Biological Evaluation

Continued Use of Multiuser Dredged Material Disposal Sites in Puget Sound and Grays Harbor

May 2015

US Army Corps of Engineers®
Seattle District

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1 INTRODUCTION

1.1 BACKGROUND

As required by Section 7(c) of the Endangered Species Act of 1973 (16USC, 1531, et seq.) the U.S. Army Corps of Engineers is requesting informal Section 7 consultation for the transport and disposal of dredged material at the eight multiuser open-water disposal sites in Puget Sound and two multiuser open-water disposal sites in Gray Harbor, co-managed by the Dredged Material Management Program (DMMP) and Corps of Engineers, for the 25-year period from 2015-2040. This Biological Evaluation (BE) for the program covers the threatened and endangered species found within the project's action area, which includes Puget Sound and Grays Harbor. The BE addresses the effects of transport, disposal, and disposal site management (including in some cases monitoring of biological and chemical inventories). Excluded from this consultation are activities related to dredging itself, which are addressed through separate Section 7 consultations. For the purposes of this BE, 'Puget Sound' refers to Puget Sound, the Strait of Juan de Fuca, Hood Canal and other parts of the Salish Sea falling within the borders of Washington State.

In Puget Sound, the Dredged Material Management Program (DMMP) agencies manage the operation and monitoring of eight open-water dredged material disposal sites for use by both federal and non-federal entities for disposal of material suitable for open-water disposal. There are five non-dispersive and three dispersive sites in Puget Sound that were selected after examining existing literature and conducting physical and biological studies in order to locate dredged material disposal sites in areas where the least environmental and human use impacts would occur. The site selection process – a part of the Puget Sound Dredged Disposal Analysis (PSDDA) study – was documented in two program environmental impact statements prepared in 1988 and 1989 (PSDDA/FEIS, 1988; 1989). The PSDDA program also developed a management plan to determine whether dredged materials are suitable for unconfined open-water disposal, and to evaluate effects of dredged material disposal at the eight selected sites (PSDDA/MPR 1988, 1989).

In Grays Harbor, the DMMP and the Corps of Engineers co-manage two dispersive multiuser open-water disposal sites for use by federal and non-federal entities. The DMMP agencies determine the suitability of dredged material for disposal at these sites; the Corps is responsible for site monitoring. These sites have been in use since the 1970's. The DMMP agencies developed dredged material evaluation procedures and a disposal site management plan for these disposal sites in 1995 (DMMP 1995).

1.2 SCOPE

The scope of the agency action that is addressed by this consultation extends to disposal of dredged material derived from maintenance dredging activities, placed by bottom-dump or split-hull barge, or by hopper dredge, in one of the ten unconfined aquatic sites delineated above, where disposal is conducted either under the Corps' civil works navigation program or under authorization through the Corps' permitting program under Clean Water Act Section 404.

1.3 EVALUATION APPROACH

The analytical approach of this Biological Evaluation focuses on assessment of the effects of dredged material disposal in the context of controls that are applied to site utilization parameters, as well as disposal site management programs, vice focusing on the various specific sources of the dredged/disposed materials themselves.

2 DREDGED MATERIAL MANAGEMENT PROGRAM

2.1 PROGRAM DESCRIPTION AND OBJECTIVES

The DMMP is an interagency approach to dredged material management in the State of Washington. The DMMP agencies include the Army Corps of Engineers, Seattle District (Corps); the Environmental Protection Agency, Region 10 (EPA); the Washington Department of Natural Resources (DNR); and Washington Department of Ecology (Ecology). The Corps serves as the lead agency for implementation of the program.

The DMMP program objectives are to provide economical disposal options for dredged material within Washington State, while ensuring protection of the aquatic environment; and to provide a consistent, scientifically-based, transparent, interagency process for the evaluation of dredged material. The program's existence allows both federal and non-federal entities to carry out maintenance and new-work dredging in an environmentally responsible manner. This dredging is necessary to maintain the navigation channels, berthing areas and marinas which play a vital role in the region's economic development and growth.

At its inception, the program focused on Puget Sound and was originally called the PSDDA program. The geographic focus expanded to coastal Washington in 1995 and to the Washington side of the Columbia River in 1998. The program name was changed to Dredged Material Management Program (DMMP) in acknowledgement of the broader geographical focus.

The PSDDA program identified eight multi-user disposal sites in Puget Sound, defined consistent and objective procedures for evaluating the suitability of dredged material for disposal at those sites, and formulated site use management plans to monitor the effects of dredged material disposal. These management plans included an adaptive management framework, which allowed the dredged material evaluation procedures to be altered based on the findings of the monitoring program. The PSDDA framework has since been applied by the DMMP agencies to dredged material management on the Pacific Coast of Washington and in the Columbia River basin. The evaluation procedures for all areas in Washington State have been consolidated, and are fully documented in the DMMP User Manual (DMMP, 2014), which is incorporated by reference.

In this BE, the multiuser disposal sites in Puget Sound are referred to either as "PSDDA sites" or "DMMP sites." The multiuser sites in Grays Harbor are referred to as "DMMP sites." Collectively, the Puget Sound and Grays Harbor sites are referred to as "DMMP sites."

While the geographic extent of the DMMP includes the entire state of Washington, the scope of coverage of this BE is restricted to the multiuser open-water sites in Puget Sound and Grays Harbor. It does not include disposal sites in Willapa Bay, the outer Pacific Coast of Washington, or the Columbia River basin. Placement of dredged material at other aquatic sites not covered in this BE will continue to be addressed through project-specific consultation.

2.2 DISPOSAL SITE DESIGNATION PROCESS

2.2.1 Puget Sound

A PSDDA site designation process conducted during the development of the 1988 and 1989 environmental impact statements (EIS) resulted in the selection of three dispersive sites and five non-dispersive sites throughout Puget Sound (Figure 1). Non-dispersive disposal sites are areas where currents are low enough that dredged material is retained within the disposal site; dispersive sites have higher current velocities, so dredged material does not accumulate within the disposal site.

The number of sites selected balanced the need for ecologically safe disposal with the need for economically and logistically viable disposal options. The selection process evaluated sites based on currents, biological sensitivities, and human activities, which are discussed in detail in PSDDA/FEIS (1988) for Phase I sites and PSDDA/FEIS (1989) for Phase II sites. Selection factors included:

- navigation activities
- recreational uses
- cultural sites
- aquaculture facilities
- utilities
- scientific study areas
- point pollution sources
- water intakes
- shoreline land use designations
- location of dredging areas
- beneficial uses of dredged material
- fish/shellfish harvest areas
- threatened and endangered species
- fish/shellfish habitat
- wetlands, mudflats and vegetated shallows
- bathymetry
- sediment characteristics
- water currents

Information on these factors was collected, mapped and overlain to identify areas of high and low resource value in Puget Sound. This allowed the agencies to identify areas with lower resource value where disposal siting would have a minimum conflict with ecological resources or human uses of Puget Sound. In addition, attempts were made to site disposal areas within 10 nautical miles (11.5 miles) of major dredging areas. After identifying these areas, additional constraints were included in the selection process.

For non-dispersive sites, these additional factors included:

- peak current speeds of less than 25 cm/sec to retain sediments within site boundaries
- distance from shore (greater than 2,500 feet)
- site size for containment of the estimated volumes of dredged sediment to be disposed
- distance from vulnerable biological resources (greater than 2,500 feet)
- depth of water (where possible, site placement between 120 and 600 feet deep[1])

For dispersive sites, these additional factors included:

- current speeds in excess of 25 cm/sec for maximum dispersal of material
- distance from shore not less than 1 nautical mile (1.2 statute miles)
- minimum water depth of 180 feet as a goal (not an absolute requirement)
- locating sites so that the ultimate fate of the dispersed material will not have a significant adverse effect on natural resources

[1]all water depths in this document are relative to mean lower low water (MLLW)

Figure 1, Table 1, and Figures B-1 to B-8 (in Appendix B) provide the location of the eight PSDDA sites, their target and disposal zone boundaries, depths, and dimensions. Each non-dispersive site consists of four elements. Ordered by size (smallest to largest), the elements consist of the target area, disposal zone, disposal site, and perimeter line. The dispersive sites consist of just two elements, the disposal zone and disposal site.

At the non-dispersive sites, the doors of bottom-dump barges must be opened within the target area to ensure that the dredged material is released within the disposal zone. Dispersive sites do not require dredged material to be placed as precisely as at non-dispersive sites. Therefore, a target area smaller than the disposal zone is unnecessary.

For non-dispersive sites, the disposal site boundary is the limit of the horizontal spread of material over a period of repeated dumps of dredged material released within the disposal zone, with allowance for flood and ebb tidal currents. For the dispersive sites, the disposal site boundaries circumscribe the limits of horizontal spread of measurable accretion (0.02 inch) of dredged material for a series of dumps within the disposal zone. Hydrodynamic modeling was performed during the siting process to determine the required size and shape of both the non-dispersive and dispersive disposal sites.

Surrounding the non-dispersive sites at a distance of 1/8 nautical mile from the site boundary is the perimeter line, which is used during monitoring events. The perimeter lines are not shown in the maps in Appendix B, but can be seen in Figure 16 for the Commencement Bay site.

2.2.2 Grays Harbor

Two DNR multiuser unconfined open-water dredged material disposal sites are located directly adjacent to the federal navigation channel near the mouth of the Grays Harbor estuary. The multiuser sites, Point Chehalis and South Jetty, are located on state-owned aquatic lands. Both sites are dispersive in nature.

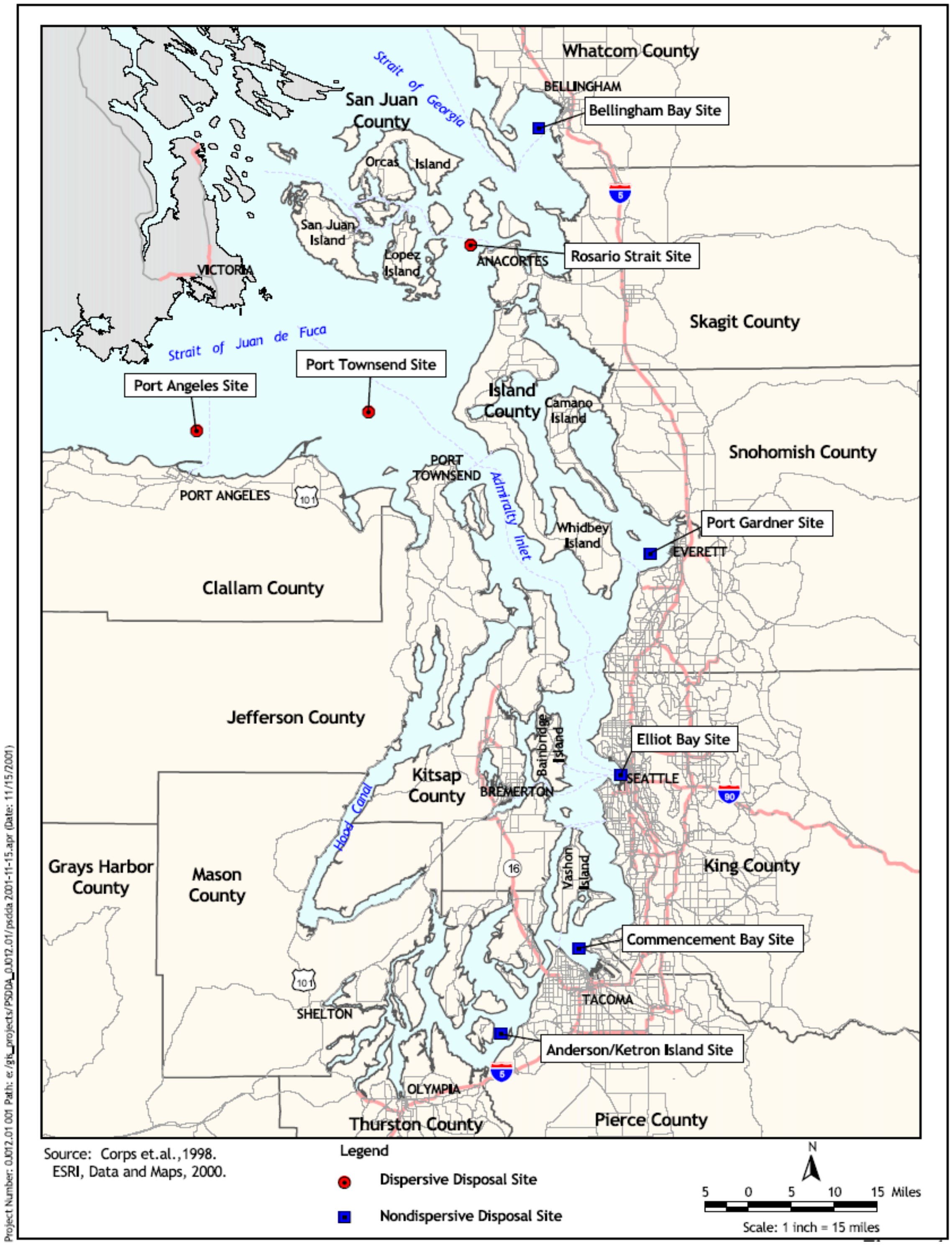
These sites were designated under the authority of Section 202 of the Water Resources Development Act of 1986, Public Law 99-662, for use in the disposal of material derived from maintenance dredging activities addressed in the Interim Feasibility Report and Final Environmental Impact Statement, Grays Harbor , Chehalis, and Hoquiam Rivers, Washington, Channel Improvements for Navigation (September 1982), as supplemented by an Environmental Assessment and Finding of No Significant Impact (15 February 1990) regarding disposal of material dredged from Grays Harbor navigation channels and a Final Environmental Impact Statement Supplement, Grays Harbor Navigation Improvement Project (May 1989).

The Point Chehalis and South Jetty sites were selected because current measurements indicated that material would be effectively carried westward out of the estuary and into the longshore drift cell, thus reducing the likelihood that material would be recirculated on to harbor mudflats, eelgrass beds, and oyster beds. Also, disposal of material was desirable at these sites to stem the undercutting of the South Jetty as a result of tidal scouring action (USACE, 1982). The Point Chehalis site was placed in an area with historically deep water and proven capacity for placement of dredged material.

The Point Chehalis site in its current configuration was established in 1976 (USACE, 2012), although dredged material disposal in the vicinity of the site has occurred since the 1940s or 1950s (USACE, 1955; USACE, 1967). The South Jetty site was established in the 1980s as part of a federal navigation improvement project and first used in 1988 (USACE, 2012).

Figure 2 and Table 1 provide the location and boundaries of the two Grays Harbor sites.

Figure 1. Dispersive and Non-dispersive Multiuser Dredged Material Disposal Sites in Puget Sound



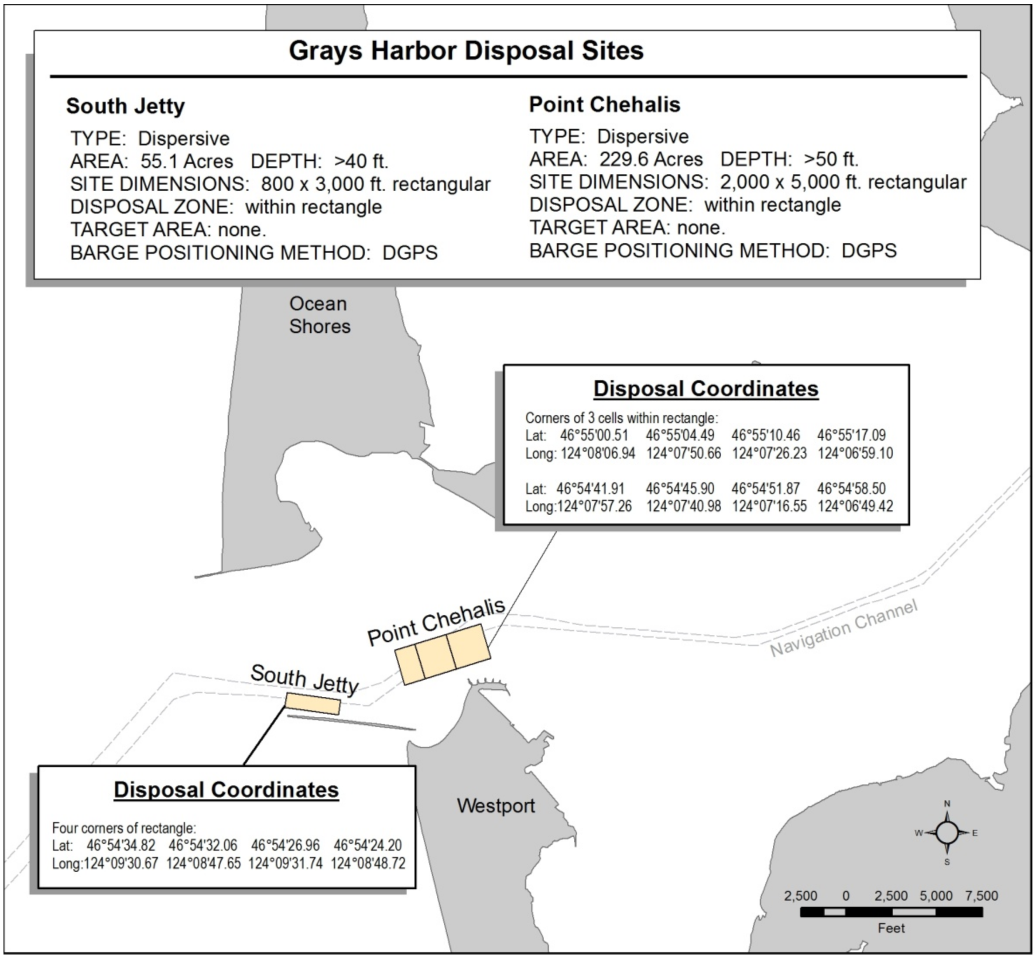
Jones & Stokes

Table 1. Puget Sound and Grays Harbor Disposal Site Descriptions

Site	Type	Area (acres)	Depth (feet)	Disposal Coordinates (NAD 83)	Disposal Zone Diameter (ft)[1]	Target Area Diameter (ft)[2]	Disposal Site Dimensions (ft)[3]	Positioning[4]
Bellingham Bay	Non-Dispersive	260	96	Lat 48° 42.82' Long -122° 33.11'	1,800	1,200	3,800 x 3,800 (circular)	VTS/AIS
Port Gardner	Non-Dispersive	318	420	Lat 47° 58.85' Long -122° 16.74'	1,800	1,200	4,200 x 4,200 (circular)	VTS/AIS
Elliott Bay	Non-Dispersive	415	300-360	Lat 47° 35.91' Long -122° 21.45'[5]	1,800	1,200	6,200 x 4,000 (tear drop shape)	VTS/radar
Commencement Bay	Non-Dispersive	310	540-560	Lat 47° 18.145' Long -122° 27.815'[6]	1,800	1,200	4,600 x 3,800 (ellipsoid)	VTS/radar
Anderson Island	Non-Dispersive	318	360-460	Lat 47° 09.42' Long -122° 39.47'	1,800	1,200	4,400 x 3,600 (ellipsoid)	VTS/AIS
Port Angeles	Dispersive	884	435	Lat 48° 11.67' Long -123° 24.94'	3,000	None	7,000 x 7,000 (circular)	VTS/radar
Port Townsend	Dispersive	884	361	Lat 48° 13.61' Long -122° 59.03'	3,000	None	7,000 x 7,000 (circular)	VTS/radar
Rosario Strait	Dispersive	650	97-142	Lat 48° 30.87' Long -122° 43.56'	3,000	None	6,000 x 6,000 (circular)	VTS/radar
Point Chehalis	Dispersive	230	>50	See Figure 2	Within Rectangle	None	2,000 x 5,000 (rectangular)	DGPS
South Jetty	Dispersive	55	>40	See Figure 2	Within Rectangle	None	800 x 3,000 (rectangular)	DGPS

1. The disposal zone is the compliance area within each site for the release of dredged material.
2. The target area is a smaller area within the disposal zone targeted by the tug operator and Coast Guard for the release of dredged material.
3. The disposal site is the bottom area that receives discharged dredged material.
4. VTS/radar = positioning monitored via radar by Coast Guard’s Puget Sound Vessel Traffic Service
   VTS/AIS = positioning monitored via Automatic Identification System by Coast Guard’s Puget Sound Vessel Traffic Service
   DGPS = positioning based on differential global positioning system coordinates
5. Coordinates shifted 300 ft south of center within the target area in 1991 following disposal site monitoring to prevent off-site migration to the north.
6. Coordinates shifted in 2007 to southeast corner of the target area to prevent excess mounding.

Figure 2. Dispersive Multiuser Dredged Material Disposal Sites in Grays Harbor



2.3 DREDGED MATERIAL SUITABILITY DETERMINATION PROCESS

Only dredged material that has been determined to be suitable for unconfined, open-water disposal can be discharged at the DMMP disposal sites in Puget Sound and Grays Harbor. The process for determining if material is suitable for disposal is described in detail in the 2014 DMMP User Manual, the procedures and standards of which are incorporated by reference and summarized below.

The typical Clean Water Act Section 404 and Section 10 permitting process (Figure 3) for a dredging project is intertwined with a second process, the dredged material evaluation process (Figure 4). The outcome of the dredged material evaluation process for each proposed disposal episode is documented by the DMMP agencies in a suitability determination. The suitability determination is a memorandum for record which provides the DMMP agencies' consensus evaluation of all chemical and biological testing data relative to the suitability/unsuitability of dredged material for open-water disposal. The suitability determination is signed by all four DMMP agencies. All suitability determinations are subsequently posted on the Corps' Dredged Material Management Office website.

Through the suitability determination process the DMMP agencies assess whether sediments to be dredged have the potential to adversely affect biological resources. If, based on this analysis, materials are determined to have the potential to adversely affect biological resources, the material is considered unsuitable for open-water disposal and must be disposed of by other means (e.g., disposal at licensed landfills). The dredged material suitability determination process consists of four tiers of evaluation and testing (Figure 5). A brief discussion of these tiers follows.

Tier 1 analysis involves the review of existing sediment data and site history, including all potential sources (e.g., outfalls, spills, etc.) for sediment contamination. If existing data are sufficient and indicate that sediments are physically removed from sources of contamination, the DMMP agencies may deem the sediments suitable, with no further testing required.

Tier 2 analysis consists of chemical testing. If the Tier 1 data are not sufficient, or there is some indication that sediments may contain contaminants (e.g., proximity to sources, spills, etc.) that may affect the quality of the aquatic environment, sediments are chemically tested under Tier 2 for both conventional parameters and chemicals of concern. Appendix A provides the guidelines currently in use in DMMP for evaluation of chemicals of concern (See pages II-112 to II-130 in PSDDA/EPTA (1988) for discussion of the Apparent Effects Thresholds process used to derive DMMP chemical guidelines). The chemistry of the material to be dredged is typically evaluated for various smaller sub-areas within the area to be dredged. These subdivided areas within a dredge site are termed Dredged Material Management Units (DMMUs). A DMMU is the smallest area/volume within the project that can be dredged independently from other areas within the site. The methodology for determining the number and location of DMMUs for each dredging project and the number of samples to be collected within each DMMU is detailed in the DMMP User Manual.

Tier 3 consists of biological testing. DMMUs with exceedances of chemical screening levels (SLs) or bioaccumulation triggers (BTs) require biological testing in Tier 3 to determine their toxicity and/or bioaccumulation potential. If the Tier 2 analysis indicates that all chemical concentrations are below the SLs and BTs, then no biological testing is necessary. If there are one or more SL exceedances, the DMMU is subjected to a suite of Tier 3 bioassays, consisting of an amphipod mortality test, a larval

Figure 3. Section 404/10 Regulatory Process

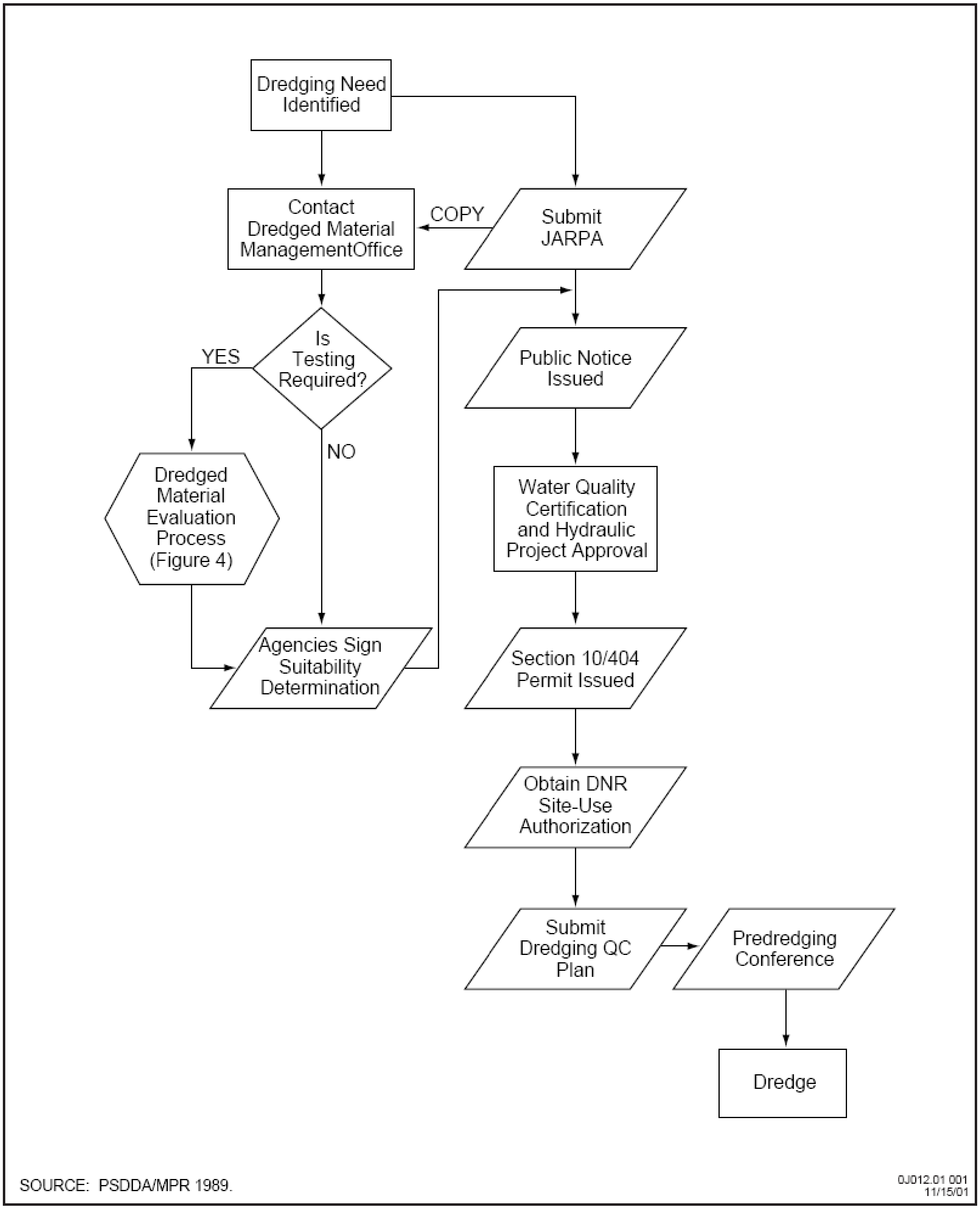
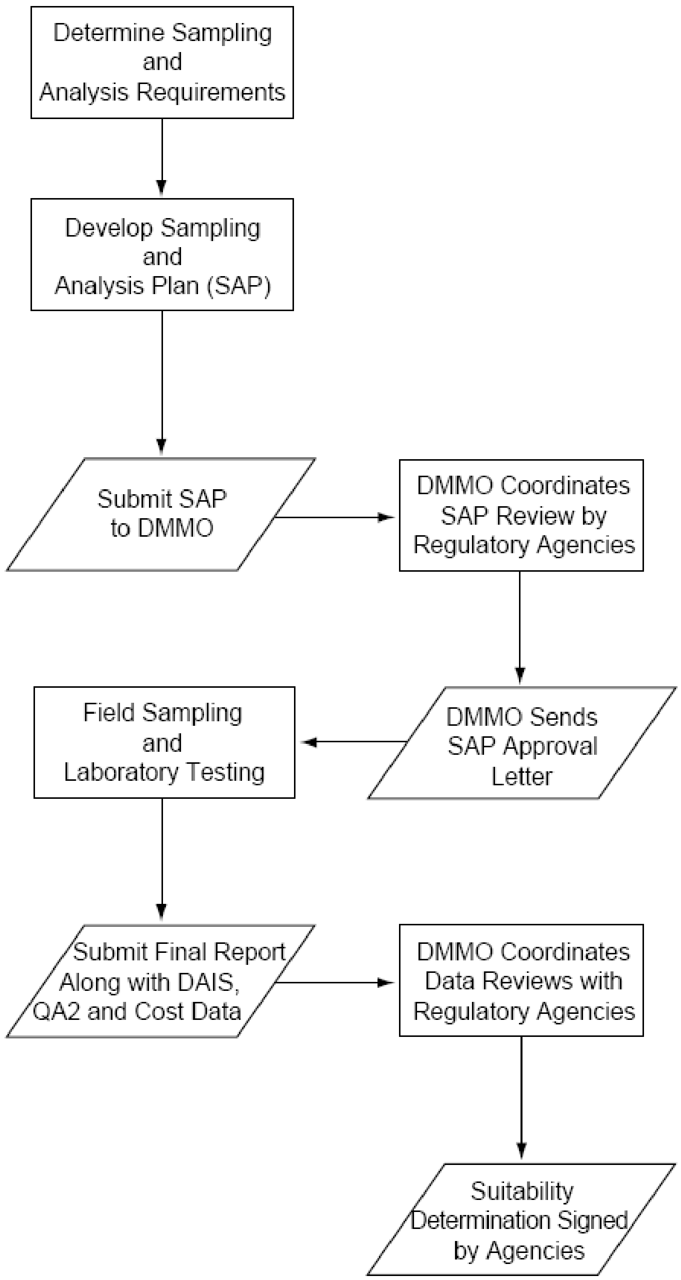


Figure 4. Dredged Material Evaluation Process



SOURCE: PSDDA/MPR 1989.

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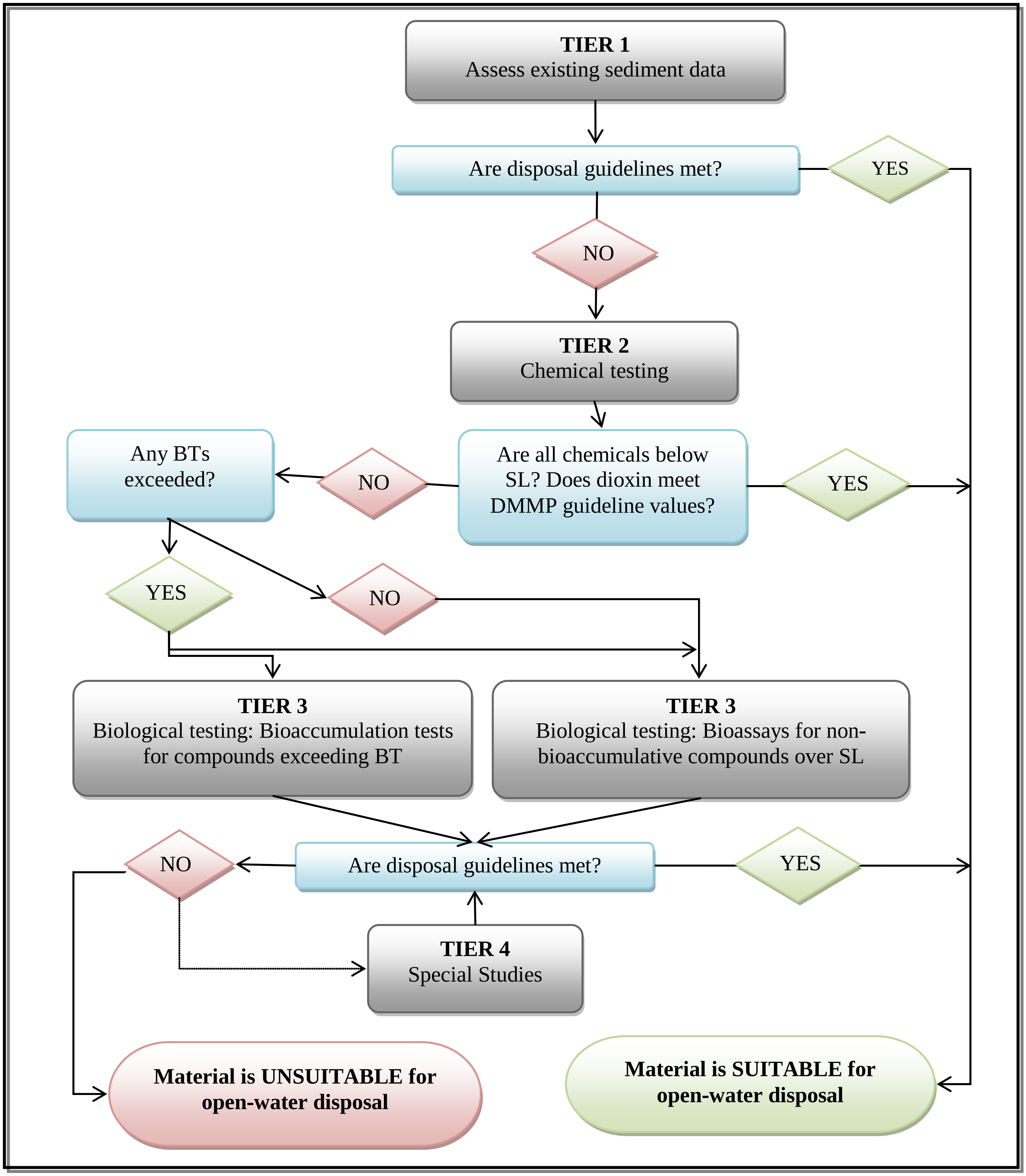
Figure 5. DMMP Tiered Testing Decision Diagram



development test, and the *Neanthes* growth test. If one or more BTs are exceeded, the DMMU is subjected to bioaccumulation testing for the chemical/s exceeding BT.

The evaluation of bioassay data is dependent on the type of disposal site proposed for use. Minor acute and sublethal adverse effects on biological resources due to chemicals of concern are allowed for dredged material placed at non-dispersive sites. This is referred to as "Site Condition II" in PSDDA/EPTA (1988) and PSDDA/EIS (1988, 1989), all three of which are incorporated by reference. Site Condition II was more precisely defined in PSDDA as "no significant acute toxicity." At dispersive sites, no adverse effects are allowed. This is referred to as "Site Condition I", which was more precisely defined in PSDDA as "no sublethal or acute toxicity."

Minor adverse effects are allowed at non-dispersive sites because the disposed material stays on site and is subjected to periodic post-disposal monitoring. Monitoring, discussed further in section 2.4, is used to verify that material placed at the non-dispersive sites is not having more-than-minor adverse biological effects on site and that the biological communities surrounding the sites are not being adversely affected. Changes to the dredged material evaluation procedures can be made if monitoring indicates that site management objectives are not being met. In contrast, dispersive sites are located in areas of high bottom currents where dredged material placed at the site is expected to be rapidly transported off-site. Post-disposal monitoring (other than bathymetry) is not possible at dispersive sites. Therefore, the evaluation of bioassay data is more restrictive for dispersive sites than evaluations made for non-dispersive sites.

Bioaccumulation testing consists of the exposure of a filter-feeder (*Macoma nasuta*) and deposit-feeder (*Nephtys caecoides*) for 28 to 45 days, depending on the chemicals of interest. Ecological effects are evaluated by statistically comparing the tissue concentrations resulting from exposure of test organisms to dredged material with bioaccumulation results from exposure to reference sediment. Human health effects are evaluated against DMMP guidelines for allowable tissue concentrations, which are a combination of risk-based numbers and Food and Drug Administration action levels. Also see the discussion in Appendix C (Consideration of DMMP Effects on Marine Mammals).

Tier 4 evaluations are conducted only if standard chemical and biological evaluations are insufficient to determine the suitability of dredged material for open-water disposal. A Tier 4 assessment is a special, non-routine evaluation which might include time-sequenced bioaccumulation or tissue analysis of organisms collected from the area to be dredged in order to determine concentrations of chemicals of concern. Tier 4 could also include a risk assessment. Tier 4 assessments are rarely needed.

2.3.1 Dioxin Regulation in Puget Sound

In December 2010, the DMMP agencies implemented revised dioxin guidelines for the regulation of dredged material disposed at the eight multiuser disposal sites in Puget Sound. Implementation of the revised guidelines followed a 3-year study, which included analysis of dioxins/furans (hereafter referred to simply as "dioxin") in sediment and tissue samples collected from the five non-dispersive sites (SAIC, 2008c), as well as determination of background sediment concentrations of dioxin at non-urban sites throughout the Sound (including Hood Canal, the San Juan Islands and the Strait of Juan de Fuca) (DMMP, 2009).

The background sediment concentration was determined to be 4 parts per trillion (pptr) 2,3,7,8-tetrachloro-p-dibenzodioxin toxic equivalents (TEQ). This value is based on an upper bound estimate of the distribution of dioxin in sediments from non-urban areas of Puget Sound. The TEQ is the summation of all 17 congeners of dioxins/furans having 2005 World Health Organization Toxic Equivalency Factors (TEFs). The revised dioxin guidelines for Puget Sound disposal sites are based on this background concentration.

2.3.1.1 Dispersive Site Guideline

The dispersive site management objective is 4 pptr TEQ. The maximum dioxin concentration allowed in any single dredged material management unit (DMMU) placed at a dispersive site is equal to the site management objective of 4 pptr TEQ. Other dioxin concentrations can be approved on a case-by-case basis, if demonstrated to be consistent with the anti-degradation provisions in the State of Washington Sediment Management Standards (SMS) rule.

2.3.1.2 Non-dispersive Site Guidelines

The non-dispersive site management objective is also 4 pptr TEQ. DMMUs with dioxin concentrations below 10 pptr TEQ are allowed for disposal as long as the volume-weighted average concentration of dioxin in material from the entire dredging project does not exceed 4 pptr TEQ. Case-by-case decisions to allow disposal of material not meeting these criteria may be made by the DMMP agencies based on the overall goal of meeting the disposal site management objective. Case-by-case considerations include material placement sequencing; possible cumulative effects of other bioaccumulative compounds within the project sediments; and the frequency of disposal site use. Small businesses with less than 4,000 cubic yards (cy) of dredged material may not be required to meet the 4 pptr volume-weighted average as long as all DMMUs are less than 10 pptr TEQ. The DMMP agencies may make this small-business exception if they determine that the disposal site management objective of 4 pptr will likely be met on an annual average basis, based on knowledge of other anticipated use of the identified disposal site.

2.3.2 Dioxin Regulation in Grays Harbor

Dioxin regulation in Grays Harbor is based on a human health risk assessment of seafood consumption related to disposal of federal channel maintenance dredged material at the South Jetty and Point Chehalis disposal sites (BCI, 1991). The maximum dioxin concentrations allowed in any single DMMU placed at the South Jetty and Point Chehalis disposal sites are 5 pptr 2,3,7,8-tetrachloro-p-dibenzodioxin and 15 pptr TEQ.

2.4 DISPOSAL SITE MONITORING

2.4.1 Dispersive Site Monitoring

Dispersive sites are located in areas of high bottom currents where dredged material placed at the site is expected to be rapidly transported off-site. This precludes monitoring for chemically-induced biological effects. Consequently, only physical conditions are monitored at the dispersive sites, with bathymetric measurements indicating whether material is accumulating or being dispersed. The Corps is responsible for physical monitoring at all the dispersive sites, both in Puget Sound and Grays Harbor.

Bathymetric surveys were conducted at the Rosario Strait, Port Townsend and Port Angeles sites prior to any disposal. Results from post-disposal surveys are compared against these baseline surveys.

2.4.2 Non-Dispersive Site Monitoring

Monitoring for non-dispersive sites consists of more rigorous evaluations to determine if the deposited material remains on-site; if the site conditions are being met; and if biological resources are being affected. Site management objectives are evaluated at all five non-dispersive sites by evaluating 3 broad monitoring questions, and 6 testable hypotheses as depicted in Table 2. Monitoring data form the basis for the annual review of the evaluation procedures and site management plans. Adjustments are made to the program as necessary to ensure subsequent compliance with the site management objectives.

The site management objectives and monitoring framework were developed as part of the PSDDA study (PSDDA/MPTA, 1988). The monitoring procedures have evolved over time as experience has been gained and dredged material evaluation procedures modified through the DMMP annual review process. The current monitoring procedures, with the exception of dioxin, are documented in SAIC, 2007. Since 2007, the monitoring procedures for dioxin have been modified to reflect changes in the dredged material evaluation procedures for these chemicals (DMMP, 2010). The monitoring framework and procedures found in PSDDA/MPTA (1988), SAIC (2007) and DMMP (2010) are incorporated by reference.

Two of the testable hypotheses in Table 2, as well as five of the action items, involve comparison of monitoring data to baseline data collected at the non-dispersive sites prior to their initial use. The baseline surveys included collection of sediment and tissue chemistry data, and infaunal taxa abundance and community structure. Dioxin was considered a "chemical of concern in limited areas" at the time of the PSDDA baseline surveys in the late 1980s and was not included in the analyses. Concern for dioxin increased in the 2000s and this chemical was added to the list of COCs for monitoring. Special monitoring surveys were conducted at the non-dispersive sites in 2005-2007, in part to determine the existing concentrations of dioxin. The sediment and tissue dioxin data resulting from these surveys became the dioxin "baseline" for future monitoring events. While not true baseline surveys (since dredged material had already been placed at each of the sites prior to 2005), these dioxin concentrations provided the DMMP agencies with a snapshot of site conditions prior to adopting more stringent evaluation procedures for dioxin.

Monitoring at non-dispersive sites involves the collection of physical, chemical and biological data within and near the site. Three types of post-disposal monitoring events are distinguished in the PSDDA monitoring framework:

Full Monitoring – Mapping of the disposal site is accomplished through the use of sediment profile imaging (SPI), which determines the depth and spread of dredged material. Box core benthic samples and SPI photos are used to provide quantitative and qualitative information on benthic infaunal conditions on-site and off-site. Chemical monitoring is used to evaluate the concentrations of chemicals of concern present on and off the site, and whether or not they are present in concentrations that could cause unacceptable adverse impacts. Biological monitoring includes toxicity bioassays to assess on-site dredged material. Additionally, off-site benthic communities are evaluated by comparing infaunal abundance and tissue chemistry at transect stations to baseline data to determine if unacceptable impacts from dredged material disposal are occurring.

Partial Monitoring – For material with no or few chemical screening level exceedances, less rigorous site monitoring occurs. Partial monitoring includes bathymetric mapping and the use of SPI to determine the pattern and depth of dredged material deposits. SPI is also used to provide information on general benthic conditions on-site and off-site. Partial monitoring includes collection of sediment at and near the site for analysis of chemicals of concern and toxicity testing. No quantitative benthic information (box cores) is collected during partial monitoring events.

Tiered Monitoring – Only a portion of the samples are analyzed to verify that deposited material is staying on-site and that site conditions are met. If analysis of samples indicates that there may be unacceptable impacts off-site, additional archived samples are analyzed to determine if biological resources are being affected.

Table 2. DMMP Non-Dispersive Site Monitoring Framework

Questions	Hypothesis	Monitoring Variable	Interpretive Guideline	Action Item when exceeded*
No.1 Does the deposited dredged material stay onsite?	**1.** Dredged material remains within the site boundary?	Sediment Profile Imagery (SPI) Onsite & Offsite	Dredged material > 3 cm at the perimeter stations	Further assessment is required to determine full extent of dredged material deposit.
	2. Chemical concentrations do not measurably increase over time due to dredged material disposal at offsite stations.	Sediment Chemistry Offsite	Washington State Sediment Quality Standards and Temporal Analysis	Post-disposal benchmark station chemistry is analyzed and compared with appropriate baseline benchmark station data.
No. 2 Are the biological effects conditions for site management exceeded at the site due to dredged material disposal?	**3.** Sediment chemical concentrations at the onsite monitoring stations do not exceed the chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal	Sediment Chemistry Onsite	Onsite chemical concentrations are compared to DMMP maximum levels.	PSDDA agencies may seek adjustments of disposal guidelines and compare post-disposal benchmark chemistry with appropriate baseline benchmark station data.
	4. Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.	Sediment Bioassays Onsite	DMMP Bioassay Guidelines (Section 401 Water Quality Certification)	Benchmark station bioassays are performed (if archived after monitoring) and compared with baseline benchmark bioassay data.
No. 3 Are unacceptable adverse effects due to dredged material disposal occurring to biological resources offsite?	**5.** No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infaunal species collected down current of the disposal site	Tissue Chemistry Transect	Guideline values Metals: 3x baseline conc. Organics: 5x baseline conc.	Compare post-disposal benchmark tissue chemistry with baseline benchmark tissue chemistry data.
	6. No significant decrease due to dredged material disposal has occurred in the abundance of dominant benthic infaunal species collected down current of the disposal site.	Infaunal Community Structure Transect	Guideline values Abundance of major taxa < 1/2 baseline macrobenthic infaunal abundances	Compare post-disposal benchmark benthic data with baseline benchmark data.

Baseline monitoring of the non-dispersive sites was conducted in 1988 (Phase I sites) and 1989 (Phase II sites) to document existing conditions and for use as a benchmark for post-disposal monitoring studies. Details of baseline studies are provided in PTI Environmental Services (1988, 1989). The types of samples collected as part of the baseline studies included sediment chemistry, toxicity (bioassays), tissue chemistry and benthic infauna.

Monitoring data collected since the inception of the PSDDA program have shown that the site management objectives are generally being met. However, a range of adaptive management actions are available in the event that monitoring data indicate potential problems with off-site movement of dredged material, elevated contaminant concentrations, or impacts to biological resources. These may include the more intensive data collection procedures identified in Table 2; shifts in disposal coordinates; modification of dredged material evaluation procedures; special studies; and temporary disposal-site closures.

2.5 CONSULTATION HISTORY

There have been several consultations on the PSDDA disposal sites (as a program). Consultations on the PSDDA disposal program and disposal sites with NMFS occurred in 1999 (NMFS #s 1999/01195 and 1999/01261), in 2000 (NMFS # 2000/00696), in 2005 (NMFS #s 2005/00484 and 2005/06457) in 2007 (2007/03507 and 2007/05324) and again in 2010 (NMFS # 2010/042490). Consultations with USFWS on the PSDDA disposal program and disposal sites occurred in 2005 ((USFWS #s 1-3-05-I-0298 and 1-3-05-IC-0299), and in 2010 (USFWS # 13410-2010-I-0542). With one exception, all of these consultations have been informal. The one exception was a formal consultation with NMFS in 2010 (NMFS # 2010/042490) due to the likelihood of adverse effects to bocaccio, canary, and yelloweye rockfish. As a result, the Corps instituted a research project to determine the probability of occurrence of bocaccio, canary rockfish, and yelloweye rockfish larvae at PSDDA disposal sites. Results indicate a low probability of occurrence at the PSDDA sites.

The disposal sites in Grays Harbor have not undergone collective ESA Section 7 consultation. Consultation on the Grays Harbor disposal sites has been via inclusion in the BEs and subsequent consultations for specific Corps maintenance dredging projects in Grays Harbor, as well as individual consultations associated with maintenance dredging authorized under Clean Water Act Section 404.

3 DESCRIPTION OF THE PROPOSED ACTION

The activities considered in this biological evaluation are the transport of dredged material from the dredging sites to Puget Sound or Grays Harbor multiuser disposal sites; the disposal of material at these sites; the return of equipment to dredging sites; and post-disposal monitoring of the sites. These same activities have occurred over the past 26 years in Puget Sound, since the 1989 designation of PSDDA disposal sites. These activities have occurred in Grays Harbor since the 1970's. The scope of the Federal action extends to disposal of material from bottom-dump or split-hull barges, or from hopper dredges, derived from maintenance dredging conducted under authority of the Corps navigation program or under Section 404 permits issued by the Corps. Material placed via other methodologies or at other locations is not addressed in this BE and is subject to independent consultation.

Although dredging projects in Puget Sound and Grays Harbor are also required to consult with NMFS and USFWS regarding potential effects on ESA-listed species and designated critical habitat, dredging activities are not considered in this biological evaluation. All permitted maintenance dredging actions that generate material for open-water disposal at multiuser disposal sites require the issuance of a Section 10 and Section 404 permit (Clean Water Act). The issuance of a Section 10/404 permit is a Federal action requiring an ESA Section 7 consultation. Therefore, the potential effects of specific dredging activities on threatened and endangered species will be addressed in separate biological evaluations prepared by individual project proponents once specific future plans are known. Maintenance dredging by the Corps also requires ESA Section 7 consultation. A separate programmatic biological evaluation has been prepared by the Corps for its maintenance dredging program.

The Corps of Engineers requests that the term of the consultation resulting from this biological evaluation be 25 years. Changes in ESA-listed species; their designated critical habitat; or modifications to the management of the multiuser open-water disposal sites that change the affects determination to ESA-listed species, their designated critical habitat, or essential fish habitat this BE, will require supplements to this BE and reinitiation of consultation.

3.1 DREDGED MATERIAL TRANSPORT

In Puget Sound, dredged material is typically transported to the disposal sites by tugboats pulling bottom-dump or split-hull barges. The barges can be of various sizes, with the ability to transport between 1,200 and 2,000 cubic yards (typically 1,500 cubic yards) of material each trip. The number of barge discharges per day varies by project, but is typically two to five per day when projects are active (worst case example: 2007 Commencement Bay disposal = 1,324,254 cy, amounting to 897 bargeloads over 203 days between 8/22/2006 and 2/28/2007; average = 4.4 bargeloads/day). The distance traveled and the number of trips required varies depending on the location and extent of the dredging activity. Hopper dredges are not used for transportation of dredged material for aquatic disposal in Puget Sound.

In Grays Harbor, dredged material is transported to the disposal sites by either a bottom-dump hopper dredge or by a tugboat and bottom-dump or split-hull barge. Hopper dredges are only used in outer reaches of Grays Harbor. The vessels used in Grays Harbor generally have the ability to transport between 800 and 6,000 cubic yards of material each trip. The number of barge discharges per day is typically between three and five, but this number varies depending on the extent of the dredging activity ongoing at the time and distance to the disposal site.

3.2 DISPOSAL ACTIVITIES

3.2.1 Dispersive Sites

Dredged material disposed at the dispersive sites is dispersed relatively quickly by the strong currents at these locations. Disposal occurs from a barge as it is being towed through the disposal site or from a hopper dredge. Disposal zones for the PSDDA dispersive sites were sized on the assumption that a barge is towed at an average speed of 3 knots and the load is completely dumped in 10 minutes. The PSDDA dispersive site boundaries were sized based on the predicted horizontal spread of dredged material released within the disposal zone.

Based on modeling conducted as part of the PSDDA site selection process (PSDDA/DSSTA, 1988), 3,000-foot diameter disposal zones were established for the dispersive sites. Based on the projected spread, the disposal site dimensions were set at a 6,000-foot diameter for the Rosario Strait site, and a 7,000-foot diameter for the Port Townsend and Port Angeles sites.

The dispersive sites in Grays Harbor are somewhat smaller, with the South Jetty site having dimensions of 800 x 3,000 feet, and the Point Chehalis site having dimensions of 2,000 x 5,000 feet. The long axis for both Grays Harbor sites is aligned with the direction of the tidal current. The determination of which disposal site to use is based on a number of factors (USACE, 2011), including:

- depth of each disposal area, as surveyed annually;
- weather and wave conditions at the time of disposal;
- type of dredged material
- presence of commercial crab pots in a disposal site and/or access lane; and
- results of pre-disposal Dungeness crab surveys.

3.2.2 Non-Dispersive Sites

The South Jetty site is the preferred disposal area for inner harbor dredged material, although when the South Jetty site is full or weather/wave conditions are hazardous then inner harbor materials are disposed at the Point Chehalis site (USACE, 2000). The Point Chehalis site is divided into three cells. The navigation channel passes through these cells; therefore, it is critical that dredged material not accumulate to the point of impeding navigation. For dredging of the federal navigation channel, the Corps directs the dredging contractor to evenly distribute the disposal loads among the cells to prevent mounding from occurring.

Dredged material disposal activities at the non-dispersive sites in Puget Sound are conducted to minimize the dispersion of dredged material. Disposal occurs from the barge as the barge is being towed through the disposal site at the minimum speed necessary to maintain control. All dredged material disposal tugs are required to record and report when and where the doors on the barge are opened and closed to ensure that all disposal occurs within the disposal zone. In addition, the DNR keeps a record of all disposal track lines that each barge traveled during disposal using DGPS.

The behavior of discharged material at non-dispersive sites was modeled as part of the original site selection process (PSDDA/DSSTA, 1988). The models showed that in 400 feet of water, material settled to the bottom within a 1,000-foot radius of the drop point. The depth of the deposits estimated from a single 1,500 cy barge load of dredged material varied from about 0.8 cm in the center of the disposal mound, to about 0.1 cm near the edges of the mound.

3.3 DISPOSAL MECHANISMS

As part of the PSDDA site selection analysis, the Corps conducted extensive numerical modeling simulations using the Disposal from an Instantaneous Dump (DIFID) model (Trawle and Johnson 1986). The model evaluated the fate and dispersal of dredged material of varying composition discharged from bottom-dump barges into waters of varying depth and current speed (PSDDA/MPR 1988, 1989). A schematic representation of a discharge event is presented in Figure 6. The same material released from a split-hull barge or hopper dredge would behave in the same way, as all three vessel types release material below the water over a short period of time.

Changes in the form and behavior of an instantaneous discharge of dredged material from a barge during its descent through the water column are described by the Corps (1986) and Pequegnat (1983). The descent from an instantaneous discharge can be divided into three phases according to the physical forces that act on the material as it descends through the water column to the bottom. These phases are convective descent, dynamic collapse, and passive diffusion.

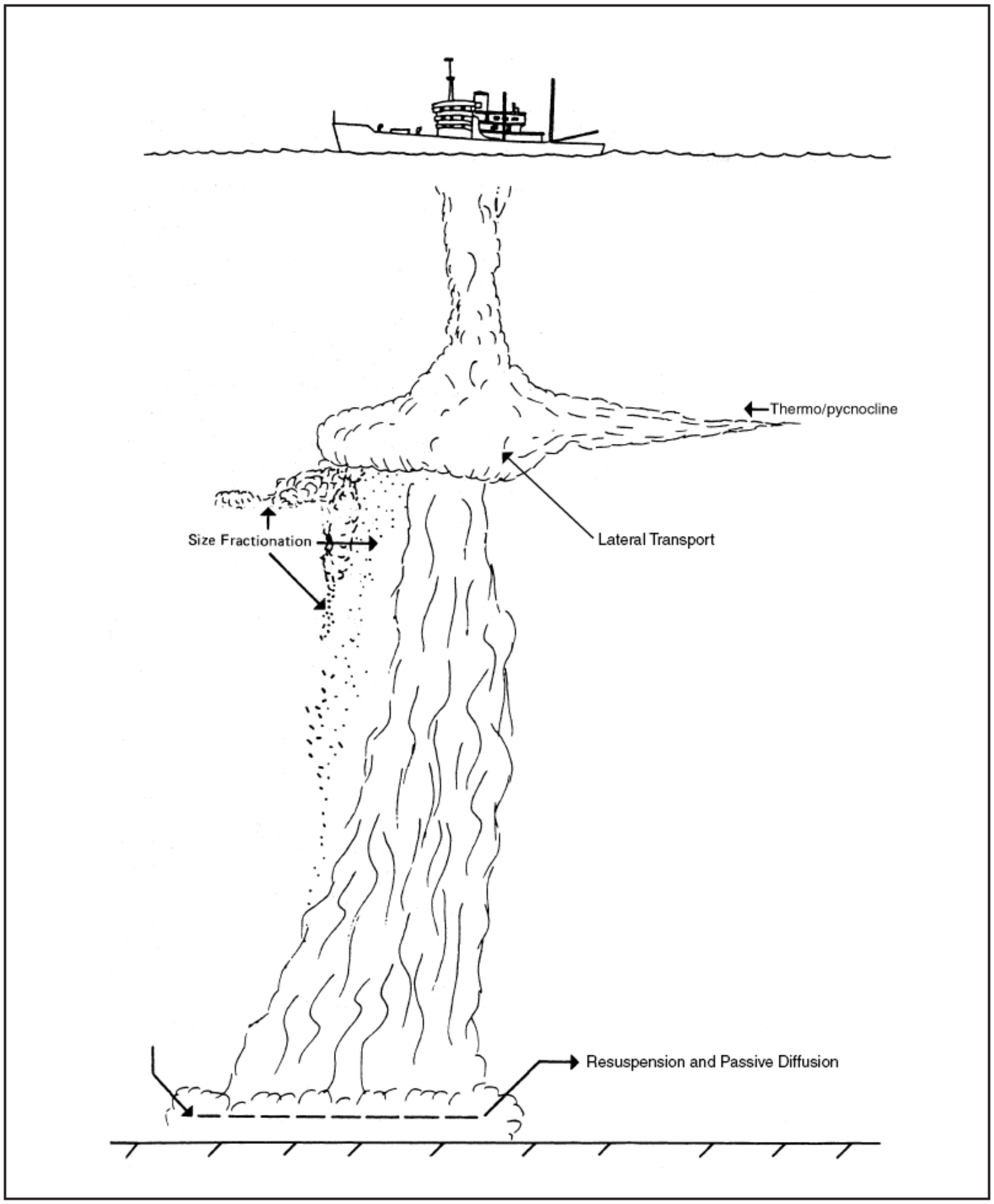
3.3.1 Convective Descent

During convective descent, the discharged material descends through the water column as a dense, well defined fluid-like jet. The consistency and behavior of the jet depends on the characteristics of the dredged material, moisture content, cohesiveness, size composition (e.g., silt, clay, sand, gravel), and the equipment used to dredge the material (clamshell, cutterhead, hopper/drag-arm). Material previously discharged at multiuser sites has been of highly variable character, and a wide range of dredged material type can be expected in future disposal activities. The dredging process for episodes employing bottom-dump barges is almost entirely performed using clamshell dredges. Clamshell dredges keep the dredged material relatively consolidated and minimize the percent moisture content (PMC). Material dredged with hopper dredges in Grays Harbor is predominantly sand, which settles out quickly in the hopper, while water entrained by the hydraulic dredging process is returned to the waters at the dredge site. This has the effect of minimizing the PMC for this material as well.

All other things being equal, the PMC will determine the amount of dredged material that will initially reach the bottom, the amount of time it takes to initially reach the bottom, the area of the bottom it covers, the direct and immediate potential impact on the pelagic water column and bottom, and the effects of the environment on the dredged material (resuspension and transport). Where the initial PMC is low, as with clamshell dredging in Puget Sound and hopper dredging in Grays Harbor, the transit time of the material through the water column is sufficiently brief that the influence of any currents in transporting the material laterally is minimal (Pequegnat 1983). In modeling conducted by the Corps (PSDDA/FEIS 1988, 1989), transit time of the material to the bottom in 400 feet of water is on the order of 30 seconds after the discharge is initiated. Due to the generally higher current speeds at the dispersive sites, lateral transport will generally be greater than at non-dispersive sites. The effect of higher current speeds on lateral transport is greater at the dispersive sites in Puget Sound than at those in Grays Harbor. The Grays Harbor sites are located in shallower water, thereby reducing the descent time and the potential for lateral transport.

As the material descends to the bottom, large volumes of water are entrained in the jet, which expands the diameter of the jet as it approaches the bottom. The Corps (1986) estimated that the diameter of the jet as it makes contact with the bottom in 400 feet of water would be approximately 250 feet. As a result of several factors, including turbulent shear, some material is separated as it descends, and settles to the bottom at a slower rate. This rate is determined by material density (size fractionation). Lateral transport of this material has been a concern in the discharge of sediments that contain contaminants. However, this is not a critical issue for the present analysis because the material discharged at the multiuser sites

Figure 6. Schematic Representation of the Fate of Dredged Material during Disposal



SOURCE: Adapted from Pequegnat 1983.

will have been evaluated thoroughly for suitability for disposal. To be suitable, the sediments must not contain unacceptable concentrations of chemicals of concern.

3.3.2 Dynamic Collapse

The dynamic collapse phase occurs as the material collides with the bottom or when the material encounters a water layer with greater ambient density (thermocline or pycnocline). As the jet material collapses, the material spreads out in all directions as a density/momentum-driven surge. The behavior of discharged material at both dispersive and non-dispersive sites was modeled as part of the original PSDDA site selection process (PSDDA/DSSTA, 1989).

For PSDDA dispersive sites, the models showed that material impacts the bottom within the disposal site boundary. An estimated 90% of material disposed from a 1,500-cy bottom-dump barge is deposited within a 1,500-foot radius of the drop point. This compares to the 3,000-foot radius of the Rosario Strait disposal site and 3,500-foot radius of the Port Angeles and Port Townsend sites. The initial depths of the deposits on the bottom were calculated to vary from 2.2 to 0.73 cm in water depths of 200 to 400 feet.

For PSDDA non-dispersive sites, the models showed that more than 95% of the material disposed from a 1,500-cy bottom-dump barge settled to the bottom within the disposal site boundary within a 1,000-foot radius of the drop point. This compares to non-dispersive disposal sites with a radius (or half the length of the long axis for non-circular sites) ranging from 1,900 feet at the Bellingham Bay site to 3,100 feet at the Elliott Bay site. The depth of the deposits on the bottom varied from about 2.2 to 1.6 cm in the center of the disposal mound in water depths of 200 to 400 feet.

The concentration of suspended solids, as well as the extent and duration of their presence in the water column, is of concern because of potential effects on biota. As expected, effects caused by suspended solids vary in concentration and duration depending on the type of material discharged and environmental conditions. Clamshell-dredged material is loaded into bottom-dump barges, which maximizes the cohesiveness of the material compared to other dredging methods. As such, the material tends to clump when discharged. This minimizes loss from the jet to the surrounding water and resuspension once it contacts the bottom. Various estimates have been made to characterize the loss of material to surrounding waters (Corps 1986). Studies have generally concluded that from 1 to 5% of the disposed material is lost from the jet to the water column during descent. However, monitoring has demonstrated that this material settles relatively quickly (within 1 hour).

The extent of the initial spread of material placed at the Grays Harbor dispersive sites would be expected to be less than at most of the PSDDA sites due to the shallower depth of water. Clamshell-dredged material placed at the Grays Harbor sites would otherwise behave similarly to clamshell-dredged material placed at the PSDDA sites. Hopper-dredged material, consisting predominantly of sand, would also tend to settle out of the water column quickly, not due to cohesiveness like clam-shelled material, but rather due to the higher settling velocity of sand compared to finer particles.

3.3.3 Resuspension and Transport of Disposed Material by Currents

This process is not a major factor at non-dispersive sites because current velocities at the sites are too low to initiate movement of the material.

The dispersive sites are located in areas where bottom currents are swift enough to completely disperse discharged dredged material out of the disposal site. For example, the three dispersive sites in Puget Sound have mean current speeds greater than 40 cm/sec and peak speeds greater than 100 cm/sec (PSDDA/DSSTA, 1989). Several field studies were performed and numerical models were created to evaluate the transport of dredged material from PSDDA dispersive sites, based on current speeds. These studies/models indicated that at all three sites a small amount of dredged material would initially accumulate on the bottom after a discharge event, but then complete erosion of the material would likely occur over a single flood or ebb tide.

Bathymetric monitoring of the Rosario Strait site in 1991, 1994, 1999, and 2009 confirmed that dredged material is rapidly dispersed and no accumulation of dredged material has occurred at that site since the 1989 baseline survey. The other two PSDDA dispersive sites have not been monitored since their baseline surveys because of relatively low site use and low volumes of material disposed at these sites over the past 26 years.

Transport of dredged material by currents can occur through relatively large distances. The direction and distance of transport varies for each site and depends on the stage of the tide during which the material is disposed. PSDDA/DSSTA (1989) evaluated far-field dispersion using a variety of methods including observation of Lagrangian drifters and numerical simulations (Crean 1983). The studies anticipated wide dispersal of the material because of the strong currents at the sites.

A fate and transport study (USACE/DNR, 2012) of the PSDDA dispersive sites confirmed the prediction of wide dispersal of material made during the siting study. Acoustic Doppler Current Profiler (ADCP) surveys at the Rosario Strait, Port Angeles and Port Townsend sites confirmed peak currents stronger than 100 cm/s at each of the sites. Dispersal of material at the Port Angeles and Port Townsend sites is predominantly in the east-west direction, parallel to the long axis of the Strait of Juan de Fuca. Peak currents at the Rosario Strait site exceed 180 cm/s, making this site the most dispersive of the three. Material placed at the Rosario Strait site is transported predominantly to the south, with smaller amounts of material moving to the north and east.

Current speeds at the Grays Harbor sites are comparable to the PSDDA dispersive sites, with mean current speeds greater than 40 cm/sec and peak speeds greater than 120 cm/sec. The Point Chehalis site is subject to high wave energy and strong, predominately westward, currents. Erosion from this site is relatively sensitive to offshore wave conditions. Despite being located in a high-energy environment, some dredged material accumulation at the Point Chehalis site does occur on a months-long basis, depending on the volume and nature of sediment disposed and the time of year disposal occurs (USACE, 2010). Annual survey records indicate that approximately 75% of material disposed at this site erodes during the dredging period, and another 15% erodes during the following winter (USACE, 2011).

The South Jetty site is also subject to fast tidal currents, predominantly westward, that sweep along the jetty toe. Dredged material placed at this site is typically quickly eroded. Unlike the Point Chehalis site, erosion from the South Jetty site is relatively insensitive to offshore wave conditions (USACE, 2010).

3.4 SITE USAGE

Table 3 details cumulative dredged material disposal at the eight Puget Sound sites since their designation (1989-1990) through 2014. Volumes for the non-dispersive sites are compared to a site capacity threshold delineated at the time of site designation (as subsequently modified in the case of the Commencement Bay site), and the estimated time to reach capacity is listed. Approximately 17 million cubic yards of dredged material have been disposed at the Puget Sound sites over the past 26 years. The Commencement Bay, Elliott Bay, Port Gardner, and Rosario Strait sites are the most heavily used, with annual averages ranging from 85,000 to 315,000 cubic yards.

The cumulative volumes in the table for the two Grays Harbor sites are for the period since implementation of the DMMP disposal site management plan in 1995 (DMMP,1995), through 2014. Over 27 million cubic yards have been placed at the Grays Harbor sites over the last 19 years. The Point Chehalis and South Jetty sites average 837,000 and 590,000 cubic yards per year respectively.

Disposal volumes vary widely from year to year at the Puget Sound sites (Table 4). All eight sites have had at least one year with no dredged material disposal. Elliott Bay is the most consistently used site, while the Port Angeles site has received material in only a single year. Total annual volume placed at the Puget Sound sites ranges from a low of approximately 124,000 cubic yards in dredging year (DY) 2014 to a high of 1.7 million cubic yards in DY 2007.

Table 3. Cumulative Volumes Placed at the Multiuser Disposal Sites

Non-dispersive Disposal Site	Cumulative Volumes (cy)	Average Volume Per Year (cy/yr)	Site Capacity (cy)[1]	Percent of Site Capacity	Estimated Time to Reach Site Capacity (Years)[2]
Bellingham Bay[3] (1990-2014)	78,883	3,155	9,000,000	0.9	>100
Port Gardner (1989-2014)	3,326,221	127,932	9,000,000	37.0	44
Elliott Bay (1989-2014)	3,030,788	116,569	9,000,000	33.7	51
Commencement Bay (1989-2014)	8,196,707	315,258	23,000,000[4]	35.6	47[2]
Anderson/Ketron Island (1990-2014)	157,215	6,289	9,000,000	1.7	>100
Dispersive Disposal Site	**Cumulative Volumes (cy)**	**Average Volume per Year (cy/yr)**	**Site Capacity (cy)**	**Percent of Site Capacity**	**Estimated Time to Reach Site Capacity (Years)[5]**
Rosario Strait (1990-2014)	2,122,509	84,900	N/A	N/A	N/A
Port Townsend (1990-2014)	55,528	2,221	N/A	N/A	N/A
Port Angeles (1990-2014)	22,344	894	N/A	N/A	N/A
Point Chehalis (1996-2014)	15,780,365	830,546	N/A	N/A	N/A
South Jetty (1996-2014)	11,355,966	597,682	N/A	N/A	N/A

1. Site capacity estimated in Phase 1 and II Disposal Site Selection Technical Appendix for non-dispersive sites is approximately 9,000,000 cubic yards.

2. Estimated time to reach site capacity = (Site Capacity – Cumulative Volume)/average annual disposal volume.

3. The Bellingham Bay disposal site has not been used since 1998; it is currently deactivated and not used for disposal pending renewal of the shoreline permit.

4. The capacity of the Commencement Bay site was increased from 9 to 23 million cubic yards following finalization of a 2010 NEPA/SEPA Supplemental Environmental Impact Statement.

5. Actual site capacity for dispersive sites is not limited, assuming complete dispersal of dredged material off site.

Table 4. Multiuser Disposal Site Volumes by Year (in cubic yards)

Dredging Year[1]	Bellingham Bay	Port Gardner	Elliott Bay	Commencement Bay	Anderson Ketron	Rosario Strait	Port Townsend	Port Angeles	Point Chehalis	South Jetty	Annual Total
1989	---[2]	0	4,097	6,648	---[2]	---[2]	---[2]	---[2]	These years preceded implementation of the DMMP disposal site management plan for Grays Harbor		10,745
1990	0	992,074	129,542	0	0	0	0	0			1,121,616
1991	0	17,261	12,000	10,900	0	566,694	0	0			606,855
1992	0	0	230,241	0	0	43,850	0	0			274,091
1993	32,883	109,500	17,282	0	10,197	176,486	22,642	0			368,990
1994	0	236,749	132,770	0	0	57,010	0	0			426,529
1995	0	143,510	93,412	290,857	8,677	25,250	0	0			561,706
1996	44,800	121,246	95,302	460,684	0	205,500	0	22,344	370,203	1,674,267	2,994,346
1997	0	102,531	18,982	0	0	0	0	0	665,388	959,249	1,746,150
1998	1,200	0	110,465	693,540	0	53,000	4,000	0	357,388	780,181	1,999,774
1999	0	0	414,794	140,319	0	140,761	1,986	0	1,460,361	1,153,621	3,311,842
2000	0	0	360,577	893,776	0	0	0	0	941,782	1,282,663	3,478,798
2001	0	248,965	557,340	265,867	0	10,419	0	0	555,247	358,873	1,996,711
2002	0	45,919	133,270	0	0	0	0	0	88,812	475,199	743,200
2003	0	0		710,675	0	38,223	0	0	85,960	824,694	1,659,552
2004	0	0	15,602	1,205,993	5,772	230,747	0	0	1,022,330	1,166,089	3,646,533
2005	0	0	77,838	949,399	8,180	23,847	0	0	671,819	740,910	2,471,993
2006	0	722,185	3,801	811,000	0	150,921	0	0	1,306,337	196,893	3,191,137
2007	0	4,400	24,250	1,324,254	10,407	20,970	10,996	0	632,366	389,127	2,416,770
2008	0	17,393	172,999	214,858	97,310	0	0	0	927,396	0	1,429,956
2009	0	10,450	20,133	18,803	0	188,580	6,856	0	931,784	21,088	1,197,694
2010	0	371,500	96,046	14,812	0	0	9,048	0	1,054,847	0	1,546,253
2011	0	44,196	11,486	179,160	0	45,865	0	0	802,046	1,012,127	2,094,880
2012	0	34,143	165,700	3,489	10,579	180	0	0	1,606,641	320,985	2,141,717
2013	0	104,199	15,266	1,673	0	144,206	0	0	1,190,142	0	1,455,486
2014	0	0	117,593	0	6,093	0	0	0	1,109,516	0	1,233,202
Site Total:	78,883	3,326,221	3,030,788	8,196,707	157,215	2,122,509	55,528	22,344	15,780,365	11,355,966	44,126,526
CY/year:	3,155	127,932	116,569	315,258	6,289	84,900	2,221	894	830,546	597,682	

1. Dredging Year: 16 June through June 15 (e.g. DY 2014 began on June 16, 2013 and ended June 15, 2014).
2. This is a PSDDA Phase II site; it was opened in Dredging Year 1990.

Annual volumes placed at the Grays Harbor sites are more consistent, averaging approximately 1.4 million cubic yards per year. The majority of the material comes from maintenance dredging of the federal navigation channel.

3.5 WORK WINDOWS FOR ESA-LISTED SPECIES

Disposal activities will occur concurrently with dredging projects. Since the timing of dredging activities is regulated by in-water work closure periods established to protect out-migrating juvenile salmon and bull trout during sensitive times in their life cycles, no additional ESA closure periods specifically for multiuser disposal sites are warranted. However, three of the eight Puget Sound sites have closure periods for the protection of other marine resources/fisheries (see Table 5 below).

Table 5. Puget Sound Site Closure Periods (non-ESA)

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

3.6 DISPOSAL SITE MONITORING

3.6.1 Dispersive Site Monitoring

Physical monitoring is conducted periodically at the dispersive sites to verify that mounding is not occurring. Physical monitoring consists of deployment of a survey vessel to the site to take bathymetric soundings, typically through the use of a multibeam sonar system. Bathymetric surveys of dispersive sites in Puget Sound are only conducted when sufficient volumes of dredged material have been placed at a site to warrant monitoring. To determine if material is remaining at the sites or dispersing, post-disposal bathymetry is compared to baseline bathymetry. Baseline studies of the PSDDA dispersive sites were performed in 1989 (PTI Environmental Services 1989).

Due to the large volumes of material placed at the Point Chehalis and South Jetty sites, the Corps routinely conducts hydrosurveys there to ensure that sediment accretion does not pose a hazard to navigation. Bathymetric surveys have been conducted at the entrance to Grays Harbor by the Corps since the late 1800s.

Chemical and biological monitoring are not performed at dispersive sites because of the highly dynamic environment in which they are located. At Rosario Strait, the most dispersive site, disposed material does not remain on site long enough to sample. At sites where temporary accumulation does occur (e.g. Point Chehalis), sediment is constantly moving through the system. The sediment at the site at the time of sampling would, at best, be a combination of dredged material and other sediment moving naturally in the estuary or between the estuary and ocean. There would be a high degree of uncertainty regarding the representativeness of the testing results with respect to the disposed dredged material. Because of the inherent problems in environmental monitoring at the dispersive sites, the interpretive guidelines for biological testing data are more stringent for dredged material placed at dispersive sites (Site Condition I) compared to non-dispersive sites (Site Condition II).

3.6.2 Non-Dispersive Site Monitoring

The frequency of post-disposal monitoring at the non-dispersive sites varies by site and disposal volume. PSDDA's initial monitoring framework envisioned that monitoring would be more frequent initially, and be reduced through time as monitoring validated adherence to the site management objectives. The initial trigger for either full or partial monitoring was placement of 150,000 cubic yards at a site. In 1996, the trigger was increased to 300,000 cubic yards. In 2002, the DMMP agencies established a volume trigger of 500,000 cy to initiate monitoring at the Commencement Bay site, Elliott Bay site, and the Port Gardner site. A 300,000 cy volume trigger remains in effect for initiating monitoring at the Bellingham Bay site and the Anderson/Ketron Island disposal site. Monitoring involves the collection of physical, chemical and biological data at five station types at and near the site. Figures 7 and 8 show a typical arrangement of the various types of stations. The monitoring program for non-dispersive sites is fully described in SAIC (2007), which is incorporated by reference and summarized in the following.

3.6.2.1 Physical Monitoring

Physical monitoring at non-dispersive sites is accomplished using a SPI camera. The camera is contained in a wedge-shaped housing which is pushed into the surface sediment. The depth of dredged material deposits are measured using images from the camera. By taking photos at numerous locations, the pattern and extent of disposed dredged material disposal can be mapped. The SPI mapping of the post-disposal distribution of dredged material at the sites is used to verify that dredged material stays within the disposal site boundary (hypothesis 1 in Table 2). A dredged material depth greater than 3 cm at one or more perimeter stations is indicative of off-site migration. In the event this occurs, further assessment is required to determine the full extent of dredged material deposits. Digital image analysis of SPI photos also provides addition information, such as the infaunal successional stage and depth of the redox potential discontinuity.

3.6.2.2 Sediment Chemistry

Sediment chemistry testing includes collection of sediment samples from on-site, perimeter and benchmark stations and analysis of the DMMP chemicals of concern (COCs) and sediment conventional parameters. Samples are collected using a van Veen grab sampler. Selected conventional parameters (grain size and total organic carbon) are also analyzed at transect stations to help evaluate benthic infaunal abundance measurements. A list of the current COCs, along with associated SLs, BTs and maximum levels (MLs) can be found in Appendix A. The COCs include polyaromatic hydrocarbons (PAHs) and other semivolatile organics; metals; pesticides; polychlorinated biphenyls (PCBs); tributyltin (TBT); and dioxin. The COC list and guideline criteria are subject to revisions and updates made through the DMMP annual review process.

Perimeter chemistry data are used to address hypothesis 2 (i.e., chemical concentrations at perimeter stations do not increase over time due to dredged material disposal). On-site chemistry is used to monitor hypothesis 3 (i.e., on-site sediment chemistry does not exceed PSDDA site condition II guidelines due to dredged material disposal). If unacceptable changes in perimeter or on-site chemistry are observed, benchmark station chemistry is evaluated to assess whether the change is due to disposal activity or to some other factor (e.g., regional change in conditions).

3.6.2.3 Sediment Toxicity

Bioassays are conducted with sediments collected from on-site stations, benchmark stations, and an appropriate reference sediment site to assess sediment toxicity. Bioassay samples are taken from the same sediment composite as the sediment chemistry samples. Three bioassays are included in the DMMP program: a 10-day amphipod acute test, a sediment larval test, and the 20-day *Neanthes* growth test.

On-site sediment bioassay results are used to test hypothesis 4 (i.e., sediment toxicity at on-site stations does not exceed the PSDDA site condition II biological response guidelines due to dredged material disposal). The role of benchmark bioassays is analogous to the benchmark chemistry analyses. If PSDDA site condition II guidelines are exceeded, then benchmark bioassay data are evaluated to determine whether the change in site conditions is due to disposal activity or to some other factor (e.g., regional change in conditions).

3.6.2.4 Tissue Chemistry

To evaluate bioaccumulation of COCs, the concentrations of selected bioaccumulative chemicals in the tissue of infaunal organisms are measured at transect and benchmark stations. The target species for measuring body burden at Port Gardner, Elliott Bay, and Commencement Bay is the sea cucumber *Molpadia intermedia*. The target species at Bellingham Bay and Anderson/Ketron is the clam *Compsomyax subdiaphana*. Species selection was based on the relative abundance of infaunal prey species with limited mobility and sufficient biomass for analysis at each of the sites.

The tissue chemistry data are used to test hypothesis 5 (i.e., no significant increase has occurred in the chemical body burden of benthic infauna species collected down-current of the disposal site due to dredged material disposal). As in the case of sediment chemistry and bioassays, benchmark data are evaluated only if transect station data reveal a significant increase in contaminant bioaccumulation.

3.6.2.5 Benthic Infauna Analysis

Benthic infauna samples are collected at transect and benchmark stations with a Gray O'Hara box core sampler. A total of five box core samples are collected at each station. Each box core sample is divided into two sections: the top 10 cm (0 to 10 cm), and the subsurface section of the core (> 10 cm to the bottom of the core). The top 10 cm section is sieved through nested sieves of 1.0 mm and 0.5 mm and each fraction is preserved. The subsurface section is sieved through a 1.0 mm sieve only and the retained sample is preserved. To maintain data comparability between years, only the 1.0 mm fraction of the top 10 cm of each transect box core sample is analyzed (identification and enumeration of organisms). The remaining sieve fractions are archived. The DMMP agencies may initiate analysis of some or all of the archived sieve fractions in order to:

a. Provide a comparable data set to compare to historical baseline data (analysis of the > 10 cm sample),
b. Evaluate abundances of deep burrowing macrofauna (analysis of the >10 cm sample), and
c. Evaluate the effects of juvenile recruitment on benthic populations (analysis of the 0.5 mm fraction).

The transect station data are used to test hypothesis 6 (i.e., no significant decrease in the abundance of dominant benthic infauna species has occurred down-current of the disposal site due to dredged material disposal). Benchmark data are evaluated only if decreases in transect station infaunal abundance exceed trigger levels described by the interpretive guidelines in Table 2.

Table 6 provides the sampling station types, the type of sampling device used, and the number of samples collected from each station type for a full monitoring event. The target species for tissue collection is also provided. Figures 7 and 8 show a typical arrangement of sampling stations, in this case from a full monitoring event at the Port Gardner site in 2010. Sampling is accomplished with a vessel large enough to deploy the SPI camera and samplers and with enough work space for sample processing. The results of physical, chemical, and biological monitoring for each of the non-dispersive sites, as well as adaptive management measures instituted, are provided in Chapter 4.

Table 6. Full Monitoring Stations and Samples for Non-Dispersive Sites

Station Type	Sample Type	BB	PG	EB	CB	AK
On-site	grab	2	3	3	3	3
Perimeter	grab	4x3[2]	4x3	4x3	4x3	4x3
Benchmark	grab[1] box core	3x3 3x5	2x3 2x5	4x3 4x5	3x3 3x5	3x3 3x5
Transect	grab[1] box core	3 3x5	3 3x5	3 3x5	3 3x5	3 3x5
SPI	SPI	53x3	58x3	67x3	59x3	50x3

[1]additional grab samples may be needed to collect adequate tissue for analysis
[2]4x3 = triplicates at each of 4 stations

BB = Bellingham Bay (target species = *Compsomyax subdiaphana*)
PG = Port Gardner (target species = *Molpadia intermedia*)
EB = Elliott Bay (target species = *Molpadia intermedia*)
CB = Commencement Bay (target species = *Molpadia intermedia*)
AK = Anderson/Ketron Island (target species = *Compsomyax subdiaphana*)

3.7 CONSERVATION MEASURES

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further assist the purposes of the ESA by carrying out conservation programs for the benefit of threatened and endangered species. A number of measures and procedures inherent in the DMMP act in combination to minimize the potential for impacts to listed species in Puget Sound and Grays Harbor. These include:

- Consolidation of dredged material disposal sites to minimize the area and locations affected by dredged material disposal.
- Siting of dredged material disposal sites in areas of relatively low habitat value or low use by biota (distance offshore, depth, areas with low known resource value).
- Siting of the Grays Harbor disposal sites so as to retain sediment circulating in the regional cell and feeding stabilizing sand to protect the South Jetty toe, thereby reducing the need for rock placement.
- Evaluation of the chemical suitability of dredged material for beneficial use as an alternative to disposal at a multiuser disposal site and documentation of this evaluation in DMMP suitability determinations; beneficial use may include capping of contaminated material at CERCLA and MTCA cleanup sites, or in-water habitat restoration projects.
- Using dredged material testing protocols to ensure the suitability of materials for unconfined, open-water discharge; updating the testing protocols as needed to protect the aquatic environment.
- Sequencing the disposal of DMMUs within a dredging project at non-dispersive sites when possible with the cleanest material disposed last, thereby improving the quality of the surface sediment at the disposal site.

- Requiring barge operators to maintain the seals on the bottom dump barges to minimize loss of sediment during transport.
- Conducting site monitoring activities (physical, chemical and biological) to determine if unacceptable impacts are occurring at disposal sites.
- Adaptively managing sites based on feedback from site monitoring events.

Figure 7. SPI Stations from Full Monitoring at Port Gardner Site (2010)

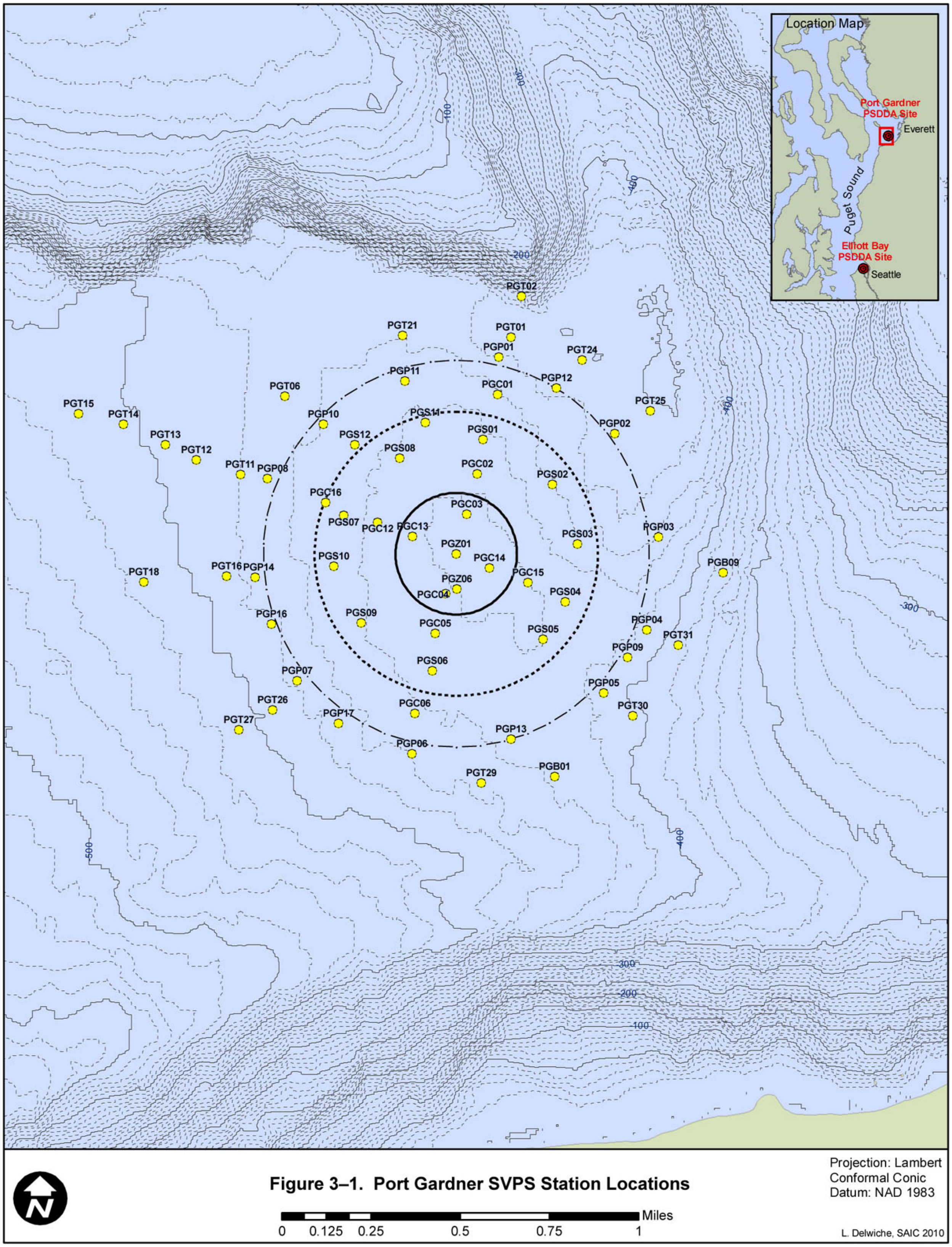
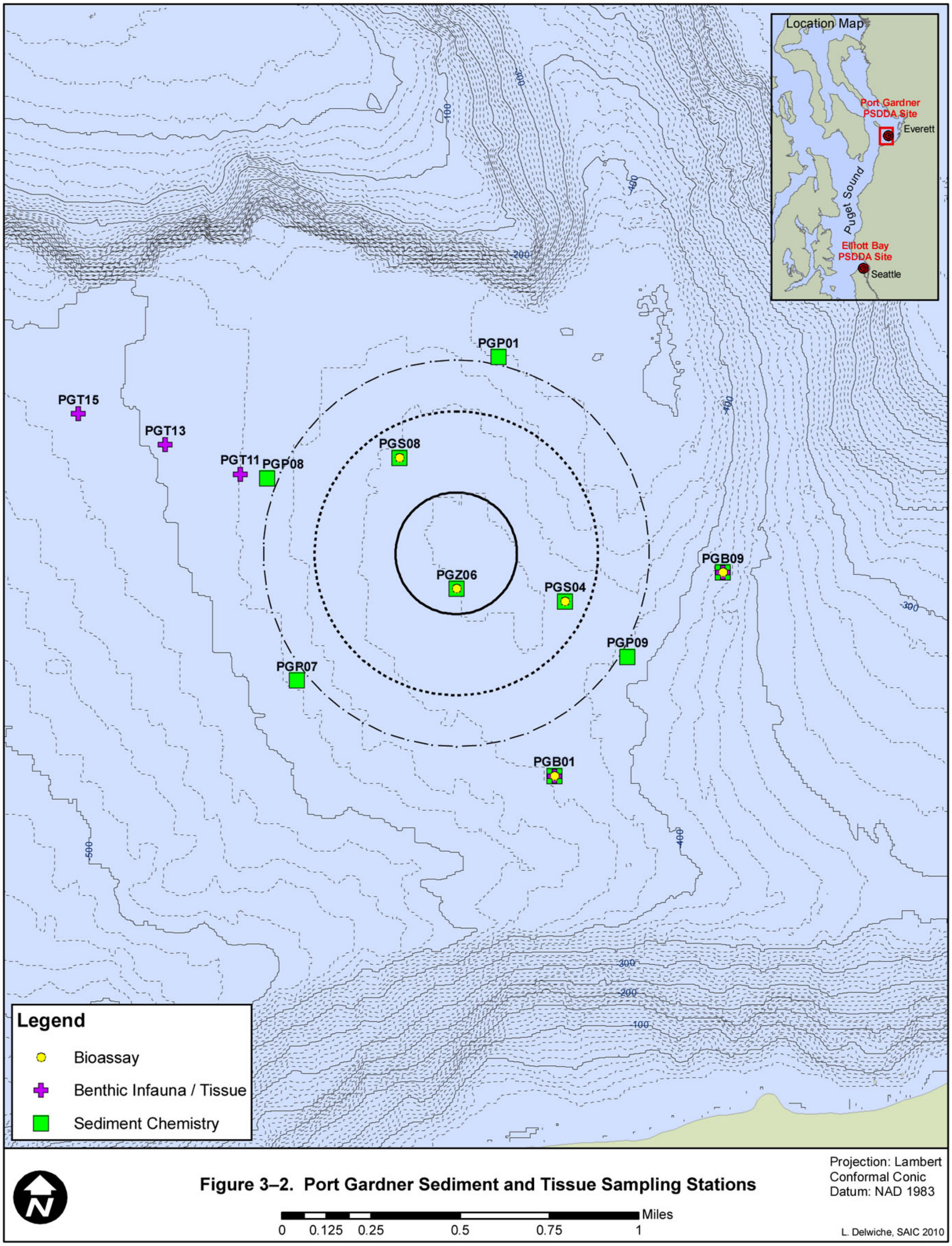


Figure 8. On-Site, Perimeter, Transect and Benchmark Stations at Port Gardner Site (2010)



4 ACTION AREA AND PROJECT AREAS

Given the wide distribution of DMMP multiuser disposal sites, the distances associated with transport of dredged material from dredging sites to the disposal sites, and the sizeable dispersal zones for material discharged at the dispersive sites, the action area for this biological evaluation is defined as Puget Sound and Grays Harbor. For the purposes of this BE, 'Puget Sound' refers to Puget Sound, the Strait of Juan de Fuca, Hood Canal and other parts of the Salish Sea falling within the borders of Washington State. Individual project areas are the specific disposal sites and their associated waters. Each of the ten sites is described in the following sections.

4.1 NON-DISPERSIVE SITES

4.1.1 Bellingham Bay Site

The Bellingham Bay site is approximately 4 miles south-southwest of the city of Bellingham, and 1.4 miles west of Post Point. The site depth is about 96 feet MLLW. The site is circular with a diameter of 3,800 feet and an area of 260 acres. This is the shallowest of the non-dispersive disposal sites.

The Bellingham Bay site is located in a low-energy depositional environment. Pre-disposal sediment conditions included a predominance of silt with 18 to 20% clay. Sediments contained a large quantity of organic material; had 5-day BOD concentrations of 2,000 to 2,500 mg/kg of sediment; contained greater than 8% volatile solids; and had a water content of about 70% (PSDDA/FEIS 1989).

Benthic studies at the Bellingham Bay site during July 1987 described a community that was dominated by two taxonomic groups, principally the bivalve *Axinopsida serricata*, and polychaete worms of the families Terribellidae, Maldanidae, Onuphidae, and Chaetopteridae. Bivalve biomass constituted 61% and polychaetes constituted 21% of the biomass in the top 5 cm of sediment at the site. Crustacean biomass was relatively insignificant throughout the Bellingham Bay study area, constituting less than 3% of the community biomass in the top 5 cm of sediment, and generally less than 1% of the community biomass below 5 cm. (PSDDA/FEIS 1989).

Of the fish found at depths greater than 66 feet, longfin smelt were the most numerous in Bellingham Bay (Donnelly et al. 1988) and would likely be forage important to salmonids. Juvenile and adult longfin smelt are abundant in the area at times and could be preyed on by adult salmon. These fish were not considered a major predator in the Benthic Resources Assessment Technique (BRAT) analysis (PSDDA/FEIS 1989) and feed on plankton rather than the benthos. Effects of dredged material disposal on longfin smelt and other forage fish would be primarily through burying of epibenthic crustaceans that may be prey for these fish (Simenstad et al. 1979). Pacific herring and sandlance prey predominantly on pelagic copepods and would not be significantly affected by changes in the benthic and epibenthic community.

Post-disposal evaluation of this site in 1993 indicated that dredged materials remained on-site, and that most of the material was in thin layers (<10 cm thick). Sediment testing at the site indicated that the concentration of chemicals of concern was well below the allowable minor adverse effects level (Site Condition II) and was generally less than the screening levels (PSDDA, 1994).

Concentrations of dioxin in sediment at three on-site stations in 2007 averaged 7.0 pptr TEQ. Dioxin concentrations in benthic invertebrates averaged 0.22 pptr; English sole averaged 0.29 pptr. This was the first time dioxin had been evaluated at the site; these concentrations are therefore considered the baseline concentrations for future monitoring events. The on-site sediment concentration of 7.0 pptr TEQ exceeds the DMMP site management objective of 4 pptr TEQ. This disposal site has had no disposal since 1998 and is currently deactivated pending renewal of the shoreline permit. Therefore, reduction in dioxin concentrations in surface sediments through placement of a layer of clean dredged material is not an option in the near-term. With time, deposition of clean glacial silt from the Nooksack River will reduce dioxin concentrations at the site. The present concentration of dioxin at the Bellingham Bay site must be put in perspective. Until 2007, the maximum concentration of dioxin allowable at the PSDDA sites was 15 pptr TEQ. Between 2007 and 2010, the maximum concentration was 10.5 pptr TEQ. The maximum concentration allowed for unrestricted upland use is 11 pptr TEQ. Therefore, while the current dioxin concentration at the Bellingham Bay site exceeds the DMMP site management objective, a concentration of 7.0 pptr TEQ is still relatively low.

4.1.2 Port Gardner Site

The Port Gardner disposal site is located 2.3 miles west of Everett Harbor. The 318-acre site is circular with a diameter of 4,000 feet. The depth of this site is 420 feet. The site is relatively flat, with slopes of less than 1 foot over a horizontal distance of 200 feet.

Currents are weak at this depositional site and move predominantly northward to westward. Pre-disposal sediment at the site was predominantly medium and fine silt with greater than 15% clay. Sediments along the south and east ends were coarser, ranging from fine to very fine sand (PSDDA/FEIS 1988).

Benthic infauna at the Port Gardner site are dominated by large polychaetes and bivalve mollusks. Benthic biomass averaged 36 g/m^2, with polychaetes making up 50%, bivalves 42%, and crustaceans only 2.4% of the biomass. The BRAT analysis for this area indicated that four benthic feeding strategy groups of fish were foraging on benthos within the site and vicinity, primarily represented by Dover and English sole (PSDDA/FEIS 1988).

Post-disposal evaluations of this site were conducted in 1990, 1994, 2006 and 2010 (PSDDA 1996; SAIC 1991, 2006, 2010). In 2006 the dredged material footprint was well within the perimeter line. There were no chemicals of concern detected above the screening level in sediment samples. Evaluation of tissue chemistry in the sea cucumber (*Molpadia intermedia*) detected only low concentrations of chemicals of concern, and no evidence that tissue concentrations of bioaccumulative chemicals were increasing over predisposal baseline conditions. In the latest monitoring event in 2010, the dredged material footprint reached as far as the perimeter line in only one location, with the thickness less than 3 cm at that location. Sediment testing indicated that concentrations of chemicals of concern were well below the allowable minor adverse effects level (Site Condition II) at the site and generally below screening levels. There was no indication of on-site toxicity or that sediment chemistry is increasing due to disposal of dredged material.

Concentrations of dioxin in sediment at three on-site stations in 2006 averaged 1.8 pptr TEQ. Dioxin concentrations in benthic invertebrates averaged 0.26 pptr; English sole averaged 0.44 pptr. This was the first time dioxin had been evaluated at the site; these concentrations are therefore considered the baseline concentrations for future monitoring events. Dioxin concentrations in on-site sediment were measured again in 2010. The average concentration at ten on-site stations was 2.0 pptr.

4.1.3 Elliott Bay Site

The Elliott Bay site is located near the mouth of the Duwamish River, about 0.85 miles from Harbor Island. The site is egg-shaped with dimensions of 6,200 by 4,000 feet, covering an area of 415 acres. The depth of the site ranges from 300 to 360 feet.

The peak current speed on the bottom at the site is less than 15 cm/second, well below the 25 cm/second threshold required to resuspend fine sediments. The direction of currents is variable in Elliott Bay, although a study by McLaren and Ren (1994) documented that sediment transport in Elliott Bay occurs in a clockwise gyre. Elliott Bay sediments are generally very fine-grained material. The inner bay sediments vary from 9 to 12% clay with the highest percentage at the greatest depths. Chemicals of concern including PCBs, PAHs, metals, organic compounds, copper, lead, zinc, cadmium, arsenic, and mercury are commonly found to be elevated in Elliott Bay (PSDDA/FEIS 1988).

The initial pre-disposal benthic infaunal survey at the Elliott Bay site indicated the benthos is dominated by large polychaetes and bivalve mollusks. Polychaetes make up 51%, mollusks 39%, and crustaceans only 4% of the biomass. The BRAT analysis for this area indicated that four benthic feeding strategy groups of fish were utilizing the benthos within the site and vicinity, primarily represented by Dover sole and English sole (PSDDA/FEIS 1988).

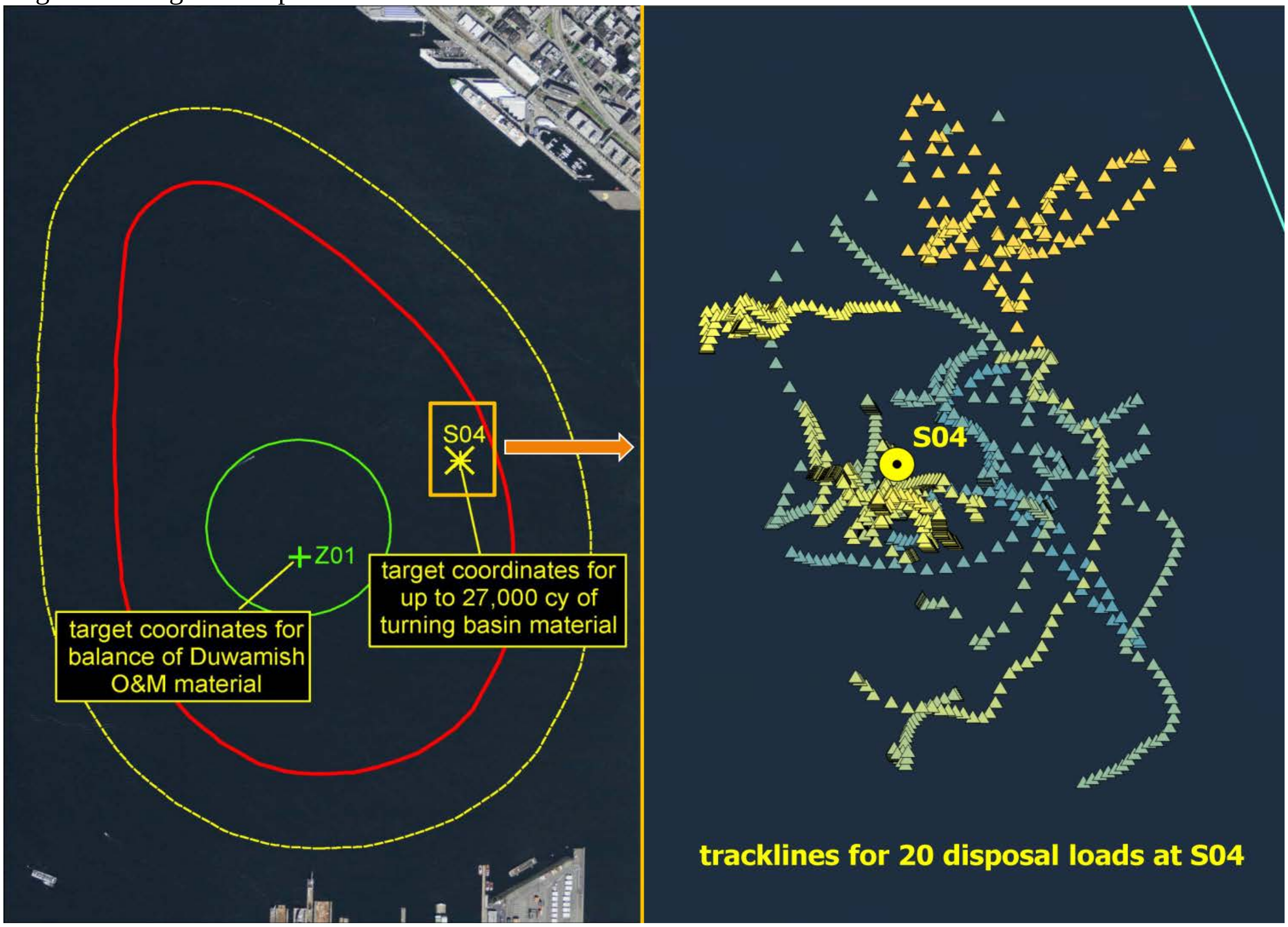
Post-disposal evaluation of this site in 1992, 2000, 2002 and 2013 indicated that dredged materials remained on-site, and that the thickest layers were in the center of the target area. Sediment testing at the site indicated that the concentration of chemicals of concern were well below the allowable minor adverse effects level (Site Condition II) and predominantly below screening levels. Comparative pre-disposal and post-disposal on-site sediment quality monitoring has shown that metals and PAH concentrations have dropped significantly due to dredged material disposal. The DMMP agencies conducted a special monitoring survey in 2005 at on-site stations to evaluate sediment chemistry following disposal of material determined to be suitable for open-water disposal from the CERCLA early action cleanup in East Waterway. The results of this monitoring noted slightly elevated PCB concentrations at one on-site station, but all chemicals were in compliance with the site management objectives. Overall, monitoring has confirmed that there are no indications of adverse environmental effects within or beyond the boundary of the disposal site (SAIC, 1992, 2000; SEA, 2002; Integral, 2014).

The disposal of 414,794 cubic yards of dredged material on-site in DY99 prompted a Full Monitoring in 2000 (SAIC, 2000). In addition to meeting the standard objectives of DMMP monitoring, this monitoring event was designed to address concerns related to potential effects of dredged material disposal on ESA-listed Puget Sound Chinook and Bull Trout (SAIC, 2001). The tests used for ESA concerns included 45-day bioaccumulation tests using the bivalve *Macoma* and polychaete *Nephtys*. The results of the 45-day bioaccumulation test showed increased accumulation of silver, copper, lead, antimony, zinc, mercury, and TBT relative to organisms exposed to reference sediment, but no levels exceeding human health standards. Coplanar PCB concentrations were uniformly low in on-site sediment and tissue samples, demonstrating that PCBs were not a concern for either endangered species passing through the site or benthic-feeding demersal flatfish species that may be foraging at the disposal site.

Concentrations of dioxin in sediment at three on-site stations in 2007 averaged 9.7 pptr TEQ. Dioxin concentrations in benthic invertebrates averaged 0.76 pptr; English sole averaged 0.69 pptr. This was the first time dioxin had been evaluated at the site; these concentrations are therefore considered the baseline concentrations for future monitoring events. Dioxin concentrations in on-site sediment were measured again in 2013. The average concentration at ten on-site stations was 6.9 pptr.

One on-site station (EB-S04) was found to have elevated dioxin concentrations in 2007 and again in 2013 (17 pptr and 30 pptr respectively). These elevated concentrations appear to have been the result of disposal of sediment from a project that was dredged prior to initiation of routine testing for dioxin in 2006. This station was subsequently targeted for disposal by the Corps of Engineers in late 2013 (Figure 9), using 27,000 cubic yards of clean sand from the turning basin at the upper terminus of the Duwamish Waterway. The effect of placing this sand cover will not be known until the next monitoring event, but it is expected to have significantly reduced the concentration of dioxin in the exposed surface sediment in the vicinity of station EB-S04.

Figure 9. Targeted Disposal at Station EB-S04 in 2013



4.1.4 Commencement Bay Site

The Commencement Bay disposal site is located approximately 0.75 mile west of Brown's Point. The site is elliptical, covering 310 acres with dimensions of 4,600 by 3,800 feet. The Commencement Bay site is located in waters 540 to 560 feet deep. The center of the site is now around 439 feet deep due to twenty-six years of disposal. In June 2007 the DMMP agencies adjusted the disposal site coordinates 565 feet southeast of the initial site center coordinates within the target area to dampen future mounding from disposal as an adaptive site management action.

Sediment grain size is small in this depositional area. Currents near the bottom move predominantly in a southern direction and are less than 25 cm/second, not fast enough to resuspend sediments (PSDDA/FEIS 1988).

Initial pre-disposal benthic infauna biomass at the Commencement Bay site was dominated by large polychaetes (67%) and bivalve mollusks (28%), with crustaceans constituting only 5% of the biomass. The BRAT analysis for this area indicated that four benthic feeding strategy groups of fish were using the area, primarily represented by Dover sole and English sole (PSDDA/FEIS 1988). Bottom trawl studies in 1986 indicated that Dover sole, English sole and ratfish were the most prevalent bottom fish at the Commencement Bay site, albeit at low numbers. Trawling conducted in 2007 at previously studied transects reconfirmed the generally low abundances of bottom fish noted during the 1986 site designation study, with Dover sole averaging 4.9 fish/hectare and English sole averaging 4.2 fish/hectare.

A post-disposal evaluation of this site in 1996 indicated that dredged material remained on-site. Dredged material at the site perimeter was <0.5 cm thick. Sediment testing at the site indicated that there was a small increase in lead sediment concentrations at one perimeter station, with several metals (copper, mercury, silver, and zinc) also increasing at one perimeter station. However, overall sediment quality was improved in 1996 over previous levels, and the biological effects guideline of “minor adverse effects” (i.e., Site Condition II; EPTA, page 2-111) was not exceeded (SAIC, 1995, 1996).

Monitoring at the Commencement Bay disposal site during 2001 documented a wider spread of dredged material than originally envisioned during the site selection/designation process (SEA, 2001). The DMMP agencies closed the site pending evaluation of off-site impacts. The evaluation showed no chemical or biological impacts (e.g., no toxicity, no depressions in benthic infauna taxa) within the expanded dredged material footprint. Additional sampling conducted verified that the benthic community was not impacted outside the disposal site. The site was re-opened in July 2002 after all additional site investigations and modeling studies were completed, and after the DMMP agencies provided assurances to the Pierce County Shoreline Board on the management actions adopted by the DMMP agencies, which included close monitoring of all disposal activity at the Commencement Bay disposal site.

Additional monitoring in 2003, 2004 and 2007 further documented that the dredged material was not impacting the benthic community and that sediment quality remained high and met the site management objectives (SAIC, 2003; 2004; 2007). The monitoring during 2003 and 2004 showed that the dredged material footprint extended outside the disposal site perimeter, similar to that observed in 2001, but not extending as far north. However, monitoring in 2007 following disposal of 1.3 million cubic yards of material showed the dredged material generally within the disposal site and perimeter line, and within the site management compliance limit (< 3 cm of dredged material at the perimeter line).

Concentrations of dioxin in sediment at three on-site stations in 2007 averaged 5.6 parts per trillion (pptr) toxic equivalents (TEQ). Dioxin concentrations in benthic invertebrates averaged 0.45 pptr; English sole averaged 0.66 pptr. This was the first time dioxin had been evaluated at the site; these concentrations are therefore considered the baseline concentrations for future monitoring events.

Because of the relatively high disposal at the Commencement Bay site between 1998 and 2006, and the projected volumes of other relatively large DMMP construction/maintenance dredging projects going through the permitting process for disposal at this site, the DMMP agencies elected to conduct a NEPA/SEPA review for the reauthorization of the Commencement Bay site. The DMMP agencies initiated a NEPA/SEPA evaluation in 2007 to evaluate the disposal site’s ability to accommodate a volume ceiling up to 23 million cubic yards to accommodate long-term regional disposal needs as part of the Pierce County Shoreline Permit process. This resulted in a NEPA/SEPA Supplemental Environmental Impact Statement (SEIS) – a supplement to the 1988 EIS – which re-evaluated the purpose and need for this site, and evaluated the existing site relative to site capacity and site management (SAIC, 2009). The Record of Decision Amendment to the SEIS was completed and signed by the Corps and EPA in 2010. The Corps and EPA issued a joint Public Notice (40 CFR 230.80) for the reauthorization of the site on February 19, 2010.

The SEIS evaluated two action alternatives and a no-action alternative. The preferred alternative (Alternative 2) included an adaptive management mound-dampening strategy that increases the site capacity to 23 million cubic yards with only a moderate increase in mound height. The management strategy involves periodic shifting of the disposal coordinates within the existing target area (i.e., a 1,200 ft diameter circle around the site center), as depicted in Figure 10. In June 2007, the DMMP agencies had implemented the first shift – 565 feet to the southeast of the site center – on a provisional basis. The preferred alternative – selected in the SEIS – adopted this provisional shift, as well as two additional coordinate shifts. The first additional shift will be 565 feet to the southwest of the site center when cumulative site disposal volume has reached 13 million cy. The second additional shift will be 565 feet to the northeast of the site center at a cumulative volume of 18 million cy. Table 7 lists the past, present and future coordinates for disposal in the preferred alternative. Figure 11 depicts the effect of these coordinate shifts on mound height. Figure 12 depicts the 2007 mound configuration, as well as those predicted for the no-action and two action alternatives. The no-action alternative included the 2007 disposal coordinate shift, but no additional shifts. Alternative 1 included only a single additional coordinate shift at 18 million cy, as opposed to the additional shifts at 13 million cy and 18 million cy under the preferred alternative. This figure illustrates that active management can significantly reduce the rate of mound height growth.

A multibeam bathymetric survey and SPI survey were conducted in 2013 to determine whether the mound configuration was changing due to the 2007 shift in disposal coordinates and to determine whether the shift was causing any material to migrate beyond the perimeter line in the direction of the shift (southeast). The multibeam survey showed a slight flattening of the mound beginning to occur (Figure 13). The SPI mapping (NewFields, 2013) showed the thickest deposits of new material had shifted to the southeast as expected. Both surveys demonstrated that dredged material was staying within the site boundary, as predicted by the modeling. At the time these surveys were performed, approximately 230,000 cubic yards had been placed at the new disposal coordinates.

Table 7. Commencement Bay Disposal Site Coordinates (past, present and future) for Preferred Alternative Evaluated in Site Reauthorization 2009 SEIS

Disposal Coordinates	Disposal Site Volume (million cubic yards)	Latitude	Longitude
Site Center (1988-2007)	0 – 7.8	47 degrees 18.210 minutes N	122 degrees 27.910 minutes W
SE corner of Target Area (2007-present)	7.8 – 13	47 degrees 18.145 minutes N	122 degrees 27.815 minutes W
SW corner of Target Area	13 – 18	47 degrees 18.143 minutes N	122 degrees 28.004 minutes W
NE corner of Target Area	18 – 23	47 degrees 18.277 minutes N	122 degrees 27.816 minutes W

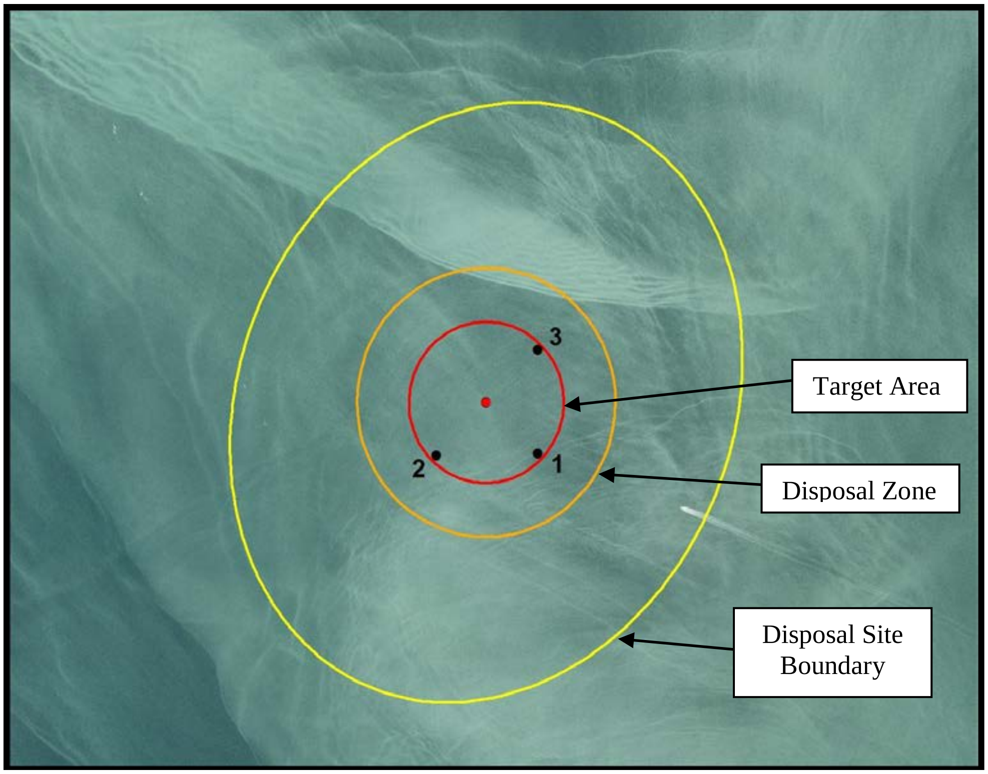


Figure 10. Commencement Bay Site Disposal Coordinates (red point) Site center coordinates (1988-2007):

(1) SE coordinates (2007 to present)
(2) SW coordinates (cumulative volume of 13 mcy to 18 mcy)
(3) NE coordinates (cumulative volume of 18 mcy to 23 mcy)

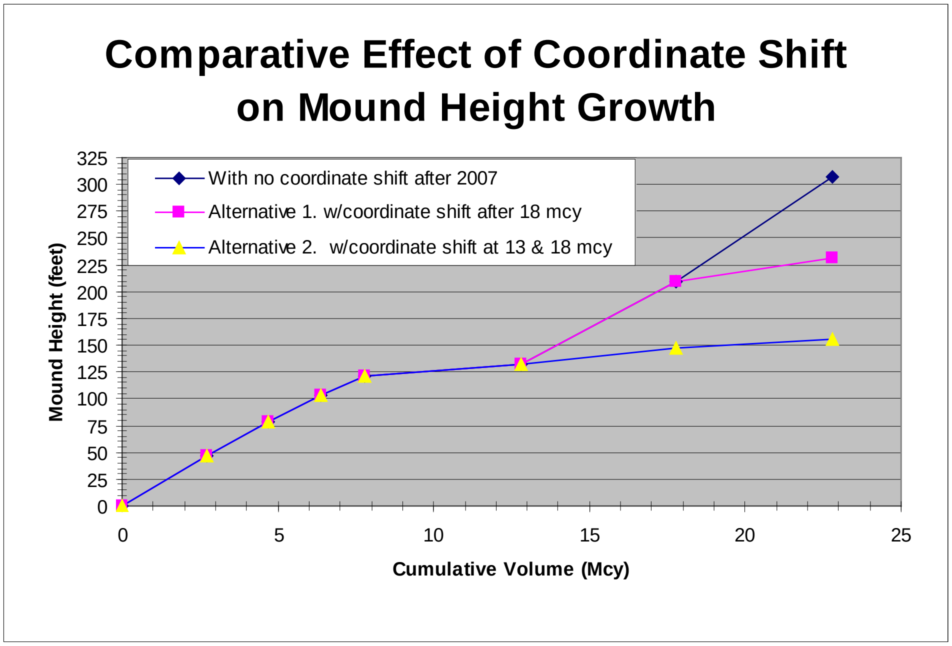


Figure 11. Comparative Effect of Coordinate Shift on Mound Height Growth for Two Action Alternatives Evaluated in SEIS

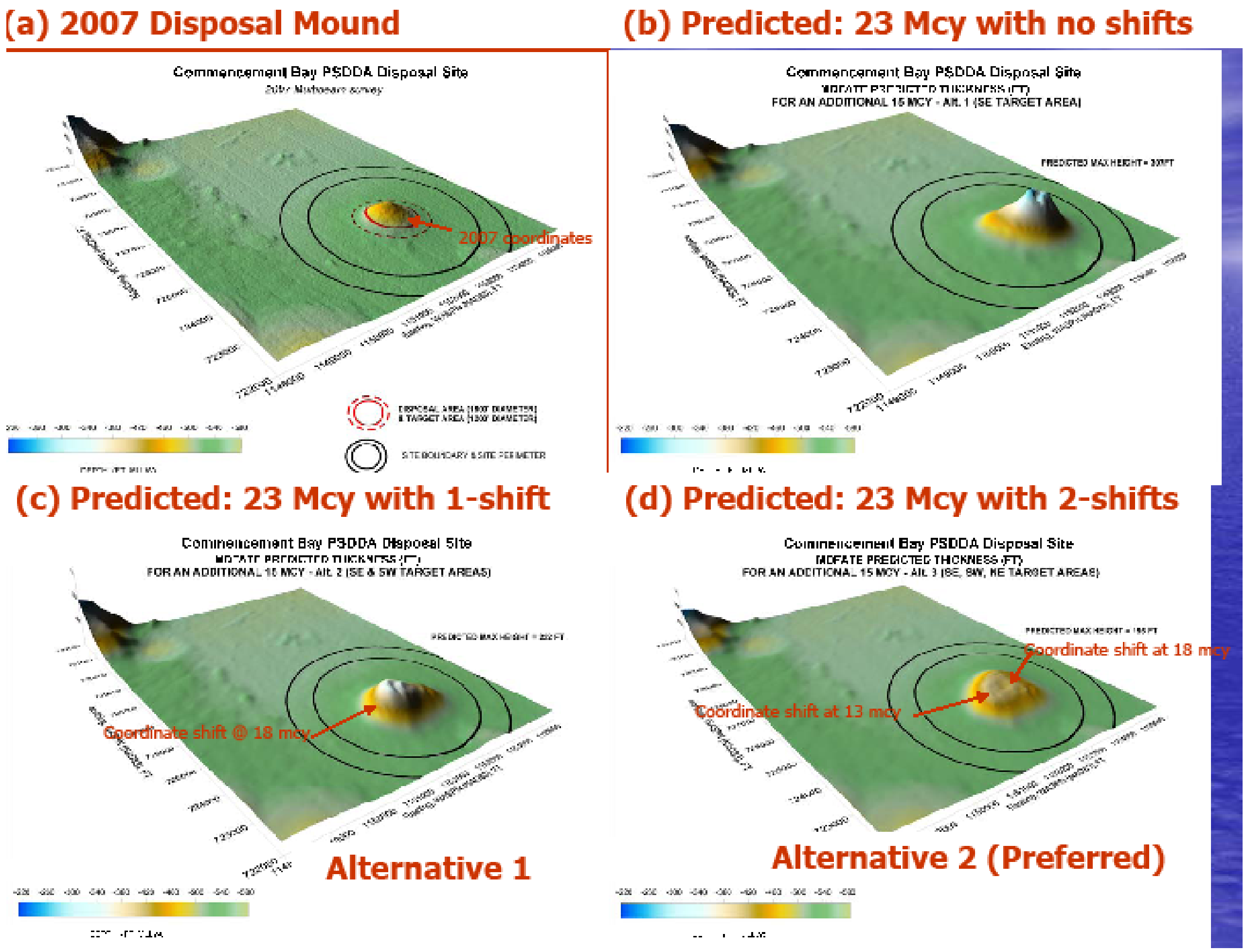


Figure 12. Commencement Bay SEIS Alternatives:

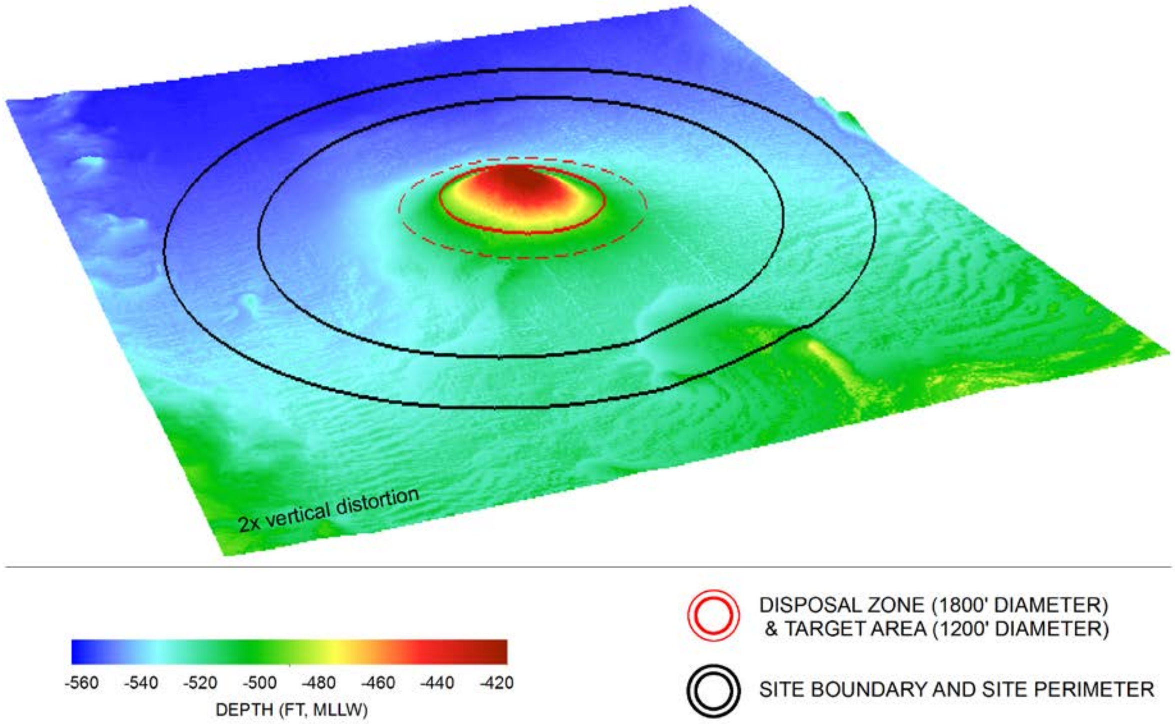
(a) site in 2007, with a mound height of 121 ft

(b) No-Action Alternative: 307 ft mound at 23 mcy with no additional coordinate shifts beyond 2007

(c) Alternative 1: 232 ft mound at 23 mcy with one additional coordinate shift at 18 mcy

(d) Alternative 2: 155 ft mound at 23 mcy with two additional coordinate shifts at 13 mcy and 18 mcy.

Figure 13. 2013 Commencement Bay Multibeam Bathymetric Survey



4.1.5 Anderson/Ketron Island Site

The Anderson/Ketron site is located approximately 3.5 miles west-southwest of the town of Steilacoom, midway between Anderson and Ketron Islands. This oval-shaped site is 4,400 by 3,600 feet, covering 318 acres. The site depth ranges from 360 to 460 feet.

Although current speeds at depths 15 meters (49 feet) or more above the bottom at the Anderson/Ketron site are at, or greater than, the critical speed for fine sediment transport (about 25 cm/sec), bottom conditions indicate that this is a depositional site (PSDDA/FEIS 1989). Pre-disposal sediment conditions indicated the sediment grain size was predominantly medium to very fine sand with 4 to 8% clay at the north and south ends. The sediment in the rest of the site was finer-grained with a higher organic content. Volatile solids ranged from less than 1% to as high as 4% (PSDDA/FEIS 1989).

The benthic infauna at the Anderson/Ketron site were somewhat different from the other non-dispersive sites in that it had a smaller biomass percentage of mollusks (12%) and a greater biomass percentage of crustaceans (42%). Polychaetes (46%) dominated the benthic infauna biomass. The predominant demersal fish at the site were English sole, Pacific tomcod, and slender sole.

This disposal site has been used only infrequently with only a relatively small quantity of material being disposed (approximately 157,000 cy). Post-disposal monitoring in 2005 (SAIC, 2005a) documented compliance with the DMMP site management objectives. The chemistry measured within the disposal site and at perimeter stations were generally below screening levels; on-site sediments were evaluated through toxicity testing and no toxicity was expressed.

Dioxin was analyzed in sediment at a single on-site station in 2005; the concentration was 3.1 pptr TEQ. Dioxin concentrations in benthic invertebrates averaged 0.28 pptr; English sole averaged 0.29 pptr. This was the first time dioxin had been evaluated at the site; these concentrations are therefore considered the baseline concentrations for future monitoring events.

The DMMP agencies conducted a special dioxin evaluation at the site in 2008 following the placement of 97,000 cy of material from the Olympia Harbor federal navigation project. The post-disposal monitoring results demonstrated that the on-site sediment concentration was lower than in 2005, with a value of 1.1 pptr.

4.1.6 Summary of Post-Disposal Monitoring at the Non-Dispersive Sites

All five non-dispersive sites have undergone post-disposal monitoring. To date, the DMMP agencies have conducted 28 post-disposal monitoring surveys at non-dispersive sites including:

- 7 full monitoring events: Port Gardner (1990, 2006) ; Elliott Bay (1992, 2000); Commencement Bay (2001, 2007); Anderson/Ketron Island (2005)
- 5 tiered-full monitoring events: Port Gardner (1994, 2010); Elliott Bay (2002); Commencement Bay (1995, 2003)
- 3 partial monitoring events: Elliott Bay (1990, 2013); Bellingham Bay (1993)
- 2 tiered-partial monitoring events: Commencement Bay (1996, 2004)
- 7 special surveys: side-scan surveys at Bellingham Bay (1993) and Elliott Bay (1995); SPI surveys at Commencement Bay (1998, 2013); on-site chemistry survey at Elliott Bay (2005); SPI and phenol at Commencement Bay (2005); dioxin survey at Elliott Bay, Commencement Bay and Bellingham Bay (2007)
- 4 bathymetric surveys at Commencement Bay (2001, 2004, 2006, 2007)

Based on PSDDA site monitoring data to date (including physical mapping, on-site and off-site chemistry, sediment toxicity, off-site infaunal bioaccumulation, and off-site benthic community structure), dredged material disposal is not causing adverse impacts at or adjacent to any of the non-dispersive sites. PSDDA/DMMP evaluation procedures, as evidenced by 25 years of monitoring results, appear to have adequately protected environmental conditions at all the disposal sites.

4.2 DISPERSIVE SITES

4.2.1 Rosario Strait Site

The Rosario Strait site is located approximately 1.2 miles south of Cypress Island, northwest of Shannon Point on Fidalgo Island. The disposal site is a 6,000-foot diameter circular area, with a 3,000-foot diameter disposal zone. The water depth ranges from 97 to 142 feet.

The seafloor at the Rosario Strait site is composed of coarse-grained sediments, rocks and cobble, typical for areas which experience strong current flows. The currents at the Rosario Strait site have a net speed of 10 to 30 cm/sec, with peak speeds as high as 180 cm/sec. Material placed at the Rosario Strait site is transported predominantly to the south, with smaller amounts of material moving to the north and east (PSDDA/DSSTA, 1989; USACE/DNR, 2012). Post-disposal bathymetric monitoring of the Rosario Strait site in 1991, 1994, 1999 and 2009 showed that material did not accumulate on site and was readily dispersed. There was no net accumulation of dredged material compared to the predisposal baseline condition.

Biota at the Rosario Strait site are typical for higher energy environments, with epibenthic organisms dominating rather than infaunal organisms. Abundance and diversity of invertebrates collected by rock dredge at the site were low. Species at stations located in and near the disposal site included non-pandalid shrimp and sea urchins. Dungeness crabs, rock crabs, and pandalid shrimp were not found at the site. Current and bottom conditions made it difficult to sample for bottomfish, and fish captured are not necessarily representative of fish in the area. During the siting studies, ringtail snailfish and incidental Dover sole, Pacific sandlance, sculpin, smooth alligatorfish and other snailfishes were captured at the site. Pelagic species which inhabit waters near the site include juvenile Pacific herring, Pacific sand lance, northern anchovy, surf smelt and longfin smelt. Although these forage fishes occur in the area, the site is located away from spawning beaches. Adults and juveniles of all five species of Pacific salmon may occur in the vicinity of the site as they migrate to and from the ocean. Other pelagic species which may occur in the vicinity of the site include steelhead, cutthroat trout and bull trout.

This site is the most frequently used dispersive site in Puget Sound, with a net cumulative volume of approximately 2.1 million cy over the past 26 years and an annual average disposal volume of about 85,000 cy.

4.2.2 Port Townsend Site

The Port Townsend site is located approximately 13.8 miles northwest of Port Townsend. The disposal site is a 7,000-foot diameter circular area, with a 3,000-foot diameter disposal zone. The water depth is approximately 361 feet. The substrate at the site is a mixture of sand, gravel and shell.

Mean current speeds at the Port Townsend site are between 30 to 50 cm/sec, with peak speeds greater than 100 cm/sec. Dispersal of material is predominantly in the east-west direction, parallel to the Strait of Juan de Fuca.

Biota at the Port Townsend site are typical for higher energy environments, with epibenthic organisms dominating rather than infaunal organisms. Common biota included pandalid shrimp, scallops and sea urchins. Twelve demersal fish species were caught during the PSDDA siting studies. The most abundant commercial species included Dover sole, rex sole, Pacific cod, walleye pollock and arrowtooth flounder. Pelagic species which inhabit waters near the site include juvenile Pacific herring, Pacific sand lance, northern anchovy, surf smelt and longfin smelt. Although these forage fishes occur in the area, the site is located away from spawning beaches. Adults and juveniles of all five species of Pacific salmon may occur in the vicinity of the site as they migrate to and from the ocean. Other pelagic species which may occur in the vicinity of the site include steelhead, cutthroat trout and bull trout.

The Port Townsend site has been used infrequently over the past 26 years, with a cumulative disposal volume of approximately 54,000 cy. The volume placed at the site to date has not been great enough to warrant a bathymetric survey.

4.2.3 Port Angeles Site

The southern border of the Port Angeles site is located approximately 4.6 miles north of Port Angeles. The disposal site is a 7,000-foot diameter circular area, with a 3,000-foot diameter disposal zone. The water depth is approximately 435 feet. The substrate at the site is a sand/gravel mix with some shell.

Peak current speeds are greater than 100 cm/sec. Dispersal of material is predominantly in the east-west direction, parallel to the Strait of Juan de Fuca.

Shrimp were seasonally abundant at the Port Angeles site. Other common invertebrates included scallops and sea urchins. Commercially important fish caught during the PSDDA siting study included English sole, Dover sole, quillback rockfish and walleye pollock. Pelagic species that inhabit waters near the site include juvenile Pacific herring, Pacific sand lance, northern anchovy, surf smelt and longfin smelt. Although these forage fishes occur in the area, the site is located away from spawning beaches. Adults and juveniles of all five species of Pacific salmon may occur in the vicinity of the site as they migrate to and from the ocean. Other pelagic species that may occur in the vicinity of the site include steelhead, cutthroat trout and bull trout.

The Port Angeles site been has used only once during the past 26 years, with a disposal volume of 22,344 cy in 1996. The volume placed at the site to date has not been great enough to warrant a bathymetric survey.

4.2.4 Point Chehalis Site

The Point Chehalis site is located near the mouth of Grays Harbor, just north of Westport. The federal navigation channel crosses through the site. The depth of this site ranges between -50 and -80 feet. It is subject to high wave energy and strong, predominately westward, currents. The irregular bottom consists of fine to medium sized sand grains of marine origin. Historically, this site has been extremely deep. Charts that predate jetty construction show water depths of 100 feet in this area. Nearly 16 million cubic yards of dredged material have been placed in this area since 1996. Annual survey records indicate that approximately 75% of material disposed at this site erodes during the dredging period, and that another 15% erodes during the following winter. Bathymetric surveys indicate that most of this eroded material moves seaward along the South Jetty. Disposal at this location reduces erosion near the Point Chehalis revetment and groins. Eventually the material is moved by currents into the adjacent Columbia River littoral cell. The Point Chehalis site is the most heavily used disposal site in Grays Harbor. Due to the large volume of material placed at this site, the Corps conducts bathymetric surveys on an annual basis.

4.2.5 South Jetty Site

The South Jetty site is located at the mouth of Grays Harbor, northwest of Westport and directly adjacent to the South Jetty. The depth of this site ranges from -40 to -60 feet. This area is subject to fast tidal currents, predominately westward, that sweep along the jetty toe. Seaward erosion of disposed material generally occurs rapidly. The irregular bottom consists of fine to medium sized sand grains of marine origin. Placement of dredged material at this site is necessary to prevent scour and undermining of the South Jetty's toe. This site is the preferred disposal area for inner Grays Harbor material. However, when weather/wave conditions are hazardous, inner Grays Harbor materials are disposed at the Point Chehalis site. Over 11 million cubic yards have been place at this site since 1996. Due to the large volume of material placed at this site, the Corps conducts bathymetric surveys on an annual basis.

5 EFFECTS ANALYSIS

5.1 WATER QUALITY

5.1.1 Turbidity

5.1.1.1 Transport Activities.

Movement of the barge to and from disposal sites generates no more than inconsequential potential physical effects on salmon, coastal pelagic, and groundfish species or habitat. Some dredged material may possibly be lost overboard on the way to disposal sites either by being blown overboard, sloughing, or leaking. Concern has been expressed that windborne, spilled, or leaking dredged material entering the water column during transport could in some way delay or otherwise affect freshwater entry of returning adult salmon or have deleterious effects on pelagic and groundfish species. The negligible potential for this outcome is reviewed in the following discussion.

Mechanical dredging operations are performed to achieve an economical load that will result in some overflow of dredged material within the allowable dilution zone. The determination of an economical load is made in the field, based on the consistency of the dredged material and the safe load capacity of the transport barge. Sometimes the dredged material dewaters quickly, allowing the load to be mounded along the centerline axis of the barge. If the dredged material contains fines and high water content, mounding is not feasible and appropriate freeboard is maintained on the confinement bulkhead (sideboards) to prevent spillage. When the barge capacity is reached, the deck area outside the perimeter bulkhead is inspected for accumulated sediment. Spilled sediments are flushed overboard with water in the dilution zone at the dredging site to provide safe access for the dredge crew and to prevent the materials from being lost overboard in transit from the dredging site to the disposal site.

The potential for effect from windborne sediments is minimal. The type of sediments that can typically be mounded on a barge (and thus would be most exposed to wind) are either more granular (contain little fine or organic material, would be relatively inert, and pass quickly through the water column) or are very cohesive (clay). More claylike sediments generally contain a high moisture content, which would resist windborne transport. The amount of time between loading and discharge of dredged materials at the disposal site is relatively short (hours), which gives finer material little time to dry (become less cohesive) during the transport process. Thus, potential for windborne transport of these types of materials is minimal.

The potential for overboard sloughing or leaking of dredged material from barges during the transport of material to the disposal sites is minimized by the design of modern barges (e.g. sideboards on the deck and seals on the bottom dump doors) and the best management practices required of dredgers by water quality certifications issued by the Department of Ecology (e.g. loading practices and deck cleaning prior to leaving the dilution zone). If any significant leaking is noted, the contractor must correct the situation before leaving the dredging dilution zone. Even if an unnoticed leak were to occur, it would result in a small trailing plume, which would be spatially insignificant (i.e., potential for an animal to contact this material in the water column would be negligible). Additionally, the prop wash from the tug boat would likely cause enough turbulence to quickly disperse the small amount of sediment. Therefore, significant sloughing or leaking of dredged material during transport to a multiuser disposal site is unlikely.

5.1.1.2 Disposal Activities.

Disposal of dredged material will result in elevated turbidity levels. During monitoring at other disposal sites across the country, maximum concentrations of suspended sediments observed during disposal activities were less than 1,000 mg/l (Pequegnat 1983). Truitt (1986) found that very little suspended sediment persists near the surface or midwater during dredged material disposal during a capping demonstration project in Duwamish Waterway. As Figure 14 demonstrates, the highest concentrations tend to occur in near-bottom waters, and are typically much lower (less than 200 mg/l) in mid and upper water depths.

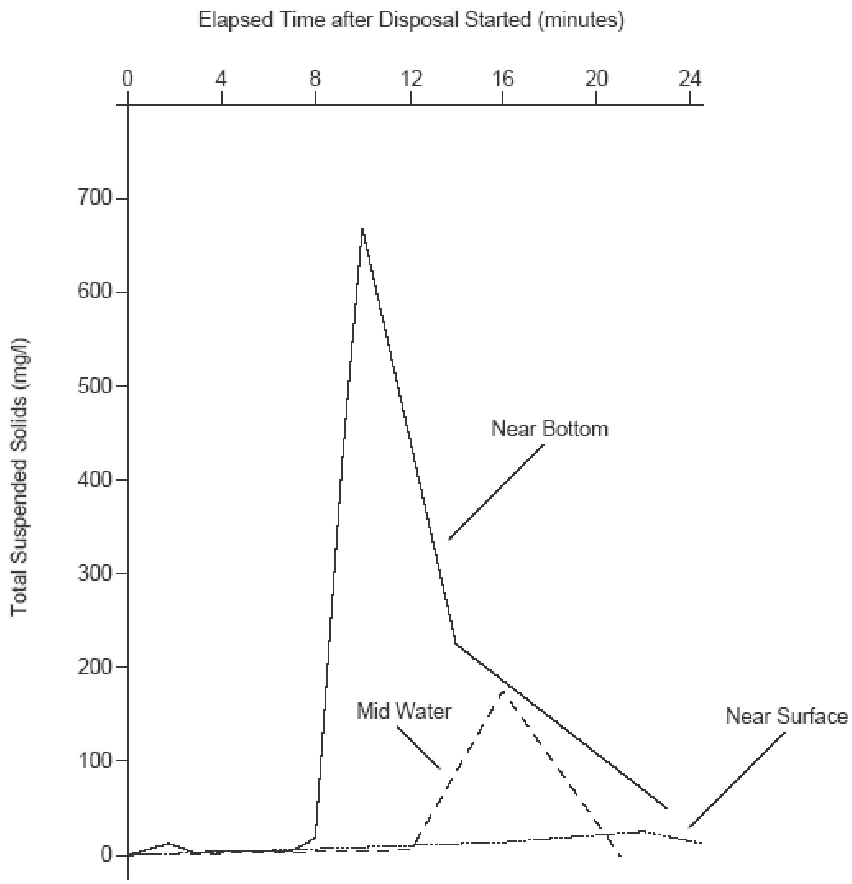
Turbidity levels generally return to ambient conditions rather quickly and relatively little material is separated from the jet as it descends into the water column when a clamshell or hopper dredge has been used (as described in Section 3.3.1). PSDDA/DSSTA (1989) evaluated the transport and duration of suspended sediment in the water column following a generic disposal event at the dispersive sites. At the end of 1 hour, calculations indicated that suspended sediment traveled 3,600 feet. Concentrations associated with this loss of sediment from the jet were approximately 0.25 mg/l, which is approximately one-quarter of the ambient concentration. After approximately 6 hours (one ebb or flood tide), the material was calculated to have traveled 21,600 feet and the concentration of suspended solids was reduced to 0.0007 mg/l. Figure 14 illustrates the relatively short duration of elevated suspended sediment concentrations in the water column at a non-dispersive site. As the graph illustrates, total suspended sediments at the middle and upper depths remained elevated for about 12 minutes.

Turbidity studies cited in Pequegnat (1983) found that lethal concentrations of suspended sediments for adult marine organisms were an order of magnitude or more higher than maximum suspended sediment concentrations observed in the field during dredging and disposal operations. In addition to the effects caused by decreased visibility for behaviors such as feeding and homing, territoriality, and avoidance responses, potential sub-lethal effects of increased suspended sediment concentrations on salmonids include: biochemical stress responses (elevated plasma glucose and cortisol levels), impaired osmoregulatory capacity, gill flaring (a response to gill irritation equivalent to a cough), impaired oxygen exchange due to clogged or lacerated gills, and reduced tolerance to infection.

Duration of suspended sediments, timing of the event, and particle size and shape have been shown to influence the potential affect of increased turbidity on Pacific salmon juveniles, but there is little specific information on thresholds of physical, physiological, or behavioral tolerances for particular species. It is unknown what threshold of turbidity might exist that serves as a cue to fish to avoid light-reducing turbidity. The primary determinate of risk level for a particular species is likely to lie in the spatial and temporal overlap between the area of elevated turbidity, the degree of turbidity elevation, the occurrence of the fish, and the options available to the fish for carrying out the critical function of their particular life-history stage (Nightingale and Simenstad 2001).

Laboratory experiments like those cited above have yielded some information on the response of fish to elevated suspended sediment concentrations, but application of this information is difficult given the often conflicting results attributable to variations in experimental design. For example, some mortality of Chinook and coho smolts occurred over short-duration exposures to suspended sediment levels from 500 mg/l to 1,400 mg/l (Newcombe and MacDonald 1991). LeGore and Des Voigne (1973) conducted 96-hour bioassays on juvenile coho salmon using re-suspended Duwamish River sediments. Acute effects were not observed at suspended sediment concentrations up to 5 percent (28,800 mg/l dry weight), and then only after prolonged exposure. This concentration is well above that measured during disposal operations.

Figure 14. Total Suspended Solids at Three Depths during Dredged Material Disposal



SOURCE: Truitt 1986 in Corps 1986.

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For short-term exposures (<4 days) to sub-lethal concentrations (14,400 mg/l), osmoregulatory capacity of salmonids is not impaired (Servizi 1990). Sockeye have been shown to exhibit gill damage at exposures of 3,100 mg/l over 96 hours (Servizi 1990). Biochemical responses and gill flaring appear to be reversible, as recovery occurs when the stressor is removed or the fish escapes the plume. However, if the stress is chronic, a metabolic cost may be incurred (Servizi 1990). Exposure to suspended sediment loads in the range of 2,000 to 4,000 mg/l caused a temporary elevation in plasma cortisol concentration, but this response was considered moderate when compared to fish exposed to handling stress and confinement (Redding et. al. 1987).

Bioassay-type tests generally measure an endpoint, often mortality, under conditions dissimilar to those organisms encounter in the field. Dose-response relationships measured under laboratory conditions tend to simulate a worst case scenario for motile organisms, which can often avoid unsuitable conditions (Clarke and Wilber, 2000). Under most scenarios, fish and other motile organisms encounter localized suspended sediment plumes for exposure durations on a temporal scale of minutes to hours (Clarke and Wilber, 2000). Testing protocols utilizing brief exposure periods and representative sediment periods would better clarify the actual hazards (Servizi 1990). A few generalizations can be taken from this literature review, however. Salmonid smolts are the life history stage most sensitive to elevated turbidity. For this reason, work closure periods are implemented to avoid dredging and disposal operations during juvenile salmon outmigration periods. It is also clear that the turbidity levels generally associated with disposal operations are not high or prolonged enough to cause acute physiological injury to adult fish.

Effects of increased suspended sediment concentrations on ESA-listed species may also include reduced foraging success and deterrence from migratory paths. Increased turbidity levels could affect the feeding success of marbled murrelets. Sediment suspended at the surface or midwater would be more likely to affect foraging than sediments dispersed on or near the bottom for all these species.. Almost all pelagic juvenile and yearling Chinook salmon captured in Puget Sound by Beamish et al. (1998) were collected at a depth of 30 meters (98 feet) or less. Most Chinook salmon caught off the east and west coasts of Vancouver Island by Taylor (1969) were found at depths of 73 meters (240 feet) or less. Acoustic telemetry work carried out in Puget Sound indicates that bull trout frequent shoreline areas and are infrequent migrants across deep waters (Goetz et al. 2004). One char monitored with a depth tag as part of the Goetz et al. (2004) study tended to spend most its time at depths of 5 to 10 meters, with mid-day migrations to deeper waters (less than 25 meters). All but two of the Puget Sound disposal sites are located in areas more than 90 meters (295 feet) deep; the exceptions are the Rosario Strait site, which is located at a depth of 30-43 meters, and the Bellingham Bay site, which is located at a depth of 29 meters. The Grays Harbor disposal sites are shallower in comparison, with the Point Chehalis and South Jetty sites located in areas between 12 and 24 meters (40-80 feet) deep. The potential for turbidity associated with dredged material transport and disposal to affect salmonid migratory paths is addressed in Section 6.1.4 below.

Disposal activities will temporarily degrade this indicator during and immediately following discharge events, but will maintain existing conditions over the long term. The available evidence summarized above indicates that suspended sediment concentrations sufficient to cause adverse effects would be limited in extent. Disposal operations will degrade water quality on a localized and temporary basis, but not over the long term nor throughout the entire action area.

5.1.2 Dissolved Oxygen

Anaerobic sediments create an oxygen demand when suspended in the water column, which decreases dissolved oxygen levels. Given the rapid descent of material dredged by clamshell and hopper dredges and the generally well-mixed nature of waters within the action area, disposal activities are not likely to lead to appreciable reductions in dissolved oxygen in the mid and upper portions of the water column.

Conditions would be degraded in a localized area on a short-term basis, but would be maintained over the long term.

At the non-dispersive disposal sites, reductions in dissolved oxygen levels would be expected to be larger and more persistent in the lower portion of the water column. However, monitoring of experimental disposal sites in Elliott Bay during and up to 9 months after disposal showed no significant long-term impacts to water quality (PSDDA/FEIS 1988). At the dispersive sites, oxygen-demanding materials would be rapidly diluted and any decrease in dissolved oxygen content in the water would be un-measurable.

5.1.3 Chemical Contamination

Small fractions of sediment-bound contaminants associated with suspended sediments may dissolve in the water column and result in impacts to water quality. However, sediments are rigorously tested for chemicals of concern and potential for biological effects before they are determined to be suitable for disposal at DMMP sites. It should be noted that the effects testing is focused on assessing benthic impacts, and not necessarily tied to protecting fish directly. The disposal sites were selected to minimize impacts to commercial invertebrate and fish resources. Any exposure to contaminants would be either avoided by fish moving through the disposal site, or of a very short duration in the water column following disposal. Dredged material that contains levels of contaminants that exceed the DMMP suitability guidelines is outside the scope of this consultation, and is disposed at Washington Department of Ecology approved confined disposal sites in upland or nearshore areas. Therefore, exposure of listed species to significant levels of contaminants is not expected.

Nutrients in sediments released to the water column when materials are discharged could affect phytoplankton production. However, any such effect would be small, temporary, and would not affect the overall productivity of the action area. Considering the nutrient inputs to nearshore waters from rivers, any changes in primary productivity would be unmeasurable.

The possibility of a fuel spill always exists. Contingency planning for fuel spills is required in Corps dredging contracts and is included in the conditions of water quality certifications for dredging projects. The Department of Ecology’s Spills Prevention, Preparedness, and Response (SPILLS) Program is the primary state authority responsible for dealing with vessel incidents involving fuel spills. Similar to the U.S. Coast Guard, Ecology conducts vessel examinations utilizing accepted industry standards. Ecology is also responsible for ensuring vessels have a state approved spill contingency plan that outlines what is necessary to ensure a rapid, aggressive and well coordinated response to a fuel spill if one were to occur. Both Puget Sound and Grays Harbor have Harbor Safety Committees which have prepared harbor safety plans. These plans include Standards of Care for the safe operation of vessels. In the event a spill were to occur, the marine community in Washington State has considerable response, containment and clean-up capabilities. In light of the BMPs, response mechanisms, and containment and cleanup capabilities that are in place, and the existing commercial vessel traffic in Puget Sound and Grays Harbor, the incremental risk of spill during transportation of dredged material is small.

5.2 SEDIMENT

5.2.1 Physical Characteristics

At the non-dispersive PSDDA sites, changes in sediment character (e.g., percent silt, clay, sand, gravel) have occurred since usage of the sites began 26 years ago. In addition to temporary impacts to benthic fauna from burial, changes in sediment character can affect the structure and productivity of benthic communities within the disposal site.

Post-disposal monitoring results at the five non-dispersive sites have indicated that the site management objectives are generally being met. Site management objectives (PSDDA/MPTA, 1988; SAIC, 2007) are evaluated at all five non-dispersive sites by evaluating 3 broad monitoring questions, and 6 testable hypotheses as depicted in Table 2. In the few cases where benthic taxa depressions were noted at transect stations (hypothesis 6), similar observations were also noted in the same benthic major taxa at benchmark stations outside the direct influence of dredged material disposal. The monitoring results have also confirmed that there have been no unacceptable adverse effects on biological resources immediately off-site due to dredged material.

Monitoring of benthic fauna just outside the Elliott Bay site in 1992 verified that there were no adverse environmental effects beyond the boundary of the disposal site (PSDDA, 1994). The abundance of major benthic taxa at the transect stations was similar to the abundances measured during baseline studies.

Full monitoring at the Commencement Bay site in 1995, 2001, 2003, and 2007 confirmed that benthic resources were not being impacted outside the site boundary by disposal of dredged material. Moreover, the results for 2001 and 2003 indicated that taxa-specific abundances actually increased from the baseline abundances for all taxonomic groups (polychaetes, crustacean, and mollusks). Apparent reductions in specific benthic taxa abundance (arthropods and mollusks) in 2007 were attributable to area-wide changes to benthic community structure, and not due to dredged material disposal. Benthic community structure observed during SPI surveys have consistently shown high benthic habitat values and evidence that benthic taxa are not being physically displaced by disposal of dredged material throughout most of the disposal site. SPI surveys have documented Climax Stage III communities (Figure 15) over most of the site, which indicates that benthic infaunal taxa are able to recover from individual disposal events. Figure 16 shows Stage I on III community structure at the majority of the SPI stations during the 2007 monitoring event. Even after a cumulative disposal volume of 8 million cubic yards at this site, the benthic community continues to exhibit a healthy, robust structure.

Changes in sediment characteristics have not occurred at the dispersive sites since materials do not mound, and are quickly dispersed. The preponderance of material disposed of at the most-used dispersive site in Puget Sound, the Rosario Strait site, is clean sand from the Swinomish River. Bathymetric surveys conducted in 1991, 1994, 1999 and 2009 verified that no material has accumulated on the bottom within the disposal site due to the highly dispersive environment.

The vast majority of material placed at the South Jetty and Point Chehalis sites comes from the Grays Harbor federal navigation channel. The material placed at these sites ranges from sand from the outer harbor reaches to sandy silt from the inner harbor reaches. Annual bathymetric surveys have demonstrated that disposed material does not result in long-term mounding.

5.2.2 Chemical Contamination

The DMMP program includes rigorous chemical testing of sediments to determine if they are suitable for unconfined, open-water disposal. Only sediments that have passed chemical (and sometimes biological) testing are allowed to be placed at the DMMP multiuser sites in Puget Sound and Grays Harbor. Effects to listed species resulting from contamination of discharged sediments would be extremely unlikely to occur.

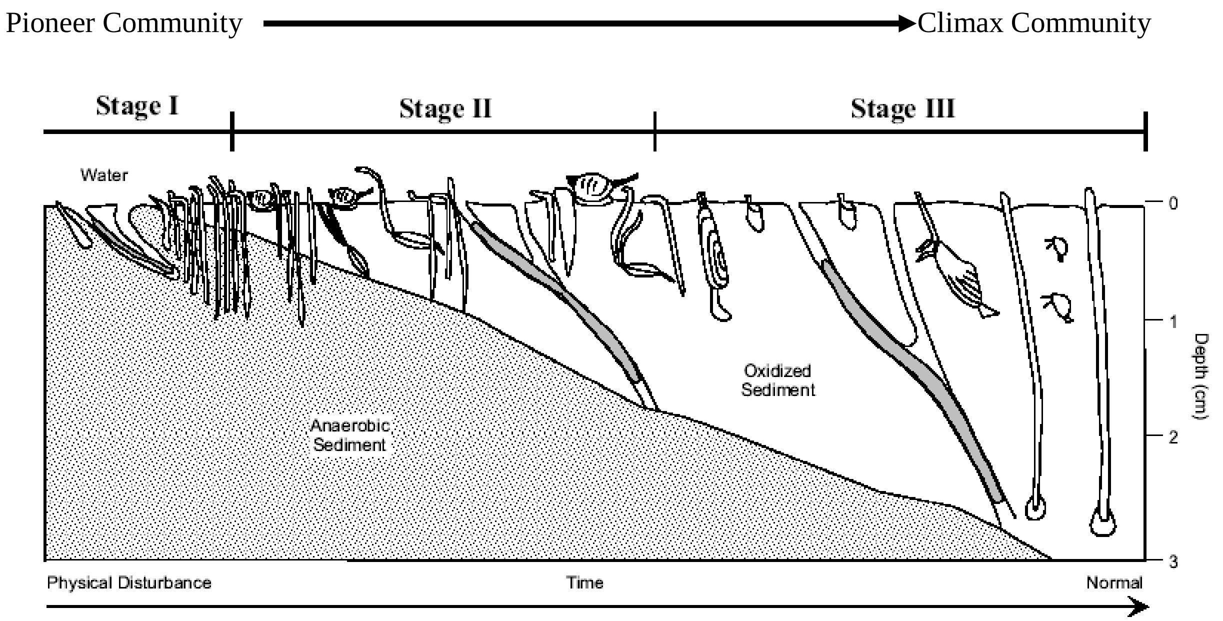

Figure 15. Idealized Development of Infaunal Successional Stages (after Pearson and Rosenberg, 1978)

5.3 HABITAT CONDITIONS

The operation of tugboats used to transport dredged material to the DMMP sites would increase ambient noise levels along the immediate travel route. Impacts of any sound disturbance would likely result in temporary, short-range displacement of animals rather than injury. Degradation would be insignificant due to the short time noise levels would increase in a given area and the minor nature of the increase. Due to the deep waters in which disposal activities occur, prop-wash from tug boats would have no effect on bathymetry in the action area.

Disposal activities will have no effect on current patterns, salinity levels, temperatures, or water column stratification within the action area. Bathymetry would not be affected at the dispersive sites, but could be altered at the non-dispersive sites.

5.3.1 Mound height effects on circulation patterns and habitat at non-dispersive sites

Mound height effects on circulation pattens in Commencement Bay were addressed in the SEIS for the Commencement Bay disposal site reauthorization (SAIC, 2009), where circulation modeling found little discernable impact from a predicted 155-foot mound after 23 million cubic yards of dredged material disposal. The existing mound height in Commencement Bay is 122 feet. At the Elliott Bay and Port Gardner sites, mound height is estimated to be less than 50 feet. The mound height at the Anderson/Ketron Island and Bellingham Bay sites is estimated to be less than 5 feet. Therefore, based on the evaluation of circulation effects at the Commencement Bay site, the effects of mound height on tidal currents, species, and habitat at the other non-dispersive sites are expected to be negligible.

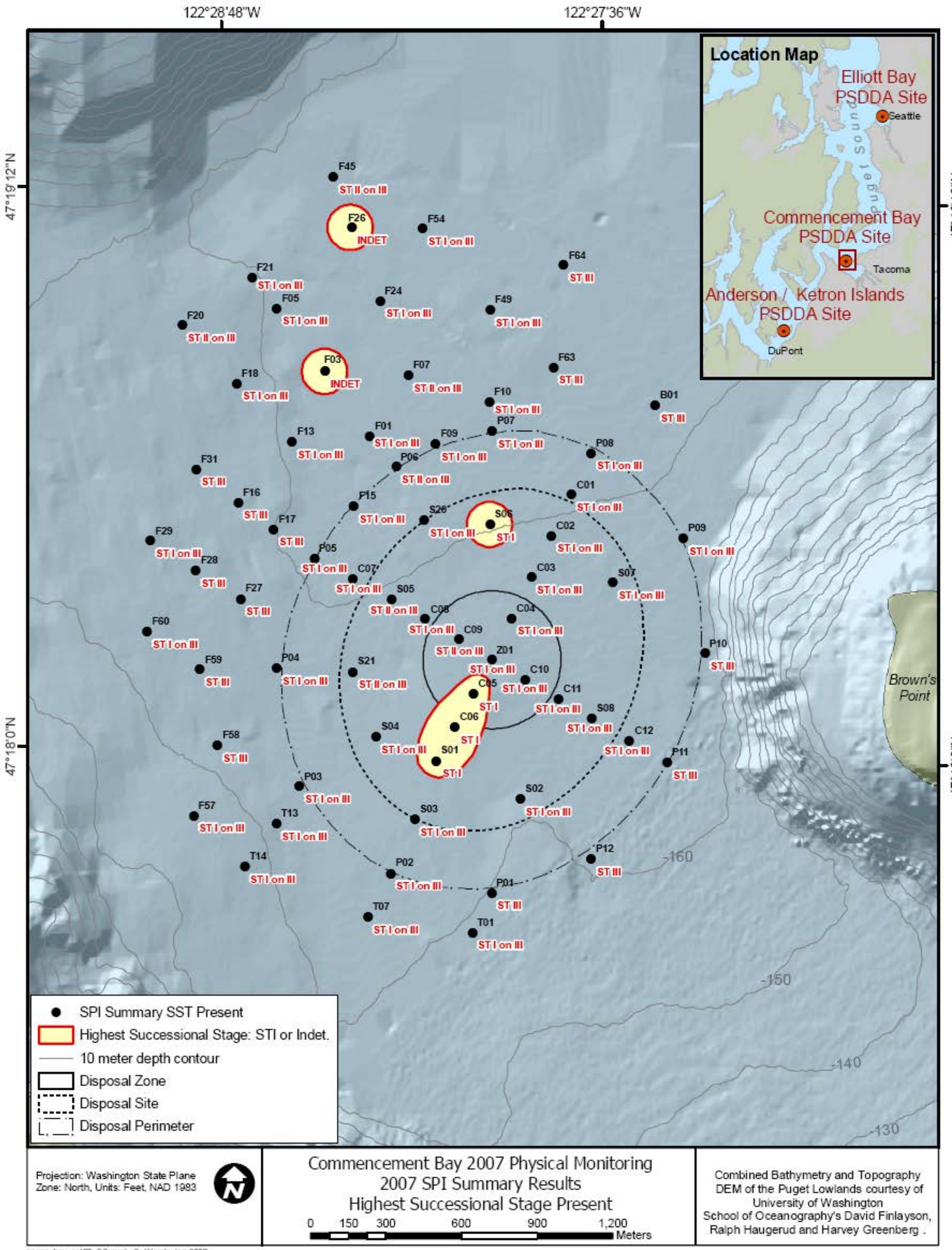

Figure 16. Commencement Bay 2007 Monitoring Results Depicting Infaunal Successional Stage Distribution (after SAIC, 2008a)

5.4 PREY AND TROPHIC STRUCTURE

The selection of dispersive and non-dispersive sites in Puget Sound was based on an evaluation of benthic resources at candidate sites in order to minimize the potential for effects to important prey resources. BRAT was used to estimate the relative amount of trophic support that a given benthic habitat provides to fish (Lunz and Kendall, 1982; Clarke and Lunz, 1985). Results of the BRAT analyses were used to help determine final site selections.

Large planktonic crustaceans (e.g., calanoid copepods and euphausiids) and forage fish (e.g., sand lance, surf smelt, and Pacific herring) are critical links in the action area's trophic structure. Therefore, water column turbidity effects to pelagic prey resources are the primary impact pathway and are the focus of the remainder of this analysis.

Forage fish are an important and abundant fish species in Washington, significant as an intermediate step in the marine food web between zooplankton and larger fish/seabirds. Disposal activities will not affect the intertidal and shallow subtidal spawning habitats of forage fish. Effects to planktonic prey organisms and forage fish are expected to be discountable.

Increased turbidity levels are not expected to significantly affect phytoplankton productivity in the action area for a couple of reasons. As discussed in Section 5.1.1.2, the portion of disposal plumes resulting in the greatest turbidity increase would be located in near-bottom waters. Phytoplankton production typically occurs in the upper portion of the water column where increases in turbidity are expected to be highly localized and temporary (on the order of minutes (see Truitt, 1986b)). Any reduction in phytoplankton productivity resulting from disposal-related turbidity would be small-scale relative to the large size of the action area, and expected to return to pre-project conditions within days. The action area is highly dynamic, with the project sites surrounded by unaffected waters, which could serve as a source for new plankton populations. Phytoplankton have rapid replication times, so that populations can double in a day; they can generally mature to reproductive life stages within 3 days and can remain viable for days to weeks (Little, 2000).

While the impacts of dredged material disposal on benthic communities are relatively well studied and understood, impacts on zooplankton have been studied less and are poorly understood. This lack of research is partly due the technical difficulties (e.g., representative sampling, need for in situ work, the subtlety of anticipated effects, and the differentiation of those effects from other anthropogenic effects) associated with studying this type of impact. However, laboratory studies reviewed by Clarke and Wilber (2000) indicate that crustaceans do not exhibit detrimental responses at dosages within the realm of suspended sediment conditions associated with disposal activities; crustaceans have been shown to tolerate high suspended sediment concentrations (up to 10,000 mg/l) for durations on the order of two weeks. The high variability in zooplankton distribution and abundance would further limit the scale of potential impacts. The localized area of effect and low frequency of disposal events would result in insignificant impacts on zooplankton.

Increased turbidity in the vicinity of the sites immediately after a disposal event could cause a temporary and localized decrease in phytoplankton productivity or cause mortality of pelagic fish eggs, larvae, and zooplankton. However, the disposal sites lack components (e.g., physical habitat structure, tidal currents) that would attract or concentrate plankton or fish. These organisms are widely distributed throughout the marine waters of Western Washington, so the localized, short-term, and infrequent disposal of dredged materials would not substantially affect populations of these organisms over the entire action area nor impact their availability as food for listed species.

6 EVALUATION OF PROJECT IMPACTS ON AFFECTED SPECIES

There are 16 ESA listed species and their designated or proposed critical habitat occurring in areas where dredged material transport and disposal are conducted in Puget Sound and Grays Harbor (Table 8).

The humpback whale and leatherback sea turtle typically occur only along the Washington coast offshore of the Grays Harbor disposal sites and only rarely enter coastal embayments. However, they are included in this BE due to occasional appearances in Grays Harbor.

Table 8. Endangered Species Act Listed Species in Puget Sound and Grays Harbor and Their Designated or Proposed Critical Habitat

Common Name	Scientific Name	Critical Habitat
Puget Sound Chinook Salmon	*Oncorhynchus tshawytscha*	Designated
Hood Canal Summer-Run Chum Salmon	*Oncorhynchus keta*	Designated
Puget Sound Steelhead	*Oncorhynchus mykiss*	Proposed
Lower Columbia River Coho Salmon	*Oncorhynchus kisutch*	Proposed*
Bocaccio Rockfish	*Sebastes paucispinis*	Designated
Canary Rockfish	*Sebastes pinniger*	Designated
Yelloweye Rockfish	*Sebastes ruberrimus*	Designated
Eulachon	*Thaleichthys pacificus*	Designated*
Coastal/Puget Sound Bull Trout	*Salvelinus confluentus*	Designated
Marbled Murrelet	*Brachyramphus marmoratus*	Designated*
Southern Resident Killer Whale	*Orcinus orca*	Designated
Humpback Whale	*Megaptera novaeangliae*	No
Leatherback Sea Turtle	*Dermochelys coriacea*	Designated*
North American Green Sturgeon	*Acipenser medirostris*	Designated
Lower Columbia River Chinook Salmon	*Oncorhynchus tshawytscha*	Designated*
Upper Willamette River Chinook Salmon	*Oncorhynchus tshawytscha*	Designated*
Columbia River Chum Salmon	*Oncorhynchus keta*	Designated*

* Critical habitat is designated or proposed, but does not occur in the action areas of this BE.

6.1 PUGET SOUND CHINOOK SALMON

The Puget Sound evolutionarily significant unit (ESU) of Chinook salmon (*Oncorhynchus tshawytscha*) was listed as a threatened species in March 1999.

6.1.1 Distribution and Timing

The distribution and timing of Chinook salmon in Puget Sound are determined by life stage (i.e., adult or juvenile), race type (i.e., ocean type or stream type), size/age of juveniles, and location of natal stream.

For "ocean type" fish, adults are generally present in Puget Sound only as they pass through on the way to their spawning streams. Migrating adults may follow the shoreline (PSDDA/FEIS, 1989), and milling of adults near the mouth of spawning streams may occur prior to entry (PSDDA/FEIS, 1988). Juvenile Chinook salmon rear extensively in the estuarine and pelagic areas of Puget Sound (Simenstad et al., 1982; Beamish et al., 1998). Initially, they tend to follow shorelines and are associated with structures

(PSDDA/FEIS, 1988, 1989; Anderson, 1990). They move offshore and into deeper water as they become larger. Although some may remain in Puget Sound for a year or more, most are present in the Sound for only a short time (i.e., a few months) before they complete their outmigration to the Pacific Ocean.

Peaks of juvenile Chinook salmon in the estuary areas of Puget Sound occur in June for most populations. They apparently disperse to deeper nearby marine areas when they reach approximately 65-75 mm in fork length (Healey, 1982; Simenstad et al., 1982). The amount of time spent in the estuary is dependent on size at downstream migration and growth in the estuary. Dispersal from the estuarine areas is relatively rapid. Average length of estuarine residence for Chinook salmon in the Nanaimo River estuary was about 20 to 25 days (Healey 1980).

6.1.2 Migratory Pathways

Puget Sound Chinook salmon juveniles and returning adults could potentially pass through the PSDDA dispersive disposal sites between their natal spawning streams and either the west coast of Vancouver Island or Georgia Strait. The literature indicates that "stream type" Chinook are common in the Georgia Strait during the spring and early summer of their first ocean year, and "ocean type" Chinook are most abundant during the summer and fall of their first ocean year (Healy 1980). Adult Chinook salmon enter the straits in mid-April (spring-run) and between mid-July and September (summer and fall run). However, both juveniles and adults tend to travel close to shore and migrate directly and rapidly between the ocean and their natal stream. Therefore, presence within areas influenced by dredged material disposal by Chinook salmon would be very transitory. Blackmouth could occur in Rosario Strait and the Strait of Juan de Fuca throughout the year.

6.1.3 Foraging and Food Web Relationships

Juvenile Chinook salmon use both their natal, freshwater streams and estuarine wetlands of Puget Sound for early rearing. The amount of time juveniles spend in estuarine areas is dependent upon their size at downstream migration and rate of growth. Juveniles disperse to deeper marine areas when they reach approximately 65-75 mm in fork length (Simenstad et al. 1982). While residing in upper estuaries as fry, juvenile Chinook have an affinity for benthic and epibenthic prey items such as amphipods, mysids, and cumaceans. As the juveniles grow and move to deeper waters with higher salinities, this preference changes to pelagic items such as decapod larvae, larval and juvenile fish, drift insects, and euphausiids (Simenstad et al. 1982).

The primary prey items for larger juveniles, blackmouth, and returning adult Chinook salmon in Puget Sound include Pacific herring (*Clupea harengus pallasi*), sandlance (*Ammodytes hexapterus*), and krill (euphausiids) (WDF 1981, Healey 1991; Beamish et al. 1998). Because these three prey organisms are also planktivores, they represent critical links between Chinook salmon and phytoplankton/zooplankton in the trophic structure of Puget Sound.

6.1.4 Evaluation of Project Impacts

Potential effects to Chinook salmon due to continued operations of the PSDDA dispersive and non-dispersive, unconfined, open-water disposal sites are insignificant. This determination is supported by numerous factors.

First, it is unlikely that the small amounts of dredged material potentially discharged to action area waters during the transport of material to the disposal site would affect physical navigation cues used by adult salmonids. Likewise, disposal events at the DMMP sites are localized enough and generally far enough from the mouths of major spawning rivers to have little potential for effect on salmonids migratory paths. Adult salmon use a variety of mechanisms to navigate from the open ocean to their natal spawning grounds (Pearcy 1992). Return from the open ocean and coastal migration are thought to involve the use of either magnetic or celestial cues. As adult salmon approach the estuaries of their natal streams, Percy suggests that they rely more on a number of "navigational landmarks" for orientation, possibly including salinity, temperature, currents and bathymetry. At some point during the nearshore migration, olfaction becomes the dominant navigational cue to guide salmon upstream. Small amounts of dredged material in the water column would not affect these navigation cues, with the possible exception of visual orientation and olfaction. As described in Section 5.1.1.1, any dredged material leaking from a transport barge would be extremely small in quantity and would be quickly dispersed.

Second, Chinook salmon may occur in areas of disposal activities; however their presence would be minimal and coincidental because there are no features at the sites that would cause Chinook salmon to congregate and they would likely be simply passing through the disposal sites during migration. Should a Chinook salmon coincidentally be present in the disposal area during a discharge event, it could experience a short period of non-lethal discomfort due to high suspended sediments in the water column. The period during which sediments in the water column are elevated is relatively short (approximately 12 minutes in midwater areas studied by Truitt [1986a, 1986b]) and localized. Fish would migrate from the area affected by the discharge and recover relatively quickly from the discomfort.

Third, the potential for toxic effects of contaminants released from discharged sediments is minimal. Sediments are determined to be suitable for discharge through a series of physical, chemical and biological testing procedures that have been subject to thorough review by the regulating agencies and the public. A white paper addressing the potential for bioaccumulative effects on killer whales and Chinook salmon was prepared by the Corps in 2006 (USACE, 2006). The analysis in the white paper demonstrated that potential effects of bioaccumulation for polychlorinated biphenyls (PCBs) and polychlorinated dioxins and furans (PCDD/F) for Chinook were discountable. This conclusion is still valid.

Meador et al. (2002) derived a PCB Residue Effects Threshold (RET) of 2.4 μg/g-wet(lipid) for protection of juvenile salmonids. This threshold is intended to indicate a value at and below which no significant adverse effects would be expected. A Sediment Effects Threshold (SET) was also derived from the relationship shown below.

EQUATION 1: Relation between Sediment and Tissue Concentrations
$[C_{fish}]/f_{lipid} = [C_{sed}]/f_{oc} * BSAF$, where tissue $/f_{lipid}$ = 2.4 μg/g-wet(lipid) = RET

Where:

- C_{fish} = concentration in fish tissue (wet weight)
- C_{sed} = concentration in sediment (dry weight)
- f_{lipid} = fraction of tissue that is lipid (dimensionless)
- f_{oc} = fraction of sediment that is organic carbon (dimensionless)
- BSAF = empirical relationship for accumulation of PCBs: BSAF = $(tissue/f_{lipid}) \div (sediment/f_{oc})$

For all but one of the DMMP non-dispersive sites, PCBs have been undetected during monitoring events, with reporting limits ranging from 3-86 μg/kg. Elliott Bay is the single exception, with on-site monitoring in 2005 (SAIC, 2005b) showing 130 μg/kg of total PCB, and an f_{oc} of 0.019, in the top 0-2 cm of sediment. This is below the SET set by both the mean and upper-bound BSAFs shown in Table 9 above. Additionally, this dredged material site is not significantly elevated over its surroundings for PCBs.

Table 9. Sediment Effect Thresholds for PCBs for Protection of Juvenile Salmonids.

Sediment Effect Threshold (SET) concentration for total PCBs based on two BSAF values.

Tissue threshold (RET) µg/g lipid	Sediment TOC % dry wt.	Sediment threshold (SET) ng/g dry wt. (BSAF = 0.16)	Sediment threshold (SET) ng/g dry wt. (BSAF = 0.32)
2.4	1.0	150	75
2.4	1.5	225	113
2.4	2.0	300	150
2.4	2.5	375	188
2.4	3.0	450	225
2.4	3.5	525	263
2.4	4.0	600	300

Lipid-normalized residue effect threshold (RET) for PCBs from Table 1. SET determined with equation 1. Sediment PCB concentrations determined as ng/g OC but presented as ng/g dry wt. Values correspond to an organic-carbon normalized sediment concentration (sed_{oc}) of 15.0 µg/g OC for the mean BSAF (= 0.16) and 7.5 µg/g OC for the 95th percentile BSAF (= 0.32) (see text).

Fourth, adult and sub-adult Chinook salmon do not typically feed at depths where benthic habitats are altered by dredged material disposal. Thus, foraging habitat for this species would not be directly affected.

Fifth, adult and sub-adult Chinook salmon typically feed on pelagic organisms, with their primary prey being forage fish (herring and sandlance). Herring and sandlance are mainly pelagic, and their forage base would not be significantly affected by disposal activities. Sandlance can be demersal at times because they have no swim bladder, and sometimes rest in or on the bottom, but typically in less than 100 meters (328 feet) of water. Spawning areas for both species are in intertidal and shallow subtidal areas which are unaffected by disposal activities. Thus, continued disposal activities would not affect the prey base of adult and sub-adult Chinook salmon.

Sixth, juvenile Chinook salmon migrate from rivers to the Sound in the spring. Timing of dredging activities and associated disposal activities is controlled to avoid outmigrating juveniles.

In summary, due to the wide distribution of this species within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on Chinook salmon would be insignificant. The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** Puget Sound Chinook salmon.

6.1.5 Puget Sound Chinook Salmon Designated Critical Habitat

Critical habitat designation for Puget Sound Chinook salmon was originally designated in February 2000. Critical habitat was re-designated in September 2005 (50 CFR Part 226, FR Vol. 70, No. 170, pages 52630-52858). This section covers the primary constituent elements determined essential to the conservation of Puget Sound Chinook salmon:

(1) Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.

Disposal sites are located in offshore marine areas. Therefore, disposal will have no effect on this PCE.

(2) Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

Disposal occurs in offshore marine areas away from freshwater habitat. Therefore, disposal will have no effect on this PCE.

(3) Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.

Disposal occurs in offshore marine areas away from freshwater habitat. Therefore, disposal will have no effect on this PCE.

(4) Estuarine areas free of obstruction with water quality, water quantity and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels, and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

The Puget Sound disposal sites are located in offshore marine areas away from areas where freshwater and saltwater mix. Therefore, disposal will have no effect on this PCE.

(5) Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulder and side channels.

Transport of dredged material from the dredging locations will likely have discountable and insignificant effects on the nearshore environment in the unlikely event of sloughing of dredged material from the barge (see section 5.1.1.1 for more detailed information). The minimum distance from shore for all disposal sites is 1,500 feet. All disposal sites are greater than the 30-meter depth defined by NOAA for critical habitat for Puget Sound Chinook salmon, except for Bellingham Bay, which is exempted from critical habitat designation (50 CFR Part 226, 2 September 2005). There are no other disposal areas in the vicinity of the nearshore, as defined in the Federal Register notice. Therefore, transport and disposal will have discountable adverse effects on this PCE.

(6) Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

The PSDDA disposal sites are located in offshore marine areas either in deep water where critical habitat is not located or in areas where the dredged material will rapidly disperse leaving disposal areas as they were prior to disposal. The effects of disposal to this PCE are expected to be insignificant and discountable.

The following excerpt from the NMFS 2005 concurrence letter for PSDDA activities nicely summarizes the effects to Chinook critical habitat:

1. The project will not result in a barrier to migration to, or through, any marine habitat. The project proposes to dispose of clean dredge material in specified locations. This will have little, or no, impact to proposed critical habitat since the impact to affected areas will be transient. Effects to migratory habitat from the project are insignificant.

2. The project will not alter the food base within the action area. Macroinvertebrate and fish prey species will continue to be available. Prey species such as surf smelt (*Hypomesus pretiosus*), sand lance (*Ammodytes hexapterus*), and Pacific herring (*Clupea harengus pallasi*) are unlikely to be impacted by the project activities because these species do not spawn in PSDDA sites. Therefore, the project is not likely to reduce the abundance of prey.

3. The proposed project has the potential to alter water quality during dumping because of mobilization of sediment into the water column. However, the effects will be local and temporary and will not significantly impact water quality.

Due to the relatively small area of pelagic habitat affected by disposal events; the temporary and discountable impacts to turbidity, dissolved oxygen, and chemical contamination; the infrequent and short-lived nature of disposal events; the ability of forage fish species to quickly leave the affected area: and the ability of benthos to survive the deposition of sediment, the overall effects of disposal activities on Chinook salmon critical habitat would be insignificant. The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** designated Puget Sound Chinook salmon Critical Habitat.

6.2 Hood Canal Summer-Run Chum Salmon

The Hood Canal Summer-Run ESU of chum salmon (*Oncorhynchus keta*) was listed as a threatened species on 28 June 2005 (70 FR 37160).

6.2.1 Distribution and Timing

Emigration of chum fry/smolt from rivers to estuaries is relatively rapid after emergence, occurring in a matter of hours to a few weeks for small drainages (Groot et al., 1995; Johnson et al. 1997). Hood Canal summer-run chum salmon appear in the estuary between February and July, with peaks in estuarine residence in February and between mid-May to mid-July (Bax et al. 1978). Juvenile chum salmon occupy the estuary for a period of time prior to migration to the ocean. Observed residence times of individuals range from 4 to 32 days, with a common residence time of approximately 24 days (Simenstad et al. 1982, Johnson et al. 1997).

Tagging studies conducted by Jensen (1956) found that juvenile chum salmon tagged in Puget Sound moved rapidly northward to the Strait of Georgia and along the west coast of Vancouver Island and continued northward within a narrow band of about 20 miles from shore, apparently moving further offshore to the southwest after reaching the Alaskan coast. Jensen (1956) found some residualism of chum salmon within Puget Sound (for months to a year); however, the extent of residualism is unclear (Johnson et al. 1997).

Most chum salmon mature between 3 to 5 years of age. The highest proportion of mature chum salmon returning to Washington streams is 3 years of age (Johnson et al. 1997). Maturing chum salmon begin to move coastward from offshore north Pacific Ocean feeding grounds in May and June, and they enter coastal waters between June and November. Hood Canal summer-run chum salmon enter their natal rivers between September and mid-October, with the exception of the Union River stock, which typically returns a month earlier (mid-August to mid-September). Swimming speed on the return migration is relatively fast, with speeds between 9 and 50 miles per day reported by various authors (in Johnson et al. 1997). Once in the estuary, chum salmon may enter the river directly or may mill in the vicinity of the natal stream prior to migrating upstream to spawn. Various authors have measured estuarine residence by returning adult chum salmon as long as 20 to 50 days (in Johnson et al. 1997).

6.2.2 Migratory Pathways

Hood Canal summer-run chum salmon that are ocean-migrating juveniles and returning adults could potentially pass through the PSDDA dispersive disposal sites while traveling between Hood Canal and either Georgia Strait or the west coast of Vancouver Island. However, both juveniles and adults tend to travel close to shore and migrate directly and rapidly between the ocean and their natal stream. Therefore, chum salmon presence within areas influenced by dredged material disposal would be very transitory.

6.2.3 Foraging and Food Web Relationships

During early estuarine residence, chum salmon feed on epibenthic and neritic organisms in shallow nearshore areas. During this period, chum salmon diets are dominated by harpacticoid copepods and gamarid amphipods (Groot et al., 1995; Bax et al. 1978; Simenstad et al. 1980). At about 45 to 55 mm, juvenile chum salmon move to deeper water and feed on pelagic organisms such as euphausiids, copepods, hyperiid amphipods, decapod larvae, and fish larvae (Groot et al., 1995; Beamish et al., 1998). Adult chum salmon continue to feed on pelagic organisms including hyperiid amphipods, fish, pteropods, euphausiids, and calanoid copepods.

6.2.4 Evaluation of Project Impacts

Potential project effects to chum salmon are very similar to those discussed for Chinook salmon in section 6.1.4. Due to the wide distribution of these species within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on chum salmon would be insignificant. The Corps has determined that the proposed action **may affect, is not likely to adversely affect** Hood Canal summer-run chum salmon.

6.2.5 Hood Canal Chum Salmon Designated Critical Habitat

Critical habitat was re-designated on September 2, 2005 (50 CFR Part 226, FR Vol. 70, No. 170, pages 52630-52858). Primary constituent elements of critical habitat are the same as for Puget Sound Chinook salmon, and the effects analyses are the same as for Puget Sound Chinook designated critical habitat (see Section 6.1.5), although in this case the potential for effects are primarily at the three dispersive sites (Port Townsend, Port Angeles, and Rosario). The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** designated Hood Canal summer run chum salmon critical habitat.

6.3 STEELHEAD

The Puget Sound steelhead (*Oncorhynchus mykiss*) was listed as threatened on May 11, 2007 (effective June 11, 2007).

6.3.1 Distribution and Timing

The present distribution of steelhead extends from Kamchatka in Asia, east to Alaska, and extending south along the Pacific Coast to the U.S. Mexico border (Busby et al., 1996). Steelhead that are anadromous can spend up to seven years in freshwater prior to smoltification and then three years in salt water prior to first spawning (though the majority of Puget Sound steelhead remain in the river for two years, and in the ocean for two years (Puget Sound Steelhead Biological Review Team, 2005)). Steelhead are iteroparous (spawn more than once) whereas the Pacific salmon is semelparous (spawn once and die).

Steelhead can be divided into two basic reproductive ecotypes, based on the state of sexual maturity at the time of river entry and duration of spawning migration (Burgner et al., 1992). The summer "stream maturing" type enters fresh water in a sexually immature state between May and October and requires several months to mature and spawn. The winter or "ocean maturing" type enters fresh water in a mature state and ready to spawn between November and April.

6.3.2 Migratory Pathways

The inshore migration pattern of steelhead in Puget Sound is not well understood; it is generally thought that steelhead smolts move quickly offshore (Hartt and Dell, 1986; Puget Sound Steelhead Biological Review Team, 2005). Both Welch (2007) and Goetz (2007) confirm this rapid migration to the ocean once the smolts enter marine waters. Both Welch and Goetz found steelhead migration covering as much as 25 km/day. Welch found that wild steelhead enter the ocean in about 2.3 days, while Goetz's data indicate residence times of 7 to 26 days, with a rough average of about 15 days. However, as Welch points out, older kelts (3 yrs of age) may tend to linger (Ruggerone, et al., 1990; Welch et al., 2004), and demonstrate a "milling" pattern of movement. So far, data is lacking to demonstrate whether juvenile steelhead stay close to the nearshore or move offshore when moving through Puget Sound or Queen Charlotte Strait (Goetz, 2007; Welch, 2007), but studies that are underway suggest to Goetz that juvenile steelhead use both inshore and offshore areas (Goetz, 2007). John Stadler, NMFS (personal communication, 2007) stated "it is generally thought that smolts move quickly offshore after entering marine waters."

6.3.3 Foraging and Food Web Relationships

Data on foraging habitats and prey base of steelhead while in Puget Sound could not be found by a search of the literature. Wydoski and Whitney (2003) report on stomach contents of juvenile steelhead in the Pacific Ocean:

"Juvenile steelhead captured in purse seines in the Pacific Ocean off the Oregon/Washington coast consumed fishes as well as various invertebrates. Fishes were most important diets of juvenile steelhead while they were at sea, making up about 60 percent of the stomach contents by weight. Fishes that were dominant in juvenile steelhead diets included juvenile rockfish, sandlance, brown Irish lord (a native sculpin), and greenling. Invertebrates that were consumed were primarily euphausiids (planktonic marine crustaceans resembling shrimp) but also included barnacle larvae, copepods, amphipods, and squids."

LeBrasseur conducted a study of stomach contents of various salmonids, including steelhead, in the northeast Pacific Ocean in May and June, 1958:

"Only 37 steelhead trout were available for examination. Among their stomach contents, fish and squid were predominant. Amphipods were generally present, whereas, copepods and euphausiids were infrequently present, and never in more than trace amounts."

The "fish" in the stomach contents were not identified to species in LeBrasseur's study. In a parallel study to that of LeBrasseur, Manzer (1968) studied salmonid stomach contents in the northeast Pacific Ocean during the winter (January-February) of 1964. Four of the seven steelhead stomachs he examined contained food in their stomachs. It appeared to Manzer that the most important food organism was squid.

Kaeriyama, et al (2004) confirmed the earlier studies, in that the principal component of steelhead diet in the north Pacific is squid (GOA stands for Gulf of Alaska):

"Analyses of steelhead diets in both the GOA and central North Pacific (CNP) showed that the dominant prey of all age groups were gonatid squid and fish. The percent composition of squid in steelhead diets was inversely related to Russian pink salmon abundance, although the relation was stronger in the CNP, where overlap in distribution of steelhead and Russian pink salmon is higher, than in the GOA. Thus, climate change may affect ocean carrying capacity of steelhead through variation in ocean habitats and density-dependent trophic interactions."

Finally, Margaret Atcheson (2010) studied food habitats of steelhead in the Gulf of Alaska (GOA) and central north Pacific Ocean (CNP). She found that:

"Steelhead caught in the GOA and CNP consumed a wide variety of prey. The dominant prey categories for steelhead were fish and squid. The primary species within these categories include Atka mackerel (*Pleurogrammus monopterygius)*, three-spined stickleback (*Gasterosteus aculeatus)*, lantern fish (*Myctophidea spp*.), and the minimal armhook squid (*Berryteuthis anonychus*)."

6.3.4 Evaluation of Project Impacts

The lack of data describing juvenile steelhead behavior while in Puget Sound makes it somewhat problematic to assess impacts of transport and dredged material disposal activities. However, the evidence gathered so far indicates that steelhead spend less time in Puget Sound than other salmonids and are, therefore, less likely to be exposed to dredged material disposal plumes or sediment at the disposal sites.

The Corps prepared a white paper analyzing the potential effects of bioaccumulation of chemicals in Puget Sound Chinook salmon and Southern resident killer whales (USACE, 2006). A second white paper was prepared in 2010 to update the analyses based on more recent study results. The paper was updated again in preparation of this BE (see Appendix C). This analysis reaffirms our original determination that effects of bioaccumulation from disposal operations are discountable in steelhead.

Despite the lack of knowledge about steelhead, factors that minimize potential effects to Chinook salmon, are also likely to apply to steelhead. Due to the wide distribution of steelhead within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on Puget Sound steelhead would be insignificant and discountable. The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** Puget Sound steelhead.

6.3.5 Steelhead Critical Habitat

Proposed critical habitat for Puget Sound steelhead includes the DMMP disposal sites in Puget Sound. This section evaluates the potential for effects to the Puget Sound steelhead PCEs proposed to be essential to their conservation:

(1) Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.

> *The PSDDA disposal sites are all located in marine waters where juvenile Puget Sound steelhead critical habitat does not occur. Therefore, the project will have no effect on this PCE.*

(2) Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

> *Disposal of dredged material occurs in sites located in marine water, where critical habitat is not proposed, and away from freshwater areas supporting juvenile development; therefore disposal will have no effect on this PCE.*

(3) Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channel, and undercut banks supporting juvenile and adult mobility and survival.

> *The disposal sites are located in marine waters away from river deltas and freshwater areas. Therefore, disposal will have no effect on this PCE.*

(4) Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

> *Disposal of dredged material will occur in offshore marine waters, where critical habitat is not proposed, and away from shorelines in areas that are not used for transition between fresh- and salt-water. The effects of disposal to this PCE are expected to be insignificant and discountable.*

(5) Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

> *Disposal will have no effect on nearshore marine areas because the disposal sites are all located at least 1,500 feet away from shore. Also, critical habitat is not proposed in marine waters. Therefore, dredged material disposal will have discountable effects on this PCE.*

(6) Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

> *The PSDDA disposal sites are located in offshore marine areas either in deep water where critical habitat is not located or in areas where the dredged material will rapidly disperse leaving disposal*

areas as they were prior to disposal. The effects of disposal to this PCE are expected to be insignificant and discountable.

The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** proposed Puget Sound Steelhead critical habitat.

6.4 LOWER COLUMBIA RIVER COHO SALMON

The Lower Columbia River coho salmon (*Oncorhynchus kisutch*) was listed as threatened on 28 June 2005 (70 FR 37160).

6.4.1 Distribution and Timing

The species distribution in North America extends from Alaska to California (Sandercock, 1991). The present distribution of Lower Columbia River coho in freshwater consists of the Lower Columbia River and its tributaries below Bonneville Dam, exclusive of the Willamette River. Marine distribution includes the Pacific Ocean north and south of the Columbia River (Johnson et al., 1991). Lower Columbia River coho are anadromous and typically spend two years in salt water prior to spawning. Lower Columbia River coho remain in freshwater for approximately one and a half years. Lower Columbia River coho are semelparous (spawn once and die).

The timing of spawning runs of wild Lower Columbia River coho is not well-understood (Johnson et al., 1991).

6.4.2 Migratory Pathways

Marine migratory pathways are not well-understood (Johnson et al., 1991). The marine distribution (including migratory pathways) is the offshore waters of the northeast Pacific Ocean (Hart, 1973).

6.4.3 Foraging

During freshwater residence, coho salmon feed primarily on stream and terrestrial insects. As coho salmon grow, they will also prey on small fish during their freshwater residence. In marine conditions, coho salmon are opportunistic, feeding on small salmonids, forage fish (e.g. herring and sand lance) and invertebrates such as amphipods and crab megalope (Sandercock, 1991; Hart, 1973).

6.4.4 Evaluation of Project Impacts

The lack of data describing juvenile Lower Columbia River coho behavior while in coastal embayments of Washington State makes it somewhat problematic to assess impacts of transport and dredged material disposal activities. However, the evidence gathered so far indicates that Lower Columbia River coho spend less time in Grays Harbor than other salmonids and are, therefore, less likely to be exposed to dredged material disposal plumes or sediment at the disposal sites.

Despite the lack of knowledge about Lower Columbia River coho, factors that minimize potential effects to Chinook salmon, are also likely to apply to Lower Columbia River coho. Due to the wide distribution of Lower Columbia River coho within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on Lower Columbia River coho would be insignificant and discountable. The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** Lower Columbia River coho.

6.4.5 Lower Columbia River Coho Critical Habitat

Proposed critical habitat for Lower Columbia River coho does not include the action areas.

The Corps has determined that the proposed action will have **no effect** on proposed Lower Columbia River coho critical habitat.

6.5 PUGET SOUND ROCKFISH

Three species of rockfishes were listed by NMFS on July 27, 2010 (NMFS, 2010). Bocaccio was listed as endangered, while Canary and Yelloweye rockfish were listed as threatened.

In 2010, the Corps of Engineers submitted a BE for the continued use of the PSDDA disposal sites to the Services for informal consultation. The BE included a determination of **may affect, but is not likely to adversely affect** for the three ESA-listed species of rockfish. The NMFS did not concur with this determination and issued a biological opinion (NMFS # 2010/042490), concluding that the proposed action was **not likely to jeopardize the continued existence** of these species. This opinion was based, in large part, on estimates of rockfish larvae that could potentially be exposed to sediment disposal activities on an annual basis.

One of the conservation recommendations made by NMFS in the biological opinion was to:

> *Conduct or support comprehensive ichthyoplankton surveys near each of the PSDDA program dispersive and non-dispersive sites within the Puget Sound/Georgia Basin.*

Subsequent to issuance of the biological opinion, the DMMP agencies provided funding and staff time to the Northwest Fisheries Science Center (NWFSC) to support a survey of larval rockfish in Puget Sound surface waters, including at six of seven PSDDA disposal sites covered by the biological opinion. The results of that study are evaluated in Appendix D and described in section 6.4.4.

6.5.1 Bocaccio (Sebastes paucispinis)

Bocaccio are an elongated rockfish, of the scorpion fish family, that ranges from northern British Columbia to central Baja California. These fish were once quite common on steep walls of Puget Sound, but are now quite rare. Adults generally occupy water 50-250 meters in depth over rocky outcroppings, boulder fields, and sloping walls and will school with both conspecifics and other species of rock fish. Occasionally the adults will migrate onto mudflats adjacent to rocky substrates. Adults can also be found well off the substrata up in the water column. Parturition in British Columbia (dates for Washington are not available) occurs in February of each year (O'Connell, 1987; Wyllie Echeverria, 1987). Larval Bocaccio are pelagic, drifting with the currents, usually occupying surface waters. By age 3.5 months the young will settle and recruit to inshore waters. Juveniles are found in much shallower waters over rocky substrate with various understory kelps and/or sandy bottoms with eelgrass. Approximately one month after settling, juveniles start to school. Adults and large juveniles feed on small fish and squid, whereas larvae and small juveniles feed on copepods, krill, diatoms, dinoflagellates and various larvae (Love et. al, 2002).

6.5.2 Canary Rockfish (S. pinniger)

Canary rockfish range from northern British Columbia to northern Baja California, potentially living to be 80+ years old. Adults occupy depths of 80-200 meters in areas with considerable current around pinnacles and high relief rock, often schooling with both conspecifics and other species of rockfish.

Parturition occurs in February each year (O'Connell, 1987; Wyllie Echeverria, 1987). Larval canary rockfish are pelagic, at the mercy of the currents, and tend to be present in the upper 100 meters of the water column. After 3-4 months the pelagic juveniles settle onto shallow benthic substrates such as tide pools and kelp beds. As juveniles grow they start to group and move into depths of 15-20 meters at the interface between rock and sand during the day and then disperse onto the sand flats at night. The juveniles gradually move from shallower to deeper area towards the end of summer. Adults and subadults feed on small fish and invertebrates while juveniles feed on copepods, krill eggs and various larvae (Love et. al., 2002).

6.5.3 Yelloweye Rockfish (S. ruberrimus)

Yelloweye rockfish, a member of the scorpion fish family, range from the eastern portions of the Aleutian Islands to Northern California and can live up 118 years. Adults and subadults occupy rocky areas with refuge such as crevices, caves, and boulder piles. They are usually solitary but can co-occur with one to a few individuals of another species of rockfish. Occasionally, they will wander onto mudflats adjacent to rocky areas. Parturition appears to occur in May each year (O'Connell, 1987; Wyllie Echeverria, 1987). Very little is known about the larval stage of yelloweye rockfish (year 1), but young juveniles can be found on vertical walls with cloud sponges and anemones at depths greater than 15 meters. Yelloweye rockfish spend the majority of their time on the substrata where they feed on small fish, shrimp, crab, and lingcod eggs (Love et. al, 2002).

6.5.4 Evaluation of Project Impacts

6.5.4.1 Larval Rockfish

The most likely interaction between the three ESA-listed species of rockfish and dredged material disposal is during the larval life history stage. As indicated previously, the DMMP agencies provided funding and staff time to NWFS to support a survey of larval rockfish in Puget Sound surface waters with an objective of establishing the abundance of the larval life history stage in the surface waters above the PSDDA disposal sites. A total of 217 rockfish larvae were caught at six disposal sites over an 11-month period, an average of just over 3 larvae per month per disposal site. The number of rockfish larvae collected in a single month at a single disposal site ranged from 0 to 33. Of the 217 rockfish larvae collected, 119 were collected during the annual fish closure (15 Feb to 15 June), a period when disposal does not occur. This means that only 98 larvae were collected during the normal disposal window. If the closed periods are excluded, the highest monthly count recorded was 18 larval rockfish at the Anderson/Ketron Island site in September.

None of the captured larval rockfish could be identified as being one of the ESA-listed rockfish species by external characteristics (only boccacio can be identified by external characteristics during their larval phase and none were found). Genetic analysis of the collected larvae was not possible because the samples were inadvertently preserved in formalin instead of ethanol. At this stage, it is unknown whether any listed rockfish larvae were collected during the field research.

If the rockfish larvae collected by NWFSC could have been identified to species level, the fraction of the total catch belonging to the three listed species could have been calculated. In the absence of these data, the Corps used the fractions provided in the biological opinion (NMFS, 2010). An evaluation of potential effects of dredged material disposal to ESA-listed rockfish larvae, using data from Green and Godersky (2012) and the fractions of each species found in NMFS (2010), can be found in Appendix D. The evaluation in Appendix D resulted in the estimates in Table 10.

Table 10. USACE Estimates of ESA-Listed Rockfish Larvae Likely to be Exposed to Sediment Disposal Activities at the DMMP Non-Dispersive Sites on an Annual Basis

	BB	PG	EB	CB	AK
number of yelloweye larvae affected	0.4	560	2,170	5,680	128
number of canary larvae affected	0.5	840	3,260	8,530	192
number of Bocaccio larvae affected	0.01	18	71	185	4

BB: Bellingham Bay
PG: Port Gardner
EB: Elliott Bay
CB: Commencement Bay
AK: Anderson-Ketron Island

An analysis of fecundity (Appendix D) resulted in a conclusion that the number of ESA-listed rockfish larvae potentially affected by all of the dredged material disposal at all of the non-dispersive sites over a year's time is equivalent to less than 50% of the number of larvae produced by a single 20-cm long rockfish.

Another way to provide perspective on the estimates in Table 10 is to consider natural mortality. The natural mortality of larval rockfish before they settle out of the water column is very large. By the time they settle to the substrate or into the lower water column, and take up a demersal life style, the numbers have been reduced by over 97 percent (R. Pacunski, WDFW Biologist, January 2014). The mortality associated with dredged material disposal would have no detectable effect on the overall mortality rate associated with the larval life history stage. Therefore, the effects to larval rockfish can be considered discountable.

6.5.4.2 Adult Rockfish

As stated in the 2010 biological opinion, listed adult rockfish are unlikely to occupy demersal habitats at either dispersive or non-dispersive sites because of the relative lack of structural complexity at the sites. Even if adults were to be present, the short-term and temporary nature of disposal operations makes possible effects to adults discountable.

Due to the discountable effects to rockfish larvae, the lack of presence of the adult stage of listed rockfish at the PSDDA disposal sites, and the analysis that indicates discountable bioaccumulative effects, the proposed action **may affect, but is not likely to adversely affect** bocaccio, canary rockfish or yelloweye rockfish.

6.5.5 Designated Critical Habitat

Critical habitat for these species, designated in November 2014, occurs from extreme high water out to the deepest areas of Puget Sound. Three of the PSDDA disposal sites are partially or wholly within proposed critical habitat including: the Bellingham Bay disposal site, Elliott Bay disposal site, and Rosario Strait disposal site. In both Bellingham Bay and Elliott Bay the dredged material deposited in the disposal sites is similar to the sediment already present in the disposal sites. The Rosario Strait disposal site is dispersive and the material does not accumulate.

Critical habitat is designated from extreme high water out to 30 meters (lower limit of photic zone) for juveniles, and from 30 meters and out for adults and where rugosity is high enough.

Primary constituent elements include the following:

(1) Quantity, quality, and availability of prey species to support individual growth, survival, and reproduction, and feeding opportunities.

> *Disposal in deep water in Puget Sound occurs at nondispersive disposal sites where the deposited material remains within the disposal site. The material that is deposited in the nondispersive disposal sites is in sufficiently thin layers to allow infauna to burrow back to the new substrate surface and continue their life style. There is likely some disruption of the epibenthic community, but it recovers rapidly so the Corps does not anticipate any detectable effect on listed rockfish food supply. Dredged material is also deposited in dispersive disposal sites where the material is dispersed with little or no disruption of the benthic community. Therefore, dredged material disposal will have discountable adverse effects on this PCE.*

(2) Water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

> *Dredged material disposal results in minor increases in turbidity, however this is localized and of short duration and likely has an undetectable effect on listed rockfish. Any BOD or COD remaining in dredged material that is placed at dispersive disposal sites will rapidly dissipate. The nondispersive disposal sites have DO levels near the bottom that are only slightly lower than surface levels, and only slightly lower than DO levels in shallow water. DO depressions following disposal would be expected to occur due to BOD and COD expressed within the suspended dredged material that forms within the disposal plume, but would be expected to be short-term and inconsequential in terms of impacts to larval resources except those exposed directly to the disposal plume, which manifests itself near the bottom, where these larvae are not found (D. Kendall Corps biologist May 2014). Therefore disposal will have discountable adverse effects on this PCE.*

(3) The type and amount of structure and rugosity that supports feeding opportunities and predator avoidance.

> *Dredged material disposal will have only minor effects on the structure and rugosity that supports feeding opportunities and predator avoidance. Disposal of dredged material occurs in either nondispersive or dispersive disposal sites. Material deposited in dispersive disposal sites is dispersed and does not accumulate. As a result, there is no detectable effect on the physical or biological ecology of these disposal sites. Dredged material deposited in nondispersive disposal sites results in the formation of mounds with gently sloping shoulders. The result is a substrate that is very similar to the relatively flat, featureless depositional areas in which the nondispersive sites were designated. Therefore, dredged material deposited in dispersive or nondispersive disposal sites will not significantly alter substrate conditions in the disposal sites. Disposal will have discountable adverse effects on this PCE.*

The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** rockfish critical habitat.

6.6 EULACHON

The southern DPS of eulachon (*Thaleichthys pacificus*) was listed as threatened by NMFS on March 18, 2010. Eulachon spawn in major rivers such as the Columbia, and larger tributaries to the Columbia, such as the Cowlitz. Outside of the Columbia River Basin eulachon are far less common.

6.6.1 Distribution

Eulachon have been reported sporadically, though not commonly, in Puget Sound drainages. The most recent that the Corps is aware of is a report by R. Ladley (Puyallup Tribe, pers. comm. 2013) of small numbers of adult eulachon captured in a salmon fry trap in the Puyallup River, with confirmation by NMFS. To the Corps' knowledge, this is the southernmost documentation of eulachon in Puget Sound. It is possible, though not likely, that eulachon adults could be present during disposal operations in Commencement Bay. Willson et al (2006) identified the Nooksack as the only other Puget Sound spawning area.

Eulachon have been reported in rivers draining into Grays Harbor, especially the Wynoochee River (WDFW and ODFW 2001, Willson et al. 2006). The Oregon Department of Fish and Wildlife (ODFW) and the WDFW (WDFW and ODFW 2001, p. 12) noted that in 1993, when the eulachon run into the Columbia River was delayed (presumably due to cold water conditions), they were noted in large abundance in the Quinault and Wynoochee rivers, outside the Columbia Basin. It appears that eulachon are sporadic visitors to Grays Harbor and occasionally spawn in Grays Harbor rivers. Spawning migration into Grays Harbor probably occurs on those unusual occasions when environmental conditions in the Columbia River are suboptimal, resulting in adult eulachon straying into other river systems. Therefore the occurrence of eulachon in Grays Harbor would likely be unusual and happen only occasionally.

6.6.2 Evaluation of Project Impacts

Eulachon occur in waters as deep as 300 meters. As there is a possibility that eulachon might be in the vicinity during disposal operations, the operation could disrupt behavior of adults and juveniles. However, because of their very sporadic and unusual presence in areas where disposal may occur, the potential effects are considered to be discountable. Therefore, the Corps has determined that the proposed project **may affect, but is not likely to adversely affect** the southern eulachon DPS.

6.6.3 Critical Habitat

In October 2011, NMFS designated critical habitat for the threatened southern DPS (76 FR 65323). In Washington – other than the lower Columbia – eulachon critical habitat is designated only in the lower Quinault and Elwha rivers. Thus, transport and disposal of dredged material at Puget Sound and Grays Harbor multiuser sites will have **no effect** on designated critical habitat for eulachon.

6.7 COASTAL/PUGET SOUND BULL TROUT

The Coastal/Puget Sound population segment of bull trout (*Salvelinus confluentus*) was listed as a threatened species in October 1999. Bull trout populations have declined through much of the species' range; some local populations are extinct, and many other stocks are isolated and may be at risk (Rieman and McIntyre 1993). A combination of factors including habitat degradation, expansion of exotic species, and exploitation has contributed to the decline and fragmentation of indigenous bull trout populations.

6.7.1 Distribution and Timing

The scope of this BE includes four of the five analysis areas (as defined in 64 FR 58910): Coastal; Strait of Juan de Fuca; Hood Canal; and Puget Sound. Within these analysis areas are included the following rivers in which bull trout occur: Elwha River, Angeles Basin, Dungeness River, Skokomish River, Nisqually River, Puyallup River, Green River, Lake Washington Basin, Snohomish River-Skykomish River, Stillaguamish River, Skagit River, Nooksack River and Chehalis River.

Bull trout in Puget Sound drainages exhibit four types of life history strategies. The three freshwater forms include ad fluvial forms, which migrate between lakes and streams; fluvial forms, which migrate within river systems; and resident forms, which are non-migratory. The fourth strategy, anadromy, occurs when the fish spawn in fresh water after rearing for some portion of their life in the ocean. The anadromous form of bull trout has been little studied; however, larger juvenile and adult bull trout are known to migrate through the marine waters of Puget Sound (Goetz 1989). The anadromous form may spend as many as 200 days annually in marine waters (Kraemer, 1994). Recent studies conducted by the Corps in Northern Puget Sound systems provide information on the migration patterns of anadromous native char. In the Skagit and Snohomish rivers, native char sub-adults migrate downstream between April and May at two or three years of age. By early autumn sub-adult native char are approximately 250-300 mm long when they move back to the lower portions of their natal streams where they are thought to overwinter. Native char migrate back to the marine environment as early as February where they spend several months in preparation for the spawning migration. Mature native char (age=4, >400 mm in length) leave the tidal waters in May through July and begin their upstream spawning migration. The FWS assumes bull trout could be found anywhere in Puget Sound.

Native char are present in the lower Chehalis River beginning in early March and continuing through mid-July (R2 Resource Consultants, 2006). A substantial body of evidence indicates that bull trout are least likely to be present in the lower Chehalis River/Grays Harbor from mid-July through the end of February, substantiating the USFWS bull trout in-water work closure period for marine waters (February 15 - July 15). The extent of bull trout use of outer Grays Harbor is unknown.

6.7.2 Migratory Pathways

The Corps has been conducting acoustic tag studies on bull trout for several years, primarily to determine presence and absence of native char in various locations in Puget Sound along with determining migration timing and migration/movement routes. The results of these studies indicate that native char are strongly associated with the near shore environment, the vast majority of which are detected along shorelines at a water depth of less than 18.0 meters. The few native char detected in water depths greater than 18.0 meters were still located in area less than 100.0 meters from the shoreline (Goetz, et al, 2004).

In 2000, USFWS requested that the Corps undertake a literature review and three year sampling effort of the reaches of the Grays Harbor navigation channel in order to establish patterns of bull trout use. The results of the literature review and sampling effort indicate that bull trout are present in the lower Chehalis River beginning in mid- to late February and continuing through mid-July. The tagged fish appeared to display a preference for the mainstem reach of the Chehalis River between the Elliott Slough Turning Basin and Cow Point Reach.

6.7.3 Foraging and Food Web Relationships

Surf smelt (*Hypomesus pretiosus*), Pacific herring (*Clupea harengus pallasi*), Pacific sand lance (*Ammodytes hexapterus*), pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon, and numerous invertebrate species composed the majority of the prey species for bull trout residing in northern Puget Sound (Kraemer 1994). Miller et al. (1977) captured a single bull trout in 1976 during tow net surveys conducted in Padilla Bay (North Puget Sound), which had consumed 61 Dungeness crab (*Cancer magister*) megalops, twelve macroinvertebrates, six gammarid shrimp, and four ostracods. Footen (2000) captured seven (7) bull trout (mean FL = 360 mm) in Shilshole Bay during the late spring of 2000. Stomach contents were composed of: Pacific sand lance (61%); juvenile Chinook salmon (27%); and juvenile chum salmon (12%). Pentilla (2003) captured five bull trout during forage fish beach seine surveys conducted in northern Puget Sound in 1974- 1975. Informal observations of the stomach contents of these fish captured in Utsalady Bay (northwest Camano Island) were primarily composed of surf smelt and juvenile herring.

In Puget Sound, nearshore residency periods of forage fish (Pacific sand lance, Pacific herring, and surf smelt) overlap with bull trout (Bargmann 1998; Emmett et al. 1991). Further, anadromous bull trout opportunistically utilize forage fish species (surf smelt, Pacific herring, and Pacific sand lance) almost exclusively when they are present in the nearshore marine habitats. Due to the importance of forage fish species to bull trout and many other Puget Sound species, changes in abundance of forage fish can impact a substantial number of fish, mammals, and birds (West 1997). Forage fish in Puget Sound play an important role as a midlevel food web species. Typically the populations of mid-level populations vary greatly in size and have dramatic influences on the higher trophic levels (as prey items) and the lower trophic levels (as predators) and act as both up and down control rather than in the typical bottom up or top down control mechanisms (Bakun 1996).

Ample prey resources are available in Half Moon Bay in Grays Harbor, but no native char have been identified in this area as part of R2 Resources Consultants studies described above.

6.7.4 Evaluation of Project Impacts

In general, potential effects on native char are similar to those experienced by Chinook salmon (see Section 6.1.4), however the potential for native char to be present in the disposal areas is much more unlikely than Chinook salmon due to their strong affinity to the nearshore environment (Goetz, et al, 2004).

Bioaccumulative effects are expected to be less likely than in Chinook salmon, again due to the propensity of bull trout to remain in relatively shallow nearshore environments. In addition, and perhaps more importantly, the bull trout preference for fishes such as sandlance and herring, which also tend to remain in nearshore environments, means that their exposures to contaminants through the DMMP open-water disposal program are discountable, since the forage fish themselves have little chance to encounter contaminants through bioaccumulation as a result of open-water disposal in Puget Sound and Grays Harbor.

Therefore, due to the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; the low likelihood of bioaccumulative effects; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on bull trout would be insignificant. The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** Coastal-Puget Sound bull trout.

6.7.5 Coastal/Puget Sound Bull Trout Proposed Critical Habitat

The USFWS designated critical habitat for the Coastal/Puget Sound population segment of bull trout (USFWS 2005). In February 2010, the USFWS proposed revisions to designated critical habitat for the entire range of listed bull trout. This section covers the primary constituent elements determined essential to the conservation of Coastal/Puget Sound bull trout (50 CFR Part 17, FR Vol. 69, No. 122, page 35776):

(1) Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia.

> *The disposal sites are in a marine area. There are no fresh water habitats in the project vicinity. Therefore dredged material disposal will have no effect on this PCE.*

(2) Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.

Designated critical habitat extends offshore to a depth of 33 feet (10 meters). This equates to the average depth of the photic zone, and is consistent with the offshore extent of the nearshore habitat identified under the Puget Sound Nearshore Ecosystem Restoration Project (Corps and WDFW 2001). The area between MHHW and minus 10 meters is considered the habitat most consistently used by bull trout in marine waters based on known use, forage fish availability, and ongoing migration studies (Kramer 1994; Goetz, et al, 2004), and captures geological and ecological processes important to maintaining these habitats.

The DMMP disposal sites are all greater than 50 feet in depth. Disposal events will temporarily increase turbidity at the location of release. However, the concentration of suspended sediment in nearshore areas is not expected to reach levels that would impede migration. The activity of tug/barge and hopper dredge movement is transitory and does not constitute obstruction of migration. As a result the Corps has determined that the proposed action has discountable effects on Coastal/Puget Sound bull trout migratory corridors.

(3) An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.

Dredged material disposal will not affect the food base of bull trout because the DMMP disposal sites are located offshore either in deep water where critical habitat and prey are not located or in areas where the dredged material will rapidly disperse leaving the disposal area as it was prior to disposal. The aquatic macroinvertebrates found at DMMP disposal sites do not constitute significant prey for subadult and adult bull trout, which are the life stages likely to be found in nearshore estuarine areas. Bull trout prey (juvenile salmonids and forage fish) are unlikely to be affected by dredged material disposal operations. Therefore, disposal will have discountable adverse effects on this PCE.

(4) Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities, and structure.

Dredged material disposal will not result in the degradation of shoreline complexity. Disposal sites are located offshore, either in deep water where this PCE is not located, or in areas where the dredged material will rapidly disperse, leaving the disposal area as it was prior to disposal. Therefore dredged material disposal will have no effects on this PCE.

(5) Water temperatures ranging from 2 to 15 °C (36 to 59 °F), with adequate thermal refugia available for temperatures at the upper end of this range. Specific temperatures within this range will vary depending on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shade, such as that provided by riparian habitat; and local groundwater influence.

Dredged material transport and disposal will not affect water temperatures in the marine environments in which the disposal sites are located. Therefore the proposed action will have no effect on this PCE.

(6) In spawning and rearing areas, substrate of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount of fine sediment, generally ranging in size from silt to coarse sand, embedded in larger

substrates, is characteristic of these conditions. The size and amounts of fine sediment suitable to bull trout will likely vary from system to system.

The disposal sites are in a marine area. There are no spawning areas in the vicinity of the sites. Therefore dredged material disposal will have no effect on this PCE.

(7) A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, minimal flow departure from a natural hydrograph.

The disposal sites are in marine areas. There are no fresh water habitats in the project vicinity. Therefore dredged material disposal will have no effect on this PCE.

(8) Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

The continued transport and open-water disposal of dredged material would have no effect on the available quantity of water, and would have discountable and temporary effects on water quality. If minor (localized) short-term water quality degradation were to occur, it would not affect reproduction and will have negligible and discountable effects on growth and survival primarily because dredged material disposal will be conducted when bull trout are not present and water quality will return to pre-disposal conditions within hours of disposal. Therefore, disposal will have discountable adverse effects on this PCE.

(8) Sufficiently low levels of occurrence of non-native predatory (e.g., lake trout, walleye, northern pike, smallmouth bass); interbreeding (e.g., brook trout); or competing (e.g., brown trout) species that, if present, are adequately temporally and spatially isolated from bull trout.

The continued transport and open-water disposal of dredged material would have no effect on predatory or competitive species of coastal/Puget Sound bull trout.

Based on the foregoing analysis, the Corps has determined that the proposed action **may affect, but is not likely to adversely affect** coastal/Puget Sound bull trout designated critical habitat.

6.8 MARBLED MURRELET

The marbled murrelet (*Brachyramphus marmoratus*) was listed as a threatened species in October 1992. Primary causes of population decline include the loss of nesting habitat, and direct mortality from gillnet fisheries and oil spills. Critical habitat has been designated for this species in Washington, but it occurs in terrestrial nesting habitat and not in the marine waters of the action area, and is not discussed further in this BE.

6.8.1 Distribution

Marbled murrelets are permanent residents of Puget Sound, but the species is not abundant anywhere in Puget Sound (Speich and Wahl 1995). The majority of birds are found as singles or in pairs in a band about 300 to 2000 meters from shore (Strachan et al. 1995). The murrelet forages by pursuit diving in relatively shallow waters, usually between 20 and 80 meters in depth, but there have been observations of diving in waters more than 100 meters deep (Strachan et al. 1995).

Regional patterns of marbled murrelet activity in marine waters tend to be seasonal, and are tied to exposure to winter storm activity. There is a general shift of birds from the Strait of Juan de Fuca and

British Columbia during spring and summer to areas in the San Juan areas and eastern bays during the fall and winter (Speich and Wahl 1995). Murrelets commonly aggregate near localized food sources, resulting in a clumped distribution. They are regularly found in specific areas (e.g., Hood Canal, Rosario Strait/San Juans), as foraging distribution is closely linked to areas of tidal mixing where prey congregate. However, occurrences are highly variable as they move from one area to another often in short periods of time.

Marbled murrelets are generally present in Grays Harbor during the fall, winter, and spring, (Speich and Wahl, 1995). Sightings are rare during the nesting season (May-September). The highest numbers occurred in habitats close to shore, generally out to the 50-meter depth contour. Murrelets are commonly seen in the navigation channel (Speich and Wahl, 1995). No designated critical habitat is located in or along the shoreline of Grays Harbor.

6.8.2 Foraging and Food Web Relationships

The primary prey items for marbled murrelets in Puget Sound include Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea harengus*), and krill (euphausiids) (Burkett, 1995). The preference for forage fish, which tend to remain in nearshore environments, means that their exposure to contaminants through the DMMP open-water disposal program is discountable, since the forage fish themselves have little chance to encounter contaminants through bioaccumulation as a result of open-water disposal in Puget Sound and Grays Harbor. Euphausiids are at a lower trophic level, and, even if exposed to disposal of dredged material, the likelihood of bioaccumulative effects in marbled murrelets as a result of preying on krill near an open-water disposal site is considered to be discountable.

6.8.3 Evaluation of Project Impacts

6.8.3.1 PSDDA Sites

Potential effects from continued operation of the PSDDA non-dispersive and dispersive, open-water disposal sites to the marbled murrelet are insignificant and discountable. This determination is supported by numerous factors.

First, marbled murrelets tend to be closely associated with the shoreline, generally feeding in waters less than 30 meters in depth and less than 500 meters from shore (Sealy, 1975) thus marbled murrelets would rarely be present at any of the disposal sites.

Second, should a marbled murrelet coincidentally be present in the disposal area during a discharge event, potential take from collisions is extremely unlikely as tugs and barges travel slowly, allowing marbled murrelets to quickly migrate away from the approaching barge and move to an undisturbed area.

Third, marbled murrelets would be expected to avoid the sediment plume while feeding, especially since their forage species would likely avoid the sediment plume as well. The period during which sediments in the water column are elevated is relatively short (approximately 12 minutes in midwater areas studied by Truitt [1986a, 1986b]) and localized. Both forage fish and marbled murrelets would migrate from the area affected by the discharge and recover relatively quickly from the stress caused by the falling sediment.

Fourth, the potential for toxic effects of contaminants released from discharged sediments is minimal. See discussion in Section 6.7.2 above.

Fifth, marbled murrelets primarily feed on pelagic organisms and do not typically feed at depths where benthic habitats are altered by dredged material disposal. Thus, foraging habitat for these species would not be directly affected.
Finally, as noted above, marbled murrelets typically feed on pelagic organisms, where their primary foods are forage fish (herring and sand lance). Herring, and sand lance are also pelagic, and their forage base would not be significantly affected by disposal activities. Sand lance can be demersal at times because they have no swim bladder, and sometimes rest in or on the bottom, but typically in less than 100 meters of water. Spawning areas for both of these species are in intertidal and shallow subtidal areas which are unaffected by disposal activities. Thus, continued disposal activities would not affect the prey base of marbled murrelets.

6.8.3.2 Grays Harbor Sites

The proposed action will have no effect on marbled murrelet nests or nesting habitat, and minimal impact on nesting season foraging behaviors given the general lack of sightings during the time when dredged material transport from late spring outer Grays Harbor dredging operations are underway (March – June). Transport of dredged material associated with outer Grays Harbor dredging, and disposal of material dredged during inner Grays Harbor activities (July-February), will occur in and adjacent to foraging habitat. Some disturbance to prey items and foraging behaviors can be expected. A 5-year review of the status of marbled murrelets (USFWS 2009) indicated that the marbled murrelet abundance continues to decline. One of the causes appears to be starvation, where the preferred prey items are increasingly difficult for the marbled murrelet to find and, therefore, they are shifting their focus to other forage fish with lower caloric value. Since marbled murrelets are not likely to be present through most of the nesting season when the impact of dredged material transport and disposal would be most noticeable, the impact on marbled murrelets is likely small, especially considering the total amount of forage habitat available in relation to the amount of forage habitat disturbed by disposal operations.

Noise produced by tow boats and hopper dredges during transport of dredged material may disturb foraging marbled murrelet and cause them to move to other forage areas. The effects of anthropogenic disturbance on marbled murrelet at sea are not well documented, but marbled murrelet have been shown to habituate to heavy levels of boat traffic (Strachan et al., 1995). Increases in turbidity associated with disposal could reduce visibility in the immediate vicinity of disposal activities, thereby reducing foraging success for any murrelets that remain in the area. This effect will be highly localized and subside rapidly upon completion of the disposal operations. Marbled murrelets are relatively opportunistic foragers; they have flexibility in prey choice, which likely enables them to respond to changes in prey abundance and location. This indicates that if marbled murrelets are present in the immediate vicinity of disposal activities, and they are disturbed while foraging, they will likely move without significant injury.

Based on the above analysis the continued operation of the DMMP dispersive and non-dispersive, unconfined, open-water disposal sites **may affect, but is not likely to adversely affect** the marbled murrelet. Designated critical habitat for marbled murrelet is in terrestrial areas; thus the proposed action will have **no effect** on critical habitat for this species.

6.9 SOUTHERN RESIDENT KILLER WHALES

The Southern Resident killer whale (SRKW) was listed as endangered on November 18, 2005 (70 FR 69903). Primary causes of population decline include habitat loss, decline in availability of prey items, pollution (PCBs, dioxins, furans), and noise disturbance from vessel traffic and whale watching. Critical habitat was designated November 29, 2006, consisting of the marine waters of Puget Sound, San Juan Islands and Strait of Juan de Fuca greater than 20 feet deep. Rivers and streams flowing into the Puget Sound are not designated as critical habitat.

The following analysis evaluates the potential risks to the population of Southern resident killer whales (*Orcinus orca*) from the transport and open-water disposal of dredged material at the DMMP multiuser sites. The information provided is based on a review of literature and on-going studies of bioaccumulation in killer whales and their prey. A more comprehensive treatment can be found in Appendix C.

6.9.1 Listing and Potential Threat from Biomagnification

When SRKW was listed, the Corps included analysis of the species in its BE for transport and disposal of dredged material at open-water PSDDA sites in March 2005. NMFS concurred with that assessment, but later expressed concerns that effects to the endangered SRKW from bioaccumulation of contaminants were not adequately addressed. These concerns precipitated preparation of a white paper (USACE, 2006), which affirmed that transport and open-water disposal of dredged material is not likely to adversely affect SRKW. NMFS concurred with this finding in 2007. In response to slightly different concerns, a second white paper was prepared to supplement the 2010 BE for transport and disposal of dredged material at open-water PSDDA sites and, again, NMFS concurred with that assessment. The 2010 white paper has been updated and is included as Appendix C in this BE.

Several factors may affect SRKW survival and well-being, but the main factors are physical disturbance of behavior patterns by boat noise or intrusive boating activities, reduction of food source (primarily adult resident Chinook salmon), and bioaccumulation of persistent bioaccumulative toxins (PBTs).

Under the DMMP site management plan for non-dispersive sites, disposal site-related effects, including toxicity and bioaccumulation, are limited to Site Condition II (minor adverse effects), as determined through chemical, toxicity, and bioaccumulation testing. Sediment with higher-than-minor potential for adverse effects must be disposed of at an approved upland confined disposal site, or in an approved confined nearshore or aquatic site.

6.9.2 Distribution

Although killer whales have been observed in tropical waters and the open sea, they are most abundant in coastal habitats and high latitudes. In the northeastern Pacific Ocean, killer whales occur in the eastern Bering Sea (Braham and Dahlheim, 1982) and are frequently observed near the Aleutian Islands (Scammon, 1874; Waite et al., 2002). They reportedly occur year round in the waters of southeastern Alaska (Scheffer, 1967) and the intercoastal waterways of British Columbia and Washington State (Balcomb and Goebel, 1976; Bigg et al., 1987; Osborne et al., 1988). There are occasional reports of killer whales along the coasts of Washington, Oregon, and California (Norris and Prescott, 1961; Fiscus and Niggol, 1965; Rice, 1968; Gilmore, 1976; Black et al., 1997), both coasts of Baja California (Dahlheim et al., 1982), the offshore tropical Pacific (Dahlheim et al., 1982), the Gulf of Panama, and the Galapagos Islands. In the western North Pacific, killer whales occur frequently along the Soviet coast in the Bering Sea, the Sea of Okhotsk, the Sea of Japan, and along the eastern side of Sakhalin and the Kuril Islands (Tomilin, 1957). There are numerous accounts of their occurrence off the coasts of China (Wang, 1985) and Japan (Nishiwaki and Handa, 1958; Kasuya, 1971; Ohsumi, 1975). Data from the central Pacific are scarce. They have been reported off Hawaii, but do not appear to be abundant in these waters (Tomich, 1986; Carretta et al., 2001). Northwest marine waters are frequented by three ecotypes of killer whales: resident, transient, and offshore (Ford et al. 1998). Resident killer whales are further distinguished as northern residents (NRKW) that are often found in the waters off northeast Vancouver Island, BC, and southern residents (SRKW) that are often found in the waters off southeast Vancouver Island and into Puget Sound.

6.9.2.1 Southern Residents

The Southern Resident killer whale assemblage contains three pods-- J pod, K pod, and L pod--and is considered a stock under the MMPA (NOAA 2004). Their range during the spring, summer, and fall includes the inland waterways of Puget Sound, Strait of Juan de Fuca, and Southern Georgia Strait. Their occurrence in the coastal waters off Oregon, Washington, Vancouver Island, and more recently off the coast of central California in the south and off the Queen Charlotte Islands to the north has been documented. Little is known about the winter movements and range of the Southern Resident stock. Southern Residents have not been seen to associate with other resident whales, and mitochondrial and nuclear genetic data suggest that Southern Residents interbreed with other killer whale populations rarely if at all (Hoelzel et al., 1998; Barrett-Lennard, 2000; Barrett-Lennard and Ellis, 2001).

Southern resident killer whales have been sighted several times in the vicinity of Grays Harbor (Krahn et al. 2004). These sightings occurred in March and April. The distribution of this stock is strongly linked to the availability of prey, the primary item being adult Chinook salmon. Spring and fall Chinook are present in Grays Harbor. Peak river entry timing for spring Chinook is January and February, and October for fall Chinook (WDFW et al. 1994).

6.9.3 Foraging and Food Web Relationships

Killer whales are classified as top predators in the food chain and Southern Resident killer whales are fish eaters. Resident killer whale populations preferentially feed on Chinook, which comprise about 96% of their total diet (Ross et al. 2000, Hayteas and Duffield 2000, and Jarman et al. 1996). Hanson et al. (2010) estimate from fecal analysis that 80-90% of the Chinook consumed by SRKW originate from the Fraser River (including the South Thompson River), and only 6 to 14% originate from natal streams in the Puget Sound region. However, these latter Chinook have fed in Puget Sound, where PCBs occur at higher concentrations than in the Fraser River. So, despite a much larger range than Puget Sound and the Strait of Juan de Fuca, a significant portion of the PCB burden in SRKW is believed to come from Puget Sound. PCB concentrations in Grays Harbor sediment are low relative to those in Puget Sound. Contributions from Grays Harbor sediment to the PCB burden of SRKW are discountable.

Appendix C addresses what is known of biomagnification and the relative contribution of the DMMP open-water disposal sites to this process. It is clear that SRKW as well as harbor seals have accumulated high levels of contaminants (particularly PCBs, PCDD/F, and PBDEs) in their tissues, and that a significant amount of their body burden arises from exposure to prey derived from Puget Sound and the Strait of Juan de Fuca. Numerous studies (e.g., Ylitalo et al. 2005, West et al. 2011) confirm presence of relatively high levels of PCBs in herring, hake, Chinook salmon and SRKWs. SRKW appear to assimilate 4-6.6 times as much PCB as the northern resident populations, partly because of higher PCB concentrations in prey, and partly because SRKW prey have lower lipid content, requiring more prey consumption (Cullon et al. 2009).

6.9.4 Evaluation of Project Impacts

Potential effects to killer whales due to continued operation of the DMMP dispersive and non-dispersive, unconfined, open-water disposal sites are insignificant. This determination is supported by the following discussion.

<u>Short term impacts to SRKW from barge transport/release of chemicals.</u> Should a killer whale coincidentally be present *en route* to or in the disposal area during a discharge event, it would experience a short period of non-lethal discomfort due to high suspended sediments in the water column. The water column elevation is localized and of short duration (approximately 12 minutes in mid-water areas studied by Truitt [1986a, 1986b]). Killer whales would migrate from the area affected by the discharge and

recover relatively quickly from the discomfort. Effects of elevated water column suspended sediments would be short in duration and localized, and are not expected to be lethal or significantly affect killer whales.

Low potential impacts to SRKW's pelagic prey base from biomagnifying chemicals. SRKW feed primarily on adult Chinook salmon. As the presence of salmon in the disposal areas would be rare, it is unlikely that there would be significant increase in transfer of contaminants to the whales. Adult Chinook salmon typically feed on pelagic organisms, principally forage fish (herring and sandlance) and gonatid squid. This forage base would not be significantly affected by disposal activities. Herring are generally plankton feeders, and while sandlance can sometimes rest in or on the bottom because they have no swim bladder, they typically do so in water less than 100 meters (328 feet) deep. Spawning areas for both species are in intertidal and shallow subtidal areas unaffected by disposal activities.

Trophic models and uncertainties. Assessment of the effects of the Dredged Material Management Program on a top predator that feeds on pelagic prey is difficult. Quantitative trophic models (Gobas 1993, Arnot and Gobas 2004, Windward 2008, and Gobas and Arnot 2010) for predicting transfer of PCBs from sediment to biota and subsequently through the food-web to higher predators have been applied in the Great Lakes, San Francisco Bay, the Lower Duwamish Waterway Superfund Site in Seattle, and Lake Washington in Seattle. These models use mechanistic relationships of release of PCBs from sediment into water and benthos, and calculate biomagnification via food-web transfers. None of the models are constructed at a suitable scale to support decision-making with regard to sediment management on the scale of dredged material disposal sites. For instance, the Great Lakes, San Francisco Bay, and Lake Washington models are at the system level, and utilize measures of central tendency for sediment over wide areas as inputs. One model, the Lower Duwamish Food Web Model, is constructed on a series of 2-mile (on average) reaches, extending for a total length of five miles of that waterway, and was mainly applied to bottomfish and invertebrates.

The primary input of PCBs to these models is via sediment, due to the affinity of PCBs for that medium. However, in Puget Sound, with several highly contaminated riverine and near-shore environments, the distribution of PCBs in sediment is extremely skewed, i.e., has a few observations that are very high, and many that are low to moderate, which makes it difficult to select a reasonable input parameter for parameterizing a model. Orders of magnitude exist between the PCB concentrations found in such highly contaminated areas and the near-urban or non-urban areas of the Sound. In Puget Sound monitoring data sets, there are also variable PCB analytical methodologies (209 congeners, or a subset of congeners, or Aroclors) resulting in a wide range of analytical sensitivities, which contribute to the difficulty of calculating representative input parameters for PCBs.

Another issue of scale involves the size of the dredged material sites relative to Puget Sound, which consists of some 2,600 km^2. In comparison, the combined area of the five non-dispersive sites is approximately 13 km^2. Several of these sites are infrequently used.

As noted above, SRKW prey species "sample" their prey from specific areas of Puget Sound, and the prey also "sample" their environment consisting of water, sediment, and plankton. Pelagic fish are much less clearly linked to the sediment than are demersal fish. The existing models either ignore or greatly simplify behavior that affects exposure of fish to their environment. However, once concentrations are known from Chinook, there are well-calibrated models for predicting or explaining dietary inputs to SRKW (e.g., Hickie et al. 2007). To build and calibrate a model that relates sediment concentrations by location and depth (to accommodate fish behavior) is beyond the scope and resources of the DMMP agencies. As no calibrated model is available that is able to assess effects of dredged material disposal at unconfined, open-water sites in Puget Sound, DMMP has relied upon site monitoring and inventories from testing of dredged material for suitability, which is the best information available to assess bioaccumulation in Puget Sound. This is summarized in Appendix C.

Low potential for an increase in availability of biomagnifying compounds to SRKW due to dredged material disposal. While the current conditions of contamination in Puget Sound have the potential to affect SRKW, the programmatic effects of transport and disposal of dredged material containing biomagnifying substances to SRKW are discountable for the following reasons. First, the potential for toxic effects of contaminants released from discharged sediments is managed through a carefully designed program that examines impacts from sediment to benthos, epibenthos, and fish through a series of physical, chemical and biological testing procedures which have been subject to thorough review by the regulating agencies and the public. Second, because the DMMP has resulted in sediment levels at open-water disposal sites that are at or below the mean concentrations for PCBs and other chemicals observed in the vicinity of the sites, the dredged material program has not exacerbated sediment contamination in Puget Sound, and thus would not cause additional adverse effects to SRKW. (See Appendix C for further discussion.) For dioxins, the 2010 DMMP guidelines include a site management objective of 4 pptr TEQ (or less), which was derived from a survey of non-urban background concentrations in Puget Sound.

Noise. Noise pollution from marine vessel traffic and how it may affect orca vocalizations and hearing is one of the main concerns with decline in the southern resident killer whale population. Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals. Excessive noise levels may mask echolocation and other signals used by the species, as well as temporarily or permanently damage hearing sensitivity (NMFS 2005b).

Three studies that measured the killer whale audiogram show the range is approximately 500Hz up to 105kHz with varying sensitivities; the range of highest sensitivity is 18-42kHz, which includes their most common clicking noise at 20kHz (Hall and Johnson 1971, Bain et al. 1993, Szymanski et al. 1999). Very little data are available for the important parameter of received noise levels for killer whale tolerances and reactions. Erbe (2002) measured boat noise source levels at 145 to 169 dB re 1 μPA at 1m, and found this noise level elicited a behavioral response at 200m, and masked killer whale vocalizations at 14km distance. This study also found orca vocalizations to fall in the range of 105 to 124 dB re 1 μPA. The operation of most large marine vessels, including tugs that would have the barges for open-water sediment disposal, produce up to 180 dB, but mostly within the range of 80-1000 Hz, which is mostly below the hearing threshold of killer whales (generally above 6kHz) (Kipple and Gabriele, 2007). While the operation of the tug and barge would increase ambient noise levels along the immediate travel route, impacts of any sound disturbance would likely result in temporary, short-range displacement of animals rather than injury.

Noise generated by operation of the tug and barge will not significantly add to the typical noise spectrum that is already present in Puget Sound and marine waters around the San Juan Islands. Notably, tug captains are instructed to stay clear of any killer whales that are sighted within the vicinity of the vessel. For these reasons, the effect of noise on killer whales produced by the tug and barge operations would be insignificant and would not lead to harassment of southern resident killer whales.

In summary, due to the wide distribution of these species within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on killer whales would be insignificant. The Corps has determined that the proposed action **may affect, but is not likely to adversely affect** Southern Resident killer whales.

6.9.5 Designated Critical Habitat

The action area falls within the Puget Sound marine area designated as critical habitat for the southern resident killer whale population. The 3 primary constituent elements (PCEs) of the designated critical habitat are:

(1) Water quality to support growth and development.

> *Disposal occurs in areas where southern resident killer whales can be found, however disposal operations must be in compliance with water quality certification conditions established by Ecology. Any effects on water quality are temporary, typically lasting only minutes. Minor and temporary turbidity increases caused by the disposal of dredged material will not cause a significant decline in water quality such that growth and development of SRKW would be affected.*

(2) Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development as well as overall population growth.

> *Southern resident killer whales feed primarily on Chinook and chum salmon. Adult Chinook and chum salmon can easily swim around dredged material transport barges and tugs. Therefore, transport of dredged material will have no effect on this PCE. Dredged material disposal occurs away from the shorelines where juvenile Chinook and chum salmon are typically found. While bioaccumulation of contaminants in tissues is an issue – as shown in the Appendix C – the contribution of the disposal activities and the disposal sites themselves is negligible and discountable and has insignificant effects on the food web upon which the southern resident killer whales depend.*

(3) Passage conditions to allow for migration, resting, and foraging.

> *As discussed above, tugs and barges transporting and disposing of material at the PSDDA disposal sites would not block passage of killer whales through the area, especially as encounters with killer whales are extremely rare.*

The continued use of open-water disposal sites in Puget Sound will have insignificant effects on the three key primary constituent elements. For these reasons, continued use of the DMMP open-water disposal sites in Puget Sound **may affect, but is not likely to adversely affect** designated critical habitat for Southern Resident killer whales.

6.10 HUMPBACK WHALE

The humpback whale (Megaptera novaeangliae) was listed as endangered on 2 June 1970. The primary cause for decline in the population of the humpback whale was due to whaling in the early part of the 20th century (ARKive [Internet]). Today the primary cause for population decline is the whales' vulnerability to changes in the marine environment. Other possible causes in population decline are pollution and potential alteration of fish stocks resulting from climate change. No critical habitat has been designated for the humpback whale.

6.10.1 Distribution

Humpback whales are found in tropical and polar seas in shallow, coastal areas (ARKive [Internet]). They occur seasonally off the coast of Washington along the continental shelf and shelf-edge waters (NMFS, 2004.) The summer distribution of humpback whales is linked to local distribution of prey, which is driven by oceanographic conditions; factors such as upwelling and converging currents affect the abundance and availability of prey items (NMFS, 1991). Calambokidis et al. (2004) found humpback whales concentrated to the west and southwest of the Strait of Juan de Fuca entrance, between Juan de Fuca Canyon and the outer edge of the continental shelf. About every other year humpback whales will stray into Puget Sound but tend not to stay for extended periods of time. Although, in late spring 2004 a small humpback whale spent about two weeks in the Puget Sound near Tacoma.

6.10.2 Foraging and Food Web Relations

There are known humpback whale feeding grounds off the coast of California, Oregon, and Washington. These whales feed primarily on krill, herring, and capelin. Humpback whales utilize a wide range of feeding techniques, at times involving more than one individual and resembling a form of cooperative participation. (NMFS, 2004)

6.10.3 Evaluation of Project Impacts

Potential effects to humpback whales due to continued operations of the DMMP dispersive and non-dispersive, unconfined, open-water disposal sites are insignificant. This determination is supported by numerous factors.

First, the likelihood of a humpback whale being present in Grays Harbor or Puget Sound and in the disposal area during a discharge is improbable at best. Humpback whales are present in Washington coastal waters during the summer. However, transport of material from outer harbor dredging occurs in the spring. Humpback whales are known to occur off-shore of Grays Harbor during the beginning of inner harbor dredging, but the potential for disturbance will be limited to disposal of material at the Point Chehalis and South Jetty sites.

Second, the potential for toxic effects of contaminants released from discharged sediments is minimal. Sediments are determined to be suitable for discharge through a series of physical, chemical and biological testing procedures, which have been subject to thorough review by the regulating agencies and the public, and, since humpbacks seldom, if ever, feed in Grays Harbor or Puget Sound, the exposure to contaminants will be insignificant and discountable.

Third, effects of elevated water column suspended sediments would be short in duration and localized, and are not expected to be lethal or significantly affect humpback whales. If a humpback whale were in the disposal area during a discharge event, it could experience a short period of non-lethal discomfort due to the high suspended sediment concentration in the water column. The period during which sediments in the water column are elevated is relatively short (approximately 12 minutes in midwater areas studied by Truitt [1986a, 1986b]) and localized. Humpback whales would migrate from the area affected by the discharge and recover relatively quickly from the discomfort.

Fourth, although humpback whales are sensitive to vessel movements and noise it is expected that if the whales are present they would move out of the way of the vessels and related noise. Because of the low occurrence of humpback whales in Grays Harbor and Puget Sound it is unlikely that there will be contact between the whales and the vessels. Noise disturbance of humpback whales off the coast of Grays Harbor is unlikely since they are present in Washington coastal waters during the summer, and dredged material transport associated with outer harbor dredging occurs in the spring.

In summary, due to the low occurrence of these whales within the action area; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on humpback whales would be insignificant. The Corps determined that the proposed action **may affect, but is not likely to adversely affect** humpback whales.

6.11 LEATHERBACK SEA TURTLE

The leatherback sea turtle (*Dermochelys coriacea*) was listed as endangered on 2 June 1970. The primary cause for decline of the leatherback turtle is due to accidental capture in fisheries and the over harvest of eggs. Other causes for decline in this species are habitat loss, boat strikes, and ingestion of discarded plastics (ARKive [Internet]). Although critical habitat has been identified for this species, it does not occur within the project area, and is not addressed further in this BE.

6.11.1 Distribution

Leatherback sea turtles inhabit the shelf and offshore waters of the Pacific Ocean, including Washington, during the summer months. Aerial surveys indicate that when off the Pacific coast, leatherbacks usually occur in continental slope waters (NMFS and USFWS 1998a). Their use of the inland waters of Washington is accidental at best (NMFS, 2004). There are no nesting areas located in Washington.

6.11.2 Foraging and Food Web Relationships

Adult leatherback sea turtles primarily feed on jellyfish and other soft-bodied species in temperate waters (ARKive [Internet]).

6.11.3 Evaluation of Project Impacts

Because leatherback sea turtles only use the inland waters of Washington accidentally and mechanisms of potential impact would be insignificant even if a sea turtle were present during disposal operations, the Corps has determined that the proposed action **may affect, but is not likely to affect** leatherback sea turtles.

6.11.4 Designated Critical Habitat

Proposed critical habitat for the leatherback sea turtle in the northeastern Pacific Ocean is the nearshore area from Cape Flattery, Washington, to the Umpqua River (Winchester Bay), Oregon and offshore to a line approximating the 2,000-meter isobath. This area is the principal Oregon/Washington foraging area and includes important habitat associated with Heceta Bank, Oregon. The greatest densities of a primary prey species, *Cyanea fuscescens*, occur north of Cape Blanco, Oregon and in shallow inner-shelf waters. The PCEs that NMFS identified as essential for the conservation of leatherback sea turtles when it proposed to revise critical habit to include marine waters off the U.S. West Coast, including the action area, are:

(1) Occurrence of prey species, primarily scyphomedusae of the order Semaeostomeae (Chrysaora, Aurelia, Phacellophora, and Cyanea) of sufficient condition, distribution, diversity, and abundance to support individual as well as population growth, reproduction, and development.

> *No effects on prey quantity or quality from dredged material transport and disposal in Grays Harbor are anticipated.*

(2) Migratory pathway conditions to allow for safe and timely passage and access to/from/within high use foraging areas.

> *Transport of dredged material from outer harbor dredging in Grays Harbor could potentially intersect migratory pathway of leatherbacks. However, in-water noise from transport and disposal would have a discountable effect on leatherback sea turtle passage. The effects of the action will be either insignificant or discountable.*

The Corps has determined that continued use of the DMMP open-water disposal sites **may affect, but is not likely to adversely affect** proposed leatherback sea turtle critical habitat.

6.12 GREEN STURGEON

The green sturgeon, (*Acipenser medirostris*), is a widely distributed, marine-oriented sturgeon found in nearshore waters from Baja California to Canada (NOAA 2007). Their estuarine/marine distribution and the seasonality of estuarine use are largely unknown.

Green sturgeon are anadromous, spawning in the Sacramento, Klamath and Rogue rivers in the spring (NOAA 2007). Spawning occurs in deep pools or holes in large, turbulent river mainstreams. Specific characteristics of spawning habitat are unknown but are likely large cobbles, but can range from clean sand to bedrock (NOAA 2007).

Two distinct population segments (DPS) have been defined for green sturgeon – a northern DPS with spawning populations in the Klamath and Rogue rivers, and a southern DPS that spawns in the Sacramento River (NOM 2007). The southern DPS was listed as threatened in 2006. According to the Final Rule, the southern DPS includes all spawning populations of green sturgeon south of the Eel River in California. The northern DPS remains a species of concern.

6.12.1 Distribution

Green sturgeon congregate in coastal waters and estuaries, where they are vulnerable to capture in salmon gillnet and white sturgeon sport fisheries. Green sturgeon are known to enter Washington estuaries, including Grays Harbor, during late summer when water temperatures are more than 2 degrees Celsius warmer than adjacent coastal waters (Moser and Lindley 2007). Lindley et al. (2011) documented tagged individuals in Grays Harbor during June-October. Large juveniles and small adult green sturgeon are common in the seawater and mixing zones of Grays Harbor during high salinity periods (Monaco et al. 1990).

That they are known to occur in Puget Sound was learned largely through radio tag detections (Goetz, 2010).

6.12.2 Foraging and Food Web Relationships

Sturgeon migrations are thought to be related to feeding and spawning (Bemis and Kynard 1997). They suggested that green sturgeon move into estuaries of non-natal rivers to feed. However, the empty gut contents of green sturgeon captured in the Columbia River gillnet fishery suggests that these green sturgeon were not actively foraging in the estuary (T. Rien, Oregon Department of Fish and Wildlife, pers. comm. in Moser and Lindley (2007)). The fact that they are caught on baited hooks incidentally during the sport season for white sturgeon in the Columbia River suggests they are feeding in the estuaries. Feeding behavior while in Puget Sound is unknown; however, in California, sturgeon generally feed on benthic invertebrates, such as shrimp, crabs, worms, mollusks, and epibenthic crustaceans. Adult green sturgeon caught in Washington had preyed on sand lance and callianassid shrimp (P. Foley, University of California, Davis, unpublished data, as cited in Moyle *et al*. 1992).

6.12.3 Evaluation of Project Impacts

Green sturgeon are rare in Puget Sound, and are unlikely to be found at the depths of the open-water PSDDA disposal sites. Even if they were to be present, effects would be insignificant due to the short-term and temporary nature of disposal operations, and the lack of significant elevation of PCBs and PCDD/F in sediment at the sites relative to the without-dredging condition.

Due to the lack of spawning habitat in the Chehalis River basin and juvenile life history characteristics, the transport and disposal of dredged material at the Grays Harbor sites will have no impact on juvenile green sturgeon or spawning. Disposal-induced reductions in water quality will be limited in spatial extent. Temporary increases in turbidity due to dredged material disposal is not a concern because green sturgeon cause sediment re-suspension during feeding, thus they are adapted to elevated concentrations of suspended solids. Adult sturgeon that occur in Grays Harbor are sufficiently large and mobile enough to avoid burial by disposal plumes from bottom dump barges and hopper dredges. Short-term effects of any disturbance related to disposal will likely result in displacement of green sturgeon rather than injury.

A small fraction of prey resources may be lost due to burial of benthic organisms during disposal at the Point Chehalis and South Jetty sites. However, green sturgeon are opportunistic predators that eat a variety of prey and switch foods as prey availability changes (Turner 1966). Effects to the green sturgeon prey base will be discountable at the Grays Harbor multiuser disposal sites given the small portion of their foraging range impacted and the wide variety of prey utilized by this species.

Evaluation of impacts due to the transport and disposal of dredged material at multiuser sites in Puget Sound and Grays Harbor leads to a determination of **may affect, but not likely to adversely affect** for continued use of these sites.

6.12.4 Designated Critical Habitat

Critical habitat for the green sturgeon southern DPS was designated in October 2009. It includes Grays Harbor and waters in the Strait of Juan de Fuca east to the northwestern shoreline of Whidbey Island, and then across Puget Sound from Partridge Point to Point Wilson at Port Townsend, and north up to the southern edge of the San Juan Islands (see map from FR Vol. 74, No. 195 / Friday, October 9, 2009, p. 52351; Figure 17). Designated critical habitat includes two of the PSDDA disposal sites: Port Angeles and Port Townsend. The Rosario Strait disposal site is just north of the northern extent of designated critical habitat.

Effects to designated green sturgeon critical habitat are covered under the seven Primary Constituent Elements (PCE) essential for the conservation of the green sturgeon as outlined below:

(1) Food resources. Abundant prey items within estuarine habitats and substrates for juvenile, subadult, and adult life stages.

> *Dredged material disposal operations would have insignificant effects on infaunal and bottom-dwelling organisms, as no significant populations of these organisms occur at the Port Angeles or Port Townsend disposal sites.*
>
> *Grays Harbor provides adequate prey species for juvenile, subadult, and adult green sturgeon and primarily consist of benthic invertebrates and fish, including crangonid shrimp, burrowing thalassinidean shrimp (particularly the burrowing ghost shrimp), amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies. During dredging operations benthic organisms will likely be depressed in the areas directly impacted by disposal of dredged material. However, given that the amount of area disturbed is small relative to the entire area of Grays Harbor, it is unlikely that dredged material disposal will appreciably diminish benthic prey resources. Therefore dredged material disposal at the Grays Harbor sites will not adversely impact this PCE.*

(2) Water flow. Within bays and estuaries adjacent to the Sacramento River (i.e., the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds.

Dredged material disposal at the multiuser sites in Grays Harbor and Puget Sound will have no effect on this PCE.

(3) Water quality. Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages.

During disposal operations the dissolved DO may be depressed slightly below ambient conditions and that only within the sediment plume. The actual depression will not reach levels low enough to cause stress or death of green sturgeon. Temperatures will not be depressed below ambient conditions. As addressed in Section 5.1 and 5.2, water and sediment chemistry may be insignificantly altered as a result of open-water disposal of dredged materials. The potential for bioaccumulation of contaminants in green sturgeon tissues is considered to be insignificant. Therefore continued use of the Puget Sound and Grays Harbor disposal sites will not adversely impact this PCE.

(4) Migratory corridor. A migratory pathway necessary for the safe and timely passage of Southern DPS fish within estuarine habitats and between estuarine and riverine or marine habitats.

Continued use of open-water disposal sites in the Strait of Juan de Fuca will not affect migratory corridors for green sturgeon. Dredged material disposal at the Point Chehalis and South Jetty sites will not prevent safe and timely passage between Grays Harbor and the ocean. Green sturgeon will be able to easily avoid disposal events. Therefore the action will have no effect on this PCE.

(5) Depth. A diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages.

The Port Angeles, Port Townsend, Point Chehalis and South Jetty disposal sites are all dispersive; dredged material that is disposed at these sites is either rapidly dispersed or erodes within a short time and does not accumulate on the bottom. Depth of water is therefore not affected by disposal operations.

(6) Sediment quality. Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.

As addressed in the BE, water and sediment chemistry may be insignificantly altered as a result of open-water disposal of dredged material. The potential for bioaccumulation of contaminants in green sturgeon tissues is considered to be discountable.

In conclusion, continued open-water disposal at the Port Angeles, Port Townsend, Point Chehalis and South Jetty disposal sites **may affect, but is not likely to adversely affect** designated critical habitat for green sturgeon.

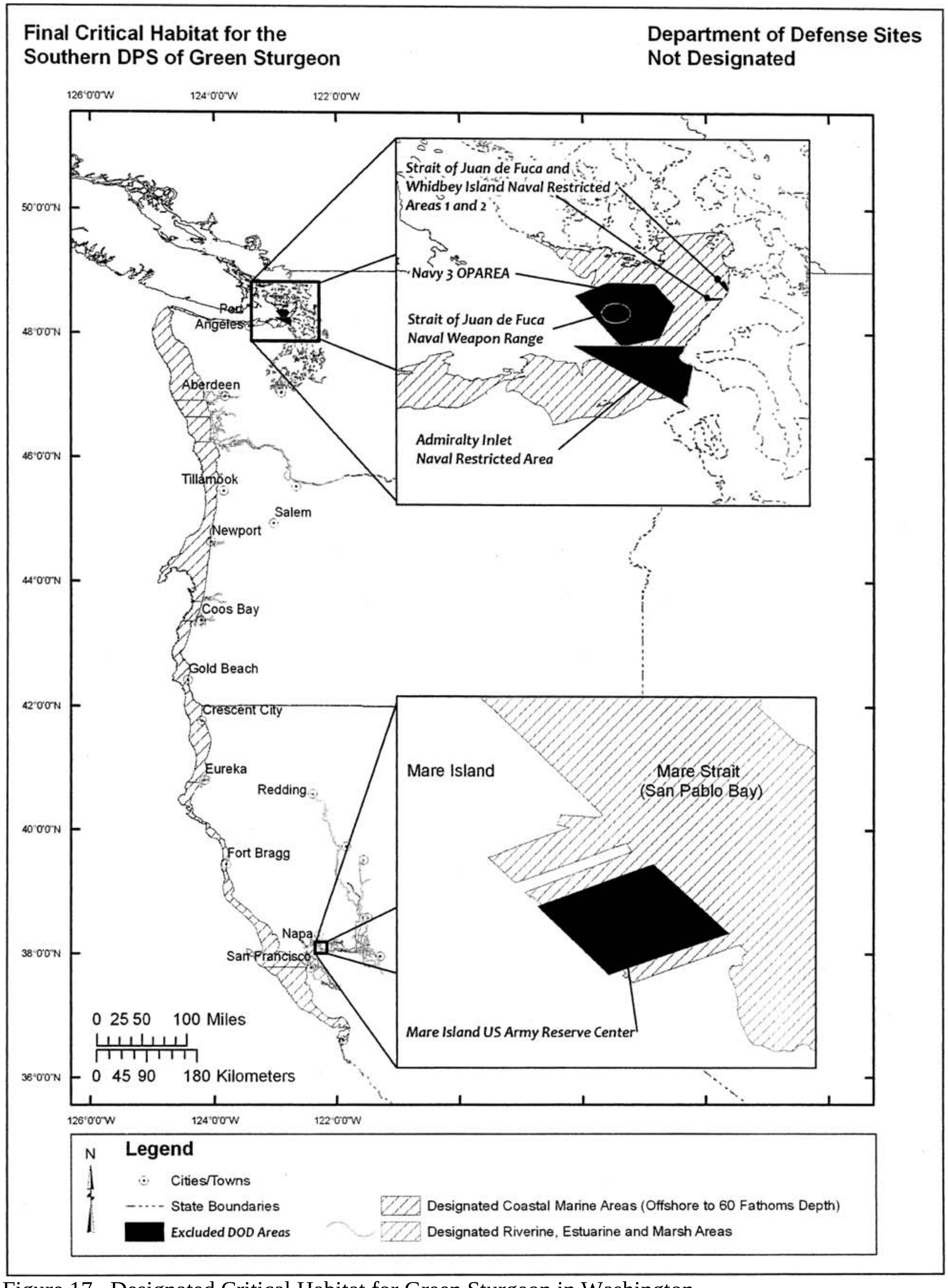

Figure 17. Designated Critical Habitat for Green Sturgeon in Washington

6.13 Lower Columbia River Chinook Salmon, Upper Willamette River Chinook Salmon, and Columbia River Chum Salmon

The Lower Columbia River Chinook salmon ESU, Upper Willamette River Chinook salmon ESU, and Columbia River Chum salmon ESU were listed as threatened on 28 June 2005 (70 FR 37160).

6.13.1 Distribution

The Lower Columbia River Chinook salmon ESU includes all naturally spawned populations of Chinook salmon in the Columbia River and its tributaries from its mouth at the Pacific Ocean upstream to a transitional point east of Hood River in Oregon and the White Salmon River in Washington. The ESU includes spring, fall (tule), and late fall (bright) type Chinook salmon. Fall Chinook salmon enter freshwater typically in August through October to spawn in large river mainstems and have an ocean type life history that emigrates from freshwater as subyearlings.

The Upper Willamette River Chinook salmon ESU includes all naturally spawned populations of Chinook salmon residing in the Clackamas River and above Willamette Falls, but below impassable natural barriers (e.g., long-standing, natural waterfalls). Upper Willamette River Spring Chinook Salmon are "Gulf of Alaska" migrants. They migrate to the north upon ocean entry. The juveniles of this ESU emigrate as both stream and ocean types.

The Columbia River Chum salmon ESU includes three major population groups, with 16 historical populations of which 13 are functionally extirpated or at very high risk of extinction in Oregon and Washington between the mouth of the Columbia River and the Cascade crest (Myers et al. 2006). Columbia River chum salmon fry emigrate from March through May shortly after emergence. The juveniles of this ESU have the ocean type life history. Juvenile Columbia River chum salmon use estuaries to feed before beginning long-distance oceanic migration.

These ESUs are included in this BE under the assumption that some of the ocean type emigrants may utilize the nearshore and intertidal habitat in Grays Harbor during their early ocean life history. The effects of transport and disposal of dredged material at the Point Chehalis and South Jetty sites on these three species will be similar and they occupy similar habitat in their juvenile life history stages, thus they are treated as a single group.

6.13.2 Evaluation of Project Impacts

Dredged material transport from the outer harbor of Grays Harbor occurs in April or May, months when lower Columbia River Chinook salmon, upper Willamette River Chinook salmon and Columbia River chum salmon juveniles may be present in the estuary. The dredged material is transported and dumped via bottom dump barge or hopper dredge, the bottoms of which are at least 10 feet below the surface. It is unlikely that juvenile salmon would be foraging in the deep water found at the Point Chehalis and South Jetty disposal sites. However, in the event they were migrating through the area at the time of disposal, it is unlikely they would be found at the depth at which the dredged material is released. In addition, the transport vessels will create a disturbance that the juveniles will likely avoid. The juveniles are highly mobile and should they be in the area when dredged material is transported and disposed they can easily avoid the vessels and disposal event.

Clam-shell dredging of the inner harbor is conducted when juvenile salmon are not present in the estuary. Therefore, transport and disposal associated with inner-harbor dredging would have no effect on these species.

The Corps has determined that dredged material transport and disposal in Grays Harbor **may affect, but is not likely to adversely affect** lower Columbia River Chinook salmon, upper Willamette River Chinook salmon, and Columbia River chum salmon.

6.13.3 Designated Critical Habitat

Critical habitat for these three species has been designated, but does not occur in the action areas. Therefore, dredged material transport and disposal activities will have **no effect** on designated critical habitat for these species.

6.14 INTERRELATED AND INTERDEPENDENT EFFECTS

Per 50 CFR 402.02, interdependent actions are those that have no independent utility apart from the proposed action. Interrelated actions are those that are part of a larger action and depend on the larger action for justification.

The dredging activities that generate material for disposal at the DMMP sites are interrelated to the proposed action. Interrelated effects associated with dredging operations will occur within portions of the action area, but removed from the individual DMMP sites where most disposal impacts will occur. Therefore, interrelated actions will not increase the size of disposal impacts to a level where take would occur. Because all interrelated dredging projects are either federal navigation projects, or projects requiring federal authorization in the form of a Clean Water Act Section 404 permit, each dredging project or group of projects (maintenance dredging programs) would undergo Section 7 consultation independently.

6.15 CUMULATIVE EFFECTS

"Cumulative effects include the effects of future State, tribal, local and private actions, not involving a Federal action, that are reasonably certain to occur within the action area under consideration. Future Federal actions requiring separate consultation (unrelated to the proposed action) are not considered in the cumulative effects section" (50 CFR 402.12).

The Corps knows of no future non-federal actions that are reasonably certain to occur, aside from ongoing vessel navigation, that may adversely affect a listed, proposed, or candidate species within the action area. All dredging projects that generate material for disposal at DMMP sites are either federal navigation projects or require a federal permit. Tables 3 and 4 in Section 3.4 detail what is known about disposal actions at the Puget Sound sites over the last 26 years and at the Grays Harbor sites over the last 19 years. It is likely that future disposal actions will follow this pattern.

6.16 CONCLUSION

Table 11 summarizes the effect determinations made for each of the species potentially occurring in the project vicinity.

Table 11. Determination Summary Table

Species	Effect Determination	Designated Critical Habitat/Proposed Critical Habitat
Puget Sound Chinook Salmon *Oncorhynchus tshawytscha*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Hood Canal Summer-Run Chum Salmon *Oncorhynchus keta*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Puget Sound Steelhead *Oncorhynchus mykiss*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Lower Columbia River Coho Salmon *Oncorhynchus kisutch*	May affect, not likely to adversely affect	No effect
Bocaccio Rockfish *Sebastes paucispinis*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Canary Rockfish *S. pinniger*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Yelloweye Rockfish *S. ruberrimus*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Eulachon *Thaleichthys pacificus*	May affect, not likely to adversely affect	No effect
Coastal/Puget Sound Bull Trout *Salvelinus confluentus*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Marbled Murrelet *Brachyramphus marmoratus*	May affect, not likely to adversely affect	No effect
Southern Resident Killer Whale *Orcinus orca*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Humpback Whale *Megaptera novaeangliae*	May affect, not likely to adversely affect	NA
Leatherback Sea Turtle *Dermochelys coriacea*	No effect	No effect
North American Green Sturgeon *Acipenser medirostris*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Lower Columbia River Chinook Salmon *Oncorhynchus tshawytscha*	May affect, not likely to adversely affect	No effect
Upper Willamette River Chinook Salmon *Oncorhynchus tshawytscha*	May affect, not likely to adversely affect	No effect
Columbia River Chum Salmon *Oncorhynchus keta*	May affect, not likely to adversely affect	No effect

7 ESSENTIAL FISH HABITAT EVALUATION

7.1 ESSENTIAL FISH HABITAT DESIGNATIONS

The Magnuson-Stevens Sustainable Fisheries Act requires Federal agencies to consult with NMFS regarding actions that may affect essential fish habitat (EFH) for Pacific coast groundfish, coastal pelagic species, and Pacific salmon. The Act defined EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Essential Fish Habitat is the habitat (waters and substrate) required to support a sustainable fishery and a managed species’ contribution to a healthy ecosystem. Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish. Substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities.

The action areas previously described in this document are part of the Puget Sound Basin and southern coast of the Strait of Juan de Fuca, and Washington State coastal estuaries. The EFH for Puget Sound and the southern coast of the Strait of Juan de Fuca has been designated as EFH for various life stages of 29 species of groundfish, four coastal pelagic species, and three species of salmon (Table 12); and the EFH composite for the Washington coastal estuaries has been designated as EFH for various life stages of 24 species of groundfish, four coastal pelagic species, and two species of Pacific salmon (Table 13) according to the NMFS Fisheries Management Plans (PFMC 1998, PFMC 2003, PFMC 2004). The proposed actions may impact EFH of groundfish, coastal pelagic species, and Pacific salmon species listed in tables 12 and 13.

Table 12. Essential Fish Habitat use in Puget Sound and Strait of Juan de Fuca by species and life history stage based on the NMFS EFH habitat database.

Scientific Name	Common Name	Adult	Juvenile	Larvae	Egg
Groundfish Species					
Anoplopoma fimbria	Sablefish	X	X	X	X
Citharichthys sordidus	Pacific sanddab	X			
Eopsetta jordani	Petrale sole	X			
Glyptocephalus zachirus	Rex sole	X			
Hexagrammos decagrammus	Kelp greenling	X		X	
Hippoglossoides elassodon	Flathead sole	X			
Hydrolagus colliei	Spotted ratfish	X	X		
Isopsetta isolepis	Butter sole	X			
Lepidopsetta bilineata	Rock sole	X			
Merluccius productus	Pacific hake	X	X		
Ophiodon elongatus	Lingcod			X	
Parophrys vetulus	English sole	X	X		
Platichthys stellatus	Starry flounder	X	X		
Psettichthys melanostictus	Sand sole	X	X		
Raja binoculata	Big skate	X			

Scientific Name	Common Name	Adult	Juvenile	Larvae	Egg
Raja rhina	Longnose skate	X	X		X
Scorpaenichthys marmoratus	Cabezon	X	X	X	X
Sebastes auriculatus	Brown rockfish	X			
Sebastes caurinus	Copper rockfish	X	X		
Sebastes diploproa	Splitnose rockfish		X	X	
Sebastes entomelas	Widow rockfish		X		
Sebastes flavidus	Yellowtail rockfish	X			
Sebastes maliger	Quillback rockfish	X	X		
Sebastes melanops	Black rockfish	X	X		
Sebastes mystinus	Blue rockfish	X	X	X	
Sebastes nebulosus	China rockfish	X	X		
Sebastes nigrocinctus	Tiger rockfish	X			
Sebastes paucispinis	Bocaccio		X		
Squalus acanthias	Spiny dogfish	X			
Coastal Pelagic Species					
Engraulis mordax	Anchovy	X	X	X	X
Sardinops sagax	Pacific sardine	X	X	X	X
Scomber japonicus	Pacific mackerel	X			
Loligo opalescens	Market squid	X	X	X	
Pacific Salmon					
Oncorhynchus tshawytscha	Chinook salmon	X	X		
Oncorhynchus kisutch	Coho salmon	X	X		
Oncorhynchus gorbuscha	Pink salmon	X	X		

Note: The Fishery Management Plan groups juveniles/larvae/eggs together, any could be in the area.

Table 13. Essential Fish Habitat use in Washington coastal estuaries by species and life history stage based on the NMFS EFH habitat database.

Scientific Name	Common Name	Adult	Juvenile	Larvae	Egg
Groundfish Species					
Citharichthys sordidus	Pacific sanddab			X	
Eopsetta jordani	Petrale sole			X	X
Gadus macrocephalus	Pacific cod			X	
Galeorhinus galeus	Soupfin shark	X	X		

Scientific Name	Common Name	Adult	Juvenile	Larvae	Egg
Hippoglossoides elassodon	Flathead sole		X	X	X
Hydrolagus colliei	Spotted ratfish	X	X		
Lepidopsetta bilineata	Rock sole			X	X
Microstomus pacificus	Dover sole				X
Ophiodon elongatus	Lingcod		X		X
Parophrys vetulus	English sole	X	X		X
Platichthys stellatus	Starry flounder	X	X	X	X
Psettichthys melanostictus	Sand sole				X
Raja inornata	California skate	X			X
Sebastes auriculatus	Brown rockfish			X	
Sebastes caurinus	Copper rockfish			X	
Sebastes melanops	Black rockfish		X		
Sebastes proriger	Redstripe rockfish			X	
Squalus acanthias	Spiny dogfish	X	X		
Coastal Pelagic Species					
Engaulis mordax	Northern anchovy	X	X*	X*	X*
Loligo opalescens	Market Squid	X	X*	X*	X*
Sardinops sagax	Pacific sardine	X	X*	X*	X*
Scomber japonicas	Pacific (chub) mackerel	X	X*	X*	X*
Pacific Salmon					
Oncorhynchus kisutch	Coho salmon	X	X		
Oncorhynchus tshawytscha	Chinook salmon	X	X		

Note (*): The Fishery Management Plan groups juveniles/larvae/eggs together, any of which could be in the area. Also, all life history stages can be found in waters off Washington, but this is dependent upon surface water temperatures being higher than 10 degrees Celsius.

7.2 Effects of Dredged Material Transport and Disposal on EFH

7.2.1 Transport of Dredged Material

Transport of dredged material is addressed in Section 3.1 of this BE. In light of the high volume of existing commercial marine traffic in Puget Sound and Grays Harbor, transport of dredged material as described in that section is very unlikely to have any incremental adverse effect on EFH.

7.2.2 Disposal of Dredged Material

Dredged material disposal may impact EFH of the species listed in Tables 12 and 13 by:

- Smothering epibenthic and benthic organisms within the direct impact area. As the jet of dredged material impacts the bottom, there is a density/momentum-driven surge of material away from the impact point. As the material settles, a gradient in the thickness of the newly deposited material tends to emerge, with thicker deposits near the impact site and thinner deposits at greater distances from the center of the site. If the disposed material settling on the bottom is thick enough, it can smother epibenthic and benthic fauna. Monitoring studies at PSDDA sites indicate that the benthic communities were able to recover when dredged material cover was less than 10 cm thick (Corps 1992). Monitoring has consistently shown relatively rapid re-establishment of the benthic community to a climax situation with the highest order of succession (Stage III communities) present at the majority of stations within the dredged material footprint within months of the most recent disposal.

Several factors have been found to be important in determining the rate at which a disturbed site is recolonized by soft-bottom benthic invertebrate species. Naturally-occurring soft bottom sediments are frequently disturbed because wave actions and currents can move soft sediments about. Resident organisms are adapted to such natural perturbations and tend to recover quickly. Recovery of the motile organisms on disturbed soft-bottom habitats can occur by adult migration, as well as by larval sediment and growth; both phenomena are more rapid on soft-bottom habitats than hard.

- Altering the sediment character (e.g. percent silt, clay, sand, gravel) at some non-dispersive disposal sites, resulting in potential changes to the benthic community structure and productivity. These changes are limited to the sites themselves and not the surrounding area. Monitoring of benthic fauna just outside the Elliott Bay site in 1992 verified that no adverse environmental effects occurred beyond the boundary of the disposal site. The abundance of major benthic taxa at off-site transect stations was similar to the abundances measured during baseline studies (PSDDA, 1994).
- Increasing turbidity and suspended sediment in the vicinity of the disposal sites, causing a temporary and localized decrease in phytoplankton productivity or mortality of pelagic fish eggs, larvae, and zooplankton. However, elevated turbidity levels will temporary and rapidly dissipate once disposal is complete (Truitt, 1986a). Also, the disposal sites lack components that would attract or concentrate plankton or fish. This factor could reduce effects, especially on mackerel, anchovy, and sardines. These species often feed in areas of high plankton abundance (e.g. upwelling fronts). Entrainment of copepods or krill could occur because of their small size and limited ability to move, as could entrainment of their food organisms (e.g., phytoplankton, rotifers, etc.). However, the localized effects of disposal probably will not significantly impact planktonic or pelagic invertebrate populations. These organisms are widely distributed throughout the action areas, and the disposal of dredged material would not substantively affect area-wide populations of these organisms.

Open-water disposal of dredged material would constitute a detectable adverse effect to EFH. The conservation measures below are designed to mitigate the adverse effects caused by disposal.

7.3 CONSERVATION MEASURES

A number of measures and procedures inherent in the DMMP act in combination to minimize the potential for impacts to EFH in Puget Sound and Grays Harbor. These include:

- Evaluation of the chemical suitability of dredged material for beneficial use as an alternative to disposal at a multiuser disposal site and documentation of this evaluation in DMMP suitability determinations; beneficial use may include capping of contaminated material at CERCLA and MTCA cleanup sites, or in-water habitat restoration projects.

- Consolidation of dredged material disposal sites to minimize the area and locations affected by dredged material disposal.
- Siting of Puget Sound non-dispersive disposal sites in areas of relatively low habitat value or low use by biota (distance offshore, depth, areas with low known resource value).
- Using dredged material testing protocols to ensure the suitability of materials for unconfined, open-water discharge; updating the testing protocols as needed to protect the aquatic environment.
- Sequencing the disposal of DMMUs within a dredging project at non-dispersive sites when possible with the cleanest material disposed last, thereby improving the quality of the surface sediment at the disposal site.
- Conducting site monitoring activities (physical, chemical and biological) to determine if unacceptable impacts are occurring at disposal sites.
- Adaptively managing sites based on feedback from site monitoring events.

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Appendix A

Screening Level (SL), Bioaccumulation Trigger (BT), and Maximum Level (ML) Guideline Chemistry Values (Dry Weight Normalized)

2015 DMMP MARINE SCREENING LEVEL (SL), BIOACCUMULATION TRIGGER (BT), AND MAXIMUM LEVEL (ML) GUIDELINE CHEMISTRY VALUES

CHEMICAL	Screening Level	Bioaccumulation Trigger	Maximum Level
METALS (mg/kg)			
Antimony	150	---	200
Arsenic	57	507.1	700
Cadmium	5.1	11.3	14
Chromium	260	260	---
Copper	390	1,027	1,300
Lead	450	975	1,200
Mercury	0.41	1.5	2.3
Selenium	---	3	---
Silver	6.1	6.1	8.4
Zinc	410	2,783	3,800
ORGANOMETALLIC COMPOUNDS (µg/L)			
Tributyltin (interstitial water; µg/L)	---	0.15	---
Tributyltin (bulk; µg/kg)	---	73	---
PAHs (µg/kg)			
Total LPAH	5,200	---	29,000
Naphthalene	2,100	---	2,400
Acenaphthylene	560	---	1,300
Acenaphthene	500	---	2,000
Fluorene	540	---	3,600
Phenanthrene	1,500	---	21,000
Anthracene	960	---	13,000
2-Methylnaphthalene	670	---	1,900
Total HPAH	12,000	---	69,000
Fluoranthene	1,700	4,600	30,000
Pyrene	2,600	11,980	16,000
Benz(a)anthracene	1,300	---	5,100
Chrysene	1,400	---	21,000
Benzofluoranthenes (b+k)	3,200	---	9,900
Benzo(a)pyrene	1,600	---	3,600
Indeno(1,2,3-c,d)pyrene	600	---	4,400
Dibenz(a,h)anthracene	230	---	1,900
Benzo(g,h,i)perylene	670	---	3,200
CHLORINATED HYDROCARBONS (µg/kg)			
1,4-Dichlorobenzene	110	---	120
1,2-Dichlorobenzene	35	---	110
1,2,4-Trichlorobenzene	31	---	64
Hexachlorobenzene (HCB)	22	168	230
PHTHALATES (µg/kg)			
Dimethyl phthalate	71	---	1,400
Diethyl phthalate	200	---	1,200
Di-n-butyl phthalate	1,400	---	5,100
Butyl benzyl phthalate	63	---	970
Bis(2-ethylhexyl) phthalate	1,300	---	8,300

CHEMICAL	Screening Level	Bioaccumulation Trigger	Maximum Level
Di-n-octyl phthalate	6,200	---	6,200
PHENOLS (µg/kg)			
Phenol	420	---	1,200
2-Methylphenol	63	---	77
4-Methylphenol	670	---	3,600
2,4-Dimethylphenol	29	---	210
Pentachlorophenol	400	504	690
MISCELLANEOUS EXTRACTABLES (µg/kg)			
Benzyl alcohol	57	---	870
Benzoic acid	650	---	760
Dibenzofuran Hexachlorobutadiene	540 11	--- ---	1,700 270
N-Nitrosodiphenylamine	28	---	130
PESTICIDES (µg/kg)			
4,4'-DDD	16	---	---
4,4'-DDE	9	---	---
4,4'-DDT	12	---	---
Total DDT (sum of 4,4'-DDD, 4,4'-DDE and 4,4'-DDT)	---	50	69
Aldrin	9.5	---	---
Total Chlordane	2.8	37	---
Dieldrin	1.9	---	1,700
Heptachlor	1.5	---	270
PCBs (µg/kg)			
Total PCBs	130	38[a]	3,100
DIOXINS/FURANS (µg/kg)			
Total TEQ (Puget Sound)	4[b]	4/10[c]	---
Total TEQ (Grays Harbor)	---	15	---
2,3,7,8- TCDD	---	5	---

[a]This value is normalized to total organic carbon, and is expressed in mg/kg (TOC normalized).
[b]Site management objective for dispersive and non-dispersive sites; for non-dispersive sites, the volume-weighted average for a project must be at or below 4 ng/kg TEQ unless bioaccumulation testing is performed; for dispersive sites, all DMMUs must be at or below 4 ng/kg TEQ unless bioaccumulation testing is performed.
[c]To qualify for open-water disposal at a dispersive or non-dispersive site, DMMUs above 4 ng/kg or 10 ng/kg respectively would need to pass bioaccumulation testing.

Appendix B

Puget Sound Disposal Sites

Figure B-1. Rosario Strait Disposal Site

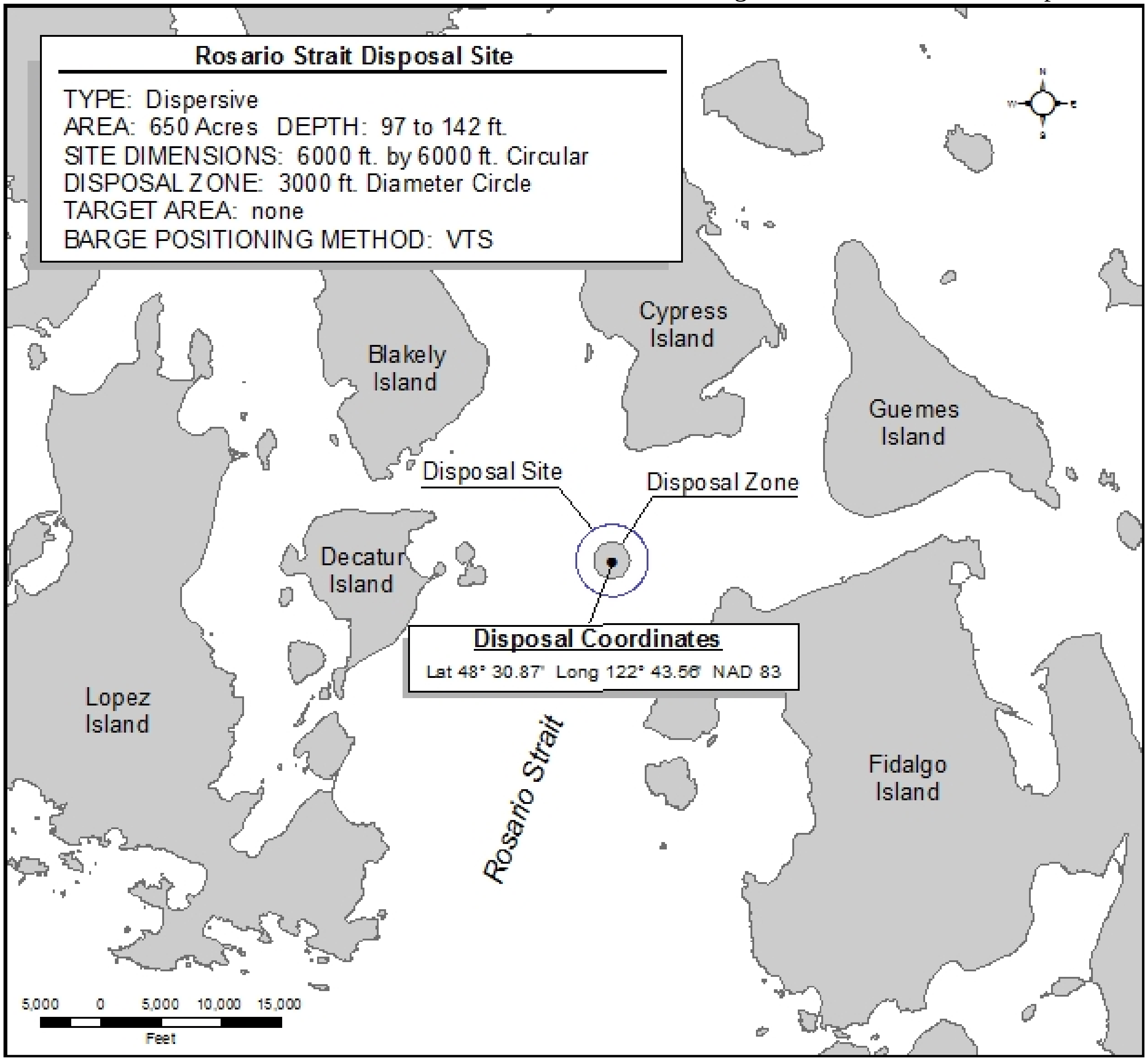


Figure B-2. Port Townsend Disposal Site

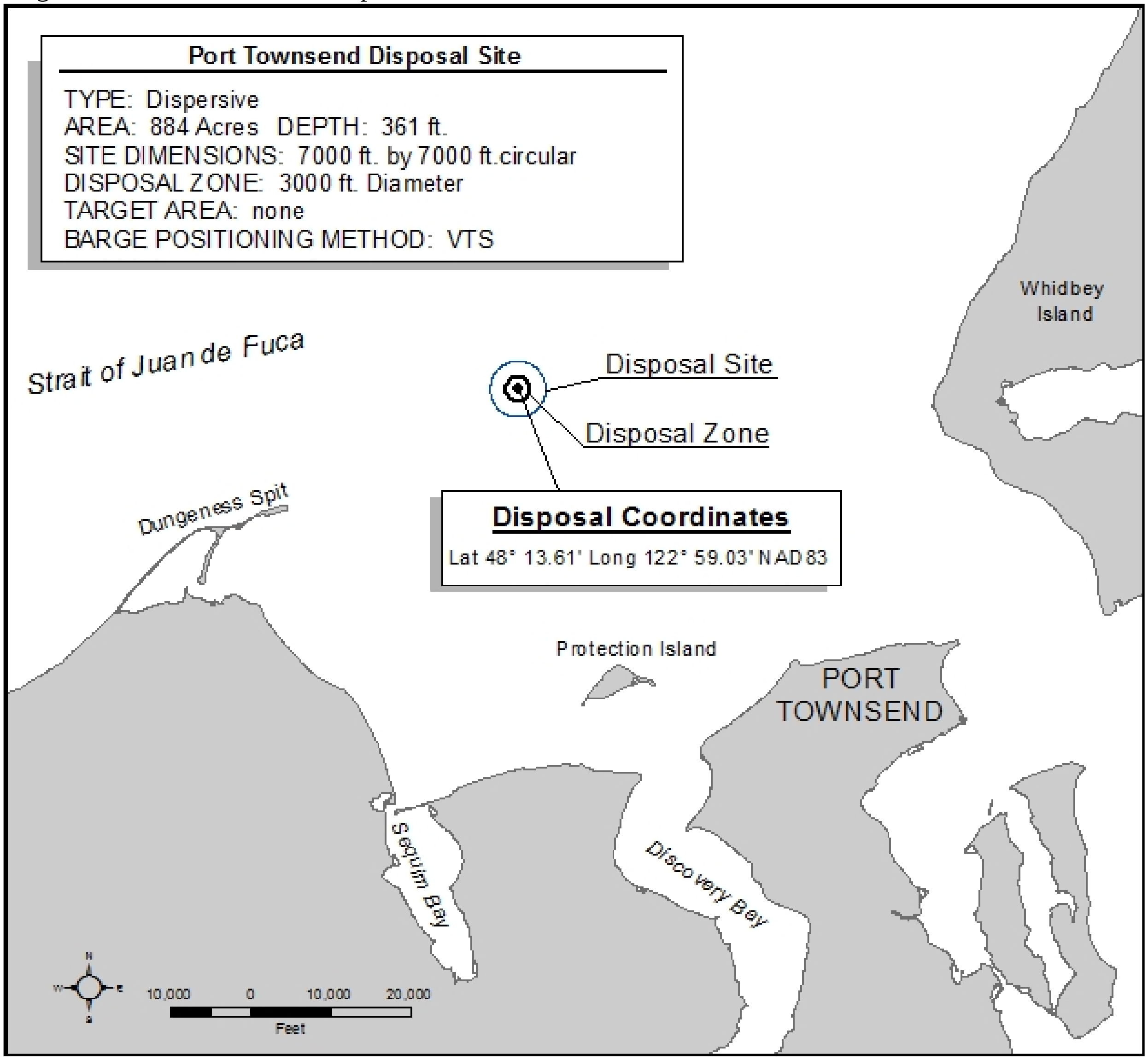


Figure B-3. Port Angeles Disposal Site

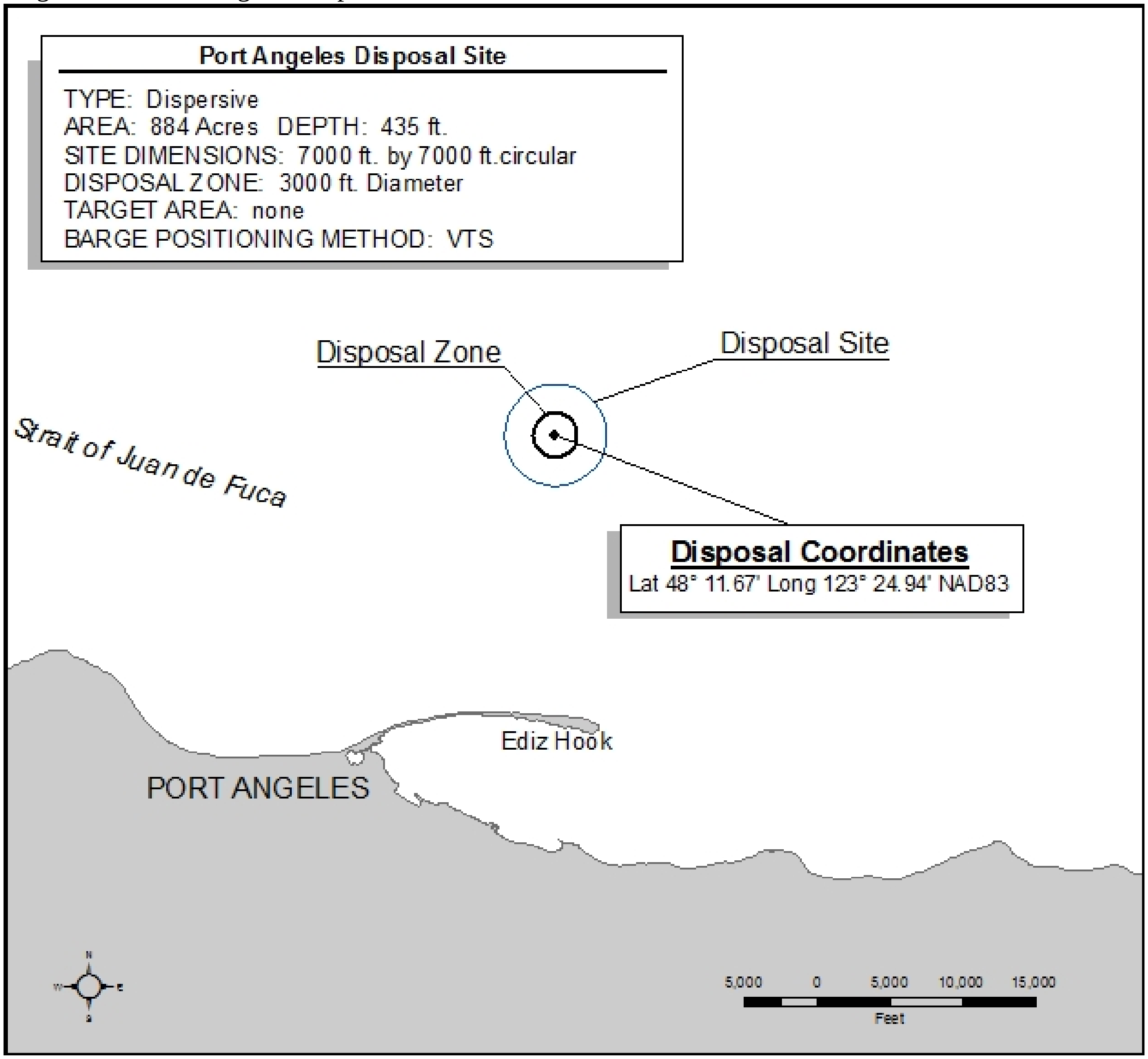


Figure B-4. Bellingham Bay Disposal Site

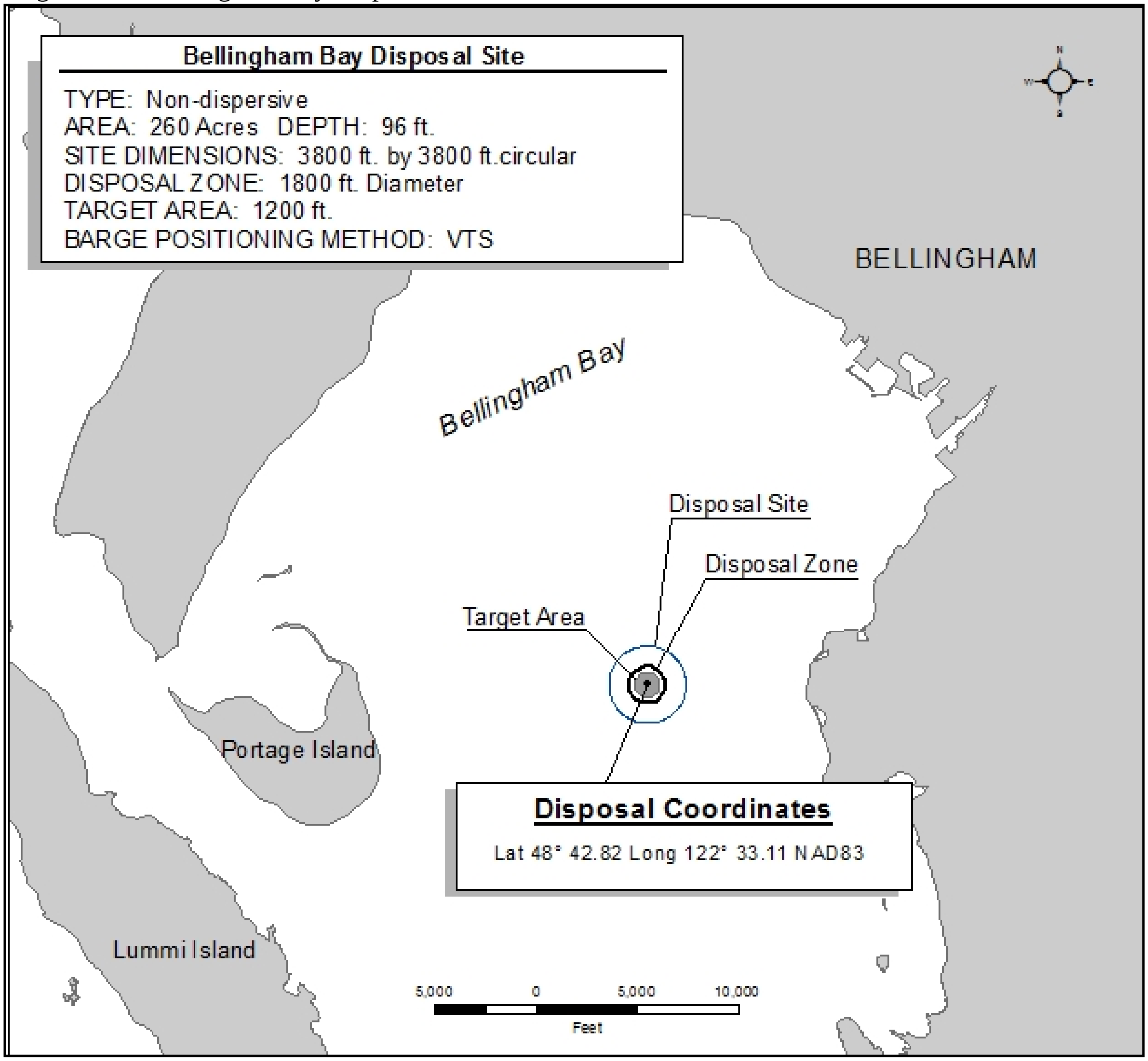


Figure B-5. Port Gardner Disposal Site

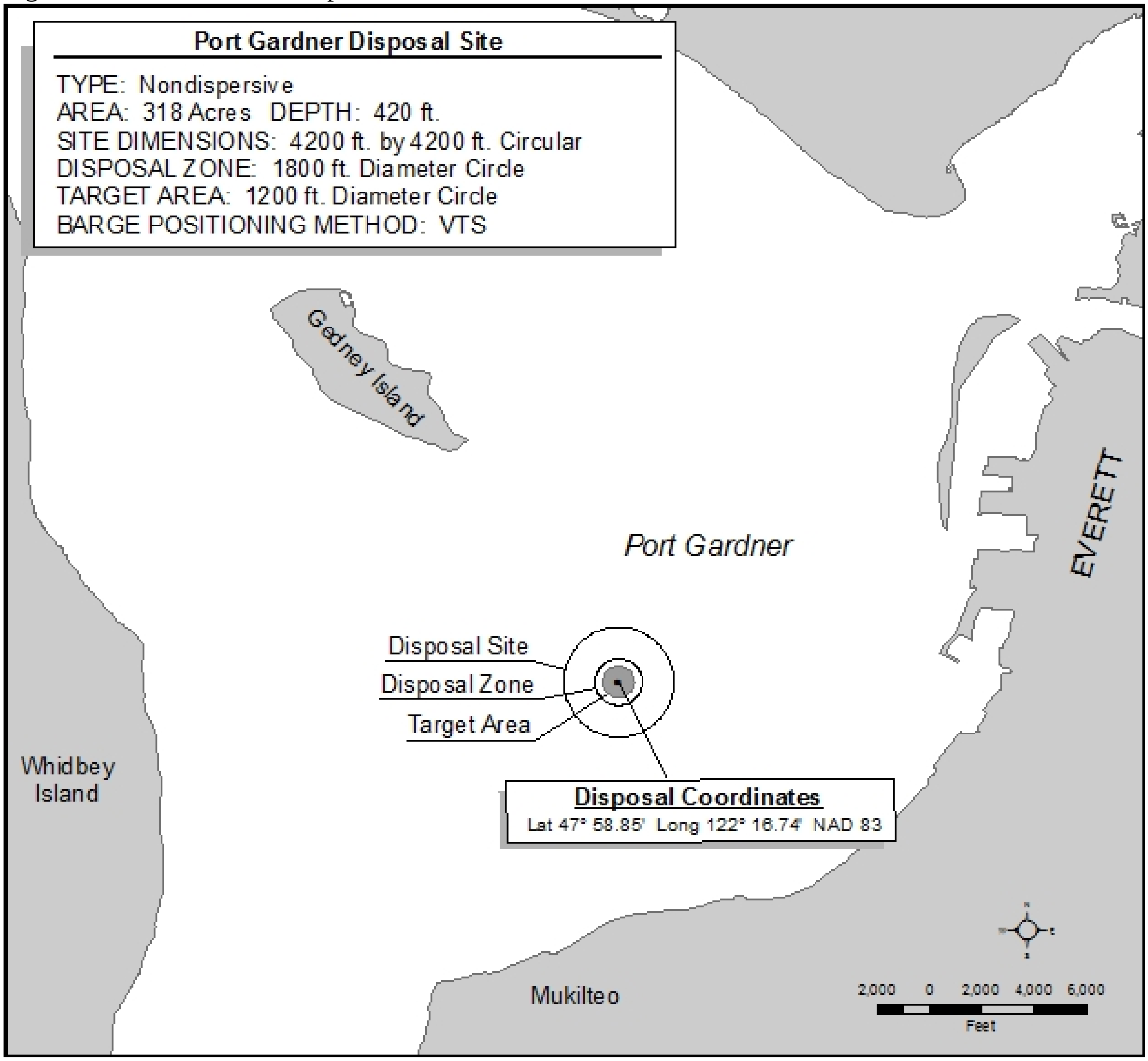


Figure B-6. Elliot Bay Disposal Site

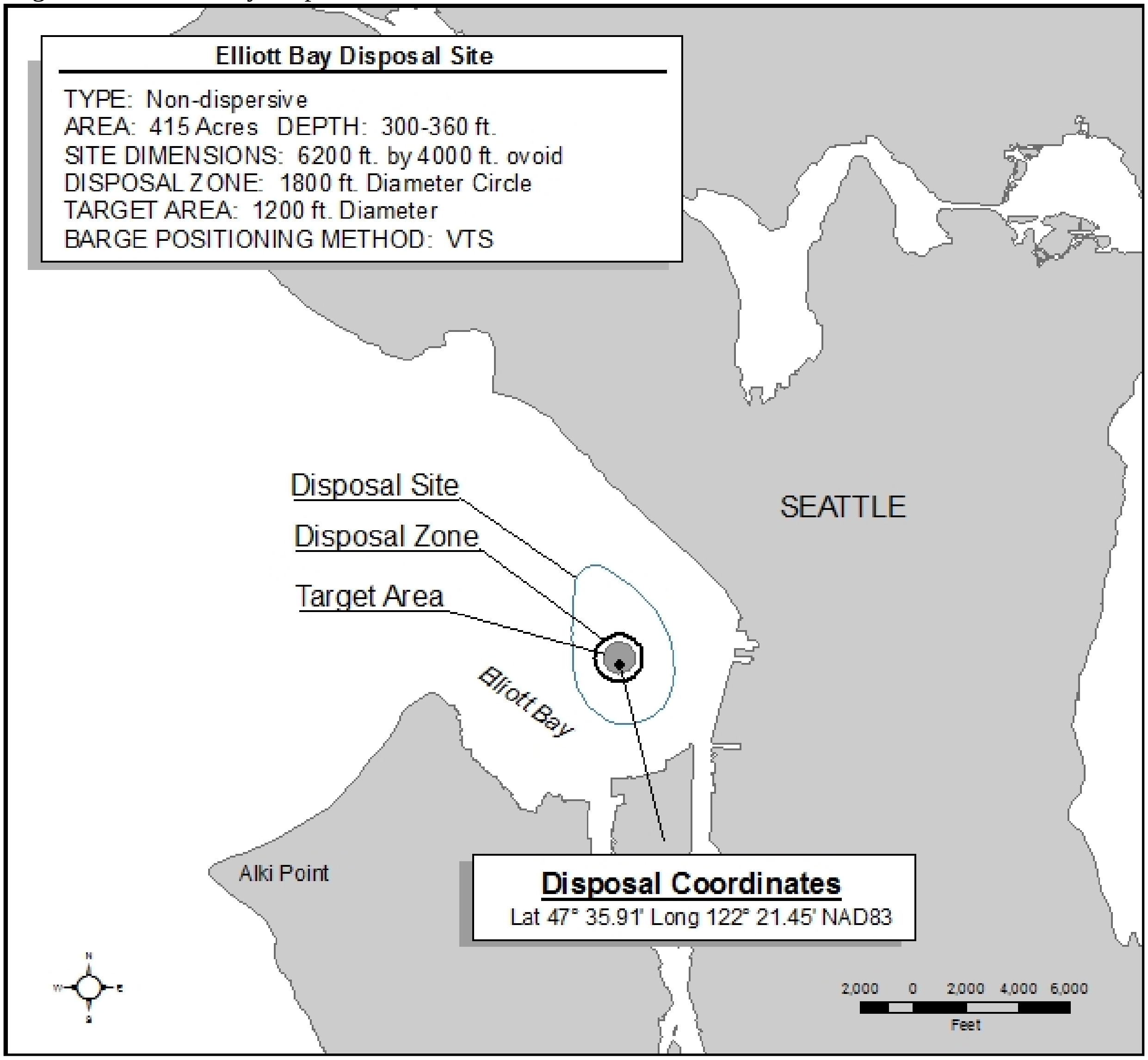


Figure B-7. Commencement Bay Disposal Site

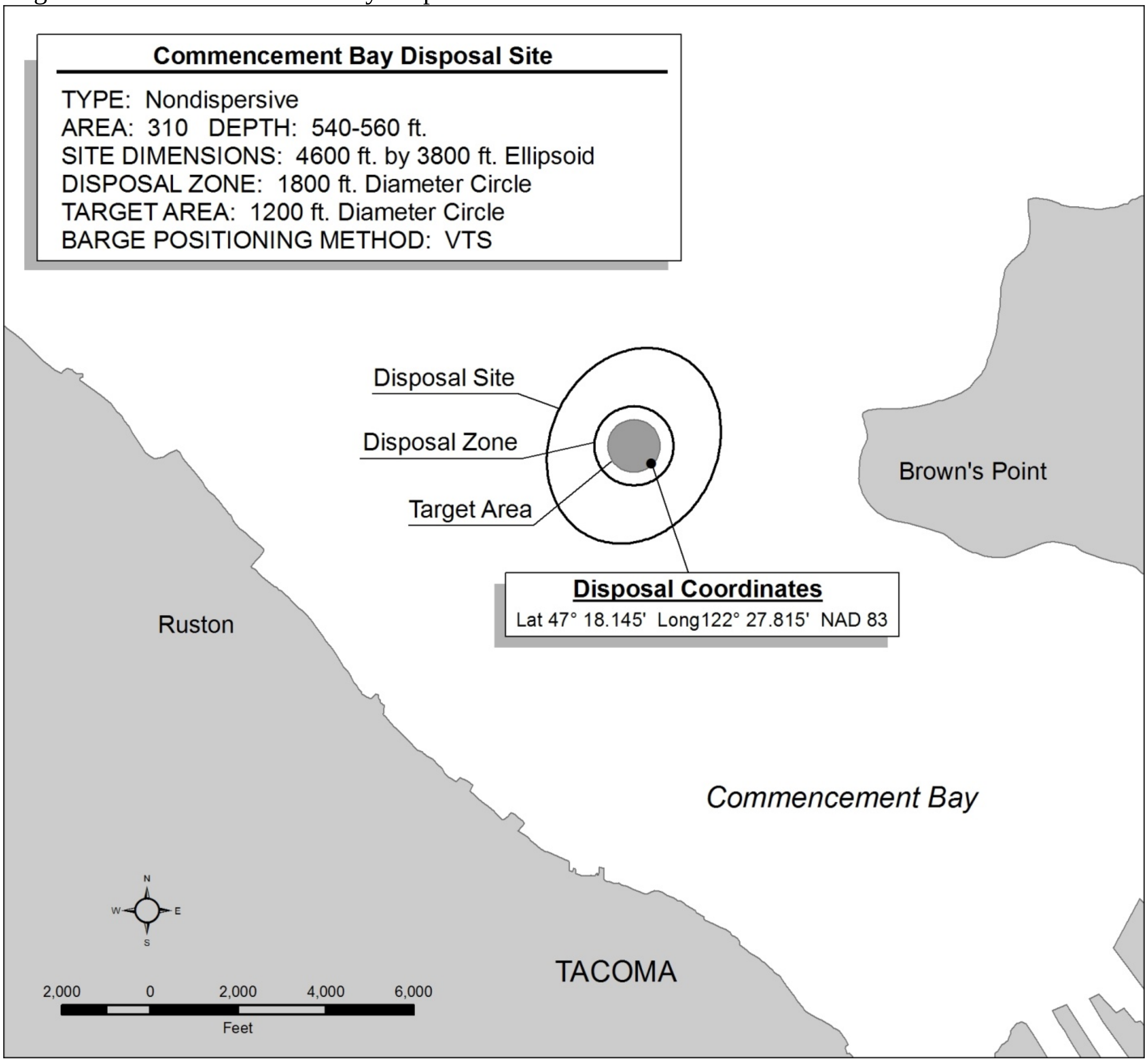
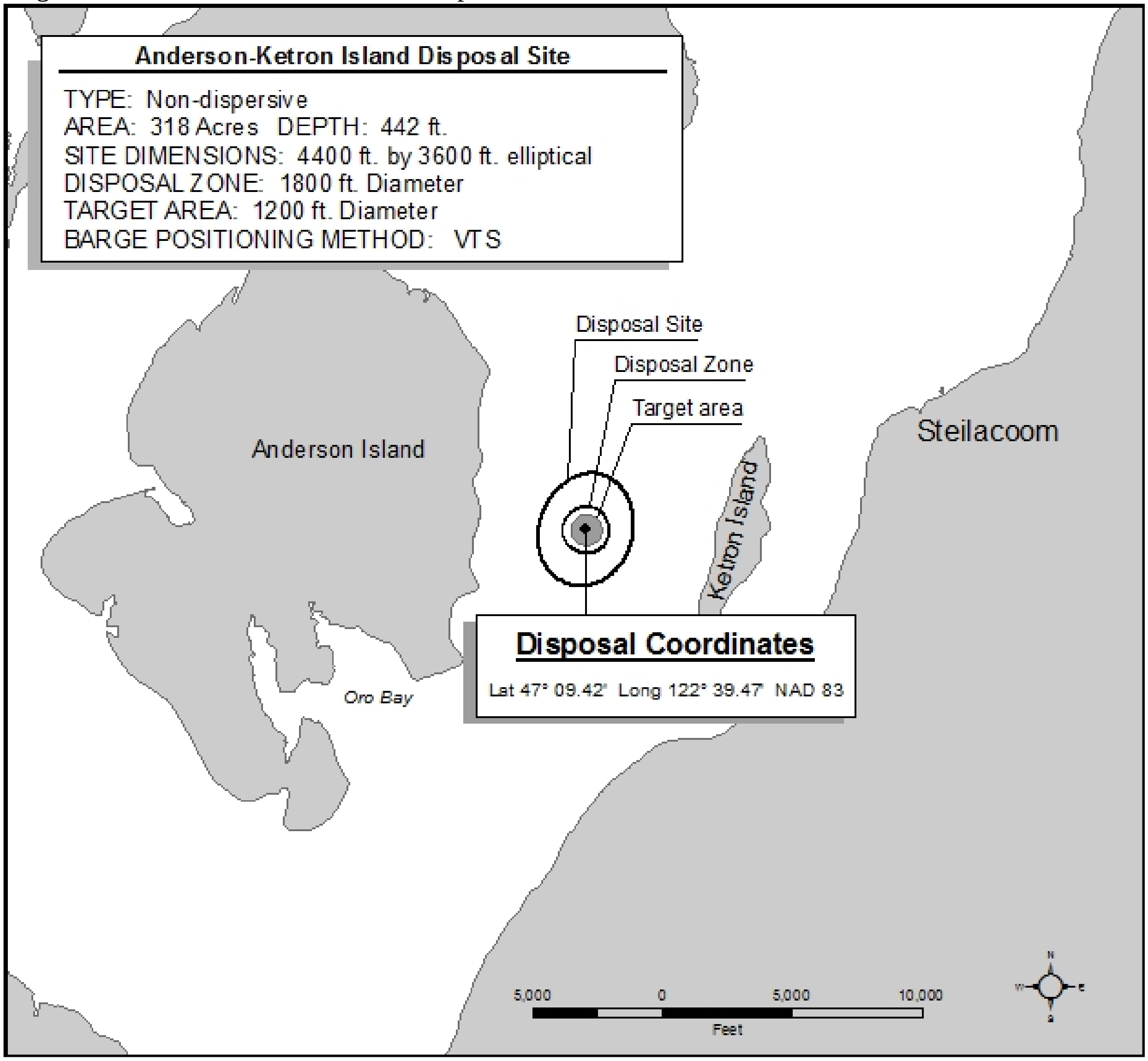


Figure B-8. Anderson/Ketron Island Disposal Site



Appendix C

Consideration of DMMP Effects on Marine Mammals

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Summary

This appendix updates the 2010 DMMP Programmatic Biological Evaluation (PBE) Appendix B, for the 2015 determination. It recounts the evidence for endangerment and food-web relationships from sediment to Southern Resident killer whale (SRKW), Steller sea lion, and harbor seal, and describes how the Dredged Material Management Program's (DMMP's) ongoing evaluation of suitability of dredged material for unconfined, open-water disposal and site management includes elements to protect marine mammals.

A number of lines of evidence suggest that persistent bioaccumulative toxicants (PBTs) such as total polychlorinated biphenyls (ΣPCB[1]), total polychlorinated dioxins/furans (ΣPCDD/F), and total polybrominated diphenyl ethers (ΣPBDEs) are present in the food web in the Salish Sea at levels that may have toxic effects on organisms protected under the ESA or the Marine Mammal Protection Act. Model projections indicate that ΣPCBs are slowly declining but the killer whales will continue to be exposed for some generations to come. Numerous sources relate rapid increases in ΣPBDE in anadromous fish, marine invertebrates, and marine mammals. Lebeuf et al. (2004) indicated a ΣPBDE doubling time of 2.2-3 years in beluga whales in the St. Lawrence estuary. For killer whales, Mongillo (2009) cites research indicating J pod individuals that frequent Puget Sound have higher PCB concentrations than the more northerly ranging K or L pods, and the predicted blubber ΣPBDE doubling time for all three pods ranges from 3 to 4 years.

SRKW, Steller sea lions, and harbor seals consume prey species that frequent Puget Sound (the purview of the DMMP). Under the ESA, NMFS (2006) has designated SRKW Critical Habitat (CH) that includes seven of the eight DMMP open-water disposal sites. Designated CH includes a Primary Constituent Element that addresses prey suitability: "(2) Prey species of sufficient quantity, *quality*, and availability to support individual growth, reproduction, and development, as well as *overall population growth* " (emphasis added). SRKW appear to assimilate 4-6.6 times as much ΣPCB as the northern resident populations, partly because of higher PCB concentrations in prey and partly because SRKW prey have lower lipid content, requiring more prey consumption (Cullon et al. 2009). SRKW consume fish, with Chinook salmon (*Oncorhynchus tshawytscha*) as a major part of their diet; in turn, adult Chinook consume herring, which feed on zooplankton and smaller pelagic fish. Steller sea lions and seals consume pelagic and demersal fish and shellfish. Numerous studies (e.g., Ylitalo et al. 2005, West et al. 2011) have confirmed the presence of relatively high levels of ΣPCB in herring, hake, and Chinook salmon, and noted the relationship to SRKW. ΣPCB levels in Puget Sound biota are higher than in San Francisco Bay, despite comparably high levels of sediment ΣPCB. Puget Sound is a partially "closed" system for sediment, due to 2 sills near the outlet into the Strait of Juan de Fuca; San Francisco Bay is an open system which loses sediment to offshore currents.

Quantitative food-web models for predicting transfer of ΣPCB from sediment to biota and subsequently through the food-web to higher consumers have been developed for the Great Lakes, San Francisco Bay (Gobas et al. 2010), and, in the Seattle area, for the Lower Duwamish Waterway Superfund Site (Lower Duwamish Work Group, LDWG 2010). For Puget Sound and adjacent Canadian waters, monitoring and modeling efforts by Shaw et al. (2005), West et al. (2008, 2011), Arnot and Gobas (2004), Condon et al.(2005), and Álava et al.(2012) have undertaken to understand effects of ΣPCB (and reported ΣPBDE levels) in Chinook and other species representing diet of SRKW. The West et al. (2011) study confirmed that, for pelagic fish (including hake, which are trophically similar to Chinook

[1] The Σ symbol is used to indicate total as it relates to a sum of PCB or PBDE congeners.

salmon) within Puget Sound, the more developed basins are correlated with higher concentrations of PBTs than less developed or reference basins.

Álava et al. (2012) presents an ecosystem level, steady-state ΣPCB food-web bioaccumulation model subdivided by resident killer whale CH areas including Puget Sound. This model relates ΣPCB content in sediment, surface water, and prey tissue residues to the resident killer whales of British Columbia and Puget Sound. It estimates killer whale uptake based upon equilibrium partitioning calculations from one environmental compartment to another, for example, ΣPCB migration from sediment into surface water, benthos, plankton, benthic fish, pelagic fish, and into killer whales. "Backward" calculations are used to develop a sediment value protective of SRKW by estimating concentrations in Chinook that are associated with critical mammalian toxicological benchmarks. The report states that <u>geometric mean</u> sediment ΣPCB concentrations of 0.058-0.0044 µg/kg dw at 1.9% OC (average organic carbon content for Puget Sound) are "target concentrations that would, once attained, presumably protect (southern) resident killer whales from PCB-related adverse health effects…. This critical concentration may be a useful tool to identify whether areas are at all suitable for disposal of PCB contaminated sediments."

In 2010, following the last PBE for this program, based on the soon-to-be-published Álava et al. model, Canada's Department of Fisheries and Oceans (2010) provided an "advice" paper under Canada's Species at Risk Act (analogous to the ESA) to Environment Canada in order to inform decisions under its Disposal at Sea program. The advice (slightly reworded) follows.

a) Recommends that disposing of dredged material into CH containing ΣPCBs at concentrations higher than ambient PCB concentrations could increase the dietary availability of ΣPCBs to killer whales.

b) Recommends disposal of greater-than-ambient PCB levels into nondispersive (i.e., net depositional) sites as opposed to dispersive sites, in order to bury ΣPCBs, and reduce overall habitat exposure for killer whales.

c) Recommends use of congener-specific (high resolution) methods to characterize ΣPCBs and ΣPBDEs.

d) Notes that, while modeling predicts sediment levels from 0.012 to 0.2 µg/kg dw would protect killer whales, it is acknowledged that many areas are greater than this (both in coastal BC and in adjacent US waters). [2]

e) Recommends additional understanding of ΣPCB pathways in coastal waters, emphasizing sources, sinks, sedimentation rates, and substrate types in dredged and disposal sites to inform future risk-based decisions regarding fate and consequences of disposal activities in killer whale Critical Habitat.

The DMMP was aware of both the "advice" paper and the unpublished model at the time of the 2010 PBE, and participated in a meeting regarding the development of the papers. At the time of the

[2] We note that the sediment numbers mentioned here are 3-4 times higher than those in the later, peer-reviewed Alava et al. (2012) paper. However, as discussed below, both the citations state values that are well below natural background values for Puget Sound in general.

last PBE it was not possible to cite the papers, because they were then confidential Canadian documents subject to internal review. The DMMP PBE did consider the essential information. See Section 6 for this consideration.

This Appendix merges information from the 2010 PBE with updates from the monitoring program over the intervening five years as well as recent dredged material characterizations. It concludes that the programmatic actions of transport, placement, and disposal of dredged materials with biomagnifying substances are unlikely to increase the existing levels of contamination to the food web. Therefore, continued disposal of approved sediments at the DMMP open-water disposal sites in Puget Sound will have discountable effects on ESA-listed species, including SRKW. Continued disposal will also have discountable effects on harbor seals, Steller sea lions and other mammals protected under the Marine Mammal Protection Act.

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Table of Contents

FIGURES

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1. Objectives

This document is an appendix to the Biological Evaluation for the *Continued Use of Dredged Material Management Program (DMMP) Dredged Material Disposal Sites*, *Seattle District, U.S. Army Corps of Engineers*, pursuant to Sections 7(a)(2) and 7(c) of the Endangered Species Act (ESA) of 1973, as amended. It addresses some requirements under the ESA, and discusses biomagnifying compound suites present in dredged material in Puget Sound as they relate to the programmatic actions of determination of suitability of dredged materials for disposal at unconfined, open water disposal sites, and the physical transport and disposal of dredged materials at unconfined, open-water sites in Puget Sound.

As context to this appendix, several lines of evidence suggest that persistent, bioaccumulating toxicants (PBTs) such as polychlorinated biphenyls (ΣPCBs), polychlorinated dioxins/furans (ΣPCDD/F), and polybrominated diphenyl ethers (ΣPBDEs) are entering the food web in Puget Sound at concentrations that may have toxic effects on organisms protected under the ESA or the Marine Mammal Protection Act (MMPA).

This document describes a) the evidence for endangerment and food-web relationships from sediment to Southern Resident killer whale (SRKW, *Orcinus orca*), the Steller sea lion (*Eumetopias jubatus*), and the Harbor seal (*Phoca vitulina*); and b) how the Dredged Material Management Program (DMMP) evaluates its programmatic actions in terms of impacts to mammalian species protected under the ESA and/or MMPA in Puget Sound.

The DMMP is the joint responsibility of the US Army Corps of Engineers (Seattle District USACE), US EPA Region 10, and the State of Washington Departments of Ecology and Natural Resources. Activities addressed under this program include dredged material placement at approved disposal sites, and nondispersive disposal site management. Sediment dredging occurs under individual or nationwide permits granted by USACE, and are scrutinized in Biological Evaluations/Assessments and consultations as needed; the consultation associated with permitting is not addressed in this document.

The endangered population discussed in this paper is the SRKW. The SRKW, as well as the Steller sea lion and the harbor seal are protected under the MMPA.

2. Issue Formulation - Evidence of Effects on Marine Mammals

SRKW are a top predator with both migrant and resident populations in Puget Sound (Calambokidis et al. 1984 and Ross et al. 2000). Critical Habitat has been established for SRKW in Washington waters (Figure 1, page following.) For the location of DMMP disposal sites, compare Figures 7 and 9; all but the Port Townsend site in northern Puget Sound are in SRKW Critical Habitat.

SRKWs have demonstrated significant decreases in population in the last 30 years, likely associated with pollution. Ross et al. (2005) stated:

> "Marine mammals are often exposed to high concentrations of persistent organic pollutants as a result of their long lives, relative inability to breakdown such contaminants, and their high position in marine food chains. We previously demonstrated that southern resident killer whales are heavily contaminated with polychlorinated biphenyls (PCBs). Our harbour seal monitoring work has supported evidence that Puget Sound is a regional PCB hotspot. In a further attempt to characterize local killer whale habitat quality, we measured new generation flame retardants, polybrominated diphenyl ethers (PBDEs), in non-migrating harbour seals from four sites in Washington State and British Columbia. Our results suggest that the largely unregulated PBDEs represent a significant and emerging concern at the top of the coastal food chain. In a study of harbour seal "food baskets", PCBs and DDT represented the major contaminant classes in the diet of Strait of Georgia seals, but PBDEs have taken second place in the diet of Puget Sound seals. Increasing concentrations over time, and higher concentrations in Puget Sound seals and their prey, highlight the emergence of this new concern in this transboundary region. This information should be relevant to Conservation Planning for the southern resident killer whale community."

The recovery plan for SRKW (NMFS 2008), says the following with respect to environmental contaminants:

> "Ross et al. (2000a) described the organochlorine loads of killer whale populations occurring in British Columbia and Washington. Male transient killer whales were found to contain significantly higher levels of total PCBs (ΣPCBs hereafter) than Southern Resident males, whereas females from the two communities carried similar amounts… Both populations had much higher ΣPCB concentrations than Northern Resident whales. A similar pattern exists in Alaska, where transients from the Gulf of Alaska and AT1 communities contained ΣPCB levels more than 15 times higher than residents from the sympatric Prince William Sound pods of the southern Alaska community (Ylitalo et al. 2001). Profiles of specific PCB congeners were similar among the three killer whale communities from British Columbia and Washington, with congeners 153, 138, 52, 101, 118, and 180 accounting for nearly 50 percent of ΣPCB load (Ross et al. 2000a). Recent results from a much broader sample of killer whale communities from the North Pacific suggest that all transient populations and the Southern Residents possess high ΣPCB levels, whereas other resident populations and offshore whales have lower levels (G. M. Ylitalo et al., unpubl. data)."

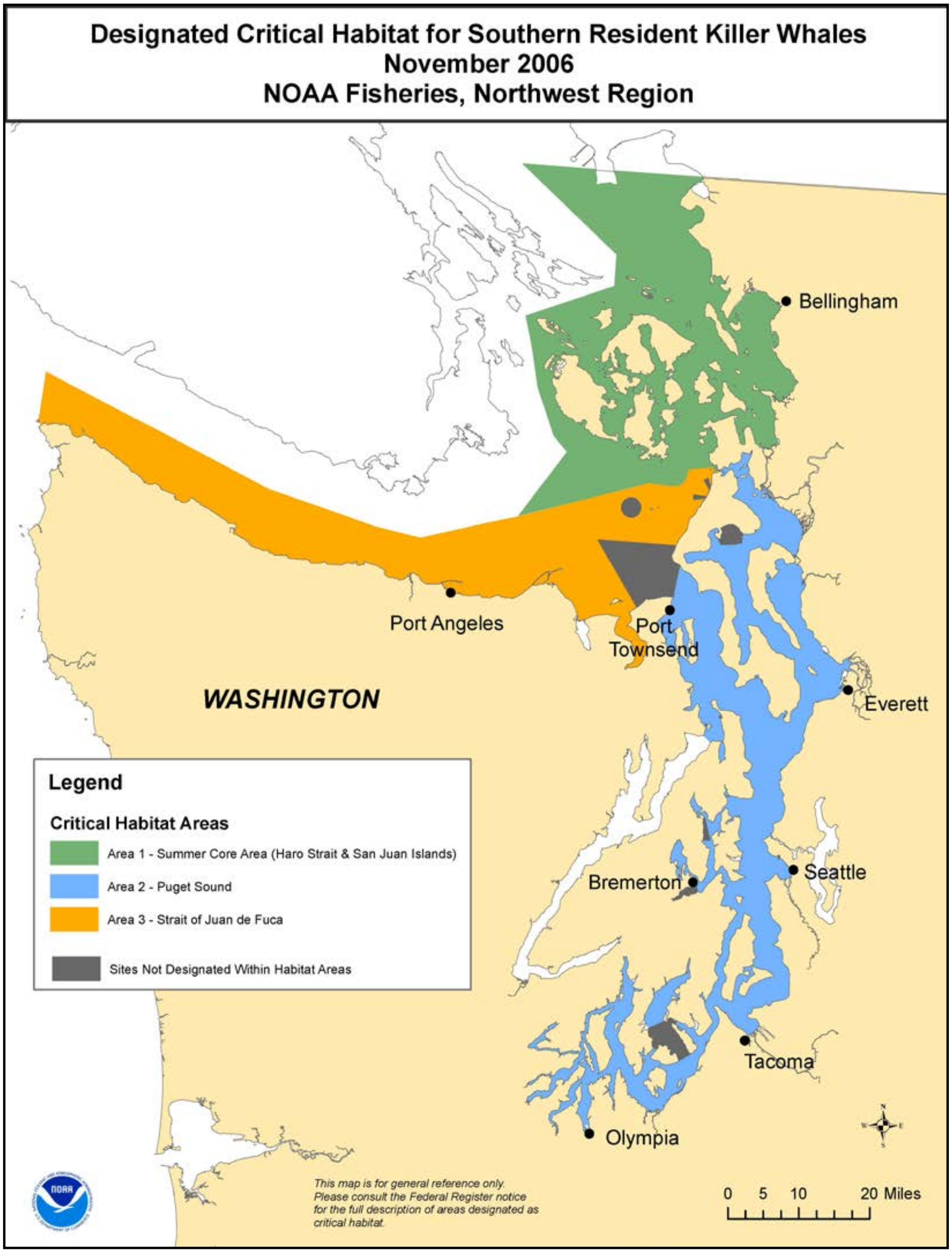

Figure 1. Designated SRKW Critical Habitat in Washington
[http://www.fakr.noaa.gov/protectedresources/whales/killerwhales/attachmentb.pdf

Tissue Levels of PCB in Marine Mammals

Ross et al. (2000) stated, "Southern Resident and transient killer whales of British Columbia can now be considered among the most contaminated cetaceans in the world."   As of spring 2014, the SRKW population totals 80 individuals (J Pod has 25, K Pod, 19, and L Pod, 36).http://www.whaleresearch.com/#!orca-population/cto2

Biomagnification of PCBs into transient killer whale populations is significantly higher than in SRKW or northern resident killer whales, probably related to transient's preferred diet of marine mammals (Hayteas and Duffield 2000, and Ross et al. 2000). Migrant pods may be exposed to more contaminated prey items during migration than resident populations (Hayteas and Duffield 2000).

Regarding harbor seals, Puget Sound populations are more contaminated than the more northerly populations (Figure 2).

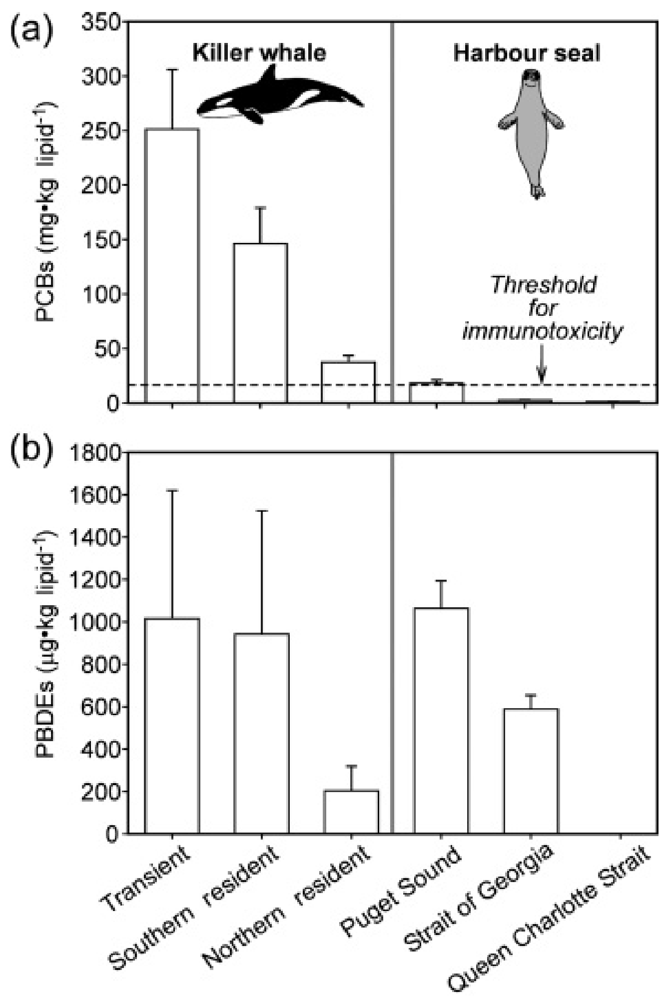

Figure 2. Comparison of Killer Whale and Harbor Seal Body Burdens of ΣPCB and ΣPBDE in US and Canada, from Ross et al. (2000).

Ross et al. (2000) and Krahn et al. (2007) reported SRKW ΣPCB concentrations for the periods 1993-6 and 2004-6, respectively (Figure 3). There is a suggestion of reduction in ΣPCB in male SRKW.

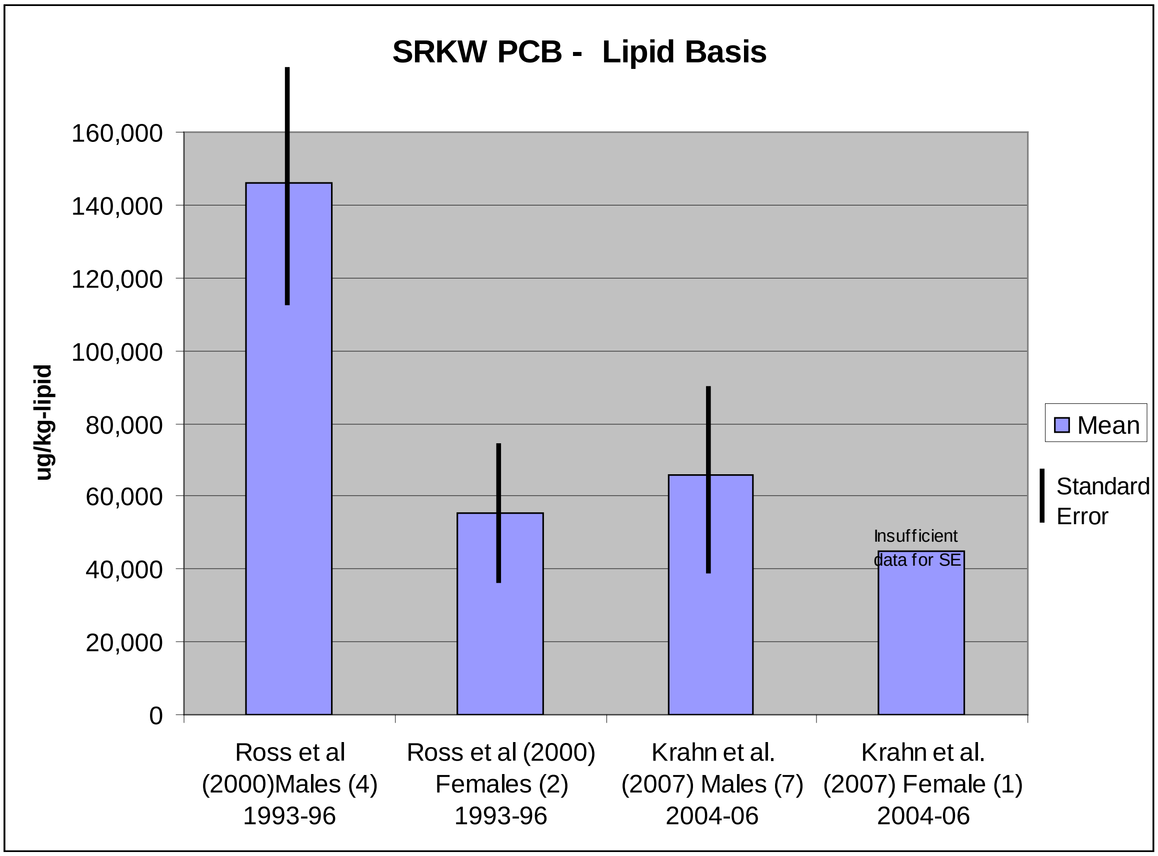

Figure 3. Southern Resident Killer Whale Blubber ΣPCB (regraphed from cited sources)

Resident killer whale populations preferentially feed on Chinook, which comprise about 96% of their total diet (Ross et al. 2000, Hayteas and Duffield 2000, and Jarman et al. 1996). Hanson et al. (2010) estimate from fecal analysis that 80-90% of the Chinook consumed by SRKW originate from the Fraser River (including the South Thompson River), and only 6 to 14% originate from natal streams in the Puget Sound region. However, these latter Chinook have fed in relatively PCB-rich Puget Sound. So, despite a much larger range than Puget Sound and the Straits of Juan de Fuca, a significant portion of the PCB burden in SRKW is believed to come from Puget Sound.

Prey fish concentrations of ΣPCBs from the Puget Sound Ambient Monitoring Program (PSAMP) were summarized in Washington Department of Health (2006). For English sole, all of Puget Sound had a range of 2-462 µg/kg-wet, and a mean of 38.6 µg/kg-wet. In the same units, the following are area-wise means: urban (73.6), near-urban (17.2), and non-urban (9.3). English sole are demersal; therefore their body burdens are better correlated with their location.

O'Neill et al. (2006) noted that Chinook salmon from Puget Sound are approximately three times more contaminated with PCBs than other northeastern Pacific Chinook populations because of the increased residence time of some stocks or individuals in Puget Sound. Wild coho salmon from Puget

Sound also have higher PCB levels than coho from the southern Georgia Basin, likely associated with their longer residence in Puget Sound.

The Puget Sound Chinook-muscle-ΣPCB range was 11-223 µg/kg-wet, with a mean of 73.2 µg/kg-wet for fish caught in saltwater. The means for saltwater Chinook in central and south Puget Sound were very similar (70.6 and 75.6 µg/kg-wet, respectively). Correlation of concentration with location was much less notable with these pelagic fish. DOH (2006) noted that PSAMP data indicated higher PCB concentrations are found in resident Chinook salmon (blackmouth) caught in winter in south Puget Sound than non-resident fish captured in Puget Sound during the spring or fall fishery. The authors used a Washington Department of Fisheries regression model of PCB to body length to estimate PCB concentration in blackmouth muscle tissue could range from 65 µg/kg -wet at the minimum legal length to a large fish with 100 µg/kg - wet.

Herring is a food source for many animals that are higher in the food web. Juvenile and adult herring inhabit the water column and are eaten by seals, diving birds, and many marine fish species including Chinook and coho salmon which are both prey eaten by SRKW. Between 1999 and 2003, PSAMP results from 1,055 three-year old male herring in 6 of 14 major Puget Sound and Georgia Basin stocks were reported by O'Neill et al. (2006). Results are shown in Figure 5 below. ΣPCB in whole bodies of herring from Port Orchard and Squaxin (central and southern Puget Sound, respectively) were four to nine times higher than those from the Georgia Basin. Levels of ΣPCB in Puget Sound herring are similar to levels measured in herring from the Baltic Sea in Northern Europe, one of the most highly contaminated marine ecosystems in the world (O'Neill, et al. 2006)

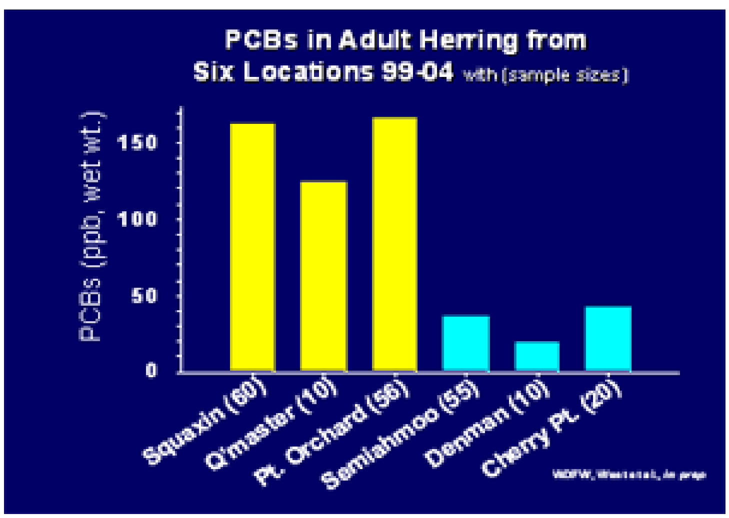

Figure 4. ΣPCB in Adult Herring from Six Puget Sound Locations, 1999-2004.

West et al. (2011) report that for Pacific hake (*Merluccius productus*) and walleye pollock (*Theragra chalcogramma*) tissue PBT data are consistent with other pelagic species such as Pacific herring and Pacific salmon species evaluated previously. Hake are similar in feeding behavior to resident Chinook, and lipid-normalized PCB congener patterns in hake were comparable to those found in Chinook. ΣPCB, PBDE, and organochlorine pesticides occurred in a clear gradient of concentrations, from high in Puget Sound basins that have experienced extensive development, to low in basins where watersheds have been less developed. For ΣPCBs, the data suggest focused, point sources of ΣPCBs that have migrated throughout the ecosystem from urbanized areas over a long period. For ΣPBDE, patterns suggested ubiquitous, terrestrial sources; congener and ΣPBDE patterns were similar across regions, but total concentrations were greater in developed portions of Puget Sound.

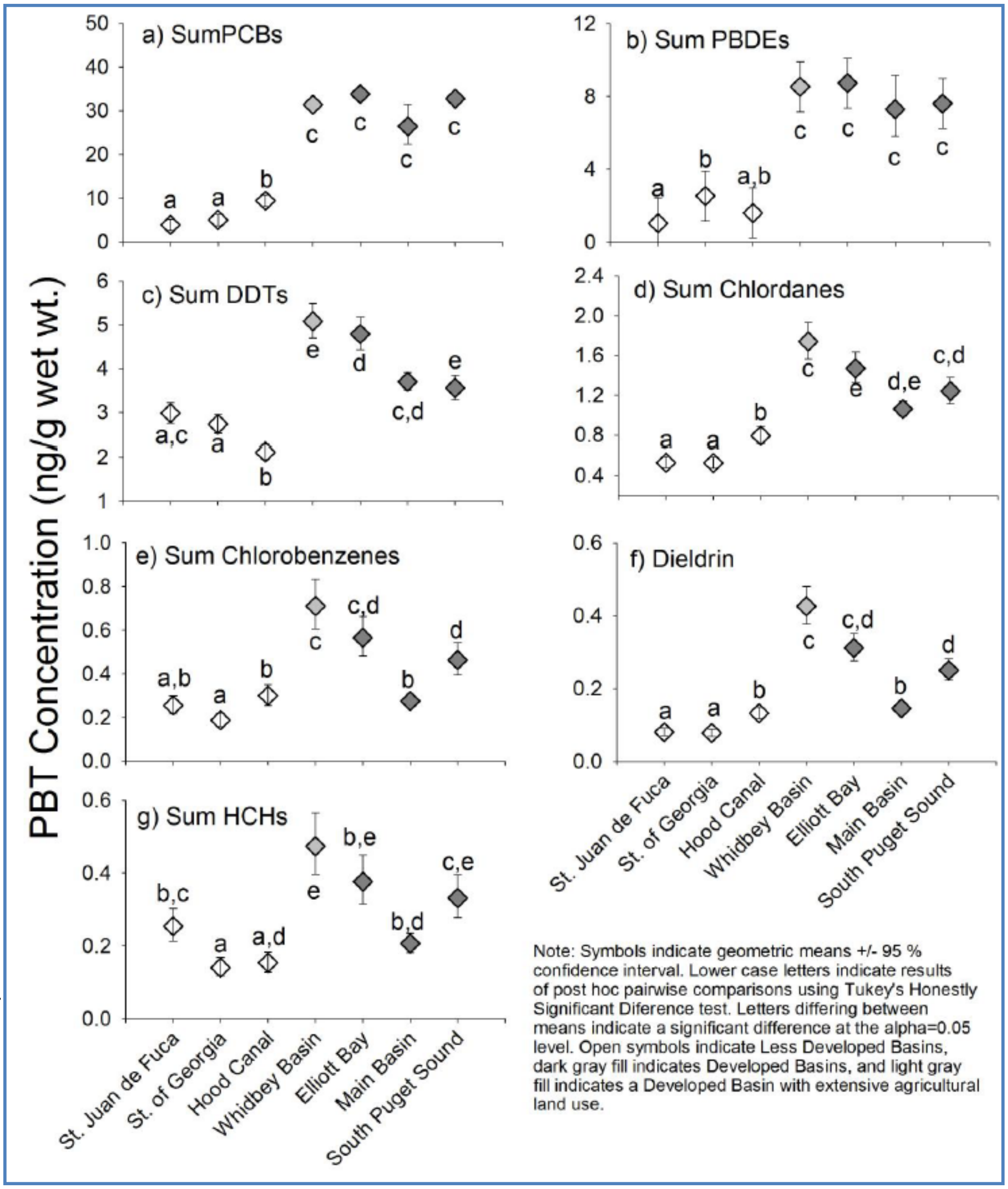

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Figure 5. Summary of seven persistent bioaccumulative toxic chemicals in pre-reproductive Pacific hake from seven sampling Basins in PugetSound. (West et al. 2011)

Steller sea lions declined precipitously in the 1970s to 1990s, and the western distinct population segment (DPS) is listed as endangered. However, the eastern DPS, which includes all Steller sea lions in Washington State, has since recovered and was removed from the list of threatened species in December 2013 (NMFS, 2013). Steller sea lion numbers vary seasonally in Washington, with haulout sites primarily along the outer coast from the Columbia River to Cape Flattery, as well as along the Vancouver Island side of the Strait of Juan de Fuca. This species may also be found occasionally on navigation buoys in Puget Sound. Although breeding rookeries are located along the Oregon and British Columbia coasts, no breeding rookeries are found in Washington (WDFW, 2000). Their prey species consist of fish, bivalves, cephalopods and gastropods, including herring, capelin, sand lance, pollock, mackerel, rockfish , cod, salmon and squid (NMFS, 2014).

Concentrations of ΣPCB in some Steller sea lions from Alaska approach or exceed levels that cause physiological problems in other marine mammals. Myers and Atkinson (2005) measured 239 Steller sea lions from the Gulf of Alaska, pups from southwest Alaska and three captive animals. Myers and Shannon (2005, 2006) noted the following in conference proceedings (slightly rearranged here):

> "Kannan et al. (2000) recommended a PCB threshold concentration of 11,000 ng/g lipid weight for marine mammal blood.
>
> - Western Alaskan sea lion pups' mean ΣPCBs was 5,155 ± 610 µg/kg - lipid weight (below threshold levels). However, 9 out of 76 pups (or 12%) exceeded the threshold concentration.
> - [PCB related] TEQs measured in the blood of immune-compromised harbor seals (DeSwart et al., 1994, 1996; Ross et al., 1995) was 72 pg/g (ng/kg) lipid. Western Alaskan pups' TEQ averaged 71 pg/g (ng/kg) lipid."

Toxic Effects of PCB and PCDD/F on Marine Mammals

These two compound suites' toxicity are treated together, as they are believed to be related. In the petition to list SRKW (CBD, 2001) , the following statements appear (but the words in square brackets are an added clarification).

> "On the basis of studies in other mammals, additional adverse health effects of DDT and metabolites, PCBs, dioxins, and furans are possible in killer whales, and even likely in individuals with high exposure. Exposure to mono-*ortho* and di-*ortho* PCB (non dioxin-like) congeners and metabolites may result in effects not mediated by the same biochemical pathways as 2,3,7,8-TCDD, and therefore not predicted by TEQs. Such effects include neurobehavioral, neurochemical, carcinogenic, and endocrinological changes (Ahlborg et al., 1992). Because these types of effects are difficult to observe in wild populations, there is no way to account for such effects in Southern Resident killer whales with available information.
>
> Direct assessments of DDT, PCB, dioxin, and furan effects in many species of mammals (as well as fish and birds) have proven these organochlorines to be potent agents of numerous adverse health effects (Eisler and Belisle, 1996; Eisler, 1986; Smith, 1991). For example, Beland et al. (1993) and DeGuise et al. (1995) documented high incidences of tumors, including malignant neoplasms, in St. Lawrence beluga whales contaminated with…PCBs, (8.3 – 412 mg/kg lipid weight in blubber) and lower levels of dioxins and furans (Muir et al. 1996). From an Atlantic beluga whale population estimated at 500 animals, 18 collected post-mortem had tumors, a rate of 3.6 percent. The possibility that such effects occur in Southern Resident killer whales is relevant to its risk of extinction: an animal fighting an infection or the development of a tumor, one that has neurobehavioral abnormalities, liver disease or an altered endocrine system, or some combination of these effects, will be less fit for survival in the wild."

Ross et al. (2000) states the following.

> "…low to moderate concentrations of both the `dioxin-like' and the non-`dioxin-like' PCBs, PCDDs and PCDFs are known to cause immunotoxicity, neurotoxicity, reproductive impairment

and endocrine disruption in laboratory animals (Brouwer et al., 1998; Vos and Luster, 1989) and wildlife species (Colborn et al., 1993; Fry, 1995; Guillette et al., 1995; Luebke et al., 1997).

Additionally, PCBs have been linked to cancer in both humans (Bertazzi et al. 2001) and California sea lions (Ylitalo et al. 2005), and are listed as probable human carcinogens by the US EPA and International Agency for Research on Cancer (ATSDR 2000)."

Vitamin A is important in many mammalian developmental, reproductive, and immunological processes. Mos et al. (2007) noted that vitamin A physiology is under strict physiological regulation in all mammals. PCBs and structurally related compounds including PCDD/F can interfere with vitamin A transport, storage and metabolism, thereby promoting more rapid excretion. Observed vitamin A disruption in harbor seals suggests that PCBs are adversely affecting free-ranging marine mammals. Vitamin A may represent a sensitive biomarker in toxicological studies of marine mammals.

Adverse tissue-residue effects concentrations for these compounds for marine mammals are summarized in Table 1. The affected organism is listed in the left column; the basis column shows the tissue residue source. For instance, the first row indicates that mammals may be adversely affected when their tissue residue exceeds the value shown in the third column. The fourth row discloses data based upon observed effects to dolphin as they apply to SRKW tissue residue. Note that all SRKW measured by Ross (2000) and Krahn et al. (2007) (Figure 3) exceeded all of these lipid-based whale-tissue toxicity thresholds. Also, the entire range of the Puget Sound Chinook PCB values cited in DOH (2006) are above the Chinook-based dietary threshold, and the mean is nearly an order of magnitude higher than that threshold.

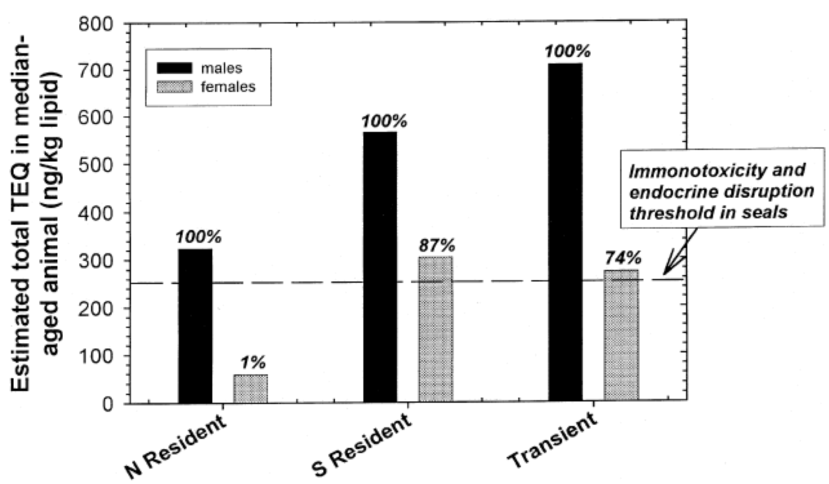
Table 1. Residue-based PCB and PCDD/F TEQ Toxicity Values for Marine Mammals

Compound: Organism (study)	Basis	Residue Effects Concentration
ΣPCB: Toxicity to Fish-eating Wildlife (Hickie et al. 2007)	Marine Mammal Tissue	50,000 µg/kg -wet
ΣPCB: Harbor Seal (Ross et al. 1996)	SRKW Tissue	17,000 µg/kg-lipid
ΣPCB: Revised Harbor Seal (Mos et al. 2010)	SRKW Tissue	1,300 µg/kg-lipid
ΣPCB: Bottlenose dolphin (Hall et al. 2007)	SRKW Tissue	10,000 µg/kg-lipid
ΣPCB: Chinook (Hickie et al. 2007) to protect 95% of SRKW below the toxicity threshold at the top of the table	Chinook Tissue in SRKW Diet	8 µg/kg -wet
ΣPCB: Harbor seal pups (Johnson et al. 2007) [A]	Fish Tissue in Seal Diet	0.8 µg/kg-wet
ΣPCDD/F TEQ (includes ΣPCB): toxicity to Harbor seals (Ross et al. 2005)	Marine Mammal Tissue	255 ng TEQ/kg (lipid)
ΣPCDD/F TEQ: Harbor seals exhibiting immune suppression (DeSwart et al., 1994, 1996; Ross et al., 1995)	Marine Mammal Tissue	72 ng TEQ/kg (lipid)

[A] Johnson et al. (2007) state, "The No Adverse Effects Level (NOAEL) for mink (*Mustela vison* - $NOAEL_{mink}$) was converted to effects levels for harbor seal pups ($NOAEL_{SealPup}$) by scaling the dose to the ratio of mink body weight to body weight (bw) of harbor seal pups: $NOAEL_{SealPup} = NOAEL_{Mink}(bw_{Mink}/bw_{SealPup})^{¼}$ according to the method of Sample et al. (1996)."

Tissue Levels of PCDD/F

Ross (2000) measured ΣPCDD/F dioxin-like Toxicity Equivalents (TEQ) from SRKW Northern Resident, and Transient populations. Unlike ΣPCB, there were no significant differences amongst these populations. Figure 6 illustrates the results, using 1998 Toxicity Equivalence Factors. [3] The authors concluded that, although ΣPCDD/F TEQ is less than PCB dioxin-like congeners, it still exceeds body burdens that are known to represent harm to harbor seals based upon mammalian toxicity equivalence factors. Ross et al. (2004) conclude that it appears that ΣPCB contamination in Puget Sound indicates localized sources, but that ΣPCDD/F are much more widespread (possibly suggesting atmospheric deposition), although there are some source-related signals for PCDD/F for the Strait of Georgia.



Estimated total dioxin Toxic Equivalents (TEQ_{98}; ng kg^{-1} lw) in 12-year-old male and 25-year-old female killer whales from each of the three communities studied. These represent the median ages for the southern resident community, with the age-adjusted estimates allowing for a more direct comparative evaluation of risk among the three communities. Numbers above each bar represent the estimated percentage of males and females from the three free-ranging killer whale communities ($N = 212$, 89 and at least 219 individuals, respectively) in British Columbia that exceed the toxicity threshold established previously for harbour seals (De Swart et al., 1995; Ross et al., 1995).

Figure 6. PCDD/F TEQ from Ross (2000)

[3] These have changed since (WHO 2005), but the changes were not likely to substantially modify these results.

Tissue Levels of PBDE

Harbor seals provide a picture of tissue ΣPBDE that is also relevant for SRKW. Ross et al. (2005) compared PBDE concentrations from harbor seals in British Columbia and Washington (Figure 2). It is clear that harbor seals are significantly more contaminated in Puget Sound. The pattern holds for herring as well (Figure 6), which are a food source for seals.

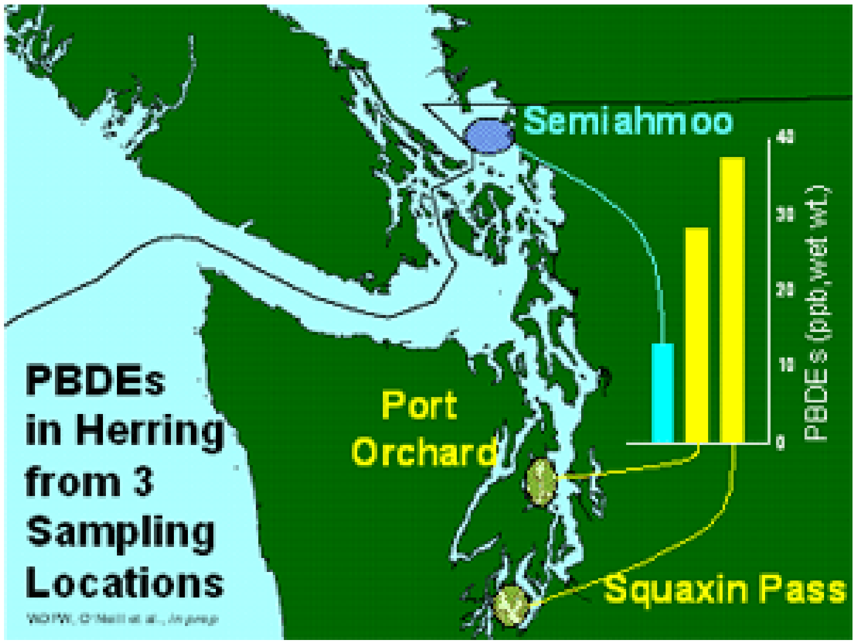


Figure 7. PBDEs in Herring from Puget Sound and Strait of Georgia (Dutch and Aasen 2007)

Ross et al. (2005) state: "An analysis of harbor seal samples collected between 1984 and 2003 revealed that PBDE concentrations in harbor seals from Gertrude Island, South Puget Sound, increased from 15 to 1,064 micrograms of pollutant per kilogram of fat – a meteoric increase of 1500 percent." (Figure 8).

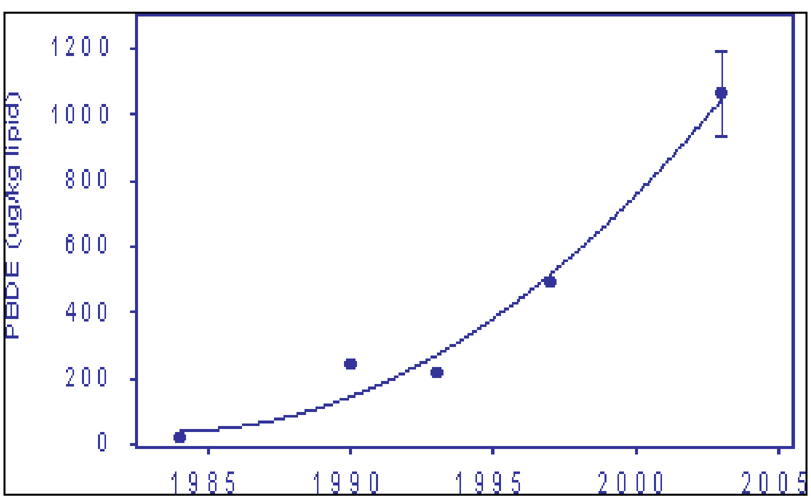


Figure 8. Increase in PBDE in Harbor Seal Fat, South Puget Sound, 1984-2003.

Lebeuf et al. (2004) indicated a ΣPBDE doubling time of 2.2-3 years in beluga whales in the St. Lawrence estuary, and Mongillo (2009) cites research indicating J pod individuals, which frequent Puget Sound, have higher ΣPCB concentrations than the more northerly ranging K or L pods, and the predicted blubber ΣPBDE doubling time for all three pods ranges from 3 to 4 years.

Regarding PBDE in prey fish, Puget Sound Resident salmon sampled in 2003 and 2004 had PBDE at 40 µg/g, about 28 times higher than those levels reported for Chinook salmon returning to northern British Columbia (O'Neill et al. 2006).

Dutch and Aasen (2007) report the following.

> "Eleven of the 12 congeners measured in the sediments were also measured in tissue from 5 species of fish collected from Puget Sound by O'Neill and West, Washington Department of Fish and Wildlife. Of these, seven were detected in the fish tissue, while four (BDE-71, -138/166, -183, and -209) were usually below method detection limits. … All species accumulated BDE-47 in the highest concentrations, while BDE-49 was relatively high in the herring and Chinook samples. Congeners BDE-99 and -100 were relatively high in all species except the Quillback Rockfish. Congeners BDE-66, -153, and - 154 were present, but relatively low in all five species. Levels of PBDEs in English Sole muscle tissue were highest in and near urban/industrial bays and decreased in more rural areas …. Levels of PBDEs in herring tissue were highest in southern [Puget Sound] stocks and lowest in the most northern stocks. Whether high or low, proportions of the various BDE congeners appeared to remain consistent within species between locations."

Toxic Effects of PBDE

PBDEs are a class of endocrine disrupting compounds that have been found to affect neurological development, thyroid hormone levels and immune function in animals (Rayne et al. 2004). Studies in laboratory animals link PBDEs with effects on hormone (thyroid) function, which are critical to normal brain function. PBDEs are very similar in structure to PCBs, are extremely persistent, and bind to sediments and fat. US EPA (2008) issued an Oral Reference Dose for deca-BDE (BDE-209) of 7 µg/kg body weight per day based on rat studies, with an Uncertainty Factor of 300. Deca-BDE is also a *possible human carcinogen* according to the citation. The Oral Reference Dose is not lipid-normalized; the range of average US male and female 30-50 year old body fat is 13-25%, so the lipid-normalized value would be 6.75-54 µg/kg body weight per day [lipid].

Summary of Hazards

There is sufficient information on biomagnification and toxic effects of PCB, PCDD/F, and PBDEs to SRKW, Steller sea lions, and harbor seals in Puget Sound.

3. PCBs, PCDD/Fs and PBDEs in Puget Sound Sediments

This section is intended to provide context for later discussion of the relationship between DMMP actions and the subject species.

a PCB

Estimates of ΣPCB by mass in sediments. Data sets are difficult to compare, and it is difficult to confidently calculate a central tendency measure for Puget Sound. This is because of variable PCB analytical methodologies used in Puget Sound (measuring all 209 congeners, or a subset of 19 congeners multiplied by 2 to equal the 209 [a.k.a the NOAA method], sum of homologues, or Aroclor mixtures), the associated wide range of analytical sensitivities, as well as variable of methods to express results from datasets with a large number of nondetects. From a brief survey of analytical information in 2010, it is apparent that the Puget Sound sediment distribution of ΣPCB is skewed, with extreme values in the Lower Duwamish Waterway, and Elliott Bay, and in Everett Harbor. Based on the following paragraphs, the mean or median ΣPCB concentration in Puget Sound surface (0-10 cm) sediments likely falls between about 3 µg/kg (for nonurban areas) to approximately 54 µg/kg (for a representative mixture of urban and nonurban locations), and into the hundreds of µg/kg in urban Elliott Bay. Thus, estimates of central tendency of ΣPCB from Puget Sound are highly variable, as are the underlying data. It matters greatly whether (and how) urban sites are included in the evaluation.

A query on Washington State's Environmental Information Management (EIM) System conducted for the 2010 Appendix B to the 2010 PBE selected ΣPCB results from the 0-10 cm depth for the years 1998-2009. There were a total of 513 marine subtidal and intertidal samples selected, and the EIM query did not exclude information on clean-up sites, and was not balanced with regard to urban versus nonurban area sampled; both of these facts likely bias the results, and the query is shown only to demonstrate all of the available data from the period. Slightly more than 90% of these data were detected values. The dataset did not conform to any parametric distribution, and a nonparametric (Kaplan-Meier) statistical analysis was conducted using EPA's software, ProUCL version 4.00.04 (most recent version 5.0 – EPA (2013)). The range of minimum to maximum concentrations was 5 orders of magnitude.

Table 2. EIM Query and Dutch et al. (2003) Estimates of Puget Sound ΣPCB by Mass.

Compound(Measure)	n	Minimum	Mean	Maximum
EIM: ΣPCB (µg/kg , congener+Aroclor)	513	0.105	261.2 ± 43.4 (by KM ± Standard Error)	11,000
Dutch et al. (2003) (µg/kg , 19 congeners x 2)	300	8.37	80.23	4,892
Dutch et al. (2003) (µg/kg , detected congeners only)	300	ND	50.11	4,658

The Dutch et al. paper includes information from Long et al. (2003), which evaluated 300 Puget Sound Ambient Monitoring Program (PSAMP) sediment sampling results for ΣPCBs taken from 1997 to 1999. This report appears to be more balanced than the EIM query shown, but does include urban bays. Regional means varied significantly (detected congeners only, in µg/kg): Strait of Georgia (0.1), Whidbey Basin (131.16), Admiralty Inlet (2.42), Central Puget Sound (76.06), and South Puget Sound (3.34).

PCB congener 153 was generally the highest concentration, followed by concentrations of congeners 101, 118, 138. The range of ΣPCBs was 2 orders of magnitude. The distribution of ΣPCB results was highly skewed towards the lower concentrations or non-detected values. Dutch et al. (2003) stated that 21 of the 300 samples exceeded the State of Washington PCB Sediment Quality Standard of 12 mg/kg organic-carbon normalized for ΣPCBs; and that these represented an area of only about 7.2 km^2, or about 0.3%, of the surveyed area of 2,363 km^2.

DMMP (2009) conducted a survey using the US EPA vessel OSV Bold, which showed considerably lower values, as it targeted only nonurban areas of Puget Sound and sought to exclude locations near outfalls or known cleanup sites. Seventy samples were taken.   Only Aroclor 1268 was detected, and that only in 9% of samples, from Carr Inlet, Holmes Harbor, and South Sound. Detected ΣPCBs (Aroclors) ranged from 2.1 µg/kg to 31 µg/kg. A total of 166 PCB individual and co-eluting congeners (shown in brackets) were reported. The pentachlorobiphenyls [90+101+113], [110+115], 118, and the hexachlorobiphenyls [153+168] were detected in 94% of samples. The hexachlorobiphenyls [129+138+163] were detected in 96% of samples. Summarized congener-based sediments in this nonurban study are shown in Table 3.

Table 3. OSV Bold (DMMP 2009) Statistical Summary of Puget Sound Non-Urban Sedimentary ΣPCB and ΣPCDD/F by Mass.

Compound(Measure)	Minimum	50^{th} Percentile	90^{th} Percentile	Maximum
ΣPCB (µg/kg , all congeners; KMSum[A])	0.0385	0.765	2.79	10.6
ΣPCDD/F (µg/kg , all congeners; KM Sum)	0.00582	0.112	0.282	0.485

[A] Kaplan-Meier Summation is a nonparametric technique for summation without using surrogate values for nondetected congeners

The State of Washington Department of Ecology's (2013) Draft Sediment Cleanup Manual II (SCUM-II) used the concept of "natural background" to set final cleanup criteria for PBTs (and other contaminants) unless risk-based values are higher.

> *"Natural background means the concentration of a hazardous substance consistently present in the environment that has not been influenced by localized human activities. For example, several metals and radionuclides naturally occur in the bedrock, sediment, and soil of Washington state due solely to the geologic processes that formed these materials and the concentration of these hazardous substances would be considered natural background. Also, low concentrations of some particularly persistent organic compounds such as polychlorinated biphenyls (PCBs) can be found in surficial soils and sediment throughout much of the state due to global distribution of these hazardous substances. These low concentrations would be considered natural background."* Washington Administrative Code (WAC) 173-204-505(11).

The draft SCUM-II states the means of determining natural background is an expanded OSV Bold dataset, defined by the 90th percent upper tolerance limit on 90th percentile coverage. No data are included in the manual for ΣPBDEs.

Table 4. Puget Sound Natural Background (Ecology 2013)

PBT	Puget Sound Natural Background
ΣPCB (congeners)	3.5 μg/kg dw
ΣPCB (2,3,7,8-TCDD Toxicity Equivalents)	0.2 ng TEQ/kg dw
ΣPCDD/F	4 ng TEQ/kg dw

Ecology has also developed the concept of "regional background" intended to include concentrations of chemicals that are primarily from diffuse sources such as storm water and atmospheric deposition, but can also include chemical concentrations from "globally" distributed sources. Regional background requires determinations by Ecology and for most sites is not currently available.

Information compiled for the Lower Duwamish Waterway Superfund Site Feasibility Study (LDWG 2012) includes PCB data from Washington Department of Ecology and King County in the Green River above the Lower Duwamish Superfund Site. These data are being used to ascertain inputs to that urbanized water- and air-shed to support the ongoing bed-load estimates Feasibility Study. The data include sediments and suspended solids quantified by the congener method for PCBs. These data suggest a baseline input to the river and Sound from the Seattle area near the high end of the mean values for the foreseeable future. The data in Table 5 are King County 2004-2007 data.

Table 5. Statistical Summary of ΣPCB by Mass in Urbanized Freshwater Bodies Draining into Puget Sound

Compound(Measure)	n	Minimum Detected	Median	Mean	Maximum
Sediment in Green River; ΣPCB (µg/kg , congener; 0.5*DL method)	73	0.3	10	17	140
Suspended Solids in Green River; ΣPCB (µg/kg, congener; 0.5*DL method)	29	1	11	42	367
0-2 cm in Lake Washington; ΣPCB (µg/kg, congener; 1*DL method; recalculated from gamma distribution)	52	1.8	11	14.3	57

Also in Table 5, Era-Miller (2010) surveyed the top 2 cm of sediments in Lake Washington for ΣPCBs by the congener method. The study included modeling of biomagnification into northern pikeminnow. The model was determined to be sensitive to freely-dissolved water concentrations (which, however, were not measured in the study).

Figure 9 displays the marine ΣPCB data and suggests a plausible range for average Puget Sound ΣPCBs (µg/kg) for datasets that include some urban samples; it also includes Ecology's natural background for comparison.

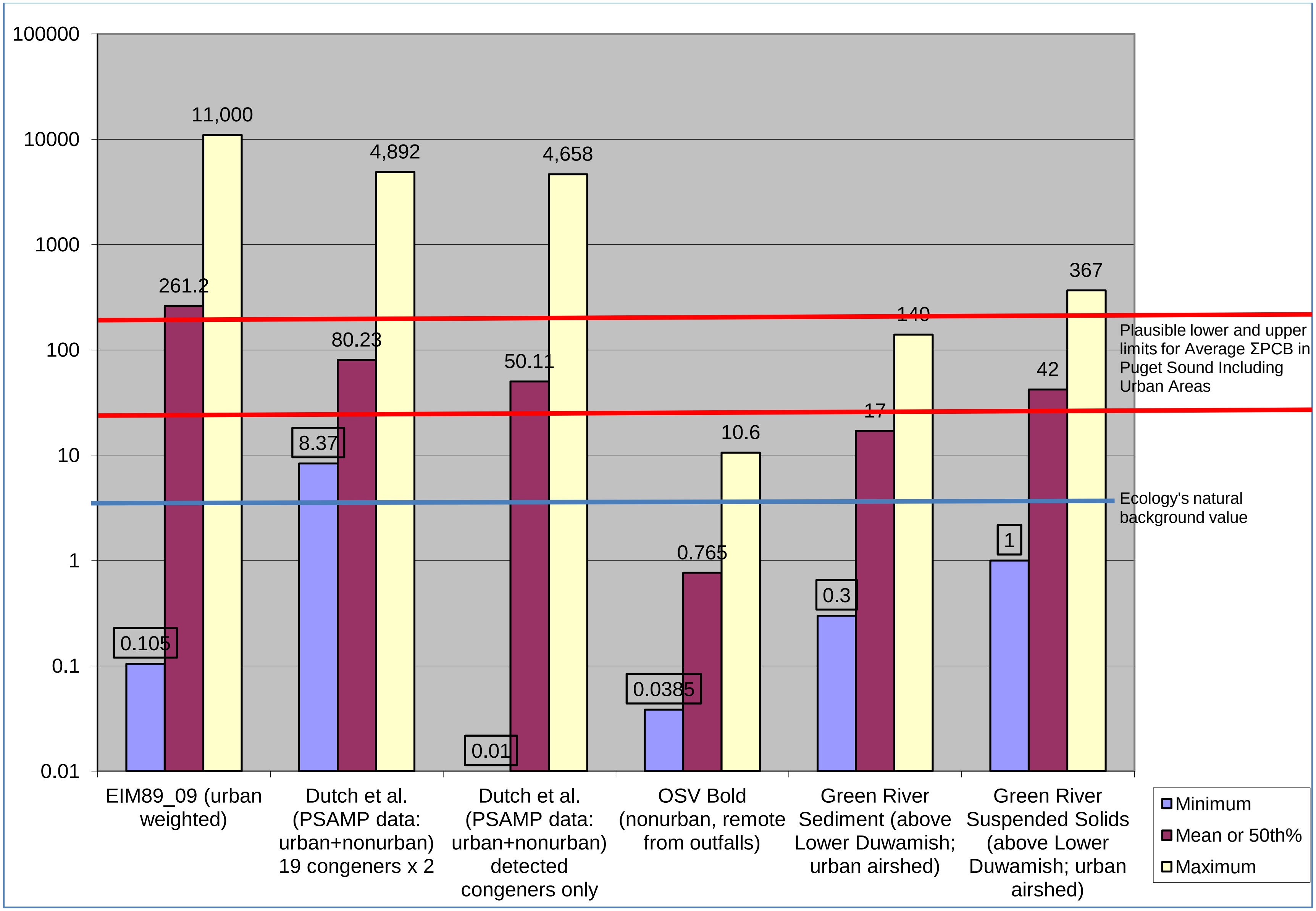


Figure 9. Synopsis of Puget Sound sediment ΣPCB (µg/kg dw) from several surveys, and comparison to Ecology's natural background (blue line)

Estimates of PCB by sediment toxicity equivalents (TEQ) to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

Inouye (2009) presented a paper at a June, 2009 DMMP Dioxin Workshop which described a query on the EIM database for Puget Sound marine sediment ΣPCB, and estimation of PCB TEQs from congeners. [4]

Table 6. PCB TEQ from Washington Department of Ecology EIM Database With and Without Cleanup Sites.

Summation Method	n	Minimum, ng/kg	50th Percentile ng/kg	90th Percentile, ng/kg	Maximum, ng/kg
All EIM Stations					
SUM TEQ (ND=0)	1,649	0	0.06	0.06	1,359
SUM TEQ (ND=0.5*DL)		6E-05	0.18	0.36	1,384
EIM Minus Cleanup Sites					
SUM TEQ (ND=0)	803	0	0	0.18	140
SUM TEQ (ND=0.5*DL)		6E-05	0.05	0.25	140

In the DMMP (2009) Bold study, PCB congener TEQs were calculated using the World Health Organization (2005) toxic equivalency factors for mammals, and the Kaplan-Meier nonparametric method for summation of non-detected values. The non-urban sites in this study (Table 7) were significantly lower than those reported by Inouye (2009), which included urban areas (Table 5). Figure 9 compares the values from EIM and Bold. Figure 10 shows a map of the Bold TEQ results.

Table 7. OSV Bold (DMMP 2009) Statistical Summary of Puget Sound Non-Urban Sedimentary PCB and PCDD/F by Toxicity Equivalents.

Compound(Measure)	Minimum	50th Percentile	90th Percentile	Maximum
Bold PCB TEQ (ng/kg, dioxin-like congeners, KMSum)	0	0.0035	0.0071	0.168
PCDD/F TEQ (ng/kg, 2,3,7,8-chlorine-substituted congeners, KMSum)	0.047	0.774	2.69	11.6

Figure 10 shows the distribution of PCB TEQ in the OSV Bold survey.

As noted in Table 4, Ecology selected a natural background for PCB TEQ of 0.2 ng TEQ/kg dw and PCDD/F 4 ng TEQ/kg, based upon an expanded (“Bold Plus”) dataset.

[4] http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/DMMP_Draft_PCB_presentation_062409.pdf

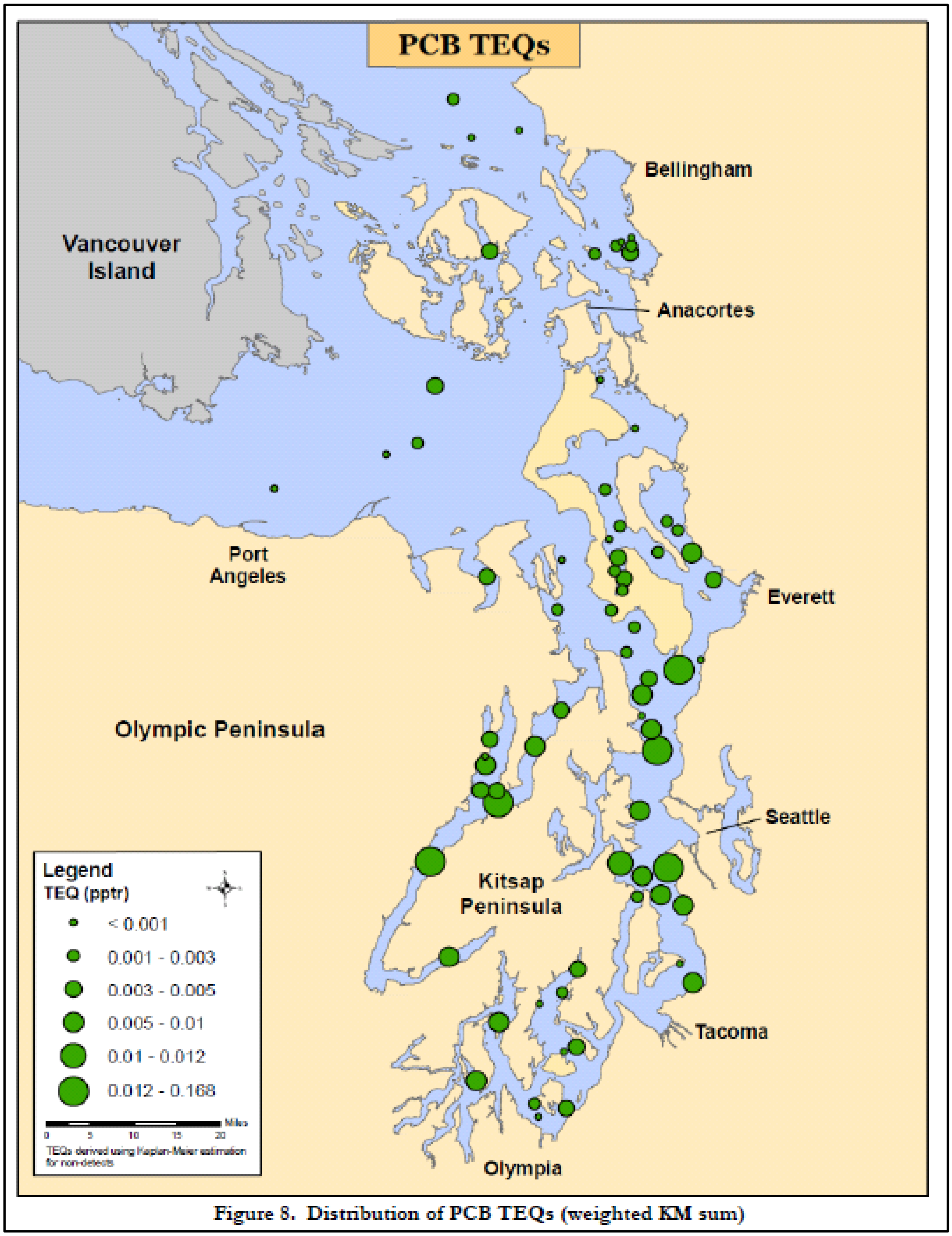


Figure 10. PCB TEQs from DMMP (2009)

Ecology (2011, shown in Figure 11 below) estimated annual atmospheric and runoff loadings of ΣPCBs to the surface of the Puget Sound, using three scenarios: scenario 1 - no seasonal or spatial differentiation, scenario 2 - spatial differentiation of sub-basins, and scenario 3 - spatio-temporal differentiation of fluxes in sub-basins. The atmospheric loading estimates are shown in a dot and whisker plot with the dot representing the 50^{th} and the whiskers the 25th and 75th probability of exceedance for atmospheric deposition (ATMDEP) and surface runoff (RUNOFF) loading of ΣPCB.

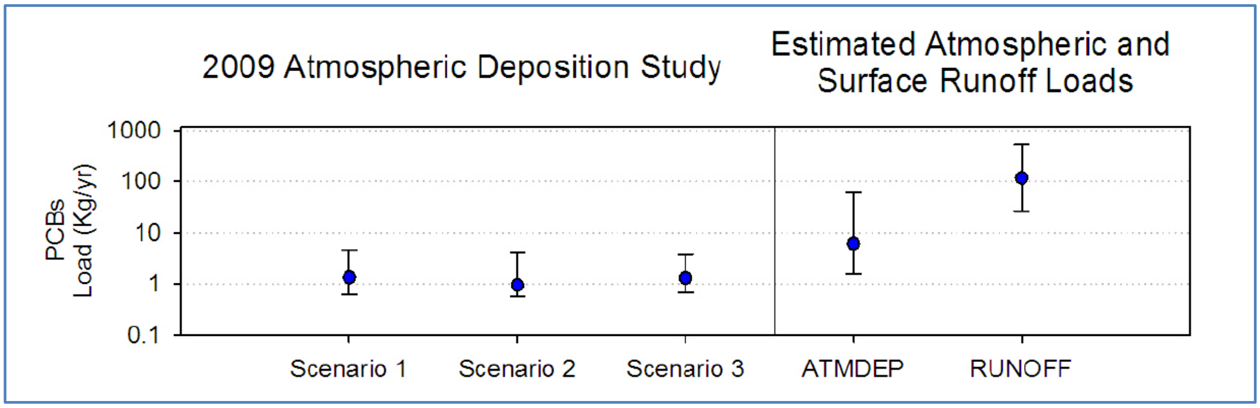


Figure 11. Ecology Loading Calculations for ΣPCB in Puget Sound (total area)

b. PCDD/F

This URL (http://www.nws.usace.army.mil/Missions/CivilWorks/Dredging/Dioxin.aspx) summarizes ΣPCDD/F TEQs for Puget Sound, Grays Harbor, and adjacent freshwater bodies. Puget Sound is shown in Figure 12. As noted above, Ecology (2013) has recommended additional reference sediment samples (the "Bold Plus" dataset) available in an appendix to the citation.

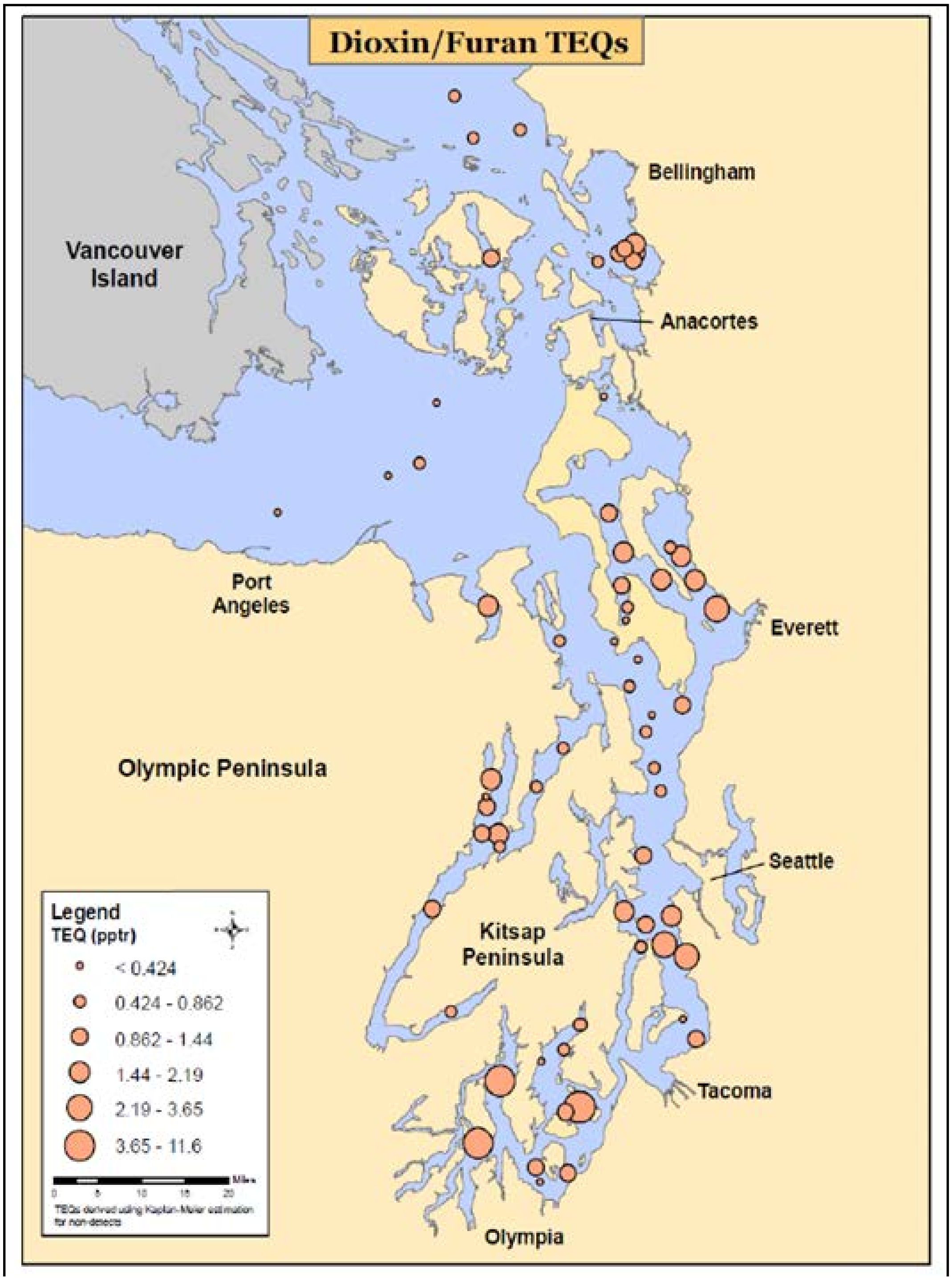


Figure 12. Distribution of PCDD/F in Puget Sound

c. PBDE

Ross et al. (2009) state the following.

> "…the single congener BDE-209, the main ingredient in the Deca-BDE formulation, has surpassed the legacy PCBs and DDT as the top contaminant by concentration. Limited biomagnification of BDE-209 in aquatic food webs reflects its high log K_{ow} and preferential partitioning into the particle phase. As a result, large environmental reservoirs of BDE-209 are being created in sediments, and these may present a long-term threat to biota: BDE-209 breaks down into more persistent, more bioaccumulative, more toxic, and more mobile PBDE congeners in the environment."

Information in Figures 13 and 6 is excerpted from a poster by Dutch and Aasen (2007). They indicate that, in terms of PBDE tissue concentration, and a predominance of higher molecular weight congeners, Central Sound is more highly contaminated than North Sound, which is more contaminated than South Sound.

> "In April 2005, the 5 penta-BDE congeners measured in 2004 … BDE-209, the primary congener in commercial deca-BDE mixtures; and BDE-49, -66, -71, -138, -183, and -184, were measured at ten PSAMP temporal stations located throughout Puget Sound. Of 422 measured values, 16% were detected, while 83% were undetected. As in Hood Canal, BDE-47 and -99 were detected most frequently. Congener BDE-47 was detected at all 10 stations; while BDE-99 was detected at 5 stations, including the deep, depositional Shilshole Bay (sta. 29) and Point Pully (sta. 38) stations, and the stations near urban/industrial areas including Port Gardner (sta. 21), Sinclair Inlet (sta. 34), and the Thea Foss Waterway (sta. 40). Congener BDE-209 was also detected at these 5 stations, and at the station in Budd Inlet (sta. 44). Congeners BDE-49, -66, -71, and -100, were detected at 3, 1, 2, and 1 station(s), respectively."

In 2010, USACE performed an EIM query for marine sediments in Puget Sound. Sample-wise ND=0 and Kaplan-Meier statistics were used due to inconsistent reporting (many samples only list a subset of congeners without showing associated detection limits for the non-reported ones), and variable detection limits.

Table 8. Statistical Summary of PBDEs from 2010 EIM Query for Puget Sound Sediments (dry weight).

Data Set	n	Percent Detect	Minimum Detect µg/kg	Maximum Nondetect, µg/kg	50^{th} Percentile µg/kg	90th Percentile, µg/kg	Maximum, µg/kg
ΣPBDE	201	91.54	0.069	5.5	3.7 ± 0.496	12.69	42.67

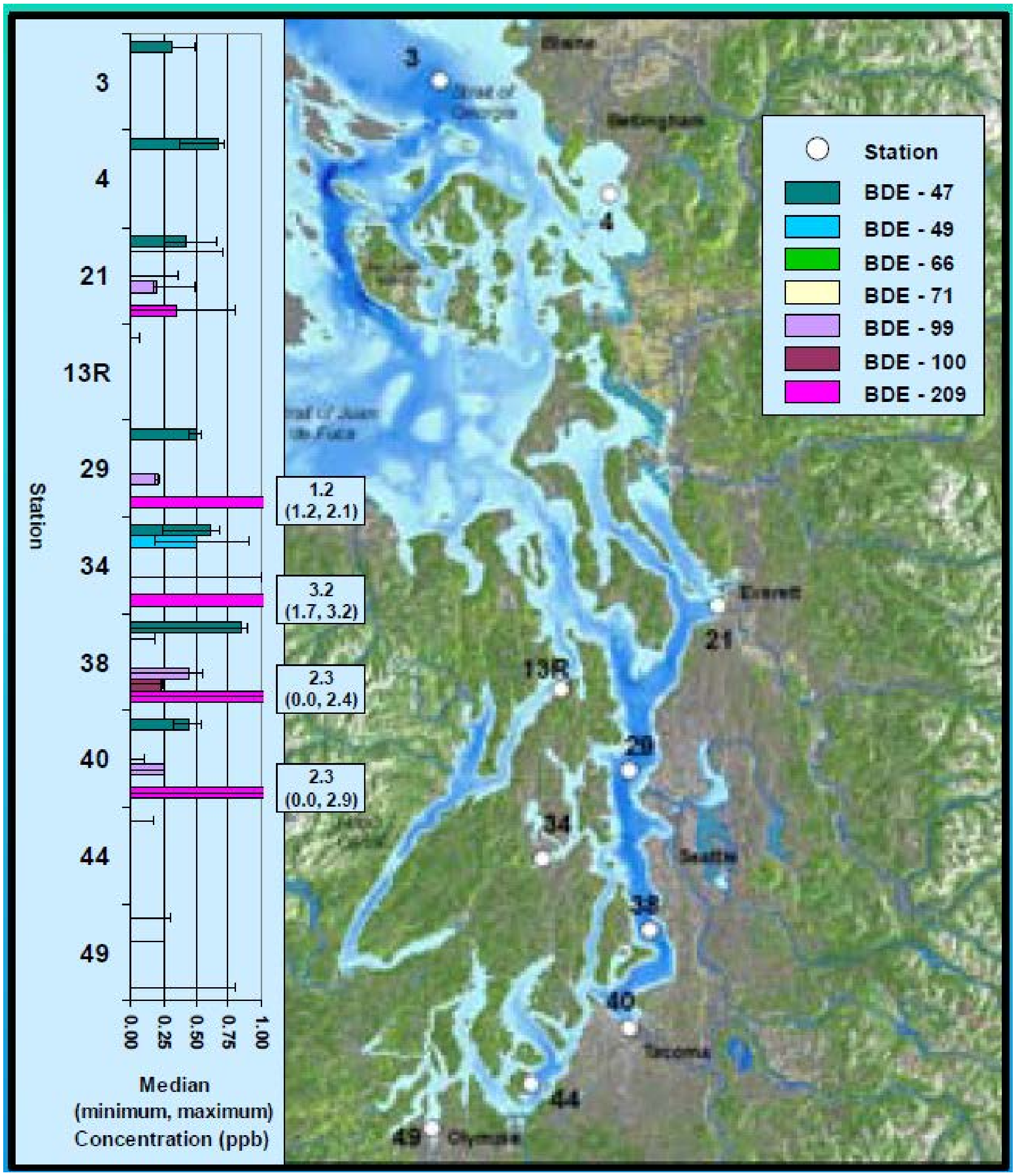


Figure 13. Distribution of PBDE congeners in Puget Sound Sediments (from Dutch and Aasen, 2007)

Ecology (2011) has estimated atmospheric flux of PBDE to the surface of Puget Sound. The median atmospheric deposition flux of total PBDE was 7.0 ng/m2/d. The urban/industrial sites of Tacoma have significantly higher total PBDE fluxes than all other study stations, which were statistically similar; see Figure 13. The dry season has higher fluxes than the wet season for PBDE. Among all target PBDEs measured, BDEs-47, 99, and 209 are the major congeners in the samples and BDE-209 is the most abundant congener. The proportional contribution of these three congeners is similar across sampling stations in Puget Sound, suggesting there is a regional consistency in the sources. Ecology's estimated median mass loading of total PBDE in Puget Sound ranges from 15.6-20.3 Kg/yr, using three estimation scenarios (described above for ΣPCB loading). The report notes that a similar magnitude of median PBDE mass loading (17.1±6.5 Kg/yr) was reported for the Strait of Georgia, which has a similar surface area to Puget Sound.

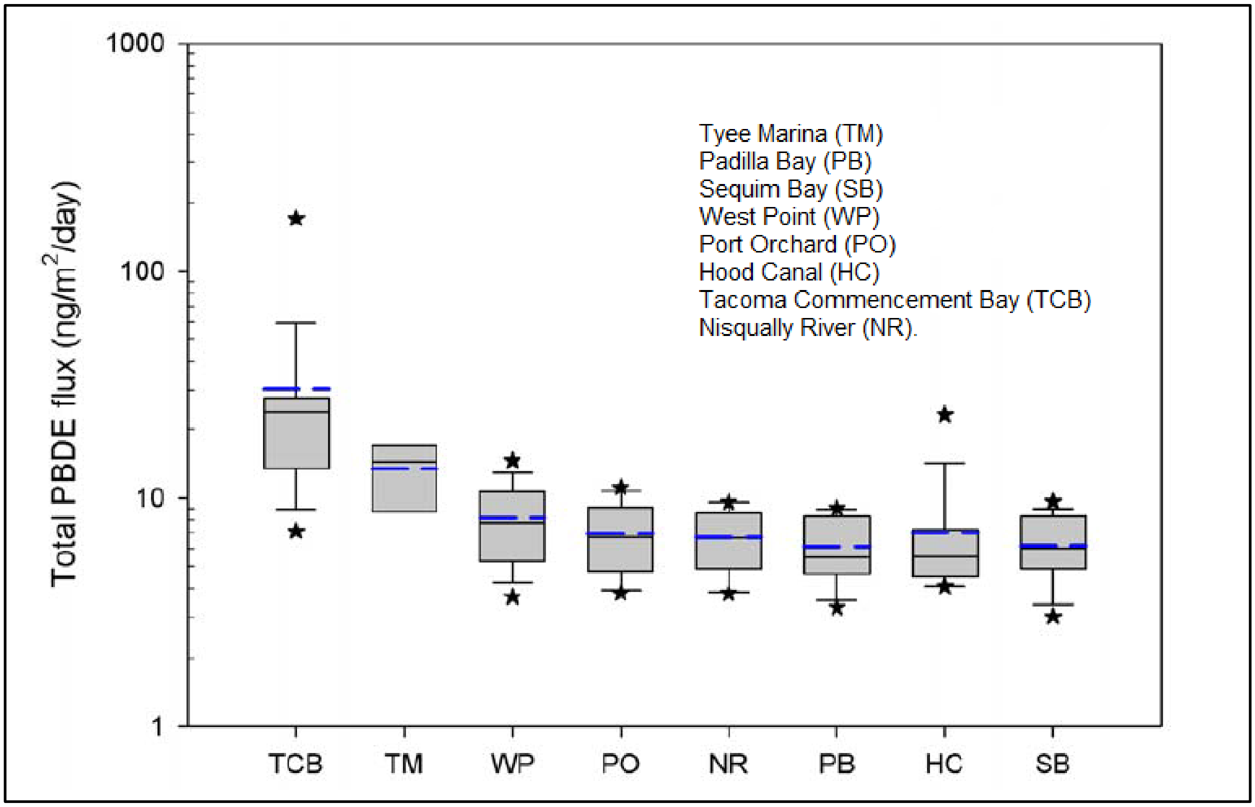


Figure 14. Total PBDE Flux to Puget Sound at Several Stations (Ecology 2011).

4. Current Programmatic DMMP Considerations of ΣPCB, ΣΣPCDD/F, and ΣPBDE

Under the DMMP, disposal-site-related effects including toxicity and bioaccumulation are limited to "minor adverse" effects to benthic organisms, as determined through testing for chemistry, toxicity, and (for persistent bioaccumulative toxicants) bedded bioaccumulation tests. At times, site specific evaluations including risk assessment and trophic modeling are used as tools for making this determination. The *Users' Manual* (DMMP 2013) describes dredged material testing procedures. Sediments proposed for disposal associated with an unacceptable level of adverse effect must be disposed of at an approved upland confined disposal site, or in an approved confined aquatic site. For PCBs, testing for benthic toxicity is required above the screening level; and testing for bioaccumulation potential above a bioaccumulation threshold. For ΣPCB, these consist of a benthic toxicity triggered by 130 µg/kg-dry, and human health effects triggered by the bioaccumulation trigger of 38 mg/kg (organic carbon normalized) which, if exceeded in dredged materials proposed for unconfined, open-water disposal leads to bioaccumulation testing using benthic test species listed in Section 10.2 of the cited manual. For the Elliott Bay site (only), a benthic target tissue level of 0.6 mg/kg ww was established for protection of human health (Section 10.4 of the manual). Significance of bioaccumulation is presently determined by comparison to a tissue-based toxicity threshold, based upon subsistence fishers' consumption of seafood.

The DMMP list of Bioaccumulative chemicals of concern includes ΣPCB and ΣPCDD/F. ΣPCDD/F are chemicals of concern for limited areas in the DMMP, and have become routine for all projects in DMMP within reason-to-believe areas since 2007. Because safe sediment values that relate to human health for seafood consumption appear to be below background values, the DMMP has proposed a "background-based" sediment management goal for nondispersive and dispersive sites. The DMMP agencies (DMMP, 2010) proposed an interim Puget Sound non-urban-background-based criterion for the placement of sediments at dispersive sites, and for non-dispersive sites a background-based goal that would be adaptively managed. This is 4 ng TEQ/kg, which approximates the 90^{th} percentile of nonurban sites. [5]

The DMMP actively seeks to review the list of PBTs that are chemicals of concern, based on emergent information regarding bioaccumulation, biomagnification and toxicity. A list of "candidate" chemicals of concern currently (DMMP 2003) includes ΣPBDE; but this compound suite has not yet been determined necessary to test in all dredged material to date. However, Federal projects are tested as funds are available, and nondispersive site monitoring includes PBDE.

Materials proposed for placement at Puget Sound open-water sites are tested to assure that they do not exceed contaminant thresholds. Striplin et al. (1991) showed that non-dispersive site concentrations predicted based on volume-weighted averages from characterization were similar to actual monitoring data from these sites. The DMMP has committed to adaptively managing the non-dispersive sites for ΣPCDD/F, and is considering additional revisions to address ΣPCB.

The DMMP is committed to updating its programmatic guidelines with the most relevant scientific information related to the consequences of its activities. Scientific literature has increasingly indicated

[5] The DMMP agencies added several existing reference studies to the OSV Bold data set in making this determination. This explains slight variance with Table 6.
http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/DMMP_Proposed_Changes_to_Interim_Guidelines_for_Dioxins_4-19-2010.pdf

that members of top marine mammal species are adversely affected by persistent and toxic organic compounds that biomagnify (i.e., increase in concentration in tissue towards higher trophic levels). The compound suites discussed in this paper – ΣPCB, ΣPCDD/F, and ΣPBDE – are believed to be the chief biomagnifying compounds affecting marine mammals in Puget Sound. Biomagnification to upper trophic levels may occur at hundreds or thousands of times greater than environmental concentrations. Section 2b below describes the rationale for concern for biomagnification of these compounds, which may occur at low levels in dredged materials handled in the program.

The following paragraphs summarize programmatic considerations. To date, the DMMP has generally only evaluated ecological effects to lower trophic levels, including site benthos and bottom-foraging fish, and also prospective effects to human health. This is because the quantitative linkage between open-water dredged material disposal and prey species for marine mammals is highly uncertain. Open water dredged material disposal sites are generally in deep Puget Sound waters (Rosario Straits and Bellingham Bay sites are exceptions). All dredged material unconfined, open-water sites were selected for low quantities of benthic organisms relative to their surroundings, and represent areas of low resource density compared to most of Puget Sound. Thus, site management has focused on effects arising from anticipated close contact of sediment and site biota.

Chinook salmon are a pelagic species that constitute about 96 % of the food source for SRKW-- Ross et al. (2000). Programmatic evaluations of potential effects due to dredged material placement on Chinook have cited the low likelihood of exposure to site chemicals. To illustrate, the following text is abridged from the PBE, which has citations to support the statements.

- Although adult and subadult Chinook salmon may coincidentally occur near areas of disposal activities, there are no site features that would encourage Chinook salmon to congregate.
- During disposal, Chinooks' exposure to dredged material related substances would be very short-term, a matter of minutes to an hour.
- The potential for toxic effects of contaminants released from discharged sediments is minimal, since sediments have been subjected to a series of physical, chemical and biological testing procedures and thorough review by the regulating agencies and the public.
- Other than minor transitory effects during disposal activities, foraging habitat for Chinook would not be adversely affected by transport, placement, and management of the sites, as adult and sub-adult Chinook primarily feed on pelagic organisms that do not typically feed at depths of dredged material disposal sites.
- Chinooks' forage base would not be significantly affected by disposal activities. Herring and sandlance spawn in intertidal and shallow subtidal areas. Although sandlance can sometimes rest on the bottom, this typically occurs in less than 100 meters of water, shallower than most DMMP sites.
- Dredging activities and associated disposal activities are regulated to avoid out-migrating juvenile Chinook as they migrate from rivers to the Sound in the spring. During the early phases of estuarine/Puget Sound residence, juveniles reside in near-shore waters (typically no deeper than 30 to 70 meters) feeding on epibenthic and pelagic organisms, which would be unaffected by disposal activities. Most juveniles continue to occupy the nearshore environment during their migration to the Pacific Ocean, although they could coincidentally occur in surface waters near dredged disposal areas. Effects of elevated water column suspended sediments would be short in duration and localized (as noted above), and are not expected to adversely affect migrating juvenile salmon.

Accurate prediction of effects from disposal events and sites to reflect trophic links to pelagic organisms such as Chinook is difficult. Benthic fish, such as halibut, English sole, and sablefish are eaten by SRKW (although at a low percentage of the diet), and by Steller sea lions and harbor seals; these fish may forage at both nondispersive and dispersive dredged material sites. The DMMP monitoring program periodically checks benthos in the vicinity of the nondispersive sites for elevations in tissue chemistry for ΣPCB. In some instances, fish trawls have been made as well. However, the program has not used a mechanistic multi-level trophic model to marine mammals because there are many uncertainties, and confirming links to pelagic food webs is a difficult undertaking. These include the following.

- Trophic relationships/pathways are documented in the literature, but fish behavior, including feeding ranges and the time a forage fish could potentially be exposed to site related chemicals are not sufficiently known at this time.
- DMMP requires characterization of dredged material by the less sensitive Aroclor method, but is considering, as presented at the 2014 Sediment Management Annual Review Meeting, more precise methods including both the lower resolution GC/MS homologue method and the high resolution GC/MS congener methods.[6] The high-resolution congener method has been used in nondispersive site monitoring since 2010, and in selected Federal navigation dredging programs; it is not required for all projects.
- ΣPBDEs have been added to the DMMP's list of potentially bioaccumulative substances for nondispersive site monitoring. Recent data are summarized for Port Gardner and Elliott Bay nondispersive sites, using a more sensitive method.
- ΣPCDD/F have been used since before the 2010 PBE for nondispersive sites.
- No existing trophic model is at a suitable scale nor calibrated to estimate trophic effects arising from dredged material management sites and activities.

The DMMP addressed bioaccumulation and biomagnification for PCDD/F in fish and crabs for the first time in 2006-7, and used both a trophic model (Gobas, 1993) and subsequent monitoring for the non-dispersive South Sound Anderson-Ketron site; model predictions were within 200% of the findings, although the model tended to predict high. The only analyte suite considered was PCDD/F, due to low concern for PCBs at this site. Crab were evaluated using published biota-sediment accumulation factors, but not modeled. Higher trophic modeling (for instance, from benthos to plankton to pelagic predators) was not believed warranted. Biomagnification for herring and Chinook were not evaluated, as water depths were greater than adult Chinook frequent while feeding, and due to the scarcity of benthic fauna at the site, the water depth, and the low solubility of PCDD/F (as determined from the literature).

For SRKW, a small proportion (<4%) of benthic prey species such as halibut, haddock, and sablefish are present in the diet. For Steller sea lions and seals, the proportion of bottom fish and other benthic species is higher. However, it is unlikely that either Steller sea lions or seals would spend time foraging at the depths of the sites. The pathway to their food would likely include migrating fauna; such migration patterns confound and attenuate the influence of each site on higher predators. Additionally, Steller sea lions are only present in Puget Sound for a short portion of their annual cycle. Contribution of the dredged material placed at open-water sites to exposure by these animals is indirectly and

[6] The most recent presentation is http://www.nws.usace.army.mil/Portals/27/docs/civilworks/dredging/SMARM%20minutes/SMARM-2014-Minutes-Final%20.pdf -- paper 10: Results of PCB Homologue Studies.

indefinitely linked to their consumption by marine mammals, and where it occurs, should be considered in the context of the Puget Sound background levels for ΣPCB, ΣPCDD/F and PBDE.

5. Site Chemical Inventories for PCB, PCDD/F and PBDE

The purpose of this section is to update the quantities of dredged material placed at DMMP disposal sites in Puget Sound, and the inventory of PCB, PCDD/F, and PBDE in context of vicinity and background ranges of the chemicals. Cumulative site use statistics for volume of materials placed from program inception to date are shown in Figure 15.

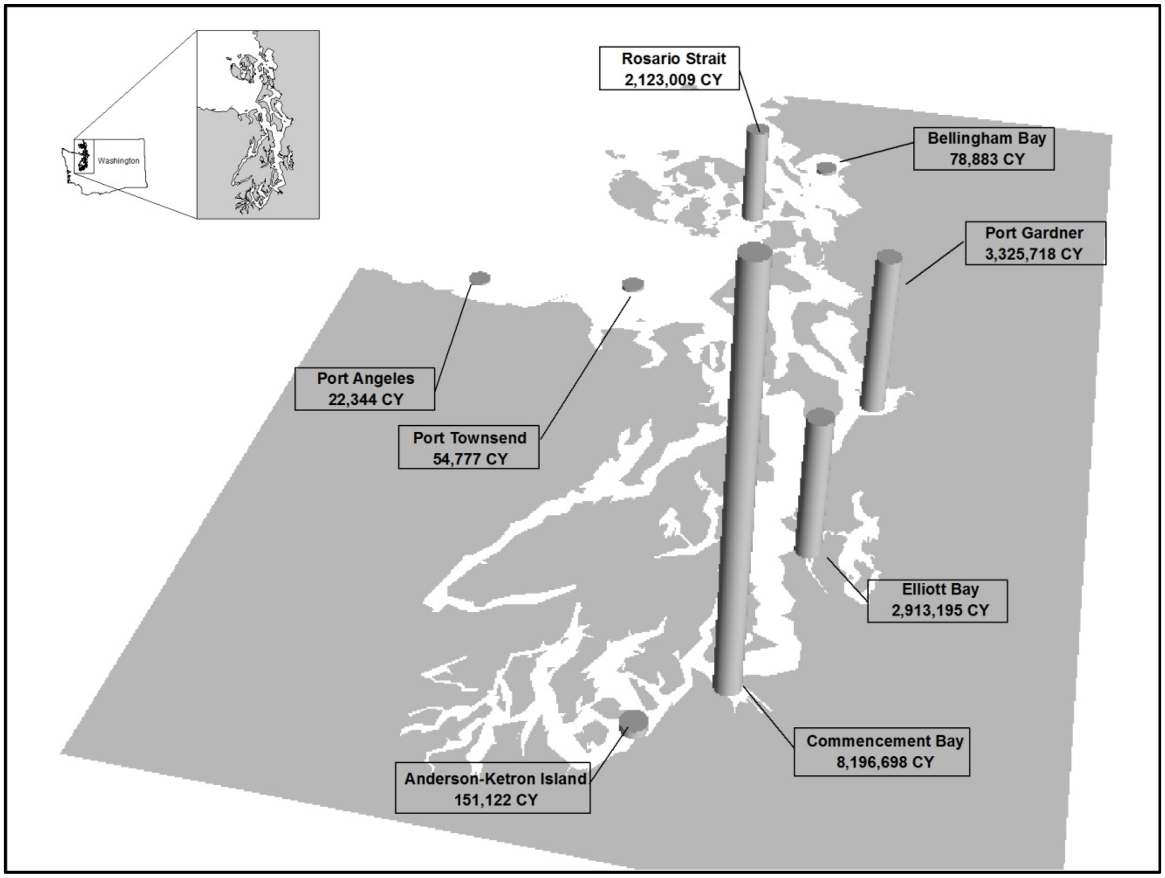


Figure 15. Cumulative disposal volumes in CY (over 25 years) as of May, 2014

a. Non-dispersive Sites

The monitoring program for these sites is activated by a disposal volume trigger according to the Management Plan for each site, or accumulation of 3 cm of sediment at the perimeter line[7], or by special considerations including concern for site conditions. In what follows, unaffected perimeter and "benchmark" stations are considered offsite stations; Z stations collected within the site perimeter are designated onsite. Programmatically, these stations are used to detect changes of the site that potentially affect site surroundings. The following text comparison is also made to the range of means and 50th percentiles from the general Puget Sound data sets described above.

1) ΣPCB

[7] The perimeter line boundary extends 1/8 nautical mile outside the disposal site boundary

Table 11 displays the results of site monitoring from 1990-2010 for four of the five nondispersive sites. Despite a range of Reporting Limits (RLs) for PCBs by the Aroclor method, there is no systematic difference between the onsite and offsite stations. Note that the programmatic use of RLs for characterizing nondetected values results in “less than” values that are typically 3 or more times above detection limits; and thus the sensitivity of the analyses is greater than shown. For example, estimated (J-qualified) values never appear in these data sets at values below the RL. Through 2010, in every case but Elliott Bay (shown in later paragraphs), the values shown are below the maximum reporting limits, and the site conditions are within the plausible range of Puget Sound average concentrations discussed above. For the 2010-2014 period, higher resolution methods were employed for monitoring at two nondispersive sites, Port Gardner near Everett and Elliott Bay near Seattle. These are summarized in graphics following the 2010 tables below.

For each site, EPA (2013)’s statistical program ProUCL version 5 was used to generate box and whisker plots and conduct 2-sample hypothesis testing. The boxes represent the 25th and 75th percentiles of the data distribution; the 50th percentile is shown by a horizontal line; and the arithmetic mean is displayed as a number within the box. The nonparametric Wilcoxon-Mann-Whitney (WMW) and Quantile (Q) tests were used to compare “Z” and “S” stations (representing centroid of the disposal zone and radii within the site) against “P” (perimeter or offsite stations, offset at 1/3 nautical mile from disposal zone) stations. These test a null hypothesis that the onsite data are higher than the perimeter data. The graphics also show “B” or benchmark stations – these are located in the direction of suspected bay-specific sources, and used to determine whether these are contributing as well. (Benchmark stations were considered qualitatively in what follows.) The method for estimating sums varies according to the form in which the data were available. DMMP (2010) for the Port Gardner site showed the 2,3,7,8-tetrachloro-dibenzo-p-dioxin toxicity equivalents by the half-quantitation limit method, but did not summarize the total PCB by congeners; this was done for this report, and the Kaplan-Meier method used, per programmatic guidance. (ProUCL was used to calculate this with Efron’s correction.)

<u>Port Gardner</u>.

Figure 16 shows Port Gardner’s 2010 ΣPCB data. The onsite mean and range appear to be above the offsite stations, (onsite mean of 6.9 µg/kg dw, compared to offsite mean of 4.66 µg/kg dw); the WMW test confirms that it is statistically significantly higher at $p \leq 0.05$; however, the Q test does not confirm that it is elevated. Port Gardner is a central Puget Sound area that is within the plausible range of ΣPCB described in Figure 19. All means shown in this figure exceed the PCB natural background of 3.5 µg/kg dw.

As shown in Figure 17, onsite Port Gardner TEQs (mean 0.06 ng TEQ/kg dw) are lower than perimeter stations (mean 0.1 ng TEQ/kg dw), and both WMW and Q tests confirm that they are not higher. By inspection, the benchmark station appears to suggest an unrelated source. Note that none of the means or ranges shown in this figure exceed the PCB TEQ natural background of 0.2 ng TEQ/kg dw.

In summary, ΣPCBs onsite at Port Gardner are close to natural background, although one of two statistical tests suggested they are slightly elevated, while onsite PCB TEQs are lower than offsite. Port Gardner is located in central Puget Sound, where PCBs tend to be higher than in other basins.

Table 9. PCB Statistics (Aroclor Method) from Monitoring at Nondispersive Sites Except Elliott Bay through 2010.

	Anderson-Ketron		Bellingham Bay		Commencement Bay		Port Gardner[a]		Units
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	
Number of Observations	4	20	1	6	16	135	11	32	Count
Proportion of Detections	0	0	0	0	0	0	0	0	%
Minimum Non-detected	<3	<3	<20	<20	<2	<7	<6	<6	µg/kg
Maximum Non-detected	<3	<3	<20	<20	<51	<86	<49	<67	µg/kg

[a] – The detection limits for 2010 monitoring at this site were 19 and 20 µg/kg dw

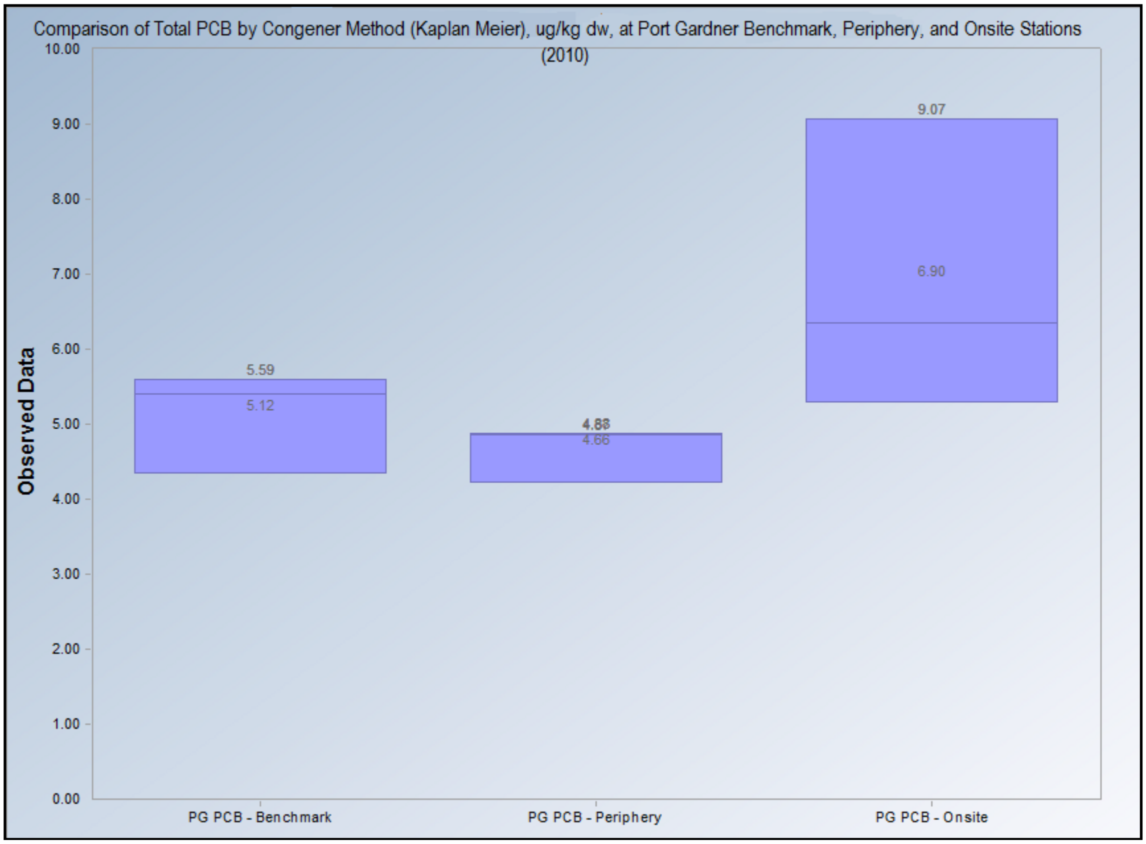


Figure 17. Port Gardner 2010 ΣPCB, Kaplan-Meier Sum, µg/kg dw

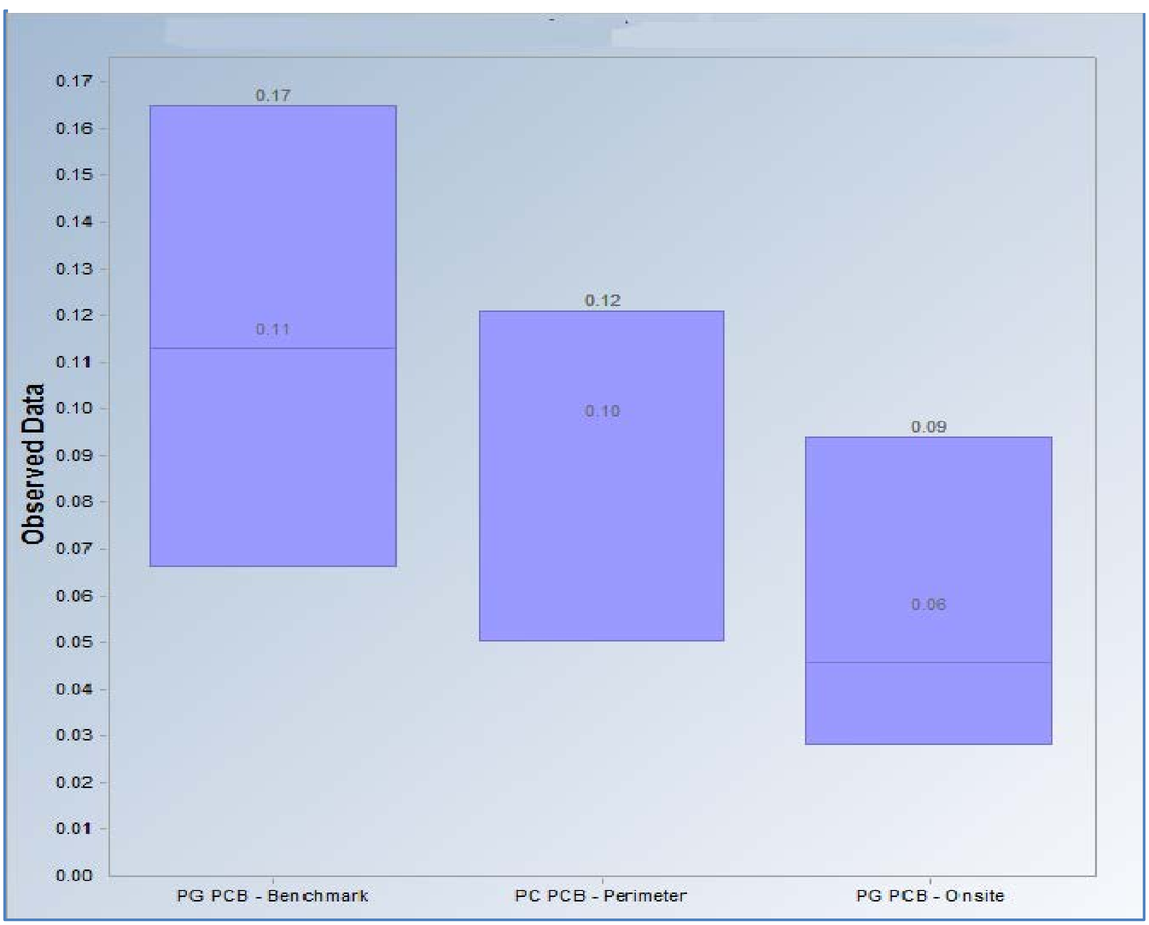


Figure 16. Port Gardner PCB, ng TEQ/kg dw

Elliott Bay

The prior PBE stated that Elliott Bay site surroundings, as represented by the offsite perimeter stations, have always been higher than or comparable to onsite stations since the disposal sites began use in 1990 (Figure 18). This is confirmed by data shown after that figure. ΣPCB Aroclors (Figure 19), ΣPCB (Figure 20), and PCB and PCDD/F toxicity equivalents (Figure 21) show similar patterns.

- For Aroclors, the onsite concentration ΣPCB is less than offsite stations (Figure 18). The Lower Duwamish Waterway Work Group's (LDWG 2010) Phase 2 Remedial Investigation estimated a generalized Elliott Bay PCB mean background to be 135 µg/kg dw. This is essentially identical to the offsite stations (Figure 18).
- For ΣPCB by the Kaplan-Meier summation method (Figure 19), peripheral (i.e., offsite) stations are higher than the onsite station as confirmed by the WMW and Q tests at $p<0.05$. The same is true for ΣPCDD/F TEQ. The PCB congener method shows considerably more variability than the Aroclor method for benchmark and (especially) peripheral stations, with the peripheral mean about 5 times the Arocolor based mean.
- Onsite TEQs for ΣPCB and ΣPCDD/F are above Ecology's natural background of 0.2 and 4 ng TEQ/kg, respectively. This is consistent with high ambient values in Elliott Bay. Conclusions regarding benchmark stations' contribution to the site are mixed – ΣPCB suggests that peripheral values are greater than benchmark, but both PCB and PCDD/F TEQs suggest benchmark stations are higher, and may contribute to the site.
- The TEQs from PCDD/F are substantially higher than TEQs from PCB. Onsite values are about 1:6 (PCB to PCDD/F).
- All measured Elliott Bay values (onsite, peripheral, and benchmark) are above Ecology's PCB ΣTEQ natural background of 0.2 ng TEQ/kg dw.

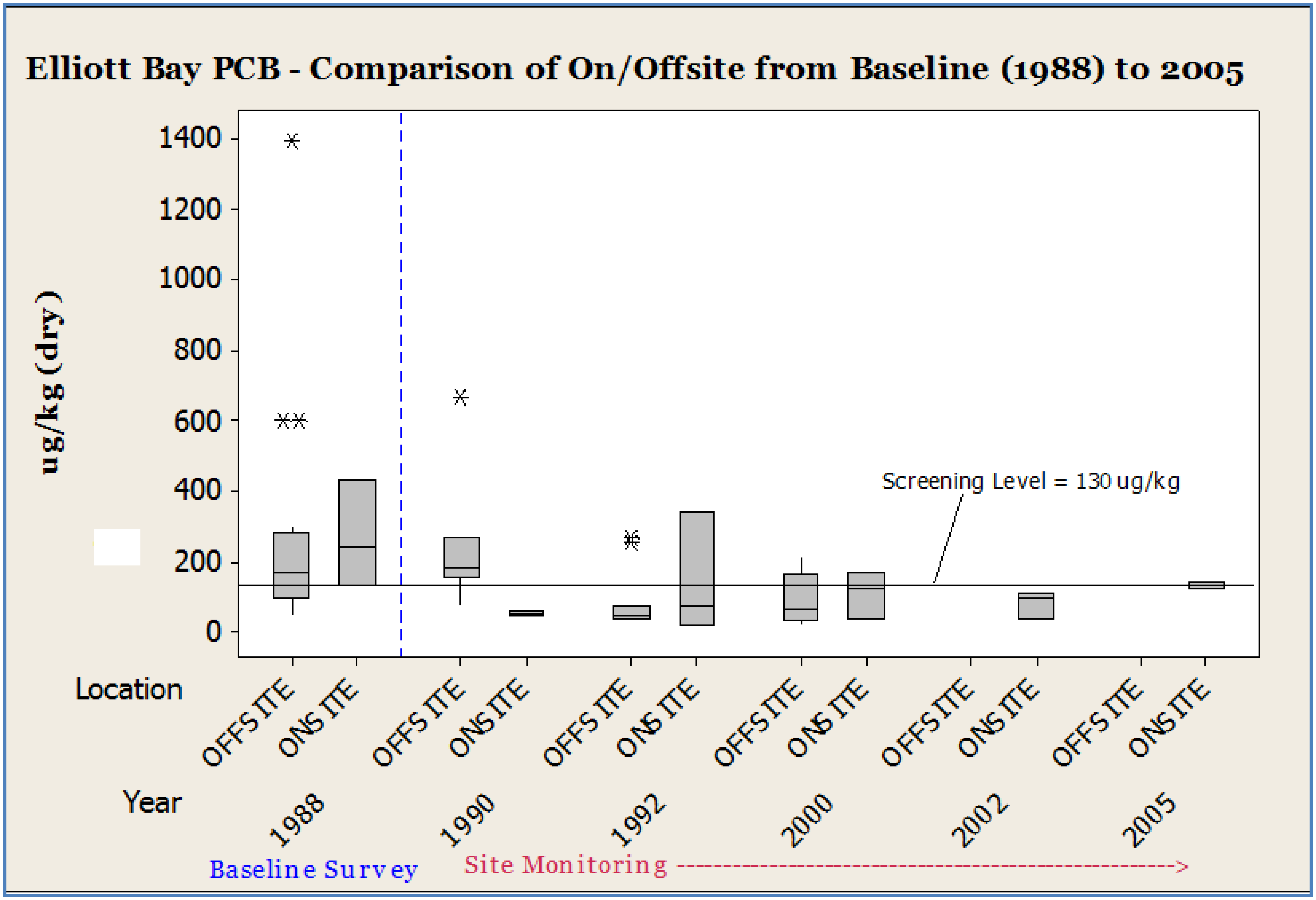


Figure 18. Comparison of On/Offsite Elliott Bay PCB from Baseline (1988) to 2005.

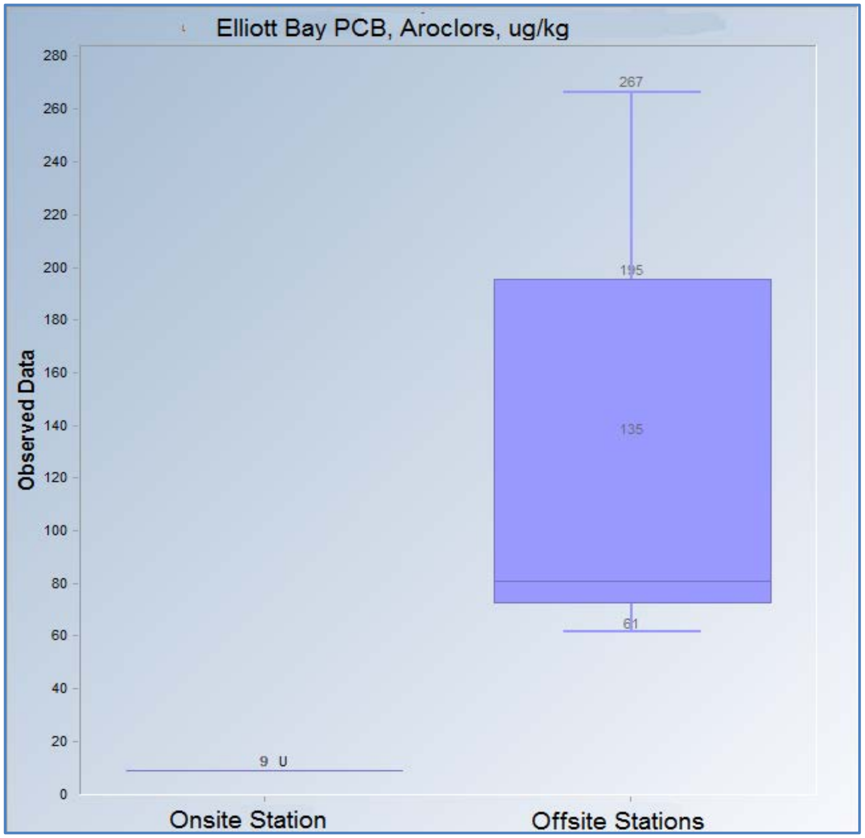


Figure 18. PCB Aroclors, µg/kg dw from 2013 Partial Monitoring Event. U indicates that the onsite value was not detected with a quantitation limit of 9 µg/kg dw

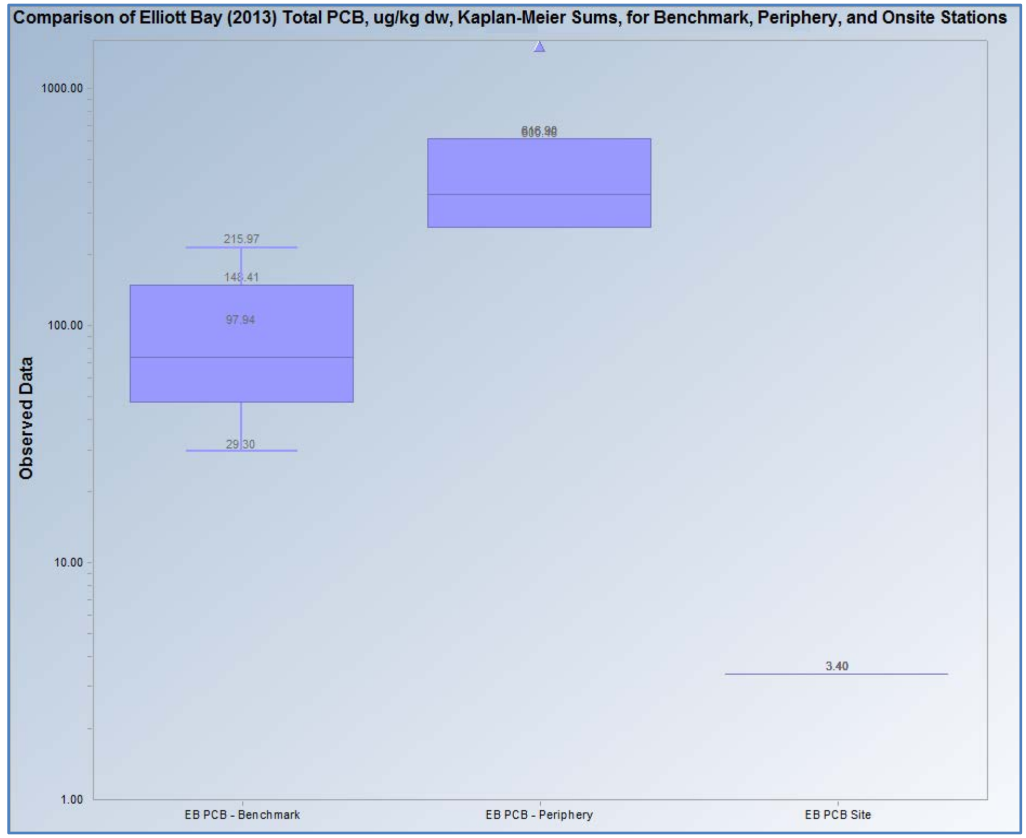


Figure 20. Comparison of Elliott Bay (Partial Monitoring Event, 2013) Total PCBs as Sum of Homologues, µg/kg dw, at Benchmark, Perimeter, and Onsite Stations. Note logarithmic scale.

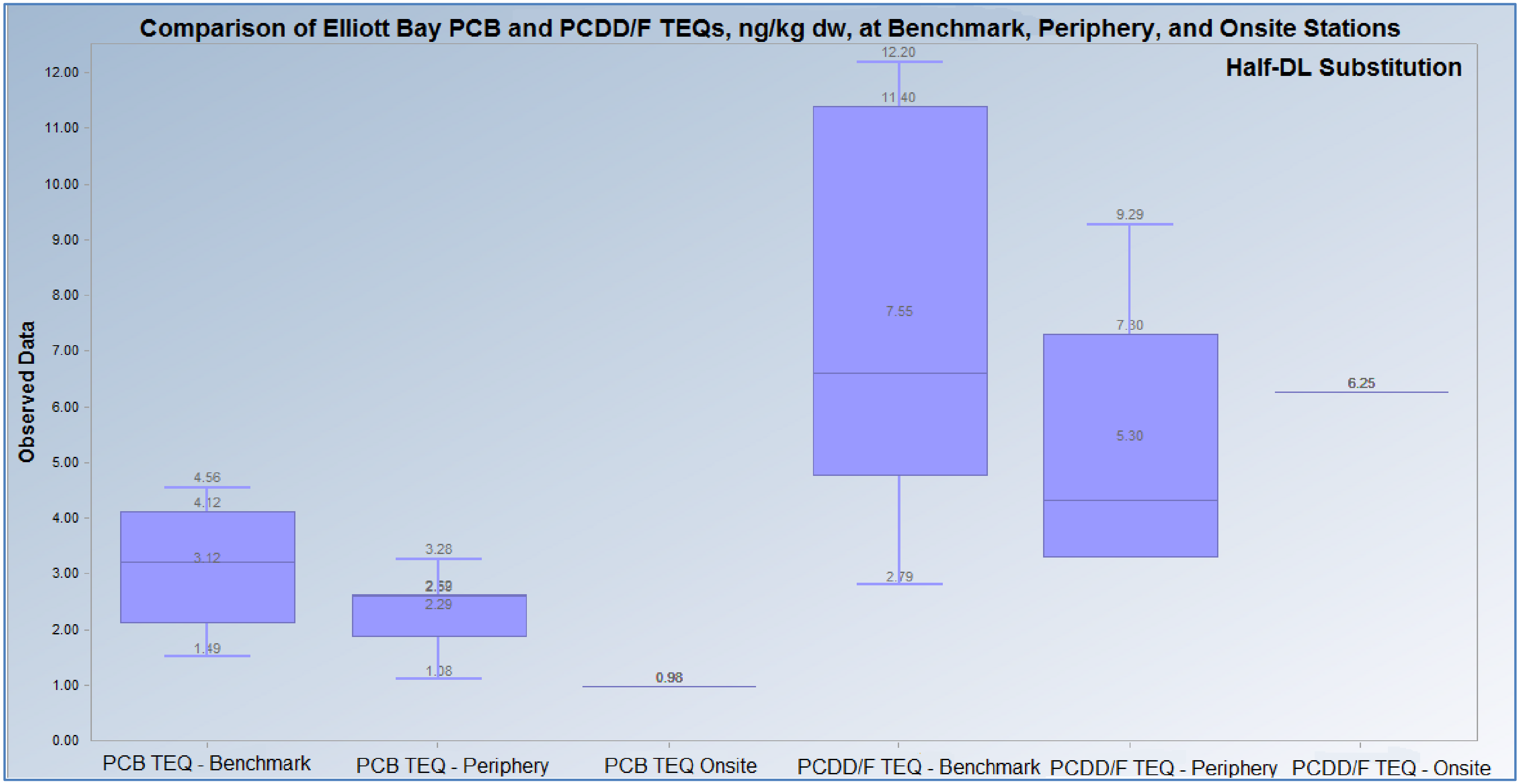


Figure 21. Comparison of Elliott Bay (Partial Monitoring Event, 2013) PCB and PCDD/F TEQ a, ng TEQ/kg dw half-detection limit substitution

PCB Loading Comparison for Elliott Bay. The following compares the USACE navigation dredging program for the Lower Duwamish Waterway (LDW) to the PCB annual export to downstream water bodies. LDWG (2012) prepared a recent FS (in particular, see Appendix M, Part 2) which calculated sediment transport through the LDW. This will be used as a point for comparison to the annual navigation dredging program activities and to the Ecology estimate of atmospheric and runoff loading.

Using most recent (and typical) 2011-2012 biennial dredging data, USACE dredged 47,200, cubic meters per year, which at 61% solids content amounts to 40,300 metric tons (MT) per year.[8] In the most recent characterization (which used the Aroclor method), 5 of 16 dredged materials management units (DMMU) had undetected PCBs at Detection Limits ranging from 19 to 93 µg/kg dw; from this, we used ProUCL version 5.0 to calculate a mean overall concentration of 39 µg/kg dw. Three below-detection-limit estimation methods (results of which are shown in Figure 22) were used to depict for the PCB budget as regards the dredging program:

- Low end estimate: substitution of 5 µg/kg dw for nondetected DMMUs; this represents the mean of Ecology's (2008) Green/Duwamish River surface sediment samples which contained fines >30%; this was also used as a low-end estimator by LDWG (2012).
- Midrange (most likely) estimate: the normal Regression-on-Order Statistic (ROS) used to replace nondetected values, in accordance with recommendation in ProUCL version 5.0.
- High range estimate: substitution of the 19 µg/kg dw value (that is, the detection limit of 4 of the 5 nondetected values) for all nondetected DMMUs.

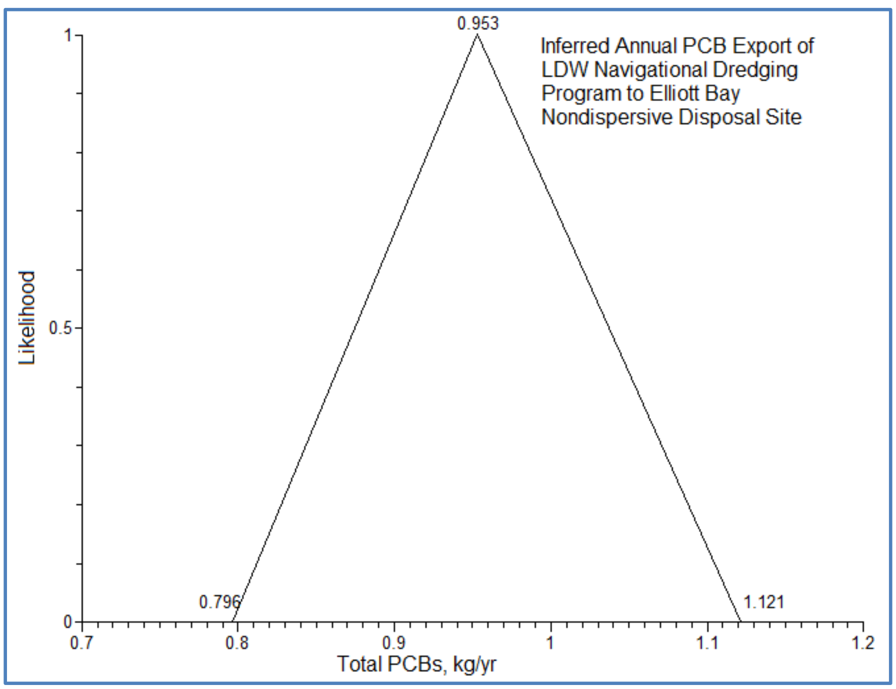


Figure 22. Inferred Annual PCB Export, kg/yr, of LDW Navigation Dredging Program to Elliott Bay Nondispersive Disposal Site

The Lower Duwamish Work Group (LDWG 2012) estimated that, in addition to the navigation program, 584 MT (or a little more than 1% of the total navigation dredging) of sediment per year) are

[8] This does not include the contribution from other, non-Federal projects, which is small in comparison.

transported via erosion and lateral sources from the waterway to downstream areas (East and West Waterways and Elliott Bay at large). LDWG (2012) estimated that the spatially-weighted average PCB concentration in LDW is 380 µg/kg dw, or about 10 times the concentration in the Turning Basin and adjacent reaches that are regularly dredged to maintain the Federal channel. Apart from the dredging program, the ΣPCB exports attributable to erosion of sediments LDW were 3.7 kg/yr ΣPCB by bed sediment erosion and 0.2 kg/yr PCB from lateral sources, for a total of 3.9 kg/yr. Adding this to the navigation program, the total annual ΣPCB export is 4.7-5.0 kg PCB/yr.

Thus, the Federal program transports from 16% to 24% of the PCBs from the LDW, as high volume, low-concentration PCB dredged sediments. With the program, these materials are placed into a managed nondispersive disposal site and data presented above suggests that the values onsite are lower than ambient (or, in the case of both total PCBs by homologue sums and TEQ, below Ecology's natural background) concentrations. Without dredging in the turning basin, sediments would accumulate and, upon mixing with the existing contaminated sediments, necessitate more frequent dredging of more highly PCB-contaminated materials. (EPA has directed ongoing "Early Actions" at some of the most PCB-contaminated areas on the LDW, and has published a Proposed Plan for environmental dredging of the highly PCB-contaminated sediments in the LDW, which will likely begin within the next 10 years. Thus, the Federal navigation dredging program is actively transporting and managing the bulk of the sediment in the LDW, diverting sediment from shoals in the waterway, facilitating future cleanup of this contaminated area, while maintaining dredged sediment disposal site ΣPCBs at comparable or lower concentrations as the Elliott Bay surroundings.

For Puget Sound context, as noted in Figure 12 (and cited in Ecology 2013), the estimated export of sediments from the LDW (navigation and erosion and lateral loads) is about 5% of the incoming runoff related input.

2) ΣPCDD/F

The ND=0.5*DL and ND=0 methods was used to compare on- and offsite ΣPCDD/F TEQs, and to the 4 ng TEQ/kg background value in the Revised Interim Dioxin Guidelines (which is also Ecology's natural background value). Figures 21a through 21e show these comparisons. The key to the illustrations follows:

- Site codes: *AK* = Anderson-Ketron. *BB* = Bellingham Bay, *CB* = Commencement Bay, *EB* = Elliott Bay, and *PG* = Port Gardner.
- Location designations: *ONS* = onsite, *OFS* = offsite.
- The methods for summation of toxicity equivalents are *Half* = one-half of DL substituted for non-detected values, and *Zero* = zero substituted for non-detected values.

In the box-plots, medians are shown by the line in the box, and means are shown by ⊕ or (in updated blue figures 20 and 22e), the mean is a number in the box.

For Port Gardner and Anderson-Ketron Island sites, the onsite mean values are less than the offsite values and also less than the 4 ng TEQ/kg dw site management goal and Ecology's natural background value. For Bellingham Bay, the onsite mean is close to the offsite value. For Elliott Bay, onsite is statistically indistinguishable from offsite by the WMW and Q tests, as noted above under PCB TEQ. Both onsite and offsite for Bellingham and Elliott Bay disposal sites are greater than the management goal of 4 ng TEQ/kg dw. For Commencement Bay, both the onsite and offsite means, which are very similar, exceed the goal. Future management of these sites will hopefully bring onsite values near or below the background-based goal.

The onsite and offsite sediment data below from 1995-2009 indicate that disposal of dredged material does not appear to have increased the contaminant inventory at any of the nondispersive sites. Figure 23 has several parts that compare between onsite (ONS) and offsite (OFS) Stations at 5 nondispersive open-water dredged disposal sites.

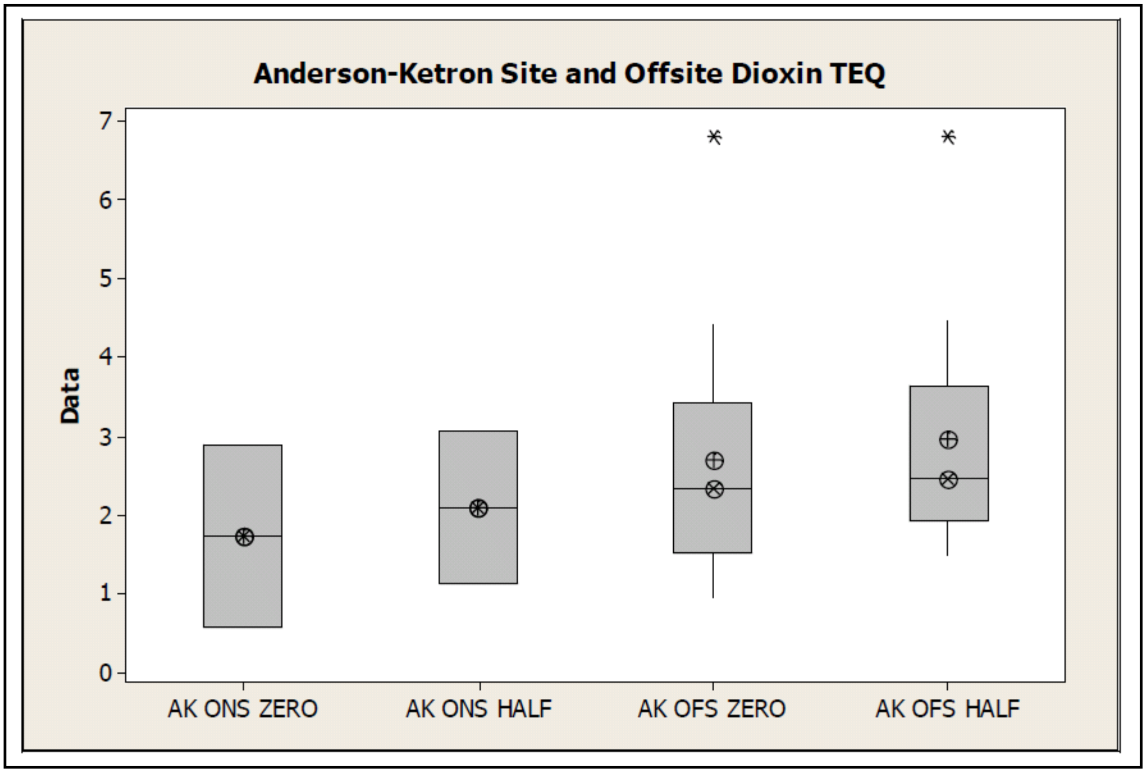


Figure 23 a. Anderson-Ketron

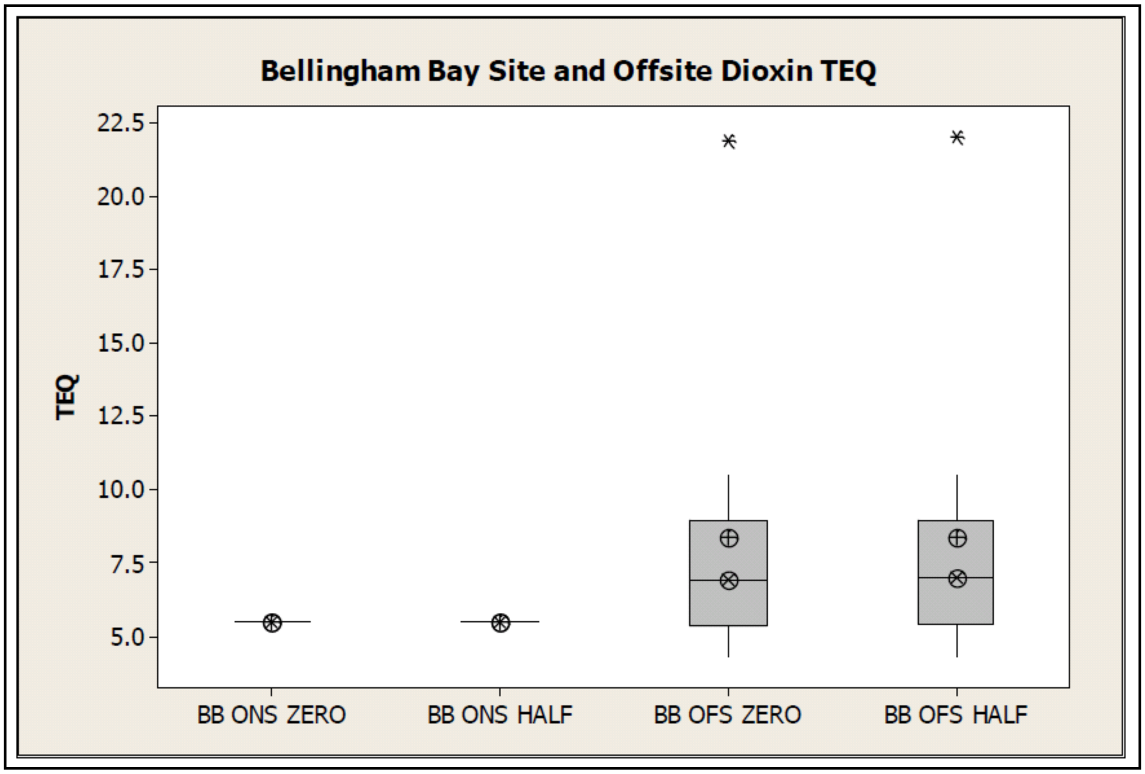


Figure 23b. Bellingham Bay to 2010

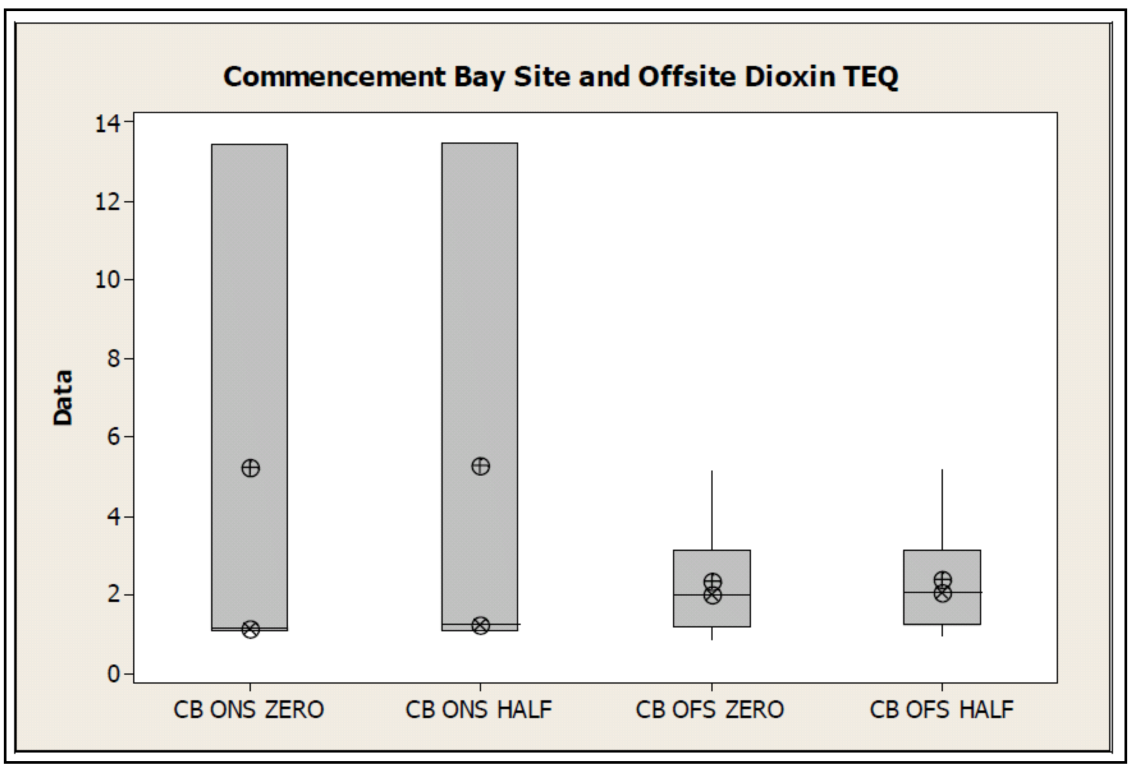


Figure 23c. Commencement Bay to 2010

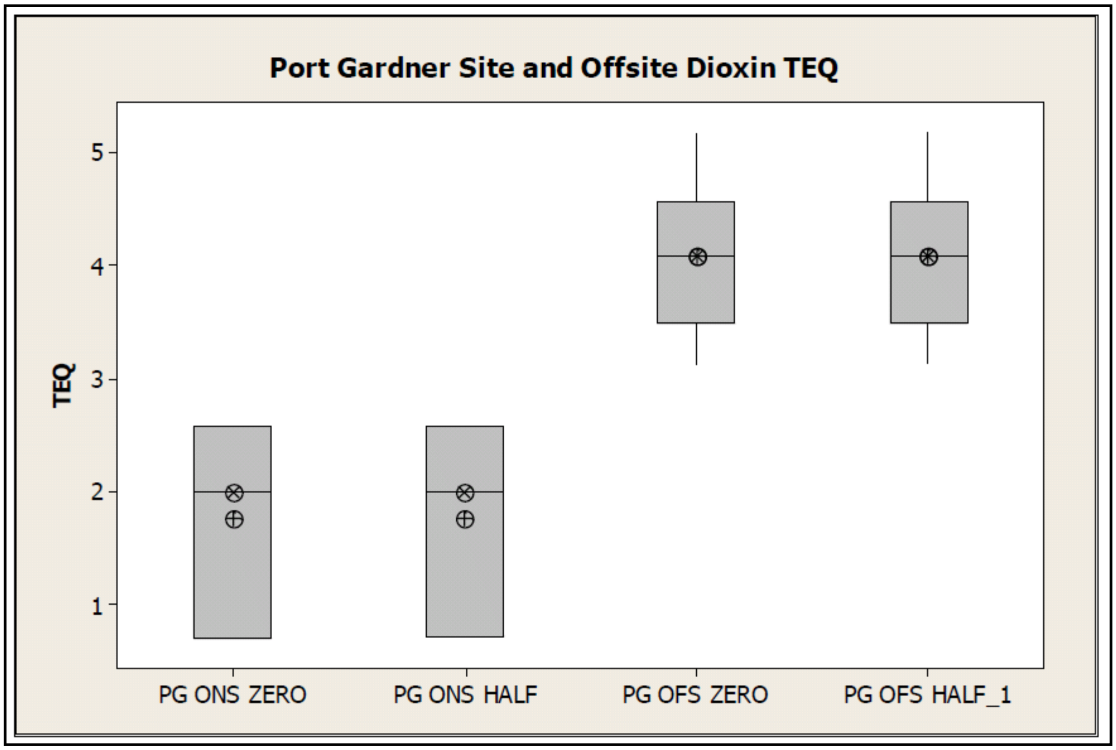


Figure 23d. Port Gardner Through 2009

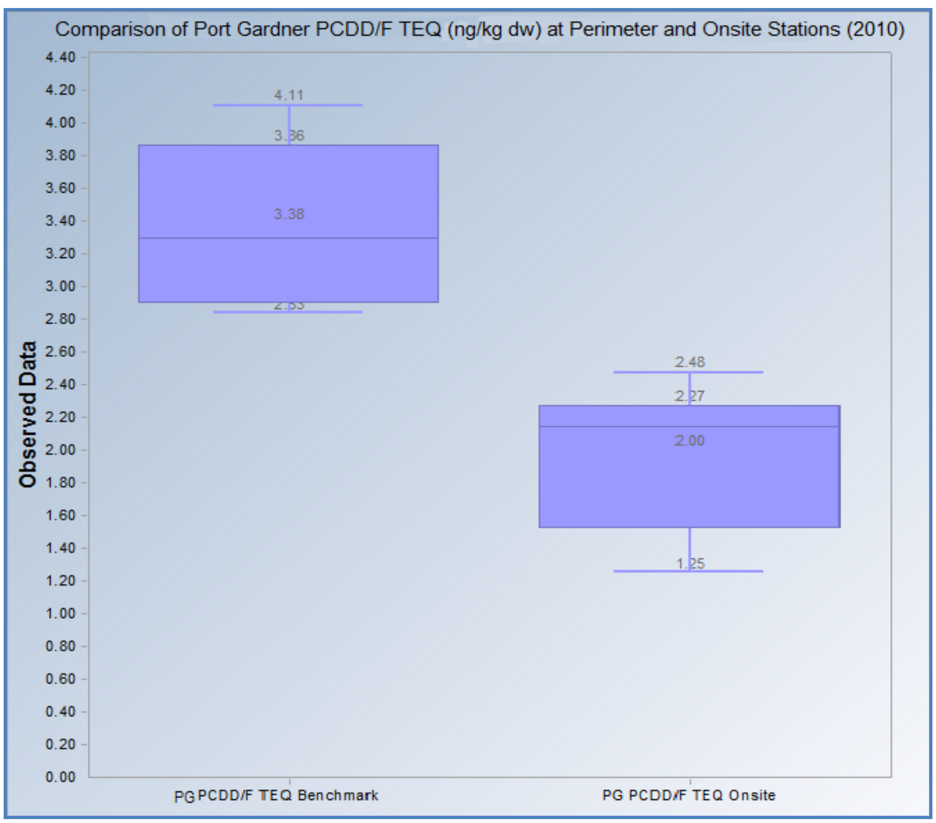


Figure 23e. Port Gardner in 2010 Characterization (Half DL Method)

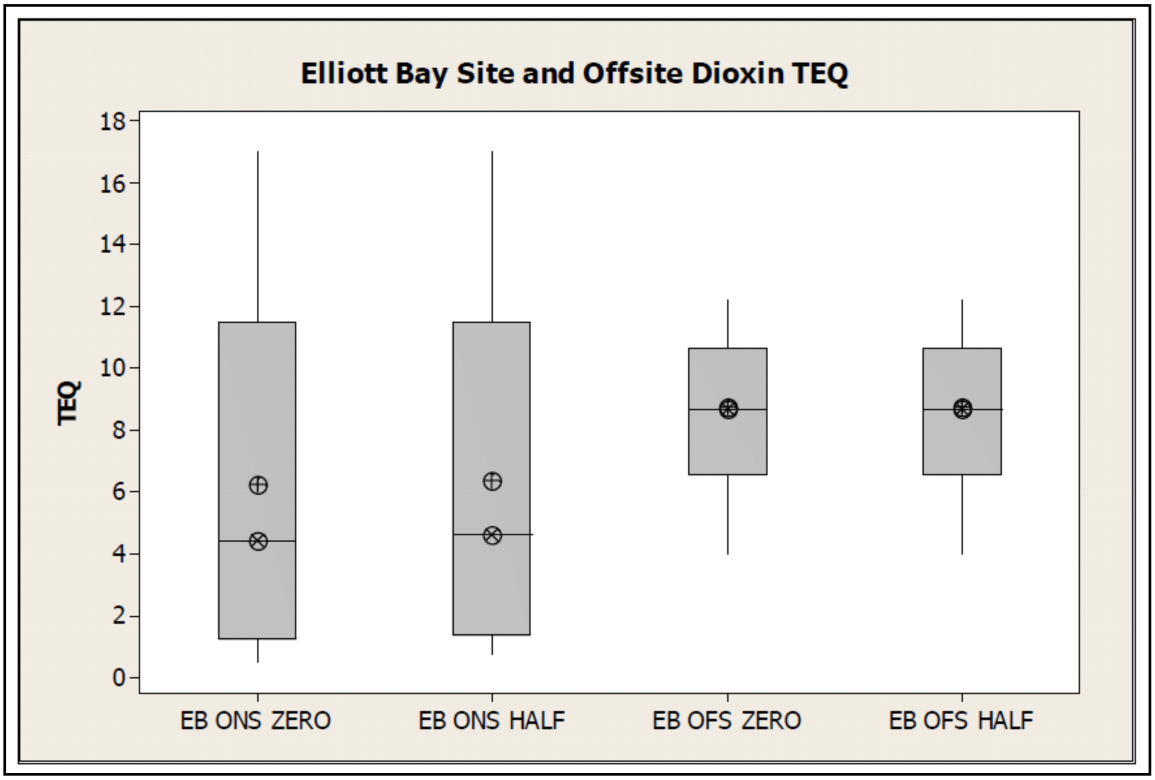


Figure 23f. Elliott Bay Through 2009.   For 2013 Elliott Bay Characterization, see Figure 20, right half of graphic.

3) ΣPBDE

Although dredged material is not routinely tested for ΣPBDE except in certain Federal navigation projects, site monitoring data for sediment and benthic tissue are available for nondispersive sites, and are shown through 2009 in Table 10 on the following page. All sediment values were non-detected, with the RLs displayed.   Accordingly, higher-resolution analytical methodologies have since been used in the site monitoring program; new site tissue data have yet to be collected. Since 2009, Port Gardner and Elliott Bay sediments have been characterized (Figures 23-25).

- For both Port Gardner and Elliott Bay sites, ΣPBDE onsite values no greater than offsite (WMW and Q tests), and appear to be lower. Elliott Bay (Figure 25) typifies the predominance of congener 209, as noted by researchers cited above.
- For both sites, the offsite mean and median values are compared to those of Dutch and Aasen (2007 – see Figure 14). In recent DMMP monitoring, BDE 209 was 1.14 µg/kg dw at Port Gardner, and 1.81 µg/kg dw at Elliott Bay; this is similar to or a bit higher than Dutch and Aasen's station 21 (0.3 µg/kg dw) and station 29 (1.2 µg/kg dw), as shown in Figure 14. Onsite values were substantially lower than the Dutch and Aasen ranges.   This suggests that disposal site use is not worsening the near-field conditions, although the ambient conditions may be increasing for ΣPBDE (as noted by several researchers).

Table 10. ΣPBDE Statistics from Monitoring at Nondispersive Sites Through 2009

	Anderson-Ketron		Commencement Bay		Port Gardner		Elliott Bay		Units
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	
Sediment									
Number of Observations	3	21	3	12	3	12	3	4	Count
Proportion of Detections	0	0	0	0	0	0	0	0	%
Minimum Non-detected	<19	<19	<20	<20	<19	<19	<99	<55	µg/kg (dry)
Maximum Non-detected	<20	<20	<20	<20	<20	<20	<140	<130	µg/kg (dry)
Tissue									
Number of Observations	--	6	--	14	--	5		3	Count
Proportion of Detections	--	0	--	0	--	0		0	%
Minimum Non-detected	--	<3	--	<26	--	<33		<73	µg/kg (wet)
Maximum Non-detected	--	<3	--	<33	--	<33		<76	µg/kg (wet)

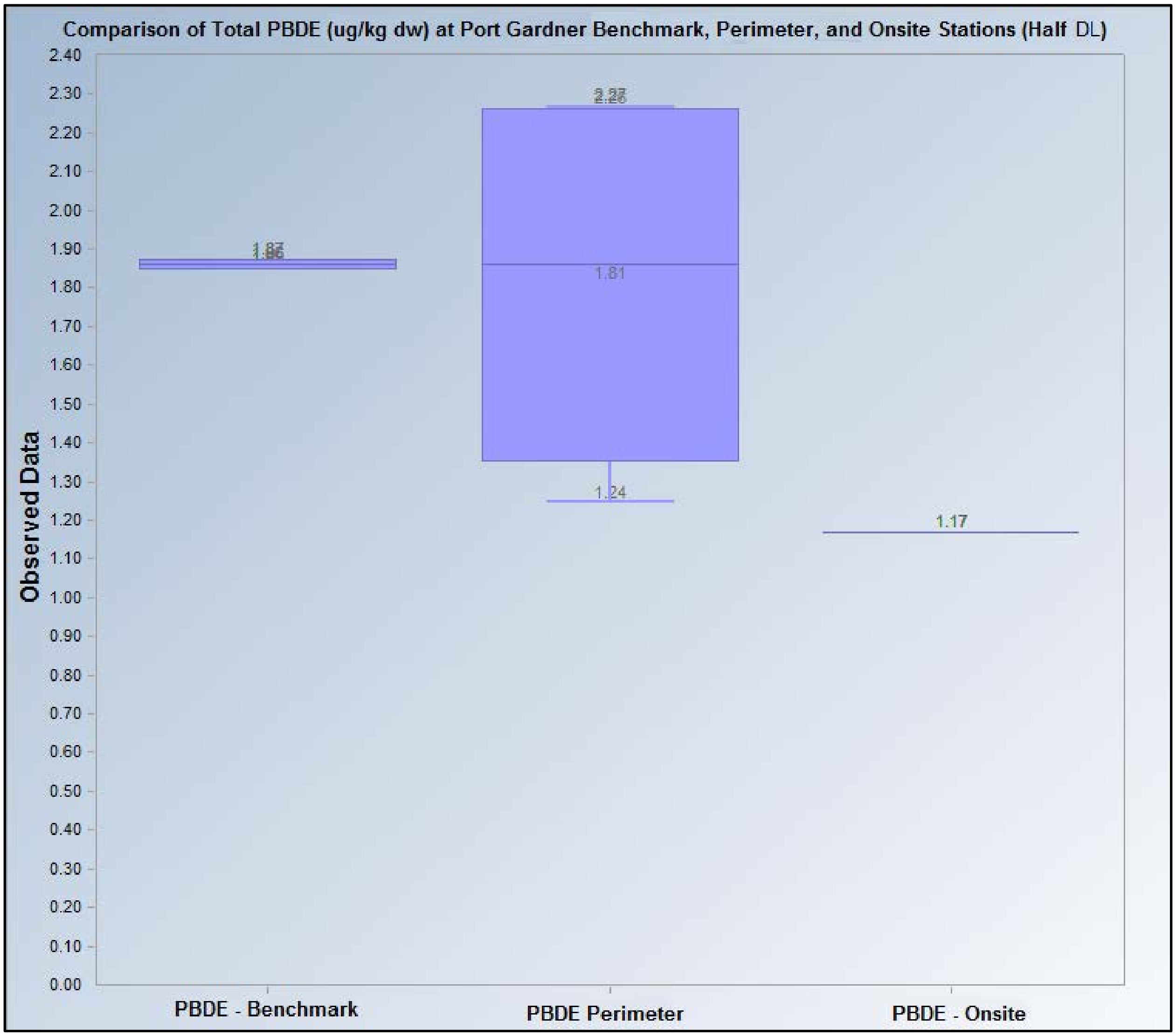


Figure 24. Comparison of ΣPBDE (µg/kg dw) at Elliott Bay Disposal Site Benchmark, Perimeter, and Onsite Stations (2010). Sum of detected PBDE congeners by half-DL substitution.

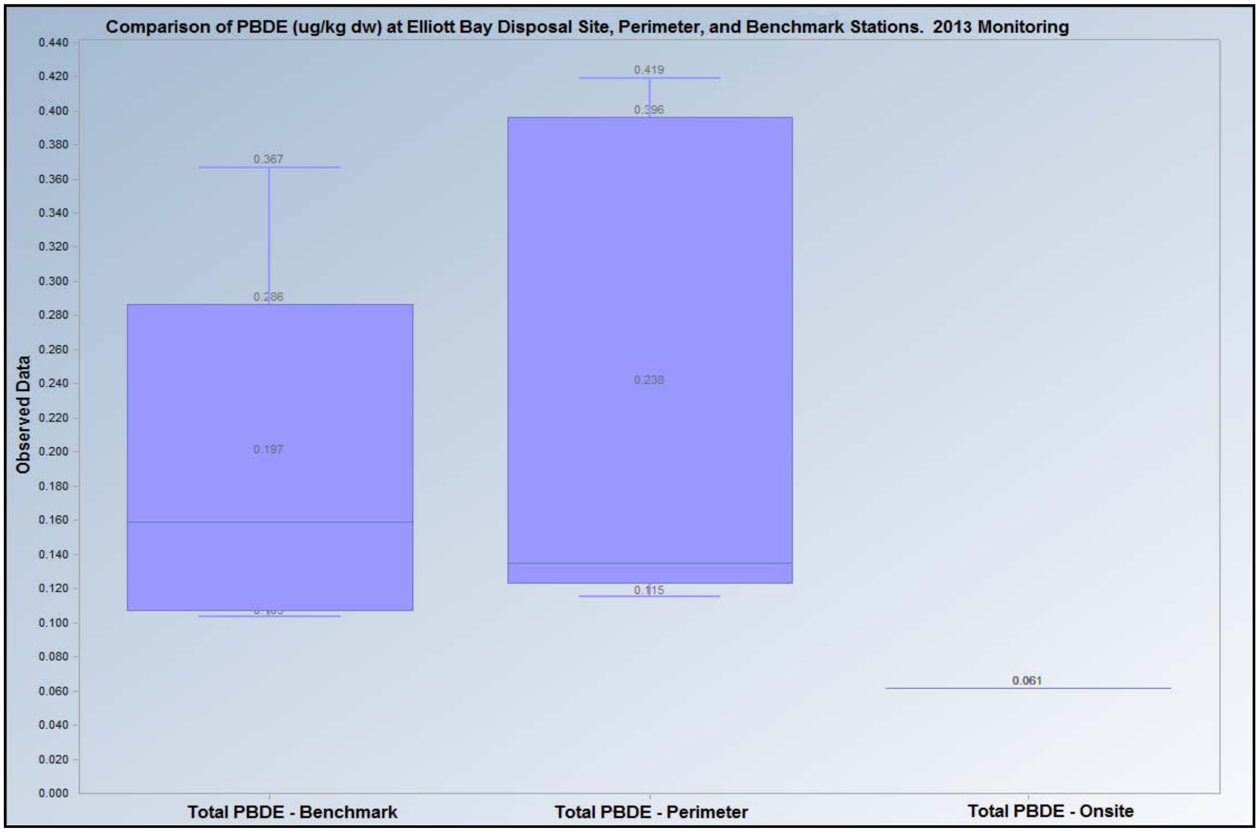


Figure 25. Comparison of ΣPBDE (µg/kg dw), 2013 Elliott Bay Site Benchmark, Perimeter, and Onsite Stations

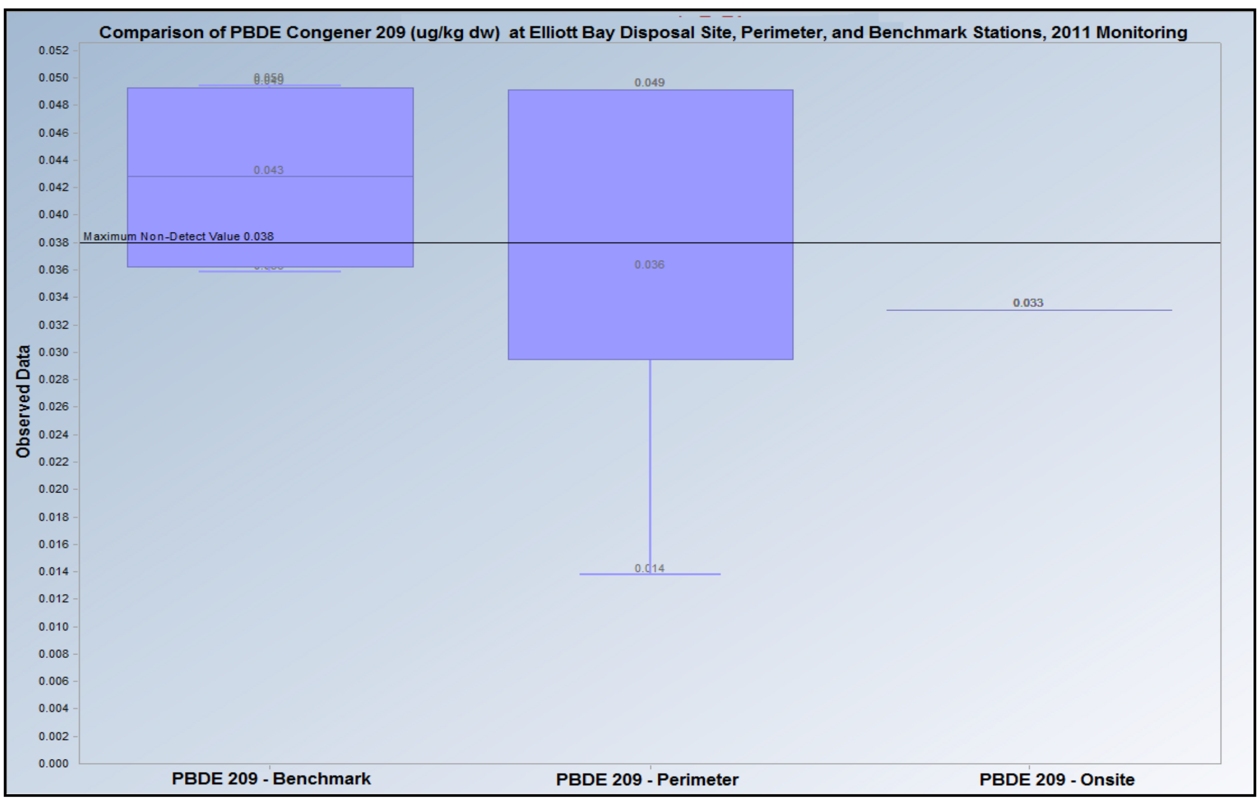


Figure 26. Comparison of PBDE Congener 209 (µg/kg dw), 2013 Elliott Bay Site Benchmark, Perimeter, and Onsite Stations

4) Summary for Nondispersive Sites

Non-dispersive dredged material disposal site monitoring is ongoing to determine whether there is a significant increase of PBTs or an exceedance of the background-based site management goal for PCDD/F TEQ. Site monitoring has demonstrated that the dredged material evaluation procedures are keeping onsite sediment concentrations of ΣPCB, ΣPCDD/F and ΣPCDE below offsite concentrations, with one exception. At Port Gardner, one measure of ΣPCB (total homologues) suggests onsite is greater than offsite, but one of two statistical tests disagrees, and another measure, PCB TEQ, indicates that onsite is not significantly greater than offsite. In Elliott Bay, where the urban surroundings are significantly elevated relative to the rest of Puget Sound, there is evidence that on-site ΣPCB is lower (cleaner) than offsite ΣPCB. In addition, a case was made for how the dredging program facilitates another regional cleanup program by bypassing sediment from accumulating in the highly polluted LDW.

b. Dispersive Sites

Under the program, no site monitoring occurs for DMMP dispersive sites, so the contaminant inventory relies upon the chemistry of the materials characterized for the Suitability Determinations. The disposed materials rapidly migrate offsite due to strong currents. There are two sites in SRKW Critical Habitat: Port Angeles and Rosario Strait. Port Angeles has only been used once, in 1996. Rosario is summarized below. PCB Aroclor data only are available from Rosario Strait.

1) ΣPCB

Only the Aroclor method has been used to characterize dredged material deemed suitable for these sites. Note the low frequency of detected PCB in these samples in Table 11, which represents the 2008-2012 period. Many of the larger-volume Dredged Material Management Units (DMMUs) were nondetected at the stated detection limits, and one-third were from Swinomish Channel maintenance, which has historically constituted very clean sands and has been used for beneficial purposes including capping in Elliott Bay.

Table 11. Rosario Strait PCB Site Statistics, 2008-2012

Parameter	Value	Units/Type
Amount of Dredged Material Disposed	234,625	CY in 4 years
Mass of Solids Disposed (60% Solids by Weight)	179,384	Metric Tons dw
Range of Detection Limits	19-39 (mean 20)	µg/kg dw
Frequency of Detection	10%	
Maximum Detected	24	µg/kg dw
Mean Concentration (0 DL Detection Method - 1/2 DL Method;)	6.3 - 15	µg/kg dw
Estimated Annual ΣPCB Loading Associated with Above 2 Mean Concentrations	0.24 -0.57	kg PCB dw /year

DMMP (2012) reviewed sediment transport at Rosario; it is a single layered system with a net southerly direction, with a mean current speed of 50 cm/s and a 99th percentile speed of 134.7 cm/sec. Ninety percent of the material that has been disposed a the Rosario site is predominantly sand (92%) and gravel (~8%); one small project in 1992 had higher fines, but low mass. A Particle Tracking Model for a predominantly sand disposal presented is shown in Figure 26 over a 72 hour period. It is apparent that material rapidly moves offsite.

Note that the range for annual loading shown in Table 16 is a probable high-biased estimate, and it does not reflect “new” PCBs, but instead PCBs that are moved about in the aquatic environment. Ecology’s (2011 – see Figure 12) estimated mass loading of total ΣPCB in Puget Sound ranges from ~100 kg/yr from runoff and ~8 kg/yr from atmospheric deposition. Given the Rosario Strait site dynamics, which quickly moves the dredged material off-site, we do not believe it would be possible to measure the low ΣPCB input against the backdrop of Puget Sound.

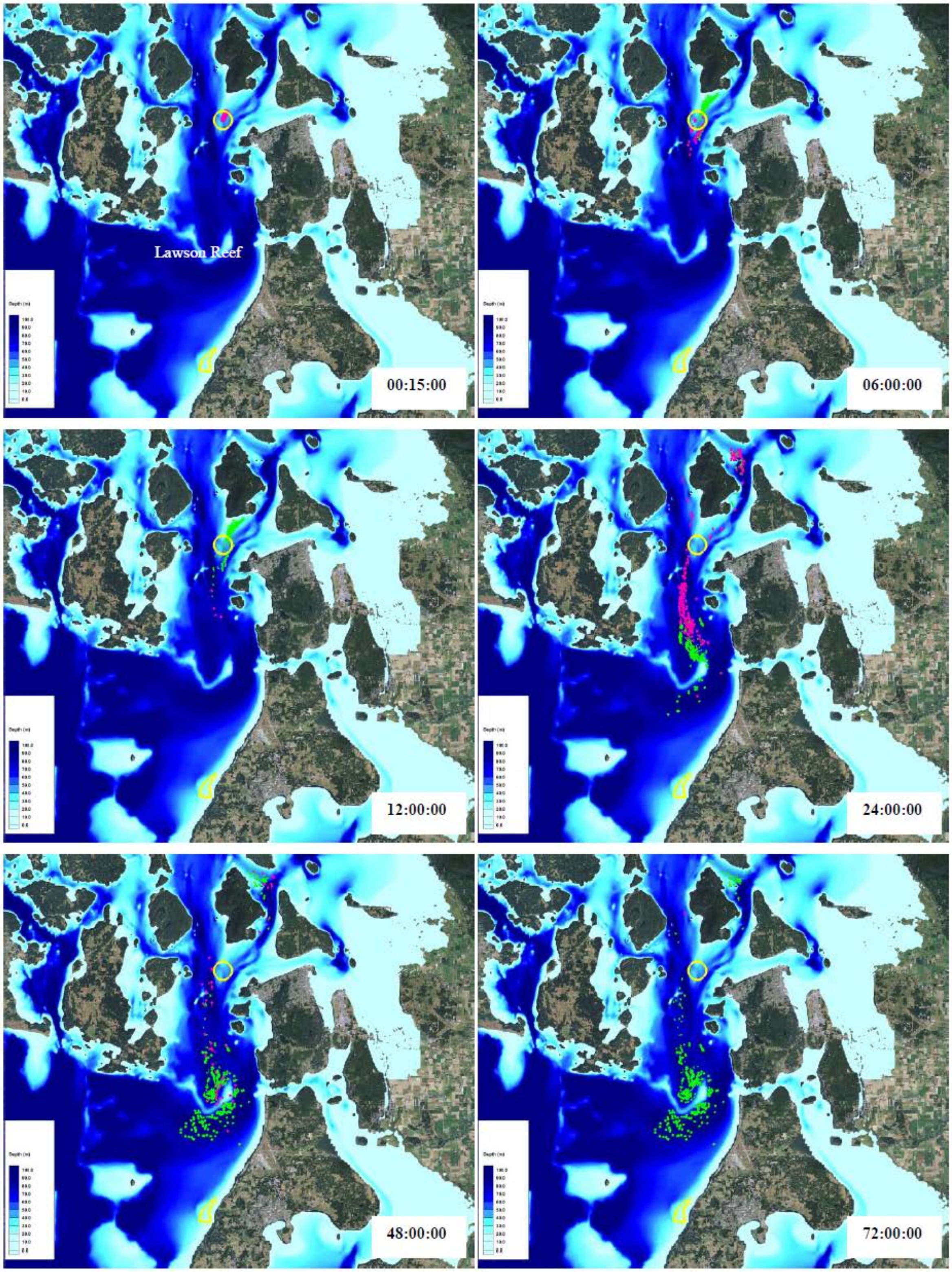


Figure 27. Rosario Straits Sands Results Based upon Disposal on August 12, 2011. Yellow circle is the site boundary, magenta areas are active parcels of the model, and green are inactive parcels.

2) ΣPCDD/F

As can be seen in Table 12, the Rosario Strait dispersive site have only received low or undetected levels of PCDD/F, and the average and range appears to be well below Ecology's natural background value of 4 ng TEQ/kg dw.

Table 12. Rosario Straits PCDD/F Statistics by Dredged Material Management Unit (DMMU) Permitted for Placement (ND=0.5*DL method), to 2009. *(No more recent testing has been done.)*

Parameter	Value	Units/Type
Number of Observations	9	Count
Proportion of Detections	100	%
Minimum	0.16	ng TEQ/kg
Maximum	1.8	ng TEQ/kg
Mean ± Standard Error	0.69 ± 0.19	ng TEQ/kg

3) ΣPBDE

No data are available for this compound suite for any dispersive site.

6. Consideration of Canada Department of Fisheries and Oceans Advice for Dredged Material Management

While the DMMP acknowledges that there is evidence suggesting that the existing range of Puget Sound sediments likely affects health of SRKW, Steller sea lions, and harbor seals, the above review of PBTs onsite and offsite at nondispersive sites concentrations, and an inventory of these compounds for the dispersive sites indicates that the dredged materials placed do not result in an elevation relative to their surroundings. These surrounding bodies of water may be locally elevated (central Puget Sound and Commencement Bay in particular); and all of Puget Sound appears to be higher than values suggested by Álava et al. (2012) and Canada Department of Fisheries and Oceans (2010) to be protective of SRKW.

Here is how the DMMP addressed the specific recommendations of the advice paper.

a) Disposing of dredged material into Critical Habitat (higher than ambient ΣPCB concentrations are predicted to increase the delivery of PCBs to killer whales.

The DMMP agrees that there is a demonstrated relationship with sediment and water concentrations, pelagic food-web concentrations and assimilation of ΣPCB into SRKW; however, the large scale of the model and the conflation of sediment and water concentrations (our program only manages sediment) limits ability to use the model for directed management decisions. This appendix describes how management policies generally converge with the recommendations, however. The number of inputs to Puget Sound and the Straits of Juan de Fuca are large. It is important to understand that the DMMP does not accept upland materials for in-water disposal, and does not "create" sediments containing PBTs, but "manages" them in a well-defined, science-based program that is annually updated as new information arises. It is difficult to distinguish how or if the program results in increases in sediment loads on the scale in this model. If these sediments they were not dredged and placed in unconfined, open-water sites, ΣPCBs and ΣPBDE would remain in the aquatic environment, e.g., in a riverbed or river delta and continue to contribute PBTs to the food web. For reasons presented in this appendix, careful review of prospective project contributions and management and monitoring of nondispersive sites suggests that the program's contribution of PCBs are less than or comparable to ambient levels within sub-regions (e.g., Elliott Bay) or within Puget-Sound ranges or natural background so far as this is understood.

b) *Dispose greater-than-ambient PCB levels into nondispersive (i.e., net depositional) sites as opposed to dispersive sites, in order to bury PCBs, and reduce overall habitat exposure for killer whales.*

The DMMP has 5 nondispersive sites and 3 dispersive sites (for which, sediments do not remain onsite and are rapidly dispersed). One dispersive site, Port Townsend, is not in SRKW Critical Habitat; the dispersive Port Angeles site has seldom been used; and only the Rosario Strait site receives significant volumes of dredged materials. Disposed dredged materials have had low PCB concentrations at the Rosario site, as explained in the text.

c) *Use congener-specific (high resolution) methods to characterize PCBs and PBDEs.*

The DMMP has adopted monitoring using high-resolution GC/MS methods to monitor ΣPCB, ΣPCDD/F, and ΣPBDEs at nondispersive sites. The program also uses these methods in Federal projects (although, because these are expensive, they are not always required for non-federal projects).

d) *While modeling predicts sediment levels from 0.012 to 0.2 µg/kg dw would protect killer whales, it is acknowledged that many areas are greater than this (both in coastal BC and in adjacent US waters).*

Both these values and those in Álava et al. (2012) -- 0.058-0.0044 µg/kg dw at 1.9% OC – are considerably below ambient values in Puget Sound. The State of Washington Department of Ecology's (2013) Sediment Cleanup Manual II (SCUM-II) uses "natural background" to set final cleanup criteria unless risk-based values are higher. As noted above, the natural background (90% coverage with 90% upper tolerance limit of the "OSV Bold Plus" dataset[9]) were shown in Table 4 above.

For ΣPBDE no natural background value has yet been set by Ecology, as this was not an analyte suite in the Bold and other studies. Historic and recent DMMP disposal site monitoring data have been compared above to these values as well as to the ambient conditions surrounding the sites. In several instances described above in regards to nondispersive site monitoring and management, the onsite concentrations are similar to or below these natural background values. In others, they are higher, but not statistically elevated above the surrounding perimeter stations.

[9] The OSV Bold dataset consists of 70 samples taken on a stratified random grid with adjustments so that nearby industries or cleanup areas were avoided. The "plus" information consists of additional Puget Sound reference area data accepted by the Department of Ecology as suitable for inclusion. The entire dataset is in Appendix L of the citation.

e) *Additional understanding of PCB pathways in coastal waters, emphasizing sources, sinks, sedimentation rates, and substrate types in dredged and disposal sites to inform future risk-based decisions regarding fate and consequences of disposal activities in killer whale Critical Habitat.*

The flux of ΣPCB and ΣPBDE in dissolved and particulate form in the open waters of Puget Sound and the Strait of Georgia and their bioavailability are currently being evaluated by the State of Washington Departments of Fisheries and Wildlife (WDFW) and Ecology, and researchers in Canada. (These are briefly described in the text above, but it is difficult to use the Puget Sound PBT budgets to do more than contextualize the low contribution of the DMMP activities.)

In the Sediment Management Annual Review Meetings (SMARM), the best available science is considered and will continue to be considered in programmatic terms. The Álava et al (2012) model used to calculate safe ΣPCB levels for SRKW tends to conflate sediment and surface water as a source for bioavailable PCBs, and does not distinguish whether sediments are shallow or deep. Most dredged disposal sites are in relatively deep water, and while there are feasible linkages to a much shallower pelagic species (such as Chinook), these linkages are not well understood. It is difficult to evaluate, in terms of disposal site management, how sediment levels of PBTs affect overlying water and the pelagic food web. Few regional studies have collected data in such a manner that a linkage from sediment to plankton and to the pelagic food web may be quantified. An example is a recent paper by Desforges et al. (2014), which showed ΣPBDE relationships in plankton and other pelagic species along a transect from a strong sediment source in relatively shallow water, but generalizing this to Puget Sound disposal sites is difficult.

Per Table 1 of the 2015 PBE, most sites are at 91-171 m below mean lower low water (MLLW). The two exceptions are the nondispersive Bellingham Bay site and the dispersive Rosario site; these are 29-43 m below MLLW. Additionally, surface water discharge of PBTs is not well understood In Puget Sound, for which there are a number of industrial-and/or urban-affected rivers. In the text, we have summarized recent Ecology papers on atmospheric and runoff into Puget Sound, and looked in particular at the export model for sediment ΣPCB in Lower Duwamish Waterway. These values were used to contextualize the movement of PBTs in the program, although (as stated), the PBTs in sediments managed here are already in the aquatic environment, and it is not the mass, but the pathways from the disposal sites that matter most.

The DMMP related placement of PBTs is close to ambient levels or (in the case of the highly urbanized Elliott Bay site) appears to be cleaner than the ambient sediments. As models are refined and validated, the DMMP will follow progress and consider program implications.

7. Conclusion

The programmatic actions of transport, placement, and disposal of dredged materials with biomagnifying substances are unlikely to increase the existing levels of contamination to the food web. We are aware of no other related Federal decisions that would cause cumulative damages in conjunction with the DMMP activities.

Therefore, continued disposal of approved sediments at the DMMP open-water disposal sites in Puget Sound will have discountable effects on ESA-listed species, including SRKW and Steller sea lions. Continued disposal will also have discountable effects on harbor seals regulated under the MMPA.

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Appendix D

Evaluation of DMMP Effects on ESA-Listed Rockfish

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Introduction

There are 29 species of rockfish (genus *Sebastes*) known to occur in the marine waters of Western Washington (J. West, WDFW Biologist, January 2014). Most are demersal, and some are pelagic. All have internal fertilization and extrude small larvae in the thousands to millions. The larvae are typically found in the upper regions of the water column with the plankton where they feed and are preyed upon. During the larval life history stage, all of the locally occurring rockfish species are indistinguishable from one another, except for bocaccio which can be distinguished by its distinctive color pattern. As the larvae grow they begin to take on the color patterns of the adult life history stage. This usually occurs after the larvae (juveniles) take up a demersal or lower water column existence.

Three of the 29 locally occurring species of rockfish were listed under the Endangered Species Act (ESA) in 2010. Bocaccio (*Sebastes paucispinis*) was listed as endangered, while canary (*S. pinniger*) and yelloweye (*S. ruberrimus*) were listed as threatened. The U.S. Army Corps of Engineers, Seattle District (Corps) conducted a Section 7 consultation with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) (together the Services) on the continued use of Puget Sound Dredged Disposal Analysis (PSDDA) sites in 2010 (USACE, 2010) for the disposal of dredged material in the aquatic environment. There were two earlier Section 7 consultations with the Services prior to 2010 (Corps 2005, 1999). The 1999 and 2005 Section 7 consultations were informal, resulting in letters of concurrence. The Corps' effect determination for the 2010 Section 7 consultation was *may affect, not likely to adversely affect* for all species of concern at the PSDDA sites. The USFWS agreed and returned a letter of concurrence. The NMFS agreed with the effect determinations for all but the three listed rockfish species and wrote a biological opinion (NMFS, 2010) based on the assumption that listed rockfish larvae would be injured or killed by the jet of material released from bottom-dump transport barges as dredged material was disposed.

The biological opinion recommended, among other things, that the Corps conduct, or support, comprehensive ichthyoplankton surveys at each of the PSDDA program dispersive and nondispersive disposal sites affected by the rockfish listing to determine the abundance and time of occurrence of listed rockfish larvae.

Larval Rockfish Occurrence at the Puget Sound Dredged Disposal Analysis Sites

The Dredged Material Management Program (DMMP) agencies collaborated with the Northwest Fisheries Science Center (NWFCS) of NMFS in 2011 and 2012 to conduct sampling to enumerate the larval life history stage of the three listed species in the vicinity of the PSDDA disposal sites (Greene and Godersky, 2012). In conjunction with a larger survey, the NWFSC sampled the waters above six of the eight PSDDA disposal sites: Anderson/Ketron Island, Bellingham Bay, Commencement Bay, Elliott Bay, Port Gardner and Rosario Strait. The two locations not sampled were the Port Townsend and Port Angeles dispersive disposal sites, both located in the Strait of Juan de Fuca. Sampling was conducted monthly for 11 months at each of the six sampled disposal sites for a total of 64 samples (Port Gardner was not sampled during April and May of 2012). A total of 217 larval rockfish were collected in the 64 samples (Table 1). The average catch was 3.39 larvae across all disposal sites and months sampled. The largest single catch was 33 larvae at the Anderson/Ketron Island disposal site in April 2011.

In-water work windows have been established by the Washington Department of Fish and Wildlife for the protection of fish in marine and estuarine areas of the state. Dredging and the subsequent disposal of dredged material at the PSDDA sites may only occur during the work window. The typical work window is July 16 – February 15. The monthly average number of rockfish larvae caught during this time period was 2.08 across all sample locations. The largest single catch during the work window was 18 larvae at the Anderson/Ketron Island disposal site in September 2011. There were only 4 larvae caught during the five months of October through February.

Table 1. Catches of larval rockfish at six PSDDA disposal sites sampled from April 2011 through February 2012.

				Work Window, July 16 – February 15								
Disposal Site	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Totals**
Anderson/Ketron	33	15	0	0	2	18	0	0	0	0	1	**69**
Bellingham Bay	0	0	0	0	0	0	0	0	0	0	1	**1**
Commencement Bay	1	24	0	8	13	0	1	0	0	0	0	**47**
Elliott Bay	16	18	5	11	3	10	0	0	0	0	0	**63**
Port Gardner	NS	NS	5	4	2	0	0	0	0	0	0	**11**
Rosario Strait	0	0	0	1	11	13	1	0	0	0	0	**26**
Totals:	**50**	**57**	**10**	**24**	**31**	**41**	**2**	**0**	**0**	**0**	**2**	**217**

NS = not sampled

None of the captured larval rockfish could be identified to species. Since larval Bocaccio can be distinguished by their color pattern and were not identified in the samples, it was assumed that no Bocaccio larvae were caught. That left Canary rockfish and Yelloweye rockfish as possibilities. Positive identification of these two species can only be made through genetic analysis. However, genetic analysis was not possible because the samples were inadvertently preserved in formalin instead of ethanol. Therefore, it is unknown whether any listed rockfish larvae were collected during the study.

Greene and Godersky (2012) converted the monthly count data to densities using the dimensions of the net used to collect the rockfish larvae and the length of the tows. Table 2 shows the densities for each site for each month during the typical work window.

Table 2. Larval rockfish densities (fish/1000 m^3) at six PSDDA disposal sites For the months of July 2011 through February 2012 (Greene and Godersky, 2012)

	Work Window, July 16 – February 15								
Disposal Site	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mean**
Anderson/Ketron	0	12.6	135.9	0	0	0	0	7.2	**19.5**
Bellingham Bay	0	0	0	0	0	0	0	7.2	**0.9**
Commencement Bay	50.2	81.6	0	6.3	0	0	0	0	**17.3**
Elliott Bay	69.0	26.8	88.5	0	0	0	0	0	**23.0**
Port Gardner	25.1	12.6	0	0	0	0	0	0	**4.2**
Rosario Strait	6.3	69.0	81.6	6.3	0	0	0	0	**20.4**

Estimated Numbers of Rockfish Larvae Affected by Dredged Material Disposal

NMFS (2010) estimated the number of listed rockfish injured or killed annually at each of the PSDDA non-dispersive disposal sites. The estimates were based on ranges of rockfish densities from the San Juan Islands (Weis, 2004); the fraction of rockfish caught by recreational anglers that were ESA-listed species; the volume of water through which a barge load of material passes during disposal; and the volume of material placed at each site annually. The volume of water affected by each barge load of material was calculated by multiplying the depth of the disposal site by a conservative estimate of the cross-sectional area of the dredged material plume. Table 3 provides the estimates made by NMFS:

Table 3. Estimated Numerical Ranges of Larval ESA-listed Rockfish Likely to be Exposed to Sediment Disposal Activities on an Annual Basis (Table 4 from NMFS, 2010)

Disposal Site	Range of estimated annual yelloweye rockfish larvae exposed	Range of estimated annual canary rockfish larvae exposed	Range of estimated annual bocaccio larvae exposed
Port Gardner	1,401.5 to 68,743.2	2,170.1 to 7,233.7	45.2 to 150.7
Elliott Bay	1,040 to 3,466.2	1,610.1 to 5,367	33.5 to 111.8
Commencement Bay	4,751 to 15,835.0	7,355.6 to 24,518.7	153.2 to 510.8
Anderson/Ketron Island	69 to 19.9	107 to 356.6	2.2 to 7.4
Bellingham Bay	8.4 to 28.07	13 to 43.5	0.3 to 0.90
Total range of larvae	7,269.4 to 88,092.4	2,170 to 37,519.5	234.5 to 781.7

Assumptions:

1) the cross-section of the disposal plume is a circle with diameter of 250 ft
2) the entire water column from surface to site bottom has the same density of rockfish larvae
3) barge size = 1,500 cubic yards

In the preparation of this BE the Corps found errors of two kinds in the calculations used by NMFS to derive the entries in Table 3. The first error was a systematic mathematical error that affected all entries in the table. The cross section of the discharge plume was assumed to be a circle with diameter 250 feet in NMFS (2010). In attempting to reproduce the entries in Table 3, the Corps discovered that the formula πd^2 appears to have been used in calculating the ranges appearing in the table. The correct formula for the area of a circle is πr^2. This means that the entries in Table 3 must be divided by 4 to yield the correct results. The second error was random in nature and only affected estimates in Table 3 for yelloweye at Port Gardner and Anderson-Ketron. The range of rockfish densities taken from Weis (2004) to derive the ranges in Table 3 was 0.75 to 2.5 larvae per 1,000 cubic meters. Therefore, the ratio of the upper number in each range in Table 3 divided by the lower number should be 2.5/0.75 or 3.33. This holds true for all the ranges in Table 3 except for yelloweye at Port Gardner and Anderson-Ketron. Accurate numbers can be derived for these entries by analyzing the ratios of ranges from site to site. Because the assumptions made in NMFS (2010) are independent of species, the ratio of the lower number in each range for one site compared to the lower number in each range for another site should be the same regardless of species. The same should be true when comparing the upper end of each range. For example, the Commencement Bay numbers are all exactly 5 times the Elliott Bay numbers. Applying this methodology and comparing the Port Gardner and Anderson-Ketron sites to Elliott Bay, the entries for yelloweye were able to be corrected. Table 4 shows the ranges of ESA-listed rockfish, with both types of errors corrected.

Table 4. Corrected Estimated Numerical Ranges of Larval ESA-listed Rockfish Likely to be Exposed to Sediment Disposal Activities on an Annual Basis

Disposal Site	Range of estimated annual yelloweye rockfish larvae exposed	Range of estimated annual canary rockfish larvae exposed	Range of estimated annual bocaccio larvae exposed
Port Gardner	350 to 1,170	543 to 1,810	11.3 to 37.7
Elliott Bay	260 to 867	403 to 1,340	8.4 to 28.0
Commencement Bay	1,190 to 3,960	1,840 to 6,130	38.3 to 128
Anderson/Ketron Island	17.3 to 57.6	26.8 to 89.2	0.6 to 1.9
Bellingham Bay	2.1 to 7.0	3.3 to 10.9	0.08 to 0.22
Total range of larvae	1,820 to 6,060	2,820 to 9,380	58.7 to 196

Assumptions:

1) the cross-section of the disposal plume is a circle with diameter of 250 ft
2) the entire water column from surface to site bottom has the same density of rockfish larvae
3) barge size = 1,500 cubic yards

For the current BE, the Corps estimated the number of ESA-listed rockfish larvae potentially affected by dredged material disposal using density data found in Greene and Godersky (2012), rather than the densities from Weis (2004). In addition, more realistic assumptions were made regarding the volume of water affected by each disposal event. A description of the assumptions made in the Corps' estimates follows.

The cross-sectional area of the disposal plume at the point of discharge is assumed to be equal to the dimensions of the dredged material compartment of the dump scow when the doors open. This area was calculated for General Construction's Point Defiance split-hull dump scow (Exhibit 1). The dredged material compartment is 40 feet wide by 128 feet long, with an area of 5,120 ft^2. The capacity of this scow is 1,375 cubic yards. A scow with capacity of 1,500 cy was used in NMFS (2010), so the cross-sectional area of the Point Defiance was increased proportionally to estimate the area of the compartment in a 1,500 cubic yard barge. Applying a multiplier of 1,500/1,375 yields a cross-sectional area of 5,590 ft^2.

To simplify calculation of the volume of water affected by a disposal event, the three-dimensional shape of the disposal plume can be modeled using a truncated cone (Exhibit 2). To yield a cross-sectional area equal to the dimensions of the dump scow, the diameter of the upper surface of the truncated cone would need to be approximately 84 feet (25.6 m). The diameter of the lower surface of the truncated cone is assumed to be 250 feet (76.2 m) for a disposal site with a depth of 400 feet (PSDDA/DSSTA, 1988). This is the same assumption made in NMFS (2010).

Rockfish larvae are typically found in the upper 80 meters of the water column (Federal Register, 2013). For sites deeper than 80 meters (Port Gardner, Commencement Bay, Elliott Bay and Anderson-Ketron Island), the diameter of the truncated cone at a depth of 80 meters was calculated. For sites shallower than 80 meters (Bellingham Bay), the diameter of the truncated cone at the depth of the site was calculated.

Using the mean monthly density of rockfish larvae during the dredging season at each site (Table 2); the average annual disposal volumes from Table 3 of the BE; the ESA-listed fractions of recreational rockfish catches from NMFS (2010); and the volume of water affected by the disposal plume; the numbers of listed rockfish larvae potentially affected by disposal were calculated. These estimates are provided in Table 5.

Table 5. USACE Estimates of ESA-listed Rockfish Larvae Likely to be Exposed to Sediment Disposal Activities on an Annual Basis

	BB	PG	EB	CB	AK
Disposal site depth (m)	29.3	128	91.4	149	128
maximum depth of rockfish larvae (m)	29.3	80	80	80	80
diameter of plume at the point of release (m)	25.6	25.6	25.6	25.6	25.6
diameter of plume at the maximum depth of rockfish larvae (m)	37.7	58.8	58.8	58.8	58.8
volume swept by disposal plume (in thousands of m^3)	23.3	117.6	117.6	117.6	117.6
average annual volume of disposed dredged material (cubic yards)	3,155	127,932	116,932	315,258	6,289
number of 1,500 cy barge loads per year	2.1	85.3	78.0	210.2	4.2
mean monthly rockfish density during the dredging window (larvae/1000 m^3)	0.9	4.2	23	17.3	19.5
fraction yelloweye	0.008	0.008	0.008	0.008	0.008
fraction canary	0.012	0.012	0.012	0.012	0.012
fraction Bocaccio	0.00026	0.00026	0.00026	0.00026	0.00026
number of yelloweye larvae affected	0.4	337	1,697	3,421	77
number of canary larvae affected	0.5	506	2,530	5,131	115
number of Bocaccio larvae affected	0.01	11	55	111	2.5

BB: Bellingham Bay
PG: Port Gardner
EB: Elliott Bay
CB: Commencement Bay
AK: Anderson-Ketron Island

Fecundity

In order to evaluate the potential effect of disposal on the ESA-listed species of rockfish, it is important to compare the estimates of larval impact to the fecundity of these species. Maximum size (length) and maximum fecundity were obtained for 19 of the local species of rockfish for which data on both parameters were available (Table 6). The data were obtained from Love et al. (2002). As can be seen from Figure 1, there is a tight relationship between length and fecundity. The best-fit relationship was expressed as $y=4.1976x^{2.9532}$ with a correlation coefficient of $R^2=0.8872$.

Table 6. Maximum size and fecundity for 19 species of Rockfish found in Western Washington (Love et al. 2002).

Common name	Maximum Size (cm)	Maximum Fecundity (eggs/female)
Blue Rockfish	53	525,000
Bocaccio Rockfish	91	2,298,000
Black Rockfish	69	1,200,000
Brown Rockfish	56	339,000
Canary Rockfish	76	1,900,000
Chillipepper Rockfish	59	538,000
Copper Rockfish	66	640,000
Darkblotched Rockfish	58	610,000
Greenstripe Rockfish	43	295,000
Half Banded Rockfish	25	31,000
Pacific Ocean Perch Rockfish	53	505,000
Puget Sound Rockfish	18.3	58,000
Rosy Rockfish	36	95,000
Splitnose Rockfish	46	255,000
Stripetail Rockfish	41	230,000
Vermilion Rockfish	76	2,600,000
Widow Rockfish	59	1,113,000
Yelloweye Rockfish	91	2,700,000
Yellowtail Rockfish	66	1,993,000

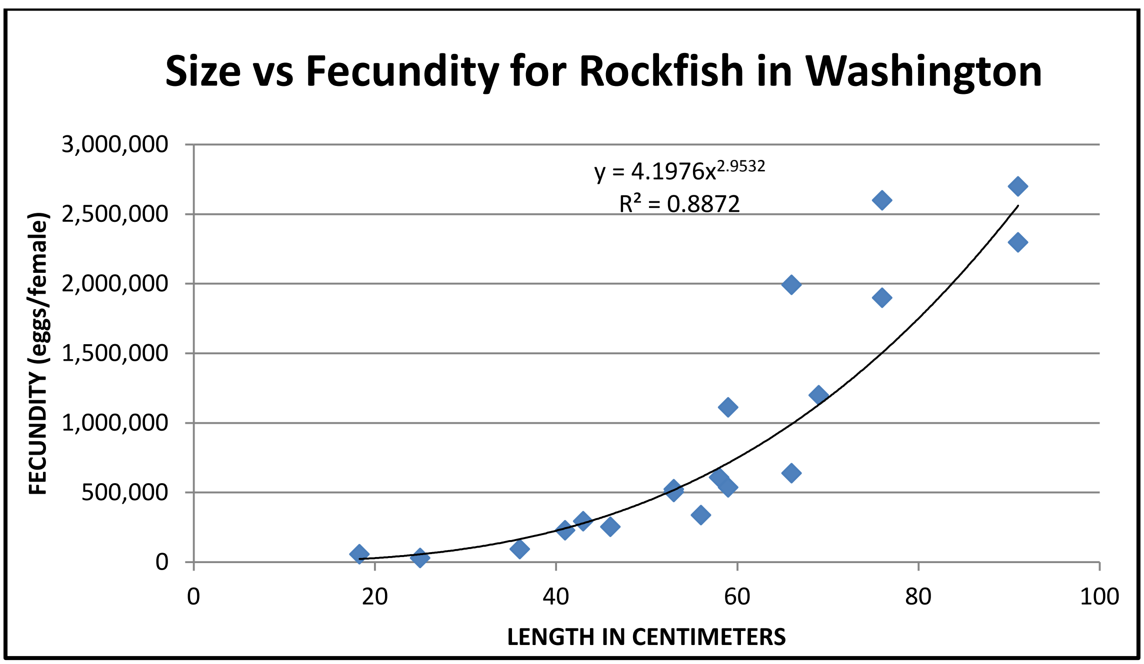

Figure 1. Maximum fecundity plotted against maximum size for 19 species of rockfish found in Western Washington. Note that each data point represents a separate species.

There are several implications of this analysis including: 1) egg size is likely similar across all species analyzed; 2) fecundity is determined by fish size (length) not by species; and 3) fecundity is similar across all species at any given size.

Evaluation

A comparative evaluation of the magnitude of potential effects from the proposed action is made somewhat problematic given the errors in the estimates made in the 2010 biological opinion. If the Corps' exposure estimates in Table 5 are compared to the corrected NMFS exposure estimates in Table 4, it can be seen that the Corps' estimates for Port Gardner are below the corrected estimates for all species. For Bellingham Bay, the Corps' estimates are below the corrected NMFS estimates for yelloweye and canary rockfish, and the Corps' estimate for Bocaccio falls within the corrected NMFS range. The Corps' estimates for Commencement Bay are within the corrected NMFS ranges for all species. The Corps' estimates for Elliott Bay and Anderson-Ketron are above the corrected NMFS ranges for all species.

If the Corps' estimates are to be compared against the estimates upon which the biological opinion was based, then the Corps' estimates in Table 5 need to be compared against the uncorrected NMFS estimates in Table 3. In comparing Tables 3 and 5, the numbers of potentially affected larvae estimated by the Corps at the Bellingham Bay and Port Gardner sites are well below those estimated in the biological opinion for all species. The Corps' estimates for Commencement Bay are also below the ranges estimated by NMFS. For Elliott Bay and Anderson-Ketron, the Corps' estimates are at the low end of the ranges estimated by NMFS (note that the upper end of the NMFS range for yelloweye at Anderson-Ketron should have been 229).

The Corps estimates that a total of approximately 5,500 yelloweye rockfish larvae; 8,300 canary rockfish larvae; and 180 Bocaccio larvae could potentially be affected on average each year by the entirety of dredged material disposal at the DMMP non-dispersive sites. This is a grand total of approximately 14,000 ESA-listed rockfish larvae. Using the equation provided in Figure 1, this is less than 50% of the larvae produced by a single 20-cm long rockfish.

The NMFS estimated that the total number of ESA-listed rockfish larvae potentially affected annually by disposal at the non-dispersive sites falls in the range of approximately 9,700 to 126,000 larvae (NMFS, 2010). The Corps' estimate of 14,000 falls very near the lower end of that range. This is despite the higher larval densities used in the Corps' calculations.

Assumptions

1. The larval densities found by Greene and Godersky (2012) are representative of the actual densities found at the DMMP disposal sites.
2. Larval rockfish density is uniform in the upper 80 meters of the water column.
3. Viable rockfish larvae are not found deeper than 80 meters.
4. The fractions of ESA-listed rockfish found in NMFS (2010) are applicable to the DMMP disposal sites.
5. The truncated-cone model used by the Corps provides reasonable estimates of the volume of water affected by disposal.
6. All rockfish larvae exposed to the disposal plume are injured or killed.
7. Rockfish fecundity is similar across all species for a given size (length).

Uncertainties

1. Interannual variation could not be addressed.

References

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