Best Management and Technical Practices for Site Assessment and Remediation

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EPA
United States Environmental Protection Agency
Best Management Practices for Site Remediation
High-Resolution Site Characterization and Remediation
http://www.clu-in.org/characterization/technologies/hrsc/

- Increases sampling density
  - Delineates hydrogeology; focus on heterogeneity
  - Correlates contaminant mass locations to stratigraphy

- Delineates zones of contamination (source mass)
  - Targets application of remedies
  - Reduces remedy footprint and cost of operation

- Uses collaborative data sets to manage uncertainty
  - Verifies screening results with fixed-based analytical confirmation
  - Improves weight-of-evidence with multiple data types

- Electronic databases and 3-D visualization of contaminant distribution

- More effective treatment
  - Higher confidence that site is fully characterized for design
  - Tighter source identification and delineation
  - More accurate mass and volume estimates
  - Targeted vs. shotgun remedy design and implementation
  - Improved monitoring of remedy performance

- Reduced treatment costs
  - Treatment focused on the problem area
  - Reduced residual contamination
  - Saving in treatment compounds and waste handling
  - Reduced need for long-term O&M
Importance of CSM to Remedial Design

- Challenge for investigations → advance CSM sufficiently for remedial design with limited available funds
- CSM evolves and matures as additional data are acquired
  - Use as a tool for stakeholder consensus
  - Strike balance between costs of investigation and remedy
- *In situ* treatment design and application is most effective when based on a mature CSM
- Mature CSM gives more confidence in the remedy selection and design
- CSM can be used to guide design changes during remediation
Use CSMs to Manage Remediation

- Reach stakeholder consensus on remedial requirements
- Negotiate remedial option with regulatory authorities
- Benchmark remediation
  - Determine what data are required to achieve each CSM version
- Refine understanding of source area dimensions
- Demonstrate site no longer poses risk or unacceptable risk
- Use updated CSM to document “revised baseline” for future use
Comprehensive Exit Strategy Design

**Project Type**
- Multiple Sites
- Single Sites

**Strategy Levels**
- Organizational
- Programmatic
- Site-Specific / Stakeholder
- Technical / Media
- Administrative

**Strategy Gap Assessment**
- What specific elements are needed from each level?

= Comprehensive Exit Strategy Plan
Components of an Exit Strategy

- **RAOs**
  - Short term and long-term

- **CSM**
  - Sources and release mechanisms - Detailed site hydrogeological model - Contaminant fate and transport - Current and future receptors - Uncertainties

- **Actions to be taken to achieve RAOs**
  - Individual components
  - Operation, control, monitoring

- **Performance metrics and decision logic**
  - Engineered components - Interim milestones for short-term RAOs - Final completion through achievement of RAOs

- **Contingency plans/ Alternative exit strategies**
  - Evaluating different approaches
  - Justifying alternative strategy
Process applies a subsurface vacuum that:
» draws fresh air through the unsaturated zone
» inducing flux, mass transfer, and removal of VOCs in soil above water table
Typically 2 to 4 inches in diameter, with a screen length of 10 to 15 feet

Ideally spaced to achieve an overlapping of the ROI and adequate pore volume exchange

Determine well spacing and configuration through pilot test or modeling

May involve air injection in combination with air extraction
SVE: Factors Affecting Success - - Performance Considerations

♦ Contaminant characteristics
♦ Soil properties
♦ Site conditions
♦ System design
♦ Performance affected by several factors

♦ Preferential flow
  » Air will preferentially flow through higher permeability zones, providing less remediation to lower permeability zones

♦ Asymptotic mass removal
  » Remediation often limited by contaminant diffusion from lower to higher permeability zones where vapors are extracted

♦ Short circuiting
  » Short circuiting of air flow may occur in shallow or poorly constructed wells, reducing the ROI

♦ High water table
  » Rising water levels can blind screen intervals near the water table

♦ Off-gas treatment
  » Optimal method for off-gas treatment may vary over time as mass loading decreases

♦ Aerobic degradation
  » Increased air flow through subsurface can increase biodegradation of contaminants amenable to aerobic degradation
SVE Considerations to Avoid Overdesign

- Recognize that majority of mass will be removed in a few months
- Mass removal after first few months will be diffusion limited
- All wells do not need to come online or be online at the same time
- Mass contributions after first few months come from more focused source areas rather than broader soil vapor plumes (some wells will no longer need to operate)
- Wells can be operated on a rotating basis to reduce costs while mass diffuses out of tighter parts of the formation
♦ Off-gas treatment units (such as granular activated carbon [GAC] or thermal oxidizers) can be rented.

♦ A system designed for maximum flow and maximum contaminant loading will be oversized (overdesigned in a few months).

♦ Pulsed operation of wells or operation of wells on a rotating schedule can be accomplished during weekly system checks.
  » Elaborate control systems and automated valves are often not needed.

♦ Fracking can increase flow rates, however, note that increased flow will be from preferential paths.
SVE Operational Data Considerations for CSM

♦ What is the trigger point for shutting down the system and transitioning to monitoring only?

♦ What is the trigger point for changing off-gas treatment?

♦ Based on operating wells and extracted vapors, can you determine the approximate location of previously known source and better target that remaining source material?

♦ Would some existing vapor extraction wells serve as valuable vapor injection wells?
Air Sparging

Direct injection of air below the water table.

Must be operated in conjunction with an SVE system to collect vapors.

Air-injection wells

Dissolved phase contamination

SVE wells

Dissolved VOCs in groundwater transfer to air bubbles
AS: Factors Affecting Success -- Performance Considerations

♦ Contaminant characteristics
♦ Soil properties (permeability)
♦ System design, including:
  » Air distribution (zone of influence)
  » Air injection pressure and flow rates
♦ In general, the ROI for AS wells is between 5 and 10 feet

♦ Channeling
  » Sparge bubbles will establish preferential pathways and leave some zones untreated
♦ Aerobic degradation
  » Aerobic degradation of contaminants amenable to aerobic degradation may occur but is difficult to quantify
♦ Adequate characterization needed to treat entire target volume
AS Design and Operational Considerations

♦ Recognize potential for:
  » Discontinuing operation of some sparge points
  » Adding new sparge points during operation

♦ Pulsed operation is beneficial but can be accomplished during weekly system checks
  » Elaborate control systems and automated valves are often not needed

♦ Recognize diminishing returns and reduced risk and transition to monitoring only or another remedial technology

♦ Green considerations
  [www.cluin.org/greenremediation](http://www.cluin.org/greenremediation)
ISCO

Treatment process in which oxidizing chemicals are placed in direct contact with the contaminant, destroying or immobilizing the contaminant.

• Minimal waste generation
• Targeted delivery
• Minimal surface impact
• Fast response
• Flexibility

Treatment of fuel, solvents, and pesticides in either the saturated or unsaturated zone. More effective if design is based on high-resolution site characterization.
ISCO System: Factors Affecting Success

♦ Optimal matching of oxidant and contaminants
  » Treatability study may be necessary
  » Some oxidation products can be purchased "off the shelf"
    › Vendors will review site data for low or no cost

♦ Level of definition of the contaminated zone

♦ Contact between oxidant and contaminant
  » Inject oxidant directly into contaminated zone
  » Avoid "daylighting" reaction via multiple, smaller injections
  » Preferential flow paths can adversely affect oxidant delivery

♦ Ensuring oxidant not affected by natural material
  » Naturally occurring organic carbon will consume oxidant
  » Certain metals in soil and groundwater will impair performance
Inject reagents will follow preferential paths, including along a direct-push drive rod to the surface or the next most permeable interval.

Consider pros and cons of different delivery systems.

<table>
<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| **Permanent Injection Wells** | • Available for multiple injection events  
• Can carefully construct to target specific intervals  
• Allows for recirculation systems  
• Can be sampled  
• Well-suited when injection is slow  
• Fewer refusal issues than direct push | • More costly to install each location/interval  
• Increases site infrastructure |
| **Direct-Push**       | • Flexible with respect to locating new injection points/ intervals  
• Ability to collect data in new locations | • Preferential flow along drive rods  
• Potential false impressive of targeting specific injection intervals  
• Potential for refusal  
• Costly when injection is slow |
Match the oxidant to the contaminant – engage multiple vendors for multiple products during design

<table>
<thead>
<tr>
<th>Oxidant</th>
<th>Amenable COCs</th>
<th>Reluctant COCs</th>
<th>Recalcitrant COCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O₂/Fe</td>
<td>TCA, PCE, TCE, DCE, VC, BTEX, CB, phenols, 1,4-dioxane, MTBE, tert-butyl alcohol (TBA), high explosives</td>
<td>DCA, CH₂Cl₂, PAHs, carbon tetrachloride, PCBs</td>
<td>CHCl₃, pesticides</td>
</tr>
<tr>
<td>Ozone</td>
<td>PCE, TCE, DCE, VC, BTEX, CB, phenols, MTBE, TBA, high explosives</td>
<td>DCA, CH₂Cl₂, PAHs</td>
<td>TCA, carbon tetrachloride, CHCl₃, PCBs, pesticides</td>
</tr>
<tr>
<td>Ozone/H₂O₂</td>
<td>TCA, PCE, TCE, DCE, VC, BTEX, CB, phenols, 1,4-dioxane, MTBE, TBA, high explosives</td>
<td>DCA, CH₂Cl₂, PAHs, carbon tetrachloride, PCBs</td>
<td>CHCl₃, pesticides</td>
</tr>
<tr>
<td>Permanganate (K/Na)</td>
<td>PCE, TCE, DCE, VC, BTEX, PAHs, phenols, high explosives</td>
<td>Benzene, pesticides</td>
<td>TCA, carbon tetrachloride, CHCl₃, PCBs</td>
</tr>
<tr>
<td>Activated Persulfate</td>
<td>PCE, TCE, DCE, VC, BTEX, CB, phenols, 1,4-dioxane, MTBE, TBA</td>
<td>PAHs, explosives, pesticides</td>
<td>PCBs</td>
</tr>
</tbody>
</table>

isko Design and Performance Considerations

♦ Use pilot testing to confirm natural oxidant demand and success of delivering reagents

♦ Consider reactivity when selecting oxidant concentrations
  » High peroxide concentrations will generate gas and backpressure
  » Other oxidants may cause floc formation and fouling
  » Some oxidants (such as permanganate) can be added as a slurry for longer-term activity

♦ Consider oxidant persistence (implications for injection approach)
  » Fenton’s reagent and ozone are consumed in minutes to hours
  » Permanganate and persulfate last days to weeks to months
Remediation after first one or two events will be diffusion limited (rebound)

Measure backpressure during injections and analyze results
  » More permeable vs. less permeable zones
  » Fracturing caused by injections
  » Failure of seals
  » Confirm reagent goes where you want it to go based on initial characterization

Additional safety precautions/procedures when treating LNAPL with ISCO due to heat generation and reactivity, temperatures can rise above flashpoint
ISCO Remediation Designed Using High-Resolution Site Characterization and 3-D Visualization

Injection Interval Pattern for the Two Plumes

Plume A

Plume B

8 ft injection interval to treat deeper PHC contamination

Plume B Injection Interval

4 ft Injection Interval

Plume A Injection Interval

ISCO Remediation Designed Using High-Resolution Site Characterization and 3-D Visualization

Liquid Hopper

Injection Head

Liquid Feed Hose

Injection Assembly

Injection Nozzle

Injection Interval Exposed When Tip Pulled Back
◆ Common refrain - “Just dig it up and get rid of it”
◆ Not that easy - Must ask these questions first:
  » Is contaminated area fully delineated?
  » Is size and depth of the excavation clearly established?
  » What is the depth to groundwater?
  » Does remedy require excavation below the water table
    › Is dewatering necessary to support redevelopment construction?
    › Does UST removal or soil remediation require over-excavation, as is sometimes done in certain State programs?
  » What are the consequences of leaving some contamination in place?
    › Are the impediments to “getting it all” really that much greater than years of long-term remediation?

(continued)
Soil Excavation and Off-Site Disposal

♦ Not that easy - must ask these questions first:
  » Have cleanup standards and RAOs been clearly established?
  » Has a method for determining completion been established?
  » What are the disposal requirements for the contaminants?
  » What are the acceptance criteria for the disposal facility; and how far away it is?
  » Have site logistics such as contaminated/clean backfill soil staging and equipment storage been addressed?

♦ Disposal of PHC soils easier/less expensive than CVOC-contaminated soils disposal

♦ Be cognizant of State guidance to avoid over-excavation
  » Accurately estimate soil volumes to limit scale of land-farming or disposal
Pre-Excavation Design Considerations

Characteristics of soil to be handled
- Volume - Moisture content – wet/dry - Soil properties – clay soil will expand after excavation

Location
- Proximity of buildings – Accessibility with basic excavation equipment - Availability and location of staging areas

Type of contamination
- Worker protection - Disposal/reuse options - Air/dust generation and monitoring - Transportation regulations

Engineering practice
- Excavation stability – OSHA - Water control - Material segregation - Seasonal variation in handling characteristics
Post-Excavation Design Considerations

- Offsite disposal
  - Waste classification
  - Transportation
  - Disposal facility permit
  - Manifest tracking

- Soil reuse
  - Reuse options
  - Exposure controls

- Backfilling
  - Source for clean backfill material
  - Placement in excavation and geotechnical considerations

- Post-excavation performance testing
  - Bottom and sidewall sampling to verify achievement of cleanup levels
Remediation of contaminants by enhancing microbial activity to degrade (or stabilize) contaminants by oxidation, reduction, or cometabolism...

- Oxidation (aerobic degradation of benzene)
- Reduction (reductive dehalogenation of TCE)
- Cometabolism – degradation of a variety of contaminants by enzymes produced by bacteria using other compounds for energy

Biostimulation – Amendments added to enhance microbial activity

Bioaugmentation – Addition of microbes for remediation

Various approaches
- Direct-push injections
- Discrete injections in permanent injection points
- Recirculation systems
- Source area treatment or biobarriers

Various amendment options
Bioremediation: Factors Affecting Success

- Contaminated media
- Aerobic or anaerobic conditions
- Physical parameters
  - pH
  - Temperature
  - Naturally occurring organic matter (carbon)
  - ORP
  - DO
- Moisture content of unsaturated zone
- Existing microbial populations
- Mature CSM; impact area well-defined
Different schools of thought on “fast-burn” vs. “slow-burn” substrate for treating chlorinated solvents

Different options for delivering oxygen for treating BTEX
- ORC injections
- ORC socks or in situ submerged oxygen curtain (iSOCs™)
- Air sparging with or without ozone or oxygen addition
- Nutrient addition may also be needed

Consider injection approaches (see ISCO discussion)

Recirculation help disperse reagents and reduce number of injection points

Design a robust performance monitoring program. Multiple events will likely be needed. Have the data to optimize the next event
- DO, ORP, Fe+2, NO₃⁻, SO₄²⁻, VOCs, pH, alkalinity
- Increase frequency of monitoring (such as monthly instead of quarterly), additional performance monitoring events...
  - Help confirm results
  - Provides additional insight
  - Helps better distinguish between effects/results from consecutive injection events
Relies on natural processes to remediate contamination.

Relies on:
- Volatilization of contaminant
- Biological processes
- Chemical processes

Success depends on:
- Type and amount of contaminant
- Size and depth of contaminated area
- Favorable soil and groundwater conditions
- Sufficient time
General MNA Considerations

♦ May require ICs
♦ Usually applied to low-level groundwater impacts
♦ 1999 OSWER directive 9200.4-17P
  » Requires rigorous site characterization
  » Evaluate efficacy of MNA using “lines of evidence”
  » Performance monitoring
♦ Impose a stewardship obligation on property owner
♦ Requires a groundwater monitoring system
  » Upgradient monitoring wells
  » In-plume monitoring wells
  » Downgradient sentinel wells
Initial Screening of MNA Applicability

- Do state regulations allow MNA as a remedial method?
  - Many States require majority of source mass be removed
  - Presence of mobile LNAPL may preclude consideration
  - May be acceptable for limited non-mobile, residual phase LNAPL

- Has the source been removed to the maximum extent practicable?

- Is plume size and concentration reducing such that remediation will be achieved within a reasonable time?

- Are there any receptors that could be affected?
Key Components of Typical MNA CAP

♦ Documentation of adequate source control
♦ Comprehensive site characterization
♦ Showing lines of evidence to support MNA
♦ Performance objectives
  » Tools are available to support remedy evaluation
    › remfuel
      http://www.epa.gov/ada/csmos/models/remfuel.html
♦ Evaluation of timeframe for meeting remediation objectives
♦ Long-term performance monitoring
♦ Contingency plan
Pilot Studies

♦ Before conducting a pilot test, confirm (to the degree possible) that full-scale application is practical and appropriate
  » Don’t conduct unnecessary pilots

♦ Collect too much rather than too little data

♦ Several phases of successful pilot studies could actually be a successful full-scale remedy

♦ Evaluate failed pilot study results to confirm implementation issues were not the reason for failure. Consider the benefit of redoing a pilot study before abandoning a technology

♦ Increase the likelihood of success through sound research and bench-scale studies

♦ Be sure the pilot test addresses the most critical parts of the remedy (such as reagent delivery to the tough locations)
Treatment Trains

♦ Combination of remediation technologies usually applied in a “treatment train” via flexible record of decision/CAP
  » Aggressive ISCO to treat source
  » PRB or PRZ to treat plume
  » MNA for “tail” of plume with low concentrations
  » State requirements-“make every conceivable effort, utilizing every available technology”

♦ Prepare a corrective action plan to outline the preferred cleanup option for the site
  » Public has the opportunity to comment on preferred option
  » Consider the comments and may revise final cleanup
  » Determination of the final cleanup for a site is documented in its final site closure documents
Green BMPs for Characterization and Remediation

♦ For more information on Green BMPs for Bioremediation, refer to this fact sheet
♦ www.cluin.org/greenremediation
Select Case Studies
Example 1- Wyckoff Region 10

Existing Work Products

<table>
<thead>
<tr>
<th>Y-Length, ft</th>
<th>X-Width, ft</th>
<th>Z-Height, ft</th>
<th>Treatment Box Soil Volume, cu. yds.</th>
<th>TarGOST Impacted Soil Volume @ 10%RE in Treatment Box, cu. yds.</th>
<th>TarGOST 10%RE Percent of Treatment Box Volume, cu. yds.</th>
<th>TarGOST 20%RE Percent of Treatment Box Volume, cu. yds.</th>
<th>TarGOST 50%RE Percent of Treatment Box Volume, cu. yds.</th>
<th>TarGOST 100%RE Percent of Treatment Box Volume, cu. yds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box A</td>
<td>160.00</td>
<td>170.00</td>
<td>45.00</td>
<td>33,836</td>
<td>12,882</td>
<td>38%</td>
<td>7%</td>
<td>6%</td>
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<tr>
<td>Box B</td>
<td>200.00</td>
<td>210.00</td>
<td>30.00</td>
<td>38,532</td>
<td>5,534</td>
<td>14%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>Box C</td>
<td>180.00</td>
<td>165.00</td>
<td>23.00</td>
<td>15,302</td>
<td>10,491</td>
<td>72%</td>
<td>19%</td>
<td>5%</td>
</tr>
<tr>
<td>Box D</td>
<td>180.00</td>
<td>112.00</td>
<td>10.00</td>
<td>5,861</td>
<td>2,253</td>
<td>38%</td>
<td>15%</td>
<td>0%</td>
</tr>
<tr>
<td>Box E</td>
<td>305.00</td>
<td>300.00</td>
<td>28.00</td>
<td>77,146</td>
<td>13,371</td>
<td>17%</td>
<td>3%</td>
<td>0%</td>
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<tr>
<td>Box F</td>
<td>300.00</td>
<td>300.00</td>
<td>22.00</td>
<td>72,706</td>
<td>14,734</td>
<td>20%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>246,389</td>
<td>55,255</td>
<td>22%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 10%RE TarGOST Impacted Soil Volume Inside Wall: 59,489
% Captured in Boxes: 93%

FFS- TarGOST® and 3D Visualization
Example 2 - Hamilton Labree Region 10

HRIA RI work products

HRIA MIPHPT Geology
HRIA PCE GW
HRIA PCE Soil

PDI- MIP, HPT, 3D
Superfund Soil Cleanup
CO Smelter

• **RPM must balance**
  - Technical challenges, variability in soil, sampling design
  - Risk management- exposure/pathway, background, risk assessment
  - Community needs/input
  - Resources, budget

• **Enter the Demonstration of Applicability (DMA)**
  - Establishes that proposed technologies and strategies
    - provide information appropriate to meet project decision criteria
    - perform as advertised by the vendor
  - Assesses performance of field analytical technology compared to fixed-base laboratory
  - Highlights laboratory and field method advantages and challenges
  - Provides initial look at CSM assumptions; augments planned data collection/CSM development
  - Develops relations between visual observations and direct sensing tools
  - Provides flexibility to change tactics based on DMA rather than full implementation
  - Optimizes sequencing, staffing, load balance, unitizing costs
Colorado Smelter OU1
DMA- May/June 2015

• **OU1**
  - 12 Residential properties, 0.07-0.47 acres
  - 52 total DU’s
    - 3-6 DU’s/property- front, side, back, drip zone, garden, play area, carport/earthen drive, apron
    - 4 depth horizons- 0-1/0-2’, 2-6’, 6-12’, 12-18’
    - 5-point and 30-point incremental samples
    - Triplicates

• **OU2**
  - 6 Slag/smelter areas
    - 0-2’ interval, 5 point incremental samples

• **XRF (bulk, prepped, subsampled)**
  - ICP 20% of DU/depth, bioaccessability and geospeciation (Pb, As)
DMA Findings and Recommendations

- **XRF performance/comparability**
  - As and Pb compared to 5 SRMs
    - 2 instruments- High $R^2$ on linear regressions
  - As and Pb compared to ICP
    - High $R^2$ on linear regressions
DMA Findings and Recommendations

- **Sampling design and sample prep**
  - Design evaluated 30-pt, 5-pt, triplicates, depths
  - 154 5-pt/depth intervals, 20 30-pt/depth intervals
  - Variability in triplicates- 30-pt performs slightly better
  - Decision error rates- 5-pt and 30-pt comparable, 5-pt easily meets objectives (<20% false pos, <5% false neg)
  - Triplicates- not necessary at all DUs, 5% to measure variability and monitor decision error rates
  - Depth profiles- clarify 0-2’, all 4 intervals necessary

- **Sample prep/subsampling**
  - Higher variability in bulk samples expected
  - Variability low in replicates of prepped samples
  - Potential for subsampling error removed
    - Submitting entire sample for digestion
DMA Findings/Recommendations- Addressing Hotspot/Dilution Concern

• **Hotspots**

  “Even an ant walks off a wine cork at some point”- Marc Stifelman RA EPA R10

  – Accounted for in exposure scenarios/risk assessment
  – Release and transport mechanisms not consistent with hotspot potential
  – Most DU’s extremely small, good coverage
  – Variability in triplicates low
  – Variability between 30-pt and 5-pt limited
  – Decision error rates relatively unchanged, exceed project goals
DMA Findings/Recommendations-

Addressing Hotspot/Dilution Concern

- **Dilution**
  - All samples are some form of a composite
  - We actually want an estimate of the mean
  - DU’s sized to represent exposure scenarios
  - No mixing of increments from DU’s, properties, OU’s etc.
    - Where dilution can be a consideration
  - Variability in triplicates low
  - Variability between 30-pt and 5-pt limited
  - Decision error rates relatively unchanged
Cache La Poudre River
Fort Collins, Colorado
Case Study
City of Fort Collins awarded a brownfields grant in 2001

- Expand existing community center over old city landfill
- Initiated investigation targeting the potential impacts of the landfill and the surrounding area on indoor air quality of the proposed building
Brownfields Investigation

- Landfill operated from late 1930s until 1963
- A MGP operated from 1904 until 1927 immediately across the street
- Post 1927, a gasoline distribution business (including a gas station) operated on the MGP parcel
- Machine shop operated to the immediate southwest of the landfill
- Sites adjacent to major recreational use river
- Varying stakeholder views on sources and causes – managed through use of evolving CSM
♦ October 2002, NAPL liquid (previously not observed on-site) discovered in the river

♦ Subsequent investigation by Brownfields Program indicated it to be fairly substantial

♦ October 2003, site referred to the removal program and site assessment performed by the Superfund Technical Assessment and Response Team 2 contract
Contaminants

♦ **Groundwater**
  » BTEX, MTBE plume
  » PAH plume
  » TPH
  » Chlorinated solvent plume

♦ **Subsurface soil and river sediments**
  » NAPL containing PAHs
  » BTEX
  » TPH
Investigation Techniques

♦ Conventional
  » Exploratory trenches in the river
  » Soil gas sampling over the entire landfill and river bank
  » Soil borings and groundwater well installation

♦ Innovative/Real-Time Measurement
  » Direct-push groundwater sampling methods
  » Electromagnetic geophysical methods
  » High-resolution resistivity geophysical methods
  » On-site GC/MS analysis of VOCs in groundwater
  » Passive soil gas
  » Passive diffusion bag groundwater sampling methods
  » Open-path Fourier transform infrared spectroscopy
Baseline CSM

LEGEND

- WATER TABLE (APPROXIMATE)
- BENZENE AND NAPHTHALENE PLUME BOUNDARY
- POST-PINEY CREEK ALLUVIUM (UPPER HOLOCENE)
- BROADWAY ALLUVIUM (PLEISTOCENE)
- PIERRE SHALE
- LANDFILL
- CACHE LA POURDRE RIVER

NOT TO SCALE

AZTLAN CENTER
FORT COLLINS, COLORADO

FIGURE 2
SITE CROSS-SECTION

NOTE: LINE OF CROSS-SECTION SHOWN ON FIGURE 3
Characterization Stage CSM

LEGEND

- Post-Piney Creek Alluvium (Upper Holocene)
- Broadway Alluvium (Pleistocene)
- Weathered and Fractured Pierre Shale
- Landfill
- Interbedded Caolche/Cemented Sandstone Layers
- Petroleum Hydrocarbons and Naphthalene
- Dissolved Plume Boundary
- Non-Aqueous Phase Liquids (DNAPL)
- Light Non-Aqueous Phase Liquids (LNAPL)
- Water Table (Approximate)
- Well Screen Interval

NOTE: LINE OF CROSS-SECTION SHOWN ON FIGURE 3

AZTLAN CENTER
FORT COLLINS, COLORADO

FIGURE 2
CONCEPTUAL SITE MODEL DIAGRAM
AND GEOLOGIC CROSS-SECTION

U.S. EPA REGION XII
IN COOPERATION WITH
BROWNFIELDS TECHNOLOGY SUPPORT CENTER
Results of Investigation

- NAPL = coal tar, likely mixed with gasoline and diesel components
- NAPL sank down through the alluvium to the top of area bedrock and traverses toward the river
- Near the landfill, NAPL moved entirely into fractures in the bedrock, eventually accumulating under river
- NAPL in the river sediments over a 300’ stretch
- Underneath the river in the bedrock over a 600’ stretch
- NAPL migrated slightly past the river in deep bedrock (20-25’ bgs) fractures
After Friendly Negotiations

♦ Excavated the contaminated sediments and bedrock in and underneath the river
♦ Installed a vertical sheet pile barrier with hydraulic controls to intercept the NAPL
♦ Provided for long-term water treatment
Remediation in a Nutshell
Benefits of Triad BMPs for Characterization / Remediation

- Estimated cost savings of ~30% compared with more traditional approach (multiple mobilizations, fixed-based analytical methods)

- Increased size and quality of data set used to make decisions

- Adequate characterization assured functional mitigation strategy was installed appropriately in first attempt

- Difficult to evaluate cost savings associated with installation of poorly-designed initial remedy
  - Remedy cost was ~$13 million
  - Installation of poorly designed system would have been very expensive in long run
First community center in the United States certified Leadership in Energy and Environmental Design (LEED®) Gold

North Aztlan Community Center
Case Study: Excavation of TPH-Contaminated Soil — Removal
Case Example – Delineation of TPH Contamination from UST Release Using Collaborative Data Sets and Imaging

- 10,000 gallon heating oil UST leaked released No. 2 fuel oil
- Limited site investigation consisted of monitoring wells
- Proposed residential development on former school site
- Delineate TPH contamination zone and define core impact area for the purposes of remediation
Delineation of PHC Contamination in Soil Caused By UST Release

- PHC in soil delineated using an FFD
  - Employs UV light source to locate TPH

- Locations of depth-discrete soil and groundwater samples were selected based on FFD Logs

- Data sets were imaged using ArcGIS 3-D Imaging Software to depict contaminated zone

- To support remedial action design, visualization used to:
  - Gain regulatory acceptance regarding completeness of delineation
  - Decide on limits of excavation before construction
  - Design the excavation project and estimate volumes
FFD Pushes Used to Delineate Extent of Contamination

- Begin at locations of known highest TPH impact or free product in well
- Test instrument response
- Next “go to” location with little to no TPH impact
- Perform dynamic field based “step outs” to instrument “flat line”
- When FFD shows no response (“flat Line”) confident TPH below 100 ppm
Shells represent FFD signal strength from 150 mv to 1200 mv.

"Flat line" FFD log profiles at edges.

“Flat line” FFD log profiles at edges.

Area of increased signal response.

FFD logs “hung” from the land surface raster.

Core contaminated area.

TPH contamination model.
Collaborative Data Sets Demonstrate Delineation
♦ Extent of TPH-contamination verified through collaborative data set and visualization

♦ Various cleanup options can be quickly evaluated:
  » Total removal to beyond 150 mv shell
  » Removal to extent of 500 mv shell which correlates with approximately 5 to 6,000 ppm TPH
  » Free product and core contaminated area removal for maximum risk reduction benefit
Engineering Analysis – Cross Sections Showing Distribution of Fuel Contamination and Location of Excavation

[Diagram of excavation area with cross sections A-A' and B-B']
Sheet Piling Cutoff Wall Installed Along Edge of Roadway

- TPH-contaminated area near a roadway excavated
- Sheet piling installed along border between school site and roadway
Well Point Dewatering System

- TPH-contaminated soil extended below water table
- Well point system installed to depress water table at location where TPH-contaminated soil was excavated

Activated carbon water treatment canisters
TPH-Contaminated Soil Removal

- Soil contaminated with PHC from UST Release
- Clean backfill staged on site prior to excavation to minimize open excavation time
- Excavated with dewatering system support
- Oxygen Release Compound spread in with backfill to promote biodegradation of residual TPH compounds
- Backfill material spread and compacted
Excavation of TPH-contaminated Soil

Dewatering system
Oxygen Release Compound Added to Promote Biodegradation of Residual TPH

Soil density testing instrument

Oxygen Release Compound spread in backfill
Stockpiling, Spreading, and Compacting Cleanup Backfill
Real-time measurement technologies can provide high-density data sets that can rapidly advance the CSM.

Probe electronic signals are compatible with ArcGIS and other imaging software and can be easily visualized in 3-D.

Sorting image by signal strength can provide indication of contaminant concentration distribution.

Discrete sample soil and groundwater locations can be selected to verify signal strength, concentration correlation and confirm delineation.

Image (the CSM) is recreated using collaborative data:
  » Electronic signals from probe
  » Discrete sample analytical results

Mature CSM 3-D visualization can be used for selection and design of remedial action.
Case Study – Fannon Petroleum Site, Virginia

♦ Fuel Depot since late 1800s
♦ Most recent facility since 1962
♦ ASTs and USTs
♦ > 500,000 gallon capacity
♦ Early 1980s release
Systematic Planning Considerations

♦ Unconsolidated geology (relatively uncomplicated)
  » MIP with collection of soil samples for laboratory analysis

♦ Developer with plan (residential)

♦ Identify hot spots requiring remediation

♦ Define threshold contamination level above which remediation was necessary

♦ Stakeholder concurrence and acceptance
  » City, owners, citizens

♦ Identified receptors
MIP Survey
MIP Results

- Closely correlated with plume defined by conventional investigation methods
- MIP identified previously unknown contamination
- Plume appeared to intersect sanitary/storm sewer system
- Some adjustments to construction plan (such as depth of structures)
- Negotiated environmental redevelopment actions which could be potentially be reimbursed under state UST fund
Remedial Actions

♦ Excavation and removal of 28 USTs
♦ Excavation and disposal of 35,317 tons of petroleum-impacted soil
♦ Recovery and disposal of 1,000 gallons of free-phase petroleum
♦ Ongoing subsurface remediation at down-gradient adjacent property
♦ Continued reduction in amount of subsurface contamination
♦ Post-CAP monitoring in near future
Redevelopment 2008/2009

Before

After