SEDIMENT METALS VERIFICATION STUDY for SINCLAIR AND DYES INLETS, WASHINGTON

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Introduction

Sinclair and Dyes Inlets near Bremerton, Washington, are on the State of Washington's 1998 303(d) list of impaired waters because of fecal coliform contamination in marine water, metals in sediment and fish tissue, and organics in sediment and fish tissue (**Figure 1**). This study was conducted to address the 303(d) segments that are listed for metal contaminants in marine sediment (two in Sinclair Inlet, one in Dyes Inlet, **Figure 2**), because significant cleanup and source control activities have been conducted in the Inlets since the data supporting the 1998 303(d) listings were collected. The study outcomes are expected to help prioritize management actions if sediment remains a source of water quality impairment.

Objectives

The Metals Verification Study was designed to answer the questions:

- Have sediment metals concentrations decreased since cleanup and source reduction actions?
- Do present-day concentrations of metals in Sinclair and Dyes Inlet sediment still exceed Washington State Sediment Quality Standards? If so, where?

Hydrodynamic modeling has shown significant water exchange and sediment transport between Sinclair and Dyes Inlets. Another objective was to provide metals and particle size data to support contaminant loading, transport modeling, and sediment trends analysis throughout Sinclair and Dyes Inlets.

Methods

Sample Collection and Analysis

A total of 160 surface sediment samples from Sinclair Inlet, Dyes Inlet, Port Orchard Passage, and Rich Passage were screened for copper, lead, and zinc using X-Ray Fluorescence (XRF). 40 samples (25%) were selected for confirmatory metals analysis by ICP-MS for cadmium, silver, and arsenic in addition to copper, lead, and zinc. A regression relationship between the ICP-MS and XRF datasets was developed to estimate copper, lead, and zinc concentrations for all samples. If a segment was listed for cadmium or silver, at least three samples in that segment were analyzed by ICP-MS as the XRF method detection limit is not low enough to evaluate concentrations relative to state sediment quality standards.

Abstract

This study was conducted to address metal contaminants listed on the State of Washington's 1998 303(d) list of impaired waters, specifically those waters located in Sinclair and Dyes Inlets near Bremerton, Washington. Hydrodynamic modeling has shown significant water exchange and sediment transport between Sinclair and Dyes Inlets. The primary objectives of the study were to document the current sediment metal concentrations in Sinclair and Dyes Inlets and evaluate whether the sediment concentrations exceed sediment quality criteria for metals. Significant cleanup and source control activities have been conducted in the Inlets since the data supporting the 1998 303(d) listings were collected. Another objective was to provide metals data to support contaminant loading and transport modeling throughout Sinclair and Dyes Inlets. A total of 160 sediment samples from Sinclair Inlet, Dyes Inlet, Port Orchard Passage, and Rich Passage were screened for copper, lead, and zinc using X-Ray Fluorescence (XRF). About 40 samples (25%) were selected for confirmatory metals analysis by ICP-MS. Linear regression was used to estimate metal concentrations from the XRF screening data for the 120 samples that were not analyzed by ICP-MS. Sediment metals concentrations are markedly reduced since source control and sediment cleanup actions. The study outcomes are expected to help prioritize management actions where sediment remains a source of sediment quality impairment.

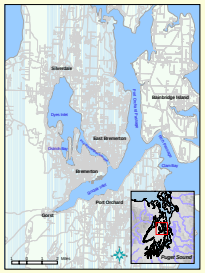

Figure 1. Location of Sinclair and Dyes Inlet study area, Puget Sound, Washington

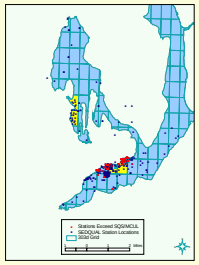

Figure 2. Existing sediment quality data prior to Metals Verification Study, 303(d) segments listed for sediment metals

In Dyes Inlet, Port Orchard Passage, and Rich Passage (Figure 3)

- Stratified sampling design to place 59 stations outside Sinclair Inlet
  - Highest density of samples in 303(d)-listed segments in Ostrich Bay
  - Moderate density of samples in Dyes Inlet depositional zone
  - Low density of samples in passages outside Sinclair & Dyes
- All samples were analyzed by XRF; 15 were selected for ICP-MS using same criteria as for OUB-Marine, but with greater emphasis on spatial distribution

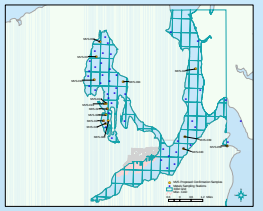

Figure 3. MVS Sampling stations in Dyes Inlet, Port Orchard Passage, and Rich Passage

Sinclair Inlet, Operable Unit B-Marine (Figures 4 and 5)

- Received splits of 103 composite samples collected during monitoring of Operable Unit B-Marine (OUB-Marine) of the Puget Sound Naval Shipyard,
  - 71 from 500-ft grid within OUB-Marine (OUBM)
  - 32 from 1500-ft grid outside of OUB-Marine (OOUB)
- All samples were analyzed by XRF; 25 were selected for ICP-MS using these criteria:
  - At least 3 samples from within each 303-d listed segment
  - Any sample with at least one metal concentration greater than 90% of the state minimum cleanup level (MCUL)
  - Other samples to cover range of XRF concentrations for ICP-MS correlation
  - Other samples for representative spatial distribution

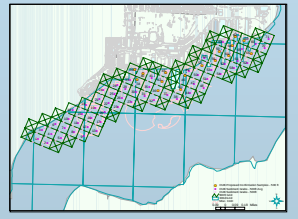

Figure 4. Sinclair Inlet 500-ft grid composites in Operable Unit B-Marine (OUBM Grids)

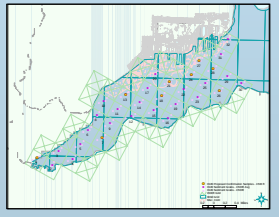

Figure 5. Sinclair Inlet 1500-ft grid composites outside OUB-Marine (OOUB Grids)

Results

The relationship between XRF screening and ICP-MS confirmatory analytical results are shown in Figure 6. The XRF results for copper and lead correlated well with standard analytical method (ICP-MS) results. Zinc correlates well up to XRF concentrations of about 200 ppm, but when the XRF concentration was 250 ppm or higher, there was not a strong linear relationship between the two methods for zinc.

- Measured ICP-MS concentrations of cadmium and silver were below SQS in all sediment samples; the present-day data do not support 303(d) listing based on silver or cadmium in sediment
- Measured or predicted ICP-MS concentrations of lead were below SQS and MCUL in all sediment samples; the present-day data do not support 303(d) listing based on lead in sediment
- Measured or predicted ICP-MS concentrations of copper exceeded the SQS and MCUL in only 2 of the 103 samples, the composites representing OUBM Grids 52 and 67 (Figures 7 and 8)
- Measured or predicted ICP-MS concentrations of zinc exceeded the SQS in 9 of the 103 samples, all of which were located near stormwater outfalls (OUBM Grids 46,52, 59, 60, 64, 66, 67, 68, and OOUB Grid 1).
- The measured zinc concentration in the OUBM Grid 60 composite was the only metal that exceeded its MCUL. This sample did not have good agreement between XRF screening and ICP-MS confirmatory results, probably because of sample inhomogeneity (each analysis is from a different aliquot of homogenized sediment).

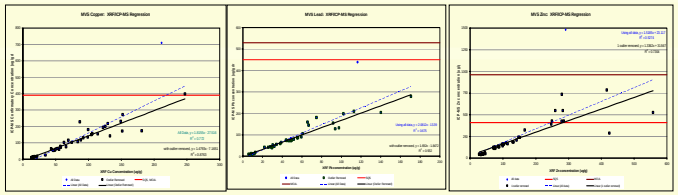

Figure 6. Relationship between XRF Screening Method and ICP-MS Confirmatory Analysis Method Results for Copper, Lead, and Zinc in Sediment

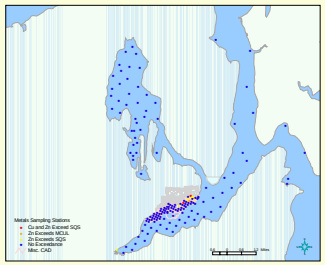

Figure 7. Results for entire Metals Verification Study Area

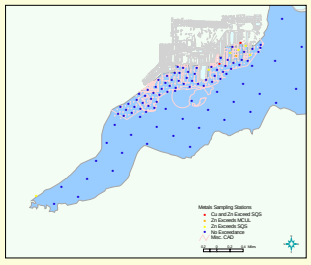

Figure 8. Results for Sinclair Inlet OUBM and OOUB

Conclusions

- Sediment quality in Sinclair Inlet has improved markedly since implementation of cleanup and source control actions.
- Metal concentrations meet Washington Sediment Quality Standards for lead, cadmium, silver, and arsenic in all sediment throughout Sinclair and Dyes Inlets
- Metal concentrations meet Washington Sediment Quality Standards for copper and zinc in all but a few samples concentrated near known sources where pollution controls, stormwater monitoring, and sediment monitoring are in place
- The XRF method with ~20% confirmatory analyses by ICP-MS provides cost-effective alternative of screening a large number of samples for copper, lead, and zinc.
- Samples with highest XRF concentrations or those that would predict concentrations near an action level (e.g., SQS) are always recommended for confirmatory analysis because there are fewer data to support the linear relationship between methods.