BRITISH COLUMBIA
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Ministry of Environment

PROTOCOL 13
FOR CONTAMINATED SITES

Screening Level Risk Assessment

Prepared pursuant to Section 64 of the
Environmental Management Act

Approved: _____ _____
Director of Waste Management Date

Effective Date: August 1, 2008

1.0 Definitions

"Approved Professional" means a person who is named on a roster established under section 42 (2) of the *Environmental Management Act*.

"bioaccumulative substances" means substances with any of the following characteristics: bioaccumulation factors (BAF) greater than 5,000; bioconcentration factors (BCF) greater than 5,000; or Log octanol-water partition coefficients (Log K_{ow}) greater than 5.

"conceptual model" means a written description and an picture of the geologic, hydrogeologic, and environmental conditions of a site. A conceptual model also depicts the type and extent of subsurface contamination, defines the pathways for contaminant migration, and identifies potential receptors.

"DNAPL" means a dense nonaqueous phase liquid having a specific gravity greater than 1.0. DNAPL is considered present when:

- free liquid is found in soil;
- free liquid is found in monitoring wells at an apparent thickness greater than 2 mm; or
- individual DNAPL substances are detected in water at concentrations exceeding 1% of their theoretical solubility limit.

"high density urban area" means an area within a municipal boundary, excluding areas that are characterized predominantly by detached single-family dwellings or zoned or used for urban parks.

"high risk site" means a site classified as high risk according to a protocol approved by a Director.

"high water mark" has the meaning as defined in the Riparian Areas Regulation.

"LNAPL" means a light nonaqueous phase liquid having a specific gravity less than 1.0. LNAPL is considered present when:

- free liquid is found in soil; or
- free liquid is found in monitoring wells at an apparent thickness greater than 2 mm.

"ministry" means the Ministry of Environment.

"potential terrestrial habitat" means land that satisfies any of the following conditions:

a) urban park land use classification applies;
b) contains over 50 m^2 (where residential land use applies at the site) or over 1,000 m^2 (where commercial or industrial land use applies at the site) of contiguous undeveloped land; or
c) lies within 300 m (where residential, commercial or industrial land use applies at the site) of sensitive habitat.

"preferential flow pathway" means a soil pathway that is significantly (greater than one order of magnitude) more water or gas permeable than the soil media that surrounds it.

Note: Preferential flow pathways can include the backfill around underground utilities, or possibly the utilities themselves, (e.g. sewers, water and gas lines) and surface depressions (e.g. ditches, trenches or excavations) that intersect and drain shallow aquifers. Preferential flow pathways can also consist of naturally occurring and contiguous higher conductivity units (e.g. historic creek and stream beds, buried channels and outwash deposits) within lower conductivity materials in addition to fractured or fissured media.

"receiving environment" means any land, water, sediment, bog, swamp, or muskeg containing receptors, or an area subject to a compensation agreement. It does not include artificial watercourses such as drainage or irrigation ditches/canals, standing water, treatment ponds, or artificial watercourses such as those whose primary purpose is to convey storm water.

"receptor" means a living plant, animal or human that may be exposed to a substance.

"sensitive habitat" includes:

a) national, provincial, regional or municipal parks;
b) sensitive ecosystems;
c) areas supporting sensitive species; and
d) wetlands or riparian assessment areas as defined in section 1 of the Riparian Areas Regulation.

"undeveloped land" means any bare or vegetated soil, excluding gravelled walkways, roadways, parking areas, and soil or vegetation in planters (i.e. landscaped soil confined by a container or lying on top of a structure).

"volatile or semi-volatile substances" includes volatile petroleum hydrocarbons (VPH), light extractable petroleum hydrocarbons (LEPH), and all substances listed in the draft "Director's Interim Criteria for Contaminated Sites: Air Concentration Criteria" [1].

2.0 Introduction

This protocol describes the procedures required to complete a screening level risk assessment (SLRA) for a contaminated site in British Columbia. The intention of SLRA is to evaluate whether contamination at a specific site poses acceptable or unacceptable risks to human health and the environment. Such an evaluation includes a simple assessment of exposure pathways and receptors. Contaminated sites that are deemed to have no unacceptable risks (i.e. pass SLRA) are considered to satisfy Contaminated Sites Regulation risk-based standards and are eligible for a Certificate of Compliance. No further remediation is required at these sites as long as site conditions do not change.

Application of this protocol requires that a Stage 1 preliminary site investigation (PSI), Stage 2 PSI, and detailed site investigation (DSI) have been conducted at the site in accordance with ministry approved procedures, guidance and best professional practice. If volatile or semi-volatile substances have been identified as potential contaminants of concern on the site, then soil vapour assessment must also be completed in accordance with ministry-approved guidance [2]. The ministry's expectation is that soil, sediment, groundwater, and surface water contamination have been adequately characterized and delineated and that soil vapours have been assessed in accordance with approved guidance before an SLRA is carried out.

A SLRA may not be used to evaluate a "high risk site" or a site classified as agricultural land use without pre-authorization of the Director. A SLRA may be completed by environmental consultants who are not Approved Professionals.

This protocol also includes the Director's advice regarding application of the Contaminated Sites Regulation "nonaqueous phase liquids not present" generic numerical soil and water standards.

The information in this protocol is based largely on the scientific background information and methodologies provided by the Science Advisory Board for Contaminated Sites in British Columbia (SABCS), in its report commissioned by the B.C. Ministry of Environment [3]. The physical and chemical data reported here is also largely reproduced from the report. Dr. Ian Hers of Golder Associates Ltd., Dr. Jean Cho, and Dr. Uli Mayer also provided valuable advice in the subsequent preparation of this protocol.

This protocol includes some departures from both previous ministry policies and SABCS recommendations. The ministry anticipates that future changes or amendments may also be warranted. Such revisions and amendments will be incorporated in later editions of this document.

3.0 Overview

The screening level risk assessment procedure comprises five main steps:

1. Problem formulation (Section 4.1): environmental consultants must review and summarize site conditions and develop a conceptual model for the site.
2. Check for exemptions/precluding conditions (Section 4.2): environmental consultants should check whether any beneficial use exemptions apply and must determine if any precluding conditions are present at the site.
3. Evaluation of potential exposure scenarios (Section 4.3): environmental consultants must complete the SLRA Questionnaire, which assesses the potential for human or ecological receptors to be exposed to contaminated soils, vapour or groundwater.
4. Determination of risk (Section 4.4): environmental consultants use the results of the SLRA Questionnaire to conclude whether contamination at a site poses an acceptable or unacceptable risk.
5. Reporting of SLRA results (Section 5): environmental consultants must provide a summary report in support of the SLRA.

A flow chart summarizing the overall SLRA evaluation process (steps 1 through 4 above) is provided in Figure 1. The flowchart is provided for illustrative purposes only. The Questionnaire must be completed and takes precedence over the flowchart.

3.1 Contamination derived from eligible beneficial uses

Soil, sediment, groundwater or surface water contamination that does not extend significantly beyond (i.e. more than 1 m laterally from) an eligible beneficial use is not considered to constitute an unacceptable risk. Specific contaminants and eligible beneficial uses include the following:

(a) zinc localized around galvanized materials;

(b) copper localized around copper pipe or bare wire; and

(c) wood preservative localized around preserved wood (preserved wood includes that treated by all types of preservatives including, but not limited to, boron, chromium, copper, arsenic, chlorophenols, and constituents of creosote.

The beneficial use exemption is applicable at active or closed sites as long as the beneficial use applies. However, the exclusion is not applicable where the beneficial use is historical and is no longer used for its intended purpose. The beneficial use exemption also does not apply at sites where the beneficial use materials were produced or stored.

3.2 Precluding conditions

Sites that are classified as high risk sites or as agricultural land use sites cannot be evaluated using this protocol without pre-authorization by the Director. In addition, this protocol shall not be used to screen sites that contain:

- ionizing organic substances,
- inorganic substances with soil pH < 5,
- bioaccumulative substances within the top 1 m of soils,
- presence of LNAPL or DNAPL,
- soil vapours (for all land uses except Wild Lands land use),
- very high permeability soil (e.g. cobbles) or complex hydrogeologic units (e.g. fractured bedrock, karst terrain),
- deep-rooting plants or trees (root structures extending below 1 m depth) in areas of contamination,
- contaminated sediments or surface water except where the contamination is related to a beneficial use,
- preferential flow pathways that transport contaminated groundwater or soil vapours directly to a receiving environment or water well, or
- groundwater contamination that extends offsite and is at concentrations that exceed standards protective of drinking water use (at sites where drinking water use is applicable).

4.0 Methodology

4.1 Problem formulation

The problem formulation step involves a review of site information, summarizing site conditions, and preparation of a conceptual model. The objectives of this step are to summarize site information relevant from a risk perspective, identify issues that may pose acceptable or unacceptable risks (Step 2, Section 4.2), and facilitate the evaluation of exposure scenarios (Step 3, Section 4.3) and determination of risk (Step 4, Section 4.4).

The problem formulation step must be completed based on site investigations that satisfy the requirements of a PSI and DSI (as indicated by sections 58 and 59 of the Contaminated Sites Regulation) and be conducted in accordance with ministry approved guidance and procedures. The site investigation information must be sufficient to characterize site conditions and to identify and delineate all areas of contamination both on- and offsite.

Once site conditions have been reviewed and summarized, a conceptual model of those conditions must be prepared. The conceptual model for the site must describe the:

- source and distribution of contaminants (how contamination developed and its current and potential future extent);
- fate and transport pathways (how contaminants behave in the subsurface and how they might be transported and where); and
- receptors (who or what may be affected).

The conceptual model must also be illustrated in a graphic format (e.g. as shown in Figure 2). Such diagrams are intended to be simple communication tools that visually summarize site conditions and the linkages between contamination sources, exposure pathways, and receptors.

4.2 Check for exemptions and precluding conditions

Following problem formulation, environmental consultants should check whether any beneficial use exemptions apply and must determine if any precluding conditions are present at the site. Exemptions for contamination due to eligible beneficial uses are described in Section 3.1. Precluding conditions are described in Section 3.2.

4.3 Evaluation of potential exposure scenarios

Following evaluation of potential beneficial uses and precluding conditions, environmental consultants must evaluate whether human or ecological receptors are likely to be exposed to potentially harmful concentrations of contaminated soils, vapour or groundwater. Potentially harmful concentrations are those that exceed:

- generic numerical soil and water standards (Contaminated Sites Regulation, Schedules 4, 6, and 10);
- matrix numerical soil standards (Contaminated Sites Regulation, Schedule 5);
- air concentration criteria [1]; or
- Director's interim standards or criteria.

Environmental consultants must complete this evaluation step by completing the SLRA Questionnaire. The questionnaire has eight series of questions (24 questions in total) that qualitatively assess whether complete ("operative") exposure pathways are present for seven potential exposure scenarios and one default scenario. The scenarios are summarized as follows:

- Three series of questions (eight questions in total) evaluate the potential for human exposure to contaminated soils or dust (questions HS-1 to HS-3), vapour (Questions HV-1 and HV-2) and groundwater (questions HW-1 to HW-3).
- One series of questions (five questions in total) evaluates the potential for terrestrial biota to be exposed to contaminated soils (questions TS-1 to TS-5).

Specific to this pathway, questions TS-4 and TS-5 must be answered by a registered professional biologist.

- Three series of questions (nine questions in total) evaluate the potential for exposure of aquatic biota, crops, and livestock to contaminated groundwater (questions AW-1 to AW-3, IW-1 to IW-3, and LW-1 to LW-3, respectively).
- The remaining series (two questions in total) evaluates the potential for exposure to groundwater contamination greater than default numerical environmental quality standards (questions DF-1 and DF-2).

Other exposure scenarios (e.g. exposure of aquatic biota to contaminated sediments and surface water or exposure of humans to soil vapours at sites where Wild Lands land use does not apply) are not considered within SLRA and are beyond its scope (except as allowed for a beneficial use – see Section 3.2, "Precluding Conditions"). If the problem formulation stage indicates that precluding conditions or other exposure scenarios are present, an SLRA may not be used for those site conditions giving rise to, or affected by, the precluding condition or exposure scenario.

All eight exposure scenarios must be evaluated. However, it may not be necessary to answer all questions within an exposure scenario, or all 24 questions.

The questions are to be answered in the sequence indicated, and require a "yes" or "no" response. Some questions may also require provision of a supporting rationale, figures, tables, calculations or forms (as indicated in the notes section of the questionnaire). A "yes" response to any question indicates the potential presence of a contaminant, pathway, or receptor; and "yes" responses to all questions within a scenario indicate the presence of an "operative" pathway for that exposure scenario. A "no" response to any question indicates that a contaminant, pathway or receptor is not present for that exposure scenario; and that an exposure pathway may be "inoperative." If a "no" response is provided to a given question within a scenario (i.e. within a series), then the remaining questions within that exposure scenario need not be answered (see Figure 1).

4.4 Determination of risk

The results of the SLRA Questionnaire are used to determine whether contamination at a site poses acceptable or unacceptable risks.

Sites for which there are "yes" responses to all questions within an exposure scenario (i.e. an operative pathway) are considered to have an unacceptable risk for that scenario. Sites which have an unacceptable risk for one or more exposure scenarios are considered to fail the SLRA. Further remediation – or completion of a detailed risk assessment – is warranted for these sites to address the failed exposure scenarios.

Sites for which a "no" response was provided for at least one question within each of the eight exposure scenarios (i.e. all pathways are inoperative) are considered to have no unacceptable risks. Providing no precluding conditions apply, such sites are deemed to satisfy Contaminated Sites Regulation risk-based standards and are eligible for a Certificate of Compliance. No remediation is required for the specified land and water uses as long as conditions at the site remain the same.

5.0 Reporting

An SLRA report must be completed in accordance with this protocol. At a minimum, an SLRA report must include:

- a summary description of the site conditions, the environmental investigations completed, and any remediation conducted;
- a conceptual model for the site, including diagrams summarizing site conditions and linkages between contaminants, exposure pathways, and receptors (e.g. see the example in Figure 2);
- a completed SLRA Questionnaire and supporting diagrams, plan maps, cross sections, and forms (e.g. Forms A-1, A-2, B-1, B-2, and B-3, as appropriate);
- a modeling report including simulation files on electronic media (if Bioscreen is used for groundwater transport assessment – see Appendix A);
- specification of any eligible beneficial uses (including associated contaminants and contaminated media) and precluding conditions that apply based on the completed SLRA;
- specification of the contaminants addressed in the SLRA;
- specification of any necessary risk management measures (e.g. prescribed long term monitoring and maintenance measures to be implemented to ensure the long term integrity of any surface barriers, if present at the site); and
- conclusions regarding whether contamination at a site poses acceptable or unacceptable risks.

The report must also include a written signed statement from the report author(s) that:

- the SLRA was completed in accordance with this protocol; and
- any persons signing the statement have demonstrable experience in remediation of the type of contamination at the site for which the statement applies and are familiar with the remediation carried out on the site.

6.0 References

1. B.C. Ministry of Environment (2006). Director's Interim Criteria for Contaminated Sites: Air Concentration Criteria (Draft). Victoria, B.C. http://www.env.gov.bc.ca/epd/remediation/requests_for_comments/archives/feb07/air_conc.htm

2. B.C. Ministry of Environment (2008). Interim Guidance for Contaminated Sites, Site Vapour Assessment. Victoria, B.C. http://www.env.gov.bc.ca/epd/remediation/guidance/index.htm#4

3. Science Advisory Board for Contaminated Sites in British Columbia (August 2005). Report on Screening Level Risk Assessment SLRA Level 1 and SLRA Level 2. Vancouver, B.C. http://www.sabcs.chem.uvic.ca/docs.html

4. US DOE Risk Assessment Information System, Toxicity & Chemical-Specific Factors Data Base. http://rais.ornl.gov/index.shtml

5. Domenico, P.A. (1987). An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species. Journal of Hydrology, 91.

6. B.C. Ministry of Environment. British Columbia Field Sampling Manual: 2003 – For Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment and Biological Samples. http://www.env.gov.bc.ca/air/wamr/labsys/field_man_03.html

7. Suarez, M.P. and Rifai, H.S., (1999). Biodegradation Rates for Fuel Hydrocarbons and Chlorinated Solvents in Groundwater. Bioremediation Journal, 3(4).

8. US EPA Region 9 Superfund PRG InterCalc Tables (Physical Chemical Data). http://www.epa.gov/region09/waste/sfund/prg/index.html

9. Canadian Council of Ministers of the Environment (April 2001). Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale Supporting Technical Document. Winnipeg, Manitoba. http://www.ccme.ca/assets/pdf/pn_1399_phc_sr_std_1.1_e.pdf

7.0 Additional information

1. Science Advisory Board for Contaminated Sites in British Columbia (February 2006). Approaches and Methods for Evaluation of Light Non-Aqueous Phase Liquid Mobility – Hydrogeological Assessment Tools Project. Vancouver, B.C. http://www.sabcs.chem.uvic.ca/docs.html

2. Science Advisory Board for Contaminated Sites in British Columbia (February 2006). Hydrogeological Assessment Tools to Determine the Rate of Biodegradation for Organic Contaminants in Groundwater. Vancouver, B.C. http://www.sabcs.chem.uvic.ca/docs.html

APPENDIX A

Soil Leachate and Groundwater Transport Assessment (Questions HW-3, AW-3, LW-3, and IW-3 in SLRA Questionnaire)

This assessment considers the potential for contaminated groundwater to migrate to a downgradient receptor. Contaminated groundwater may originate from both soils (i.e. soil leachate) and groundwater within a source zone.

This assessment involves three steps:

1) determination of soil leachate concentrations;
2) calculation of predicted groundwater concentrations resulting from mixing of soil leachate with groundwater; and
3) calculation of predicted groundwater concentrations at the location of a receptor.

Steps 1 and 2 must be completed. Step 3 need only be completed if predicted groundwater concentrations originating from leachate or measured groundwater concentrations exceed the applicable Contaminated Sites Regulation standards (Schedules 6 and 10).

1.0 Determining soil leachate concentrations

Soil leachate concentrations can be determined through soil leaching tests (for inorganic substances, where soil pH is 5 or greater) or calculation from partitioning equations (for organic substances).

For inorganic substances, soil leachate concentrations are determined by leaching tests using soil samples collected from the areas where the maximum soil concentrations were measured for each contaminant of concern. Where soil pH is between 5 and 5.5, the U.S. Environmental Protection Agency (USEPA) toxicity characteristic leaching procedure (TCLP), Method 1311, must be used. If the soil pH is greater than 5.5, the USEPA's synthetic precipitation leaching procedure (SPLP), Method 1312, should be used with a weak acid (Fluid #3, with a pH of 5).

For organic contaminants, soil leachate concentrations are calculated from partitioning equations (Equation A-1) and measured soil concentrations.

$$C_L = \frac{C_S}{(K_{oc} f_{oc} + \eta_w/\rho_b + H' \eta_a/\rho_b)} \times 1000 \qquad \text{Equation A-1}$$

where η_a = air filled porosity (default value 0.241)
η_w = water filled porosity (default value 0.119)
ρ_b = dry bulk density (default value 1.7 g/cm^3)

H' = dimensionless Henry's law constant (**Table A-1**)
K_{oc} = organic carbon partitioning coefficient (**Table A-1**)
f_{oc} = fraction of organic carbon (default value 0.006)
C_S = soil concentration (mg/kg)
C_L = soil leachate concentration (µg/L)
1000 = conversion factor

Leachate concentrations must be calculated for each contaminant of concern using the maximum measured soil concentration for each contaminant and values from Table A-1. Note that Table A-1 only lists selected organic substances. Values for organic substances not listed in Table A-1 may be obtained, where available, from the US Department of Energy Risk Assessment Information System (RAIS) database [4].

Site specific values may be substituted for selected parameters (η_a, η_w, ρ_b and f_{oc}) in Equation A-1.

Soil leachate concentrations, and parameter values used to derive them are to be summarized on **Form A-1**.

2.0 Calculating predicted groundwater concentrations originating from leachate

Upon determination of soil leachate concentrations, the corresponding contaminant concentration in groundwater beneath contaminated soils may be obtained by dividing the measured (for inorganic substances) or calculated (for organic substances) leachate concentrations by a dilution factor (DF) to account for mixing across the water table. Calculation of the predicted groundwater concentration originating from leachate is as per Equation A-2.

$$C_{gw'} = C_L / DF \qquad \text{Equation A-2}$$

where $C_{gw'}$ = predicted groundwater concentration (µg/L)
C_L = soil leachate concentration (from Step 1 above)
DF = the dilution factor, selected as the lowest of the following that apply to the site:

where contamination extends below the seasonal high water table:
- DF=1;

where contamination does not extend to the seasonal high water table:
- DF=20 (for sites where groundwater is flowing to a well for drinking water, irrigation water, or livestock watering uses); or
- The value calculated from Equation A-3 (for sites where groundwater is flowing to surface water).

$$DF = 1 + \frac{V\,d}{I\,L} \qquad \text{Equation A-3}$$

where V = Darcy flux or specific discharge (m/yr)

I = infiltration rate (default value 0.55 m/yr)
L = contaminant source length parallel to groundwater flow (m)
d = mixing zone depth (default value 0. 5 m, or Equation A-4)

$$d = 0.044\, L^{1.23} + d_a \{ 1 - \exp (- \frac{L\, I}{V\, d_a}) \}$$ Equation A-4

where d_a = aquifer thickness (m)

Predicted groundwater concentrations originating from soil leachate and parameter values used to derive them are to be summarized on **Form A-1**.

Following calculation of predicted groundwater concentrations, the environmental consultant must determine whether any values exceed the corresponding Contaminated Sites Regulation numerical water standards and proceed in accordance with the following:

- If "yes" for any contaminant or sample location, then proceed to Step 3 to calculate predicted groundwater concentrations at the location of the receptor.
- If "no" for all contaminants and sample locations, but measured groundwater concentrations exceed Contaminated Sites Regulation water standards, proceed to Step 3 to calculate predicted groundwater concentrations at the location of the receptor based on groundwater data.
- If "no" for all contaminants and sample locations, and measured groundwater concentrations are less than Contaminated Sites Regulation water standards, then enter a "no" response to Question HW-3, AW-3, IW-3, or LW-3, as appropriate (i.e. soil to groundwater contaminant transport pathway is incomplete).

3.0 Predicted groundwater concentrations at the receptor location

Predicted groundwater concentrations at the location of the receptor are calculated using a 2 dimensional steady-state solution [5] to the advection-dispersion equation for contaminant transport (Equation A-5).

$$C(x_R) = C_{gw} \exp \{ \frac{x_R}{2\alpha_L} [1 - (1 + \frac{4 \lambda \alpha_L R}{v})^{0.5}] \} \operatorname{erf} \{ \frac{Y}{4(\alpha_T x_R)^{0.5}} \}$$ Equation A-5

where $C(x_R)$ = predicted groundwater concentration at the location of the receptor (μg/L)
C_{gw} = groundwater concentration at the source (μg/L). Use the maximum measured groundwater concentration based on site characterization data or $C_{gw'}$ calculated from Step 2 (above), whichever is greatest.
x_R = distance from the downgradient edge of the contaminant plume to the receptor (m). For the purposes of this calculation, a receptor is considered present at: the property line (for Question HW-3); at 10 m from the high water mark of a surface water body (for Question AW-3); or, the nearest well (for Questions IW-3 and LW-3).

= allowable range is 10 m ≤ x_R ≤ 1000 m.

Y = source zone width (m)
= maximum extent of contaminated groundwater perpendicular to the groundwater flow direction

α_L = longitudinal dispersivity (m)
= 0.1 x_R or 10 m, whichever is less.

α_T = transverse dispersivity (m)
= 0.1 α_L

λ = Biodegradation Rate (**Table A-1**, or 0 $years^{-1}$)

R = Retardation Coefficient
= $1 + K_{oc} f_{oc} \rho_b / \eta_w$ (for organic compounds)
= $1 + K_d \rho_b / \eta_w$ (for inorganic compounds)
where K_d = distribution coefficient (default value is 0 mL/g)
K_{oc} = organic carbon partitioning coefficient (**Table A-1**)
f_{oc} = fraction of organic carbon (default value 0.006)
ρ_b = dry bulk density (default value 1.7 g/cm^3)
η_w = water filled porosity (default value 0.3)

v = average linear groundwater velocity (default value of 5 m/yr or site calculated value, whichever is greater)

erf = error function

Predicted groundwater concentrations at the receptor location must be calculated for each contaminant of concern using values from Table A-1. Where a biodegradation rate is not specified in Table A-1, a default value of 0 $years^{-1}$ must be used. A default distribution coefficient value of 0 mL/g must be used for inorganic substances. Site-specific values for aquifer and groundwater properties may be used in Equation A-5.

Note that Table A-1 only lists selected organic substances. Partitioning coefficients for organic substances not listed in Table A-1 may be obtained, where available, from the RAIS database noted previously.

Predicted groundwater concentrations at the receptor location and parameter values used to calculate them are to be summarized on **Form A-2**.

Environmental consultants may also use Bioscreen as the groundwater contaminant transport model as long as:

- individual substances are modeled;
- a constant (non-declining) source is specified;
- biodegradation is modeled as a first-order decay process;
- simulations are conducted to steady-state conditions;
- the vertical transverse dispersivity is set to 0 m;
- values for transport parameters are as specified for Equation A-5; and
- a modeling report is provided including tabulated data similar to Form A-2 and simulation files on electronic media, along with specification of all parameter values, simulation results, and sensitivity analyses.

Bioscreen is a screening model developed by the U.S. Air Force Center for Environmental Excellence and the U.S. Environmental Protection Agency. The model is

based on the Domenico 3 dimensional transient analytical solute transport solution [5]. The model is available for download at:
http://www.epa.gov/ada/csmos/models.html.

Following calculation of all predicted groundwater concentrations at the location of the receptor, the environmental consultant must determine whether any values exceed the corresponding Contaminated Sites Regulation numerical water standards and proceed in accordance with the following:

- If "yes" for any contaminant or sample location, then enter a "yes" response to Question HW-3, AW-3, IW-3, or LW-3, as appropriate (i.e. contamination has the potential to reach a receptor). The site fails the screening level risk assessment for this exposure scenario.
- If "no" for all contaminants and sample locations, then enter a "no" response to Question HW-3, AW-3, IW-3, or LW-3, as appropriate (i.e. contamination does not have the potential to reach a receptor). The site passes the screening level risk assessment for this exposure scenario.

Forms A-1 and A-2 are located in the SLRA Questionnaire and Forms attachment. See Figure 3 for a summary graphical depiction of the soil leachate and groundwater transport assessment process.

Table A-1. Substance chemical properties

Substance	Henry's Constant, H' (-)	Organic carbon partition coefficient, K_{oc} (mL/g)	Biodegradation rate, λ (years^{-1})
acetaldehyde	2.73E-03	1.8E+01	
acetone	1.62E-03	5.8E-01	
acetone cyanohydrin	5.31E-04		
acetonitrile	1.41E-03	1.6E+01	
acrolein	4.99E-03	2.1E+01	
acrylonitrile	5.64E-03	8.5E-01	
ammonia	6.58E-04		
benzene	2.27E-01	5.9E+01	9.7E+00 [a]
benzotrichloride	1.06E-02		
benzyl chloride	1.68E-02	5.0E+01	
bis(2-chloroethyl)ether	6.95E-04	7.6E+01	
bis(2-chloroisopropyl)ether	1.36E-02	6.1E+01	
bis(2-chloromethyl)ether	8.42E-03	1.2E+00	
bis(2-chloro-1-methylethyl)ether	4.62E-03	6.1E+01	
bromobenzene	1.10E-01	2.2E+02	
bromodichloromethane	8.67E-02	5.5E+01	
bromoform	2.19E-02		
bromomethane	2.55E-01	9.0E+00	
1,3-butadiene	3.01E+00	1.2E+02	
carbon disulfide	5.89E-01	4.6E+01	
carbon tetrachloride	1.13E+00	1.7E+02	
chlorine	4.78E-01		
2-chloroacetophenone	1.41E-04	3.3E+02	
chlorobenzene	1.27E-01	2.2E+02	
4-chlorobenzotrifluoride	1.42E+00		
2-chloro-1,3-butadiene	2.29E+00	5.0E+01	
1-chlorobutane	6.83E-01	5.0E+01	
1-chloro-1,1-difluoroethane	2.4E+00	5.8E+01	
chlorodifluoromethane	1.66E+00	5.8E+01	
chloroethane	4.54E-01	1.5E+01	
chloroform	1.50E-01	4.0E+01	
chloromethane	3.61E-01	3.5E+01	
beta-chloronaphthalene	1.31E-02	1.6E+03	
o-chloronitrobenzene	3.8E-04	6.5E+01	
p-chloronitrobenzene	5.52E-04	6.5E+01	
2-chlorophenol	4.58E-04		
2-chloropropane	7.15E-01	5.1E+01	
3-chloropropene	4.50E-01		
2-chlorotoluene	1.46E-01	1.6E+02	
crotonaldehyde	7.93E-04	8.4E+02	
cumene	4.70E-01		
cyanide (hydrogen cyanide)	5.44E-03		

a Benzene biodegradation rate assumes aerobic conditions within groundwater. Aerobic conditions must be confirmed by measurement of dissolved oxygen concentrations > 3 mg/L in upgradient monitoring wells. Flow-through cells or other appropriate devices/methods must be used to minimize exposure of groundwater to atmospheric oxygen during measurement. See section 8 of the British Columbia Field Sampling Manual [6] for further information.

Table A-1. Substance chemical properties

Substance	Henry's Constant, H' (-)	Organic carbon partition coefficient, K_{oc} (mL/g)	Biodegradation rate, λ (years^{-1})
cyanogen	2.16E-01	2.6E+01	
cyanogen bromide	2.10E-01	2.6E+01	
cyanogen chloride	7.94E-02	2.6E+01	
n-decane	2.11E+01		
1,4-dibromobenzene	3.65E-02		
dibromochloromethane	3.20E-02	4.7E+02	
1,2-dibromo-3-chloropropane	6.01E-03	1.3E+02	
1,2-dibromoethane	2.73E-02	4.4E+01	
1,2-dichlorobenzene	7.85E-02	6.2E+02	
1,3-dichlorobenzene	1.08E-01	6.2E+02	
1,4-dichlorobenzene	9.85E-02	6.2E+02	
1,4-dichloro-2-butene	3.48E-01	4.8E+01	
dichlorodifluoromethane	1.40E+01	5.8E+01	
1,1-dichloroethane	2.30E-01	3.2E+01	
1,2-dichloroethane	4.82E-02	1.7E+01	
1,1-dichloroethylene	1.07E+00	5.9E+01	
1,2-dichloroethylene (cis)	1.67E-01	3.6E+01	
1,2-dichloroethylene (trans)	3.83E-01	5.3E+01	
1,2-dichloropropane	1.15E-01	4.4E+01	
1,3-dichloropropene	1.45E-01	4.6E+01	
dicyclopentadiene	2.56E+00	5.7E+02	
diisopropyl methylphosphonate	1.79E-03		
dimethylamine	3.70E-03	2.2E+00	
n,n-dimethylaniline	2.32E-03		
epichlorohydrin	1.24E-03	3.5E+00	
ethyl acetate	5.48E-03	5.9E+01	
ethyl acrylate	1.39E-02	8.4E+02	
ethylbenzene	3.22E-01	3.6E+02	7.7E-02
ethylene oxide	6.05E-03	2.2E+00	
ethyl ether	5.03E-02	1.4E+01	
ethyl methacrylate	2.34E-02	8.4E+02	
Freon 113	2.15E+01	1.6E+02	
furan	2.21E-01		
1,3-hexachlorobutadiene	4.21E-01		
hexachlorocyclopentadiene	1.10E+00		
hexachloroethane	1.59E-01		
n-hexane	7.36E+01		
isobutanol	4.00E-04	6.2E+01	
LEPHs/LEPHw	5.7E-02	2.5E+03	1.5E-01
maleic hydrazide	1.08E-09	4.2E+01	
methacrylonitrile	1.01E-02	8.5E-01	
methomyl	8.05E-10	1.5E+01	
methyl acetate	4.70E-03	2.2E+00	
methyl acrylate	8.05E-03	8.4E+02	
methylcyclohexane	1.76E+01		
methyl ethyl ketone	2.33E-03	4.5E+00	
methyl isobutyl ketone	5.64E-03	1.3E+02	
methyl mercaptan	1.28E-01		

Table A-1. Substance chemical properties

Substance	Henry's Constant, H' (-)	Organic carbon partition coefficient, K_{oc} (mL/g)	Biodegradation rate, λ ($years^{-1}$)
methyl methacrylate	1.38E-02	1.3E+01	
a-methylstyrene	1.04E-01	3.6E+02	
methyl tertbutyl ether (MTBE)	2.40E-02	6.0E+00	
nitrobenzene	9.81E-04	6.5E+01	
n-nitroso-di-n-butylamine	5.40E-04	2.6E+02	
2-nitrotoluene	5.11E-04	6.5E+01	
3-nitrotoluene	3.80E-04		
4-nitrotoluene	2.30E-04		
phosphine	1.00E+00		
polychlorinated biphenyls	1.40E-02	4.5E+04	
polycyclic aromatic hydrocarbons			
acenaphthene	7.44E-03	4.9E+03	
anthracene	2.27E-03	2.4E+04	
benz[a]anthracene	4.91E-04	2.3E+05	
benzo[a]pyrene	1.87E-05	7.9E+05	
benzo[b]fluoranthene	2.69E-05	7.9E+05	
benzo[k]fluoranthene	2.39E-05	8.0E+05	
chrysene	2.14E-04	4.0E+05	
dibenz[a,h]anthracene	5.03E-06	2.6E+06	
fluoranthene	3.62E-04	7.1E+04	
fluorene	3.93E-03	1.4E+04	
indeno(1,2,3-c,d)pyrene	1.42E-05	2.7E+06	
naphthalene	1.80E-02	1.2E+03	1.7E-02
phenanthrene	1.73E-03	2.1E+04	
pyrene	4.87E-04	1.1E+05	6.7E-02
propylene oxide	2.85E-03	2.5E+01	
pyridine	4.50E-04		
styrene	1.12E-01	7.8E+02	
1,1,1,2-tetrachloroethane	9.89E-02	9.3E+01	
1,1,2,2-tetrachloroethane	1.50E-02	9.3E+01	
tetrachloroethylene (PCE)	7.24E-01	1.6E+02	
tetrahydrofuran	2.90E-03	9.5E-01	
toluene	2.71E-01	1.8E+02	2.3E+00
1,2,3-trichlorobenzene	5.13E-02		
1,2,4-trichlorobenzene	5.81E-02	1.8E+03	
1,1,1-trichloroethane	7.03E-01	1.1E+02	
1,1,2-trichloroethane	3.37E-02	5.0E+01	
trichloroethylene	4.03E-01		
trichlorofluoromethane	3.97E+00	1.6E+02	
1,1,2-trichloropropane	1.30E-02	5.1E+01	
1,2,3-trichloropropane	1.40E-02	5.1E+01	
1,2,3-trichloropropene	7.20E-01	5.1E+01	
triethylamine	6.09E-03	2.2E+00	
1,2,4-trimethylbenzene	2.52E-01		
1,3,5-trimethylbenzene	3.59E-01		
vinyl acetate	2.09E-02	5.3E+00	
vinyl bromide	5.03E-01	1.3E+02	
vinyl chloride	1.14E+00	1.9E+01	

Table A-1. Substance chemical properties

Substance	Henry's Constant, H' (-)	Organic carbon partition coefficient, K_{oc} (mL/g)	Biodegradation rate, λ (years^{-1})
vinyl toluene	3.21E-01		
VPHs/VPHw	5.10E-01	1.6E+03	3.6E-01
VPHv	na		
xylenes	2.71E-01	4.1E+02	7.7E-02

Note: Substance chemical properties were compiled primarily from RAIS database [4]. Other data sources included US EPA Region 9 Superfund PRG InterCalc Tables [8], Suarez and Rifai [7] and Canada-Wide Standard for Petroleum Hydrocarbons [9].

APPENDIX B

Habitat and Receptor Assessment
(Question TS-5 in SLRA Questionnaire)

This assessment evaluates whether the site contains suitable habitat for specific local species. This assessment may only be completed by a registered professional biologist.

The potential for onsite terrestrial habitat to be used by specific receptor groups is evaluated in three steps: (1) determination of potential receptors; (2) selection of site-specific receptors; and, (3) assessment of habitat suitability. The procedure parallels the problem formulation sections and the "effects assessment-site observation" sections described in the Tier 1 ecological risk assessment protocol.

1.0 Determining potential receptors

Potential site receptor groups to be considered vary depending on land use and geographic location of the site. **Form B-1** indicates those wildlife receptors that must be considered on the basis of the different land uses (other receptors may be considered as deemed appropriate by the assessor). The assessor must also complete a site visit and check for the presence of terrestrial plant types on the site.

2.0 Selection of appropriate site-specific receptors

Using **Form B-1** as a reference, the assessor must complete **Form B-2**, which documents the land use and geographic location of the site along with observed receptor groups based on a site visit and interviews with local residents. The assessor must also indicate the potential for the presence of receptors which have not been observed during the site visit or indicated by local or onsite sources. The potential for a receptor's presence is evaluated on the basis of an office review of available information on potential receptor groups (e.g. biogeoclimatic zone lists, Committee on the Status of Endangered Wildlife in Canada [COSEWIC] lists, etc.). The receptor identification should also consider the rules (specified for each land use) within ministry ecological risk assessment protocols and/or guidance. Finally, the assessor must indicate which receptor groups will be carried forward to the assessment of habitat suitability.

Any COSEWIC-listed, red-listed, or blue-listed species that may be present in the vicinity of the site must be listed and considered individually. Guidance for identifying COSEWIC species and their geographic range is available at the following url: http://www.cosewic.gc.ca/eng/sct5/index_e.cfm. Guidance for identifying red and blue-listed species and their geographic range is available at the following url: http://www.env.gov.bc.ca/cdc/.

3.0 Assessment of habitat suitability

The undeveloped land onsite is evaluated in terms of habitat suitability for each of the selected receptor groups on **Form B-2**. The habitat suitability for each receptor group (including any COSEWIC or red/blue-listed species) is evaluated by completing the decision matrix in **Form B-3**. The decision matrix considers the following three factors:

- *Size of the undeveloped land and whether or not it is suitable for the receptor in question*. Factors such as the home range of the species should be considered while evaluating the size criterion. A "yes" answer indicates that the undeveloped land is large enough to support the receptor in question, and a "no" indicates that the land is too small to support the receptor.
- *Degree of fragmentation of the undeveloped land in terms of the specific habitat requirements of the receptor*. A "yes" answer indicates that the land is sufficiently connected or in sufficient proximity of additional habitat features, and a "no" would indicate that the undeveloped land is isolated from any additional habitat requirements of the receptor.
- *Quality of the undeveloped land*. This may include types of vegetation, presence or absence of important habitat features for the receptor, percent cover, and extent of human disturbance or degradation of the land.

The assessor should also state if it is his or her professional opinion as to whether the vegetation at the site is stressed because of site conditions or whether the vegetative conditions are typical for that geographic area at the time of the site inspection. Consideration should be given to aspects such as sites that are subject to physical impacts as a result of: traffic; storage of products on land such as lumber, pipes, etc.; or maintenance requirements (e.g. the Fire Code) that require vegetation at many industrial sites to be controlled.

Following consideration of the three factors above (i.e. size, degree of fragmentation, quality), the assessor should indicate whether or not the receptor in question is likely to use the undeveloped land as habitat.

- If "yes" for any receptor, then enter a "yes" response to Question TS-5 (i.e. the site does contain suitable habitat for specific local species).
- If "no" for all receptors, then enter a "no" response to Question TS-5 (i.e. there are no unacceptable risks to the terrestrial environment via direct exposure).

The assessor must provide rationale on **Form B-3** in support of any decisions made. Forms B-1 through B-3 are included in the SLRA Questionnaire and Forms attachment.

Protocol 13

Screening Level Risk Assessment

Questionnaire and Forms

Screening Level Risk Assessment (SLRA) Questionnaire

		Yes	No	Note
GENERAL				
Complete problem formulation.				
Check for any exemptions and preclusions that may apply.				
HUMAN EXPOSURE SCENARIOS				
Exposure to Contaminated Soils or Dust (HS-1 to 3)				
HS-1	Do substance concentrations in soil exceed the applicable standards?	☐	☐	1,2
HS-2	Are contaminated soils located within 1 m of ground or an excavation surface?	☐	☐	3
HS-3	Is the ground surface above contaminated soils uncovered?	☐	☐	4
Exposure to Contaminant Vapours (HV-1 to 2)				
HV-1	Do substance concentrations in soil vapour exceed the applicable criteria (for wildlands land use only)?	☐	☐	5
HV-2	Are humans present on the site for greater than 2 hours per day, 1 day per week?	☐	☐	6
Exposure to Contaminated Groundwater (HW-1 to 3)				
HW-1	Does drinking water use apply at the site?	☐	☐	7
HW-2	Do substance concentrations in soil or groundwater exceed the standards for the protection of drinking water?			8,2
HW-3	Is there the potential for soil leachate or contaminated groundwater to migrate to an onsite well used for drinking water or beyond the property line, at concentrations greater than the drinking water standards?	☐	☐	9
ECOLOGICAL EXPOSURE SCENARIOS				
Terrestrial Exposure to Contaminated Soils (TS-1 to 5)				
TS-1	Do substance concentrations in soil exceed the applicable standards?	☐	☐	10
TS-2	Are contaminated soils located within 1 m of ground surface?	☐	☐	3
TS-3	Is the ground surface above contaminated soils uncovered?	☐	☐	4
TS-4	Is there *potential terrestrial habitat* present? [This question to be completed by a Professional Biologist (RPBio)]	☐	☐	11
TS-5	Does the site contain suitable habitat for specific local species? [This question to be completed by a Professional Biologist (RPBio]	☐	☐	12
Exposure of aquatic biota to contaminated groundwater (AW-1 to 3)				
AW-1	Does aquatic life water use apply at the site?	☐	☐	7
AW-2	Do substance concentrations in soil or groundwater exceed the standards for the protection of aquatic life?	☐	☐	13,2
AW-3	Is there the potential for soil leachate or contaminated groundwater to migrate to downgradient surface water bodies, at concentrations greater than the Aquatic Life water standards?	☐	☐	9
Exposure of crops to contaminated groundwater (IW-1 to 3)				
IW-1	Does irrigation water use apply at the site?	☐	☐	7
IW-2	Do substance concentrations in soil or groundwater exceed the standards for the protection of irrigation watering?	☐	☐	14,2
IW-3	Is there the potential for soil leachate or contaminated groundwater to migrate to a well used for irrigation watering, at concentrations greater than the Irrigation water standards?	☐	☐	9

Screening Level Risk Assessment (SLRA) Questionnaire (Continued)

Exposure of livestock to contaminated groundwater (LW-1 to 3)				
LW-1	Does livestock water use apply at the site?	☐	☐	7
LW-2	Do substance concentrations in soil or groundwater exceed the standards for the protection of livestock watering?	☐	☐	15,2
LW-3	Is there the potential for soil leachate or contaminated groundwater to migrate to a well used for livestock watering, at concentrations greater than the livestock water standards?	☐	☐	9
DEFAULT STANDARDS				
DF-1	Do substance concentrations in groundwater exceed the default generic numerical water standards for VH_{w6-10} or EPH_{w10-19}?	☐	☐	
DF-2	Is there the potential for soil leachate or contaminated groundwater to migrate offsite, at concentrations greater than the VH_{w6-10} or EPH_{w10-19} water standards?	☐	☐	9

SLRA Questionnaire Notes

1. Use the applicable land use standards in *Schedule 4, Schedule 5 (Intake of contaminated soil)* or *Schedule 10.*
2. Any applicable Directors' interim standards or criteria must also be applied.
3. Cross-sections showing the vertical extent of soil contamination must be provided to support a "no" response to this question. Environmental consultants must also consider the potential for exposure of construction workers/utility workers to contaminated soils (e.g. within a temporary excavation, utility corridor).
4. This question evaluates if there is a permanent barrier (e.g. pavement or concrete) at ground surface, above the contaminated soils, to prevent potential exposure to contaminants. A scaled plan map showing the lateral extent of contaminated soils, barriers present, and absence of bare or vegetated soil at ground surface must be provided to support a "no" response to this question.
5. Use the criteria provided in the draft *Director's Interim Air Concentration Criteria* [1]. This pathway may only be applied at sites where wildlands land use applies (i.e., may not be applied where agricultural, urban park, residential, commercial or industrial land uses apply).
6. This question evaluates the potential for vapour exposures to humans at wildlands sites. At such sites, human exposure during limited periods of the year (i.e., hunting camps) may be compared to the prescribed exposure threshold of 2 hours/day, 1 day/week by averaging total annual exposure over a 90 day period. Actual human exposure must be indicated in the SLRA report.
7. For evaluation of water uses, refer to Technical Guidance document 6, "Applying Water Quality Standards to Groundwater and Surface Water."
8. For soils, use the applicable land use standards in *Schedule 4, Schedule 5 (Groundwater used for drinking water)* or *Schedule 10.* For groundwater, use standards in *Schedule 6 (Column V – Drinking Water)* or *Schedule 10 (Column VI – Drinking Water (DW) Water Standard)*.
9. This question is answered by evaluating: (a) soil leachate concentrations (**Form A-1**); and (b) contaminant transport along a groundwater flow path to the respective receptor (**Form A-2**). The forms, and details on how to complete them, are provided in **Appendix A.** Provide completed forms (**Form A-1** and **A-2**) to support a "no" response to this question. See Figure 3 for graphical depiction of the soil leachate and groundwater transport assessment process.
10. Use the applicable land use standards in *Schedule 4* or *Schedule 5 (Toxicity to soil invertebrates and plants, Livestock ingesting soil and fodder or Major microbial functional impairment*).
11. This question must be answered by a registered professional biologist (RPBio.). See Section 2 (Definitions) for a definition of *potential terrestrial habitat*. See Figure 4 for graphical depiction of the potential terrestrial habitat evaluation process.
12. This question must be answered by a registered professional biologist (RPBio.). This question is answered by: (1) determining possible site receptors based on land use (**Form B-1**); (2) selecting appropriate receptors (**Form B-2**); and (3) assessing habitat suitability for each receptor (**Form B-3**). The forms, and details on how to complete them, are provided in **Appendix B**. Provide completed forms (**Form B-1** through **B-3**) to support a "no" response to this question.
13. For soils, use the applicable land use standards in *Schedule 4* or *Schedule 5 (Groundwater flow to surface water used by aquatic life)*. For groundwater, use standards in *Schedule 6 (Column II – Aquatic Life)* and Protocol 10.
14. For soils, use the applicable land use standards in *Schedule 4* or *Schedule 5 (Groundwater used for irrigation watering)*. For groundwater, use standards in *Schedule 6 (Column III – Irrigation)*.
15. For soils, use the applicable land use standards in *Schedule 4* or *Schedule 5 (Groundwater used for livestock watering)*. For groundwater, use standards in *Schedule 6 (Column IV – Livestock)*.

Form A-1. Soil Leachate Concentrations

Question being answered (e.g. AW-3): _____ **Applicable Standard[1] (circle): DW AW IW LW**

Parameter	Units	Default Value	Site-Specific Value
Water-filled porosity, η_w	-	0.119	
Air-filled porosity, η_a	-	0.241	
Soil bulk density, ρ_b	g/cm^3	1.7	
Fraction organic carbon, f_{oc}	-	0.006	
Aquifer thickness, d_a	m		
Mixing zone depth, d	m	0.5	
Infiltration rate, I	m/yr	0.55	
Darcy flux, V	m/yr		

Soil Sample Location / ID	**Contaminant**	**C_S** Maximum soil concentration *(mg/kg)*	**C_L [2]** Leachate concentration (organic substances) (*Eqn A-1*) *(µg/L)*	Leachate concentration (inorganic substances) *(µg/L)*	**L** Length of source zone[3] *(m)*	**DF** Dilution Factor (*Eqn A-3*) *(-)*	**C_{gw},** Predicted groundwater concentration (*Eqn A-2*) *(µg/L)*	**CSR Standard[4]** *(µg/L)*

[1] DW, AW, IW and LW abbreviate drinking water, aquatic life water, irrigation water and livestock water use respectively.

[2] Leachate concentrations are determined using leaching tests (for inorganic substances) or partitioning equations (for organic substances) as indicated in Appendix A.

[3] This term only applied where soil contamination is above the water table. For this case, L=maximum lateral extent of soil contamination parallel to the direction of groundwater flow. If soil contamination extends below water table, leave blank and enter DF=1.

[4] Cite Contaminated Sites Regulation groundwater standard listed in Schedules 6 or 10 for the pathway being assessed (i.e. AW, DW, IW, LW).

Form A-2. Groundwater Transport

Question being answered (e.g. AW-3): _____ **Applicable Standard[1] (circle): DW AW IW LW**

Parameter	Units	Default Value	Site-Specific Value
Water-filled porosity, η_w	-	0.3	
Soil bulk density, ρ_b	g/cm^3	1.7	
Fraction organic carbon, f_{oc}	-	0.006	
Source zone width[2], Y	m		
Average linear groundwater velocity, *v*	m/yr	5	

Soil or Groundwater Sample ID / Location	**Contaminant**	**C_{gw}** Groundwater concentration at source[3] *(μg/L)*	**x_R** Distance to receptor[4] *(m)*	**α_L** Longitudinal dispersivity *(m)*	**α_T** Transverse dispersivity *(m)*	**R** Retardation Factor *(-)*	**$C(x_R)$** Predicted concentration at receptor *(Eqn A-5)* *(μg/L)*	**CSR Standard[5]** *(μg/L)*

[1] DW, AW, IW and LW abbreviate drinking water, aquatic life water, irrigation water and livestock water use respectively.

[2] Maximum extent of contaminated groundwater in the source zone perpendicular to the groundwater flow direction.

[3] Enter the maximum measured groundwater concentration based on site characterization data or concentration predicted from soil leaching ($C_{gw'}$), whichever is greatest.

[4] Allowable range is 10 m ≤ x_R ≤ 1000 m (see Appendix A).

[5] Cite Contaminated Sites Regulation groundwater standard listed in Schedules 6 or 10 for the pathway being assessed (i.e. AW, DW, IW, LW).

Form B-1. Recommended Receptors Based on Current Land Use

Wildlife receptors	Industrial	Commercial	Residential	Agricultural	Urban park
Terrestrial salamanders	Yes	Yes	Yes	Yes	Yes
Frogs/Toads	Yes	Yes	Yes	Yes	Yes
Reptiles	Yes	Yes	Yes	Yes	Yes
Waterfowl	If adjacent to water	If adjacent to water	If adjacent to water	Yes	If adjacent to water
Marsh birds/Waders	If adjacent to water	If adjacent to water	If adjacent to water	If adjacent to water	If adjacent to water
Upland game birds	No	No	No	Yes	Yes
Raptors (eagles, hawks, falcons, owls)	Yes	Yes	Yes	Yes	Yes
Shorebirds	If adjacent to water	If adjacent to water	If adjacent to water	Yes	If adjacent to water
Songbirds	Yes	Yes	Yes	Yes	Yes
Insectivorous mammals	Yes	Yes	Yes	Yes	Yes
Small herbivorous mammals	Yes	Yes	Yes	Yes	Yes
Bats	Yes	Yes	Yes	Yes	Yes
Small/medium carnivores	No	No	Yes	Yes	Yes
Large carnivores	No	No	No	Yes	Yes
Ungulates	No	No	No	Yes	Yes
COSEWIC / red / blue-listed species (evaluate individually)	Yes	Yes	Yes	Yes	Yes
Soil invertebrates	Yes	Yes	Yes	Yes	Yes
Terrestrial plants: check those that apply (i.e. found onsite during site visit)					
Trees: coniferous					
Trees: deciduous					
Shrubs					
Herbs: forbs					
Herbs: grasses					
Mosses, liverworts					
Lichens					
Fungi					
COSEWIC / red / blue-listed species	Yes	Yes	Yes	Yes	Yes

Date of site visit(s): _____

Form B-2. Selection of Appropriate Site-Specific Receptors

Land use: _____

Location of site: _____

Wildlife receptors	Based on land use[1]	Observed[2] (by assessor)	Observed (other sources)	Not observed[3]	Professional opinion regarding presence of receptor
Terrestrial salamanders					
Frogs/Toads					
Reptiles					
Waterfowl					
Marsh birds/Waders					
Upland game birds					
Raptors (eagles, hawks, falcons, owls)					
Shorebirds					
Songbirds					
Insectivorous mammals					
Small herbivorous mammals					
Bats					
Small/medium carnivores					
Large carnivores					
Ungulates					
Shrubs					
Grasses					
Ornamentals					
Trees: coniferous					
Trees: deciduous					
Herbs and forbs					
Mosses, lichens and fungi					
Other					
Red- or blue-listed species (B.C. Conservation Data Centre)					
COSEWIC-listed species (evaluate as individuals)					

[1] Receptors chosen based on current land use (from **Form B-1**).

[2] Specify date of observation/site visit.

[3] Receptor not observed. Indicate potential (i.e. “Nil”, “Low” or “High”) that receptor will actually be present at the site based on office review of available information.

Form B-3. Habitat Suitability

(to be completed for each receptor selected from **Form B-2**)

Receptor: _____

Observed onsite or potential for presence onsite: **Yes** _____ **No** _____

Habitat size	Connectivity of fragments	Quality	Move to ecological risk assessment
Yes	Yes	Not applicable	**Yes**
		Not applicable	**Yes**
	No	Yes	**Yes**
		No	**No**
No	Yes	Yes	**Yes**
		No	**No**
	No	Not applicable	**No**
		Not applicable	**No**

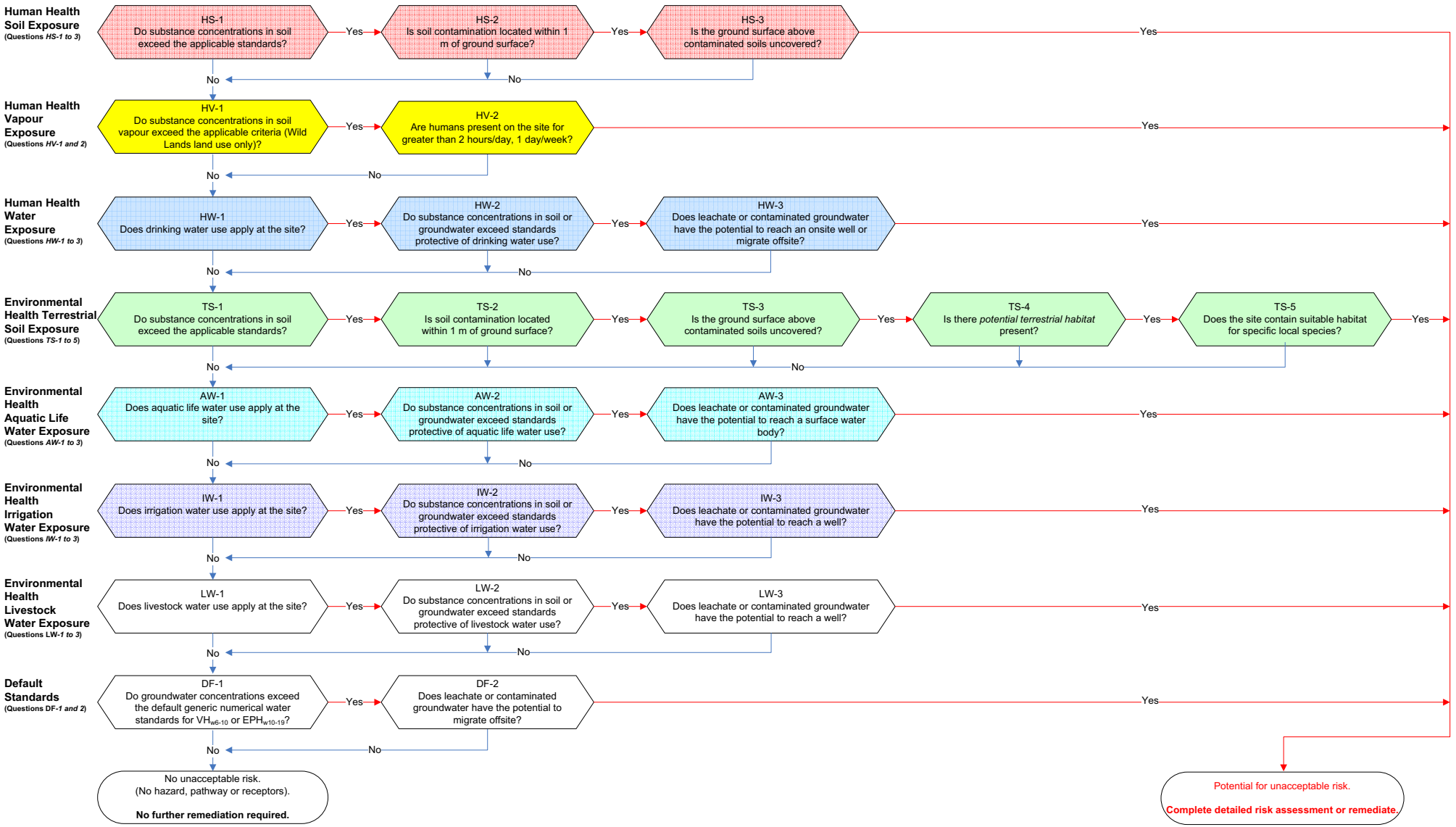
Note: "Yes" indicates that the habitat or habitat characteristic is favourable for a species.

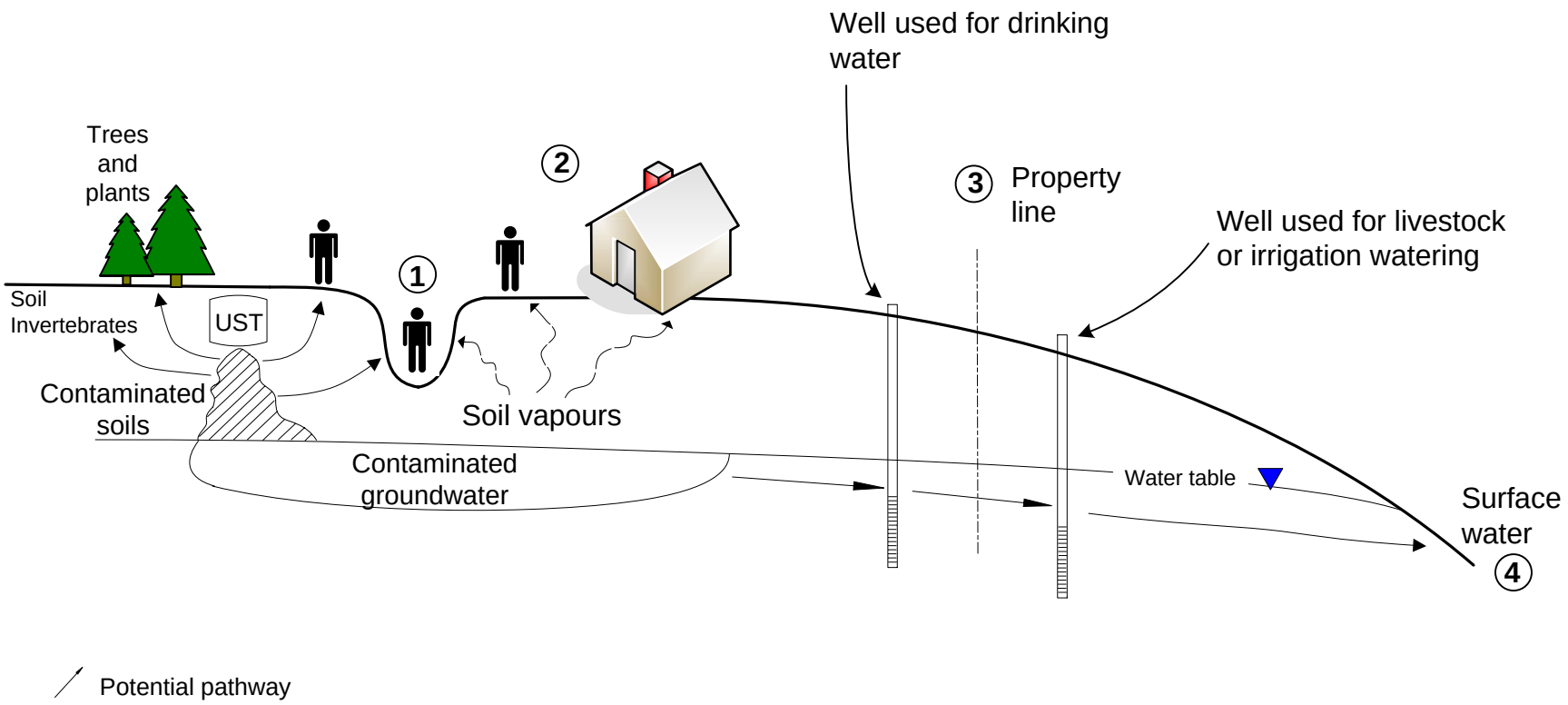
Ecological risk assessment required? Yes_____ No_____

Physical signs of impacts on plants or invertebrates? Yes_____ No_____

Comments:

FIGURE 1. Screening Level Risk Assessment Flowchart.
(Note: This flowchart is provided for illustrative purposes only. The questionnaire included in SLRA must be completed and takes precedence over this flowchart).





Notes

1. Screening Level Risk Assessment (SLRA) requires consideration of potential exposures to construction workers in excavations.
2. SLRA requires evaluation of potential indoor and outdoor air exposure to vapours.
3. SLRA may not be used if contaminated groundwater (exceeding drinking water use (DW) standards) has migrated beyond the property line (at sites where DW standards are applicable).
4. SLRA may not be used if contaminated groundwater (exceeding aquatic life water use (AW) standards) has reached a surface water body.

FIGURE 2. Site Conceptual Model (example).

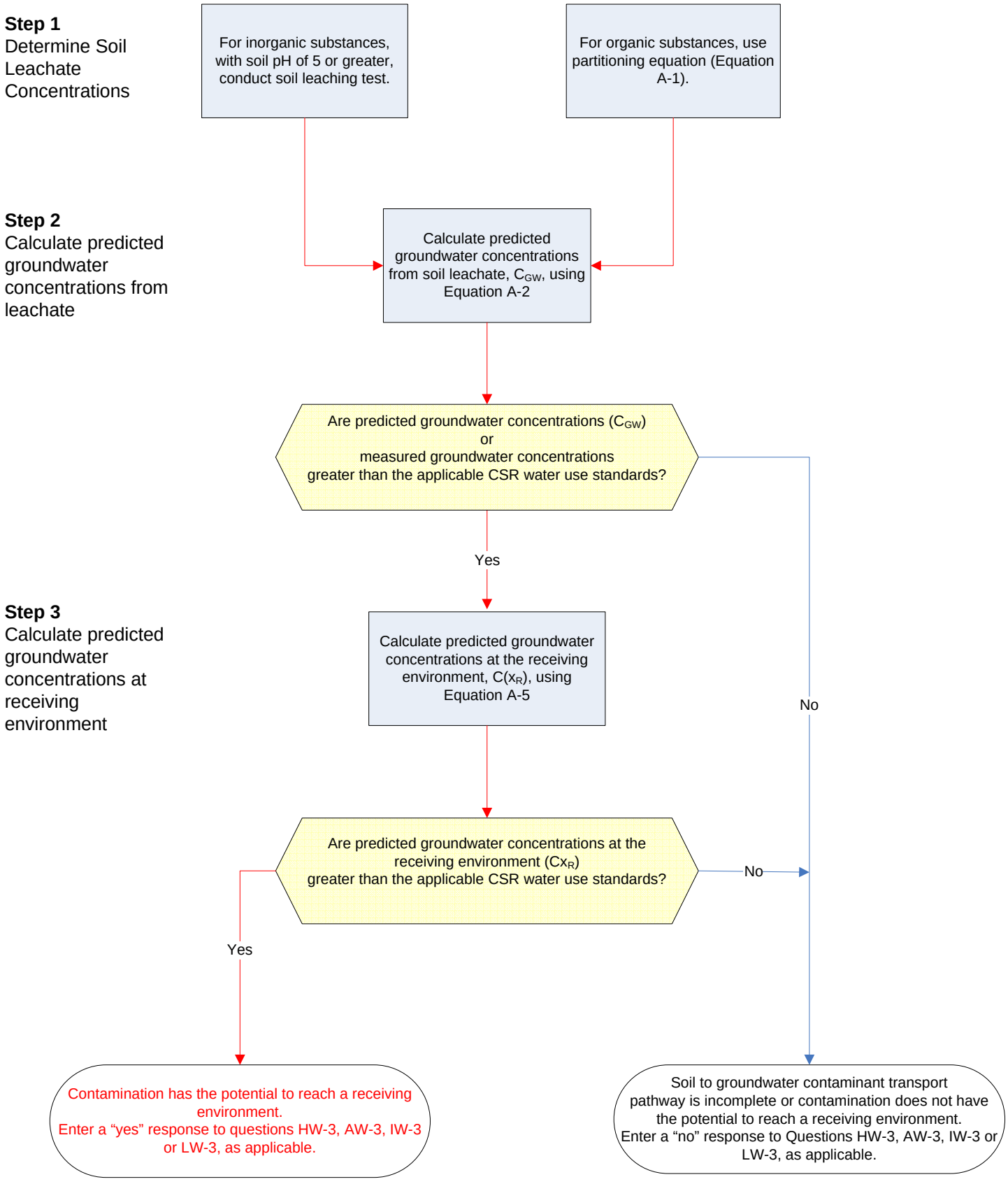


FIGURE 3. Soil Leachate and Groundwater Transport Assessment Flowchart.
(Note: This flowchart is provided for illustrative purposes only. The questionnaire and process description in Appendix A take precedence over this flowchart).

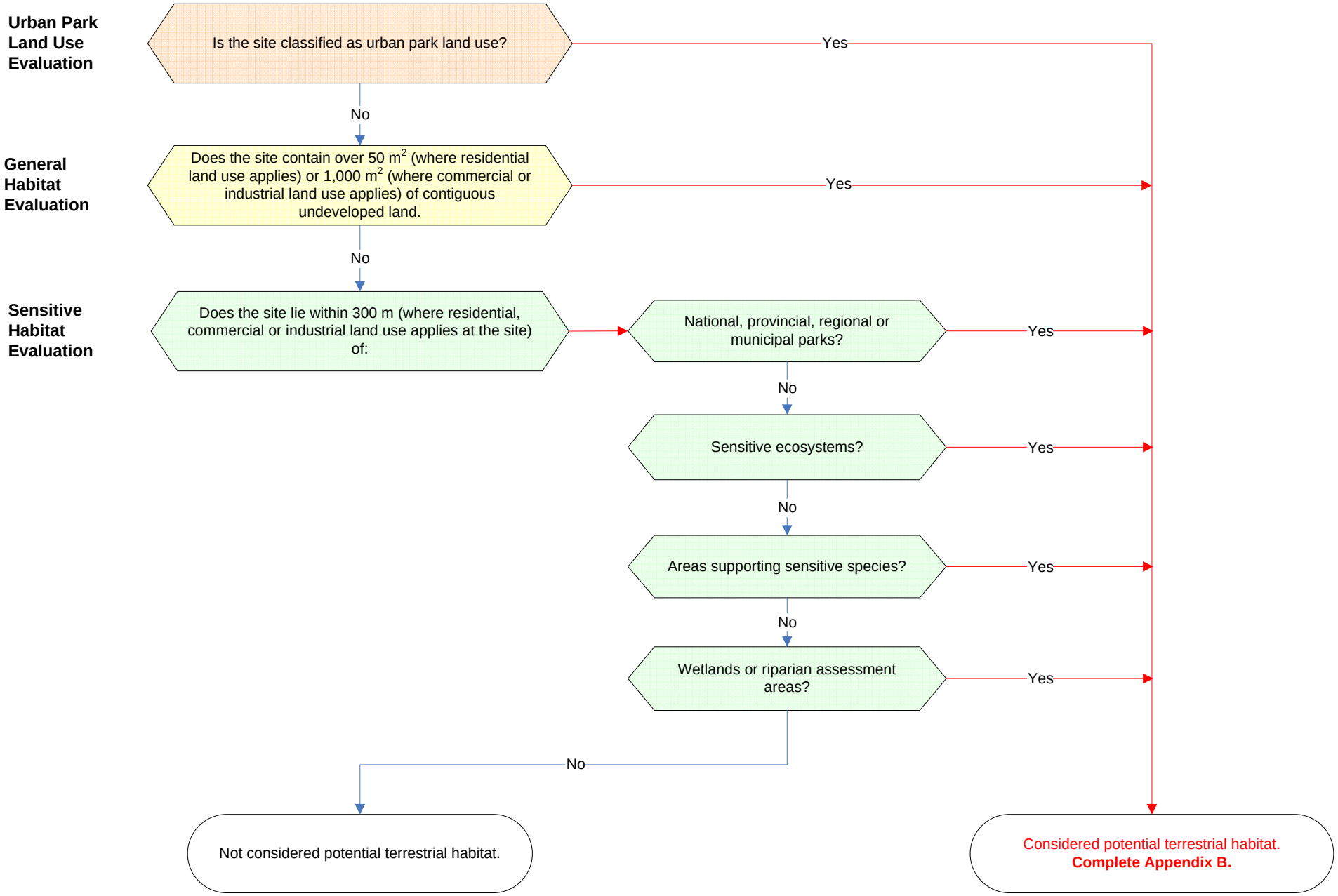


FIGURE 4. Potential Terrestrial Habitat Evaluation Flowchart.
(Note: This flowchart is provided for illustrative purposes only. The definitions and questionnaire in SLRA take precedence over this flowchart).