

Innovative Methods for LNAPL Remedy Optimization



Prepared for:

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Presentation Objectives

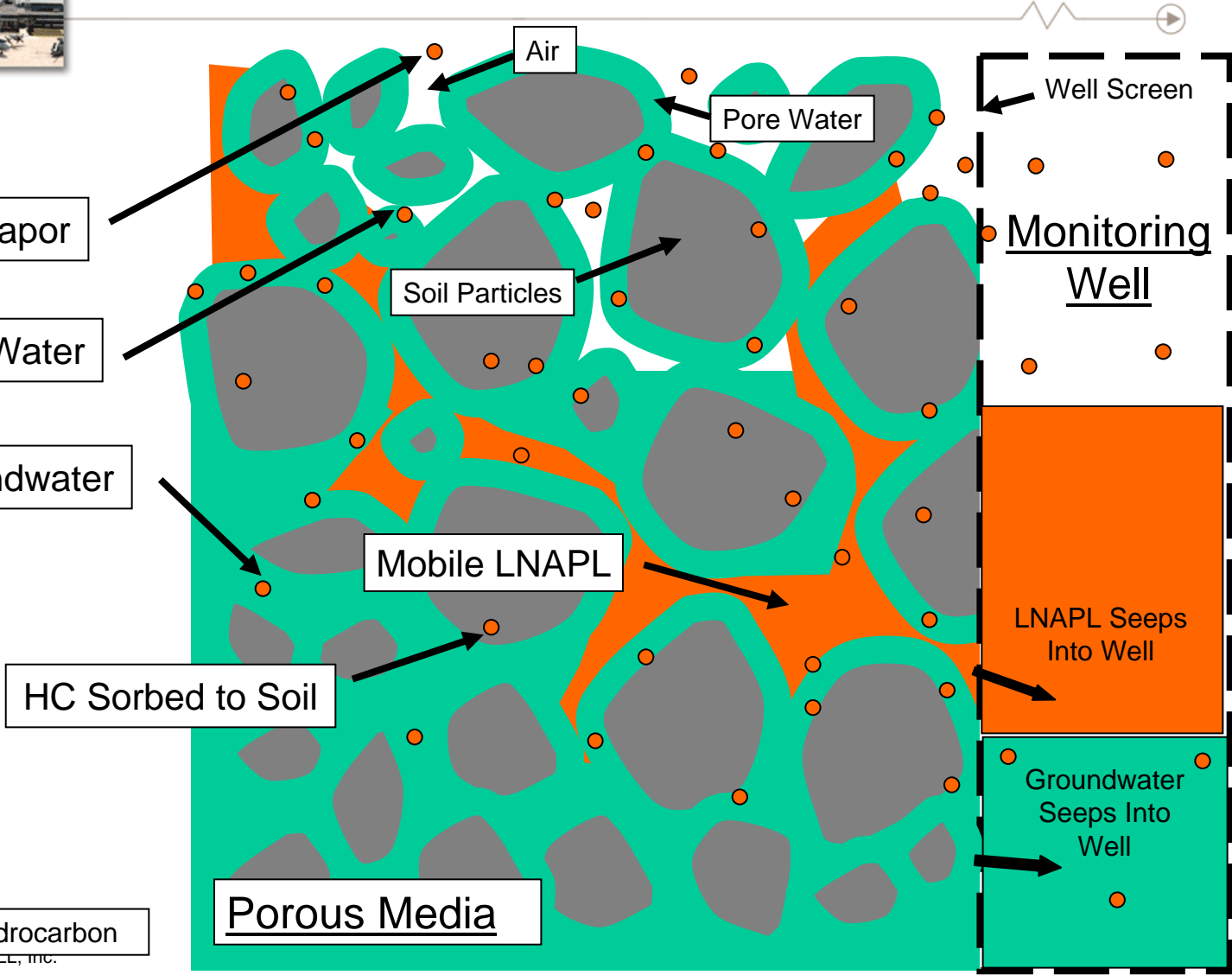
- Present proven methods to optimize LNAPL remedies:
 - LNAPL Analysis and Mobility Modeling
 - Time to Clean Up Modeling
- Demonstrate how they improve site management and reduce costs
- Discuss advantages and disadvantages of these technologies
- Discuss how these methods might be applied on your projects



The LNAPL Problem: Mobile Condition



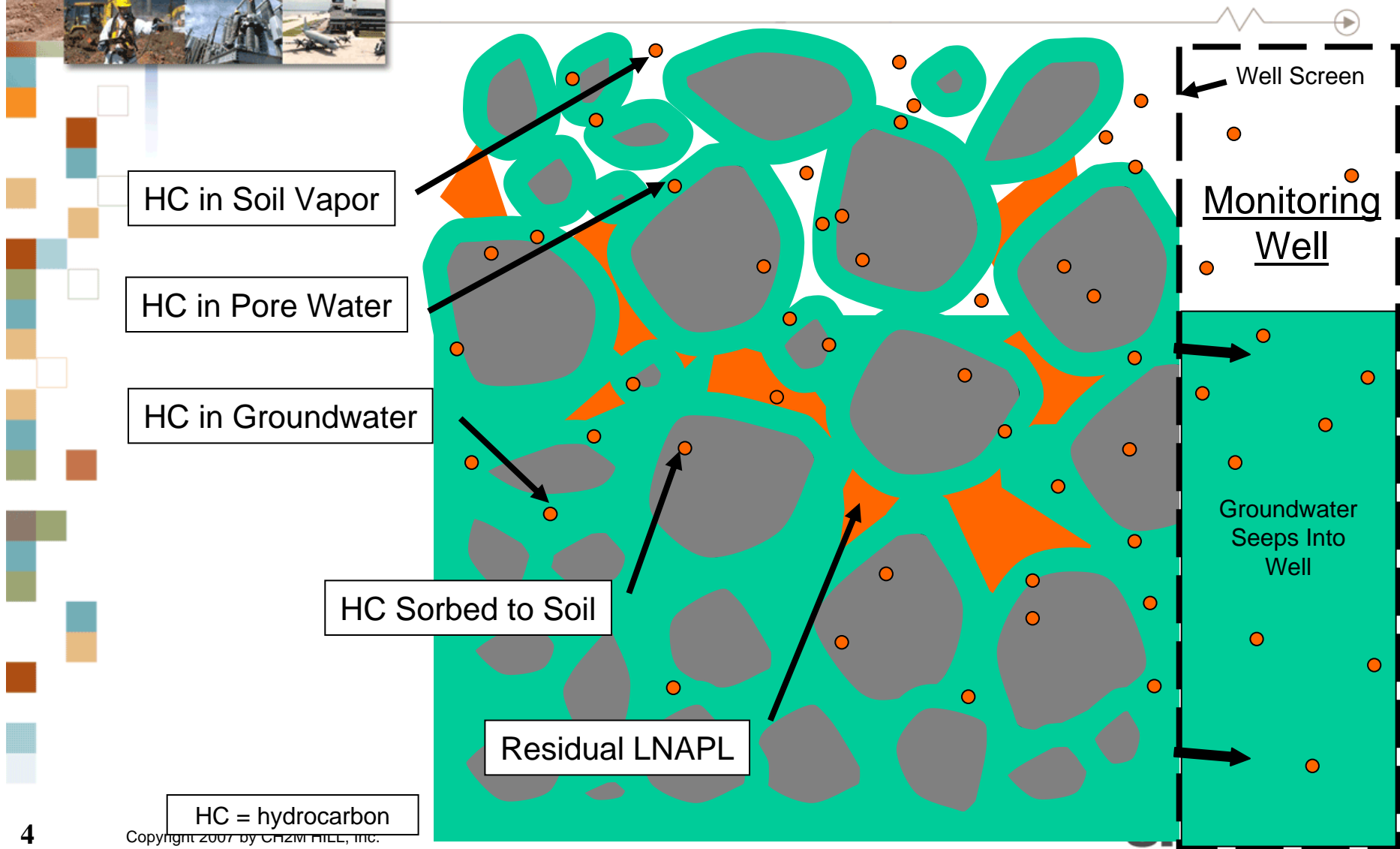
- HC in Soil Vapor
- HC in Pore Water
- HC in Groundwater



HC = hydrocarbon



The LNAPL Problem: Residual Condition





The Need for LNAPL Remedy Optimization

- A plethora of treatment technologies are available, but
- Remedial progress is typically limited due to geologic heterogeneities and
- Usually progresses toward a point of diminishing returns
- Selection of appropriate technology is critical and
- Implementation of an optimization program to track progress and maintain a cost-effective approach



Here are Two Methods to Assist

- LNAPL Evaluation and Mobility Modeling
- Time to Clean Up Modeling



LNAPL Analysis and Modeling

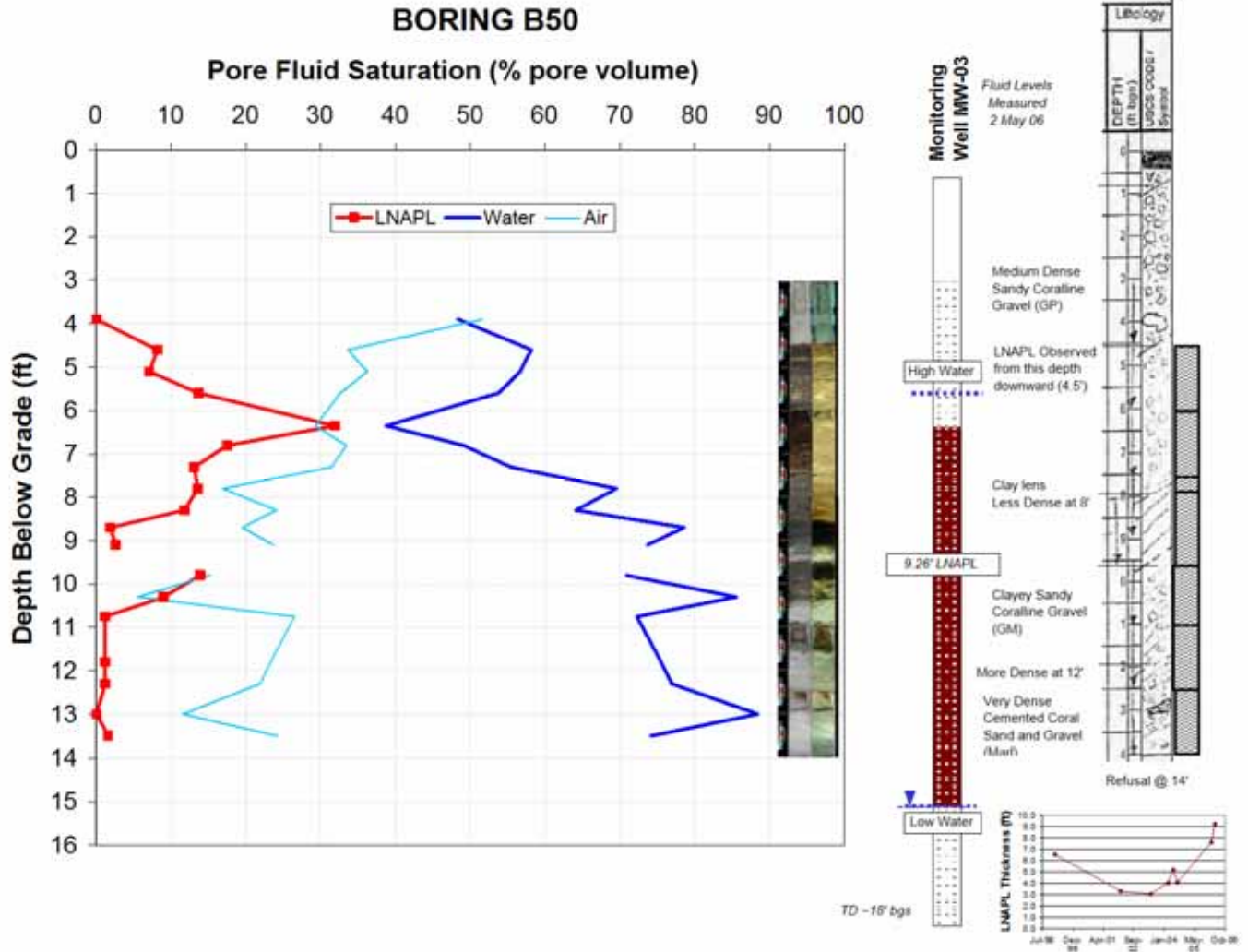
- Option for sites with:
 - Unproductive recovery systems
 - Complex LNAPL conceptual models
 - LNAPL mobility concerns
- Process of intact soil coring, LNAPL analysis, and mobility modeling
- Objective: to quantifiably understand the LNAPL condition and potential for mobility and recoverability



LNAPL Coring and Lab Analysis

- Intact core sampling – use of a good drilling and sampling method is key
- Oil field analyses including, but not limited to:
 - Pore fluid saturation (PFS)
 - Capillary pressure testing
 - LNAPL fluid properties (density, viscosity, surface tension)
 - Mobility testing (lab centrifuge)

Example Soil Core Data Profile





LNAPL Mobility Modeling

- Based on adaptation of established soil science and pioneered by American Petroleum Institute
- Not applicable for all sites
- Performed on select set of sample depths - location of potential mobility front, i.e., the LNAPL saturation peak



LNAPL Mobility Modeling Process



- Sequence through series of calculation steps (for each unique soil type):
 - Derive air/water capillary characteristics
 - Use scaling parameters to predict PFS profile and compare to measured profile to “calibrate” model
 - Calculate LNAPL relative permeability and hydraulic conductivity
 - Estimate LNAPL pore velocity



LNAPL Modeling Results – Three Sites



Parameter	Site 1 – FL	Site 2 - HI	Site 3 – AZ
Dominant Soil Type	Fine-medium sand	Coralline sand and gravel	Gravelly, silty fine-medium sand
LNAPL Type	JP-4 and JP-8	JP-4 and JP-8	Jet Fuel A and JP-4
Max. In-Well Thickness (ft)	2.5	9.2	4.5
Smear Zone Depth Interval (ft bgs)	35 - 50	4 - 11	60 - 80
Max. LNAPL Pore Fluid Saturation (% Pv)	3.3	32	11
Purpose for LNAPL Modeling	Full-scale remedy design	Existing remedy optimization	Full-scale remedy design



LNAPL Modeling Results – Three Sites (continued)



Parameter	Site 1 – FL	Site 2 - HI	Site 3 – AZ
Dominant Soil Type	Fine-medium sand	Coralline sand and gravel	Gravelly, silty fine-medium sand
Estimated Max. LNAPL Conductivity (cm/sec)	1×10^{-5}	8×10^{-5}	3×10^{-6}
Max. Estimated LNAPL Pore Velocity in Plume Core (ft/yr)	0.7	0.4	2.3
Result	AS-SVE accepted as full-scale remedy	Proposal to shut down multi-phase extraction system	Bioventing and SVE accepted as full-scale remedy



Demonstrated Benefits of LNAPL Analysis and Modeling

- Allowed understanding of magnitude of LNAPL mobility and directly effected the remediation strategy decisions
- Relatively low cost (range \$30-70k) considering that the results can be utilized for myriad of purposes:
 - Risk assessment
 - Remediation technology selection
 - Establishing remedial action objectives
 - Treatment system design
 - Fluid recovery system shutdown analysis (optimization)



Second Method to Assist LNAPL Remedy Optimization



- LNAPL Evaluation and Mobility Modeling
- Time to Clean Up Modeling



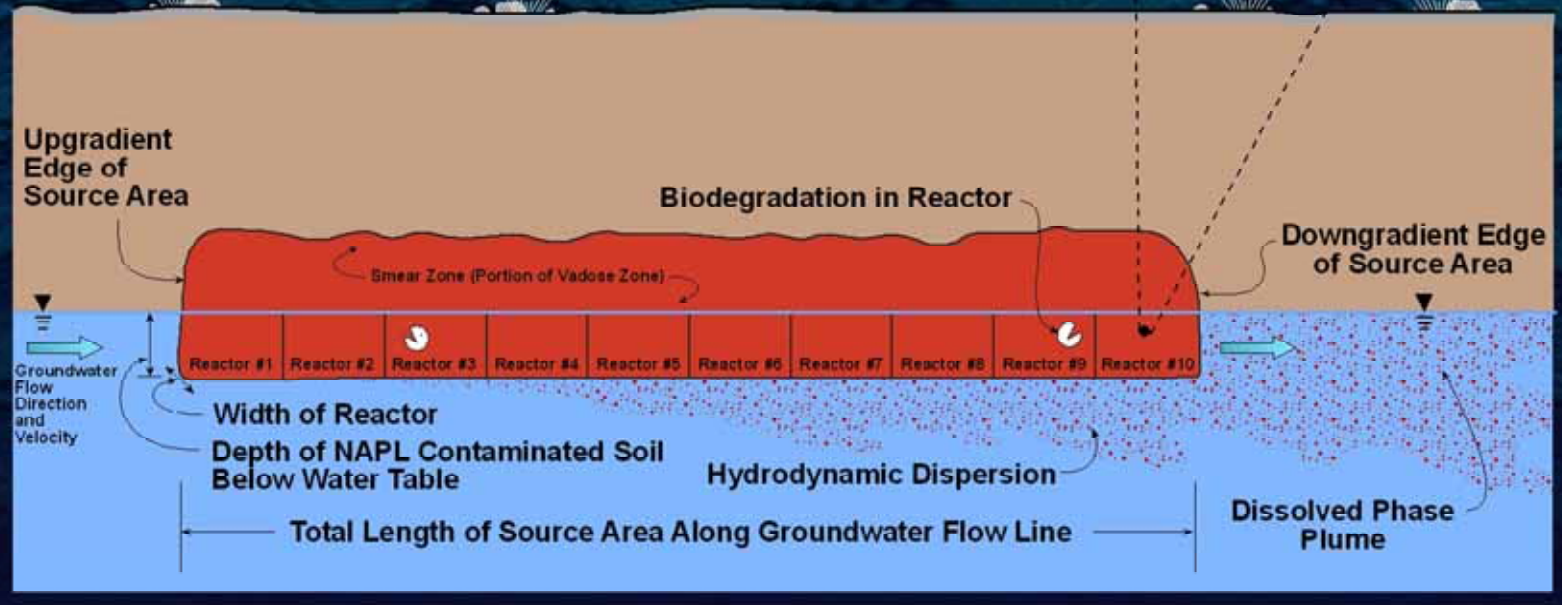
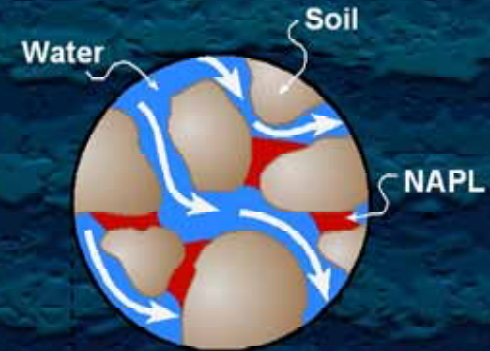
Time to Clean Up Modeling



- Screening level, spreadsheet tool
- Predicts the effects of natural attenuation (NA) and treatment in source areas
- Performs phase-partitioning calculations and mass balance for hydrocarbon mixtures
- Predicts changes in groundwater and soil contamination concentrations over time
- Can be used to derive a remediation timeframe given target cleanup goals

Saturated Zone Dissolution and Natural Attenuation

- Equilibrium between NAPL and groundwater
- Mass transported/lost from source zone via advection and dispersion
- Cascading, complete-mix reactors



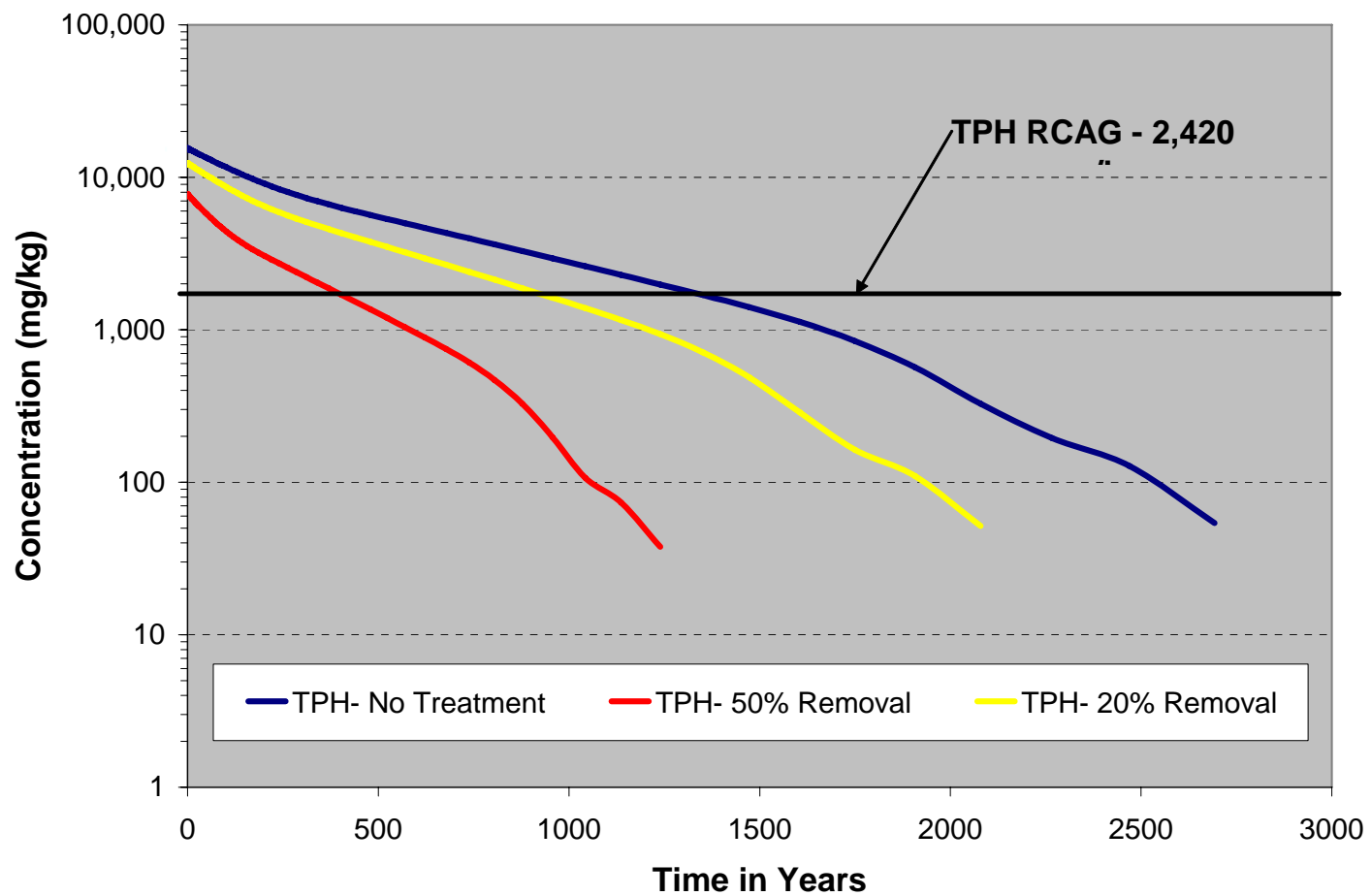


To Demonstrate, Here are Three Examples

- Effectiveness of Fluid Recovery System for Treatment of TPH in Low Groundwater Flow Conditions
- Effectiveness of Air Sparging (AS) for Treatment of Dissolved Benzene in Highly Conductive Aquifer
- Estimating Mass Removal to Meet Clean Up Goals

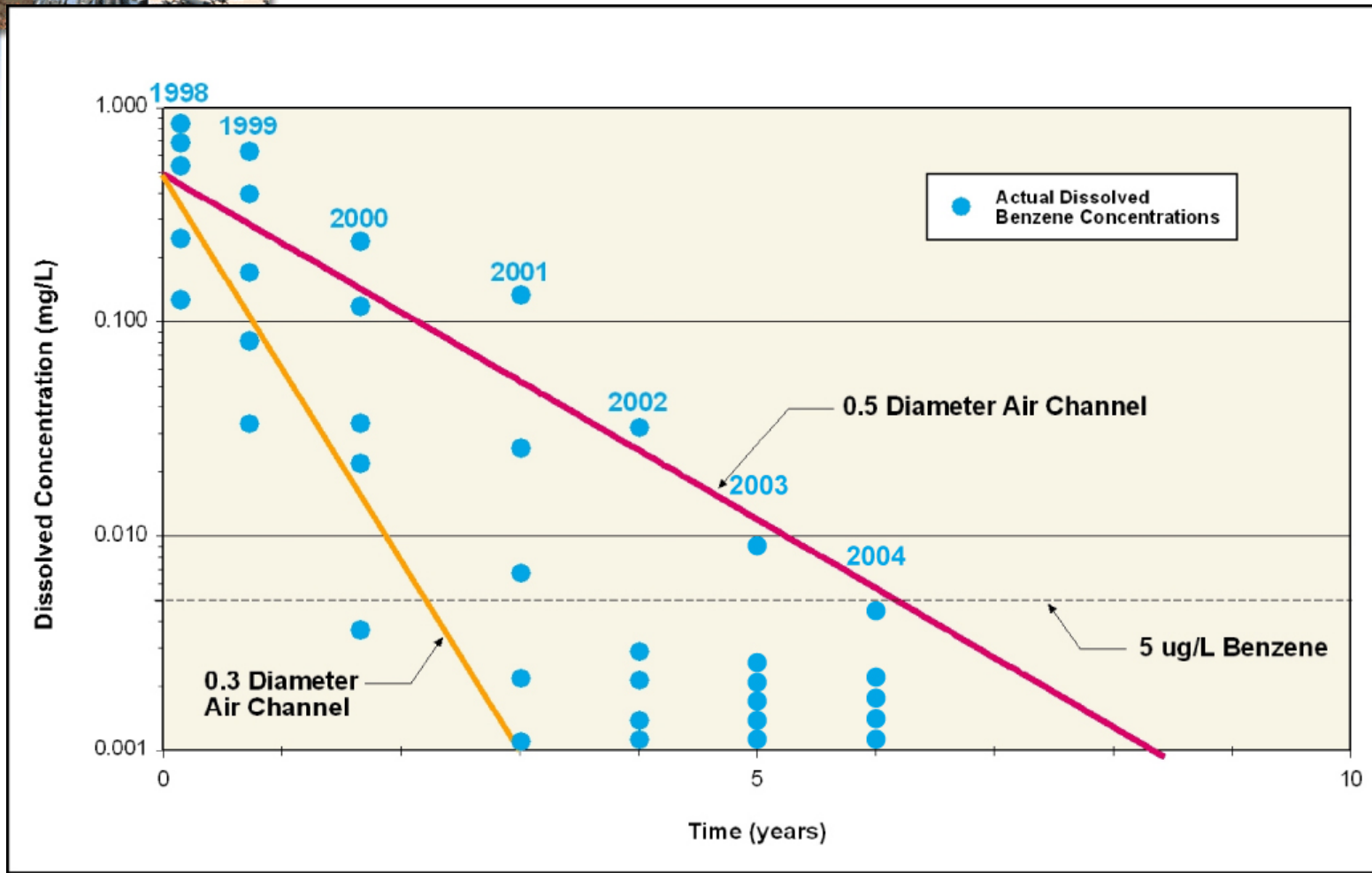


Remediation of Jet Fuel TPH Using Product Recovery



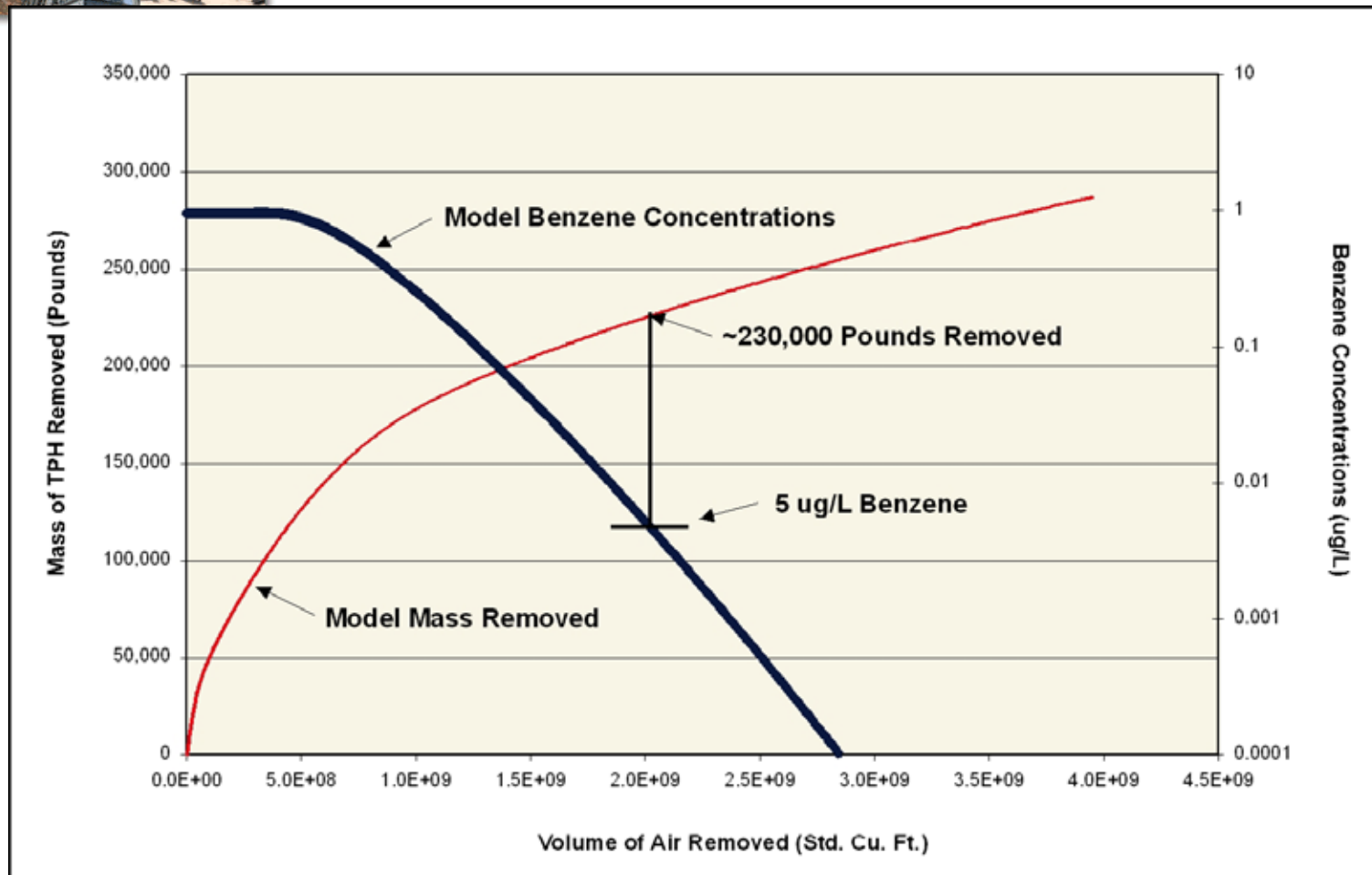


Dissolved-phase Remediation Using AS for Benzene





Modeling Mass Removal to Meet Cleanup Goal





Estimating % of Total Mass Removal Required

Mass of TPH to Remove to Prevent Benzene Migration to Groundwater

	TPH Mass (lbs)	Soil Concentration (mg/kg)
Contamination pre-treatment	2,000,000	9,400
Treatment required	320,000	1,500
Remaining contamination	1,680,000	7,900



Resultant Savings Estimate



Cost Item	2002 IRAR Revised Estimate (1998 \$\$)	2003 Revised Estimate (2002 \$\$)	Cost Savings (2002 \$\$)
Capital Cost	3,978,126	3,978,126	0
Annual Operating Cost	10,738,500	8,145,900	2,592,600
Total Cost	14,716,626	12,124,026	2,592,600



Demonstrated Benefits of TTCU Modeling

- Low cost (range \$3-\$10k)
- Significantly improved understanding of remedy longevity under multiple scenarios
- On front end - provides basis for operation milestones and point of diminishing returns for active remedies
- On back end - Supports strategy optimization efforts where recovery systems, for example, have reached asymptotic levels
- Models spatial variation in source treatment and allows for prediction of treatment effectiveness (AS, SVE, and heating)



Presentation Synopsis

- Technology Advantages
 - Improved understanding of LNAPL conceptual model and source longevity
 - Assists optimization of site management plans and exit strategies (with realistic milestones and endpoints)
 - Can result in significant \$ savings
- Technology Disadvantages
 - Cost:benefit analysis may not justify it use
 - May generate more questions than answers and lead to significant characterization
 - Does not remediate the site for you!



The End



- Any Questions?

