Environment and Climate Change Canada
Environnement et Changement climatique Canada

Federal Contaminated Sites Action Plan (FCSAP)

Ecological Risk Assessment Guidance - Module 5: Defining Background Conditions and Using Background Concentrations

Version 1.0

Prepared by Environment and Climate Change Canada

October, 2019

Canada

DISCLAIMER

Standard Citation: Federal Contaminated Sites Action Plan (FCSAP). 2020. Ecological Risk Assessment Guidance - Module 5: Defining Background Conditions and Using Background Concentrations. Version 1.0, March 2020. Ottawa: Her Majesty the Queen in Right of Canada. ISBN 978-0-660-33974-0

Cat. No.: En14-92/5-2020E-PDF
ISBN: 978-0-660-33974-0

Environment and Climate Change Canada
Public Inquiries Centre
7th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-997-2800
Toll Free: 1-800-668-6767 (in Canada only)
Email: ec.enviroinfo.ec@canada.ca

1 Table of Contents

List of Figures

Acronyms

ANOVA	Analysis of Variance
APEC	Area of Potential Environmental Concern
BACI	Before-After-Control-Impact
BC MOE	British Columbia Ministry of the Environment
BC MWLAP	British Columbia Ministry of Water, Land and Air Protection
BTV	Background Threshold Value
CCME	Canadian Council of Ministers of the Environment
CEQGs	Canadian Environmental Quality Guidelines
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
CSMWG	Contaminated Sites Management Working Group
CSQG	Canadian Soil Quality Guidelines
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DQI	Data Quality Indicator
DQOs	Data Quality Objectives
EC	Environment Canada (now ECCC)
ECCC	Environment and Climate Change Canada
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESA	Environmental Site Assessment
FACS	Federal Approach to Contaminated Sites
FCSAP	Federal Contaminated Sites Action Plan
Foc	Fraction of Organic Carbon
HQ	Hazard Quotient
LOE	Lines-of-Evidence
MECP	Ministry of the Environment, Conservation and Parks
NMDS	Non-metric Multidimensional Scaling
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PFAS	Perfluoroalkyl Substances
ROC	Receptor of Concern
TOC	Total Organic Carbon
TRV	Toxicity Reference Value
TSS	Total Suspended Solids
QA/QC	Quality Assurance/Quality Control
US EPA	United States Environmental Protection Agency
95% UCLM	95% Upper Confidence Limit of the Mean

Glossary

***Ambient Background Concentrations* –** Represent concentrations of chemicals in the environment reflecting natural and regional anthropogenic (not site-related) sources of chemicals.

***Background Sample* –** A field collected sample of sediment, soil or water collected from a site thought to be relatively free of contamination and included in the sampling program because of its geochemical similarity (e.g., particle size, hardness, organic content) to the samples collected from the contaminated site.

***Contaminants of Concern (COCs)* –** Contaminants that have been selected for evaluation during the ERA, usually based on a completed problem formulation. A contaminant is any physical, chemical, biological or radiological substance in air, soil or water that has an adverse effect; any chemical substance whose concentration exceeds background concentrations or which is not naturally occurring in the environment.

***Ecological Risk Assessment (ERA)* –** ERA is the process that evaluates the likelihood and/or magnitude of potential adverse ecological effects (current or future) as a result of exposure to one or more stressors (in the context of contaminated sites, the stressors are usually chemical). A risk cannot exist unless: (1) the stressor has an inherent ability to cause adverse effects, and (2) it is coincident with or in contact with an organism long enough and at sufficient intensity to elicit the identified adverse effect(s).

Guideline – A value that is recommended for the screening of environmental data, such as tissue residues or concentrations in abiotic media. A guideline usually differs from a standard in that a guideline does not convey a legal requirement or formal responsibility. Canadian Environmental Quality Guidelines are intended as nationally endorsed science-based goals for environmental quality.

***Hazard Quotient* (HQ)** – A numerical ratio that divides an estimated environmental concentration or other exposure measure by a response benchmark. Typically, the response benchmark is a value assumed to be protective of the receptor of concern. HQ values below one (1.0) indicate negligible potential for harm, whereas HQ values above one (1) indicate that an adverse response is possible, and that more precise or accurate evaluation of risks may be warranted to address uncertainty.

***Lentic System* –** An inland aquatic ecosystem (typically freshwater) characterized by standing water (e.g., ponds and lakes).

***Lines of evidence* (LOE)** – Any pairing of exposure and effects measures that provides evidence for the evaluation of a specific assessment endpoint. Typically, a line of evidence requires use of one or more measurement endpoints. If the focus of the LOE is an effects measure (e.g., a toxicity test), the paired exposure measure may be quantitative (e.g., contaminant concentrations) or categorical (e.g., on-site versus a reference condition).

***Lotic System* –** An inland aquatic ecosystem (typically freshwater) characterized by flowing water (e.g., rivers and streams).

Mixing Zone - The mixing zone is the portion of the receiving water that dilutes the contaminant in the aquatic or marine environment.

Multivariate – A form of statistics encompassing the simultaneous observation and analysis of more than one statistical variable. In ERA, the most common multivariate methods are clustering, correspondence analysis, factor analysis, principal components analysis, and multidimensional scaling.

Natural Background Concentrations - Represent naturally-occurring concentrations of chemicals in the environment, primarily reflecting natural geologic variations.

Problem Formulation **–** The problem formulation is a planning and screening process that defines the feasibility, scope, and objectives for the risk assessment. This process includes examination of scientific data and data needs, regulatory issues, and site-specific factors.

Qualitative – Adjective describing an approach that is narrative, referring to the characteristics of something being described, rather than numerical measurement.

Quantitative – Adjective describing an approach that is numerical (applies mathematical scores, probabilities, or parameters) in the derivation or analysis of risk estimates.

Quality Assurance/Quality Control (QA/QC) **–** Quality assurance refers to the management and technical practices designed to ensure an end product (in this case, background sampling) of known or reliable quality. Quality control refers to the techniques and procedures used to measure and assess data quality and the remedial actions to be taken when the data quality objectives (DQOs) are not met.

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.

Reference Area – A location, group of locations, or experimental treatment designed to reflect the ambient physical and chemical conditions of a contaminated medium or location in the absence of the stressors of concern in the risk assessment (i.e., site-related COCs). For example, in a study of soil contamination, the reference condition should reflect the climate, substrate, and habitat factors relevant to the site but with no incremental contamination relative to background conditions.

Risk Characterization – The process of estimating the magnitude (and where relevant, the probability) of adverse ecological impacts based on the information obtained from the exposure and effects assessments. Risk characterization also translates complex scientific information into a format that is useful for risk managers, by conveying the ecological consequences of the risk estimates along with the associated uncertainties.

Stressor – Any substance or process that may cause an undesirable response to the health or biological status of an organism.

Threshold – Dividing line (in units of exposure concentration or dose) between a zone of potential response and a zone of negligible response. Thresholds may be estimated using theory, data, or a combination of both. In nature, thresholds generally do not occur as precise or static entities, due to the variations among individuals and environmental factors that influence responses. Therefore, a threshold is usually expressed as a best estimate considered protective of most of the population, and often includes a margin of safety in the derivation.

Toxicity Reference Value **(TRV)** – An exposure concentration or dose that is not expected to cause an unacceptable level of effect in receptor(s) exposed to the contaminant of potential concern. A TRV is a specific type of threshold, as defined above.

Type I errors **–** Type I errors (probability of which is commonly designated as alpha [α]) occurs when an investigator concludes there is a significant difference between samples when actually there is none. The common target value for conventional hypothesis tests is 0.05 (US EPA, 2009). However, a larger alpha [α] translates into a greater statistical power, and for power analysis, the alpha-level is often relaxed from the traditional 0.05 to 0.1.

Type II errors **–** Type II errors (probability of which is commonly designated as beta [β]) occurs when an investigator concludes there is no significant difference when actually there is. The common target value for conventional hypothesis tests is 0.20 (US EPA, 2009).

Uncertainty – In risk assessment, uncertainty is the state of having limited knowledge where it is impossible to exactly describe an existing state or future outcome. Uncertainties come in many forms, including measurement uncertainty, random variations, conceptual uncertainty, and ignorance.

Upper Confidence Limit of the Mean **(UCLM)** – A statistical measure of the upper bound of a confidence interval for the mean value of an environmental parameter, such as the expected environmental concentration of a substance.

Xenobiotic – A substance that is foreign to a body or ecological system.

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 risk management tool at federal contaminated sites.

To support ERAs, the Contaminated Sites Expert Support of Environment and Climate Change Canada (ECCC) has developed guidance documents supplemental to the existing Canadian Council of Ministers of the Environment (CCME) guidance (CCME 1997). The FCSAP ERA guidance consists of a comprehensive main ERA document (FCSAP 2012a) and five specific technical guidance modules:

- Ecological Risk Assessment Guidance – Module 1: Toxicity Test Selection and Interpretation;
- Ecological Risk Assessment Guidance – Module 2: Selection or Development of Site-specific Toxicity Reference Values;
- Ecological Risk Assessment Guidance – Module 3: Standardization of Wildlife Receptor Characteristics;
- FCSAP Supplemental Guidance for Ecological Risk Assessment – Module 4: Causality Assessment Module – Determining the Causes of Impairment at Contaminated Sites: Are Observed Effects due to Exposure to Site-Related Chemicals or due to Other Stressors;
- Ecological Risk Assessment Guidance – Module 5: Defining Background Conditions and Using Background Concentrations;
- Ecological Risk Assessment Guidance - Module 6: Ecological Risk Assessment for Amphibians on Federal Contaminated Sites
- Ecological Risk Assessment – Module 7: Default Wildlife Toxicity Reference Values (TRVs) Recommended for Use at FCSAP Sites.

This technical guidance module (Module 5) will focus on how existing background conditions (namely, background concentrations of contaminants of concern [COCs[1]]) can be quantified and used to inform ERAs at federal contaminated sites.

The objectives of the FCSAP ERA guidance documents are to provide custodians and their consultants the necessary tools to support sound management recommendations and improve national consistency in the management of federal contaminated sites.

1.1 Scope of Module

This module defines background conditions, with a particular focus on quantifying and understanding background concentrations of COCs in support of ERAs. Specifically, guidance is provided on:

1. determining when sampling to establish background concentrations is warranted in an ERA (Section 2.1);
2. defining suitable reference areas and collecting enough samples to characterize background concentrations (Section 2.2);
3. estimating background concentrations in the absence of suitable reference areas (Section 2.3); and
4. integrating information about background COC concentrations into ERAs (Section 2.4).

Although the term 'background conditions' encompasses a wide variety of conditions (e.g., climate, substrate, habitat factors, etc.), the focus of this module is on determining background COC concentrations in soil, surface water, groundwater, and sediment.

This module is not intended to be a prescriptive tool as each site, and the landscape in which it is found, is unique and should be assessed individually. The intended audience includes experienced risk assessment practitioners who would benefit from procedural guidance on the characterisation and interpretation of background conditions with respect to the assessment of ecological risk.

1.2 Role of Background Conditions and Background Concentrations in ERA

ERAs are typically conducted at contaminated sites to assess the effects of chemical stressors (i.e., COCs), associated with site-related activities (e.g., historical spills or ongoing point-source effluent discharges), on identified receptors of concern (ROCs). In this context, the term 'background conditions' can be used to describe a wide variety of features that would be expected to exist if site-related activities had not occurred. These conditions include biological parameters (e.g., species diversity, abundance, habitat availability, community health, etc.) and COC concentrations. Depending on the nature of the site, background concentrations may be defined either with respect to natural or pre-existing ambient conditions (CCME 2016a).

> *Natural vs. Ambient Background Concentrations (CCME 2016a)*
>
> **Natural Background**: Representative, naturally occurring concentrations of chemicals in the environment, primarily reflecting natural geologic variations.
> **Ambient Background**: Representative concentrations of chemicals in the environment reflecting natural and regional anthropogenic (not site-related) sources of chemicals.

As described in FCSAP guidance (FCSAP, 2012a), many approaches could be applied to establish background conditions, including sampling multiple reference sites, interpreting historical conditions, or using ecological principles to specify expected conditions in the absence of contamination (Stoddard et al. 2006). The background concentrations of COCs expected to occur in various on-site media in the absence of site-related contributions are important for defining the background conditions at any contaminated site.

The overall expected background conditions are the implied baseline for comparison in any ERA. Therefore, determining any site-related risks to ROCs should reflect an increase in risk at the site compared to pre-existing background (natural or ambient) conditions. Thus, an understanding of applicable background conditions can provide valuable context to many components of an ERA. These background conditions are particularly relevant to problem formulation, risk characterization, and the development of any site-specific remediation standards triggered by the results of an ERA where appropriate.

At the problem formulation stage, understanding background concentrations can help identify COCs. This process generally begins with a preliminary list of previously quantified potential on-site COCs, which is then narrowed down based on a variety of considerations, including a comparison of reported chemical concentrations to applicable guidelines[2]. Chemicals may be identified as COCs if their concentrations in samples collected from the site exceed identified guidelines. However, in some cases, pre-existing natural or ambient background concentrations may be enough to exceed generic guidelines. For example, naturally occurring concentrations of arsenic and other inorganics can be present in soils at levels that exceed national or provincial guideline values. In such cases, it may be appropriate to compare site concentrations to background concentrations rather than to guidelines.

Risk characterization requires an understanding of general background conditions to provide context to various lines of evidence (LOE). For example, many measured endpoints require comparing concentrations to a reference condition if a gradient design is not used, or feasible (e.g., species richness value, see FCSAP 2012a). During an ERA, this ‘reference condition’ should “reflect the ambient physical and chemical conditions of a contaminated medium or location in the absence of the stressors of concern in the risk assessment” (FCSAP, 2012a), making it equivalent to the background condition described above[3]. Similarly, if background COC concentrations have been established, site-related risks to ROCs (as calculated using a hazard quotient [HQ] approach) could be compared to background risk levels as another line of evidence. This approach would quantify the relative contribution of background COC concentrations to overall identified risks to ROCs. For example, if the background concentration of a COC in soil at a site is 15 µg/g, and the site concentration is 20 µg/g, then 75% of the exposure at the site, and associated risks, can be related to background conditions.

Finally, if an ERA leads to the development of site-specific remediation standards (FCSAP, 2012a), the CCME (2006) guidance indicates that it is generally not appropriate to remediate contaminated sites to a level below relevant background concentrations.

[2] The term ‘guidelines’ in this context is intended to encompass numeric environmental quality guidelines, criteria, standards or any other regulatory or policy benchmark that may be used for COC screening (FCSAP, 2012a).
[3] Background conditions may be determined by evaluating other locations “with physical and biological attributes similar to those of the study area, but for the release of site-related chemicals” (CCME 2016a). Such areas are often interchangeably referred to as “control sites”, “reference sites”, or “reference areas”.

2 Guidance

2.1 When to Sample for Background Concentrations

As noted in Section 1.2, background concentrations can provide valuable context at different stages of an ERA. However, off-site sampling to establish background concentrations is not required for every ERA. For example, there are situations for which the additional cost and effort required to evaluate background concentrations would unlikely provide added value within an ERA. Two such examples follow:

1. Where preliminary data indicate that COC concentrations at the site do not exceed the applicable generic environmental guidelines or trigger values. In such cases, risks to ecological receptors are unlikely to be predicted regardless of the background conditions. Therefore, no further details regarding background concentrations are required.

2. Where the COCs at the site of interest are foreign to an organism or system (i.e., xenobiotic in nature), such as perfluoroalkyl substances (PFAS). In such cases, the natural background concentrations can reasonably be assumed to be zero and further sampling is not required (Crommentuijn et al. 2000). Note: there could be merit in evaluating ambient background concentrations if the xenobiotic contaminant is widespread. Although the natural background concentrations can reasonably be assumed to be zero, the ambient background concentrations from non-site anthropogenic sources may be worth considering in the ERA.

Additionally, the need for background sampling may be precluded if sufficient existing data can be used to define background concentrations. Potential sources for such data include:

1. Existing historical information on the impacted site prior to the activity, or from a reference site that would be considered suitable to provide background conditions. In such circumstances, it is important to validate that the data obtained are indeed appropriate, and meet data quality objectives (DQOs). Note: the fate and transport characteristics of the COCs are important considerations in determining the relevance of historic information; and

2. Various federal or provincial databases – depending on the location of the site being assessed, there may be publicly available information summarizing the regional background concentrations for a wide variety of potential COCs. Examples of such situations include:

    a. Dillon Consulting Ltd. (2011) provided a review of Environment Canada's (EC) background soil database (2004-2009) for the Atlantic Region, with reference to other regions in Canada. Also, many of the supporting documents for the CCME soil quality guideline cite references for background concentrations of metals in soil. Additionally, certain provinces have published background ranges for a wide variety of substances that can be accessed; and

b. The Ontario Ministry of the Environment, Conservation and Parks (MECP) has published extensive background soil standards based on the “Ontario Typical Range” (i.e., the 97.5th percentile of a chemical in surface soils in Ontario that are not contaminated by point sources). Likewise, the BC MOE (2017a) and Quebec’s Ministère de l’Environnement et de la Lutte contre les changements climatiques (MELCC, 2019, annex 1) provide expected concentrations of metals in soils for the various regions of the Provinces. These data may be used as an additional line of evidence to characterize background concentrations of soil COCs.

For cases where COCs may occur naturally at a site, applicable guidelines are exceeded, and there are no suitable existing data that can be used to define background concentrations, additional sampling and/or analysis to characterize background concentrations may be warranted.

2.2 Sampling Reference Areas to Evaluate Background Concentrations

Estimates of COC background concentrations may be determined by evaluating other locations “with physical and biological attributes similar to those of the study area, but for the release of site-related chemicals” (CCME 2016a). This module will see such areas be referred to as “reference areas”, though they are often interchangeably referred to as “control sites” and “reference sites”.

Characterizing site-specific background concentrations determines the natural range of COC concentrations in soil, sediment, groundwater or surface water associated with the site’s geographic area or anthropogenic influences, which are unrelated to the site-specific contaminant impacts. As such, the selected reference area(s) should be as similar as possible to the site with respect to everything other than chemical concentrations resulting from site-related activities. In some cases, it may be difficult to identify and/or sample a suitable reference area. For example, if the site is isolated within an urban landscape, or the site is a unique feature with no nearby features similar in nature. In these cases, identifying background concentrations may be possible based on site data only (see Section 2.3). The following sections provide guidance regarding sampling effort, experimental design, and sampling procedures for cases where it is possible to identify suitable reference areas.

2.2.1 Sampling Effort

One challenge in developing a sampling program is determining an appropriate sample size (i.e., number of samples) to characterize the parameter of interest and to provide sufficient information on which to base conclusions. The number of samples required depends upon the study objectives, the DQOs, the desired level of certainty, and site-specific considerations (FCSAP, 2012a). Various jurisdictions have published guidance documents on sampling used to characterize background conditions for contaminated site assessment programs, but only occasionally is the minimum sample size explicitly provided in these documents. Where minimum background sample sizes are specified, they range from two (2) to thirty (30) (refer to Appendix A). The United States Environmental Protection Agency (US EPA) (2015) recommends a minimum of at least ten (10) background samples. More often, it is recommended that statistical methods that rely on either observed or expected variance of the site parameters be applied to determine the minimum sample size (refer to Appendix A). Guidance regarding this DQO-based approach for sample size selection is provided by the US EPA (2006a, 2006b, 2015).

The number of samples collected may not always meet the statistically recommended minimum sample number due to various budgetary and/or logistical constraints. In these cases, practitioners need to use their best professional judgement when designing sampling programs and/or using previously collected datasets. Statistical procedures can be applied to assess the data's statistical power for their intended use (US EPA 2015). Data analysis can be potentially limited due to smaller than recommended background sample sizes and should be addressed within the uncertainty sections of the ERA.

If sampling varies across a gradient in a medium that may influence COC concentrations (e.g., soil horizons, sediment depth, aquifers, or water column position), the minimum number of samples should apply to each stratum of that medium as appropriate in support of the ERA.

2.2.2 Experimental Designs

Experimental design determines the distribution of sampling locations across the sampled area in space and time. Developing an experimental design to include sampling of background concentrations is likely to take place during either Step 3 (Initial Testing Program) or 5 (Detailed Testing Program) of the Federal Approach to Contaminated Sites (FACS)[4], depending on the existing information about the site and likelihood of finding COCs.

The selection of specific reference areas should be based on criteria that are defined *a priori* (CCME 2016a). These criteria should represent the environmental variables that can influence background concentrations of COCs and, when relevant, should be consistent between the contaminated site and reference area(s). Examples of *a priori* criteria that could be identified include (Apitz et al. 2002):

- Physical nature of soil or sediment (e.g., grain size, organic carbon content);
- Flow dynamics (e.g., fast vs. slow or no flow);
- Chemical composition (e.g., contributions from road runoff, atmospheric deposition, naturally-occurring inorganic chemicals);
- Habitat type (specific aquatic or wetland habitats);
- Biological composition (e.g., benthic invertebrate communities);
- Geomorphology (e.g., braided, meandering, channelized streams);

> *Experimental Designs*
>
> Green (1979) first introduced the concept of study designs for impact assessments and set the standard for robust sampling designs when he introduced the Before-After-Control-Impact (BACI) design. This concept was then further developed with repeated or paired-BACI designs (Hurlbert 1984; Stewart-Oaten et al. 1986). Underwood (1991, 1992, 1993, 1994) took these concepts further with the concepts of asymmetrical designs.
>
> Unfortunately, at most contaminated sites, the option of gathering before-impact information is not available and thus typically, a more simplified control-impact or gradient sampling experimental design is applied.

[4] Published by the Contaminated Sites Management Working Group (CSMWG) (CSMWG, 2000) and adopted by FCSAP in the Decision-Making Framework (DMF) (FCSAP, 2018).

- Hydrogeology (e.g., aquifers recharging gaining water bodies);
- Wetland classification (e.g., bog, fen, swamp, marsh, shallow water);
- Oceanographic conditions (e.g., currents);
- Tidal conditions (ebb vs. flood tide); and
- Proximity to the contaminated site.

Once the *a priori* criteria of reference site selection are identified, the experimental design that best suits the site can be selected. When there is an objective of refining ERAs, two experimental designs are most applicable to characterizing background conditions: gradient-based designs and control-impact designs.

2.2.2.1 Gradient-Based Design

Gradient-based design is the preferred approach for assessing effects of COCs on ROCs as it provides advantages over the control-impact design (Ellis and Schneider 1997; FCSAP 2012a), described below. The gradient-based approach has similarities to an exposure-response (or dose-response) relationship where the relationship between several concentrations of a COC and the measured endpoint can be more appropriately analyzed using regression analyses (linear or non-linear). Therefore, the gradient-based approach is more likely to identify the causal relationships between COCs and ROCs. The gradient-based approach is advantageous in circumstances where the extent of an impact is only a small portion of a system (e.g., a site along a marine shoreline) as the reference sites can be in closer proximity to the impacted site and will likely have more similar biophysical characteristics. These sites should ideally differ only in the concentrations of the COCs.

This approach relies on the assumption that the contamination associated with each on-site contaminant source decreases with distance from that source, and eventually becomes indistinguishable from the background conditions (i.e., a COC-concentration gradient). Although this is a reasonable assumption, the distance required to establish a suitable reference area cannot always be determined in the field. This uncertainty often necessitates supplemental sampling efforts.

As illustrated in Figure 1, when applying this sampling approach, collect samples from at least four (4) reference sites at increasing distances from the contaminant source to capture a gradient of COC concentrations that terminate at background concentrations (i.e., where COC concentrations are stable within background variability). Given that there is often uncertainty about what represents background along a gradient, sampling at more than four (4) reference sites may ultimately be required. These reference sites need not be located in a linear transect away from the source of impact and may be located in different directions and distances from the contaminated site so long as they capture a gradient of COC concentrations down to background conditions. Within each reference site, it is recommended that a minimum of three (3) randomly located discrete samples be taken, for a minimum total of twelve (12) discrete samples. However, this level of sampling effort is not always possible or within the scope of many ERAs. Statistical procedures should be applied to assess the statistical power of the data for their intended use (US EPA 2015). Practitioners need to use their best professional judgement when designing sampling programs, and potential limitations with respect to data analysis due to smaller than recommended background sample sizes should be highlighted (what was done and what could have been done) in the problem formulation and uncertainty sections of the ERA.

The gradient-based design is not appropriate for contaminated sites where the site-related contamination is likely to influence the entire system to some degree. Examples of this situation include a spill of contaminants into a wetland or small lake, or a release into a small area of soils confined by bedrock (as might be the case in northern sites). In these circumstances, the control-impact approach described below may be more appropriate to characterize background conditions. Note: There is no accepted definition that defines systematically between small and large lakes. The professional judgment of an expert should be used to establish whether the gradient-based or control-impact approach should be used for the selection of sampling sites as appropriate.

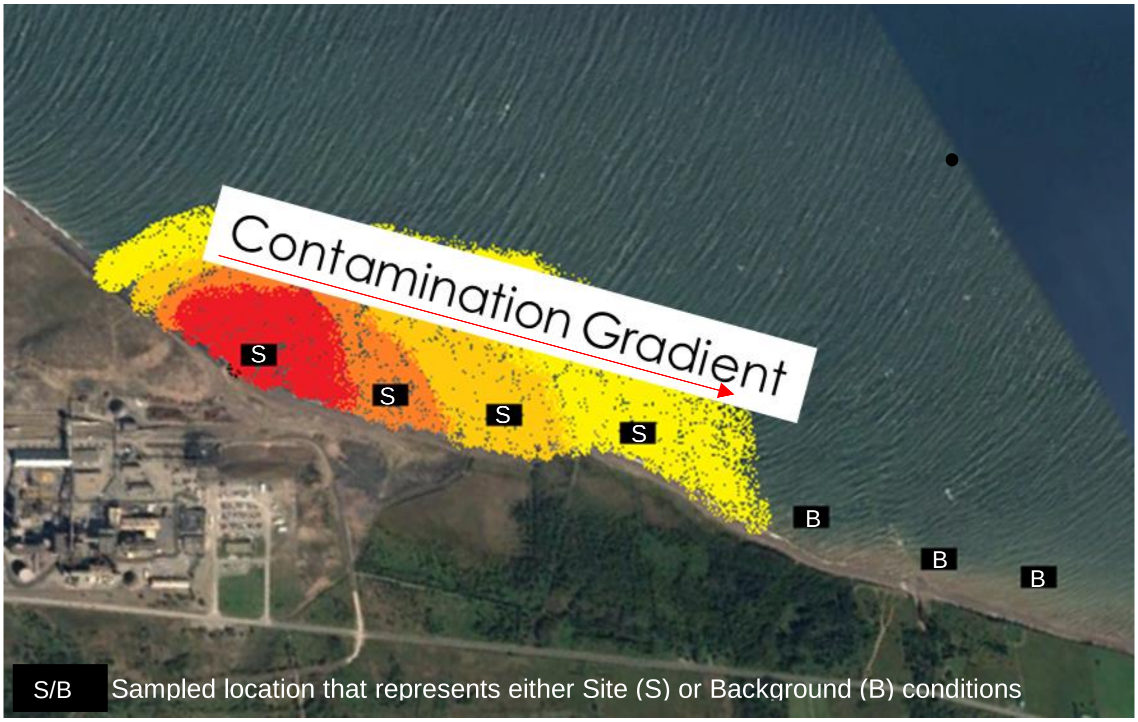

Figure 1: Example of gradient-based sampling approach

2.2.2.2 Control-Impact Design

Where a gradient-based sampling design is not appropriate for the environmental conditions of a contaminated site, a control-impact sampling design is recommended to characterize background conditions, as illustrated in Figure 2. The control-impact design is a valid approach but has some limitations compared to the gradient-based approach.

Ideally, the physical, chemical, and biological conditions of the reference site(s) selected should closely match that of the contaminated site, except for site-related COC concentrations. For example, if the contaminated site consists of a small bog wetland within a coniferous forest area, the reference site(s) should represent similar bog wetlands within coniferous forests having similar soil types. Other wetland types, such as fens or swamps, may have different physical processes and biological communities and may not represent the background conditions of the contaminated site as well as wetlands of the same class. Consistency in site characteristics will optimize the ability to make meaningful comparisons.

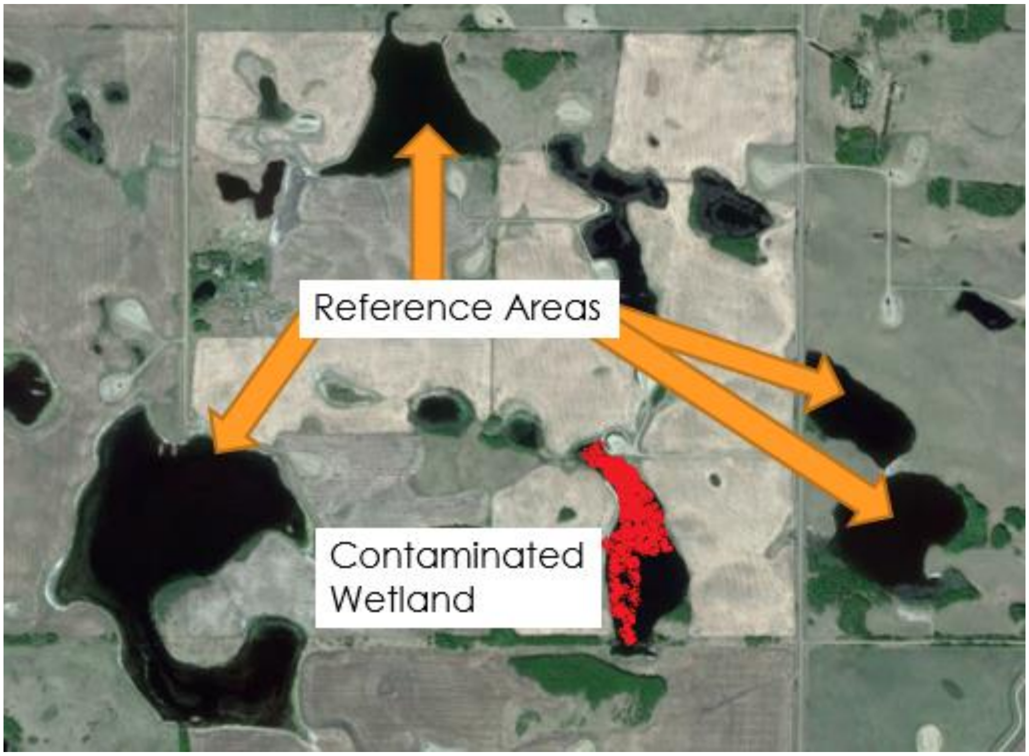

Figure 2: Example of control-impact sampling approach.

2.2.2.3 Groundwater

Guidance from BC Protocol 9 for Contaminated Sites (BC MWLAP, 2004) as well as Yukon Environment (Yukon, 2011) provide procedures regarding the placement of background-monitoring well locations for monitoring and sampling groundwater. Gradient-based sampling approaches are likely better suited for sites where groundwater bearing zones are in soil types with equivalent porous media (e.g., generally homogenous and isotropic soils such as sand units). Control-impact sampling approaches are better suited for challenging settings such as sites with groundwater bearing zones in fractured bedrock. Both BC (BC MWLAP, 2004) and Yukon Environment (Yukon, 2011) stipulate that background wells should be in the same geographic area and in the same groundwater flow system.

Background groundwater COC concentrations can be quantified using either the gradient-based or control-impact sampling approaches (as noted above), insomuch that background well locations should be located cross-gradient or up-gradient of any identified human-made point source contamination (BC MWLAP, 2004). As groundwater monitoring wells may remain at a property until being decommissioned based on accepted site closure conditions, any background well(s) must be carefully selected, particularly if landowners have established and approved off-site locations, because of the potential long-term access needed for subsequent sampling/monitoring events.

2.2.3 Sampling Procedures

2.2.3.1 Soil Sampling

Depending on the regional nature of the contaminated site, the experimental design used during soil sampling may follow either of the two sampling approaches (i.e., gradient-based design or control-impact design). In the event neither of these design approaches for obtaining samples can be used for a contaminated site, see Section 2.3.

Regardless of the approach, the reference sites sampled to represent background conditions should match the contaminated site as closely as possible with respect to:

1. Ecological/habitat characteristics (eco-zone);
2. Geographical characteristics (location, climate, topography);
3. Physical/chemical characteristics of the soil (particle size, fraction of organic carbon [Foc], pH);
4. Hydrology and hydrogeology; and
5. Soil sampling depth, horizon, and sampling methods (protocols should be similar at both the contaminated site and reference sites). As noted in FCSAP guidance (FCSAP, 2012a), the appropriate sample depths may vary by site and by receptor group. As a default, soil sampling from the top 1.5 m of soil can be considered relevant to surface soil exposure for ERA; however, this depth may be refined on a site-specific basis.

Within an urban area, the preference for independent sites should be given to undeveloped and undisturbed areas, such as parks or large residential lots, and particularly those that are naturally forested. If an area, suspected to have received contaminated fill, is near other point sources of contamination, or if there is evidence of ecosystem impairment caused by soil contamination, it would not represent a suitable site for establishing natural or ambient background concentrations. When available, historical records for the reference areas and adjacent lands should be consulted, and the previous land-use documented. Because of the practical difficulty in locating an ideal reference area (in urban zones for example), it is often necessary to select locations with COC concentrations that are equivalent to regional background concentrations (i.e., relying on ambient rather than natural background conditions).

2.2.3.2 Surface Water and Sediment Sampling

Quantifying background surface water and sediment COC concentrations often requires a combination of the gradient-based and control-impact sampling approaches, with a tendency to rely more heavily on the latter for smaller systems (e.g., small lakes and wetlands). Larger aquatic systems (e.g., marine coastlines or large lakes) may not have suitable independent sites for a control-impact design; therefore, a gradient sampling approach may be the only option. In circumstances where reference areas may not be available, statistical approaches to derive background concentrations based on site-collected data may also be considered (see Section 2.3).

The choice of experimental design for sampling aquatic (water and sediment) reference areas is dependent on the characteristics of the source of contamination (e.g., either as a point source on the site or as diffuse seepage from a groundwater plume), the nature of the aquatic environment, and the characteristics of the resulting contaminated area and associated mixing zone. The mixing zone represents the area around the point source or directly adjacent to the area of contaminant discharge where dilution of the contaminants occurs within the surface water and sediment. It is the area affected by COCs, though typically with decreasing concentrations at increasing distances from the source. If background conditions are characterized using a control-impact study design when there is a mixing zone caused by a contaminant source, and if separate areas of the same waterbody will be sampled, then the reference sites must be located outside of the contaminated area and the mixing zone.

The size of the mixing zone is dependent on several factors, including the magnitude of the discharge to the receiving water body. In larger lakes and marine systems however, where the shoreline is characterized as “high energy” (i.e., turbulent with rapid mixing) and the mixing zone is relatively small, it is advantageous to choose reference sites using the gradient-based sampling method. As with soil sampling, this approach allows for the selection of reference areas that are relatively close to the contaminated site and are therefore more likely to have similar physical, chemical and biological characteristics. However, because there is often a large degree of uncertainty regarding the distance required to reach ambient/natural background concentrations, the need for supplemental sampling efforts is common. Therefore, if access to the site is limited, it may be appropriate to include a number of independent reference sites in the original sampling plan as well. These would be associated with the same lake or marine system but would be located farther away.

For contaminated sites in smaller lakes or wetland areas (lentic systems) where the mixing zone may include the entire aquatic habitat, it is necessary to locate independent reference sites (CCME 2016a). Suitable waterbodies, such as lakes of similar size or wetlands of similar type, within the same watershed should be targeted. For larger lentic systems, reference sites within the same waterbody may be selected, provided that the impacts of the contaminant source do not extend into those reference sites.

If contaminants at the site are entering into surface water from a well-defined point source with a consistent flow (a lotic system), independent reference sites should be chosen at upstream locations (CCME 2016a). The mixing zone should extend downstream, although this should be verified, as some areas may experience tidal or seasonal changes in water flow direction. The water and sediment quality from the area immediately upstream of the point of discharge usually provides the best reference for the contaminated mixing zone. If there are other non-site related discharge points further upstream, these may also contribute to COC concentrations in water and sediment. In this case, upstream reference locations may provide information about ambient, rather than natural, background concentrations. Additional sample locations may be required if the protection goals established for the ERA require comparison to natural background concentrations.

Regardless of the approach, reference sites intended to be representative of background conditions should match the contaminated site as much as possible with respect to:

- Ecological characteristics of the aquatic habitat and the surrounding terrestrial habitat;
- Geographical characteristics (location, size/area);
- Temporal characteristics (e.g., season in which samples were collected). This factor is of particular relevance to water bodies that experience significant seasonal changes (e.g., increased flow rate in streams during spring run-off) that may affect COC concentrations in water and/or sediment;
- Physical/chemical characteristics of the surface water (e.g., pH, hardness, dissolved organic carbon [DOC], dissolved oxygen [DO], and total suspended solids [TSS]) and sediment (e.g., pH, total organic carbon [TOC], and particle size distribution); and
- Water depth.

Once appropriate reference areas have been identified, surface water and/or sediment sampling methods applied at these locations should be as similar as possible to those applied to collect surface water and/or sediment samples from the contaminated site. Ideally, both surface water and sediment should be collected as a pair at each sampling location; however, this may be limited due to site conditions. Within each independent sampling site, care must be taken to avoid disturbing sediment that would impact other sampling locations and work should be completed moving in an upstream direction, if applicable.

2.2.3.3 Groundwater Sampling

> Reference documents provide guidance on groundwater sampling, including CCME (2016a) and provincial or regional sampling protocols or guidance. Background groundwater monitoring wells should be developed, purged, monitored, and sampled using methodologies consistent with those used for monitoring wells on the impacted site, based on the COCs.

BC MWLAP (2004) and Yukon Environment (Yukon, 2011) provide guidance on statistical determination of local background concentrations in groundwater where data fall within a single statistical population, as well as when they do not. BC MWLAP (2004) references Technical Guidance 12, Statistics for Contaminated Sites (BC MOE, 2005) for additional information to support statistical approaches for analysing background concentrations based on data collected. The BC Ministry of Environment and Climate Change Strategy has also established regional background groundwater concentrations for select inorganic substances (arsenic, lithium, selenium, vanadium and uranium) for three regions in BC. The details are presented in Technical Bulletin #3 – Regional Background Concentrations for Select Inorganic Substances in Groundwater (BC MOE, 2018). The ministry has also published Protocol 9 - Determining Background Groundwater Quality that provides a consolidated suite of substances for which regional background concentrations are published.

Regardless of the approach, reference sites intended to be representative of background groundwater conditions should match the contaminated site as much as possible with respect to:

- Groundwater flow regime; and
- Geology.

Furthermore, the depth of installation and strata in which the screens are installed in the background monitoring wells should be consistent with the groundwater monitoring well installations in the impacted area at the site.

Both BC MOE (2017b) and Yukon Environment (Yukon, 2011) also stipulate a minimum number of three monitoring well locations for characterizing background groundwater conditions. Both documents stipulate that background monitoring wells should be sampled at least twice to address temporal variability, and sampling plans should also be prepared to address seasonal effects. The time intervals between the proposed temporal and seasonal sampling events depend on several site-specific factors and should be planned by a hydrogeologist familiar with the site's water regime.

2.2.3.4 Sampling QA/QC Procedures

The sampling program should follow appropriate quality assurance (QA) and quality control (QC) procedures including the cleaning of equipment between samples, proper labeling and storage of sampling containers, record keeping and file storage, and the collection of appropriate duplicate, replicate, or split samples.

Specific sampling procedures and QA/QC protocols for soils are available from FCSAP (2012b), as well as in CCME (2016b). For surface water and sediment, additional information is found in CCME (2011, 2016b), BC MOE (2013), and Alberta Environment and Parks (Alberta Environment 2006). Information for QA/QC for groundwater programs can be found in CCME (2016a).

Environmental samples should be analyzed for all the COCs identified at the contaminated site, in addition to standard suites of chemistry parameters (e.g., metals) and should only be analyzed by laboratories that are properly accredited for the parameters/variables of interest.

2.3 Estimating Background Concentrations without Suitable Reference Areas

In some cases, identification and/or sampling of a suitable reference area may be difficult (e.g., the site is isolated within an urban landscape or the site is a unique feature with no nearby features of similar nature). In these situations, confirmation is recommended to ensure that no existing data could be used to define background concentrations (e.g., existing historical information from the site or applicable federal or provincial databases). If no suitable existing data are identified, it may be possible to evaluate background concentrations of COCs based solely on samples collected from the contaminated site using multivariate statistical analyses.

This approach assumes that samples collected from a contaminated site include samples from both high impact areas (i.e., higher contamination levels) and lower impact areas (e.g., margins of the site with less contaminant impact). Multivariate statistical techniques such as non-metric, multidimensional scaling (NMDS) and cluster analysis can then be applied to attempt to identify the subset of on-site samples with lower contamination levels. For example, the statistical approaches may be able to identify certain pairs of chemicals that have relatively constant ratios in background samples (due to natural correlation) and then categorize samples with ratios that have become skewed (due to site-related contributions of only one chemical) as ‘contaminated’. A detailed discussion of this multivariate approach (described as the ‘geochemical method’) is provided in a guidance document prepared by the United States Naval Facilities Engineering Command (US NAVFAC 2002).

If this statistical approach is to be taken, additional sampling of the contaminated site may be necessary. The minimum sample size recommended for statistical derivation of background conditions is thirty (30) as recommended by several researchers on this topic (Ouellette 2012; Ander et al. 2013), including the British Standards Institute (BSI, 2011) . Where initial sampling programs have been completed and less than thirty (30) samples were taken, additional sampling should be completed. To the extent possible, samples used for this approach should be standardized for sampling depth (e.g., soil horizon) and other variables that may affect the COC concentrations. Again, it needs to be acknowledged that this sampling effort is not always possible or within the scope of many ERAs. Practitioners need to use their best professional judgement when designing sampling programs.

The use of a site-specific statistical approach should be fully explained and documented within the ERA along with information on soil geology, hydrogeology, and historical land use.

2.4 Application of Background Concentrations in ERAs

2.4.1 Data QA/QC

Prior to analyzing historical data or data collected from reference sites to characterize background concentrations for a contaminated site, a QA/QC process should be undertaken to ensure the dataset is valid. The concept of data quality indicators (DQIs) is described in CCME (2016a; see section 2.6.5, 2.8, 7.10, and 11.3.5) as it pertains to Precision, Accuracy, Representativeness, Comparability, and Completeness (PARCC). Note that PARCC criteria are sometimes described as including "S" (Sensitivity) (NJ EPA 2014). Additional resources on data QA/QC include BC MOE (2001a) and the New Jersey EPA guidance document (NJ EPA 2014).

Checklist for Data Validation (CCME 2016a)

- Are the data complete and based on the sampling and analysis plan?
- Is the documentation complete including field data records, test pit, borehole and monitoring well logs, analytical laboratory reports, and all other supporting documentation?
- Have all test holes and sampling locations been clearly indicated on scaled drawings?
- Have the QA/QC data been reviewed and are they within acceptable limits? Are re-tests or verification tests required? Can the data be relied upon?
- Have apparent outliers been evaluated and addressed?
- Has the data been checked for possible transcription and manipulation errors?
- Have all Areas of Potential Environmental Concern (APECs) been adequately assessed for applicable COPCs?
- Have the investigation objectives been met, including all data required for risk assessment purposes?
- Has available previous work that can be reliably used been synthesized in the data interpretation?
- Have the sampling design objectives been met? Based on the updated conceptual site model, has sufficient sampling been completed at the site based on the study boundaries, APECs and populations identified?
- Do the results make sense relative to the conceptual site model and hypothesis for site contamination?
- Have the correct criteria or standards been used for all relevant media?
- Has off-site migration of contamination been identified?
- Is further assessment required to delineate the horizontal and/or vertical extent of contamination at a site?

To assist with the QA/QC process, data should be plotted using plotting approaches such as frequency tables, box plots, histograms, cumulative frequency plots, and correlation plots.

Note that one question within the data validation checklist (CCME 2016a; call out box to the right) raises the issue of outliers. Care should be taken when classifying (and potentially discarding) data as outliers (BC MOE 2001b). The inclusion of outliers in background concentration calculations can result in inaccurate values and decisions (US EPA 2015). Therefore, it is important to determine whether samples are truly representative of the underlying data set, or whether they may represent data entry or sampling errors (i.e., the sample does not belong to the population of interest). Therefore, if the data for an ERA appear to contain one or more outliers, consultation with a statistician on the use of appropriate analytical techniques may be warranted.

2.4.2 Identification of COCs

Regardless of whether the site consists of terrestrial or aquatic habitat, COCs are typically defined as those compounds associated with site-specific anthropogenic activities, which have resulted in concentrations that exceed the relevant environmental quality guidelines (e.g., Canadian Environmental Quality Guidelines [CEQGs] or the Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Site [FCSAP, 2016]) in varying environmental media (for instance, soil, sediment, groundwater or surface water). However, it is recognized that in some cases, pre-existing natural or ambient background concentrations may be sufficient to exceed generic guidelines. In such cases, it may be appropriate to compare site concentrations to background concentrations rather than to guidelines to eliminate chemicals that do not exceed pre-existing natural or ambient background concentrations from the COC list.

Generally, two types of approaches could be applied to compare site concentrations to background concentrations, depending on the available data:

- Point-by-point comparisons of site observations with an estimated or previously established background threshold value (BTV); or
- Hypothesis testing approaches.

2.4.2.1 Point-by-point comparisons to BTVs

In the point-by-point comparison method, each measured concentration from the site is compared to a single BTV, where the BTV represents the upper limit of underlying background concentration distribution (e.g., 95th percentile). If no samples from the site exceed the BTV, it is assumed that site concentrations are not elevated above background. However, a single exceedance of the BTV provides evidence that concentration at the site may be higher than background, which could potentially be confirmed using further statistical analyses (see discussion of hypothesis testing approaches, below).

This comparison method may be the only possible route of comparison between site and background concentrations if the background concentration data have been selected from a publicly available database as described in Section 2.1. For example, the Ontario Typical Range values published by MECP represent the 97.5th percentile of a chemical in surface soils in Ontario that are not contaminated by point sources. Therefore, these values could be adopted directly as BTVs, representative of ‘Ontario’ background conditions.

Alternatively, BTVs can be calculated based on the background concentration data collected from appropriate reference sites (as described in Section 2.2). Potential BTVs include upper percentiles, upper prediction limits, upper tolerance limits, or upper simultaneous limits. For a detailed discussion of each of these potential BTVs (and how to calculate them), refer to US EPA (2015). In practice, the upper percentile is one of the most commonly used. As discussed above, a study commissioned by Public Works and Government Services Canada (PWGSC, now Public Services and Procurement Canada) in 2010 (PWGSC, 2010) indicates that the Ontario MECP background values are based on 97.5th percentiles, while provincial agencies in Quebec and British Columbia have adopted 98th and 95th percentiles, respectively.

Once a BTV is identified, the point-by-point comparisons of site data to the BTV can be a useful tool with respect to eliminating COPCs from anthropogenic site contamination. However, if the maximum site sample exceeds the BTV, this does not indicate conclusively that the overall distribution of the site data is significantly different from the background data. In this case, it may be appropriate to apply hypothesis testing approaches, as described below, if the data permit (PWGSC 2010).

2.4.2.2 Hypothesis testing approaches

There are two approaches when comparing reported concentrations within the contaminated area with those from the reference areas. Depending on the nature and distribution of the data, these are either by using an appropriate parametric or non-parametric, two-sample hypothesis test or taking a multivariate approach (see BC MOE 2001c, 2001d; CCME 2016a; US EPA 2002a, 2002b; 2015). Readers should also be aware of the risks associated with small sample sizes and the potential for Type I and Type II errors, along with the assumptions of parametric and non-parametric approaches.

Examples of statistical tests that may be applied to compare two sample populations (e.g., the samples from the contaminated site are one population and samples from the reference areas are the other) include:

- the Student's t-test (parametric); or
- the Wilcoxon-Mann-Whitney test (non-parametric).

For samples taken along a gradient, a regression analysis may be applied to the data to determine if the slope of the concentration gradient is statistically significant (BC MOE 2001e). Similarly, an Analysis of Variance (ANOVA) may be applied to determine if there is a significant difference in the means and variance estimates of different reference areas sampled along a gradient. A Tukey test may also be performed with an ANOVA to determine which of the sites sampled (contaminated and reference areas) are significantly different from one another. Details regarding how to select an appropriate hypothesis testing approach and how to perform these tests are provided in US EPA (2015). Overall, the appropriate test to compare concentrations between sites will depend on the nature of the data involved and should be confirmed with the assistance of a statistician. If the appropriate hypothesis-testing approach demonstrates that the on-site concentrations are significantly higher than the natural or ambient background concentrations (based on a significance level determined prior to running analyses), the contaminant should be retained as a COC. In contrast, substances found on-site at concentrations that are above guidelines but not statistically different from the ambient or natural background concentrations should be excluded as COCs.

2.4.3 Support for Lines of Evidence in ERA Risk Characterization

With respect to the risk characterization, background information on the COC concentration may permit the comparison of exposure, and subsequently help predict risk to ROCs on-site, as an additional line of evidence. The relative contribution to risks associated with background concentrations would be discussed qualitatively in the risk characterization section.

In this case, it may be appropriate to use the background concentration data collected from appropriate reference sites (as described in Section 2.2) to generate a background exposure point concentration (EPC). During contaminated site risk assessments, EPCs are routinely estimated as the 95% upper confidence limit of the mean (95% UCLM) (US EPA 2015). This 95% UCLM is selected because it provides a reasonable upper limit of the average long-term exposure that a ROC may receive to COCs on site (i.e., one can be 95% confident that the true population mean is less than the 95% UCLM). To provide a direct comparison of the proportion of ROC exposure to a COC from background vs. site-related sources, the 95% UCLM of the background concentrations should also be calculated. A detailed discussion of different methods that can be applied to generate estimates of the 95% UCLM (and how to calculate them) can be found in US EPA (2015).

2.4.4 Development of Site-specific Remediation Standards

If the results of an ERA lead to the development of site-specific remediation standards (FCSAP 2012a), the CCME (2006) guidance indicates that it is generally not appropriate to remediate contaminated sites to a level below relevant background concentrations. Therefore, it is recommended that any potential site-specific remediation standards should be contrasted to an upper limit of the background distribution (i.e., a BTV as discussed in Section 2.3). If the proposed site-specific remediation standard exceeds the BTV, no further adjustment is necessary. However, if the proposed site-specific remediation standard is lower than the BTV, the BTV may provide a more appropriate final site-specific remediation standard. This approach would prevent the development of site-specific remediation standards that are lower than relevant background concentrations.

3 Conclusion

This module has provided technical guidance on defining background conditions and the use of background concentrations during ERAs. It further provided readers with the information necessary to determine when background conditions should be characterized, how to select reference areas, guidance on sampling designs, analysis and application of data relevant to ERAs. This module is not intended to be a prescriptive tool to be used on every contaminated site, as each site, and the landscape in which it is found, is unique and should be assessed individually.

The application of background concentrations during risk characterization in ERAs requires specific COCs to be considered, the ambient conditions of the site as determined using background sampling, and the potential exposure pathways and duration of exposure for identified ROCs. Consider these ERA components during the conceptual site model formulation and design of the sampling program to include background.

Whenever uncertain about the best approaches to treat data, custodians and/or their consultants should consult with a statistician or Expert Support.

References

Alberta Environment. 2006. Guidelines for Quality Assurance and Quality Control in Surface Water Quality Programs in Alberta. Publication No. T/884. ISBN: 0-7785-5082-6. 67pp

Ander, E.L., C. C. Johnson, M. R. Cave, B. Palumbo-Roe, C. P. Nathanail, and R. M. Lark. 2013. Methodology for the determination of normal background concentrations of contaminants in English soil. Science of the Total Environment. 454-455: 604-618

Apitz, S.E., J.W. Davis, K. Finkelstein, D.L. Hohreiter, R. Hoke, R.H. Jensen, J.M. Jersak, V.J. Kirtay, E.E. Mack, V. Magar, D. Moore, D. Reible, and R. Stahl. 2002. Critical Issues for Contaminated Sediment Management. U.S. Navy, Space and Naval Warfare Systems Center, San Diego, CA, USA. MESO-02-TM-01.

BC MOE (British Columbia Ministry of Environment). 2001a. Contaminated Sites Statistical Application Guidance Document No. 12-11. Statistical QA/QC: A guide for project managers, reviewers, data analysts, and interpreters on statistical quality assurance and quality control. 4pp

BC MOE (British Columbia Ministry of Environment). 2001b. Contaminated Sites Statistical Application Guidance Document No. 12-8. Outliers: A guide for data analysts and interpreters on how to evaluate unexpected high values. 4pp

BC MOE (British Columbia Ministry of Environment). 2001c. Contaminated Sites Statistical Application Guidance Document No. 12-5. Nonparametric Methods: A guide for data analysts and interpreters on statistical methods that do not require a distribution model. 4pp

BC MOE (British Columbia Ministry of Environment). 2001e. Contaminated Sites Statistical Application Guidance Document No. 12-2. Bivariate Description: A guide for report writers, reviewers, data analysts and interpreters on exploratory data analysis for two variables. 4pp

BC MOE (British Columbia Ministry of Environment). 2005. Technical Guidance 12 on Contaminated Sites – Statistics for Contaminated Sites.

BC MOE (British Columbia Ministry of Environment). 2013. British Columbia Field Sampling Manual. For Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples. 2013 Edition, ISBN 0-7726-2741-X

BC MOE (British Columbia Ministry of Environment). 2017a. Protocol No. 4 for Contaminated Sites: Establishing background concentrations in soils. 12pp.

BC MOE (British Columbia Ministry of Environment). 2017b. Technical Guidance on Contaminated Sites – Groundwater Investigation and Characterization – version 2, November 1 2017. 16 pp.

BC MOE (British Columbia Ministry of Environment). 2018. Technical Bulletin 3 for Contaminated Sites: Regional Background Concentrations for Select Inorganic Substances in Groundwater. 4pp.

BC MWLAP (British Columbia Ministry of Water, Land and Air Protection). 2004. Protocol 9 for Contaminated Sites – Determining Background Groundwater Quality. 4pp

BSI (British Standards Institute). 2011. Soil Quality: guidance on the determination of background values. BS EN ISO 19258:2011. International Organisation for Standardisation [revision of BS ISO 19258: 2005]

CCME (Canadian Council of Ministers of the Environment). 1997. A Framework for Ecological Risk Assessment: Technical Appendices.

CCME (Canadian Council of Ministers of the Environment). 2006. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. Report CCME PN 1332. http://ceqg-rcqe.ccme.ca/download/en/351

CCME (Canadian Council of Ministers of the Environment). 2011. Protocols Manual for Water Quality Sampling in Canada.

CCME (Canadian Council of Ministers of the Environment). 2016a. Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment - Volume 1 Guidance Manual. 343pp

CCME (Canadian Council of Ministers of the Environment). 2016b. Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment - Volume 3 Suggested Operating Procedures. 217pp

CSMWG (Contaminated Sites Management Working Group). 2000. A Federal Approach to Contaminated Sites. 64pp

Crommentuijn T, Polder M, Sijm D, de Bruijn J, van den Hoop M, van de Plassche E. 2000. Evaluation of the Dutch environmental risk limits for metals by application of the added risk approach. Environmental Toxicology and Chemistry 19: 1692-1701.

Dillon Consulting Limited. 2011. Review of Environment Canada's Background Soil Database (2004-2009), Version No. 1. Report 11-4434-1000. 77pp plus appendices.

Ellis, J.I., and D. C. Schneider. 1997. Evaluation of a gradient sampling design for environmental impact assessment. Environmental Monitoring and Assessment 48: 157-172

FCSAP (Federal Contaminated Sites Action Plan). 2012a. Federal Contaminated Sites Action Plan: Ecological Risk Assessment Guidance Document. Cat. no. En14-19/1-2013E-PDF

FCSAP (Federal Contaminated Sites Action Plan). 2012b. Federal Contaminated Sites Action Plan: Ecological Risk Assessment Guidance Document. Module 3: Standardization of wildlife receptor characteristics. Cat. No. EN14-92/3-2013E-PDF

FCSAP (Federal Contaminated Sites Action Plan). 2016. Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites (including the 2016 Federal Interim Groundwater Quality Guidelines Memo).

FCSAP (Federal Contaminated Sites Action Plan). 2018. Decision-Making Framework (DMF). Version 3.01, April 2018. Ottawa: Her Majesty the Queen in Right of Canada.

Green, R. H. 1979. Sampling Design and Statistical Methods for Environmental Biologists, John Wiley and Sons Inc, USA.

Hurlbert, S. J. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs. 54: 187–211.

NJ EPA (New Jersey Department of Environmental Protection). 2014. Data Quality Assessment and Data Usability Evaluation Technical Guidance. Site Remediation Program. Version 1.0. April 2014. 138 pp.

Beaulieu, Michel. 2019. Guide d'intervention – Protection des sols et réhabilitation des terrains contaminés. Québec, ministère de l'Environnement et de la Lutte contre les changements climatiques, 219 p. + annexes.

Ouellette, H. 2012. Lignes directrices sur l'évaluation des teneurs de fond naturelles dans les sols, Québec, ministère du Développement durable, de l'Environnement, de la Faune et des Parcs, ISBN 978-2-550-49918-3, 25pp.

PWGSC (Public Works and Government Services Canada). 2010. Technical Assistance Document No. 1. Background Soil Quality Data, Newfoundland and Labrador. Rev. 1

Stewart-Oaten, A., Murdoch, W. M. and Parker, K. R. 1986. Environmental impact assessment: "pseudoreplication" in time? Ecology 67: 929–940.

Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson and R.H. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4): 1267-1276.

Underwood, A. J. 1991. 'Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations', Australian Journal of Marine and Freshwater Research 42: 569–587.

Underwood, A. J. 1992. 'Beyond BACI. The detection of environmental impacts on populations in the real, but variable, world', Journal of Experimental Marine Biology and Ecology 161: 145–178.

Underwood, A. J. 1993. 'The mechanics of spatially replicated sampling programs to detect environmental impacts in a variable world', Australian Journal of Ecology 18: 99–116.

Underwood, A. J. 1994. 'On beyond BACI: sampling designs that might reliably detect environmental disturbances', Ecological Applications 4: 3–15.

US EPA (United States Environmental Protection Agency). 2002a. Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites. Office of Emergency and Remedial Response.

US EPA (United States Environmental Protection Agency). 2002b. Role of Background in the CERCLA Cleanup Program. U.S. Environmental Protection Agency Office of Soil Waste and Emergency Response Office of Emergency and Emergency Remedial Response.

US EPA (United States Environmental Protection Agency). 2006a. Data Quality Assessment: Statistical Methods for Practitioners, EPA QA/G-9S. EPA/240/B-06/003. Office of Environmental Information, Washington, DC. Download from: http://www.epa.gov/quality/qs-docs/g9s-final.pdf

US EPA (United States Environmental Protection Agency). 2006b. Guidance on Systematic Planning Using the Data Quality Objective Process, EPA QA/G-4, EPA/240/B-06/001. Office of Environmental Information, Washington, DC. Download from: http://www.epa.gov/quality/qs-docs/g4-final.pdf

US EPA (United States Environmental Protection Agency). 2015. ProUCL Version 5.1.002 User Guide.

US NAVFAC (United States Naval Facilities Engineering Command). 2002. Guidance for Environmental Background Analysis: Volume I: Soil. NFESC User's Guide UG-2049-ENV.

Yukon Environment (Yukon). 2011. Protocol for the Contaminated Sites Regulation under the Environment Act. Protocol 10 – Determining Background Groundwater Quality. 4pp

Appendix A: List of Selected Relevant Guidance Documents

The following table provides the reader with a list of additional guidance documents that may be of assistance in designing a sampling program for sampling reference sites for ERAs, statistical analyses, and sampling methods. This list is not considered comprehensive.

Author	Document Title	Year	Description
Ouellette, Hugues Government of Quebec	Lignes Directrices sur l'Evaluation des Teneurs de fond Naturelles Dans les Sols	2012	• How to assess background, determine background • Statistical assessment of n<50 • Examples of statistical assessments for background
Yukon Environment	Protocol for the Contaminated Sites Regulation Under the Environment Act. Protocol No 10: Determining Background Groundwater Quality	2011	• Groundwater specific • Definition of background with respect to groundwater • Location selection of background wells and sampling • Uses 95th percentile of data set for determination of background
Government of Alberta	Contaminated Sites Policy Framework	2014	• Definition of background in soil or groundwater • Background sample locations
US Environmental Protection Agency	Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites	2002	• Definition of background used at CERCLA sites • Background sampling • Data analysis
US Environmental Protection Agency	Role of Background in the CERCLA Cleanup Program	2002	• Focus on anthropogenic background vs natural background and cleanup levels • Case studies provided on use of background, and screening of COPCs

Author	Document Title	Year	Description
British Columbia Ministry of Environment and Climate Change Strategy	Technical Guidance on Contaminated Sites #16: Soil Sampling Guide for Local Background Reference Sites	2017	• Definition of soil background • Background reference site soil sampling • Minimum number of samples required for reference • Statistical data evaluation of background results
British Columbia Ministry of Environment	Technical Guidance on Contaminated Sites #12: Statistics for Contaminated Sites	2005	• Description of 16 guidance documents which make up the “Statistics for Contaminated Sites” series
British Columbia Ministry of Environment	Technical Bulletin for Contaminated Sites #3: Regional Background Concentrations for Select Inorganic Substances in Groundwater	2018	• Establishes regional background concentration estimates for arsenic, lithium, selenium, vanadium and uranium in groundwater in British Columbia
British Columbia Ministry of Water, Lands and Air Protection	Site Remediation Protocols, Protocol 4 for Contaminated Sites: Establishing Background Concentrations in Soil	2019	• Soil specific • Background by zones in the province • Siting of reference sites
British Columbia Ministry of Water, Lands and Air Protection	Site Remediation Protocols, Protocol 9 for Contaminated Sites: Determining Background Groundwater Quality	2004	• Groundwater specific • Definition of background with respect to groundwater • Location selection of background wells and sampling
Florida Department of Environmental Protection	Guidance for Comparing Background and Site Chemical Concentrations in Soil	2012	• Definition of background • Background sampling minimum # n=7 • 95% UCL usage for n=10+ • Statistical comparison of site and background data • What not to use for background statistics • Case studies

Author	Document Title	Year	Description
Wisconsin Department of Natural Resources	Guidance for Determining Soil Contaminant Background Levels at Remediation Sites	2013	• Definition of background soil quality • Minimum background sampling n=4 • Statistical determination of background
Florida Department of Environmental Protection	Guidance for Comparing Background and Site Chemical Concentrations in Groundwater	2013	• Minimum background samples n=12 • Non-statistical approach for background • Statistical approach for background
Environmental protection Authority of South Australia	EPA Guidelines: Site Contamination- Determination of Background Concentrations	2008	• Definition of natural and ambient background • Selection of reference sample sites for soil, groundwater, vapour, surface water
British Columbia Ministry of Water, Land and Air Protection	DRAFT - Protocol 9 for Contaminated Sites: Determining Background Groundwater Quality	No date	• Regulations applicable to BC with regards to background groundwater quality • Statistical determination of local background
Illinois Environmental Protection Agency	Fact Sheet 9: Background Determination (website)	No date	• Soil background determinations incl. statistics • Groundwater background determinations-minimum samples
British Columbia Ministry of Environment and Climate Change Strategy	Protocol 4 for Contaminated Sites: Establishing Background Concentrations in Soil	2017a	• Successful remediation guidance • Definition of contaminated site and remediated site as per BC regs • Reference site criteria
Wisconsin Department of Natural Resources	Consensus-Based Sediment Quality Guidelines: Recommendations for Use and Application	2003	• Sediment reference or background considerations
The Interstate Technology & Regulatory Council	Contaminated Sediments Remediation	2014	• Role of background conditions in remedial technologies • Definition of background

Author	Document Title	Year	Description
Ohio EPA	Evaluation of Background Metal Soil Concentrations in Franklin County-Columbus Area	2013	• Methods of background value determination • Statistical analysis examples • Case study

Additional information can be obtained at:

FCSAP Secretariat
Contaminated Sites Division
17th floor, Place Vincent Massey
351, boul. St-Joseph
Gatineau, QC, K1A 0H3
E-mail: ec.pascf-fcsap.ec@canada.ca