BRITISH COLUMBIA

Ministry of Water, Land and Air Protection

CRITERIA FOR CONTAMINATED SITES

Criteria for Managing Contaminated Sediment in British Columbia

Technical Appendix

Prepared pursuant to Section 11.1(d) of the Contaminated Sites Regulation under the *Waste Management Act*

Approved: _____ _____

Director of Waste Management Date

For further information, contact:

Contaminated Sites Program
Environmental Management Branch
Environmental Protection Division
Ministry of Water, Land and Air Protection
P.O. Box 9342 Stn Prov Govt
Victoria, British Columbia V8W 9M1

Telephone: (250)-387-4441

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PREPARED BY

Michael W. Macfarlane[1], Donald D. MacDonald[2], and Christopher G. Ingersoll[3]

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[1] Contaminated Sites Program
Environmental Management Branch
Environmental Protection Division
Ministry of Water, Land and Air Protection
P.O. Box 9342 Stn Prov Govt
Victoria, British Columbia V8W 9M1

[2] MacDonald Environmental Sciences Ltd.
#24 - 4800 Island Highway North
Nanaimo, British Columbia V9T 1W6

[3] United States Geological Survey
4200 New Haven Road
Columbia, Missouri 65201

PREFACE

Traditionally, concerns relative to the management of aquatic resources have focussed primarily on water quality. However, contaminated sediments also represent an important environmental concern for several reasons. First, sediment-associated contaminants can be directly toxic to sediment-dwelling organisms. Secondly, contaminated sediments can impact fish communities through direct toxicity and reductions in the abundance of fish food organisms. Thirdly, certain contaminants can bioaccumulate in the food web and, in so doing, adversely affect piscivorous wildlife and human health. Bioaccumulation in fish and other aquatic organisms can also result in the imposition of consumption advisories for fish and shellfish that adversely affect the uses of aquatic ecosystems. Finally, contaminated sediments can compromise human health due to direct exposure during wading or swimming. As such, contaminated sediments in freshwater, estuarine, and marine ecosystems pose potential hazards to aquatic organisms, aquatic-dependent wildlife species, and human health (Long and Morgan 1991; Ingersoll *et al.* 1997).

In British Columbia, the federal and provincial governments share authority for assessing and managing contaminated sediments and their effects in the environment, under the *Fisheries Act* (*FA*), the *Canadian Environmental Protection Act (CEPA), 1999* and, the *Waste Management Act (WMA)*. Currently, standard procedures for assessing contaminated sediments have not been established by either order of government. In addition, sediment quality criteria (SedQC) have not been formally established for assessing or managing contaminated sites. Consequently, decisions regarding the selection of assessment procedures and the establishment of remedial targets are being made on a site-by-site basis. It is the position of the agencies, referenced below, that this approach is unsustainable in the longer term.

In recognition of the need to establish harmonized procedures for assessing and managing contaminated sites in British Columbia, a federal/provincial sediment technical committee, consisting of representatives of the British Columbia Ministry of Water, Land, and Air Protection (BCWLAP; the Ministry), Environment Canada (EC), and Fisheries and Oceans Canada (DFO) was established in January, 1998. This committee, known as the ***Federal/Provincial***

Technical Committee on the Development of Sediment Quality Criteria for Assessing and Managing Contaminated Sites, was charged with the task of developing a framework for assessing and managing contaminated sediments, a guidance manual to support the design and implementation of sediment quality assessments at contaminated sites, and SedQC to support the management of contaminated sediments in British Columbia. In the ensuing four years, the committee produced the following documents:

- ***Director's Criteria for Managing Contaminated Sediment Sites: Criteria for Managing Contaminated Sediment in British Columbia***; (BCWLAP 2003);
- ***Criteria for Managing Contaminated Sediment in British Columbia: Technical Appendix.*** (Macfarlane *et al.* 2003);
- ***Development and Applications of Sediment Quality Criteria for Managing Contaminated Sediment in British Columbia*** (MacDonald *et al.* 2003);
- ***Guidance Manual to Support the Assessment of Contaminated Sediment in Freshwater, Estuarine, and Marine Ecosystems in British Columbia: Volume I - An Ecosystem-Based Framework for Assessing and Managing Contaminated Sediments*** (MacDonald and Ingersoll 2003a);
- ***Guidance Manual to Support the Assessment of Contaminated Sediment in Freshwater, Estuarine, and Marine Ecosystems in British Columbia: Volume II - Design and Implementation of Sediment Quality Investigations in Freshwater Ecosystems*** (MacDonald and Ingersoll 2003b);
- ***Guidance Manual to Support the Assessment of Contaminated Sediment in Freshwater, Estuarine, and Marine Ecosystems in British Columbia: Volume III - Interpretation of the Results of Sediment Quality Investigations*** (Ingersoll and MacDonald 2003); and,
- ***Guidance Manual to Support the Assessment of Contaminated Sediment in Freshwater, Estuarine, and Marine Ecosystems in British Columbia: Volume IV - Supplemental Guidance on the Design and Implementation of Detailed Site Investigations in Marine and Estuarine Ecosystems*** (MacDonald and Ingersoll 2003c).

These documents describe the framework for assessing and managing contaminated sediments in B.C., provide guidance on the assessment of contaminated sediments, and present the numerical SedQC and their applications that were recommended by the committee members.

Under the tiered management process set forth under the Contaminated Sites Regulation (CSR), a responsible party may choose between either the criteria-based approach or the risk-based approach to address concerns regarding sediment quality conditions at a contaminated site. In the criteria-based approach, evaluations of sediment chemistry data, at a site are conducted using sediment chemistry data, in conjunction with the SedQC. In the risk-based approach, multiple lines of evidence are used to support decision-making activities at a site. It may be appropriate to select the criteria-based approach (i.e., which relies on the assessment of whole-sediment chemistry data using numerical SedQC) at small sites where the costs of collecting the detailed data needed to support human and ecological risk assessments are likely to exceed remediation costs. At larger, more complex sites, the costs associated with conducting detailed risk assessments may be justified to reduce uncertainties and focus limited resources on selecting the remedial actions that provide the greatest benefits relative to human health and the environment. Regardless of the size or complexity of a site, the remediation of sediments **may not** be approved by the regulatory agencies if the resulting remedial impacts are more significant than leaving the sediments in place.

Central to the Ministry's view to remediating sediment quality and restoring ecosystem health is that control of contaminants at their source remains the primary imperative for remedial actions. Only through the abatement of inputs of contaminants to the receiving environment can other sediment management actions, such as sediment removal, be economically viable, ecologically relevant, and sustainable.

This document describes the application of the generic SedQC only. It is intended to identify the requirements and expectations for sites where the responsible persons (as defined in the *Waste Management Act*; BC 1996) have elected to remediate sediments to achieve final contaminant concentrations in

sediments that are less than or equal to the criteria. It is important to understand that the SedQC presented in this document are not intended to be used to assess ambient sediment quality conditions or to establish sediment quality objectives at sites other than those identified under the CSR.

Additional information on the assessment and remediation of contaminated sites is provided in the detailed companion document entitled, *Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater, Estuarine, and Marine Ecosystems in British Columbia* (MacDonald and Ingersoll 2003a; 2003b; 2003c; Ingersoll and MacDonald 2003). Guidance on the derivation of site-specific criteria is provided in MacDonald *et al.* (2003), while information on the application of the risk-based approach to site remediation is provided in BCE (1998a) and USEPA (1989). The steps that should be undertaken to conduct an assessment of the risks to aquatic receptors associated with exposure to contaminated environmental media is provided in MacDonald *et al.* (2002).

Environment Canada, Fisheries and Oceans Canada and the Ministry are committed to a periodic review of these criteria, and the approach used to establish them, in order to ensure that they are consistent with the best scientific information available at the time.

1.0 INTRODUCTION

The provincial *Waste Management Act* provides detailed guidance on a range of issues related to the assessment and management of contaminated sites, including standards for soil and water. While no specific guidance on the management of contaminated sediments was established in the CSR, the need to develop such guidance is indicated in the *Waste Management Act*. Specifically, Section 26(1) of the *Act* states that:

> *"a contaminated site means an area of land in which the soil or any groundwater lying beneath it, or the water or the underlying sediment, contains: a special waste; or, another prescribed substance in quantities or concentrations exceeding prescribed criteria, standards, or conditions."*

Thus, criteria for assessing and remediating contaminated sediments in freshwater, estuarine, and marine environments are required to support the assessment and management of sediments at contaminated sites in British Columbia and to ensure such work is undertaken in a consistent and logical manner.

The regulatory authority under which the Director may establish standards for use in the assessment and remediation of contaminated sites can be found in Section 26(1) of the *Waste Management Act* (BC 1996) and Section 11(1)(d) of the Contaminated Sites Regulation (BC 2002).

This document provides additional guidance to and details on the Ministry's ***Criteria for Managing Contaminated Sediment in British Columbia***. These criteria are to be used to determine if sediments are contaminated, to assess the need for remedial measures, and to develop remediation targets (i.e., target clean-up concentrations of chemicals of potential concern [COPCs]) for sediments at contaminated sites. The definitions and terms used in this document are included in Appendix 1.

2.0 EXISTING FRAMEWORK FOR MANAGING CONTAMINATED SITES IN BRITISH COLUMBIA

The procedures for assessing and remediating contaminated sites that fall under provincial jurisdiction are specified in two components of the *Waste Management Act*, including the CSR and the Special Waste Regulation. The site management process proposed under the CSR is intended to establish rules for assessing and remediating contaminated sites in the province. The process consists of five main elements, including site identification and screening; site investigation and determination/decision; planning; remediation; and, monitoring and evaluation. However, every site need not proceed through each component of the process (MacDonald and Ingersoll 2003a; 2003b). The following summary of the framework in intended to provide an overview of the existing contaminated site management process (Figure 1). More detailed information on the elements of this framework is included in the CSR and in a series of associated Fact Sheets that have been published by the Ministry.

2.1 SITE IDENTIFICATION AND SCREENING

The first step in the site assessment and management process involves screening the site under consideration. This step in the process is initiated through the preparation of a site profiles. In British Columbia, site profiles must be submitted to the responsible government agency when an application for subdivision, zoning, development, demolition of a structure, or removal of soil is received by a local government or when ordered by a regional manager. Following its submission, the site profile is assessed by provincial or local government official and a determination is made regarding the need for further investigations at the site. No further action is required at sites that are considered not to be potentially contaminated.

2.2 SITE INVESTIGATION AND DETERMINATION

Information from the site profile or other sources may indicate that a site is potentially contaminated. In this situation, preliminary and/or detailed site investigations (i.e., PSIs and DSIs) may be required to determine if the site is contaminated, as defined under the CSR. Initially, a Stage I PSI is conducted to determine the probability that a site is contaminated. This assessment is conducted using archival records, conducting site visits, and relying on knowledge of the historical activities that were conducted on site. Next, a Stage II PSI or a DSI is conducted to provide the additional information needed to confirm or refute the potential for site contamination, primarily by sampling and chemical analysis of environmental media. The results of the Stage II PSI and/or DSI are used to determine if a site is contaminated, as defined under the CSR. More specifically, the measured concentrations of COPCs in whole sediments from the site are compared to the numerical SedQC to determine if the site is contaminated. The determination of whether a site is contaminated (as defined under the CSR) is generally made by the Director. Detailed guidance on the information requirements for PSIs and DSIs is provided in MacDonald and Ingersoll (2003b; 2003c).

2.3 SITE MANAGEMENT PLANNING

The first priority in the planning stage of the site management process is to determine who is potentially responsible for the contamination and who is potentially liable for clean-up costs. In addition, the need for and relative priority for remediation is assessed at this stage of the process. Other important planning steps include activating the remediation process (either through a voluntary remediation agreement or a remediation order), developing a remediation action plan, and initiating the approvals process.

The development of sediment quality standards (SedQS) represents another important step in the site management planning process. The legislation provides for the use of two distinct approaches to the establishment of SedQS at sediment contaminated sites, including the criteria-based approach and the risk-based

approach. Using the criteria-based approach, SedQS may be established by directly adopting the SedQC or by deriving site-specific SedQS. By comparison, risk-based SedQSs can be established at risk levels that are less than or equal to those upon which the sediment quality criteria are based (i.e., a 20% probability of an EC_{20} or greater for sensitive sites and a 50% probability of an EC_{20} or greater for typical sites). Such numerical or risk-based standards can be used for determining if remedial measures are required at the site and if they have been satisfactorily completed.

2.4 REMEDIATION

The remediation step in the process covers all of the activities that are associated with cleaning-up or securing a contaminated site. The legislation defines two broad types of remediation, including removal of contaminated materials (so that they no longer remain at the site) and treatment of the contaminated materials on-site. The legislation also provides environmental quality standards that are used to determine when the cleanup is complete. Alternatively, risk-based procedures may be used to determine the level of contamination that can remain on-site. In such situations, additional institutional controls may have to be established to assure that specific uses of the site and nearby areas are not unacceptably impacted.

2.5 MONITORING AND EVALUATION

Following the implementation of remedial measures, confirmatory sampling and analysis is normally conducted to determine if they have reduced the level of contamination or risk to tolerable levels. A Certificate of Compliance (C of C) is issued if the numerical standards in the CSR have been satisfied or if risk-based standards and related assessment procedures have been appropriately applied. When the contamination is managed on-site, certain conditions must be met by the site manager. Such conditions are generally established to assure the protection of the environment and human health, or the notification of potentially affected parties (e.g., future site owners).

3.0 DEVELOPMENT NUMERICAL SEDIMENT QUALITY CRITERIA FOR SEDIMENT CONTAMINATED SITES

Numerical SedQC were developed to support the assessment and management of sites with contaminated sediments in British Columbia (Table 1 and 2). This section of the document describes the purpose of the SedQC, the factors that were considered in establishing the SedQC, and the approach that was used to derive the SedQC. In addition, the results of an evaluation of the numerical SedQC is presented to provide essential information on the extent to which the SedQC are consistent with their narrative intent (i.e., to assess their reliability). Finally, guidance is provided to support the assessment of sites that are known or suspected to contain bioaccumulative COPCs.

3.1 PURPOSE OF THE SEDIMENT QUALITY CRITERIA

This document presents the SedQC for assessing and managing contaminated sediments in British Columbia. The criteria presented in this document are intended to apply to sites with contaminated sediments. The SedQC are intended to apply throughout sediment contaminated sites. In the context of the document, aqueous sediments are defined as sedimentary deposits comprised primarily of particles < 6.35 mm (Singleton 1995).

As indicated above, the criteria presented in this document are solely intended to facilitate the assessment and management of sediments at contaminated sites. They are not intended to replace the sediment quality guidelines (SQGs) that have been established to support broader environmental management objectives in the Province (BCE 1998b; CCME 1999). That is, the SQGs continue to represent the long-term targets for sediments in all areas, except those regulated under the CSR. It is important to note that the SedQC are intended to define the concentrations of sediment-associated contaminants which, if exceeded, pose unacceptable risks to sediment dwelling organisms. However, these effects-based SedQC may not

provide an adequate basis for assessing risks to piscivorous wildlife or human health that are associated with food web transfer of persistent, bioaccumulative substances from sediments to aquatic organisms. For this group of substances, bioaccumulation-based SedQC are also needed to support the assessment and management of contaminated sediments. Such SedQC values are largely unavailable at this time, however. Currently, bioaccumulation risks are most effectively assessed through the application of tissue residue guidelines (TRGs) and related approaches (CCME 1999).

The criteria contained in this document should not be used alone in situations where contaminants may be released from sediments or where contaminated sediments may be deposited elsewhere. Additional factors (such as the potential for off-site impacts, etc.) need to be assessed and applicable policy and regulatory requirements need to be considered under such circumstances. For example:

- The provisions of the Special Waste Regulation (BC 1988) provide a basis for *in-situ* management and classification of special wastes;
- The Contaminated Site Regulation (BC 1997; 2002) defines the maximum acceptable concentrations for COPCs for disposal on land and specifies groundwater protective thresholds;
- Pursuant to the *Waste Management Act* (BC 1996), persons conducting or providing remediation must give preference to alternatives that provide permanent solutions to the maximum extent practicable; and,
- It is Ministry preference that for certain types of substances (e.g., non-aqueous phase liquid; NAPL) removal be undertaken to the extent feasible and that these materials be disposed of appropriately.

In addition to these special circumstances, a tiered-testing approach has been specified by Environment Canada for evaluating the acceptability of dredged materials for open water disposal.

Caution needs to be applied at sites containing materials other than fine sediments that could be present below bodies of water, such as gravel, cobble, boulders, logs, wood fiber, hog fuel, slag, tires, paint chips, asphalt, or solidified coal tar.

The criteria herein were not expressly developed in consideration of these materials; nevertheless, these materials could pose potential hazards to the health of benthic invertebrate communities and/or to other organisms. The criteria herein may be used at sites containing such materials; however, the potential impacts are best addressed on a site specific basis.

3.2 FACTORS CONSIDERED IN ESTABLISHING THE SEDIMENT QUALITY CRITERIA

The narrative objectives set forth herein recognize that water-based economic activities (such as shipping, operation of small craft marinas, waterfront development, and tourism-related activities) are essential to the vitality of communities in the province. While these activities contribute significantly to the local economies, they also have the potential to degrade water quality conditions (i.e., through spills or stormwater runoff) and/or reduce the stability of sediments (i.e., through navigational dredging or disturbance by the wash from vessel propellers). The agencies do not expect, nor propose, that these activities cease in the province. Rather, these agencies recognize that the potential for maintaining an unaltered benthic invertebrate community is likely reduced in these areas, even in the absence of chemical contamination in the sediments.

In recognition of the challenges that are associated with the management of sediments at contaminated sites in British Columbia, two types of narrative effects-based SedQC were established for assessing and managing contaminated sediments (Table 1):

- Sediment Quality Criteria for Sensitive Contaminated Sites ($SedQC_{SCS}$); and
- Sediment Quality Criteria for Typical Contaminated Sites ($SedQC_{TCS}$).

Both types of SedQCs are intended to identify the concentrations of COPCs below which risks to sediment-dwelling organisms are considered to be tolerable (i.e., $\leq EC_{20}$). Because sensitive contaminated sites contain species or habitats of special importance, the SedQC are established at levels that ensure that the

frequency of adverse effects is low at these types of sites. The $SedQC_{SCS}$ and $SedQC_{TCS}$ are intended to offer a high and a moderate level of protection for sediment-dwelling organisms, respectively. However, the narrative objectives for both sets of effects-based SedQC do not address the potential for bioaccumulation, nor the associated effects on those species that consume aquatic organisms (i.e., wildlife and humans). The tissue residue guidelines presented in Table 2 provide a basis for determining if bioaccumulative substances occur in the tissues of aquatic organisms at levels that pose hazards to aquatic-dependent wildlife.

3.3 APPROACH TO ESTABLISHING THE SEDIMENT QUALITY CRITERIA

Both theoretical and empirical approaches have been used to derive SQGs for freshwater, estuarine, and marine ecosystems in North America. Seven distinct approaches were evaluated to support the selection of procedures for deriving SedQC for contaminated sites in the province, including: the screening level concentration, effects range and effects level, apparent effects threshold, equilibrium partitioning, logistic regression modeling, consensus-based, and tissue residue approaches (Crane *et al*. 2000; MacDonald *et al.* 2003). Following a review of these approaches, the Federal/Provincial Technical Committee developed a strategy for deriving numerical SedQC that consisted of several steps, including:

- Establishment of sediment management objectives (SMOs) for sediment contaminated sites;
- Identification of preliminary benchmarks for sediment chemistry;
- Development of concentration-response relationships for COPC mixtures in freshwater and marine sediments; and,
- Derivation of numerical SedQC.

Each of these steps are described in detail in MacDonald *et al.* (2003) and briefly in the following sections of this report.

3.3.1 ESTABLISHMENT OF SEDIMENT MANAGEMENT OBJECTIVES

The Federal/Provincial Technical Steering Committee has established SMOs for both sensitive contaminated sites and typical contaminated sites. These SMOs articulate the narrative intent of the SedQC that are to be established for the sediment contaminated site. At sites with sensitive habitats, the principal SMOs are to restore sediments to a state that will facilitate restoration of productive and diverse benthic macroinvertebrate communities in the ***near-term*** and to minimize the risks to organisms at higher trophic levels in the food web. For this reason, the SedQC for sensitive sites ($SedQC_{SCS}$) need to be established at levels that provide a relatively high level of protection for sediment-dwelling organisms. That is, the $SedQC_{SCS}$ need to define concentrations of COPCs below which there is a relatively low probability (i.e., roughly 20%) of observing statistically significant adverse effects in standardized toxicity tests with sensitive benthic species and life stages.

At typical contaminated sites, the principal SMOs are to restore sediments to a state that will facilitate restoration of productive and diverse benthic macroinvertebrate communities in the ***longer-term*** and to minimize the risks to organisms at higher trophic levels in the food web. For this reason, the $SedQC_{TCS}$ need to be established at levels that provide a moderate level of protection for sediment-dwelling organisms. That is, the $SedQC_{TCS}$ are intended to define the concentrations of COPCs below which there is a moderate probability (i.e., about 50%) of observing statistically significant adverse effects in standardized toxicity tests with sensitive benthic species and life stages.

3.3.2 IDENTIFICATION OF PRELIMINARY BENCHMARKS FOR SEDIMENT CHEMISTRY

Because they have been developed for use throughout Canada and because they have been extensively evaluated, the Canadian sediment quality guidelines were used to establish the preliminary benchmarks for sediment chemistry (CCME

1999). More specifically, the probable effect levels (PELs) were adopted as the preliminary benchmarks for sediment chemistry because their narrative intent was generally consistent with the SMOs that were defined earlier. Accordingly, the PELs provided a useful starting point for developing SedQC that specifically addressed the SMOs for typical and sensitive contaminated sites. At this stage of the process, it was understood that the preliminary benchmarks would need to be refined to be consistent with the SMOs for the two types of sites.

3.3.3 DEVELOPMENT OF CONCENTRATION-RESPONSE RELATIONSHIPS FOR COPC MIXTURES IN FRESHWATER AND MARINE SEDIMENTS

Although the PELs were generally consistent with the SMOs that were established for sediment contaminated sites, they required refinement before they could be applied at typical and sensitive contaminated sites. To facilitate refinement of the PELs, matching sediment chemistry and sediment toxicity data from throughout North America were compiled and used to derive concentration-response relationships for sediments containing complex mixtures of COPCs. These relationships described how the frequency of response (i.e., incidence of toxicity to freshwater or marine amphipods) changed with increasing concentrations of COPCs [i.e., as estimated by mean PEL-quotients (PEL-Qs)]. Mean PEL-Qs are calculated as follows:

$$\text{Mean PEL-Q} = \frac{\text{Mean PEL-Q}_{\text{metals}} + \text{mean PEL-Q}_{\text{PAHs}} + \text{PEL-Q}_{\text{tPCBs}}}{n}$$

where:

PEL-Q = COPC concentration (in dry wt.) / corresponding PEL for that COPC; and,

n = number of classes of chemicals for which sediment chemistry data were available (i.e., 1 to 3).

Mean PEL-Q_{metals} is calculated using the data and PELs for arsenic, cadmium, chromium, copper, mercury, lead, and zinc.

Mean PEL-Q_{PAHs} is calculated using the data and PELs for up to 13 parent polycyclic aromatic hydrocarbons (PAHs)

The resultant concentration-response relationships are presented in MacDonald *et al.* (2003). These relationships make it possible to determine the concentration of COPCs (i.e., mean PEL-Qs) that corresponded to a 20% incidence of sediment

toxicity (i.e., a 20% probability of observing roughly a 20% reduction in survival, which is referred to as the P_{20} value) and a 50% incidence of sediment toxicity (i.e., a 50% probability of observing roughly a 20% reduction in survival, which is referred to as the P_{50} value). The P_{20} value and the P_{50} value are consistent with the SMOs for sensitive and typical contaminated sites, respectively.

3.3.4 DERIVATION OF NUMERICAL SEDIMENT QUALITY CRITERIA

Because they were directly relevant to the SMOs for sensitive and typical contaminated sites, the P_{20} and P_{50} values were used to refine the preliminary benchmarks for sediment chemistry (i.e., to calculate numerical SedQC; Table 1). More specifically, the $SedQC_{SCS}$ for both marine and estuarine sites and freshwater sites were established by multiplying the PELs for individual COPCs by the P_{20} value for freshwater sediments (0.62; it was not possible to determine a P_{20} value for marine sediments; MacDonald *et al.* 2003). Similarly, the $SedQC_{TCS}$ were established by multiplying the PELs for individual COPCs by the average P_{50} value for freshwater and marine sediments (1.2; MacDonald *et al.* 2003). Hence, the $SedQC_{SCS}$ are considered to define the concentrations of COPCs below which there is a $\leq$20% probability of observing significant adverse effects on sediment-dwelling organisms. By comparison, the probability of observing toxicity to sensitive sediment-dwelling organisms is considered be $\geq$50% at COPC concentrations above the $SedQC_{TCS}$ (i.e., based on the results of 28- to 42-d toxicity tests with the freshwater amphipod, *Hyalella azteca*, and 10-d toxicity tests with the marine amphipods, *Ampelisca abdita* and *Rhepoxynius abronius*).

3.4 EVALUATION OF THE SEDIMENT QUALITY CRITERIA

In response to stakeholder concerns received by the Ministry during the reviews of the draft Criteria document, it was agreed that an evaluation of the reliability of the SedQC would be conducted and used to determine if they generally met their narrative intent (i.e., the SMOs). The evaluation of effects-based SedQC for the protection of sediment-dwelling organisms focussed on SedQC for seven trace metals, 13 individual PAHs, total PAHs, total PCBs, nine organochlorine pesticides, and 2,3,7,8-tetrachlorodibenzo-*p*-dioxins toxic equivalents (2,3,7,8-TCDD TEQs). The evaluations of reliability were conducted using the refined SEDTOX database, which encompasses data from Canada and the United States (USEPA 2000; Field *et al.* 1999; 2002). In this evaluation, the $SedQC_{SCS}$ were considered to provide a highly reliable basis for assessing the quality of sediments if the incidence of sediment toxicity below the criteria values was less than 20%. The $SedQC_{TCS}$ values were considered to be highly reliable if greater than 50% of the sediment samples with COPC concentrations above the criteria values were toxic to sediment-dwelling organisms. The SedQC were considered to be moderately reliable if the observed incidence of toxicity was within 10% of the target level for that type of SedQC (i.e., <30% incidence of toxicity for SQC_{SCS} and >40% incidence of toxicity for SQC_{TCS}). A lower level of reliability was ascribed if the incidence of toxicity deviated by more than 10% from the target level for that type of SedQC. Such evaluations were conducted if 10 or more samples were available for the concentration interval under consideration (i.e., <$SedQC_{SCS}$).

The results of this evaluation demonstrated that the $SedQC_{SCS}$ generally provide a reliable basis for identifying COPC concentrations below which there is a low probability of observing toxicity to freshwater or marine amphipods (MacDonald *et al.* 2003). For metals, the incidence of sediment toxicity ranged from 13% (lead; n=203) to 32% (chromium; n=72) at COPC concentrations below the $SedQC_{SCS}$ for freshwater sediments and from 14% (copper; n=1358) to 27% (arsenic; n=1780) at COPC concentrations below the $SedQC_{SCS}$ for marine sediments. The incidence of toxicity to freshwater and marine amphipods was also low (8 to 21%, n=145 to 204; and, 12 to 19%, n=1163 to 1374, respectively) when concentrations of individual PAHs or total PAHs were below the $SedQC_{SCS}$.

For total PCBs, the incidence of toxicity below the $SedQC_{SCS}$ was 7% for freshwater sediments (n=123) and 11% for marine sediments (n=1207). The incidence of sediment toxicity was also less than 20% at COPC concentrations below the $SedQC_{SCS}$ for 7 of 9 (n=27 to 178) and 8 of 9 (n=927 to 1546) organochlorine pesticides in freshwater and marine sediments, respectively. Finally, the incidence of toxicity was 20% in freshwater (n=5) and marine (n=20) sediments with concentrations of 2,3,7,8-TCDD TEQs below the $SedQC_{SCS}$. By comparison, the incidence of sediment toxicity was generally much higher [i.e., 50 to 100% for freshwater sediments (n=33 to 70) and 39 to 100% for marine sediments (n=2 to 518)] at COPC concentrations above the $SedQC_{SCS}$ (i.e., when the SQC_{SCS} was exceeded by any amount). Collectively, these results indicate that the $SedQC_{SCS}$ for 29 of 33 substances were highly or moderately reliable for assessing freshwater sediments and that the $SedQC_{SCS}$ for all 33 were highly or moderately reliable for assessing marine and estuarine sites.

The $SedQC_{TCS}$ were also found to provide a reliable basis for identifying COPC concentrations above which there is a relatively high probability of observing toxicity to freshwater or marine amphipods. For metals, the incidence of sediment toxicity ranged from 62% (zinc; n=45) to 89% (cadmium; n=35) at COPC concentrations above the $SedQC_{TCS}$ for freshwater sediments and from 33% (arsenic; n=12) to 78% (cadmium; n=63) at concentrations above the $SedQC_{TCS}$ for marine sediments. The incidence of toxicity to freshwater and marine amphipods was also elevated (48 to 89%, n=20 to 45; and, 61 to 79%, n=84 to 277, respectively) when concentrations of individual PAHs or total PAHs were above the $SedQC_{TCS}$. For total PCBs, the incidence of toxicity above the $SedQC_{TCS}$ was 54% for freshwater sediments (n=26) and 69% for marine sediments (n=235). The incidence of sediment toxicity was greater than 50% at COPC concentrations above the $SedQC_{TCS}$ for 8 of 9 (n=1 to 36) and 7 of 9 (n=1 to 304) organochlorine pesticides in freshwater and marine sediments, respectively. Finally, the incidence of toxicity was 75% in freshwater sediments (n=4) and 100% in marine sediments (n=8) with concentrations of 2,3,7,8-TCDD TEQs above the $SedQC_{TCS}$. Collectively, these results demonstrate that the $SedQC_{TCS}$ for 28 of 33 substances were highly or moderately reliable for assessing freshwater sediments, while the $SedQC_{TCS}$ for 30 of 33 substances were highly or moderately reliable for assessing marine and estuarine sediments.

The highly reliable and moderately reliable SedQC should be used directly at contaminated sites in the province. In addition, those SedQCs with lower reliability can also be used to assess and manage sediment quality conditions. However, a responsible person may wish to derive site-specific SedQC in such cases to reduce uncertainty in the assessment. MacDonald *et al.* (2003) provide guidance on the derivation of such site-specific SedQCs.

3.5 Evaluation of Sediment Quality Conditions at Sites that are Contaminated with Bioaccumulative Substances

The effects-based SedQC promulgated in this document (Table 1) were developed to define the concentrations of COPCs that need to be achieved at sensitive and typical contaminated sites to facilitate the restoration of productive and diverse benthic macroinvertebrate communities in the near-term and the longer-term, respectively. Although numerical SedQC are also needed to define tolerable levels of COPCs relative to the protection of aquatic-dependent wildlife and human health, insufficient information is currently available to establish defensible SedQC for these uses of aquatic ecosystems. Nevertheless, the TRGs presented in Table 2 provide a basis for determining if bioaccumulative substances are likely pose unacceptable risks to aquatic-dependent wildlife (See Section 5.0). These TRGs should be applied to all sites that are known or suspected to be contaminated with bioaccumulative COPCs.

4.0 Applications of Numerical Sediment Quality Criteria

The numerical effects-based SedQC that are presented in Table 1 are intended to provide a basis for assessing and managing contaminated sediments throughout British Columbia. Accordingly, this section of the document describes the intended uses of these SedQC and presents the administrative rules that govern

their application of the SedQC at sensitive and typical sites in the province. The applications of the SedQC for identifying sites with contaminated sediments and for establishing remedial targets for sediment contaminated sites are also discussed. Finally, a number of considerations relating to the assessment and remediation of contaminated sediments are described.

4.1 INTENDED USES OF THE SEDIMENT QUALITY CRITERIA

The SedQC presented herein are intended to serve as benchmarks which define the conditions needed to protect sediment-dwelling organisms at sites with contaminated sediments. These benchmarks may be used in a variety of ways, including:

- As indicators of sediment quality at a site (i.e., during site screening);
- For identifying the COPCs (i.e., during site investigation);
- To support the design of sampling programs (i.e., during site investigation);
- For interpreting sediment chemistry data (i.e., during site investigation);
- For identifying potentially unacceptable levels of risk to the environment at a site (i.e., during site investigation);
- For determining if a site is contaminated (i.e., during site investigation);
- For determining the factors that are most likely associated with measured or potential effects (i.e., sediment toxicity);
- For determining if site remediation, risk assessment, or risk management are necessary (i.e., following detailed site investigation);
- As a basis for establishing site management goals and remediation targets (i.e., during remedial action planning);
- As a basis for developing legally-enforceable standards (i.e., during remediation planning);

- For evaluating the adequacy of site remediation (i.e., confirming that site remediation has been successfully completed); and,
- For the purposes of issuing certification of satisfactory site remediation.

The criteria are not intended to be applied or interpreted as thresholds to pollute up to. Nor should they be interpreted as acceptable thresholds for ambient environmental quality outside of the boundaries of a contaminated site.

4.2 ADMINISTRATIVE RULES FOR APPLYING SEDIMENT QUALITY CRITERIA AT SENSITIVE CONTAMINATED SITES

The $SedQC_{SCS}$ values apply to sites identified as meeting the definition of a sensitive contaminated site as established in Schedule 2. These criteria are considered to be broadly applicable because differences in land use activities do not influence the importance of sediments to benthic organisms (i.e., sediments represent essential habitats for benthic organisms). The information in Schedule 2 and other supporting documentation will be used by the agencies to determine if the $SedQC_{SCS}$ apply at a contaminated site.

One of the most important uses of the SedQC is for determining if a sensitive site is contaminated, as defined under the CSR. In this application, the SedQC are used during Stage 1 or Stage II of the preliminary site investigation. In the Stage I PSI, the existing sediment chemistry data for the site are collected, collated, and evaluated to determine if they are sufficient for making the determination (MacDonald and Ingersoll 2003b). Some of the factors that need to be considered when evaluating the existing data include: the age of the data, the geographic coverage of the data, the analytes measured (as compared to the COPCs for the site), the quality of the data (i.e., accuracy, precision, detection limits), sampling depth, and the sampling design utilized. In the event that insufficient data are available, then a Stage II PSI needs to be conducted to acquire the sediment chemistry data required to complete the determination.

Following acquisition of the necessary and sufficient information on the chemical characteristics of sediments, the sediment chemistry data for the site is compared to the numerical SedQC. To ensure the proper application of the SedQC, administrative rules have been established to guide determinations of sites as contaminated or uncontaminated. The administrative rules for sensitive contaminated sites state that:

1. A sensitive site is a contaminated site if any of the following conditions exist:
   - The 90th percentile concentration of one or more COPCs equals or exceeds their respective $SedQC_{SCS}$ (i.e., 9 of 10 measurements must be below the SedQC to designate a site as uncontaminated) and exceeds upper limit of background for that substance (i.e., mean + 2SD);
   - The concentration of one or more analytes exceeds their respective $SedQC_{SCS}$ by a factor of two or more in any sediment sample and exceeds upper limit of background for that substance (i.e., mean + 2SD);
   - The 90th percentile mean $SedQC_{SCS}$-quotients ($SedQC_{SCS}$-Q) for the contaminant mixture equals or exceeds 1.0 (see Appendix 1 for more information on the calculation of mean SedQC-Qs); or,
   - The mean $SedQC_{SCS}$-Q for the contaminant mixture in any sediment sample equals or exceeds 2.0.

2. The $SedQC_{SCS}$ are to be applied to a depth of 100 cm (i.e., 0-100 cm) in areas where the sediment bed has been demonstrated to be stable (i.e., non-erosional, not subject to navigational dredging).

3. The $SedQC_{SCS}$ will apply to depths of greater than 100 cm in areas where the sediment bed has been demonstrated to be unstable (i.e., erosional, subject to navigational dredging) or the stability of the bed is unknown.
4. The $SedQC_{SCS}$ will apply to depths of greater than 100 cm in areas where it is demonstrated that there is on-going transport of COPCs

from depth into the shallower portions of the sediment bed at rates capable of contaminating sediments in the top 100 cm to levels exceeding the $SedQC_{SCS}$.

5. The $SedQC_{SCS}$ must be used during the site investigation process to determine if a sensitive site contains contaminated sediments.

6. The $SedQC_{SCS}$ will apply at contaminated sites that have sediments that border or include habitat protection or conservation zones, or where biological habitat mapping [e.g., such as has been conducted by Fraser River Estuary Management Program (FREMP) or Burrard Inlet Environmental Action Plan (BIEAP)] have designated the area as a high productivity zone. Schedule 2 provides a checklist of factors to be considered in applications to the Ministry in support of the selection of SedQC values.

7. The $SedQC_{SCS}$ should be used to determine if remedial measures are needed at a sensitive site and to establish target cleanup goals for contaminated sediments.

8. The presence of sediments containing contaminant concentrations qualifying as Special Wastes as defined under the Special Waste Regulation, necessitates exceptions to the limits of potential remedial actions. Where Special Waste is present, remedial measures should focus on the removal of these wastes, to the extent feasible. The handling, treatment and disposal of these materials is to be conducted in accordance with the provisions of the Special Waste Regulation.

4.3 ADMINISTRATIVE RULES FOR APPLYING SEDIMENT QUALITY CRITERIA AT TYPICAL CONTAMINATED SITES

The $SedQC_{TCS}$ values can be applied at most contaminated sites (i.e., sites of simple to moderate complexity) to establish clean-up targets to guide the design and implementation of remedial action plans (i.e., decisions regarding the remediation of contaminated sites can be made using sediment chemistry data alone).

More comprehensive assessments (i.e., using the risk-based approach) should be considered and conducted at sites with large volumes of contaminated sediments, at sites that are contaminated with highly bioaccumulative substances, and/or sites with substances for which $SedQC_{TCS}$ are not currently available (i.e., sites of medium to high complexity). Such assessments should be designed to obtain high quality data on the concentrations of COPCs in sediments, on the toxicity of sediments, on the structure of benthic macroinvertebrate communities, and on the levels of bioaccumulative substances in fish and invertebrate tissues.

At typical sites, pollution prevention initiatives, active source control measures (e.g., best management practices, effluent treatment upgrades), active remediation, and natural recovery may be considered in achieving the Ministry's long-term goals of protecting and maintaining the designated uses of aquatic ecosystems.

One of the most important uses of the SedQC is for determining if a typical site is contaminated, as defined under the CSR. In this application, the SedQC are used during Stage 1 or Stage II of the preliminary site investigation (MacDonald and Ingersoll 2003b). In the Stage I PSI, the existing sediment chemistry data for the site are collected, collated, and evaluated to determine if they are sufficient for making the determination. Some of the factors that need to be considered when evaluating the existing data include: the age of the data, the geographic coverage of the data, the analytes measured (as compared to the COPCs for the site), the quality of the data (i.e., accuracy, precision, detection limits), sampling depth, and the sampling design utilized. In the event that insufficient data are available, then

a Stage II PSI needs to be conducted to acquire the sediment chemistry data required to complete the determination.

Following acquisition of the necessary and sufficient information on the chemical characteristics of sediments, the sediment chemistry data for the site is compared to the numerical SedQC. To ensure the proper application of the SedQC, administrative rules have been established to guide determinations of sites as contaminated or uncontaminated. The administrative rules for typical contaminated sites state that:

1. A typical site is a contaminated site if any of the following conditions exist:
    - The 90th percentile concentration of one or more COPCs equals or exceeds their respective $SedQC_{TCS}$ (i.e., 9 of 10 measurements must be below the SedQC to designate a site as uncontaminated) and exceeds upper limit of background for that substance (i.e., mean + 2SD);
    - The concentration of one or more analytes exceeds their respective $SedQC_{TCS}$ by a factor of two or more in any sediment sample and exceeds upper limit of background for that substance (i.e., mean + 2SD);
    - The 90th percentile mean $SedQC_{TCS}$-Q for the contaminant mixture equals or exceeds 1.0 (see Appendix 1 for more information on the calculation of mean SedQC-Qs); or,
    - The mean $SedQC_{TCS}$-Q for the contaminant mixture in any sediment sample equals or exceeds 2.0.
2. The $SedQC_{TCS}$ are to be applied to any sediment depth.
3. The $SedQC_{TCS}$ must be used during the site investigation process to determine if a typical site contains contaminated sediments.
4. The $SedCQ_{TCS}$ should be used to determine if remedial measures are needed at a typical site and to establish target clean-up goals for contaminated sediments.
5. The presence of sediments containing contaminant concentrations qualifying as Special Wastes, as defined under the Special Waste

Regulation, necessitates the imposition of limitations on potential remedial actions. Where Special Waste is present, remedial measures should focus on the removal of these wastes, to the extent feasible. The handling, treatment and disposal of these materials is to be conducted in accordance with the provisions of the Special Waste Regulation.

4.4 APPLICATION OF SEDIMENT QUALITY CRITERIA FOR IDENTIFYING SITES WITH CONTAMINATED SEDIMENTS

The SedQC promulgated herein must be used to determine if a site contains contaminated sediments, as defined under the *Waste Management Act.* As a first step, the designated uses of the aquatic ecosystem at and nearby the site must be established. Next, the COPCs are identified, using the procedures described in MacDonald and Ingersoll (2003b). Subsequently, the concentrations of COPCs at the site are determined and compared to the SedQC that have been established for each of the designated uses and the results interpreted in accordance with the guidance provided in Sections 4.2 and 4.3.

4.5 ESTABLISHMENT OF REMEDIATION TARGETS FOR SEDIMENT CONTAMINATED SITES

British Columbia Ministry of Water, Land and Air Protection has adopted two approaches for managing sediment contaminated sites in British Columbia: a criteria-based approach; and, a risk-based approach. A responsible person, as defined under the CSR, may choose either approach for addressing contamination in sediments at a contaminated site.

Criteria-Based Approach - The criteria-based approach provides a basis for defining acceptable concentrations of COPCs at a site relative to the protection of aquatic life, wildlife, and/or human health (i.e., SedQC). These criteria provide the basis for determining when a site is contaminated, when sediment remediation

is needed, and when sediment remediation has been satisfactorily completed. The criteria-based approach is particularly relevant for establishing remediation targets when removal of contaminated sediments is the preferred remedial option. At such sites, the SedQC can be adopted directly as remediation targets. More specifically, the SedQC should be adopted directly as remediation targets at sites with COPC concentrations above background levels and typical levels of organic carbon (i.e., 0.4 to 10.1% for freshwater sediments; 0.1 to 4.7% for marine and estuarine sediments). These ranges of total organic carbon (TOC) concentrations represent the 95% prediction limits for the data represented in the Biological Effects Database for Sediments (i.e., which was used to derive the underlying benchmarks for sediment chemistry; MacDonald *et al.* 1996; Smith *et al.* 1996).

MacDonald *et al.* (2003) and Ingersoll and MacDonald (2003) describe procedures for calculating site-specific SedQC. These procedures are designed to account for unique assemblages of benthic organisms in the vicinity of the site and atypical levels of key variables at the site (e.g., TOC; see MacDonald *et al.* 2003 for further guidance). The site-specific procedures are intended to support the derivation of criteria that are more directly relevant to a specific site, yet provide levels of protection to receptors similar to those offered by the generic criteria. Such site-specific SedQC can also be adopted as remediation targets at sediment contaminated sites.

Risk-Based Approach - The second approach to sediment remediation involves the application of risk assessment and risk management procedures. The risk-based approach can be used to support remedial action planning at any contaminated site in British Columbia. This approach is often used where the scale, scope, and uncertainty of remedial efforts identified using the criteria-based approach can be reduced. Typically, this is done by demonstrating to the satisfaction of the Ministry that risks are less than or equal to those upon which the criteria are based (i.e., a 20% probability of an EC_{20} at sensitive sites and a 50% probability of an EC_{20} at typical sites). Where this can be satisfactorily demonstrated, a greater choice of risk management and remedial options generally becomes available for use at the site. Central to the Ministry's goal of restoring ecosystem health at contaminated sites is the view that control of COPCs at their source remains the primary imperative for remedial actions. It is

only through the abatement of inputs of COPCs to the receiving environment that other sediment management actions, such as sediment removal, become economically viable, ecologically successful, and sustainable.

In the risk-based approach, the potential risks posed by sediment-associated COPCs, to both human health and the environment, are evaluated on a site-specific basis and compared to risk levels that are considered to be tolerable and technically-feasible to achieve (Ingersoll *et al.* 1997; Wenning and Ingersoll 2002). The risk-based approach is particularly relevant to contaminated sites at which the effects of sediment-associated COPCs can be mitigated by reducing exposure through specific risk management actions (e.g., containment, *in-situ* treatment, partial removal), or where exposure can be demonstrated to be reduced through administrative, engineered or natural processes of chemical attenuation. The risk-based approach may involve the application of tiered assessments, which incorporate more site-specific information and increasingly sophisticated assessment methods during the course of the process.

There are numerous procedures and methods that can be used for conducting ecological and human health risk assessments. Where the risk-based approach is used, exposures to a COPC at a site must be reduced, if necessary, to protect human health and the environment. To protect human health, exposures to substances must be reduced so that the level of risk associated with exposure to a substance is less than or equal to the risk-based standards established in the CSR. Ecological risk assessments should be conducted in accordance with Contaminated Site Protocol #1: Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia (BCMELP 1998; Landis *et al.* 1997). The Tier 1 document provides specific guidance for addressing concerns related to exposures of aquatic organisms and aquatic-dependent wildlife species to toxic and bioaccumulative substances. For aquatic systems, risks resulting from exposure to substances must be reduced to the acceptable ecological risk levels specified in the Tier 1 protocol (i.e., typically the EC_{20} values). Additional Tier 1 Guidance for sediments is anticipated to be developed by the Ministry at a future date. In the near-term, the Calcasieu Estuary baseline ecological risk assessment (MacDonald *et al.* 2002) provides a

reasonable model for designing ecological risk assessments at high risk sediment contaminated sites.

Upon completion of a risk assessment, the Ministry will decide whether the information available is adequate to justify a risk management decision. Generally four possible decisions outcomes result, including:

- The information is adequate to conclude that human health and ecological risks are acceptable and, hence, there is no need for further remediation;
- The information is adequate to conclude that human health and ecological risks are acceptable under the proposed risk management plan and, hence, the proposed remediation measures may be implemented;
- The information is inadequate and the uncertainty too high to make a decision, therefore, the risk assessment is rejected pending the provision of additional data; or,
- The information is adequate and indicates there exists a real or potential unacceptable risk under the proposed risk management plan, therefore, modification to the risk management plan and further or alternative remediation measures are required.

The Ministry's decision will be based on its confidence in the results the risk assessment and its ability to accurately reflect the conditions of the site and the state of the science in exposure and effects assessments. The extent of human health and ecological protection, the technical feasibility of proposed remediation measures, and the degree of permanence of these remediation measures are additional considerations taken into account by the Ministry.

4.6 ADDITIONAL CONSIDERATIONS RELATING TO THE ASSESSMENT AND REMEDIATION OF CONTAMINATED SEDIMENTS

Decisions regarding which approach to use at a site should be made using site-specific information (Wenning and Ingersoll 2002). For example, it may be prudent to select the criteria-based approach at small sites where the cost of collecting the detailed data needed to support human and ecological risk assessments is likely to greatly exceed the costs for remediation. Also, the remediation of small sites based on the criteria-based approach may be technically less challenging and offer the potential for accelerated regulatory compliance over the alternative. At larger, more complex sites, however, the costs associated with conducting detailed risk assessments may be justified to reduce uncertainties and focus limited resources on the remedial actions that provide the greatest benefits.

The effects-based SedQC for whole sediments, listed in Table 1, provide a basis for establishing remediation targets (i.e., target clean-up levels) under the criteria-based approach for sites with contaminated sediments in British Columbia. Remediation targets specify tolerable concentrations of substances in whole sediments. For bioaccumulative COPCs, the TRGs, listed in Table 2, can be used to establish remediation targets for whole sediments when used in conjunction with Ministry-approved sediment-biota bioaccumulation factors (BSAFs; where the remediation target = TRG ÷ BSAF). The criterion for the most sensitive designated use of the aquatic ecosystem must be selected as the remediation target for each COPC.

Where approved by the Ministry and Fisheries and Oceans Canada, the $SedQC_{TCS}$ criteria can be adopted directly as the remediation targets within an approved sediment zone. Where site-specific SedQC have been established by a responsible person and have been approved following review by the Ministry and/or federal agencies, site-specific criteria can be adopted as the remediation targets. Guidance on the derivation of site-specific SedQC is provided in MacDonald *et al.* (2003).

5.0 TISSUE RESIDUE GUIDELINES

At sites that are known or suspected to be contaminated with bioaccumulative substances, responsible persons are required to conduct a bioaccumulation assessment. Such an assessment could involve the collection and analysis of the tissues of resident aquatic organisms (i.e., benthic invertebrates, fish), bioaccumulation testing, and/or bioaccumulation modelling to determine if bioaccumulative substances pose unacceptable risks to human health or ecological receptors. Such assessments should also be designed to facilitate determination of tolerable levels of bioaccumulative substances in sediments, as this information will be required to support remedial action planning.

The Ministry recognizes the need to establish bioaccumulation-based SedQC for several classes of bioaccumulative substances, including metals, PAHs, PCBs, polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD and PCDFs), and organochlorine pesticides. Establishing SedQC for bioaccumulative substances, while feasible, would necessitate assumptions for a default foodweb and physical environment setting. Rather than imposing these assumptions, the agencies recommend the use of empirical contaminant measurements of these substances in benthos and prey items present at a site to identify potential regulatory concerns. The TRGs for the protection of wildlife (Table 2) are intended to protect predatory wildlife species from adverse effects associated with the bioaccumulation of contaminants in benthos, fish, and shellfish tissues consumed by wildlife species (i.e., indirect exposure pathways). An ecological risk assessment will be required at sites where the contaminant concentrations in tissues of benthos and/or fish are shown to exceed the TRGs.

6.0 CRITERIA FOR SUBSTANCES FOR WHICH GENERIC CRITERIA ARE NOT AVAILABLE

Tables 1 and 2 contain numerical criteria and guidelines for a variety of substances that have the potential to contaminate sediments in freshwater, estuarine, and marine systems. While these tables provide criteria for many of the substances that occur in sediment and/or biological tissues at contaminated sites, other substances may be encountered for which criteria are not listed in the tables.

The Ministry should be consulted for guidance regarding the significance of such non-scheduled substances at a site.

7.0 POTENTIAL FOR OFF-SITE IMPACTS OF SEDIMENT-ASSOCIATED CHEMICALS OF POTENTIAL CONCERN

The criteria provided in this document are primarily intended to apply to *in situ* whole sediments at sites with contaminated sediments. However, contaminants in sediments may also be released from a site by a number of means, including:

- Sediment transport by natural processes, such as tidal action and erosion (i.e., the hydrodynamics of the aquatic system in question);
- Evaporative losses of volatile organic chemicals from exposure of contaminated sediments to air (e.g. due to tidal effects or draw-down effects in lakes or rivers);
- Surface water recharge from contaminated pore water;
- Sediment re-suspension resulting from the wash from propellers of pleasure craft and commercial vessels;
- Excavation and redeposition of contaminated sediments; and,
- Transfer of bioaccumulative substances to sediment-dwelling organisms and, subsequently, into the food web.

The criteria contained in this document are not intended to be the sole basis for assessing environmental quality at sites where contaminants may be released from sediments or contaminated sediments may be re-deposited elsewhere. At such sites, additional factors (such as off-site impacts) also need to be assessed and applicable policy and regulatory requirements need to be considered. For example, the provisions of the Special Waste Regulation (BC 1988) provide a basis for *in-situ* management and classification of special wastes. The CSR defines maximum acceptable concentrations for COPCs in sediments that may be deposited to land. The CSR (BC 1997; 2002) also lists the Ministry's standards for the protection of groundwater and groundwater flow to surface waters. In addition, interim contaminant testing guidelines have been specified by

Environment Canada to determine the acceptability of contaminated sediments for disposal at designated open water disposal sites.

8.0 SPECIAL WASTE REGULATION

The SedQC and TRGs presented in Tables 1 and 2 are intended to provide a basis for evaluating sediment contamination, identifying the need for remedial actions, and establishing remediation targets at contaminated sites in British Columbia. These criteria should be used in conjunction with the requirements of the Special Waste Regulation (BC 1988). Sediments with COPC concentrations in excess of the levels specified in the Special Waste Regulation must be removed to the extent feasible and disposed of in accordance with the provisions of the Special Waste Regulation. In addition, in accordance with the provisions of the CSR, sediments containing certain types of substances (e.g., non-aqueous phase liquid; NAPL) must also be removed to the extent feasible and disposed of in an appropriate manner.

9.0 FEDERAL LEGISLATION

In addition to the criteria and guidelines set out in Tables 1 and 2 and discussed above, the following federal legislation and policies need to be taken into account in the assessment and, particularly, in the remediation of contaminated sediments:

9.1 FISHERIES ACT

Section 35 - Any person proposing works that have the potential to alter fish habitat at a sediment contaminated site should consult with DFO before proceeding with such works. Subsection 35(1) of the federal *Fisheries Act* prohibits any work or undertaking that results in the harmful alteration, disruption, or destruction of fish habitat. Works conducted in or adjacent to fish habitat have the potential to alter fish habitat. Such works include, but are not limited to, vegetation removal within or adjacent to a watercourse or water body and in-water works (works carried out instream or within the marine

environment). If proposed works associated with a project at a sediment contaminated site could result in the unavoidable harmful alteration to fish habitat, an Authorization under Section 35(2) of the Federal *Fisheries Act* would be required from DFO before those works could proceed.

Section 36 - Discharges of contaminated ground or surface water from contaminated sites can impair sediment and water quality, and negatively affect fishery resources and habitat if they are not adequately managed. The deposit of deleterious substances into waters frequented by fish is a violation of subsection 36(3) of the *Act*. Compliance with Section 36(3) of the *Act* is a requirement and must be considered when evaluating sediment contamination and identifying the need for remedial actions.

9.2 MIGRATORY BIRDS CONVENTION ACT AND REGULATION

The *Migratory Birds Regulations* enacted under the *Migratory Birds Convention Act* are aimed at the conservation and protection of migratory birds. Section 35 of the *Regulations* prohibits the deposit of oil, oil wastes, or any other substances harmful to migratory birds in any waters or areas (including land) frequented by migratory birds. Like Section 36(3) of the *Fisheries Act*, compliance with Section 35 of these *Regulations* is mandatory; hence, they must be considered when evaluating sediment contamination and identifying the need for remedial actions.

9.3 CANADIAN ENVIRONMENTAL PROTECTION ACT 1999 AND REGULATIONS

Proclaimed on March 31, 2000, the *Canadian Environmental Protection Act (CEPA)* 1999 is an act respecting pollution prevention and the protection of the environment and human health in order to contribute to sustainable development. The *Act* provides the federal government with tools to protect the environment and human health, establishes strict deadlines for controlling certain toxic substances, and requires the virtual elimination of toxic substances which are bioaccumulative, persistent, and result primarily from human activity.

Substances declared "toxic" as defined by *CEPA* Part 5 (Controlling Toxic Substances) are added to the List of Toxic Substances in Schedule 1 of the *Act*. Under *CEPA* Part 5, regulations or other instruments can be made to facilitate preventive or control actions for substances declared "toxic" and included on the List of Toxic Substances. Such tools may be used to control any or all aspects of the substance's life cycle from the design and development stage to its manufacture, use, storage, transport and ultimate disposal. In the context of managing contaminated sites, regulations or other control instruments developed under *CEPA* may apply in respect of certain toxic substances present on the site.

Part 7, Division 3 of *CEPA* and the *Disposal at Sea Regulations* should be consulted. In Canada, disposal at sea is controlled by a system of permits administered and issued by Environment Canada. The permit system allows Canada to meet international obligations under the London Convention, 1972 and the 1996 Protocol to the London Convention. Compliance with regulations made under *CEPA* is mandatory.

9.4 CANADIAN ENVIRONMENTAL ASSESSMENT ACT

The *Canadian Environmental Assessment Act (CEAA)* is administered by the Canadian Environmental Assessment Agency. All federal departments, agencies, and crown corporations are required to conduct environmental assessments of proposed projects where:

- The federal government is the proponent;
- A project involves federal funding;
- A project involves the sale or lease of federal land; or,
- A project involves the issuance of a federal permit, license or other approval.

Activities related to contaminated sediment management and remedial options may trigger an environmental assessment under *CEAA* and may require mitigation measures. For example, DFO may be required to carry out an assessment under

CEAA of a proposed remediation project at a sediment contaminated site when the remediation work to be undertaken requires an authorization under Section 35 of the *Fisheries Act.*

9.5 TREASURY BOARD FEDERAL CONTAMINATED SITES MANAGEMENT POLICY

In 2002, the federal government established the Treasury Board Federal Contaminated Sites Management Policy as part of the federal contaminated sites management framework. This policy states that federal departments and agencies ensure sound environmental stewardship of federal real property in their care by avoiding contamination and by managing contaminated sites in a consistent and systematic manner that recognizes the principle of risk management and results in the best value for the Canadian taxpayer. Implementation of this policy at federal contaminated sites involves rational priority setting for investment choices through a systematic identification and categorization of risks and the development of management plans, early focus on reducing risks to human health, safety, and the environment, optimal use of financial and technological resources through the use of a risk management approach, and the development of best management practices related to the management of contaminated sites.

For more information, contact the Environmental Management Branch, at (250) 387-4441.

10.0 REFERENCES

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SCHEDULE 1. GLOSSARY OF TERMS AND ACRONYMS

2,3,7,8-TCDD TEQs	2,3,7,8-tetrachlorodibenzo-*p*-dixions
BCE	British Columbia Environment (now Ministry of Water, Land and Air Protection).
BCWLAP	British Columbia Ministry of Water, Land, and Air Protection
Benthic organisms	The species, including both infaunal (organisms that live primarily within the sediment matrix) and epibenthic (organisms that live primarily on the surface of the sediment) species, that utilize habitats in or on the sediments located at the bottom of streams, lakes, oceans, or other aquatic systems.
BIEAP	Burrard Inlet Environmental Action Program.
Bioaccumulation	The net accumulation of a substance by an organism as a result of uptake from all environmental sources.
BSAFs	Sediment-biota bioaccumulation factors
C of C	Certificate of Compliance
CCME	Canadian Council of Ministers of the Environment.
CEAA	*Canadian Environmental Assessment Act*
CEPA	*Canadian Environmental Protection Act*
Contaminant	Substance that is present at elevated levels in sediment or pore water as a result of human activities.
Contaminated sediment	Sediment containing chemical substances at concentrations that pose a known or potential threat to human health or the environment (i.e., in excess of the criteria presented in Table 1).
COPCs	Chemicals of potential concern.
CSR	Contaminated Site Regulation.
DFO	Fisheries and Oceans Canada

DSI	Detailed site investigation.
EC	Effects concentration. A statistically or graphically estimated concentration that is expected to produce one or more specific effects in of a group of organisms under specified conditions.
EC_{20}	Concentration of a substance that causes adverse effects to 20% of a population of organisms.
EC_{50}	Concentration of a substance that causes adverse effects to 50% of a population of organisms.
Ecological risk assessment	The process that evaluates the likelihood that adverse ecological effects are occurring as a result of exposure to one or more stressors.
Ecosystem	The biotic community and abiotic environment within a specified location in space and time.
Exposure	Co-occurrence of or contact between a stressor and an ecological component (i.e., receptor).
FA	*Fisheries Act*
FREMP	Fraser River Estuary Management Program.
Habitat	The environment in which receptors are found. Receptors may live exclusively within a single type of habitat or may use several types of habitats.
IDZs	Initial dilution
n=	Number of samples
NAPL	Non-aqueous phase liquid
P_{20}	Concentration of a substance that is associated with a 20% probability of observing a 20% reduction in survival
P_{50}	Concentration of a substance that is associated with a 50% probability of observing roughly a 20% reduction in survival

PAHs	Polycyclic aromatic hydrocarbons.
PCBs	Polychlorinated biphenyls.
PCDD and PCDFs	Polychlorinated dibenzo-*p*-dioxins and dibenzofurans
PEL	Probable effect level.
PEL-Qs	PEL-quotients
Pore water	Water occupying the spaces between sediment particles.
PSI	Preliminary site investigation.
Receptor	An organism or group of organisms that are or have the potential to be exposed to a stressor.
Remediation targets	The conditions that should be met in sediments following remediation to achieve the desired sediment management objectives. Remediation targets are typically expressed as the concentrations of contaminants of potential concern in bulk sediments and/or pore water. However, narrative remediation targets may also be established at sites with contaminated sediments (e.g., sediments should not adversely affect amphipod survival, growth, or reproduction, as measured in 42-d toxicity tests).
Responsible person	A person as described in Section 26.5 of the *Waste Management Act* (Supplement).
Risk	The probability or likelihood that an adverse effect will occur.
SD	Standard deviation
Sediment	Particulate matter which usually lies below water. For the purpose of applying the criteria, sediments are intended to include to soft, aqueous, sedimentary deposits that are comprised primarily of fine-grained particles (i.e., < 6.35 mm). Sediments are not intended to include other materials, such as gravel, cobble, boulders, logs, wood fibre, hog fuel, slag, paint chips, asphalt, or coal tar.
SedQC	Sediment quality criteria.

SedQC-Q	Sediment quality criteria quotient
$SedQC_{SCS}$	Sediment quality criteria for sensitive contaminated sites.
$SedQC_{TCS}$	Sediment quality criteria for typical contaminated sites.
SedQS	Sediment quality standards
SEDTOX database	Sediment Toxicity Database which is administered by MacDonald Environmental Sciences Ltd.
SMO	Sediment management objective.
Source	An anthropogenic input or activity that releases or creates a stressor in the environment.
SQG	Sediment quality guideline.
Stressor	Any physical, chemical, or biological component of an ecosystem which can induce an adverse response in a receptor.
TEQs	Toxic equivalents.
TOC	Total organic carbon.
TRG	Tissue residue guideline.
Whole sediment	Sediment and associated pore water which have had minimal manipulation.
WMA	*Waste Management Act*

SCHEDULE 2. FACTORS FOR CONSIDERATION IN THE APPLICATION OF THE CRITERIA FOR SENSITIVE CONTAMINATED SITES ($SEDQC_{SCS}$)

Areas to which the SQC_{SCS} should be applied include:

- Areas, sites or reaches which support red and blue listed plants and animal species, or nests designated under the *Wildlife Act*.
- Habitats used by endangered or threatened species, or Species of Special Concern under the *Species at Risk Act*.
- Watercourses, wetlands, forested riparian areas, mudflats and intertidal zones that are important to preservation of fish and wildlife.
- Reaches of aquatic habitats that are important to fish spawning or serve as important rearing habitat for fish.
- Reaches of aquatic environments encompassing, and/or bordering habitat compensation or restoration sites, or other areas that are intended or designed to create, restore or enhance biological or habitat features.
- Areas of unique habitat that are identified in provincial or municipal landuse plans.
- Reaches of the aquatic environment that exist within provincial marine parks, provincial parks, or ecological reserves.
- Areas and aquatic habitat included within provincial Wildlife Management Areas.
- Areas covered under conservation agreements and areas designated as "Environmentally Sensitive" in municipal landuse plans or strategies.

Marinas, docks, wharves and associated infrastructure located within these areas may be assessed making use of the SQC_{TCS} criteria limits. To make use of the SQC_{TCS} in these circumstances, the proponents must present information to support their proposal to the appropriate agencies. This information should include:

- The identification of existing resources in the area;

- The identification of offsite contaminant sources; and,
- The measures taken to eliminate onsite sources of contamination.

TABLE 1 GENERIC SEDIMENT QUALITY CRITERIA[1, 2]

COLUMN I	COLUMN II	COLUMN III	COLUMN IV	COLUMN V
	FRESH WATER[3]		MARINE and ESTUARINE WATER[4]	
Substance	Sensitive Contaminated Sites ($SedQC_{SCS}$)	Typical Contaminated Sites ($SedQ_{TCS}$)	Sensitive Contaminated Sites ($SedQC_{SCS}$)	Typical Contaminated Sites ($SedQC_{TCS}$)
Inorganic Substances				
arsenic	11 000	20 000	26 000	50 000[10]
cadmium	2 200	4 200	2 600	5 000
chromium	56 000[10]	110 000	99 000	190 000
copper	120 000	240 000	67 000	130 000
lead	57 000	110 000	69 000	130 000
mercury	300	580	430	840
zinc	200 000	380 000	170 000	330 000
Polychlorinated Biphenyls (PCBs)				
Total PCBs[5]	170	330	120	230
Polycyclic Aromatic Hydrocarbons (PAHs)				
Low Molecular Weight PAHs (LMW-PAHs)				
acenaphthene	55	110	55	110
acenaphthylene	80	150	79	150
anthracene	150	290	150	290
fluorene	89	170	89	170
naphthalene	240	470	240	470
2-methylnaphthalene	120	240	120	240
phenanthrene	320	620	340	650
High Molecular Weight PAHs (HMW-PAHs)				
benz(a)anthracene	240	460	430	830
benzo(a)pyrene	480	940	470	920
chrysene	530	1 000	520	1 000
dibenz(a,h)anthracene	84	160	84	160
fluoranthene	1 500	2 800	930	1 800
pyrene	540	1 100	870	1 700
Total PAHs[6]	10 000	20 000	10 000	20 000
Pesticides				
chlordane	5.5	11	3.0	5.7
dieldrin	4.1	8.0	2.7	5.2
sum DDD	5.3	10	4.8	9.4
sum DDE	4.2	8.1	230	450
sum DDT	3.0	5.7	3.0	5.7
endrin	39	75[10]	39	75[10]
heptachlor	1.7	3.3[10]	1.7	3.3
heptachlor epoxide	1.7	3.3[10]	1.7	3.3
lindane (gamma-BHC)	0.86[10]	1.7[10]	0.61	1.2[10]

COLUMN I	COLUMN II	COLUMN III	COLUMN IV	COLUMN V
	FRESH WATER[3]		MARINE and ESTUARINE WATER[4]	
Substance	Sensitive Contaminated Sites ($SedQC_{SCS}$)	Typical Contaminated Sites ($SedQ_{TCS}$)	Sensitive Contaminated Sites ($SedQC_{SCS}$)	Typical Contaminated Sites ($SedQC_{TCS}$)
Chlorinated Phenols				
pentachlorophenol	400[7]	800[7]	360[8]	690[8]
Polychlorinated Dioxins and Furans (PCDDs and PCDFs)				
2,3,7,8-TCDD TEQs[9]	0.13[10]	0.26[10]	0.13	0.26[10]

Footnotes

1. All values are in µg/kg dry weight (DW) unless otherwise stated. Substances must be analyzed using the methods specified in the protocols approved under Section 53 of the Contaminated Sites Regulation or alternate methods acceptable to the director.
2. Criteria are for total substance concentrations.
3. Criteria to protect freshwater aquatic life.
4. Criteria to protect marine and/or estuarine aquatic life.
5. Total PCBs includes: The sum of four to seven Aroclor mixtures (i.e., 1016, 1221, 1232, 1242, 1248, 1254, and/or 1260) or the sum of ≥20 individual PCB congeners; no criterion was included for Aroclor 1254 because the CCME interim PEL for Aroclor 1254 was inconsistent with the PEL for tPCBs and the PEL for Aroclor 1254 was derived using different methods.
6. Total PAHs includes: 2-methylnaphthalene; acenaphthene; acenaphthylene; anthracene, benz(a)anthracene; benzo(a)pyrene; chrysene; dibenz(a,h)anthracene; fluorene; fluoranthene; naphthalene; phenanthrene; pyrene.
7. Adopted from New York Department of Environmental Conservation (1994).
8. Adopted from Washington Department of Ecology (1991).
9. As calculated using data on PCDDs, PCDFs, and PCBs, and associated toxicity equivalency factors.
10. Denotes less reliable SedQC or SedQC that could not be fully evaluated.

TABLE 2 TISSUE RESIDUE GUIDELINES FOR BIOACCUMULATIVE SUBSTANCES [1, 2, 3, 4]

COLUMN I		COLUMN II
Substance		**Tissue Residue Guideline**
Organic Mercury		
methyl mercury		33
Polychlorinated Biphenyls (PCBs)		
total PCBs	mammalian	0.79 ng TEQ[5] /kg
	avian	2.4 ng TEQ[5] /kg
Pesticides		
DDD[6]		14
DDE[6]		14
DDT[6]		14
Polychlorinated Dioxins and Furans (PCDDs and PCDFs)		
2,3,7,8-TCDD TEQs[7]	mammalian	0.71 ng TEQ[5] /kg
	avian	4.75 ng TEQ[5] /kg

Footnotes

1. All values are in µg/kg unless otherwise stated. Substances must be analyzed using methods specified in protocols approved under section 53 of the Contaminated Sites Regulation or alternate methods acceptable to the director.
2. All values are expressed in terms of wet weight (WW).
3. Standards are for total substance concentrations.
4. All values adopted from the Canadian Council of Ministers of Environment (CCME) 2001.
5. Expressed as Toxic Equivalent Unit (TEQ) based on World Health 1998 TEF values for fish (Van den Berg *et al.* 1998).
6. TRG is for total DDT, which is equal to DDD+DDE+DDT (CCME 2001).
7. As calculated using data on PCDDs, PCDFs, and PCBs, and associated toxicity equivalency factors.

APPENDIX 1 PROCEDURES FOR CALCULATING MEAN SEDIMENT QUALITY CRITERIA-QUOTIENTS

Determination of whether or not a site is contaminated necessitates several steps. First, the 90th percentile concentrations of each COPC are calculated and compared to the SedQC. Next, the upper limits of background concentrations of each COPC are calculated and compared to the 90th percentile concentration of each COPC. If the 90th percentile concentration of one or more COPCs exceeds the SedQC and the upper limit of background, then the site is considered to contain contaminated sediments. The presence of COPC concentrations that exceed the SedQC by a factor of two or more is also considered to be indicative of the presence of contaminated sediments.

In addition to comparing the concentrations of each COPC to their respective SedQC, sites can also be designated as contaminated through the application of mean sediment quality criteria-quotients (SedQC-Qs). Using this procedure, the mean SedQC-Q is calculated for each sediment sample for which sediment chemistry data are available. Then, the 90th percentile mean SedQC-Q is calculated using the data on all of the sediment samples collected at the site. If the 90th percentile mean SedQC-Q exceeds one, then the site is considered to contain contaminated sediments. To calculate the mean SedQC-Q for a sediment sample, the following equation is used:

$$\text{Mean SedQC-Qs} = \frac{\text{Mean SedQC-Q}_{\text{metals}} + \text{mean SedQC-Q}_{\text{PAHs}} + \text{SedQC-Q}_{\text{tPCBs}}}{n}$$

where:

SedQC-Q = COPC concentration (in dry wt.) / corresponding SedQC for that COPC; and,

n = number of classes of COPCs (metals, total PAHs, total PCBs) for which data are available.

An example of how to calculate mean SedQC-Q for a typical freshwater site is provided in the following spreadsheet:

COPCs	Concentration	SedQC	SedQC-Q	Mean SedQC-Q
Metals (mg/kg DW)				
arsenic	40	20	2.0	
cadmium	12.6	4.2	3.0	
chromium	55	110	0.5	
copper	120	240	0.5	
lead	220	110	2.0	
mercury	1.74	0.58	3.0	
zinc	190	380	0.5	
Mean SedQC-Q metals			**1.4**	
Total PAHs (µg/kg DW)	16000	20000	**0.80**	
Total PCBs (µg/kg DW)	690	230	**3.0**	
Mean SedQC-Q				***1.7***

It is important to note that the mean SedQC-Q is calculated by dividing the sum of the SedQC-Qs for up to three classes of COPCs by the number of classes of COPCs for which data are available (in this example, n=3). This procedure for calculating the mean SedQC-Q was selected from a total of 11 methods that were investigated by Ingersoll *et al.* (2001). Although there are additional classes of COPCs for which SedQC are available, procedures for calculating mean SedQC-Qs using more than the three principal classes of COPCs have not been developed.

FIGURE 1. GENERAL PROCESS FOR MANAGING CONTAMINATED SITES IN BRITISH COLUMBIA.