2005 Full Monitoring at the Anderson/Ketron Islands PSDDA Disposal Site

Draft Data Report

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WASHINGTON STATE DEPARTMENT OF
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LIST OF ACRONYMS AND ABBREVIATIONS

µg	microgram
µm	micrometer
°	Degree
Φ	phi
ARI	Analytical Resources, Inc.
BCOC	bioaccumulative contaminants of concern
BT	bioaccumulation trigger
CAS	Columbia Analytical Services
cm	centimeter(s)
DMMP	Dredged Material Management Program
DNR	Department of Natural Resources
DW	dry weight
Ecology	Washington State Department of Ecology
HPAH	high molecular polycyclic aromatic hydrocarbons
kg	kilogram(s)
LPAH	low molecular polycyclic aromatic hydrocarbons
mg	milligram(s)
ML	maximum level (DMMP chemical criteria)
N	Nitrogen
NCMA	Normalized combined mortality/abnormality
OSI	organism-sediment index
PCB	polychlorinated biphenyl
PSDDA	Puget Sound Dredged Disposal Analysis
QA1	Quality Assurance Level 1
QA/QC	Quality Assurance/Quality Control
QASAP	Quality Assurance, Sampling and Analysis Plan
R/V	research vessel
RPD	redox potential discontinuity
RSD	relative standard deviation
SAIC	Science Applications International Corporation
SL	screening level (DMMP chemical criteria)
SMS	Washington State Sediment Management Standards
SQS	Washington State Sediment Quality Standards
SVOA	semivolatile organic compound
SVPS	sediment vertical profiling system
TOC	total organic carbon
TS	total solids
TTL	target tissue level
TVS	total volatile solids
UEMP	Updated Environmental Monitoring Plan
U.S. EPA	U.S. Environmental Protection Agency, Region 10
USACE	U.S. Army Corps of Engineers
VOA	volatile organic analysis
WW	wet weight

1.0 INTRODUCTION

This report presents the results of the 2005 full monitoring program conducted at the Anderson/Ketron Islands non-dispersive dredged material disposal site in Puget Sound, Washington. The Washington State Department of Natural Resources (DNR) conducted this study through a contract with Science Applications International Corporation (SAIC).

The Dredged Material Management Program (DMMP) is responsible for the environmental management of dredged material in western Washington. The DMMP is an interagency partnership consisting of the DNR, the U.S. Army Corps of Engineers, Seattle District (USACE), the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency, Region 10 (U.S. EPA). The DMMP provides guidance for evaluating proposed dredged material to determine its suitability for unconfined, open-water disposal, obtaining disposal site use permits, and monitoring disposal sites following dredged material disposal. In Puget Sound, this guidance is outlined in the Puget Sound Dredged Disposal Analysis (PSDDA) program. The PSDDA dredged material management plan was first implemented in June of 1988 for central Puget Sound sites (Phase I) and in September of 1989 for north and south Puget Sound sites (Phase II) (PSDDA 1988a-d, 1989a,b).

The Anderson/Ketron Islands PSDDA disposal site is located near Steilacoom, WA, and was established in 1989 during the Phase II studies for northern and southern Puget Sound (PSDDA, 1989a,b). The 2005 full monitoring program is the first monitoring event conducted at the Anderson/Ketron site since completion of the baseline studies (PSDDA, 1989b). To date, the site has received little use with a total of 32,826 cubic yards (cy) of dredged material placed at the site since 1989. However, a full monitoring program was conducted in 2005 in anticipation of increased use of the Anderson/Ketron site in 2006 (Port of Olympia dredging), and to provide a new baseline dataset for comparing future site monitoring results.

In addition to providing a new baseline dataset, the following objectives are identified for the 2005 full monitoring program at the Anderson/Ketron Islands PSDDA site:

- Ensure that disposal activities comply with federal Clean Water Act Section 404(b)(1) guidelines.
- Verify PSDDA predictions concerning site conditions following disposal events.
- Provide the State of Washington, federal agencies, and the public with disposal site monitoring information.
- Contribute data for the annual review of the DMMP dredging and disposal site evaluation process.

2.0 REVIEW OF THE PSDDA MONITORING PLAN

This section briefly describes the PSDDA monitoring program design and presents modifications to the sampling and testing program as implemented in 2005. A comprehensive review can be found in the Updated Environmental Monitoring Plan (UEMP) (SAIC, 2005a).

2.1 PSDDA Monitoring Framework

The full PSDDA monitoring plan (PSDDA 1988a-d) assesses the physical, chemical, and biological effects of dredged material disposal at approved Puget Sound confined aquatic disposal sites and their surrounding environments. Under the monitoring framework, specific hypotheses were formulated to answer three questions:

1. Does the dredged material stay on site?
2. Has dredged material disposal caused the biological effects conditions for site management to be exceeded at the site?
3. Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?

A summary of the monitoring framework and the specific hypotheses and interpretive guidelines are presented in Table 2-1. Under a full monitoring program, all three questions in the PSDDA monitoring framework are addressed. However, some analyses are tiered (e.g., analysis of benchmark chemistry and bioassays) and are only conducted if triggered by the interpretive guidelines within the context of the PSDDA monitoring framework. The PSDDA monitoring framework includes a sampling design that monitors seven station types at and in the vicinity of the disposal site. In addition, an offsite reference station is included to provide a control for sediment toxicity testing. The station types and their purpose are described in Table 2-2. Anderson/Ketron stations are identified with an "AK" prefix followed by a "station type" designation and a unique number.

Five monitoring parameters have been identified to assess the environmental effects of dredged material disposal: sediment vertical profiling system (SVPS) photography, sediment chemistry, sediment toxicity, tissue chemistry, and benthic infaunal community structure (Table 2-3). Specific interpretive guidelines and trigger values have been established for each monitored parameter (see Table 2-1). If guideline values for a given parameter are exceeded during a monitoring event, a potential disposal impact is indicated, and the benchmark station monitoring and baseline data are compared and evaluated.

Table 2-1. The PSDDA monitoring framework.

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Item (When exceedances noted)[1]
No. 1 Does the deposited dredged material stay on site?	1. Dredged material remains within the site boundary.	Sediment Vertical Profiling System (SVPS) Onsite and Offsite	Dredged material layer is greater than 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[2]	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 [PSDDA-defined Site Condition II] exceeded at the site due to dredged material disposal? (PSDDA 1988b)	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 off site?	5. No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infauna species collected downcurrent of the disposal site.	Tissue Chemistry Transect	Guideline values Metals: 3x the baseline concentrations Organics: 5x the baseline concentrations	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 downcurrent of the disposal site.	Infaunal Community Structure Transect	Guideline values Abundance of major taxa < ½ baseline macrobenthic infauna abundances.	Compare post-disposal benchmark benthic data with baseline benchmark data.

1 To determine if observed changes in chemical conditions or infaunal benthos are due to dredged material disposal, data from the benchmark stations are considered. All decisions are subject to DMMP agency review and best professional judgment.

2 The 2005 full monitoring survey at the Anderson/Ketron is the first monitoring event conducted at the disposal site. Therefore, temporal analysis was not conducted.

Table 2-2. Station types and purpose for the PSDDA sampling design.

Station	Designation Letter	Location	Purpose
Zone	Z	Within disposal target zone.	Assess sediment chemistry and toxicity of dredged material deposited in the target area (Question 2).
Site	S	Within the site boundary but outside of the target zone.	In conjunction with zone data, site station sediment chemistry and toxicity are used to evaluate Question 1.
Perimeter	P	Located 0.125 nautical miles from the site boundary.	Physical and chemical data are obtained to determine if dredged material is present beyond the site boundary and document the chemical character of sediments outside the site boundary (Question 1).
Transect	T	Situated along a radial transect that extends outward from the perimeter line. Located in the direction of dredged material transport.	Sampled for benthic infauna abundance and infauna tissue contaminant body burden to evaluate biological resource impacts offsite (Question 3).
Benchmark	B	Located in the vicinity of the disposal site, but beyond the region affected by disposal activity.	Used to identify potential changes in sediment quality that may be unrelated to dredged material disposal. Data are evaluated only if site, perimeter, or transect data indicate that conditions at or adjacent to the site have changed relative to baseline conditions and to test hypotheses that observed changes are due to dredged material disposal[1]. Data may be used to evaluate Hypotheses 2 through 6.
Central Transect	C	Situated along two perpendicular lines that bisect the disposal site and may extend beyond its boundaries.	Used for physical measurements to map the post-disposal distribution of dredged material (Question 1).
Reference	R	Located in areas documented to be free of potential sources of contamination (e.g., Carr Inlet). Location is selected on the basis of grain size comparability with the bioassay test sediments.	Sediments used as a control for physical effects in toxicity testing.

1 All data types (physical, sediment chemistry, tissue chemistry, sediment toxicity, and benthic infauna) may be collected. Benchmark sediments are generally archived until disposal site analyses indicate benchmark data are needed for full evaluation. However, benchmark chemical analyses for volatile organics, mercury, sulfides, and ammonia are conducted in conjunction with disposal site sediments due to holding time constraints.

Table 2-3. PSDDA disposal site station types and monitoring tools.

Station	SVPS	Sediment Chemistry	Bioassays	Benthic Infauna	Tissue Chemistry
Zone (Z)	●	●	●		
Site (S)	●	○	○		
Perimeter (P)	●	●			
Transect (T)	●			○	○
Benchmark (B)		● (A)	● (A)	○ (A)	○ (A)
Central Transect (C)	●				
Floating (F)	●				
Reference (R)			●		

○ Monitoring tools used for an intensive full monitoring program

● Monitoring tools used for a partial monitoring or full monitoring program

(A) Archived

2.2 2005 Modifications to Sampling and Testing Procedures

2.2.1 Tissue Chemistry Sample Collections

Based on the 1989 baseline survey results at Anderson/Ketron (PTI, 1989), *Compsomyax subdiaphana* clams and *Molpadia intermedia* sea cucumbers were the target organisms for tissue samples at the transect and benchmark stations. Triplicate tissue sample collections were proposed at three transect stations (AKT01, AKT02, and AKT03), and three benchmark stations (AKB01, AKB02, and AKB03). However, during the 2005 survey, *Molpadia* was nearly absent at all stations sampled, and *Compsomyax* was scarce at all stations with the exception of AKT01 and AKB03. Therefore, triplicate tissue samples were collected and analyzed at stations AKT01 and AKB03 only.

2.2.2 Benthic Sample Collections

Three transect (AKT01, AKT02, and AKT03) and three benchmark (AKB07, AKB02, and AKB03) stations were sampled for benthic infauna using a 0.06 m^2 stainless Gray O'Hara box core. Benchmark station AKB01 was originally proposed for sampling. However, the presence of sandy sediments at AKB01 prevented the collection of acceptable samples with the box core. Therefore, station AKB01 was replaced with AKB07, in consultation with the DMMP agencies. Station AKB07 is located to the east of AKB01 and contains a higher proportion of fine grained sediments.

2.2.3 Benchmark Chemistry Analysis

Sediment samples collected at the three benchmark stations were analyzed for all DMMP conventionals and chemicals of concern, including butyltins, and the bioaccumulative chemicals of concern (BCOC), lists 1 and 2. The benchmark samples were analyzed because the 2005 monitoring results are proposed as the new baseline for the Anderson/Ketron disposal site.

3.0 METHODS

This section provides a summary of the sampling design, data collection, and field sampling method for the 2005 full monitoring program at the Anderson/Ketron PSDDA site. All sampling activities were conducted aboard the research vessel (R/V) *Kittiwake*. Detailed procedures of sampling and analysis methodologies are provided in the Quality Assurance, Sampling and Analysis Plan (QASAP) (Appendix A). A complete description of schedule, site conditions, field procedures, and coordinates for occupied stations is found in the Cruise Report (Appendix B). A summary of samples collected and types of analyses is provided in Table 3-1.

3.1 SVPS Survey

The Anderson/Ketron SVPS survey was conducted on June 27–28, 2005. SVPS images were collected using a digitally equipped Benthos Model 3731 Sediment Profile Camera. Triplicate images were collected at 57 stations, and a total of 171 images were analyzed (Figure 3-1). Stations sampled during the first day of the survey included perimeter, central cross, zone, and benchmark stations. The images were downloaded to a laptop computer periodically throughout the day to verify successful data acquisition. A "quick-look" assessment of the digital images was conducted following the first day of the survey to prepare a preliminary dredged material map. Historical dredged material was found to be limited to areas near the site center. Therefore, stations for the second day's survey included site stations to help delineate the historical footprint boundary. In addition, transect stations were occupied and additional benchmark stations were sited near station AKB01. Coarse grained sediments were observed at AKB01 and it was anticipated that acceptable benthic samples could not be collected at this station.

Following completion of the field survey, a computer image analysis system was used to analyze the SVPS images for the presence of dredged material and other physical and biological parameters. These parameters include sediment grain size major mode, prism penetration depth, surface boundary roughness, presence or absence of mud clasts, apparent RPD depth, infaunal successional stage, and calculation of the organism-sediment index (OSI) (Rhoads and Germano, 1982). Results were reviewed by an SAIC senior scientist following completion of the image analysis.

3.2 Benthic Infauna Sample Collections

Three transect (AKT01, AKT02, AKT03) and three benchmark (AKB02, AKB03, AKB07) stations were sampled for benthic infauna using a 0.06 m^2 stainless Gray O'Hara box core. Five replicate samples were collected at each station for a total of 30 box core samples. Benthic infaunal collections were accomplished following the procedures detailed in the QASAP (Appendix A). Each box core sample was divided into two sections: the top 10 cm (0 to 10 cm) and the remaining section of the core (>10 cm to bottom of core). The top 10 cm was sieved through 1.0 mm and 0.50 mm nested sieves. The >10 cm section was sieved through the 1.0 mm screen only. Each box core was comprised of three benthic samples, for a total of 90 benthic samples collected.

A total of 15 transect station samples were sorted to major taxonomic group, identified to the lowest practicable level, and enumerated by Columbia Science of Royston, B.C. Evaluation of the benthic community data was conducted by Caenum Environmental Associates of Seattle, Washington. The benchmark samples were preserved for long-term storage and are currently archived at the SAIC warehouse in Bothell, WA. Following completion of the 2005 monitoring program, the archived benthic samples will be transferred to DNR.

Table 3-1. Analyses or archiving conducted for individual replicate samples collected from Anderson/Ketron. A "✓" indicates analysis conducted, "---" = no analysis, "A" = archived sample.

Station Type	Grain Size, TOC	TS	TVS	Ammonia , T. Sulfides	Metals (w/o Hg)	Hg	VOA	SVOA/PEST/PCBs	BCOCs	*Compsomyax* (BCOCs)	Benthos	Bioassay
Onsite												
AKZ01	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	✓
AKS03	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	✓
AKS10	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	✓
Perimeter												
AKP01-A	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP01-B	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP01-C	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP02-A	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP02-B	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP02-C	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP03-A	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP03-B	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP03-C	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP04-A	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP04-B	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
AKP04-C	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	---	---
Transect												
AKT01-A	✓	---	---	---	---	---	---	---	---	✓	✓	---
AKT01-B	---	---	---	---	---	---	---	---	---	✓	(see note)	---
AKT01-C	---	---	---	---	---	---	---	---	---	✓	✓	---
AKT02-A	✓	---	---	---	---	---	---	---	---	---	✓	---
AKT02-B	---	---	---	---	---	---	---	---	---	---	✓	---
AKT02-C	---	---	---	---	---	---	---	---	---	---	✓	---
AKT03-A	✓	---	---	---	---	---	---	---	---	---	✓	---
AKT03-B	---	---	---	---	---	---	---	---	---	---	✓	---
AKT03-C	---	---	---	---	---	---	---	---	---	---	✓	---
Benchmark												
AKB02-A	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	(A)	(A)
AKB02-B	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	(see note)	---
AKB02-C	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	(A)	---
AKB03-A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	(A)	(A)
AKB03-B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	(A)	---
AKB03-C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	(A)	---
AKB07-A	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	(A)	(A)
AKB07-B	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	(A)	---
AKB07-C	✓	✓	✓	✓	✓	✓	✓	✓	✓	---	(A)	---
Reference												
CR-23W	✓	✓	✓	✓	---	---	---	---	---	---	---	✓
CR-24	✓	✓	✓	✓	---	---	---	---	---	---	---	✓

Note: Five replicates benthic infauna samples were collected from each transect and benchmark station.

"✓" = Analysis Conducted, "---" = no analysis, (A) = Archive, TS = Total Solids, TVS = Total Volatile Solids, TOC = Total Organic Carbon, T. Sulfides = Total Sulfides, Hg = Mercury, SVOAs = Semi-Volatile Organic Analysis, PEST/PCB = Pesticides and PCBs, VOA = Volatile Organics Analysis, BCOCs – Bioaccumulative Contaminants of Concern.

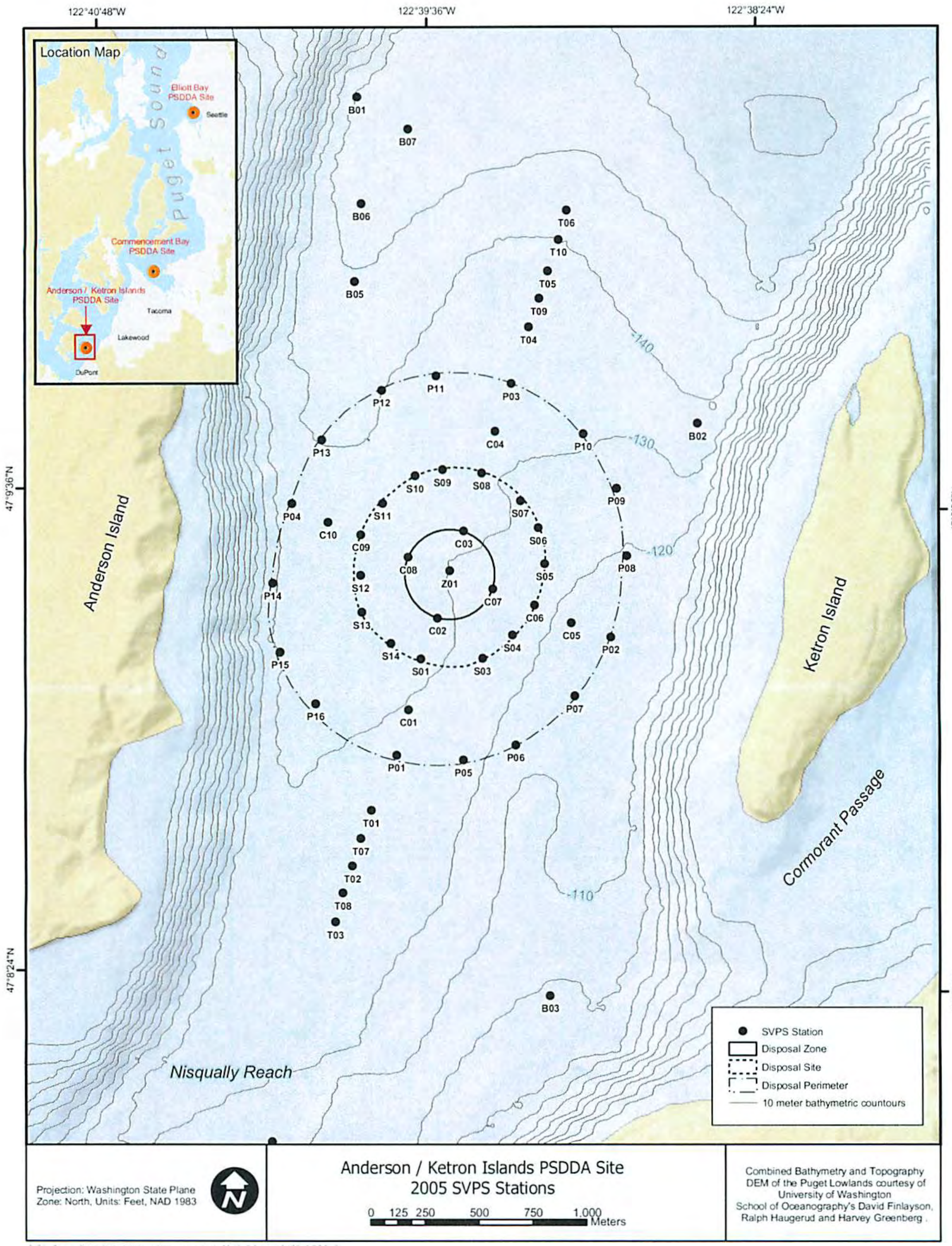

Figure 3-1. Anderson/Ketron SVPS stations in 2005.

3.3 Sediment Chemistry

Thirteen Anderson/Ketron stations were sampled to acquire sediments for chemical testing (Figure 3-2). Collection methods were consistent with the QASAP. Stations sampled included three onsite stations (AKZ01, AKS01, and AKS10), four perimeter (AKP01, AKP02, AKP03, and AKP04), three benchmark (AKB07, AKB02, and AKB03), and three transect (AKT01, AKT02, and AKT03). Two reference sediments were also collected from Carr Inlet (CR-23W and CR-24) for sediment conventional parameters and bioassays. A full summary of sediment chemistry collections and station locations for all samples collected are tabulated in the cruise report (Appendix B).

The onsite, perimeter, and benchmark samples were analyzed for all DMMP parameters and chemicals of concern, including butyltins, and the bioaccumulative chemicals of concern (BCOC), lists 1 and 2. All benchmark samples were analyzed under this task order to provide a new baseline for the benchmark sediment chemistry. Transect samples were sampled for grain size and total organic carbon (TOC). The Carr Inlet reference samples were analyzed for conventional parameters. Chemicals analyses were conducted by Columbia Analytical Services (CAS), of Kelso, Washington, and Analytical Resources, Inc. (ARI), of Tukwila, Washington.

3.4 Tissue Chemistry

Although triplicate tissue samples were proposed at the Anderson/Ketron transect and benchmark stations, only two stations (transect AKT01 and benchmark AKB03) showed sufficient *Compsomyax subdiaphana* clam densities to collect triplicate tissue samples (see Section 2.2.2). *Molpadia intermedia* sea cucumbers were nearly absent at all stations sampled. Each *Compsomyax* specimen collected was rinsed with site seawater and weighed. Cumulative weight measurements were made for each replicate sample. A total of six tissue replicate samples were submitted to ARI of Tukwila, Washington, and analyzed for lipids, moisture content, and the BCOCs, lists 1 and 2.

3.5 Bioassays

Bioassay testing was conducted on three onsite station sediments (AKS10, AKZ01, and AKS03) from Anderson/Ketron and two reference sediments (CR-23W and CR-24) collected from Carr Inlet, WA. The DMMP sediment bioassays included the 10-day acute amphipod test using *Eohaustorius*, the sediment larval test using *Mytilus galloprovincialis*, and the 20-day *Neanthes* mean growth test. In addition, benchmark samples were collected at three stations (AKB07, AKB02, and AKB03) and archived in accordance with the tiered PSDDA testing strategy. Bioassay testing of the onsite and reference sediments was conducted by Northwestern Aquatic Sciences of Newport, Oregon. Benchmark bioassay sediment samples are archived at 4°C at the SAIC warehouse.

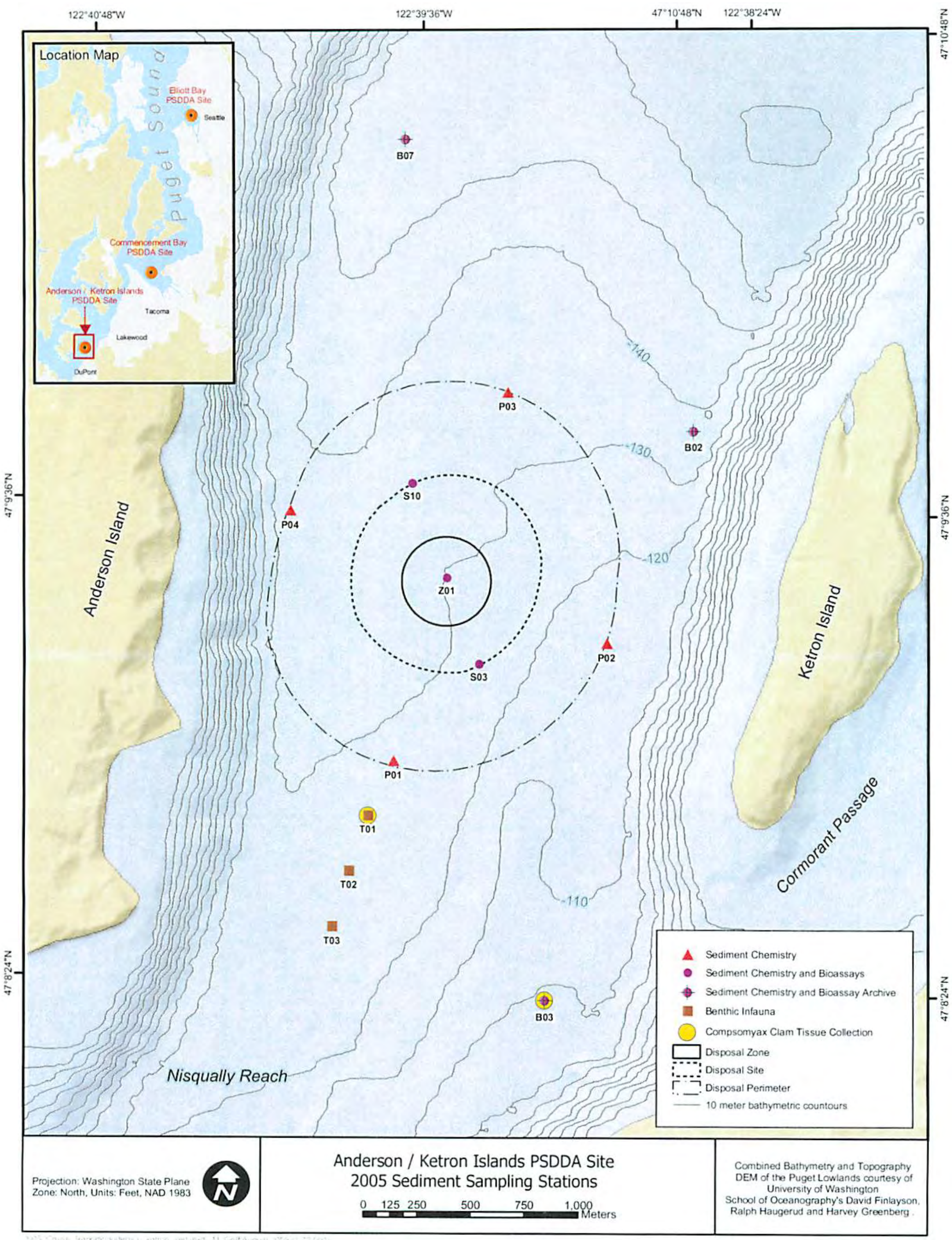

Figure 3-2. Anderson/Ketron sediment and tissue sampling stations in 2005.

4.0 RESULTS

This section presents the results of the SVPS survey, sediment and tissue chemistry analysis, bioassay testing, and benthic infauna analysis conducted during the 2005 Anderson/Ketron Islands full monitoring survey. An evaluation of the data in accordance with the PSDDA monitoring framework is provided in Section 5.0.

4.1 Sediment Vertical Profiling System Survey

SVPS images were collected at 57 stations at the Anderson/Ketron disposal site to map the distribution of dredged material and determine other physical (grain size major mode, prism penetration depth, boundary roughness), chemical (apparent RPD), and biological (successional stage and OSI) characteristics of site sediments. Triplicate images were analyzed at each station. A full summary of the image analysis results is provided in Appendix C.

4.1.1 Ambient Sediment Characteristics

Reflecting the fact that the Anderson/Ketron PSDDA site has not received large volumes of dredged material to date, surface sediments in most areas of the disposal site show ambient sediment characteristics. Within the site perimeter, ambient sediments consist of tan to gray slightly sandy silts and clays with reduced sediments at depth. Sediments are unconsolidated (water-rich) with deep apparent RPD depths (Figure 4-1). Numerous feeding voids are present, indicating the presence of deposit feeding organisms, which is a characteristic of well developed benthic communities.

Ambient sediments along the perimeter of the Anderson/Ketron site are similar to onsite ambient sediments, with the exception of stations along the eastern and western perimeter. Ambient sediments at these stations show a slight enrichment in fine sand (Figure 4-2). These perimeter stations are located at the base of the slopes near Anderson and Ketron Islands, and the sands are likely transported down naturally from the upper slope. Similar ambient sediment characteristics have been observed in Commencement Bay, near the base of the slope to Browns Point (SAIC, 2005b). Ambient sediments to the far north and south of the disposal site are coarse-grained, consisting of tan to gray silty fine sands (Figure 4-3). Station AKT03, located to the far south of the disposal site, shows the presence of possible sand ripples. Camera prism penetration is lower at these north and south stations due to the presence of compact, coarse-grained sediments. A similar distribution of coarse grained sediments was observed during the baseline survey of the Anderson/Ketron disposal site (PTI, 1989)

A few site and perimeter stations showed banding of reduced sediments at depth, which may be evidence of redox rebounds (Figure 4-4). A redox rebound (RPD depth decreases and rebounds upward) can be caused by decreases in pore water irrigation by the benthos and/or a higher rate of oxygen consumption at depth (Rhoads and Germano, 1982). For example, following deposition of organic material on the seafloor (e.g., seston deposits), decomposition of the material increases the oxygen demand of the sediments, resulting in a decrease of the RPD. Surface organic matter also tends to attract pioneering Stage I organisms, which are filter feeders that are less effective in pore water exchange and are associated with shallow RPD depths (Rhoads and Germano, 1982). Alternatively, the subsurface banding of reduced sediments could also be relict RPDs, although recent or historical dredged material is not apparent in areas outside of the disposal zone. A relict RPD occurs when a relatively thin layer of dredged material is deposited over ambient sediments. The RPD at depth is called a relict RPD, and a new RPD will be formed at the sediment surface.

AKS06-C AKP16-B

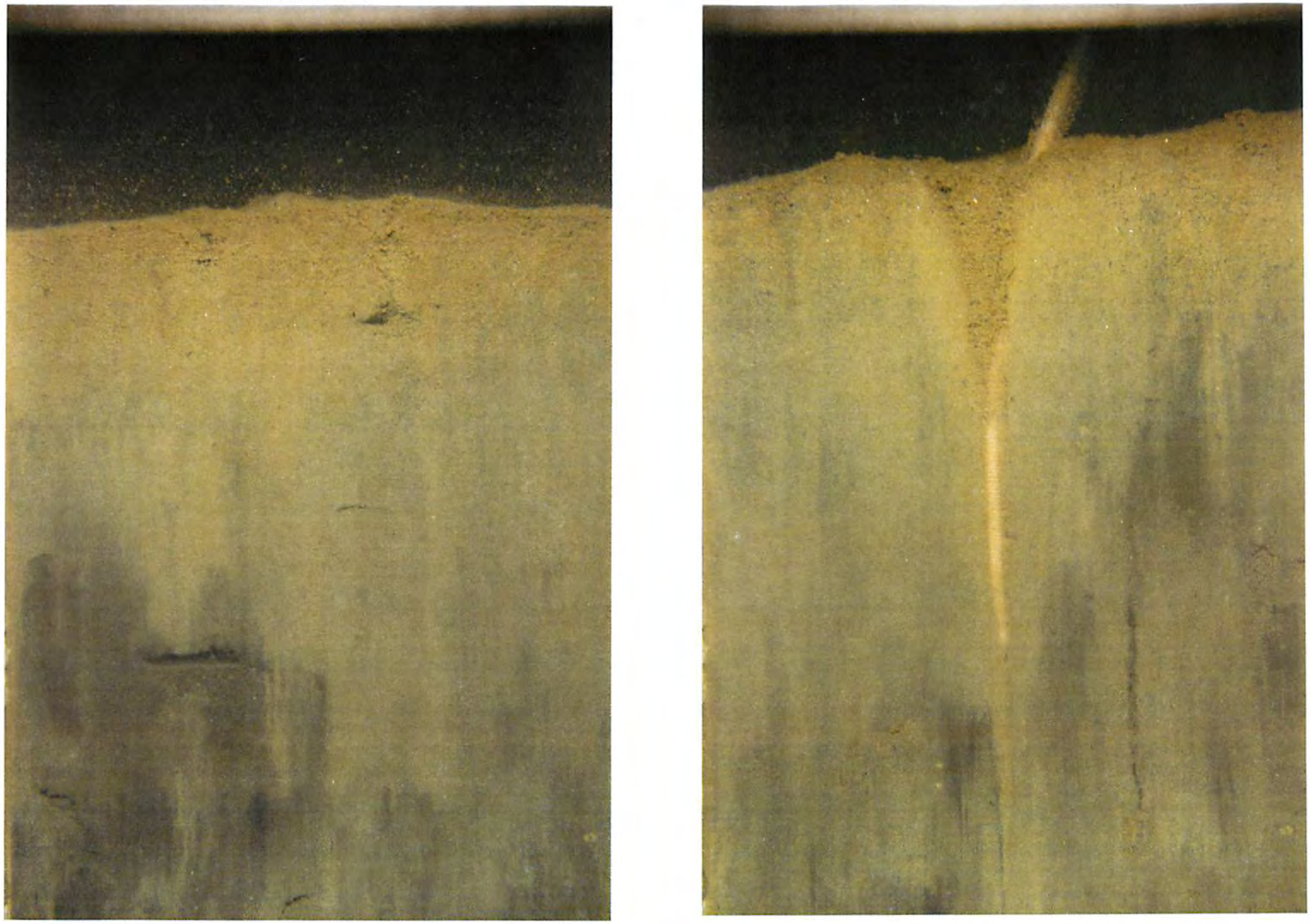

Figure 4-1. SVPS images from stations AKS06-C and AKP16-B showing fine-grained ambient sediments at the Anderson/Ketron site. The ambient sediments consist of soft, tan to gray, slightly sandy silt-clays. Reduced sediments are present at depth. Both stations exhibit deep apparent RPD depths and feeding voids created by head-down deposit-feeding organisms (Stage III successional stage). At Station AKP16-B, a sea whip (order Pennatulacea) is present in the center of the image.

AKP08-C

AKP14-A

Figure 4-2. SVPS images from perimeter stations AKP08-C and AKP14-A showing ambient sediments containing a higher proportion of sand along the eastern and western perimeter of the Anderson/Ketron site. The sand may originate from the upper slope of Anderson and Ketron Islands. Station AKP08-C shows small feeding voids and polychaetes at depth. At station AKP14-A, large and small fecal pellet structures are visible on the sediment surface (arrows).

AKB01-A

AKT03-A

Figure 4-3. SVPS images from stations AKB01-A and AKT03-A showing coarse-grained ambient sediments to the far north and south of the disposal site. At station CBB01-A, the ambient sediments consist of relatively homogeneous brownish gray silty fine sand. Stage I tubes are visible on the surface and feeding voids and polychaetes are visible at depth. Surface sediments at station CBT03-A consist of gray silty sand and a possible bedform/ripple is present at the sediment surface.

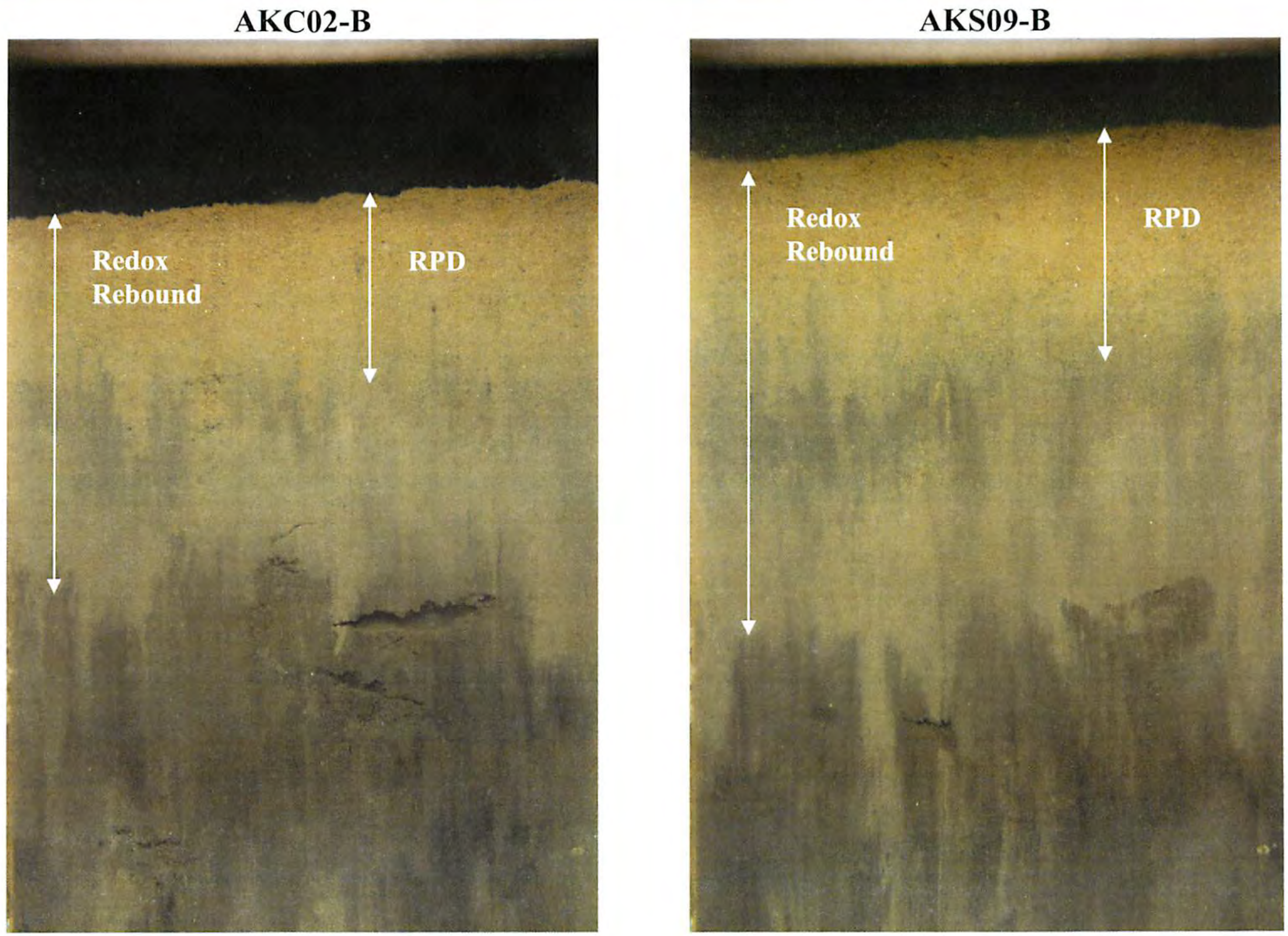

Figure 4-4. SVPS images from stations AKC02-B and AKS09-B showing possible redox rebounds. A redox rebound (RPD depth decreases and rebounds upward) can be caused by decreases in pore water irrigation by the benthos and/or a higher rate of oxygen consumption at depth. Both stations show similar RPD depths and redox rebound depths. Alternatively, the subsurface bands of reduced sediments could be relic RPDs related to dredged material disposal. However, recent dredged material deposition is not apparent at these stations (see Section 4.1.1).

4.1.2 Dredged Material Identification and Distribution

Dredged material is identified in SVPS images by its contrasting optical appearance relative to the ambient bottom. Multiple disposal events at a site will result in sedimentary layering with varying colors and textures, or a mixed and chaotic sedimentary fabric. Dredged material from port or harbor environments can often be organic-rich and reduced. Grain size, color and reflectivity, high boundary roughness, and sedimentary fabric are parameters that can be used to distinguish the presence of dredged material in SVPS images.

Use of the Anderson/Ketron site has been relatively low, with a total of 32,826 cy of dredged material taken to the site since the baseline survey in 1989. Over a year has passed since the most recent dredged material was placed at the site (June 2004). Thus, enough time has passed for the resident benthic infauna to recolonize the dredged material deposits and for bioturbation of onsite sediments to resume. Evidence of dredged material is absent at the Anderson/Ketron site, with the exception of two onsite stations (AKZ01 and AKC03) (Figure 4-5). The dredged material consists of brown to tan fine sandy silt, with traces of fine shell particles. Camera prism penetration is lower compared to surrounding stations, suggesting a higher proportion of coarse grained sediments (dredged material) at these onsite stations. The dredged material is identified as historic due to the well developed RPD, presence of feeding voids, and mottled sedimentary texture due to bioturbation (Figure 4-6).

It is possible that historic dredged material is present in more areas than the two onsite stations at the Anderson/Ketron site (i.e., beyond the disposal zone). However, the dredged material was likely deposited as thin layers outside of the disposal zone, and bioturbation has obscured the visual signature of the dredged material.

4.1.3 Physical and Sedimentary Features

Physical and sedimentary features determined from SVPS images include grain size major mode, camera prism penetration, and boundary roughness. Grain size major mode in phi (Φ) sizes for the 2005 SVPS survey at Anderson/Ketron is presented in Figure 4-7. The reported grain size major mode is the most prevalent grain size present in each image. Historic dredged material at the site center was comprised primarily of silt and clay (>4 Φ). Although the fine sand fraction is greater at the site center than in the surrounding areas, the predominant grain size is still >4 Φ. Ambient sediments at the Anderson/Ketron site were also comprised of silt and clay, with the exception of sediments to the far north and far south. These areas appear to be more hydrodynamically active, and surface sediments consist of very fine sand (4-3 Φ).

Camera prism penetration depths provide a relative measure of sediment bearing capacity. Unconsolidated, water-rich, fine grained sediments that experience bioturbation will generally have deep camera prism penetration. Conversely, coarse grained, compact sediments will have shallow prism penetration. SVPS camera prism penetration measurements for the 2005 SVPS survey are presented in Figure 4-8 and show a distribution pattern similar to grain size major mode. The lowest prism penetration depths are observed to the far north and south of the disposal site where coarse grained ambient sediments are present. Similarly, onsite stations AKZ01 and AKC03 show lower prism penetration depths due to the presence of historic dredged material deposits.

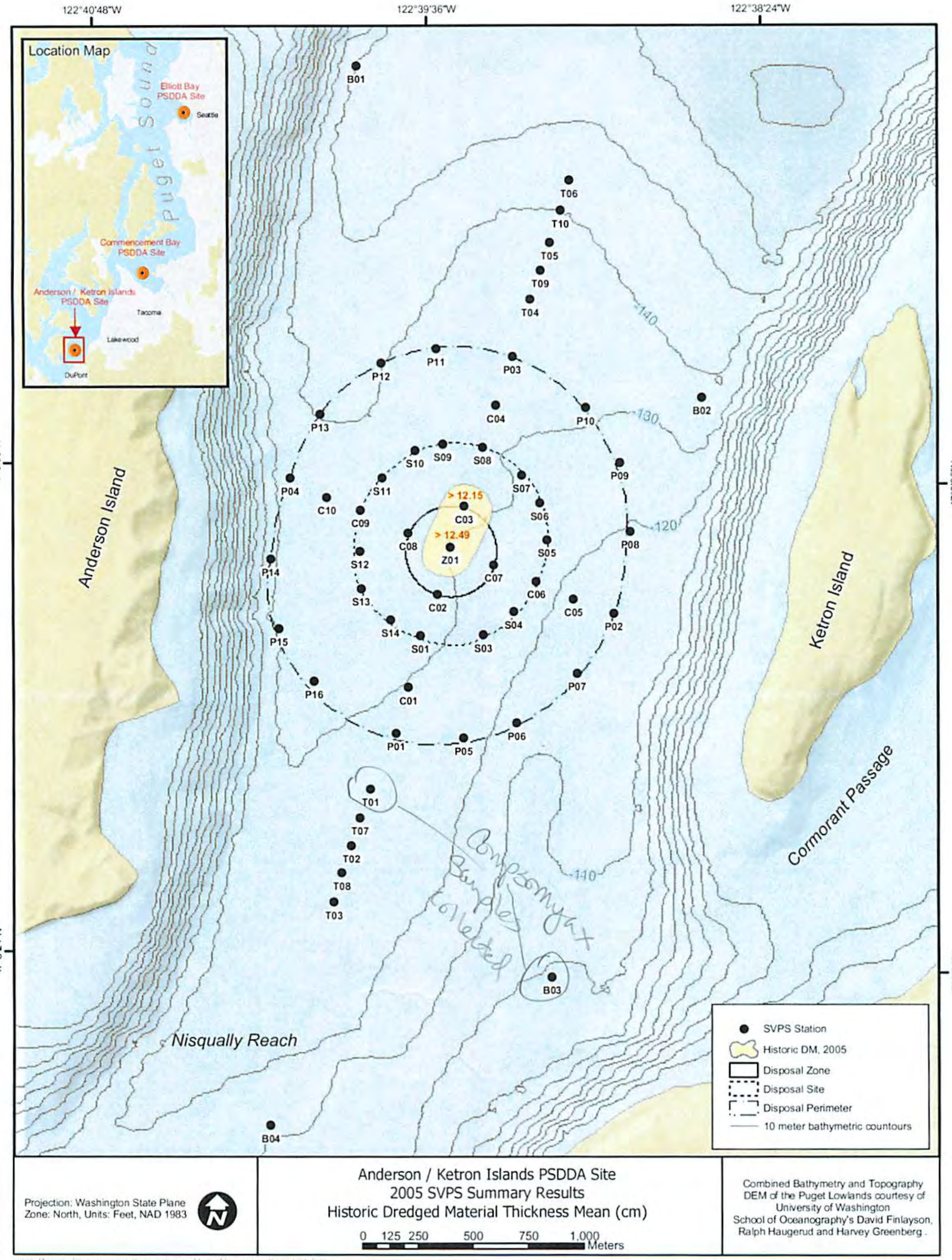

Figure 4-5. Historic dredged material footprint at Anderson/Ketron during the 2005 SVPS survey.

AKZ01-A

AKC03-A

Figure 4-6. SVPS images from stations AKZ01-A and AKC03-A showing historic dredged material within the disposal zone. The dredged material consists of brown to tan fine sandy silt, with traces of fine shell particles. Discrete layering of dredged material is no longer visible due to extensive bioturbation of the sediments. Lower penetration of the camera prism suggests a higher proportion of coarse grained sediments (dredged material) at these onsite stations. The dredged material is identified as historic due to the well developed RPD, presence of feeding voids, and mottled sedimentary texture due to bioturbation.

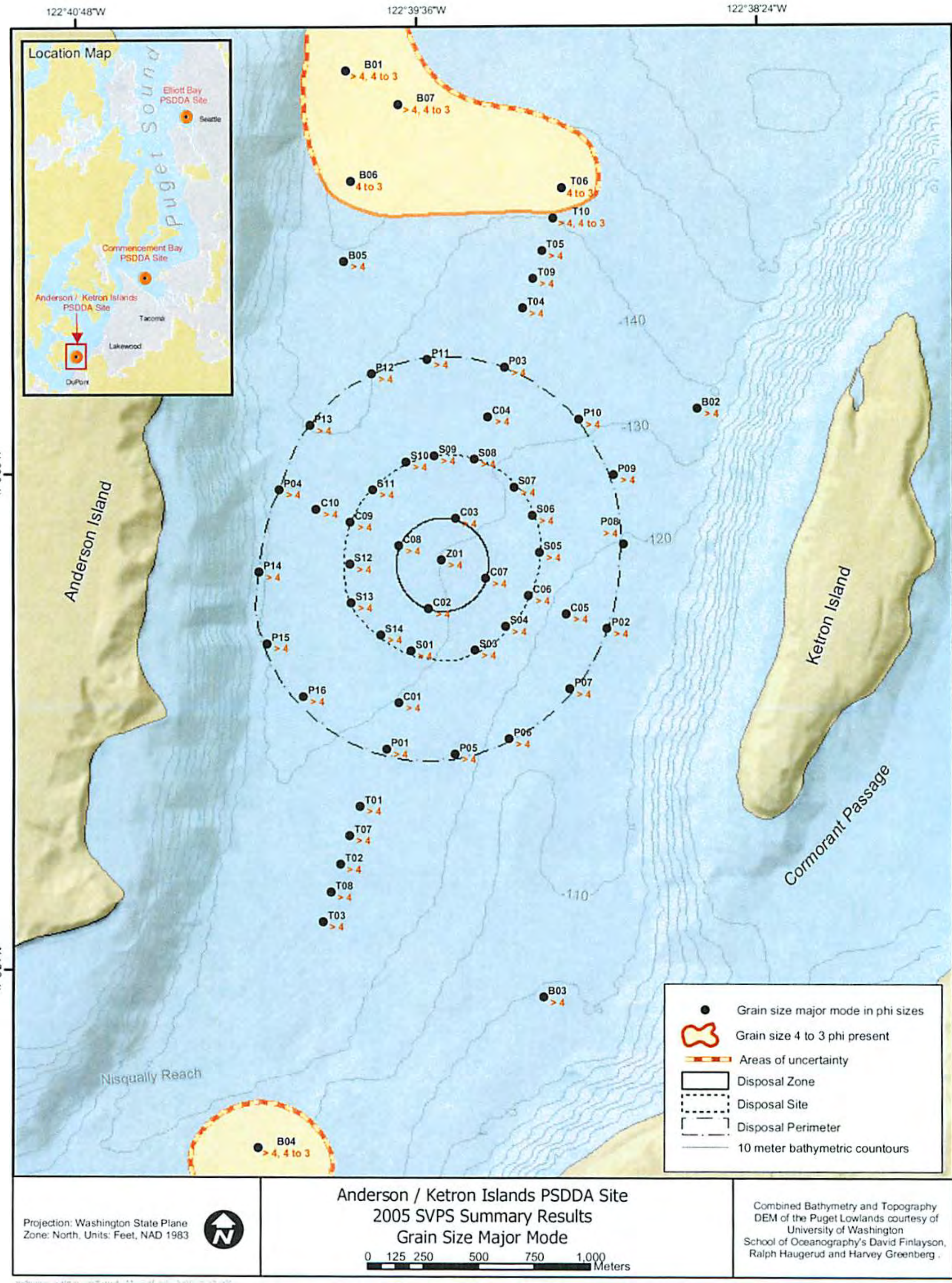

Figure 4-7. Grain size major mode in phi measured during the 2005 SVPS survey.

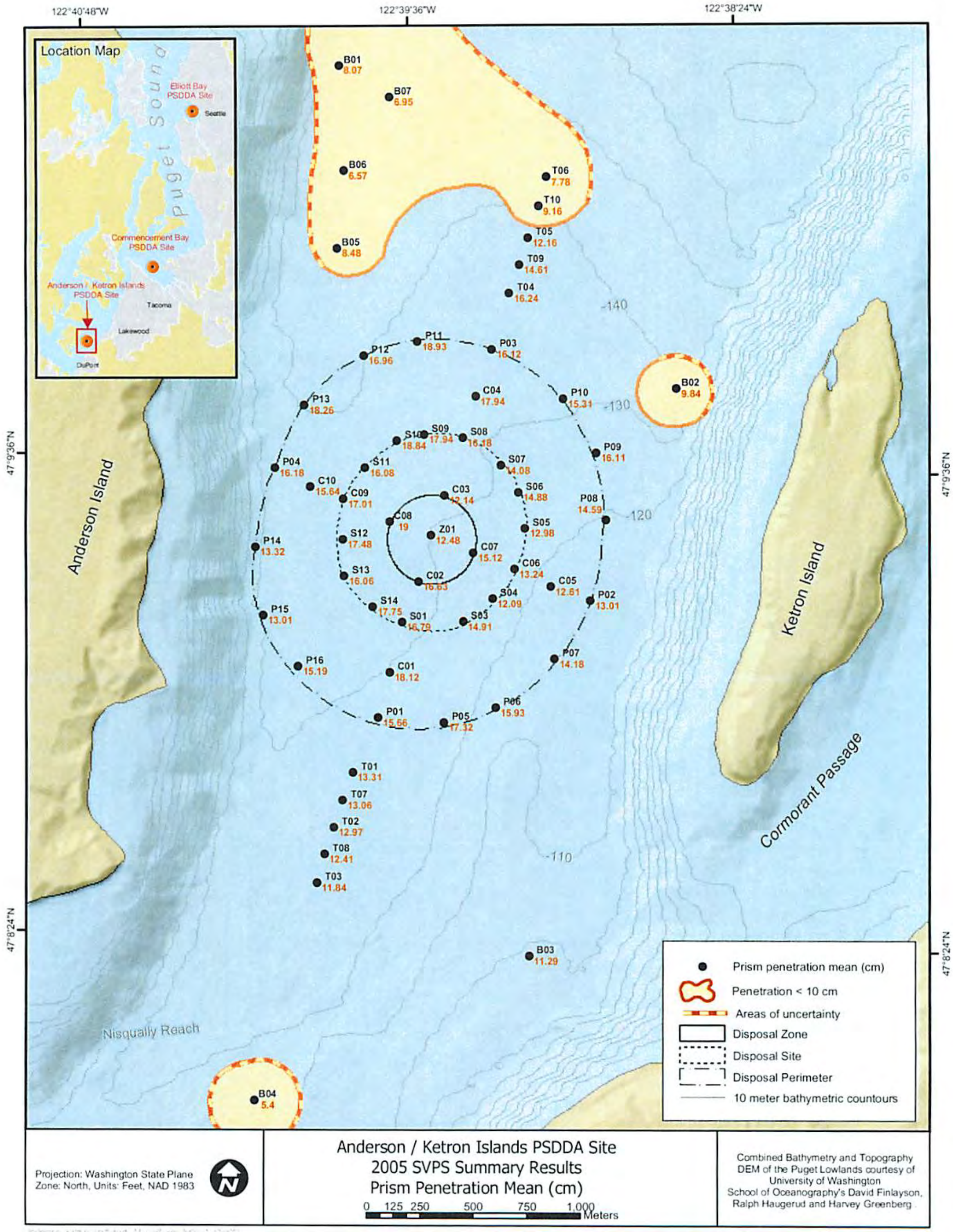

Figure 4-8. SVPS mean prism penetration depth during the 2005 SVPS survey.

Mean bottom boundary roughness measurements are presented in Figure 4-9. Mean small-scale boundary roughness (surface relief) is the difference between the highest and lowest penetration depth measured in a SVPS image. Biogenic activity that creates boundary roughness includes fecal mounds, burrow excavations, and foraging and feeding pits. Physical boundary roughness includes ripples, mud clasts, and irregular surface features due to bottom currents and/or dredged material disposal. The major mode of total boundary roughness measured during the 2005 survey was 0.75 to 1.0 cm, which is similar to boundary roughness measurements during the baseline survey (PTI, 1989). Examples of Anderson/Ketron images showing high biogenic boundary roughness are provided in Figure 4-10. Biogenic roughness is found mainly within and in close proximity to the disposal site. Physical boundary roughness is found to the north and south of the site. An example of physical boundary roughness can be seen at station AKT03, where possible ripples are present on the sediment surface (Figure 4-3).

4.1.4 Chemical and Biological Features

Chemical and biological parameters include the apparent RPD depth, benthic infaunal successional stage, and calculation of the OSI. These parameters provide an assessment of the overall health of the benthic habitat at the Anderson/Ketron Islands disposal site.

Apparent Redox Potential Discontinuity

The apparent RPD depth estimates the depth of oxygenation in the upper sediment column and reflects the degree of bioturbation by infaunal organisms. Mean apparent RPD depths are relatively deep throughout the Anderson/Ketron site, ranging from 1.47 to 4.54 cm, with an average depth of 2.95 cm (Figure 4-10). Shallower apparent RPD depths (<2.5 cm) were measured to the north of the disposal site and to the far south near Nisqually Reach, where coarse grained sediments are present. Shallower RPD depths were also measured at perimeter stations AKP14 and AKP15, located at the toe of the slope to Anderson Island. The major mode of mean apparent RPD depths measured during the 2005 SVPS survey was 3.0 to 3.5 cm, which was slightly deeper than the major mode measured during the 1989 baseline survey (2.5 to 3.0 cm).

Benthic Infaunal Successional Stage

Benthic infaunal communities generally follow a three-stage succession following the disturbance of seafloor (Pearson and Rosenberg, 1978; Rhoads and Germano, 1986). Stage I infauna typically colonize the sediment surface soon after disturbance (e.g., following dredged material disposal). These opportunistic organisms may consist of small, tubicolous, surface-dwelling polychaetes. Stage II organisms are typically shallow-dwelling bivalves or tube-dwelling amphipods. Stage II communities are considered a transitional community before reaching Stage III, the high-order successional stage consisting of long-lived, infaunal deposit-feeding organisms. Stage III invertebrates may feed at depth in a head-down orientation and create distinctive feeding voids visible in SVPS images.

Infaunal successional stages measured during the 2005 SVPS survey are presented in Figure 4-11. Stage III benthic communities were observed at all stations at the Anderson/Ketron site. The benthic communities are well developed and at the highest order of succession, with no evidence of significant impact from historic dredged material disposal.

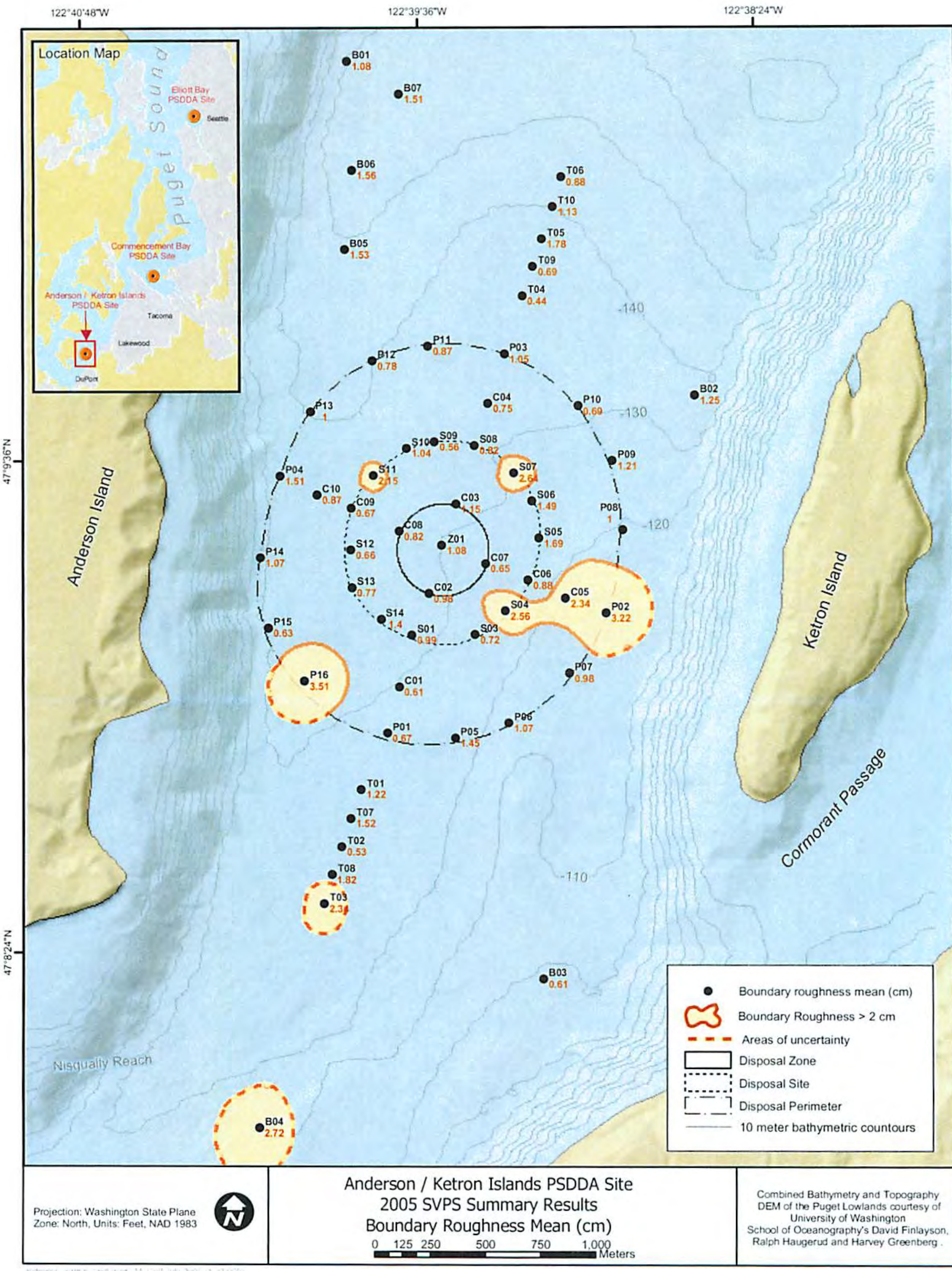

Figure 4-9. Bottom boundary roughness measured during the 2005 SVPS survey.

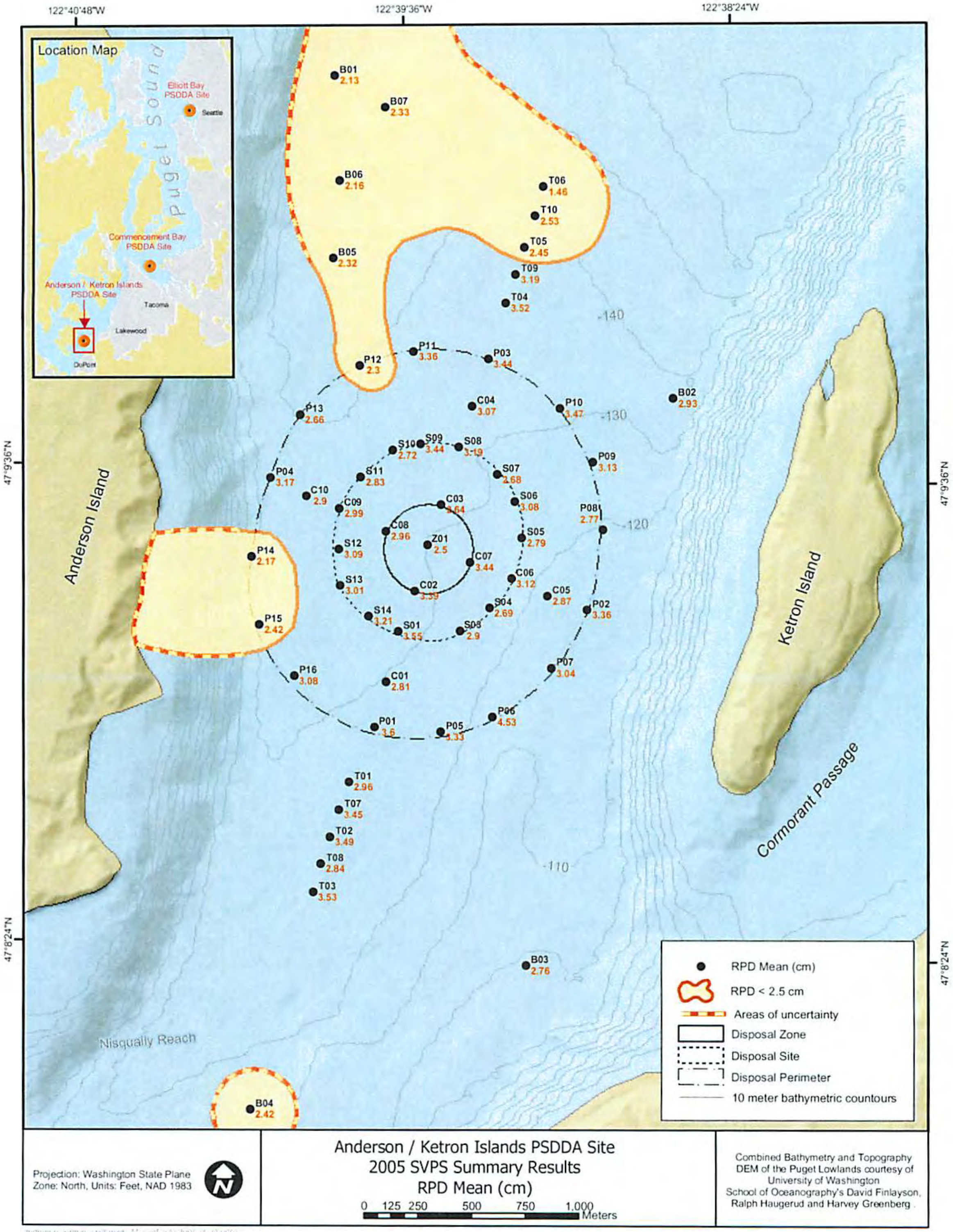

Figure 4-10. Apparent RPD depths measured during the 2005 SVPS survey.

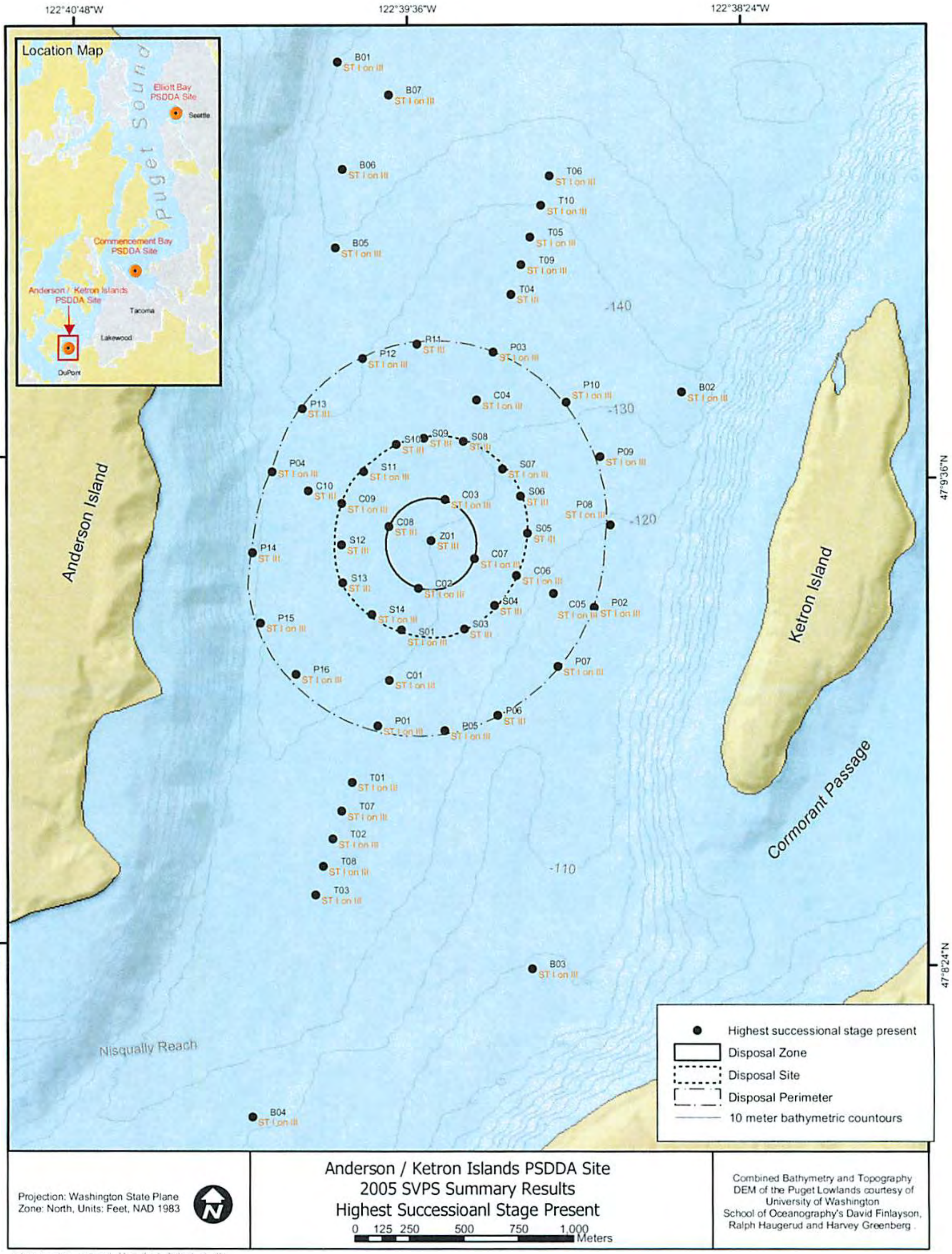

Figure 4-11. Infaunal successional stage measured during the 2005 SVPS survey.

Organism-Sediment Index

The OSI is a numerical index from -10 to +11, which provides a measure of general benthic habitat quality based on dissolved oxygen conditions, depth of the apparent RPD, infaunal successional stage, and presence or absence of sedimentary methane (Rhoads and Germano, 1986). The lowest value is assigned to an area with low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and the presence of methane gas in the sediment. The highest value is given to an aerobic bottom with a deep apparent RPD, evidence of a mature macrofaunal assemblage, and no methane gas bubbles. OSI values greater than or equal to +6 are generally considered to represent healthy or undisturbed benthic habitat quality.

Relatively high OSI values were measured in all areas of the Anderson/Ketron site. Mean OSI values at the Anderson/Ketron disposal site ranged from +5.67 to +10.32, with a major mode of +9 (Figure 4-12). Only station AKB06, located north of the disposal site in the coarse grained ambient sediments, had an OSI less than +6. Stations showing the presence of historic dredged material (AKZ01 and AKC03) had mean OSI values of 8.67 and 7.67, respectively.

4.2 Sediment Chemistry

Sediment chemistry sampling locations for the 2005 full monitoring program at Anderson/Ketron included three onsite (AKZ01, AKS03, AKS10), four perimeter (AKP01, AKP02, AKP03, AKP04), three transect (AKT01, AKT02, AKT03), three benchmark (AKB02, AKB03, AKB07) stations. Two reference (CR-23W and CR-24) stations from Carr Inlet were also sampled. The onsite, perimeter, and benchmark station sediment samples were analyzed for the DMMP conventionals and chemicals of concern, including tributyltin, and the BCOCs, lists 1 and 2. The transect station samples were analyzed for grain size and TOC to assist with the interpretation of the benthic infauna analysis results. The reference samples were analyzed for the DMMP conventionals in support of the toxicity testing.

The Quality Assurance Level 1 (QA1) independent data review of sediment chemistry results was conducted by Herrera Environmental Consultants of Seattle, WA. The QA1 review demonstrated that the data are of generally high quality, and suitable for use (as qualified) in addressing the PSDDA monitoring questions and hypotheses. Summary tables of the sediment chemistry analytical results for each sampling location are provided in Appendix D. Results are compared to the DMMP sediment screen level/maximum level (SL/ML) list, Washington State Sediment Management Standards (SMS)/Sediment Quality Standards (SQS), and bioaccumulation triggers (BT), where appropriate. The data quality summary, QA1 checklists, and analytical laboratory data reports are found in Appendix E.

4.2.1 Conventional Parameters

Sediment conventional parameters summary statistics are presented in Table 4-1. Conventional parameters for onsite, perimeter, transect, and baseline stations were generally consistent among station types, with the exception of grain size and sulfides. The site-wide average for percent fines was 43.4%, ranging from a low of 15.6% at station AKB07 to a high of 70.5% at station AKS10. Benchmark stations consistently had the lowest percent fines of all stations (15.6 to 30.3 % fines). Conversely, all replicate samples from the north and south perimeter stations (AKP01 and AKP03 located along the central site axis) consistently had the highest percent fines compared to the site-wide average (52.6 to 54.9% and 58.8 to 59.5%, respectively).

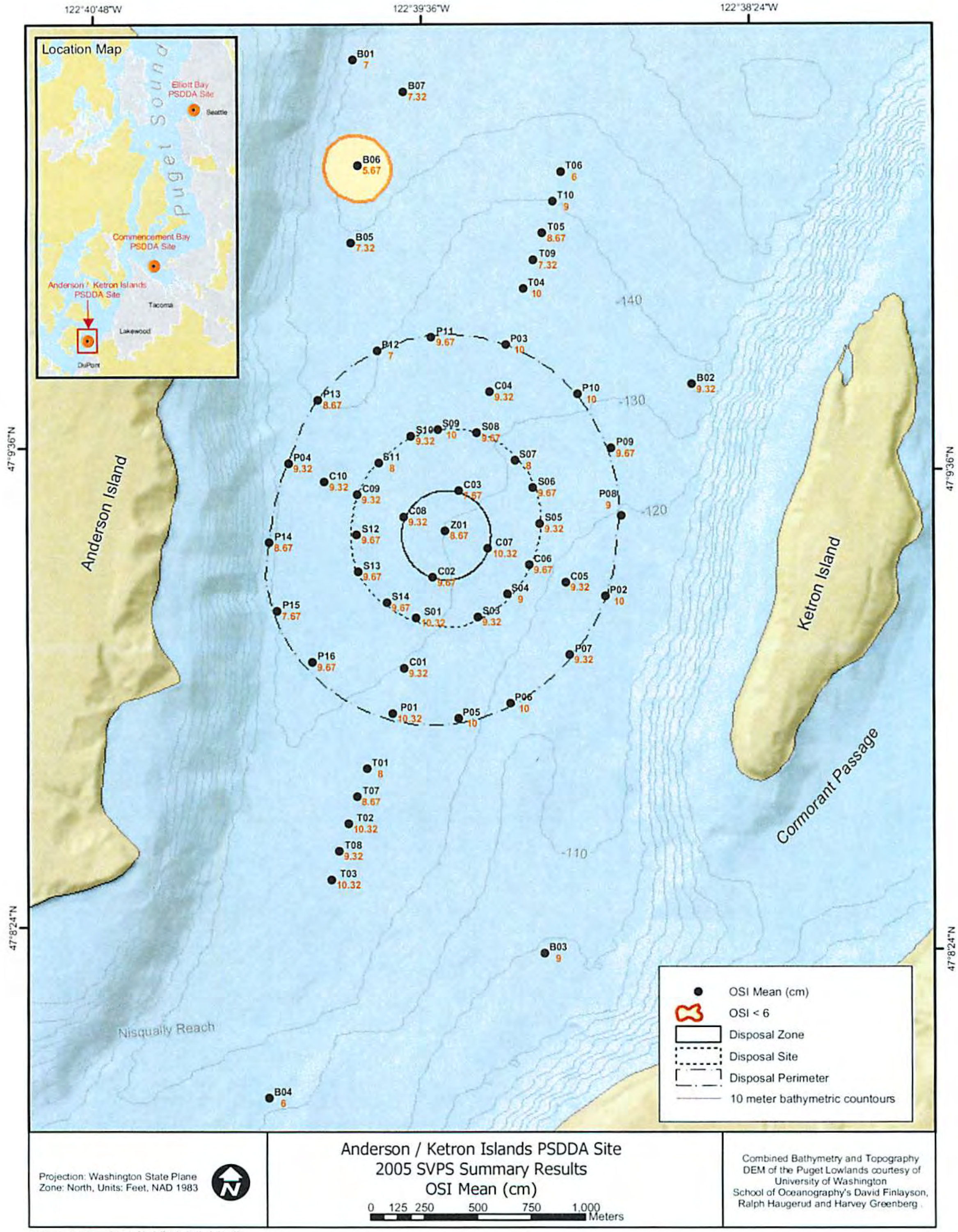

Figure 4-12. Organism Sediment Index values measured during the 2005 SVPS survey.

Table 4-1. Conventional parameters summarized by station type.

Conventional Parameter		% Gravel	% Sand	% Fines	% Silt	% Clay	TOC (% DW)	Sulfides (mg/kg DW)	Ammonia (mg-N/kg DW)	TVS (%)	Total Solids (%)
Onsite	Min	0.0	29.7	34.1	19.8	14.2	1.1	63.0	6.3	4.0	34.5
	Max	1.1	68.7	70.5	37.5	33.1	1.8	263.0	18.9	7.3	51.8
	Average	**0.4**	**46.1**	**55.2**	**30.7**	**24.5**	**1.5**	**173.3**	**13.2**	**5.9**	**40.8**
Perimeter	Min	0.0	37.7	31.4	17.9	13.5	0.9	6.9	10.9	3.4	36.6
	Max	0.1	68.1	60.9	31.8	31.5	4.3	353.0	40.6	6.6	51.1
	Average	**0.0**	**52.1**	**47.5**	**25.2**	**22.4**	**1.7**	**117.0**	**18.5**	**5.1**	**42.7**
Benchmark	Min	0.0	67.6	15.6	7.2	8.3	0.5	1.9	9.9	2.4	51.8
	Max	1.0	83.3	30.3	17.4	13.7	1.5	46.0	22.3	3.7	59.8
	Average	**0.1**	**74.2**	**24.9**	**13.3**	**11.5**	**0.9**	**15.8**	**12.4**	**3.1**	**55.2**
Transect	Min	0.0	50.8	36.6	21.2	15.5	0.9	--	--	--	--
	Max	0.2	57.0	54.6	31.7	22.9	1.3	--	--	--	--
	Average	**0.1**	**54.7**	**46.0**	**26.6**	**19.4**	**1.1**	--	--	--	--
Site-wide for Anderson/ Ketron	Min	0.0	29.7	15.6	7.2	8.3	0.5	1.9	6.3	2.4	34.5
	Max	1.1	83.3	70.5	37.5	33.1	4.3	353.0	40.6	7.3	59.8
	Average	**0.2**	**56.8**	**43.4**	**24.0**	**19.5**	**1.3**	**102.0**	**14.7**	**4.7**	**46.2**
Reference	Min	0.0	30.4	28.4	24.9	3.5	0.4	3.4	21.9	1.8	61.6
	Max	0.1	69.1	63.2	55.2	8.0	0.7	13.4	52.7	3.0	70.7
	Average	**0.1**	**49.8**	**45.8**	**40.0**	**5.7**	**0.6**	**8.4**	**37.3**	**2.4**	**66.2**

TOC Total Organic Carbon
TVS Total Volatile Solids
DW Dry Weight
-- Not Analyzed

Sulfides ranged from 1.9 mg/kg (AKB07) to 353.0 mg/kg (AKP03), with a site-wide average of 102.0 mg/kg. Among the stations sampled, AKP03, AKS03, and AKS10 had the highest concentrations of total sulfides and total volatile solids. Ammonia concentrations ranged from 6.3 to 52.7 mg-N/kg and were highest at AKP03 (40.6 mg-N/kg) and the Carr Inlet reference station CR-24 (52.7 mg-N/kg). With the exception of one high TOC value (4.3 %) at station AKP04, TOC concentrations at Anderson/Ketron were generally consistent throughout the site, ranging from 0.5 % to 2.5 %.

4.2.2 Metals

DMMP metals of concern were detected at low levels in all Anderson/Ketron sediment samples submitted for analysis. The metals concentrations were below the DMMP SL guidelines and the Washington State SQS criteria. Antimony concentrations were qualified with an "N" in all replicates, meaning the matrix spike recovery was not within established control limits. In general, perimeter stations had the highest concentration of metals, followed by onsite stations, then benchmark stations (Table 4-2). On average, the 2005 metals concentrations at Anderson/Ketron were slightly lower than 1989 baseline study levels (Table 4-3). Chromium and selenium were not analyzed during the 1989 study.

Table 4-2. Metals analysis summary by station type.

	Onsite			Perimeter			Benchmark		
Metals in mg/kg DW	Min	Max	Average	Min	Max	Average	Min	Max	Average
Antimony	0.5 N	0.6 N	0.5 N	0.3 N	0.7 N	0.5 N	0.2 N	0.8 N	0.4 N
Arsenic	6.5	8.8	7.2	5.8	10.1	8.1	5.3	8.1	6.0
Cadmium	0.3	0.4	0.3	0.3	0.4	0.4	0.2	0.3	0.3
Chromium	16.3	21.6	18.1	15.4	23.5	20.1	11.6	21.7	16.6
Copper	21.8	35.0	26.2	17.6	34.2	28.3	15.6	24.8	20.6
Lead	13.0	23.5	16.5	10.4	21.8	17.5	9.3	15.1	11.2
Mercury	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nickel	24.0	25.2	24.5	15.0	29.7	21.9	12.2	27.4	17.8
Selenium	0.7 B	1.5 B	1.2 B	0.6 B	1.8 B	1.3 B	0.6 B	1.0 B	0.8 B
Silver	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1
Zinc	38.9	56.0	44.6	43.2	61.5	52.2	35.7	49.7	40.1

B Estimated concentration that is less than the MRL but greater than or equal to the MDL.
N Matrix spike recovery was not within established control limits.

Table 4-3. Average metal concentrations summarized by station type and survey year.

	Onsite		Perimeter		Benchmark	
Metals in mg/kg DW	1989*	2005	1989	2005	1989*	2005
Antimony	2.5 G	0.5 N	1.54 G	0.5 N	1.2 G	0.4 N
Arsenic	15.20	7.2	10.35	8.1	6.60	6
Cadmium	0.44	0.3	0.42	0.4	0.31	0.3
Chromium	NA	18.1	NA	20.1	NA	16.6
Copper	45.00	26.2	33.28	28.3	25.30	20.6
Lead	26.10	16.5	18.80	17.5	14.20	11.2
Mercury	0.16	0.1	0.11	0.1	0.07	0.1
Nickel	27.00	24.5	24.68	21.9	17.60	17.8
Selenium	NA	1.2 B	NA	1.3 B	NA	0.8 B
Silver	0.35	0.2	0.26	0.2	0.18	0.1
Zinc	89.80	44.6	124.85	52.2	58.50	40.1

* Only one station was sampled in 1989 - value is not an average of stations.
B Metal was detected in the associated blank sample. Value reported is blank-corrected down to detection limit.
G Estimated concentration is greater than value shown.
N Matrix spike recovery was not within established control limits.
NA Not analyzed.

4.2.3 Organic Compounds

A summary of detected organic compounds in Anderson/Ketron sediments is provided in Table 4-4. DMMP volatile organic compounds, chlorinated aromatic hydrocarbons, pesticides, and PCBs (as Arochlors) were not detected in any of the sediment samples, with the exception of a trace concentration of trichloroethene at station AKB07 (Replicate B only), with an estimated concentration of 0.82 µg/kg. Phthalates, HPAH, LPAH, and miscellaneous extractables were detected in benchmark, perimeter, and onsite sediment samples. Detected phthalate compounds included di-n-butyl phthalate in all samples, and

Table 4-4. Summary of detected organic compounds by station type during the 2005 survey.

2005 Detected Organic Parameters	PSDDA SL	ONSITE				PERIMETER				BENCHMARK			
		Frequency	Min.	Max.	Maximum Location	Frequency	Min.	Max.	Maximum Location	Frequency	Min.	Max.	Maximum Location
LPAH in µg/kg DW													
Phenanthrene	1500	1/3	19 U	26	AKS03	6/12	19	56	AKP04-A	0/9	-	-	-
Anthracene	960	0/3	-	-	-	4/12	19	26	AKP04-A/ AKP03-A	0/9	-	-	-
HPAH in µg/kg DW													
Fluoranthene	1700	3/3	25	30	AKS03	11/12	20	52	AKP03-C	4/9	20	23	AKB02-B
Pyrene	2600	3/3	22	28	AKS03	11/12	20	47	AKP03-C	1/9	8.3 U	21	AKB02-B
Chrysene	1400	1/3	19 U	23	AKS03	6/12	19	27	AKP03-C	0/9	-	-	-
Benzofluoranthenes	3200	0/3	-	-	-	7/12	19	54	AKP03-C	0/9	-	-	-
Benzo(a)pyrene	1600	0/3	-	-	-	3/12	19	23	AKP03-C	0/9	-	-	-
Butyltins													
TBT porewater (µg/L)	0.15	3/3	0.0011	0.0015	AKS03	4/4	0.0011	0.0017	AKP03-A	2/3	0.00093	0.0012	AKB03-B
Tri-n-butyltin cation (µg/kg)	-	1/3	0.11 U	0.9	AKS10	1/4	0.11 U	0.69	AKP01-A	0/9	-	-	-
Phthalate Esters in µg/kg DW													
Di-n-butylphthalate	5100	3/3	110	130	AKS10	12/12	31	160	AKP01-A	9/9	33	63	AKB03-B
bis(2-ethylhexyl)phthalate	8300	0/3	-	-	-	6/12	19	30	AKP03-C	1/9	20 U	21	AKB02-A
Phenols in µg/kg DW													
Phenol	420	1/3	20 U	25	AKZ01	0/12	-	-	-	0/9	-	-	-
Miscellaneous Extract. in µg/kg DW													
Benzoic Acid	650	1/3	59 U	230	AKZ01	1/12	59 U	280	AKP01-B	0/9	-	-	-
Volatile Organics in µg/kg DW													
Trichloroethene	160	0/3	-	-	-	0/12	-	-	-	1/9	0.47 U	0.82	AKB07-B

U Undetected at the reported concentration.
Frequency = number of detects / number of replicates

bis(2-ethylhexyl)phthalate detected at low concentrations at stations AKB02, AKP01, AKP03, and AKP04. HPAH compounds fluoranthene and pyrene were detected at low concentrations at all perimeter and onsite stations, with estimated concentrations of fluoranthene at two benchmark stations and pyrene at one benchmark station. Chrysene, benzofluoranthenes, and benzo(a)pyrene were detected at low levels at most perimeter stations, with a low concentration of chrysene also detected at onsite station AKS03. LPAH compounds anthracene and phenanthrene were detected at stations AKP03 and AKP04, with phenanthrene also detected at AKS03. Miscellaneous extractables and phenol compounds were not detected, with the exception of benzoic acid detected at AKP01 and AKZ01, and phenol also detected at AKZ01.

Detection limits for all organic compounds were below DMMP screening levels and all detected compounds were below their respective DMMP and SMS chemical criteria. However, hexachlorobenzene, which was undetected in all samples, had several TOC-normalized values that exceeded the Washington State SQS chemical criteria. Since acceptably low detection limits were achieved for this compound (6.0 µg/kg DW), the reason for exceeding the SQS is due in part to the low concentrations of TOC at these stations (0.52 to 1.53 % DW)

For comparison, a summary of sediment chemistry data from the 1989 baseline study at Anderson/Ketron is provided in Table 4-5. All organic compounds detected in 2005, with the exception of di-n-butylphthalate and phenol, were also detected in 1989 at trace levels at the perimeter, benchmark, and onsite stations. Chemical concentrations were found at similarly low levels during both surveys, with the exception of benzoic acid. In 2005, benzoic acid was detected in two sample replicates at 230 µg/kg (AKZ01) and 280 µg/kg (AKP01-B). In 1989, station AKP04 has a maximum benzoic acid concentration of 28 µg/kg. These concentrations are below the DMMP SL of 650 µg/kg.

4.2.4 Bioaccumulative Contaminants of Concern (BCOCs)

The 2005 Anderson/Ketron site monitoring included sediment analysis for List 1 (primary list of BCOCs; required for analysis) and List 2 (candidate list of BCOCs; strong concern and priority for study) chemicals. A summary of detected BCOCs in Anderson/Ketron sediments is provided in Table 4-6. The sediment chemistry results of the BCOC analysis and a comparison to the DMMP bioaccumulation triggers (BTs) for List 1 contaminants are presented in Appendix D. BTs for comparison to List 2 BCOCs have not yet been developed.

BCOCs detected in sediment samples included metals and HPAHs (Lists 1 and 2), and butyltins in porewater. All List 1 metals were present at low levels below the BT concentrations. Hexavalent chromium, a List 2 metal, was detected at 0.185 mg/kg at benchmark station AKB07. List 1 HPAH compounds fluoranthene and pyrene were detected at low concentrations at all perimeter and onsite stations, with traces of fluoranthene at two benchmark stations and pyrene at one benchmark station. Benzo(e)pyrene and perylene (List 2 HPAHs) were only detected at perimeter station AKP03. Pesticides, phenols, and halogenated compounds were not detected in any samples. Detected concentrations and detection limits of all List 1 BCOCs were below their respective BT values.

4.2.5 Field Variability

An acceptability criterion of 50% relative standard deviations (RSD) between replicates collected at the sampling locations was used for each parameter. The majority of field variability results were acceptable, with exceptions summarized in Table 4-7. The most frequent and highest RSD values above 50% occurred at station AKP04. As can be expected, the most frequent and highest RSD values were observed for percent gravel.

Table 4-5. Summary of detected organic compounds during the 1989 baseline survey.

1989 Detected Organic Parameters	PSDDA SL	PERIMETER Frequency	PERIMETER Min. Conc.	PERIMETER Max. Conc.	PERIMETER Maximum Location	BENCHMARK* Frequency	BENCHMARK* Conc.	ONSITE* Frequency	ONSITE* Conc.
LPAH in µg/kg DW									
Anthracene	960	4/4	6	10	AKP03	1/1	5.1	1/1	6.2
Phenanthrene	1500	4/4	13	31	AKP03	1/1	5.1	1/1	25
HPAH in µg/kg DW									
Fluoranthene	1700	4/4	24	53	AKP03	1/1	15	1/1	25
Pyrene	2600	4/4	23	55	AKP03	1/1	15	1/1	27
Benzo(a)anthracene	1300	4/4	9	21	AKP03	1/1	8	1/1	11
Chrysene	1400	4/4	14	32	AKP03	1/1	9	1/1	20
Benzofluoranthenes	3200	4/4	37	72	AKP03	1/1	22	1/1	41
Benzo(a)pyrene	1600	4/4	14	29	AKP03	0/1	-	1/1	15
Indeno(1,2,3-cd)pyrene	600	1/4	6 U	7.9	AKP04	0/1	-	0/1	-
Benzo(g,h,i)perylene	670	1/4	6 U	8.9	AKP04	0/1	-	0/1	-
Butyltins in µg/kg DW									
Tributyltin	-	2/4	2.5	3	AKP01	0/1	-	1/1	2.4
Phthalate Esters in µg/kg DW									
Diethyl phthalate	1200	1/4	5.6 U	6	AKP01	0/1	-	0/1	-
bis(2-ethylhexyl)phthalate	8300	4/4	32	52	AKP02	1/1	26	1/1	27
Di-n-octyl phthalate	6200	1/4	6 U	17	AKP04	0/1	-	0/1	-
Phenols in µg/kg DW									
Pentachlorophenol	400	1/4	13 U	54	AKP04	0/1	-	0/1	-
Miscellaneous Extract. in µg/kg DW									
Benzoic Acid	650	1/4	28 U	28	AKP04	0/1	-	0/1	-

* Only one benchmark and one onsite station were sampled during the baseline survey.

U Undetected at the reported concentration.

Frequency = number of detects / number of replicates.

Table 4-6. Summary of detected BCOCs in Anderson/Ketron sediments.

2005 BCOCs Detected Organic Parameters	PSDDA BT	ONSITE				PERIMETER				BENCHMARK			
		Frequency	Min.	Max.	Maximum Location	Frequency	Min.	Max.	Maximum Location	Frequency	Min.	Max.	Maximum Location
LIST 1 (REQUIRED FOR ANALYSIS)													
Metals in mg/kg DW													
Arsenic	507.1	3/3	6.5	8.8	AKS10	12/12	5.8	10.1	AKP01-A	9/9	5.3	8.1	AKB07-A
Cadmium	11.3	3/3	0.3	0.4	AKS03	12/12	0.3	0.4	AKP03-C	9/9	0.2	0.3	AKB07-A
Chromium	267	3/3	16.3	21.6	AKS10	12/12	15.4	23.5	AKP04-A	9/9	11.6	21.7	AKB07-C
Copper	1027	3/3	21.8	35.0	AKS10	12/12	17.6	34.2	AKP03-C	9/9	15.6	24.8	AKB07-A
Lead	975	3/3	13.0	23.5	AKS10	12/12	10.4	21.8	AKP01-B	9/9	9.3	15.1	AKB07-A
Mercury	1.5	3/3	0.1	0.1	AKS10	12/12	0.1	0.1	AKP01-B	9/9	0.1	0.1	AKB03-B
Nickel	370	3/3	24.0	25.2	AKS10	12/12	15.0	29.7	AKP04-C	9/9	12.2	27.4	AKB07-C
Selenium	3	3/3	0.7 B	1.5 B	AKS10	12/12	0.6 B	1.8 B	AKP03-A	9/9	0.6 B	1.0 B	AKB03-B, AKB03-C
Silver	6.1	3/3	0.2	0.2	AKS10	12/12	0.1	0.2	AKP01-A	9/9	0.1	0.1	AKB03-C
Zinc	2783	3/3	38.9	56.0	AKS10	12/12	43.2	61.5	AKP03-C	9/9	35.7	49.7	AKB07-A
HPAH in ug/kg DW													
Fluoranthene	4600	3/3	25	30	AKS03	11/12	22	52	AKP03-C	4/9	20	23	AKB02-B
Pyrene	11980	3/3	22	28	AKS03	11/12	20	47	AKP03-C	1/9	8.3 U	21	AKB02-B
Butyltins													
TBT Porewater (ug/L)	0.15	3/3	0.0011	0.0015	AKS03	4/4	0.0011	0.0017	AKP03-A	2/3	0.00093	0.0012	AKB03-B
LIST 2 (STRONG CONCERN AND PRIORITY FOR STUDY)													
Metals in mg/kg DW													
Hexavalent Chrome	-	-	-	-	-	-	-	-	-	1/9	0.169 U	0.185 E	AKB07-A
HPAH in ug/kg DW													
Benzo(e)pyrene	-	-	-	-	-	2/12	20	21	AKP03-C	-	-	-	-
Perylene	-	-	-	-	-	3/12	20	24	AKP03-A	-	-	-	-

B Estimated concentration that is less than the MRL but greater than or equal to the MDL.
E Estimated concentration based on QA1 data validation.
U Undetected at the reported concentration.

Table 4-7. Field Variability results exceeding 50% RSD.

Station	Parameter	RSD	Station	Parameter	RSD
AKP01	Total Sulfides (mg/kg DW)	53.5%	AKP04	Anthracene	86.6%
	Fluoranthene	71.1%		Chrysene	56.5%
	Pyrene	51.6%		Benzo(a)pyrene	105.8%
	Total HPAH	70.9%		Bis(2-ethylhexyl)phthalate	59.1%
	Bis(2-ethylhexyl)phthalate	89.8%		Heptachlor	108.0%
	Benzoic Acid	95.3%	AKB02	Percent Gravel (>2.0 mm)	160.6%
AKP02	Total Sulfides (mg/kg DW)	50.9%		Fluoranthene	61.7%
	Percent Gravel (>2.0 mm)	173.2%		Pyrene	58.1%
	Chrysene	82.1%		Total HPAH	75.2%
	Benzofluoranthenes	83.6%		bis(2-Ethylhexyl)phthalate	87.7%
AKP03	Percent Gravel (>2.0 mm)	173.2%	AKB03	Total Sulfides (mg/kg DW)	91.1%
	Benzo(a)pyrene	66.2%		Fluoranthene	60.0%
AKP04	Total Organic Carbon (% DW)	66.4%	AKB07	Total Sulfides (mg/kg DW)	114.3%
	Percent Gravel (>2.0 mm)	173.2%		Antimony	59.3%

RSD Relative standard deviation.

4.3 Tissue Chemistry

Compsomyax subdiaphana clam tissue samples were collected from stations AKT01 and AKB03 and analyzed for the DMMP BCOCs, lists 1 and 2. Tissue chemistry results are summarized in this section and compared to the DMMP target tissue levels (TTL) and the guidelines values derived from the 1989 baseline data[1]. The Quality Assurance Level 1 (QA1) independent data review of tissue chemistry results was conducted by Herrera Environmental Consultants of Seattle, WA. The QA1 review demonstrated that the data are of generally high quality, and suitable for use (as qualified) in addressing the PSDDA monitoring questions and hypotheses. Summary tables of the tissue chemistry results are provided in Appendix D. The data quality summary, QA1 checklists, and all raw tissue chemistry data may be found in Appendix E.

With the exception of undetected arsenic at AKB03, replicate A, all BCOC List 1 metals were detected at low levels below the TTL concentrations in all tissue samples (Table 4-8). All List 1 & 2 HPAH, halogenated compounds, phenols, pesticides, butyltins, and hexavalent chromium were undetected at levels below the TTL values. In general, the 2005 tissue chemistry results are comparable to concentrations measured during the 1989 baseline study. Metals concentrations in 2005 were slightly lower in Anderson/Ketron tissues, with the exception of nickel and copper, which were slightly higher. However, all concentrations were well within the 1989 derived guideline values (Table 4-8).

[1] Guideline values represent a 3X multiplier for metals baseline concentrations and a 5X multiplier for organic baseline concentrations. Benchmark tissues could not be collected during the 1989 baseline. Therefore, benchmark guideline values are not available.

Table 4-8. Summary of detected metals concentrations in Anderson/Ketron tissue samples.

Metals in mg/kg WW	TTL (mg/kg)	AKT01					AKB03				
		Frequency	Min.	Max.	Avg.	Guideline Value (based on 1989 data)	Frequency	Min.	Max.	Avg.	Guideline Value (based on 1989 data)*
Arsenic	10.1	3/3	1	2	1.33	5.4	2/3	1	1	1.00	NA
Cadmium	—	3/3	0.17	0.26	0.21	1.83	3/3	0.28	0.32	0.30	NA
Chromium	—	3/3	0.2	0.2	0.20	NA	3/3	0.2	0.5	0.37	NA
Copper	—	3/3	2.82	9.79	6.68	6	3/3	5.43	10.2	8.01	NA
Lead	—	3/3	0.6	0.7	0.63	7.5	3/3	0.9	1.3	1.10	NA
Mercury	1	3/3	0.01	0.01	0.01	0.09	3/3	0.01	0.018	0.01	NA
Nickel	20000	3/3	0.6	1.5	1.00	1.74	3/3	1	1.5	1.17	NA
Selenium	—	3/3	0.28	0.77	0.51	NA	3/3	0.51	0.73	0.64	NA
Silver	200	3/3	0.34	1.54	0.93	4.5	3/3	0.9	1.45	1.25	NA
Zinc	—	3/3	10	14.4	11.83	57	3/3	11.7	16.7	14.67	NA

NA Not analyzed in 1989.
WW Wet weight.
* Benchmark tissue samples could not be collected in 1989.
Note: All organic compounds were undetected at concentrations below the TTLs.

4.4 Bioassays

DMMP bioassay testing was conducted on three onsite station sediments (AKZ01, AKS03, and AKS10). The sediment bioassays included the 10-day acute amphipod test using *Eohaustorius estuarius*, the sediment larval test using *Mytilus galloprovincialis*, and the 20-day *Neanthes* mean growth test. The complete bioassay reports and quality assurance review are provided in Appendix F. Each of the bioassay tests were conducted within the 8-week holding time and data quality was acceptable for all three tests. In addition, a confirmatory retest of the *Neanthes* bioassay was conducted beyond the 8-week holding time as described below.

Results of the bioassay tests are summarized in Table 4-9. For the amphipod test, mortality was less than or equal to 10 percent for all samples, and the mean ranged from 1.0 (AKZ01) to 4.0 percent (AKS03) at the onsite stations. All samples passed the DMMP nondispersive guidelines for the amphipod test.

For the *Neanthes* mean growth test, the reference sediments failed the DMMP performance standards. Reference sediment CR-23W had a mean survival rate of 76 percent that failed to meet the performance standard of 80 percent, and the reference growth/control growth ratio for CR-24 was 0.79, which was just below the 0.80 standard. The negative control had 100 percent survival and mean growth rates were within performance standards. Therefore, as a conservative alternative, the negative control was used for test interpretation. The mean growth rate was 0.92 mg/indiv/day for AKZ01 and AKS03, and 1.04 mg/indiv/day for AKS10. Growth rates were comparable to the control and all samples passed the non-dispersive guidelines. Due to unusually high *Neanthes* mortality rates for sample AKS10 (3 of 5 replicates produces no surviving worms), the DMMP decided to conduct a confirmatory retest of the sample after the 8-week holding period. The retest of sample AKS10 resulted in no mortality, acceptable control and reference performance, and an acceptable mean growth rate (Table 4-9).

For the larval test, normalized combined mortality/abnormality (NCMA) ranged from a minimum of 15.8 percent at AKS10 to a maximum of 27.6 percent at AKZ01. The NCMA was acceptable for AKS03 and AKS10 and passed the non-dispersive guidelines. Station AKZ01 had a two-hit failure for the sediment larval test, resulting from a normals comparison between the test and control of 0.72, below the 0.80 guideline criteria. The difference between the test and reference was statistically significant (p=0.10), but the difference in ratios between the reference and test was below the 0.30 criteria (0.11), so only the two-hit failure applies. A confirmatory response is not indicated because the amphipod and *Neanthes* tests passed for AKZ01. Therefore, the larval test for AKZ01 passed the non-dispersive guidelines.

In summary, the amphipod test had acceptable morality rates, below or equal to 10% for all samples. The NCMA results for the sediment larval test were acceptable for AKS03 and AKS10. A two-hit failure occurred for the larval test at AKZ01, but was not corroborated by the other bioassay tests. The *Neanthes* test had acceptable growth rates for all samples and elevated mortalities at AKS10 were not of concern, based on the results of the retest. DMMP bioassay evaluation guidelines were not exceeded for any of the bioassays.

Table 4-9. Bioassay results for onsite, reference, and control sediments.

Sample	Amphipod Test (*Eohaustorius estuarius*) Mortality (%)	Sediment Larval (*Mytilus galloprovinvialis*) NMCA (%)	20-Day *Neanthes* Mean Growth Rate (mg/indiv/day)
Control (1st trial)	0.0	NA	0.97
Control (2nd trial)	NA	NA	1.12
AKZ01	1.0	27.6	0.92
AKS03	4.0	19.8	0.92
AKS10 (1st trial)	2.0	15.8	1.04
AKS10 (2nd trial)	NA	NA	1.03
CR-23W	2.0	14.4	0.89
CR-24 (1st trial)	0.0	17.7	0.77
CR-24 (2nd trial)	NA	NA	0.94

Notes:
NMCA = Normalized combined mortality/abnormality – normalized to the seawater control
NA = Not applicable (seawater control, or test not run)
CR-23W is the coarse grained reference for AKZ01
CR-24 is the fine grained reference for AKS03 and AKS10

4.5 Benthic Community Analysis

Five replicate samples were collected for benthic community analysis from six stations adjacent to the disposal site. Five replicate samples from three of the six stations (AKT01, AKT02, and AKT03) were processed and the infaunal organisms identified to the lowest taxonomic level possible. Samples from the remaining three stations (AKB01, AKB02, and AKB03) were archived for future analysis. A complete list of stations sampled for benthic community analysis can be found in Table 3-1. All stations were sampled using a 0.06 m^2 Gray-O'Hara box core. Data from the 2005 survey was compared to data from the 1989 survey to determine whether disposal activities have resulted in an altered benthic community. Each box core sample was divided into two fractions, from the sample surface to a depth of ten centimeters, and all sediments greater than ten centimeters depth. The samples were rinsed through 1.0 mm and 0.5 mm nested sieve screens and only the surface fraction of the 1.0 mm sieved sample was processed and analyzed. The following benthic community endpoints were determined and calculated for each benthic replicate sample:

- Polychaete abundance
- Mollusca abundance
- Crustacea abundance
- Echinoderm abundance
- Miscellaneous taxa abundance
- Total taxa abundance
- Total and major taxa richness
- Shannon-Wiener Diversity Index
- Swartz Dominance Index
- Evenness Index

The raw species and abundance data can be found in Appendix G, and the data are summarized in Table 4-10.

4.5.1 Benthic Community in 1989

The previous monitoring event at the Anderson/Ketron Island disposal site occurred in 1989 and was conducted by PTI (1989). This sampling event marked the baseline survey at the disposal site. In 1989, three transect stations (AKT01, AKT02, and AKT03) and three benchmark stations (AKB01, AKB02, and AKB03) were sampled for benthic community analysis. At stations AKT01, AKT02, AKT03, and AKB02, the samples were analyzed for the abundance of the major taxonomic groups only. Samples were not analyzed to the lowest taxonomic level possible; as a result there is no species richness data available to compare to samples collected during the 2005 survey. Results from this sampling event are presented in Table 4-11. The results show that all four stations sampled and analyzed at the disposal were strongly dominated by crustacean arthropods. Polychaetous annelids were the next most abundant taxa group, but at most represented fewer than 50 percent of the arthropod abundance.

4.5.2 Benthic Community in 2005

The three transect stations sampled in the 2005 survey were collected at similar water depths with similar grain size characteristics. The greatest total abundance was found at station AKT02, with average values of 108.2 individuals per 0.06 m^2. The station with the greatest number of taxa was AKT03, where 35.2 taxa were found (Table 4-10). Annelids were the dominant taxa group at all stations, with the greatest mean total abundance occurring at station AKT03 with 51.0 individuals per 0.06 m^2. The molluscs were the next most dominant taxa group with the greatest mean total abundance occurring at station AKT01 with 40.0

Table 4-10. Benthic community summary statistics for stations at the Anderson Ketron Island disposal site in 2005.

Station	AKT01							
Replicate	A	B	C	D	E	Pooled	Mean	Standard Dev
Total Abundance	83	116	86	97	129	511	102.2	19.791
Miscellaneous Abundance	4	4	9	4	6	27	5.4	2.191
Mollusca Abundance	22	70	20	37	51	200	40.0	20.940
Arthropoda Abundance	12	12	9	7	14	54	10.8	2.775
Annelida Abundance	45	30	48	49	58	230	46.0	10.173
Total Number of Taxa	22	26	25	35	28	136	27.2	4.868
Miscellaneous No. of Taxa	3	2	5	3	3	16	3.2	1.095
Mollusca No. of Taxa	4	7	4	10	5	30	6.0	2.550
Arthropoda No. Of Taxa	3	5	4	4	4	20	4.0	0.707
Annelida No. of Taxa	12	12	12	18	16	70	14.0	2.828
Shannon-Wiener Diversity	2.278	2.288	2.598	2.761	2.486	NA	2.48	0.207
Pielou Eveness Index	0.737	0.702	0.807	0.777	0.746	NA	0.75	0.040
Swartz Dominance Index	6	8	14	16	8	NA	10.4	3.878
Station	**AKT02**							
Taxa Group	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev**
Total Abundance	159	91	113	91	87	541	108.2	30.186
Miscellaneous Abundance	11	4	6	11	7	39	7.8	3.114
Mollusca Abundance	57	21	42	33	21	174	34.8	15.238
Arthropoda Abundance	32	12	19	9	10	82	16.4	9.555
Annelida Abundance	59	54	46	38	49	246	49.2	7.981
Total Number of Taxa	31	29	35	32	27	154	30.8	3.033
Miscellaneous No. of Taxa	6	4	3	7	5	25	5.0	1.581
Mollusca No. of Taxa	5	6	6	5	6	28	5.6	0.548
Arthropoda No. Of Taxa	4	4	5	3	3	19	3.8	0.837
Annelida No. of Taxa	16	15	21	17	13	82	16.4	2.966
Shannon-Wiener Diversity	2.802	2.669	2.847	2.930	2.691	NA	2.79	0.109
Pielou Eveness Index	0.816	0.793	0.801	0.845	0.817	NA	0.81	0.020
Swartz Dominance Index	12	11	12	13	9	NA	11.4	1.356
Station	**AKT03**							
Taxa Group	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev**
Total Abundance	113	83	95	136	100	527	105.4	20.206
Miscellaneous Abundance	7	5	7	9	12	40	8.0	2.646
Mollusca Abundance	29	22	11	63	14	139	27.8	20.897
Arthropoda Abundance	14	9	31	18	21	93	18.6	8.264
Annelida Abundance	63	47	46	46	53	255	51.0	7.314
Total Number of Taxa	33	34	36	36	37	176	35.2	1.643
Miscellaneous No. of Taxa	5	2	3	5	7	22	4.4	1.949
Mollusca No. of Taxa	4	8	7	7	6	32	6.4	1.517
Arthropoda No. Of Taxa	4	3	5	4	4	20	4.0	0.707
Annelida No. of Taxa	20	21	21	20	20	102	20.4	0.548
Shannon-Wiener Diversity	2.885	3.137	3.223	2.607	3.049	NA	2.98	0.243
Pielou Eveness Index	0.825	0.889	0.899	0.727	0.844	NA	0.84	0.069
Swartz Dominance Index	7	14	16	10	14	NA	12.2	3.250

Table 4-11. Summary statistics for benthic stations sampled during the 1989 survey.

Station	AKT01							
Replicate	A	B	C	D	E	Pooled	Mean	Standard Dev.
Total Abundance	187	253	343	170	232	1185	237	68.018
Miscellaneous Abundance	9	2	4	2	3	20	4	2.915
Mollusca Abundance	13	15	4	9	15	56	11.2	4.712
Arthropoda Abundance	123	215	169	140	179	826	165.2	35.710
Annelida Abundance	42	21	166	19	35	283	56.6	61.906
Station	**AKT02**							
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev.**
Total Abundance	131	256	201	222	219	1029	205.8	46.300
Miscellaneous Abundance	1	2	1	2	1	7	1.4	0.548
Mollusca Abundance	8	13	19	16	18	74	14.8	4.438
Arthropoda Abundance	98	221	153	174	179	825	165	44.850
Annelida Abundance	24	20	28	30	21	123	24.6	4.336
Station	**AKT03**							
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev.**
Total Abundance	160	192	125	188	199	864	172.8	30.557
Miscellaneous Abundance	1	1	3	0	2	7	1.4	1.140
Mollusca Abundance	20	13	6	5	11	55	11	6.042
Arthropoda Abundance	104	150	92	155	165	666	133.2	32.859
Annelida Abundance	35	28	24	28	21	136	27.2	5.263
Station	**AKB02**							
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev.**
Total Abundance	134	149	134	139	174	730	146	16.808
Miscellaneous Abundance	3	5	4	4	5	21	4.2	0.837
Mollusca Abundance	6	6	5	6	13	36	7.2	3.271
Arthropoda Abundance	76	91	91	92	107	457	91.4	10.968
Annelida Abundance	49	47	34	37	49	216	43.2	7.155

individuals per 0.06 m^2. The greatest abundance of arthropods occurred at station AKT03 with a mean of 18.6 individuals per 0.06 m^2.

Shannon-Wiener diversity, Pielou evenness index, and Swartz dominance index increased slightly with distance from the disposal site. However, the variability, as measured by the sample standard deviation, indicates that the differences may not be significant. Biomass values (grams /0.06m^2) for the 2005 survey stations are presented in Table 4-12. Among the transect stations, the greatest total biomass was found at station AKT02 with a mean value of 5.33 grams /0.06m^2. With the exception of station AKT02, whose biomass was dominated by the burrowing echiuroid *Arhynchite pugettensis*, the biomass of polychaetes dominated the other stations. Table 4-13 lists the 10 most dominant species observed at each of the transect station. The bivalve *Axinopsida serricata*, and the polychaete *Levinsenia gracilis* very strongly dominated the benthic community at all transect stations. Subdominant taxa which were found at much lower abundances than the dominant taxa included: *Parvilucina tenuisculpta*, *Pinixxa occidentalis* Cmplx, Euphilomedes carcharodonta, and *Protomedeia* sp.

4.5.3 Comparison of Benthic Community between 1989 and 2005

Statistical comparisons of the results between the 1989 and 2003 survey can be found in Table 4-14. The tests were conducted using a one tailed t-test with an alpha value of 0.05 as the significance level. Statistical analysis was conducted using the statistical software package SYSTAT (Vers. 11.01). Statistical comparisons were made between each transect station from the 1989 and 2005 sampling events. Additionally, in 1989, station AKB02 was sampled and analyzed; these results were compared to data from each of the three transect station sampled in 2005. In this case, the resulting probabilities were adjusted using a multiple comparison test to account for testing multiple stations to the same benchmark station.

The data from the transect stations indicated that there was a significant reduction in the abundance of arthropods at all three transect stations compared to the same stations sampled during the 1989 survey. There was a significant increase in the abundance of molluscs at stations AKT01 and AKT02, and annelids at stations AKT02 and AKT03. However, the increase in the abundance of molluscs and annelids does not make up for the decrease in the abundance of arthropods as shown by the total abundance of the taxa groups. A similar pattern was seen in the comparison between the 1989 benchmark station and the three transect stations sampled in 2005, with significant decreases in arthropod abundance and increases in the abundance of molluscs. However, unlike the transect station comparison, there was no significant difference in the abundance of annelids between the 1989 benchmark station and the 2005 transect stations. While the significant loss of arthropods from the transect stations can be quantified, the missing species cannot be identified because samples from the 1989 survey were not identified to the lowest taxonomic level.

Table 4-12. Biomass data for stations sampled at the Anderson/Ketron Island disposal site in 2005 (weight in grams).

Station					**AKT01**			
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev.**
Total Biomass	2.3397	2.2267	3.9857	3.6198	3.0961	15.2680	3.0536	0.7721
Miscellaneous Biomass	0.0976	0.0657	0.0934	0.1757	0.0241	0.4565	0.0913	0.0555
Mollusca Biomass	0.0480	0.0951	0.0950	0.3097	0.0747	0.6225	0.1245	0.1053
Arthropoda Biomass	0.0903	0.0229	0.7788	0.0344	0.0912	1.0176	0.2035	0.3231
Annelida Biomass	2.1038	2.0430	3.0185	3.1000	2.9061	13.1714	2.6343	0.5171
Station					**AKT02**			
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev.**
Total Biomass	3.3171	10.1098	8.9907	1.7924	2.4354	26.6454	5.3291	3.9113
Miscellaneous Biomass	0.0438	8.0431	5.1966	0.1577	0.0194	13.4606	2.6921	3.7244
Mollusca Biomass	0.1857	0.5877	1.6516	0.6901	0.0564	3.1715	0.6343	0.6276
Arthropoda Biomass	0.2030	0.1931	0.0711	0.0152	0.0584	0.5408	0.1082	0.0847
Annelida Biomass	2.8846	1.2859	2.0714	0.9294	2.3012	9.4725	1.8945	0.7872
Station					**AKT03**			
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**Standard Dev.**
Total Biomass	4.5523	5.3404	4.8858	1.4979	4.1312	20.4076	4.0815	1.5109
Miscellaneous Biomass	0.7117	2.9016	0.0595	0.0625	0.0926	3.8279	0.7656	1.2259
Mollusca Biomass	0.0669	0.1887	0.1585	0.1698	0.1739	0.7578	0.1516	0.0485
Arthropoda Biomass	0.2584	0.1268	0.5824	0.0431	0.1973	1.2080	0.2416	0.2067
Annelida Biomass	3.5153	2.1233	4.0854	1.2225	3.6674	14.6139	2.9228	1.2028

Arhynchite P.
burrowing
echiuroid
"spoon worm"
unsegmented

Compsomyax ↑er biomass bigger than Macoma
No baseline tissue
Molpadia not enuf (used for Elliott Bay + CB sites)
used for Bellingham site
Prob not found during taxa/biomass benthic sampling
separate sampling effort for collect of tissue for analysis

was found in stomachs of flat fish

Commercial Labs need 60 g; rethink this

Table 4-13. Dominant and subdominant taxa at stations sampled at the Anderson/Ketron Island disposal site in 2005.

Opportunistic spp — & can vary greatly — very small

Station	AKT01							
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**STD**
Axinopsida serricata	14	53	8	22	40	137	27.40	18.70
Levinsenia gracilis	31	10	28	26	28	123	24.60	8.35
Parvilucina tenuisculpta	4	8	8	2	5	27	5.40	2.61
Pinnixa occidentalis Cmplx	8	0	1	3	7	19	3.80	3.56
Euphilomedes carcharodonta	3	5	4	0	1	13	2.60	2.07
Protomedeia sp.	1	2	3	2	5	13	2.60	1.52
Glycera nana	3	2	3	1	3	12	2.40	0.89
Praxillella pacifica	2	0	4	2	4	12	2.40	1.67
Pennatulacea	0	1	3	2	3	9	1.80	1.30
Macoma sp.	2	2	0	2	2	8	1.60	0.89
Station	**AKT02**							
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**STD**
Axinopsida serricata	35	10	32	24	14	115	23.00	10.91
Levinsenia gracilis	22	30	15	9	23	99	19.80	8.04
Pinnixa occidentalis Cmplx	18	6	7	0	5	36	7.20	6.61
Protomedeia sp.	12	3	5	5	0	25	5.00	4.42
Parvilucina tenuisculpta	8	3	5	5	1	22	4.40	2.61
Macoma sp.	8	4	2	1	2	17	3.40	2.79
Pennatulacea	4	1	4	3	3	15	3.00	1.22
Sigambra nr. *bassi*	4	5	2	0	4	15	3.00	2.00
Nereis procera	4	1	3	3	3	14	2.80	1.10
Euphilomedes carcharodonta	1	0	5	3	4	13	2.60	2.07
Station	**AKT03**							
Replicate	**A**	**B**	**C**	**D**	**E**	**Pooled**	**Mean**	**STD**
Levinsenia gracilis	23	13	12	15	24	87	17.40	5.68
Axinopsida serricata	22	8	1	53	1	85	17.00	21.87
Euphilomedes carcharodonta	7	3	10	8	3	31	6.20	3.11
Protomedeia sp.	2	4	9	4	8	27	5.40	2.97
Parvilucina tenuisculpta	4	7	3	4	6	24	4.80	1.64
Pinnixa occidentalis Cmplx	4	2	5	3	8	22	4.40	2.30
Lepidasthenia berkeleyae	3	4	4	3	3	17	3.40	0.55
Spiophanes berkeleyorum	3	6	3	2	1	15	3.00	1.87
Amphiodia urtica/periercta	1	4	3	1	3	12	2.40	1.34
Euphilomedes producta	0	0	6	3	2	11	2.20	2.49

fish eat siphons

Saved these & Yoldia sp. frozen

Table 4-14. Results of *t*-testing at the transect stations comparing data from the 1989 transect and benchmark stations to the transect stations sampled in 2005. t = Calculated *t*-test value, P = Probability of significant difference. Shaded cells indicate a statistical difference between mean values.

Station	AKT01				AKT02				AKT03			
Abundance Endpoint	1989	2005	t	P	1989	2005	t	P	1989	2005	t	P
Total Abundance	237	102.2	4.3	>0.05	205.8	108.2	3.9	>0.05	172.8	105.4	4.1	>0.05
Miscellaneous Abundance	4	5.4	0.9	0.4	1.4	7.8	4.5	>0.05	1.4	8	5.1	>0.05
Mollusca Abundance	11.2	40	3	>0.05	14.8	34.8	2.8	>0.05	11	27.8	1.7	0.1
Arthropoda Abundance	165.2	10.8	9.6	>0.05	165	16.4	7.2	>0.05	133.2	18.6	7.6	>0.05
Annelida Abundance	56.6	46	0.4	0.7	24.6	49.2	6.1	>0.05	27.2	51	5.9	>0.05

benchmark

Station	1989 AKB02 to 2005 AKT01				1989 AKB02 to 2005 AKT02				1989 AKB02 to 2005 AKT03			
Abundance Endpoint	1989	2005	t	P	1989	2005	t	P	1989	2005	t	P
Total Abundance	146	102.2	3.8	>0.05	146	108.2	2.4	>0.05	146	105.4	3.5	>0.05
Miscellaneous Abundance	4.2	5.4	1.1	0.3	4.2	7.8	2.5	0.1	4.2	8	3.1	>0.05
Mollusca Abundance	7.2	40	3.5	>0.05	7.2	34.8	4.0	>0.05	7.2	27.8	4.2	0.1
Arthropoda Abundance	91.4	10.8	15.9	>0.05	91.4	16.4	11.5	>0.05	91.4	18.6	7.4	>0.05
Annelida Abundance	43.2	46	0.5	0.6	43.2	49.2	1.3	0.2	43.2	51	1.7	0.6

5.0 EVALUATION OF THE MONITORING DATA

This section evaluates the 2005 environmental monitoring data collected at Anderson/Ketron using the PSDDA interpretive guidelines described in Section 2.0. The evaluation is organized according to the questions and hypotheses of the PSDDA monitoring framework.

5.1 Question 1: Does the Dredged Material Stay Onsite?

5.1.1 SVPS Results

Hypothesis No. 1: Dredged material remains within the disposal site boundary.

The 2005 SVPS survey at the Anderson/Ketron site did not identify the presence of dredged material beyond the disposal site perimeter that exceeded the 3 cm DMMP interpretive criteria. Under the monitoring framework for non-dispersive dredged material disposal sites, ***PSDDA Hypothesis No. 1 is accepted*** (i.e., dredged material remains within the disposal site boundary).

5.1.2 Perimeter Chemistry

Hypothesis No. 2: Chemical concentrations at offsite stations do not measurably increase over time due to dredged material disposal.

A review of the 2005 perimeter station chemistry found that all detected chemicals were well below the Washington State SQS criteria. In addition, the detection limits for all undetected compounds were below the DMMP SLs and SQS criteria, with the exception of hexachlorobenzene. The detection limit for hexachlorobenzene had several TOC-normalized values that exceeded the SQS chemical criteria. However, since this chlorinated aromatic compound was undetected and the detection limits were below the DMMP SLs, the results are not considered significant. The 2004 partial monitoring in Commencement Bay also found undetected hexachlorobenzene values that exceeded the SQS criteria, due to low TOC concentrations in Commencement Bay perimeter sediments (SAIC, 2004).

A statistical time-trends analysis was not conducted because the 2005 full monitoring survey is the first monitoring event at the Anderson/Ketron site. Therefore, based on the comparison of perimeter chemistry results to the SQS criteria, ***PSDDA Hypothesis No. 2 is accepted*** (i.e., chemical concentrations do not increase over time at offsite stations).

5.2 Question 2: Has dredged material disposal caused the biological effects condition for site management to be exceeded at the site [Site Condition II (PSDDA, 1988)]?

5.2.1 Onsite Chemistry

Hypothesis No. 3: Sediment chemical concentrations at the onsite monitoring stations do not exceed chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.

PSDDA Site Condition II is evaluated by comparing onsite chemical concentrations to the DMMP maximum levels (MLs). DMMP MLs are chemical concentrations above which adverse biological effects are expected to occur. Onsite chemistry results did not exceed the DMMP ML values. Therefore, ***PSDDA Hypothesis No. 3 is accepted.***

5.2.2 Bioassays

Hypothesis No. 4: Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.

The suite of DMMP bioassays conducted was evaluated according to the DMMP evaluation guidelines for non-dispersive disposal sites (PSDDA 1989b, PSDDA 2000). The three onsite stations passed the DMMP bioassay interpretive criteria for all toxicity tests. Therefore, ***PSDDA Hypothesis No. 4 is accepted.***

5.3 Question 3: Are unacceptable adverse effects due to dredged material disposal occurring to biological resources offsite?

5.3.1 Tissue Chemistry

Hypothesis No. 5: No significant increase has occurred in the chemical body burden of benthic infaunal species collected down current (transect stations) of the disposal site due to dredged material disposal.

The 2005 *Compsomyax subdiaphana* clam tissue chemistry results are summarized in Table 4-8. Samples from stations AKT01 and AKB03 were analyzed for the DMMP BCOCs, Lists 1 and 2. Metals were detected at low levels below the TLL concentrations and were well within the 1989 derived guideline values. All organic compounds, butyltins, and hexavalent chromium were undetected. Therefore, ***Hypothesis No. 5 is accepted*** (i.e., the chemical body burden of down current benthic infaunal species has not increased significantly due to dredged material disposal).

5.3.2 Benthic Infauna Analysis

Hypothesis No. 6: No significant decrease in the abundance of dominant benthic infaunal species collected down current (transect stations) of the disposal site has occurred due to dredged material disposal.

Comparisons of the abundance of major benthic taxa (i.e., annelid, arthropod, mollusca, and miscellaneous) between the 2005 transect monitoring data and the 1989 transect baseline data are presented in Table 4-13. Statistical analysis of the Anderson/Ketron benthic community data indicates significant reductions in the abundance of crustacean arthropods with significant increases in the abundance of molluscs and polychaetous annelids. The reduction in crustacean arthropods at all transect stations exceeds the PSDDA interpretive guideline value of less than half of the baseline abundance.

Studies have shown that crustacean arthropods tend to be a taxonomic group that is susceptible to environmental change whether the change is anthropogenic or naturally occurring. Since the last survey at the disposal site was sixteen years previous and the 1989 benthic community samples were not identified to the lowest level possible, it is not possible to positively to determine the cause of the change. However, the PSDDA monitoring framework requires that Hypothesis No. 6 should be addressed in the strictest terms. Therefore, ***PSDDA Hypothesis No. 6 is rejected*** (i.e., a significant decrease in the abundance of crustacean arthropods collected down current of the disposal site has occurred).

6.0 CONCLUSIONS

The conclusions to the 2004 full monitoring program at Anderson/Ketron are presented below. Table 6-1 summarizes the data within the context of the PSDDA monitoring framework.

6.1 Does the Dredged Material Remain On Site?

Physical and chemical monitoring results from the 2005 survey at Anderson/Ketron suggest that the dredged material remains within the boundaries of the disposal site. The 2005 SVPS survey did not identify dredged material accumulations outside of the site perimeter. Perimeter chemistry concentrations were below the Washington State SQS criteria. Hexachlorobenzene was undetected but exceeded the SQS criteria in several samples due to low TOC concentrations in Anderson/Ketron sediments.

6.2 Is Site Condition II Exceeded?

Chemistry results from onsite stations AKZ01, AKS03, and AKS10 were compared to the DMMP maximum screening levels (MLs). No onsite ML values were exceeded. Bioassay testing of the same onsite stations passed the DMMP bioassay interpretive criteria. Therefore, PSDDA Site Condition II chemical criteria are not exceeded.

6.3 Were Biological Resources Affected Offsite?

Compsomyax subdiaphana clam tissue samples were collected at one down current (AKT01) and one benchmark (AKB03) station and analyzed for the DMMP BCOCs, Lists 1 and 2. All chemical contaminants were below the TLL concentrations and within the 1989 derived guideline values.

Benthic infauna community analysis in 2005 found a significant decrease in the abundance of arthropods compared to the 1989 baseline sampling event at the Anderson/Ketron Island disposal site. Additionally, significant increases were seen in the abundance of molluscs and annelids.

Table 6-1. Results of the 2005 Anderson/Ketron PSDDA monitoring framework.

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Taken
No. 1 Does the deposited dredged material stay onsite?	1. Dredged material remains within the site boundary	Sediment Vertical Profiling System (SVPS) Onsite and Offsite	Dredged material layer is greater than 3 cm at the perimeter stations? **NO**	
	2. Chemical concentrations do not measurably increase over time due to dredged material disposal at offsite stations.	Sediment Chemistry Offsite	SQS exceeded? **NO** Temporal increases? **NO**[1]	
No. 2 Are the biological effects conditions for site management [PSDDA-defined Site Condition II] exceeded at the site due to dredged material disposal? (PSDDA 1988b)	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 exceed DMMP maximum levels? **NO**	
	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 bioassays exceed guidelines? **NO**	
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 infauna species collected down current of the disposal site.	Tissue Chemistry Transect	Guideline tissue chemistry values exceeded? **NO**	
	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	Abundance of major taxa < ½ baseline macrobenthic infauna abundances? **YES**	Analysis of benchmark benthic samples may be warranted (see Section 7.1).

1. Although statistical temporal analysis was not conducted, a comparison of the 1989 and 2005 sediment chemistry results shows chemical concentrations to be low in both years, with no apparent increases over time.

7.0 RECOMMENDATIONS

7.1 Analysis of Archived Benchmark Benthic Samples

Crustacean arthropods tend to be a taxonomic group that is susceptible to environmental change whether naturally occurring or due to anthropogenic causes. The significant decrease in crustaceans suggests environmental degradation. However, the decrease does not appear to be related to dredged material disposal since the Anderson/Ketron site has received little use since the 1989 baseline study.

Due to the length of time since the baseline studies at the Anderson/Ketron Islands disposal site, the results of the 2005 full monitoring program are proposed as a new baseline. Therefore, it may be important to understand the reason for the significant reduction in crustaceans. Evaluation of the benchmark benthic samples may provide insight as to whether the reduction in crustacean arthropods is site wide, or limited to areas in close proximity to the disposal site. Analysis of the benchmark benthic samples would also complete the data set to be used as a baseline for future monitoring events at the Anderson/Ketron disposal site.

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