

Revision of the Puget Sound Ambient Monitoring Program (PSAMP) Sediment Component Sampling Design



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Abstract

The Washington State Department of Ecology's Marine Sediment Monitoring Team (MSMT) is currently revising the Puget Sound Ambient Monitoring Program (PSAMP) Sediment Component. With assistance from EPA and regional stakeholders, the current probabilistic sampling design has been refined using a spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design, and a refined list of sampling parameters is being generated. A nested set of sampling frames, including the whole sound, eight Puget Sound sediment sampling regions, and 5 strata within each of the 8 regions has been defined and will be sampled on a rotational cycle, alternating 7 years of regional sampling with 3 years of focus embayment sampling. Results will include annual spatial extent characterization of sediment quality (based on the sediment triad of toxicity, chemistry, and benthic infauna), along with temporal comparison of annual data and analyses to sediment baseline data. Details of this refined study design are described in this poster presentation, and comment on the design is solicited.

Introduction/Background

The Puget Sound Ambient Monitoring Program (PSAMP) is a long-term multidisciplinary program mandated by the Washington State legislature to monitor the health and quality of Puget Sound's marine resources. The original design of the PSAMP Sediment Component, implemented in 1989, included annual sampling and analysis of sediment triad data (i.e., contaminants, toxicity, and the composition of the infaunal invertebrate assemblages) for a suite of 76 subjectively chosen sampling locations throughout Puget Sound. Sediment characteristics from each station were quantified and described (Lansó et al., 1998a,b), but due to the non-random nature of the sampling design, station attributes could not be used to describe broader regions. In a joint 3-year partnership with the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (NSTT) Bioeffects Monitoring Program, the PSAMP Sediment Component sampling design was modified and a probabilistic random stratified sampling design was adopted for sediment sampling throughout Puget Sound from 1997-1999. A baseline of data was generated quantifying the spatial extent (i.e., km²) of sediment contamination and toxicity, and a Sediment Quality Triad "weight-of-evidence" index, incorporating results of the toxicity testing, chemical analyses, and characterization of the benthos, was developed as an environmental indicator characterizing sediment quality throughout Puget Sound (Long et al., 1999, 2000, 2002, and in preparation). This probabilistic design is currently being refined to one which is spatially balanced, with sample results correctly proportionally weighted to the amount of the study area they represent. In addition, with advice and input from the PSAMP Steering Committee, the Puget Sound study area has been broadened, and new sediment sampling regions (i.e., reporting units) have been defined and aligned with those of the other PSAMP components. Input has also been obtained from Sediment Component clientele regarding revision of toxicological testing and measurement of chemical contaminants, providing better alignment with State of Washington regulatory mandates.

PUGET SOUND AMBIENT MONITORING PROGRAM GOALS

The following goals were set by the PSAMP Steering and Management Committees in 1997 for all components of the PSAMP, and are the underpinnings of the revised Sediment Component design:

- 1) Assess the health of Puget Sound and its resources (and document geographic patterns in the condition of the Sound and its resources)
- 2) Document natural and human-caused changes over time in the ecological components of Puget Sound
- 3) Through ongoing monitoring programs identify existing environmental problems [and, where possible, identify the reasons for these problems]
- 4) Provide data and other information to assist the Puget Sound Action Team and others in measuring the success of environmental programs
- 5) Support research activities by making available scientifically valid data

PSAMP Sediment Component Objectives/Subobjectives

The following objectives and subobjectives were developed from the broader PSAMP goals for the revised PSAMP Sediment Component by the Marine Sediment Monitoring Team (2002):

- 1) Assess the health of Puget Sound sediments and document geographic patterns in the condition of the sediments by:
 - Determining spatial patterns in physical sediment parameters,
 - Determining spatial patterns in sediment toxicity,
 - Determining spatial patterns in chemical contamination, and
 - Determining spatial patterns in infaunal assemblage structure.
- 2) Determine relationships between the above sediment parameters to determine potential effects of both natural stressors and contaminated sediments on biota.
 - Document natural and human-caused changes over time in Puget Sound sediments by:
 - Determining temporal patterns in physical sediment parameters,
 - Determining temporal patterns in sediment toxicity,
 - Determining temporal patterns in chemical contamination, and
 - Determining temporal patterns in infaunal assemblage structure.
- 3) Identify existing sediment problems and, where possible, provide data for in-depth point/non-point source investigations
 - Identification of existing sediment problems will be addressed in objectives/subobjectives 1-2.
 - Coordinate with and provide data to Ecology's Toxic Cleanup Program, Sediment Management Unit, and Contaminant Studies Unit, and other appropriate regional sediment programs and stakeholders.
- 4) Provide sediment data to assist the Puget Sound Action Team and others in measuring the success of environmental programs by:
 - Identifying and quantifying appropriate sediment indicators and their endpoint (criteria) values that can be examined over space and time to determine the condition of the environment (i.e., its spatial extent of impacted sediments increasing or decreasing over time?).
- 5) Support sediment-related research activities by making available scientifically valid sediment data:
 - Build and maintain adequate network with sediment "clients" throughout the Puget Sound region to understand and target the needs of sediment-related research activities conducted in Puget Sound.
 - Produce sediment data that has undergone appropriate QA/QC procedures ensuring high quality and scientific validity, and
 - Make this high quality sediment data available via Sediment Monitoring Team website, SEDQUAL database, and EIM database.

PSAMP Sediment Component Indicators

The following sediment indicators have been targeted for analysis in the revised PSAMP Sediment Component, and will be measured at every station:

Toxicity Testing (1-4 tests, funding dependent)

- Amphipod 10 day test – mortality (solid phase)
 - *Eohaustorius estuarius*
- Bivalve or Echinoderm larvae development 48-hour test -abnormality, mortality (elutriate test):
 - *Crassostrea gigas*,
 - *Mytilus edulis*, or
 - *Dendraster excentricus*
- Urchin fertilization - % fertilization (pore water)
 - *Strongylocentrotus purpuratus*
- Microtox™ – decreased luminescence after exposure (pore water)

Physical characteristics

- Grain size, TOC
- Temperature
- Salinity
- DO
- Observations (e.g., odor, color, RPD, epibiont)

Chemical contaminants

- A "core" set of chemical contaminants will be evaluated at every station. The core contaminants will consist of those compounds for which regulatory criteria and sediment guidelines have been developed. Values will be compared with Washington State Sediment Management Standards (Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSL) - WA Ch. 173-204 RCW) and to sediment guidelines developed from NOAA's National Status and Trends national database (Effects Range Median (ERM) - Long et al., 1995). A "core" suite of compounds will include:

- Metals
- BNA semivolatile organics
- PAHs
- Chlorinated Pesticides
- PCB Aroclors and Congeners

- A "rotational" set of compounds will be chosen to characterize the impact of specific anthropogenic activity in the region to be studied that year. This list will change annually to reflect known or suspected contaminant issues in the different regions studied annually. A suite of "rotational" compounds will be chosen in part, based on the cost of analyses, and include the following suggested compounds:

- Butyl tins
- Dioxins/Furans
- Pharmaceuticals
- Estrogen mimics,
- Ecology's persistent, bioaccumulative toxic (PBT) or EPA's bioaccumulative chemicals of concern (BIOC) not on core list
- Ordinance compounds (RDX, perchlorates)
- PCDDs (polychlorinated dibenzo-p-dioxins)
- PCDFs (polychlorinated dibenzofurans)

Benthic Indices

- Total Abundance
- Major Taxa Abundance
- Taxa Richness
- Pielou's Evenness (J')
- Swartz's Dominance Index (SDI)
- Dominant taxa list

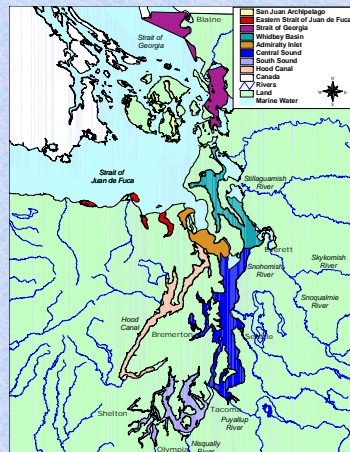


Figure 1. 8 sediment monitoring regions defined for the revised PSAMP Sediment Component.

Table 2. PSAMP Sediment Component sampling schedule for 2002-2012, with annual rotation through 8 regions and focus-embayment samplings.

Puget Sound Sediment Sampling Regions and Embayments	Year Sampled										
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
San Juan Archipelago											
Eastern Strait of Juan de Fuca, Admiralty Inlet	x										x
embayment sampling		x									
Strait of Georgia			x								
embayment sampling				x							
Whidbey Basin					x						
embayment sampling						x					
Central Sound (north)							x				
embayment sampling								x			
Strait of Georgia			x								
embayment sampling				x							
Central Sound (south)								x			
embayment sampling									x		
South Sound										x	
embayment sampling											x
Hood Canal											x
embayment sampling											

* St. of J. de Fu. and San Juan regional monitoring in 2002 completes the "whole sound" spatial sampling from 1997-1999 PSAMP/NOAA work.
 ** 3 years of focused embayment monitoring (2003-2005) will alternate with 7 years of regional monitoring (2006-2012), then repeat in 10-year cycles.

Sampling Design

Regional and embayment rotational sampling:

With guidance from the PSAMP Steering Committee, the Puget Sound sediment study area has been divided into 8 sediment monitoring regions (Figure 1) defined by hydrologic, bathymetric, and geological features of Puget Sound, as well as the distribution of biota (fish, birds, and marine mammals) throughout the Sound. In addition, 5 sediment monitoring strata (Figure 2), defined by major geographic features and degree of anthropogenic activity (Table 1), are defined within each region. Forty (40) sediment samples will be collected annually, alternating 7 years of regional sampling with 3 years of focus embayment sampling (Table 2). Data generated will then be summarized regionally to spatially characterize the sediments in each monitoring region, the strata within each region, and ultimately, Puget Sound as a whole. Newly collected regional data will be compared with historical data to determine changes between sampling periods. Annual data summaries will include spatial extent characterization of sediment quality in each of the 8 regions and focus embayments, along with temporal comparison of these calculations to the 1997-1999 sediment baseline data. Based on PSAMP Sediment Component priorities, a sample allocation or allocation schedule was developed to place a greater number of samples in rural and urban strata (greatest need for ambient monitoring characterization), less in basins and passage strata, and the least number of samples in the harbor strata (these areas are well characterized by regulatory program monitoring activity).

Probabilistic Survey Design:

With assistance from EPA's Environmental Monitoring and Assessment Program (EMAP) Design Team (EPA Office of Research and Development, Corvallis, OR), a probabilistic survey design was generated that selects sites using a generalized random tessellation stratified (GRTS) multi-density survey design, as described by Stevens (1997), Stevens and Olsen (1999), and Stevens and Olsen (2002). In general terms, a hexagon grid is randomly located over the study region and a random point is selected in each hexagon cell. The number of hexagon cells is sufficiently large to guarantee all sample size requirements are met. These random points are then assigned unequal weights before the final set of sites are selected. The GRTS design incorporates a hierarchical randomization process to ensure the sample is spatially-balanced across the PSAMP study region. It also allows sites to be selected with unequal probability to satisfy the sample size requirements by basin and category. The unequal probability, i.e., multi-density, selection is similar to defining explicit strata to meet all the sample size requirements. In the event that a site is determined to be unselectable for any reason, the design also includes an over sample of sites that are used in the order given to replace the unselectable sites. Station lat/longs selected with assistance of random-selection software have been generated for the next 20 years of sampling.

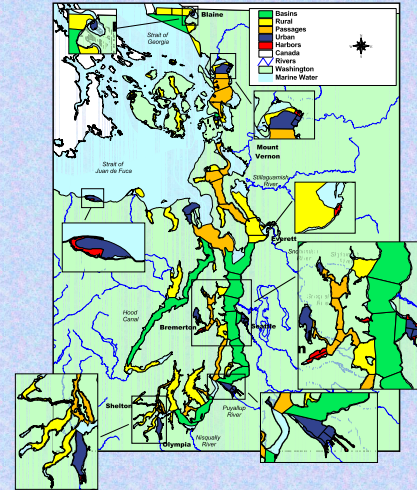


Figure 2. 5 sediment monitoring strata defined for the revised PSAMP Sediment Component.

Table 1. Strata definitions

Strata Type	Natural features	Anthropogenic features
Harbor	semi-enclosed embayments, terminal inlets - head of shallow	maritime activity, commercial vessel traffic, and/or ports, and/or shipyards bay/estuary adjacent to urban/industrial centers
Urban	semi-enclosed embayments, sometimes head of bay/estuary, includes outer shallow to mid-depth	high numbers of point and/or nonpoint sources of discharge frequently dredged presence of docks, breakwaters, jetties
Basin	deep associated with a sill	adjacent to urban/industrial centers lower numbers of point and/or nonpoint source discharge may or may not be adjacent to urban/industrial centers
Passage	bounded by two shorelines and open at both ends (i.e., doesn't end in an embayment) deep	lowest numbers of point and/or nonpoint source discharge (although some receive treated effluent from municipal point source outfalls)
Rural	not associated with a sill includes semi-enclosed embayments and terminal inlets, as well as larger inlets shallow to deep	not adjacent to urban/industrial centers or maritime activity, adjacent land mass is largely undeveloped, lightly populated lowest numbers of point and/or nonpoint source discharges frequently used as reference locations

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