Failing to plan is... planning to waste a lot of ________ (fill in the blank).
“CAP to Closure”

• What does this mean?
• How many states require one?
• Do you usually reach NFA in one try?
• Is the CAP ever updated?
  • How are modifications made?
  • How are costs reconciled?
• How do you judge remedial progress?
Adaptive Site Management

1. Develop Interim Objectives and Adaptive Remedial Strategy
2. Develop Long-Term Management Plan
3. Design and Implement Remedy
4. Monitor and Evaluate Performance
   - Are Interim Objectives Met?
     - Yes
     - Are Site Objectives Met?
       - Yes
       - Initiate Closure Process
     - No
   - No
5. Re-Evaluate Remedy Basis
   - No
   - Is a Contingency Remedy Specified?
     - No
     - Can Remedy Be Optimized?
       - No
       - Is Progress Acceptable?
         - Yes
         - Re-Evaluate Remedy Basis
         - No
       - Yes
         - Initiate Closure Process
       - No
     - Yes
   - Yes
   - Re-Evaluate Remedy Basis
   - No
   - Re-Evaluate Remedy Basis

Remediation Management of Complex Sites (ITRC, November 2017)
21 Technology “Tools”

1. Excavation
2. Skimming
3. Vacuum enhanced skimming (LNAPL & vapor)
4. Total liquid extraction (LNAPL & water)
5. Multi-phase extraction (LNAPL, water, & vapor)
6. Water/hot water flooding
7. Surfactant-enhanced subsurface remediation
8. Cosolvent flushing
9. Steam injection
10. Electrical resistance heating
11. Air sparging/soil vapor extraction (AS/SVE)
12. In-situ chemical oxidation
13. Natural source zone depletion (NSZD)
14. Physical or hydraulic containment
15. In-situ soil mixing (stabilization)
16. Thermal conduction heating
17. In-situ smoldering
18. Biosparging/bioventing
19. Enhanced anaerobic biodegradation
20. Activated carbon
21. Phytotechnology

LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies (ITRC, March 2018)
LNAPL Remedial Technology Groups

- **Mass Control** - Contain LNAPL at a defined boundary
- **Mass Recovery** - Remove LNAPL mass to limit migration
- **Phase Change** - Abate unacceptable COCs

Technologies (i.e. processes) sometimes overlap groups.

LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies (ITRC, March 2018)
Processes

Efficiency

Biological
Chemical
Physical

Concentration

High

Phase Change
Mass Control / Recovery
## Technically Achievable

### Examples Include:

<table>
<thead>
<tr>
<th>Remedial Mechanism</th>
<th>Technically Achievable / Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LNAPL Recoverability</td>
<td>LNAPL Transmissivity (0.1 to 0.8 ft²/day)</td>
</tr>
<tr>
<td>2. Volatilization</td>
<td>Vapor Pressure 10-100X less than gasoline</td>
</tr>
<tr>
<td>- AS</td>
<td></td>
</tr>
<tr>
<td>- SVE</td>
<td></td>
</tr>
<tr>
<td>3. Injection</td>
<td>Soil texture limits delivery of oxidant/other media</td>
</tr>
<tr>
<td>- ISCO</td>
<td></td>
</tr>
<tr>
<td>- Carbon</td>
<td></td>
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<tr>
<td>4. Biodegradation</td>
<td>Rate of degradation won’t achieve goal in timeframe</td>
</tr>
<tr>
<td>- Biovent / Biosparge</td>
<td></td>
</tr>
<tr>
<td>- NSZD/MNA</td>
<td></td>
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</tbody>
</table>
“Treatment Train”
(Consecutive Remedies)

- **PLANNING** to use multiple remedial technologies *in sequence* to achieve closure

- Sequence remedial technologies based on contaminant concerns and remedial objectives
  - Consider starting with a primary technology (excavation?) tailored for higher contaminant mass
  - Continue with a 2nd treatment technology (ISCO?) and possibly a tertiary polishing step (CBI?) to address remaining contaminant mass and to eliminate contaminant concerns
Treatment Trains

**Good**
- When planned with SMART objectives, metrics for transition, and endpoints
- Orderly implementation

**Bad**
- Unplanned, lack SMART objectives, metrics for transition, and endpoints
- “Throwing” more technologies at the problem
SMART?

- **S**pecific - Targeted treatment area and technology-specific endpoints are clearly stated
- **M**easurable – Performance metrics that demonstrate progress towards the endpoint
- **A**greed Upon – Concerns, goals, objectives, treatment areas, metrics, endpoints
- **R**ealistic – Demonstrated ability to achieve objective
- **T**ime-Based – Target date of remedial endpoint being achieved

Achieving a remedial endpoint does not necessarily mean that all contaminant concerns have been eliminated
Concurrent Remedies

• Using multiple technologies on a site at the same time, in *different target zones* due to differing contaminant concentrations
  
  • Use primary technologies in the source area (e.g. excavation).
  
  • Use secondary or tertiary technologies on *periphery* of contaminated area, and in deeper zones.

• Still rely on SMART performance metrics to measure remedial progress
Example: Treatment Areas
Don’t forget the third dimension!!!

- Biovent?
- Sparging?
- Skimming
- Enhanced bio?
Performance Metrics

Measurable characteristics that track the progress of a selected technology to achieve a remedial objective and abate a contaminant concern

**ASK:** What conditions do you expect to change as you remediate the site? And how quickly?
Performance Metrics

- Technology-specific!
- Track progress toward endpoint
- Verify that remedy is being implemented effectively
- Allow for mid-course corrections
- Allow for CSM updates
Performance Metrics Examples

- **AS/SVE** - Air emission samples to evaluate contaminant recovery
- **ISCO** - Data to evaluate distribution of an in-situ application (e.g. pH, ORP, DO)
- **SVE** - Interim or final soil confirmation samples
- **MNA** – Organic/ inorganic/ biological samples
Remedial Milestones
(Interim Objectives)

Anticipated points throughout remediation implementation to evaluate progress towards remedial endpoint (for a performance metric).
Remedial Milestone Examples

- LNAPL reduction = 10% of volume estimate per quarter/month
- Emissions decrease 30% per quarter/month
- Dissolved phase concentrations remediated to 25%, 50%, 75% of endpoint (with timeframe)

Remember!
Declines are exponential, not linear (90% of the result takes 10% of the time?)
Endpoints

• Also technology-specific!
• Defined as:
  1. LNAPL concern has been addressed, or
  2. Practicable limit of the technology reached

• If technology reaches its practicable limit before LNAPL concern is abated, then the endpoint marks the transition to the next technology in the treatment train
Endpoint Identification
(Final Objective)

• Predetermined value that describes when a technology has achieved the limits of beneficial application

• Should account for expectations of the selected remedial technology

• Does not necessarily eliminate all contaminant concerns described in the CSM

The endpoint may not be your site goal!