Savannah River National Laboratory

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The DOE's ALTEMIS Project: Combining Innovative Technologies to Improve Long Term Management of Radionuclide Contaminated Sites

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Savannah River National Laboratory

Federal Remediation Technologies Roundtable

Monday June 13, 2022

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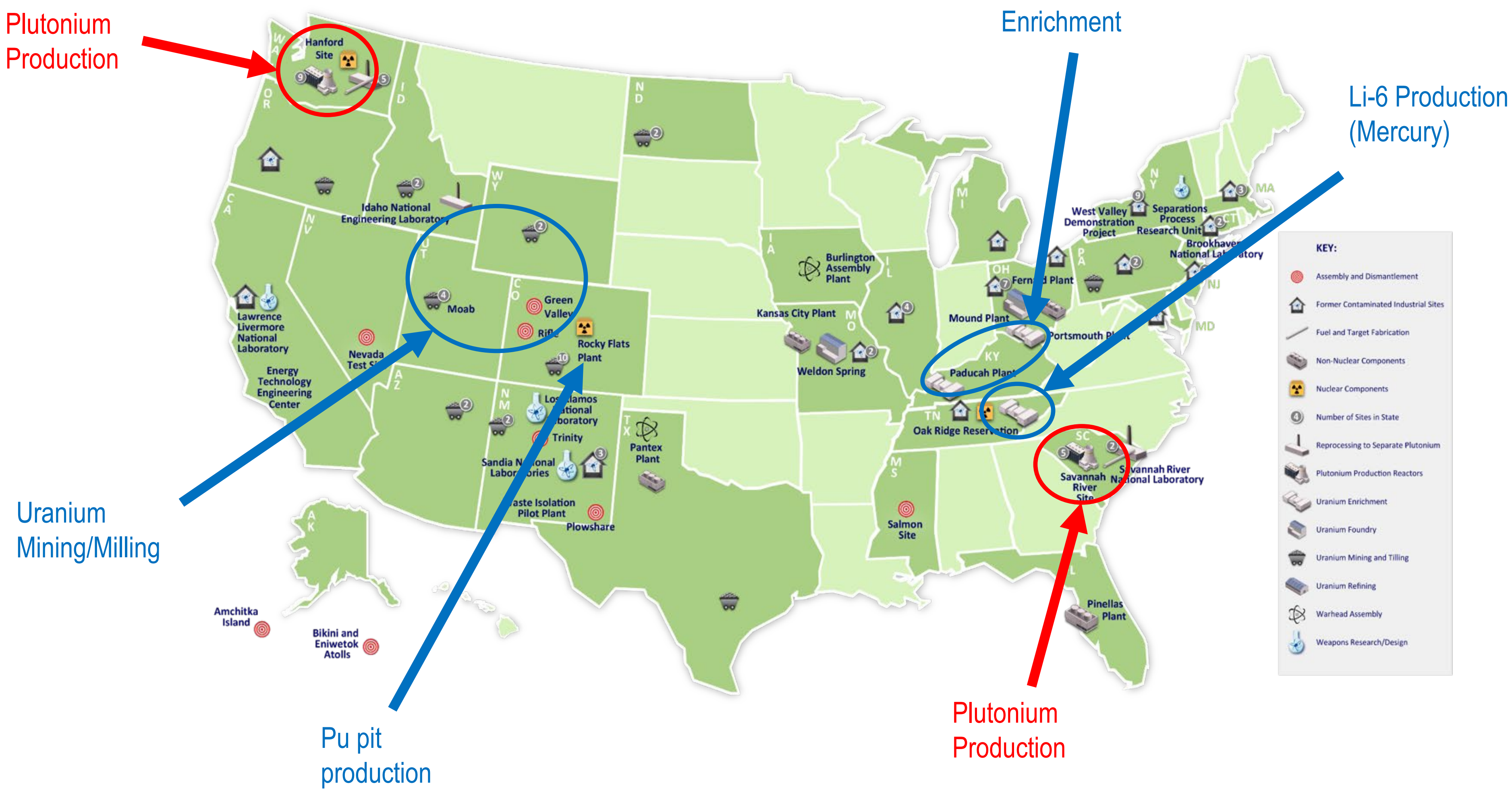
U.S. DEPARTMENT OF ENERGY

BSRA Battelle Savannah River Alliance, LLC

Nuclear Weapon Production Sites



Nuclear Weapon Production Sites: Remediation

30+ years of remediation
100+ sites → 16 sites

Large-volume low-concentration plumes have been challenging

ALTEMIS – Advanced Long-Term Environmental Monitoring Systems

- **GAO estimates that EM's liability for environmental cleanup across the country will exceed $550 billion**
- **Long term monitoring after sites have been cleaned up is a large component of that liability**
- **DOE-EM Technology Office is sponsoring SRNL-led program**
  - Multi-lab and multi-agency team: SRNL, LBNL, PNNL, UC Berkeley, FIU/CRESP/MSIPP

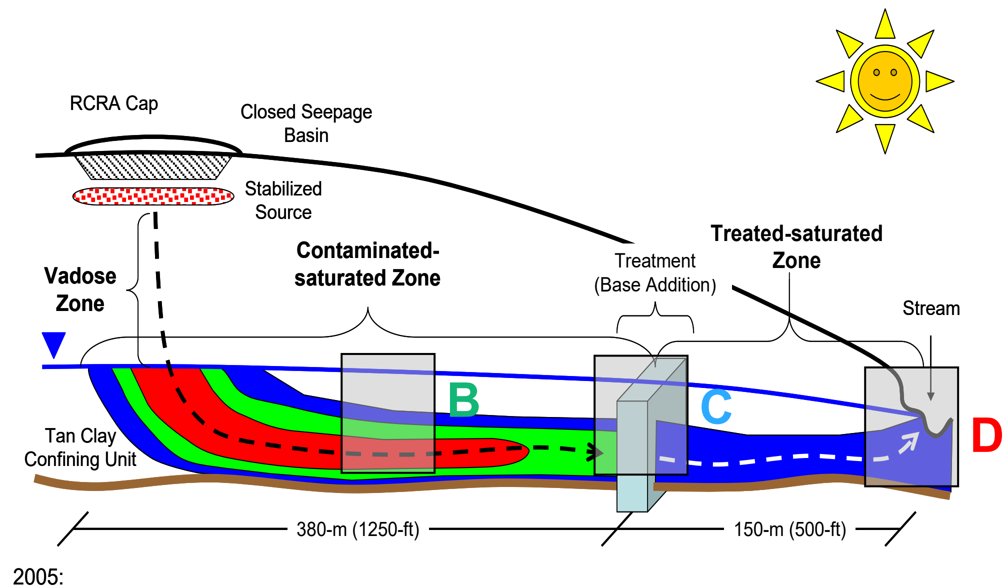
ALTEMIS: Advanced Long Term Environmental Monitoring Systems

Savannah River National Laboratory
- Development of overall site closure strategy
- Geochemical characterization and modeling
- Innovative groundwater sensor network
- Design for technology demonstrations

Lawrence Berkeley National Laboratory
- Sensors and modeling
- Artificial intelligence and machine learning
- Innovative sensor/spatial systems for monitoring key seepline process

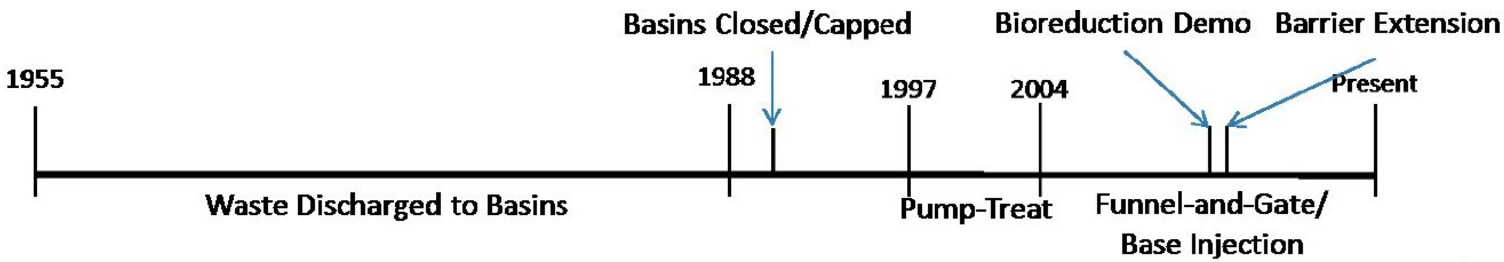
Pacific Northwest National Laboratory
- Electrical resistance tomography

Florida International University and CRESP
- Watershed modeling
- Artificial intelligence and machine learning

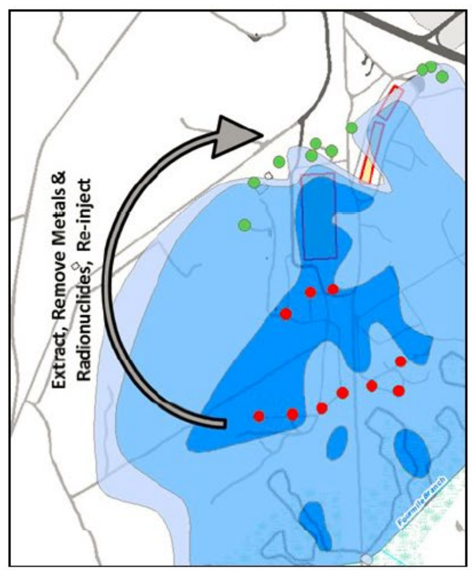


Remedial History: F-Area Seepage Basins

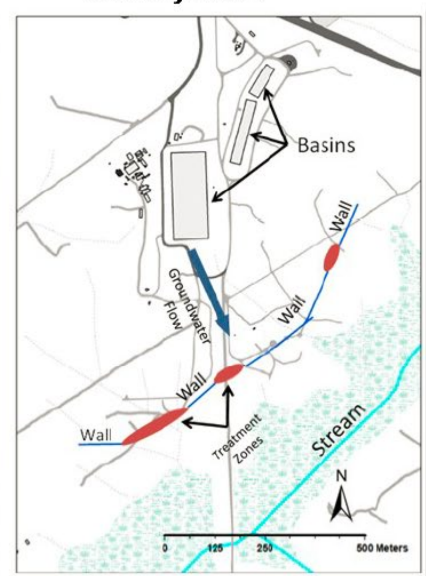
- Phased Remedial Strategy – Source Zone isolation, Active Remediation, Enhanced Attenuation
- Enhanced attenuation strategies have improved remediation of low concentration plumes but have created the potential for creation of secondary source terms (e.g., I-129, U, Sr-90)
- Require continuous monitoring over the course of the next several decades to ensure compliance with regulatory requirements



Basin Operation



Pump/Treat/Re-inject

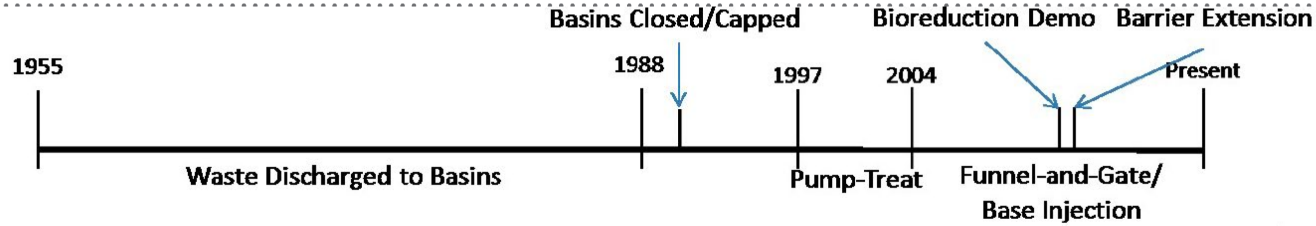


Funnel-Gate/Base Injection

ALTEMIS – Overarching Goals

- Develop and implement an integrated strategy to improve monitoring of a complex groundwater site that will be effective over 25-30 years
- Use of sensor and remote monitoring strategies to develop a proactive rather than reactive monitoring approach
- Use alterative to groundwater sampling and laboratory analysis
- Improve robustness of future monitoring as residual contamination is impacted by climate change.
- Improve regulatory and stakeholder communication to expedite closure at complex site
- Transfer approach to DOE's complex plumes at Hanford, LANL, Paducah, Hanford, Moab, and other complex sites.

Potential Vulnerabilities for F-area System



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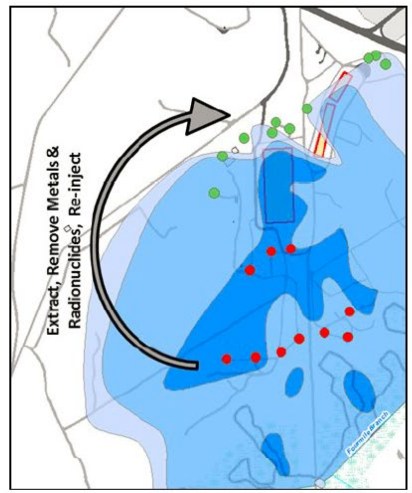

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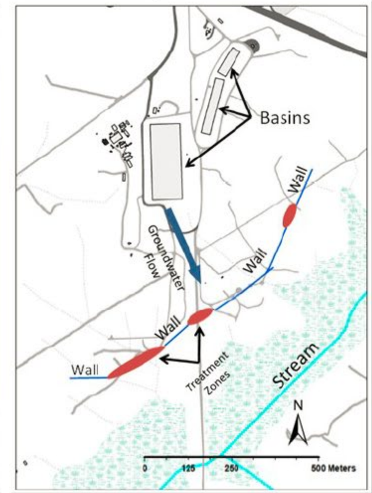


Funnel-Gate/Base Injection

- **"Zones of Vulnerability":**

Zone of Vulnerability	Vulnerable Contaminants	Threat Conditions	Long-Term Monitoring Focus
Basin soils and vadose zone	All	Infiltration through cap	Cap integrity and moisture content
Treatment zones in gates	Uranium, Sr-90, I-129	Low pH (Sr-90, uranium) and reducing conditions (I-129)	pH, ORP, groundwater flow rate
Wetlands	Uranium, Sr-90, I-129	Low pH, significant change in wetland morphology, vegetation, loss of organic matter, etc.	pH, ORP, physical configuration (e.g., topography, course of Fourmile Branch, frequency of intense rain events)

Boundary Conditions and Master Variables

Long-Term Monitoring

- Monitor for systemic changes that potentially mobilize attenuated contaminants

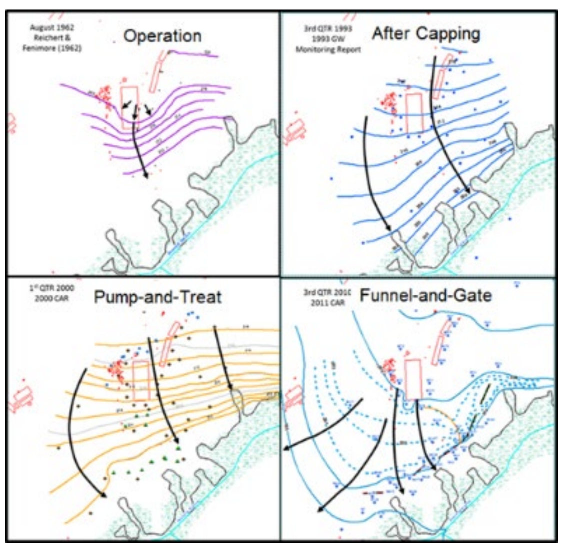
- Emphasize monitoring in ones of vulnerability
- Monitor boundary conditions
- Monitor master variables
- Use spatially integrative measures of system

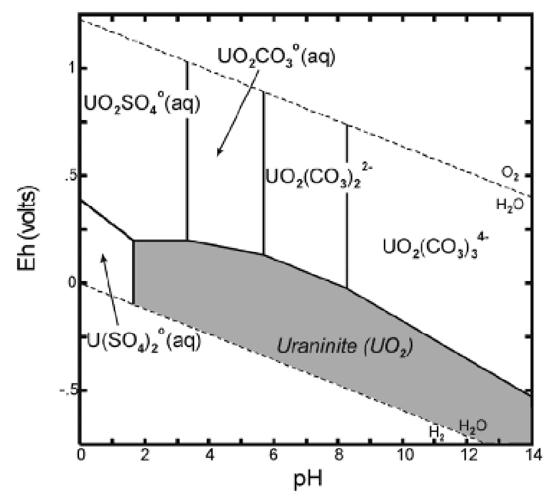
Boundary conditions are the physical forces driving groundwater movement

- **Recharge, evapotranspiration, location of drainages, potentiometric surface, etc.**

Master variables are the chemical parameters that control mobility/attenuation of contaminants

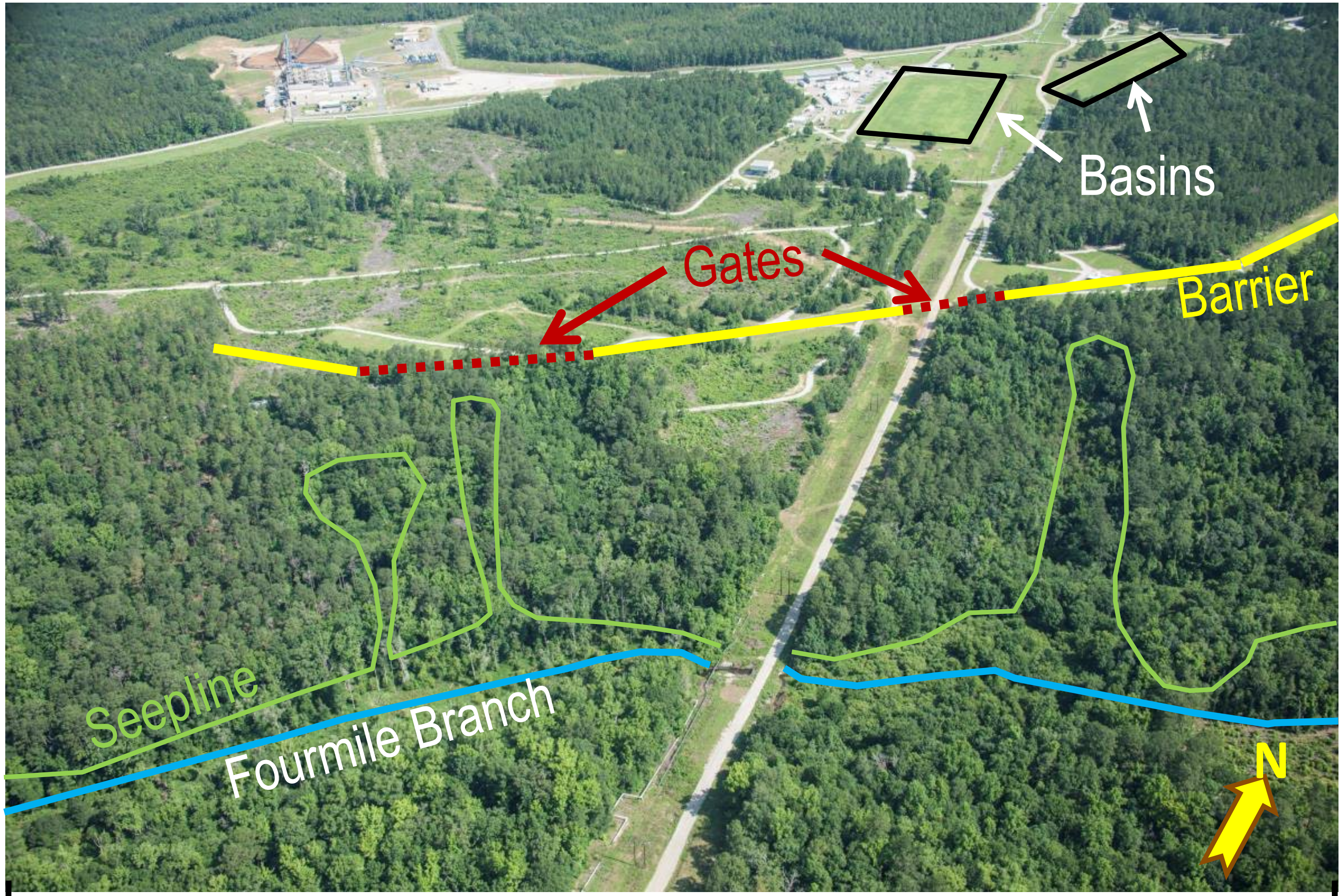
- **pH, redox potential, ionic strength, etc.**





(From Krupka and Serne, 2002)

Zones of Vulnerability



Approximately 1 Kilometer

Conceptual Model

Zones of Vulnerability – locations in the subsurface where contaminants are attenuated and subject to remobilization

Basin Capping/Closure

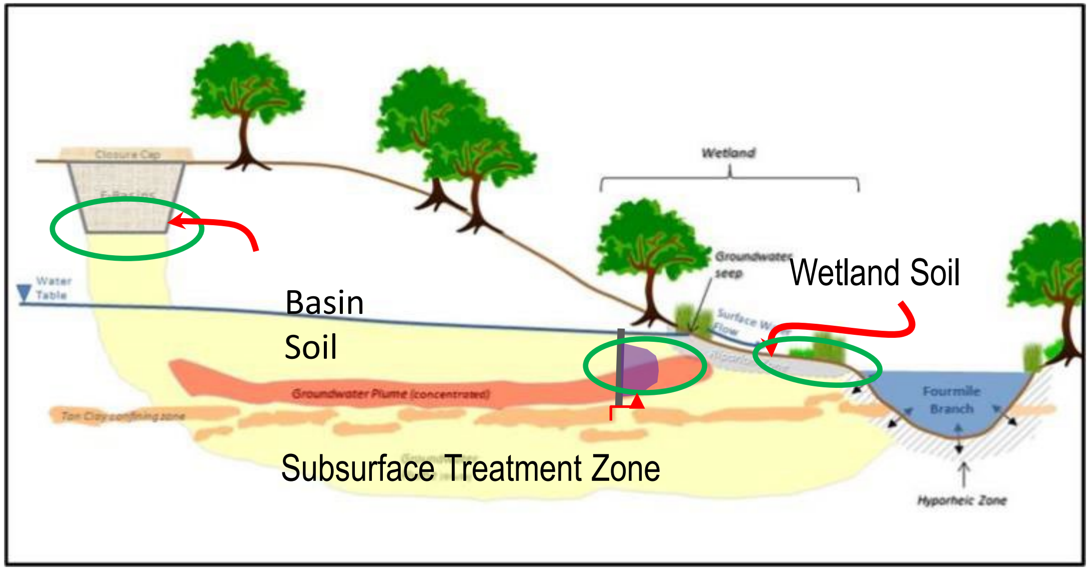
- Contaminants remain in basin soils
- Prevent infiltration that would drive contaminants deeper

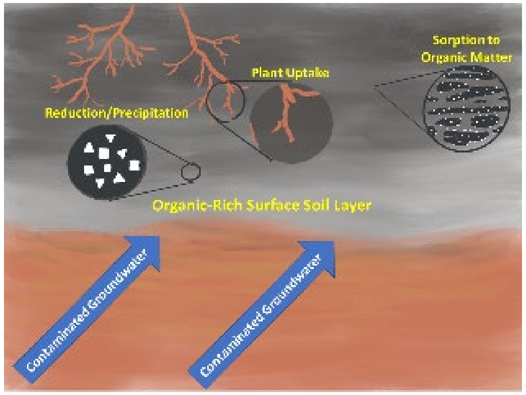
Subsurface Barrier w/Treatment Zones

- U and Sr-90 attenuated by raising pH
- I-129 attenuated by precipitation of AgI

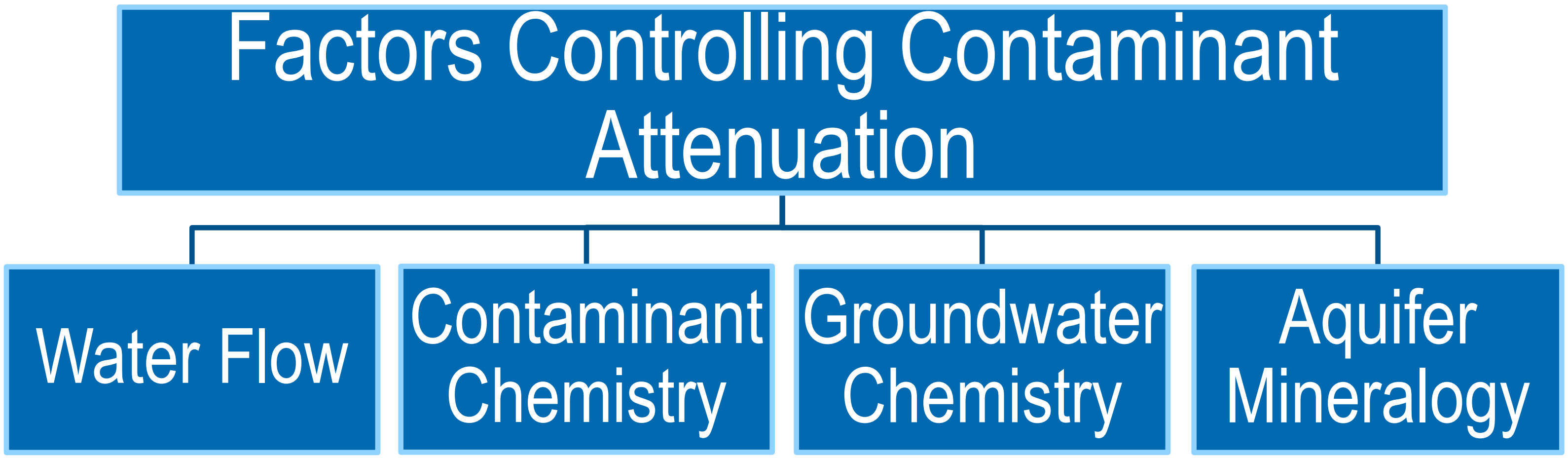
Wetlands

- Contaminants attenuated by processes in organic-rich soils
- Sorption to organic matter, plant uptake, reduction/precipitation for some contaminants





General Factors Controlling Contaminant Attenuation



Monitoring Basin Soils Beneath Low Permeability Cap

Method of attenuation is to minimize infiltration through contaminated basin soils

- **Only care about integrity of cap continuing to limit water flow**

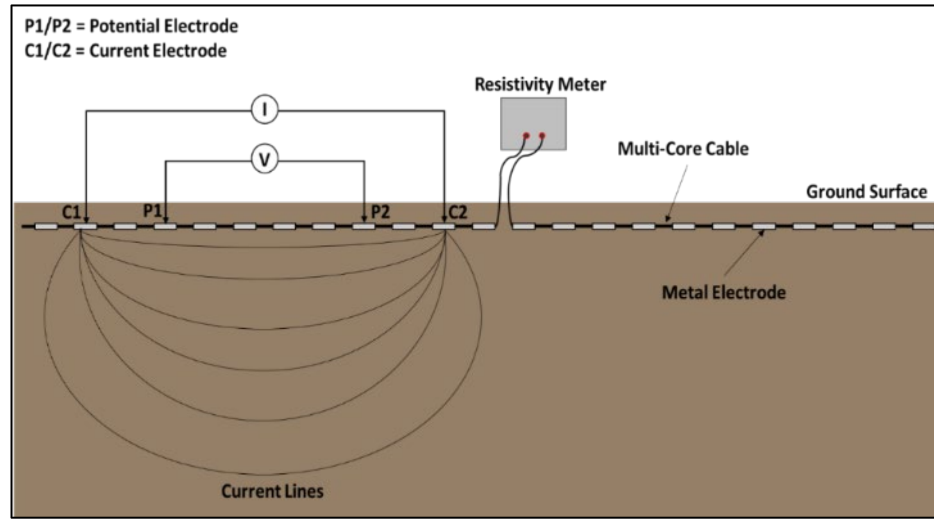
Monitor subsidence, erosion, vegetation, etc.

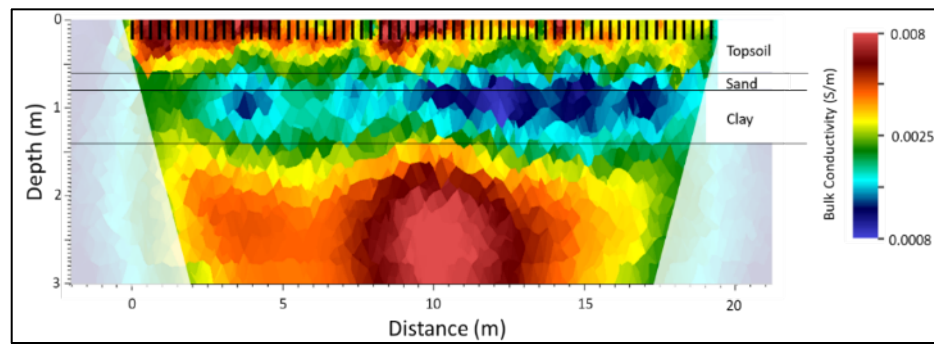
- **Use UAV systems**

Monitor moisture content in cap clay layer and in soils beneath cap

- **Electrical resistance tomography (ERT)**

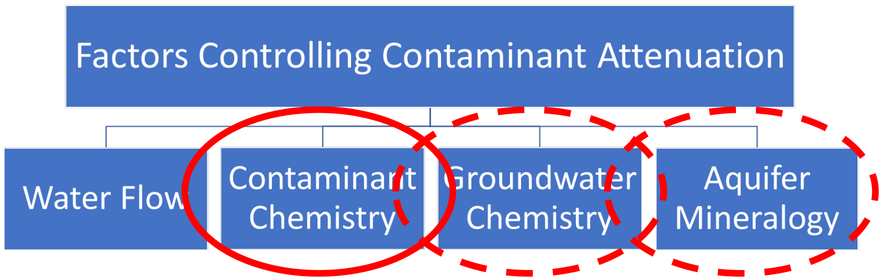
Electrical Resistance Tomography





ERT results of initial survey of conductivity within and beneath cap (Johnson, PNNL)

Monitoring Treatment Zones in Gates



Aqueous Speciation (soluble species) of Contaminants

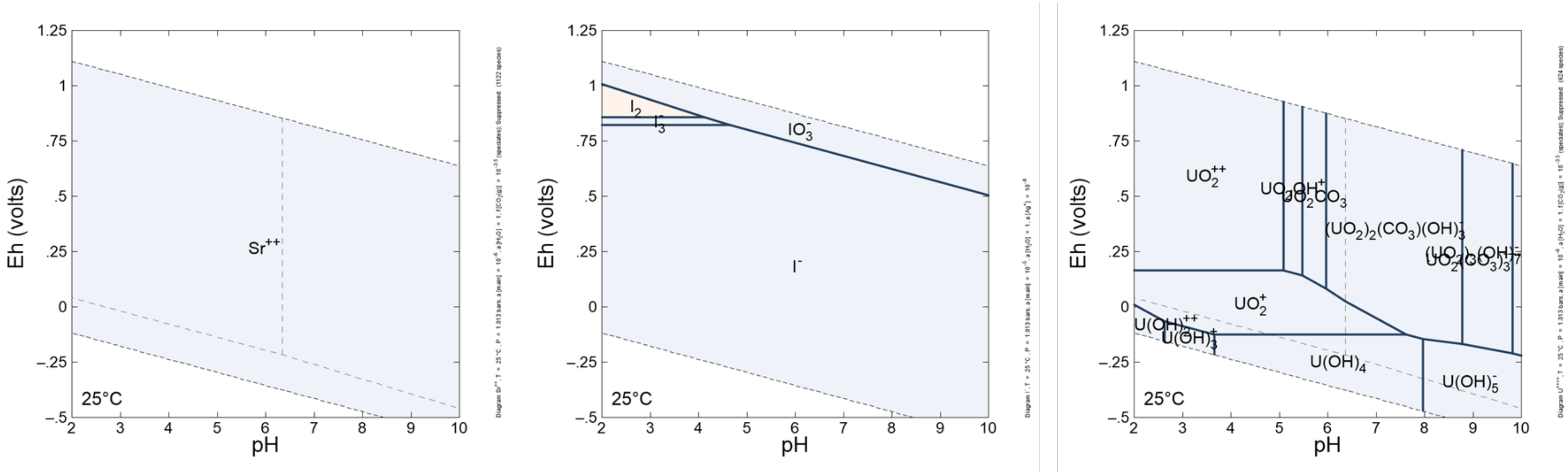
- **Speciation controls adsorption and solubility**
- **Sr-90 simple, only 1 dominant species**

I-129 speciation more complex, pH and redox sensitive

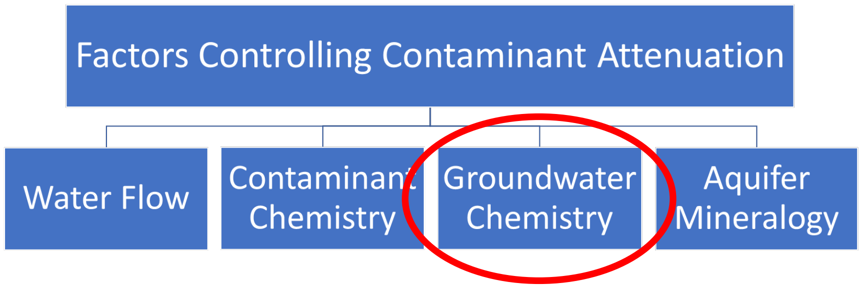
- **Forms soluble organic complexes**

Uranium complex, pH and redox sensitive

- **May for soluble organic complexes**



Monitoring Treatment Zones in Gates



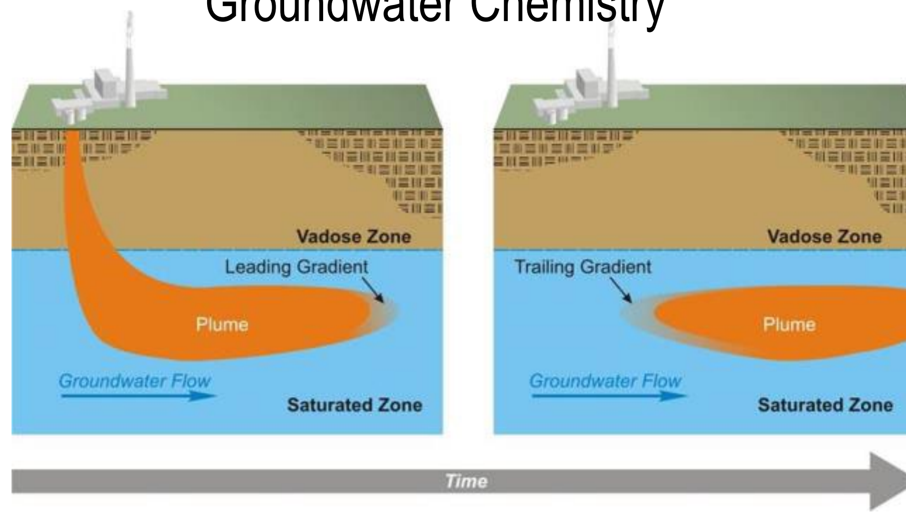
Groundwater chemistry is evolving as "clean" groundwater from upgradient passes through contaminated zones, pH will continue to increase until it reaches background

- Background pH=5.5 to 6.5
- Promotes continued adsorption of Sr-90 and uranium in treatment zones
- Monitor pH at perimeter and upgradient of treatment zones to warn of introduction of acid to system

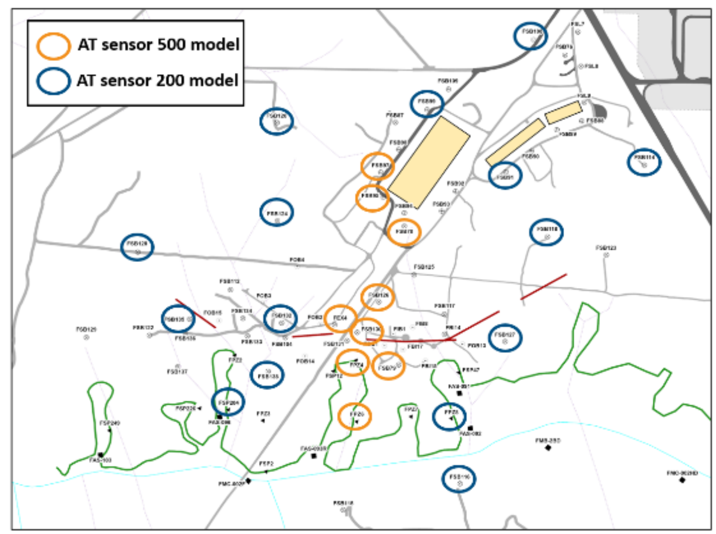
Groundwater is currently and will remain oxic

- Promotes stability of AgI
- Monitor redox potential (Eh) to warn of introduction of reductants (electron donors)

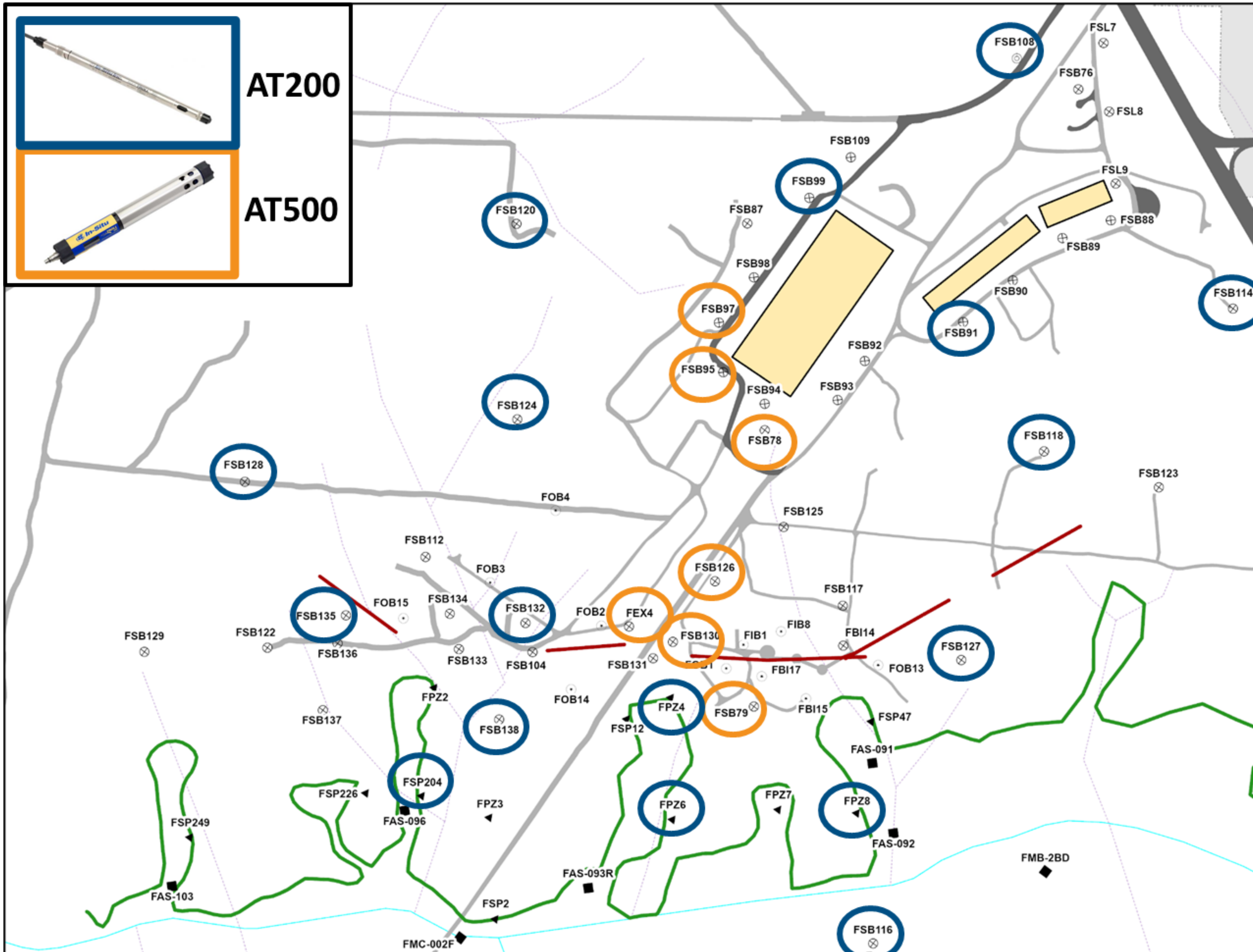
Groundwater Chemistry



Sensor Deployment



Optimized Sensor Network Layout

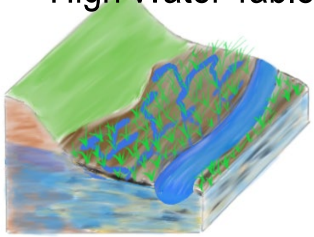


Monitoring Wetlands

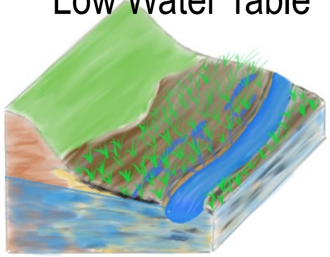
Wetlands are very dynamic environment

- Surface water moves around
- Erosion – soil moves around
- Biological effects
- Upward flow of contaminated water from LAZ

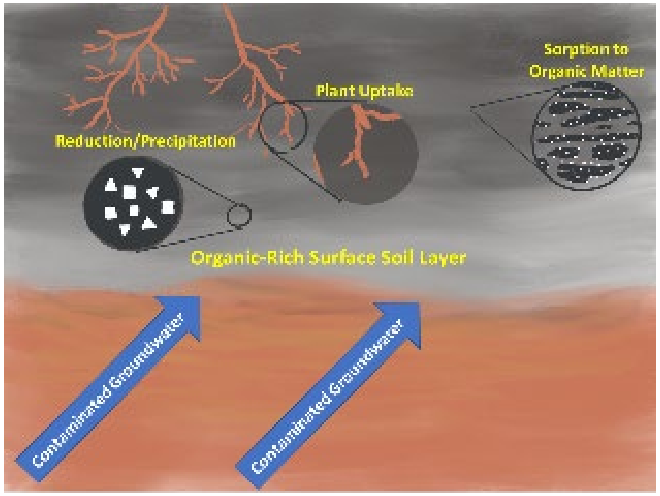
High Water Table



Low Water Table

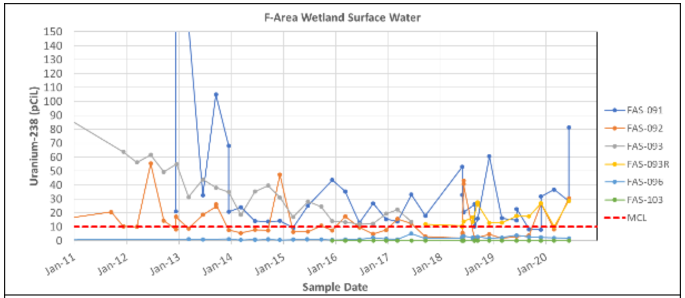


Likely Attenuation Mechanisms Associated with Organic Layer

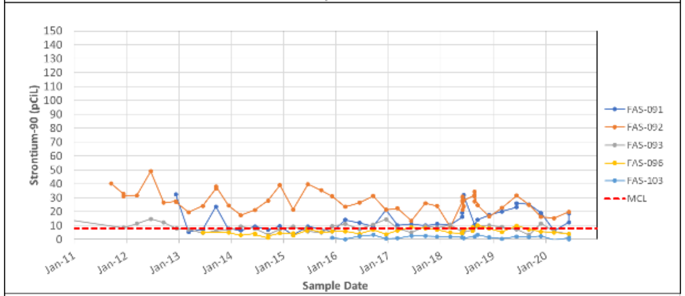


Wetland Surface Water Concentrations vs. Time

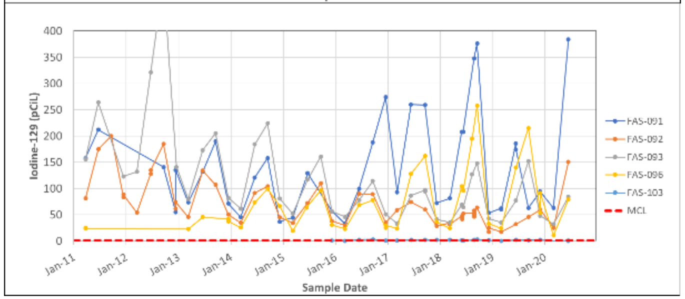
U-238



Sr-90



I-129



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