Conceptual Site Model (CSM) Discussion

Presentation to: KY AIPG

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Department for Environmental Protection
Environmental & Public Protection Cabinet

To Protect and Enhance Kentucky's Environment

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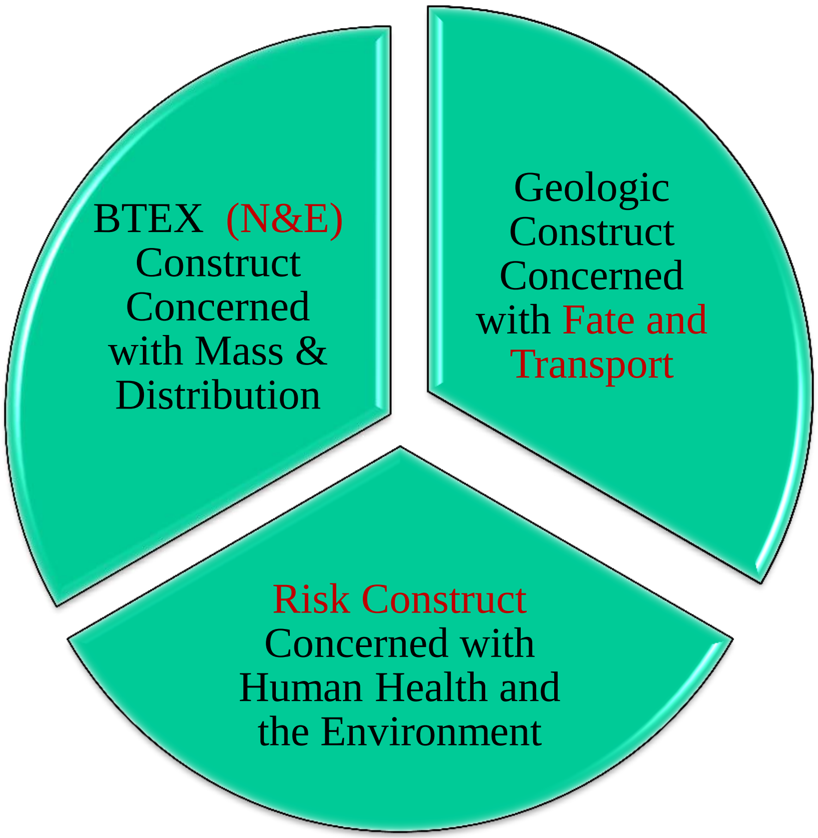
What is the CSM?

The CSM is intended to be a 3d “big picture” of site conditions which illustrates

- Nature and Extent (UST nature is limited)
  - contaminant distributions (UST BTEX and PAHs)
  - SI Outline envisions spatial extent while decision making only requires extent “sufficient to make a decision”
- Fate and Transport
  - release mechanisms
  - migration routes
- Risk Pathways and Receptors

Structural Elements in Building Integrated Strategy (UST example)



- Purpose of the CSM is to gather and integrate all relevant data and information to
  - Develop an integrated corrective action **strategy…**
  - Develop a picture which informs specific answerable questions
  - Select **tactics** to answer specific questions

What is the Value of the CSM?
Without an Integrated Picture or Structure it's difficult to:

- **Prioritize** efforts
  - Target media and pathways
  - Target reduction of risk
    - Human Health
    - Environment
    - Undefined fears?
- **Focus** on goals
  - Contaminate Mass Reduction and/or immobilization
- **Expose** data gaps
  - Knowns
  - Unknowns
- **Document** the changing site picture (Don't throw field notebooks away)
  - Development is iterative as data is gathered
  - Change is measured against controls

CSM and the Scientific Method

- For each suggestion regarding the collection of data, you should **state the question** being asked, i.e., In order to determine…collect X data. You should **provide the possible results with alternative conclusions**, e.g., if X is greater than or equal to 1.6 mg/L we will conclude that a LNAPL source is present. If X is less than 1.6 mg/L we will conclude a LNAPL source is not present. You should **state the alternatives** regarding the direction of the project.
- USEPA Data Quality Objectives (DQO Process)
  http://www.epa.gov/osw/hazard/correctiveaction/resources/guidance/qa/epaqag4.pdf
- First 3 steps of the DQO Process
  - State the Problem – Concise description supported sufficient understanding to define the problem
  - Identify the Decision – What question(s) one will attempt to answer, and what actions are anticipated depending on results
  - Indentify the Inputs to the Decision – Identify the information needs

*Many CSMs: 3 Examples

The CSM is not unique to UST or environmental remediation but rather applies to every science question.

Three CSMs that come to mind: UST Specific Examples

- CSM Metaphysical (Imagined & Evolving 3d picture of the site)
- CSM Model used the University of Kentucky and upon which UST soil and groundwater screening levels are based
- CSM Report 401 KAR 42:060 $14,939.00

The Metaphysical CSM

The CSM You Carry in Your Head!

- Metaphysics (Speculation)
  - What is there?
  - What is it like?
- What is the conceptual model before data are collected and analyzed?
- This model continues to evolve and mature as informed by data.

Uncertainty decreases

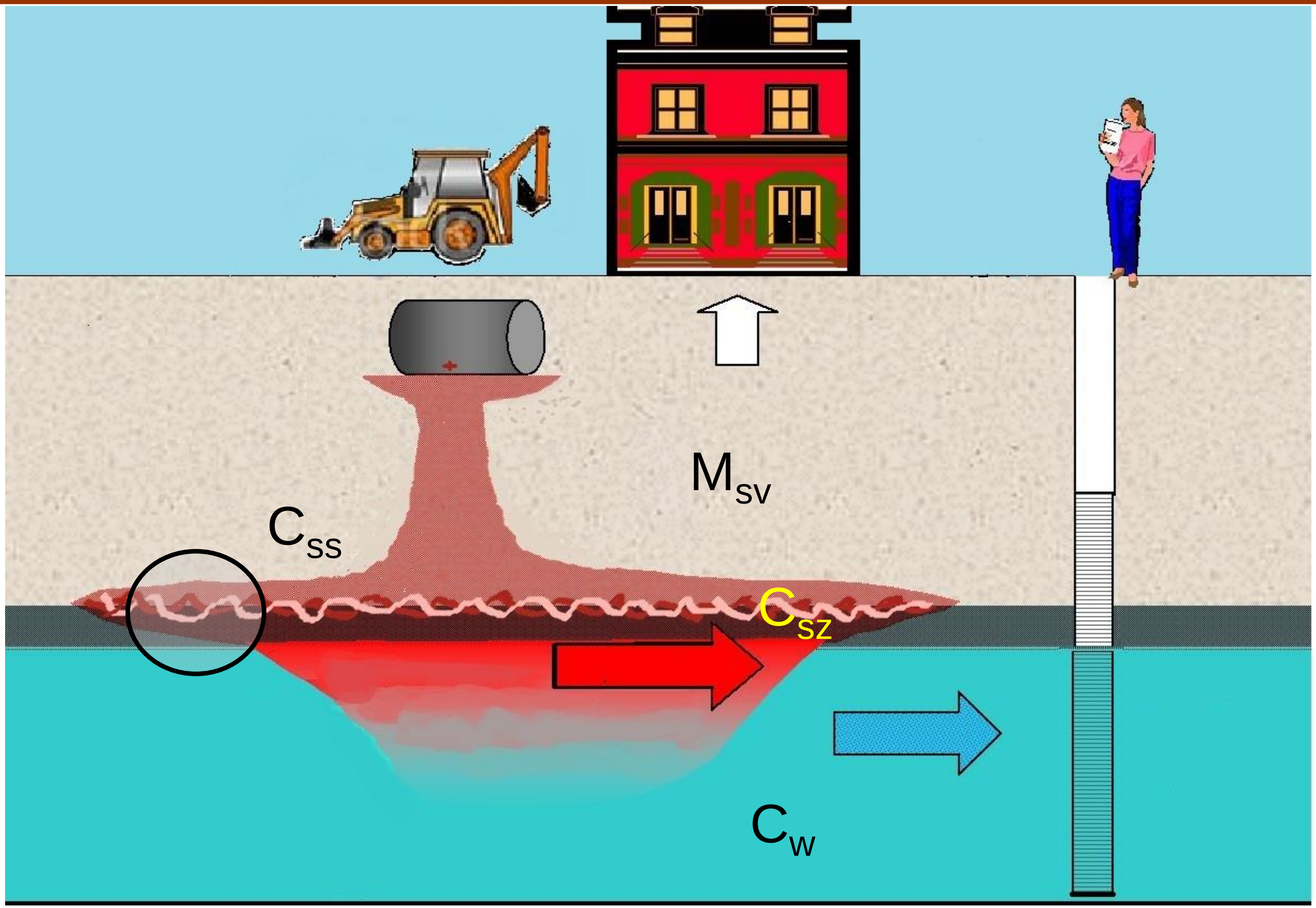
As data is collected

Model edges closer to reality

Three General Considerations

- Has the primary source (tank system size) been removed or remediated (leaking tanks or piping) and has the secondary source material been removed or remediated to the extent practical?
- What are the site specific natural geologic and hydrogeologic conditions?
- What is the site and area specific land use(s)?

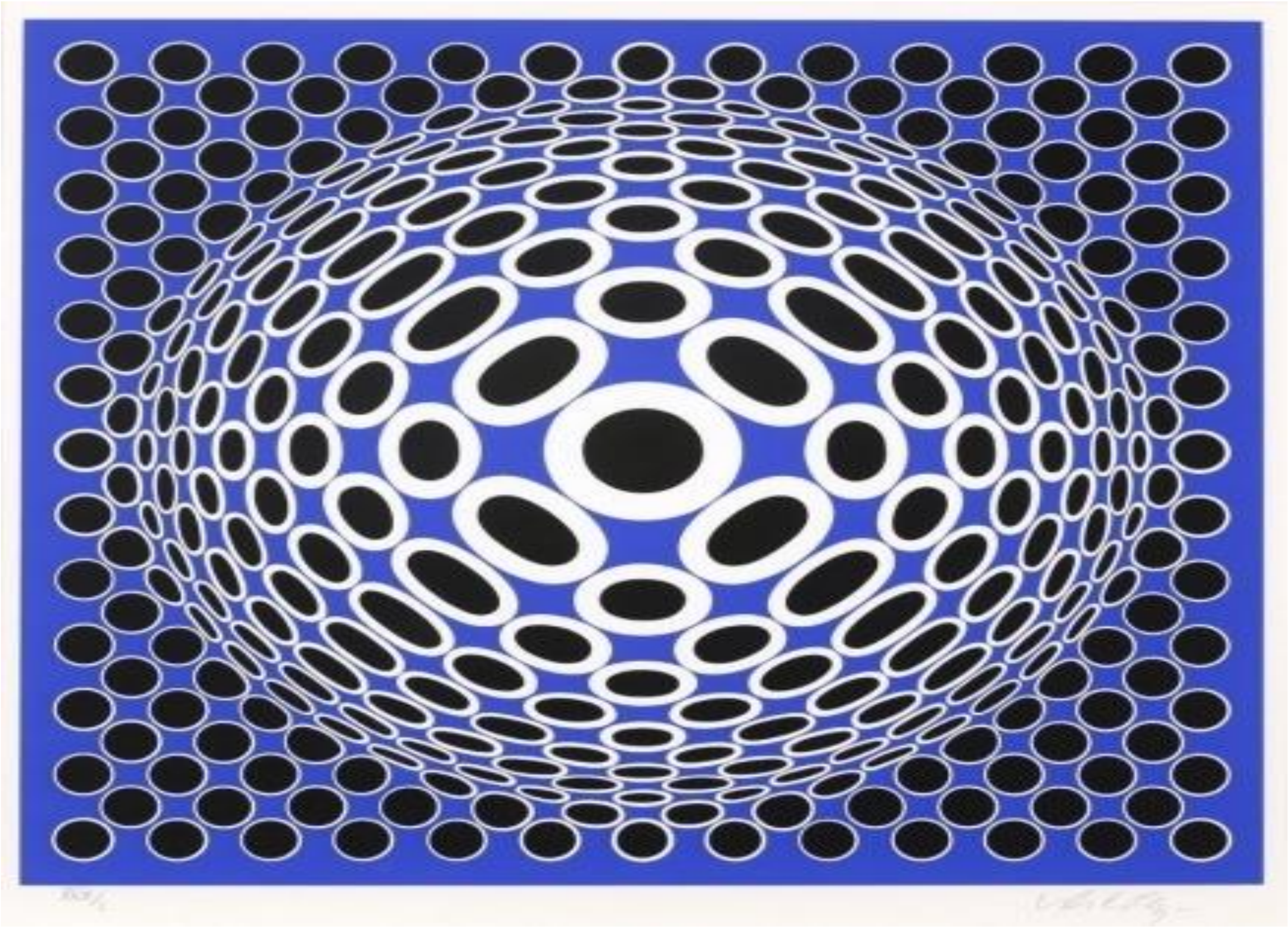
Metaphysical CSM Risk Picture
Generic Pathways of Cont. Migration (Fate & Transport)



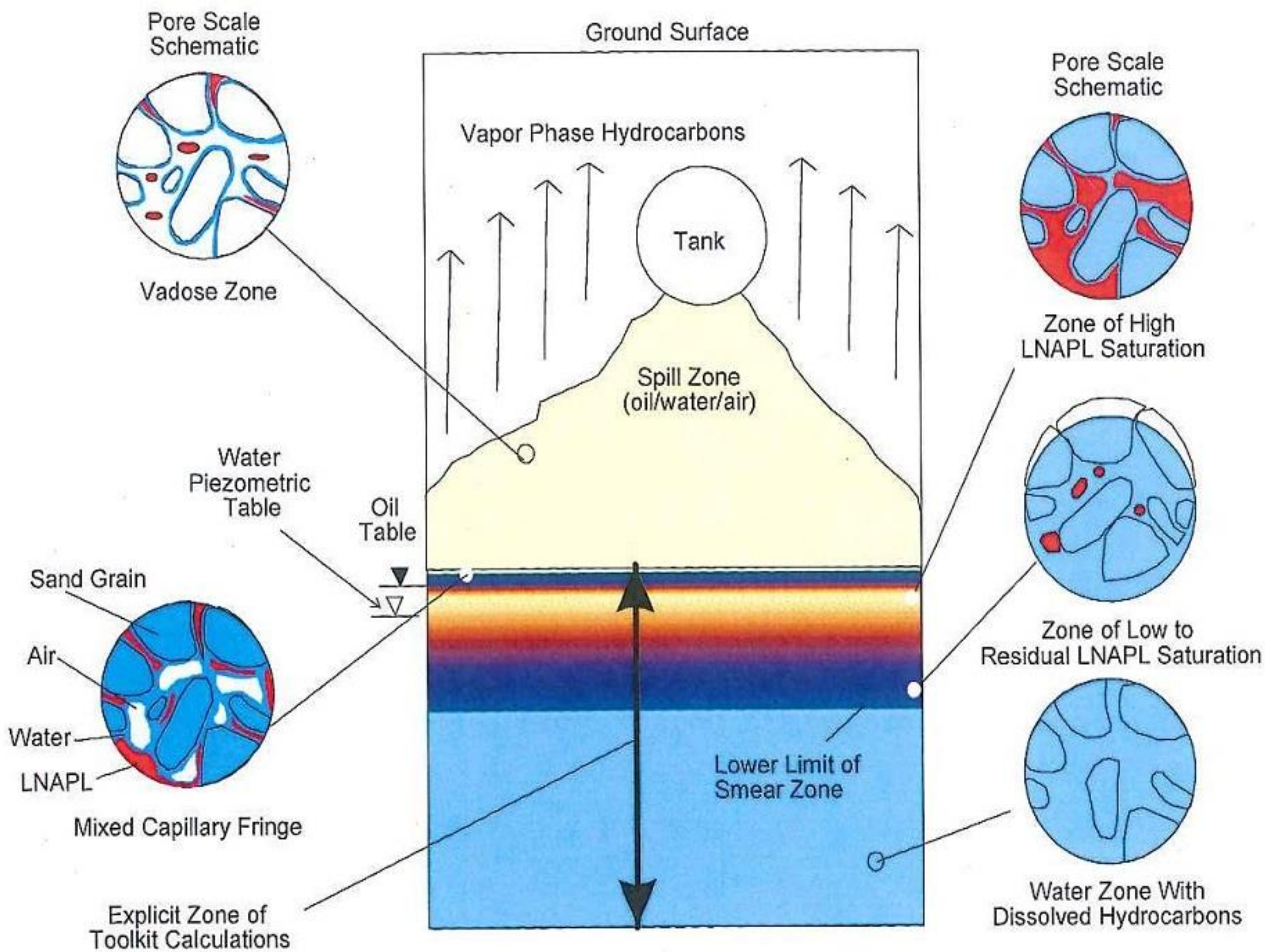
Imagining a LNAPL Release

- Physical Nature
  - Lighter than water so floats on the water generally but does not float like one might expect having seen oil on water in an open container.
  - LNAPL release is a problem of multiple fluid phases sharing pore space!
- LNAPL migrates downward due to gravity (driving head)
- Above the groundwater zone volatile LNAPL components separate into soil gas and from vapor plumes
- With sufficient mass, LNAPL will contact the saturated zone and spread laterally and based on solubility and dissolve into the groundwater
- Once the surface release (driving head) stops, subsurface LNAPL ceases to spread taking a shape determined by pressures needed to displace water in a soil matrix.
  - Example: A ship will sink until it displaces water equal to its weight. *
- The water table fluctuates trapping LNAPL as blobs below the water table. This entrapped LNAPL is called the “smear zone”.
- Dissolved phase moves with the groundwater usually extended no more than a few hundred feet (300 ft ≈ 100 m) (dissolved phase plume)
- Biological and physical attenuation occurs ultimately leaving behind “mostly” the non-carcinogenic and low solubility – high viscosity petroleum components (Yep, they stink!)

Groundwater Zone with LNAPL



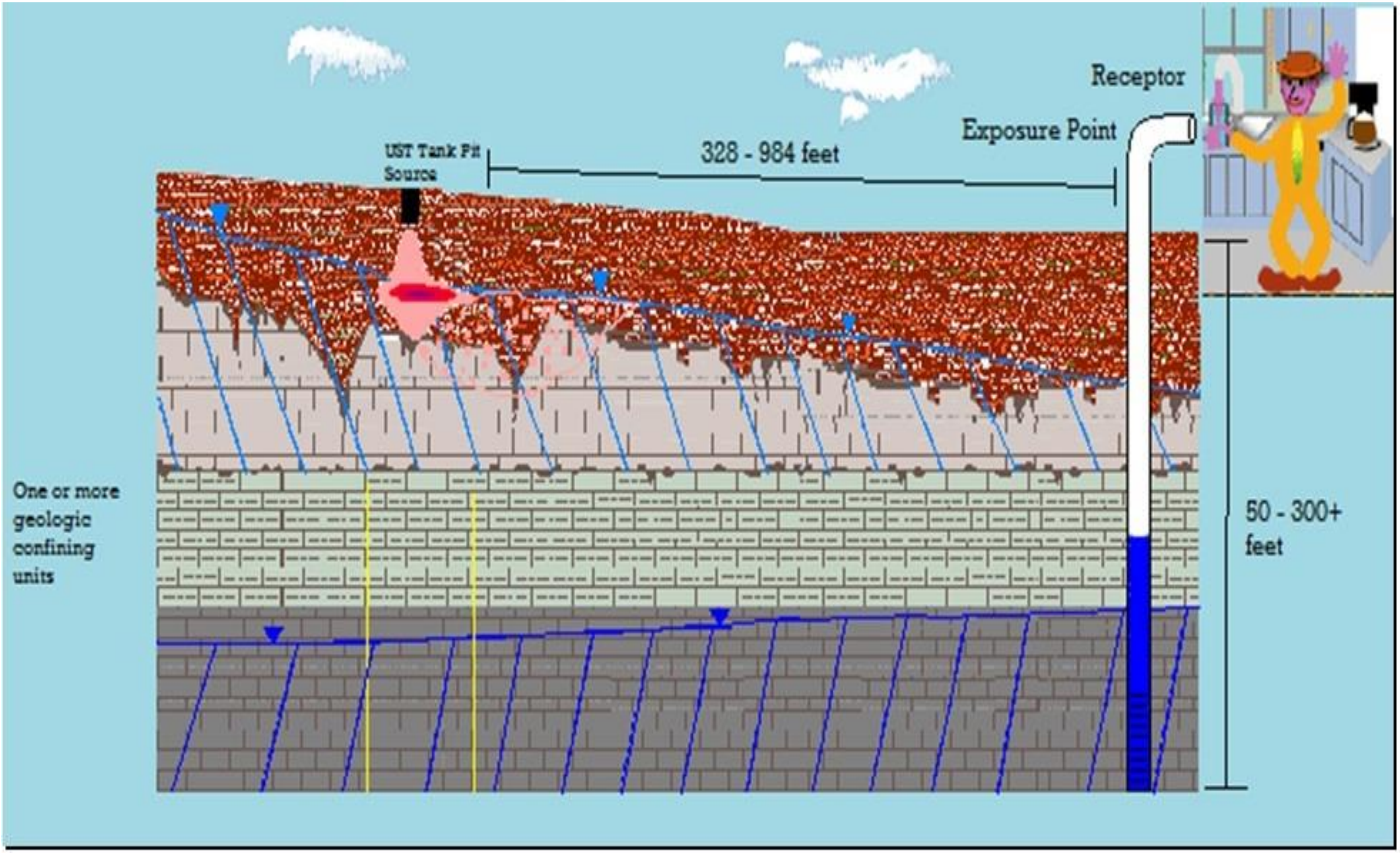
Imagining the Details CSM (from API)



Lesson Regarding LNAPL in Monitoring Well

- Observed LNAPL thickness in monitoring well
  - Not typically in equilibrium
  - Varies with soil type
  - Changes with fluctuations in the water table
  - Must be viewed in larger context of confined, unconfined, perched water table
  - Poor indicator of LNAPL recovery
- Transmissivity correlates with LNAPL recovery

CSM Emphasis Upon Geology (More Realistic CSM)



Driving the Metaphysical toward the real by collecting data!

Site Check or Closure → **Initial Investigation** → **Corrective Action** → **Reoccurring Theme***

The metaphysical evolves and matures toward actual

- Surrounding Population
- Land Use
- Subsurface Soil Conditions
- Subsurface Potential Pathways such as Sewers and Waterlines
- Locations of Wells Potentially Affected
- Water Quality
- Fundamental Geology
- Climate Conditions

* 40 CFR 280 Subpart F

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Behold Sand

Estimation of Mass in Unsaturated Soil and Smear Zone

- Estimation of contamination mass in unsaturated soil

  Volume (m^3) · Density (kg/m^3) = Mass (kg)

  Volume = (a geometric shape or sum of geometric shapes)

  – Soil bulk density clay soil 1900 kg/m^3, silty soil 2100 kg/m^3

  – Mass (kg) · Conc. of Contamination (mg/Kg) = mg contamination

  Concentration of contamination averaged appropriate to the dataset

  *Perhaps use ProUCL

- Estimation of contamination mass in smear zone

  Volume (m^3) · Density (kg/m^3) · Conc. of Cont. (mg/kg) = mg Cont.

  Volume = (a geometric shape or sum of geometric shapes)

  http://dnr.wi.gov/files/PDF/pubs/rr/RR614.pdf

Estimation of Mass in Groundwater Source Zone

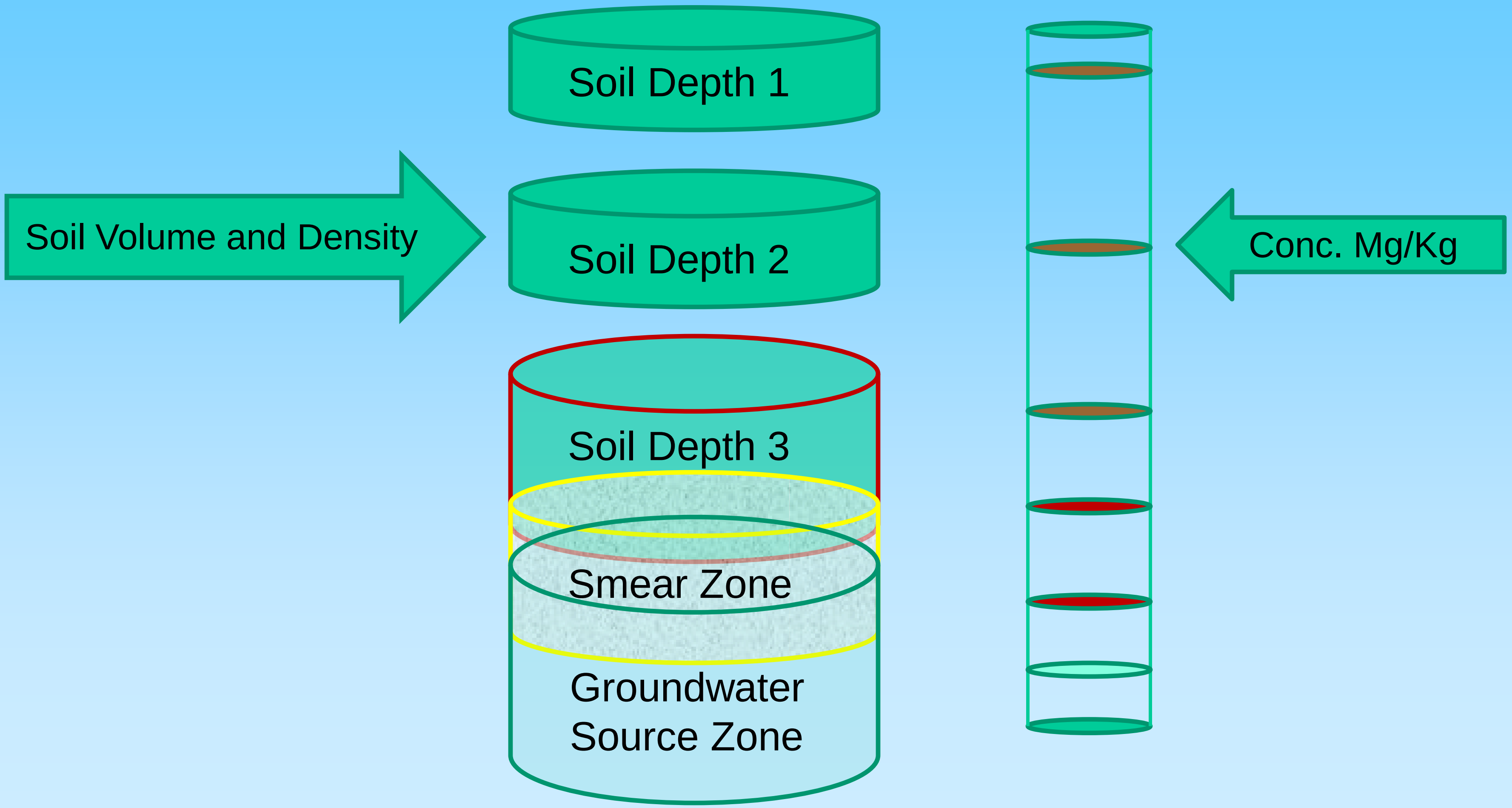
- Calculate the total area occupied by water
- Area (m^2) · Height (m) · Porosity$_{total}$ · Cont. Conc. (mg/L) · 1000L/1m^3 = mg

Concentration of contamination averaged appropriate to the dataset

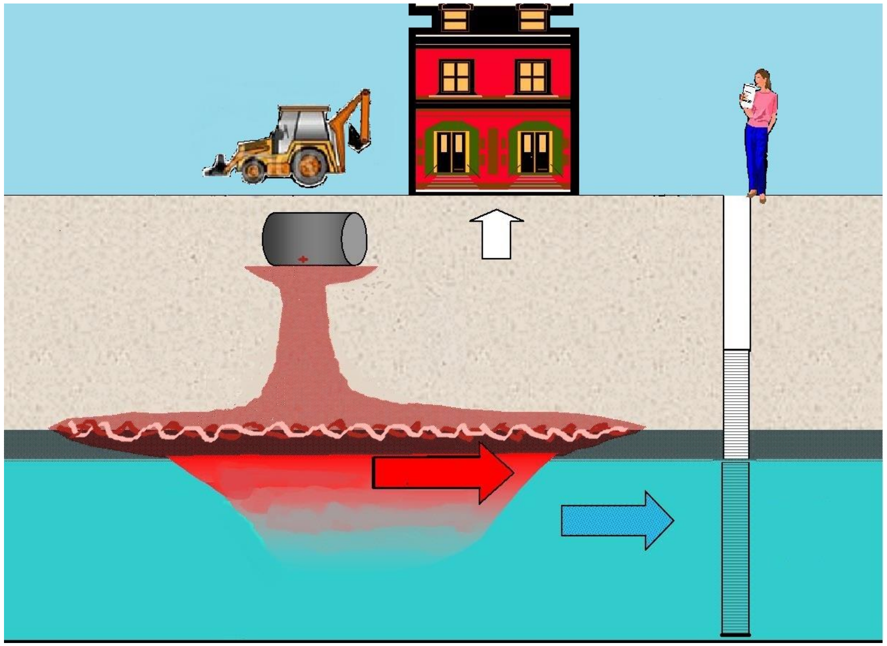
Soil Type	**Porosity (*n*)**
Clay	0.38(0.09)
Loam	0.43(0.10)
Silt	0.46(0.11)

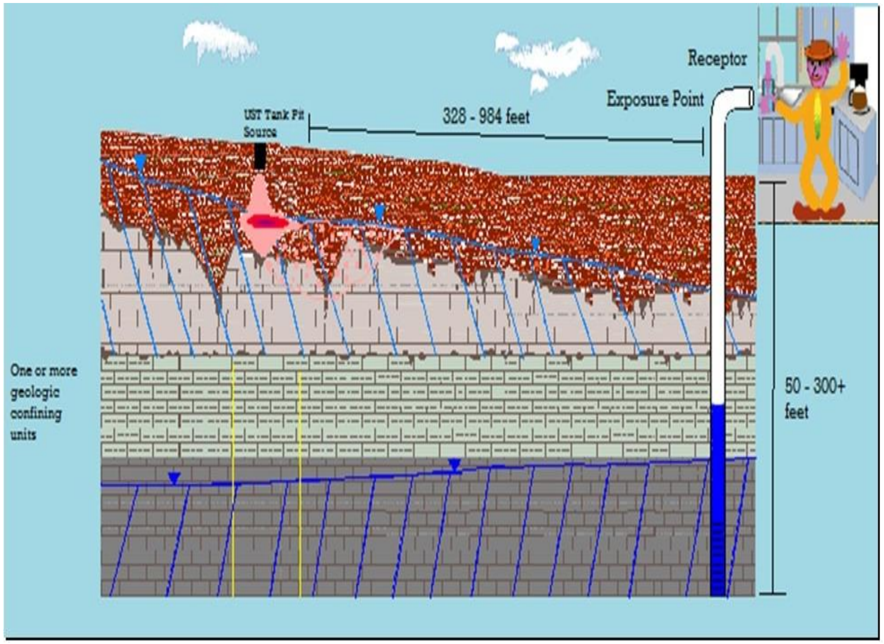
Examination of Boring and Well for Understanding Source Mass

- Soil bore and well representation. Volume (m^3) · Density (kg/m^3) · Conc. of Cont. (mg/kg) = mg Cont.



Estimates of Human Health & Environmental Risks Depend on CSM Risk Pathways & Receptors





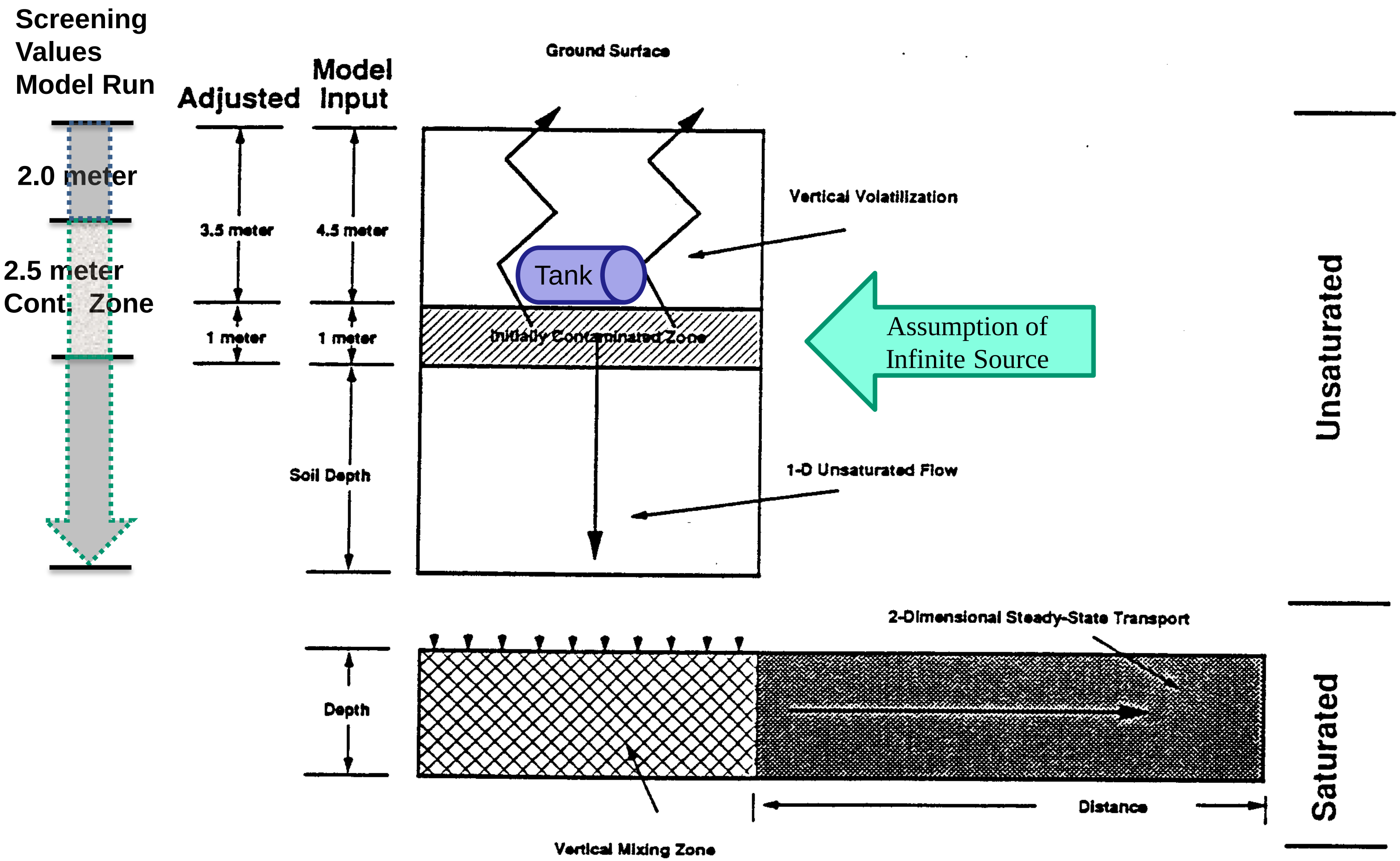
Exposure of a Receptor

- Picture Realistic Exposures (Wide-angle view regarding site and release) cataloging "risk factors"
  - Type of Contamination (BTEX & PAHs)
  - Concentration (mass of contamination)
  - Receiving media (air, soils and water in soil, water)
  - Transport pathways (transport to aquifer)
  - Fate in the environment (duration)
  - Exposure media (air, water, soil)
  - Exposure Route (ingestion, inhalation, dermal absorption)
  - Receptor (child or adult resident, worker, recreational user, etc.)

If there is no exposure there is no health risk!

If there is no receptor, there is no health risk!

*UK CSM which Supports Screening Levels



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Not Designed to Replace Site Specific Analysis

- A generic migration pathway
- Relates soil concentration to groundwater concentration (Linear partitioning $C_s = K^*C_w$)
- Homogeneous or uniform layered soil conditions, homogeneous fluid and chemical parameters.
- Simple linear relationship between soil impact and media impacts "…not intended to characterize an individual site…." UK Study Paul M. McGinley 1994
- "…a screening-level tool…not designed…to be used in site-specific analysis…." UK Study Paul M. McGinley 1994

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*Elements of Analysis & Tools for Site-specific Analysis

- CSM Report 401 KAR 42:060

1. CSM Report Format
2. Summary of Report's Findings
3. Site and Area Description
4. Chronology of Events
5. Site Geology, Stratigraphy and Hydrogeology
6. Well and Well Head Protection Area Survey
7. Conduit Survey (Water lines, gas lines, utilities, etc.)
8. Contamination Mass Calculations and Distribution (Vadose, Smear, etc.)
9. Constituents of Concern Dissolved Phase Trend Analysis
10. Preliminary Technology Screening (Remediation Tools)
11. Other Relevant Data and Information
12. Conclusions and Recommendations
13. References
14. Figures and Tables

Appendices

Examine the Data Occurs Before CMS

- Start with understanding your data (Avoid mixing vadose zone, smear zone and saturated zone data)
- 95% Upper Confidence Limit (ProUCL software) http://www.epa.gov/osp/hstl/tsc/software.htm
- Coefficient of Variation (CV) an estimate decision error $C_V = \sigma/\mu$
- Groundwater Statistics ITRC (Ready early next year)
- Spatial Analysis and Decision Assistance (SADA) http://www.tiem.utk.edu/~sada/index.shtml

Setting

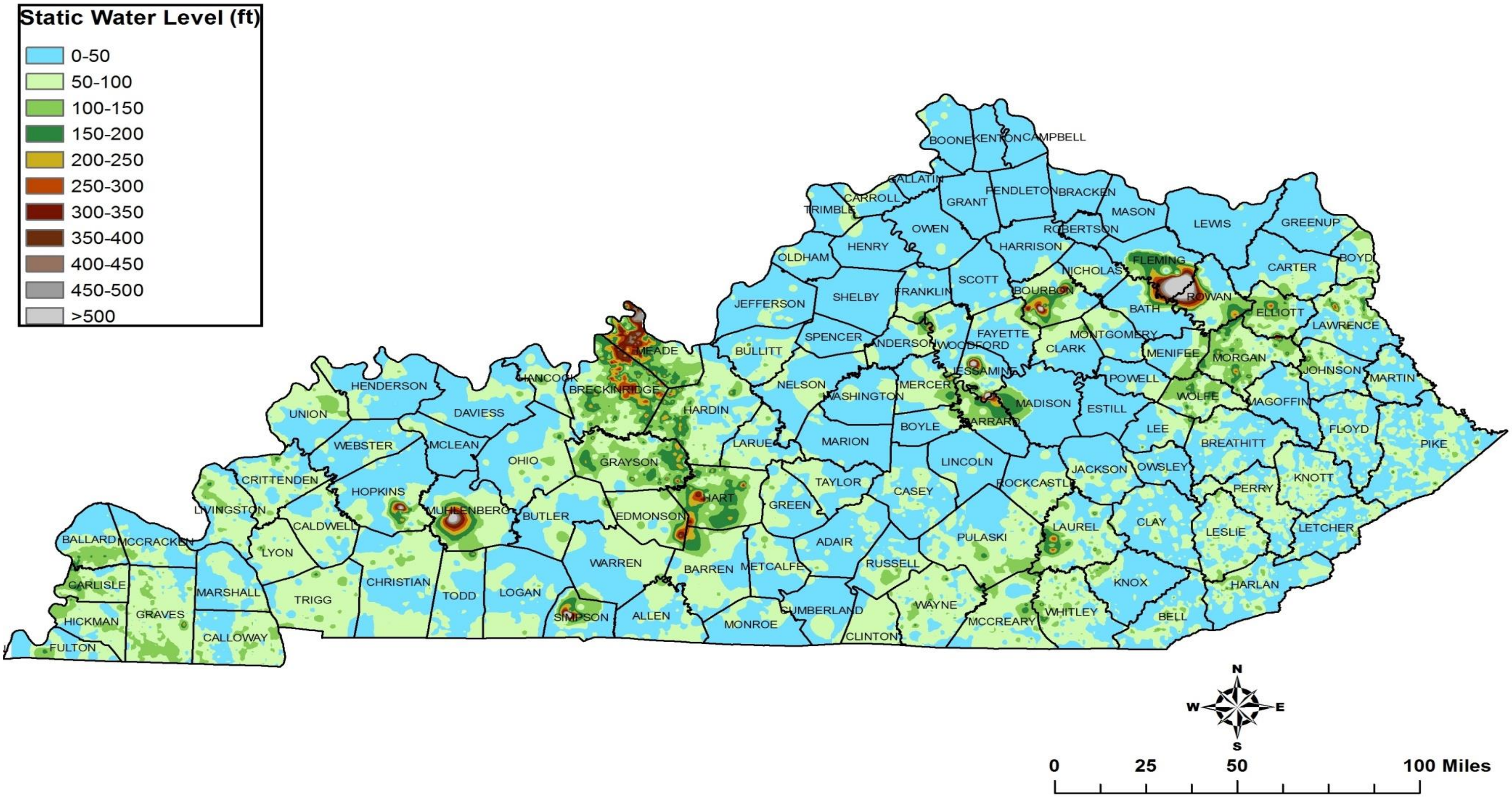
(site & area description, site geology, stratigraphy and hydrogeology, well head protection areas)

- Geologic Setting (What's the character?)
  - Karst geology (Well Integrated and Epikarst)
  - High clay content soils (Soils, Natural Resources Conservation Service) http://soils.usda.gov/survey/online_surveys/kentucky/
  - Shallow bedrock
  - Hydrogeology (KY Geological Information) http://kgs.uky.edu/kgsmap/KGSGeoPortal/KGSGeoPortal.asp
  - Surface and subsurface water use in immediate area
- Exposure Setting (Immediate & local land use)
  - Urban
  - Rural
  - Commercial
  - Reasonable and likely potential receptors
  - Other sources of like contamination

Land Use

- Zoning controls on land use
  - Lexington http://www.lexingtonky.gov/index.aspx?page=609
  - Louisville http://www.lojic.org/
- Visual examination of present land use
  - Google Earth
- Projections as to future use, e.g., map of present and projected municipal water supply
  - Kentucky Geological Survey Groundwater Resources in KY http://www.uky.edu/KGS/water/library/webintro.htm
  - Highway Departments (Check each District)
- Unique Land use restrictions (Rockwell Logan example)

Static Water Levels of Registered Domestic Use Wells in Kentucky



Transport Pathways

- Air: API BioVapor and USEPA Guidance (Now in Public Comment)
- Soil/Water: Soil-water Partitioning & Dilution-Attenuation Factor Slider Calculator to develop soil cleanup concentrations protective of groundwater based on the USEPA Soil Screening Level. Freundlich equation based on sorption of liquid to solid. That which is not held by the solid is soil leachate. Follows the simple model in USEPA Soil Screening Guidance. Dilution Attenuation? http://www.seview.com/calc/spedaf.htm
- Water: LNAST (LNAPL Dissolution & Transport Screening Tool API) Evaluate LNAPL Impacts to Groundwater
- Conduit Survey (Gas lines, utilities, etc.)

Mean Plume Length

Study Source	Date of Study	Number of Sites or Other Basis	Percentage/Maximum Plume Size	Mean or Median Plume Size
Ref. via UK Meyer; Salanitro[i]	1993	Half-life	328 feet (100 meters)	NA
South Dakota (Meyer)[ii]	1993	75 sites	95% = 300 feet (91 meters)	NA
Lawrence Livermore National Laboratory, Rice, et al.[iii]	1995	271 sites	90% = 255 feet (78 meters)	NA
Shih, et al.[iv]	2004	500 sites	90% = 350 feet (107 meters)	198 feet (60 meters)
Texas Study (Mace, et al.)[v]	1997	217 sites	75% = 250 feet (76 meters)	NA
Florida RBCA[vi]	1998	117 sites, 33 counties	75% = 200 feet (61 meters)	Median = 90 feet (27 meters)
Kansas & Iowa (Ruiz-Aguilar, et al.)[vii]	2003	NA	NA	193 feet (59 meters) Median = 156 feet (48 meters)
Mean of lengths 75% =		280 feet (85 meters)		
Mean of lengths 90% =		308 feet (94 meters)		
Mean of mean lengths =			196 feet (60 meters)	
Summary of Results From Four Studies: Livermore Study, Texas, Florida & Hydrogeologic Data Base for Ground-Water Modelling (Newell et al., 1990)[viii]	1998	604 sites	90[th] percentile 319 feet (97 meters) 75[th] percentile 203 feet (62 meters)	Median 132 feet (40 meters)

Plume Length Groundwater Velocity & Time

http://www.api.org/environment-health-and-safety/clean-water/ground-water/lnapl/hydrocarbon-removal

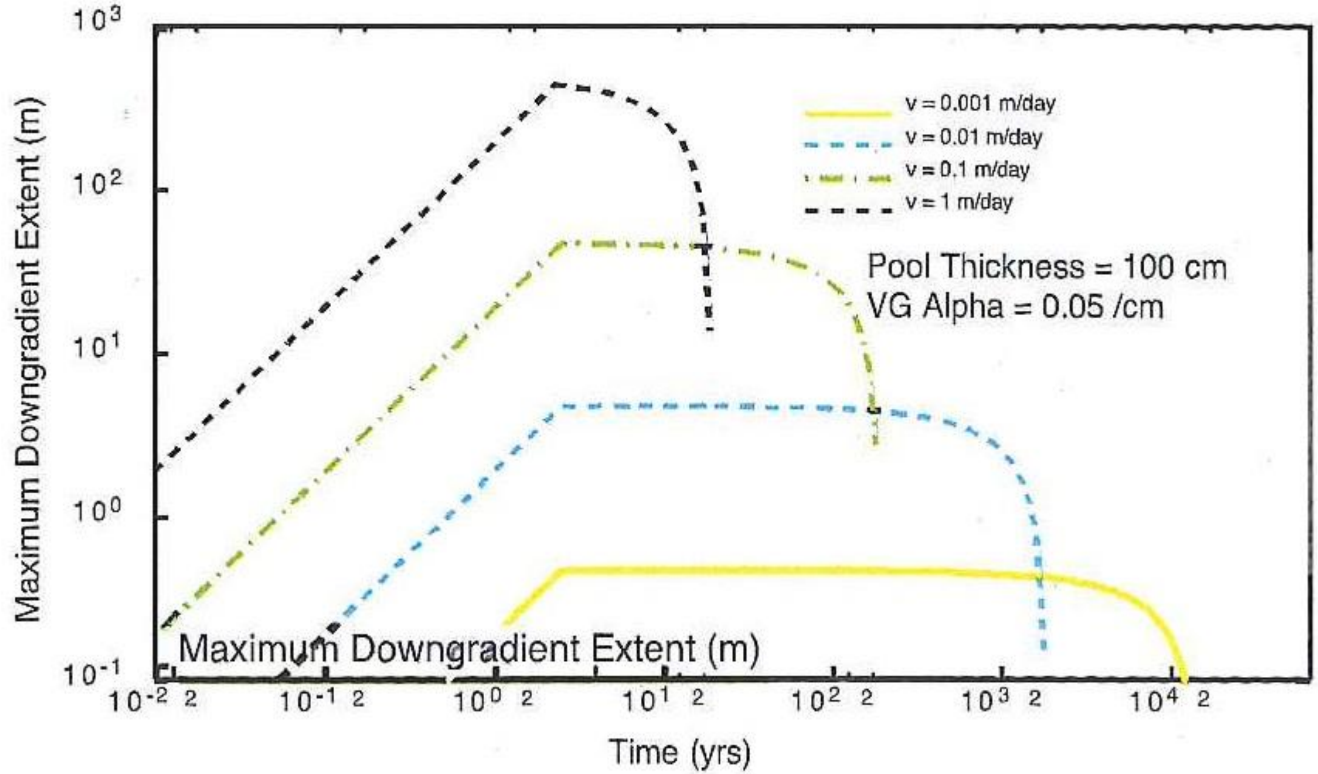


Figure E-10. The effect of groundwater velocity on the downgradient extent of benzene at a uniform decay rate.

BTEX ½-Life from 1995 UK Study

Table 1 BTEX Environmental Half-life Values (Days)[1]

Constituent	Air	Soil	Groundwater	Surface Water
Benzene	0.10 – 21.0	16.0 – 360.0	53.0 – 693.0	0.20 – 16.0
Toluene	0.42 – 4.3	4.0 – 22.0	7.0 – 100.0	0.23 – 16.0
Ethylbenzene	0.36 – 3.6	3.0 – 10.0	6.0 – 230.0	0.25 – 10.0
Xylene[2]	0.11 – 1.1	7.0 – 28.0	14.0 – 100.0	7.0 – 28.0

Understanding Extent of Contamination

The extent of contamination will not necessarily be coincident with the area requiring cleanup but in general will be somewhat larger.

A. Abatement of free product ***migration*** is (generally) a minimum objective. See similar 40 CFR § 280.64(b)

B. Does the level of contamination in soil (rock) or water support continued plume growth? Mass Question

C. Has migration of contaminated groundwater stabilized such that contaminated groundwater is expected to remain within a demonstrable area? Dissolved Phase Question

1. Levels are low
2. Concentrations are not persistent or consistent
3. Results are not duplicated

D. Does it appear probable that the leading edge of the plume has ceased migrating?

What does finished look like?

Considering

The toxicity, persistence, and migration potential

Hydrogeologic characteristics of the site and surrounding area

Proximity, quality, and current and future uses of nearby surface water and ground water

Probable effect on human health and the environment

The site does not constitute a significant risk or hazard

Considering

Regulatory requirements

Concentration reduction or immobilization and potential of the employed technologies

Potential of additional reduction in mass, toxicity, or mobility verses costs and implementability

Community acceptance

No additional work on this site is practical

Three Useful Sources for Understanding and Estimating Risk (or Hazard)

- Risk Assessment Guidance for Superfund Vol. 1 Human Health Evaluation Manual (Part A) EPA/540/1-89/002
  - http://rais.ornl.gov/guidance/epa_hh.html
- What is Risk Assessment?
  - http://rais.ornl.gov/tutorials/whatisra.html#steps
- RAIS The Risk Information System Oak Ridge National Laboratories
  - http://rais.ornl.gov/guidance/epa_hh.html Select TOOLS, Select PRGs, Select Chemical Calculator

Three Useful Sources for Understanding LNAPL

- American Petroleum Institute: Evaluating Hydrocarbon Removal from Source Zones….

  http://www.api.org/environment-health-and-safety/clean-water/ground-water/lnapl/hydrocarbon-removal
- ITRC Internet based training LNAPLs

  http://www.itrcweb.org/Training?topicID=13
- Wisconsin Guidance on Natural Attenuation

  http://dnr.wi.gov/files/PDF/pubs/rr/RR614.pdf

Setting Cleanup Objectives &

- R**emedial action objectives** are the goals for protecting human health and the environment at the site. The remedial action objectives specify contaminants and media of concern, potential exposure pathways, and remediation goals.
- R**emediation goals** can be either applicable or relevant and appropriate requirements (ARARs) of other Federal and State environmental laws or risk-based concentrations.
- **Remedies**
  - No Action
  - Monitored natural attenuation
  - Containment (i.e., capping)
  - In-place treatment
  - Complete or partial removal or treatment

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