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Sustainable Remediation Approaches using a Common-Sense Approach to Enhanced Attenuation

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Track 1.4: LTS Practices & Challenges at DOE Legacy Sites

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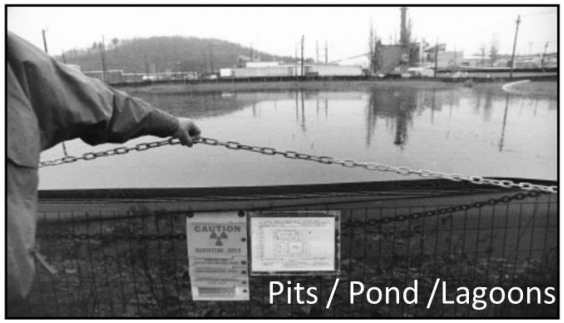
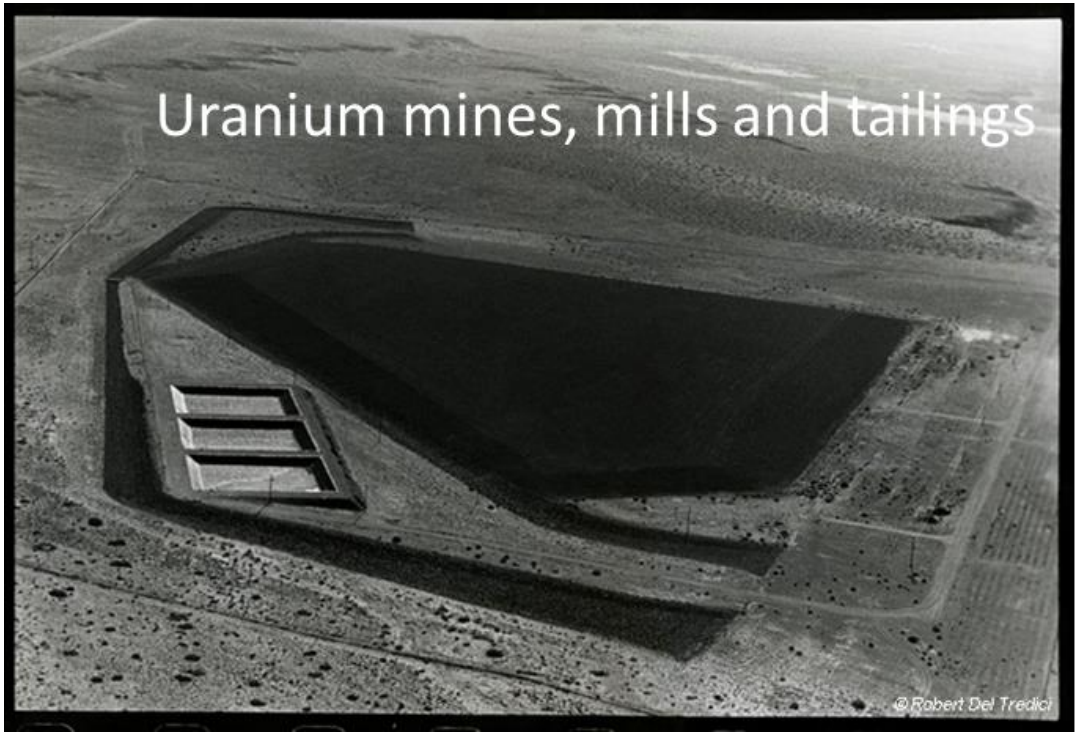
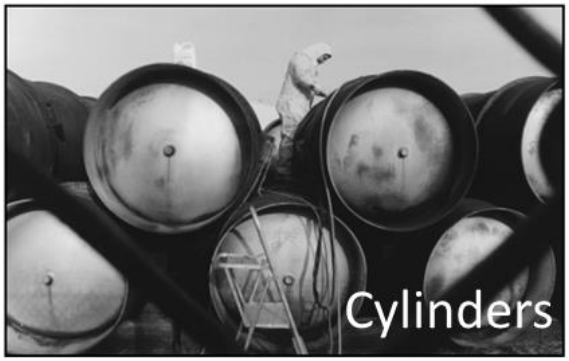
Diverse Stewardship Challenges require…







Attenuation Based Remedies

- **Monitored Natural Attenuation**

  Cleanup strategy that relies on "*a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater*."

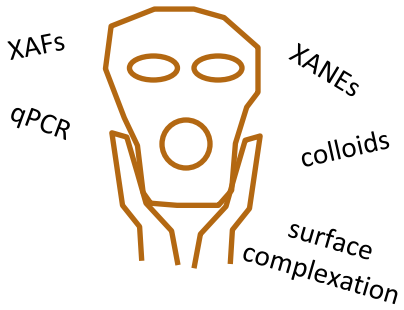
- **Enhanced Attenuation**

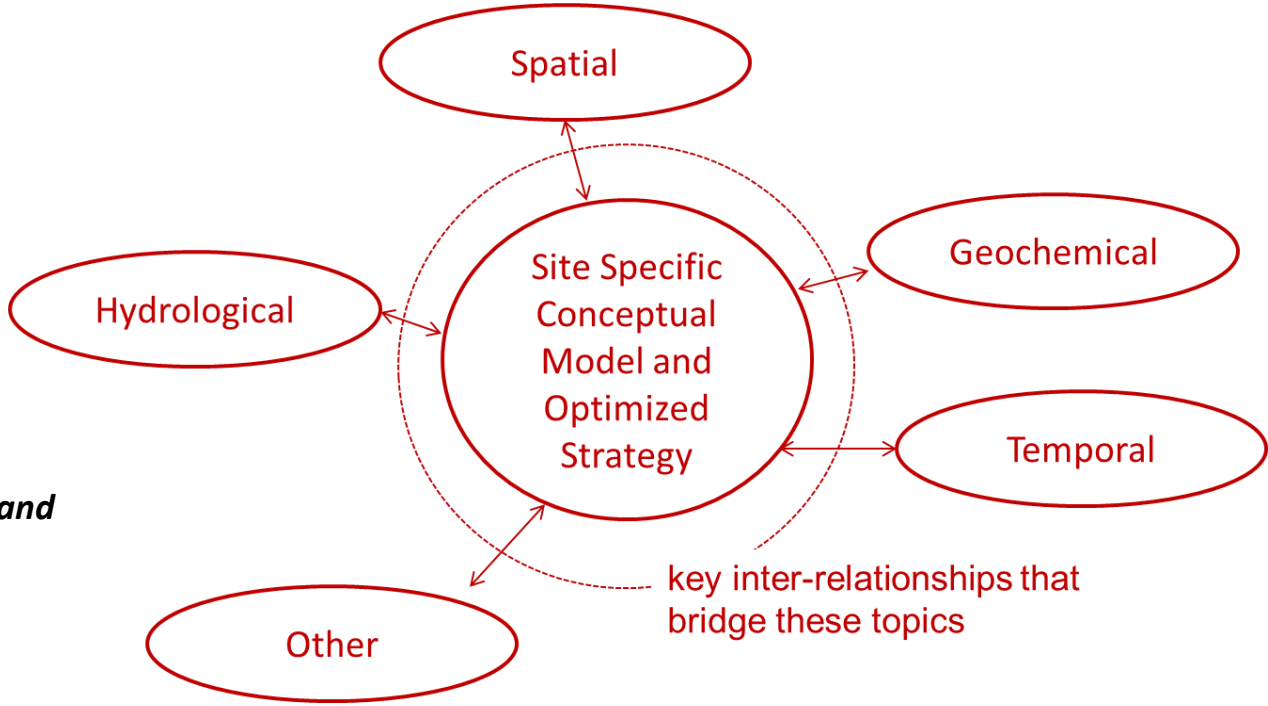
  Any type of intervention implemented in a source-plume system to sustainably increase the magnitude of attenuation by natural processes.

- **Diverse contaminants require…**
  - organic contaminants → degradation and mass removal.
  - metals and radionuclides → reduce mobility and/or toxicity

Technical frameworks… a key to success

Avoid paralysis from perceived complexity





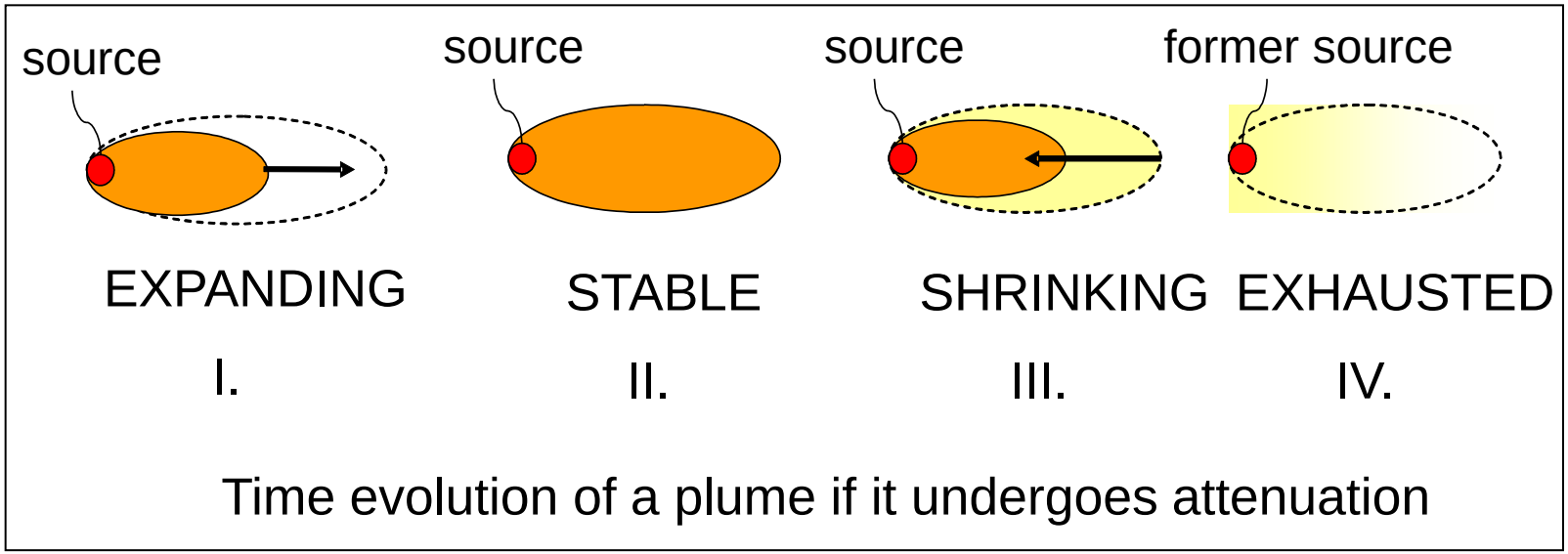
Focusing Science on the Problem at Hand

Start with what is known

- Nature of source
- Contaminant Distribution
- Biogeochemical Conditions in plume
- Background Biogeochemical Conditions
- Geology and Hydrology
- General Contaminant Chemistry

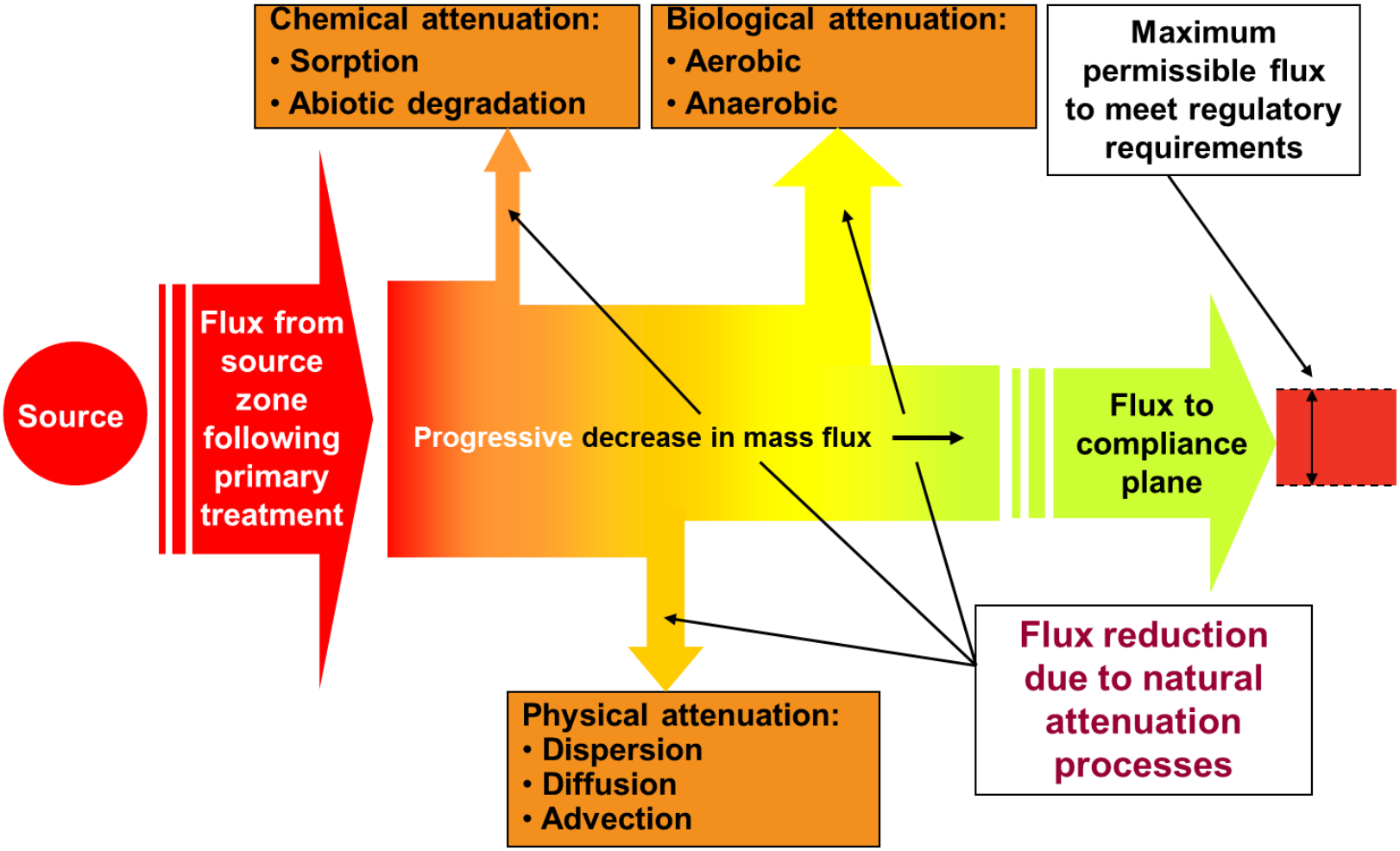
Often know 80% to 90% of what is needed for Legacy Management Success

Plume Dynamics

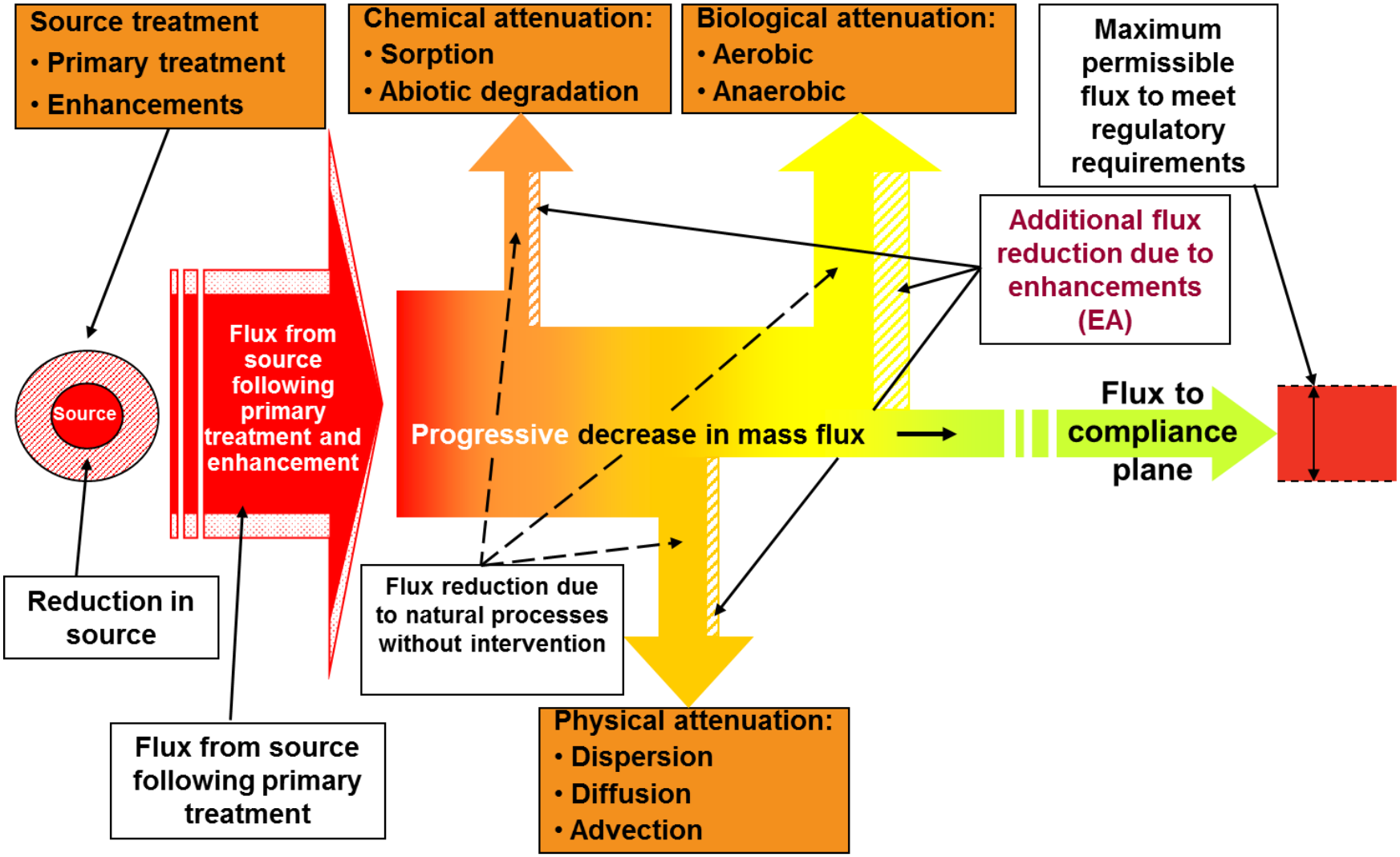


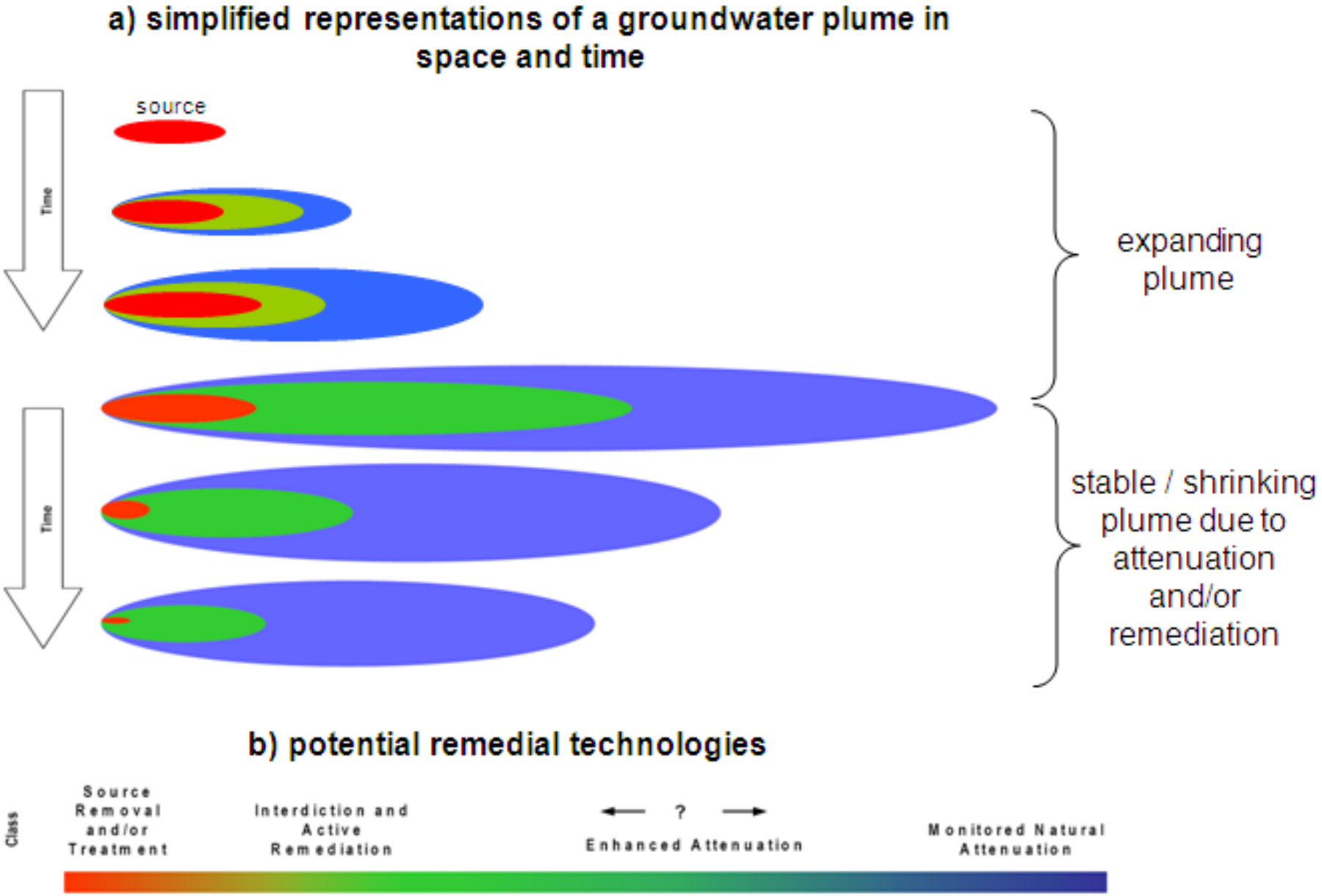
- **Plume status is controlled by the balance of source mass flux and attenuation capacity in plume**
- **Some of the "requirements" for MNA**
  - Source remediation to extent practicable
  - Plume poses minimal risk and remediation goals met in reasonable timeframe
  - Plume is stable or collapsing
  - Monitoring to assure attenuation mechanisms in place and sustainable
  - Triggers to implement contingency plans as needed

Simplified Mass Balance and Natural Attenuation

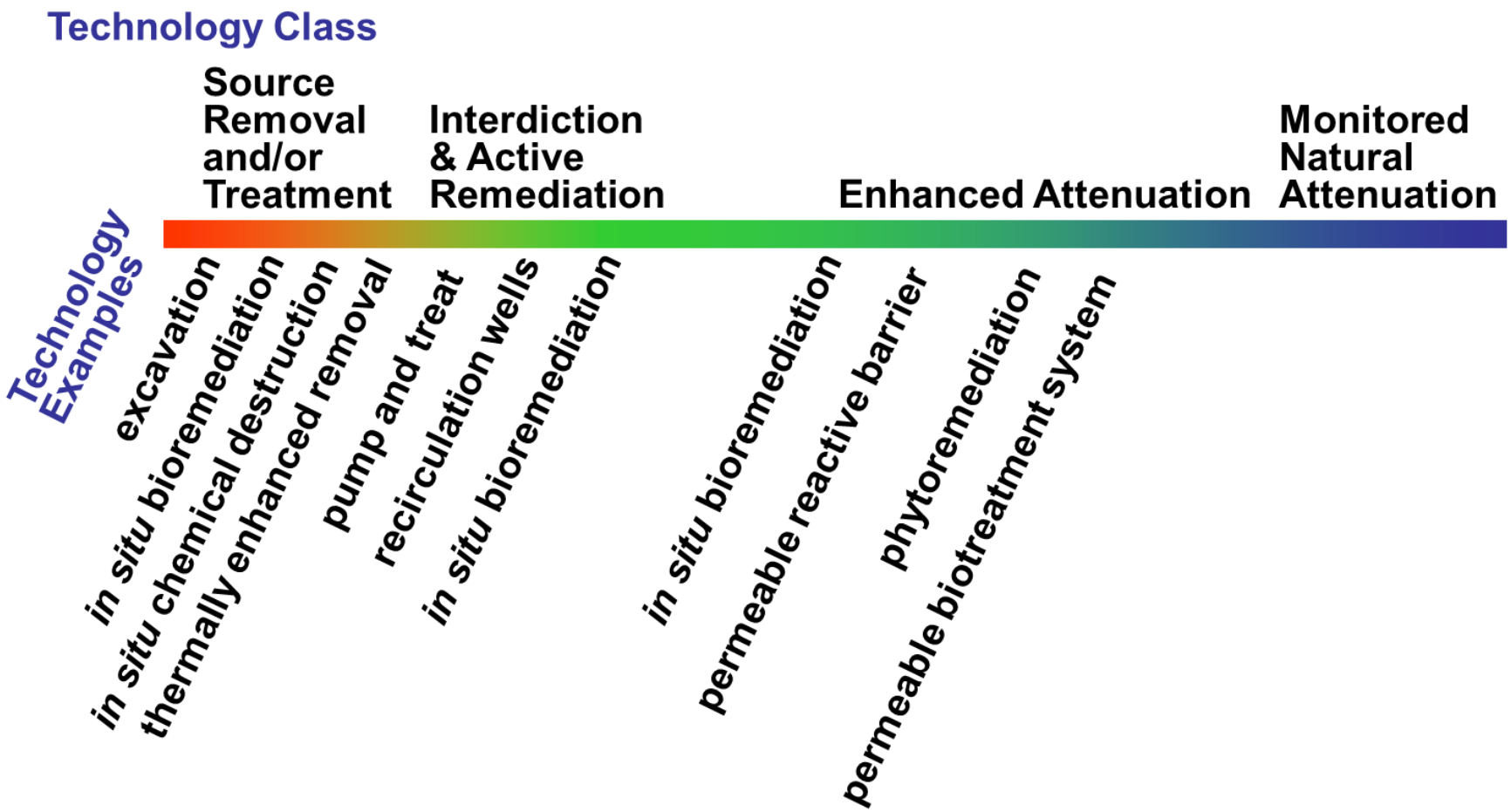


General Enhanced Attenuation Mass Balance Concept




a) simplified representations of a groundwater plume in space and time
source
Time
Time
expanding plume
stable / shrinking plume due to attenuation and/or remediation
b) potential remedial technologies
Technology Class
Source Removal and/or Treatment
Interdiction and Active Remediation
?
Enhanced Attenuation
Monitored Natural Attenuation

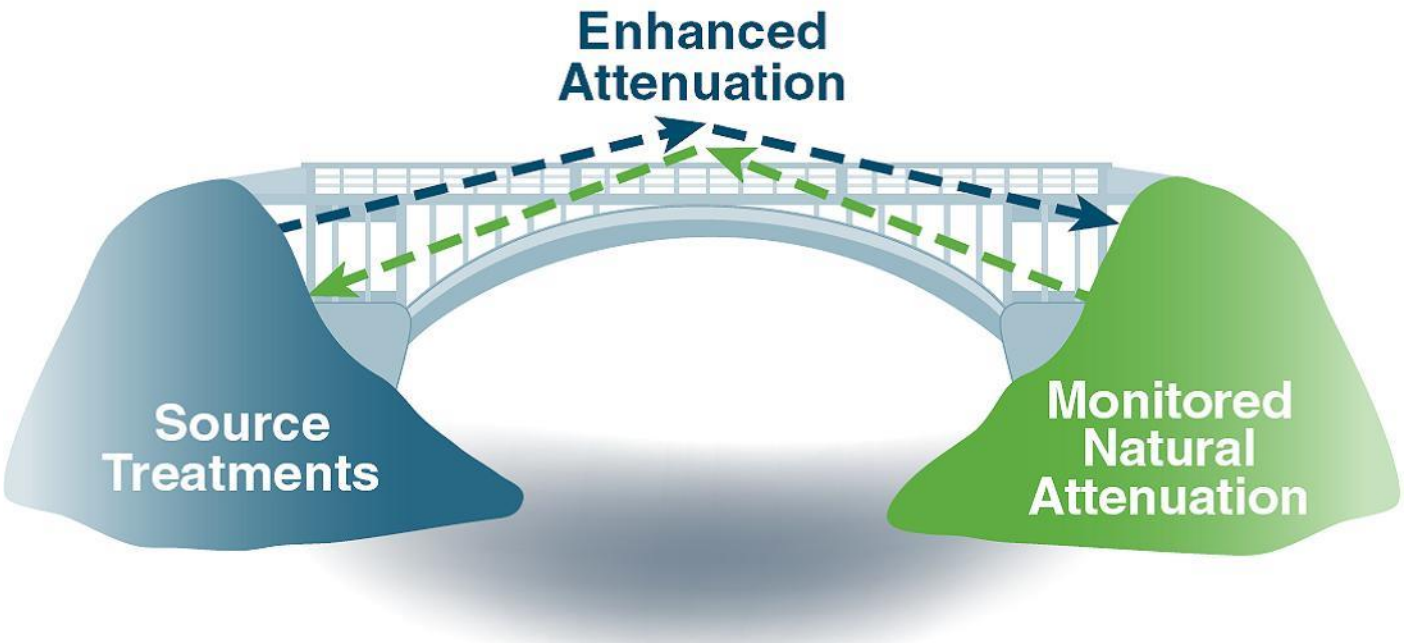
Continuum of Remediation Technologies



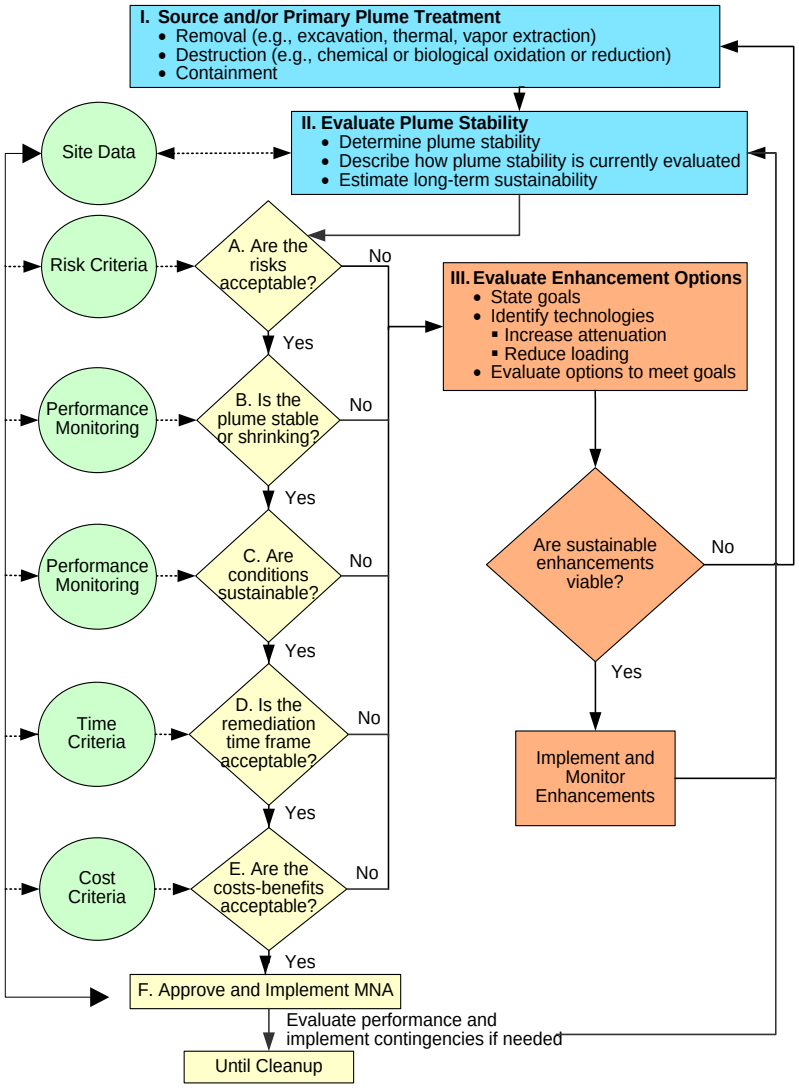
Enhanced Attenuation (EA)

A "Bridge" between Source Treatments and MNA
(← →)

Developed by a team of the Interstate Technology and Regulatory Council (ITRC)



EA – Implementation Process – Decision Flowchart



Enhanced Attenuation Decision Flowchart

Figure 2-1 of the ITRC Technical & Regulatory Guidance Document for Enhanced Attenuation of Chlorinated Organics

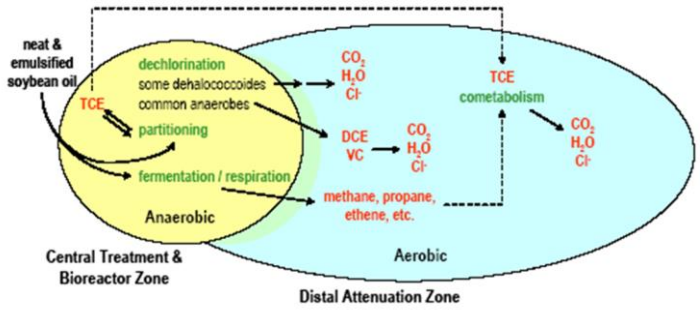
Also available on the Enhance Attenuation: Chlorinated Organics Team resource page at http://www.itrcweb.org .

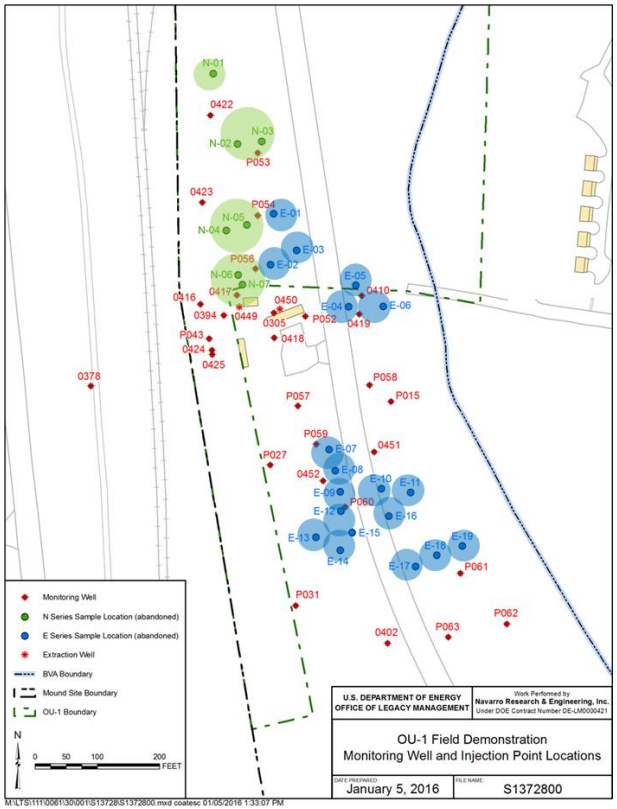
Case Studies

- Mound OU1 (contaminated groundwater from former landfill)
- F-Area Groundwater at the Savannah River Site (contaminated groundwater from former seepage basins)
- Brainstorming for Tuba City (former uranium mill and tailings disposal site)

Mound OU1 Groundwater

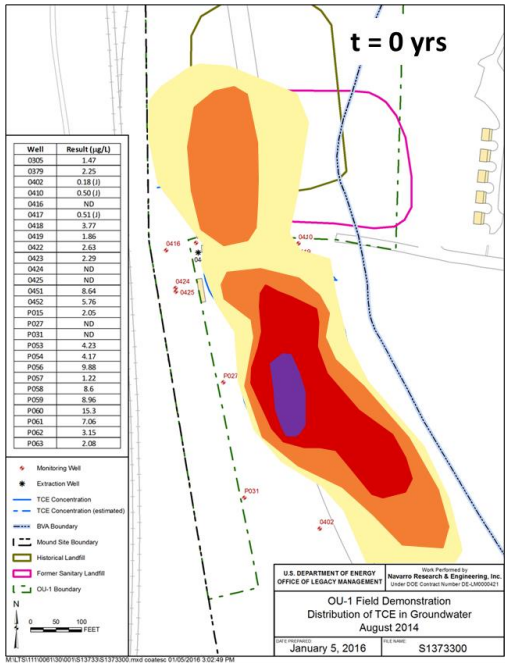
- **Source removal "complete" ☑**
- **Operating groundwater pump and treat ☑**
- **Transition groundwater remedy to Enhanced Attenuation using Structured Geochemical Zones**
  - Relies on groundwater flow through succession of anaerobic and aerobic zones
  - Anaerobic zones stimulate rapid parent-compound degradation
  - Aerobic areas encourage rapid daughter-products degradation
  - Basis for using structured zones: relative degradation rate of various cVOCs under anaerobic and aerobic conditions

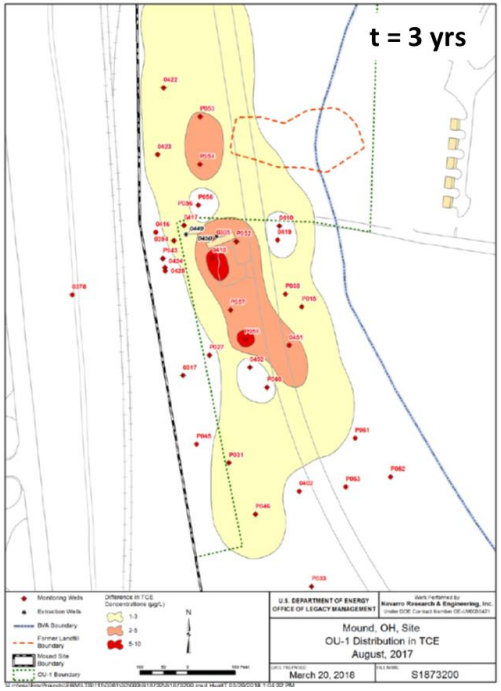




Mound Results

- Enhanced attenuation accelerated progress toward remedial objectives and reduced costs
- The "Core Team" of DOE and regulators will meet to consider the questions:





… "has the EA remedy effectively transitioned the site into monitored natural attenuation?" and "is attenuation likely to continue to be effective, timely, and sustainable?"

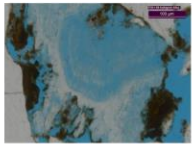
If these criteria are met, then the site will be formally transitioned to MNA.

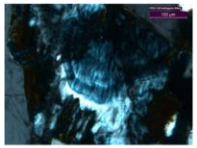
SRS F Area Groundwater

Enhanced Attenuation – Using a Wall and Gate System

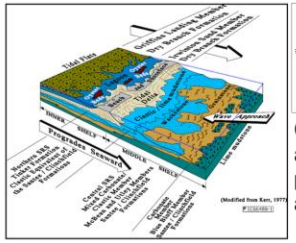
Basic Geochemistry ⟷ **Applied Lab and Field Studies** ⟷ **System Design and Optimization** ⟷ **Deployment**

Subsurface Contaminant Geochemistry

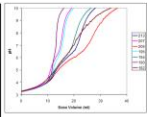




Study of inter-related topics: solution-solid-contaminant interactions, potential treatment amendments, and long term stability of in-situ stabilized phases

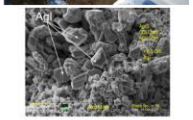


Focus on natural and plume induced facies and the chemical dynamics at the leading and trailing edges of the plume

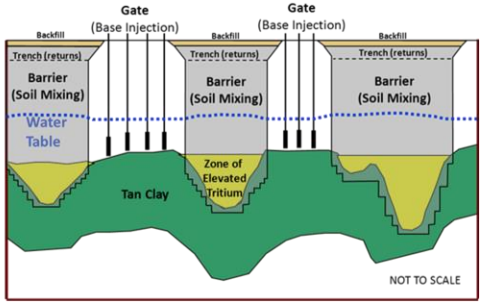


Column studies and pH titrations of plume impacted aquifer sediments

Confirmatory field studies



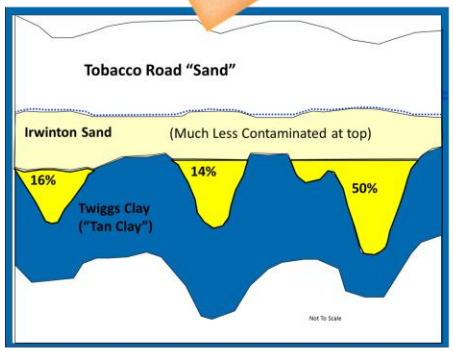
Development of innovative treatment reagents



In Situ Treatment using Wall and Gate for Combined Hydrologic and Geochemical Control

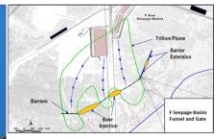
Problem: Groundwater Contamination from Seepage Basins

40 years of seepage basin operation resulted in low pH groundwater plume containing radionuclides and metals. 10 years of pump and treat had limited impact on the plume and cost over $12 million per year to operate.



Refined geological conceptual model and identified target areas of opportunity for in situ treatment deployment

Active work with stakeholders and regulators to facilitate transition from baseline pump & treat system to innovative in situ treatment

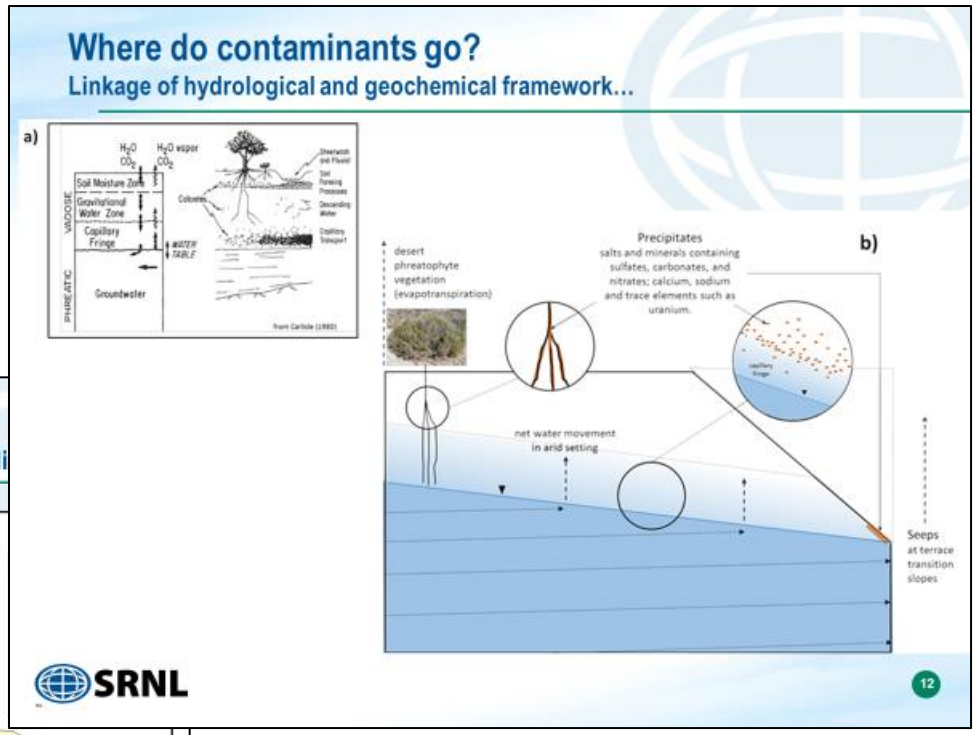


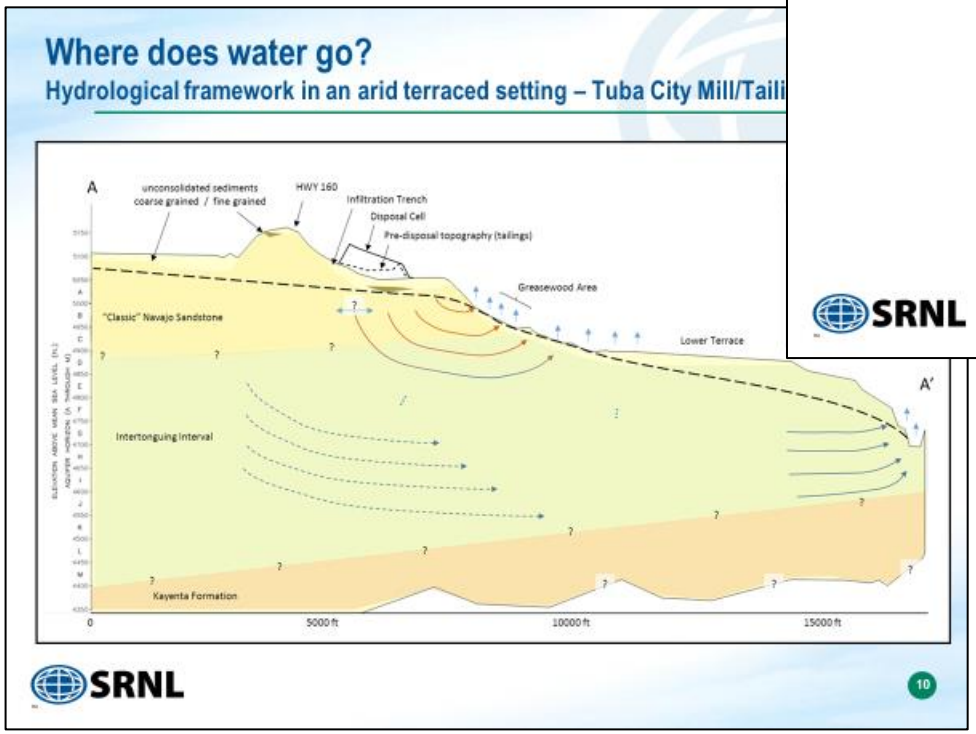
Installed bariers ("walls") to block plume and force water through treatment zones ("gates")

Alkaline treatment solution periodically injected into the gate area to create permeable reactive treatment zone to immobilize contaminants

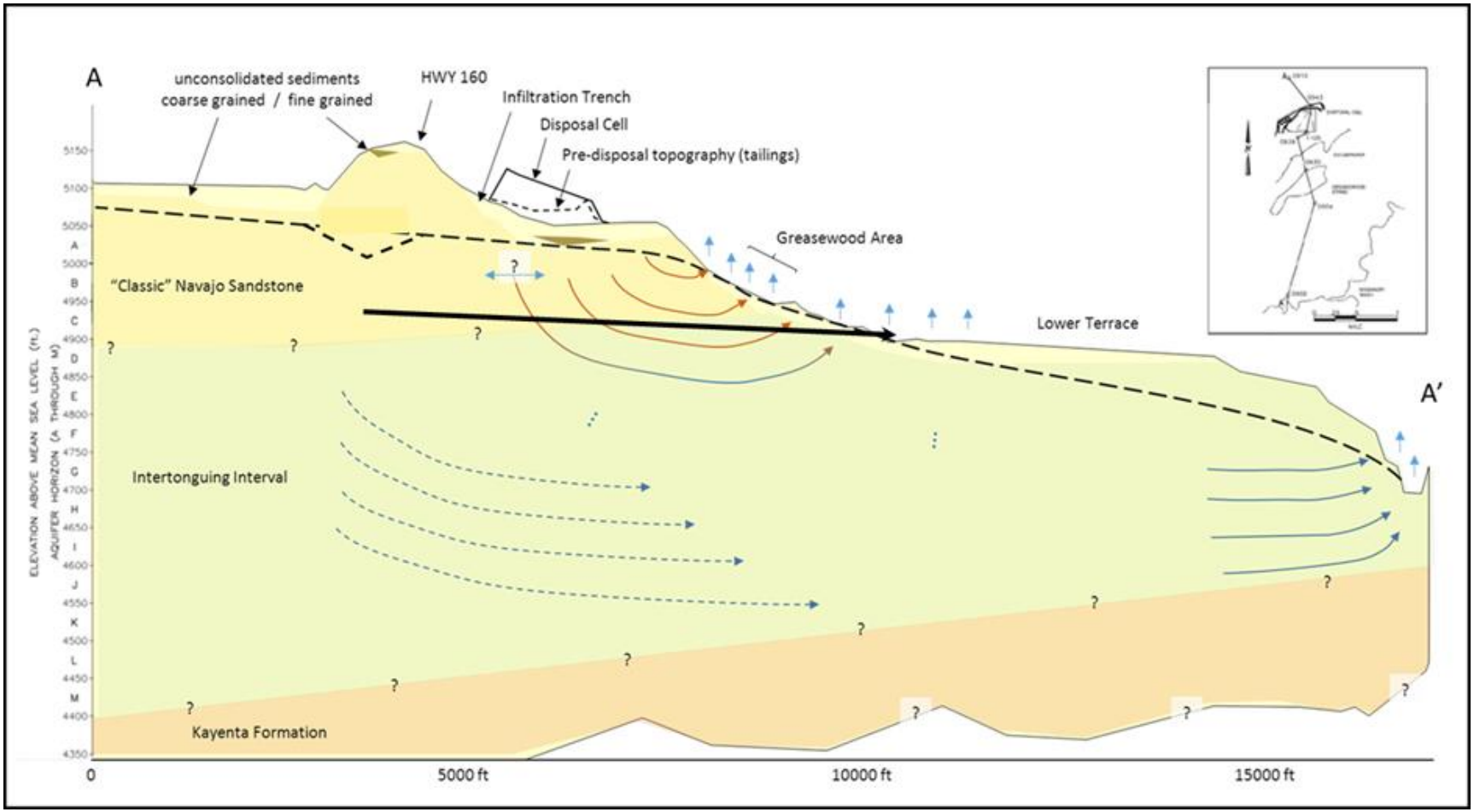
Savings: $300M

Tuba City Mill Site





Tuba City Mill Site – Brainstorming Ideas…



Groundwater Bypass?

Key Points

- **Enhanced Attenuation Remedies represent a powerful strategy to address the diversity of DOE environmental challenges.**
- **Enhanced Attenuation Remedies support formulation of alternative end states and foster creative options for long term monitoring**
- **Enhanced Attenuation Remedies need to consider (and be consistent with) the biology, chemistry, geology, hydrology and other conditions and the projected biogeochemical evolution over time**
- **Many examples:**
  - Hydrological and geochemical controls in arid environments that work together to limit the size of groundwater plumes and can extend plume flushing times
  - Geochemical conditions at the trailing edge of the plume that help stabilize contaminants
  - …