SEDIMENT EVALUATION FRAMEWORK FOR THE PACIFIC NORTHWEST

NORTHWEST REGIONAL SEDIMENT EVALUATION TEAM **MAY 2018**

US Army Corps of Engineers®
Northwestern Division

EPA
United States Environmental Protection Agency

NOAA FISHERIES
West Coast Region

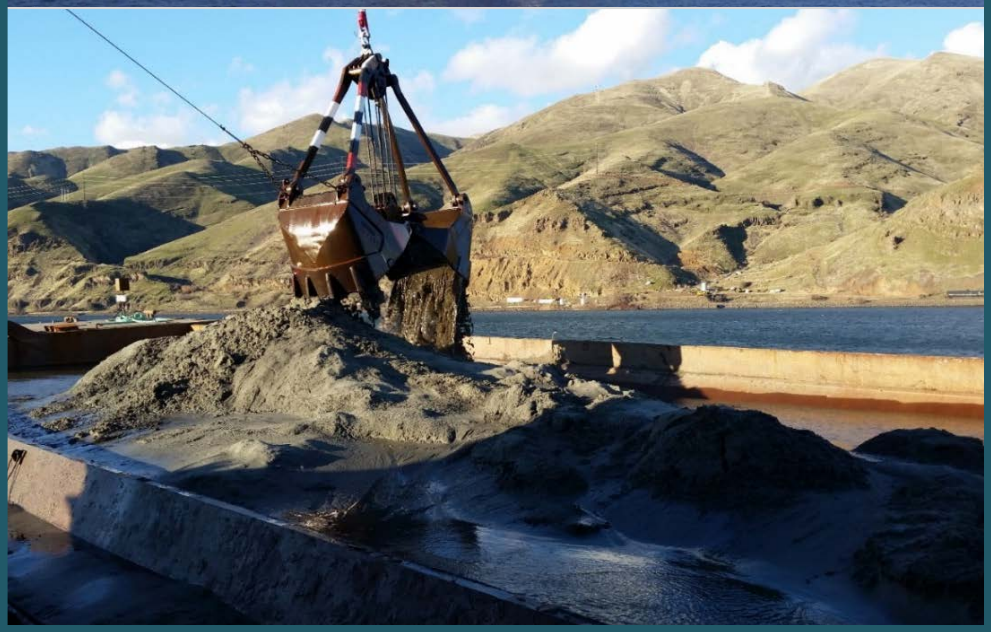
U.S. Fish & Wildlife Service

DEQ
State of Oregon Department of Environmental Quality

Idaho Department of Environmental Quality

Department of Ecology
State of Washington

Washington State Department of Natural Resources



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PREPARED BY THE
NORTHWEST REGIONAL SEDIMENT EVALUATION TEAM AGENCIES:

U.S. ARMY CORPS OF ENGINEERS
(NORTHWESTERN DIVISION AND PORTLAND, SEATTLE, AND WALLA WALLA DISTRICTS)

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Photos, front cover:

Top: Port of Tacoma, Commencement Bay, Puget Sound, Washington (Mt. Rainier in background)

Middle: Maintenance Dredging, Willamette River federal channel, Portland, Oregon (Mt. St. Helens in background)

Bottom: Maintenance dredging, Snake River federal channel near Clarkston, Washington/Lewiston, Idaho

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Abbreviations, Acronyms, and Symbols

µg/kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter
µm	micrometer or micron
ASTM	American Society for Testing Materials
BCoCs	bioaccumulative chemicals of concern
BT	bioaccumulation trigger
CAD	confined aquatic disposal
CDF	confined disposal facility
CFR	Code of Federal Regulations
cm	centimeters
CoCs	chemicals of concern or contaminants of concern
Corps	US Army Corps of Engineers
CSM	conceptual site model
CWA	Clean Water Act
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DMMO	Seattle District Dredged Material Management Office
DMMP	Washington Dredged Material Management Program
DMMU	dredged material management unit
DoD	Department of Defense
EC	effective concentration
Ecology	Washington Department of Ecology
EDL	estimated detection limit
EIM	Environmental Information Management (Ecology database)
EMPC	estimated maximal potential concentration

EPA	US Environmental Protection Agency
EPH	extractable petroleum hydrocarbons
ERDC	US Army Engineer Research and Development Center
ESA	Endangered Species Act
FPM	Floating Percentile Method (for calculating freshwater screening levels)
g	gram
gal	gallon
HDPE	high-density polyethylene
Hg	mercury
HPAH	high molecular weight polynuclear aromatic hydrocarbons (fluoranthene, pyrene, benz (a)anthracene, chrysene, benzo(b,j+k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz (a,h)anthracene, and benzo(g,h,i)perylene)
IDEQ	Idaho Department of Environmental Quality
L	liter
LC	lethal concentration
LPAH	low molecular weight polynuclear aromatic hydrocarbons (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene)
MAR	management area rank
MDL	method detection limit
mg/kg	millgrams per kilogram (parts per million)
mL	milliliter
MLLW	mean lower low water
mm	millimeter
MNR	monitored natural recovery
MPRSA	Marine Protection, Research and Sanctuaries Act, aka Ocean Dumping Act
MRL	method reporting limit (aka PQL, SQL)
NA	not available/not applicable
NAD	North American Datum
NCMA	normalized combined mortality and abnormality (sediment larval bioassay terminology)

NDT	National Dredging Team
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service (National Oceanic and Atmospheric Administration)
NOEC	no observable effect level
NPDES	National Pollutant Discharge Elimination System
NWRDT	Northwestern Regional Dredging Team
NWTPH-Dx	NorthWest Total Petroleum Hydrocarbons, diesel and residual range hydrocarbons
NWTPH-Gx	NorthWest Total Petroleum Hydrocarbons, gasoline range hydrocarbons
ODEQ	Oregon Department of Environmental Quality
ODMDS	ocean dredged material disposal site (selected/designated under MPRSA)
Opinion	biological opinion issued by NMFS or USFWS
oz	ounce
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls (Aroclors)
PCDD/PCDF	polychlorinated dibenzodioxins and polychlorinated dibenzofurans
PDS	post-dredge surface
pg/kg	picograms per kilogram (parts per trillion)
ppt	parts per thousand (salinity)
PQL	practical quantitation limit (aka SQL, MRL)
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Partnership
PSET	Portland Sediment Evaluation Team
QA	quality assurance
QC	quality control
Ref Tox	reference toxicant (bioassay terminology)
RSET	Northwestern Regional Sediment Evaluation Team
SAP	sampling and analysis plan
SCR	sediment characterization report

SDM	suitability determination memorandum
SEF	*Sediment Evaluation Framework for the Pacific Northwest*
SETAC	Society of Environmental Toxicology and Chemistry
SIM	Selective Ion Monitoring
SLs	benthic toxicity screening levels (freshwater or marine)
SQL	Sample Quantitation Limit (aka MRL, PQL)
SSD	species sensitivity distribution
SVOCs	semivolatile organic compounds
TCDD	tetrachlorodibenzodioxin
TEF	toxicity equivalency factor
TEQ	TCDD toxicity equivalent
the Services	NMFS and USFWS, collectively
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSS	total suspended solids
TTL	target tissue level
U	undetected/nondetected result
USFWS	US Fish and Wildlife Service
UTL	upper tolerance limit
VPH	volatile petroleum hydrocarbons
WDNR	Washington Department of Natural Resources
WGS	World Geodetic System
WQ	water quality

Chapter 1. Introduction

1.1 Overview

The US Army Corps of Engineers (Corps) and US Environmental Protection Agency (EPA) share federal responsibility for regulating dredged material within waters of the United States under section 404 of the Clean Water Act (CWA) and for regulating dredged material in ocean waters under section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA). Under section 401 of the CWA, the states of Washington, Oregon, and Idaho must also certify that aquatic discharges do not violate state and federal water quality standards.

This *Sediment Evaluation Framework for the Pacific Northwest* (SEF) provides a framework for assessing and characterizing sediment to determine the suitability of dredged material for unconfined, aquatic disposal; determine the suitability of post-dredge surfaces; and predict effects on water quality during dredging. The SEF describes procedures for evaluating potential contaminant-related environmental impacts of dredging and the aquatic placement of dredged material in inland waters and the disposal of dredged material in ocean waters. The framework is designed for use in the Pacific Northwest, defined here as the States of Washington, Oregon, and Idaho. It will be periodically revised and updated as warranted by advances in regulatory practice and technical understanding.

This 2016 SEF was prepared by the Northwestern Regional Sediment Evaluation Team (RSET) agencies[1] and it replaces the 2009 SEF (Corps et al. 2009). It also replaces the freshwater benthic toxicity screening levels (SLs) published in the 2006 interim final SEF (Corps et al. 2006).

1.1.1 Purpose

The SEF serves as the Pacific Northwest's joint regional implementation manual for the two national sediment testing manuals:

- *Evaluation of Dredged Material Proposed for Ocean Disposal* (Ocean Testing Manual), which satisfies MPRSA sediment testing requirements (EPA and Corps 1991)
- *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual* (Inland Testing Manual), which satisfies CWA sediment testing requirements (EPA and Corps 1998)

Specifically, the SEF does the following:

- Provides a framework for characterizing marine and freshwater sediment quality in coordination with the public, stakeholders, and regulatory resource agencies.

[1] Includes the US Army Corps of Engineers (Northwestern Division: Seattle, Portland, and Walla Walla Districts), Environmental Protection Agency-Region 10, US Fish and Wildlife Service, National Marine Fisheries Service, Washington Department of Ecology, Washington Department of Natural Resources, Oregon Department of Environmental Quality, and Idaho Department of Environmental Quality.

- Provides a uniform framework under which the Corps meets CWA and MPRSA sediment testing requirements for both Corps civil works dredging and Corps Regulatory Program (Regulatory) permit evaluations.
- Provides a uniform framework for other federal and state agencies with statutory responsibilities related to the evaluation of dredged material.
- Identifies a regional database to track the long-term trends in sediment quality for specific dredging projects/locations and for the region.
- Provides procedures or references other regional/national guidance to assist in identifying and evaluating alternative sediment management options.
- Evaluates the *need* for federal and/or state environmental cleanup activities[2], but not the actual cleanup remedy or removal action.

The SEF incorporates the best available science to evaluate discharges of dredged material; the RSET developed the SEF with the following qualities in mind:

- **Consistent**—Make sediment evaluation procedures as consistent as possible throughout the Pacific Northwest.
- **Flexible**—Evaluation procedures must be flexible enough to allow for exceptions due to project and site-specific concerns and be scalable to projects of any size.
- **Accountable**—The need for, and cost implications of, evaluation procedures must be justifiable to the individual stakeholder/permittee and to the public, and the local review teams who perform sediment evaluations must strive to meet civil works deadlines and Regulatory permitting timeframes.
- **Cost Effective**—Evaluation procedures must be timely and cost-effective.
- **Objective**—Evaluation procedures must be clearly stated, logical, and objectively applied to each project.
- **Dynamic**—Evaluation procedures must be based on best available technical and policy information; the RSET agencies are committed to periodically revising the SEF to incorporate the latest, best available science.
- **Understandable**—Evaluation procedures must be clear and concise.
- **Technically Sound**—Evaluation procedures must be reproducible, have adequate quality assurance and quality control guidelines, and have standardized protocols.

1.1.2 Applicability and Limitations

The SEF is primarily used to evaluate the suitability of dredged material for unconfined, aquatic placement. However, the SEF may also be used to evaluate discharges of dredged material associated with non-navigational projects (e.g., ecosystem restoration projects), as well as for antidegradation evaluation under the states' authorities. Geographically, these evaluation procedures apply to dredging projects in the states of Washington, Oregon, and Idaho (generally conforming to the Seattle, Portland, and Walla Walla Corps District boundaries [Figure 1-1]).

[2] For environmental cleanup activities, the states of Washington, Oregon, and Idaho will exercise their regulatory authority via their cleanup statutes (see section 1.2.5). EPA will manage federal cleanup activities per the Comprehensive Environmental Response, Compensation, and Liability Act (i.e., Superfund).

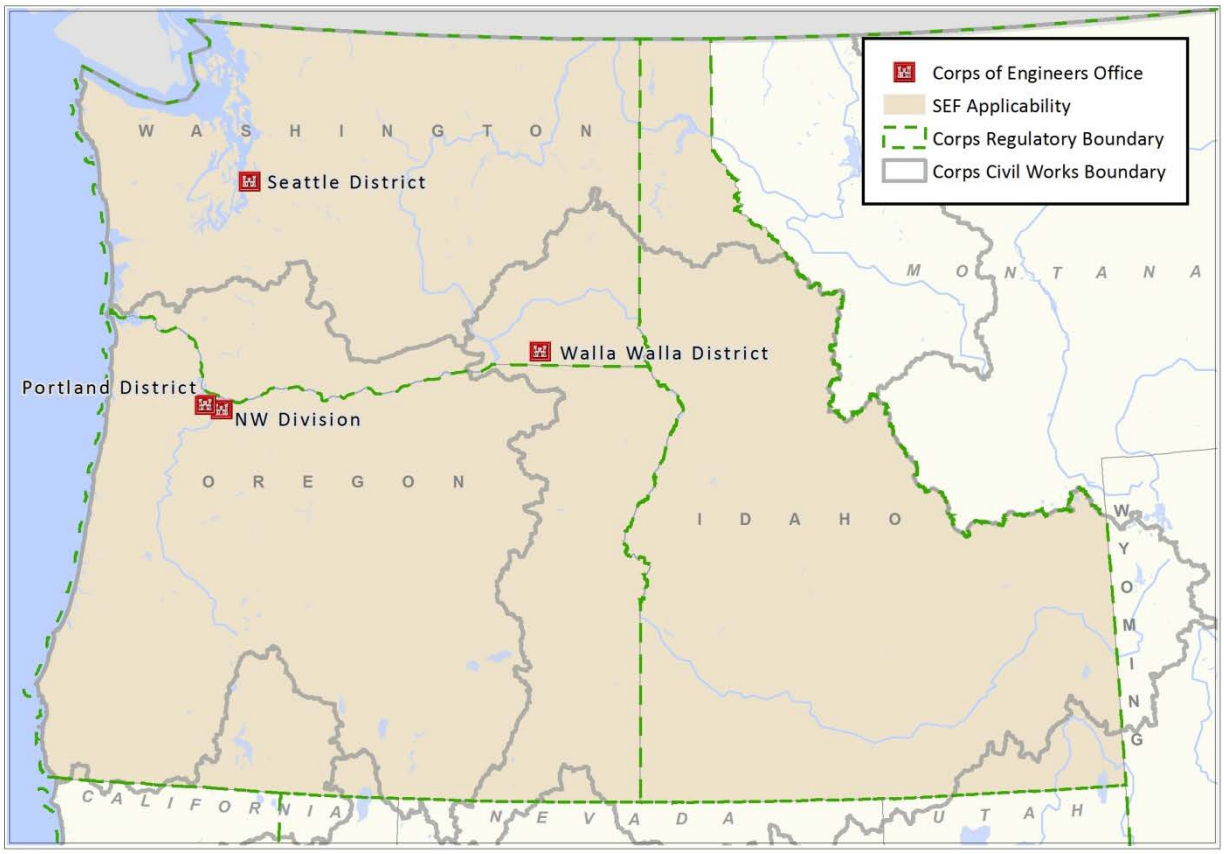

Figure 1-1. Geographic extent of SEF applicability.

The SEF ensures consistency and public accountability for the assessment, characterization, and management of sediments in the Pacific Northwest region. This manual is aligned with other regional programs including the successful Dredged Material Management Program (DMMP) in the state of Washington and the Portland Sediment Evaluation Team (PSET) in Oregon. All pertinent federal and state laws, regulations, and guidance are considered in this SEF. As the regional implementation manual for the Pacific Northwest region, the SEF is consistent with the guidelines of the national-level sediment assessment manuals. Nothing in this SEF alters or limits agency responsibilities or imposes mandatory requirements beyond existing statute or regulation.

The SEF guidance regarding sample handling, storage, analysis, and biological testing is consistent with federal and state cleanup program guidance, which ensures consistent data quality across the programs. However, this manual does not provide guidance for characterizing a contaminated site in order to make decisions regarding how the site will be managed. All sediment evaluations for cleanup actions are to be coordinated through the appropriate state and federal cleanup programs (see section 1.2.4).

1.1.3 SEF Tiered Sediment Evaluation

The SEF provides a risk-based sediment assessment framework that describes methods and procedures to evaluate dredging and the discharges of dredged material and inform sediment management decisions made by regulatory authorities. The SEF chapters follow the sequence of sediment evaluation for a

project. However, the chapters are also written to enable the reader to obtain information from one technical aspect, if desired, without necessarily reading the entire manual.

The SEF uses a two-tiered evaluation process to assess the suitability of project sediments for unconfined, aquatic disposal (Figure 1-2):

- Level 1—Project Description and Site History Information—includes the following:
  - Defining the scope of the project (section 3.1)
  - Collecting historically available data (section 3.2)
  - Developing the Conceptual Site Model (CSM, section 3.3)
  - Synthesizing available information to establish the management area rank for the project (section 3.4).

If the Level 1 information is sufficient to conclude that the risk to ecological receptors is minimal and dredged material is suitable for aquatic disposal, then there is no need to collect additional data and a sediment suitability determination can be made at the end of Level 1 review. If the Level 1 information is insufficient to determine dredged material suitability, then Level 2 sediment evaluation is required.

- Level 2—Sediment Physical, Chemical, Biological, and Water Quality Evaluations—has two parts:
  - Level 2A documents sediment chemical and physical characteristics of the project. Steps in the Level 2A evaluation include the following:
    - Sediment sampling and analysis plan (SAP) development and field sampling (Chapter 4)
    - Laboratory sediment analysis and data quality assurance (Chapter 5)
    - Sediment data reporting and comparison to regional sediment quality guidelines (Chapter 6)
  - If sediment chemical concentrations are above the regional sediment quality guidelines, Level 2B analyses are used to evaluate potential effects on water quality and ecological/human receptors. Level 2B evaluations may include one or more of the following:
    - Toxicity testing (Chapter 7)
    - Bioaccumulation evaluation (Chapter 8)
    - Other special evaluations (elutriate testing, water quality modeling, dredging residuals evaluations, etc.) (Chapter 9).

The ultimate product of the SEF review is a sediment suitability determination for the project. Employing the methods prescribed in the SEF, the project proponent can provide sufficient information for the interagency local review team (see section 1.3) to make a sediment suitability determination for the project. The sediment suitability determination memorandum (SDM) informs the Corps project manager (civil works or Regulatory Program) if project sediments are suitable for unconfined, aquatic disposal. The project proponent can use the information in the SDM to design the dredging project and identify appropriate disposal options. The SDM can also inform agencies of the need for project controls to meet state and federal regulatory requirements (Chapter 10).

Many sections of this SEF are cross-referenced to alert readers to relevant issues that might be covered elsewhere in the manual. This cross-referencing is particularly important for certain chemical or toxicological applications in which sample processing or laboratory procedures are associated with specific field sampling procedures.

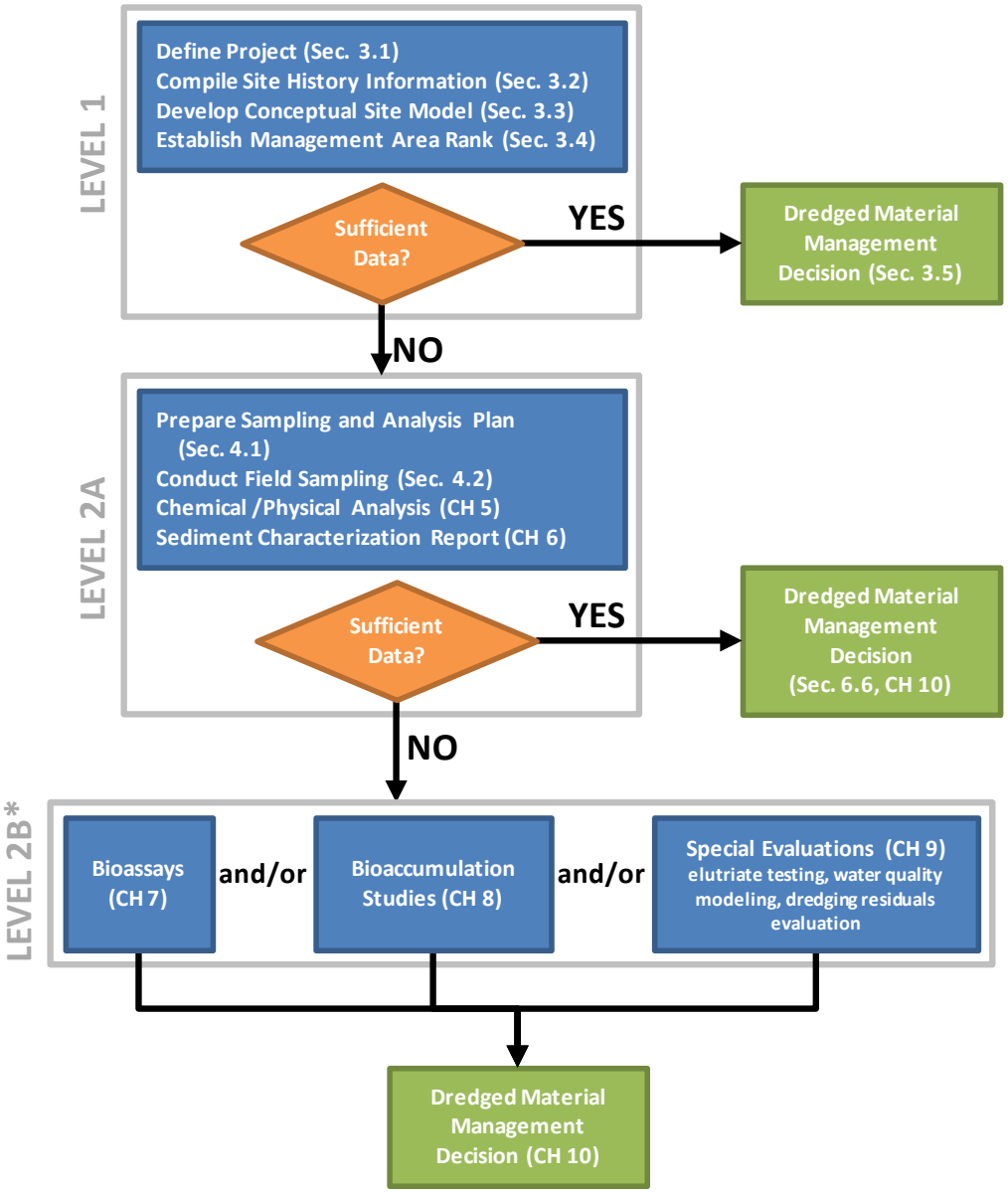

Figure 1-2. SEF tiered evaluation process.

1.2 Regulatory Basis for Sediment Evaluation

Several state and federal entities have regulatory authority governing the management of dredged material and contaminated sediment in the Pacific Northwest. This section briefly describes the federal and state regulatory authorities governing sediment evaluation.

1.2.1 Clean Water Act

Section 404

The Federal Water Pollution Control Act of 1972 (amended and renamed the Clean Water Act of 1977) governs the discharge of dredged or fill material into waters of the United States (inland of and including the territorial sea). The geographical limits of jurisdiction under the CWA include all waters of the United States as defined at 33 CFR 328.3.

Section 404(b)(1) requires the EPA, in conjunction with the Corps, to promulgate guidelines for the discharge of dredged or fill material to ensure that such proposed discharge will not result in unacceptable adverse environmental impacts either individually or in combination to waters of the United States. The Corps and EPA also have authority under the section 404(b)(1) guidelines to identify, in advance, sites that are either suitable or unsuitable for the discharge of dredged or fill material into waters of the United States. Section 404(b)(1) assigns to the Corps the responsibility for authorizing all such proposed discharges and requires application of the guidelines in assessing the environmental acceptability of the proposed action. The Corps is also required to examine the least environmentally damaging practicable alternative to the proposed discharge, including alternatives to disposal into waters of the United States.

Subpart B of the 404(b)(1) guidelines (40 CFR 230.10–230.11) identifies restrictions on the discharges of dredged or fill material into waters of the United States and the factual determinations that must be made in accordance with the restrictions. Subpart G of the 404(b)(1) guidelines (40 CFR 230.60–230.61) identifies regulatory procedures for the general evaluation of discharges; Subpart G also identifies procedures for chemical, biological, and physical evaluation and testing of dredged and fill materials. In the Pacific Northwest, the SEF guidance is designed to help ensure that Corps civil works projects and federal permits comply with the CWA 404(b)(1) guidelines.

Section 401

CWA section 401 allows states to issue water quality certifications (with or without conditions), deny certification, or waive certification for any activity that results in a discharge to a water of the United States and requires a federal permit or license. A water quality certification certifies that the activity complies with all applicable federal and state water quality standards, limitations, and restrictions. No license or permit may be issued by a federal agency until the water quality certification required by section 401 has been granted. Further, no license or permit may be issued if certification has been denied. The SEF guidance can be used to evaluate the potential water quality effects at the dredge area and at the disposal site. In the Pacific Northwest, the following agencies administer section 401 programs in their respective states: Oregon Department of Environmental Quality (ODEQ), Washington Department of Ecology (Ecology), and Idaho Department of Environmental Quality (IDEQ).

1.2.2 Marine Protection Research and Sanctuaries Act

The MPRSA (also called the Ocean Dumping Act, 33 USC 1401 *et seq*.) governs the transportation of dredged material for the purpose of disposal into ocean waters. The EPA has authority under section 102 to designate ocean dredged material disposal sites (ODMDSs). The Corps is required to use designated ODMDSs to the extent feasible. Where infeasible, the Corps may, with the concurrence of EPA, select

alternative ocean disposal sites using the EPA site selection criteria (see 40 CFR Parts 227–228). The Corps must consider project effects to navigation, economic and industrial development, and foreign and domestic commerce and the availability of alternative sites.

The Corps may issue permits for ocean disposal under section 103 of the MPRSA. After the proposed permit action has been reviewed by EPA for compliance with the ocean dumping criteria and received EPA's concurrence, the Corps may issue a permit for ocean disposal. If EPA determines the criteria are not met, disposal may not occur without a waiver of the criteria by EPA.

The criteria for evaluating the environmental impacts of ocean disposal, including disposal of dredged material, is provided in Subpart B of the ocean dumping regulations (40 CFR 227.4–227.13). In the Pacific Northwest, the SEF sediment testing guidance helps ensure that disposal of dredged material in the ocean is compliant with the MPRSA ocean dumping criteria.

1.2.3 Endangered Species Act

Section 7(a)1 of the Endangered Species Act (ESA) directs all federal agencies to conserve endangered and threatened species and to use their authorities to further the purposes of the ESA in recovering ESA-listed species such that they can be delisted. Section 7(a)2 of the ESA outlines interagency cooperation procedures for federal action agencies to consult with the US Fish and Wildlife Service (USFWS) and/or National Marine Fisheries Service (NMFS) (together the Services) to ensure the actions they fund and/or permit do not jeopardize the existence of any ESA-listed species or adversely modify designated critical habitat in the action area of the project.

Upon receipt of a request to consult from another federal agency, the NMFS and/or the USFWS—the agencies with the legislative mandate to oversee ESA listings and recovery planning—prepare Letters of Concurrence if they agree with the requesting agency that the federal action is *not likely to adversely affect* the subject listed species or its critical habitat.

If the action is considered by the Services to "take" a listed species or adversely affect its habitat, incidental to the otherwise lawful action (terms defined under 16 USC §1532), the Services will prepare a Biological Opinion (Opinion). Opinions provide an exemption for the take of listed species while specifying the extent of take allowed, the Reasonable and Prudent Measures necessary to minimize impacts from the federal action, and the nondiscretionary terms and conditions associated with the Reasonable and Prudent Measures to aid in avoiding and minimizing the take identified in the Opinion. In the extreme, some federal actions consulted on are interpreted to jeopardize the continued existence of an ESA-listed species or adversely modify their critical habitat(s). Under such conditions, the Services will issue an Opinion with those findings and Reasonable and Prudent Alternatives to which the action agency will be obligated to implement to ensure the action will not jeopardize the species and/or adversely modify its designated critical habitat. Sediment evaluations (conducted in accordance with the SEF) provide the Services with evidence to support the analyses and decisions associated with the section 7 consultation.

For more information about ESA-listed species and section 7 consultations, see the following websites: *https://www.fisheries.noaa.gov/welcome*; *https://www.fws.gov/oregonfwo/*; *https://ecos.fws.gov/ipac/*.

1.2.4 Other Applicable Federal and State Laws and Regulations

Numerous federal and state laws pertain directly or peripherally to dredging operations and dredged material placement/disposal. These are briefly summarized in Table 1-1.

Table 1-1. Summary of federal and state laws that may pertain to dredging projects.

Authority (Agency)	Regulated Activities/Actions	Jurisdiction
Federal		
National Environmental Policy Act (NEPA) (federal action agency)	Actions undertaken by the federal government	All federal actions, including applications for federal permits or other forms of authorization that are not otherwise exempted from NEPA
Comprehensive Environmental Response, Compensation, and Liability Act, i.e., Superfund (EPA)	Cleanup of uncontrolled or abandoned hazardous-waste sites as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment	Sites listed on EPA's National Priorities List, as well as external sources and/or actions that may affect contamination within the Superfund site
Section 10 Rivers and Harbors Act (Corps)	Construction of structures in or over navigable waters of the United States; the excavation from or depositing of material in navigable waters; other work affecting the course, location, condition, or capacity of navigable waters	Navigable rivers and lakes: extends laterally to the entire water surface and bed of a navigable water body, which includes all the land and waters below the ordinary high-water mark; ocean and coastal waters within a zone 3 geographic (nautical) miles seaward from the baseline (i.e., the Territorial Seas); wider zones are recognized for the outer continental shelf
Fish and Wildlife Coordination Act (USFWS and NMFS; state wildlife resource agencies)	Land, water, and interests may be acquired by federal construction agencies for wildlife conservation and development	Where waters or channel of a water body are modified by a department or agency of the United States
Magnuson-Stevens Fishery Conservation and Management Act (NMFS)	Actions affecting commercial fisheries	Federally managed species with designated essential fish habitat
Marine Mammal Protection Act (NMFS)	Actions resulting in the lethal take, nonlethal take, or incidental harassment of marine mammals	All species of whales, dolphins, porpoises, seals, and sea lions; marine mammal habitat
Public Law 92-583, Coastal Zone Management Act (delegated to coastal states by the National Oceanic and Atmospheric Administration)	Effective management, beneficial use, protection, and development of coastal zone; federal agency activities or permits that affect the coastal zone must be consistent with the enforceable policies of the approved state management program in Oregon and Washington	See Oregon and Washington state program jurisdiction below

Authority (Agency)	Regulated Activities/Actions	Jurisdiction
Section 106 National Historic Preservation Act (Advisory Council on Historic Preservation; state historic and tribal preservation offices)	Federal actions affecting cultural resources; federal actions affecting tribal cultural resources, treaty fishing access sites, usual and accustomed areas, traditional cultural properties, and/or other resources important to the respective tribes	Cultural and tribal resources; federal action agency coordinates with State Historic and Tribal Preservation Offices and attempts to avoid or minimize impacts to cultural and/or tribal resources and mitigate unavoidable impacts; federal action agency makes final determination of project effect
State of Washington		
State Environmental Policy Act (state agencies, counties, cities, ports, and special districts)	State actions	Issuing permits for private projects; construction of public facilities; adopting regulations, policies, or plans
Hydraulic Project Approval (Washington Department of Fish and Wildlife)	Actions that affect the natural flow of state waters	Waters under the state's jurisdiction
Aquatic Lands Act (Washington Department of Natural Resources [WDNR])	Leases state-owned aquatic lands for development, manages state-owned aquatic lands, and charges a fee for the discharge or use of dredged material	Discharge or removal of dredged material on state aquatic lands; aquatic or nearshore disposal may be subject to WDNR's management
Model Toxics Control Act (Ecology)	Governs remedial actions in the state	State remedial actions, including sediment cleanup under state Sediment Management Standards
Washington Shoreline Management Act (Ecology)	Actions that may affect shoreline use, shoreline natural resources, access to public areas, and preservation of recreational opportunities	Shorelines of the state—all marine waters, streams > 20 cubic feet per second mean annual flow, lakes 20 acres or larger; upland areas extending 200 feet landward from the edge of these waters; biological wetlands and river deltas, and some or all of the 100-year floodplain when associated with one of the above waters
Washington State Coastal Zone Management Program (Ecology)	Effective management, beneficial use, protection, and development of coastal zone; federal agency activities or permits that affect the coastal zone must be carried out in a manner consistent, to the maximum extent practicable, with the enforceable policies of the approved state management program	The 15 coastal counties that front saltwater
Sediment Management Standards	National Pollutant Discharge Elimination System discharges; discharge of dredged and fill material; identification and remediation of cleanup sites; actions which expose or resuspend surface sediments which exceed the sediment quality standards	Marine, low salinity and freshwater surface sediments under the state's jurisdiction

Authority (Agency)	Regulated Activities/Actions	Jurisdiction
State of Oregon		
Removal/Fill Law (Department of State Lands)	Removal, fill, or alterations equal to or exceeding 50 cubic yards of material within beds or banks of waters in Oregon	Waters of the state, including wetlands
State Beaches (Oregon State Parks)	Placement of dredged material on state beaches	Beaches of the state
Oregon Solid and Hazardous Waste Rules (ODEQ, Solid Waste Program)	Upland disposal of dredged material	All lands within Oregon
Oregon State Cleanup Authority (ODEQ, Cleanup Program)	Remedial actions within the state	State remedial actions at contaminated sites, including sediment cleanup
Coastal Zone Management Act (Oregon Coastal Management Program, Department of Land Conservation and Development)	Effective management, beneficial use, protection, and development of coastal zone; federal agency activities or permits that affect the coastal zone must be carried out in a manner consistent, to the maximum extent practicable, with the enforceable policies of the approved state management program	Inland to the crest of the coastal range, except for the following: along the Umpqua River where it extends upstream to Scottsburg; along the Rogue River where it extends upstream to Agness; and except in the Columbia River Basin where it extends upstream to the downstream end of Puget Island
State of Idaho		
Rules and Standards for Hazardous Waste; Solid Waste Management Rules; Idaho Water Quality Standards (IDEQ, Water Quality Division and Waste Management and Remediation Division)	Protection of water quality, disposal of dredged materials, and any remedial actions within the state	All lands in the state and all state waters
Lake Protection Act (Idaho Department of Lands)	Projects affecting lakes and reservoirs in the state	Lakes and reservoirs in the state
Stream Channel Protection Act (Idaho Department of Water Resources, Stream Channel Protection Program)	Any type of alteration work, including recreational dredge mining, done inside the ordinary high water marks of a continuously flowing stream	Perennial waters of the state

Regulations surrounding the DMMP open-water disposal sites differ from those applicable to ocean disposal sites, the latter of which fall under EPA's regulatory authority under the MRPSA. The DMMP open-water disposal sites fall under the federal regulatory authority of the CWA, Washington State's Sediment Management Standards, and other state and local permitting processes specific to Washington.

1.3 Regional Sediment Evaluation Team

1.3.1 Development of the SEF

The first national sediment testing manual for CWA discharges was published by the Corps and EPA in 1976, followed in 1977 by the EPA/Corps national testing manual for ocean dredged material disposal (EPA and Corps 1976, 1977). When there was reason to believe contaminants were present, the Corps districts used the national manuals to guide sediment evaluations. These documents were replaced by the

1998 Inland Testing Manual (for CWA discharges) and the 1991 Ocean Testing Manual (for MPRSA ocean disposal) (EPA and Corps 1991, 1998). However, the Seattle District and Portland District had developed regional sediment testing guidance consistent with national manuals, well in advance of the publication of the last national manuals.

Coordinated multiagency dredged material management in the Pacific Northwest began in 1985 after studies documented degraded sediment and water quality in Puget Sound, Washington (Seattle District). Public concern and plunging confidence in agency management of dredged material led to the loss of state shoreline permits for the Elliott Bay disposal site and brought 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, aquatic disposal of dredged material. PSDDA was implemented in two phases, the first in June 1988 for central Puget Sound and the second in September 1989 for north and south Puget Sound (PSDDA 1998). The PSDDA program provided publicly acceptable and environmentally safe regulation of unconfined, aquatic dredged material disposal at eight Puget Sound disposal sites. In 1995, a long-term interagency management strategy was also developed and implemented for the coastal estuaries of Grays Harbor and Willapa Bay. With the expansion of PSDDA oversight into Washington water bodies beyond Puget Sound, the PSDDA name was changed to the Washington Dredged Material Management Program (DMMP).[3]

Concurrent with the PSDDA study, in 1986 the Portland District used a three-tiered approach for routine evaluation of sediment quality at the District's coastal and inland federal navigation projects (typically every 5 years). Portland District's tiered evaluation approach was presented at a February 1988 water quality seminar held by the Corps Hydrologic Engineering Center in Charleston, South Carolina (Corps 1988). In follow-up efforts, the Portland District incorporated the Washington Sediment Management Standards in coordination with ODEQ.

In 1994, national-level dredging policy was developed by an interagency workgroup and endorsed by President Clinton in 1995. The 1994 National Dredging Policy promoted the following principles:

- The Regulatory Program’s process must be timely, efficient, and predictable, to the maximum extent practicable.
- Advanced dredged material management planning must be conducted on a port or regional scale by a partnership that includes the Federal government, the port authorities, state and local governments, natural resource agencies, public interest groups, the maritime industry, and private citizens. To be effective, this planning must be done prior to individual federal or non-federal dredging project proponents seeking individual project approval.
- Dredged material managers must become more involved in watershed planning to emphasize the importance of point and nonpoint source pollution controls to reduce harbor sediment contamination.
- Dredged material is a resource, and environmentally sound beneficial use of dredged material for such projects as wetland creation, beach nourishment, and development projects must be encouraged.

[3] Includes US Army Corps of Engineers–Seattle District, Environmental Protection Agency–Region 10, Washington Department of Ecology, and Washington Department of Natural Resources.

The National Dredging Team[4] (NDT) was established in 1995 to implement the National Dredging Policy. The NDT continues to facilitate communication, coordination, and resolution of dredging issues among the participating federal agencies.

In turn, the NDT established regional dredging teams at the eight Corps divisions in the US. The regional dredging teams may elevate dredging issues to the NDT for resolution; however, the NDT encourages resolution of issues at the lowest authorized management level. The regional dredging teams are expected to use all available means to resolve issues prior to elevating an issue to the NDT.

In accordance with the NDT's expectations, the Northwestern Regional Dredging Team (NWRDT) established the Regional Management Team[5] to address dredged material evaluation consistency issues on the lower Columbia River between Washington and Oregon. In 1998, the Regional Management Team completed the *Dredged Material Evaluation Framework – Lower Columbia River Management Area* (DMEF [EPA et al. 1998]), which was based to a large extent on testing procedures developed in the PSDDA study. The DMMP implemented the DMEF and *Dredged Material Management Program User Manual* (Corps et al. 2015 [current version]) in Washington, and the Regional Management Team implemented the DMEF in Oregon for Portland District dredged material evaluations.

The philosophical and technical underpinnings of this SEF stem from the 2002 Society of Environmental Toxicology and Chemistry (SETAC) Pellston Workshop on the "Use of Sediment Quality Guidelines and Related Tools for the Assessment of Contaminated Sediments" (SETAC 2002). The Pellston Workshop was sponsored by SETAC and held August 17–22, 2002, in Fairmont, Montana. This workshop brought together 55 experts in the field of sediment assessment and management from Australia, Canada, France, Germany, Great Britain, Italy, the Netherlands, and the United States for 6 days of discussion on the use of sediment quality guidelines and other sediment assessment tools.

Following the SETAC meeting, in 2002 the NWRDT established the RSET to prepare the first SEF (the 2006 interim final SEF) for the northwestern states. Notably, it was the first time that USFWS, NMFS, Walla Walla District, and Idaho DEQ participated in developing the regional framework. It was also the first framework to employ freshwater SLs developed using the Floating Percentile Method ([FPM] Ecology 2003). Public participation and the input of scientific experts was solicited and incorporated in the review, and the 2006 interim final SEF was published in September 2006 with the commitment to finalize the document in the near term.

By late 2007, sufficient resources and data were available to finalize the SEF and update the FPM-derived freshwater SLs using a much larger dataset of paired sediment chemistry and freshwater bioassays. However, the new freshwater SLs were not incorporated into the May 2009 SEF because comments generated during the Washington public review period delayed their acceptance and utilization.

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[4] Includes the US Department of Transportation, US Fish and Wildlife Service, US Army Corps of Engineers, US Environmental Protection Agency, National Oceanic and Atmospheric Administration, and US Coast Guard

[5] Included the US Army Corps of Engineers (Northwestern Division; Seattle and Portland Districts), Environmental Protection Agency – Region 10, Washington Department of Ecology, Washington Department of Natural Resources, and Oregon Department of Environmental Quality (replaced by the Project Review Group in 2007; the PRG was renamed as the "Portland Sediment Evaluation Team" in 2011)

The 2016 version of the SEF incorporated the updated, FPM-derived freshwater screening levels and procedures for considering natural background concentrations of metals, as presented in the November 17, 2014, RSET white paper: "Proposal to Revise Freshwater Sediment Screening Levels" (contained in Appendix A). Users of this manual may also note changes in the organization of the document. The RSET has reduced or eliminated excess verbiage and restructured the document to closely follow the steps in the sediment evaluation process (see Figure 1-2).

In this version, we changed the following:

- Chapter 3: updated the conceptual site model (CSM) table and provided examples of how to prepare a CSM; clarified the "high" management area ranking definition.
- Chapter 10: provided debris management language.
- Global correction of errata.

1.3.2 RSET Mission and Structure

Mission

The RSET is committed to updating the SEF with the best available science, consistent with state, regional, and national policies. To meet this responsibility, the RSET is composed of regional governmental technical experts and regulatory agency representatives who are familiar with sediment evaluation procedures, CWA and MPRSA regulations and permitting procedures, and dredging equipment and limitations. With public input, the RSET will continue to ensure that the SEF and the procedures found therein are technically sound, verifiable, understandable, objective, regionally consistent, dynamic, flexible, accountable, and cost-effective (see section 1.1.1).

The RSET agencies meet monthly to discuss emerging issues and complete ongoing work by technical workgroups. The RSET agencies operate by consensus to amend the SEF and provide guidance regarding SEF implementation (both technical and regulatory aspects). If sufficient funding is available, the RSET may also solicit experts to work on technical issues through state and/or federal contracts. The RSET's public review process gives stakeholders an opportunity to provide input on SEF content and implementation (see section 1.3.3 and Appendix B).

Structure

The structure of the NWRDT is shown in Figure 1-3. The NWRDT is composed of the Executive Steering Committee and the Navigation/Regulatory Steering Committee. In 2002, the RSET was established by the NWRDT to prepare the SEF. The RSET is staffed by technical and policy specialists from the participating agencies; much of the RSET staff includes staff from the local review teams in the Seattle, Portland, and Walla Walla Corps Districts. The local review teams implement the SEF guidance in their respective districts/states and report emerging issues to the RSET.

1.3.3 Public Review and the SEF

The SEF is a continuation of the sediment evaluation process started in the Pacific Northwest 30 years ago with the advent of the PSDDA. Over the years, updates and improvements to this process received full state and federal public involvement through public notices and public meetings. All comments

received prior to or during the public notice process were fully considered in the final version of this manual.

An important aspect of the SEF is its ability to continuously evolve. As new information becomes available, the RSET agencies will revise and refine the SEF content. The RSET is committed to maintaining and updating the SEF through regularly scheduled public meetings. The RSET strongly encourages public stakeholders to prepare technical papers or provide comments pertaining to sediment evaluation in the Pacific Northwest and present these papers and comments at RSET meetings. As long as there are topics to present and technical or policy issues to discuss with stakeholders, the RSET shall strive to meet annually.

Changes to the 2016 SEF will be documented. The process used for recording the receipt of proposed changes, comments submitted during public review of proposed changes, and the decision regarding inclusion of changes will use the process and format included in Appendix B, SEF Change Process.

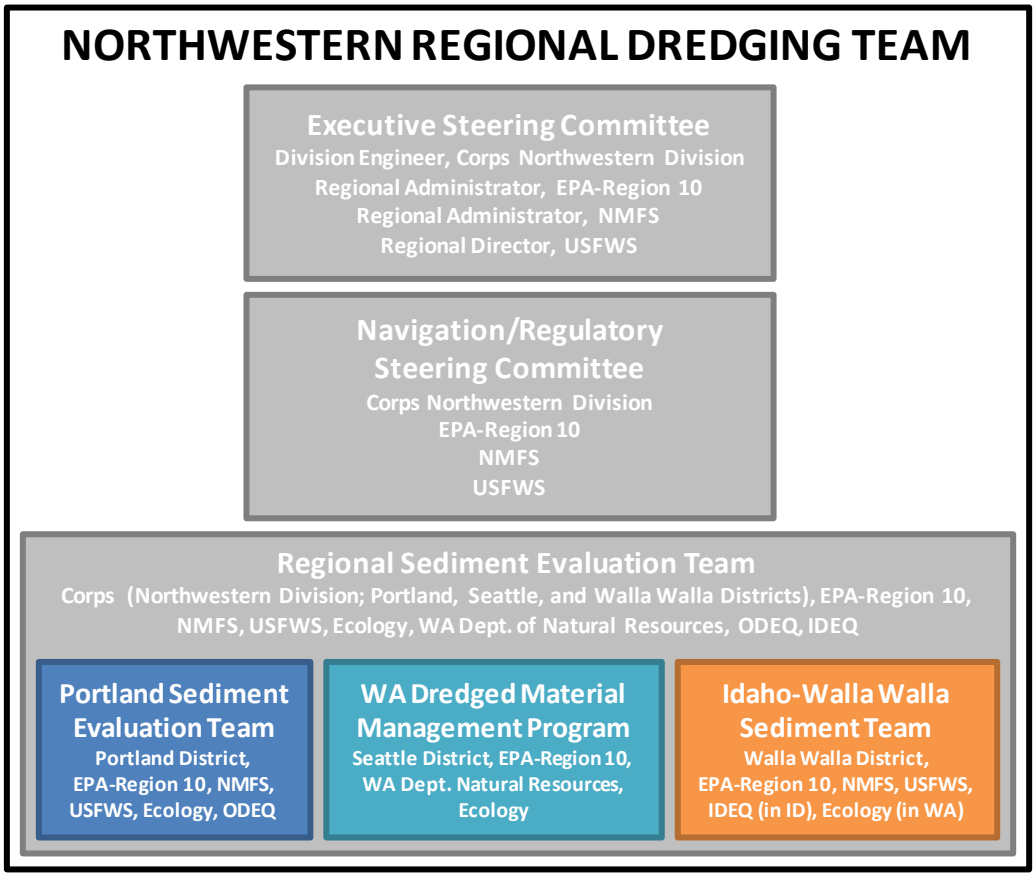

Figure 1-3. Hierarchy of the Regional Dredging.

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Chapter 2. Regulatory and Civil Works Project Evaluations and the SEF

2.1 Evaluation of Regulatory and Civil Works Projects

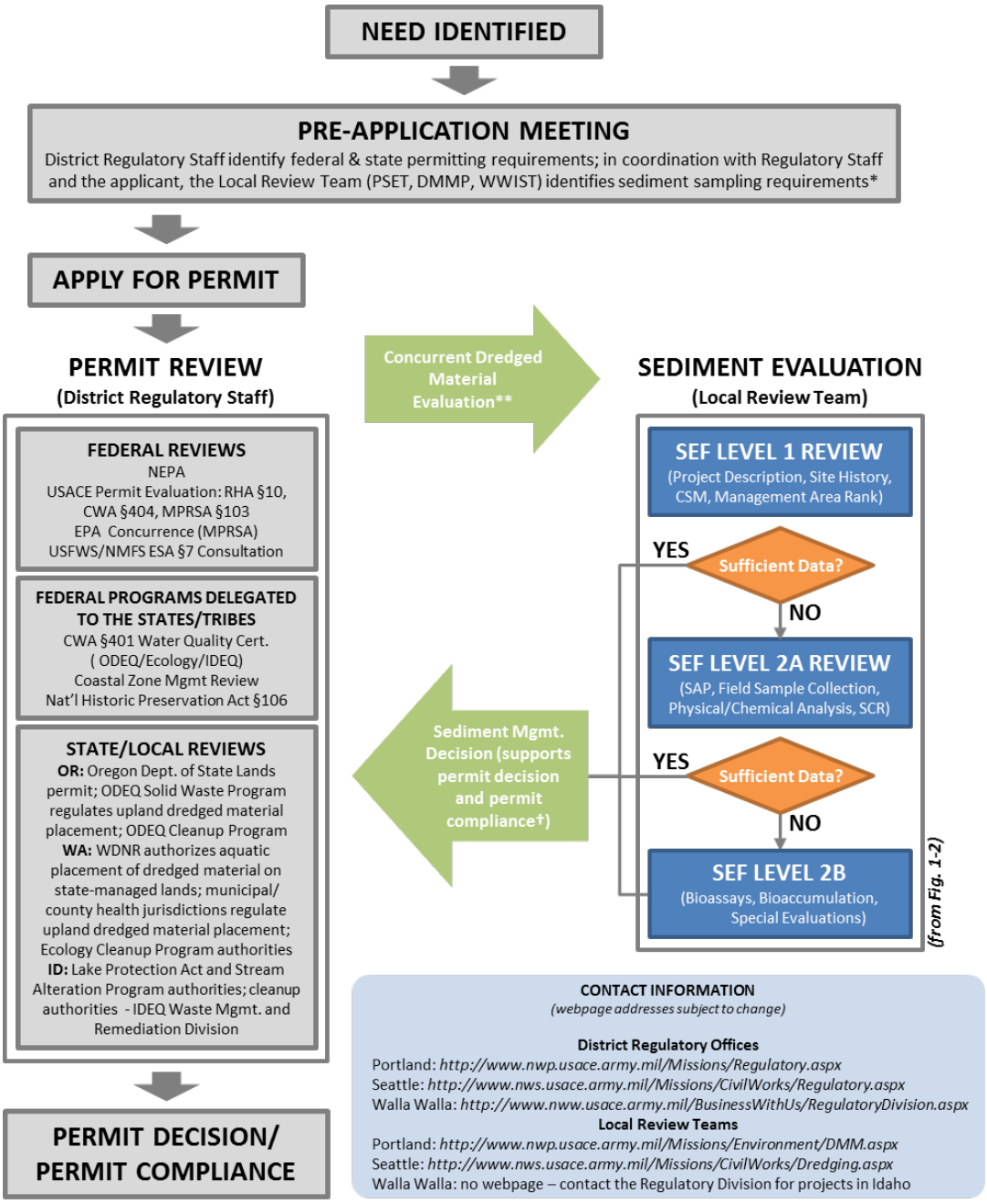
2.1.1 Regulatory Program Permit Evaluations

The Portland, Seattle, and Walla Walla District Regulatory Programs issue permits under the Corps' CWA, River and Harbors Act, and MPRSA authorities. The Regulatory permit review consists of a series of progressive steps that include the Corps CWA, Rivers and Harbors Act, and/or MPRSA evaluation as well as coordination and consultation with other state and federal agencies (Figure 2-1). The Corps' Regulatory project managers can assist permit applicants with the Regulatory permitting process and inform them of the state and federal reviews. A detailed discussion of the Corps' Regulatory permitting processes is beyond the scope of this chapter; the regulations for Corps permit evaluations can be found at 33 CFR, sections 320 to 332.

The SEF satisfies the sediment quality evaluation requirements prescribed by CWA and MRPSA; the evaluation is handled by the local review team associated with the district issuing the permit (Figure 2-1). The sediment quality evaluation is also used to support the CWA section 401 state water quality certification and the ESA section 7 consultation when listed species are known to use the project area and/or the area is designated critical habitat for listed species. Though the SEF is primarily used to assess material dredged from navigation projects, it may also be used to evaluate aquatic discharges proposed in ecosystem restoration projects and other in-water projects that propose dredging sediments.

Proponents of dredging and habitat restoration projects are encouraged to identify regulatory permitting requirements (including sediment sampling) prior to submitting a permit application to the Regulatory Program. Ideally, the sediment evaluation will occur prior to the applicant submitting the permit application. There are several advantages to this approach:

- Streamlines ESA section 7 consultation—The NMFS and USFWS commonly need the sediment quality evaluation to complete the ESA consultation.
- Streamlines CWA section 401 state water quality certification—The state water quality agencies (ODEQ, Ecology, and IDEQ) typically require the sediment quality evaluation prior to completing their project review and issuing (or denying) the CWA section 401 water quality certification.
- Prevents delays in the permit evaluation—The sediment quality evaluation may change the initially conceived project plan. For example, the dredged material disposal site and/or disposal methods may change as a result of the sediment quality evaluation. Also, post-dredge surface management may be necessary. These changes can cause permit processing delays:
    - If there are significant changes to the project, the Corps must reissue the public notice (for a 15- to 30-day comment period).
    - Project changes feed directly back into the section 7 ESA consultation and section 401 water quality certification review, which can cause delays.



** - The appropriate Corps District Regulatory Office handles pre-application meetings; questions pertaining specifically to sediment sampling requirements may be directed to the appropriate local review team.*

*** - Contaminated sediments can impact project design and dredged material placement options. Project design changes can increase agency review timelines and affect the project schedule. Pre-application sediment quality review is not required to start the application process; however, the resource agencies strongly encourage it.*

† - For multiple-year maintenance dredging permits, periodic sediment evaluation may be conditioned in the permit.

Figure 2-1. Regulatory permit evaluation and sediment evaluation interface.

2.1.2 Civil Works Project Evaluations

Figure 2-2 conceptually illustrates the phases of a Corps civil works project through its lifespan and the points at which sediment evaluation may be necessary to obtain environmental clearances. As it is with projects permitted by the Regulatory Program, the SEF may be used to evaluate both federal navigation projects and ecosystem restoration projects undertaken by the Corps' Civil Works Program. The evaluation is handled by the local review team associated with the district managing the civil works project. The rationale for sampling during a given project phase appears in Figure 2-2.

Procedures for the operation and maintenance of Corps federal navigation projects, including the routine evaluation of dredged material under CWA and MPRSA, can be found at 33 CFR 335–338. Corps civil works projects also require coordination and consultation with other state and federal agencies to comply with other federal laws. One notable distinction between the civil works sediment evaluation process and Regulatory permit evaluations is that the Corps does not issue itself a permit for civil works projects. Rather, the Corps complies with the substantive requirements of the CWA and MPRSA, including the sediment evaluation procedures prescribed in regulation.

2.2 Local Review Teams

The primary role of the local review teams is to evaluate dredged material suitability for both Regulatory-permitted and civil works dredging projects. The local review teams are responsible for implementing the SEF guidance in their respective territories and providing technical assistance to civil works project managers and the regulated public. The geographic area covered by each of the local review teams is generally aligned with the Regulatory Program boundary of the associated state and Corps district (see Figure 1-1). The structure and practice of each local review team varies between the districts, but application of the sediment evaluation process described herein is consistent across district boundaries.

2.2.1 Portland Sediment Evaluation Team (PSET)

The PSET agencies include the Portland District Sediment Quality Team, EPA-Region 10, Washington Department of Ecology, ODEQ, NMFS, and US Fish and Wildlife Service. The PSET meets weekly to review dredging projects in the state of Oregon.[6] Within the Portland District, the Sediment Quality Team manages the dredging project evaluations for the District's civil works projects and the Regulatory Program, providing technical assistance on the dredging permit process, sediment quality evaluations, and dredged material management issues. PSET staff is available to answer questions, assist in developing SAPs, and help troubleshoot during sediment sampling and testing. The Sediment Quality Team's PSET Lead coordinates SAP and data reviews with the other PSET agencies, prepares the SAP approval letter, and drafts suitability determinations.

[6] Projects proposed by Washington public ports along the Columbia River (from the mouth to river mile 309) are permitted by the Portland District's Regulatory Program and reviewed by the PSET.

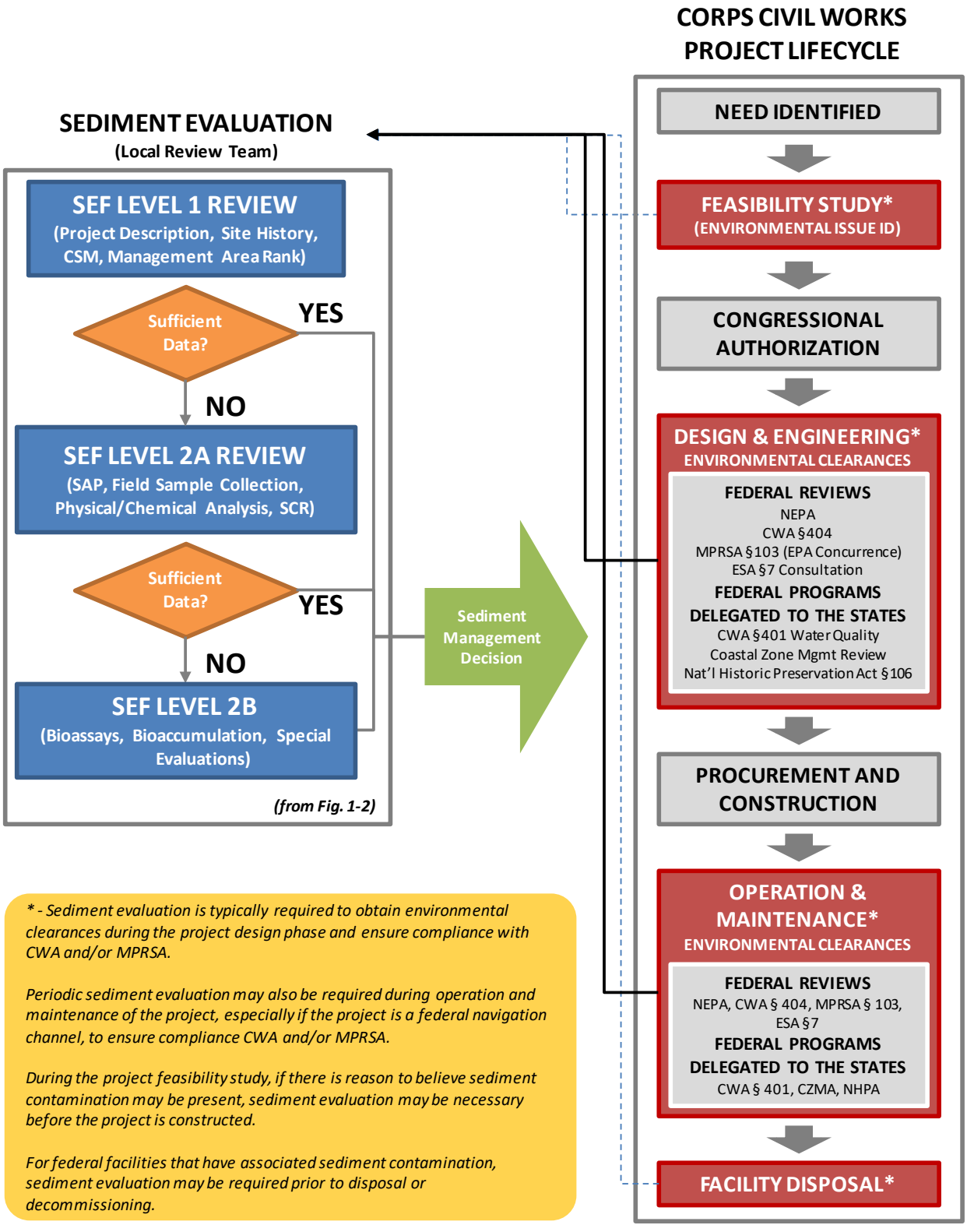


Figure 2-2. Sediment evaluation during the lifespan of a Corps civil works project.

2.2.2 Washington Dredged Material Management Program (DMMP)

The Washington DMMP agencies include the Seattle District Dredged Material Management Office (DMMO), EPA-Region 10, Washington Department of Ecology, and the Washington Department of Natural Resources. The DMMP has published a user manual, which is substantively consistent with guidance in the SEF and provides detailed guidance for projects in the state of Washington. The DMMP meets monthly to review dredging projects in the state of Washington. The Seattle District DMMO manages the dredging project evaluations for the District's civil works projects and the Regulatory Program, providing technical assistance on the dredging permit process, sediment quality evaluations, and dredged material management issues. DMMO staff is available to answer questions, assist in developing SAPs, and help troubleshoot during sediment sampling and testing. The DMMO coordinates SAP and data reviews with the other DMMP agencies, prepares the SAP approval letter, and drafts suitability determinations.

2.2.3 Walla Walla-Idaho Sediment Team

The Walla Walla District civil works staff operates locks and dams on the Snake River and maintains the Snake River federal navigation channel up to Lewiston, Idaho. The Walla Walla District's Regulatory Division handles permit reviews in the State of Idaho. Since maintenance dredging occurs infrequently in the Walla Walla District, the team meets on an as-needed basis. The Walla Walla-Idaho Sediment Team includes staff from Walla Walla District, EPA-Region 10, NMFS, US Fish and Wildlife Service, Ecology (Washington projects), and IDEQ (Idaho projects).

2.3 Dispute Resolution

As it is with the RSET agencies, the local review teams operate by consensus. Each local review team strives to consistently implement the technical and regulatory aspects of the SEF within its geographic area. The local review teams also have the opportunity to coordinate on the RSET's monthly conference call; this regular coordination ensures that the SEF is consistently applied across the Portland, Seattle, and Walla Walla Districts.

On occasion, disagreements may arise. The parties in dispute should attempt to resolve any issues at the lowest possible level. The local review team leader (staffed by the Corps) will manage the dispute resolution process. If the dispute cannot be resolved at the local review team level, the local review team leader will elevate the issue to staff at the appropriate managerial level.

The public review process outlined in Chapter 1 (section 1.3.3) provides a forum for SEF users to bring issues forward.

If users of the SEF identify inconsistencies or errors in the document outside of the RSET public meeting comment period, these issues may be brought to the attention of the RSET chairpersons (Northwestern Division and EPA-Region 10) at any time. The RSET Policy Team will strive to rectify the identified issues in a timely manner.

Chapter 3. SEF Level 1 Evaluation

Both the CWA and MPRSA allow the use of available information to make a preliminary determination concerning the need for dredged material testing. The decision to not perform additional testing must be based on knowledge of site conditions and historical data to provide a "reasonable assurance that the proposed discharge material is not a carrier of contaminants.[7,8]" This principle is known as "reason to believe," and it is the foundation of the Level 1 evaluation.

In the Level 1 evaluation, the proponent defines the project (Section 3.1), compiles historical data (Section 3.2), and develops the conceptual site model (CSM) (Section 3.3). This information is used by the local review team to establish the management area rank (MAR) for the project (Section 3.4) and determine if sediment sampling is necessary using a weight of evidence approach. If existing Level 1 information and subsequent project ranking indicates exposure to a contaminant is minimal, then there is no need to collect further data and sediment management decisions can be made at the end of the Level 1 evaluation (Section 3.5). Level 2 evaluation occurs when data are insufficient for making a decision with the Level 1 information and additional information is needed (Figure 3-1).

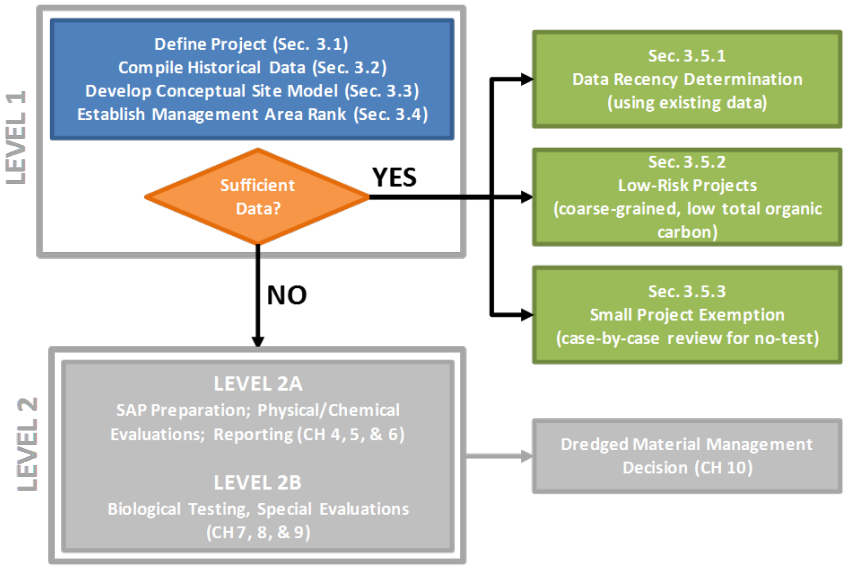


Figure 3-1. Overview of the Level 1 evaluation.

Based on identification of potential sources of contaminants or the results of prior sediment testing in or around the project area, the proponent may already know that sediment chemical and/or physical testing is necessary. In such cases, a sampling and analysis plan (SAP) may be prepared directly (per Chapter 4) without a separate Level 1 information evaluation by the local review team. However, the Level 1 information (i.e., the project description and conceptual dredging plan, site history, CSM, and proposed project MAR) must still be included in the SAP.

[7] CWA, 40 CFR §230.60(b)

[8] MPRSA, 40 CFR §227.13(b)(3)(ii)

3.1 Project Description and Conceptual Dredging Plan

Defining the project is one of the most important steps in sediment evaluation. The requirements for a complete Corps Regulatory permit application are defined at 33 CFR 325.1(d). Similar information is required for the local review team to conduct the Level 1 evaluation. A conceptual dredging plan is the ideal tool to provide a complete project description; the plan should include:

1. Project location, including the area(s) to be dredged and the location(s) of the proposed disposal site(s).
2. A current hydrographic survey showing project drawings, sketches, or plans with the dredging project dimensions clearly labeled: length, width, depth, including advanced maintenance (if planned), over-depth limit, side slope and box cut material, and anticipated sloughing material.
3. Drawings, sketches, or plans showing the site and plans for disposal of the dredged material
4. Figures showing existing storm drainages and outfalls, and special aquatic sites (e.g., wetlands, eelgrass beds, ponds, lakes) relative to the project footprint.
5. Type, composition, and volume of the material to be dredged.
6. Site characteristics that could affect movement of contaminants (e.g., vessel traffic [prop wash, hull displacement, and wakes], river flows, tidal and wave action, bar scalping, and proximity to other dredged sites or channels).
7. Method(s) of dredging.
8. Method(s) of transportation and disposal of the material.

The physical geometry and volume of sediments proposed for dredging must be determined from a pre-sampling bathymetric survey[9]. The total dredging volume calculation should include the material within the authorized project prism, advanced maintenance material (if proposed), over-depth material, material dredged from side slopes and box cuts, and sediments anticipated to slough from under piers and wharves (Tavolaro et al., 2007). For habitat restoration projects, terrestrial topographic surveys and proposed cut-fill lines, waterline (ordinary high water mark or mean higher high tide line), and wetland boundaries should be included in the project design drawings. This information will be used to establish dredged material management units (DMMUs) across the dredging projects. These terms are discussed in Chapter 4.

3.2 Site History Information

The Level 1 site history information helps identify if contaminants may occur in project sediments and if, as identified later in the CSM, ecological receptors (benthic organisms, fish, humans, etc.) may be exposed to contaminants released from dredging or disposal activities. This information, along with the detailed project description, is critical to help the local review team understand the project implementation and the potential risks presented by the dredging and disposal action(s).

[9] Hydrographic survey data should be collected, edited, and provided in accordance with the Corps' November 30, 2013 Engineering and Design Hydrographic Surveying Technical Guidance Manual No. 1110-2-1003.

The Level 1 site history information should summarize both past and present sources of contaminants that may influence sediment chemistry in the dredging area. The CSM (Section 3.3) development is also based on critical components derived from the site history. Local review teams use the site history information to establish the MAR (Section 3.4). The project ranking helps the local review team decide if physical and/or chemical testing is necessary. If sampling is required, the ranking is used to establish the number of field samples and DMMUs necessary to adequately characterize the dredged material (and the post-dredge surface, if applicable).

The following outline identifies the information that must be included in the Level 1 site history information:

1. Prior and current land uses within the watershed that may have contributed contaminants to sediment in the project area and adjacent lands.
2. Outfalls information, such as construction year, type, flow volume (capacity), and National Pollution Discharge Elimination System (NPDES) data. Industrial processes at or near the site and hazardous substances used/generated at these sites. Atmospherically deposited pollutants within the airshed.
3. Specific information on environmental cleanups, brownfields, leaking underground storage tanks, etc.:
    a. For the State of Oregon: *http://www.oregon.gov/DEQ/*. Specific site information can be found at: *http://www.deq.state.or.us/lq/ecsi/ecsiquery.asp?listtype=lis&listtitle=Environmental+Cleanup+Site%20Information+Database*.
    b. For the State of Washington: *https://ecology.wa.gov/Spills-Cleanup* or *https://ecology.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-sites/Locate-contaminated-sites*.
    c. For the State of Idaho: *http://www.deq.idaho.gov/waste-mgmt-remediation/*.
4. CERCLA-listed site information. See *http://www.epa.gov/superfund/sites/npl/index.htm*
5. Spill events. These sites may provide information: *https://fortress.wa.gov/ecy/coastalatlas/storymaps/spills/spills_sm.html?&Tab=nt3*; *https://fortress.wa.gov/ecy/facilitysite/MapData/MapSearch.aspx?RecordSearchMode=New* *http://www.deq.state.or.us/lq/ecsi/ecsiquery.asp?listtype=lis&listtitle=Environmental+Cleanup+Site%20Information+Database*.
6. Results of any previous sediment and biological testing presented in tables side-by-side with the most recent SEF benthic toxicity screening levels and bioassay interpretive criteria.
7. Any historical dredging activity and data/information from that activity.

3.3 Conceptual Site Model

The CSM is an illustrative and written tool that identifies contaminant release mechanisms in the dredging project and the potential pathways by which receptor organisms could be exposed to contaminants during and after the dredging operation. These concepts are illustrated in Figure 3-2.

Development and refinement of the CSM helps identify investigative data gaps in the sediment characterization process and ultimately supports regulatory decision making (e.g., new sediment chemical

data collected in the dredge area may trigger changes to the project, which may in turn change the CSM). The types of contaminants present in the dredged material and their persistence and ability to be metabolized by receptor organisms may also influence the CSM.

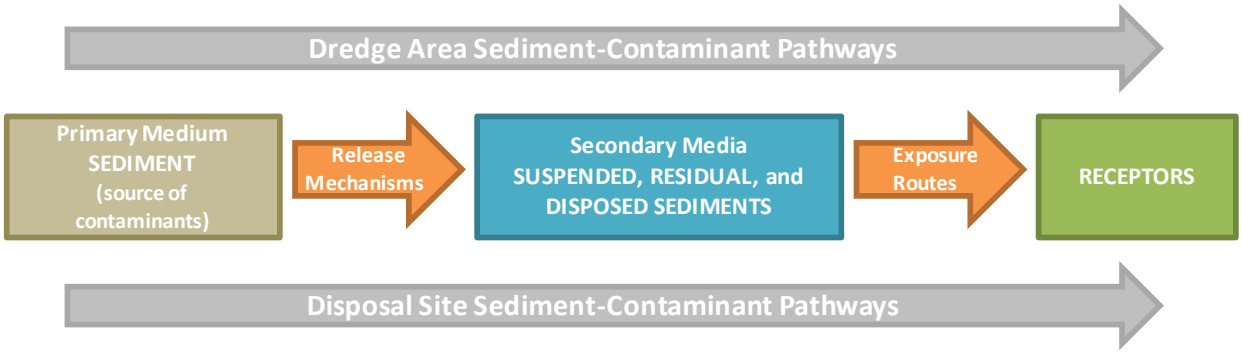


Figure 3-2. Conceptual Diagram of CSM Processes and Pathways.

For the purposes of this guidance, the SEF CSM only focuses on the aquatic portions of the dredging project. However, the CSM can be expanded to include other disposal options (e.g., upland confined disposal facilities) and receptor organisms (e.g., terrestrial animals). The Corps' (2003) *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual* can be used to evaluate these pathways. Other state regulatory programs (state cleanup programs, state section 402 (CWA) NPDES programs, and ODEQ Solid Waste Program) may also have state-specific requirements to evaluate these contaminant pathways.

The CSM worksheet (Table 3-1) is used to illustrate the project-specific release mechanisms and the completeness of various exposure routes connecting sediment-borne contaminants with potential receptor organisms. These pathways may be broken or rendered insignificant by controlling release mechanisms and/or reducing or eliminating contaminant exposure routes to potential receptors. The CSM worksheet should be completed as though contaminants are present in the sediment. The detailed project description will help the CSM preparer determine if a particular pathway is "complete," "complete but insignificant," or "incomplete" (see definitions below). The CSM should also consider receptor lifecycles (e.g., are anadromous fish runs active in the project area, what is the timing of project implementation relative to particularly sensitive life stages of receptor organisms?).The act of dredging releases sediment as secondary media; receptor organisms can be exposed to these secondary media through the direct contact and dietary exposure routes.

The CSM must be presented in narrative format with the other Level 1 information and should also be presented graphically, per Table 3-1. The CSM narrative should support and justify the completeness of each pathway. Terminology associated with the CSM is defined in sections 3.3.1, 3.3.2, and 3.3.3. Examples are provided in section 3.3.4.

3.3.1 Secondary Media and Release Mechanisms

The following terms (*adapted from* Bridges et al., 2008) appear in the CSM and describe the secondary media (in bold) and their respective release mechanisms for contaminants at the dredging and disposal

areas:

***Suspended Sediment, Dredge Area (Water Column)* –** Dislodging, resuspension, and/or dispersal of bedded sediment particles into the water column at the dredge area

***Generated Residuals* –** Redeposition (at the dredge area) of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing

***Undisturbed Residuals* –** Exposure of buried sediments by dredging

***Suspended Sediment, Disposal Site (Water Column)* –** Suspension (release) of sediment in the water column during disposal

***Disposal Material* –** Deposition of dredged sediment at the disposal site

3.3.2 Exposure Routes

There are two types of exposure routes by which receptors are exposed to, and potentially affected by, secondary media:

Direct Contact The receptor organism comes into direct, physical contact with sediment-borne contaminants (secondary media) released during the dredging and/or disposal operation, either through contact with contaminated sediment particles or when contaminants are liberated from particles into the water column.

Dietary (Food and Water) Uptake and Contaminant Accumulation in Tissue The receptor organism 1) ingests sediment directly and accumulates sediment-borne contaminants in their tissue, or 2) consumes contaminated plant matter or other organisms and accumulates contaminants in its tissue (tertiary media).

Table 3-1. Conceptual Site Model for Dredging and Disposal Activities.

Secondary Media (Generated by Dredging) Release Mechanisms (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		**Receptors and Habitat**				
			Benthic Inverts	Fish	ESA Species	Birds/Mammals	Humans
DREDGE AREA PATHWAYS (between the sediment and receptors in the dredge area)							
Suspended Sediment (Water Column) Resuspension of sediment during dredging →	Direct Contact →						
	Dietary →	Tertiary Media (Tissue) →					
Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →						
	Dietary →	Tertiary Media (Tissue) →					
Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →						
	Dietary →	Tertiary Media (Tissue) →					
UNCONFINED, AQUATIC DISPOSAL PATHWAYS* (between disposed sediment and disposal site receptors)							
Suspended Sediment (Water Column) Suspension of sediment during disposal and release of interstitial water →	Direct Contact →						
	Dietary →	Tertiary Media (Tissue) →					
Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →						
	Dietary →	Tertiary Media (Tissue) →					

Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete

***** Other disposal options (confined aquatic disposal, upland confined disposal, etc.) are briefly described in Chapter 10. However, the evaluation of contaminant pathways and receptor exposure routes associated with confined disposal facilities is outside the scope of the SEF review.

3.3.3 Pathway Completeness

As stated above, the CSM worksheet should be completed as though contaminants are present in the sediment. Across both secondary and tertiary media, and in consideration of the exposure routes, the pathway completeness is determined for each potential receptor. The pathway completeness terminology is defined with examples below.

Complete In a complete pathway, contaminants in sediment are released through one or more of the mechanisms identified above, and the receptors may be exposed to contaminants by direct contact or dietary exposure route. Examples of complete pathways include direct exposure of fish and benthic organisms to contaminants in resuspended sediments. The surface exposed after the dredging operation

may include both undisturbed (in-situ) residual contamination as well as residuals from the dredge prism that settled over the dredge area (generated residuals).

Complete but Insignificant Complete but insignificant pathways could occur as follows:

- The contaminants are released through one or more of the release mechanisms identified above, but receptor exposure is reduced in time and/or space. For example, if dredging is conducted at the beginning or end of a salmonid work window, then salmon are less likely to come into direct contact with contaminants suspended or dissolved in the water column; they are not expected to be present, or would be present in extremely reduced numbers. Another example of a complete but insignificant pathway might include human exposure to bioaccumulatives in undisturbed residuals via the dietary exposure route: if the dredge area contribution to human food supply is sufficiently small, then the dietary pathway may be rendered complete but insignificant.
- Receptors are present in or near the dredge area, but release mechanisms are controlled to limit receptor exposure. For example, contaminant resuspension and generated residuals may be significantly reduced by using an environmental bucket in areas with little debris. Another example of limiting contaminant release includes the use of best management practices such as silt curtains or other forms of containment to minimize dispersal of resuspended contaminants.

Incomplete Pathways and exposure routes may be rendered incomplete in one of four ways:

- Release of potential contaminants is contained such that one or more receptor pathways are broken. For example, if dredging is conducted "in the dry" when water levels are low, then receptor pathways through the water column and settled sediment media would be incomplete. Complete work area isolation (e.g., by installing coffer dams or working on the shoreward side of a sheet pile wall) would also render one or all of the pathways incomplete.
- Receptors are physically or temporally excluded from the dredging/disposal operation. For example, humans are unlikely to come into direct contact with undisturbed residuals exposed at a deep draft berth.
- The secondary media (and corresponding release mechanisms) are absent from the project. For example, if sediment is dredged from the toe of a concrete boat ramp, then the pathways and exposure routes for undisturbed residuals would be rendered incomplete.
- Project design eliminates pathways. If the project proponent proposes to place the dredged material in an upland location, then the disposal site pathways are all rendered incomplete.

3.3.4 Conceptual Site Model Examples

Completing the CSM worksheet can be a daunting task, especially if the preparer is unfamiliar with the SEF or has never participated in cleanup site investigations. Examples of the CSM worksheet and narrative have been prepared for four types of projects. An alternative example of the "moderate volume" project is also provided to illustrate the iterative nature of the CSM:

- Small volume, short duration, shallow-draft new work and maintenance dredging project
- Moderate volume, moderate duration, deep-draft new work dredging project and alternative scenario informed by sediment chemical and biological data

- Large volume, long duration, deep-draft maintenance dredging project
- Small volume, moderate duration restoration project with beneficial use of dredged material

Example 1 Narrative and CSM Worksheet: Columbia River Bar Pilots, Astoria, Oregon

Project Location:	Astoria, Oregon
Waterbody/river mile (RM):	Columbia River/14.8
Total proposed dredging volume (cy):	~200 (new work) + 400 (maintenance) = ~600 (five yr. total)
Max. proposed dredging depth:	-10 ft. MLLW
Dredging area:	~0.12 ac.
Dredging method:	Cutterhead pipeline
Dredged material transport:	Pipeline
Proposed disposal location(s):	In-water, dispersive (adjacent flowlane) in 30-70 ft. of water
Proposed dredging date(s):	<1 week during the In-water work window (Oct. 1 to Dec. 31)

Example 1. Conceptual Site Model for Dredging and Disposal Activities, Columbia River Bar Pilots Dredging Project, Astoria, Oregon.

Secondary Media (Generated by Dredging) and Associated Release Mechanisms (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		**Receptors and Habitat**				
			Benthic Inverts	Fish	ESA Species	Birds/Mammals	Humans
DREDGE AREA PATHWAYS (between the sediment and receptors in the dredge area)							
Suspended Sediment (Water Column) Resuspension of sediment during dredging →	Direct Contact →		I	I	I	I	X
	Dietary →	Tertiary Media (Tissue) →	I	I	I	I	I
Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
UNCONFINED, AQUATIC DISPOSAL PATHWAYS (between disposed sediment and disposal site receptors)							
Suspended Sediment (Water Column) Suspension of sediment during disposal and release of interstitial water →	Direct Contact →		I	I	I	I	X
	Dietary →	Tertiary Media (Tissue) →	I	I	I	I	I
Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		I	I	I	I	X
	Dietary →	Tertiary Media (Tissue) →	I	I	I	I	I
Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete							

Sources of Sediment Contamination – The project is located along the south bank of the Columbia River in the lower estuary. This waterfront area of Astoria, Oregon, historically supported canneries and lumber mills. This portion of the shoreline is currently used for shallow and medium draft navigation, moorage of small and large boats, and recreation. The shoreline and aquatic areas are significantly altered with riprap, bulkheads, piers and wharves, treated and untreated pilings, and docks. Possible contaminants include heavy metals, PAHs, and petroleum hydrocarbons. The project is adjacent to the bank in quiescent waters, and fine-grained sediments are likely.

Secondary Media (Dredge Area) – At the dredge area, the cutterhead pipeline dredge will not likely suspend sediments into the water column. Dredged sediment is hydraulically pumped in a slurry through the pipeline from the cutterhead to the point of discharge at the end of the pipeline, and sediment suspended near the cutterhead would be sucked up through the pipeline.

Generated residuals may result from fallback at the cutterhead; side slope material may also slough into the dredge area. Because the initial round of dredging is new work, the undisturbed residuals are anticipated to be composed of native, uncontaminated sediments.

Secondary Media (Disposal Site) – At the dispersive flow lane disposal site, suspended sediments are expected in the water column at the end of the pipeline and downstream. However, suspended sediments will only be an issue during dredging, which is expected to take less than one week to complete.

Due to the small volume (200 cy) and short duration of the dredging project (<1 week), disposed material will be dispersed from the point of discharge in less than one week.

Benthic Invertebrates, Fish, and ESA-listed Fish Receptors – These receptors that recolonize or occupy the dredge area and surrounding area could be exposed to contaminants in generated residuals and undisturbed residuals via direct contact and dietary uptake. At the site of dredging, the pathway was considered complete but insignificant for both direct and dietary exposures due to the minimization of suspended sediments. Generated and undisturbed residuals pathways are considered complete for both direct and dietary exposures. At the disposal site, these receptors could be temporarily exposed to suspended sediments and disposed material at the disposal site. However, these pathways were determined to be complete, but insignificant, because the flow lane disposal site is dispersive, the project volume, and the short duration of the project.

Aquatic-Dependent Bird and Mammal Receptors – Birds and mammals were evaluated jointly in the CSM. For the birds, seabirds (gulls, shearwaters, terns, etc.) and waterfowl (ducks, mergansers, loons, grebes, etc.) were considered. Sea lions, seals, and otters were considered for the mammals. All pathways were determined to be complete but insignificant for these receptors due to their wide foraging ranges, the duration of the project, and the short residence period, minimization of suspended sediments at the dredge site, and low volume of the dredged material at the disposal site.

Human Receptors – All direct exposure pathways to human receptors were determined to be incomplete. However, all dietary pathways were determined to be complete but insignificant, because it is assumed that humans may hunt or fish in the dredge area or the disposal site.

Example 2 Narrative and CSM Worksheet: Port of Seattle T-5, Seattle, Washington

Project Location:	Seattle, Washington
Waterbody/river mile (RM):	West Waterway, mouth of the Duwamish R.
Total proposed dredging volume (cy):	51,000 cy (new work)
Max. proposed dredging depth:	-58 ft. MLLW (includes 1 ft. advanced maintenance and 2 ft. overdepth allowance)
Dredging area:	~18 ac.
Dredging method:	Clamshell
Dredged material transport:	Tug and dumping scow
Proposed disposal location(s):	Elliott Bay non-dispersive disposal site (300-360 ft. water depth)
Proposed dredging date(s):	3 weeks during the in-water work window (July 16 to Feb 15)

Example 2. Conceptual Site Model for Dredging and Disposal Activities, Port of Seattle, Terminal 5.

Secondary Media (Generated by Dredging) and Associated Release Mechanisms (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		**Receptors and Habitat**				
			Benthic Inverts	Fish	ESA Species	Birds/Mammals	Humans
DREDGE AREA PATHWAYS (between the sediment and receptors in the dredge area)							
Suspended Sediment (Water Column) Resuspension of sediment during dredging →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
UNCONFINED, AQUATIC DISPOSAL PATHWAYS (between disposed sediment and disposal site receptors)							
Suspended Sediment (Water Column) Suspension of sediment during disposal and release of interstitial water →	Direct Contact →		I	I	I	I	X
	Dietary →	Tertiary Media (Tissue) →	I	I	I	I	I
Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I

Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete

Sources of Sediment Contamination – The project is located in Seattle's industrialized West Waterway just downstream of the Lower Duwamish Waterway Superfund Site. Terminal 5 provides berthing space for container ships and a rail line to transport containers to and from the terminal. Historically, T-5 was home of the Ames Shipbuilding and Drydock Co.; land from the Bethlehem Pacific Coast Steel Co. was also purchased to expand the terminal. The Wycoff Plant, also on current Port property, produced creosote-treated timber piles for marine construction. The EPA added T-5 to its list of Superfund sites in 1983. Remediation included the removal of 8,000 tons of contaminated soil and onsite capping of less contaminated soils; the T-5 cleanup was completed in 1997. The last round of sediment testing was performed in 2013 to support maintenance dredging at T-5 to -47 ft. (south end) and -52 ft. MLLW (north end); all 7,500 cy were determined to be unsuitable for aquatic disposal.

Upstream of T-5, the Lower Duwamish has been industrialized since the early 1900s. Early activities included operation of sawmills, lumber yards, wood treatment facilities, cement and brick companies, steel mills and foundries, and marine construction. Waste disposal practices in the 1950s and earlier included local landfills for solid waste, soil infiltration for liquid waste, and direct disposal of liquid and solid waste into the waterway. Hazardous substances from upland industrial activities entered the environment through spills, leaks, dumping, and other inappropriate management practices. Current industrial uses include shipyard operations, manufacturing (airplane, cement, and chemical, e.g., paint, glue, resin, and wood preservatives), cargo storage and transport, metal manufacturing and recycling, and petroleum storage.

Secondary Media (Dredge Area) – At the dredge area, suspended sediments will likely be generated from the clamshell dredging operation; suspended sediments are only expected to be present for the duration of the dredging operation. Generated residuals will likely include fallback from the dredge bucket and sloughing of sediment from the T-5 pier face. The proposed dredging is new work to deepen the existing facility by approximately 7 feet. Due to the historical land uses upstream and adjacent to the dredge area, pockets of undisturbed, residual contaminants may be exposed. Both generated and undisturbed residuals are expected to persist after dredging is completed. Sediments of uncertain quality, transported from upstream of T-5, are expected to accumulate in the dredge area.

Secondary Media (Disposal Site) – Suspended sediment will be intermittently generated after each load is dumped at the Elliott Bay disposal site. The T-5 dredged material will remain exposed to the aquatic environment until additional dredged material from other projects covers the disposed material.

Benthic Invertebrates, Fish, and ESA-listed Fish Receptor – Pathways from suspended sediment, generated residuals, and undisturbed residuals to these receptors would be complete in the dredge area, because dredging activity would be constant throughout the duration of the project. At the disposal site, pathways to these receptors from both suspended sediment and the disposal material were determined to be complete. However, the suspended sediment pathway was determined to be insignificant due to the intermittent nature of disposal at the Elliott Bay disposal site.

Aquatic-Dependent Bird and Mammal Receptors – Birds and mammals were evaluated jointly in the CSM. For the birds, seabirds (gulls, murres, murrelets, shearwaters, terns, etc.) and waterfowl (ducks, mergansers, loons, grebes, etc.) were considered. Sea lions, seals, and sea otters were the mammals considered for this CSM. All pathways were determined to be complete but insignificant for these receptor organisms due to their wide foraging ranges and the moderate duration of the project.

Human Receptors – All direct exposure pathways to human receptors were determined to be incomplete as it is unlikely that people would have direct contact to either dredge material or water containing suspended sediments. However, all dietary pathways at the dredge area and disposal area were determined to be complete but insignificant because it is assumed that humans may fish or hunt animals that used either the dredge area or the disposal site, but the organisms that might be consumed (fish, crab) would have minimal exposure due to their wide foraging ranges.

Alternative Example 2 Narrative and CSM Worksheet: Port of Seattle T-5, Seattle, Washington

This example illustrates how the project CSM can change with new data. From the previous example, current and historical contaminant sources and land uses remain constant. In this example, Level 2A sediment testing was completed for eight dredged material management units (DMMUs) and underlying Z-layer (post-dredge surface) sediments. All DMMUs were determined to be suitable for unconfined, aquatic disposal. However, the Z-layer sediments beneath DMMU 1 exceeded the marine screening level for total PCBs. The Port performed Level 2B marine, solid-phase, toxicity bioassays on the DMMU 1 Z-layer sediment. The test sediment did not meet SEF, Chapter 7 performance criteria, and the toxicity tests failed. The post-dredge surface beneath DMMU 1 was determined to be unsuitable for unconfined aquatic exposure.

Based on these results, the Port evaluated measures that would reduce/eliminate the exposure of the contaminated post-dredge surface. The Port proposed to overdredge DMMU 1 by one foot, and place a 1-foot sand cover over the contaminated post-dredge surface. The following CSM worksheet illustrates how project modifications can reduce or eliminate contaminant exposure.

Placement of a post-dredge sand cover renders all direct and dietary exposure pathways to ecological and human receptors at the dredge area incomplete. Additionally, the sand cover effectively isolates residuals generated from fallback and redeposition of suspended sediment; the only source of generated residuals is potential sloughing of the pier face material. As such, the direct and dietary exposure pathways for generated residuals remained classified as complete, but insignificant.

Alternative Example 2. Conceptual Site Model for Dredging and Disposal Activities, Port of Seattle, Terminal 5 with post-dredge surface management.								
Secondary Media (Generated by Dredging) and Associated Release Mechanisms (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		**Receptors and Habitat**				
			Benthic Inverts	Fish	ESA Species	Birds/Mammals	Humans
DREDGE AREA PATHWAYS (between the sediment and receptors in the dredge area)							
Suspended Sediment (Water Column) Resuspension of sediment during dredging →	Direct Contact →		**C**	**C**	**C**	**I**	**X**
	Dietary →	Tertiary Media (Tissue) →	**C**	**C**	**C**	**I**	**I**
Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →		**I**	**I**	**I**	**I**	**X**
	Dietary →	Tertiary Media (Tissue) →	**I**	**I**	**I**	**I**	**I**
Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		**X**	**X**	**X**	**X**	**X**
	Dietary →	Tertiary Media (Tissue) →	**X**	**X**	**X**	**X**	**X**
UNCONFINED, AQUATIC DISPOSAL PATHWAYS (between disposed sediment and disposal site receptors)							
Suspended Sediment (Water Column) Suspension of sediment during disposal and release of interstitial water →	Direct Contact →		**I**	**I**	**I**	**I**	**X**
	Dietary →	Tertiary Media (Tissue) →	**I**	**I**	**I**	**I**	**I**
Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		**C**	**C**	**C**	**I**	**X**
	Dietary →	Tertiary Media (Tissue) →	**C**	**C**	**C**	**I**	**I**
Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete							

Example 3 Narrative and CSM Worksheet: Coos Bay Federal Navigation Channel, Coos Bay-North Bend-Charleston, Oregon

Project Location:	Coos Bay-North Bend-Charleston, Oregon
Waterbody/river mile (RM):	Coos Bay/RM 0-50 to 12+00
Total proposed dredging volume (cy):	800,000 cy (annual maintenance)
Max. proposed dredging depth:	-40 ft. MLLW (includes 3 ft. advanced maintenance)
Dredging area:	~90 ac. (channel acreage = ~360 ac.)
Dredging method:	Hopper dredge
Dredged material transport:	Hopper dredge
Proposed disposal location(s):	Ocean Dredged Material Disposal Site F (20-160 ft. water depth) Site F from 20-60 ft. is dispersive; 60-160 ft. is semi-dispersive to non-dispersive
Proposed dredging date(s):	6 to 8 weeks (between May 1 and Oct 31)

Example 3. Conceptual Site Model for Dredging and Disposal Activities, Coos Bay Federal Navigation Channel (RM 0-50 to 12+00).

Secondary Media (Generated by Dredging) and Associated Release Mechanisms (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		**Receptors and Habitat**				
			Benthic Inverts	Fish	ESA Species	Birds/Mammals	Humans
DREDGE AREA PATHWAYS (between the sediment and receptors in the dredge area)							
Suspended Sediment (Water Column) Resuspension of sediment during dredging →	Direct Contact →		X	X	X	X	X
	Dietary →	Tertiary Media (Tissue) →	X	X	X	X	X
Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
UNCONFINED, AQUATIC DISPOSAL PATHWAYS (between disposed sediment and disposal site receptors)							
Suspended Sediment (Water Column) Suspension of sediment during disposal and release of interstitial water →	Direct Contact →		X	X	X	X	X
	Dietary →	Tertiary Media (Tissue) →	X	X	X	X	X
Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		C	C	C	I	X
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I
Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete							

Sources of Sediment Contamination – The Coos Bay federal navigation project is located on the southern Oregon Coast, approximately 200 miles south of the Columbia River. There are approximately 30 tributaries feeding the estuary, but the main stem flow is provided by the Coos River, which discharges to the bay at a point 14 miles from the estuary mouth. The federal channel provides deep draft navigation access for bulk carriers transporting logs across the Pacific Ocean to markets in East Asia. Sediment from the Coos Bay entrance bar up to river mile 12 is sandy material; this is because this reach is dominated by strong river and tidal currents. Sediments from river mile 12 to 15 tend to be mixed sand, silty sand, silt, and organic silt. Sediment quality investigations have been carried out in 1980, 1989, 1994, 1995, 1998, 1999, 2004, 2009, and most recently in 2014. Dredged material from the federal channel has been determined to be suitable for aquatic disposal in multiple rounds of sampling. The federal channel is almost exclusively dredged by the Portland District's hopper dredges, *Yaquina* and *Essayons*.

Off-channel berths have also been sampled and analyzed for contaminants per the SEF; generally, dredged material from these facilities has been determined suitable for unconfined, aquatic disposal as well. Sources of contamination include urban runoff inputs from the cities of Coos Bay, North Bend, and Charleston. Industries along the federal navigation channel are primarily related to wood products (wood chip and timber export facilities).

Secondary Media (Dredge Area) – Suspended sediments at the dredge area are minimal, because dredging is performed hydraulically with a hopper dredge. As such, the suspended sediment exposure pathway was determined to be insignificant for all receptors. Sand is slurried up the drag arms into the hopper, and there is virtually no opportunity for sediment to go into suspension. Any sand that does go into suspension as the drag arms are lifted off the river bottom rapidly falls back. Generated residuals primarily consist of side slope movement of sand. Undisturbed residuals are exposed by dredging, but by the next dredging season, these sediments are covered by new deposition.

Secondary Media (Disposal Site) – Based on grain size data, residence time of the Coos Bay federal channel material is ephemeral at Site F, ranging from 2 to 15 minutes per disposal event.

Benthic Invertebrate, Fish, and ESA-listed Fish Receptors – Since both dredging method and disposal site characteristics minimize the presence of suspended sediments, benthic organisms, fish, and ESA-listed fish would not be affected by suspended sediment at either the dredge area or at the disposal site; however, all other exposure pathways (generated and undisturbed residuals, and the disposed dredged material) would be complete.

Aquatic-Dependent Bird and Mammal Receptors – Birds and mammals were evaluated jointly in the CSM. For the birds, seabirds (gulls, murres, murrelets, shearwaters, terns, etc.) and waterfowl (ducks, mergansers, loons, grebes, etc.) were considered. Sea lions, seals, and sea otters were the mammals considered for this CSM. The suspended sediment pathways at the dredge area and disposal site were determined to be incomplete due to dredging method and ephemeral suspended sediments at the disposal site. All other exposure pathways (generated and undisturbed residuals, and the disposed dredged material) were determined to be complete or complete, but insignificant.

Human Receptors – All direct exposure pathways to human receptors were determined to be incomplete. However, all dietary pathways at the dredge area were determined to be complete, but insignificant, because it is assumed that humans may fish or hunt animals that used either the dredge area or the disposal site.

Example 4 CSM Narrative: Beneficial use of Port of Ilwaco dredged material for restoration at Willapa National Wildlife Refuge, Washington

Project Location:	Ilwaco, Washington
Waterbody/river mile (RM):	Columbia River (Baker Bay)/ RM 3 to 4
Total proposed dredging volume (cy):	About 15,000 cy
Max. proposed dredging depth:	Boat basin maintain to depths between -6 and -12 ft. MLLW; Up to 12 feet of material excavated from upland disposal cells
Dredging area:	Boat basin: ~40 acres
Upland disposal facility area (extraction site):	2.3 acres
Dredging method:	Pipelined from boat basin to disposal site; Excavated mechanically for transport to restoration site
Dredged material transport:	Overland via dump truck to restoration site
Proposed disposal location(s):	Upland and shoreline restoration sites at Willapa NWR
Proposed dredging date(s):	September to October 2017

Example 4. Conceptual Site Model for beneficial use of Port of Ilwaco dredged material for restoration at Willapa National Wildlife Refuge.

Secondary Media (Generated by Dredging) and Associated Release Mechanisms (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		**Receptors and Habitat**				
			Benthic Inverts	Fish	ESA Species	Birds/Mammals	Humans
DREDGE AREA PATHWAYS (between the sediment and receptors in the dredge area)							
Suspended Sediment (Water Column) Resuspension of sediment during dredging →	Direct Contact →		X	X	X	X	X
	Dietary →	Tertiary Media (Tissue) →	X	X	X	X	X
Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →		X	X	X	I	I
	Dietary →	Tertiary Media (Tissue) →	X	X	X	I	X
Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		X	X	X	I	I
	Dietary →	Tertiary Media (Tissue) →	X	X	X	I	X
UNCONFINED, AQUATIC DISPOSAL PATHWAYS (between disposed sediment and disposal site receptors)							
Suspended Sediment (Water Column) Suspension of sediment during disposal and release of interstitial water →	Direct Contact →		I	I	I	I	I
	Dietary →	Tertiary Media (Tissue) →	I	I	I	I	X
Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		C	C	C	I	I
	Dietary →	Tertiary Media (Tissue) →	C	C	C	I	I

Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete

Backgound - The Port of Ilwaco's maintenance dredging project is located along the south bank of the Columbia River in the lower estuary (northwest side of Baker Bay) in Ilwaco. The Port of Ilwaco periodically conducts maintenance dredging of the Port of Ilwaco Boat Basin (boat basin) to remove accumulated material and restore depths for boats using the basin. The Port's upland disposal facility is located alongside the boat basin and maintenance material from the boat basin is pipelined into the facility.

Material disposed at the upland facility is being considered for beneficial use in an aquatic habitat restoration project on Willapa Bay by the Willapa National Wildlife Refuge. Refuge staff expressed concerns about potential contamination of the material and requested a chemical characterization to ensure the material can be used for habitat enhancement efforts that would benefit aquatic organisms. In this example, the upland disposal facility that received dredged material from the boat basin is the dredged material extraction site. The disposal site for the material proposed for removal from the dredged material extraction site is the restoration area on the refuge. *Sources of Sediment Contamination* – The Port of Ilwaco dredges approximately 1 to 3 feet of accumulated sediment from the boat basin each year, with a maximum annual volume of 50,000 cubic yards. The sediment in the boat basin is ranked "low" based on multiple consecutive sampling events within the boat basin and in the Federal Navigation channel near West Baker Bay. Potential sources of contaminants in the boat basin include petroleum compounds from boat operations and fueling, and other contaminants that may be in sediment transported by the Columbia River from upstream areas and deposited into settling area near the mouth of the river. In 2001, low levels of DDT were found in sediment that was dredged and disposed in the Port's upland facility, which is the extraction site for material proposed for use in restoration.

Secondary Media (Dredged Material Extraction Site) –The dredged material extraction site is upland and not considered aquatic habitat, and berms around the facility would prevent upland material from being transported to aquatic areas. Therefore, no sediments would be suspended in the water column and this pathway was considered incomplete for all receptors. Contaminants could be made available through generated residuals (slope adjustment or failure during or after excavation) or from exposing a new contaminated surface during excavation (undisturbed residuals).

Secondary Media (Restoration Area) – The aquatic habitat on the refuge that will receive the Port of Ilwaco's dredged material is the area of primary concern in this example. Exposure to suspended sediments (and contaminants) in the water column would only occur if the material is placed in existing aquatic habitat. The primary concern at the restoration area is that receptors will be attracted to the restored habitat and become exposed via direct contact with the dredged material or dietary exposure.

Benthic Invertebrate Receptors – The benthic invertebrate receptor pathway is incomplete at the dredged material extraction site because they are not present. At the restoration area, benthic organisms could be exposed by direct contact or dietary routes during restoration, but the duration of exposure would be considered short and insignificant or the organisms would be disrupted by the physical disturbance of habitat manipulation. Since benthic organisms that recolonize the restoration area could be exposed to contaminants in the disposal material used for the restoration project via direct contact and dietary uptake, the pathway from these two routes of exposure is considered complete.

Fish and ESA-listed Fish Receptors – The fish and ESA-listed fish receptor pathway is incomplete at the dredged material extraction site because fish are not present. At the restoration area, fish could be

exposed by direct contact or dietary routes during restoration, but they would likely avoid the area due to disturbance during project construction and the duration of exposure would be considered short and insignificant. Since fish (including ESA-listed species) that occupy or would eventually be attracted to the restoration area could be exposed to contaminants in the disposed residuals via direct contact and dietary uptake, the pathway from these two routes of exposure are considered complete.

Aquatic-Dependent Bird and Mammal Receptors – Birds and mammals were evaluated jointly in the CSM. Seabirds (gulls, shearwaters, terns, etc.) and waterfowl (ducks, mergansers, loons, grebes, etc.) were considered, along with mammals such as sea lions, seals, and otters. Exposure to suspended sediment within the water column at the dredged material extraction site was considered incomplete because the project area is upland. The remaining pathways at the dredged material extraction site and the restoration area were considered complete for both the direct contact and dietary exposure routes, but insignificant due to the wide foraging ranges and the relatively short duration of excavation or restoration activities.

Human Receptors – At the dredged material extraction site, the water column exposure pathway was incomplete because the project is upland. The direct exposure route to human receptors for the generated and undisturbed residuals was determined to be a complete pathway due to inhalation of dust during excavation and other activities at both project areas. However, exposure would likely be insignificant due to near background concentrations observed in samples previously collected from material disposed at the facility, and the short duration of exposure. The dietary exposure route for the generated and undisturbed residuals pathway was determined to be incomplete at the dredged material extraction site because it is unlikely that terrestrial animals at the facility are hunted and consumed. At the restoration area, human exposure via direct contact to suspended sediment was considered a complete pathway because exposure could occur during restoration activities, but the exposure was considered insignificant due to the short duration and use of personal protective equipment during placement of materials. The dietary exposure route was considered complete during disposal and deposition of material in the restoration area due to the potential for humans to eat fish that may have used the restoration area, but insignificant due to the small size of the restoration area compared to large range and relatively large size of fish that would use the site and be caught by humans. The dietary exposure route for humans via contaminants in suspended sediment was considered an incomplete pathway due to the short duration of sediments in suspension during restoration activities, and the low likelihood that fish targeted for consumption by humans would be in the area long enough to accumulate bioaccumulative contaminants within the water column.

3.4 Management Area Rank (MAR)

The project MAR is assigned using the lines of evidence from the Level 1 information. The MAR allows judgments to be made on the level of risk for the site. Reaches or sites where sufficient information has been gathered are ranked as one of five possible levels: very low, low, low-moderate, moderate, or high. In that order, the MARs represent a scale of increasing potential for concentrations of contaminants of concern and/or adverse biological effects. Table 3-2 identifies the lines of evidence used to determine the project MAR (PSDDA 1988, DMMP 2015).

Table 3-2 Management area rank definitions.

Management Area Rank	Lines of Evidence to Establish Rank
Very Low	Based on the site history information review, the site is sufficiently removed from potential sources of sediment contamination and there are no known or suspected contaminated sites within the watershed. Bioaccumulative compounds are not likely present at levels of concern based on review of historical data and comparison to region-specific bioaccumulation triggers (Chapter 8). Sites with strong current and/or tidal energy typically consist of coarse-grained sediment with at least 80 percent of the bulk sediment retained in a No. 230 sieve and total organic carbon (TOC) content of less than 0.5 percent†. Typical locations include gravel bars, mainstem channels such as the lower Columbia River, and coastal inlets subject to the ebb and flood of tide.
Low	Low concentrations of non-bioaccumulative contaminants of concern may be present at site (at or below SL values) and/or no significant response in biological tests. Sites have higher percentage of finer grained sediments (and associated organic material) but few sources of potential contamination exist. Bioaccumulative compounds are not likely present at levels of concern based on review of historical data and comparison to region-specific bioaccumulation triggers (Chapter 8). Depositional materials do not originate from or near contaminated areas and do not contain chemical contaminants at levels of concern. Typical locations include areas adjacent to entrance channels, rural marinas, navigable side sloughs, and rural recreational docks.
Low-Moderate	A "low" rank may be warranted for the site, but sufficient data are unavailable to validate the "low" rank.
Moderate	Concentrations of chemicals of concern in project sediments are in a range known to cause adverse response in biological tests. Locations where sediments are subject to sources of contamination, where existing or historical use of the site or contamination within the watershed has the potential to cause sediment contamination, or bioaccumulation has been identified as a potential problem for higher level receptors. Areas characterized with aggregating materials that could have originated near contaminated areas. 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.
High	One or more of the following conditions are present in the project area: high concentrations of contaminants of concern in sediments (relative to screening levels) and/or significant adverse responses in at least one of the last two cycles of biological tests; locations where sediments are subject to numerous sources of sediment contamination, including industrial runoff, past releases, and stormwater outfalls, or where existing or historical use of the site or within the watershed has the potential to cause sediment contamination; bioaccumulation has been identified as a problem for receptors exposed to accumulated sediments that originated from contaminated sources. Typical locations include urban areas and shoreline areas with major industrial development. Projects located within or adjacent to state or federal cleanup sites may require more intensive sampling and/or higher-resolution chemical analyses.
† - These values are guidelines and the local review team may use discretion in their application. Photographic evidence of grain size (e.g., a photo of a gravel bar obstructing navigation) may be sufficient to rank a project "very low" without having the proponent analyze for TOC, because low TOC is presumed. Project sediments may also fall within the appropriate grain size and TOC range, but be located in close proximity to sources of contamination (making the project ineligible for a "very low" management area rank).	

The MAR is used by the local review team to determine the following: 1) the need for sediment testing; 2) the number of stations and samples to be sampled and analyzed; 3) the frequency of testing for projects that are periodically dredged; 4) the sufficiency of existing data to make a dredged material management decision. More than one MAR may be assigned to a single project depending upon the size of the proposed dredging area, volume proposed for dredging, and the distribution of potential contaminant sources. After gathering the Level 1 information, the proponent may propose the MAR for the project. However, the local review team makes the final decision regarding the MAR(s) for the project.

In order to down-rank an area (or individual DMMU, if more than one MAR is assigned), at least two rounds of sampling are required[10]. The MAR will be reviewed and updated by the local review team based on the new sediment testing results or the occurrence of events that may change project conditions, such as spills of hazardous materials or the identification of new chemicals of concern within the watershed. The MAR may be immediately adjusted upward by the agencies based on a single round of elevated chemistry, a bioassay failure, or by adversely changed conditions in or near the dredge area.

3.5 SEF Level 1 Determinations

The Level 1 evaluation concludes with a determination of the MAR and a decision regarding the need for sediment testing. If assessment questions can be satisfactorily addressed using Level 1 information and chemicals of concern can be managed sufficiently, the local review team may be able to make a determination that no testing is required. If Level 1 information is insufficient to make a positive suitability determination, then project sediments must be sampled and tested to document their physical and chemical characteristics. With sufficient information, the local review team may make one of the types of Level 1 determinations described in the following sections.

3.5.1 Data within Recency

Although sediment data do not technically expire, older data may no longer be relevant to the proposed project. Since many dredging projects are located in dynamic environments, the recency guidelines were developed by the RSET agencies to provide a "life expectancy" for project data. The recency-of-data guidelines identify the duration of time for which physical, chemical, or biological information is considered adequate for decision-making without further testing. The recency period is based on the MAR of the subject DMMU(s) (Table 3-3).

The recency guidelines determine how long the local review team's dredged material suitability determination may be used to support new-work or maintenance dredging. Provided that sediments are determined suitable for unconfined, aquatic disposal, dredging may occur during the data recency period without additional sample collection; this is especially important in areas where rapid shoaling occurs.

[10] With the local review team's concurrence, a partial characterization (i.e., analyzing a subset of the SEF chemicals of concern) may be used to down-rank an area.

Table 3-3. Recency of Data†

Management Area Rank	Data Recency Guideline (Years)*
Very Low	10
Low	7
Low-Moderate	6
Moderate	5
High	3
* - At the local review team's discretion, data recency may be extended if project data are slightly beyond the recency guidelines. † - Years from the last date of sample collection (e.g., a moderate-ranked project sampled in May of 2016 would need to be resampled in May 2021).	

If new sources of contaminants (e.g. oil or fuel spills) are identified within the recency period, then data from the prior round of sampling may be determined to be unusable by the local review team, and additional sampling may be required. It is advisable that project proponents be forthright and report any new sources of contamination to the local review team prior to maintenance dredging; this will help avoid aquatic disposal of potentially contaminated material and possible state- or federally-mandated cleanup.

3.5.2 Small Project Evaluations

Chemical analysis of sediments in small-volume projects may be determined to be unnecessary by the local review team due to the potentially lower risk of adverse effects at the dredging and disposal sites. In some cases, proponents of small projects may be able to capitalize on the work of others by using current sediment physical and chemical data from adjacent projects. Since there is significant uncertainty in evaluating risk of potentially contaminated materials without sediment testing, local review teams will make these determinations on a case-by-case basis. The following guidelines will be considered by the local review team during the evaluation of small projects:

- Intentional partitioning of a dredging project to reduce or avoid testing requirements is not allowed.
- Multiple small discharges can cumulatively affect the disposal site; the project volume will be evaluated in as large a context as possible.
    - For multiple rounds of maintenance dredging in a small project, the local review team will consider the total volume proposed over the life permit.
    - For multiple neighboring dredging projects, undertaken by one dredging contractor using a common disposal site, the local review team will consider the total volume of all of the projects over life of each permit.

Areas where threatened and/or endangered species are present may require characterization, even if sediment-borne contaminants are unlikely to occur in the project area. Additionally, there is no exemption from testing within high-ranked areas.

3.5.3 Low-Risk Project Evaluations

Very Low-Ranked Projects Both CWA and MPRSA sediment testing regulations contain provisions which exclude projects from chemical testing[11,12]. Materials deposited by strong river or tidal currents, and predominantly composed of sand, gravel, or other naturally occurring inert material, may not require chemical testing as long as contaminant sources are not present in, near, or up-current of the dredge area. The project proponent may be required to demonstrate that materials in the dredge area meet the guidelines for the "very low" MAR (≥80% of the bulk sediment retained in a No. 230 sieve and ≤0.5% TOC content) by providing photographic and/or analytical evidence of physical characteristics from the site. For very large projects (e.g., the Lower Columbia River federal navigation channel), confirmation samples may still be required to verify sand content and TOC content.

Projects with Isolated Work Areas If projects are planned in such a manner as to render all contaminant pathways incomplete (as documented in the CSM), then sediment sampling may not be required by the local review team, even if contaminants are present at concentrations above the regional benthic toxicity screening levels (SLs). Through the project description and CSM, the project proponent must clearly demonstrate that project area sediments will be isolated during project construction and that project area sediments following construction will not present a contaminant exposure risk to receptors. The determination to test, or not, will be made by the local review team on a project-by-project basis.

3.6 Federal and State Cleanup Actions and the SEF

The guidance regarding sample handling, storage, chemical analysis, and biological testing found in the SEF is consistent with methods used by the state cleanup programs and EPA's federal cleanup program, ensuring consistent data quality across the programs. However, this manual does not provide guidance for characterizing a contaminated site in order to make decisions regarding how the site will be managed. All sediment evaluations for cleanup actions are to be coordinated through the appropriate state and federal cleanup programs. The SEF review does not apply to these projects.

[11] CWA, 40CFR§230.60(a)

[12] MPRSA, 40CFR§227.13(b)

3.7 References

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U.S. Army Corps of Engineers. 2003. "Evaluation of dredged material proposed for disposal at island, nearshore, or upland confined disposal facilities - Testing Manual," Technical Report ERDC/EL TR-03-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Chapter 4. Sampling and Analysis Plan and Field Sampling

After the Level 1 information review, if the local review team determines the site history information is insufficient to make a dredged material management decision, then the Level 2A evaluation is triggered. The Level 2A evaluation involves generating additional chemical and/or physical data to support dredged material and new surface material management decisions, and the SAP identifies the sampling and analytical requirements to generate these data (Figure 4-1). Depending on the project site history information, the proponent may also wish to include Level 2B analyses in the SAP (Level 2B analyses are covered in Chapters 7, 8, and 9). The Level 2B analyses may be conducted concurrently with the chemical and physical testing or directly after Level 2A if the chemical testing results trigger biological testing.

The SAP must be approved by the local review team prior to implementation. The approved SAP serves as an agreement between the local review team, the project proponent, the sampling contractor(s), and the contract lab(s) regarding field sampling methods and laboratory analytical methods that will be used to characterize project sediments. All parties involved with field sample collection need to review and adhere to the approved SAP to ensure that the project DMMUs are correctly sampled. Laboratory staff needs to review and adhere to the approved SAP to ensure the correct laboratory analyses are performed and the laboratory data meet the prescribed data quality objectives. If sampling occurs without an approved SAP, or the field crew/laboratory fails to follow the approved SAP**, and the resultant data are insufficient to support a decision**, the project proponent will be required to resample for the project.

4.1 Sampling and Analysis Plan Preparation

Field sampling and laboratory testing can be the most expensive part of the sediment characterization process. That is why a thorough, detailed, and approved SAP must be in-hand prior to field sampling. **A checklist of the minimum requirements for a SAP appears in section 4.1.1.** The draft SAP must be submitted to the local review team for review and approval. **If the SAP is incomplete**, resubmittal and additional review by the local review team will be necessary prior to proceeding with sampling. If no major modifications to the draft SAP are required, the local review team will issue a memorandum or email allowing sampling and analysis to proceed per the approved SAP. The local review team may also allow implementation of the SAP with minor modifications. Additional guidance is provided for the following topics:

- Allocation of DMMUs (section 4.1.2)
- Post-dredge surface (section 4.1.3)
- Selection of sediment sampling equipment (section 4.1.4)
- Compositing scheme (section 4.1.5)
- Conventional parameters and physical screening (section 4.1.6)
- Sampling approaches for full characterization (section 4.1.7)
- Chemical analyses (section 4.1.8)
- Biological testing and special evaluations (section 4.1.9)
- Timing of sampling (section 4.1.10)

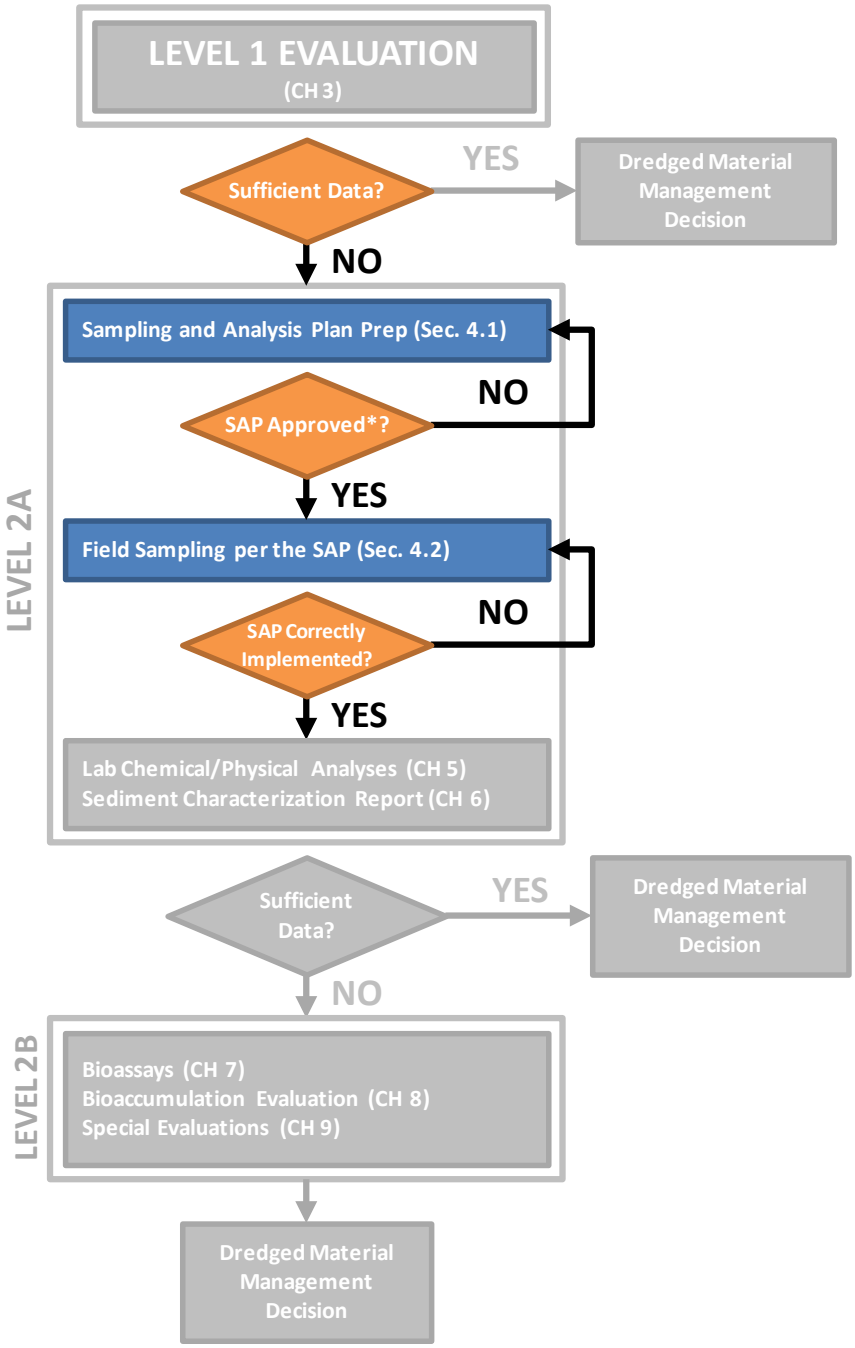

Figure 4-1. SEF tiered evaluation process: sampling and analysis plan and field sampling.

4.1.1 Sampling and Analysis Plan Checklist

The thoroughness of the SAP greatly contributes to the success (or failure) of the field sampling event. The following checklist is provided to help guide the SAP preparation. A SAP that does not contain the following minimum information **will be determined to be inconsistent with this guidance**, and revision and resubmission will be required:

Project Description

- ☐ Maps of vicinity and project area and plan view of site
- ☐ Project description, recent bathymetric survey data, one or more cross-sections of the dredging prism, dredging depth including overdepth in the appropriate vertical datum, side-slope ratios, and proposed disposal site
- ☐ Project volume, including side-slopes and overdepth, and contingency factor used in volume calculations
- ☐ Project schedule
- ☐ Personnel involved with the project and their respective responsibilities, including project planning and coordination, field sampling, chemical and biological testing labs, quality assurance (QA) management, data validation and final report preparation

Level 1 Site History Information and CSM (see sections 3.2 and 3.3)

- ☐ Site history information
- ☐ CSM

Characterization Plan

- ☐ Proposed management area rank (MAR) and justification (section 3.4)
- ☐ Statement of data quality objectives
- ☐ Computation of the minimum number of DMMUs needed to characterize the dredge prism (section 4.1.2)
- ☐ Allocation of DMMUs across the dredge prism with illustrative maps and cross sections (section 4.1.2)
- ☐ If required, identification of the Z-layer (i.e., the interval of sediment below the maximum dredge cut) within the dredging project and justification of selected Z-layer depth with illustrative maps and cross sections (section 4.1.3)
- ☐ Selection of sediment sampling equipment (section 4.1.4)
- ☐ Allocation of field samples across DMMUs and Z-layer(s), and development of a compositing plan (section 4.1.4 and 4.1.5)

Sampling

- ☐ Table of sampling locations including coordinates, and the elevations (reported in local vertical datum) of the mudline, design depth, advanced maintenance (if planned), overdepth, and the Z-layer; preliminary determination of core lengths necessary to collect dredge prism and Z-layer samples at each sample station (may be included in the compositing plan, section 4.1.5)
- ☐ Horizontal datum and coordinate system
- ☐ Horizontal positioning system and accuracy of sampling stations
- ☐ Method for real-time determination of tide or river levels including procedure for establishing or verifying vertical control
- ☐ Sample acceptance criteria (e.g., penetration and recovery criteria for cores)
- ☐ Description of the use of water depths, tide or river elevations, penetration and recovery data to determine the break between DMMU samples and Z-samples, and the break between DMMUs for stratified DMMUs
- ☐ Location where sample processing will occur (e.g., on-board vessel, onshore, laboratory)
- ☐ Decontamination procedures

- ☐ Table of analytical groups (e.g., semivolatiles, metals, bioassays) with planned sample volumes, container sizes and types, holding times, and sample storage requirements, including archived samples
- ☐ Description of field/sampling log information that will be collected, including logs of failed sampling attempts and discarded field samples (and reason for field sample rejection)
- ☐ Copy of the sample logging form
- ☐ Description of core or grab sample logging procedures
- ☐ Chain-of-custody procedures
- ☐ Proposed sampling schedule

Chemical Analysis

- ☐ Plans for physical and chemical laboratory testing, including sediment conventional parameters and CoCs
- ☐ Table(s) of current CoCs, with relevant screening levels (marine and/or freshwater) clearly indicated (with correct units of measure), including extraction/digestion methods, analytical methods, and sample quantitation limits for all CoCs
- ☐ Table(s) of QA parameters, frequency of analysis, and acceptance guidelines
- ☐ Identification of sediment reference materials to be used for semivolatiles, pesticides, and metals, including the sediment reference material certificates and the acceptance ranges the lab plans to use for quality control
- ☐ Dioxin quality assurance and interpretation guidelines, if dioxins/furans analysis is required
- ☐ Validation stage for each analytical group
- ☐ Statement acknowledging that laboratory method reporting limits/limits of quantitation must be at or below SLs to avoid bioassays
- ☐ Chemistry lab reporting requirements, including case narrative describing analytical issues/problems

Biological Testing (if planned)

- ☐ Selection of tiered or concurrent bioassays
- ☐ Bioassays to be used, species-selection rationale (including consideration of species sensitive to grain size), and a brief description of the testing protocols
- ☐ Decision-making process for determining whether to purge for ammonia or sulfides and/or run an LC50 test for ammonia
- ☐ Decision-making process for determining whether to use the larval resuspension protocol
- ☐ Statement that larval test will be aerated
- ☐ Water quality monitoring parameters, schedule, and acceptance limits
- ☐ Proposed collection location of reference sediments and how reference sediments will be matched to test sediments; the wet-sieving protocol should be included
- ☐ Table with bioassay interpretation criteria and reference/control performance standards
- ☐ List of data to be provided to the local review team in the event that bioassays are needed; sediment conventional parameters (especially ammonia and sulfides) for the DMMUs to be tested
- ☐ Bioassay lab reporting requirements

***Reporting Requirements*—**All of the following are required elements of a sediment characterization report (SCR) and must be listed in the SAP:

- ☐ Modifications to the SAP required by the local review team, if any

- ☐ Explanations of any deviations from approved SAP
- ☐ Sampling equipment and protocols used
- ☐ Methods used to locate sampling positions
- ☐ 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 (vertically corrected to the appropriate local vertical datum)
- ☐ Figure showing target and actual sampling locations with DMMU outlines
- ☐ Penetration depth of the sampling equipment and core or grab sample recovery data
- ☐ Compositing scheme with actual core lengths and depths (referenced to the local vertical datum and actual mudline depth)
- ☐ Table of analyzed conventional parameters, including appropriate data qualifiers; for nondetected ("U"-qualified) results, the method reporting limit (MRL) must be reported
- ☐ Table of sediment chemical testing results, including data qualifiers
  - ☐ Chemical results must be presented side-by-side with the appropriate screening levels (marine or freshwater)
  - ☐ Chemical exceedances must be highlighted in the data table
  - ☐ All data qualifiers must be clearly defined
  - ☐ For nondetected ("U"-qualified) results, if the MRL is above the screening level, both the MRL and method detection limit (MDL) must be reported in the data table
- ☐ Chemistry QA review and validation results
- ☐ Summary tables of bioassay results, QA data, and interpretation
- ☐ Appendices:
  - ☐ Field sampling event log
  - ☐ Core and/or grab sample logs
  - ☐ Photolog of the sampling event
  - ☐ Chain-of-custody forms
  - ☐ Laboratory chemistry data report (including the case narrative)
  - ☐ Bioassay laboratory report
  - ☐ Data validation report
- ☐ EIM electronic data deliverable and sample location parameters worksheet
- ☐ Comprehensive laboratory data package (electronic submittal only)

4.1.2 Allocation of DMMUs

A 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 local review team. **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 ultimate goal of sampling a dredging project is to adequately characterize the dredged material (and the Z-layer, if deemed necessary). This characterization is accomplished by dividing the project into DMMUs, taking representative field samples from each DMMU, and compositing the field samples from each DMMU for testing. The total number of DMMUs and the number of field samples collected from each DMMU are determined by the MAR. Sampling locations 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.

The occurrence of point sources in the vicinity of the project must also be considered when locating field samples within each DMMU. However, sampling with the intent of pinpointing hotspots in the dredge areas should *not* be the goal of characterization.

***Management Area Rank and DMMU Size*—**The MAR (discussed in section 3.4) dictates the maximum volume of material that can be included in a single DMMU. The MAR may already be established for a given geographic area or type of facility; the proponent should consult with the local review team during SAP preparation to gauge which MAR(s) are appropriate for their project. The local review teams have established maximum volumes of dredged material per DMMU based on historical precedence and regional experience. For example, Table 4-1 presents the recommended maximum volume of dredged material per DMMU, as determined by the MAR, for projects in the Portland District. The *DMMP User Manual* (Corps et al. 2015) should be consulted for projects in the Seattle and Walla Walla District projects in the state of Washington.

Table 4-1. DMMU maximum volume guidelines (Portland District).

Management Area Rank	Volume Threshold (cubic yards)
Very Low	up to 300,000
Low	100,000
Low-Moderate	70,000
Moderate	40,000
High	5,000

The local review team may adjust DMMU maximum volumes and stipulate the number of field samples to be composited per DMMU on a project-by-project basis. It may be necessary to establish smaller or slightly larger DMMUs depending on the physical layout of the project, proximity to clean-up sites, or past characterization data. If the proponent proposes to exceed these thresholds (e.g., a 43,000 cubic yard DMMU is proposed in a moderate-ranked area), then justification must be provided in the SAP to allow for a larger-volume DMMU.

***Dredging Project Dimensions and Zones*—**DMMUs must be selected to characterize the entire dredging prism; the authorized project depth rarely represents the targeted dredge depth (as dictated by the dredging contract). Figure 4-2 illustrates the various dredging project dimensions and zones that should be considered in the designation of DMMUs; definitions (adapted from ERDC 2007) follow. Note that there are subtle differences between the local review teams in how these dimensions are used to determine the authorized dredge depth, allocate DMMUs, and determine the appropriate Z-sample interval. Examples provided below are from the PSET.

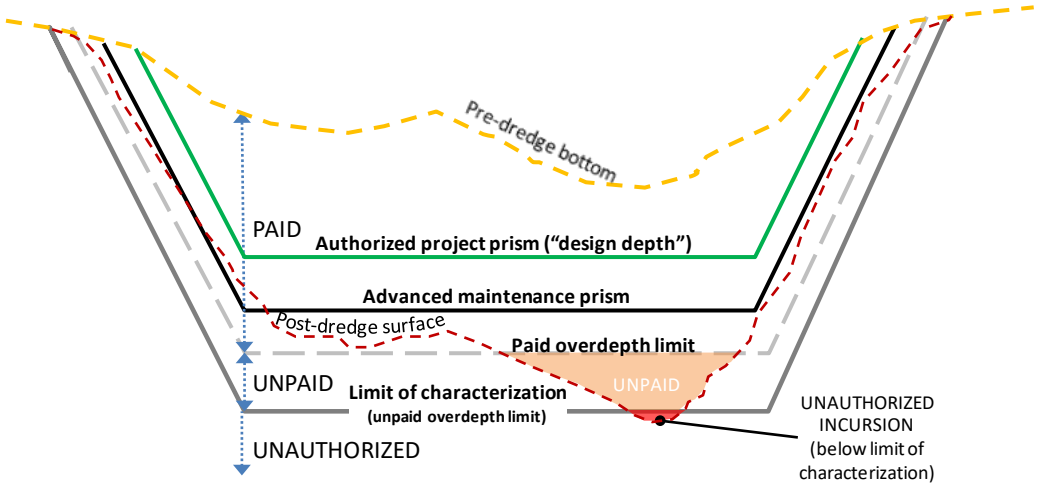

Figure 4-2. Dredging project dimensions and zones.

Authorized Project Prism—The dredging project dimensions are the depth and width of the channel authorized by Congress (for Corps-operated federal navigation channels) or the design depth authorized by a Regulatory permit (for non-Corps dredging projects).

Advanced Maintenance Prism (Optional)—The advanced maintenance prism is the depth and/or width designated beyond the authorized project prism in rapidly shoaling areas. The purpose of the advanced maintenance prism is to avoid frequent re-dredging.

Paid Overdepth Limit—Paid allowable overdepth dredging (depth and/or width) is a construction design method for dredging that occurs outside the required authorized dimensions and advanced maintenance prism (as applicable) to compensate for physical conditions and inaccuracies in the dredging process and allow for efficient dredging practices. The concept of paid overdepth can best be understood in the contracting context. To maximize profit, the dredging contractor will target dredging operations to the paid overdepth limit and minimize dredging within the unpaid overdepth limit (defined below).

Unpaid Overdepth Limit (Limit of Characterization)—Unpaid overdepth dredging is dredging outside the paid overdepth limit that may occur due to such factors as unanticipated variation in substrate, incidental removal of submerged obstructions, or wind or wave conditions that reduce the operator's ability to control the excavation head. Unpaid overdepth can best be understood in the contracting context. Although the dredging contractor will target the paid overdepth limit, precision dredging to this depth would reduce production, resulting in less profit. The unpaid overdepth limit provides a buffer between the paid overdepth limit and the zone of unauthorized dredging (i.e., dredging beyond the limit of characterization). Dredging within the unpaid overdepth level allows the dredging contractor to increase production and still stay within the limit of characterization. Per Figure 4-3, the limit of characterization is always at the bottom elevation of the Z-layer samples. However, the Z-interval selection may differ slightly between the local review teams.

Zone of Unauthorized Dredging—Dredging is considered to be unauthorized if it is beyond the limit of characterization. Material dredged from this zone is unpaid and may result in regulatory

and/or contractual penalties if incursions into this zone are widespread. Regulatory penalties may include (but are not limited to) fines and/or additional sediment characterization in the area(s) dredged below the limit of characterization. Contractual penalties may include (but are not limited to) fines, post-dredge surface management (in contaminated sediments), exclusion from bidding on future contracts, and/or (in cases of extreme negligence) dismissal from the job.

At a minimum, the DMMUs selected for the project should encompass the total dredge volume and include the authorized project prism, the advanced maintenance prism (if proposed), and the paid overdepth limit (Figure 4-3A). The bottom elevation of the DMMUs may also be extended a foot (or more) into the unpaid material to account for inherent vertical inaccuracies of the dredging equipment (Figure 4-3B). In either case, the Z-layer typically extends 2 feet below the bottom elevation of the DMMUs. For PSET, the limit of characterization (i.e., the bottom elevation of the Z-layer) defines the line between unpaid and unauthorized dredging. DMMP does not distinguish between paid and unpaid overdepth at the time of characterization. For DMMP, the limit of characterization (i.e., the bottom elevation of the Z-layer) extends 2 feet beyond the planned overdepth.

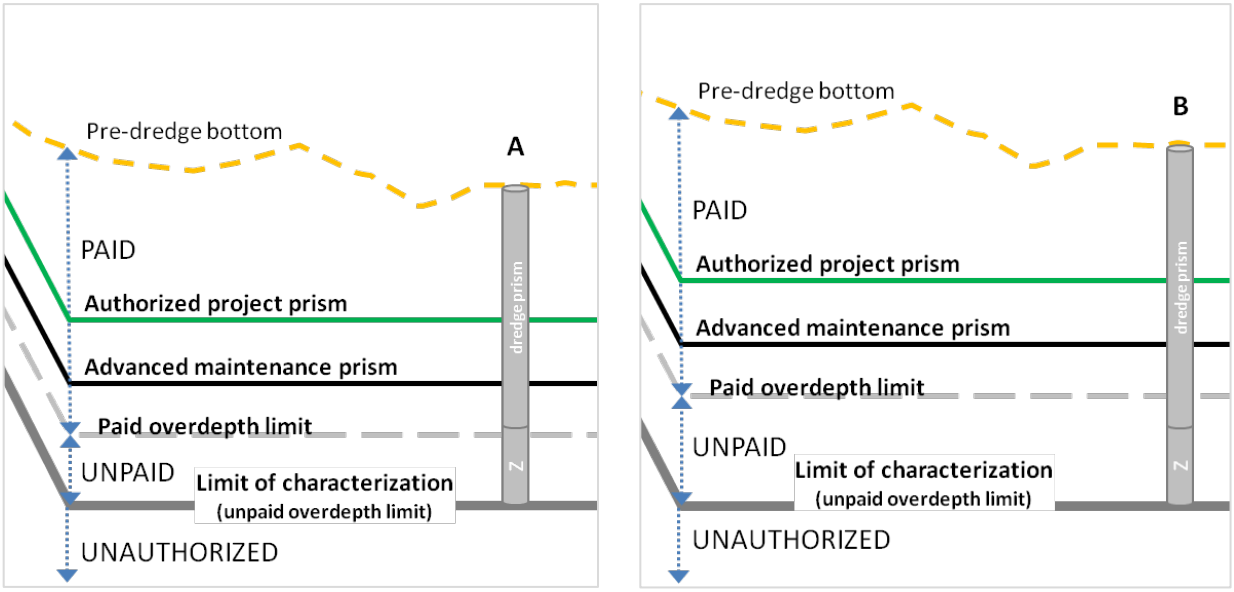

Figure 4-3. Dredging project dimensions and zones and two dredge prism sampling strategies.

Configuration of DMMUs—Within a single project, there may be several different ways to configure the DMMUs. The conceptual dredging plan can be used to guide the configuration of the DMMUs in the project. Questions regarding the configuration of project DMMUs should be addressed to the appropriate local review team; early coordination, prior to submitting the SAP, will save the project proponent time. The following parameters should be considered when configuring project DMMUs:

Varying Dredged Material Composition—Separate DMMUs should be assigned within a project if there are differences in grain size, debris content, or likelihood to encounter contamination. For example, two DMMUs—DMMUs 1 and 2—were selected to characterize the Baker Bay West Channel federal navigation project at Ilwaco, Washington (Figures 4-4 and 4-5, respectively). The two DMMUs were selected based on differences in grain size (and rank, as dictated by the

grain size). DMMU 1 is ranked low and the shoals are composed of fine-grained material (approximately 60% fines). DMMU 2 is ranked very low and shoals within the DMMU are coarse-grained (>95% sand).

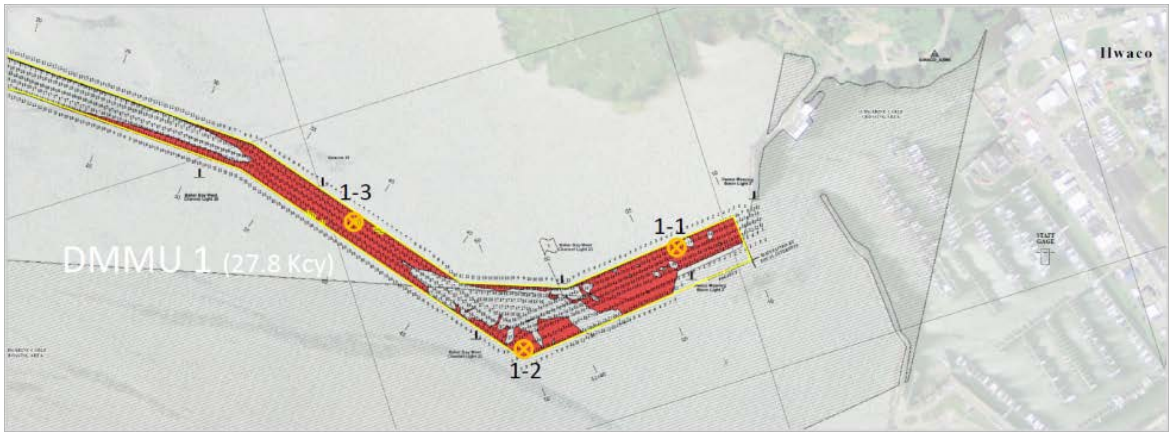

Figure 4-4. Baker Bay West Channel—DMMU 1 is ranked low and composed of fine-grained sediment; DMMU 2 (Figure 4-5) is ranked very-low and composed of sand.

Shoaling Patterns—Shoals that have similar characteristics and are in close proximity to one another can be designated as a single DMMU. For example, in Figure 4-5, DMMU 2 encompasses a group of shoals that consistently form in the same part of the federal navigation channel.

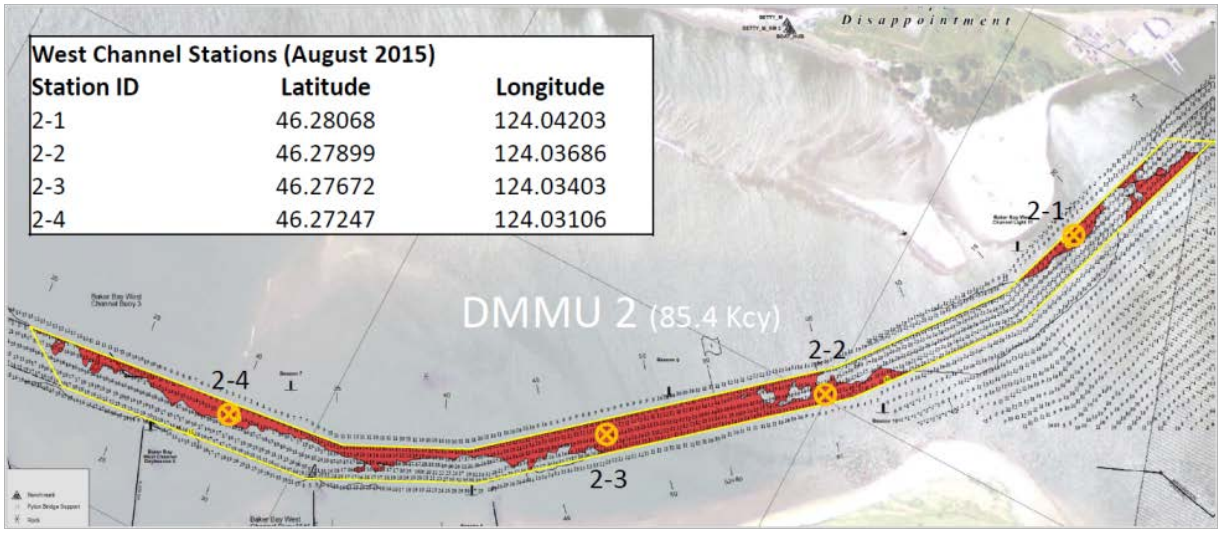

Figure 4-5. Baker Bay West Channel—shoals (in red) consistently form at the same locations.

Dredge Depth—If the planned dredge depths vary within a project, it may make sense to assign DMMUs to each depth (Figure 4-6). Doing so makes compositing dredge prism and Z-layer subsamples between core samples much easier, and where contamination varies with depth, it provides valuable information for managing contaminated post-dredge surfaces.

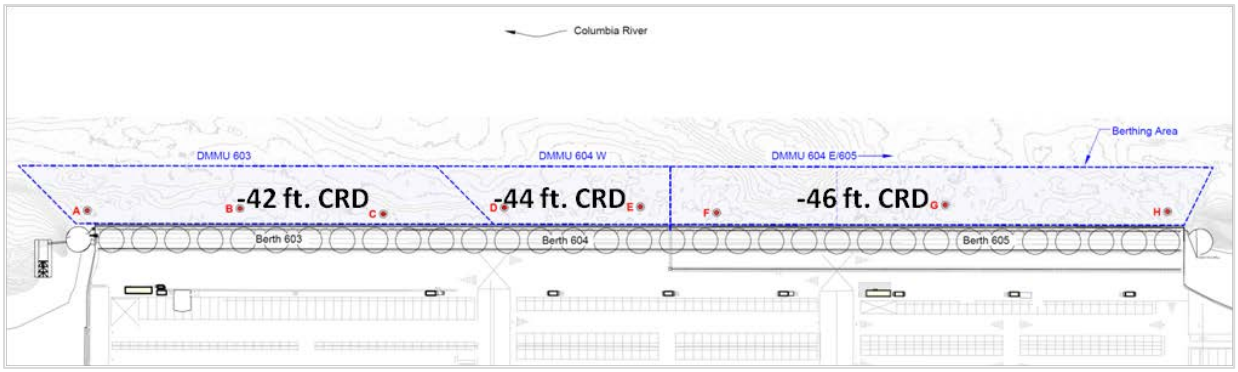

Figure 4-6. DMMUs selected based on depth (CRD = Columbia River Datum).

Dredge Area Shape—Man-made or natural features may dictate the layout of DMMUs within a dredging project. For example, an access channel may bisect a boat basin, potentially resulting in three DMMUs: the two bisected parts of the boat basin would form two DMMUs, and the access channel would form the third DMMU. In the example below, the low-ranked West Mooring Basin of the Salmon Harbor Marina (Umpqua River) was constructed with three subbasins (Figure 4-7). Designating a DMMU in each subbasin would increase analytical costs, but the proponent would have more flexibility if contamination was encountered in one of the DMMUs.

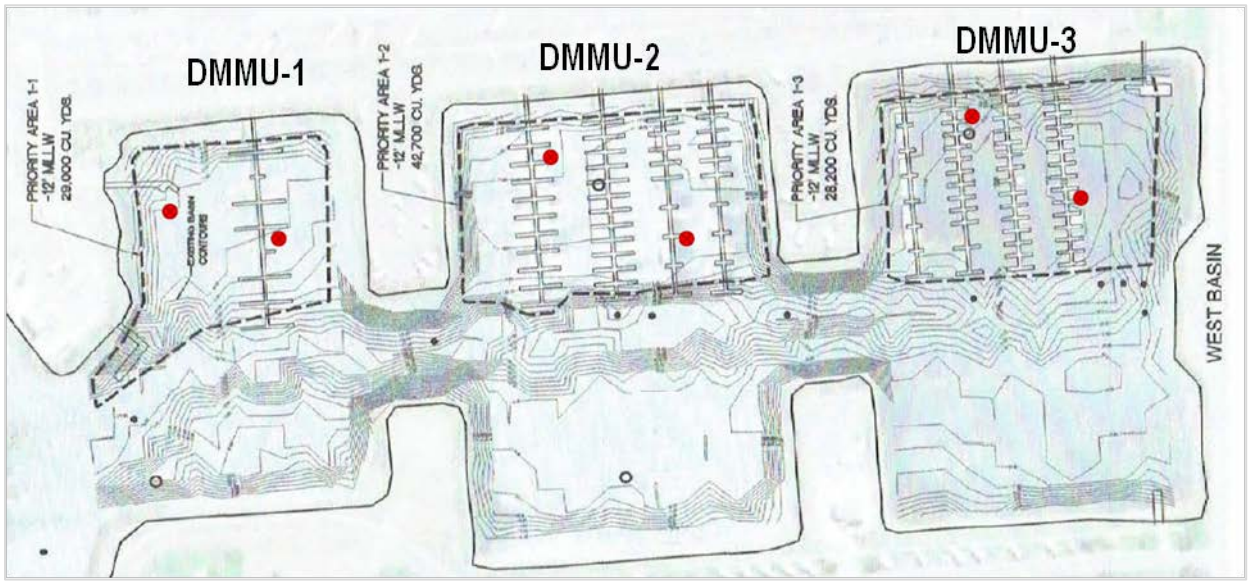

Figure 4-7. DMMUs defined by the shape of the dredge area.

Planned Dredge Cuts—The project may also be divided into DMMUs based on the sequence of dredge cuts, as indicated in the conceptual dredging plan (e.g., the dredger may work from the shoreline side slope toward the center of the channel or berth). These cuts can be designated as separate DMMUs (Figure 4-8). The Z-layer material beneath the side slope cut may also be used to predict the quality of the generated residuals (discussed in section 4.1.3 and Chapter 9).

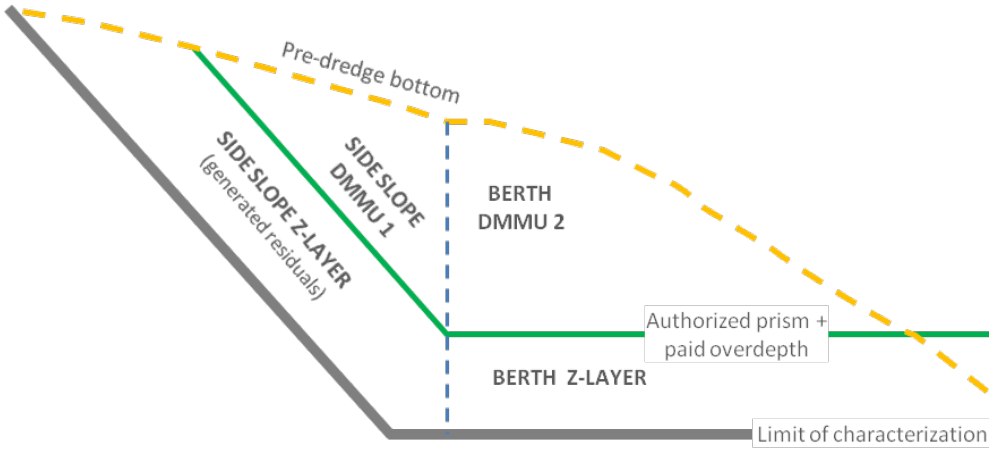

Figure 4-8. DMMU (and Z-layer) selection based on the geometry of the dredge cut.

Stratified DMMUs—Stratification of DMMUs only makes sense in thick dredge prisms (typically ≥6 feet thick), because DMMUs that are less than 3 feet thick may not be truly independently dredgeable. DMMUs should be configured side-by-side in dredge prisms <6 feet thick. Stratified DMMUs are not required just because the dredge prism is ≥6 feet thick; the conceptual dredging plan should be used to determine if stratification makes sense.

The dredging project design may dictate that DMMUs be vertically stratified (instead of side-by-side). For example, a port plans to deepen a berth at one of their marine terminals in the next 5 years, but in the interim, the berths still require routine maintenance dredging. The maintenance material and deepening material can be divided into surface and subsurface DMMUs, respectively. The deepening material DMMU could also double as the Z-layer unit during the maintenance cycle(s) leading up to deepening (Figure 4-9).

Designation of stratified DMMUs may also be necessary to characterize and manage contaminated sediments if concentrations increase or decrease with depth. Figure 4-10A depicts a contamination profile in which the shoaling material in the marine berth is composed of contaminated sediments from surrounding sources; contamination decreases with depth into the native sediments. Figure 4-10B depicts an "inverted" contamination profile in which the shoaling material comes from relatively clean sources of material; contamination increases with depth as historically contaminated sediments are encountered (native, "clean" sediments are well below the limit of characterization and depth necessary to operate the marine facility).

Finally, stratifying DMMUs can significantly decrease the number of cores needed to characterize the dredge prism, thereby reducing the field time. This concept is illustrated in Figure 4-11.

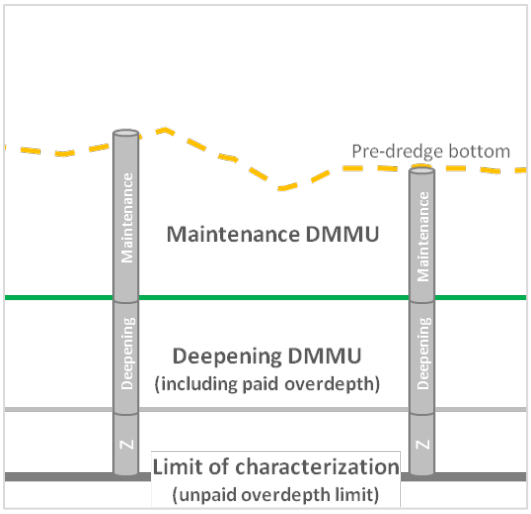

Figure 4-9. Stratified maintenance and deepening DMMUs.

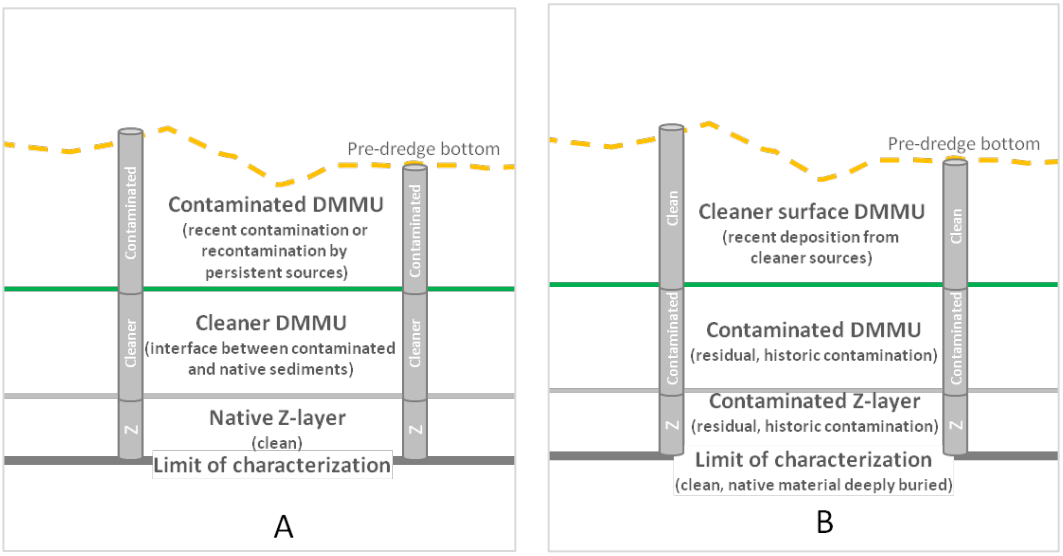

Figure 4-10. Stratified DMMUs can be designated to characterize potentially contaminated sediments and mange for contamination that (A) decreases with depth or (B) increases with depth.

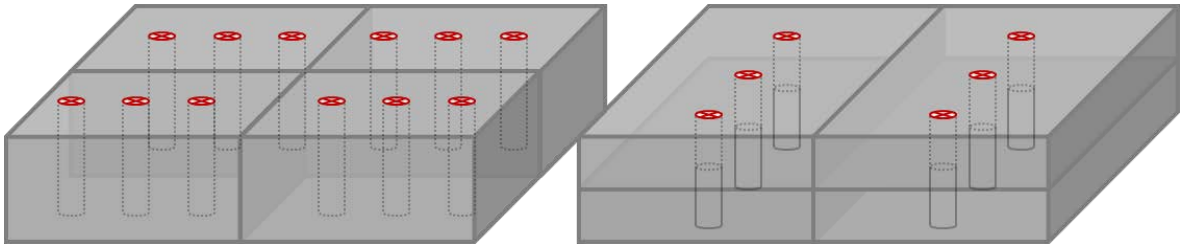

Figure 4-11. Dredge prism characterization requiring four DMMUs and three subsamples per DMMU. Side-by-side DMMUs require 12 cores; stratifying the DMMUs requires only 6 cores.

4.1.3 Post-Dredge Surface

Dredging residuals are the remaining (contaminated or uncontaminated) sediments in the dredge area that will come into direct contact with biota and the water column after completion of dredging. Dredging residuals are collectively composed of **undisturbed residuals** and **generated residuals,** which form the **post-dredge surface (PDS)** (Figure 4-12). These terms are defined below (ERDC 2008a):

Undisturbed Residuals—Sediments (contaminated or uncontaminated) that were previously buried and exposed by the dredging operation. Z-layer samples (Z-samples) are used to predict concentrations of undisturbed residuals in the **predicted PDS.**[13] The Z-samples are collected *in-situ* with a core sampler during pre-dredge field sampling. **For the purposes of this manual, predicted PDS concentrations are primarily characterized by the Z-samples.**

Generated Residuals—Sediments that were dislodged or suspended during the dredging operation and redeposited in the dredge area. Generated residuals include: (1) fallback from the excavation head; (2) fallback from debris removal; (3) sloughing into the dredge area from adjacent slope failure in undredged areas; and (4) deposition of sediments resuspended during the dredging operation.

For the purposes of this manual, the contribution of generated residuals to the predicted PDS chemistry is usually assumed to be negligible. However, if there is reason to believe that generated residuals may have a measurable influence on chemical concentrations in the predicted PDS, then their contribution should be modeled (see Chapter 9 [Special Evaluations], Section 9.2). Direct measurement of generated residuals is typically not feasible due to varying contributions from the four potential sources; predicted concentrations of generated residuals must be modeled to determine their contribution to the predicted PDS.

The relative contributions of undisturbed and generated residuals to the predicted PDS chemistry are used by the local review team to determine the following:

- The suitability of the PDS for unconfined, aquatic exposure
- Project compliance with the state antidegradation policy

Washington, Oregon, and Idaho each have water quality antidegradation policies implemented by their respective state water quality agencies. Discussion of the specifics of each state's antidegradation policy

[13] Actual PDS concentrations can be determined through post-dredge sampling. However, pre-dredge sampling of the Z-layer is required for regulatory determinations regarding the suitability of project sediments.

is beyond the scope of this manual. The state water quality agency representative from the local review team should be queried to determine the nuances of the state's antidegradation policy. Generally, the states implement this policy by comparing concentrations in the dredge prism to the predicted PDS concentrations. Section 6.6 describes the antidegradation evaluation in greater detail.

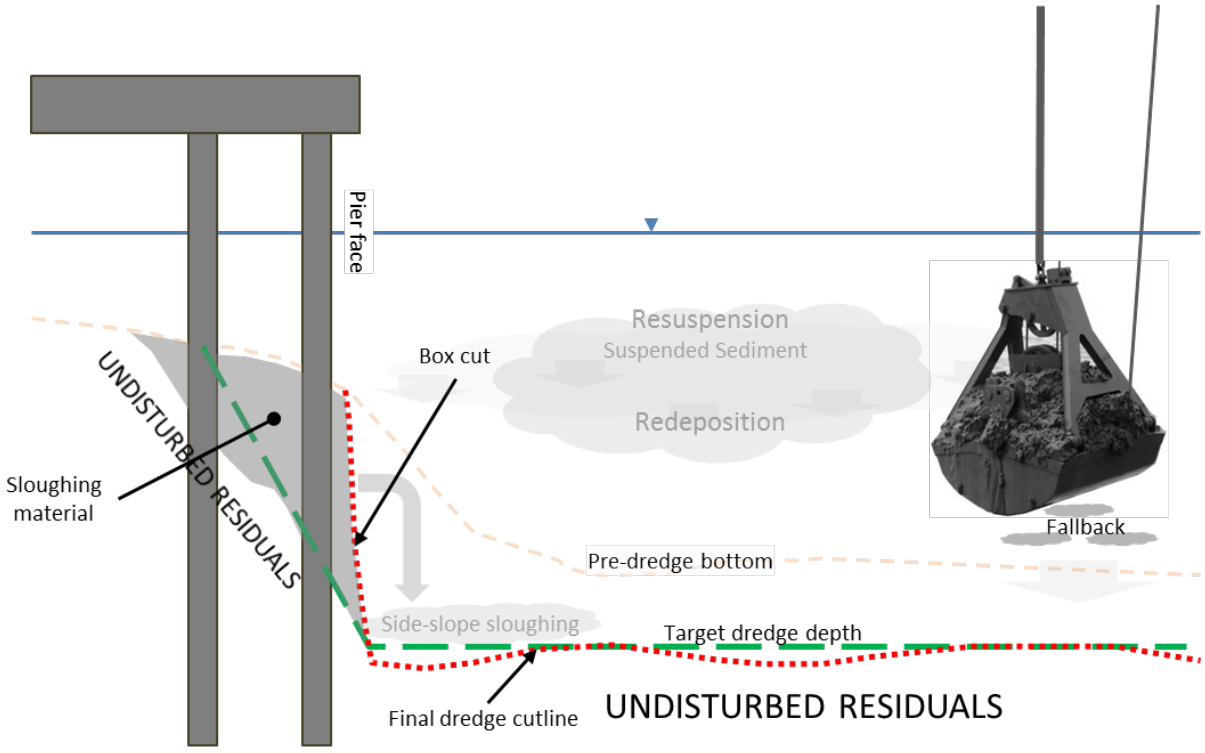

Figure 4-12. Dredging residuals are composed of generated residuals(*) and undisturbed residuals.

Z-Layer Characterization—The local review team should be consulted to determine if Z-layer analysis is required. **In most projects, 2-ft-thick Z-samples are collected.** Selection of the depth interval of the Z-layer—as it relates to the paid and unpaid overdepth—and the rationale for its selection must be clearly articulated in the SAP. For DMMP, the Z-layer has been standardized to be the 2-ft interval beyond the planned overdepth. Z-samples can either be analyzed concurrently with the dredge prism or archived for later analysis, pending the results of the dredge prism characterization. The following should be considered when archiving Z-samples:

- Archived sediment for chemical analyses must be maintained at -18 °C.[14]
- Archived sediment for bioassays and grain size analysis must be maintained at 4 °C.

[14] Ammonia and sulfides analyses should be conducted directly after sample collection. The holding time for these analyses is 7 days, and the samples cannot be frozen.

- For marine sediments, porewater extraction will not be required for tributyltin testing of Z-samples due to the short holding time and large volume of sediment required. If porewater samples of overlying dredged material are collected and exceed 0.15 micrograms per liter (µg/L) of tributyltin, bulk testing of frozen sediment samples for both the dredged material and Z-samples will be conducted for evaluation under the antidegradation policy.
- 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 unsuitable for unconfined, open-water disposal, the associated underlying Z-sample must be analyzed to characterize the Z-layer. The proponent may confer with the local review team to determine which analyses are necessary.
- If there is reason to believe that concentrations of CoC increase with depth, the local review team may require Z-samples to be analyzed concurrently with analysis of the DMMUs.
- Z-sample analyses will initially include sediment conventional parameters and CoCs. If the results of the chemical analysis indicate that the sediment to be exposed by dredging will be degraded relative to the existing sediment, then biological testing may be required if chemical concentrations exceed the screening levels. If insufficient Z-sample material was archived, the proponent may be required to resample locations in order to perform biological testing.

If the vertical extent of sediment contamination is unknown, it may be prudent to stratify two (or more) Z-layers to allow for greater flexibility in planning the dredging operation (Figure 4-13). If there is reason to believe a contaminant gradient may be present in the Z-layer, then two or more 1-foot Z-samples should be archived independently from each sampling location to enable assessment of the trend in contamination with depth.

Z-sample collection may not be required if any of the following apply:

- The project is ranked very low (PSET).
- The CSM indicates the Z-layer will not be exposed (as when a cap or cover is placed).
- The CSM indicates the Z-layer is known to be composed of inert materials such as concrete or bedrock (e.g., if sediments have accumulated over a concrete boat ramp).

***Characterization of Generated Residuals*—**Generally speaking, generated residuals contribute minimally to the PDS chemistry; therefore, the Z-layer characterization of undisturbed residuals is most often used to determine the post-dredge surface suitability. However, if there is reason to believe that conditions exist that may result in significant generated residuals, then the SAP should include analyses to predict them. The Corps' Engineering Research and Development Center (ERDC) report, "Technical Guidelines for Environmental Dredging of Contaminated Sediments," summarizes several methods that can be used to predict generated residuals (ERDC 2008b). Generated residuals characterization is discussed in more detail in section 9.2.

4.1.4 Selection of Sediment Sampling Equipment

Two general types of samplers are used to collect sediment samples: core samplers and grab samplers. The type of sampler required depends on the type of project. The goal of dredged material characterization is to collect a discrete or composite sample that will be representative of the DMMU. The

accuracy of the vertical representation can be increased by taking core samples from the sediment/water interface down to the maximum proposed depth of dredging (including overdepth). Likewise, by increasing the number of samples taken across the DMMU, the horizontal representativeness of the data can be improved. The sampling methodology to be used, the rationale for selecting a core or grab sampler (or both), and the specific make and model of sampler(s) that will be used should be presented in the SAP.

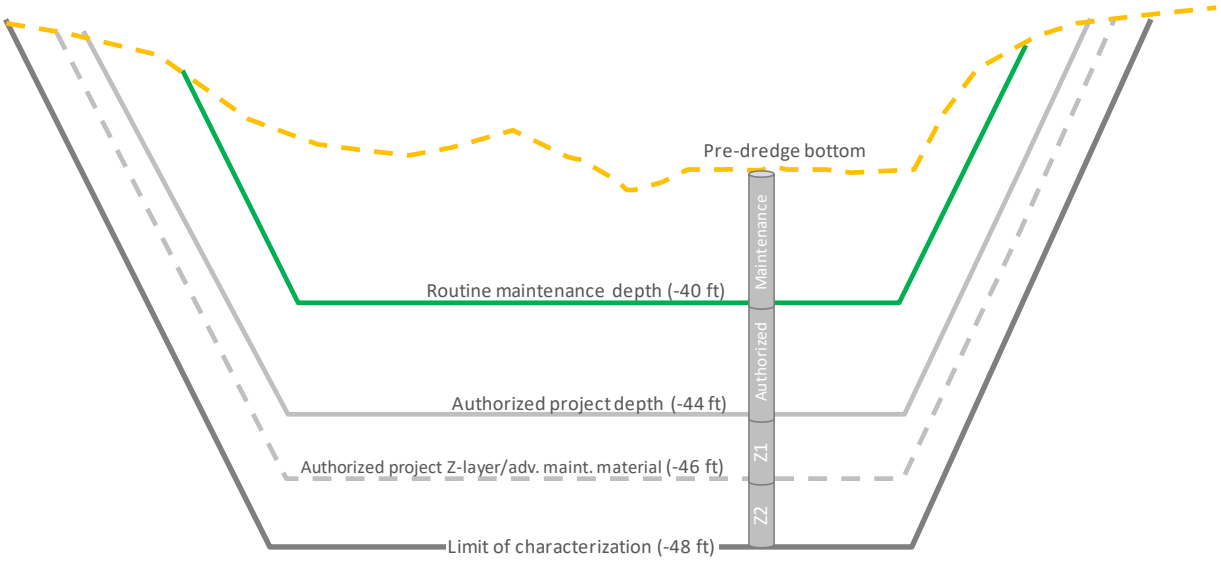

Figure 4-13. This sampling design offers maximum flexibility.

This marine industrial berth is authorized to -44 feet, but the port only maintains the berth to -40 feet to accommodate the lessee's current needs. In 2 years, the lessee plans to bring in vessels that require the full authorized depth; 2 feet of advanced maintenance is also requested. Samples have never been collected below -43 feet (the limit of characterization for routine maintenance), and site history indicates that contamination may increase with depth. Stratifying both the DMMUs and Z-layers gives the port maximum flexibility in the project design if contamination is encountered.

Core Samplers—There are numerous options available for obtaining core samples. These include vibracorers, gravity corers, impact corers, box cores, piston corers, hydraulic push corers, augers with split spoons, Shelby tubes, etc. The methodology chosen will depend on availability, cost, efficacy, type of sediment, and anticipated sediment recoveries. Core samplers are typically used in the following situations:

- Dredge prism and/or Z-layer composition is unknown (new-work dredging)
- Project sediments are heterogeneous (i.e., sediment layers have different characteristics or contaminant concentrations are potentially non-uniform)
- Stratified DMMUs are planned
- Z-layer samples are planned (section 4.1.3)

Grab Samplers—Grab samplers collect samples from the sediment surface. There are numerous options for collecting grab samples, including the Ponar, Van Veen, power-grab, and Birge-Ekman. Grab samplers are typically used in frequent shoaling areas in which the dredge prism and Z-layer composition are not expected to change from one dredging cycle to the next, and project sediments are homogeneous

(sediments are well-mixed and contaminant concentrations are likely to be vertically uniform). When core sampling is planned in coarse-grained sediments, a grab sampler should be included as a contingency in case core samples cannot be recovered or core recovery is low.

4.1.5 Compositing Scheme

Once the project DMMU(s) and Z-layer interval(s) are selected, the number of subsamples per DMMU must be determined, and the compositing scheme must be developed. The number of subsamples per DMMU is dictated by the predicted heterogeneity within the DMMU and its shape. After the subsample locations have been selected, the planned core lengths, depths (referenced to the local vertical datum), and thickness of each stratum must be included in the compositing scheme along with the composite sample and subsample identifiers.

The compositing scheme serves as a roadmap for the entire field sampling event and is an essential component of the SAP. A thorough compositing scheme can prevent field sampling errors, because it accomplishes the following:

- Identifies the target elevations for the dredge prism and Z-layer sediment
- Displays the sample station location coordinates
- Identifies which subsamples will go into which composite sample; it is critical to provide this table to the laboratory if subsamples will be composited by the laboratory

An example compositing scheme appears in Table 4-2.

Table 4-2. Example compositing scheme for vibracore sampling the dredge prism and Z-layer.

Core Sample Station ID	Sample Station Location (N lat., W long.)	Est. Mudline Elevation (ft MLLW)	Dredge Prism (mudline to -14 ft MLLW)			Z-layer (-14 to -16 ft MLLW)		
			Sample Interval	Subsample ID	DP Composite ID (Vol.)	Sample Interval	Subsample ID	Z Composite ID
CHK-VC-01	46.280721, 124.042037	-10.5	-10.5 to -14.0	CHK-DP-01		-14.0 to -16.0	CHK-Z-01	
CHK-VC-02	46.279052, 124.036960	-12.0	-12.0 to -14.0	CHK-DP-02	CHK-DMMU01 (72.4 Kcy)	-14.0 to -16.0	CHK-Z-02	CHK-Z01
CHK-VC-03	46.276763, 124.034098	-11.5	-11.5 to -14.0	CHK-DP-03		-14.0 to -16.0	CHK-Z-03	

Notes: MLLW = mean lower low water, DP = dredge prism, Kcy = thousand cubic yards

Sample identifiers for the discrete or composite samples submitted for laboratory analysis must be unique to avoid entry of duplicate sample identifiers into the Washington Department of Ecology's Environmental Information Management (EIM) database (see also section 6.5). For example, the sample identifier "CHK-DMMU01" (Table 4-2) provides much information about the dredge prism sample, including the name of the project (Chinook federal channel) and the DMMU identified within the Chinook project (DMMU01). Although the sample ID may be repeated in the same location, the sample date is associated with each EIM data entry, enabling the data user to differentiate between sampling events.

4.1.6 Conventional Parameters and Physical Screening

Sediment conventional parameters provide information about the physical nature of the dredged material and aid in interpreting chemical and biological test results. Conventional parameters include grain size, total solids, total organic carbon, total sulfides, ammonia, and total volatile solids.[15] These analyses are used in the characterization of both marine and freshwater systems. The analytical methods recommended for most of these conventional parameters appear in Table 5-1. The analytical program for conventional parameters must be summarized in the SAP.

The PSET may allow physical screening without chemical analysis if the PSET has assigned a very low MAR to the project. Project proponents must provide sufficient justification in the project Level 1 information to support the very low rank and only physical screening. Projects eligible for physical screening must be unlikely to have sediment contamination and the presence of coarse-grained materials and low TOC content (**≥80% of the bulk sediment retained on a no. 230 sieve and ≤0.5% TOC content**) must be verified every 10 years (per the recency guidelines in Table 3-2). **Projects ranked low, low-moderate, moderate, or high by PSET, are not eligible for physical screening, even if project sediments meet the sand and TOC guidelines listed above.**

For DMMP, physical screening without chemical analysis may be allowed if the dredged material is composed primarily of sand, gravel, and/or inert materials and the sediments are from locations far removed from sources of contaminants. This description is similar to the qualifications for a very low rank used by the PSET.

The following grain size classes are used by the local review teams for physical screening:

- Cobbles: >64 mm
- Gravel: 2 mm to 64 mm
- Sand: 62.5 µm to 2 mm
- Silt: 3.9 to 62.5 µm
- Clay: 0 to 3.9 µm

Sediment chemistry must be analyzed in samples with <80% sand and >0.5% TOC. If the approximate percentages of sand and fines (silt and clay) cannot be gauged in the field by wet sieving, visual estimation, or texture "by feel," then additional material should be collected and archived pending the results of the grain size analysis. Physical screening samples should also be archived (pending the results of the TOC analysis) if any organic staining is noted while logging the sample.

4.1.7 Sampling Approaches for Full Characterization

If full characterization sampling and analysis is required for a project, the applicant will be required to sample the sediment for conventional parameters, sediment chemistry, and (if necessary) bioassays. There are three sampling approaches that the dredging proponent may take:

[15] DMMP requires total volatile solids analysis for all DMMUs. For PSET, total volatile solids analysis is required if there is reason to believe that wood waste may be present in the dredge area.

- *Concurrent Testing*—Collect sufficient sediment for chemical analysis and bioassays. Run these tests concurrently.
- *Tiered Testing*—Collect sufficient sediment for chemical analysis and bioassays, but archive adequate sediment under the appropriate holding conditions for later use in bioassays, pending the results of the chemical analysis.
- *Tiered Testing with Resampling*—Collect only enough sediment to conduct the chemical analyses and, if bioassays are required, resample the site.

The proposed sampling approach should be clearly documented in the SAP. The RSET recommends that sufficient material be collected for tiered bioassays in all projects, especially in projects that are ranked low-moderate, moderate, or high. Concurrent testing or tiered testing and collection of sufficient material is encouraged (but not required), because this approach provides chemical and biological data on subsamples of a single homogenized sediment sample. This sampling approach also eliminates the need to collect additional sediment if bioassays are necessary to complete the dredged material evaluation. The only situation where resampling is recommended is bioaccumulation testing, which requires a large volume of sediment that is impractical to collect prior to chemical analysis.

Concurrent testing is the least time consuming approach and is likely the most economical when the need for bioassays is expected. For tiered testing, the sediment archived for bioassays must be stored in the dark at 4 °C with zero headspace (or with headspace purged with nitrogen) while chemical tests are completed. **Maximum sample holding time for bioassays is 56 days. The 56-day holding time starts the day the first cores or grab samples representing a DMMU are collected.**

Tiered testing with resampling should only be considered if the need for biological testing is not expected. If bioassay testing is not planned, and one or more CoCs exceed the screening levels, the proponent must either (1) place the material in a confined disposal facility or (2) collect additional sediment for bioassays and reanalysis of sediment conventional parameters and chemistry. The resampling effort for biological testing must occur at the same stations as the previous sediment chemistry samples. Even if the new sediment samples show no chemical exceedances, the bioassays must still be conducted, because one or more screening levels were exceeded in the initial chemical analysis.

4.1.8 Chemical Analyses

The chemical analytical program for the project, including laboratory quality assurance/quality control (QA/QC) procedures, must be clearly summarized in the SAP.

Marine and/or Freshwater—The proponent must state whether the project is in a marine or freshwater system (or both), because the lists of CoCs are different. The marine and freshwater CoCs (and the respective SLs) are listed in Table 6-2. Selection of the appropriate suite of chemical analyses and the respective screening levels (marine or freshwater) is based on the location at which sediment toxicity is being evaluated. Dredging residuals will be evaluated at the dredge area; the effects of open-water disposal of dredged material will be evaluated at the disposal site. Per the national Inland Testing Manual (EPA and Corps 1998), salinity defines the system that the project is in:

- Salinity ≤ 1 part per thousand (ppt) = freshwater
- Salinity > 1 ppt and ≤25 ppt = estuarine
- Salinity > 25 ppt = marine

In estuarine systems, the local review team will determine which set of chemical analyses (freshwater or marine) will be used to evaluate the dredging project. If the dredge area is in a freshwater system and the disposal area is in a marine system (or vice versa), then both the freshwater suite and marine suite of CoCs may need to be analyzed.

***Standard List of CoCs*—**Chemical analytical requirements are described in detail in Chapter 5; the sediment sample preparation methods and analytical methods appear in Table 5-1. **Analysis of the standard list of CoCs is typically required for projects near current or historical sources of contamination and/or projects that have not been recently characterized** (i.e., the most recent data exceed the recency guidelines in Table 3-2).

***Site-Specific CoCs*—**Analysis of site-specific CoCs may be required if the Level 1 site history information indicates that one or more of these chemicals may be present in the dredge area, as outlined by the following examples:

- Tributyltin (and other organotins) analysis may be required in areas affected by vessel maintenance and construction activities, marine shipping, and frequent vessel traffic (e.g., shipyards, boatyards, marinas, and marine terminals) because tributyltin was used as an antifoulant in marine vessel paints.
- Dioxin and furan contamination is associated with industrial processes involving chlorine such as chemical and pesticide manufacturing, wood treatment, and pulp and paper bleaching. Additionally, dioxins/furans are formed through combustion processes such as waste incineration, structural fires and—historically—by the burning of hog fuel. Dredging projects in close proximity to these potential sources may require confirmation analysis of dioxins and furans.
- Total petroleum hydrocarbon (TPH) testing is now mandatory for freshwater sediments but is not at marine sites. However, testing for TPH may be required at marine sites where petroleum products have been released to the aquatic environment (e.g., crude oil or fuel spills, waterfront petroleum storage tank or pipeline leaks, marinas and mooring basins).
- Organophosphate pesticides and potentially other types of pesticides (i.e., triazines) may be considered in areas dominated by agricultural land use and in sediments affected by cropland runoff, particularly in certain eastern drainages where large portions of the watershed are under cultivation.
- Guaiacol and chlorinated guaiacols may be present in sediments where kraft pulp mills are or were located. Only guaiacol, and not chlorinated guaiacols, will be measured near sulfite pulp mills because these mills do not use a bleaching process.

Exclusion of CoCs If sufficient historical sediment data are available, then the proponent may request that the local review team waive the analysis of one or more groups of chemicals. To exclude a group of chemicals from analysis, the proponent must provide sufficient justification in the SAP. For example, pesticide contamination may never have been detected in a small, coastal marina because sources of these contaminants are not present in the watershed or airshed.

4.1.9 Biological Testing and Special Evaluations

Bioassay testing methods are described in Chapter 7. Bioaccumulation risk evaluation and testing methods are discussed in Chapter 8. Special evaluations, including elutriate testing procedures, are

described in Chapter 9. Per section 4.1.7, any or all of these Level 2B analyses may be tiered or run concurrently with the analysis of sediment chemical and conventional parameters.

The maximum sediment sample holding time for biological testing is 56 days. The 56-day holding time starts the day the first core or grab sample representing a DMMU is collected. Between 5 and 30 liters (L) of material may be required for biological testing, depending on the type of test. A 4-inch diameter vibracore sampler generates approximately 1 L of sediment per 10 linear inches (25 centimeters [cm]) of core sample. A 3-inch diameter vibracore generates approximately 1 L of sediment per 13 linear inches (33 cm) of core sample. Project proponents should plan to collect enough core samples to meet the volume requirements for the planned test(s).

When planning bioassays, project proponents should be aware that some test species are sensitive to fines (silt and clay); if the site has not been previously characterized for grain size, contingency species should be identified in the SAP.

4.1.10 Timing of Sampling

Sampling must be accomplished in accordance with the approved SAP, well in advance of the planned dredging events. This allows time for sample testing, data review (by both the proponent and the local review team), and permitting.

Areas that receive large volumes of material due to shoaling during winter storm events or spring freshets (i.e., high flows and increased sediment transport due to spring snowmelt or heavy rainfall) also need to be sampled prior to dredging. These projects may require dredging shortly after deposition by winter storms or freshets, and there is often insufficient time to complete sediment characterization of all material that will eventually be dredged. Instead, material that is already in place prior to the winter storm season is sampled and tested, and the assumption is made that subsequently deposited sediments are of a similar quality. Because the physical and chemical composition of the material deposited from year to year is often similar, sampling in advance is allowed. This approach balances both the need to provide representative sampling and the need to provide an evaluation process adaptable to rapid shoaling patterns. This approach also avoids the proponent's reliance on "emergency dredging" that precludes sediment sampling and testing prior to dredging. In these cases, the number of DMMUs and field samples will be based on pre-sampling bathymetric surveys, records from previous dredging events, and best professional judgment.

4.2 Field Sampling Protocols and Field Quality Assurance

The approved SAP serves as an agreement between the local review team, the project proponent, the sampling contractor(s), and the contract lab(s) regarding field sampling methods and laboratory analytical methods that will be used to characterize project sediments. All of the planning that goes into the SAP can be undone through poor implementation of the SAP by an untrained and/or unprepared field crew. Errors made during the sampling event can result in longer review times by the local review team, rejection of some or all of the sample data, resampling of the project sediments and reanalysis of the samples, and/or post-dredge sediment characterization (if the Z-layer is improperly characterized).

This section identifies field sampling protocols and field quality assurance measures that should be incorporated into the SAP and carefully followed to ensure that the approved SAP is implemented as was intended. An abridged field sampling checklist is provided in section 4.2.1. Additional guidance is provided for the following topics:

- Presampling conference call (section 4.2.2)
- Horizontal and vertical positioning methods (section 4.2.3)
- Sample collection and handling procedures (section 4.2.4)
- Common field sampling errors (section 4.2.5)

4.2.1 Field Sampling Checklist

The following checklist is intended to guide the sampling event. This checklist is by no means complete; some of the items listed below may not be necessary for every sampling event. Sampling staff are encouraged to adapt this list, in-part or entirely, to meet their field sampling needs.

Paperwork

- ☐ SAP (approved by the local review team)
- ☐ Field checklist
- ☐ Field map(s) with recent hydrosurvey and target field sample locations
- ☐ Sample summary table/compositing scheme (see example, Table 4-2)
- ☐ Waterproof field log book
- ☐ Waterproof grab and/or core sample log forms (with known fields completed)
- ☐ Chain-of-custody forms
- ☐ Copy of Table 5-1 (Recommended Sediment Analytical Methods and Sample Quantitation Limits) to send with chain-of-custody
- ☐ Laboratory addresses
- ☐ Shipping forms for cooler shipment
- ☐ Cooler labels for dry ice (if used as a sample preservative)

Sampling Equipment

- ☐ Sediment sampler
- ☐ Generator/power supply for powered samplers
- ☐ Contingency grab sampler (for core sampling in sand)
- ☐ Extra parts/sampler repair kit
- ☐ Core liners (or sacrificial aluminum cores)
- ☐ Core catchers
- ☐ Core caps
- ☐ Duct tape
- ☐ Tools for core setup and processing (core samplers only)

Horizontal and Vertical Positioning Equipment

- ☐ GPS and onboard chart plotter
- ☐ Depth finder (and measurement of sensor below waterline)
- ☐ Lead line

- ☐ Smartphone or onboard computer with access to tides or river levels
- ☐ Staff gauge or electronic gauge vertical datum information

Decontamination Equipment

- ☐ Distilled, deionized water (at least 3 gallons)
- ☐ Phosphate-free, laboratory-grade decontamination soap
- ☐ Brushes and pole-brush (for cores and core liners)
- ☐ Primary wash bucket
- ☐ Stainless steel wash/rinse pan(s)

Sample Processing and Handling

- ☐ Boxes of latex-free, nitrile gloves (multiple sizes)
- ☐ Hand sanitizer
- ☐ Paper towels
- ☐ Stainless steel bowls/pans/trays for sample processing and compositing
- ☐ Stainless steel spatula/spoons
- ☐ Aluminum foil
- ☐ Pre-labeled sample jars (checked against SAP) and extras (if breakage)
- ☐ Jar labels, extras
- ☐ Jars preloaded with zinc acetate for sulfide samples
- ☐ 1-gallon Ziploc bags (physical samples only)
- ☐ Duct tape
- ☐ Camera
- ☐ Wet-sieving equipment

Sample Packing and Shipping

- ☐ Coolers
- ☐ Sample preservative (wet, blue, or dry ice)
- ☐ Completed chain-of-custody forms
- ☐ Custody seals for coolers
- ☐ Copy of SAP tables summarizing:
  - ☐ List of analytes
  - ☐ SEF sample quantitation limits and screening levels
  - ☐ Compositing scheme and instructions (for samples composited at the lab)
- ☐ Photocopy or photograph of completed chain-of-custody forms
- ☐ 1 gallon Ziploc storage bag for chain-of-custody forms and copy of the SAP tables
- ☐ Temperature blank
- ☐ Retained copy of shipping form or courier receipt

Tools

- ☐ Screwdriver
- ☐ Pliers
- ☐ Pipe wrench
- ☐ Crescent wrench
- ☐ Hack saw

- ☐ Box cutters and/or knife
- ☐ Circular saw (with jig) or power shears (for cutting core liners)
- ☐ Wire cutters
- ☐ Hammer
- ☐ Rubber mallet
- ☐ Tape measure

Personal Equipment

- ☐ Personal flotation device (life vest or coat)
- ☐ Hard hat
- ☐ Steel-toed boots or shoes (rubber/leather)
- ☐ Leather or rubber work gloves
- ☐ Rain gear (jacket and pants)
- ☐ Cold weather gear
- ☐ Drinking water
- ☐ Field food
- ☐ Hat and/or sun protection
- ☐ First-aid kit

4.2.2 Presampling Conference Call

The local review team may require a presampling conference call with the dredging proponent's sampling team. The purpose of this call is to go through the SAP to ensure that both the local review team and the sampling team understand the details of the sampling event and identify potential pitfalls or missing information that may compromise the quality of the samples being collected for laboratory analysis. The local review team will review the following information with the sampling team:

- Project sampling details, including experience of the sampling team using the sampling equipment in the type of material and depths to be sampled
- Horizontal positioning and establishment of vertical control and adjustment of sampling depths for unanticipated changes in mudline elevation
- Criteria for accepting/rejecting samples
- For core sampling:
  - Measurement of core penetration and recovery
  - Penetration and recovery acceptance/rejection criteria
  - Differentiation of DMMU(s) and Z-layer material based on recovery
- Compositing of subsamples and who will be doing the compositing (field team or lab)
- Agreement on the laboratory analyses to be conducted and sample quantitation limits to be achieved
- Determination of sampling date(s) and identification of local review team contact(s) for coordination during the sampling event
- The potential circumstances requiring communication with the local review team (e.g., relocation of sampling stations due to refusal; recovery rates not meeting acceptance criteria)

4.2.3 Horizontal and Vertical Positioning Methods

***Horizontal Positioning*—**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 SAP; if strong currents and/or swell make sampling on the target station difficult or impossible, it should be noted in the field log. A 3-meter accuracy can be obtained with a range of positioning hardware, such as microwave transponders, differential or real-time kinematic GPS, electronic distance measuring devices, etc. The exact positioning system to be used and associated QA/QC procedures should be documented in the SAP.

Sampling location data will be entered into Ecology's EIM database; locations must be 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 must be tied to NAD 83 or WGS 84 to allow the conversion of location data to latitudes and longitudes. The North American Datum of 1927 (NAD 27) is outdated and should not be used.

***Vertical Positioning*—**Precise vertical positioning of the sampling equipment is required to ensure that the designated DMMU(s) and Z-layer(s) are sampled as planned. Vertical positioning must be sufficiently accurate to ensure the core sampler is not under-penetrating (i.e., only a portion of the Z-layer interval is collected). Over-penetration (i.e., driving the core beyond the Z-interval) may be necessary to ensure that the entire Z-interval is sampled and retained within the core barrel. The amount of over-penetration needed for sample retention in the core barrel will depend on the type, cohesiveness, and density of the material expected in the Z-interval. However, it is important to keep over-penetration to a minimum since the recovery rate generally decreases with sampling depth as internal friction within the core barrel increases.

If over-penetration is necessary, it is critical that material below the limit of characterization not be included in the Z-layer or dredge prism samples when the cores are processed. Likewise, it is critical that the Z-layer sample material not be mixed with the dredge prism sample material. Field personnel should attempt to achieve a vertical accuracy of ±0.1 foot. Depths and core lengths should also be recorded to the nearest 0.1 foot on the sample log form.

The following steps should be taken to ensure correct vertical positioning of the sampling equipment:

- Determine the location of the staff gauge closest to the project. If the project area is adjacent to a federal navigation channel, the locations of staff gauges are usually marked on the Corps' hydrographic surveys. The Corps hydrographic survey section or team may be able to provide information regarding both Corps and non-Corps (i.e., National Oceanic and Atmospheric Administration, US Geological Survey) gauges.
- If a staff gauge cannot be read from the sample location, an electronic gauge (e.g., Hazen gauge) can be used to transmit tide/river levels to the sampling team. The QA/QC procedures associated with its use should be documented in the SAP.
- If access to a staff or electronic gauge is not possible, real-time tide or river levels can be determined using one of the many available smartphone applications. The tide or river level station to be used during sampling must be specified in the SAP, along with any time or water-level correction needed for the project location. Field staff must take time throughout the event to

verify that real-time measurements obtained from the internet are consistent with the local staff gauge. Use of predicted tide or river levels is not recommended unless core sample processing will take place following post-correction of predicted water levels.

- Determine the depth to mudline just before each sample is collected:
  - Actual depth should be measured with a lead line or fathometer.
  - Measurements with a depth finder must be corrected relative to the lead line measurement.
  - If a depth finder is used, the sampling vessel should pass over the target sample location to determine if the sediment surface is level.
  - If the surface is uneven or sloped, the lead line should be used to determine the sampling depth.
- If a core sample is collected:
  - Calculate the needed penetration depth (plus approximately 1 foot extra, for material lost in the core catcher) and required core barrel length. For example, if the mudline is at -9.5 feet MLLW and bottom elevation of the Z-layer is -16.0 feet MLLW, the core barrel must be at least 6.5+1 feet long to sample the dredge prism material and all of the Z-layer interval.
  - Measure the actual depth of core penetration (the procedure for doing this should be included in the SAP).
  - Determine percent core recovery in the field:

$$\% \text{ Core Recovery} = \frac{retrieved\ core\ length}{(mudline\ elevation - max.penetration\ elevation)}\ x\ 100$$

  - Determine if core recovery is acceptable.
- If a grab sample is collected, note the mudline depth and sampler penetration depth on the sample log form.

4.2.4 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 analytical results may be skewed or otherwise compromised, and the data may be rejected by the local review team. Procedures for decontamination, sampler deployment, sample logging, sample extrusion, compositing, transport, chain of custody, archiving, and storage should all be discussed in the SAP and rigorously followed in the field.

In general, a sample volume of 7 L of sediment will be needed to provide adequate volume for physical, chemical, and standard biological analysis of one sample. Recommended container volumes (by type of analysis) appear in Table 4-3. Bioassay analysis requires a minimum of 5 L; physical and chemical analysis requires approximately 2 L of sediment for the primary analysis plus extra for chemical retesting. Additional volume may be required if tributyltin porewater analysis is planned.

Bioaccumulation testing requires a minimum of 15–25 L (up to 30 L for co-testing of two species) of sediment beyond the amount needed for standard physical, chemical, and benthic toxicity testing. Because of the large volume required for bioaccumulation testing, a second round of sampling would become necessary, along with physical and chemical retesting of the DMMUs in question. For all projects where samples are taken with coring devices, sediment that will be exposed by dredging (i.e., the Z-layer) must also be sampled.

***Decontamination Procedures*—**It is recommended that sampling containers, mixing bowls, and spatulas 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 noncontaminating 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 that would otherwise be found acceptable for open-water disposal being found unacceptable. While not strictly required, an adequate decontamination procedure is highly recommended and should be documented in the SAP. 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 Liquinox).
3. Rinse equipment thoroughly with clean *in situ* water.
4. Triple rinse with analyte-free deionized water.

The sampling team 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 sites contaminated with organic chemicals or heavy metals, respectively, or sites with a higher possibility of encountering contamination. Consult the *Puget Sound Protocols and Guidelines* for more specific guidance (PSDDA 1988).

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 core liners (or core 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.

***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 potential sources such as the sampling platform, grease from winches, engine exhaust, discharges from outboards, etc.

As described in section 4.2.3 (Vertical Positioning), core sampling methodology should include the means for determining when the core sampler has penetrated to the required depth. If the core sampler is driven beyond the proposed dredging depth, field records and core logging must be adequate to allow the proper core sections 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 pilothouse of the sampling vessel, as there may be a significant difference between the location of the GPS receiver and the point of sampler deployment.

***Core Acceptance Guidelines*—**The dredge prism and Z-samples collected in the field must be representative of the intended decision units. A sufficient length of sediment must enter the core barrel and be retained before the line between the dredge prism and Z-sample material can be determined. The percent recovery must be determined in the field to ensure that each core is acceptable. As part of the field quality assurance planning, the SAP must include acceptance criteria for the following:

- *Core Penetration*—If the core is under-penetrated, part or all of the Z-layer may not be sampled. If the core is over-penetrated, material from beneath the Z-layer may be included in the Z-sample and/or dredge prism; the dredge prism and Z-sample material may also be mixed. The field crew should be aware of how to process the cores and know to discard any material collected below the Z-layer. The sampling team should have sufficient experience to control core penetration and reject cores that do not achieve the target penetration depth. Samples collected from under- or over-penetrated cores may be rejected by the local review team, and resampling may be required.
- *Percent Recovery*—The basic formula for core recovery appears in section 4.2.3. Under ideal conditions, percent recovery would be 100%, but due to variability in sediment type and coring conditions this is rarely the case. To ensure that the dredge prism is being adequately characterized, **the recommended core acceptance guideline for percent recovery is at least 75%. If 75% recovery is not possible due to substrate limitations, these limitations must be summarized on the sample log forms and a narrative provided in the SCR. The sampling team should make at least three attempts per station to obtain core samples with ≥75% recovery before relocating sampling stations or accepting cores with lower recoveries. Before relocating sampling stations or accepting lower-recovery core samples, the local review team should be contacted for guidance.** The importance of achieving high core recoveries is discussed in section 4.2.5.

***Sample Holding Times*—**For some large projects, many cores are collected and composited together to form an analytical sample. Sometimes core samples are collected over multiple days and stored over ice or in a refrigerated room until all core samples 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 sample is collected.** Cores should be held for the minimum time possible before processing. Sample storage criteria appear in Table 4-3.

***Sulfides Subsampling*—**Where appropriate, the sulfides subsamples should be taken immediately upon extrusion of cores or immediately after accepting a grab sample for use. Local review team procedures vary. For composited samples, PSET requires one core section or grab sample to be randomly selected for the sulfides sampling. DMMP recommends sulfides testing of composited samples. Sediments that are directly in contact with core liners or the sides of the grab sampler should not be used.

For sulfides sampling, 5 mL of 2 Normal zinc acetate per 30 grams (g) of sediment should be placed in a 4-ounce sampling jar. Jars containing the zinc acetate should be prepared in advance to reduce the possibility of zinc cross-contamination in the field. Sediments for the sulfides analysis should be placed in the jar, covered, and shaken vigorously to completely expose the sediment to the zinc acetate; sulfides sampling jars should indicate that zinc acetate has been added as a preservative.

Table 4-3. Sample storage criteria.

Sample Type	Holding Time[1]		Sample Size[2]	Container Type
	4 ± 2 °C	-18 ± 2 °C		
Particle size	6 months	Do not freeze	100–200 g (75–100) mL	16 oz. glass or HDPE; Ziploc or similar freezer bag
Total solids, total volatile solids, and total organic carbon	14 days	6 months	125 g (100 mL) per each	8 oz. glass or HDPE
Metals (except Hg)	6 months	2 years	50 g (40 mL)	4 oz. glass
Mercury	28 days	Do not freeze	50 g (40 mL)	
Semivolatiles, pesticides, and PCBs	14 days until extraction; 40 days after extraction	1 year until extraction	150 g (120 mL)	SVOCs: 8-oz glass Pesticides/PCBs: 8-oz glass
Total petroleum hydrocarbons	14 days	Do not freeze	100 g (80 mL)	8-oz glass
Ammonia	7 days	Do not freeze	25 g (20 mL)	4-oz glass
Total sulfides	7 days[3]	Do not freeze	50 g (40 mL); add zinc acetate and shake sample vigorously	4-oz glass
Tributyltin (porewater)	7 days[4]	Do not freeze	Sufficient sediment to collect 200 to 500 mL of porewater	2 x 32-oz glass
Tributyltin (bulk)	14 days	6 months	50 g (40 mL)	4-oz glass
Dioxins/furans	14 days until extraction	1 year until extraction	100 g (80 mL)	8-oz amber glass
Bioassays	8 weeks[4]	Do not freeze	5 L	Glass, HDPE, or polyethylene bags
Bioaccumulation	8 weeks[4]	Do not freeze	15 to 20 L	Glass, HDPE, or polyethylene bags
Archive (chemical reanalysis)	—	Varies	1 L	16-oz glass (minimum)

[1] During transport to the lab, samples will be stored on ice. The archived samples will be frozen immediately upon receipt at the lab. Samples in jars to be frozen must include headspace to prevent breakage.

[2] 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 retesting.

[3] The sulfides sample will be preserved with 5 mL of 2N zinc acetate for every 30 g of sediment.

[4] Headspace purged with nitrogen.

Sample Log Forms—As sediment is collected, whether by core or grab, sampling/field logs must be completed. The field forms to be used must be included in the SAP. The SAP preparers may request example log forms from the local review team. Logs from low-recovery cores and rejected samples must be retained and included in the SCR. The following information must be recorded on the sample log forms, at a minimum:

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 and water 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, including refusal
6. Percent recovery of each core sample and percent recovery calculations
7. The measured water depth at each sampling station and the tidal or river stage at the time of sampling at each station
    a. The measured water depth must be corrected to the appropriate vertical datum
    b. The method/procedure used to determine the real-time tidal or river stage must 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, and any other distinguishing characteristics or features
9. Deviations from the approved sampling plan and rationale for deviations

***Sample Extrusion, Core Logging, Compositing, and Subsampling*—**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 facility on land. Grab samples are processed immediately upon sampling.

If cores are to be transported to a remote facility for processing, they should be stored upright and iced, both onboard the sampling vessel and during transport. The cores should be sealed in such a way as to prevent leakage and contamination; both ends of the core are commonly capped and secured with duct tape. The top of the core sample should be clearly marked on the core liner or core tube. If the cores are not processed immediately, the sampling team must consider the integrity of the cores during transport and storage to prevent loss of stratification and ensure that appropriate storage conditions are maintained. As additional sediment settling in the core may have occurred during storage, the percent recovery should be recalculated to determine the correct dredge prism and Z-layer sample intervals. For core or split-spoon sampling, the extrusion method should include procedures to prevent contamination from surrounding sources.

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 must 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 mudline elevation, penetration elevation and recovery, and indicate the core sections representing the DMMUs and Z-samples. Core depths should be logged based on collected depths prior to any corrections made for percent recovery.

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 to a

uniform color and consistency and should occasionally be stirred while the composite sample is jarred for shipment to the laboratory. Doing so will ensure that the composite remains well-mixed and that settling of coarse-grained sediments does not occur.

At least 7 L of homogenized sample needs to be prepared to provide adequate volume for physical, chemical, and standard biological laboratory analyses. Bioassays require a minimum of 5 L while physical and chemical testing requires approximately 1 L of sediment for immediate analysis and 1 L for archive. **Additional sample volume may be necessary for analysis of additional special CoCs, especially for porewater tributyltin.** Physical, chemical, and bioassay samples should be taken from the same composite. Portions of each composite sample will be placed in appropriate containers obtained from the testing laboratories (Table 4-3).

After compositing and subsampling are performed, the sample containers must be refrigerated or stored on ice until delivered to the analytical laboratory. The samples held for bioassays should be stored in the dark at 4 °C in containers with zero headspace, or with headspace purged with nitrogen, for **up to 56 days** pending the initiation of any required biological testing. Each sample container should be clearly labeled with the project name, sample/composite identification, types of analyses to be performed, date and time, and initials of persons preparing the sample and referenced by entry into the sample log book.

***Sample Transport and Chain-of-Custody Procedures*—**Sample transport and chain-of-custody procedures should follow the Puget Sound Estuary Partnership 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 US 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. Samples must be preserved on ice:
    a. Blue ice is recommended.
    b. If wet ice is used, it should be double-bagged and well-sealed.
    c. If dry ice is used, the block(s) should be sufficiently insulated to avoid freezing the sediment (which may result in breakage due to expansion of water in the sediment).
    d. Dry ice should not be used to transport biological testing samples.
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 and a copy of the SAP tables (analytical methods, sample quantitation limits, compositing scheme, etc.) 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.

4.2.5 Common Field Sampling Errors

The planning that goes into the sampling event can be undone through poor implementation of the SAP by an untrained and/or unprepared field crew. Acceptance of cores with low recoveries (due to substrate- or equipment-related limitations) can also introduce error into the sampling event. Human- and substrate-related errors can result in longer review times by the local review team, rejection of some or all of the sample data, resampling of the project sediments and reanalysis of the samples, and/or post-dredge sediment characterization (if the Z-layer is improperly characterized). Human-related error and substrate-related error are discussed below.

***Human-Related Error*—**Human-related errors stem from lack of preparation, inexperience, and inattention to detail by the sampling team. Poorly executed field sampling methods, lack of understanding of horizontal and vertical positioning, and sloppy field notes/sample logs have all contributed to mischaracterization of sediments from multiple dredging projects in the Pacific Northwest (DMMP and PSET 2014). Examples of human error include the following:

- Not correcting for tides or river levels
- Not measuring the depth to mudline
- Not measuring the depth of core penetration
- Not calculating core recovery (or assuming 100% recovery without measuring depth of penetration)
- Making recovery corrections from the bottom of the core (not the top)
- Incomplete and/or incorrect field records and data reporting

When negligence or errors by the sampling team are evident, the local review teams will always err on the side of being environmentally conservative. Data from poorly executed sampling events will take longer to review because the reviewing agencies must determine which data are usable. If the project is incorrectly sampled, portions of the data may be rejected, and the local review team may require additional sampling and analysis for the dredging project. If the Z-layer was not characterized, or if it cannot be determined if the Z-layer material was actually sampled, post-dredge characterization may be required as well.

***Substrate-Related Error during Core Sampling*—**The formula for calculating core recovery appears in section 4.2.3. Low recovery is typically caused by substrate limitations; incomplete recovery may occur if wood debris is present in the profile or if the profile is composed of coarse-grained (sandy) sediment. If

the substrate contains gravelly or cobbly material, the core barrel may not penetrate at all; this is referred to as "core refusal."

McGuire et al. (2012) summarize two types of phenomena that can lead to low core recoveries (and uncertainty in sediment sample collection):

- *Sample Shortening*—Also known as sample "compression" or "compaction," friction on the interior core barrel wall and downward pressure of the core sampler result in the incomplete recovery or "shortening" of the core sample, such that the length of the obtained core sample is less than the depth of penetration below the mudline. Sample shortening can be linear or nonlinear; practitioners typically assume the former.
- *Stratigraphic Bypass*—Forces on the inner core wall prevent sediment intake through one or more strata. Stratigraphic bypass is rarely assumed to occur and can only be ascertained if sudden penetration of the core sampler is observed.

When core recovery is high, the occurrence of shortening and/or bypass is likely minimal. However, as core recovery decreases, it is unclear whether shortening, bypass, or a combination of both contributed to the low recovery. As core recovery decreases, uncertainty that the planned decision units were correctly sampled increases. This uncertainty is exacerbated if two or more subsamples are required to generate the DMMU or Z-layer composite sample. Representative characterization of the dredging project sediments is the primary objective of field sampling events undertaken using this guidance; establishing a minimum core recovery of 75% reduces the error in representativeness to an acceptable level.

4.3 References

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Chapter 5. Sediment Conventional and Chemical Testing Protocols and Data Quality

This chapter describes the Level 2A sediment conventional and chemical parameter testing protocols used to evaluate dredged material suitability and presents the revised list of CoCs associated with the updated freshwater SLs. This chapter also briefly summarizes the minimum federal and state quality assurance requirements that environmental laboratories must meet to generate the data used for dredged material evaluations conducted in accordance with the CWA and MPRSA. Figure 5-1 illustrates sediment testing and laboratory data quality assurance within the SEF review process.

5.1 Sediment Conventional and Chemical Parameter Protocols

The purpose of chemical characterization of dredged and Z-layer material is to identify sediment-borne contaminants that may cause adverse biological effects. Sediment conventional data (i.e., total solids, organic carbon, sulfides, ammonia, and grain size) provide general characteristics of the sediment and are important to consider in the event that bioassays are conducted.

A standard list of CoCs is routinely analyzed to characterize the dredge prism material (and the surface exposed after dredging, if required) (Table 5-1). The standard list of CoCs differs between marine and freshwater environments. Selection of the appropriate suite of CoCs is based on the location at which sediment toxicity is being evaluated. The surface exposed after dredging will be evaluated for the CoCs appropriate for the dredge area; the effects of open-water disposal of dredged material will be evaluated using the CoCs appropriate for the disposal site. Per the national Inland Testing Manual, waters with salinities less than 1 part per thousand (ppt) are considered freshwater, waters with salinities greater than 25 ppt are considered marine, and waters with salinities between 1 and 25 ppt are considered estuarine (EPA and Corps 1998). The marine guidelines are typically used for estuarine sediment. The local review team will determine which set of CoCs (freshwater or marine) will be used to evaluate the dredging project; in some cases, both the freshwater and marine CoCs may need to be analyzed.

In addition to the standard list of CoCs, contaminants or other deleterious substances identified in the CSM that do not have established screening levels may also be added to the list of analytes for a specific project if there is reason to believe the contaminants may be present at levels of concern.

Laboratories in the Pacific Northwest that specialize in sediment testing are familiar with the methods listed in Table 5-1 and can routinely achieve the recommended sample quantitation limits. Quantification of the chemicals at or below the lowest applicable screening level (marine or freshwater SL1) is required for interpretation and screening of chemical data. Nondetected but potentially present chemicals with sample quantitation limits exceeding SL1 may trigger the need for bioassay testing.

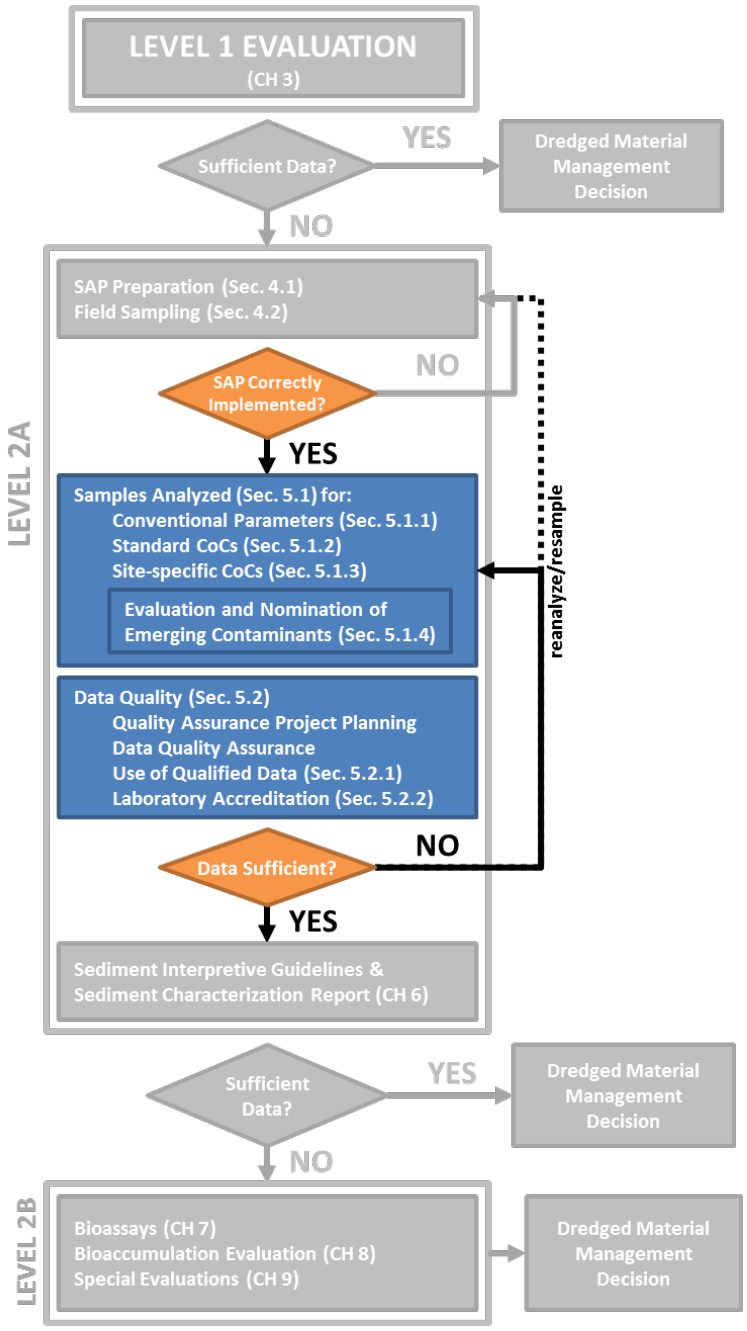

Figure 5-1. Laboratory chemical and physical analysis within SEF tiered evaluation process.

The RSET-recommended chemical and conventional parameter analytical methods for sediments and sample quantitation limits (also known as reporting limits) presented in Table 5-1 follow national and regional protocols referenced in the table.

Any requests for modifications to these protocols or use of alternative analytical methods should be requested in the SAP (see Chapter 4). Protocol modifications and/or the use of alternative analytical methods require local review team approval.

5.1.1 Conventional Parameter Testing Protocols

Conventional parameters should be analyzed according to the following specifications:

***Grain Size*—**Sediment grain size may be determined using either the PSEP (1986) or American Society for Testing Materials (ASTM) Method D-422 (modified). These methods subdivide the fines (i.e., silt and clay fractions) using pipette and hydrometer, respectively. The Puget Sound Estuary Partnership (PSEP) protocol is generally recommended for site investigations but ASTM may be preferable for engineering calculations. One of the following sieve series must be used: (1) sieve numbers 5, 10, 18, 35, 60, 120, and 230 (PSEP) or (2) sieve numbers 4, 10, 20, 40, 60, 140, 200, and 230 (ASTM D-422 modified). In both protocols, fine-grained material is defined as the material passing the No. 230 sieve. The use of hydrogen peroxide, which was used in the past to break up organic clumps, is not recommended.

***Water Content*—**Water content will be determined using ASTM D-2216. While this value is not often reported, it is required to convert sediment wet weight analytical values to a dry weight basis.

***Sediment Classification*—**Designation will be made in accordance with US Soil Classification System, ASTM D-2487, using the results of the grain size analysis.

***Total Solids*—**The total solids percentage is used to determine how much actual sediment is analyzed in a given chemical analysis. Total solids data can also be used to predict production rates in pipeline dredging operations. The total solids percentage is determined by the PSEP (1986) or Standard Methods 2540G protocol.

***Total Volatile Solids*—**The total volatile solids represents the fraction of total solids that are lost on ignition at a higher temperature than used to determine total solids and is a crude estimate of the amount of organic matter. Total volatile solids are determined by using either PSEP (1986) or Standard Methods 2540G.

***Total Organic Carbon*—**TOC is a key index parameter that affects the adsorptive capacity and bioavailability of organic contaminants and some metals in sediments. Sediment TOC analysis should follow PSEP (1997) for sample preparation (i.e., sample drying, homogenization, and acidification to remove inorganic carbon), with modifications suggested by Bragdon-Cook (1993) for high-temperature combustion followed by nondispersive infrared detection. Acidification, combustion, and nondispersive infrared detection analysis should be conducted according to the instrument manufacturer's instructions, as specified in Standard Methods 5310B and EPA Method 9060A.

***Ammonia and Sulfides*—**The analysis of ammonia and sulfides is critical if bioassays are planned; these naturally occurring compounds may contribute to sediment toxicity and confound biological testing results. Ammonia and sulfides should be analyzed using PSEP (1986).

Table 5-1. Recommended sediment analytical methods and sample quantitation limits.

Parameter (unit)	Sample Preparation Method	Sample Analysis Method	Sample Quantitation Limit (MRL) [1]
CONVENTIONAL PARAMETERS			
Total Solids [M/F] (%)	—	PSEP 1986 or SM 2540G	0.1
Total Volatile Solids[M/F] (%)	—	PSEP 1986 SM 2540G	0.1
Total Organic Carbon [M/F] (%)	PSEP 1997 and Bragdon-Cook 1993	SM 5310B or EPA 9060A	0.1
Total Sulfides [M/F] (mg/kg)	—	PSEP 1986/Plumb 1981	1.0
Ammonia [M/F] (mg/kg)	—	Plumb 1981	0.1
Grain Size [M/F] (%)	—	PSEP 1986 or ASTM D-422 mod	1.0
STANDARD CHEMICALS OF CONCERN			
Metals (mg/kg)			
Antimony [M]	EPA 3050B	EPA 6010D/6020B	0.5
Arsenic [M/F]	EPA 3050B	EPA 6010D/6020B	5
Cadmium [M/F]	EPA 3050B	EPA 6010D/6020B	0.5
Chromium [M/F]	EPA 3050B	EPA 6010D/6020B	5
Copper [M/F]	EPA 3050B	EPA 6010D/6020B	5
Lead [M/F]	EPA 3050B	EPA 6010D/6020B	5
Mercury [M/F]	EPA 7471B	EPA 7471B	0.05
Nickel [F]	EPA 3050B	EPA 6010D/6020B	5
Selenium [F]	EPA 3050B	EPA 6010D/6020B	1
Silver [M/F]	EPA 3050B	EPA 6010D/6020B	0.5
Zinc [M/F]	EPA 3050B	EPA 6010D/6020B	5
Polynuclear Aromatic Hydrocarbons (µg/kg)			
Low molecular weight PAHs			
Naphthalene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Acenaphthylene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Acenaphthene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Fluorene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Phenanthrene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Anthracene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
2-Methylnaphthalene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20

Table 5-1. Recommended sediment analytical methods and sample quantitation limits.

Parameter (unit)	Sample Preparation Method	Sample Analysis Method	Sample Quantitation Limit (MRL) [1]
High-molecular weight PAHs			
Fluoranthene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Pyrene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Benzo(a)anthracene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Chrysene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Benzofluoranthenes [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Benzo(a)pyrene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Indeno(1,2,3-c,d)pyrene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Dibenzo(a,h)anthracene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Benzo(g,h,i)perylene [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Chlorinated Hydrocarbons (µg/kg)			
1,4-Dichlorobenzene [M]	EPA 3550C-mod[3]	EPA 8270D	20
1,2-Dichlorobenzene [M]	EPA 3550C-mod[3]	EPA 8270D	20
1,2,4-Trichlorobenzene [M]	EPA 3550C-mod[3]	EPA 8270D	20
Hexachlorobenzene [M]	EPA 3550C-mod[3]/3540C	EPA 8270D/8081B	10
Phthalates (µg/kg)			
Dimethyl phthalate [M]	EPA 3550C-mod[3]	EPA 8270D	20
Diethyl phthalate [M]	EPA 3550C-mod[3]	EPA 8270D	20
Di-n-butyl phthalate [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Butyl benzyl phthalate [M]	EPA 3550C-mod[3]	EPA 8270D	20
Bis(2-ethylhexyl)phthalate [M/F]	EPA 3550C-mod[3]	EPA 8270D	100
Di-n-octyl phthalate [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Phenols (µg/kg)			
Phenol [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
2-Methylphenol [M]	EPA 3550C-mod[3]	EPA 8270D	20
4-Methylphenol [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
2,4-Dimethylphenol [M]	EPA 3550C-mod[3]	EPA 8270D	20
Pentachlorophenol [M/F]	EPA 3550C-mod[3]	EPA 8270D	100
Miscellaneous Extractable Organic Compounds (µg/kg)			
Benzyl alcohol [M]	EPA 3550C-mod[3]	EPA 8270D	50
Benzoic acid [M/F]	EPA 3550C-mod[3]	EPA 8270D	100
Carbazole [F]	EPA 3550C-mod[3]	EPA 8270D	500
Dibenzofuran [M/F]	EPA 3550C-mod[3]	EPA 8270D	20
Hexachlorobutadiene [M]	EPA 3550C-mod[3]	EPA 8270D	10
N-Nitrosodiphenylamine [M]	EPA 3550C-mod[3]	EPA 8270D	20

Table 5-1. Recommended sediment analytical methods and sample quantitation limits.

Parameter (unit)	Sample Preparation Method	Sample Analysis Method	Sample Quantitation Limit (MRL) [1]
Pesticides (µg/kg)			
DDE (p,p'-, o,p'-) [M/F]	EPA 3540C	EPA 8081B	2
DDD (p,p'-, o,p'-) [M/F]	EPA 3540C	EPA 8081B	2
DDT (p,p'-, o,p'-) [M/F]	EPA 3540C	EPA 8081B	2
Aldrin [M]	EPA 3540C	EPA 8081B	2
Chlordane compounds [M] (cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane)	EPA 3540C	EPA 8081B	2
Dieldrin [M/F]	EPA 3540C	EPA 8081B	2[2]
Heptachlor [M]	EPA 3540C	EPA 8081B	2[2]
Endrin ketone [F]	EPA 3540C	EPA 8081B	2
beta-Hexachlorocyclohexane [F]	EPA 3540C	EPA 8081B	2
Polychlorinated Biphenyls (µg/kg)			
Total Aroclors [M/F] (1016, 1221, 1232, 1242, 1248, 1254, and 1260) [4]	EPA 3540C	EPA 8082A	10
SITE-SPECIFIC CHEMICALS OF CONCERN			
Butyltins			
Tributyltin, porewater (µg/L) [M]	Krone 1989/DMMP 1998/ EPA 8270-SIM	Krone 1989/EPA 8270-SIM	0.03
Mono- [F], di- [F], tri- [M/F], and tetra- [F] butyltin (µg/kg)	Krone 1989/ EPA 8270-SIM	Krone 1989/EPA 8270-SIM	5
Total Petroleum Hydrocarbons (mg/kg)			
TPH-diesel [F]	NWTPH-Dx/EPA 3630C/3665A	NWTPH-Dx	25
TPH-residual [F]	NWTPH-Dx/EPA 3630C/3665A	NWTPH-Dx	50
Dioxins/ Furans (ng/kg)			
2,3,7,8-TCDD [M/F]	EPA 8290A/1613B	EPA 8290A/ 1613B	1
Dioxins/furans (other) [M/F]	EPA 8290A/1613B	EPA 8290A/ 1613B	1–10

Note: [M] = marine screening only; [F] = freshwater screening only; [M/F] = both marine and freshwater

[1] MRLs are based on dry sample weight assuming no interferences; site-specific method modifications may be required to achieve these MRLs in some cases.

[2] The standard method MRL is above the screening levels. For these CoCs, labs should ensure that MDLs are below the screening levels and report MDL for nondetects.

[3] EPA Method 3550C is modified to add matrix spikes before the dehydration step, not after.

[4] See section 6.1.2 for rules for PCB summation.

5.1.2 Chemical Parameter Testing Protocols

There are three categories of CoCs that may be tested to evaluate the suitability of dredging project sediments for unconfined, aquatic disposal: standard, site-specific, and bioaccumulative.

***Standard List of CoCs*—**This is the default list of constituents analyzed in a majority of dredging projects. Past studies have shown that many of the CoCs on the standard list are relatively widespread in the Pacific Northwest and may have multiple sources. The standard CoCs have one or more of the following characteristics:

- Demonstrated or suspected adverse ecological or human health effect (toxicity)
- Relatively widespread distribution above natural or background conditions (as defined within the applicable state) in the Pacific Northwest (common occurrence)
- Potentially toxic forms are persistent in the environment for years or decades

The standard CoCs for marine and freshwater systems are listed in Table 6-2, along with benthic toxicity SLs. CoCs are also flagged in Table 5-1 as being marine-only, freshwater-only, or both. Recommended analytical methods and quantitation limits are presented in Table 5-1.

Use of methods other than those presented in Table 5-1 may result in unacceptable reporting limit issues. In particular, review groups have had issues with labs reporting technical chlordane rather than conducting analysis of the individual total chlordane components. Analysis of technical chlordane typically results in nondetect values greater than the screening level for the sum of individual technical chlordane compounds.

If the Level 1 site history information or analysis of new data (collected in accordance with SEF guidelines) shows that certain CoCs are not present in the project vicinity, the local review team may not require analysis for the CoCs unless there is a changed condition at the site.

***Site-Specific Chemicals of Concern*—**These are constituents to be considered for analysis in special areas or in association with particular sources, activities, or land uses. Testing will be required only when those sources, activities, or land uses are present or have historically been present in the vicinity of the project site.

***Bioaccumulative CoCs*—**These are constituents with the potential to bioaccumulate in higher-level organisms (e.g., humans, fish, birds, mammals). See Chapter 8 and Appendix C for a discussion and list of BCoCs.

5.1.3 Testing Protocols for Site-Specific Chemicals of Concern

Site-specific CoCs may be associated with particular activities, industries, or land uses. They may exhibit locally high concentrations. Many of these chemicals do not have analytical methods or quantitation limits specified in Table 5-1 as they have no screening levels; thus, specific methods and detection limits must be determined on a site-specific basis (depending on the agreed to screening level for the site-specific CoCs). The following site-specific CoCs will be considered for inclusion in a project's suite of CoCs when there is a reason to believe a current or historical source of these chemicals is or has been present.

***Butyltins*—**Testing for butyltins per the method of Krone et al. (1989) or EPA 8270-SIM may be required in areas affected by vessel maintenance and construction activities, marine shipping, and frequent vessel traffic (e.g., shipyards, boatyards, marinas, and marine terminals). For marine and freshwater systems, the recommended tributyltin analysis has moved to bulk analysis rather than porewater for logistical reasons, although applicants may propose porewater analysis, since in marine sediments, porewater analysis has been shown to improve the reliability of toxicity predictions (Michelsen et al. 1996).

***Dioxins and Furans*—**Testing for polychlorinated dibenzodioxins and polychlorinated dibenzofurans (PCDD/PCDF) may be required in areas potentially impacted by known sources of dioxin/furan compounds or in areas where elevated levels of dioxin/furan compounds have been demonstrated in past testing. Dioxins/furans are typically formed as an unintentional byproduct of many industrial processes involving chlorine, such as waste incineration, chemical and pesticide manufacturing, wood treatment, and pulp and paper bleaching. Additionally, dioxins/furans are formed through other combustion processes, including structural fires and—historically—by the burning of hog fuel. Analysis of dioxin/furan compounds in sediment by EPA Method 1613B or 8290A is recommended. For detailed QA/QC requirements for these compounds, please see *Polychlorinated Dioxins and Furans (PCDD/F): Revisions to the Supplemental Quality Assurance Project Plan* (DMMP 2010a) and *Revised Supplemental Information on Polychlorinated Dioxins and Furans (PCDD/F) for use in Preparing a Quality Assurance Project Plan (QAPP)* (DMMP 2010b).

***Organophosphate Pesticides*—**Testing for organophosphate pesticides and potentially other types of pesticides (e.g., triazines) may be considered in areas dominated by agricultural land use and in sediments affected by cropland runoff, particularly in certain eastern drainages where large portions of the watershed are under cultivation. Analysis by EPA Method 8141B is recommended.

***Total Petroleum Hydrocarbons (TPHs)*—**Testing for TPH is now mandatory for freshwater sediments but not at marine sites. However, testing for TPH may be considered at marine sites where quantities of petroleum product have been released to the aquatic environment (e.g., crude oil or fuel spills, waterfront petroleum storage tank or pipeline leaks). NWTPH-Dx (including diesel and residual range hydrocarbons) is the recommended method for bulk petroleum analysis in sediments. Because sediments are often comprised of weathered and unresolved petroleum mixtures, it is recommended that TPH be quantified using diesel and motor oil standards. Sediment samples should be processed using sulfuric acid and silica gel cleanup steps to remove potential interferences from other organic compounds and biogenic materials. Quantitation of bulk petroleum using EPH/VPH analysis (extractable and volatile petroleum hydrocarbons) is not currently recommended for sediments.

Volatile, gasoline-range petroleum compounds dissipate relatively quickly in sediments and are rarely observed at concentrations of concern unless an ongoing source of light-end petroleum is present. As a result, the need for analysis of NWTPH-Gx (gasoline range hydrocarbons) or component volatile organic compounds (e.g., ethylbenzene, xylene) is expected to be relatively rare.

***Guaiacols*—**Guaiacol and chlorinated guaiacols may be present in sediments where kraft pulp mills are located. Only guaiacol, and not chlorinated guaiacols, will be measured near sulfite pulp mills because these mills do not use a bleaching process. Samples are extracted using EPA 3550C and analyzed by EPA method 8270D, which is modified to add matrix spikes before rather than after the dehydration step.

5.1.4 Evaluation and Nomination of Emerging Contaminants

An "emerging contaminant" may be added to the list of site-specific CoCs if it is found at least occasionally in sediments of the Pacific Northwest at levels likely to be associated with ecological or human health effects, including direct effects to aquatic organisms and/or indirect effects through bioaccumulation. If it is unclear whether the chemical is present in sediments at potentially toxic levels, structure-activity relationships may be helpful in predicting potential effects. In addition, federal, state, and/or local agencies and academic institutions should be encouraged to collect additional data (e.g., through regional monitoring programs or special research projects) until sufficient data are available to nominate the chemical for inclusion in the SEF.

In considering a candidate for inclusion as a site-specific CoC, the regional database (Washington Department of Ecology's EIM database) and technical literature will be reviewed to determine whether a listing is warranted, not warranted, or indeterminate because of insufficient data. The weight-of-evidence for establishing a reason to believe the chemical is causing sediment toxicity includes the following considerations:

- Local/regional contaminant sources (usage rates, industrial associations)
- Environmental occurrence (frequency and magnitude of detection in regional monitoring data)
- Toxicity (presence in the environment above ecological or human health toxicity thresholds or structure-activity relationship basis)
- Likelihood for bioaccumulation to levels of concern
- Persistence (half-life, ability to degrade)
- Mobility (hydrophobicity, partitioning behavior)

A site-specific CoC may be promoted to the standard CoCs list if the chemical is found to be prevalent in sediments of the Pacific Northwest at concentrations commonly associated with biological effects, or if a sufficient body of data has accumulated to allow the development of reliable sediment SLs. The development of SLs will typically require 100 or more synoptic data points (i.e., paired chemical and biological testing results) from multiple studies and aquatic environments over a range of concentrations.

On the other hand, a chemical may be delisted from the standard CoC list if one (or more) of the following occurs:

- The chemical is no longer prevalent in the Pacific Northwest at levels of concern (e.g., concentrations have dropped significantly below the toxicity-based levels in response to source controls).
- The chemical is shown to have reduced toxicity based on more recent toxicological data, and observed concentrations in sediment are below this level.

The rationale for listing or delisting site-specific CoCs or standard CoCs will be considered on a case-by-case basis using the guidelines listed above.

5.2 Sediment Data Quality

This section describes the importance of QA/QC for laboratory-generated environmental data used in dredged material evaluations. QA activities provide a formalized system for evaluating the technical

adequacy of sample collection and laboratory analysis activities. These QA activities begin before samples are collected and continue after laboratory analyses are completed.

QA/QC project planning is necessary to ensure that the physical, chemical, and biological data generated during dredged material evaluations meet overall program and specific project needs. Establishing data quality objectives and QA/QC procedures is fundamental to meeting project data quality criteria and to providing a basis for good decision-making. QA/QC activities are grouped by four project stages (illustrated in Figure 5-2):

- Project planning (covered in Chapter 4), including study design (systematic planning process, sampling design rationale), SAP preparation and approval, lab selection and contracting, vessel/sampling equipment selection and contracting, field and laboratory activity scheduling, and project team coordination
- Field sampling and onsite field measurements (also covered in Chapter 4) recording the appropriate field data to ensure that samples are collected from the correct DMMU(s) (water depth and correction for river stage or tides, sample logging, sample storage and preservation, chain of custody procedures)
- Laboratory measurements (sample login and custody, storage and handling conditions, holding time, physical measurements, chemical analytical results, biological testing)
- Data review (data verification and validation, reconciliation with project data quality objectives) and reporting.

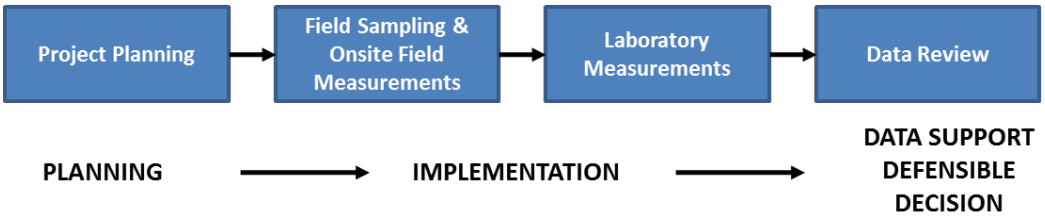

Figure 5-2. Quality assurance stages of a project.

The final project Q/A stage, the comprehensive laboratory data quality review, ensures that the project data are of sufficient quality to support dredged material evaluations made under the SEF (Q/A considerations for field sample collection are covered in Chapter 4; Q/A considerations for biological testing are covered in Chapters 7 and 8). Reviewers of laboratory data generated for dredged material evaluations include the contract laboratory, the project proponent, the proponent's contractor (if applicable), and the local review team.

The data reviewers determine if the level of data quality is acceptable to make an unqualified (or qualified) management decision, or if rejection of the data is necessary due to their low quality. *The onus is on the project proponent to provide justification for the acceptance of qualified data.* Ultimately, the local review team determines whether qualified data meet the data quality objectives and are satisfactory to use in the dredged material evaluation. The data review and interpretation process is outlined in Figure 5-3.

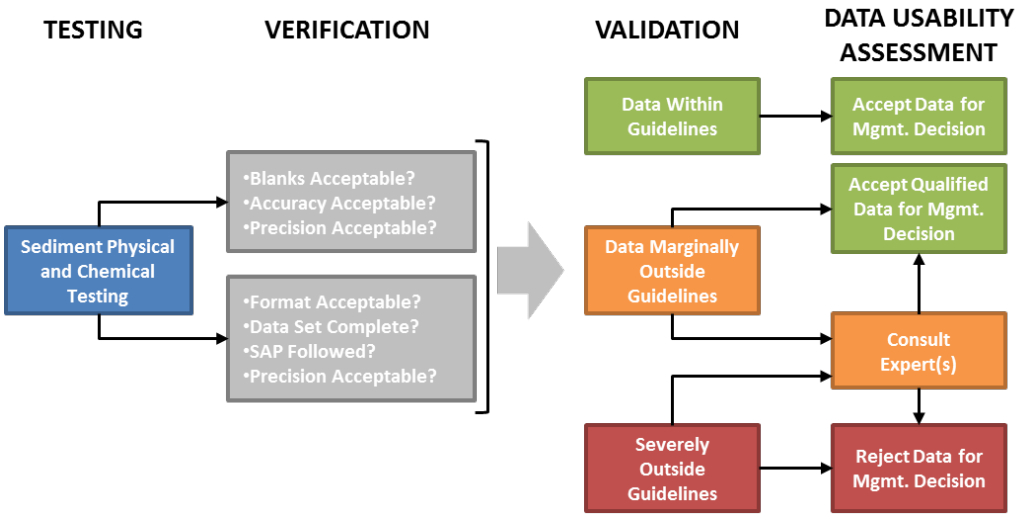

Figure 5-3. Quality assurance process for data review and interpretation.

The data review process is generally divided into three steps: verification, validation, and the data usability assessment:

Verification—Review data for compliance with methods, procedures, and contracts. This step should be completed by both the data generator and the project proponent.

Validation—Review data for conformity with quality objectives stated in the SAP. This step should be performed by entities that did not participate in the data generation. Both the proponent (or proponent's contractor) and the local review team should review the field sampling procedures used and laboratory data and supporting QA procedures (e.g., blanks, spiked samples, duplicates).

Data Usability Assessment—Assess results of previous data review steps to determine usability of data for making decisions. The usability assessment should be performed by the full project team (contract laboratory, proponent, and proponent's contractor[s]). External to the project team, the local review team will independently review the data package for usability in the dredged material evaluation.

The data usability assessment is completed in the context of the data's use in decision-making for the project. The assessment considers whether data meet project quality objectives as they relate to the decision to be made and evaluates whether data are suitable for making that decision. All types of data (e.g., field notes and sampling logs, on-site analytical, off-site laboratory) are relevant to the usability assessment. The usability assessment is the final step of data review and can only be performed on data of known and documented quality (i.e., verified and validated data).

In particular, data that were qualified during data validation should be reviewed carefully if they are central to a sediment management decision. The nature of the data quality problem, the magnitude of any effect on the precision, and the magnitude and direction of any bias should be considered. The data quality issue and its effect on the sediment management decision should be justified in the SCR.

When project-required measurement performance criteria are not achieved and project data are not usable to adequately address environmental questions (i.e., to determine if the sediment quality guidelines have

been exceeded) or to support project decision-making, then the usability report should address how this problem will be resolved and discuss the potential need for resampling and/or reanalysis.

Federal and state guidance documents for quality assurance project planning are listed below:

- The Department of Defense's (DoD) 2013 *DoD Quality Systems Manual for Environmental Laboratories*, Version 5.0 (or most current version)
- EPA's 2002 *Guidance for Developing Quality Systems for Environmental Programs* (EPA QA/G-1, reissued in January 2008)
- EPA's 2002 *Guidance for Quality Assurance Project Plans* (EPA QA/G-5a)
- The PSEP's 1997 *Recommended Quality Assurance and Quality Control Guidelines for the Collection of Environmental Data in Puget Sound*
- Washington Department of Ecology's (Ecology's) 2008 *Sediment Sampling and Analysis Plan Appendix (SAPA): Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards*

5.2.1 Qualified Data: Analytical Sensitivity and Quantitation Limits

Analytical sensitivity is generally described using two limits: the method detection limit (MDL) and method reporting limit (MRL) (also known as the sample quantitation limit, practical quantitation limit, limit of quantitation, and others; EPA 1989; DoD and DOE 2013). The MDL is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. The MDL studies are conducted using ideal, laboratory-prepared samples of a spiked clean matrix. The MRL is established by the low standard of the initial calibration curve or low-level calibration check standard. At a minimum, the MRL should be three to five times the MDL. For analysis of dioxins and PCB congeners using high-resolution gas chromatographic/mass spectrometric methods, the sample-specific estimated detection limit (EDL) is analogous to the MDL, and the MRL may be estimated based on the lower calibration limit, statistical analysis of historical method blank data, or other method specified by the laboratory.

To generate useable data, achieve data quality objectives, and support sediment management decisions, the MRLs should be less than the SLs listed in Table 6-2.

Regarding analytical sensitivity, the following three scenarios are possible during the data usability assessment:

***MRL is less than SL*—**All reasonable steps should be taken, including additional cleanup steps, re-extraction, etc., to keep the MRLs below the sediment screening levels. Assuming all other QA/QC criteria are met, this produces data of the greatest utility.

***MDL exceeds SL*—**In this scenario, the analytical method used is not sufficiently sensitive to make an informed sediment management decision. An undetected result with an MDL exceeding the SL will be considered an exceedance of the SL unless it can be demonstrated that all reasonable steps were taken to control the MDL and MRL, including additional cleanup procedures, re-extraction, and re-analysis as necessary. In such cases, the local review team may consider the results of other analytes in the same class of compounds, site history, existing sediment quality data from the site vicinity, and other lines of

evidence to determine whether the elevated MDL represents a significant data gap and a potential false negative error.

***MDL is less than SL; MRL exceeds SL*—**In some circumstances, matrix interference, high water content, or other sample characteristics may compromise the sensitivity of the analytical method. However, it must be shown that all reasonable steps were taken to control the MRL, including additional cleanup procedures, re-extraction, and re-analysis. These data are acceptable for use in sediment management decisions but may result in a requirement to run bioassays, unless the laboratory reports the analyte as undetected at the MDL.

For undetected compounds, laboratories should report both the MDL and the MRL. If problems or questions arise regarding the ability to achieve sufficiently low MDLs and MRLs, the project proponent should contact the local review team. In all cases, sediments or extracts should be archived under proper storage conditions until the chemistry data are deemed acceptable by the local review team. This gives the project proponent the option for re-analysis and lower-level quantitation, if necessary.

Laboratories have the ability to identify and provide estimated concentrations of CoCs below the MRL and above the MDL; however, quantitations in this region have a lower accuracy and precision compared to quantitations above the MRL. Laboratories shall be required to report estimated values between the MDL and the MRL; typically, these values will be qualified with a "J" flag because they are below the lowest calibration standard.

Note that sediment chemistry data generated using the methods and data quality guidelines are compared to the benthic toxicity SLs presented in Table 6-2. Several of the CoCs in Table 6-2 have substantially lower freshwater SLs than the marine SLs (e.g., phthalates). Analytical laboratories should be aware that they need to achieve lower analytical detection limits to prevent nondetected exceedances of the SLs.

5.2.2 Federal and State Laboratory Accreditation Programs

Environmental laboratory accreditation programs ensure that accredited laboratories have systems and procedures in place to generate data of sufficient quality for federal and state regulatory decision-making.

It is highly recommended that sediment physical and chemical testing that is conducted in accordance with the SEF be performed by laboratories accredited through the Department of Defense's Environmental Laboratory Accreditation Program. The Corps is part of the DoD and is the federal agency responsible for maintaining federal navigation channels and issuing CWA and (with EPA concurrence) MPRSA Regulatory permits for dredging and in-water disposal of dredged material.

Laboratories must be certified by the appropriate state environmental laboratory accreditation program based on where the project/disposal site is located, if one is established (Oregon Environmental Laboratory Accreditation Program in Oregon; Washington Department of Ecology Environmental Laboratory Accreditation Program in Washington).

5.3 References

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Chapter 6. Sediment Chemical Interpretive Guidelines and the Sediment Characterization Report

The majority of dredging projects in the Pacific Northwest are evaluated through the Level 2A sediment chemical and physical characterization step covered here in Chapter 6 (see Figure 6-1). Some projects require Level 2B evaluations (bioassays, bioaccumulation studies, or other special evaluations). Those evaluations are discussed in Chapters 7, 8, and 9.

Once the project proponent receives the sediment chemical and physical data from the laboratory, they must correctly report those data in the SCR provided to the local review team. To report the data correctly, the project proponent should rely on the laboratory reports and electronic data deliverables from the laboratory to create a table that reports the data with the appropriate data qualifiers, chemical summation methods, nondetect reporting conventions, etc. Once the project proponent has correctly summarized their data, they can compare the data to the sediment interpretive guidelines. Once finished, the project proponent provides the SCR and electronic data deliverables to the local review team. The local review team evaluates this information and formalizes the interagency dredged material management decision in an SDM.

***Sediment Interpretive Guidelines and Screening Levels*—**RSET has accepted new freshwater SLs as of 2015 (RSET 2015). Those screening levels and an approach for considering natural background (for metals) are included in this chapter, along with the marine screening levels. The RSET continues to develop guidance for protecting water quality and sensitive, nonbenthic species at higher trophic levels (section 6.3). Placeholder sections are included in this chapter for water quality-based screening levels and a fish-protective SL and risk evaluation framework for polynuclear aromatic hydrocarbons (PAHs). Until programmatic work is completed on the water quality-based screening levels, draft water quality-based SLs may be used on a case-by-case basis as determined by the local review team or CWA §401 certification permit writer. WQ-based SLs are found in Section 2 of the RSET 2015 issue paper in Appendix A of this document. Note that Appendix A also contains a disclaimer from USFWS and NMFS regarding applicability of these SLs for protection of ESA-listed species.

6.1 Data Reporting

Before chemical testing results can be compared to benthic screening levels, the project proponent must evaluate the quality control data associated with the testing results (Chapter 5), assign data qualifiers, and sum the results for the appropriate groups of chemicals (i.e., PCBs). Data qualification and summation are addressed in sections 6.1.1 and 6.1.2, respectively.

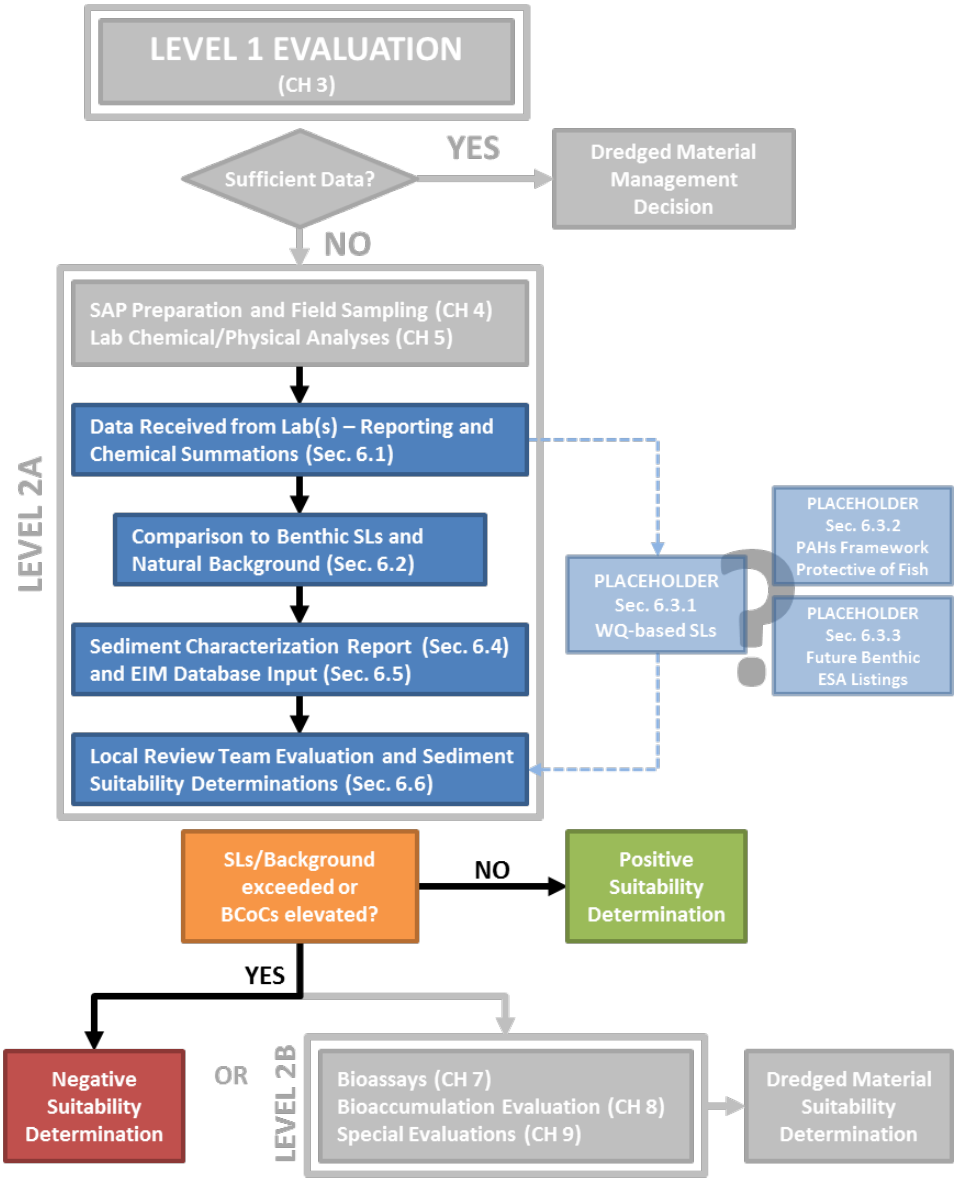


Figure 6-1. SEF tiered evaluation and the sediment interpretive guidelines and data reporting.

6.1.1 Data Qualifiers

Each laboratory may differ in their terminology and definitions for analytical detection limits. Thus, the local review teams will use the terminology provided in this section (Figure 6-2), and the project proponents should incorporate this terminology into their SCR. The RSET is aware that the language surrounding laboratory analytical limits may change; EPA is working on a national approach, and the new terminology will be accepted when EPA finalizes its documentation. When reporting data, laboratory-specific definitions of the qualifiers should be included in the SCR.

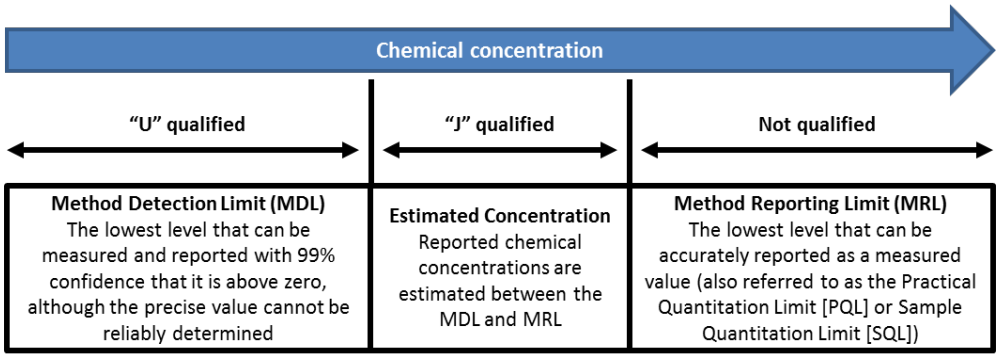


Figure 6-2. Visual representation of data qualifiers based on detection and reporting limits.

Nondetects—For nondetected compounds ("U" qualified data), laboratories should report both the MDL and the MRL. If problems or questions arise regarding the ability to achieve sufficiently low MDLs and MRLs, the project proponent should contact the local review team. In all cases, sediments or extracts should be archived under proper storage conditions until the local review team has completed the project evaluation and issued the SDM. This retains the option for re-analysis and lower-level quantitation, if necessary, provided sample holding times are not exceeded.

Estimated Concentrations—Laboratories have the ability to identify and provide estimated quantitations of CoCs at concentrations below the MRL and above the MDL; however, quantitations in this region have lower accuracy and precision compared to quantitations above the MRL. Project proponents should require their laboratory to report estimated values between the MDL and the MRL. In the SCR, the project proponent should qualify these results with a "J" flag because they are below the lowest calibration standard. For the purposes of dredged material evaluation, these estimated values are treated as detections.

Nondetects, Elevated Detection Limits—If matrix interference or other issues result in elevated sample-specific detection limits such that the reported detection limit is above applicable screening levels, bioassays may be required. Thus, project proponents should require their laboratory to do their best to lower MDLs to below the SLs. This may require additional sample cleanup, alternative sample preparation, or alternative analytical methods, which should be clearly documented in the data report.

Dioxin/Furans, Estimated Detection Limits—The laboratory shall report each of the 2,3,7,8-chlorine substituted polychlorinated dibenzodioxins/furans (PCDD/F) congeners on a dry-weight basis. Estimated detection limits (EDLs) and reporting limits shall be reported for each of these congeners (see below). For the purpose of toxicity equivalence (TEQ) summation, detections at concentrations >EDL but <MRL, and which were reported as estimated maximum potential concentrations (EMPCs), shall be reported as nondetects (U) elevated at the EMPC value. EMPC values >MRLs with mass-ion ratios adjusted to meet the criteria are flagged as estimated and reported as detected compounds.

> *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 value is the best one to use to get the lowest defensible TEQ values.
>
> The estimated detection limit is defined as follows:

$$EDL = \frac{2.5 \times H_x \times Q_{is}}{H_{is} \times W \times RF_n}$$

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 grams, of the sample
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 picograms, of the internal standard added to the sample before extraction

6.1.2 Chemical Summations

Many of the benthic SLs are sums of individual compounds (e.g., total low molecular weight polynuclear aromatic hydrocarbons [LPAHs], total high molecular weight polynuclear aromatic hydrocarbons [HPAHs]); isomers (e.g., total benzofluoranthenes); or groups of compounds (e.g., total PCB Aroclors). Additionally, some bioaccumulative chemicals with common modes of action are normalized to the most toxic form and summed (e.g., dioxins/furans). In general, the analytical laboratory will report results for individual chemicals, congeners, and isomers, and the data user will perform any required summations. With the exception of dioxins/furans, the rules for chemical summation are as follows:

- The estimated values between the MDL and the MRL (i.e., J-flagged values) are included in the summation at face value and the sum is also J-flagged. Values that are J-flagged due to minor quality control deviations are also handled in this way.
- If all constituents in a chemical group are undetected, the group sum is reported as undetected, and the highest MDL and MRL of all the constituents are reported as the MDL and MRL for the group sum.
- If the data are a mixture of detected and nondetected, the sum is calculated by adding only the detected concentrations.

PAHs

- Low molecular weight PAHs (LPAHs) include the following compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- High molecular weight PAHs (HPAHs) include the following compounds: fluoranthene, pyrene, benz (a)anthracene, chrysene, benzo(b,j+k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz (a,h)anthracene, and benzo(g,h,i)perylene.
- Total PAHs includes the sum of all LPAH and HPAH compounds, plus 1-methylnaphthalene.
- Total benzofluoranthenes include the sum of the b, j, and k isomers.

Total PCBs (as Aroclors)—Total PCB Aroclors for both marine and freshwater sediments include the sum of Aroclor-1016, 1221, 1232, 1242, 1248, 1254, and 1260. If analyzed, Aroclor-1262 and Aroclor-1268 should be reported but not included in the total PCB summation.

It should be noted that total PCBs calculated by summing PCB Aroclor mixtures are not comparable to total PCBs calculated by summing individual PCB congeners due to fundamental differences in the methods of analysis and quantitation.

***DDT Isomers*—**Marine SLs are reported for the individual 4,4'- isomers of DDT, DDE, and DDD; no summations are performed. Freshwater SLs are reported for total DDT, DDE, and DDD, each of which represents the sum of the 4,4'- and 2,4'- isomers.

***Total Chlordane*—**Total chlordane is the sum of two major compounds (cis-chlordane and trans-chlordane, also known as alpha-chlordane and gamma-chlordane, respectively) and three minor compounds (cis-nonachlor, trans-nonachlor, and oxychlordane) derived from technical chlordane and its metabolites (DMMP 2007). If PCBs are present in a sample, they may interfere with the three minor chlordane compounds, causing elevated reporting limits. If the three minor compounds are undetected at significantly higher reporting limits compared to the major compounds, due to PCB interference, then the local review team may allow the minor compounds to be excluded from the total chlordane summation. Note that total chlordane is not the same as technical chlordane.

***Dioxins and Furans*—**Dioxins/furans are a group of 210 chlorinated organic compounds (congeners) with similar chemical structures. 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 toxicity equivalency factor (TEF) of 1.0 (Table 6-1). The TEQ is calculated by multiplying the TEF of each congener by the concentration of the congener and summing the results. The use of TEQ for addressing both human health and ecological risks has been approved by EPA as well as the World Health Organization and is therefore an acceptable approach under this SEF.

The laboratory shall report each of the 2,3,7,8-chlorine substituted PCDD/F congeners on a dry-weight basis. Estimated detection limits and reporting limits shall be reported for each of these congeners. The 17 congeners of interest are tabulated as TEQ, both with nondetected values (U) = ½ EDL and with U = 0. (The difference between these values gives data reviewers a sense for how much the EDL substitution affects the TEQ summation.)

Statistically rigorous approaches for summing PCDD/F congeners when nondetects are reported are available for risk assessments, cleanup, and determining background concentrations (e.g., Kaplan Meier). However, statistical approaches for nondetected data are not required for evaluating routine dredging projects.

Table 6-1. Toxicity equivalency factors (TEFs) for PCDDs and PCDFs.1

Dioxins/Furans	Congeners/Isomers	Toxicity 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-HxCDD	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)

6.2 Benthic Toxicity Screening Levels and Natural Background

This section presents marine and freshwater sediment numeric screening levels for specific pollutants for the protection of benthic organisms (6.2.1), as well as an overlay for metals natural background levels (6.2.2).

Note that the benthic SLs presented do not account for bioaccumulative effects. Currently, bioaccumulation guidelines (and their application) are state-specific. If BCoCs are present at levels of concern, then a separate bioaccumulation assessment may need to be performed (see Chapter 8 for further discussion).

6.2.1 Benthic Toxicity Screening Levels

The benthic toxicity SLs presented in Table 6-2 were developed to predict potential adverse biological effects of the dredged material on benthic and epibenthic organisms at the disposal site and manage risk at the dredge area during the dredging operation and in the post-dredge surface (Z-layer) sediments. These SLs were derived from regional paired sediment chemistry and benthic toxicity testing data (bioassays) from sediment sites in the Pacific Northwest (Washington and Oregon). Different statistical models were used to derive marine and freshwater values, but both were designed to be consistent with the same

narrative definition of effects levels. These two statistical models, the FPM and the Apparent Effects Thresholds are described in more detail later in this chapter (section 6.2.3).

The ammonia and sulfides SLs are generally used to inform bioassay testing regarding the potential for nontreatment effects from these chemicals; sediments containing only elevated ammonia and/or sulfide concentrations (and no other chemical exceedances) may be determined suitable for unconfined, aquatic placement without bioassays.

The SL1 corresponds to a concentration below which adverse effects to benthic communities would not be expected. In the State of Washington, the SL1 is equivalent to the sediment quality standard. The SL2 corresponds to a concentration above which more than minor adverse effects may be observed in benthic organisms. In the State of Washington, the SL2 is equivalent to the cleanup screening level. In Table 6-2, the ">" symbol indicates that the toxicity threshold is unknown but above the listed concentration. Chemical concentrations greater than SL1 but at or below the SL2 correspond to sediment quality that may result in minor adverse effects to the benthic community.

The list of CoCs the project proponent will need to test for is based on whether the dredge site and disposal area are in freshwater and/or marine waters (Table 6-2). The CoC lists are different because of: (1) the history and context of screening level development; (2) the use of different datasets and statistical models; (3) physiochemical differences of the chemicals between the marine and freshwater systems (metals in particular); and (4) potential biological differences between the test organisms.

The selection of the set of SLs to be applied to the project—marine or freshwater—will be based on the location at which sediment toxicity is being evaluated (i.e., the effects of in-place sediments or newly exposed surface material will be evaluated using the SLs appropriate for the dredge site, and the effects of open-water disposal of dredged material will be evaluated using the SLs appropriate for the disposal site). The local review team will follow the specifications of the Inland Testing Manual in defining these environments (EPA and Corps 1998). Salinities ≤1 part per thousand (ppt) are considered freshwater; salinities >25 ppt are considered marine; and salinities >1 and ≤25 ppt are considered estuarine. In estuarine environments, the local review team must be consulted to determine which CoCs to analyze for and the appropriate SLs to compare the results against.

In some cases, both marine and freshwater SLs will need to be used. For example, if freshwater sediments are proposed to be dredged and disposed at an open-water marine disposal site, marine SLs and test organisms are appropriate for assessing impacts of dredged material at the disposal location; however, freshwater SLs and test organisms are appropriate for assessing impacts of the post-dredge sediment surface at the dredge site.

If a chemical is not listed in Table 6-2, or if no SL is given for a listed chemical, then the chemical is not a CoC for routine evaluations. However, lack of an SL does not necessarily mean the chemical has not been evaluated; rather, it means that either the chemical is not a concern for benthic organisms where dredging projects are likely to occur in the Pacific Northwest or data were insufficient to calculate a SL. For projects where a chemical without an SL is present at concentrations that are significantly elevated over those typically encountered at other sites (e.g., cleanup or chemical spill of compounds not on the list), three approaches are possible:

- Identify a surrogate within the listed CoCs with similar chemical and toxicological properties to evaluate the potential for biological effects from the unlisted chemical.
- Use toxicity data from a literature review in the dredged material evaluation.
- Conduct bioassays to directly measure site-specific toxicity.

Table 6-2. Benthic toxicity screening levels.

Chemical of Concern	Benthic Toxicity Screening Levels			
	Freshwater (Floating Percentile Methodology)		Marine (Apparent Effects Thresholds)	
	SL1[1]	SL2[2]	SL1[1]	SL2[2]
CONVENTIONAL PARAMETERS[3]				
Ammonia (mg/kg)	230	300	—	—
Total sulfides (mg/kg)	39	61	—	—
STANDARD CHEMICALS OF CONCERN				
Metals (mg/kg)				
Antimony	—	—	150	>150
Arsenic	14	120	57	93
Cadmium	2.1	5.4	5.1	6.7
Chromium	72	88	260	270
Copper	400	1,200	390	>390
Lead	360	>1,300	450	530
Mercury	0.66	0.8	0.41	0.59
Nickel	26	110	—	—
Selenium	11	>20	—	—
Silver	0.57	1.7	6.1	>6.1
Zinc	3,200	>4,200	410	960
Polynuclear Aromatic Hydrocarbons (µg/kg)				
Total PAHs	17,000	30,000	—	—
Total low molecular weight PAHs	—	—	5,200	>5,200
Naphthalene	—	—	2,100	>2,100
Acenaphthylene	—	—	560	1,300
Acenaphthene	—	—	500	>500
Fluorene	—	—	540	>540
Phenanthrene	—	—	1,500	>1,500
Anthracene	—	—	960	>960
2-Methylnaphthalene	—	—	670	>670

Table 6-2. Benthic toxicity screening levels.

Chemical of Concern	Benthic Toxicity Screening Levels			
	Freshwater (Floating Percentile Methodology)		Marine (Apparent Effects Thresholds)	
	SL1[1]	SL2[2]	SL1[1]	SL2[2]
Total high molecular weight PAHs	—	—	12,000	17,000
Fluoranthene	—	—	1,700	2,500
Pyrene	—	—	2,600	3,300
Benz(a)anthracene	—	—	1,300	1,600
Chrysene	—	—	1,400	2,800
Benzo(b,j,+k)fluoranthene	—	—	3,200	3,600
Benzo(a)pyrene	—	—	1,600	>1,600
Indeno(1,2,3-c,d)pyrene	—	—	600	690
Dibenz(a,h)anthracene	—	—	230	>230
Benzo(g,h,i)perylene	—	—	670	720
Chlorinated Hydrocarbons (µg/kg)				
1,4-Dichlorobenzene	—	—	110	110
1,2-Dichlorobenzene	—	—	35	50
1,2,4-Trichlorobenzene	—	—	31	51
Hexachlorobenzene	—	—	22	70
Phthalates (µg/kg)				
Dimethylphthalate	—	—	71	160
Diethylphthalate	—	—	200	>200
Di-n-butyl-phthalate	380	1,000	1,400	>1,400
Butyl benzyl phthalate	—	—	63	900
bis(2-ethylhexyl)phthalate	500	2,200	1,300	1,900
Di-n-octyl-phthalate	39	>1,100	6,200	>6,200
Phenols (µg/kg)				
Phenol	120	210	420	1,200
2-Methylphenol	—	—	63	>63
4-Methylphenol	260	2,000	670	>670
2,4-Dimethylphenol	—	—	29	>29
Pentachlorophenol	1,200	>1,200	400	690
Miscellaneous Extractable Compounds (µg/kg)				
Benzyl alcohol	—	—	57	73
Benzoic acid	2,900	3,800	650	>650
Carbazole	900	1,100	—	—
Dibenzofuran	200	680	540	>540
Hexachlorobutadiene	—	—	11	120
N-nitrosophenylamine	—	—	28	40

Table 6-2. Benthic toxicity screening levels.

Chemical of Concern	Benthic Toxicity Screening Levels			
	Freshwater (Floating Percentile Methodology)		Marine (Apparent Effects Thresholds)	
	SL1[1]	SL2[2]	SL1[1]	SL2[2]
Pesticides and their breakdown products (µg/kg)				
Dichlorodiphenyldichloroethanes (DDDs)	310	860	16	—
Dichlorodiphenyldichloroethylenes (DDEs)	21	33	9	—
Dichlorodiphenyltrichloroethanes (DDTs)	100	8,100	12	—
Aldrin	—	—	9.5	—
Total chlordane (sum of cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane)	—	—	2.8	—
Heptachlor	—	—	1.5	—
Dieldrin	4.9	9.3	1.9	—
beta-Hexachlorocyclohexane	7.2	11	--	—
Endrin ketone	8.5	—	—	—
Polychlorinated Biphenyls (µg/kg)				
Total Aroclors	110	2,500	130	1,000
SITE SPECIFIC CHEMICALS OF CONCERN				
Butyltins				
Monobutyltin (µg/kg)	540	>4,800	—	—
Dibutyltin (µg/kg)	910	130,000	—	—
Tributyltin (µg/kg)	47	320	73[4]	—
Tributyltin (porewater, µg/L)	—	—	0.15[5]	—
Tetrabutyltin (µg/kg)	97	>97	—	—
Bulk Total Petroleum Hydrocarbons (TPHs) (mg/kg)				
TPH-diesel	340	510	—	—
TPH-residual	3,600	4,400	—	—

Notes: "—"SL not calculated/determined; ">" indicates the toxicity threshold is unknown but above the concentration shown.

[1] SL1 corresponds to a concentration below which adverse effects to benthic communities would not be expected.

[2] SL2 corresponds to a concentration above which more than minor adverse effects may be observed in benthic organisms. Chemical concentrations at or below the SL2 but greater than the SL1 correspond to sediment quality that may result in minor adverse effects to the benthic community.

[3] Ammonia and sulfides are generally used to inform bioassay testing regarding the potential for nontreatment effects from these chemicals; sediments containing *only* elevated ammonia and/or sulfide concentrations (and no other chemical exceedances) may be determined suitable for unconfined, aquatic placement without bioassays.

[4] The marine tributyltin SL1 is a bioaccumulation test trigger, not a bioassay test trigger.

[5] The tributyltin porewater SL is listed here for those projects for which porewater is tested. It is not a required analysis.

6.2.2 Derivation of the Benthic Screening Levels

Marine Benthic Toxicity Guidelines—Sediment benthic screening levels for marine sediments were developed using the Apparent Effects Thresholds approach (PSEP 1988). These values are well established in the Pacific Northwest and have been in use for over two decades in regional dredging programs (e.g., EPA and Corps 1988; EPA et al. 1998), federal cleanup programs (e.g., Commencement Bay, EPA 1989), and state of Washington cleanup programs (WAC 173-204). The marine screening

levels in Table 6-2 were derived from the same dataset used to develop the state of Washington marine Sediment Quality Standards. The pesticide SLs were taken from the lowest Apparent Effects Thresholds reported by the Corps (1996).

Freshwater Benthic Toxicity Guidelines—Because freshwater systems are much more variable than marine systems (pH, hardness, etc.), and these variations may impact the toxicity of some chemicals, the Apparent Effects Thresholds approach did not work for developing freshwater benthic screening levels. A multiyear RSET effort led to the revision of the freshwater benthic toxicity guidelines based on the FPM (Ecology 2011). The updated values, which include data from a greater geographic scope (including projects on both the east and west sides of the Cascades in Washington and Oregon) and acute and chronic/sublethal bioassay endpoints, were developed through a multiagency workgroup process. In 2013, these values were promulgated as Washington State sediment standards for the protection of freshwater benthic communities (WAC 173-204) and subsequently accepted by RSET. For more details on the approach, reviews, and responses to comments associated with these values, refer to the documentation associated with the Ecology rulemaking process that can be found at *https://fortress.wa.gov/ecy/publications/SummaryPages/1309055.html* (rulemaking documentation) and *https://fortress.wa.gov/ecy/publications/SummaryPages/1309044* (responsiveness summary).

6.2.3 Natural Background

The Pacific Northwest is known to have naturally elevated metals concentrations, in large part due to the volcanic nature of the region. In some areas, natural background sediment concentrations of metals can exceed the freshwater benthic SLs. Therefore, background concentrations must be taken into account when evaluating dredging projects in these areas. However, background concentrations vary between regions, watersheds, and water body types. Very little natural background data exist for freshwater sediments. Substantially more data are available for soil background values near freshwater areas; however, the applicability of soil background to sediments has not previously been addressed for Washington, Idaho, or Oregon.

Because metals background varies geographically, and the rules for the three states differ, each state has its own proposed background approach for sediments, based on a combination of soil or sediment background. State-specific approaches are presented below. At this time, RSET will use a background approach for metals only; organic compounds are not included due to differences in state regulations. Future work by the RSET may focus on background concentrations for other naturally occurring CoCs.

Oregon—For dredging projects on the lower Willamette River, the Willamette upstream sediment natural background metals values calculated for the Portland Harbor Superfund area will be used (LWG 2012, or most current values). Sediment natural background concentrations may also be calculated for other areas of the state if sufficient data are available. Local soil background will be used in other parts of Oregon if no sediment background data are available (ODEQ 2013).

Washington—Based on data in Ecology's publication #09-03-032 (*Baseline Characterization of Nine Proposed Freshwater Sediment Reference Sites, 2008*) (Ecology 2009), many metals in Washington

sediment had higher concentrations compared to the background values from the Willamette; thus, Willamette background may not be appropriate for Washington.

Since sufficient Washington sediment data are not yet available, the DMMP agencies developed interim background values using Washington State soil data from Ecology's publication #94-115 (*Natural Background Soil Metals Concentrations in Washington State, 1994*) (Ecology 1994). Using this data set, nickel was the only metal that had a background concentration (90th percentile = 38 milligrams per kilogram [mg/kg]) higher than the benthic SL1. Therefore, in Washington, the DMMP agencies will use this value for the nickel SL1 until sufficient sediment data are available to calculate background.

***Idaho*—**Natural background concentrations of metals in sediments exceeding benthic or water quality-based screening levels may indicate the character of highly mineralized soils and the variable composition of sediment parent material found in many Idaho watersheds. In the event that natural sediment background levels are not available, soils and parent material representative of watershed sediment could be used as a reference for screening level thresholds. In certain circumstances, use of site-specific screening levels for the protection of beneficial uses may override considerations for application of background sediment concentrations as screening thresholds. Idaho will examine this issue on a case-by-case basis as it arises.

Examples for sources of this information include the following:

- US Environmental Protection Agency—Record of Decision Bunker Hill Mining and Metallurgical Complex OU 3 (September 2002)
- US Geological Survey—Geochemical and Mineralogical Data for Soils of the Conterminous United States (2013)
- Idaho Geological Survey Maps— *www.idahogeology.org/Products/MapCatalog*

RSET Marine Metals Background Sediment Concentrations

Since marine SLs based on benthic toxicity are much higher than background for metals, it is unlikely that comparison to background would be required for decision-making purposes in marine systems. Currently, natural background concentrations of metals in marine sediments are not established outside of the Puget Sound Region. If background metals concentrations are believed to be elevated above the marine SLs due to the local geology and/or natural inputs from the watershed, proponents may work with their local review team to develop a site-specific metals background.

6.2.4 Screening Evaluation of Chemical Results

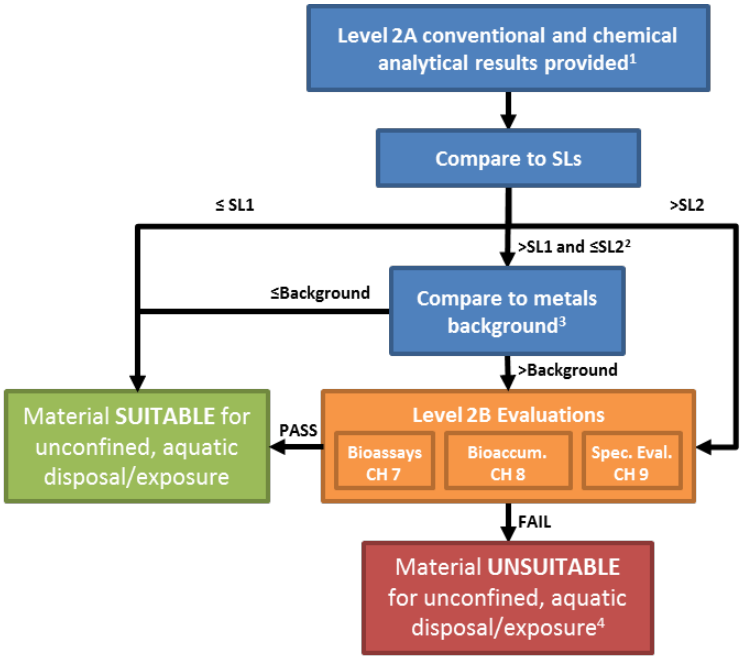
The background-based SLs must be used in conjunction with the benthic toxicity SLs as illustrated in Figure 6-3. Where background metals are above the benthic toxicity SLs, the SL will default to background. There are many possible scenarios of the combined application of the SLs and metals natural background, as shown in the matrix below.

		Metals					
		Below Background			***Above Background***		
		≤SL1	**>SL1 and ≤SL2**	**>SL2**	**≤SL1**	**>SL1 and ≤SL2**	**>SL2**
Organic CoCs	**≤SL1**	Suitable	Suitable	Bioassays	Suitable	Bioassays	Bioassays
	>SL1 and ≤SL2	Bioassays	Bioassays	Bioassays	Bioassays	Bioassays	Bioassays
	>SL2	Bioassays	Bioassays	Bioassays	Bioassays	Bioassays	Bioassays

Suitable—DMMU(s) are determined to be suitable for unconfined, open-water disposal.

Bioassays—The DMMU(s) proposed for open-water disposal must undergo bioassay testing. (Chapter 7).

- **If the material passes bioassays**, the material will be determined suitable for unconfined, open-water disposal.
- If bioassay testing is not performed, and the material was below SL2s for all CoCs, the material will be determined unsuitable for unconfined, open-water disposal.
- If the material fails bioassays at the SL2 level (Chapter 7), or if the proponent does not conduct bioassays on material with SL2 chemical exceedances for any CoC, the local review team will share the information with the appropriate cleanup program.



[1] Specific to the state in which the project is located, the sediment SLs may also be used to predict toxicity of the new surface material (i.e., the surface exposed after dredging) and address water quality concerns at the dredge area. The SLs do not address bioaccumulative effects (see Chapter 8).

[2] If concentrations in the project sediment exceed the SLs for organic contaminants and/or bulk total petroleum hydrocarbons, then the proponent would move directly to SEF biological testing protocols (orange box). Background concentrations are only applied to metals if the metals concentrations exceed the SLs.

[3] Background metals concentrations are specific to the state in which the project is located, as determined by the state water quality agency.

[4] If bioassay results are > SL2, or the proponent opts out of bioassay testing when sediments are > benthic SL2, then the project will be referred to cleanup program. The state cleanup program has discretionary authority to designate cleanup sites. The SEF review process does not apply to projects designated as cleanup sites; the state cleanup program manages additional site investigations and establishes site-specific cleanup objectives.

Figure 6-3. Application of the SLs and background metals for dredged material evaluations.

Whether designated for open-water or confined disposal, short-term water quality effects may be caused by the disturbance and resuspension of sediments, especially contaminated sediments, during the dredging operation, and sediment quality effects may be caused by dredging residuals after completing dredging activities. The evaluation of water column effects and dredging residuals are discussed in detail in Chapter 9.

Disposal options for both suitable and unsuitable material are discussed in Chapter 10.

6.3 Placeholder Screening Levels

6.3.1 Water Quality-based SLs—Placeholder for the Protection of Water Quality

Freshwater water quality-based (WQ-based) SLs were proposed concurrently with the revised freshwater SLs (FPM-derived) and the background-based SLs for metals (RSET 2014). The proposed WQ-based sediment values were determined by applying chronic (instead of acute) WQ criteria to the elutriate test trigger formula (presented in Chapter 9). However, public comments highlighted technical issues with the WQ-based SLs, and the proposed values will not be implemented at this time other than on a case-by-case basis as determined by the local review team or CWA §401 water quality certification permit writer. The RSET will work to resolve the technical issues identified by the public. The elutriate test triggers (based on acute WQ criteria and presented in Chapter 9) will continue to be implemented as they were in the 2009 SEF (RSET 2009) until such time that new values are accepted through the annual RSET meeting process.

6.3.2 PAHs Framework—Placeholder for the Protection of Fish

The RSET agencies are committed to developing regional screening levels for the protection of fish from the impacts of dredging and dredged materials in both freshwater and marine systems. A total PAHs SL was proposed by the RSET in 2014. However, public comment outlining technical issues with the proposed total PAHs SL were substantive, and the SL will not be implemented at this time. The RSET will work to address the technical issues and comments received regarding this approach. Any new values will be accepted through the annual RSET meeting process.

6.3.3 Future Listing of Benthic Invertebrate ESA species

If benthic invertebrate species are listed as threatened or endangered and are determined to occur in an area where dredging is proposed, then species-specific benthic screening levels may be used in the evaluation of dredged material for protecting the listed species. These situations will be handled on a case-by-case basis and in consultation with the US Fish and Wildlife Service, NMFS, and state agencies.

6.4 Sediment Characterization Report

All of the following are required elements of an SCR:

1. A summary of the sampling event:
   a. Sampling equipment and protocols used
   b. Methods used to locate sampling positions

   c. Table with coordinates of actual sampling locations, measured water depth at each location, tidal stage or river level at the time of sampling each station, and mudline elevations corrected to mean lower low water (MLLW), Columbia River Datum, or other local vertical datum (depending on the project location)
2. Deviations from the approved SAP
3. A plan view showing target and actual sampling locations with an overlay of DMMU boundaries
4. A table summarizing the compositing scheme, depth to mudline and the top and bottom elevations of each DMMU and corresponding Z-layer interval, actual core lengths and depth of penetration, and core recovery (referenced to the project vertical datum and the mudline)
5. Table of analyzed concentrations for all CoCs, lab and validation qualifiers, method reporting limits and MDLs, relevant SEF SLs, and all SL exceedances highlighted
6. Chemistry QA review and summary of the data validation results
7. If bioassays are conducted, summary table(s) of bioassay results and QA summary of the bioassay data and interpretation, with failures highlighted
8. If other Level 2B evaluations were conducted, summary tables, QA, and interpretation
9. Appendices/attachments:
   a. Sampling/field log
   b. Core logs: core penetration and recovery data (if cores used) and whether recovery correction was used
   c. Photos of the sampling event
   d. Chemistry data report (including a case narrative)
   e. Data validation report
   f. Bioassay report and reports for any other Level 2B evaluations
   g. EIM-ready data (electronic submittal only): Seattle District, submit the data to Corps for QA and entry; other districts, contact the local review group for the EIM data submission process
   h. Chain-of-custody form(s)

The local review team will review the SCR prior to issuing the dredged material and PDS suitability determination memorandum (SDM). The local review team will do the following:

- Review deviations from the SAP and determine what effect (if any) the deviation(s) had on data quality and usability.
- Verify that the samples collected in the field and submitted for laboratory analysis were actually representative of the DMMUs and PDS layers designated in the approved SAP.
- Conduct an independent QA review of the SCR data tables, the laboratory report(s), and the EIM electronic data deliverable.

If deviations from the SAP are significant (e.g., if samples were collected from the wrong depths or outside of the dredging boundary), then the local review team must conduct a data usability analysis to determine which project data (if any) can be used. Additionally, the local review team must verify that the laboratory detection and reporting limits meet the sample quantitation limits specified in Chapter 5; this is especially important for nondetected chemical parameters. If the data provided are determined to be unusable, the proponent may have to resample and/or reanalyze project sediments to provide sufficient information for the local review team to prepare the SDM.

Once the local review team has completed the SCR review and obtained all pertinent information from the proponent, the SDM can be prepared.

6.5 EIM Electronic Data Deliverable

The Environmental Information Management System (EIM) is the Washington Department of Ecology's (Ecology's) main database for environmental monitoring data. EIM contains records on physical, chemical, biological, and habitat analyses and measurements. EIM centers on three main elements: study, locations, and results (including bioassay, well water levels, and time-series data). Supplementary information about the data (metadata) is also stored, including information about environmental studies, monitoring locations, and data quality.

EIM is a system made up of several applications that allow users to upload, edit, search, map, and download data. EIM also provides help on many topics. In 2007, EIM/MyEIM replaced SEDQUAL, Ecology's old sediment-specific standalone database, search, and analysis tool, with a modern web-based and advanced search, mapping, and analysis application that harnessed the power of the EIM system. The MyEIM analysis tool can be used to compare the sediment chemistry and bioassay data to the benthic chemical and biological numeric criteria for freshwater and marine sediments. MyEIM is best used with Microsoft Internet Explorer 7–11, although other browsers might be compatible. Pop-up blockers can prevent MyEIM from accessing outside resources or from downloading data. Ecology recommends turning off the pop-up blocker when using MyEIM. Those submitting data will need to establish an account in order to use MyEIM. The instructions to set up a MyEIM account are provided at *https://fortress.wa.gov/ecy/eimreporting/Default.aspx*.

The RSET has selected Ecology's EIM as the preferred regional repository for all sediment chemical and biological data generated in accordance with the SEF. Data from EIM were used to generate the freshwater SLs presented in Table 6-2, and continued population of the database will allow the RSET to periodically update and refine the SLs. Each Corps district will establish procedures to ensure that sediment chemical and biological testing data from both federal and nonfederal projects are entered into the database. Project proponents will provide the local review team with the laboratory electronic data deliverable in Washington EIM format. A QA review of the EIM electronic data deliverable by the local review team is required prior to entering any sediment chemical or biological data into the EIM database. EIM is located at *https://fortress.wa.gov/ecy/eimreporting/Default.aspx*. Laboratory sediment and tissue chemistry data and bioassay data should be submitted in the electronic EIM template format, which can be downloaded from *https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database/EIM-submit-data*.

Data submitters will need to establish an EIM Loader account in order to submit data. The instructions are provided at *https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database/EIM-submit-data*. Submitting data is best done using Internet Explorer, although other browsers might be compatible.

For assistance using EIM/MyEIM, contact the EIM/MyEIM Team at *https://fortress.wa.gov/ecy/eimhelp/Contact*.

6.6 Sediment Suitability Determinations

6.6.1 Dredged Material Suitability

Dredged material suitability for open-water disposal (placement of the material in-water at designated disposal sites or flow lane locations) will be made by the local review team based on comparisons to the interpretive guidelines, which include benthic SLs (section 6.2.1); background where applicable (section 6.2.3); bioassays (Chapter 7); and bioaccumulation evaluation when applicable (Chapter 8). The local review team may also identify other appropriate SEF Level 2B tests (and/or studies) necessary to further evaluate unconfined, aquatic disposal alternatives. The results of the suitability evaluation are documented in a SDM as described below.

6.6.2 Post-Dredge Surface (PDS) Suitability

For projects that did not have Z-layer analysis triggered (section 4.1.3), and for which the dredge prism had no SL exceedances, the local review team may consider the PDS to be suitable for unconfined, aquatic exposure; no further action is required. When Z-layer analysis is triggered (section 4.1.3), or post-dredge samples are being used for anti-degradation purposes, the local review team's PDS suitability determination is reliant on the chemical testing results:

- If PDS concentrations are below the SL1 (or applicable natural background), then the PDS is determined to be suitable for unconfined, aquatic exposure; no additional testing is triggered.
- If PDS concentrations are between SL1and SL2, but less than or equal to those in the pre-dredge surface, the local review team will determine if biological testing will be required. If biological testing is conducted, the PDS will be determined to be suitable for unconfined, aquatic exposure if it has less toxicity and bioaccumulation potential then the pre-dredge surface. If the PDS will have higher toxicity or bioaccumulation potential than the pre-dredge surface, then it is unsuitable for unconfined, aquatic exposure.
- If PDS concentrations exceed SL2, then bioassays (and bioaccumulation testing if needed) must be run. The results from the biological testing will be used to determine the suitability for unconfined, aquatic exposure.
- If dredging results in the exposure of a PDS having higher chemical concentrations than the pre-dredge surface and concentrations in the PDS exceed the SL1, then the PDS is unsuitable for unconfined, aquatic exposure, unless the material passes bioassay testing (and bioaccumulation testing if needed).

In the event that the local review team finds the PDS unsuitable for unconfined, aquatic exposure, the project proponent may be required to perform response actions to reduce or eliminate contaminant exposure. Some potential options are described in Chapter 10.

6.6.3 Suitability Determination Memorandum (SDM)

The SDM is a record of the local review team's evaluation of the sediment testing data. The local review team must ensure that the suitability determinations for DMMUs and PDS are clearly documented in the SDM. It is possible for a project to have both suitable and unsuitable materials, and it is the local review

team's responsibility to clearly define the division between suitable and unsuitable sediments in the SDM. The SDM also includes the recency date (Chapter 3); no additional testing will be required during the recency period of the suitability determination (dictated by the management area rank), unless new sources of contamination are identified.

6.7 References

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Chapter 7. Biological Toxicity Testing

Level 2B testing is required when chemical testing results indicate the potential for unacceptable adverse environmental or human health effects resulting from aquatic disposal of dredged material (Figure 7-1). The present chapter focuses on toxic effects to bottom-dwelling (benthic) organisms. Chapter 8 addresses potential effects to human health and other higher trophic level species through bioaccumulation, which cannot be assessed using the toxicity tests presented in this chapter. A Level 2B bioaccumulation evaluation is required when there is an established "reason to believe" that CoCs in the tissues of benthic organisms may pose a potential risk to human or ecological health through the dietary exposure pathway.

This chapter includes information on recommended Level 2B bioassay tests and species, quality control requirements, and the bioassay interpretive criteria used for decision-making in marine and freshwater systems. References for regionally recommended bioassay testing methods and modifications are provided for more detailed information on test protocols and test interpretation. Additional information on bioassays is also provided in Appendix D.

A standard suite of bioassays is used to evaluate the potential toxicity to benthic organisms and is required when one or more sediment screening levels (SL1s; see Table 6-2) are exceeded in the dredged material or the new surface material. The results of these sediment bioassays are used in evaluating the suitability of dredged sediment for aquatic disposal. Figure 7-1 outlines the benthic toxicity testing element of Level 2B.

Prior to the 1980s, the assessment of water and sediment quality was often limited to physical and chemical characterizations. However, quantifying chemical concentrations alone is not always adequate to assess potential adverse environmental effects from interactions among chemicals or from bioavailability of chemicals to aquatic organisms. Because the relationship between total chemical concentrations and biological availability and interaction is poorly understood, controlled biological testing is performed to provide additional lines of evidence for evaluating potential environmental effects. The sediment testing regulations promulgated under both the CWA and MPRSA prescribe bioassay testing when there is reason to believe the dredged sediments may be toxic to the benthos. The approach most often adopted is to expose representative aquatic/benthic species to test media to assess lethal and sublethal effects. Testing using multiple species reduces uncertainty about the impact to the benthic community, limits errors in interpreting these tests, and provides information on bioavailability for different feeding guilds.

Solid phase biological testing measures the effects of sediment-associated CoCs based on exposures to bedded sediment. The marine and freshwater species currently used for bioassay testing in the Pacific Northwest are specified in this chapter and are compatible with regional and national guidance documents. Several additional biological tests are under development or review and may be added in the future. Marine test species may be selected based on criteria such as salinity at the proposed aquatic disposal site, dredged material grain size, and seasonal availability of organisms. The test species proposed for a specific project must be approved by the local review team prior to use and documented in the SAP. If recommended species are not available, laboratories may propose the use of an alternative species as listed in this chapter. Use of alternative species should only proceed after coordination with the local review team.

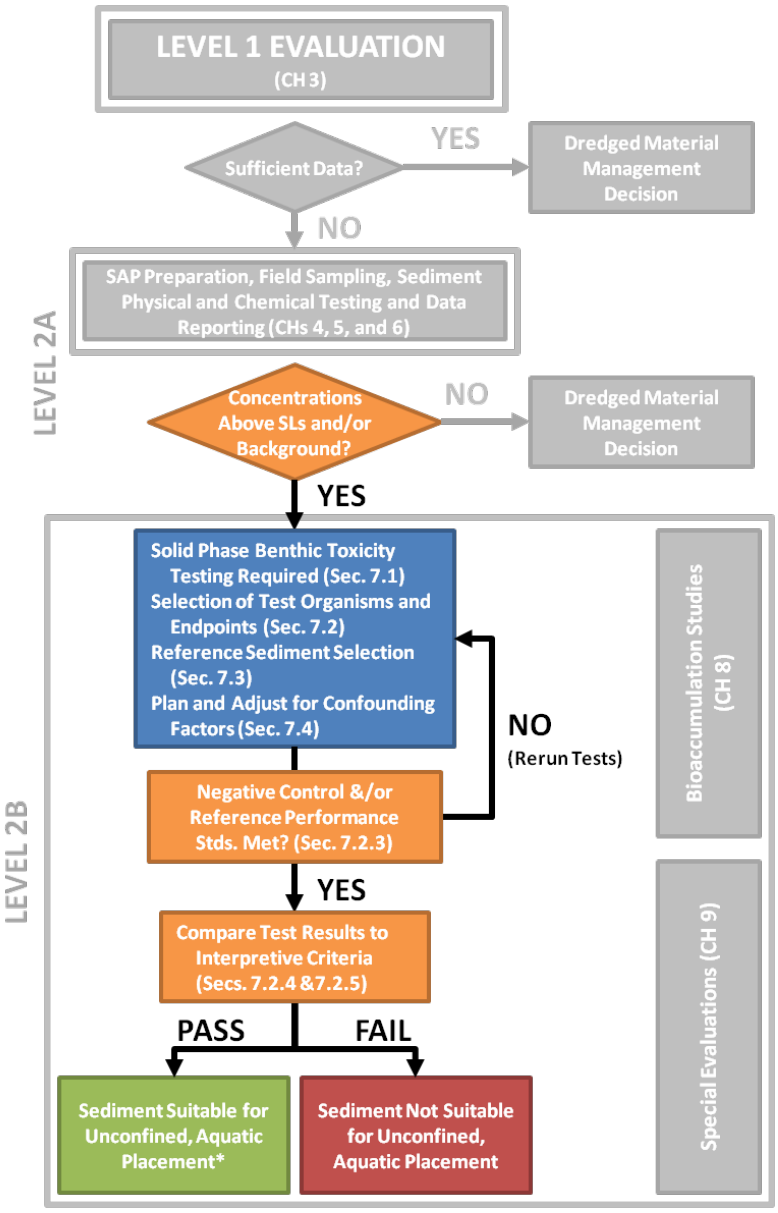

Figure 7-1. Overview of Level 2B benthic toxicity testing element.

Laboratories providing biological effects data for projects evaluated under this SEF must be accredited by either the Department of Defense Environmental Laboratory Accreditation Program or the National Environmental Laboratory Accreditation Conference Institute. In the state of Washington, labs must be accredited by the Department of Ecology for the methods used.

For dredging projects in freshwater systems that plan on using marine/ocean disposal sites, marine bioassays will be required to assess effects at the disposal site (if biological testing is necessary). Additionally, freshwater bioassays may also be required if there is concern regarding the sediment quality of the new surface material, residuals, or based on other regulatory (e.g., cleanup program) requirements.

7.1 General Bioassay Information

This section covers aspects of bioassay testing that are common to marine, estuarine, and freshwater bioassay testing.

If there is any reason to believe that contaminants may exceed the benthic toxicity thresholds (i.e., the SLs), the RSET agencies strongly recommend that sufficient test sediment for bioassays be archived during the Level 2A sampling (physical and chemical characterization). If bioassays are not initially proposed and a sufficient volume of sediment has not been collected during the Level 2A sampling, a supplemental SAP must be prepared prior to initiating biological testing, and the additional sediments collected for the bioassays must be re-analyzed for the CoCs.

7.1.1 Volume, Holding Times, and Storage Temperature

Typically, 5 L of sediment must be collected for bioassays. Test and reference sediments must be stored at 4 °C ± 2 ° (**not frozen**) with zero headspace or under nitrogen and can be held for up to 8 weeks.

7.1.2 Reference Sediments

For marine sediments, federal and state regulations prescribe the use of bioassay reference sediments for test comparison and interpretations that closely match the grain size characteristics of the test or disposal site sediments. The reference sediment provides a point of comparison for evaluating the non-treatment effects due to grain size. If chemical concentrations in the reference area are not well documented, a complete chemical characterization may be required. However, all reference sediments should be analyzed for TOC, ammonia, sulfides, and grain size (PSEP 1995). Ideally the reference material should fall within 10% of the fines content (silt and clay) of the test sediments; however, RSET recognizes it is often difficult to match sediment grain size that precisely. Best professional judgment will be used when reference material matching is problematic. More than one reference sediment may be required for large projects with a wide range of percent fines. For dredged material with relatively coarse-grained sediments (>80%) or sand, the project proponent can opt to rely solely on the control sediment.

There are very few approved freshwater reference sediment locations identified at this time. Because the origins of the freshwater SLs were based on comparison to control, freshwater bioassays do not require reference sediment but instead rely on comparison to controls; however, use of reference sediment is strongly recommended. If the dredging proponent intends to use reference sediment, they should coordinate with the reviewing agencies for reference site selection. A RSET white paper was prepared that provides a process for identifying freshwater reference sediment collection sites (DMMP 2008). It is recommended that project proponents use this process in identifying project- or area-specific freshwater reference sediment collection locations.

Wet-sieving is imperative to find 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 volume 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 at a reference site before a reference sediment with the proper grain size is found. Homogenization of the sediment prior to wet-sieving is recommended.

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 a horizontal accuracy of ±3 meters.

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

Reference site selection and reference sample collection must be coordinated with the local review team, as well as any other state or federal agency with regulatory interest in the bioassay results. For the Puget Sound region and for Grays Harbor and Willapa Bay in the state of Washington, the DMMP User Manual (DMMP 2015a) provides additional information on reference sediment collection sites and sampling guidelines for these collection sites.

7.1.3 General Bioassay Quality Assurance

This section contains the QA/QC requirements for solid phase biological testing. The parameters covered include the following:

- Negative control and reference sediment
- Quality control limits for the negative control treatment
- Quality control limits for the reference treatment
- Replication
- Positive control
- Water quality monitoring

General procedures are given first, followed by specific performance standards for each bioassay. These standards aid in interpreting the bioassay responses because they control for nontreatment effects that may produce confounding factors not associated with the toxicity of the contaminants of interest.

Negative Controls—For the bedded sediment testing (both marine and freshwater), negative controls are run with each test batch. Negative controls provide an estimate of test organism general health during the test exposure period. This control is clean, nontoxic water or sediment taken from outside the study area. For marine amphipods, negative control is sediment from the organism collection site. For the laboratory-cultured *Neanthes*, negative control sediments must be collected from an appropriate area, typically a clean sand beach such as West Beach, Whidbey Island (Washington), or Yaquina Bay (Oregon). For larval tests, negative seawater controls are required (no sediment, only seawater). Sediments proposed for use as negative controls must be approved prior to commencing the bioassays. If a new area is being proposed, sufficient data must be submitted before its use can be approved by the agencies.

***Reference Sediments*—**Reference sediments are used to control for potential effects of different physical characteristics of sediments; for example, control sediments are often sandy in nature, while reference sediments should be selected to better match the physical characteristics of the test sediment, which are often more silty than control sediments.

Table 7-1 summarizes the performance standards for negative controls and reference sediment for marine/estuarine toxicity tests, and Table 7-4 provides the same information for freshwater toxicity tests.

Failure of reference or control sediments to meet these standards may result in the requirement to rerun the bioassays. The decision to rerun the bioassays is contingent on the performance of the test organism(s) in the test sediment (e.g., retesting may not be required if organism survival in the test sediment is high when running a mortality test, indicating little or no effect from sediment contaminants). In some cases, control sediments may be substituted for failed reference sediments if they have similar characteristics or if the local review team agrees that this is appropriate.

***Positive Controls*—**A positive control (sometimes called the reference toxicant test) will be run for each bioassay. Positive controls are chemicals known to be toxic to the test organism and provide an indication of the sensitivity of the particular organisms used in a bioassay. Positive controls are performed on spiked fresh/seawater and compared with historical laboratory reference toxicity test results to confirm that organism responses are within control limits established by the testing laboratory. The LC_{50} or EC_{50} must be within the 95% confidence interval of responses expected for the toxicant or resulting data will be flagged and data usability may be compromised.

***Water Quality Monitoring*—**Water quality monitoring of the overlying water should be conducted for the bioassays. For the marine biological tests, interstitial salinity, ammonia, and sulfides should be measured prior to test initiation and purging and/or reference toxicant testing procedures implemented if ammonia or sulfides exceed specified limits for a given test species as described further in section 7.2.3. Daily measurements of salinity, temperature, pH, and dissolved oxygen should be conducted for the marine amphipod and sediment larval tests. These measurements should be made every 3 days for the 20-day *Neanthes* growth test. For both freshwater and marine testing, ammonia and total sulfides should be measured at test initiation and termination for all three tests where either of these chemicals is suspected as being a problem. For the freshwater biological tests, daily measurements of temperature and dissolved oxygen should be conducted for the amphipod and midge tests. Conductivity, hardness, and alkalinity should be measured at test initiation and termination for the amphipod and midge tests, as these parameters are critical to understanding metals toxicity. Parameter measurements must be within the limits specified for each bioassay (DMMP 2015a; Ecology 2015) or resulting data will be flagged and data usability may be compromised.

7.2 Marine Bioassays

Marine bioassays are required when the test sediments and/or the proposed disposal location for dredged material are in a brackish or saline environment (freshwater bioassays are discussed in section 7.3). For marine bioassays, five laboratory replicates of test sediments, reference sediments, and negative controls will be run for each bioassay.

7.2.1 Marine Species Selection

Three bioassays, including both acute and chronic tests to characterize the toxicity of whole sediments, are recommended in the Pacific Northwest. The following bioassays used for marine/estuarine evaluations include an acute amphipod test, a chronic *Neanthes* test, and a sediment larval test:

- 10-day Amphipod Acute Mortality Test:
  - *Rhepoxynius abronius*
  - *Ampelisca abdita*
  - *Eohaustorius estuarius*
- 20-day Chronic Growth Test using the polychaete worm, *Neanthes arenaceodentata* (Los Angeles karyotype)
- Sediment Larval Test:
  - Echinoderm
    - *Dendraster excentricus*
    - *Strongylocentrotus purpuratus*
    - *Strongylocentrotus droebachiensis*
  - Bivalve
    - *Crassostrea gigas*
    - *Mytilus galloprovincialis*

The marine bioassay protocols are described by the PSEP and can be found in the *Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments* (PSEP 1995). These protocols are consistent with national guidance on bioassay testing.

If a species identified in the SAP is not available at the time of testing, laboratories may propose the use of an alternative species listed in this section. Use of alternative species should only proceed after coordination with the local review team.

Amphipod bioassays are acute tests that measure the survival of infaunal amphipods to evaluate the toxicity of sample sediments. Amphipod selection is based on test sediment grain size and salinity.

- *Eohaustorius estuarius* is the preferred amphipod test species. It is a free-burrowing amphipod, which can tolerate a broad range of porewater salinities (approximately 0–36 ppt [EPA 1994; Redmond et al. 2000; ASTM 2008]), and is suitable for use for a wide range of grain sizes. Some evidence indicates that its survival is affected by high percent clay (>20% [DMMP 1999] or >70% [Environment Canada 1992]).
- *Rhepoxynius abronius* is also a free-burrowing amphipod, which requires a porewater salinity of at least 25 ppt. It has been shown to be sensitive to sediments with high (>60%) fines particularly those with high clay content and has been shown to exhibit mortalities greater than 20% in clean, reference area sediments with greater than 60% fines (DeWitt et al. 1988; DMMP 1993a).
- *Ampelisca abdita*, a tube-dwelling amphipod, can be used with porewater salinities from 0 to 34 ppt as long as the overlying water is at least 28 ppt (EPA 1994) and for sediments with at least 10% fines (EPA 1994; ASTM 2008). However, it is not native to the Pacific Northwest and may not be available from suppliers at the specified juvenile life stage year-round.

Larval tests use the planktonic larval form of a benthic invertebrate to test for acute toxicity for this life stage. Larvae are introduced into test chambers consisting of test sediment and overlying water directly after fertilization. Development and survival of one of the following echinoderm or bivalve test species are tracked for the 48 to 60 hours of larval growth:

- The sand dollar, *Dendraster excentricus,* is the recommended echinoderm species. Echinoderm species selection is primarily based on seasonal availability of individuals in spawning condition.
- Mussels, *Mytilus galloprovincialis*, are available in spawning condition most of the year and are the recommended bivalve species. Oysters, *Crassostrea gigas*, can also be tested, but care should be taken to not use triploid organisms. Oysters may also be more restricted for use than mussels due to seasonal availability of individuals in spawning condition.

The 20-day juvenile infaunal growth test 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 basis. The ash-free dry-weight procedure eliminates sediment remaining in the gut, thereby providing a more accurate measurement of the change in biomass during the exposure. See DMMP 2013 for details of the procedure.

7.2.2 Interpretive Criteria and Performance Standards for Marine Bioassays

The response of bioassay organisms exposed to composited sediment representing each DMMU will be statistically compared to the response of these organisms in reference treatments (or default to control treatments if the reference sediment does not meet specified performance standards). This evaluation will determine whether dredged material is suitable or unsuitable for unconfined, aquatic disposal.

Marine biological test interpretation in the Pacific Northwest relies on two levels of observed response in the test organisms. These are known as “one-hit” or “two-hit” failures (the term “hit” refers to an exceedance of a specified biological response threshold). The bioassay-specific guidelines for each of these response categories are listed below. In general, a one-hit failure is a marked response in any one biological test. A two-hit failure is a lower intensity of response that must be found in two or more biological tests for the test sediment to be found unsuitable for aquatic disposal in a dredged material situation. The “one-hit” and “two-hit” nomenclature was developed for the PSDDA program and is used for interpreting marine/estuarine toxicity tests (see Table 7-1).

***One-Hit Failure*—**When any one biological test shows a test sediment response relative to the negative control and reference sediment that exceeds the one-hit failure bioassay-specific response guidelines and the difference from the reference response is statistically significant, the DMMU is judged to be unsuitable for aquatic disposal.

***Two-Hit Failure*—**When any two biological tests show test sediment responses that are less than the one-hit failure bioassay-specific guidelines but exceed the two-hit failure bioassay-specific response guidelines relative to negative control and reference, and the difference from reference response is statistically significant, the DMMU is judged to be unsuitable for aquatic disposal.

The method for determining statistical significance is discussed in the DMMP User Manual (DMMP 2015a). This reference also contains a description of the BIOSTAT bioassay software developed by the Seattle District. This software contains the statistical tests to determine sediment suitability.

Table 7-1 provides a summary of interpretive criteria as well as negative control and reference sediment performance standards for the marine bioassays. A narrative summary of the interpretive criteria are provided below.

***Amphipod Bioassay*—**For the amphipod bioassay, mean test mortality greater than 20% absolute over the mean negative control response and greater than 10% (dispersive) or 30% (nondispersive) absolute over the mean reference sediment response, and statistically different from the reference (alpha = 0.05), is considered a one-hit failure.

***Juvenile Infaunal Growth Test*—**Juvenile *Neanthes* growth test results that show a mean test individual growth rate less than 80% of the mean negative control growth rate and less than 70% (dispersive) or 50% (nondispersive) of the mean reference sediment growth rate, and are statistically different from the reference (alpha = 0.05), are considered a one-hit failure.

***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.

$$\text{NCMA (\%)} = \left(1 - \frac{\text{number of normal larvae from test or refence treatment}}{\text{number of normal larvae from seawater control}}\right) \times 100$$

If the mean NCMA for a test sediment is greater than 20%, is 15% (dispersive) or 30% (nondispersive) absolute over the mean reference sediment NCMA, and is statistically different from the reference (alpha = 0.10), it is considered a one-hit failure.

When any two biological tests (amphipod, juvenile infaunal growth, or sediment larval) exhibit test sediment responses that are less than the bioassay-specific reference-comparison guidelines described above for a one-hit failure but are statistically significant compared to the reference sediment (and less than 70% 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 7-1. Interpretive criteria and performance standards for marine biological tests.

	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 Mortality	$M_C \leq 10\%$	$M_R - M_C \leq 20\%$	$M_T - M_C > 20\%$ and M_T vs. M_R SS ($p = 0.05$) **AND**			
			$M_T - M_R > 10\%$	NOCN	$M_T - M_R > 30\%$	NOCN
Larval Development	$N_C \div I \geq 0.70$	$N_R \div N_C \geq 0.65$	$N_T \div N_C < 0.80$ and N_T/N_C vs. N_R/N_C SS ($p = 0.10$) **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 ($p = 0.05$) **AND**			
			$MIG_T/MIG_R < 0.70$	NOCN	$MIG_T/MIG_R < 0.50$	$MIG_T/MIG_R < 0.70$

Notes: **Interpretive Criteria Abbreviations:** M = mortality; N = normal larvae; I = initial count; MIG = mean individual growth rate (mg/individual/day); SS = statistically significant; NOCN = no other conditions necessary

Interpretive Criteria Subscripts: $_R$ = reference sediment; $_C$ = negative control; $_T$ = test sediment

7.2.3 Marine Bioassay Confounding Factors

***Special Considerations for Sediment Larval Bioassays*—**Because the larval stage is a sensitive one, care must be taken during the test to control for nontreatment factors that may affect larval survival and development. The PSEP protocols should be followed carefully to ensure that useable data are collected (PSEP 1995).

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 likelihood of performance problems increases during that time. Biological testing should 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) in lieu of the standard PSEP protocol for test termination 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 sediment review 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.

***Ammonia and Sulfide Nontreatment Influences in Marine Bioassays*—**The potential for ammonia and sulfides to complicate bioassay evaluations of dredged material has been addressed in the following DMMP clarification papers:

- DMMP (1993b)—The *Neanthes* 20-day Bioassay: Requirements for Ammonia/Sulfides Monitoring and Initial Weight
- DMMP (2001)—Reporting Ammonia LC50 Data for Larval and Amphipod Bioassays
- DMMP (2002)—Ammonia and Amphipod Toxicity Testing
- DMMP (2004)—Ammonia and Sulfide Guidance Relative to *Neanthes* Growth Bioassay
- DMMP (2015b)—Modifications to Ammonia and Sulfide Triggers for Purging and Reference Toxicant Testing for Marine Bioassays

The DMMP agencies conducted a literature search and set the lowest available no observable effect concentration (NOEC) as a trigger for purging bioassay containers prior to testing. Triggers were established for only the most toxic constituents—namely un-ionized ammonia and hydrogen sulfide—rather than for total ammonia and total sulfides. For ammonia, half the NOEC is used as a trigger for reference toxicant (Ref Tox) testing. The purging and Ref Tox trigger concentrations are presented in Table 7-2. Un-ionized ammonia and hydrogen sulfide concentrations must be derived from measurements of total ammonia and sulfides using test-specific pH, temperature, and salinity measurements.

Table 7-2. Ref Tox and purging triggers for the various bioassays.

Trigger	Bedded Sediment Tests				Larval Tests	
	Neanthes	***Ampelisca***	***Eohaustorius***	***Rhepoxynius***	**Bivalve**	**Echinoderm**
Un-ionized ammonia (mg/L) Ref Tox	0.23	0.118	0.4	0.2	0.02	0.007
Un-ionized ammonia (mg/L) Purge	0.46	0.236	0.8	0.4	0.04	0.014
Hydrogen sulfide (mg/L) Purge	3.4	0.0094	0.122	0.099	0.0025	0.01

The DMMP agencies recommend determining the need for purging or Ref Tox testing *prior* to commencing actual bioassay testing. Following are details of the recommended procedure:

1. Bulk ammonia and sulfides measurements should be done by the chemistry lab on composited sediment representing each DMMU. Exceptions to this procedure for total sulfides might need to be made for sediment testing performed for both cleanup and dredging characterization and for projects where wood waste in new surface material may be an issue. In those cases, total sulfides should be performed on single cores.
2. While bulk measurements made by the analytical laboratory can provide an early warning of potential nontreatment effects in bioassays, these measurements are not always predictive of the ammonia and sulfide concentrations to which bioassay organisms will actually be exposed. Aqueous concentrations measured by the bioassay lab are more meaningful in this regard. For bedded sediment tests using *Neanthes*, *Eohaustorius*, and *Rhepoxynius*, porewater is the medium of exposure. For the tube-building amphipod *Ampelisca*, as well as the bivalve and echinoderm species used in the larval development test, the overlying water is the medium of exposure.

Therefore, for those DMMUs that will undergo bioassays, ammonia and sulfides need to be measured in the medium of exposure prior to running the bioassays.

This measurement can be accomplished by the bioassay lab for *Neanthes*, *Eohaustorius*, *Rhepoxynius*, and *Ampelisca* by setting up a single beaker for each DMMU in the manner that would be done for the amphipod and juvenile infaunal bioassays: 175 mL of sediment are placed in a beaker, with seawater added to bring the total volume up to 950 mL. The beaker is aerated and allowed to equilibrate for 24 hours. Total ammonia, total sulfides, pH, temperature, and salinity are then measured in the porewater (for *Neanthes*, *Eohaustorius*, and *Rhepoxynius*) and the overlying water (if *Ampelisca* is used).

For the larval test, a single beaker for each DMMU is set up as it would be for the bioassay: 18 mL of sediment are placed in a beaker along with 900 mL of seawater. The sediment is suspended by shaking vigorously for 10 seconds and then allowed to settle for 4 hours. Total ammonia, total sulfides, pH, temperature, and salinity are then measured in the overlying water.

During bioassay testing, temperature and salinity are maintained within standard ranges. In contrast, pH is monitored but not adjusted. Using the temperature and salinity that will be maintained during each of the bioassays, plus the pH measured in the overlying water and porewater, the un-ionized ammonia and hydrogen sulfide concentrations are calculated.

3. If un-ionized ammonia and hydrogen sulfide concentrations in the interstitial water are below the purging triggers in Table 7-2, or if any of the CoCs exceeding SLs are subject to significant loss or alteration of bioavailability during purging (to be determined in consultation with the local review team), the bioassays are set up normally, without sacrificial beakers or purging. An ammonia Ref Tox test is run concurrently with a bioassay if the Ref Tox trigger is exceeded for the test organism being used.
4. If a purging trigger is exceeded for the species being used—and contaminant loss or alteration of bioavailability due to purging has been determined not to be a significant issue—purging is conducted.

Details for purging procedures, reporting requirements, and case-by-case determinations for purging can be found in DMMP 2015b.

7.3 Freshwater Bioassays

If the bioassay test sediment and/or the proposed disposal location for dredged material is in a low salinity environment (5 ppt or below), then freshwater bioassays will be used. For freshwater bioassays, eight laboratory replicates of test sediments, reference sediments (when used), and negative controls will be run for each bioassay (per ASTM and EPA guidance).

Ammonia and sulfides are generally used to inform bioassay testing regarding the potential for nontreatment effects from these chemicals; sediments containing only elevated ammonia and/or sulfide concentrations (and no other chemical exceedances) may be determined suitable for unconfined, aquatic placement without bioassays. However, if other CoCs are present above their screening levels, and bioassay testing is proposed, then the applicants should contact their local review team to determine whether or not purging the ammonia and/or sulfides prior to testing should be conducted.

7.3.1 Freshwater Bioassay Species Selection

Freshwater bioassays used to assess toxicity of sediments must include the following:

1. Two different test species: the amphipod, *Hyalella azteca*, and midge, *Chironomus dilutus*
2. A total of three endpoints (acute and chronic)
3. One chronic test: 20-day *Chironomus* or 28-day *Hyalella*
4. One sublethal (growth) endpoint

Table 7-3 indicates which bioassay endpoints fall into which category. For freshwater bioassay test protocols, follow EPA (2000) or ASTM (2010). A typical bioassay suite that meets these guidelines would be the *Chironomus* 20-day growth and mortality test and the 10-day *Hyalella* mortality test.

Table 7-3. Freshwater biological tests, species, and applicable endpoints.

Species, Biological Test, and Endpoint	Acute Effects Biological Test	Chronic Effects Biological Test	Lethal Effects Biological Test	Sublethal Effects Biological Test
Amphipod, *Hyalella azteca*				
10-day mortality	X		X	
28-day mortality		X	X	
28-day growth		X		X
Midge, *Chironomus dilutus*				
10-day mortality	X		X	
10-day growth	X			X
20-day mortality		X	X	
20-day growth		X		X

7.3.2 Performance Standards for Freshwater Bioassays

Standard protocols exist for each of these tests, established both by ASTM and EPA (EPA 2000; ASTM 2010). Either protocol may be used for the freshwater bioassays. Adherence to the protocol performance standards aids in interpreting bioassay responses by limiting effects from factors other than sediment toxicity due to the contaminants of interest. Performance standards for reference and control sediment, as well as interpretive criteria for these longer-term freshwater tests, are provided in the tables below.

7.3.3 Freshwater Bioassay Interpretive Criteria

The freshwater bioassay interpretive criteria appear in Table 7-4. For the purposes of these interpretive criteria, the term “hit” is used in interpreting bioassays and refers to an exceedance of a specified biological response threshold. Because the derivation of freshwater SLs was different from that used for the marine values (DMMP 2015c), there are no “one-hit” or “two-hit” definitions for freshwater bioassays. However, there are SL1 and SL2 hits; failure of either of these SLs results in the material being considered unsuitable for unconfined, aquatic disposal. Additionally, SL2 level hits are used in antidegradation evaluation and to determine whether or not the project may be referred to the state cleanup program.

Another difference between the freshwater and marine bioassay interpretive criteria is comparison to control, not reference sediment. This difference is because comparison to control was used in development of the numeric standards (due to lack of sufficient reference data). Thus, freshwater bioassay data are compared to controls, with use of a reference sediment being optional. If a reference sediment is used, then control would be replaced with reference in the bioassay formulas for comparison to screening levels, and the response must be statistically different from *both* reference and control (alpha = 0.05).

Table 7-4. Interpretive criteria and performance standards for freshwater biological tests.

Bioassay/ Endpoint[1]	Performance Standard[2]		Screening Level 1 (SL1)	Screening Level 2 (SL2)
	Control[3]	Reference		
Hyalella azteca				
10-day mortality	$M_C \leq 20\%$	$M_R \leq 25\%$	$M_T - M_{C/R} > 15\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)	$M_T - M_{C/R} > 25\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)
28-day mortality	$M_C \leq 20\%$	$M_R \leq 30\%$	$M_T - M_{C/R} > 10\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)	$M_T - M_{C/R} > 25\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)
28-day growth	$MIG_C \geq 0.15$ mg/ind	$MIG_R \geq 0.15$ mg/ind	$(MIG_{C/R} - MIG_T)/MIG_{C/R} > 0.25$ and MIG_T vs $MIG_{C/R}$ SD ($p \leq 0.05$)	$(MIG_{C/R} - MIG_T)/MIG_{C/R} > 0.40$ and MIG_T vs $MIG_{C/R}$ SD ($p \leq 0.05$)
Chironomus dilutus				
10-day mortality	$M_C \leq 30\%$	$M_R \leq 30\%$	$M_T - M_{C/R} > 20\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)	$M_T - M_{C/R} > 30\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)
10-day growth	$MIG_C \geq 0.48$ mg/ind	$MIG_R/MIG_C \geq 0.8$	$(MIG_{C/R} - MIG_T)/MIG_{C/R} > 0.20$ and MIG_T vs $MIG_{C/R}$ SD ($p \leq 0.05$)	$(MIG_{C/R} - MIG_T)/MIG_{C/R} > 0.30$ and MIG_T vs $MIG_{C/R}$ SD ($p \leq 0.05$)
20-day mortality	$M_C \leq 32\%$	$M_R \leq 35\%$	$M_T - M_{C/R} > 15\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)	$M_T - M_{C/R} > 25\%$ and M_T vs $M_{C/R}$ SD ($p \leq 0.05$)
20-day growth	$MIG_C \geq 0.60$ mg/ind	$MIG_R/MIG_C \geq 0.8$	$(MIG_{C/R} - MIG_T)/MIG_{C/R} > 0.25$ and MIG_T vs $MIG_{C/R}$ SD ($p \leq 0.05$)	$(MIG_{C/R} - MIG_T)/MIG_{C/R} > 0.40$ and MIG_T vs $MIG_{C/R}$ SD ($p \leq 0.05$)

Notes: Abbreviations: M = mortality; MIG = mean individual growth (mg/individual/day); SD = standard deviation; mg = milligrams; ind =individual

Subscripts: C = control; R = reference; T = test; C/R= control or reference, depending on which is used

[1] These tests and parameters were developed based on the most current ASTM protocols.

[2] Reference performance standards are provided for sites where the local review team has approved a freshwater reference sediment site(s) and reference results will be substituted for control in comparing test sediments to criteria.

[3] The control performance standard for the 20-day test (0.60 mg/individual) is more stringent than for the 10-day test and the agencies may consider, on a case-by-case basis, a 20-day control has met QA/QC requirements if the mean individual growth is at least 0.48 mg/individual.

SL1 Hit Definitions

***Amphipod 10-day Mortality Bioassay*—**For the amphipod (*Hyalella azteca*) bioassay, mean test mortality greater than 15% over the mean control response, and statistically different from the control (alpha = 0.05), is considered an SL1 failure.

***Amphipod 28-day Mortality/Growth Bioassay*—**For the amphipod 28-day mortality bioassay, mean mortality in test sediment greater than 10% over the mean control response, and statistically different from the control (alpha = 0.05), is considered an SL1failure. For the growth test, a mean reduction in growth rate greater than 25% of control and statistically different from the control (alpha = 0.05), is considered an SL1 failure.

***Midge 10-day Mortality/Growth Bioassay*—**For the midge (*Chironomus dilutus*) 10-day mortality test, a mean mortality in test sediment of 20% over mean control response, and statistically different from control (alpha = 0.05), is an SL1 failure. For the midge 10-day growth test, a mean reduction in growth greater than 20% of control and statistically different from control (alpha = 0.05) is considered an SL1 failure.

***Midge 20-day Mortality/Growth Bioassay*—**For the midge 20-day mortality test, a mean mortality in test sediment of 15% over the mean control response, and statistically different from the control (alpha = 0.05), is considered an SL1 failure. For the growth test, a mean reduction in growth greater than 25% of control and statistically different from control (alpha = 0.05) is considered an SL1 failure.

SL2 Hit Definitions

In Washington and Oregon, material failing SL2 definitions may result in the project being referred to the state cleanup program. Additionally, the SL2 is used in antidegradation evaluations as the upper limit in exposed surfaces even if it is less toxic than overlying sediments. Again, if a reference sediment is used, then the control data are replaced with reference data in the bioassay formulas, and the response must be statistically different from both reference and control (alpha = 0.05).

***Amphipod 10-day Survival Bioassay*—**For the amphipod bioassay, mean test mortality greater than 25% over the mean control response, and statistically different from the control (alpha = 0.05), is considered an SL2 failure.

***Amphipod 28-day Mortality/Growth Bioassay*—**For the amphipod 28-day mortality bioassay, mean mortality in test sediment greater than 25% over the mean control response, and statistically different from the control (alpha = 0.05), is considered an SL2 failure. For the growth test, a mean reduction in growth greater than 40% of control and statistically different from the control (alpha = 0.05), is considered an SL2 failure.

***Midge 10-day Mortality/Growth Bioassay*—**For the midge 10-day mortality test, a mean mortality in test sediment of 30% over mean control mortality and statistically different from control (alpha = 0.05) is an SL2 failure. For the midge 10-day growth test, a mean reduction in growth greater than 30% of control and statistically different from the control (alpha = 0.05) is considered an SL2 failure.

Midge 20-day Mortality/Growth Bioassay—For the midge 20-day mortality test, a mean mortality in test sediment of 25% over the mean control response, and statistically different from the control (alpha = 0.05), is considered an SL2 failure. For the growth test, a mean reduction in growth greater than 40% of control and statistically different from the control (alpha = 0.05) is considered an SL2 failure.

7.4 Fish Toxicity Testing—Placeholder

At this time, RSET and DMMP do not have fish toxicity SLs, recommended test species, or bioassay interpretive criteria. However, the agencies are working to develop SLs and testing protocols that are protective of fish.

7.5 References

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Chapter 8. Bioaccumulation Evaluation

8.1 Introduction

Both the CWA and MPRSA require the use of available information to make a preliminary determination concerning the need for testing of the material proposed for dredging. The decision to not perform additional testing, and to instead rely on existing information, must be documented from site history information in order to provide a "reasonable assurance that the proposed discharge material is not a carrier of contaminants." [16] This principle is colloquially referred to as "reason to believe," and it is the foundation of the sediment evaluation procedures prescribed herein, including the bioaccumulation evaluation.

Bioaccumulation is the accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated water and sediment. The bioaccumulation evaluation begins with simple screening and progresses to more detailed laboratory or in-situ bioaccumulation testing (Figure 8-1). The steps of the bioaccumulation evaluation are briefly introduced in this section and expanded upon in the following sections.

Under both the CWA and MPRSA, a bioaccumulation evaluation is necessary to support aquatic disposal of dredged material if there is reason to believe that the contaminants in dredged material may bioaccumulate, bioconcentrate, and/or biomagnify in aquatic food webs up to levels that may be harmful to potential receptor organisms, including human beings. Two conditions must be present to trigger a bioaccumulation evaluation:

- BCoCs must be present in the project sediments.
- Concentrations of BCoCs in the project sediments must be at levels that are potentially harmful[17] to receptor organisms (or their predators) exposed at the dredge area or disposal site.

BCoCs are frequently present in sediments in the Pacific Northwest region. However, the potential for BCoCs to cause harm to receptor organisms (and their predators) via bioaccumulation pathways can be difficult to document.

The CSM worksheet (presented in Chapter 3) is a useful tool to identify exposure pathways to bioaccumulative contaminants associated with the dredging project. The CSM is also used to determine the completeness of each pathway for each receptor organism. Bioaccumulative exposure pathways that are "incomplete" or "insignificant" may not require additional evaluation.

In some parts of the Pacific Northwest region, bioaccumulation triggers (BTs) provide a preliminary screen of the potential for BCoCs to accumulate to harmful levels in receptor organisms and/or their predators (section 8.3). Where they are available, it is also important to consider regional background BCoC concentrations (section 8.4) when determining the need for bioaccumulation testing. Similar to the

[16] CWA, 40 CFR §230.60(b); MPRSA, 40 CFR §227.13(b)(3)(ii)

[17] The concept of contaminants being harmful to aquatic organisms (and the need for biological evaluations) appears at CWA, 40 CFR §230.61(b); MPRSA, 40 CFR §227.13(c)

toxicity screening levels comparison, if the background concentration for a BCoC is below the BT then the local review team will use the BT to determine the need for bioaccumulation testing. However, if regional background concentrations of a BCoC are above the BT, then a test sediment would need to exceed both the BT and background concentration in order to meet the requirement for bioaccumulation testing.

Guidance for bioaccumulation testing was developed by the Corps and EPA for use across the nation (sections 8.5 and 8.6). The bioaccumulation testing procedures and guidelines presented in this chapter are consistent with the national Inland Testing Manual (EPA and Corps 1998). Bioaccumulation test interpretation guidelines for various receptor organisms appear in section 8.5.

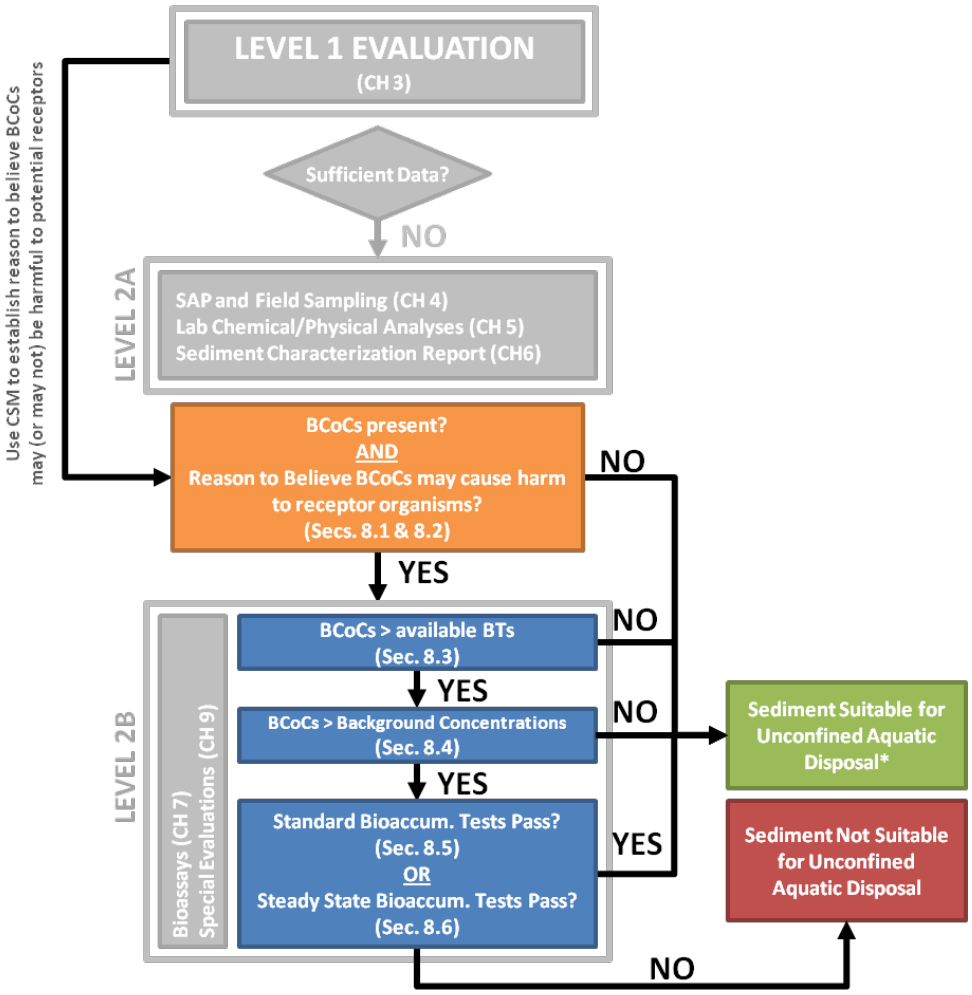

Figure 8-1. Bioaccumulation evaluation steps.

8.2 Bioaccumulative CoCs

The RSET has accepted the approach for identifying BCoCs outlined by the Washington DMMP (DMMP 2007). This approach relies on a review of the occurrence of contaminants in sediments and tissue, chemical properties of contaminants such as the octanol-water partitioning coefficient (K_{ow}) and the

known toxicity of the contaminants to human or ecological receptors, and comparison of predicted or observed tissue levels to available residue-effects levels. Contaminants are placed on one of four lists depending on the amount of information available and the weight-of-evidence indicating their potential to bioaccumulate, prevalence in the region, and toxicity.

Three subregions in the Pacific Northwest have been identified, each with its own primary BCoC list. The BCoC lists for these subregions are similar but have minor differences related to chemical usage and detection. **Specific to the subregion that the project is located in, only the "List 1" primary BCoCs are considered in the bioaccumulation evaluation (Table 8-1).** Those BCoCs in Table 8-1 that are not also found in Table 6-2 (e.g., methoxychlor) will be considered on a case-by-case basis as "site-specific chemicals of concern." If there is reason to believe that one or more of these BCoCs may be present in dredged material at concentrations of concern for bioaccumulation, those particular chemicals will be added to the CoC list for sediment analysis.

The chemicals in List 2 (candidate BCoCs), List 3 (potential BCoCs), and List 4 (non-BCoCs) will be reviewed by the local review team to identify any potential concerns; these lists are specific to each subregion within the Pacific Northwest and appear in Appendix C.

Table 8-1. List 1 bioaccumulative chemicals of concern by subregion.

Bioaccumulative Chemical of Concern	Puget Sound, Strait of Juan de Fuca, and Coastal Washington	Oregon, including the Columbia River where it borders Oregon and Washington	Eastern Washington and Idaho
Metals			
Arsenic	X	X	X
Cadmium	—	X	X
Chromium	—	—	X
Copper	—	—	X
Lead	X	X	X
Mercury	X	X	X
Selenium	X	X	X
Organometallic Compounds			
Tributyltin (bulk)	X	X	—
Tributyltin (porewater)	X	--	—
Polynuclear Aromatic Hydrocarbons			
Fluoranthene	X	X	X
Pyrene	X	X	X
Chlorinated Hydrocarbons			
Hexachlorobenzene	X	X	X
Phenols			
Pentachlorophenol	X	X	X
Pesticides			
Total DDT (∑ 4,4'-DDD, 4,4'-DDE and 4,4'-DDT)	X	X	X
Total chlordane[1,2]	X	X	X
Methoxychlor[2]	—	X	—
Dieldrin	—	X	X

Table 8-1. List 1 bioaccumulative chemicals of concern by subregion.

Bioaccumulative Chemical of Concern	Puget Sound, Strait of Juan de Fuca, and Coastal Washington	Oregon, including the Columbia River where it borders Oregon and Washington	Eastern Washington and Idaho
γ-Hexachlorocyclohexane[2] (Lindane)	—	X	—
Endosulfans[2]	—	X	—
Dioxins/Furans			
2,3,7,8-TCDD (TEQ)	X	X	—
2,3,7,8-TCDD (congener)	—	X	—
Dioxin/furan congeners	—	X	—
Polychlorinated Biphenyls			
PCBs (congeners)	—	X	—
PCBs (total Aroclors)	X	X	—

[1] Total chlordane includes cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane.

[2] This BCoC is not included in Table 6-2 for freshwater sediment analysis; if there is reason to believe this BCoC may be present in dredged material at concentrations of concern for bioaccumulation, it will be added to the CoC list for sediment analysis.

8.3 Bioaccumulation Triggers

A BT is the bulk sediment concentration of a BCoC above which the contaminant could accumulate to levels of concern in the tissues of receptor organisms utilizing the dredge area or the disposal site. The fundamental assumption behind each sediment BT is that there is a demonstrated relationship between concentrations of the BCoC in sediments and in tissues of aquatic life exposed to those sediments.

In areas where they are available, BTs provide a preliminary screen of the potential for BCoCs to accumulate to harmful levels in receptor organisms or their predators. However, regional sediment BTs have not been developed for the Pacific Northwest region due to the broad range of site-specific factors influencing sediment contaminant bioaccumulation potential and regulatory differences in the way each state evaluates BCoCs. The RSET may look to the states to develop BTs for particular watersheds or geographic areas in partnership with the federal agencies.

If available, existing BTs may be used if they are protective and consistent with the concepts presented in this chapter. The local review team should be consulted to determine which BTs are appropriate for a given project and how they should be applied. In Washington, the DMMP has published BTs in its local guidance, the *Dredged Material Evaluation and Disposal Procedures User Manual* (DMMP 2014). In Oregon, the PSET uses the screening level values published in ODEQ's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (2007). In areas without sediment BTs, or for individual chemicals for which BTs are not yet available, a comparison to background concentrations should be conducted (see section 8.4).

Appendix E (section E.4) provides general guidance for developing sediment BTs on a watershed- or project-specific basis.

8.4 Comparison to Background

Derivation methods for sediment BTs contain conservative assumptions in light of uncertainties and may result in very low values. Some BT calculations result in values that are below background concentrations and detection limits (MRLs). In these cases, the use of a sediment BT may be replaced by a comparison of the sediment BCoC level to background levels, or MRLs.

The first step in this process is to establish background concentrations for the project site (the dredge area and disposal site) in question. The specific definition of "background" often depends on state regulations and may include natural concentrations or, in some cases, globally distributed anthropogenic compounds. Sediment data for a particular watershed or region obtained from Ecology's EIM database may be used to establish project-specific background levels; if EIM data are unavailable, then sampling may be required in order to develop local background concentrations. In this case, the project proponent should coordinate with the local review team in advance of the sampling to ensure that the resulting data will be useful.

Once background concentrations have been identified for an area, whether on a regional- or watershed-specific basis, these data will be used for comparison to project sediment data. Working with the proponent, the local review team will determine one or more threshold values that represent the upper end of the background concentration distribution for each BCoC. The background data set used to calculate the threshold(s) will be available for comparison as well. If projects have less than 10 sediment samples, then each sample must be individually compared to the calculated background threshold(s). If projects have 10 sediment samples or more, then the single-sample comparison approach described above may be used, or project proponents have the additional option of comparing the project sediment BCoC distribution to the background BCoC distribution directly, without using a threshold, to determine if the sediment levels exceed background levels for the BCoC.

The specific statistical methods are based on the results of an October 7, 2008, statistical experts workshop (RSET 2008).

- Nonparametric methods that do not rely on assumptions about the specific type of data distribution are to be used. Substitutions for nondetects are not required and should not be conducted. See the workshop report for nonparametric, nonsubstitution methods of calculating sums for classes of compounds such as dioxin/furan TEQ.
- For calculating an upper threshold concentration based on a background data set with 10 or more samples, use an upper tolerance limit (UTL), which is a confidence limit on a percentile of the underlying population. Decisions regarding which specific percentile(s) and confidence on the percentile(s) to use will be determined by the state. The UTL should be calculated using the Kaplan-Meier nonparametric method.
- For calculating an upper threshold concentration based on a background data set with less than 10 samples, ad hoc methods based on upper percentiles are recommended. Again, the specific percentile(s) will be determined by the state.
- For single-sample comparisons, project samples will be compared to the UTL (or other threshold, as appropriate), and if equal to or less than the UTL, the sediments will be considered suitable for open-water disposal from a bioaccumulative chemical standpoint. If above the UTL, the sediments will be considered unsuitable. A similar comparison could be conducted to evaluate whether a sample at a cleanup site exceeds background levels for the BCoCs.

- Alternatively, the agencies may choose to conduct comparisons on a volume-weighted basis, with volume-weighted average concentrations not to exceed the UTL and an upper threshold for individual DMMUs. This approach takes into account the area-wide nature of exposures that could lead to bioaccumulation and allows for limited averaging within and/or among projects disposed at the same time.
- For comparisons of project distributions to background distributions, both populations must have at least 10 samples. The comparison is to be made with the Wilcoxon-Mann-Whitney nonparametric test (or the Gehan test if data contain multiple detection limits for a given analyte). If the project distribution is not statistically greater than the background distribution, the project sediments represented by the distribution will be considered suitable for open-water disposal from a bioaccumulation standpoint. An additional comparison of the tails of the distributions may be conducted at agency discretion using a quantile test to determine whether individual project samples may be unrepresentative of the upper tail of the background distribution.
- All statistical tests should be conducted using a professional statistical package that contains the nonparametric tests described above.

8.5 Standard Bioaccumulation Testing

The project proponent may opt to conduct bioaccumulation testing concurrently with the sediment chemical analyses if the site history information indicates that bioaccumulation testing may be required or if other project constraints exist, such as the need to avoid delays caused by a second round of sampling and laboratory analysis.

Three basic methods can be used to evaluate bioaccumulation potential:

- *Laboratory Bioaccumulation Testing*—Sediments from the site or project area are collected and taken to a laboratory, where two species are exposed to the sediments under controlled conditions. At the end of the test, tissue concentrations are measured and compared to the target tissue levels (TTLs) listed in Table 8-5, provided steady-state conditions are achieved or can be estimated (see below). For BCoCs without TTLs, expose the same two test species to a reference sediment and compare tissue BCoC concentrations with those of the organisms exposed to the project sediment. Laboratory testing is the most commonly used approach in dredged material evaluations because it can simulate the bioaccumulation potential of both surface and subsurface sediments.
- *In Situ Bioaccumulation Testing*—Test organisms are placed in the field in webbing or cages and exposed to sediments at the site or project area for a specified length of time. This approach assesses bioaccumulation of BCoCs from the surface sediments but does not involve exposure to deeper subsurface sediments that may be associated with a typical dredge prism. It is also more time-consuming and costly compared to laboratory bioaccumulation testing. In situ bioaccumulation testing should only be performed in cases where contamination is known to be consistent throughout the dredge prism profile.
- *Collection of Field Organisms*—Fish and/or benthic infauna (frequently shellfish) may be collected from the site or project area for chemical analysis of contaminants in their tissues. Species to be collected are selected based on their site fidelity; representativeness of feeding guilds at the site; exposure and feeding strategies; and commercial, recreational, and cultural

significance. Depending on the location, it may be important to determine beforehand the level of effort that will be required to collect sufficient biomass in order to meet the tissue volume requirements for the required BCoC analysis. As with in situ bioaccumulation testing, this approach can be used to assess conditions in surface sediments but does not address subsurface contamination and thus should only be used in cases where contamination is known to be homogenous throughout the dredge prism profile.

For the reasons cited above, **laboratory bioaccumulation testing is preferred by the RSET agencies.** Methods and considerations for laboratory bioaccumulation testing are described in the following sections. In situ bioaccumulation testing and testing of field organisms may be allowed by the local review teams on a case-by-case basis; these are briefly described below.

***Holding Time, Volume, and Chemical Reanalysis Requirements*—**Given the holding time limitations (8 weeks at 4 °C) and the large volume of sediment required (10–30 L), it is usually necessary to resample project sediments in order conduct laboratory bioaccumulation testing. Under these circumstances, it is necessary to also reanalyze the newly collected sediment for the CoCs (i.e., those that originally triggered the requirement for bioaccumulation testing). Analytical methods for sediment are described in Chapter 5.

***Reference Sediment*—**The reference site selection guidelines for benthic toxicity bioassays (presented in Chapter 7) also hold true for bioaccumulation bioassays. See section 7.1.2 for information regarding reference sediments.

***Test Organism Selection*—**An important consideration in standard bioaccumulation evaluations is the selection of appropriate laboratory test species. Bioaccumulation testing is normally conducted using two species, which reduces uncertainty (e.g., intra- and inter-species differences in ability to bioaccumulate the contaminants, time required to reach steady-state conditions, etc.). Test species selection should consider trophic level, the major exposure pathways identified in the CSM, feeding strategies, etc.

Additionally, studies have shown that the time required for any given species to achieve a steady-state tissue concentration of a CoC may vary, or are not well known (Windom and Kendall 1979; Rubenstein et al. 1983). As such, for a given chemical triggering a bioaccumulation test, the proponent 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 proponent should coordinate with both the local review team and the contract testing laboratory to determine the appropriate test species. The Inland Testing Manual requires bioaccumulation testing with species from two different trophic niches, including the following:

- A suspension-feeding/filter-feeding organism
- A burrowing, deposit-feeding organism

Marine Test Species—In the Pacific Northwest, the marine bioaccumulation test is usually conducted with both an adult bivalve (*Macoma nasuta*) and an adult polychaete (*Nephtys caecoides*). Depending on availability, *Alitta* (*Nereis*) *virens* (sandworm), *Arenicola marina*, and *Abarenicola* spp. (lugworms) may also be suitable test organisms (see section 8.5.1).

Freshwater Test Species—For freshwater sediments, the test will be conducted with the oligochaete *Lumbriculus variegatus* and Asiatic clam (*Corbicula fluminea*). Other bivalves (clams and mussels), gastropods (snails), or decapods (crayfish) may potentially be used as test organisms (see section 8.5.2). Users should note testing difficulties with Asiatic clams in contaminated sediments; the clams can literally "clam-up" and stop siphoning in toxic substrates altogether. As such, it is critical to ensure that steady-state concentrations are reached or can be estimated for this organism. An alternative species should be selected if it is determined that this test organism is not siphoning.

Exposure Duration—After the test organism species are selected, the laboratory initiates the bioaccumulation tests, which may last up to 45 days. The extension of the exposure period to the sediment for up to 45 days is acceptable for marine species (DMMP 2014) and requires special protocols that call for addition of supplemental sediment during the exposure period. Testing of these types of extended exposures has not been conducted with Asiatic clams. If a proponent proposes extended exposure times for this species, testing must be done to ensure that the health of the organism is maintained during the longer exposure time (i.e., no substantial loss of weight or lipid content for individual organisms). The test organisms are exposed to the test sediment (i.e., BCoC-contaminated material), the reference sediment (typically provided by the proponent in consultation with the review team), and a negative control sediment provided by the lab.

Test Quality Assurance—Bioaccumulation testing methods include the following laboratory controls:

- Test organism water acclimatization procedures prior to test initiation
- Maintain photoperiod (12 hours light/12 hours dark) and temperature
- Monitor water quality parameters:
  - Marine systems: dissolved oxygen, salinity, pH, total ammonia, and sulfides
  - Freshwater systems: dissolved oxygen, hardness, alkalinity, conductivity, pH, total ammonia, and sulfides
- Monitor and record organism survival daily and remove dead individuals from test chambers

At the end of the exposure period, organisms are sieved from the test, reference, and control sediments and transferred to replicate aquaria containing clean water for 24 hours to purge the gut contents. Organisms from the test, reference, and negative control sediments are frozen and submitted for tissue analysis. The preparation and analytical methods for BCoCs in tissue, and respective sample quantitation limits, appear in Table 8-2.

Table 8-2. Recommended tissue analytical methods and sample quantitation limits.

Parameter	Prep Method	Analysis Method	Sample Quantitation Limit (SQL)[1,2]
Conventionals (%)			
Lipids	Bligh/Dyer	Bligh/Dyer	0.01
Metals (mg/kg)			
Arsenic	EPA 3050B/PSEP	EPA 6010/6020/7010	0.05–0.2
Cadmium	EPA 3050B/PSEP	EPA 6010/6020/7010	0.05–0.2
Lead	EPA 3050B/PSEP	EPA 6010/6020/7010	0.05–0.2
Mercury	EPA 7471	EPA 7471	0.01–0.02
Selenium	EPA 3050B/PSEP	EPA 6010/6020/7010	0.05–0.2
Polynuclear Aromatic Hydrocarbons (µg/kg)			
Fluoranthene	3540C, 3541, or 3550B	EPA 8270-SIM/8270	1–5
Pyrene	3540C, 3541, or 3550B	EPA 8270-SIM/8270	1–5
Miscellaneous Semivolatiles (µg/kg)			
Hexachlorobenzene	3540C, 3541, or 3550B	EPA 8081	1
Pentachlorophenol	3540C, 3541, or 3550B	EPA 8270-SIM/8270	25
Pentachlorophenol	3540C, 3541, or 3550B	EPA 8151	5
Chlorinated Pesticides (µg/kg)			
DDE (p,p'-, o,p'-)	3540C, 3541, or 3550B	EPA 8081	2
DDD (p,p'-, o,p'-)	3540C, 3541, or 3550B	EPA 8081	2
DDT (p,p'-, o,p'-)	3540C, 3541, or 3550B	EPA 8081	2
Chlordane compounds[3]	3540C, 3541, or 3550B	EPA 8081	2
Dieldrin	3540C, 3541, or 3550B	EPA 8081	2
Endosulfans	3540C, 3541, or 3550B	EPA 8081	2
Lindane	3540C, 3541, or 3550B	EPA 8081	2
Methoxychlor	3540C, 3541, or 3550B	EPA 8081	10
Polychlorinated Biphenyls (µg/kg)[4]			
PCB Aroclors	3540C, 3541, or 3550B	EPA 8082	5–10
PCB congeners	3540C, 3541, or 3550B	EPA 8082	0.5–2
PCB congeners (low level)	EPA 1668A	EPA 1668A	0.01–0.1
Dioxins/Furans (ng/kg)[5]			
2,3,7,8-TCDD	EPA 8290/1613	EPA 8290/1613	1
Dioxins/furans (other)	EPA 8290/1613	EPA 8290/1613	1–10
Organotins (µg/kg)[5]			
Tributyltin	EPA 3550B or NMFS	Krone	10

mg/kg = milligrams per kilogram; µg/kg = micrograms per kilogram; ng/kg = nanograms per kilogram

[1] All sample quantitation limits are expressed on a wet-weight basis

[2] SQLs are highly dependent on sample size; details should be confirmed with the laboratory.

[3] Chlordane compounds include cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane; in samples with interference from PCBs, the SQLs for cis- and trans-nonachlor and oxychlordane may be elevated.

[4] Selection of PCBs analytical method will be determined on a project-specific basis.

[5] Dioxins/furans and tributyltin are site-specific CoCs; analysis of these constituents will be determined on a project-specific basis.

8.5.1 Standard Bioaccumulation Testing—Marine

Protocols for tissue digestion and chemical analysis will follow the PSEP-recommended procedures for metals and organic chemicals (DMMP 2014; PSEP 1997a; PSEP 1997b). Species-specific test and reference sediment volume requirements for marine bioaccumulation testing appear in Table 8-3.

Table 8-3. Test, reference, and sediment volume requirements for marine bioaccumulation testing.

Species	Organism Type; Trophic Niche	Minimum Sediment Volume Requirement
Macoma nasuta	Saltwater clam; filter feeder	250-400 mL per beaker x 10 beakers per replicate x 5 replicates = 12.5–20 L
Nephtys caecoides/ *Alitta virens*	Marine catworm; deposit feeder/ sandworm; deposit feeder	200 mL per worm x 20 worms per replicate x 5 replicates = 20 L
Arenicola marina/ *Abarenicola* spp.	Lugworm; deposit feeder/ lugworms; deposit feeders	500 mL per beaker x 4 beakers per replicate x 5 replicates = 10 L
Co-testing: *M. nasuta*/ *N. caecoides*	See above	4 liters per replicate x 5 replicates = 20 L plus 10 L for replenishment

Per EPA's marine bioaccumulation testing protocols (Lee et al. 1989), test organisms are subject to a 28-day exposure period (test, reference, and negative control), after which chemical analysis of the test organism tissues is conducted to determine the concentration(s) of BCoC(s). The 28-day exposure time assumes that the test organism tissue is expected to reach steady-state. A literature review by the DMMP indicates that PCBs, tributyltin, DDT, Hg, and fluoranthene take longer than 28-days to reach steady-state in test organisms than the other BCoCs. Therefore, a 45-day exposure period should be used for these chemicals during standard bioaccumulation testing; the 28-day period is sufficient for the other BCoCs (see Chapter 10 in DMMP 2014). For site-specific CoCs, the project proponent should consult with the local review team to determine the appropriate length of exposure to test sediments.

The following bioaccumulation testing protocol updates for marine sediments (developed by the DMMP) should be used:

- For tests requiring a 45-day exposure period, 175-mL of test or control/reference sediment must be added to each replicate 10-gallon aquarium/test chamber on a weekly basis.
- 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. The 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 an effects-based TTL for growth.
- The bioaccumulation results for each DMMU undergoing bioaccumulation testing are compared to the TTL for the specific BCoC(s) detected. No further action is required for mean test sediment tissue concentrations greater than or equal to the TTL because the DMMU has failed the interpretative guidelines and is unsuitable for unconfined, aquatic disposal. Test sediment tissue samples with concentrations less than the TTL are subjected to a one-tailed, one-sample t-test (alpha level of 0.05) to determine whether the test tissues are significantly less than the TTL.
- For BCoCs without TTLs, a one-tailed t-test is used to determine if the tissue concentrations resulting from exposure to the test sediment are significantly higher than tissue concentrations for reference sediment. An alpha level of 0.1 is used (rather than 0.05) when making this statistical comparison to reflect the higher likelihood for within-sample variability, and to increase the power of the test to discriminate between reference and test tissue concentrations.
- To conserve laboratory space and reduce the volume of sediment required, proponents may have the laboratory 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 test species separately; co-testing the two species in the same aquaria substantially reduces the required volume of sediment for bioaccumulation testing.

8.5.2 Standard Bioaccumulation Testing—Freshwater

For freshwater sediments, the test should be conducted with the oligochaete *Lumbriculus variegatus* and a second species to be determined at the time of testing (Asiatic clam, *Corbicula fluminea*, is a common, locally available, freshwater test organism). Bioaccumulation testing methods for *Lumbriculus variegatus* are prescribed in ASTM E-1688 and EPA/600/R-99/064, Method 100.3 (EPA 2000). The *Corbicula fluminea* test is conducted based on methods and guidance described in ASTM E-1688 and EPA/600/R-99/064 (EPA 2000). Protocols for tissue digestion and chemical analysis will follow the PSEP-recommended procedures for metals and organic chemicals (DMMP 2014; PSEP 1997a; PSEP 1997b). Species-specific test and reference sediment volume requirements for freshwater bioaccumulation testing appear in Table 8-4.

Table 8-4. Test, control, and reference sediment volume requirements for freshwater bioaccumulation testing.

Species	Organism Type; Trophic Niche	Minimum Sediment Volume Requirement
Lumbriculus variegatus	Blackworm; deposit feeder	Five 4–6 L test chambers w/ 1–2 L of sediment per chamber = 10 L[a]
Corbicula fluminea	Asiatic clam; filter feeder	5 aquaria (i.e., 5 replicates) = 25–30 L

[a] Greater volume of sediment and more organisms may be required depending on how much tissue is needed for tissue chemical analysis.

The test exposure duration will normally be 28 days utilizing the EPA protocol (Lee et al. 1989), after which a chemical analysis will be conducted on the tissue to determine the concentrations of BCoCs. As mentioned earlier, extending the exposure period to up to 45 days may be required to ensure tissue concentrations have reached steady state for larger organisms such as the Asiatic clam. If a proponent proposes extended exposure times for this species, testing should ensure that the health of the organism is maintained during the longer exposure time (no substantial loss in weight or lipid content).

8.5.3 Marine In-Situ Tests

Marine and estuarine bivalves have long been used in monitoring programs throughout the United States and internationally, and protocols for their use are well-established (see ASTM 2001). Species that are indigenous to the Pacific Northwest and appropriate for estuarine or marine salinities include the following:

- Mussels: *Mytilus trossulus, M. californianus, M. galloprovincialis, M. edulis*
- Oysters: *Crassostrea gigas, Ostrea lurida*
- Clams: *Macoma balthica, Protothaca staminea*

Other selections are also possible; see ASTM (2001) for a complete list of marine and estuarine species, their geographic distributions, and salinity tolerances.

8.5.4 Freshwater In Situ Tests

Because fewer freshwater in situ bioaccumulation tests have been completed for Pacific Northwest dredging projects, a thorough review was conducted to evaluate which species may be appropriate for these tests. Three groups of organisms are recommended as satisfying the criteria (see Test Organism Selection above) and are present in the Pacific Northwest. In order of preference (Salazar and Salazar 1998), these include: (1) bivalves; (2) gastropods; and (3) decapods (crayfish). Freshwater protocols are also provided in ASTM (2001).

Corbicula fluminea is recommended as the first choice for in situ freshwater assessments of bioaccumulation potential because it has been used extensively in laboratory testing, field monitoring, and in-situ assessments of both toxicity and bioaccumulation potential (however, *Corbicula* should not be used in areas where it has not yet been introduced). Either a gastropod or freshwater crayfish would be potentially useful as a second species. A gastropod test may be recommended for areas where threatened, endangered, or candidate species of snails occur, such as in some waterways of Idaho. *Lumbriculus variegatus* has also been suggested by several agencies as a potential species that could be used. Further identification of in situ species will be conducted by the RSET as needed.

8.5.5 Collection of Field Organisms

This assessment involves measurements of tissue concentrations from individuals of the same species collected from the project site and a suitable reference site. A determination is made based on a statistical comparison of the magnitude of tissue contaminant levels in organisms collected within the boundaries of the reference site with that of organisms living at or near the project site. The selection of species to target for field collection is an important component of study design. Life history parameters such as trophic status, feeding guilds, habitat preferences, and foraging ranges should be considered and discussed with the local review team prior to conducting such a field program to ensure consistency with project objectives.

Collecting a sufficient number of individuals of the same species, size range, and age at both the reference site and the project site can make this type of assessment difficult. Temporal and spatial variability in bioaccumulation can violate steady-state assumptions and further confound data interpretation. For these reasons, steady-state bioaccumulation tests performed in the laboratory are the preferred approach. Nevertheless, field measurements of tissue burdens are often a critical part of the weight of evidence in a bioaccumulation assessment and can be designed to address specific questions required for regulatory decision-making.

8.5.6 Target Tissue Levels

A TTL is defined as the tissue concentration of a BCoC, measured in the tissues of the bioaccumulation test organisms, above which potential harm to the target organism (via bioaccumulative effects) is inferred. **The local review team will determine which TTLs are appropriate for a given project and how they should be applied**. TTL selection should consider the range of potential receptors in or near the project (or receptors consuming fish or shellfish from the project area and their predators) and determine the degree to which the project area is used by each receptor. The TTL(s) selected should be based on the most sensitive receptor expected based on CoC toxicity data.

In the state of Washington, the DMMP has published TTLs in its local guidance manual, the *Dredged Material Evaluation and Disposal Procedures User Manual* (DMMP 2014, Table 10-4). In Oregon, the RSET Bioaccumulation Subcommittee developed an approach to deriving TTLs for three general groups of receptors:

- Aquatic life including ESA-listed species and special-status species (fish, mussels, snails, etc.)
- Wildlife consuming fish and invertebrates
- Humans consuming fish and shellfish

The remainder of this section provides a summary of the RSET approach to deriving TTLs.

TTLs for the first two groups of receptors are based on back-calculation using established risk assessment techniques and receptors common in the Pacific Northwest (see Appendix E). Tissue levels for protection of aquatic life are based on tissue-residue-effects data contained in databases, such as the Environmental Residue Effects Database, once quality assurance has been applied.

Tissue levels protective of humans (consuming fish and shellfish contaminated via dredging and/or disposal operations) should be based on a state's CWA effective water quality standards for the protection of human health and the underlying assumptions that go into the derivation of those values (e.g., fish and shellfish consumption rates, body weight, etc.). States review and potentially update their water quality standards on a triennial basis so project proponents and review teams need to review and consider any changes that have occurred.

The approaches and input values used to derive each of the TTLs listed in Tables 8-5 and 8-6 are provided in Appendix E. This information can be used to support project- or site-specific evaluation of bioaccumulation risks. The local review team and project proponent may modify the input values or approach based on site-specific factors (e.g., wildlife and ESA receptors present). Appendix E provides the formulae used to calculate the TTLs and identifies the parameters that can be modified to develop site-specific TTLs.

***Target Tissue Levels to Protect Aquatic Life*—**The TTLs shown in Table 8-5 for fish and other aquatic life were calculated using the species-specific life history parameters and the toxicity reference values for the BCoCs identified in Appendix E, section E.1. The two types of values shown in Table D-4 differ in their method of derivation: those based on the species sensitivity distribution (SSD) approach and interim values calculated from water quality criteria and bioconcentration factors (ODEQ 2007). The interim values are intended for use until enough data are available to apply the SSD approach.

Table 8-5. Target tissue levels (TTLs) for the protection of aquatic life.

Chemical	SSD-Derived TTL[1]	Ambient Water Quality Criteria Interim TTLs (mg/kg ww)	
		Freshwater	Marine
Arsenic	--	6.6	1.6
Lead	--	0.12	0.40
Mercury	0.11 mg/kg ww	--	--
Selenium	7.9 mg/kg dw	--	--
Tributyltin[2]	0.02 mg/kg ww (freshwater) 0.19 mg/kg ww (marine)	--	--
Fluoranthene	--	19	19
Fluorene	--	NA	NA
Pyrene	--	1.0	1.0
Hexachlorobenzene	--	32	32
Pentachlorophenol	0.001 mg/kg ww	--	--
Total chlordanes	--	0.06	0.056
DDTs—total	0.09 mg/kg ww	--	--
4,4'-DDE	--	0.054	0.054
4,4'-DDD	--	0.054	0.054
Dieldrin	--	0.26	0.26
Total endosulfans	--	NA	NA
gamma-HCH (Lindane)	--	NA	NA
Methoxychlor	--	NA	NA
Total PCB Aroclors	1.4 mg/kg lipid	--	--
Dioxins/furans/coplanar PCBs	--	NA	NA

Notes: NA = not available; ww = wet weight

[1] Because these TTLs are compiled from the literature, they do not all have the same units.

[2]Two values for tributyltin: 1 based on effects to gastropods; 1 based on an evaluation of multiple species (see Table D-1).

***Target Tissue Levels to Protect Aquatic-dependent Wildlife*—**The TTLs for wildlife that consume aquatic organisms (Table 8-6) were calculated using the species-specific life history parameters and the toxicity reference values for the BCoCs identified in Appendix E, section E.2. Values are presented for ESA species (based on the no-observed-adverse-effect level) and for population-level protection of other wildlife species in the Pacific Northwest (based on the lowest-observable-adverse-effect level). The lowest of the species-specific values are shown in Table 8-6 for two different types of environments:

- TTL_{DW} is based on protecting wildlife that consume marine species expected to be found in the vicinity of deep water, nondispersive disposal sites, such as the ocean disposal sites offshore of Oregon. This value is protective of the bald eagle, osprey, northern sea otter, and orca whale.
- TTL_{NS} is based on protecting wildlife species that consume aquatic life found in shallower coastal and inland areas. The TTL_{NS} would apply to marine or riverine dispersive disposal sites, projects in nearshore marine or estuarine areas, projects in freshwater areas, or beneficial use projects. It covers a wider variety of species, such as great blue heron, belted kingfisher, hooded merganser, black-necked stilt, American avocet, spotted sandpiper, bald eagle, osprey, river otter, northern sea otter, American mink, and harbor seal.

Table 8-6. Target tissue levels (mg/kg ww) for the protection of aquatic-dependent wildlife.

Chemical	Deep Water (Ocean Sites)		Nearshore/Inland Sites	
	TTL_{DW} ESA	TTL_{DW} Population	TTL_{NS} ESA	TTL_{NS} Population
Arsenic	11	53	2.7	14
Lead	7.8	39	2.0	10
Mercury	0.06	0.12	***0.02***	0.03
Selenium	1.4	6.9	0.35	1.8
Tributyltin	28	42	8.2	21
Fluoranthene	7.4	36	3.8	19
Fluorene	790	3900	410	2000
Pyrene	7.4	36	3.8	19
Hexachlorobenzene	NA	NA	NA	NA
Pentachlorophenol	32	160	8.1	41
Total Chlordanes	1.2	5.1	0.26	1.3
DDTs - Total	0.01	0.05	0.01	0.05
Dieldrin	0.34	1.7	0.09	0.42
Total Endosulfans	NA	NA	NA	NA
gamma-HCH (Lindane)	NA	NA	NA	NA
Methoxychlor	NA	NA	NA	NA
Total PCB Aroclors	0.04	0.18	0.04	0.18
Dioxins/Furans/coplanar PCBs TEQ[1]	***9.6 x 10^{-7}***	2.6 x 10^{-5}	***5.0 x 10^{-7}***	8.5 x 10^{-6}

Notes: NA = not available

Bold values - values are known to be near or below sample quantitation limits (Table 8-2).

[1] Methods for calculating dioxin/furan/PCB TEQs are presented in Appendix E, section E.2.6.15.

Target Tissue Levels to Protect Human Health—The development of TTLs for the protection of human health is highly site- and state-specific. If human health TTLs must be developed for a project, refer to section 9.3 for state-specific risk assessment procedures.

8.5.7 Data Interpretation

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):

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

$$[\ H_o: \mu \geq TTL \quad H_a: \mu < TTL\ ]$$

Where

$\overline{x}$ = mean tissue concentration of the BCoC in the test organism
s^2 = variance
n = 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 MDL 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 (μ) is not significantly less than the TTL. In this case, the null hypothesis (H_o) is that the tissue concentration is greater than or equal to the TTL.

If the mean tissue concentration of one or more of the BCoCs is greater than or equal to the TTL, then no statistical testing is required and the dredged material is determined to be unsuitable for unconfined, aquatic disposal. If the mean tissue concentration of a BCoC is less than the applicable TTL, and the null hypothesis is rejected (per the one-tailed, one-sample t-test), the dredged material would be suitable for unconfined, aquatic disposal from a bioaccumulative chemical standpoint.

Note that a statistically significant difference between the dredged material and reference sediment (or TTLs) does not provide a quantitative prediction that an ecologically important or human health-related impact would occur; ecological and human impacts would need to be quantified through an ecological risk assessment (described in Chapter 9). Rather, this framework considers statistically significant increases above certain concentrations as compared to the reference sediment (or TTLs) as potentially undesirable.

8.6 Steady-State Bioaccumulation Testing

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. Based on project-specific need, a determination of steady-state bioaccumulation may be necessary. This may be accomplished using time-sequenced laboratory bioaccumulation testing (Lee et al. 1989) or by collecting field samples at the project site.

A time-sequenced bioaccumulation test involves collection and analysis of tissue residues periodically over the course of exposure such that steady-state concentration can be determined more accurately than relying on a fixed exposure period. The necessary species, apparatus, and test conditions for laboratory testing are the same as those utilized for the steady-state bioaccumulation test. However, the requirements for sediment volume and the number of test organisms are necessarily greater, to accommodate analysis of the various time intervals (typically 7, including time-zero) and assuming 5 replicates per time interval. Tissue 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 the

concentration of contaminant that would occur in tissue after constant exposure conditions have been achieved.

Steady-state bioaccumulation evaluations of data collected would follow the interpretation guidance specified in section 8.5. Calculating steady-state concentrations following time-sequenced testing should follow data analysis procedures outlined in the Inland Testing Manual (ITM Appendix D, paragraph D3.2.1, pages D-47 to D-51) (EPA and Corps 1998). Time-series bioaccumulation data are very expensive to obtain because of the extensive number of chemical analyses required, and the data should be carefully analyzed.

8.7 References

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Chapter 9. Special Evaluations

In most cases, the methods and procedures presented in Chapters 3–8 are sufficient to evaluate the potential environmental effects of dredging and disposal activities, as well as the potential risk of in-place sediments left behind at the dredge site. However, in some cases additional information may be needed beyond the standard suite of physical, chemical, and biological tests to make informed sediment management decisions. This chapter briefly describes the types of special evaluations that may be required on a case-by-case basis to support federal and state regulatory evaluations. Because of their unique and site-specific nature, the design of sampling and analytical procedures for special evaluations requires close coordination with the local review team. The following circumstances may warrant conducting special evaluations to resolve ambiguities or uncertainties in the sediment management decision-making process:

- Biological testing results (i.e., bioassay tests, bioaccumulation tests, tissue analyses) are indeterminate.
- Sediments and/or tissues contain chemicals that are likely present in toxic amounts, but screening levels or threshold values have not yet been established.
- Sediments and/or tissues contain unusual chemical mixtures that are suspected of causing synergistic or antagonistic effects.
- Sediments and/or tissues contain chemicals (or materials such as wood waste) for which the biological tests described in Chapters 7 and 8 are inappropriate.
- Additional information is needed to evaluate potential risks to ESA-listed species, particularly in sensitive critical habitats (such as spawning areas and high-functioning juvenile refugia for salmonids) that may be impacted by project activities.
- Dredging, disposal, or other in-water construction activities have the potential to cause unacceptable water quality impacts (e.g., sediment pollutant loads exceed the corresponding elutriate trigger level; see Table 9.1).
- Site conditions and/or dredging methods could potentially generate significant quantities of contaminated dredging residuals.

If special evaluations are determined necessary by the local review team, site-specific tests or evaluations and interpretive criteria will be specified in coordination with the proponent. Special evaluations may include, but are not limited to, the following (Figure 9-1):

- Evaluation of potential impacts to water quality (section 9.1)
- Evaluation of generated residuals in the post-dredge surface (section 9.2)
- Human health/ecological risk assessment (section 9.3)

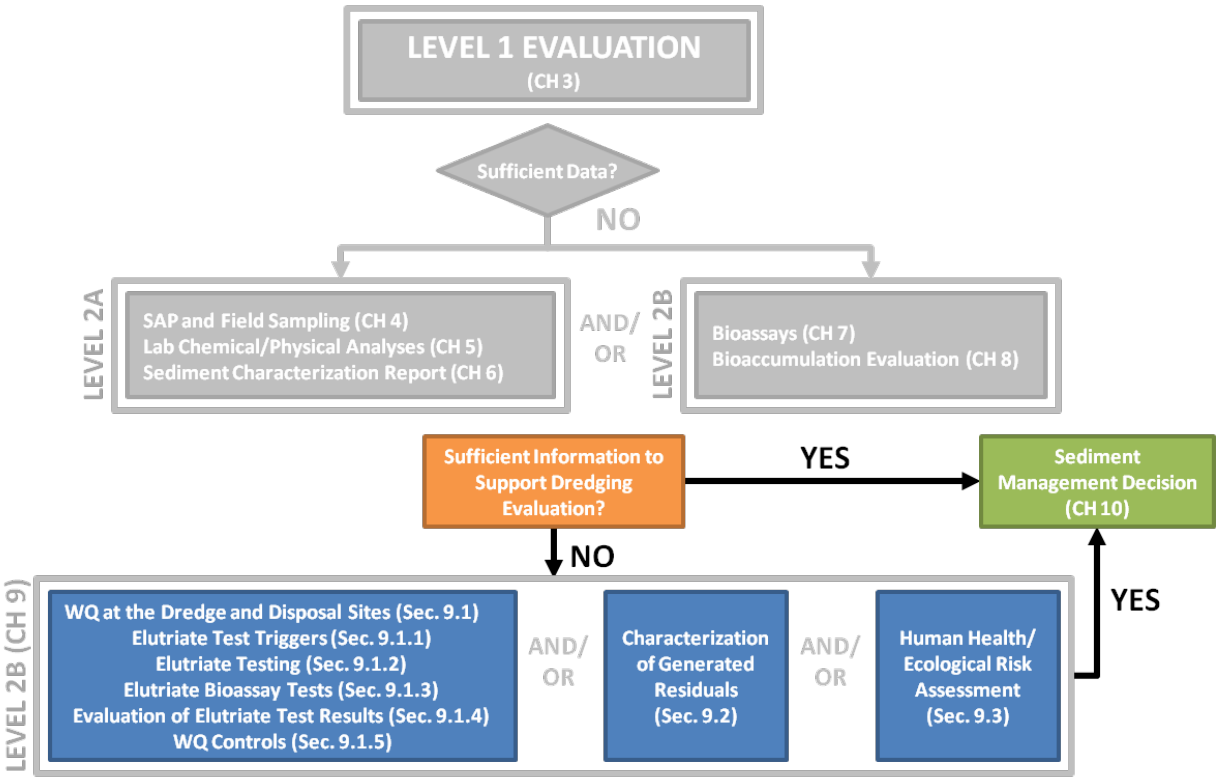

Figure 9-1. Overview of special evaluations with respect to the sediment evaluation process.

9.1 Water Quality at the Dredge and Disposal Sites

Water quality effects caused by introducing sediment and sediment-associated contaminants into the water column must be considered at the point(s) of dredging and point(s) of disposal, as applicable. The impacts to water quality from sediment and sediment-associated contaminants can be assessed by testing the sediment elutriate. The RSET has calculated elutriate test triggers for chemicals (resulting from dredging operations) that are based on EPA acute water quality criteria (section 9.1.1). This approach to assessing the water quality impacts of sediment and sediment-associated contaminants underwent public review during the development and release of the 2009 SEF. Elutriate test triggers based on chronic water quality criteria are still under review and will be accepted through the annual review process. The agency charged with issuing the CWA §401 water quality certification is responsible for identifying the specific water quality standards and criteria used to regulate each project.

If an elutriate test trigger is exceeded by the concentration of the chemical in the sediment (as determined by Level 1 or 2A data), or if the state water quality agency believes that other CoCs without elutriate test triggers may cause acute or chronic water quality effects, then laboratory elutriate testing may be necessary. Laboratory chemical-specific and bioassay elutriate tests (described in sections 9.1.2 and 9.1.3) were developed by the Corps' Environmental Laboratory at the ERDC to predict water quality effects during dredging and disposal activities, particularly when contaminated sediments are being disturbed. In interpreting the test results, the mixing zone(s) and impacts to the receiving waters must be considered

(section 9.1.4). If the elutriate test results indicate that water quality may be unacceptably degraded by the dredging operation, then water quality controls may be required (section 9.1.5).

9.1.1 Elutriate Test Triggers

Elutriate test trigger values can be used as an initial screening evaluation to determine if laboratory elutriate testing is required during site characterization. If dredge prism sediment concentrations are below the elutriate test triggers, then the dredged material is not expected to cause adverse water quality effects at the point of dredging. The freshwater and marine elutriate test triggers appear in Tables 9-1 and 9-2, respectively.

Table 9-1. Elutriate testing triggers for freshwater sediment.*

Chemical	Acute WQC	Reference	$logK_d$	Reference	Trigger (mg/kg)
Arsenic	340	EPA 2015	4.00	EPA 2005a	3400
Cadmium	0.52	EPA 2015	4.70	EPA 2005a	26
Chromium (III)	183.07	EPA 2015	5.10	EPA 2005a	23047
Copper	3.64	EPA 2015	4.70	EPA 2005a	182
Lead	13.88	EPA 2015	5.60	EPA 2005a	5527
Mercury	1.40	EPA 2015	5.30	EPA 2005a	279
Nickel	144.92	EPA 2015	4.60	EPA 2005a	5769
Silver	0.30	EPA 2015	4.90	EPA 2005a	24
Zinc	36.5	EPA 2015	5.10	EPA 2005a	4595
				TOC (fraction) =	0.01
				TSS (mg/L) =	100
Chemical	**Acute WQC**	**Reference**	**$logK_{oc}$**	**Reference**	**Trigger (µg/kg)**
Pentachlorophenol	8.72	EPA 2015	2.77	EPA 1996a	51
p,p' DDT	1.10	EPA 2015	6.42	EPA 1996a	7970
Dieldrin	0.24	EPA 2015	5.28	EPA 2002a	384
Tributyltin	0.46	EPA 2015	4.40	EPA 1996b	113
PCBs	2	ODEQ	5.49	ODEQ	4722

* Water quality criteria (WQC) for all metals except silver are hardness and pH dependent; PCP is pH dependent. For derivation of the water quality criteria, a water hardness of 25 mg/L $CaCO_3$ and pH: 7.0 were used.

Table 9-2. Elutriate testing triggers for marine sediment.

Chemical	Acute WQC	Reference	$logK_d$	Reference	Trigger (mg/kg)
Arsenic	69	EPA 2015	4.00	EPA 2005a	690
Cadmium	42	EPA 2015	4.70	EPA 2005a	2105
Chromium (III)	1100	EPA 2015	5.10	EPA 2005a	138482
Copper	4.8	EPA 2015	4.70	EPA 2005a	241
Lead	210	EPA 2015	5.60	EPA 2005a	83603
Mercury	1.80	EPA 2015	5.30	EPA 2005a	359
Nickel	74	EPA 2015	4.60	EPA 2005a	2946
Silver	1.9	EPA 2015	4.90	EPA 2005a	151
Zinc	90	EPA 2015	5.10	EPA 2005a	11330
				TOC (%) =	1.0%
				TSS (mg/L) =	100
Chemical	**Acute WQC**	**Reference**	**$logK_{oc}$**	**Reference**	**Trigger (µg/kg)**
Pentachlorophenol	13	EPA 2015	2.77	EPA 1996a	77
p,p' DDD	0.13	EPA 2015	6.00	EPA 1996a	650
p,p'-DDE	0.13	EPA 2015	6.65	EPA 1996a	1062
p,p' DDT	0.13	EPA 2015	6.42	EPA 1996a	942
Aldrin	0.71	EPA 2015	6.39	EPA 1996a	5045
Chlordane	0.09	EPA 2015	2.08	EPA 1996a	0.1
Dieldrin	0.71	EPA 2015	5.28	EPA 2002a	1136
Heptachlor	0.053	EPA 2015	6.15	EPA 1996a	310
gamma-BHC (lindane)	0	EPA 2015	3.67	EPA 2002b	7
Tributyltin	0.42	EPA 2015	4.40	EPA 1996b	103
PCBs	10	ODEQ	5.49	ODEQ	23608

Elutriate triggers were calculated using the EPA's National Recommended Water Quality Criteria (2015 or most current version) for aquatic life and equilibrium partitioning rules and agency-recommended partitioning coefficients, as specified in EPA guidance documents (EPA 1996a,b; 2002a,b; 2005a). These calculations are described later in this section and the resulting values are presented in Tables 9-1 and 9-2.

When National Recommended Water Quality Criteria are not available, the elutriate trigger calculations used Level 2B secondary water quality criteria derived by the Oak Ridge National Laboratory (ORNL 1997). ODEQ's value for PCBs is used in the calculations. The EPA National Recommended Water Quality Criteria for human health were not used because human health-based criteria assume lifetime exposures such that direct comparisons of receiving water criteria with pollutant concentrations in intermittent discharges (such as those associated with dredging) are not appropriate.

If dredge prism sediment concentrations indicate that elutriate testing should be conducted on constituents that do not have state-promulgated or nationally recommended water quality criteria, the local review team will use best professional judgment to determine guidelines to evaluate potential water quality effects. This may include considering standards or criteria in use in other states or in the peer-reviewed scientific literature.

The derived elutriate triggers are to be used as guidance values to determine if laboratory elutriate testing is required during site characterization. The freshwater and marine elutriate test triggers presented in Tables 9-1 and 9-2 were only developed for compounds on the SEF list of CoCs. A summary of relevant water quality criteria, EPA-recommended partitioning coefficients, and elutriate testing triggers are also compiled in these tables.

Elutriate testing triggers for metals are derived using the following equation:

$$ET_{metal} = K_d \times WQC/1000$$

where:

ET_{metal} = the elutriate trigger for the particular metal (dissolved) in question in mg/kg sediment
K_d = the metal partitioning coefficient in L/kg
WQC = the acute water quality criterion for the metal in µg/L (see below for a discussion on hardness and freshwater metal criteria)
1000 = a conversion factor to provide results in milligrams per kilogram sediment

The calculation of elutriate testing triggers for organic constituents is modified in two important ways. First, the equilibrium partitioning coefficients are a function of the organic carbon content of the sediments:

$$K_d = K_{oc} \times f_{oc}$$

where:

K_d = the organic chemical partitioning coefficient in L/kg
K_{oc} = the organic carbon (oc)-partitioning coefficient for the organic chemical in L/kg-oc
f_{oc} = the decimal fraction of organic carbon in kg-oc/kg-sed

Second, because organic constituents are regulated on a "total" basis (whereas metals are regulated on a "dissolved" basis), both the dissolved and the particulate-associated fractions of the water column's organic chemical concentration should be considered.

$$WC_{total} = WC_{diss} + WC_{part}$$

$$WC_{diss} = SED_{bulk} / K_d$$

$$WC_{part} = SED_{bulk} \times TSS_{inc} \times 10^{-6}$$

where:

WC_{total}, WC_{diss}, WC_{part} = the total, dissolved, and particulate water column concentrations of the organic chemical in µg/L, respectively
SED_{bulk} = the bulk sediment concentration of the organic chemical in the dredge prism in µg/kg
TSS_{inc} = the incremental added mass of suspended solids in the water column generated by the dredging or placement action in mg/L
10^{-6} = a conversion factor to provide results in micrograms per kilogram sediment

Rearranging these equations, solving for SED_{bulk} and setting WC_{total} to the applicable WQC yields the following equation for deriving elutriate testing triggers for organic constituents:

$$ET_{organic} = WQC / [(TSS_{inc} \times 10^{-6}) + K_d^1]$$

where:

$ET_{organic}$ = the elutriate trigger for the particular organic chemical (total) in question in µg/kg sediment
WQC = the acute water quality criterion in µg/L
10^{-6} = a conversion factor to provide results in milligrams per kilogram sediment

In Tables 9-1 and 9-2, elutriate testing triggers for organic chemicals are presented for 1% TOC and dredging-induced TSS concentrations of 100 mg/L TSS. The site-specific TOC content is determined from chemical analysis of the dredge prism, as discussed in Chapter 6. The site-specific TSS concentrations generated by the dredging action may be predicted using computer models, as discussed in section 9.1.4. The range of TSS concentrations used in these tables were the upper concentrations derived from a literature survey of TSS concentrations measured during various dredging projects, as compiled by the Los Angeles Contaminated Sediments Task Force (Anchor Environmental 2003). The TSS concentrations at distances of 100 to 300 feet from the dredges, consistent with typical mixing zone dimensions (see section 9.1.4), ranged from about 10 mg/L to 100 mg/L. If significantly different TOC or TSS concentrations are expected at the project site, partitioning calculations should be modified accordingly, in consultation with the local review team.

The local review team can provide a spreadsheet to calculate site-specific elutriate triggers based on site-specific factors such as K_d, f_{oc}, TSS, water hardness, and pH. However, site-specific alterations must be approved by the local review team. The spreadsheet contains calculations for all compounds that have EPA-promulgated water quality criteria plus PCB criteria from ODEQ. In order to develop generally protective elutriate triggers for dredging sites and aquatic placement of dredged material, the parameters in the formula were assigned the following default values:

- Total organic carbon: 1%
- Total suspended solids: 100 mg/L
- Water hardness: 25 mg/L $CaCO_3$
- pH: 7.0

The new default value of 25 mg/L $CaCO_3$ for water hardness differs from the 2009 SEF default (100 mg/L $CaCO_3$) and is based on a survey of water hardness in the Willamette River (Portland Harbor RI/FS August 29, 2011). This change generated lower SLs and was considered more realistic and protective than the old SEF default.

Elutriate testing triggers derived in this manner are expected to be conservatively protective for the following reasons:

- The contaminant mass on the sediments is assumed to be an infinite source. In reality, as the mass on the sediment particles is depleted through desorption to the water column, decreasing equilibrium concentrations will be observed in both water and sediments.
- When sediments are suspended during dredging, equilibrium concentrations in the water column are assumed to be achieved instantaneously. In reality, sediment desorption kinetics may delay

the achievement of equilibrium, causing water column concentrations to be less than their theoretical maximum values.

- Equilibrium water column concentrations are estimated for the point of dredging. Typically, contaminant concentrations are further attenuated to between one-half and one-tenth of their initial values as a result of mixing within the construction zone, between the dredge and the point where attainment of the water quality standard is required (see section 9.1.4).

9.1.2 Elutriate Tests for Dredging and Disposal

Elutriate tests have been developed to characterize water quality at the point of dredging and point of disposal:

- Dredging elutriate tests assess potential impacts at the site of dredging (DiGiano et al. 1995).
- Standard elutriate tests assess unconfined, aquatic disposal of dredged material (EPA and Corps 1977).
- Modified elutriate tests and column settling tests assess discharges from a confined dredged material disposal facility (Palermo 1986; Palermo and Thackston 1988).

These tests are described in more detail in the Inland Testing Manual (EPA and Corps 1998) and Upland Testing Manual (EPA and Corps 2003). These manuals and the local review team should be consulted to determine when to perform these tests and which tests are most appropriate for the situation.

9.1.3 Elutriate Bioassay Tests

If water quality criteria are predicted to be exceeded at the mixing zone boundary based on elutriate test chemistry and predicted mixing zone dilution and dispersion (see 9.1.4), then the project proponent may elect to perform serial-dilution bioassay tests on the elutriate water, as specified in the Inland Testing Manual (EPA and Corps 1998, sections 6.1 and 11.1). Alternatively the project proponent may elect to forego bioassay testing and instead implement engineering controls as needed to comply with water quality criteria and the conditions of the water quality certification (section 9.1.5).

Elutriate bioassay tests are designed to provide a more site-specific measurement of water column toxicity and contaminant bioavailability. If the receiving water of concern is freshwater and contains salmonid species, then Rainbow Trout (*Oncorhynchus mykiss*) should be included as one of the test species for elutriate bioassay testing whenever possible. Before elutriate bioassay testing is conducted, an addendum to the SAP must be prepared for review and approval by the local review team. The addendum should describe the proposed test organisms, test design, laboratory methods, and evaluation criteria.

If, after allowance for mixing, the predicted water column concentration does not exceed 1% of the toxic (LC_{50} or EC_{50}) concentration as determined from the elutriate bioassay tests, the dredged material is predicted not to be acutely toxic to aquatic organisms (EPA and Corps 1998).

9.1.4 Evaluating Elutriate and Elutriate Bioassay Test Results

The elutriate testing and hydrodynamic modeling results are used to estimate water column concentrations in the receiving water at the point of compliance (typically the authorized mixing zone boundary as specified in the CWA §401 water quality certification for the project). The estimated water

column concentrations for the chemicals associated with the sediment are compared to water quality standards or criteria that are based on aquatic organism exposure durations consistent with the duration of the construction activity.

Because dredging operations are intermittent and discontinuous in time and space, acute water quality criteria are considered appropriate for such evaluations (EPA and Corps 1998). The averaging period for acute water quality criteria is typically instantaneous, although some criteria represent 1-hour average exposures to the chemical. The averaging period for chronic water quality criteria can be as short as 4 hours (for metals) and as long as 4 days (for some organics). Thus, both acute and chronic standards may be applicable for assessing water quality impacts from dredging and disposal, even though the duration of activities may be shorter than what is typically considered a chronic exposure period. The project proponent should coordinate with the local review team to determine if chronic exposure periods should be considered in assessing the need for elutriate testing.

***Mixing Zones*—**The guidelines at 40 CFR §230.10(b) state in part that, "No discharge of dredged or fill material shall be permitted if it: (1) causes or contributes, after consideration of disposal site dilution and dispersion, to violations of any applicable State water quality standard." This requirement applies at the edge of a state designated mixing zone (EPA and Corps 1998).

Elutriate test results are intended to simulate water quality conditions at the point of discharge (for both dredging and disposal activities). To estimate whether CoCs associated with the sediment will violate water quality standards, hydrodynamic modeling may be needed to characterize the degree of dilution and dispersion that occurs between the point of discharge and the mixing zone boundary, per the guidelines at 40 CFR §230.10(b).

Hydrodynamic modeling results are typically expressed in terms of a dilution factor, which describes the reductions in water column concentrations that occur during transport through the mixing zone. The Automated Dredging and Disposal Alternatives Modeling System (Schroeder et al. 2004), developed by the Corps Environmental Laboratory at ERDC, includes several computer modules to assist in designing and evaluating dredging and disposal operations. In particular, the program modules DREDGE (Hayes and Je 2000) and STFATE (EPA and Corps 1998) predict water quality effects associated with dredging and open-water disposal operations, respectively. These models have benefited from nearly two decades of field calibration and validation studies under a variety of operational and site conditions. Standard dilution models such as PLUMES (Frick et al. 2001) and CORMIX (Jirka et al. 1997) may be used to evaluate mixing and dilution of point-source discharges (e.g., outfalls conveying dredging elutriate return flows from upland or nearshore confined disposal facilities). These dilution models are recommended for use by state water quality programs in Washington, Oregon, and Idaho (ODEQ 2007; Ecology 2008; IDEQ 2016).

***Receiving Water Impacts*—**The elutriate chemical analysis and hydrodynamic modeling results are used to estimate water column chemical concentrations in the receiving water at the point of compliance, typically the authorized mixing zone boundary as specified in the §401 water quality certification for the project. The estimated water column chemical concentrations are compared to water quality standards or criteria that are based on exposure durations consistent with the duration of the construction activity. Because dredging and related in-water construction activities (e.g., capping, disposal) are intermittent and discontinuous in time and space, acute water quality criteria are typically considered appropriate for such

evaluations (EPA and Corps 1998), but in some cases chronic criteria may be used. The agency responsible for issuing the §401 water quality certification will establish the specific water quality standards and criteria that will be used to regulate the project.

If sediment chemical concentrations indicate that elutriate testing should be conducted on constituents that do not have state promulgated or nationally recommended water quality criteria, the local review team will use best professional judgment to determine criteria to use in evaluating potential water quality effects. This may include considering standards or criteria in use in other EPA regions, states, or in the peer-reviewed scientific literature.

9.1.5 Water Quality Controls

If unacceptable water quality effects are predicted to occur outside the authorized mixing zone, the project proponent must consult with the appropriate water quality agency to determine what additional water quality controls or best management practices should be implemented to mitigate these effects. Additional water quality controls may also be required if water quality effects are difficult to predict or highly uncertain. These controls may include, but are not limited to, the following:

- Deployment of silt curtains, absorbent booms, or other physical containment devices
- Modification of operational procedures or equipment to minimize contaminant releases to the water column (e.g., use of environmental dredge buckets, slower dredging rates, etc.)
- Restriction of in-water construction activities to periods when more favorable mixing and dilution can be achieved and/or sensitive species or their life stages are not present
- Specifying a more rigorous water quality monitoring program during construction that could include “early warning” stations, contingency plans, and adaptive management of construction operations to anticipate and avoid development of unacceptable water quality effects

9.2 Characterization of Generated Residuals

Generally speaking, generated residuals contribute minimally to the post-dredge surface chemistry; therefore, the Z-layer characterization is most often used to determine the post-dredge surface suitability. ERDC’s report “Technical Guidelines for Environmental Dredging of Contaminated Sediments” summarizes several methods that can be used to predict generated residuals (Palermo et al. 2008). However, the following project parameters should be examined to gauge if generated residuals will contribute significantly to the chemical composition of the post-dredge surface:

- Concentrations of CoCs in the sediment being dredged.
- Sediment properties such as in situ dry bulk density (solids concentration, solids content, or water content), organic content, particle-size distribution, and mineralogy.
- Site conditions such as water depth, currents, waves, and presence of hardpan or bedrock.
- Nature and extent of impediments, such as debris, loose cobbles, boulders, and obstructions.
- Operational considerations such as the thickness of dredge cuts, dredging equipment type, method of operation, and skill of the operator. The type of excavation head used in the dredging operation can also contribute to generated residuals (ERDC 2008).

If there is reason to believe that conditions may result in significant generated residuals, then the SAP should include analyses to predict them. Palermo et al. (2008) summarize several methods that can be used to predict generated residuals.

Grab samples can directly quantify the influence of generated residuals on the post-dredge surface chemistry. Quantifying generated residuals is especially critical in projects with known dredge prism contamination. Significant quantities of generated residuals may result in the contamination of what would otherwise have been a clean post-dredge surface (as in Figure 9-2A). Conversely, generated residuals from an "inverted" contamination profile (as in Figure 9-2B) may actually ameliorate the level of contamination in Z-layer sediments (Hollis et al. 2012; McMillan et al. 2012). Post-dredge grab samples can be planned in the SAP, if the need for them is anticipated (e.g., expected or known contaminant levels above corresponding screening levels).

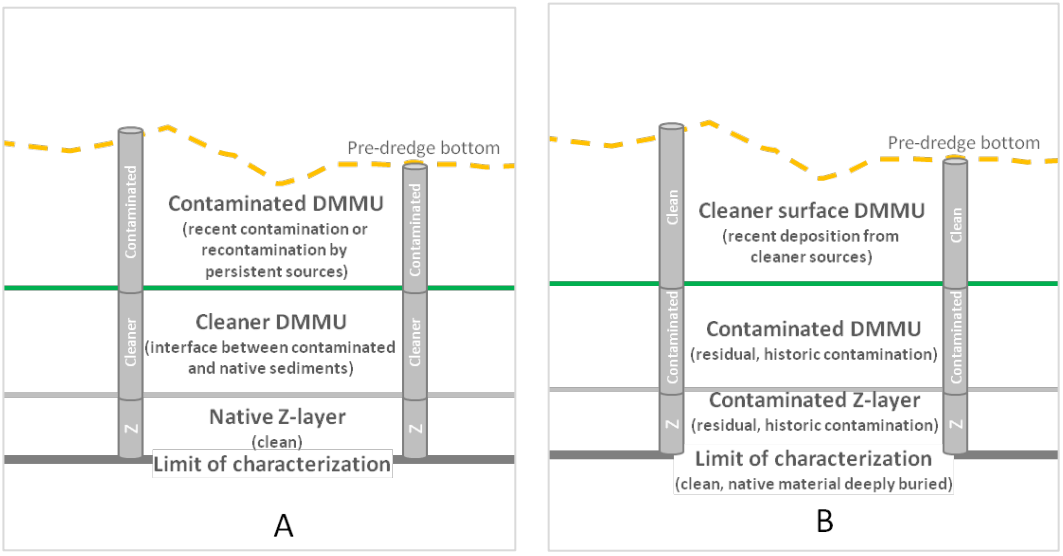

Figure 9-2. Depending on the contamination profile, significant contributions of generated residuals may result in (A) a more contaminated post-dredge surface (than indicated by the Z-layer analysis) or (B) Z-layer contamination in the post-dredge surface with cleaner generated residuals.

9.3 Human Health/Ecological Risk Assessment

When deemed appropriate by the local review team, a human health and/or ecological risk assessment may be requested to evaluate a particular CoC, such as dioxin, mercury, DDT (and metabolites), PCBs, and others. National guidance on chemicals such as dioxin is subject to change as new information becomes available. Project-specific risks to human and ecological health should be evaluated using the best available current technical information and risk assessment models.

A case-specific risk assessment must be developed with all interested parties participating. If a risk assessment is the method of choice for a special evaluation, either as a stand-alone task or in conjunction with bioassay tests (Chapter 7) and/or tissue analysis (Chapter 8), then it must be accomplished with active participation by the proponent, the local review team, and a state risk assessment expert. If one of

the links appearing below is broken, contact the appropriate state water quality agency to obtain a copy of the most recent guidance.

9.3.1 Oregon State Risk Assessment Guidance

The State of Oregon's cleanup law emphasizes risk-based decision-making. State statute and rules require that ODEQ first considers human health risk and considers residual risk to ecological receptors. The ODEQ oversees cleanup of contaminated sites, including those involving sediments, via a process that parallels the EPA Superfund process. A remedial investigation, risk assessment, and feasibility study are completed to provide the basis for selecting a remedy. Oregon has specific rules defining acceptable risk, which can be found at OAR 340-122-0115.

In their 1998 *Guidance for Ecological Risk Assessment*, ODEQ has developed a process that uses a multilevel approach (ODEQ, 1998). The multilevel approach is intended to facilitate more efficient use of resources, which ensures necessary work is done and risk managers receive information sufficient to support effective remedial action decisions.

For human health risk assessment, both statute and rules provide the option of performing either a deterministic risk assessment or a probabilistic risk assessment. The ODEQ has developed a guidance document for each of these options in their 2010 *Human Health Risk Assessment Guidance* (ODEQ, 2010).

9.3.2 Washington State Risk Assessment Guidance

The State of Washington adopted Sediment Management Standards, which are found in Chapter 173-204 Washington Administrative Code. These standards were promulgated for the purpose of reducing and ultimately eliminating adverse effects on biological resources and significant health threats to humans from surface sediment contamination. These standards apply to marine, low-salinity, and freshwater surface sediments within the state of Washington and can be found at *https://fortress.wa.gov/ecy/publications/SummaryPages/1309055.html*.

Copies of Ecology's human health risk assessment guidance documents in Chapter 173-340 Washington Administrative Code under the Model Toxics Control Act can be downloaded at *https://fortress.wa.gov/ecy/publications/documents/9406.pdf*. Related documentation providing human health risk assessment details for sediments can be found in the *Sediment Cleanup Users Manual II* (SCUM II) at *https://fortress.wa.gov/ecy/publications/SummaryPages/1209057*.

9.3.3 Idaho State Risk Assessment Guidance

The IDEQ's 2012 *Risk Evaluation Manual for Petroleum Releases* presents a roadmap for evaluating risk from discovery through cleanup (IDEQ, 2012). This manual presents a description of the steps in the risk evaluation process and general information related to the data requirements and implementation of the risk evaluation process. It is a manual to determine whether groundwater, surface water, or soil at a particular location is contaminated to the extent it poses a human health risk. It will help evaluate whether an investigation or cleanup is needed and, if so, what its scope and nature should be. This manual provides a consistent method for addressing contamination.

9.3.4 Federal State Risk Assessment Guidance

In addition to the state-specific guidance cited above, the following EPA and Corps documents may also be consulted for additional guidance on risk assessment procedures and parameters:

- EPA 1998. Guidelines for Ecological Risk Assessment. EPA/630/R095/002F. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.
- EPA. 1989. Risk Assessment Guidance for Superfund, Volume 1 – Human Health Evaluation Manual, Part A, Interim Final. EPA/540/1-89/002. Publication 9285.7-01A. Office of Emergency and Remedial Response, Washington D.C.
- EPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (interim final). EPA 540-R-97-006. Environmental Response Team, Edison, NJ.
- Corps. 1999. Risk Assessment Handbook Volume I: Human Health Evaluation. EM 200-1-4.
- Corps. 2010. Risk Assessment Handbook Volume II: Environmental Evaluation. EM 200-1-4.
- Cura, J.J., Heiger-Bernays, W., Bridges, T.S., and D.W. Moore. 1999. Ecological and Human Health Risk Assessment Guidance for Aquatic Environments. Technical Report DOER-4, Corps of Engineers' Engineer Research and Development Center, Dredging Operations and Environmental Research.

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EPA and Corps. 2003. *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities* (Upland Testing Manual). US Army Engineers Research and Development Center. ERCD/EL TR-03-1.

EPA. 1989. *Risk Assessment Guidance for Superfund, Volume 1 – Human Health Evaluation Manual,* Part A, Interim Final. Washington, DC: Office of Emergency and Remedial Response. EPA/540/1-89/002. Publication 9285.7-01A.

EPA. 1996a. *Soil Screening Guidance Users Guide*. EPA-540/R-96/018

EPA. 1996b. "Recommendations for Screening Levels for Tributyltin in Puget Sound Sediment." EPA Region 10.

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EPA. 2002b. "Equilibrium Partitioning Sediment Guidelines: Non-ionic Organics." EPA-822/R-02/042.

EPA. 2005a. "Partition Coefficients for Metals in Surface Water, Soil, and Waste." EPA-600/R-05/074.

EPA. 2005b. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (2005)*. Office of Solid Waste and Emergency Response. EPA-540-R-05-012.

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IDEQ (Idaho Department of Environmental Quality). 2012. *Idaho Risk Evaluation Manual for Petroleum Releases*. August 2012, 58 pp + appendices.

IDEQ. 2016. *Idaho Mixing Zone Implementation Guidance*. *Prepared by* IDEQ's Water Quality Division. 57 pp + Appendices.

Jirka, G.H., R.L. Doneker, and S.W. Hinton. 1997. *User's Manual for CORMIX: A Hydro-Dynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters*. EPA 823/B-97-006.

McMillan, J., M. Hollis, L. Inouye, and J. Freedman. 2012. "Sediment Characterization of the Post-Dredge Surface: Comparison of In-Situ and Post-Dredge Grab Samples in Freshwater and Marine Sediments in the Lower Columbia River Basin and Puget Sound." Presentation by Portland District and Port of Portland staff at the WEDA Pacific Chapter Conference, 7 September 2012, Seward, AK.

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ODEQ. 2007. *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment.*

ODEQ. 2010. *Human Health Risk Assessment Guidance* (10-LQ-023). 25 pp + Appendices.

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Schroeder, P.R., M.R. Palermo, T.E. Myers, and C.M. Lloyd. 2004. The Automated Dredging and Disposal Alternatives Modeling System (ADDAMS), EEDP-06-12, Vicksburg, MS: US Army Engineer Research and Development Center.

Chapter 10. Dredged Material Disposal and Post-Dredge Surface Management

Under this guidance, a management decision can be made for the dredged material and the post-dredge surface (PDS) at one of three stages (Figure 10-1):

- Sediment is determined suitable for unconfined, aquatic disposal/exposure after the Level 1 site history review (per Chapter 3)
- Sediment is determined suitable (or unsuitable) for unconfined, aquatic disposal/exposure after the Level 2A physical and chemical characterization (per Chapters 4, 5, and 6)
- Sediment is determined suitable (or unsuitable) for unconfined, aquatic disposal/exposure after the Level 2B biological testing and/or special evaluations are completed (Chapters 7, 8, and 9)

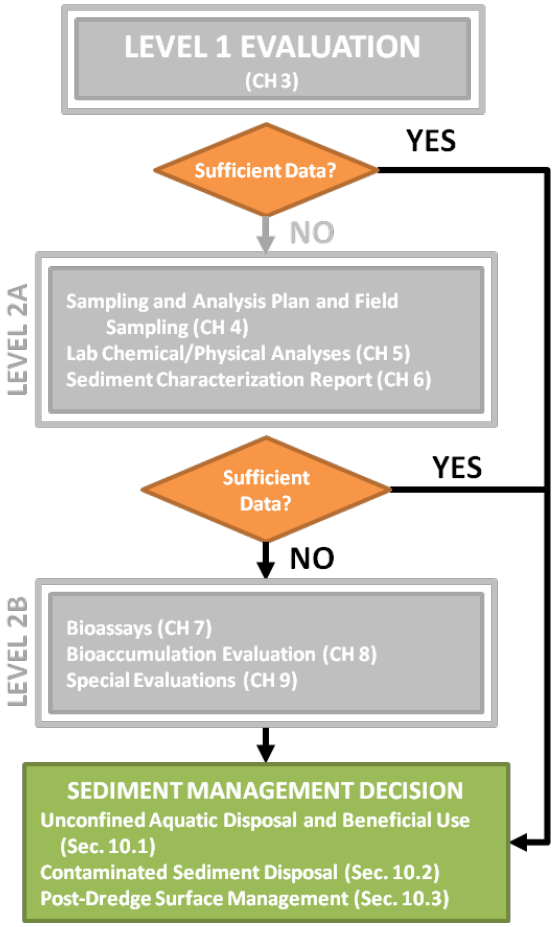

Figure 10-1. The sediment evaluation process culminates in a management decision.

The local review team documents the suitability of the dredged material for unconfined, aquatic disposal. The project proponent must identify their preferred dredged material disposal location as part of the Level 1 information submittal. However, depending on the project location and the suitability of the dredged material, the project proponent's range of possible disposal sites may be limited. In some cases only one

disposal option may be available. Additionally, if the dredged material contains debris, the project proponent may be required to remove the debris prior to disposal. The local review team will work with the project proponent and the Regulatory or civil works project manager to identify applicable dredged material disposal and debris management options consistent with the suitability determination.

The local review team also documents the suitability of the PDS for unconfined, aquatic exposure. If the post-dredge surface is unsuitable, the project proponent's range of possible PDS management options may be limited. In some cases only one PDS management option may be available. The local review team will work with the project proponent to identify PDS management options that are consistent with the suitability determination.

This chapter describes the types of disposal options for suitable or unsuitable dredged material and identifies potential management strategies for contaminated post-dredge surfaces. Detailed guidelines for environmental dredging can also be found in *Technical Guidelines for Environmental Dredging of Contaminated Sediments (ERDC/EL TR-08-29)* (ERDC, 2008).

10.1 Unconfined Aquatic Disposal and Beneficial Use

Options for unconfined, aquatic disposal and beneficial use of suitable dredged material are described in this section. All aquatic disposal options must be coordinated with the local review team.

As a part of the permit review (or compliance), the Regulatory Project Manager must coordinate with the appropriate Corps Navigation Project Manager for in-water disposal planned in or adjacent to Corps federal navigation channels on the Columbia River and the Oregon Coast. Similarly, the Regulatory Project Manager must coordinate with the appropriate Corps Navigation Project Manager for dredged material disposal at sites selected by the Corps (under the CWA[18]) at the mouth of the Columbia River or along the Oregon Coast. In order to use a multiuser site in Puget Sound, Grays Harbor or Willapa Bay (managed by the Washington DMMP), the proponent must obtain a "site use authorization" from the Washington Department of Natural Resources.

Coordination with the EPA and Corps Ocean Dumping Coordinators is required to use ocean dredged material disposal sites (ODMDSs) designated by EPA under section 102 of the MPRSA or selected by the Corps under section 103 of the MPRSA. Concurrence by the EPA Regional Administrator is required for all projects (both Corps and non-Corps) proposing transport to and disposal of dredged material at an ODMDS.

10.1.1 Dispersive Disposal

Dredged material placed at dispersive sites does not stay on site, but is rapidly dispersed with the tides or river current. Examples of dispersive sites include:

- Puget Sound dispersive disposal sites at Port Angeles, Port Townsend, and Rosario Strait, in Washington
- In-bay, estuarine sites (e.g., Point Chehalis in Grays Harbor; Site G in Coos Bay)

[18] 33CFR335.2

- Nearshore CWA or MPRSA disposal sites in the Pacific Ocean (e.g., the North Jetty Site at the mouth of the Columbia River and the shoreward half of ODMDS-F at Coos Bay, Oregon)
- Flow lane disposal in the Columbia River
- Dispersive beneficial use sites/projects throughout the states of Idaho, Oregon, and Washington

Because the material moves offsite, disposal actions planned at dispersive sites may be subject to more stringent sediment management guidelines (e.g., thresholds for dioxins/furans concentrations in the Puget Sound). Monitoring at these sites is not be possible, because the disposed material is rapidly transported off site.

10.1.2 Non-Dispersive Disposal

Dredged material placed at non-dispersive sites stays on site, and sequential disposal events result in a combination of mixing with, and burial of, previously-placed dredged material. These sites are subject to post-disposal monitoring and management. Examples of non-dispersive sites include:

- Puget Sound non-dispersive disposal sites at Anderson/Ketron Island, Bellingham Bay, Commencement Bay, Elliott Bay, and Port Gardner, in Washington
- Offshore ODMDSs in the Pacific Ocean (e.g., the Deep Water Site off the mouth of the Columbia River and Yaquina Bay North ODMDS at Newport, Oregon)
- Non-dispersive beneficial use sites/projects throughout the states of Idaho, Oregon, and Washington

10.1.3 Beneficial Use of Dredged Material

"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 regional sediment management goals, the RSET agencies support the productive reuse of dredged material. There are numerous resources and case studies available regarding the beneficial uses of dredged material. Two federal guidance documents provide general information and planning considerations:

- *Identifying, Planning, and Financing Beneficial Use Projects Using Dredged Material* (Beneficial Use Planning Manual) (USEPA and USACE, 2007)
- Corps Engineer Manual No. 1110-2-5026, *Beneficial Uses of Dredged Material* (USACE, 1987)

Depending on its characteristics, particularly grain size and sediment chemistry, dredged material may be suitable for beach nourishment projects, structural or non-structural fill, landfill cover(s), habitat development projects, wetland enhancement/restoration projects, capping contaminated-sediment sites, or a variety of other uses. The use of suitable dredged material in habitat and wetland creation, enhancement, and restoration offers a unique opportunity to use sediments as a resource and, at the same time, restore, and improve degraded habitats in ocean, riverine, estuarine, and adjacent uplands.

Degraded lands such as active and inactive landfills, brownfield sites, and quarry sites can offer another unique opportunity to combine the use of dredged material with the environmental and economic restoration of otherwise unproductive or contaminated properties. All of these sites have disturbed environments and limited natural resource value in their present condition. Many of these sites also

generate leachate and surface water runoff that contaminate surrounding soils, aquifers, and surface water. The beneficial use of dredged sediment for land remediation under properly controlled conditions and in conjunction with engineering and institutional controls can provide a safe and economical way of remediating these sites.

Project proponents considering beneficial-use of dredged material should bring these projects to the attention of the local review team early in the evaluation process. The proponent will be asked to provide either a brief written project description, or provide a presentation of the proposed project. Early coordination is critical, especially if the state claims ownership of the dredged material desired for reuse. If the dredged material is not state-owned, the project proponent should approach the material owner and negotiate for its use.

Materials proposed for unconfined, aquatic beneficial use must be tested per the methods described in this guidance. Additional chemicals may need to be analyzed, or alternative screening levels may be requested by another agency. Detected chemicals of concern must fall below the applicable screening levels (presented in Chapter 6); if necessary, bioassays must pass the interpretive criteria presented in Chapter 7. The local review team's suitability determination memorandum will document the sediment quality of project sediments relative to the SEF SLs. Material that has concentrations of chemicals greater than the SL1 but lower than the SL2 (i.e., the cleanup screening level) may be allowed for beneficial use on a case-by-case basis after consideration of site-specific factors and coordination with landowners and/or resource agencies. However, physical and chemical compatibility of the sediments for a particular in-water beneficial use must be approved by appropriate regulatory agencies, and in some cases more stringent screening levels may apply (e.g., habitat creation projects).

10.1.4 Debris Management

Both CWA[19] and MPRSA[20] prohibit the discharge of debris at disposal sites, where its discharge may 1) create a navigation hazard, 2) result in negative habitat alterations, or 3) be otherwise contrary to the public interest. Debris originates from both anthropogenic and non-anthropogenic sources, and includes (but is not limited to): rock, semi-consolidated dredged material, rip rap, logs/fallen trees, pilings and treated wood, scrap wood, concrete fragments, tires, marketable spilled products (aggregate, wood chips, scrap metal, etc.), discarded large metal and plastic objects (shopping carts, appliances, cables, rebar, wiring, chains, pipes, etc.), and other trash.

In coordination with civil works project managers, Regulatory project managers, and the regulated public, the local review teams are responsible for establishing district/state-specific procedures to manage debris. The need to manage debris is informed by:

Empirical Evidence—Dredging records, sediment sampling, and other types of surveys (trawls, remotely operated vehicles, video sleds, etc.) indicate debris is either present or absent.

[19] 40CFR230, CWA 404(b)(1) Guidelines, Subparts A, B, and H

[20] 40CFR227.5 (MPRSA, Prohibited materials)

Proposed Dredging Method—Hydraulic dredging methods (pipeline and hopper dredges) typically exclude debris from the dredged material. Mechanical dredging, with either an open or closed bucket, indiscriminately excavates the sediment and the debris interspersed therein.

Dredging Frequency—Projects that are frequently maintained are less likely to contain debris than projects that are dredged once per decade.

Proximity to Debris Sources (Reason to Believe)—Projects in urban settings or rural projects that receive natural debris inputs (branches and logs from fallen trees) are more likely to contain debris than projects that are removed from debris sources.

If debris management is deemed to be necessary by the local review team, they will coordinate with the civil works or Regulatory project manager (and project proponent) to develop a debris management plan. The plan may require that a debris screen (aka "grizzly") placed over the receiving barge/scow or other satisfactory method for removal and isolation of debris until it can be disposed at an appropriate upland facility.

10.2 Contaminated Sediment Disposal

Identification of reasonable disposal sites for contaminated sediments must take into account multiple criteria, including ecologic, geologic, hydrogeologic, economic, social, and other factors. This section identifies potential disposal options for contaminated sediments. Depending on the acceptance criteria of the receiving facility, debris management may be required (as described in the section above).

10.2.1 Confined Aquatic Disposal

In confined aquatic disposal (CAD) facilities, contaminated sediments are placed in an existing or constructed subaquatic pit and capped with a thick cap. See Section 10.3.3 for general information and considerations on thick cap installation. The primary design components of a CAD facility are the physical (i.e., thickness and gradation) and chemical quality of the cap, depth, topography, and currents at the site. A CAD can be built without a net loss of habitat and in some instances, result in a net gain.

10.2.2 Nearshore Confined Disposal Facility

In a nearshore confined disposal facility (CDF) contaminated sediments are placed behind an engineered structure (berm or dike) in the shallow, nearshore environment for containment of dredged material. The confinement dikes or structures in a nearshore CDF enclose the disposal area, isolating the dredged material from adjacent waters during placement. In this document, nearshore confined disposal does not refer to subaqueous capping or CAD.

Nearshore confined disposal facilities provide an opportunity to confine the dredged material and incorporate development of upland areas. Potential effects to groundwater flow and existing structures in the adjacent upland area must be considered during the engineering of these facilities. Nearshore confined disposal facilities may result in a net loss of aquatic habitat that could require mitigation.

10.2.3 Upland Disposal

Upland disposal facilities can include either existing municipal landfills (mixed), or on-site fills dedicated solely to the sediment remediation project. For either type of landfill, materials require dewatering, and effluent from the material may require testing (see Chapter 9, Special Evaluations) if it is discharged back into the adjacent water body.

Solid Waste Landfills—Existing solid waste landfills may accept contaminated sediments, as long as those sediments are not designated as hazardous waste. Sediments that are hazardous waste must be sent to a Subtitle C landfill. Each landfill has acceptance criteria for waste materials, and the landfill operator should be contacted to determine additional sampling, testing, and reporting requirements (which are different from those presented in this document).

Upland Confined Disposal Facilities—Upland CDFs are developed adjacent to the dredge location or offsite where the project proponent has responsibility for the development and management of the facility. In the state of Washington, upland disposal is regulated by the local municipality, although return water from such sites may be regulated by Ecology, either through an existing industrial stormwater NPDES permit or as part of the dredging project individual 401. Upland disposal of dredged material in Oregon is regulated by ODEQ's Solid Waste Program and requires a solid waste letter of authorization or exemption for disposal or placement of dredged sediment at an upland site. Similarly, upland disposal of dredged material in Idaho is regulated by IDEQ's Solid Waste Program.

CDFs must be designed to eliminate contaminant transport pathways. Sediment and site water must be intensively managed in cells to ensure that the contaminated materials are retained and do not pose a risk to humans and other receptors. When the upland CDF is full, it can be capped and beneficially used for commercial or industrial development.

10.3 Post-Dredge Surface Management

If the local review team determines that the post-dredge surface is unsuitable for unconfined, aquatic exposure, then the proponent must identify how the post-dredge surface will be managed to reduce or eliminate exposure of the dredging residuals to the environment. Management strategies can be implemented during dredging to reduce generated residuals and after dredging to manage both undisturbed residuals and generated residuals. The management strategies identified by the project proponent should be developed collaboratively with local review team involvement. To ensure the efficacy of the selected management option(s), the local review team and/or the permitting agencies may also require a monitoring component.

10.3.1 Reducing Generated Residuals during Dredging

Methods for characterizing dredging residuals (i.e., generated residuals + undisturbed residuals) are briefly discussed in Chapters 4 and 9. Generated residuals will occur in every dredging project, but the degree of their formation is a function of a number of factors including:

- Sediment properties such as in situ dry bulk density (solids concentration, solids content or water content), organic content, particle-size distribution, and mineralogy.

- Site conditions such as water depth, currents, waves, and presence of hardpan or bedrock.
- Nature and extent of impediments, such as debris, loose cobbles, boulders, and obstructions.
- Operational considerations such as the thickness of dredge cuts, dredging equipment type, method of operation, and skill of the operator.

Operational Controls—If dredge prism sediments are contaminated, the local review team may require that generated residuals be minimized through the application of operational control measures. Operational controls to manage generated residuals may include changes in dredging methods and/or in operation of the equipment. Examples of operational controls to reduce generated residuals include:

- Reducing the dredging rate, especially as the bucket approaches the sediment surface and extraction of the bucket from the sediment surface after closing
- Reducing bucket over-penetration, which can cause sediment to be expelled from the vents in the bucket or cause excess sediment to be piled on top of the bucket and fall back during bucket retrieval
- Eliminating overflow from barges during dredging or transport or managing/treating return water
- For pipeline dredging, modifying the depth of the cutterhead, rate of swing of the ladder and of the rotating cutterhead, and reducing the speed of advance of the dredge
- Sequencing the dredging by moving upstream to downstream
- Varying the number of dredging passes (vertical cuts) to increase sediment capture
- Using properly sized tugs and support equipment
- Using an environmental bucket

If generated residuals are a concern, the local review team should work collaboratively with the proponent to identify operational controls (ERDC, 2008).

Engineered Controls—Engineered controls may also be used on a limited basis to keep suspended sediments from migrating offsite. However, these can be very costly and are typically used for cleanup dredging. Examples of engineered controls include silt curtains and screens, cofferdams, and sheet-pile enclosures. Before an engineered control is selected, the following questions should be asked:

- Are there more cost-effective operational controls that would reduce generated residuals?
- Is deployment of the engineering control feasible given site conditions?
- What is the function and purpose of the engineering control?
- What is known about the effectiveness of the engineering control on similar projects?
- What information is available on selection, design, specification, and deployment of engineering controls on similar projects?
- What is the risk to federally protected species in the dredge area if the engineering control is implemented (entrainment)?

Silt curtains and silt screens (typically referred to as curtains) are the most commonly required engineered controls. Curtains are made of impervious materials, such as coated nylon, and primarily redirect all water flow around the enclosed area; screens are made from synthetic geotextile fabrics, which allow some water flow, but retain a large fraction of the suspended solids inside the screened area.

The effectiveness of silt curtain installation is primarily determined by the hydrodynamic conditions at the site. Silt curtains are most effective in relatively shallow, quiescent water (currents <2.5 ft/s), without significant tidal fluctuations. As water depth increases and turbulence caused by currents and waves increases, it becomes increasingly difficult to isolate the dredging operation from the ambient water effectively. Conditions that will reduce the effectiveness of the silt curtain include:

- Strong currents
- High winds.
- Changing water levels.
- Excessive wave height (including ship wakes).
- Drifting ice and debris.
- Continual movement of equipment into or out of the curtained area.

The effectiveness of silt curtains is also influenced by the quantity and type of suspended solids, the mooring method, and the characteristics of the barrier. A cleanup dredging pass may be necessary to remove residuals that are redeposited within the silt curtain, or other containment barrier (ERDC, 2008).

10.3.2 Monitored Natural Recovery

Monitored natural recovery (MNR) refers to a remedial approach in which natural processes such as sedimentation, sediment mixing, and chemical degradation, reduce contaminant concentrations over time. MNR is a potential approach for managing post-dredging residuals if the layer thickness and concentrations of the residuals would allow for MNR within acceptable time frames (as determined by the resource agencies). The following project-specific parameters should be evaluated to determine if MNR is an acceptable management strategy for contaminated post-dredge surfaces:

- Contaminant type(s) and concentration(s)
- Sedimentation rate (calculated across the dredge area, using historical bathymetry)
- Quality of the shoaling material
- Currents and stability of the shoaling material
- Mudline slope

If MNR is accepted, post-dredge sampling and analysis of the contaminant(s) must be conducted to verify that the site is, in fact, recovering. At a minimum, post-dredge samples should be collected at two points:

- Within one week after the dredging project is completed (if the project is large and multi-phased, then post-dredge sampling must be conducted after the completion of each phase of dredging)
- Approximately halfway through the estimated recovery period, to verify the efficacy of MNR

10.3.3 Capping

Capping is one method to isolate contaminated sediment from the surrounding aquatic environment. Capping is typically used in conjunction with cleanup projects, not maintenance dredging projects, and caps typically require long-term monitoring to ensure the cap is functioning as desired. Over time, and coupled with successful source control, waterways can be expected to recover and constitute much-improved habitat for invertebrates, fish, and birds. Capping may be considered as an option when the

costs of removal are deemed greater than the benefit, and navigation depths are not a concern. There are two types of caps:

Thin Cap (Residuals Cover/Enhanced Natural Recovery)—A thin cap is less than 3 feet thick and composed of unconsolidated, clean sands/silts, placed without armoring materials, in low-energy environments. A thin cap can be used for dredged materials with lower contaminant concentrations in which hazards to human health and the environment are low. Thin capping improves the chemical or physical properties of the upper sediment bed, which constitute the biologically active zone. Note that most dredging projects use what regulatory agencies refer to as "cover," not a cap; sand cover typically consists of a nominal 1-ft layer and post-project monitoring is typically not required.

Thick Cap (Engineered Isolation Cap)—A thick cap is greater than 3 feet thick and composed of clean sands/silts with armoring to protect from scouring in high-energy environments. A thick cap is engineered to manage dredged material with higher contaminant concentrations, and it is typically permanent. As such, capping is best implemented in off-channel areas or within deep areas of the waterway that are well below the current maximum dredging depth (or future planned dredging depth).

A properly installed thick cap can be placed over contaminated dredged materials to effectively contain and isolate them from the benthos and overlying water column and habitat. A thick cap must be designed to resist:

- Mechanical scour from vessel traffic (bow thrusters; prop wash)
- Natural scour from wave action or strong river current
- Penetration by burrowing organisms
- Contaminant migration through the cap (upward or laterally) into the surrounding water body

10.4 References

DMMP. 2014. Dredged Material Evaluation and Disposal Procedures: User Manual (December 2014). *Prepared by* the Seattle District Dredged Material Management Office.

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USACE. 1987. Beneficial Uses of Dredged Material (EM 1110-2-5026). 30 June 1987.

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Appendix A.
RSET White Paper:
Proposal to Revise Freshwater Screening Levels

Part 1: Benthic Screening Levels (p. A-4)

Part 2: Water Quality-based Screening Levels (p. A-8)

Part 3: Consideration of Background Concentrations of Metals
(p. A-13)

RSET White Paper: Proposal to Revise Freshwater Sediment Screening Levels

October 2015: The DMMP has accepted Parts 1 and 3 of the tiered approach with the understanding that the RSET agencies will continue to work on technical issues identified in Part 2

November 17, 2014

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As noted, Parts 1 and 3 will be applied; Part 2 is on hold until further notice

The three parts of this paper must be used in conjunction with each other; they may not be applied separately. Examples of how the three sets of screening levels will be applied appear in Appendix A, and Figure 1 presents a flow chart on how the values are applied. An impact analysis conducted for the Washington Dredged Material Management Program's 2013 Sediment Management Annual Review Meeting presentation on this approach is supplied in Appendix B.

Due to Endangered Species Act concerns, the following disclaimer was developed by the U.S. Fish and Wildlife Service and the National Marine Fisheries Services:

The revised freshwater sediment benthic toxicity screening levels were derived with the analytical tools used to develop the Washington State Sediment Management Standards (SMS) (WAC 173-204-563). The standards were developed by Washington with the intent to protect benthic invertebrate communities. The Regional Sediment Evaluation Team is proposing to adopt these as regional freshwater screening levels. The Washington SMS were not intended to address bioaccumulative impacts (potential effects to higher trophic levels such as fish, wildlife, or humans) or effects to listed species as required by the Endangered Species Act (ESA). When used as part of an overall evaluation framework, the standards proposed may address the fish prey base but not direct effects on species of fish or invertebrates listed as threatened or endangered. Fish and some sensitive invertebrates (particularly snails and mussels) respond to some contaminants in sediment in a way that may not be accounted for in benthic invertebrate tests, and impacts to fish can occur at lower concentrations than those considered protective of invertebrate communities. As well, benthic bioassays are more indicative of population-level or community-level effects, whereas the ESA requires analysis of effects to individuals within the population. Additionally, waters with more unique attributes or high-quality habitat may include certain species that are especially vulnerable to sediment contaminants and may not be protected by the revised benthic screening levels.

While the Sediment Evaluation Framework for the Pacific Northwest and the framework proposed in the 2014 RSET white paper advance the protection of most exposed benthic populations during and following a dredging event, it may not be adequately protective of more sensitive species or individuals from listed species. In some instances, subsequent or additional analyses may be required by the National Marine Fisheries Service or the U.S. Fish and Wildlife Service (the Services) during RSET review. In particular, the Services are concerned about the following:

- *The protectiveness of the proposed approach for petroleum compounds such as polyaromatic hydrocarbons (PAHs)*
- *Bioaccumulative compounds such as DDT and its metabolites and polychlorinated biphenyls*
- *The metals copper, lead, and, zinc, which in the dissolved form, can have particular effects to fish and the invertebrate prey base at low concentrations.*

Of particular concern to the Services is exposure of fish and the invertebrate prey base to contaminants remaining near the sediment surface post-dredging. The newly disturbed surface may not provide adequate protection for fish or listed invertebrate species, especially if the areas are within high quality habitat for these species.

To address some of these concerns, the Services will propose a sediment screening level and approach to evaluate PAHs that is considered protective of fish by the end of 2014, an approach to address specific bioaccumulative compounds by the end of 2015, and may require applicants to compare test results to Probable Effect Concentrations (PECs; MacDonald et al. 2000) for copper, lead and zinc.

Part 1: Benthic Screening Levels

Part 1 was accepted for implementation in October 2015

INTRODUCTION

In the early 2000s, Ecology evaluated existing freshwater sediment benthic toxicity screening levels (SLs), and determined that the existing SLs either had extremely high false positive rates, or extremely high false negative rates, depending on how they were derived (SAIC and Avocet, 2002). In 2003, Ecology released a report that led to the 2006 freshwater SLs currently used by the Regional Sediment Evaluation Team (RSET) (SAIC and Avocet, 2003). These values were based on the Floating Percentile Method (FPM) and the dataset and endpoints available at the time. In 2007, the RSET began to revise the freshwater benthic toxicity SLs using FPM with a larger dataset and additional endpoints. The final FPM report was released in 2011 (Avocet, 2011). Through rulemaking, Ecology promulgated these freshwater sediment values in the Sediment Management Standards (SMS) as freshwater benthic sediment standards (WAC 173-204-563) on February 22, 2013. Revised standards were also adopted for freshwater bioassays. The RSET agencies review and consider new approaches and best available science whenever appropriate and are evaluating Washington's freshwater benthic sediment standards for incorporation into the *Sediment Evaluation Framework for the Pacific Northwest* (SEF) for use in evaluating freshwater sediments.

These standards were developed for the protection of benthic invertebrate communities, and were not intended to address bioaccumulative impacts; potential effects to higher trophic levels such as fish, wildlife or humans; effects to individual organisms as required under the federal Endangered Species Act (ESA); or other species with state protection. As a result, there are concerns that if the sediment benthic standards are used alone, they would not adequately protect aquatic communities including ESA-listed fish species. The RSET agencies agree that additional measures are needed to be more protective of the aquatic environment; for example, SLs must protect other ecological receptors such as federally-listed and non-listed fish in addition to benthic invertebrates, and must account for the potential effects of bioaccumulative compounds, as appropriate.

To address these concerns, the RSET Freshwater Technical Working Group developed the following multi-tiered approach based on: 1) the revised benthic freshwater SLs; 2) water quality-based sediment SLs that would be more protective of the aquatic environment; 3) fish and wildlife-based SLs which include bioaccumulative compounds; and 4) background-based SLs for selected metals. While details of the multi-tiered approach were not finalized in time to be formally proposed at the 2013 RSET meeting, a presentation regarding future implementation was made. A discussion regarding the fish and wildlife-based bioaccumulative SLs ensued and concerns were expressed that the RSET agencies were considering implementation of these guidelines without appropriate public input. Further, concern was expressed that implementing of bioaccumulative SLs for freshwater sediment would set a precedent for their use in the marine environment.

Based on the feedback received at the RSET meeting, the RSET agencies decided to delay development of fish and wildlife-based SLs and proceed instead with adoption of the revised freshwater benthic SLs the water quality-based SLs, and the site-specific background SLs for some metals for use in the SEF. The present paper focuses on the first element – adoption of the revised freshwater benthic SLs for use in the SEF. The latter two elements are addressed in separate parts of this white paper. The fish and wildlife SLs and bioaccumulation concerns will be addressed in a separate process and will cover both freshwater and marine sediment evaluations.

PROBLEM STATEMENT

1. Freshwater SLs were not published in the May 2009 version of the SEF, and SEF users have been applying 2006 interim screening levels to determine dredged material suitability in freshwater environments. The 2006 interim SLs were developed using the FPM on a limited dataset (primarily from the Columbia and Lower Willamette Rivers) and did not include chronic bioassay data.

2. The 2009 SEF currently recommends only 10-day bioassays, while the revised Washington State standards require the use of at least one longer-term (20- or 28-day) exposure, which is a more sensitive bioassay.

APPROACH

The proposed approach includes the revised freshwater benthic SLs (Washington's FPM-based sediment management standards for benthic communities) and a bioassay over-ride. Similar to marine SLs, sediments failing the revised freshwater benthic SLs can be tested using bioassays to gather additional information for decision-making. Adoption of the revised benthic SLs in the SEF will also improve the results of bioassay testing by including a long-term exposure test.

The revised freshwater benthic SLs must be used in conjunction with the water-quality based SLs and the background concentration of metals outlined in Parts 2 and 3 of this white paper (Water Quality-based SLs, and Consideration of Background Concentrations of Metals). To be found suitable for in-water disposal, sediment must pass the revised freshwater benthic SLs (or bioassays if one or more SLs are exceeded). In addition, sediment concentrations must also be compared against the corresponding WQ-based SLs to ensure that water quality standards would not be exceeded. If the natural background for certain metals is higher than either the revised benthic or WQ-based SL, then the background value can be substituted as the SL.

DERIVATION OF THE VALUES

Development of Screening Levels for Benthic Communities

The revised freshwater benthic SLs are the combined result of the RSET Freshwater subgroup (2007 through 2009) and the Washington rule revision process that culminated in the adoption of the freshwater benthic SLs as standards in 2013 (WAC 173-204-563). The benthic SLs were derived using the FPM model, which is described in Ecology's publication #11-09-05, *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Avocet, 2011).

PROPOSED VALUES AND APPLICATION FOR SEDIMENT EVALUATIONS

The proposed benthic SLs are presented in Table 1.

If project sediment data exceed one or more of the revised benthic SLs, then the material is considered unsuitable for in-water placement unless bioassays are conducted. However, sediments with sulfide and/or ammonia concentrations exceeding SLs, but with no other SL exceedances, may not require bioassays. Project proponents should consult with their local review team if sulfide and/or ammonia are present in sediments.

Tiered Biological Testing for Benthic Toxicity Assessment

If the revised benthic SLs are exceeded, then applicants may conduct bioassays to gather additional information for decision-making. These results may over-ride the benthic SL exceedances. Details for conducting bioassays are provided in Chapter 7 of the SEF. Bioassays should include three endpoints using both *Hyalella* and *Chironomus*, at least one chronic endpoint (20-day *Chironomus* or 28-day *Hyalella*), and at least one sub-lethal endpoint (growth). Three endpoints are required because the FPM numbers were developed using these bioassays.

Table 1. Proposed RSET Freshwater Benthic Screening Levels

	BENTHIC Screening Levels	
Analyte	SL1	SL2
Metals (mg/kg)		
Arsenic	14	120
Cadmium	2.1	5.4
Chromium	72	88
Copper	400	1200
Lead	360	>1300
Mercury	0.66	0.8
Nickel	26	110
Selenium	11	>20
Silver	0.57	1.7
Zinc	3200	>4200
Organic contaminants (ug/kg)		
4-Methylphenol	260	2000
Benzoic acid	2900	3800
beta-Hexachlorocyclohexane	7.2	11
bis(2)-Ethylhexyl)phthalate	500	22000
Carbazole	900	1100
Dibenzofuran	200	680
Dibutyltin	910	130000
Dieldrin	4.9	9.3
Di-n-butyl-phthalate	380	1000
Di-n-octyl-phthalate	39	>1100
Endrin ketone	8.5	**
Monobutyltin	540	>4800
Pentachlorophenol	1200	>1200
Phenol	120	210
Tetrabutyltin	97	>97
DDDs	310	860
DDEs	21	33
DDTs*	100	8100
PAHs	17000	30000
PCB Aroclors	110	2500
Tributyltin	47	320
Bulk Petroleum Hydrocarbons (mg/kg) (NW-TPH method)		
TPH-Diesel	340	510
TPH-Residual	3600	4400
Conventionals (mg/kg)[3]		
Ammonia	230	300
Total sulfides	39	61

* Elutriate-based DDT value is based on the sum of sum of o,p'- and p,p'-DDXs

** no SL2 available

[1]SL1 corresponds to a concentration below which adverse effects to benthic communities would not be expected.

[2]SL2 corresponds to a concentration above which more than minor adverse effects may be observed in benthic organisms. Chemical concentrations at or below the cleanup screening level but greater than the sediment quality standard correspond to sediment quality that may result in minor adverse effects to the benthic community.

[3]Ammonia and sulfides are generally used only to inform bioassay testing; sediments only containing elevated ammonia and/or sulfides (and no other chemical exceedances) may be determined suitable for aquatic placement.

Part 2 is on hold until further notice; agencies continue to work on technical issues. However, these SLs and associated approaches may be applied on a case by case basis if deemed necessary by permitting agencies.

Part 2: Water Quality-based Screening Levels

INTRODUCTION

Part 1 of this white paper presented the history of development of freshwater benthic screening levels (SLs) and proposed revised benthic SLs based on recently promulgated standards for the State of Washington. As indicated in part 1, the RSET agencies agreed that additional measures are needed to be more protective of the wider aquatic environment, especially federally-listed and non-listed fish. This part proposes one such additional measure, the use of water quality-based SLs. Other measures, such as evaluation fish and wildlife-based SLs which include bioaccumulative compounds, are still under development.

PROBLEM STATEMENT

Sediment is resuspended in the water column during dredging and remains in suspension for short periods of time during in-water placement. Washington's benthic Sediment Management Standards, developed under the Floating Percentile Method (FPM) and proposed as revised benthic SLs for the SEF, only account for chemical toxicity to benthic invertebrate communities and may not be protective of sensitive fish species and other organisms during dredging and disposal. Since non-benthic species occur in the vicinity of nearly all dredging projects and dredged material placement sites in the Pacific Northwest, the RSET has identified the need to develop SLs that are protective of non-benthic receptors of concern.

APPROACH

As part of the requirements of the Clean Water Act, each state developed rules called water quality standards designed to meet the Clean Water Act requirements of fishable, swimmable water. Within these standards are numeric criteria developed to be protective of a wide range of receptors. Therefore, it is presumed that development of sediment SLs based on those criteria would protect species not covered by the proposed revised benthic SLs derived using the FPM approach. The approach proposed in this paper derives default SLs from EPA's recommended water quality criteria using typical values for hardness, pH, and TOC. These default SLs do not account for site-specific conditions or differences between state water quality standards and federal water quality criteria. The WQ-based SLs can easily be modified on a case-by-case basis to use state water quality standards and/or site-specific water quality values. As with the revised benthic SLs, tiered testing procedures (see "*Tiered Testing for Exceedances of Water Quality-based Screening Levels"* below) are included for the WQ-based SLs.

DERIVATION OF THE VALUES

Development of Screening Levels for Non-Benthic Receptors (Water Quality -based SLs)

For development of SLs that are protective of non-benthic receptors such as fish, RSET proposes using the same equilibrium partitioning approach that was used to develop the Elutriate Triggers (ETs) in Chapter 10 of the Sediment Evaluation Framework (SEF, 2009). Since 2009, the SLs have been expanded to include chronic water quality criteria, and these have been renamed "water quality-based SLs." The equations for calculating these triggers are described below.

Water Quality -based SLs for metals (in mg/kg) are derived using the following equation:

$$\textbf{WQ-based } SL_{metal} = \textbf{Log } K_d \textbf{ x WQC/1000}$$

where:

K_d is the metal partitioning coefficient in L/kg.

WQC is the water quality criterion in µg/L.

The calculation of Water Quality -based SLs for organic constituents is modified in two important ways. First, the equilibrium partitioning coefficients are expressed as a function of the organic carbon content of the sediments. Second, because organic constituents are regulated on a "total" basis (whereas metals are regulated on a "dissolved" basis), both the dissolved and the particulate fractions of the water column concentration need to be considered.

The Water Quality -based SLs for organics (in µg/kg-sed) are derived using the following equation:

$$\textbf{WQ-based } SL_{organic} = WQC / [(TSS_{inc} \times 10^{-6}) + (K_{oc} \times f_{oc})^{-1}]$$

where:

WQC is the water quality criterion in µg/L.

K_{oc} is the organic carbon partitioning coefficient in L/kg-oc.

f_{oc} is the decimal fraction of organic carbon in kg-oc/kg-sed.

TSS_{inc} is the incremental added mass of suspended solids in the water column generated by the dredging or placement action in mg/L.

10^{-6} is a conversion factor of milligrams per kilogram of sediment.

For the lower screening level (SL1), EPA chronic WQ criteria were used in the calculations; the higher screening level (SL2) used the EPA acute water quality criteria. This approach was used for all compounds that have EPA-promulgated water quality criteria. In order to develop generally-protective SLs for dredging sites and aquatic placement of dredged material, the parameters in the formula were assigned the following default values:

- Total organic carbon: 1%
- Total suspended solids: 100 mg/L
- Water hardness: 25 mg/L $CaCO_3$
- pH: 7.0

The default value of 25 mg/L $CaCO_3$ for water hardness differs from the 2009 SEF default (100 mg/L $CaCO_3$), and is based on a survey of water hardness in the Willamette River (Portland Harbor RI/FS August 29, 2011). This change generated lower SLs and was considered more realistic and protective than the SEF default.

PROPOSED VALUES AND APPLICATION FOR SEDIMENT EVALUATIONS

The water quality-based SLs must be used in conjunction with the revised benthic SLs and the background concentration of metals outlined in parts 1 and 3 of this white paper (Benthic SLs, and Consideration of Background Concentrations of Metals). Sediment may pass the revised benthic SLs and therefore not require bioassays for determining suitability for in-water disposal or for new surface material toxicity evaluation. Sediment concentrations should also be compared against the corresponding WQ-based SL to ensure that water quality standards would not be exceeded. If the natural background for certain metals exceed either the WQ-based SLs or benthic SLs, then the background value can be substituted as the SL.

WQ-based SLs may be modified with agency approval using local or site-specific water quality information regarding hardness, pH, and sediment TOC. These parameters can be used to calculate water quality-based SLs that are specific to a project. Site specific values may be required if your location contains ESA-listed species or some other unique characteristic revealed during development of the conceptual site model. If local water quality data are available, then you may be directed to use it. Keep in mind that SLs are not designed to protect beneficial uses beyond those of aquatic life uses (e.g., recreation, domestic water supply, etc.), there may be other considerations depending on your location.

The primary intent of the WQ-based approach is to augment the revised benthic SLs to better address potential contaminant exposure to fish in the water column. Because contaminants within sediment porewater or adhered to sediment particles become liberated (released) when sediment is disturbed, they can impact organisms in the water column near the area of disturbance (i.e., at the dredge or inwater disposal site). WQ-based SLs provide an estimate of porewater concentrations that could be harmful to aquatic life when compared to the sediment chemistry concentrations analyzed in a dredge prism sample. Typically, when WQ-based SLs are exceeded in the dredge prism sample, elutriate testing would then be conducted to provide a more accurate estimate of porewater contaminants. Because fish in the water column would not be exposed directly to porewater, additional modeling may be considered before or after conducting elutriate tests to provide a better estimate of contaminant concentrations released into the water column from dredging or inwater disposal.

A secondary goal of the WQ-based SLs is to protect fish with sediment-dwelling life stages. In particular, juvenile pacific lamprey (ammocoetes), which live and feed on algae directly within the sediment (Kastow 2002), could be exposed directly to porewater contaminants when colonizing the surface sediment exposed by dredging. Lamprey ammocoetes would be the fish most at risk from this type of exposure due to their unique burrowing and feeding behavior. Using the WQ-based SLs for ammocoetes would be considered protective because they appear to be generally as sensitive as salmonids to specific contaminant groups based on water exposure tests (Anderson et. al 2010). To better address risk to lamprey ammocoetes, contaminants in both the dredge prism and new surface material samples (when analyzed) should be compared against WQ-based SLs, especially in cases where contaminants in the underlying surface (i.e., area that will be exposed after dredging) exceed SLs or exceed concentrations in the dredge prism sample. Exceedance of WQ-based SLs in the dredge will trigger elutriate testing, or in some cases modeling, which is further described below.

The proposed default WQ-based SL values are presented in Table 2. Typically, projects are screened against the SL1; the use of SL2 values will depend on project-specific variables, including project design and duration of the project. If sediment concentrations are below the applicable WQ-based SLs, then the material may be suitable for in-water disposal (keep in mind that the material must also pass the revised benthic SLs). If the sediment concentrations for one or more chemical exceed the applicable SLs, then the project proponent may opt to undergo tiered testing as described below.

Tiered Testing for Exceedances of Water Quality-based Screening Levels

Tiered testing procedures for WQ-based SL exceedances may use several approaches, depending on the concerns at the dredge and placement sites. These could include elutriate testing (discussed below), development of site-specific water quality SLs, or site-specific mixing zone modeling to determine if water quality would be met at the point of compliance.

Elutriate Testing

Elutriate testing attempts to mimic conditions during dredging and in-water disposal so water column pollutant concentrations can be predicted in the laboratory. There are several tests developed to determine water quality consequences. If the concern is for suspension of pollutants during dredging, then the dredging elutriate test (DRET) should be used (Di Giano et al., 1995). To evaluate potential impacts at in-water placement sites, the standard elutriate test should be used (EPA/USACE, 1998). Results from elutriate testing are then compared to the applicable water quality criteria (acute or chronic). If concentrations exceed the applicable criteria, then modeling should be conducted to determine if the criteria will be met at the project's point of compliance. If the criteria cannot be met at the point of compliance, then other disposal options or special project Best Management Practices (BMPs), such as silt curtains, would be considered.

Use of Site-Specific Water Quality Parameters

If site-specific data are available, then the proponent may be required to, or have the option to, calculate site-specific screening levels using water quality data from the dredging or placement site. Site-specific SLs can be developed using the spreadsheet provided in Attachment 1, where site organic carbon and expected suspended sediments can be taken into account. Site-specific ambient water chemistry (hardness and pH) can also be collected and used in this spreadsheet to further refine the site-specific screening levels. Development of site-specific SLs is subject to approval by the RSET agencies.

Table 2. Proposed Water Quality-based Screening Levels

Analyte	WQ-BASED SLs (EPA)[1] SL1 chronic	SL2 acute
Metals (mg/kg)		
Arsenic	1900	3400
Cadmium[2]	4.7	26
Chromium(III)[2]	2998	23047
Copper[2]	137	182
Lead[2]	215	5527
Mercury	154	279
Nickel[2]	641	5769
Silver[2]	--	24
Zinc[2]	4595	4595
Organic contaminants (ug/kg)		
Pentachlorophenol	39	51
DDTs[3]	7	7970
PCB Aroclors	33	4722
Tributyltin	18	113

[1]U.S. EPA National Recommended Water Quality Criteria (2006) have been used to calculate table values. You may be required to use state-specific water quality standards. In coordination with the local review team, you may also be able to use site-specific parameters (pH, sediment TOC, hardness) to adjust the water quality-based SLs.

Contact the applicable agency for this information. Other water quality values used to derive these screening levels were a pH of 7.0 and a sediment total organic carbon content of 1.00% dry weight.

[2]A hardness of 25mg/L calcium carbonate was used to calculate the water quality criteria for these metals; arsenic and mercury are not affected by changes in water hardness.

[3]Elutriate-based DDT value is based on the sum of o,p'- and p,p'-DDXs

Part 3: Consideration of Background Concentrations of Metals

Part 3 was accepted for implementation in October 2015

INTRODUCTION

Part 1 of this white paper presented the history of development of freshwater benthic screening levels (SLs) in Washington and the addition of these benthic SLs to the *Sediment Evaluation Framework of the Pacific Northwest*. The benthic SLs were calculated using the floating percentile method on a database of freshwater chemical and bioassay testing results and provide the best available science regarding chemical thresholds for adverse effects on benthic communities. Part 2 presented water quality-based SLs for the protection of non-benthic species. However, thoughtful implementation of the benthic and WQ-based SLs also requires consideration of background concentrations for chemicals of concern, particularly metals. The development of a background approach for metals in freshwater sediment is presented in this part.

PROBLEM STATEMENT

The Pacific Northwest region is known to have naturally elevated metals concentrations, in large part due to the volcanic nature of this region. In some areas, the background sediment concentrations of metals can exceed the benthic and WQ-based SLs. Therefore, background concentrations must be taken into account when evaluating dredging projects in these areas. However, background concentrations vary between regions, watersheds, and water body types. Very little natural background data exist for freshwater sediments and, while substantially more data are available for soil background values near freshwater areas, the applicability of soil background to sediments has not previously been defined in policy for Washington or Oregon.

APPROACH

The background-based SLs must be used in conjunction with the benthic and water quality SLs outlined in parts 1 and 2 of this white paper (benthic SLs, and WQ-based SLs). Where background metals are above other proposed SLs, the SL will default to background. Because metals background varies geographically, and the rules for the participating states differ, each state has its own proposed background approach, based on a combination of soil or sediment background.

DERIVATION OF THE VALUES

Development of RSET Freshwater Sediment Background Concentrations for Use in Oregon State

For dredging projects on the Lower Willamette River, the Willamette upstream sediment natural background metals values calculated for the Portland Harbor Superfund area will be used (LDWG 2012). Sediment natural background concentrations may also be calculated for other areas of the state if sufficient data are available. If no sediment background data are available, local soil background will be used in other parts of Oregon (ODEQ, 2013).

Development of RSET Freshwater Sediment Background Concentrations for Washington State

Based on data in Ecology's publication #09-03-032 (*Baseline Characterization of Nine Proposed Freshwater Sediment Reference Sites*, 2008), many metals in Washington sediment had higher concentrations compared to the background values from the Willamette, thus Willamette background may not be appropriate for Washington.

Using available sediment data for Washington State and performing outlier analysis, only nickel appears to clearly have sediment background higher than a benthic or WQ-based screening level – in this case, the benthic SL1 (see Appendix C). However, more freshwater sediment data are needed before a statistically robust background concentration can be calculated.

Since it appears that the Willamette sediment background may not be appropriate for Washington sediments, and sufficient Washington sediment data are not yet available, the DMMP agencies developed interim background values using Washington State soil data from Ecology's publication #94-115 (*Natural Background Soil Metals Concentrations in Washington State*, 1994). Using this data set, nickel had a background concentration (90^{th} percentile = 38 mg/kg) higher than the benthic SL1 (see Appendix A). In Washington, the DMMP agencies propose using this value for the nickel SL1 until sufficient sediment data are available to calculate background.

Development of RSET Freshwater Background Sediment Concentrations for Idaho State:

Natural background concentrations of metals in sediments exceeding benthic or WQ-based screening levels may indicate the character of highly mineralized soils and the variable composition of sediment parent material found in many Idaho watersheds. In the event that natural sediment background levels are not available, soils and parent material representative of watershed sediment could be used as a reference for screening level thresholds. In certain circumstances, use of site specific screening levels for the protection of beneficial uses may override considerations for application of background sediment concentrations as screening thresholds. Idaho will examine this issue on a case by case basis as it arises.

Examples for sources of this information include the following:

U.S. Environmental Protection Agency. *Record of Decision Bunker Hill Mining and Metallurgical Complex OU 3*. September 2002.

U.S. Geological Survey. *Geochemical and Mineralogical Data for Soils of the Conterminous United States.* 2013.

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U.S. Environmental Protection Agency. *Record of Decision Bunker Hill Mining and Metallurgical Complex OU 3*. September 2002.

U.S. Geological Survey. *Geochemical and Mineralogical Data for Soils of the Conterminous United States.* 2013.

Glossary of Terminology

Benthic Screening Levels (Benthic SLs): Sediment screening levels based on regional data and the Floating Percentile Model (Avocet, 2011).

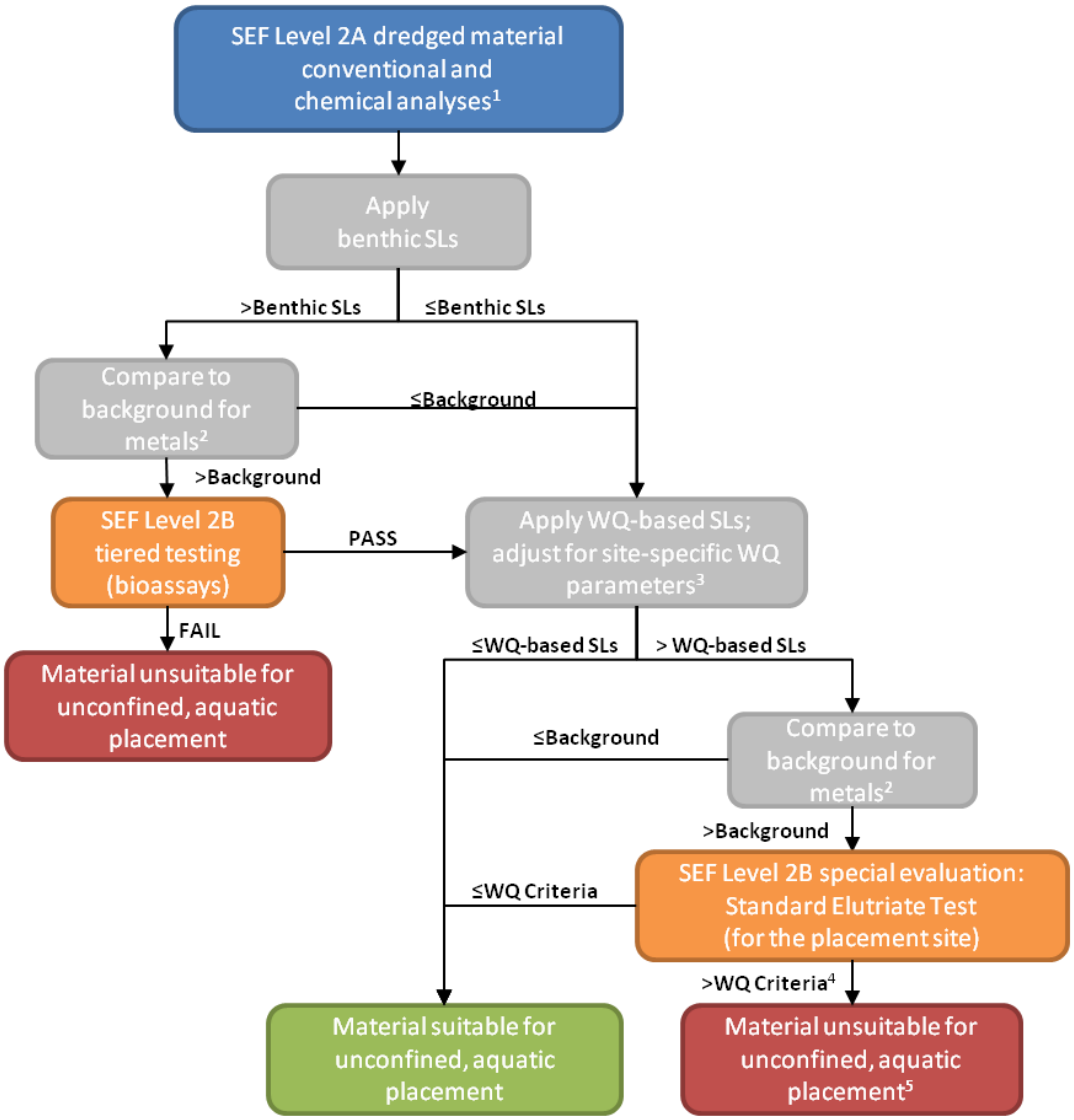
Elutriate Test: A sediment test where water and sediment are shaken, allowed to settle for a pre-determined amount of time, and the overlying water and suspended sediments are analyzed for chemical concentrations.

Elutriate Trigger (ET): An elutriate trigger is a sediment screening level (SL) calculated by multiplying the applicable water quality criteria (µg/L) by the logarithm of an applicable equilibrium constant of the sediment (L/kg) divided by 1,000. The result is a screening level or elutriate test trigger in mg/kg. The equilibrium constant or K_d value, as it applies to dredged material, is a measure of how much of a metal or organic constituent remains bound to sediment particles and how much is expected to dissolve in the water column. These trigger levels were originally developed in the SEF for acute water quality criteria (WQC) only. This paper expanded the use to include chronic WQC, and re-named the resulting sediment SLs as the WQ-based SLs.

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.

Water Quality-based Screening Levels (WQC-based SLs): Sediment SLs based on water quality criteria and equilibrium partitioning.

Figure 1. Application of proposed freshwater screening levels for the aquatic placement of dredged materials.



1 - Specific to the state in which the project is located, this process may also be used to predict toxicity of the new surface material (i.e., the surface exposed after dredging) and address water quality concerns at the dredge area.
2 - Background concentrations are used only for metals and are specific to the state in which the project is located, as determined by the state water quality agency (WA - Ecology; OR - ODEQ; ID - IDEQ).
3 - In coordination with the local review team, site-specific total organic carbon, hardness, and pH may be used to adjust the water quality-based SLs at the dredge area and placement area.
4 - The standard elutriate test or modeling indicate WQ criteria would be exceeded at the dredged material placement site. Modeling efforts must be coordinated with local review team.
5 - Dredging with upland disposal may still be a viable option. The dredging elutriate test (DRET) and water-quality compliance modeling would need to be conducted to assess the effects of dredging at the dredge area. Depending on the results, modifications to the dredging project may be proposed to ameliorate adverse water quality effects in the dredge area.

Appendix A. Example projects

This appendix contains three examples of the application of the SLs presented in this paper.

Case 1 is for the Port of Vancouver (2008), where there were exceedances of both benthic SLs and WQ-based SLs. In this case, Berths 8/9 had several chemical exceedances. The Port opted out of bioassays, so the dredged material was considered unsuitable for in-water disposal. Additionally, the TBT exceeded the benthic SL2, as well as the elutriate trigger (now called the WQ-based SL, at that time it was the elutriate trigger for acute WQ criteria). The Port conducted DRET testing, and then modeled the resulting data to predict water quality during dredging.

Case 2 is from the Port of Anacortes, Pier 2 (2013), and is another example of TBT, where TBT was the only constituent that exceeded any SL. The memorandum below documents the process by which the Port of Anacortes evaluated the potential impacts to water quality. While this project is marine rather than freshwater, the evaluation is more thorough due to its more recent evaluation, and so was included as an example here.

Case 3 is from Chester Morse Lake Pump Plant (2014). The material was being evaluated for in-water disposal, and failed only the nickel benthic SL, triggering comparison to background (at this time, WQ-based SLs were not in place so were not evaluated). The DMMP suitability determination attached below describes the process by which the project was evaluated.

Appendix B. DMMP impact evaluation of the proposed SLs (from SMARM 2014)

IMPACT ANALYSIS

The DMMP agencies evaluated the potential impact of the proposed freshwater approach on projects. Data from DMMP freshwater projects over a five-year span (2009-2013) were compared to the new SLs, to determine if there would have been significant changes in the evaluation (suitable or non-suitable). There were 12 projects with 43 DMMUs, mostly in the Columbia River but also including Lake Union (one project, seven DMMUs) and Lake Washington (two projects, four DMMUs).

Of these 43 DMMUs, 25 DMMUs had no change in decisions (six passed both sets of SLs, 16 had detected exceedances of both sets of SLs, and three had non-detected exceedances of both sets of SLs) (Table 3). Two DMMUs passed the 2006 SLs but had detected proposed SL exceedances for nickel. These DMMUs would now require bioassays or site-specific background evaluation for nickel. Both of these were in the same project (South Lake Union).

Twelve DMMUs passed the 2006 SLs but had non-detects above SL (five for silver, five for pentachlorophenol (PCP), two for PCB) that previously had no exceedances of the 2006 guidance. These non-detect exceedances could be avoided for silver and PCP- the proposed silver (0.57 ppm) and PCB SLs (33 ppb) and are at or above the Ecology median PQLs (0.5 ppm and 33 ppb respectively) (Ecology draft SCUM II, appendix F). If sediment concentrations were actually present above the SL, the PCB exceedances would have triggered further evaluation based on the WQ-based SL (elutriate testing, modeling) and the silver exceedance would have triggered bioassays. For PCP, the standard methodology (typically SW8270D) PQL (265 ppb) and MDL (48 ppb) are above the proposed WQ-based SL (39 ppb). Non-detects exceeding the proposed PCP SL would normally trigger further evaluation (elutriate testing, modeling). Although an alternative method (EPA 8270 LL) could reach PQLs and MDLs below the proposed SL, unless there is a reason to believe that PCP is an issue at the project site, the agencies will not require the alternative method and instead will require reporting of PCP down to the MDL. Only detected exceedances of the WQ-based SL will trigger further evaluations.

Three DMMUs that exceeded the 2006 SLs (Cd, Zn, and bis(ethylhexyl)phthalate) had no detected exceedances of the proposed SLs, but did have non-detected exceedances for PCP. Bioassays were not run on two of these DMMU, so it is not known whether the exceedances of the 2006 guidelines were associated with toxicity; however, bioassays were conducted and passed for the project with the Cd exceedance (Kitittas).

A single DMMU had a non-detect exceedance of the 2006 SLs (Hg) and a detected exceedance of the proposed nickel SL; either exceedance would have triggered bioassays.

Table 3. Matrix Comparing DMMU Evaluations for Impact Analysis

	All COCs are less than or equal to proposed SLs	One or more detected exceedance of proposed SLs	One or more non-detects exceed proposed SLs
All COCs are less than or equal to 2006 SLs	6	2 (Ni)	12 (5 Ag, 5 PCP, 2 PCB)
One or more detected exceedance of 2006 SLs	0	16	3 (PCP)
One or more non-detects exceeded 2006 SLs	0	1 (2006 Hg, proposed Ni)	3

Appendix C. Supplemental analysis of available sediment and soils data for Washington State.

Dredging projects need a way to determine when background concentrations of metals in freshwater sediments may be above the risk-based screening values (benthic SL or WQ-based SL). According to the SMS, when natural background concentrations are above risk-based values, background concentrations over-ride the screening values.

For freshwater, there are no established sediment natural background values. Data from both Washington state soil ("Natural background soil metals concentrations in Washington state", Ecology publication #94-115) and sediment data (Ecology's publication #09-03-032, "Baseline characterization of nine proposed freshwater sediment reference sites, 2008") were examined to determine which, if any, metals may need to default to natural background. Soil 90th percentile[1] and sediment 90/90 UTLs were compared to the sediment SLs (benthic, WQ-based) (Table 2). Only four metals had values higher than SL: Ni, As, Cu, and Hg, which could be the basis of an over-ride.

Because it is preferable to have a sediment background value for use in dredging rather than defaulting to soil values, the sediment data from publication #09-03-032 were examined more closely to determine whether that data could be used to generate Washington state freshwater background concentrations. The data were not normally distributed for any of the metals, and while outlier analysis indicated there may be some outliers, there is insufficient data for the non-normally distributed dataset to prove that the potential outliers were either in or out of the background distribution. For this analysis, outliers were removed from the data set, and the 90/90UTLs re-calculated and compared to their respective SLs. Only Ni remained higher than the risk-based SLs; no outliers had been identified for this metal.

In order to determine if sufficient nickel data were available, the approach used in the regional background studies was applied. The precision for the 95%UCL on the mean was higher than 25%, indicating more samples are needed to better characterize the upper part of the distribution that is used to set the background value.

The RSET FW technical group is proposing that the Willamette upstream natural background values calculated for the Portland Superfund area be used for metals natural background unless there are other data to support natural background for other regions. Based on data in Ecology's publication #09-03-032, many metals in Washington sediment had higher concentrations compared to the background values from the Willamette, thus Willamette background may not be appropriate for WA.
Using available sediment data for the state and biasing towards lower concentrations by using outlier analysis, only Nickel appears to clearly have sediment background higher than risk-based level.

[1] 90th percentile reported in the publication was used for soil since the publication did not have the individual data values available to calculate the 90/90UTL.

However, statistics indicate that more freshwater sediment data are needed for nickel to better define the upper tail, which is what defines the background concentration. Since it appears that the Willamette sediment background may not be appropriate for WA sediments, but sufficient WA sediment data is not available, the DMMP needs an approach for assessing nickel in the interim. Either the 90th percentile of WA soil data or the 90/90UTL of existing WA sediment reference (Ecology's publication #09-03-032) data can be used in the interim. Given the uncertainties around the sediment data, and the fact that the soil data are lower than the sediment, the DMMP proposes to continue to use the soil background data for nickel until sufficient sediment background concentrations can be established.

Table A-1. Metals concentrations (ppm dry wt) in selected sediments and soil. More Washington state freshwater sediment data are needed to determine usable background concentrations. Nickel is the only metal where Washington sediment and soil were above the SL after outliers were removed.

Metal (lowest risk-based SL in parentheses)	Willamette sed bkg (95th %ile)	WA sed (all data) (90/90UTL)	WA sed (outliers removed) (90/90UTL)	WA soil (90th %ile)
Arsenic (14)	3.8	17	6.5	7
Cadmium (2.1)	0.2	0.7	0.5	1
Chromium (72)	32.7	60	no outliers	42
Copper (110)	38.0	146	49	36
Lead (160)	14.3	53	12	17
Mercury (0.66)	0.1	0.22	0.14	0.04
Nickel (26)	**26.1**	**57**	**no outliers**	**38**
Selenium (11)	0.4	2	0.6	na
Silver (0.6)	0.7	0.19	0.13	na
Zinc (3200)	105.0	110	no outliers	85

Appendix B. Public Process to Change the SEF

Introduction

A major strength of the SEF is its ability to continuously evolve. As new information becomes available, the RSET agencies will revise and refine the SEF content in a publicly coordinated process. The RSET envisions an annual cycle for changes to the SEF and strongly encourages public stakeholders and member agencies to:

- Prepare technical papers and/or provide comments pertaining to sediment evaluation in the Pacific Northwest, and
- Present these papers and/or provide comments at the RSET's annual meeting

Public input helps to strengthen the SEF and increase its utility for all users. This appendix describes the process for making substantive changes to the SEF.

Applicability

Who can Propose a Change? Any member of the public, including stakeholders (port authorities, dredgers, consultants), special interest groups, and staff representing local/state/tribal/federal governmental interests (including RSET agency representatives), may propose a change to the SEF through this public process.

Substantive vs. Non-Substantive The process outlined in this appendix should only be used to propose substantive changes to the SEF. Substantive changes include those that would result in changing the content of the SEF; changes may be technical in nature or pertain to regional policies concerning dredged material evaluation. The technical and policy workgroups will limit their reviews to proposed changes that are within the scope of the SEF.

Non-substantive changes to the SEF (grammatical changes, correcting typographic errors, replacing broken webpage links, etc.) are not subject to this extended process; these minor edits should be brought to the attention of the Corps (Northwestern Division) and EPA Region 10 RSET Leads.

Geographic Scope Proposed changes to the SEF must be regional in scope; the changes proposed must be able to be applied throughout the Pacific Northwest Region. Changes concerning processes and procedures that are state- or district-specific are outside of the RSET's purview and must be addressed by the appropriate local review team.

Guidance vs. Rule The SEF is the Pacific Northwest's regional implementation manual for the national sediment testing manuals. The SEF provides the best available technical guidance regarding how dredged material should be tested. While it is generally anticipated that the RSET agencies will follow the procedures in the SEF, agency decision-makers retain the discretion to accept alternative approaches on a case-by-case basis, where determined to be appropriate. The document does not, and is not intended to impose any legally binding requirements on federal agencies, the States, or the regulated public. Nor does the SEF alter the statutory and regulatory framework for permitting decisions under section 404 of the CWA and section 103 of the MPRSA.

RSET Review Process for Changes to the SEF

The proponent of the proposed change will use the form below (or provide an issue paper with all of the major headings). If the proponent or the RSET believe that a presentation would improve the RSET's understanding, a portion of the next scheduled monthly RSET teleconference can be devoted to the presentation. The presentation should include the completed SEF change process form and any references used to support the proposed change.

If the nature of the proposed change is technical, the technical workgroup will be assigned manage the review process; if the proposed change concerns regional sediment evaluation policy, then the policy workgroup will manage the review process. The policy review group will also review any technical changes proposed to the SEF by the technical workgroups.

Public Review Process for Changes to the SEF

Public review of proposed changes to the SEF will occur during the RSET's annual meeting (typically held in mid-November) and subsequent public comment period. To improve the public's understanding, the proponent may present the proposed change during the annual meeting. Changes proposed after the RSET's annual meeting and public comment period will be reviewed and addressed during the next year's meeting. The Corps will email the proposed change (in the format below) to the Regulatory public notice email distribution lists of each District (Portland, Seattle, and Walla Walla) as well as the Seattle District's DMMO list. Because the SEF is regional guidance and not federal rule, notice of proposed changes will not be published in the Federal Register.

A 30-day comment period will be provided; however, this can be extended based on the recommendations of the workgroup(s) and/or reasonable requests for extensions, so long as the request is within the original 30-day comment period. The proponent of the proposed change may provide additional information and supporting documentation to the RSET to help address public comments. However, any new information or supporting documentation will require an additional public comment period.

The RSET workgroup(s) will collect, discuss, and address all comments received within the public comment period, recording each comment and its source using the form below. After considering all comments, the RSET workgroup(s) will develop their recommendation(s) regarding the proposed change and either accept the change or reject it.

Accepting Changes to the SEF

The Corps and EPA RSET Leads will make every effort to drive consensus between the workgroup members regarding the ultimate language and content of the proposed change. If the proposed change is accepted by all members of the workgroup, then the RSET policy workgroup will make a final decision based on:

- Public comments, and
- Recommendations from the appropriate RSET workgroup

If the workgroup members cannot come to a consensus on the proposed change, the recommendation will be elevated for resolution through the Northwestern Regional Dredging Team hierarchy (Figure B-1).

Following a final consensus decision, the revision will be made, and the appropriate parts of the SEF will be republished. Agency senior leaders will be briefed regarding any changes to the SEF made under this public process. The forms (and comments) documenting the change will be kept on EPA's website (to be named later).

Rejection of Changes to the SEF and Dispute Resolution

If a proposed change to the SEF is contrary to state or federal regulations, the change will be rejected outright, and the SEF will not be modified.

If consensus cannot be reached at the executive leadership level (via the Regional Dredging Team elevation hierarchy, Figure B-1), then the proposed change will be rejected, and the SEF will not be modified.

Agency senior leaders will be briefed regarding the rejection of any changes proposed to the SEF under this public process. The SEF process change forms (and comments) documenting rejection of the change will be kept on EPA's website (to be named later).

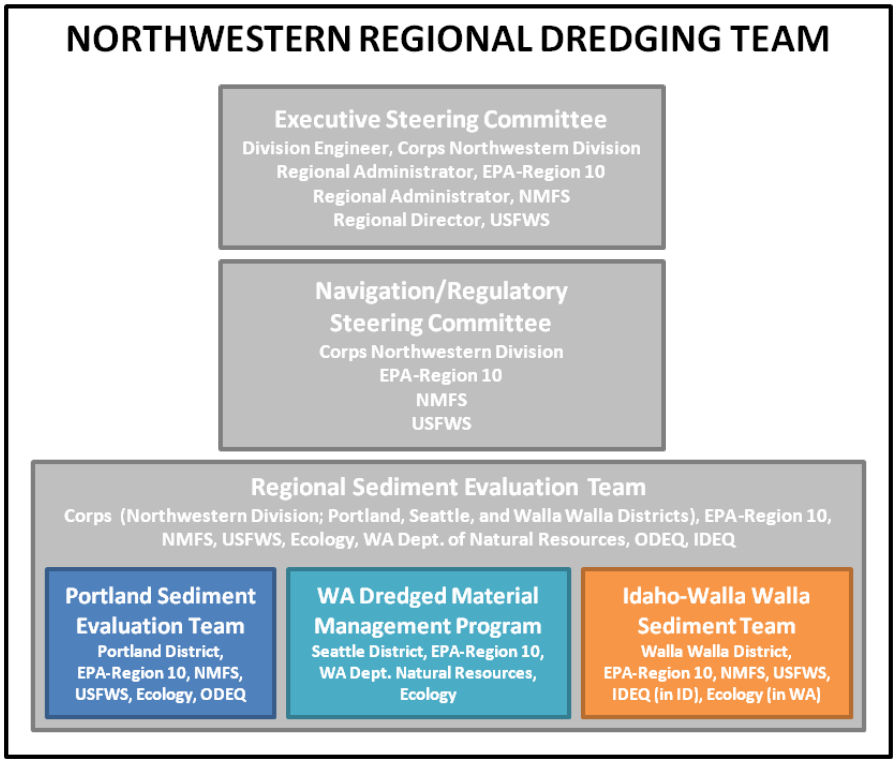


Figure B-1. Northwestern Regional Dredging Team Hierarchy.

REGIONAL SEDIMENT EVALUATION TEAM PROCESS CHANGE FORM FOR THE SEDIMENT EVALUATION FRAMEWORK FOR THE PACIFIC NORTHWEST
DRAFT RSET ISSUE PAPER NO. ***(to be assigned by the RSET)*** **– Title of Issue/Change:**
LIST OF PREPARERS and CONTACT INFORMATION:
ISSUE/CHANGE:
DISCUSSION *(provided by entity proposing change and/or appropriate workgroup)***:** **Background:**
PROPOSED LANGUAGE/ISSUE RESOLUTION:
RECOMMENDATION:
REFERENCES:
LIST OF COMMENTS/COMMENTERS:
RESPONSE TO COMMENTS:
FINAL DECISION:

Appendix C. Bioaccumulative Chemicals of Concern Lists

Introduction

The RSET adopted the approach for identifying BCoCs outlined by the DMMP (Hoffman, 2007). This approach relies on a review of the occurrence of contaminants in sediments and tissue, chemical properties of contaminants such as K_{ow} or the known toxicity of the contaminants to human/ecological receptors, and comparison of tissue levels to available residue-effects levels. Contaminants are placed on one of four lists depending on the amount of information available and the weight-of-evidence indicating their potential to bioaccumulate, prevalence in the region, and toxicity. Because many bioaccumulative guidelines are below detection limits, our ability to definitively determine that contaminants are not present at risk-based levels is limited. Complete lists for all three Corps Districts, along with accompanying notes, are provided below; these lists are periodically updated by the local review teams.

List 1: Primary Bioaccumulative Chemicals of Concern. These are the primary chemicals expected to be addressed as part of a bioaccumulation evaluation. Chemicals are placed on List 1 based on hydrophobicity, frequency of detection in sediments and tissues, and known human health and ecological risks.

List 2: Candidate Bioaccumulative Chemicals. Chemicals are placed on List 2 because they meet some of the above criteria and may be BCoCs, but not enough data are available on their occurrence in the region to place them on List 1. Emerging chemicals of concern can often be found on this list. The RSET agencies may request analyses for one or more of these chemicals if there is a strong reason to believe that they may be significant for a given project.

List 3: Potentially Bioaccumulative Chemicals. Chemicals are placed on List 3 when they do not meet any of the definitions of the other three lists. Typically List 3 chemicals are just beginning to receive national attention due to their potential for persistence and/or being detected in monitoring programs. Chemicals are often placed on this list because it is not yet known if they present risks to human health and the environment.

List 4: Not Currently Considered Bioaccumulative. Chemicals are placed on List 4 if they are not likely to bioaccumulate due to their chemical properties or if they have been analyzed for but not found/only infrequently found in regional sediments and tissues.

The RSET made one modification to the approach outlined in Hoffman (2007). In the original approach, all standard divalent metals were placed on List 1, because they were measured in tissues at concentrations exceeding residue-effects levels. It is recognized that aquatic species bioaccumulate trace metals to varying degrees and with varying toxicological consequences depending on their ability to regulate trace metals. Thus, many of these metals do not substantially bioaccumulate, and retaining them on List 1 would likely lead to an unnecessary number of bioaccumulation evaluations. Metals with organic forms were placed on List 1; other metals were placed on List 4. This provides a more consistent treatment of metals and organic chemicals and a better reflection of the actual tendency to bioaccumulate. The Seattle District reviewed and adopted this update in 2009.

Seattle District

The Seattle District lists are excerpted from Hoffman (2007).

Seattle District List 1: Primary Bioaccumulative Chemicals of Concern

Arsenic
Chlordane
DDTs – Total
Dioxins/Furans
Fluoranthene
Hexachlorobenzene
Lead
Mercury
Pentachlorophenol
PCBs – Total Aroclors
Pyrene
Selenium
Tributyltin

Seattle District List 2: Candidate Bioaccumulative Chemicals

1,2,4,5-Tetrachlorobenzene
4-Nonylphenol, branched
Benzo(e)pyrene
Biphenyl
Chromium VI
Chlorpyrifos
Dacthal
Diazinon
Endosulfan
Ethion
Heptachloronaphthalene
Hexachloronaphthalene
Kelthane
Mirex
Octachloronaphthalene
Oxadiazon
Parathion
Pentabromodiphenyl ether
Pentachloronaphthalene
Perylene
Tetrachloronaphthalene
Tetraethyltin
Trichloronaphthalene
Trifluralin

Seattle District List 3: Potentially Bioaccumulative Chemicals

1,2,3,4-Tetrachlorobenzene
1,2,3,5-Tetrachlorobenzene
C2-phenanthrene/anthracene
C3-chrysenes/benzo(a)anthracene

1,2,3-Trichlorobenzene
1,3,5-Trichlorobenzene
1-methylnaphthalene
1-methylphenanthrene
2,6-Dimethyl naphthalene
2-methylnaphthalene
4,4'-Dichlorobenzophenone
4-bromophenylphenyl ether
Acenaphthene
Acenaphthylene
Aldrin
Alpha-BHC/Alpha-benzene hexachloride
Anthracene
Antimony
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Bis(2-ethylhexyl) phthalate
Butyl benzyl phthalate
C1-chrysenes/benzo(a)anthracene
C1-dibenz(a,h)anthracene
C1-fluoranthene/pyrene
C1-fluorenes
C1-naphthalenes
C1-phenanthrene/anthracene
C2-chrysenes/benzo(a)anthracene
C2-dibenz(a,h)anthracene
C2-fluorenes
C2-naphthalenes
C3-dibenz(a,h)anthracene
C3-fluorenes
C3-naphthalenes
C3-phenanthrene/anthracene
C4-chrysenes/benzo(a)anthracene
C4-naphthalenes
C4-phenanthrene/anthracene
Chrysene
Dibenzo(a,h)anthracene
Dibenzothiophene
Dieldrin
Di-n-butyl phthalate
Di-n-octyl phthalate
Endosulfan sulfate
Ethoxylated nonylphenol phosphate
Fluorene
Gamma-BHC/Gamma-hexachlorocyclohexane
Heptachlor epoxide
Hexachlorobutadiene
Indeno(1,2,3-c,d)pyrene
Methoxychlor
Nonylphenol
Pentachloroanisole
Phenanthrene
Polybrominated terphenyls
Polychlorinated alkenes
Polychlorinated terphenyls
Pronamide
Tetradifon
Toxaphene

Seattle District List 4: Not Currently Considered Bioaccumulative Chemicals

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Bromoxynil
Cadmium
Chromium
Copper
Dicamba
Dichlobenil
Dimethyl phthalate
Diuron
Endrin
Ethylbenzene
Fenitrothion
Guthion
Heptachlor
Hexachloroethane
Methyl parathion
Methyltin trichloride
Naphthalene
Nickel
N-nitroso diphenylamine
Phenol
Silver
Tetrachloroethene
Trichloroethene
Triphenyltin chloride
Zinc

Portland District

Comprehensive tissue data were not available from all areas regulated by the Portland District. However, the following list was generated through a review of the Portland Harbor tissue data for fish and shellfish, and is considered likely to capture any contaminants likely to be present in most areas. The same criteria used in Seattle District were used to develop the Portland District lists. Some List 3 chemicals on the more comprehensive Seattle District list were added to List 3 for Portland District for completeness.

Portland District List 1: Primary Bioaccumulative Chemicals of Concern

Dieldrin
Dioxin/furan TCDD toxicity equivalent
Fluoranthene
Fluorene
gamma-Hexachlorocyclohexane
Hexachlorobenzene
Mercury
Methoxychlor
Pyrene
Selenium
Total Chlordanes
Total DDTs
Total Endosulfans
Total PCB Aroclors
Total PCB Congeners
Tributyltin

Portland District List 2: Candidate Bioaccumulative Chemicals

1,2,4,5-Tetrachlorobenzene
4-Nonylphenol, branched
Arsenic
Benzo(e)pyrene
Biphenyl
Chlorpyrifos
Chromium VI
Dacthal
Diazinon
Ethion
Heptachloronaphthalene
Hexachloronaphthalene
Kelthane
Octachloronaphthalene
Oxadiazon
Parathion
Pentabromodiphenyl ether
Pentachloronapthalene
Perylene
Tetrachloronapththalene
Tetraethyltin
Trichloronapththalene
Trifluralin

Portland District List 3: Potentially Bioaccumulative Chemicals

1-Methylnaphthalene
1-Methylphenanthrene
1,2,3,4-Tetrachlorobenzene
Butylbenzyl phthalate
Butyltin ion
Carbazole

1,2,3,5-Tetrachlorobenzene
1,2,3-Trichlorobenzene
1,3,5-Trichlorobenzene
2-Methylnaphthalene
2,6-Dimethylnaphthalene
4,4'-Dichlorobenzophenone
Acenaphthene
Acenaphthylene
Aldrin
Alkylated PAHs
alpha-Hexachlorocyclohexane
Anthracene
Antimony
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Beryllium
beta-Hexachlorocyclohexane
Bis(2-ethylhexyl) phthalate
Chrysene
delta-Hexachlorocyclohexane
Dibenzo(a,h)anthracene
Dibenzofuran
Dibenzothiophene
Dibutyl phthalate
Diphenyl
Endrin ketone
Ethoxylated nonylphenol phosphate
Indeno(1,2,3-cd)pyrene
Nonylphenol
Pentachloroanisole
Pentachlorophenol
Phenanthrene
Polybrominated terphenyls
Polychlorinated alkenes
Polychlorinated terphenyls
Pronamide
Retene
Tetrabutyltin
Tetradifon

Portland District List 4: Not Currently Considered Bioaccumulative Chemicals

1,2-Dichlorobenzene
1,2-Diphenylhydrazine
1,2,4-Trichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2-Chloronaphthalene
2,3,4,5-Tetrachlorophenol
2,3,5,6-Tetrachlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
Dimethyl and diethyl phthalates
Di-n-octyl phthalate
Diuron
Endosulfan sulfate
Endrin
Endrin aldehyde
Ethylbenzene
Fenitrothion
Guthion
Heptachlor
Heptachlor epoxide

2,4-Dinitrotoluene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,6-Dinitrotoluene
2-Chlorophenol
2-Methylphenol
2-Nitroaniline
2-Nitrophenol
3-Nitroaniline
3,3'-Dichlorobenzidine
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
4,6-Dinitro-2-methylphenol
Aniline
Azobenzene
Benzoic acid
Benzyl alcohol
Bis(2-chloro-1-methylethyl) ether
Bis(2-chloroethoxy) methane
Bis(2-chloroethyl) ether
Bis(2-chloroisopropyl) ether
Bromoxynil
Cadmium
Chromium
Copper
Dibutyltin ion
Dicamba
Dichlobenil
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Isophorone
Lead
Methyl parathion
Methyltin trichloride
Mirex
Naphthalene
Nickel
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosodipropylamine
Oxychlordane
Phenol
Silver
Tetrachloroethene
Toxaphene
Trichloroethene
Triphenyltin chloride
Zinc

Walla Walla District

Comprehensive tissue and sediment data were not available from all areas regulated by the Walla Walla District. Therefore, the approach used for the Seattle and Portland Districts cannot be applied until more data become available. The following list was generated through the use of multiple lines of evidence. A review of published toxicity, half-life, bioaccumulation factors, peer-reviewed literature, and use patterns was conducted, but no single line of evidence was considered definitive. Information on industrial and manufacturing chemicals of concern is extremely limited due to the lack of industrial development in the Walla Walla District. Considerable information on use patterns and environmental fate is available for agricultural chemicals for southeast Washington, Idaho, and eastern Oregon. The criteria used to develop the four lists were based on multiple lines of evidence for each constituent and do not rely on discreet cut-off values. A more detailed report describing the multiple line-of-evidence evaluation is in preparation; please contact the Walla Walla District for more information.

Walla Walla District List 1: Primary Bioaccumulative Chemicals of Concern

Arsenic

Chlordane

Dieldrin

Dioxins/Furans

DDTs – (includes DDD and DDE degradation products)

Fluoranthene

Hexachlorobenzene

Lead

Mercury

Pentachlorophenol

Pyrene

Selenium

Walla Walla District List 2: Candidate Bioaccumulative Chemicals

Cypermethrin

lambda-cyhalothrin

Triphenyltin

Zeta cypermethrin

Walla Walla District List 3: Potentially Bioaccumulative Chemicals

DCPA

Fenbutatin

Ethyl parathion

Walla Walla District List 4: Not Currently Considered Bioaccumulative Chemicals

Abamactin
Aceflourfen
Acefate
Acetamiprid
Acebenzolar
Aceflourfen
Acifluorfen*
Aclonifen*
Acrolein*
Ametryn
Amitriz
Azadirachtin
Azoxystrobin
Benefin
Benomyl
Benzyladenine
Bifenthrin
Bifenzate
Boscalid
Bromacil
Bromoxynil
Buprofezin
Butylate
Cadmium
Calcium polysulfide
Carbofuran
Carfetrazone ethyl
Clorimuron
Chlorsulfuron
Chromium
Clethodim
Clodinafop-propargil
Diclofop methyl
Dicloran
Dicofol
Difenzoquat
Diflufenzopyr sodium
Dimethipin
Dimethomorph
Disulfoton
Diuron
Dodecadien
Dodecanol
Endothal
Esfenvalerate
Ethalfluralin
Ethephon
Ethion
Etoxazole
Famoxadone
Finamidone
Fenamiphos
Fenarimol
Fenbuconazole
Fenhexamid
Fenoxaprop P
Fenpropathrin
Fipronil
Fluazifop P butyl
Flucarbazone
Fludioxnil
Flumetsulam
Fluoxypr 1-methyl hex
Flutolanil

Clofentazine
Clomazone
Clopyralid
Copper
Copper salts
Cyanamid
Cyanazine
Cycloate
Cyfluthrin
Cymoxanil
Cymorazine
Cyprodinil
Desmedipham
Dicamba potassium salt
Dicamba sodium salt
Imazamthabenz
Imazamox
Imazapyr
Imazethapyr
Imidacloprid
Indoxacarb
Isoxaflutole
Kresoxim methyl
Lactofen
MCPA sodium salt
MCPB
Mesosulfuron methyl
Mesotrione
Metalaxyl
Methidathion
Methomyl
Methoxychlor
Metasulfuron methyl
Formesafen
Fonofos
Foramsulfuron
Formetanate
Fosetyl al
Gibberelic acid
Giberellins A4 A7
Glufonisate ammonium
Halosulfuron
Harpin
Hexazinone
Hexythiazox
Pyrazon
Pyrethrins
Pyridaben
Pyridate
Pyrimethanil
Pyriproxyfen
Quizalofop
Quizalofop ethyl
Rimsulfuron
Sethoxydim
Silver
Spinosad
Spiromesifen
Streptomycin
Streptomycin sulfate
Sulfentrazone
Sulfosulfuron
Tebufenozide

Mevinphos
Monocarbamide
Myclobutanil
NAA
NAD
Naled
Napropamide
Naptalam
Nicosulfuron
Nickel
Oryzalin
Oxydementon methyl
Oxytetracycline
Oxythioquinox
*PCBs – Total Aroclors
Phenmedipham
Phosphamidon
Picloram
Piperonyl butoxide
Primsulfuron
Prohexidione calcium
Propachlor
Propamocarb hydrochloride
Propaconazole
Prosulfuron
Pymetrozine
Tebuprimphos
Tefluthrin
Terbacil
Tetradecanol
Thiamethoxam
Thifensulfuron
Thiodicarb
Tralkoxydim
Triadimefon
Triasulfuron
Triazole
Tribenuron
*Tributyltin
Tridiphane
Trifloxystrobin
Triflumazole
Trifluralin
Triflusulfuron methyl
Triforine
Vernolate
Vinclozolin
Z, 8, Dodecanol acetate
Z, 8, Dodecanol
Zinc
Zinc phosphide
Zoxamide

* Chemicals are not used or not detected in the area.

Appendix D. Biological Testing Toolbox

Appendix D is companion to Chapter 7 (Biological Toxicity Testing) and Chapter 8 (Bioaccumulation Evaluation). This appendix identifies test species for marine and freshwater benthic toxicity testing and bioaccumulation testing, other biological endpoint tests, and references for laboratory test species selection and endpoint laboratory assays.

Biological Testing Methods Evaluation

(Instructions follow the table)

Tool / Test Species	Method	Measurement Endpoints	Marine, Estuarine, or Freshwater	Reference No.	Acute / Chronic/ Chronic Surrogate	Sublethal Endpoint	Ease of Use	Repeat-ability	Organism Availability/ Seasonality	Holding Constraints	Protocol Status	Field Valid-ation	Current Interp. Criteria	Cost
Solid Phase Sediment Toxicity Tests (relevant for in-place sediments, effects at disposal site)														
Bivalve larvae (oyster-*Crassostrea gigas*)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	M
Bivalve larvae (*Mytilus* spp.)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	LM
Sea Urchin (*Strongylocentrotus purpuratus*)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	LM
Sand dollar (*Dendraster excentricus*)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	LM
Ampelisca abdita	10-day	Survival	Marine, estuarine	1, 2	A	N	2	1	2	N	3	Y	N, W	M
Eohaustorius estuarius	10-day	Survival	Marine, estuarine	1, 2	A	N/Y	1	1	1	N	3	Y	N, W	M
Rhepoxynius abronius	10-day	Survival/ reburial	Marine	1, 2	A	N/Y	1	1	1	N	3	Y	N, W	M
Grandidierella japonica	10-day	Survival	Marine, estuarine	2, 3	A	N	1	1	1	N	2		N	M
Leptocheirus plumulosus	10-day	Survival	Marine, estuarine	2, 3	A	N	1	1	1	size/age	3	Y	N, W	M
Corophium spp.	10-day	Survival	Marine, estuarine	2	A	N	2	1	2	?	2		N	M
Neanthes arenaceodentata	10-day	Survival	Marine, estuarine	4	A	N	1	1	only one supplier	size/age	3		N, W	M
Mysid shrimp	10-day	Survival	Marine, estuarine	5	A	N	1	1	1	N	1		?	M
Shrimp (*Panaeus, Palomonetes*)	10-day	Survival	Marine	2	A	N	1	1	3	?	2		N	M
Hyalella azteca	10-day	Survival	Estuarine, freshwater	2, 6, 7	A	N	1	1	1	N	3		N, W	M
Chironomus spp.* - Midge	10-day	Survival, growth	Freshwater	2, 6, 7	A	Y	1	1	1	N	3	Y (EPA 2000b)	N, W	M
Lumbriculus variegatus	10-day	Survival	Freshwater	2	A	Y	1	1	1	N	2		N	M
Tubifex tubifex	10-day	Survival	Freshwater	2	A	Y	1	1	1	N	2		N	M
Pristina spp. (naidia oligochaete)	10-day	Survival	Freshwater	2	A	Y	1	?	3	?	2		N	M

Tool / Test Species	Method	Measurement Endpoints	Marine, Estuarine, or Freshwater	Reference No.	Acute / Chronic/ Chronic Surrogate	Sublethal Endpoint	Ease of Use	Repeat-ability	Organism Availability/ Seasonality	Holding Constraints	Protocol Status	Field Valid-ation	Current Interp. Criteria	Cost
Hexagenia spp. (mayfly larvae)	10-day	Survival	Freshwater	2	A	Y	1	?	3	?	2		N	M
Anodonta spp. (freshwater mussel)	10-day	Survival	Freshwater	2	A	Y	1	?	3	?	2		N	
Neanthes arenaceodentata	20-day	Survival & growth	Marine, estuarine	1, 4	C	Y	1/2	1	only one supplier	size/age	3	Y	N, W	M
Armandia brevis	28-day	Survival & growth	Marine	8, 9, 10, 11	C	Y	2	?	3	age	2		?	H
Leptocheirus plumulosus	28-day	Survival/ growth/ repro.	Marine, estuarine	3, 12	C	Y	2/3	1/2	1	size/age	3	Y	N, W	H
Hyalella azteca	28-day	Survival & growth	Estuarine, freshwater	7	C	Y	2	2	1	N	3	Y (EPA 2000b)	N	H
Hyalella azteca	42-day	Survival & growth	Estuarine, freshwater	7	C	Y	2	2	1	N	3		N	H
Chironomus spp.* - Midge	20-day	Survival & growth	Freshwater	7	C	Y	1	2	1	age	3	Y	N, W	M
Chironomus spp.* - Midge	40-day	Life cycle	Freshwater	6, 7	C	Y	1	2	1	age	3	Y	N	M
Chironomus riparius	10- to 30-day	Survival, growth, head capsule width, emergence	Freshwater	6	C	Y	2	2	1	age	3		N	M
Hexagenia spp. - Mayfly	21- day	Survival & growth	Freshwater	6	C	Y			3	age	3		N	M
Daphnia, Ceriodaphnia	7-day	Survival, growth, repro.	Freshwater	6	C	Y	1	1	1	N	3		N	M
Diporeia spp. - Amphipod	28-day	Survival & behavior	Freshwater	6	C	Y			2/3	N	2		N	M
Tubifex tubifex	28-day	Survival & repro.	Freshwater	6	C	Y			1	N	2		N	M
Elutriate/Suspended Particulate (relevant for disposal site and effects during dredging event)														
Shrimp (*Palaemonates* sp., *Penaeus* sp.)	96-h	Survival	Marine	2	A	N	1	1	2	N	2		N	M
Cladocerans (*Daphnia, Ceriodaphnia)*	96-h	Survival	Freshwater	2	A	N	1	1	1	N	3		N	M
Fish, marine (*Menidia, Cypridon, Leurethes*)	96-h	Survival	Marine	2	A	N	1	1	1/2	N	3		N	M
Fish, freshwater *(Pimephales, Lepomis, Onchyrynchus, Ictalurus)*	96-h	Survival	Freshwater	2	A	N	1	1	1/2	N	3		N	M

Tool / Test Species	Method	Measurement Endpoints	Marine, Estuarine, or Freshwater	Reference No.	Acute / Chronic/ Chronic Surrogate	Sublethal Endpoint	Ease of Use	Repeat-ability	Organism Availability/ Seasonality	Holding Constraints	Protocol Status	Field Valid-ation	Current Interp. Criteria	Cost
Speckled Sandab (*Citharichtys stigmaeus*)	96-h	Survival	Marine	2	A	N	1	1	1	N	3		N	M
Cladocerans (*Daphnia, Ceriodaphnia)*	7-day	Survival & repro.	Freshwater	6	C	Y	1	1	1	N	3		N	L
Opossum Shrimp (*Mysidopsis bahia* or *Holmesimysis costata*)	96-h	Survival	Marine, estuarine	2	A	N	1	1	1	N	3		N	M
Microtox (Northwest method)	15-min	Bioillumination	Marine, estuarine, & freshwater	1	CS	Y	3	1	1	N	3	?Y	W	L
Sediment Bioaccumulation (Laboratory assay)														
Bivalve (*Macoma nasuta, Yolinda* sp., *Tapes* sp.)	28-day	Tissue burden	Marine	1, 13	NA	NA	1	NA	1	N	3		N, W	H
Nereis virens, Arenicola marina	28-day, 45-day	Tissue burden	Marine	1, 13	NA	NA	1	NA	1	N	3		N	H
Corbicula fluminea	28-day	Tissue burden	Freshwater	35	NA	NA	1	NA	1	N	2		N, W	H
Nepthys caecoides	28-day, 45-day	Tissue burden	Marine	1	NA	NA	1	NA	1	N	3		N, W	H
Neanthes arenaceodentata	28-day	Tissue burden	Marine	2	NA	NA	1	NA	only one supplier	size/age	3		N	H
Lumbriculus spp.	28-day	Tissue burden	Freshwater	13	NA	NA	2	NA	1	Y	3		N, W	H
Armandia brevis	28-day	Tissue burden	Marine	9	NA	NA	3	NA	3	age	1			H
Diporeia spp. - Amphipod	28-day	Tissue burden	Freshwater	13					3		1		N	H

** Recent literature notes that two species of Chironomus have likely been used in toxicity testing, all under the name of Chironomus dilutus. Since there is no way to determine which species may have been used in assays used to develop the FWSQGs, either species is acceptable, but correct species identification should be reported. See ASTM E1706-05*

Instructions for Biological Testing Methods Evaluation

Provided below are definitions of categories and their ranking codes.

Method

This category refers to the test duration.

Measurement Endpoints

This category refers to the possible test endpoint; however, some of these endpoints may not be used in every case (for example reburial).

Marine, Estuarine, Freshwater

No explanation necessary.

Reference No.

Numbers refer to the References Section in this appendix.

Acute/Chronic/Chronic Surrogate

A = acute; C = chronic; CS = chronic surrogate.

Sublethal Endpoint

A yes/no question—does the test have a sublethal endpoint?

Ease of Use

1 = easy, no special training; 2 = moderately hard, requires experience; 3 = difficult or tricky, requires special training.

Repeatability

1 = round-robin tests or established control charts indicate a robust test—used frequently and shown to be reliable; 2 = endpoint is a little tricky and results variable; 3 = lack of data regarding repeatability.

Organism Availability/Seasonality

1 = readily available year-round; 2 = readily available during a particular season; 3 = difficult to acquire.

Holding Constraints

A yes/no question—some animals are not held, so although they may be difficult to hold prior to testing, this is not an issue.

Protocol Status

1 = experimental; 2 = a protocol has been established; 3 = standard test that is applied routinely or commercially.

Field Validation

Has there been a field validation study conducted to evaluate whether this tool is protective of the environment? A yes in this category does not imply that the field validation study indicated that the tool was indeed effective.

Current Interpretive Criteria

Do interpretive criteria exist for this method? If so, are there criteria in the Pacific Northwest (W) or anywhere else in the U.S. (N)?

Cost

L = <$200–$300 per sample; M = <$1,000 per sample; H = >$1,000 per sample. Varies depending on number of samples and special circumstances. Bioaccumulation tests are generally considered expensive—but even with bioaccumulation tests, there is variation depending on the length of test, test volume, and test species.

Biological Endpoints

These endpoints are not commonly used in dredged sediment evaluations. For reviews and selected assays, please see the References Section that follows this table.

Tool/Test Species	Reference No.
Sublethal Cellular Assays/Biomarkers	
Genotoxicity - Anaphase Aberration	1
Genotoxicity DNA Damage Index/Adducts	14
Genotoxicity - Micronucleii	15
Mixed-Function Oxygenases (MFOs) - EROD Activity	16, 17,18
MFOs - Benzopyrene hydroxylase (BPH)	19
Glutathione-S-transferase	18, 20, 21
P-glycoprotein	22
Oxidative Stress - Catalase	19, 23
Oxidative Stress - Superoxide dimutase (SOD)	19, 23, 24
Glutathione peroxidase	18, 25
Glutathione reducatase	18, 25
Glutathione redox states	18
Total glutathione (GSH)	25, 26
Liquid peroxidation - thiobarbituric acid reactive substances (TBARS)	25, 26
Metallothioneins	27
Heat-shock proteins	28
Achetylcholinesterase inhibition (AChE)	20
General overviews: biomonitoring	29, 30
General bioassessment, freshwater	31
General bioassessment, estuarine/marine	32
General overview, estuarine biomarkers	33
General overview, markers of oxidative stress	34

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Appendix E. Derivation of Bioaccumulation Target Tissue Levels and Sediment Bioaccumulation Triggers

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This appendix identifies methods that can be used for calculating target tissue levels (TTLs) for various exposure pathways in sections E.1 to E.3 below. The TTLs will be used as part of reason to believe, to periodically review the regional bioaccumulative chemicals of concern (BCoC) lists over time, and as criteria against which the results of bioaccumulation testing can be compared to determine whether sediment BCoC levels are suitable for open-water disposal or require other disposal approaches. The TTLs can also be used to determine whether the post-dredge surface BCoC levels will present unacceptable bioaccumulation risks. The human health TTLs in this appendix are provided for illustrative purposes. **Once the local review team and project proponent have identified potential exposure pathways, they will need to work with the state water quality program to establish the designated uses of the water bodies where the dredging operation and sediment disposal will take place and develop TTLs based on those uses.** Where those exposure pathways potentially exist, TTLs must be used that ensure the waterbody remains "fishable and swimmable," consistent with the Clean Water Act.

Derivation methods for TTLs contain conservative assumptions and methods that may result in very low values, although every attempt will be made to derive values that are realistic while still being protective and in compliance with state and federal regulations. Some of the calculations do result in TTLs that are below background concentrations and detection limits. In these cases, the use of a TTL will default to a comparison to background tissue levels, or detection limits if background levels are undetected. The agencies continue to be involved in extensive regulatory, legal, technical, and stakeholder discussions around this issue, and further developments can be expected over time. These developments will be subsequently incorporated into the SEF.

While sediment bioaccumulation triggers (BTs) have not yet been developed by RSET, section E.4 discusses derivation methods that could be used on a regional, site-, or project-specific basis to do so. In addition, the Oregon Department of Environmental Quality (ODEQ) recently developed sediment BTs that can be used (ODEQ 2007).

E.1. TTLs for Aquatic Life

This section presents the approach used to develop TTLs for aquatic life. This TTL represents the concentration or target level of a bioaccumulative contaminant in tissue that is considered protective of aquatic organisms (fish and invertebrates). The tissue residue approach (TRA) has been used to generate protective TTLs that can be applied to both laboratory bioaccumulation tests and field-collected organisms, where sufficient data were available to do so.

In addition, ODEQ has recently derived TTLs for fish, shellfish, and aquatic organisms for 19 constituents based on the regional BCoC list (ODEQ 2007): 17 of these TTLs were derived using the Water Quality Criteria Bioaccumulation Factor approach (WQC-BCF) described in section E.1.5 and 2 were derived using the RSET recommended Species Sensitivity Distribution (SSD) approach as described in section E.1.4.

The following sections provide information on the TRA methodology and the two specific methods for deriving TTLs that were used for the values presented in the SEF. The final section and Table E-1 present the currently proposed TTLs for aquatic life. Table E-2 presents the aquatic life TTLs from the ODEQ sediment bioaccumulation guidance (ODEQ 2007) for constituents not included in Table E-1. These

levels can be used as interim values until aquatic life TTLs can be derived for these constituents based on the RSET recommended methodology.

There is no regulatory consensus on some of the specific details of the SSD methodology that RSET is recommending for the development of aquatic life TTLs. For example, there are differences in opinion amongst regulatory agencies as to which hazardous concentration percentile (HC_p) should be selected for identifying a protective aquatic life TTL. For the purpose of this version of the SEF, the rationale for the selected HC_p is provided (see section E.1.4). As the use of SSDs to develop aquatic life TTLs becomes more widespread, greater consistency in the application of the methodology will likely emerge amongst regulatory agencies. The aquatic life TTLs will likely be revised in the future to reflect the standard of practice in the use of this methodology.

Table E-1. Aquatic life TTLs based on SSDs.

Chemical	Responses	Species	TRV HC_{05}	HC_{05} Method	Citation for Data
TCDD (TEQ)	Mortality	Fish ELS	0.039 ng/g lipid	From paper	Steevens et al. 2005
Mercury	Mortality, growth, reproduction, behavior	Fish	0.11 mg/kg ww	From paper	Beckvar et al. 2005
Tributyltin	Growth	All spp.	0.19 mg/kg ww	Burrlioz	Meador et al. 2002b
Tributyltin	Reproduction	Gastropods	0.02 mg/kg ww	Burrlioz	Meador et al. 2002b
Selenium	Sublethal	Fish ELS and juveniles	7.91 mg/kg dw	From criterion	EPA 2004
Total PCBs (Aroclors)	All	Salmonids	1.4 mg/kg lipid	Burrlioz	Meador et al. 2002a
DDT	Mortality, growth, reproduction	Fish adult	0.09 mg/kg ww	From paper	Beckvar et al. 2005
Chlorophenols[a]	Mortality	All spp.	0.011 µmol/g ww	Burrlioz	Meador 2006
Pentachloro-phenol	All sublethal	All spp.	0.001 mg/kg ww	Burrlioz	Meador 2006
All hydrophobic organics[b]	Mortality	All spp.	2.16 µmol/g lipid	Burrlioz	Di Toro et al. 2000

Notes: ELS = early life stage; dw = dry weight; ww = wet weight

[a] Several compounds (2 CP, 3 CP, 4 CP, 2,3 DCP, 2,4 DCP, 2,5 DCP, 2,6 DCP, 3,5 DCP, 2,3,5 TCP, 2,4,5 TCP, 2,4,6 TCP, 2,3,4,6 TeCP; CP is chlorophenol, DCP, TCP, and TeCP and di-, tri-,tetra chlorophenol)

[b] Based on several compounds (1,2 and 1,4 dichloro-, difluoro-, and dibromobenzene, 1,2,3 and 1,2,4 trichlorobenzene, 1,2,3,4 tetrachlorobenzene, pentachlorobenzene, 1,1,2,2 tetrachloroethane, naphthalene and fluoranthene)

Table E-2. Aquatic life TTLs based on AWQC (ODEQ 2007).

Chemical	CASRN	Freshwater TTL (mg/kg) ww	Marine TTL (mg/kg) ww
Arsenic	7440-38-2	6.6	1.6
Cadmium	7440-43-9	0.15	0.15
Chlordane	57-74-9	0.06	0.056
4,4'-DDE	72-55-9	0.054	0.054
4,4'-DDD	72-54-8	0.054	0.054
Dieldrin	60-57-1	0.26	0.26
Lead	7439-92-1	0.12	0.40
Pyrene	129-00-0	1.0	1.0
Flouranthene	206-44-0	19	19
Hexachlorobenzene	118-74-1	32	32

Notes: ww = wet weight; refer to ODEQ (2007) for additional information on these TTLs

E.1.1. Chemicals for Which Aquatic Tissue Quality Guidelines Can Be Derived

In theory, tissue TTLs can be derived for any chemical or compound that is bioaccumulated into aquatic biota tissues. As shown by McCarty et al. (1991), for organic chemicals with a log $K_{OW} < 1.5$, the chemical concentration in the water phase of the organism dominates toxicity, and total body residues associated with toxicity should be similar to the respective water-based toxicity metric.

Tissue TTLs should not be derived for chemicals that fall into three rather broad categories:

1. Chemicals that do not appreciably bioaccumulate
2. External toxicants and irritants
3. Bioaccumulative compounds that do not result in measurable tissue residues due to rapid biotransformation

Some chemicals are quite toxic without appreciable bioaccumulation. Cyanide is one example of a highly toxic chemical with a low bioaccumulation potential. Many chemicals in this group have high water solubility that may not preferentially partition from water to tissues, resulting in low tissue concentrations associated with toxicity.

External toxicants do not need to enter the body of an organism to elicit toxicity. These chemicals, such as contact herbicides and some irritants, act by destroying the cell wall or inducing mucus that can suffocate the gills. Many metals at high external exposure concentrations can also act this way. Additionally, iron and aluminum are two chemicals that, under certain conditions of water quality, form flocculent materials that coat the gills of aquatic species, causing death by suffocation without entering the body of the organism.

One example of rapidly biotransformed compounds are the polycyclic aromatic hydrocarbons (PAHs). Because PAHs are extensively transformed in vertebrates, a tissue residue response curve cannot be determined for fish; however, this can be accomplished for invertebrates due to a weak cytochrome P450

system. For PAHs, recent work has demonstrated that fluorescent aromatic compounds (FACs) in bile can be used to assess bioaccumulation and toxicity. Meador et al. (2006, 2008) found a high correlation between bile FACs, dietary intake of PAHs, and toxicity in juvenile salmon. Biliary FACs are a surrogate measure of the internal tissue concentration and would be appropriate for characterizing exposure and toxicity in fish. The PAH metabolites in bile will be considered by RSET in future evaluations once candidate thresholds are developed by the National Oceanic and Atmospheric Administration.

E.1.2. Protocols for Developing TTLs

Two approaches are described here for developing tissue TTLs:

1. Using existing critical body residue (CBR) values. Chemical-specific values are considered as a mean or preferably analyzed with a species sensitivity distribution (SSD). From the SSD, a protective tissue TTL is determined.
2. Predicted tissue-residue toxicity metrics using existing or modeled exposure media toxicity metrics and bioaccumulation factors (e.g., WQC-BCF approach).

Tissue TTLs can be developed for some chemicals using existing residue-effects information from the technical literature. The preferred approach is to examine the data as a SSD; however, if only a few data points are available (<4), a mean and standard deviation may be determined and used as the chemical-specific TTL. For chemicals without sufficient residue-effects information, a bioaccumulation model may be used to develop tissue TTLs; however, these values will have a higher level of uncertainty.

The strengths and limitations of each of the two primary tissue TTL development methods are described below, as are some of the available options within the two approaches.

E.1.3. Using Existing Critical Body Residue (CBR) Values and Species Sensitivity Distribution (SSD) Approach

The first step in this method for deriving TTLs is to identify existing CBR values. The Environmental Residue Effects Database (ERED; Bridges and Lutz 1999) and Jarvinen and Ankley (1999) are the two primary sources of residue-effects information that could be used to develop SSDs. One difficulty with using measured residue effects data to derive tissue TTLs is data availability. There is simply less information available in the literature on tissue residues associated with toxicity than there is on water column or sediment concentrations associated with toxicity. The EPA AQUIRE database, the repository of toxicity data for chemicals in water, contains over 180,000 records. In contrast, the ERED database contains approximately 4,000 records. This limitation does not preclude the use of literature data to derive tissue TTLs, but the limited available information for many chemicals in turn limits both the number and reliability of tissue TTLs derived from the literature.

The ERED database contains primarily results from studies examining survival, growth, and reproductive endpoints and has not compiled much of the available residue-effects literature on other responses, such as biochemical, physiological, morphological, and behavioral effects of bioaccumulated chemicals. Other specialized databases on tissue residues are being developed and introduced, such as the PCB residue database summarizing residue-effect data for dioxin-like toxicity in fish, mammals, and birds (EPA 2008).

In addition, the methods by which the residue-effects information is published and reported impose additional restrictions on the ability of scientists to evaluate and draw inferences from the existing data. Unlike water-based toxicity data, nearly all of which is reported as dose-response statistics (e.g., LC_{50}, EC_{20}, etc.), relatively little of the residue-effects literature is reported as such. Unfortunately, a large percentage of the available tissue-based toxicity metrics are expressed as lowest observed effects residues (LOERs), which are determined as the lowest dose producing a statistically significant adverse response compared to the control. The LOERs are dependent on the quantal nature of allocating exposure concentrations (often few and far between), a function of sample size (often low), highly prone to Type II error (finding no effect when in fact an effect exists), low power of the test, and a bright-line significance value ($\alpha = 0.05$) that ignores biologically important results. Occasionally, the no observed effects residue (NOER) is used, which also exhibits potential flaws because it is not based on a toxicity response but represents negative evidence. The NOER values do not provide reliable information regarding the probability that a given toxicant concentration will not cause a biological response and therefore should not be used directly to calculate TTLs.

Empirical Data

Once all available studies have been examined, those that are deemed acceptable are used to compile a list of values (e.g., LR_{50}, ER_{10}, LOER values). From these data, basic statistics such as mean, variance, and confidence intervals are produced with the algorithms. For tissue-residue toxicity data, many of the data sets are expected to follow a normal distribution because of the expected uniformity across species. For example, the LR_{50} data for chlorophenols and tributyltin as well as the TBT growth CBRs presented in this review are normally distributed (Meador 2006). When chemical-specific data sets are normally distributed, a mean and standard deviation may be calculated; however, these data can be subjected to an SSD evaluation (see below). If data sets contain less than 4 CBRs, it is appropriate to simply calculate a mean and the lower 95% confidence interval (LCI) of the mean for use as the TTL. For those TTL values that are determined as a simple mean, a TTL for these data would be the lower 95% confidence limit of the mean. If the data are not normally distributed, an SSD approach is preferred (see below). For those chemical-specific CBRs that are lognormally distributed, the appropriate algorithms also should be used because the standard equations are biased. Gilbert (1987) provides algorithms for calculating these basic statistics for log-normally distributed data.

E.1.4. SSD Approach

The SSD approach has been used extensively to examine toxic responses (Posthuma et al. 2002a). It has been used in various forms to determine water quality in Europe, water quality criteria (WQC) in the United States by the EPA (Stephan et al. 1985), to derive sediment quality guidelines (Long and Morgan 1991), and in various frameworks for ecological risk assessment.

The SSD can be strictly an empirical cumulative distribution function or a line may be fitted to the data based on the known distribution (e.g., lognormal) using the mean and standard deviation for the data. In recent years, the hazardous concentration percentile (HC_p; p = percentile) has become the standard way to select a concentration for protection. In many applications, the HC_{05}, or that concentration representing the 5th percentile of the SSD, is selected to protect the 100 - p percentile of all species. The HC_p for protection may be simply the 5th percentile of the observed data or an interpolated value from a fitted distribution. One major drawback to the latter approach is the selection of the best distribution to fit the

data. Goodness of fit tests (e.g., Kolmogorov-Smirnoff; K-S) can be used to test the chosen distribution. If the K-S test fails, alternate methods are recommended. Recently, bootstrap techniques have been applied to data sets to determine HC_p values (Newman et al. 2000). The main advantage of bootstrapping is that it is applied to the raw data and is nonparametric (no distribution is assumed); however, relatively large data sets are required (i.e., > 20 values).

There is one software program (Burrlioz) that can be used to fit toxicity data to species sensitivity distribution. This program was developed by the CSIRO in Australia (https://research.csiro.au/software/burrlioz/). This program will fit the entered values to the Burr Type 3 (Shao 2000), log-logistic, and lognormal distributions. Burrlioz also calculates the HC_p effect concentration at various percentiles and the percent confidence interval for that HCp.

When an SSD is used to derive tissue TTLs, a policy decision is required to determine at what level of effect (or the proportion of species to be protected) the TTL should be set. For consistency with EPA's WQC derivation methodology and several ERA frameworks, the 5th percentile of the adverse effects data for survival, reproduction, and growth is used as the selected TTL in the SEF (Stephan et al. 1985; Posthuma et al. 2002a).

The minimum number of values required for a chemical-specific, tissue-based SSD has not been determined. The number of data points needed to characterize the toxicity response is a function of the variability among species and the randomness of the selection. Most SSDs are constructed with media-based exposure metrics that are more variable than those based on tissue residues. For media exposures, the European Union Technical Guidance Documents prescribes 10 values from at least 8 taxa and the Netherlands requires 4 values from 4 taxa (Posthuma et al. 2002b). In some cases, an SSD with few data points will not change appreciably when more points are added. A minimum of 4 data points from 4 taxa for generating an SSD has been selected for calculating TTLs under RSET. This value is also supported by Pennington (2003), who examined sample size on SSDs and HC_{05} determinations.

The aquatic life TTLs presented in Table E-1 are based on the HC_{05} point estimate as discussed above. Table E-1 also provides the source of the HC_{05} point estimate, either the original literature reference or the Burrlioz software program described above.

E.1.5. Toxicity-Bioaccumulation Modeling Approach

A more general modeling approach for calculating TTLs may be used as was done by ODEQ when developing the majority of the aquatic life TTLs presented in the Sediment Bioaccumulation Guidance (ODEQ 2007). For this method, a tissue CBR is derived from the product of an established water quality criterion and a generic bioconcentration factor (or bioaccumulation factor) that has been calculated using toxicokinetics, quantitative structure activity relationships (QSARs), or that represents the 95th percentile of all BCFs for that chemical. As many water quality criteria and bioconcentration factors are already available, this approach can be used to quickly generate tissue TRVs for a number of chemicals. The ODEQ used readily available BCFs from EPA's water quality criteria documents (ODEQ 2007).

Tissue toxicity reference values (TRVs) derived using the WQC-BCF approach have many uncertainties, including the accuracy of water quality criteria used as an input to the model and using a single BCF (or BAF) to derive applicable tissue TRVs. Addressing these uncertainties during tissue TRV development

may result in TRVs with large safety factors relative to the safety factors of tissue TRVs derived from SSDs. This method is the less preferred of the two described in this section.

E.1.6. Factors to Consider

Biological Responses

One issue of concern that applies to both the bioaccumulation modeling and SSD generation approaches is selecting the toxicological endpoints to incorporate into TTL derivation. The list of endpoints to be considered is dependent on the statute. The Clean Water Act (CWA); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and Endangered Species Act (ESA) each prescribe a different approach for protecting species, and they allow for a different set of biological responses in the derivation of such protective concentrations. The standard set of adverse responses includes effects on survival, reproduction, and growth. Other endpoints are available for consideration when developing tissue TTLs, including toxicant effects on behavior, physiology, morphology, and biochemistry. Evaluation of these additional endpoints in TTL development may be of particular importance for fish species such as salmonids, where contaminant impacts on swimming behavior or olfactory ability may have significant adverse effects on the ability of the fish to return to their natal streams to spawn.

If sufficient data are available, separate TTLs should be developed for fish and invertebrates. These two major groups often exhibit differences in the abundance and affinity of receptors for some toxicants and they often exhibit different biological responses for the same dose. For example, dioxin is far more toxic to fish than to invertebrates. Additionally, these two groups may detoxify toxicants differently resulting in major differences in the biologically effective internal dose. This difference is true for metals and some organics that are metabolized at different rates.

Endangered Species

Threatened and endangered species listed under the ESA are an important concern. Salmonids are one of the most commonly listed aquatic species that occur at many sites where the RSET framework will be applied. For media-based exposure, salmonids are often one of the most sensitive species because of their high rates of prey ingestion and ventilation. For this reason, a species in the family Salmonidae is required for determination of a water quality criterion (Stephan et al. 1985). There are very few data for testing this hypothesis with tissue-residue toxicity statistics. In theory, it is expected that salmonids would exhibit similar sensitivity as other species; however, this is not certain. One review of tissue-residue toxicity metrics for chlorophenols and pentachlorophenol did show that some salmonids were more sensitive than other species, but not in every case (Meador 2006). It is highly recommended that residue-effects data for a surrogate species for an ESA listed species (e.g., rainbow trout for listed salmonids) be considered during any tissue TTL development.

For the SEF, two approaches will be used to develop TTLs protective of ESA species. First, for those TTLs that are derived using SSDs, the species included in the SSD will be evaluated to determine whether a salmonid or other ESA surrogate species was included and whether the corresponding TTL derived is protective of that species. If so, then the TTL will be considered protective of ESA species. For situations where ESA species or a surrogate toxicity data are not available, the TTL will be derived based on a

NOER calculated using uncertainty factors as described in detail below. This analysis is still being conducted and ESA protective TTLs will be added to the SEF in the future revisions/updates to this document.

Uncertainty/Safety Factors

Uncertainty always exists when developing guidelines or threshold values to be used for environmental protection. This uncertainty often necessitates the use of uncertainty (safety) factors to account for variability and to ensure that the proposed values will protect the intended species under most circumstances. Potential factors to be considered include laboratory to field uncertainty, predominance of mortality metrics, extrapolations of effect to no effect values, temporal factors, and species factors (ecologically or economically important species and ESA-listed species).

If a TTL is based mostly on mortality, it will not be useful for field assessments. Once organisms reach tissue concentrations likely to cause mortality, the population impacts will be severe and the probability of finding those individuals in field collections will be very small. A tissue TTL should be based on sublethal responses so that there is the possibility of observing those tissue concentrations in the field and evaluating when the levels are approaching important effect concentrations.

In situations where the low effect values are not based on an ESA species or surrogate, to derive an ESA-protective TTL, a low effect value (e.g., 5th percentile of LOERs) should be extended to a no effect value (NOER), which can be accomplished with a safety factor (uncertainty factor). In many applications, a factor of 10 has been applied (Chapman et al. 1998; Duke and Taggart 2000); however, in some cases that value is higher (Pennington 2003).

For the current framework, it is recommended that the 5th percentile (HC_{05}) of sublethal values be used. Any mortality-based toxicity metrics used in the derivation of a TTL will be subjected to a default lethal-to-sublethal ratio (LSR) of 10.

E.1.7. Summary of Aquatic Life TTLs

At this stage of the RSET process, it is recommended that existing tissue TTLs be used that have been developed for various toxicants and groups of species. Available TTLs are presented in Table E-1. Some of these values were used as recommended by the authors, when consistent with the recommended RSET approach. Other data sets were used with the Burrlioz program to calculate HC_{05} values and the LCI of that value. Species mean values were determined where multiple values occurred in the data set. In situations where TTLs were based on mortality endpoints, an LSR of 10 was used to calculate a LOER value.

The TTLs presented in Table E-1 were derived based on the recommended empirical data-SSD approach. In addition, the ODEQ sediment bioaccumulation guidance (ODEQ 2007) has an aquatic life TTL for cadmium based on an SSD approach.

Table E-2 provides aquatic life TTLs for compounds for which SSD-based TTLs were not available but for which ODEQ has calculated TTLs based on the WQC-BCF methodology and the cadmium SSD TTL based on the HC_{05} point estimate.

E.2. TTLs for the Protection of Aquatic-Dependent Wildlife

This section presents the approach used to develop TTLs for aquatic-dependent wildlife. This TTL represents the concentration or target level of a bioaccumulative contaminant in prey items that are considered protective of birds and mammals that prey on aquatic species such as fish or invertebrates. Thus, contaminants present in prey items at or below the trigger level are predicted not to harm the most sensitive life stage of bird or mammal predators. Because it can be difficult and costly to directly measure tissue concentrations in higher-order receptors, prey items are considered in this framework, which can be monitored to determine if action is warranted to protect aquatic-dependent wildlife from bioaccumulative chemicals in a watershed. Though sediment ingestion is another pathway by which chemicals can enter aquatic-dependent wildlife, the dietary (food ingestion) pathway tends to be the dominant source for bioaccumulative chemicals (Bridges et al. 1999).

TTLs for aquatic-dependent wildlife may not be protective of the prey species themselves (TTLs to protect prey species were developed above in section E.1). However, TTLs that are protective of upper trophic level species are typically protective of species lower in the food chain. These TTLs are derived based on dietary toxicity reference values (TRVs) previously established and reported for the protection of sensitive life stages of higher trophic level species. Therefore, TRVs for the receptors (or surrogate species) identified in a watershed must be available to calculate TTLs for specific aquatic-dependent wildlife (see section E.2.3 for a list of available TRVs).

E.2.1. Selection of Aquatic-dependent Wildlife Receptors

Candidate aquatic-dependent wildlife receptors for freshwater and marine systems were identified by the Bioaccumulation Subcommittee to be considered "representative" or "sentinel" wildlife receptors based on feeding guilds expected for aquatic dependent wildlife in this region. These are presented in Table E-3 and include several avian and mammalian species that consume large amounts of fish and/or shellfish in their diets.

Most of these receptors are found in both freshwater and marine environments. Depending on the type of water body under consideration, shorebirds (such as the stilt, avocet, or sandpiper) may also serve as representative receptors because these birds typically consume aquatic invertebrates including insects and crustaceans, which may bioaccumulate metals/metalloids to a higher degree than fish consumed by predominantly fish-eating birds. Mammals that commonly feed on crustaceans and fish in watersheds include river otter, sea otter, and mink.

Recognizing the difficulties of developing TTLs on a site-specific basis, guidance is provided here for developing TTLs for wildlife prey items that are more broadly applicable to a wide range of areas. If the wildlife sentinel species discussed herein are for some reason less appropriate for a particular site or project, the same general approach may then be used to develop TTLs for the prey items of additional wildlife species. However, it is likely that the concepts presented in this appendix will be applicable to most if not all areas where BCoCs that could impact higher trophic level wildlife are present.

Table E-3. Common aquatic-dependent wildlife receptors in freshwater and marine systems.

Candidate Wildlife Receptors	Scientific Name	Present in RSET Region?	Dominant Food Items
Birds			
Great Blue Heron	*Ardea herodias*	Yes	Fish, crustaceans, small mammals
Belted Kingfisher	*Ceryle alcyon*	Yes	Fish and crayfish
Hooded Merganser	*Mergus serrator*	Yes	Small fish and invertebrates
Black-Necked Stilt	*Himantopus mexicanus*	Yes (summer)	Aquatic (including emergent) insects, small fish
American Avocet	*Recurvirostra americana*	Yes (summer)	Mostly crustaceans and insects (including emergent)
Spotted Sandpiper	*Actitis macularia*	Yes	Aquatic insects, mollusks, worms, crustaceans
Bald Eagle	*Haliaeetus leucocephalus*	Yes	Fish, fish-eating and non-fish eating birds, some mammals
Osprey	*Pandion haliaetus*	Yes	Fish
Mammals			
North American River Otter [1]	*Lutra canadensis*	Yes	Fish predominantly; also crustaceans (crayfish)
Northern Sea Otter [2,3]	*Enhydra lutris lutris*	Yes	Marine shellfish and invertebrates
American Mink [1]	*Mustela vision*	Yes	Crustaceans (crayfish), fish
Harbor Seal [2]	*Phoca vituluna*	Yes	Marine fish, salmon, macroinvertebrates
Orca Whale [2]	*Orcinus orca*	Yes	Fish, marine mammals

[1] Predominantly a freshwater species
[2] Predominantly a marine species
[3] Washington State only

E.2.2. Calculating TTLs

TTLs for selected receptor species were calculated using one of the following two equations. In instances where an estimate of the daily food ingestion rate (FIR) is available on a total mass basis (e.g., kg wet weight), the following equation was used to calculate the TTL:

$$\mathbf{TTL_w} = \frac{\mathbf{TRV_w}}{\mathbf{(FIR/BW)}} \qquad \textbf{Equation E-1}$$

where:

TTL_w = aquatic-dependent wildlife tissue bioaccumulation trigger (mg/kg, wet weight)
TRV_w = toxicity reference value for wildlife receptor (mg/kg body weight/day)
FIR = daily food ingestion rate for wildlife receptor (kg wet weight/day)
BW = body weight for wildlife receptor (kg)

In instances where an estimate of the FIR_a was estimated using an allometric scaling calculation that provides a daily FIR_a in units of kg/kg-body weight/day, the following equation was used to calculate the TTL:

$$\mathbf{TTL_w} = \frac{\mathbf{TRV_w}}{(\mathbf{FIR_a})} \qquad \textbf{Equation E-2}$$

where:

TTL_w = aquatic-dependent wildlife tissue bioaccumulation trigger (mg/kg, wet weight)
TRV_w = toxicity reference value for wildlife receptor (mg/kg-body weight/day)
FIR_a = daily food ingestion rate for wildlife receptor (kg wet weight/kg-body weight/day)

Food ingestion rates and body weights of site-specific wildlife species of interest were selected from available literature sources, including EPA's *Wildlife Exposure Factors Handbook* (EPA 1993b). Similarly, allometric scaling equations to calculate food ingestion rates for site-specific species were taken from EPA (1993b) and Nagy (2001).

E.2.3. Toxicity Reference Values (TRVs)

The TRVs used to calculate TTLs were selected from the identified primary literature sources that are protective of the receptors. The TRVs provide information about the likelihood of biological effects to aquatic-dependent wildlife (e.g., reduced survival, growth, and reproduction) and address what level of bioaccumulation constitutes an "unacceptable adverse effect." Additional site- or project-specific parameters can be used to fine-tune the model and potentially adjust the TTL in an area, if warranted.

The use of TRVs in this document is consistent with the ODEQ's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (2007). The ODEQ (2007) uses the lowest-observable-effect-level (LOAEL) as the basis for calculating TTLs protective of populations of the site-specific receptor and the no-observed-adverse effect level (NOAEL) to be protective of individuals of the site-specific receptor.

Additionally, ODEQ (2007) uses several extrapolations if the desired toxicity threshold was not identified in the literature. The NOAELs were extrapolated to LOAELs by multiplying the NOAEL by 5. The LOAELs were extrapolated to NOAELs by multiplying the LOAEL by 0.1 (ODEQ 2007).

The hierarchy of sources of TRVs for use in developing aquatic-dependent wildlife TRVs as determined by the Bioaccumulation Subcommittee is as follows:

1. EPA avian and mammalian NOAEL TRVs identified in the soil-screening level (SSL) guidance documents (EPA 2005-2007)
2. ODEQ (2007) avian and mammalian NOAEL and LOAEL TRV's selected for use

E.2.4. Aquatic-Dependent Wildlife Receptors Parameters

As presented in Equations E-1 and E-2, the life history parameters required for the selected representative receptor species are body weight (BW) and food ingestion rate (FIR). The body weights selected for TTL calculations were based on mean female body weights, when available, as the NOAEL TRVs are frequently based on reproductive endpoints from exposure to female organisms. If mean female body weights were not available, mean adult body weights were used.

The following sections of text summarize the information used to select representative BW and FIR for aquatic-dependent wildlife species for which TTLs were calculated. These parameters are summarized in Table E-4.

Table E-4. Life history parameters for common aquatic-dependent wildlife receptors in freshwater and marine systems.

Candidate Wildlife Receptors	Body Weight (kg)	Food Ingestion Rate (FIR)
Birds		
Great Blue Heron	2.2	0.388 kg ww/day
Belted Kingfisher	0.147	0.50 kg/kg -BW/day
Hooded Merganser	0.54	0.200 kg ww/day
Black-Necked Stilt	0.160	0.089 kg ww/day
American Avocet	0.312	0.138 kg ww/day
Spotted Sandpiper	0.0471	0.039 kg ww/day
Bald Eagle	4.5	0.54 kg ww/day
Osprey	1.88	0.395 kg ww/day
Mammals		
North American River Otter [1]	9.50	0.91 kg ww/day
Northern Sea Otter [2]	24.2	2.02 kg ww/day
American Mink[1]	0.974	0.156 kg ww/day
Harbor Seal [2]	76.5	0.458 kg ww/day
Orca Whale	7,500	280 kg ww/day

[1] Predominantly a freshwater species
[2] Predominantly a marine species

Great Blue Heron

Body Weight and Daily Food Ingestion Rate

Hartman (1961) and Palmer (1962), as cited in EPA (1993b), report that adult males (mean = 2.57 kg) are slightly heavier in weight than adult females (mean = 2.20 kg). Using the mean adult female body weight and the following regression equation referenced in EPA (1993b) relating the amount of food ingested per day to body weight for wading birds, the daily food ingestion rate was calculated to be 0.388 kg wet weight/day.

$$\log(\mathrm{FIR}) = 0.966 \log(\mathrm{BW}) - 0.640 \qquad \textbf{Equation E-3}$$

where:

FIR = daily food ingestion rate for wildlife receptor (g wet weight/day)
BW = body weight for wildlife receptor (g)

Diet Composition

Various studies referenced in EPA (1993b) confirm that the vast majority of a great blue heron's diet consists of fish. Other prey items identified include amphibians, reptiles, crustaceans, insects, birds, and mammals (EPA 1993b).

Belted Kingfisher

Body Weight and Daily Food Ingestion Rate

Salyer and Lagler (1946), as referenced in EPA (1993b), reported that the sexes are similar in size, although the female tends to be slightly larger. The BW selected to calculate the TTL is the mean of the adult BWs provided in EPA (1993b), which is 0.147 kg. The EPA (1993b) reports a FIR_a of 0.50 kg/kg-body weight/day for this species.

Diet Composition

The EPA (1993b) summarizes the literature with regards to belted kingfisher dietary habits. Belted kingfishers feed on fish that swim near the surface or in shallow waters. However, the diet of the belted kingfisher varies with availability of prey items, and when fish are not available, they have been shown to consume crayfish, other crustaceans, invertebrates, amphibians and reptiles.

Hooded Merganser

Body Weight and Daily Food Ingestion Rate

Dunning (1993) reported adult female hooded merganser BWs ranging from 0.54 to 0.68 kg and adult male body weights range from 0.68 to 0.91 kg. The BW selected to calculate the TTL is the lower of the adult female BWs provided in EPA (1993b), which is 0.54 kg. The daily food ingestion rate was estimated as a function of body weight using the following allometric equations developed for carnivorous birds (Nagy 2001).

$$\mathbf{FIR = 3.048 \times BW^{0.665}} \qquad \textbf{Equation E-4}$$

where:

FIR = daily food ingestion rate for wildlife receptor (g wet weight/day)
BW = body weight (g)

Using the lower of the average female body weight reported in Dunning (1993; 0.54 kg), the calculated food ingestion rate was 0.200 kg wet weight/day (using Equation E-4).

Diet Composition

Hooded mergansers feed primarily by diving for whatever small fish are abundant, but they will also eat aquatic invertebrates, especially as hatchlings (Csuti et al. 2001). They are also known to feed on crustaceans, aquatic insects, and small fish (Bendell and McNicol 1995).

Black-Necked Stilt

Body Weight and Daily Food Ingestion Rate

Robinson et al. (1999) reported that the weight of an adult black-necked stilt can range from 0.136 to 0.220 kg. The BW selected to calculate the TTL is the mean of the adult BWs provided in Robinson et al. (1999), which is 0.160 kg. The daily food ingestion rate was estimated as a function of body weight using Equation E-4 (Nagy 2001).

Using the mean adult BW (0.160 kg) reported in Robinson et al. (1999), the calculated food ingestion rate was 0.089 kg wet weight/day (using Equation E-4).

Diet Composition

The California Wildlife Habitat Relationship System (CWHRS 2005) reported that the black-necked stilt forages in shallow water for insects, crustaceans, mollusks, other aquatic invertebrates, and some small fish.

American Avocet

Body Weight and Daily Food Ingestion Rate

Robinson et al. (1999) reported that the weight of an adult American avocet can range from 0.275 to 0.350 kg. The BW selected to calculate the TTL is the mean of the adult BWs provided in Robinson et al. (1999), which is 0.312 kg. The daily food ingestion rate was estimated as a function of body weight using Equation E-4 (Nagy 2001).

Using the mean BW of 0.312 kg reported in Robinson et al. (1999), the calculated food ingestion rate was 0.138 kg wet weight/day (using Equation E-4).

Diet Composition

The CWHRS (2005) reported that the American avocet forages on mudflats, salt or alkali flats, in shallow-pond areas, and in salt ponds. Preferred foods include aquatic insects, crustaceans, snails, worms, and occasionally seeds of aquatic plants (Cogswell 1977, referenced in CWHRS 2005).

Spotted Sandpiper

Body Weight and Daily Food Ingestion Rate

Maxson and Oring (1980), as presented in EPA (1993b), reported average adult female and male body weights to be 0.0471 and 0.0379 kg, respectively. The BW selected to calculate the TTL is the mean of the adult female BW of 0.0471 kg. The daily food ingestion rate was estimated as a function of body weight using Equation E-4 (Nagy 2001).

Using the average adult female body weight of 0.0471 reported in EPA (1993b), the calculated food ingestion rate was 0.039 kg wet weight/day (using Equation E-4).

Diet Composition

Spotted sandpipers feed primarily on terrestrial and aquatic insects (Bent 1929; Csuti et al. 2001). They may occasionally feed on other benthic macroinvertebrates such as crustaceans, mollusks, and worms (Bent 1929; Csuti et al. 2001) or on leeches, small fish, and carrion (Oring et al. 1983).

Bald Eagle

Body Weight and Daily Food Ingestion Rate

Wiemeyer (1991), as cited in EPA (1993b), reported average adult female and male body weights for bald eagles to be 4.5 and 3.0 kg, respectively. The food ingestion rate was represented as 12% of the body weight on a wet-weight basis, based on a study by Stalmaster and Gessaman (1982), as cited in EPA (1993b), of free-flying eagles in Washington. Using the average female bald eagle body weight, the calculated food ingestion rate was 0.54 kg wet weight/day.

Diet Composition

Bald eagles are opportunistic foragers with site-specific food habits based on available prey species (Anthony et al. 1999; Buehler 2000). In most regions, bald eagles seek out aquatic habitats for foraging and prefer fish (Ehrlich et al. 1988; Buehler 2000). Bald eagles also eat carrion, various water birds, and small mammals (Csuti et al. 2001).

Osprey

Body Weight and Daily Food Ingestion Rate

Poole (1983), as cited in EPA (1993b), reported that the average adult female and male osprey body weights during courtship were 1.88 and 1.48 kg, respectively. The food ingestion rate was reported as 21% of the body weight on a wet weight basis, based on studies of adult female osprey in Massachusetts (Poole 1983, as cited in EPA 1993b). Using the average female osprey body weight of 1.88 kg, the calculated food ingestion rate was 0.395 kg wet weight/day.

Diet Composition

Osprey tend to feed solely on fish, primarily on slow-moving fish that swim near the water surface (Csuti et al. 2001). They may occasionally eat other types of vertebrate prey such as birds, reptiles, and small mammals, and they only rarely feed on invertebrates.

River Otter

Body Weight and Daily Food Ingestion Rate

The life history parameters selected for river otters are based on the accepted parameters for this species that are being used for the Portland Harbor Remedial Investigation/Feasibility Study (Windward 2005). Average adult female and male river otter body weights in western Oregon and Washington have been reported for trapped otters submitted to the US Geological Survey (Grove 2004). Body weights were reported without pelts, and weights were adjusted to estimate body weight with pelts using a methodology agreed upon by EPA, EPA's partners, and the Lower Willamette Group in the preparation of the Ecological Preliminary Risk Evaluation (Windward 2005).

Estimated pelted body weights for adult female and male river otters were 9.46 and 11.15 kg, respectively. The daily food ingestion rate for river otter was estimated as a function of body weight using the following allometric equation presented in Nagy (2001). Nagy (2001) provides two allometric

equations for carnivorous mammals under the group "carnivora" and "carnivores." The allometric equation for the group "carnivora" was used for calculating the FIR as Nagy reports that the mammalian "carnivore" group excludes fish-eating mammals (Nagy 2001).

$$\mathbf{FIR = 0.348 \times BW^{0.859}} \qquad \textbf{Equation E-5}$$

where:

FIR = daily food ingestion rate (g wet weight/day)
BW = body weight (g)

Using the female adult river otter body weight of 9.5 kg, the calculated female food ingestion rate was 0.91 kg wet weight/day.

Diet Composition

River otters are opportunistic carnivores that take advantage of food that is most abundant and easiest to catch, although fish are their primary prey (EPA 1993b). Other components of their diet may include aquatic invertebrates (including crayfish, mussels, clams, and aquatic insects), frogs, snakes, turtles, and occasionally scavenged small mammals and birds (Coulter et al. 1984; Csuti et al. 2001).

Northern Sea Otter

Body Weight and Daily Food Ingestion Rate

Kenyon (1969), as cited in WDFW (2004), reported average adult female and male sea otter body weights to be 24.2 and 37.9 kg, respectively. The daily food ingestion rate for the sea otter was estimated as a function of body weight using Equation E-5 (Nagy 2001).

Using the female river otter body weight of 24.2 kg, the calculated female food ingestion rate was 2.02 kg wet weight/day.

Diet Composition

Sea otters are a highly generalized consumer; most individuals specialize in one to four prey types and prey types differ among individuals (WDFW 2004). Observation of Washington state sea otters indicated that they preyed exclusively on invertebrates including clams, chitons, sea cucumbers, octopus, crabs, and sea urchins (WDFW 2004).

American Mink

Body Weight and Daily Food Ingestion Rate

Hornshaw et al. (1983), as presented in EPA (1993b), reported average farm-raised adult female and male BWs for mink in the summer to be 0.974 and 1.734 kg, respectively. The daily food ingestion rate was estimated as 16% and 12% of body weight on a wet weight basis, based on studies of farm-raised female and male mink in Michigan (Bleavins and Aulerich 1981), as presented in EPA (1993b). Using the female mink parameters, the calculated food ingestion rate for females was 0.156 kg wet weight/day.

Diet Composition

Mink are opportunistic feeders and consume a range of prey including muskrats, fish, frogs, crayfish, small mammals, and birds found near water (Csuti et al. 2001). The prey items of Mink are largely dependent on availability, and portions of fish in the mink diet vary widely across field studies.

Harbor Seal

Body Weight and Daily Food Ingestion Rate

Body weights for adult male and female harbor seals (84.6 and 76.5 kg, respectively) were based on Pitcher and Calkins (1979), as cited in EPA (1993b). The FIR for harbor seals was calculated using an allometric equation (Equation E-6) developed by Boulva and McClaren (1979), as cited in EPA (1993b).

$$\mathbf{FIR = 0.089 \times BW^{0.76}} \qquad \textbf{Equation E-6}$$

where:

FIR = daily food ingestion rate (g wet weight/day)
BW = body weight (g)

Using the adult female harbor seal body weight of 76.5 kg, the calculated female food ingestion rate was 0.458 kg wet weight/day.

Diet Composition

The harbor seal's diet varies seasonally and includes bottom-dwelling fish and species that can be caught in periodic spawning aggregations (e.g., herring, lance, and squid; EPA 1993b).

Orca Whale

Body Weight and Daily Food Ingestion Rate

The NMFS (2008) reported that adult male killer whales can reach weights up to 10,000 kg and female killer whales can reach weights up to 7,500 kg. The daily food ingestion rate for the orca whale was estimated as a function of body weight using Equation E-5 (Nagy 2001).

Using the female adult orca whale body weight of 7,500 kg, the calculated female food ingestion rate was 280 kg wet weight/day.

Diet Composition

Literature information on the diet composition of resident orcas in Puget Sound indicates that both northern and southern resident killer whales eat Chinook salmon preferentially (Ford and Ellis 2006). Chum salmon becomes the primary salmonid in the diet September–October once the other species of salmon return to the rivers. Very little is known about what the resident whales eat during the other months of the year.

E.2.5. TRVs for Avian Receptor Species

The following sections present the avian wildlife TRVs that were used for calculating wildlife TTLs. As discussed above, NOAEL and LOAEL TRVs were selected using the hierarchy of sources presented in section E.2.3. The selected avian wildlife TRVs are summarized in Table E-5.

Arsenic

The avian NOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL Report for Arsenic (EPA 2005a). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 2.24 mg arsenic/kg body weight/day. This TRV was reported to be the lowest NOAEL value for the reproduction, growth, or survival endpoints.

The avian LOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV is reported to be 11.2 mg arsenic/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Table E-5. Avian TRVs.

Chemical	Avian NOAEL TRV (mg/kg/day)	Avian LOAEL TRV (mg/kg/day)	Reference
Arsenic	2.24	11.2	(1)
Lead	1.63	8.20	(1)
Mercury	0.013	0.026	(2)
Selenium	0.29	1.40	(1)
TBT	6.8	17.0	(2)
Fluorene	—	—	
Fluoranthene	—	—	
Pyrene	—	—	
Pentachlorophenol	6.73	33.7	(1)
Hexachlorobenzene	—	—	
p,p'-DDE	0.227	1.14	(1)
p,p'-DDD	0.227	1.14	(1)
p,p'-DDT	0.227	1.14	(1)
Methoxychlor	—	—	
Total Chlordanes	0.214	1.07	(2)
Dieldrin	0.0709	0.35	(1)
Total Endosulfan	—	—	
gamma-HCH (Lindane)	—	—	
Total PCBs Aroclors	0.2	0.6	(2)
Dioxins/Furans/coplanar PCBs TEQ	1.4×10^{-6}	7.0×10^{-6}	(2)

Note: — = not available
(1) EPA Soil Screening Level Reports; LOAEL values extrapolated from NOAEL TRVs by multiplying by 5
(2) ODEQ (2007)

Lead

The avian NOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for lead (EPA 2005c). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 1.63 mg lead/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV is reported to be 8.2 mg lead/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Mercury

The avian NOAEL and LOAEL TRVs for methylmercury selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The avian TRVs were originally cited in EPA's Eco-SSL report (EPA 2006). The avian NOAEL and LOAEL TRVs were reported to be 0.013 mg mercury/kg body weight/day and 0.026 mg mercury/kg body weight/day, respectively.

Selenium

The avian NOAEL TRV for selenium selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for selenium (EPA 2007e). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 0.29 mg selenium/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for selenium selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 1.45 mg selenium/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Tributyltin (TBT)

The avian NOAEL and LOAEL TRVs for tributyltin selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The avian TRVs were originally cited in Sample et al. (1996) and were reported as NOAEL/LOAEL values for the Japanese quail. The form of tributyltin used in this study was reported to be bis(tributyltin)oxide (TBTO). The resulting NOAEL and LOAEL TRVs for tributyltin were 6.8 mg tributyltin/kg body weight/day and 16.9 mg tributyltin/kg body weight/day, respectively.

PAHs

The availability of avian TRVs for the PAHs identified as BCoCs (fluorene, fluoranthene, and pyrene) were evaluated by reviewing the Eco-SSL document for PAHs (EPA 2007d). The conclusion of the Eco-SSL evaluation of avian TRVs for PAHs was that insufficient information exists to derive TRVs for PAHs.

Pentachlorophenol

The avian NOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for pentachlorophenol (EPA 2007c). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 6.73 mg pentachlorophenol/kg body weight/day. This TRV was reported to be the lowest NOAEL for the reproduction, growth, or survival endpoints.

The avian LOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 33.7 mg pentachlorophenol/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Hexachlorobenzene

No avian TRVs for hexachlorobenzene were identified from the sources used to derive wildlife TTLs.

DDT and Metabolites

The availability of avian TRVs for DDT and its metabolites DDD and DDE were evaluated by reviewing the Eco-SSL document for DDT and metabolites (EPA 2007a). This report found sufficient data for the derivation of avian NOAEL TRV for DDT and that this TRV was also applicable for the metabolites of DDT (i.e., DDD and DDE). Therefore, for calculating wildlife TTLs for DDT and its metabolites, the NOAEL TRV value in EPA (2007a) was used.

The avian NOAEL TRV for DDT and its metabolites used in calculating the wildlife TTL is presented in EPA's Eco-SSL report for DDT and its metabolites (EPA 2007a). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 0.227 mg DDx/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for DDT and its metabolites selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 1.135 mg DDx/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Methoxychlor

No avian TRVs for methoxychlor were identified from the sources used to derive wildlife TTLs.

Total Chlordanes

The avian NOAEL and LOAEL TRVs for total chlordanes selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The avian TRVs were originally cited in Sample et al. (1996) and reported as a NOAEL/LOAEL value for the red-winged blackbird. The ODEQ divided this NOAEL/LOAEL value by an uncertainty factor of 10 to account for interspecies variability. The resulting NOAEL and LOAEL TRVs for total chlordanes were 0.214 mg chlordanes/kg body weight/day and 1.07 mg chlordanes/kg body weight/day, respectively.

Dieldrin

The avian NOAEL TRV for dieldrin selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for dieldrin (EPA 2007b). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 0.0709 mg dieldrin/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for dieldrin selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 0.35 mg dieldrin/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Total Endosulfan

No avian TRVs for total endosulfan were identified from the sources used to derive wildlife TTLs.

gamma-HCH (Lindane)

No avian TRVs for lindane were identified from the sources used to derive wildlife TTLs.

Total PCB Aroclors

The avian NOAEL and LOAEL TRVs for total PCB Aroclors (as Aroclor 1254) selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The avian TRVs were originally cited in EPA (1995) and reported as the NOAEL/LOAEL values for Aroclor 1254 developed for the Great Lakes Water Quality Initiative. The NOAEL and LOAEL TRVs for total PCB Aroclors (as Aroclor 1254) were 0.2 mg PCBs/kg body weight/day and 0.6 mg PCBs/kg body weight/day, respectively.

Dioxin/Furan/PCB Congeners TEQs

The avian NOAEL TRV for dioxin/furan/PCB congeners selected for use in calculating the wildlife TTL is presented in ODEQ (2007). Dioxin, furan, and PCB TEQs are expressed as 2,3,7,8-TCDD equivalents; therefore, toxicity studies involving exposure of birds to 2,3,7,8-TCDD were reviewed. The avian NOAEL TRV was originally cited in EPA (1995) and was reported as the NOAEL value for 2,3,7,8-TCDD developed for the Great Lakes Water Quality Initiative. The NOAEL TRV for dioxin/furan/PCB congeners was 1.4×10^{-6} mg TEQ/kg body weight/day.

The avian LOAEL TRV for dioxin/furan/PCB congeners selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV was extrapolated from the NOAEL value by multiplying by 5. The LOAEL TRV for dioxin/furan/PCB congeners was calculated to be 7.0×10^{-6} mg TEQ/kg body weight/day.

E.2.6. TRVs for Mammalian Receptor Species

The following sections present the mammalian wildlife TRVs that were used for the calculation of wildlife TTLs. As discussed above, NOAEL and LOAEL TRVs were selected using the hierarchy of sources presented in section E.2.3. The mammalian wildlife TRVs are summarized in Table E-6.

Table E-6. Mammalian TRVs.

Chemical	Mammalian NOAEL TRV (mg/kg/day)	Mammalian LOAEL TRV (mg/kg/day)	Reference
Arsenic	1.04	5.2	(1)
Lead	4.7	24	(1)
Mercury	0.016	0.027	(2)
Selenium	0.143	0.72	(1)
TBT	2.34	3.5	(2)
Fluorene	65.6	328	(1)
Fluoranthene	0.615	3.05	(1)
Pyrene	0.615	3.05	(1)
Pentachlorophenol	8.42	42.1	(1)
Hexachlorobenzene	—	—	
p,p'-DDE	0.147	0.74	(1)
p,p'-DDD	0.147	0.74	(1)
p,p'-DDT	0.147	0.74	(1)

Table E-6. Mammalian TRVs.

Chemical	Mammalian NOAEL TRV (mg/kg/day)	Mammalian LOAEL TRV (mg/kg/day)	Reference
Methoxychlor	—	—	
Total Chlordanes	0.458	2	(2)
Dieldrin	0.015	0.08	(1)
Total Endosulfan	—	—	
gamma-HCH (Lindane)	—	—	
Total PCBs Aroclors	0.12	0.23	(2)
Dioxins/Furans/coplanar PCBs TEQ	8.0×10^{-8}	2.2×10^{-6}	(2)

Note: — = not available
(1) EPA Soil Screening Level Reports; LOAEL values extrapolated from NOAEL TRVs by multiplying by 5
(2) ODEQ (2007)

Arsenic

The mammalian NOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for arsenic (EPA 2005a). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 1.04 mg arsenic/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV is reported to be 5.2 mg arsenic/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Lead

The mammalian NOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for lead (EPA 2005c). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 4.70 mg lead/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV is reported to be 23.5 mg lead/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Mercury

The mammalian NOAEL and LOAEL TRVs for methylmercury selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The mammalian TRVs were originally cited in EPA (1995) and reported as the NOAEL/LOAEL values for methylmercury developed for the Great Lakes Water Quality Initiative. The NOAEL and LOAE TRVs for methylmercury were 0.016 mg methylmercury/kg body weight/day and 0.027 mg methylmercury/kg body weight/day, respectively.

Selenium

The mammalian NOAEL TRV for selenium selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for selenium (EPA 2007e). The mammalian NOAEL TRV for both carnivorous

and insectivorous mammals was reported to be 0.143 mg selenium/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for selenium selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 0.715 mg selenium/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Tributyltin (TBT)

The mammalian NOAEL and LOAEL TRVs for tributyltin selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The mammalian TRVs were originally cited in Sample et al. (1996) and reported as NOAEL/LOAEL values for the mouse. The form of tributyltin used in this study was reported to be bis(tributyltin)oxide (TBTO). The ODEQ divided these NOAEL/LOAEL values by an uncertainty factor of 10 to account for interspecies variability. The resulting NOAEL and LOAEL TRVs for tributyltin were 2.34 mg tributyltin/kg body weight/day and 3.5 mg tributyltin/kg body weight/day, respectively.

PAHs

The availability of mammalian TRVs for the PAHs identified as BCoCs (fluorene, fluoranthene, and pyrene) were evaluated by reviewing the Eco-SSL document for PAHs (EPA 2007d), which separated PAHs into two classes: low-molecular weight PAHs (LPAH, includes fluorene) and high-molecular weight PAHs (HPAH, includes fluoranthene and pyrene).

The mammalian NOAEL TRVs for LPAH and HPAH selected for use in calculating the wildlife TTL are presented in EPA's Eco-SSL report for PAHs (EPA 2007d). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 65.6 mg LPAH/kg body weight/day (will be used for fluorene) and 0.615 mg HPAH/kg body weight/day (will be used for fluoranthene and pyrene). These TRVs were determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRVs for LPAH and HPAH selected for use in calculating the wildlife TTL were calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 328 mg LPAH/kg body weight/day (will be used for fluorene) and 3.05 mg HPAH/kg body weight/day (will be used for fluoranthene and pyrene). These TRVs were extrapolated from the NOAEL TRVs by multiplying by 5.

Pentachlorophenol

The mammalian NOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for pentachlorophenol (EPA 2007c). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 8.42 mg pentachlorophenol/kg body weight/day. This TRV was reported to be the geometric mean of NOAEL values for the reproduction and growth endpoints.

The mammalian LOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 42.1 mg pentachlorophenol/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Hexachlorobenzene

No mammalian TRVs for hexachlorobenzene were identified from the sources used to derive wildlife TTLs.

DDT

The availability of mammalian TRVs for DDT and its metabolites DDD and DDE were evaluated by reviewing the Eco-SSL document for DDT and metabolites (EPA 2007a). This report states that there were sufficient data for the derivation of mammalian NOAEL TRV for DDT and that this TRV was also applicable for the metabolites of DDT (i.e., DDD and DDE). Therefore, for the calculation of wildlife TTLs for DDT and its metabolites, the NOAEL TRV value in EPA (2007a) was used.

The mammalian NOAEL TRV for DDT and its metabolites selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for DDT and its metabolites (EPA 2007a). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 0.147 mg ddx/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for DDT and its metabolites selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ's sediment bioaccumulation guidance (ODEQ 2007). The mammalian LOAEL TRV is 0.735 mg ddx/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

The TTLs for total DDTs presented in Table 8-6 of the main report (TTLs for protection of aquatic-dependent wildlife) are based on the egg-based TRV presented in section E.2.8.1.

Methoxychlor

No mammalian TRVs for methoxychlor were identified from the sources used to derive wildlife TTLs.

Total Chlordanes

The mammalian NOAEL and LOAEL TRVs for total chlordanes selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The mammalian TRVs were originally cited in Sample et al. (1996) and reported as NOAEL/LOAEL values for the mouse. The ODEQ divided these NOAEL values by an uncertainty factor of 10 to account for interspecies variability. The resulting NOAEL and LOAEL TRVs for total chlordanes were 0.458 mg chlordanes/kg body weight/day and 0.915 mg chlordanes/kg body weight/day, respectively.

Dieldrin

The mammalian NOAEL TRV for dieldrin selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for dieldrin (EPA 2007b). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 0.015 mg dieldrin/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for dieldrin selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 0.075 mg dieldrin/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Total Endosulfan

No mammalian TRVs for total endosulfan were identified from the sources used to derive wildlife TTLs.

gamma-HCH (Lindane)

No mammalian TRVs for lindane were identified from the sources used to derive wildlife TTLs.

Total PCB Aroclors

The mammalian NOAEL and LOAEL TRVs for total PCBs selected for use in calculating the wildlife TTL are presented in ODEQ (2007). The mammalian TRVs were originally cited in Millsap et al. (2004) and reported as the NOAEL/LOAEL values for total PCBs developed for mink. The NOAEL and LOAEL TRVs for total PCBs were 0.12 mg PCBs/kg body weight/day and 0.23 mg PCBs/kg body weight/day, respectively.

The TTLs for total PCBs Aroclors presented in Table 8-6 of the main report (TTLs for protection of aquatic-dependent wildlife) are based on the egg-based TRV presented in section E.2.8.1.

Dioxin/Furan/PCB Congeners TEQ

The mammalian NOAEL and LOAEL TRVs for dioxin/furan/PCB congeners TEQ selected for use in calculating the wildlife TTL are presented in ODEQ (2007). Dioxin, furan, and PCB TEQs are expressed as 2,3,7,8-TCDD equivalents. The mammalian TRVs were originally cited in Tillit et al. (1996) and reported as the NOAEL/LOAEL values developed for mink. The NOAEL and LOAEL TRVs for dioxin/furan/PCB congeners were 8.0×10^{-8} mg TEQ/kg body weight/day and 2.2×10^{-6} mg TEQ/kg body weight/day, respectively.

The TTLs for dioxin/furan/PCB congeners TEQ presented in Table 8-6 of the main report (TTLs for protection of aquatic-dependent wildlife) are based on the egg-based TRV presented in section E.2.8.1.

E.2.7. TTLs for Aquatic-Dependent Wildlife

The TTLs for aquatic-dependent wildlife were calculated using the species-specific life history parameters selected in section E.2.4 combined with the TRVs for the BCoCs identified in sections E.2.5 and E.2.6. As previously discussed, TTLs for wildlife were calculated using either Equation E-1 or Equation E-2 depending on how the FIR was calculated for the selected sentinel wildlife species.

The TTLs for aquatic-dependent wildlife are presented in Tables E-7 through E-10.

Table E-7. NOAEL based TTLs for avian aquatic-dependent wildlife.

Chemical	Great Blue Heron	Belted Kingfisher	Hooded Merganser	Black-necked Stilt	American Avocet	Spotted Sandpiper	Bald Eagle	Osprey
Arsenic	12.7	4.5	6.1	4.0	5.1	2.7	19	11
Lead	9.24	3.3	4.4	2.9	3.7	2.0	14	7.8
Mercury	0.07	0.03	0.04	0.02	0.03	0.02	0.11	0.06
Selenium	1.6	0.58	0.78	0.52	0.66	0.35	2.4	1.4
TBT	38	14	18	12	15	8.21	57	32
Fluorene	—	—	—	—	—	—	—	—
Fluoranthene	—	—	—	—	—	—	—	—
Pyrene	—	—	—	—	—	—	—	—
Pentachloro-phenol	38	14	18	12	15	8.13	56	32
Hexachloro-benzene	—	—	—	—	—	—	—	—
p,p'-DDE	1.3	0.45	0.61	0.41	0.51	0.27	1.9	1.1
p,p'-DDD	1.3	0.45	0.61	0.41	0.51	0.27	1.9	1.1
p,p'-DDT	1.3	0.45	0.61	0.41	0.51	0.27	1.9	1.1
Methoxychlor	—	—	—	—	—	—	—	—
Total Chlordanes	1.21	0.43	0.58	0.38	0.48	0.26	1.8	1.0
Dieldrin	0.40	0.14	0.19	0.13	0.16	0.09	0.59	0.34
Total Endosulfan	—	—	—	—	—	—	—	—
gamma-HCH (Lindane)	—	—	—	—	—	—	—	—
Total PCBs Aroclors	1.13	0.40	0.54	0.36	0.45	0.24	1.7	0.95
Dioxins/Furans / coplanar PCBs TEQ	7.9×10^{-6}	2.8×10^{-6}	3.8×10^{-6}	2.5×10^{-6}	3.2×10^{-6}	1.7×10^{-6}	1.2×10^{-5}	6.7×10^{-6}

Notes: TTLs in units of mg/kg wet weight; — = not available

Table E-8. LOAEL based TTLs for avian aquatic-dependent wildlife.

Chemical	Great Blue Heron	Belted Kingfisher	Hooded Merganser	Black-Necked Stilt	American Avocet	Spotted Sandpiper	Bald Eagle	Osprey
Arsenic	63	22	30	20	25	14	93	53
Lead	46	16	22	15	19	9.9	68	39
Mercury	0.15	0.05	0.07	0.05	0.06	0.03	0.22	0.12
Selenium	8.22	2.9	3.9	2.6	3.3	1.8	12	6.9
TBT	96	34	46	31	38	21	140	81
Fluorene	—	—	—	—	—	—	—	—
Fluoranthene	—	—	—	—	—	—	—	—
Pyrene	—	—	—	—	—	—	—	—
Pentachloro-phenol	191	67	91	60	76	41	280	160
Hexachloro-benzene	—	—	—	—	—	—	—	—
p,p'-DDE	6.5	2.3	3.1	2.1	2.6	1.4	9.5	5.4
p,p'-DDD	6.5	2.3	3.1	2.1	2.6	1.4	9.5	5.4
p,p'-DDT	6.5	2.3	3.1	2.1	2.6	1.4	9.5	5.4
Methoxychlor	—	—	—	—	—	—	—	—
Total Chlordanes	6.1	2.1	2.9	1.9	2.4	1.3	8.9	5.1
Dieldrin	1.9	0.70	0.95	0.63	0.79	0.42	2.9	1.7
Total Endosulfan	—	—	—	—	—	—	—	—
gamma-HCH (Lindane)	—	—	—	—	—	—	—	—
Total PCBs Aroclors	3.4	1.2	1.6	1.1	1.4	0.72	5.0	2.9
Dioxins/Furans; coplanar PCBs TEQ	3.9×10^{-5}	1.4×10^{-5}	1.9×10^{-5}	1.3×10^{-5}	1.6×10^{-5}	8.5×10^{-6}	5.8×10^{-5}	3.3×10^{-5}

Notes: TTLs in units of mg/kg wet weight; — = not available

Table E-9. NOAEL based TTLs for mammalian aquatic-dependent wildlife.

Chemical	North American River Otter	Northern Sea Otter	American Mink	Harbor Seal	Orca Whale
Arsenic	11	12	6.5	174	28
Lead	49	56.3	29	785	126
Mercury	0.17	0.19	0.10	2.67	0.42
Selenium	1.5	1.71	0.89	23.89	3.8
TBT	24	28	15	391	63
Fluorene	684	786	410	10957	1757
Fluoranthene	6.4	7.4	3.8	102	16.5
Pyrene	6.4	7.4	3.8	102	16.5
Pentachlorophenol	88	101	53	1406	225
Hexachlorobenzene	—	—	—	—	—
p,p'-DDE	1.5	1.8	0.92	24.5	3.9
p,p'-DDD	1.5	1.8	0.92	24.5	3.9
p,p'-DDT	1.5	1.8	0.92	24.5	3.9
Methoxychlor	—	—	—	—	—
Total Chlordanes	4.8	5.5	2.9	76.5	12.3
Dieldrin	0.16	0.18	0.09	2.51	0.40
Total Endosulfan	—	—	—	—	—
gamma-HCH (Lindane)	—	—	—	—	—
Total PCBs Aroclors	1.2	1.4	0.75	20	3.2
Dioxins/Furans/ coplanar PCBs TEQ	8.3×10^{-7}	9.6×10^{-7}	5.0×10^{-7}	1.3×10^{-5}	2.1×10^{-6}

Notes: TTLs in units of mg/kg wet weight; — = not available

Table E-10. LOAEL based TTLs for mammalian aquatic-dependent wildlife.

Chemical	North American River Otter	Northern Sea Otter	American Mink	Harbor Seal	Orca Whale
Arsenic	54	62	32	868	139
Lead	250	288	150	4009	643
Mercury	0.28	0.32	0.17	4.5	0.72
Selenium	7.5	8.6	4.5	120	19
TBT	36	42	22	585	94
Fluorene	3400	3900	2000	54800	8800
Fluoranthene	32	36	19	509	82
Pyrene	32	36	19	509	82
Pentachlorophenol	439	504	260	7032	1128
Hexachlorobenzene	—	—	—	—	—
p,p'-DDE	7.7	8.9	4.6	124	20
p,p'-DDD	7.7	8.9	4.6	124	20
p,p'-DDT	7.7	8.9	4.6	124	20
Methoxychlor	—	—	—	—	—
Total Chlordanes	9.8	11.2	5.9	157	25.2
Dieldrin	0.84	0.9	0.50	13.4	2.1
Total Endosulfan	—	—	—	—	—
gamma-HCH (Lindane)	—	—	—	—	—
Total PCBs Aroclors	2.4	2.7	1.4	38.4	6.2
Dioxins/Furans/ coplanar PCBs TEQ	2.3×10^{-5}	2.6×10^{-5}	1.40×10^{-5}	3.7×10^{-4}	5.9×10^{-5}

Notes: TTLs in units of mg/kg wet weight; — = not available

E.2.8. TTLs Using Egg-Based Toxicity Reference Value Studies

In addition to providing dietary-based TTLs protective of aquatic dependent wildlife, TTLs were also calculated using bird egg-based TRVs. Some types of chemicals such as DDE, PCBs, "dioxin-like" compounds, mercury, and selenium have demonstrated effects on avian development at the level of the egg. In these cases, developing TTLs based on eggs may be more appropriate than the dietary pathway because the reproductive effects and corresponding TRVs are based on concentrations in bird eggs rather than in the diet, as the dietary pathway model may not result in TTLs that are sufficiently protective of reproductive effects. The following egg-based model for developing tissue trigger levels was used to develop the egg-based TTLs.

$$\mathbf{TTL = TRV_{egg} / BMF_{egg}} \qquad \textbf{Equation E-7}$$

where:

TTL = tissue concentration in prey protective of avian predators (mg/kg, wet weight)
TRV_{egg} = egg-based toxicity reference value (mg/kg)

BMF_{egg} = biomagnification factor from prey to egg (unitless); includes biomagnification from prey to adult, followed by adult to egg

The greatest challenge for developing egg-based TTLs at this time is the lack of available egg-based TRVs and prey-to-egg BMFs. For egg-based TRVs, the TRV values provided in ODEQ's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (ODEQ 2007) were used. The ODEQ (2007) presents NOAEL and LOAEL egg-based TRVs for dioxins/furans congeners (as 2,3,7,8-TCDD TEQs), PCBs as Aroclor 1254, DDE (applied to total DDT), and mercury.

Egg-Based TRVs and TTLs

The egg-based TRVs used to calculate egg-based TTLs are summarized in Table E-11.

Table E-11. Parameters and TTLs for egg-based prey tissue TTLs.

Chemical	Egg-Based TRV (mg/kg)			BMF_{egg}			Bird Egg TTL (Bald Eagle)		Bird Egg TTL (Osprey)	
	NOAEL	LOAEL	Ref.	Bald Eagle	Osprey	Ref.	NOAEL	LOAEL	NOAEL	LOAEL
Mercury	0.5	2.5	(1)	2.8	2.8	(1)	0.18	0.89	0.18	0.89
DDT (total)	1.0	4.2	(1)	75	87	(1)	0.01	0.06	0.01	0.05
Dioxins/ Furans/ coplanar PCBs TEQ	3.0×10^{-4}	4.0×10^{-4}	(1)	16	10	(1)	1.9×10^{-5}	2.5×10^{-5}	3.0×10^{-5}	4.0×10^{-5}
Total PCBs Aroclor	4.0	20	(1)	110	11	(1)	0.04	0.18	0.36	1.8

Notes: TTLs in units of mg/kg wet weight; Reference (1) - ODEQ 2007.

Dioxin/Furan/PCB Congeners TEQ

Egg-based TRVs for dioxin/furans/PCB congeners TEQ were selected from those values provided in ODEQ (2007). Dioxin/furan TRVs are expressed as 2,3,7,8-TCDD equivalents; therefore, the egg-based TRV presented for 2,3,7,8-TCDD TEQs in ODEQ (2007) were selected.

The egg-based NOAEL and LOAEL TRVs for dioxin/furans/PCB congener TEQ were reported to be 0.0003 mg/kg and 0.0004 mg/kg, respectively.

Total PCBs

Egg-based TRVs for total PCB (as Aroclor 1254) were selected from those values provided in ODEQ (2007). The egg-based NOAEL and LOAEL TRVs for PCB TEQs were reported to be 4.0 mg/kg and 20.0 mg/kg, respectively.

DDE (applied to Total DDT)

Egg-based TRVs for total DDT were selected from those values provided in ODEQ (2007). The egg-based NOAEL and LOAEL TRVs for total DDT were reported to be 1.0 mg/kg and 4.2 mg/kg, respectively.

Mercury

Egg-based TRVs for mercury were selected from those values provided in ODEQ (2007). The egg-based NOAEL and LOAEL TRVs for mercury were reported to be 0.5 mg/kg and 2.5 mg/kg, respectively.

Biomagnification Factor (BMF_{egg}) from Prey to Egg

The BMF_{egg} values for deriving egg-based TTLs were selecting using the same sources presented above for the selection of egg-based TRVs. The ODEQ (2007) presents BMF_{egg} values for both the bald eagle and osprey for the following compounds: PCB TEQs, total PCBs as Aroclors, DDE, and mercury. As there are BMF_{egg} values provided for all compounds for which egg-based TRVs were available, the ODEQ values were selected for the calculation of TTLs. The BMF_{egg} values from ODEQ (2007) are presented in Table E-11.

Prey Tissue Bioaccumulation Triggers

Prey TTLs developed using egg-based TRVs were calculated using Equation E-5 and the species-specific (bald eagle or osprey) BMF_{egg} factors provided in ODEQ (2007). The calculated TTLs are presented in Table E-11.

E.3. TTLs for Human Health

This section describes how the TTLs presented in Table 8-5 of the main report were derived for protection of human health. For the purposes of this assessment, only human health risks associated with consumption of bioaccumulative chemicals in fish or shellfish are considered. For dredged material disposal, particularly in deep-water areas, this will be the only complete exposure pathway. At some sediment sites, it may be necessary to also consider other potential pathways (e.g., direct human contact with sediments). However, where fish and shellfish consumption is one of the potential exposure pathways, the food-related pathway typically is a more substantial contributor to site risks than direct contact with sediments. Thus, the initial focus on fish and shellfish consumption is appropriate.

The TTLs address both carcinogenic and noncarcinogenic effects of BCoCs by applying a carcinogenic slope factor (CSF) for carcinogenic effects and a reference dose (RfD) for noncarcinogenic effects. The EPA-approved toxicity values are described on the EPA Integrated Risk Information System web site[1] and EPA's Provisional Peer Reviewed Toxicity Values for Superfund.[2] The TTLs for carcinogenic effects of BCoCs were calculated using the following equation and exposure assumptions:

[1] *www2.epa.gov/iris*

[2] *http://hhpprtv.ornl.gov/*

$$TTL_H\ (mg/kg) = \frac{TR \times AT_c \times BW}{EF \times ED \times FI \times IR \times 0.001\ kg/g \times CSF}$$ **Equation E-8**

where:

TTL_H = target tissue level in fish or shellfish tissue (mg/kg wet weight)
TR = target risk for individual carcinogens ($1x10^{-6}$)
AT_c = averaging time (70 years x 365 days/year)
BW = body weight (70 kg)
0.001= conversion of grams fish to kg
EF = exposure frequency (365 days/year)
ED = exposure duration (30 or 70 years)
FI = fraction of intake assumed from site (1.0)
IR = ingestion rate for fish and shellfish (54, 142, or 584 g/day)
CSF = carcinogenic slope factor [chemical-specific; $(mg/kg\text{-}day)^{-1}$]

For noncarcinogenic effects, the following equation and exposure assumptions were used to derive TTLs for fish and shellfish tissue:

$$TTL_H\ (mg/kg) = \frac{THQ \times BW \times AT_n \times RfD}{EF \times ED \times FI \times IR \times 0.001\ kg/g}$$ **Equation E-9**

where:

TTL_H = target tissue concentration in fish or shellfish (mg/kg wet weight)
THQ = target hazard quotient (1)
AT_n = averaging time (30 or 70 yrs x 365 days/year)
BW = body weight (70 kg)
0.001 = conversion of grams to kg
EF = exposure frequency (365 days/year)
ED = exposure duration (30 or 70 years)
FI = fraction of intake assumed from site (1.0)
IR = ingestion rate for fish and shellfish (54, 142, or 584 g/day)
RfD = reference dose for noncancer effects (chemical-specific; mg/kg-day)

E.3.1. Selecting a Target Risk and Hazard Index

For carcinogenic effects of BCoCs, a total cumulative target risk level of 10^{-5} (upper-end) was used, consistent with regulatory requirements set by ODEQ and the Washington Department of Ecology. This risk level represents the middle of the risk range (10^{-4} to 10^{-6}) typically identified as acceptable by EPA and allows for exposure to multiple carcinogenic BCoCs. To achieve this risk level, TTLs for individual BCoCs were set at risk levels of 10^{-6}.

In deriving TTLs for noncancer endpoints, a cumulative hazard index of 1.0 was used. TTLs for individual BCoCs were also derived by applying a hazard quotient of 1.0. Where multiple BCoCs are present at concentrations greater than the noncancer TTL, the agencies may consider additional evaluation

to determine whether the BCoCs could affect the same target organs at the concentrations present. If this is the case, it may be appropriate to adjust the TTLs to result in a cumulative hazard index of 1.0.

E.3.2. Exposure Assumptions

The following exposure assumptions were used to develop the default RSET TTLs for protection of human health. Following both EPA and state guidelines, the exposure estimate is intended to be a high end, but not worst-case, scenario. The exposure parameters include some values that are average for the population (e.g., body weight), some that have several possible choices (e.g., consumption rate), and some that have significant built-in safety factors and are therefore quite conservative (e.g., carcinogenic slope factors and reference doses). This combination of central tendency and upper bound exposure parameter values should result in the desired overall high end exposure.

Exposure assumptions will in general be based on the conceptual site model discussed in Chapter 3. When cleanup and navigational dredging projects are occurring in the same area, it will be especially important to ensure that the conceptual site model and exposure assumptions used are coordinated, particularly with respect to the concentrations that will remain at the project site after dredging.

Children may be more exposed to environmental toxicants because they consume more food and water per unit body weight than adults (EPA 2002). The EPA's guidelines for cancer risk assessment note that children may be more sensitive to toxic chemicals than adults and have provided limited methodology to compute enhanced children's cancer risks (EPA 2005d).

Despite a desire to assess risks posed by environmental contaminants to children, children's fish consumption rates have not been as well quantified as adult rates. For example, issues with regional estimates of tribal children's fish consumption rates include small sample sizes (CRITFC 1994; Toy et al. 1996; Suquamish 2000), inclusion of more than one child from the same household leading to lack of independence of results (Suquamish 2000), and potential reporting of adult as children's rates (CRITFC 1994). Given uncertainties in children's consumption rates, RSET guidance will utilize default exposure parameters based on adult consumption. This position may be modified on a site-specific basis or as better data on children's fish consumption are obtained.

Consumption Rates

The TTLs are intended to be protective of all populations (e.g., recreational, subsistence, Native American). To meet this objective, fish consumption rates for various populations present in the region were reviewed to determine several representative default consumption rates that could be used. Because consumption rates are highly variable among various populations, it was considered appropriate to derive more than one set of rates depending on the specific situation. Project proponents may propose, or agencies may require, use of the consumption rate that is most representative of the dredged material disposal site or project site involved. In addition to these three default consumption rates, where site-specific consumption studies have been conducted, these can be applied on a case-by-case basis, subject to agency approval. The three selected sets of consumption rates represent, conceptually, the following groups:

1. General population in a coastal state—54 g/day. This value is promulgated in MTCA for protection of the general population (WAC 173-340-730). This value would only be used if the

disposal or project site in question was not located within a tribal fishing area, urban subsistence fishing area, or active recreational fishing area.

2. High-end recreational or mid-range subsistence consumers—175 g/day. This value has recently been negotiated between EPA Region 10 and ODEQ for use in the water quality program. It falls within the first-tier (Tulalip) tribal consumption range (97.6 g/day not including salmon; 243 g/day fish and shellfish including salmon) proposed for use by EPA Region 10 as one of the default values for Superfund sites (EPA 2007f).[3] This value was derived from two studies of tribal consumption among Washington and Oregon tribes (CRITFC 1994; Toy et al. 1996). This level is also similar to that used by California EPA of 166 g/day for the 95th percentile of sports and recreational anglers (California EPA 2001). Finally, a recent study of Asian and Pacific Islander consumption rates in King County found a mean consumption of 117 g/day and an upper 90th percentile of 236 g/day (Sechena et al. 2003).
3. High-end tribal subsistence consumers—584 g/day. This value represents the upper-tier tribal subsistence value (Suquamish, not including salmon) proposed for use by EPA Region 10 as one of the default values for Superfund sites in Puget Sound (EPA 2007f, Suquamish 2000). Because it does not include salmon, a higher rate may be appropriate for areas with similar higher-tier tribal consumption where sediment contamination would be expected to contribute to contaminant body burdens in salmon (e.g., ordinarily migratory species trapped behind dams).

It is recognized that a wide variety of seafood consumption rates, ranging from 6.5 g/day to 796 g/day, are in use by various state and federal agencies and tribes in the Pacific Northwest. No single framework could hope to capture all of these. However, the three rates selected above are intended to be representative of three conceptual ranges of consumption rates and to serve as default values that users and agencies can select. Site- or project-specific risk assessments or consumption studies can be substituted for these values upon agency approval.

Note that seafood consumption rates used in risk assessment are affected by many factors, including: seafood consumption survey design, how the survey population is defined, how the source of seafood is considered in consumption rate derivation (e.g., purchased or harvested from a particular geographic area), whether nonconsumers of seafood are included in the survey sample used to derive rates, the environmental factors affecting the surveyed population (e.g., does habitat limit resource use, are there fears of chemical contamination or fish consumption advisories), whether weighting factors are applied to consumption rates for survey respondents to estimate consumption rates for a larger population, whether or not anadromous species are included in the consumption rate, and the statistic chosen to represent consumption (e.g., mean, median, 90th or 95th percentile). The references included in this section should be consulted for a complete understanding of the basis for a consumption rate included here.

[3] These consumption rates are upper percentile values from survey data that include only consumers of seafood. Rates included in EPA's Framework (EPA 2007f) are intended to represent consumption of seafood harvested from Puget Sound. The API rates cited here represent consumption of seafood regardless of source (e.g., purchased or harvested).

Exposure Duration and Frequency

Exposure duration for the general population was set at 30 years, which represents estimates of how long an average person might spend in one area and reflects EPA guidance for general population risk assessments. Exposure duration for consumption rates (2) and (3) above are intended to reflect tribal consumption, for which 70 years is considered more appropriate as site fidelity is higher than in the general population. Because the consumption rates are daily consumption rates already averaged over a year, the exposure frequency is 365 days/year.

Body Weight

A range of body weights is currently in use for various adult populations, including 63 kg for Asian and Pacific islanders, 70 kg for the general population, and 79–82 kg for tribal populations. These differences represent a very small deviation compared to the overall uncertainty in the risk-based values. Therefore, as with the consumption rate, the body weight selected for the default RSET concentrations is in the middle of this range at 70 kg.

Fractional Intake or Area Use Fraction

An additional area for consideration is the fraction of seafood harvest that may be affected by site-specific contamination. Issues that may be considered include resource sustainability, site area, overall harvest area, fidelity of site use, the role multiple smaller site remediation/disposal actions may have on larger systems, and policy regarding acceptable risks associated with resource use independent of location. The RSET TTLs were developed based on a default fractional intake of 100%. Alternative fractional intake rates may be considered, subject to agency approval, as part of a site-specific risk assessment or established regional policy. For example, tribal subsistence consumption rates established for Puget Sound use a fractional intake based on the fraction caught within Puget Sound (EPA 2007f).

Carcinogenic Slope Factors and Reference Doses

The carcinogenic slope factors and reference doses in use at the time these values were developed are listed in Table E-12. Unless otherwise noted, these values are from EPA's Integrated Risk Information System. These values will be periodically reviewed for updates and the resulting TTL_H values updated accordingly.

Table E-12. Carcinogenic slope factors and reference doses.

Chemical	CAS Number	Reference Dose (mg/kg-day)	Carcinogenic Slope Factor $(mg/kg\text{-}day)^{-1}$
Arsenic	7440-38-2	0.0003	1.5
Lead	7439-92-1	NA	NA
Mercury	7439-97-6	0.0001	—
Selenium	7782-49-2	0.005	—
Tributyltin	688-73-3	0.0003	—
Fluoranthene	206-44-0	0.04	—
Fluorene	86-73-7	0.04	—
Pyrene	129-00-0	0.03	—
Hexachlorobenzene	118-74-1	0.0008	1.6
Pentachlorophenol	87-86-5	0.03	0.12
Total Chlordanes	57-74-9	0.0005	0.35
DDTs - Total	50-29-3	0.0005	0.34
Dieldrin	60-57-1	0.00005	16
Total Endosulfans	115-29-7	0.006	—
gamma-HCH (Lindane)	58-89-9	0.0003	1.3
Methoxychlor	72-43-5	0.005	—
Total PCB Aroclors	1336-36-3	0.00002[a]	2
Dioxins/Furans/PCB congeners	1746-01-6	0.000000001	130000

Notes: NA - not available; lead is known to be toxic at very low levels, but EPA has not established toxicity values.
[a] Based on Aroclor 1254, the most frequently found Aroclor in sediments for which an RfD is available.

E.3.3. Compounds with a Common Toxic Mechanism

Tissue contaminant concentrations that trigger sediment bioaccumulation testing are usually computed for individual compounds. However, deriving TTLs on a compound-by-compound basis is not always appropriate when compounds of similar chemical structure and a common toxicity mechanism are present. In such cases, TTLs may be developed on a chemical class basis. Chlorinated dioxins/furans and polychlorinated biphenyls (CDFBs) are the primary chemical class for which TTLs have been calculated at the group level.

The toxicity of CDFBs as a group may be assessed using a toxic equivalency approach. Each compound within the CDFB group is assigned a toxic equivalency factor (TEF) describing the toxicity of that CDFB relative to the toxicity of a reference compound, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). A CDFB that is equal in toxicity to TCDD would have a TEF of 1.0. A compound that is half as toxic as TCDD would have a TEF of 0.5, and so on. Multiplying the tissue concentration of a CDFB by its TEF produces the tissue concentration of TCDD that is equivalent in toxicity (TEQ) to the CDFB concentration of concern. Computing the TEQ for each CDFB in a tissue sample followed by summing all TEQ values permits expression of all CDFB concentrations in terms of a total TCDD toxic equivalent tissue concentration (i.e., total tissue TCDD TEQ).

$$\text{Total tissue TCDD TEQ} = \Sigma C_n \times TEF_n$$

If the total tissue TCDD TEQ exceeds the TTL for TCDD, sediment bioaccumulation testing is warranted.

There have been several efforts to develop TCDD TEFs for dioxin/furans and PCBs having TCDD-like toxicity (EPA 2000). The most recent effort occurred at an expert meeting organized by the World Health Organization (WHO) in 2005 (Van den Berg et al. 2006). The 2005 WHO effort supplanted TEFs developed in 1998 (Van den Berg et al. 1998) and utilized multiple lines of evidence to develop a consensus-based list of TEFs. Table E-13 provides the WHO 2005 TEFs for dioxins, furans, and PCBs.

Table E-13. WHO 2005 TEFs for dioxins, furans, and PCBs.	
Compound	**TEF**
Polychlorinated dibenzodioxins	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
1,2,3,4,6,7,8,9-OCDD	0.0003
Polychlorinated dibenzofurans	
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
1,2,3,7,8,9-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,6,7,8,9-HpCDF	0.01
1,2,3,4,6,7,8,9-OCDF	0.0003
PCBs	
3,3',4,4'-TCB	0.0001
3,4,4',5-TCB	0.0003
2,3,3',4,4'-PeCB	0.00003
2,3,4,4',5-PeCB	0.00003
2,3',4,4',5-PeCB	0.00003
2',3,4,4',5-PeCB	0.00003
3,3',4,4',5-PeCB	0.1
2,3,3',4,4',5-HxCB	0.00003
2,3,3',4,4',5'-HxCB	0.00003
2,3',4,4',5,5'-HxCB	0.00003
3,3',4,4',5,5'-HxCB	0.03
2,3,3',4,4',5,5'-HpCB	0.00003
Abbreviations: T-tetra, Pe-penta, Hx-hexa, Hp-hepta, O-Octa, DD-dibenzodioxin, DF-dibenzofuran, CB-chlorobiphenyl	

E.4. Sediment Bioaccumulation Triggers

It can be difficult to accurately back-calculate sediment triggers from tissue levels using literature-derived BSAFs from field studies, due to large uncertainties in BSAFs for the same chemical derived from different data sets (PTI Environmental 1995). This difficulty is largely due to differences in sediment

geochemistry, bioavailability of contaminants, and food webs from one area to the next, as well as an assumption of equilibrium, which may not actually exist in many environments.

However, BSAFs can be developed on a site-specific, watershed, or disposal site basis using tissue data paired with sediment data from the home range of the species being evaluated. Care must be taken to ensure that the BSAF is meaningful (i.e., there is a statistically significant regression curve or sufficient paired sediment/tissue data to calculate a mean with low variability; Exponent 1998). It is also important to take into account the home range of the species sampled and pair the sediment and tissue data accordingly. Methods for calculating statistically meaningful BSAFs and draft BSAFs for several nonpolar organic compounds are presented in PTI Environmental (1995) and Exponent (1998).

For the purposes of the dredging program, the most relevant BSAF may be at the disposal site (for nondispersive sites), since this is where the material will reside after dredging and the long-term exposures of concern may occur. The BSAFs for the project site or water body of origin may also be used to determine the effects of dredging residuals or contaminants released during dredging. It may be possible to use past monitoring data to develop disposal site-specific BSAFs that can be applied to derive sediment BTs for each disposal site (or for a set of disposal sites that are similar in nature and receptors, such as ocean disposal sites along the coast of Oregon or those in Puget Sound). In deriving and applying such BSAFs, it will be important to consider whether sediment characteristics affecting bioavailability are similar at the disposal site and in the dredged material being disposed there.

Because of both environmental and programmatic differences, it is not necessary or even possible to use the same approach or have the same criteria for bioaccumulation in sediments. For example, tissue triggers may be developed to be protective of a wide variety of regional wildlife receptors and human exposure scenarios, but which ones will apply at any given site or disposal site will vary depending on the environment in which that site is located and the uses that are present. The BSAFs used to back-calculate from tissue levels to sediments may also vary depending on geochemical conditions and food webs present in each environment. Superfund sites with parties having the resources to conduct complex food web modeling or monitoring evaluations may develop site-specific sediment BTs, compared to small dredging projects in which standardized ratios or BSAFs calculated from regional regressions may be employed. It is most important that all programs and agencies have consistent, protective tissue levels as the same goal and are working toward meeting these watershed-wide values in a manner that best meets their project needs.

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Photos, back cover:

Left Side: Vibracore sediment sample, Columbia River estuary, Baker Bay, Washington

Top: Riparian habitat restoration project by the Kootenai Tribe on the Kootenai River near Bonners Ferry, Idaho

Middle Left: *Neanthes*, Baker Bay, near Ilwaco, Pacific County, Washington

Middle Right: Sediment sampling at Depot Slough federal channel, Toledo, Lincoln County, Oregon

Bottom: NOAA Marine Operations Center-Pacific Fleet, Port of Newport, Yaquina Bay, Oregon