Use of In Situ Real Time Monitoring for Early Warning Systems at the SRS F-Area Seepage Basins and D-Area Coal Ash Basins

Presented by: Thomas Danielson

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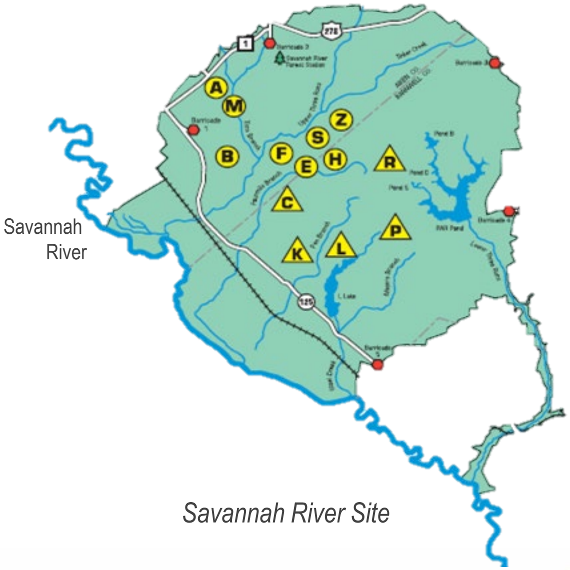
Savannah River Site Overview

SRS is a key DOE site responsible for environmental stewardship and cleanup, waste management, and disposition of nuclear materials.

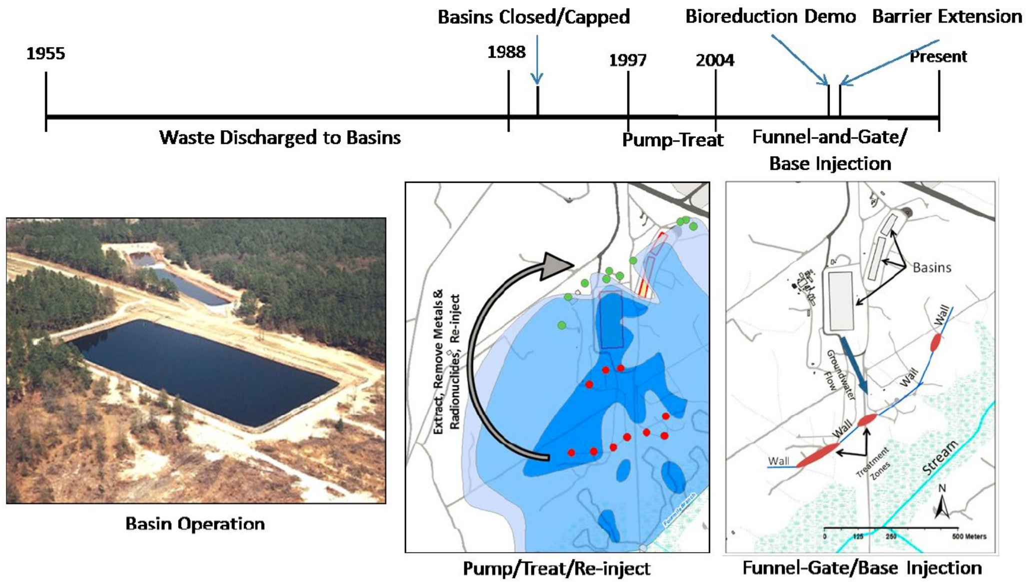
- **~ 310 square miles (~803 square kilometers)**
- **Nuclear materials production history**
  - 5 nuclear materials production reactors
  - 2 separations plants
  - Heavy water extraction plant
  - Nuclear fuel and target fabrication facility
  - Solid and liquid waste disposition processes
- **Environmental legacy**
  - 130 million liters highly contaminated liquid
  - 6 Fuel basins
  - Decommissioned radiological facilities
  - 515 radionuclide or chemically contaminated soil and groundwater waste sites
  - 5 coal fired power plants
  - Over 2 x 10^6 m^3 contaminated groundwater



Savannah River Site

Background – ALTEMIS

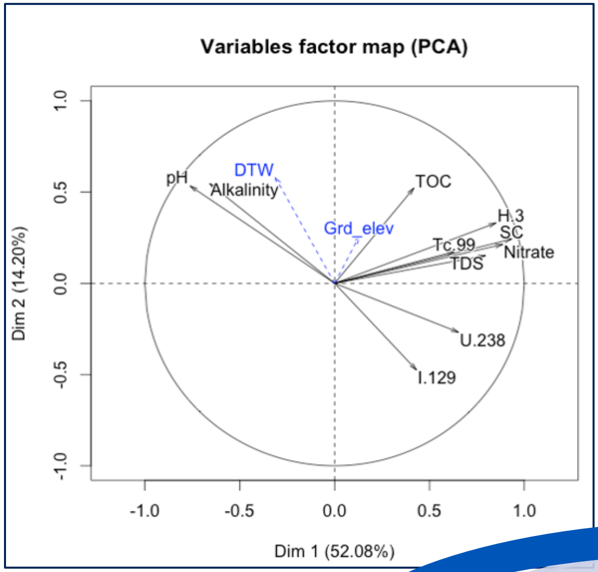
- Enhanced attenuation strategies have created the potential for secondary source terms (e.g., I-129, U, Sr-90) that will require continuous monitoring over the course of the next several decades to ensure compliance with regulatory requirements



- **"Zones of Vulnerability":**

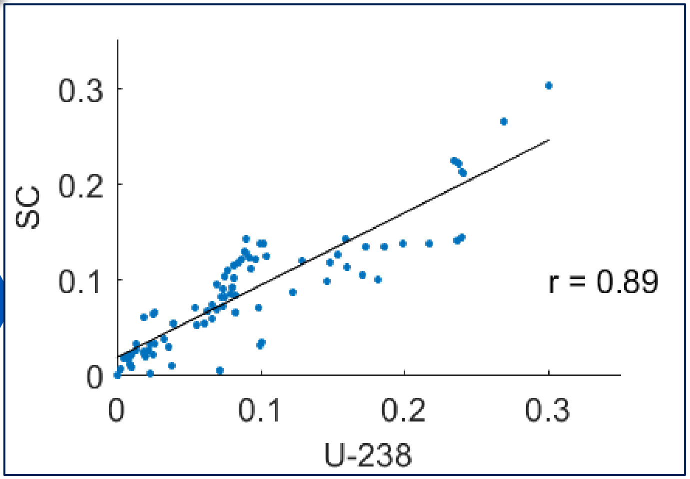
Zone of Vulnerability	Vulnerable Contaminants	Threat Conditions	Long-Term Monitoring Focus
Basin soils and vadose zone	All	Infiltration through cap	Cap integrity and moisture content
Treatment zones in gates	Uranium, Sr-90, I-129	Low pH (Sr-90, uranium) and reducing conditions (I-129)	pH, ORP, groundwater 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)

Identification of Master Variables



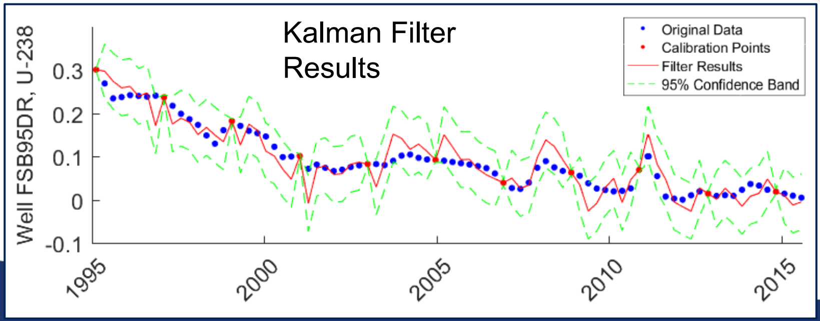
Exploratory Data Analysis

Quantification of Correlations



Contaminant Concentration Estimation

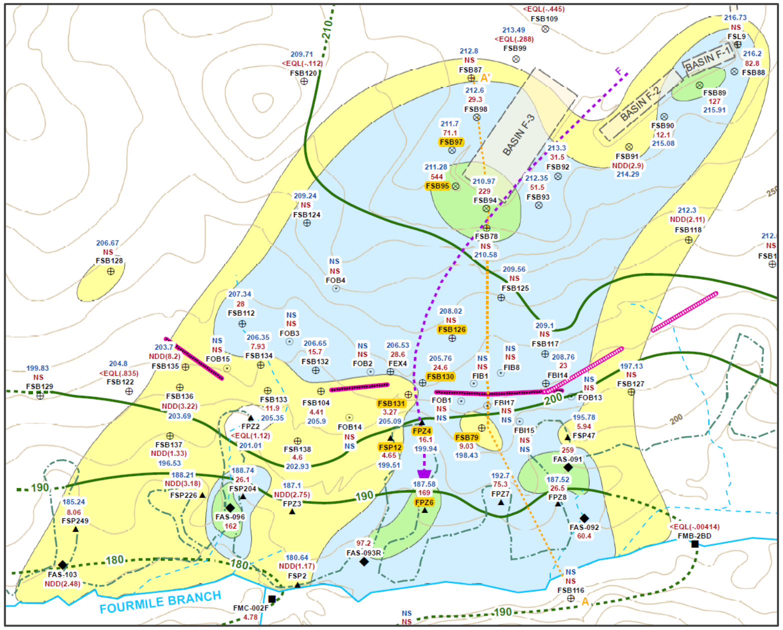
Kalman Filter

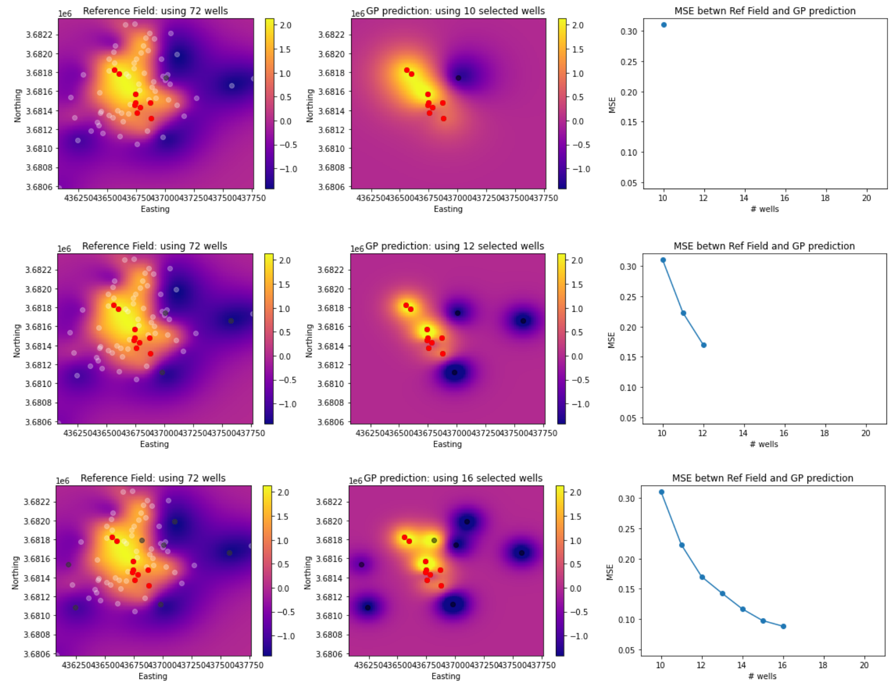


Wainwright, et al. (LBNL)

Spatiotemporal Optimization of Sensor Locations

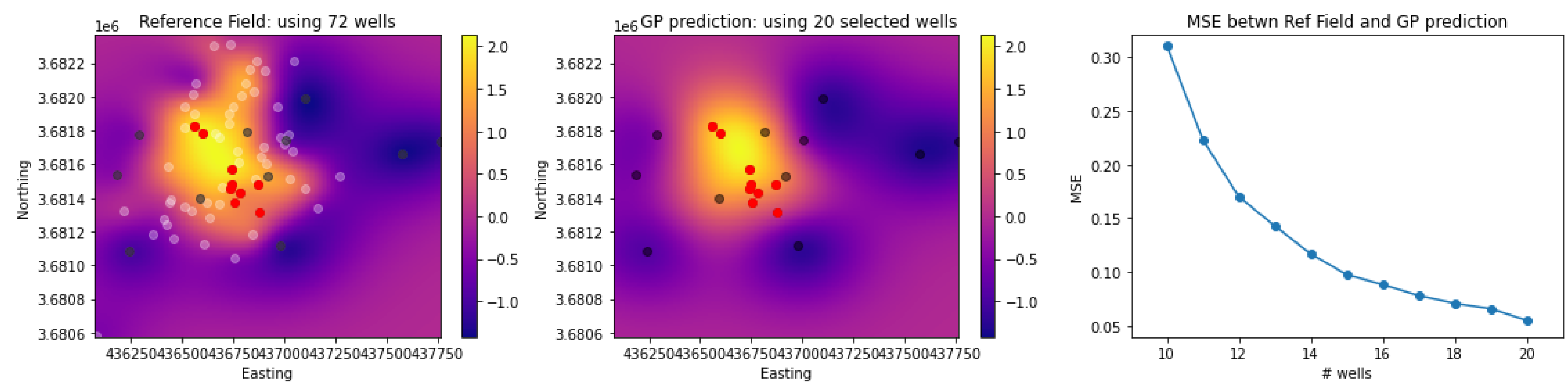
Existing Well





Iterative Refinement

Optimized Layout

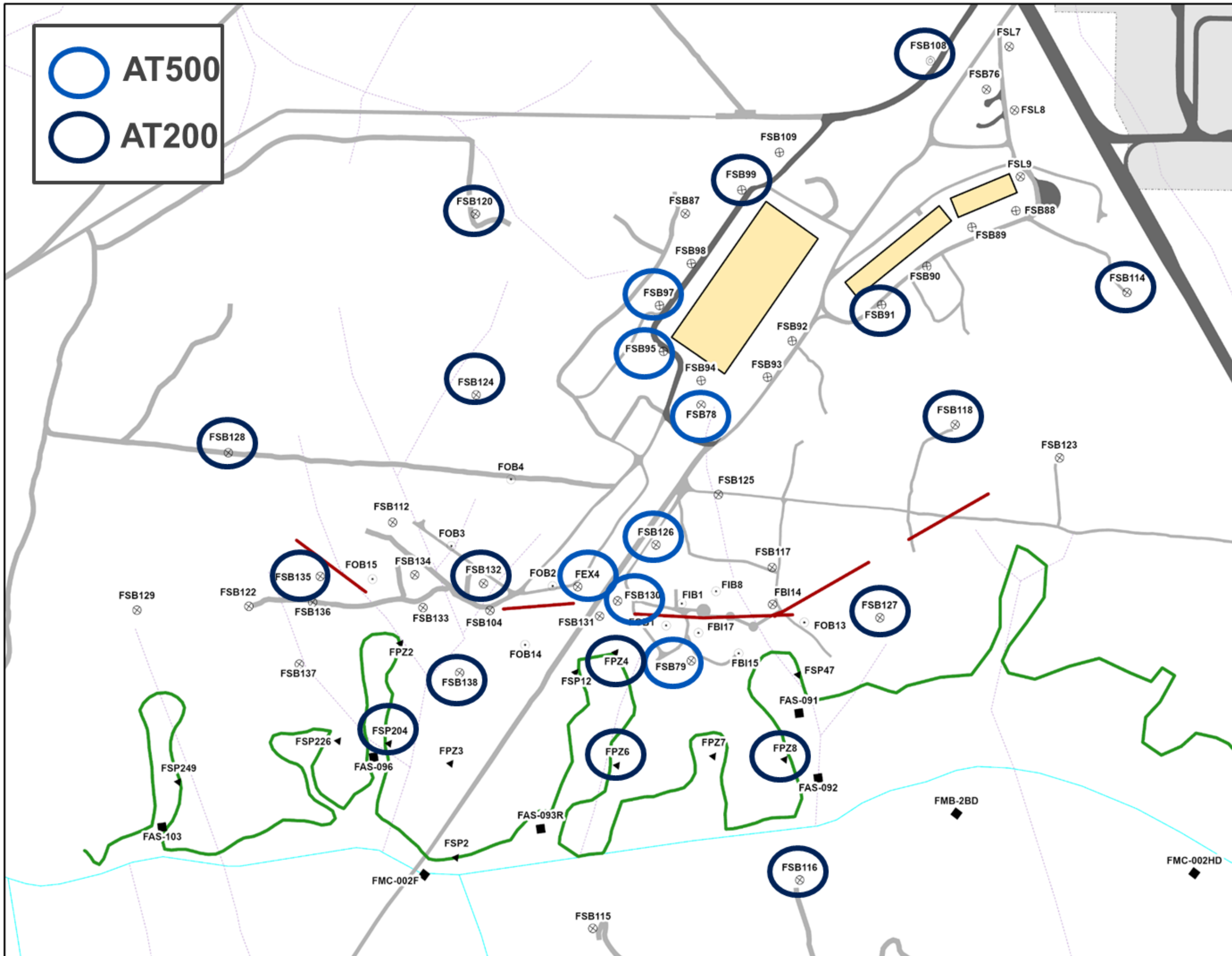


From: Wainwright, Meray, Upadhyay

Spatiotemporal Optimization of Sensor Locations

Aqua Troll 500

Aqua Troll 200



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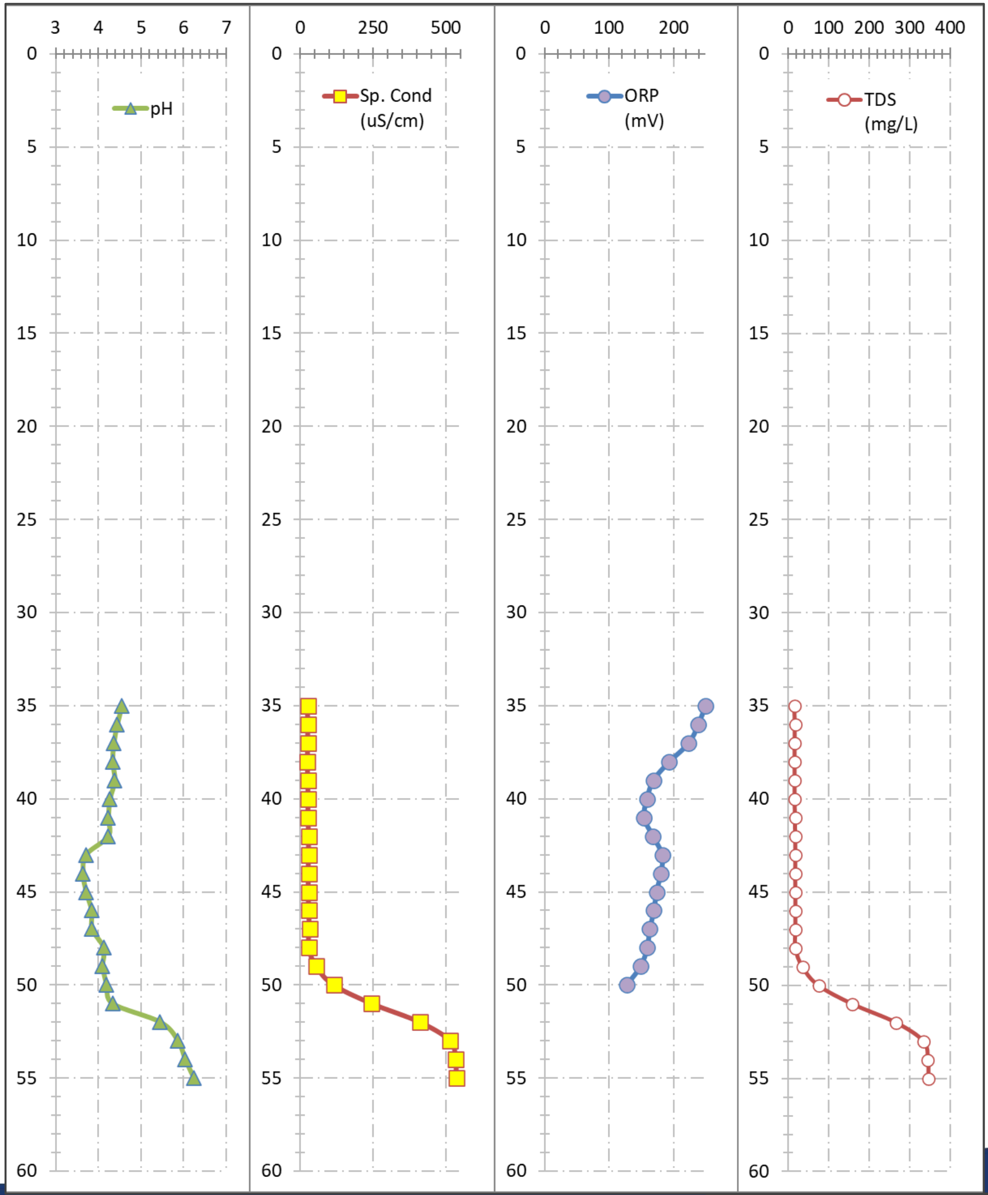
Well Re-Configuration for Sensor Installation

No Modification Required

Wellhead Modification Required



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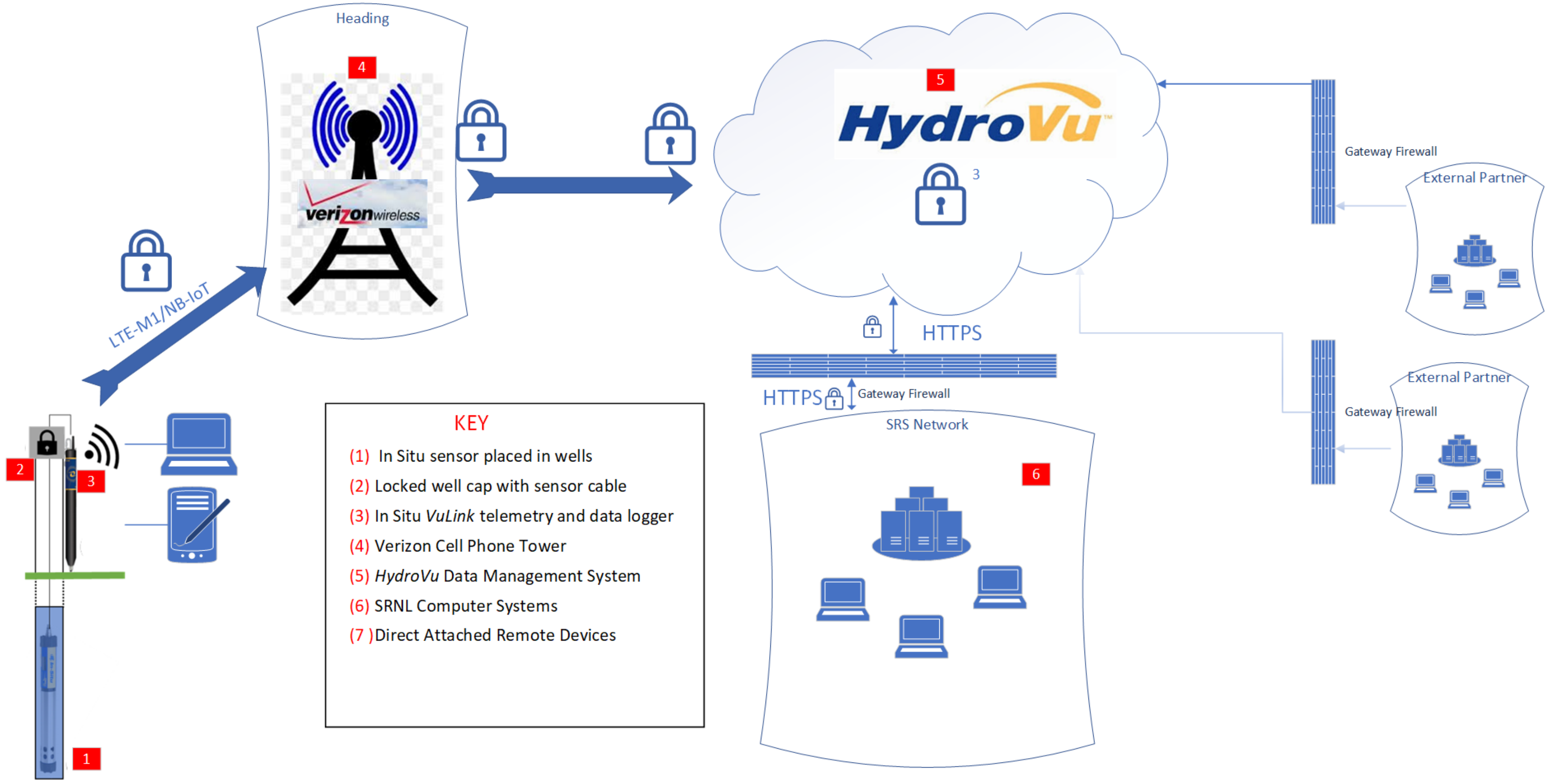
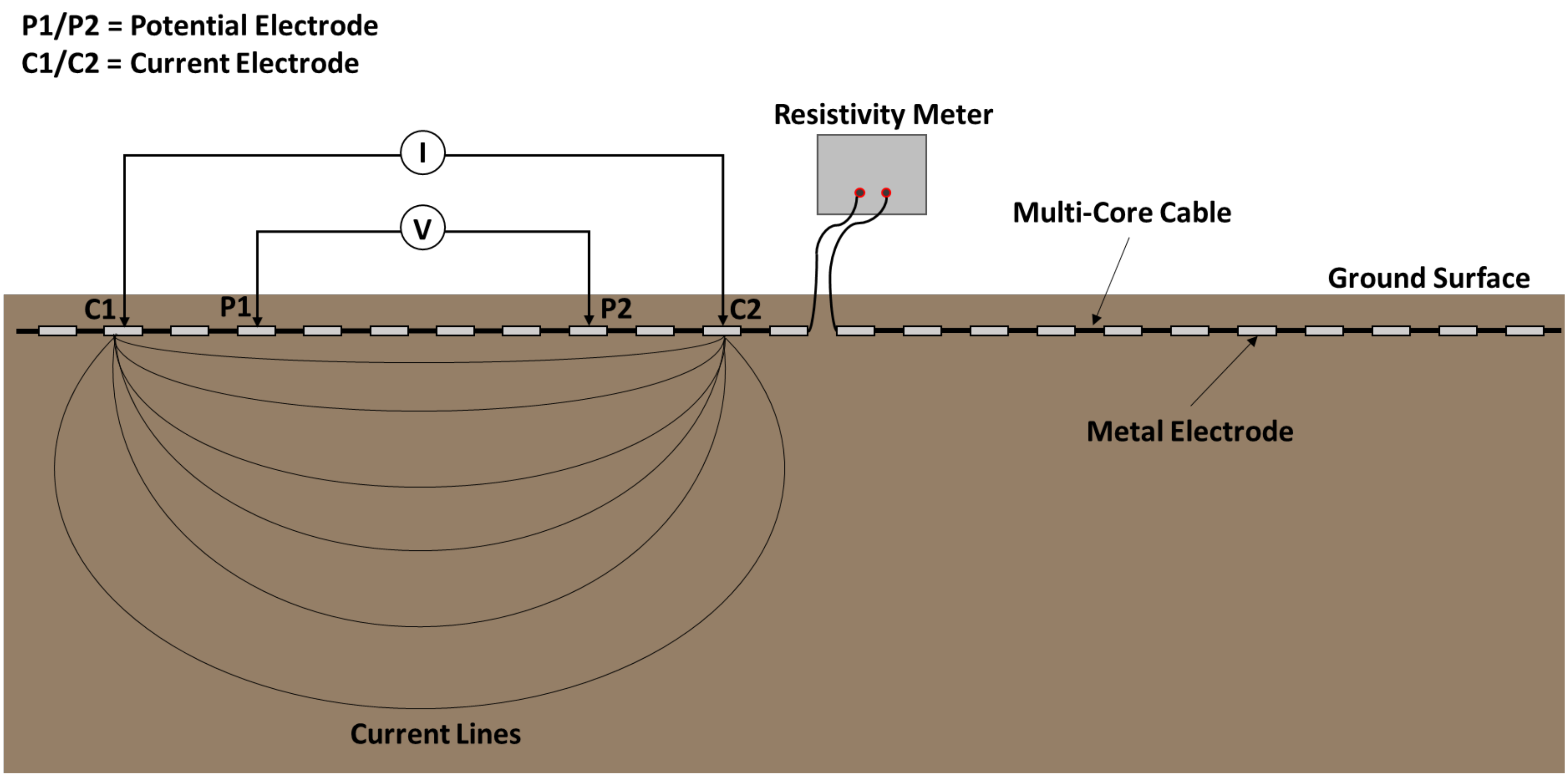
Well Sensor Data Flow



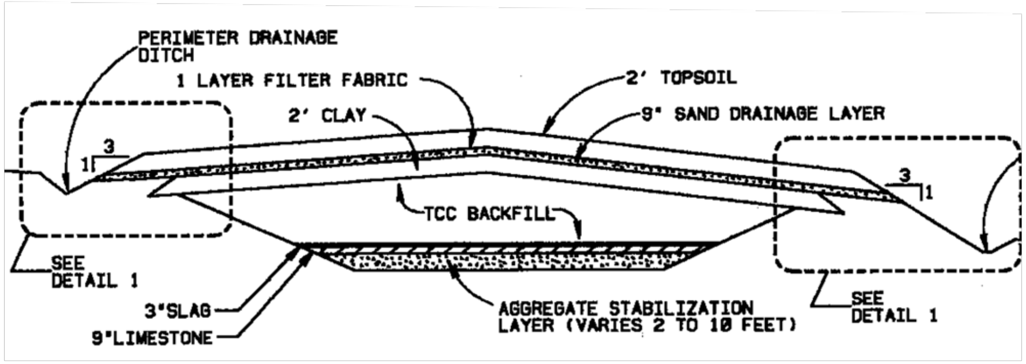
KEY

(1) In Situ sensor placed in wells
(2) Locked well cap with sensor cable
(3) In Situ *VuLink* telemetry and data logger
(4) Verizon Cell Phone Tower
(5) *HydroVu* Data Management System
(6) SRNL Computer Systems
(7)Direct Attached Remote Devices

Electrical Resistive Tomography (ERT) Overview

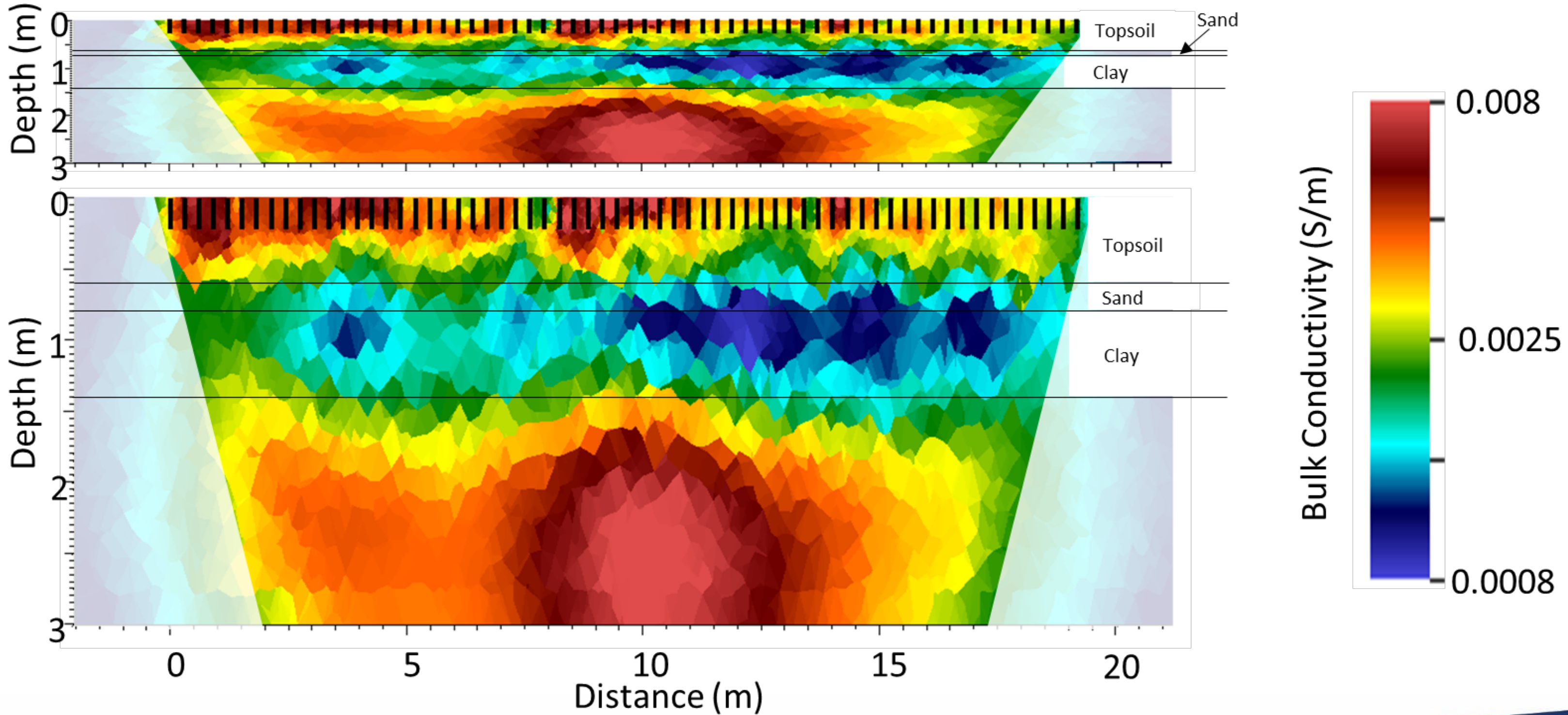


ERT Test Survey Results

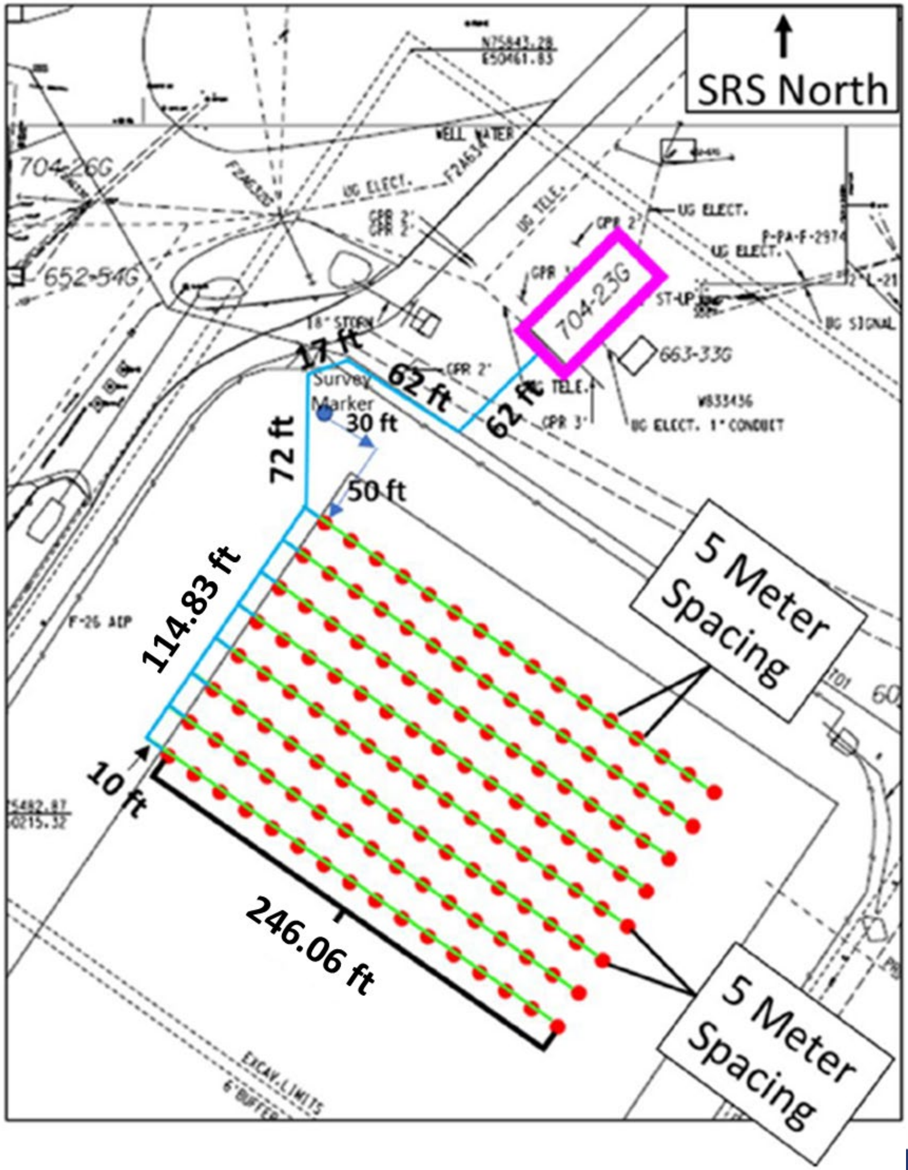


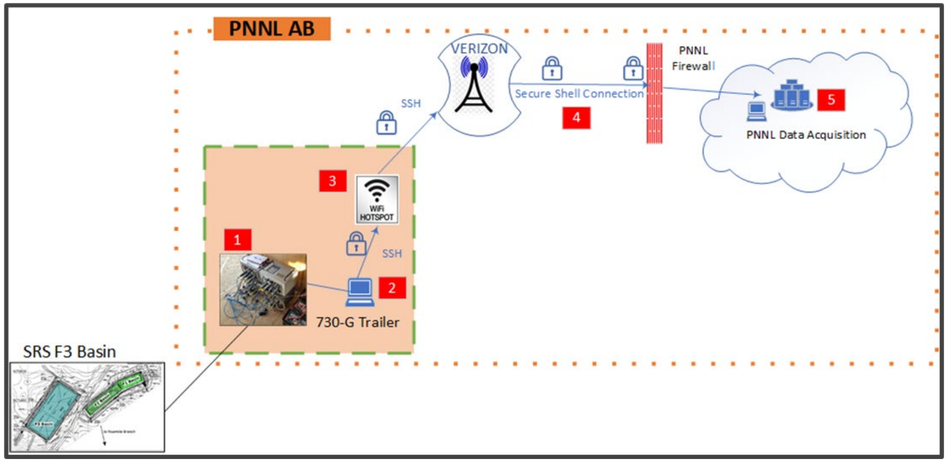
1 to 1 Vertical to Horizontal

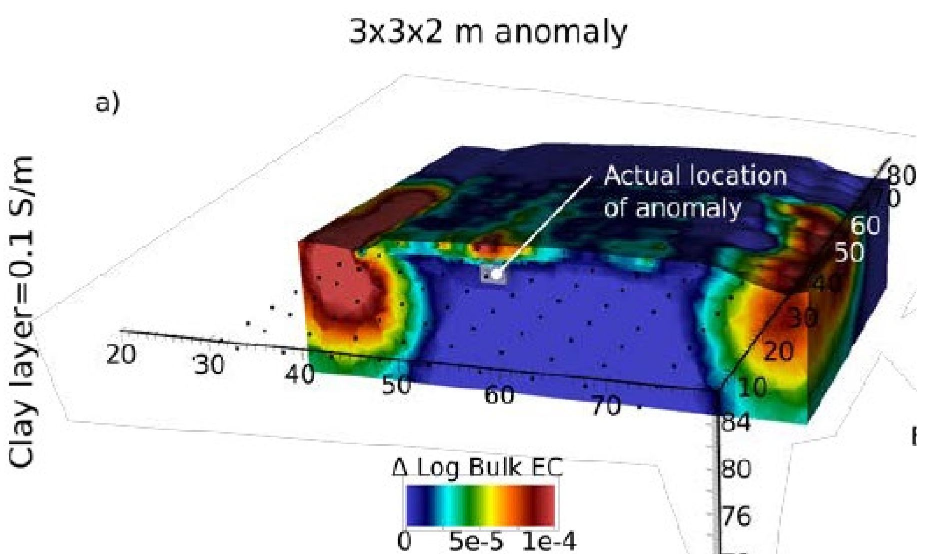
5 to 1 Vertical to Horizontal



ERT Final Setup







T. C. Johnson, J. Robinson, J. Downs, PNNL-30470.

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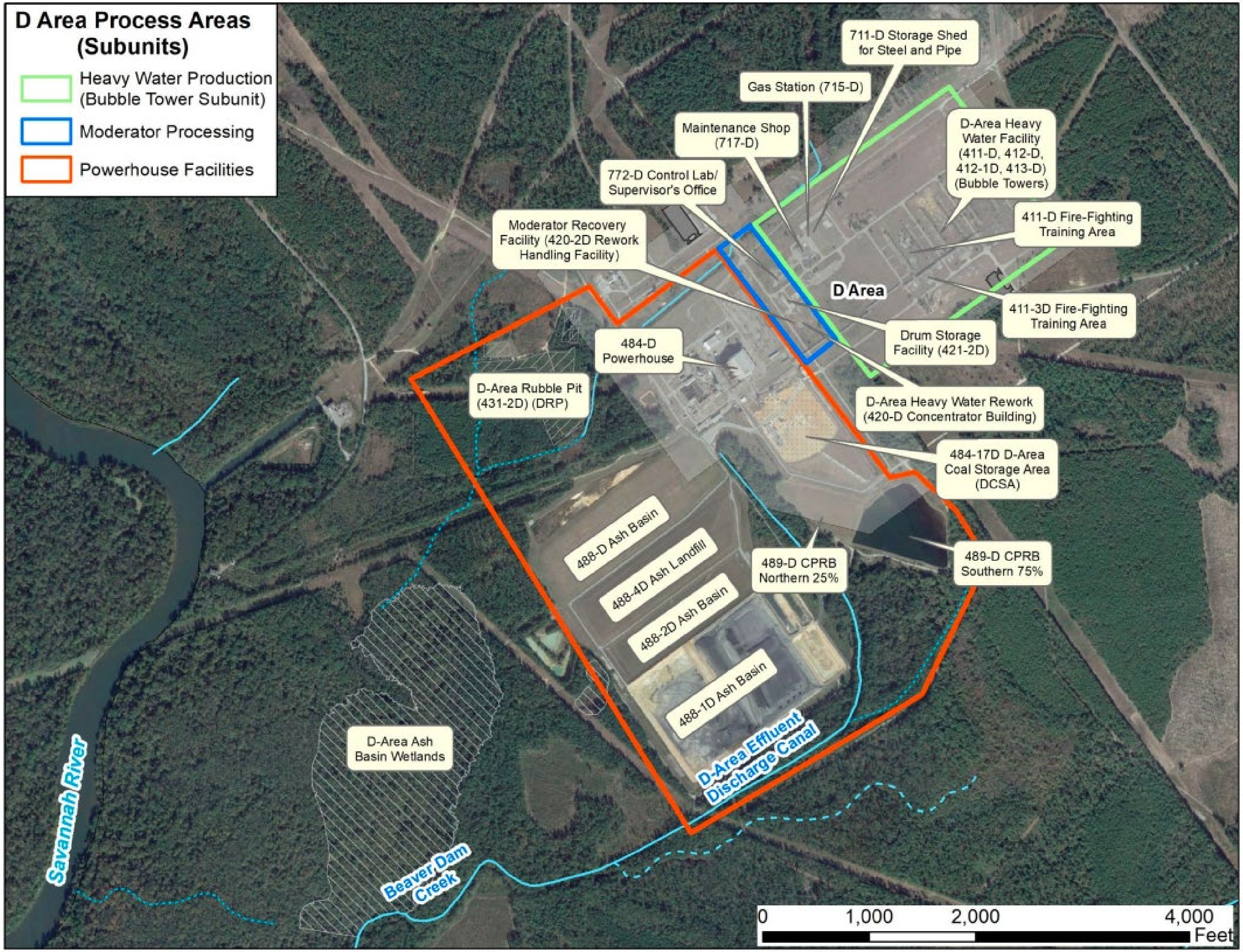
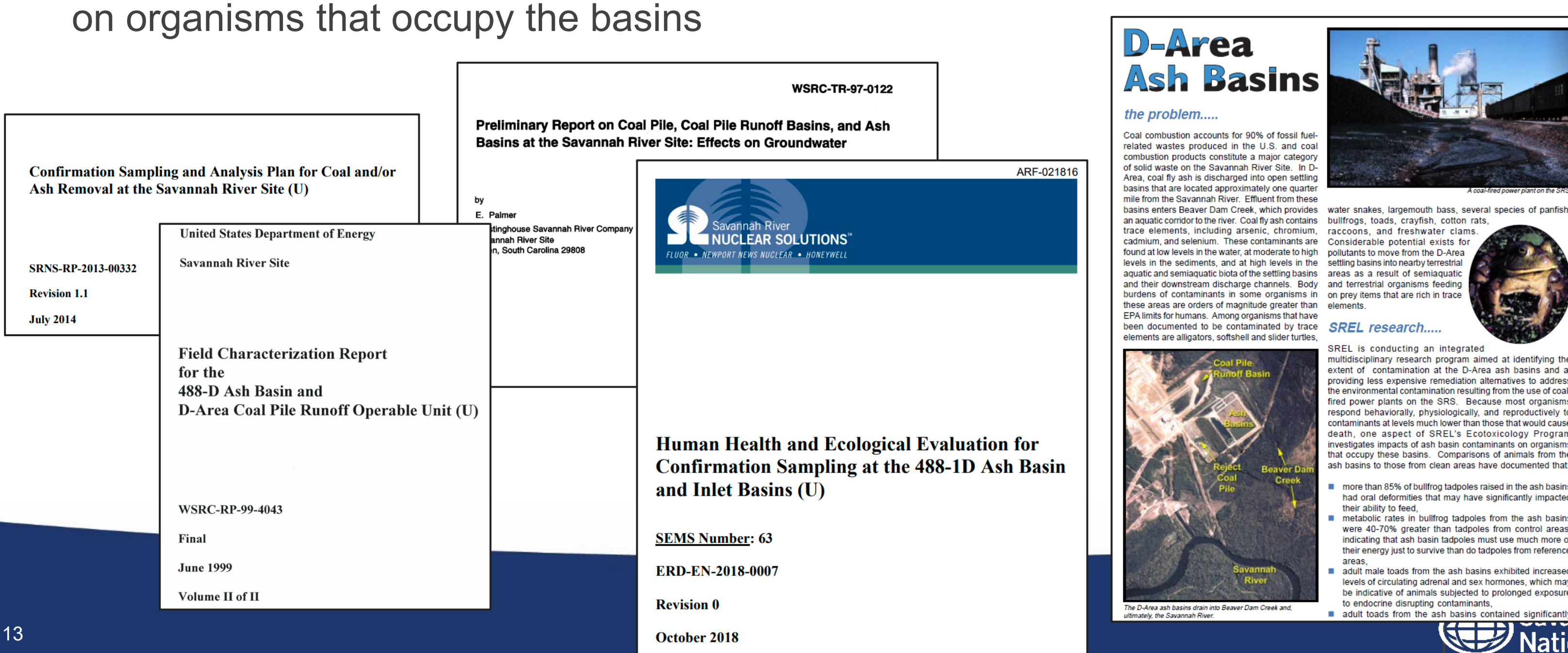
D-Area Ash Basins



Source: SRNS-RP-2021-03748

D-Area Ash Basins – Datasets

- 139 groundwater monitoring wells with data spanning mid 1980s to present day
  - Some wells were added/removed during the cleanup efforts
- 360 analytes
  - Geochemical measurements, heavy metal concentrations, radionuclides, chlorinated solvents, other organic and inorganic compounds
- Historical investigations identifying extent of contamination for closure and remediation activities
  - Example: SREL's Ecotoxicology Program investigated the impacts of ash basin contaminants on organisms that occupy the basins



Confirmation Sampling and Analysis Plan for Coal and/or Ash Removal at the Savannah River Site (U)

SRNS-RP-2013-00332

Revision 1.1

July 2014

WSRC-TR-97-0122

Preliminary Report on Coal Pile, Coal Pile Runoff Basins, and Ash Basins at the Savannah River Site: Effects on Groundwater

by

E. Palmer

United States Department of Energy

Savannah River Site

Field Characterization Report for the 488-D Ash Basin and D-Area Coal Pile Runoff Operable Unit (U)

WSRC-RP-99-4043

Final

June 1999

Volume II of II

ARF-021816

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Human Health and Ecological Evaluation for Confirmation Sampling at the 488-1D Ash Basin and Inlet Basins (U)

SEMS Number: 63

ERD-EN-2018-0007

Revision 0

October 2018

D-Area Ash Basins

the problem.....

Coal combustion accounts for 90% of fossil fuel-related wastes produced in the U.S. and coal combustion products constitute a major category of solid waste on the Savannah River Site. In D-Area, coal fly ash is discharged into open settling basins that are located approximately one quarter mile from the Savannah River. Effluent from these basins enters Beaver Dam Creek, which provides an aquatic corridor to the river. Coal fly ash contains trace elements, including arsenic, chromium, cadmium, and selenium. These contaminants are found at low levels in the water, at moderate to high levels in the sediments, and at high levels in the aquatic and semiaquatic biota of the settling basins and their downstream discharge channels. Body burdens of contaminants in some organisms in these areas are orders of magnitude greater than EPA limits for humans. Among organisms that have been documented to be contaminated by trace elements are alligators, softshell and slider turtles, water snakes, largemouth bass, several species of panfish, bullfrogs, toads, crayfish, cotton rats, raccoons, and freshwater clams. Considerable potential exists for pollutants to move from the D-Area settling basins into nearby terrestrial areas as a result of semiaquatic and terrestrial organisms feeding on prey items that are rich in trace elements.

A coal-fired power plant on the SRS.

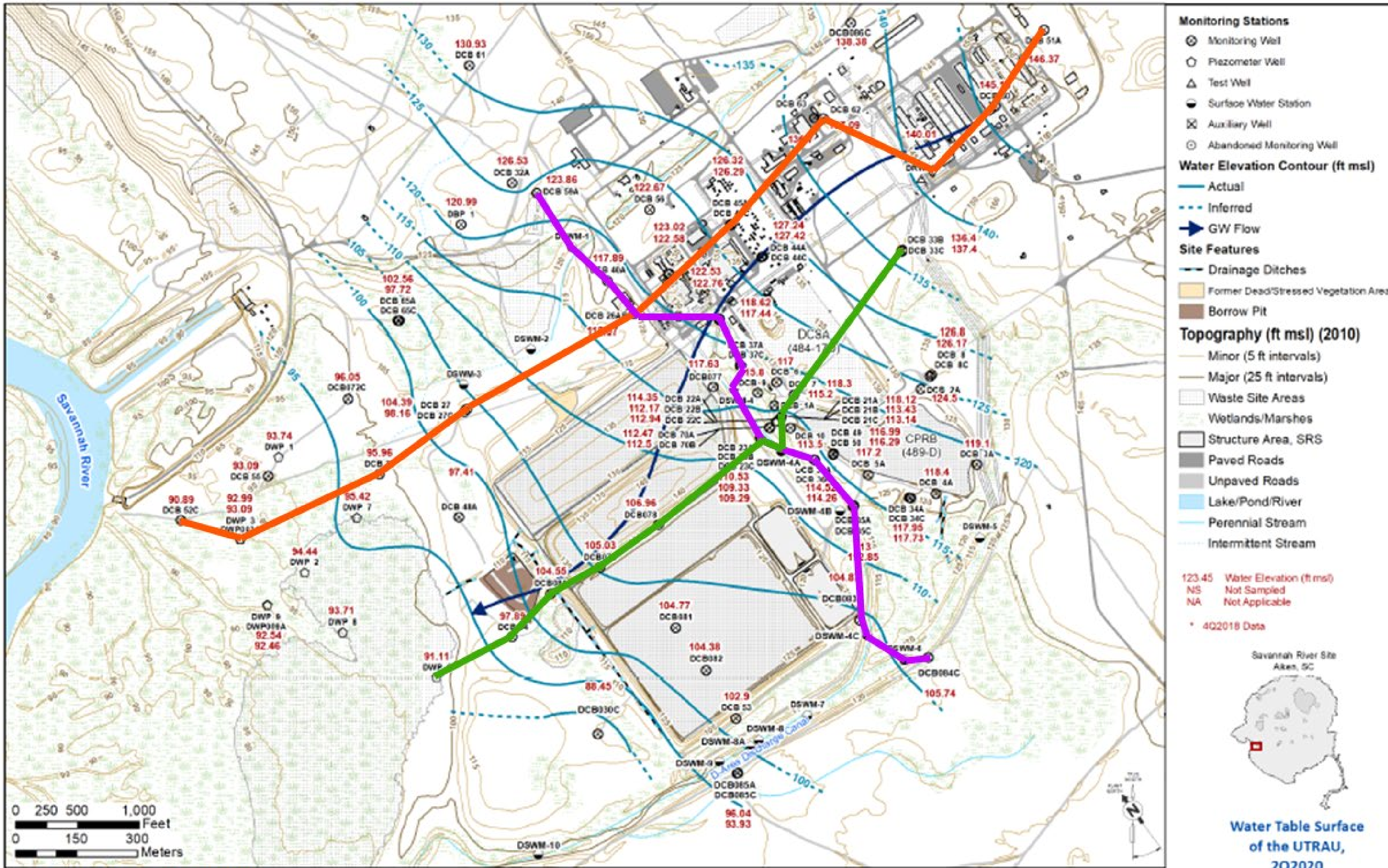
The D-Area ash basins drain into Beaver Dam Creek and, ultimately, the Savannah River.

SREL research.....

SREL is conducting an integrated multidisciplinary research program aimed at identifying the extent of contamination at the D-Area ash basins and at providing less expensive remediation alternatives to address the environmental contamination resulting from the use of coal-fired power plants on the SRS. Because most organisms respond behaviorally, physiologically, and reproductively to contaminants at levels much lower than those that would cause death, one aspect of SREL's Ecotoxicology Program investigates impacts of ash basin contaminants on organisms that occupy these basins. Comparisons of animals from the ash basins to those from clean areas have documented that:

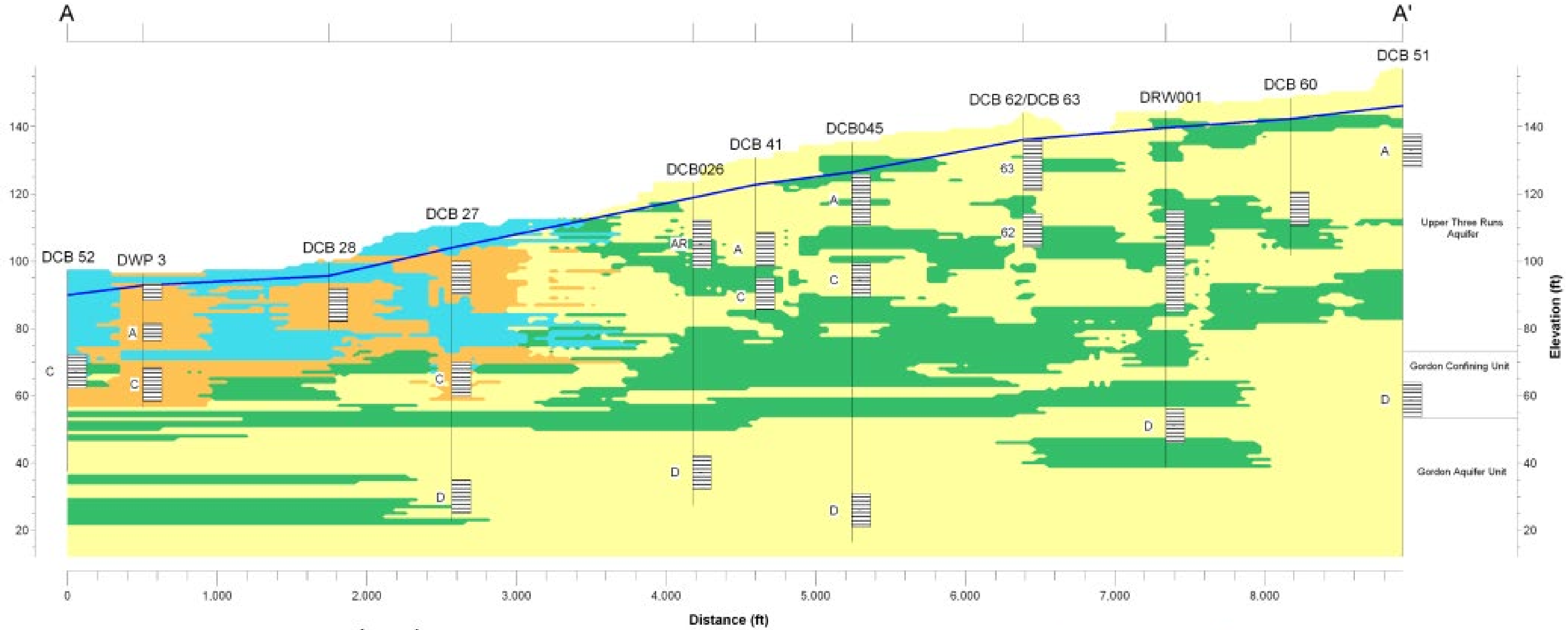
- more than 85% of bullfrog tadpoles raised in the ash basins had oral deformities that may have significantly impacted their ability to feed,
- metabolic rates in bullfrog tadpoles from the ash basins were 40-70% greater than tadpoles from control areas, indicating that ash basin tadpoles must use much more of their energy just to survive than do tadpoles from reference areas,
- adult male toads from the ash basins exhibited increased levels of circulating adrenal and sex hormones, which may be indicative of animals subjected to prolonged exposure to endocrine disrupting contaminants,
- adult toads from the ash basins contained significantly

Potentiometric Surface Upper Three Runs



Water Table Surface of the UTRAU, 2Q2020

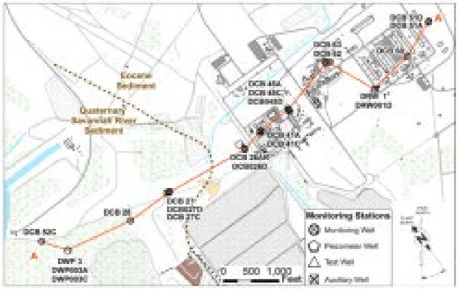
D-Area Ash Basins – Hydrostratigraphy



Legend

- clay to silty clay
- fluvial clay to silty clay
- fluvial sand to silty sand
- sand to silty sand
- SCREEN

10.1 Field pH Measurements
NS Not Sampled
EQL Estimated Quantation Limit
NDD Not Decision Data
Well/Boring
Potentiometric Surface 2Q20 (ft msl)



Source: SRNS-RP-2021-03748

D-Area Ash Basins – Beryllium

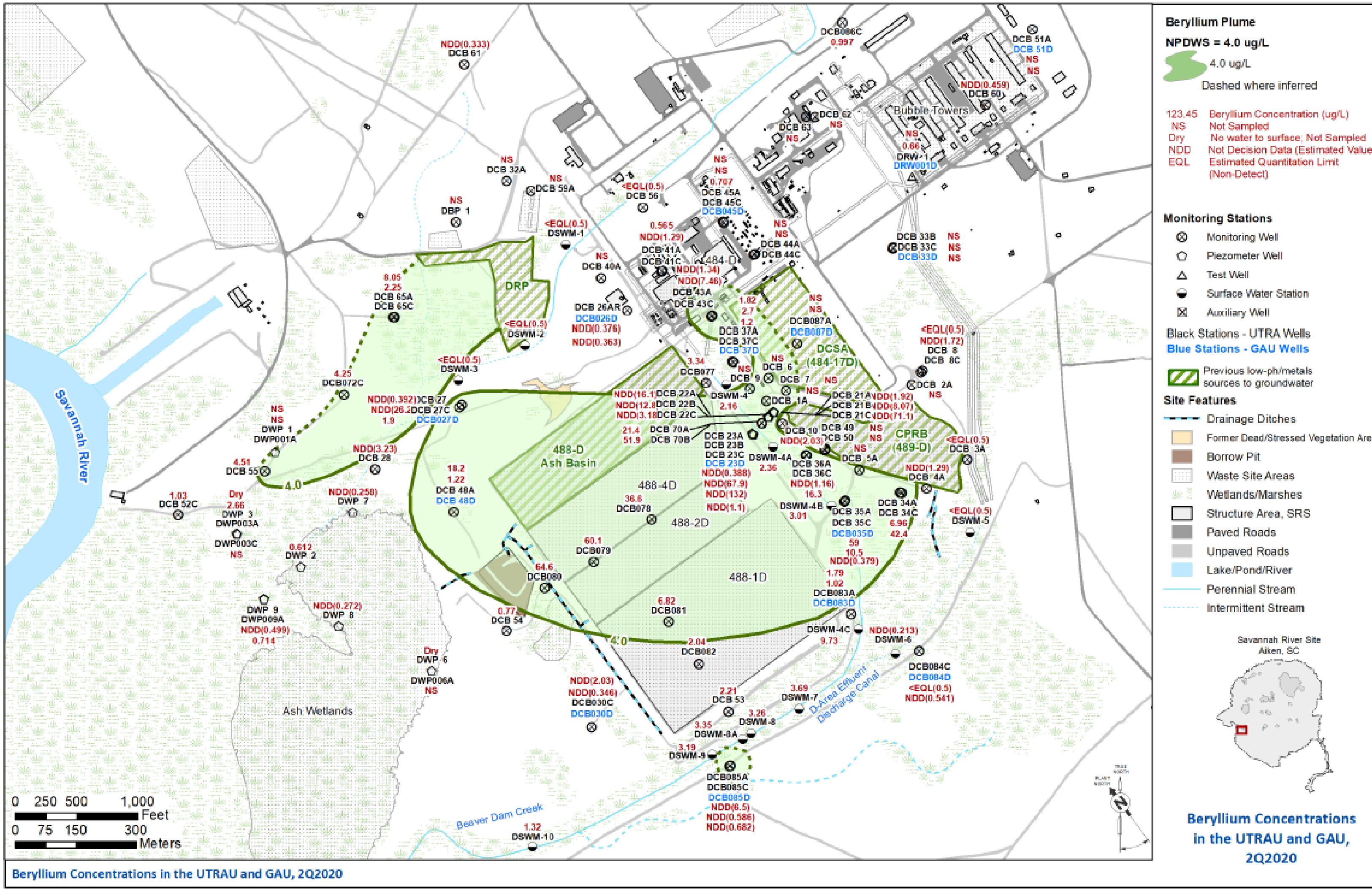


Figure D-12. Beryllium Concentrations in the Upper Three Runs and Gordon Aquifer Units, 2Q2020

Source: SRNS-RP-2021-03748

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D-Area Ash Basins – Beryllium

Figure D-16. D-Area Groundwater Cross-Section C-C' for Beryllium, 2Q2020

Source: SRNS-RP-2021-03748

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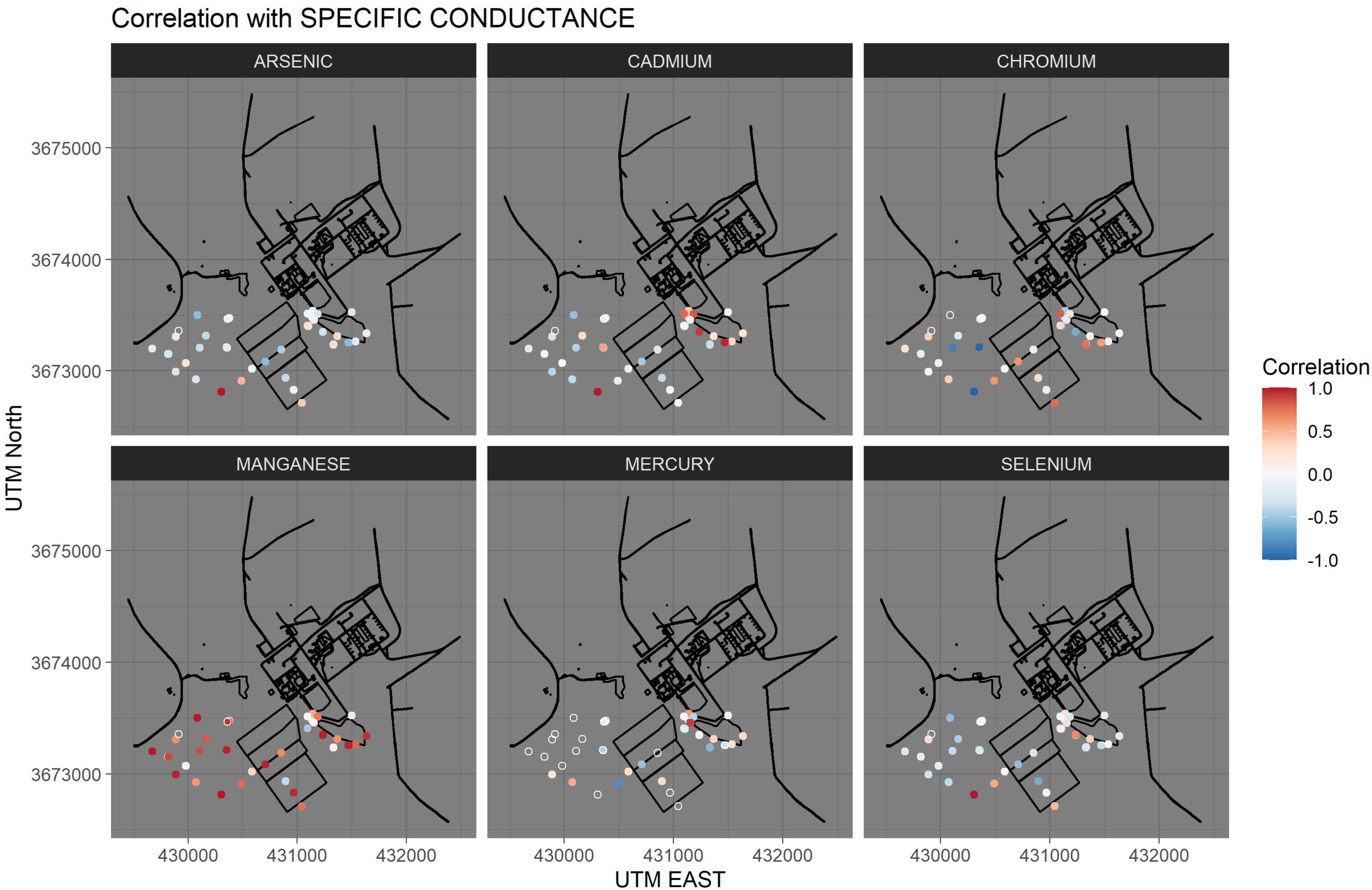
Correlations – Specific Conductance



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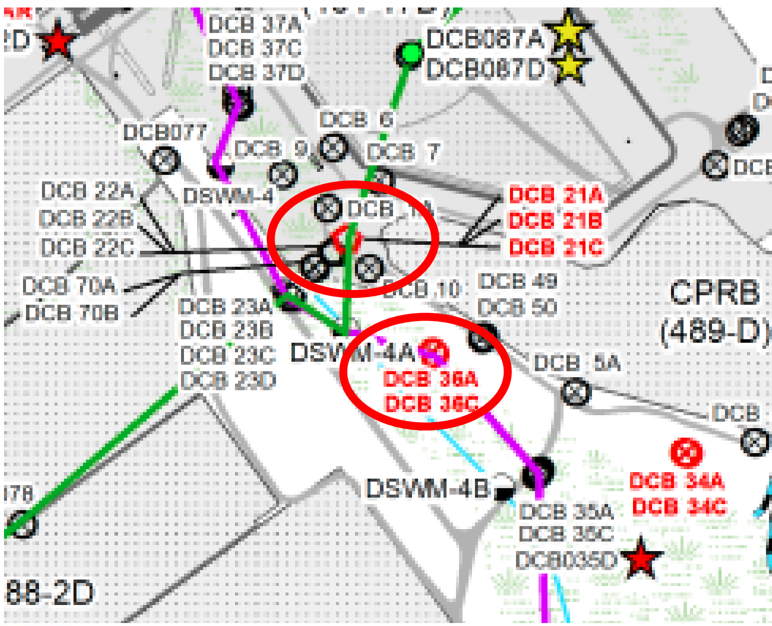
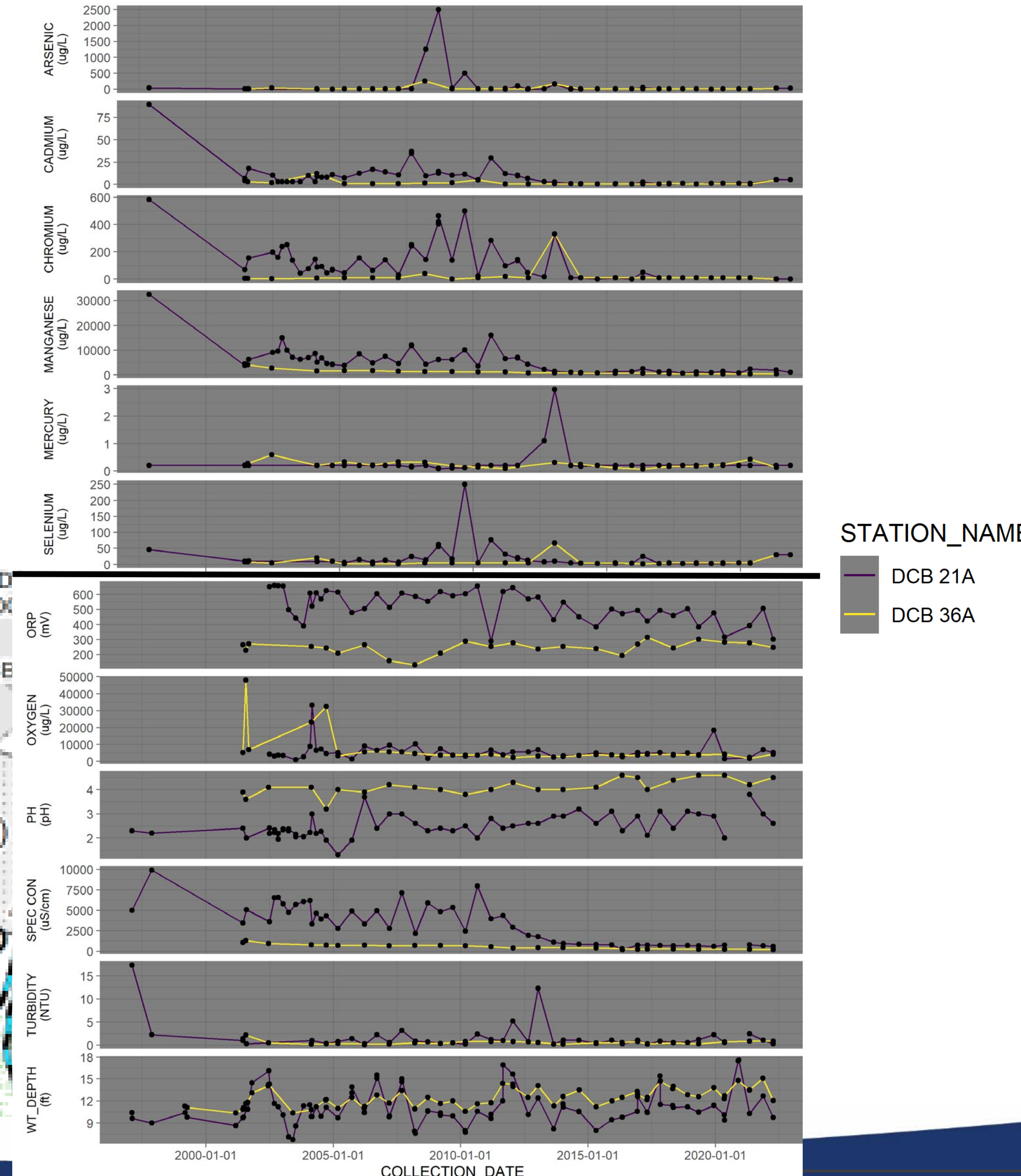
Correlations – Close Proximity Wells

- DCB 21A and DCB 36A
  - 500 feet apart
  - Well screens are at the same elevation and have the same matrix materials
  - Different measurements of analytes





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Conclusions

- Environmental datasets can be complicated to work with, but AI/ML/big data analytics provide an opportunity to create easy-to-comprehend geochemical conceptual models
- Installation of sensor networks around zones of vulnerability enhances environmental datasets and improves robustness of models
- **End Result**: A more proactive and cost-effective approach to long-term monitoring and cleanup activities

Acknowledgements

- ALTEMIS Team (Home - ALTEMIS (lbl.gov)) (DOE-EM funding)
- D-Area:
  - Jeff Summers (DOE-FECM funding)
  - Carol Eddy-Dilek
  - Elizabeth Labone
  - Emily Fabricatore
  - Brian Looney
  - Hansell Gonzalez-Raymat

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U.S. DEPARTMENT OF ENERGY

Motivation and Objectives

- SRNL has been exploring new long-term monitoring strategies for many years
  - Shift from a *reactive* monitoring strategy to a *proactive* monitoring strategy
  - Reduce costs by up to 90%
- Major ongoing field demonstration at the SRS F-Area Seepage Basins (ALTEMIS)
  - Primarily concentrated on long-term monitoring of radionuclide contaminants

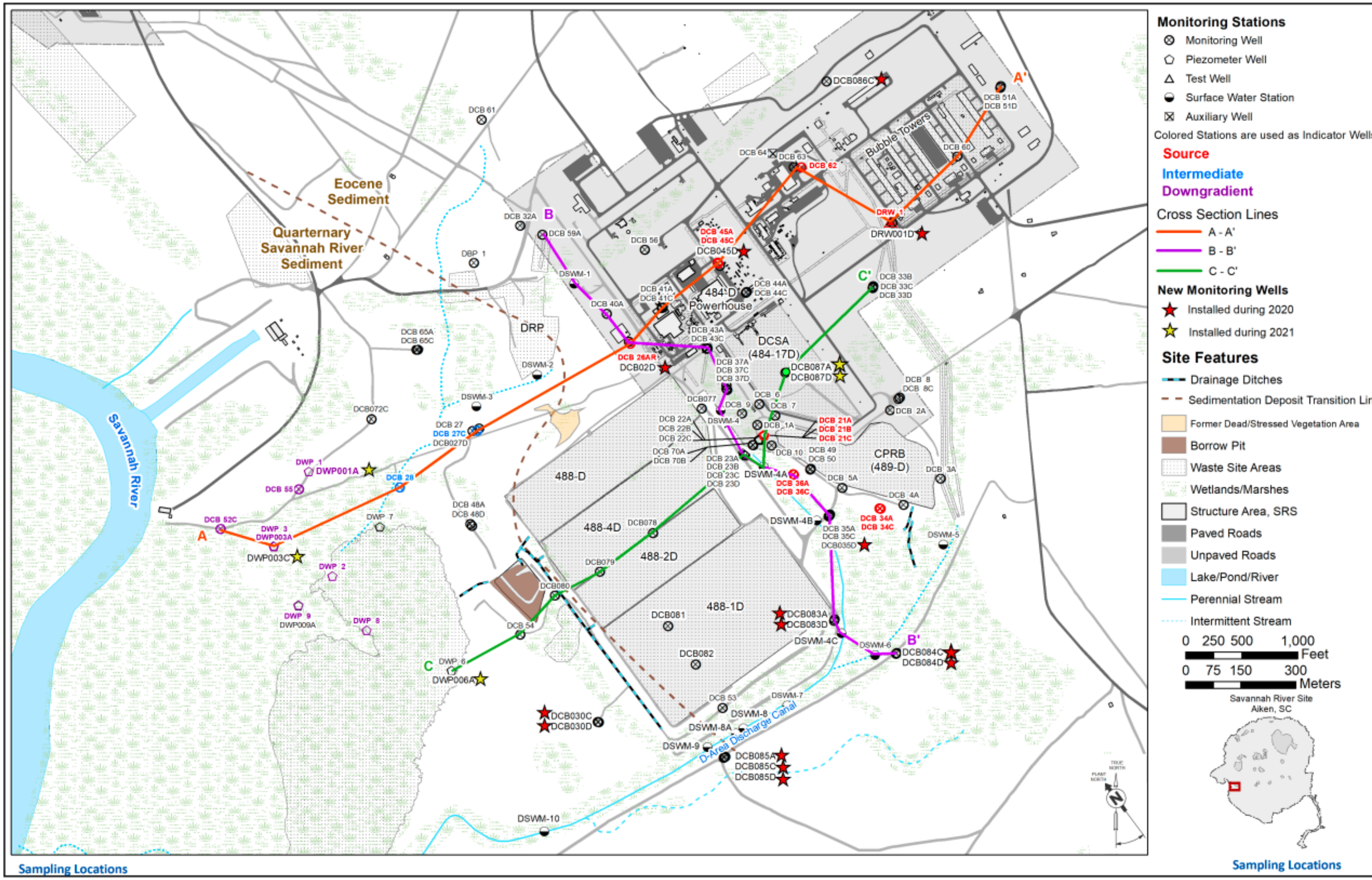
Objectives

- Explore the use of techniques developed as part of ALTEMIS applied to coal ash contaminated sites
  - Identify the master variables associated with contaminant transport using data analytics and AI/ML techniques
- Identify additional historical datasets that may be incorporated (e.g., ecology studies)

D-Area Ash Basins

- **484-D Powerhouse**: Built in 1953 and operated until 2012
  - ~160,000 tons of coal per year
  - Deactivation of the D-Area Powerhouse and associated facilities began in 2012
- **488-2D Ash Basin**: Dewatered, coal ash contaminated soils were excavated and consolidated in 488-4D Ash Landfill. Ultimately left open as stormwater retention pond.
- **488-4D Ash Landfill**: Geosynthetic cap installed over contaminated soils.
- **488-1D Ash Basin**: Dewatered, coal ash contaminated soils were excavated and consolidated in the eastern end. Geosynthetic cap installed over contaminated soils. West end kept open as a stormwater retention pond.
- **489-D Coal Pile Runoff Basin**: Clean closure, contaminated soils excavated and placed in eastern portion of 488-1D Ash Basin.
- Groundwater monitoring continues around the facility to ensure geosynthetic covers remain effective.

D-Area Ash Basins



Sampling Locations

Source: SRNS-RP-2021-03748

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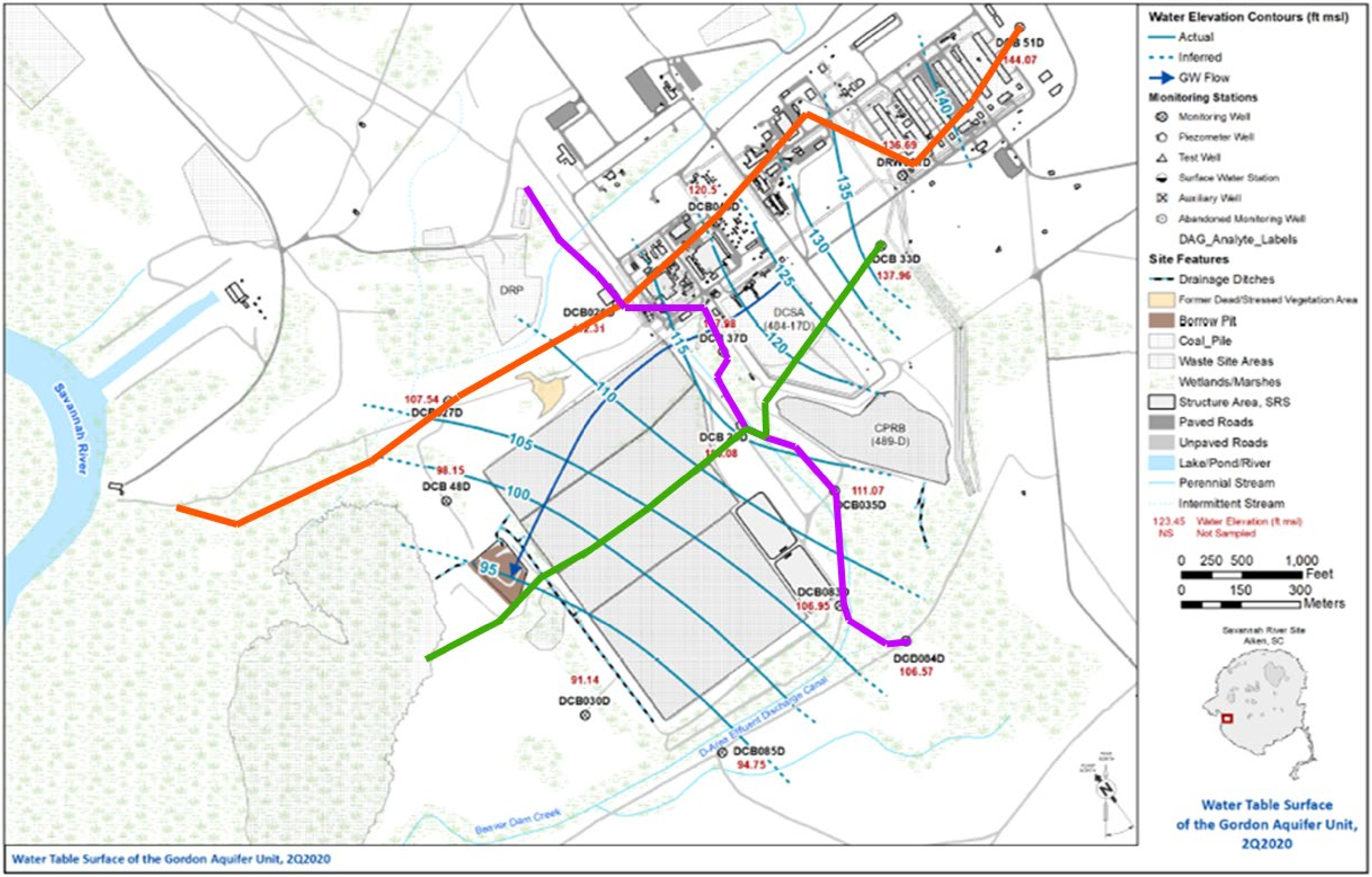
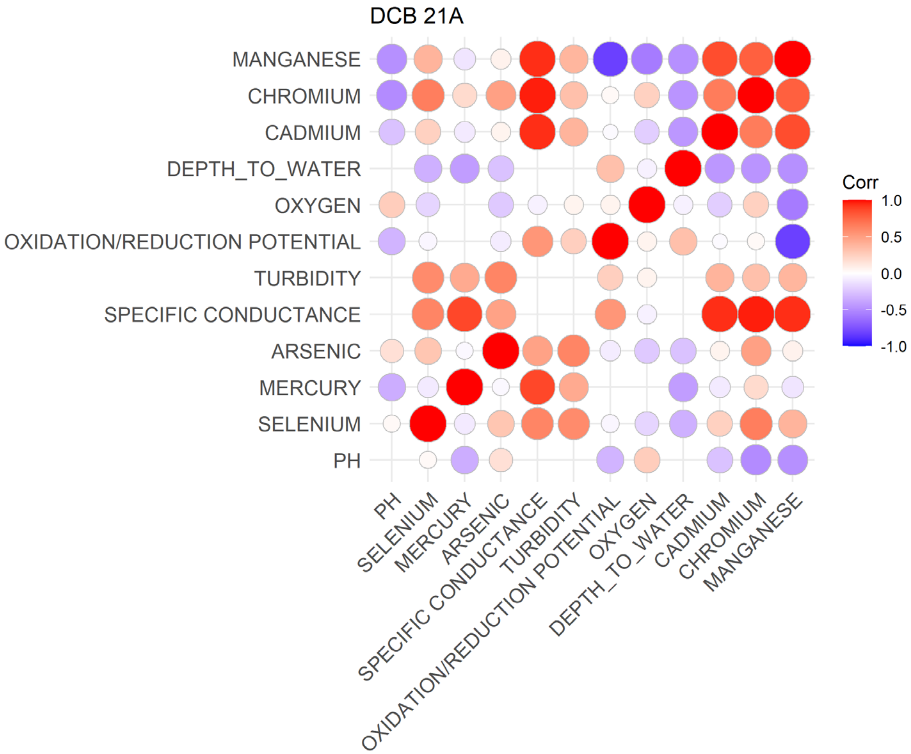
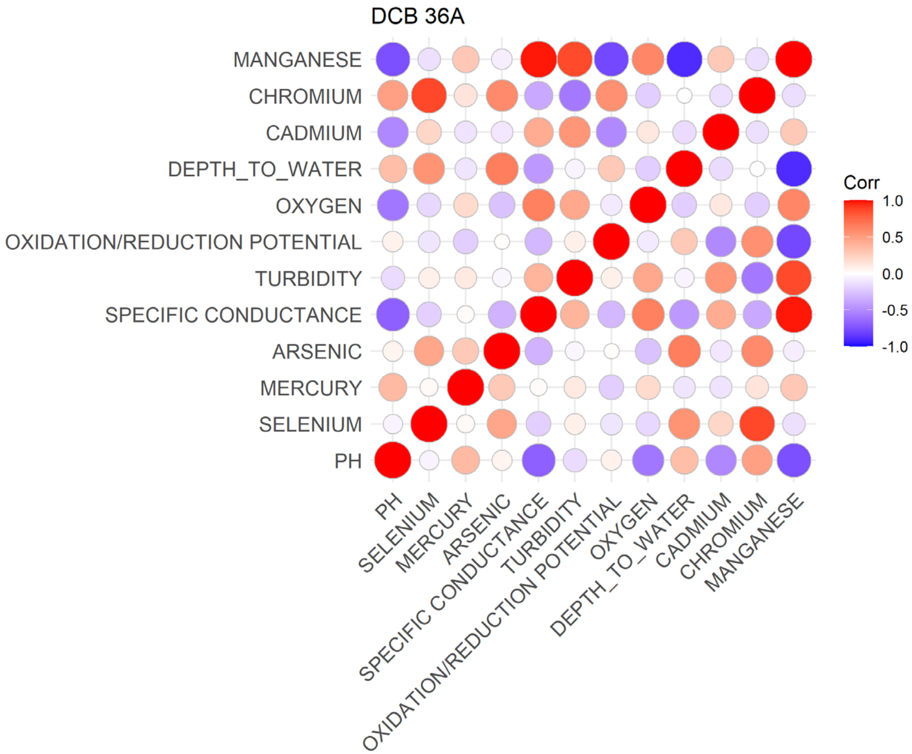
Potentiometric Surface Gordon Aquifer Unit



Water Table Surface of the Gordon Aquifer Unit, 2Q2020

Correlations – Close Proximity Wells

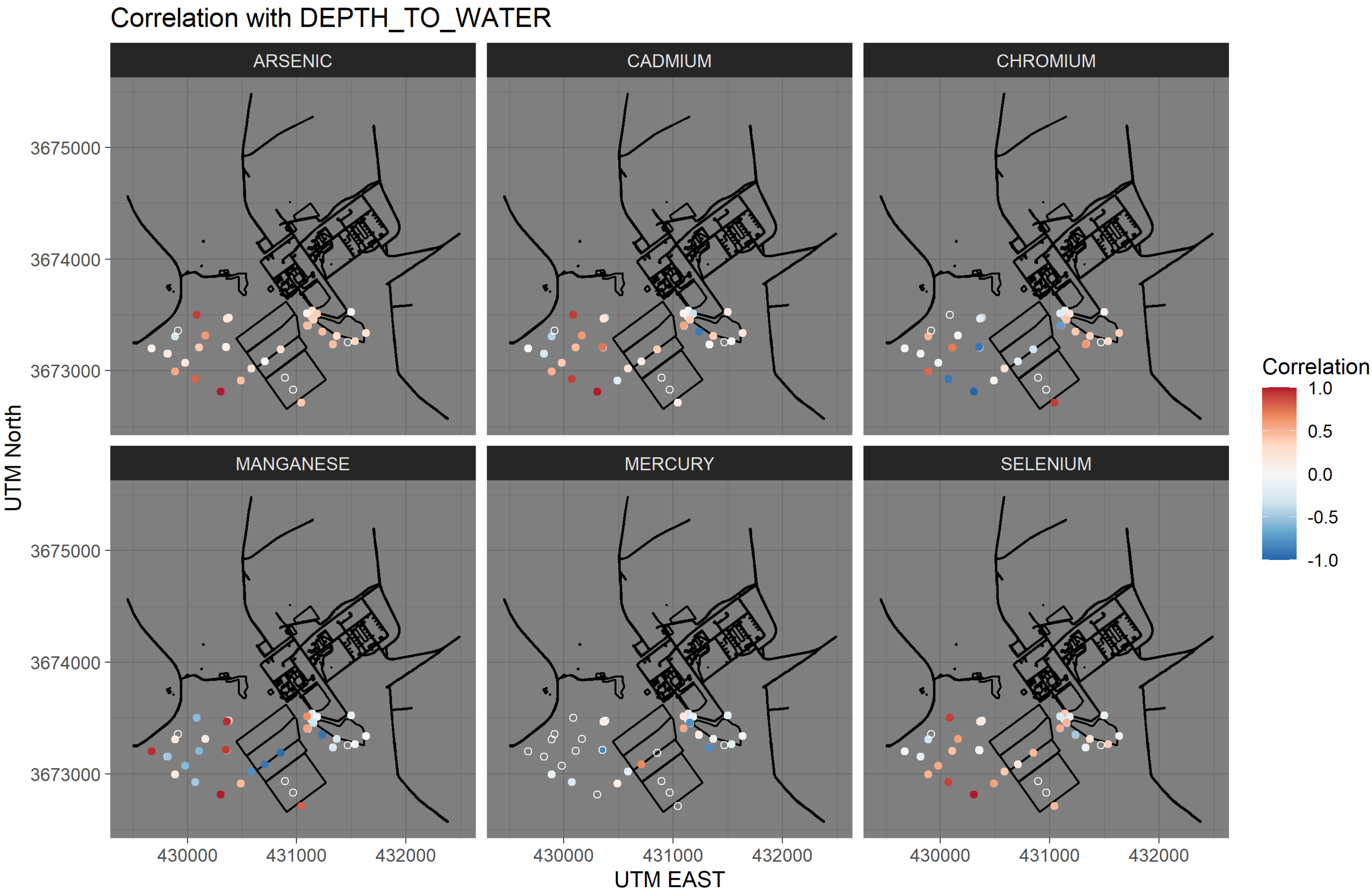




Examples of Mixed Results

- Agreement between correlations e.g., Mn vs pH
- Strong correlations, but positive vs negative e.g., Cr vs pH
- Low/No correlation e.g., Se vs pH
- Strong vs weak AND positive vs negative: Se vs Specific Conductance

Correlations – Water Table Elevation



Ongoing/Future Work

- Isolate controlling variables for contaminants of interest
  - PCA, correlation matrices, etc. to identify which geochemical analytes are correlated with contaminant concentrations
- Identify wells that allow best characterization of the contaminants over time (e.g., using Gaussian Process method)
- Apply Kalman filter technique to estimate contaminant concentrations
- Feasibility of Linking Historical D-Area Investigations with Groundwater Data
  - Literature search to identify if additional datasets exist and how they might be used

Long-Term Monitoring Paradigm as Applied to the F-Area Seepage Basins

In Situ Real-time Monitoring For Early Warning Systems (SRNL, LBNL)

- In situ sensors and In situ monitoring technologies for monitoring ***master variables***

Spatially Integrative Monitoring: Surface Cap Systems Monitoring (PNNL)

- Geophysical monitoring of the integrity of the surface cap is critical to reduce infiltration into source zones containing residual contaminant

Spatially Integrative Monitoring: Wetland Monitoring (LBNL)

- State of the-of-art spatially integrative techniques for monitoring groundwater and wetland including UAV spectral methods
- Fiber optic sensors for temperature and conductivity

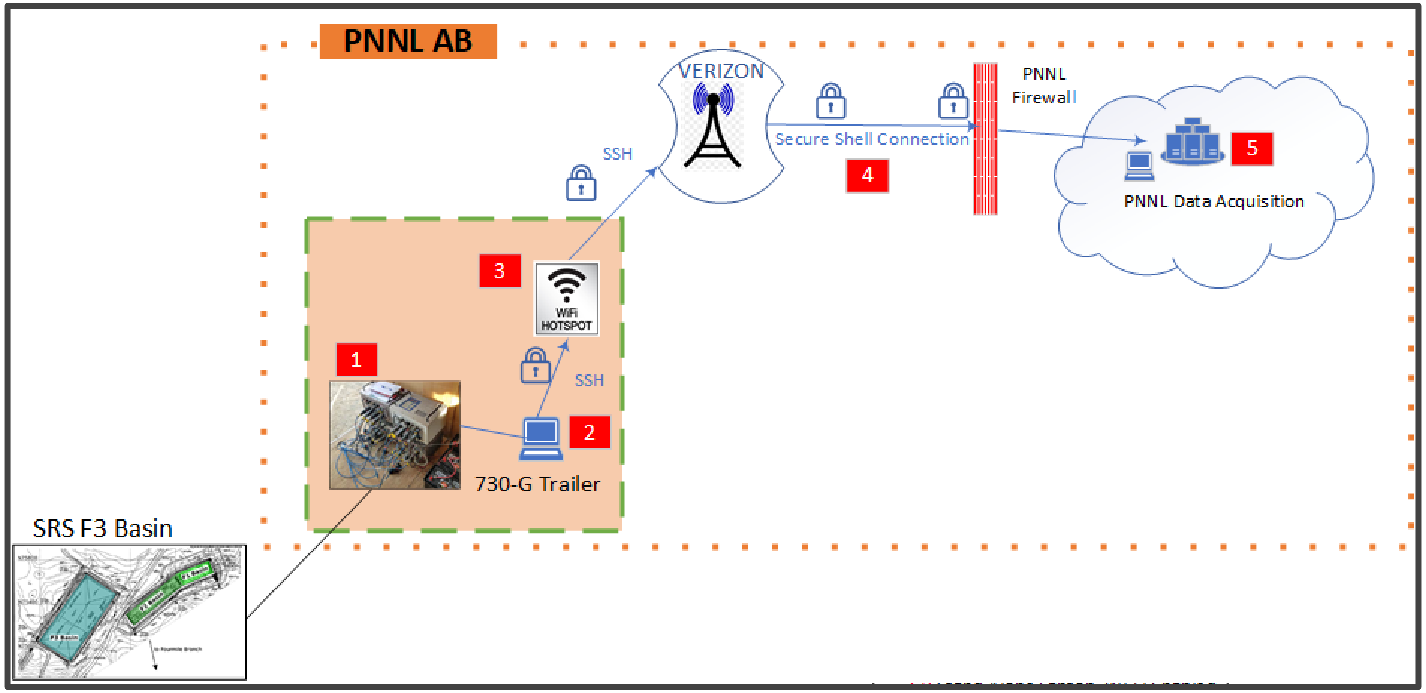
Geochemical Characterization and Monitoring (SRNL, CRESP, MSIPP)

- Mitigation of geochemical conditions that could reverse contaminant attenuation, or the contaminant release that might occur over decades or even centuries.

Goal is to create a site specific comprehensive monitoring system that will improve effectiveness, while significantly reducing overall cost. Goal is to transition approaches to other EM/LM sites.

ERT Test Survey Setup

ERT Data Flow



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D-Area Ash Basins – pH

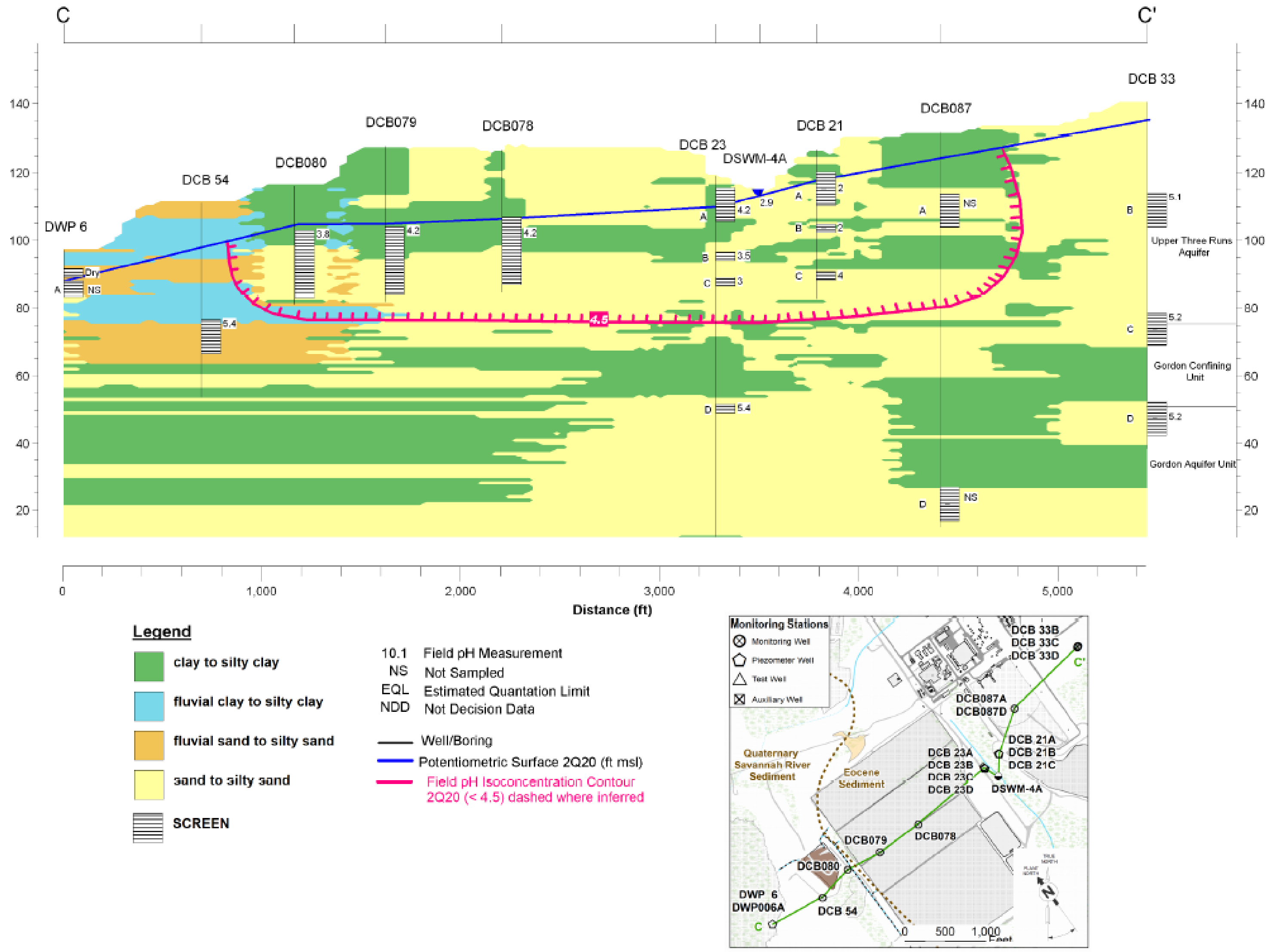

Figure D-20. D-Area Groundwater Cross-Section C-C' for pH, 2Q2020

Source: SRNS-RP-2021-03748

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