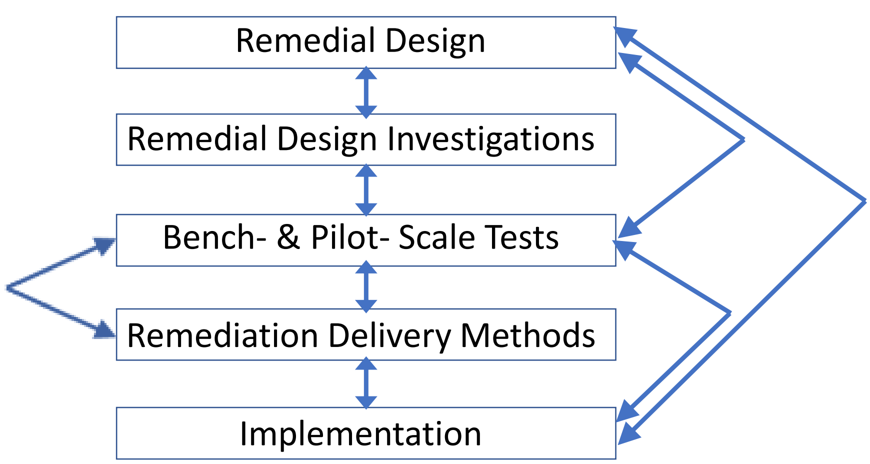
Moving from Remedy Selection to Implementation

Paul M. Dombrowski, P.E.
ISOTEC Remediation Technologies, Inc.

ISOTEC REMEDIATION TECHNOLOGIES

NEWMOA NORTHEAST WASTE MANAGEMENT OFFICIALS' ASSOCIATION

Remedy Selection to Implementation



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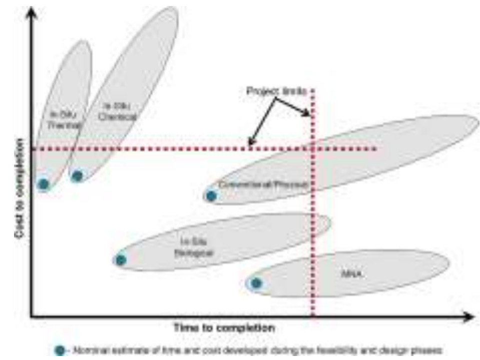
Remediation Time Line and Cost

- Time to meet goals inversely proportional to cost
- Starting concentrations vs. target/criteria
- Treatment Footprint
  - Source Treatment
  - Plume Treatment
- Long term monitoring
- Feasibility Studies often underestimate remediation costs and timelines



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Waste Site Cleanup Process

Remedial Investigation → Risk Assessment

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Feasibility Study/ Remedy Selection

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Remedial Design

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Remedial Action

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Successful Remediation

1. Treatment Area Characterization
   - Remedial Design Investigation
2. Remedial Design
   - Design remediation based on conceptual site model
3. Remedial Action
   - Utilize remediation tools to implement the design

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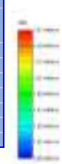
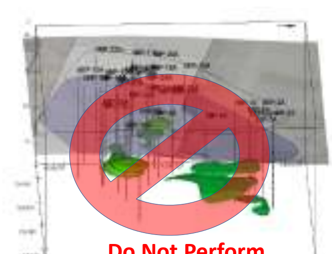
Remediation Design Investigation

- Characterization resolution required for remediation is higher than for delineation
  - Delineation checks if contamination is present
  - Remediation needs to understand how to remove those contaminants
- Goal is to develop surgical remediation plan

Depth	SB-19	SB-20	SB-21	SB-23	SB-24	SB-26	SB-27	SB-28	SB-30	SB-31	SB-32	SB-33	SB-34	SB-35	SB-36	SB-39	
23			3,370			14,000			3,420								
24	219		ND	1,650		ND						5,760			258		
25		ND	7,180				9,390	214	17,000	4,500	7,050		643	789		4,650	
26	ND		32,200	6,770	5,460	4,030	62,100					15,000					GW High
27		13,900						ND	6,440	ND	7,720	28,200	13,700	14,300	218	ND	
28	5,830	ND	2,370	1,480	473	ND	111	ND		28,600					1,610	1,510	GW Avg
29	153			ND				137	165	12,600	6,500	753	9,330	82		ND	
30		2,910	258			104							ND			3,170	GW Low
31				25,900	ND		412				248	ND	3,060	ND	ND	306	
32		94								ND				5,590		498	
33				270			82						ND				
34				137	729						ND			333		ND	
35																	
36					118									ND			

DRO Soil Concentrations (mg/kg) - analyzed at RPI Quality Assurance Laboratory





Do Not Perform Remedial Design Based on Blobs Alone

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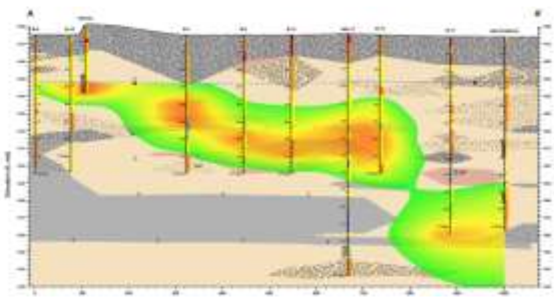
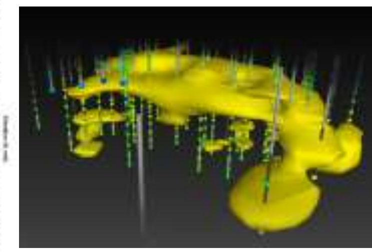
Remediation Design Integration

- High density sampling data
- High Resolution Site Characterization tools
  - MIP
  - UVOST
  - HPT
- Soil lithology





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Bench Scale Treatability Testing

- Testing conducted in lab setting
- May or may not use site media
- May involve batch or flow through testing, simple to complex
- Allows testing of many different conditions
- Duration could be hours to months
- Can evaluate multiple technologies prior to field application

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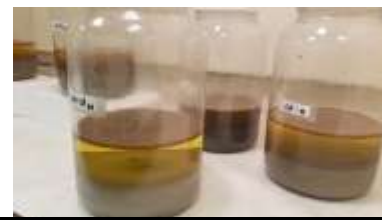
More on Bench Scale Testing

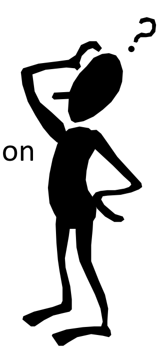
- Recommended when there are questions about chemistry/biology
  - Is an amendment effective?
  - Is a contaminant biodegradable?
  - What is best amendment and/or activating agents?
  - Treatment for mixed contaminants?
  - Optimal/appropriate dosages?
  - Inhibiting effects?

- Can include contaminant destruction or only 'Demand' tests
  - Total Oxidant Demand or Acid/Base Buffering
- Should include site soil **AND** groundwater.
  - Soil dominates chemistry & buffering
  - Majority of organic contaminant mass is sorbed



What a Treatability Test Can Tell You

- Amendment consumption
- Degradation intermediates/pathways
- Effect of controlling variables
  - pH, redox, amendment, inhibitory effects, oxidant demand, activation
- Residence time/longevity
- Contaminant degradation rates
- Optimization of a selected remedy
- Manageable, incremental risk from lab to pilot to full-scale
- Reassures stakeholders that the selected approach is feasible
- Insight into field-scale design



Field Pilot Scale Studies

- Testing conducted in field
  - At one or more areas of the site
- Recommended for questions about hydrogeology, delivery, and/or site-specific performance
- May be in source area, mid-plume, downgradient,
  - Often in more complex or difficult area of site
- Duration could be days to up to a year
- Could be conducted to supplement or replace existing remedy

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More on Pilot Scale Studies

- Evaluate site-specific effectiveness and optimize design
  - Technology effectiveness in situ
  - Delivery/distribution in heterogeneous geology
  - Injection/extraction flow rates and pressures
  - Injection/extraction spacing for full-scale
  - Changes to groundwater conditions (pH, metals)
  - Potential rebound
  - Reagent persistence
  - Logistical coordination
- May or may not apply reagents in situ
- Ex-situ demonstration (oxidation, stabilization)

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Bench & Pilot Test Objectives

- Establish clear questions that the testing is designed to answer
- Recognize that some questions may not be answered (e.g. achieve Stds.)
- Demonstrate feasibility and select best full scale technology
- Optimize design (e.g. volume, dosage, well spacing, dimensions, etc.)
- Allow for more accurate costing and scheduling

"We will add the chemicals and see what the data tells us" → "The test results are inconclusive"

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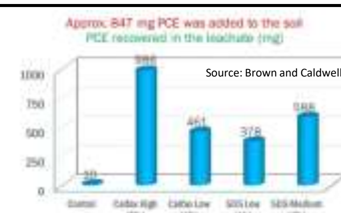
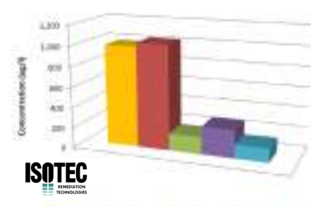
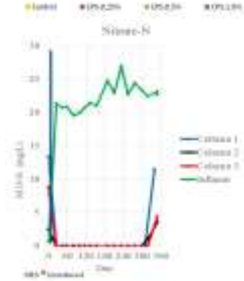
Bench Test Case Study Examples

- Which surfactant desorbs most PCE from soil?
  - Combined remedy: ISCO + surfactant
- What reductant achieves lowest concentration of cadmium?
- What is best EVO formulation for enhancing denitrification in a high flow aquifer?
  - Can EVO be made stickier?







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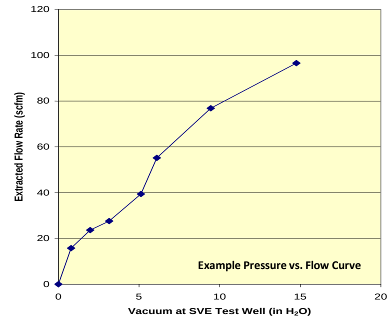
Pilot Scale Case Studies

- Water Only Injection Test
  - Bedrock, till/clay, different injection methods
- SVE Pilot Test
  - Soils tighter than anticipated
  - Higher vacuum blower available, failure averted
  - Higher vacuum & less significant ROI had big impact on design



- Cape Cod Denitrification PRB
  - 100’ Demonstration Test
  - Thousands of Feet Anticipated
  - Distribution & Longevity?

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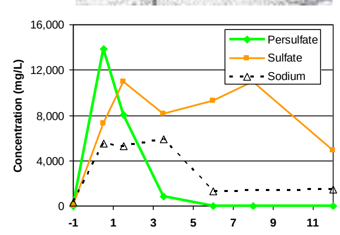
ISCO Bench + Pilot Scale Case Study

- New England Superfund Site
  - 3 multi-contaminant plumes (BTEX, cVOCs, and/or 1,4-dioxane)
- Fast-Track Schedule
  - Goal: Construction Complete 12 months after AROD
  - Remedial Design Investigation: Mobile Lab for soil and GW
  - Remedial Design required <3 months after pilot injection
  - Bench Tests: Total Oxidant Demand + Base Demand
  - Pilot tests: Injections in 3 different areas (Inj. Wells & Direct-Push)



Dombrowski, et al., 2010

- Pilot Test DQOs focus on field screening data
  - Persulfate, sulfate, sodium (ORP, conductivity)
- Largest field injection of persulfate at the time
  - Injection spacing, volumes, dosages based on pilot test
  - Completed 1 month early, on budget, and achieved objectives

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Ideal Guidance for Bench & Pilot Test Studies

Site and Chemical Complexity/ Technology	Simple CSM & Common COC(s)	Simple CSM & Unique COC(s)	Complex CSM & Common COC(s)	Complex CSM & Unique COC(s)
Mature Single Technology	Pilot Only	Bench & Pilot	Pilot Only	Bench & Pilot
Mature Multi-Technology	Pilot Only	Bench & Pilot	Pilot Only	Bench & Pilot
New Single Technology	Bench & Pilot	Bench & Pilot	Bench & Pilot	Bench & Pilot
New Multi-Technology	Bench & Pilot	Bench & Pilot	Bench & Pilot	Bench & Pilot

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- Does approach include chemical, physical, biological , or combination of processes?
- Bench test might be Total Oxidant Demand only
- Pilot test might be water only injection test

Remediation Design

- Identify Contaminants
- Remedial Objectives
- Horizontal Limits
- Vertical Limits
- Technology / Amendment Selection
- **Delivery Method**
- Injection Volume / Extraction Rate
- Performance Monitoring

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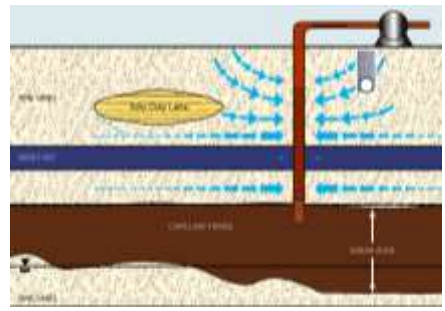
Remediation is a Contact Sport

- Cliché is true
- Focus design on delivery/extraction at contaminant mass
  - Contamination Distribution/Properties
  - Soil Profile
  - Geology/hydrogeology



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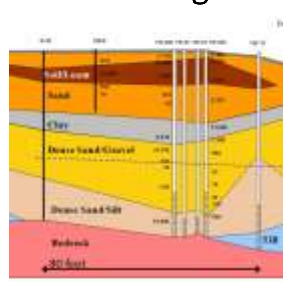
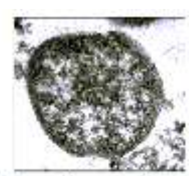
Remediation Scales

Plume Remediation Geologic Lenses Micron





Dehalococcoides mccartyi Strain 195

Macroscale design for microscale processes

- Gallons, cubic yards, pounds
- Chemical reactions + microbial activity
- Discrete data

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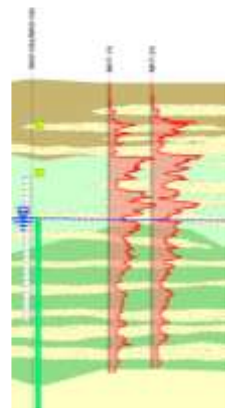
Remediation Tools

- Various delivery tools to bring your amendment to contaminants or extract contaminants
  - Injection wells/Extraction wells
  - Direct Push Technology
  - Horizontal injection/extraction wells
  - Soil blending
  - Thermal remediation



Vertical Injection

Direct-Push

Advantages

- Flexible layout – can be modified for follow-up
- Less/no soil cuttings to dispose

Disadvantages

- Difficult to advance into till, bedrock, boulders
- Mobilize drill rig for each event ($+disturbance)

Injection Wells

Advantages

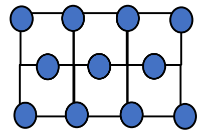
- Volume/amendment can be divided over entire event
- No geology limitation (till, bedrock, boulder)
- Single rig mobilization
- Can be adapted with redevelopment

Disadvantages

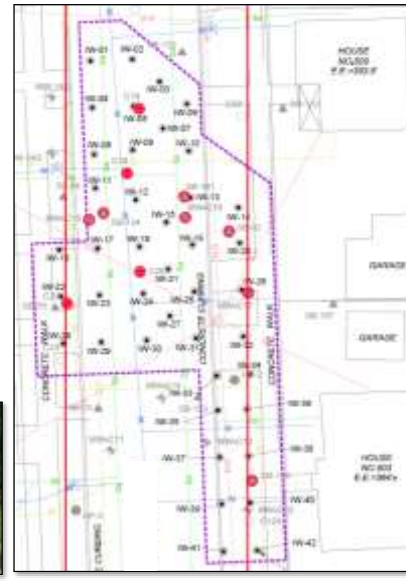
- Locations and vertical interval are fixed (limited flexibility)
- Cost/time to install & abandon
- May need nested wells based on treatment interval (10’ max. screen recommended)
- Soil cuttings to dispose ($)

Injection Spacing

- Typically a grid pattern
  - Off-set every other row



- Geology critical
  - Closer spacing in less permeable soil
- More points
  - Better contact
  - More delivery points
  - Less volume per point
  - More cost (if wells)



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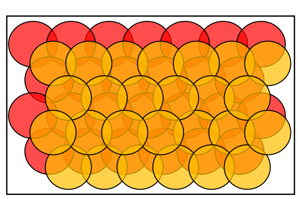
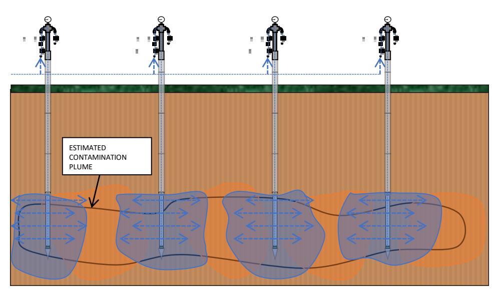
Multiple Rounds of Injection

- Injection wells – limit cost and rig disturbance (chemical affect well construction)
- Temporary Injection Points – Overlapping Treatment



Event 1 Injection Point Locations
Event 2 Injection Point Locations



-Event 1 ROI of 7.5’
-Event 2 Overall ROI is now 3.75’

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Direct Push Injection Tools

Out bottom of rods

Retractable Screen

Pressure activated injection probe

Proprietary screens (ISOTEC)

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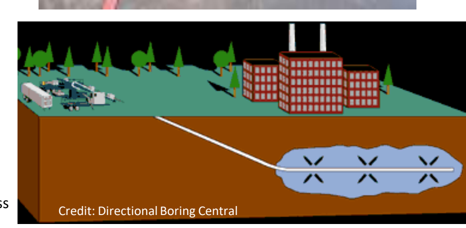
Horizontal Wells

- Advantages
  - Treat under buildings, roads, wetlands, gas stations, manufacturing facilities, airports, etc. not otherwise accessible
  - Can position horizontally or at an angle
  - Can be multi-purpose (inject fluids, sparge, extract)
  - Reduce above-ground/shallow infrastructure
- Disadvantages
  - More expensive to install
  - Vertical ROI is limited
  - Disposal of drill cuttings



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Soil Mixing

- Advantages
  - Maximize contact between amendment & contaminant
  - Applicable to unsaturated soils
  - Significant advantage in low permeability soils where injections are difficult
  - Used with many amendment types
    - Oxidants, reductants, stabilization
- Disadvantages
  - Retreatment/Access can be expensive/difficult
  - Treated area may not be suitable for infrastructure construction without soil stabilization

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Soil Mixing Application Types

Application	Key Benefits	Reagent Introduction	Depth
Bucket	Cost effective	Dry or Wet	Shallow
Auger	Ultimate Reach	While mixing	Deep
Blender	Uniform mixing	Varies	Shallow/ Intermediate
Screener	Uniform mixing	Dry	Shallow

Photo Credits: ISOTEC, Entact, ALLU, Geo Solutions

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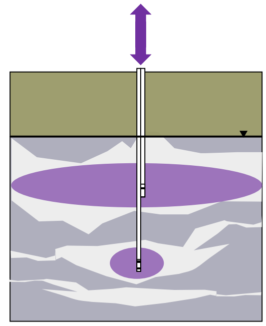
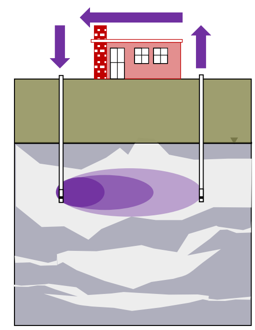
Recirculation

- Push-Pull
  - Same well
  - Minimize displacement



- Closed Loop
  - Extraction from one group of wells, addition of reagents into separate wells
    - Amended groundwater
    - Gases/soil gas
  - Enhance transport and/or reaction time



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Injection Volume (More is Better)

- Increasing ISCO injection volume improves contaminant destruction & reduces potential for rebound (over life of project)
- Krembs and Clayton (2010)

	<20% Pore Volume	>20% Pore Volume
Rebound at Sites	80%	50%
MWs with Rebound	51%	26%

- Siegrist, et al. (2011)
  - >90% reduction of contaminant for sites that injected >0.5 PV

Less Volume → Less Amendment → Less Cost

Less Success

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Remediation Design – Sensitive Receptors

- Surface Water
  - Visual/Aesthetics
  - Ecological impacts
- Utilities
  - Compatible materials to chemistry or heat
  - Preferential pathways
- Potable Water Wells
  - Byproducts
  - Aesthetics (color, taste)
- Active Buildings/Homes
  - Vapors, methane
- Pedestrians/Human Receptors
- Shallow water table

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Remediation Stalled?

- Remedial goals not met
- Treatment no longer active
  - Oxidant consumed
  - Conditions not favorable for bioremediation
  - Asymptotic extraction
- Change in conditions

Continue Current Approach
Re-apply/maintenance dose

Optimize Current Approach

Change Remediation Technology

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Changing Course

- Allow flexibility in Feasibility Study and Remedial Design
  - FS/Decision Document – select technology not an amendment
  - Consider optimization steps during FS/Decision Document phase
  - "In-situ Injection" as Alternative
  - Harness advantages of more than one technology
- Proactive Combined Remediation Planning
  - Avoid adverse impact for potential following technologies
    - Remedial byproducts: enhancement or inhibitor
  - Contaminant Mobilization

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Summary and Conclusions

- Delivery of treatment to contaminant(s) is key to successful remediation
  - Choose most appropriate remediation delivery tool
  - Focus on Geology!
- Bench and Pilot Testing Important
  - Bench testing recommended for questions about chemistry/biology
  - Pilot testing recommended for questions about hydrogeology
  - Failed test is not without value or lessons
- Collaborate with Technology Experts/Contractors
- Allow flexibility into remedial design
  - Be sensitive to changes in environmental conditions
  - Consider potential field changes during planning

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Paul M. Dombrowski, P.E. (MA, CT)
Senior Remediation Engineer
pdombrowski@isotec-inc.com
O: 617-902-9383 M: 917-971-2956

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Chemical Oxidation & Reduction/Fixation


Bioremediation


Gas Thermal Conductive Heating


Soil Mixing (Chemical Reagents & Stabilization)


Treatability Laboratory


Activated Carbon Injectates (BOS100®, CAT 100 & BOS200®)