In Situ Bioremediation (ISB) Work at Battelle/PNNL

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http://bioprocess.pnl.gov/isbio.htm

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Pacific Northwest National Laboratory (PNNL) and Battelle, Pacific Northwest Division (PNWD)

- PNNL located in Richland, Washington
- Operated for U.S. Department of Energy by Battelle
- Approximately 3,500 employees
- Breakthrough science & technology meeting key national needs
  - Fundamental Science
  - Environmental S&T
  - Energy
  - National Security
- Work for Private Clients as Battelle
  - Contract Research
  - Technology Commercialization

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Bioremediation at Battelle / PNNL

- DOE funded technology development
  - Computer-based i*n situ* bioremediation design tool (RT3D)
  - Laboratory experiments
  - Field demonstration
- Applied bioremediation at actual waste sites
  - DOE, DoD, and private clients
- Collaboration with universities and industry
  - Jim Petersen and Brent Peyton at WSU
  - IT Corporation
- Focus on remediation of chlorinated solvents *in situ*
  - Used for degreasing, dry cleaning, semi-conductor industry, etc.
  - PCE, TCE, DCE, VC (chlorinated ethenes)
  - TeCA, TCA, DCA (chlorinated ethanes)
  - CT

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Bioremediation is a Broad Field

- Defined: the use of microorganisms to transform chemical pollutants
  - goal is to make harmless substances (e.g., water, CO_2)
  - performed by bacteria or fungi
- *In situ / ex situ*
- Contaminants
  - Petroleum hydrocarbons, chlorinated solvents, metals
- Metabolisms: aerobic / anaerobic
- Contaminated media
  - Gas, aqueous liquid, non-aqueous liquid
  - Sediments, vadose (unsaturated) zone, saturated zone
- *In situ*: Accelerated bioremediation / natural attenuation

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In Situ and *Ex Situ*

- *Ex situ*
  - More control
  - Must excavate and transport
  - More worker risk
- *In Situ*
  - Less control (doesn't mean less effective)
  - Less worker risk
  - Less impact to site

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Pollutants (Contaminants)

- Petroleum hydrocarbons
  - Gas stations, oil spills
- Chlorinated solvents
  - Parts cleaning, Electronics industry, Parts degreasing
- PAHs, PCBs
  - Wood treatment, manufactured gas plants, transformer oil
- Metals
  - Acid etching, metal plating, mining runoff
- Radionuclides
  - Processing of nuclear material
- Effectiveness of bioremediation depends upon contaminant type, environmental conditions, and microbes involved

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Contaminated Media

- Gas
  - ex situ: biofilter, fluidized bed reactor
  - in situ: N/A
- Aqueous Liquid (surface water, industrial/municipal wastewater)
  - ex situ: CSTR, RBC, fluidized bed reactor
  - in situ: N/A
- NAPL
  - ex situ: N/A
  - in situ: bioslurping for LNAPL, not effective for DNAPL
- Sediments (soil and water of river, lake or marine waterway)
  - ex situ: land farming, soil composting, slurry reactors
  - in situ: natural attenuation, nothing very effective in general
- Vadose zone (soil)
  - ex situ: land farming, soil composting, slurry reactors
  - in situ: bioventing
- Saturated zone (soil and groundwater)
  - ex situ: land farming, soil composting, slurry reactors
  - in situ: accelerated *in situ* bioremediation, natural attenuation

Aerobic/Anaerobic

- Aerobic
  - uses oxygen as electron acceptor
  - applicable to petroleum hydrocarbons and some lesser chlorinated solvents
  - Generally more biomass and faster rates than anaerobic
- Anaerobic
  - uses alternate electron acceptor (e.g., nitrate, sulfate, iron, TCE)
  - requires electron donor (e.g., lactate, benzoate, hydrogen)

Accelerated ISB / Monitored Natural Attenuation

- Accelerated ISB
  - Stimulate growth by providing nutrients
  - Rates are faster (more biomass)
  - More labor and equipment
  - Can use indigenous microbes or exogenous microbes
- Monitored natural attenuation (MNA)
  - Indigenous microbes work without human intervention
  - Must show that NA can/is occurring
    - site characterization, predictive modeling, and monitoring
  - Need to monitor site for extended time period
  - Less worker risk because of minimal site activity

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Why Use Bioremediation?

- Benefits / disadvantages of bioremediation
  - Can obtain complete transformation to harmless chemicals
  - Typically lower cost, lower worker risk
  - "Natural" approach
- Must understand the process, it is complex
  - reaction
  - transport in aquifer
- Alternative technologies
  - pump and treat
  - in situ chemical oxidation

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What Does Battelle Do?

- *In situ* bioremediation (ISB) of chlorinated solvents
- Lab research of bioremediation mechanisms and rates
- Developed the RT3D code for reactive transport modeling
  - first widely-used multi-species reactive transport code
  - allows user-defined reaction mechanisms
  - publicly available tool; PNNL maintains certain capabilities
- Accelerated ISB system design
- Natural attenuation evaluation

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Sites Where Battelle Has Worked

- Accelerated ISB Design/Field Demonstrations
  - ***Naval Air Station Point Mugu***
  - Hanford
  - McClellan Air Force Base
  - Private Japanese site
- Natural Attenuation Evaluation
  - ***PPI Brooklawn site (on NPL)***
  - Dover Air Force Base

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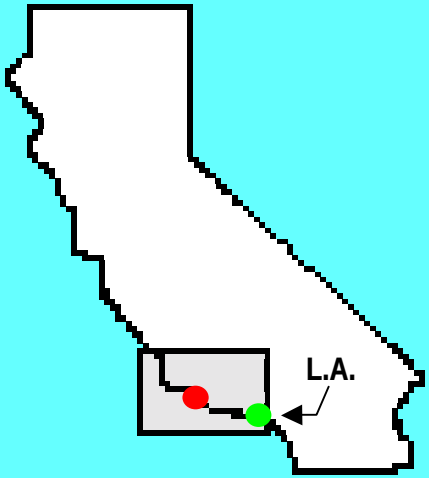
Naval Air Station Point Mugu

- Near Oxnard, California
- Former UST tank site
- TCE & DCE contamination
- Sandy aquifer with little natural groundwater flow
- Groundwater is similar to seawater
- Working with industrial partner: IT Corporation



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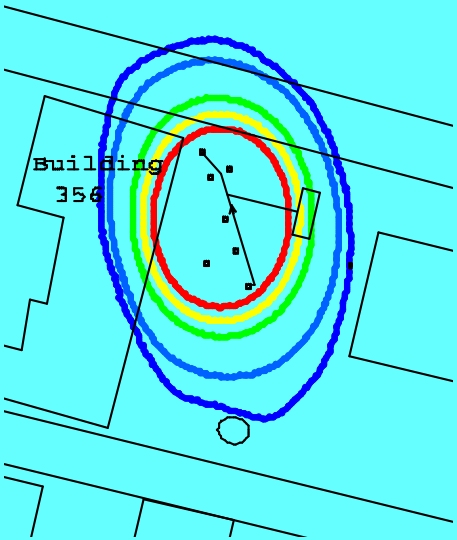
Estimated Initial Groundwater Concentration Contours

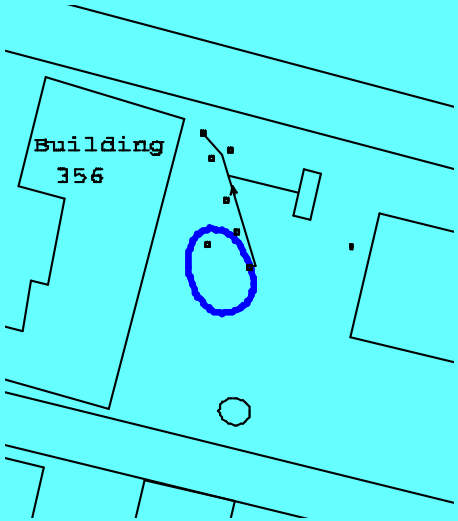
- Contour values of 5, 100, 500, 750, 1000 µg/L
- Pilot-scale test performed in center of plume

TCE



DCE

VC



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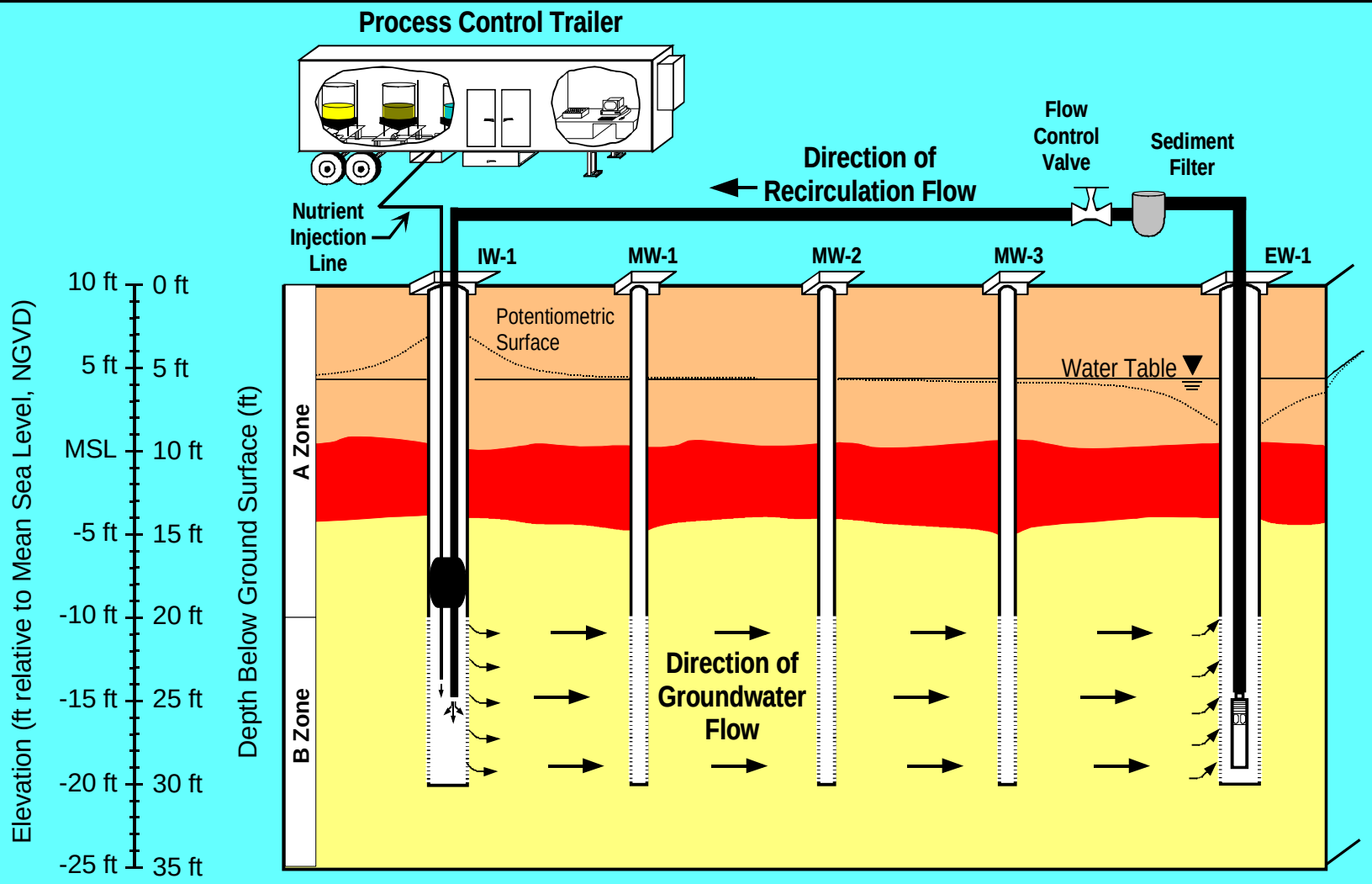
Recirculation System



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Bioremediation Process Control Trailer

- Mobile trailer for implementing accelerated ISB at either pilot-scale or full-scale

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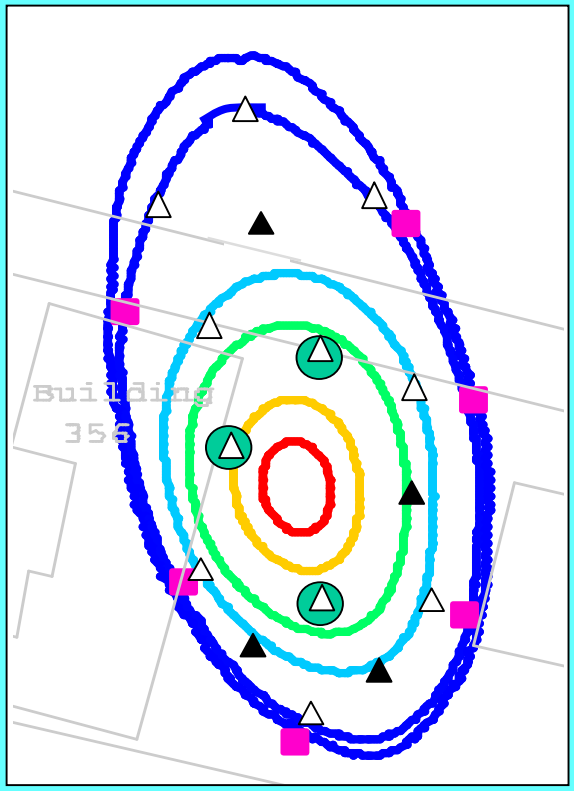
Path Forward at Point Mugu

- Anaerobic accelerated ISB has been successful in rapidly treating TCE & DCE and is slowly degrading VC
- Operate pilot scale aerobic treatment system
  - more quickly degrade VC
- Full scale treatment
  - sequentially anaerobic then aerobic



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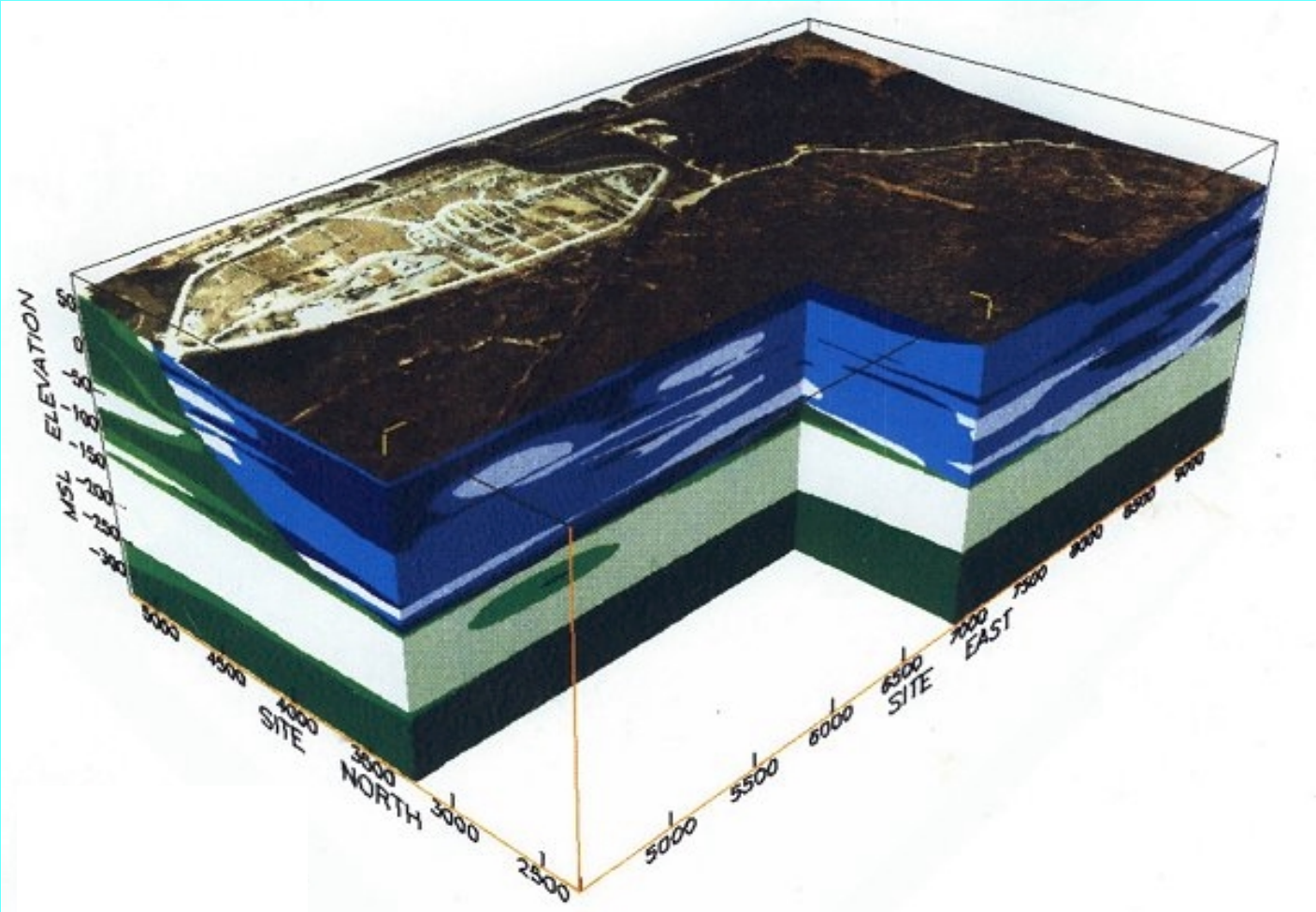
Petro-Processors Brooklawn Site

- CERCLA (Superfund) National Priority List (NPL) site
- Complex mixture of chlorinated ethenes and ethanes



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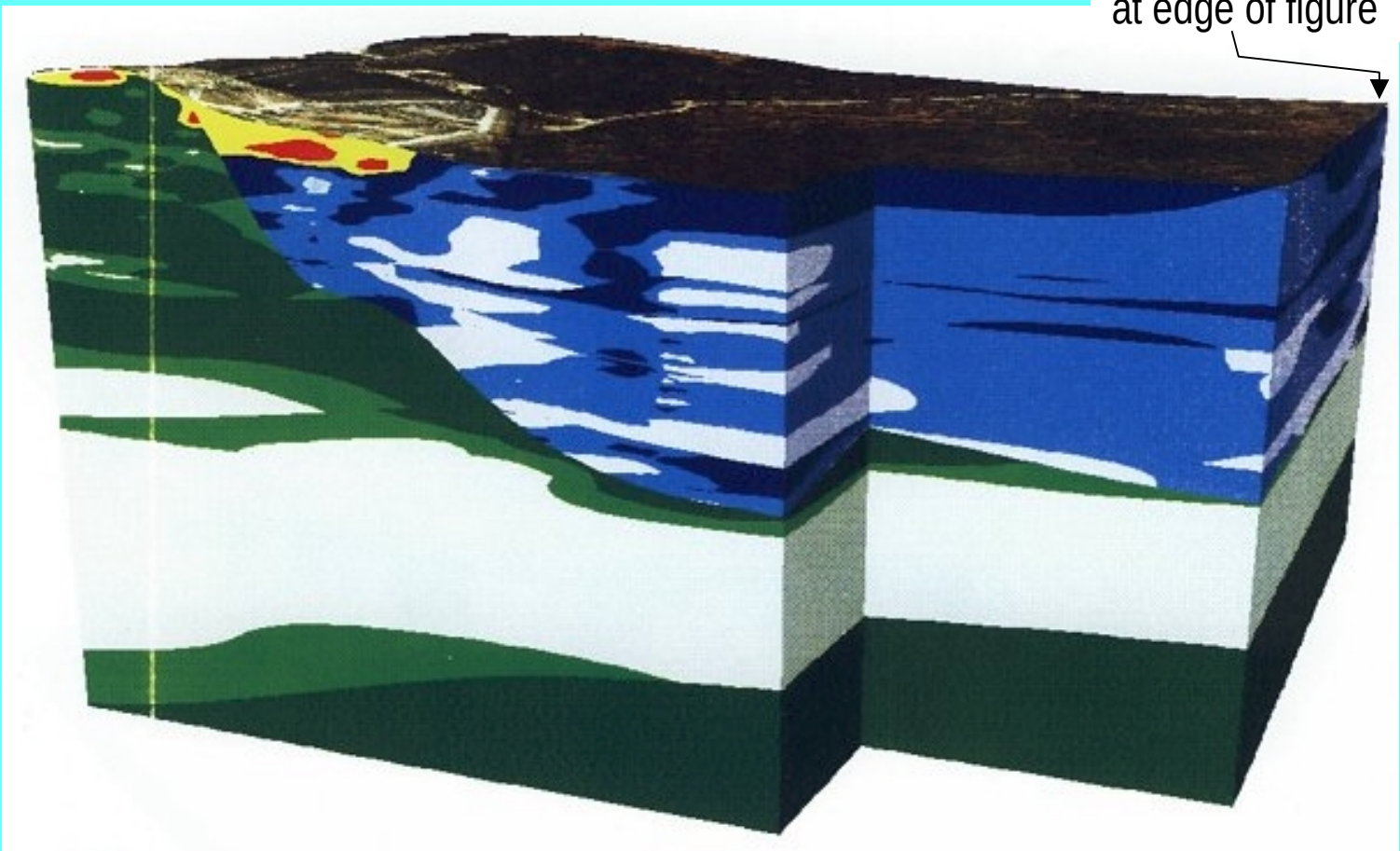
Cross Section of Brooklawn Site

- Waste lagoons (yellow/red) and lithology
  - Green is clay
  - Blue is sandy material underneath swamp



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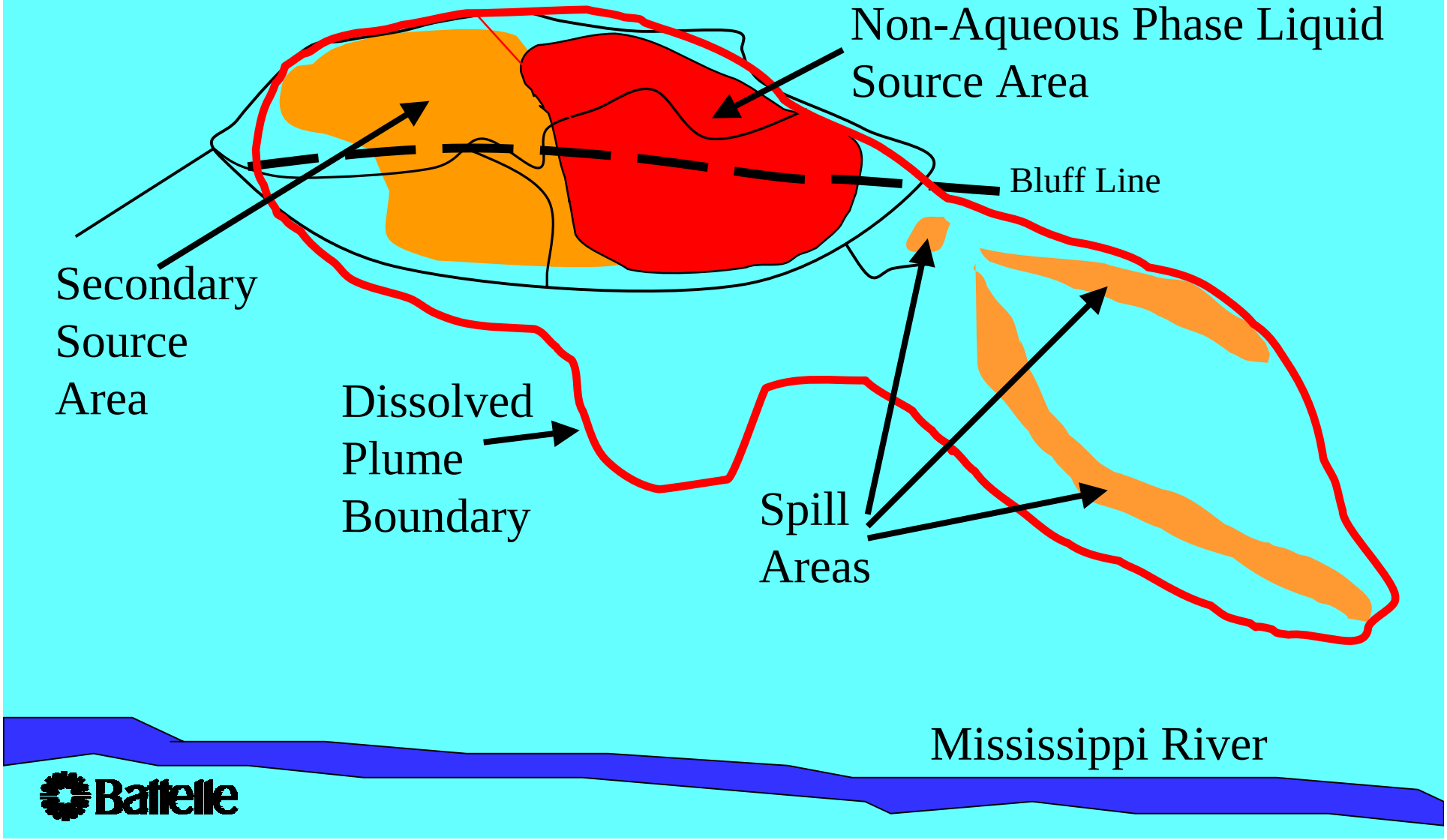
Conceptual Model of Lateral Contaminant Distribution



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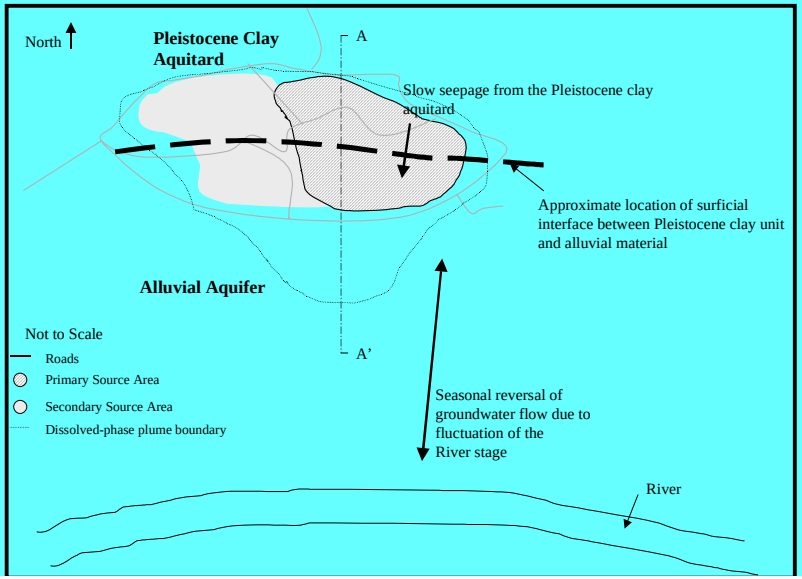
MNA Screening

- Screening per EPA Guidelines
- Geochemical data indicates natural attenuation processes occurring at site
- BIOCHLOR modeling predicts steady-state plume will be obtained



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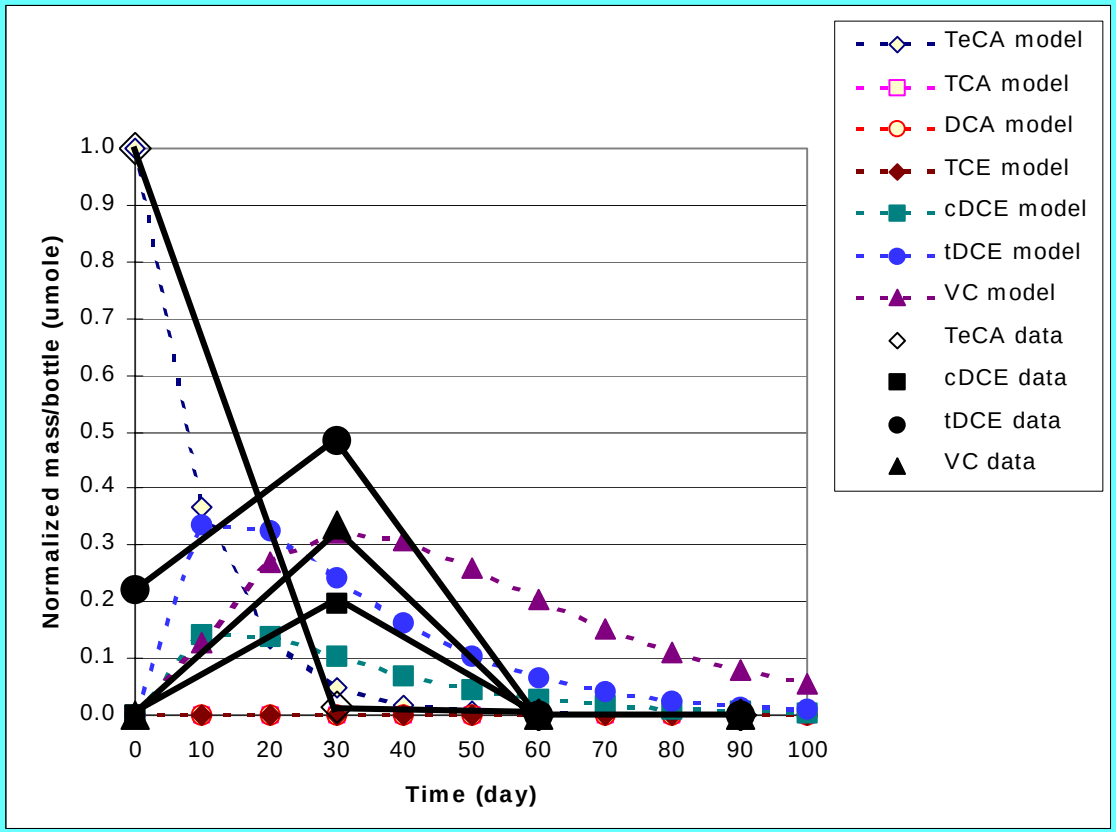
Collect Data to Support Evaluation of MNA

- Microcosm test
  - rates and pathways of degradation
  - similar to other results in the literature
- Incorporated into reaction package



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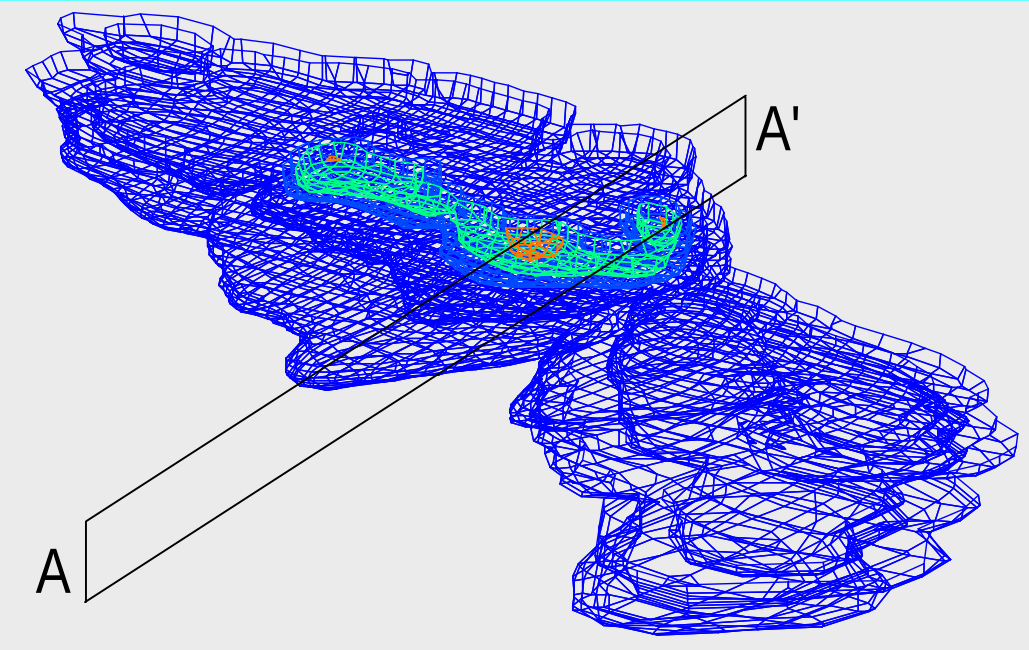
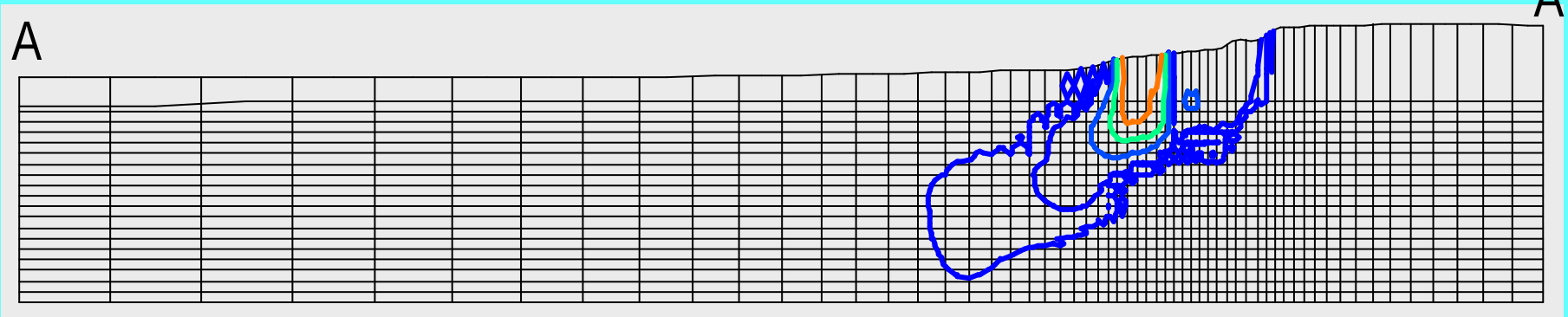
Predicted Plume Extent in 30 Years

- Vinyl Chloride
  - Outer contour at drinking water limit
- Mississippi river at location "A"





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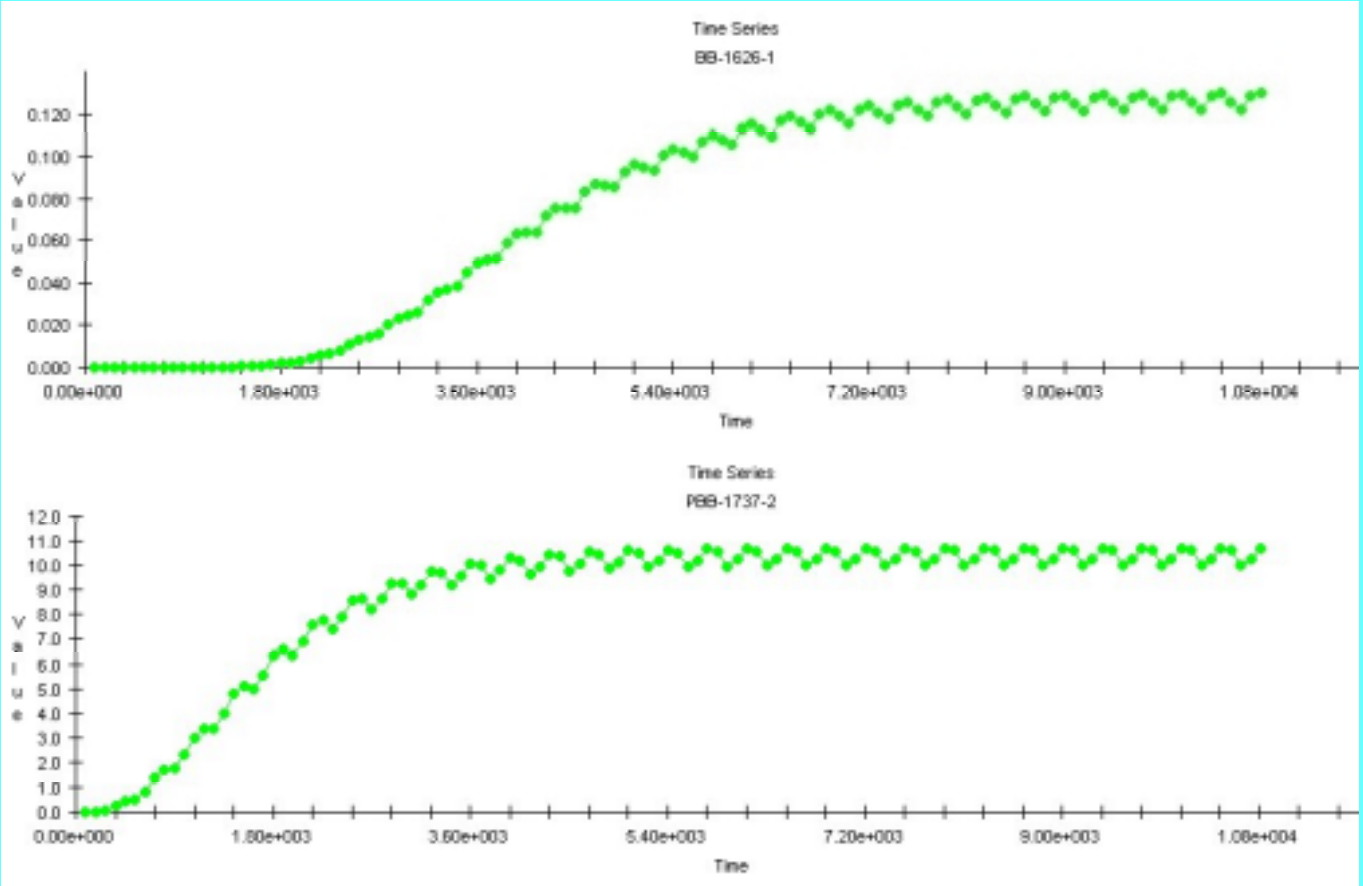
Predicted Concentrations at Specific Locations

- Predicts plume will come to steady state before impacting sensitive receptor (Mississippi River)



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Path Forward at PPI Brooklawn Site

- Screening was favorable
- Microcosm tests were very favorable
- Predictive simulations indicate that the plume will stabilize well before reaching the sensitive receptor
  - The contaminant mass entering the groundwater from the source lagoons is degraded to harmless products before reaching the Mississippi river
- Present results to EPA
  - Include long-term monitoring plan with sentry wells and evaluation of data 5-10 years in the future

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Summary

- Bioremediation useful in wide variety of situations
- Bioremediation is cost effective
- Bioremediation is protective of human health and the environment
- Battelle / PNNL at forefront of *in situ* bioremediation
  - Reactive transport modeling
  - Experience in accelerated ISB design and MNA evaluation
  - Work with industrial partners and clients to solve problems

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For More Information…

- PNNL/Battelle bioremediation web site
  - **http://bioprocess.pnl.gov/isbio.htm**
    - Copy of this presentation
    - Case studies/project summaries
    - References for further reading
- In Situ and On-Site Bioremediation: The Sixth International Symposium
  - June 4-7, 2001
  - Sheraton Harbor Island, San Diego, California
  - http://www.battelle.org/biosymp

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