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Critical Challenges.
Practical Solutions.

DEVELOPING AND VALIDATING RESERVOIR PRESSURE MANAGEMENT AND PLUME CONTROL STRATEGIES IN THE WILLISTON BASIN THROUGH A BRINE EXTRACTION AND STORAGE TEST (BEST) – PHASE II

DE-FE0026160

Mastering the Subsurface Through Technology Innovation & Collaboration:
Carbon Storage & Oil & Natural Gas Technologies Review Meeting

August 17, 2016

John A. Hamling
Principal Engineer

Critical Challenges. Practical Solutions.

Disclaimer

Thank You
Project Partners

Acknowledgments

This material is based upon work supported by the U.S. Department of Energy National Energy Technology Laboratory under Award No. DE-FE0026160.

ACTIVE RESERVOIR MANAGEMENT (ARM)

Why ARM?

- Reduce stress on sealing formation
- Divert pressure from leakage pathways
- Reduced area of review (AOR)
- Improve injectivity

Why Brine Treatment?

- Alternate source of water
- Reduce disposal volumes
- Salable products for beneficial use

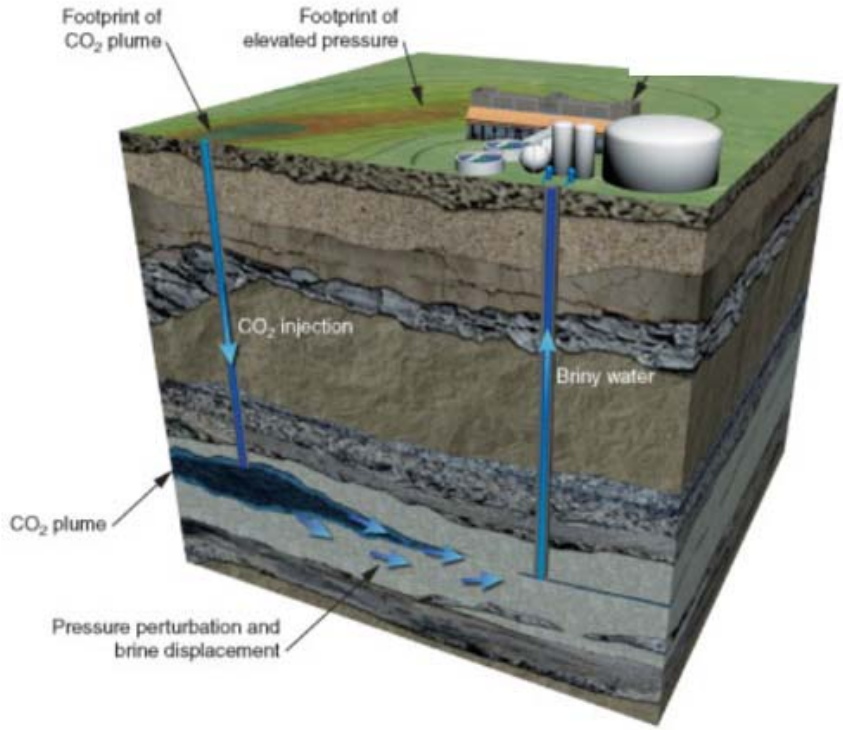


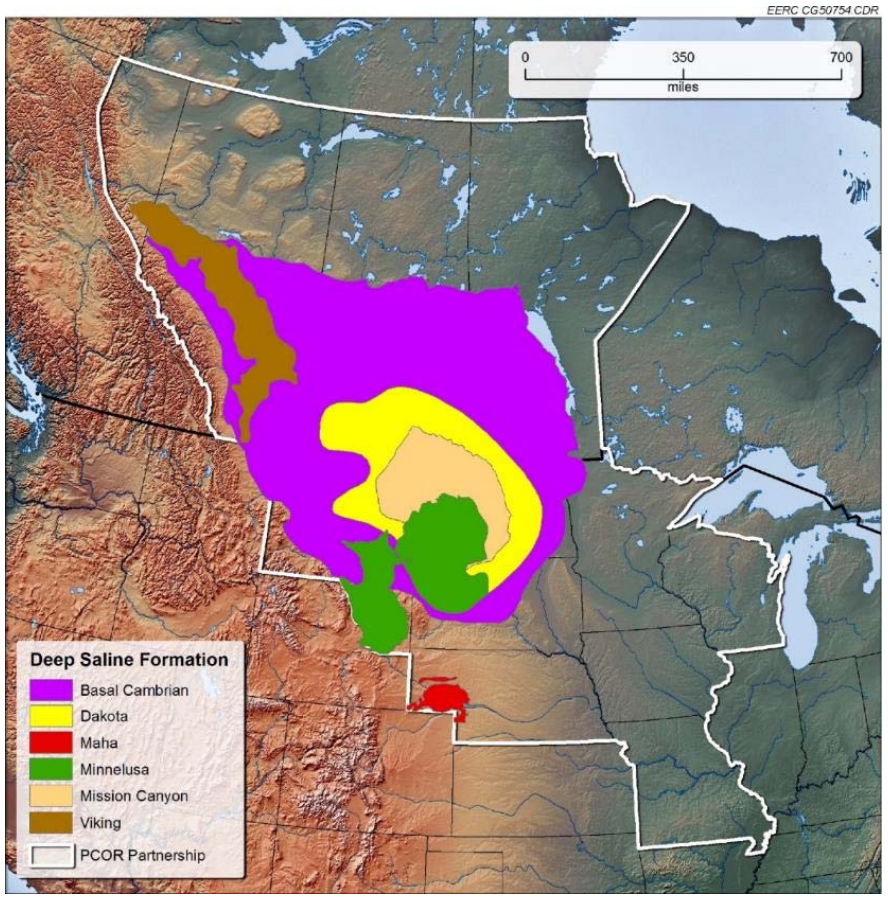
Photo modified from Lawrence Livermore National Laboratory
https://str.llnl.gov/Dec10/aines.html

BENEFITS STATEMENT

This project is expected to result in the development of engineering strategies/approaches to quantitatively affect changes in differential formation pressure and to monitor, predict, and manage differential pressure plume movement in the subsurface for future CO_2 saline storage projects. Additionally, the brine treatment technology evaluation is expected to provide valuable information on the ability to produce water for beneficial use. The results derived from implementation of the project will provide a significant contribution to the U.S. Department of Energy's (DOE's) Carbon Storage Program goals. Specifically, this project will support **Goals 1 and 2** by validating technologies that will improve reservoir storage efficiency, ensure containment effectiveness, and/or ensure storage permanence by controlling injected fluid plumes in a representative CO_2 storage target. Geologic characterization of the target horizons will provide fundamental data to improve storage coefficients related to the respective depositional environments investigated, directly contributing to Goal 3. In addition, this project will support **Goal 4** by producing information that will be useful for inclusion in DOE best practices manuals.

PHASE I

- Regional characterization
- Site screening and feasibility study
- Site selection
- Geologic modeling
- Reservoir simulation resulting in ARM schema
- Site infrastructure design and field implementation plan
  - Permitting plan
  - Risk assessment
  - Monitoring, verification, and accounting (MVA) plan
  - Site operations plan
  - Costing analysis
  - Brine treatment technology screening and selection process



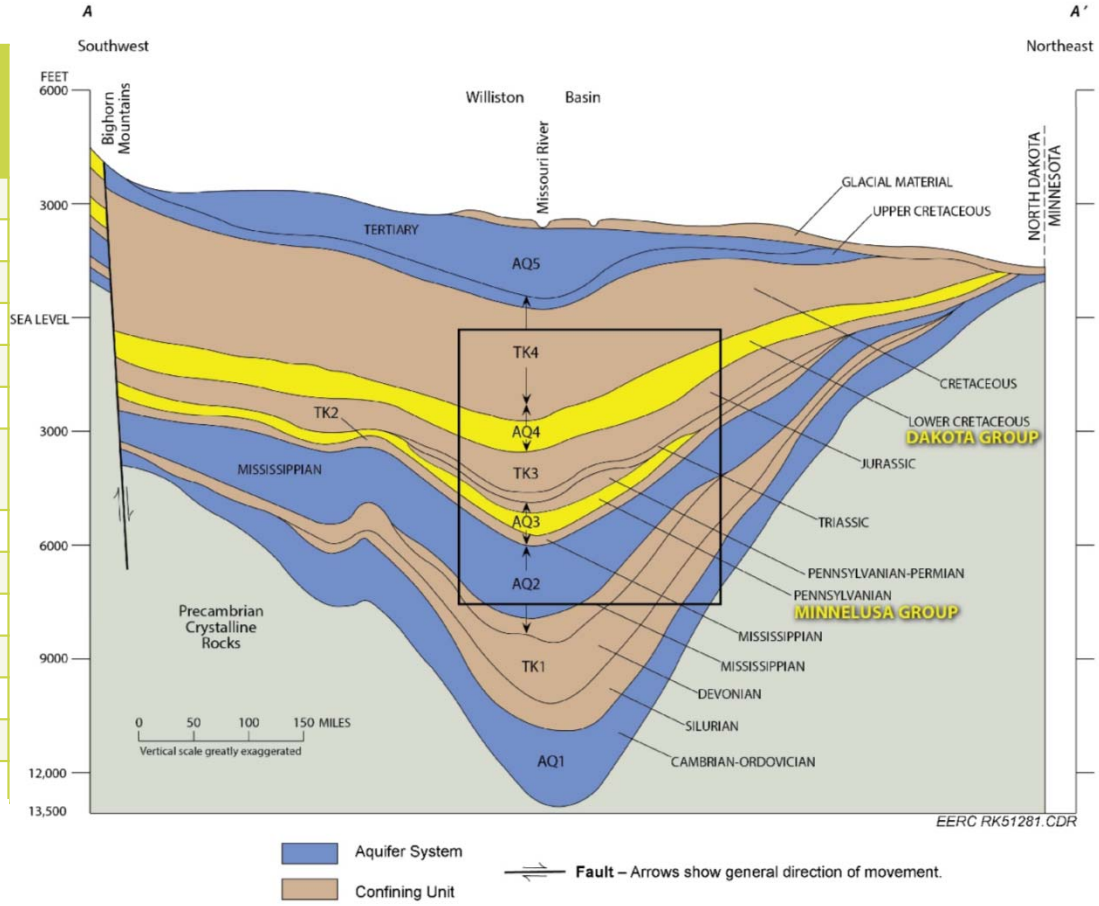
PHASE II GOALS AND OBJECTIVES

- Confirm efficacy of the ARM approaches developed during Phase I
  - Manage formation pressure
  - Predicting and monitoring plume movement
  - Validating pressure and brine plume model predictions
- Implement and operate a test bed facility for the evaluation of selected brine treatment technologies
- Three development stages over 48 months
  1. Site preparation and construction
  2. Site operations including ARM and extracted brine treatment technology testing and demonstration
  3. Project closeout/decommissioning and data processing/reporting

THE WILLISTON BASIN

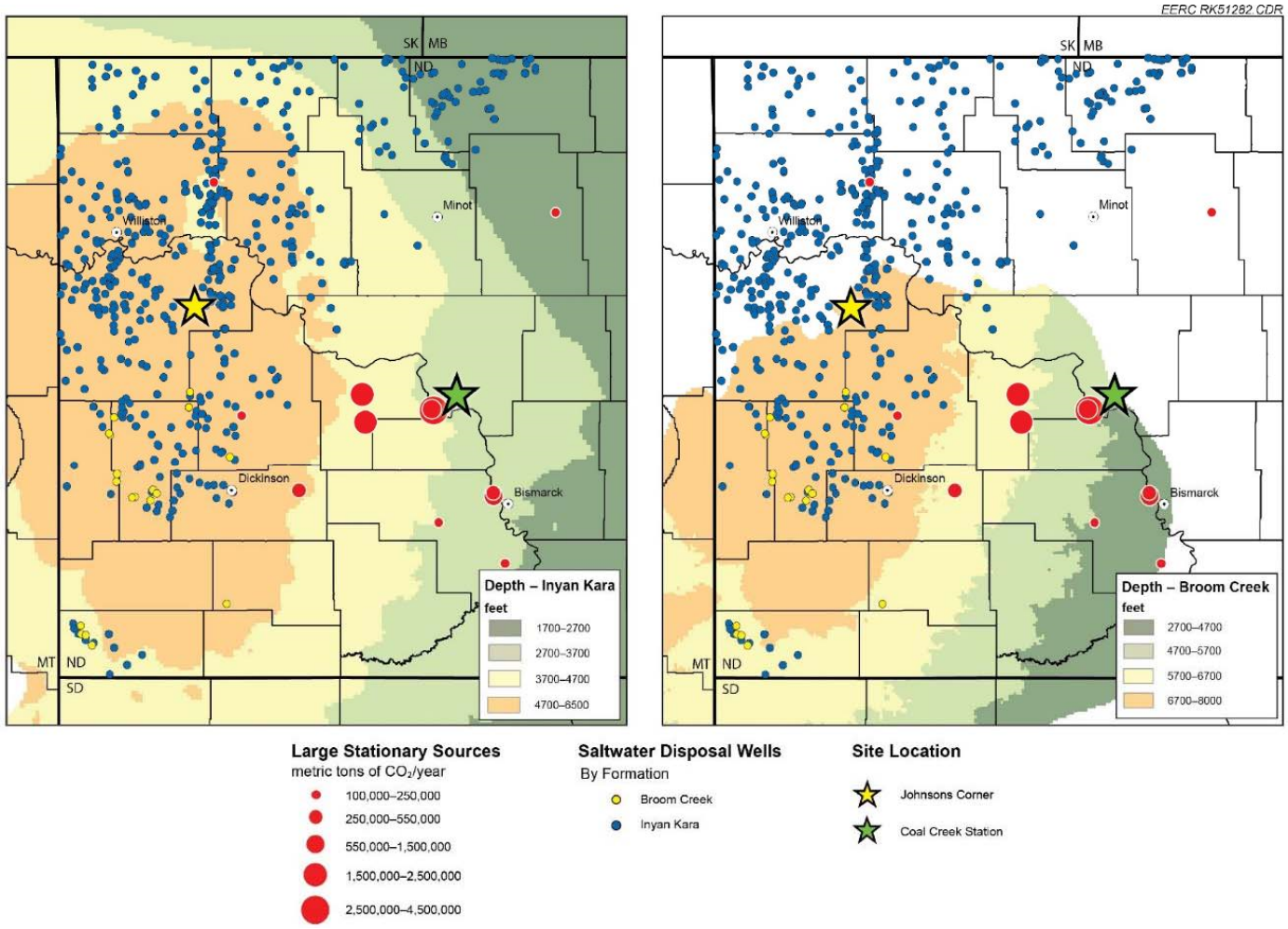
Saline Formation	CO_2 Storage Volume, billions of tons
Basal Cambrian	222–720
Beaverhill Lake Group	<1–5
Minnelusa (Williston Basin)	124–451
Elk Point Group	1–12
Dakota	135–438
Maha	21–68
Minnelusa (Powder River Basin)	10–35
Mission Canyon	65–210
Red River	2–6
Rundle Group	1–8
Viking	20–65
Winterburn Group	1–6
Woodbend Group	1–5
Total	**604–2031**

CO_2 Storage in Saline Formations in the PCOR Partnership Region (in billions of tons of CO_2) (modified from Glazewski and others, 2015)



DAKOTA AND MINNELUSA GROUPS

- Regional injection targets (CO_2 and saltwater)
- Demonstrated capacity
- Excellent proxy for CO_2 injection into deep saline formations (DSFs)
  - Distributed well network.
  - Open DSF system.
  - ARM will influence multiple square miles of formation.



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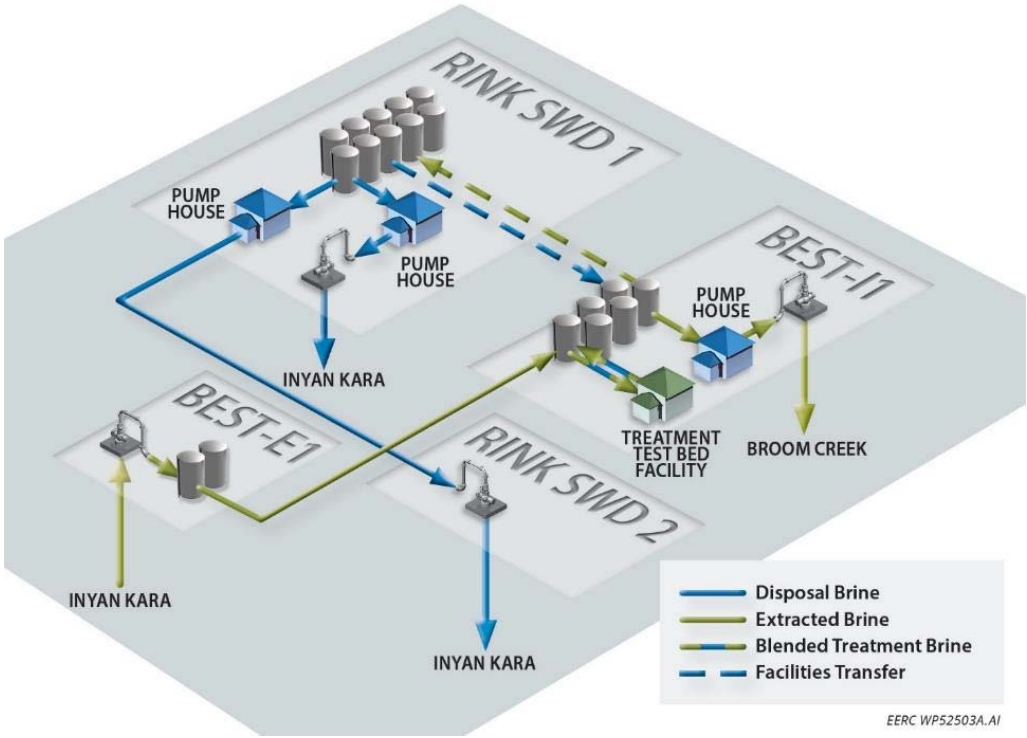
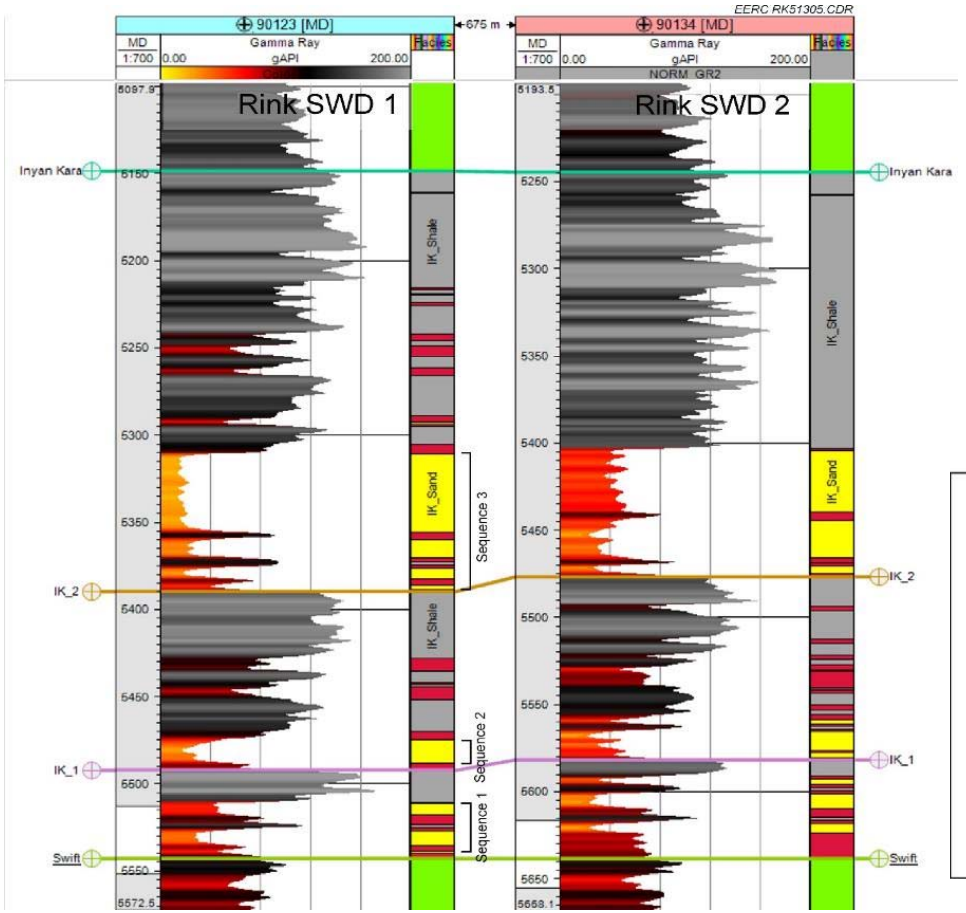
FIELD IMPLEMENTATION PLAN (FIP)

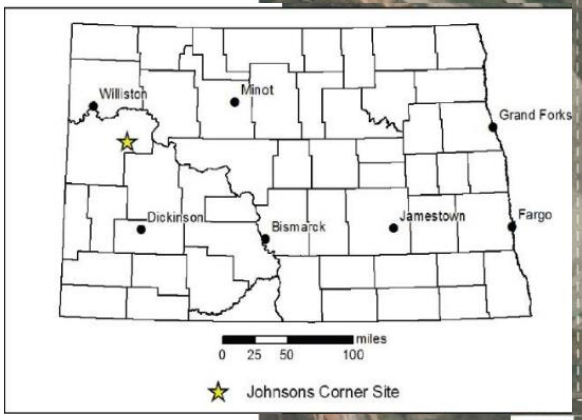
- Develop ARM strategies
- Validate performance against forecasts
- ARM economics
- Monitoring techniques
- Brine treatment technology test bed
- Demonstrate ARM implementation and operations



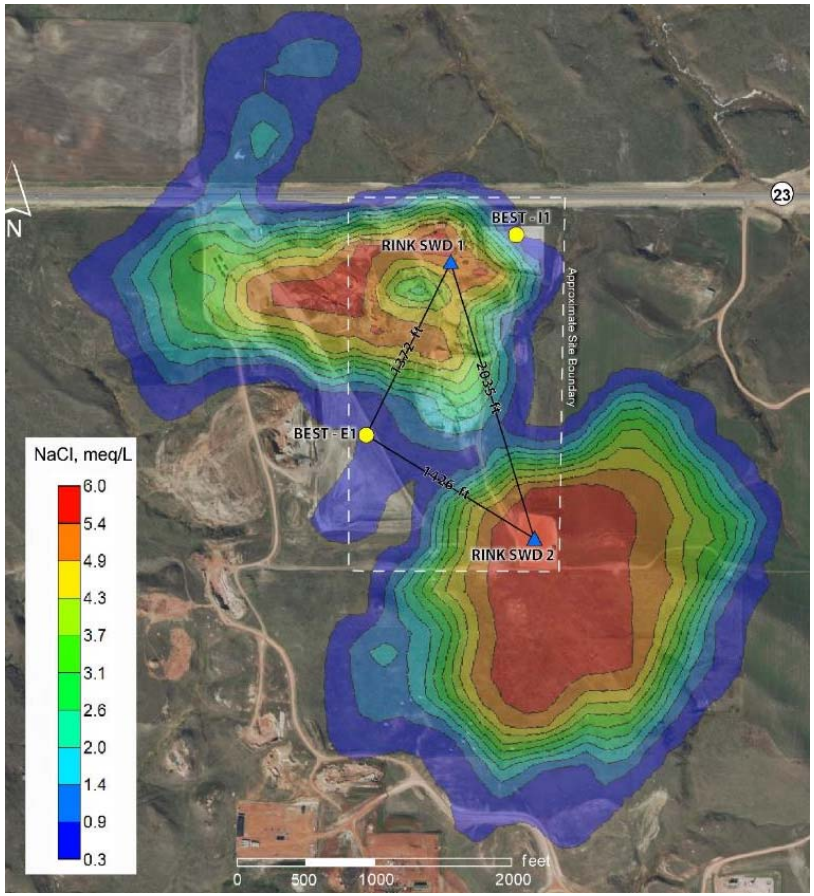
THE SITE

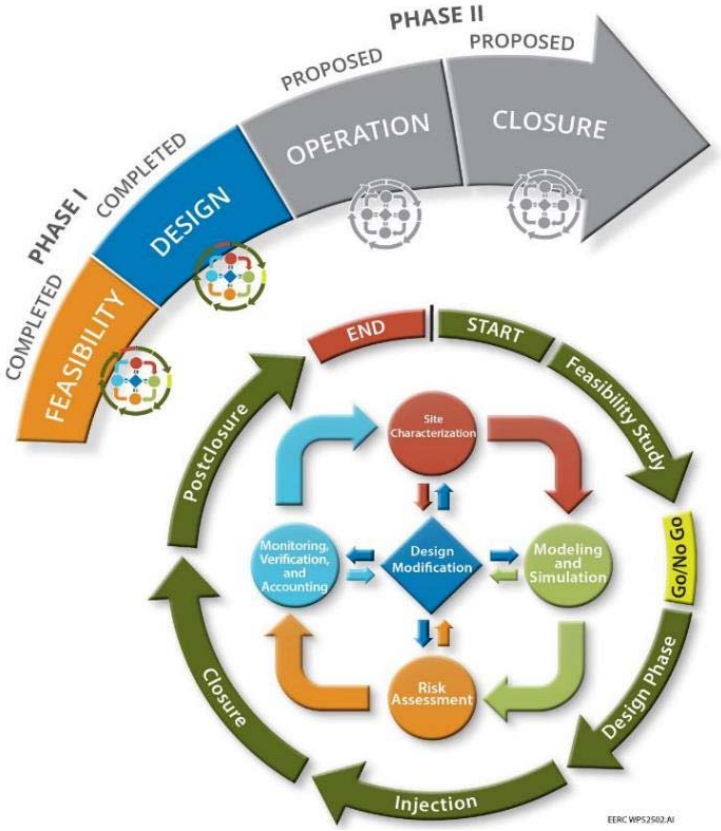
Formation	Inyan Kara	Broom Creek
Depth, ft	4927–5359	7248–7630
Thickness, ft	338–475	46–113
Average Thickness, ft	390	76



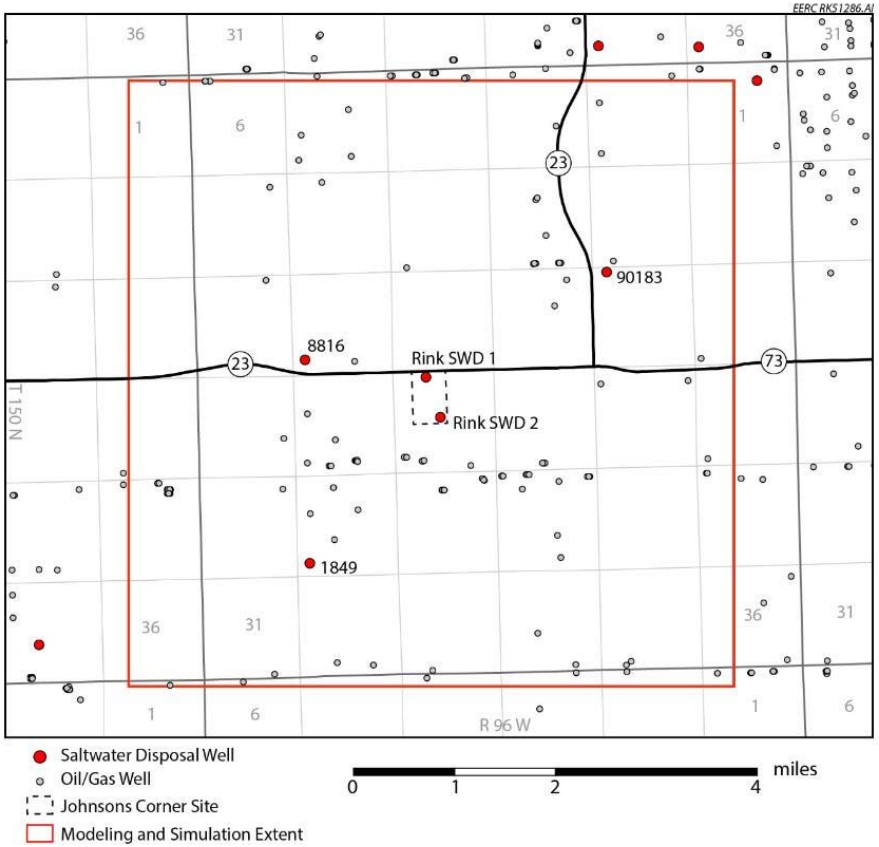


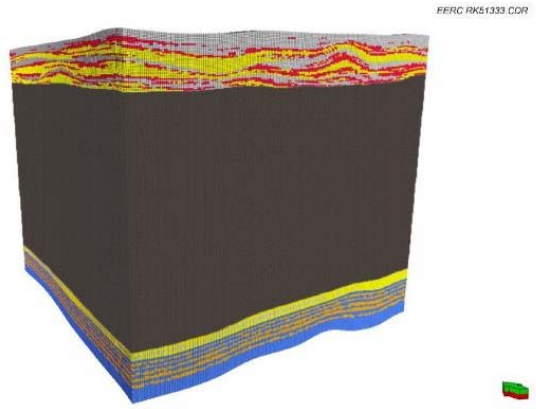
THE DESIGN (BALANCE)

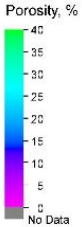


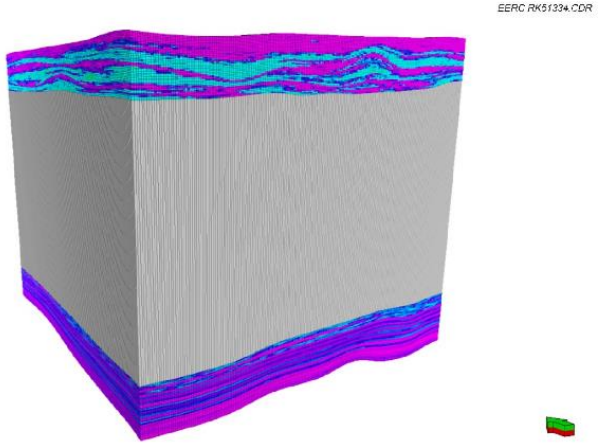


GEOMODELING

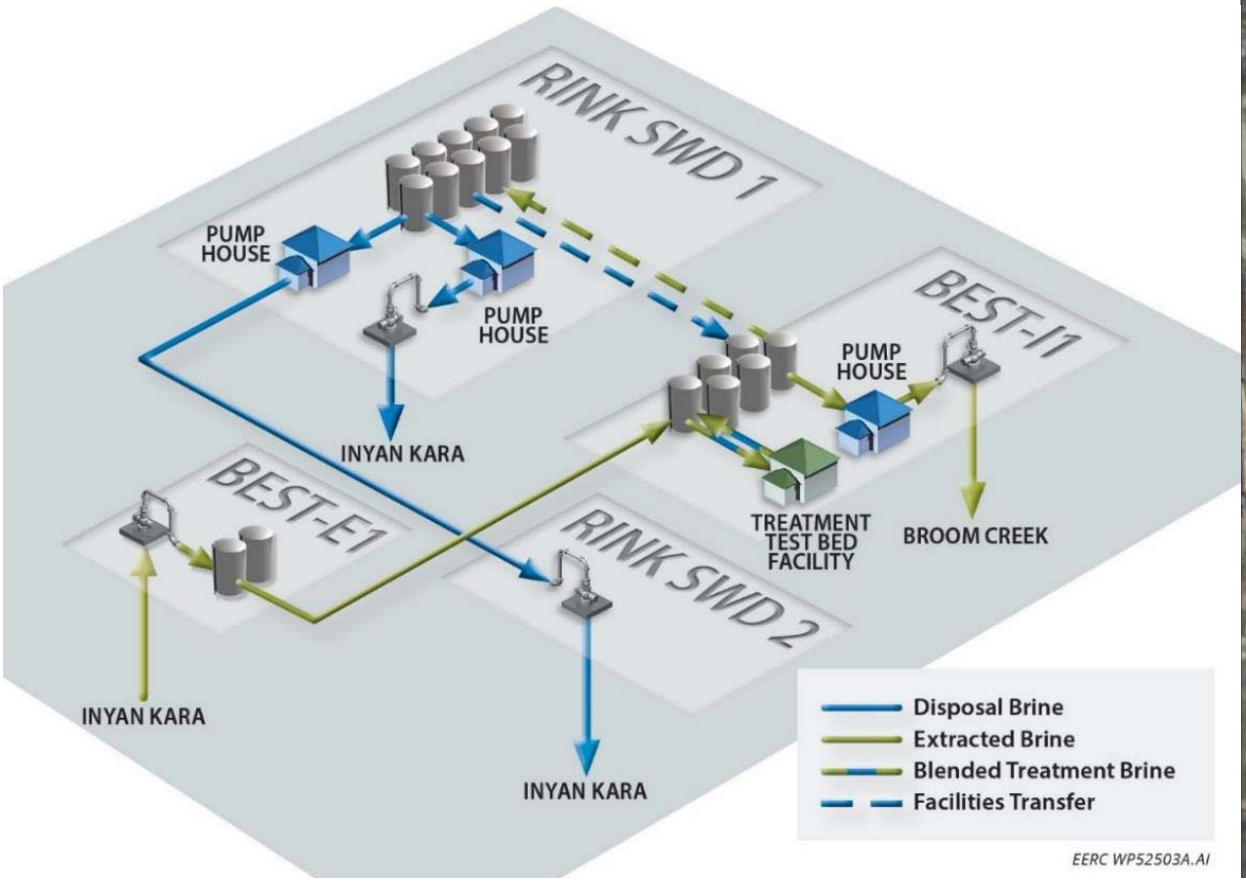


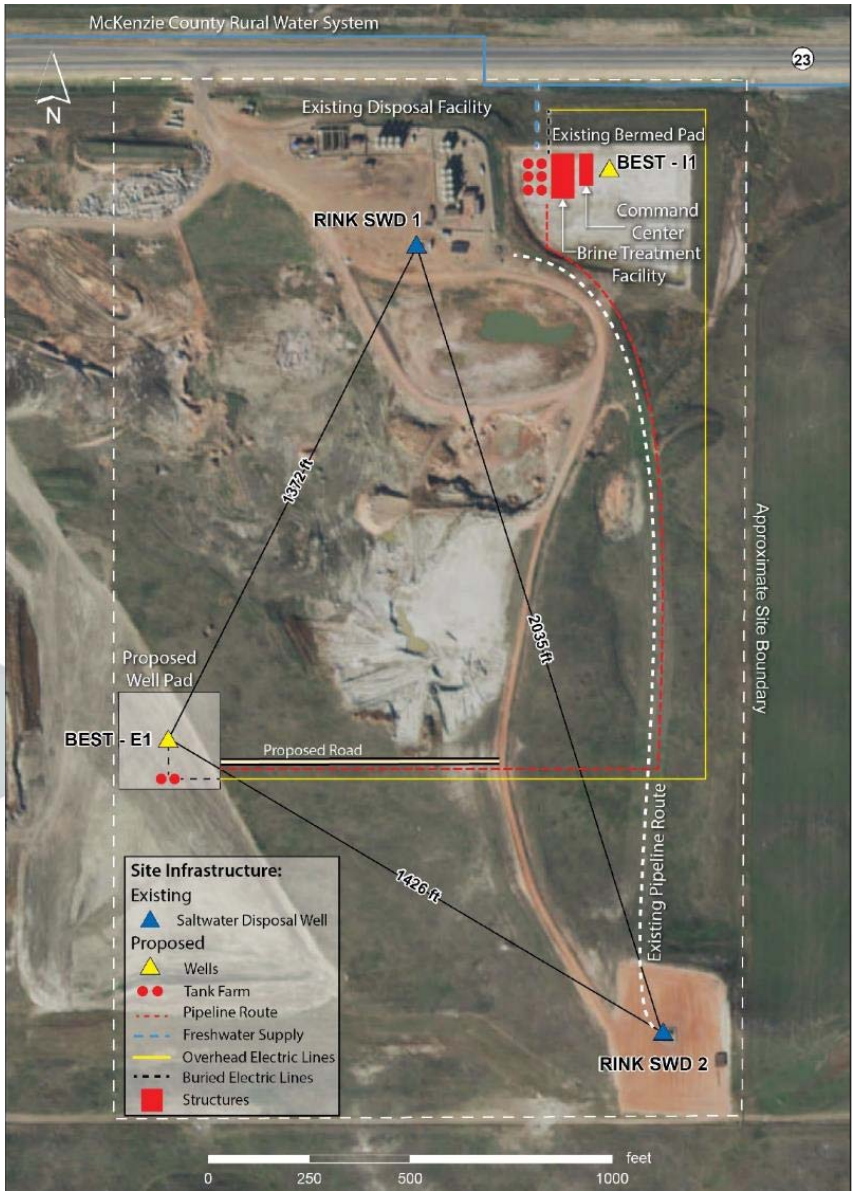




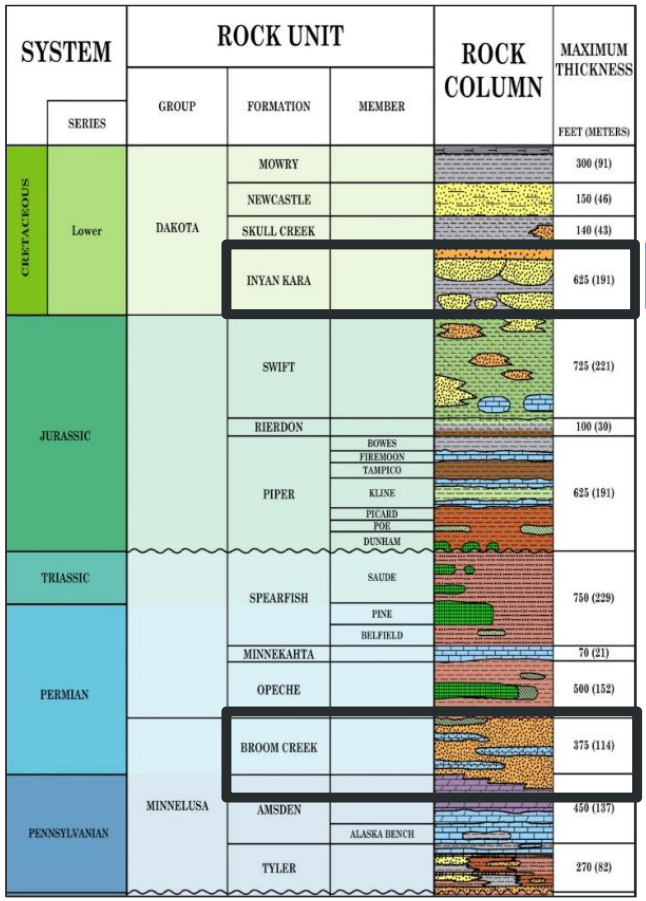


INFRASTRUCTURE





WELL COMPLETIONS

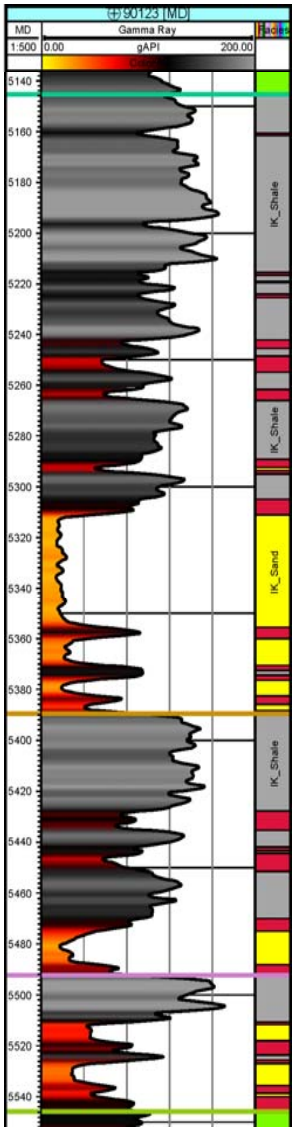


Estimated Perforated Intervals

BEST-E1

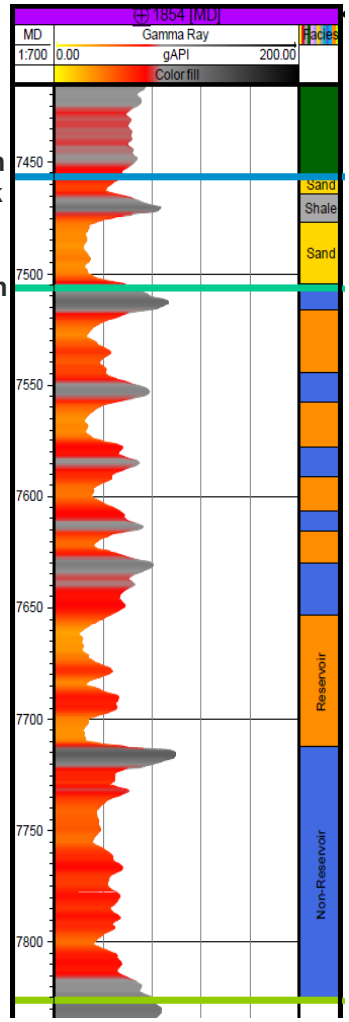
BEST-I1

Inyan Kara



Extraction Well (BEST E-1)

Swift



Broom Creek

Amsden

Injection Well (BEST I-1)

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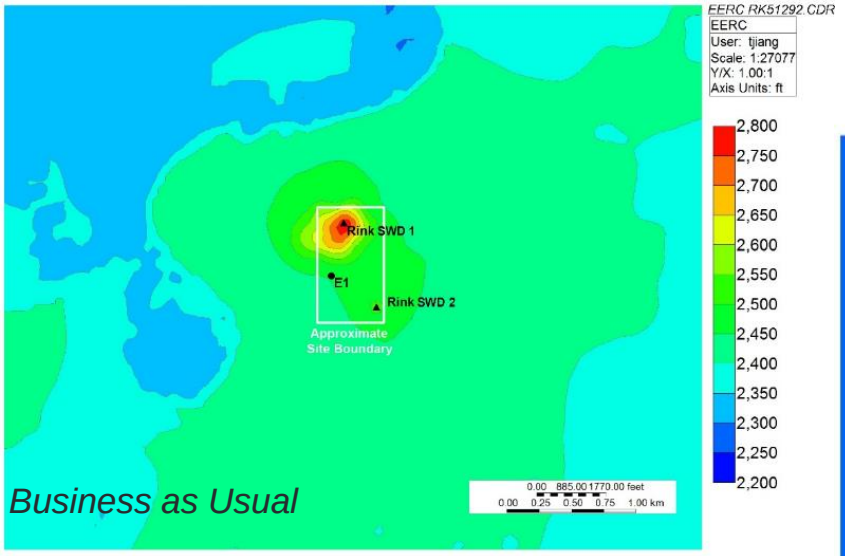
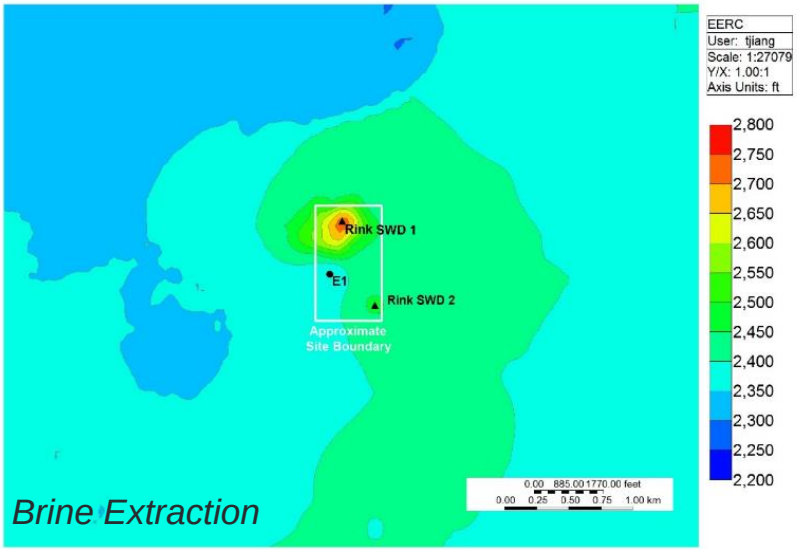
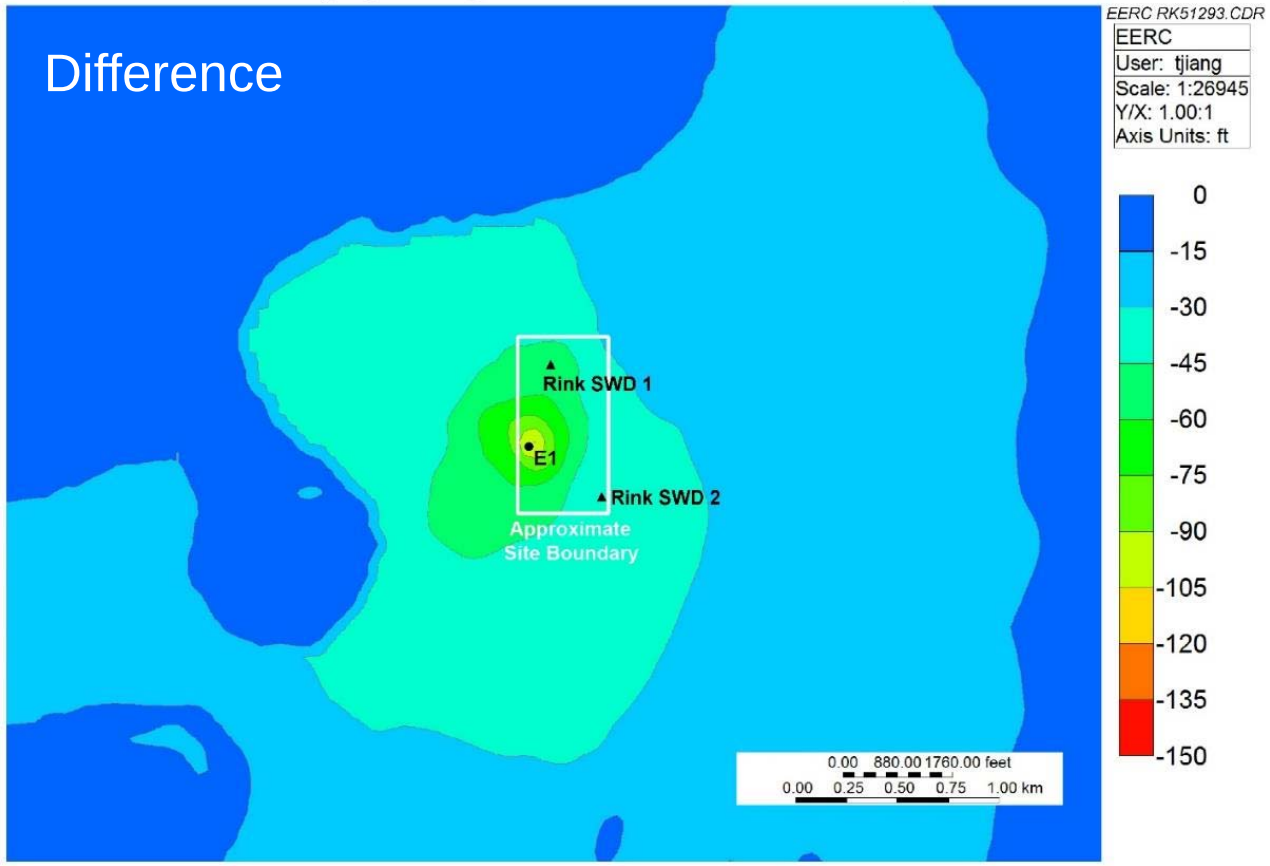
Pressure (psi) Plume at 2020 (no brine extraction) K Layer: 21



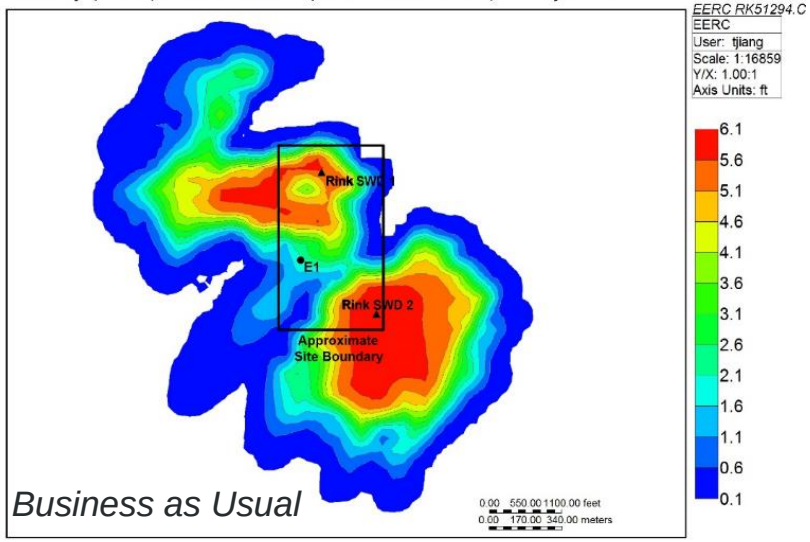
Pressure (psi) Plume at 2020 (with brine extraction) K Layer: 21



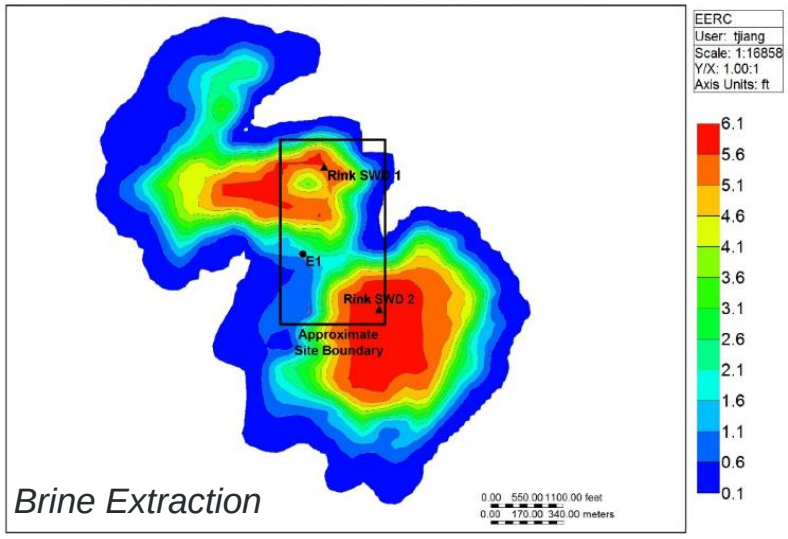
Pressure (psi) Change from Brine Extraction K Layer: 21



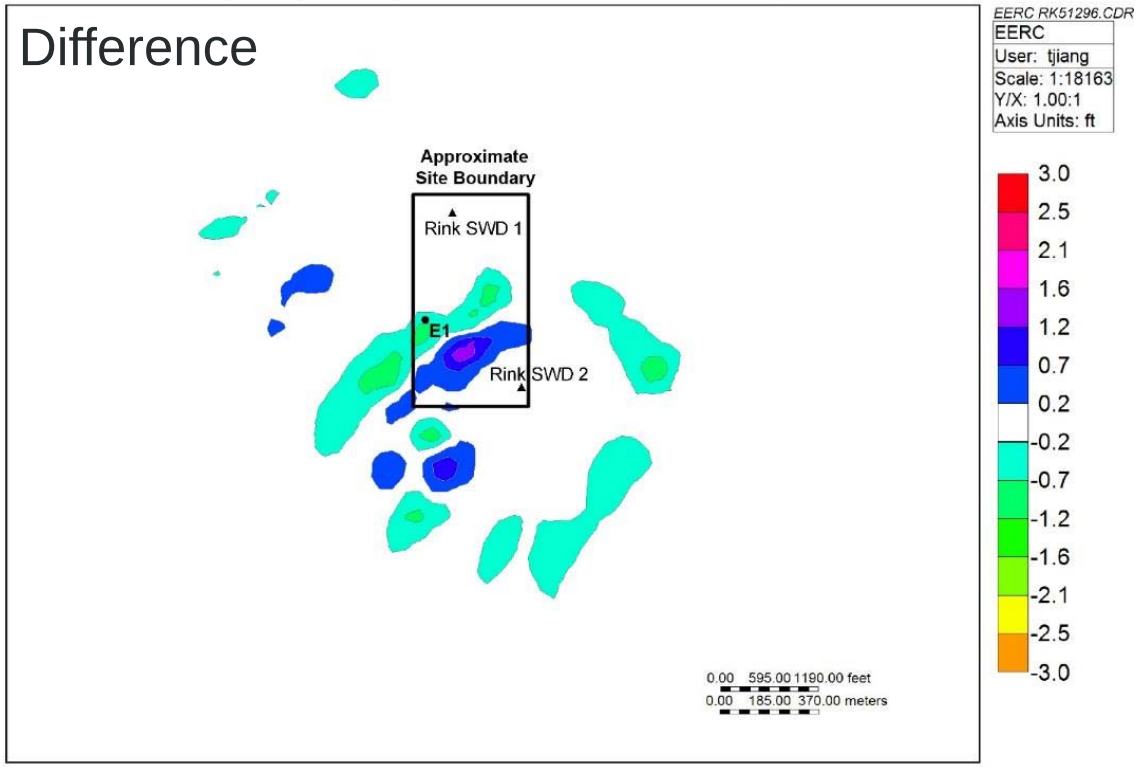
Salinity (molar) Plume at 2020 (no brine extraction) K Layer: 21



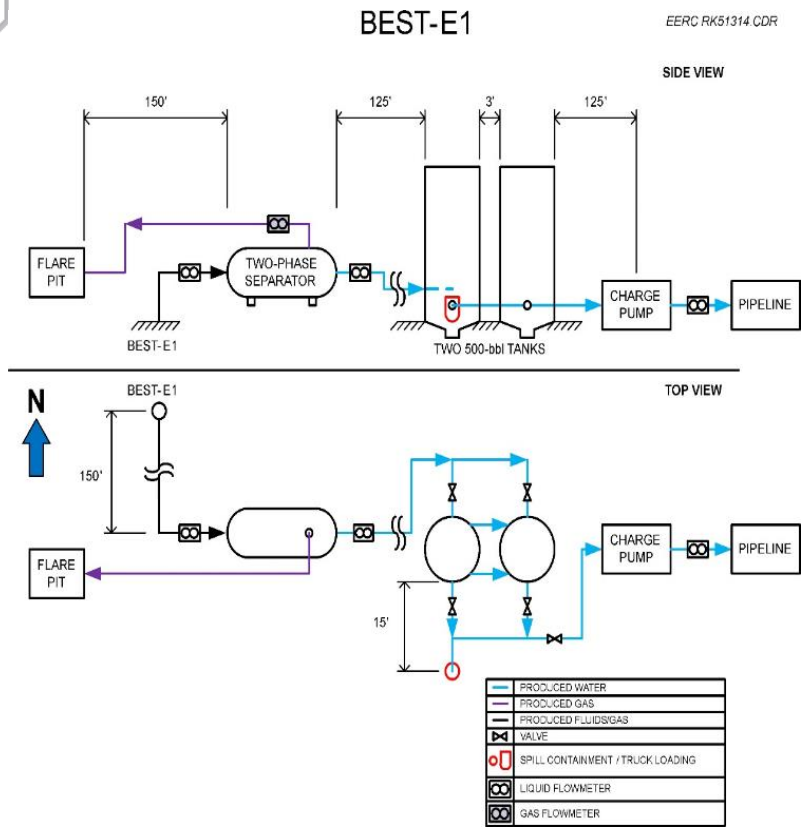
Salinity (molar) Plume after Brine Extraction K Layer: 21

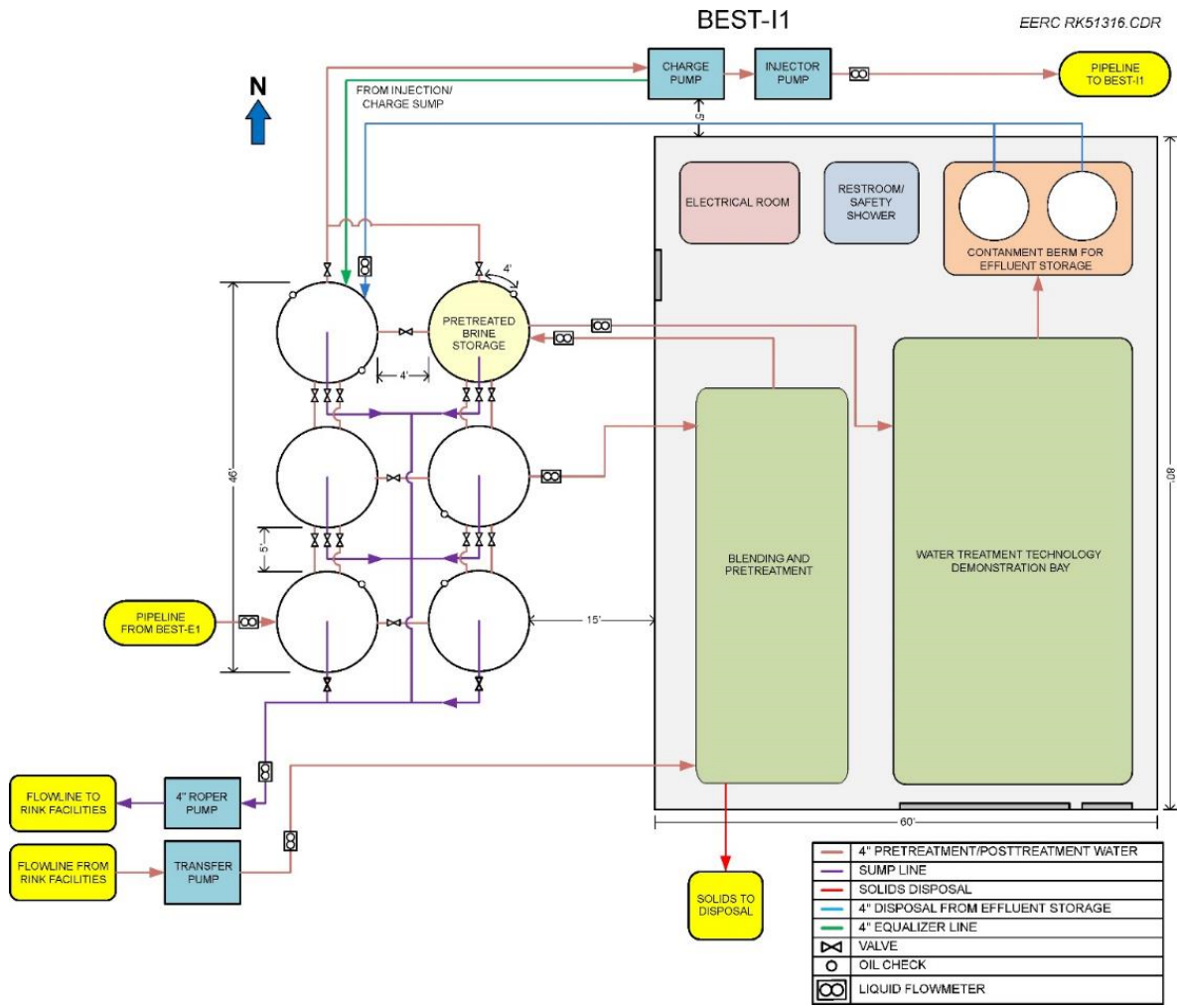


Salinity (molar) Change from Brine Extraction K Layer: 21



BRINE HANDLING

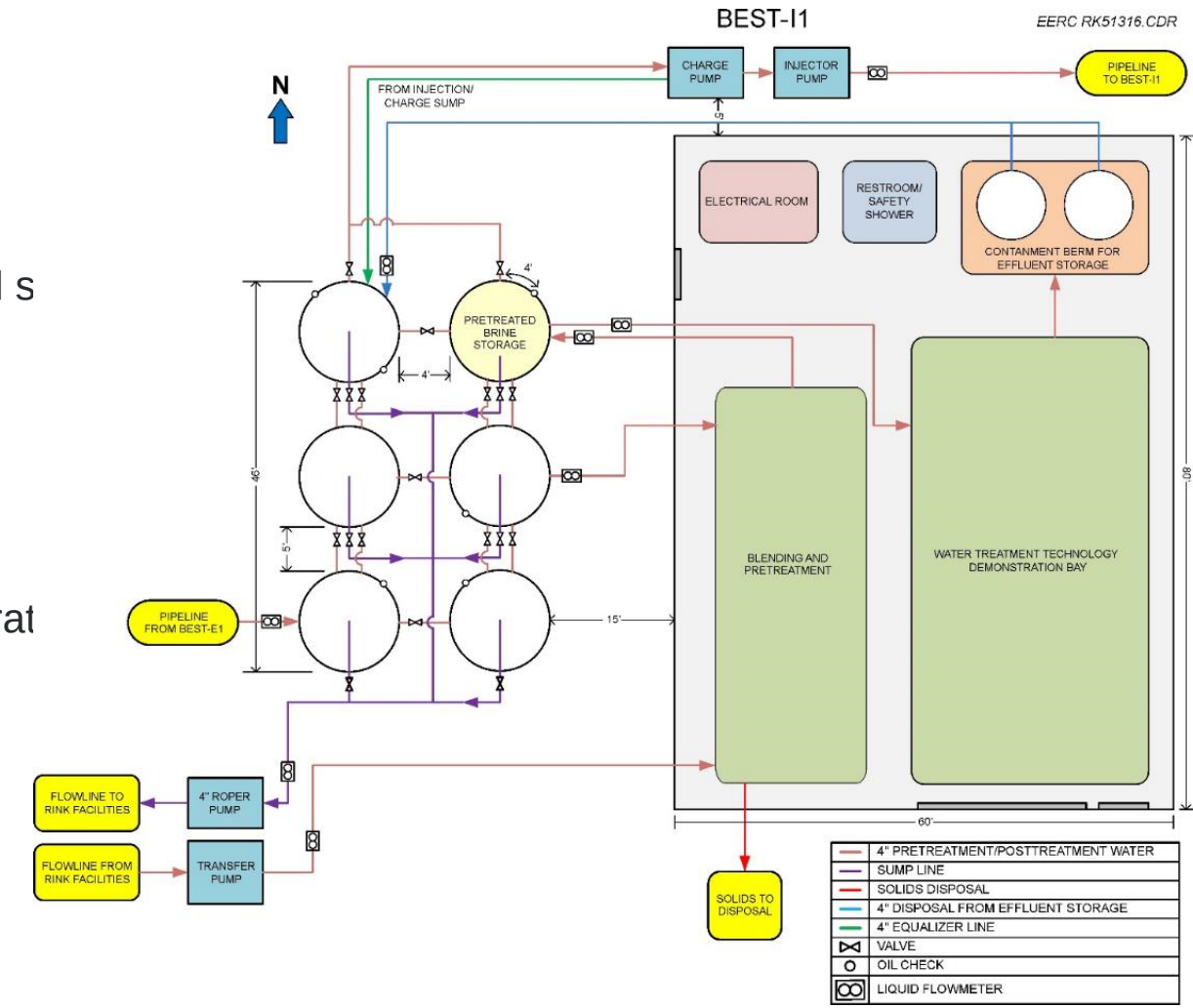




BRINE TREATMENT TEST BED

- Environmentally enclosed facility
  - 24/7, 365 operational capable
- Tailored brine compositions
  - ~5000–300,000 mg/L total dissolved s (TDS)
- Tailored rates
  - 5–25 gpm
- 30–60-day extended-duration tests
- Pretreatment provided
- Monitoring
  - Energy, flow rates, pressure, temperat chemicals, etc.
- Waste management

<u>Multiple technology demonstrations</u>



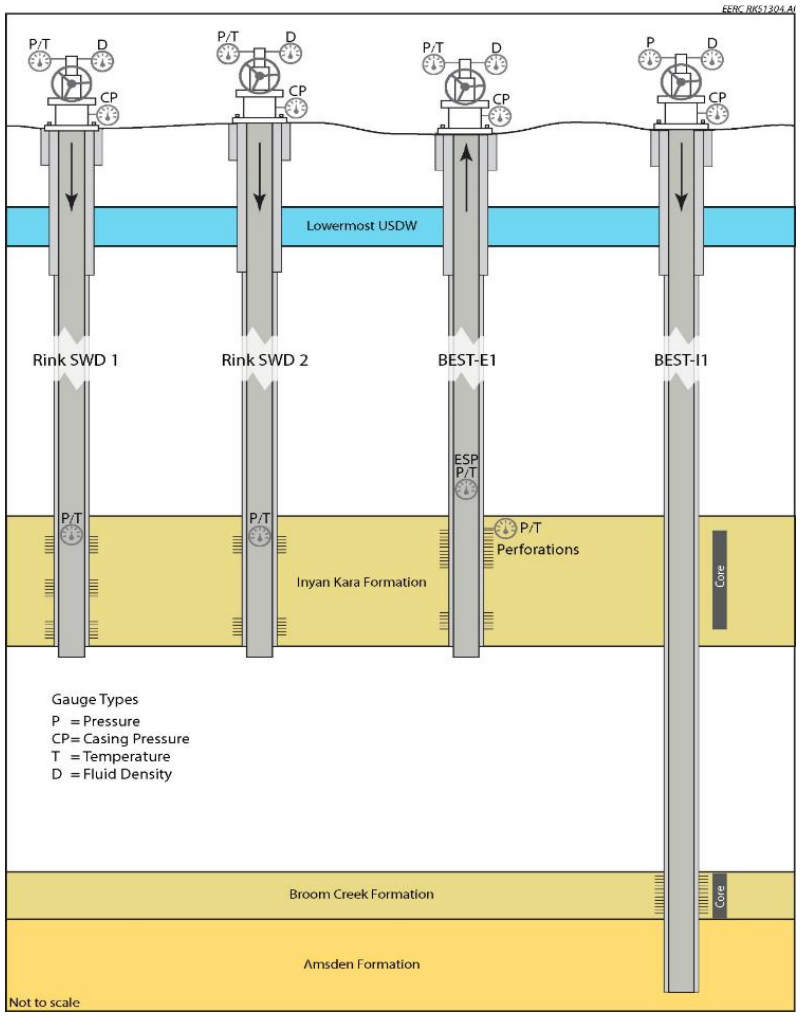
MVA PROGRAM

Reservoir Surveillance

- Well evaluation
  - Logging, coring, testing
- Borehole to surface electromagnetic (EM) survey
- Active reservoir surveillance
  - Pressure, temperature, flow rates, fluid density
- Tracer survey
- Fluid sampling

Safety and Performance

- Tank and pipeline monitoring
- Flow and density meters
- Power and chemicals
- Pipeline monitoring
- High-level/low-level shutdown
- Remote sensing



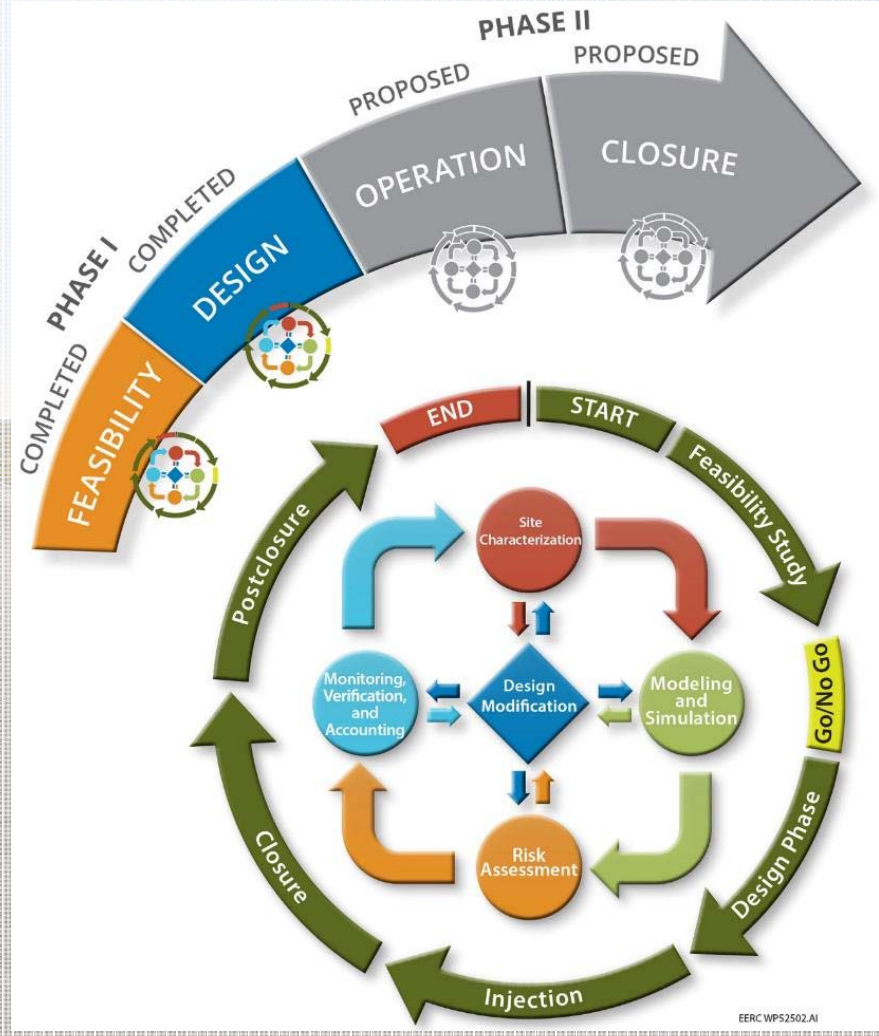
RISK ASSESSMENT

- 58 potential risks
  - Technical
  - Resource availability
  - Health, safety, and environment (HSE)
  - Site access
  - Management
- Mitigation measures built into design and implementation plan

Ready for Implementation

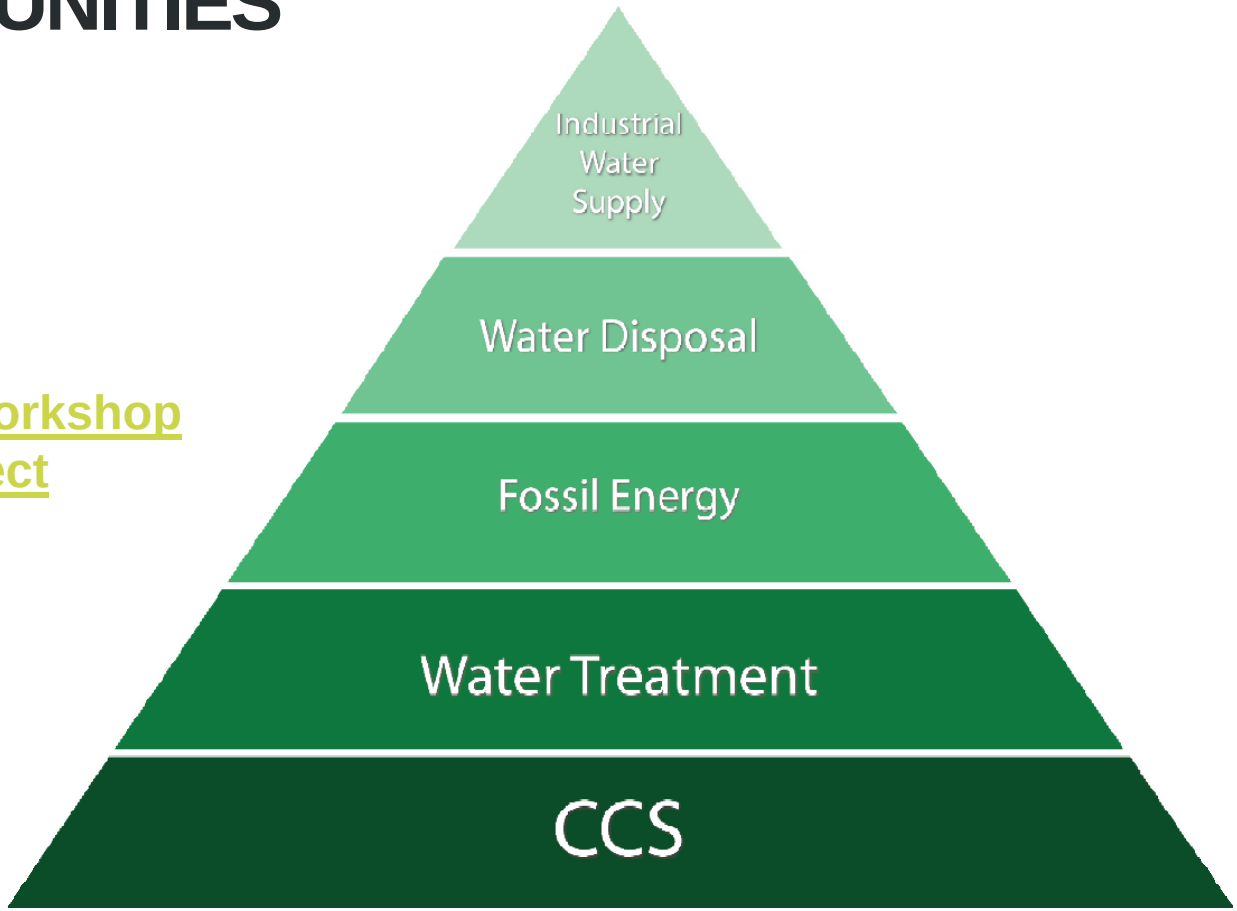
- ☑ Strong partnerships/extensive experience
- ☑ Site secured
- ☑ Established injectivity/injection history
- ☑ Existing pressure plume/confidence in ability to influence through brine extraction
- ☑ Operational flexibility (four-well design)
- ☑ Brine treatment test bed
- ☑ Commercial-scale test
- ☑ MVA plan (performance and safety)
- ☑ Permitting plan (several in place)
- ☑ Costing
- ☑ Risk assessment

Developing fundamental data and demonstrating the steps necessary to design and implement ARM for large-scale CCS projects.



SYNERGY OPPORTUNITIES

Joint Knowledge Sharing Workshop with Sister BEST Project



SUMMARY

- Benefit future CO_2 saline storage projects through development of engineering strategies which:
  - Reduce stress on sealing formations
  - Mechanism for controlling pressure and injected fluid plume
  - Reduce AOR
- Provide evidence for increased storage capacity and improved storage efficiency
- Demonstrate a means of managing risk which will contribute to increased public and regulatory acceptance
- Best Practices

CONTACT INFORMATION

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THANK YOU!

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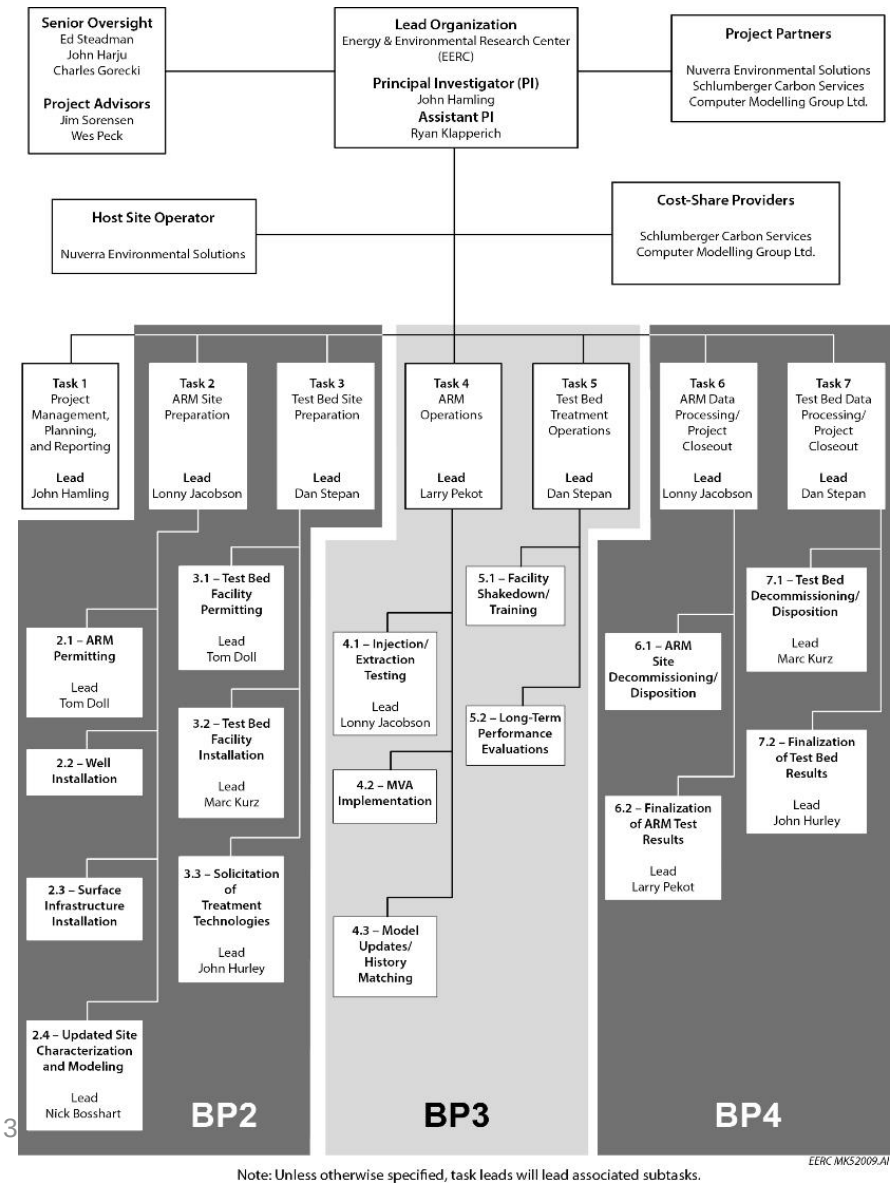
PRESENTATION OUTLINE

- Introduction
- Goals and Benefits
- Project Overview & Implementation
- Summary

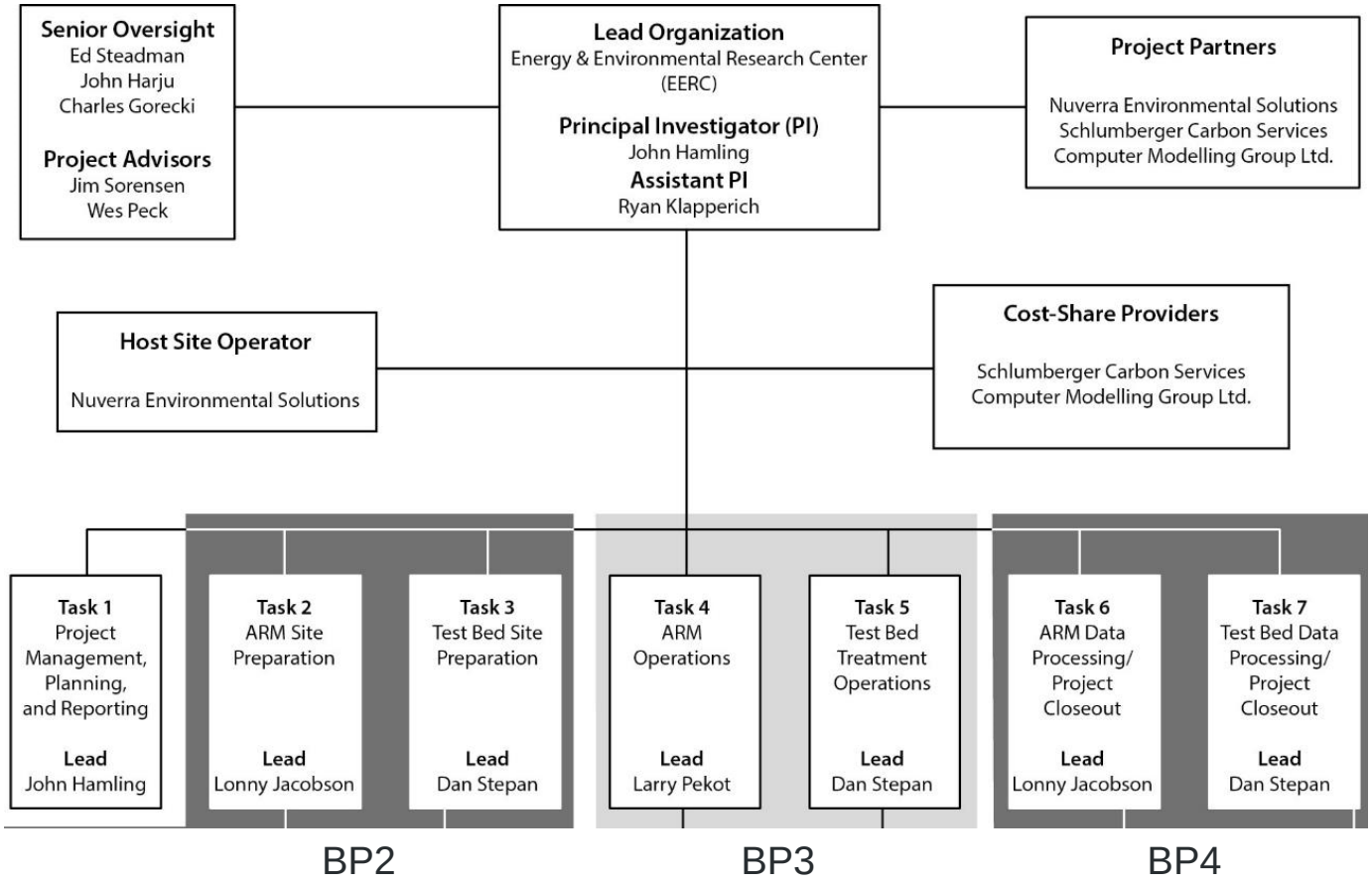
APPENDIX

ORGANIZATION CHART

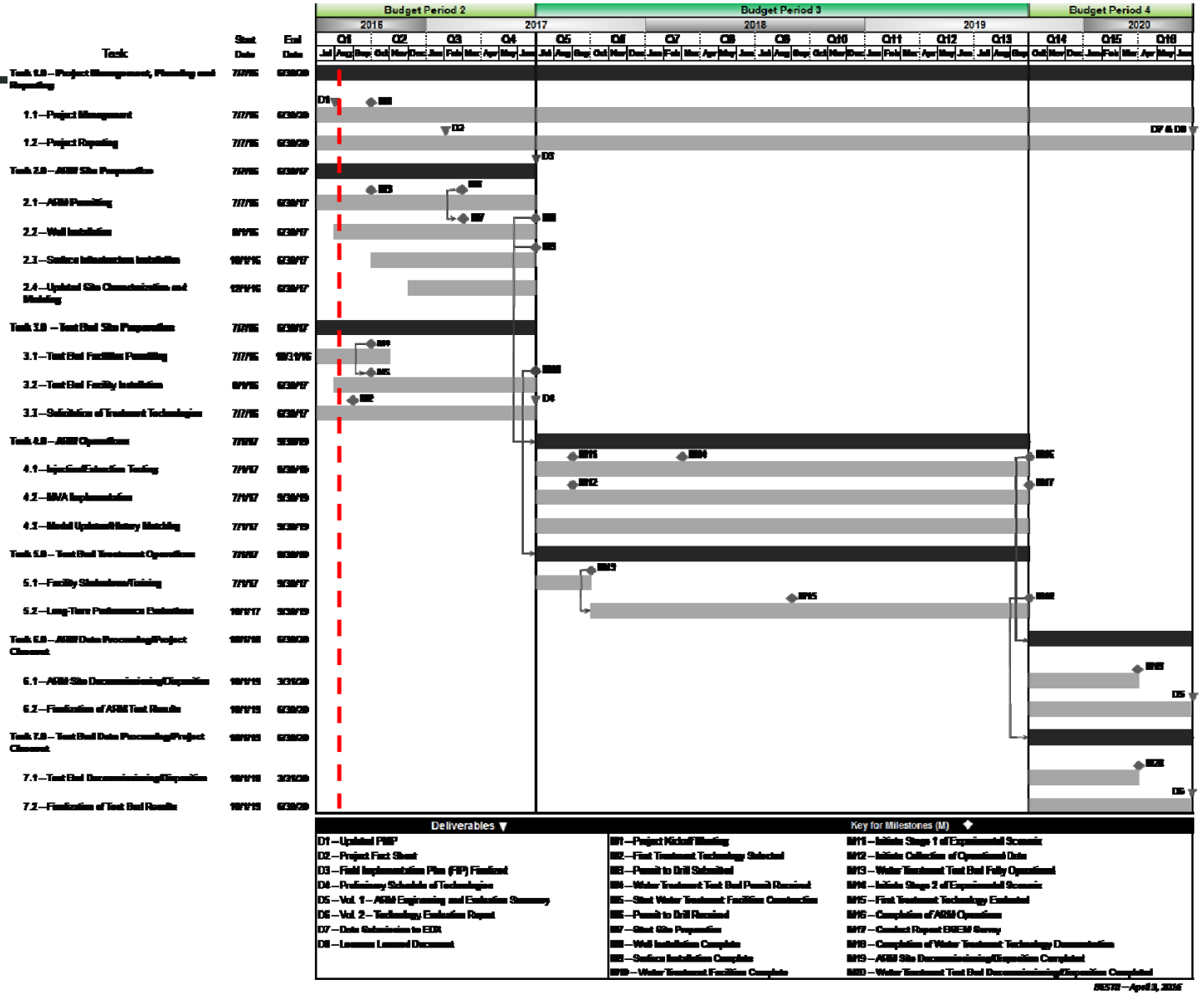


Note: Unless otherwise specified, task leads will lead associated subtasks.

ORGANIZATION CHART SIMPLIFIED



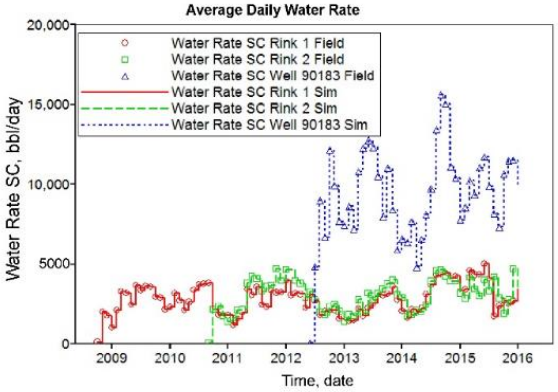
GANTT CHART

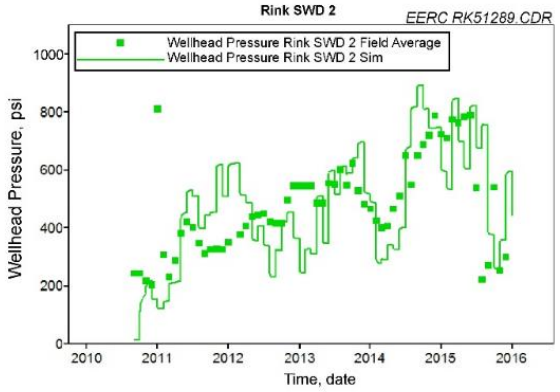

Budget Period 2
Budget Period 3
Budget Period 4
2016
2017
2018
2019
2020
Task
Start Date
End Date
Deliverables
D1 – Updated PMP
D2 – Project Fact Sheet
D3 – Field Implementation Plan (FIP) Finalized
D4 – Preliminary Schedule of Technologies
D5 – Vol. 1 – ARM Engineering and Evaluation Summary
D6 – Vol. 2 – Technology Evaluation Report
D7 – Data Submission to EDX
D8 – Lessons Learned Document
Key for Milestones (M)
M1 – Project Kickoff Meeting
M2 – First Treatment Technology Selected
M3 – Permit to Drill Submitted
M4 – Water Treatment Test Bed Permit Received
M5 – Shot Water Treatment Facilities Construction
M6 – Permit to Drill Received
M7 – Shot Site Preparation
M8 – Well Installation Complete
M9 – Surface Installation Complete
M10 – Water Treatment Facilities Complete
M11 – Initiate Stage 1 of Experimental Scenario
M12 – Initiate Collection of Operational Data
M13 – Water Treatment Test Bed Fully Operational
M14 – Initiate Stage 2 of Experimental Scenario
M15 – First Treatment Technology Evaluated
M16 – Completion of ARM Operations
M17 – Conduct Report EIS/EM Survey
M18 – Completion of Water Treatment Technology Demonstration
M19 – ARM Site Decommissioning/Disposition Completed
M20 – Water Treatment Test Bed Decommissioning/Disposition Completed
BEGIN – April 3, 2015

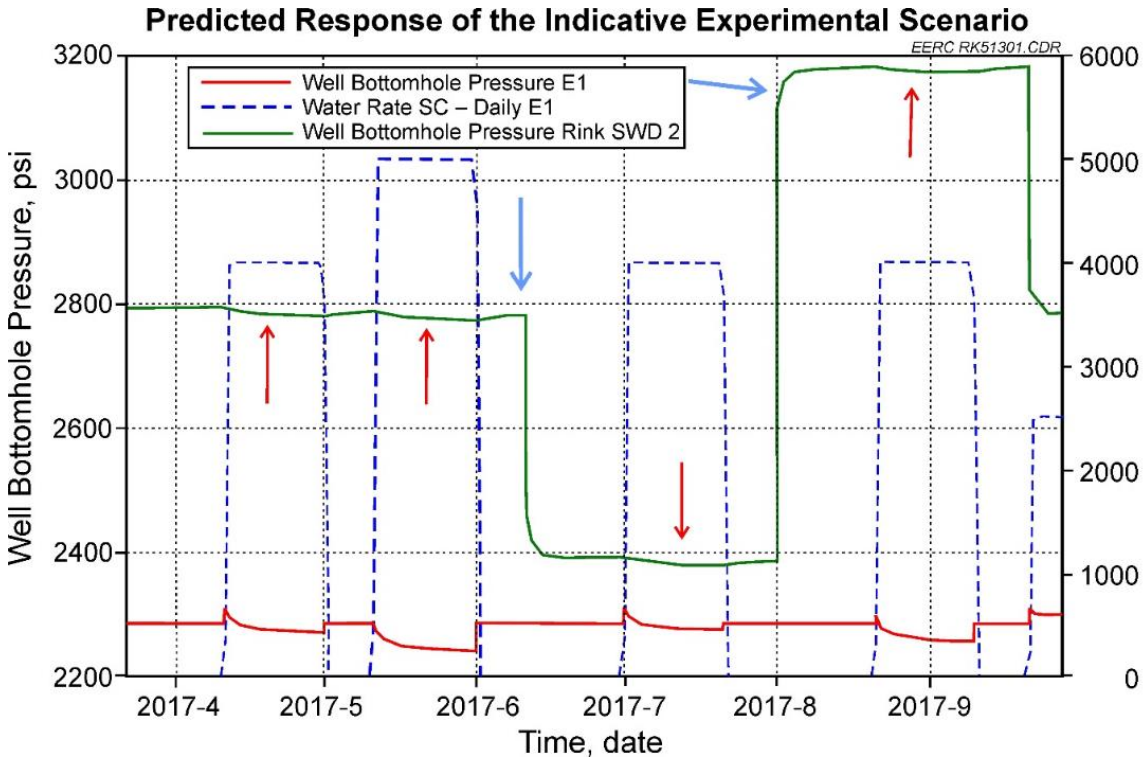
PRODUCTS

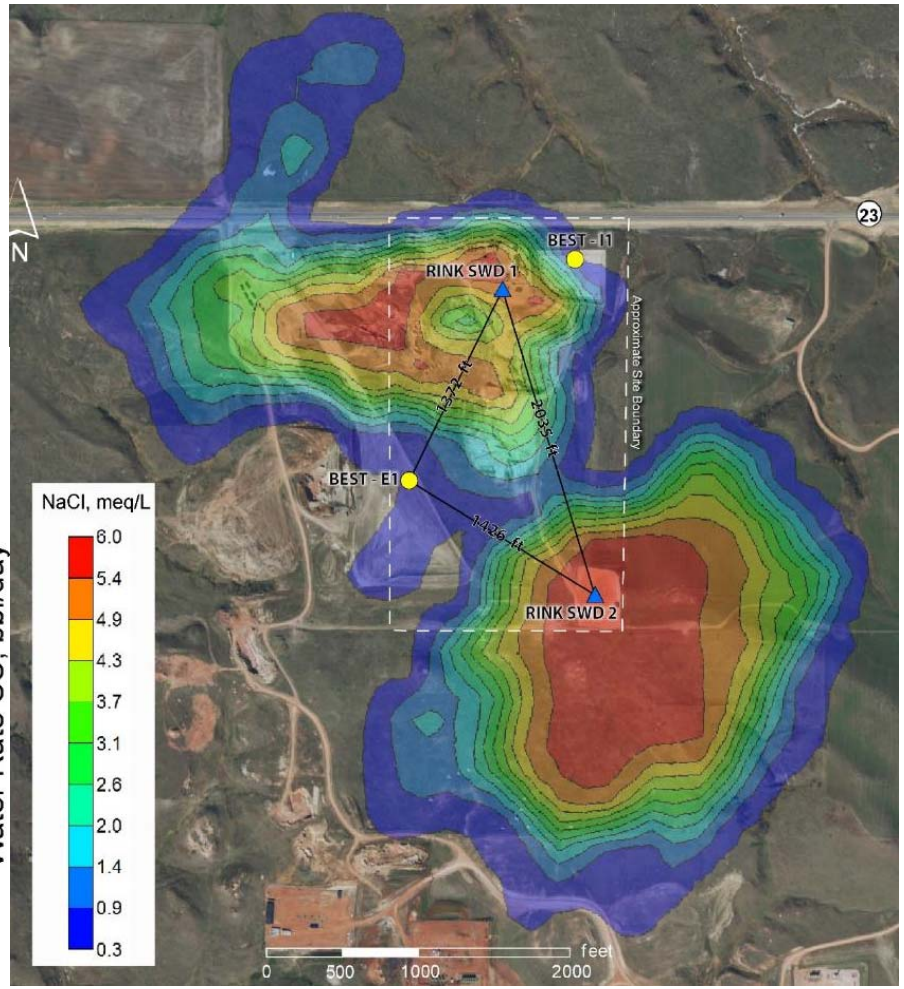
- Data and project-related information were uploaded to DOE's Energy Data eXchange (EDX) site. The submission of these files corresponds to D3. Uploaded content included the following:
  - Carbon Capture, Utilization and Storage (CCUS) Conference abstract and presentation
  - Phase I topical report
  - Porosity and permeability crossplot data for the Broom Creek, Amsden, and Inyan Kara Formations
  - Anticipated Phase II well schematics for the injection and extraction wells
  - Image of the Williston Basin stratigraphy and hydrogeologic systems
  - Image of the Williston Basin formational cross section

DYNAMIC SIMULATION









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