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ALTEMIS – Advanced Long-Term Environmental Monitoring Systems

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U.S. DEPARTMENT OF ENERGY

BSRA
Battelle Savannah River Alliance, LLC

ALTEMIS - Advanced Long-Term Environmental Monitoring Systems

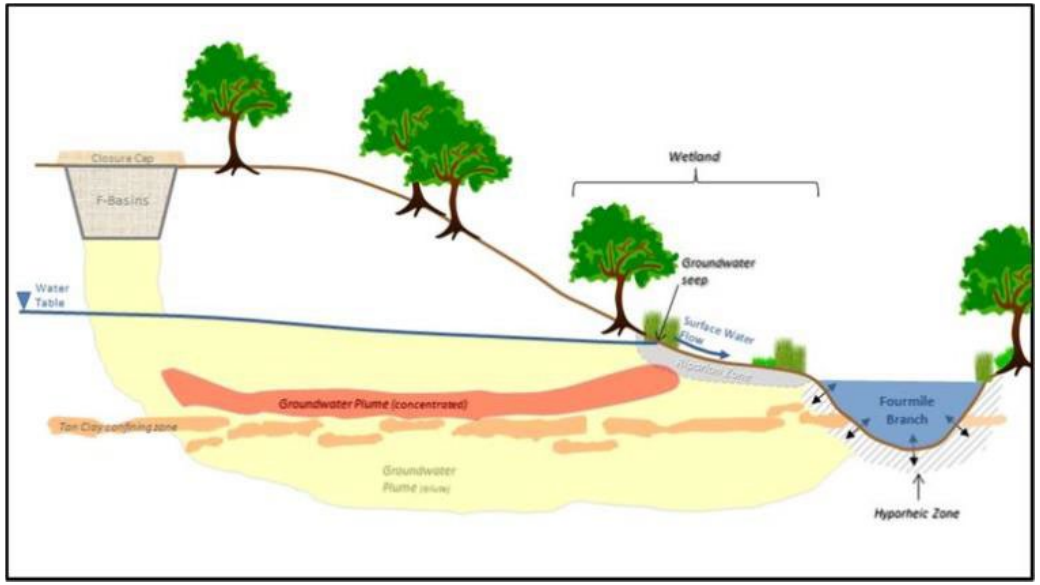
- Remediation of DOE's remaining complex groundwater contamination will take decades
- GAO estimates that EM's liability for environmental cleanup across the country will exceed $550 billion
- Long term monitoring of groundwater contamination is a large component of that liability
- DOE-EM Technology Office has sponsored a SRNL-led program since 2020
- Multi-laboratory/multi-agency team: SRNL, SRS-ACP, MIT, LBNL, PNNL, FIU/CRESP/MSIPP

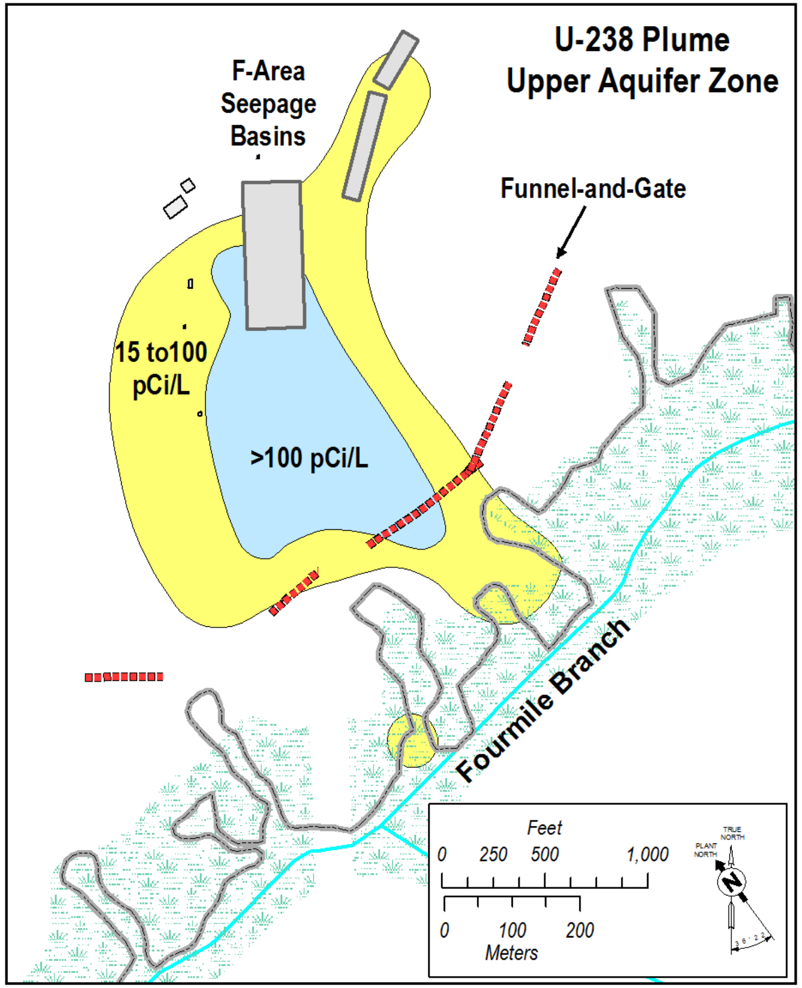
DOE ALTEMIS Testbed – SRS F-area

SRS F-area Groundwater - 30 years of discharge of low activity wastewater to basins. Major contaminants of concern are metals, uranium, tritium, and iodine.

Groundwater Testbed for Innovative Strategies

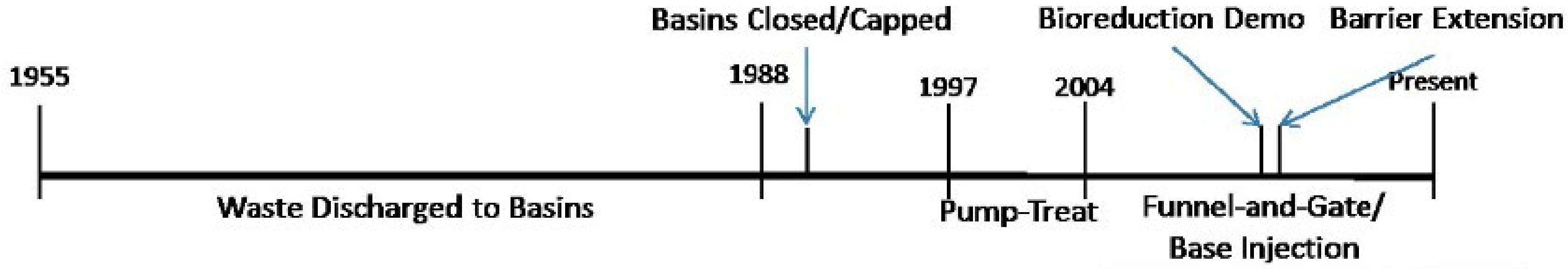
OS-Advanced Characterization (2008), ASCEM Reactive Transport Modeling (2012), ALTEMIS project (2020)



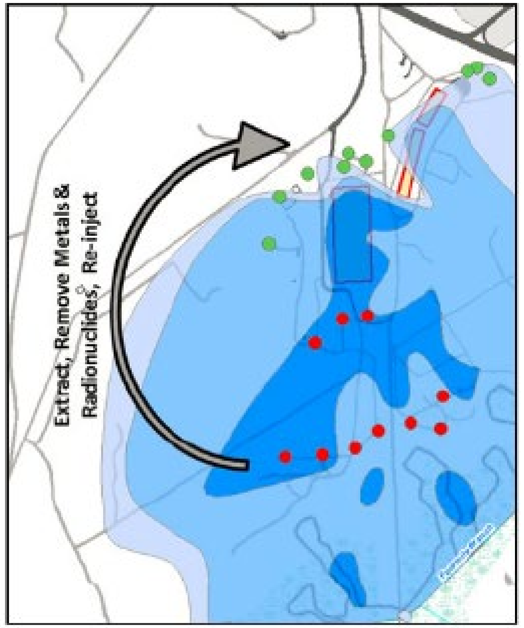


ALTEMIS F-area Testbed – Remedial History

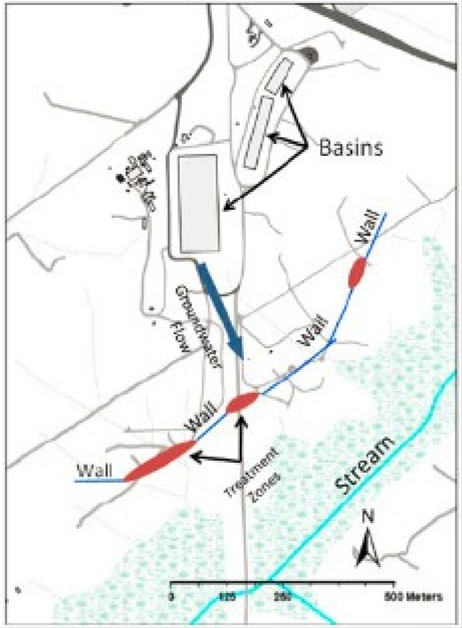
- **Phased Remediation** (1990-present) – Source Zone Isolation, Active Remediation, Enhanced Attenuation
- **Enhanced attenuation strategies** have improved remediation and reduced costs but have the potential to create secondary source terms (e.g., I^{129}, U^{238}, Sr^{90})
- Will require continuous monitoring over several decades to ensure regulatory compliance



Basin Operation

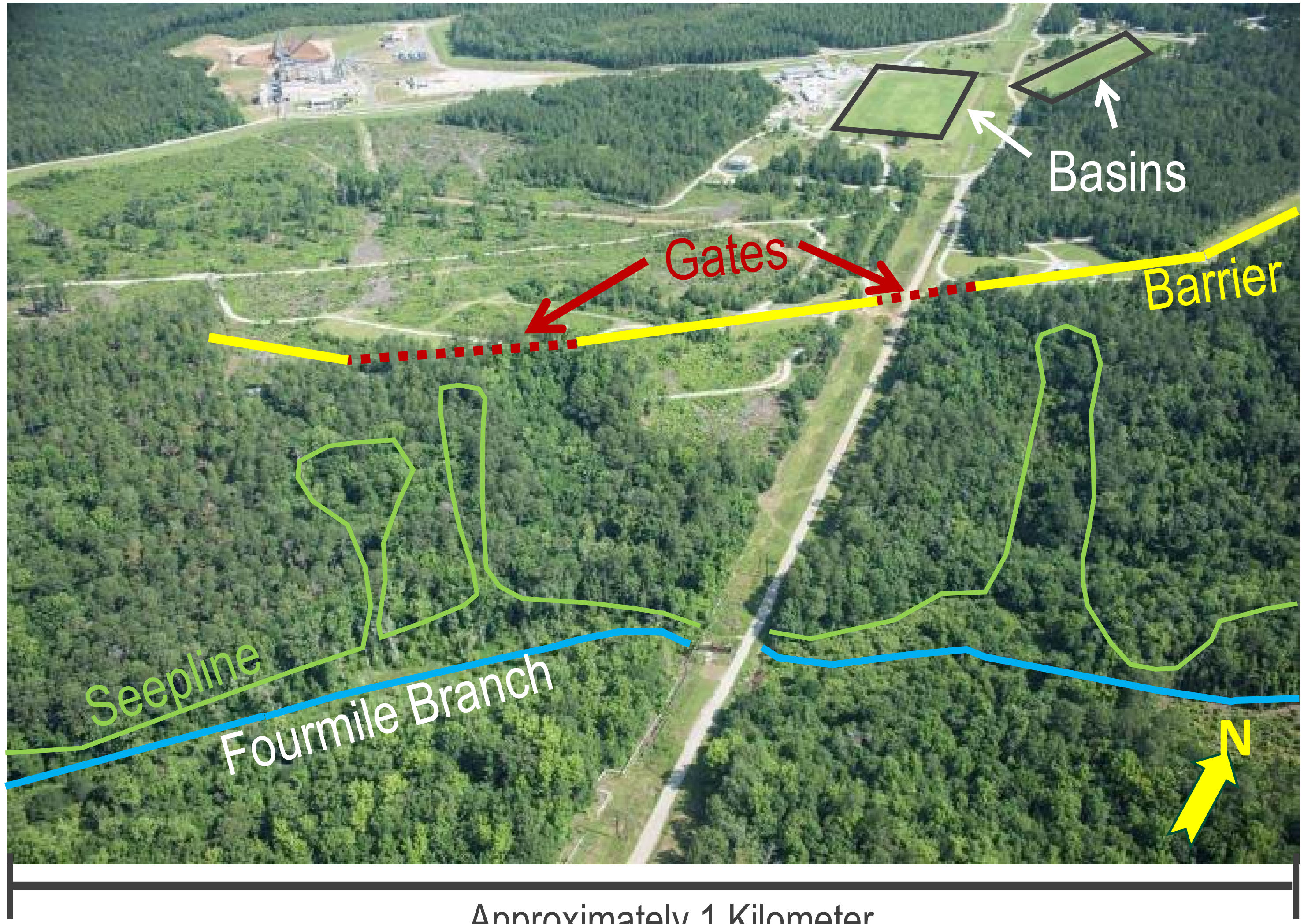


Pump/Treat/Re-inject

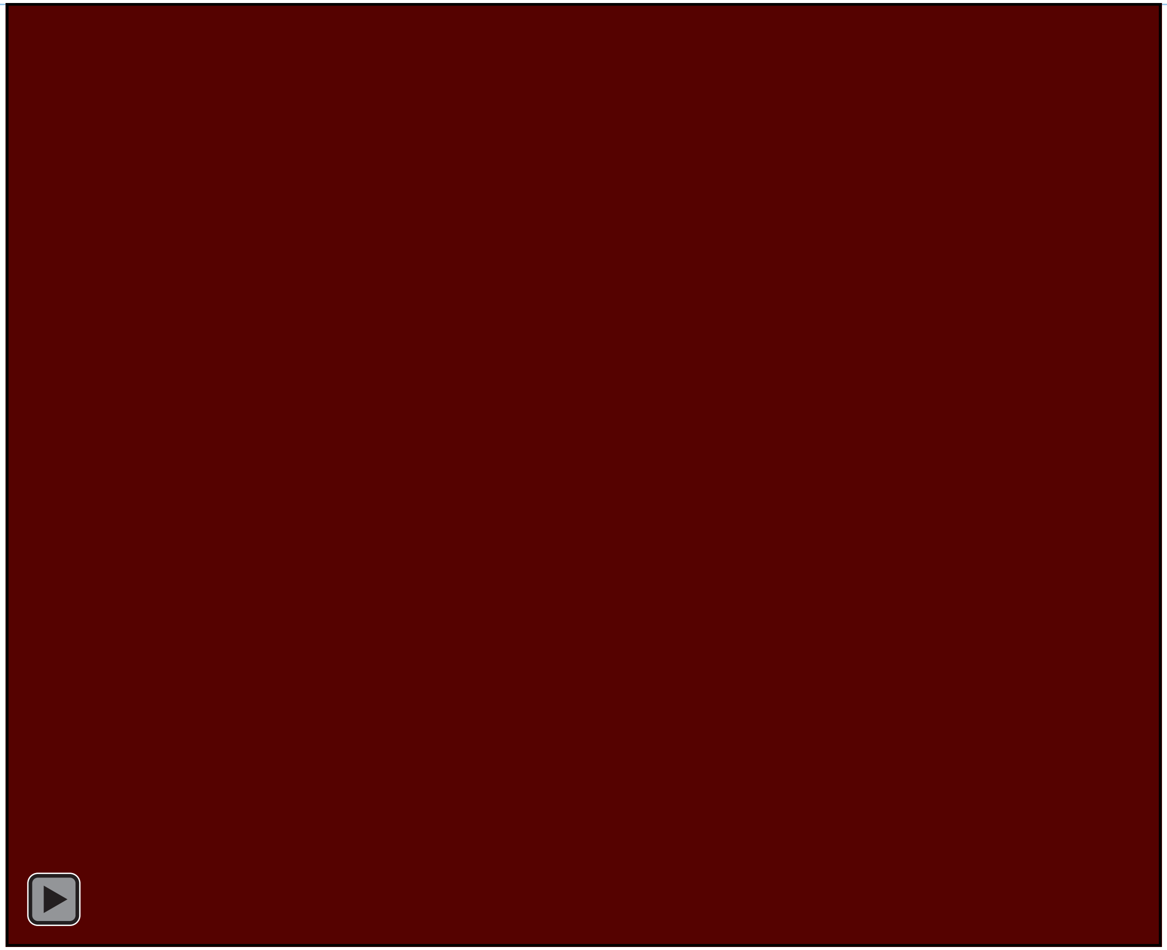


Funnel-Gate/Base Injection

SRS F-Area Seepage Basins



LBNL 3D Uranium Plume Modeling/Analysis (1956-2050)



Reactive Transport Model (ASCEM)

Detailed stratigraphy

Uranium Geochemistry

- ✓ Includes sorption, cation exchange, pH dependency on U mobility
- ✓ Strontium added (2024)

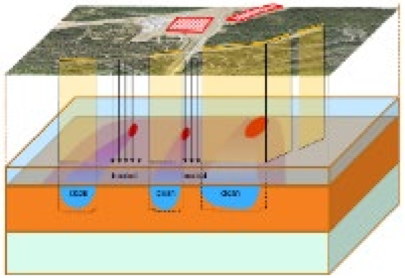
Zones of Vulnerability

Basin Capping/Closure

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

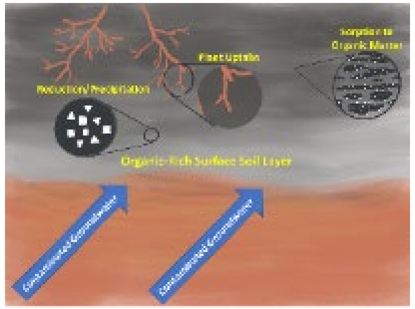
Subsurface Barrier w/Treatment Zones

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



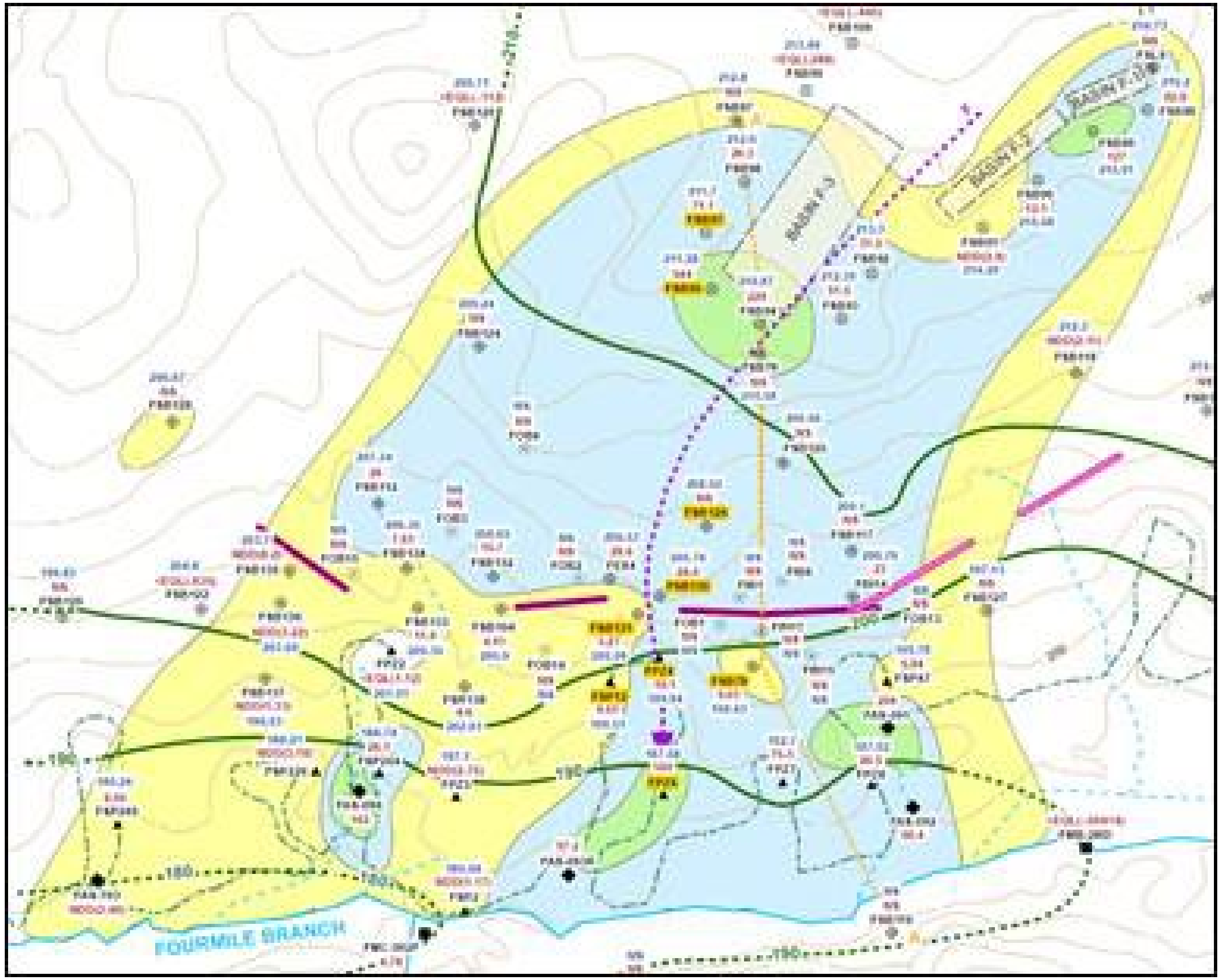
Wetlands

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



Current Monitoring Well Map/Sampling Frequency

Frequency	Number of Wells at F-Area	Constituents Sampled at each Well
Quarterly	87	Cadmium, lead, nitrate, tritium, gross alpha, nonvolatile beta, pH, specific conductivity, groundwater elevation
Semi-Annually	54	17 inorganics, 7 organics, 24 radionuclides (Table A-2 to A-4)
Annually	93	17 inorganics, 7 organics, 24 radionuclides[1]
	6	242 additional constituents to be sampled (Figure A-1)



Proposed New Paradigm for Long Term Monitoring (LTM)

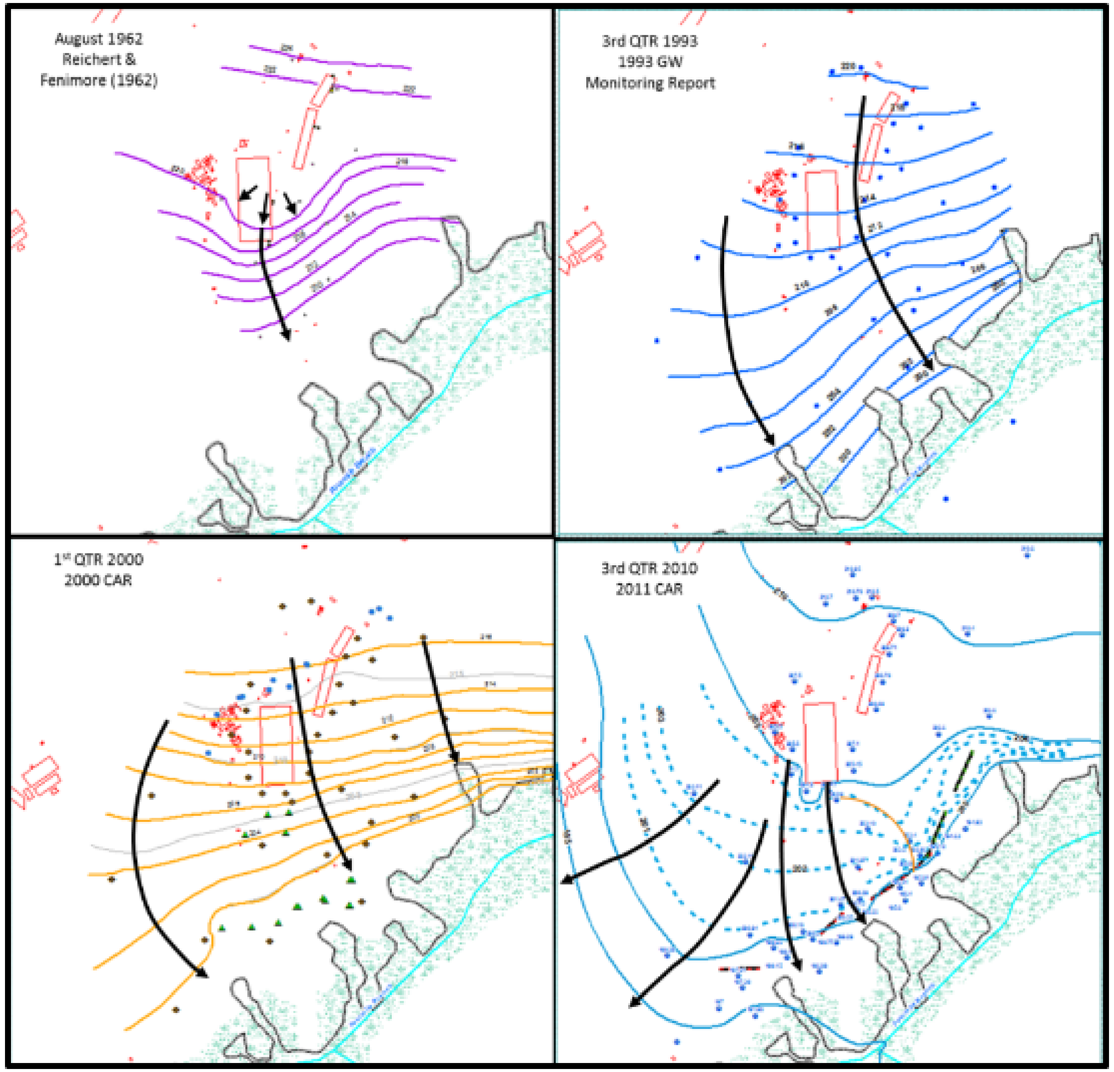
Monitor boundary conditions and master variables rather than actual concentrations

- Physical processes responsible for groundwater movement such as water levels, rainfall, etc.
- Chemical processes (e.g., pH, redox, conductivity, etc.) responsible for attenuation of contaminants

"Groundwater always flows down hill"

- Water level measurements indicate distinct changes in flow pattern

Need notification if groundwater flow directions change



Proposed New Paradigm for LTM

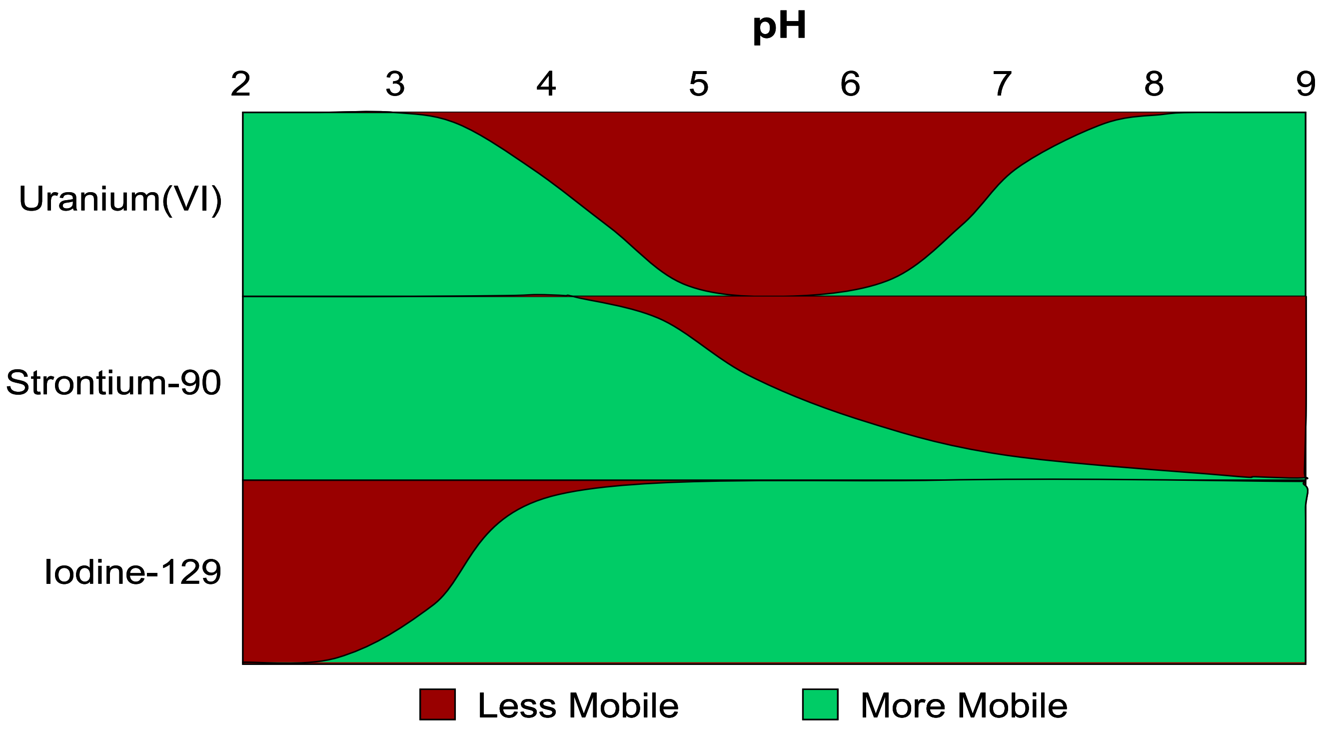
Primary objective is to monitor stability of attenuated contaminants

Monitor Boundary Conditions and Master Variables

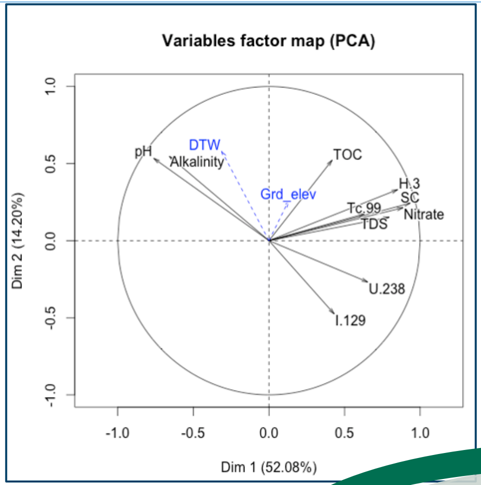
- Physical processes responsible for groundwater movement such as water levels, rainfall, etc.
- Chemical processes (e.g., pH, redox, conductivity, etc.) responsible for attenuation of contaminants

Provides leading information

- Changes in stability of hydraulic/geochemical conditions signal potential remobilization of attenuated contaminants
- Promotes proactive decision making

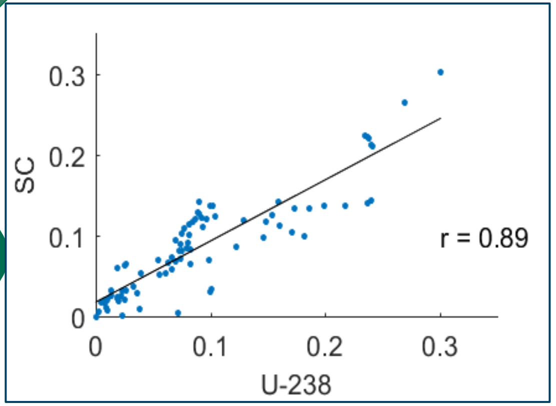


ALTEMIS AI/ML Overview – Principal Component Analysis



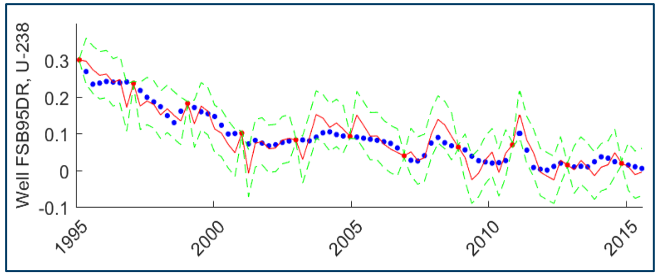
Exploratory Data Analysis

Quantification of Correlations



Contaminant Concentration Estimation

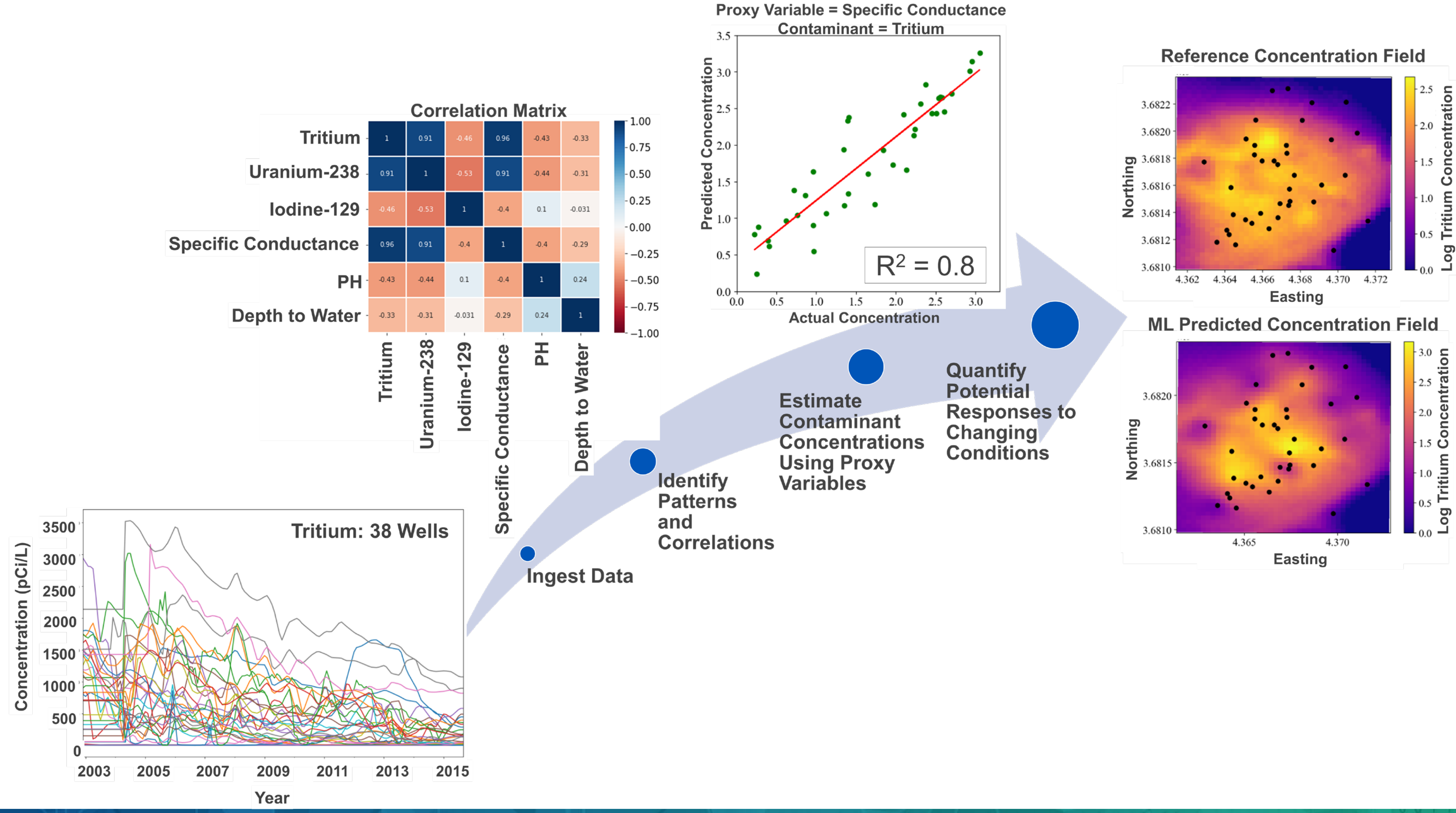
Kalman Filter



ALTEMIS AI/ML Goals:

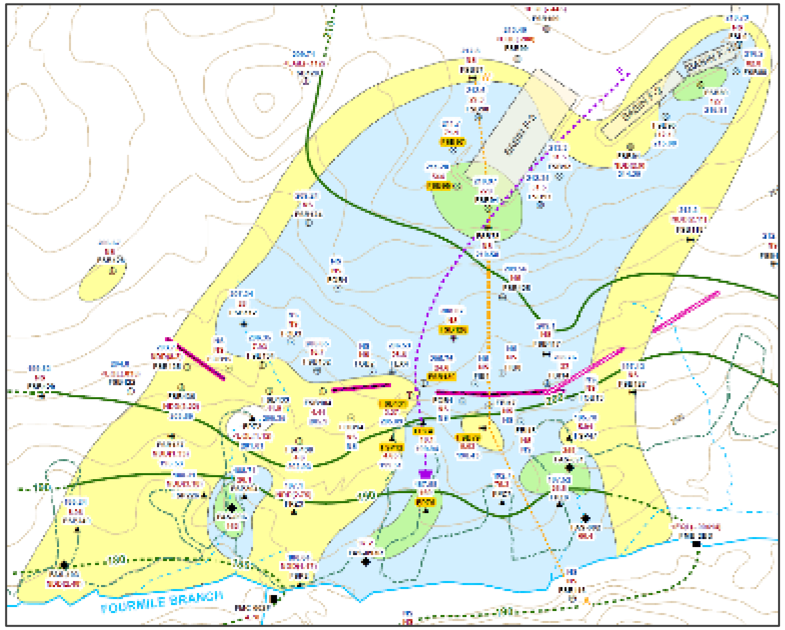
- Identify spatiotemporal patterns of contaminant concentrations
- Optimize the placement of in situ real-time monitoring networks to capture contaminant concentration distributions and measure proxy variables
- Estimate spatiotemporal contaminant concentrations using proxy variables
- Quantify responses to climate disturbances such as flooding or drought

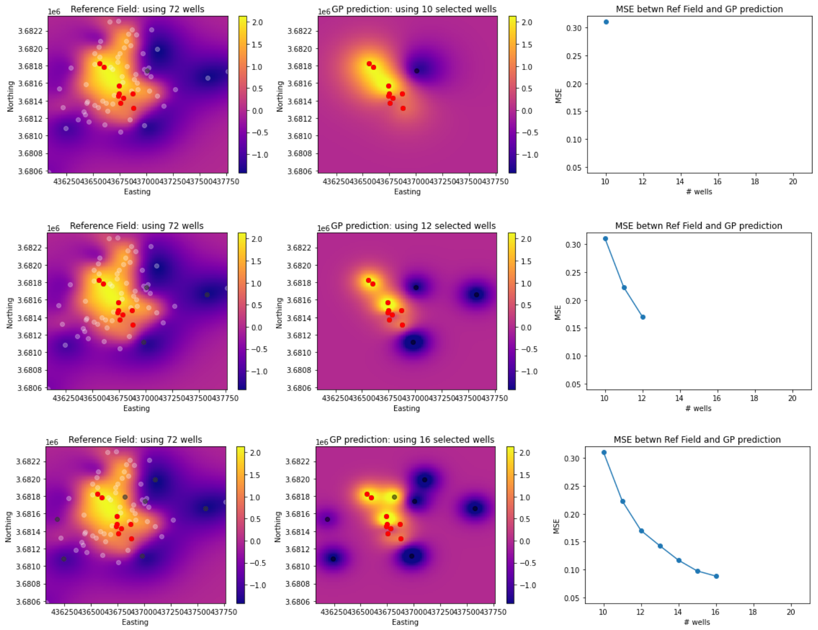
AI/ML: Spatiotemporal Contaminant Concentration Prediction Pipeline



Spatiotemporal Optimization of Sensor Locations

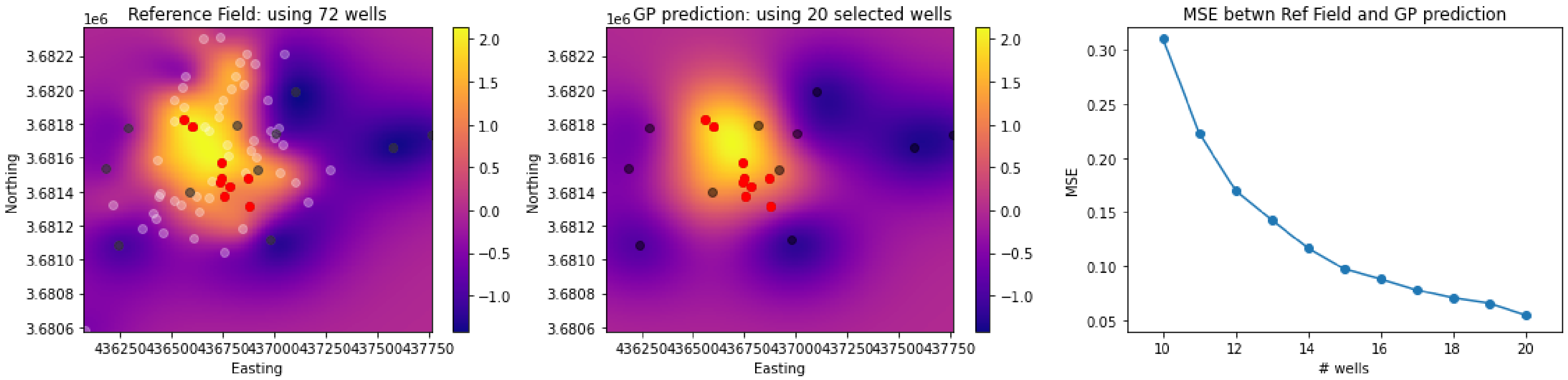
Existing Well Locations



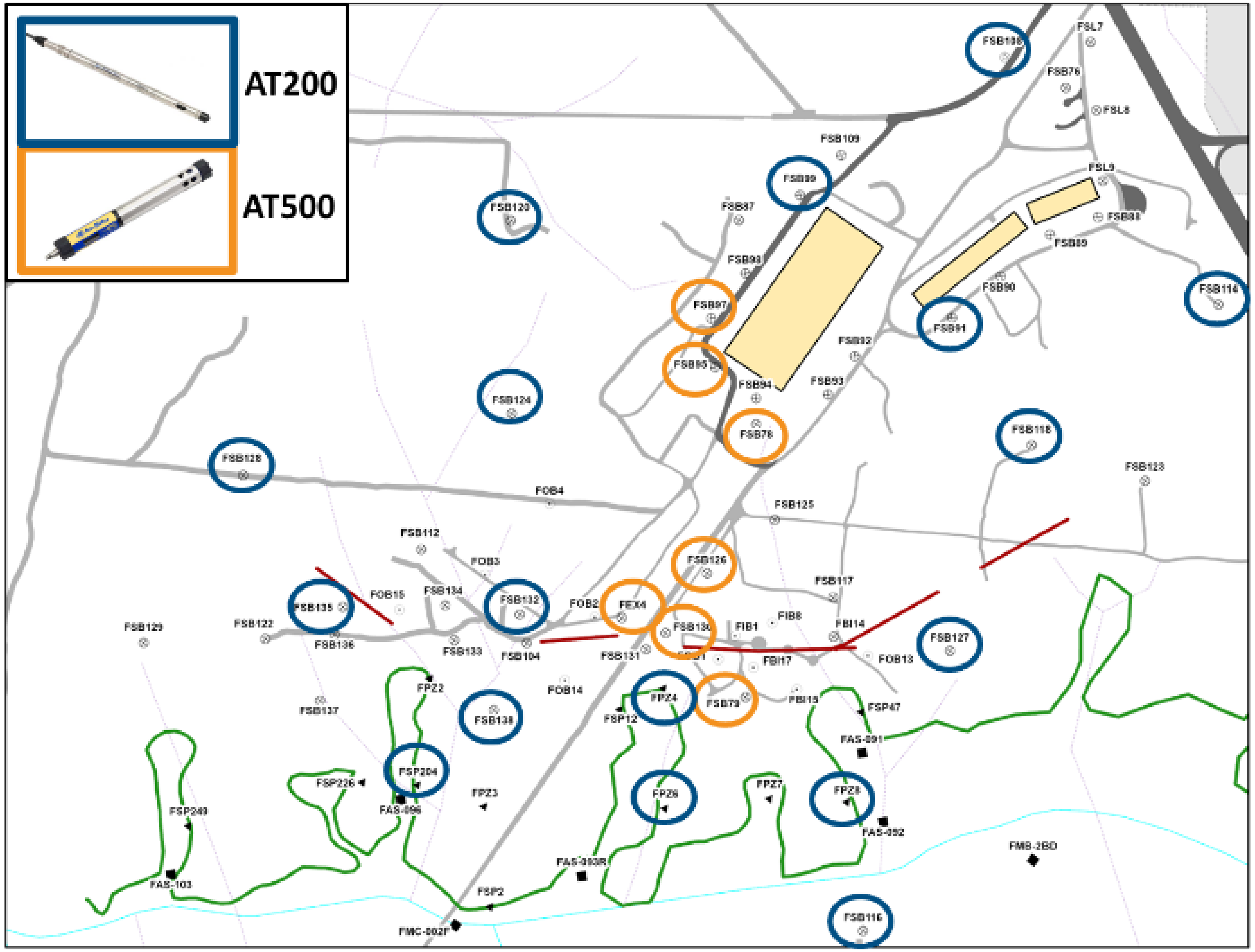


Iterative Refinement

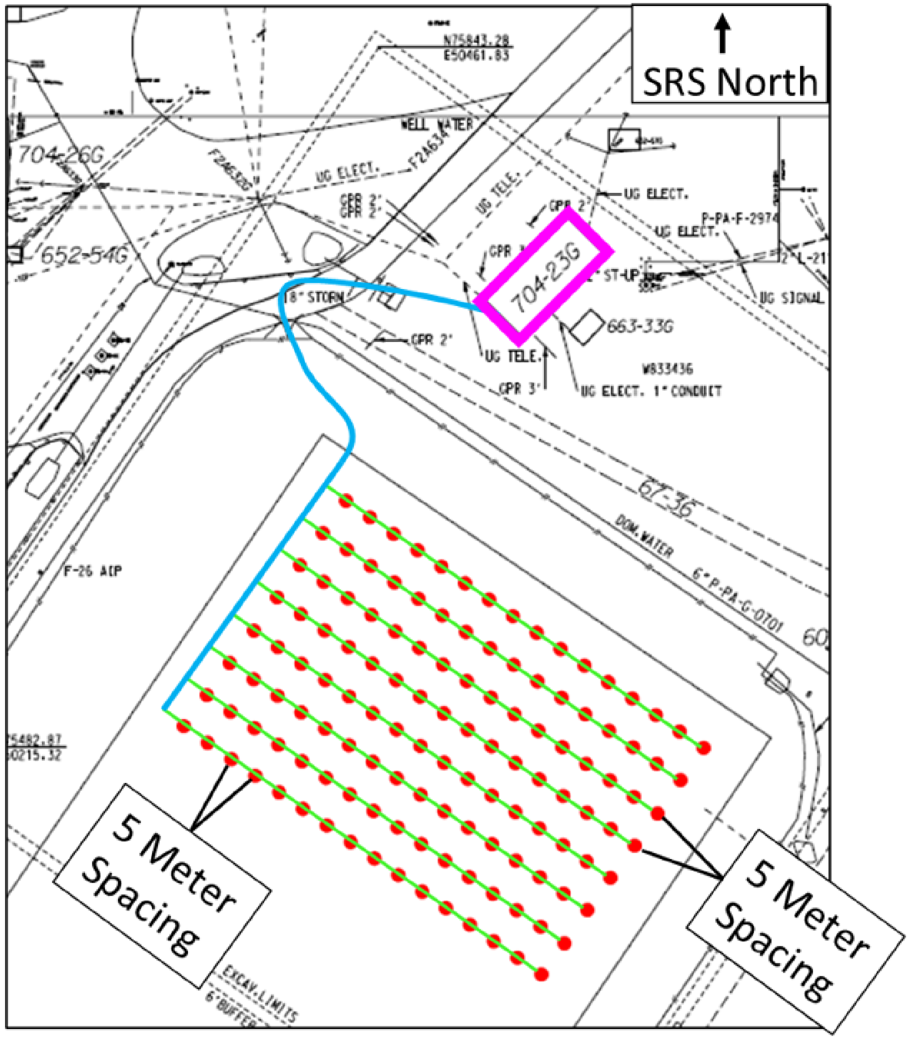
Optimized Layout



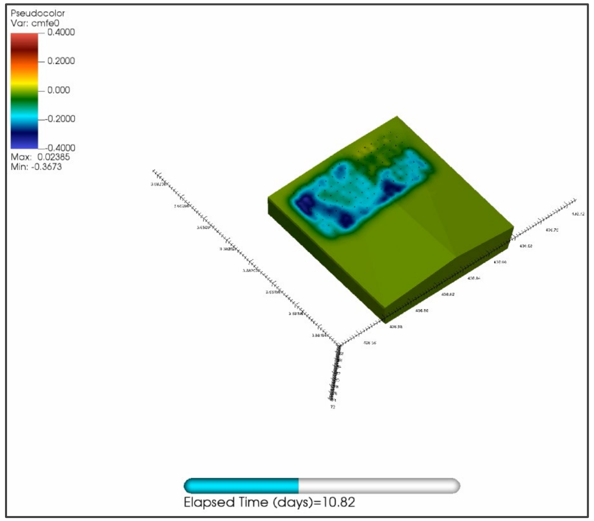
Optimized Sensor Network Layout

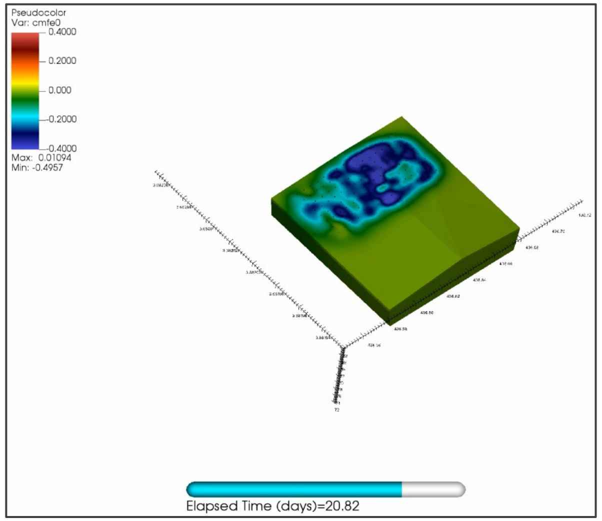


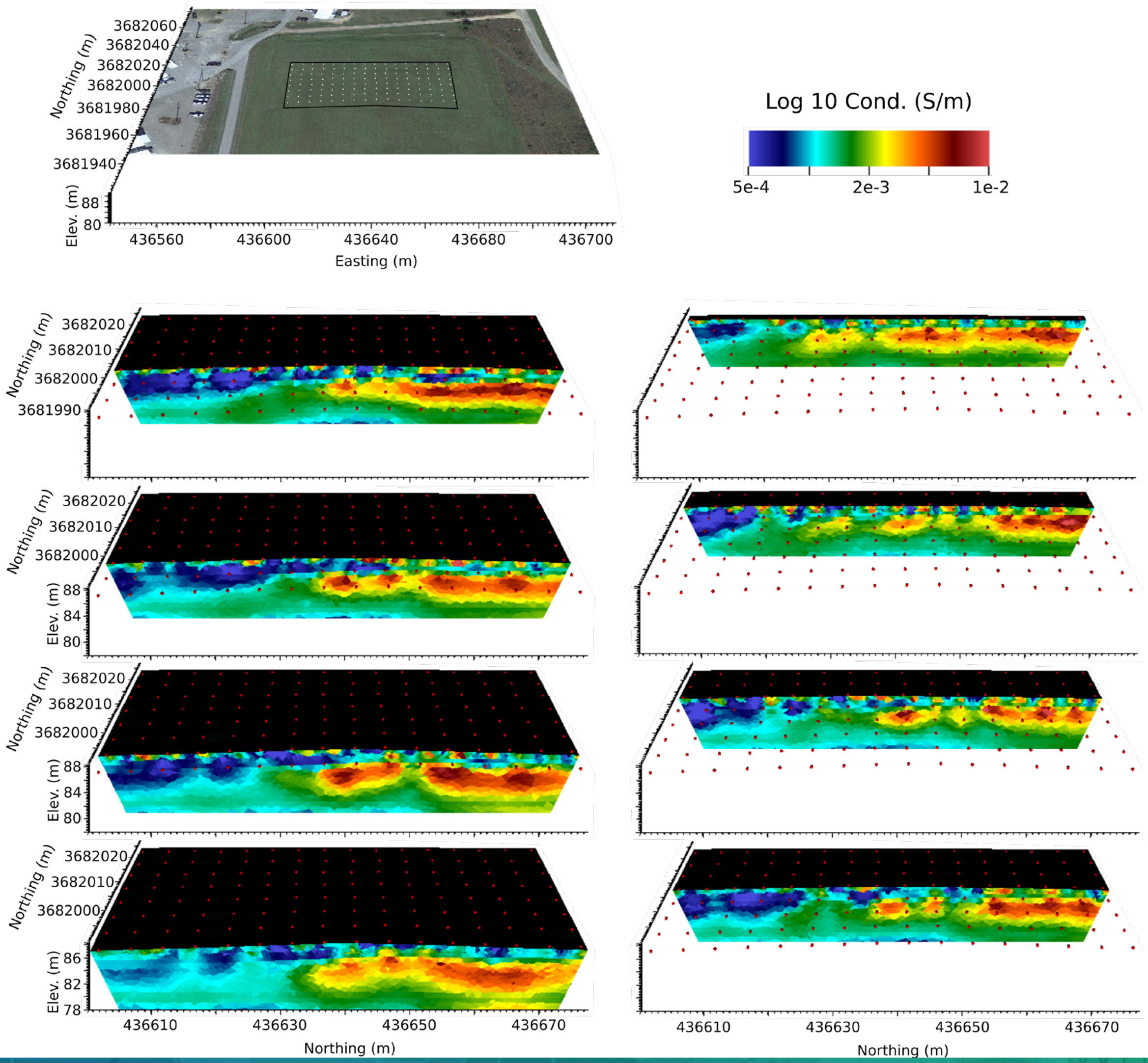
Electrical Resistance Tomography



Monitoring Basin Soils Beneath Low Permeability Cap







Wetland/Seepline Monitoring

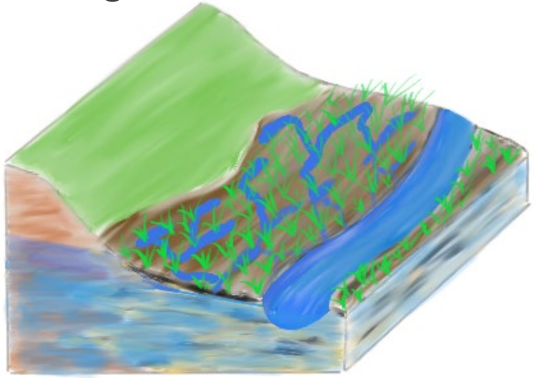
<u>Objective:</u> Monitor wetlands to ensure no remobilization of attenuated contaminants

<u>Vulnerability:</u> Physical and chemical conditions change, releasing dissolved and/or particulate-bound contaminants

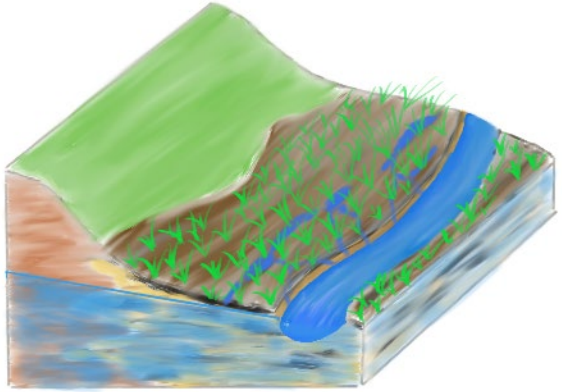
<u>Monitoring Tools/Technologies:</u>

- Spatially Integrative Tools
  - ➢ Periodic UAV surveys: LiDAR, gamma, photogrammetry
    - Topography, vegetation, contaminant distribution, springs distribution, etc.
  - ➢ Distributed Fiber Optic Sensors
    - Temperature, soil moisture
- Point Source Measurements
  - ➢ Sensors in surface water

High Water Table



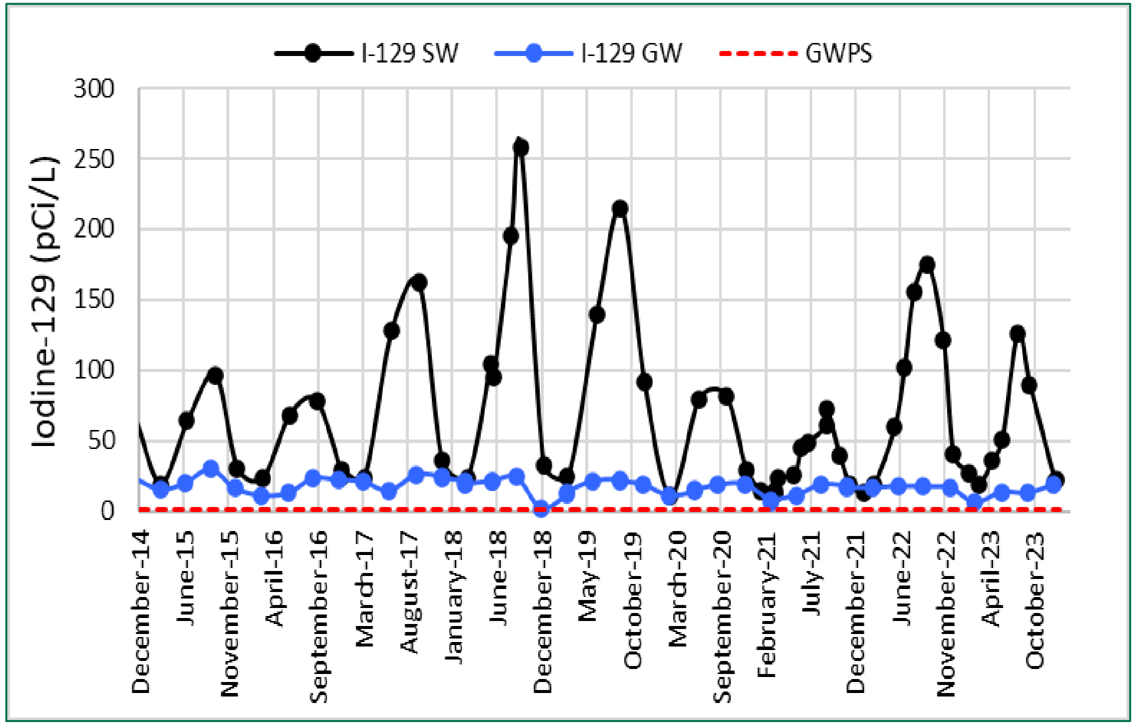
Low Water Table



F-Area Wetlands: Seasonal Variations of I-129

Wetland sensor network

Shallow piezometer wells and surface water sensors to monitor changes in groundwater/ surface-water chemistry that could potentially remobilize contaminants.



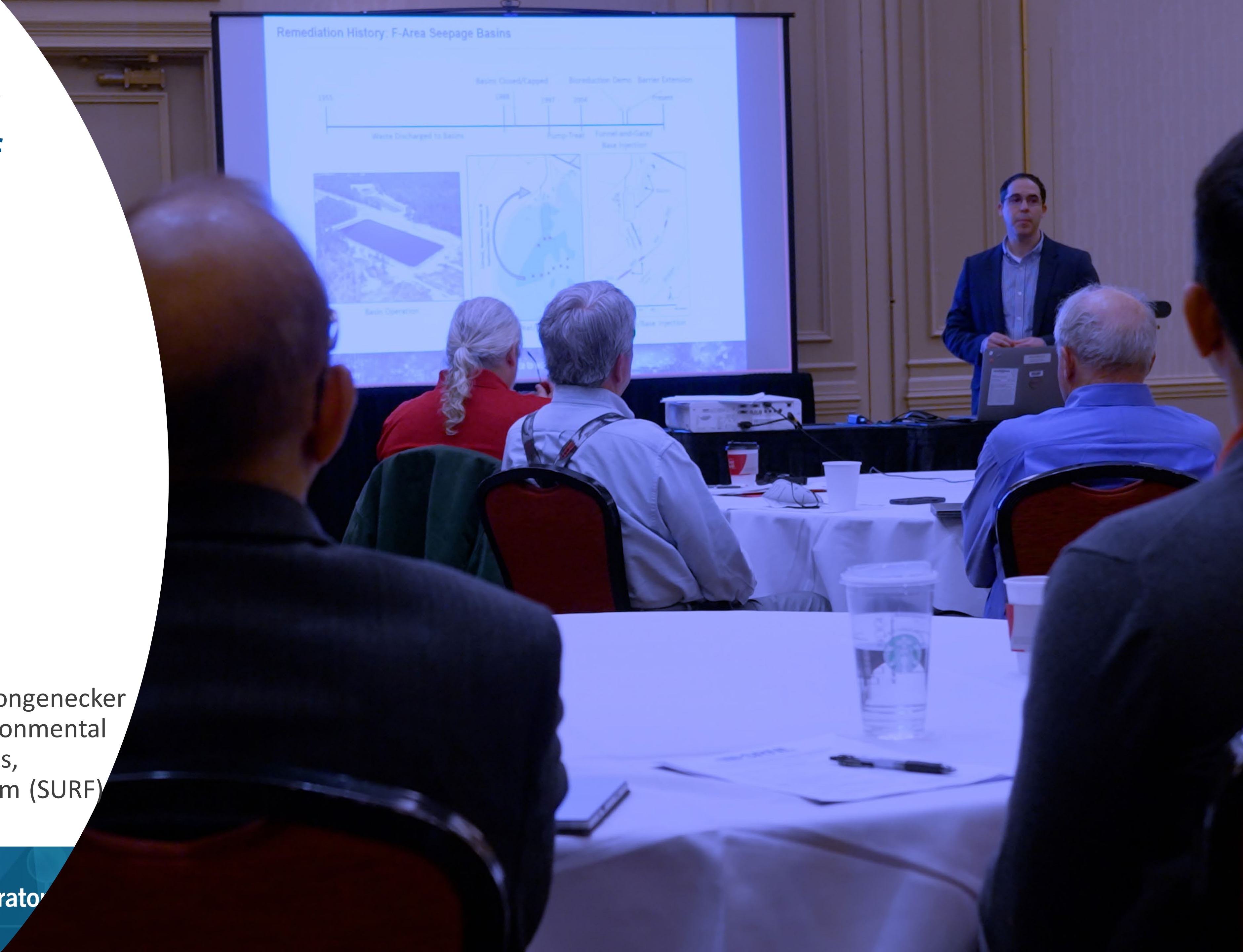
Path Forward – F-area test bed

- Sensor network installation at the F-Area completed
- Current field activities focused on monitoring and maintenance of sensors.
- Development of a data management system to house the transmittal, storage, and access of the continuous sensor data.
- Use statistical tools to optimize monitoring.
- Use AI/ML approaches to automatize data process, make predictions and anomaly detection.

- Hosted workshop on Innovative Strategies for Long-Term Monitoring of Complex Groundwater Plumes at DOE's Legacy Sites
- Application to other sites/problems (Oak Ridge Y-12, Sellafield, Office of Fossil Energy, Canadian Nuclear Laboratory)

Innovative Strategies for Long-Term Monitoring of Complex Groundwater Plumes at DOE's Legacy Sites

- ALTEMIS lessons learned → applicability to arid sites
- Over 70 attendees
  - HQ: DOE-EM, DOE-LM
  - Labs: SRNL, LBNL, PNNL
  - DOE Sites: Moab
  - Academia: MIT, FIU, Clemson
  - Industry: Geosyntec, CRESP, Longenecker & Associates, Panoramic Environmental Consulting, Subsurface Insights, Sustainable Remediation Forum (SURF)
  - International: Sellafield



Application to other sites/problems

The ALTEMIS paradigm , i.e., development of robust conceptual model and identification of controlling variables to be used to predict contaminant concentrations is widely applicable.

Issue 1: Application to other sites

- Many DOE sites are in arid regions – wide variety of effective and efficient monitoring tools
- Hosted workshop with EM and LM
- Selection of potential arid site application -- Moab
- OR Y-12 – Monitoring Hg – Controlling variables are temperature, humidity, and barometric pressure

Issue 2: Data Density Issues

- Coal Ash – Monitoring Arsenic/Antimony

Issue 3: Implementation of strategies is not trivial

- Develop a process that site technical people can implement
- Initial sites will require facilitation
- Need to develop toolbox to select appropriate tools

Implementation at other sites

- Canadian Nuclear Lab, Sellafield, Moab, Oak Ridge

ALTEMIS Collaborators

Savannah River National Laboratory

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