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Site Characterization and Confirmation Testing

This document contains guidance for investigating and characterizing fill and soil at, and from, sites that may be contaminated.

The procedures outlined here are not applicable to every site; others may also be used. Whatever the procedures, however, it is the responsibility of the site owner or operator to ensure that contaminated material is properly characterized and remediated. Adherence to applicable BC laws, regulations, and standards is also required.

Guidance for *in situ* characterization and confirmation sampling is presented in Part I; and advice on batch testing of materials in stockpiles suspected to be contaminated (*ex situ* testing) is presented in Part II.

In situ characterization preferred

The ministry prefers that materials be characterized *in situ* (in the ground).

This allows spatial relationships between contaminant sources and contaminated materials to be established, making the nature and extent of any contamination easier to determine. It also minimizes the volumes of waste that need to be managed.

BC's soil quality classes

The Contaminated Sites Regulation under the *Environmental Management Act* enables the categorization of materials such as fills and soils into eight soil quality classes:

- hazardous waste (HW)
- waste (>applicable land use standards <HW)
- industrial quality (<IL)
- commercial quality (<CL)
- residential quality (<RL)
- urban park quality (<PL)
- agricultural quality (<AL)
- wildlands quality (<WL)

BC's water quality classes

Four water quality classes can also be defined. A material may be categorized into one of those classes through a comparison with the numerical standards in the Contaminated Sites Regulation.

Part I. *In Situ* Characterization and Confirmation Sampling

As the ministry's preferred approach for classifying sites, *in situ* characterization of materials is used at a majority of sites. This approach typically involves the following key principles and components:

- Investigations are based on historical site activities. Hot spots and probable hot spots are targeted for sampling and analysis using statistical sampling methods.
- Site characterization requires identifying potential contaminants of concern (PCOCs) and potential mechanisms of contaminant movement.

The intensity of a site investigation is determined by the complexity of past and present site use, the site size, types of PCOCs,

and potential mechanisms of contaminant transport.

- Investigations are normally staged.
- Preliminary site investigations target probable contaminated areas (suspect hot spots) and sampling generally is carried out using a coarse grid with 25- to 50-m spacing between sample locations.
- Preliminary site investigations can confirm or refute suspect contamination, and can provide estimates of the extent, magnitude, and variability of contamination.
- Detailed site investigations focus on suspect areas and use step-outs from suspect locations of between 5 and 7 m, and grid sampling of between 10 and 20 m in larger suspect areas.
- Detailed site investigations define the lateral and vertical extent, magnitude, and variability of contamination, and provide estimates of contaminant distributions, substance concentration means, upper confidence limits of the means, 90th percentiles, etc.

General *in situ* investigation and characterization guidance

Definition of *in situ* discrete sample

1. An *in situ* discrete sample is material:

- collected from similar *in situ* fill or soil at one location;
- confined to collection within a contiguous volume of 1 m^3;
- collected over a maximum depth of 0.5 m within the upper 1 m from the existing site surface, or from an identifiable historical site surface; or collected over a maximum depth of 1 m at depths greater than 1 m from the surface;
- *not* collected from two distinct fill or soil zones;
- *not* collected on two sides of an air/water interface (or unsaturated/saturated soil zone interface); and
- *not* made up of a mixture of obviously contaminated material and obviously non-contaminated material as determined by field observations such as sight, smell, gas meters, etc., even if these materials have similar physical characteristics (e.g., both are silty sands).

Volume that an *in situ* discrete sample represents

2. One *in situ* discrete sample, as long as it is properly collected, prepared, and analyzed and is a part of a sampling and analysis program that is accurate and precise, is considered to represent a volume of:

- 10 m^3 of material designated as waste; or
- 5 m^3 of material designated as hazardous waste

where, volume = $\pi r^2 d$ and d = 0.2–1.0 m of vertical depth.

Use of step-out sampling at hot spots

3. When an analysis result for an *in situ* discrete sample exceeds the numerical standards relevant to the existing or intended site use, then step-out sampling is recommended. At each step-out location, similar fill or soil at relatively equivalent depths is sampled.

- Where the *in situ* discrete material is *classified as commercial or industrial quality*, three step-outs should be collected for analysis at a distance of no more than 7 m from the original discrete sample location, and preferably at equal distances from each other along the circumference of a circle with a 7m maximum radius from the original discrete sample location.[1,2]

[1] The step-out protocol for suspect commercial or industrial quality material is formulated so that three discrete samples are collected

- Where the *in situ* discrete material is *classified as waste*, four step-outs should be collected for analysis at a distance of no more than 7 m from the original discrete sample location, and preferably at equal distances from each other along a circle with a 7 m maximum radius from the original discrete sample location.[2,3]
- Where the *in situ* discrete material is *classified as hazardous waste*, four step-outs should be collected for analysis at a distance of no more than 4 m from the original discrete sample location, and preferably at equal distances from each other along a circle with a 4 m maximum radius from the original discrete sample location.[2,4]

Confirmation of adequate remediation

4. If chemical concentrations in step-out samples are below the numerical soil remediation standards applicable to the existing or intended site use, then:

- 10 m^3 of contaminated material (5 m^3 for hazardous waste), as characterized by the original *in situ* discrete sample, should be excavated and managed, treated, or disposed of appropriately; and
- following excavation, the remaining material in the walls and floor of the excavation should be sampled and analyzed to confirm removal of all contaminated material.

The recommended practice for this confirmation of remediation is as follows.

- Discrete samples should be collected from each excavation face.
- From any excavation surface, one discrete confirmation sample should be collected such that there is at least one sample within a grid based on 10-m increments (5-m increments for hazardous waste). More closely spaced confirmation sampling may be necessary where thin identifiable layers are suspect.
- Samples should be collected within a 0.25 m perpendicular distance from a face or excavation floor.
- For commercial or industrial quality material, up to four discrete samples collected within one orientation (i.e., vertical wall or horizontal surface) may be composited.
- For waste material, up to two discrete confirmation samples may be composited.
- Where the original discrete sample is hazardous waste, only discrete confirmatory samples should be analyzed.
- If composites are used, then an n-sample composite is compliant only if its concentration is below the regulatory or criterion limit *divided* by n.
- For composites that are noncompliant, follow-up analysis of each of the discrete samples is required.
- Where confirmation analysis results are less than site remediation standards, no further action is required; and
- Where confirmation analysis results exceed site remediation standards, each discrete confirmation sample should be analyzed. Contaminated material in the location indicated by these results should then be

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and analyzed for a suspect volume of 150 m^3 (i.e., one sample per 50 m^3 of suspect material).

2 In the absence of information on the specific locations of contamination, the ministry recommends that step-out samples be equally spaced around the circumference of a circle. *A priori* information, either from historical land use or previous data analysis, may suggest anisotropies in the spatial distribution of the contaminants, and step-out locations may need to be adjusted accordingly.

3 The step-out protocol for suspect waste is designed so that four discrete samples are collected and analyzed for a suspect volume of 150 m^3 (i.e., one sample per 35–40 m^3 of suspect material).

4 The step-out protocol for suspect hazardous waste is designed so that four discrete samples are collected and analyzed for a suspect volume of 50 m^3 (i.e., one sample per 10–15 m^3 of suspect material).

excavated. Excavation should proceed in maximum 10-m^3 increments (5- m^3 increments for hazardous waste), followed by confirmation sampling.

Identifying additional contamination

5. If substance concentrations in one or more of the step-out samples are above the numerical soil remediation standards applicable to the existing or intended site use, then*:*

- 10 m^3 of contaminated material (5 m^3 if hazardous waste) around the original discrete sample and the step-out samples are classified as exceeding the numerical remediation standards, as is all material in a similar depth strata or type between these sampling points;
- another set of step-out sampling and analyses should be completed and the above procedure repeated until such time as all step-outs are below remediation standards for the existing or intended site use; and
- classified material should be excavated and appropriately managed, treated, or disposed of, followed by confirmation sampling and analysis as outlined above.

***Ex situ* material reclassification**

6. When excavated material has been classified as described above, it should be managed consistent with the applicable material quality class. If the owner of the material wishes to confirm or refute the existing class, a statistically equivalent sampling and analysis program is required. Prior approval by the ministry should be obtained for any reclassification protocol (see Part II below). It should be noted that:

- In general, a material classified by *in situ* characterization cannot be reclassified by subsequent batch testing of excavated material unless:
  - the batch testing protocol is statistically more rigorous than for the *in situ* protocol;
  - excavated material has been tracked, inventoried, and mapped; and
  - it can be shown that precautions have been taken against mixing and dilution during excavation, material handling, and stockpiling.

Note
The ministry recommends use of *in situ* classification and confirmation test protocols instead of *ex situ* protocols, where soils are characterized after excavation. *In situ* protocols can use contaminant distribution patterns and *a priori* knowledge of probable areas of activity-related contamination, as well as likely mechanisms of contaminant movement. *Ex situ* protocols are subject to accidental or unavoidable mixing and dilution during excavation and material handling.

Part II. Batch Testing of Suspect Material in Stockpiles (*Ex Situ*)

The following guideline is rule based (deterministic) and is intended for application subject to the conditions specified.

Other procedures are acceptable

As noted earlier, the procedures in this document are not applicable to all sites and others may be used. Site-specific designs may be acceptable, but must be based on sound statistical principles, be appropriate to the method of excavation employed, and be capable of being validated at a level of certainty acceptable to the ministry. Whatever the procedures, it is the responsibility of the site owner or operator to ensure that contaminated

material is properly characterized and remediated.

Adherence to applicable BC laws, regulations, and standards is also required.

Stockpile (*ex situ*) sampling procedure

This procedure is designed to characterize suspect material in stockpiles (*ex situ*). It may be used only after completion of detailed *in situ* site characterization acceptable to the ministry. It must not be used as a substitute for *in situ* characterization, nor may results from the use of this protocol be used to override *in situ* characterization results.

Suspect material is defined spatially following *in situ* investigation results. Such material is classified according to highest numerical standards class (e.g., residential, commercial, industrial) at any boundary.

Three categories of suspect material are defined:

- suspect hazardous waste (SHW),
- suspect waste (>applicable land use standards), and
- suspect industrial quality (<IL>RL)

Guidance for sampling each class of suspect material is shown in Table 1.

Table 1. Sampling guidance for suspect material

	Suspect Hazardous Waste (SHW)	Suspect Waste (<HW>applicable land use standards	Suspect Industrial Quality Material (<IL>RL)
Maximum stockpile size	50 m^3	150 m^3	250 m^3
Cell volume	10 m^3	30 m^3	50 m^3
Number of representative cell samples	5	5	5
Aliquots per representative cell sample	1	3	5
Sampling method	Collect one representative aliquot for each 10 m^3 of cell volume. Each aliquot forms one representative cell sample.	Collect one representative aliquot for each 10 m^3 of cell volume. Up to three aliquots are combined by equal volume to form one representative cell sample.	Collect one representative aliquot for each 10 m^3 of cell volume. Up to five aliquots are combined by equal volume to form one representative cell sample.

Representative cells

Table 1 introduces the concept of a *cell* of material. A cell is a portion of a stockpile. For example, a stockpile containing 250 m^3 of material has five cells, each containing 50 m^3.

In this guideline, a standard cell size of 20% of the stockpile volume has been used.

The basic assumption of this suspect material sampling procedure is that all material within a cell volume is sufficiently homogeneous that one sample can represent the characteristics of the cell volume. It is therefore important that a representative cell sample be composed of material collected throughout a cell volume. To ensure this, an aliquot should be collected for each 10 m^3 of stockpiled material.

Preparing representative cell samples

Multiple specimens from within any 10 m^3 volume may be incorporated into its

representative aliquot. Using multiple specimens reduces "nugget" effects often suspected when small sample volumes relative to a cell or stockpile volume are collected and analyzed.

Great care must be exercised to ensure that a representative aliquot is made up of equal parts (equal volumes) of the specimens collected. If it's not, sampling error will be introduced. Rigorous quality control and quality assurance, in part outlined below, is integral to site characterization.

There are obvious practical limits to the number of specimens that can be incorporated into a representative aliquot. Collecting an unbiased representative aliquot becomes more difficult as the number of specimens is increased. An unbiased sample is also more difficult to collect if cell material is not homogeneous.

Application only to *ex situ* sampling

A representative cell sample, an aliquot to represent each 10 m^3, and specimens from within a 10 m^3 volume are defined solely for use in *ex situ* batch sampling procedures where there is sufficient basis to assume that the material within a 10 m^3 volume is relatively homogeneous and of the same contaminant classification. A discrete sample is defined solely for use with an *in situ* investigation or confirmation sampling procedure.

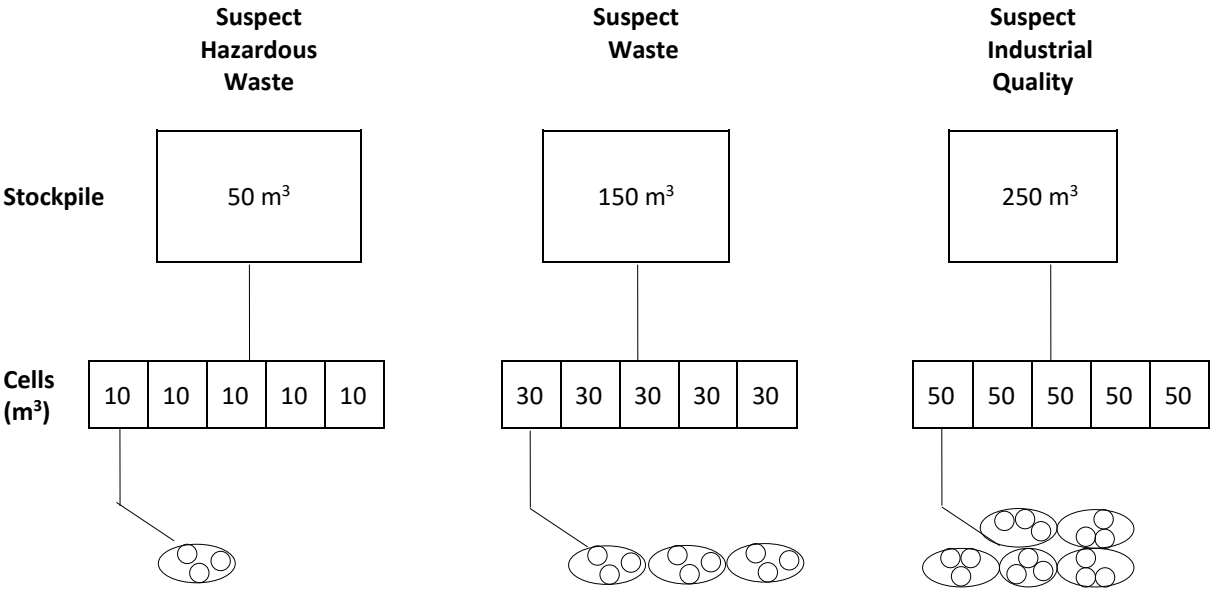

Figure 1. Stockpile sampling procedure illustrating cell samples, aliquots representing 10-m^3 volumes, and specimens from within 10 m^3 volumes.

Homogenizing and splitting cell samples

For any suspect class, a stockpile contains five cells and each cell has one representative cell sample. The following steps are used to homogenize, split, and analyze the cell samples:

- homogenize each cell sample;
- split each cell sample into two parts, and create two sets of split cell samples;
- make one composite sample from five samples of equal volume from one of the sets of split cell samples;
- analyze the composite sample for PCOCs;
- randomly select two cell samples from the remaining set of five split cell samples; and
- analyze the two randomly selected split cell samples individually for PCOCs.

Evaluation and interpretation of stockpile (*ex situ*) analysis results

Step 1. Calculate the composite sample concentration value plus the absolute value of the difference between the composite value and the mean of the representative cell samples analyzed.

$$\text{Calculated Value} = \text{Comp} + [\text{abs}(\text{Comp} - X_{disc})]$$

where

Comp = analysis concentration of composite sample
abs = absolute value
X_{disc} = mean of individual representative cell samples analyzed

Step 2. Compare the Calculated Value and two representative cell sample values according to Table 2.

Table 2. Interpretation and action guidance for stockpile analytical results

Conditions Based on Analysis of Individual Representative Cell Samples	**Calculated Value ≥ Suspect Class Numerical Soil Quality Criterion**	**Calculated Value < Suspect Class Numerical Soil Quality Criterion**
Two cell sample results exceed suspect class numerical soil quality criterion	Stockpile is classified to suspect class. No resampling accepted.	Segregate the two cells and classify to suspect class. Analyze one additional representative cell sample. • If the additional representative cell sample result is less than the suspect class soil quality criterion, the remaining cells are classified one class down from suspect class. • If the additional representative cell sample result is greater than the suspect class soil quality criterion, analyze the remaining representative cell samples and classify cell by cell. Sampling and analysis procedures must be evaluated. Institute complete QA/QC protocol on next stockpile. **Provision 2 applies.**[a]
One representative cell sample result exceeds suspect class numerical soil quality criterion	Analyze all remaining representative cell samples. Classify accordingly on cell-by-cell basis. or Manage stockpile as suspect class. **Provision 1 applies.** [a]	Segregate the one cell and classify to suspect class. Analyze one additional representative cell sample. • If the additional representative cell sample result is less than the suspect class soil quality criterion, the stockpile is classified one class down from suspect class. • If the additional representative cell sample result is greater than the suspect class soil quality criterion, segregate the cell and classify to suspect class. The remaining three cells are classified one class down from the suspect class. Sampling and analysis procedures may need to be evaluated. **Provision 2 applies.** [a]
No representative cell sample result exceeds suspect class numerical soil quality criterion	Analyze all remaining representative cell samples. Classify accordingly on cell-by-cell basis. or Manage stockpile as suspect class. **Provision 1 applies.** [a]	Stockpile classified one class down from suspect class.

[a] Provisions 1 and 2 are described below.

Provision 1. This method may only be used to classify a cell or a stockpile from a suspect class to the next lower class. Dilution effects are inherent in *ex situ* characterization techniques and are a concern. Classification that is two categories below a suspect class requires an evaluation of the numerical variability within a population and a statistical justification for a representative sample support volume.

Provision 2. If a single representative cell sample exceeds the following, then all representative cell samples for a stockpile must be analyzed and each cell classified according to the result of the cell sample.

- For *suspect hazardous waste*: no single representative cell sample shall exceed 20% of the regulatory numerical value.
- For *suspect waste*: no single representative cell sample shall exceed 100% of the applicable land use standards
- For *suspect industrial or commercial quality material*: no single representative cell sample shall exceed 200% of the residential numerical criterion.

Definition of hazardous waste

Hazardous waste is defined under the Hazardous Waste Regulation. Depending on the substance, hazardous waste may be defined by:

- total substance concentration,
- toxic equivalency concentration, or
- concentration of the liquid from a leachate extraction procedure.

Total analyses may be used to help determine if a leachate extraction test is required. Note that if a waste does not qualify as a hazardous waste based on a total analysis, it may still qualify as such based on a leachate test. The ministry recommends determining correlations between total substance concentrations and leachate extraction results, so a "trigger" level can be determined for applying the leachate extraction procedure. Correlations must be carried out and triggers established on a site-by-site basis.

Quality assurance and quality control (QA/QC) for stockpile (*ex situ*) sampling

The ministry recommends that a detailed QA/QC program be developed before starting any site work. An acceptable QA/QC program will include at least the following.

Analysis of split sample duplicates

1. Split sample duplicates of an individual representative cell sample should be analyzed.

- The ministry recommends that one of every 10 representative cell samples be analyzed in duplicate. This is a check on the laboratory analysis protocol.
- If the variability between the duplicates is less than or equal to 20%, then the average of the two results may be used as the representative cell sample result. The variability calculation is as follows:

$$\frac{(\text{Max} - \text{Min})}{(\text{Max} + \text{Min})/2} \times 100 \leq 20\%$$

- If the variability exceeds 20%, the reason for the variability should be investigated. Review should at least include:
  - inspecting the sample (e.g., for debris);
  - crosschecking sample identification with the reported laboratory result; and
  - requesting a laboratory review of notes, calculations, and protocols.
- All inquiries should be fully documented.
- If the reasons for the elevated variability cannot be isolated, then one in every five representative cell samples should be analyzed in duplicate. This frequency of split sample duplicate analysis should be continued until reasons for high variability have been determined or corrective actions

have been taken. It must also demonstrate that the analysis variability has been reduced to an acceptable level. For split sample duplicates where variability exceeds 20%, the higher of the two analysis values should be used as the representative cell sample result.

Complete repeat sampling and analysis

2. The repeat sampling and analysis of an entire stockpile should be carried out.

- A second set of representative cell samples, completely independent of the first set of cell samples, should be collected from a stockpile. Specimens, aliquots, and representative cell samples are independent. They are not split duplicates of the first set. The ministry recommends that one out of every 10 stockpiles with the same suspect class classification should have repeat characterization. This is a check on the field sampling protocol and the degree of variability within a cell and a stockpile.
- The evaluation of the duplicate characterizations of a stockpile *must* result in the same classification for the stockpile and for individual cells.
- If the evaluation of repeat characterizations for a stockpile does not result in the same classification, then, as a minimum, the following questions must be considered:
  - Was *in situ* characterization work insufficient to *estimate* contaminant variability, contaminant distribution, and boundaries of contaminated material types?
  - Was the excavation method and material-handling protocol not rigorous enough? Were material types combined, mixed, or diluted and in general inappropriately placed within a cell or stockpile?
  - Was the sampling protocol not rigorous enough? Was bias being introduced?
  - Was the cell support volume for a representative cell sample too large for the contaminant variability?
  - Was there significant laboratory error?

- Investigation and corrective action is mandatory for the continued use of this protocol. Repeat characterizations of additional stockpiles should continue until results agree. All investigations and corrective measures should be documented and submitted to the ministry.
- Stockpiles with repeat characterizations will be classified according to the highest classification indicated. Representative cell sample results take priority over composite sample results.
- The above split duplicate (step 1 above) and repeat stockpile characterization (step 2) protocols should be initiated on the first stockpile and thereafter assume the indicated frequency of application.
- Additional useful QA/QC protocols that can be incorporated into material characterization plans include:
  - providing field staff with written instructions on sampling protocols and practices acceptable to your firm (and the ministry);
  - providing sufficient senior supervision;
  - developing detailed material handling and tracking protocols;
  - ensuring that field staff maintain up-to-date field notes;
  - keeping photographic documentation of excavation and stockpiling operations; and
  - using chain of custody forms for all samples collected.

For more information, contact the Environmental Emergencies and Land Remediation Branch at site@gov.bc.ca