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**DMMP CLARIFICATION PAPER**

# Marine Sediment Quality Screening Levels: Adopting RSET Marine SLs for Use in DMMP

**Prepared by Laura Inouye (Ecology) and David Fox (Corps)**

## INTRODUCTION

One purpose of the RSET Sediment Evaluation Framework is to "provide a regionally consistent framework for evaluating the suitability of dredged material for in-water disposal." However, with publication of the Sediment Evaluation Framework in 2009, the RSET marine SLs for 15 compounds now differ from those used by the DMMP (Table 3).

To help maintain a regionally consistent framework, the Dredged Material Management Program (DMMP) is committed to adopting the RSET guidance where possible. However, before adopting the updated SLs, the DMMP agencies needed to review the technical feasibility of the new SLs and the potential impacts to projects in Washington State and the environment.

## BACKGROUND

Apparent Effect Threshold values (AETs) derived in the late 1980s (Barrick et al., 1988) are the basis of numeric guidelines adopted by the Puget Sound Dredged Disposal Analysis (PSDDA) program (PSDDA,1988; 1989) and also numeric sediment quality standards adopted by the State of Washington in the Sediment Management Standards (Ecology 1991). In an effort to keep the regional AETs current, the Department of Ecology (Ecology) incorporated new chemistry and toxicity data into the AET database in 1994 and recalculated dry weight- and organic carbon-normalized AETs (Gries and Waldow, 1996). A regulatory workgroup reviewed the recalculated AETs in a series of workshops in 1996 and 1997 and provided recommendations to the DMMP agencies. The DMMP agencies updated the program's numeric guidelines using the 1994 amphipod AETs as recommended by the workgroup, but declined to use the echinoderm-based AETs until more work could be done (DMMP, 1997).

In 1998, a sediment larval workshop was held in an attempt – among other things – to resolve issues related to the use of the 1994 echinoderm AETs (DMMP, 1998). That same year, Ecology developed AETs based on inhibition of growth in *Neanthes arenaceodentata* juveniles. However, further work was terminated before technical and policy issues could be resolved (Ecology, 1999). For this and other reasons, the 1994 echinoderm and 1998 Neanthes AETs have not been used to amend the SMS rule or update the DMMP numeric guidelines.

Between 2003 and 2005, the Regional Sediment Evaluation Team (RSET) Chemistry subcommittee met to review existing information on freshwater and marine chemistry. In 2009, RSET adopted some of

the 1994 AET values – including echinoderm – as screening level guidelines (SLs). The changes focused on revising DMMP SLs that were based on detection limits or where chemicals did not have a defined toxicity threshold. The RSET marine SLs are listed in the final Sediment Evaluation Framework document (RSET, 2009).

## PROBLEM IDENTIFICATION

There are 15 compounds for which RSET and DMMP guidelines differ. The reasons for this divergence fall into two groups:

### Group 1: Presently on DMMP list but not adopted by RSET

Group 1 includes eight compounds for which RSET did not establish SLs due to a lack of correlation between sediment chemistry and toxicity. These compounds were not included in the RSET SL list since they do not have a defined toxicity threshold. Washington State standards had not been established for these compounds for the same reason. These compounds include nickel, 1,3-Dichlorobenzene, hexachloroethane, lindane, and all volatile organics presently on the DMMP chemicals of concern (CoC) list, as shown in Table 1.

**Table 1. Group 1 compounds.**

| Chemical | DMMP Marine SL (dry weight) | RSET Marine SL (dry weight) |
|---|---|---|
| **Metals (mg/kg)** | | |
| Nickel | 140 | --- |
| **Chlorinated Hydrocarbons (µg/kg)** | | |
| 1,3-Dichlorobenzene | 170 | --- |
| **Volatile Organic Compounds (µg/kg)** | | |
| Trichloroethene | 160 | --- |
| Tetrachloroethene | 57 | --- |
| Ethylbenzene | 10 | --- |
| Total Xylene | 40 | --- |
| **Miscellaneous Extractables (µg/kg)** | | |
| Hexachloroethane | 1400 | --- |
| **Pesticides/PCBs (µg/kg)** | | |
| gamma-BHC (Lindane) | 10 | --- |

To be entirely consistent with RSET, the DMMP would drop all these chemicals from their CoC list. But before dropping these compounds the DMMP agencies need to ensure that exceedances of the DMMP SLs for these compounds in past dredging projects have not been associated with bioassay failures.

**Group 2: Different Marine SLs for DMMP and RSET**

The second group of compounds has different SLs for RSET than those currently in place for DMMP. This group consists of chromium, hexachlorobutadiene, aldrin, total chlordane, dieldrin, heptachlor, and DDT, DDD, and DDE, as shown in Table 2. To be consistent with RSET, all DMMP Marine SLs would be set equal to the RSET SLs.

**Table 2. Group 2 compounds.**

| Chemical | DMMP Marine SL (dry weight) | RSET Marine SL (dry weight) |
|---|---|---|
| **Metals (mg/kg)** | | |
| Chromium | 267 (BT) | 260[1] |
| **Miscellaneous Extractables (µg/kg)** | | |
| Hexachlorobutadiene | 29 | 11[2] |
| **Pesticides (µg/kg)** [3] | | |
| p,p'-DDD | --- | 16 |
| p,p'-DDE | --- | 9 |
| p,p'-DDT | --- | 12 |
| Total DDT (sum of 4,4') DDX) | 6.9 | --- |
| Aldrin | 10 | 9.5 |
| Chlordane (total) | 10 | 2.8 |
| Dieldrin | 10 | 1.9 |
| Heptachlor | 10 | 1.5 |

## EVALUATION OF TECHNICAL FEASIBILITY AND POTENTIAL IMPACTS OF UPDATED RSET SLs

**Technical Feasibility -** The technical feasibility of the updated RSET SLs was evaluated through a comparison to practical quantitation limits (PQLs). The PQL represents the lowest level that can be accurately reported as a measured value. That often depends on the lowest concentration standard used to generate the calibration curve. The method detection limit (MDL) is the lowest level that can be measured and reported with 99% confidence that is it above zero, although the precise value cannot be reliably determined. The reporting limit (RL) is usually equivalent to the PQL. However, the RL may be less than the PQL, depending on contract requirements, the laboratory, and parameter in question. Values between the PQL and the MDL are often reported with a "J" qualifier.

[1] Based on PSDDA 1998, and adopted into Washington State SMS rule.
[2] Hexachlorobutadiene value differs from the DMMP SL (29 ppb). The 11 ppb value presented here was proposed for the Washington State SMS rule (Ecology, 1991) although the OC-normalized value was eventually promulgated into the rule.
[3] All pesticide SL values differ from the DMMP SL values. Most of these values are based on a draft report reassessing amphipod and echinoderm larval AETs (Gries and Waldow, 1996).

**Potential Impacts–** The DMMP agencies utilized two primary sources of data in the evaluation of potential environmental and project impacts:

1. The Corps' Dredged Analysis Information System (DAIS) database, which includes data for approximately 260 projects and 20 disposal site monitoring events; and
2. DMMP suitability determinations for the dredging projects.

Evaluations are summarized for each compound or class of compounds below.

***Analysis of Group 1 Chemicals***

**Nickel**: This metal is abundant in crustal material (soils) and is nearly always detected in sediments. However, The DMMP has observed exceedances of the 140 mg/kg SL in only four projects (three of which were in Squalicum Waterway in Bellingham Bay). Three of these projects had at least one dredged material management unit (DMMU) for which nickel was the only SL exceedance. In two of these cases, the DMMP agencies did not require bioassays because the lowest apparent effects threshold (LAET), upon which the SL was based, was not a well-established number (it was listed as > 140 mg/kg). In the third case, bioassays were performed for three DMMUs for which nickel was the only SL exceedance. All three DMMUs passed the guidelines for non-dispersive disposal. One of these DMMUs was found unsuitable for dispersive disposal. Nickel was also found at concentrations above the SL at the Bellingham Bay non-dispersive disposal site in the 1993 monitoring event, but was not shown to be associated with toxicity, as the full suite of bioassays passed.

**Lindane**: This compound has been detected in numerous projects, but only twice above the existing DMMP SL of 10 ug/kg. There was only one DMMU for which Lindane was the only SL exceedance, but bioassays were not run on this DMMU for other reasons. It was also detected at levels exceeding the maximum level (ML) of 31 ug/kg at the Commencement Bay non-dispersive disposal site in the 2003 monitoring event, but was not shown to be associated with toxicity, as the full suite of bioassays passed.

**1,3-Dichlorobenzene, hexachloroethane, trichloroethene and tetrachloroethene**: These compounds have only been detected in a few projects (three projects for 1,3-dichlorobenzene, trichloroethene, tetrachloroethene; five projects for hexachloroethane). None of these detections have been SL exceedances. There have been no exceedances of the DMMP SL at any of the non-dispersive disposal sites.

**Ethylbenzene and total xylenes**: Ethylbenzene has been detected in 11 projects, four of which had exceedances of the DMMP SL of 10 ug/kg, and one of which exceeded the DMMP ML of 50 ug/kg. Xylenes have been detected in 20 projects, four of which had exceedances of the DMMP SL of 40 ug/kg, and three of which exceeded the DMMP ML of 160 ug/kg. There have been no exceedances of the DMMP SL at any of the non-dispersive disposal sites. Although bioassays were triggered and failures were observed in several projects, in no case was ethylbenzene or total xylenes the only CoC involved. In each case, there were multiple exceedances of other SLs and MLs. Based on this

experience, it is highly likely that elevated concentrations of ethylbenzene and total xylenes will be accompanied by SL exceedances for other COCs. These latter SL exceedances will still result in the performance of bioassays, so that dropping ethylbenzene and total xylenes would have no adverse effect on the ability of chemical testing to detect potentially toxic sediments.

***Analysis of Group 2 Chemicals***

**Chromium**: The RSET SL is 260 mg/kg and is the 1988 AET for benthic community effects. This is also the value adopted for the SQS in the Washington State Sediment Management Standards rule (Ecology, 1991). The DMMP agencies did not set an SL for chromium in 1988 but did establish a bioaccumulation trigger (BT) of 267 mg/kg in 2003 (Hoffman, 2003). There are no projects in DAIS that exceed 260 mg/kg. Therefore, adopting the RSET SL and lowering the BT to equal the SL would have had no impact on past projects.

**Hexachlorobutadiene**: The RSET SL is 11 ug/kg and is based on the 1988 AET for benthic community effects (Barrick et al., 1988). The same value was adopted as the SQS (Ecology, 1991). The current DMMP SL of 29 ug/kg is 10% of the highest 1986 AET (HAET) (290 ug/kg; PSDDA, 1988).

Hexachlorobutadiene has been detected in five DMMP projects, two of which fell between the RSET and DMMP SLs. Only one of these projects (in the Sitcum Waterway) would have had bioassays triggered by this compound alone. Therefore, adopting the lower SL would have had a relatively small impact regarding the requirement for bioassays. However, half of the projects had reporting-limit exceedances of the RSET SL for this compound. A review of reporting limits for nondetects in DAIS revealed that, while highly variable, the average was 10.99 ug/kg. The Department of Ecology's Sampling and Analysis Plan Appendix (SAPA; Ecology, 2008) recommends a practical quantitation limit (PQL) of 11 ug/kg. With improving analytical capabilities, the lower SL should be achievable.

**Aldrin**: The RSET SL is 9.5 ug/kg and is based on both the amphipod and echinoderm AET values recalculated in 1994. This is compared to the DMMP SL of 10 ug/kg based on detection limits that were achievable in the late 1980s. Aldrin has been detected in multiple projects, but only three times between 9.5 and 10 ug/kg. Those cases were all accompanied by other SL exceedances, so that reducing the SL would have had no effect on the number of bioassays required. The Ecology SAPA (2008) recommended a PQL of 1.7 ug/kg, so analytical capabilities should be sufficient for the lower SL.

**Total chlordane**: The RSET SL is 2.8 ug/kg and is set by the 1994 AET for amphipod mortality. This is compared to the DMMP SL of 10 ug/kg. The DMMP SL was set by detection limits at the time the PSDDA SLs were adopted. Chlordane is in reality a mix of chemicals, and has been reported in many ways over the years – as total chlordane, technical chlordane, alpha-chlordane, and simply as "chlordane". In 2007, DMMP defined "total chlordane" programmatically as the sum of cis-chlordane (aka alpha-chlordane), trans-chlordane, cis-nonachlor, trans-nonachlor and oxychlordane. These compounds have been detected in numerous projects, with 19 projects having detected concentrations

falling between the RSET and DMMP SLs. In seven of these projects, chlordane alone would have triggered bioassays for one or more DMMUs, but all but one of these projects already had bioassays run for other DMMUs, so that bioassay testing for these projects would not have been triggered by chlordane alone. A single project, located in the Duwamish Waterway, would have had bioassays triggered solely by this class of compounds (i.e., there were no exceedances of any other SLs for any of the DMMUs). The balance of the 19 projects had DMMUs with multiple exceedances of SLs for other compounds - in addition to chlordane - that would have triggered bioassays within the DMMUs. Although there have been 51 projects - some recent - with reporting limits above the RSET SL, the Ecology SAPA (2008) recommended a PQL of 1.7 ug/kg for chlordane, so analytical capabilities should be sufficient for the lower SL.

**Dieldrin and heptachlor**: The RSET SLs for dieldrin and heptachlor are 1.9 ug/kg and 1.5 ug/kg respectively, and both were set by 1994 AETs – the echinoderm AET for dieldrin and the amphipod AET for heptachlor. This is compared to the DMMP SL of 10 ug/kg for both compounds. The DMMP SLs were set by detection limits at the time the PSDDA SLs were adopted.

Dieldrin has been detected in multiple projects, with 18 projects (64 DMMUs) having detected exceedances between the RSET and DMMP SLs. In six of these projects, dieldrin alone would have triggered bioassays for one or more DMMUs, but each of these projects already had bioassays run for other DMMUs, so that bioassay testing for these projects would not have been triggered by dieldrin alone. A single project, located in Grays Harbor, would have had bioassays triggered solely by this compound (i.e., there were no exceedances of any other SLs for any of the DMMUs). The balance of the 18 projects had DMMUs with one or more exceedance of SLs for other compounds.

Heptachlor has been detected in multiple projects, with ten projects (24 DMMUs) having detected exceedances between the RSET and DMMP SLs. In two of these projects, heptachlor alone would have triggered bioassays for a single DMMU, but each of these projects already had bioassays run for other DMMUs, so that bioassay testing for these projects would not have been triggered by heptachlor alone. A single project, located in Lake Washington, would have had bioassays triggered solely by this compound (i.e., there were no exceedances of any other SLs for any of the DMMUs). The balance of the ten projects had DMMUs with one or more exceedance of SLs for other compounds.

For both dieldrin and heptachlor, the Ecology SAPA- recommended PQL is higher than the RSET SL (dieldrin PQL is 2.3 ug/kg; heptachlor PQL is 1.7 ug/kg). Given PQLs that are only slightly higher than the SLs, and the fact that reporting limits may be lower than the PQLs, laboratories should be able to generate “J” flagged data at or below the SL. However, for dieldrin, there have been 118 projects with reporting limits above 1.9 ug/kg, and for heptachlor, there have been 53 projects with reporting limits above 1.5 ug/kg, many of these being recent projects. Based on this data, the RSET SLs appear to be beyond what has been historically achieved by analytical laboratories.

**DDT, DDD, and DDE**: While DMMP has an SL of 6.9 ug/kg for the summed p,p'-DDX compounds (aka "total DDT"), RSET has a separate SL for each of the p,p'-DDX constituents. RSET's SLs are 16 ug/kg for DDD, 9 ug/kg for DDE, and 12 ug/kg for DDT. The SLs for DDD and DDE are based on the 1988 AET for benthic community effects. The RSET SL for DDT is based on the 1994 AET for echinoderm abnormality. Given that the individual RSET SLs are all greater than the DMMP SL for the summed constituents, there would be no economic or analytical project impact from the adoption of the RSET SLs.

Evaluation of potential environmental impacts showed that of 196 DMMUs where the DMMP SL for total DDT was exceeded, there were only six DMMUs where a) Total DDT was the only SL exceedance; b) bioassays would not also have been triggered by exceedances of the RSET DDX SLs; and c) the bioassays failed. All of these were in high-ranked areas, and no single DMMU exceeded 4,000 cy.

In three of the six cases, there were other, more plausible, explanations for the bioassay failures (e.g. high ammonia/sulfides, QA issues). In addition, further evaluation of the DAIS data provided evidence that DDT may not be toxic at levels as low as the existing DMMP SL. There were 42 DMMUs for which a) the SL for total DDT was exceeded; b) bioassays would not also have been triggered by exceedances of the RSET DDX SLs; c) there was one or more SL exceedance for other CoCs; and d) the bioassays still passed. The DAIS data, therefore, appear to corroborate the RSET re-evaluation of the AETs and provide a strong argument for eliminating the DMMP SL of 6.9 ug/kg for total DDT.

## PROPOSED ACTION/MODIFICATION

The DMMP agencies propose accepting all the RSET SLs, with minor caveats. Our evaluation determined that the environmental risk and economic impact of this action is low, and the technological challenges manageable.

**Nickel, lindane, 1,3-dichlorobenzene, hexachloroethane, total DDT, and the volatile compounds trichloroethene, tetrachloroethene, ethylbenzene, and total xylenes, will be dropped from the standard DMMP CoC list.**

Dropping the volatiles (trichloroethene, tetrachloroethene, ethylbenzene and xylenes) from the standard list of chemicals of concern would eliminate an entire analytical group, thereby simplifying field sampling and reducing testing costs. Because volatiles have never been the sole trigger for bioassay testing in the 23-year history of DMMP, the risk of otherwise suitable dredged material containing unacceptable levels of volatiles appears to be small. All compounds whose SLs are being dropped will continue to be monitored at the disposal sites.

**The RSET SLs for chromium, hexachlorobutadiene, aldrin, total chlordane, dieldrin, heptachlor, DDT, DDD, and DDE, will be adopted.** Project proponents and laboratories should be aware that the Ecology-recommended PQLs will need to be met or surpassed for hexachlorobutadiene, total chlordane, dieldrin and heptachlor in order to avoid SL exceedances. It is recognized that it will take time for some laboratories to accomplish this. Therefore, best professional judgment (BPJ) will be applied by the DMMP agencies during dredging year 2012 when sample-specific reporting limits are above the SLs for any of these four chemicals. The ability of laboratories to meet the revised SLs will be reviewed prior to the 2012 SMARM. Further need for BPJ beyond the 2012 SMARM will be evaluated at that time.

**Bioaccumulation Triggers (BTs) will continue to exist for chromium and total DDT.** The chromium BT will be changed to 260 mg/kg to match the new SL. The existing BT for total DDT (the sum of 4,4'-DDD, 4,4'-DDE and 4,4'-DDT) will remain unchanged at 50 ug/kg.

**Table 3. Summary table of all proposed changes.**

| Chemical | DMMP Marine SL (dry wt) | DMMP Basis for SL[1] | RSET Marine SL (dry wt) | RSET Basis for SL[1] | Ecology recommended PQL |
|---|---|---|---|---|---|
| **Metals (mg/kg)** | | | | | |
| Chromium | 267 (BT) | DMMP BCoC | 260[2] | 1988 AET B | 87 |
| Nickel | 140 | 1988 AET A&B | ---[3] | --- | 47 |
| **Tributyltin:** ***NO CHANGES PROPOSED*** | | | | | |
| **Polynuclear Aromatic Hydrocarbons (µg/kg):** ***NO CHANGES PROPOSED*** | | | | | |
| **Chlorinated Hydrocarbons (µg/kg)** | | | | | |
| 1,3-Dichlorobenzene | 170 | 1988 AET | ---[5] | --- | 57 |
| **Phthalates (µg/kg):** ***NO CHANGES PROPOSED*** | | | | | |
| **Volatile Organic Compounds (µg/kg)** | | | | | |
| Trichloroethene | 160 | EqP ML/10 (PSDDA, 1988 = EPTA) | ---[5] | --- | 3.2 |
| Tetrachloroethene | 57 | 1988 AET B | ---[5] | --- | 3.2 |
| Ethylbenzene | 10 | | ---[5] | --- | 3.2 |
| Total Xylene | 40 | | ---[5] | --- | 3.2 |
| **Phenols (µg/kg):** ***NO CHANGES PROPOSED*** | | | | | |
| **Miscellaneous Extractables (µg/kg)** | | | | | |
| Hexachloroethane | 1400 | EqP ML/10 (PSDDA, 1988 = EPTA) | ---[5] | --- | 20 |
| Hexachlorobutadiene | 29 | 1986 AET A/10 | 11[4] | 1988 AET B | 10 |
| **Pesticides/PCBs (µg/kg)** [5] | | | | | |
| p,p'-DDD | --- | --- | 16 | 1988 AET B | 3.3 |
| p,p'-DDE | --- | --- | 9 | | 2.3 |
| p,p'-DDT | --- | --- | 12 | 1994 AET E | 6.7 |
| Total DDT (sum of 4,4') | 6.9 | 1986 ∑HAET/10 | --- | --- | 6 |
| Aldrin | 10 | Analytical detection limits ~ 1989 | 9.5 | 1994 AET A | 1.7 |
| Chlordane (total) | 10 | | 2.8 | | 1.7 |
| Dieldrin | 10 | | 1.9 | 1994 AET E | 2.3 |
| Heptachlor | 10 | | 1.5 | | 1.7 |
| gamma-BHC (Lindane) | 10 | | --- | --- | 1.7 |

[1] A = Amphipod; B = Benthic; E = Echinoderm
[2] Based on PSDDA 1988, and adopted into Washington State SMS rule.
[3] These compounds were not included in the RSET SL list since they do not have a defined toxicity threshold. No values were promulgated in the Washington State SMS rule, so for consistency, they were not included in the RSET SL list.
[4] Hexachlorobutadiene value differs from the DMMP SL (29 ppb). The 11 ppb value presented here was proposed for the Washington State SMS rule (Ecology, 1991) although the OC-normalized value was eventually progmulated into the rule.
[5] All pesticide SL values differ from the DMMP SL values. Most of these values are based on a draft report reassessing amphipod and echinoderm larval AETs (Gries and Waldow, 1996).

**REFERENCES**

Barrick, R., S. Becker, L. Brown, H. Beller, and R. Pastorok, 1988. Sediment Quality Values Refinement, Volume I. 1988 Update and Evaluation of Puget Sound AET. Prepared for the U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, Washington. 66 pages + appendices.

DMMP, 1996. Minutes to the 1996 Sediment Management Annual Review Meeting (SMARM). Apparent Effects Thresholds. Presented on behalf of the DMM P agencies on May 8, 1996 by Tom Gries.

DMMP, 1997. Revisions to DMMP Screening and Maximum Level Guidelines. An Issue Paper prepared for the DMMP agencies by Tom Gries, Department of Ecology.

DMMP, 1998. Minutes to the 1998 Sediment Management Annual Review Meeting (SMARM). Update on Regulatory Work Group Recommendations on AETs. Presented on behalf of the DMMP agencies on May 13, 1998 by Tom Gries.

Ecology. 1991, revised 1995. Sediment Management Standards
http://apps.leg.wa.gov/WAC/default.aspx?cite=173-204

Ecology, 1999. Letter on decision not to proceed with Sediment Management Standards rule revisions.
http://www.ecy.wa.gov/programs/tcp/smu/sed_update-sms.htm

Ecology. 2008. Sediment Sampling and Analysis Plan Appendix. Ecology Publication No. 03-09-043.
http://www.ecy.wa.gov/biblio/0309043.html

Gries, T. and K. Waldow, 1996. Progress Re-evaluating Puget Sound Apparent Effects Thresholds, Volume I: 1994 Amphipod and Echinoderm Larval AETs . Draft report.

Hoffman, E. 2003. Revisions to the Bioaccumulative Contaminants of Concern (BCOC) List. DMMP Issue paper. ttp://www.nws.usace.army.mil/PublicMenu/documents/DMMO/BCOC.pdf

PSDDA. 1988. Puget Sound Dredged Disposal Analysis: Evaluation Procedures Technical Appendix, Phase I. (EPTA) U.S. Army Corps of Engineers - Seattle District, U.S. Environmental Protection Agency - Region 10, Washington State Department of Natural Resources, Washington State Department of Ecology.

PSDDA. 1989. Puget Sound Dredged Disposal Analysis: Management Plan Report – Unconfined Open-Water Disposal of Dredged Material, Phase II. (MPR-II) U.S. Army Corps of Engineers - Seattle

District, U.S. Environmental Protection Agency - Region 10, Washington State Department of Natural Resources, Washington State Department of Ecology.

RSET, 2009. Sediment Evaluation Framework (SEF) for the Pacific Northwest.http://www.nwp.usace.army.mil/docs/d_sediment/references/final_SEF_May_2009.pdf

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

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