ITRC DRAFT Document: Optimizing Injection Strategies & In Situ Remediation Performance

FRTR: SYNTHESIZING EVOLVING CSMs WITH APPLICABLE REMEDIATION TECHNOLOGIES

Team Leads: Dave Scheer, Minnesota PCA & Janet Waldron, Massachusetts DEP
Presented by: Kristopher McCandless, Virginia DEQ
What is ITRC?

ITRC is a state-led coalition working to advance the use of innovative environmental technologies and approaches to translate good science into better decision-making.
Our Unique Network

- State/City/Local Government: 44%
- Federal Government: 10%
- Private Sector: 37%
- Academia: 10%
- Stakeholders: 5%
- International Organizations: 2%

907 Members

As of March 7, 2019
Federal Government Participants
Benefits to DOD and DOE

- Facilitate interactions between federal managers and state regulators
- Increase consistency of regulatory requirements for similar environmental problems in different states
- Provide harmonized approaches to using innovative technology across the nation
- Reduce review and approval times for those innovative approaches
ITRC Accomplishments

*Educates* state regulators on the use of innovative technologies

*Promotes* the use of innovative technologies

*Unites* state approaches to complex topics

*Inspires* collaboration over adversarial relationships
How Can YOU Benefit from ITRC?

- Use ITRC Documents
- Take ITRC Training Courses
- Join ITRC Teams
2020 Teams

- Use of Soil Background Concentrations in Risk Assessment (NEW)
- Per- and Polyfluoroalkyl Substances (PFAS) Update & Training
- 1,4-Dioxane (Continuing until Dec. 2020)
- Harmful Cyanobacterial Blooms (Continuing until Dec. 2020)
- Incremental Sampling Methodology Update (Continuing until Dec. 2020)
- Vapor Intrusion Mitigation Training (Continuing until Dec. 2020)
- Advanced Site Characterization Tools (ASCT) (Due in Early 2020)
- Optimizing Injection Strategies & In Situ Remediation Performance (Due in April 2020)
Optimizing Injection Strategies and In Situ Remediation Performance

DRAFT
INTERNET BASED DOCUMENT & TRAINING

(GOING PUBLIC IN APRIL 2020)

Team Leads:
Dave Scheer, Minnesota PCA
Janet Waldron, Massachusetts DEP
What is Optimization?

Optimization is the effort (at any clean-up phase) to identify and implement actions that improve effectiveness and cost-efficiency of that phase.

This is the EPA definition cited in ITRC’s 2016 Geospatial Analysis Optimization document.
Foundation of this Document

- 2011 Integrated DNAPL Site Strategy (IDSS)
- 2015’s IDSS Site Characterization and Tool Selection Document
- Optimization addressed in other contexts
  - Performance-Based Environmental Management (ITRC RPO-2, 2007)
  - Geospatial Analysis for Optimization (2016) (GRO-1, 2016)
Purpose of this Document

High Resolution Site Characterization Tools: Downhole geophysics, MiHPT/LIF/OIP, LIDAR, ER, tracer test, GPR, Packer testing

Amendment Selection Table

Design Wheel

Remedial Design Characterization

Delivery Factsheets

Bench or Pilot Test

Performance Monitoring

OPTIMIZATION TOOL BOX
Structure of this In Situ Optimization Document

- Remedial Design Characterization (Ch 2)
- Amendment, Delivery, Dose Design (Ch 3)
- Implementation & Feedback (Monitoring) Optimization (Ch 4)
- Regulatory Perspectives (Ch 5)
- Community & Tribal Stakeholder Considerations (Ch 6)

Hot links * Tables * Mouse-over Definitions * Factsheets * References * Case Studies
Who is this Document written for?

- The remediation manager who has had a failure of some type:
  - Has pushed or moved the plume where they didn’t want it go
  - Amendment is reacting with the geochemistry
  - Delivery method not compatible with hydrogeology
  - Have successfully cleaned up 50% of the mass and but stalled out for the rest

- The practitioner who is just about to start an in situ remediation project and wants to make sure they have chosen the correct remedy

- This document is NOT a 101 class for remediation! It assumes a basic CSM has been established and the hydrogeology is known
Out of all the proposals received by state regulators for remediation projects, about 40% of regulators deemed the first submittal as **incomplete**.

**Why?**

- proposed remedy was not fully supported by the CSM
- CSM was inadequate
- inadequate amendment placement according to the CSM
Main goal: clean up sites.

Traditional approach to the remedial process was linear.
Interactive/Iterative Approach

- Evolution of environmental work has led to the realization that an iterative approach is required to efficiently clean up sites.
- ITERATIVE: To state repeatedly, repetitious, repetitive
- INTERACTIVE: Acting one upon (or with) the other
ITRC Documents Support Interactive/Iterative Approach

ITRC IDSS Document

- Conceptual Framework
- Remedial Objectives
- Treatment Technologies
- Monitoring
- Remedial Evaluation

ITRC In-Situ Optimization Document

- Remedial Design Characterization
- Optimization process fits into the Site Strategy document during the selection and evaluation of appropriate remedial technologies, and during implementation and assessment of the selected remedy. Application of the Site Strategy document then carries the process through to site closure.

Figure 1-1. Relationship between the (ITRC 2011c) and the in situ treatment optimization
Common goal: **clean up sites**

The interactive/iterative approach will support the conceptual site models that change with new information.

In Situ remediation is particularly suited to the adaptive approach as unknowns are refined with bench tests, and pilot tests.
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Contaminant</th>
<th>Challenges, Lessons Learned, and/or Best Practices</th>
<th>Discussion, Document Section, Links</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>All</td>
<td>Reliance of MW data vs a full understanding of contaminant mass distribution vs lithology vs permeability (K) available through higher resolution site characterization (HRSC) technology</td>
<td>Continuous profiling tools such as MiHPT, MiHPT-CPT, LIF, LIF-CPT, LIF-CPT-MiHPT, MIP, MIP-CPT-MiHPT etc. or continuous rock coring coupled with high density soil or rock sampling and physical and chemical analyses. <a href="https://www.itrcweb.org/Guidance/ListDocuments?TopicID=5&amp;SubTopicID=49">link</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unrealistic expectations without a full understanding of site specific challenges - e.g. matrix back diffusion, which can lead to contaminant concentration rebound after initial improvement in concentrations post-injection</td>
<td>Link to Ch 2 Knowledge of delivery and amendment limitations in achieving contact and adequate residence time with mass sorbed to the soil matrix.</td>
</tr>
<tr>
<td>Bedrock</td>
<td>Bedrock</td>
<td>The amount of contaminant mass sorbed into bedrock secondary porosity</td>
<td><a href="https://www.itrcweb.org/Guidance/ListDocuments?TopicID=5&amp;SubTopicID=60">Link</a> to ITRC- FracRX-1 2017,</td>
</tr>
<tr>
<td>Soil</td>
<td>Soil</td>
<td>Lack of understanding of contaminant mass sorbed into finer grained soils.</td>
<td>Application of MiHPT, MiHPT-CPT coupled with high density soil sampling to determine extent and distribution of contaminant mass ITRC ISC-1 2015 <a href="https://www.itrcweb.org/Guidance/ListDocuments?TopicID=5&amp;SubTopicID=49">link</a></td>
</tr>
<tr>
<td>Ground Water</td>
<td>Ground Water</td>
<td>Variability of K and calculated seepage velocity in contaminated intervals is needed to estimate ROI (radius of influence) delivery approaches and residence time within ROI.</td>
<td>Higher resolution slug testing, tracer testing, or pilot testing with monitoring to determine amendment distribution in effective pore space</td>
</tr>
<tr>
<td>Amendment Class</td>
<td>Amendment Specifics</td>
<td>Challenges, Lessons Learned, and/or Best Practices</td>
<td>Discussion, Document Section, Links</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------</td>
<td>--------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>All</td>
<td>Reaction kinetics is consistent with time of contact.</td>
<td>Link Appendix A. for specific discussion of amendments, kinetics and persistence of each amendment. Link 3.3.2 &amp; 3.5.1</td>
<td></td>
</tr>
<tr>
<td>ISCO All</td>
<td>Bench testing actual dosing vs using default values to determine oxidant demand that is representative of full scale implementation</td>
<td>Link Appendix A, Klozur Persulfate Oxygen Demand, <a href="http://www.peroxychem.com/media/179425/peroxychem-peroxyn-talk-2007-5-klozur-persulfate-oxidant-demand.pdf">http://www.peroxychem.com/media/179425/peroxychem-peroxyn-talk-2007-5-klozur-persulfate-oxidant-demand.pdf</a></td>
<td></td>
</tr>
<tr>
<td>Persulfate</td>
<td>The background geochemistry including total oxidant demand (TOD) is essential to identify the loading of base activator (NaOH). Persulfate can be used as direct oxidant or in an AOP mode with multiple options for activation to generate radicals. If base activation is used...</td>
<td>Link To Chemical Oxidants Bench Testing to determine buffering capacity of the soil <a href="http://www.peroxychem.com/media/247761/peroxychem-klozur-persulfate-alkaline-activation-guide-01-04-esd-17.pdf">http://www.peroxychem.com/media/247761/peroxychem-klozur-persulfate-alkaline-activation-guide-01-04-esd-17.pdf</a></td>
<td></td>
</tr>
<tr>
<td>Anaerobic All</td>
<td>Anaerobic biotreatment technologies are typically effective when geochemical conditions such as relatively lower redox (e.g., lower than -200 mV) are achieved. Depending on specific geochemical conditions inorganic compounds, AEs (anandam ide externally added) such as oxygen and one or more AEA (anandam ide externally added) such as...</td>
<td>It is essential to collect background and baseline geochemical data including electron acceptor demand and to understand the existing biodegradation pathways before designing the loading for the amendment. Use a highly soluble amendment to stimulate sulfate reduction and design with a longer lasting...</td>
<td></td>
</tr>
<tr>
<td>Soluble</td>
<td>Low persistence requires multiple injection events to overcome matrix back diffusion</td>
<td>Typically used to get anaerobic conditions started and then followed by non-soluble. Link to A1.3</td>
<td></td>
</tr>
<tr>
<td>Solids</td>
<td>Mulch, chitin, or other solids must be emplaced by trenching, soil mixing, or fracturing</td>
<td>Must achieve adequate loading to promote degradation reaction within treatment zone which is dependent upon width of PRB trench and groundwater flow rate</td>
<td></td>
</tr>
<tr>
<td>Aerobic All</td>
<td>Estimating diffusive transport of slow released oxygen source in finer grained soils to develop ROI.</td>
<td>Find the appropriate gas diffusion coefficient or conduct a treatability study (Allaire et. al., J. Environ. Monit. 2008, 10, 1326-1336). Link to A1.1</td>
<td></td>
</tr>
<tr>
<td>Solids</td>
<td>Short lived release of oxygen from hydrogen peroxide requires multiple events</td>
<td>Develop a good design basis for the amount of hydrogen peroxide needed considering its persistence and residence time within ROI, and plan for multiple injection events or continuous feed system if warranted. Consider different oxygen source. Link to A1.1</td>
<td></td>
</tr>
<tr>
<td>Amendment Class</td>
<td>Field Implementation - Technology, Amendment</td>
<td>Challenges, Lessons Learned, and/or Best Practices</td>
<td>Discussion, Document Section, Links</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------------------------------</td>
<td>------------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>All</td>
<td>&lt; fracture pressure injection</td>
<td>The inability of the injection system, as designed and operated, to maintain injection pressures below fracture pressures required for distribution</td>
<td>Do not exceed fracture pressures to maintain controlled distribution</td>
</tr>
<tr>
<td></td>
<td>&gt; fracture pressure injection</td>
<td>The inability of the injection system, as designed and operated, to maintain injection pressure and flow rates above fracture pressures required for distribution</td>
<td>Review pump curves of pressure vs. flow.</td>
</tr>
<tr>
<td></td>
<td>&gt; fracture pressure solids emplacement</td>
<td>The inability of the emplacement system, as designed and operated, to maintain injection pressures above fracture pressures required for distribution</td>
<td>Review pump curves of pressure versus flow and size of solids it can pump</td>
</tr>
<tr>
<td>DPT Delivery</td>
<td>Losing pressure control as rods are added or removed to achieve target depths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injection Wells</td>
<td>Don't exceed pressure rate of well seal to avoid compromising well for future injection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISCO</td>
<td>Maintaining injection pressures and flows during startup at multiple manifolded injection locations</td>
<td>Ensure system design and operating procedures prevent fracturing of the formation. Consider automated systems as best practice.</td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td>Daylighting events do not stop once flow is shut down. Exothermic energy input has been excessive and is driving pressure release for a</td>
<td>Maintain injection rates, according to demonstrated specification to minimize daylighting.</td>
<td></td>
</tr>
<tr>
<td>Permanganate</td>
<td>Have adequate neutralization chemicals available for daylighting or spill events.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anaerobic</td>
<td>Not achieving anoxic and pH specification for dilution water.</td>
<td>Note pH may drop at least one order of magnitude (one pH unit) after mixing with amendment</td>
<td></td>
</tr>
<tr>
<td>Solids</td>
<td>Daylighting events do not stop once flow is shut down.</td>
<td>Maintain emplacement rates as those specified and demonstrated to minimize daylighting.</td>
<td></td>
</tr>
</tbody>
</table>
When in situ remedies fail or produce less than optimal outcomes, it is often due to a lack of detailed data or an insufficiently developed CSM.

The success of in situ remedies is directly related to a thorough understanding of site and subsurface conditions.

Remedial design characterization (RDC) is the collection of additional data, above and beyond what are typically generated as part of general site characterization studies, necessary to develop a sufficiently detailed CSM, which enables a design basis for an in situ remedy.
RDC: Remedial Design Characterization

Objectives:

Identify the data required to obtain a focused understanding of the geologic, hydrogeologic, geochemical, and microbial nature of the site conditions in specific support of in situ remedial actions. These parameters inform the remedial approach and technology selection.

- Geology - stratigraphy, mineralogy, fractures, soil properties that define flow regimes
- Hydrogeology – heterogeneities, aquifer properties that influence flow and transport
- Geochemistry - identify electron acceptors, competitors, and metal mobilization risks
- Microbiology - assess degradation potential
### Another Comprehensive Tool for RDC

<table>
<thead>
<tr>
<th>Parameters</th>
<th>In Situ Approach</th>
<th>Remediation Phase/Step</th>
<th>Alternatives</th>
<th>Remedial Design</th>
<th>Performance Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Abiotic</td>
<td>Biotic</td>
<td></td>
</tr>
<tr>
<td>Provenance and Mineralogy</td>
<td>M</td>
<td>High</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Stratigraphy</td>
<td>M</td>
<td>Medium</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Degree of Weathering of Geologic Formation</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Fracture Representative Aperture and Length</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Fracture Connectivity / Rock Quality Designation</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Fracture Orientation</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Grain Size Distribution</td>
<td>M</td>
<td>Low</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>M</td>
<td>Low</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Fraction of Organic Carbon</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
<tr>
<td>Primary and Secondary Porosity</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Physical Properties**

- **M, L = Applicability**
- **Hi, Med, Low (colors) = Relative importance of data at the remediation phase indicated**

Table 2-2 (Appendix C) Geology, Hydrogeology, Geochemistry, Microbiological Considerations Spreadsheet
Improve the CSM – Why do it?

Why spend more money on characterization, when you could be spending it on cleanup?

When in situ remedies fail, it is often due to a lack of detailed data or an insufficiently developed CSM.

Figure 2-1. Conceptual Project Lifecycle costs with and without RDC (Modified from ITRC 2015)
Chapter 3: Amendment, Dose, Delivery Design

THE DESIGN WHEEL
### Amendment Selection Table

<table>
<thead>
<tr>
<th>Treatment Type</th>
<th>Description/ Summary</th>
<th>Target COCs</th>
<th>Typical Injection/Emplacement Technologies Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Biotic Amendments (A.1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobic bioremediation (A1.1) / Biological oxidation</td>
<td>Aerobic degradation occurs predominantly in near-surface saturated and vadose zone environments (Only for sparging, calcium peroxide doesn’t work in vadose zone). Naturally occurring aerobic microorganisms are widely dispersed, and usually react efficiently with supplemental oxygen provided via amendments that release oxygen; low to moderate doses of hydrogen peroxide, calcium peroxide, or magnesium peroxide.</td>
<td>Petroleum hydrocarbons and some fuel oxygenates (e.g., methyl tertiary-butyl ether [MTBE]).</td>
<td>Air/ozone direct injection&lt;br&gt;Air sparging&lt;br&gt;Introduction of oxygen via diffused emission&lt;br&gt;Direct vapor phase injection</td>
</tr>
<tr>
<td>Co-metabolic aerobic bioremediation (A1.2)</td>
<td>Co-metabolism involves degradation of contaminants using enzymes produced by microorganisms as a result of consumption of a primary substrate such as methane, propane, ethane, etc. that may be injected into the subsurface. The microorganisms do not benefit from the degradation process and can thrive in the absence of the contaminants. Most co-metabolic processes occur under aerobic conditions and may require oxygen additions to stimulate/support degradation.</td>
<td>Chlorinated solvents (TCE, DCE, VC, DCA)&lt;br&gt;Chloroform&lt;br&gt;MTBE&lt;br&gt;1,4-dioxane&lt;br&gt;THF&lt;br&gt;Explosives&lt;br&gt;Atrazine&lt;br&gt;PAHs&lt;br&gt;Some pesticides</td>
<td>Trenching/Soil Mixing&lt;br&gt;Direct push injection&lt;br&gt;Permanent injection wells&lt;br&gt;Biosparge wells for gases</td>
</tr>
<tr>
<td>Anaerobic bioremediation (A1.3) / biological reduction</td>
<td>Contaminants are degraded via a reductive process by certain types of microbes under anaerobic conditions. Fermentable organic substrates are injected or placed into the subsurface to enhance the production of hydrogen, which is in turn used by the microbes in the reductive reactions.</td>
<td>Chlorinated solvents&lt;br&gt;Many pesticides and munitions&lt;br&gt;Certain inorganic compounds&lt;br&gt;Petroleum Hydrocarbons (typically by introduction of electron acceptors like nitrate and/or sulfate)</td>
<td>Direct push injection&lt;br&gt;Permanent injection wells&lt;br&gt;PRBs</td>
</tr>
</tbody>
</table>
Amendment Dosage & Delivery

- Amendment Dose Requirements
  - Background Demands
  - Target Demands
  - Volume Considerations

- Amendment Delivery Optimization
  - Grid patterns, Injection & Drift, Recirculation
  - Overcoming Delivery Problems
    - Fouling and well rehabilitation
<table>
<thead>
<tr>
<th>Hydrogeologic Characteristics</th>
<th>Delivery Technique</th>
<th>Direct Push Injection (DPI) [link # D1]</th>
<th>Injection Through Wells &amp; Boreholes [link # D2]</th>
<th>Electro-Kinetics (This is injection through wells) [link # D3]</th>
<th>Solid Emplacement [Link # D4]</th>
<th>Permeable Reactive Barriers (PRBs) [link # D7]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gravels</td>
<td>(Sonic)</td>
<td>¹</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Cobbles</td>
<td>(Sonic)</td>
<td>¹</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Sandy Soils (Sm, Sc, Sp, Sw)</td>
<td></td>
<td>¹</td>
<td>¹</td>
<td>0</td>
<td>⁰</td>
<td>⁰</td>
</tr>
<tr>
<td>Silty Soils (MI, Mh)</td>
<td></td>
<td>¹</td>
<td>⁰</td>
<td>¹</td>
<td>¹</td>
<td>¹</td>
</tr>
<tr>
<td>Clayey Soils (Cl, Ch, Oh)</td>
<td></td>
<td>¹</td>
<td>⁰</td>
<td>¹</td>
<td>¹</td>
<td>¹</td>
</tr>
<tr>
<td>Weathered Bedrock</td>
<td></td>
<td>¹</td>
<td>⁰</td>
<td>¹</td>
<td>¹</td>
<td>¹</td>
</tr>
<tr>
<td>Competent/Fractured Bedrock</td>
<td></td>
<td>NA</td>
<td>¹</td>
<td>NA</td>
<td>⁰</td>
<td>⁰</td>
</tr>
<tr>
<td>K d 10⁻³ To 10⁻⁴ (Low Perm Soils)</td>
<td></td>
<td>¹</td>
<td>⁰</td>
<td>¹</td>
<td>¹</td>
<td>¹</td>
</tr>
<tr>
<td>K e 10⁻³ (High Perm Soils)</td>
<td></td>
<td>¹</td>
<td>⁰</td>
<td>⁰</td>
<td>⁰</td>
<td>⁰</td>
</tr>
<tr>
<td>Depth &gt; Direct Push Capabilities</td>
<td></td>
<td>NA</td>
<td>¹</td>
<td>⁰</td>
<td>⁰</td>
<td>⁰</td>
</tr>
</tbody>
</table>
Chapter 4: Implementation, Monitoring, Data Analysis

THE OPTIMIZATION STAIRCASE
Chapter 4: Optimization Staircase

- Implementation & Optimization Staircase
  - Results of pilot or bench test may lead to another pilot or bench test before going for full scale site implementation
  - Optimization not meant to create endless cycle of testing, but a cost effective, efficient remediation strategy

- Adaptive Implementation and Feedback Optimization
  - Data set for CSM and corresponding design (amendment, dose, delivery) will never be perfect or fully complete
  - Staircase always allows for feedback to a design step or the CSM
## Chapter 4: Monitoring

### Process and Performance Monitoring

<table>
<thead>
<tr>
<th>Table 4-1. Typical observations during process monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Type</strong></td>
</tr>
<tr>
<td>Water Level</td>
</tr>
<tr>
<td>Pressure</td>
</tr>
<tr>
<td>Pressure</td>
</tr>
<tr>
<td>Physical Parameters</td>
</tr>
</tbody>
</table>
Chapter 5: Regulatory Perspectives

Adaptive Regulatory Process

[Diagram showing the adaptive management's application in the Superfund process with labels such as 'Preliminary Assessment/Site Investigation', 'Remedial Investigation/Feasibility Study', 'Remedial Action Decision or Record of Decision', 'Remedial Action Implementation', 'Assess Performance', 'Identify Technologies', 'Investigate', 'Build', 'Optimize', 'Operate', and more.]

- Adaptive Management's Application in the Superfund Process
- ROD: Record of Decision
- ROD-A: Record of Decision Amendment
- ESD: Explanation of Significant Differences
- RI/FS: Remedial Investigation/Feasibility Study
- RD/RA: Remedial Design/Remedial Action
- O&M: Operation and Maintenance
A Powerful Remediation Design Tool for 2020
Thank You!

Stay Updated on ITRC’s Activities

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