer to the Puget Sound Protocols and Guidelines (PSEP, 1997a), which describe field collection and processing methods.

7.5.1 Decontamination Procedures

It is recommended that sampling containers be decontaminated by the laboratory or manufacturer prior to use. All sampling equipment and utensils such as spoons, mixing bowls, extrusion devices, sampling tubes and cutter heads, etc., should be made of non-contaminating materials and be thoroughly cleaned prior to use. The intention of these procedures is to avoid contaminating the sediments to be tested, since this could possibly result in dredged material, which would otherwise be found acceptable for open-water disposal, being found unacceptable. While not strictly required, an adequate decontamination procedure is highly recommended. Typical decontamination procedures for sampling equipment include the following steps:

1. Remove excess sediment with a brush and *in situ* water
2. Clean with a phosphate-free detergent solution (such as Alconox)
3. Rinse equipment thoroughly with clean *in situ* water
4. Triple rinse with analyte-free de-ionized water

The dredging proponent assumes a higher risk of sample contamination by not following an established protocol. Additional decontamination steps such as a solvent rinse or dilute acid rinse may be necessary for contaminated sites or sites with a higher possibility of encountering contamination. Consult the Puget Sound Protocols and Guidelines for more specific guidance.

After decontamination, sampling equipment should be protected from recontamination. Any sampling equipment suspected of contamination should be decontaminated again or removed from use. During core sampling, extra sampling tubes should be available on-site to prevent interruption of operations should a sampling tube become contaminated. Sampling utensils should be decontaminated again after all sampling has been conducted for a given DMMU to prevent cross-contamination. Disposable gloves are typically used and disposed of between DMMUs.

7.5.2 Sample Collection

Sampling procedures and protocols will vary depending on the sampling methodology chosen. Whatever sampling method is used, measures should be taken to prevent contamination from contact with sources of contamination such as the sampling platform, grease from winches, engine exhaust, etc. Core sampling methodology should include the means for determining when the core sampler has penetrated to the required depth. If the core is driven beyond the proposed dredging depth, field records and core logging must be adequate to allow the proper core section(s) to be taken post-sampling for inclusion in the sample composite. The sampling location must be referenced to the actual deployment location of the sampler, not to another part of the sampling platform such as the bridge of a sampling vessel.

7.5.3 Core Acceptability and Percent Recovery

In order for the samples collected to be a good representation of the DMMU, each core collected needs to be representative of the sediment column being characterized. The criteria that will be used to determine if a core is acceptable for use need to be outlined in the SAP. At a minimum these should include acceptance criteria for core penetration and percent recovery.

Percent recovery is defined as the length of sediment retrieved divided by the length of the core penetration. Under ideal conditions percent recovery would be 100%, but due to variability in sediment type and coring conditions this is rarely the case. In order to assure that the dredge prism is being adequately characterized, the DMMP agencies require that the minimum percent recovery be defined in the SAP. The recommended core acceptance criterion for percent recovery is at least 75%, although this will vary for some projects.

7.5.4 Holding Times

For some large projects, many cores are collected and composited together to form an analytical sample. Sometimes cores are collected over multiple days and stored over ice or in a refrigerated room until all cores to be composited for a DMMU are collected. In this situation, the holding time for the sample begins on the day that the first core is collected. Cores should be held for the minimum time possible before processing.

7.5.5 Sulfides Sub-sampling

Volatiles are no longer on the standard list of chemicals of concern, and do not require collection or analysis, except if specifically requested by the DMMP agencies. The sulfides sub-samples should be taken immediately upon extrusion of cores or immediately after accepting a grab sample for use. For composited samples, one core section or grab sample should be randomly selected for the sulfides sampling. Sediments which are directly in contact with core liners or the sides of the grab sampler should not be used.

For sulfides sampling, 5 mls of 2 Normal zinc acetate per 30-g of sediment should be placed in a 4-ounce sampling jar. It is recommended that jars containing the zinc acetate be prepared in advance in order to reduce the possibility of zinc cross-contamination in the field. The sulfides sample sediments should be placed in the jar, covered, and shaken vigorously to completely expose the sediment to the zinc acetate.

The sulfides sampling jars should be clearly labeled with the project name, sample/composite identification, type of analysis to be performed, date and time, and initials of person(s) preparing the sample, and referenced by entry into the log book. The sulfides sampling jars should indicate that zinc acetate has been added as a preservative.

7.5.6 Sampling Logs

As sediment is collected, whether by core or grab, sampling/field logs must be completed. The following should be included in this log:

1. Date and time of collection of each sediment sample.
2. Names of field supervisors and person(s) collecting and logging in the sample.
3. Weather conditions.
4. The sample station number and individual designation numbers assigned for individual core sections.
5. Penetration depth and notation of any resistance of the sediment column to coring.
6. Percent recovery of each core and percent recovery calculations.
7. The measured water depth at each sampling station and the tidal stage at the time of sampling at each station. The measured water depth should then be corrected to mean lower low water (MLLW) by subtracting the tidal stage. The method/procedure used to determine the real-time tidal stage should be documented in the log.
8. For grab samples: physical sediment description, including type, density, color, consistency, odor, stratification, vegetation, debris, biological activity, presence of an oil sheen or any other distinguishing characteristics or features.
9. Any deviation from the approved sampling plan.

7.5.7 Extrusion, Core Logging, Compositing and Sub-sampling

Depending on the sampling methodology and procedure proposed, sample extrusion, core logging, compositing and subsampling may take place. If core sampling is conducted, these activities can either occur at the sampling site (e.g., on board the sampling vessel) or at a remote facility. Grab samples are processed immediately upon sampling. If cores are to be transported to a remote facility for processing, they should be stored upright on ice onboard the sampling vessel and during transport. The cores should be sealed in such a way as to prevent leakage and contamination. If the cores will be sectioned at a later time, thought needs to be given to core integrity during transport and storage to prevent loss of stratification. For cores or split-spoon sampling, the extrusion method should include procedures to prevent contamination.

Core logging can provide valuable information, not only for sediment characterization, but also for the dredging contract itself. It is recommended that core logging be conducted using the Unified Soil Classification System. The core logs should also include a qualitative physical description, including density, color, consistency, odor, stratification, vegetation, debris, biological activity, presence of an oil sheen or any other distinguishing characteristics or features. Finally, the core logs should also record the penetration, recovery and indicate the core sections representing the DMMUs and Z-samples.

For composited samples, representative volumes of sediment should be removed from each core section or grab sample comprising a composite. The composited sediment should be thoroughly mixed until homogenized to a uniform color and consistency, and should occasionally be stirred while individual samples are taken of the homogenate. This will ensure that the mixture remains homogenous and that settling of coarse-grained sediments does not occur.

Seven (7) liters of homogenized sample needs to be prepared to provide adequate volume for physical, chemical and standard biological laboratory analyses. Bioassays require a minimum of five (5) liters while physical and chemical testing requires approximately one (1) liter of sediment. Additional sample volume may be necessary for analysis of additional special COCs, especially for porewater TBT, and for archive material. Physical, chemistry and bioassay samples should be taken from the same homogenate. Portions of each composite sample will be placed in appropriate containers obtained from the testing laboratories (**Table 7-2**).

After compositing and sub-sampling are performed, the sample containers should be refrigerated or stored on ice until delivered to the analytical laboratory. The samples reserved for bioassays should be stored in the dark at 4 degrees C in containers with zero headspace, or with headspace purged with nitrogen, for **up to 56 days** pending initiation of any required biological testing. Each sample container should be clearly labeled with the project name, sample/composite identification, type of analysis to be performed, date and time, and initials of person(s) preparing the sample, and referenced by entry into the log book.

Table 7-2. Sample storage criteria

SAMPLE TYPE	HOLDING TIME	TEMP [2]	SAMPLE SIZE [1]	CONTAINER
Particle Size	6 Months	4 degrees C	100-200 g (75-150 ml)	16 oz. Glass or HDPE
Total Solids	14 Days	4 degrees C	125 g (100 ml)	8 oz. Glass or HDPE
	6 Months	-18 degrees C		
Total Volatile Solids	14 Days	4 degrees C	125 g (100 ml)	
	6 Months	-18 degrees C		
Total Organic Carbon	14 Days	4 degrees C	125 g (100 ml)	
	6 Months	-18 degrees C		
Metals (except Mercury)	6 Months	4 degrees C	50 g (40 ml)	4 oz. Glass
	2 years	-18 degrees C		
Mercury	28 Days	-18 degrees C	50 g (40 ml)	
Semi-volatiles, Pesticides And PCBs	14 Days until extraction	4 degrees C	150 g (120 ml)	SVOC: 8 oz. Glass Pesticides/PCBs: 8 oz. Glass
	1 Year until extraction	-18 degrees C		
	40 Days after extraction	4 degrees C		
Ammonia	7 Days	4 degrees C	25 g (20 ml)	4 oz. Glass
Total Sulfides	7 Days	4 degrees C [3]	50 g (40 ml)	4 oz. Glass
Tributyltin (porewater)	7 Days	4 degrees C [4]	Sediment sufficient to collect 200-500 ml of porewater	(2) 32 oz. Glass
Dioxins/Furans	14 days until extraction	4 degrees C	100 g (80 ml)	8 oz. amber glass jar
	1 year until extraction	-18 degrees C		
Bioassay	8 Weeks	4 degrees C [4]	5 liters	(5) 1 liter Glass or HDPE
Bioaccumulation	8 Weeks	4 degrees C [4]	variable [5]	Glass or HDPE
Archive	Variable	-18 degrees C	1 liter	min. 16 oz. Glass

[1]Recommended minimum field sample sizes for one laboratory analysis. Actual volumes to be collected have been increased to provide a margin of error and allow for retests.
[2] During transport to the lab, samples will be stored on ice. The mercury and archived samples will be frozen immediately upon receipt at the lab. Jars to be frozen must include headspace to prevent breakage.
[3]The sulfides sample will be preserved with 5 ml of 2 Normal zinc acetate for every 30 g of sediment.
[4]Headspace purged with nitrogen.
[5]See **Table 10-3**.

7.5.8 Sample Transport and Chain of Custody Procedures

Sample transport and chain-of-custody procedures should follow the PSEP protocols, which include the following guidelines:

1. If sediment cores are taken in the field and transported to a remote site for extrusion and compositing, chain-of-custody procedures should commence in the field for the core sections and should track the compositing and subsequent transfer of composited samples to the analytical laboratory. If compositing occurs in the field, chain-of-custody procedures should commence in the field for the composites and should track transfer of the composited samples to the analytical laboratory.
2. Samples should be packaged and shipped in accordance with U.S. Department of Transportation regulations as specified in 49 CFR 173.6 and 49 CFR 173.24.
3. Individual sample containers should be packed to prevent breakage and transported in a sealed ice chest or other suitable container.
4. Blue ice is recommended; if ice is used it should be double-bagged and well-sealed.
5. A temperature blank should be included in each cooler.
6. Each cooler or container containing sediment samples for analysis should be delivered to the laboratory within 24 hours of being sealed.
7. A sealed envelope containing chain-of-custody forms should be enclosed in a plastic bag and taped to the inside lid of the cooler.
8. Signed and dated chain-of-custody seals should be placed on all coolers prior to shipping.
9. The shipping containers should be clearly labeled with sufficient information (name of project, time and date container was sealed, person sealing the container and consultant's office name and address) to enable positive identification.
10. Upon transfer of sample possession to the analytical laboratory, the chain-of-custody form should be signed by the persons transferring custody of the sample containers. The shipping container seal should be broken, and the condition of the samples should be recorded by the receiver, including the temperature of the temperature blank.
11. Chain-of-custody forms should be used internally in the lab to track sample handling and final disposition.

8 TIER II: CHEMICAL TESTING

Following an assessment of existing information for a project in Tier 1, chemical testing of the dredged material is usually required. Chemical analysis includes both the measurement of "conventional" parameters and the measurement of concentrations of chemicals which have been identified by DMMP as chemicals of concern (COCs) for the project.

8.1 SEDIMENT CONVENTIONAL PARAMETERS

Sediment conventionals provide information about the physical nature of the dredged material and aid in interpreting chemical and biological test results. Table 6-1 lists the conventional parameters required for analysis and recommended analytical methods.

Table 8-1. Sediment Conventionals and Recommended Analytical Methods

SEDIMENT CONVENTIONAL	ANALYSIS METHOD
Total solids	PSEP (1986)
Total volatile solids (TVS)	PSEP (1986)
Grain size	PSEP (1986)/ASTM D-422 (modified)
Total organic carbon (TOC)	EPA 5310B/EPA 9060 (modified)
Total sulfides	PSEP (1986)/Plumb (1981)
Ammonia	Plumb (1981)

Grain size may be determined using either PSEP (1986) or ASTM Method D-422 (modified), which subdivide the silt-clay fraction by pipette and hydrometer respectively. One of the following sieve series must be used: 1) Modified EPA - sieve numbers 4, 10, 18, 35, 60, 120, 230 or 2) Modified ASTM - sieve numbers 4, 10, 20, 40, 60, 140, 230. The fine-grained fraction must be classified by phi size (+5, +6, +7, +8, >8). The delineation of sand vs. gravel fractions is achieved through use of the #10 sieve (2 mm). Similarly, the delineation of fines (silt and clay) vs. sand is achieved through use of the #230 sieve (62.5 microns). It is therefore critical that these two sieve sizes be used in analyzing grain size.

Appendix D of *Recommended Guidelines for Measuring Organic Compounds in Puget Sound Water, Sediment and Tissue Samples* (PSEP, 1997b) must be consulted for required modifications of methods EPA 5310B and EPA 9060 for the analysis of TOC.

8.2 STANDARD LIST OF CHEMICALS OF CONCERN

Chemicals of concern generally have the following characteristics:

- A demonstrated or suspected effect on ecological receptors or human health.
- One or more present or historical sources, resulting in high concentration when compared to natural conditions, and of sufficient magnitude to be of concern.
- A potential for persisting in a toxic form for long periods in the environment.
- A potential for entering the food web (bioavailability).

Chemicals of concern that have been shown to be widespread in the environment are included on the standard list of DMMP COCs. Chemical testing, when required, will involve analysis of these COCs. **Table 8-2** lists these chemicals and presents the currently-used marine and freshwater guideline values for each chemical.

Table 8-2. DMMP COCs and regulatory guidelines

	CHEMICAL	CAS[1] NUMBER	Analyze for all chemicals in standard list; only analyze for chemicals in non-standard list if DMMP reason-to-believe guidelines require them			Use for freshwater dredged material within DMMP jurisdiction	
			DMMP GUIDELINES			INTERIM FW (2006)	
			SL	BT	ML	SL1	SL2
STANDARD CHEMICALS OF CONCERN	METALS (mg/kg dry weight)						
	Antimony	7440-36-0	150	---	200	---	---
	Arsenic	7440-38-2	57	507.1	700	20	51
	Cadmium	7440-43-9	5.1	11.3	14	1.1	1.5
	Chromium	7440-47-3	260	260	---	95	100
	Copper	7440-50-8	390	1,027	1,300	80	830
	Lead	7439-92-1	450	975	1,200	340	430
	Mercury	7439-97-6	0.41	1.5	2.3	0.28	0.75
	Nickel	7440-02-0	---	---	---	60	70
	Selenium	7782-49-2	---	3	---	---	---
	Silver	7440-22-4	6.1	6.1	8.4	2.0	2.5
	Zinc	7440-66-6	410	2,783	3,800	130	400
	PAHs (µg/kg dry weight)						
	Naphthalene	91-20-3	2,100	---	2,400	500	1,300
	Acenaphthylene	208-96-8	560	---	1,300	470	640
	Acenaphthene	83-32-9	500	---	2,000	1,100	1,300
	Fluorene	86-73-7	540	---	3,600	1,000	3,000
	Phenanthrene	85-01-8	1,500	---	21,000	6,100	7,600
	Anthracene	120-12-7	960	---	13,000	1,200	1,600
	2-Methylnaphthalene[2]	91-57-6	670	---	1,900	470	560
	Total LPAH	---	5,200	---	29,000	6,600	9,200
	Fluoranthene	206-44-0	1,700	4,600	30,000	11,000	15,000
	Pyrene	129-00-0	2,600	11,980	16,000	8,800	16,000
	Benz(a)anthracene	56-55-3	1,300	---	5,100	4,300	5,800
	Chrysene	218-01-9	1,400	---	21,000	5,900	6,400
	Benzofluoranthenes (b, j ,k)	205-99-2 205-82-3 207-08-9	3,200	---	9,900	600	4000
	Benzo(a)pyrene	50-32-8	1,600	---	3,600	3,300	4,800
	Indeno(1,2,3-c,d)pyrene	193-39-5	600	---	4,400	4,100	5,300
	Dibenz(a,h)anthracene	53-70-3	230	---	1,900	800	840
	Benzo(g,h,i)perylene	191-24-2	670	---	3,200	4,000	5,200
	Total HPAH	---	12,000	---	69,000	31,000	55,000
	CHLORINATED HYDROCARBONS (µg/kg dry weight)						
	1,4-Dichlorobenzene	106-46-7	110	---	120	---	---
	1,2-Dichlorobenzene	95-50-1	35	---	110	---	---
	1,2,4-Trichlorobenzene	120-82-1	31	---	64	---	---
	Hexachlorobenzene (HCB)	118-74-1	22	168	230	---	---
	PHTHALATES (µg/kg dry weight)						
	Dimethyl phthalate	131-11-3	71	---	1,400	46	440
	Diethyl phthalate	84-66-2	200	---	1,200	---	---
	Di-n-butyl phthalate	84-74-2	1,400	---	5,100	---	---
	Butyl benzyl phthalate	85-68-7	63	---	970	260	370
	Bis(2-ethylhexyl) phthalate	117-81-7	1,300	---	8,300	220	320

	CHEMICAL	CAS[1] NUMBER	Analyze for all chemicals in standard list; only analyze for chemicals in non-standard list if DMMP reason-to-believe guidelines require them			Use for freshwater dredged material within DMMP jurisdiction	
			DMMP GUIDELINES			INTERIM FW (2006)	
			SL	BT	ML	SL1	SL2
STANDARD CHEMICALS OF CONCERN	Di-n-octyl phthalate	117-84-0	6,200	---	6,200	26	45
	PHENOLS (µg/kg dry weight)						
	Phenol	108-95-2	420	---	1,200	---	---
	2-Methylphenol	95-48-7	63	---	77	---	---
	4-Methylphenol	106-44-5	670	---	3,600	---	---
	2,4-Dimethylphenol	105-67-9	29	---	210	---	---
	Pentachlorophenol	87-86-5	400	504	690	---	---
	MISCELLANEOUS EXTRACTABLES (µg/kg dry weight)						
	Benzyl alcohol	100-51-6	57	---	870	---	---
	Benzoic acid	65-85-0	650	---	760	---	---
	Dibenzofuran	132-64-9	540	---	1,700	400	440
	Hexachlorobutadiene	87-68-3	11	---	270	---	---
	N-Nitrosodiphenylamine	86-30-6	28	---	130	---	---
	PESTICIDES & PCBs (µg/kg dry weight)						
	4,4'-DDD 4,4'-DDE 4,4'-DDT sum of 4,4'-DDD, 4,4'-DDE and 4,4'-DDT	72-54-8 72-55-9 50-29-3	16 9 12 ---	--- --- --- 50	--- --- --- 69	---	---
	Aldrin	309-00-2	9.5	---	---	---	---
	Total Chlordane (sum of cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, oxychlordane)	5103-71-9 5103-74-2 5103-73-1 39765-80-5 27304-13-8	2.8	37	---	---	---
	Dieldrin	60-57-1	1.9	---	1,700	---	---
	Heptachlor	76-44-8	1.5	---	270	---	---
	Total PCBs (Aroclors)	---	130	38 [3]	3,100	60	120
NON-STANDARD COCs [4]	ORGANOMETALLIC COMPOUNDS						
	Tributyltin ion (interstitial water; ug/L)	56573-85-4	---	0.15	---	---	---
	Tributyltin ion (bulk; ug/kg)[5]	56573-85-4	---	73	---	75	75
	DIOXINS/FURANS						
	Total TEQ (pptr dry wt)	See DMMO Dioxin page	4 – 10[6]	10[6]	---	---	---
	GUAIACOLS						
	Guaiacol (2-methoxyphenol) and chlorinated guaiacols (3,4,5-trichloroguaiacol; 4,5,6-trichloroguaiacol; tetrachloroguaiacol)	---	No guidelines determined			---	---

(1) Chemical Abstract Service Registry Number
(2) 2-Methylnaphthalene is not included in the summation for total LPAH.
(3) This value is normalized to total organic carbon, and is expressed in mg/kg carbon.
(4) Analyses required only when there is sufficient reason-to-believe for presence in given project or location.
(5) Bulk sediment measurement of TBT is used only when porewater extraction cannot be accomplished.
(6) Puget Sound only; see the text for other areas in Washington State.

8.2.1 Chemical Evaluation Guidelines

Apparent Effects Threshold values (AETs) were the main basis for establishing DMMP evaluation guidelines for marine sediment. For freshwater sediment, the floating percentile method (FPM) was used. For details regarding AETs, see PSDDA, 1988. For details regarding FPM, see SAIC and Avocet, 2003. The Department of Ecology adopted new freshwater sediment standards in February 2013. These new standards will become effective on September 1, 2013 at which time they will replace the freshwater standards shown in **Table 8-2**.

Screening and Maximum Levels

The “screening level” (SL) is defined as the chemical concentration at or below which there is no reason to believe that dredged material disposal would result in unacceptable adverse effects. For most COCs, the SL is set equal to the lowest Apparent Effects Threshold (LAET). DMMUs with chemical concentrations present at levels above the SL require biological testing before a decision can be made on the suitability for unconfined, open water disposal.

The “maximum level" (ML) is equal to the highest Apparent Effects Threshold (HAET) – a chemical concentration at which all biological indicators with AETs show significant effects. The ML values are no longer used by the DMMP agencies as pass/fail indicators, but rather serve to provide valuable information to project proponents. While some DMMUs with ML exceedances have passed biological testing, the majority have failed. By comparing sediment chemical data to the MLs, a dredging proponent can better judge how to proceed with the project, i.e., whether to invest more time and money into further testing for unconfined, open-water disposal, or to rechanneled that effort into other disposal options and testing for those options (e.g., leach ate tests for upland disposal).

With regard to the SLs and MLs, the following scenarios are possible:

1. All chemicals are **at or below their SLs**; no biological testing is needed; the DMMU is considered suitable for unconfined, open water disposal at any DMMP site.
2. One or more chemicals are present at levels **between SL and ML**; standard biological testing is needed (see Chapter 9).
3. One or more chemicals are present at levels above the ML. Standard biological testing may still be pursued but there is a high probability that the dredged material will fail Tier 3 testing.

Bioaccumulation Trigger

Bioaccumulation trigger (BT) values are used as guidelines to determine when bioaccumulation testing is required. If any chemical of concern exceeds the bioaccumulation trigger guideline value, additional information gained via bioaccumulation testing will be required in order to determine whether dredged material is suitable for unconfined, open-water disposal. Discussion on bioaccumulation testing is presented in Chapter 10.

8.2.2 Analytical Methods

There are no required analytical methods for standard chemicals of concern in the Dredged Material Management Program. Any established and well-documented method that is capable of meeting the QC requirements outlined in this chapter may be used. The Puget Sound Estuary Program protocols should be consulted for sample cleanup procedures and method modifications. The methods to be used for a project must be clearly articulated in the SAP and approved by the DMMP agencies prior to testing. **Table 8-3** lists the most commonly used sediment methods for the standard COCs.

Table 8-3. Analytical Methods for Standard COCs

CHEMICAL Standard Chemicals of Concern	PREP METHOD	ANALYSIS METHOD
METALS:		
Antimony, Arsenic, Cadmium, Chromium, Copper, Lead, Silver, Zinc	EPA 3050B	EPA 6010/6020
Selenium	EPA 3050B	EPA 6020/7440
Mercury	CLP-M-245.5	EPA 7471
PAHs	EPA 3541/3550	EPA 8270D
CHLORINATED HYDROCARBONS:		
1,2-Dichlorobenzene, 1,4-Dichlorobenzene, 1,2,4-Trichlorobenzene	EPA 3550	EPA 8260B/8270D
Hexachlorobenzene (HCB)	EPA 3540/3550	EPA 8270D/8081
PHTHALATES	EPA 3550	EPA 8270D
PHENOLS	EPA 3550	EPA 8270D
MISCELLANEOUS EXTRACTABLES:		
Benzyl alcohol, Benzoic acid, Dibenzofuran, N-Nitrosodiphenylamine	EPA 3550	EPA 8270D
Hexachlorobutadiene	EPA 3540/3550	EPA 8270D/8081
PESTICIDES & PCBs:		
Pesticides	EPA 3540/3541/3550	EPA 8081
PCB Aroclors	EPA 3540/3550	EPA 8082

Selected ion monitoring may be used in the event that reporting limits cannot be brought below SL.

8.2.3 Summing PAHs, Benzofluoranthenes, DDT, Chlordane and PCBs

For comparison to SL, BT and ML values, a group summation is performed for the following families of chemicals using all detected concentrations. Undetected results are not included in the sum. Estimated values between the method detection limit and the laboratory reporting limit (i.e., J-flagged values) are included in the summation at face value. If all constituents of a group are undetected, the group sum is reported as undetected, and the highest laboratory reporting limit of all the constituents is reported as the group sum.

- LPAH is the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene and anthracene.
- HPAH is the sum of benzofluoranthenes, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenz(a,h)anthracene and benzo(g,h,i)perylene.
- Benzofluoranthenes are the sum of the i, j and k isomers.
- Total DDT is the sum of 4,4'-DDD, 4,4'-DDE and 4,4'-DDT.
- Total chlordane is the sum of cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor and oxychlordane.
- Total PCBs include the sum of the following Aroclors: 1016, 1221, 1232, 1242, 1248, 1254, and 1260. If present, Aroclor-1262 and 1268 should be reported but not included in the total PCB summation.

The group sums, as well as the concentrations of individual constituents, must be included in the sediment characterization report.

8.3 DIOXINS

Polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs) are commonly referred to together as "dioxins", or simply "dioxin." Dioxins are a group of 210 chlorinated organic compounds with similar chemical structures, or congeners. The toxicity of the various congeners varies considerably. The 17 congeners that have chlorine atoms located in the 2,3,7,8 positions (e.g., 2,3,7,8-TCDD or 1,2,3,7,8-PeCDF) are the dioxins of known concern for health effects in fish, wildlife, and humans. Of these, 2,3,7,8-TCDD is considered the most toxic and is used as a benchmark for estimating the toxicity of the other 16 congeners; as such, it is assigned a toxic equivalency factor (TEF) of 1.0. **Table 8-4** provides the TEFs for all 17 congeners of regulatory concern. The Toxicity Equivalence (TEQ) is calculated by multiplying the TEF of each congener by the concentration of the congener, and summing the results. The resulting TEQ is used in evaluating the suitability of dredged material for open-water disposal.

Dioxins are produced by natural events and are also unintentional byproducts of certain industrial processes. Natural events include forest fires or volcanic activity. Industrial processes include incomplete combustion of materials in the presence of chloride, such as burning of fuels, municipal and domestic waste incineration, as well as chlorine bleaching of pulp and paper, and creosote and chlorinated pesticide manufacturing. Structural fires may also be a source of dioxins.

Like the standard DMMP chemicals of concern, dioxins are widespread in the environment. However, due to the cost of analysis, dioxins are only required to be analyzed when there is a reason to believe they might be present at a project site, or where dispersive disposal is proposed.

Table 8-4. Toxicity Equivalency Factors (TEFs) for PCDDs and PCDFs[1]

	CONGENERS / ISOMERS	TOXIC EQUIVALENCY FACTOR (TEF)
Dioxins	2,3,7,8-TCDD	1
	1,2,3,7,8-PeCDD	1
	1,2,3,4,7,8-HxCDD	0.1
	1,2,3,6,7,8-HxCCD	0.1
	1,2,3,7,8,9-HxCDD	0.1
	1,2,3,4,6,7,8-HpCDD	0.01
	OCDD	0.0003
Furans	2,3,7,8-TCDF	0.1
	1,2,3,7,8-PeCDF	0.03
	2,3,4,7,8-PeCDF	0.3
	1,2,3,4,7,8-HxCDF	0.1
	1,2,3,6,7,8-HxCDF	0.1
	2,3,4,6,7,8-HxCDF	0.1
	1,2,3.7,8,9-HxCDF	0.1
	1,2,3,4,6,7,8-HpCDF	0.01
	1,2,3,4,7,8,9-HpCDF	0.01
	OCDF	0.0003

[1] World Health Organization Human and Mammalian TEFs, from van den Berg et al (2006)

8.3.1 Dioxin Reason-to-Believe Guidelines

Testing for dioxins and furans is required on a case-by-case basis in areas where there is reason to suspect presence of these chemicals. Significant factors which can trigger a "reason-to-believe" that dioxin may be present and thus result in the requirement for dioxin testing include the following:

- Location within an urban bay and having no historical information showing that dioxin is below interim guidelines.
- Proximity to current or historical point sources, such as outfalls.
- Proximity to chlor-oxide bleach process pulp mills, chlor-alkali or chlorinated solvent manufacturing plants, former wood treatment sites, phenoxy herbicide manufacture and/or use and handling areas.
- Proximity to areas with high polychlorinated biphenyl (PCB) concentrations.
- Proximity to former hog fuel burners/boilers and areas with previous structural, vessel or other fires or incineration sources.
- Proximity to areas previously sampled that showed elevated levels of dioxin.

Dioxin testing will be required for all projects meeting one or more of the reason-to-believe factors described above. Deeper underlying sediments, which are confirmed as "native," may be exempt from testing. Native material within the dredge prism, and lying directly under sediment that is being tested for dioxins, should be archived for possible dioxin analysis.

8.3.2 Revised Interim Guidelines for Dioxin Evaluation in Puget Sound

In December of 2010, the DMMP agencies implemented revised interim guidelines for dredging projects in Puget Sound (DMMP, 2010a). The guidelines included a Disposal Site Management Objective of 4 pptr TEQ, which was derived from data on background concentrations of dioxins in the Sound. Due to differences in the nature of dispersive and nondispersive disposal sites, separate guidelines were developed to achieve the Site Management Objective at the two types of sites.

1. ***Dispersive Sites****:* Dredged material placed at dispersive sites does not stay on site, but is rapidly dispersed with the tides. Post-disposal monitoring is not possible. Therefore, only DMMUs meeting the Disposal Site Management Objective of 4 pptr TEQ may be placed at dispersive sites.

   In addition, because post-disposal monitoring is not possible at dispersive sites, projects for which dioxin testing would not normally be required under the reason-to-believe guidelines, may be required to undergo dioxin analysis of a reduced number of sediment samples. The decision to conduct this testing will be based on the size of the project, the grain-size characteristics of the dredged material, and the availability of dioxin data in the vicinity of the dredging project.

   The Puget Sound dispersive-site guidance applies to the Port Angeles, Port Townsend and Rosario Strait disposal sites.

2. ***Nondispersive Sites****:* Dredged material placed at nondispersive sites stays on site, and sequential disposal events result in a combination of mixing with, and burial of, previously-placed dredged material. This mixing and burial allowed the DMMP agencies to adopt more flexible guidelines for nondispersive disposal, while still achieving the Disposal Site Management Objective of 4 pptr TEQ in surface sediment. Further, periodic post-disposal monitoring provides the feedback necessary to ensure that the Disposal Site Management Objective is being met.

   For nondispersive sites, DMMUs with dioxin concentrations below 10 pptr TEQ will be allowed for disposal as long as the volume-weighted average concentration of dioxins in material from the entire dredging project does not exceed the Disposal Site Management Objective of 4 pptr TEQ. Where possible, disposal of DMMUs is sequenced such that those with higher dioxin concentrations are disposed before those with lower concentrations.

   Case-by-case decisions to allow disposal of material not meeting these guidelines may be made by the DMMP agencies based on the overall goal of meeting the Disposal Site Management Objective. Case-by-case considerations will include the following: (a) material placement sequencing; (b) consideration of the possible cumulative effects of other bioaccumulative compounds within the project sediments; and (c) the frequency of disposal site use.

   When the sediment dioxin concentration in a dredging unit exceeds the 10 pptr TEQ screening level and the dredging unit is found unacceptable for nondispersive disposal under case-by-case decision-making, the dredging proponent will have the option of pursuing bioaccumulation testing to determine whether or not individual DMMUs could qualify for open-water disposal.

Small businesses with total dredged volume less than 4,000 cubic yards may not be required to meet the volume-weighted average concentrations of 4 pptr if dioxin in all suitable DMMUs is less than 10 pptr TEQ and DMMP review determines that the Disposal Site Management Objective of 4 pptr will likely be met on an annual average basis, based on knowledge of other anticipated use of the identified disposal site.

The Puget Sound nondispersive-site guidance applies to the Bellingham Bay, Port Gardner, Elliott Bay, Commencement Bay and Anderson-Ketron disposal sites.

8.3.3 Guidelines for Dioxin Evaluation in Grays Harbor

Dioxin evaluation guidelines in Grays Harbor are based on a risk assessment conducted for a navigation improvement project in the early 1990's (USACE, 1991). For the dispersive sites in Grays Harbor, each disposed DMMU must have a 2,3,7,8-TCDD concentration less than or equal to 5 ng/kg and a TEQ of less than or equal to 15 ng/kg. DMMUs with concentrations above these levels would be required to undergo bioaccumulation testing in order to qualify for open-water disposal.

8.3.4 Guidelines for Dioxin Evaluation in Other Areas of Washington State

Dioxin evaluation guidelines have not been developed in other areas of Washington State. Dioxin results for areas outside of Puget Sound and Grays Harbor will be evaluated on a case-by-case basis. For non-Port projects on the Washington side of the Columbia River, dioxin concentrations in dredged material have been compared to background values for sediment samples taken downstream of Puget Island, which ranged from 0.65 to 2.89 pptr TEQ as of 2009.

8.3.5 Dioxin Analysis and Reporting

Specifying data analysis procedures for PCDD/F is considerably more difficult than for other chemicals in the DMMP list. The DMMP clarified preferred analysis methods at the 2010 SMARM, in *Polychlorinated Dioxins and Furans (PCDD/F): Revisions to the Supplemental Quality Assurance Project Plan* (DMMP, 2010b) and *Revised Supplemental Information on Polychlorinated Dioxins and Furans (PCDD/F) for use in Preparing a Quality Assurance Project Plan (QAPP)* (DMMP, 2010c). **Please refer to the full documents for complete guidance.** In summary, for dioxin analysis, the DMMP requires:

1. **Sediment sampling and holding**. These procedures are generally similar to semivolatile chemicals in the DMMP. Frozen samples may be held for one year prior to extraction.
2. **Analytical method**. The identification of PCDD/F congeners at low concentrations is difficult, and there is significant possibility of interfering compounds (such as diphenyl ethers) causing the reporting of artificially elevated values. The DMMP agencies recommend EPA Method 1613B: Tetra- Through Octa-Chlorinated Dioxins and Furans by Isotope Dilution High Resolution Gas Chromatography/High Resolution Mass Spectrometry as the most suitable method for sediment.
3. **Data evaluation/validation methods**. Because of the complexity of the method, the extremely low reporting limits, and the high potential for interfering compounds such as chloro diphenyl ethers, it is recommended that the dioxin data be subjected to Stage 4 data validation by an experienced independent validator.

   If the applicant chooses not to validate the data, the primary method of data evaluation will consist of analysis of the Puget Sound Sediment Reference Material (PS-SRM). The DMMP will review the primary results against the Method 1613B acceptance limits or those in the QAPP. Based upon the DMMP review of precision, accuracy, representativeness, and completeness measures as well as the PS-SRM, full validation of the dioxin raw data may, nevertheless, be required. Should the DMMP request validation, the project must provide it, using a person with demonstrated experience accomplishing validation for PCDD/F. The raw data associated with the analysis of dioxins must be made available to the DMMP agencies upon their request.

4. **Data Reporting**. The laboratory shall report each of the 2,3,7,8-chlorine substituted PCDD/F congeners on a dry-weight basis. Estimated detection limits (EDLs) and reporting limits shall be reported for each of these congeners. The 17 congeners of interest shall be tabulated as TEQ, both with nondetected values (U) = ½ EDL and with U = 0. (The difference between these values gives data reviewers an idea of how much the EDL substitution affects the TEQ summation.) For the purpose of TEQ summation, estimated maximum potential concentrations (EMPCs) shall be reported as nondetects (U) at the EMPC value. Details regarding EDLs are as follows:

Estimated Detection Limit

The estimated detection limit is a sample- and analyte-specific detection limit that is based on the signal-to-noise ratio present in the sample for each analyte at the time of analysis. This is the best value to use to get the lowest defensible TEQ values.

The estimated detection limit is defined as follows:

$$\mathrm{EDL} = \frac{2.5 \times \mathrm{H}_x \times \mathrm{Q}_{is}}{\mathrm{H}_{is} \times \mathrm{W} \times \overline{\mathrm{RF}}_n}$$

where:

EDL = estimated detection limit for homologous 2,3,7,8-substituted PCDDs/PCDFs.

H_x = sum of the height of the noise level for each quantitation ion for the unlabeled PCDDs/PCDFs.

H_{is} = sum of the height of the noise level for each quantitation ion for the labeled internal standard.

W = weight, in g, of the sample.

$\overline{\mathrm{RF}}_n$ = calculated mean relative response factor for the analyte (with n = 1 to 17 for the seventeen 2,3,7,8-substituted PCDDs/PCDFs).

Q_{is} = quantity, in pg, of the internal standard added to the sample before extraction.

5. **Deliverables Necessary for Stage IV data validation:**

   a. **Case Narrative**

      - Case narrative per batch of samples, including: a summary of samples received and samples analyzed; list of analytical methods used and modifications; samples requiring dilutions and re-analysis and reasons; description of any problems encountered during sample shipment, extraction and/or analysis; corrective actions taken and any data limitations; list of manually integrated peaks with the original and manually reintegrated peak areas;, and definitions of all laboratory qualifiers applied.

   b. **PCDD/PCDF Data**

      - Summary of analytical results arranged in chronological order. Example calculations. Tabulated analytical results (identification and quantitation) of the specified target analytes, mass-ion ratios and recoveries of the associated labeled compounds. Include lab name, lab sample ID, lab file ID, sample prep method, date received, date extracted, date analyzed, sample matrix, amount of sample extracted, dilution factor (if any), injection volume, final extract volume, and sample specific EDLs and RLs. For solids, reporting units and concentrations need to be identified on a dry weight basis (include percent moisture).
      - Toxicity Equivalence Summary - Tabulated adjusted concentrations for the target analytes based on toxicity equivalent factors. PCDD/PCDF toxicity of the 17 congeners of interest shall be calculated and tabulated as TEQs, using the product of the TEFs with (1) non-detected values (U) = ½ EDLs and (2) with non-detected values (U) = 0. Table 8-4 presents the specified mammalian TEFs for each of the 17 congeners. For the purpose of TEQ summation, detections at concentrations >EDLs but <RLs and which were reported as estimated maximum potential concentrations (EMPCs) shall be reported as non-detects (U) elevated at the EMPC value. EMPC values >RLs with mass- ion ratios adjusted to meet the criteria are flagged as estimated and reported as detected compounds.
      - Tabulated total homologue concentrations shall be completed for each sample, blank, and Quality Control (QC) sample analyzed. EMPC values shall be flagged "*", and the Estimated Detection Limit (EDL) shall be qualified "U" on the form.
      - Complete data system report, including but not limited to quantitation reports and area summaries, selected ion current profile (SICP) for each sample including dilution and re-analysis. SICPs must be presented so the two major quantitation ions, the relevant labeled compounds and chlorinated diphenyl ether (CDPE) interferences are on one page. The internal standards can be presented on another page. The SICPs must show the full retention time window scanned for each ion. Enlarge any SICP peak for any 2,3,7,8-substituted congener present below the signal-to noise (S/N) ratio of 10 or below the RLs.
      - The following information shall be included in all laboratory “raw data sheets”: sample number, date and time of analysis, retention time or scan number of the identified target compound, ions used for quantitation with measured areas, area table, on-column concentration including units, S/N ratios, lab file ID, Analyst ID.

- In all instances where the data system report has been edited, or where manual integration or quantitation has been performed, the HRGC/HRMS operator shall identify the changes made to the report, by initialing and dating all handwritten changes, and shall include the integration scan range. In addition, a hardcopy printout of the chromatogram displaying the manual integration shall be included in the raw data.
- Second column confirmation is required for all samples in which 2,3,7,8-TCDF is positively identified at, or above, the RLs by analysis on a DB-5 (or equivalent) HRGC column, or if 2,3,7,8-TCDF is reported as an Estimated Maximum Possible Concentration (EMPC) at, or above, the RL.

c. Quality Control and Supporting Data

- Instrument Performance Check
- Window Defining Mix Summary
- Chromatographic Resolution Checks
- Analytical Sequence Summary Checks
- Fortified blank (LCS) recovery results (1 per batch)
- SRM run and recovery results
- Method blanks and list of samples associated with the method blanks
- Initial calibration summary and raw data
- Calibration verification summary and raw data

d. Miscellaneous Data

- Copy of laboratory's method SOP
- Sample receipt documentation and sample control
- Extraction, extract clean-up, and instrument run logs
- Standard Traceability documentation
- Communication logs

8.4 CHEMICALS/CONSTITUENTS OF CONCERN FOR LIMITED AREAS

In addition to the standard list of standard chemicals of concern, there are COCs that may need to be measured for certain dredging projects in certain limited areas. These chemicals include those from the following list, which are further discussed below.

- Guaiacol (2-methoxyphenol) and chlorinated guaiacols (3,4,5-trichloroguaiacol; 4,5,6-trichloroguaiacol; tetrachloroguaiacol)
- Tri-, tetra-, and pentachlorobutadienes
- Tributyltin
- Wood waste

Other COCs may need to be analyzed for specific projects depending on site-specific information.

8.4.1 Guaiacol and Chlorinated Guaiacols

Guaiacol and chlorinated guaiacols are measured in areas where kraft pulp mills are located. Only guaiacol will be measured near sulfite pulp mills (chlorinated guaiacols are not expected in processes that do not involve bleaching).

8.4.2 Tributyltin

Tributyltin (TBT) testing is indicated in areas near marinas, boatyards, shipyards, combined sewer overflows (CSOs), treatment plant outfalls and in urban areas, especially Commencement Bay, Elliott Bay, Duwamish River, Lake Washington ship canal, Salmon Bay and Lake Union.

The available evidence indicates that neither sediment chemistry screening levels nor the existing DMMP bioassays may be as useful in predicting environmental effects as measurement of TBT concentrations in interstitial water and tissues. Therefore, the standard tiered testing approach utilizing bulk sediment chemistry and short-term bioassays is not considered appropriate for evaluating the potential adverse effects of TBT.

Measurement of TBT in interstitial water may provide a more direct measure of potential bioavailability, and hence toxicity, than bulk sediment concentrations. Therefore, interstitial water analysis replaces bulk sediment analysis as the initial step in a tiered assessment of TBT toxicity for DMMP projects. Centrifugation is preferred for collecting sediment interstitial water (for detailed guidance on interstitial water collection and sample handling refer to DMMP, 1998 - Tributyltin Analysis: Clarification of Interstitial Water Extraction and Analysis Methods - Interim. Alternative interstitial water extraction methods may be used in cases where centrifugation is not an effective technique, (e.g., for very sandy sediments) and will be decided on a case-by-case basis by the DMMP agencies. In the event that interstitial water cannot be extracted or archived sediment is being analyzed, the DMMP agencies may approve the use of bulk sediment analysis on a case-by-case basis.

Acceptable methods for measuring TBT involve tropolone/methylene chloride extraction, followed by Grignard derivitization and analysis by GC/MS (e.g., Krone *et al*., 1989), GC/MS SIM (e.g., PSEP, 1997b), or GC/FPD (e.g., Unger *et al*., 1986).

If the TBT concentration in the interstitial water of a DMMU is above 0.15 ug TBT/L, bioaccumulation testing must be conducted using the DMMP bioaccumulation guidelines in effect at the time of testing. If unacceptable tissue concentrations are measured at the end of the bioaccumulation test, the sediment will be found unsuitable for open-water disposal. It should be noted that standard toxicity bioassays (amphipod mortality, larval development, and *Neanthes* growth tests) are not triggered by exceedances of the 0.15 ug TBT/L threshold, as these bioassays have been shown to be ineffective in the evaluation of TBT toxicity (PSDDA/SMS, 1996).

8.4.3 Wood Waste

Wood waste can range in size from intact logs down to fine bark and sawdust. The DMMP program requires logs and large debris to be removed prior to disposal. No debris greater than 24 inches in any dimension is allowed at the open-water disposal sites. Sediments with large pieces of wood debris may require debris removal by passing the dredged material through a 24” X 24” steel screen. The quantity of wood debris that would pass through a 24” X 24” screen must be visually assessed during field collection of sediments. If the sediment contains a significant quantity of smaller wood debris, the sediments must be analyzed in the laboratory to quantify the wood fraction.

The wood fraction can be quantified in the laboratory on either a volume or a weight-specific basis. While quantifying wood debris in sediments on a volumetric basis may be more ecologically meaningful, it is much more difficult and less accurate than quantifying it on a weight-specific basis. Therefore, dredged material assessment of wood debris will be accomplished on a dry-weight basis, then converted to a volumetric basis by multiplying the weight-based number by two (example: 25% by weight ≅ 50% by volume). The dry-weight fraction of debris is estimated by quantifying the organic fraction. Dredged material containing an organic fraction greater than 25% dry weight will be required to undergo biological testing to assess the suitability of the material for unconfined open-water disposal. Likewise, dredged material containing an organic fraction less than 25% dry weight will be considered suitable for unconfined open-water disposal without further testing unless one or more chemicals of concern exceed chemical screening levels.

One method for determining the dry-weight fraction of wood waste is quantification by ASTM D-2974C Method A, with the sample size increased to 100-300 grams. Other methods may be proposed by the applicant in lieu of this approach, but must be included in the SAP and approved by the DMMP agencies.

For additional information see DMMP/SMS, 1997 - Management of Wood Waste under DMMP and SMS Cleanup Program.

If bioassays are triggered by wood waste, additional information must be obtained in preparation for biological testing. Sediment grain size is an important consideration when selecting the species to be used in the amphipod test and choosing appropriate reference sediments. However, the presence of wood waste in the sediment sample would bias the results of standard grain-size analysis. Therefore, in addition to the standard grain-size testing, applicants should conduct grain-size analysis on the residue left from the wood-waste analysis. This organic-free grain-size distribution should be used in conjunction with the standard grain-size distribution in selecting the appropriate amphipod species and reference sediment.

8.5 QUALITY CONTROL

The quality of chemical data submitted to characterize dredged material proposed for open-water disposal at a DMMP site must be assessed before it may be used for regulatory decision-making. This section provides general quality assurance (QA) guidelines, as well as guidelines specific to the analysis of tributyltin and dioxin.

8.5.1 Laboratory Accreditation

Laboratories are required to be accredited by the Department of Ecology for sediment methods used to generate chemical and biological data for DMMP projects. Accredited labs may be found at https://fortress.wa.gov/ecy/laboratorysearch/.

8.5.2 Sample Detection Limits and Reporting Limits

Ideally, the reporting limits (aka limits of quantification or practical quantification limits) for all COCs will be below the SLs. If this is not possible - due to matrix interference or sample dilution - it is imperative that sample detection limits be below the SLs. Failure to bring reported nondetects for an analyte below the SL could result in the agencies requiring the extraction and analysis of archived sediment, or biological toxicity testing, to verify the suitability of sediments for open-water disposal.

The following guidelines must be followed when reporting results of chemical analysis:

1. Laboratories must report estimated concentrations that fall between the sample detection limit and reporting limit. Such estimated concentrations should be accompanied by a "J" qualifier.
2. Laboratories must report both the reporting limit and the sample detection limit for any COC concentration that is accompanied by a "U" flag.
3. For mixtures of chemicals, such as Total PCBs, the reported values of detected constituents - including "J" values falling between the sample detection limit and the reporting limit - will be summed. In the event that all constituents are undetected, the single highest sample detection limit will be used as the value for the mixture and will be accompanied by a "U" qualifier.

The following scenarios are possible and need to be understood and handled appropriately:

1. One or more chemicals-of-concern (COC) have nondetects exceeding screening levels while all other COCs are quantitated or reported as nondetects at or below the screening levels: the requirement to conduct biological testing will be triggered solely by the nondetects. In this case the chemical testing subcontractor should do everything possible to bring sample detection limits down to or below the screening levels, including additional cleanup steps, re-extraction, etc. Selected ion monitoring may be used, if necessary. All such actions must be documented in the lab report. In the event that nondetects cannot be brought below the SLs, the Dredged Material Management Office must be contacted immediately. Failure to do so could result in the need to collect new field samples for analysis or trigger bioassays, an expensive endeavor.
2. One or more COCs are reported as nondetects above the SLs for a lab sample, but below respective bioaccumulation triggers (BT), and other COCs have quantitated concentrations above screening levels: The need to do bioassays is based on the detected exceedances of SLs and the nondetects above SL become irrelevant. No further action on the part of the chemical testing subcontractor is necessary.
3. One or more COCs are reported as nondetects above the SL and BT, and other COCs have quantitated concentrations above screening levels: the need to do bioassays is based on the detected exceedances of SLs but all other nondetects must be brought below BTs to avoid the requirement to do bioaccumulation testing. As in scenario "1" above, everything possible should be done to lower the sample detection limits.

In all cases, to avoid potential problems and leave open the option for retesting, sediments or extracts should be kept under proper storage conditions until the chemistry data are deemed acceptable by the regulatory agencies.

8.5.3 Data Quality Objectives

Data quality objectives are the quantitative and qualitative terms used to describe how good the data needs to be in order to meet the project's objectives. Typical data quality objectives include precision, accuracy, representativeness, comparability and completeness.

1. ***Precision:*** The precision is evaluated using the Relative Percent Difference (RPD) values between the duplicate sample results.

$$RPD = \frac{ABS(R1 - R2)}{\left(\frac{R1 + R2}{2}\right)} \times 100$$

R1 = Recovery for MS or duplicate 1

R2 = Recovery for MSD or duplicate 2

2. ***Accuracy:*** For parameters analyzed in the laboratory, accuracy will be evaluated using percent recovery (%R) of the target analyte in spiked samples and, where applicable, also the recoveries of the surrogates in all samples and QC samples.

$$\%Recovery = \frac{SSR - SR}{SA} \times 100$$

SSR = Spiked Sample Result

SR = Sample Result

SA = Spike Added

3. ***Representativeness*** is the degree to which data from the project accurately represent a particular characteristic of the environmental matrix which is being tested. Representativeness of samples is ensured by adherence to standard field sampling protocols and standard laboratory protocols. The design of the sampling scheme and number of samples should provide representativeness of each matrix being sampled.

4. ***Comparability*** is the measurement of the confidence in comparing the results of one sampling event with the results of another achieved by using the same matrix, sample location, sampling techniques and analytical methodologies.

5. ***Completeness****:* Completeness is the percentage of valid results obtained compared to the total number of samples taken for a parameter. %Completeness may be calculated using the following formula:

$$\%\ Completeness = \frac{\#\ of\ valid\ results}{\#\ of\ samples\ taken} \times 100$$

8.5.4 General Quality Assurance Guidelines

The chemistry QA/QC requirements summarized in **Table 8-5** must be met to ensure data quality and usability for dredged material characterization and suitability determinations. Due to analytical complexity, dioxin QA is covered in a separate section (8.5.4).

Table 8-5. Laboratory QA/QC Requirements for Conventionals and COCs

Analysis Type	Method Blanks[1]	Replicates[1]	Triplicates[1]	CRM/RM	MS/MSD[1]	Surrogates[2]
Semivolatiles[3,4]	X[5]	X[6]		X	X	X
Pesticides[3,4]	X[5]	X[6]		X	X	X
PCBs[3,4]	X[5]	X[6]		X[7]	X	X
Metals	X	X		X	X	
Ammonia	X		X			
Total Sulfides	X		X			
Total Organic Carbon	X		X	X		
Total Solids			X			
Total Volatile Solids			X			
Grain Size			X			
Tributyltin	X	X[6]			X	X

Notes:

CRM = Certified Reference Material; RM = Reference Material; MS/MSD = matrix spike/matrix spike duplicate

[1] Frequency of Analysis (FOA) = 5 percent or one per batch, whichever is more frequent.

[2] Surrogate spikes required for every sample, including matrix spiked samples, blanks, and reference materials.

[3] Initial calibrations required before any samples are analyzed, after each major disruption of equipment, and when ongoing calibration fails to meet criteria.

[4] Ongoing calibration required at the beginning of each work shift, every 10–12 samples or every 12 hours (whichever is more frequent), and at the end of each shift.

[5] FOA = one per extraction batch.

[6] Matrix spike duplicates may be used.

[7]The Puget Sound Sediment Reference Material must be used.

Most laboratories performing DMMP chemical analysis use modified EPA Contract Lab Program (EPA CLP) methods. These methods have their own QA "control" limits for precision, matrix spike recovery and surrogate spike recovery, which have been established through inter-laboratory testing. Laboratories rely on the CLP control limits to determine when data quality may be inadequate and corrective action is necessary.

In addition to the CLP limits in common use, the Puget Sound Estuary Program (PSEP) has established both "warning" limits and "action" limits for these same QA parameters. PSEP defines warning limits as "numerical criteria that serve to alert data reviewers and users to possible problems within the analytical system. When a warning limit is exceeded, the laboratory is not obligated to halt analyses, but the reported data may be qualified during subsequent QA/QC review." Action limits are defined as "numerical criteria that, when exceeded, require specific action by the laboratory before data may be reported. Action limits are intended to serve as contractual controls on laboratory performance." The terms "action limit" and "control limit" are similar and used interchangeably.

Table 8-6 includes QA limits which are as consistent as possible with both PSEP and CLP. A system of warning and action limits, similar to PSEP, is used. In most cases, PSEP quantitative levels have been adopted as well. The warning and action limits listed in the table were adopted by the DMMP agencies for use in QA1 evaluations.

For matrix spike and surrogate spike recoveries, independent warning limits were established for volatiles, semivolatiles and pesticides. These limits meet the PSEP definition of warning limits and screen data effectively relative to the EPA CLP control limits. The chemical-specific EPA CLP control limits were adopted for use as action limits for surrogate spike recoveries and for a basis of evaluation in the application of best professional judgment for matrix spike recoveries. Where certified reference materials (CRMs) are available, the interlaboratory-derived 95% confidence interval (CI) should be used as an objective evaluation tool. This alternative is endorsed by PSEP.

Table 8-6. DMMP Warning and Action Limits

QA Element	Warning Limits	Action Limits
Precision		
Conventionals:	None	20% coefficient of variation (CV)
Metals:	none	20% relative percent difference (RPD) or CV
Organics:	35% RPD or COV	50% CV or a factor of 2 for duplicates
Accuracy: Matrix Spikes		
Metals:	none	75-125% recovery
Organics:		none (zero percent recovery may be cause for data rejection however)[1]
Volatiles:	70-150% recovery	
Semivolatiles and Pesticides:	50-150% recovery	
Reference Materials		
Metals:	none	95% CI if specified for a particular CRM; 80-120% recovery if not.
Semivolatiles/Pesticides:	none	95% CI for CRMs. No action limit for uncertified RMs.
PCBs	PS-SRM advisory limits	None at this time
Surrogate Spikes		
Organics:		EPA CLP chemical-specific recovery limits
Volatiles:	85% minimum recovery	
Pesticides:	60% minimum recovery	
Semi-volatiles:	50% minimum recovery	

[1]Rigorous control limits are not recommended due to possible matrix effects and interferences.

8.5.5 Dioxin QC Performance Criteria

QC performance criteria for the analysis of dioxins must be presented in the sampling and analysis plan and approved by the DMMP agencies. Laboratories will be required to meet these performance criteria as well as take the specified corrective action if performance criteria are not met. Example criteria and corrective actions are provided in **Table 8-7**and **Table 8-8**. These tables of QC requirements are not all-inclusive of method 1613B requirements. Other method-required QC checks, criteria and corrective actions can be found in the EPA *National Functional Guidelines for Chlorinated Dioxin/Furan Data review* (EPA, 2011) and must also be followed.

It is critical for reporting limits to be sufficiently low when analyzing dredged material for dioxin. Target reporting limits for DMMP projects are presented in **Table 8-9**.

All projects will be required to analyze the Puget Sound Sediment Reference Material (PS-SRM) with each analytical batch. Acceptance criteria for the reference material must be included in the sampling and analysis plan. If results fall outside the acceptance range, the laboratory may be required to reanalyze.

Table 8-7. Summary of Quality Control Procedures

QC Check	Minimum Frequency	Acceptance Criteria	Laboratory Corrective Action*
Ongoing Precision And Recovery	1 per analytical batch (≤ 20 samples)	Recovery within acceptance criteria in Table 8-8 of the QAPP guidance document	1. Check calculations 2. Reanalyze batch
Stable-isotope-labeled compounds	Spiked into each sample for every target analyte	Recovery within limits in Table 8-8	1. Check calculations 2. Qualify all associated results as estimated
		Ion abundance ratios must be within criteria in Table 9 of method 1613B	1. Reanalyze specific samples. 2. Reject all affected results outside the criteria 3. Alternatively, use of secondary ions that meet appropriate theoretical criteria is allowed if interferences are suspect. This alternative must be approved by the DMMP agencies.
Laboratory duplicate	5% or 1 per batch (≤20 samples)	Relative percent Difference ≤ 30%	1. Evaluation of the homogenization procedure and evaluation method 2. Reanalyze batch
Method blank	1 per analytical batch (≤ 20 samples)	Detection ≤ minimum level in Table 2 of Method 1613B	1. If the method blank results are greater than the reporting limit, halt analysis and find source of contamination; reanalyze batch. 2. Report project samples as non-detected for results ≤ to the reported method blank values
GC/MS Tune	At the beginnings of each 12 hour shift. Must start and end each analytical sequence.	>10,000 resolving power @ m/z304.9825 Exact mass of 380.9760 within 5 ppm of theoretical value.	1. Re-analyze affected samples 2. Reject all data not meeting method 1613B requirements
Initial Calibration	Initially and when continuing calibration fails.	Five point curve for all analytes. RSD must meet Table 4 requirements for all target compounds and labeled compounds. Signal to noise ratio (S/N) >10. Ion abundance (IA) ratios within method specified limits.	

QC Check	Minimum Frequency	Acceptance Criteria	Laboratory Corrective Action*
Window Defining/Column Performance Mix	Before every initial and continuing calibration.	Valley <25% for all peaks near 2378-TCDD/F peaks.	
Continuing Calibration	Must start and end each analytical sequence.	%D must meet Table 4 limits for target compounds & labeled compounds. S/N >10. IA ratios within method specified limits.	
Confirmation of 2,3,7,8-TCDF	For all primary-column detections of 2,3,7,8-TCDF	Confirmation presence of 2,3,7,8-TCDF in accordance with method 1613B requirements	Failure to verify presence of 2,3,7,8-TCDF by second column confirmation requires qualification of associated 2,3,7,8-TCDF results as non-detected at the associated value.
Sample data not achieving target reporting limits or method performance in presence of possibly interfering compounds	Not applicable	Not applicable	Rather than simply dilute an extract to reduce interferences, the lab should perform additional cleanup techniques identified in the method to insure minimal matrix effects and background interference. Thereafter, dilution may occur. If re-analysis is required, the laboratory shall report both initial and re-analysis results.
Puget Sound Sediment Reference Material	One per analytical batch	Result must be within acceptance ranges	1. Extraction and analysis should be evaluated by the lab and re-analysis performed of the entire sample batch once performance criteria can be met. 2. If analysis accompanies several batches with acceptable PS-SRM results, then the laboratory can narrate possible reason for PS-SRM outliers.

* If re-analysis is required, the laboratory shall report initial and re-analysis results

TABLE 8-8. QC Acceptance Criteria for PCDD/F

	Test Conc., ng/mL[1]	IPR[2]		OPR[3] (%)	I-CAL[4] %	CAL/VER[5] (%) (Coeff. of Variation)	Labeled Compound % Recovery in Sample	
		RSD (%)	Recovery				Warning Limit	Control Limit
Native Compound								
2,3,7,8-TCDD	10	28	83-129	70-130	20	78-129	-	-
2,3,7,8-TCDF	10	20	87-137	75-130	20	84-120	-	-

	Test Conc., ng/mL[1]	IPR[2]		OPR[3] (%)	I-CAL[4] %	CAL/VER[5] (%) (Coeff. of Variation)	Labeled Compound % Recovery in Sample	
		RSD (%)	Recovery				Warning Limit	Control Limit
1,2,3,7,8-PeCDD	50	15	76-132	70-130	20	78-130	-	-
1,2,3,7,8-PeCDF	50	15	86-124	80-130	20	82-120	-	-
2,3,4,7,8-PeCDF	50	17	72-150	70-130	20	82-122	-	-
1,2,3,4,7,8-HxCDD	50	19	78-152	70-130	20	78-128	-	-
1,2,3,6,7,8-HxCDD	50	15	84-124	76-130	20	78-128	-	-
1,2,3,7,8,9-HXCDD	50	22	74-142	70-130	35	82-122	-	-
1,2,3,4,7,8-HxCDF	50	17	82-108	72-130	20	90-112	-	-
1,2,3,6,7,8-HxCDF	50	13	92-120	84-130	20	88-114	-	-
1,2,3,7,8,9-HxCDF	50	13	84-122	78-130	20	90-112	-	-
2,3,4,6,7,8-HxCDF	50	15	74-158	70-130	20	88-114	-	-
1,2,3,4,6,7,8-HpCDD	50	15	76-130	70-130	20	86-116	-	-
1,2,3,4,6,7,8-HpCDF	50	13	90-112	82-122	20	90-110	-	-
1,2,3,4,7,8,9-HpCDF	50	16	86-126	78-130	20	86-116	-	-
OCDD	100	19	86-126	78-130	20	79-126	-	-
OCDF	100	27	74-146	70-130	35	70-130	-	-
Labeled Compounds								
$^{13}C_{12}$-2,3,7,8-TCDD	100	37	28-134	25-130	35	82-121	40-120	25-130
$^{13}C_{12}$-2,3,7,8-TCDF	100	35	31-113	25-130	35	71-130	40-120	24-130
$^{13}C_{12}$-1,2,3,7,8-PeCDD	100	39	27-184	25-150	35	70-130	40-120	25-130
$^{13}C_{12}$-1,2,3,7,8-PeCDF	100	34	27-156	25-130	35	76-130	40-120	24-130
$^{13}C_{12}$-2,3,4,7,8-PeCDF	100	38	16-279	25-130	35	77-130	40-120	21-130
$^{13}C_{12}$-1,2,3,4,7,8-HxCDD	100	41	29-147	25-130	35	85-117	40-120	32-130
$^{13}C_{12}$-1,2,3,6,7,8-HxCDD	100	38	34-122	25-130	35	85-118	40-120	28-130
$^{13}C_{12}$-1,2,3,4,7,8-HxCDF	100	43	27-152	25-130	35	76-130	40-120	26-130
$^{13}C_{12}$-1,2,3,6,7,8-HxCDF	100	35	30-122	25-130	35	70-130	40-120	26-123
$^{13}C_{12}$-1,2,3,7,8,9-HxCDF	100	40	24-157	25-130	35	74-130	40-120	29-130
$^{13}C_{12}$-2,3,4,6,7,8-HxCDF	100	37	29-136	25-130	35	73-130	40-120	28-130
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDD	100	35	34-129	25-130	35	72-130	40-120	23-130
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDF	100	41	32-110	25-130	35	78-129	40-120	28-130
$^{13}C_{12}$-1,2,3,4,7,8,9-HpCDF	100	40	28-141	25-130	35	77-129	40-120	26-130
$^{13}C_{12}$-OCDD	200	48	20-138	25-130	35	70-130	25-120	17-130
Cleanup Standard								
$^{37}Cl_4$-2,3,7,8-TCDD	10	36	39-154	31-130	35	79-127	40-120	35-130

(Table shown with permission from AXYS Analytical Services LTD (2005), Vancouver, BC, Canada. *Analysis of Polychlorinated Dioxins and Furans by Method 1613B* -- MSU-018 Rev. 5, 07-Jun-2005)

[1] QC acceptance criteria for IPR, OPR, and samples based on a 20 µL extract final volume
[2] IPR: Initial Precision and Recovery demonstration
[3] OPR: Ongoing Precision and Recovery test run with every batch of samples.
[4] Initial Calibration
[5] CAL/VER: Calibration Verification test run at least every 12 hours

Table 8-9. Target Reporting Limits for dioxins/furans

Dioxins and Furans	Reporting Limit (ng/kg dry wt)
2,3,7,8-TCDD	1.0
1,2,3,7,8-PeCDD	1.0
1,2,3,4,7,8-HxCDD	2.5
1,2,3,6,7,8-HxCDD	2.5
1,2,3,7,8,9-HxCDD	2.5
1,2,3,4,6,7,8-HpCDD	2.5
OCDD	5.0
2,3,7,8-TCDF	1.0
1,2,3,7,8-PeCDF	2.5
2,3,4,7,8-PeCDF	1.0
1,2,3,4,7,8-HxCDF	2.5
1,2,3,6,7,8-HxCDF	2.5
1,2,3,7,8,9-HxCDF	2.5
2,3,4,6,7,8-HxCDF	2.5
1,2,3,4,6,7,8-HpCDF	2.5
1,2,3,6,7,8,9-HpCDF	2.5
OCDF	5.0

8.5.6 TBT QC Performance Criteria: Sample Collection/Interstitial Water Analysis

The DMMP agencies recommend QC performance criteria rather than providing a step-by-step protocol for the extraction, derivitization, and analysis of TBT. The criteria presented in Table 6-10 must be met in order to verify that sample cleanup, extraction and derivitization methods are being performed correctly. Laboratories will be required to meet these performance criteria as well as take the specified corrective action if performance criteria are not met. Deviations from the specified performance criteria will be considered by the DMMP agencies on a project-specific basis. Justification for alternative performance criteria must be submitted in writing and receive agency approval prior to the initiation of testing. As discussed in earlier guidance (Michelsen, *et al*., 1996), TBT analytical results should be reported as the TBT ion.

If the TBT concentration in the interstitial water is quantitated above 0.15 ug TBT/L, bioaccumulation testing of project sediments must be conducted using the DMMP bioaccumulation guidelines. Bioassay testing will not be required unless other chemicals of concern exceed screening levels. If unacceptable tissue concentrations are measured at the end of the bioaccumulation test, the sediment will be found unsuitable for open-water disposal. For additional information, see the SMARM issue paper Testing, Reporting, and Evaluation of Tributyltin Data in PSDDA and SMS Programs (1996).

Table 8-10. Summary of quality control procedures for TBT in interstitial water

QC CHECK	MINIMUM FREQUENCY	ACCEPTANCE CRITERIA	CORRECTIVE ACTION
Laboratory Control Sample (LCS) [1]	1 per analytical batch (≤ 20 samples)	Recovery 50 – 150%	1. Check calculations 2. Reanalyze (matrix or injection problems) 3. If still out, re-extract and reanalyze LCS and assoc. samples (if available); If not available flag data.
Matrix spike (MS) and matrix spike duplicate (MSD) [1]	1 MS/MSD pair per analytical batch (≤ 20 samples)	Recovery 50 – 150% and relative percent difference (RPD) ≤ 30%	1. Evaluate for supportable matrix effect. 2. If no interference, re-extract and reanalyze MS/MSD once (if available). 3. If still out, report both sets of data.
Surrogate spike [1] (Tripentyltin recommended)	1 per sample	Recovery 50 – 150%	1. Check calculations. 2. Evaluate for supportable matrix effect 3. If no interference is evident, re-extract and reanalyze affected sample(s) (if available) and flag any outliers.
Method blank[2]	1 per analytical batch (≤ 20 samples)	Target analyte < 3x the reporting limit (RL)	1. Flag if target > 3x RL but less than 0.075 ppb.[3] 2. Rerun batch and ID contamination source if target >0.075 ppb.

[1]All QC samples should be run using the same sample handling as is used on the environmental samples.
[2] Method blank can include centrifugation step or, alternatively a centrifugation blank can be run separately from the analytical method blank.
[3] 0.075 ppb TBT is used here as a benchmark for evaluating blank performance because it represents a concentration that is one-half the interstitial water screening level (0.15 ppb) that is being used by the DMMP agencies to determine the need for bioaccumulation testing. Note that a minimum interstitial water volume of 200-500 ml will be needed to attain reporting limits less than 0.075 ppb TBT.

9 TIER 3 BIOLOGICAL TESTING: BIOASSAYS

Tier 3 biological testing of dredged material is required when chemical testing results indicate the potential for unacceptable adverse environmental or human health effects. Biological testing could include:

Bioassays– used to evaluate potential toxicity effects on benthic invertebrates – discussed in this chapter.

Bioaccumulation tests--used to evaluate the bioavailability of certain chemicals which are known or suspected agents affecting human or ecological health in the marine environment– discussed in Chapter 10.

9.1 ACUTE AND CHRONIC BIOASSAYS

The standard suite of bioassays in Tier 3 sediment evaluations is triggered by **exceeding** one or more screening levels for chemicals of concern in the dredged material (see **Table 8-2**).

Laboratories providing biological effects data for DMMP projects must be accredited by the Department of Ecology for the methods used to produce the data. Additional information related to bioassay testing under the DMMP can be found at the DMMO website.

9.1.1 Marine Bioassays

The suite of three bioassays used in the DMMP program includes both acute and chronic tests to characterize toxicity of whole sediment. Bioassays used for marine/estuarine evaluations are:

1. 10-day amphipod mortality test (acute toxicity)
2. 20-day juvenile infaunal growth test (chronic toxicity)
3. Sediment larval development test (acute toxicity)

The protocols for the required bioassays can be found in the Puget Sound Protocols and Guidelines (PSEP, 1995), and DMMP protocol updates. The protocols describe field collection and processing methods, bioassay specific QA/QC, and data reporting procedures. Also, general protocols are provided for field collection of surficial test sediments and for general QA/QC procedures that apply to all sediment bioassays.

9.1.2 Freshwater Bioassays

The standard freshwater bioassays used in the DMMP program include both acute and chronic tests to characterize toxicity of whole sediment. Bioassays used for freshwater environments are:

1. ***Hyalella azteca*** 10-day survival (acute toxicity)
2. ***Chironomus dilutus*** 10-day survival and growth (acute and chronic toxicity)

Protocols, QA requirements and interpretation guidelines for freshwater bioassays can be found in the RSET Sediment Evaluation Framework, Interim Final, Section 7.2.2 (see page 86 of SEF). Other sources for freshwater bioassay test protocols include USEPA, 2000 and ASTM, 2005.

9.2 BIOASSAY SPECIES

The DMMP recommends the following listed species for marine bioassay testing.

Further information on species selection is provided in the test-specific sections below. **If recommended species are not available, please contact the DMMO prior to initiating testing with a non-recommended species.**

1. 10-Day Amphipod Mortality Test
    a. ***Eohaustorius estuarius*** – most commonly used species; can be used with grain-size distributions ranging from 0 to 100, as long as the clay fraction <20%; and in interstitial salinities ranging from 2 ppt to 28 ppt.
    b. ***Ampelisca abdita*** – recommended if test sediment contains greater than 20% clay and salinities of 28 ± 1 ppt
    c. ***Rhepoxynius abronius*** – alternative species for use in coarser-grained sediments (i.e. fines <60%) and salinities of 28 ± 1 ppt.
2. 20-Day Juvenile Infaunal Growth Test
    a. ***Neanthes arenaceodentata*** (Los Angeles karyotype)
3. Sediment Larval Development Test.
    a. Bivalve: ***Mytilus galloprovincialis***
    b. Echinoderm: ***Dendraster excentricus***

9.3 10-DAY AMPHIPOD MORTALITY TEST

This bioassay is an acute test that measures survival of infaunal amphipods to evaluate the toxicity of sample sediments.

9.3.3 Amphipod Species Selection

The DMMP agencies generally recommend using *Eohaustorius estuarius*, as this species is relatively insensitive to salinity changes and effects of grain size, except for high clay (>20%) content. *Ampelisca abdita* is also relatively insensitive to the effects of grain size and is the recommended species when testing sediments with relatively high clay content (>20%). *Rhepoxynius abronius* has shown sensitivity to high percent fines in sediments, particularly high clay content sediments, and has exhibited mortalities greater than 20 percent in clean, reference area sediments (DeWitt *et al*., 1988; Fox, 1993). It should only be selected when testing coarser sediments (<60% fines). Proposed species must be coordinated through the DMMO, and the rationale for species selection must be documented in the sampling and analysis plan for the proposed dredging project. Appropriate negative control sediment must be used for the test species selected. More information on amphipod species selection can be found in DMMP 1999.

9.4 20-DAY JUVENILE INFAUNAL GROWTH TEST (*NEANTHES*)

This bioassay is a sublethal bioassay, testing for chronic rather than acute (fatal) toxicity to the nereid worm *Neanthes arenaceodentata.* The growth of this worm is used as an indication of sublethal toxicity. Testing results should be reported on an ash-free dry-weight (AFDW) basis.

The AFDW procedure eliminates weight from sediment in the gut, thereby providing a more accurate measurement of the change in biomass during the exposure period.

9.5 SEDIMENT LARVAL DEVELOPMENT TEST

The sediment larval test uses the planktonic larval form of a benthic invertebrate to test for acute toxicity to this life stage. Larvae are introduced into chambers of test sediment and overlying water directly after fertilization. Development and survival are tracked for the 48 to 60 hours of larval growth.

9.5.1 Larval Species Selection

This test uses larvae of either an echinoderm or bivalve species. *Dendraster excentricus* is the recommended echinoderm species and *Mytilus galloprovincialis* is the recommended bivalve species. If both of these species are unavailable, laboratories may propose use of alternative species such as the bivalve *Crassostrea gigas.* **Use of alternative species should proceed only after DMMP coordination and approval.**

9.5.2 Special Considerations for Sediment Larval Bioassay

Because the larval stage is a sensitive one, care must be taken during the test to insure that non-treatment factors for larval survival and development are controlled. The PSEP Protocols should be followed carefully to insure that useable data are collected.

For the sediment larval test, adults must be collected in spawning condition or must be induced to spawn in the laboratory. Therefore, seasonality plays a role in selecting a test organism for this bioassay. Viable test organisms are most difficult to obtain in the fall and early winter and the probability of performance problems increases during that time. The DMMP agencies recommend that biological testing be avoided late in the calendar year if at all possible.

When testing dredged material with high concentrations of fines, wood waste or other flocculent material, applicants may elect to use the resuspension protocol (see DMMP, 2013 Clarification Paper) in lieu of the standard PSEP protocol termination procedure, in order to reduce false positives from normally developing larvae being entrained in the flocculent material. The decision to use the resuspension protocol should be made in coordination with the DMMP agencies for approval before use. For routine testing of sediments with lower fractions of fines, wood waste or flocculent material, the standard PSEP protocol should be used.

9.6 QUALITY ASSURANCE/QUALITY CONTROL IN BIOASSAYS

The following QA/QC guidelines apply to the standard suite of marine bioassays:

9.6.1 Negative Control and Reference Samples

For the amphipod and juvenile infaunal species biological tests, a negative control sediment is run with each test batch. The negative control sediment for the amphipod test is taken from the test organism collection site (see additional information in 9.6.2). The juvenile infaunal growth test, using laboratory-cultured *Neanthes arenaceodentata*, requires collection of negative control sediment from an appropriate area such as West Beach, Whidbey Island. For the sediment larval test, a negative seawater control is required. The negative control provides an estimate of test organism general health during the test exposure period.

In addition to the negative control, at least one reference sediment must be run with each test batch, for all three bioassays. Reference sediment is collected from one of the reference sediment collection sites in Puget Sound, Grays Harbor or Willapa Bay and should be compatible on a grain-size basis with the dredged material. The primary purpose of the reference sediment is to control for non-treatment effects due to grain size. For dredged material with relatively coarse-grained sediments (> 80% sand), the dredger can opt to rely solely on the control sediment (see guidance below on when it is appropriate to use control sediments as a reference).

9.6.2 Selection of Negative Control Sediments

An appropriate negative control sediment must be used for the amphipod mortality and *Neanthes* growth tests. PSEP (1995) provides the following description of native habitat for various amphipods: "*Rhepoxynius abronius* and *Eohaustorius estuarius* typically inhabit well-sorted, fine sand while *Ampelisca abdita* is a tube-dwelling amphipod found mainly in protected areas and is often abundant in sediments with a high organic content. It generally inhabits sediments from fine sand to mud and silt without shell, although it can also be found in relatively coarser sediments with a sizable fine component." The best way to ensure a good negative control is to collect the control sediment from the same location at which the test organisms are collected.

Neanthes arenaceodentata is cultured in the lab rather than field-collected. However, PSEP (1995) states that, "For the *Neanthes* bioassay, sand should be used as the control sediment." West Beach of Whidbey Island is most often used as a collection site for clean control sediment. From PSEP (1995), "*Neanthes* maintained in West Beach sand exhibited low mortality and high percentage increases in biomass during the exposure period, indicating that West Beach sand is a suitable material for a control sediment."

PSEP (1995) also states that, "All bioassays must be conducted using well-established negative (clean) controls. Such controls are clean, nontoxic seawater and/or sediment samples taken from outside each study area." Sediments proposed for use as negative controls must be approved before bioassays commence. If an area without a proven track record is proposed for collection of negative control sediment, sufficient data (such as grain size, organic carbon content, chemical data, bioassay results) must be submitted before its use can be approved by the regulatory agencies.

9.6.3 Use of Control Sediments as Reference Sediments

When reference sediment fails to meet its performance standard, and more than one reference has been collected, DMMP/EMS (1996) provides procedures for statistical comparisons. If no reference sediments meet performance standards, or if the control sediment is closer in grain size to one or more stations being evaluated than any of the remaining reference sediments, the control sediment could be considered an acceptable substitute for the reference sediment and the data interpreted accordingly.

If a control sediment is substantially dissimilar to the site stations and a failed reference sediment in its physical characteristics (e.g., >25% difference in fines), it may still be used as a substitute for the reference station if both the agencies and the project proponent agree that this is appropriate. Otherwise, the data will be considered unusable and the bioassay(s) in question will need to be rejected and possibly rerun.

9.6.4 Quality control limits for the negative control treatment

All three bioassays have negative control performance standards that must be met (see Table 9-4). In the amphipod and juvenile infaunal bioassay tests, control mortality over the exposure period must be less than or equal to 10 percent. This represents a generally accepted level of mortality of test organisms under control conditions, where the bioassay (in terms of test organism health) is still considered a valid measure of effects of the test treatments. If control mortality is greater than 10 percent, the bioassay test will generally have to be repeated, although that determination must be made in consultation with the agencies through the DMMO. Additionally, for the Neanthes 20-day growth bioassay there is a negative control performance guideline of > 0.72 mg/ind/day as a target growth rate, with negative control growth rates below 0.38 mg/ind/day considered a QA/QC failure. Laboratories failing to achieve a control growth rate > 0.38 mg/ind/day may be required to retest. For the sediment larval test, the performance standard for the seawater negative control combined endpoint (mortality + abnormality) is 30 percent or less.

9.6.5 Quality control limits for the reference sediment

Performance guidelines for reference sediments are listed in Table 9-4. The mean amphipod test mortality for the reference sediment must not exceed 20 percent absolute over the mean negative control sediment mortality. For the juvenile infaunal growth test, the reference sediment mean mortality must be less than or equal to 20 percent at the end of the exposure period, and the mean growth rate must be greater than or equal to 80 percent of the control sediment's mean growth rate. The seawater-normalized combined endpoint (mortality + abnormality) observed in the reference sediment for the sediment larval test must not exceed 35 percent. Failure to meet the reference sediment performance standard for a bioassay may require that the bioassay be rerun with a new reference sediment. If a performance guideline is not met for reference sediment, the DMMO should be contacted as soon as possible to coordinate with the agencies regarding a retest.

9.6.6 Positive control - reference toxicant

An appropriate reference toxicant must be run with each batch of test sediments as a positive control to assess the test organism sensitivity. The LC_{50} or EC_{50} must be within the 95 percent confidence interval of responses expected for the toxicant used.

9.6.7 Water quality monitoring

Temperature, aqueous salinity, pH, and dissolved oxygen should be monitored on a daily basis for the amphipod and sediment larval tests, and every three days for the 20-day *Neanthes* growth test. Total sulfides and ammonia should be measured at least at test initiation and termination for all three tests (reference earlier sections discussing interferences here). Interstitial salinity should be measured prior to test initiation. The test protocols for each of these bioassays specify acceptable ranges for these parameters. Water quality data can be critical in the interpretation of bioassay results.

9.7 BIOASSAY INTERPRETIVE CRITERIA

The response of bioassay organisms exposed to the sediment sample representing each DMMU will be compared to the response of these organisms in both control and reference treatments. This comparison will determine whether the material is suitable for unconfined, open water disposal relative to the Clean Water Act (CWA) Section 404(b)(1) Guidelines (see **Table 9-1**).

The determination of an environmentally significant response involves two conditions: first, that the response in the tested DMMU must be greater than 20 percent different from the control response; and, second, that a comparison between mean test and mean reference responses be statistically significant. For the latter determination, the following guidelines are to be followed:

1. Multiple comparison tests (e.g., ANOVA, Dunnett's) are not to be used.
2. A null hypothesis shall be selected that reflects the one-tailed t-test approach and the type of endpoint being evaluated.
3. Bioassay data expressed in percent should be transformed prior to statistical testing using the arcsine –square-root transform to stabilize the variances and improve the normality of the data. *Neanthes* growth data may require a square root or log transformation.
4. Bioassay data should then be tested for normality and homogeneity of variances, using the Shapiro-Wilk test (W test) and Levene's test, respectively.
5. Bioassay data passing both tests should be tested for statistical difference using a one-tailed Student's t-test.
6. Data passing the W test but failing Levene's test should be tested for statistical difference using the approximate t-test.
7. Data failing the W test but passing Levene's test should be tested for statistical difference using the non-parametric Mann-Whitney test.
8. Data failing both the W test and Levene's test should be converted to ranks and tested with a t-test.

Seattle District has developed statistical analysis software called BioStat to facilitate bioassay statistical comparisons with appropriate reference sediments. Submittal of screen shots or statistical reports from BioStat will provide the documentation necessary to support summarized interpretations of bioassay data in the sediment characterization report.

9.7.8 Single-hit failure

When **any one** biological test exhibits a test sediment response that exceeds the bioassay-specific guidelines relative to the negative control and reference, and which is statistically significant in comparison to the reference, the DMMU is judged to be unsuitable for unconfined open-water disposal (see **Table 9-1**).

Amphipod Bioassay. For the amphipod bioassay, mean test mortality greater than 20 percent absolute over the mean negative control response, and greater than 10 percent (dispersive) or 30 percent (nondispersive) absolute over the mean reference sediment response, and statistically significant compared to reference (alpha = 0.05), is considered a "hit" under the "single-hit" guidelines.

Juvenile Infaunal Growth Test. Juvenile infaunal growth test results that show a mean individual growth rate (AFDW) less than 80 percent of the mean negative control growth rate, and less than 70 percent (dispersive) or 50 percent (nondispersive) of the mean reference sediment growth rate, and statistically significant compared to reference (alpha = 0.05),constitute a hit under the single-hit rule.

Sediment Larval Bioassay. For the sediment larval bioassay, test and reference sediment responses are normalized to the negative seawater control response. This normalization is performed by dividing the number of normal larvae from the test or reference treatment at the end of the exposure period by the number of normal larvae in the seawater control at the end of the exposure period, and multiplying by 100 to convert to percent. The normalized combined mortality and abnormality (NCMA) is then 100 minus this number. If the mean NCMA for a test sediment is greater than 20 percent, and is 15 percent (dispersive) or 30 percent (nondispersive) greater than the mean reference sediment NCMA, and statistically significant compared to reference (alpha = 0.10), it is considered a hit under the single-hit rule.

9.7.9 Double-hit failure

When **any two** biological tests (amphipod, juvenile infaunal growth or sediment larval) exhibit test sediment responses which are less than the bioassay-specific reference-comparison guidelines noted above for a single-hit failure, but are statistically significant compared to the reference sediment (and less than 70 percent of the mean reference sediment growth rate for the *Neanthes* bioassay for nondispersive sites), the DMMU is judged to be unsuitable for unconfined open-water disposal.

Table 9-1. Solid Phase Bioassay Performance Standards and Evaluation Guidelines

Bioassay	**Negative Control Performance Standard**	**Reference Sediment Performance Standard**	**Dispersive Disposal Site Interpretation Guidelines**		**Nondispersive Disposal Site Interpretation Guidelines**	
			1-hit rule	2-hit rule	1-hit rule	2-hit rule
Amphipod	$M_C \leq 10\%$	$M_R - M_C \leq 20\%$	$M_T - M_C > 20\%$ and M_T vs. M_R SS (p=.05) and		$M_T - M_C > 20\%$ and M_T vs. M_R SS (p=.05) and	
			$M_T - M_R > 10\%$	NOCN	$M_T - M_R > 30\%$	NOCN
Larval	$N_C \div I \geq 0.70$	$N_R \div N_C \geq 0.65$	$N_T \div N_C < 0.80$ and N_T/N_C vs. N_R/N_C SS (p=.10) and		$N_T \div N_C < 0.80$ and N_T/N_C vs. N_R/N_C SS (p=.10) and	
			$N_R/N_C - N_T/N_C > 0.15$	NOCN	$N_R/N_C - N_T/N_C > 0.30$	NOCN
Neanthes growth	$M_C \leq 10\%$ and $MIG_C \geq 0.38$	$M_R \leq 20\%$ and $MIG_R \div MIG_C \geq 0.80$	$MIG_T \div MIG_C < 0.80$ and MIG_T vs. MIG_R SS (p=.05) and		$MIG_T \div MIG_C < 0.80$ and MIG_T vs. MIG_R SS (p=.05) and	
			$MIG_T/MIG_R < 0.70$	NOCN	$MIG_T/MIG_R < 0.50$	$MIG_T/MIG_R < 0.70$

M = mortality, N = normal larvae, I = initial count, MIG = mean individual growth rate (mg/individual/day)

SS = statistically significant, NOCN = no other conditions necessary, N/A = not applicable

Subscripts: R = reference sediment, C = negative control, T = test sediment

9.8 ELUTRIATE BIOASSAY TESTING

The Tier 3 evaluation of dredged material in some cases may include bioassay testing of dredging elutriate to estimate water quality impacts (USACE *et al*, 2009). Elutriate testing for biological effects is not routinely required for regulated or federal dredging projects evaluated under CWA Section 404 for DMMP disposal. This test is conducted only when the Washington Department of Ecology requires it for assessment of potential water column toxicity effects relative to a particular chemical of concern.

In the event that elutriate testing is required for marine sediments at the dredging site, the echinoderm/bivalve larval test will be conducted to evaluate water column effects. The appropriate assessment is described in the SEF (see pages 10-3 to 10-13). More specificity on the serial dilution bioassay tests performed on the elutriate water can be found in the Inland Testing Manual (EPA/Corps, 1998, Sections 6.1 and 11.1). In the event that freshwater sediments at the dredging site require elutriate testing, and where salmonid species are present, elutriate testing should be conducted with rainbow trout (*Oncorhynchus mykiss*). The following species may be used for the larval water column bioassay test:

- Echinoderm: *Dendraster excentricus* (marine)
- Bivalve: *Mytilus galloprovincialis* (marine)
- Rainbow trout: *Oncorhynchus mykiss* (freshwater)

9.9 REFERENCE SEDIMENT COLLECTION SITES

Bioassays must be run with a reference sediment which is well-matched to the test sediments for grain-size. **Table 9-2** contains information about each of the Puget Sound sites that are recommended for use. **Table 9-3** contains information about reference sites for Grays Harbor and Willapa Bay. Other reference areas may be utilized with DMMP review and approval if:

- biological tests are initially run using the proposed reference area along with an already recognized reference area.
- chemical (DMMP contaminants of concern) analysis is performed for the proposed area.

Table 9-2. Reference Sediment Collection Areas for Puget Sound.

	CARR INLET	SAMISH BAY	HOLMES HARBOR	SEQUIM BAY
Fines (%):	5-85	11-96	3-96	19-85
TOC (%):	0.2-11.8	0.4-29.0	0.2-31.0	2.3-2.7
Reference:	PTI, 1991; SAIC, 2001	PTI, 1991; SAIC, 2001	PTI, 1991; SAIC, 2001	DAIS

The sampling protocol used for the collection of reference sediment can affect its performance during biological testing. The following guidelines should be followed when collecting reference sediments:

- Use experienced personnel.
- Follow PSEP protocols.
- Sample from biologically active zone.

- Avoid anoxic sediment below the Redox Potential Discontinuity (RPD) horizon.
- Use wet-sieving method.
- Fix sulfides sample with zinc acetate.

Table 9-3. Reference Sediment Collection Sites for Grays Harbor and Willapa Bay. [1]

PARAMETER	STATION					
	3.9 MILE ODMDS	**WBS5**	**WBS7**	**GHS4**	**GHS6**	**GHS7**
Location	SE of 3.9 Mile Site[2]	Grassy Point	Bay Center	Stearns Bluff	Elk River	North Bay
GPS Latitude (WGS84)	46° 51.00'	46° 38.04'	46° 37.90'	46° 55.73'	46° 52.52'	47° 00.35'
GPS Longitude (WGS84)	124° 13.73	124° 01.78'	123° 56.80'	123° 59.03'	124° 04.78'	124° 05.79'
Fines (%)	10	0	35-52	12	2	7-59
TOC (%)	0.10	0.02	0.51-1.0	0.25	0.06	0.15-1.1

[1] Adapted from The *Grays Harbor and Willapa Bay Dredged Material Management Study: Expanded Reference Area Sediments* final report (SAIC, 1993)
[2] Station4 from the 3.9-Mile ODMDS site.

Wet-sieving is imperative for finding a good grain-size match with the test sediment. Wet-sieving is accomplished using a 63-micron (#230) sieve and a graduated cylinder; 100 ml of sediment is placed in the sieve and washed thoroughly until the water runs clear. The volume of sand and gravel remaining in the sieve is then washed into the graduated cylinder and measured. This represents the coarse fraction; the fines content is determined by subtracting this number from 100. Because of the wide heterogeneity of grain size in the reference areas, it may be necessary to perform wet-sieving in several places before a reference sediment with the proper grain size is found. It is important that the sediment sample analyzed by wet-sieving is representative of the sediment that will be used for bioassays. Homogenization of the sediment prior to wet-sieving is recommended.

It should be noted that wet-sieving results will not perfectly match the dry-weight-normalized grain size results from the laboratory analysis, but should be relatively close (generally within 10%). It is requested that wet-sieving results be submitted along with the laboratory data so that a regression line for each embayment can be developed which more accurately predicts the dry-weight fines fraction from the wet-sieving results found in the field. Reference station coordinates should also be reported, with an accuracy of ± 3 meters.

In addition to wet-sieving in the field, reference sediments must be analyzed in the laboratory for total solids, total volatile solids, total organic carbon, grain size, ammonia and sulfides. The methods and QA guidelines used for analysis of sediment conventionals in test sediments should also be used for reference sediments.

9.10 AMMONIA AND SULFIDE NON-TREATMENT INFLUENCES

The potential for ammonia and sulfides to complicate bioassay evaluations of dredged material has been addressed in the following DMMP clarification papers:

- DMMP (1993) - The *Neanthes* 20-day Bioassay – Requirements for Ammonia/Sulfides Monitoring and Initial Weight
- DMMP (2001b) - Reporting Ammonia LC50 data for Larval and Amphipod Bioassays,
- DMMP (2002a) - Ammonia and Amphipod Toxicity Testing
- DMMP (2004a) - Ammonia and Sulfide Guidance Relative to *Neanthes* Growth Bioassay

Despite the numerous clarification papers addressing these chemicals, there remain data gaps and inconsistencies in the existing guidance that limit the DMMP agencies' ability to adequately interpret the effects of these non-treatment factors or prevent them altogether. Existing deficiencies in the DMMP guidance can be categorized as follows:

Ammonia*:* Threshold concentrations that would trigger purging and/or reference toxicant testing have been established for the amphipod and *Neanthes* bioassays, but not for the larval test.

Hydrogen Sulfide*:* Threshold concentrations that would trigger purging1 have been established for the *Neanthes* bioassay, but not for the amphipod and larval bioassays.

Predicting Non-treatment Effects*:* The DMMP agencies currently rely on the concentration of sulfides and ammonia in bulk sediment samples to predict potential problems in the bioassays due to these chemicals. There are two flaws in this approach. First, the bulk sediment tested for sulfides and ammonia may not be representative of the sediment that will eventually be used for bioassays, due to differences in holding times and conditions. Second, with the exception of ammonia for *Neanthes*, there are no established triggers based on bulk sediment concentrations. The other established triggers are based on water measurements; comparisons can only be made after ammonia and sulfide measurements are taken at the beginning of the bioassays themselves, at which point it is typically too late to initiate a purging procedure and prevent nontreatment effects from occurring.

Effects Level of Purging Triggers: There is a discrepancy in the effects levels currently used to trigger purging. For the amphipod bioassay, the purging trigger is set at the no-effects level, while for *Neanthes* it is set at the minor-effects level. If purging is not conducted until the minor-effects level is reached, non-treatment effects can be expected to occur for concentrations above the no-effects level but below the purging trigger. For example, the ammonia trigger for purging in the *Neanthes* test is set at a concentration that could be expected to result in mortality of 20% and a growth reduction of 31-35% relative to the controls (DMMP, 2004a). While within-batch Ref Tox tests can provide evidence of toxicity due to ammonia, the length of the Ref Tox test is much shorter than that of the amphipod and *Neanthes* bioassays. Therefore, quantifying the contribution of ammonia to toxicity in these bioassays based on the results of Ref Tox tests is extremely difficult. With respect to sulfides, it is not practical to even run Ref Tox tests, so setting the purging trigger at the minor-effects level is even more problematic.

Interstitial Measurements: The DMMP water quality monitoring requirements include testing of interstitial samples for ammonia and sulfides in the *Neanthes* and amphipod bioassays.

Interstitial testing requires the use of sacrificial beakers because the sediment in the beaker must be “sacrificed” in order to extract the porewater. This is not a problem unless purging is required. In order to monitor interstitial ammonia and sulfides concentrations during purging, a series of sacrificial beakers must be set up so that porewater can be extracted and measured every 1 to 3 days. The additional sediment needed for sacrificial beakers must be collected during project sampling, which means that additional cores may need to be taken to provide adequate volume.

These questions are presently being addressed by the DMMP via a draft clarification paper (Modifications to Ammonia and Sulfide Triggers for Purging and Reference Toxicant Testing) and subsequent public comments. This section will be updated when the paper is finalized.

10 TIER 3 BIOLOGICAL TESTING: BIOACCUMULATION

Bioaccumulation is the accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, or dredged material. Tier 3 bioaccumulation testing of dredged material is required when results of sediment chemical analysis for bioaccumulative chemicals of concern (BCOCs) indicate the potential for unacceptable adverse environmental or human health effects. The tissue residues derived from bioaccumulation tests are compared to the DMMP's target tissue levels (TTLs) and reference values to assess the potential for both human- and ecological-health related effects. Important elements of this testing process are described below.

10.1 BIOACCUMULATIVE CONTAMINANTS OF CONCERN (BCOCS) AND TRIGGERS FOR BIOACCUMULATION TESTING

In 2003, the DMMP adopted a revised list of Bioaccumulative Contaminants of Concern (see DMMP, 2003c Issue Paper and DMMP, 2007 Technical Basis document) using a systematic approach that considered multiple lines of evidence for determining the bioaccumulative risk posed by a particular chemical. Revising the DMMP's BCOC list involved creation of four separate BCOC lists. **List 1** (**Table 10-1**) is the primary list of bioaccumulative contaminants of concern. Analysis for these 17 chemicals in sediments (and potentially in tissues) is required to determine dredged material suitability. Analysis of PCDDs/PCDFs and TBT are required only on a case-by-case basis. **Lists 2 and 3** define chemicals of potential concern for bioaccumulative effects but for which definitive data are still lacking – analysis of these chemicals is not routinely required. **List 4** chemicals are those which the DMMP does not consider to be bioaccumulative.

When measured sediment concentrations of the List 1 contaminants exceed the bioaccumulation trigger (BT) values presented in **Table 8-2**, bioaccumulation testing must be performed before suitability of the test sediment for open-water disposal can be determined. The BT is set at a sediment concentration that constitutes a "reason to believe" that the chemical would accumulate in the tissues of target organisms. As a general approach, BTs were established for human health COCs at concentrations in the upper 30th percentile of the concentrations allowable for unconfined, open-water disposal (i.e., 70 percent of the difference between the SL and ML) (EPTA, 1988). The DMMP agencies revised TBT guidance in DMMP, 1996, and established a porewater BT for this chemical. The BT for Chromium was set equal to the SL in a DMMP, 2011 clarification paper. The 2003 revisions to the BCOC list did not involve revisions to existing BT values. However, interim BT values were developed for six of the new List 1 chemicals using the same algorithm used in EPTA (PSDDA, 1988). The interim BT for selenium was developed in consideration of sediment concentrations reported in the literature to be associated with adverse ecological effects from bioaccumulation. These newly-established BTs were all designated as "interim" pending a reexamination of the BT derivation approach, which will be accomplished when resources are available as part of the RSET process, as well as through the ongoing Ecology SMS rule revisions, which will be implemented in September 2013.

The DMMP agencies will evaluate bioaccumulative COCs at non-dispersive and dispersive sites in Puget Sound on a case-by-case basis using best professional judgment based on the latest science, and regional background approaches being developed by Ecology in Puget Sound. Until that time, the approach and guidelines outlined in this section are those that will be used by the DMMP. However, modifications proposed by applicants, based on RSET guidelines, may be considered on a case-by-case basis.

Table 10-1. List 1 Bioaccumulative Chemicals of Concern

CHEMICAL	METHOD INFORMATION	LOG K_{ow}[1]	BT (dry wt basis[2])
METALS			
Arsenic	SW846 M.6010/6020	N/A	507.1 mg/kg
Cadmium	SW846 M.6010/6020/7131	N/A	11.3 mg/kg
Chromium	SW846 M.6010/6020	N/A	260 mg/kg
Copper	SW846 M.6010/6020	N/A	1027 mg/kg
Lead	SW846 M. 6010/6020/7421	N/A	975 mg/kg
Mercury	SW846 M.7471	N/A	1.5 mg/kg
Selenium	SW846 M. 6010/6020/7740	N/A	3 mg/kg[3]
Silver	SW846 M. 6010/6020/7761	N/A	6.1 mg/kg
Zinc	SW846 M.6010/6020	N/A	2783 ug/kg
ORGANOMETALLIC COMPOUNDS			
Tributyltin (interstitial water) (bulk sediment)	Krone/Unger	3.7-4.4	0.15 ug/L 73.2 ug/kg
ORGANICS			
Fluoranthene	SW846 M.8270	5.12	4,600 ug/kg
Pyrene	SW846 M.8270	5.11	11,980 ug/kg
CHLORINATED HYDROCARBONS			
Hexachlorobenzene (HCB)	SW846 M.8081	5.89	168 ug/kg
PHENOLS			
Pentachlorophenol	SW846 M.8270	5.09	504 ug/kg
PESTICIDES/PCBs			
Total DDT (sum of 4,4'-DDD, 4,4'-DDE and 4,4'-DDT)	SW846 M.8081	(5.7 - 6.0)[4]	50 ug/kg
Chlordane[5]	SW846 M.8081	6.32	37 ug/kg
Dioxins/Furans	EPA 1613	5.5-13.9	10 ng/kg[6]
Total Aroclor PCBs	SW846 M.8081/2	(3.6-11)[7]	38 mg/kg OC

[1] Octanol/Water Partitioning Coefficients (log K_{OW}) for organic chemicals of concern for bioaccumulation in Puget Sound.
[2] Except where noted otherwise
[3] Based on review of sediment effect values from the literature and best professional judgment.
[4] Range of individual chemicals making up the total.
[5] Chlordane includes cis-Chlordane, trans-Chlordane, cis-Nonachlor, trans-Nonachlor, and oxychlordane. Components of chlordane were clarified at the 2007 SMARM.
[6] The BT for Puget Sound established with implementation of new interim dioxin guidelines in 2010.
[7] Range of individual congeners making up the total.

10.2 BIOACCUMULATION TEST SPECIES SELECTION

Selection of appropriate species is an important consideration for Tier 3 bioaccumulation tests. Studies have shown that the time required for any given species to achieve a steady-state tissue concentration of a chemical of concern may vary (see **Table 10-2**), or are not well known (Windom and Kendall, 1979; Rubenstein, Lores, and Gregory, 1983). As such, for a given chemical triggering a Tier 3 bioaccumulation test, the applicant should consider selecting species that will assimilate the target chemical near its steady-state concentration (if known) within the exposure period or consider extending the exposure period. The Inland Testing Manual requires bioaccumulation testing with species from two different trophic niches, including: 1) a suspension-feeding/filter-feeding organism and 2) a burrowing deposit-feeding organism. In the northwest, the Tier 3 marine bioaccumulation test is usually conducted with both an adult bivalve (*Macoma nasuta*) and an adult polychaete (*Nephtys caecoides*). For recommended freshwater species, consult the RSET SEF.

10.3 BIOACCUMULATION TEST PROTOCOL

The standard Tier 3 bioaccumulation test utilizes the EPA protocol (Lee *et al*. 1989) and a 28-day exposure period, after which a chemical analysis is conducted of the tissues to determine the concentration of bioaccumulative chemicals of concern identified in the sediments. Protocols for tissue digestion and chemical analysis will follow the PSEP-recommended procedures for metals and organic chemicals.

For many chemicals in **Table 10-1**, it was originally assumed that the standard 28-day exposure would be sufficient for a steady-state tissue concentration to be reached. After examining the observed steady state exposures depicted in **Table 10-2**, the DMMP agencies deemed it unlikely that steady state will have been reached after 28 days for select chemicals. Therefore the DMMP agencies increased the exposure time from 28 to 45 days for the BCOCs with regularly occurring BT exceedances during DMMP project testing to better approximate steady-state conditions. A 45-day exposure should be used for PCBs, TBT, DDT, Hg, and Fluoranthene during required bioaccumulation testing. For the remaining BCOCs, which have not had BT exceedances to date, if BT exceedances are observed the DMMP agencies would evaluate the need to extend the exposure period beyond the 28-day exposure period before bioaccumulation testing is initiated. Given the holding time limitations (8 weeks) and the large volume of sediment required, it has always been necessary to resample project sediments in order conduct bioaccumulation testing for all previous bioaccumulation testing conducted. Under these circumstances, it is necessary to also reanalyze the newly-collected sediment for the chemicals of concern that originally triggered the requirement for bioaccumulation testing. If the chemical concentration(s) found in the bioaccumulation test sediment are less than that measured in the original sediment analyzed, the DMMP will require that the measured tissue concentrations of that chemical be mathematically adjusted. The resulting adjusted tissue concentration reflects the bioaccumulation of a given chemical that would have been expected from exposure to the original sediment sample.

Bioaccumulation protocol updates adopted by DMMP:

- Use a 45-day exposure time when conducting bioaccumulation testing for specific chemicals of concern for bioaccumulation (PCBs, TBT, DDT, Hg, Fluoranthene) to ensure steady-state chemical concentrations in the tissues of the test species (*Macoma nasuta* and *Nephtys caecoides*). Increasing the exposure to 45 days will require once weekly supplemental additions of 175-mL of test or control/reference sediment to each replicate10-gallon aquarium/test chamber.
- Wet-weight biomass (of a subset of 10 individual organisms/replicates) should be measured at the beginning and end of the bioaccumulation exposure period for test, control and reference samples. This estimate of net individual growth during the exposure period will be used as an additional metric to evaluate the health of the test animals, and to build a database that may support establishing a benthic effects-based target-tissue level.
- Each DMMU undergoing bioaccumulation testing is compared to the TTL interpretation guidelines for a specific BCOC. For test sediment tissues quantitated greater or equal to the TTL no further action is required, as the DMMU fails DMMP interpretative guidelines. DMMU quantitated less than the TTL are subjected to a one-tailed one-sample t-test to determine whether the test tissues are significantly less than the TTL.
- Use an alpha level of 0.1 (rather than 0.05) when making statistical comparisons between tissue concentrations in test and reference samples to reflect higher likelihood for within-sample variability, and to increase the power of the test to discriminate between reference and test tissue concentrations. Note that an alpha level of 0.05 should be used when making comparisons between test tissues and target tissue levels (TTLs).
- To conserve laboratory space and reduce the volume of sediment required, applicants can/will expose *Macoma nasuta* and *Nephtys caecoides* together in the same test chambers. The total sediment requirement for co-testing is 30 liters. A considerable volume of sediment is required for testing each single test species (**Table 10-3**), and co-testing of two species in single aquaria substantially reduces the volume of sediment required for bioaccumulation testing.

Table 10-2. Percent of Steady-State Tissue Residues of Selected Metals and Neutral Organics from 10 and 28 day Exposures to Bedded Sediment[1]

COMPOUND	% OF STEADY STATE[2] TISSUE RESIDUE		SPECIES	EST. BY	REFERENCES[3]
	10-DAY	28-DAY			
METALS					
Copper	75	100	*Macoma nasuta*	G[5]	Lee (unpublished)
Lead	81	100	*Macoma nasuta*	G	Lee (unpublished)
Cadmium	17	50	*Callianassa australiensis*	G	Ahsanulla et al., 1984
Mercury	ND[4]	ND[4]	*Neanthes succinea*	G	Kendall, 1978
PCBs					
Aroclor 1242	18	87	*Nereis virens*	G	Langston, 1978
Aroclor 1254	12	82	*Macoma balthica*	G	Langston, 1978
Aroclor 1254	25	56	*Nereis virens*	K[6]	McLeese et al., 1980
Aroclor 1260	53	100	*Macoma balthica*	G	Langston, 1978
Total PCBs	21	54	*Nereis virens*	G	Pruell et al., 1986
Total PCBs	48	80	*Macoma nasuta*	G	Pruell et al., 1986
Total PCBs	23	71	*Macoma nasuta*	G	Boese (unpublished)
PAHs					
Benzo(a)pyrene	43	75	*Macoma inquinata*	G	Augenfield et al., 1982
Benzo(b,k)fluoranthene	71	100	*Macoma nasuta*	G	Lee (unpublished)
Chrysene	43	87	*Macoma inquinata*	G	Augenfield et al., 1982
Fluoranthene	100	100	*Macoma nasuta*	G	Lee (unpublished)
Phenanthrene	100	100	*Macoma inquinata*	G	Augenfield et al., 1981
Phenanthrene	100	100	*Macoma nasuta*	G	Lee (unpublished)
Pyrene	84	97	*Macoma nasuta*	G	Lee (unpublished)
TCDD/TCDF					
2,3,7,8-TCDD	6	22	*Nereis virens*	G	Pruell et al., 1990
2,3,7,8-TCDD	63	100	*Macoma nasuta*	G	Pruell et al., 1990
2,3,7,8-TCDF	43	62	*Nereis virens*	G	Pruell et al., 1990
2,3,7,8-TCDF	92	100	*Macoma nasuta*	G	Pruell et al., 1990
MISCELLANEOUS					
4,4-DDE	20	50	*Macoma nasuta*	G	Lee (unpublished)
2,4-DDD	31	56	*Macoma nasuta*	G	Lee (unpublished)
4,4-DDD	32	60	*Macoma nasuta*	G	Lee (unpublished)
4,4-DDT	17	10	*Macoma nasuta*	G	Lee (unpublished)

[1] Modified from Inland Testing Manual (Table C), using data updated from Boese and Lee (1992).
[2] Steady-state values are estimates, as steady-state is not rigorously documented in these studies.
[3] See Boese and Lee (1992) for complete citations.
[4] ND = Not Determined. Observed AFs (accumulation factors) for field tissue levels compared with sediment levels (normalized to dry weight) averaged 4 for this species, but ranged from 1.3 to 45 among other benthic macroinvertebrate species. Laboratory 28-day exposures to bedded sediment indicated uptake fit a linear regression model over the exposure period and experimental conditions and did not approach a steady-state condition. Tissue levels observed (*N. succinea)* at 28 days amounted to only 2.5 % of the total sediment-bound Hg potentially available.
[5] G = Steady-state residue estimated by visual inspection of graphs of tissue residue versus time.
[6] K = Steady-state residue estimated from a 1st-order kinetic uptake model.

Table 10-3. Species-specific sediment volume requirements for MARINE bioaccumulation testing

SPECIES	MINIMUM SEDIMENT REQUIREMENT
Macoma nasuta	250-400 ml per beaker x 10 beakers per replicate x 5 replicates = **12.5-20 liters**
Nereis virens	200 ml per worm x 20 worms per replicate x 5 replicates = **20 liters**
Arenicola marina OR *Abarenicola spp.*	500 ml per beaker x 4 beakers per replicate x 5 replicates = **10 liters**
Co-testing: Macoma/Nephtys	4 liters per replicate x 5 replicates = **30* liters**

Highlighted: This alternative has become the generally accepted protocol for bioaccumulation testing within DMMP.

* Recent testing experience from one testing laboratory has recommended increasing the volume collected from both test and reference sediment locations from 20 to 30 liters.

10.4 BIOACCUMULATION TEST INTERPRETATION

The DMMP's numerical test interpretation guidelines, or target tissue levels (TTLs), were derived from human-health risk assessments, FDA action levels, or (in the case of TBT) ecological effects. Tissue residues from bioaccumulation testing are compared to the TTLs to assess whether there has been unacceptably high bioaccumulation in benthic organisms resulting from exposure to the test sediments.

10.4.1 Human Health Effects

Most of the TTLs were developed during the PSDDA study for deep-water disposal sites, using consumption rates of bottom fish by recreational anglers, the home range of bottom fish and the size of the Elliott Bay disposal site (EPTA, 1988). For those chemicals with FDA action levels lower than the risk-based concentrations, the FDA action levels were adopted. The TTL for total PCBs was revised in 1999 based on an updated human-health risk assessment that considered subsistence seafood ingestion rates of Native American and Asian/Pacific Islander groups (DMMP, 1999). Table 10-4 shows the current TTLs used by the DMMP for suitability determinations. DMMUs are compared to the values in this table using the approach described below.

The DMMP implemented a new interim dioxin guideline in December 2010, and the revised guidelines will be used in a case-by-case decision-making approach that is consistent with the narrative human health standard in the SMS rule. A project-specific case-by-case evaluation would be necessary to allow consideration of the disposal of material with dioxin levels higher than 10 pptr-TEQ. Evaluation of material with dioxin concentrations greater than 10 pptr-TEQ may require bioaccumulation testing.

A target tissue level (TTL) to be used in the bioaccumulation evaluation has not been determined for dioxins at this time. In the absence of a TTL, the dredging proponent who selects the option of bioaccumulation testing will be required to include exposure of test organisms to a suitable reference sediment as part of the bioaccumulation test. Concentrations in the project test-sediment tissue would be compared against concentrations in the reference-sediment tissue to determine the bioavailability of sediment dioxin and, thereby, the suitability of dredged material for open water disposal. Over time, a tissue database will be developed, which may allow for the adjustment of this protocol. The explicit interpretative framework for evaluating the dioxin bioaccumulation testing results would need to be developed by the DMMP before testing is initiated.

Interpretation of bioaccumulation test results requires a statistical comparison of the mean tissue concentration of contaminants in animals exposed to dredged material to the TTL. The statistic employed is the one-tailed one-sample t-test (alpha level of 0.05):

$$t = \frac{\bar{x} - TTL}{\sqrt{\frac{s^2}{n}}}$$

where " $\bar{x}$ ", "s^2", and "n" refer to the mean, variance, and number of replicates associated with a contaminant's tissue concentrations from bioaccumulation testing of the proposed dredged material. For undetected chemicals, a concentration equal to one-half the detection limit will be used in the statistical analysis.

Use of the one-sample t-test is necessary to allow experimental results for bioaccumulation testing to be compared to the TTLs, which are constants. A one-*tailed* t-test is appropriate since there is concern only if bioaccumulation from the dredged sediment is not significantly less than the TTL. The null hypothesis in this case is that the tissue concentration is greater than or equal to the TTL.

If the mean tissue concentration of one or more contaminants of concern is greater than or equal to the TTL, then no statistical testing is required. The conclusion is that the dredged material is not acceptable for open-water disposal. If the mean tissue concentration of a chemical of concern is less than the applicable TTL, a one-tailed one-sample t-test is conducted and the dredged material is considered acceptable for open-water disposal if the null hypothesis is rejected.

The RSET SEF (see Section 8.4.1.3, pages 8-8) has developed TTLs for BCOCs that are protective of human health, which may be considered by DMMP on a case-by-case basis.

10.4.2 Ecological Effects

It should be noted that subsistence human exposures usually drive the lowest TTLs for highly bioaccumulative COCs. The results of a Tier 3 bioaccumulation test will be compared directly with reference results (or ecological TTLs if these are available) for statistical significance. Significant bioaccumulation of chemicals of concern in test species relative to reference areas may demonstrate the potential for food-web effects. For undetected chemicals, a concentration equal to one-half the detection limit will be used in the statistical analysis. If the results of a statistical comparison show that the tissue concentration of the chemical(s) of concern in test sediments is statistically higher (one-tailed t-test, alpha level of 0.1) than the reference sediment, the dredged material will be evaluated further to determine the potential ecological significance of the measured tissue residues.

The four factors summarized below will be reviewed as part of the suitability determination process when bioaccumulation of contaminants in dredged material tests shows significantly higher accumulation of one or more chemicals of concern. In reviewing these factors, the best available regional guidance will be used to assess the relative importance of each factor to the regulatory decision.

1. How many contaminants demonstrate bioaccumulation from dredged material relative to reference sediments?
2. What is the magnitude of the bioaccumulation from dredged material compared to reference sediments?
3. What is the toxicological importance of the contaminants (e.g., do they biomagnify or have effects at low concentrations?). In assessing the toxicological importance, ecologically-based TTLs may be set on a project-specific basis by the regulatory agencies based on a review of the current residue-effects literature. A statistical comparison will be made to ecologically-based TTLs using the one-sample t-test described under human-health effects.
   - One exception to the project-specific nature of ecologically-based TTLs is the TTL for TBT (Table 10-4), which was adopted from a CERCLA risk assessment (EPA, 1999) that used a weight-of-evidence approach. The TBT TTL represents a residue that is associated with reduced growth in a number of invertebrate species including polychaetes and crustaceans and is , therefore, broadly applicable.
4. What is the magnitude by which contaminants found to bioaccumulate in laboratory test tissues exceed the tissue burdens of comparable species found at or in the vicinity of the disposal site?

If results of the bioaccumulation test in Tier 3 are found to be equivocal, or there is a concern that steady-state body burdens in test organisms were not achieved and/or cannot be estimated, further testing may be required in Tier 4 before a regulatory decision can be made on the suitability of the dredged material for unconfined open-water disposal.

Table 10-4. Target Tissue Concentration Values for Chemicals of Concern

CHEMICAL	TTL mg/kg ww
Arsenic	10.1
Cadmium	TBD
Chlordane [1]	0.3 *
Chromium	TBD
Copper	TBD
Dioxins/Furans	TBD
Fluoranthene	8400
Hexachlorobenzene	180
Lead	TBD
Mercury	1.0 *
Pentachlorophenol	900
Pyrene	TBD
Selenium	TBD
Silver	200
TBT	0.6 [2]
Total Aroclor PCBs	0.75 [3]
Total DDT [4]	5.0*
Zinc	TBD

Legend:
ww = wet weight; dw = dry weight; SSD = species sensitivity distribution approach; AWOC = ??
*FDA Action Level
TBD = to be determined on a project-specific basis.
[1] Chlordane includes the chlordane isomers and metabolites cis-Chlordane, trans-Chlordane, cis-Nonachlor, trans-Nonachlor, and oxychlordane
[2] The target tissue level for TBT was derived from a CERCLA risk assessment and is based on site-specific considerations of ecological risk for benthos found in the Harbor Island/Elliott Bay area, but the DMMP concluded it is appropriate for use at other DMMP disposal sites.
[3]The target tissue level for PCBs is based on site-specific considerations of subsistence human exposure in Elliott Bay and may not be appropriate for all disposal sites.
[4] Total DDT is determined by summing the p,p'- isomers of DDT and its metabolites (DDD and DDE).

11 TIER 4 EVALUATIONS

If standard chemical and/or biological evaluations of dredged material are unable to determine suitability of dredged material, a Tier 4 assessment may be required. A Tier 4 assessment is considered a special, non-routine evaluation and will require discussions among the agencies and the dredging proponent to determine the specific testing or assessment requirements. If two or more chemicals of concern during a Tier 2 evaluation exceed the maximum level (ML) guidelines, or if any one chemical exceeds the ML by more than 100 percent, the material will be considered unsuitable for unconfined open-water disposal unless a Tier 4 assessment is conducted. Alternative analyses that may be conducted in this tier may include any or all of the following.

11.1 STEADY STATE BIOACCUMULATION TEST

In a Tier 4 evaluation, bioaccumulation testing may be necessary to determine, either by time-sequenced laboratory bioaccumulation testing (Lee *et al*., 1989) or by collection of field samples, the steady state concentrations of contaminants in organisms exposed to the dredged material as compared with organisms exposed to the reference material. Tier 4 evaluations of data collected would follow the interpretation guidance specified in Chapter 10.

11.1.1 Time-Sequenced Laboratory Testing

As an alternative to accepting the 45 day exposure as a reflection of steady state conditions, an applicant may elect to conduct a time-sequenced bioaccumulation test. If organisms are exposed to biologically available contaminants under constant conditions for a sufficient period of time, bioaccumulation will eventually reach a steady-state in which maximum bioaccumulation has occurred, and the net exchange of contaminant between the sediment and organism is zero. By testing tissue residues periodically over the course of exposure, this steady-state concentration can be determined more accurately than relying on a single exposure period.

The necessary species, apparatus and test conditions for laboratory testing are the same as those utilized for the Tier 3 bioaccumulation test. Tissue sub-samples taken from separate containers during the exposure period provide the basis for determining the rate of uptake and elimination of contaminants. From these rate data, the steady state concentrations of contaminants in the tissues can be calculated, even though the steady state may not have been reached during the actual exposure. For the purposes of conducting this test, steady state is defined as "the concentration of contaminant that would occur in tissue after constant exposure conditions have been achieved."

An initial time-zero sample is collected for each species for tissue analysis. Additional tissue samples are then collected from each of the five replicate reference and dredged-material exposure chambers at intervals of 2, 4, 7, 10, 18, and 28 days. Alternative time intervals may be proposed by the agencies. It is critical that sufficient tissue is available to allow the interval body burden analyses at the specified detection limits for the chemical(s) of concern.

Calculating steady-state concentrations following time-sequenced testing should follow data analysis procedures outlined in the Corps/EPA Inland Testing Manual (Appendix D, Paragraph D3.2.1, pages D-47 to D-51). Bioaccumulation data are very expensive to obtain, because of the extensive number of chemical analyses required, and the data should be carefully and correctly analyzed.

11.1.2 Field Assessment of Steady State Bioaccumulation

Measuring concentrations in field-collected organisms may be considered as an alternative to laboratory exposures. A field sampling program designed to compare dredging and reference tissue levels of the same species allows a direct comparison of steady state contaminant tissue levels. The assessment involves measurements of tissue concentrations from individuals of the same species collected within the boundaries of the dredging site and a suitable reference site. Collecting sufficient numbers of individuals of the same relative size ranges and biomass of the same species to enable tissue analyses at the reference and dredging site can make this type of assessment problematic. A determination is made based on a statistical comparison of the magnitude of contaminant tissue levels in organisms collected within the boundaries of the reference site, compared with organisms living within the area to be dredged.

11.1.3 Human Health/Ecological Risk Assessments

When deemed appropriate by the agencies, a human health and/or ecological risk assessment may be required to evaluate a particular chemical of concern, such as dioxin, mercury, PCBs, etc. In the case of chemicals like dioxin, national guidance is in a rapid state of flux, and project-specific risks to human health or ecological health should be evaluated using the best available technical information and risk assessment models.

11.2 OTHER CASE-SPECIFIC STUDIES

Biological effects tests in Tier 4 should only be used in situations that warrant special investigative procedures. To address unique concerns, special studies not formally approved for use may be recommended to evaluate a specific dredged material issue. The nature and details of these studies would have to be worked out on a case-by-case basis through discussions with the DMMP agencies.

Tests considered may include chronic/sublethal tests, field studies such as benthic infaunal studies, experimental studies such as *in situ* toxicity tests or toxicity identification evaluations (TIE procedure; see Ankley *et al*, 1992), and/or no effects levels for aquatic life. In such cases, test procedures have to be tailored for specific situations, and general guidance cannot be offered. Such studies, when conducted, require design and evaluation specific to the need arising, with the assistance of administrative and scientific expertise from the agencies and other sources as appropriate.

Prediction of the movement of contaminants from sediment into and through pelagic food webs is technically challenging and should only be dealt with in a Tier 4 evaluation, if deemed necessary. General approaches may be explored which bracket likely concentrations of specific contaminants at different trophic levels based on an empirical model derived from a variety of marine food webs (Young, 1988, Lachmuth *et.al*., 2010). Other methods may be recommended, such as bioenergetic based toxicokinetic modeling, if deemed appropriate to address a particular concern.

12 ANTIDEGRADATION EVALUATIONS

As part of each sediment characterization that includes core sampling, the DMMP agencies requires the collection and archiving of a sample (Z-sample) from each core, consisting of the first two feet of material extending beyond the proposed project overdepth (Section 5.9). These samples represent the new surface sediment that would be exposed following dredging. The exposed sediment must meet the SMS antidegradation policy (WAC 173-204-120), which seeks to manage "sediment quality so as to protect existing beneficial uses and move towards attainment of designated beneficial uses" (Ecology, 1995).

Antidegradation evaluations are site-specific and often require best professional judgment on the part of the DMMP agencies. There have been a number of guidance documents written by the DMMP agencies to address testing of Z-samples and evaluation of the data for compliance with the antidegradation policy (PSDDA, 1988; DMMP 2001a, 2008a, 2010d). This chapter provides a summary of those documents.

12.1 WHEN TO TEST Z-SAMPLES

Chemical analysis of Z-samples is required if the testing results for the overlying dredged material are a) found to be unsuitable for unconfined aquatic disposal, or b) if any other project in the vicinity has shown evidence of subsurface sediments with greater contamination than surface sediments, or c) if there is any other site-specific reason to believe that the sediment to be exposed by dredging may fail to meet the antidegradation policy.

In a small number of cases, where there is reason-to-believe that concentrations of chemicals of concern increase with depth, the DMMP agencies may require Z-samples to be analyzed concurrently with analysis of the dredged material; or the dredging proponent may opt for concurrent testing to save time. However, for the majority of projects, a decision about Z-sample analysis will be made after review of the chemistry/bioassay data associated with the dredged material.

12.2 DETERMINING ANALYSIS REQUIREMENTS

Z-sample analyses will initially consist of sediment conventional and chemical analyses. At a minimum, the conventionals to be analyzed include grain size, total organic carbon, total solids and total volatile solids. If there is a possibility that bioassays may need to be run, then ammonia and sulfides data will also be important. As for chemicals-of-concern, typically only those chemicals that were elevated in the overlying dredged material will need to be tested in the Z-samples. However, the overall data set will need to be taken into consideration in making this call. For example, if two adjacent DMMUs are found unsuitable for open-water disposal, one due to elevated PCBs and the other due to elevated TBT, then the DMMP agencies could require the z-samples underlying both DMMUs to be tested for both PCBs and TBT.

Bioassays may become necessary if chemistry testing alone does not provide enough information for the antidegradation evaluation. For example, there have been cases in which DMMUs with no SL exceedances have failed biological testing. In such cases it might be necessary to run bioassays on the Z-samples to test for toxicity not predicted by the chemistry results. Due to holding time constraints (56 days for bioassays), the Z-samples may need to be recollected before bioassays can be run.

Bioaccumulation testing of Z-samples may also be necessary in some situations. However, it is anticipated that bulk sediment concentrations (or porewater results in the case of TBT) could be used in most cases to determine the bioaccumulation potential of the Z-samples relative to the overlying dredged material. If the calculated bioaccumulation potential exceeds acceptable limits, the dredging proponent always has the option to conduct bioaccumulation testing to determine the actual bioaccumulation potential.

12.3 EVALUATING COMPLIANCE WITH THE ANTIDEGRADATION POLICY

As indicated previously, antidegradation evaluations can be complicated and often require best professional judgment on the part of the DMMP agencies. DMMP (2008a) should be referenced for more detail, but the following guidelines are expected to cover the majority of antidegradation evaluations:

- If the newly-exposed sediment meets the SMS Sediment Quality Standards (SQS), it is generally also compliant with the antidegradation policy. Exceptions include chemicals without numeric SQS values, such as dioxin and tributyltin.
- Newly exposed sediment may not exceed the SMS Cleanup Screening Levels (CSL) or DMMP MLs.
- If chemical concentrations are higher in the Z-samples than in the overlying dredged material and exceed SQS (or SL for COCs with no numeric SQS), then bioassays might be required to evaluate the material for toxicity. Toxicity would need to be below SQS in order to meet the antidegradation guidelines.
- If chemical concentrations are lower in the Z-samples than in the overlying dredged material, but still exceed SQS (or SL for COCs with no numeric SQS) and/or BT, the DMMP agencies will review the bioassay and/or bioaccumulation results from the overlying dredged material before requiring the Z-samples to be tested biologically.
- Dioxin concentrations will be evaluated using the following guidelines:
  - TEQs less than 4 pptr meet the antidegradation standard
  - TEQs greater than 10 pptr generally do not meet the antidegradation standard, but will be evaluated on a case-by-case basis
  - TEQs between 4 and 10 pptr will be compared to concentrations in the overlying dredged material

12.4 WHAT HAPPENS IF THE SEDIMENT IS NOT COMPLIANT?

If the sediment to be exposed by dredging does not meet the antidegradation standard, there are two options available:

- Dredge deeper until acceptable material is reached
- Overdredge and place a clean layer of sand over the area

12.5 OTHER CONSIDERATIONS

The complexity of dredging projects varies considerably. Following are additional considerations for Z-sample collection and analysis:

- Multiple Z-layers might need to be collected depending on anticipated conditions at the project site. For example, if there is a high probability of encountering elevated chemical concentrations in the newly exposed sediment, the dredging proponent might want to collect Z-samples from 0-2, 2-4 and 4-6 feet beyond the planned overdepth in order to reach uncontaminated native material.

- Projects with planned upland disposal might not ordinarily be required to test the dredged material for DMMP disposal. However, an antidegradation evaluation will still be required by the Department of Ecology. This evaluation could involve sampling and testing of the sediment that will be exposed by dredging.
- In those cases where the sediment to be exposed by dredging is resampled to collect sediment for biological testing, the resampled sediment must undergo DMMP chemical testing to provide a synoptic dataset.
- Due to time constraints the dredging proponent may desire to forego biological testing of the Z-layer and proceed directly to overdredging and/or placement of a clean sand layer over the new sediment surface.

12.6 POST-DREDGE EVALUATIONS

In certain situations, the post-dredge sediment surface (top 10 cm) may be subject to sediment quality evaluation at the discretion of the DMMP agencies. This may be necessary if Z-samples could not be collected due to the presence of rip rap; where underpier sloughing occurs and the underpier sediment could not be evaluated prior to dredging; in cases of dredging violations where material that has not been approved for open-water disposal is dredged; or where dredging residuals are of concern. Post-dredge evaluations will be conducted on a case-by-case basis.

13 DREDGING AND DISPOSAL

13.1 PREPARING TO DREDGE

Once all necessary permits are obtained, planning for dredging and disposal can proceed. Only bottom-dump barges are authorized at DMMP non-dispersive sites. On a limited basis flat top barges may be authorized at dispersive sites with prior review and approval (DMMP, 2008a). Dredgers must coordinate as follows:

- Applicant should apply for DNR Site Use Authorization (SUA) at least three weeks prior to the pre-dredge meeting to allow adequate SUA processing time (see DMMP, 2009).
- At least 14 days prior to the beginning of dredging and disposal work, notify the Corps of Engineers Regulatory Branch, at (206)764-3495.
- Submit a Dredging and Disposal Quality Control Plan for distribution to agencies, including DMMP representatives, at least 7 days prior to scheduled pre-dredge conference.
- Attend a pre-dredge conference (see Section 13.3) at least 7 days prior to the start of dredging.

Please note that some permits may have additional requirements or earlier plan submission requirements. Applicants should carefully read conditions of other permits to determine if earlier submittals are required.

13.2 DREDGING AND DISPOSAL QUALITY CONTROL PLAN (QCP)

This document helps ensure that the dredging and disposal are in compliance with the DMMP suitability determination and permits, that the necessary coordination has been done, and that reporting procedures are in place. It is submitted at least 7 days prior to the pre-dredge conference and reviewed carefully at the conference. The QCP should provide the following information:

1. Project description; including project and vicinity maps, in-situ volume estimate, and bulking factor (see Section 13.5).
2. Figures showing the area to be dredged, dredging depths (including overdredge), sideslopes and disposal site.
3. Dredging and disposal vessels and equipment.
4. Schedule of dredging and disposal activities, and the allowable work windows for the dredging and disposal sites
5. Dredging/disposal personnel, responsibilities, and contact information
6. Dredging method and procedures, including:
    - measures to control or minimize potential water quality impacts
    - separation of contaminated material from sediments suitable for open-water disposal
    - decontamination of dredging equipment, if required
    - plan for removal of floatable and non-floatable debris (see 13.4)
    - horizontal and vertical controls during dredging (see 13.5)

- real-time dredged volume estimation method, such as barge measurement or daily bathymetry

7. Disposal method and procedures, including:
   - names, types (e.g. bottom dump) and capacities of barges and dump scows (see 13.5)
   - identification of tow boats (by name and call letters)
   - tug operator's name and telephone number
   - target disposal coordinates
   - navigation equipment and positioning protocol for disposal, including communication with the Coast Guard's Vessel Traffic Service for DMMP disposal sites in Puget Sound
   - procedure for initiation of dump sequence when on site
   - disposal data recording and reporting procedures
   - disposal site, whether it be in-water or upland
8. Water quality monitoring plan and contingencies for water quality exceedances
9. Coordination procedures with the regulatory agencies, including contact information and notification requirements
10. Tribal coordination for nighttime disposal
11. Spill control and response measures
12. Post-dredge hydrographic survey

The dredging and disposal quality control plan must be approved by the DMMP agencies prior to commencement of open-water disposal.

13.3 PRE-DREDGE CONFERENCE

All regulated projects that are evaluated are required to have a pre-dredge conference with the regulatory agencies prior to the initiation of dredging. Generally, for projects in Puget Sound a physical meeting is required, but for projects involving routine maintenance dredging over several cycles, a pre-dredge conference call may be substituted for a meeting on a case-by-case basis. For projects in Grays Harbor and Willapa Bay, conference call pre-dredge meetings are generally required in lieu of meetings due to logistical considerations (DMMP, 2003a).

The meeting (or conference call) will be coordinated by the Regulatory Branch, US Army Corps of Engineers. Attendees will include, at a minimum, the applicant, the dredging contractor, and representatives from the Corps, DNR and Ecology. EPA and WDFW may also choose to attend. The meeting will be used to review the disposal locations, water quality certification, dredging QCP, DNR site use authorization and any other permit conditions. Completion of the pre-dredge conference will be documented as part of the Regulatory Branch permit file.

Depending on the location and size of the dredging project, the disposal site to be used, and the presence/absence of material unsuitable for open-water disposal, the pre-dredge conference might take the form of an in-person meeting or conference call.

Modifications to the QCP that are made at the predisposal conference must be incorporated into a final control plan and submitted to the agencies for approval prior to dredging A predisposal dry run may be required by the Corps. At the discretion of the Corps, the regulatory project manager may ride out to the disposal site during the predisposal dry run or any disposal run to verify positioning accuracy.

13.4 DEBRIS MANAGEMENT

In general, debris is not allowed to be disposed at the DMMP open-water sites. This includes all floatable debris and large non-floatable debris such as logs, piling, rip-rap and concrete. Occasionally it may include smaller non-floatable woody debris such as sawdust, bark or wood chips, if these are inseparable from the sediment and are present in small enough proportion (less than 50% by volume). Large woody debris is most often segregated from sediment using a clamshell bucket during the dredging operation. In cases where a heterogeneous mix of smaller woody debris and sediment exists, which otherwise meets DMMP disposal guidelines, open-water disposal may occur as long as none of the debris measures more than two feet in it longest dimension. Occasionally, a relatively small quantity of rip-rap may be approved for open-water disposal. However, a 2-ft by 2-ft steel mesh must be used during the dredging operation to remove larger pieces of rip-rap. Pre- and post-disposal monitoring may be required at the disposal site, on a case-by-case basis, to verify the absence of problem debris.

13.5 DREDGED MATERIAL VOLUME ESTIMATES

Exceedances of permitted dredging volumes may result in monetary fines or work stoppages. In `followed to reduce the potential for permit violations:

1. Additional shoaling may occur between the time of sampling and dredging. It is the project proponent's responsibility to identify the need for a volume adjustment as a result of any post-sampling shoaling. Volume adjustments should be made prior to issuing the public notice. If significant shoaling occurs after the public notice has been issued, written requests for permit revisions must be made to the permitting agencies as early as possible and before dredging commences.
2. An estimate of the bulking factor, and a justification for its selection, must be included in the QCP.
3. A description of the barge measurement method for volume must be included in the QCP.
4. A description of the procedures to ensure vertical and horizontal dredging control must be included in the QCP. Such procedures prevent over-dredging and may reduce the need for confirmatory surveys in areas where suitable and unsuitable dredged materials are in close proximity.
5. Once dredging has begun, if the dredging proponent or contractor determines that significant dredging has occurred outside the permitted dredging prism, vertical and horizontal control must be re-established immediately and DNR and the Corps contacted as soon as possible.
6. When the daily barge estimates, corrected for bulking, tally to fifty percent of the permitted in-situ volume, the dredging contractor must confer with the Corps, DNR and the dredging proponent. Based on the experience of the dredging contractor during the first half of the project, a correction in the bulking factor will be made if necessary. Dredging progress (based on condition surveys or spatial coverage) will then be compared to the corrected barge measurements (using the revised bulking factor) as a

check on the adequacy of the permitted in-situ volume. A decision will be made by the DMMP as to whether permit revisions for an increased volume will be necessary. Details of this coordination procedure must be included in the QCP.

7. As dredging proceeds, the contractor must closely monitor dredging progress and notify the agencies as soon as possible if an exceedance of the permitted volume appears likely. Revision of the permits may be made as necessary. Dredging must stop when the sum of the daily barge estimates, corrected for bulking using the revised bulking factor, reaches the permitted in-situ volume. DNR and the Corps must be notified at this time. If the dredging has not been completed, a determination will be made as to the cause of the impending volume exceedance and permit volumes revised as appropriate.

8. Post-dredge surveys will be reviewed by the agencies, as necessary, to ensure that the dredging plan has been followed.

13.6 DREDGING AND DISPOSAL CLOSURES

13.6.1 WDFW Closures

The Washington Department of Fish and Wildlife (WDFW) establishes closure periods in various parts of Puget Sound to protect aquatic resources. In-water work, including dredging and disposal, cannot be conducted during closed periods. WDFW Habitat Managers should be contacted directly to determine the closure periods for dredging and disposal of specific project.

WDFW requires additional closures at three of the Puget Sound disposal sites to protect resources (**Table 13.1**). Routine inwater work windows for ESA listed species generally apply for the disposal sites as depicted in **Table 13-2**. Dredging site closures are more variable and are established for each dredging action during endangered species act (ESA) consultation for each Section 10/404 permit to protect outmigrating salmonid juveniles and bull trout, and in Grays Harbor, there is additional consideration for green sturgeon and eulachon.

Table 13-1. Puget Sound DMMP Site Closure Periods (Non ESA)

Disposal Site	Disposal Site Closure Period	Reason
Port Townsend	September 1 to November 30	Fall shrimp closure
Port Angeles	September 1 to November 30	Fall shrimp closure
Bellingham Bay	November 1 to February 28	Crab/shrimp closure

Table 13-2. Routine Inwater Work Closure Periods (ESA)

Disposal Site	Dredging/Disposal Site Closure Period	Reason
All Puget Sound Sites	February 14 (midnight) to June 15	Outmigrating salmonid smolts and bull trout
Coastal Washington Estuarine disposal sites	February 14 (midnight) to July 15	bull trout, green sturgeon, eulachon

13.6.2 Native American Fisheries

The following special site-use condition will be specified by the Corps in all permits that include open-water disposal:

Disposal operations must not interfere with Indian treaty fishing at the disposal site, including gill nets and other fishing gear. The permittee must coordinate any nighttime disposal with the Seattle District Corps Regulatory Branch Project Manager. Approval must be received from the District Engineer prior to conducting nighttime disposal.

13.6.3 Endangered Species Act

Under the Endangered Species Act (ESA), all in-water projects are evaluated for impacts to listed species. The Seattle District Corps of Engineers undergoes formal consultation under Section 7 of the ESA to address the potential use effects of the DMMP disposal sites on federally listed species. Current programmatic Biological Evaluations, Biological Opinions and concurrence letters are posted on the DMMP website. Every five years—or when a new species is listed—the Corps updates ESA coordination and documentation. Disposal windows or restrictions may be modified as part of that coordination.

13.7 DISPOSAL SITE INFORMATION

Table 13-3 and **Table 13-4** contain descriptive information about the DMMP disposal sites. **Figure 13-1** is a schematic delineating the target area and disposal zone within a generic non-dispersive disposal site. In the non-dispersive sites the disposal barges should open within the target area to ensure dredged material is released within the disposal zone. The zone allows for some difficulties in maneuvering. For dispersive sites, the target area and the disposal zone are one and the same. **Figures 13-2** through **13-11** show all DMMP disposal sites and are suitable drawings for public notices.

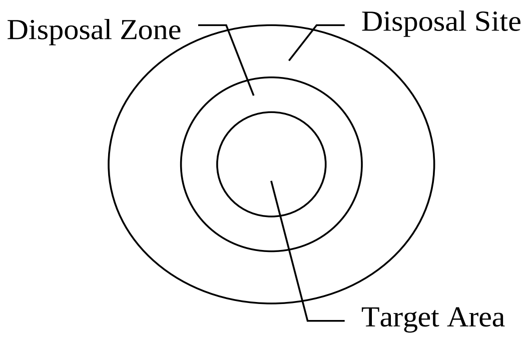

Figure 13-1. Disposal Zone vs. Target Area

13.8 DISPOSAL POSITIONING

13.8.1 Coast Guard Notification and VTS Monitoring

The United States Coast Guard (USCG) must be notified by email at D13-PF-LNM@uscg.mil at least 14 days prior to commencing dredging operations, so the project information can be issued in the Local Notice to Mariners. Dredging operations north of a line between Bush Point on

Whidbey Island and Nodule Point on Marrowstone Island must monitor VHF-FM Channels 13 and 5A. Dredging operations south of this line must monitor VHF-FM Channels 13 and 14.

For projects using the DMMP disposal sites in Puget Sound, The USCG Puget Sound Vessel Traffic Service (VTS) also known as "Seattle Traffic" must be contacted by radio prior to each disposal for positioning and verification of location within the disposal site target area. Disposal may not commence until verification is received from the USCG. Information required by the USCG must be provided for recording of the dump.

Use of the Port Angeles dispersive site will require special coordination with VTS because the disposal site is located within the shipping lanes into Port Angeles Harbor. Applicants using this disposal site will be required to follow the Port Angeles VTS Coordination Operations Plan.

13.8.2 Dump-Site Position Recording Equipment

Projects using hopper dredges are required to use monitoring equipment from the National Dredging Quality Management (DQM) program, administered by the Corps of Engineers. This equipment utilizes differential global positioning to provide a record of disposal events.

For more information about DQM, see http://dqm.usace.army.mil

13.8.3 Flowlane Disposal

This alternative is generally used for dispersive disposal within the Columbia River, and has been used selectively in Willapa Bay since 2009. The DMMP agencies will generally require a simulation of flowlane disposal based on the characteristics of the fine grained material proposed for dredging using the Corps' DREDGE model to evaluate total suspended solids (TSS) relative to the plume as compared to background observed at a distance of approximately 1,000 ft from the discharge point. The DMMP agencies would review the characteristics of the material and the results of the DREDGE model analysis to determine whether flowlane disposal would be authorized or not on a project-specific basis. However, before authorizing the use of a flowlane disposal site for repeated use, the DMMP agencies would have to formally review and approve this disposal alternative under NEPA/SEPA.

Table 13-3. Puget Sound Disposal Site Descriptions

Site	Area (acres)	Depth (ft)	Disposal Zone diameter (ft)	Target Area diameter (ft)	Disposal Site Dimensions (ft)	Disposal Coordinates (NAD83: Lat/Long)	Positioning VTS/ DGPS
Anderson/Ketron Island (nondispersive)	318	442	1,800 (circle)	1,200 (circle)	4,400 x 3,600 (ellipsoid)	Lat: 47° 09.42’ Long: 122° 39.47’	VTS (AIS)*
Bellingham Bay (nondispersive)	260	96	1,800 (circle)	1,200 (circle)	3,800 x 3,800 (circular)	Lat: 48° 42.82’ Long: 122° 33.11’	VTS (AIS)
Commencement Bay (nondispersive)	310	540-560	1,800 (circle)	1,200 (circle)	4,600 x 3,800 (ellipsoid)	Lat: 47° 18.145’ Long: 122° 27.815’	VTS
Elliott Bay (nondispersive)	415	300-360	1,800 (circle)	1,200 (circle)	6,200 x 4,000 (Tear drop shape)	Lat: 47° 35.91’ Long: 122° 21.45’	VTS
Port Gardner (nondispersive)	318	420	1,800 (circle)	1,200 (circle)	4,200 x 4,200 (circular)	Lat: 47° 58.85’ Long: 122° 16.74’	VTS
Port Angeles (dispersive)	884	435	3,000 (circle)	none	7,000 x 7,000 (circular)	Lat: 48° 11.67’ Long: 123° 24.94’	VTS
Port Townsend (dispersive)	884	361	3,000 (circle)	none	7,000 x 7,000 (circular)	Lat: 48° 13.61’ Long: 122° 59.03’	VTS
Rosario Strait (dispersive)	650	97-142	3,000 (circle)	none	6,000 x 6,000 (circular)	Lat: 48° 30.87’ Long: 122° 43.56’	VTS

VTS = USCG Vessel Traffic Service; **DGPS** = Differential Global Positioning System; **AIS** = Automatic Identification System

*Automatic Identification Systems (AIS) are designed to be capable of automatically providing information about a ship to other ships as well as to coastal authorities.

Table 13-4. Grays Harbor and Willapa Bay Disposal Site Descriptions

Area	Site (Dispersive)	Area (acres)	Depth (ft)	Disposal Zone	Disposal Site Dimensions (ft)	Site Coordinates (NAD83) (Latitude/Longitude)		Positioning VTS/DGPS
GRAYS HARBOR	Point Chehalis (Estuarine)	229.6	>50 ft	Within rectangle, partitioned into 3 cells (2,000 x 5,000 ft)	2,000 x 5,000 ft. (rectangle)	46°55'00.51" 46°55'04.49" 46°55'10.46" 46°55'17.09" 46°54'41.91" 46°54'45.90" 46°54'51.87" 46°54'58.50"	124°08'06.94" 124°07'50.66" 124° 07'26.23" 124°06'59.10" 124°07'57.26" 124°07'40.98" 124° 07'16.55" 124°06'49.42"	DGPS
						(Corners of 3 cells within rectangle)		
	South Jetty (Estuarine)	55.1	>50 ft	Within rectangle (800 X 3,000 ft)	800 X 3,000 ft. (rectangle)	46°54'34.82" 46°54'32.06" 46°54'26.96" 46°54'24.20"	124°09'30.67" 124°08'47.65" 124°09'31.74" 124°08'48.72"	DGPS
						(4 corners of rectangle)		
	Half Moon Bay (beneficial use)	2.9 (1A) 52.6 (1) 37.3 (2)	15.5 ft (1A) 10-15 ft (1) 11-26 ft (2)	Variable within each subarea, see Figure	Variable within each subarea (Area 1A, Area 1, Area 2), see Figure	Variable within each subarea		DGPS
	South Beach (beneficial use)	1,223.4	17-46 ft	Within Quadrilateral (6,400 x 7,700 ft x 6,200 x 9,500 ft)	6,400 x 7,700 ft x 6,200 x 9,500 ft (Quadrilateral)	46°54'23.23" 46°54'29.23" 46°52'51.62" 46°53'05.60"	124°10'14.39" 124°08'42.22" 124° 09'41.30" 124°08'14.60"	DGPS
						(4 corners of Quadrilateral)		

Area	Site (Dispersive)	Area (acres)	Depth (ft)	Disposal Zone	Disposal Site Dimensions (ft)	Site Coordinates (NAD83) (Latitude/Longitude)		Positioning VTS/DGPS
	3.9-Mile SW Ocean Site	58.4 (circle) 1,056.6 (paralle-ogram)	>120 ft	1,800 ft diameter circle within parallelogram	6,000 x 8,000 ft. (parallelogram)	Site presently inactive		DGPS
						46°51'55.68	124°14'40.53	
						(center of circle)		
						46°51'56.19" 46°52'57.51" 46°52'08.67" 46°51'07.35"	124°15'03.91" 124°13'51.34" 124° 13'02.50" 124°14'15.06"	
						(4 corners of parallelogram)		
						(center of circle)		

Area	Site	Area (acres)	Depth (ft)	Disposal Zone	Disposal Site Dimensions (ft)	Latitude	Longitude	Positioning
WILLAPA BAY	Cape Shoalwater (Estuarine)	178.9	5-19 ft	USCG buoy G "13"	3,000 x 5,196 x 6,000 ft. triangle	46°42'05.34"	124°01'21.50"	USCG Buoy G13
						(coordinates for USCG buoy G "13")		
	Goose Point (Estuarine)	58.4	30–48 ft	1,800 ft diameter circle	1,800 ft diameter circle	46°39'27.60"	123°59'46.04"	DGPS

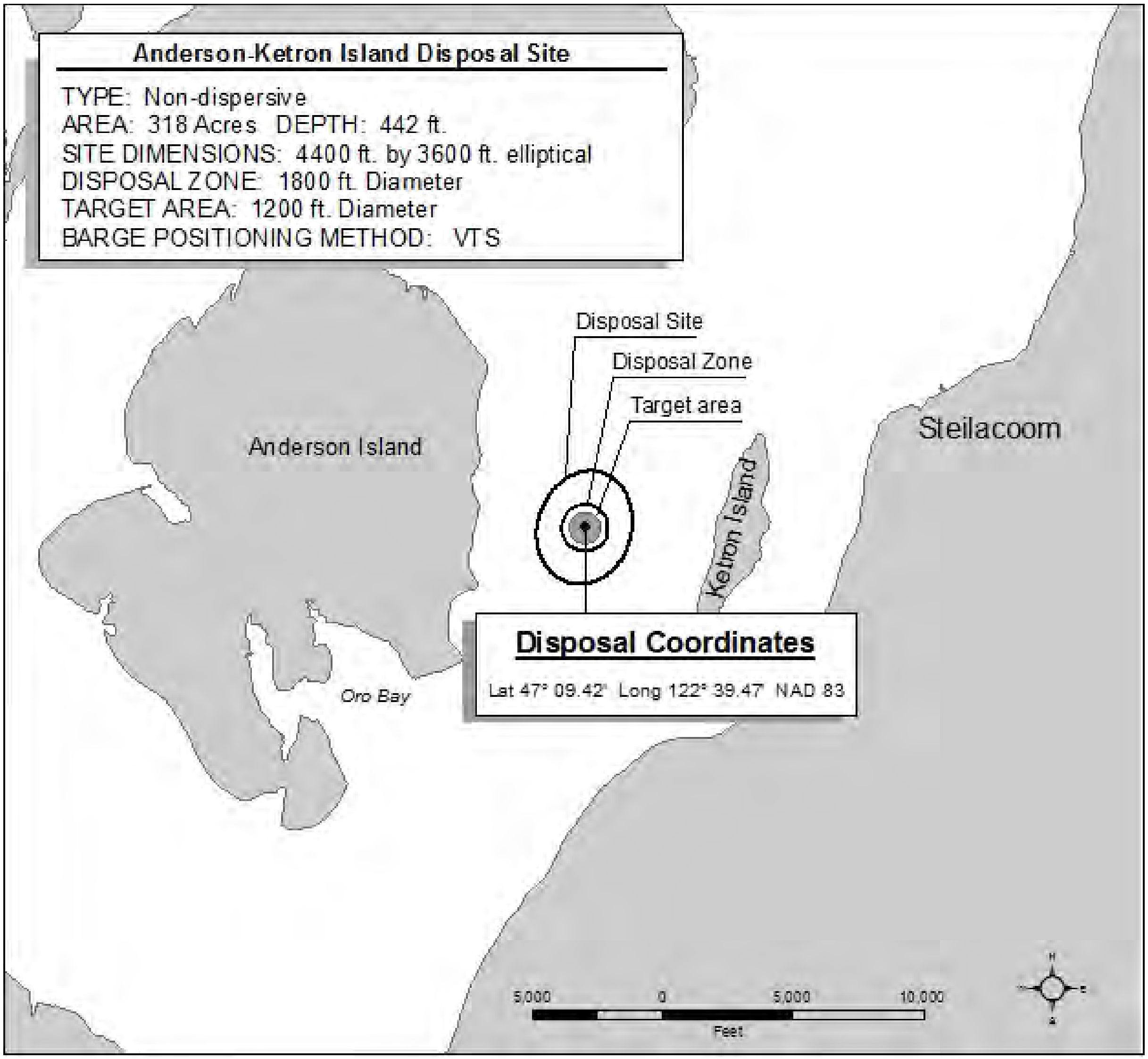

Figure 13-2. Anderson-Ketron Non-Dispersive Disposal Site

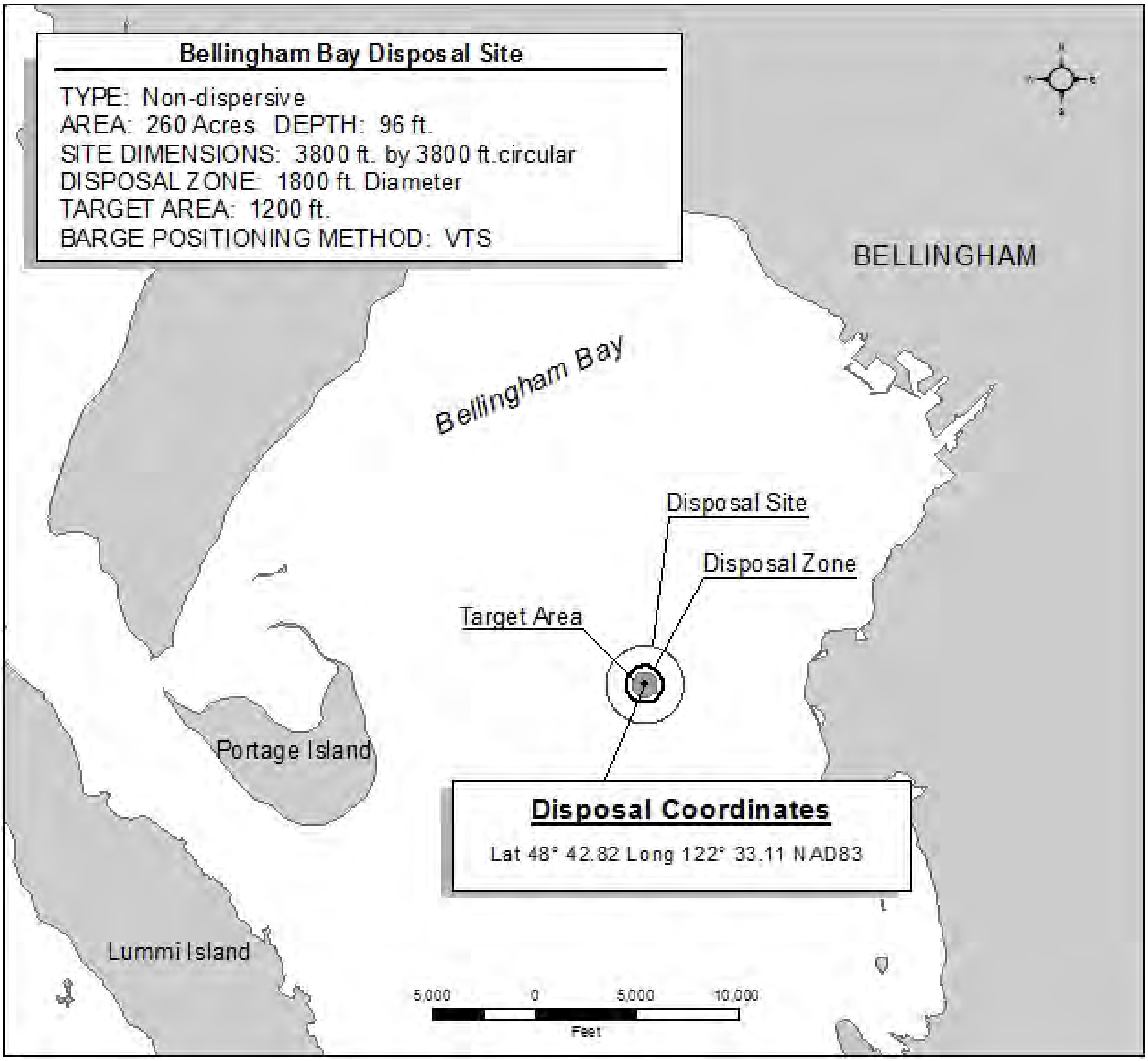

Figure 13-3. Bellingham Bay Non-Dispersive Disposal Site

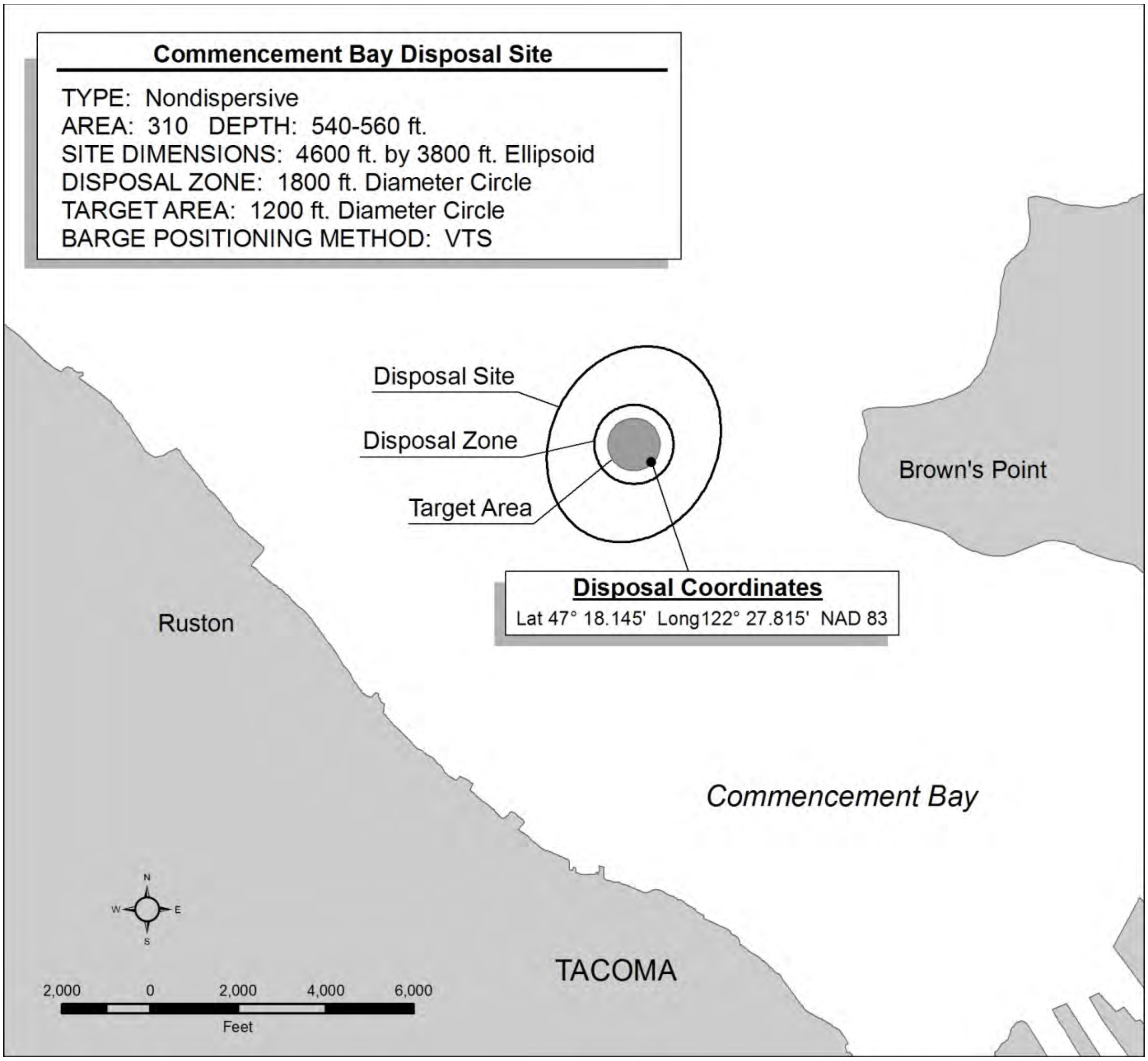

Figure 13-4. Commencement Bay Non-Dispersive Disposal Site

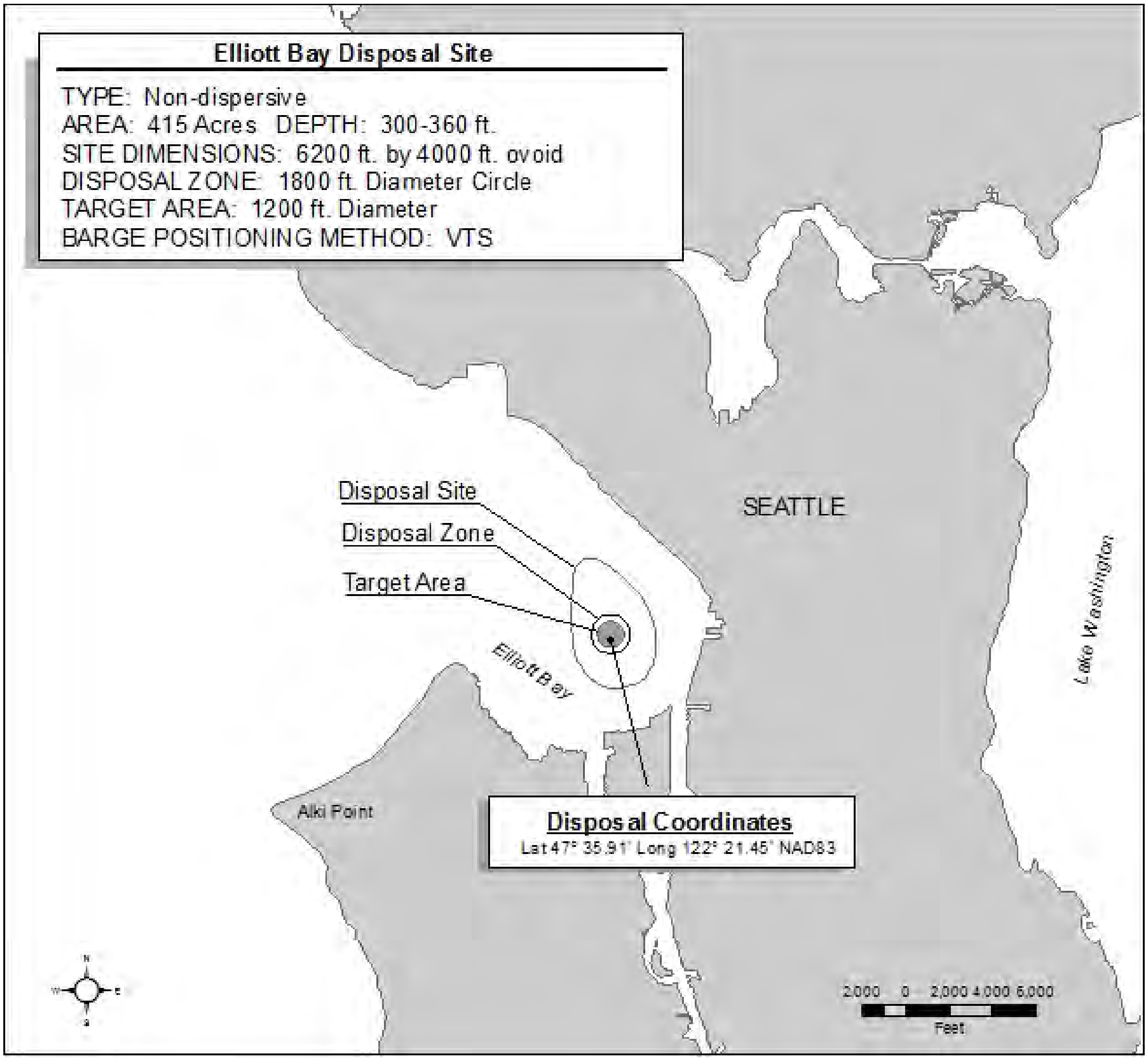

Figure 13-5. Elliott Bay Non-Dispersive Disposal Site

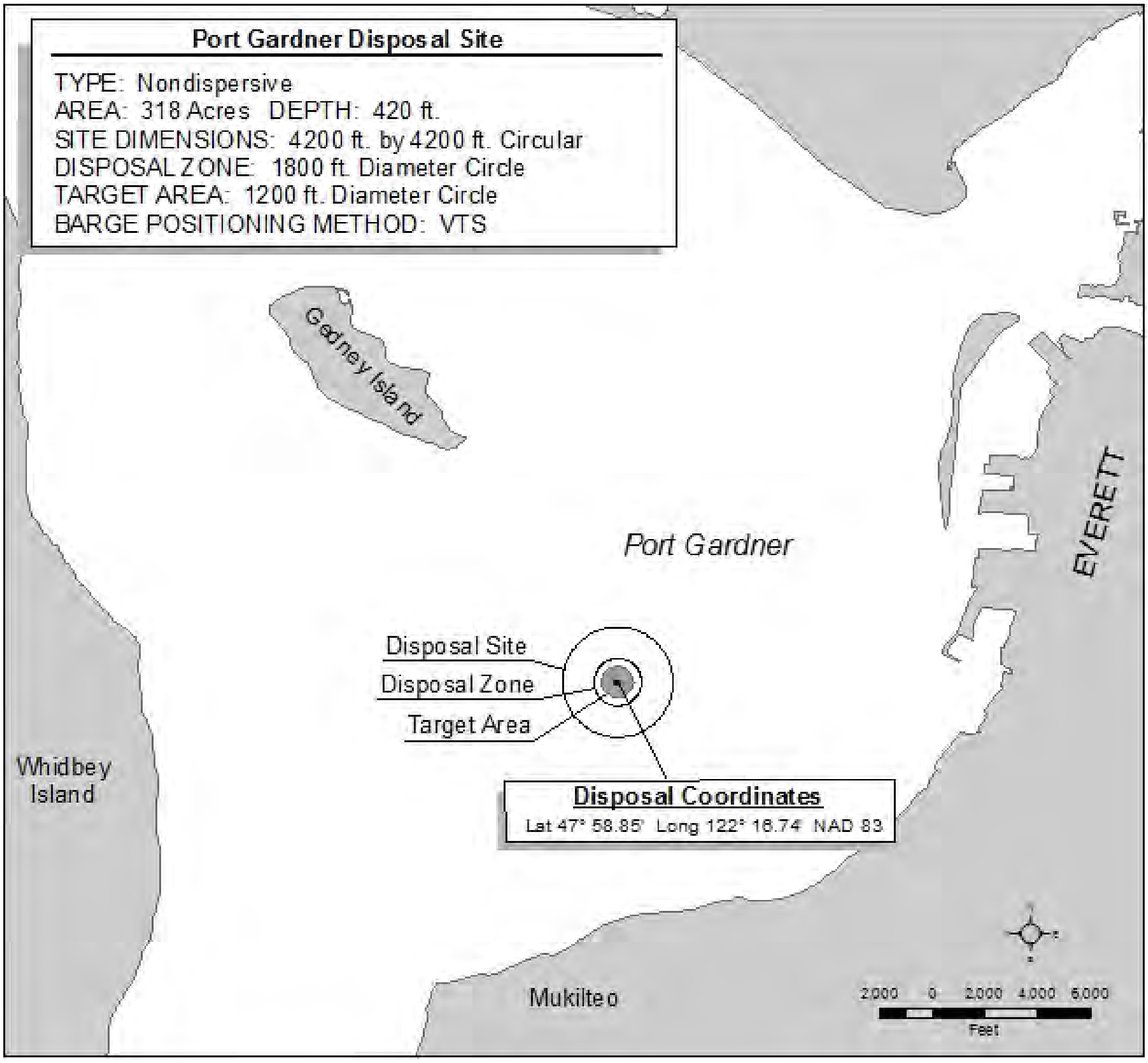

Figure 13-6. Port Gardner Non-Dispersive Disposal Site

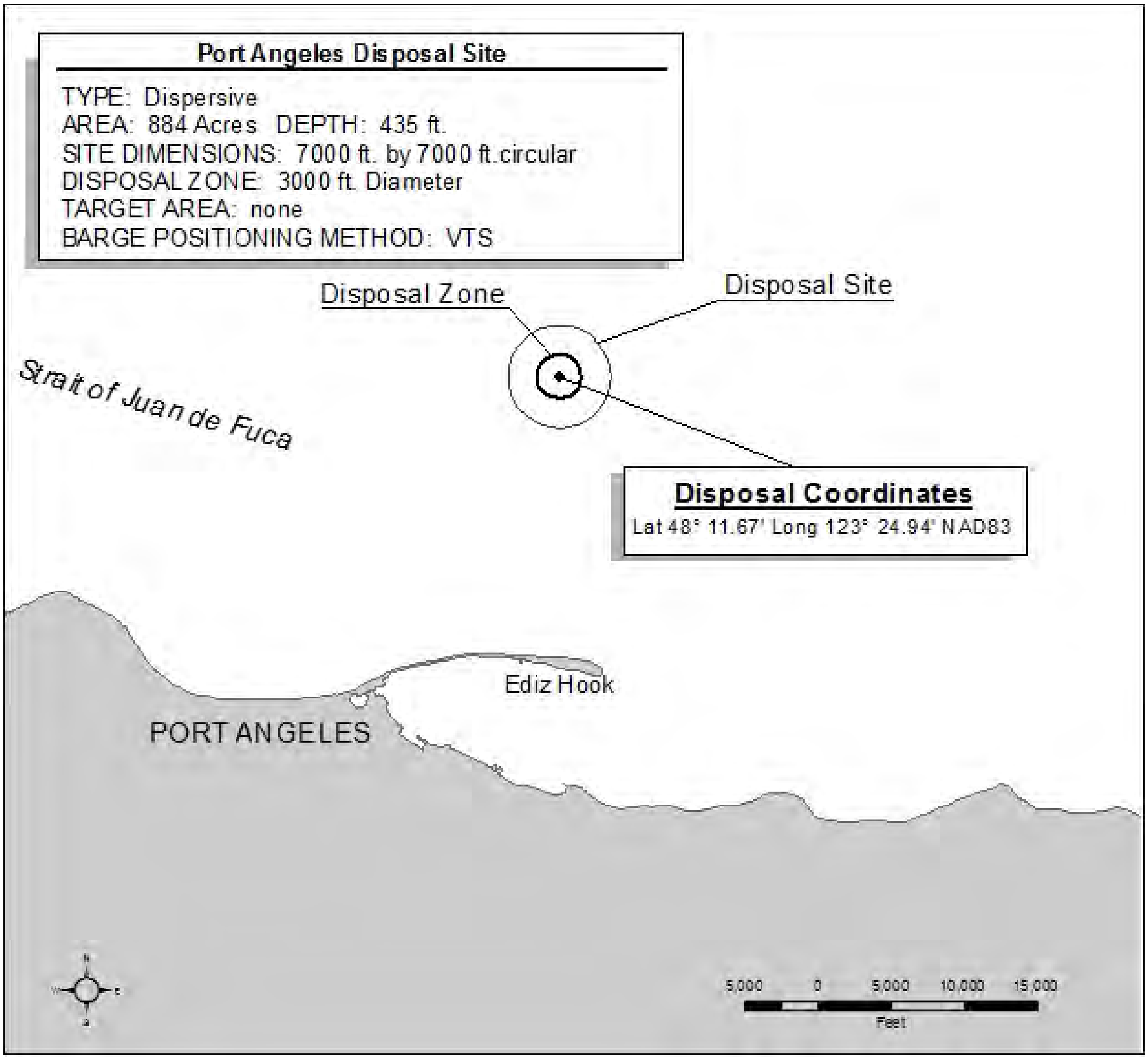

Figure 13-7. Port Angeles Dispersive Disposal Site

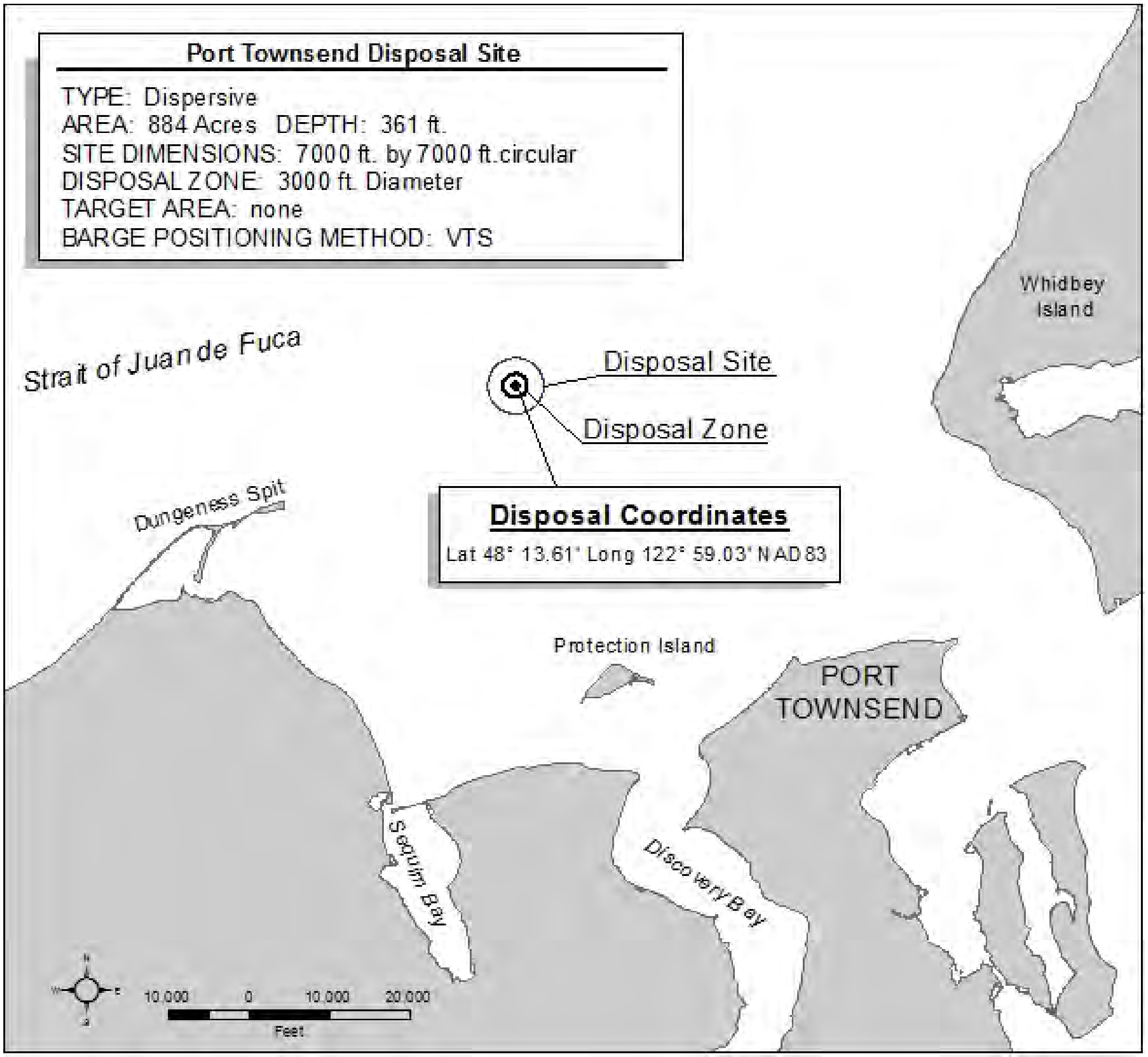

Figure 13-8. Port Townsend Dispersive Disposal Site

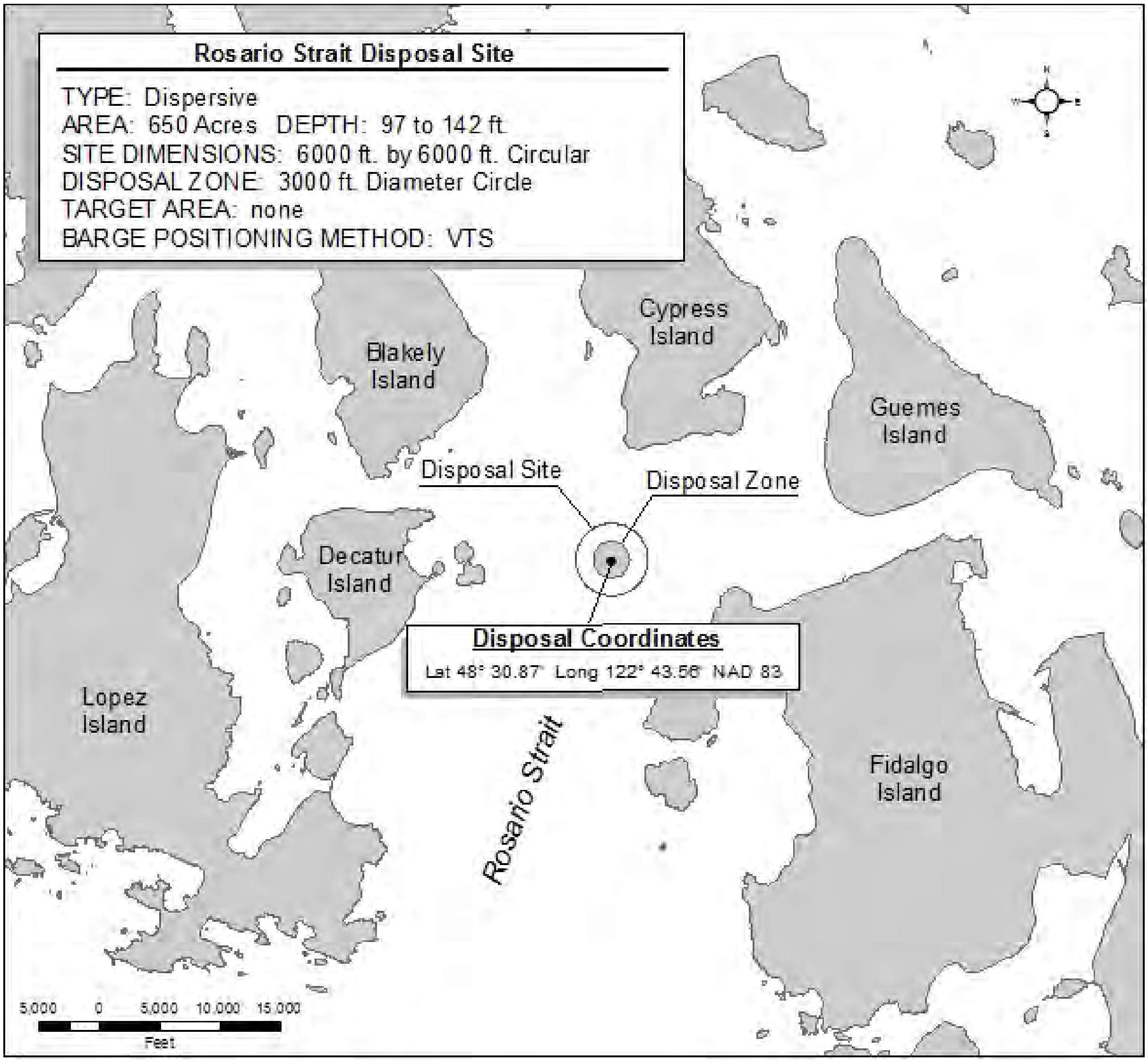

Figure 13-9. Rosario Strait Dispersive Disposal Site

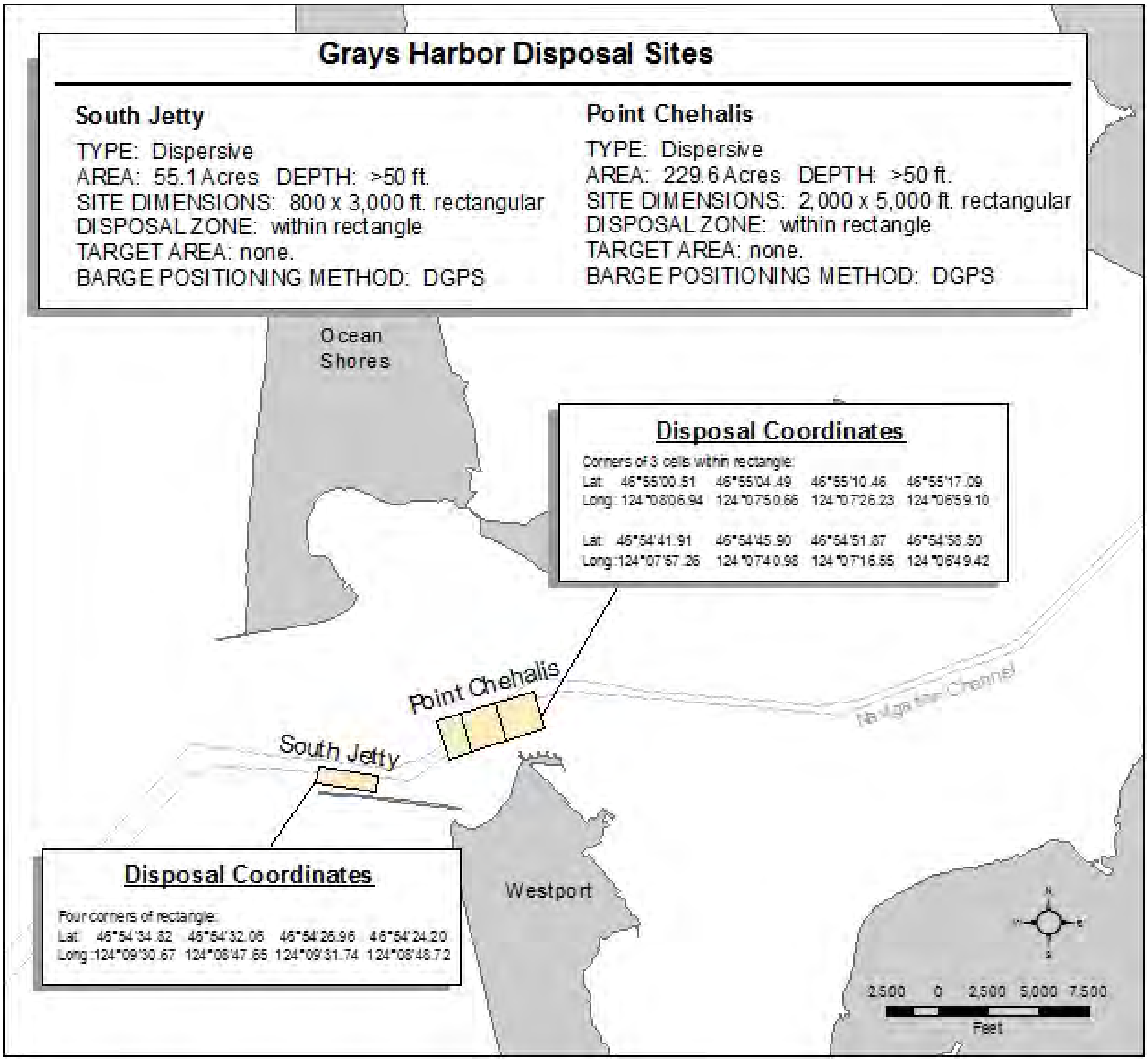

Figure 13-10. Grays Harbor Dispersive Disposal Sites

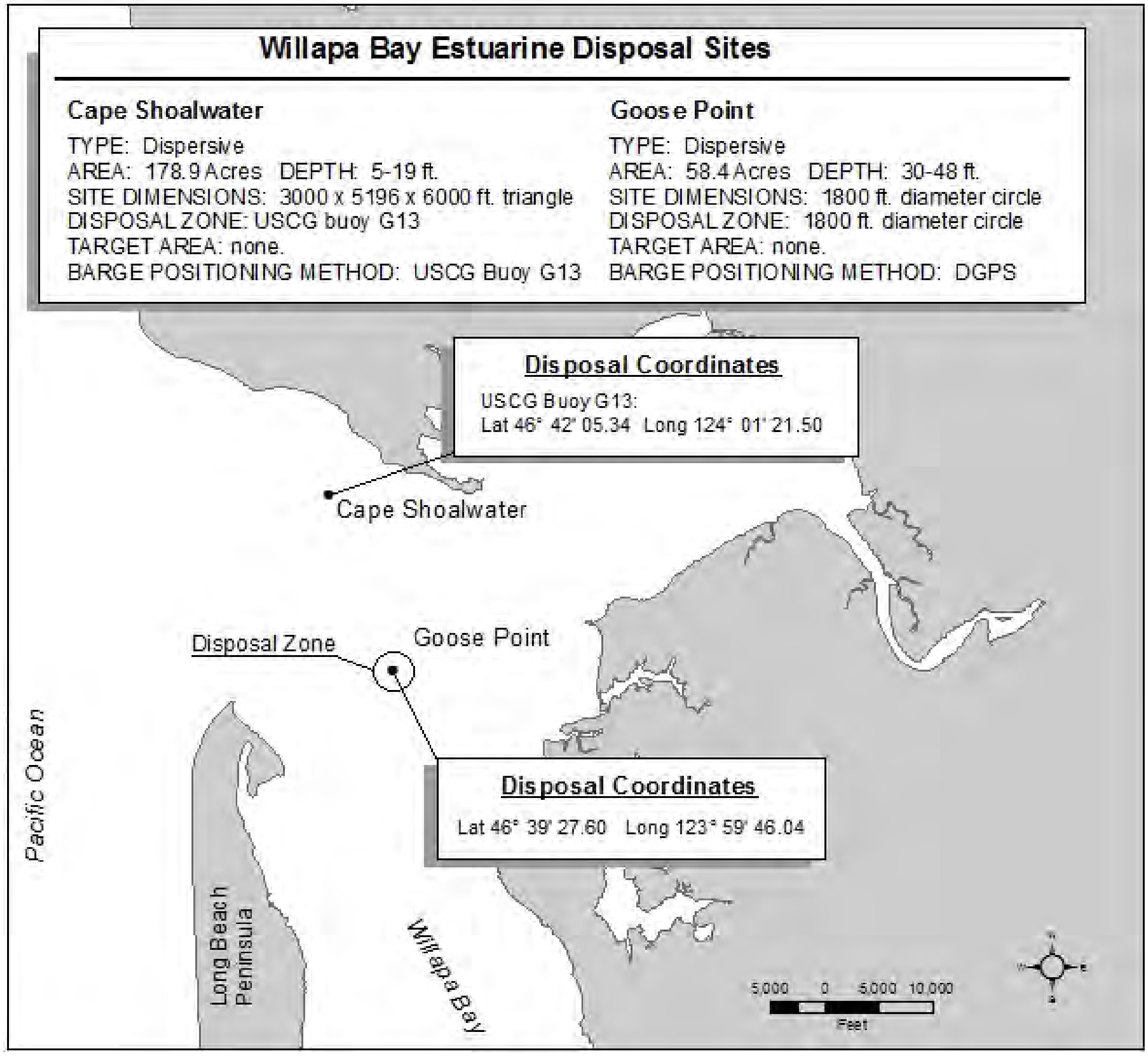

Figure 13-11. Willapa Bay Dispersive Disposal Sites

14 BENEFICIAL USE

14.1 BENEFICIAL USES GUIDELINES

"Beneficial use" is the placement or use of dredged material for some productive purpose. While the term "beneficial" indicates some "benefit" is gained by a particular use, the term has come to generally mean any "reuse" of dredged material. As part of overall sediment management in Washington, the regulatory agencies responsible for sediment management support the productive reuse of dredged material.

Applicants considering potential beneficial-use projects should bring these projects to the attention of the DMMP agencies early in the evaluation process, especially if DNR owns the dredged material desired for reuse. When DNR is not the owner of the material, a project proponent should approach the material owner and negotiate for its use. The project proponent will be asked to provide either a brief written project description, or provide a presentation of the proposed project. In some dredging years conflicts among potential users of dredged material may arise. In these situations, agency representatives and project proponents will need to discuss potential projects, resolve conflicts and determine priority for use of the material.

To ensure a beneficial-use project's viability, evaluation of the proposed dredged material is required.

14.2 SEDIMENT CHARACTERIZSATION OF BENEFICIAL-USE MATERIAL

Unconfined aquatic projects (such as beach nourishment, habitat restoration, and in-situ capping) are projects where dredged material may come directly into contact with the surrounding aquatic environment. For most projects, detected chemicals of concern must fall below SQS (Sediment Quality Standards) levels and any bioassays must pass SQS criteria. Material that has levels of chemicals greater than SQS but lower than CSL (Cleanup Screening Level) may be appropriate for beneficial use on a case-by-case basis after consideration of- site-specific factors. DMMP Suitability Determinations will document the sediment quality of each project relative to SMS SQS and CSL criteria, and provide an assessment of a project's suitability for in-water beneficial use

1. **Dioxin:** Projects in the Puget Sound basin: If the dredged material is below the Puget Sound background of 4 pptr TEQ, then it qualifies for in-water beneficial use.
2. **Other areas of the state**: The dredged material needs to be compared to "background" or one or more reference stations. For example, in Grays Harbor the DMMP agencies have compared dredged material to the aggregate data from six reference stations within Grays Harbor for beneficial use at Half Moon Bay and South Beach. On the Columbia River, the range of dioxin TEQs measured at background stations downstream of Puget Island has been used to evaluate flow-lane disposal. Beneficial use on the Washington side of the lower Columbia River would be treated similarly.

As always, best professional judgment may need to be applied in making case-by-case determinations.

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