Federal Contaminated Sites Action Plan (FCSAP)

Ecological Risk Assessment Guidance

Module 2: Selection or Development of Site-specific Toxicity Reference Values

March 2010

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1. BACKGROUND

The Federal Contaminated Sites Action Plan (FCSAP) was developed to support federal departments, agencies and consolidated crown corporations to reduce the risks to human health and the environment, as well as to reduce the financial liabilities associated with federal contaminated sites. Under FCSAP, ecological risk assessments (ERAs) are commonly used as a site management tool at federal contaminated sites. The FCSAP Ecological Risk Assessment Focus Group is developing guidance for ERA supplemental to the existing CCME guidance ((1996a, 1997). The FCSAP ERA guidance consists of a comprehensive main ERA document and several specific technical guidance modules. .This document is a technical guidance module on toxicity reference values (TRVs). This module provides general guidance on using published TRVs and on developing site-specific TRVs as site-specific benchmarks for ERAs on federal contaminated sites. It is assumed that, as appropriate, FCSAP Expert Support has participated in aspects of the risk assessment process relevant to TRV derivation (see **Sections 2 and 4** of the main ERA document).

1.1. Toxicity Reference Values in Ecological Risk Assessment

This document contains the technical guidance for development of Toxicity Reference Values for use in ERA. TRV development occurs in the Effects Assessment stage of an ERA.

Definition of a TRV[1] – An exposure concentration or dose for a contaminant of potential concern (COPC) that is not expected to cause an unacceptable level of effect in a receptor of concern (ROC). TRVs are contaminant-specific, receptor-specific and possibly site-specific (i.e., depending on the assumptions used in their derivation, they may have limited applicability across sites).

Risk-based environmental quality guidelines and standards are essentially a subset of TRVs, but are typically developed for broader application (e.g., for the range of environmental conditions and species across Canada) and are therefore usually more conservative than TRVs used in ERA. This is because the latter can be tailored to apply to the specific situation addressed by the ERA.

TRVs can be classified into three types according to how they are calculated and applied:

- **Dose-based TRV** (units of mg chemical/kg body weight/day). TRVs based on doses are often used for wildlife when evaluating risks via dietary ingestion of contaminants. Risks to wildlife are often assessed using food chain models that include all oral sources (e.g., food, water, incidental soil/sediment ingestion).

- **Concentration-based TRV in exposure media** (units of mg chemical/kg media or mg/L). These TRVs are often used for lower trophic species that are in direct and constant contact with exposure media such as water, sediment, pore water or soil. However, this TRV type could also be used for upper trophic level receptors (e.g., by

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[1] The TRV is equivalent to the term "toxicological benchmark concentration (BC)" discussed in the CCME general guidance for ERA (CCME 1996, 1997).

back-calculating from a dose-based TRV to a food-based exposure media concentration that is not expected to result in any adverse effects to wildlife ROCs that consumes the prey.); tissue residue guidelines (TRGs) are an example of this approach (e.g., CCME 1999a). Example receptor groups include terrestrial plants, soil invertebrates, aquatic plants, benthic invertebrates and fish.

- **Concentration-based TRV in tissues** (units of mg chemical/kg tissue). These types of TRVs are most commonly applied to contaminants that bioaccumulate in receptor organisms through the diet and/or contact with exposure media. They can be used for various receptor groups including fish, invertebrates, plants and wildlife. Critical body residue (CBR) is another term that is often used to refer to a tissue-based TRV. The CBR refers to an internal body or tissue concentration that causes a toxicological response in a receptor (McCarty and Mackay 1993).

In the Effects Assessment, TRVs would be developed for most ROC/COPC (receptor of concern/contaminant of potential concern) combinations. The main exceptions would be for:

1. Situations where there are no relevant published toxicity data and where site-specific toxicity testing is not an option.

2. For those ROCs with measurement endpoints relying on direct measures of effects in the field or laboratory (e.g., using benthic community structure or sediment toxicity testing to assess potential effects to benthic infauna from exposure to a mixture of COPCs).

3. When no *a priori* acceptable effects levels have been selected. In this case, however, many the procedures described herein would still be used to generate a response profile (i.e., only the last step of identifying a single TRV associated with a specific magnitude of response would be skipped; see **Section 4** of the main ERA Guidance document).

In combination with an exposure estimate[2] (in same units as the TRV) for a receptor from the study site, TRVs are often used during the risk characterization phase of an ERA to derive hazard quotients (HQs). The HQ is the ratio between the estimated exposure level and the TRV. An HQ of 1is generally used as the benchmark in ERA for interpreting whether adverse effects are possible (i.e., HQ above 1) or negligible (i.e., HQ below 1). Specifically, if exposure levels to receptor(s) at the study site do not exceed a TRV, then no unacceptable risks to receptor(s) would be expected. If exposure levels to receptor(s) at the study site do exceed a TRV, then it is possible, but not certain, that unacceptable effects are occurring. Typically in the latter case further information is required to reduce uncertainty and refine risk estimates.

1.2. Scope of Module

This module provides general guidance on using published TRVs and on developing site-specific TRVs. Approaches that are presented for deriving site-specific TRVs include developing literature-based TRVs, modifying existing guidelines, and using toxicity testing to develop site-specific TRVs. Selecting the most appropriate site-specific approach is often related to the

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[2] CCME (1996, 1997) uses the terminology "expected environmental concentration (EEC)" to refer to the exposure concentration for receptor(s) at the study site (i.e., numerator of the HQ).

objectives and issues being addressed by the ERA as well as the nature and complexity of the site. Because site-specific TRVs derived from the literature are more commonly used than the other methods, greater emphasis is placed on this approach in this document.

Readers of this module should note that recommendations for the development and application of wildlife TRVs have recently been proposed (Allard et al. 2010) by a group of experienced Canadian and American risk assessors and ecotoxicologists[3], through a subcommittee of the Ecological Risk Assessment Advisory Group (ERAAG) of the Society of Environmental Toxicology and Chemistry (SETAC) North America. Their recommendations focus on technical (not policy) issues including aspects of data extraction and interpretation, selection of endpoints that relate to survival or fitness of organisms, extrapolation between species, and derivation of TRVs in the context of variability in chemical-specific toxicological data sets and species-specific variations in response. Guidance on the application of TRVs, particularly for moving beyond the use of HQs, is also provided. Although the emphasis of Allard et al. (2010) is on wildlife TRVs, many of their recommendations also apply to other receptor groups. For these reasons, guidance presented in this module is generally consistent with the technical recommendations of Allard et al. (2010).

2. GUIDANCE

The main sections of this module are structured as follows:

- Review of options for TRV selection

- Review of published TRVs

- Derivation of site-specific TRVs, including:

    - Literature-based TRVs

    - Modifying existing guidelines to develop site-specific TRVs

    - Site-specific toxicity test-based TRVs

2.1. Options for TRV Selection

The two main options for obtaining TRVs are to use published TRVs or to derive site-specific TRVs. The major advantage of using published TRVs is that they are easy to access and, therefore, require less effort in their application. While developing site-specific TRVs can be time intensive, these TRVs can be tailored to meet the site-specific objectives and conditions of the ERA, which can result in a more reliable assessment of risk.

As mentioned in **Section 1.1**, risk-based environmental quality guidelines and standards are essentially a subset of TRVs. While they are usually conservative due to their need to apply

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[3] Authors include: Patrick Allard, Anne Fairbrother, Bruce K. Hope, Ruth N. Hull, Mark S. Johnson, Lawrence Kapustka, Gary Mann, Blair McDonald, and Bradley E. Sample. Note that some of these authors were also involved in earlier efforts leading to publication of TRVs often used in ERA (e.g., ORNL, Eco-SSLs).

across a broad range of conditions and organisms (e.g., across Canada), they still provide a basis for evaluating chemical exposure at contaminated sites. For this reason, they may be considered a third source of TRVs. However, risk-based environmental quality guidelines usually provide a basis for screening chemicals during the problem formulation phase of the ERA rather than during the effects assessment. For this reason, this module provides limited review of available guidelines, and instead focuses on approaches for modifying these guidelines (e.g., using site-specific data) to derive site-specific TRVs (**Section 2.3.3**).

Ultimately, the risk assessor has to choose or derive TRVs that are defensible for their application in an ERA. More detailed discussion on the advantages and limitations of the various options is provided in the following sections to help guide this process.

2.2. Review of Published TRVs

While there are only a few sources of published TRVs (e.g., Oak Ridge National Laboratory [ORNL] guidance documents, US EPA Eco-SSLs, Quebec 2000), they have been widely used in ERA and they also have regulatory precedent in many jurisdictions. A description of the key sources of published TRVs, including advantages and limitations of each, is provided in **Table 1**.

It is recognized that the published TRVs listed in Table 1 may have been developed using methods that are not recommended when developing site-specific TRVs (e.g. allometric scaling, use of uncertainty factors – see Allard *et al.* 2010). While these methods are discouraged when developing new TRVs, FCSAP recognizes that it may not be feasible to develop site specific TRVs at all federal contaminated sites. In absence of published TRVs that are developed based on recommendations in this technical guidance module, those TRVs listed in Table 1 maybe used provided that the risk assessor has given adequate consideration to their inherent limitations.

One of those methods discouraged for TRV derivation is the use of no-observed-adversed-effect levels (NOAELs) or lowest-observed-adverse-effects levels (LOAELs). Unfortunately, there are several instances where published TRVs are based on NOAELs or LOAELs. These designations are typically determined based on statistical significance either within individual laboratory studies (e.g., ORNL) or among toxicity data sets (e.g., Eco-SSLs).

It has been widely recognized for some time that reliance on statistical significance alone, however, is problematic (Stephan and Rogers, 1985; Bruce and Versteeg, 1992; Suter, 1996; Chapman et al., 1996). NOAEL- and LOAEL-based TRVs are not innately related to biologically relevant thresholds, nor do they provide information on the magnitude of effects in the reported studies so they are limited in their ability to express ecological significance. For instance, a NOAEL may not necessarily be equivalent to a "no effect" dose (Van der Hoeven, 1997) due to factors affecting a study's ability to detect statistical differences (e.g., study design, replication).

For these reasons, published TRVs reliant on NOAELs and LOAELs are of limited use in ERA. Rather, the development of site-specific TRVs provides a more technically sound option to support risk assessment (see **Section 2.3**). If NOAEL/LOAEL-based published TRVs are used, then their limitations should be openly discussed with risk managers. At a minimum, the published accounts of the underlying studies used to derive the published TRVs should be obtained to allow consideration of the observed magnitude of effect and any other relevant data (e.g., response magnitude for all exposure levels tested) (see **Section 2.3.2.3** for more details).

2.3. Derivation of Site-specific TRVs

There are several options for deriving site-specific TRVs. These options have been divided into three main categories:

- **Literature-based TRVs** – Literature-based TRVs, which are developed using published toxicological data, are one of the most common forms of site-specific TRVs. They can be applied to various types of receptors and contaminants. The level of detail and effort for deriving a TRV can vary substantially from basing the TRV on a single study through to use of multiple studies following a thorough literature review. Literature sources can include primary literature or secondary sources such as databases, data compilations, and documentation from other ERAs or regulatory guidelines. Developing literature-based TRVs are discussed in detail in **Section 2.3.2**.

- **Modifying Existing Guidelines to Develop Site-specific TRVs** – Another option for developing site-specific TRVs is to modify existing environmental quality guidelines. Because guidelines are generally derived for exposure media (water, sediment, soil) and in some cases for tissues, this approach could be used for concentration-based TRVs. In most cases, the approach involves reviewing guideline derivation methods and assumptions (e.g., CCME 1998, 1999c, 2006, 2007) and making modifications to the methods or assumptions to develop a TRV that is relevant to the site and receptors. Modifying existing guidelines to develop site-specific TRVs is discussed in detail in **Section 2.3.3**.

- **Site-specific Toxicity Test-based TRVs** – A third option involves conducting a site-specific toxicity testing program where TRVs would be derived from doses or concentrations that cause effects to test organisms (which could be organisms collected from the site) exposed to site media (e.g., water, sediment, soil). These TRVs would most commonly be applied to aquatic life exposed to water-borne contaminants but could also be applied for soil or sediment exposed organisms for which toxicity tests are available. A separate Environment Canada guidance module is available on toxicity testing Toxicity testing is presented herein only in the context of how it can be used to develop site-specific TRVs. Developing TRVs based on site-specific toxicity tests is discussed in detail in **Section 2.3.4**.

Guidance on the approach and methods for each of the options is described in the following sections. **Section 2.3.1** discusses general considerations along with general ERA concepts that should be considered when deriving TRVs. The subsequent sections provide detailed guidance on the three main approaches for TRV derivation as listed above.

2.3.1. Considerations and Related Concepts

The first step in deriving site-specific TRVs is to consider the context for which they are being derived. In particular, it is important to ensure appropriate linkage to the conceptual model and the assessment and measurement endpoints as laid out in the ERA's problem formulation. Related ERA topics and concepts that need to be considered are briefly described below**:**

- **Contaminants of potential concern (COPCs)** – COPCs are identified in the problem formulation of an ERA, generally by screening concentrations in site media with

appropriate environmental criteria or guidelines. Because toxicological effects are contaminant specific, TRVs should be developed for each COPC of interest at the study site. Where possible, the influence of site-specific modifying factors should be explicitly considered. An exception to contaminant-specific TRVs would be using a single TRV to represent a class of contaminants with a common mode of action. For example, quantitative approaches have been developed for certain contaminant groups (e.g., toxic equivalents [TEQ] approaches for dioxins/furans, PCBs and PAHs [e.g., CCME 2002]). Consideration should be given to potential additive, synergistic or antagonistic interactions between or among COPCs. Where this cannot be explicitly considered in the ERA (e.g., using a TEQ approach), the interactions may best be addressed within the uncertainty assessment. TRVs for COPCs without any data can sometimes be derived using quantitative structure-activity relationships (QSARs or other modeled data).

- **Exposure pathways** – As part of the problem formulation, routes of contaminant exposure to receptors at the study site are determined. The type of TRV developed for the site should reflect the relevant exposure pathway(s). For example, if water-borne contaminants are of concern to fish, a TRV based on a water concentration may be appropriate. If the substance is bioaccumulative, then a tissue-based concentration TRV may be more suitable.

- **Receptors of Concern (ROCs) -** It is important to develop TRVs that reflect Receptors of Concern at the study site. Due to data limitations for many native species, TRVs are often derived from studies conducted on laboratory species. These laboratory species may be considered surrogates or, in some cases, effects data are extrapolated from the laboratory species to the site-specific ROCs. Approaches to extrapolating between species are discussed later in this guidance module (**Section 2.3.2.4**).

- **Level of biological organization -** ROCs can be defined at various levels of biological organization (e.g., individual organisms, populations, communities). While the local population level is often the intended protection entity in ERA, TRVs are typically based on organism-level attributes of a population (e.g., frequency of mortality or average reduction in growth or reproduction), which are assumed to provide adequate protection for populations (Suter et al., 2005). The link between organism-level attributes and population-level effects is not quantitatively defined in most ERAs. The level of biological organization to be protected can influence the scope of literature review or toxicity testing used in the TRV development.

- **Protection goals and acceptable effect levels** – For most ERAs, the type and level of protection that is intended for each receptor or receptor group at a site are described in the problem formulation. A protection goal may be a narrative statement that is then operationalized as an "acceptable effect level" (AEL) that clarifies the magnitude of effects that would be acceptable for a specific measurement endpoint or a group of measurement. Protection goals may vary among ROCs and among sites depending on several factors including:

    - Overall management goal(s) for the site.

    - Listed status of a study species (e.g., if it is considered to be endangered or threatened). Guidance for ERA often recommends that listed species be afforded a higher degree of protection than common species (e.g., BC MOE 1997).

- Land-use designations at the study site (for terrestrial sites only; there are no analogous designations for aquatic ecosystems). Often, **s**ites with greater human alteration are given less value in terms of providing ecological habitat and resources. This can be seen in regulatory criteria and guidelines at the federal and provincial levels (e.g., CCME 2006, BC MOE 1997, SAB 2006, Quebec 2000). For example, provincial policy goals in Quebec and British Columbia allow for a 40% (Quebec)/50% (BC) impairment in a sublethal endpoint at an industrial site, but only a 20% effect level is considered acceptable at a residential site.

It should be noted that a standardized effect size does not necessarily translate into a consistent level of protection for all receptors. For example, 20% reproductive impairment may have significant ecological effects at the population level of one species (e.g. whales), but may be insignificant for another species with a high intrinsic rate of population growth (e.g. water fleas). The ecological significance of a specified effect level should be carefully considered during problem formulation.

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*ECx versus ICx Definition – It should be noted that for endpoints other than mortality, there is some confusion about the meaning of ECx (Effect Concentration) or EDx (Effect Dose). A true ECx/EDx typically applies to dichotomous variables and is the concentration/dose at which the percentage of the test population demonstrating a specific response relative to controls over a specified time period is x – for example, for an EC20/ED20, 20% of individuals tested at a specific concentration or dose may exhibit a specified level of reproductive impairment (e.g., 20% of bivalve larvae failed to develop normally). An ECx/EDx can also be applied for mortality – for example 20% of the test population died; however, this is more commonly referred to as an LCx (Lethal Concentration) or LDx (Lethal Dose). In contrast, an ICx (Inhibitory Concentration) or IDx (Inhibitory Dose) is the concentration at which x% impairment occurs in a continuous response variable – for example, for an IC20/ID20, the average individual organism in the test population would be expected to exhibit 20% reproductive impairment relative to control over a specified time period. Many guidance documents use the term ECx loosely and provide examples that are either ECx or ICx. Terminology used in **Tables 1** and **2** reflect the terms used in the original references. Terminology used in the text of this module reflects the definitions provided in this text box. Both types of endpoints may be suitable for the development of TRVs. In ERAs, greater emphasis should be placed on clarifying these terms and on understanding how they relate to the Assessment Endpoints.*

- **Assessment and measurement endpoints -** Assessment and measurement endpoints (see Section 2 of the main ERA guidance document for more details) can influence the types of endpoints considered in the TRV development, and how the TRV will be used. One type of measurement endpoint involves comparing predicted receptor exposures to a TRV that corresponds to an acceptable effect level. For example, if the receptor group is a shrew population, a measurement endpoint may involve comparing an estimated COPC dose through dietary exposure to the TRV dose that results in 20% reduced growth.

- **Regulatory requirements and policy guidance** – Depending on the jurisdiction where the ERA is being completed, there may be a need to consider provincial as well as federal regulatory requirements and policy. This may affect the TRV derivation process.

2.3.2. Literature-based TRVs

2.3.2.1. Literature Review

The first step in deriving a literature-based TRV is to compile effects studies from the literature to develop a dose-response or concentration-response data set. The scope of the literature review can vary greatly depending on factors such as availability of data for a particular contaminant and receptor group, complexity of the study site (e.g., number of contaminants) and level of effort available to develop a TRV. TRVs derived from a more comprehensive data set will be more reliable than TRVs derived from single studies.

Several sources can be consulted during a literature review:

1. *Electronic database search engines (e.g., TOXNET, Web of Science, Science Direct)* – These databases are often available from university or other libraries for obtaining primary reference lists for journal articles and sometimes reports. Key words should be kept broad to ensure all relevant literature is obtained (e.g., "arsenic", "mammals", "reproduction").

2. *Electronic toxicological databases (e.g., EPA ECOTOX)* – These often allow the user to obtain data summaries and references from a large compiled data set by setting certain selection criteria (e.g., species, contaminant, types of effects).

3. *Reference lists from secondary sources* – These include sources such as published TRVs (e.g., Quebec 2000, US EPA 2007), technical documents for regulatory guidelines (e.g. CCME 1998, 1999c, 2006, 2007), data compilations (e.g., Agency for Toxic Substances & Disease Registry [ATSDR; http://www.atsdr.cdc.gov/substances/index.asp]), citation lists from journal articles and other compiled sources (books, reports, previously published or accessible ERAs).

Table 2 provides information on some common sources of databases used to obtain published toxicological data for TRV derivation. The decision on which source to use depends on the situation; the attributes described for each source will help guide the decision.

The risk assessor should document the type of literature review conducted (e.g., search engines consulted, date consulted, keywords, number of articles retrieved, etc.). Regardless of the literature review method used, primary literature sources should be retrieved and consulted to ensure that there are no transcriptional errors and that data are interpreted and applied in a manner consistent with the site-specific TRV development. This requirement also allows the user to assess the study design and data quality.

2.3.2.2. Data Quality and Selection Criteria

Primary literature should be assessed in terms of data quality and relevance. Guidance for conducting literature searches, including data quality and selection criteria are presented in US EPA (2005), USACHPPM (2000), SAB (2006), CCME (1998, 1999c, 2006, 2007), and Klimisch et al. (1997). The following is a brief outline of key considerations:

- Phylogeny of the test species

- Comparative physiology

- Age/life stage/sex of test species

- Biological relevance of toxicity endpoint types

- Chemical form (or purity)

- Treatment levels

- Exposure route

- Exposure duration

- Concentration/dose confirmation

- Ingestion rates in feeding studies

- Test organism mass

- Study design and statistical methods

- Environmental test conditions

2.3.2.3. Derivation Methods for TRVs

Once a toxicity data set has been assembled, there are various options for deriving TRVs. As described elsewhere (e.g., Suter et al. 2000, SAB 2006, Allard et al. 2010) and discussed below, these options will vary according to the quantity and specificity of toxicity data used, and the objectives set in the ERA's problem formulation. Regardless of the approach used, the TRV derivation process should be well documented to ensure transparency.

TRVs are ideally derived with a thorough understanding of the underlying mechanism of toxicity and physiological differences between species. Most ERA guidance for contaminated sites (e.g., BC MOE 2007; SAB 2006, Quebec 2000) promotes the derivation of TRVs derived directly from underlying dose-response or concentration-response relationships (i.e., point estimate ICx/IDx or ECx/ECd values) because of their greater biological relevance. This approach, which leads to the calculation of HQs, allows flexibility in the ERA for using different protection goals at sites with different land uses (e.g., in BC, provincial contaminated sites practices allow for higher effect levels [50%] to occur on industrial lands relative to residential lands [20%]) and for different receptor groups (e.g., listed versus common species) and allows for other site-specific considerations. Using a TRV based on a dose-response or concentration-response relationship can provide data to support probabilistic risk assessments because the distribution of effects allows for assessment of the probability and magnitude of effects.

In practice, data availability usually determines which method is used to develop site-specific TRVs. Generally, there is much more toxicity data available for aquatic receptors relative to terrestrial receptors. The following is a brief description of options for TRV derivation for situations ranging in data availability from low to high (for further information see Allard et al. 2010):

- **Quantitative Structure-Activity Relationships (QSARs)** – When no toxicity data are available (e.g., evaluation of proposed compounds), QSARs provide a possible method of estimating the toxic properties of a compound using the physical and structural characteristics of this compound relative to a toxicity data set from similarly structured compounds. Options for QSAR derivation are beyond the scope of this module; see Suter et al. (2000) for more details.

- **Single Study TRV** – In data poor situations, a TRV can be derived from a single literature-based study or a few studies by focusing on individual treatments to extract doses/concentrations and their respective effect sizes without quantifying the underlying relationship. For instance, if a study had only a few treatments, this would involve determining an effect size for each treatment by comparing the magnitude of toxicological response in a given treatment to the control response (e.g., 40% sublethal impairment relative to control). Data from each treatment are then compiled and plotted (i.e., effect magnitude relative to dose or concentration). The scatterplot can be examined visually to derive a TRV reflecting the acceptable effects level (e.g., ICx/ECx) selected in the ERA's problem formulation. This may involve choosing the endpoint that most closely matches your AEL (e.g., if your AEL is 20% and your data show effect sizes of 0%, 25% and 50%, then you could choose the 25% effect level for the TRV [n.b., the uncertainty associated with this TRV would include, among other things, the lack of conservatism relative to the target AEL]).

- **Dose- or Concentration-response Relationships** – Depending on the amount of toxicity data available, different approaches can be taken to evaluate and display dose- or concentration-response relationships. When sufficient data exist, receptor-specific models can be developed (e.g., Kerr and Meador 1996; Moore et al. 1997, 2003). If data are more limited, they can be pooled from different species or endpoints to develop a "combined" model. IDx/EDx or Benchmark Dose (BMD) methods can then be used to derive TRVs (Moore and Caux 1997; USACHPPM 2000; US EPA 1995, 2000). **Figure 1** shows how this can be done for multiple study dose-response data sets where dose-response curves are fitted for (a) a single species, or (b) multiple species. The single species example is for effects to loon from methyl mercury. The multiple species curve represents effects to all birds from methyl mercury. This is different from the Species-Sensitivity-Distribution (SSD) approach in that the multispecies curve represents the dose-response relationship for birds in general, without any explicit consideration of inter-species differences in sensitivity (i.e., since insufficient data are available, this would be an important uncertainty). In contrast, the SSD approach is based on a sound understanding of the relative sensitivities of a number of taxa.

  Depending on the goals of the ERA, an IDx-based TRV could be obtained from either the single species (e.g., if that species is the ROC) or multiple species (e.g., if there is no species-specific data for an ROC) curves. If data are insufficient to fit a statistical dose-response model, there are still better options for TRV derivation than relying on NOAEL/LOAEL estimates. One example would involve plotting the dose- or concentration-response data (e.g., a scatterplot) so that it can be examined visually (as suggested for single-study TRVs above); the underlying relationship can be used to select a TRV. **Figure 2** shows an example of a multiple study scatterplot for effects to fish from exposure to mercury, related to mercury tissue concentrations. The tissue concentration –

response graphs for growth, reproduction and behaviour show ICx data. The graph for mortality shows ECx data. A point estimate (ICx or ECx) can be obtained from either graph and be used as TRV. In all cases, the dose- or concentration-response relationship (strong or weak) can also provide insights into uncertainty and the possible implications of exposures exceeding the TRV.

- **Species Sensitivity Distributions (SSDs)** – SSDs emphasize protection of multiple species, or communities, rather than individual species (Posthuma et al. 2001). Using SSDs involves plotting a consistent toxicological endpoint (e.g., EC25 or LC50) for multiple species exposed to a particular contaminant. This provides information on the relative sensitivities of the tested species, and can be used to determine a TRV that protects the community. SSDs have been commonly applied for aquatic species (e.g., Brix et al., 2001), but rarely to terrestrial wildlife. Frampton et al. (2006) provide an example of SSD application to soil invertebrates. CCME currently uses the SSD approach for derivation of soil (2006) and water (2007) quality guidelines. **Figure 3** shows an example of an SSD plot for endosulfan in freshwater (units are ng/L; CCME 2010)

Figure 1a. Example of single species dose-response model for reproductive effects to loon from methyl mercury exposure.
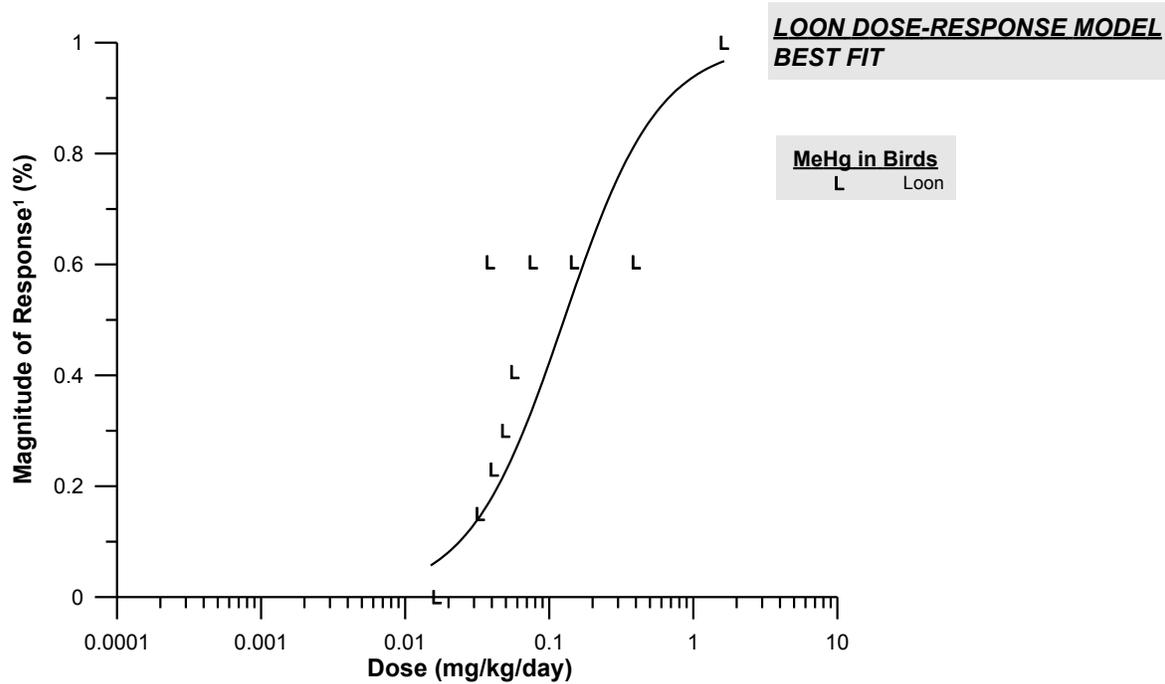
Figure 1b. Example of multi-species dose-response model for reproductive effects to birds from methyl mercury exposure.
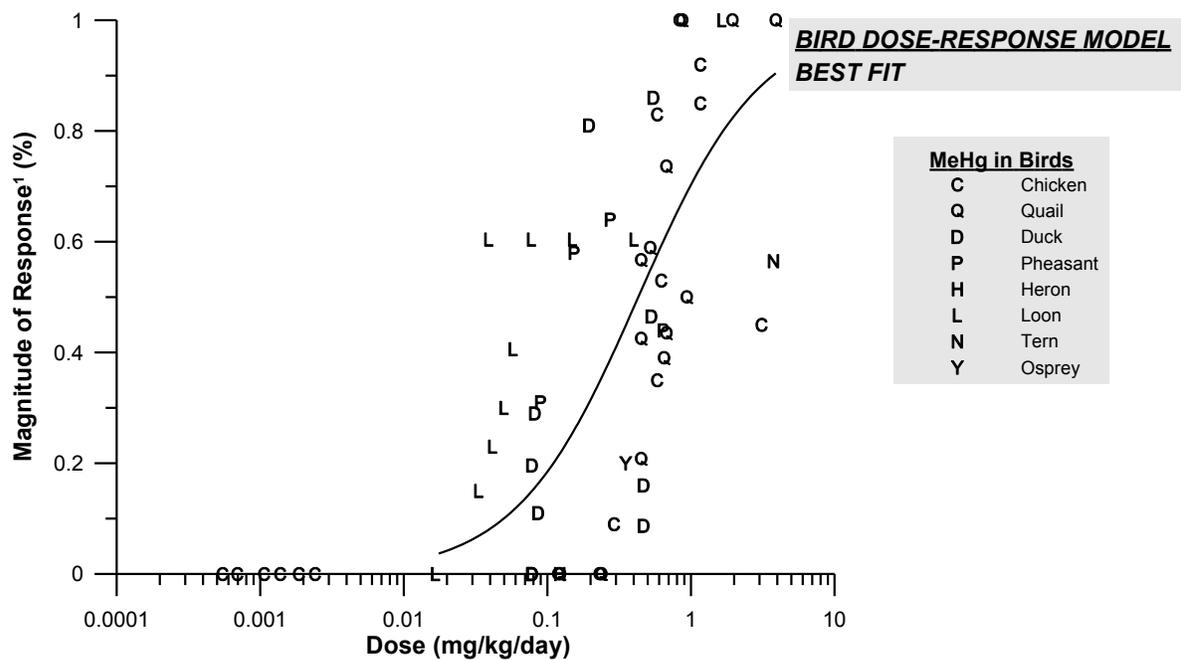
[1] The magnitude of response y-axis scale extends from 0 to 1 (e.g., 0.5 corresponds to a 50% effect size such as reduction in reproductive output relative to control).

Figure 2. Example of a tissue concentration-response data set for lethal (mortality) and sublethal (growth, reproduction, behavior) effects measured against total mercury concentrations (mg/kg wet) in fish tissue. Data can be used for TRV derivation.
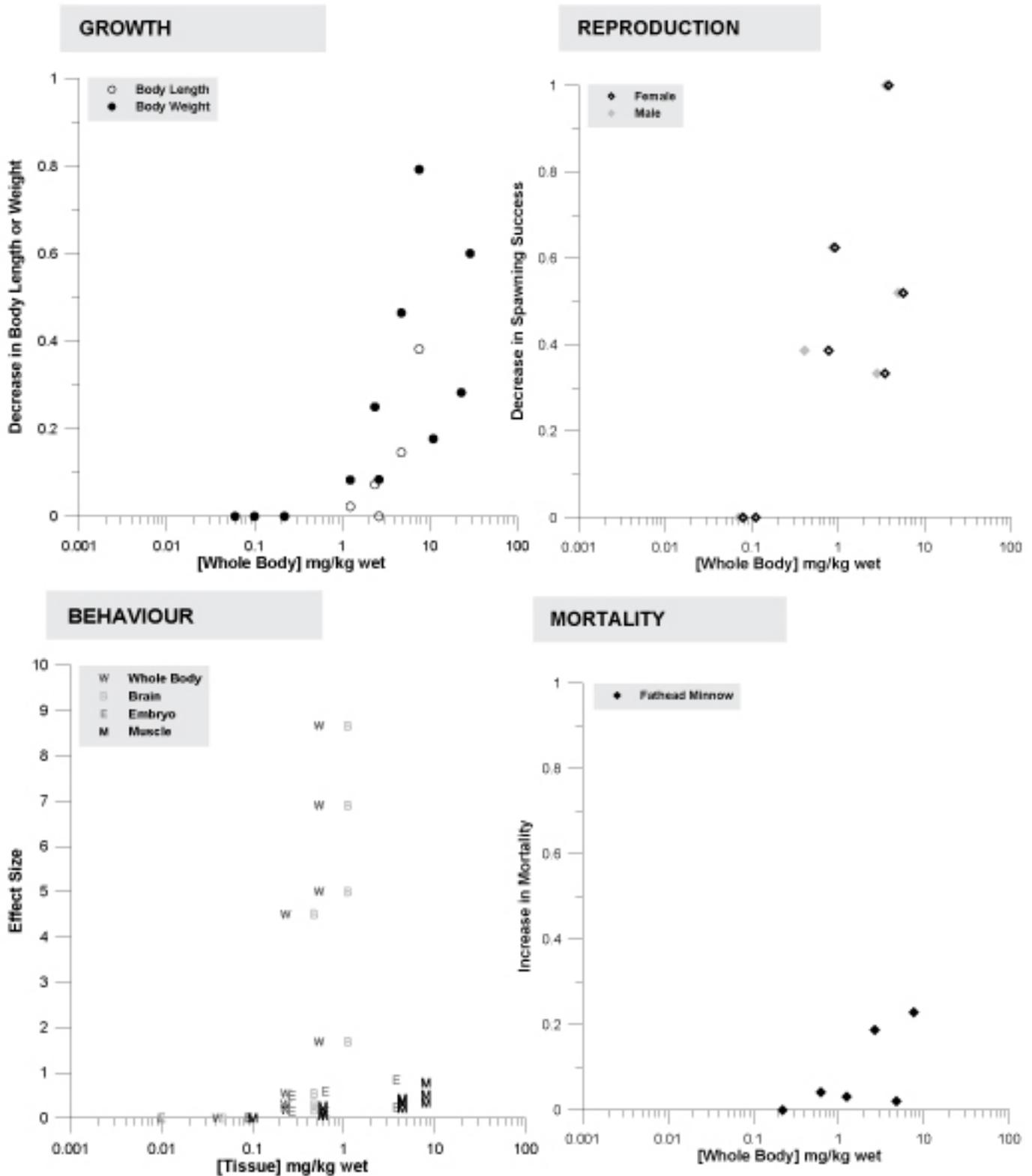
Figure 3. Long-term SSD representing the toxicity of endosulfan in freshwater consisting of acceptable long-term endpoints of aquatic species versus proportion of species affected (from CCME 2010).
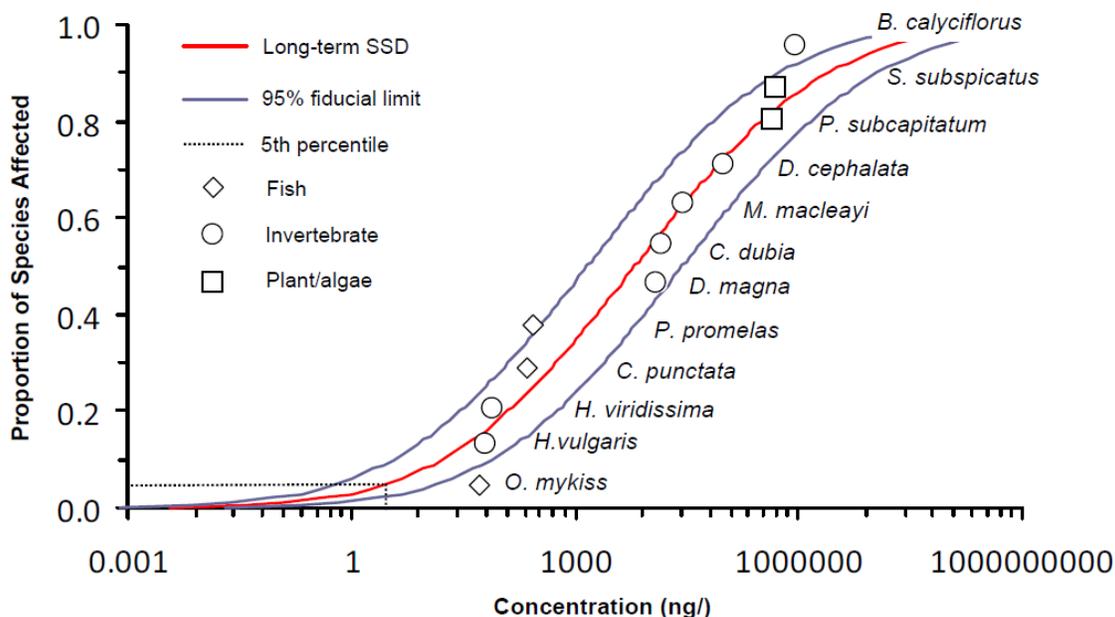
2.3.2.4. Uncertainty and Extrapolations

Uncertainty in TRV development can stem from a number of factors. McDonald and Wilcockson (2003) discuss this further in relation to TRV development for wildlife food chain models.

Steps to reduce uncertainty have been discussed in this document, such as:

- Assessing data quality and study methods

- Increasing the number of studies consulted for development of the TRV

- Examining factors that may result in differences between the laboratory-based data and exposures at the study site (e.g., bioavailability, appropriateness and sensitivities of test species, duration of exposure).

Often, extrapolating results from the laboratory to the field is required. Because very few toxicity studies are conducted using relevant wildlife species, results of studies performed using common laboratory species are extrapolated to wild species (EPT, 1996; Mineau et al., 1996; Chapman et al., 1998; Suter et al., 2000). Allard et al. (2010) suggest that extrapolating between species is acceptable, but that extrapolation across classes of organisms is not acceptable. Cross-class extrapolations are not recommended because there is high uncertainty, particularly with increasing taxonomic distance. The authors provide support for this recommendation for aquatic organisms (e.g., Suter et al., 1986 and Suter and Rose, 1988), as well as for wildlife (birds, mammals, reptiles) (e.g., Luttik and Aldenberg, 1997, Johnson et al., 2007). Options for inter-species extrapolations include:

1. **Allometric scaling** follows the premise that species sensitivity is related to basal metabolic rate, which is related to body weight. Some empirical evidence indicates that allometric scaling of contaminant sensitivity may be applicable to mammals (Suter et al., 2000), but perhaps not to birds (Mineau et al., 1996). However, factors other than basal metabolic rate may also influence species sensitivities. For instance, physiological differences (e.g., gastrointestinal physiology) between taxonomic groups often provide a rationale for applying uncertainty factors rather than allometric scaling (EPT, 1996). Furthermore, evidence supporting use of scaling factors is based largely on acute toxicity data (Suter et al. 2000). Given the limitations of allometric scaling, its use has been discouraged (see Allard et al. 2010). Consequently, allometric scaling methods should only be used when supported by scientific rationale.

2. **Uncertainty factors** are often applied in ERAs (as well as criteria derivation) as part of a policy decision to address uncertainties (e.g., extrapolation between taxa, extrapolation from acute to chronic, laboratory to field, etc.) by adding an extra margin of safety to empirical data. Uncertainty factors are arbitrary factors (as low as two times, as high as several orders of magnitude) applied to point estimates to estimate a safe level for a substance in the environment (Chapman et al., 1998). As these authors point out, "the unfortunate reality is that in too many cases there is no attempt to obtain data. Instead, too much information is extrapolated from too few data." Uncertainty factors, if used, should be supported by a scientific rationale (see Allard et al. 2010).

3. **Using unmodified data from test species** involves basing TRVs on the available toxicological data. There is greater justification for this approach when using a broadly based data set with multiple endpoints and test organisms. The more species represented in the data set, the more likely that inter-species variability in sensitivities has been captured and can be propagated in the ERA. This approach can also be considered more transparent as fewer factors are introduced into the relationship.

2.3.3. Modifying Existing Guidelines to Develop Site-specific TRVs

Typically, environmental quality guidelines are developed by regulatory authorities with the objective of establishing safe limits of exposure for ecological receptors within the entire jurisdiction. They are usually intended to be conservative to protect the most sensitive species from chronic, long-term exposures to contaminants. Often guidelines are developed for different types of resource uses. However, because of their application over broad spatial scales and conditions, they may not be appropriate for conditions encountered on a site-specific basis. For this reason, it may be appropriate to modify guidelines to represent local conditions.

In theory there are various approaches that can be applied to derive site-specific TRVs from guidelines (BC MOE 1997, BC MOE 2004, US EPA, 1984, 1994, CCME 1998, 1999c, 2006, 2007). Some of these include:

*   **Application of the background concentration** (e.g., in cases where substances are naturally elevated, historical data for the study site or upstream/offsite data that reflect the natural background concentration for the local area can be used).

*   **Recalculation of the guidelines** (e.g., evaluation of resident species at the study site relative to species used in the guidelines; examination of site-specific properties of

exposure media – such as physical and chemical properties (e.g., pH, redox, organic carbon content); or examination of uncertainty factors and other assumptions which may reduce or enhance toxicity).

- **Application of effects ratio** (e.g., uses the ratio between toxicity of a contaminant in site media to that in laboratory media, which is then applied to adjust the regulatory guideline; usually applied to water). This method essentially takes site-specific factors that modify the toxicity of a COPC into consideration.

The reader should evaluate specific environmental quality guidelines to determine options for their modifications (e.g., CCME 1996b, 1999 a, b, d, 2001, CCME 2008). An overview of the CCME guideline derivation documents is presented in **Table 3**.

Note that another option available to risk assessors involves the use of environmental quality guidelines from other jurisdictions. This option should be considered on a case-by-case basis and only be pursued if the use of guidelines from other jurisdictions provides a more scientifically-defensible approach.

2.3.4. Site-specific Toxicity Test-based TRVs

Site-specific toxicity testing can also be used to derive a TRV. Specific guidance on toxicity testing is provided in a separate Technical Guidance Module of the FCSAP ERA Guidance. In contrast to other TRV derivation methods, site-specific testing can provide a more realistic basis for predicting risks at a given site by considering key factors that can modify toxicity (e.g., COPC bioavailability) or by testing resident organisms. While these concepts apply to a wide range of receptors (e.g., including wildlife), their use is generally limited to plants, invertebrates and fish.

Incorporating site-specific toxicity testing information into the TRV derivation process requires the following special considerations (i.e., in addition to those discussed elsewhere in this guidance module):

- Selection of toxicity test (e.g., species and duration – see Technical Guidance Module on Toxicity Testing).).

- Selection of a toxicity testing regime that best mimics the range of site conditions (e.g., COPC concentrations; concentrations of modifiers such as pH, total organic carbon, sulphides/oxyhydroxides, hardness, biotic ligands, temperature; and receptor acclimation/adaptation).

- Study design to support development of concentration-response relationships for each COPC-ROC combination.

Once the site-specific concentration-response relationships have been established, the process for deriving the TRV is consistent with the approach discussed earlier for literature-based TRVs, where a TRV corresponding to a particular effect level is selected.

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Table 1. Published Sources of TRVs.

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
US EPA Eco-SSL*	Combination of statistical and effects-based soil concentrations	Terrestrial Plants Soil Invertebrates	Soil	17 metals 4 organics including DDT and metabolites, dieldrin, pentachlorophenol, total PAHs [Note TRVs are not derived for all ROCs and contaminants]	Geometric mean of MATC[a], EC10 and EC20 data Only data with acceptable data quality evaluation scores, bioavailability scores are included	Reproduction, population dynamics, growth, biomass (plants only), physiology (plants only)	EC20 (assumption that MATC[a] is less than an EC20)	Comprehensive literature review Published recently and data are up-to-date Considers multiple studies and ecological endpoints and provides data summaries and references	Data with moderate bioavailability scores are excluded for some contaminants (if enough high scoring data are available) but used for others
US EPA Eco-SSL*	Statistically-based dietary doses	Birds Mammals	Dietary ingestion	17 metals 4 organics including DDT and metabolites, dieldrin, pentachlorophenol, total PAHs [Note TRVs are not derived for all ROCs and contaminants]	Geometric mean of NOAELs (if lower than the lowest bounded LOAEL), or Highest bounded NOAEL, lower than the lowest bounded LOAEL	Reproduction and growth	"NOAEL"	Comprehensive literature review Published recently and data are up-to-date Considers multiple studies and ecological endpoints and provides data summaries and references	Approach is quantitative but lacking some ecological relevance, for example: TRV is based on statistical significance, not magnitude of effect Dose-response information is lost Unbounded NOAEL and LOAEL data are disregarded
Oak Ridge National Laboratory	17 types of benchmark water concentrations Intended as	Aquatic biota	Water	Numerous metals and organics	17 types of benchmarks are provided including: Acute and chronic national water quality criteria, Lowest test EC20, Sensitive species	Various including reproductive output, fish recruit	Various – presents different types of endpoints	Provides compendium of guidelines/benchmark concentrations	Intended for screening purposes May not be appropriate for site-specific or detailed

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
(Suter and Tsao 1996)	screening values for identifying contaminants of potential concern				EC20, Fish population EC25	abundance, population abundance	with various protection levels		ERAs
Oak Ridge National Laboratory (Jones et al., 1997)	18 types of benchmark sediment concentrations Intended as screening values for identifying contaminants of potential concern	Benthic invertebrate biota	Sediment	Numerous metals and organics	18 types of benchmarks are provided including: Effects range-low, Effects range-medium, Threshold effect level, Probable effect level, Ontario MOE lowest effect level, Ontario MOE severe effect level, National sediment quality criteria, Equilibrium partitioning benchmarks. Values are primarily calculated by other organizations and jurisdictions and are summarized by ORNL.	Various effects to benthic organisms for field based assessments and laboratory exposures.	Various – presents different types of endpoints with various protection levels	Provides compendium of guidelines/benchmark concentrations	Intended for screening purposes May not be appropriate for site-specific or detailed ERAs
Oak Ridge National Laboratory*# (Efroymson et al., 1997a, 1997b)	Benchmark soil concentrations Intended as screening values for identifying contaminants of potential concern	Terrestrial plants Soil invertebrates Soil functional groups (microorganisms)	Soil	Plants - 31 metals, 38 organics Earthworms – 9 metals, 26 organics Other invertebrates – 6 metals and 4 organics Soil functional groups – 24 metals and 8	A literature search using databases and reference lists was conducted to identify candidate studies for TRV development	Growth, yield, survival, metabolic activity (plants) Survivorship, growth, reproduction (soil invertebrates) Respiration, carbon substrate or nitrogen	10th percentile of LOECs[b] for various plant/soil invertebrate/ microbial species Also presents screening benchmark concentrations used in other	Comprehensive literature review Includes more contaminants than the Eco-SSL References and regulatory guidelines from other jurisdictions are provided Effects levels are reported in	Reviews are dated more than 10 years old and data are not being updated Difficult to manipulate for site-specific applications

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
				organics		fixation, enzyme activity, mycelial growth (soil functional groups)	jurisdictions such as CCME and RIVM	appendices (or relate to 20% response)	
Oak Ridge National Laboratory*# (Sample et al., 1996)	Statistically-based dietary doses Primarily intended for screening assessments	Birds Mammals	Dietary ingestion	85 contaminants including metals and organics	A literature search using databases and reference lists was conducted to identify candidate studies for TRV development TRVs reported as NOAELs and LOAELs calculated from a single selected study	Reproduction (68% of TRVs), mortality (16% of TRVs), liver/kidney toxicity, longevity, weight loss, growth, blood chemistry (remaining 16% of TRVs)	"NOAEL" or "LOAEL"	Covers many contaminants Provides information summary for each study	TRV is based on statistical significance, not magnitude of effect Only a single study is reported for each contaminant Endpoint for TRV is sometimes mortality
US EPA Region 9 Wildlife TRVs	Statistically-based dietary doses	Birds Mammals	Dietary ingestion	Birds – 13 contaminants including metals and organics Mammals – 20 contaminants including metals and organics	TRVs reported as Low-TRV (NOAELs) and High-TRV (LOAELs) calculated from a selected study	Primarily growth, reproduction, developmental, mortality Also includes neurobehavioural, cancer, immunotoxicity, organ effects, anorexia, hair loss	"NOAEL" or "LOAEL"	Provides a TRV value Some contaminants reported here are not included in the Eco-SSLs	Limited data set
OMOE 2007	Objective was statistical (LOEL) based	Birds Mammals	Food ingestion, soil	Various metals and organics 15 TRVs	CCME – TRVs calculated for Ontario valued ecosystem components	Growth, reproduction, mortality,	"LOEL"	Easy-to-access values for recommended	Underlying toxicological data set may be limited

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
	TRV. Other data was used such as LD50 ÷ 10 fold safety factor		ingestion, inhalation, dermal (chemical specific)	calculated using CCME soil guidelines 46 TRVs from ORNL (Sample et al., 1996)	(VECs[c]) from controlled dose-response studies referenced in CCME soil criteria documents (CCME 2006) ORNL – TRVs for Ontario VECs were calculated using allometric scaling from the ORNL TRVs	organ effects, neurotoxicity See endpoints under ORNL for ORNL based TRVs		VECs in Ontario	Uses allometric scaling
CEAEQ, 2000 Based on: Efroymson et al., 1997a, 1997b	Benchmark soil concentrations	Terrestrial plants Soil invertebrates Soil microorganisms	Soil	Plants - 16 metals, 16 organics Soil invertebrates – 9 metals, 17 organics Soil microorganisms – 15 metals and 5 organics	Developed from data obtained from the ORNL document (which includes other data sources and databases)	Growth, yield, survival, metabolic activity (plants) Survivorship, growth, reproduction (soil invertebrates) Respiration, growth, nitrogen fixation (microorganisms).	Protection (effect level) based on land use, as follows: threatened or endangered species, or species at risk (plants only) (10%), residential or recreational (20%), commercial or industrial (40%).	Includes more contaminants than the Eco-SSL Effects levels are reported in tables for each contaminant	Reviews are dated more than 10 years old and data are not being updated Difficult to manipulate for site-specific applications
CEAEQ, 2000 Based on: Sample et al., 1996	Statistically-based dietary doses	Birds Mammals	Dietary ingestion	Mammals – 12 metals, 16 organics, 2 inorganics Birds – 12 metals, 3 organics, 1 inorganic	Developed from data obtained from the ORNL document (which includes other data sources and databases) Lethality endpoint data multiplied by a safety factor of 0.1 when exposure is <1year and 0.5 when	Lethality Reproduction (offspring weights and survival; reproductive organ weights; generally, offspring and parental	Protection (effect level) based on sensitivity and/or land use, as follows: threatened or endangered species, or	Covers many contaminants Provides information summary for each study	Only a single study is reported for each contaminant Endpoint for TRV is sometimes mortality

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
					exposure is >1year Sub-lethal endpoint data multiplied by a safety factor of 1/5 when exposure is <1year	health) Sub-lethal (biochemical, histological, dietary, etc.)	species at risk (10%), residential or recreational (20%), commercial or industrial (40%).		

[1]Sources of TRVs:

*Recommended by BC MOE, 2007. #Recommended by Quebec, 2000.

US EPA Eco-SSL. Available from: http://www.epa.gov/ecotox/ecossl/

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US EPA Region 9 Wildlife TRVs. See reference list (**Section 3**) for citation. Available from: http://www.dtsc.ca.gov/AssessingRisk/upload/Eco_Btag-mammal-bird-TRV-table.pdf

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[2]Acronyms:

[a]MATC = maximum acceptable threshold concentration = geometric mean of study no observed adverse effect concentration (NOAEC) and lowest observed adverse effect concentration (LOAEC)

[b]LOEC = lowest observed effects concentration defined as the lowest concentration causing a greater than 20% response level (NOECs = no observed effects concentration and were defined as the highest concentration resulting in a 20% or lower response level)

[c]VEC = valued ecosystem component = equivalent to a receptor of concern (ROC).

Also see text for ECx/ICx or EDx/IDx and NOAEL/LOAEL or equivalent terms such as NOEL/LOEL or NOEC/LOEC; CEAEQ = Centre D'Expertise en Analyse Environnementale du Quebec

Table 2. Sources of Databases for Site-Specific TRV Development.

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
EPA ECOTOX Database*	Database Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	Aquatic species (invertebrates, plants, fish, amphibians) Terrestrial plants Wildlife (birds, mammals) Microorganisms are not included	Various (water, soil, dietary ingestion) Sediment only exposures are not included	Multiple (number not reported but comprehensive)	Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	Accumulation, cellular, mortality, behavior, ecosystem physiology, biochemical, growth, population, reproduction	Study-specific (e.g., NOEC, LOEC, LC50, LD50, unspecified)	Very comprehensive data set Updated on a regular basis	Data are not summarized for the purpose of deriving a TRV It is recommended that primary literature sources be consulted to understand the context of the data retrieved from the database
Integrated Risk Information System (IRIS)*	Oral reference dose (RfD), inhalation reference concentration (RfC), and carcinogenicity assessment based on an effects-size based target response. TRVs are intended for human health risk assessment.	Humans (but often based on mammalian data)	Dietary ingestion (including drinking water) Inhalation exposure	548 substances including metals and organics 53 substance reviews completed since 1997 are available in pdf format on the website	Usually based on a statistical lower confidence limit on the benchmark dose or concentration. The target benchmark response is the change in response rate over background and is usually in the range of 5-10%, which is the lower limit of responses typically observed in	Carcinogenic and noncarcinogenic endpoints including reproduction, development, and other sublethal effects (contaminant specific)	The target benchmark response is the change in response rate over background and is usually in the range of 5-10%.	Studies on mammals are reported and could be used for mammalian TRV development Comprehensive peer-review process	TRVs are calculated for humans only

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
					well-conducted animal experiments.				
California EPA Wildlife Exposure Factor and Toxicity Database*	Database Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	Over 125 terrestrial species Birds Mammals Amphibians (limited ecotoxicity data, mostly biological data) Reptiles (limited ecotoxicity data, mostly biological data)	Tissue concentrations Soil exposure concentrations Dietary exposure concentrations Field and laboratory exposures	Over 180 chemical substances including metals and organics	Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	Various (accumulation, behavioural, cellular, reproduction, growth, mortality, population size, ect.)	Study-specific	Effects descriptions are useful (provides more details than EcoTOX) Also provides biological information that can be used in ERA	Data are not summarized for the purpose of deriving a TRV It is recommended that primary literature sources be consulted to understand the context of the data retrieved from the database
EPA Aquatic Toxicity/Tissue Residue Database	Database with 2866 records Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	190 freshwater and marine aquatic organisms: Invertebrates Fish Aquatic life-stage amphibians	Various (water, sediment, food, injection)	200 inorganic and organic chemicals	Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	Survival, growth, reproduction	Study-specific	Useful information on the TOXRES record form	Data are not summarized for the purpose of deriving a TRV It is recommended that primary literature sources be consulted to understand the context of the data retrieved from the database Organized by chemical but difficult to navigate through and does not generate report

TRV Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
EPA PCB Residue Database	Database Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	Mostly aquatic and aquatic-dependent species Fish Birds Mammals	Tissue concentrations (critical residues) resulting from water, dietary, gavage, and injection exposures	PCBs, dioxins, furans	Specific TRVs are not provided Provides data to develop TRVs (based on database summaries or primary literature reference lists)	Behaviour, biochemical, cellular, mortality, growth, physiology, population, reproduction	Study-specific (NOEC/LOEC, LCx/ ECx, LDx/EDx, LTx/ETx[a],% mortality)	User-friendly database search and results can be easily exported	Data are not summarized for the purpose of deriving a TRV It is recommended that primary literature sources be consulted to understand the context of the data retrieved from the database

[1]Sources of Databases and Guidelines for TRV Development:
EPA ECOTOX Database. Available from: http://cfpub.epa.gov/ecotox/ ;California EPA Wildlife Exposure Factor and Toxicity Database. Available from:
http://endeavor.des.ucdavis.edu/calecotox/species.asp; EPA Aquatic Toxicity/Tissue Residue Database. Available from: http://cfpub.epa.gov/ecotox/
EPA PCB Residue Database. Available from: http://cfpub.epa.gov/ecotox/; CCME Regulatory Guidelines - see reference list (**Section 3**) for citations.
[2]Acronyms:
[a]LTx/ETx = tissue residue resulting in x% lethal (L) or sublethal effect (E) response size
Also see text for ECx/ICx or EDx/IDx and NOAEL/LOAEL or equivalent terms such as NOEL/LOEL or NOEC/LOEC

Table 3. CCME Guideline Derivation Documents.

Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
CCME 2007 Water Quality Guideline Derivation Protocol (See CCME 1999b for guidelines)	Species sensitivity distribution (SSD)	Aquatic species Algae Plants Invertebrates Fish Amphibians	Water	More than approximately 100 metals and organics	For long-term effects, 5th percentile of the SSD distribution of no-effects to low-effects data, which are ideally derived from data less than an EC10. If this is not available data showing responses up to an EC50 can be used. For acute effects, the same approach is applied but the target response is LC50/EC50.	Growth, reproduction, survival, and non-traditional endpoints (e.g., behaviour, physiological changes) IF the ecological relevance of the non-traditional endpoints can be demonstrated.	Long-term effects – less than EC10 is the target response; up to an EC50 is allowed. Acute effects – target response size is an LC50/EC50	Guidelines are continually being developed for new substances and existing guidelines are updated High ecological relevance as approach considers SSDs based on effect-size based targets which should be protective of communities	Intended for use throughout Canada, and generally used for screening. May not be appropriate for site-specific applications or detailed ERA.
CCME 1999c Sediment Guideline Derivation Protocol (See CCME 2001 for guidelines)	Statistically-based from effects and no-effects data distributions. Considers multiple species and endpoints.	All life stages of aquatic life (marine, freshwater, estuarine) Bacteria Algae Plants Benthic invertebrates Fish	Sediment exposures	Various metals and organics. Approximately 23 freshwater sediment guidelines and 33 marine sediment guidelines.	National Status and Trends Program (NSTP) Approach[3] – Uses Biological Effects Database for Sediments (BEDS) and classifies data into "effect" and "no effect" data. Guidelines selected as the geometric mean of the 15th percentile of effects data and the 50th percentile of no-effects data = threshold effects level (TEL), and the geometric mean of the 50h percentile of effects data and the 85th percentile of no-effects data = probable effects level (PEL). Interim sediment quality guidelines (ISQG) are developed if data are limited. Spiked-Sediment Toxicity Test (SSTT) Approach – Most sensitive	Altered benthic communities (e.g., richness, abundance) field sediment toxicity, histopathological disorders in demersal fish, EC50/LC50 in SSTT toxicity tests, toxic concentrations predicted by equilibrium partitioning from water-based exposures. SSTT endpoints	NSTP based on percentile of effects and no-effects data distributions. SSTT based on LOELs. Both approaches are statistically-based but consider multiple species and	Guidelines are continually being developed for new substances and existing guidelines are updated. Considers multiple species and endpoints	Some field data used in the BEDS database include contaminant mixtures. Intended for use throughout Canada, and generally used for screening. Allows some level of effects. May not be

Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
					LOEL from chronic study showing sublethal endpoint multiplied by a safety factor. (If acute study data is more sensitive then it is used, e.g., LD50, EC50). Study must show dose-response and LOEL must be statistically significant.	must be considered ecologically relevant (e.g., growth, reproduction, developmental effects).	endpoints.		appropriate for site-specific applications or detailed ERA.
CCME 2006 Soil Quality Guideline Derivation Protocol (See CCME 1999d for guidelines)	Species sensitivity distribution (SSD)	Plants Soil Invertebrates Microbes	Direct contact with soil	Approximately 30 contaminants including metals and organics.	Agriculture/ Residential/ Parkland – 25th percentile of the estimated species sensitivity distribution Target response is an EC25/IC25 or alternatively a Threshold Effects Concentration. Commercial/Industrial – 50th percentile of the estimated species sensitivity distribution Target response is an EC25/IC25 or alternatively a Effects Concentration - Low.	Biological impairment of a species ability to survive and reproduce (e.g., mortality, reproduction, growth).	Target response is an EC25/IC25 or alternatively a NOEC.	Guidelines are continually being developed for new substances and existing guidelines are updated High ecological relevance as approach considers SSDs based on effect-size based targets which should be protective of communities	Intended for use throughout Canada, and generally used for screening. May not be appropriate for site-specific applications or detailed ERA.
CCME 2006 Soil Quality Guideline Derivation Protocol (See CCME 1999d for guidelines)	Effects-size based TRV (if possible) for species most at threat. Default is statistically-based TRV	Birds Mammals (Including livestock) Freshwater Life	Direct contact with soil, incidental ingestion of soil, food ingestion, ingestion of contaminated water, contact with contaminated	Approximately 30 contaminants including metals and organics.	Determine species most at threat (highest exposure-to-TRV (threshold) ratio). Data to include at least two mammalian studies and one avian study. Target response is an ED25/ID25 or alternatively a LOAEL.	Biological impairment of a species ability to survive and reproduce (e.g., mortality, reproduction, growth).	Target response is an ED25/ID25 or alternatively a LOAEL.	Guidelines are continually being developed for new substances and existing guidelines are updated High ecological relevance as approach considers SSDs	Intended for use throughout Canada, and generally used for screening. May not be appropriate for site-specific applications or detailed ERA.

Source[1]	TRV Type	ROC Groups Covered	Exposure Pathways	Contaminants Covered	Derivation Methods[2]	Ecological Endpoints[2]	Protection Goals and Acceptable Effects Levels	Advantages	Limitations
			water					based on effect-size based targets which should be protective of communities	
CCME 1998 Tissue Residue Guideline Derivation Protocol (See CCME 1999a for guidelines)	Statistically-based TRVs including uncertainty factors and conservative assumptions to protect the most sensitive Canadian wildlife.	Birds Mammals (Amphibians and reptiles may be considered when information is available)	Ingestion of aquatic food sources. Dosing via oral route is acceptable, other routes are not unless supporting arguments are provided.	6 Persistent, bioaccumulative compounds (i.e., DDT, PCBs, MeHg, dioxins, furans, toxaphene)	Determine the tolerable daily intake (TDI) dose from dietary dosing studies (i.e., average LOAEL and NOAEL, divided by uncertainty factor). NOAEL may be estimated from LOAEL. Determine reference concentration (RC) by dividing TDI by the highest food intake:body weight ratios for Canadian wildlife (i.e., female mink and Wilson's storm petrel). Lowest RC is selected for TRG (or may have separate bird and mammal TRG).	Ecologically important adverse effects (e.g., reproduction, embryonic development, early survival, growth, mortality, neurotoxicity, carcinogenic effects). Endpoints are contaminant-specific.	Lowest effect threshold dose (i.e., average of LOAEL and NOAEL). May also include an uncertainty factor to account for sub-chronic exposures and use of mortality as an endpoint.	Appropriate measurement for bioaccumulative substances	Intended for use throughout Canada, and generally used for screening. May not be appropriate for site-specific applications or detailed ERA.

[1] CCME Regulatory Guidelines - see reference list (**Section 3**) for citations.

[2] Acronyms:

LTx/ETx = tissue residue resulting in x% lethal (L) or sublethal effect (E) response size

Also see text for ECx/ICx or EDx/IDx and NOAEL/LOAEL or equivalent terms such as NOEL/LOEL or NOEC/LOEC

[3] A second approach for guideline derivation was considered and calculated from the BEDS database, i.e., guidelines were selected from effects data as the 10th percentile = effects range low, (ERL) and the 50th percentile = effects range mdian (ERM). However, the TEL/PEL approach was adopted for CCME guideline development.

List of Acronyms

AEL	Acceptable effect level
BC	Benchmark concentration
BMD	Benchmark dose
CBR	Critical body residue
CCME	Canadian Council of Ministers of the Environment
COPC	Contaminant of Potential Concern
EC	Effect concentration
Eco-SSL	Ecological soil screening level
ED	Effect dose
EEC	Expected environmental concentration
ERA	Ecological Risk Assessment
ERAAG	Ecological Risk Assessment Advisory Group
FCSAP	Federal Contaminated Sites Action Plan
HQ	Hazard quotient
IC	Inhibitory concentration
ID	Inhibitory dose
LC	Lethal concentration
LD	Lethal dose
LOAEL	Lowest-observed-adverse-effects level
NOAEL	No-observed-adverse-effects level
ORNL	Oak Ridge National Laboratory
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PF	Problem Formulation
QSAR(s)	Quantitative structure-activity relationship(s)
ROC	Receptor of Concern
SETAC	Society of Environmental Toxicology and Chemistry
SSD	Species sensitivity distribution
TRG	Tissue residue guideline
TRV	Toxicity reference value

Glossary

Acceptable effect level – The magnitude of effects that would be acceptable for a specific measurement endpoint.

Assessment endpoint – An assessment endpoint is an explicit expression of the environmental value to be protected. An assessment endpoint must include a receptor (or receptor group – i.e., a 'thing' to be protected) and a specific property of that receptor. For example, if the receptor is a fish community, endpoint properties could include the number of species, the frequency of deformities, the trophic structure, etc.

Contaminants of Potential Concern – Contaminants that have been selected for evaluation in the ERA. The process used to select COPCs is not covered in this module.

Critical body residue – An internal body or tissue concentration that causes a toxicological response in a receptor.

Exposure pathways – The routes of exposure from environmental media (soil, water, air and/or aquatic sediment) to the receptors of concern.

Measurement endpoint – A measurement endpoint is a parameter that measures or describes an effect on a ROC (e.g., an individual organism, population, functional group or community), or that measures or describes a change in an attribute of an assessment endpoint or its surrogate in response to a stressor to which it is exposed.

Receptor of Concern – Any non-human individual organism, species, population, community, habitat or ecosystem that is potentially exposed to contaminants of potential concern and that is considered in the ERA.

Tissue residue guidelines – Regulatory criteria or guidelines that refer to an internal body or tissue concentration in a receptor.

Wildlife – In the context of ERA, the term is generally applied to birds and mammals, but can be extended to reptiles and amphibians as well.

Acknowledgments

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