GEOSCIENTISTS
NOVA SCOTIA

Geoscience Professional Practice Guideline for Conducting Phase 1 and Phase 2 Environmental Site Assessments in Nova Scotia

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THE ASSOCIATION OF PROFESSIONAL GEOSCIENTISTS
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1.0 Introduction

1.1 Purpose, Scope and Limitations

The purpose of this document is to provide a technical and operational practice guideline for professionals in conducting an environmental site assessment (ESA) in Nova Scotia. It is intended to develop and maintain a consistent standard of practice to protect the public and articulate a common level of expectation. It is not intended to be, and should not be expected to be prescriptive or all-encompassing of environmental site assessment methodology or equipment or procedures. However, it should form the basis for competent professional practice and for the evaluation and application of new practices.

This guideline also incorporates reference to the specific requirements of the Nova Scotia Environment (NSE), Contaminated Sites Regulations (the "Regulations") and the associated Ministerial Protocols (the "Protocols"), made under the Nova Scotia Environment Act.

Note, for the purpose of this guideline and for the filing of documents defined under the Regulations and Protocols, environmental site assessment activities include:

- **the identification / confirmation of the presence of contaminants;**
- **the delineation of the area and extent of the adverse environmental impact; and**
- **site remediation, monitoring and verification or compliance testing, if conducted, as part of the Phase 2 ESA or ESA for Limited Remediation, as well as follow-up activities.**

In many situations, the completion of the above noted work may involve field work conducted in phases, over a period of time, and sequentially. Site professionals will necessarily be familiar with compartmentalizing such work into multiple reporting phases, including, for example, a Phase 2 ESA work report, a supplemental Phase 2 ESA work report, or, if required, a Phase 3 ESA report, as well as Remediation reporting.

The scope of these activities may be referred to as Phase 3 ESA, however, for the purposes of this guideline, the activities comprising all phases of the ESA work are considered to be an extension of a Phase 2 ESA. This is also the case under the Regulations.

For the purposes of this professional practice guideline, the various elements of a remedial program, the approach and technologies used, as well as long term risk management (which may utilize engineering or administrative controls), are not covered, with the exception of confirmatory sampling in order to conform to the Regulations. All these activities are considered to be an extension of the methodologies defined by a Phase 2 ESA. Therefore, the Phase 2 ESA could be more accurately described herein as "intrusive investigations, delineation and confirmatory sampling program".

The NSE Protocols that outline the environmental site assessment process from initial site assessment to closure referenced in this document include the following;

1. Notification of Contamination Protocol (PRO-100, July 6, 2013);
2. Environmental Site Assessment for Limited Remediation Protocol (PRO-200, July 6, 2013);
3. Phase 1 Environmental Site Assessment Protocol (PRO-300, July 6, 2013);
4. Phase 2 Environmental Site Assessment Protocol (PRO-400, July 6, 2013);
5. Remediation Levels Protocol (PRO-500, July 6, 2013);
6. Remedial Action Plan Protocol (PRO-600, July 6, 2013); and
7. Confirmation of Remediation Protocol (PRO-700, July 6, 2013).

Under the NSE Regulations and Protocols, if contamination is present, then a phased environmental assessment is triggered and, depending on what remediation pathway is chosen (full or limited), then a Phase 1 and Phase 2 ESA is required or alternatively a Limited ESA may completed. It is important to note that a Remedial Action Plan (RAP) is required under both site remediation pathways.

This document describes the procedures that may be followed to meet the Phase 1 and/or Phase 2 Environmental Site Assessment ("ESA") requirements. These are also identified in the Confirmation of Remediation Protocol, including the submission of a Record of Site Condition ("RSC") after completion of a "limited property remediation" (see Sections 13 and 14 of the Regulations) or a Declaration of Property Condition ("DPC") after the completion of a "full property remediation" (see Sections 15 and 16 of the Regulations), or on completion of the Phase 1 and/or Phase 2 ESA work or site investigation conducted as a due diligence investigation, independent of the Regulations, when no further investigation is warranted or required.

The NSE Regulations stipulate that all forms and checklists (from notification to closure) as well as an RSC and a DPC can only be submitted by a Site Professional ("SP"). It is a requirement that the SP must ensure that the supporting documents and reports meet the requirements set out in the Regulations and Protocols.

The site assessment principles and methodologies described in this guidance document are consistent with the minimum requirements of the Canadian Standards Association Phase I and Phase II ESA standards (CSA Standard Z769-01 and Z769-00), with the exception of hazardous material and building material assessments and inventories. These are not specifically required by the NSE Protocols and therefore, are considered to be beyond the scope of this guideline.

It should also be recognized that in addition to regulatory requirements, a SP may conduct site specific assessments (particularly a Phase 1 ESA) for client specific, business, or due diligence reasons. It is important to note that there are requirements within the CSA standards (e.g. hazardous material and building material assessments and inventories) that are not specifically required by the NSE Protocols. A review of these specific requirements is beyond the scope of this guideline.

This document may therefore be used as a guide for conducting an environmental site assessment where the assessment is intended, or subsequently required, for the submission of documents under the NSE Regulations. In that case, all of the requirements set out in the Regulations and Protocols, including the reporting forms and checklists, must be met.

Note: The guidance provided in this document is not intended to be prescriptive or all-encompassing and does not replace the need for the SP to exercise professional judgment in conducting the environmental site assessment.

It is important to note the regulatory definitions and requirements that are described in this guideline document are provided as professional practice guidance only. The SP must refer to the Regulations and the Protocols, as well as other applicable legislation and regulations to ensure their work meets the appropriate regulatory requirements.

This document should not be considered or construed or relied upon to be a replacement for the Regulations or the Protocols or to contain legal advice or legal opinion. In the event that a difference is identified between this professional practice guideline document and the

Regulations or the Protocols, the Regulations and the Protocols shall prevail.

The preparation of this guidance document was completed under the supervision of a Steering Committee with representatives from the Association of Professional Geoscientists of Nova Scotia (APGNS, Geoscientists Nova Scotia), the Association of Professional Engineers of Nova Scotia (APENS, Engineers Nova Scotia) and Nova Scotia Environment (NSE). Although this guideline is believed to be reliable and accurate, the document and all material set forth herein are provided without warranties of any kind, either express or implied, including but not limited to warranties of accuracy or completeness of information contained in the document or the suitability of the information or guidance contained in the document for any particular purpose.

1.2 Overview of the NSE, Contaminated Sites Regulations

Environmental site assessments in Nova Scotia are regulated by Nova Scotia Environment (NSE). As of July 6, 2013, NSE requires such work to be conducted or supervised by a licensed professional (Site Professional) with specific experience and environmental liability insurance.

Beginning in 2006, amendments to the Nova Scotia Environment Act were introduced to provide the legislative authority for the Governor in Council to create regulations respecting contaminated sites in Nova Scotia. In particular, these legislative amendments enabled a regulatory framework providing for the preparation and content of environmental site assessment reports and other types of environmental reports required for a contaminated site. Section 91 of the Environment Act provides the regulation making abilities of the Governor in Council related to contaminated sites, including those changes made in 2006.

On March 6, 2011, the Contaminated Sites Regulations were passed by an Order in Council, with an effective date of July 6, 2013. NSE's stated intent was to introduce greater certainty in the responsibility for remediation of contaminated sites and the standards to which contaminated sites need to be remediated.

It should be noted that the Regulations also involve a significant transfer of responsibility from government regulators to the SP. The Regulations impose two duties on the "person responsible" for a contaminated site, either of which may be incorporated into the responsibility of the Site Professional:

- the SP responsible for the site investigation, has the duty to notify, regardless of the business relationship with the client/responsible party, and

- the SP, when retained by the client/responsible party, has a duty to supervise the remedial measures.

For clarity, the SP is considered responsible for notification, but not necessarily responsible for undertaking the remediation, if required. It should also be noted that the follow-up to the notification may not involve the same SP.

The Regulations and Protocols provide a detailed framework for filing notifications, site assessments, remediation plans, risk management plans, and confirmation of remediation of contaminated sites in Nova Scotia. The Regulations specify the qualifications and specific work experience of a SP who is considered responsible for conducting or supervising the work required by the Regulations.

The Protocols provide detailed requirements that are not specified in the Regulations and this guidance document provides additional professional practice requirements not specified in the Protocols. The Regulations require the person responsible for a contaminated site undertake either “limited remediation” or “full property remediation”. These guidelines describe the minimum requirements for completion of the Phase 1 ESA, the Limited and/or Phase 2 ESAs as specified by the Regulations and the Protocols.

The majority of notification and remediation responsibilities can only be completed by a SP. In some cases there may be more than one SP involved or responsible for specific portions of the project. In each case, the SP, responsible for that stage of the project work, is required to make key determinations of whether a notification is required. Similarly, the SP responsible for the next stage of the project work is also required to be consulted on all the decisions which are relevant to the remediation process. The SP is the only individual who is acceptable to prepare and submit ESA reports and remedial action plans (“RAP”). The SP is required to certify that the information included in the RSC or DPC is accurate.

The NSE position is that the credibility and reliability of the outcome of the site assessment and remediation is dependent on the expertise and integrity of the SP. The RSC and DPC reports are intended to provide a level of assurance to the public. It is the SP who provides the certainty that identified remediation levels are appropriate and that they have been met.

The "full property remediation" leads to a DPC which, as defined by the Regulations, in turn leads to a limited form of protection from enforcement action including a Ministerial Order. The outcome of the "limited remediation" stream, the RSC, does not offer the same protection from enforcement as defined by the Regulations. Therefore, the only reliance provided in this process is on the assurance provided by the RSC, which is solely reliant on the expertise and integrity of the SP overseeing the assessment and remediation.

1.3 Site Professional (SP)

The key issue addressed in this guideline document is, the Nova Scotia Environment, Contaminated Sites Regulations (the "Regulations"), Section 5, "Qualifications for Site Professionals", stipulate the necessary qualifications for an individual to be designated a "Site Professional" ("SP"), including the following mandatory experience requirements.

The SP must:

- have a valid "certificate of registration" or "license to practice" issued under the ***Geoscience Profession Act***; or
- have a valid "certificate of registration" or "license to practice" issued under the ***Engineering Profession Act***; and
- have at least 5 years of experience in contaminated site investigation, management and remediation, (to be confirmed at the request of the Department and in the manner required by the Department), including experience in all of the following:
    - conducting a phase 1 environmental site assessment;
    - conducting a phase 2 environmental site assessment;
    - developing a remedial action plan; and
    - implementing a remedial action plan.

It is also stipulated that all ESA work, including the filing of the above noted reports, must be conducted by, or under the supervision of a SP, as defined in the Regulations. Further, the Regulations specify that an individual must not hold themselves out to be a "Site Professional" unless they have the qualifications specified above.

The Regulations also require that the SP must have and maintain specified liability insurance coverage. The minimum liability insurance requirements and other details are provided in the Regulations (see Section 6).

The role of the SP, as stated by NSE, is significant and includes:

- *"there is a legal requirement to notify NSE of a contaminated site when determined in accordance with the Notification of Contamination protocol";*
- *as the Notification Protocol indicates, the requirement to notify is applicable when the SP is working on behalf of a person responsible for a contaminated site;*
- *"the overall responsibility and accountability for conducting or supervising the site assessment, remedial planning, confirmatory reporting and filing of closure documents to NSE";*
- *"professional obligations to self-identify, meet, maintain and demonstrate specified experience and qualifications necessary to be recognized as a site professional under the regulations";*
- *"practice with appropriate coverage of professional insurance as specified within the Regulations";*
- *"apply sound independent judgment, expertise and decision making in the appropriate application of technical approaches within the regulatory framework of the Regulations and Protocols"; and*
- *"file regulatory documents and statements under professional seal."*

Although not specifically addressed by NSE in the Regulations, the professional Code of Ethics requires that a professional must ensure they are not in a position of a conflict of interest. In the context of this professional practice guideline, an example of a conflict of interest might be, the SP or their employer holding an undisclosed direct or indirect interest in the subject property that may interfere with the professional's responsibilities under the Regulations or Protocols or this professional practice guideline.

Subject to the conflict of interest provisions noted above, any SP who is an employee, shareholder, director, partner or principal of a firm, company or partnership and who wishes to submit any environmental site assessment document(s), must declare the potential conflict of interest in that document and must also include a statement of their status or involvement or an equivalent document with the RSC or DPC or the other due diligence environmental site assessment report.

1.4 Environmental Site Investigation Requirements

In the context of the NSE Regulations and Protocols, an environmental site assessment, conducted under a full property remediation, must consist of a Phase 1 ESA and a Phase 2 ESA. A Phase 1 ESA is not specifically required for a limited remediation (L1 or L2) except in cases where a responsible party (client) wishes to evaluate the entire property (L3).

For reference, the conditional and unconditional remediation level options, as well as the exemptions for substances considered as background, are described more fully in the Remediation Levels Protocol (PRO-500) as well as the Notification Protocol (PRO-100).

In some instances, a due diligence Phase 1 ESA may lead to a Phase 2 ESA. If potential contamination is indicated by the Phase 1 and verified by the Phase 2 ESA, notification under the Regulations and Protocols is required and, the person responsible will enter into the Contaminated Sites process. Additional intrusive subsurface investigation may be required to delineate the horizontal and vertical extent of contamination, both on and off the subject property and, prior to filing for regulatory closure, confirmatory sampling must be carried out (see the Confirmation of Remediation Protocol, PRO-700).

In other instances, non-environmental subsurface work (for example, a construction project) may lead to the discovery of contaminant concentrations above the criteria applicable to the site that require notification under the Regulations and Protocols. This will also require the person responsible to enter into the Contaminated Sites process, including site assessment and/or intrusive subsurface investigation.

In still other cases, for example should a sudden and/or unexpected release occur, an emergency response is triggered. The emergency response, containment, recovery and an assessment of residual contaminant impacts may lead to an environmental site assessment and intrusive subsurface investigation under the Regulations and Protocols. If however, the release is cleaned up within thirty (30) days as described in the Notification of Contamination Protocol (PRO-100), under the supervision of a SP, the SP may submit an exemption form to the Minister.

In all cases, if a Declaration of Property Condition (DPC) is required, a Phase 1 ESA and a Phase 2 ESA must be completed. If a Record of Site Condition (RSC) is applicable, a Phase 1 ESA is not required under the Regulations unless the person responsible chooses to evaluate the full site conditions (L3).

As noted earlier, the Regulations stipulate that a Record of Site Condition (RSC) and a Declaration of Property Condition (DPC) can only be submitted by a Site Professional (SP).

Also, NSE considers it to be the responsibility of the SP to ensure that all of the supporting reports meet the requirements specified in the Regulations and Protocols.

2.0 Phase 1 ESA

A Phase 1 ESA is conducted to assess the potential that current or historical uses of the property, or a portion of the property, or from adjacent properties or nearby locations, have contributed to the presence of one or more contaminants. The scope of the Phase 1 ESA is to assess the full property for all potential contaminants that may be present in soil, groundwater, sediment or surface water.

A Phase 1 ESA is required by the Regulations where Full Property Remediation is being completed (in accordance with Section 15 of the Regulations) and a DPC is required. The Protocols (ESA for Limited Remediation) allow for an optional full property assessment approach under the Limited Remediation pathway, L3, which also requires the filing of a Phase 1 ESA.

The components of a Phase 1 ESA are set out in the Regulations and Protocols (Phase 1 ESA Protocol, PRO-300 and the associated Phase 1 ESA Checklist, CHK-300).

The NSE Regulations and Protocols do not require reporting with respect to the following materials or substances of concern:

- asbestos-containing materials (ACM);
- urea foam formaldehyde insulation (UFFI);
- radon;

- mould; and
- any other substances specifically related to, or found in, construction or building materials that are not present in soil, sediment, groundwater or surface water.

The NSE rationale is that the above materials are to be managed in accordance with other regulations and standards. However, the investigation and reporting of these materials is a requirement of the Canadian Standards Association (CSA), Phase I ESA Standard Z769-01. Therefore, inclusion of these materials may be a requirement associated with a Phase 1 ESA completed for a client specific business or due diligence investigation. The professional must identify the specific requirements and end use of the Phase 1 ESA document in the preparation of the scope of the investigation. Note that in this case, the Phase 1 ESA may not be filed with NSE, unless and until follow-up intrusive work determined that exceedences to the Tier 1 criteria are identified at the site, which would trigger a requirement for notification.

The Phase 1 ESA involves:

- a review of available records, both historical and current, regarding the activities at the subject property as well as the surrounding properties, including a title search(s) and the presence of utilities;
- a site visit or reconnaissance; including the conducting of interviews with individuals who are knowledgeable about the property, site history and site activities;
- an evaluation of the information gathered;
- the preparation of a written report; and
- the submission of the report to the property owner or responsible party.

2.1 Records review

The Phase 1 ESA protocol checklist (CHK-300) provides a list of the required information records. In addition, the CSA Standard Z768-01 provides examples of the types of background information and other sources of information that should be reviewed or obtained to complete a full Phase 1 ESA.

An RSC or DPC may be completed and submitted to NSE, if required, for example by the client as part of a property transaction. If the conclusion of the Phase 1 ESA indicates that there is no evidence of the potential for adverse environmental impact, the Regulations do not require that the report be submitted to NSE.

The SP who undertakes or supervises the Phase 1 ESA work must ensure they have sufficient, appropriate, and current knowledge and expertise to identify types of property uses that are suspected to pose environmental risks to soil, groundwater, surface water and/or sediment. In addition, the SP must also be familiar with the relevant sources of background information that should be consulted.

The Phase 1 ESA study area must encompass the subject property and the immediately adjacent properties. In some cases it may be appropriate for the SP to enlarge the study area to include other potential sources.

In most cases, a records review should be conducted before site visit or reconnaissance occurs. This is recommended practice as it will provide the SP with a preliminary understanding of the potential issues of environmental concern at the properties. This will assist in the completion of an effective site visit or reconnaissance and interviews.

The preliminary information that should be assessed by the SP prior to visiting the subject site may include, but not be limited to, the following:

- fire insurance maps;
- topographical maps;
- geological maps (bedrock and surficial);
- detailed site plans, "as-built" drawings including the locations of underground utility / service;
- aerial photographs, extending to pre-development, if available;
- city or municipal directories;
- equipment maintenance and/or spill records;

- previous environmental reports;
- drilled well records (potable water);
- access to municipal services (sewerage) or presence of an on-site disposal field;
- inventories of chemicals handled or stored at the site, including MSDS information;
- records or reports detailing current and former commercial/industrial activities; and
- health and safety issues at the site which may be a concern to the site personnel.

Based on the preliminary site information, the acquisition and review of additional materials may be considered in preparation for the site visit. The SP may require additional information as a means of attempting to fully understand the property issues prior to any site visit.

The list of documents, for which the SP must make all reasonable inquiries, to obtain and review during the course of a Phase 1 ESA extends beyond the preliminary information noted above, and, for example, may include:

- fire insurance plans for all parts of the Phase 1 ESA property and surrounding properties (all available through public and/or private sources);
- search of title of the Phase 1 property that goes back to the date of its first known 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 1 property);
- copies of reports prepared in respect of all or part of the Phase 1 property by or on behalf of a current or former owner(s) respecting environmental conditions including:
    - environmental site assessment reports,
    - remediation reports,
    - reports prepared in response to an order, incident, offence, spill, discharge of contaminants or inspections maintained or requested by the NSE as well as municipal, federal, or other regulatory agencies, and
    - reports relating to the presence of a contaminant on, in or under the Phase 1 ESA property or the existence of an area of potential environmental concern;

- information relative to the subject property maintained by Environment Canada;

- PCB information, available through a freedom of information request (FOIPOP) made to the NSE, including any waste generator records, if the presence or use or storage etc of PCB's is suspected;

- current or past certificates of approval, permits for water withdrawal, industrial approvals or certificates of property use or similar documents related to the development activities and environmental condition of the Phase 1 property and surrounding properties;

- waste management records, including current and historical waste storage locations and waste generator and waste receiver information maintained, e.g. environmental monitoring records or environmental management system records;

- aboveground or underground fuel handling or storage tanks information maintained by NSE Environmental Registry;

- notices and instruments, including closure documents, posted to NSE Registry;

- aerial photographs of the Phase 1 ESA study area, including surrounding properties;

- topographic maps (typically starting with 1:50,000 NTS series), which illustrate the location of the Phase 1 ESA property in relation to any water bodies in the Phase 1 ESA study area and document regional topography;

- geological (surficial and bedrock) maps, physiographic maps or other similar documents developed to evaluate the regional and local geology, stratigraphy, and depth to bedrock in the Phase 1 ESA study area;

- well construction records and other relevant data for any operating or abandoned wells in the Phase 1 ESA study area, in order to identify:

    - the location of any such wells,
    - the stratigraphy / lithology of the overburden, from ground surface to bedrock,
    - the depth to bedrock, bedrock lithology, presence of water-bearing fractures, and
    - the depth to the water table.

- site operating records, including, but not limited to:

    - regulatory permits and records related to areas of potential environmental concern,

  - material safety data sheets (MSDS),
  - underground utility drawings, locates, “as-built” diagrams,
  - inventories of chemicals, chemical usage and chemical storage areas,
  - inventory of above ground (ASTs) and underground storage tanks (USTs),
  - environmental monitoring data,
  - waste management records;
  - process, production and maintenance documents;
  - records of spills or discharges of contaminants;
  - emergency response and contingency plans;
  - environmental inspection and/or audit reports; and
  - site plan of facility showing specialized operations including areas used for production or processing or manufacturing.

In the absence of other information regarding the history of the subject site, the SP may conduct a chain of title search for the subject site that extends back to the first known developed use.

Examples of other information that could be used to meet the objectives of the records review and in place of a title search going back to first known developed use may include the following:

- fire insurance maps;
- aerial photographs;
- interviews with building officials and local residents; and
- city zoning records.

Aerial photographs must be reviewed for a Phase 1 ESA. It is advisable for the SP to use historical aerial photographs from sources such as the Service Nova Scotia map library, the National Air Photo Library, or commercial suppliers rather than relying solely on imagery obtained on-line or from the internet. The series of aerial photographs examined by the SP should cover the site from pre-development, through development and potential uses, as well as major changes in developed uses, of the property. When including aerial photographs in Phase 1 ESA reports, the SP should indicate the location of the subject property and other significant features or locations, including, but not limited to, a north indicating arrow, an indication of the scale ratio (e.g. 1:10,000), as well as a scale bar and a title block with project information and other relevant data.

Physiographic, topographic, and geologic maps or similar documents may provide information useful to the development of a "Phase 1 ESA conceptual site model". Note, there is no requirement in either the CSA Phase 1 ESA Standard or NSE Regulations and Protocols to include a "Phase 1 ESA Conceptual Site Model" in the Phase 1 ESA report. However, it is anticipated that in the process of planning and reporting of a Phase 1 investigation, the professional will develop a general understanding of the characteristics of the property that will equate to a "Phase 1 ESA Conceptual Site Model", which may or may not be documented as such. The model will be preliminary and, based on the available information regarding the hydrogeological regime and the contaminants of concern (COC), limited, it may be considered a useful planning tool in the event that a Phase 2 ESA is warranted or required.

The following information sources may be useful in developing the Phase 1 conceptual site model:

- location(s) of potential contaminating activities;
- location(s) of water bodies, wetlands and other sensitive receptors, (the SP should refer to the Atlantic PIRI Ecological checklist (www.atlanticrbca.com));
- location(s) of current or previous pits or quarries;
- location(s) of utilities, e.g. pipelines or similar infrastructure that may constitute preferential pathways for contaminant migration;
- soil and bedrock; water well records, mineral exploration records or reports, geological mapping or surveys,
- topographic information that may assist in inferring the shallow groundwater flow direction(s), and
- presence and location(s) of on-site buildings in relation to potential COC's (e.g. transformers, chemical storage areas, etc).

2.2 Conducting Interviews

It is beyond the scope of this guideline to provide a standardized interview format for a Phase 1 ESA. However, the SP 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 identification of potentially contaminating activities.

The interview should include questions intended to verify or supplement any missing or incomplete information identified during the preliminary records review. It is advisable that the SP develop a written interview form or checklist (in consultation with the Phase 1 ESA requirements and checklist provided in PRO-300) in order to document the interview. Key information from the interview should be summarized in the Phase 1 report, however, it is not normally required to include this written record of the interview or checklist in the Phase 1 ESA report.

Interview questions should be designed to obtain factual information. Speculative questions or answers should be avoided in order to provide sound information on which to make professional judgments. Speculative answers should be recorded in context with appropriate professional analysis for the purposes of making defensible conclusions and professional recommendations.

2.3 Site Visit / Reconnaissance

The site visit and reconnaissance should be documented using written notes and photographs. The notes should include, but not be limited to:

- date(s) and time(s) of the site reconnaissance visit(s);
- weather conditions at the time of the site visit, including any weather or seasonal related conditions that hinder or otherwise limit visual observations at the site;
- name and title or position or responsibility of the person providing access to the site or accompanying the SP during the site reconnaissance;
- relevant comments from the site owner or representative;
- photographs of the site, as well as inside and outside of the facility;
- a list of areas which were not accessed and reasons why;
- a list of industrial or manufacturing processes or operations or potentially contaminating activities on the subject site or adjacent properties;
- location(s) of chemical or materials storage and handling;

- location(s) of USTs and ASTs;
- location(s) of floor drains, sumps and pits, as well as discharge points;
- location(s) of catch basins, manholes and storm sewer grates, as well as discharge points;
- location(s) of surface water drainage systems, swales, ditches and water flow direction;
- type(s) of heating and cooling systems;
- location(s) of power transformers (if any), and the age of each unit;
- location of building entry and exit points including loading bays and waste collection;
- location(s) and/or area(s) of stressed vegetation;
- location(s) and/or area(s) of surface stains;
- information regarding adjacent and surrounding sites and activities (e.g. facility names, addresses, and any potentially contaminating activities that are reported or observed); and
- the location of waste storage or handling area(s) and type(s) of waste stored or handled.

Note: Utility services and other infrastructure have the potential to be preferential pathways for contaminant transport on or off the site. In addition to information obtained during the site reconnaissance, the SP may be able to obtain information regarding the depth and configuration of utilities through facility plans or "as-built" drawings for the subject property, or from information available from municipal works departments or public utilities commissions.

2.4 Review and Evaluation of Information

The SP will review and evaluate the information from the records review, interview(s), site visit and reconnaissance in order to prepare:

- a tabular summary of current and past uses of the Phase 1 property; and
- a tabular summary of areas of potential environmental concern.

The Phase 1 ESA information should also include:

- the size and location(s) of site buildings, paved and unpaved areas of the property;
- the age(s) of structures currently and formerly on the property;
- location(s), sizes, ages and uses or contents (if known) of current and former ASTs and USTs on the property;
- potable and non-potable water supply wells on the property and in the study area;
- catch basins, drains, sumps and pits as well as discharge points;
- known or suspected areas of waste storage and/or management;
- details and locations of chemical handling and storage;
- details and location(s) of power transformers, if any;
- locations and details of any known underground utilities at the property;
- locations and details of potentially contaminating activities;
- location(s) and area(s) of known spills or releases;
- location(s) of oil/water separators, hydraulic lifts or similar equipment;
- locations and details of any known drainage works, sewage works or similar facilities; and
- locations of water bodies, wetlands, areas of natural significance, or other sensitive receptors.

2.5 Reporting

The Phase 1 ESA includes the preparation of a written report to provide a record of the scope and relevant findings of a Phase 1 ESA in a clear and organized manner consistent with the CSA Standard and/or the NSE Phase 1 ESA Protocol (PRO-300) and associated checklist (CHK-300).

The report must identify:

- conclusions related to information obtained from the records review, site visit, and interview(s);

- the potential or actual contaminant concentrations above the criteria applicable to the site, if present and as determined during the historical investigation(s), to be supported by the rationale; and

- the potential or actual chemicals of concern, if present, and affected media identified at the property, if applicable.

The Phase 1 ESA report must document limitations, including a description, rationale and significance to the observations or conclusions presented in the report. Figures provided in the Phase 1 ESA report, including the graphical components of a Phase 1 conceptual site model, if included, should be prepared to scale. The north arrow, scale bar and title block should be considered essential elements of the figure as are property boundaries, PID numbers, current land use, location(s) of water bodies (streams, etc), and potable water well(s), if known.

The Phase 1 ESA report must include a clear and concise statement indicating whether potential adverse environmental impact has been identified. It must also clearly state if further environmental site assessment and/or investigation is required or recommended to assess and/or confirm potential contamination and/or confirm and/or delineate historical contamination determined during previous investigations.

3.0 Phase 2 ESA / Intrusive Investigation

CSA defines the purpose of a Phase 2 ESA is to confirm the presence of, and to characterize the substances of concern, at a given site (CSA Standard, Phase II Environmental Site Assessment, Z769-00). The characterization may range from a simple identification to a full delineation of the contamination on-site. That project work, the intrusive investigation, is the subject of documentation in this guideline.

If the Phase 1 ESA report concludes that the previous or current operations or activities at or surrounding the subject site represent potential for adverse environmental impact (i.e. potential contamination concentrations above the criteria applicable to the site), at the subject property, a Limited ESA or Phase 2 ESA is required in order to meet the requirements to issue a RSC or DPC. Contamination, if present in soil, groundwater, surface water and sediment must be compared to the applicable regulatory criteria, e.g. the Tier I Environmental Quality Standards (EQS) determined using Notification of Contamination Protocol (PRO-100). In any case, the SP must document the rationale for undertaking the Phase 2 ESA in the project report.

The NSE Regulations and Protocols provide specific requirements for carrying out a Phase 2 ESA (Phase 2 ESA Protocol PRO-400 and the associated checklist CHK-400). The requirements include sufficient vertical and horizontal sampling to delineate the extent of contaminants that may be present at the property and potentially off-site. The NSE Regulations indicate that if the SP “knows or ought to know” that contaminant migration “has or may have occurred” off-site, then delineation of impact must include off-site investigation and third-party permission is required. If third-party access is denied for any reason, a third-party denial access form is provided under Remedial Action Protocol (PRO-600).

The Phase 2 ESA is normally triggered by the results of the Phase 1 ESA, however, in the case of limited remediation (i.e., as defined by the L1 or L2 ESA), a Phase 1 ESA is not required and may not have been a consideration. A limited remediation may be undertaken due to the presence of contamination from a single source (known release or event) with single or multiple contaminants of concern and, due to the focused nature of a L1 (soil impacts only) or L2 (multiple media impacted) ESA under the Limited Remediation Pathway, the end result is the filing of a Record of Site Condition (RSC). It is important to note that a L3 ESA covers the entire property and requires that a Phase 1 ESA be completed and filed.

The NSE Regulations require that if the Phase 2 ESA indicates that one or more of the sampled media contains contaminants that exceed the Tier I Environmental Quality Standards (EQS) provided in the Notification of Contamination Protocol tables (PRO-100), then the following may be considered:

- remediation of the affected media (i.e., soil, groundwater, surface water or sediments) to the extent that Tier I EQS are no longer exceeded; or

- remediation of soil and groundwater to Tier 2 Pathway Specific Standards (PSS) determined using Remediation Levels Protocol (PRP-500); (note that there are no PSS set out for sediment or surface water as direct contact is considered the only operable exposure pathway for these media); or

- undertake a Tier 2, Site Specific Risk Assessment (SSRA) to develop site specific target levels (SSTLs); or

- undertake a combination of remediation and risk assessment.

The NSE Regulations and Protocols do not prescribe remediation methodologies, but they do describe considerations regarding remediation measures, such as, default assumptions for the use of Tier I EQS. They also outline the remediation levels or methods and type of closure granted (conditional or unconditional), and the long term exposure management measures, if required.

The Protocols describe the requirements for confirmatory or verification sampling of soil, groundwater and air (soil vapour, sub-slab and indoor air) either during and/or post-remediation, including the frequency of each, and ties the results to the site specific Remedial Action Plan (RAP).

This guideline document focuses on providing guidance on soil and groundwater assessment in the context of a Limited or Phase 2 ESA. The assessment of surface water or sediment or air (soil vapour, sub-slab and indoor air) including the collection of representative samples, is beyond the scope of this document.

The requirements for soil importation as part of the remediation process are addressed in Confirmation of Remediation Protocol (PRO-700).

Note: For the purpose of this professional practice guideline, the site assessment activities subsequent to and resulting from a Phase 2 ESA, are considered to be a continuation of the methods or procedures described for a Limited or Phase 2 ESA under the Regulations. For the purpose of this professional practice guideline document, a Phase 2 ESA also refers to and includes activities completed as an intrusive investigation and confirmatory sampling.

3.1 Application of a Limited or Phase 2 ESA

An intrusive investigation may be characterized as a Limited ESA (L1, L2 or L3) or a Phase 2 ESA. The NSE Regulations allow for intrusive investigation as a Limited ESA. For L1 and L2 ESA, this is defined as being limited to the portions of a property which have been affected by a known release or event. It is applicable if sampling of soil, sediment, surface water or groundwater determines that there is an exceedance of the Tier I EQS at the site. The L3 ESA evaluates the entire property and, therefore, triggers a Phase 1 ESA followed by a Phase 2 ESA.

The NSE Regulations also indicate that an exceedance of the Tier 1 EQS triggers a requirement for notification as per the Notification of Contamination Protocol (PRO-100). The Protocol also outlines exemptions to the notification requirement (e.g. limited volume of contaminant or extent of impact, as well as exemptions for background occurrences). In addition, the Protocol identifies the requirement for notification of third party properties if the SP knows or ought to know that contaminant migration has or may have occurred.

3.2 Planning the Intrusive Site Investigation

For a Limited ESA, the identified media and contaminants of concern form the basis of planning the sampling locations. For example, an L1 ESA involves the assessment of soil contamination following a release from a single source with single or multiple contaminants of concern. However, an L2 ESA involves the assessment of soil, sediment, groundwater or surface water from a single source with single or multiple contaminants. The L3 ESA involves the assessment of soil, sediment, groundwater or surface water from single or multiple sources with single or multiple contaminants and is applicable where the assessment of the entire property is required and the result includes a Record of Site Condition (RSC). As noted above, the L3 ESA requires a Phase 1 ESA as well as a Phase 2 ESA.

For a Phase 2 ESA, the observations and conclusions of the Phase 1 ESA, which may have formed part of a Phase 1 Conceptual Site Model, normally forms the basis for planning the sampling locations, the media to be sampled and the potential contaminants of concern to be assessed. The exception to this is when contaminant concentrations in excess of NSE Tier 1 EQS are encountered without a Phase 1 ESA having been completed.

The planning for the Phase 2 ESA must include:

- a preliminary understanding of the site characteristics, including the likely source(s) of contamination and expected location(s) of contaminants,

- presumed shallow groundwater flow direction(s), normally based on the site topography and proximal wetlands, water courses or bodies of water,

- evaluating the potability and the presence of water supply wells on the subject site,

- evaluating the potential presence of confining and unconfining layers, normally based on mapping of the bedrock and surficial geology in the area, and

- evaluating the likely contaminant transport mechanisms, including the existence of potentially preferential pathways for contaminant transport, (e.g. subsurface infrastructure, storm drainage or sanitary sewer connections or utility conduits) and the presence of buildings and their occupancy/use.

The preliminary conceptual site model will be revised and/or refined as field data are gathered during the Phase 2 ESA (refer to the discussion on preparation of the Phase 1 ESA CSM) and must be presented in the Phase 2 ESA report.

The final selection of sampling locations will be influenced by site-specific constraints and safety hazards, such as the physical layout of the property, location of site buildings, the presence of underground utilities and overhead power lines, as well as access to adjacent or third-party properties. These constraints should be assessed at an early stage to determine how they may influence the final sampling locations in relation to the Phase 2 ESA conceptual site model. This should be documented so that the significance of deviations from the Phase 2 ESA conceptual site model can be assessed, and if required, an alternate or supplemental sampling strategy can be developed.

Other information about the property that may be available but that may not have been included in the Phase 1 ESA, if it was conducted, should also be reviewed and assessed. The SP should, to the extent possible, ensure that the reports are consistent with the technical requirements specified in the Regulations and Ministerial Protocols and, if possible, that reliance has been confirmed for inclusion in the work.

When planning the intrusive investigation the SP must consider whether the property use or activities at the subject property or adjacent properties may have changed since the Phase 1 ESA, if it was conducted. It is recommended that the SP visit the subject property to assess the actual conditions and plan the investigation accordingly. The plan may include a provision for an iterative round of sampling, particularly where extensive contamination is expected. Sampling locations should be planned near the up-gradient and down-gradient property boundaries so that the implications of contaminant movement from or to adjacent or surrounding properties can be assessed. Cross-gradient locations should also be assessed in order to confirm groundwater flow (i.e. do not construct wells in a straight line).

The NSE Protocol, ESA for Limited Remediation (PRO-200) outlines the minimum sampling requirements for an L1, L2 and L3 ESA. In general, the overall requirements are as follows:

3.2.1 Soil

The Phase 2 ESA Protocol (PRO-400) outlines the minimum sampling requirements, as follows:

- soil - one soil sampling location for every potential source area; and
- to determine the horizontal and vertical extent of soil contamination exceeding the Tier 1 standards, on and off the site, for each contaminant.

The SP must ensure that the laboratory sampling for petroleum hydrocarbons is in accordance with the latest version of Atlantic RBCA User Guidance and for all other contaminants, the latest guidance from CCME.

The Confirmation of Remediation Protocol (PRO-700, Table 1, Section 3) outlines the confirmation sampling requirements as, soil samples must be collected from the side walls and floor of the excavation. Composite sampling for VOCs is not considered acceptable by the Regulations.

3.2.2 Soil Vapour

The SP must be cognizant that where contaminated soil below any part of a building footprint may be proposed to be left in place (e.g. as part of remediation/risk assessment), full assessment/delineation and verification, through soil vapour, sub-slab sampling and/or indoor air sampling, may be required. These methods must follow the latest version of the Atlantic RBCA Guidance document to assess the potential for unacceptable risks associated with vapour inhalation.

3.2.3 Groundwater

As required by the Regulations and Protocols:

- for an L1 site with a potable well or spring supplied water source the water supply must be tested for the contaminants of concern;

- for an L2 ESA, a Phase 1 ESA is not required, as the assessment is limited to portions of properties affected by a known release or event; all other aspects of PRO-400 Phase 2 ESA Protocol must be followed; and

- an L3 ESA involves a Phase 1 and Phase 2 ESA;

The Phase 2 ESA Protocol (PRO-400) outlines the minimum sampling requirements, as follows:

- at least 3 drilled boreholes on the site with groundwater samples collected from each;

- determine horizontal and vertical extent of groundwater contamination exceeding Tier 1 standards, on and off the property, for each contaminant; (note that based on the contaminant of concern, this may require at least one nested monitor well, i.e., two or more wells installed to different depths and screened within separate zones); and

- groundwater samples must be collected and tested at sites with potable well or a spring supplied water source.

As noted above, the SP must ensure that the sampling and laboratory analysis for petroleum hydrocarbons is in accordance with the latest version of Atlantic RBCA User Guidance and for all other contaminants, the latest guidance from CCME.

3.2.4 Other Media

Although not the focus of this guideline document, if there are potential impacts to sediment or surface water, the sampling program must determine whether contaminant concentrations in sediment or surface water exceed applicable Tier I EQS.

3.3 Development of Standard Operating Field Procedures (SOP)

A Standard Operating Procedure (SOP) is defined herein as a document that describes the preferred procedures that, in most circumstances are to be followed in conducting the various components of an intrusive investigation. The SP will, based on experience, recognize and document where deviations are appropriate. Many professionals will have access to corporate SOP’s and these are normally considered to be important “internal” documents. There is no requirement under the Regulations to file an SOP. However, in terms of the assurance and reliance on the project work, the SOP may form the basis for a discussion of due diligence and therefore it is recommended that it should be developed and maintained as part of the project record.

The development and application of a prescriptive SOP is beyond the scope of this document. It is anticipated that the SOP may incorporate site-specific considerations, in addition to the SP's professional judgment, the integration of up-to-date information from regulatory jurisdictions, as well as the review and integration of information from the scientific literature. It is standard practice for many companies to conduct an internal review of their SOPs on a routine basis.

There are several published examples of SOPs available (e.g. USEPA Environmental Response Team, 2010; National Water Research Institute, Environment Canada, Monitoring Well Decommissioning Model, 2002) for reference. It is recommended that the SP 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:

3.3.1 Scope and Application of the SOP

This section should describe the intended application of the SOP for the intrusive investigation (e.g. test pit construction, borehole drilling, monitor well installation, development, soil sampling, stockpile sampling, groundwater sampling, and others as required).

3.3.2 Material and Equipment Requirements

This section should describe the materials and equipment that will be required in executing the SOP, and provide a description of how the equipment is to be prepared and used. As applicable, calibration procedures, equipment decontamination and waste disposal procedures should be documented. Equipment requirements should also include the personal protective equipment (PPE) requirements that are necessary to safely execute the work.

3.3.3 Sample Container, Collection, Handling and Preservation Requirements

Where the SOP addresses the collection of representative samples, the types of containers required or recommended should be included in the SOP. Where containers are to be prepared by the SP, or someone working under the direction of the SP, 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 collection, handling and labeling 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 groundwater samples are to be collected without headspace and are to be closed immediately following collection. Low flow sampling equipment should be considered when sampling groundwater for volatile contaminants.

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 labeling 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) may be described, as may the procedures for sample homogenization if appropriate. Specific requirements for trip blanks, equipment blanks, filter blanks, etc, may also be described.

3.3.4 Chemical Reagents

A description of any chemical reagents or substances required in the execution of the SOP may be provided. This section may include the specific quality or requirements for these reagents (to be specified by the laboratory, if applicable), as well as procedures for the safe handling, use, and disposal of these substances including WHMIS requirements and MSDS information.

3.3.5 Standard Procedures / Methodologies

This section should provide a step-by-step methodology for completion of the procedure for which the SOP should be referenced. 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).

3.3.6 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.

3.3.7 Calculations

Any calculations that may be required in the execution of the SOP should be documented in this section. For example, an SOP for field testing of an aquifer to determine its hydraulic properties should include a description of the method used (e.g., small scale slug test or bail down test, large scale pumping test with observation wells) and the numerical analysis of the data to calculate hydraulic conductivity.

3.3.8 Quality Assurance and Quality Control (QA/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, laboratory sampling, collection of an appropriate number of field duplicates, as well as trip blanks, equipment blanks, filter blanks, etc, as well as the interpretation of results (e.g. comparison of primary and duplicate results, calculation of detection limits, etc).

3.3.9 References

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

3.3.10 Health and Safety Plan

The SOP should incorporate a stand-alone Health and Safety Plan, modified to be site specific where required, that must be followed by field personnel, including sub-contractors, under the direction of the SP. This Health and Safety Plan should be communicated to the field staff prior to the start of field work and must meet the requirements of the Nova Scotia Occupational Health and Safety Act and the Regulations. Many professionals will have access to rigorous internal corporate H&S programs and will have developed safe work practices to cover routine tasks, such as, working around heavy equipment. There are also many reference materials for general work site safety as well as precautions that should be taken when working on a contaminated site.

The SOP must address the topic of safety in the field as well as communications, roles and responsibilities. It should be anticipated that “tool box” safety meetings will be scheduled on a regular basis as well as in response to any significant change in site activities. The attendance at these meetings must be mandatory and the subject and discussions must be part of the work record.

The SP must ensure that all necessary notifications and clearances from all applicable utilities, agencies or relevant parties have been addressed before undertaking any excavation or drilling operations. If a suspected underground utility has not been positively identified in the field, consideration should be given to retaining a private utility locator to provide further evidence that no utility is present. Should doubt remain, consideration should be given to “daylighting” the proposed borehole location prior to excavation or drilling.

Any activities around heavy machinery, including moving, swinging, rotating equipment and tools such as a drill rig or an excavator is considered hazardous. For example, site work will often include the use of excavators or other heavy equipment which have limitations on operator visibility that must be recognized. Similarly, drilling equipment includes rotating parts as well as hoisting tools, but communications are limited due to high noise levels. Field personnel should be generally familiar with the components of a drill rig including the location of safety features, such as, the engine kill switch.

Field crews must always wear appropriate Personal Protective Equipment (PPE) which, for example, may consist of (as a minimum): hard hats, safety boots, high visibility safety vests, and safety glasses. The use of disposable gloves is recommended when handling soil and water samples. All site personnel should avoid wearing loose clothing around operating equipment. Personnel should never stand near the edge of open test pit excavations and never enter an excavation deeper than 1.2 metres. Excavated pit or trench walls must be properly sloped or supported.

The SP should consult reference materials for the appropriate level of PPE when working with specific contaminants which are anticipated to be present at the site. It may be necessary to equip field crews with protective “Tyvek”-type suits, respirators or full supplied air SCBA-type equipment, depending on site conditions.

4.0 Selection of Regulatory Criteria

The selection of the appropriate regulatory criteria depends on several factors including:

- the current and previous property use (i.e., agricultural, residential/ parkland, commercial, or industrial; note that residential/parkland land use includes campgrounds but does not include undeveloped wild lands, such as, national or provincial parks which are included under agricultural land use due to the consideration of ecological pathways);
- the “potable” or “non-potable” use of groundwater, as per the PRO-100, Notification of Contamination Protocol, Appendix 2, Determination of Groundwater Potability;
- proximity of the site to surface water, wetlands or other environmentally sensitive features; and
- the soil composition, type, clay content, grain size and texture; note that the selection of fine-grained criteria requires the support of laboratory data, i.e., grain size analysis, representative of site conditions and collected from the “appropriate soil zone”.

5.0 Development and Application of Conceptual Site Models

A Conceptual Site Model (CSM) 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 is an aid to the assessment and, where applicable, the remediation of a site.

At a preliminary stage, data assembled during the Phase 1 ESA, if it was conducted, would form the basis of the CSM, if available. As additional data becomes available during the Phase 2 ESA, the CSM can be prepared / updated and used to refine the work program. As noted in the sections below, this is particularly important in the assessment of Dense Non Aqueous Phase Liquids (DNAPL) impacted sites where refinements to the CSM are critical decision points in the investigation process. Each characterization phase is designed to test and refine this model.

The iterative process should continue throughout remedial design and during remedial operations.

The extent of preliminary information available to guide the development of the CSM 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 most sites such information may be lacking, unavailable or unreliable. The SP should assess the reliability of the Phase 1 CSM when planning the Phase 2 ESA. Deviations from the Phase 1 CSM may be warranted, based on a SP's observations or independent knowledge about the site conditions, however, the rationale for such deviations must be documented.

In addition to a specific regulatory requirement, the importance of a well developed CSM for planning, supervising and conducting an intrusive site investigation cannot be underestimated by a SP. The purpose of a CSM is to provide the framework for the application of environmental quality standards in relation to the three fundamental aspects of an environmental site assessment, which are;

1. The source of contamination, including the physical, chemical and behavioral properties of contaminants and their hazards to human health and the environment.

    - information on the handling, storage, transportation, use, monitoring, and disposal of chemicals of concern at the site;

    - locations, volumes, and timing of any known releases;

2. The pathways to be evaluated for surface migration or subsurface movement of contaminants of concern, including indirect, direct and preferential pathways (such as utilities and conduits) that may be present on and off the site as appropriate.

    - locations of subsurface infrastructure, e.g. underground piping, structures, or utilities which might influence subsurface flow;

    - regional/local geologic (bedrock and surficial), topographic and hydrogeologic mapping or reports, soil surveys, climatic data, and design and "as built" records and site plans, historical air and/or ground photos of the site; and

3. The receptors to be evaluated for the contaminants of concern, including human health

and ecological receptors on and off the site as appropriate.

- preliminary information, available from the literature, concerning pertinent contaminant transport and fate parameters for the site-specific contaminants.

6.0 Sampling and analysis plan

The planning of a Phase 2 ESA will typically involve decisions regarding:

- the type of sampling program to be undertaken and the equipment required,
- the locations and media that are to be sampled,
- the contaminants of potential concern to be analyzed based on the potentially contaminating materials, equipment or activities identified during the Phase 1 ESA,
- the methods of sample collection,
- the number of samples to be collected for quality assurance and quality control (QA/QC) purposes,
- the process for determining which samples (e.g. soil) will be submitted for analysis (based on field observations, head space analysis, etc), and
- the parameters to be analyzed.

The sampling plan must be developed with the objective of assessing the potential areas or issues of environmental concern identified during the Phase 1 ESA.

The sampling plan should be based on the CSM, 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 2 ESA. For example, it may not be desirable to drill boreholes to the depth stated in the sampling plan if gross contamination (e.g. mobile or 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 2 ESA, the sampling plan developed at this stage may not entirely reflect the final field program that is implemented. The SP undertaking the Phase 2 ESA should not be constrained by the sampling plan when field conditions require deviations.

7.0 Non Aqueous Phase Liquids (NAPLs)

Non-aqueous phase liquids (NAPLs) are liquids that exist as a separate, immiscible phase when in contact with water and are typically classified as either light (LNAPLs), which have densities less than water, or dense (DNAPLs), which have densities greater than water.

The term NAPL should be used only in a generic application to NAPL assessments or related issues. It should not be used in lieu of the term “free product” or “free-phase product”. Instead, where appropriate, the more descriptive terms “residual NAPL”, “mobile NAPL”, or “migrating NAPL” should be applied.

7.1 Definitions

As noted above, NAPL is a nonaqueous-phase liquid or a nonaqueous-phase liquid solution composed of one or more organic compounds that are immiscible or sparingly soluble in water.

An LNAPL is a light, or low density, nonaqueous-phase liquid having a specific gravity less than one and composed of one or more organic compounds that are immiscible or sparingly soluble in water.

The term LNAPL should be used only in a generic application to LNAPL assessments or related issues. It should not be used in lieu of the term “free product” or “free-phase product”. Instead, where appropriate, the more descriptive terms “residual LNAPL”, “mobile LNAPL”, or “migrating LNAPL” should be applied.

7.2 Residual NAPL

Residual NAPL (DNAPL and LNAPL) is the range of NAPL saturation up to the point at which the capillary pressure equals pore entry pressure, i.e the condition of maximum NAPL saturation. Below the maximum saturation, NAPL distribution is discontinuous and it is immobile under the applied gradient (slope). At this saturation, where the NAPL is discontinuous and does not have the ability to flow, it is considered residual. The NAPL is essentially trapped in the pores of the soil matrix under normal conditions. Not only is residual NAPL difficult to recover by hydraulic means (i.e. pumping) and it can be difficult to effectively or accurately evaluate its location and extent in the site assessment.

Residual NAPL in the soil matrix could lead to mobile NAPL with changes in the site conditions for example, seasonal groundwater fluctuation or continued/additional release. Residual NAPL can be present both above and below the groundwater surface and therefore should be considered in the assessment of the vadose zone as well as the aquifer for delineation, as well as mass calculations, and the development of the conceptual site model.

7.3 Mobile NAPL

Mobile NAPL exceeds residual saturation noted above. The term is applied when NAPL is present in the soil matrix at a high enough saturation to be hydraulically connected in the pore spaces so that it can “flow”. If a monitor well is constructed where mobile NAPL is present, the NAPL will accumulate in a well. With sufficient groundwater flow gradient, it has the potential to move or expand its footprint, but it is not actively spreading vertically or laterally, for example, when NAPL is first observed to accumulate in a monitor well due to a change of groundwater level. Mobile NAPL is potentially “recoverable” using hydraulic methods.

7.4 Migrating NAPL

Migrating NAPL, observed to spread or expand laterally or vertically or otherwise, results in an increased volume of the NAPL. This is normally indicated or identified in the conceptual site model by time series data or observations. Migrating NAPL does not include NAPL that is noted as present in a monitor well, within the historical extent of the NAPL, and due to seasonal groundwater fluctuation.

Migrating NAPL occurs when the vertical and/or horizontal extent of the NAPL is expanding. This is most likely to be present immediately, or soon after, a release occurs or if the release is ongoing. However, site specific conditions or changes in site conditions may allow NAPL to migrate for extended periods of time, therefore, all migrating LNAPL is also mobile LNAPL but not vice versa.

7.5 Risks and Concerns Associated with DNAPL and LNAPL

There are a number of potential risks or concerns associated with NAPL in the subsurface that the SP must be aware of and incorporate into the planning of site assessment work as well as any updates to the conceptual site model and, if required, the remedial or site management activities.

- **NAPL Mobility**: NAPL can migrate significant distances if the source of the release (e.g., a leaking underground storage tank) is not eliminated or recovered; depending on site conditions, NAPL may migrate vertically or laterally and has the potential to impact surface water bodies, water supply wells, and underground infrastructure or utilities that intercept the release;

- **Explosive Vapour Hazard**: vapours released from NAPL may migrate into underground services or utilities or other confined spaces; they may accumulate at concentrations which represent an explosion hazard; elevated vapour concentrations may also occur during excavations within NAPL source zones;

- **Vapour Health Risk**: volatilization of the NAPL and vapour migration into indoor or ambient air may pose unacceptable risk to human health;

- **NAPL Toxicity**: direct contact with the NAPL in soil, groundwater or surface water may present an unacceptable risk to human health and/or ecological risks;

- **NAPL Dissolution**: fluctuation of the water table may spread the NAPL vertically or laterally within a soil, creating a "smear zone" of NAPL which may extend below the water table; groundwater that comes in direct contact with NAPL may become contaminated with the NAPL; NAPL components in the dissolved-phase may migrate away from the NAPL zone, contaminate surface water bodies and water supply wells, and may pose human health and ecological risks through direct exposure pathways such as ingestion or dermal contact; the NAPL dissolved plume may also be a source of soil vapour contamination which may migrate to indoor air;

- **Direct Contact Risk:** Similar to vapor intrusion, the presence of NAPL complicates the evaluation of the soil direct contact pathway. Soils containing NAPL can pose a direct contact risk to humans and risks to environmental receptors; and

- **Aesthetic and Nuisance Concerns**: the presence of the NAPL and the generation of odours may pose an aesthetic or odour nuisance concern.

8.0 Considerations when Assessing Light Non-Aqueous Phase Liquids (LNAPLs)

LNAPLs, immiscible chemicals which have densities less than water, include products such as gasoline, diesel or furnace oil, jet fuel and various lubricants. LNAPLs are commonly found at and, to some extent, below the top of the water-saturated soil zone.

8.1 Movement of NAPL

The movement of LNAPL through the subsurface is controlled by several processes. An LNAPL release will move downward in the surface soil (vadose zone) by gravity. A small volume release will move through the unsaturated zone until it is immobilized or stabilized within the soil pores by capillary forces. Some will be left behind as residual NAPL, immobile and trapped in the soil pore spaces. A larger volume LNAPL release will migrate downward and laterally until it encounters the water table, where buoyancy forces and increasing water content in the soil matrix impede the vertical movement of LNAPL.

The LNAPL, by definition with a lower density than water, will migrate vertically through the soil matrix until vertical equilibrium is reached. It will then spread laterally along the water table, normally in the direction of the water table gradient. Vertical equilibrium usually occurs before horizontal equilibrium, and the NAPL will continue to spread laterally until horizontal equilibrium is reached. The vertical and horizontal spread of NAPL is limited by buoyancy, capillary forces, NAPL conductivity, geological heterogeneity, and declining hydraulic force of the NAPL gradient.

As the NAPL body spreads the degree of NAPL saturation decreases, which reduces the NAPL conductivity. Once the counteracting mechanisms (i.e. decreasing conductivity, decreasing gradient, and entry pressure combined with loss mechanisms of biodegradation, dissolution, and volatilization) are greater than the NAPL head, migration ceases. The migration of NAPL (DNAPL or LNAPL) requires displacement of air and water from the soil pores. It takes less force for NAPL to displace air than water; therefore, NAPL preferentially enters air-filled pores. It takes less pressure for NAPL to enter a larger pore; however, in an air-NAPL system (i.e. no water), the NAPL will also be in smaller pore spaces because it is the wetting fluid in that system. Heterogeneity of the soil, pore geometry, and the presence and amount of water in the pores all strongly affect NAPL migration. NAPL can migrate below the surface of the groundwater; the depth below will be determined by the degree of heterogeneity and the NAPL head. NAPL can also be present and migrate in hydraulically confined stratigraphic units.

The NAPL will reach the water table and, despite having a density lower than water it can be driven into the saturated zone by the vertical NAPL head. For the NAPL to migrate in the saturated zone, it must first displace the water from the pore spaces. NAPL will continue to migrate downward into pores below the water table until vertical equilibrium is reached. This occurs when NAPL head (downward force) is less than or equal to the sum of the buoyancy force (LNAPL) and the entry pressure of the aquifer pore (upward forces).

Vertical equilibrium usually occurs before horizontal equilibrium, and the NAPL will continue to spread laterally until horizontal equilibrium is reached. As noted above, the vertical and horizontal spread of NAPL is limited by buoyancy, capillary forces, NAPL conductivity, and declining hydraulic force of the NAPL gradient.

The presence of mobile NAPL (i.e., NAPL above residual saturation) in a given well does not necessarily mean that the NAPL body is migrating, just that it has the potential to migrate. In order for migration to occur at the edges of the NAPL body (i.e. expansion), the NAPL head (i.e. potential energy or gradient) must be high enough to overcome the entry capillary pressure of adjacent soil pores.

As the NAPL body spreads the degree of NAPL saturation decreases, which reduces the NAPL conductivity. Once the counteracting mechanisms (decreasing conductivity, decreasing gradient, and entry pressure combined with loss mechanisms of biodegradation, dissolution, and volatilization) are greater than the NAPL head, the NAPL body becomes mobile but not migrating.

Three conditions related to residual LNAPL distribution in soil/groundwater that the SP must be aware of, plan and incorporate into the CSM;

1. Saturated residual soil, potential vertical and lateral migration to the shallow water table leading to mobile LNAPL and/or migrating LNAPL body due to soil / bedrock properties, capillary resistance, hydraulic head and gradient;

2. Mobile and/or migrating LNAPL; following termination or elimination of the release, lateral movement may be dissipated; mobility of the LNAPL product may or may not be limited to accumulation/flow within monitor wells; and

3. Residual saturation, LNAPL accumulation within the monitor well may be minimal or not present; may be reintroduced due to seasonal fluctuations in groundwater table.

9.0 Considerations when assessing Dense Non Aqueous Phase Liquids (DNAPLs)

As noted in the sections above, non-aqueous phase liquids (NAPLs) are liquids that exist as a separate, immiscible phase when in contact with water and are typically classified as either light (LNAPLs), which have densities less than water, or dense (DNAPLs), which have densities greater than water.

The first step in the assessment of a potential DNAPL release or impact is a consideration of the types of chemicals which may be present at the site. The major types of DNAPLs are halogenated solvents, coal tar and creosote, PCB oils and miscellaneous or mixed chemicals. The most extensive is halogenated (primarily chlorinated) solvents due to their widespread use and specific properties (high density (greater than 1.01 g/cm^3), low viscosity, low solubility (less than 2%) and high toxicity).

There are a wide variety of chemical products and wastes that may comprise a DNAPL and the physical and chemical properties of the DNAPL can vary considerably from that of pure compounds to the complex chemical mixtures (waste or off-specification materials, process residues and spent materials, and in-situ weathering).

The site assessment work plan must be developed to assess the site but must also recognize and minimize the potential for inducing unwanted contaminant migration during the assessment and/or remedial activities. The project specific objectives should include, but not be limited to;

- identify the release / source area and estimate the quantity(s) and type(s) of DNAPLs released and present in the subsurface; plan for mobile and/or residual;
- delineation of the subsurface DNAPL zone;
- determination of the soil / bedrock stratigraphy (barriers, traps, migration pathways (infrastructure services, fractures, etc.));
- determination of the DNAPL fluid properties, migration rate and fate;
- determination of the fluid-media (soil, water) properties; and

- minimize the investigation risk.

The site characterization must be a continuous, iterative process, whereby each phase of the investigation, and remediation, is used to refine the CSM. The interpretation and delineation of subsurface geological conditions (stratigraphy and structure) is critical since the movement of the DNAPL is largely controlled by the properties of the DNAPL and the subsurface capillary properties. Therefore, it is important to determine the spatial distribution of fine-grained capillary barriers and/or preferential pathways (e.g. site infrastructure, fine-grained / coarse-grained soil materials, and bedrock fractures, etc).

The chemical phases and transport must be evaluated and understood (i.e., vapour migration, dissolved plume movement, sorption, and degradation all influence fate and transport). Other considerations include heterogeneity of the soil and/or bedrock, diffusion of the contaminant and time.

9.1 Non-Invasive Methods

Non-invasive assessment methods may be employed during the early phases of a DNAPL assessment, to control costs, develop and enhance the CSM, and to reduce the potential risks. Specifically, surface geophysical surveys, soil gas analysis and air photo interpretation may be employed.

- surface geophysical surveys; to investigate soil and bedrock stratigraphy and hydrogeology; evaluate electrically conductive contaminants, buried waste; optimize the locations for subsurface sampling; equipment may include ground penetrating radar (GPR), electromagnetic (EM) conductivity, magnetometer or metal detection equipment;

- soil gas analysis; may be an effective screening tool; most halogenated solvents (e.g. chloroform, vinyl chloride, carbon tetrachloride, etc.) have high vapour pressure and will volatilize in the vadose zone, thus presenting a vapour plume around the DNAPL source; soil gas surveys may have some limited applicability to the detection of contaminants in the vadose zone, however, in most cases the effectiveness is restricted to the area proximal to the shallow contaminant plume; and

- air photo interpretation; historical documentation may identify waste disposal practices and/or locations, site infrastructure excavations, surface drainage, vegetative stress, soil staining as well as hydrogeological (slope) and geological (bedrock outcrop) features.

9.2 Invasive Methods

Based on the site CSM and the non-invasive investigation, the site assessment will generally require direct sampling. This may include;

- construction of drill holes (boreholes) and/or test pits to sample and characterize subsurface soil and/or bedrock; and
- installation of monitor well(s) to sample subsurface fluids, survey fluid level(s), conduct hydraulic testing or downhole geophysical surveys.

The risk of enlarging the zone of DNAPL chemical contamination through the use of intrusive methods must be an important consideration in planning the site assessment. Drilling, well installation and pumping activities present the greatest risk of promoting DNAPL migration. Drilling and well installation may create vertical pathways. If the drilling is not closely monitored, it is possible to drill through a DNAPL zone without detecting the presence of the DNAPL or the barrier / confining layer. Similarly, pumping may increase the hydraulic gradient(s) and mobilize a stagnant or stable DNAPL plume and induce vertical or lateral movement. This is particularly problematic in fractured bedrock where the potential fluid velocity(s) may be high.

Specifically, the SP must evaluate the available information (the CSM) and determine if the risks cannot be adequately minimized. If so, an alternate assessment method should be used. Alternatively, the SP must determine if the objectives should be waived.

9.3 Drilling Methods

Conventional drilling methods have a high potential or risk of promoting the downward migration of DNAPL. To minimize the risks the SP should:

- avoid unnecessary drilling within the DNAPL zone;
- ensure that the drilling operations have considered the potential for intersecting DNAPLs and have prepared the operating personnel (drill crew and site supervisors) and equipment to effectively address the potential;

- minimize the time during which the drill hole is open;
- minimize the length of the drill hole which is open at any time;
- use telescoped casing drilling techniques to isolate the shallow, contaminated zones from the deeper zones;
- use continuous, split spoon type sampling equipment and carefully examine the samples before allowing drilling to resume to avoid drilling through the underlying barrier layer (i.e. stop drilling at the top of the underlying boundary layer); each sample point should be a decision point regarding the continuation of drilling; depending on the characterization of the DNAPL, specialized testing may be required to correctly recognize the DNAPL contamination and drilling should not resume until the field characterization of the sample is complete;
- consider the use of specialized equipment and/or materials for construction of the drill hole; (e.g. high density drilling fluid, normally re-circulated to maintain the hydrostatic head and prevent the DNAPL from entering the drill hole, etc.);
- if ground conditions and the depth of the DNAPL contamination zone permits, applications such as direct push sampling, (which can employ on-site, real-time data collection) may be applicable, however, in areas of shallow and/or fractured bedrock (e.g. most of Nova Scotia), this will not be suitable;
- select appropriate well materials (casing and screen) as well as the composition and placement of grouting / sealing materials; these will be based on the specific chemistry of the contaminants; consider sealing the entire cased interval to minimize the potential for vertical migration.

The risk of DNAPL migration is greatly increased in areas of fractured bedrock, heterogenous strata, multiple release locations, a large release volume, and barrier layers that are not easily defined (e.g. a thin silt barrier unit rather than a thick clay underlying a sand unit). Therefore, a staged or “outside in” approach should be employed. This must include limited shallow depth drilling inside the DNAPL zone with deeper wells constructed beyond the edge of the DNAPL zone. This may allow improvement of the CSM before drilling in the DNAPL zone, but not through the DNAPL zone and thereby reduce the associated risks. Drilling through the DNAPL zone may remobilize a possibly immobile DNAPL.

9.4 Well Construction

Site assessment monitor wells are installed to characterize immiscible fluid distribution, flow direction(s) and rate, groundwater quality and hydraulic properties. The location, design and construction of drill holes and monitor wells at a DNAPL assessment site require special consideration of:

- site conceptual model and specific data collection objectives; as knowledge of the site increases or expands, the CSM must be updated;

- the effect of well design (screen length relative to the confining layer and the contaminant zone; sandpack composition, grain size, roundness and sphericity, etc), and location on immiscible fluid movement in the monitor well and in the near-well environment;

- the compatibility of well construction and sampling materials with NAPLs and dissolved chemicals; and

- well development options; (well development should be limited to "gentle" pumping and removal of fine particles to minimize DNAPL redistribution).

9.5 Sampling

It is important to note that sampling of monitor wells to determine presence and/or thickness of DNAPL must be evaluated in conjunction with an understanding of the geological / hydrogeological conditions as observed during the drilling operations. The survey of the well should assist in the determination of fluid potentials, flow direction(s) and immiscible fluid distribution. For example, care should be used to slowly insert and retrieve any measuring or sampling device to avoid creating an emulsion at the interface.

Various sampling devices can be employed to collect representative samples without altering the stability of the DNAPL in the well. It is beyond the scope of this document to detail those devices here, but they include bottom-loading bailers, mechanical discrete-depth samplers, double check valve bailers, or in deeper wells (e.g. >10 m) a dedicated downhole submersible pump, such as a bladder pump, or other low flow sampling device that does not induce a significant pressure gradient (i.e. potentially degassing the VOCs) may be applicable. The SP should consider the time and cost to decontaminate and/or replace sampling equipment as a factor in the assessment planning.

The presence of DNAPL's in the drill hole / well sample can be:

- determined directly by visual examination of the subsurface samples; (e.g. UV fluorescence or addition of hydrophobic dye may be applicable);

- inferred by the interpretation of chemical analysis of the subsurface samples; (compare measured chemical concentrations to effective solubility limits for groundwater); or

- suspected based on the interpretation of anomalous chemical distribution and hydrogeological data.

9.6 Analysis

There is no textbook or cookbook approach to a site assessment involving DNAPLs. It is the responsibility of the SP to recognize that each site presents a variety of contaminant accumulation and transport conditions and issues. Additional site assessment methods (tracers, interpretation of chemical distributions and ratios, hydraulic testing, etc.) are beyond the scope of this guideline document. It can only be emphasized that site characterization, data analysis and refinement of the CSM are critical activities and must be completed within the framework of the project objectives.

It is critical for the SP to develop a work plan that recognizes that the examination of soil, rock and fluid samples obtained as part of the drill hole construction process must focus on the identification of DNAPL presence and the potential barrier or confining layers. Decisions regarding the continuation of drilling, monitor well construction and/or drill hole abandonment must be made in conjunction with the SP’s observations rather than other factors such as timing or budget.

10.0 Conducting the Intrusive Site Investigation

10.1 General

The SP should ensure that all the requirements of the field sampling program are considered during the planning stage of the Phase 2 ESA. The program should outline the sampling method(s) that are to be used and the sample handling, storage, shipping and laboratory submission procedures and requirements. This will help ensure that consistent procedures are followed between sampling locations and particularly when sampling may be conducted by different field personnel.

The planning for field sampling should result in field sampling personnel having full knowledge of sampling procedures to be used, observations of field and soil / bedrock conditions to be recorded, the planned sampling locations, criteria for relocating planned sampling sites, methods of recording site locations, proper containers and labeling of samples, and proper procedures for storing and delivering samples to the analytical laboratory. If necessary, the analytical laboratory should be consulted with to verify the requirements for sample collection, containers, preservatives, field filtering, handling, transport, 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, appropriate PPE, and field conditions for which safety protocols should be in place (i.e. excavations, encountering buried pipes and storage tanks, mobile equipment, noise etc.)

10.2 Drilling – equipment, methodology and best practices

The assessment required for most sites requires relatively shallow investigation and commonly includes the drilling of boreholes. The two most common types of drilling equipment and techniques used in routine investigations are the geotechnical auger drills (standard or hollow stem equipment to penetrate soils or weathered bedrock) and core drills (wireline equipment to drill boulders and/or bedrock).

Geotechnical auger equipment and methods are favoured for environmental site assessment work. There are no fluids introduced during drilling and samples are normally obtained prior to advancing the drill bit. Diamond core drilling uses a water-based fluid to lubricate the downhole equipment (bottom hole assembly) and to carry the drilled solids (rock cuttings) from the borehole. Samples are obtained by advancing and retrieving the core barrel. The drill fluid (water and additives, e.g. viscosifiers) may influence subsurface conditions giving misleading results. The circulated drill fluid may also transport contaminants to the surface where they may be difficult to control.

Other drilling equipment and techniques, such as cable tools or air-rotary/hammer, are more commonly used in the construction of water wells, but they are not normally adapted for environmental assessment work. However, they may have applications in deep drilling scenarios where DNAPLs, which have a density greater than water, are included in the contaminants of concern. The detailed discussion of water well drilling equipment as well as other methods (e.g. vibracore, direct push or directional drilling) is beyond the scope of this guidance document but may have specific applications.

10.3 Equipment Selection

Geotechnical and diamond core drills come in a wide range of sizes and power levels. Most geotechnical drills are also outfitted with wireline coring equipment and can accommodate shallow construction requirements. The SP should consult with the drilling contractor in order to select the appropriate equipment for the specific location and requirements. The geotechnical drills are commonly tire or track mounted so it will be necessary to consider size (length, width and height) and maneuverability when selecting drilling equipment. The SP must ensure that all borehole locations can be accessed by the rig being considered.

In some cases, limitations on space and area will limit the accessibility of conventional auger and core drills, particularly in confined exterior areas or indoor investigations. “Direct push” or hydraulic soil probe equipment may be considered, however, they have been shown to have limited application based on site conditions (e.g. boulders, fractured or shallow bedrock, etc.).

10.4 Clearances for Intrusive Work

10.4.1 Layout

All borehole and test pit locations should be clearly identified in the field. This may require using bright markers, stakes or paint marks on hard ground surfaces such as asphalt or concrete. The locations must be located accurately so that they can be identified on scaled site plans and/or maps.

10.4.2 Approvals

Prior to the construction of any borehole or test pit, the location(s) of all site services must be checked by all the relevant agencies and/or utilities for the presence of buried underground services. Clearances should be obtained, in writing, from agencies/utilities such as (but not limited to):

- site owner/operator;
- municipal water and sewer department;
- telephone;
- electric;
- gas; and
- telecommunications.

Test locations must be selected so as not to interfere with overhead lines.

10.5 Diamond Core Drilling

10.5.1 Cleaning & Maintenance

The SP is responsible to ensure that the drilling contractor has appropriate procedures in place to guard against the possibility of introducing contamination to a site via inadequately prepared equipment. Environmental investigation equipment may move from one assessment / contaminated site to the next and, without due diligence to cleaning and maintenance, cross-contamination can occur. In some cases, drills and mechanical excavators may be cleaned before transport to a site, preferably using steam methods. The contractor should keep a maintenance record which should be available to the SP on request.

The SP is responsible to ensure that the drilling contractor will provide equipment in good running order and all fixtures related to hydraulics and fuel must be sound.

All tools used to perform subsurface work should also be cleaned before transport to the site. Cleaning is also required between sampling intervals and test hole locations to prevent cross-contamination. On large, complex or sensitive projects, it may be necessary to establish a decontamination station for cleaning of equipment and tools and dealing with the effluent generated by cleaning.

Common cleaning methods for equipment and tools include: high pressure steam combined with a mild soapy water solution, using phosphate-free detergent. In locations considered “sensitive”, it equipment cleaning using hexane and methyl alcohol may be required. In these cases, the equipment should be rinsed with distilled water before being reintroduced to the subsurface.

10.5.2 Drilling Fluids

Water used in the formulation of drilling fluid in a diamond drilling operation should be pre-tested in order to fully understand its chemical and physical properties. This may prevent the introduction of misleading components to the subsurface. Any chemical additives, viscosifiers, pH stabilizers, etc., must be documented by the field personnel. Wherever possible, biodegradable products should be utilized and it may be necessary to control the return fluid for off-site disposal.

10.5.3 Non-Petroleum Based Greases

The use of petroleum-based grease(s) used on drilling tools such as drill rod connections should be avoided, particularly on sites where petroleum hydrocarbons (NAPL’s) are the contaminants of concern. The SP should ensure that the drilling contractor uses vegetable-based greases.

10.5.4 Tools

The common geotechnical augers are either standard (4 inch / 100 mm) or hollow stem (5 inch / 130 mm) diameter. If the ground condition permits, standard augers are removed from the borehole to advance a split spoon type sampler. If the borehole will not remain open for sampling, the bit face on the hollow stem auger can be removed to accommodate the split spoon sampler. Both types of equipment will accommodate a 2 inch / 50 mm diameter monitor well.

Wireline diamond core drilling tools are sized for different applications. The most common size for environmental assessment applications is HQ since the resulting borehole diameter will accommodate the construction of a 2 inch / 50 mm diameter monitor well. A summary of coring equipment sizes is shown in the table below.

Core drilling involves continually advancing the borehole to the desired sampling interval using steel casing as required to hold the drillhole open. As noted above, the contractor should be advised not to use petroleum-based grease on casing and /or drill rod threads.

Table 1. Wire Line Coring Bits

SIZE	CORE DIAMETER (mm)	CORE DIAMETER (inches)	HOLE DIAMETER (mm)	HOLE DIAMETER (inches)
AQ	27.0	1.062 - 1 1/16	48.0	1.890 - 1 57/64
BQ	36.4	1.433 - 1 7/16	60.0	2.360 - 2 23/64
NQ	57.5	1.875 - 1 7/8	75.5	2.980 - 2 63/64
HQ	63.5	2.500 - 2 ½	96.0	3.782 - 3 25/32
PQ	85.0	3.345 - 3 11/32	122.6	4.827 - 4 53/64

Casing is normally fabricated to Imperial measure and comes in 2, 5 and 10 foot lengths (0.6m, 1.5m and 3.0m). Field personnel should measure and mark and record each casing length used in the borehole in order to accurately track and record the borehole depth. Field personnel should also measure and record all of the bottom hole assembly equipment, e.g. the length of the casing “shoe”, reaming shell and bit, etc., to accurately monitor the borehole depth.

10.6 Auger Drilling Method

Borehole construction using standard auger equipment is the preferred method for environmental investigation. Geotechnical auger rigs can be mounted on a variety of carriers making them highly adaptable to a wide range of conditions. Mobilizing and moving this equipment from one site to another is normally very quick and cost-effective.

10.6.1 Advancing an Auger Hole

The two basic types of geotechnical augers are: solid stem and hollow stem. Environmental drill rigs are normally equipped with both types. Both auger types come in 1.6m (5 foot) lengths and the drill is equipped with a hydraulic drive head which can feed this length into the ground in one stroke. The first piece of auger to go into the ground is equipped with a bit that has hardened “teeth” to cut subsurface material. As the augers are “screwed” into the ground, cuttings are returned to the surface on the flights of the mandrill auger to accumulate on the ground surface around the borehole. These cuttings may be either returned to the borehole when it is completed or they must be collected for disposal. If the cuttings are contaminated, they must be dealt with in the same manner as any other contaminated soil and disposed of at an approved location.

The geotechnical drill rigs used to advance augers are very powerful and have a high torque. It may be possible to drill into weathered bedrock (especially sandstone, shale and other soft rocks).

10.6.2 Solid Stem Augers

Solid stem augers are designed for use in cohesive subsurface materials which will allow a hole to stay open when the augers are removed. The augers are drilled to the desired depth and then removed from the borehole in order to place the sampling equipment back down to obtain a soil sample. Even in cohesive materials, the depth to which one can drill with solid stem augers, and still have the borehole remain open each time, is limited. Commonly, a depth of about 10 metres (30 feet) is the limit however in some locations this maximum depth is considerably greater.

The normal diameter of solid stem augers is 100 mm (4 inches).

10.6.3 Hollow Stem Augers

Hollow stem augers, as the name implies, consist of auger “flights” welded to the outside of heavy gauge steel pipe. The augers are not normally removed from the borehole each time a sample is required. They are larger in diameter (up to 200 mm or 8 inches) than solid stem augers. Hollow stem augers can be used in most types of ground conditions.

The augers are drilled into the ground in 1.5m (5 foot) increments. A “plug” is fixed to the end of drill rod or bar inside the auger stem to prevent material from rising up into the augers as they are advanced. Once the desired depth is achieved, the “plug” and rods are removed from the hollow stem and the sampling device is lowered to the bottom of the borehole on the same drill rods or bars to collect the sample.

The field personnel must record the equipment required to advance the borehole. The total depth of the borehole is determined by measuring the amount of auger visible above ground surface (stick up) and subtracting that from the total length of equipment drilled into the ground.

The SP must ensure that the field personnel keep accurate records during all stages of drilling.

10.7 Soil Assessment Methodology

Soil is normally defined as the unconsolidated, naturally occurring surficial materials, including rock fragments, minerals and organic materials, which are the result of the natural breakdown or weathering of rock and organic matter, or that has been transported by natural processes, and which overlies the bedrock.

Soil may be subdivided into “coarse-grained” (greater than 50% sand and gravel size particles; greater than 0.075 mm; 75 microns; or material that does not pass through a 200 mesh sieve) and “fine-grained” (greater than 50% fine sand, silt and clay size particles; less than 0.075 mm; 75 microns; or that passes through a 200 mesh sieve), (see Notification of Contamination Protocol PRO-100).

In many cases, the surficial material on a site may be glacial till which is comprised of poorly sorted, fine to coarse grained, deposits, with fragments and particles that are both less than and greater than 2.0 mm in diameter. In these situations, the SP must make an evaluation, based on the predominant particle size present in the deposit, whether the material would meet the definition of coarse or fine grained soil and collect samples for analysis and site characterization accordingly.

The assessment of the physical characteristics of the soil is a fundamental component of an intrusive investigation. 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 determination of grain size may be an important consideration and in fact is a requirement if the SP wishes to apply fine grained soil quality criteria under the Regulations and Protocols in assessing and remediating contaminated sites.

The results of the soil sampling may also help indicate, along with the results of the Phase 1 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 SP and field personnel conducting soil sampling must consider this variability in assessing potential contamination of a Phase 2 ESA property.

Soil sampling should be conducted in all areas of potential environmental concern (APEC's) identified in the Phase 1 ESA. For the purpose of filing an RSC or DPC, the sampling locations should be chosen such that the contamination in each area exceeding the applicable Tier I EQS 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 Tier I EQS. Similar considerations should be applied in establishing the vertical extent of soil contamination.

10.8 Soil Sampling Methods in Boreholes

10.8.1 Split Spoon or Barrel Sampler

Environmental drilling uses equipment and tools which have been adapted from the mineral exploration or geotechnical engineering industries. For example, the split spoon or split tube or barrel sampler was designed for use by geotechnical engineers to investigate sites foundation design. It is the most common method of sampling soils for environmental work.

Normally, the sampler has an overall length of 80 cm (32 inches) of which 61 cm (24 inches) is split. The barrel is 50 mm (2 inches) in diameter and is split in half lengthwise. The two halves are held together by fittings which attach to the threaded portions at each end. The drive end is hardened steel and the edge is beveled to enable it to "cut" into the ground. The upper connecting portion has a ball valve incorporated to allow water to escape (but not return to) the sampler as it is driven into the ground.

The 50 mm diameter split spoon / barrel sampler is specifically designed for use in the Standard Penetration Test (SPT). This test provides data on the relative density (and bearing capacity) of soils. The definition of an SPT is, the number of blows required to drive a split spoon sampler a total of 1 foot (0.3 metres) using a 140 pound hammer dropping 30 inches. Blow counts are often useful in determining the depth of soil horizons.

The sampler is designed to be driven at least 46 cm (18 inches) into the ground in 15 cm (6 inch) increments. The blows required to drive each 15 cm (6 inch) interval are recorded. The first 15 cm (6 inch) increment is disregarded as a seating load then the remaining two numbers are added to derive blows/0.3 m (1 ft.). This is an important number in geotechnical engineering called the "N value". Many samplers are built to be driven 61 cm (24 inches) into the ground. Again, the blows during the first increment are disregarded. Numbers 2 & 3 as well as 3&4 are added. Between the resulting two values, whichever total is less is considered the N value.

The sampler is affixed to the end of a rod and lowered to the bottom of the borehole. A 63 kg (140 lb) hammer is then used to drive the sampler into the ground in 15 cm (6 inch) increments. The hammer must be dropped from a height of exactly 76 cm (30 inches) in order to derive SPT information. The operator must ensure that the connection between the sampler and drill rod is tightened using pipe wrenches. As the sampler is lowered into the borehole, all drill rod joints must be tightened with wrenches. The use of petroleum grease on the rod threads is not permitted. The sampler is lowered to the bottom of the borehole. The visible portion (stick-up) of the rod should be measured and recorded to ensure that the sampler is properly at the bottom of the borehole and not resting on the borehole wall.

The operator will mark three or four lines on the drill rods at 15 cm (6 inch) intervals with a piece of chalk prior to driving the rod. The field personnel should count the blows required to drive each 15 cm (6 inch) interval. In many instances, the sampler will not penetrate the complete 46 cm to 61 cm. This is to be noted as "Refusal". The number of blows required to achieve the actual penetration are recorded. Blow counts are normally discontinued when they exceed 50 to achieve 150 mm of penetration in order not to damage the drilling tools.

The operator will return the sampler to the surface, disassemble the apparatus and split the barrel exposing the soil sample. The field personnel should always note which end of the sampler represents the bottom of the borehole.

Normally, with solid stem augers, there are several inches of waste soil at the top of the sampler which represents slough material that fell into the borehole and was penetrated before encountering undisturbed soil. This is not normally the case with hollow stem augers. The field personnel should discard or ignore this waste or slough material and measure the remaining portion in the tube. This measurement is termed the "Sample Recovery".

10.8.2 Logging

The field personnel must observe and record all aspects of the soil sample, termed "logging" the sample. The observations and notes should include, but not be limited to:

- colour, grain size, texture, lithology (gravel, pebbles, sand, silt, clay), moisture content (dry, damp, wet, etc);
- units, layers, changes in soil or rock type, contacts (sharp, gradational, etc);
- presence of groundwater (indicated by saturation); and
- any indication of contamination/impact including odour, discolouration, presence of residual or mobile (free-phase) hydrocarbon or other chemical product, etc.

The SP should ensure that the operator thoroughly cleans and rinses the split tube sampler, as well as any other re-use equipment, before it is reassembled and reused in the borehole. The wash fluid should be a mild soapy water solution with phosphate-free detergent. More rigorous cleaning with hexane or methyl alcohol may be required. The wash water should be free of contaminants. If possible, the equipment should be rinsed with distilled water and the re-assembly should not use petroleum-based greases.

10.8.3 Thin Wall / Shelby Tube Sampler

Alternatively, a Thin Wall or "Shelby" Tube sampler may also be used. It is commonly used to obtain samples for laboratory testing of geotechnical properties as well as samples for determination of porosity and permeability. It is effective in fine-grained cohesive soils such as silts and clays to recover relatively undisturbed samples.

The Shelby tube is a thin steel or aluminum pipe of 50 or 75 mm diameter cut to suitable lengths (usually 61 cm). The sampler is not driven into the ground but pushed - either by hand or using the force of the hydraulic head on the drill rig, hence it has limited application here.

Thin wall tube samples must be extruded from the tube using a tool in the laboratory. It is therefore not possible to log the sample in the field in the same manner as the split tube type sample.

In some areas, a thin wall Shelby-type tube may be used to extract samples from the walls of a test pit or soil recovery excavation or a soil treatment stock pile.

10.8.4 Auger Samples

In some cases, where soil conditions do not permit the collection or representative soil samples using conventional samplers, samples obtained from the auger flights may provide a screening tool or a general indication of trends in soil conditions. These samples are not considered reliable and are therefore discouraged.

Samples may be collected directly from the auger flights after the auger string is removed from the borehole. However, it will be difficult or impossible to determine what depth the sample represents. Alternatively, the material that returns to ground surface as auger cuttings may be sampled.

Either method gives only an approximation of subsurface conditions both in terms of soil profiling and contaminant conditions.

10.9 Test Pits

In some cases, test pits may be used to investigate relatively shallow soil. Test pits may be constructed by hand but more commonly with a back-hoe or an excavator. In most cases, the width of the test pit may not need to be greater than the width of the backhoe bucket.

Test pits are an effective assessment tool with a depth limit of approximately 5 to 6 metres. They are normally advanced to bedrock or below the groundwater level and are not usually suitable for investigating conditions below the bedrock surface. They create a significant area of disturbance at ground surface and may not be selected for investigating in developed or landscaped areas.

Although in certain circumstances, it may be possible to install a monitor well in a test pit for site screening purposes, however, it must be recognized that it is difficult to construct an effective monitor well in a test pit and the samples obtained will not be considered representative of the site conditions. Specifically, NSE has indicated that the analytical data will not be acceptable for assessment or confirmation sampling. Therefore, it not recommended as a best practice.

10.9.1 Soil Sampling

Two main types of soil samples are collected from a test pit: composite and discrete. Discreet samples are required for confirmatory testing (see the requirements for confirmatory sampling in PRO-700 Confirmation of Remediation Protocol). Composite samples may be useful in characterizing a site, or for determining the appropriate off-site disposal option, as they may reflect conditions over a larger profile either vertically or horizontally, however, they may not be representative of "worst case" conditions and are not suitable for all parameters (e.g. volatiles).

In constructing a test pit to the desired depth it may be preferable to have the backhoe excavate in stages, stopping to allow the field personnel to record the conditions and obtain the required samples. The field personnel must record visual observations of conditions on the test pit wall and the sample location. Measurements must be taken consistently from the same point on the ground surface which must be part of the site survey. Representative soil samples should be logged, handled and stored using the same protocols described for borehole samples.

It may be possible to obtain composite or discrete samples with a trowel or spade directly from the walls of the excavation. Personnel must not be permitted to enter an excavation that is more than 1.2 metres deep in order to collect samples or examine the soil stratigraphy, etc. If samples are required at depths of greater than 1.2 metres, the samples must be recovered using the backhoe or excavator bucket. Sampling tools must be cleaned after each sampling event in order to prevent cross-contamination.

10.10 Sampling Frequency

10.10.1 Boreholes

The frequency of soil sampling is dependent on any number of factors including the complexity of soil conditions, the anticipated depth to the groundwater table, the types and concentrations of the contaminant(s) of concern, and whether or not bedrock is encountered. In relatively straightforward assignments using boreholes in an "unconfined" aquifer situation, the rule of thumb is to obtain continuous soil samples to the groundwater table. This gives a complete picture of the soil profile including changes in soil lithology and trends in levels of contamination with depth.

This means that split tube (or other suitable method) samples are obtained “back to back” down to the water table. If groundwater was encountered at a depth of 6 metres (20 feet), 10 split tube samples would be obtained. This would be applicable to situations where unconfined groundwater is encountered within relatively shallow depths in the order of 6 to 10 metres. If groundwater is deeper, the SP must determine the requirements to derive a complete understanding of all factors affecting hydrogeology. Typically, samples obtained every 1.5 metres below a depth of 6 to 10 metres will be sufficient, however, this will vary based on the site conditions, depth to bedrock and project requirements.

10.10.2 Test Pits

Test pits allow an actual visual inspection of subsurface conditions. Bulk samples should be obtained of the various materials encountered and in sufficient quantity to allow a complete evaluation of subsurface conditions including changes in contaminant conditions.

As noted above, while it is technically possible to install a monitor well in a test pit in order to obtain screening information, it is difficult to construct them properly and, NSE has indicated that the analytical data for the samples obtained will not be acceptable for assessment or confirmation sampling. Therefore, it is not recommended as a best practice.

Based on the requirements of the investigation, six (6) or more test pit samples may be collected, either from discrete depths or alternatively from the sidewalls and the base with an extra sample for vertical delineation. In any case, the SP must determine that a sufficient number of samples are collected to obtain vertical delineation of contamination in the area of the test pit.

10.10.3 Groundwater Assessment Methodology

Groundwater sampling in a Phase 2 ESA is mandatory for all Full Property Remediation work as well as when conducting Limited Remediation using a L2 or L3 approach. It is also required where there is potable groundwater use on the subject site or adjoining sites and where there is potential for groundwater impact (see Notification of Contamination, PRO-100, Appendix 2, Determination of Goundwater Potability). In any case, if an assessment of the groundwater is not undertaken as part of the investigation, the rationale must be provided.

A sufficient number of groundwater monitoring wells should be installed to delineate the horizontal and vertical extent of groundwater impact. The number and depth of the monitor wells will depend on many factors including the depth of the water table, the presence of confined and unconfined groundwater units, multiple aquifers, depth to bedrock, the size (area) of the site, and the potential type(s) and source(s) areas of contaminants.

In general, at least one monitor well must be installed in each area of potential environmental concern (APEC) where groundwater impact is considered likely. Monitor 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 monitor wells, not constructed in a line, will be required to establish the direction of groundwater flow in each groundwater unit. However, it must be stressed that the minimum number of monitor wells may not be sufficient to determine the extent, nature and prevalence of groundwater contamination at a property.

The maximum depth of the monitor wells will be determined by anticipated type of contaminant (i.e., LNAPL, DNAPL or inorganic material) present on the site and variable depths may be required for adequate assessment. This will depend on the initial results and information available regarding the hydrogeological conditions (e.g. vertical gradient). In addition, the type and depth to bedrock, the presence of a confining layer(s) or aquitard(s) must also be considered in determining the depth of drill penetration. 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 or providing a pathway for migration of the contamination into an unimpacted groundwater unit (see DNAPL discussion).

The Regulations and Ministerial Protocols require that contamination be delineated in groundwater in both the lateral and vertical directions. Lateral delineation typically requires several monitor wells. Vertical delineation, particularly on a DNAPL site, may require the use of one or more multi-level monitor wells. Additional guidance on the vertical delineation of groundwater impacts is presented below.

In the case of LNAPLs, the soil sample vapour readings (head space analysis) may be a useful tool for determining the vertical extent of groundwater impact, if soil sampling sis extended below the groundwater table. However, this tool would not be relevant in areas of shallow, fractured bedrock.

Where practicable, particularly on an LNAPL site, the SP may consider using soil headspace vapour screening results in conjunction with soil sample laboratory analytical results as evidence that vertical delineation has been achieved.

In the case of DNAPLs, the SP must develop a vertical delineation plan carefully (refer to the section on considerations for assessing DNAPLs). This may include 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.

10.11 Monitor Well Installation

Monitor wells are typically constructed using prefabricated PVC well materials. Monitor wells must not be constructed using standard steel or galvanized pipe. Stainless steel may be required in some locations or for specific applications.

10.12 Materials

The principal components of a monitor well / piezometer are:

- **Screen Section** – PVC, available in various diameters with 50 mm (2") being the most common, however, in some cases the use of stainless steel may be required based on the contaminants of concern to be evaluated. The slot sizes are well defined in the water well drilling industry (#10, #20, #30 and #40 slot sizes are most common). Ideally, the slot size is selected based on the grain size distribution characteristics of the soil. It is very common to use #20 in Atlantic Canada. In unusual circumstances, well screen can be improvised by cutting slots or drilling holes in solid 50 mm diameter PVC pipe, however, this is not a recommended best practice. The screen is usually positioned from the bottom of the borehole to a point ABOVE THE WATER TABLE so that LNAPLs (lower density than water) can be intercepted.

- **Solid Section (Casing)** - Solid PVC pipe of same diameter as screen (typically 50 mm). The pipe must be insert joint / flush-joined (i.e. not threaded and coupled) to screen section and gasketed. Joints are normally low profile square threads gasketed with an o-ring seal and must not be glued or taped. Note that in DNAPL investigations, a section of soild casing should be added below the screen section to act as a sump.

- **Screen Sock** - A synthetic geotextile material sleeve slipped over the screen section to inhibit clogging of the screen. In recent years, this has NOT typically been used in the construction of piezometers for groundwater sampling due to concerns that the fabric may preferentially hold certain contaminants.

- **Sandpack** - Clean (washed), sized, silica sand is placed around the screened section of the borehole to prevent clogging and increase the efficiency of the well. The grade of the sand to be used depends on the grain size of the intersected formation as well as the slot size, but it is common to use #2 silica sand with #20 screen.

- **Bentonite (Wyoming bentonite or sodium montmorillinite clay)**; A swelling clay sourced from Wyoming; it absorbs water and swells to approximately 10 times its original volume; it is used to seal and isolate the lower section of a well from surface water infiltration and to prevent the vertical migration of contaminants within the annulus; it is available as powder or as sized pellets; note that water-based, bentonite drilling fluid (viscosifier) used in mineral and petroleum drilling mud and may be applicable for hydraulic well control in some DNAPL applications; however, as a viscosifier, it has been largely displaced by water-based, biodegradable polymer fluids.

- **Bottom Cap / Well Point** - A PVC cap or well point is placed at the bottom of the screen to prevent material from entering the well from the bottom.

- **Top Plug / Compression Plug** - A lockable compression fitting or well plug is placed at the top of the casing to prevent material from entering the well from the top; note that in some cases the compression plug may not allow the water level to reach equilibrium, in which case the water level may rise significantly in the well on removal of the plug).

- **Well Cover / Wellhead Enclosure** - Either flush-mount box (flush with ground surface and secured with a bolted cover) or above-ground casing pipe /monument (a steel well head protector secured with a lock).

- **Grout / Asphalt Apron** - An apron is placed around the wellhead enclosure to prevent surface waters from entering the well; normally a Portland cement/sand mix, quick set grout, or cold patch asphalt.

10.13 Installation

The PVC well materials are normally factory wrapped in plastic. The SP and field personnel must ensure that all well materials are transported and stored in a clean environment. Well materials should always be handled using gloves. The use of disposable gloves is recommended.

The SP will determine the length of the screened section of the well based on observations from the drilling of the borehole and an estimate of the depth to groundwater. For LNAPLs, it is important to select a screen length that will span the water table, including recovery from drilling operations and seasonal changes. For other contaminants of concern (e.g. metals), screen placement will be determined by the SP based on site-specific conditions.

The operator should lower the screen and well point into the open borehole (solid stem auger method), inside the casing (diamond drill method) or inside the hollow stem augers. Then add the required sections of PVC casing to bring the installation to ground surface.

A measuring tool (e.g. a weighted measuring tape) may be lowered down the borehole annulus between the PVC and the borehole wall.

Silica sand is poured slowly into the borehole annulus until the sand reaches a point at least 0.3 metres above the screened section. The measurement should be checked with the weighted tape measure.

In the open borehole method, the installation of the sandpack can be done in one step. When installing the well in casing or hollow stem augers, the casing or augers must be pulled back periodically so as to prevent the sandpack and well materials from becoming jammed in the drilling tools.

Pour bentonite (or other suitable seal material) into the borehole annulus up to a point that creates the desired thickness of well seal. Depending on site conditions and contaminants of concern, a 0.3 to 0.5 metre thick well seal above the screen section and, if required, near the ground surface, may be sufficient, however, this may not be suitable for a deeper well installation where a seal to surface is required to prevent vertical contaminant migration. Check with the weighted tape measure. Pull the casing/hollow stem augers as necessary.

Once the well seal is completed, the hollow stem augers or casing can be completely removed from the borehole. The borehole annulus may be backfilled with clean soil. The upper seal may be required in order to prevent vertical infiltration of surface water.

The installation is completed by placing the appropriate wellhead enclosure and constructing the grout apron. Slope the apron from the enclosure downwards to the surrounding ground.

10.14 Groundwater Sampling

Groundwater samples can be obtained in several basic ways, including collection techniques that use bailers or pumps that normally involve purging the well first, or passive sampling techniques that collect water samples over time using diffusive or semi permeable in-situ dedicated sampling devices. The Regulations and Protocols do not stipulate specific requirements for obtaining representative groundwater samples. The SP must select a groundwater sampling program based on the site conditions and the contaminant of concern, as well as repeatable consistent procedures for the duration of site work. Several types of groundwater sampling pumps are available (e.g. peristaltic, mechanical, piston, bladder, gas drive and inertial, etc). These are each specifically designed for environmental applications.

The most common groundwater sampling method for intrusive investigations is the use of a dedicated PVC bailer or a Waterra inertial pump system. It is beyond the scope of this guidance document to review or present all options for groundwater sampling equipment. For example, low flow sampling equipment ensures sample collection from the screened interval, minimizes disturbance to the well by limiting drawdown (e.g., less potential for metals concentrations to be artificially elevated due to turbidity; this may be more representative of actual groundwater conditions; it has also been reported that turbidity of the water may be related to elevated PAH and extractable petroleum hydrocarbon concentrations), and minimizes the amount of purge water to be dealt with. In addition, low flow sampling via bladder pump may decrease the amount of volatiles that may be lost during traditional sampling methods if, for example, VOCs are a contaminant of concern. Sampling equipment must be specific to the project and appropriate to evaluate the contaminant(s) of concern.

10.15 Bailers

Bailers are typically constructed using a PVC tube (usually 1 metre length), approximately 30 mm diameter and equipped with a ball valve at the bottom. Specialized bailers are available, constructed of stainless steel or with a double check valve system. These may be applicable to sampling for specific chemicals or DNAPLs.

The bailer is lowered into the monitor well to intersect the groundwater. The floating ball valve opens as it enters the water allowing the bailer to sink and be filled. The bailer is then recovered and the sample can be collected. For DNAPLs, the bailer should be weighted so that it goes to the bottom of the well. A double check valve system may also be required.

The SP must select the bailer materials in consideration of the contaminants of concern. For example, PVC may degrade in the presence of some chemicals requiring the use of stainless steel materials and equipment.

10.16 Inertial Pumps

The "Waterra" system consists of a PVC, Stainless Steel or Teflon foot valve placed on the bottom of a length of PVC or Teflon tubing which is then lowered into the well. Because the system is inexpensive, it is common to "dedicate" a length of PVC tubing and a foot valve to each monitor well. This simplifies repetitive sampling and prevents cross-contamination between wells. The proper name of this system is "Inertial" because it is the rapid raising and dropping of the hose and foot valve into the groundwater that causes water to rise to the surface by inertia. This rapid "jerking" of the hose can be done with a machine or by hand. It is considered to be simple, inexpensive, effective and maintenance free, however, the SP must be aware of the potential disadvantages of the equipment due to induced disturbance and turbidity of the water.

10.17 Well Development

It is best practice to "develop" a well before undertaking a purging and sampling program to ensure the efficiency of the well screen and sandpack over time. It also removes drilling fluid and silt, clay and fine sand from the sand pack surrounding the monitor well and helps to prevent clogging of the screen. During well development, field water quality data may also be collected/measured to document the stabilization of pH, temperature and conductivity. It must be noted that if the well is not properly developed, the groundwater analytical data collected will not be representative of the formation water.

10.18 Well Purging

Following initial well development, wells where standard sampling is employed, the well should be purged before obtaining a groundwater sample. This is done to ensure that stagnant water is removed and replaced with water which better reflects conditions in the aquifer. For instance, groundwater in the immediate region of a monitor well characterized by contamination with volatile organics, will lose much of the volatiles through exposure to air in the well. Purging brings in fresh water which has not lost components due to volatilization.

Note that purging the well is not required for low flow sampling but initial well development is required for all wells. During low flow sampling, specific indicator parameters are measured until these reach stabilization and then the well can be sampled. In some cases no purge sample collection may be applied.

10.19 Casing Volume

As a best practice, purging involves the removal of at least 3 "casing volumes" from the well using a bailer or pump apparatus. In high yield wells, a bailer may not be suitable.

The calculation of "casing volume" normally includes the entire volume of that portion of the borehole (not just the PVC casing) which is situated below groundwater. Therefore, the thickness of the saturated zone penetrated by the well is one variable and the radius of the well, not just the radius of the PVC casing, is the other.

- So, for example:

a 200 mm diameter hollow stem auger borehole;
drilled to a total depth of 7.6 metres;
the depth to the groundwater was measured at 4.6 metres;
what is the volume of water that must be purged from this well?

- Answer:

the saturated thickness penetrated by well (h): 7.6 - 4.6 = 3.0 metres (300 cm);
casing (borehole) radius (r): 100 mm (10 cm);
casing volume (CV): $\pi r^2 \times h = 94{,}200 \text{ cm}^3$ (94.2 litres).

- Therefore:

the volume to be purged: CV x 3.0 = 94.2 litres x 2.5 = 283 litres

The volume of purged water is tracked as it is pumped or bailed into a container of known volume. Note, if the purge water is suspected to be contaminated, it should be disposed of at an appropriate facility or an alternative method, such as low or passive flow sampling equipment and techniques may be considered. At times, a well may go “dry” during purging. If this happens, the well should be allowed to recover prior to sampling. This may take up to 24 hours but will be dependent on the site specific recharge rate.

10.20 Sample Containers

The SP should confirm with the laboratory what their sample storage protocols are. The laboratory will instruct as to what type and size of container is to be used and what preservatives in what quantity, must be added. The following table is intended only as a general guide for types and sizes of sample containers, preservatives and sample holding times. The SP must confirm the specific requirements, sample containers, holding times, etc, with the laboratory.

Table 2. Typically Recommended Sample Containers, Preservatives and Maximum Holding Times

Compounds	Sample Container	Preservation	Holding Time
Major cations	P, G; 100 to 1000 mL	HNO3 to pH < 2	6 months
Major anions	P, G; 100 to 1000 mL	cool, 4°Cc	14 to 28 days
N species, P	P, G; 100 to 500 mL	H2SO4 to pH < 2	14 to 28 days
Mercury	G; 100mL	Potassium dichromate	28 days
Hexavalent Chromium	G; 60 mL	Sodium hydroxide	28 days
Metals	P, G; 50 to 100 mL	HNO3 to pH < 2	6 months
Cyanide	P, G; 500 mL	NaOH to pH < 12	14 days
Volatile organics	G; 10 to 250 mL	cool, 4°C, no headspace, and as advised by laboratory	5 to 14 days before analysis or extraction
Semi- and non-volatile organics	G; 100 to 1000 mL	cool, 4°C, and as advised by laboratory	7 days before analysis or extraction

Notes:
Laboratory may have alternate or additional requirements.
Most laboratories provide prepared sample containers and detailed instructions regarding preservatives.
P = Plastic; G = glass

Samples collected for inorganic analyses may require field or laboratory filtering. In some cases, (e.g. analysis for metals) it is preferable for filtering to be completed in the field using disposable filters, followed by the appropriate acidification. The SP must confirm the specific sample handling and preparation requirements with the laboratory.

11.0 Site Survey Data

The survey measurements of static groundwater levels must be obtained after the water table has had a chance to recover to static conditions. Water levels measurements should not be taken directly after development or purging but should be noted. In most cases, the well should stabilize for at least 24 hours, however, in specific cases a more detailed evaluation may be required to confirm static conditions (e.g. tidally influenced areas).

Measurements are normally obtained using an electronic water level meter or an oil / water interface probe. In calculating the groundwater elevation in a given well, care should be taken to measure the depth of water from the same reference point on the well each time the groundwater elevation is being measured. The groundwater elevation must also be referenced to a common datum (know or assumed) as detailed below. In some cases, a water level logger may be required and placed for an extended period of time to measure fluctuations in water level conditions.

11.1 Test Locations and Elevations

All test locations (boreholes and test pits) must be located accurately in three dimensions. It is not always necessary to conduct detailed transit surveys to accomplish this. If there are accurate, good scale maps or plans of the site and area, dimensions/distances can be obtained to landmarks such as existing buildings.

11.2 Datum

Determination of the third dimension (i.e. elevation), requires survey level circuit from a known benchmark such as a National Survey Monument of known geodetic elevation. This will provide elevation data that can easily be related to surface topographic elevation data.

In the event that a known datum is not located nearby, a temporary benchmark can be established on or near the site and given an assumed datum (typically, 100.00 m).

In any event, elevation data for groundwater levels are critical to developing maps of groundwater contours, and determining groundwater flow directions and gradients.

12.0 Determination of Hydraulic Conductivity

It is rarely possible to determine a single value of hydraulic conductivity (i.e. the permeability coefficient; the soil or bedrock's ability to transmit water; the rate of flow of water through a unit of area under a hydraulic gradient) that is truly representative of the site due to the heterogeneity of formations frequently encountered. Usually, a range of hydraulic conductivities is considered acceptable. However, when a number of single well response tests have been taken from wells in the same stratigraphic unit, the geometric mean of the hydraulic conductivity values can be used to represent the average hydraulic conductivity of this unit.

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 SP should be aware of the inherent limitations of hydraulic conductivity measurements in determining a representative hydraulic conductivity for the site. Measurements of hydraulic conductivity may be compared to literature values, however, these values often span several orders of magnitude and may not be applicable to the subject site. The SP 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).

12.1 Single Well Response Tests

Single well response tests (slug 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. In order to calibrate the water level recorder, the static water level must be measured with a water level tape prior to the test and the start and end times must be recorded.

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 monitor well be adequately developed. Repeated tests at a single location can be performed to assess for potential well effects (i.e. the draw-down versus time curve for each test should be identical regardless of slug size).

There are several accepted methods to analyze data from a single well response test for determining hydraulic conductivity in a confined aquifer. The SP must include the details of the test procedure and data analysis including the rational for the selection of the method given the site-specific conditions.

12.2 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, not in a straight line, is theoretically required to determine the direction of groundwater flow. This is applicable to theoretical homogeneous hydrogeological conditions, which are rarely present. Therefore, the SP should typically plan on installing additional monitor 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.

12.3 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 site 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.

13.0 QA/QC Measures

13.1 Field QA/QC

Quality Assurance/Quality Control (QA/QC) measures are an essential component of Phase 2 ESA sampling programs. The PIRI analytical protocol documents should be consulted for specific 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 to achieve the objectives of the work;

- allow for monitoring of equipment, staff and contractor performance; and
- verify the quality of the data to confirm the reliability and representativeness of the data.

Note: 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.

13.2 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 labeled, and not lost, broken, or exposed to conditions that may affect the sample's integrity.

The following subsections provide guidelines for field sample management.

13.3 Field Handling

Prior to entering the field area where sampling is to be conducted, the sampler should have the necessary sampling instruments/equipment and the equipment should be in proper working condition, calibrated in accordance with manufacturer's recommendations, and be decontaminated prior to use.

Samples should be placed in coolers and surrounded with bags of ice or freezer packs to ensure that the temperature of the samples remains approximately 4°C or as specified by the laboratory. When sampling is done in extremely cold weather conditions, it may be necessary to prevent freezing.

Field personnel performing water sampling tasks should check the sample preparation and preservation requirements to ensure compliance with the project QA/QC requirements. Typical sample preparation may involve sample filtration, pH adjustment (i.e. acidification), and/or preservation, collection with no heard space (air bubbles), or simply cooling to 0 to 10°C with a target of 4°C.

13.4 Sample Labeling

Samples should be properly labeled with unique sample identification data 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. If adequate site information is available (i.e., number of boreholes / monitor wells, etc.), sample containers may be pre-labeled by the laboratory.

The following information, as a minimum, may be recorded either on the sample container or on the chain of custody document as well as on the field reference notes:

- project name and identification number;
- date;
- borehole / monitor well / test pit number;
- soil / water / surface water / sediment, etc;
- sample tracking number / unique sample ID; and
- sample depth, if necessary or relevant.

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), Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) and any other applicable regulations and standards should be followed.

13.5 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. The sample containers may be placed in sealable plastic bags to keep the labels legible should melting ice in the cooler come into contact with the sample containers. Suitable packing material (e.g. bubble wrap) may be used to prevent glass sample containers from shifting in the coolers and breaking.

13.6 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.

Having an uninterrupted chain of custody of all samples is extremely important. Samples must be kept either under supervision or in a secure location at all times up until delivery to the laboratory. The laboratory must sign an acknowledgement of their receipt and must be prepared to take responsibility for the security of the samples.

The chain-of-custody form, completed at the time of sampling, should contain at least the sample identification number, date and time of sampling, analysis required, number of sample bottles 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. Comments regarding potentially hazardous (or suspected contamination) samples should be flagged on the chain of custody form so the laboratory can take appropriate precautions (e.g. high level of VOC’s in the sample may impair or shut down laboratory equipment).

13.7 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 and holding times must be determined in consultation with the laboratory.

After bottling or bagging the samples from a borehole or test pit, immediately place the sample in a cooler equipped with ice packs to keep the temperature at approximately 4°C. The storage cooler must be kept in a secure place to prevent tampering and out of direct sunlight and heat. Samples not delivered immediately must be stored in a refrigerator at about 4°C. The “shelf life” of samples will vary with the contaminant of concern, as per the laboratory requirements.

All field QA/QC project sampling tasks should be outlined in the project work plan, including the requirement for and frequency of field quality control samples. The sampling plan should specify the number and type of field QA/QC samples that field personnel should collect and submit to the laboratory.

13.8 Travel Blanks

Travel (or trip) blanks are prepared, usually by the laboratory on request, 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.

13.9 Field Blanks

A field blank consisting of a sample of "clean" water (usually supplied by the laboratory on request), is opened at the site and collected to evaluate the influence of field ambient conditions on the sampling process and analytical results. 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.

13.10 Equipment Blanks

Equipment blanks are QA/QC samples taken to determine if field equipment cleaning procedures are effective and/or if field sampling equipment (e.g., tubing, filters) may be contributing to the reported concentrations. The field blanks are prepared by rinsing the equipment with water and collecting the rinsate for analysis. The laboratory may supply de-ionized water for this process to avoid any possible contribution from outside sources (e.g., potable tap water may contain elevated metals concentrations). In most cases, potable tap water is acceptable for equipment rinsing, but distilled or de-ionized water should be considered for final rinsing and collection of the rinsate for analysis.

Equipment blank samples are not needed if dedicated sampling equipment is used. As noted above, equipment blanks may be required when low flow sampling protocols are implemented.

13.11 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, given a unique identifier (i.e., blind field duplicate) and the location where it was collected (primary sample ID) is noted in the field notes. Field duplicates should be collected in conjunction with the primary sample (e.g. one bottle for each at a time).

14.0 Borehole / Monitor Well Decommissioning / Abandonment

Boreholes should be abandoned so that they do not serve as a conduit for contamination or represent a safety hazard. Boreholes can be filled with native materials if contamination is not suspected or indicated and/or field and/or laboratory results confirm no adverse impacts.

Monitor wells should be abandoned, under the supervision of the SP and in accordance with the Regulations as set out in Confirmation of Remediation protocol (PRO-700, Section 4.2). The property owner (i.e. the person responsible, see Section 1.2), must ensure that the boreholes / monitor wells are properly and effectively abandoned when they are no longer needed for assessment and/or monitoring.

It should be noted that the monitor wells may be used for monitoring long after the intrusive investigation is completed, therefore, the SP must ensure that the owner (the person responsible) is aware of this requirement, preferably in writing at the initiation of the project.

Monitor Well Decommissioning / Abandonment Procedures:

- Remove all sampling equipment and other obstructions from the monitor well.
- If not already known, measure and record the static water level, diameter of the well casing, and the total depth of the well.
- Calculate and record the theoretical volume of grout materials needed to fill the well based on the well measurements.
- Remove entire casing if feasible, preferably by overdrilling, otherwise, expose and cut casing at least 0.6 m below grade surface where feasible. Prepare for well grouting.

- Well grout materials for typical decommissioning must be installed by either:
    - **pressure grout method** - place an appropriate mix of neat cement or a sand/cement pre-mix concrete (no gravel), or a high solids bentonite grout or other non-shrinking liquid grout from the bottom of the well to the top of casing using a tremie pipe or hose; the volume of grout placed in a well should be based on the estimated amount needed to fill the well plus a percentage excess to account for washouts or permeable formation material; where possible, place at least 0.3m additional grout above the top of the casing, followed by a minimum of 0.3m compacted natural fill to be level to grade surface; or,
    - **hand placement of dry granular bentonite chips** – for a typical shallow monitor wells, i.e. less than 6.1m (20 ft) deep, and up to 61m (200 ft) deep, medium or coarse grade, dry screened bentonite chips may be installed by hand pouring.
- For monitor wells greater than 61 m (200 ft) deep it is recommended that only coarse grade (i.e. 3/4 inch or greater) dry screened bentonite chips be used for hand placement.
- All dry granular bentonite chips used must be adequately screened over a wire mesh screen during placement to prevent fine particles that are typically present in bags from entering the well and causing premature swelling and bridging.
- Bentonite chips must be poured slowly into a well no faster than manufacturer recommended rates.
- Bentonite grout levels must be checked periodically using a weighted line to ensure bridging is not occurring in the well.
- The volume of bentonite chips placed in a well should closely match the estimated amount needed for sealing; fill to the top of the casing.
- Where possible, place at least 0.3 m additional grout above the top of the casing, followed by a minimum of 0.3 m compacted natural fill to be level to grade surface.
- Complete at surface by ensuring mounding, paving or grading to eliminate surface water ponding, as well as using topsoils to promote the establishment of vegetation, if appropriate; the potential for grout settlement should be considered and accounted for.
- Prepare a “well decommissioning” report / log including the details of the work for submission to the person responsible.

15.0 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 intrusive investigation.

The ultimate management of soil and groundwater residues will depend on the analytical results. If the soil meets the applicable Tier 1 or derived Tier 2 pathway specific or site specific target levels, it may be permissible to spread the soil on the site if it is feasible to do so. Similarly, if the groundwater is not impacted above standards applicable to the site, and there is no sheen or visible product, the extracted groundwater may be poured on the ground, away from the well, provided that the contents do not drain to surface water or to off-site properties.

Note: Waste Management and Backfill Material are covered by PRO-700 Confirmation of Remediation Protocol. For example, information regarding stockpiled soils for disposal and manifests for materials transported off-site are requirements of CHK-700 Confirmation of Remediation Checklist.

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, normally after TCLP (Toxicity Characteristics Leachate Procedure) testing for waste classification under NSE Guidelines for Disposal of Materials at a Landfill. 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 or DSP is required for the property, the SP must ensure that the residues have been properly managed or disposed of off-site and documented. All monitor wells should be properly abandoned, unless they are required for ongoing monitoring as a condition of management or risk assessment. The SP must ensure that the person responsible is aware of this requirement.

16.0 Review and Evaluation of Information and Data

Review, interpretation and evaluation of the information obtained in conducting the intrusive investigation are mandatory requirements under the Regulation and Protocols. The information record should include, but not be limited to:

- the project name and location, and the project identification 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;
- maps/sketches of sampling locations; and
- weather conditions and/or any limitations that may affect the sample or the sampling protocol (e.g., rain, extreme heat or cold, wind, etc.).

The outcome of the review and interpretation of information is the development of a Phase 2 conceptual site model (see discussion on the preparation of a CSM) that includes graphical (i.e. plan view and cross section documents) and narrative descriptions of areas of environmental concern for the site. This CSM should include a stratigraphic and hydrostratigraphic model of the subject site.

The stratigraphic model must be based on a review and interpretation of borehole data that has been obtained by the SP or under the direction of the SP, and supplemented with information from other sources, reviewed and accepted by the SP.

The interpretation of hydrostratigraphic units may be based on an interpretation of hydraulic conductivity testing conducted as per this guidance document.

The Phase 2 ESA CSM is required under the Regulations and Ministerial Protocols (PRO-400 Phase 2 Environmental Site Assessment Protocol) to include information regarding the vertical and lateral distribution of contaminants.

The SP must consider contaminant distribution in the context of the site stratigraphy and hydrogeology 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.

As required by the Regulations and Ministerial Protocols (PRO-200; PRO-500; PRO-600 and PRO-700), information regarding the potential for vapour intrusion must also be evaluated based on conditions encountered (e.g. exceedences of Tier 1 EQS, soil to be left below a building, etc).

Where contaminants are present in excess of applicable Tier 1 EQS standards, and will not be remediated to meet these standards, the Regulations require filing an RSC (conditional closure). In that case, the Phase 2 ESA CSM must 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 information should be incorporated into the Phase 2 ESA CSM. Note that conditional closure involving impacted third party properties requires written agreement by each third party of the conditions being imposed (e.g., restricted land use).

17.0 Additional Investigation and/or Development of Remedial Action Plans

Based on the findings of a Phase 2 ESA, the SP may be required to develop a Remedial Action Plan (RAP) for the site (see the Remedial Action Plan Protocol, PRO-600). The RAP must be based on the conceptual site model, identify the contaminants of concern, the remedial actions intended to address each of the contaminants, and the remedial objectives for the site (i.e. Tier 1 EQS standards and/or risk assessment-derived standards).

The RAP should also include, but not be limited to:

- quantities of contaminated media (soil, groundwater, etc) to be remediated;

- intended destination(s) for any media intended to be transported, treated or disposed of off-site; and

- where materials are intended for off-site transport, treatment or disposal constitute hazardous wastes, the RAP should include appropriate transportation requirements (e.g. manifesting), any waste generator requirements, and the identification of pre-treatment facilities (if applicable).

18.0 Conclusions and Reporting Requirements

The Phase 2 ESA report should be a stand-alone report that describes, in detail and with the required supporting materials, all aspects of the Phase 2 ESA program. The report should include a summary of the results and findings of the Phase 1 ESA report upon which the Phase 2 ESA program was based.

The format and contents of a Phase 2 ESA report, prepared in support of an RSC submission, are described in the Phase 2 Environmental Site Assessment Protocol (PRO-400, Section 4.1).