Optimization and GSR Case Studies: Experiences from Applications

Dave Becker, USACE

Doug Sutton, HGL, Inc.

Federal Remediation Technologies Roundtable
General Meeting
November 6, 2014

Optimization, and Green & Sustainable Remediation (GSR) Practices Applied Throughout the Remedy Life Cycle

Presentation Outline

- Recent optimization and GSR focus
  - Remedial Strategy
  - Design and Implementation
- Remedial strategy examples
- Implementation examples

Recent Optimization and GSR Focus

- Biggest optimization and GSR gains have come from two primary areas
  - Remedial strategy
  - Design/implementation
- Both of these rely on…
  - Updated/improved CSMs
  - Planning
  - Good science and engineering

Remedial Strategy

- Consideration of the long-term prognosis for the site
  - Source/migration control vs. restoration
  - Reduce extent of contamination to reduce future risk/liability
  - Varies for small to large sites
  - Consideration of newer technologies
  - Modeling can help with the development of strategy
- Prioritization of remedy components
- Consideration of new data and refinement of CSM
  - Include in modeling
- Clear understanding of agency's programmatic goals

Financial and environmental resources are wasted when the strategy is not well planned or followed

Remedial Strategy, Key Concepts

- Management of the source
  - Reduce mass discharge from source to allow MNA or shorten timeframe of downgradient active remediation
    - Treatment
    - More effective source containment
- Reduce extent of contamination
  - Areal extent usually in dissolved phase
  - Reduce extent above standards
  - Back diffusion limitations to be considered
  - Reduction in potential future liability, risk

Remedial Strategy, Implementation

- The attainment of these interim goals requires consideration of:
  - Recent data – learn quite a bit from operating the initial remedy, must update the conceptual model
  - New technologies – both remedial and characterization
    - In-situ remedial technologies
    - Mass discharge, attenuation capacity considerations

Remedial Strategy, Implementation

- The prioritization of strategic components
  - Sequence of actions
  - Contingencies
  - Achieve improvements that are easy to implement first
  - Milestones for intermediate remedial goals
    - Modeling can help develop realistic milestones

Remedial Strategy: Agency Goals

- Experience is:
  - Many project teams don't have a clear understanding of the agency's programmatic goals
    - Focus often to minimize current costs
    - Agencies may want to reduce out-year costs with investment now
    - Trade-off – financial investment in more aggressive actions vs. remedial lifespan
    - Can be cheap, can be fast, can't be both
  - Agencies need to clearly communicate goals, priorities

Examples

- Large sites – ground water plumes in sandy aquifers
  - EPA Region 9 site, Arizona
    - Focus on attaining containment
    - Changes in external stresses shifted plume >1 mile cross gradient, increased risk
    - Recommendation - improve source flux capture, treat source area
    - Plume shift demonstrate concentrations can be reduced ≈ MCLs
    - Flow, transport modeling very important to assess actions
  - FUDS Sites, Nebraska
    - Initial containment remedy for large plume
    - Evaluating alternatives to reduce plume size
    - Model supporting decisions, to optimize the remedy

Examples, Continued

- Small Sites
  - EPA Region 7 Site, Missouri
    - Pumping to contain source flux
    - Source of continuing mass not clear
    - Recommend additional investigation under industrial building
    - Treatment of remaining source mass, possibly with ISCO
  - EPA Region 2 Site, New Jersey
    - Pumping for containment of toxic metal
    - Consider alternatives to irreversibly immobilize metal instead
    - Required additional characterization to understand complex geochemistry
    - Modeling done to support analysis

Examples, Continued

- Army Site, Missouri
  - Complex source areas in low permeability materials
  - Plumes extend to high permeability drinking water aquifer
  - Contractor continued somewhat ineffective containment
  - Updated conceptual model, updated ground water model
  - Recommended changes in strategy prior to new contract
  - Many suggestions adopted by performance-based contractor

Design/Implementation

- Filling critical data gaps in the CSM
- Use of high resolution data where appropriate
- Designing to the CSM
- Modeling
- Pilot testing

Financial and environmental resources are wasted when remedy design and implementation is generic

Design/Implementation Example #1 (Biobarriers)

- Three dry cleaner sites with PCE plumes in groundwater
- Biobarriers considered as part of FS, selected in ROD, or already implemented to address plumes
- Biobarriers are components of overall site remedy

- Non-optimal design leads to…
  - Extra injection events
  - Overuse (or underuse) of substrate
  - Additional cost and environmental footprint

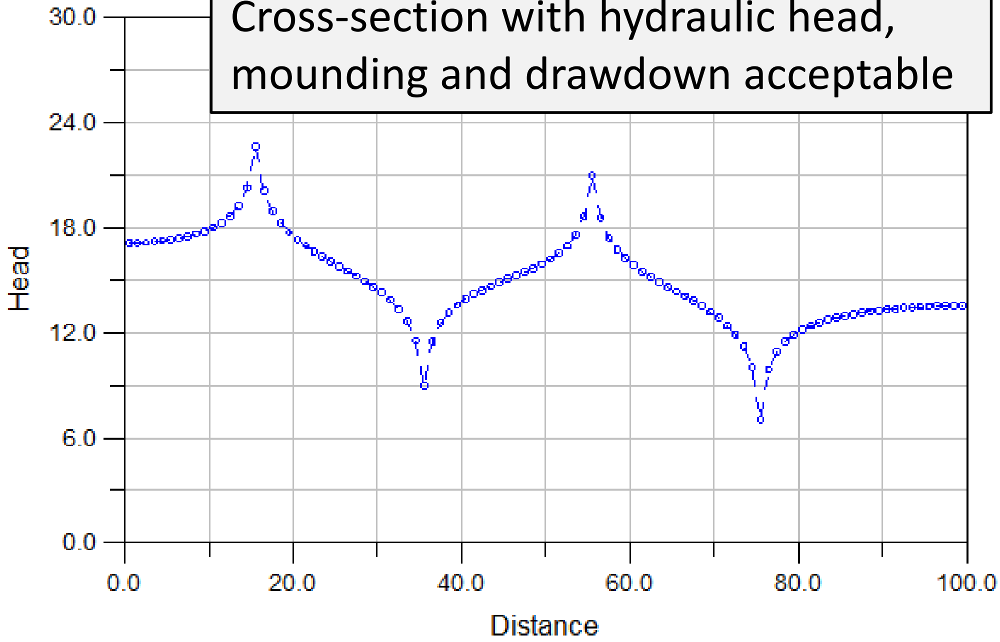
Design/Implementation Example #1 (Biobarriers)

- Use past experience and modeling to help with conceptual design or design
  - Sufficient data to understand aquifer depth interval and width that require substrate
  - Hydraulic conductivity (and distribution) needed to estimate well spacing, flux of contamination, residence time within reactive zone, and flux of competing electron acceptors
  - Substrate dose and delivery concentration
  - Site-wide modeling to estimate timeframes for cleanup between remedial components

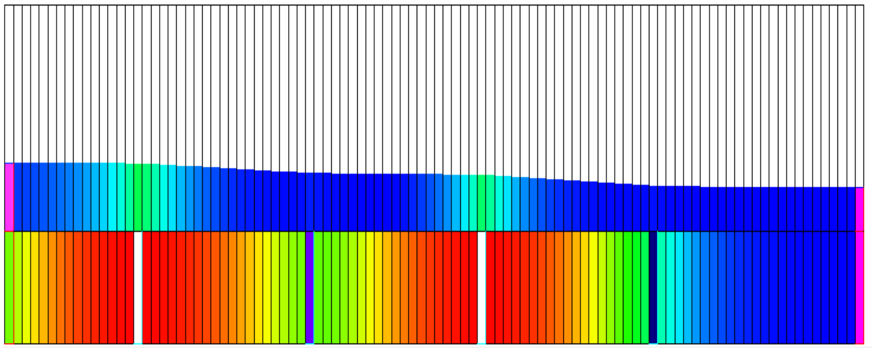
Design/Implementation Example #1 (Biobarriers)

- Model simulations help identify appropriate injection rates and well spacing
  - o Well yield
  - o Mounding
  - o Substrate distribution

Cross-section with hydraulic head, mounding and drawdown acceptable

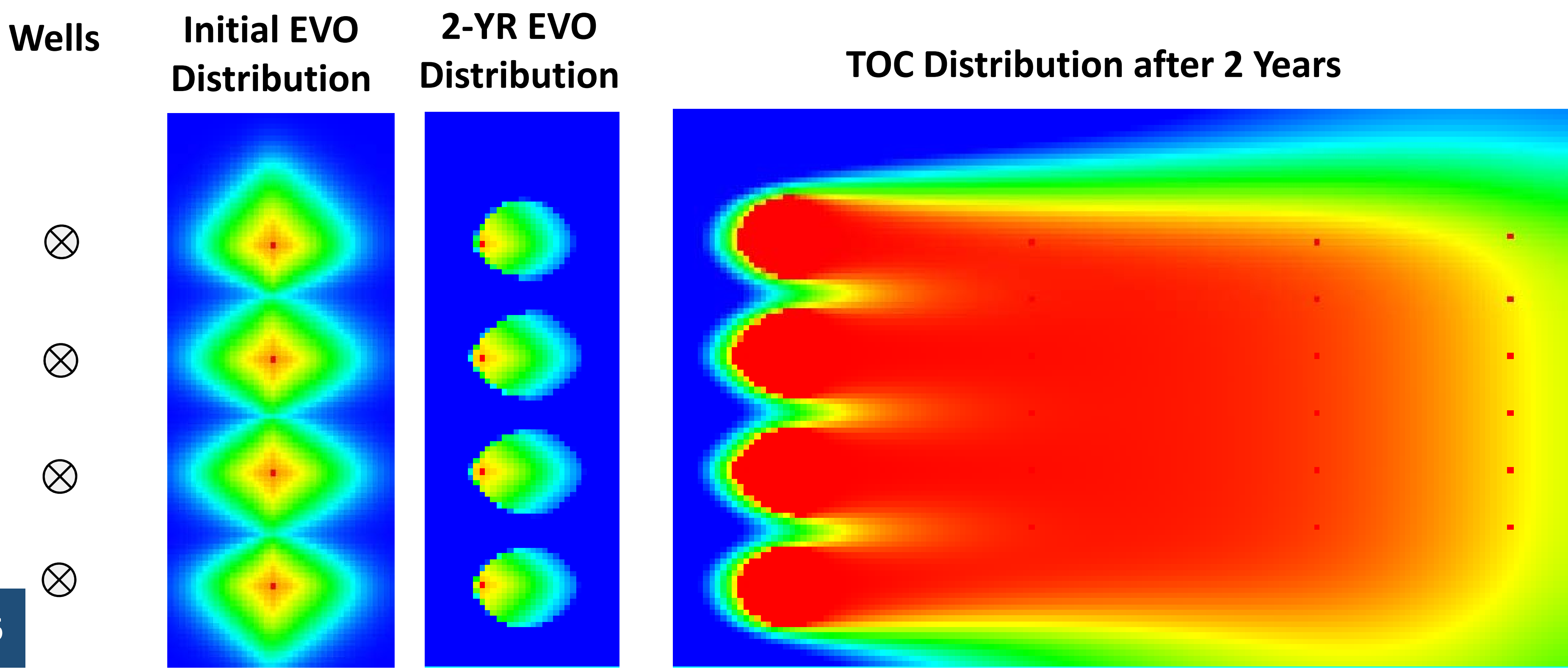


Cross-section with substrate distribution after 24 hours of injection.



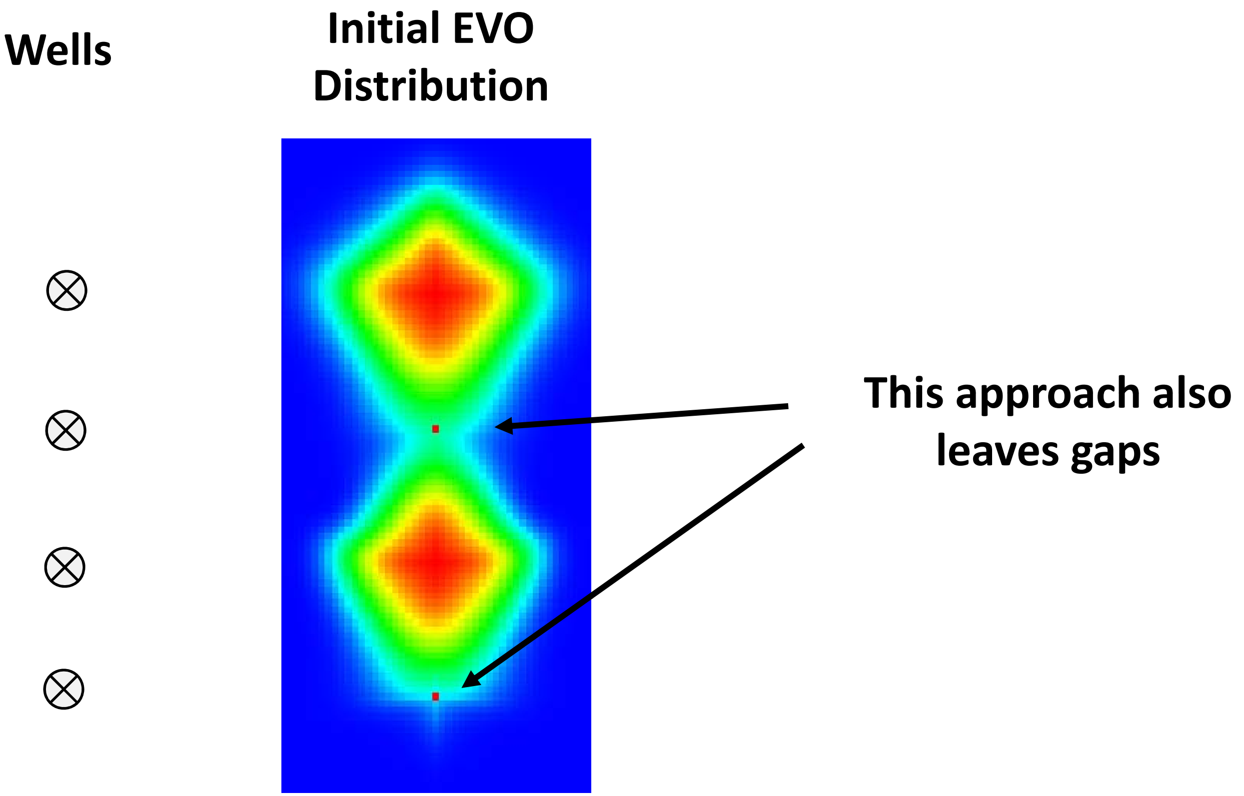
Design/Implementation Example #1 (Biobarriers)

- Model simulations help evaluate injection/extraction patterns
  - Option 1 – 4 wells each injecting 5 gpm of 0.5% solution for 24 hours



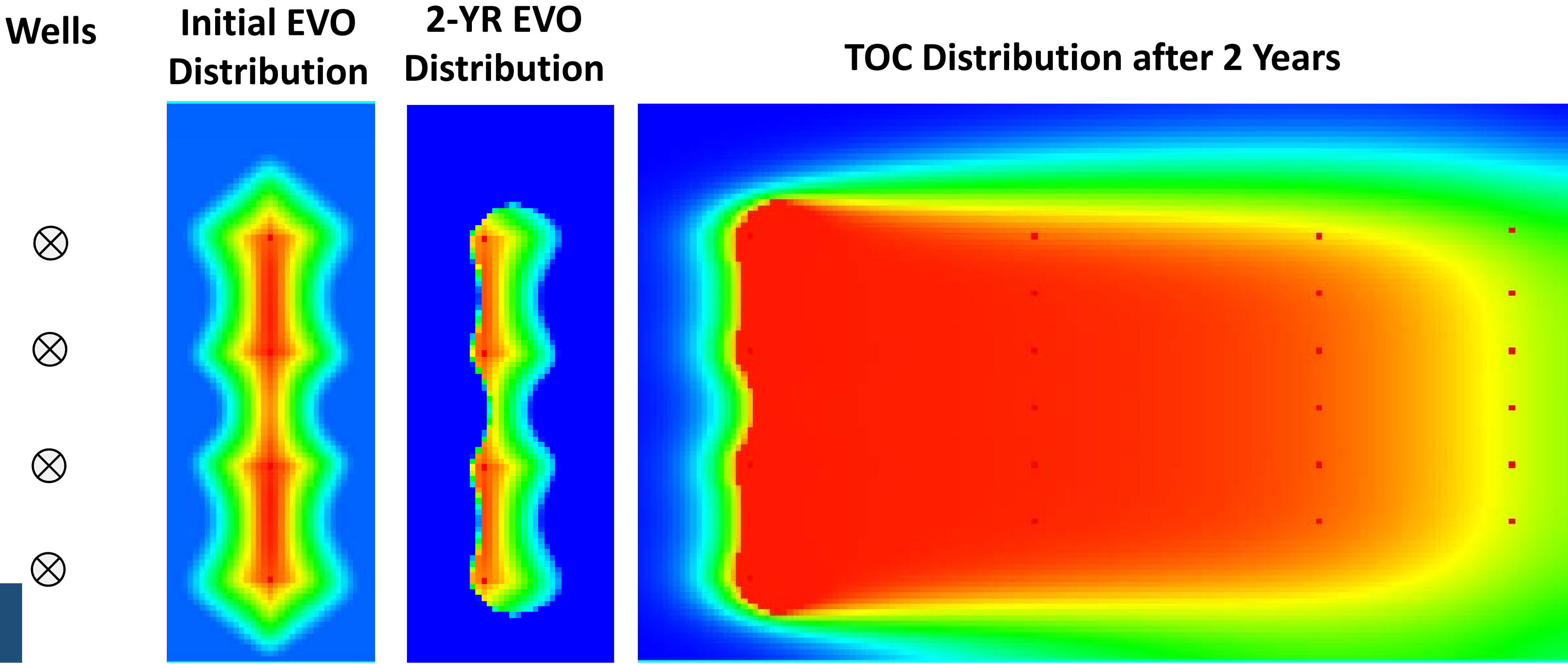
Design/Implementation Example #1 (Biobarriers)

- Model simulations help evaluate injection/extraction patterns
  - Option 2 – 2 wells each extracting 10 gpm and two wells injecting 10 gpm of 0.5% solution for 24 hours



Design/Implementation Example #1 (Biobarriers)

- Model simulations help evaluate injection/extraction patterns
  - Option 3 – 2 wells each extracting 10 gpm and two wells each injecting 10 gpm of 0.5% solution for 12 hours (wait 15+ days to stabilize) and then reverse injection and extraction for an additional 12 hours.



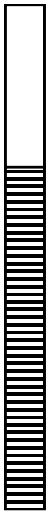
Design/Implementation Example #1 (Biobarriers)

- Cost and environmental footprint varies significant based on design and implementation

Option 1	Option 2	Option 3
• 30,000 gallons of potable water • Direct-push injections or new wells needed to fill gaps within 2 years	• 30,000 gallons of extracted groundwater • Gaps in barrier will develop within 2 years • No new wells or direct-push injections should be needed to fill gaps	• 30,000 gallons of extracted groundwater • No gaps for 4+ years

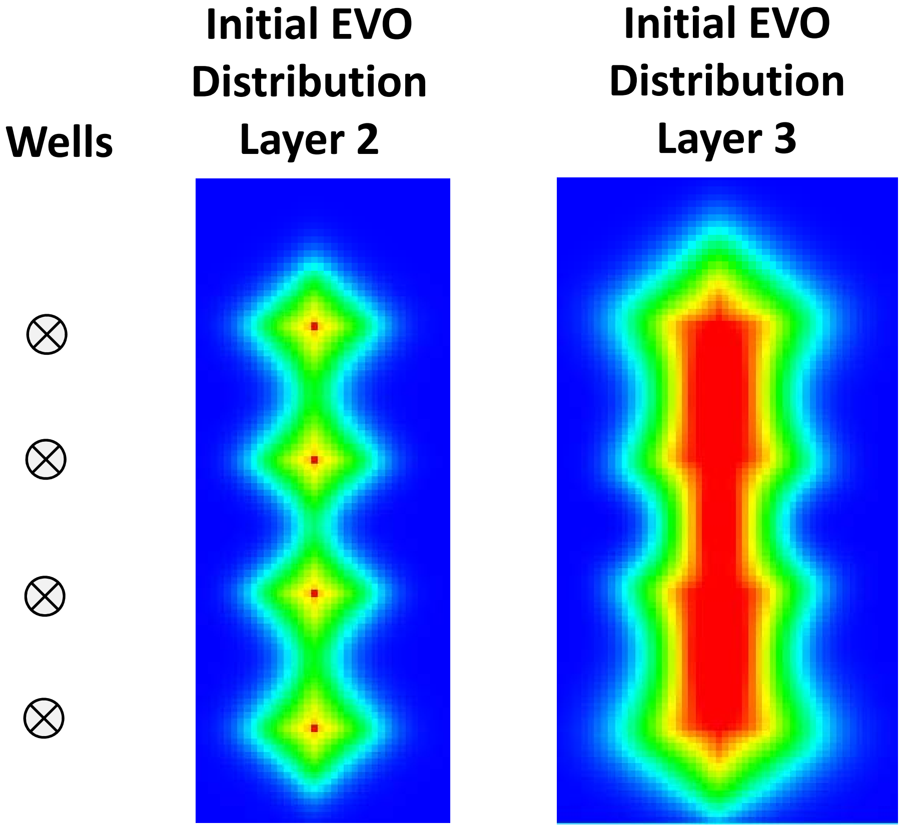
Design/Implementation Example #1 (Biobarriers)

- Model simulations identify affect of horizontal hydraulic conductivity distribution on reagent distribution



1	Saturated thickness = 5ft K = 2 ft/day
2	Saturated thickness = 5ft K = 10 ft/day
3	Saturated thickness = 5ft K = 30 ft/day

Gaps will develop in shallow aquifer, additional injections in same wells will “waste” substrate



Design/Implementation Example #2 (Enhanced In Situ Bioremediation of Coal Tar)

- Coal tar contamination with BTEX and naphthalene
- Treatment with oxygen and nutrient delivery
- Non-optimal design leads to…
  - Extra oxygen delivery
  - Longer system operation
  - Well fouling
  - Other issues

Design/Implementation Example #2 (Enhanced In Situ Bioremediation of Coal Tar)

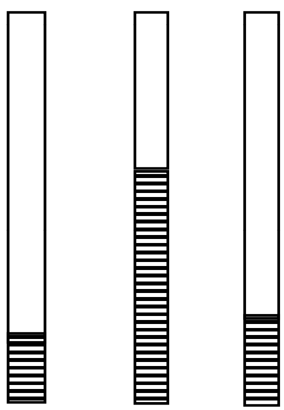
- Use past experience, modeling, and other analysis to help with conceptual design
  - Sufficient data to understand aquifer depth interval and width that require oxygen delivery
  - Evaluate oxygen delivery mechanisms and injection/extraction scenarios
  - Evaluate other amendments (e.g., nutrients and surfactants)
  - Evaluate dissolved iron concentrations over time to evaluate potential for well fouling

Design/Implementation Example #2 (Enhanced In Situ Bioremediation of Coal Tar)

Sparge Points – Limited ROI in deep layer. Wasted oxygen delivery to upper layers.

Injection Wells – Wasted oxygen delivery to middle layer.

Injection Wells – Optimal delivery.

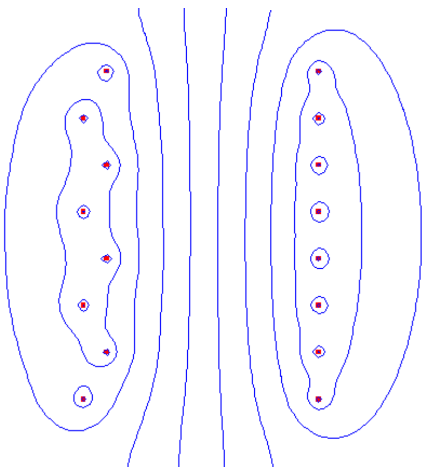


10 ft	Unsaturated Zone
10 ft	Saturated Zone. No NAPL impacts (zone of waste oxygen delivery)
5 ft	Saturated Zone. NAPL impacts (target for oxygen delivery)

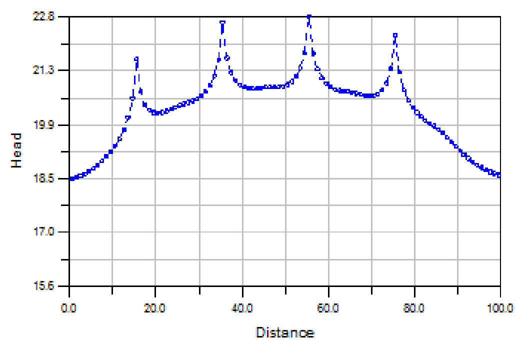
Design/Implementation Example #2 (Enhanced In Situ Bioremediation of Coal Tar)

- Model simulations help identify appropriate injection/extraction rates, well spacing, and other parameters

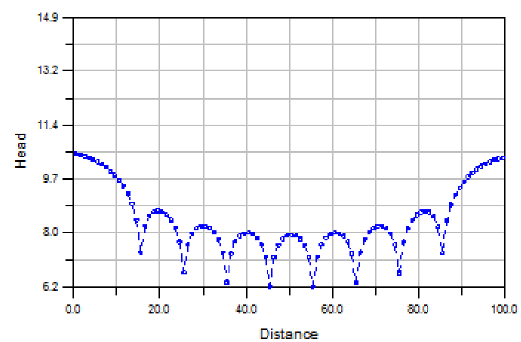
Injection **Extraction**



Mounding Near Injection

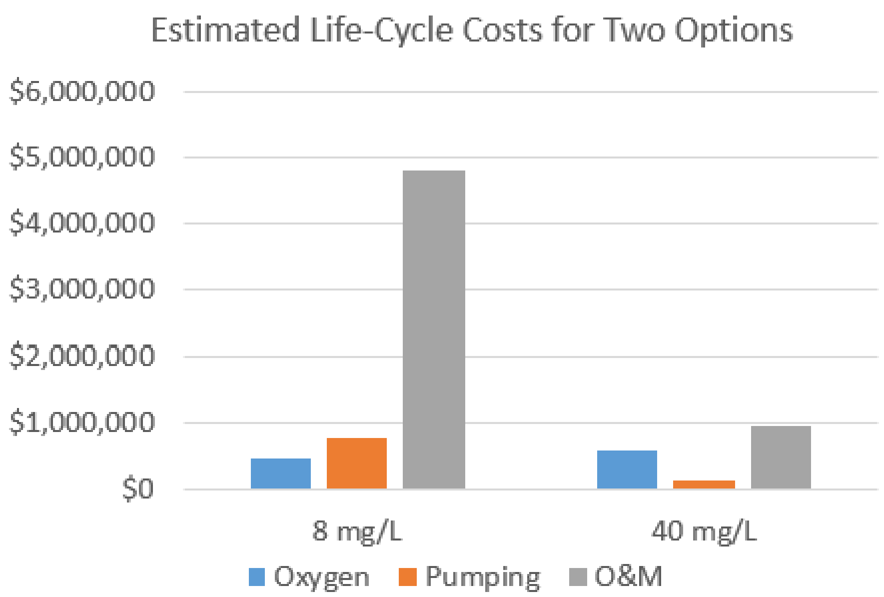


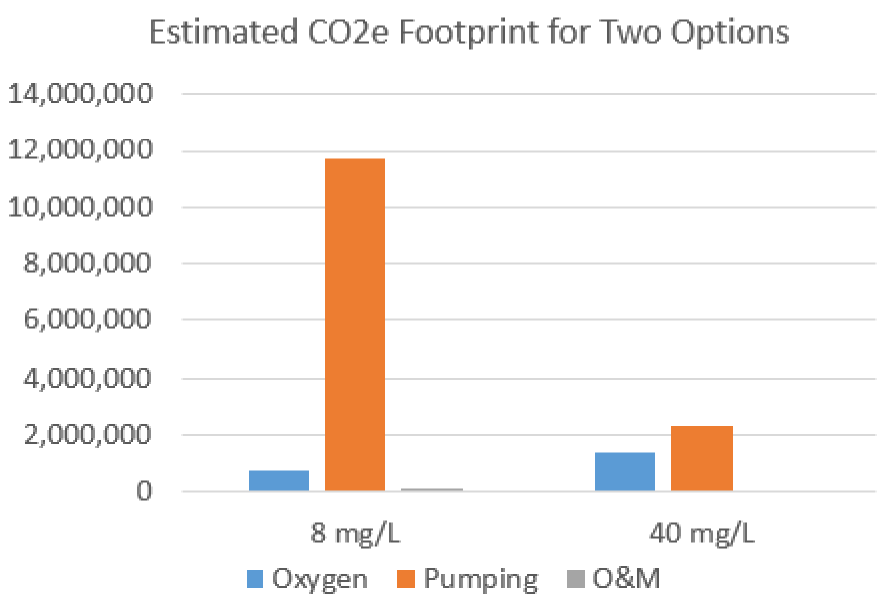
Drawdown Near Extraction



Design/Implementation Example #2 (Enhanced In Situ Bioremediation of Coal Tar)

- Evaluate oxygenation through
  - aqueous injection at 8 mg/L – using air for oxygenation
  - aqueous injection at 40 mg/L – using pure oxygen for oxygenation

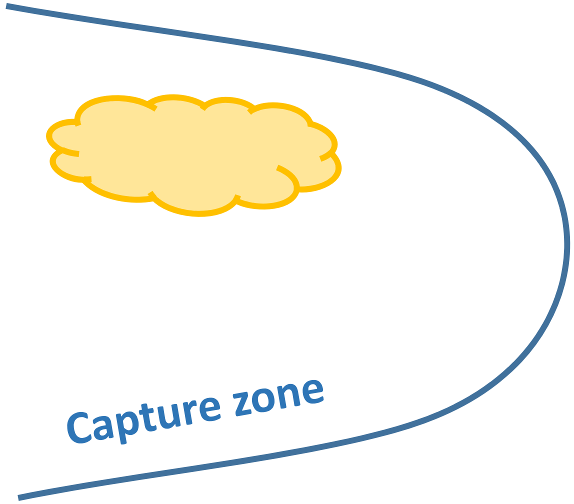




Other Examples of Design/Implementation

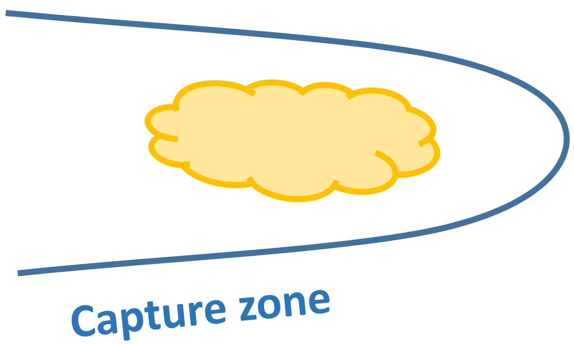
- Optimizing hydraulic capture (with or without use of modeling) can reduce extraction rates and improve GAC efficiency

Scenario 1 – 100 gpm
Influent concentration – 500 µg/L



47,500 kWh/yr
12,000 lbs GAC/yr

Scenario 2 – 50 gpm
Influent concentration – 1,000 µg/L



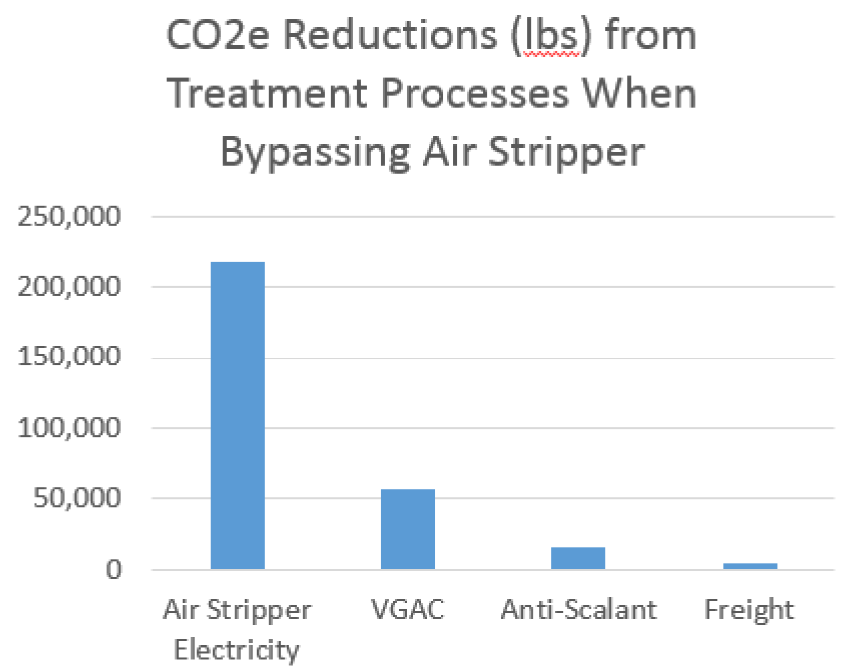
23,750 kWh/yr
7,800 lbs GAC/yr

Other Examples of Modeling Applications During Optimization

- Case 1 – Evaluate the potential for deep water supply well to be impacted by site-related contamination. Evaluate particle traces, contaminant mass flux, and dilution between stratigraphic units.
- Case 2 – Evaluate a historic conceptual model that high water supply well yield was the result of native backfill in the well annulus that connected well screen interval to productive shallow interval.
  - Annulus could only provide 5 to 10 gpm of the 300 gpm.
  - Modeling with sensitivity analysis helped confirm the water supply well could reasonably extract 300 gpm from intermediate and deep aquifer intervals.
  - Conceptual model for contaminant transport should not assume high volumes from annulus.
  - Modeling also helped evaluate potential plume extent to guide additional monitoring well installation.

Other Examples of Design/Implementation

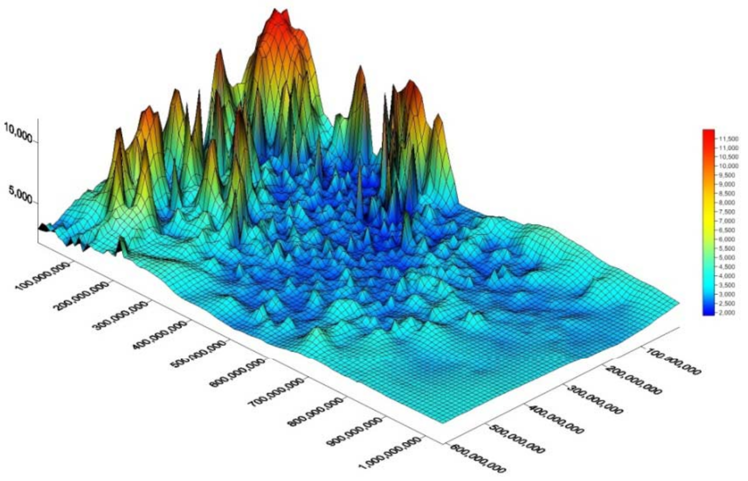
- P&T system to treat TCE
- Baseline system includes
  - Air stripping
  - Off-gas treatment
  - Anti-scaling agent
  - LGAC
  - Reinjection
- Recommendation – bypass air stripper
  - Avoids scaling and reduces cost and footprint associated with air stripper and off-gas treatment



Modeling Optimization

- ESTCP demonstration of transport optimization codes (ER-200010, 2004)
  - Evaluated plume restoration using P&T
  - Found 3 to 50% improved solutions over trial & error, average 20% (Improvement to 50% if fixed costs are removed)
  - Had cost savings that varied depending on site complexity
  - At one site, up to $10 million in cost savings possible
  - At another, up to $600,000 in cost savings

- There have been great improvements in optimization software and computational power since 2004
- With reaction modeling packages, modeling optimization does not need to be limited to P&T



Conclusions

- Third-party optimization yields large GSR benefits through improving strategy and design/implementation
- Improving strategy and design/implementation relies heavily on a well-develop CSM.
- Modeling has proven to be useful tool for providing these optimization results that reduce cost, improvement protectiveness, and reduce the environmental footprint.