Association of Professional Geoscientists of Ontario

Guidance for Environmental Site Assessments under Ontario Regulation 153/04 (as amended)

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1.0 INTRODUCTION

1.1 Purpose and Scope

The purpose of this document is to provide technical and operational guidance for conducting an environmental site assessment (ESA) to meet the requirements of Ontario Regulation 153/04, as amended. The document describes the procedures that may be followed to meet the phase one and phase two ESA requirements for submitting a Record of Site Condition (RSC) to the Ontario Ministry of the Environment (MOE) on completion of the phase one or phase two ESA. Guidance on additional site characterization required to support the Modified Generic Risk Assessment procedure as defined in the Regulation is also provided.

An RSC can only be submitted by a Qualified Person (QP), and the QP must ensure that the supporting reports meet the requirements set out in the Regulation.

The general site assessment principles and methodology described in this document are consistent with the requirements of the Canadian Standards Association phase one and phase two ESA standards (CSA Standard Z769-01 and Z769-00). This document may therefore also be used as a guide for conducting environmental site assessments when an RSC is not required. (Such assessments might be referred to as a "due diligence" site assessments). Where environmental site assessments are intended to support the submission of an RSC, the requirements of the Regulation, including Schedules D and E must be met.

The guidance provided in this document is not intended to be prescriptive and does not replace the need for a QP to exercise professional judgement in conducting the site assessment.

Regulatory definitions and requirements described in this guidance document are provided for convenience only. QPs must refer to the regulation and other applicable statutes and regulations to ensure that their work meets the regulatory requirements. In no way should this document be considered or construed to be a replacement for the regulations or contain legal advice. In the event that a difference is identified between this guidance document and the applicable regulations, the regulations shall prevail.

2.0 OVERVIEW OF THE LEGISLATION

2.1 Historical Context

The Brownfields Statute Law Amendment Act was passed in November 2001 to provide legislative the authority to amend several statutes in Ontario to encourage the revitalization of brownfields while ensuring that the environment is protected. Amendments were made to the Environmental Protection Act (EPA) as well as other statutes, including the Municipal Act and the Planning Act, to meet the objectives of facilitating brownfield revitalization.

This guidance document focuses on the amendments to the EPA that describe the technical requirements for assessing environmental conditions at brownfields. Amendments to the other Acts that deal with liability and fiduciary issues associated with brownfield revitalization are not discussed in this document.

Amendments to the Environmental Protection Act (EPA)

The EPA was amended by adding a new part, Part XV.1, to it. Ontario Regulation 153/04 was created in October, 2004 under Part XV.1 of the EPA. The key aspects of this regulation are as follows:

- provision of soil, sediment and groundwater quality standards known as "generic site condition standards" based on defined land-use designations (agricultural, residential/parkland/institutional, and industrial/commercial/community) and groundwater use (i.e., whether the groundwater is considered "potable" or "non-potable" as defined in the Regulation);
- a description of the procedure to be followed for assessing the environmental condition of a property;
- adoption of the CSA phase one and phase two ESA standards (CSA Standards Z769-00 and Z769-01) for the purpose of conducting phase one and phase two ESAs under the Regulation ;
- the use of risk assessment, if needed, to develop property-specific standards;
- the use of risk management measures to manage environmental risks;
- protocols for environmental sampling and analysis;
- inclusion of a form known as the Record of Site Condition (RSC) summarizing the environmental condition of a property to be submitted to the Ministry of the Environment for filing on the Brownfields Environmental Site Registry;
- mandatory provisions for completing and submitting the RSC;
- possible registration of RSC on the property title through an instrument known as the Certificate of Property Use (CPU), when the Director determines that the risk management measures used justify the issuance of a CPU;
- liability protection from orders for property owners who file the RSC; and
- definition of the qualifications required for persons ("Qualified Persons") undertaking site assessments, risk assessments and submission of the RSC for filing.

Ontario Regulation 153/04 was amended in December 2009 through Ontario Regulation 511/09. The amendments made in December 2009 provide updated generic site condition standards, modifications to risk assessment process, an enhanced procedure for submitting RSCs, and new definitions for phase one and phase two ESAs. Other minor amendments have been made since December, 2009, and further proposed minor amendments are currently released for public comment. The amended regulation takes effect on July 1, 2011.

The new requirements for phase one and phase two ESAs remain consistent with the overall site assessment approach described in the CSA standards but provide detailed, prescriptive requirements that must be followed when the reports are to be used in support of submission of the RSC for filing.

Ontario Regulation 153/04 and its amendments are collectively referred to hereafter in this guidance document as the "Regulation".

The above legislative summary is provided for convenience only. Readers of this document should refer to the gazetted regulation available on the Ontario Legislative Assembly internet site (www.ontla.on.ca). Guidance on implementation of the Regulation and technical updates are available on the Ministry's internet site (www.ene.gov.on.ca).

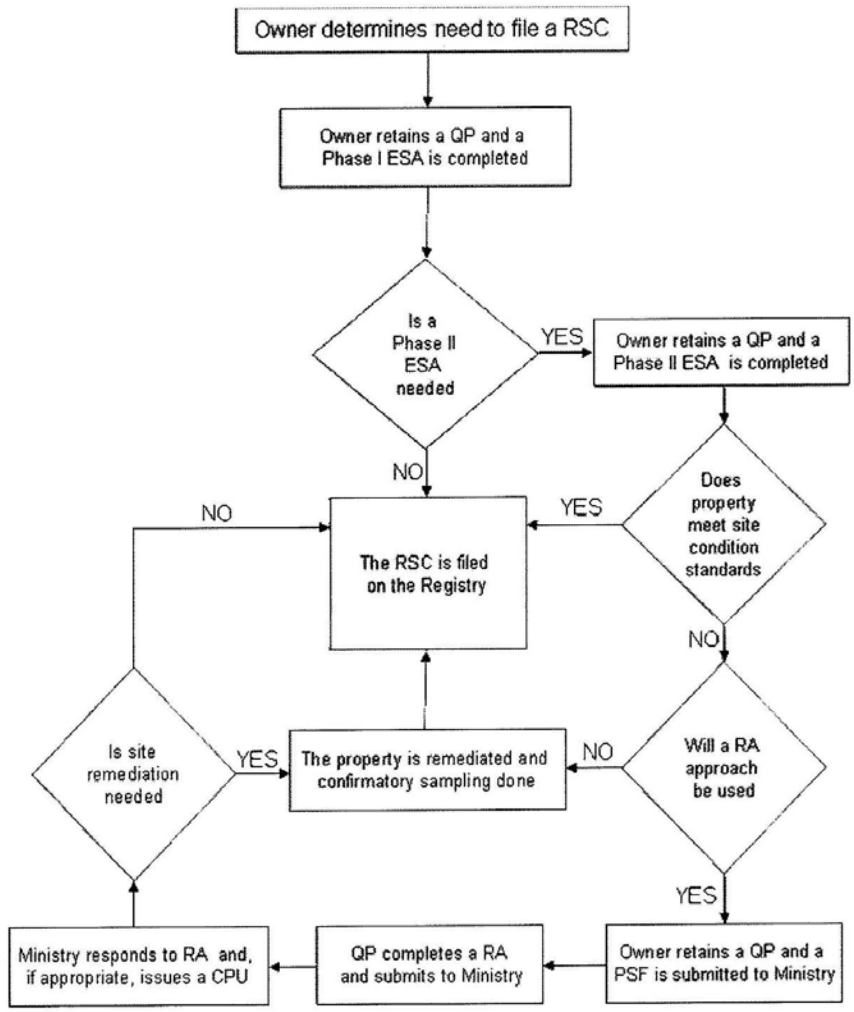
2.2 Overview of the Environmental Site Assessment Process

This section provides a simplified overview of the environmental site assessment process in the context of the Regulation. Definitions of phase one and two environmental site assessments provided in this document are for convenience only. Readers are directed to the Regulation for the specific definition and requirements of phase one and two environmental site assessments.

Environmental site assessment in the context of the Regulation means the evaluation of environmental conditions (soil as defined in the Regulation, groundwater and sediment quality) at a specific location (often a distinct property or site but can include nearby locations or a broader area where warranted).

An overview of the environmental site assessment and RSC filing process is illustrated in Figures 1 and 2, below

Figure 1: Overview of the RSC Process



Notes for Figure 1:

1. "CPU" means a certificate of property use
2. "ESA" means an environmental site assessment
3. "Ministry" means Ministry of the Environment
4. "PSF" means a pre-submission form
5. "QP" means a qualified person
6. "RA" means risk assessment
7. "RSC" means a record of site condition

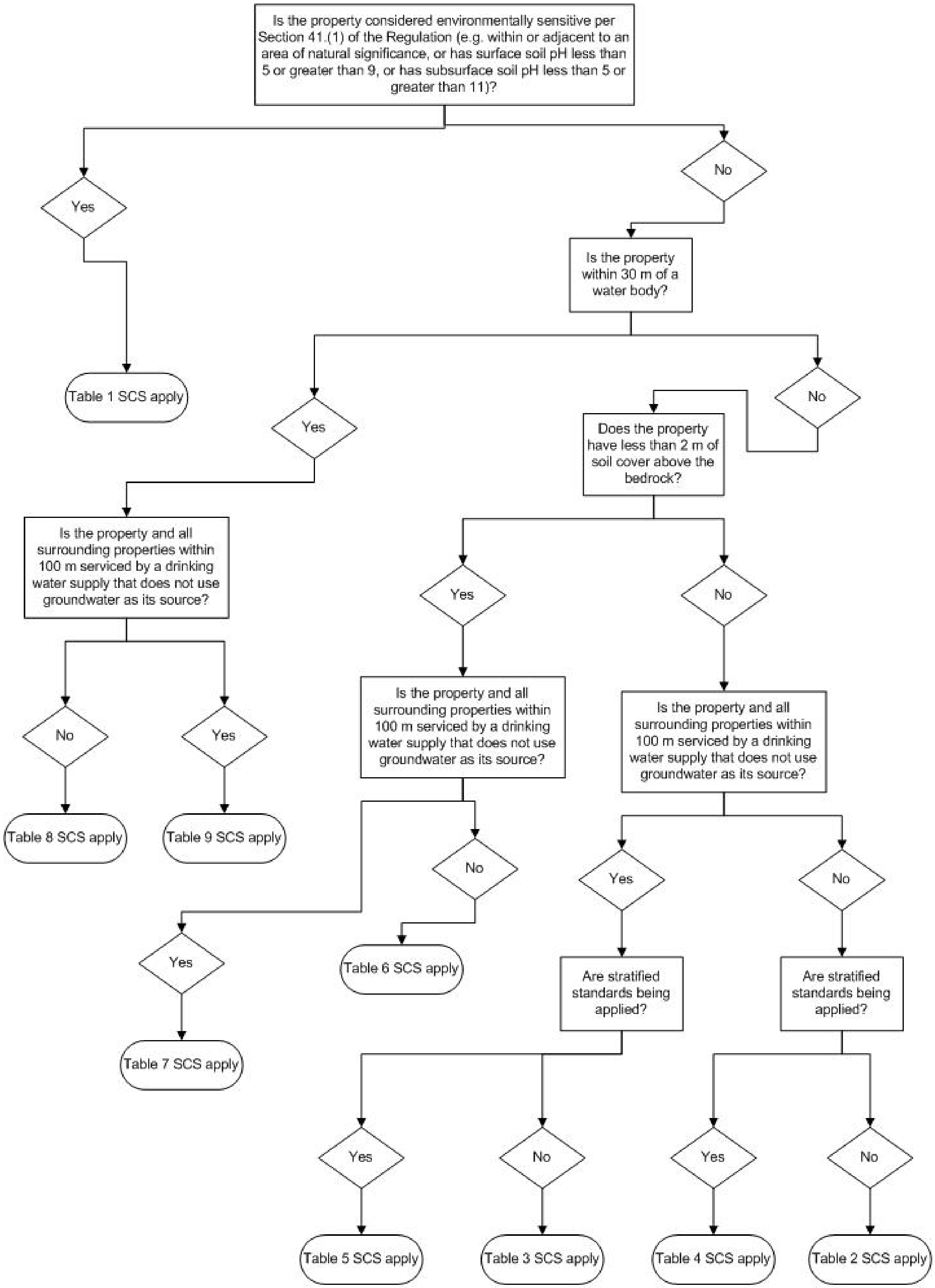


Figure 2: Process for Selecting Site Condition Standards (SCS)

Phase One Environmental Site Assessment

- A phase one ESA is conducted to determine the likelihood that one or more contaminants (defined in the *Environmental Protection Act* as resulting directly or indirectly from human activities) are present at the property due to activities on the property, or at nearby or up-gradient locations. For properties where the QP has determined through a phase one ESA that contaminants are not likely to be present above the applicable Site Condition Standards, then that phase one ESA may be used to support the filing of a Record of Site Condition.
- The specific requirements for conducting a phase one ESA are set out in Part VII of the Regulation.

Phase Two Environmental Site Assessment

- A phase two ESA is conducted to determine the location (3-dimensional extent) and concentration of one or more contaminants at a property by analyzing samples of soil, groundwater, and sediment, if present, at the property. The phase two ESA is usually based on the findings of the phase one ESA.
- The specific requirements for carrying a phase two ESA are set out in Part VIII of the Regulation.
- If the phase two ESA indicates that all sampled media at the property do not exceed the applicable generic standards provided in the Regulation, then an RSC may be completed and submitted as described in the section below (Completing and Submitting an RSC**)**.
- If the phase two ESA indicates that one or more contaminants exceed the generic standards provided in the Regulation, then the following may be considered:

  a) remediation of the affected media (i.e., soil, groundwater or sediments) to the extent that generic standards are no longer exceeded;

  b) risk assessment to develop property specific standards; or

  c) a combination of remediation and risk assessment.
- The Regulation does not prescribe remediation methodologies, but describes the requirements for confirmatory or verificational sampling and analysis following remediation, as well as the requirements for soil importation as part of the remediation process (Schedule E Sections 30 – 41, and O. Reg. 153/04 Section 55).
- *(Note: for the purpose of submitting an RSC, the Regulation includes site remediation and verification, if conducted, as part of the phase two ESA. These activities often have been referred to as Phase III ESA in the industry. The activities comprising a Phase III ESA are considered to be part of a phase two ESA under the Regulations)*
- Specific requirements for completing risk assessments are described in Part IX of the Regulation.

Completing and Submitting an RSC

The Regulation requires the filing of an RSC prior to changing land use to a more sensitive use (e.g. industrial or commercial land-use changing to residential or parkland use). However, the filing of an RSC may also be requested for purposes outside of a change in land-use, such as:

- a condition of property financing;
- a condition of property sale;
- a condition imposed by a municipality in the process of planning or building approvals.

Part V of the Regulation describes the requirements for completing and submitting an RSC to the MOE. Once the conditions described in the Regulation have been met, the MOE will indicate that the RSC is satisfactory and it will be posted on the Environmental Site Registry.

2.3 Defined Persons

Part II of the Regulation describes several "defined persons" in the context of the site assessment process. Of most relevance to this guidance document is the "Qualified Person, other than risk assessment", and specifically a qualified person (or QP) for environmental site assessment (often abbreviated as QP_{ESA}).

The Regulation includes mandatory responsibilities for environmental practitioners. It requires that phase one and two ESAs shall only be completed under the supervision of a QP_{ESA}, and that RSCs shall only be completed and submitted by a QP_{ESA}. The completing of an RSC requires that the QP provide several certifications spelled out in the Regulation.

The Regulation stipulates who has the qualifications to be a QP_{ESA}. The qualifications are:

(a) the person holds a licence, limited licence or temporary licence under the *Professional Engineers Act;* or

(b) the person holds a certificate of registration under the *Professional Geoscientists Act, 2000*, and is a practising member, temporary member or limited member of the Association of Professional Geoscientists of Ontario.

Another type of person defined in the Regulation is a "qualified person, risk assessment (often abbreviated as QP_{RA}). A QP_{RA} can supervise the preparation of a risk assessment under the Regulation. The qualifications of QP_{RA} include a specified degree, and years of relevant experience. Details are presented in the Regulation.

The Regulation also requires that QPs have liability insurance policies in place. The minimum amount of insurance and other details are provided in the Regulation.

A QP must not be in a conflict of interest, which is defined as the QP or their employer holding a direct or indirect interest in the RSC property.

Furthermore, and subject to the conflict of interest provisions summarized above, any QP who is an employee, shareholder, director, partner or principal of a firm, company or partnership and who wishes to submit an RSC or risk assessment, will need to file a copy of the Certificate of

Status (if a corporation) or equivalent document for a firm or partnership. Details as to the timing of when these documents must be filed are presented in the Regulation.

3.0 ENVIRONMENTAL SITE ASSESSMENT

An environmental site assessment in the context of the Regulation must consist of a phase one ESA and, if required based on the findings of the phase one ESA, a phase two ESA. A phase two ESA is also mandatory in certain circumstances as outlined in Section 32 of the Regulation, including: current or former existence of a potentially contaminating activity on the property or any part of the property, or current or former use of the property as a service garage, bulk liquid dispensing facility (including a gasoline outlet) or for the operation of dry cleaning equipment.

3.1 PHASE ONE ESA

The phase one ESA is conducted to determine the likelihood that current and historical uses of the property (or a portion of the property) have contributed to the presence of one or more contaminants on the property. It involves:

- a review of available records, both historical and present, about the property and the surrounding properties;
- a site reconnaissance; interviews with individuals knowledgeable about the property;
- evaluation of the information gathered;
- preparation of a written report; and
- submission of the report to the property owner.

Readers are directed to the CSA Standard Z768-01 for examples on the types of background information and other sources of information that should be reviewed or obtained to complete a phase one ESA.

An RSC may be completed and submitted for filing on the Environmental Site Registry if the phase one ESA indicates that there is no evidence of the likelihood of contamination.

QPs involved with phase one ESA work should ensure that they have sufficient knowledge and expertise to identify the types of property uses that are known to pose contamination risks to soil, groundwater and sediment. This would include an evaluation of those property uses against the list of Potentially Contaminating Activities (PCAs) listed in Table 2 of the Regulation. In addition, the QP must know the relevant sources of background information to consult in order to verify whether or not PCAs have occurred on a given property.

The Regulation requires the phase one ESA study area to encompass the subject site and the surrounding 250 metres. In areas where a large industry or potential source for contaminants to the subject site is just outside the initial study area, the QP may wish to enlarge the study area to include it.

Guidance in the Regulation indicates that at least a portion of the preliminary records review be conducted before site reconnaissance occurs, in order to provide the QP with an understanding of the potential issues of environmental concern at the Site before conducting the site reconnaissance and interviews. Preliminary information that should be assessed by the QP prior to visiting the subject site may include the following:

- Fire insurance maps;
- Topographical maps;
- Geological maps;
- Site plans;
- Aerial photographs extending back to the first developed use of the property, if available;
- City directories;
- Spill records;
- Previous reports;
- Well records; and
- Former coal tar gasification and landfill locations.

Depending on the nature of the subject site and the QP's professional judgment, review of additional materials should be considered before the site reconnaissance or interviews occur, in order to guide the QP's subsequent observations and questions. The list of materials, for which the QP must make all reasonable inquiries, to obtain and review during the course of a phase one ESA (per Schedule D of the Regulation) extends beyond this preliminary information, and includes:

- fire insurance plans for all parts of the phase one property;
- search of title of the phase one property that goes back to the date of its first developed use (unless other information from the records review satisfies the objectives of the records review, and a title search back to the date of the first developed use would not contribute to obtaining information about the environmental condition of the phase one property);
- copies of reports prepared in respect of all or part of the phase one property by or on behalf of a current or former owner respecting environmental conditions at the phase one property including:
    - environmental site assessment reports,
    - remediation reports,
    - reports prepared in response to an order or request of the MOE, and
    - any other reports relating to the presence of a contaminant on, in or under the phase one property or the existence of an area of potential environmental concern.

- National Pollutant Release Inventory information maintained by Environment Canada,
- PCB information maintained by the MOE,
- Current or past certificates of approval, permits to take water, certificates of property use or similar instruments related to the environmental condition of the phase one property and any property adjacent to the phase one;
- The inventory of coal gasification plants that is maintained by the MOE;
- Records, for the phase one property and adjacent properties concerning environmental incidents, orders, offences, spills, discharges of contaminants or inspections maintained by the MOE;
- Waste management records, including current and historical waste storage locations and waste generator and waste receiver information maintained pursuant to Ontario Regulation 347 (which pertains to waste management);
- reports submitted to the MOE related to the environmental conditions of the phase one property and any property on, under or adjacent to the phase one property, as may be obtained through a Freedom of Information search;
- Retail fuel storage tanks information maintained by the Technical Standards and Safety Authority,
- Notices and instruments, including records of site condition, posted in the Environmental Site Registry,
- Listings of areas of natural significance maintained by the Ministry of Natural Resources, and "areas of environmental significance" defined by municipalities;
- Landfill information maintained by the MOE;
- Aerial photographs of the phase one study area;
- Topographic maps (Ontario Base Map series), which illustrate the location of the phase one property in relation to any water bodies in the phase one study area and document regional topography;
- Physiographic maps or other similar documents (in order to define regional physiography in the phase one study area and to obtain information about the surficial soil and bedrock in the phase one study area);
- Geological maps or other similar documents in order to define the regional geology in the phase one study area and to obtain information about the stratigraphy of the overburden, from ground surface to bedrock, including approximate depth to bedrock and type of bedrock;
- Well records and other relevant data for any operating or abandoned wells in the phase one study area, in order to identify :
    - the location of any such wells,
    - the stratigraphy of the overburden, from ground surface to bedrock,

- approximate depth to bedrock, and
- approximate depth to the water table.

- Site operating records, including:
  - Regulatory permits and records related to areas of potential environmental concern,
  - Material safety data sheets,
  - Underground utility drawings,
  - Inventories of chemicals, chemical usage and chemical storage areas,
  - Inventory of above ground storage tanks (ASTs) and underground storage tanks (USTs),
  - Environmental monitoring data, including data created in response to an order or request of the MOE,
  - Waste management records;
  - process, production and maintenance documents related to areas of potential environmental concern;
  - Records of spills and records of discharges of contaminants
  - Emergency response and contingency plans;
  - Environmental audit reports, and
  - A site plan of facility showing areas of production and manufacturing.

It is a requirement of the Regulation that, in the absence of other information regarding the history of the subject site, the QP is to conduct a chain of title search for the subject site that extends back to the first developed use. Some examples of other information from the records review that could be used to meet the objectives of the records review and avoid the necessity for a title search going back to first developed use may include the following:

- Fire insurance maps;
- Aerial photographs;
- Interviews with building officials and local residents;
- City zoning records.

Even if such information is available, the QP is still required to obtain an up-to-date chain of title for the subject property. In this case, it is not required that the chain of title extends back to the first developed use.

The review of aerial photographs is a mandatory requirement for a phase one ESA under the Regulation. It is advisable that QPs use historical aerial photographs from sources such as map libraries, the National Air Photo Library, or commercial suppliers rather than relying solely on internet or online imagery. The series of aerial photographs examined by the QP should cover all developed uses, and major changes in developed uses, for the property. When including aerial photographs in phase one ESA reports, the QP should indicate the location and extent of the subject property and the phase one ESA Study Area.

Although these sources may not directly contain information on issues of actual or potential environmental concern at the subject site, physiographic maps, topographic maps, geologic maps or similar documents may provide information useful to the development of a ”phase one ESA conceptual site model”. In using these sources, information that the QP may find useful in developing the conceptual site model includes:

- Locations of PCAs;
- Locations of water bodies (defined in the Regulation as being a permanent feature) and other sensitive receptors;
- Locations of quarries, oil and gas wells;
- Locations of pipelines or similar structures that may constitute preferential pathways for contaminant migration;
- Soil and rock types; and
- Topographic information that may assist in inferring groundwater flow directions.

Although water well records are often consulted in the development of a phase one ESA conceptual site model, these may not be available for the vicinity of all subject sites. Oil well records are another source of geologic information that the QP may reference to supplement missing or incomplete sources of geological information. One source of these records may be accessed at:

http://www.ogsrlibrary.com/

For an enhanced investigation property (refer to Section 3.2 of this document), the QP should review facility layout drawings or similar site operating records as applicable and reasonably accessible. It is recommended that the QP review these documents with reference to Table 2 of the Regulation (i.e. Potentially Contaminating Activities) in order to assess whether these areas may be potential issues of environmental concern for the subject property.

It is beyond the scope of this guidance document to provide a standardized interview for a phase one ESA. The QP should design the interview with consideration to the issues of actual or potential environmental concern identified during the preliminary records review, as well as the list of Potentially Contaminating Activities listed in Table 2 of the Regulation. The interview should also include questions intended to verify or supplement any missing or incomplete information identified during the preliminary records review. It is advisable that the QP develop a written interview form or checklist in order to document the interview, and that this written record of the interview be incorporated into the phase one ESA report.

The site reconnaissance should be documented using written notes and photographs showing each identified issue of potential concern. Issues that the QP may wish to document include, but are not limited to, :

- Dates and times of the site reconnaissance;
- Weather;
- Name of person providing access to the site or accompanying the QP during the site reconnaissance;
- Any relevant comments from the site owner or representative;
- Photographs inside and outside of the facility;
- Areas not accessed and reasons why;
- Processes or potentially contaminating activities occurring within or outside of the subject site;
- Locations of chemical storage and handling;
- Locations of current or former USTs and ASTs;
- Locations of drains, sumps and pits;
- Locations of manholes and storm sewer grates;
- Heating and cooling systems;
- Locations of building entry and exit points (these may have been locations for incidental historical disposal of wastes);
- Locations and areas of stressed vegetation;
- Locations of stains;
- Information regarding neighbouring sites (e.g. facility names, addresses, and any potentially contaminating activities that are observed); and
- Locations of waste storage areas and types of waste stored.

Utility services may have the potential to be preferential pathways for contaminant transport on or off the site since they are usually constructed with granular backfill surrounding the actual utility. In addition to information obtained during the site reconnaissance, QPs may be able to obtain information regarding the depth and configuration of utilities through facility as-built drawings for the subject property, or from information available from municipal works departments or public utilities commissions.

Review and Evaluation of Information

The review and evaluation of information from the records review, interviews and site reconnaissance is required to be conducted by the QP in order to prepare:

- A tabular summary of areas of potential environmental concern;
- A tabular summary of current and past uses of the phase one property; and
- A phase one conceptual site model.

The phase one conceptual site model should provide both a graphical and narrative summary of the information synthesized from the records review, interviews and site reconnaissance components of the phase one ESA. The information that should be depicted and described includes:

- The buildings, paved and unpaved areas of the property;
- The age(s) of structures currently and formerly on the property;
- Locations, sizes, ages and uses or contents (if known) of current and former ASTs and USTs on the property;
- Potable and non-potable water wells on the property and within the phase one study area;
- Drains, sumps and pits;
- Known or suspected areas of waste storage and/or management;
- Details and locations of chemical storage;
- Locations, details and approximate ages of underground utilities at the property;
- Locations and details of potentially contaminating activities as listed in Table 2 of the Regulations;
- Locations of known spills or releases;
- Locations of oil/water separators, hydraulic lifts or similar equipment;
- Locations and details of drainage works, sewage works or similar facilities;
- Locations of water bodies, areas of natural significance, or other sensitive receptors within the phase one study area.

Reporting

A mandatory requirement of a phase one ESA is a written report, which must be prepared by or under the supervision of a QP. The phase one ESA report is required to provide a written record of the scope and findings of a phase one ESA. This report is required to be formatted according to the headings and sections prescribed in Table 1 of the Regulation. Figures provided in the phase one ESA report, including the graphical components of the phase one conceptual site model are required to be to scale and to include prescribed elements such as a north arrow and title block.

A key objective of the phase one ESA report is to indicate whether further investigation is required in order to submit a Record of Site Condition for filing.

Soil brought to a Phase One Property

In some cases, a QP may determine at the completion of a phase one ESA that a phase two ESA is not required in order to certify a Record of Site Condition. However, based on development or grading plans for the property, there may be a requirement to import soil to the phase one property. In this circumstance the QP is required to determine in accordance with Schedule F of the Regulation that soil intended to be brought from a source property to the RSC property meets the Table 1 Site Condition Standards with respect to all contaminants that the QP considers to be contaminants of concern based on the history of the source site.

In this case, the QP should develop a sampling and analysis program for the soil to be brought to the RSC property, considering the guidance provided in Section 5 of this document. The QP is required to document the analysis of the soil in accordance with the requirements of Schedule F of the Regulation.

3.2 PHASE TWO ESA

If the QP determines that there is a likelihood of contamination at the property, or the assessment is conducted at a property where certain past or present property use activities as defined in the Regulation occurred, then a phase two ESA must be completed in order to complete the RSC.

A phase two ESA is conducted to determine the location and concentration of one or more contaminants in soil, groundwater and sediments at a property. The concentrations are then compared with the applicable generic site condition standards for soil, sediments and groundwater provided in Tables 1- 9 of the Regulation.

Sufficient lateral and vertical sampling of these media should be undertaken to delineate the extent of contaminants that may be present at the property and to assess the likelihood that the contaminants may migrate onto or away from the property. The RSC may be filed if the results of the phase two ESA indicate that the sampled media at the property meet the applicable generic site condition standards. The options for submitting an RSC for filing if the applicable site condition standards are not met include site remediation or risk assessment or a combination of both. The Regulation includes site remediation and verification sampling within the scope of a phase two ESA.

The specific requirements for conducting a phase one ESA, including the content of the report, are described in Part VII and Schedule D of the Regulation. Phase two ESA requirements are set out in Part VIII and Schedule E.

The detailed requirements for conducting a phase two ESA are set out in Schedule E, Parts I – V of the Regulation as follows:

Part I – Application

Part II – Planning Site Investigation

Part III – Conducting the Site Investigation

Part IV – Review and Evaluation of Information

PartV –Phase Two Environmental Site Assessment Report

The following sections of this document provide guidance on meeting each of the requirements as described above.

This document focuses on providing guidance on soil and groundwater assessment in the context of a phase two ESA. It does not deal with sediment assessment. Guidance on sediment assessment can be found in the Ministry of Environment document “Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An Integrated Approach, May 2008”.

4.0 APPLICATION OF A PHASE TWO ESA

A phase two ESA is mandatory if it is identified or suspected through the phase one ESA that:

- a potentially contaminating activity currently exists or has been undertaken at the property or any part of the property; or
- the property is currently used or has been used as a service garage, bulk liquid dispensing facility which include gasoline outlets, or for the operation of dry cleaning equipment. Such a property is defined as an "enhanced investigation property" in the Regulation.

Exception to completing a phase two ESA at such a property is made if the property is currently used for:

- agricultural, community, institutional, parkland or residential property uses since the previous uses as an enhanced investigation property, and an RSC has been filed since that use of the property;
- or a part of a property that is used or has ever been used as a quarry for the production of oil and gas and consisting of oil or gas well at the property.

5.0 PLANNING THE SITE INVESTIGATION

The phase one ESA should form the basis of planning the sampling locations, media to be sampled and contaminants of concern to be analyzed in the phase two ESA. The phase one ESA Conceptual Site Model should be used as a guide to select the specific locations for sampling, the selection of environmental media (e.g. soil, groundwater and sediment), as well as the range of contaminants to be analyzed. Based on the available information, a preliminary phase two "conceptual site model" should be developed in order to assist in the planning of the phase two ESA. This conceptual site model represents a preliminary understanding of the site characteristics, including the presence of confining and unconfining layers, expected locations of contaminants, likely contaminant transport mechanisms, and the existence of potentially preferential pathways for contaminant transport such as sewers or utility conduits. The preliminary conceptual site model may be revised or refined as field data are gathered during the phase two ESA.

Site-specific constraints such as the physical layout of the property and safety hazards due to the presence of underground utilities, overhead power lines, and building structures may constrain the final selection of the sampling locations. These constraints should be assessed at an early stage to determine how they may influence the final sampling locations in relation to the phase one ESA conceptual site model. This should be documented so that the significance of deviations from the phase one ESA conceptual site model can be assessed, and if required, an alternate sampling strategy can be developed.

Other information about the property that may be available and is not included in the phase one ESA should also be assessed. This could include phase two ESA reports prepared by other consultants. The QP should ensure that he/she may rely on the reports and that the reports would meet the overall technical requirements specified in the Regulation.

The QP responsible for conducting the phase two ESA should assess whether the property use activities at the property may have changed since the phase one ESA was conducted and should undertake the investigation accordingly. It is recommended that the QP visit the property to assess the actual conditions and plan the investigation accordingly. The plan should include a provision for iterative round of sampling particularly where extensive contamination is expected. In such cases, it may be preferable to conduct the initial investigation in the less contaminated portion of the property so that sampling in the more heavily contaminated areas can be planned more carefully following analysis from the preliminary round of sampling. Sampling locations should be planned near the up-gradient and down-gradient property boundaries so that the implications of contaminant movement from or to neighbouring properties can be assessed. Trans-gradient locations should also be assessed in order to confirm groundwater flow.

5.1 Development of Standard Operating Procedures (SOPs)

An SOP is a document that describes the procedures to be followed in conducting phase two ESAs. The development of prescriptive Ontario-wide SOPs is beyond the scope of this document, as an SOP may incorporate site-specific considerations, the QP's professional judgment, the integration of up-to-date information from regulatory guidance in Ontario and other jurisdictions, as well as the review and integration of information from the scientific literature.

QPs should refer to the Ontario Ministry of the Environment document "Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act, March 9, 2004, amended as of July 1, 2011". This document provides contaminant-specific requirements that must be followed for sampling, preservation and analysis of soil and groundwater.

Several sources of published SOPs (e.g. USEPA Environmental Response Team, 2010) are available. It is recommended that QPs consult these sources in the development of their SOPs.

A summary of the key elements that may be included in the SOP is provided below:

1. Scope and Application of the SOP

   This section should describe the intended application of the SOP (e.g. borehole drilling, soil sampling, stockpile sampling, groundwater sampling, etc.)

2. Equipment Requirements

   This section should describe the equipment required to be used in executing the SOP, and provide a description of how the equipment is to be prepared and used. Calibration procedures, if applicable, should be described, as should equipment decontamination or disposal procedures. Equipment requirements should also include personal protective equipment (PPE) requirements that are necessary to safely execute the work.

3. Sample Container, Sample Collection, Handling and Preservation Requirements

Where the SOP involves the collection of samples, the types of containers should be included in the SOP. Where containers are to be prepared by the QP, or someone working under the QP's direction, preparation procedures should be included. Specific requirements for containers and sample volumes should be coordinated with the analytical laboratory that will be undertaking the analysis of the samples.

Procedures for the filling, handling and labelling of sample containers, and sample preservation should be provided in the SOP. For example, where samples are to be collected for analysis of volatile contaminants, the SOP should indicate that samples are to be collected without headspace and are to be closed immediately following collection. Further details on soil collection and handling requirements for analysis of volatile contaminants are prescribed in the Analytical Protocol Document.

Sample handling requirements should also clearly indicate the requirements for temporary storage and transportation of the samples prior to laboratory submission or field analysis. For example, the requirement for cooling or refrigeration of the samples should be indicated, as should the procedures for transportation, shipping container labelling and chain-of-custody completion during transport.

Procedures for the collection of QA samples should also be included in the SOP. For example, considerations such as the sequence of filling original and duplicate samples (e.g. alternating samples) should be described, as should the procedures for sample homogenization if appropriate.

4. Chemical Reagents

A description of any chemical reagents or substances required in the execution of the SOP should be provided. This section should include the specific quality or purity requirements for these reagents (if applicable), as well as procedures for the safe handling, use, and disposal of these substances.

5. Prescriptive Procedures

This section should provide a step-by-step methodology for completion of the procedure for which the SOP should be developed. Preparatory steps, including those that are required for worker health and safety (e.g. air monitoring, subsurface utility clearance, etc.) and protection of the natural environment (e.g. establishment of containment structures, etc.) should be included, as should decontamination and waste disposal procedures (if applicable).

6. Interferences and Potential Problems

   This section should describe the potential problems or sources of error that may be realized in the execution of the SOP. For example, a procedure for the sampling of material in stockpiles may caution against sampling areas (e.g. the stockpile surface) that may have undergone settling or segregation based on particle sizes, which could create a bias in the sampling results.

7. Calculations

   Any calculations that may be required in the execution of the SOP should be documented in this section. For example, an SOP for slug tests used to assess hydraulic conductivity should include a description of the methods that will be used in the numerical analysis of the data.

8. Quality Assurance(QA)/Quality Control (QC)

   This section should include a description of QA/QC procedures that will be applied to all aspects of the investigation including field sampling, sample collection handling and preservation, sample shipment, chain-of-custody records, and laboratory sampling.

9. References

   This section should include a listing of references or other information sources that can direct the user to more detailed background information.

10. Health and Safety Plan

    The SOP should include a site-specific Health and Safety Plan that must be followed by all field staff. This Health and Safety Plan should be completed prior to the start of field work.

5.2 Selection of Site Condition Standards

The selection of the appropriate site condition standards depends on several factors including:

- the property use category of the site (i.e., agricultural, residential, parkland, commercial, institutional or industrial use);
- whether a “full-depth” or “stratified” soil assessment approach is considered;

- the “potable” or “non-potable” condition of groundwater;
- proximity of the site to surface water or other environmentally sensitive features;
- the soil thickness at the property; and
- the soil texture.

Please refer to Parts I and IX of the Regulation for the definitions and conditions which must be met in selecting the appropriate site condition standards. The standards are provided in Tables 1 – 9 of the Regulation.

Figures 1 and 2 (pages 5 and 6) illustrate the steps involved in conducting an environmental site assessment and selecting the site condition standards.

5.3 Development of a Conceptual Site Model

A conceptual site model is a preliminary representation of the hydrogeological conditions at a site based on a simplified summary of the available existing information. The conceptual site model aids in the assessment and, where applicable, the remediation of a site. At a preliminary stage, data assembled during the phase one ESA will form the basis of the conceptual site model. As additional data become available during the phase two ESA, the conceptual site model can be updated and used to refine the work program.

The extent of preliminary information available to guide the development of the conceptual model can vary from site to site. At some sites, sufficient preliminary information may be available to provide a good understanding of the three-dimensional site characteristics to guide the selection of the sampling locations, both laterally and vertically. At other sites such information may be lacking, unavailable or unreliable. The QP should assess the quality and reliability of the phase one conceptual site model when planning the phase two ESA. Deviations from the phase one conceptual site model may be warranted based on a QP’s observations or independent knowledge about the site conditions; however, such deviations should be documented and justified.

5.4 Sampling and analysis plan

The planning of a phase two ESA will typically involve decisions regarding the type of sampling program to be undertaken, the locations and media that are to be sampled, the contaminants of potential concern to be analyzed based on the potentially contaminating activities identified during the phase one ESA, the methods of sample collection, and the number of samples to be collected for quality assurance and quality control purposes.

The sampling plan should be developed with the objective of assessing the potential areas or issues of environmental concern identified during the phase one ESA. The sampling plan developed prior to the start of the field work is intended to reflect good practice but it must include inherent flexibility to accommodate variations in the actual subsurface conditions. The sampling plan should be based on the conceptual site model developed on the basis of existing preliminary information, but should be flexible enough to allow modifications to or deviations from the plan to account for unexpected conditions encountered when conducting the phase two ESA. For example, it may not be desirable to drill boreholes to the depth stated in the sampling plan if gross contamination (e.g. free product) is unexpectedly encountered at a particular location. Conversely, if the achievement of the planned depth of investigation coincides with increasing contaminant levels, deeper sampling may be warranted to achieve vertical delineation.

As iterative sampling is an important component in a phase two ESA, the sampling plan developed at this stage may not reflect the final field program that is implemented. The professional undertaking the phase two ESA should not feel constrained by the sampling plan when field conditions require deviations from this initially developed plan.

6.0 CONDUCTING THE SITE INVESTIGATION

6.1 Planning for Field Sampling

All the requirements of the field sampling program should be considered during the planning stage of the phase two ESA. The program should outline the sampling method(s) that are to be used and the sample handling, storage, shipping and laboratory submission procedures. This will help ensure that consistent procedures are followed between sampling locations and when sampling is conducted by different personnel.

The planning for field sampling should result in sampling personnel having full knowledge of sampling procedures to be used, observations of field and soil conditions to be recorded, the planned sampling locations, criteria for relocating planned sampling sites, methods of recording site locations, proper containers and labelling of samples, and proper procedures for storing and delivering samples to the analytical laboratory. If deemed necessary, contact should be made with the analytical laboratory during the planning stage to verify hold times etc.

Planning for sampling should include consideration of the health and safety of the sampling personnel, the public and the environment. This includes the potential for exposure to hazardous materials, dangers posed by equipment, and field conditions for which safety protocols should be in place (i.e., excavations, encountering buried pipes and storage tanks, mobile equipment, noise etc.)

The above considerations should be documented in the SOP.

6.2 Scope of the Site Assessment

(a) Soil

Under the Regulation soil is defined as unconsolidated naturally occurring mineral particles and other naturally occurring materials resulting from the natural breakdown of rock or organic matter that are less than 2 mm in diameter (or that passes through the US No. 10 sieve).

Conversely, rock is a naturally occurring aggregation of mineral particles that are greater than 2 mm in diameter (or do not pass through the No. 10 sieve). Particles greater than 2 mm in diameter are not considered as soil for the purposes of the Regulation.

Poorly sorted coarse grained glacial deposits may be comprised of particles that are both less than and greater than 2 mm in diameter. In these situations, the QP must make a judgement based on the predominant particle size present in the deposit whether the material would meet the definition of soil and collect samples for analysis accordingly.

The assessment of soil quality is mandatory in a phase two ESA. Soil sampling and analysis will indicate whether soil conditions are appropriate for the site use or whether site remediation or a risk assessment is necessary. The results of the soil sampling will also help indicate, along with the results of the phase one ESA, if the groundwater at the property may be contaminated and should also be sampled.

Adequate planning of the sampling program must occur in order to assure that samples represent the areas and depths desired, that sample variability is properly determined and accounted for, and that there are sufficient numbers of samples at the appropriate locations to fulfill the purposes of the sampling.

Within any soil there is inherent variability in physical and chemical properties. The degree of variability varies according to numerous factors, including the size of the area, mode of contamination, the physical/chemical properties of the contaminant, stratigraphy and soil type. These factors can produce spatial variability that is considerably larger than that encountered in other media. The personnel conducting soil sampling should consider this variability in assessing potential contamination of a phase two ESA property.

Soil sampling should be conducted in all potentially contaminated areas identified in the phase one ESA. For the purpose of filing an RSC, the sampling locations should be chosen such that the contamination in each area exceeding the applicable generic site condition standards is fully delineated and the maximum level of each contaminant of concern is established. This will require the spatial distribution of sampling locations both in the area of suspected contamination and outside this area to establish the lateral extent of contamination exceeding the generic site condition standards. Similar considerations should be applied in establishing the vertical extent of soil contamination.

(b) Groundwater

Groundwater sampling in a phase two ESA is mandatory under the Regulation when the property is an “enhanced investigation property” (i.e., it is or was used as a garage, a bulk dispensing facility, including a gasoline outlet, or for the operation of dry cleaning equipment). At other properties, the QP may exercise discretion on the need for groundwater assessment. For example, if the soil is found to be impacted with metals at shallow depth with the deeper soil unimpacted, and the phase one ESA indicates that there are no contaminating activities in the vicinity of the site, the QP may decide that groundwater assessment may not be required. The rationale for not undertaking groundwater assessment should be provided. Notwithstanding the regulatory flexibility, however, it is considered good practice to conduct groundwater assessment routinely at all sites in order to establish the baseline groundwater conditions.

Sufficient monitoring wells should be installed to delineate the horizontal and vertical extent of groundwater impact. The number and depth of the monitoring wells will depend on many factors including the depth of the water table, the presence of confined and unconfined groundwater units multiple aquifers, and depth of bedrock. In general, at least one monitoring well should be installed in each potentially identified area of contamination where groundwater impact is considered likely. Monitoring wells should also be placed in the inferred upgradient and downgradient areas from the suspected source of contamination in order to establish background groundwater quality at the site and assess the likelihood of off-site impact. At least three monitoring wells installed in a triangular manner and not in a line will be required to establish the direction of groundwater flow in each groundwater unit.

The maximum depth of the monitoring wells will be determined by type of contaminant (i.e., LNAPL, DNAPL or inorganic and the presence of a confining layer or aquitard. It may be necessary to drill the wells through the confining layer to establish the vertical “clean line” for the groundwater, but this should be conducted with caution to avoid the possibility of dragging down contamination into an unimpacted groundwater unit.

The Regulation requires that contamination be delineated in groundwater in both the lateral and vertical directions. Lateral delineation typically requires a sufficient number of monitoring wells; however, vertical delineation requires the use of at least one multi-level monitoring well in at least one area of impact to establish the potential for vertical groundwater flow and depth of contamination. Additional guidance on the vertical delineation of groundwater impacts is as follows:

- In the case of combustible LNAPLs, the soil sample combustible vapour readings may be useful for targeting the vertical zone that would have the potential of having groundwater that would meet the MOE site conditions standards.
- Where possible, for combustible LNAPLs, the QP may consider relying on soil headspace combustible vapour screening results in conjunction with soil sample laboratory analytical results as sufficient evidence that vertical delineation has been achieved. For example, if all soil screening results below an observed zone of contamination are below approximately 200 ppm and laboratory analytical data for one or more samples from below the observed contamination confirm that the soil meets the applicable MOE site condition standards, then further vertical delineation may not be necessary. Where groundwater contamination is known or suspected, samples from each of multiple screened well intervals may be necessary to confirm vertical groundwater delineation.
- In the case of DNAPLs, the QP is encouraged to develop a vertical delineation plan carefully. This may include first screening the groundwater in the first confining layer below the observed contamination outside of the suspected source area rather than drilling in the source area.

If it is required to drill in the source area to undertake vertical delineation, it is important that the contamination in the source area is not transferred to greater depths during the drilling process. This is typically achieved using grout and casings and a "telescoping methodology". Further guidance on soil and groundwater assessment is provided in the following sections.

6.3 Assessment of Soil Conditions

Soil sampling should be conducted in all potential or known areas of contamination identified in the phase one ESA or from other information including field observations during the field component of the phase two ESA. The purpose of the sampling is to determine if contaminants of concern are present in soil above the applicable MOE site condition standards. The actual spatial pattern and number of soil samples will depend on the assumed distribution of the contaminants based on existing information and field observations. The depth(s) of sampling will depend on the nature and location of the source (i.e. underground vs. surface) of the contamination, soil stratigraphy and type (i.e. sand vs. clay), and type of contaminant (i.e. retardation factor; LNAPL, DNAPL or inorganic; depth to the water table; soil screening results). Soil sampling should extend laterally and vertically beyond the zone of contamination.

It is important to sample the surface soil to address sensitive receptors (e.g. toddlers) that have the highest potential for adverse affect upon exposure to this soil.

> Sites with "no soil"
>
> In some situations all soil on a property may have been excavated to bedrock and to the property boundary for the purpose of future construction purposes. In other situations, bedrock may be exposed across the entire property with no soil cover present. For such situations, the Ministry proposed an amendment to the Regulation on February 25, 2011 to allow an RSC to be filed on the basis of groundwater sampling alone if there is no soil present or the soil sampling conducted prior to excavation of the soil dose not meet the conditions for filing an RSC based on a phase two ESA. The proposal has not been adopted as of the date of completion of this site assessment guidance document. Readers should refer to the most recent version of the Regulation to ensure that they are following the regulatory provisions in force at the time of conducting their work.

6.3.1 Soil Sampling Plan Design

The soil sampling plan should be based on the available background information, usually obtained from a review of the phase one ESA, any other existing site information and visual observations of site conditions. The sampling locations should target the areas identified as potential or actual sources of contamination. Rationale for the selection of each sampling location and any deviations from the planned sampling should be provided.

This "judgement" or "focused" sampling method is the most commonly used method in phase two ESAs where potential or actual sources of contamination exist. Where such information is not available, the sampling locations may be randomly distributed across the site. At sites covered with imported fill of unknown quality the sampling locations should be selected on a systematic grid basis in order to obtain a representative indication of fill quality.

6.3.2 Soil Sampling Methods

6.3.2.1 Manual Soil Sampling Devices

Manual soil sampling may be employed to collect soil samples to a maximum depth of about one metre. Soil samples should be manually obtained from the surface soil to address concerns with dermal contact by site users with this soil. Simple tools for manual soil collection are described below.

Device	Use	Advantages	Disadvantages
Trier	Loose surface soil	Inexpensive, easy to use and decontaminate	Difficult to use in dry, stony or sandy soil
Scoop, shovel or trowel	Loose to compact surface soil	Inexpensive, easy to use and decontaminate	Difficult to use in dry, stony or sandy soil, difficult to obtain sample at a specific depth
Tulip bulb planter	Loose to compact surface soil 0 to 15 centimetres	Easy to use and decontaminate. Can provide samples with uniform diameter and volume, less soil disturbance, samples suitable for volatiles analysis	Limited depth capability, not suitable for hard soils
Soil/subsoil probe or corer (e.g. Oakfield sampler)	Loose to compact surface soils 0 to 60 centimetres	Easy to use, soil core has less disturbance, suitable for volatiles analysis	Limited depth capability, difficult to use in hard, stony soils, decontamination requires more effort
Dutch auger (hand auger)	Surface soils to approximately 1 metre	Can be used to greater depths than above equipment, can be used in more firm and cohesive soils	Borehole walls may collapse under certain soil conditions, soil mixing occurs, not suited for volatiles

6.3.2.2 Mechanical Soil Sampling Devices

Auger drills

Truck-mounted drills are used for deeper soils. They include hollow stem and solid stem augers. Hollow stem augers are commonly used as soil sampling can be conducted by inserting a sampling device through the hollow stem. Solid stem augers may be used in formations such as hard tills where the borehole does not collapse when the stem is removed to permit the taking of discrete soil samples. However, solid stem augers are typically not used for environmental investigations.

Direct-push device

Soil samples can also be collected from a discrete depth using the Geoprobe® direct push sampling system. The device is capable of recovering a discrete soil core contained inside a sampling tube fitted with a drive shoe. The sampling tube can be split into two halves to expose the soil core.

Hydrovac or Daylighting

Hydrovac or daylighting involves removal of soil using a high-pressure water jet. This method is used when drilling is required near underground buried utilities and sensitive infrastructure. The daylighting exposes the buried infrastructure allowing decisions for the safe collection of soil samples to be made.

Backhoes and Excavators

Test pits or trenches excavated with a backhoe or excavator offer the capability of collecting soil samples from very specific intervals and allow visual observations of in-situ soil conditions. The maximum depth of a test pit that can be excavated with a backhoe is generally up to 5 metres.

6.3.3 Soil Sample Collection Devices

Split Spoon

The split spoon sampler is a split cylindrical barrel, typically 0.5 m to 0.6 m long and about 5 cm in diameter that is threaded at both ends. The leading end has a bevelled cutting shoe and the other end can be attached to the drill rod. An auger drill rig is used to advance the borehole to a target depth. The auger stem is removed, and the spoon is attached to the drill rod. The drill rig hammer is then used to drive the split spoon into the soil at the bottom of the borehole filling it with soil. The split spoon is then withdrawn, from the borehole, removed from the drill rod and opened for sample collection. Typically, a split spoon sample is collected for every 0.75 m borehole depth increment although the frequency of sampling can be determined by the QP. Split spoons may be fitted with basket or spring retainers to improve ample recovery in non-cohesive soils.

Shelby Tube

A Shelby tube is a thin-walled push tube with a ball-check to aid in holding the sample during retrieval. Shelby tubes are typically used in geotechnical investigations where undisturbed samples of non-cohesive soils and clays are required. The tube is pressed into the undisturbed clay or silts by hydraulic force applied to the end of the drill rod to which the tube is attached. If samples for chemical analyses are required, the soil inside the tube is removed for sample collection. If geotechnical parameters are required the tube is capped and sent to the geotechnical laboratory.

6.3.4 Collection of Soil Samples from Boreholes

Once the split-spoon that is driven into the borehole for sample collection is opened, soil recovery and soil classification observations are made and recorded. The top several centimetres of material in the spoon are discarded before removing any portion for sampling as this material normally consists of material that has sloughed-off from the borehole wall after removal of the augers. When sampling the soil core from the split-spoon sampler, a decontaminated stainless steel sampling device (i.e., a putty knife, trowel, spoon or similar implement) should be used. The sample should not be touched by bare hand or gloves and contact and handling of the sample should be kept to a minimum. Any smeared soil on the outer layer of the core should be removed using the sampling device, prior to sampling the soil (to limit the potential for cross-contamination). If possible, the sample core should be split longitudinally, along the length of the split-spoon sampler. If varying levels of contamination or varying soil types are observed within the length of the split-spoon core sample, then a sample should be taken from each distinct zone within the split-spoon sample.

The collection of soil samples for the laboratory analysis of volatile contaminants possesses the greatest risk of the loss of contaminants due to the disruption of the soil matrix within the split-spoon during handling. It is not recommended that the soil be exposed for an extended length of time (i.e. >2 minutes) once the split-spoon has been opened if the soil is to be used for soil headspace vapour measurements or laboratory chemical analysis of volatile contaminants.

Note that every split-spoon sample taken from a borehole does not need to be submitted for laboratory analysis; however, it is required that sufficient samples be analyzed to permit the vertical delineation of contamination. The sample submitted to the laboratory must not be that used for field vapour screening. Typically, all split spoon samples are split in field with one portion used for field screening and the other portion being place in laboratory supplied containers for potential laboratory analysis.

Samples being submitted to the laboratory for the analysis of volatile contaminants should not be composited or mixed in the field. These samples should be transferred to pre-charged soil sampling containers with methanol preservation or hermetically sealed sampling devices. The sample containers should be kept cool with ice.

For boreholes, it is best practice that a minimum of one sample for each borehole be sent to the laboratory for the analysis of the contaminants of concern. The following procedures should be followed:

If contamination is not detected in the borehole samples based on field screening (i.e. physical observations, soil headspace vapour screening results, etc.), one sample should be submitted from the borehole.

If contamination is detected in the borehole samples based on field screening, the sample with the highest apparent level of contamination should be submitted and the sample from the first suspected non-impacted interval underneath the contaminated zone should also be submitted in order to provide vertical delineation of the contamination.

6.3.5 Collection of Soil Samples from Test Pits

Test pits can be a good method of assessment and are often used prior to drilling, allowing the QP to better select drilling locations. Test pits have the advantage of providing better observations of the subsurface and larger soil samples. Test pits should not be used for groundwater assessment.

A test pit should be advanced until field screening indicates there is no evidence of contamination. Where possible, a test pit should be advanced to a sufficient depth to provide vertical delineation unless the depth of contamination is beyond that which can be assessed with the excavator.

Soil samples from test pits should be collected from the excavator bucket. It is unsafe to enter a test pit or stand near the test pit. Caution should be exercised when collecting the samples and measuring the depths from which they were taken. In order to collect a discrete sample using and excavator a sample should be collected from single point at the base of the test pit. This is done by first advancing the test pit to the desired depth and clearing its base such that sloughing and collapse of soil is not occurring. Then the operator should provide relatively small (i.e., compared to the bucket) volume of soil from a discrete position and depth and minimizing disruption of the soil. This is preferred to filling the excavator bucket with soils scraped from the entire depth interval being sampled. Often the soil on top of the tooth of a bucket is sufficient for sampling.

When the soil sample is being collected, a clean pair of nitrile gloves should be worn and a stainless steel sampling device should be used to scrape off the surface soil. The soil sample should be transferred into a sample bottle or a plastic bag if it is to used for field screening. At least one sample should be collected from each test pit. However, two or more samples may be collected if contamination is encountered, in order to achieve vertical delineation. At sites with LNAPL contamination, it is recommended that soil samples be collected near the water table.

When excavating a test pit, contaminated and uncontaminated soils should be kept in separate stock piles based on field screening. After completion of the test pits the soils excavated should be backfilled into their approximate original positions. A test pit should be nominally compacted using the excavator bucket in 0.3 m to 0.6 m lifts. Heavily contaminated soil may be segregated and removed from the site.

6.3.6 Collection of Soil Samples from Excavations

Soil samples are typically collected from excavations during the removal of infrastructure or remedial actions requiring removal of soil for off-site disposal or ex-situ treatment.

Verification sampling of the walls and floor of the excavation may be conducted to confirm the limits of the contamination. This typically involves dividing walls and floors of the excavation into a grid pattern. If possible, soil samples may be obtained from the walls of the excavation using a scoop fixed to pipe and lowered into the excavation. It is more practical however to collect samples directly from the backhoe bucket at each desired sampling interval. The soil sample should not be taken from the centre of the bucket and not near the edge of the bucket in order to minimize the possibility of cross contamination due to smearing of soil along the wall of the excavation.

Schedule E, Table 3 of the Regulation provides the minimum confirmation sampling requirements for floors and walls of excavation as follows:

Floor Area (m^2)	Floor Samples	Sidewall Samples
<25	2	2
25-50	2	3
50-100	3	3
100-250	3	5
250-500	4	6
500-750	4	7
750-1000	5	8

6.3.7 Sampling from Soil Stockpiles

Materials in soil stockpiles may be intended for reuse on a property as backfill, either in its current form or once actions to reduce the concentrations of contaminants have been completed, or may be intended for use at another property. The Regulation specifies the frequency of required sampling, but does not prescribe the procedures for characterizing stockpiled materials.

As a general principle, the sampling of stockpiles should consider that segregation of materials by grain size may occur during materials handling and stockpiling. Materials at or near the surface of the stockpile may be rain-washed or otherwise segregated, and should therefore not be considered as representative of the stockpile contents. In general, surficial materials should be avoided during stockpile sampling. Prior to the collection of samples, the upper 0.3 to 0.6 metres or more of the surficial material should be removed from the area to be sampled. Similarly, the bottom 25% of the stockpile should be avoided, as coarser material may have segregated out of the pile (USACE, 2001). Sampling of this material may under-represent the concentration of contaminants that may be associated with the finer fractions of the stockpiled materials.

The characterization of stockpiled materials is generally most representative if the sample density and/or volume are increased (USACE, 2001). Characterization of stockpiles is best conducted by the collection of multiple samples throughout the stockpile. This may be accomplished by subdividing each stockpile into an array of grid cells or zones, and selection of specific cells for sampling using a random number generator. It is preferable to use powered sampling equipment to allow for collection of samples deeper within the stockpile. Samples collected for analysis of volatile contaminants of concern (e.g. VOCs) should be collected as grab samples. Samples collected for analysis of less volatile contaminants can be composited if appropriate to provide overall characterization of the stockpiled material.

As an alternative to the collection of samples within the entire stockpiled volume, and particularly if the use of powered equipment to sample deeper within the stockpile is not feasible, then it may be possible to assign numbers to zones along the perimeters of the stockpile at various height intervals within the stockpile (e.g. ¼, ½, and ¾ of the stockpile height, or 1/3 and 2/3 of the stockpile height), and to select specific intervals and locations for sampling using a random number selection algorithm. Sampling using manual equipment should include methods to reduce the potential for ravelling of material into the sampling area from higher within the stockpile. For example, a board or form may be driven into an area above the sampling location in order to achieve this objective.

For the collection of composite samples, the use of clean disposable gloves compatible with the type and level of contamination is advised. All of the samples to be composited should be combined into a chemically compatible vessel (e.g. a stainless steel bowl or container). Liquids should be drained away, and vegetation or other non-soil materials (e.g. vegetation, debris, etc.) should be removed (MDA, 2005). The subsamples should be combined in approximately equal proportions and transferred to laboratory-supplied containers for analysis.

Table 2 in Schedule E of the Regulation provides the following minimum stockpile sampling frequency

Pile Volume	Minimum Number of Field Screening Samples	Minimum Number of Samples for Laboratory Analysis
< 50m^3	5	1
>50m^3 to150m^3	15	3
>150m^3 to 500m^3	30	5
>500m^3 to 1500m^3	50	10
>1500m^3	75	15

It should be noted that these are the minimum number of samples to be taken for characterizing soil within the stockpile. The QP should therefore exercise professional judgement in deciding whether a higher sampling frequency is needed based on visual observations and a history of the origin of the soil, if available. The presence of some contaminants in soil, e.g. metals, is not easily discernible through field screening. This should be taken into account in assessing the reliability of field screening in such situations. A higher sampling frequency may be warranted if contaminants not easily discernible through field screening are likely to be present. The sampling frequency would also depend on the final disposition of the soil. For example, a higher sampling frequency may be warranted if the stockpiled soil is to be used in a residential setting as opposed to its disposal as waste in a landfill site.

6.3.8 Composite Soil Sampling

Composite soil sampling involves combining two or more discrete soil samples into a single composite sample in order to obtain a better representation of soil quality. The average of soil quality of two or more soil samples may be used to better represent the soil quality at a sampling location. The Regulation defines a "sampling location" as an area of the property that does not have a radius larger than two metres. The soil samples used for averaging of soil quality should be collected from the same depth horizon and within an area of less than two metres in radius.

Compositing of soil samples for assessing volatile contaminants should not be done as this would result in loss of the volatiles.

6.3.9 Handling of Soil Samples

Soil samples should be handled in accordance with the SOP.

For soils being analyzed for organics with very low regulatory limits (such as polycyclic aromatic hydrocarbons (PAHs), pesticides, herbicides, and dioxins/furans), the soil should not be touched by a glove made from a plastic (e.g. latex, nitrile). For these parameters, the soil should only be in contact with a clean stainless steel sampling device (e.g. a putty knife, trowel, or spoon). For soils being analyzed for organics with higher regulatory limits (such as petroleum hydrocarbons (PHC) and benzene, toluene, ethylene, xylenes (BTEX)), contact with clean gloves is acceptable, but such contact should be minimized.

Samples being submitted to the laboratory for VOC analysis should not be composited or mixed in the field. Discrete grab samples should be taken from soil that best represent the contamination of the sampling location and then transferred directly into containers. Sample containers being submitted to the laboratory for analysis of volatiles analysis contain zero headspace (i.e., packed tightly with soil).

6.3.10 Analysis of Soil Samples

6.3.10.1 Visual and Physical Observation of Soil Samples

Visual observations of soil samples should be made and the results recorded in the field log. The visual observations should include any evidence of staining, discolouration or phase-separated contaminants (e.g. free petroleum product in the soil sample). Debris, foreign materials and similar inclusions should also be recorded in order to gain an understanding of the soil characteristics. Observations on soil texture and soil colour should also be included. The results of visual observations should be included in test pit logs, borehole logs and, if deemed necessary, excavation floor and wall drawings contained in the report that is prepared to summarize the field work that was performed.

Any chemical odours that are observed in the normal course of collection of the soil samples should be recorded. For health and safety reasons, it is recommended that samples should not be deliberately and directly smelled to make such observations. It is only necessary to note such occurrence when noticed in the ambient air and as such adjectives such a “mild, weak or strong” are not necessary.

6.3.10.2 Soil Screening Instruments

Field screening instruments may be used to obtain a preliminary indication of contaminant levels in the soil samples. The instruments include Photo-Ionization Detectors, Flame Ionization Detectors, Combustible Gas Detectors, Field Chromatographs, Colourimetric Detectors, Immunoassay, and X-Ray Fluorescence. A description of the theory and application of these instruments can be found in the Environment Canada publication - TAB # 6: Alternative Field Screening Methods. Information obtained using screening instruments should be considered as “semi-quantitative” and is intended to be used in guiding assessment activities. Screening information must not be used for assessing whether or not a property meets a Site Condition Standard.

A recommended procedure for VOC field screening is described below.

6.3.10.3 VOC Soil Screening Methodology

During drilling or test-pitting, soil samples should be collected from each stratigraphic unit of interest and logged for soil type and staining. Care must be taken to minimize losses of volatile components during sampling and storage prior to determining soil head space vapour measurements. The split sample method is recommended, with one sample screened for head space vapours and the other potentially being submitted for laboratory analysis. As discussed previously, discrete samples must be taken in order to minimize the loss of volatile components. For excavations, it is recommended that samples be collected from at least 0.1 metre below the surface of the wall or excavation floor.

The instrument manufacturer’s recommended procedure for preparing and calibrating the instrument and using it in the field should be followed. Any filters and connections in the instruments probe attachment should also be inspected daily. Performance based criteria should be part of the consultant’s operating practices for operating the instrument. If the performance based criteria are not met, the instrument should be recalibrated or repaired such that it meets the criteria before being used for soil field screening. The methane elimination efficiency should be checked at least quarterly,

The Qualified Person should be aware of the applications and limitations of screening techniques, and should choose the field screening instrumentation most appropriate to the type of contaminant(s) anticipated.

The following procedure may be used for screening soil samples for VOCs:

- Soil should be placed immediately into a small plastic bag to about one quarter full with soil and be tightly sealed leaving a nominal headspace;
- Break apart chunks of soil by manually kneading the soil within the closed bag;

- Allow the soil vapours to equilibrate for a few minutes before conducting the headspace readings. (In winter the plastic bag and soil may require warming (i.e., in a vehicle with the heater on) before taking the screening measurement) ;
- Insert the combustible gas detector probe into the headspace in the bag while preventing VOC/air leakage; and
- Record the peak headspace vapour concentration measured.

The soil screening bags should not be exposed to direct sunlight for an extended period of time and should not be stored until the end of the day in order to perform soil screening measurements all at once.

Soil from the plastic bags should not be submitted for laboratory analysis of VOCs, but may be used for analysis of non-volatile contaminants or physical parameters (e.g. grain size analysis).

QPs should refer to Analytical Protocol Document for further guidance on VOC sampling procedures.

6.3.10.4 Soil Texture

Soil texture (grain size) should be assessed because some of the site condition standards are based on soil texture. The standards are generally more stringent for coarse-grained soils compared to medium/fine textured soil. The selected soil texture must be applicable to at least two-thirds of the site being assessed. If the QP is intending to use the fine/medium soil textural standards, then it is a mandatory requirement of the Regulation that grain analysis is conducted.

Soil texture can normally be determined in the field based on visual observation. At least one representative soil sample from the soil horizons of concern or most frequently sampled soil interval should be collected for laboratory analysis using the ASTM Method # D24587.

The QP should take into account the overall hydrogeological setting in classifying the site based on texture and be aware that conduits or sand lenses may be the dominant factors in contaminant transport. Where such conditions are likely to be present or when there does not appear to be good correlation between the overall borehole stratigraphy and the soil texture measurements, the QP should consider using the generally more stringent coarse-grained texture for the purpose of selecting the applicable soil standard.

6.3.10.5 Laboratory Analysis of Soil Samples

A sufficient number of soil samples should be collected and sent to an accredited analytical laboratory for chemical analysis to fully delineate the contamination at the site. The findings of the phase one ESA, visual observations of the soil samples, field screening results and the QP's own judgement will guide the number of soil samples collected for analysis and the range of contaminants to be analyzed.

A representative number of samples should be analyzed for pH, as this parameter affects the mobility of soil contaminants. It is recommended that at least one soil sample be collected for pH analysis from the surface soil (0 -1.5m) and one sample from the sub-surface soil (> 1.5m) from within each identified contaminant source or potential contaminant source area on the property.

The QP should note that there is a mandatory requirement in the Regulation to collect one duplicate soil sample for each ten soil samples submitted to the laboratory. However, QPs should note that soil heterogeneity may affect the range of analytical results reported between the original sample and the duplicate sample. For non-volatile contaminants, homogenization of samples may provide a more representative indication of variability attributable to the sampling and analysis program.

6.4 Groundwater Assessment

A basic understanding of the site hydrogeology is a first step in groundwater assessment at the phase two ESA property. A hydrogeological conceptual site model developed on the basis of existing information will aid in determining the monitoring well placement strategy to obtain data on the groundwater conditions.

6.4.1 Design of a Groundwater Sampling Program

The objective of a groundwater sampling program in the context of a phase two ESA under the Regulation is to determine the groundwater quality at a site in relation to the applicable potable or non-potable groundwater site condition standards. The assessment should also consider the potential for migration of contaminants both onto the property and to off-site properties.

The number and location of groundwater monitoring wells required to establish the groundwater quality will vary, depending on the complexity of the site hydrogeology, and the location and extent of the contaminant sources or areas of concern identified. In general, the following monitoring well placement strategy should be considered:

- An up-gradient monitoring well, preferably at the property boundary, to characterize background groundwater quality;
- One or more wells within the contaminated areas;
- Cross-gradient wells on either side of the contaminated area , to define the lateral extent of contamination;
- One or more wells down-gradient from the areas of contamination;
- Nested wells to assess vertical groundwater flow.

  In developing a groundwater sampling program, the QP may incorporate the use of existing monitoring wells, if these wells are in good condition.

6.4.2 Monitoring Well Installation

6.4.2.1 Regulatory Requirements for Monitoring Well Installation and Abandonment

The regulatory requirements for monitoring well installation and abandonment are prescribed under Ontario Regulation 903. The regulation specifies requirements for licensing of well drillers and contractors, submission of well drilling records to the Ministry of the Environment, and abandonment of the monitoring wells when they are no longer needed. The submission of the well drilling and abandonment records is the responsibility of the licensed well drillers conducting the work.

6.4.2.2 Monitoring Well Drilling Methods

The truck-mounted hollow stem auger drilling method is the most commonly used drilling technique for installing groundwater monitoring wells at a phase two ESA property. This method is preferred because it is simple to use and does not require any drilling fluids or air that could affect groundwater quality. Portable, hollow and solid stem drilling rigs or direct push drilling equipment can be used for shallow sampling or when truck-mounted drilling equipment cannot be used. "Direct-push" drilling and sampling may also be considered.

Other drilling methods include air, water and mud rotary drilling techniques. These methods may be used in difficult conditions (e.g. bouldery formations) or for bedrock, but their use for a phase two ESA is less common. These methods introduce fluids which can affect the quality of groundwater; hence the monitoring wells should be properly developed prior to sampling. In addition, air rotary drilling may result in the stripping of VOCs and further migration of contaminants. Where drilling fluids are used, the QP should ensure that contaminants are not introduced into the subsurface.

If monitoring wells are installed in grossly contaminated areas, suitable drilling and well installation measures should be implemented to prevent migration of contamination from the soil down to the water table and deeper into lower hydrostratigraphic units.

Well construction materials should not be stored directly on the ground, or in the vicinity of potentially contaminating materials (e.g. soil cuttings, waste drums, etc.). Monitoring well materials (e.g. PVC risers and screens) should be kept in the original manufacturer's plastic sleeves as long as possible to minimize the potential for contamination. Latex, nitrile or cotton gloves are recommended for use while handling monitoring well materials and should be discarded if they become contaminated.

6.4.2.3 Monitoring Well Construction

A monitoring well consists of the well casing and the well screen. The well casing provides access from the surface to a sampling location (i.e. the well screen) in the subsurface. The well casing is also commonly referred to as the well riser. The well casing (and associated seals and grout) prevents collapse of the borehole and inter-zonal hydraulic connection. The monitoring well casing and screen provide access to the groundwater at the zone of interest in the subsurface.

The fundamental parameters associated with the design of a monitoring well include:

- Borehole and well diameters;
- Screen length and location;
- Well casing and screen materials; and
- Screen slot size and filter pack.

Borehole and Well Diameters

The monitoring well is installed within a borehole drilled into the ground to allow for monitoring within a specific hydrostratigraphic unit of interest. The diameter of the borehole should be sufficiently large to accommodate the monitoring well casing, annular materials and tremie pipes used for filter pack or seal placement. The borehole diameter must be such that the annular space surrounding the monitoring well conforms to O.Reg. 903.

The diameter of the monitoring well (installed within the borehole) will be governed by the purpose of the installation. In general, wells installed for monitoring groundwater should be at least 2.5 centimetres (1 inch) in diameter, and are typically 5 centimetres (2 inches) in diameter. This allows small diameter bladder pumps, bailers, or inertial pumps to be installed. Wells of smaller diameter should be avoided, but may be used at the discretion QP.

Screen Length and Placement

The monitoring well screen length should be consistent with the desired monitored interval and geologic conditions encountered (i.e. stratigraphy and water table elevation). Screens should not straddle multiple hydrostratigraphic units, and must be properly sized and placed to avoid creating preferential pathways for contaminants to migrate between hydrostratigraphic units.

It is recommended that shallow water-bearing horizons be characterized first before drilling into deeper formations, if groundwater characterization of the deeper formations is required. It may be necessary to seal the shallower formations by grouting, installing casings or using inflatable packers to prevent cross-contamination.

Typical well screens are 1.5 to 3.0 metres (5 to 10 feet) in length. The Regulation requires that the length of the well screen within the saturated formation not exceed 3.0 m. Considerations for the length or placement of a well screen include:

- Monitoring for LNAPL at the water table may require longer well screens because of seasonal fluctuations in water table elevations;
- Monitoring for evidence of DNAPL in an aquifer typically involves placement of well screens at the bottom of the aquifer, directly above the aquitard;
- Monitoring for geochemical parameters may require shorter well screens in aquifers where geochemical conditions vary significantly with depth, to reduce the potential for mixing of water from distinct vertical geochemical zones; and
- Well screens that are excessively long in the saturated zone may misrepresent the chemistry of dissolved contaminants by mixing impacted and non-impacted

groundwater from different depths within the aquifer. The potential for well bore dilution should be considered by the Qualified Person in the design of all wells.

- Short well screens placed near the top of the water table are preferable for assessing the potential for partitioning of vapours from groundwater to soil gas.

Well Casing and Screen Materials

Polyvinyl chloride (PVC) is the most commonly used material for monitoring wells used for assessing groundwater quality at brownfield sites in Ontario. It is made of sturdy, lightweight construction and can easily be threaded for joining casing sections.

High (parts-per-thousand) concentrations of some organic chemicals may degrade PVC. In cases where conditions are too harsh to use PVC casings, the QP may consider the use of other monitoring wells made of other materials (e.g., stainless steel or Teflon)

Well Screen Slot Size and Filter Pack

The well screen slot size should be designed based on the materials used in the filter pack (also referred to as a sandpack) adjacent to the screen. The filter pack is intended to minimize the entry of soil particles into the well during sampling and is selected based on the geologic materials in which the monitoring well is screened. The filter pack is an inert granular material with a grain size and gradation selected to stabilize the hydrogeologic unit adjacent to the screen. ASTM Standard D5092-90 (ASTM, 2001) provides specifications for designing the well screen slot size and filter pack.

The elevation of the top of the filter pack is to be selected in the field based upon the geologic conditions encountered. For shallow overburden wells, it is common to extend the filter pack to above the top of the water table to account for the anticipated seasonal fluctuation of the water table. In deeper overburden wells, the filter pack should span the length of the specific hydrogeologic unit that will be monitored. The filter pack should not extend through a confining layer, causing two or more separate permeable layers to become connected. Where practical, the filter pack should extend a minimum of 0.6 metre (2 feet) above the top of the well screen.

As a general practice, filter socks should not be installed over monitoring well screens. The filter sock may reduce the measured hydraulic conductivity in coarse-grained formations and can physically entrap contaminants with high viscosity. Filter socks should only be used when fine particulates are adversely affecting analytical results and all other methods of reducing these fines in the groundwater sample (e.g. optimizing the sand filter pack/well screen slot size combination, trying alternate well development methods or using low-flow sampling methodologies) have not been effective. In general, the proper installation and development of a well should be adequate to minimize the amount of sediment entering the well.

Multi-Level Monitoring Wells

In some cases, sampling from multiple discrete intervals at a given location may be required using multi-level monitoring wells. Such wells may be installed within a single borehole with the well screens placed at varying depths and properly sealed to isolate the zones where separate groundwater samples are required. Multi-level monitoring wells may also be placed at varying depths in closely-spaced boreholes.

Filter Pack

When placing the filter pack into the borehole, a minimum of 0.15 metre (6 inches) of the filter pack material may be placed under the bottom of the well screen to provide a firm base. In cases where DNAPL is present, it may not be desirable to have a filter pack "sump" beneath the well and therefore this requirement may not be followed. The elevation for the top of the filter pack should be selected in the field based upon the geologic conditions encountered; however, is typically 20% of the screen length or 0.6 m (2 feet).

When selecting a filter pack material, Section 6.3.1 in ASTM standard D 5092 (Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifer) may be consulted; however, in most situations commercially available silica sand is adequate for most applications.

Bentonite Plug and Annular Seal

After the filter pack has been installed, a bentonite plug should be placed directly on top of the filter pack to prevent water draining from the annular seal into the well screen and affecting the monitoring results. The annular seal is a low permeability material which is placed above the bentonite plug between the well casing (i.e. riser pipe) and the borehole wall to maintain alignment of the well.

Surface Completion

The ground surface around the monitoring well should be sloped to drain surface water away from the well. A protective casing and lockable well cap should be installed to protect the well and prevent unauthorized access.

Above ground installations (monument casings) and flush mount casings are available. Leaving an unprotected PVC riser sticking above the ground surface is not recommended, unless the site is secure and has no vehicular traffic in the area of the monitoring wells.

Monument Casings

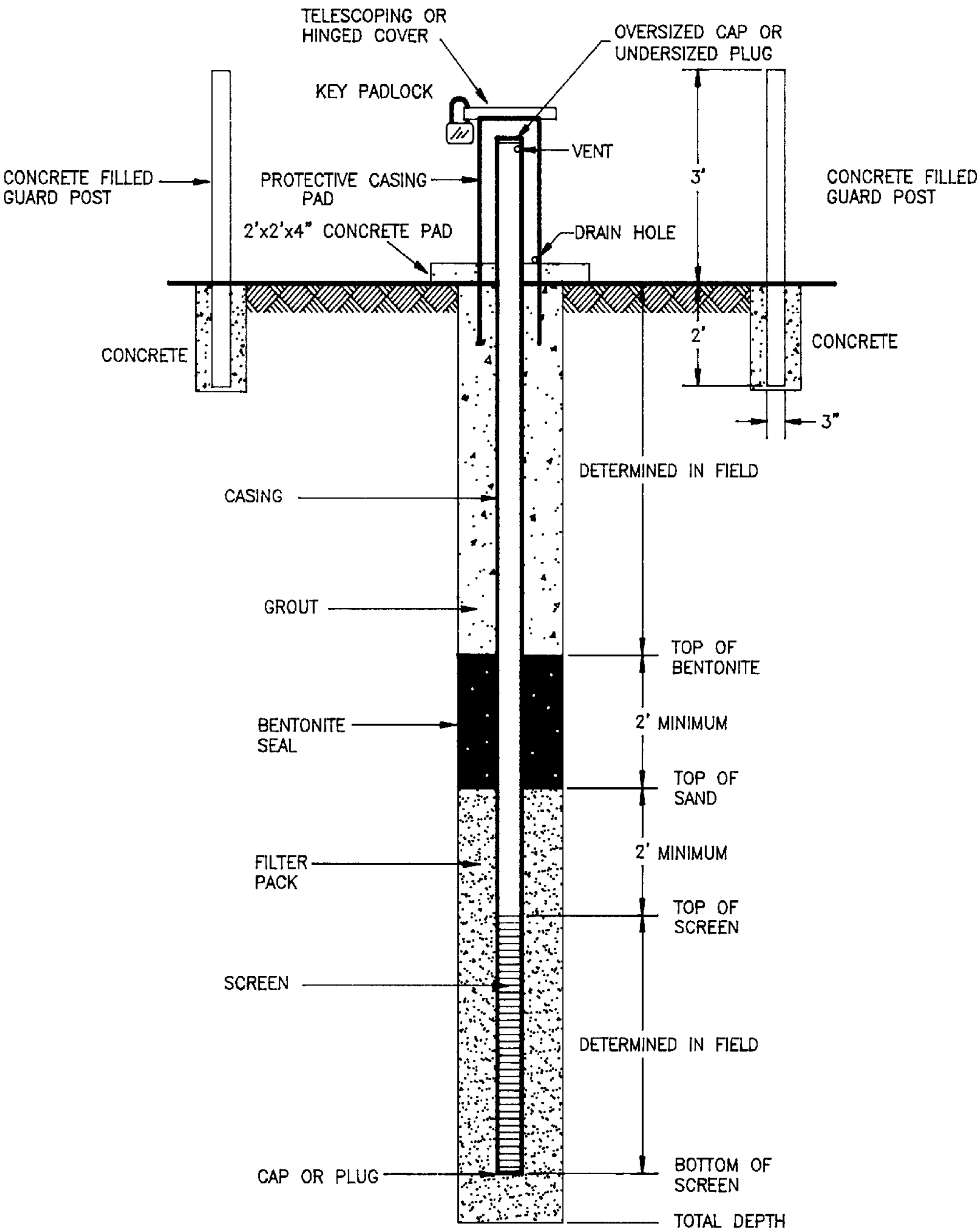
Above ground installations, such as monument casings, are often preferred. These offer the advantages of better visibility, less maintenance, and fewer problems associated with water intrusion and freezing within the casing. Monument casings can be installed to a greater depth below ground surface, and are therefore less susceptible to frost heave.

Above ground risers should be protected by steel monument casings that have been sealed into the ground with concrete. The steel monument casing should have a lockable cap. The PVC riser should be capped inside the monument casing.

Flush Mount Casings

Flush mount installations are usually necessary in areas with vehicular or pedestrian traffic. They are also preferred in some sites for aesthetic reasons. A lockable cap should be installed on the riser, inside the flush mount casing. This will discourage vandalism of the monitoring well. When installed in the street or any other area with high vehicular traffic, the flush mount casing should have sufficient strength to avoid being damaged. Avoid casing with brass lids in this settings as these are prone to damage to vehicular traffic.

A typical monitoring well construction is shown on the next page. (*Source: USEPA SOP#2048)*


TELESCOPING OR
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OVERSIZED CAP OR
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KEY PADLOCK
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CONCRETE FILLED
GUARD POST
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GUARD POST
2'x2'x4" CONCRETE PAD
DRAIN HOLE
2'
CONCRETE
CONCRETE
3"
DETERMINED IN FIELD
CASING
GROUT
TOP OF
BENTONITE
BENTONITE
SEAL
2' MINIMUM
TOP OF
SAND
FILTER
PACK
2' MINIMUM
TOP OF
SCREEN
SCREEN
DETERMINED IN FIELD
CAP OR PLUG
BOTTOM OF
SCREEN
TOTAL DEPTH

6.4.2.4 Monitoring Well Development

The primary goal of well development is to ensure that water extracted from the well is representative of groundwater conditions in the formation surrounding the well.

The objectives of well development include:

- Rectify clogging or smearing of formation materials that occurred during drilling of the borehole;
- Stabilize the formation and filter pack materials;
- Retrieve lost drilling fluids;
- Improve well efficiency (i.e. the hydraulic connection between the sandpack and the formation);
- Restore physical properties of the formation that may have been disturbed during the drilling process; and
- Grade the filter pack to effectively trap fine particles that may otherwise interfere with water quality analyses.

6.4.2.5 Monitoring the Well Development Process

Well development typically requires the removal of three to ten well volumes of groundwater or, if low yielding, pumping the well until it is dry up to three times over a one to two-day period (i.e. typically 10 to 30 well volumes). The groundwater elevation in the pumped well should be allowed to reach static equilibrium before a subsequent round of pumping is initiated.

For the purpose of phase two ESA monitoring wells, which are not water supply wells, the removal of a maximum of 10 well volumes is often considered the cut-off for development efforts unless monitoring indicates that continued pumping will improve the representativeness of the water being pumped from the well.

Development is considered complete once the groundwater is silt-free (or no further improvement is observed). Silt-free conditions may not be attainable in wells screened in fine-grained soils. Stable levels of measured field parameters such as pH, temperature, specific conductance, dissolved oxygen and turbidity may also be used to determine the cut-off of well development. However, it is often difficult to determine when stabilized measurements are attained, hence these measurements may not always provide good indication of stabilized conditions and the QP may decide when well development is considered complete based on the volume of water removed.

If water is introduced into the formation during the borehole or well installation processes, then sufficient water should be purged to also ensure that all water added to the formation has been removed and representative groundwater samples can be obtained. Due to mixing with formation water this may require up to three times the water lost.

A record of the well development process should be kept.

6.4.2.6 Monitoring Well Development Methods

Monitoring well development methods include pumping and over-pumping, surging, bailing, airlift pumping and air or water jetting. The most typical methods used for well development are:

- Pumping and over-pumping;
- Bailing;
- Surging; or
- Combinations of the above.

Methods that use one-directional flow (pumping or over-pumping) may produce bridging of particles within the filter pack. Methods that induce flow reversal (surging, bailing, jetting) are preferred and will produce a stable filter pack. Any standard well development method is considered acceptable provided that the goal of obtaining representative formation water is achieved.

The use of air jetting as a well development method is not recommended for sites where sampling of VOCs or geochemical parameters is to be conducted. Air-jetting introduces air into the formation water, which can cause volatilization of VOCs and other changes to groundwater geochemistry through oxidation.

Pumping and Over-Pumping

The easiest, least expensive, and most commonly employed technique of monitoring well development is some form of pumping.

Pumps that may be used for well development include submersible pumps, centrifugal pumps, or manual and mechanical inertial pumps. During development by pumping, the pump intake is raised and lowered through the length of the screened interval. This will ensure that the sandpack surrounding the entire length of the well screen is properly developed. For a typical 3 m screen installed under the Regulation, this would involve developing at least two positions over the screened interval.

During the development process, the initial water removal should be slow and gentle. Water should be removed with increasing vigour as the well is developed. Well development requires a sufficient application of energy to disturb the filter pack, freeing the fine particles and allowing them to be drawn into the well. The coarser fractions then settle and stabilize the well screen. The well should ultimately be pumped at a rate that is higher than the anticipated sampling rate.

Limitations to pumping and over-pumping include:

- Pumping or over-pumping alone may not adequately develop a well. Only one-directional flow is produced which can cause bridging in the filter pack and formation; and
- The presence of fines in well purge water may damage some types of pumps.

Due to its low cost and simplicity, pumping and/or over-pumping are the well development methodologies that are typically used during the development of groundwater wells at most phase two ESA properties.

Bailing

In relatively clean, permeable formations where water flows freely into the well, bailing can be an effective development technique. The bailer should be of sufficient weight to free fall through the water column. The bailer is allowed to fall freely through the monitoring well. The displacement caused by the bailer produces an outward surge of water proportional to the volume of the boiler. This tends to break up bridging that has developed within the formation.

As the bailer fills and is rapidly withdrawn, the drawdown created in the borehole causes the particulate matter outside the well intake to flow through the well intake and into the well. Subsequent bailing removes the sand and other particulate matter from the well. Bailing should be continued until the water is free from suspended particulate matter, or until the level of particulates ceases to change.

Surging

Surge blocks can be used to destroy the bridging of the fine formation particles and to create the agitation that is necessary to develop a monitoring well. A surge block is used alternatively with either a bailer or pump, so that material that has been agitated and loosened by the surging action is removed; however, it is now possible to purchase inertial pumps equipped with a surge block so that this material can be removed during surging.

The surge block assembly should be of sufficient weight to free fall through the water in the well and create a vigorous outward surge. Surging begins at the top of the well screen so that sand or silt loosened by the initial surging action cannot cascade down on top of the surge block and prevent removal of the surge block from the well.

Surging however is not commonly used to develop monitoring wells. Not all drill rigs have the capability to move the surge block at progressively increasing speeds (which is required when developing a well) and additional time and care is needed to thoroughly clean the surge block to prevent cross-contamination between monitoring wells.

6.4.2.7 Monitoring Well Survey and Documentation

Once the well is installed, a survey should be conducted to define the elevation and horizontal position of each new monitoring well location. A permanent survey point, usually the top of the casing should be used as the reference point for all groundwater level measurements. A survey referenced to an established geodetic benchmark is required under the Regulation.

A record of the monitoring well installation and development process should be kept. This should include: monitoring well identification, date, depth of borehole, and well construction details.

6.4.3 Groundwater Sampling Methods

6.4.3.1 Groundwater Level Measurement

Static water levels should be obtained prior to monitoring well sampling each time the monitoring well is sampled. Water levels in monitoring wells should be allowed to stabilize a minimum of 24 hours after well construction and/or development before measurement.

Water levels should be accurately measured, using an electronic water level detector, measuring tape or other device with similar accuracy.

Measurement of the groundwater level should be conducted prior to purging of the monitoring well, as water levels may not return quickly to the original water level after purging of the monitoring well.

Water level measurements used to define the elevation of the water table or potentiometric surface at a site should be collected within the same day, if possible, in order to minimize the effects of changing barometric pressure. The water level measuring device should be cleaned after each measurement in order to prevent cross-contamination between monitoring wells.

6.4.3.2 NAPL Layer Detection

At sites with potential NAPL contamination, NAPL and its thickness can be detected in conjunction with water level measurement by using an interface probe.

A transparent bailer fitted with a bottom-draw valve and lowered slowly into the well to withdraw a sample from the top of the water column or the bottom of a well (depending on whether light or dense NAPL is suspected) can be used to provide visual confirmation of the presence of NAPL. This method is often superior to the interface probe in detecting the presence of a very small thickness of NAPL or sheen. The bailer should however only be used after the interface probe measurement is taken. The bailer is used to confirm the negative interface probe reading (i.e., NAPL not detected by the interface probe) or, if a positive reading is obtained, to give a rough estimate of the thickness of the free product.

Monitoring well measurements of NAPL should include depth to the NAPL phase, depth to water table and the thickness of the NAPL layer. This measurement should be performed before the NAPL is removed or the monitoring well is purged.

6.4.4 Determination of Hydraulic Conductivity

It is rarely possible to determine a single value of hydraulic conductivity that is truly representative of the site due to the heterogeneity of formations frequently encountered. Usually, a range of hydraulic conductivities is considered acceptable.

Field measurements of hydraulic conductivity may be obtained using standard methods including single well response tests, multi-well pumping tests, and field permeameters.

Hydraulic conductivity may also be estimated by laboratory methods through the use of laboratory permeameters and grain size analysis (i.e. sieve analysis). These methods however are generally not recommended, particularly for fine-grained soils, because the small sample sizes used may not be truly representative of the formation.

The QP should be aware of the inherent limitations of hydraulic conductivity measurements in determining a representative hydraulic conductivity for the site. Although it is a requirement of the Regulation that measurements of hydraulic conductivity be verified through a comparison to literature values, these values often span several orders of magnitude and may not always be useful. The QP may wish to consider comparison of field- or laboratory-based measurements to empirically derived estimates of hydraulic conductivity (e.g. using Hazen's rule or similar equations for porous media, or empirical fracture aperture-hydraulic conductivity relationships for fractured rock)

Single Well Response Tests

Single well response tests provide only a point estimate (and order of magnitude precision) of hydraulic conductivity but are rapid and relatively inexpensive. Estimated hydraulic conductivity from such tests can differ by an order of magnitude or more relative to the hydraulic conductivity value(s) determined from pumping tests.

A slug test involves the sudden removal, addition or displacement of a known volume of water and the subsequent monitoring of the changes in water level as it returns to equilibrium. Commercially available automatic water level recorders with data processing software facilitate the water level measurements and hydraulic conductivity calculations. The measurements may also be made manually using a water level tape.

The rate of change of the water level is a function of the hydraulic conductivity of the formation and the geometry of the well. Hydraulic properties determined by slug tests are representative of the material in the immediate vicinity of the well only, and therefore the test results may be affected by the filter pack of the well. It is important that the monitoring well be well developed. Repeated test at a single location can be utilized to assess for potential well effects as the draw-down versus time curve for each test should be identical regardless of slug size.

There are several methods to analyze data from single well response tests. These include the Bouwer and Rice slug test, Hvorslev slug test method and the Cooper method for determining hydraulic conductivity in a confined aquifer. The QP should decide on the most appropriate method given the site-specific conditions.

6.4.5 Groundwater Flow Direction and Hydraulic Gradient

At sites where groundwater contamination is suspected and hydrogeologic characterization is required, a sufficient number of wells should be installed to adequately assess the groundwater flow direction and gradient. The exact number of wells required will depend on the complexity of the site hydrogeology. A minimum of three wells installed in a triangular manner, not in a straight line, is theoretically required to determine the direction of groundwater flow. This applies to homogeneous hydrogeological conditions which are rarely present at brownfield sites. The QP should therefore typically plan on installing additional monitoring wells to determine the direction of groundwater flow.

More detailed characterization of vertical groundwater flow should be performed where vertical migration of contaminants in groundwater is suspected. Issues such as density of the contaminants, presence of water-bearing zones and permeable lenses beneath the zone of contamination, and the interconnectivity of hydrostratigraphic units should be considered when determining to what extent the vertical component to groundwater flow should be assessed. If required, nested wells or piezometers may be installed.

Groundwater Velocity

An estimate of the average linear groundwater velocity should be included in the groundwater characterization and may consist of either an average representative value for the phase two ESA property or a range of maximum/minimum values. This is required to assess the potential for impact at the down-gradient property boundary due to migration of groundwater.

Groundwater velocity can be calculated based on the hydraulic conductivity, hydraulic gradient and formation porosity. All sources of the parameter estimates should be provided, with a clear listing of assumptions used in the calculations.

6.4.6 Sampling of Groundwater for Chemical Analysis

6.4.6.1 Groundwater Sampling Equipment

Inertial Pump (Foot Valves)

Inertial pumps can be used for groundwater well purging and sampling. They are inexpensive, can be used in wells as small as 1.25 centimetres (0.5 inch) diameter, can be dedicated to each monitoring well and are operated by hand. The typical manual purge rate is 2 to 8 litres per minute. Gas-powered and mechanical actuators are also available if they are required to operate the inertial pump. Inertial pumps are generally suitable for sampling wells that are less than 20 metres deep.

Bailers

Bailers are inexpensive, easily portable, can be decontaminated and require no external power source. A dedicated bailer may be used for sampling each well to avoid the possibility of cross-contamination between wells.

Bailers should be constructed of inert material. Single or double check-valve bailers can be used for LNAPL and DNAPL sampling, respectively. It is preferable to use a bottom emptying device with a valve to minimize aeration of the groundwater sample. Bailers should be lowered slowly into the well to minimize disturbance of the water column.

Small Diameter Submersible Centrifugal Pumps

These pumps were developed for contaminated site applications and can be used in small diameter monitoring wells. Higher flow rates can be used for well development and lower flow rates (0.1 litre per minute) for well sampling.

Care and control of pumping rate is a critical factor in sample quality. Pumps should be cleaned between sampling locations to avoid cross-contamination.

Bladder Pumps and/or Peristaltic Pumps

Bladder pumps and peristaltic pumps are typically used in applications where a low-flow rate is required (i.e. low-flow sampling). Often, low-turbidity samples can be obtained without filtration. Flow rates higher than 100 millilitres per minute can increase the loss of volatile constituents. Use of bladder pumps reduces the water-purge volume requiring treatment but they can also be time-consuming for low-flow applications. In addition, the pumps are difficult to decontaminate between sampling locations. Peristaltic pumps, which limit groundwater contact to the sample tubing only, are less susceptible to decontamination issues. Bladder pumps are suitable for sampling a wide range of contaminants at phase two ESA sites.

Tubing and Accessories

Numerous (flexible) materials are available for use with groundwater samplers. Tubing of some kind is required for all pump devices.

High and low density polyethylene tubing are commonly used with submersible pumps and inertial pumps. High density polyethylene is preferred for deep sampling using inertial pumps. Polyethylene tubing is commonly used in the industry and is considered an acceptable material for monitoring well sampling. The tubing should be dedicated to a single groundwater monitoring well to eliminate the potential for cross-contamination between wells.

6.4.6.2 Pre-Sampling Activities

A number of pre-sampling activities or measurements are often required prior to obtaining a groundwater sample for analysis.

Headspace Monitoring

Field vapour measurements may be taken from inside the casing of a monitoring well using a combustible vapour detector to indicate the potential for contamination of the groundwater by VOCs. The vapour concentration is measured by placing the combustible vapour detector probe inside the monitoring well casing no less than 15 centimetres (6 inches) below the top of the casing). The combustible vapour detector reading should be taken immediately after the cap has been removed from the top of the monitoring well casing in order to minimize the loss of volatiles from within the casing.

These measurements may serve as a guide for the selection of groundwater samples for VOC sampling and should and not be relied upon on their own as a quantitative indication of contaminant levels. . At some sites, the presence of natural gas in the formation can result in high vapour concentrations in the well headspace. Appropriate precautions should be taken if high vapour concentrations are measured resulting in safety concerns for field staff.

Monitoring Well Purging Methods

Water standing in a well may not be representative of the conditions within the water-bearing formation due to changes in the chemistry of standing water in the well bore.

Purging of 3 to 5 times the volume of standing water is generally considered to be acceptable to ensure that representative groundwater samples are obtained. The well should be allowed to recover sufficiently after purging before collecting a groundwater sample. Wells screened in formations with low transmissivity may go dry before the required water volume can be removed. It is recommended that the well be purged dry at least once and the sample be collected after the well recovers.

Continued removal until certain field measured parameters (e.g. pH, temperature, turbidity, dissolved oxygen, oxidation-reduction potential (ORP), and specific conductance have stabilized may also be used to determine well purging requirements, However, it is often difficult to determine when stable conditions have been attained on this basis, and it may therefore not be necessary to routinely monitor these parameters to determine well purging requirements.

Purging and sampling using a low-flow pump ("low-flow purging and sampling") is a preferred method particularly for sampling of VOCs or in monitoring wells that are not completely silt-free. This method minimizes the velocity of the formation water entering the well screen. Drawdown is kept to a minimum (i.e., less than 10 cm) by adjusting the pumping rate. The goal is to ensure that water inside the well screen and in the formation is minimally disturbed while obtaining representative formation water. This helps to minimize losses of volatile contaminants in groundwater samples and, reduces the turbidity (i.e., silt content) of the samples. Turbid groundwater samples may yield "false-positive" detection for certain parameters such as PAHs that have a tendency to be highly adsorbed on silt particles. Low-flow purging and sampling is recommended for the analysis of PAHs.

Sampling of groundwater without purging the well ("no-purge groundwater sampling") is an option that may be considered by a QP. It would be most useful where ongoing monitoring is required. This reduces the volume of purged groundwater generated. Studies have shown that the sample analytical results without purging are often quite comparable with results using conventional purging (Powell, R.M., and Puls, R.W., 1993). However, "no-purge" sampling has not yet gained wide acceptance. The QP may consider using this method for groundwater monitoring on a site-specific basis in conjunction with supporting monitoring data obtained with conventional purging.

6.4.6.3 Groundwater Sample Collection

The objective of groundwater sampling is to obtain a representative sample. Decisions about sampling methodology and procedures should consider the properties of the contaminants of concern, well configuration (screen depth and length) and should be designed to mitigate potential effects on the integrity of the groundwater sample. Per the requirements of Schedule E of the Regulation, groundwater samples used in certifying a record of site condition should not be collected from a test pit, excavation, borehole, or undeveloped monitoring well.

Groundwater samples should not be transferred from one container to another during sampling. The samples should be placed immediately in an ice-chilled cooler immediately after sampling and kept at 0 to 10°C (target of 4°C) until delivery to the laboratory. Groundwater samples should be submitted promptly to the laboratory, typically with 48 hours of collection, in accordance with the provisions in the Analytical Protocol Document.

QPs should be aware that there is a mandatory requirement in the Regulation to collect one field groundwater duplicate sample per ten groundwater samples collected.

Field Filtration

The provisions in the Analytical Protocol Document on field filtering of groundwater samples collected from monitoring wells should be followed. Note that field filtering is required for analysis of metals including mercury, but not for methyl mercury.   Groundwater samples being analyzed for organic parameters should not be field-filtered. Samples collected from drinking water wells should not be field-filtered either for metals or organic parameters.

When field-filtering of the groundwater samples is required, in-line positive-pressure filtration should be used. Vacuum-filtration is not considered acceptable due to degassing effects. The standard filtration device is the 0.45 μm filter. It is recommended that the filter be first flushed with the groundwater before the sample is collected. The sample should be directly introduced into the sample bottle containing the proper preservative.

Sample Splitting

Sample splitting is usually done for field QA/QC samples, or for peer-review/second party verification of sampling results. Splitting of water samples should be done as follows:

- For non-volatile or semi-volatile parameters, the groundwater samples should be transferred alternately into the two sample bottles until both bottles are filled simultaneously.
- For VOC samples, each sample bottle should be completely filled and capped separately, to minimize losses of volatiles.

Confirmation Sampling Requirements

Confirmation sampling, conducted after remediation of a site where contaminants have been identified, is intended primarily to confirm the effectiveness of the remedial measures, and to assess whether the applicable site condition standards or risk assessment-derived standards have been met for each contaminant.

The soil and groundwater sampling principles described above are also applicable to confirmation sampling programs. Under the Regulation, the QP is required to ensure that samples are collected and analyzed for each contaminant in any area and for all environmental media (soil, groundwater and/or sediment) where the contaminant was present at a concentration greater than the applicable standard before remediation occurred.

Where remediation is conducted through the introduction of a substance into one or more wells (e.g. chemical oxidation, biostimulation, etc), best practices and the Regulation require that confirmation samples be taken from monitoring wells other than those used for injection.

Where remediation is conducted through excavation, the QP or someone working under the QP's direction is required to collect soil samples from the excavation floor and walls. The minimum number of samples to be collected is set out in Table 3 of Schedule E of the Regulation.

Where in situ remediation of groundwater is conducted, confirmation that the applicable standards have been met requires the analysis of samples from four consecutive quarterly sampling events, for a total of one year of sampling. The first monitoring event must be conducted at least 90 days after the last remedial action.

Where the remediation of soil is conducted to address both soil and groundwater impacts, confirmation that the applicable groundwater standards have been met requires the analysis of samples from two consecutive quarterly sampling events, for a total of six months of monitoring. The first monitoring event is required to be conducted at least 90 days after the last remedial action.

Water level measurements should be taken in the monitoring wells from which the confirmation samples are being taken.

6.5 Site Characterization Requirements for the Modified Generic Risk Assessment Process

This section is intended to provide guidance on conducting those components of phase two ESAs that are intended to support the use of Modified Generic (Tier 2) risk assessment for the development of property-specific soil and groundwater standards. The use of the Modified Generic risk assessment process may necessitate additional efforts to characterize the geology and hydrogeology of a site, or to assess other environmental media such as soil gas, in order to justify modification of the generic values used by the MOE in the development of the generic soil and groundwater standards under the Regulation.

<u>Hydrogeological Assessment</u>

The Modified Generic risk assessment process allows for the adjustment of four parameters pertaining to site hydrogeology:

1. The minimum distance from areas of the site where contaminants are present to the nearest downgradient surface water body;
2. The minimum depth below the soil surface to the highest annual water table;
3. Aquifer horizontal hydraulic conductivity; and
4. Aquifer horizontal hydraulic gradient.

<u>Distance to the Nearest Downgradient Water Body</u>

QPs should use multiple lines of evidence in the determination to the distance to the nearest downgradient water body. Groundwater elevation data, collected from three or more groundwater monitoring wells arranged in a non-linear pattern will be a primary line of evidence in the determination of the direction of downgradient water bodies. The means of assessing the generalized downgradient direction of groundwater flow is provided below in this section. However, measurements of the groundwater elevations and apparent flow directions at the site alone may not provide sufficient information as to the direction of regional groundwater flow, and may reflect localized influences on hydrogeology (e.g. buried utilities).

Supplemental information that may be considered by a QP in identifying the location of, and distance to, downgradient water bodies includes:

- Water level elevation from nearby surface water bodies;
- Location and regional topographic information as determined through available topographic maps and/or survey data.

Subject to appropriate Approvals being obtained, tracer studies may have application to the determination of the direction of groundwater flow from the subject site to the nearest downgradient water body. This approach may be warranted in areas of complex groundwater flow, such as fractured bedrock settings.

<u>Minimum Depth below the Soil Surface to the Highest Annual Water Table</u>

The determination of the highest annual water table (i.e. minimum water table depth) may be of benefit where volatile organic compounds (VOCs) are contaminants are of concern, as modeling of property specific standards for these contaminants is sensitive to the vertical distance between the contaminant source and potential receptors (e.g. building occupants or outdoor air).

The approach used in assessing the highest annual water table is dependent on the availability of historical water level data. Per the requirements of O. Reg. 153/04, the QP should assess whether two or more years of quarterly water level data are available. If these data are available, then the QP should:

- Review these data to identify the highest groundwater elevations over any three month period; and
- Conduct monitoring of water levels monthly during this three month period identified as having the potential for the highest water levels.

In the absence of two or more years of historical water level data, the QP should conduct twelve months of monitoring to identify the highest groundwater elevation. If this is not feasible given project constraints, then the QP should use available information, including an assessment of seasonal precipitation and runoff patterns to make inferences regarding anticipated water level fluctuations. One water level measurement is taken, and either one metre is subtracted from the measurement (i.e. the water table is assumed to be one metre higher as compared with the measured value, or the QP considers seasonal information in conjunction with the measured value to provide a reasonable estimate of the minimum depth to the water table.

Aquifer Horizontal Hydraulic Conductivity

The Regulation requires that for each aquifer considered by the QP to carry or convey contaminants, the horizontal hydraulic conductivity shall be determined by the QP. Three general categories of methods exist for the estimation of hydraulic conductivity:

1. Empirical relationships between hydraulic conductivity and grain size;

2. Laboratory determination of hydraulic conductivity using a permeameter; and

3. Field methods, including slug tests, pumping tests, and in situ methods such as the Hydraulic Profiling Tool (HPT).

Guidance on the selection of specific methods of determining hydraulic conductivity is beyond the scope of this guidance, being left to the QP's professional judgment. However, the following general principles should be applied in the estimation of hydraulic conductivity:

- Regardless of the method used, if field methods (e.g. slug tests or pumping tests) are used to estimate horizontal hydraulic conductivity, the resultant estimates should be compared with literature values for the geological medium being tested. This is a mandatory requirement of the Regulation.

- It is recommended that field method-based estimations of hydraulic conductivity in porous media (i.e. other than fractured bedrock), in addition to being compared to literature values, also be compared with empirical estimates of hydraulic conductivity based on grain size. Literature values typically range over several orders of magnitude, and may not provide a reliable confirmation of the field-based estimates.

- In using laboratory-based methods of hydraulic conductivity estimation, best efforts should be undertaken to re-establish the in situ density of the soil. Laboratory methods are sensitive to the packing density of the samples, and may produce hydraulic conductivity estimates that are not consistent with in situ values if this in situ density is not approximated in the laboratory testing program. It is preferable to minimize sample disturbance using sample collection.

- Field-based methods (e.g. slug tests or pumping tests) are generally considered to provide more accurate results as compared with laboratory-based methods, as they are less sensitive to sample disturbance (Driscoll, 1989).

- Interpretation of field-based test results should take into account the geological and hydrogeological conditions at the site. For example, QPs should consider that pinch-outs of more permeable layers may produce boundary conditions that may affect estimates of hydraulic conductivity at certain times during the course of the assessment. Recharge conditions (e.g. rainfall during the course of the test) that could affect the results should also be considered. Well efficiency should also be considered; as well losses during the early stages of a pumping test may skew the results if not considered in the analysis of the results.

Slug tests, in which a cylinder of known volume or a known volume of potable water is introduced into the well bore and the decline in water level measured as a function of time, are the most commonly used field-based methods of hydraulic conductivity estimation. However, QPs should be aware that borehole skin effects may affect hydraulic conductivity in low permeability formations such as glacial tills. Two potential borehole skin effects may influence the resultant estimate of hydraulic conductivity:

- Smearing of silts and clays during drilling with augers can produce a borehole skin having a lower hydraulic conductivity than the surrounding formation. Underestimation of hydraulic conductivity by up to two orders of magnitude have been reported (Yang and Gates, 1997); or

- Well development may remove silt- and clay-sized particles from the area of the formation surrounding the well screen. This removal of fine particles may produce an overestimation of hydraulic conductivity.

To reduce the potential influence of skin effects on estimations of hydraulic conductivity, QPs should use late-time data in the analysis of slug tests (Yang and Gates, 1997). Proper well development, intended to remove smeared silt- and clay-sized particles, should also be conducted after well installation and prior to slug testing.

Aquifer Hydraulic Gradient

Modification of the horizontal hydraulic conductivity from the value used in the development of the generic standards allows for property-specific standards to be developed for those parameters driven by groundwater migration to aquatic receptors (as is the case for many metal and PAH parameters). The Regulation requires a determination of hydraulic gradient based on a minimum of three monitoring wells having a non-linear distribution. Further guidance on the estimation of hydraulic gradient is not provided in the Regulation. QPs may refer to published literature (e.g., NC DENR, 2010) for more prescriptive guidance.

Soil Vapour Assessment

The Ministry is currently developing a comprehensive guidance document on soil vapour assessment. QPs are directed to consult the Ministry guidance for specific guidance on soil vapour investigations once the document is released.

A general description on soil vapour sampling and assessment is provided below.

The Modified Generic Risk Assessment process allows for the collection of soil vapour data to use as a point of comparison to modeled soil vapour and indoor air concentration data for volatile contaminants of concern. The Ministry's models incorporate the Johnson and Ettinger (1991) model, which has been reported to overestimate vapour migration into buildings by at least one order of magnitude (e.g. Wilson 2008). One source of potential conservatism in the model relates to the estimation of soil vapour concentrations as compared with actual field data. Comparison of actual MGRA model results to actual soil vapour concentration data provides an assessment of vapour intrusion risk that may better account for site-specific geological and hydrogeological conditions.

However, QPs should be aware of the need to carefully design and implement the soil vapour investigation program if results are to be representative.

An assessment of soil vapour concentrations should focus on areas proximal to the source. These areas typically exhibit less spatial and/or temporal variability in soil vapour concentrations as compared with areas that are more distant from the source. Samples collected from depths nearer to the source are less affected by weather, seasonality and effects of building heating. Regardless, repeated testing of soil vapour concentrations may be necessary to accurately assess concentrations in light of seasonal variability.

In determining the depth of soil vapour monitoring probes, QPs should consider the depth to groundwater. Higher moisture levels in deeper soil may not permit the collection of representative soil vapour data. Groundwater monitoring wells screened across the water table, if appropriately purged and equipped with suitable caps to allow for the collection of soil vapour samples, can be used for soil vapour sample collection.

Soil gas probes installed beneath building floor slabs may be of benefit to confirm whether vapour intrusion is a risk. However, QPs should consider these installations in light of the minimum depth requirements for soil vapour samples supporting a Modified Generic Risk assessment as specified in the Regulation. QPs should also be aware that shallow sub slab soil gas data may be affected by influx of indoor air into shallow soils, as may occur in the case of positive building pressurization (McHugh et al, 2008).

For the installation of soil vapour probes, QPs should use methods that reduce potential disturbance to the soils. For example, direct push or auger drilling equipment would be considered suitable for these installations. Methods such as water- or mud-rotary should be avoided.

Two general types of soil gas probe installations exist:

1. Prefabricated soil gas implants, typically constructed using stainless steel screens; and
2. PVC installations, typically constructed in a manner similar to groundwater monitoring wells.

If using PVC installations, QPs should ensure that shorter screens and smaller screen diameters are typical for soil gas probe installations as compared with groundwater monitoring wells. Screen lengths are specified by the Regulation as being a maximum of 50 cm. However, screen lengths of 10 to 30 cm are adequate. Diameters less than 25 mm are typically used in order to minimize purge volumes. As with groundwater monitoring wells, the use of adhesives for joining pipe sections should be avoided.

Probes installed in the vadose zone (i.e. above the water table) should be constructed with an annular seal that reduces the potential for leakage. Bentonite, if not hydrated during installation, may not provide a suitable seal. Bentonite seals should be hydrated using potable water during installation.

QPs should consider leak testing probes before sample collection. Potential areas of leakage include annular seals and connections between piping, tubing and sample vessels. Leak testing typically incorporates the use of a liquid (e.g. isopropanol-soaked towels, or an isopropanol vessel contained within a shroud) or helium in order to detect leaks. The use of isopropanol or butane may interfere with lab results, which may necessitate re-sampling. The use of helium typically provides the ability to detect leaks in the field using a hand-held instrument. Helium is introduced into a shroud placed over the soil gas probe, and a soil gas sample is collected by pumping into a tedlar bag. A portable helium detector is used to analyze the bag contents and assess leakage.

As with groundwater monitoring wells, soil gas probes should be purged before sampling. The removal of three times the internal volume of the probe and associated sample tubing is typical. A maximum purge rate of 100-200 millilitres per minute should be used to avoid stripping of contaminants and/or leakage of ambient air through surface seals (Cal DTSC, 2003). Similarly, if sampling using an evacuated canister, an appropriately calibrated flow regulator should be used to maintain a flow rate less than 200 mL/min.

Fraction of Organic Carbon Analysis

The MGRA process allows for the collection of soil fraction of organic carbon (Foc) data to modify the standards for certain volatile contaminants. Foc may correlate to the ability of a soil to adsorb or bind these contaminants. O. Reg. 153/04 provides specific guidance as to the numbers and depths of sample locations. The following guidance is provided on the collection of soil samples for Foc in order to supplement the guidance provided in the Regulation:

- Foc samples should be determined based on sampling locations that are not impacted by petroleum hydrocarbons or other organic contaminants;

- Surface organic layers of soil should not be used in the determination of Foc.

Collection of samples for Foc analysis from organic rich layers (e.g. topsoil) or from contaminated soils may result in an overestimation of the ability of a soil to adsorb volatile contaminants (Ohio EPA, 2007). In assessing the numbers and locations of samples for Foc analysis, QPs should consider soil heterogeneity, as Foc may vary widely across any given site.

6.6 Field Decontamination Procedures

Decontamination procedures are important for preventing cross-contamination between sampling areas.

Laboratory sample bottles should always be stored in a clean environment away from potential contaminant sources. Chemical resistant gloves, typically nitrile, should be worn during soil sampling activities. Gloves should be changed for each sample collected and submitted for laboratory analysis.

Manual sampling tools and drilling equipment should be cleaned between sampling locations. Manual sampling tools, such as putty-knives, spatulas, trowels, spoons, soil corers and augers tool should be brushed clean, rinsed with water. Drill augers, backhoe buckets and sampling equipment may be cleaned with a high-pressure water jet.

6.7 Quality Assurance (QA)/Quality Control (QC)

6.7.1 Field QA/QC

Quality Assurance/Quality Control (QA/QC) measures are an essential component of phase two ESA sampling programs. The Analytical Protocol document should be consulted for specific regulatory provisions.

A QA/QC program is described as the overall "management system" that ensures defined standards of quality are met within a stated level of confidence. Quality control (QC) consists of the day-to-day activities (in the field or laboratory) used to control the quality of the product or service so that the needs of the users are met. Quality assurance (QA) consists of the measures or checks that are put in place to confirm that the quality control (QC) activities are effective.

A well-designed QA/QC program will:

- Ensure that data of sufficient quality is obtained, for proper site management decisions or cleanup/remediation design;
- Allow for monitoring of staff and contractor performance; and
- Verify the quality of the data for the regulatory agency.

While this section provides recommended guidelines for managing the QA/QC program, it is important to note that a QA/QC program should be developed on a site-specific basis.

Sample Management

Sample management is the continuous care given to each sample from the point of collection to receipt at the analytical laboratory. Good sample management ensures that samples are properly recorded, properly labelled, and not lost, broken, or exposed to conditions that may affect the sample's integrity.

The following subsections provide guidelines for field sample management.

Field Handling

Prior to entering the field area where sampling is to be conducted, the sampler should ensure that all materials necessary to complete the sampling are on hand.

Samples should be placed in coolers and surrounded with bags of ice or freezer packs to ensure that the temperature of the samples remains below 10°C. When sampling is done in extremely cold weather conditions, proper protection of groundwater samples should be provided to prevent freezing.

Personnel performing groundwater sampling tasks should check the sample preparation and preservation requirements to ensure compliance with the project QA/QC requirements. Typical sample preparation may involve pH adjustment (i.e. preservation), sample filtration and preservation, or simply cooling to 0 to 10°C with a target of 4°C.

Sample Labelling

Samples should be properly labelled as soon as possible after collection. The minimum data to be included on a sample label should be confirmed with the laboratory prior to sample collection.

For transportation of potentially dangerous or hazardous materials (i.e. potentially flammable, explosive samples, etc.), the packaging or documentation requirements of the courier company, Workplace Hazardous Materials Information System (WHMIS), Transportation of Dangerous Goods (TDG), Ontario Ministry of Labour, and any other applicable regulations and standards should be followed.

Packaging

Sample container preparation and packing for shipment should be completed in a well-organized and clean area, free of any potential for contamination. All sample containers should have sample labels and clear, wide packing tape may be placed over the sample label for protection. The sample containers should be placed in sealable plastic bags to keep the labels legible should melting ice in the cooler come into contact with the sample containers.

Chain-of-Custody Records

Chain-of-Custody (CoC) forms must be completed for all samples shipped. The chain-of-custody form documents the transfer of sample containers from the field to the laboratory.

The chain-of-custody form, completed at the time of sampling, should contain at least the sample number, date and time of sampling, and the name of the sampler. Contact information should also be provided. The chain-of-custody document must be signed and dated by the sampler when transferring the samples during shipment or upon relinquishing the samples to the analytical laboratory.

Each sample cooler being shipped to the laboratory should contain a chain-of-custody form.

Shipment

"Holding time" refers to the period in time between the collection of the sample, and the analysis of the sample in the laboratory.

Samples should be delivered to the analytical laboratory as soon as possible after sampling. Under the Regulation, samples must be delivered to the laboratory within 48 hours after collection unless preserved and handled in accordance with the guidance provided in the Analytical Protocol Document.

All field QA/QC project sampling tasks should be outlined in the project work plan.

Table 2 provides a summary of the field quality control samples considered appropriate for soil and groundwater sampled during phase two ESAs. These frequencies should be considered as minimums and may need to be increased at some phase two ESA properties.

Table 2: Types and Frequency of Field QA/QC Samples

Matrix	Travel Blank	Field Blank	Equipment or Rinsate Blank	Field Duplicate
Soil	Not Applicable	Not Applicable	Not Applicable	Yes
Groundwater	Yes	Yes	Optional	Yes
Frequency	A minimum of one sample per site[1], with sample shipment	A minimum of one sample per 10[a], with sample shipment	A minimum of one sample per sample shipment, if dedicated equipment not used, for each matrix sampled	A minimum of one per 10 per cent of all samples, with a minimum of one per sample shipment

The sampling plan should specify the number and type of field QA/QC samples that field personnel should submit to the laboratory. A field duplicate sample will be taken by the field personnel and submitted to the laboratory for QA/QC.

Travel Blanks

Travel (or Trip) blanks are prepared before the sampling event and sent to the site in the shipping containers designated for the project. These samples are intended to be kept with investigative samples and be submitted for analysis with the project samples. The travel blanks should not be opened and are intended to determine if the sample shipping or storage procedures influence the analytical results.

Field Blanks

A field blank consisting of a sample of clean water, usually supplied by the laboratory, is collected to evaluate the influence of field ambient conditions on the sampling process. Field blanks are submitted to the laboratory without identification as a blank. The frequency of field blank submission will be determined by the project QA/QC requirements.

Equipment Blanks

Equipment field blanks are QA/QC samples taken to determine if field equipment cleaning procedures are effective. The field blanks are prepared by rinsing the equipment with water and collecting the rinsate for analysis. Potable tap water is generally acceptable for equipment rinsing, but distilled or de-ionized water may be considered for final rinsing and collection of the rinsate for analysis.

Equipment blank samples are not needed if dedicated sampling equipment is used.

Field Duplicates

A field duplicate sample is a second sample taken from a sample location and submitted along with the initial sample. Field duplicates are collected and submitted to assess the potential for laboratory data inconsistency and the adequacy of the sampling and handling procedures. A duplicate sample is collected from the same source utilizing identical collection procedures.

The results of the duplicate sampling may be used to assess the adequacy of the field sampling, the heterogeneity of the sample matrix, and the laboratory analytical precision.

6.7.2 Laboratory QA/QC

Laboratory QA/QC procedures are described in the Analytical Protocol Document. A summary of the key requirements is provided below.

Laboratory QA/QC samples include laboratory duplicates, method blanks, spiked blanks, and matrix spikes. For organics parameter analysis of a sample, chemical surrogates are added and surrogate recoveries calculated for each individual sample. The laboratory should indicate on the Certificate of Analysis (CoA) that the test method was in statistical control when the analysis was performed. The CoA should also flag any other quality issues with the analyses (e.g. results for QA/QC samples during the analytical run being outside the acceptance criteria specified by the test reference method).

Laboratory QA/QC results should be included with the analytical laboratory report and should be reviewed carefully as part of the overall data assessment. Due to rigorous implementation of QA/QC protocols and establishment of standard operating procedures, it is expected that the contribution to overall variability of the results reported for samples analyzed by an accredited laboratory will be relatively small.

Only laboratories accredited to the ISO/IEC Standard 17025 by an internationally recognized accreditation body can be used for phase two ESA analytical work (Section 47 of the Regulation). Accreditation is given only to laboratories that demonstrate competence in their field of testing and conform to ISO/IEC Standard 17025 – General Requirements for the Competence of Testing and Calibration Laboratories.

In addition to quality system accreditation, the accreditation process provides accreditation for unique combinations of analyte, matrix and method. For analyte/matrix combinations which are commonly performed, e.g. metals in soil, the accreditation body usually requires successful participation in a proficiency testing (PT) program as a requirement of accreditation. Only laboratories that have current accreditation to analyze these parameters should be chosen to perform the analysis of samples collected for purposes of a phase two ESA and submitting a Record of Site Condition for filing.

6.8 Borehole and Well Abandonment

Boreholes should be properly abandoned so that they do not serve as conduits for contamination or represent a safety hazard.

Monitoring wells should be abandoned in accordance with the provisions of Ontario Regulation 903. It is the property owner's responsibility to abandon the wells when they are no longer needed for ongoing monitoring. As the monitoring wells may be used for monitoring long after the phase two ESA is completed, the QP should advise the owner in writing of this requirement.

6.9 Residue Management

The drill cuttings from the borehole drilling and well installation, and purged groundwater should be properly managed (e.g., by transferring the cuttings and water into separate drums) during the phase two ESA investigation.

The ultimate management of soil and groundwater residues will depend on the analytical results. If the soil meets the applicable full-depth generic site conditions, it is permissible to spread the soil on the site if it is feasible to do so. Similarly, if the groundwater is not impacted and there is no sheen or visible product, the extracted groundwater may be poured on the ground provided that the contents do not drain to surface water or to off-site properties.

If on-site management of the residues is not feasible due to the large quantities generated, then off-site disposal may be required. The soil may be disposed of as waste at an approved landfill site after TCLP (Toxicity Characteristics Leachate Procedure) testing for waste classification under Ontario Regulation 558/00. The water should be managed as a liquid waste and transferred to a facility licensed to receive liquid wastes. Haulers who are licensed to transport such wastes should be used to transfer the residues to the receiving facilities.

If an RSC is required for the property, the QP should ensure that the residues have been properly managed or disposed of off-site and all monitoring wells have been properly abandoned, if they are not needed for ongoing monitoring that may be required as a condition of a risk assessment, before completing the RSC and submitting it to MOE for review and filing.

7.0 Review and Evaluation of Information

Review, interpretation and evaluation of the information obtained in conducting the phase two ESA are mandatory requirements of a phase two ESA under the Regulation.

In the context of providing information for this review, the following information should be documented in the course of conducting the phase two ESA, using field logs and/or a field notebook, as appropriate:

- the project name and location, and the project number;
- sample collection equipment (where appropriate);
- field analytical equipment, and other equipment used to make physical measurements
- Calculations, results, and calibration data for field sampling, field screening measurements, and field physical measurements
- Sampling location identification;
- Time of sample collection;
- Description of the sample location;
- A description of the sample and how it was collected;
- An identification of the person who collected the sample; how the sample was collected;
- Maps/sketches of sampling locations; and
- Weather conditions that may affect the sample (e.g., rain, extreme heat or cold, wind, etc.)

The outcome of the review and interpretation of information is the development of a phase two conceptual site model that includes graphical (i.e. plan view and cross section documents) and narrative descriptions of areas of potential environmental concern for the site. This conceptual site model should include a stratigraphic and hydrostratigraphic model of the subject site. The stratigraphic model should be based on a review and interpretation of borehole data that has been obtained by the QP or under the QP's direction, and supplemented with information from other sources as has been reviewed and accepted by the QP. The interpretation of hydrostratigraphic units should be based on an interpretation of hydraulic conductivity testing as conducted per Section 6 of this guidance document.

With respect to contaminants on, in or under the subject property, the phase two ESA Conceptual Site Model is required under the Regulation to include information regarding the vertical and lateral distribution of contaminants. One commonly used approach to depicting the distribution of contaminants include extrapolation to the nearest testing location (e.g. borehole, monitoring well or test pit) that meets the applicable standard for that contaminant.

The QP should consider contaminant distribution in the context of site stratigraphic and hydrostratigraphic information in interpreting the potential distribution of contaminants. For example, pinch-outs of permeable soils or the presence of lower-permeability soils may affect contaminant distribution. Statistical methods, such as kriging, may be of benefit if the data are of sufficient spatial density to allow for reliable interpretation. Where there is uncertainty in the distribution of contaminants, methods such as indicator kriging may be useful in identifying the range of contaminant distributions that may be possible.

A requirement of the Regulation is that, if available, information regarding the potential for vapour intrusion should be evaluated. In making this evaluation, QPs should consider the guidance provided in Section 6.5 in the collection of samples for soil vapour analysis.

Where contaminants are present in excess of applicable generic site condition standards and will not be remediated to meet these standards, it is a requirement of the Regulation that for the purposes of filing an RSC, the phase two ESA conceptual site model include an evaluation of the human and ecological receptors that are located on, in or under the subject site, as well as the receptor exposure points and routes of exposure for these contaminants. This falls within the risk assessment ("RA") process defined in the Regulation. The QP should consult with the Qualified Person for Risk Assessment ($QP_{RA)}$ in incorporating this information into the phase two ESA conceptual site model.

8.0 Development of a Remedial Action Plan

Based on the findings of a phase two ESA, the QP may be required to develop a remedial action plan (RAP) for the site. The RAP should identify the contaminants of concern, describe the remedial actions intended to address each of the contaminants, and describe the remedial objectives for the site (i.e. generic site condition standards and/or risk assessment-derived standards).

Additional information that the QP may wish to include in the RAP can include:

- Quantities of contaminated media (soil, groundwater and sediment) to be remediated;
- Intended destinations for any media intended to be transported, treated or disposed of off-site; and
- Where materials intended for off-site transport, treatment or disposal constitute hazardous wastes as defined under Ontario Regulation 347, the RAP should include appropriate transportation requirements (e.g. manifesting), HWIN generator registration requirements, and the identification of pre-treatment facilities (if applicable).

8.1 Soil brought to a Phase two property from another site

The Regulation provides specific provisions for the importation of soils onto a receiving site. The provisions are summarized below for convenience. QPs refer to the relevant provisions of the Regulation to ensure that they comply with them.

The regulatory provisions are generally intended to ensure that the importation of soils will not introduce "new" contamination onto the receiving site either in terms of new contaminants or increased concentrations of existing contaminants. QPs should therefore conduct appropriate testing on the receiving site (the scope of such testing to include both Phase I and II ESAs) in order to:

- allow for assessment of COCs and their concentrations on the receiving site; and
- Support RSC filings for the receiving site.

In addition, the Regulation imposes restrictions on the nature of the receiving site that can accept soils:

- The receiving site must currently be used, or have been used in the past, for one of the following purposes:
- Industrial uses;
- Use as a bulk liquid dispensing facility, including a gasoline outlet;
- Use as a garage; or
- Use for the operation of dry cleaning equipment.
- The receiving site must have had at least one of a wide-ranging list of potentially contaminating activities. QPs should refer to the list of potentially contaminating activities provided in the Regulation to ensure that they comply with this provision.
- The receiving site must contain one or more contaminants of concern at concentrations above the MOE generic site condition standards that are applicable to the site.

Soil to be placed on the receiving property must be required to be imported either for:

- Backfilling of excavations; or
- Grading.

Soils being placed on the phase two property are required to meet one of the following two standards:

- The MOE generic site condition standards that apply to the receiving property; or
- The property specific standards developed for the receiving site in a risk assessment that has been accepted by a Director of the MOE Standards Development Branch.

The Regulation provides guidance on timing and frequency of testing that is required in order to confirm whether the soil meets these standards for reuse:

- Soil must be tested before leaving the source site;
- Soil must be tested at the following frequency for all contaminants of concern identified by a QP, considering the characteristics and history of the source and receiving sites:
    - For soil quantities up to 5,000 cubic metres (m^3), one sample per 160 m3 is required to be analyzed.
    - For soil quantities exceeding this initial 5,000 m3, one sample per 300 m3 is required to be analyzed for the contaminants of concern.

Testing is required to be conducted by a laboratory accredited for the contaminants of concern by the Standards Council of Canada or the Canadian Association for Laboratory Accreditation.

Where the conditions on the receiving site described above are not met, the soil imported to the phase two property is required to meet the Table 1 site condition standards.

The scope of testing, the quantity of soil imported, and the locations and depths of placement, should be documented in the phase two ESA report.

9.0 Phase two ESA report

The phase two ESA report should be a stand-alone report that describes all aspects of the phase two ESA program. The format and contents of a phase two ESA report prepared in support of an RSC submission are prescribed under Table 1 of the Regulation. As the phase two report should be a standalone report, it is advisable that the report summarize the phase one ESA report and phase one ESA conceptual site model, rather than simply referencing the phase one ESA report.

Although common practice in Ontario is to report information regarding the scope and results of site remediation activities separately from the phase two ESA reporting that precedes it, it is a requirement of the phase two ESA reporting format under the Regulation that information regarding the remediation program be included as an appendix to the phase two ESA report.

10.0 Completion of the Record of Site Condition

If the results of the phase two ESA indicate that the applicable generic site condition standards are met, then the QP may complete the electronic RSC form that can be downloaded from the Brownfields Electronic Site Registry and submit it to MOE for review and filing. The procedures for completing and submitting the RSC for filing are described in Part V and Schedule A of the Regulation.

If the applicable site condition standards are not met, then the options to be considered to allow submission of the RSC for filing are as follows:

1. Remediation of soil or groundwater to the applicable generic standards:

   The Regulation does not deal with soil or groundwater remedial technologies, but it specifies confirmatory sampling requirements following soil and groundwater remediation. The requirements are specified in Part III (Sections 39 and 40) of the Regulation, and include four consecutive quarterly rounds of confirmatory groundwater sampling starting 90 days after remediation when in-situ remedial techniques are utilized. The QP should be aware of the confirmatory sampling requirements as they would affect the timing of completion and submission of the RSC for filing.

   Guidance on soil and groundwater remedial methods is beyond the scope of this guidance document. However, the guidance on soil and groundwater sampling provided in this document is applicable to the confirmatory sampling that will be required

2. Completion of a Risk Assessment:

The Risk Assessment (RA) procedures, including Modified Generic Risk Assessment ("Tier 2"), are described in Schedule C of the Regulation. The RA must be completed and submitted by a QP_{RA} to MOE for review and acceptance. The QP_{RA} educational and experience requirements are specified in Part II of the Regulation. The certification statements in the RSC following MOE acceptance of the RA the must be completed by a QP_{ESA}.

Guidance on the full Risk Assessment is beyond the scope of this document. Guidance on additional soil and groundwater assessment that must be completed to support a Modified Generic Risk Assessment is provided in Section 6.5 of this document.

11.0 REFERENCES

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