Optimization and GSR Case Studies: Experiences from Applications

Dave Becker, USACE
Doug Sutton, HGL, Inc.

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

• Recent optimization and GSR focus
  o Remedial Strategy
  o Design and Implementation
• Remedial strategy examples
• Implementation examples
Recent Optimization and GSR Focus

• Biggest optimization and GSR gains have come from two primary areas
  o Remedial strategy
  o Design/implementation

• Both of these rely on...
  o Updated/improved CSMs
  o Planning
  o 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
• Management of the source
  o Reduce mass discharge from source to allow MNA or shorten timeframe of downgradient active remediation
    ▪ Treatment
    ▪ More effective source containment
• Reduce extent of contamination
  o Areal extent usually in dissolved phase
  o Reduce extent above standards
  o Back diffusion limitations to be considered
  o Reduction in potential future liability, risk
Remedial Strategy, Implementation

• The attainment of these interim goals requires consideration of:
  o Recent data – learn quite a bit from operating the initial remedy, must update the conceptual model
  o New technologies – both remedial and characterization
    ▪ In-situ remedial technologies
    ▪ Mass discharge, attenuation capacity considerations
• 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
• Experience is:
  o 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
  o Agencies need to clearly communicate goals, priorities
• Large sites – ground water plumes in sandy aquifers
  o 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
  o FUDS Sites, Nebraska
    ▪ Initial containment remedy for large plume
    ▪ Evaluating alternatives to reduce plume size
    ▪ Model supporting decisions, to optimize the remedy
• Small Sites
  o 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
  o 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...
  o Extra injection events
  o Overuse (or underuse) of substrate
  o Additional cost and environmental footprint
Design/Implementation Example #1 (Biobarriers)

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

Cross-section with hydraulic head, mounding and drawdown acceptable

Cross-section with substrate distribution after 24 hours of injection.
• Model simulations help evaluate injection/extraction patterns
  o 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

![Initial EVO Distribution](image)

This approach also leaves gaps
• Model simulations help evaluate injection/extraction patterns
  o 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

<table>
<thead>
<tr>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 30,000 gallons of potable water</td>
<td>• 30,000 gallons of extracted groundwater</td>
<td>• 30,000 gallons of extracted groundwater</td>
</tr>
<tr>
<td>• Direct-push injections or new wells needed to fill gaps within 2 years</td>
<td>• Gaps in barrier will develop within 2 years</td>
<td>• No gaps for 4+ years</td>
</tr>
<tr>
<td></td>
<td>• No new wells or direct-push injections should be needed to fill gaps</td>
<td></td>
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</tbody>
</table>
Model simulations identify affect of horizontal hydraulic conductivity distribution on reagent distribution.

1. Saturated thickness = 5ft, \( K = 2 \text{ ft/day} \)

2. Saturated thickness = 5ft, \( K = 10 \text{ ft/day} \)

3. Saturated thickness = 5ft, \( K = 30 \text{ ft/day} \)

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
  o Sufficient data to understand aquifer depth interval and width that require oxygen delivery
  o Evaluate oxygen delivery mechanisms and injection/extraction scenarios
  o Evaluate other amendments (e.g., nutrients and surfactants)
  o 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.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
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<tbody>
<tr>
<td>10 ft</td>
<td>Unsaturated Zone</td>
</tr>
<tr>
<td>10 ft</td>
<td>Saturated Zone. No NAPL impacts (zone of waste oxygen delivery)</td>
</tr>
<tr>
<td>5 ft</td>
<td>Saturated Zone. NAPL impacts (target for oxygen delivery)</td>
</tr>
</tbody>
</table>
Design/Implementation Example #2 (Enhanced In Situ Bioremediation of Coal Tar)

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

- Capture zone
- 47,500 kWh/yr
- 12,000 lbs GAC/yr

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

- Capture zone
- 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.
  o Annulus could only provide 5 to 10 gpm of the 300 gpm.
  o Modeling with sensitivity analysis helped confirm the water supply well could reasonably extract 300 gpm from intermediate and deep aquifer intervals.
  o Conceptual model for contaminant transport should not assume high volumes from annulus.
  o 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

![CO2e Reductions (lbs) from Treatment Processes When Bypassing Air Stripper](chart)
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.