CSAP PD Webinar

SLRA and Groundwater Models
- Nov.10th, 2016

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Society of Contaminated Sites Approved Professionals of British Columbia

WEBINAR FORMAT:

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- Questions should be typed in in the chat box and will be answered by the presenters at the end of the presentation.

SPEAKERS

Bob Symington, P.Geo., Principal and AP at Gandalf Consulting Ltd. (604) 633-2750.

Mark Adamson, PGeo – Geo-Environmental Group Manager, Golder Associates Ltd. (604) 296-4399
Senior Geoscientist and Approved Professional (Standards), CSAP CPD Committee member. Mark has worked in contaminated sites remediation for 20 years in the UK, Ireland and British Columbia.

Christine Thomas, M.Sc., RPBio, Senior Risk Assessor, Golder Associates Ltd., Vancouver. CSAP Risk Assessment Approved Professional.

Stephen Munzar, Senior Hydrogeologist and Partner, Core6 Environmental Ltd. (250) 818-0838. Expert contaminant hydrogeologist and groundwater flow and contaminant transport modeller.

George Szefer – Senior Contaminated Sites Officer (Surrey), Science and Standards (604) 582-5323. Co-authored the current version of the P13 - SLRA and is working on pending revisions to the current document.

Remi Odense – Risk Assessment Officer, Science and Standards in Victoria (250) 387-9512. Senior Risk Assessor with MOE and advisor on ecological and human health aspects of the P13 - SLRA and is working on pending revisions to the current document .

Christine Thomas & Mark Adamson

10 Nov, 2016

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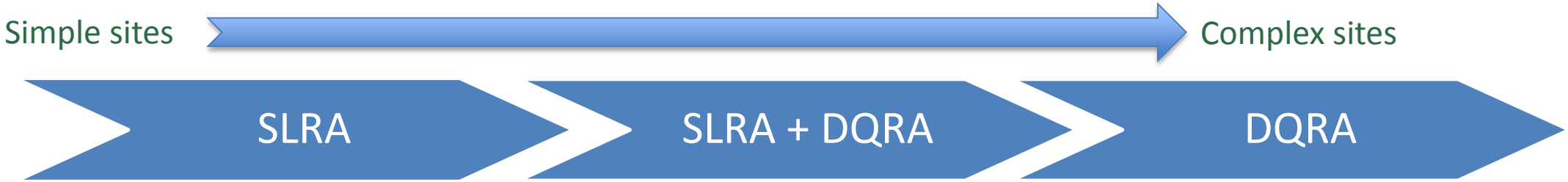
Applications of SLRA

- can be used alone at low risk, simple sites to support an application for a CoC
- can also be used in tandem with Detailed Quantitative Risk Assessment (DQRA) at more complex sites
  - Screen out pathways where no further RA is needed
  - Identify pathways to be carried forward to DQRA

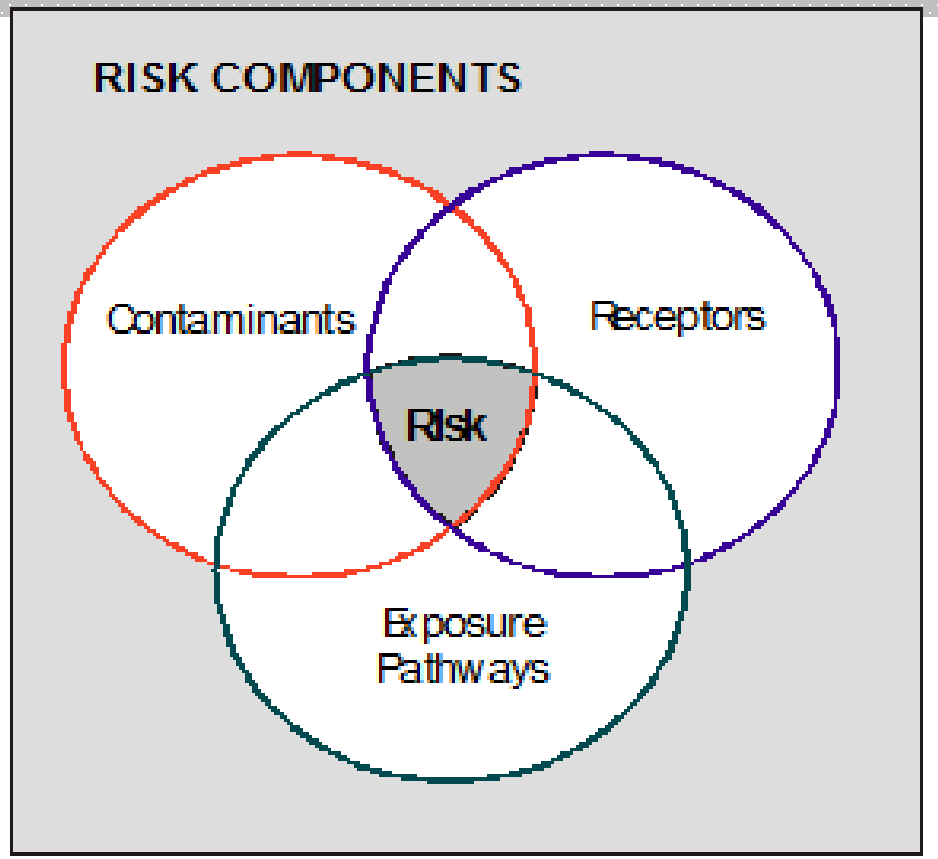


Components of a SLRA

- Problem formulation and conceptual model
- Evaluation of precluding conditions
- Evaluation of potential exposure scenarios
- Determination of risk
- Reporting

Problem Formulation

Purpose: to identify contaminants of concern, receptors, and how exposure to the contamination could occur



Problem Formulation

What to include in your SLRA report:

- Summarize site conditions that are relevant from a risk assessment perspective
- Develop a conceptual site model

Relies on information from PSI and/or DSI which must be sufficient to characterize and delineate all areas of contamination

Problem Formulation

- Site history
- Geology
- Topography
- Hydrogeology
- Groundwater usage
- Hydrology

- Current and future land use*
- Site location and description*
- Contaminants carried forward from site investigation
- Identification of receptors present (human and ecological)*

Conceptual Site Model (CSM)

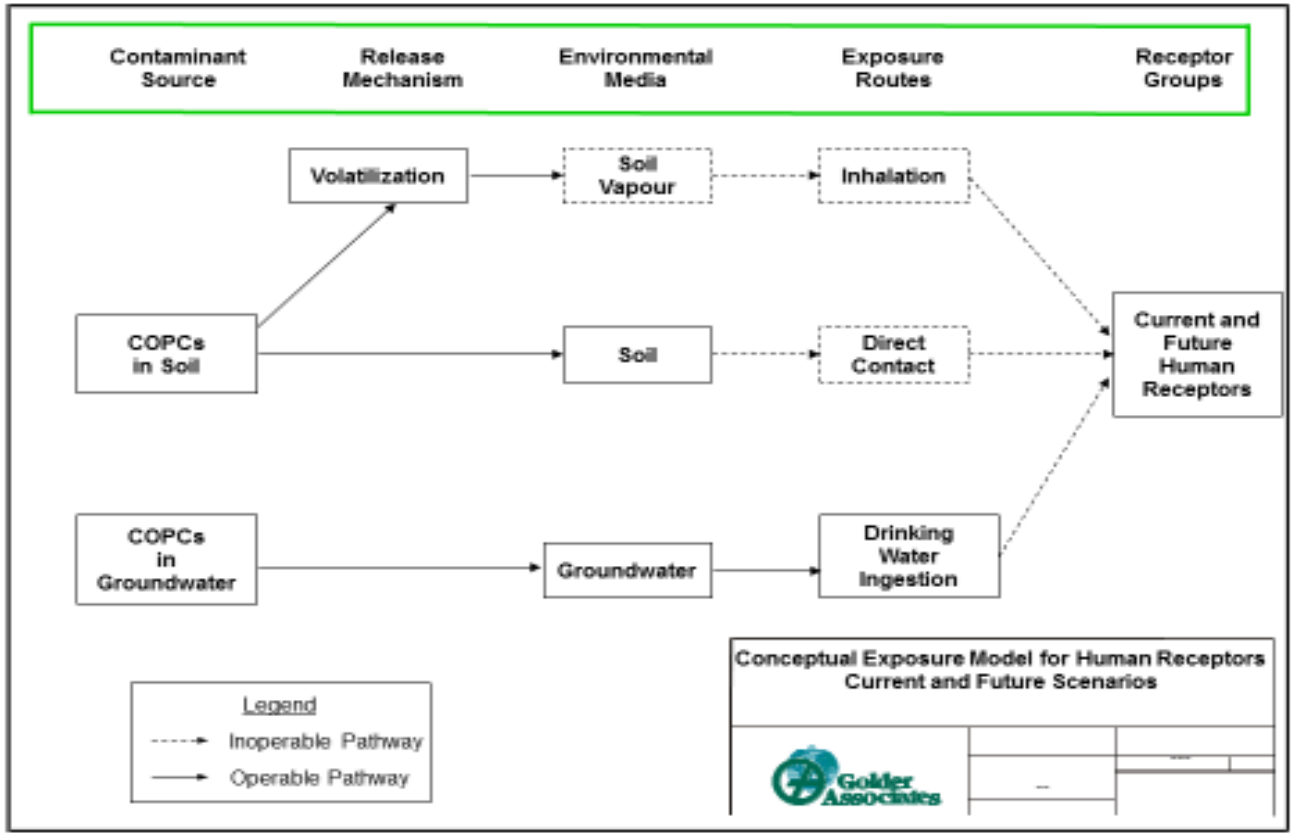
Development of a CSM that summarizes:

- Contamination
  - Source and distribution of contaminants
- Fate, transport and exposure pathways
  - How contaminants behave in the subsurface and how they might be transported to receptors,
- Receptors
  - Who or what could be affected by contamination

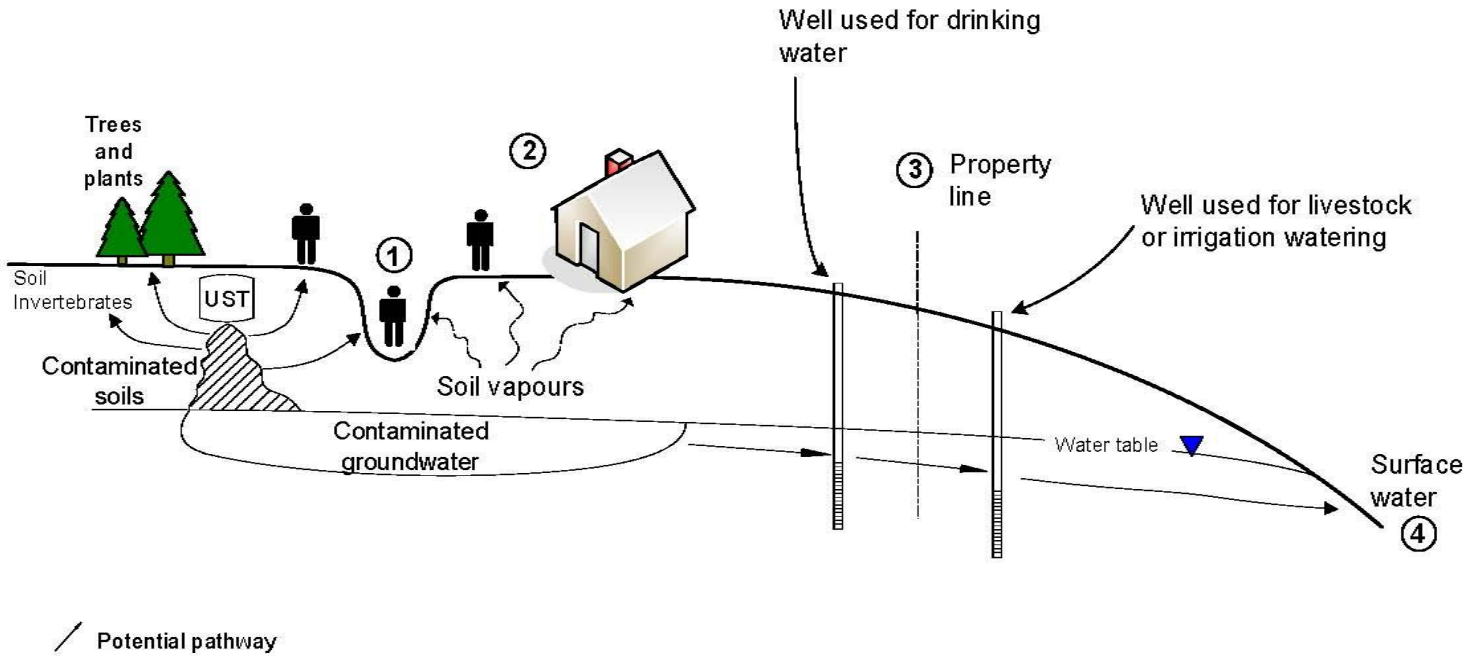
Conceptual Site Model (CSM)

- CSM needs to be illustrated in a graphic format
- Purpose of the graphic is to simply communicate the linkages between contamination sources and receptors

Conceptual Site Models – box CSM



Conceptual site models - Illustration



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Precluding Factors

- Check for exemptions and precluding factors

- 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).

Precluding Factors

- Having a precluding condition on your site does not prevent application of SLRA
- Can still apply SLRA for the other exposure pathways and address the precluded pathway in DQRA
- Useful to check BC MoE Q&A

Evaluation of Exposure Scenarios - SLRA Questionnaire

- Assesses the potential for human or ecological receptors to be exposed to contaminated soils, vapours or groundwater
- Questions require a yes or no answer with some requiring supporting information/rationale

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

Evaluation of Exposure Scenarios - SLRA Questionnaire

- A yes response to all questions in a series indicates that the pathway is operable
- Following a no response to a question within a scenario, the remaining questions don't need to be answered

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

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TECHNICAL GUIDANCE ON CONTAMINATED SITES

Version 4 November 2015

Supplemental Guidance for Risk Assessments

This document provides risk assessors and Approved Professionals guidance related to the performance of human health and ecological risk assessments for contaminated sites in British Columbia. It supplements existing provisions in protocols under the *Environmental Management Act* (the Act) for risk assessment and is subject to change as our risk assessment methodology, policy and guidance is updated.

Screening level risk assessment

Protocol 13, "Screening Level Risk Assessment" (SLRA) is intended to evaluate whether contamination at a specific site meets or exceeds benchmark screening criteria for human health and the environment. The SLRA process involves a simple default assessment of key exposure pathways and receptors.

Contaminated sites that meet SLRA benchmark screening criteria are considered to satisfy Contaminated Sites Regulation (CSR) risk-based standards. No further risk assessment or remediation is required at such sites as long as site conditions do not change. Ongoing environmental monitoring, to ensure maintenance of site conditions, may be necessary at SLRA assessed sites.

Risk assessors are cautioned that the use of SLRA is subject to precluding conditions, and cannot be used at high risk sites or at sites where contaminated vapours, surface water, or sediments require risk assessment.

Quantitative risk assessment

Human health risk assessment

Detailed human health risk assessments under the Act should include all applicable human receptors known, or reasonably inferred, to be present at a site, including uniquely sensitive or exposed human receptor subgroups such as:

a) susceptible age groups (e.g. children and the aged),
b) hypersensitive individuals (e.g. pregnant women, PICA children, etc.),
c) vulnerable individuals known to suffer compromised health impacts (e.g. chemical hypersensitivity, impaired pulmonary function, immunodeficiency, etc.), and
d) uniquely exposed individuals (e.g. subsistence consumers).

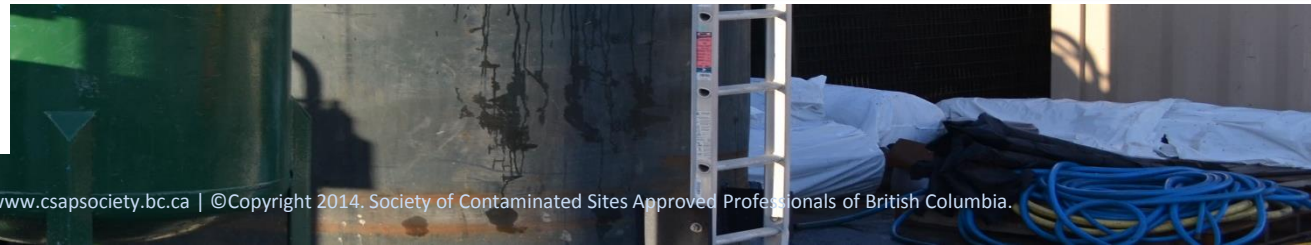
Further, provision of rationale for site-specific inclusion or exclusion of sensitive receptors is expected in all detailed human health risk assessments.

Note
It is not required to include acute/subchronic exposures for subsurface (utility, trench, and construction) workers in quantitative human health risk assessments for CSR regulatory purposes. Worker health and safety is the responsibility of WorkSafeBC under the *Workers Compensation Act* and the Occupational Health and Safety Regulation. WorkSafeBC requirements must be met at contaminated sites. Operative chronic (>90 days) occupational exposure pathways do need to be included for subsurface workers in risk assessments for CSR regulatory purposes.

1

Note
It is not required to include acute/subchronic exposures for subsurface (utility, trench, and construction) workers in quantitative human health risk assessments for CSR regulatory purposes. Worker health and safety is the responsibility of WorkSafeBC under the *Workers Compensation Act* and the Occupational Health and Safety Regulation. WorkSafeBC requirements must be met at contaminated sites. Operative chronic (>90 days) occupational exposure pathways do need to be included for subsurface workers in risk assessments for CSR regulatory purposes.

1,2
3
4



Human Exposure to Contaminant Vapours

- No screening mechanism in SLRA for vapour pathway for any landuse, including wildands

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

- Vapour > Sch 11 is a precluding condition, pathway moves to DQRA
- Updates to P13 will likely remove the application of vapours at a wildlands site

Terrestrial Exposure to Contaminated Soils

- If answer yes to TS-1 to 3, need to involve an RPBio
- Follow the series of questions in Figure 4 that evaluate:
  - Land use
  - Size of habitat (undeveloped land)
  - Proximity to sensitive habitat

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

Terrestrial Exposure to Contaminated Soils

- If answer yes to TS-4 (i.e., potential terrestrial habitat):

  Apply approach in Appendix B

  i) Identify potential receptors based on land use (Form B1)

  ii) Select appropriate receptors (Form B2)

  iii) Assess habitat suitability for each receptor (Form B3)

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

Example Site

- Residential site, several houses with basements, primarily unpaved and vegetated. Contamination consists of:
- LEPH and zinc in soil
- No groundwater contamination
- No soil vapour contamination
  - i.e., meets Sch 11 standards

Human Exposure to Contaminated Soil or Dust

LEPH:

- exceeds Sch 4 stds
- Exceedances at depths > 1 m

Exposure to Contaminated Soils or Dust (HS-1 to 3)				
		Yes	No	Note
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

Human Exposure to Contaminated Soil or Dust

Zinc:

- Does not exceed Sch 5 HH matrix stds

Exposure to Contaminated Soils or Dust (HS-1 to 3)				
		Yes	No	Note
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

Human Exposure to Contaminant Vapours

- After applying TG4 vapours don't exceed Sch 11 (done as part of the PSI/DSI)
- Not Retained

Terrestrial Exposure to Contaminated Soils

LEPH

- exceeds Sch 4 stds
- Exceedances at depths > 1 m from surface

Terrestrial Exposure to Contaminated Soils (TS-1 to 5)				
		Yes	No	Note
TS-1	Do substance concentrations in soil exceed the applicable standards?	✓		1,2
TS-2	Are contaminated soils located within 1 m of ground or an excavation surface?		✓	3
TS-3	Is the ground surface above contaminated soils uncovered?			4
TS-4	Is there *potential terrestrial* habitat present?			11
TS-5	Does the site contain suitable habitat for specific local species			12

Terrestrial Exposure to Contaminated Soils

Zinc

- Exceeds Sch 5 ECO matrix std
- Exceedances occurred at depths within 1m of surface
- No surface cover

Terrestrial Exposure to Contaminated Soils (TS-1 to 5)				
		Yes	No	Note
TS-1	Do substance concentrations in soil exceed the applicable standards?	✓		1,2
TS-2	Are contaminated soils located within 1 m of ground or an excavation surface?	✓		3
TS-3	Is the ground surface above contaminated soils uncovered?	✓		4
TS-4	Is there *potential terrestrial* habitat present?			11
TS-5	Does the site contain suitable habitat for specific local species			12

Terrestrial Exposure to Contaminated Soils

Zinc

- Potential habitat present (RL site with >50 m^2 of contiguous undeveloped land)
- Site contains suitable habitat and receptors

Pathway retained for DQRA

Terrestrial Exposure to Contaminated Soils (TS-1 to 5)				
		Yes	No	Note
TS-1	Do substance concentrations in soil exceed the applicable standards?	✓		1,2
TS-2	Are contaminated soils located within 1 m of ground or an excavation surface?	✓		3
TS-3	Is the ground surface above contaminated soils uncovered?	✓		4
TS-4	Is there *potential terrestrial* habitat present?	✓		11
TS-5	Does the site contain suitable habitat for specific local species	✓		12

Components of a SLRA

- Problem formulation and conceptual model
- Evaluation of precluding conditions
- Evaluation of potential exposure scenarios
- Determination of risk
- Reporting

Stephen Munzar

10 Nov, 2016

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Groundwater Pathway Assessment

When does it need to be completed?

- When groundwater contamination is identified
- When contamination in soil is sufficiently high enough to result in groundwater contamination

What is involved?

- Combination of **soil leachate assessment** and **aqueous transport modeling**

Precluding Factors

- Ionizing organic substances (e.g. chlorinated phenols)
- Inorganic substances with soil pH <5
- Presence of LNAPL or DNAPL
- Very high permeability soil (e.g. cobbles) or complex hydrogeology units (e.g. fractured bedrock, karst terrain)
- Preferential flow pathways that transport contaminated groundwater or soil vapours directly to a receiving environment or water well
- 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).

Soil Leachate and Transport Assessment

Three Main 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

Note: depending on site conditions, not all steps may be required

1. Determining Soil Leachate Concentrations (C_L)

Different for inorganic vs. organic constituents:

Inorganic = leachate tests

- TCLP if soil pH 5 to 5.5
- SPLP if soil pH > 5.5

Organic = partitioning equation (Equation A-1)

$$C_L = \frac{C_S}{(K_{oc} f_{oc} + \eta_w/\rho_b + H' \eta_a/\rho_b)} \times 1000$$

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

1. Determining Soil Leachate Concentrations (Cont'd)

- Leachate concentrations are calculated for each contaminant of concern
- Some flexibility for organic substances to use site specific input values into partitioning equations (e.g. η_a, η_w, ρ_b and f_{oc})
- MoE currently working on new leachate procedures for Protocol 2, results of which may influence methods used here in P13

2. Calculating Predicted Groundwater Concentrations ($C_{gw'}$) from Leachate (C_L)

$$C_{gw'} = C_L / DF$$ **Equation A-2**

Where,

$C_{gw'}$ = predicted groundwater concentration (µg/L)
CL = soil leachate concentration (from Step 1 above)
DF = the dilution factor

- Note: There is no dilution if soil contamination has reached water table (DF = 1)

2. Calculating Predicted Groundwater Concentrations ($C_{gw'}$) from Leachate (C_L)

Where soil contamination is above the water table:

- For DW, IW, LW pathway assessments:

  DF = 20

- For AW pathway assessments:

$$DF = 1 + \frac{V\,d}{I\,L}$$

Equation A-3

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2. Calculating Predicted Groundwater Concentrations ($C_{gw'}$) from Leachate (C_L)

$$DF = 1 + \frac{V\,d}{I\,L}$$

Equation A-3

V = Darcy flux or specific discharge / effective porosity (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)

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

Equation A-4

where d_a = aquifer thickness (m)

2. Calculating Predicted Groundwater Concentrations ($C_{gw'}$) from Leachate (C_L)

Results - 3 possible outcomes:

1. Calculated $C_{gw'}$ > standard for any contaminant -> go to Step#3
2. Calculated $C_{gw'}$ < standards for all contaminants but measured groundwater concentrations still greater than applicable standards -> go to Step #3
3. Calculated $C_{gw'}$ < standards for all contaminants and measured groundwater concentrations also less than standards => soil to groundwater and groundwater pathway is incomplete (no further work required)

Step #3 = Calculating the Predicted Groundwater Concentration at the Receptor

3. Calculating Predicted Groundwater Concentrations at the Receptor $C(X_R)$

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).

Two methods permitted:

1. **Equation A-5, or**
2. **US EPA BIOSCREEN** (https://www.epa.gov/water-research/bioscreen-natural-attenuation-decision-support-system)

Equation A-5

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

Equation A-5

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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)*

US EPA BIOSCREEN

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

Run Name

Data Input Instructions:

115 or 0.02 → *1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).*

Variable* → *Data used directly in model.*

20 → *Value calculated by model. (Don't enter any data).*

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	0.0	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	0.0E+00	*(cm/sec)*
Hydraulic Gradient	*i*	0	*(ft/ft)*
Porosity	*n*	0	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	0.0	*(ft)*
Transverse Dispersivity*	*alpha y*	0.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	0	*(ft)*

3. ADSORPTION

Retardation Factor*	*R*	0.0	*(-)*
or		or	
Soil Bulk Density	*rho*	0	*(kg/l)*
Partition Coefficient	*Koc*	0	*(L/kg)*
FractionOrganicCarbon	*foc*	0.0E+0	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	0.0E+0	*(per yr)*
or		or	
Solute Half-Life	*t-half*		*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	0	*(ft)*
Modeled Area Width*	0	*(ft)*
Simulation Time*	0	*(yr)*

6. SOURCE DATA

Source Thickness in Sat.Zone* 10 *(ft)*

Source Zones:

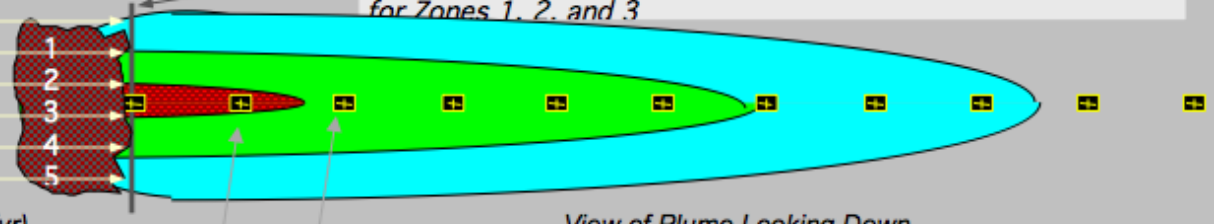
Width* (ft)	Conc. (mg/L)*
0	0

Source Halflife (see Help):

Infinite	Infinite	*(yr)*
Inst. React.	1st Order	
Soluble Mass	infinite	*(Kg)*

In Source NAPL, Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)											
Dist. from Source (ft)	0	0	0	0	0	0	0	0	0	0	0

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

3. Calculating Predicted Groundwater Concentrations at the Receptor $C(X_R)$

Model input parameters include:

$C(x_R)$ = 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)

3. Calculating Predicted Groundwater Concentrations at the Receptor $C(X_R)$

Sources for model input parameters:

- Most input parameters have default values which are listed in P13
- A site specific velocity ***v*** can be used only if it is greater than 5 m/year
- Site specific values for η_a, η_w, ρ_b and f_{oc} can also be used
- For ***H', Koc, λ***, values are listed in Appendix A-1. For substances not listed in Appendix A-1 the RAIS Database can be used (www.rais.ornl.gov)

3. Calculating Predicted Groundwater Concentrations at the Receptor $C(X_R)$ - Results

- If $C(X_R)$ = less than applicable standard, no pathway to receptor
- If $C(X_R)$ = greater than applicable standard, potential pathway to the receptor exists (SLRA fails for this exposure pathway)

3. Flow and Transport Model Assumptions and Limitations

Both modeling methods are based on Domenico (1987) three-dimensional analytical solute transport model. The model simulates the effects of advective transport, dispersion, adsorption, and biodegradation through first-order decay.

Note: if BIOSCREEN is to be used, additional settings are required for use in P13 to make it equivalent of Equation A-5

These models are used to simulate relatively simple geologic and hydrogeologic conditions and have several imbedded assumptions and limitations

3. Assumptions

The key assumptions for use of both models are:

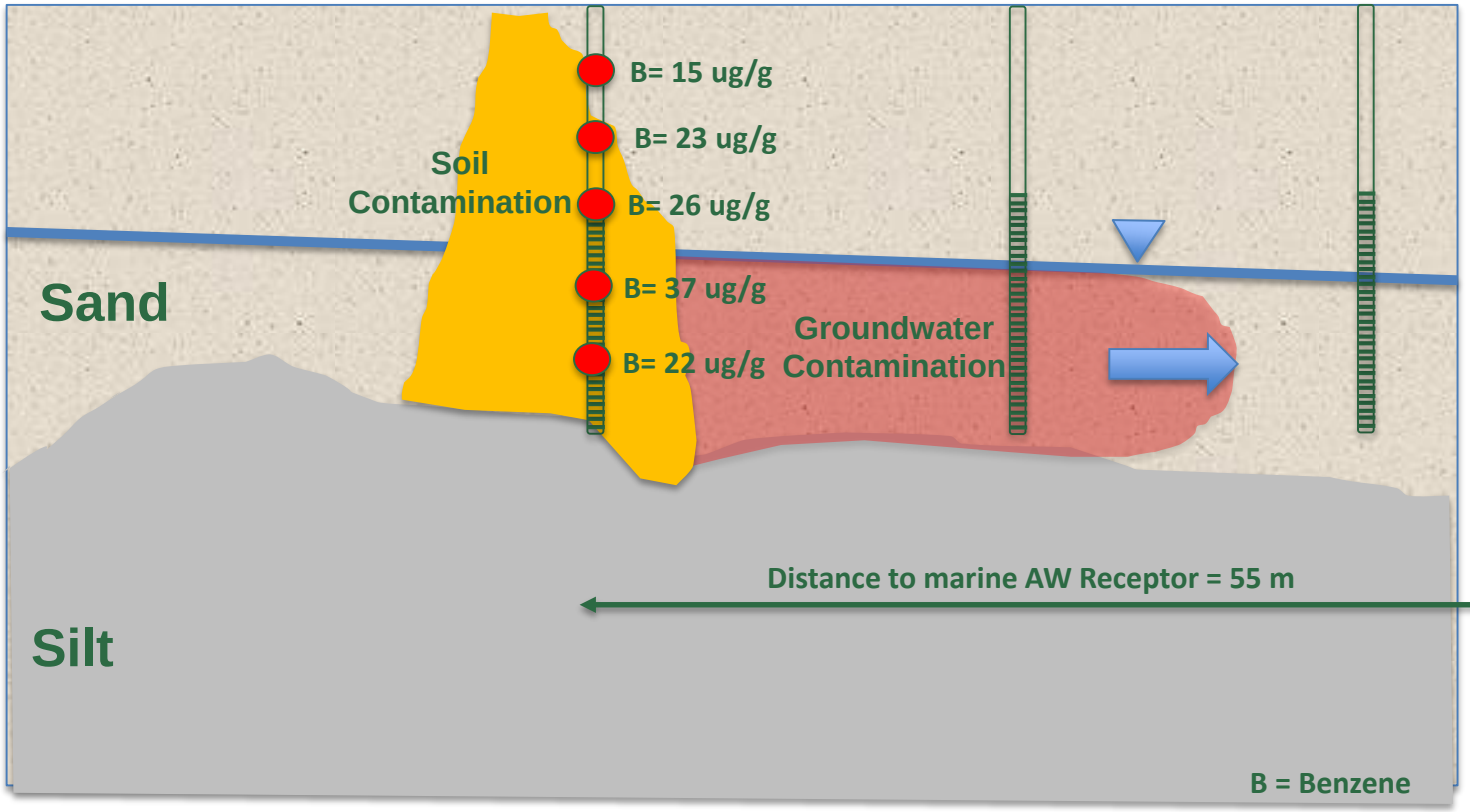
1. The aquifer and flow field are homogeneous and isotropic
2. The groundwater velocity is fast enough that molecular diffusion in the dispersion terms can be ignored (may not be appropriate for simulation of transport through clays)
3. Adsorption is a reversible process represented by a linear isotherm

3. Limitations

The key limitations of the models are:

1. The models should not be applied where pumping systems create a complicated flow field
2. The models should not be applied where vertical flow gradients affect contaminant transport
3. The models should not be applied where hydrogeologic conditions change dramatically over the simulation domain

Example Problem / Site



Maximum reported groundwater concentration in wells C_{gw} = 320 ug/L

Example (Cont'd)

- Benzene contamination reported in soil:
  - CSR AW marine applies – standard = 2.5 ug/g
  - Shallow *unsaturated zone* benzene concentrations = 15, 23, and 26 ug/g
  - Deeper *saturated zone* benzene concentrations = 22 and ***37*** ug/g

- Using the max (37 ug/g) benzene concentration C_L = ***81,108 ug/L***

And since max soil contamination is in saturated zone**, DF = 1:**

Therefore, $C_{gw'}$ = C_L = *81,108 ug/L*

Example (Cont'd)

- Since $C_{gw'}$ ***(81,108 ug/L)*** is greater than C_{gw} ***(320 ug/L)***, $C_{gw'}$ is used to calculate $C(X_R)$
- The horizontal distance to the AW marine receptor = 55 m
- $C(X_R) = <<1$ ***ug/L***
- Since ***C(XR)*** is less than the CSR AW standard of 1000 ug/L, there is no pathway to the AW receptor

Conclusions and Key Take Aways

- Groundwater pathways to receptors can be assessed using Protocol 13 under relatively simplified site conditions
- Optimal scenario for groundwater pathway assessment is:
  - Hydrocarbon contamination (i.e. not metals)
  - Relatively low concentrations in soil and/or groundwater
  - AW pathway assessment (DW pathways less likely to work favorably)
  - Sites located longer distances from receptors (e.g. AW receptors)
- A good understanding of the geology, hydrogeology, and contaminant distribution is required
- Under more complex conditions, a Detailed Risk Assessment may be required

Questions?

Please type your question for the presenters or for Remi Odense or George Szefer into the chat box.

Thanks for Your Participation

Please look for information on our upcoming webinar:

Risk Conditions and PVPs, Risk Based CoCs, AG11 Communications

~ Feb 2017 ~