Hydrocarbon Model Modification for the Domestic Use Aquifer, Dilution Factor 4

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Today's Presentation

- Site conditions
- Tier 1 model assumptions for the DUA
- Site-specific adjustment for DF4
- Summary: conclusions, regulatory feedback, value

Site Conditions

Site Description

- Wellsite within an agricultural land use, cultivated setting
- Dominant soil lithology is fine-grained
- Average depth of shallow groundwater is **2.2 mbgs**
- Two adjoining wellsites
- Nearby freshwater aquatic life (FAL) receptor to the northeast

Groundwater Information

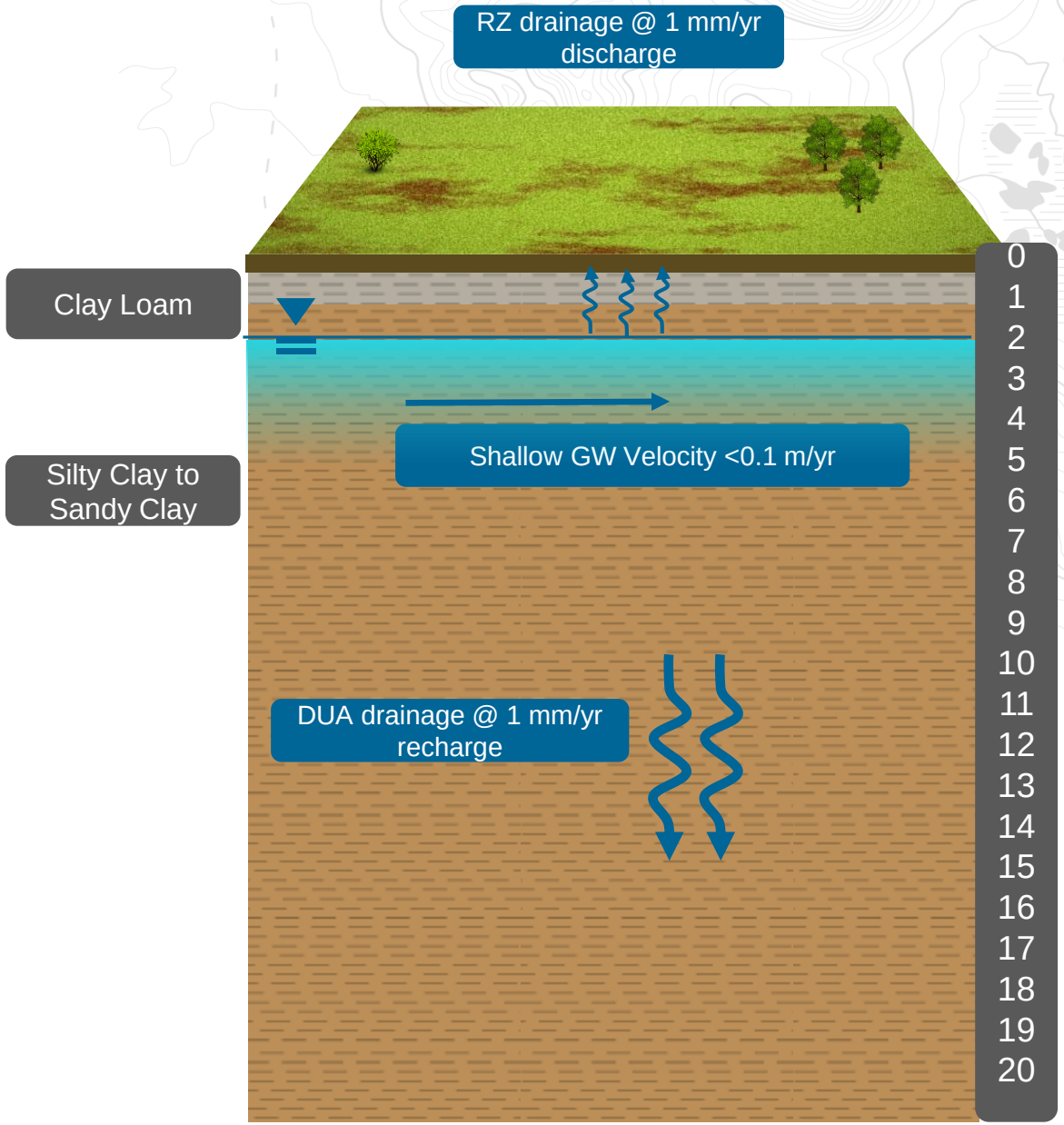
- Hydraulic conductivities measured in 4 monitoring wells and it ranged from 2.6×10^{-9} m/s – 1.14×10^{-8} m/s, with an average conductivity of **6.65×10^{-9} m/s**

Monitoring Well	Sampling Date	Screened Interval (m)	Hydraulic Conductivity (m/s)	Lithology	Method
MW15-02A	6-Oct-17	2.5 – 4.0	8.7×10^{-9}	Clay	KGS and Bower & Rice
MW15-03B	6-Oct-17	6.5 – 7.5	2.6×10^{-9}	Sandy Clay	KGS and Bower & Rice
MW15-04A	6-Oct-17	2.5 – 4.0	1.1×10^{-8}	Clay	KGS
MW15-04B	6-Oct-17	6.5 – 7.5	3.9×10^{-9}	Sandy Clay	KGS
		Average	**6.65×10^{-9}**		

- Estimated shallow groundwater lateral flow velocity of **0.007 m/yr**
- Based on the measured vertical gradients, our modelled drainage rate of **1 mm/yr recharge (downwards)** toward the DUA

Relevant Receptors

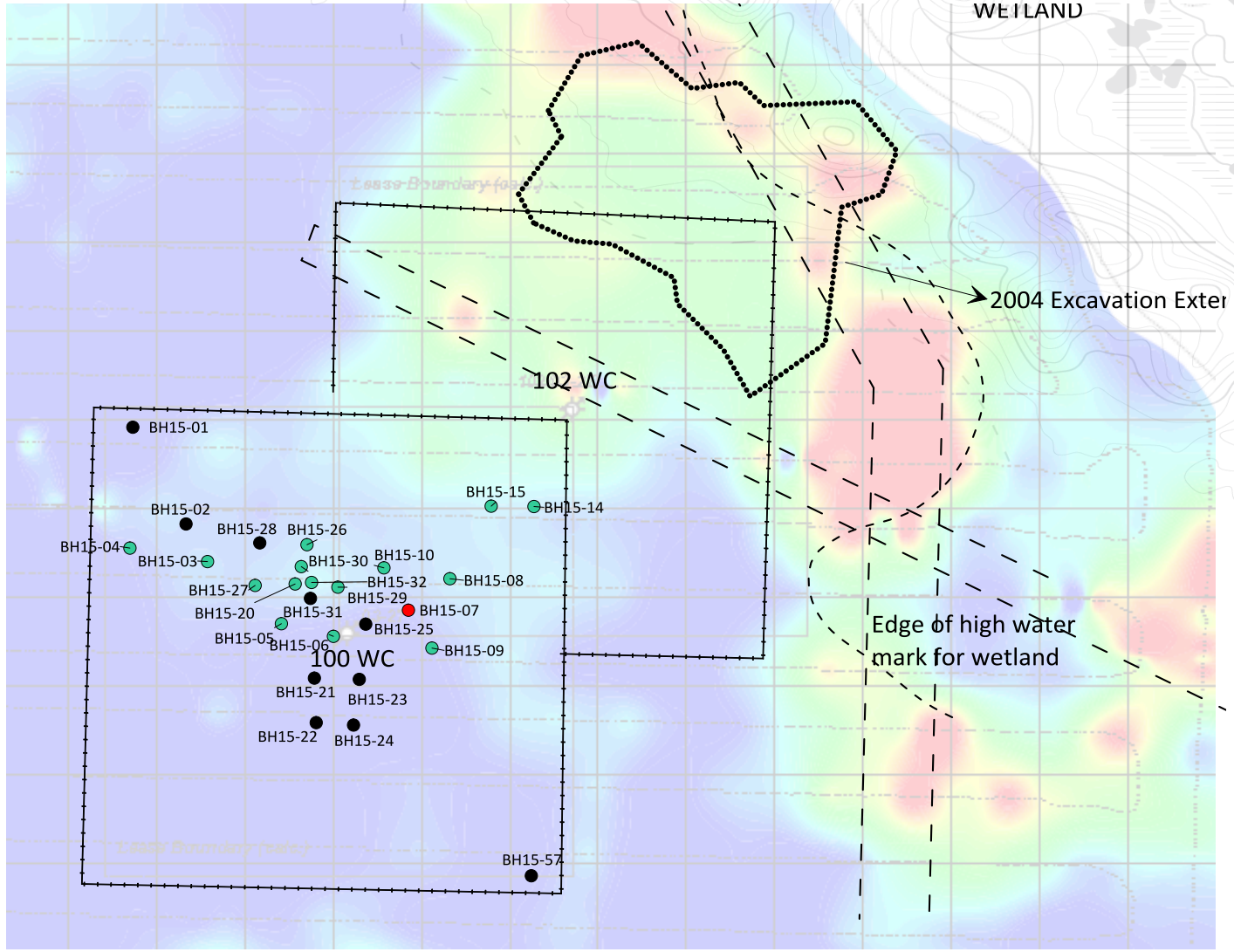
- Five water wells located within 1,000 m of the site – the shallowest was completed at 23 mbgs in the direction of shallow groundwater flow
- No potential DUA was encountered at the maximum investigation depth of **20 mbgs**



Contaminant Information

- Elevated levels of ethylbenzene were measured at 2.3-3.0 mbgs. Vertical closure at 3.5-4.0 mbgs.
- Lateral closure achieved in all directions

Parameter	Concentration (mg/kg)	Tier 1 Guideline (mg/kg)
B	<0.005	0.046
T	<0.05	0.52
E	0.162	0.073
X	<0.1	0.99
F1	13	210
F2	62	150
F3	240	1300
F4	99	5600



Tier 1 Model Assumptions for the DUA

Tier 1 Surface Soil Guideline - Ethylbenzene

Parameter	DSC (mg/kg)	VI – Bsmt (mg/kg)	VI – Slab (mg/kg)	DUA (mg/kg)	DSC (mg/kg)	Livestock Soil/Food Ingestion (mg/kg)	Wildlife Soil and Food Ingestion (mg/kg)	FAL (mg/kg)	Livestock watering (mg/kg)	Wildlife watering (mg/kg)
Ethylbenzene	1700	1000	930	0.073	120	1600	640	NGR	36	NGR

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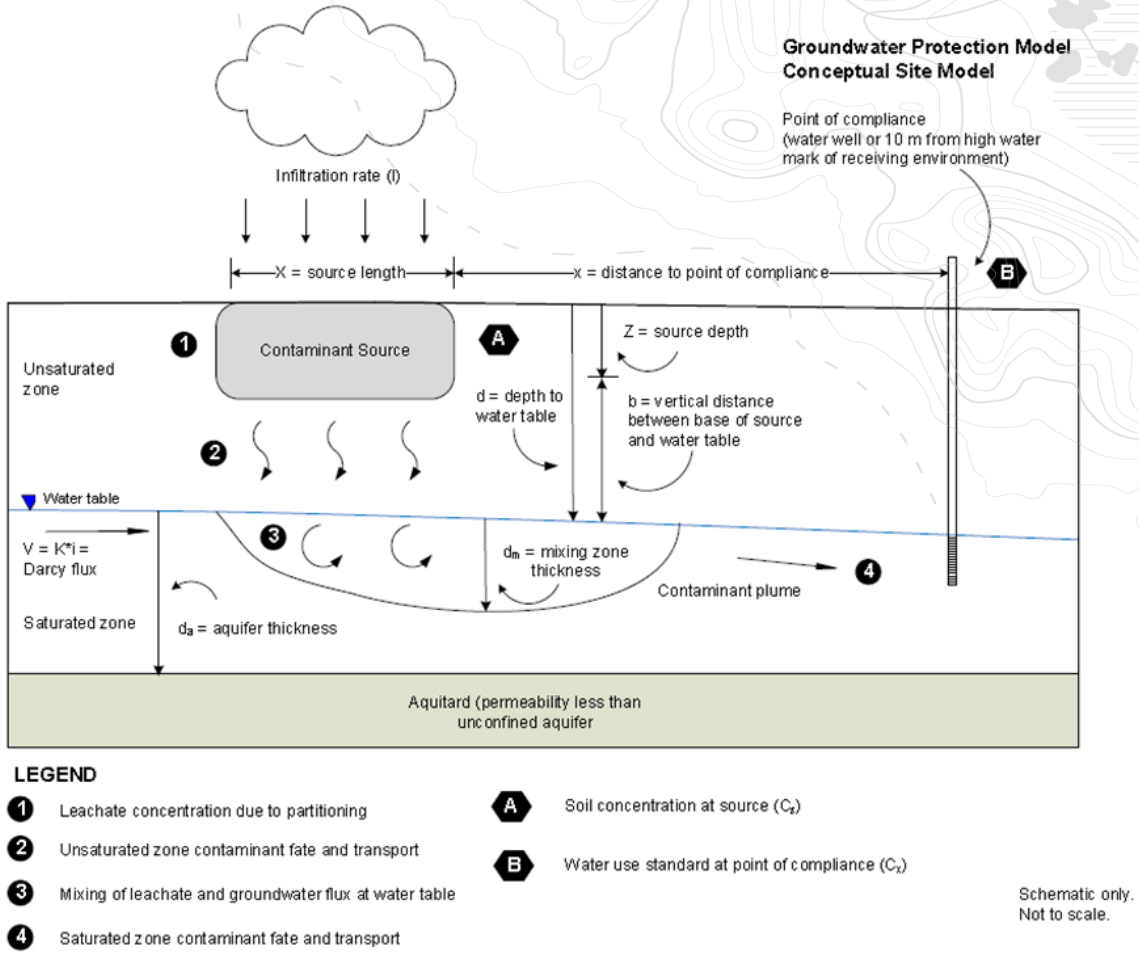
Majority of light-end PHC guidelines constrained by DUA
Fine: BTEX; Coarse: EX

Tier 1 Soil Remediation Guideline

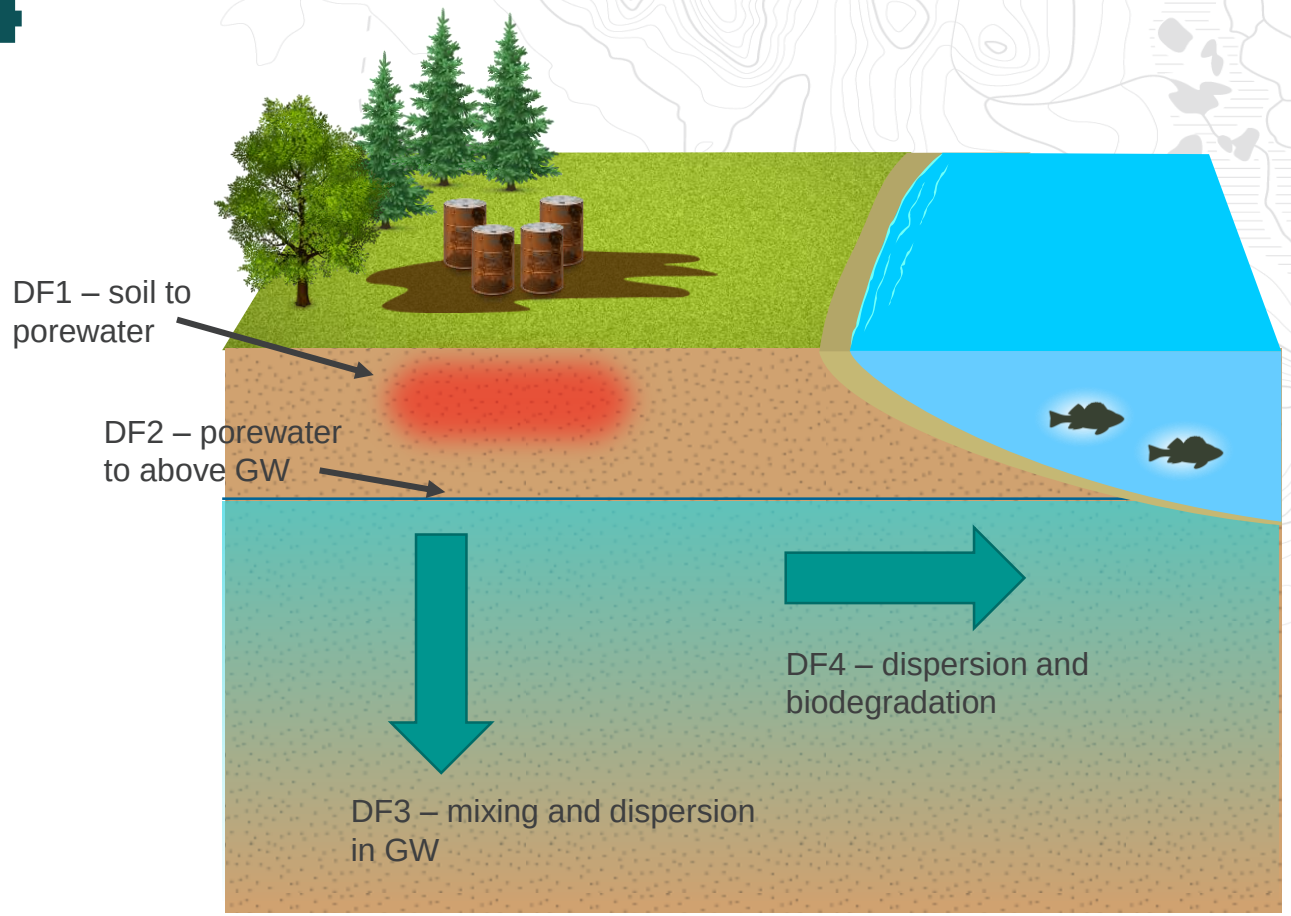
- Soil remediation guideline for the groundwater pathways was calculated using the model and equations from CCME (2006) protocol
- Groundwater pathways include:
  - Protection of a DUA – no offset distance
  - Protection of aquatic life in a nearby surface water body – assumed a minimum offset distance of 10 m
  - Protection of livestock watering including wells and dugouts
  - Protection of wildlife from the consumption of water in a nearby surface water body – assumed a minimum offset distance of 10 m



CCME (2006): A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines

Dilution Factors 1 to 4

- The model considers four processes:
  - DF1 – partitioning from soil to pore water
  - DF2 – transport of leachate from the base of contamination to the groundwater table
  - DF3 – mixing of leachate with groundwater
  - DF4 – lateral transport in groundwater to a downgradient receptor



Conservative Tier 1 Assumptions

- DF4 is only calculated for the protection of the aquatic life and wildlife watering pathways.
- For DUA in Tier 1, DF4 is assumed to be 1.0
- Assumes shallow groundwater is the DUA
- Assumes no offset, and contamination is in contact with the DUA
- Results in no attenuation of concentrations to the DUA

Site-specific Adjustment for DF4

Overview of Model Adjustments

$$DF4 = \frac{4}{\exp(A) \times erfc(B) \times [\mathrm{erf}(C) - \mathrm{erf}(D)]}$$

$$A = \frac{x}{2D_x}\left\{1 - \left(1 + \frac{4L_s D_x}{v}\right)^{1/2}\right\}$$

$$B = \frac{x - vt\left(1 + \frac{4L_s D_x}{v}\right)^{1/2}}{2(D_x vt)^{1/2}}$$

$$C = \frac{y + Y/2}{2(D_y x)^{1/2}}$$

$$D = \frac{y - Y/2}{2(D_y x)^{1/2}}$$

$$L_s = \frac{0.6931}{t_{1/2s}}(e^{-0.07d}) \qquad D_x = 0.1x$$

$$v = \frac{V}{\theta_t R_s} \qquad D_y = 0.01x$$

$$R_s = 1 + \frac{\rho_b K_{oc} f_{oc}}{\theta_t}$$

- DF4 is used to calculate the vertical transport towards a potential DUA at 20 mbgs
- Analogous to lateral transport to FAL receptor
- Site-specific changes:
  - Decay constant (Ls)
  - Depth to groundwater (d)
  - Lateral distance from the source to receptor (x)

Site-Specific DF4 Adjustment – Decay Constant

$$L_s = \frac{0.6931}{t_{1/2s}}(e^{-0.07d})$$

- Chemical half-life :
  - No adjustment for the half-life value
  - Tier 1 uses the chemical life of contaminants in the saturated zone as a default value, which is higher than the unsaturated zone, and therefore, more conservative.
- The decay constant (Ls) is a function of the depth to groundwater (d) and the chemical half-life of a contaminant in the saturated zone ($t_{1/2s}$)
- Decay constant (Ls) value decoupled for this assessment
  - Based on the default shallow groundwater depth for DF2
  - Based on the depth of potential DUA for DF4
  - As the depth of groundwater increases, decay constant decreases
  - Deeper depth was used – more conservative

Source:
Suarez, Monica P. and Hanadi S. Rifai. (1999). *Biodegradation Rates for Fuel Hydrocarbons and Chlorinated Solvents in Groundwater.* Bioremediation Journal Volume 3, Issue 4. Pages 337-362.

Site-Specific DF4 Adjustment – Receptor Distance

$$D_x = 0.1x$$

$$D_y = 0.01x$$

- Lateral distance from the source to the receptor (x):
  - For the site, it is the distance between the bottom of impact to the depth of a potential DUA
  - Affects the calculation of the longitudinal dispersivity (in the direction of groundwater flow, Dx) and transverse dispersivity (perpendicular to groundwater flow, Dy)
  - Values are not adjusted in the formulas as their influence is relative to flow direction
- Chemical diffusion was not accounted for in DF4, but it is not anticipated to be an issue for ethylbenzene due to its solubility

Calculated Tier 2 Guidelines

Parameter	Fine (mg/kg)					Coarse (mg/kg)				
	0m	5m	10m	15m	NMLP	0m	5m	10m	15m	NMLP
Benzene	0.046	0.605	4.07	20.1	0.2	0.078	0.108	0.145	0.197	0.073
Toluene	0.52	NGR	NGR	NGR	26	0.95	7.8	39.3	155.9	0.12
Ethylbenzene	0.073	NGR	NGR	NGR	36	0.14	5.2	63.9	NGR	42
Xylene	0.99	NGR	NGR	NGR	65	1.9	26.4	184	NGR	12

Notes:

1. 0 m = Tier 1
2. NGR = no guideline required, exceeds solubility limit
3. Distances = receptor distances
4. NMLP = next most limiting pathway

Factors NOT Adjusted

- DF1 to DF3 unchanged
- Default values for K and i – resulting in default DF3 values
- Default values for drainage rate – very sensitive and quite influential
- Generally applied conservative assumptions in all cases
- Calculation of the retardation factor (Rs) and velocity of contaminant (v) - based on chemical parameters, soil and hydrogeological characteristic

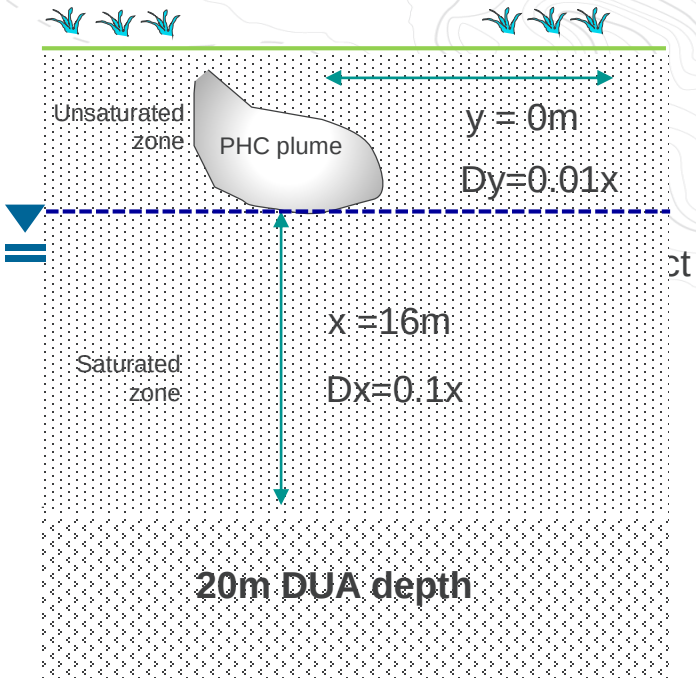
$$v = \frac{V}{\theta_t R_s}$$

$$R_s = 1 + \frac{\rho_b K_{oc} f_{oc}}{\theta_t}$$

Summary, Feedback & Conclusions

Summary

- Minor ethylbenzene impacts to a depth of 3 mbgs
- Impacts are delineated vertically and laterally
- Default Tier 1 guideline for ethylbenzene is based on the protection of the DUA
- For the DUA at Tier 1, soil remediation guideline is calculated assuming that the contaminant is in contact with the DUA, with no offset or attenuation (DF4 = 1)
- DF4 was used to calculate the vertical migration of contaminant to the receptor (the DUA)



Regulatory Feedback

- Regulatory consultation in 2019 – cautiously optimistic
  - Some reservation about how this approach will be implemented
  - Concerns with preferential flow paths
  - Not applicable for short receptor distances
  - Prefers a certain level of conservatism in comparing revised guideline and exceedance
  - The level of site complexity dictates the level of required evidence
  - Sensitivity analysis is important to demonstrate the effects pf parameter adjustments
  - Known models are preferred
  - Conservative assumptions, especially for sensitive parameters, strengthen the argument
  - **This approach is considered to be site-specific risk assessment and requires evaluation on a site by site basis with respect to the above

Cost / Benefit

- Fairly small volume – conservatively estimated at 300 m3 or 540t
- @ $80/tonne = $43,200
- Relevant data acquired during our investigation
- Additional reporting and regulatory review <<< savings in dig and dump
- >> Value with >> larger volumes

Value

- Simplicity vs. complexity
- Ease of application, ease of screening level review
- Potential application without additional field investigation
- Potential application without groundwater information
- Application on fine and coarse-grained sites
- Caution: SSRA, with >> Complexity = >> Due Diligence

Thank-you

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