# LNAPL AND THE MCP

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# Housekeeping Issues

- Obtaining copies of Slides
- Audience Rights

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# OUTLINE

- Summarize LNAPL White Paper Part I
- Introduce LNAPL White Paper Part II
- LNAPL Semantics
- LNAPL Characterization Framework
- Mobility Evaluation

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# LNAPL and the MCP-PART 1

- Problems with the Tank and Pancake Model
- Need for regulatory and practice standard change
- Characterize LNAPL as a Soil Contaminant
- Eliminated “Product” Thickness as a regulated parameter

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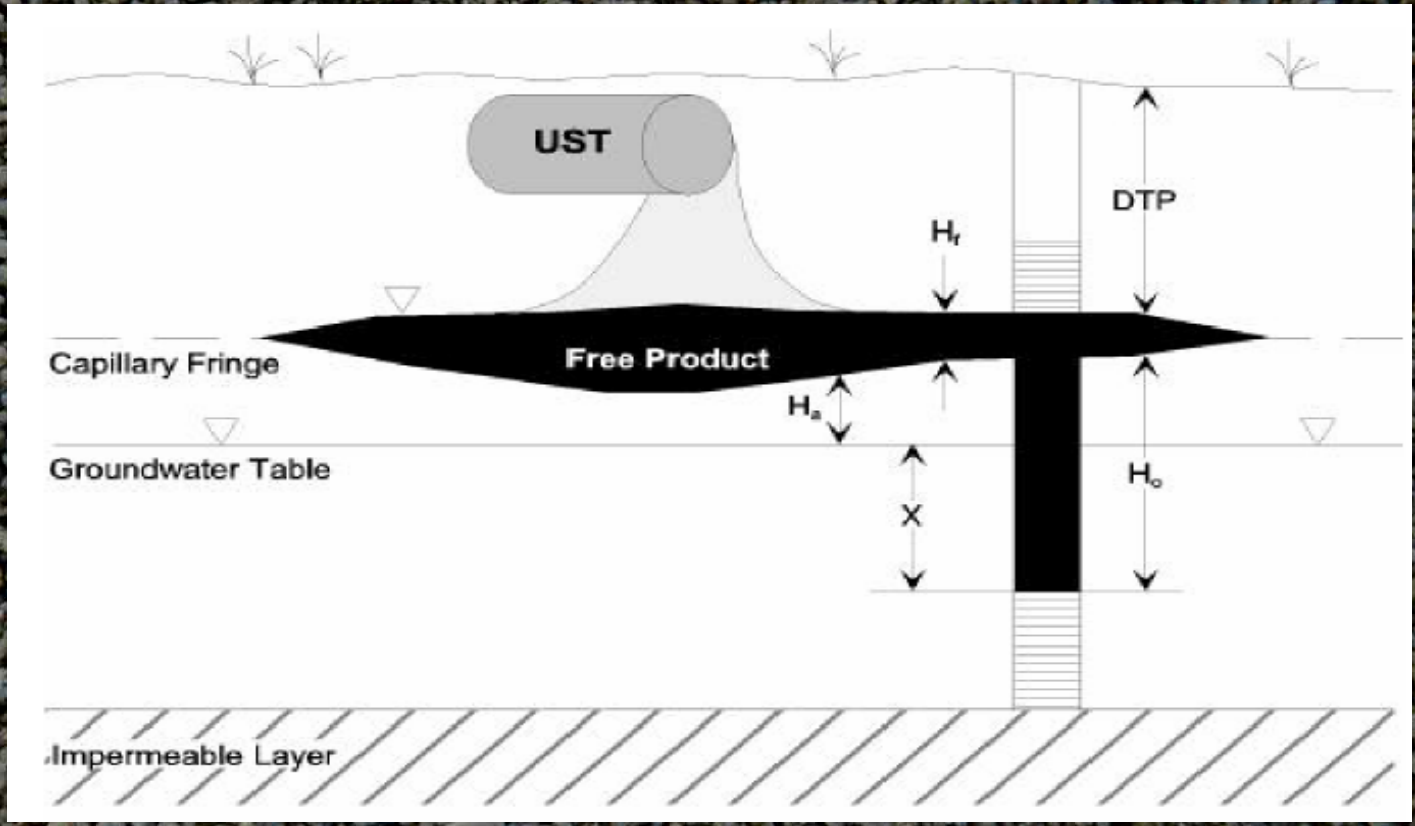
# THE OLD WAY OF THINKING ABOUT LNAPL

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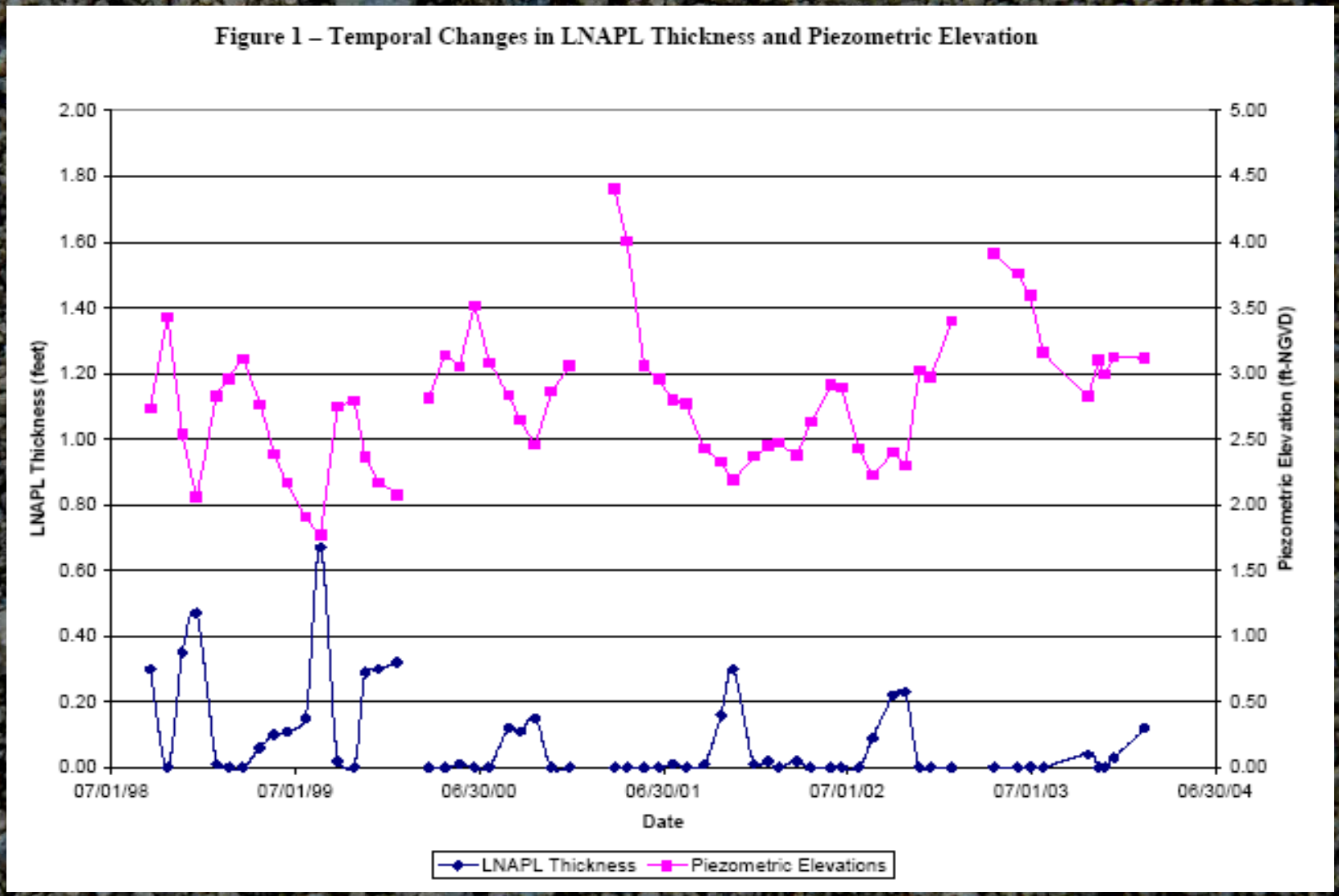
# PRODUCT THICKNESS MEASUREMENTS

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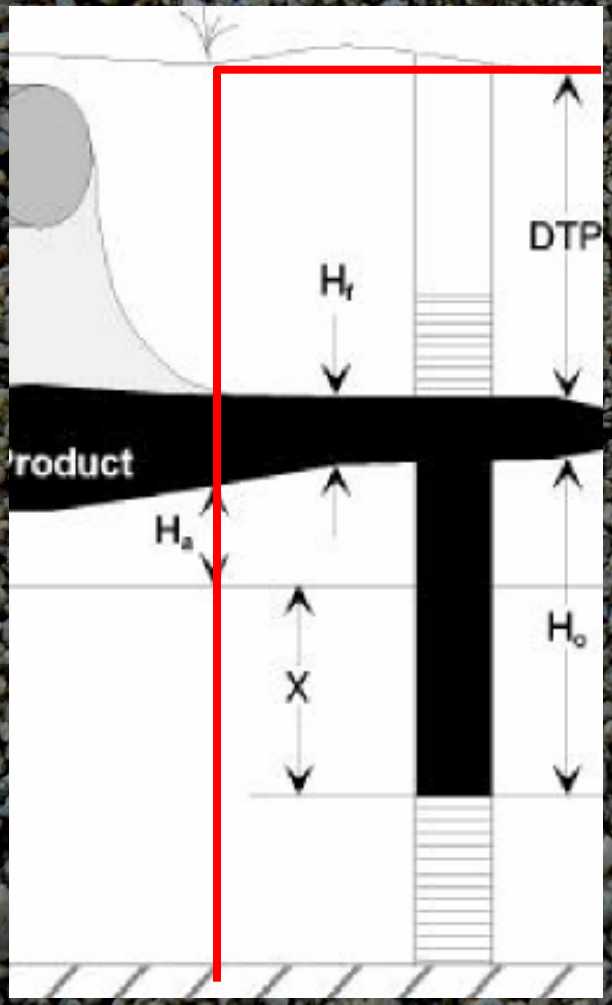
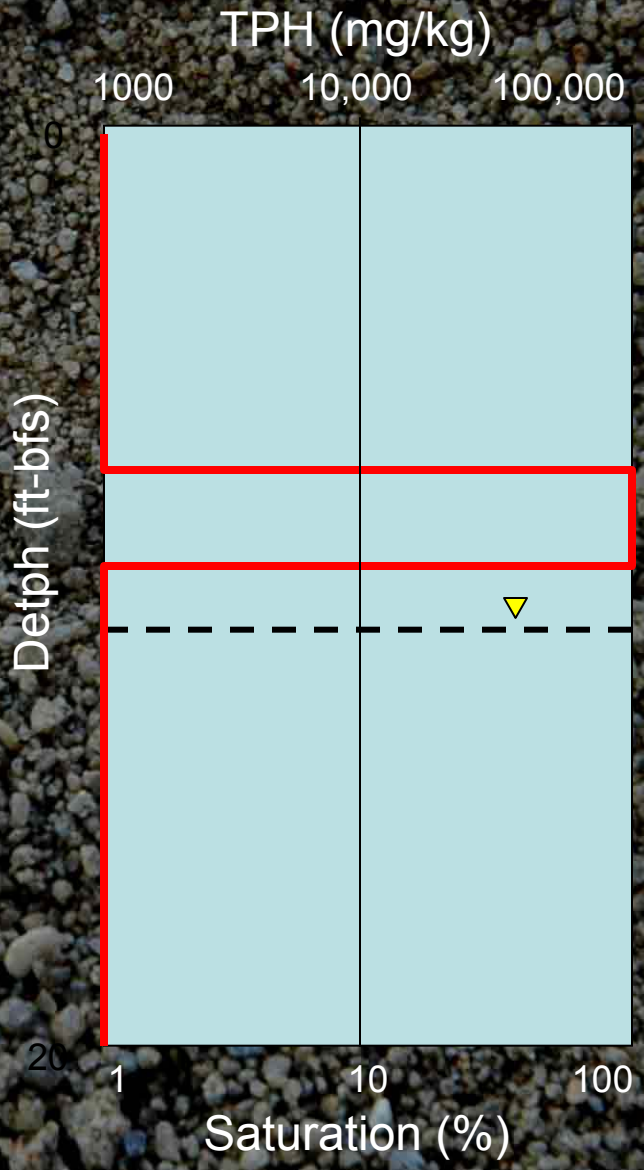
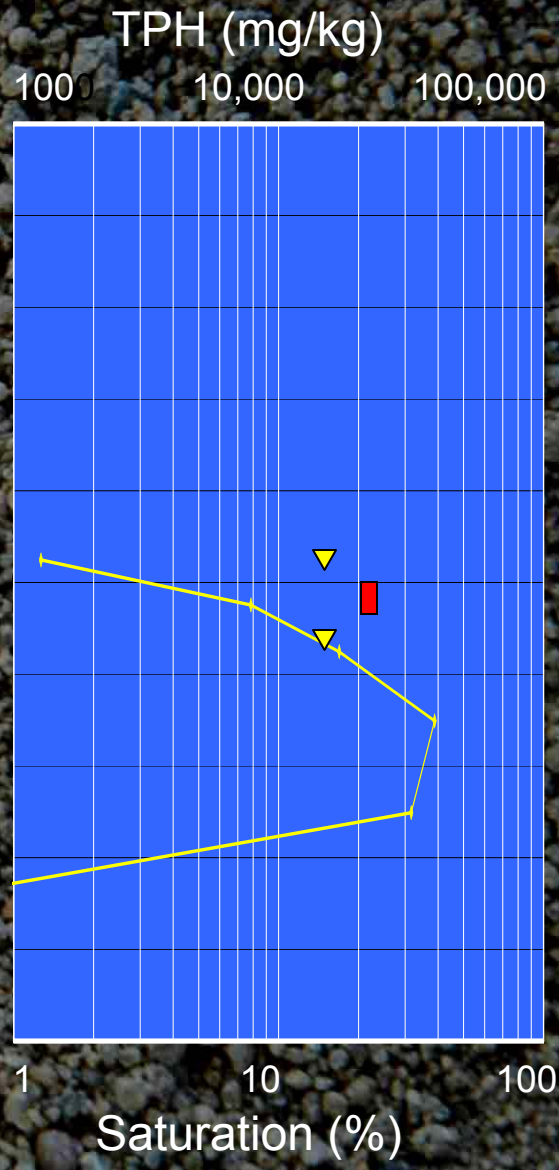
Source: LSPA 2005

# VERTICAL PROFILE

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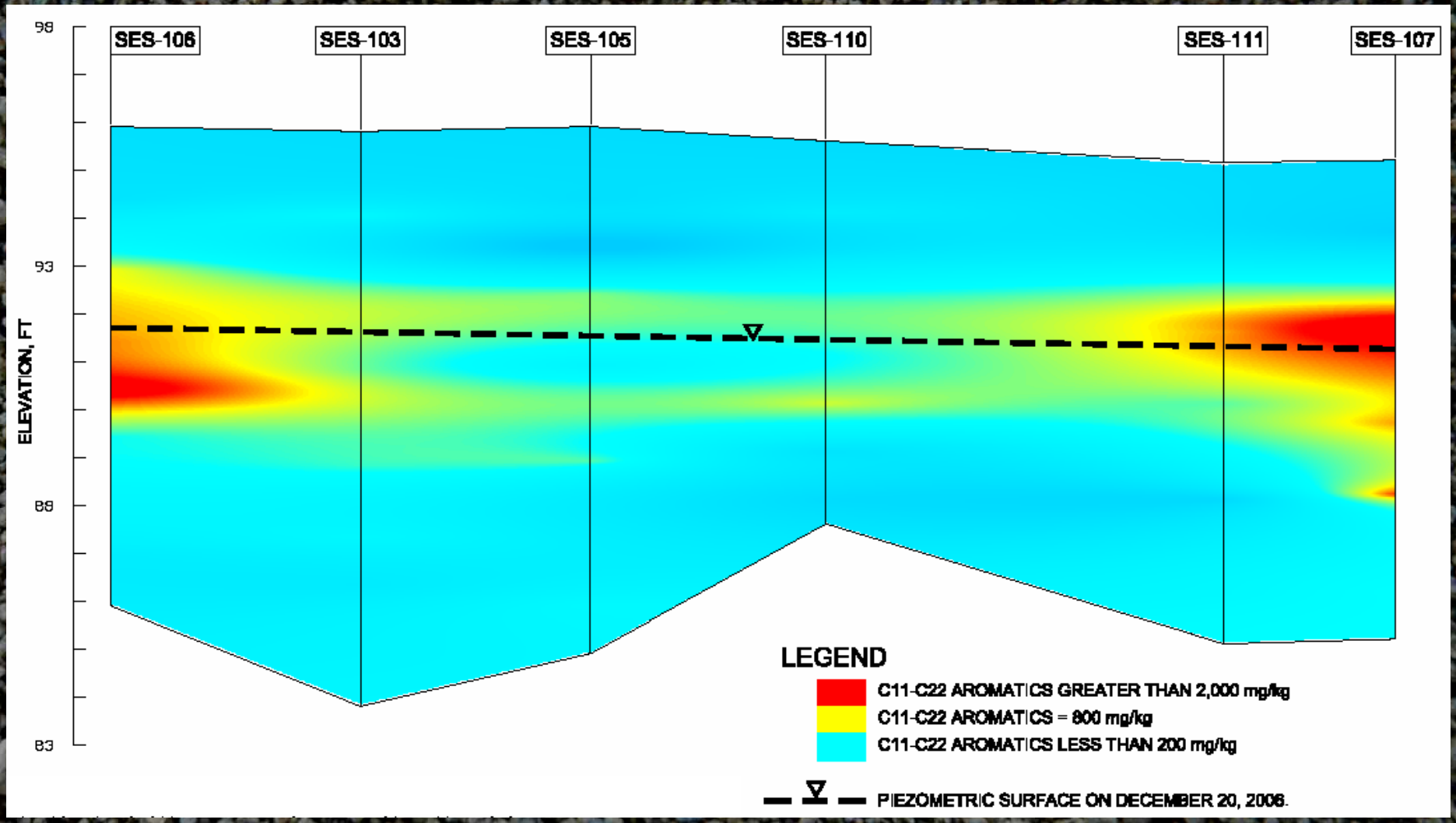
# THE NEW WAY OF THINKING ABOUT LNAPL

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# WHITE PAPER PART 2 OUTLINE

- Regulatory Change Recommendations
- New Definitions
- LNAPL Characterization Framework
- Practice Standard Changes
- Risk Characterization Changes
- Mobility Evaluations

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# REGULATORY CHANGE RECOMMENDATIONS

- Change definitions in MCP for NAPL, Source, Mobility
- Eliminate the ½" UCL for NAPL
- Retain the concentration based UCLs
- Simplify LNAPL reporting to a single condition that is independent of LNAPL thickness
- Define and regulate "Mobility"

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# SUGGESTED DEFINITIONS

and other semantics issues

## CURRENT MCP DEFINITION OF LNAPL

- Nonaqueous Phase Liquid and NAPL each means oil and/or hazardous material that is present in the environment as a continuous separate phase as measured in a groundwater monitoring well or otherwise observed in the environment.

## SUGGESTED DEFINITION OF LNAPL

- Nonaqueous Phase Liquid and NAPL each means oil and/or hazardous material, or a mixture thereof, that is present in the environment as a separate non-gaseous phase liquid, that is relatively immiscible with water.

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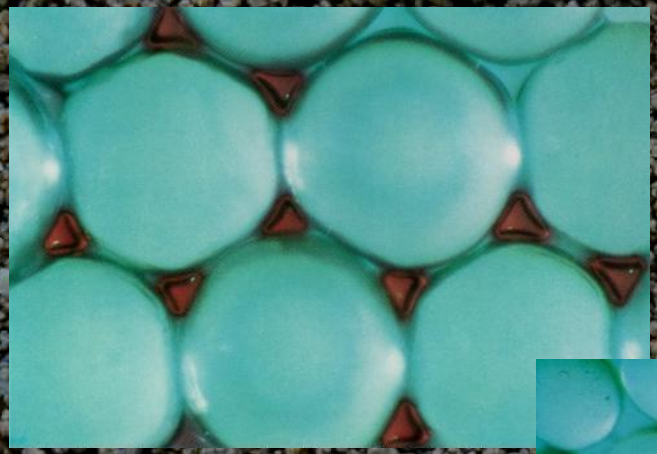

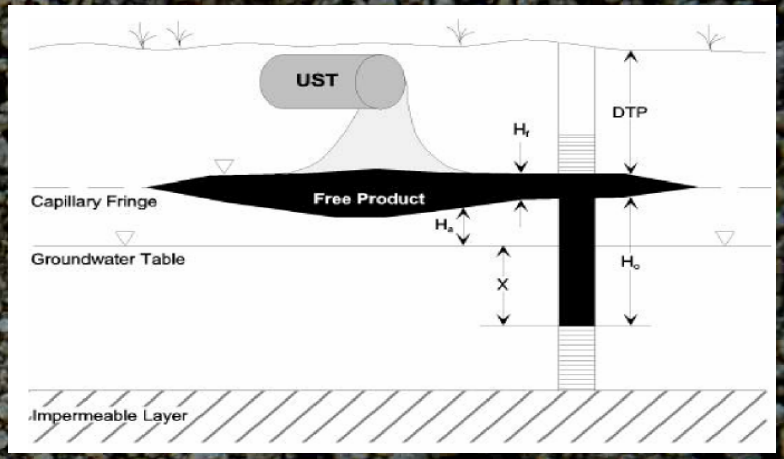


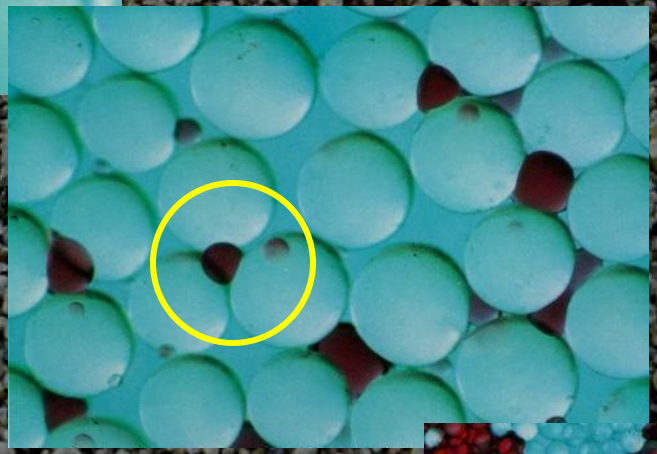

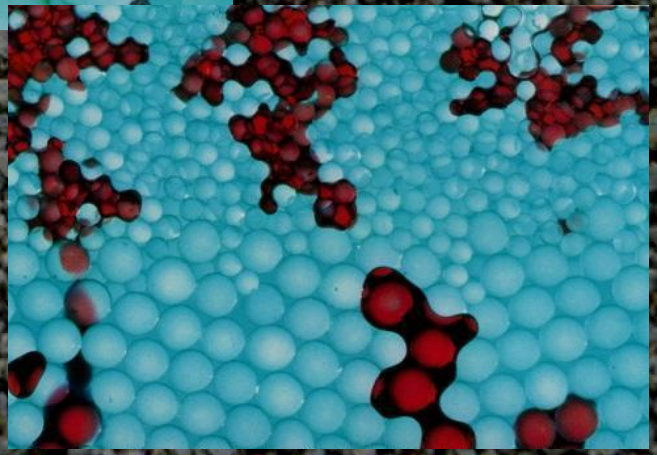

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# DEFINITION FOR RESIDUAL NAPL SOURCE

Residual NAPL Source means NAPL that exists in the soil pore space or rock fractures, that has the potential to act as on ongoing source for intermedia transfer of contaminants to soil, groundwater, or soil vapor, for an indefinite period of time.

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# WORDS TO USE AND WORDS TO LOSE

## LOSE THESE ONES

- Separate Phase
- Floating Product
- Free Phase
- Product Thickness
- “True” “Apparent”

## USE THESE ONES

- Mobile/Non-mobile
- Residual
- Plume Stability
- Saturation
- Specific Volume
- Specific Mass
- Relative Permeability
- Recoverable

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# NAPL CHARACTERIZATION FRAMEWORK

- Goal is to have LSPs speaking the same LNAPL language
- Recognize that LNAPL is best characterized as a soil contaminant
- Seek a consistent way to identify the presence of LNAPL in soil
- Determine mobility state of LNAPL

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# PRESENCE OF LNAPL IN SOIL

- How to determine that LNAPL is present in soil?
- Can not use visual, olfactory or thickness based criteria
- What are the minimum and maximum concentrations/saturations of LNAPL in Soil?
- Soil Saturation Limit, $C_{sat}$

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# SOIL SATURATION LIMIT

- Definition of the soil saturation limit (from Broust et. al., API June 2000:

*"For a pure chemical, NAPL will not be present at concentrations above the soil saturation limit…"*

$$C_{sat,\ soil,\ i} = S_{i\ *} \left[ \frac{\Theta_w + K_{oc,i^*} f_{oc^*} \rho_s + H_{i\ *} \Theta_a}{\rho_s} \right]$$

Pore Water

Sorbed to organic carbon

Vapor Phase

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# SOIL SATURATION LIMIT FOR SOME COMMON NAPLs

| NAPL | Aqueous Solubility (mg/l) | $C_{sat, soil}$ (mg/kg) |
|---|---|---|
| Fuel Oil | 4 | 18 |
| Gasoline | 164 | 106 |
| TCE | 1100 | 1045 |

Source: Broust, 2000

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# RESIDUAL SATURATION/CONCENTRATION

What does residual concentration ($C_{res}$) mean?

Again, from Broust:

$C_{res}$ is *"….a soil concentration….below which the NAPL, if present, will not migrate due to convection or gravity."*

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# HOW DO WE DETERMINE $C_{res}$

- Published values in the literature
- Laboratory Tests
  - Centrifuge (ASTM D425)
  - Permeameter

Note that centrifuge test results may be highly conservative

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# $C_{res}$ INFLUENCES

NAPL Viscosity

- $C_{res}$ Increases with increasing viscosity

Soil Type

- $C_{res}$ decreases with increasing particle size

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# CONCENTRATION AT 100% NAPL SATURATION

What is the NAPL Concentration at 100% Saturation?

Easy to calculate:

$$C_{max} = \frac{n\, G_{napl}}{(1-n) G_{solids}}$$

Where $G_{napl}$ = specific gravity of NAPL and

$G_{solids}$ = specific gravity of solids

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# CONCENTRATION AT 100% NAPL SATURATION

| Porosity | $C_{max}$ (mg/kg) |
|---|---|
| 0.25 | 100,000 |
| 0.5 | 300,000 |

Calculation assumes the following:

- $G_{napl}$ = 0.81
- $G_{solids}$ = 2.7

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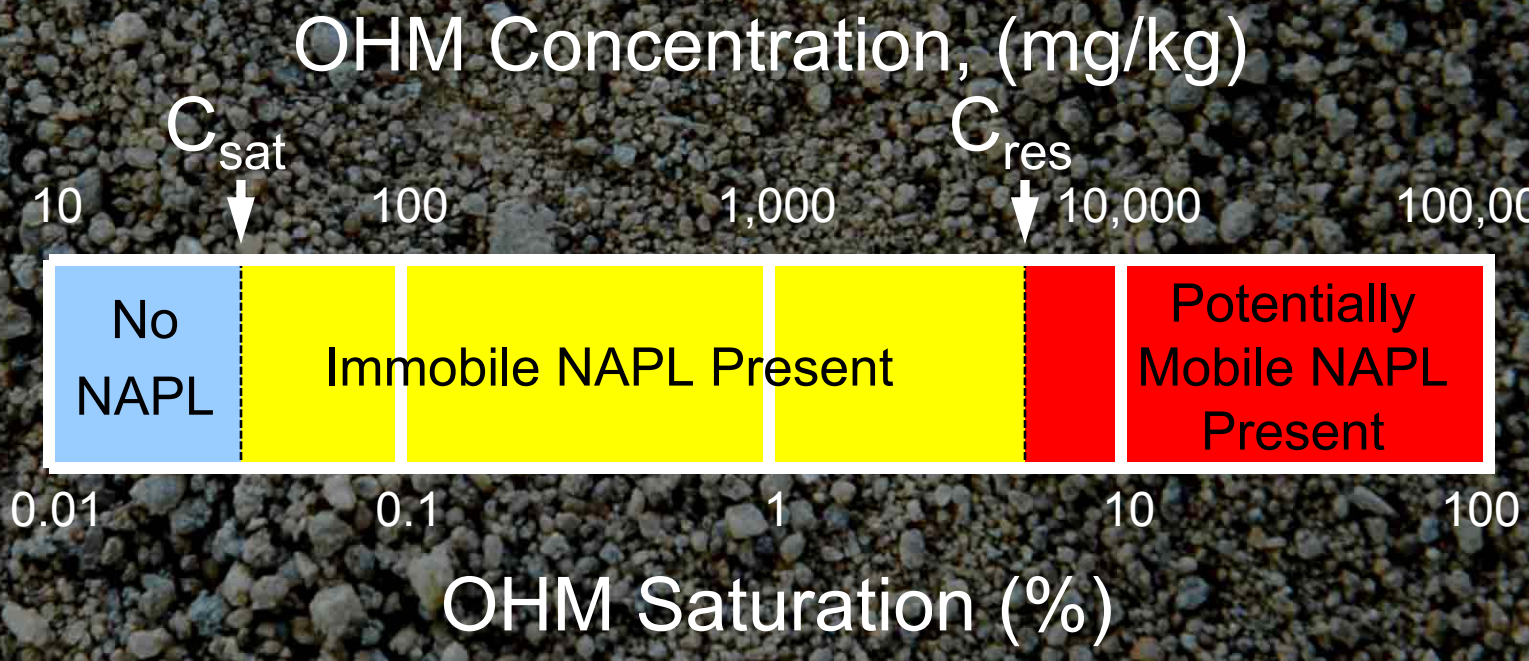
# PUTTING IT ALL TOGETHER INTO "THE LNAPL CONTINUUM"

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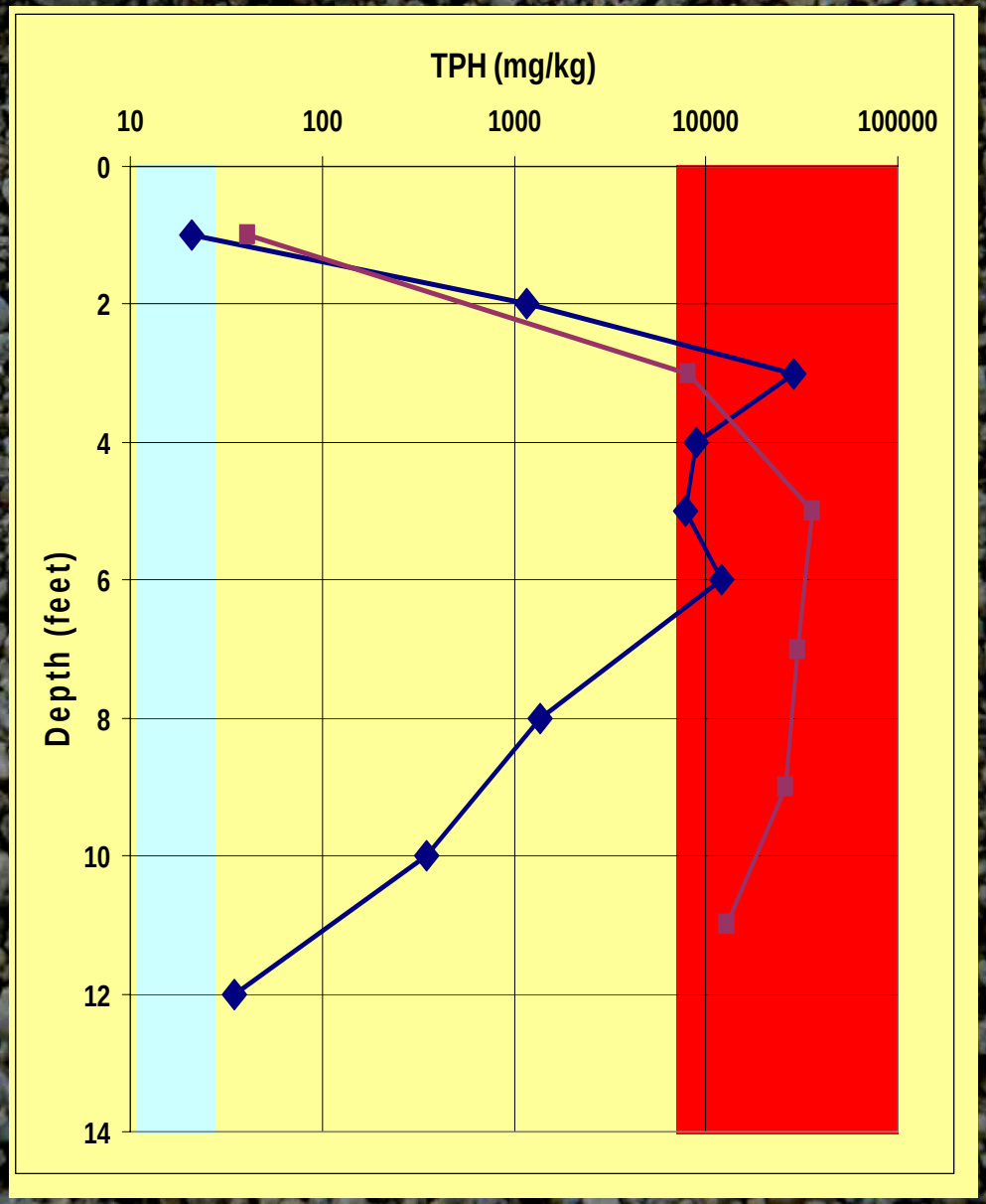
# USE TO EVALUATE VERTICAL PROFILES

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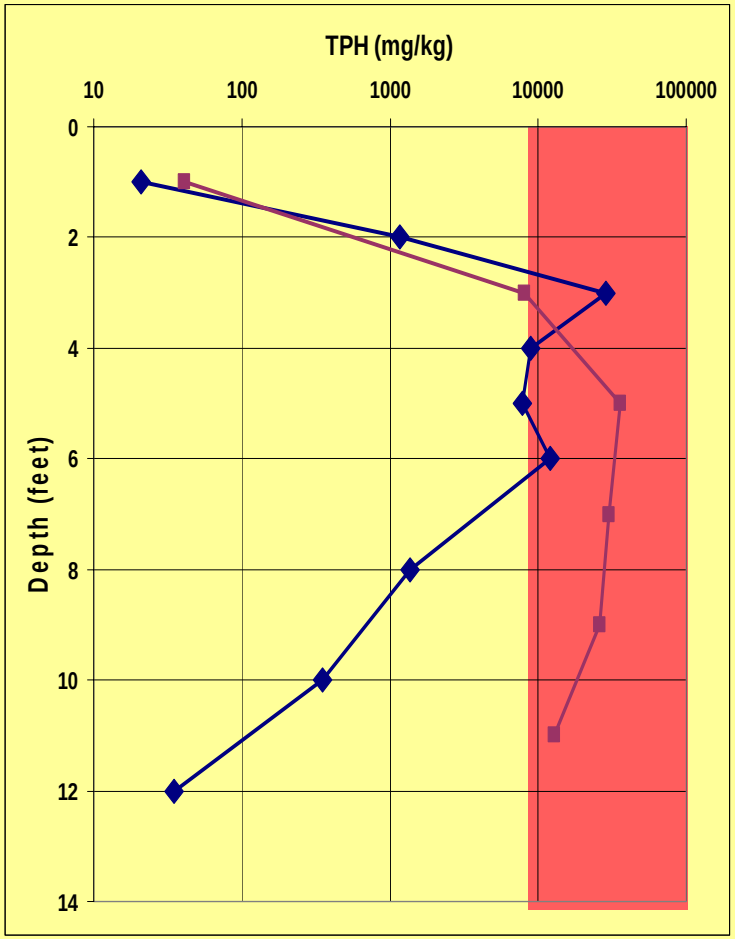
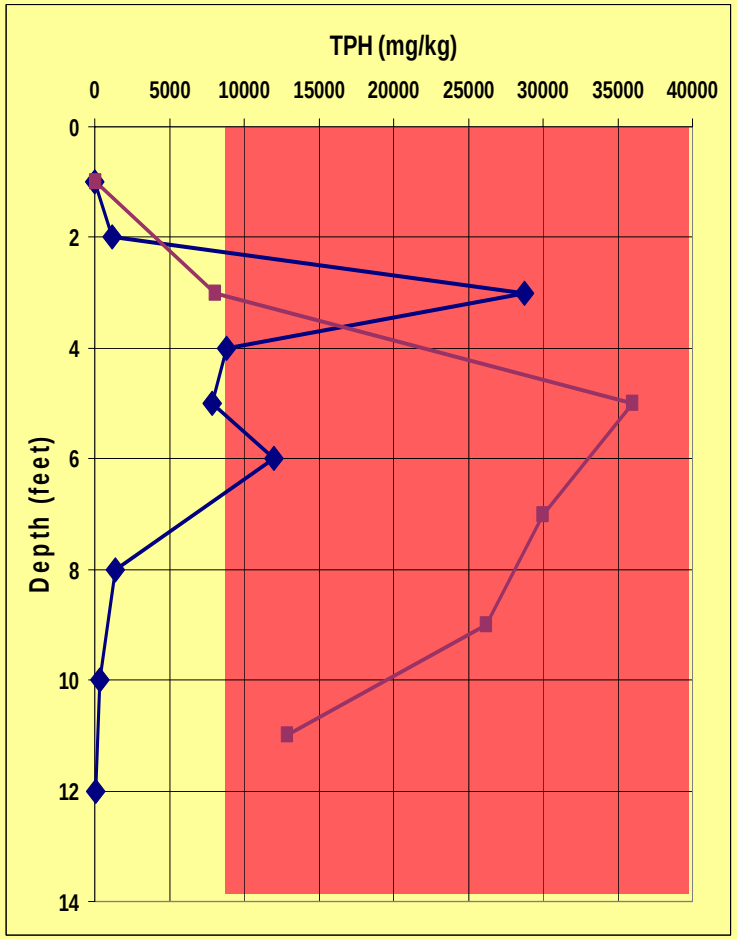
# SAME DATA SHOWN LOGATRITHMICALLY AND ARITHMETICALLY

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# LNAPL WHITE PAPER - PART II

(continued)

## RISK CHARACTERIZATION RECOMMENDATIONS

- Use standard risk assessment procedures, but eliminate LNAPL thickness as a parameter of concern
- Document removal of continuing "Source"
- Evaluate indoor air pathway using soil vapor data (not soil or groundwater data)
- Use soil concentration data for construction worker risk
- Consider modification of dermal adherence factors
- Perform mobility analysis to evaluate future risks

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# RECOMMENDED MOBILITY EVALUATION PROCEDURES

- Method 1 – Weight of Evidence
- Method 2 – Comparison to $C_{res}$
- Method 3 – Site Specific Mobility Evaluation

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# Method 1 Weight of Evidence

- Soil Type/Hydraulic Conductivity
- Product Type/Viscosity
- Known or Estimated Release Volume
- Environmental Setting/Receptors
- Recovery history

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# Method 2 – Compare to Residual

- May be best where some removal has occurred
- Use of estimated (published) values for residual discouraged

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Method 3 – Site Specific Mobility Evaluation
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# DEFINING MOBILITY

LNAPL Seepage Velocity = (Conductivity to LNAPL) x (Driving Force)

Mathematically this can be written as

$$v_{LNAPL} = -\left(\frac{kk_{rLNAPL}\rho_{LNAPL}g}{\mu_{LNAPL}nS_{LNAPL}}\right)\left(\frac{dh_{LNAPL}}{dx}\right)$$ (see footnote 5)

API® Soil and Groundwater Research Bulletin Number 18

May 2003

The volumetric flux of product $q_o$ ($L^3/L^2$-T) at any point in the continuous product interval can be described as:

$$q_o = -\frac{kk_{ro}}{\mu_o}\left(\frac{dP_o}{dx} + \rho_o g\frac{dz}{dx}\right) \qquad (1)$$

**Methods for Determining Inputs to Environmental Petroleum Hydrocarbon Mobility and Recovery Models**

API PUBLICATION NUMBER 4711
JULY 2001

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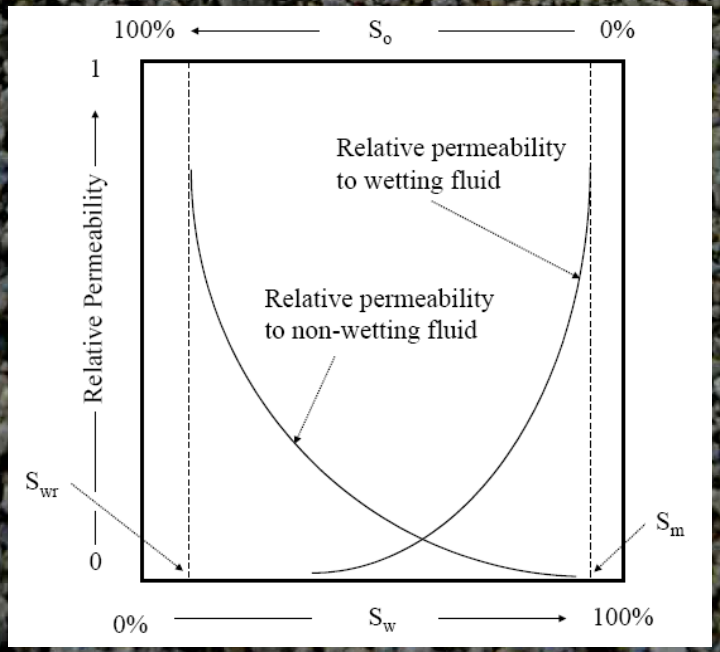
# DEFINING MOBILITY
## (continued)

The **mobility** of the product is defined as:

$$M_o = \frac{kk_{ro}}{\mu_o} \qquad (2)$$

Unfortunately, the fraction of pore space filled with product ($S_o$), and consequently the relative permeability to product ($k_{ro}$), changes with position. As such, mobility ($M_o$) is a function of position within the interval of continuous product. Variation in **product saturation** ($S_o$) reflects locally varying differences in pressure between the non-wetting and wetting phase pressures.

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