Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

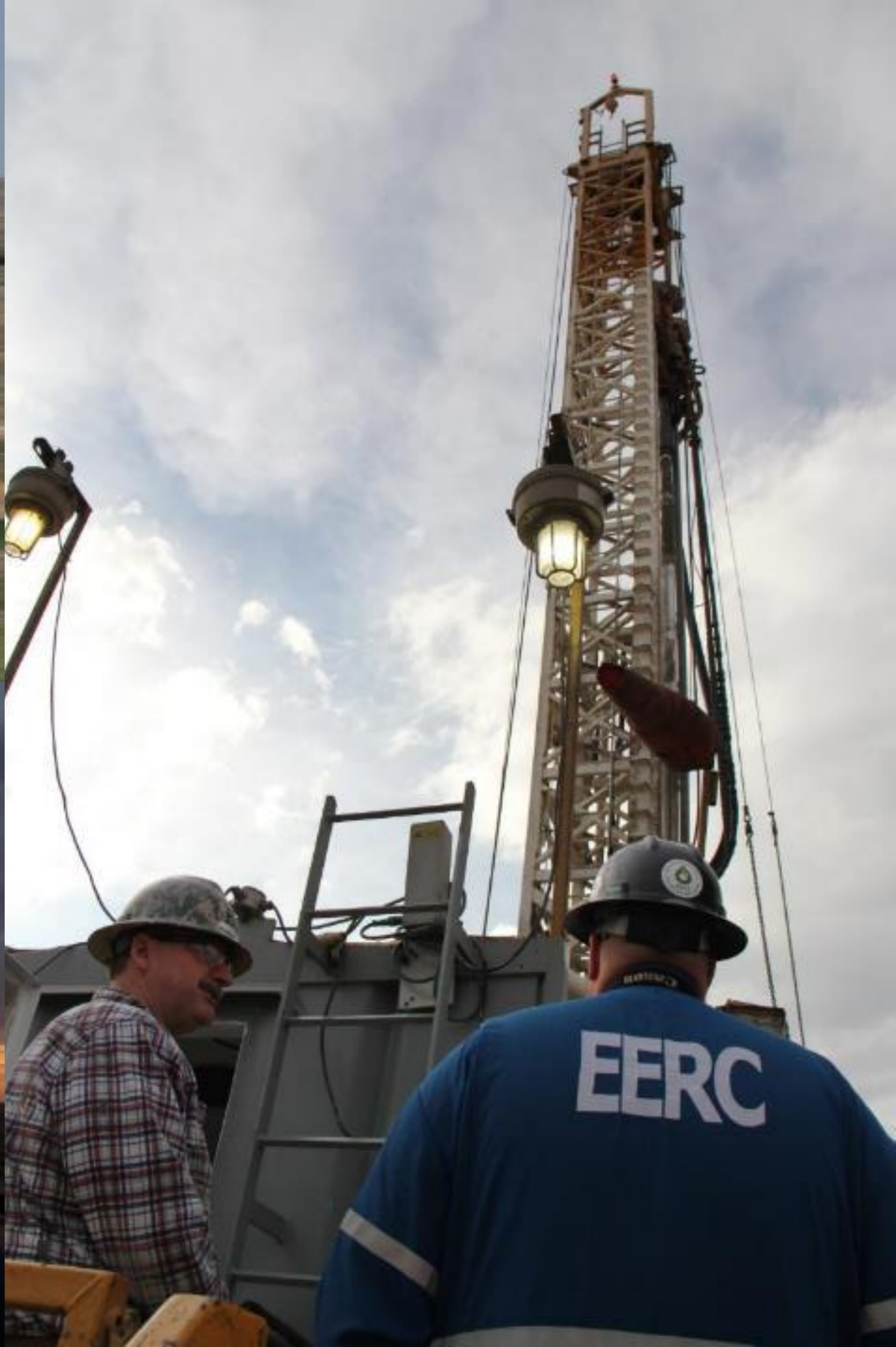
Developing and Validating Pressure Management and Plume Control Strategies in the Williston Basin Through a Brine Extraction and Storage Test (BEST) DE-FE0026160

U.S. Department of Energy National Energy Technology Laboratory
Carbon Storage Virtual Project Review Meeting
September 8, 2020, 2:50 p.m. EDT

John Hamling
Assistant Director, Integrated Projects

NORTH DAKOTA

BRINE EXTRACTION AND STORAGE TEST



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PROGRAM OVERVIEW

Objectives:

- Validate efficacy of brine extraction as a means of active reservoir management (ARM)
  - Applications that can enable the implementation and improve the operability of industrial carbon capture and storage (CCS) projects.
  - Manage injection performance and formation pressure.
  - Model, predict, monitor, and validate movement of fluids and pressure.
  - Provide data set to enable evaluation and design of ARM applications at compatible CCS sites.
  - Improve use and efficiency of geologic CO_2 storage resources

- Implement and operate a brine treatment technology development and test bed facility
  - Enable development of brine treatment technologies capable of treating high-total dissolved solids (TDS) brines associated with geologic CO_2 storage target.

Project Details:

- Phase II project: $21,323,604
  - DOE Share: $17,103,044
  - Cost Share: $4,220,560
    - ♦ Schlumberger: $2,800,000
    - ♦ CMG: $1,420,560

- Period of Performance:

  July 2016 – May 2022

PARTNERS

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

EERC

Nuverra Environmental Solutions

CMG

Schlumberger Carbon Services

MAJOR CONTRACTORS

AE2S CONSTRUCTION

AE2S INDUSTRIAL

HAM'S WELL SERVICE WESTHOPE, ND

This material is based on work supported by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) under Award No. DE-FE0026160.

GEOLOGIC CO_2 STORAGE

CONSIDERATIONS FOR INDUSTRIAL PROJECTS

- Buoyant fluid
- Large volumes = large footprint
- Access to pore space
  - Leasing, unitization/amalgamation, trespass
- Compliance with regulatory and incentive programs
- Assuring permanence for incentives or credits
  - Conformance and storage efficiency

Because of a host of technical, social, regulatory, environmental, and economic factors, brine disposal tends to be more accessible and generally quicker, easier, and less costly to implement compared to dedicated CO_2 storage.

Brine extraction can enable dedicated CO_2 storage and improve the geologic CO_2 storage potential of a site.

TWO COMPLEMENTARY COMPONENTS

Active Reservoir Management (ARM) Test

- Reduce stress on sealing formation
- Geosteer injected fluids
- Divert pressure from potential leakage pathways
- Reduce area of review (AOR)
- Improve injectivity, capacity, and storage efficiency
- Validate monitoring techniques and model performance

Brine Treatment Test Bed

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

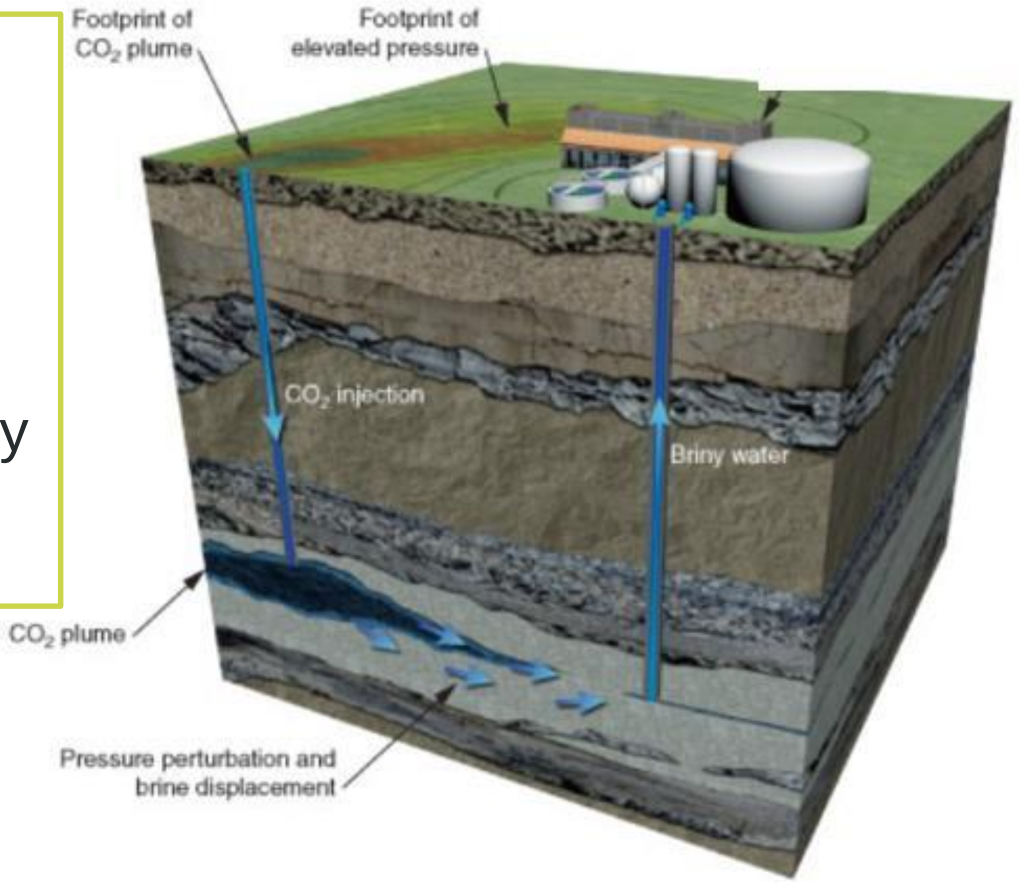
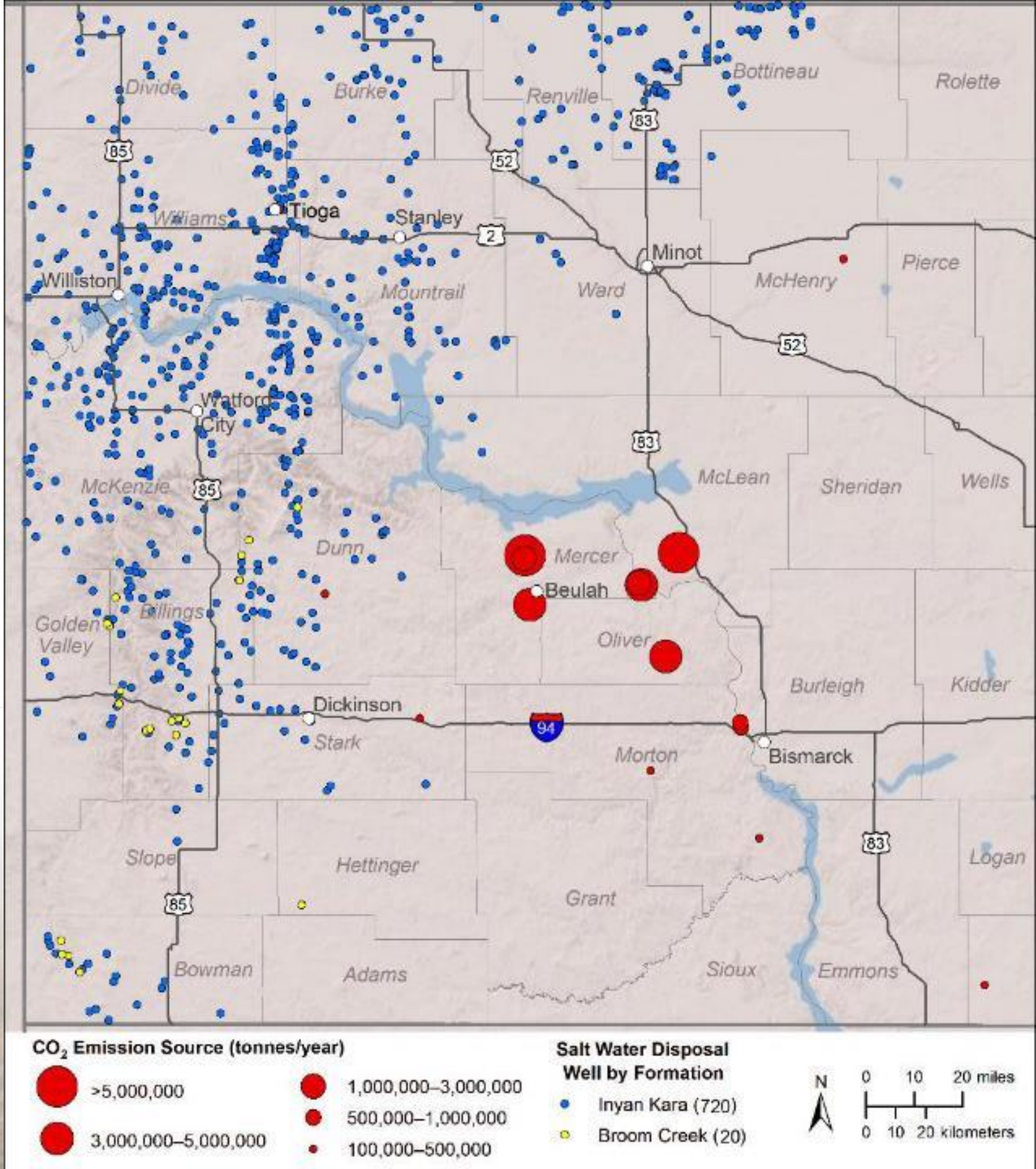


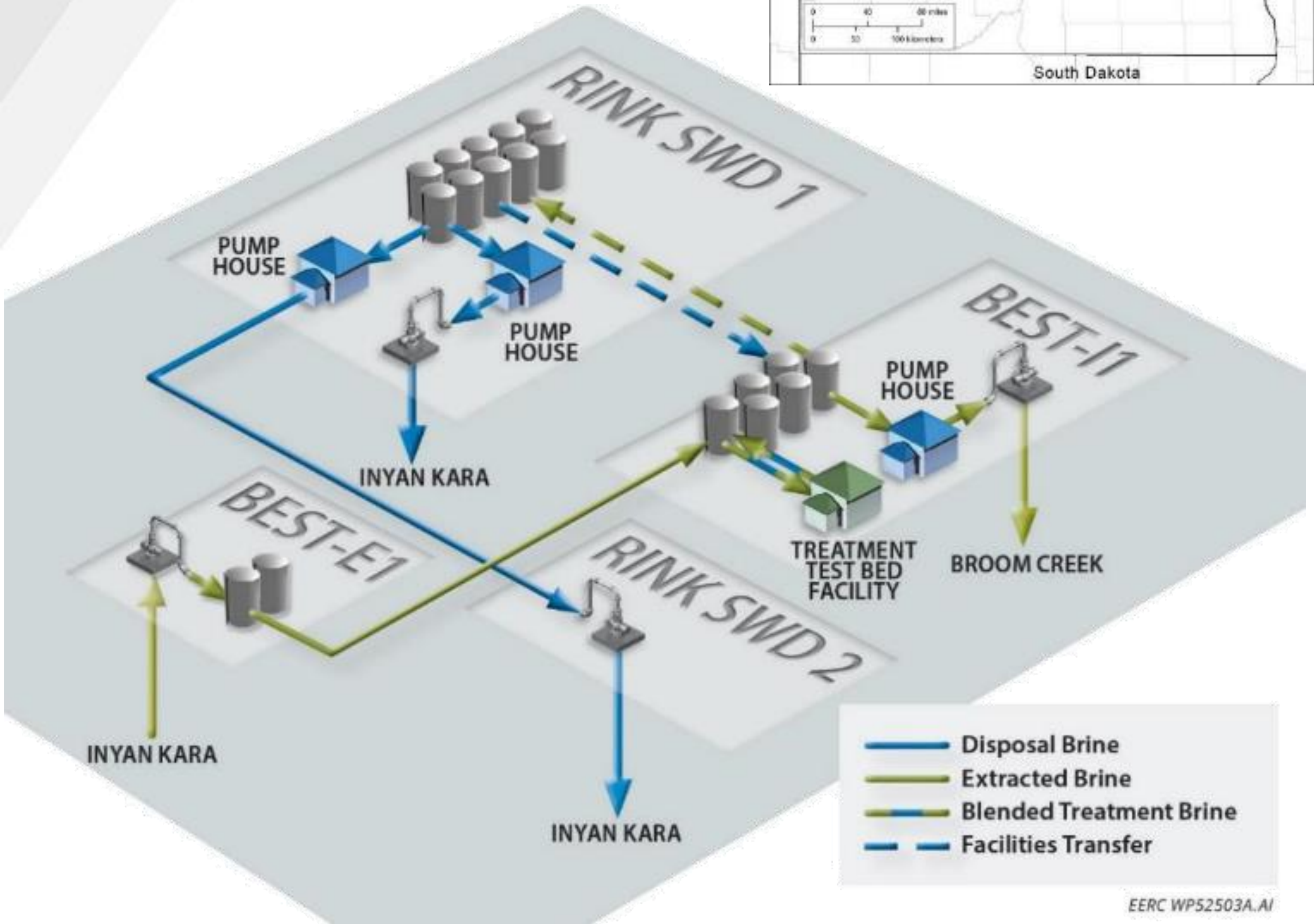
Illustration modified from Lawrence Livermore National Laboratory https://str.llnl.gov/Dec10/aines.html

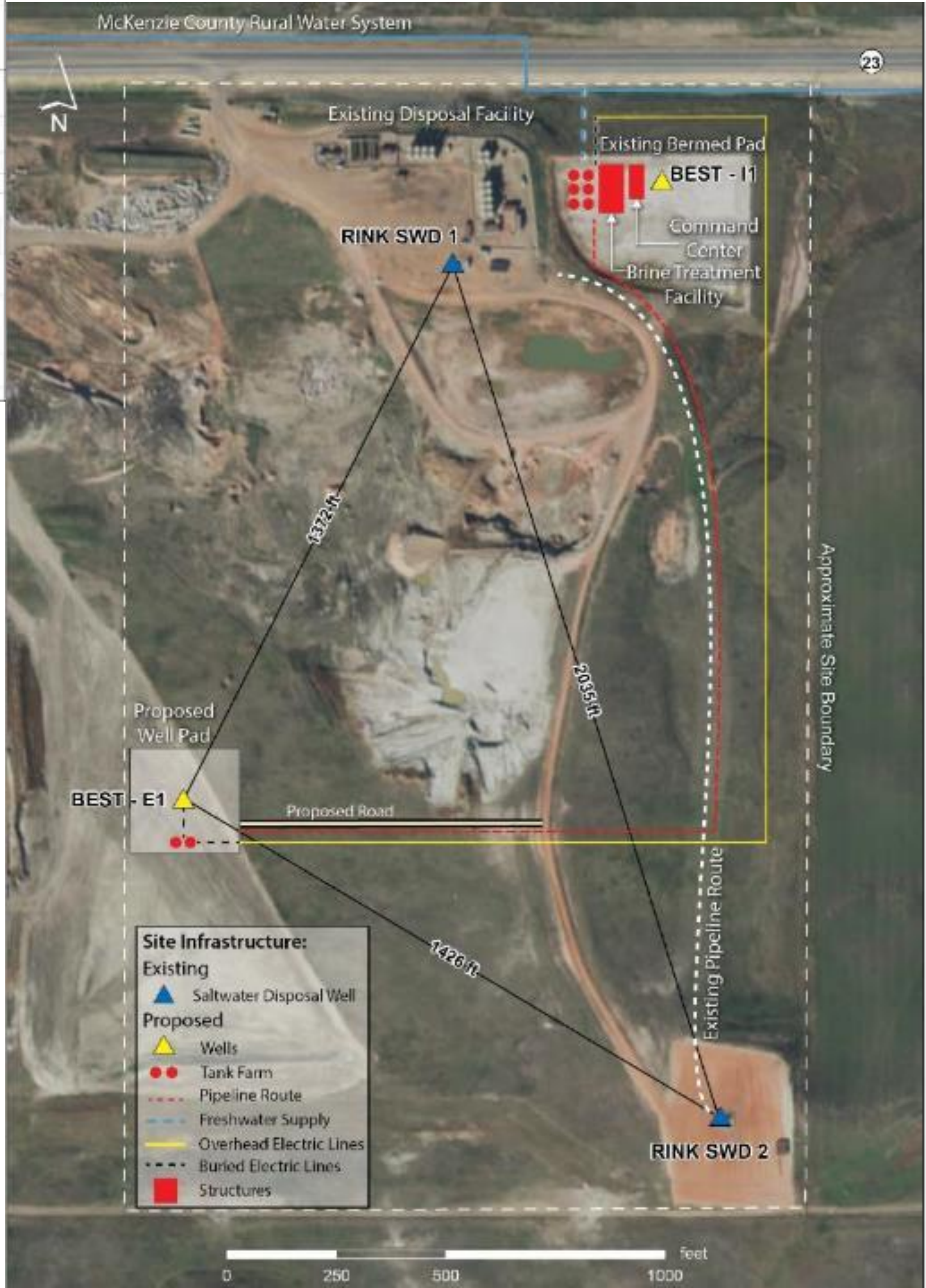
ACTIVE WATER DISPOSAL SITE AS A PROXY FOR DEDICATED CO_2 STORAGE



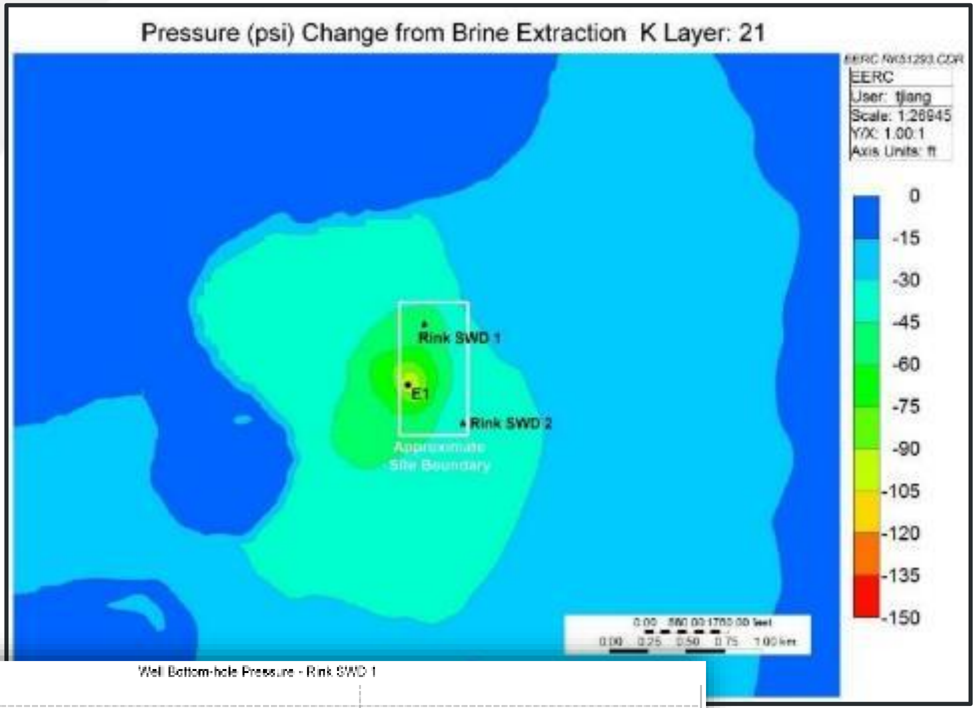
THE SITE

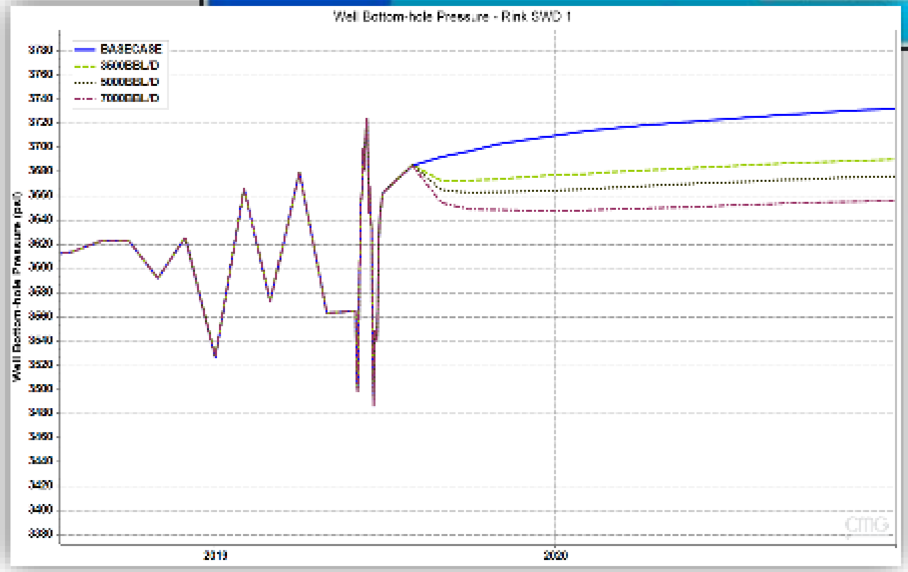

Saskatchewan
Manitoba
CANADA
UNITED STATES
Williston
Minot
BEST Site
North Dakota
Grand Forks
Montana
Minnesota
Bismarck
Dickinson
Fargo
South Dakota

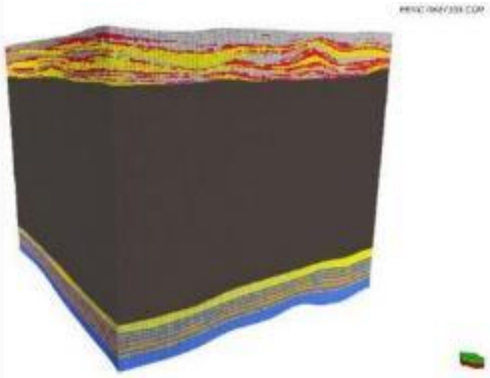

RINK SWD 1
PUMP HOUSE
PUMP HOUSE
BEST-I1
PUMP HOUSE
INYAN KARA
BEST-E1
TREATMENT TEST BED FACILITY
BROOM CREEK
RINK SWD 2
INYAN KARA
INYAN KARA
Disposal Brine
Extracted Brine
Blended Treatment Brine
Facilities Transfer
EERC WP52503A.AI

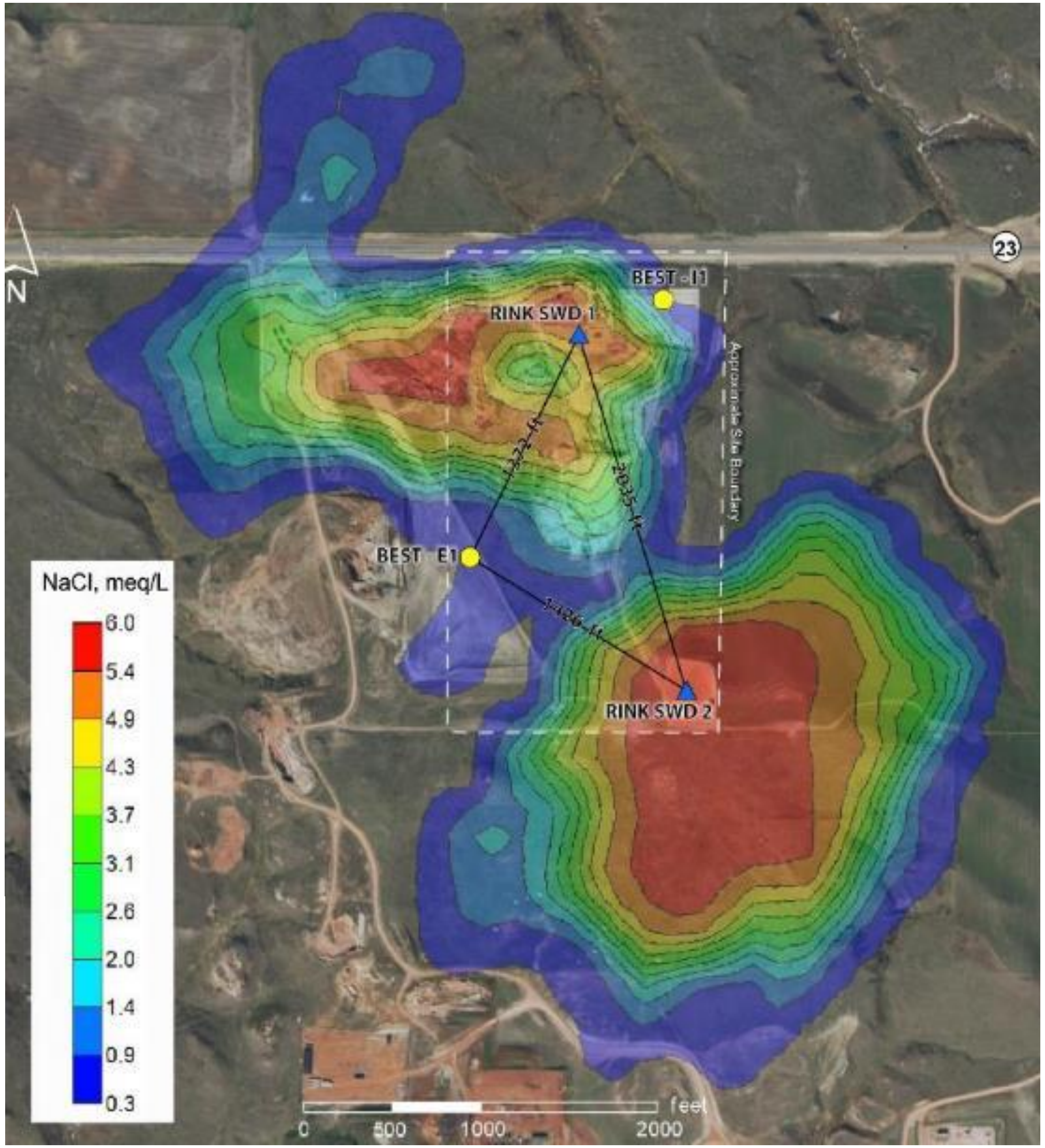

McKenzie County Rural Water System
23
N
Existing Disposal Facility
Existing Bermed Pad
BEST - I1
Command Center
Brine Treatment Facility
RINK SWD 1
1372 ft
2035 ft
Proposed Well Pad
BEST - E1
Proposed Road
Approximate Site Boundary
Existing Pipeline Route
1426 ft
RINK SWD 2
Site Infrastructure:
Existing
Saltwater Disposal Well
Proposed
Wells
Tank Farm
Pipeline Route
Freshwater Supply
Overhead Electric Lines
Buried Electric Lines
Structures
feet
0
250
500
1000

THE DESIGN (BALANCE)









PROJECT SCHEDULE

2019

- Test bed operational **June 2019**
- ARM field implementation plan (FIP) initiated
- Identification and screening of technologies for testing at ND brine treatment test bed user facility
- First technology selected and tested

2020

- Select and schedule technologies for testing at ND brine treatment development and test bed facility
- Adapt and continue ARM FIP, data collection, and interpretation

2021

- ARM and test bed operations planned through **September 2021**
- Interpretation and applications for industrial geologic CO_2 storage projects.

North Dakota Brine Treatment Facility and ARM Test Operating Time Frame

SUCCESS CRITERIA

Validate efficacy of ARM applications to industrial CO_2 storage projects (though a field test).

Demonstrate the steps necessary to design and implement ARM for industrial CCS projects.

Enable development of water treatment technologies with application to treating high-TDS brines associated with geologic CO_2 storage targets.

CHALLENGES

Technological:

- High salinity brine (100,000 to >300,000 mg/L TDS).
- Potential for fluid interactions, scaling, corrosion, TENORM (technologically enhanced naturally occurring radioactive material), biogenic gas, solids handling and relative volume of concentrated effluent streams.
- Measurable ARM response

Logistical:

- Environmental conditions … **Winter!**
- Extracted water temperature.
- Variability and cyclicity of SWD.
- Offset wells.
- Leak monitoring and SCADA reliability.
- Pressurization of test formation (remove ESP).
- Technology access (BSEM survey).
- Waste handling

Economic:

- Geologic injection is cost-efficient and convenient.
- Freshwater is inexpensive and abundant.
- Limited demand for brine treatment (ahead of market).

LESSONS

Public/private partnership is key.

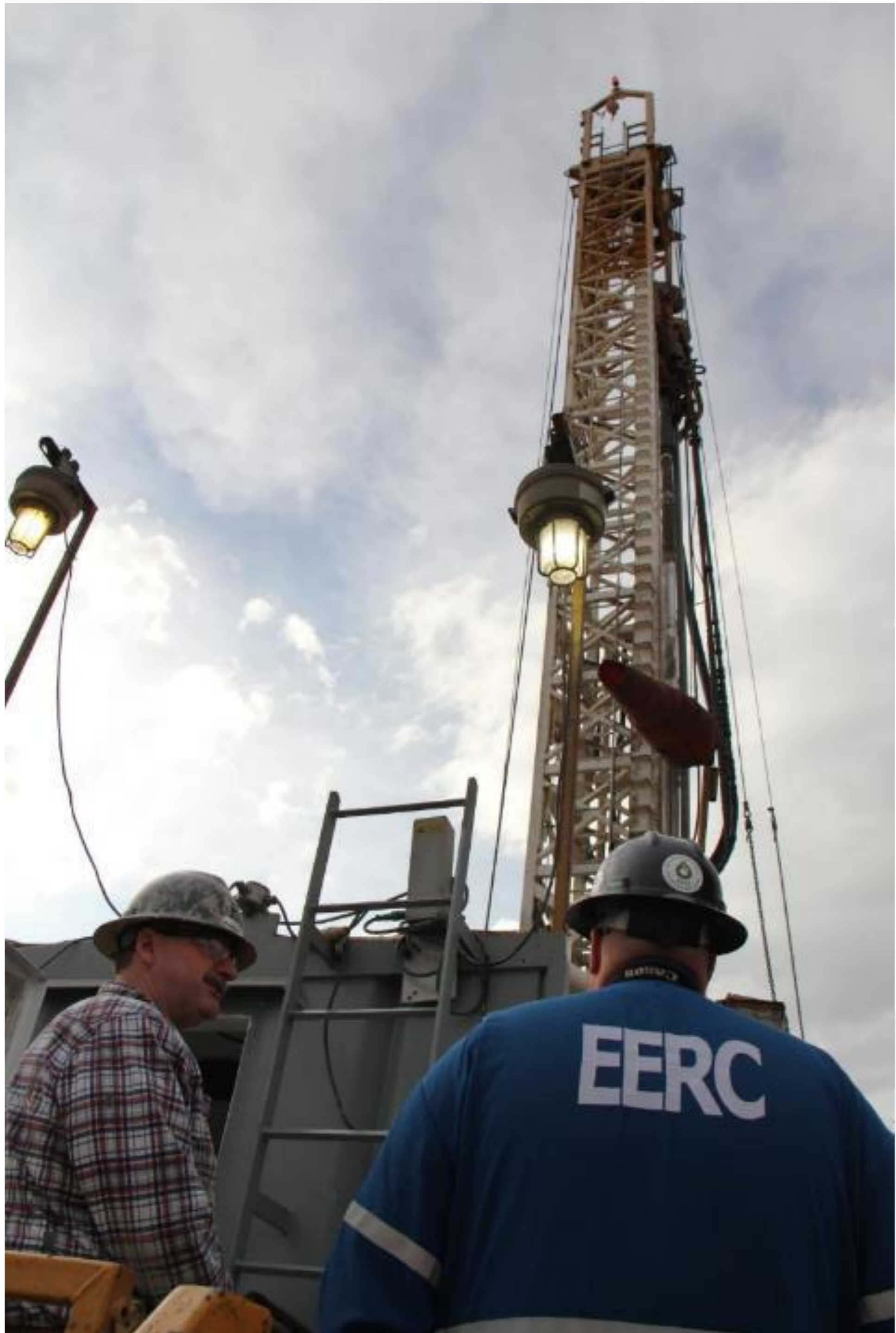
Adaptability.

Committed partners, leverage stakeholder experience.

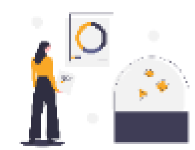
Maintain an up-to-date risk register, mitigate risks where prudent, incorporate flexibility where possible, robust designs and contingency plans, be adaptive as conditions change.

Large field tests have elevated risks and dynamic conditions.

Risk, cost, and objectives must be managed together.



MACHINE LEARNING METHODS



ASSUMPTION

- The geology is not stimulated.
- Brine extraction is easier than CO_2 injection.
- Brine extraction increases CO_2 injection capacity.

APPROACH

- Choose only the paired scenario where rink wells are on, the E1 well is either on or off.
- Build ML model to estimate rink well pressure when E1 is off, then predict rink well pressure when E1 is on.

Analysis Workflow

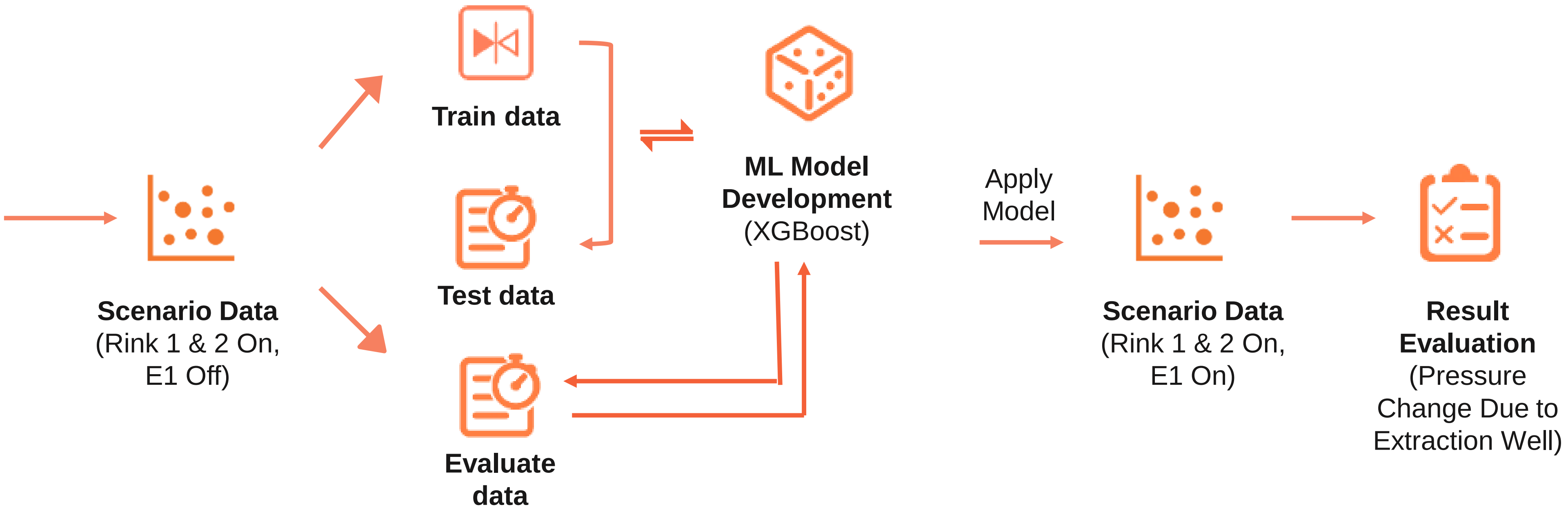
Rink 1: On
Rink 2: Off
E1: Off

Rink 1: On
Rink 2: On
E1: Off

Rink 1: On
Rink 2: On
E1: Off

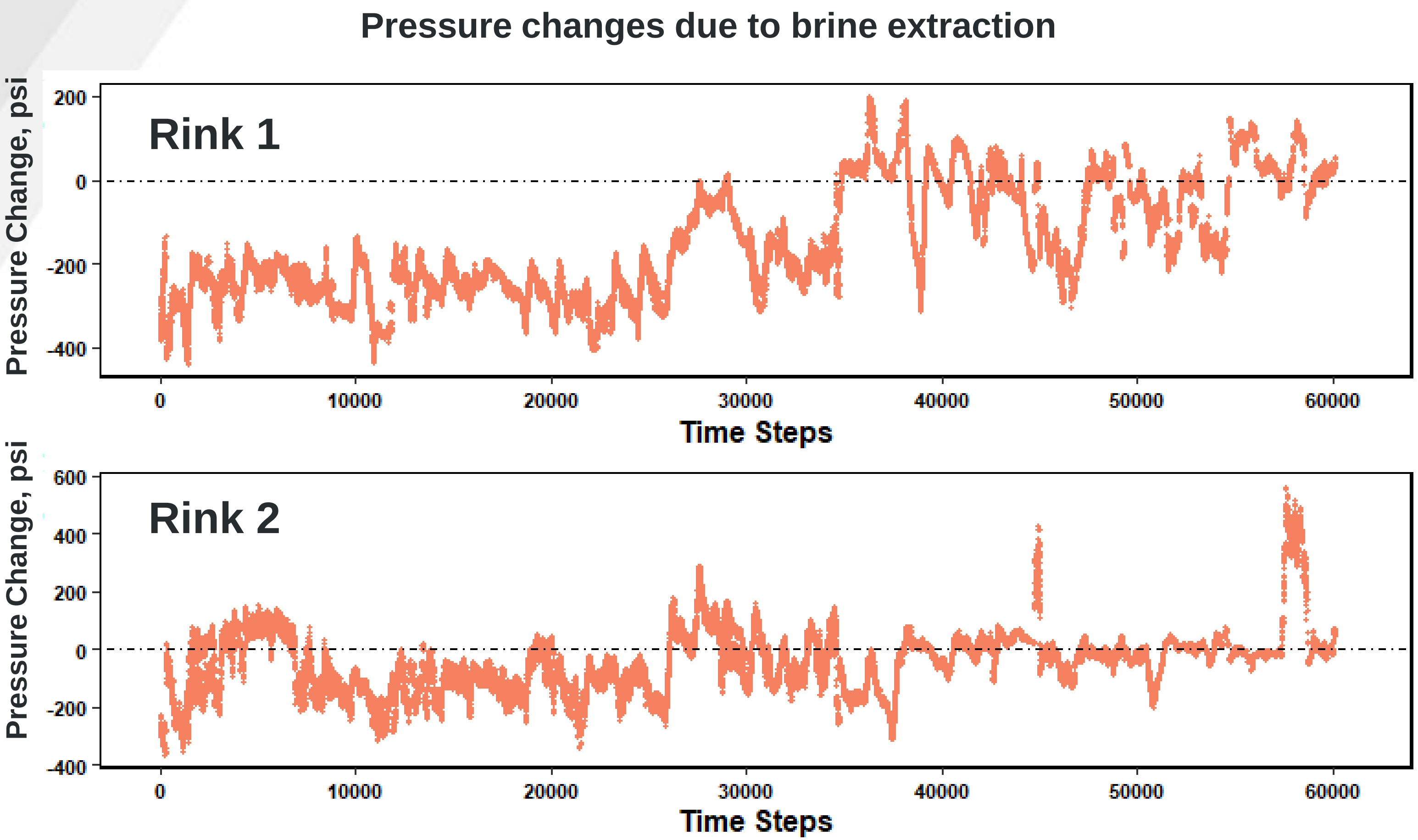
Rink 1: On
Rink 2: On
E1: On

Rink 1: Off
Rink 2: On
E1: Off



ACTIVE RESERVOIR MANAGEMENT

RESPONSE



- Brine extraction data validates **reduction of injection pressures** for offset wells.

- Evaluations of early testing show expected reservoir response.
  - Rink 1 well: Pressure decreases about 56 psi (95% CI: 54–58 psi) due to extraction.
  - Rink 2 well: Pressure decreases about 19 psi (95% CI: 18–20 psi) due to extraction.

ACCOMPLISHMENTS

ACTIVE RESERVOIR MANAGEMENT

ACCOMPLISHMENTS

ACTIVE RESERVOIR MANAGEMENT

- Drilling and site construction completed.
- Baseline BSEM survey completed.
- Achieved target rate of 5000 bbl/day.
- **<u>Site is operational</u>**
- Updated performance models.
- Updated and initiated FIP.
- Several site equipment upgrades to mitigate risks associated with high-temperature reservoir fluids (pumps, flow lines, gauges, etc.).

ACCOMPLISHMENTS

ACTIVE RESERVOIR MANAGEMENT

15 months of operation,
~ 2 million barrels of brine moved
and counting....

- Interference testing complete
  - Extraction/injection ratios (1:4, 1:3, and 5:12)
  - Signal detected
  - Physics-based models calibrated, predictions co-validated against ML analytics and measured observations.

- High-rate and extended duration testing (ongoing)
  - Industry downturn coupled w/ COVID-19 resulted in unanticipated reduction in SWD rates
    - ♦ Expanded ARM test conditions [extraction/injection ratios *approaching 6:1*]

HOW ARM CAN ENABLE COMMERCIAL GELOGIC CO_2 STORAGE

A HYPOTHETICAL EXAMPLE

- Collaboration with Thomas Buscheck (Lawrence Livermore National Laboratory)
  - Model developed and calibrated for CO_2 storage in a continuous, open saline reservoir.
    - ♦ Developed, in part, with data provided by the ND BEST project for SWD operations injecting into Inyan Kara Formation.

- Modeled scenario
  - Inject 2.0 MT/year of CO_2 from October 1, 2008, to March 1, 2019, with concurrent SWD.
  - Six brine extraction wells (~11,000 bpd/well) with reinjection >12 miles away.
    - ♦ >95% reduction in AOR
      - From 249 km^2 to 9 km^2
        - ▪ Area within reservoir with pressures 75 psi or more above the original reservoir pressure at the end of the injection period
    - ♦ > 90% reduction in postinjection monitor period
      - From 26 years to 2 years
        - ▪ Time for reservoir pressure to decline to less than 75 psi above original reservoir pressure at the injection well following injection period

Results summarized from: Task 4: Active Reservoir Management (FEW-0191) presented by Thomas Buscheck of Lawrence Livermore National Lab at the U.S. Department of Energy National Energy Technology Laboratory, Addressing the Nation's Energy needs Through Technology innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technology Integrated Review Meeting, August 26–30, 2019.

ACCOMPLISHMENTS TO DATE

BRINE TREATMENT DEVELOPMENT FACILITY

North Dakota water treatment test bed facility available for demonstration of produced water treatment technologies.
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Enable development, pilot testing, and advancement of commercially viable extracted and produced water treatment technologies that can meaningfully reduce brine disposal volumes and provide an alternate source of water and/or salable products for beneficial use.
TEST BED FACILITY CAN REPLICATE EXTRACTED WATERS THAT ARE REPRESENTATIVE OF LOCATIONS/ SOURCES THROUGHOUT THE UNITED STATES
SITE SPECS
Two overhead doors
Heated and insulated
Air handling/exchange
Temporary water storage tanks for demonstration supply
Waste handling and disposal on site
FACILITY CAN BE READILY ADAPTED FOR USE WITH ALTERNATE FLUID COMPOSITIONS OR TREATMENT PROCESSES
Pretreatment and conditioning can be modified to replicate broader influent specifications
CONTROL ROOM
Influent and effluent flow rates and composition
This is a collaborative effort with Nuverra Environmental Solutions and the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL).
John Harju, Marc Kurz, Ryan Klapperich, Lonny Jacobson, and Robert Jensen
undeerc.org
EERC
Nuverra
ENERGY
NETL
Schlumberger

CARBONATED BRINE STORAGE

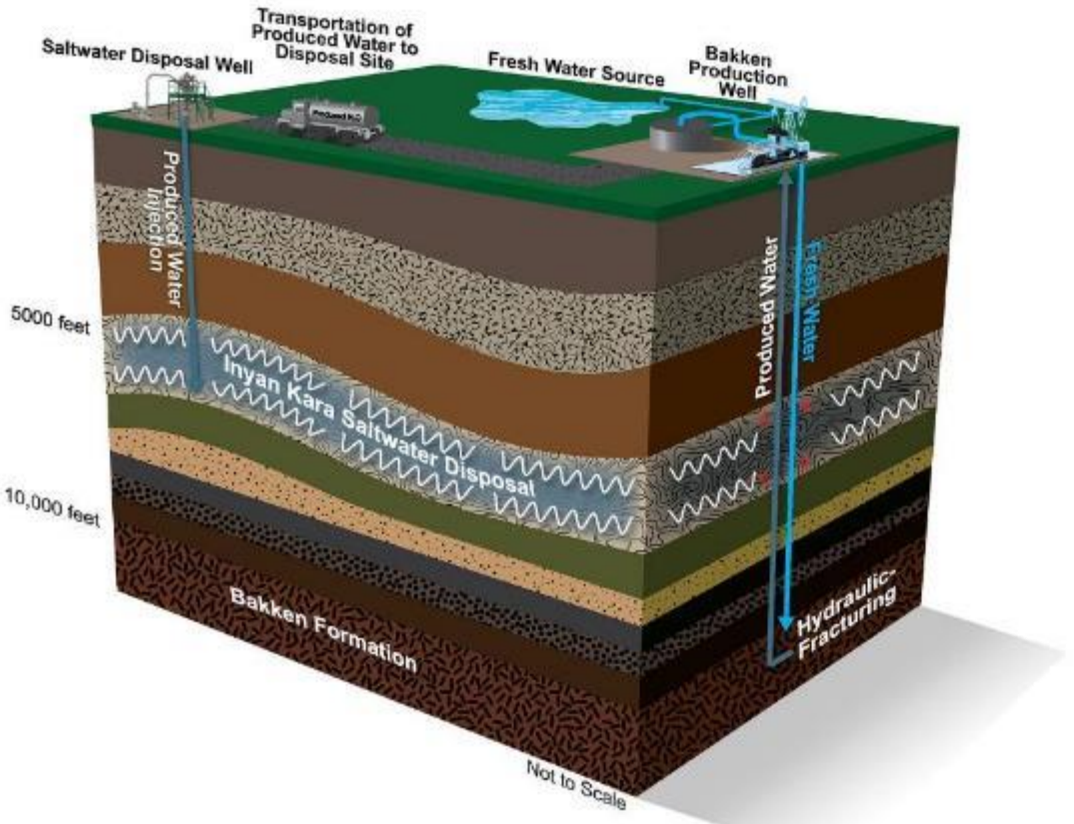
NRAP COLLABORATION

- **Hypothesis –** Coinjection of dissolved CO_2 into saltwater disposal (SWD) wells could accommodate meaningful quantities of geologic CO_2 storage with a significantly reduced risk profile that is easier to permit that could enable a distributed CO_2 storage model.
  - Conduct screening-level techno-economic feasibility assessment.
  - Compare risk profile of carbonated brine storage vs supercritical CO_2 injection.
  - Leverage models and SWD operating knowledge obtained through ND BEST.
  - Reconnaissance-level assessment of barriers to implementation and recommendations for beneficial NRAP tool feature set.

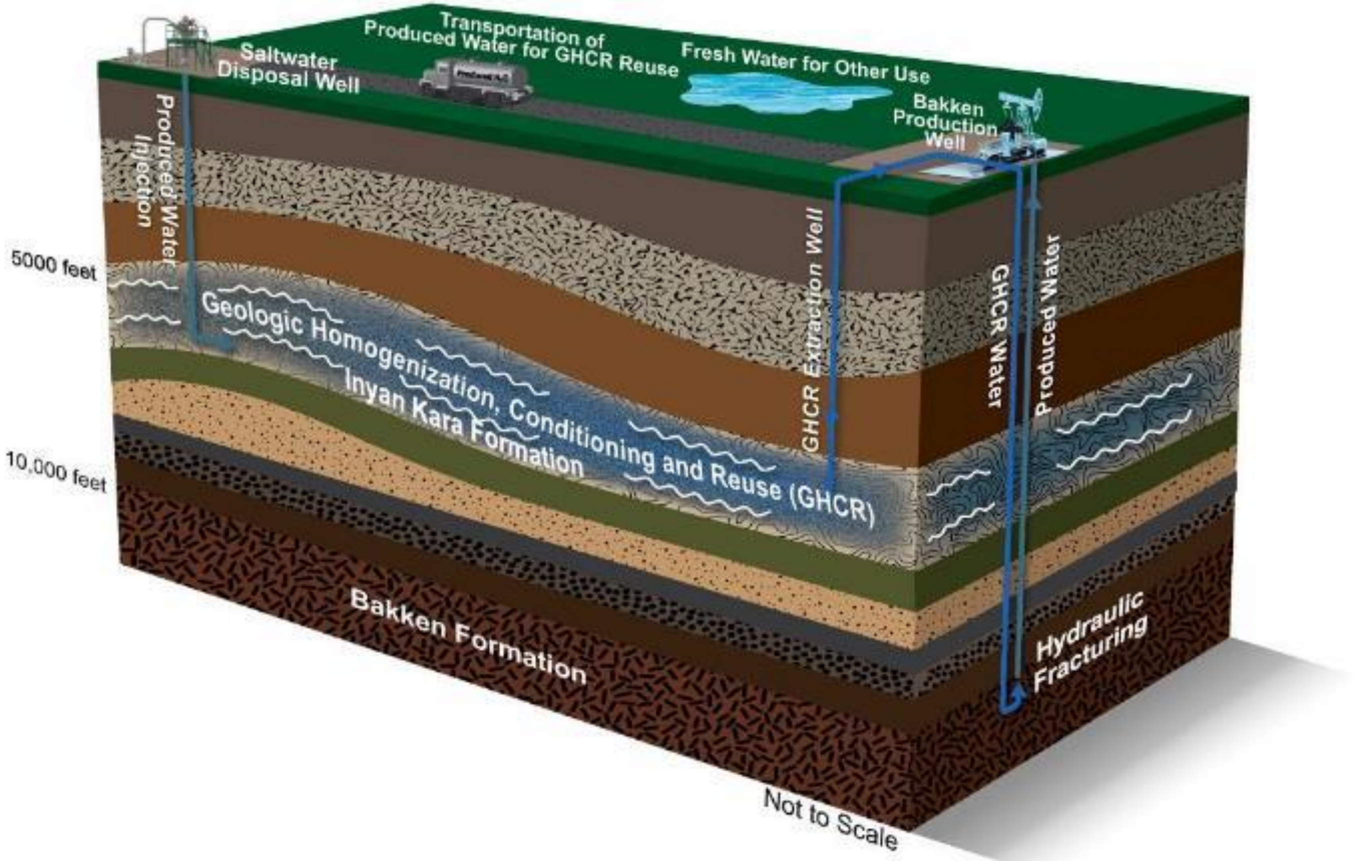
GEOLOGIC HOMOGENIZATION CONDITIONING AND REUSE

SYNERGY

Traditional Approach



GHCR Approach



Leverage BEST field test to provide proof-of-concept of GHCR concept.

NORTH DAKOTA BRINE TREATMENT FACILITY

SYNERGY

Facility can be readily adapted for use with alternate fluid compositions or treatment processes.

- Alternate water sources trucked and offloaded at site.
- Pretreatment and conditioning can be modified to replicate broader influent specifications.
- Blending of additives to replicate target fluid chemistries.
- Application of cascade technologies (e.g., power/thermal supply, pretreatment/conditioning…).
- On-site SWD and waste handling.

NORTH DAKOTA BRINE TREATMENT FACILITY

POTENTIAL ADAPTATION FOR EXPANDED APPLICATION

- Oil and gas fluid conditioning (e.g., emulsion breaking, corrosion, scale inhibitors, fluid compatibility testing, etc.)
- Produced water treatment
- Electric power generation wastewater treatment
- Industrial and municipal waste and water treatment
- Mineral resource recovery
- Agricultural water treatment
- Geologic conditioning and homogenization as a means of water pretreatment
- Benchmarking the economic and technical limits of water treatment technologies (e.g., MVR)
- Collaboration with other federal, state, or industry groups

NEXT STEPS

- Complete ARM field test.
- Acquire time-lapse BSEM survey.
  – Validate ARM influence on injected fluid distribution.
- Calibrate physics-based and ML ARM models.
- Evaluate the theoretical efficacy of ARM applied to CCS scenarios.
- Develop and test two or more additional technologies at the ND Brine Treatment Technology Development and Testbed Facility.

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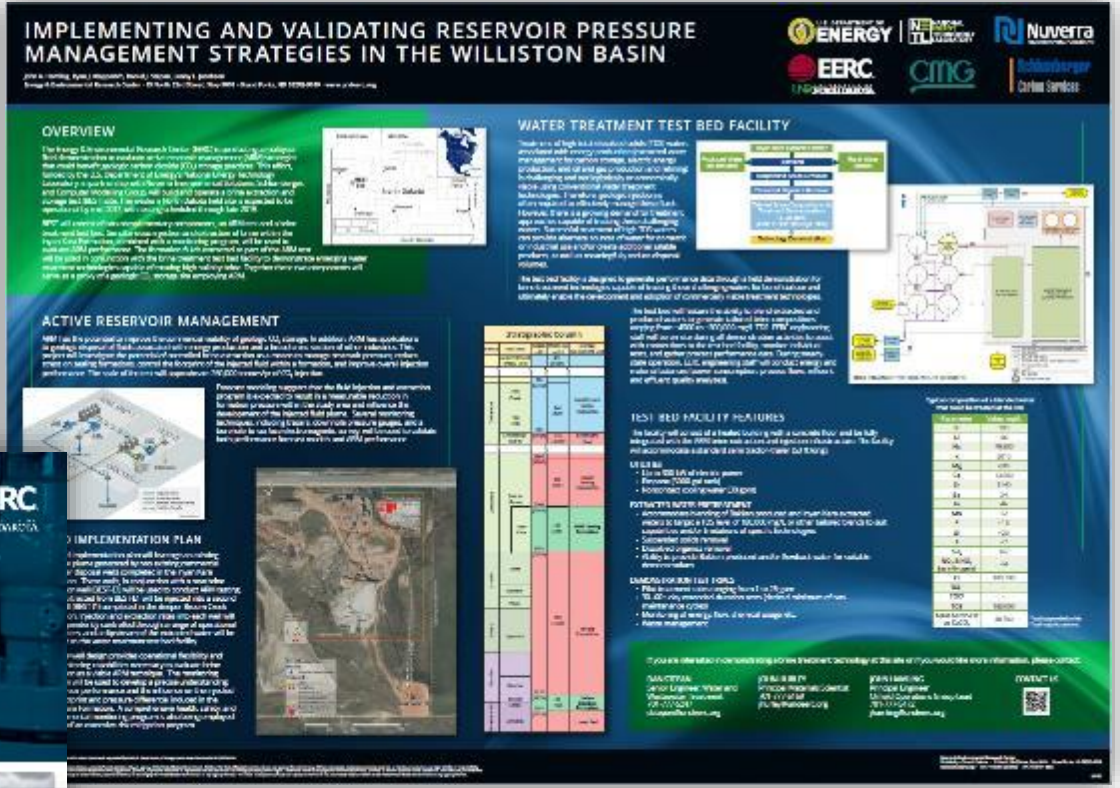
INFORMATION AND OUTREACH



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THANK YOU

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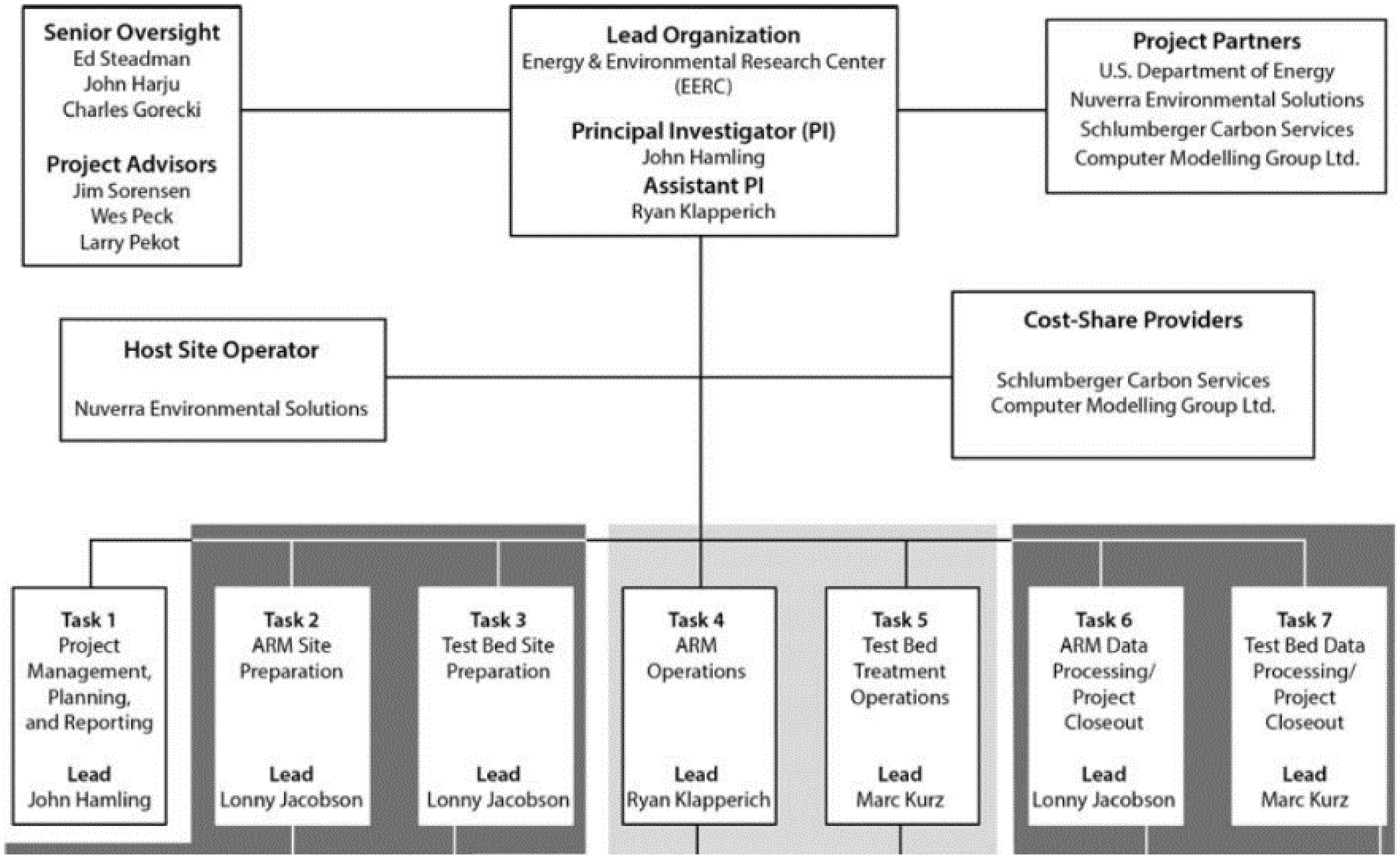
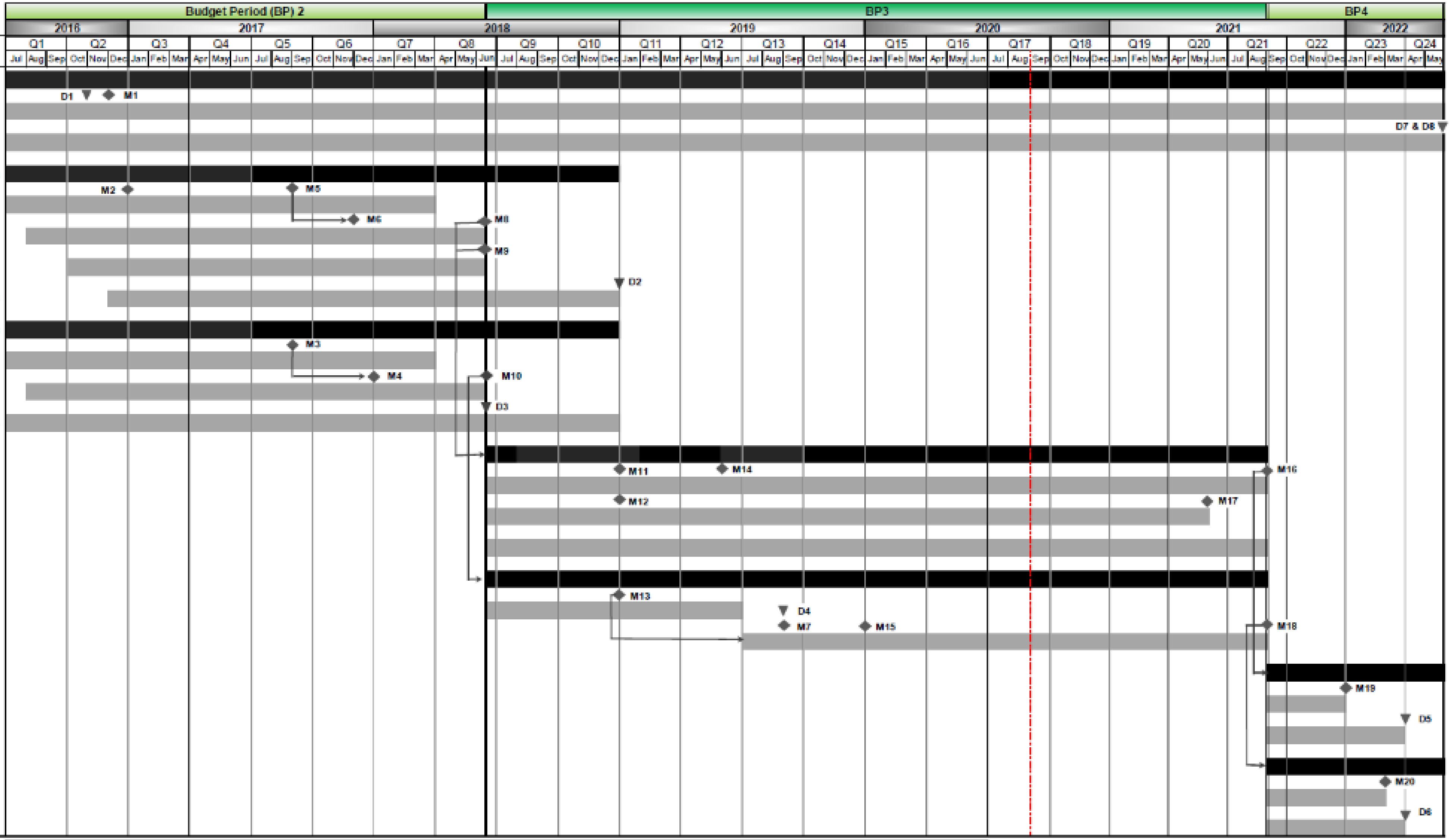
APPENDIX

ORGANIZATION CHART



Gantt Chart, Deliverables, and Milestones

Task	Start Date	End Date
Task 1.0 – Project Management, Planning and Reporting	**7/7/16**	**5/31/22**
1.1 – Project Management	7/7/16	5/31/22
1.2 – Project Reporting	7/7/16	5/31/22
Task 2.0 – ARM Site Preparation	**7/7/16**	**12/31/18**
2.1 – ARM Permitting	7/7/16	3/31/18
2.2 – Well Installation	8/1/16	6/15/18
2.3 – Surface Infrastructure Installation	10/1/16	6/15/18
2.4 – Updated Site Characterization and Modeling	12/1/16	12/31/18
Task 3.0 – Test Bed Site Preparation	**7/7/16**	**12/31/18**
3.1 – Test Bed Facilities Permitting	7/7/16	3/31/18
3.2 – Test Bed Facility Installation	8/1/16	6/15/18
3.3 – Solicitation of Treatment Technologies	7/7/16	12/31/18
Task 4.0 – ARM Operations	**6/16/18**	**8/31/21**
4.1 – Injection/Extraction Testing	6/16/18	8/31/21
4.2 – MVA Implementation	6/16/18	5/31/21
4.3 – Model Updates/History Matching	6/16/18	8/31/21
Task 5.0 – Test Bed Treatment Operations	**6/16/18**	**8/31/21**
5.1 – Facility Shakedown/Training	6/16/18	6/30/19
5.2 – Long-Term Performance Evaluations	5/1/19	8/31/21
Task 6.0 – ARM Data Processing/Project Closeout	**9/1/21**	**5/31/22**
6.1 – ARM Site Decommissioning/Disposition	9/1/21	12/31/21
6.2 – Finalization of ARM Test Results	9/1/21	3/31/22
Task 7.0 – Test Bed Data Processing/Project Closeout	**9/1/21**	**5/31/22**
7.1 – Test Bed Decommissioning/Disposition	9/1/21	2/28/22
7.2 – Finalization of Test Bed Results	9/1/21	3/31/22



Note: The contract modification for Phase II was fully executed on September 9, 2016.

Red line indicates the end of the 5 year program.

Deliverables ▼	Milestones (M) ◆	
D1 – Updated PMP	M1 – Project Kickoff Meeting	M11 – Initiate Stage 1 of Experimental Scenario
D2 – Field Implementation Plan (FIP) Finalized	M2 – Permit to Drill Submitted	M12 – Initiate Collection of Operational Data
D3 – Water Treatment Technology Selection Process Summary	M3 – Water Treatment Test Bed Permit Received	M13 – Water Treatment Test Bed Fully Operational
D4 – Preliminary Schedule of Technologies	M4 – Start Water Treatment Facilities Construction	M14 – Initiate Stage 2 of Experimental Scenario
D5 – Vol. 1 – ARM Engineering and Evaluation Summary	M5 – Permit to Drill Received	M15 – First Treatment Technology Evaluated
D6 – Vol. 2 – Technology Evaluation Report	M6 – Start Site Preparation	M16 – Completion of ARM Operations
D7 – Data Submission to EDX	M7 – First Treatment Technology Selected	M17 – Conduct Repeat BSEM Survey
D8 – Lessons Learned Document	M8 – Well Installation Complete	M18 – Completion of Water Treatment Technology Demonstration
	M9 – Surface Installation Complete	M19 – ARM Site Decommissioning/Disposition Completed
	M10 – Water Treatment Facilities Complete	M20 – Water Treatment Test Bed Decommissioning/Disposition Completed

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