REPORT ON:

Recommended Procedures for Identification of High Priority Contaminated Sites in British Columbia

Submitted to:
The Ministry of Environment
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Submitted by:
Science Advisory Board
For Contaminated Sites in British Columbia

EXECUTIVE SUMMARY

The new proposed regulatory regime for contaminated sites in British Columbia is intended to reduce the active involvement of the Ministry of Environment (the Ministry) at all sites other than "high priority" contaminated sites and sites undergoing risk-based remediation. A procedure is necessary to identify the "high priority" sites that potentially would require Ministry overview. This report references the sites as HPMO sites- High Priority for Ministry Overview.

The Ministry asked the Science Advisory Board for Contaminated Sites in British Columbia (SABCS) to recommend a system that would identify HPMO sites. This technical document constitutes the report of the Science Advisory Board. The SABCS recommends:

- The use of a dichotomous (yes/no) system to identify HPMO sites.
- The use of approaches and science adopted for the CSST and SLRA 1 and 2 procedures to ensure consistency throughout the contaminated sites management process.
- The process would identify only two categories of sites: "high priority" sites that require immediate attention and Ministry oversight and "non-high priority" sites that would not require active involvement of the Ministry but would be managed by Approved Professionals.
- The evaluation would be based on a site's current situation, not on a potential situation (i.e., is the site of concern, given the current pathways and receptors?).

THREE LEVELS OF IDENTIFYING HPMO SITES ARE RECOMMENDED:

1. Level 1- Definition of Prohibiting Conditions for Contaminated Sites

Prohibiting conditions at a contaminated site are those that show or imply the likely need for immediate intervention. Those conditions are:

- o Known adverse effects on humans or sensitive environments at or adjacent to the site,
- o The presences of fire or explosion hazard as the site currently exists,

- The presence of chemical odours from a surface or subsurface source, when verified by testing, indicate the contaminants in air are in excess of air emissions limits such as 10 times the air limits provided in the guidance on 'Air Quality Preliminary Quantitative Risk Assessment (Health Canada, 2005), or
- Impact on local drinking water or other water resources used by agriculture, livestock or aquatic life such that the water is deemed unsafe for consumption use or as a habitat.

In addition, decommissioning activities at sites with a high probability of having prohibiting conditions are also to be brought to the early attention of the Ministry. Such sites include those previously used for purposes such as:

- coal gasification;
- wood preservation facilities in operation prior to 1988;
- oil refining,
- mining operations,
- smelters and their surroundings,
- bulk chemical storage and distribution facilities,
- hazardous waste storage or treatment facilities, and,
- municipal and industrial landfills.

2. Level 2 Procedure – Use of High Priority Screening Values & Exposure Pathway Assessment

Site data are to be compared with "high priority screening values" (HPSVs). As described in this document, the finding of media with concentrations of chemicals in excess of the HPSVs will require subsequent consideration (i.e., a Level 2 Assessment) of additional factors such as contaminant characteristics, contaminant pathways and available receptors to determine if a site is an HPMO site.

The development of HPSVs and the factors for consideration must be consistent with all other tools currently under development for the B.C. contaminated site management process, e.g. the revised CSST protocols and the screening level risk assessment approach. The following Table 1 summarizes the proposed HPSVs:

Table 1: Summary of Proposed High priority Screening Values

Proposed High Priority Screening Values (HPSVs) for:	Recommended HPSVs
Human Health - Soil and Vapour	HPSVs for soil and vapour have been developed for Health Canada. The SABCS agrees with the Health Canada approach of using a cancer risk of 10^{-4} for any carcinogenic substances and a hazard quotient of 10 for development of HSPVs for human health .The SABCS CSST task force has determined that the exposure factors and assumptions used to develop the Health Canada HPSVs, are scientifically supportable, and the SAB recommends those HPSVs be used as the B.C. HPSVs for human health protection.
Human Health- Drinking Water	HPSVs equivalent to ten times the Schedule 6 standards for drinking water are recommended.
Ecological – Soil for Protection of Groundwater	No soil HPSVs for protection of aquatic life are recommended. Groundwater quality and the assessment of potential migration of the contaminants to receptors should be used for high priority site identification.
Ecological- Soil for Protection of Plants and Invertebrates	No soil or soil ecology HPSVs for protection of plants, invertebrates and small mammals are recommended. An assessment of site conditions is recommended at this time.
Ecological - Groundwater for Protection of Aquatic Species	The use of Rainbow trout 96-hr LC50's for individual substances is recommended at this time as screening values for protection of freshwater environments, and 96-hr LC50's for salmonids should be used as HPSVs for protection of marine environments.

3. Level 3 Identification of HPMO Sites

The SABCS encourages the use of an iterative process throughout the overall site investigation process to identify sites as high priority and to likewise verify that some sites are actually not of high priority. For example, if subsequent investigations at a site or remediation at the site reveals new areas of contamination not previously identified, or if a detailed risk assessment indicate the presence of a risk above conditions noted in this report, then the site should be brought to the attention of the Ministry as an HPMO site.

Likewise if a detailed risk assessment indicates that an ecological or human health risk is within the conditions specified within this report (or if the elevated levels of contamination are selectively removed), then there should be provision for the site to be declassified as an HPMO site.

TABLE OF CONTENTS

List of Appendices

1.0 INTRODUCTION

The new proposed regulatory regime for contaminated sites in British Columbia is intended to reduce the active involvement of the Ministry of Environment (the Ministry) in all sites other than "high priority" contaminated sites and sites undergoing risk-based remediation. A procedure is necessary to identify the "high priority" sites that potentially would require Ministry overview[1]. The Ministry has contemplated the use of two approaches within the procedure:

1. A simple, facts-based process, largely consisting of trigger conditions that would readily identify HPMO sites with a minimum of data.

2. Use of a high priority[2] contaminated site classification system. The approach will initially rely on a comparison of data for a site with a schedule of numerical values that will be referred to as high priority screening values (HPSVs). For a site where high priority screening values are exceeded, there will be consideration of other additional factors such as contaminant characteristics, contaminant pathways and available receptors, to form the basis for classifying a site as a HPMO site.

The Ministry asked the Science Advisory Board for Contaminated Sites in British Columbia (SABCS) to recommend a system that would identify HPMO sites. The Board formed a work group to evaluate science-based options for the identification process, and to provide a recommended approach. This technical document constitutes the report of the SABCS to the Ministry of Environment.

[1] Such sites will be referenced in this report as "high priority for Ministry overview" (HPMO sites).

[2] A definition of an HPMO site relative to the concept of "high priority" or "high risk" is discussed in Section 2 of this report.

2.0 DEFINITION OF SITES REQUIRING MINISTRY OVERVIEW

For the purpose of this report, several sections of the B.C. Environmental Management Act (EMA) were reviewed to identify the types of contaminated sites that likely represent those that are regulatory priorities for active involvement and subsequent actions by the Ministry and hence would require the overview of the Ministry under the proposed regulatory regime for management of contaminated sites in British Columbia.

Section 41 (1)

"A director may order an owner or operator of a site, at the owner's or operator's own expense, to undertake a preliminary site investigation or a detailed site investigation and to prepare a report of the investigation in accordance with the regulations and any applicable protocol if the director reasonably suspects on the basis of a site profile, or any other information, that the site "

(b) "contains substances that may cause or threaten to cause adverse effects on human health or the environment."

Section 48 (3)

"For the purpose of deciding whether to require a person to undertake remediation under subsection (2), a director may consider whether remediation should begin promptly, and must consider each of the following:

(a) adverse effects on human health or pollution of the environment caused by contamination at the site;

(b) the potential for adverse effects on human health or pollution of the environment arising from contamination at the site;"

Section 48 (9)

"The director may provide in a remediation order that a responsible person is not required to begin remediation of a contaminated site for a specified period of time if the contaminated site does not present an imminent and significant threat or risk to

(a) human health, given current and anticipated human exposure, or

(b) the environment."

A review of current approaches used by others indicates several references to sites that would be of high priority:

- CCME NCSCS[3] indicates sites of highest concern will be those that will exhibit observable or measurable impacts on the surrounding environment, or have a high potential for causing negative impacts.
- In the state of Oregon, a "high risk" situation (presence of a "hot spot") exists if contamination of water results in a significant adverse effect on the beneficial use of that resource. For media other than water, a hot spot exists if the site presents an unacceptable risk and the contamination is highly concentrated, highly mobile or cannot be reliably contained.
- The Minister's Review Panel on Contaminated Sites indicated a site is "high risk" when it has "substances that pose an unacceptable risk to human health or the environment and thus requires Ministry oversight".

Based on the review of the Environmental Management Act, the work group of the SABCS for the purpose of this report initially defined a HPMO site (high priority for ministry review) as:

> *"A site where there is an imminent threat or risk to human health or the environment, (given current and anticipated human or ecological exposure), and where there is high priority for immediate attention and regulatory oversight."*

Following further discussion with the Ministry, an alternative definition was developed, and it is as follows:

> *"A site where there is or exists a significant potential of adverse effects to human health or the environment associated with contamination and where regulatory oversight is required."*

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[3] Canadian Council of Ministers of Environment (CCME) 1992. National Classification System for Contaminated Sites.

3.0 RESULTS OF SABCS REVIEW

3.1 CONSULTATION PROCESS

To develop the approach for identifying HPMO sites, the Science Advisory Board for Contaminated Sites (SABCS) undertook several consultative and review procedures:

- A meeting was arranged with Ministry representatives to clarify the scope of the proposed work and to ascertain whether the Ministry had a preferred approach to a process that would identify sites as defined in Section 2.

The results of this discussion indicated that two approaches are desirable:

A process where immediate overview is required by the Ministry. The screening factors for this process would include trigger conditions that establish a site as potentially high concern with a limited amount of available data. Ministry actions could result in emergency intervention or issuance of a remediation order. As will be described later in this report, the information for many such sites would likely be obtained from sources other than Approved Professionals[4].

A process that would be part of the contaminated site evaluation system used by Approved Professionals. Site conditions will be compared to a set of high priority screening values (also previously referred to as upper cap numeric values[5] or "hot spot" numbers). A subsequent evaluation process would be used to determine whether, at a site, there is or exists a significant potential of adverse effects to human health or the environment associated with contamination.

[4] Originally referred to as: Licensed Environmental Professionals (recently proposed to be re-named as Contaminated Sites Approved Professionals, or CSAPs)

[5] The term "hot spot numbers" is used by other regulatory agencies (e.g. Oregon, Denmark). The Health Canada designation of high priority screening values will be adopted for the purposes of this report. Other possible terminology includes "upper cap numbers" and "high risk potential numbers".

At the time of this meeting, the Ministry suggested consideration of the approaches and/or criteria developed by the CCME National Classification System for Contaminated Sites (NCSCS):

Subsequently, the following activities occurred:

- A literature search was conducted to obtain information from other jurisdictions that may be of use to the subject project.
- A workshop was held on September 13, 2004 to discuss a proposed approach. The workshop at the time was entitled “High Risk Screening and Classification System (HRSCS)”. The workshop was attended by senior personnel representing several environmental consulting firms; representatives of the Ministry of Water. Land and Air Protection, Environment Canada, and Health Canada; as well as members of the Science Advisory Board (**Appendix D**).
- Meetings with the Ministry occurred February, March and July 2005 to further discuss approaches to the process, including a telephone meeting with the Oregon Department of Environmental Quality.
- Joint consultations occurred with the consultant (URS) to Health Canada in the development of the report “High Priority Classification System for Soil at Contaminated Sites”.
- Consultations among SAB members occurred at Board meetings during 2004 and 2005 to discuss specific components of this report.

3.1.1 Assumed Guidelines for Development of Process to Identify HPMO Sites

Based on the consultation and review process the following guidelines were used to develop the process to identify HPMO sites:

- Within the HPMO identification process, sites would not be ranked by use of “high, medium (moderate) or low risk” or by use of a numerical ranking. The SABCS recommends that there be two categories, “high priority” sites that require immediate attention and Ministry oversight and “non-high priority” sites that would not require active involvement of the Ministry.

- Non-high priority sites that contain contaminants in excess of the CSR standards would be managed by Approved Professionals, and are recognized as potentially requiring remediation or risk management albeit on a longer time frame.

- The SABCS recommends the use of a dichotomous (yes/no) system to identify HPMO sites. The SABCS review of existing classification systems and related comments received by the SABCS, suggest that there is a degree of uncertainty and complexity with numerical scoring classification approaches developed by other regulatory agencies[6]. Questions arose with regard to the confidence and the reliability of the "scores" developed by the approaches. Tests of several scoring systems were undertaken by the work group for several sites in British Columbia previously identified to be of "high priority" concern (i.e., subject to Ministry orders), and in all instances the systems did not identify those sites to be of the concern deemed by regulatory authorities. As well, it was noted for given sites, there could be considerable variations in scoring among individuals with variances as much as +/- 25%.

- For the purpose of consistency, the recommended system to identify HPMO sites would use approaches and science adopted for the CSST[7] and SLRA[8] 1 and 2 processes.

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[6] As an example, the New Zealand 2001 "risk screening system for contaminated sites" uses a multiplicative matrix for determining risk levels. A site can be readily removed from a high-risk category by a low factor for just one of the six selected evaluation parameters. The Washington State Ranking Method consists of approximately 70 pages of multiplication and additive algorithms and data elements for evaluation. The approach approximates the considerations that would be used in a risk assessment. The State of Oregon screening assessment is simpler, however factors overlap with those considered in the SRA-2 approach. The Oregon assessment also has provision for professional judgement. The SABCS also heard comments regarding the use of the CCME National Classification System (NCSCS). The comments suggested there was potential for wide variance in selection of "scores", and for the sole purpose of determining "high risk" sites, selected components, rather than the whole of the NCSCS approach is recommended by the SABCS.

[7] CSST: Contaminated Sites Soil Taskgroup (1996). The CSST protocols are currently under review by a Task Force of the SABCS.

[8] Screening Level Risk Assessment process as developed by the SABCS.

- Every attempt would be made to make the process as “simple as possible”. A level of expertise in the science of contaminated sites is nonetheless required.

- The designation of a “high priority site” should be an iterative process with several levels of determination. There must be the ability to also identify sites as “high priority” based on knowledge obtained throughout subsequent investigation processes and/or remediation (e.g. the unexpected finding of buried transformers containing PCB during remediation) , and likewise there must be the ability to “declassify” sites from “high priority” to “non-high priority” throughout the contaminated sites investigation and remediation process.

- By administrative mechanisms yet to be determined by the Ministry, the Ministry would be notified of sites that meet the criteria as “high priority” sites. The Ministry will review the site information, and verify that a site is “high priority.” The formal designation of a site as “high priority” will be the responsibility of the Ministry.

The SABCS notes that all sites with contamination above CSR standards will remain in the contaminated site management system and further assessments (e.g., risk assessments), remediation, or management as per Section 56 of the Environmental Management Act will occur. Therefore it is proposed:

- The HPMO classification system should be in a simplistic form that would identify most sites likely to be of high priority concern (i.e., a system that would attempt to capture all HPMO sites at the early stage of the process would be much more complex than a system that would capture 95% of all HPMO sites).

- The system developed to identify “high priority” sites should be capable of, and limited to, identifying sites similar to those previously subjected to Ministry orders. Examples of sites for which orders have been issued are identified in the Ministry’s web page:

  http://wlapwww.gov.bc.ca/epd/epdpa/contam_sites/legal_decisions/orders/index.html

- It should not be considered that the failure to identify an HPMO site in the early stages of the process would constitute a “fatal flaw”. Sites not initially identified would likely represent sites with unusual conditions and they would be identified at a later stage as investigations progress.

4.0 PROPOSED HIGH PRIORITY CLASSIFICATION SYSTEM

The proposed system for identification of high priority sites (HPMO) is outlined in **Figure 4.1** and provides an overview of the proposed system relative to the entire contaminated site process as proposed by the Ministry.

4.1 LEVEL 1 SCREENING SYSTEM

The Level 1 identification procedure to identify HPMO sites is a simple facts-based test of a site to identify trigger conditions. Sites in this category:

- May be subject to the need for immediate intervention.
- Are likely brought to the initial attention of the Ministry by other sources such as the public[9], public health officers or other government departments, such as the Ministry of Health or Environment Canada[10].
- Have scenarios (or trigger conditions) that in the past have often led to issuance of remediation orders at other sites in the Province (e.g. impact on domestic water wells[11]; evidence of releases of contaminants to the environment[12],[13]; reported impacts on the environment[10]).

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[9] As for example: presence of odours in residential basements. Although no B.C. occurrence is known, see the case example in the following web page address: http://www.epa.gov/oilspill/pdfs/boyd_04.pdf

[10] As for example: mercury contamination noted by Federal authorities, in biota and sediments adjacent to a contaminated site. See the following web page address: http://www.env.gov.bc.ca/epd/epdpa/contam_sites/legal_decisions/orders/CanOxy/os16149_reasons.html

[11] See: http://www.env.gov.bc.ca/epd/epdpa/contam_sites/legal_decisions/orders/wildwood_gas_bar/order_wildwood.html

[12] http://www.env.gov.bc.ca/epd/epdpa/contam_sites/legal_decisions/orders/koppers/index.html

- Reflect all “high risk” situations as identified in the SABCS Screening Level Risk Assessment Documents (SLRA-1 and SLRA-2 documents), e.g., presence of measured vapour concentrations of concern with regard to explosive or acute toxic effects.
- Include conditions listed in the CCME National Classification System for Contaminated Sites (NCSCS) Short Evaluation Form (e.g., impact on quality of local drinking water; presence of vegetation stress or other environmental impacts; known adverse impacts on humans).

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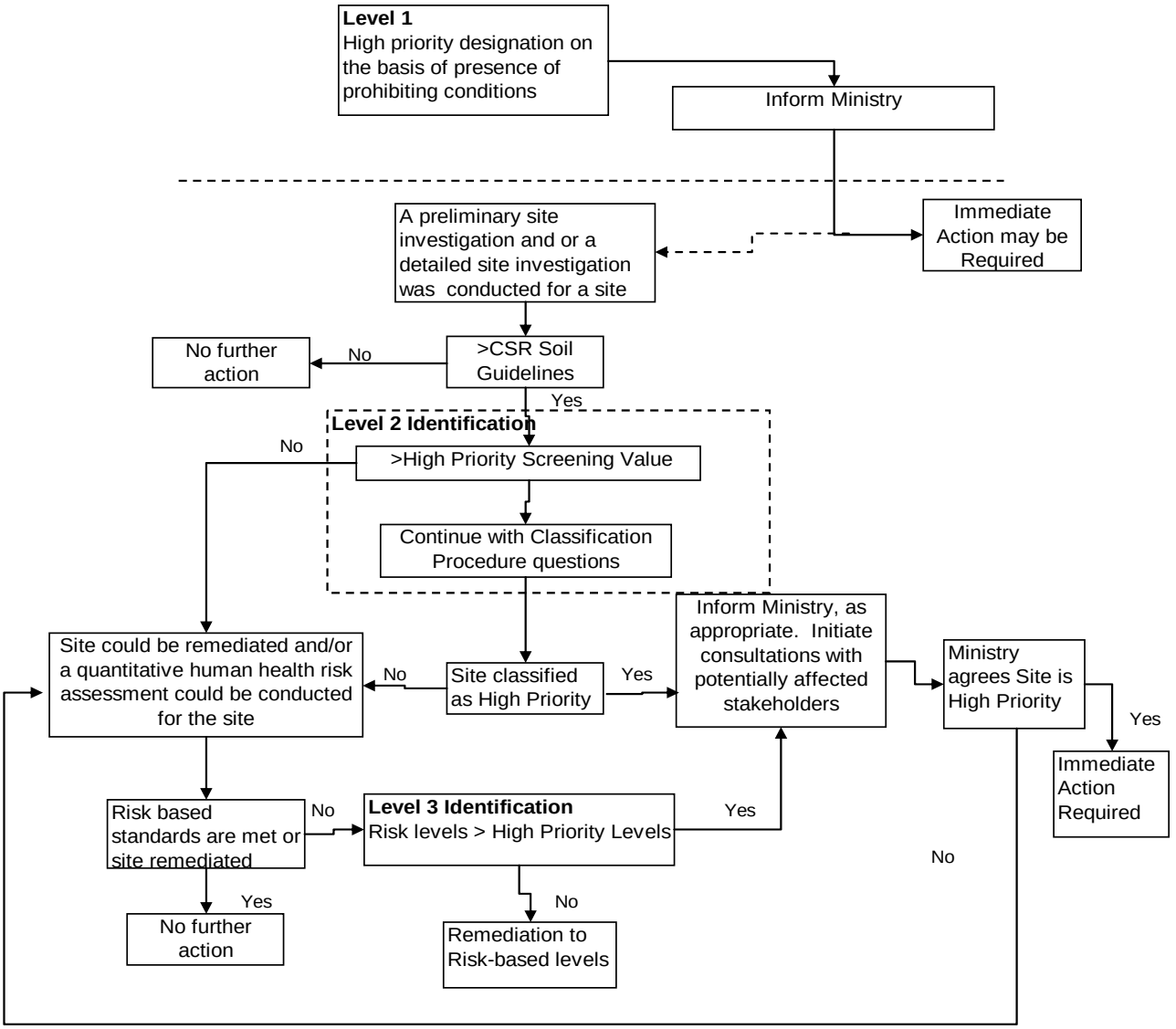
[13] http://www.env.gov.bc.ca/epd/epdpa/contam_sites/legal_decisions/orders/oak_street/index.html

Figure 4.1
Overall High Priority Classification Framework



As well, certain industries have a history of frequent site contamination issues and when site investigations are conducted at such industrial sites (e.g., following decommissioning of a pre-1988 wood preservation plant or sites that have historical evidence of coal gasification operations), then there should be notification to the Ministry of the site investigation program. If such sites were subsequently verified not to be HPMO sites, then there would be no need for further Ministry oversight.

4.1.1 Definition of Prohibiting (or Trigger) Conditions

A Level 1 identification of a HPMO site results when one or more of the following prohibiting conditions are associated with a site:

- *Known adverse effects on humans or sensitive environments*[14], Adverse effects for the purpose of this criterion are those noted by regulatory agencies during their routine monitoring of human health and the environment, or noted by agencies in response to public or other complaints or concerns (i.e., the conditions were identified prior to any involvement by Contaminated Sites Approved Professionals). Adverse effects on humans would include reported occurrences of morbidity diagnosed as being associated with exposure to a chemical or a known occurrence of a biomarker of effect[15] (e.g., lead levels in blood of local population is greater than normal). Environmental effects would include –evidence of release to the environment and uptake of bioaccumulative substances by biota above normal background levels; -absence of biota in receiving waters adjacent to a property; or -evidence of the lack of soil invertebrates and, the lack of plant growth or severely stunted and/or chlorotic plants (particularly agronomic species) in large underdeveloped areas where growth would normally be expected, and where it cannot be demonstrated the

[14] As stated in the CCME National Classification System for Contaminated Sites

[15] : As may be publicly reported by national health surveys or by public health officers.

absences/reduced growth occur due to physical effects (e.g. soil conditions, disturbances).

- *Fire or explosion hazard at the site as it currently exists*,[16] The hazard would be indicated by measurement of ambient air, indoor or outdoor chemicals in excess of 20% of the lower explosive limit (LEL); [17]

- *Chemical odours from a surface or subsurface source, when verified by testing, indicate the contaminants in air are in excess of air emissions limits such as 10 times the air limits provided in the guidance on 'Air Quality Preliminary Quantitative Risk Assessment (Health Canada, 2005)*[18]*;*

- *Impact on local drinking water or other water resources used by agriculture, livestock or aquatic life such that the water is deemed unsafe for consumption, use or as a habitat(as per example in footnote 11).*

Any one of the above conditions at a site would classify the site as high priority for Ministry overview (i.e., a HPMO site). With regard to the Level 1 process, it is noted that:

- Sites with any of the above characteristics, as a matter of course, would have been brought to the immediate attention of the Ministry, by various sources as discussed earlier in this section. In addition to consideration of the need for possible emergency intervention (such as provision of alternative water supplies), the Ministry will likely mandate immediate studies to assess the site or sites possibly responsible for any of the above characteristics (as shown in Figure 4.1).

The Level 1 initial screening test or list of prohibitive conditions is an iterative process that should not necessarily cease after the first stage screening.

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[16] : As suggested in the SABCS Stage 1 Screening Level Risk Assessment

[17] : Samples are to be representative of environments where human exposure occurs e.g. soil vapour measurements are not included under this condition.

[18] : As suggested in URS report "High Priority Classification System for Soil at Contaminated Sites, April 2005 prepared for Health Canada and the SABCS (draft report).

As information is gathered within the subsequent studies (i.e. via a PSI/DSI), the results situation can be more accurately assessed by the Ministry. The information may also indicate that the site should not be a HPMO site.

In addition, the decommissioning of sites previously used for any of the following purposes would also be brought to the attention of the Ministry as potential HPMO sites:

- Coal gasification;
- Wood preservation at facilities constructed prior to provision of the 1988 Environment Canada guidelines for design of wood preservation plants;
- Petroleum refineries;
- Pulp and paper manufacturing;
- Metal refining;
- Electroplating,
- Bulk chemical storage, distribution facilities,
- Hazardous waste storage or treatment facilities,
- Mine tailings and impoundments, and,
- Municipal and industrial landfills.

As noted previously, subsequent investigations and application of the Level 2 process (described in Section 4.2) may subsequently find that a property used for any one of the above noted industries should not be a HPMO site, and the Ministry would be notified accordingly.

4.2 LEVEL 2 IDENTIFICATION OF HIGH PRIORITY (HPMO) SITES

Assessments for site contamination in British Columbia are conducted in accordance with Ministry protocols. The results of a Stage II PSI or a DSI would compare the observed concentrations of potential contaminants of concern (PCOCs) with the Contaminated Sites Regulation (CSR) generic or matrix numeric standards. The revised regulatory process will also require that the site data be compared with the "high priority screening values" (HPSV)[19].

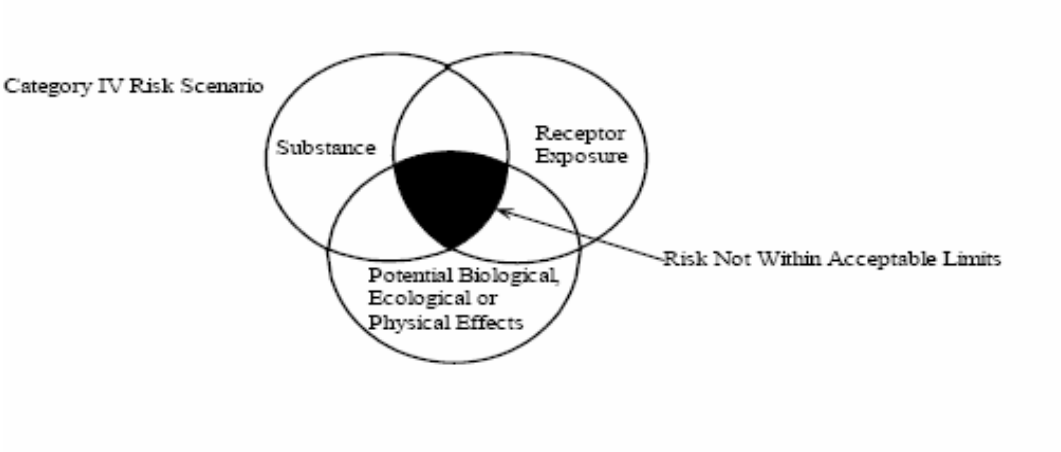
[19] The Ministry has suggested that the HSPVs would represent contaminant concentrations capable of causing significant harm to humans and/or ecological receptors.

The High Priority Screen Values (HPSVs) developed to date and recommended by the SAB, are summarized in Appendix A. The derivations of the HPSVs are further described in this report.

The finding of media with concentrations of chemicals in excess of the HPSVs will require a Level 2 assessment. It is noted that the determination of media with contaminants in excess of HPSVs will require an assessment of the extent of such contamination e.g., vertical and horizontal distribution in soil, and/or groundwater containing contaminants at levels above HPSVs at a site.

The Level 2 approach involves assessing the hazards and the exposure pathways that are present at a site. The hazard is assessed by comparing chemical concentrations to high priority screening values and the exposure potential for each chemical is assessed through a series of yes/no questions. The yes/no questions consider the mobility of the contaminant(s), as well as the presence of a receptor. They also consider the land use of the site, the presence and absence of direct exposure pathways including the presence/absence of barriers.

The principles used in the Level 2 approach are the same as those accepted by the science community for the preparation of quantitative risk assessments as illustrated below in the following figure.



4.2.1 Level 2 Assessment for Protection of Human Health

Part 1: Derivation of Human Health High Priority Screening Values

Soil

The HPSVs for human health represent contaminant concentrations in soil that are capable of causing harm to human health and when considered in combination with other site conditions, will form the basis for classifying a site as high priority.

High priority screening values (HPSVs) for soils are risk-based concentrations for chemicals in soil, that are calculated on the assumption that the direct soil contact pathways, ingestion, dermal contact and inhalation of particulate, are complete.

A report for Health Canada has already developed HPSVs for protection of human health[20]. The report for Health Canada provides HSPVs for residential and industrial use. The report intends that land used for recreational purposes

[20] URS, April 2005. "High Priority Classification System for Soil at Contaminated Sites, prepared for Health Canada and the SABCS

such as playgrounds and parks and institutional land uses such as schools, day cares, hospitals, may be evaluated using the high priority screening values for residential land use. Land used for commercial purposes may be evaluated using the high priority screening values for industrial sites.

The method used to develop the HPSVs for Health Canada is also documented in in the URS report. Should a chemical not have a HPSV, the HPSV may be calculated using the method described in the report to Health Canada.. The HPSVs were calculated based on a non-carcinogenic hazard quotient of 10 and a cancer risk of 1×10^{-4}. If a non-carcinogenic and carcinogenic HPSV was calculated for a chemical the lower concentration of the two was selected as the soil HPSV for that chemical.

It is noted the SABCS CSST Task Force is in the process of reviewing the 1996 CSST protocols including the protocol to derive soil standards for protection of human health. Exposure factors used to derive the initial Schedule 5 standards for protection of human health are under review and changes to those standards may occur, depending upon the results of the review of the Task Force. The SABCS notes that the exposure factors to develop the CSR standards for protection of human health should be the same as the exposure factors to develop the HPSVs, with the differences being the target values for the non-carcinogenic hazard quotient and the acceptable cancer risk.

Following a preliminary review of the approach used by Health Canada to develop its HPSVs, the CSST Task Force has indicated the exposure model used in the Health Canada approach is scientifically supportable and hence recommends the use of the Health Canada HPSVs at this time.

The SABCS therefore recommends that the:

- The Human Health HPSVs for use in British Columbia be based on a non-carcinogenic hazard quotient of 10 and a cancer risk of 1×10^{-4}.

- The Health Canada priority screening values (HPSVs) for soil for protection of human health be adopted for use in the high priority site identification process.

The Health Canada HPSVs for soil are summarized in Tables A-1 and A-2 of Appendix A of this report.

Soil Vapour

The SABCS task force to develop the Screening Level Risk Assessments[21] has stated that determinations of concentrations of volatile chemical in soil (i.e., expressed as weight volatile chemical/weight soil) are not reliable indicators of potential human health effects, and that soil vapour measurements would be more appropriate. Table A-3 in Appendix A of this report summarizes the HPSVs for soil vapour, and indoor air quality that were developed by URS in its report for Health Canada.

HPSVs for soil vapours are essentially those concentrations that may result in an indoor air concentration greater than ten times the air screening concentration for protection of human health (ASC_{HH}) (URS/Health Canada 2005). If the indoor vapour concentration of a chemical is greater than its ASC_{HH} times ten, the site is a high priority site.

The development of soil vapour high priority screening value (HPSVs) was a three step process. The first step involved the calculation of an acceptable indoor (or above ground) air screening concentration for human health (ASC_{HH}) for residential and industrial receptors. The second step was to multiply the ASC_{HH} by 10, to derive "high priority" values for indoor air quality, i.e., a hazard quotient of 10 or a cancer risk of 1 X $10^{-4.}$ The third step involved the back calculation of the soil vapour HPSV from the ASC_{HH} x 10 using the CCME (2000) and Health Canada (2005) approach for vapour intrusion.

[21] Science Advisory Board for Contaminated Sites in British Columbia, 2005. "Report on Screening Level Risk Assessment SLRA Level 1 and SLRA Level 2". Submitted to the Ministry of Environment, August 2005.

The calculation of the initial ASC_{HH} for indoor air was based on non-carcinogenic toxicity values, tolerable concentrations[22] (TCs), reference concentrations (RfCs), and carcinogenic toxicity values, cancer units risks and slope factors. These toxicity values were compiled from recognized regulatory authorities such as Health Canada, the Canadian Council of Ministers of the Environment (CCME), and the US Environmental Protection Agency (USEPA). These Principal documents/databases considered for the vapour toxicity values include:

- Health-Based Tolerable Daily Intakes / Concentrations and Tumorigenic Doses / Concentrations for Priority Substances (Health Canada 1996);
- Integrated Risk Information Database (USEPA 2004); and
- Canada-Wide Standards (CWS) for Petroleum Hydrocarbons Supporting Technical Document (CCME 2000).

The ASC_{HH} for a chemical with respect to residential receptors was equal to the TC or RFC when the chemical was a non-carcinogen and was equal to the unit cancer risk[23] when the chemical was a carcinogen. Indoor air ASC_{HH} for industrial receptors were based on the same TCs or RFCs and unit cancer risks as used to estimate the residential ASC_{HH}, but included a time adjustment factor to account for the reduction in exposure from the 24 hours per day 365 days be year assumed for the residential receptor. The exposure times for the residential and industrial receptors are summarized in the table below.

[22] The TC is the amount of a contaminant that is safe for humans to inhale every day for an entire lifetime.

[23] The unit cancer risk employed was the concentration resulting in a cancer risk of $1x10^{-5}$.

Recommended Human Health Characteristics for Generic Human Health Risk Assessment for Chemicals in Air

Parameter	Land Use	
	Residential	Industrial
Hours per day on site	24	8
Days per week on site	7	5
Weeks per year on site	52	52
Years per lifetime on Site (for amortization of cancer exposures)	75	75

The time adjusted ASC_{HH} for the industrial receptor was calculated using the following equation:

Time Adjusted ASC = (unadjusted ASC_{HH}*)/(Fraction of time spent at site relative to the residential receptor).*

The back calculation of the soil vapour HPSVs from the ASC_{HH} x 10 follows the approach put forward by the Health Canada (2005) and CCME (2000).

The soil vapour HPSV was calculated using dilution factors presented in Health Canada (2005). The dilution factor used was that for coarse soils and assumed a one and a half metre distance between the contamination and the building foundation (residential dilution factor = 1.56E-03 and industrial dilution factor = 2.5E-04). The following equation was used to calculate the soil vapour HPSV:

soil vapour HPSV (mg/m3) = ASC_{HH} *indoor air(mg/m3) x 10/ Dilution Factor*

The soil vapour HPSVs would have to be applied on the basis of site investigation studies that indicate the presence at the site, of any of the volatile chemicals listed in Table A-3.. In the case of a building on the site, Table A-3 provides the indoor air

concentrations that would constitute high priority concern. The indoor air concentrations could also be used on an optional basis to verify whether above ground concentrations are at levels of high priority concern.

Groundwater

The Schedule 6 CSR groundwater standards for protection of human health are based on the Health Canada guidelines for drinking water.

The procedures[24] used by Health Canada to develop the guidelines are based on science - accepted protocols for risk assessments and include:

- Derivation of maximum acceptable concentrations (MACs) for chemicals that are not considered carcinogenic, on the basis of tolerable daily intakes [i.e., a hazard quotient no greater than one (1)].

- When possible, the upper 95% confidence limit for the lifetime cancer risk associated with the MAC is less than 10^{-5} to 10^{-6}.

  Based on the limits used to develop HSPVs for soil, similar limits for groundwater intake would be used, i.e., a maximum hazardous quotient of 10 and a maximum cancer risk of 10^{-4}. This would simply require a multiplication factor of ten to the Schedule 6 standards for protection of drinking water, i.e., the hazard quotient would be ten and the cancer risk would in the order of $10^{-4.}$.

[24] Guidelines for Canadian Drinking Water Quality, Health Canada

Part 2 - Classification System Questions for Human Health Protection

Upon the finding of concentrations at a site in excess of the HSPVs, the following yes/no questions are used to consider the potential risk of each chemical that is in excess of the HSPVs.

Initial Question:

I-1 Is there evidence that the HPSV concentrations in soil, groundwater or soil vapour extend beyond the boundary of the property (i.e., are HPSV concentrations found at the boundary of the property)?

***IF YES**, conduct a separate classification process for the neighbouring property*[25]

(i.e. Proceed to Question G-1).

***If NO**, proceed to Question G-1.*

General Questions:

G-1 Are any of the human health HPSVs for soil vapour exceeded?[26]

***IF NO**, go to H-2 re: groundwater quality.*

***IF YES**, proceed to the following questions.*

G-2 Are volatile toxic contaminants present in soil vapour at concentrations greater than listed in Table A-3?

***IF YES,** go to Question G-3.*

***If NO,** proceed to Question G-4.*

G-3 Is the following true?

Are there current buildings or is there human activity within 30 m horizontally or vertically of detected soil vapours above Table A-3 air screening levels?

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[25] Assume concentrations in soil and groundwater at the neighbouring property are equivalent to those of the subject site.

[26] The HPSVs derived by Health Canada are listed in Table A-3 of Appendix A and are recommended for use in B.C. at this time.

IF YES, *Proceed to Question G-4*

If NO, *proceed to Question G-5.*

G-4 Are indoor concentrations in the current buildings or are above ground concentrations greater than the HPSVs listed for indoor air in Table A-3?

IF YES**,** *the site is a high priority site.*

IF NO, *proceed to question G-5.*

G-5 Is the area with high priority screening value exceedences for soil located in or migrating to the upper 1 m of soil?

IF NO*, then proceed to Question H-2.*

IF YES*, proceed to Question G-6.*

G-6 Is the area with high priority screening value exceedences covered by a barrier that will prevent human contact with the soil including but not limited to:

- **pavement/cement,**
- **buildings; or**
- **a soil barrier of at least 1 m of uncontaminated fill, such as topsoil for landscaping[27].**

IF NO*, then proceed to the human exposure questionnaire (starting at Question H-1).*

IF YES*, proceed to Question H-2.*

<u>Human Health Exposure Questions:</u>

[27] Should a continuous layer of uncontaminated fill greater than 1.0 m be present above the contamination (i.e. a soil cap) the appropriate immediate action may be to prohibit the removal or mixing of soils that form the soil cap until an investigation is completed for the site and appropriate actions have been taken to prevent harm to human health.

H-1 Is human exposure likely, i.e., are humans likely participating in outdoor activities on, or within 10m of, an area where the 90th percentile of any parameter exceeds a human health high priority screening value exceedences for soil, and[28]:

i. Is there exposure by residents to the area in excess of 1.5 hours per day[29]?

ii. Is there exposure by recreational users and trespassers, to the area in excess of 1.5 hours per day?

iii. Is there exposure by commercial or industrial workers to the area for periods greater than 8 hours per day?

***IF NO**, then the site is not a high priority site providing the conditions of H-2 are met.*

***IF YES,** the site is a high priority site.*

H-2 Does the groundwater contamination beneath the identified area contain screening value exceedences greater than ten times the Schedule 6 drinking water standards?

***IF NO**, and there is no exposure to soil containing HPSVs as per prior assessment criteria, then the site is not a high priority site.*

***IF YES,** then proceed to Question H-3.*

H-3 Is the edge of the groundwater plume with HPSVs within 30 m of a drinking water well?

***IF YES,** the site is a high priority site.*

***IF NO,** Go to H-4*

H-4 Does the cross-plot analysis as outlined in the SABCS SLRA indicate the concentration of a dissolved organic contaminant in groundwater at the nearest domestic water well will be greater than the HPSV?[30]

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[28] As per G-5 the high priority screening value exceedences are in uncovered areas and within 1 metre of the surfaces.

[29] Should exposure in the contaminated zone have the potential to exceed 1.5 hours, the site occupants may be requested to avoid that area of the property, or a temporary cap, soil or synthetic may be placed over the contaminated zone pending a complete investigation and/or remedial action. However, should such action prove difficult, immediate remedial action may be necessary. Health Canada guidance for risk assessments assumes 1.5 hours exposure per day.

IF YES, *the site is a HPMO site.*

IF NO, *go to Question H-5****.***

H-5 Does the groundwater contain metals at levels greater than HPSVs?

If YES *Go to H-6.*

IF NO, Go to H-7.

H-6 Is an existing well within a 50-year travel time OR do SABCS HAT[31] procedures indicate that metals will reach a domestic well at levels greater than HPSVs?

If YES or UNCERTAIN then the site is an HPMO site.

IF NOT, Go to H-7

H-7 Are apparent LNAPL thicknesses in wells greater than 0.15 metre, or are DNAPLs found in the groundwater?

IF YES, go to H-8

IF NO, The site is not an HPMO site**.**

H-8 Do SABCS HAT procedures indicate that NAPLs are mobile and will migrate to within 30 m of a drinking water supply well?

If YES OR UNCERTAIN *then the site is an HPMO site.*
If NO, the site is not an HPMO site.

[30] If the concentration of dissolved organic contaminants is less than HPSV, go to Question H-4

[31], Hydro geological Assessment Tools as developed by the SABCS, e.g. use of PHREEQC2 model.

4.2.2 Level 2 Assessment for Ecological Protection

The SABCS finds that the derivation of high priority screening values for ecological receptors is highly complex.

In particular, there is not an adequate scientific database to derive HPSVs for soil plants and invertebrates at this time.

At this time, the most meaningful option of assessing potential impacts of contaminants to ecological components is provided within the detailed risk assessment phase. However the SABCS is faced with the task of recommending a procedure that can be used by all Approved Professionals as a first step in the proposed contaminated site management process to determine if there is a "high" potential for ecological impacts. Based on the "safety factors" noted below, the SABCS is comfortable in providing a simplistic and generalized process for environmental screening of a site because as noted in Section 3.1.1:

- A site with contaminants in media at concentrations in excess of the CSR standards remains in the regulatory process, and will be subject to further assessment by the SLRA and the detailed risk assessment procedures. (Alternatively, remediation may occur at any stage to remove the contaminants to acceptable levels.)
- Iterative approaches may be used, whereby a site may be elevated to the status of an HPMO site, following receipt of new results and/or data interpretations.

Part 1: Derivation of Ecological High Priority Screening Values

Soil

For Protection of Aquatic Life

Groundwater HPSVs are suggested to replace the need for soil HPSVs as screening values for assessment of potential impact to aquatic life. HPSVs for soil to protect aquatic life are not suggested in the HPMO identification process, due to the complexity of predicting possible impacts of soil contamination on groundwater quality.

The SABCS is aware that a large majority of contaminated sites in British Columbia are historical in nature (i.e., the chemicals are no longer used or produced at the site, and there is some state of equilibrium between the concentrations in soil and groundwater). Therefore knowledge of groundwater concentrations would be more pragmatic and science-defensible in terms of a preliminary assessment of the potential impacts of contaminated soil on adjacent water bodies.

For Protection of Soil Invertebrates and Plants

During 2005 the SABCS provided a contract to Golder Associates ("Golder') to conduct a scientific review of the Ministry's Contaminated Sites Standards Task Group (CSST) soil standards derivation protocol. Questions to Golder related to the scientific basis of the CSST including, whether significant scientific developments have occurred since the preparation of the CSST protocol in 1996 and whether there is a need to improve the scientific viability of the 1996 protocol. The review of the protocol to develop the current CSR soil standards for protection of soil invertebrates and plants indicated a number of issues such as:

- There is limited soil toxicity data currently available in the literature that meets acceptable criteria[32] for the development of soil guidelines to protect plants and invertebrates. A June 2005 Golder review of the literature concluded that the

  database to develop soil criteria for protection of both plants and invertebrates is only adequate for cadmium, lead and pentachlorophenol.

- Different toxicological endpoints have been used by different agencies to derive soil protection guidelines. The 1996 CSST derivation protocol is inconsistent with CCME. The Golder review indicated concern about the CSST approaches relating to the use of reported toxicity data.

- Other issues relating to the 1996 CSST protocol as identified by Golder included the lack of a provision for incorporating bioavailability of contaminants.

[32] Based on a 2003 EPA review of the literature

It is obvious the understanding of soil toxicity to invertebrates and plants is very complex, and the science is at an elementary stage. As a result, the derivation of science-based HPSVs for protection of soil invertebrates and plants is not feasible within the intended time frame for the new regulatory process (i.e., March 2006). It may be several years before a reasonable data base is available to provide better and more scientifically defensible CSR Schedule 5 standards and HPSVs for protection of soil invertebrates and plants.

Based on discussions with SAB members, it is concluded that for now there can be no HPSV values for protection of soil invertebrates and plants, and that the current option is to defer to the prohibiting condition, i.e. evidence of lack of invertebrates/plants where growth would normally be expected, with consideration of possible physical effects such as disturbance and soil conditions.

Groundwater

Protection of Aquatic Life

Two approaches were considered for groundwater HPSVs for protection of aquatic life. Both approaches consider existing regulations and regulatory precedents.

1. Use of Reported 96-hr LC50 Values for Rainbow Trout

   Basis for Approach

   The B.C. Waste Management Act Municipal Sewage Regulations require that a discharge "passes a 96 hour LC50 bioassay test as defined by Environment Canada's Biological Test Method, Reference Method for Determining Acute Lethality of Effects to Rainbow Trout, Reference Method EPS 1/RM/13".

   The above bioassay test is virtually the sole scientific test for legal charges under Section 37(4) of the Federal Fisheries Act. [e.g. Regina v. MacMillan Bloedel (Alberni) Limited (1979); Regina v. Corporation of the City of Kingston (2002)]. There is a large database for the 96-hr LC50's for Rainbow trout.

2. Factor of Ten Multiplier on Schedule 6 Numbers for Protection of Aquatic Life

Basis for Approach

Within Section 9(2)e of the Municipal Sewage Regulation, there is a provision that states bioassay testing is not required if:

"the discharge is diluted such that at the outside boundary of the initial dilution zone the dilution ratio exceeds 100:1 and the discharger demonstrates to the satisfaction of the manager that the discharge does not adversely affect the receiving environment,"

It is known that Schedule 6 groundwater standards are 10 times the BC ambient approved and working guidelines for protection of aquatic life. A further 10 fold multiplier on the existing Schedule 6 groundwater numbers would represent a 100 fold factor. Except in very unusual situations,[33] the dilution ratio of groundwater within a mixing zone[34] as defined by the Ministry will likely be much greater than 100.

A comparison of the two approaches was conducted for eight representative contaminants and the results are shown in **Appendix D**. The comparison notes:

- For some contaminants such as copper and benzene, the reported 96-hr LC50 values are not significantly different from the Schedule 6 standards to protect aquatic life. On the other hand there are significant differences between the Schedule 6 standards for polycyclic aromatic hydrocarbons and reported 96-hr LC50 values. Varying toxicological endpoints have been used to derive the guidelines upon which the Schedule 6 standards are based, hence the observed range of differences.

[33] i.e. Except for areas where groundwater seeps from a contaminated area may constitute a significant portion of surface water flow. Such situations would likely occur at sites with mine tailings and impoundments.

[34] For releases from a contaminated site

- There is generally a wide range of reported 96-hr LC50 values resulting from exposure of Rainbow trout for any given chemical. Means to select the “best” data source will have to be defined.

Beta Test of Approaches

Field data for nine contaminated sites in British Columbia were provided to the work group of the SABCS on a confidential basis, for the purpose of beta testing the application of the two approaches. The testing program indicated:

- Of the data for five sites where service stations were located:
    - Four had one or more groundwater wells where 96-hr LC50 concentrations were exceeded (benzene and toluene). Two of the sites had one or more groundwater wells where benzene and/or toluene concentrations exceeded a value equivalent to 10 times the Schedule 6 standard for protection of aquatic life.
    - None of the 5 sites had any individual PAHs in excess of their reported 96-hr LC50 values. At least one well from each of four of the five sites, contained one or more individual PAHs in excess of 10 times of their reported Schedule 6 standard for protection of aquatic life.
- Groundwater from one decommissioned industrial site had no occurrences of metals or organic compounds in excess of either their 96-hr LC50 values or values in excess of 10 times the Schedule 6 standard for protection of aquatic life.
- A second industrial site had groundwater contamination as noted above for service stations, i.e., benzene and toluene above reported 96-hr LC50 levels and individual PAHs were within the reported 96-hr LC50 values (but greater than 10 times reported Schedule 6 standard for protection of aquatic life).

It is noted in most of the cases described above; the number of groundwater wells with the elevated concentrations represented a small fraction of the total number of groundwater wells, indicating the need for additional evaluation of data prior to labelling a site as a HPMO site.

Two additional sites were selected as probably representative of sites that in the opinion of the work group should represent HPMO sites. Both the 96-hr LC50 and the values obtained by multiplying Schedule 6 standards by ten were effective in identifying the sites as possible HPMO sites.

Recommended Approach

At this time, it is provisionally recommended that 96-hr LC50 values for Rainbow trout be used as HPSVs for groundwater to protect freshwater aquatic life and 96-hr LC50 values salmonid species be used as HPSVs for groundwater to protect marine aquatic life. The reasons for the recommendations are:

- Legal precedents
- The availability of a large database of 96-hr LC50 values for Rainbow trout and marine salmonids, which can be readily assessed for selection of the most appropriate data.

There is a probability that certain industry-specific sites may have a frequent presence of soil and/or groundwater in excess of the HPSVs (e.g. gas station sites with benzene releases). Following implementation of the high priority site identification procedure, there will be a need to evaluate the results of the Level 2 assessments that would follow the initial HPSV identification process (e.g., evaluation of migration of benzene substrates in groundwater) and hence determine the frequency of sites that would be designated as HPMO sites[35].

[35] Level 2 assessments may indicate that the HPSVs for some parameters could actually be higher than indicated in this report, due to subsequent factors such as biodegradation, chemical oxidation, strong adsorption to soil, etc.

If it is found that the combined LC-50 approach and the Level 2 assessment are overly conservative in designating sites as HPMO sites, then reassessment of the approaches will have to be considered.

Approach to Obtain Toxicity Information

The SAB funded a pilot study to compile 96-hr LC50 values for Rainbow trout.

The screening level for aquatic toxicity was based on acute responses as being indicative of greater likelihood of immediate adverse impacts in the receiving environment. Further emphasis was placed on values derived for rainbow trout (*Oncorhynchus mykiss*) because of the longstanding use of that species for defining toxicity in accordance with provisions of the *Fisheries Act*. Because of inherent variability associated with results obtained from toxicity tests conducted at different laboratories, additional consideration was given to quantifying such variability and applying that factor to increase the confidence that a derived screening value would actually be associated with toxicity if tested by an independent laboratory. Thus, the screening value not only provides a strong indication of a high likelihood for adverse effects, it also indicates a high probability that, if tested for toxicity, the sample would fail, leading directly to potential regulatory action under the *Fisheries Act*. Finally, it was recognized that while trout are generally among the more sensitive aquatic species and do have regulatory status, they may not be the most sensitive indicators of potential environmental damage for all toxicants. Consequently, for those substances which trout exhibit comparatively less sensitivity, additional steps were taken to derive a screening value that would reflect contaminant concentrations associated with actual environmental harm.

A limited number of 96-hr LC50 values were derived for use as groundwater HPSVs for protection of aquatic life, and are summarized in Appendix A with further details of the approach and examples of the derived concentrations provided in Appendix C.

Part 2: Classification System Questions for Ecological Protection

The following yes/no questions consider the possible impact of each chemical of potential concern by comparison of each chemical concentration to the HPSV, land use, and the presence absence of exposure pathways

Initial Question:

I-1 Is there evidence that the HPSV concentrations in soil or groundwater extend beyond the boundary of the property (i.e., are HPSV concentrations found at the boundary of the property)?

***IF YES**, conduct a separate classification process for the neighbouring property (i.e. proceed to question G-1).*

***If NO**, proceed to Question G-1.*

General questions:

G-1 Does the site have more than 0.5 ha undeveloped land?

***IF NO**, go to E-1.*

***IF YES**, proceed to the following questions.*

G-2 Is there evidence of lack of invertebrates/plants and/or stressed vegetation in the undeveloped land (area > 0.5 ha) where such growth would normally be expected?[36]

***IF NO**, then proceed to Question E-1.*

***IF YES**, The site is a high priority site.*

[36] Sites where physical disturbance had occurred within the past five years would be precluded from this question. (i.e. go to question E-1). As well the adequacy of the soil to sustain terrestrial biota must be considered- e.g. a gravel pit would not be expected to maintain a viable terrestrial community.

Ecological Exposure Questions:

E-1 Are "bioaccumulative substances"[37] present in site soils at levels in excess of 10X CSR standards AND:

▪ Is there prior evidence[38] of bioaccumulation in biota at, or adjacent to the site above normal background levels? OR

▪ Do sediments in the adjacent receiving environment contain bioaccumulative substances in excess of 10X sediment quality criteria?

IF NO, *then proceed to Question E-2.*

IF YES, *site is a potential "high priority' site.*

E-2 Does the area contain groundwater with contaminants in excess of the "high priority screening values" (Table A-4) for protection of aquatic life?

IF NO, *site is not an ecological " high priority" site. Exit Ecological Exposure Questionnaire.*
IF YES, *proceed to E-3.*

E-3 Is the edge of the groundwater plume with HPSVs within 30 m of a receiving water body?

IF YES, *the site is a high priority site.*
IF NO, *Go to E-4*

E-4 Are the contaminants dissolved organic compounds?

If YES, *go to E-5*
If NO, *go to E-6*

[37] Bioaccumulative substances have bioaccumulation factors >5000 or bioconcentration factors >5000 or Log Kow >5.0.

[38] E.g. from prior government reports

E-5 Does the cross-plot analysis as outlined in the SABCS SLRA indicate the concentration of a dissolved organic contaminant in groundwater at the point of discharge to the receiving environment will be greater than the HPSV?

IF YES, *the site is a HPMO site.*

IF NO, *go to E-6.*

E-6 Does the groundwater contain metals at levels greater than HPSVs?

IF YES, Go to E-7.

IF NO, Go to E-8.

E-7 Is a water body within a 50 year travel time OR do SABCS HAT[39] procedures indicate that metals will reach a receiving environment at levels greater than HPSVs?

If YES OR UNCERTAIN, *the site is an HPMO site.*

If NO, *go to Question E-8*

E-8 Are apparent LNAPL thicknesses in wells greater than 0.15 metre, or are DNAPLs found in the groundwater?

IF YES, go to E-9.

IF NO, The site is not an HPMO site.

E-9 Do SABCS HAT procedures indicate that NAPLs are mobile and will migrate to the nearest receiving environment?

If YES OR UNCERTAIN, *the site is an HPMO site.*

If NO, *the site is not an HPMO site.*

[39], Hydro geological Assessment Tools as developed by the SABCS, e.g. use of PHREEQC2 model.

4.3 LEVEL 3: SITES IDENTIFIED AS "HIGH RISK" BY USE OF RISK ASSESSMENT

The proposed Ministry process for contaminated sites is such that Screening Level Risk Assessments will occur at all sites with contaminants in excess of CSR standards (unless remediation is selected as an immediate solution). Subsequent detailed risk assessments are likely for a number of sites, in particular sites containing media with concentrations in excess of HPSVs. Due to the standard of care required for screening level and detailed risk assessments and due to the necessary consideration of site-specific conditions, the process will provide a thorough means of assessing risk. The approach also enables a better handle on assuring human health and ecological protection, since it is possible that media with concentrations above CSR standards but less than upper cap numbers may combine to constitute unacceptable risks that would not be determined in a generalized screening process.

As part of a Level 3 identification process for HPMO sites, the Task Force recommends, that for due diligence purposes, the Ministry will be notified if a risk assessment (screening or detailed) indicate one or more of the following conditions:

- The calculated human health cancer risk for the given use of a site, for any one carcinogen, is greater than one in 10,000;
- The calculated cumulative (additive) cancer risk for the given land use of a site, for all carcinogens combined, is greater than two in 10,000;
- The calculated human health hazard quotient for the given land use of the site, for any one threshold substance, is greater than 10; or
- The calculated human health hazard index for the given land use of the site, for all threshold substances combined, is greater than 20.
- The calculated hazard quotient for terrestrial biota at the site is greater than "ten" or greater than an acceptable level determined by the risk assessor. A similar assessment is applicable to the ecological hazard quotient as noted above for the human health hazard quotient.

- The SRA-2 and/or DRA determination of groundwater transport of a contaminant indicates that a discharge to the receiving environment could be in excess of the 96-hr LC50 for salmonids. This criterion is based on legal precedent via the Federal Fisheries Act.

5.0 SUMMARY OF RECOMMENDATIONS

The following provides a summary of the recommendations of the SABCS:

a) The classification system presented in this report focuses on the sole objective of determining whether a site requires Ministry oversight or whether it does not.

b) Three levels of evaluation are recommended:

   i. Level 1, consisting of trigger conditions based on current information that would label a site as a HPMO site (e.g. contamination of a municipal water supply).

   ii. Level 2, consisting of initial identification of potential HPMO sites by the presence of concentrations of contaminants in media at levels in excess of determined High Priority Screening Values (HPSVs), followed by dichotomous approach for the assessment of the potential for exposure to the contaminants by humans or wildlife.

   iii. Level 3, where subsequent investigations at a site including detailed risk assessments indicate the presence of a risk above conditions noted in this report.

c) The SABCS encourages the use of an iterative process throughout the overall site investigation process to identify sites as high priority and to likewise verify that some sites are actually not of high priority. .

d) Use of the HPMO identification system will require data obtained by Detailed Site Assessment, i.e., the finding of HPSVs in a Stage II PSI will require additional work by use of a detailed site assessment to define the extent of contamination at levels above HPSVs.

e) The SABCS does NOT support the application of “high risk screening values” as standards. The SABCS supports the use of “high risk screening values” for use as a tool in the classification system only.

f) The status of the high risk screening values (as summarized in Appendix A) is as follows:

i. *Soil- Human Health:* The exposure assumptions used for preparation of a report to Health Canada have been briefly reviewed by the SABCS CSST Task Force, and it is recommended the Health Canada HPSV's for soil (for protection of human health) be used as HPSVs in B.C. The SABCS agrees with the Health Canada approach of using a maximum cancer risk of 10^{-4} and a maximum hazard quotient of 10 for development of HSPVs for human health.

ii. *Soil Vapour - Human Health*: Numbers obtained in the report to Health Canada are recommended for use at this time. The prior use or storage of volatile substances at the site implies the need for soil vapour assessments.

iii. *Groundwater - Human Health*: The Health Canada drinking water guidelines are adjusted to the risk levels used for development of the soil HSPVs for protection of human health. Essentially the HSPVs for drinking water will be 10 times the human health standards in Schedule 6. Confidence in the numbers is good.

iv. *Soil - Protection of Soil Invertebrates and Plants:* The scientific database to develop HSPVs is not adequate. It is suggested that for now, evidence of lack of invertebrates/plants where growth would normally be expected, may indicate a prohibiting condition, providing there is consideration of possible physical effects and soil conditions.

v. *Soil- Protection of Aquatic Life*: Given that sites with soil containing contaminants in excess of CSR standards for protection of aquatic life are subject to further specialized studies using the SABCS SLRA approaches, it is suggested that for identifying HPMO sites, existing groundwater concentrations be used to assess the potential impacts of contaminated soils on adjacent waterbodies.

vi. *Groundwater- Protection of Aquatic Life:* It is proposed that 96-hr LC50 values (Rainbow trout) of chemicals be used as HSPVs for groundwater that may discharge to freshwater systems, and 96-hr LC50 values for salmonids should be used as "screens" for groundwater discharging to marine systems.

APPENDIX A

Summary of High Priority Screening Values

Human Health Protection

- **Soil- as per Tables A-1 and A-2**
- **Soil vapour- as per Table A-3**
- **Groundwater- ten times Schedule 6 standards for protection of drinking water**

Environmental Protection

- **Groundwater to protect aquatic life- as per Table A-4**
- **Soil to protect invertebrates and plants: no HPSVs (site visits required to assess site conditions as per report text)**
- **Soil to protect aquatic life- no HPSVs (i.e. emphasis is on groundwater quality)**

TABLE A-1: HIGH PRIORITY SCREENING VALUES FOR SOIL – Residential Land Use

Chemical	Residential HPSV for soil (mg/kg)	CSR Residential Standards (mg/kg)
INORGANIC SUBSTANCES		
Antimony	760	20
Arsenic	110	100
Barium	30000	500
Beryllium	4000	4
Cadmium	1500	3/ 35
Chromium	2000	
Chromium- hexavalent	1900	100
Cobalt	19000	50
Copper	57000	15000
Cyanide	33000	10/ 50
Fluoride	250000	400
Lead	7400	500
Mercury	600	15
Molybdenum	9500	10
Nickel chloride	2100	100
Nickel oxide	SAT	100
Nickel subsulphide	SAT	100
Nickel sulfate	62000	100
Nickel, metallic	SAT	100
Nickel, oxidic/sulphidic/soluble	SAT	100
Nickel, soluble	SAT	100
Selenium	10000	3
Silver	8500	20
Tin	620000	50
Vanadium	17000	200
Zinc	610000	10000
CHLORINATED HYDROCARBONS		
Chlorinated alkanes		
1,2-Dichloroethane	40000	5
1,1,2-Trichloroethane	650	5
1,1,2,2-Tetrachloroethane	1600	5
Chlorinated Propane (1,2-Dichloropropane)	1900	5
Dichloromethane (Methylene Chloride)	**102000**	5
Trichloromethane (Chloroform)	1.9	5
Chlorinated alkenes		
1,1,2-Trichloroethene (Trichloroethylene, TCE)	**760000**	200
1,1,2,2-Tetrachloroethene (Tetrachloroethylene, PCE)	**27000**	1000

Chemical	Residential HPSV for soil (mg/kg)	CSR Residential Standards (mg/kg)
Chlorinated benzenes		
Monochlorobenzene	**820000**	2
1,2-Dichlorobenzene	**820000**	1
1,3-Dichlorobenzene	**57000**	1
1,4-Dichlorobenzene	**209000**	1
1,2,3-Trichlorobenzene	1700	2
1,2,4-Trichlorobenzene	3100	2
1,3,5-Trichlorobenzene	1700	2
1,2,3,4-Tetrachlorobenzene	3800	2
1,2,3,5-Tetrachlorobenzene	460	2
1,2,4,5-Tetrachlorobenzene	430	2
Pentachlorobenzene	2000	2
Hexachlorobenzene	202	1
Miscellaneous chlorinated hydrocarbons		
Polychlorinated Biphenyls (PCBs) (group)	**1800**	5
Polychlorinated Dioxins and Furans	**0.002**	0.00035
Chlorinated phenols		
2,4-Dichlorophenol	**150000**	0.5
2,4,6-Trichlorophenol	9960	0.5
2,3,4,6-Tetrachlorophenol	**20400**	0.5
Pentachlorophenol (PCP)	**1520**	100
GLYCOLS		
Ethylene Glycol	SAT	65000
MONOCYCLIC AROMATIC HYDROCARBONS		
Benzene	680	1000
Toluene	17000	40000
Styrene	210000	5
Xylene	SAT	65000
PHENOLIC SUBSTANCES		
Phenols (group)	**101000**	1
POLYCYCLIC AROMATIC HYDROCARBONS		
Anthracene	**500000**	
Benzo(a)pyrene	57	5
Benzo(b)fluoranthene	570	1
Benzo(k)fluoranthene	570	1
Dibenz(a,h)anthracene	87	1

Indeno(1,2,3-c,d)pyrene	570	1
Naphthalene	**38000**	5
Pyrene	**53000**	10
PESTICIDES		
DDT (2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane)	18000	15

*** SAT – the estimated concentration exceeds the concentration of the pure component.**

TABLE A-2: HIGH PRIORITY SCREENING VALUES FOR SOIL- Commercial & Industrial Land Use

Chemical	Industrial HPSV for soil (mg/kg)	CSR Commercial/Industrial Land Use Standards
INORGANIC SUBSTANCES		
Antimony	14000	40
Arsenic	170	300
Barium	550000	2000
Beryllium	85000	8
Cadmium	24000	100
Chromium	44000	
Chromium-hexavalent	8100	300
Cobalt	320000	300
Copper	SAT	50000
Cyanide	400000	100/ 500
Fluoride	SAT	2000
Lead	190000	1000
Mercury	13000	40
Molybdenum	170000	40
Nickel Chloride	23000	500
Nickel Oxide	SAT	500
Nickel subsulphide	SAT	500
Nickel sulfate	170000	500
Nickel, metallic	SAT	500
Nickel, oxide,sulphidic/soluble	490000	500
Nickel, soluble	860000	500
Selenium	260000	10
Silver	110000	40
Tin	SAT	300
Vanadium	310000	
Zinc	SAT	30000
CHLORINATED HYDROCARBONS		
Chlorinated alkanes		
1,2-Dichloroethane	63000	50
1,1,2-Trichloroethane	1400	50
1,1,2,2-Tetrachloroethane	2500	50
Chlorinated Propane (1,2-Dichloropropane)	28000	50
Dichloromethane (Methylene Chloride)	SAT	50
Trichloromethane (Chloroform)	3	50
Chlorinated alkenes		
1,1-Dichloroethene (Dichloroethylene)	102000	50?

1,1,2-Trichloroethene (Trichloroethylene, TCE)	SAT	600
1,1,2,2-Tetrachloroethene (Tetrachloroethylene, PCE)	480000	3500
Chemical	**Industrial HPSV for soil (mg/kg)**	**CSR Commercial/Industrial Land Use Standards**
Chlorinated benzenes		
Monochlorobenzene	SAT	10
1,2-Dichlorobenzene	SAT	10
1,3-Dichlorobenzene	SAT	10
1,4-Dichlorobenzene	SAT	10
1,2,3-Trichlorobenzene	12000	10
1,2,4-Trichlorobenzene	59000	10
1,3,5-Trichlorobenzene	12000	10
1,2,3,4-Tetrachlorobenzene	27000	10
1,2,3,5-Tetrachlorobenzene	3300	10
1,2,4,5-Tetrachlorobenzene	11000	10
Pentachlorobenzene	51000	10
Hexachlorobenzene	370	10
Miscellaneous chlorinated hydrocarbons		
Polychlorinated Biphenyls (PCBs) (group)	30000	15
Polychlorinated Dioxins and Furans	0.02	0.001
Chlorinated phenols		
2,4-Dichlorophenol	SAT	5
2,4,6-Trichlorophenol	20000	5
2,3,4,6-Tetrachlorophenol	510000	5
Pentachlorophenol (PCP)	2700	300
GLYCOLS		
Ethylene Glycol	SAT	200000
MONOCYLIC AROMATIC HYDROCARBONS		
Benzene	1200	4000
Toluene	SAT	100000
Styrene	SAT	50
Xylene	SAT	200000
PHENOLIC SUBSTANCES		
Phenols (group)	SAT	10
POLYCYCLIC AROMATIC HYDROCARBONS		
Anthracene	SAT	10
Benzo(a)pyrene	110	15

Benzo(b)fluoranthene	1100	10
Benzo(k)fluoranthene	1100	10
Dibenz(a,h)anthracene	150	10
Indeno(1,2,3-c,d)pyrene	1100	10
Naphthalene	680000	15
Pyrene	750000	100
PESTICIDES		
DDT (2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane)	250000	50

TABLE A-3: HIGH PRIORITY SCREENING VALUES FOR VAPOURS

Chemical	Health Canada Screening Concentration (Indoor Air) for Protection of Human Health (ASC_{HH}) (µg/m3)		High Priority Screening Values (Indoor Air or Above Ground) ASC_{HH} x 10 (µg/m3)		High Priority Screening Values - Soil vapour Concentration (mg/m^3)	
	Residential	Industrial	Residential	Industrial	Residential	Industrial
Benzene*	3	19	30	190	1.9	76
Carbon tetrachloride*	0.67	4.2	6.7	42	0.4	16.8
Dichlorobenzene, 1,2-	120	550	1200	5500	77	2200
Dichlorobenzene, 1,4-	19	86	190	860	12	344
Dichloroethane, 1,2- *	5.6	35	56	350	3.6	140
Dichloroethylene, 1,1-	40	180	400	1800	26	720
Dichloromethane	600	2,700	6000	27000	385	10800
Hexachlorobenzene*	0.054	0.34	0.54	3.4	0.035	1.36
Monochlorobenzene	3.2	36	32	360	2.1	144
Pentachlorobenzene	0.35	4.1	3.5	41	0.2	16.4
Styrene	18	84	180	840	12	336
Tetrachloroethylene	72	330	720	3300	46	1320
Toluene	760	3,500	7600	35000	487	14000
Trichlorobenzene, 1,2,4-	1.4	6.4	14	64	0.9	25.6
Trichloroethylene*	16	100	160	1000	10	400
Xylenes, mixed isomers	36	160	360	1600	23	640

Table A-4 - Summary of proposed screening values compared with Schedule 6 values for protection of aquatic life.

Variable	Proposed screening values (µg/L)	Schedule 6 values (aquatic life) (µg/L)
Copper [1]	290	30 [3], 20 [4]
Cadmium [1]	5.4	0.3 [3], 1.0 [4]
Zinc [1]	1,632	75 [3], 100 [4]
Arsenic	21,000	50 [3], 120 [4]
Lead	3,180	50 [3], 20 [4]
Chromium (VI)	13,139 at pH > 6.5; 6,570 at pH ≤ 6.5	10 [3], 150 [4]
DDT	21.9	0.01
Benzene	20,488	4000 [3], 1000 [4]
Toluene	21,459	390 [3], 3300 [4]
Ethylbenzene	21,624	2000 [3], 2500 [4]
Naphthalene	5,825	10
Phenanthrene	3,200	3
VPH	15,674	1,500
LEPH	7,106	500
Tetrachloroethylene	14,746	1,100
Pentachlorophenol [2]	395	12
Tetrachlorophenol	475	28

[1] value varies with hardness; reported at a hardness of 50 mg/L as $CaCO_3$

[2] value varies with pH; reported at pH 7.8

[3] Freshwater aquatic life

[4] Marine aquatic life

APPENDIX B

Beta Test of Groundwater HPSVs for Protection of Aquatic Life (96 hr LC50 Versus 10X Schedule 6 Standards

Concentrations in ug/L (likely selected values are noted in bold)

Chemical	Schedule 6	96-hr LC50 ppb (R. trout- freshwater) Marine (fish)	10X Schedule 6
Arsenic	50 (Freshwater)	-13,340 (III)[40] -***10,800*** (V)[41] -10,800 (V)[42] -550[43] (28 day)	**500**
	120 (Marine)	-3,800 (10-day)[44] -***10,300***-14,900 (96-hr LC50)[45]	**1200**
Chromium VI	10 (Freshwater)	-12300-38600[46] -180-190 (28 day)[47] ->***170*** and <15610[48] -100[49]	**100**
	150 (Marine)	-***16,300***-200,000[50]	**1500**
Copper [51]	Freshwater: 20 (H: <50)-90(H. >200) Marine: 20	10 (H:13)- 125(H:360)[52] 20 (H: 20)-890(H:290)[53] 17-10,240[54]	**200-900**
Pentachlorophenol	1-27.5 (Freshwater)	***34-121***[55] 18[56] 18-3000[57]	**10-275**
Naphthalene	10	***1500***-6700[58]	**100**

[40] US EPA Ambient Water Quality Criteria 1984 Sodium arsenite
[41] US EPA Ambient Water Quality Criteria 1984 sodium arsenate.
[42] CCME Lowest known acute toxic concentration of arsenic V for fish (Rainbow trout)
[43] CCME 28 day LC50 for Rainbow trout
[44] CCME 10-day LC54 pink salmon
[45] CCME striped bass and stickleback respectively
[46] ECOTOX 96-hr LC50 Rainbow trout (potassium dichromate)
[47] ECOTOX 28 day LC50 chromium oxide
[48] ECOTOX 28 day LC50 from chromium
[49] Quoted in CCME 2002 72 hr. LC50 for Rainbow trout
[50] Ranged quoted in CCME 2002 for several marine species
[51] The high variances in reported LC50 values require further assessment of the data.
[52] Cited in Ministry of Environment Technical Appendix, Water Quality Criteria for Copper 1987 page 34
[53] Cited in US EPA Red Book page 56 Table 5
[54] Cited in CCME as range in acute toxicity data for 41 genera
[55] Eisler, 1989, PCP hazards to fish, wildlife and invertebrates: a synoptic review. U.S. Fish and Wildlife Service, report 85(1.17). Cited in Ken Brooks literature review
[56] Lowest reported 96-hr LC50 Rainbow trout cited by BC Environment. Leeuwen, C. J. Van, P. S. Griffioen, W. H. A. Vergouw and J. L. Moss-Diepeveen. 1985. Differences in Susceptibility of Early Life Stages of Rainbow Trout (*Salmo gairdneri*) to Environmental Pollutants. Aquatic Toxicology 7: 59-78.
[57] ECOTOX reported ranges 96-hr LC50 Rainbow trout
[58] ECOTOX database naphthalene 96-hr LC50 Rainbow trout

Phenanthrene	3	***3200***[59]	**30**
Benzene	4000 (Freshwater)	**5300**[60] 5300-11,700[61] 4600-476,000 (for different freshwater fish and life stages)[62] ,	**40,000**
	1000 (Marine)	700-50,000 (different marine fish and life stages)[63]	**10,000**
Toluene	390 (Freshwater)	5800[64] 5800-32,600[65] ***5460***-1,340,000 (different fish)[66]	**3900**
	3300 (Marine)	***5400***-480000 (different fish)[67]	33,000

[59] ECOTOX only one value for 96-hr LC50 Rainbow trout

[60] CCME quote; DeGraeve et al. earlier CCME document

[61] ECOTOX data base 96-hr LC50 Rainbow trout

[62] CCME 2002 benzene

[63] CCME 2002 benzene

[64] CP Chem MSDS

[65] ECOTOX data base for 96-hr LC50 for toluene and for Rainbow trout

[66] CCME 2002 toluene review: 5460 for coho; 1,340,000 for mosquito fish

[67] CCME 2002 toluene review: 5400 for pink salmon; 480000 sheepshead minnow

APPENDIX C

USE LATEST VERSION OF NAUTILUS REPORT TEST SUBSTANCES

A number of contaminants were selected for initial evaluation to fine-tune and validate the approach. These included a number of metals and organics that were selected to provide a broad range of contaminants with different environmental properties and modes of action. Specifically, the contaminants were: copper, zinc, arsenic, DDT, toluene, naphthalene, benzene, tetrachloroethylene and pentachlorophenol. Data are presented here for copper, zinc, DDT and benzene, and the remaining constituents continue to be evaluated.

DERIVATION OF SCREENING LEVELS

Rainbow trout acute toxicity data (i.e., LC50 values) and species mean acute values (SMAVs) were obtained from the USEPA water quality criteria databases wherever possible. This approach was used for two reasons: first, the USEPA approach incorporates all data associated with a particular contaminant, and not just the most sensitive values, and secondly, these studies have already been screened for data acceptability.

If a particular contaminant did not have an associated USEPA acute water quality criterion, or if the SMAV for rainbow trout was derived from a small number of LC50 values, the ECOTOX aquatic toxicity database was then queried for any additional such values. If the dataset for a particular contaminant was still limited, ECOTOX was also queried for acute toxicity data obtained with other species of salmonids in a effort to develop the most robust representation of the acute response. In cases where additional data were used, a SMAV was calculated as the geometric mean of the values for the rainbow trout data or, in cases where additional salmonid values were available, a genus mean acute value (GMAV) was calculated as the geometric mean of all of the values.

The species or genus mean acute values were used as the initial point of calculation since they were considered representative of the average value at which trout were likely to exhibit an acute response. These MAVs were then adjusted to reflect inter-laboratory variation in deriving LC50 estimates. The best estimate of this adjustment was considered to be from the USEPA inter-laboratory testing program, and includes data from literally hundreds of tests that represent a number of commonly used laboratory test species and toxicants. Inter-laboratory comparisons for rainbow trout were limited (two studies); consequently, they were pooled with results from fathead minnow tests (8 studies) to improve the robustness of the estimate over a wider range of toxicants. Thus, estimates of inter-laboratory variation were available from a total of 10 studies, representing results from 6 toxicants and nearly 300 tests (USEPA 2002).

The estimates of inter-laboratory variation were presented as coefficients of variation (CVs) in the inter-laboratory comparison studies. In other words, all of the LC50s obtained for a particular toxicant from different laboratories within a given study were averaged and the standard deviation calculated. The standard deviation was then divided by the mean value to provide a measure of the variability surrounding the mean. The resulting CV was then expressed as a percentage, the CVs from all studies ranked, and the 90^{th} percentile value determined.

The 90^{th} percentile value for the CV was then multiplied by 2 to obtain a value that represented two standard deviations from the mean. Thus, the screening level was set at a concentration such that 95 % of the labs testing the sample would concur that the sample exhibited toxicity (i.e., 95 % of the labs testing the sample would have a 90 % probability of identifying toxicity). This level of certainty is important not only in terms of establishing the potential for environmental effects, but also for determining the potential for legal exposure under the Fisheries Act.

For the purposes of comparisons, an alternative approach was used where the sample size ($n>9$) was considered sufficient to be able to generate a probability distribution with some level of confidence.

In this case, the 95th percentile of the LC50 estimates for a given contaminant was used as a direct estimate of the screening value. This approach was felt to be potentially appropriate because each dataset provided its own contaminant-specific estimate of inter-laboratory variation, which could be more appropriate to apply than a generic measure of inter-laboratory variability determined from tests conducted on a variety of toxicants.

Finally, the ratio of the SMAV (or GMAV) was compared with the acute water quality guideline values for each contaminant which have such guidelines to evaluate whether rainbow trout were a sufficiently sensitive endpoint to provide environmental protection, or if another species might be more appropriate. This was a somewhat subjective comparison, but a factor of ten was applied for purposes of this comparison. Values for which the ratio exceeded ten (i.e., where the SMAV was at a concentration more than ten times the guideline) were considered for potential follow-up activities to identify a screening level concentration that might be more protective of environmental conditions. USEPA criteria values were used for comparison since these guidelines include acute toxicity criteria more frequently that BC or CCME guidelines.

RESULTS

SCREENING LEVEL ADJUSTMENT

The 90th percentile CV calculated from the ten inter-laboratory studies was 91.2%. When multiplied by 2, this resulted in a value of 182%, or a factor of 1.82. Thus, the species/genus mean acute value for a given contaminant would be adjusted upwards by two standard deviations, resulting in:

$$\text{Screening level concentration} = \text{MAV} + (1.82 \times \text{MAV})$$

As a quick check on the relevance of this result, consider a hypothetical MAV of 50 mg/L; the screening level concentration would equal 141 mg/L.

Given that a typical acute toxicity test uses a 50 % dilution factor, this MAV and screening level values would fall within a span of two test concentrations, which is not an unreasonable level of variation for laboratory test results. Thus, this value does not appear to be overly restrictive, or excessively lenient.

RESULTS FOR INDIVIDUAL CONTAMINANTS

Copper – There were 36 values for copper in the USEPA database. Normalized to a hardness of 50 mg/L, the SMAV for rainbow trout was 102.7 µg/L and, therefore, the screening level concentration was calculated as 289.6 µg/L. This proposed value is lower than the 95th percentile derived directly from the database of copper toxicity values (352 µg/L). This suggests that the proposed screening level number of 289.6 µg/L is appropriate, and within the range of values obtained for copper. Furthermore, the SMAV was within a factor of ten of the USEPA acute toxicity criterion of 13 µg/L, indicating that rainbow trout are a reasonably sensitive species to copper.

A hardness-linked function should be applied to this value to account for the protective effect of increasing hardness on the toxicity of copper to trout.

Zinc – USEPA reported 25 values for zinc, and the SMAV was 744.4 µg/L. The calculated screening level concentration was 2099.2 µg/L, which was higher than the 95th percentile value from the zinc toxicity database of 1632.7 µg/L. Given that the calculated screening level value was outside the range of values obtained for zinc, and that the dataset represents a substantial number of test results, it appears reasonable to conclude that the estimate for laboratory variability is probably too high for this particular contaminant, and that the 95th percentile value from the database (i.e., 1639.7 µg/L) would be more appropriate as a screening level for zinc. The USEPA acute toxicity criterion of 120 µg/L is within a factor of ten of the SMAV, indicating that rainbow trout are reasonably sensitive to zinc. Because of the substantial influence of hardness on the acute toxicity of zinc, a hardness-linked function should be applied to this value. The screening value is normalized to a hardness of 50 mg/L.

DDT – There were 13 values for DDT, and the SMAV was 7.8 µg/L. The calculated screening level concentration was 21.9 µg/L, which is within the range of values reported, and less than the 95th percentile value of 27 µg/L. Thus, the screening level value of 21.9 µg/L appears to be appropriate. Furthermore, the SMAV is within a factor of ten of the acute criterion of 1.1 µg/L, indicating that rainbow trout are sensitive top this toxicant.

Benzene – Only one datapoint for acute toxicity to rainbow trout was available from the USEPA criterion for benzene, and a total of four values were available from the ECOTOX database. Four additional values were available for other salmonids of the genus *Oncorhynchus* and, consequently these eight values were used for calculation of the GMAV (9017.4 µg/L) and resulted in a proposed screening value of 20,488 µg/L. This value is somewhat higher than the 95th percentile from the dataset of 19,300 µg/L; however, because of the small number of datapoints available for toxicity of benzene, the somewhat higher value of 20,488 µg/L appears appropriate. There are no acute toxicity criteria with which to compare the proposed screening value.

Other screening values have been determined and are shown in the following table.

COMPARISON OF RESULTS WITH SCHEDULE 6 STANDARDS

TEST SUBSTANCE	CALCULATED SCREENING VALUE (ug/L)	SCHEDULE 6 STANDARD (ug/L) (Freshwater)
Copper	290 (Hardness 50 mg/L)	30 (Hardness 50-<75)
Zinc	639(Hardness 50 mg/L)	75 (Hardness <90)
DDT	22	0.01
Benzene	20,488	4000
Naphthalene	5,825	10
Toluene	21,459	390
Tetrachloroethylene	14,746	1100
Pentachlorophenol	361 (pH 7.8)[68]	12 (pH 7.7)

RESULTS FOR INDIVIDUAL CONTAMINANTS

Copper – There were 36 values for copper in the USEPA database. Normalized to a hardness of 50 mg/L, the SMAV for rainbow trout was 102.7 µg/L and, therefore, the screening level concentration was calculated as 289.6 µg/L. This proposed value is lower than the 95th percentile derived directly from the database of copper toxicity values (352 µg/L). This suggests that the proposed screening level number of 289.6 µg/L is appropriate, and within the range of values obtained for copper. Furthermore, the SMAV was within a factor of ten of the USEPA acute toxicity criterion of 13 µg/L, indicating that rainbow trout are a reasonably sensitive species to copper.

A hardness-linked function should be applied to this value to account for the protective effect of increasing hardness on the toxicity of copper to trout.

[68] Charts with screening values versus pH levels will have to be developed.

Zinc – USEPA reported 25 values for zinc, and the SMAV was 744.4 µg/L. The calculated screening level concentration was 2099.2 µg/L, which was higher than the 95th percentile value from the zinc toxicity database of 1632.7 µg/L. Given that the calculated screening level value was outside the range of values obtained for zinc, and that the dataset represents a substantial number of test results, it appears reasonable to conclude that the estimate for laboratory variability is probably too high for this particular contaminant, and that the 95th percentile value from the database (i.e., 1639.7 µg/L) would be more appropriate as a screening level for zinc. The USEPA acute toxicity criterion of 120 µg/L is within a factor of ten of the SMAV, indicating that rainbow trout are reasonably sensitive to zinc. Because of the substantial influence of hardness on the acute toxicity of zinc, a hardness-linked function should be applied to this value.

DDT – There were 13 values for DDT, and the SMAV was 7.8 µg/L. The calculated screening level concentration was 21.9 µg/L, which is within the range of values reported, and less than the 95th percentile value of 27 µg/L. Thus, the screening level value of 21.9 µg/L appears to be appropriate. Furthermore, the SMAV is within a factor of ten of the acute criterion of 1.1 µg/L, indicating that rainbow trout are sensitive top this toxicant.

Benzene – Only one datapoint for acute toxicity to rainbow trout was available from the USEPA criterion for benzene, and a total of four values were available from the ECOTOX database. Four additional values were available for other salmonids of the genus *Oncorhynchus* and, consequently these eight values were used for calculation of the GMAV (9017.4 µg/L) and resulted in a proposed screening value of 25,429 µg/L. This value is somewhat higher than the 95th percentile from the dataset of 19,300 µg/L; however, because of the small number of datapoints available for toxicity of benzene, the somewhat higher value of 25,429 µg/L appears appropriate. There are no acute toxicity criteria with which to compare the proposed screening value.

COMPARISON OF RESULTS WITH SCHEDULE 6 STANDARDS

TEST SUBSTANCE	CALCULATED SCREENING VALUE (ug/L)	SCHEDULE 6 STANDARD (ug/L) (Freshwater)
Copper	290[69]	20-90
DDT	22	0.01
Benzene	25,400	4000
Zinc	2100[70]	75-2400

[69] Hardness factor to be developed

[70] Hardness factor to be developed

APPENDIX D

List of Workshop Attendees

SAB Board of Directors

Dennis Konasewich

Paul West

Jim Malick

Marc Cameron

Will Gaherty

Glyn Fox

Michelle Mahovlich (SAB employee, not BOD)

MWLAP

Mike MacFarlane (Victoria)

Tim Bennett (Surrey office)

Consultants

John Wiens (Seacor)

Beth Power (Azimuth)

John Taylor (Hemmera)

Kristi Thornhill (Jacques Whitford)

Bill Donald (represented by another employee) (Keystone)

Lyndon Hanson (Morrow)

Greg Sutherland & Allan Zhang (O'Connor Associates)

Stephen Day (SRK)

Jennifer Man and Emilie Ouellet (Stantec)

UMA – Doug Bright

Cindy Ott (URS)

RSC

Sam Reimer

Individuals

Mark Richardson, Health Canada, Ottawa

Sanya Petrovic – Health Canada, Vancouver

Jo-Ann Aldridge, Environment Canada

Steve Hilts (Cominco)

Peter G. Miasek (Imperial Oil)

APPENDIX E

Proposed Screening Values: Rainbow Trout Toxicity

Final Report

Report date:
18 April, 2006

Submitted to:

Science Advisory Board for Contaminated Sites in British Columbia
University of Victoria,
Victoria, BC

British Columbia Office
8664 Commerce Court
Burnaby, BC
V5A 4N7

TABLE OF CONTENTS

Page

LIST OF TABLES

1.0 INTRODUCTION

Screening values are necessary for sites evaluated under the Contaminated Sites Regulation in order to prioritize sites to ensure that evaluation of highest priority sites are provided direct oversight by the BC Ministry of Environment. Consequently, efforts were undertaken to evaluate screening levels that would be expected to result in a high probability of exhibiting toxicity in a 96 hr acute toxicity test using rainbow trout for a subset of parameters which have corresponding aquatic life guidelines under Schedule 6 of the Contaminated Sites Regulation.

It should be noted that the data review conducted here did not include an evaluation of data quality and, furthermore, did not generally account for variables such as organism size and other exposure conditions (e.g., flow through versus static) that might affect toxicity. The dataset evaluated should not be considered to be a complete dataset of toxicity values available in the literature, but reflects readily obtainable and summarized data from two primary sources: USEPA water quality guidelines and the ECOTOX database.

2.0 METHODS

2.1 General Approach

The screening level for aquatic toxicity was based on acute responses as being indicative of greater likelihood of immediate adverse impacts in the receiving environment. Further emphasis was placed on values derived for rainbow trout (*Oncorhynchus mykiss*) because of the longstanding use of that species for defining toxicity in accordance with provisions of the *Fisheries Act*. Because of inherent variability associated with results obtained from toxicity tests conducted at different laboratories, additional consideration was given to quantifying such variability and applying that factor to increase the confidence that a derived screening value would actually be associated with toxicity if tested by an independent laboratory. Thus, the screening value not only provides a strong indication of a high likelihood for adverse effects, it also indicates a high probability that, if tested for toxicity, the sample would fail, leading directly to potential regulatory action under the *Fisheries Act*. Finally, it was recognized that while trout are generally among the more sensitive aquatic species and do have regulatory status, they may not be the most sensitive indicators of potential environmental damage for all toxicants. Consequently, for those substances that trout exhibit appreciably less sensitivity compared with other organisms, additional steps were taken to derive a screening value that would reflect contaminant concentrations more realistically associated with the onset of actual environmental harm.

2.2 Test Substances

Several contaminants were selected for initial evaluation to refine and validate the approach. These included a number of metals and organics that were selected to provide a broad range of contaminants with different environmental properties and modes of action. Specifically, the contaminants were: copper, cadmium, zinc, lead, chromium (VI), arsenic, DDT, benzene, toluene, ethylbenzene, naphthalene, phenanthrene, VPH, LEPH, tetrachloroethylene, tetrachlorophenol and pentachlorophenol.

2.3 Derivation of Screening Levels

Rainbow trout acute toxicity data (i.e., LC50 values) and species mean acute values (SMAVs) were obtained from the USEPA water quality criteria databases wherever possible. This approach was used for two reasons: first, the USEPA approach incorporates all data associated with a particular contaminant, and not just the most sensitive values, and secondly, these studies have already been screened for data acceptability.

If a particular contaminant did not have an associated USEPA acute water quality criterion, or if the SMAV for rainbow trout was derived from a small number of LC50 values, the ECOTOX aquatic toxicity database was then queried for any additional such values. If the dataset for a particular contaminant was still limited, ECOTOX was also queried for acute toxicity data obtained with other species of salmonids in an effort to develop the most robust representation of the acute response. In cases where additional data were used, a SMAV was calculated as the geometric mean of the values for the rainbow trout data or, in cases where additional salmonid values were available, a genus mean acute value (GMAV) was calculated as the geometric mean of all of the values.

The species or genus mean acute values were used as the initial point of calculation since they were considered representative of the average value at which trout were likely to exhibit an acute response. These MAVs were then adjusted to reflect inter-laboratory variation in deriving LC50 estimates. The best estimate of this adjustment was considered to be from the USEPA inter-laboratory testing program, and includes data from literally hundreds of tests that represent a number of commonly used laboratory test species and toxicants. Inter-laboratory comparisons for rainbow trout were limited (two studies); consequently, they were pooled with results from fathead minnow tests (8 studies) to improve the robustness of the estimate over a wider range of toxicants. Thus, estimates of inter-laboratory variation were available from a total of 10 studies, representing results from 6 toxicants and nearly 300 tests (USEPA 2000).

The estimates of inter-laboratory variation were presented as coefficients of variation (CVs) in the inter-laboratory comparison studies. In other words, all of the LC50s obtained for a particular toxicant from different laboratories within a given study were averaged and the standard deviation calculated. The standard deviation was then divided by the mean value to provide a measure of the variability surrounding the mean. The resulting CV was then

expressed as a percentage, the CVs from all studies ranked, and the 90th percentile value determined.

The 90th percentile value for the CV was then multiplied by 2 to obtain a value that represented two standard deviations from the mean. Thus, the screening level was set at a concentration such that 95 % of the labs testing the sample would concur that the sample exhibited toxicity (i.e., 95 % of the labs testing the sample would have a 90 % probability of identifying toxicity). This level of certainty is important not only in terms of establishing the potential for environmental effects, but also for determining the potential for legal exposure under the Fisheries Act.

For the purposes of comparisons, an alternative approach was used where the sample size (n>5) was considered sufficient to be able to generate a probability distribution with a reasonable level of confidence. In this case, the 95th percentile of the LC50 estimates for a given contaminant was used as a direct estimate of the screening value. This approach was felt to be potentially appropriate because each dataset provided its own contaminant-specific estimate of inter-laboratory variation, which could be more appropriate to apply than a generic measure of inter-laboratory variability determined from tests conducted on a variety of toxicants.

Finally, the ratio of the SMAV (or GMAV) was compared with the acute water quality guideline values for contaminants that have such guidelines to evaluate whether rainbow trout were a sufficiently sensitive endpoint to provide environmental protection, or if another species might be more appropriate. This was a somewhat subjective comparison, but a factor of ten was applied for purposes of this comparison. Thus, values for which the ratio exceeded ten (i.e., where the SMAV was at a concentration more than ten times the guideline) were considered for potential follow-up activities to identify a screening level concentration that might be more protective of environmental conditions. USEPA criteria values were used for this comparison since these guidelines include acute toxicity criteria more frequently that BC or CCME guidelines. Note that the factor of 10 used to compare the rainbow trout SMAV with a given acute water quality criterion includes the two-fold safety factor applied to the Final Acute Value (FAV) to derive the guideline value. Thus, in a direct comparison of toxicity (the SMAV and FAV represent LC50s), we are looking for cases in which organisms used to set the guideline are at least 5-times more sensitive than rainbow trout.

3.0 RESULTS

3.1 Screening Level Adjustment

The 90th percentile CV calculated from the ten inter-laboratory studies was 91.2%. When multiplied by 2, this resulted in a value of 182%, or a factor of 1.82. Thus, the species/genus mean acute value for a given contaminant was adjusted upwards by two standard deviations, resulting in:

Screening level concentration = MAV + (1.82 X MAV)

As a quick check on the relevance of this result, consider a hypothetical MAV of 50 mg/L; the screening level concentration would equal 141 mg/L. Given that a typical acute toxicity test uses a 50 % dilution factor, the MAV and screening level values would fall within a span of two test concentrations, which is not an unreasonable level of variation for laboratory test results. Thus, this value does not appear to be overly restrictive, or excessively lenient.

3.2 Results for Individual Contaminants

3.2.1 Copper

There were 36 values for copper in the USEPA database (USEPA 1985). Normalized to a hardness of 50 mg/L, the SMAV for rainbow trout was 102.7 µg/L and, therefore, the screening level concentration was calculated as 289.6 µg/L. This proposed value is lower than the 95th percentile derived directly from the database of copper toxicity values (352 µg/L). This suggests that the proposed screening level number of 289.6 µg/L is appropriate, and within the range of values obtained for copper.

A comparison of the SMAV for rainbow trout to the USEPA acute toxicity criterion for copper normalized to a hardness of 50 mg/L (i.e., 7.3 µg/L) indicates that they differ by a factor of 14. While this suggests that rainbow trout are a reasonably sensitive species to copper, the comparison also suggests that other species may exhibit up to a 7-fold greater sensitivity compared with trout. If these more sensitive species are considered to have strong relevance with respect to identifying a significant environmental impact, then it may be appropriate to

consider their responses in deriving a screening level value that will be broadly applied across the province.

A hardness-linked function should be applied to calculate the screening value in order to account for the protective effect of increasing hardness on the toxicity of copper to trout, as follows:

Screening value (copper) = 39.75 exp (0.9422 [ln (hardness)] – 1.7)

3.2.2 Cadmium

There were a total of 13 acute toxicity datapoints for rainbow trout in the USEPA water quality criterion for cadmium (USEPA 2001). The SMAV was 1.9 µg/L, and the screening value calculated as 5.4 µg/L. This value was within the range of acute toxicity values reported, and slightly less than the 95th percentile of the reported values. Consequently, it appears 5.4 µg/L is appropriate for use as a screening level for cadmium.

The USEPA acute water quality criterion for cadmium is 1.0 µg/L, which is close to the SMAV obtained with rainbow trout. Thus, trout appear to be appropriately sensitive to this contaminant.

Note that these data are based on a hardness of 50 mg/L, as $CaCO_3$. Thus, the screening value should be adjusted to the hardness of the sample using the following equation:

Screening value (cadmium) = 5.121 exp (1.0166 [ln (hardness)] -3.924)

3.2.3 Zinc

USEPA reported 25 values for zinc (USEPA 1987), and the SMAV was 744.4 µg/L (all values were normalized to a hardness of 50 mg/L). The calculated screening level concentration was 2099.2 µg/L, which was higher than the 95th percentile value from the zinc toxicity database of 1632.4 µg/L. Given that the calculated screening level value was outside the range of values obtained for zinc, and that the dataset represents a substantial number of test results, it appears reasonable to conclude that the estimate for laboratory variability is probably too high for this

particular contaminant, and that the 95th percentile value from the database (i.e., 1632.4 µg/L) would be more appropriate as a screening level for zinc.

The USEPA acute toxicity criterion of 66.6 µg/L for zinc at a hardness of 50 mg/L is within a factor of 11 of the SMAV, suggesting that rainbow trout are reasonably sensitive to zinc. Conversely, these data also suggest that other species may exhibit up to a 5.5-fold greater sensitivity to zinc compared with trout. As with copper, if these more sensitive species are determined to have strong relevance with respect to identifying a significant environmental impact, then it may be appropriate to consider their response in deriving a screening level value that will be applied across the province.

Because of the substantial influence of hardness on the acute toxicity of zinc, the following equation should be used to calculate the screening value:

Screening value (zinc) = 31.52 exp (0.8473 [ln (hardness)] + 0.884)

3.2.4 Arsenic

Arsenic presents an interesting case in that As (III) is generally considered more toxic than As (V), leading to a condition in which the guidelines may be established on the basis of As (III), but implemented as total arsenic because it is problematic to determine actual speciation in actual test samples. Consequently, the screening value was derived on the basis of toxicity values for As (III). A total of four acute values for rainbow trout were available from the ECOTOX database, in addition to one value from the USEPA water quality criteria document for arsenic (USEPA 1984). The SMAV was calculated as 18,769 µg/L, and the associated screening value was 52,928 µg/L. This value exceeded the 95th percentile of the actual acute toxicity values (i.e., 21,000 µg/L), and was also outside of the range of values reported. Thus, it would appear to be more appropriate to use the 95th percentile value (21,000 µg/L) as the screening level for arsenic, since the applied estimate of inter-laboratory variability seems to be too high for this particular contaminant. Note that the calculated screening value is considerably greater than the USEPA acute criterion of 340 µg/L, suggesting that the screening level for this contaminant might be more appropriately established on the basis of other organisms in order to provide a more conservation level of environmental protection. In this case, the acute criterion is driven by the sensitivity of daphnids and *Hyalella*.

3.2.5 Lead

There were 5 acute toxicity values for rainbow trout in the ECOTOX database, and two additional values for salmonids. The SMAV for rainbow trout was determined to be 1257 µg/L, which was similar to the mean acute value calculated with the other salmonid data included (i.e., 1339 µg/L). Using all of the salmonid data, the screening value was calculated as 3746 µg/L, which exceeds the 95th percentile of the acute toxicity data (3180 µg/L). Consequently, the 95th percentile value was used for the screening level. Although USEPA includes a hardness correction factor in their water quality criterion for lead, there did not appear to be any effect of hardness on the acute toxicity of lead to salmonids over the hardness range of 22 to 385 mg/L (USEPA 1980a). Consequently, no adjustment factor has been applied to the screening value. In addition, the MAV for salmonids is considerably greater than the USEPA acute water quality criterion of 34 µg/L, suggesting that other species (primarily cladocerans and gammarids) exhibit considerably more sensitivity to lead than do salmonids.

3.2.6 Chromium (VI)

There were 20 acute toxicity values for rainbow trout exposed to chromium (VI) from the ECOTOX database. The SMAV was 17,822 µg/L, and the screening level calculated as 50,258 µg/L. This value is somewhat less than the 95th percentile of the actual acute toxicity data (i.e., 53,815 µg/L), and appears to be appropriate. However, the chromium data exhibited considerable variation among LC50 estimates, with the maximum and minimum values differing by over two orders of magnitude. Moreover, the SMAV was over 30-fold greater than the lowest LC50 reported. Closer inspection of the data revealed that toxicity was related to pH, as well as the size of fish tested. Some of the data reported used fish up to 25g average weight, whereas other data were obtained with fish that were 0.2g average weight. This difference in weight accounted for a 5 to 8-fold difference in toxicity, with heavier fish exhibiting less sensitivity. Similarly, toxicity varied at least 3-fold over a pH range of 1 unit for a given size range of fish. If the dataset was reduced to those data where wet weights were consistent that typically used for Environment Canada acute toxicity tests with rainbow trout, the SMAV decreased to 4659 µg/L, with an associated screening level of 13,139 µg/L. This value still encompasses a range of pH values, so a conservative approach would entail reducing the screening value by half for samples with pH of 6.5, or less. Note that the SMAV for small trout is still over two orders of magnitude greater than the USEPA acute guideline value of 16 µg/L,

indicating that other species (primarily cladocerans) exhibit considerably greater sensitivity to Cr (VI).

3.2.7 DDT

There were 13 values for DDT, and the SMAV was 7.8 µg/L. The calculated screening level concentration was 21.9 µg/L, which is within the range of values reported, and less than the 95th percentile value of 27 µg/L. Thus, the screening level value of 21.9 µg/L appears to be appropriate. Furthermore, the SMAV is within a factor of ten of the acute criterion of 1.1 µg/L (USEPA 1980c), indicating that rainbow trout are sensitive to this toxicant.

3.2.8 Benzene

Only one datapoint for acute toxicity to rainbow trout was available from the USEPA criterion for benzene (USEPA 1980b), and three additional values were available from the ECOTOX database. This database also included six values for other salmonids of the genus *Oncorhynchus* and, consequently, a total of 10 values were used for calculation of the GMAV (10,051 µg/L), resulting in an associated screening value of 28,345 µg/L. This value is somewhat higher than the 95th percentile from the dataset of 20,488 µg/L, and also exceeds the range of the actual acute toxicity values. Thus, it appears that the 95th percentile of the actual values (i.e., 20,488 µg/L) is a more appropriate estimate for use as a screening value. There are no acute toxicity criteria against which to compare the sensitivity of salmonids.

3.2.9 Toluene

Rainbow trout acute toxicity data for toluene were available only from the ECOTOX database, which contained four values. These were augmented by an additional three acute LC50s reported for other salmonids for a total of 7 datapoints. The GMAV was 9322 µg/L, and the screening value was calculated as 26,289 µg/L. This value was outside the range of acute values reported and, consequently, the 95th percentile of the actual LC50s (i.e., 21,459 µg/L) was selected as a more appropriate estimate for use as a screening value. The USEPA does not have aquatic life criteria for toluene; the BC water quality criterion for this parameter is 39 µg/L. The substantial difference between the BC water quality criterion and the acute values for rainbow trout is attributable to the dependence on chronic toxicity test results, and the application of a 10-fold safety margin in derivation of that guideline. Acute toxicity values for a variety of

species that were summarized in the BC water quality guideline for toluene ranged from 5500 to more than 50,000 µg/L. Thus, the proposed screening value of 21,459 µg/L appears to be a reasonable estimate on the basis of likelihood of acute toxicity.

3.2.10 Ethylbenzene

Only two datapoints were available from the ECOTOX database for acute toxicity of ethylbenzene to rainbow trout. The geometric mean of the values was 7668 µg/L, and the screening value was calculated as 21,624 µg/L. The screening value was within a factor of 5 of the lower LC50, and 1.5 times greater than the higher LC50 value. In general, it is not unusual to observe at least a factor of 5 between the lowest and highest LC50 reported for a given toxicant; thus, based on limited data, selection of 21,624 µg/L appears to be a reasonable estimate of a screening level.

Because of the relative lack of data for trout, acute LC50 estimates for daphnids were also evaluated. A total of three values for ethylbenzene were reported for *Daphnia magna*, and ranged between 13,900 and 75,000 µg/L. These data further suggest that the value of 21,624 µg/L is indeed appropriate as a screening level and, in the absence of any acute water quality criterion for this contaminant, further suggest that rainbow trout exhibit an appropriate level of sensitivity to this chemical. The BC water quality criterion for ethylbenzene is 200 µg/L, and was calculated based on applying a ten-fold safety margin to the most sensitive effects data reported in the literature of approximately 2000 µg/L for immobilization of *D. magna*; this value is approximately an order of magnitude lower than the proposed screening value of 21,624 µg/L. Thus, it would appear that the proposed screening level is ecologically relevant and that trout do reflect a reasonable level of sensitivity, particularly since the BC water quality criterion is based on immobilization data, rather than a lethal response.

3.2.11 Naphthalene

Only one datapoint was available for acute toxicity to rainbow trout from the USEPA water quality criteria document for naphthalene (USEPA 1980d). Consequently, the ECOTOX database was queried, and an additional 7 acute values for rainbow trout and 4 acute values for other salmonids were found, for a total of 12 datapoints. The GMAV was calculated as 3131.7 µg/L, and the screening value as 8831.4 µg/L. This value was outside of the range of acute values reported for naphthalene and, consequently, the 95th percentile of the actual acute

toxicity values (i.e., 5825 µg/L) appears to be a more appropriate estimate for use as a screening level value. There are no acute toxicity criteria with which to compare salmonid sensitivity.

3.2.12 Phenanthrene

Only one acute toxicity value was available for rainbow trout (3200 µg/L). Assuming that this value represents a reasonable estimate of the SMAV, the screening level was calculated at 9024 µg/L. Conversely, there were 5 acute LC50 estimates reported for daphnids in ECOTOX, ranging between 212 and 960 µg/L. Based on a comparison of these values with the one value for rainbow trout, it appears that rainbow trout may not be an appropriate indicator of environmental concentrations that merit concern.

For the purposes of comparison, the geometric mean of the daphnid acute values was calculated as 488 µg/L, and the 95th percentile of the daphnid data was 937 µg/L. Thus, daphnids appear to be appreciably more sensitive than rainbow trout to phenanthrene. Based on these data, we would suggest that a reasonable compromise would be to set the screening level at the trout LC50 value of 3200 µg/L. This is a conservative estimate of the sensitivity of trout, since in the absence of more than one datapoint, there is no way to determine if this value over- or underestimates the average sensitivity of the species. Moreover, since the daphnid data suggests that they are more sensitive than trout, applying the trout LC50 without an additional factor for laboratory variation is an environmentally conservative approach.

3.2.13 Volatile Petroleum Hydrocarbons (VPH)

BC Provincial guidelines (Macfarlane and Fox, 1999) define the number of carbons (C5 – C9), as well as the proportion of aromatics to alkanes (0.2:0.8) that characterize VPH. Moreover, these guidelines define toluene and n-hexane as surrogate aromatic and alkane chemicals, respectively, for characterizing this mixture. Since this is a mixture, it is appropriate to consider the range of toxicity associated with different constituents before determining an appropriate screening level concentration.

For selected aromatics, MAVs for rainbow trout (or salmonids) are: 10,051 µg/L, 7668 µg/L, 9322 µg/L, and 7246 µg/L for benzene, ethylbenzene, toluene, and xylene, respectively. These values are similar and their distributions overlap, so the lowest screening level (i.e., 16,160 µg/L for xylene) was selected as a conservative estimate for the aromatic portion of the mixture.

Deriving an estimate for the alkane portion of the mixture was more problematic because data were not available for salmonids. Consequently, where data were available for selected hydrocarbons (primarily aromatics), comparisons were made between the salmonid MAV and acute toxicity data available for other species. These ratios were compared across different chemicals; salmonids averaged 4 times more sensitive than other species, but were up to 7-fold more sensitive, depending on the chemical. Using the most sensitive ratio, and the alkane with the greatest published toxicity (cyclohexane), a salmonid alkane acute value was calculated as 5515 µg/L, with an associated screening value of 15,553 µg/L.

Using the 0.2:0.8 ratio of aromatics to alkanes the screening value for the VPH mixture was calculated as: (0.2)(16,160) + (0.8)(15,553) = 15,674 µg/L. This value was then compared with acute toxicity of actual mixtures (i.e., gasoline) to see if it adequately characterized the toxicity of the mixture. Macfarlane and Fox (1999) mention an LC50 of 5400 µg/L for rainbow trout exposed to gasoline. This value would result in a screening level of 15,228 µg/L, which is comparable to the value calculated above and suggests that the derived screening level of 15,674 µg/L is appropriate.

3.2.14 Light Extractable Petroleum Hydrocarbons (LEPH)

A similar approach was used for calculating a screening value for LEPH, although this process was rendered more difficult by a comparative lack of data. The LEPH mixture has been defined as C10 – C18 alkanes and aromatics, and the surrogate chemicals are naphthalene and decane for aromatics and aliphatics, respectively (Macfarlane and Fox, 1999). For aromatics that fit into this category, salmonid MAVs are 3131 µg/L (naphthalene) and 3200 µg/L (phenanthrene). These two numbers are similar, and the screening number for naphthalene is therefore likely to be appropriate for aromatics in this class (i.e., 5825 µg/L). Conversely, there were no toxicity data on n-alkanes that could be used to develop a reasonable estimate of toxicity to rainbow trout. Under the assumption that the toxicity of alkanes typically decreases as the chain length increases, using the acute toxicity level for alkanes calculated above for VPHs should provide a conservative estimate of the toxicity of alkanes in the LEPH classification. Since the toxicity of naphthalene and phenanthrene are clearly greater than the single ring aromatics, the screening level of LEPHs would then be calculated as: (0.2)(5825) + (0.8)(15,553) = 13,607 µg/L. As a point of comparisons, Macfarlane and Fox (1999) reported an LC50 of 2520 µg/L for rainbow trout exposed to diesel; use of this value as an estimate of acute toxicity would result in a screening level of 7106 µg/L. Given that this value is approximately half of the value calculated

on the basis on individual chemicals, the overall lack of data associated with individual chemicals in this mixture class, and the potential for interactive effects, a conservative approach would be to use 7106 µg/L as the screening level for LEPHs.

3.2.15 Tetrachloroethylene

A total of 6 acute toxicity values were available for rainbow trout from the ECOTOX database, with no other salmonids represented. The SMAV was 5229 µg/L, and the screening value calculated as 14,746 µg/L. This value was higher than the 95th percentile of the acute toxicity values (i.e., 5825 µg/L), and also exceeded the range of the actual values reported. In considering an appropriate screening value for this chemical, it should also be noted that four of the six values were obtained from one study, and the two remaining values were from another study. Thus, this particular dataset contains only a small component of inter-laboratory variability and, consequently, we would suggest applying the calculated screening value of 14,746 µg/L, rather than the 95th percentile of the available acute toxicity data.

3.2.16 Pentachlorophenol

The pentachlorophenol (PCP) data presented an interesting challenge in that the toxicity is pH-dependent. Thus, without taking into account the pH associated with individual tests, the results would reflect unnecessarily large amount of variation. USEPA has an equation for normalizing PCP data to pH; in this case, we selected a pH of 7.8 to be consistent with the guideline. A total of 24 rainbow trout LC50 values were available from the ECOTOX database that also reported associated test pH values. Based on data normalized to pH 7.8, the SMAV was 169.9 µg/L, and the screening value was calculated as 479.0 µg/L. This value is higher than the 95th percentile of the actual acute values (i.e., 394.9 µg/L) and, therefore, the 95th percentile appears to be more appropriate for use as a screening value. In addition, the SMAV is within a factor of 10 of the USEPA acute criterion for PCP of 19 µg/L (normalized to pH 7.8), suggesting that rainbow trout exhibit an appropriate level of sensitivity to this contaminant.

In applying this screening value, a pH-linked function should be applied to the above value to account for the effect of pH on the toxicity of PCP. Thus, it will be necessary to also obtain the pH of the sample under investigation in order to establish a screening value relevant to a specific site. The pH specific screening value can be calculated according to the following function:

Screening value (PCP) = 20.26 exp(1.005*pH - 4.869)

3.2.17 Tetrachlorophenol

There were two datapoints for acute toxicity to rainbow trout in the ECOTOX database. These values were 85 and 334 µg/L, which have a geometric mean of 168.5 µg/L. The screening level was calculated as 475 µg/L. Based on a discussion similar to that provided above for ethylbenzene, this concentration should be appropriate as a screening level value.

For comparative purposes, daphnid data for tetrachlorophenol were also evaluated. In this case, there were a total of six acute LC50 values available, ranging from 90 to 2660 µg/L. The geometric mean was 331 µg/L, and the 95th percentile was 2140 µg/L. Thus, these data suggest that trout are appropriately sensitive to this contaminant, and that the screening level concentration is reasonable.

Table 1. Summary of proposed screening values compared with Schedule 6 values for protection of aquatic life.

Variable	Proposed screening values (µg/L)	Schedule 6 values (aquatic life) (µg/L)
Copper [1]	290	30 [3], 20 [4]
Cadmium [1]	5.4	0.3 [3], 1.0 [4]
Zinc [1]	1,632	75 [3], 100 [4]
Arsenic	21,000	50 [3], 120 [4]
Lead	3,180	50 [3], 20 [4]
Chromium (VI)	13,139 at pH > 6.5; 6,570 at pH ≤ 6.5	10 [3], 150 [4]
DDT	21.9	0.01
Benzene	20,488	4000 [3], 1000 [4]
Toluene	21,459	390 [3], 3300 [4]
Ethylbenzene	21,624	2000 [3], 2500 [4]
Naphthalene	5,825	10
Phenanthrene	3,200	3
VPH	15,674	1,500
LEPH	7,106	500
Tetrachloroethylene	14,746	1,100
Pentachlorophenol [2]	395	12
Tetrachlorophenol	475	28

[1] value varies with hardness; reported at a hardness of 50 mg/L as $CaCO_3$
[2] value varies with pH; reported at pH 7.8
[3] Freshwater aquatic life
[4] Marine aquatic life

4.0 REFERENCES

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