UPDATED ENVIRONMENTAL MONITORING PLAN

UNCONFINED, OPEN-WATER, DREDGED MATERIAL DISPOSAL SITES NON-DISPERSIVE PSDDA SITES IN PUGET SOUND

FINAL

January 2007

Submitted to:

WASHINGTON STATE DEPARTMENT OF
Natural Resources

Washington State Department of Natural Resources
Aquatic Resources Division
Olympia, Washington 98504

Submitted by:

SAIC
From Science to Solutions

Science Applications International Corporation
Environmental Sciences Division
18912 North Creek Parkway, Suite 101
Bothell, Washington 98011

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

µg	microgram(s)
ASTM	American Standard of Testing Materials
BCOC	bioaccumulative chemical(s) of concern
BT	bioaccumulation trigger
CAD	confined aquatic disposal
cm	centimeter(s)
COC	chemical of concern
CTS	Chemical Tracking System
CVAA	mercury digestion and cold vapor atomic absorption
cy	cubic yard(s)
DGPS	Differential Global Position System
DMMP	Dredged Material Management Program
DNR	Department of Natural Resources
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
GCMS	gas chromatography / mass spectrophotometry
GFAA	graphite furnace atomic absorption (spectrometry)
HCB	Hexachlorobenzene
HPAH	high molecular weight polycyclic aromatic hydrocarbon
ICP	inductively coupled plasma (emission spectrometry)
kg	kilogram(s)
LPAH	low molecular weight polycyclic aromatic hydrocarbon
m^2	meter(s) squared
MDL	method detection limit
mg	milligram(s)
ML	maximum level
mm	millimeter(s)
MWLS	Mountain Whisper Light Statistical
n/a	not applicable
NAD	North American Datum
ng	nanogram(s)
OC	organic carbons
PCB	polychlorinated biphenyls
ppb	parts per billion
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
PTI	PTI Environmental Services
REMOTS	Remote Ecological Monitoring of the Seafloor
RPD	Redox Potential Discontinuity
SAIC	Science Applications International Corporation
SL	screen level
SMARM	Sediment Management Annual Review Meetings
SPI	Sediment Profile Image
SQS	Sediment Quality Standards

SVPS	Sediment Vertical Profiling System
TBD	to be determined
TOC	total organic carbon
TTL	target tissue level
U.S.	United States
UEMP	Updated Environmental Monitoring Plan
USACE	U.S. Army Corps of Engineers, Seattle District
VTS	U.S. Coast Guard Vessel Traffic Services

1.0 INTRODUCTION

The environmental monitoring plans for unconfined, open-water, dredged material disposal sites in Puget Sound were first published in 1988 for Central Puget Sound (Management Plans Technical Appendix, Exhibit 1; PSDDA, 1988a), and in 1989 for North and South Puget Sound (Management Plan Report, Exhibit D; PSDDA, 1989a). The monitoring plans were designed to verify that unacceptable adverse effects have not occurred within or beyond the disposal site and to assure that dredged material disposed at the sites remains within the disposal site boundary.

Since the publication of these monitoring plans, numerous program revisions and updates have been adopted and documented in several different locations, including the minutes for the Sediment Management Annual Review Meetings (SMARM), Dredged Material Management Program (DMMP) clarification papers and biennial reports, and the disposal site monitoring reports. This Updated Environmental Monitoring Plan (UEMP) incorporates all program updates and revisions to date for physical, chemical, and biological monitoring of the five Puget Sound Dredged Disposal Analysis (PSDDA) non-dispersive sites:

1. Bellingham Bay
2. Port Gardner
3. Elliott Bay
4. Commencement Bay
5. Anderson/Ketron Islands

The PSDDA non-dispersive site locations are shown in Figure 1 and described in Table 1. The UEMP will ensure that the most up-to-date methods and guidelines are implemented for environmental monitoring of the non-dispersive disposal sites. Physical monitoring requirements for the PSDDA dispersive dredged material disposal sites are not addressed in this plan but can be found in PSDDA (1989a).

Environmental management of the disposal sites is the responsibility of the DMMP, an interagency partnership consisting of the Washington State Department of Natural Resources (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 DNR is the lead agency for conducting the chemical and biological monitoring for the program and the USACE is the lead agency for conducting physical monitoring.

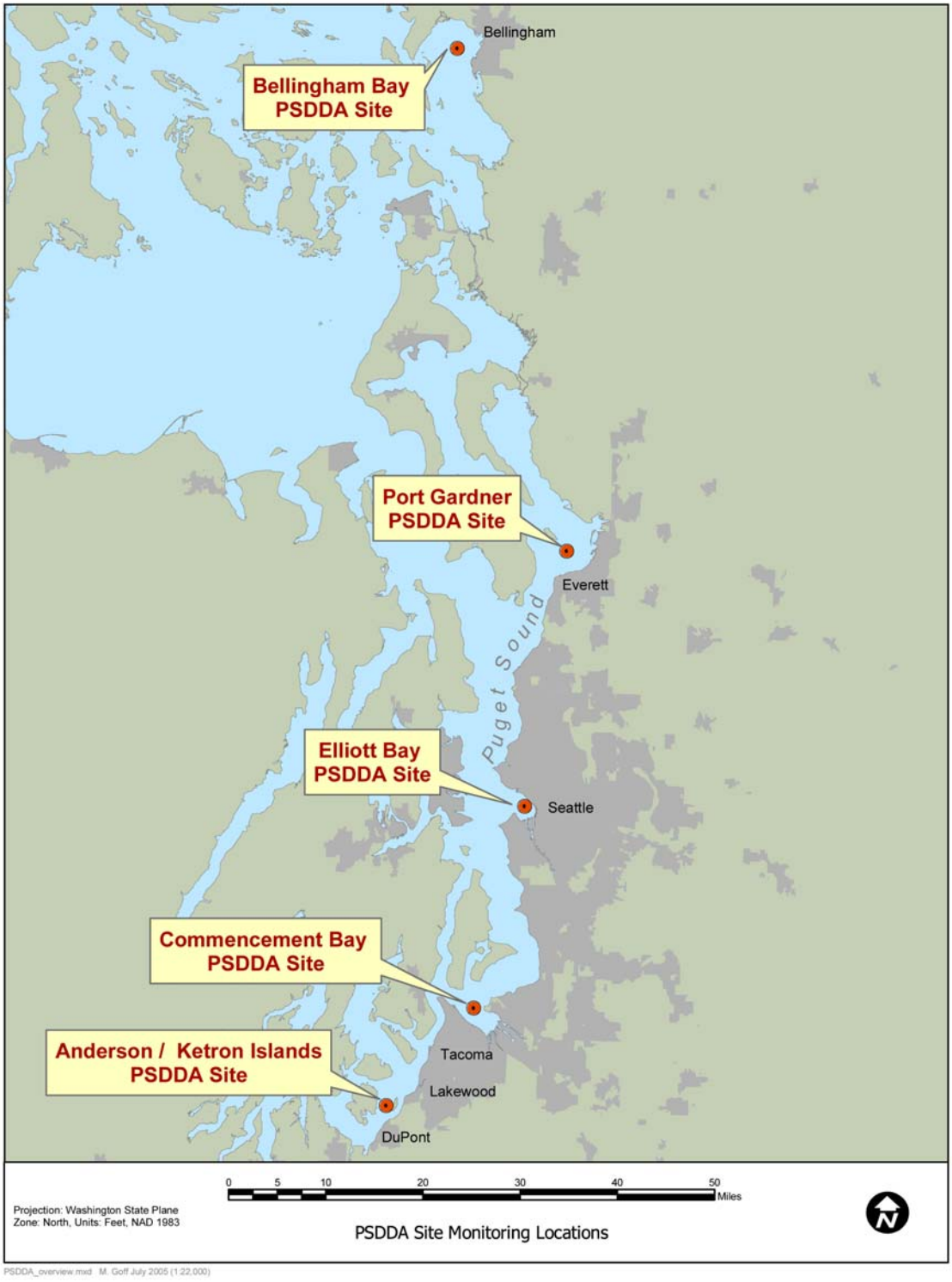


Figure 1. PSDDA non-dispersive disposal sites in Puget Sound.

Table 1. PSDDA non-dispersive dredged material disposal site characteristics (Leon and Kendall, 2004) and monitoring trigger volumes.

Site	Area (acres)	Depth (feet)	Disposal Zone Diameter (feet)	Target Area Diameter (feet)	Disposal Site Dimensions (feet)	Site Coordinates (Lat/Long: NAD83)	Positioning Confirmation	Monitoring Trigger Volume (cy)
Anderson/Ketron Islands	318	442	1,800 (circle)	1,200 (circle)	4,400 x 3,600 (ellipsoid)	47° 09.42' 122° 39.47'	DGPS	150,000
Bellingham Bay	260	96	1,800 (circle)	1,200 (circle)	3,800 x 3,800 (circular)	48° 42.82' 122° 33.11'	DGPS	150,000
Commencement Bay	310	540–560	1,800 (circle)	1,200 (circle)	4,600 x 3,800 (ellipsoid)	47° 18.21' 122° 27.91'	VTS	500,000
Elliott Bay[1]	415	300–360	1,800 (circle)	1,200 (circle)	6,200 x 4,000 (tear drop shape)	47° 35.91' 122° 21.45'	VTS	500,000
Port Gardner	318	420	1,800 (circle)	1,200 (circle)	4,200 x 4,200 (circular)	47° 58.85' 122° 16.74'	DGPS	500,000

Notes:
Positioning confirmation for actual dredged material disposal by VTS (U.S. Coast Guard Vessel Traffic Services) or DGPS (Differential Global Position System).
cy = cubic yards of dredged material

[1] Following site monitoring in 1990, the original Elliott Bay site coordinates were shifted 300 feet to the south by the DMMP agencies (Striplin, 1991). The disposal zone was not changed, so the coordinates plotted within the disposal zone will show the target zone center coordinates are off center to the south relative to the disposal zone.

2.0 PSDDA MONITORING FRAMEWORK

Environmental monitoring of the PSDDA disposal sites is conducted to ensure compliance with federal Clean Water Act Section 404(b)(1) guidelines, verify predictions concerning site conditions following dredged material disposal, keep the public and government agencies informed about disposal site monitoring activities, and contribute data for the annual review of the DMMP dredging and disposal site evaluation process. 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 overall monitoring program design remains as initially conceived and addresses three primary questions related to potential impacts from dredged material disposal:

1. Does the deposited dredged material stay on site?
2. Is the biological effects condition for site management [i.e., PSDDA-defined site condition II[2] (PSDDA, 1988b)] exceeded at the site because of dredged material disposal?
3. Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?

To clearly evaluate the monitoring questions, testable null hypotheses were developed for each concern. A null hypothesis identifies the specific effect to be monitored and defines the level that is considered to warrant additional site investigation and/or management (PSDDA, 1988a). Use of null hypotheses allows the environmental questions to be framed in such a way that they can be tested using data gathered during monitoring and allows for clear interpretation of the monitoring results. Six hypotheses were developed to address the three questions and are presented in Table 2.

Conditions at a disposal site are considered acceptable if the statements framed in the null hypotheses 1 through 6 are correct (PSDDA, 1988a). If the interpretive criteria for a null hypothesis are exceeded, the null hypothesis is considered "rejected" and action items are followed as outlined in Table 2. All decisions are subject to DMMP agency review and will follow best professional judgment.

[2] Site condition II is defined as having minor adverse effects on biological resources due to sediment chemicals. Some species may be affected within the site from long-term exposure to sediment chemicals (only sublethal effects are anticipated) (PSDDA, 1988c).

Table 2. The PSDDA monitoring framework.

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Item (When exceedances noted)[1]
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	Post-disposal benchmark station chemistry is analyzed and compared with appropriate baseline benchmark station data.
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.
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 down current 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 down current 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.

3.0 GENERAL MONITORING PLAN

Three levels of environmental monitoring have been established for the PSDDA program:

1. Full monitoring
2. Tiered-full monitoring
3. Partial monitoring

The full monitoring program addresses all three questions (null hypotheses 1 through 6) of the PSDDA monitoring framework. A tiered-full monitoring program collects all samples necessary under a full monitoring program, but it only analyzes data to initially answer the first two questions (null hypotheses 1 through 4) (SAIC, 1995a; Benson, 1996). Analysis of archived samples to address the third monitoring question (hypotheses 5 and 6) is contingent on answers to the first two questions. A partial monitoring program only addresses questions 1 and 2 (null hypotheses 1 through 4).

3.1 Volume Triggers and Monitoring Schedule

The type of environmental monitoring conducted at a disposal site is determined by the volume of dredged material disposed at a site since the baseline or most recent monitoring survey. Current dredged material volume triggers are summarized in Table 1. Although the initial trigger for full monitoring studies was 45,000 cubic yards (cy) of dredged material (PSDDA, 1988a), it was recognized that the frequency of monitoring could be lessened if monitoring showed that no significant impacts have occurred. Based on the successful management of the central Puget Sound sites to date, the monitoring trigger was raised to 500,000 cy of dredged material at the Port Gardner, Elliott Bay, and Commencement Bay sites (Brenner, 2002). This volume trigger does not apply to the lesser used Bellingham Bay and Anderson/Ketron Islands sites, where the volume trigger was raised in 1996 and now remains at 150,000 cy (Benson, 1996).

Partial monitoring is conducted when appreciable volumes of dredged material are disposed at a site, but the volume is not enough to trigger a full monitoring effort (PSDDA, 1988c). The DMMP agencies evaluate the conditions that warrant a partial monitoring effort and will follow best professional judgment.

Environmental monitoring data collection must occur during the same time period each year in order to make the data meaningful and comparable between years. Disposal site monitoring is generally limited to the period of May – June of any monitoring year (Brenner, 2002).

3.2 Sampling Design and Station Types

The PSDDA monitoring framework includes a sampling design that monitors seven station types over time 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 purposes are described in Table 3.

Table 3. 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 mile 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 off site (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).
Floating	F	Located in various locations within and outside of the disposal site	Used to help delineate the extent of the dredged material deposit. Stations are sampled for sediment and benthic infauna analysis, if necessary, to assess dredged material impacts outside of the disposal site.
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. In addition, because the freezing of bulk sediment samples may result in structural changes in the sediment which will alter the availability of tributyltin (TBT), samples to be held for future TBT analysis should have interstitial water extracted prior to freezing (Hoffman, 1998).

3.3 Monitored Variables

Five types of data are collected in order to address the hypotheses of the PSDDA monitoring framework:

1. Physical data (via sediment profile photography)
2. Sediment chemistry
3. Sediment toxicity (bioassay testing)
4. Tissue chemistry
5. Infaunal community structure

Physical, chemical, and biological data are collected during all three monitoring types (full, tiered-full, and partial) (Table 4). The number of stations, types of stations, and variables tested vary between the monitoring types. Each type of monitoring variable is discussed below.

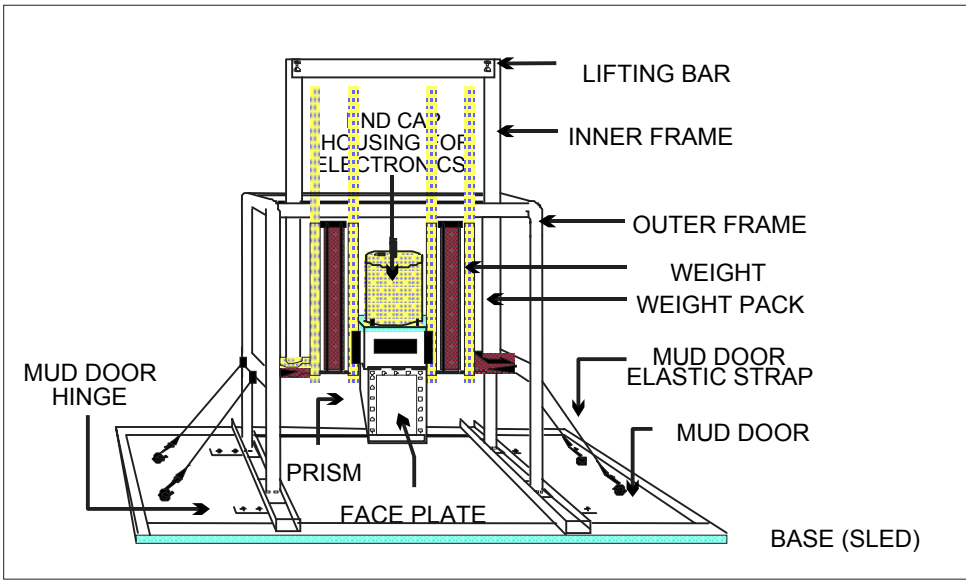
Table 4. PSDDA disposal site station types and monitoring tools.

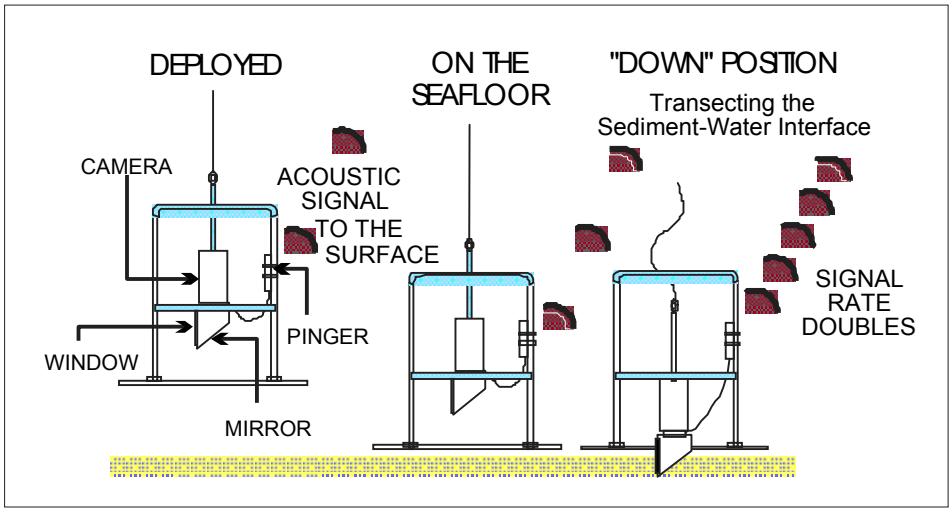
Station	SVPS	Sediment Chemistry	Bioassays	Benthic Infauna	Tissue Chemistry
Zone (Z)	●	●	●		
Site (S)	●	○	○		
Perimeter (P)	●	●			
Transect (T)	●			○	○
Benchmark (B)		● (A)	● (A)	○ (A)	○ (A)
Central Transect (C)	●				
Floating (F)	●				
Reference (R)			●		

○ Monitoring tools used for a full monitoring program
● Monitoring tools used for a partial monitoring or full monitoring program
(A) Archived

3.3.1 Sediment Vertical Profiling System

Physical monitoring data are collected using Sediment Vertical Profiling System (SVPS) photography, also known as Sediment Profile Image (SPI) photography. SVPS photographs the profile image of the sediment surface, to a depth of up to 20 cm (Figure 2). The SVPS images are analyzed using a computer-based image analysis system. Characteristics measured include the thickness of the dredged material layer, major mode and range of grain sizes, roughness of the surface boundary layer, the depth of the apparent Redox Potential Discontinuity (RPD), and infaunal successional stage (Rhoads and Germano, 1982; 1986). Analysis of triplicate images is recommended at each station, which provides a better representation of station conditions, particularly for the evaluation of dredged material and determination of successional stage (SAIC, 2004).





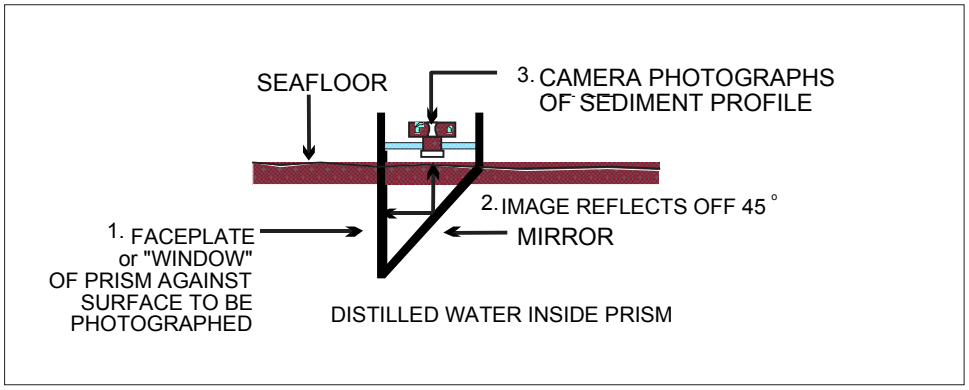


Figure 2. Schematic diagram of sediment-profile camera and sequence of operation on deployment.

The SVPS sampling survey is generally scheduled for two days. The standard SVPS sampling approach is to occupy the perimeter, central cross, and zone stations during the first survey day to determine the overall trend of the dredged material deposit. The second day is used to delineate the edges of the deposit. If a wider distribution of dredged material is expected at a site (e.g., Commencement Bay site; Striplin, 1999, 2001), a low density survey grid is used during the first survey day that spatially covers the expected dredged material footprint. Examples of each approach are shown in Figure 3.

In the PSDDA program, the primary function of SVPS imaging is to determine the post-disposal distribution of dredged material at the sites (i.e., dredged material stays within the disposal site boundary; hypothesis 1). In addition, the SVPS data help ensure that onsite sediment samples are collected from dredged material and that the offsite/transect samples are located in the direction, or most likely direction, of offsite dredged material movement. The chemical and biological inferences made from the SVPS images are used to supplement the sediment chemical and biological data.

3.3.2 Sediment Chemistry

Concentrations of the DMMP chemicals of concern (COC) and conventional parameters (total solids, total volatile solids, total organic carbon [TOC], total sulfides, ammonia, and grain size) are measured in sediments collected at the onsite (zone and site stations), perimeter, and benchmark stations. Selected conventional parameters (grain size and TOC) are analyzed at transect stations to help evaluate benthic infaunal abundance measurements. The current COC and conventional parameters list and associated screening levels (SLs), bioaccumulation triggers (BTs), and maximum levels (MLs) are presented in Table 5. The full COC list was most recently updated in SMARM (2003) with additional proposed revisions to phthalate SLs and MLs in Gries (2005). *The COC list and guideline criteria are subject to revisions and updates on a periodic basis and should be verified with the DMMP prior to initiating a monitoring event.*

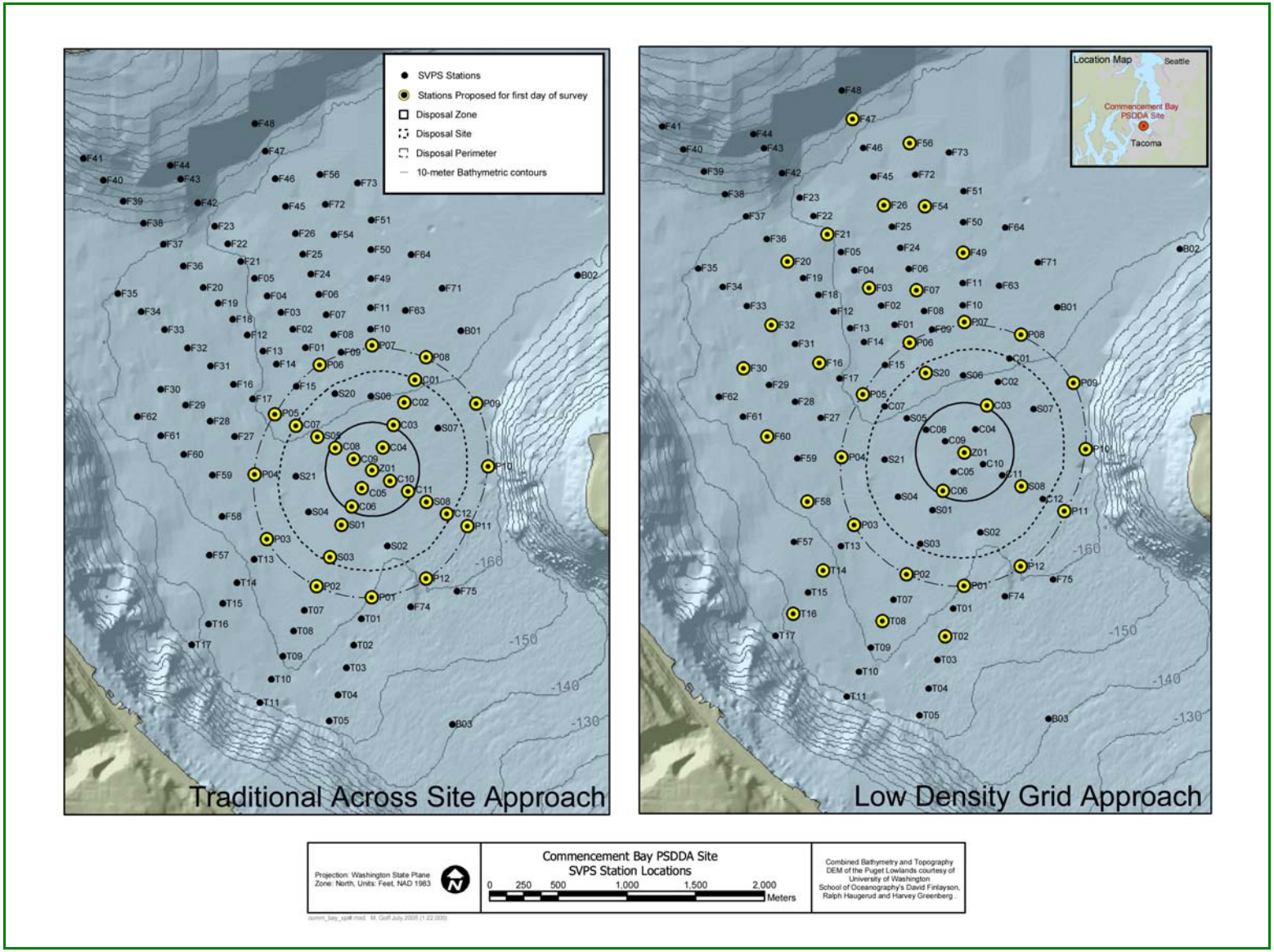


Figure 3. SVPS survey grid examples – traditional across site approach (left) and low density grid approach (right).

Table 5. PSDDA parameters (testing parameter, preparation method, analytical method, sediment method detection limit [MDL], PSDDA screening levels [SL], maximum levels [ML], and bioaccumulation triggers [BT]).

Parameter	Prep Method [1]	Analysis [1]	Sediment MDL [2]	PSDDA [2]		
				SL	BT	ML
Conventionals						
Total Solids (%)	---	PSEP [3]	0.1	---	---	---
Total Volatile Solids (%)	---	PSEP [3]	0.1	---	---	---
Total Organic Carbon (%)	---	PSEP [4]	0.1	---	---	---
Total Sulfides (mg/kg)	---	PSEP [3]	1	---	---	---
Ammonia (mg/kg)	---	Plumb 1981 [5]	1	---	---	---
Grain Size	---	PSEP [3]	---	---	---	---
Metals (ppm)						
Antimony	3050B	6020	2.5	150	---	200
Arsenic	3050B	6020	2.5	57	507.1	700
Cadmium	3050B	6020	0.3	5.1	11.3	14
Chromium	3050B	6020	0.5	---	267	---
Copper	3050B	6020	15.0	390	1027	1300
Lead	3050B	6020	0.5	450	975	1200
Mercury	7471A	7471A	0.02	0.41	1.5	2.3
Nickel	3050B	6020	2.5	140	370	370
Selenium	7740	7740	0.2	---	3	---
Silver	3050B	6020	0.2	6.1	6.1	8.4
Zinc	3050B	6020	15.0	410	2783	3800
Butyltins						
Porewater Butytins (µg/L)	Michelsen et al. 1996	Michelsen et al. 1996	0.025–0.050	0.15	0.15	---
Organics (ppb)						
LPAH						
Naphthalene	3550B	8270C	20	2100	---	2400
Acenaphthylene	3550B	8270C	20	560	---	1300
Acenaphthene	3550B	8270C	20	500	---	2000
Fluorene	3550B	8270C	20	540	---	3600
Phenanthrene	3550B	8270C	20	1500	---	21000
Anthracene	3550B	8270C	20	960	---	13000
2-Methylnaphthalene	3550B	8270C	20	670	---	1900
Total LPAH*				5200	---	29000
HPAH						
Fluoranthene	3550B	8270C	20	1700	4600	30000

Parameter	Prep Method [1]	Analysis [1]	Sediment MDL [2]	PSDDA [2]		
				SL	BT	ML
Pyrene	3550B	8270C	20	2600	11980	16000
Benzo(a)anthracene	3550B	8270C	20	1300	---	5100
Chrysene	3550B	8270C	20	1400	---	21000
Benzofluoranthenes (b + k)	3550B	8270C	20	3200	---	9900
Benzo(a)pyrene	3550B	8270C	20	1600	---	3600
Indeno(1,2,3-c,d)pyrene	3550B	8270C	20	600	---	4400
Dibenzo(a,h)anthracene	3550B	8270C	20	230	---	1900
Benzo(g,h,i)perylene	3550B	8270C	20	670	---	3200
Total HPAH				12000	---	69000
Chlorinated Hydrocarbons						
1,3-Dichlorobenzene	5030B	8260B	3.2	170	---	---
1,4-Dichlorobenzene	5030B	8260B	3.2	110	---	120
1,2-Dichlorobenzene	5030B	8260B	3.2	35	---	110
1,2,4-Trichlorobenzene	3550B	8270C	6	31	---	64
Hexachlorobenzene (HCB)	3550B	8270C	12	22	168	230
Phthalates						
Dimethyl phthalate	3550B	8270C	20	71	---	1400
Diethyl phthalate	3550B	8270C	20	200	---	1200
Di-n-butyl phthalate	3550B	8270C	20	1400	---	5100
Butyl benzyl phthalate	3550B	8270C	20	63	---	970
Bis(2-ethylhexyl)phthalate	3550B	8270C	20	1300	---	8300
Di-n-octyl phthalate	3550B	8270C	20	6200	---	6200
Phenols						
Phenol	3550B	8270C	20	420	---	1200
2 Methylphenol	3550B	8270C	6	63	---	77
4 Methylphenol	3550B	8270C	20	670	---	3600
2,4-Dimethylphenol	3550B	8270C	6	29	---	210
Pentachlorophenol	3550B	8270C	61	400	504	690
Miscellaneous Extractables						
Benzyl alcohol	3550B	8270C	6	57	---	870
Benzoic acid	3550B	8270C	100	650	---	760
Dibenzofuran	3550B	8270C	20	540	---	1700
Hexachloroethane	3550B	8270C	20	1400	---	14000
Hexachlorobutadiene	3550B	8270C	20	29	---	270
N-Nitrosodiphenylamine	3550B	8270C	12	28	---	130
Volatile Organics						
Trichloroethene	5030B	8260B	3.2	160	---	1600

Parameter	Prep Method [1]	Analysis [1]	Sediment MDL [2]	PSDDA [2]		
				SL	BT	ML
Tetrachloroethane	5030B	8260B	3.2	57	---	210
Ethylbenzene	5030B	8260B	3.2	10	---	50
Total Xylene (sum of o-, m-, p-)	5030B	8260B	3.2	40	---	160
Pesticides						
Total DDT	---	---	---	6.9	50	69
p,p'-DDE	3550B	8081A	2.3	---	---	---
p,p'-DDD	3550B	8081A	3.3	---	---	---
p,p'-DDT	3550B	8081A	6.7	---	---	---
Aldrin	3550B	8081A	1.7	10	---	---
Chlordane	3550B	8081A	1.7	10	37	---
Dieldrin	3550B	8081A	2.3	10	---	---
Heptachlor	3550B	8081A	1.7	10	---	---
Lindane	3550B	8081A	1.7	10	---	---
Total PCBs	3550B	8082	67	130	38**	3100
Dioxins/Furans						
Total Polychlorinated Dibenzo-p-Dioxins/Furans (PCDD/F)	---	1613B [6]	---	---	---	---

* Total LPAH does not include 2-Methylnaphthalene.

** Total PCBs BT value in ppm carbon-normalized.

1 Sample preparation and analytical methods (3000, 5000, 6000, 7000, 8000, and 9000 series) are from SW-846, Test Methods for Evaluation Solid Waste Physical/Chemical Methods, U.S. EPA 1986 and updates. http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm

2 Method detection limits (MDL), SLs (except TBT), MLs, and BTs (except PCBs and TBT) are on a dry weight basis.

3 Recommended Protocols for Conventional Sediment Variables in Puget Sound, Puget Sound Estuary Program, March 1986 with minor corrections April 2003.

4 Recommended Guidelines for Measuring Organic Compounds in Puget Sound Water, Sediment, and Tissue Samples – Appendix D, Puget Sound Estuary Program, 1997b.

5 Procedures for Handling and Chemical Analysis of Sediment and Water Samples, Russell H. Plumb, Jr., EPA/Corps of Engineers, May, 1981.

6 Analysis of dioxins/furans is necessary for establishing baseline conditions at each non-dispersive site and may be required as part of regular monitoring at the discretion of the DMMP.

The preferred sediment sampler for sediment chemistry analysis is the 0.2 m^2 stainless double van Veen grab sampler (Figure 4). For onsite stations, sediment samples are collected to a depth of 10 cm. At perimeter and benchmark stations, sediment samples are collected to a depth of 2 cm[3]. Sample collection procedures and acceptability criteria should follow PSEP (1997c). If over penetration is a problem with the van Veen grab sampler, a box core sampler such as the 0.06 m^2 Gray O'Hara box corer is the preferred sampler (Figure 4). A minimum of six grab samples (three deployments of the double van Veen) is required for each sediment sample composite. Triplicate composites are collected at each perimeter and benchmark station to account for variability/spatial heterogeneity at a specific location, and to allow for statistical comparisons of the replicate data over time (SAIC, 1992).

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). Onsite chemistry is used to monitor hypothesis 3 (i.e., onsite sediment chemistry does not exceed PSDDA site condition II guidelines due to dredged material disposal). If unacceptable changes in perimeter or onsite 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] When benthic fauna are collected for tissue analysis at perimeter and/or benchmark stations (e.g., special studies), the DMMP agencies may require that sediment samples be collected to a depth of 10 cm rather than 2 cm.

Figure 4. Stainless 0.2 m^2 dual van Veen grab sampler (left) and stainless 0.06 m^2 Gray O'Hara box core sampler (right).

Bioaccumulative Contaminants of Concern. A revised list of the bioaccumulative contaminants of concern (BCOCs) was finalized by the DMMP in 2003 (Hoffman, 2003). List 1 is the primary list of BCOCs that is required for analysis, and List 2 is of strong concern and considered a priority for study (Table 6). List 1 chemicals overlap with the existing PSDDA COC list. The DMMP should be consulted as to whether the List 2 chemicals should be included as part of a monitoring program. To date, List 2 chemicals have been analyzed at Elliott Bay (Striplin, 2003), Commencement Bay (SAIC, 2003) and the Anderson/Ketron sites (SAIC, 2005).

Chemicals of Concern for Limited Areas. A few additional chemicals are also of concern in limited areas of Puget Sound (Table 7; DMMP, 2000). The DMMP may require additional chemical monitoring if dredged material containing these chemicals is taken to a PSDDA disposal site. Chemicals of concern for limited areas should be confirmed with the DMMP prior to initiating a disposal site monitoring event.

Sample collection procedures, documentation, equipment decontamination, sample storage and transport, and chain-of-custody should follow procedures as outlined in the Puget Sound Estuary Program (PSEP) protocols (PSEP, 1986, 1997a-c), except where documented in the UEMP.

Table 6. Bioaccumulative chemicals of concern – DMMP Lists 1 and 2.

Chemical	BT mg/kg dry weight[a]	TTL[b] mg/kg wet weight	Analysis Method
List 1 (Required for Analysis)			
Arsenic	507.1	10.1	6020
Cadmium	11.3*	TBD	6020
Chlordane	0.037	0.3	8081A
Chromium	267*	TBD	6020
Copper	1027*	TBD	6020
Dioxins/furans[d]	TBD	n/a	1613B
Fluoranthene	4.6	8400	8270
Hexachlorobenzene	0.168	180	8081A
Lead	975*	TBD	6020
Mercury	1.5	1.0	7471A
Nickel	370	20000	6020
Pentachlorophenol	0.504	900	8270
Pyrene	11.98*	TBD	8270
Selenium	3*	TBD	7740
Silver	6.1	200	6020
Tributyltin (porewater)	0.15 µg/L	0.6[e]	Michelsen et al. 1996
Total Aroclor PCBs	38 mg/kg OC	0.75[e]	8082
Total DDT	0.05	5.0	8081A
Zinc	2783*	TBD	6020
List 2 (Strong Concern and Priority for Study)			
1,2,4,5-Tetrachorobenzene	TBD	TBD	8270C
4-Nonylphenol, branched	TBD	TBD	8270C
Benzo(e)pyrene	TBD	TBD	8270C
Biphenyl	TBD	TBD	8270C
Chlorpyrifos	TBD	TBD	8141
Chromium VI	TBD	TBD	7196A or 7199
Dacthal	TBD	TBD	8081A

Chemical	BT mg/kg dry weight[a]	TTL[b] mg/kg wet weight	Analysis Method
Diazinon	TBD	TBD	8141
Endosulfan	TBD	TBD	8081A
Ethion	TBD	TBD	8141
Heptachloronaphthalene	TBD	TBD	8270C
Hexachloronaphthalene	TBD	TBD	8270C
Kelthane	TBD	TBD	8081A
Mirex	TBD	TBD	8081A
Octachloronaphthalene	TBD	TBD	8270C
Oxadiazon	TBD	TBD	8141
Parathion	TBD	TBD	8141
Pentabromodiphenyl ether	TBD	TBD	8270C
Pentachloronaphthalene	TBD	TBD	8270C
Perylene	TBD	TBD	8270C
Tetrachloronaphthalene	TBD	TBD	8270C
Tetraethyltin	TBD	TBD	Michelsen et al. 1996
Trichloronaphthalene	TBD	TBD	8270C
Trifluralin	TBD	TBD	8081A

* Interim BT value
OC Organic carbon normalized
TBD To be determined
a Except where noted otherwise.
b The target tissue levels (TTL) are chemical concentrations in tissues used to interpret the results of bioaccumulation testing (Hoffman, 2003).
c Interim bioaccumulation trigger level.
d DMMP dioxin/furan regulatory guidance will be forthcoming, developed through a series of DMMP-convened stakeholder workshops.
e Target tissue level is based on site-specific considerations for the Elliott Bay disposal site. Separate TTLs may need to be developed for other sites.

Table 7. Chemicals of concern for limited areas.

Chemical	Conditions that May Warrant Monitoring
Guaiacols and Chlorinated Guaiacols	Dredged material originating from areas near Kraft pulp mills. Only guaiacol will be measured near sulfite pulp mills (chlorinated guaiacols are not expected in processes that do not involve bleaching).
Tri-, Tetra-, and Pentachlorobutadienes	Dredged material originating from areas with high chlorinated butadienes. Butadienes are non-priority pollutants that have been detected at highly elevated levels in certain areas of Puget Sound (e.g., Hylebos Waterway in Commencement Bay).
Dioxins and Furans	Dredged material originating from areas near the vicinity of the Weyerhaeuser (Everett), Simpson (Tacoma), and Georgia-Pacific (Bellingham) pulp mills, and Budd Inlet (Olympia).
Butyltins	Dredged material originating from areas near marinas, boatyards, shipyards, CSOs, treatment plant outfalls, and in urban areas, especially Commencement Bay, Elliott Bay, Duwamish River, Lake Washington ship canal, Salmon Bay, and Lake Union.

Source: DMMP, 2000.

3.3.3 Sediment Toxicity

Bioassays are conducted with sediments collected from onsite stations, benchmark stations, and the appropriate reference sediment site to assess sediment toxicity. Bioassay samples are taken from the same sediment composite as the sediment chemistry sample (see Section 3.3.2). Three bioassays are included in the PSDDA program: a 10-day amphipod acute test, a sediment larval test, and the 20-day Neanthes growth test. For the amphipod test, *Eohaustorius estuarius* is the recommended test species when clay content is less than 20 percent (Kendall and McMillan, 1999). Conversely, *Ampelisca abdita* is the recommended test species when clay content is greater than 20 percent. For the sediment larval test, the sand dollar *Dendraster excentricus* or the bivalve *Mytilus galloprovincialis* are the recommended test species (Kendall, 2005). Bioassay testing procedures should follow PSEP (1995) with modifications as specified by the DMMP.

Onsite sediment bioassay results are used to test hypothesis 4 (i.e., sediment toxicity at onsite 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).

3.3.4 Tissue Chemistry

To evaluate bioaccumulation of PSDDA chemicals of concern, the concentrations of selected chemicals (BCOCs) in the tissue of infaunal organisms are measured at transect and benchmark stations (Table 6). 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.* The preferred samplers for tissue collection are the 0.2 m^2 double van Veen sampler or the 0.06 m^2 box core sampler (Figure 4). For *M. intermedia* collection, sea cucumbers with a length of 8 to 12 cm are targeted for chemical analysis (SAIC, 1991a). For *C. subdiaphana* collection, clams with a shell length greater than 6 cm are targeted (Revelas, 1992). Triplicate tissue samples are collected at each station, with a minimum of 80 grams of wet dissected tissue weight per sample (tissue mass requirements should be verified with the analytical laboratory). *M. intermedia* sea cucumbers targeted for collection have a whole body to dissected tissue ratio of approximately 11 to 1 (SAIC, 1991a). Therefore, approximately 900 grams of whole body *M. intermedia* are needed per sample. Approximately 160 grams of whole body *C. subdiaphana* clams are needed per sample, based on a whole body to dissected tissue ratio of approximately 2 to 1 (SAIC, 1991a).

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 (see Table 2).

3.3.5 Benthic Infauna Analysis

Benthic infauna samples are collected at transect and benchmark stations, and a box core sampler such as the 0.06 m^2 Gray O'Hara box core should be used (Figure 4). The box core sample should be inspected according to PSEP (1987, 1997c) criteria to verify that the sample is not disturbed. 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 according to PSEP (1987) procedures. 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 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.

3.4 Full Monitoring

A full monitoring program at a PSDDA disposal site addresses all six hypotheses of the monitoring framework and measures all of the parameters at onsite, perimeter, and transect stations:

1. Mapping of the dredged material footprint using SVPS
2. Onsite chemistry and bioassays
3. Perimeter chemistry
4. Benchmark chemistry and bioassays (SAMPLES ARCHIVED)
5. Transect tissue body burden and benthic abundance
6. Benchmark tissue body burden and benthic abundance (SAMPLES ARCHIVED)

Samples from benchmark stations are collected but initially archived. Analysis of benchmark samples is contingent upon the PSDDA monitoring framework (Table 2). A baseline survey of a disposal site would be equivalent to the full monitoring program but would include the analysis of the benchmark stations. The number of samples taken is generally similar at each disposal site, but minor variations are observed due to different physical characteristics of each disposal site. The specific number of samples and stations recommended at each disposal site is outlined in the site-specific monitoring plans (Section 4.0).

3.5 Tiered-Full Monitoring

Similar to a full monitoring program, a tiered-full monitoring program addresses all six hypotheses and measures all of the monitoring parameters. However, the transect samples are collected but not initially analyzed. The samples are archived and analysis occurs only if triggered under the PSDDA monitoring framework. The following parameters are measured or samples collected and archived:

1. Mapping of the dredged material footprint using SVPS
2. Onsite chemistry and bioassays
3. Perimeter chemistry
4. Benchmark chemistry and bioassays (SAMPLES ARCHIVED)
5. Transect tissue body burden and benthic abundance (SAMPLES ARCHIVED)
6. Benchmark tissue body burden and benthic abundance (SAMPLES ARCHIVED)

The tiered-full monitoring approach was adopted as a cost saving measure; it is only implemented when previous site monitoring has shown compliance with the site management objectives, and no unexpected conditions have developed due to dredged material disposal (Benson, 1996). Although benchmark station samples are archived, chemical parameters with short analytical holding times are analyzed (total sulfides, total solids, ammonia, mercury, and volatile organic compounds (DMMP, 2000).

3.6 Partial Monitoring

Partial monitoring occurs when the volume of material going to the disposal site is not great enough to warrant full monitoring. Under a partial program, only hypotheses 1 through 4 are addressed and the following parameters are measured or samples collected and archived:

1. Mapping of the dredged material footprint using SVPS
2. Onsite chemistry and bioassays
3. Perimeter chemistry
4. Benchmark chemistry and bioassays (SAMPLES ARCHIVED)

In addition, the number of onsite stations is reduced for sediment chemistry and bioassay testing. Detailed information on sample numbers for each disposal site is provided in the site-specific monitoring plans (Section 4.0).

4.0 SITE-SPECIFIC MONITORING PLANS

The general monitoring plan is adapted to each of the disposal sites based on physical and biological conditions at the site, anticipated annual loading, and proximity of potential contaminant sources to the disposal site (PSDDA, 1988a). Modifications to the site-specific monitoring plans may be adopted by the DMMP as site use or environmental conditions change over time. The site-specific elements for each disposal site monitoring plan are described below.

4.1 Bellingham Bay Disposal Site

The Bellingham Bay disposal site is located in a relatively flat, nondispersive area of Bellingham Bay, in a water depth of 96 feet, with weak northwest to southeast currents (PSDDA 1988d). Results of the baseline studies are reported in PTI (1989a) and include physical mapping using SVPS, sediment chemistry and bioassays, benthic infauna analysis, and bioaccumulation of contaminants in clam (*Compsomyax subdiaphana*) tissues. Since the baseline surveys, only one partial monitoring survey (SAIC, 1993) has been conducted in Bellingham Bay. Site maps showing the SVPS sampling grid and sediment chemical and biological stations are provided in Figures 5 and 6, respectively. Geographic coordinates for the stations are provided in Table 8.

A summary of station sampling and analytical requirements at Bellingham Bay is provided in Table 9. A full or tiered-full monitoring program includes sampling at one onsite station (BBZ01), four perimeter stations (BBP01, BBP02, BBP03, BBP04), three transect stations (BBT04, BBT05, BBT06)[4], and three benchmark stations (BBB01, BBB02, BBB04) (Figure 6). The transect stations are not sampled during a partial monitoring program (Table 9). Changes in the selected sampling stations can occur (e.g., transect stations) based on the dredged material footprint measured during the SVPS survey (i.e, changes in offsite migration/deposition of dredged material) or other observed changes at the disposal site. All modifications to the site monitoring program should be coordinated with the DMMP.

The three benchmark stations are sited to evaluate potential changes in Bellingham Bay sediment quality that may not be related to dredged material disposal. Station BBB01 is nearest to the city of Bellingham and represents a monitor of the urban environment. Station BBB04 lies south of the disposal site and is representative of natural conditions in Bellingham Bay. Station BBB02 is located to the east of the disposal site, near potential urban activities in Fairhaven.

[4] Transect station BBT04, BBT05, and BBT06 represent the stations in the most likely down-gradient direction, based on weak bottom currents in Bellingham Bay (PSDDA 1989a).

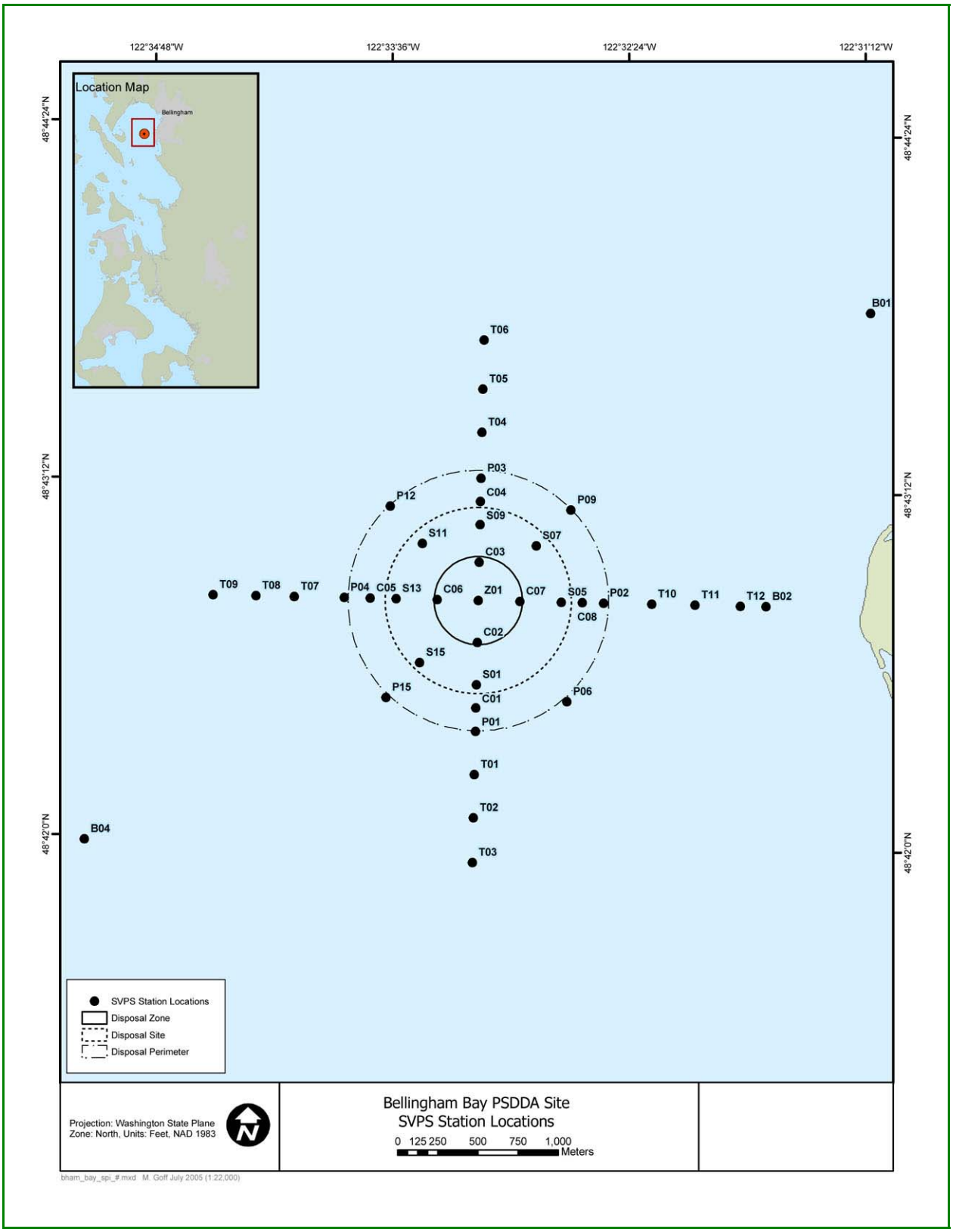


Figure 5. Bellingham Bay target SVPS locations.

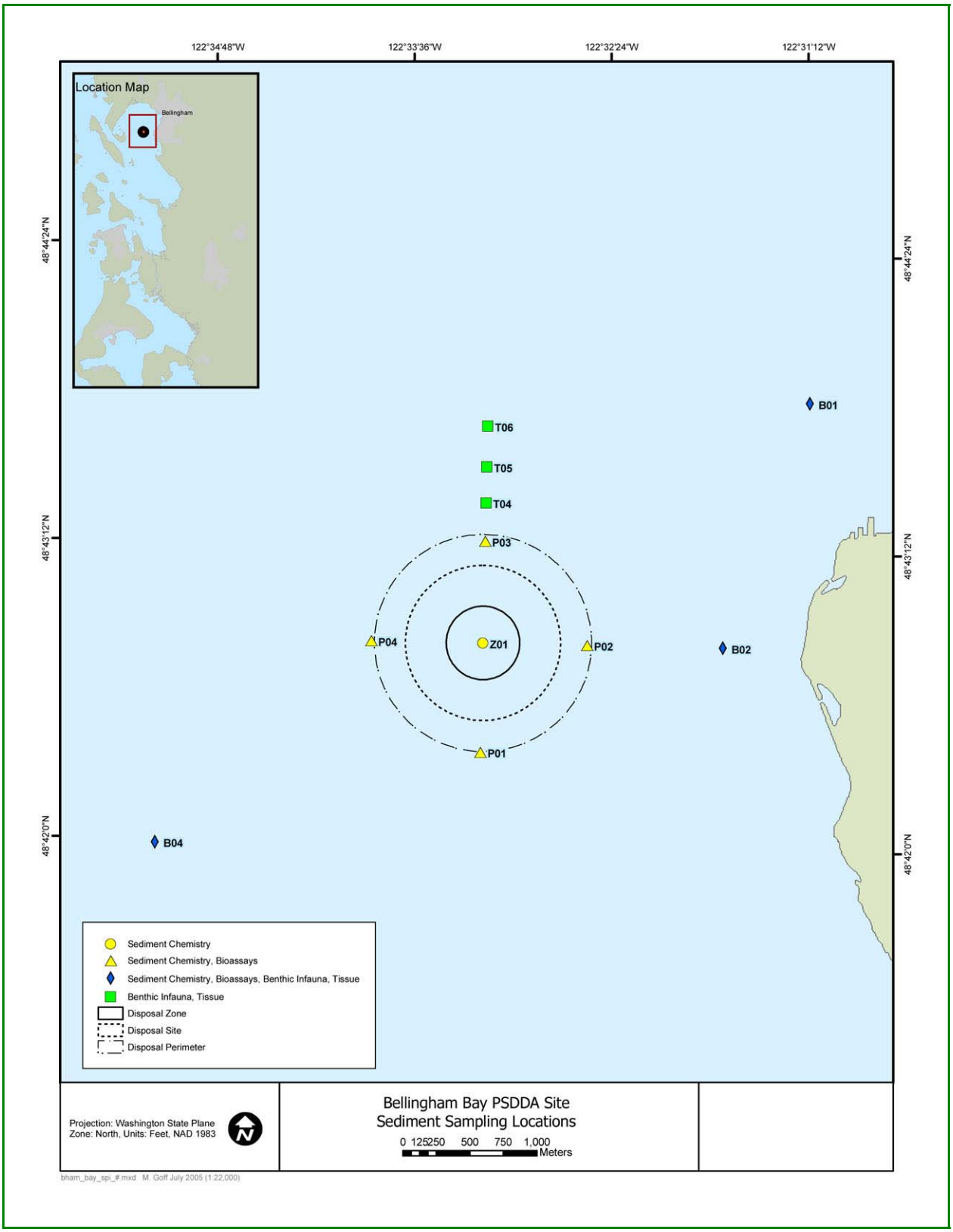


Figure 6. Bellingham Bay target sediment sampling locations.

Table 8. Bellingham Bay station target coordinates (NAD 1983).

Station	Type	Latitude N	Longitude W
BBZ01	Zone	48° 42.8156'	122° 33.1048'
BBS01	Site	48° 42.5326'	122° 33.1048'
BBS05	Site	48° 42.8156'	122° 32.6828'
BBS07	Site	48° 43.0028'	122° 32.8168'
BBS09	Site	48° 43.0707'	122° 33.1048'
BBS11	Site	48° 43.0028'	122° 33.3948'
BBS13	Site	48° 42.8156'	122° 33.5218'
BBS15	Site	48° 42.6028'	122° 33.3948'
BBP01	Perimeter	48° 42.3756'	122° 33.1048'
BBP02	Perimeter	48° 42.8156'	122° 32.4696'
BBP03	Perimeter	48° 43.2256'	122° 33.1048'
BBP04	Perimeter	48° 42.8156'	122° 33.7848'
BBP06	Perimeter	48° 42.4828'	122° 32.6446'
BBP09	Perimeter	48° 43.1258'	122° 32.6448'
BBP12	Perimeter	48° 43.1258'	122° 33.5618'
BBP15	Perimeter	48° 42.4828'	122° 33.5618'
BBT01	Transect	48° 42.2306'	122° 33.1048'
BBT02	Transect	48° 42.0857'	122° 33.1048'
BBT03	Transect	48° 41.9356'	122° 33.1048'
BBT04	Transect	48° 43.3806'	122° 33.1048'
BBT05	Transect	48° 43.5256'	122° 33.1048'
BBT06	Transect	48° 43.6900'	122° 33.1048'
BBT07	Transect	48° 42.8156'	122° 34.0378'
BBT08	Transect	48° 42.8156'	122° 34.2328'
BBT09	Transect	48° 42.8156'	122° 34.4498'
BBT10	Transect	48° 42.8156'	122° 32.2246'
BBT11	Transect	48° 42.8156'	122° 32.0046'
BBT12	Transect	48° 42.8156'	122° 31.7746'
BBB01	Benchmark	48° 43.8078'	122° 31.1476'
BBB02	Benchmark	48° 42.8158'	122° 31.6446'
BBB04	Benchmark	48° 41.9858'	122° 35.0748'
BBC01	Cross	48° 42.4546'	122° 33.1048'
BBC02	Cross	48° 42.6746'	122° 33.1048'
BBC03	Cross	48° 42.9436'	122° 33.1048'
BBC04	Cross	48° 43.1486'	122° 33.1048'
BBC05	Cross	48° 42.8156'	122° 33.6538'
BBC06	Cross	48° 42.8156'	122° 33.3138'
BBC07	Cross	48° 42.8156'	122° 32.8938'
BBC08	Cross	48° 42.8156'	122° 32.5766'

Table 9. Station sampling and analytical requirements at the Bellingham Bay site.

Parameter	Full Monitoring Stations	Tiered-Full Monitoring Stations	Partial Monitoring Stations
Onsite Chemistry	1	1	1
Onsite Bioassays	1	1	1
Perimeter Chemistry	4 (triplicates at each)	4 (triplicates at each)	4 (triplicates at each)
Benchmark Chemistry	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)
Benchmark Bioassays	3 (ARCHIVE)	3 (ARCHIVE)	3 (ARCHIVE)
Transect Benthos	3 (5 replicates each)	3 (5 replicates each; ARCHIVE)	0
Transect Tissue	3 (triplicates at each)	3 (triplicates at each; ARCHIVE)	0
Transect Chemistry[a]	3	3 (ARCHIVE)	0
Benchmark Benthos	3 (5 replicates each; ARCHIVE)	3 (5 replicates each; ARCHIVE)	0
Benchmark Tissue	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)	0
Reference Chemistry[b]	1	1	1
Reference Bioassays[c]	1	1	1
SVPS[d]	53 (triplicates at each)	53 (triplicates at each)	53 (triplicates at each)

a Transect chemistry consists of grain size and TOC only.
b Reference chemistry consists of conventional parameters only.
c Reference grain size should be similar to onsite sediments for bioassay testing.
d Approximate number of SVPS stations in two days. Station locations can be modified or additional stations added to improve delineation of the dredged material footprint.

4.2 Port Gardner Disposal Site

The Port Gardner disposal site, located in Everett, WA, is a relatively flat, non-dispersive area with weak currents that generally flow southeast to northwest at depth (PSDDA, 1988d). The average depth at the site is approximately 420 feet. Baseline studies of the Port Gardner site occurred in 1988 (PTI, 1988, 1989b). The sea cucumber *Molpadia intermedia* is the target species for tissue chemistry analysis. Since the baseline survey, a total of two PSDDA monitoring events have been conducted at the Port Gardner site:

1. 1990 partial monitoring (SAIC, 1991b)
2. 1994 tiered-full monitoring (SAIC, 1995a)

Site maps showing the SVPS sampling grid and sediment chemical and biological stations are provided in Figures 7 and 8, respectively. Geographic coordinates for the stations are provided in Table 10.

A summary of station sampling and analytical requirements at Port Gardner is provided in Table 11. A full or tiered-full monitoring program includes sampling at three onsite stations (PGZ06, PGS04, PGS08), four perimeter stations (PGP01, PGP07, PGP08, PGP09), three transect stations (PGT11, PGT13, PGT15), and two benchmark stations (PGB01, PGB09) (Figure 8). During a partial monitoring program, the onsite sampling is reduced to one station (PGZ06) and the transect stations are not sampled (Table 11). Changes in the selected sampling stations can occur (e.g., transect stations) based on the dredged material footprint measured during the SVPS survey (i.e, changes in offsite migration/deposition of dredged material) or other observed changes at the disposal site. All modifications to the site monitoring program should be coordinated with the DMMP.

The two benchmark stations are sited to evaluate potential changes in Port Gardner sediment quality that may not be related to dredged material disposal. Station PGB01 is located near the southeast perimeter of the disposal site, near the historical confined aquatic disposal (CAD) site used for dredged material from the U.S. Navy Homeport project in Everett, WA (PSDDA, 1988a). Station PGB09 is located to the east of the disposal site and was established as a benchmark station in 1994 to replace PGB02. During the 1990 full monitoring program, station PGB02 (located to the southwest of the disposal site) was determined to be unsuitable as a benchmark station based on an atypical infaunal community, unusually high clay content relative to other Port Gardner stations, and toxicity testing failures during the 1988 baseline surveys (SAIC, 1995).

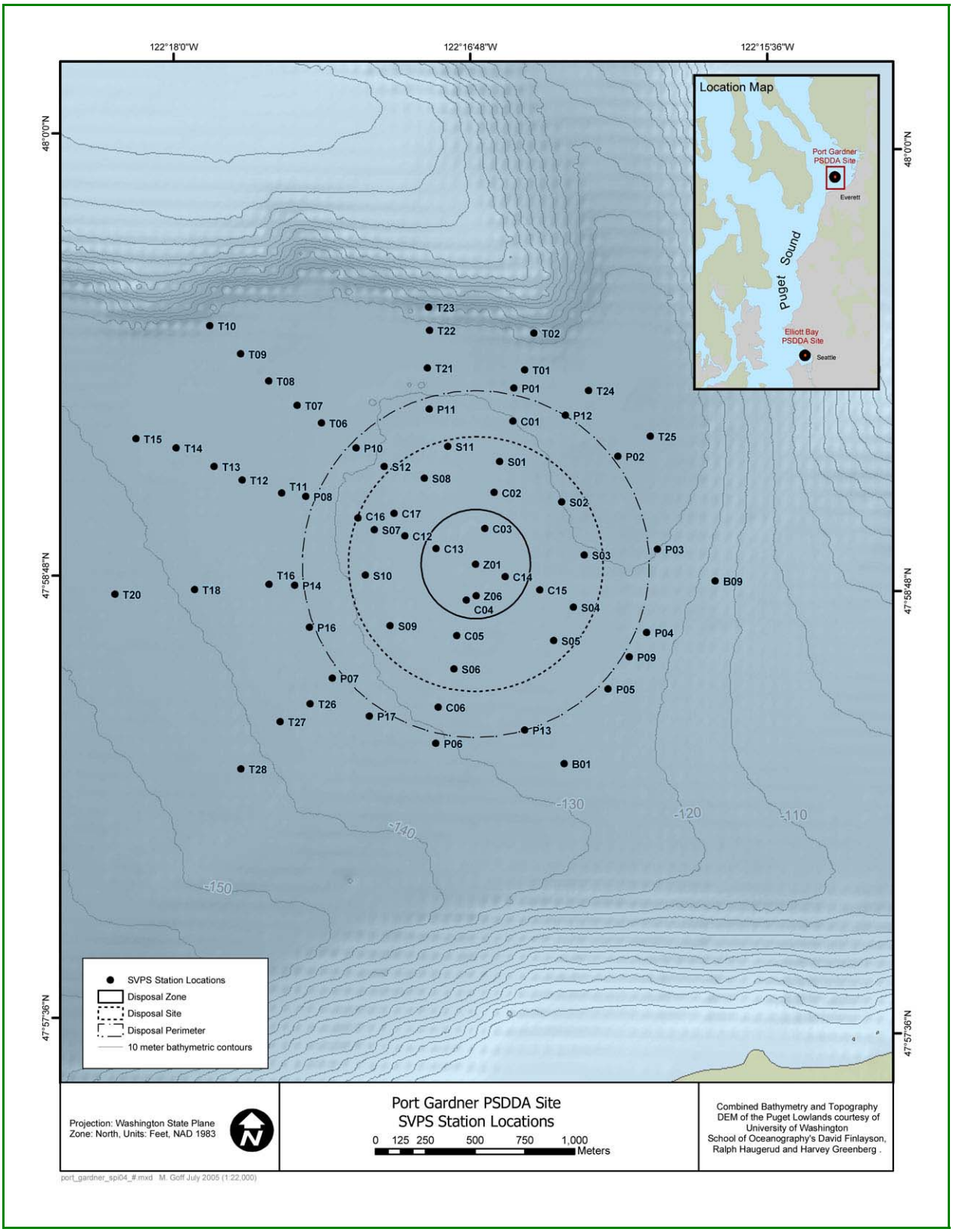


Figure 7. Port Gardner target SVPS locations.

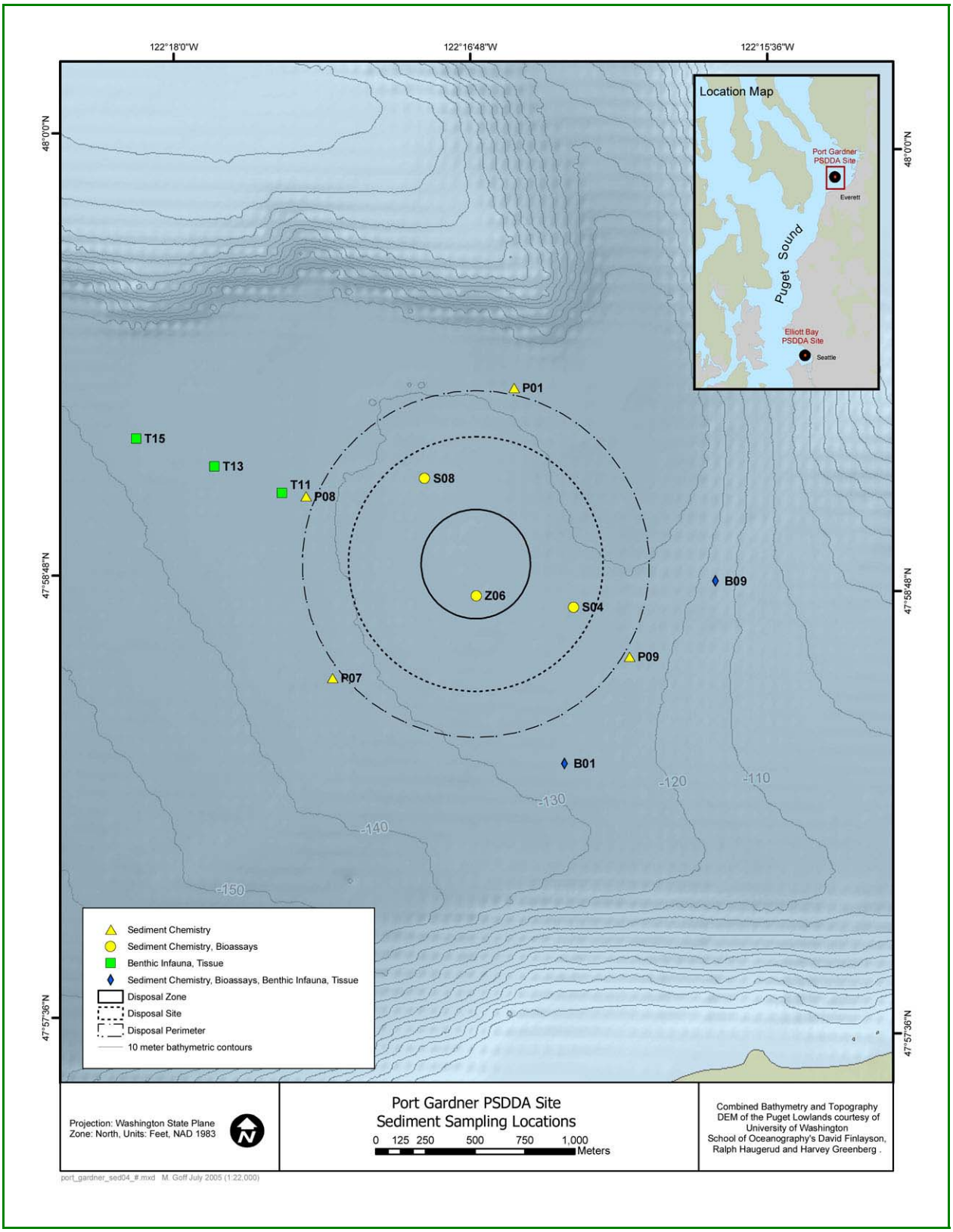


Figure 8. Port Gardner target sediment sampling locations.

Table 10. Port Gardner station target coordinates (NAD 1983).

Station	Type	Latitude N	Longitude W
PGZ01	Zone	47° 58.8526'	122° 16.7398'
PGZ06	Zone	47° 58.7670'	122° 16.7351'
PGS01	Site	47° 59.1326'	122° 16.6498'
PGS02	Site	47° 59.0260'	122° 16.3965'
PGS03	Site	47° 58.8826'	122° 16.3015'
PGS04	Site	47° 58.7410'	122° 16.3414'
PGS05	Site	47° 58.6493'	122° 16.4181'
PGS06	Site	47° 58.5670'	122° 16.8191'
PGS07	Site	47° 58.9410'	122° 17.1514'
PGS08	Site	47° 59.0830'	122° 16.9531'
PGS09	Site	47° 58.6810'	122° 17.0801'
PGS10	Site	47° 58.8169'	122° 17.1843'
PGS11	Site	47° 59.1705'	122° 16.8615'
PGS12	Site	47° 59.1130'	122° 17.1168'
PGP01	Perimeter	47° 59.3326'	122° 16.5981'
PGP02	Perimeter	47° 59.1526'	122° 16.1731'
PGP03	Perimeter	47° 58.9026'	122° 16.0065'
PGP04	Perimeter	47° 58.6759'	122° 16.0431'
PGP05	Perimeter	47° 58.5210'	122° 16.1948'
PGP06	Perimeter	47° 58.3643'	122° 16.8865'
PGP07	Perimeter	47° 58.5360'	122° 17.3098'
PGP08	Perimeter	47° 59.2766'	122° 17.4315'
PGP09	Perimeter	47° 58.6093'	122° 16.1115'
PGP10	Perimeter	47° 59.1619'	122° 17.2311'
PGP11	Perimeter	47° 59.2710'	122° 16.9391'
PGP12	Perimeter	47° 59.2609'	122° 16.3881'
PGP13	Perimeter	47° 58.4050'	122° 16.5291'
PGP14	Perimeter	47° 58.7860'	122° 17.4691'
PGP16	Perimeter	47° 58.6729'	122° 17.4061'
PGP17	Perimeter	47° 58.4350'	122° 17.1571'
PGT01	Transect	47° 59.3826'	122° 16.5565'
PGT02	Transect	47° 59.4826'	122° 16.5214'
PGT06	Transect	47° 59.2276'	122° 17.3731'
PGT07	Transect	47° 59.2743'	122° 17.4731'
PGT08	Transect	47° 59.3393'	122° 17.5898'
PGT09	Transect	47° 59.4109'	122° 17.7048'
PGT10	Transect	47° 59.4859'	122° 17.8315'
PGT11	Transect	47° 59.0359'	122° 17.5281'
PGT12	Transect	47° 59.0693'	122° 17.6898'
PGT13	Transect	47° 59.1043'	122° 17.8031'
PGT14	Transect	47° 59.1526'	122° 17.9581'
PGT15	Transect	47° 59.1760'	122° 18.1215'
PGT16	Transect	47° 58.7876'	122° 17.5731'
PGT18	Transect	47° 58.7693'	122° 17.8731'
PGT20	Transect	47° 58.7526'	122° 18.1948'

Station	Type	Latitude N	Longitude W
PGT21	Transect	47° 59.3821'	122° 16.9493'
PGT22	Transect	47° 59.4850'	122° 16.9433'
PGT23	Transect	47° 59.5478'	122° 16.9491'
PGT24	Transect	47° 59.3293'	122° 16.297'
PGT25	Transect	47° 59.2090'	122° 16.0441'
PGT26	Transect	47° 58.4650'	122° 17.3971'
PGT27	Transect	47° 58.4149'	122° 17.5171'
PGT28	Transect	47° 58.2850'	122° 17.6721'
PGB01	Benchmark	47° 58.3159'	122° 16.3665'
PGB09	Benchmark	47° 58.8190'	122° 15.7701'
PGC01	Cross	47° 59.2429'	122° 16.6001'
PGC02	Cross	47° 59.0479'	122° 16.6701'
PGC03	Cross	47° 58.9496'	122° 16.7051'
PGC04	Cross	47° 58.7550'	122° 16.7751'
PGC05	Cross	47° 58.6579'	122° 16.8101'
PGC06	Cross	47° 58.4629'	122° 16.8801'
PGC12	Cross	47° 58.9260'	122° 17.0281'
PGC13	Cross	47° 58.8930'	122° 16.9001'
PGC14	Cross	47° 58.8199'	122° 16.6191'
PGC15	Cross	47° 58.7860'	122° 16.4781'
PGC16	Cross	47° 58.9720'	122° 17.2181'
PGC17	Cross	47° 58.9860'	122° 17.0731'

Table 11. Station sampling and analytical requirements at the Port Gardner site.

Parameter	Full Monitoring Stations	Tiered-Full Monitoring Stations	Partial Monitoring Stations
Onsite Chemistry	3	3	1
Onsite Bioassays	3	3	1
Perimeter Chemistry	4 (triplicates at each)	4 (triplicates at each)	4 (triplicates at each)
Benchmark Chemistry	2 (triplicates at each; ARCHIVE)	2 (triplicates at each; ARCHIVE)	2 (triplicates at each; ARCHIVE)
Benchmark Bioassays	2 (ARCHIVE)	2 (ARCHIVE)	2 (ARCHIVE)
Transect Benthos	3 (5 replicates each)	3 (5 replicates each; ARCHIVE)	0
Transect Tissue	3 (triplicates at each)	3 (triplicates at each; ARCHIVE)	0
Transect Chemistry[a]	3	3 (ARCHIVE)	0
Benchmark Benthos	3 (5 replicates each; ARCHIVE)	3 (5 replicates each; ARCHIVE)	0
Benchmark Tissue	2 (triplicates at each; ARCHIVE)	2 (triplicates at each; ARCHIVE)	0
Reference Chemistry[b]	1	1	1
Reference Bioassays[c]	1	1	1
SVPS[d]	58 (triplicates at each)	58 (triplicates at each)	58 (triplicates at each)

a Transect chemistry consists of grain size and TOC only.
b Reference chemistry consists of conventional parameters only.
c Reference grain size should be similar to onsite sediments for bioassay testing. More than one reference may be necessary.
d Approximate number of SVPS stations in two days. Station locations can be modified or additional stations added to improve delineation of the dredged material footprint.

4.3 Elliott Bay Disposal Site

The Elliott Bay site, located in Seattle, WA, is a gently sloping area in the center of Elliott Bay at a depth ranging from 200 feet at the south edge of the site to 360 feet at the north edge. Currents at the disposal site location were found to be weak and variable (PSDDA, 1988d). Baseline surveys of the Elliott Bay site occurred in 1988 (PTI, 1988, 1989b). The sea cucumber *Molpadia intermedia* is the target species for tissue chemistry analysis. Since the baseline survey, a total of four PSDDA monitoring events have been conducted at the Elliott Bay site:

1. 1990 partial monitoring (SAIC, 1991b)
2. 1992 full monitoring (SAIC, 1992)
3. 2000 full monitoring (SAIC, 2000)
4. 2002 tiered-full monitoring (Striplin, 2002)

Site maps showing the SVPS sampling grid and sediment chemical and biological stations are provided in Figures 9 and 10, respectively. Geographic coordinates for the stations are provided in Table 12.

A summary of station sampling and analytical requirements at Elliott Bay is provided in Table 13. A full or tiered-full monitoring program includes sampling at three onsite stations (EBZ01, EBS02, EBS04), four perimeter stations (EBP01, EBP03, EBP07, EBP11), three transect stations (EBT01, EBT03, EBT05), and four benchmark stations (EBB01, EBB02, EBB03, EBB04) (Figure 10). During a partial monitoring program, the onsite sampling is reduced to one station (EBZ01) and the transect stations are not sampled (Table 13).

The four benchmark stations are sited to evaluate potential changes in Elliott Bay sediment quality that may not be related to dredged material disposal. Station EBB01 is located near the mouth of the West Waterway of the Duwamish River, which historically has represented a major source of contaminant input into Elliott Bay (U.S. EPA, 2001). Benchmark stations located to the east (EBB02) and north (EBB03) of the disposal site act as monitors to sources of contaminants that exist along the Seattle waterfront shoreline (PSDDA, 1988a). Benchmark station EBB04 is located to the west of the site between Duwamish Head and Magnolia.

Historically, much of the benthic habitat in Elliott Bay has been considered impacted due to industrial contamination (PSDDA 1988d). However, disposal site monitoring events at the Elliott Bay site have shown a general improvement in benthic habitat over time. For example, *Molpadia* sea cucumber abundance has increased in Elliott Bay. *Molpadia* tissue samples could not be collected during the 1990 and 1992 monitoring surveys due to low abundance. However, during the 2000 survey, *Molpadia* tissue samples could be collected at two of the transect stations. During the most recent 2002 survey, *Molpadia* tissues were collected at all three transects, one benchmark, one perimeter, and two onsite stations. As sediment conditions continue to improve in Elliott Bay, additional changes in sampling design and selected stations (e.g., stations targeted for tissue analysis) may be appropriate. Any proposed changes or sampling modifications should be coordinated with the DMMP.

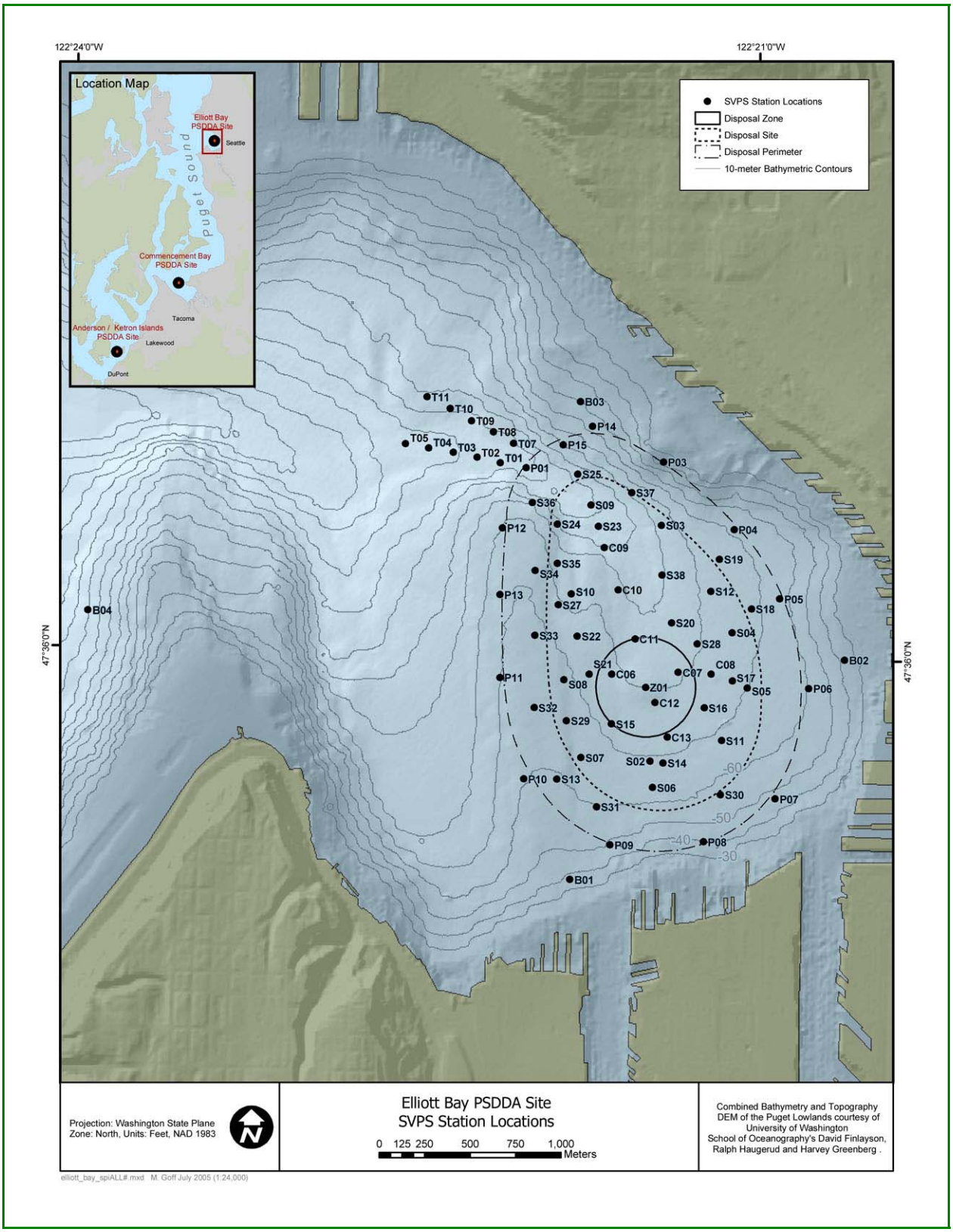


Figure 9. Elliott Bay target SVPS locations.

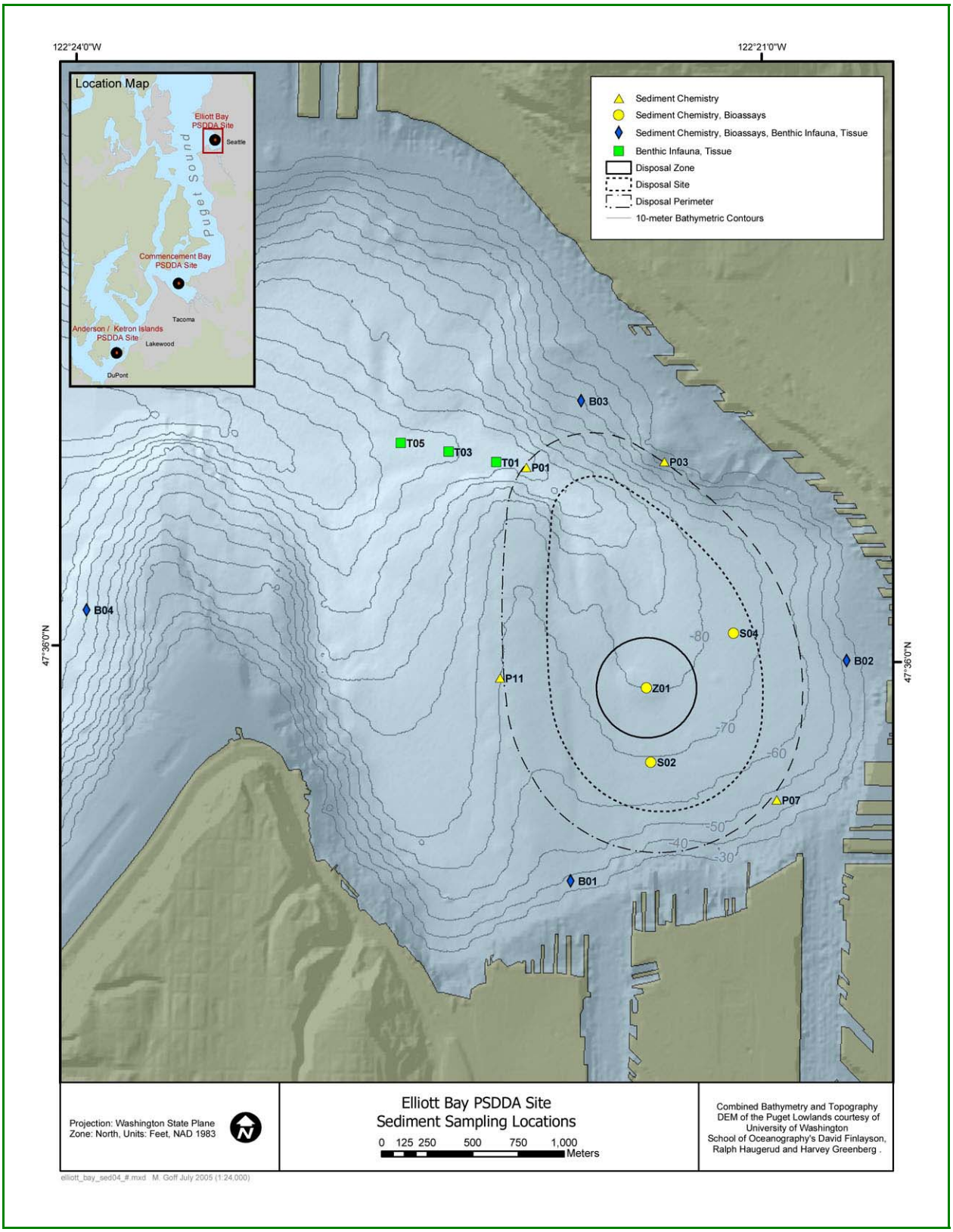


Figure 10. Elliott Bay target sediment sampling locations.

Table 12. Elliott Bay station target coordinates (NAD 1983).

Station	Type	Latitude N	Longitude W
EBZ01	Zone	47° 35.9100'	122° 21.4500'
EBS02	Site	47° 35.6908'	122° 21.4243'
EBS03	Site	47° 36.3925'	122° 21.3943'
EBS04	Site	47° 36.0775'	122° 21.0743'
EBS05	Site	47° 35.9141'	122° 21.0026'
EBS06	Site	47° 35.6125'	122° 21.4110'
EBS07	Site	47° 35.6974'	122° 21.7276'
EBS08	Site	47° 35.9275'	122° 21.8093'
EBS09	Site	47° 36.4491'	122° 21.706'
EBS10	Site	47° 36.1831'	122° 21.7846'
EBS11	Site	47° 35.7561'	122° 21.1113'
EBS12	Site	47° 36.1991'	122° 21.1713'
EBS13	Site	47° 35.6321'	122° 21.8323'
EBS14	Site	47° 35.6861'	122° 21.3663'
EBS15	Site	47° 35.7991'	122° 21.5963'
EBS16	Site	47° 35.8521'	122° 21.1903'
EBS17	Site	47° 35.9341'	122° 21.0693'
EBS18	Site	47° 36.1491'	122° 20.9913'
EBS19	Site	47° 36.2951'	122° 21.1363'
EBS20	Site	47° 36.1031'	122° 21.3413'
EBS21	Site	47° 35.9461'	122° 21.6993'
EBS22	Site	47° 36.0582'	122° 21.7553'
EBS23	Site	47° 36.3861'	122° 21.6713'
EBS24	Site	47° 36.3901'	122° 21.8523'
EBS25	Site	47° 36.5401'	122° 21.7663'
EBS27	Site	47° 36.1501'	122° 21.8413'
EBS28	Site	47° 36.0422'	122° 21.2263'
EBS29	Site	47° 35.8061'	122° 21.7953'
EBP01	Perimeter	47° 36.5558'	122° 21.9943'
EBP03	Perimeter	47° 36.5808'	122° 21.391'
EBP04	Perimeter	47° 36.3841'	122° 21.0743'
EBP05	Perimeter	47° 36.1808'	122° 20.8676'
EBP06	Perimeter	47° 35.9158'	122° 20.7326'
EBP07	Perimeter	47° 35.5858'	122° 20.8710'
EBP08	Perimeter	47° 35.4541'	122° 21.1826'
EBP09	Perimeter	47° 35.4391'	122° 21.5926'
EBP10	Perimeter	47° 35.6308'	122° 21.9776'
EBP11	Perimeter	47° 35.9308'	122° 22.0909'
EBP12	Perimeter	47° 36.3758'	122° 22.0926'
EBP13	Perimeter	47° 36.1771'	122° 22.0983'
EBP14	Perimeter	47° 36.6831'	122° 21.7053'
EBP15	Perimeter	47° 36.6261'	122° 21.8323'
EBT01	Transect	47° 36.5691'	122° 22.1076'
EBT02	Transect	47° 36.5841'	122° 22.2109'
EBT03	Transect	47° 36.5974'	122° 22.3159'

Station	Type	Latitude N	Longitude W
EBT04	Transect	47° 36.6091'	122° 22.4243'
EBT05	Transect	47° 36.6208'	122° 22.5259'
EBT07	Transect	47° 36.6274'	122° 22.051'
EBT08	Transect	47° 36.6608'	122° 22.141'
EBT09	Transect	47° 36.6925'	122° 22.2376'
EBT10	Transect	47° 36.7275'	122° 22.3326'
EBT11	Transect	47° 36.7608'	122° 22.4359'
EBB01	Benchmark	47° 35.3341'	122° 21.766'
EBB02	Benchmark	47° 36.0025'	122° 20.5776'
EBB03	Benchmark	47° 36.7558'	122° 21.7609'
EBB04	Benchmark	47° 36.1075'	122° 23.9076'
EBC06	Cross	47° 35.9471'	122° 21.6003'
EBC07	Cross	47° 35.9561'	122° 21.3083'
EBC08	Cross	47° 35.9531'	122° 21.1623'
EBC09	Cross	47° 36.3231'	122° 21.6433'
EBC10	Cross	47° 36.1981'	122° 21.5793'
EBC11	Cross	47° 36.0532'	122° 21.5003'
EBC12	Cross	47° 35.8651'	122° 21.4073'
EBC13	Cross	47° 35.7631'	122° 21.3503'

Table 13. Station sampling and analytical requirements at the Elliott Bay site.

Parameter	Full Monitoring Stations	Tiered-Full Monitoring Stations	Partial Monitoring Stations
Onsite Chemistry	3	3	1
Onsite Bioassays	3	3	1
Perimeter Chemistry	4 (triplicates at each)	4 (triplicates at each)	4 (triplicates at each)
Benchmark Chemistry	4 (triplicates at each; ARCHIVE)	4 (triplicates at each; ARCHIVE)	4 (triplicates at each; ARCHIVE)
Benchmark Bioassays	4 (ARCHIVE)	4 (ARCHIVE)	4 (ARCHIVE)
Transect Benthos	3 (5 replicates each)	3 (5 replicates each; ARCHIVE)	0
Transect Tissue	3 (triplicates at each)	3 (triplicates at each; ARCHIVE)	0
Transect Chemistry[a]	3	3 (ARCHIVE)	0
Benchmark Benthos	4 (5 replicates each; ARCHIVE)	3 (5 replicates each; ARCHIVE)	0
Benchmark Tissue	4[b] (triplicates at each; ARCHIVE)	4[b] (triplicates at each; ARCHIVE)	0
Reference Chemistry[c]	1	1	1
Reference Bioassays[d]	1	1	1
SVPS[e]	67 (triplicates at each)	67 (triplicates at each)	67 (triplicates at each)

a Transect chemistry consists of grain size and TOC only.
b Although four benchmark stations are proposed, only one station was successfully sampled for tissue in 2002.
c Reference chemistry consists of conventional parameters only.
d Reference grain size should be similar to onsite sediments for bioassay testing. More than one reference may be necessary.
e Approximate number of SVPS stations in two days. Station locations can be modified or additional stations added to improve delineation of the dredged material footprint.

4.4 Commencement Bay Disposal Site

The Commencement Bay site, located in Tacoma, WA, is a relatively flat, non-dispersive area with water depths varying from 540 to 560 feet with northwest to southeast currents (PSDDA, 1988d). Baseline studies of the Commencement Bay site occurred in 1988 (PTI, 1988, 1989b). The sea cucumber *Molpadia intermedia* is the target species for tissue chemistry analysis. Since the baseline survey and prior to 2005, a total of six PSDDA monitoring programs have been conducted at the Commencement Bay site:

1. 1995 full monitoring (SAIC, 1995b) New Baseline
2. 1996 partial monitoring (SAIC, 1996)
3. 1998 SVPS physical monitoring (Striplin, 1999)
4. 2001 full monitoring (Striplin, 2001)
5. 2003 tiered-full monitoring (SAIC, 2003)
6. 2004 partial monitoring (SAIC, 2004)

Due to the length of time between the baseline surveys and the first monitoring survey, results from the 1995 full monitoring survey were adopted as the new baseline for interpretive criteria (SAIC, 1995b). The original 1988 baseline data will still be used for examining long-term trends at the site.

Site maps showing the SVPS sampling grid and sediment chemical and biological stations are provided in Figures 11 and 12, respectively. Geographic coordinates for the stations are provided in Table 14. Due to the wider dispersal of dredged material observed since the 1998 SVPS survey (Striplin, 1999), a low density sampling grid approach can be used for the SVPS surveys at the Commencement Bay site (see Section 3.3.1).

A summary of station sampling and analytical requirements at Commencement Bay is provided in Table 15. A full or tiered-full monitoring program includes sampling at three onsite stations (CBZ01, CBS01, CBS08), four perimeter stations (CBP01, CBP03, CBP07, CBP11), three transect stations (CBT13, CBT14, CBT15; along the down-current gradient)[5], and three benchmark stations (CBB01, CBB02, CBB03) (Figure 12). During a partial monitoring program, the onsite sampling is reduced to one station (CBZ01) and the transect stations are not sampled (Table 15). Changes in the selected sampling stations can occur (e.g., transect stations) based on the dredged material footprint measured during the SVPS survey (i.e, changes in offsite migration/deposition of dredged material) or other observed changes at the disposal site. All modifications to the site monitoring program should be coordinated with the DMMP.

The three benchmark stations are sited to evaluate potential changes in Commencement Bay sediment quality that may not be related to dredged material disposal. Station CBB01 is located north of Browns Point and acts as a monitor of changes in benthic characteristics due to natural variation. Station CBB02 is located just west of Browns Point and is a monitor of sources of contamination transported by currents. Currents generally flow clockwise from the head of the bay along the shoreline towards the disposal site (PSDDA 1988d). Station CBB03 is located in inner Commencement Bay (southeast of the disposal site) and represents a monitor of the Puyallup River and urban areas of Commencement Bay as potential sources of contamination (PSDDA 1988a).

[5] Transect stations T01, T03, and T05 were sampled during the 1995 full monitoring event (SAIC, 1995b). Due to the presence of offsite dredged material in 2001, the DMMP decided to sample the transect line where the offsite material was located (T13, T14, T15, and T16) (Striplin, 2001).

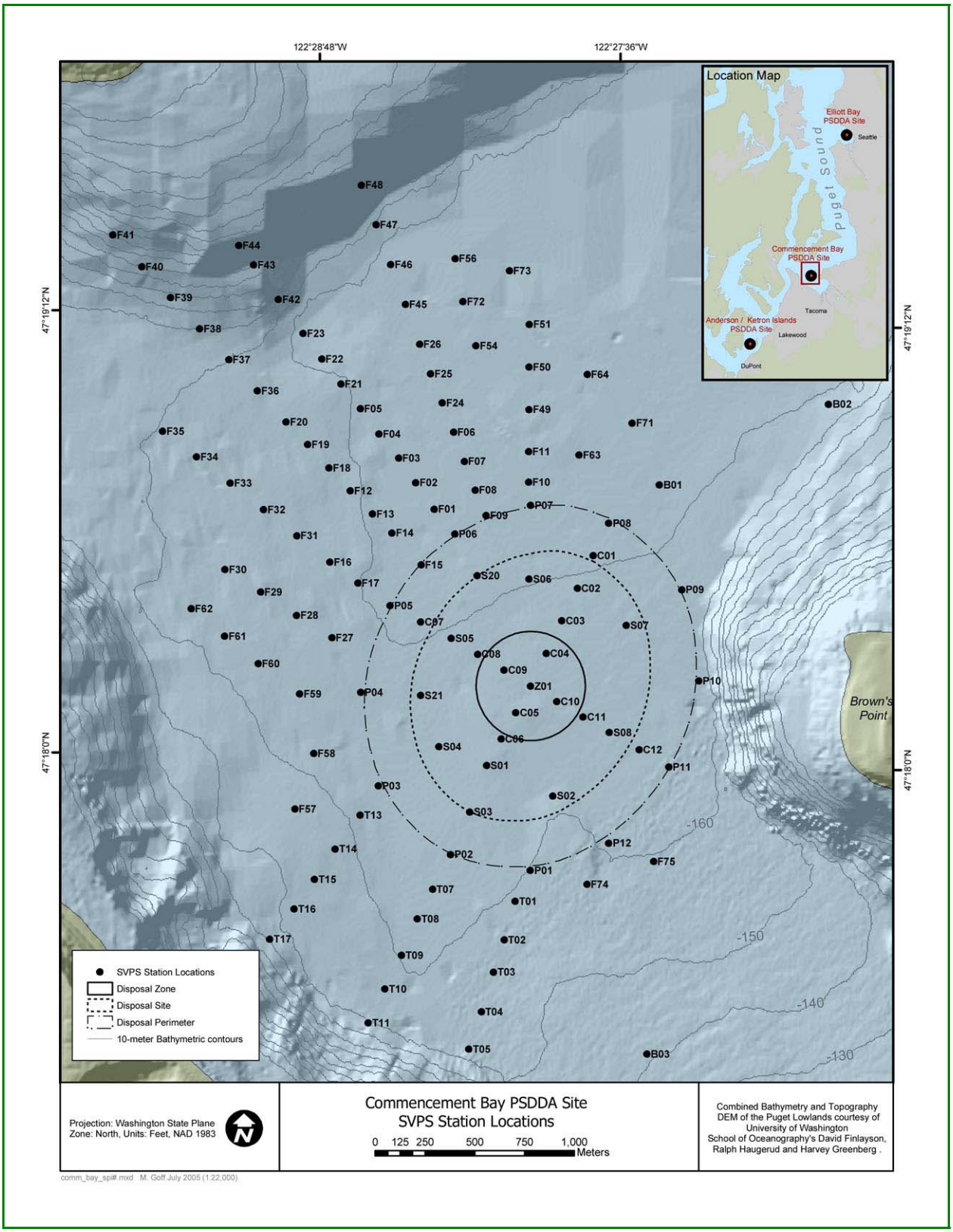


Figure 11. Commencement Bay target SVPS locations.

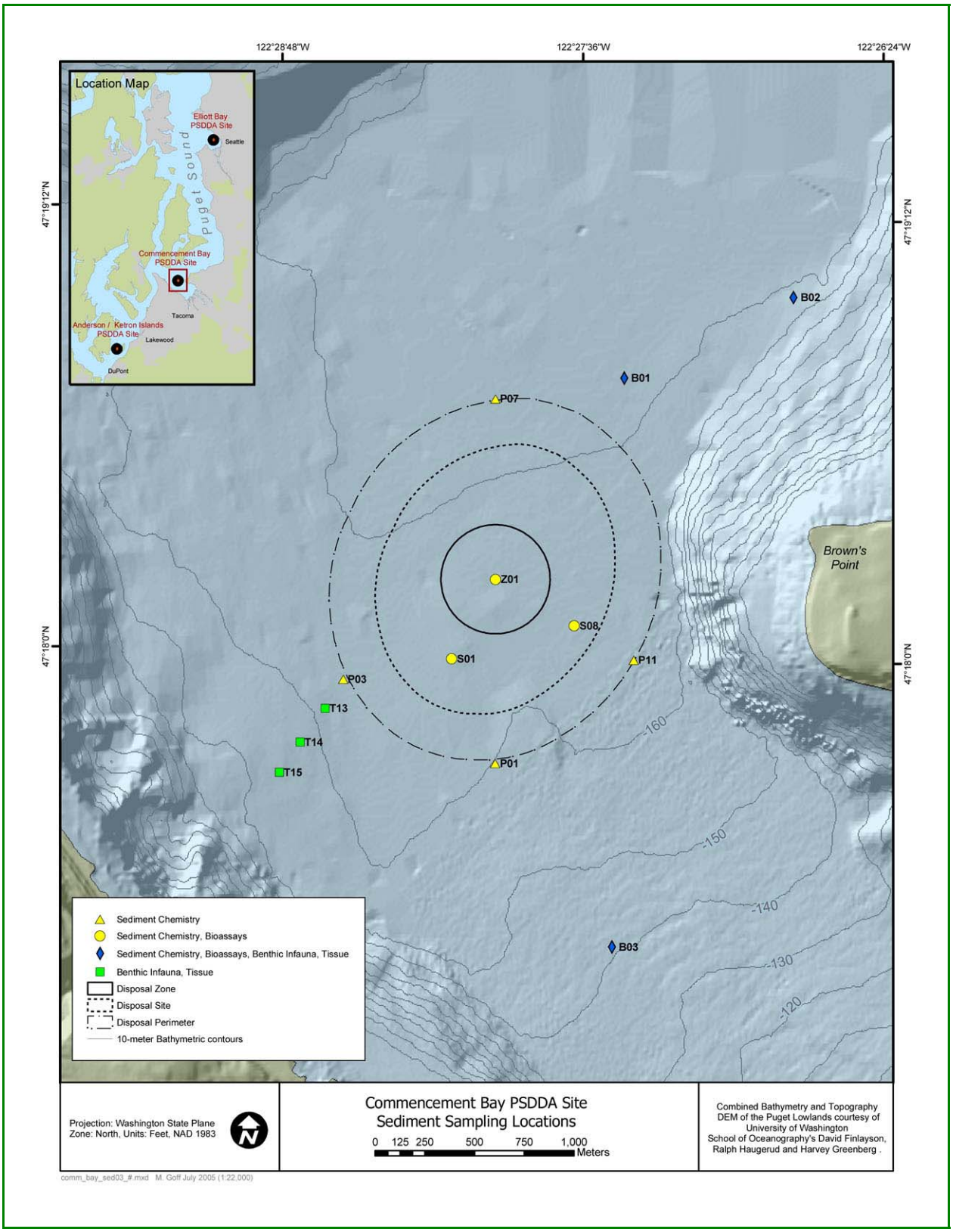


Figure 12. Commencement Bay target sediment sampling locations.

Table 14. Commencement Bay station target coordinates (NAD 1983).

Station	Type	Latitude N	Longitude W
CBZ01	Zone	47° 18.2076'	122° 27.9058'
CBS05	Site	47° 18.3327'	122° 28.2258'
CBS08	Site	47° 18.0860'	122° 27.5875'
CBS20	Site	47° 18.5040'	122° 28.1281'
CBS21	Site	47° 18.1759'	122° 28.3429'
CBP01	Perimeter	47° 17.7076'	122° 27.8908'
CBP02	Perimeter	47° 17.7460'	122° 28.2108'
CBP03	Perimeter	47° 17.9278'	122° 28.5043'
CBP04	Perimeter	47° 18.1810'	122° 28.5826'
CBP05	Perimeter	47° 18.4177'	122° 28.4725'
CBP06	Perimeter	47° 18.6160'	122° 28.2207'
CBP07	Perimeter	47° 18.6976'	122° 27.9208'
CBP08	Perimeter	47° 18.6543'	122° 27.6076'
CBP09	Perimeter	47° 18.4777'	122° 27.3108'
CBP10	Perimeter	47° 18.2310'	122° 27.2358'
CBP11	Perimeter	47° 17.9959'	122° 27.3475'
CBP12	Perimeter	47° 17.7859'	122° 27.5806'
CBT02	Transect	47° 17.5176'	122° 27.9891'
CBT03	Transect	47° 17.4294'	122° 28.0291'
CBT05	Transect	47° 17.2192'	122° 28.1208'
CBT08	Transect	47° 17.5693'	122° 28.3375'
CBT09	Transect	47° 17.4694'	122° 28.3975'
CBT11	Transect	47° 17.2843'	122° 28.5241'
CBT13	Transect	47° 17.8474'	122° 28.5742'
CBT14	Transect	47° 17.7543'	122° 28.6708'
CBT15	Transect	47° 17.6710'	122° 28.7508'
CBT16	Transect	47° 17.5893'	122° 28.8292'
CBB01	Benchmark	47° 18.7609'	122° 27.4092'
CBB02	Benchmark	47° 18.9893'	122° 26.7408'
CBB03	Benchmark	47° 17.2159'	122° 27.4108'
CBC03	Cross	47° 18.3864'	122° 27.7867'
CBC06	Cross	47° 18.0622'	122° 28.0182'
CBF01	Floating	47° 18.6820'	122° 28.3048'
CBF03	Floating	47° 18.8182'	122° 28.4512'
CBF05	Floating	47° 18.9505'	122° 28.6078'
CBF06	Floating	47° 18.8923'	122° 28.234'
CBF07	Floating	47° 18.8136'	122° 28.1886'
CBF10	Floating	47° 18.7608'	122° 27.9306'
CBF11	Floating	47° 18.8437'	122° 27.9331'
CBF13	Floating	47° 18.6655'	122° 28.5501'
CBF16	Floating	47° 18.5325'	122° 28.7160'
CBF18	Floating	47° 18.7879'	122° 28.7281'
CBF20	Floating	47° 18.9100'	122° 28.9029'
CBF21	Floating	47° 19.0159'	122° 28.6879'
CBF24	Floating	47° 18.9709'	122° 28.2819'

Station	Type	Latitude N	Longitude W
CBF26	Floating	47° 19.1290'	122° 28.3770'
CBF28	Floating	47° 18.3859'	122° 28.8448'
CBF30	Floating	47° 18.5059'	122° 29.134'
CBF32	Floating	47° 18.6711'	122° 28.9851'
CBF45	Floating	47° 19.2358'	122° 28.4371'
CBF47	Floating	47° 19.4500'	122° 28.561'
CBF49	Floating	47° 18.9580'	122° 27.9349'
CBF50	Floating	47° 19.0729'	122° 27.9388'
CBF51	Floating	47° 19.1890'	122° 27.9409'
CBF54	Floating	47° 19.1280'	122° 28.1526'
CBF56	Floating	47° 19.3632'	122° 28.2426'
CBF57	Floating	47° 17.8602'	122° 28.8348'
CBF58	Floating	47° 18.0120'	122° 28.7646'
CBF59	Floating	47° 18.1734'	122° 28.8258'
CBF60	Floating	47° 18.2526'	122° 28.9938'
CBF61	Floating	47° 18.3252'	122° 29.1294'
CBF63	Floating	47° 18.8370'	122° 27.7320'
CBF64	Floating	47° 19.0560'	122° 27.706'
CBF71	Floating	47° 18.9270'	122° 27.523'
CBF72	Floating	47° 19.2469'	122° 28.2079'
CBF73	Floating	47° 19.3330'	122° 28.0249'

Table 15. Station sampling and analytical requirements at the Commencement Bay site.

Parameter	Full Monitoring Stations	Tiered-Full Monitoring Stations	Partial Monitoring Stations
Onsite Chemistry	3	3	1
Onsite Bioassays	3	3	1
Perimeter Chemistry	4 (triplicates at each)	4 (triplicates at each)	4 (triplicates at each)
Benchmark Chemistry	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)
Benchmark Bioassays	3 (ARCHIVE)	3 (ARCHIVE)	3 (ARCHIVE)
Transect Benthos	3 (5 replicates each)	3 (5 replicates each; ARCHIVE)	0
Transect Tissue	3 (triplicates at each)	3 (triplicates at each; ARCHIVE)	0
Transect Chemistry[a]	3	3 (ARCHIVE)	0
Benchmark Benthos	3 (5 replicates each; ARCHIVE)	3 (5 replicates each; ARCHIVE)	0
Benchmark Tissue	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)	0
Reference Chemistry[b]	1	1	1
Reference Bioassays[c]	1	1	1
SVPS[d]	59 (triplicates at each)	59 (triplicates at each)	59 (triplicates at each)

a Transect chemistry consists of grain size and TOC only.
b Reference chemistry consists of conventional parameters only.
c Reference grain size should be similar to onsite sediments for bioassay testing. More than one reference may be necessary.
d Approximate number of SVPS stations in two days. Station locations can be modified or additional stations added to improve delineation of the dredged material footprint.

4.5 Anderson/Ketron Disposal Site

The Anderson/Ketron Islands disposal site is located in southern Puget Sound, situated between Anderson and Ketron Islands, and southwest of Steilacoom, WA (Figure 13). The disposal site is located in a relatively flat non-dispersive area with an average depth of approximately 420 feet (PSDDA, 1988d). Bottom current measurements during the disposal siting studies indicated moderate currents that tended to flow from north to south (PSDDA, 1989a).

Results of the baseline studies of the Anderson/Ketron Islands site are reported in PTI (1989a). The nesting clam (*Compsomyax subdiaphana*) is the target species for tissue chemistry analysis. Since the baseline surveys, only one full monitoring survey (SAIC, 2005) has been conducted at Anderson/Ketron disposal site. Due to the length of time since the baseline studies, the results from the 2005 full monitoring event were adopted as the new baseline for interpretive criteria (SAIC, 2005). The original 1989 baseline data will still be used for examining long-term trends at the site. Site maps showing the SVPS sampling grid and sediment chemical and biological stations are provided in Figures 13 and 14, respectively. Geographic coordinates for the stations are provided in Table 16.

A summary of station sampling and analytical requirements at Anderson/Ketron is provided in Table 17. A full or tiered-full monitoring program includes sampling at three onsite stations (AKZ01, AKS03, AKS10), four perimeter stations (AKP01, AKP02, AKP03, AKP04), three transect stations (AKT01, AKT02, AKT03; along the down-current gradient), and three benchmark stations (AKB07, AKB02, AKB03) (Figure 14). During a partial monitoring program, the onsite sampling is reduced to one station (AKZ01) and the transect stations are not sampled (Table 17). Changes in the selected sampling stations can occur (e.g., transect stations) based on the dredged material footprint measured during the SVPS survey (i.e, changes in offsite migration/deposition of dredged material) or other observed changes at the disposal site. All modifications to the site monitoring program should be coordinated with the DMMP.

Three benchmark stations are established to the north, south, and east of the site to represent natural conditions in the area (Figure 14). During the 2005 full monitoring survey at Anderson/Ketron, the original northern benchmark station (AKB01) was replaced due to presence of coarse sandy sediments. Station AKB07 was established to the east of AKB01 in consultation with the DMMP agencies (SAIC, 2005).

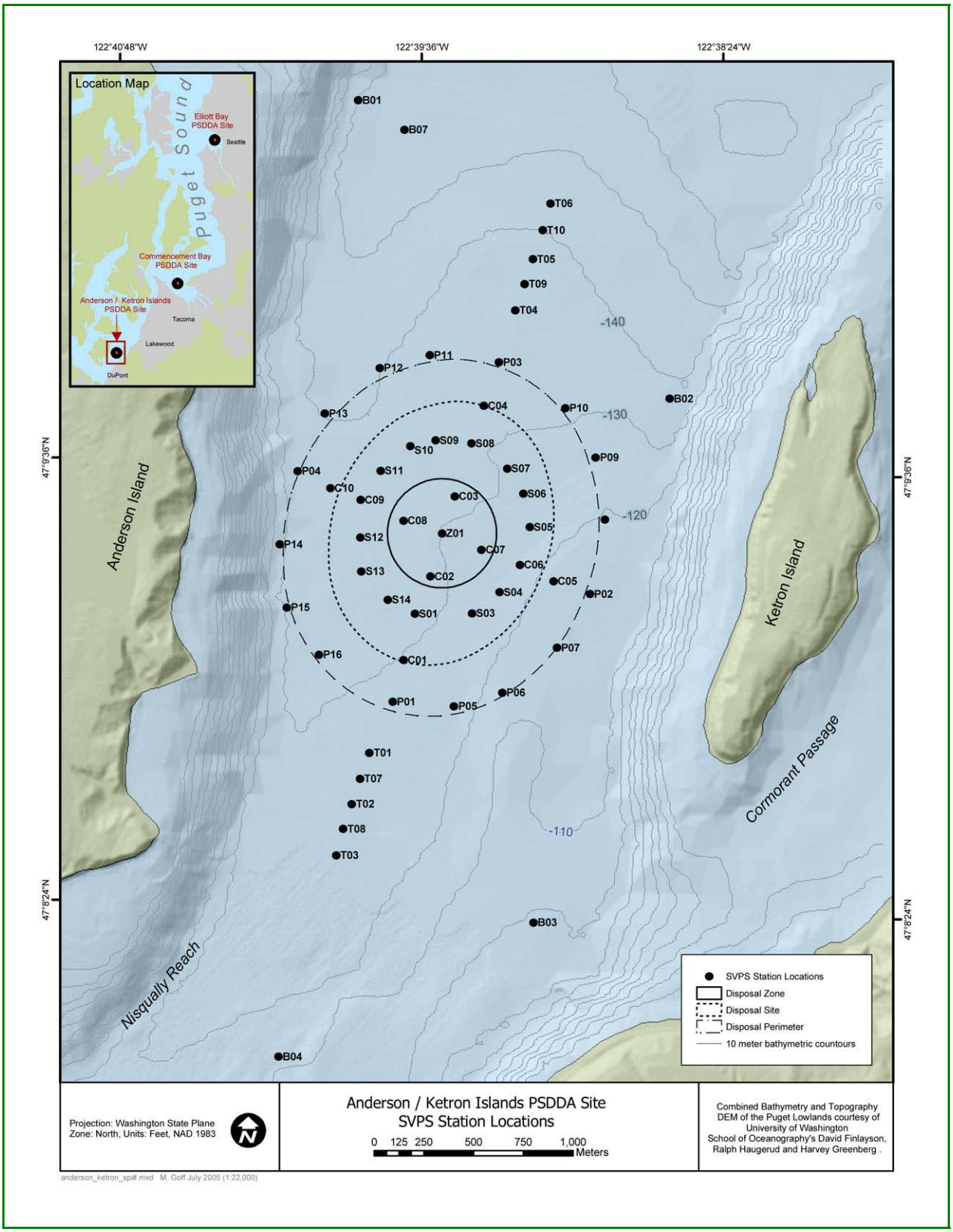


Figure 13. Anderson/Ketron target SVPS locations.

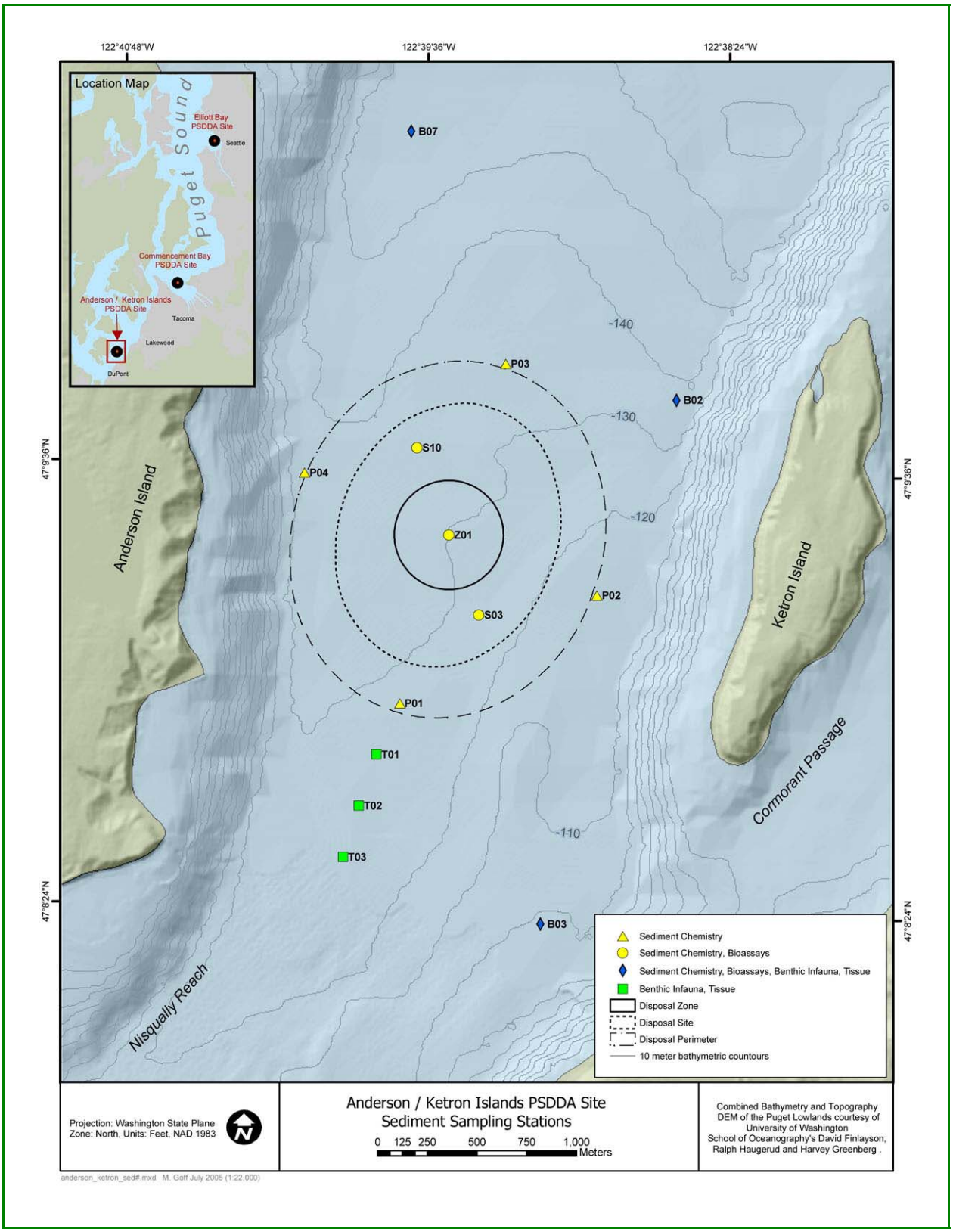


Figure 14. Anderson/Ketron target sediment sampling locations.

Table 16. Anderson/Ketron station target coordinates (NAD 1983).

Station	Type	Latitude N	Longitude W
AKZ01	Zone	47° 9.4191'	122° 39.4744'
AKS01	Site	47° 9.1991'	122° 39.5744'
AKS03	Site	47° 9.2041'	122° 39.3474'
AKS04	Site	47° 9.2631'	122° 39.2404'
AKS05	Site	47° 9.4421'	122° 39.1264'
AKS06	Site	47° 9.5321'	122° 39.1544'
AKS07	Site	47° 9.5991'	122° 39.2214'
AKS08	Site	47° 9.6651'	122° 39.3654'
AKS09	Site	47° 9.6711'	122° 39.5084'
AKS10	Site	47° 9.6541'	122° 39.6084'
AKS11	Site	47° 9.5851'	122° 39.7244'
AKS12	Site	47° 9.4031'	122° 39.7994'
AKS13	Site	47° 9.3111'	122° 39.7914'
AKS14	Site	47° 9.2358'	122° 39.6840'
AKP01	Perimeter	47° 8.9591'	122° 39.6540'
AKP02	Perimeter	47° 9.2641'	122° 38.8800'
AKP03	Perimeter	47° 9.8871'	122° 39.2644'
AKP04	Perimeter	47° 9.5791'	122° 40.0544'
AKP05	Perimeter	47° 8.9511'	122° 39.4104'
AKP06	Perimeter	47° 8.9911'	122° 39.2194'
AKP07	Perimeter	47° 9.1161'	122° 39.0064'
AKP08	Perimeter	47° 9.4671'	122° 38.8283'
AKP09	Perimeter	47° 9.6351'	122° 38.8704'
AKP10	Perimeter	47° 9.7671'	122° 38.9964'
AKP11	Perimeter	47° 9.9021'	122° 39.5404'
AKP12	Perimeter	47° 9.8641'	122° 39.7374'
AKP13	Perimeter	47° 9.7371'	122° 39.9514'
AKP14	Perimeter	47° 9.3791'	122° 40.1184'
AKP15	Perimeter	47° 9.2081'	122° 40.0844'
AKP16	Perimeter	47° 9.0821'	122° 39.9524'
AKT01	Transect	47° 8.8191'	122° 39.7424'
AKT02	Transect	47° 8.6791'	122° 39.8074'
AKT03	Transect	47° 8.5391'	122° 39.8644'
AKT04	Transect	47° 10.0292'	122° 39.2044'
AKT05	Transect	47° 10.1691'	122° 39.1394'
AKT06	Transect	47° 10.3211'	122° 39.0744'
AKT07	Transect	47° 8.7481'	122° 39.7774'
AKT08	Transect	47° 8.6111'	122° 39.8394'
AKT09	Transect	47° 10.1011'	122° 39.1694'
AKT10	Transect	47° 10.2481'	122° 39.1024'
AKB01	Benchmark	47° 10.5891'	122° 39.8494'
AKB02	Benchmark	47° 9.7991'	122° 38.5823'
AKB03	Benchmark	47° 8.3691'	122° 39.0744'
AKB04	Benchmark	47° 7.9891'	122° 40.0744'

Table 17. Station sampling and analytical requirements at the Anderson/Ketron site.

Parameter	Full Monitoring Stations	Tiered-Full Monitoring Stations	Partial Monitoring Stations
Onsite Chemistry	3	3	1
Onsite Bioassays	3	3	1
Perimeter Chemistry	4 (triplicates at each)	4 (triplicates at each)	4 (triplicates at each)
Benchmark Chemistry	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)
Benchmark Bioassays	3 (ARCHIVE)	3 (ARCHIVE)	3 (ARCHIVE)
Transect Benthos	3 (5 replicates each)	3 (5 replicates each; ARCHIVE)	0
Transect Tissue[a]	3 (triplicates at each)	3 (triplicates at each; ARCHIVE)	0
Transect Chemistry[b]	3	3 (ARCHIVE)	0
Benchmark Benthos	3 (5 replicates each; ARCHIVE)	3 (5 replicates each; ARCHIVE)	0
Benchmark Tissue[a]	3 (triplicates at each; ARCHIVE)	3 (triplicates at each; ARCHIVE)	0
Reference Chemistry[c]	1	1	1
Reference Bioassays[d]	1	1	1
SVPS[e]	50 (triplicates at each)	50 (triplicates at each)	50 (triplicates at each)

a Triplicate tissue samples are proposed at all stations; however, only one transect and one transect station had adequate clam abundance for collecting triplicate samples during the 2005 survey (SAIC, 2005).

b Transect chemistry consists of grain size and TOC only.

c Reference chemistry consists of conventional parameters only.

d Reference grain size should be similar to onsite sediments for bioassay testing. More than one reference may be necessary.

e Approximate number of SVPS stations in two days. Station locations can be modified or additional stations added to improve delineation of the dredged material footprint.

5.0 DATA INTERPRETATION AND DECISIONS ON SITE MANAGEMENT

The interpretation of environmental data collected during disposal site monitoring follows the PSDDA monitoring framework as discussed in Section 2.0 and summarized in Table 2. Action items are indicated where interpretive guidelines are exceeded. Information regarding statistical methods and power analysis used to develop the interpretive guideline values can be found in PSDDA (1988a).

The evaluation framework is designed to address three primary questions related to potential impacts from dredged material disposal:

1. Does the deposited dredged material stay on site?
2. Is the biological effects condition for site management [i.e., PSDDA-defined site condition II (PSDDA 1988b)] exceeded at the site because of dredged material disposal?
3. Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?

Six hypotheses were developed to address the three questions (Table 2). Conditions at a disposal site are considered acceptable if the statements framed in the null hypotheses 1 through 6 are correct (PSDDA, 1988a). The interpretive guidelines and action items are generally considered straightforward, with the exception of temporal analysis of site perimeter chemistry (Hypothesis 2), and the interpretation of benchmark data when the null hypotheses are considered rejected. This section provides additional details on these procedures and describes their role in disposal site management decisions.

5.1 Temporal Analysis

Under hypothesis 2 of the PSDDA monitoring framework, perimeter station chemistry at a disposal site is compared to the Washington State Sediment Quality Standards (SQS) (Ecology, 1995) to assess whether chemical concentrations in sediments are measurably increasing over time off site due to dredged material disposal (Table 2). In addition, statistical temporal analysis of perimeter chemistry is conducted using the Chemical Tracking System (CTS)[6] as described in detail in SAIC and MWLS (1996). Temporal analysis provides an early warning of whether a particular chemical, guild of chemicals (e.g., metals, HPAHs), or all (global) chemicals show an increasing trend that is statistically significant, before the SQS criteria are exceeded.

The CTS model evaluates the changes in site chemistry for each chemical or groups of chemicals as a slope, expressing the trend in concentration over time. The slopes are then evaluated to determine statistically significant increases. Although the CTS methodology is rather complex, the underlying principle of CTS is the *t*-test, which is a standard test used for comparing a mean to a specific value (SAIC and MWLS, 1996). In this approach, each chemical contributes one

[6] The guideline value approach (PTI, 1988a) for perimeter chemistry (1.25X for metals and 1.47X for organics) was found to be statistically flawed (Lester, 1995) and was replaced with comparisons to the Washington State SQS and temporal analysis using CTS.

observation to the test, the trend in chemical concentration over time. The mean trend in chemical concentration over time is compared to zero, the no change null value.

CTS is implemented using an Excel® spreadsheet. CTS accepts chemistry results in standard PSDDA monitoring report format and uses the Excel® Solver and the Maximum Likelihood method to obtain the estimated slope, statistical significance, intercept, and variance for each chemical (SAIC and MWLS, 1996). The slope as a percent change per year for each chemical and groups of chemicals is also determined. Detailed instructions for implementing CTS can be obtained from the DMMP.

5.2 Benchmark Data Interpretation

Benchmark stations are located in the vicinity of the disposal site (i.e., within the same embayment), to document the natural changes in benthic conditions in the general area. They are located in areas that are not expected to be affected by disposal operations but have similar physical and geo-chemical conditions as the disposal site.[7] Temporal changes in benchmark station conditions are expected to reflect area-wide changes in benthic conditions, rather than changes due to dredged material disposal.

When a null hypothesis is considered rejected under the PSDDA monitoring framework (i.e., an interpretive criteria is exceeded), then archived benchmark station samples are analyzed and compared to appropriate baseline benchmark levels (see Table 2). Benchmark samples are collected for sediment chemistry, bioassays, tissue chemistry, and benthic infauna. The results of a benchmark comparison will lead to one of the following scenarios:

1. If the arithmetic means of the benchmark monitoring and baseline data are not significantly different, then changes observed at offsite areas potentially reflect an impact from dredged material disposal.
2. If the arithmetic means of the benchmark monitoring and baseline data are significantly different, but that difference is less than 50 percent of the difference between the offsite station monitoring and baseline data, then the changes in offsite areas potentially reflect regional changes that are unrelated to dredged material disposal.
3. If the arithmetic means of the benchmark monitoring and baseline data are significantly different, and that difference is greater than 50 percent of the difference of the offsite station monitoring and baseline data, then the changes in offsite areas likely reflect regional changes in conditions that are unrelated to dredged material disposal.

After assessing the benchmark data, if offsite changes are concluded to be due to regional changes (Scenario 3), then no further action is required. Alternatively, if analysis of benchmark data indicates that changes at offsite stations are potentially due to dredged material disposal (Scenarios 1 and 2), then further evaluation and/or review of dredged material disposal site management practices may be warranted. A variety of actions may be considered by the DMMP:

[7] At some PSDDA sites (e.g., Elliott Bay), benchmark stations are also situated between the disposal site and known sources of contamination that could influence conditions near the disposal site (i.e., Seattle waterfront).

- Analysis of remaining archived samples for other monitoring parameters to determine the extent of changes.
- Additional field investigations to verify significant offsite movement of dredged material and determine the extent and magnitude of associated effects.
- Program adjustments, such as modification of site use conditions or amendment of disposal guidelines to bring the site into compliance with the Clean Water Act requirements of not allowing unacceptable adverse impacts.
- Major program responses such as site relocation or mitigation at the existing site.

Any action by the DMMP will be based on careful evaluation of the monitoring results and an interpretation of these findings relative to potential ecological significance (PSDDA, 1988a).

6.0 REFERENCES

Benson, T. 1996. Adjustment to site monitoring. DMMP issue paper. Prepared by Ted Benson, Washington State Department of Natural Resources for the PSDDA agencies. Prepared for the 1996 Sediment Management Annual Review Meeting.

Brenner, R. 2002. Increasing the volume trigger for environmental monitoring of non-dispersive open water disposal sites. DMMP issue paper. Prepared by Robert Brenner, Washington State Department of Natural Resources for the DMMP agencies. Final paper 6/15/2002. Prepared for the 2002 Sediment Management Annual Review Meeting.

DMMP. 2000. Dredged material evaluation and disposal procedures. A users manual for the Puget Sound Dredged Disposal Analysis (PSDDA) program. February 2000 (updated with 2003 COC table). Prepared by the U.S. Army Corps of Engineers, Seattle District, U.S. Environmental Protection Agency, Region 10, Washington State Department of Natural Resources, and Washington State Department of Ecology.

Ecology. 1995. Sediment Management Standards (SMS), Chapter 173-204 WAC, Publication No. 96-252. Washington State Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/pubs/wac173204.pdf

Gries, T.H. 2005. New DMMP guidelines for phthalates. DMMP clarification paper. Prepared by Thomas H. Gries, Washington State Department of Ecology, Toxics Cleanup Program/Sediment Management Unit, for the DMMP agencies. Prepared for the 2005 Sediment Management Annual Review Meeting.

Hoffman, E. 1998. Technical support document: Revision of the Dredged Material Management Program bioaccumulative chemicals of concern list. Prepared for the Dredged Material Management Program. September 1998. 43 pp.

Hoffman, E. 2003. Revisions to the bioaccumulative contaminants of concern (BCOC) list. DMMP issue paper. Prepared by Erika Hoffman, U.S. Environmental Protection Agency, Region X, for the DMMP agencies. Draft April 24, 2003.

Kendall, D.R. 2005. Sediment larval test species recommended for toxicity testing by the DMMP program. DMMP clarification paper. Prepared by David R. Kendall, U.S. Army Corps of Engineers, Seattle District, for the DMMP agencies. Prepared for the 2005 Sediment Management Annual Review Meeting.

Kendall, D.R., and R. McMillan. 1999. Clarification on the use of the amphipod, *Eohaustorius estuarius*, relative to grain size and salinity. DMMP clarification paper. Prepared by David R. Kendall, U.S. Army Corps of Engineers, Seattle District, and Russ McMillan, Washington State Department of Ecology, for the DMMP agencies. Prepared for the 1999 Sediment Management Annual Review Meeting.

Leon, P. and D.R. Kendall. 2004. DMMP disposal site coordinates update and clarification. DMMP clarification paper. Prepared by Peter Leon, Washington State Department of Natural Resources, and David R. Kendall, U.S. Army Corps of Engineers, Seattle District. Prepared for the 2004 Sediment Management Annual Review Meeting.

Lester, D. 1995. Refinement to PSDDA post disposal monitoring guidelines. PSDDA Issue Paper for the 1995 Sediment Management Annual Review Meeting. Prepared by Debbie Lester, Washington State Department of Natural Resources, Olympia, WA, for the PSDDA agencies.

Michelsen, T., T.C. Shaw, and S. Stirling. 1996. Testing, Reporting, and Evaluation of Tributyltin Data in PSDDA and SMS Programs. Prepared for the 1996 Sediment Management Annual Review Meeting.

Plumb, R.H. Jr. 1981. Procedures for handling and chemical analysis of sediment and water samples. Technical report EPA/CE-81-1. U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

PSDDA. 1988a. Management plans technical appendix – Phase I (Central Puget Sound). Puget Sound Dredged Disposal Analysis reports series. Cooperatively published by (in alphabetical order) U.S. Army Corps of Engineers, Seattle District; U.S. Environmental Protection Agency, Region 10; Washington State Department of Ecology; and Washington State Department of Natural Resources.

PSDDA. 1988b. Final environmental impact statement – unconfined open-water disposal sites for dredged material, Phase I (Central Puget Sound). Puget Sound Dredged Disposal Analysis Reports Series. Cooperatively published by (in alphabetical order) U.S. Army Corps of Engineers, Seattle District; U.S. Environmental Protection Agency, Region 10; Washington State Department of Ecology; and Washington State Department of Natural Resources.

PSDDA. 1988c. Evaluation procedures technical appendix – Phase I (Central Puget Sound). Puget Sound Dredged Disposal Analysis reports series. Cooperatively published by (in alphabetical order) U.S. Army Corps of Engineers, Seattle District; U.S. Environmental Protection Agency, Region 10; Washington State Department of Ecology; and Washington State Department of Natural Resources.

PSDDA. 1988d. Disposal site selection technical appendix – Phase I (Central Puget Sound). Puget Sound Dredged Disposal Analysis reports series. Cooperatively published by (in alphabetical order) U.S. Army Corps of Engineers, Seattle District; U.S. Environmental Protection Agency, Region 10; Washington State Department of Ecology; and Washington State Department of Natural Resources.

PSDDA. 1989a. Management Plan Report – Unconfined Open Water Disposal of Dredged Material, Phase II (North and South Puget Sound). Puget Sound Dredged Disposal Analysis Reports Series. Cooperatively published by (in alphabetical order) U.S. Army Corps of Engineers, Seattle District; U.S. Environmental Protection Agency, Region 10; Washington State Department of Ecology; and Washington State Department of Natural Resources. September 1989.

PSDDA. 1989b. Final Environmental Impact Statement – Unconfined Open-water Disposal for Dredged Material, Phase II (North and South Puget Sound). Puget Sound Dredged Disposal Analysis Reports Series. Cooperatively published by (in alphabetical order) U.S. Army Corps of Engineers, Seattle District; U.S. Environmental Protection Agency, Region 10; Washington State Department of Ecology; and Washington State Department of Natural Resources. September 1989.

PSEP. 1986. Puget Sound Estuary Program. Recommended protocols for measuring selected environmental variables in Puget Sound. Final Report. Prepared for the U.S. Environmental Protection Agency Region 10, Office of Puget Sound, and the U.S. Army Corps of Engineers. Tetra Tech, Bellevue, Washington.

PSEP. 1987. Puget Sound Estuary Program. Recommended protocols for sampling and analyzing subtidal benthic macroinvertebrate assemblages in Puget Sound. Prepared for the U.S. Environmental Protection Agency Region 10, Office of Puget Sound, and the U.S. Army Corps of Engineers. Tetra Tech, Inc., Bellevue, Washington.

PSEP. 1995. Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Interim Final Report. Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Seattle, WA.

PSEP. 1997a. Puget Sound Estuary Program. Recommended protocols for measuring metals in Puget Sound marine water, sediment and tissue samples. Prepared for the U.S. Environmental Protection Agency Region 10, Office of Puget Sound, and the U.S. Army Corps of Engineers. PTI Environmental Services, Inc., Bellevue, Washington.

PSEP. 1997b. Puget Sound Estuary Program. Recommended guidelines for measuring organic compounds in Puget Sound water, sediment and tissue samples. Prepared for the U.S. Environmental Protection Agency Region 10, Office of Puget Sound, and the U.S. Army Corps of Engineers. PTI Environmental Services, Inc., Bellevue, Washington.

PSEP. 1997c. Puget Sound Estuary Program. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Prepared for the U.S. Environmental Protection Agency, Region 10.

PTI. 1988. Puget Sound Dredged Disposal Analysis – baseline survey of the Phase I disposal sites. Phase I area – Central Puget Sound. Prepared for the Washington State Department of Ecology, Olympia, WA. Prepared by PTI Environmental Services, Bellevue, WA.

PTI. 1989a. Puget Sound Dredged Disposal Analysis – baseline survey of Phase II disposal sites. Prepared for the Washington State Department of Ecology, Olympia, WA. Prepared by PTI Environmental Services, Bellevue, WA. June 1989.

PTI. 1989b. Baseline survey of phase I disposal sites – analysis of archived samples. Prepared for the Washington State Department of Ecology, Olympia, WA. Prepared by PTI Environmental Services, Bellevue, WA.

Revelas, G. 1992. PSDDA Monitoring Plan and DY1992 Elliott Bay Full Monitoring, Washington State Department of Natural Resources, for the PSDDA agencies. Prepared for the 1992 Sediment Management Annual Review Meeting.

Rhoads, D.C., and J.D. Germano. 1982. Characterization of benthic processes using sediment imaging: An efficient method of Remote Ecological Monitoring of the Seafloor (REMOTS system). Mar. Ecol. Prog. Ser., v.8, pp. 115-128.

Rhoads, D.C, and J.D. Germano. 1986. Interpreting long-term changes in benthic community structure: a new protocol. Hydrobiologia 142, pp. 291-308.

SAIC. 1991a. PSDDA 1991 monitoring program. Port Gardner benchmark, station observations, tissue chemistry of invertebrates from Port Gardner and Bellingham Bay, and bioaccumulation guidelines assessment. Final Report. November 4, 1991. Submitted to Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA.

SAIC. 1991b. PSDDA 1990 monitoring. Post-disposal surveys of Elliott Bay and Port Gardner. Final report. August 1991. Submitted to Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA.

SAIC. 1992. 1992 full monitoring in Elliott Bay. Draft report. September 30, 1992. Submitted to Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA.

SAIC. 1993. Partial monitoring in Bellingham Bay. Draft Report. July 19, 1993. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA.

SAIC. 1995a. 1994 tiered-full monitoring at the Port Gardner PSDDA disposal site. Final Report. March 29, 1995. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA.

SAIC. 1995b. 1995 full monitoring at the Commencement Bay PSDDA disposal site. Prepared for the Washington State Department of Natural Resources, Olympia, WA. Prepared by Science Applications International Corporation, Bothell, WA.

SAIC. 1996. 1996 partial monitoring at the Commencement Bay PSDDA disposal site. Prepared for the Washington State Department of Natural Resources, Olympia, WA. Prepared by Science Applications International Corporation, Bothell, WA.

SAIC. 2000. 2000 full monitoring at the Elliott Bay PSDDA disposal site. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA, and Battelle Marine Sciences Laboratory, Sequim, WA.

SAIC. 2003. 2003 tiered-full monitoring at Commencement Bay, Tacoma, WA. Draft data report. November, 2003. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA.

SAIC. 2004. 2004 partial monitoring at Commencement Bay, Tacoma, WA. Draft Report. October 22, 2004. Prepared for the Washington State Department of Natural Resources, Olympia, WA. Prepared by Science Applications International Corporation, Bothell, WA.

SAIC. 2005. 2005 full monitoring at the Anderson/Ketron Islands PSDDA disposal site. Draft Report. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Science Applications International Corporation, Bothell, WA.

SAIC and MWLS. 1996. A new statistical protocol for evaluating PSDDA perimeter site chemistry. Draft Report. Prepared for the Washington State Department of Natural Resources, Olympia, WA. Prepared by Science Applications International Corporation, Bothell, WA, and Mountain Whisper Light Statistical Consulting, Seattle, WA.

SMARM. 2003. Revised screening level, bioaccumulation trigger, and maximum level table. Released for public distribution during the 2003 Sediment Management Annual Review Meeting. http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/revisedSL_MLtable.pdf

Striplin, B. 1991. Management of the Port Gardner and Elliott Bay sites. Clarification paper. Prepared by Betsy Striplin, Washington State Department of Natural Resources for the PSDDA agencies. Prepared for the 1991 Sediment Management Annual Review Meeting.

Striplin Environmental Associates. 1999. Physical monitoring of the Commencement Bay PSDDA dredged material disposal site. Prepared for the Seattle District U.S. Army Corps of Engineers, Seattle, WA. Prepared by Striplin Environmental Associates, Inc., Olympia, WA.

Striplin Environmental Associates. 2001. 2001 full monitoring in Commencement Bay, Tacoma, WA. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Striplin Environmental Associates, Inc., Olympia, WA.

Striplin Environmental Associates. 2002. 2002 tiered-full monitoring at Elliott Bay, Seattle, WA. Final data report. October 30, 2002. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Striplin Environmental Associates, Inc., Olympia, WA.

Striplin Environmental Associates. 2003. 2002 Elliott Bay monitoring. Bioaccumulative contaminants of concern. Final. July 18, 2003. Submitted to the Washington State Department of Natural Resources, Olympia, WA. Submitted by Striplin Environmental Associates, Inc., Olympia, WA.

U.S. EPA. 1986 and updates. SW-846 Manual. Test methods for evaluating solid waste, physical/chemical methods. U.S. Environmental Protection Agency. http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm