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Summary of Criteria and Guidelines for Contaminated Freshwater Sediments

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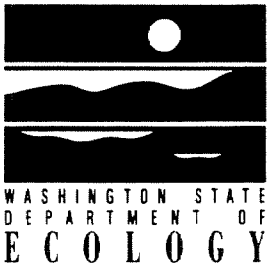
Produced for Ecology's Sediment Management Unit

Note: This report and the accompanying data table are reference documents only. Publication of this information in no way implies that any numbers or methods contained herein are currently endorsed or recommended by the Department of Ecology.



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I. INTRODUCTION

The Washington State Department of Ecology (Ecology) is developing criteria for contaminated freshwater sediments. As part of that effort, Ecology has compiled sediment guidelines and criteria from various North American sources and has summarized them in this report. This summary gives an overview of the current status of freshwater sediment criteria and provides information on the purpose and status of the individual sets of criteria.

This report contains brief descriptions of the criteria development methods used and background information on the data sources. In most cases, the original source documents were obtained. References and related publications should be consulted for more complete and detailed information.

The data compiled for this report (see Table 1) are maintained in a Lotus spreadsheet file called FSEDCRIT (Freshwater SEDiment CRITeria). The file is updated as new data become available.

In most cases, data are normalized to mg/kg dry weight for metals and mg/kg organic carbon for organics. Exceptions exist because normalization procedures for some data were either not fully defined, or other normalization methods were used.

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II. CRITERIA DEVELOPMENT METHODS

The primary methods used to derive the sediment criteria included in this report were the Background (BKG) Approach, the Equilibrium Partitioning (EQP) Approach, the Screening Level Concentration (SLC) Approach, and the Spiked Bioassay (BIO) Approach. Each method is described below:

Background Approach (BKG):

The background approach is the simplest and most straightforward of the criteria development methods. Concentrations for each contaminant of interest are determined for sites where the levels are considered to be acceptable. For metals, this is often a "pre-industrial" value derived from sediment cores. For anthropogenic organics, which should theoretically have background concentrations of zero, values from a suitable reference site are used. Ideally, application of this approach would strive to reduce pollutant loading to a point where the contaminant level of an impacted sediment was indistinguishable from that of a non-impacted sediment.

Advantages of the background approach are that it requires a minimum of field data and no quantitative toxicity assessments. The disadvantages are that it may be difficult to find suitable reference sites and to determine what levels are acceptable "background" concentrations.

Equilibrium Partitioning Approach (EQP):

The EQP approach was designed for non-polar, non-ionic organics, and is based on a series of complex physical and chemical relationships. EQP assumes that chemical concentrations in interstitial water are the major source of toxicity, and attempts to predict these concentrations from bulk sediment concentrations using solubility properties of specific chemicals. This approach can be used for non-polar organics which partition between liquid and solid sediment phases in fairly predictable ways.

For each compound of interest, EQP uses an octanol/water partition coefficient, K_{ow}, to predict an organic carbon-normalized partition coefficient, K_{oc}. To calculate sediment criteria, this value is multiplied by the water quality criteria for that compound.

A primary advantage of this approach is that it uses existing water quality criteria which are supported by extensive biological testing to predict no-effect levels for specific contaminants. It is also useful when adequate field data are not available.

Disadvantages include the assumption that contaminants are bioavailable only through exposure to interstitial water, thereby ignoring body wall absorption and ingestion. Additionally, results depend on the accuracy of the partitioning coefficients, how well the coefficients represent various chemical species and toxicities, and partitioning characteristics. Finally, the method is not yet applicable to metals or polar/ionic organics.

Screening Level Concentrations Approach (SLC):

The SLC approach uses field data (combining contaminant concentrations with in-situ benthic invertebrate abundance) and a two-stage calculation to derive sediment criteria. The first stage is to calculate a species SLC (the SSLC), defined as the 90th percentile of the concentration distribution of a specific contaminant, where at least ten species of interest are present at a minimum of ten sites.

A large number of SSLCs are then plotted as a frequency distribution. The SLC is that contaminant concentration above which 95% of the SSLCs are found. Therefore, an SLC is the highest level of a contaminant that can be tolerated by 95% of the benthic infaunal species. Since the database is assumed to contain a complete range of contaminant concentrations for the species of interest, the reference is inherently "built-in".

A significant advantage of this effects-based approach is that it infers an environmental response to contaminant concentrations. An additional advantage is that, unlike the EQP method, it can be used to derive criteria for non-polar organics, polar organics and metals.

One major disadvantage is that it does not establish a direct cause and effect relationship between a single contaminant and benthic organism survival. Also, since an SLC is always produced regardless of the concentrations of contaminants or the tolerances of the species, the result may not reflect toxicity. Another disadvantage is that the method requires a large amount of field data.

Spiked Bioassay Approach (BIO):

The bioassay approach exposes a test organism to a contaminated sediment and observes any resulting toxic effects. Hart et al., (1981) uses the spiked bioassay to determine dose-response relationships of test organisms to levels of contaminants.

Spiked sediments are prepared by adding a known amount of the contaminant(s) of interest to a sediment sample and allowing time for equilibration. Test organisms are then exposed to the prepared sediment, and toxic effects can be directly related to the known contaminant concentrations.

An advantage of this method is that individual contaminants or combinations of contaminants can be tested in known concentrations and under controlled conditions. The main disadvantages are that considerable effort must be expended for each contaminant tested, and that spiked sediments may not realistically simulate natural conditions.

III. GUIDELINES/CRITERIA SOURCES

NOTE: Capital letters in parentheses refer to columns in Table 1.

(A) Provincial Sediment Quality Guidelines:

Developed by:	Ontario Ministry of the Environment
Date:	revised May 1991
Purpose:	sediment evaluation
Status:	provisional

These guidelines have undergone several revisions since their inception. They define three levels of chronic, long-term effects on benthic organisms.

1) No-Effect Level - No toxic effects have been observed on aquatic organisms, there is no expected food chain biomagnification, and all water quality guidelines will be met.

2) Lowest-Effect Level - Indicates a level of sediment contamination that can be tolerated by most benthic organisms.

3) Severe-Effect Level - Pronounced disturbance of sediment-dwelling organisms can be expected. Contaminant concentration would be detrimental to the majority of benthic species.

(B) Wisconsin Department of Natural Resources (WDNR):

Developed by:	Wisconsin Department of Natural Resources
Date:	1985, revised 1990
Purpose:	1985 data were derived for classification of dredged material for in-water disposal, 1990 data were derived for cleanup at an EPA Superfund site.
Status:	guidelines only, no regulatory basis

In 1985 Wisconsin published sediment criteria primarily for in-water disposal of dredged material. Values for metals, pesticides and other chlorinated organics were derived using the background approach. More recent EQP data have been derived for 2,3,7,8-TCDD, some PAH compounds and several solvents, specifically for the Little Menomonee River/Moss-American Superfund Site. WDNR reports the EQP values for seven levels of total organic carbon (TOC). FSEDCRIT lists them as mg/kg organic carbon.

(C) Sediment Quality Guidelines (Beak Consultants):

Developed by:	Beak Consultants, Ontario, Canada
Date:	1988
Purpose:	produce sediment guidelines for the Ontario Ministry of the Environment
Status:	values have been partially incorporated into the Provincial Sediment Quality Guidelines (A).

Beak Consultants proposed sediment quality guidelines for metals, pesticides and PCBs in this work for the Ontario Ministry of the Environment's In-Place Pollutants Program. Guidelines for most organics were derived using the SLC approach, and most metals guidelines used background values.

The procedure used was designed to give preference to the most defensible methods. Biological effects-based methods were considered to be more defensible than partitioning methods, which were considered to be more defensible than background methods. In all cases, values were set at or above background levels.

Criteria for each contaminant were established using the following tiered system:

1. If they can be calculated, select the lowest of the effects-based guidelines (i.e., chronic Hexagenia AET, SLC, or spiked bioassay).

2. If there is no effects-based guideline, use the lowest generic equilibrium partitioning value.

3. If this value is less than the upper background limit, or if there is no effects-based or equilibrium partitioning value, use the background limit as the guideline.

(D) EPA Region V Guidelines for the Pollutional Classification of Harbor Sediments:

Developed by:	U.S. EPA Region V
Date:	1977
Purpose:	dredged material classification
Status:	guidelines only, no regulatory basis

The EPA Region V Guidelines were originally released to classify Great Lakes harbor sediments. Since the values were somewhat arbitrary and not well founded scientifically, they were considered adequate only for determining the suitability of dredged material for open water disposal. However, if either mercury or PCB's were present in excess of the

guidelines, the sediments were considered severely polluted and had to be disposed of by other means.

(E) Screening Level Concentrations for Freshwater Sediments:

Developed by:	Battelle Environmental Program Office
Date:	1986
Purpose:	evaluate SLC approach for the U.S. EPA
Status:	method evaluation only

Battelle derived screening level concentrations for five chemicals in freshwater sediments. Neff et al., (1986) made the following recommendations:

1. The SLC approach has merit and should be further evaluated and refined.

2. Reduce the number of observations required to calculate an SSLC to ten, and increase the number of SSLCs needed to calculate an SLC to 20. Statistically evaluate this relationship to produce the best approach to deriving SLCs.

3. Statistically analyze the choice of using the 90th percentile of observations for the SSLC and the fifth percentile of the SSLCs for the SLC, in order to optimize the use of available data.

4. Add data from heavily contaminated sites to the database, and evaluate any changes in the resulting SLCs.

5. Do a statistical analysis to determine the optimum range and distribution of sediment contaminant concentrations for calculating SLCs.

6. All SLC databases should be subjected to rigorous QA/QC, and criteria developed for database acceptance or rejection.

7. Investigators should be encouraged to design new benthic assessment programs for data collection on community structure, and for sediment contaminant and organic carbon concentrations.

(F) EPA Preliminary Draft Sediment Criteria for Nonpolar Organics:

Developed by:	U.S. EPA
Date:	1988
Purpose:	develop interim sediment criteria for nonpolar organics
Status:	currently being updated, some revised numbers are expected in late 1991.

EPA applied established water quality criteria to the EQP method to determine interim sediment criteria values for 11 nonpolar hydrophobic organic contaminants. Sediment criteria for eight of these compounds were derived using Final Chronic Value water quality criteria, designed to protect aquatic life from chronic toxicity. Sediment criteria for five of

these compounds were derived using Final Residue Values, designed to protect uses of aquatic life such as marketability.

Additional chronic sediment criteria for fluoranthene, pyrene, benzo(a)pyrene, and benzo(a)anthracene were calculated separately, since previously established water quality criteria were not available.

All sediment criteria in this data set are reported as mean values.

Several of these preliminary draft criteria may be superseded by interim criteria to be issued by EPA in late 1991.

(G) Ontario Ministry of the Environment Dredged Material Disposal Classification Criteria

Developed by:	Ontario Ministry of the Environment
Date:	1988
Purpose:	dredged material classification
Status:	superseded by Provincial Sediment Quality Guidelines (A)

If sediment cannot be disposed of in open water because of excessive levels of pollutants, then its suitability for either unrestricted or restricted land disposal must be determined using these criteria.

IV. OTHER GUIDELINES/CRITERIA NOT LISTED IN FSEDCRIT

There are three sets of freshwater sediment guidelines/criteria which were not included in FSEDCRIT. One of these, the "Bioeffects/Contaminant Co-Occurrence Analyses (COA) Approach", or the "Weight of Evidence Approach", is described by Long and Morgan (1990). This approach was not included because results are based predominantly on marine data, which FSEDCRIT does not address. Also, the small amount of freshwater information it does report are included in other FSEDCRIT tables. The two other data sets are the Federal Water Pollution Control Administration (FWPCA) Chicago Guidelines for the Degree of Pollution of Harbor Sediments (1968), and the Jensen criteria (1971). These sets were not included in FSEDCRIT because the values either appear elsewhere, or have been superseded by more recent efforts. Both can be found in Pavlou and Weston (1983).

Table 1. Review of criteria and guidelines for contaminated freshwater sediments. See text for sources and methods.

COMPOUND NAME	PP	Mol Wt.	A (Persaud et al. 1991) Provincial Sediment Quality Guidelines: No Effect	A: Lowest Effect	A: Severe Effect	B (WDNR,85,90) Wisconsin Dept. of Natural Resources		C (Hart et al. 1988) Sediment Quality Guidelines		D (EPA, 1977) EPA Region V Guidelines for the Pollutional Class. of Harbor Seds.: Non Polluted	D: Moderately Polluted	D: Heavily Polluted	E (Neff et al. 1986) SLC for Freshwater Sediments	F (EPA, 1988) EPA Interim Sed. Criteria for Nonpolar Organics: Chronic Basis	F: Residue Basis	G (Anon., 1988) Ont. Min. Environ. Dredged Mat'l Disposal Classification Criteria: Open Water	G: Unrestricted Land	G: Restricted Land
		METHODS=>	EQP	SLC	SLC	Note 1				BKG	BKG	BKG	SLC	EQP	EQP		Note 2	
METALS		UNITS=>		mg/kg dry	mg/kg dry			mg/kg dry		mg/kg dry	mg/kg dry	mg/kg dry				mg/kg dry	mg/kg dry	mg/kg dry
Antimony	Y	121.8	-	-	-	-		-		-	-	-	-	-	-	-	-	-
Arsenic	Y	74.9	-	6	33	10	BKG	17	SLC	<3	3-8	>8	-	-	-	8	14	20
Barium	N	137.3	-	-	-	500	BKG	-		<20	20-60	>60	-	-	-	-	-	-
Cadmium	Y	112.4	-	0.6	10	1	BKG	2.5	BIO	-	-	>6	-	-	-	1	3.5	4
Chromium	Y	52.0	-	26	110	100	BKG	100	BIO	<25	25-75	>75	-	-	-	25	120	120
Cobalt	N	58.9	-	50*	-	-		-		-	-	-	-	-	-	50	20	25
Copper	Y	63.5	-	16	110	100	BKG	85	BIO	<25	25-50	>50	-	-	-	25	100	100
Iron (%)	N	55.8	-	2	4	-		5.9	BKG	<1.7	1.7-2.5	>2.5	-	-	-	1	3.5	3.5
Lead	Y	207.2	-	31	250	50	BKG	55	BKG	<40	40-60	>60	-	-	-	50	60	900
Manganese	N	54.9	-	460	1100	-		1200	BKG	<300	300-500	>500	-	-	-	-	-	-
Mercury	Y	200.6	-	0.2	2	0.1	BKG	0.6	BKG	<1	-	>1	-	-	-	0.3	0.5	0.5
Nickel	Y	58.7	-	16	75	100	BKG	92	SLC	<20	20-50	>50	-	-	-	25	32	60
Selenium	Y	79.0	-	-	-	1	BKG	-		-	-	-	-	-	-	-	1.6	2
Silver	Y	107.9	-	0.5*	-	-		-		-	-	-	-	-	-	0.5	-	-
Zinc	Y	65.4	-	120	820	100	BKG	143	BKG	<90	90-200	>200	-	-	-	100	220	500
PESTICIDES/CHLOR. ORGS.			mg/kg dry	mg/kg dry	mg/kg OC			mg/kg OC					mg/kg OC	mg/kg OC	mg/kg OC	mg/kg dry	mg/kg dry	mg/kg dry
PCB	Y	M	0.01	0.07	530	0.05	BKG	4.00	SLC	-	-	-	0.29	-	-	0.05	<2.0	>2.0
PCB-1016	Y	M	-	0.007	53	-		0.75	SLC	-	-	-	-	-	-	-	-	-
PCB-1248	Y	M	-	0.03	150	-		3.50	SLC	-	-	-	-	-	-	-	-	-
PCB-1254	Y	M	-	0.06	34	-		5.75	SLC	-	-	-	-	-	19.5	-	-	-
PCB-1260	Y	M	-	0.005	24	-		-		-	-	-	-	-	-	-	-	-
2,3,7,8-TCDD	Y	322.0	-	-	-	3.3 E-4	EQP	-		-	-	-	-	-	-	-	-	-
2,3,7,8-TCDF	N	306.0	-	-	-	<1.0 pg/g		-		-	-	-	-	-	-	-	-	-
Aldrin	Y	362.0	-	0.002	8	0.01	BKG	0.20	SLC	-	-	-	-	-	-	-	-	-
BHC	Y	288.0	-	0.003	12	-		0.32	SLC	-	-	-	-	-	-	-	-	-
a-BHC	Y	288.0	-	0.006	10	-		0.60	SLC	-	-	-	-	-	-	-	-	-
b-BHC	Y	288.0	-	0.005	21	-		0.50	SLC	-	-	-	-	-	-	-	-	-
g-BHC (Lindane)	Y	288.0	0.0002	0.003	1	0.05	BKG	0.30	SLC	-	-	-	-	0.157	-	-	-	-
Chlordane	Y	M	0.005	0.007	6	0.01	BKG	0.75	SLC	-	-	-	0.098	-	-	-	-	-
g-Chlordane	Y	409.8	-	-	-	-		0.05	SLC	-	-	-	-	-	-	-	-	-
Chlorpyrifos	N	351.0	-	-	-	-		-		-	-	-	-	3.22	-	-	-	-
Dieldrin	Y	378.0	0.0006	0.002	91	0.01	BKG	1.90	SLC	-	-	-	0.021	19.9	0.13	-	-	-
Endrin	Y	378.0	0.0005	0.003	130	0.05	BKG	0.30	SLC	-	-	-	-	1.04	0.0532	-	-	-
Hexachlorobutadiene	Y	260.7	0.01	0.02	24	-		-		-	-	-	-	-	-	-	-	-
Heptachlor	Y	370.0	0.0003	-	-	0.05	BKG	0.20	SLC	-	-	-	-	-	0.11	-	-	-
Heptachlor epoxide	Y	386.0	-	0.005	5	-		-		-	-	-	0.008	-	-	-	-	-
Mirex	N	545.6	-	0.007	130	-		0.70	SLC	-	-	-	-	-	-	-	-	-
DDT (total)	Y	M	-	0.007	12	0.01	BKG	0.50	EQP	-	-	-	0.19	-	0.828	-	-	-
o,p'-DDT	Y	352.0	-	-	-	-		-		-	-	-	-	-	-	-	-	-
op+pp-DDT	Y	M	-	0.008	71	-		-		-	-	-	-	-	-	-	-	-
p,p'-DDD	Y	318.0	-	0.008	6	-		0.80	SLC	-	-	-	-	-	-	-	-	-
p,p'-DDE	Y	316.0	-	0.005	19	-		0.50	SLC	-	-	-	-	-	-	-	-	-
p,p'-DDT	Y	354.5	-	-	-	-		0.6,0.9	SLC	-	-	-	-	-	-	-	-	-
Ethyl parathion	N	291.3	-	-	-	-		-		-	-	-	-	0.081	-	-	-	-
Toxaphene	Y	M	-	-	-	0.05	BKG	-		-	-	-	-	-	-	-	-	-
Chloroform	Y	119.4	-	-	-	2.7	EQP	-		-	-	-	-	-	-	-	-	-
Methylene chloride	Y	84.9	-	-	-	126	EQP	-		-	-	-	-	-	-	-	-	-

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Table 1. Review of criteria and guidelines for contaminated freshwater sediments. See text for sources and methods.

	Text reference=>		A (Persaud et al. 1991) Provincial Sediment Quality Guidelines		B (WDNR,85,90) Wisconsin Dept. of Natural Resources	C (Hart et al. 1988) Sediment Quality Guidelines	D (EPA, 1977) EPA Region V Guidelines for the Pollutional Class. of Harbor Seds.			E (Neff et al. 1986) SLC for Freshwater Sediments	F (EPA, 1988) EPA Interim Sed. Criteria for Nonpolar Organics		G (Anon., 1988) Ont. Min. Environ. Dredged Mat'l Disposal Classification Criteria		
COMPOUND NAME	PP	Mol Wt.	No Effect	Lowest Effect	Severe Effect		Non Polluted	Moderately Polluted	Heavily Polluted		Chronic Basis	Residue Basis	Open Water	Unrestricted Land	Restricted Land
		METHODS=>	EQP	SLC	SLC	Note 1		BKG	BKG	BKG	SLC	EQP	EQP		Note 2	
PAH		UNITS=>		mg/kg dry	mg/kg OC		mg/kg OC					mg/kg OC				
PAH (Total)	-	M	-	2	11000	89 EQP	-	-	-	-	-	-	-	-	-	-
LPAH	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphthalene	Y	128.2	-	-	-	1240 EQP	-	-	-	-	-	-	-	-	-	-
2-Methylnapthalene	N	142.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acenapthylene	Y	152.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acenapthene	Y	154.2	-	-	-	92 EQP	-	-	-	-	732	-	-	-	-	-
Fluorene	Y	166.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	Y	178.2	-	-	-	-	-	-	-	-	139	-	-	-	-	-
Anthracene	Y	178.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HPAH	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	Y	202.3	-	-	-	1216 EQP	-	-	-	-	1883	-	-	-	-	-
Pyrene	Y	202.3	-	-	-	-	-	-	-	-	1311	-	-	-	-	-
Benzo(a)anthracene	Y	228.3	-	-	-	-	-	-	-	-	1317	-	-	-	-	-
Chrysene	Y	228.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzofluoranthenes	Y	252.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	Y	252.3	-	-	-	89 EQP	-	-	-	-	1063	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	Y	276.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	Y	276.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dibenzo(a,h)anthracene	Y	278.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER				mg/kg dry	mg/kg dry		mg/kg dry	mg/kg dry	mg/kg dry		mg/kg OC		mg/kg dry			
Oil & Grease	N	M	-	1500*	-	1000 BKG	-	<1000	1000-2000	>2000	-	-	-	1500	-	-
Volatile Solids (%)	N	M	-	-	-	-	-	<5	5-8	>8	-	-	-	-	-	-
Loss on Ignition (%)	N	M	-	-	-	-	-	-	-	-	-	-	-	6	-	-
COD	N	M	-	-	-	-	-	<40000	40000-80000	>80000	-	-	-	-	-	-
Cyanide	Y	26.0	-	0.1*	-	-	-	<0.10	0.10-0.25	>0.25	-	-	-	0.1	-	-
Total Phosphorous	N	M	-	600	2000	-	-	<420	420-650	>650	-	-	-	1000	-	-
Ammonia	N	17.0	-	100*	-	-	-	<75	75-200	>200	-	-	-	100	-	-
TOC (%)	N	M	-	1	10	-	-	-	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	N	M	-	550	4800	-	-	<1000	1000-2000	>2000	-	-	-	2000	-	-
Aniline	N	93.1	-	-	-	-	-	-	-	-	-	0.0662	-	-	-	-
Toluene	Y	92.2	-	-	-	5250 EQP	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	Y	106.2	-	-	-	11000 EQP	-	-	-	-	-	-	-	-	-	-

BKG - Background Method
SLC - Screening Level Method
EQP - Equilibrium Partitioning Method
BIO - Bioassay Method (Spiked)

mg/kg = ug/g = parts per million.
mg/kg dry = mg/kg dry weight.
mg/kg OC = mg/kg organic carbon

PP - Priority Pollutant.
M - Mixture, precise molecular weight is indeterminable.

METHODS> Means all entries in that column were derived using the method indicated. Methods used by WDNR (1985, 1990) and Ecology Consultants (Hart et al., 1988) are listed individually. See Note 1.
Note 1: BKG derived values reported in mg/kg dry weight. EQP derived values reported in mg/kg organic carbon.
Note 2: Methods data not currently available.
* For Provincial Sediment Quality Guidelines, indicates values borrowed from Ministry of Environment Dredged Disposal Criteria

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REFERENCES

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