RemTech 2004

Using the One Dollar Model to Answer the Million Dollar Question

or

Assessment of Natural Attenuation (Fate and Transport Modelling) Within the Regulatory Framework

by

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What We Want You To Think About...

1. Regulatory models are unlikely to simulate site-specific fate and transport very well (even though it's tempting to try...)
2. The calculation of equivalent parameter values may allow a further level of site-specificity for Tier 2 at more complex sites
3. Perhaps we may wish to calculate some guidelines probabilistically (again)

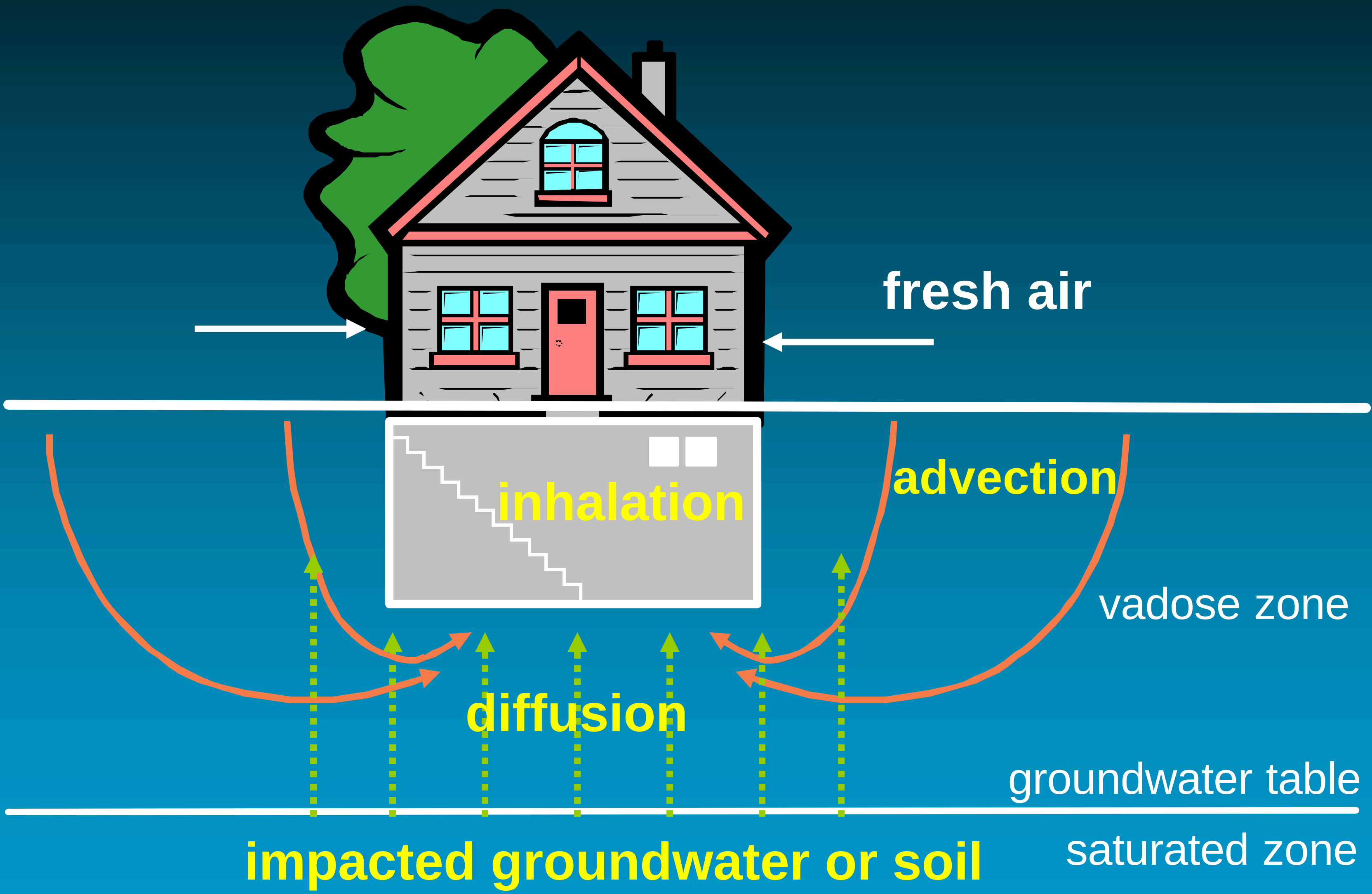
Thought #1

Regulatory models are unlikely to simulate site-specific fate and transport very well (even though it's tempting to try...)

Features of Regulatory Models

- Analytical models assume simple, homogeneous geology and regular boundary conditions
- They simplify (or ignore) certain contaminant fate and transport mechanisms
- Not all input parameters can be adjusted (and/or within limits)

Johnson & Ettinger (1991) Model



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Tier 1 and 2 Model Assumptions: Vapour Migration

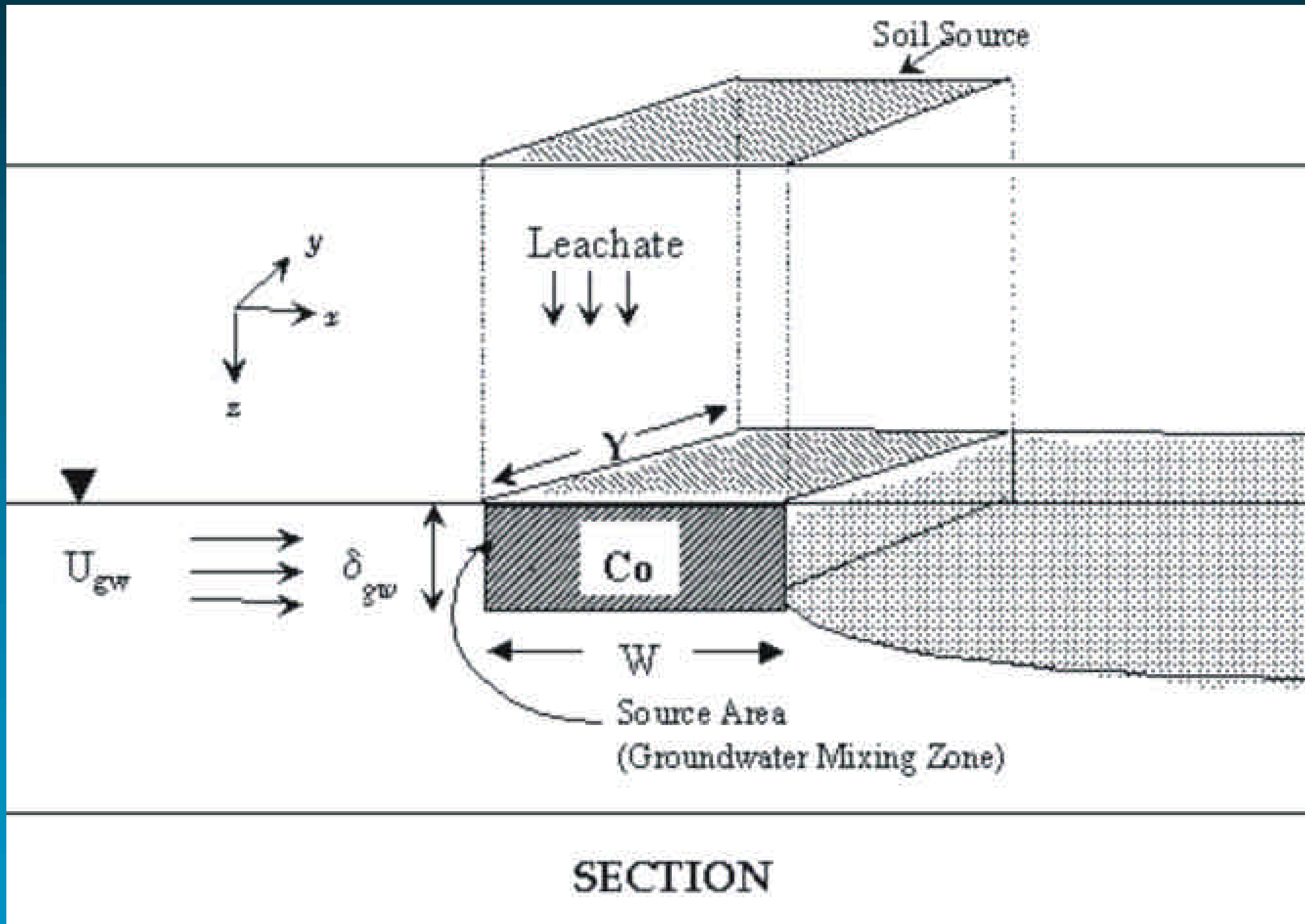
- One layer of soil with uniform properties and moisture content
- Default building dimensions and construction features
- No biodegradation
- Vapour movement in steady state

Conservative!

Real-World Vapour Migration Issues

- **Soil properties and moisture content change with space and time**
- **Biodegradation does occur**
- **Unique building sizes and construction**
- **Transient vapour movement (esp. diffusion)**

Domenico (1987) Model



Tier 1 and 2 Model Assumptions

- Uniform geology and groundwater flow field
- Constant contaminant sources
- No rainfall infiltration dilution
- Simple biodegradation

Conservative!

Real World GW Transport Issues

- Non-uniform geology and groundwater flow fields
- Contaminant sources with irregular shape, limited size and changing concentration
- Dilution by rainfall infiltration during migration
- Complex biodegradation

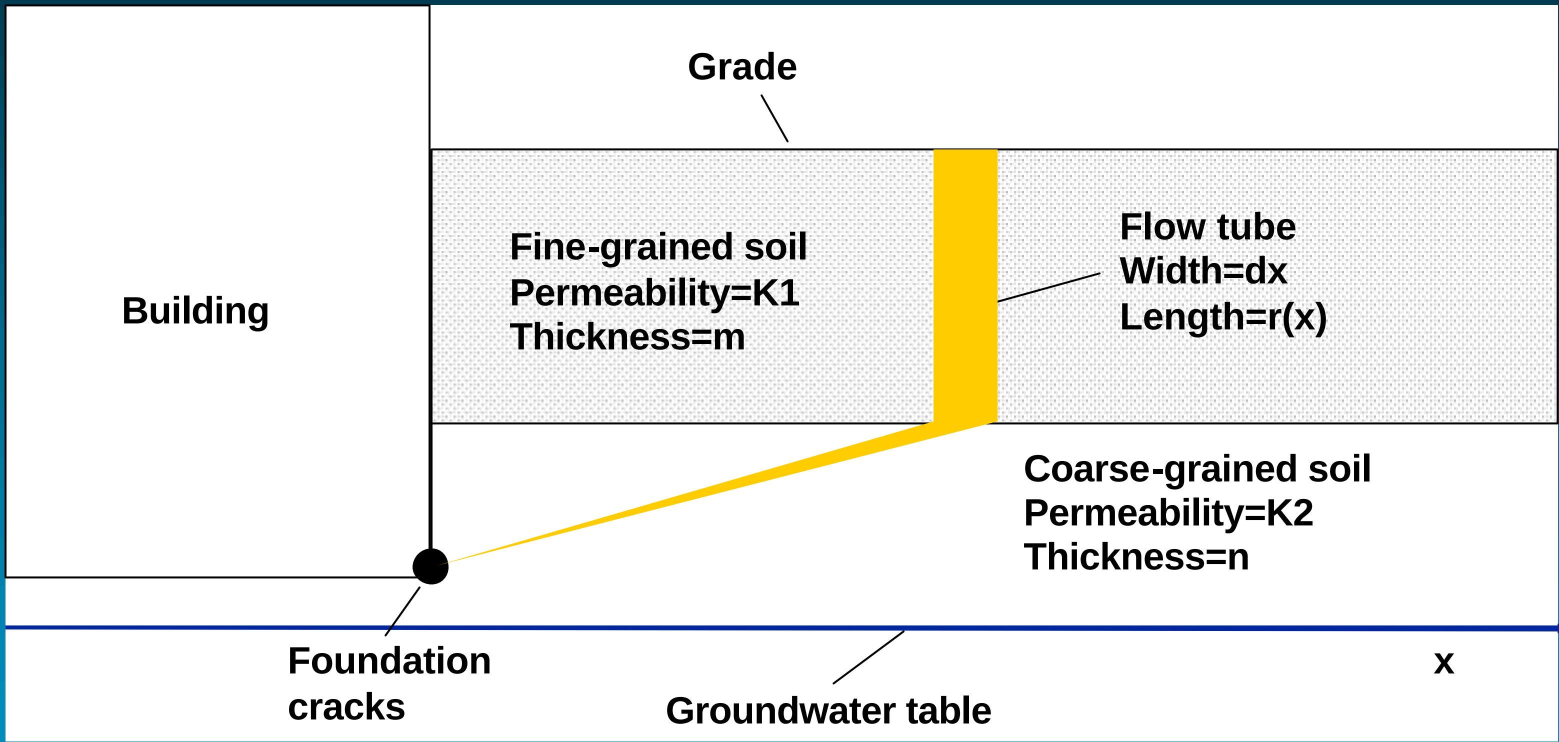
Conclusion #1

- Use Regulatory Models to establish site-specific criteria- not for predictive purposes
- Calibration of Tier 2 models may be impossible or meaningless

Thought #2

The calculation of equivalent parameter values may allow a further level of site-specificity for Tier 2 at more complex sites

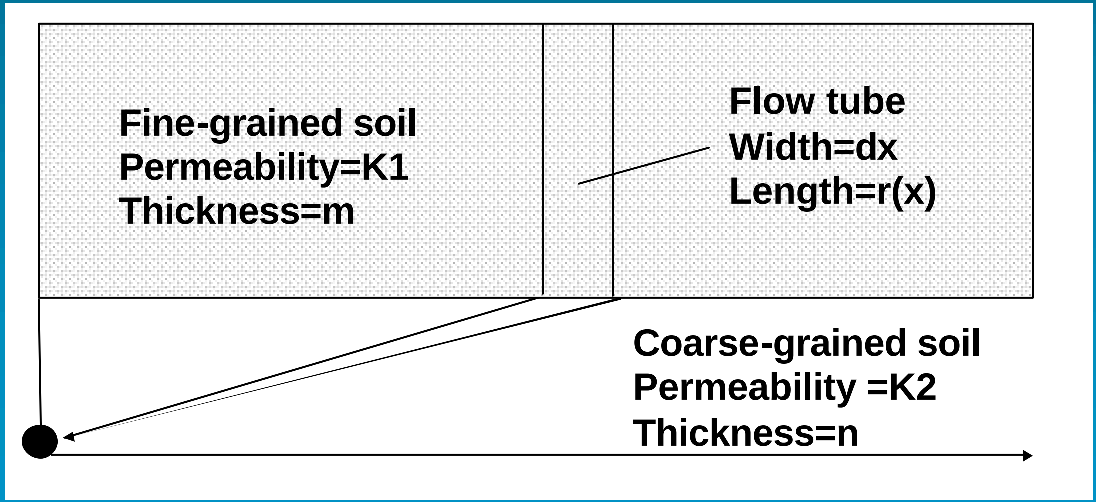
Calculation of Equivalent Permeability (Vapour Flow)



Conceptual model for air flow into building foundation cracks through two layers of soil

Calculation of Flow Rate

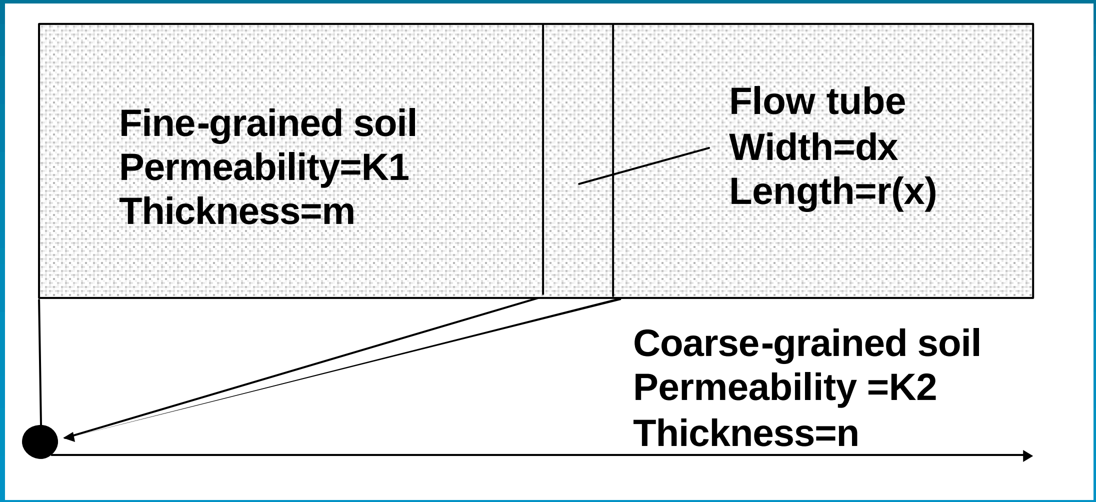
- For each of the simplified flow tubes as shown, the average air pressure gradient, permeability, tube width and air flow rate can be determined
- The total flow rate is then calculated for the entire system



Calculation of Equivalent Permeability

The equivalent permeability for the whole flow system can be calculated by:

$$k = \frac{k_1 k_2 (m+n)}{m(k_1 - k_2)} \ln\left(\frac{(m+n)k_1}{mk_2 + nk_1}\right)$$



Comparison of Calculated Vapour Flow Rates

k_1 (cm^2)	k_2 (cm^2)	Equivalent k (cm^2)	Calculated Flux Using Two Layer Modflow Model (m^3/day)	Calculated Flux Using J&E Model (m^3/day)		
				Using k_1	Using k_2	Using Equivalent k
1.00E-08	1.00E-06	5.19E-08	**0.55**	0.08	8.10	**0.49**
1.00E-08	1.00E-07	2.78E-08	**0.19**	0.08	0.81	**0.26**
1.00E-08	1.00E-08	1.00E-08	**0.08**	0.08	0.08	**0.08**

Conclusion #2

- **Should there be an opportunity to use equivalent parameters or to use other predictive models to determine/adjust Tier 2 input parameters (i.e. bulk K)?**

Thought #3

Perhaps we may wish to calculate guidelines probabilistically (again)

Probabilistic Case Study

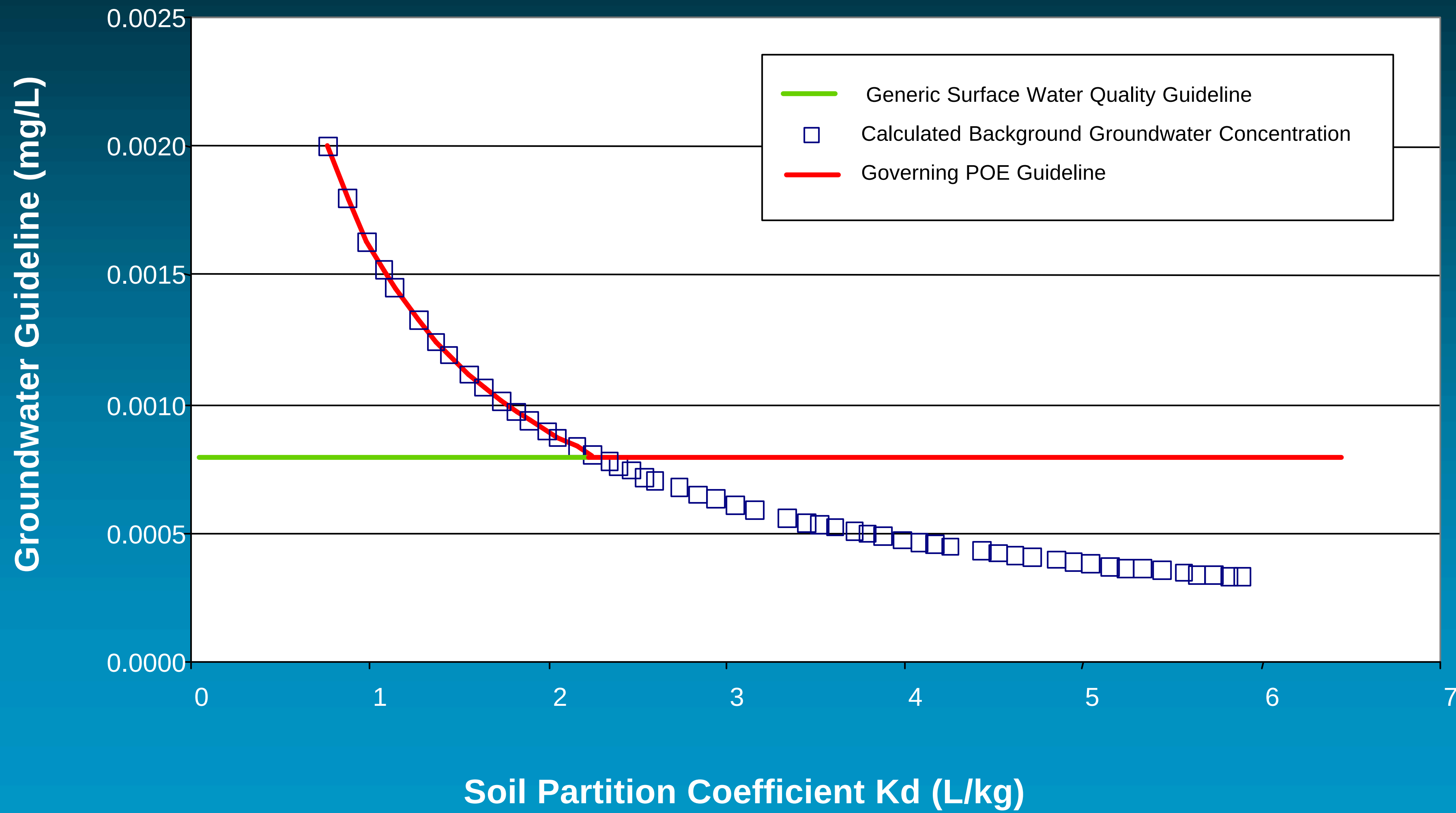
- The AENV DF1 and DF4 models (based on Domenico model) were used to establish probabilistic site-specific soil and groundwater criteria (metals, hydrocarbons) to protect offsite surface water receptors
- To reflect their variation, hydraulic conductivity, hydraulic gradient and partitioning coefficient were input into the model as a range of values rather than as single numbers

Guideline Calculation Procedure

The site-specific soil and groundwater criteria were iteratively calculated in a 5-step procedure:

1. **Select the relevant surface water quality objective (SWQO)**
2. **Calculate the groundwater concentration in equilibrium with generic background soil guideline for different Kd values (Cbk)**
3. **Point of Exposure (POE) guideline is the greater of the SWQO and Cbk**
4. **Back-calculate 90th percentile groundwater and soil guidelines for a given distance upgradient of the POE**
5. **Repeat Steps 3 and 4 for different distances from the POE**

Steps 1 to 3: Determine POE Guideline



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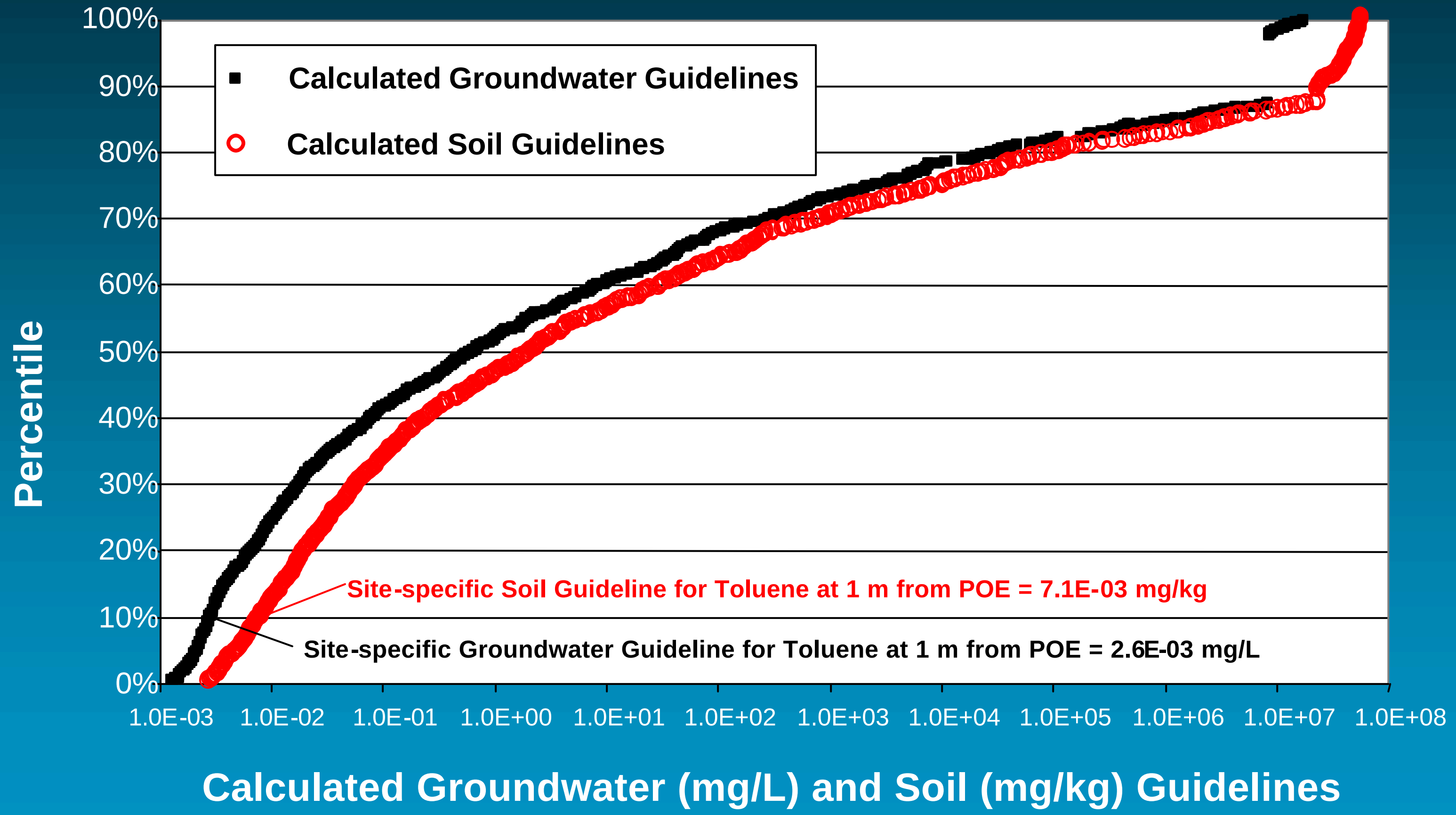
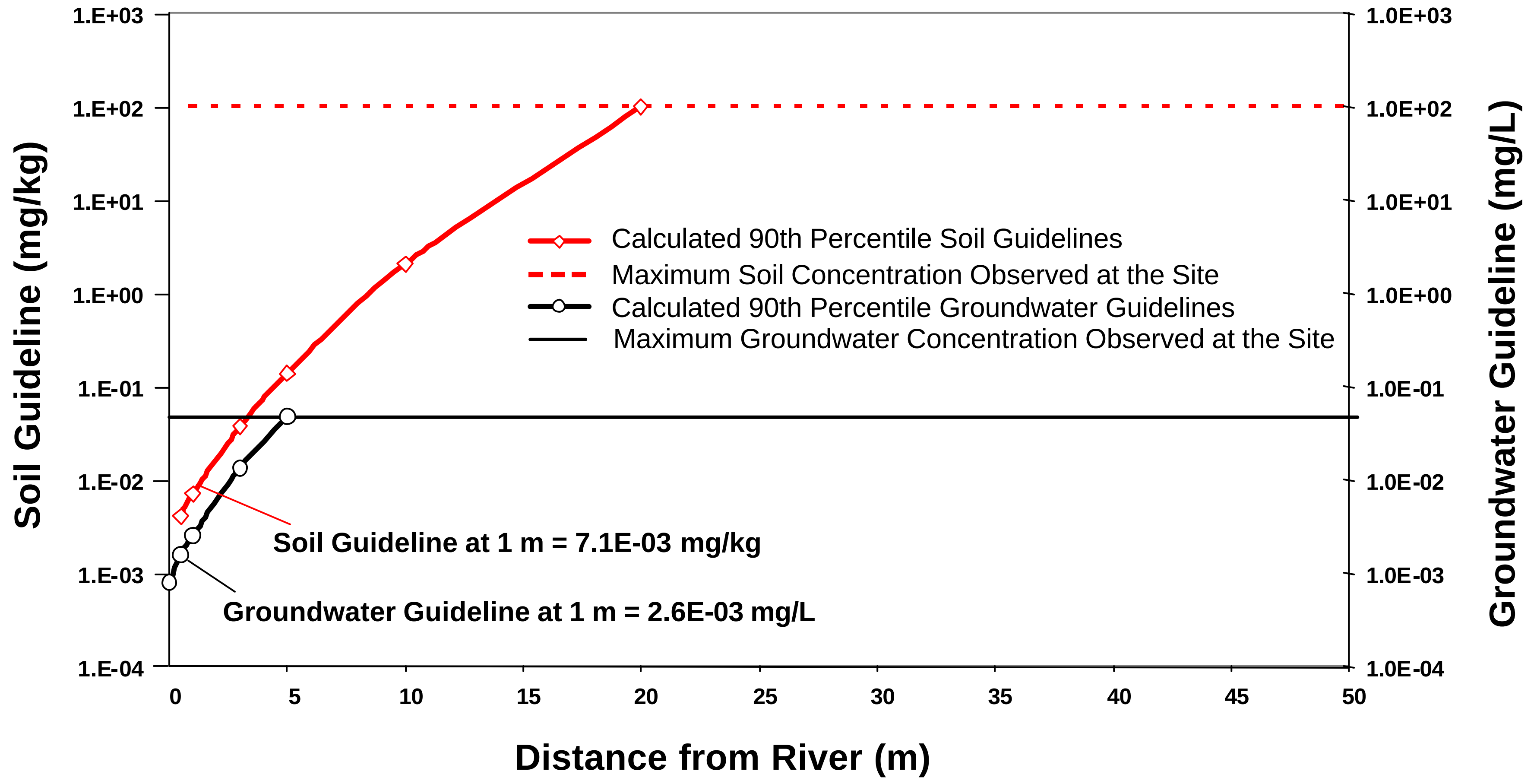
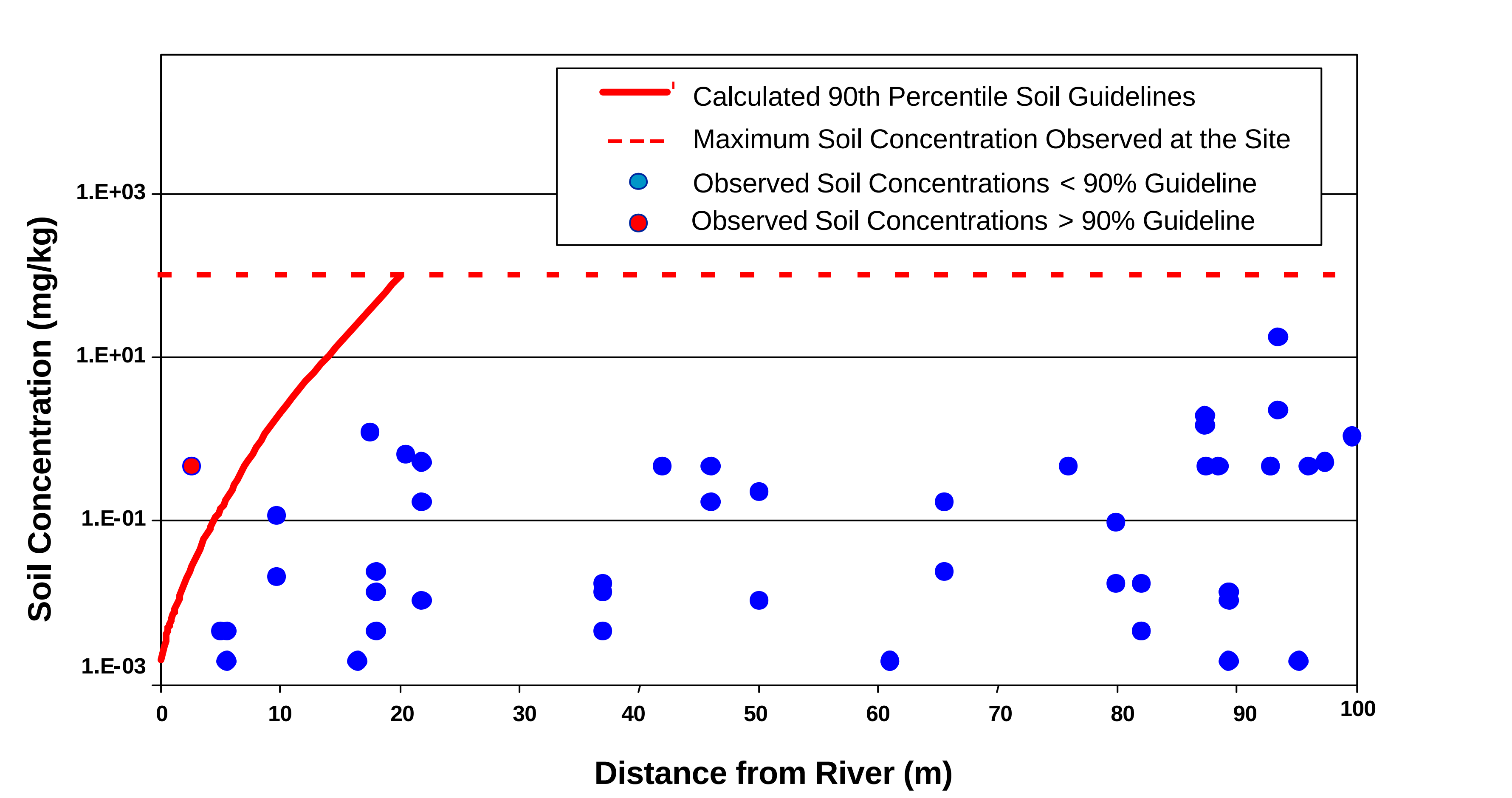
Step 4: Determine Percentiles of Distance-Specific Guidelines



Step 5: Calculate Guidelines for Increasing Distances from POE



Comparison to Site Data



Conclusion #3

- Evaluate and communicate model uncertainty caused by input parameter uncertainty (or variation). Probabilistic implementation?

Closing Comments

- The regulatory models should be used only for establishing site-specific criteria, not for simulating actual concentrations.
- Calculating equivalent parameter values may help to represent more complex (but still relatively simple) geological conditions

Closing Comments (continued)

- Probabilistic calculations may be helpful in accounting for and communicating the effects of variability/uncertainty on model results

THANK YOU!