DNAPL Source Zones

Mark L. Brusseau
University of Arizona

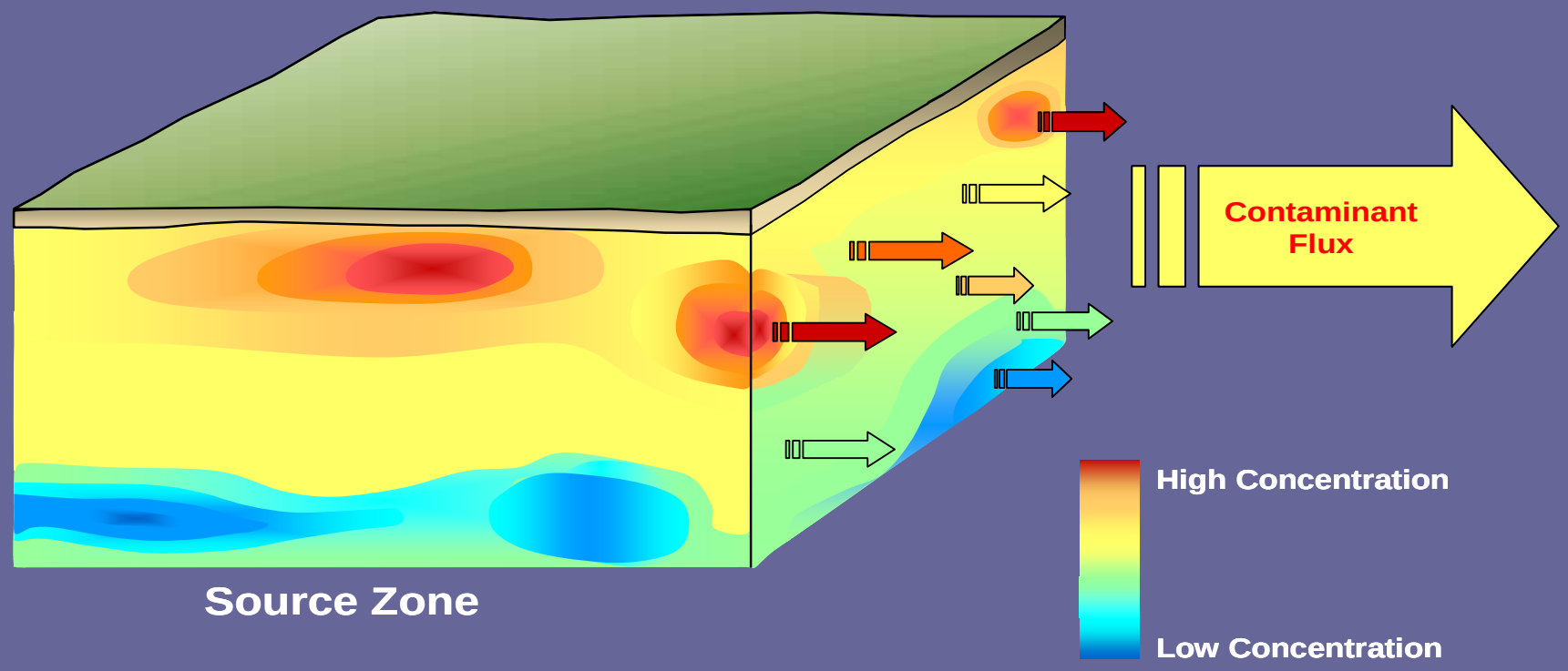
DNAPL Source Zones

- Long-term Source of Contamination
- To Remediate or not to Remediate
- Analysis of Mass-flux/Mass-removal Behavior

Source-zone Mass Flux

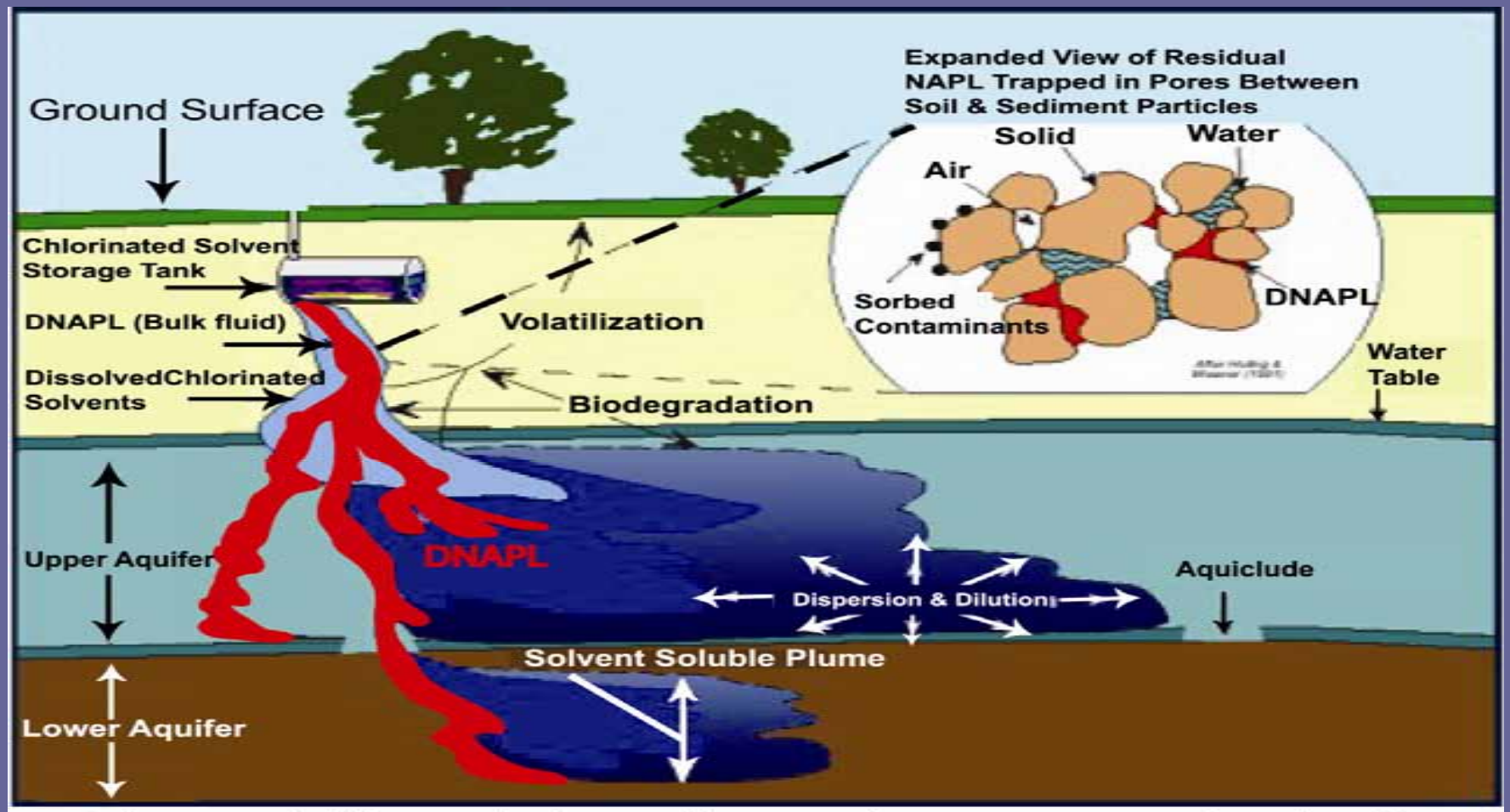
Input for dissolved-phase groundwater plume

(Often primary risk driver for site)



(Figure adapted from EPA)

Source-zone Architecture & Mass-transfer Dynamics



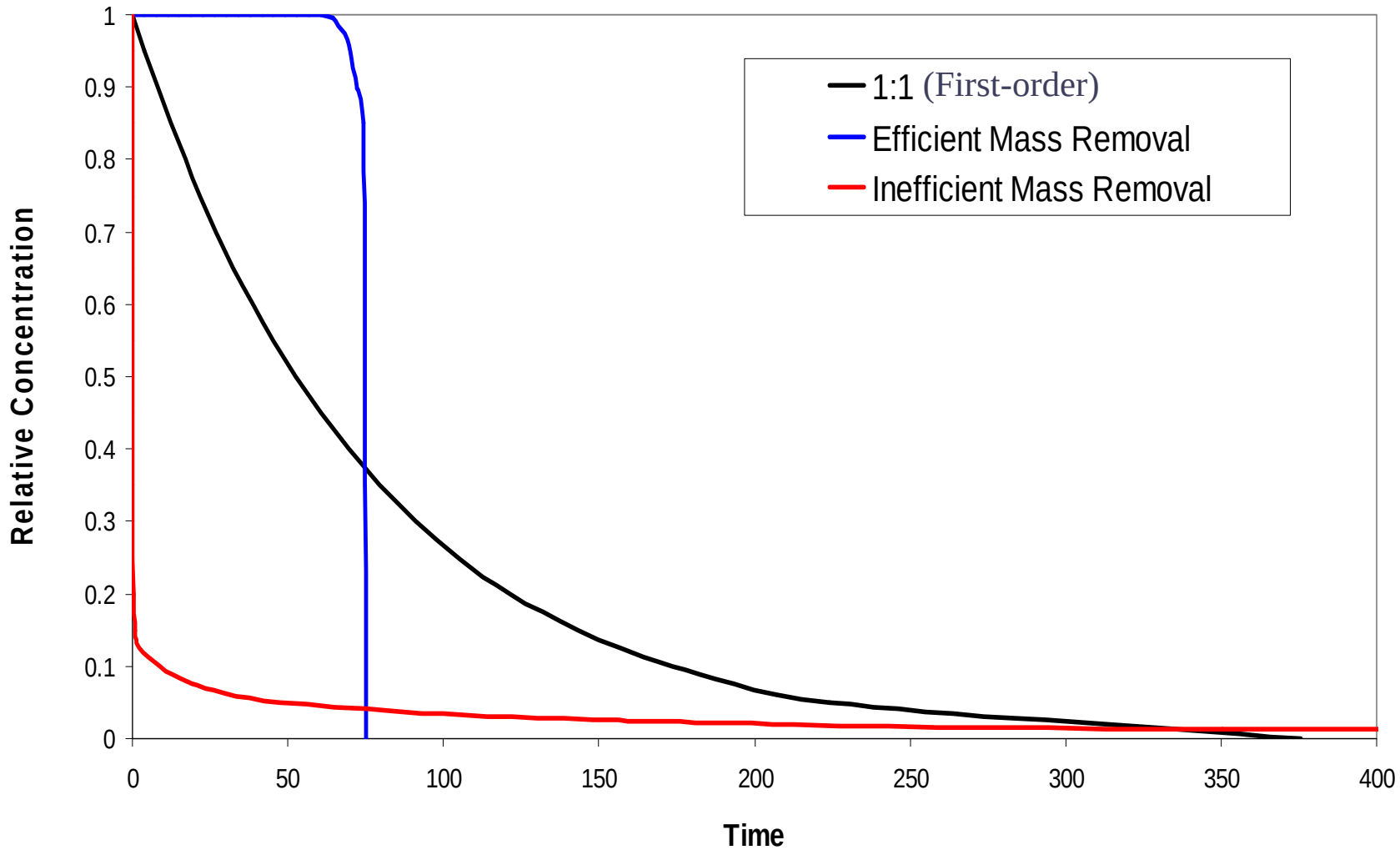
Schematic of Chlorinated solvent pollution as dense non-aqueous phase liquids migrating downward in an aquifer and serving as a source for a solvent soluble plume. Also shown are natural attenuation processes (Modified USEPA 1999).

Mass Flux Reduction vs Mass Removal

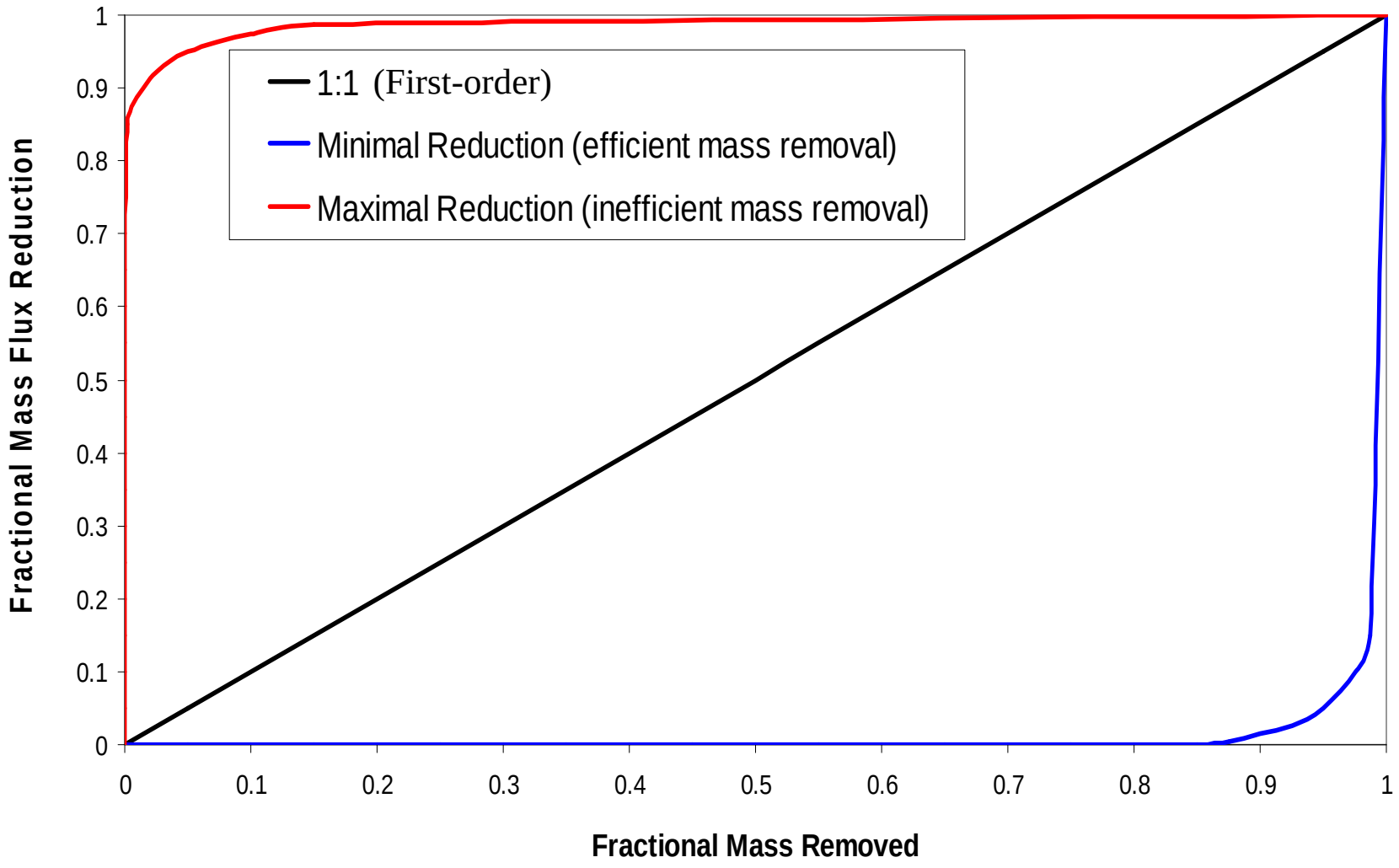
[MFR-MR]

A key metric for assessing remediation-system effectiveness

Mass Removal Behavior



MFR-MR Relationship

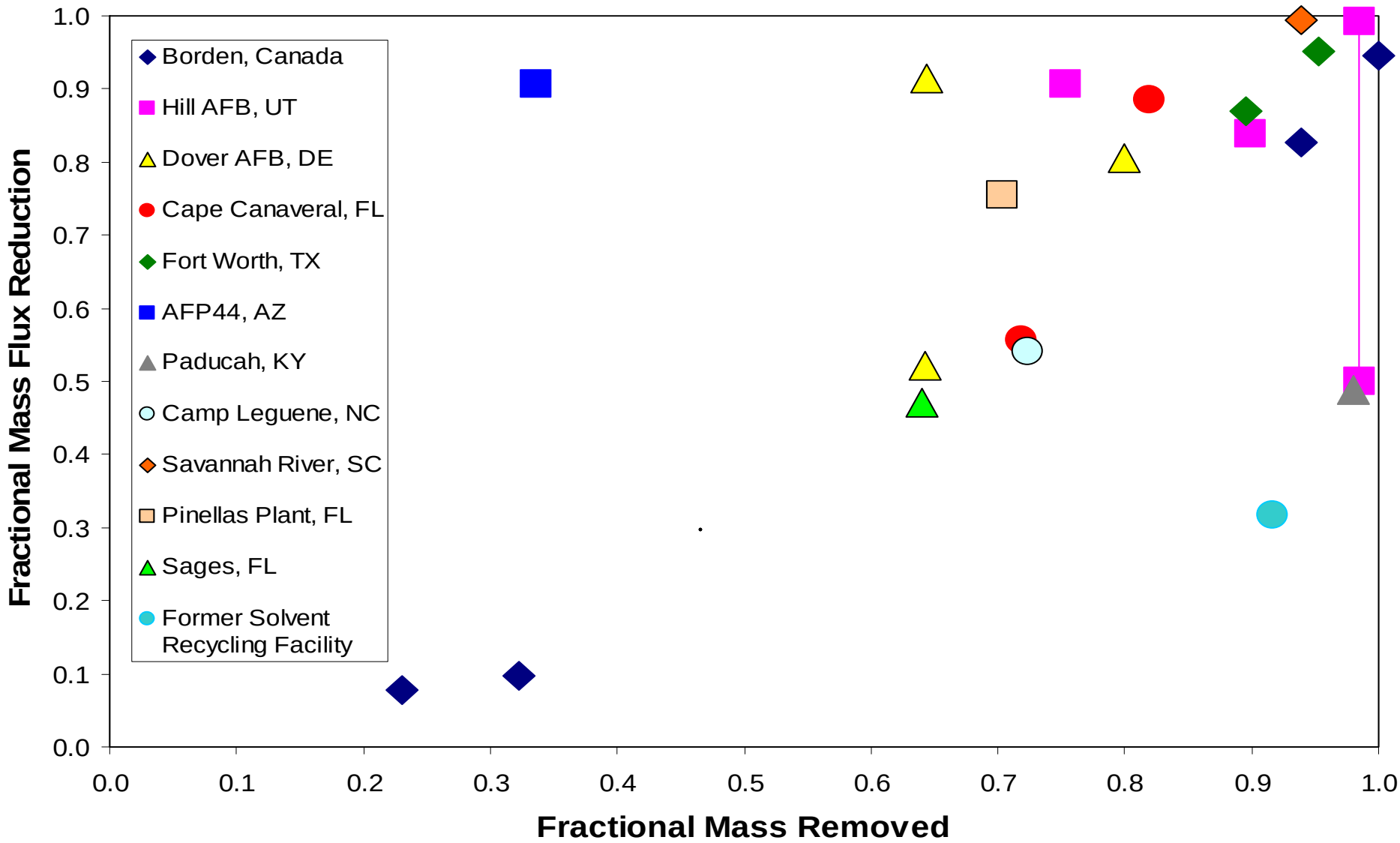


Field Applications

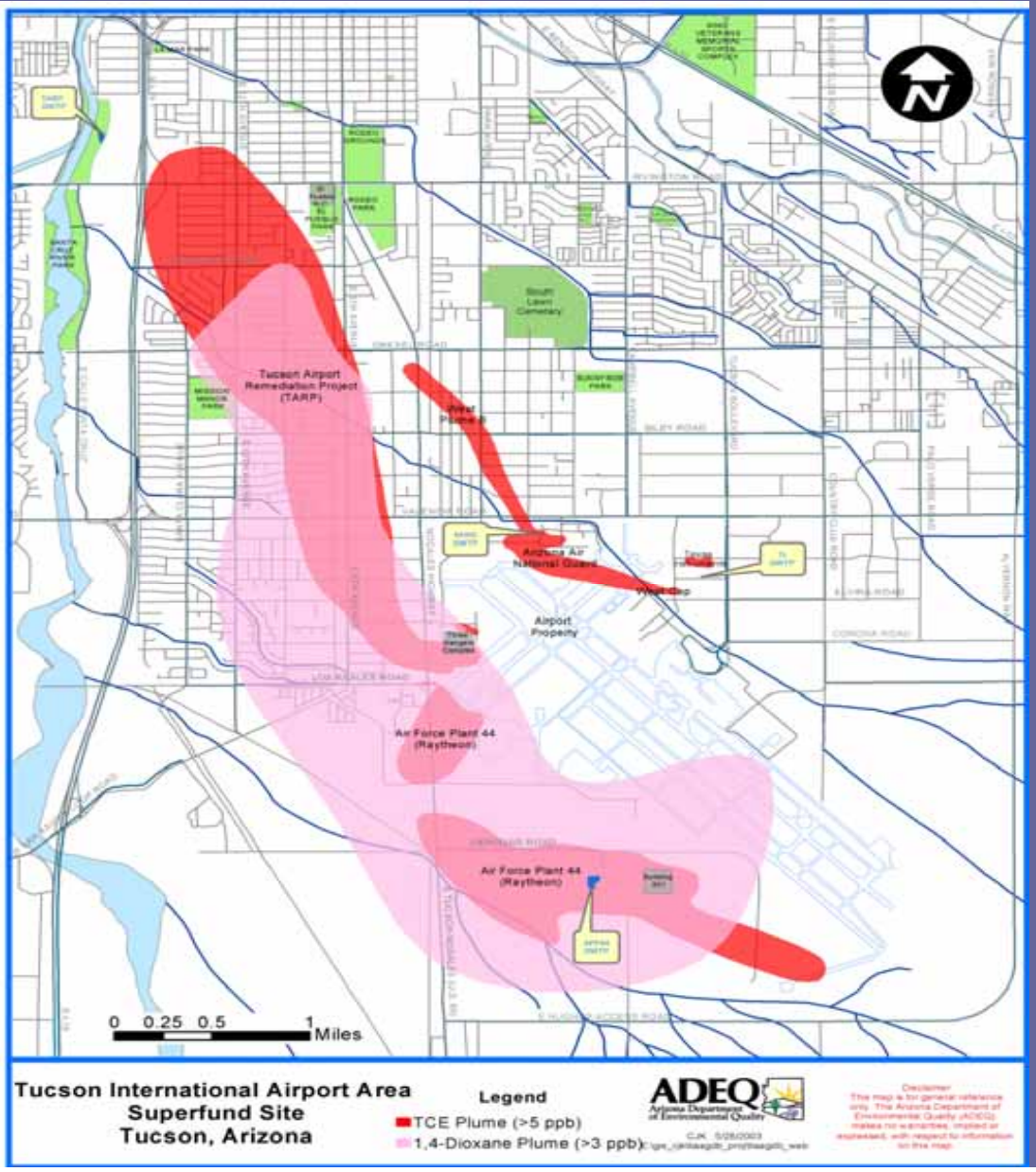
- Mass flux measurements have been made at several sites
- Most applications are in association with pilot studies
- Vast majority are endpoint analyses

End-Point Analysis of MFR-MR

[DiFilippo and Brusseau, 2008]



Full-scale Application: TIAA Site



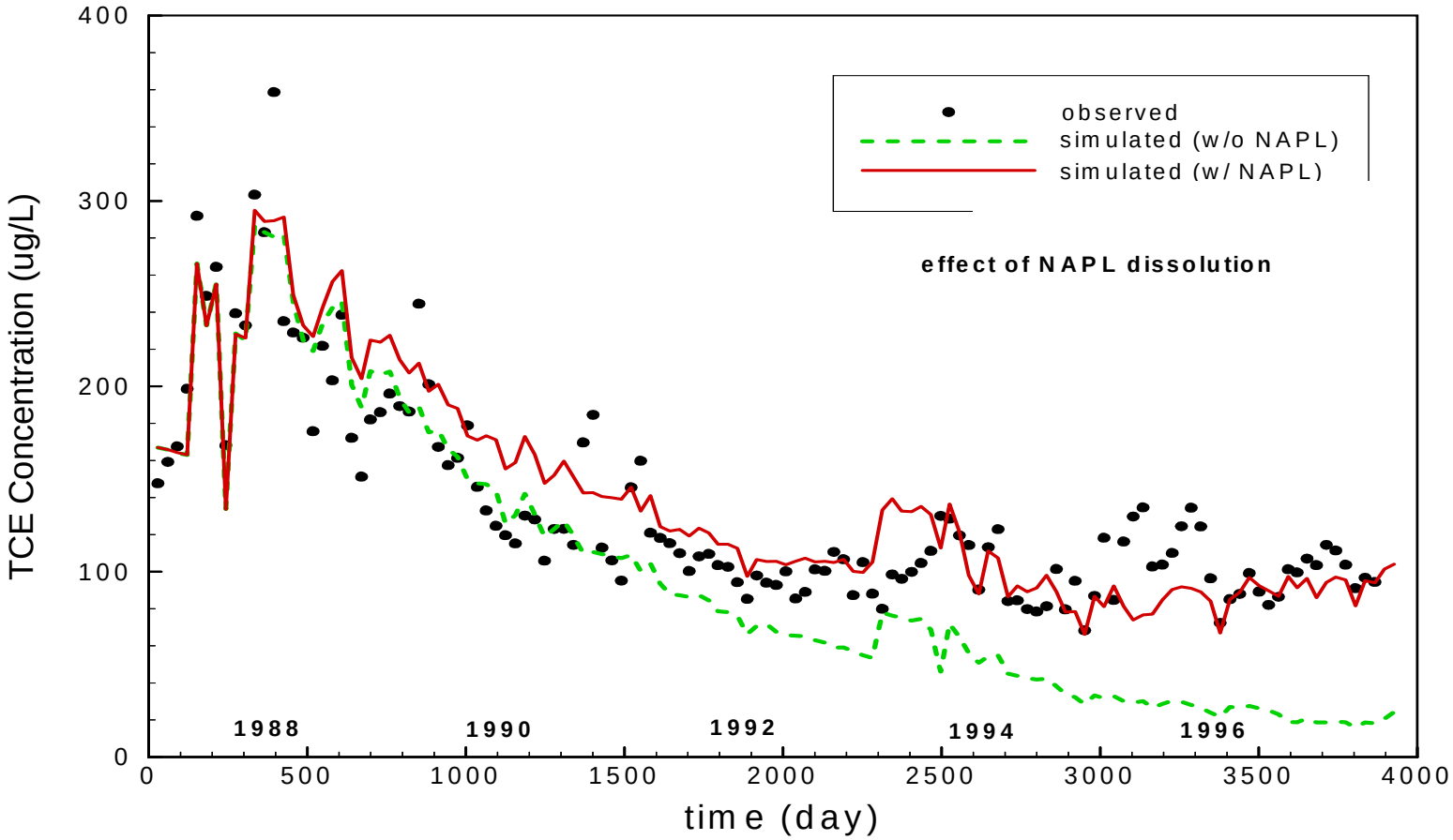
- **Site Remediation under Superfund and DOD-IR**
- **Multiple source zones and PRPs**
- **16 years of research at portions of the complex**

UA TIAA Study

- Site Characterization
  - Source-Zone TCE Mass Flux
  - TCE Spatial Distribution (areal, vertical)
  - DNAPL presence
  - Advective, Diffusive, Dispersive Transport
- Laboratory Experiments--- Mass Transfer Processes
- Mathematical Modeling--- Plume Behavior, S-Z Flux
- Pilot Source-zone Remediation Projects

Contaminant Elution

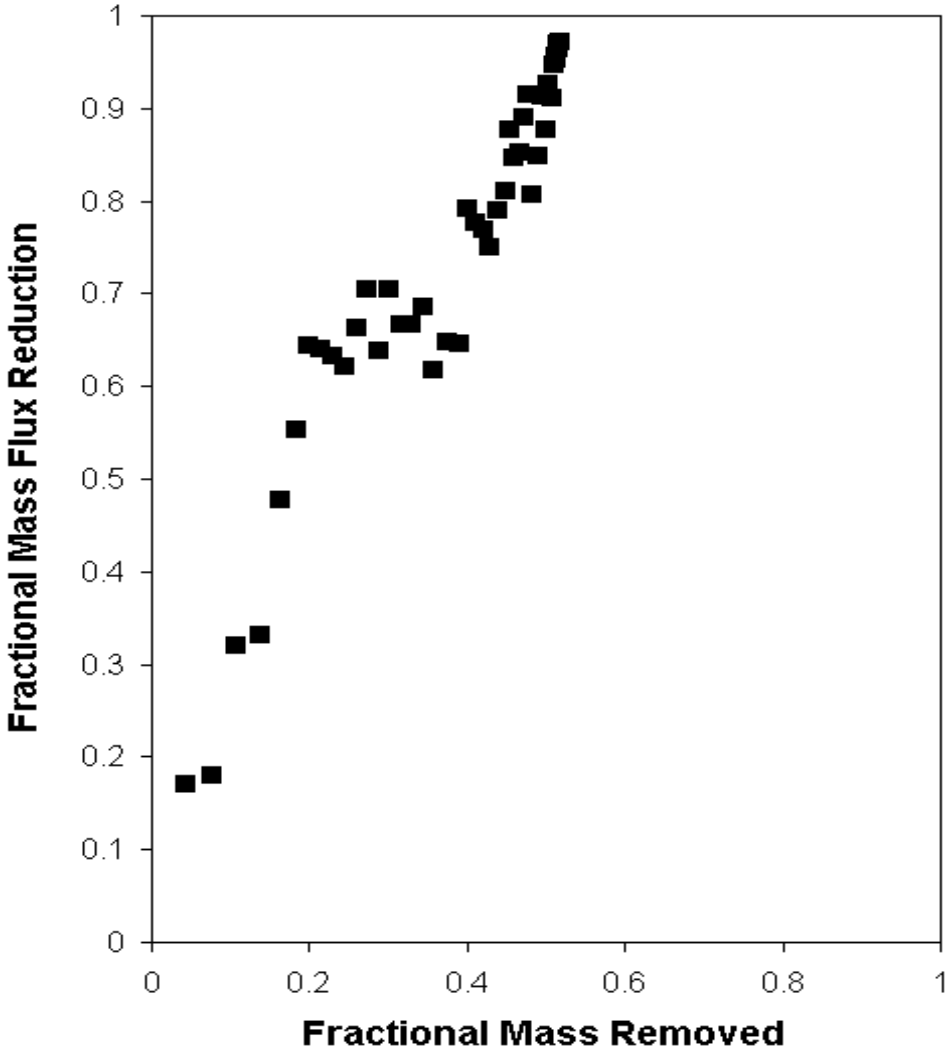
[Zhang and Brusseau, 1999]

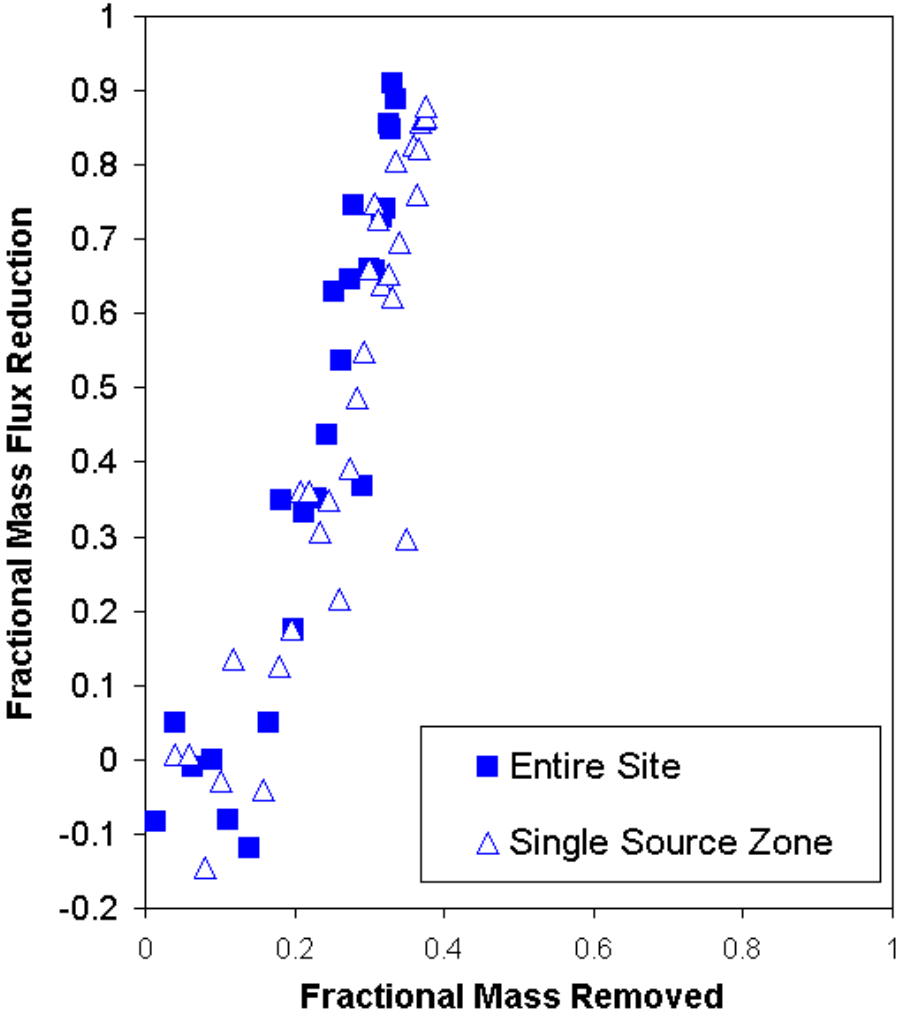


Comparison of the Simulated Influent TCE Conc. at Treatment Plant with the Observed Data

MFR-MR Results

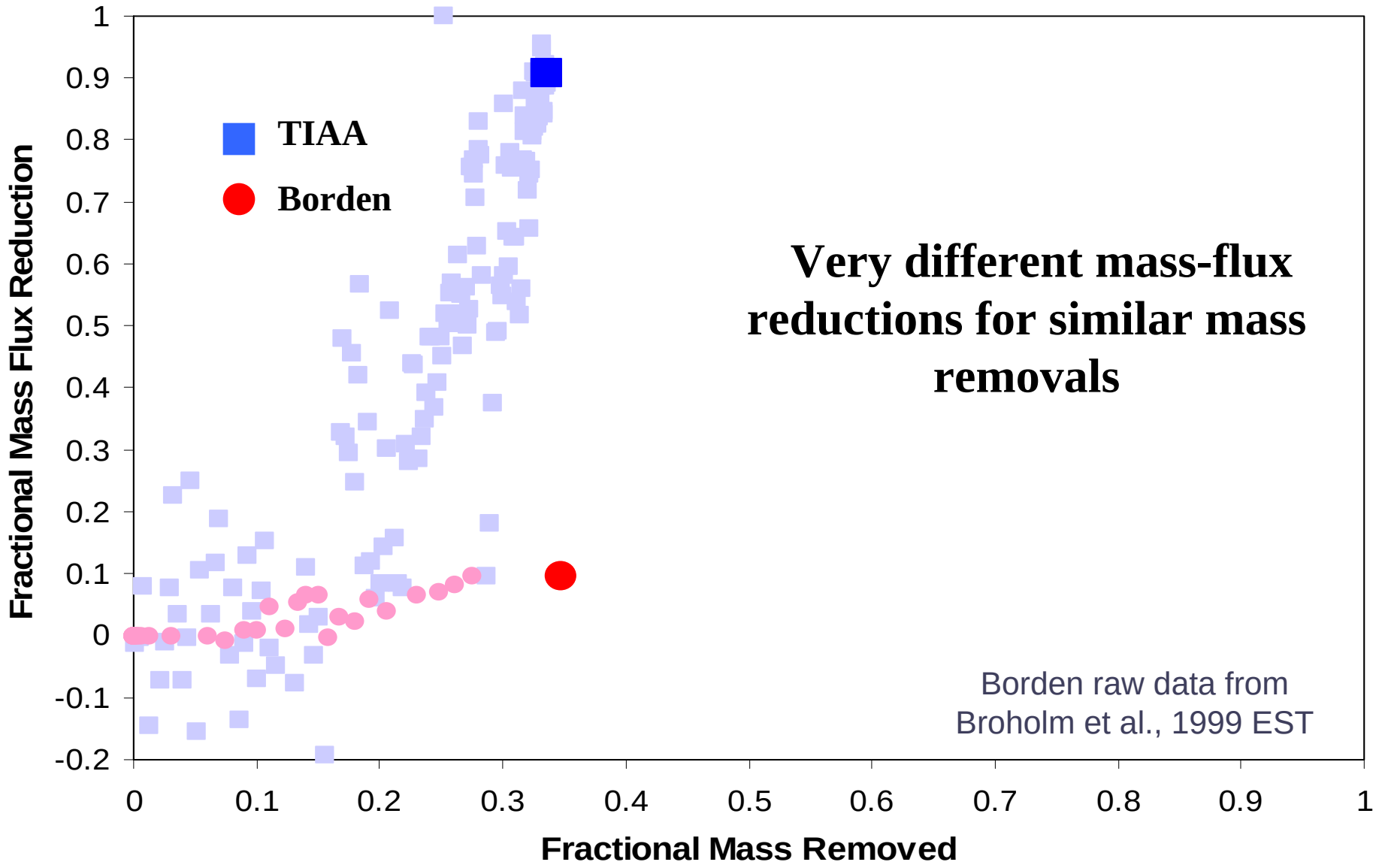
[Brusseau et al., 2007, DiFilippo and Brusseau, 2008]





Time-Continuous Analysis of MFR-MR

[DiFilippo and Brusseau, 2008]



Comparison of the Sites

- Differences
  - Source-zone Architecture (Degree of Heterogeneity, NAPL Distribution)
  - Source-zone Age
  - Other (temporal and spatial scales)

* Investigating these factors

Intermediate-scale Research

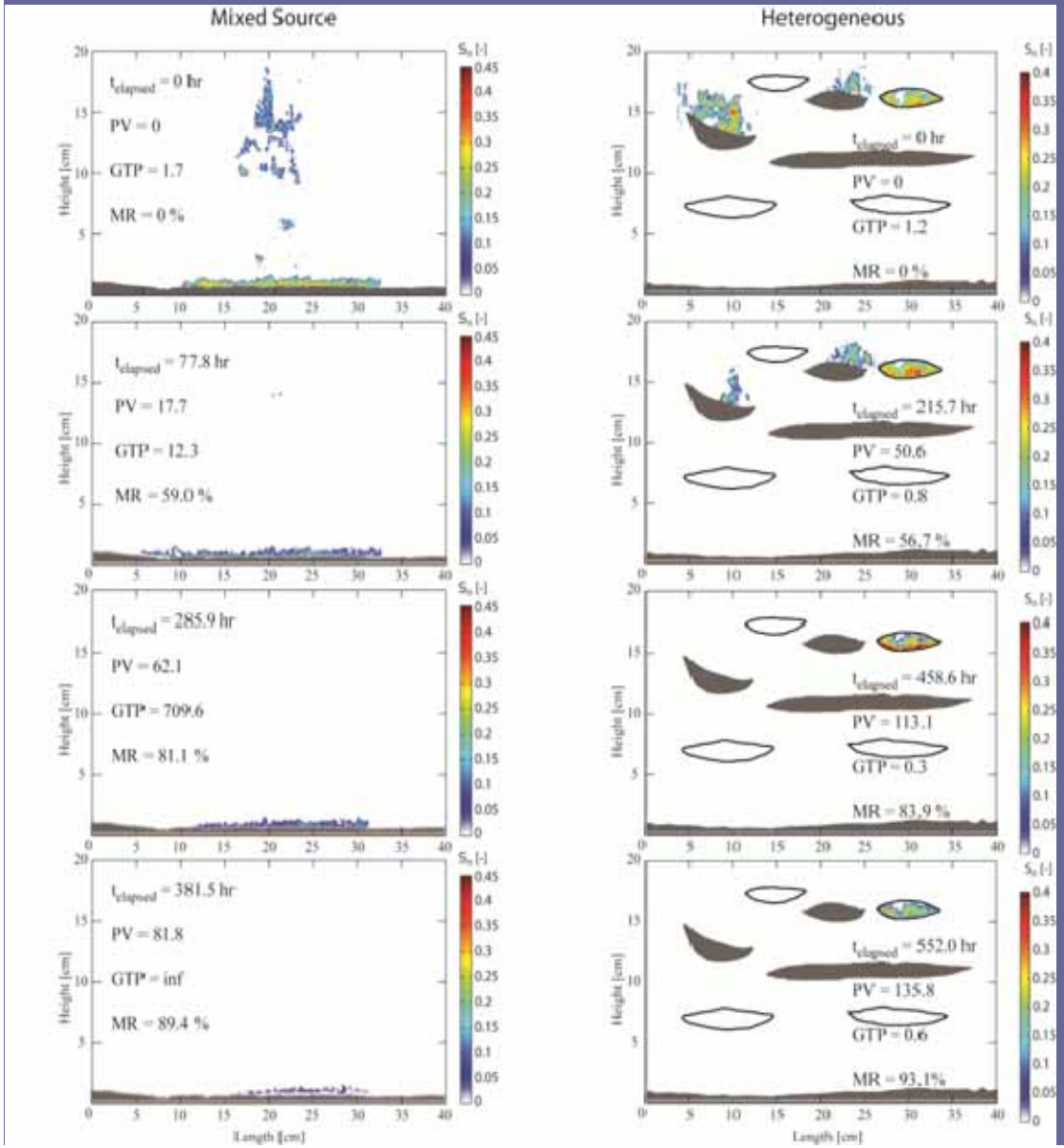
- **Conducted with Flow Cells**
  - Well-defined conditions

- **Develop DNAPL Source Zone**
- **Characterize Architecture**

  (Imaging; Tracer Tests)
- **Water Flush**

  (Monitor Q, C)
- **Simulate w/ Model**

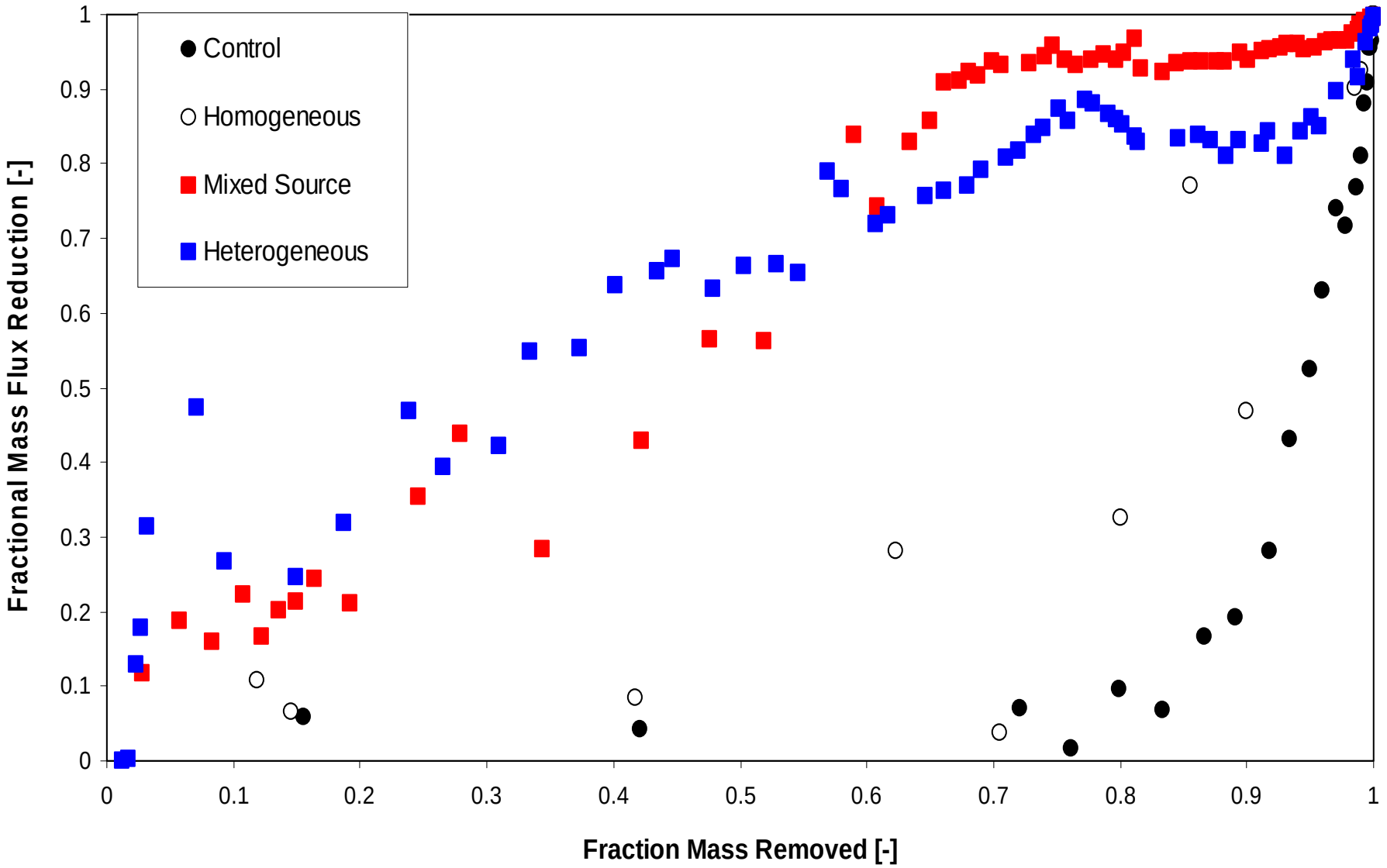
NAPL Distribution



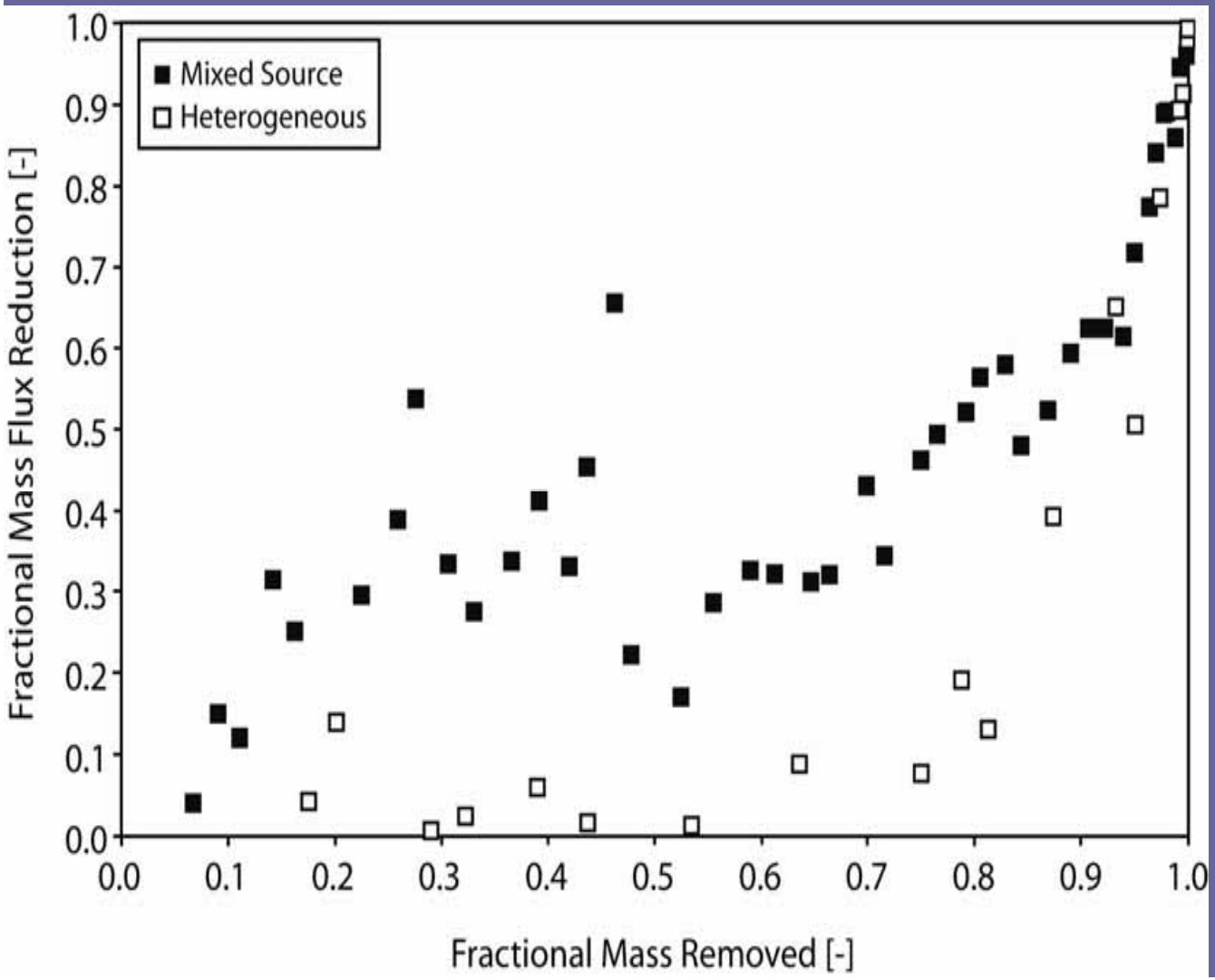
In-situ Measurement of NAPL Saturation

[Brusseau et al., 2008; DiFillipo et al., 2010]

Flow-cell Data



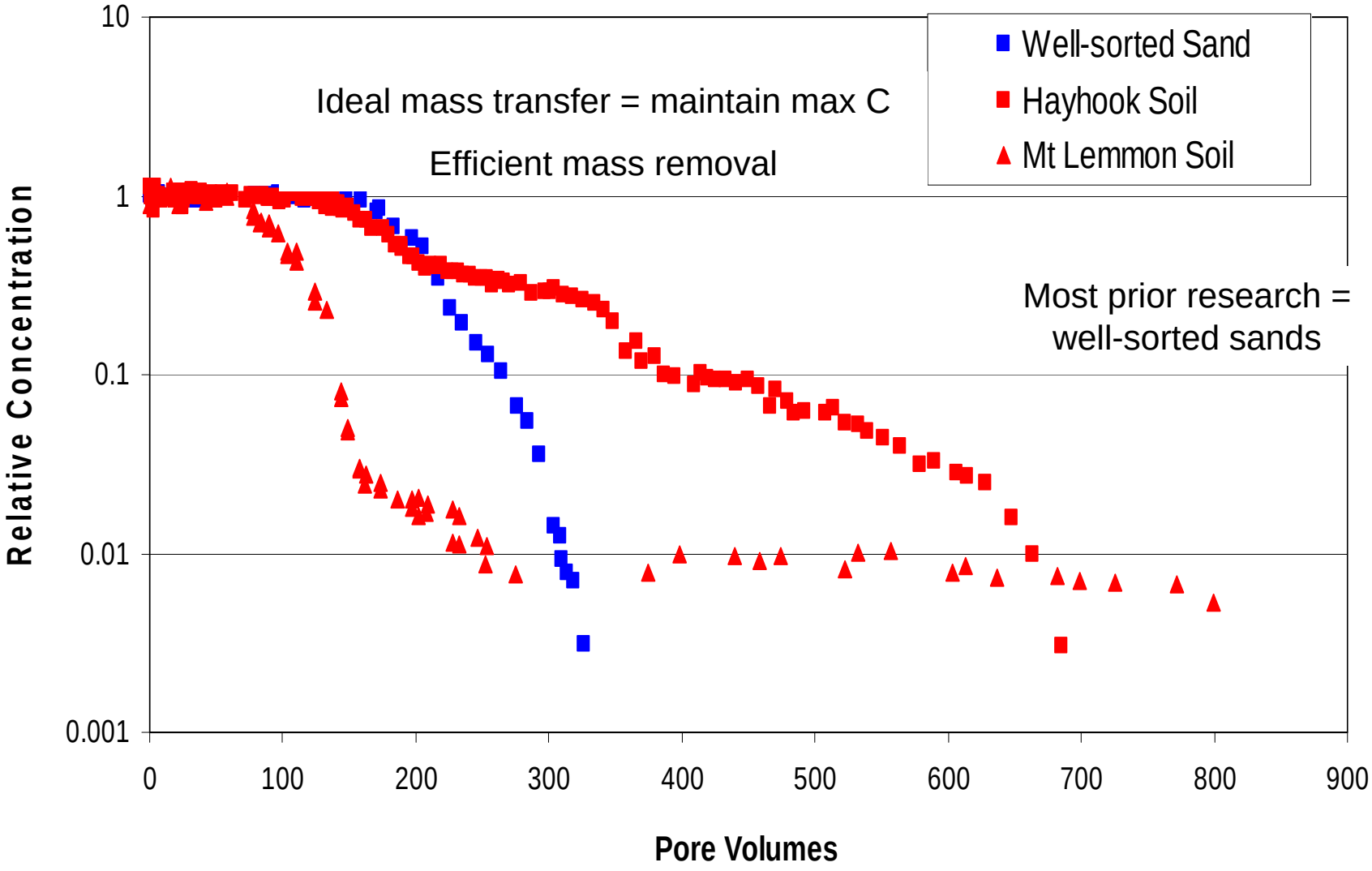
Impact of Source-zone Age



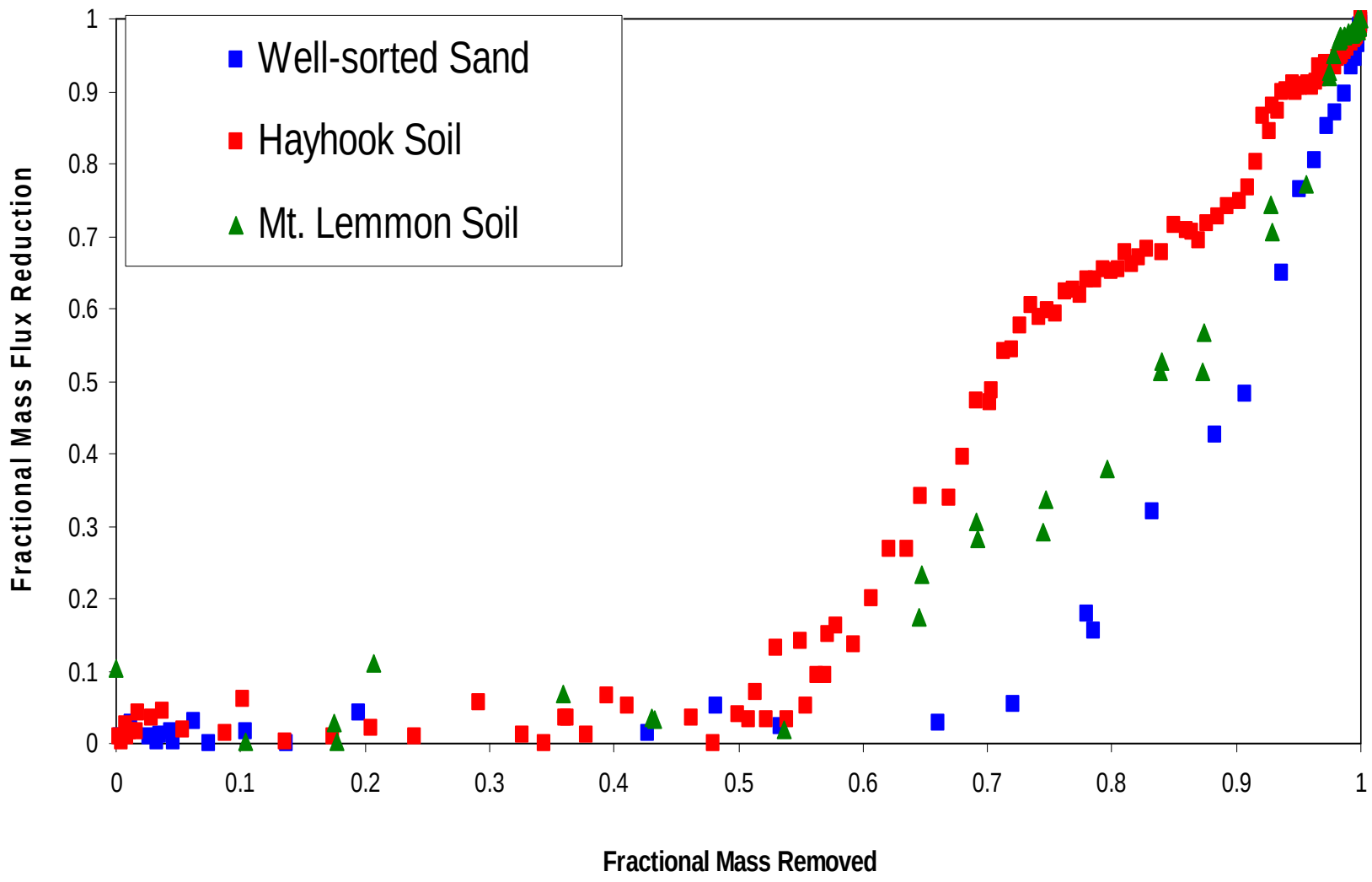
MFR-MR Re-analyzed After Removal of Readily-accessible Mass

Significantly Different Behavior

Column-scale Experiments

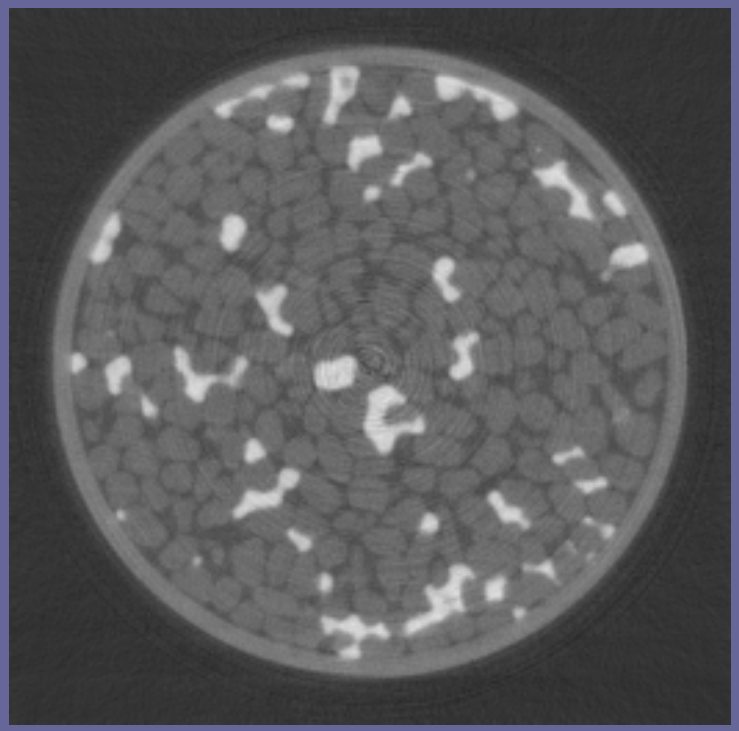


Column-scale Experiments



Pore Scale Research: Synchrotron X-ray microtomography

DOE APS facility



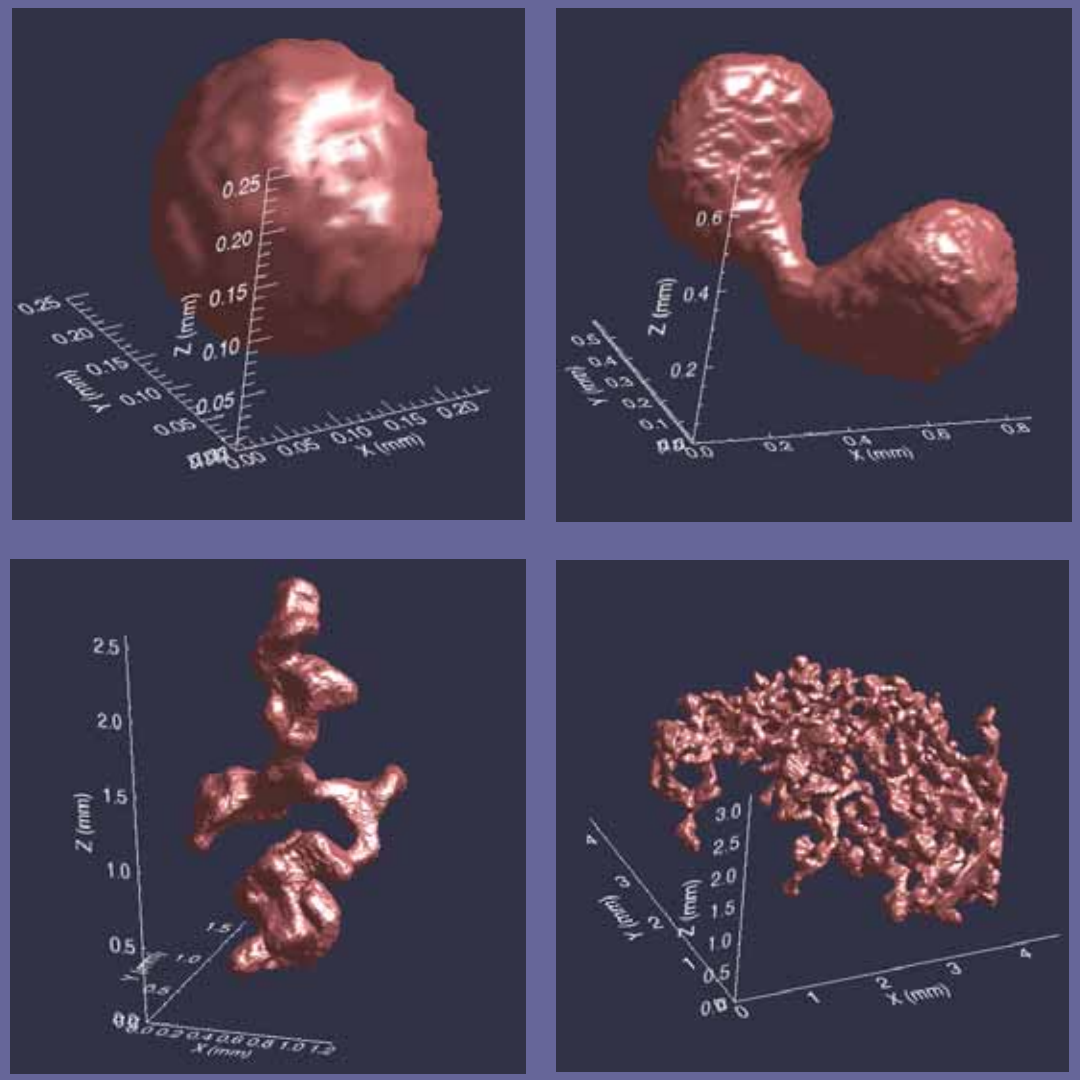
5 mm

NAPL = white

Water = Black

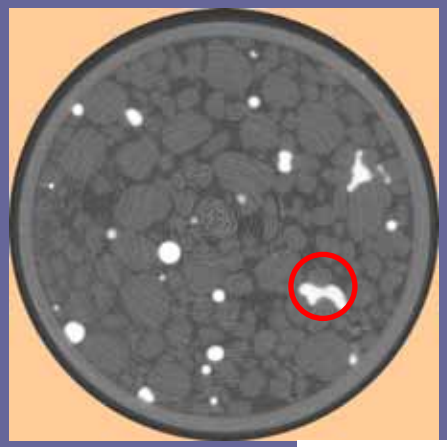
Solid = Gray

NAPL Blob Morphology

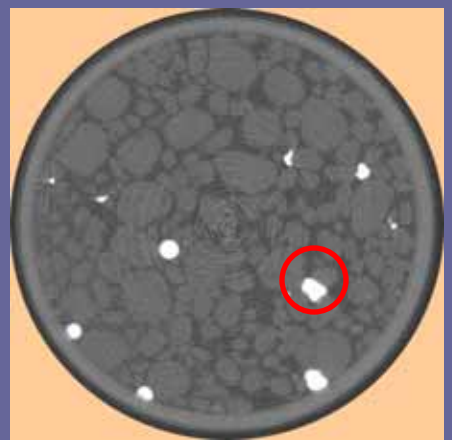


NAPL Dissolution Dynamics

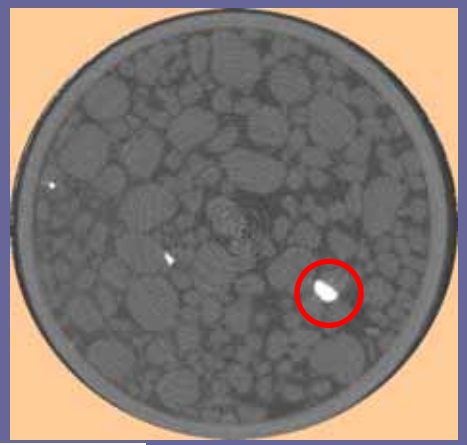
Initial

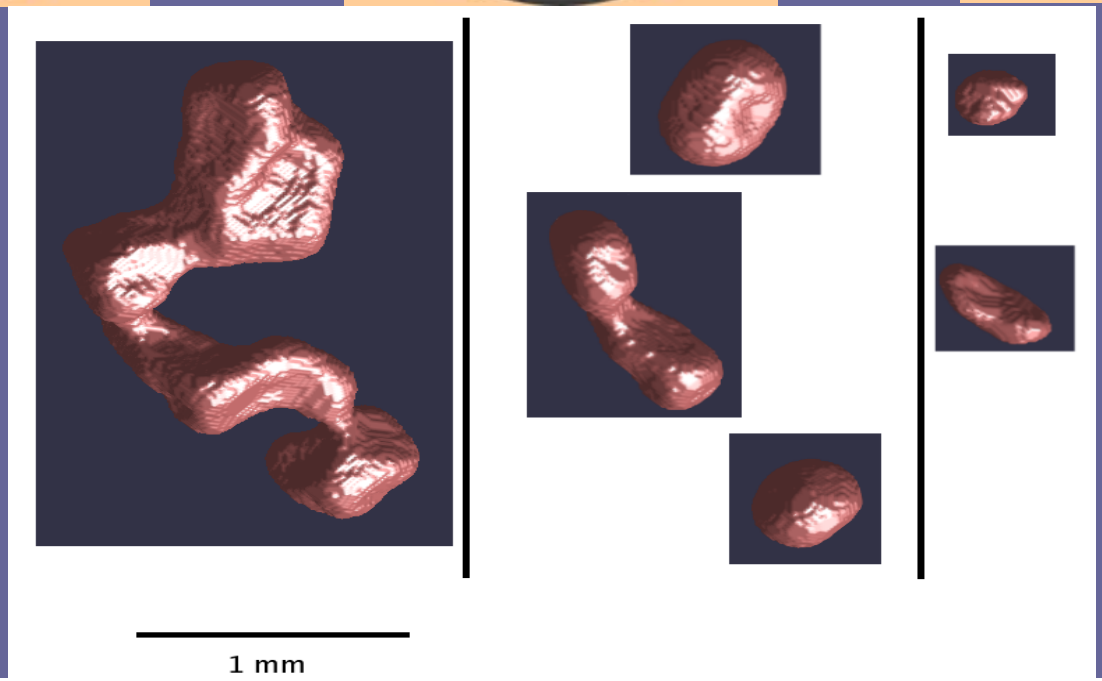


Time Step 1



Time Step 2





Summary

- MFR-MR Relationship Useful for Evaluating Behavior
- NAPL Distribution and Flow-field Dynamics are Key
  - Hydraulic Accessibility of NAPL
- Constraints to Full Characterization at the Field Scale
- What Site Information can Support Application

Acknowledgements

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References

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