EGI Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH 50 YEARS

Uinta Basin Carbonsafe II: Storage Complex Feasibility

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Uinta Basin CarbonSAFE

Acknowledgement

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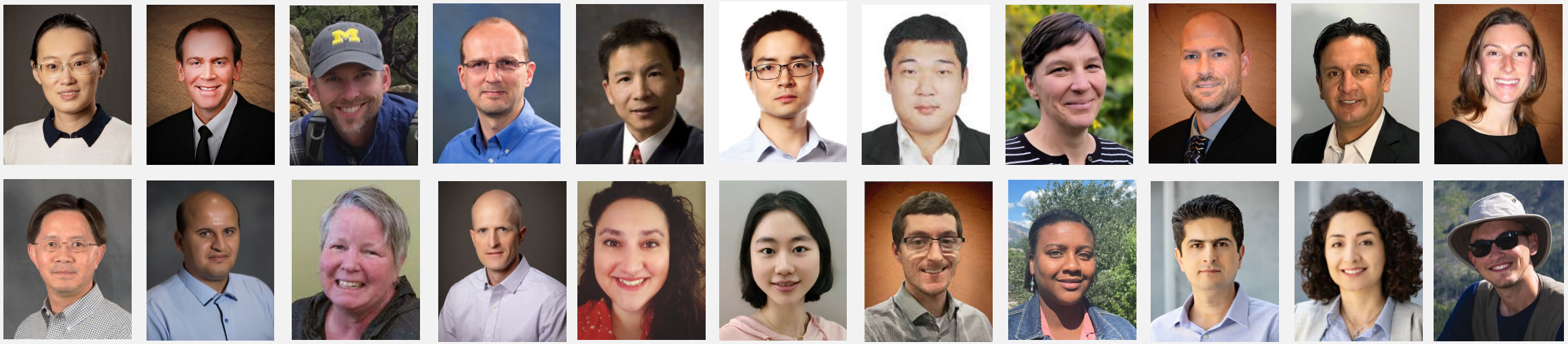
We acknowledge our project manager, Ashley Urosek, and the management team, for their great support.

Our Project Team

Key Personnel



Collaborative Institutes

EGI Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH

UTAH DNR UTAH GEOLOGICAL SURVEY

Los Alamos NATIONAL LABORATORY EST. 1943

Carbon Solutions LLC

THE UNIVERSITY OF UTAH

New Mexico Tech GRADUATE STUDENT ASSOCIATION

UNIVERSITY OF WYOMING

HOHN ENGINEERING, PLLC

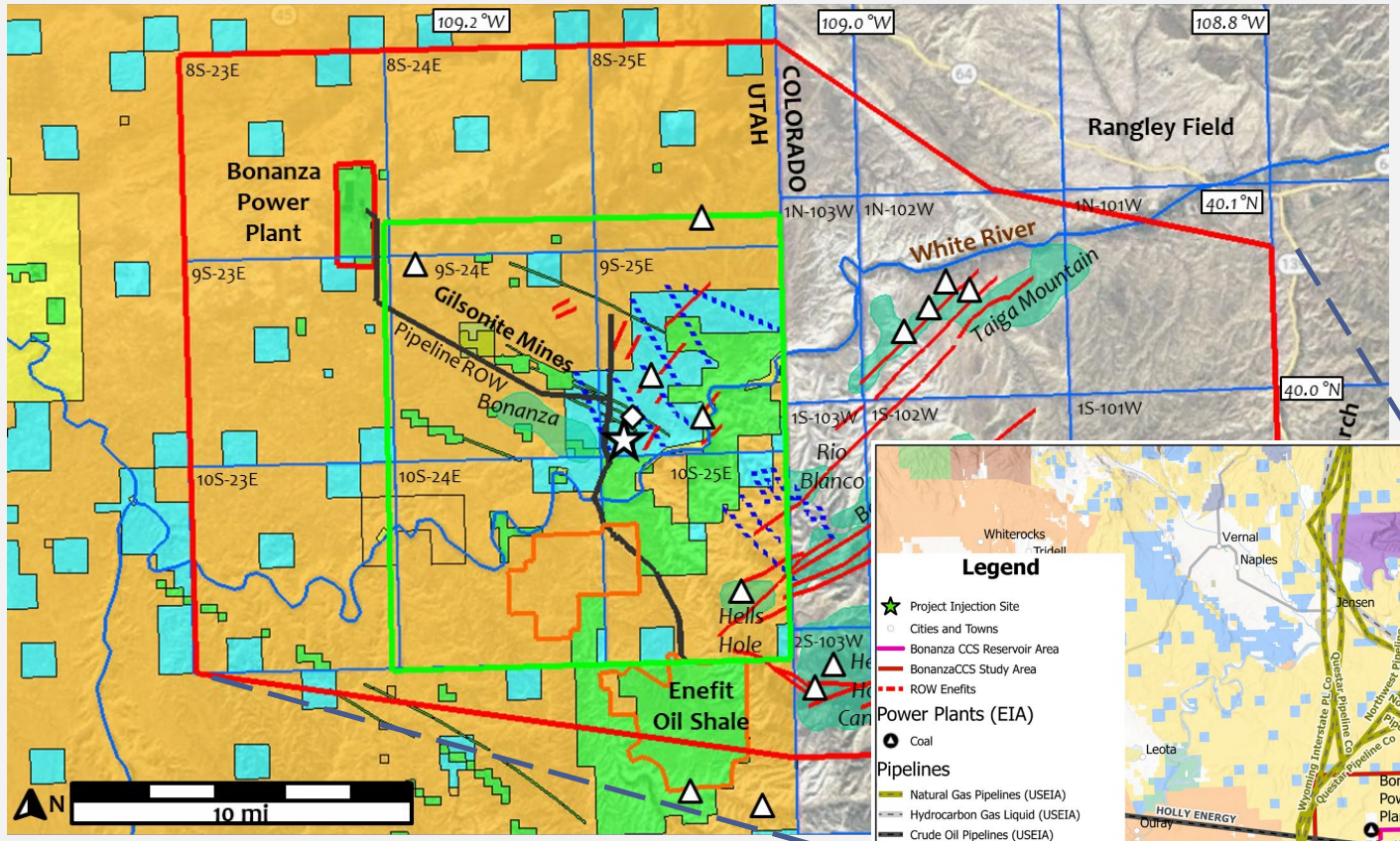
DESERET POWER ELECTRIC COOPERATIVE

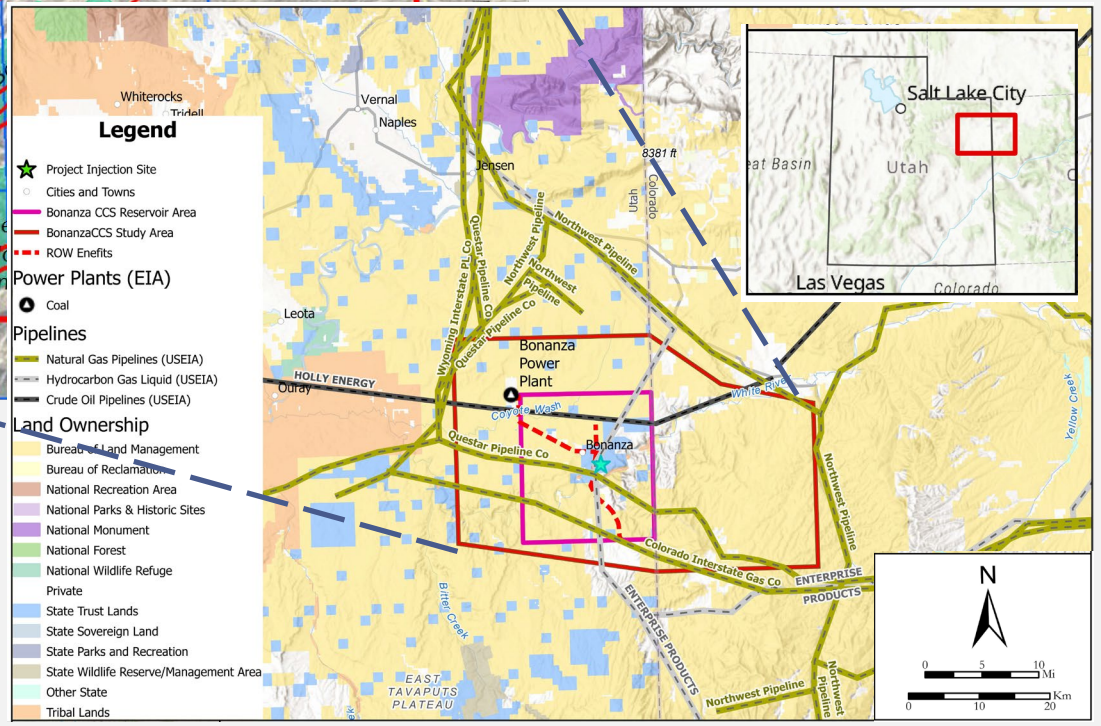
Project Goals

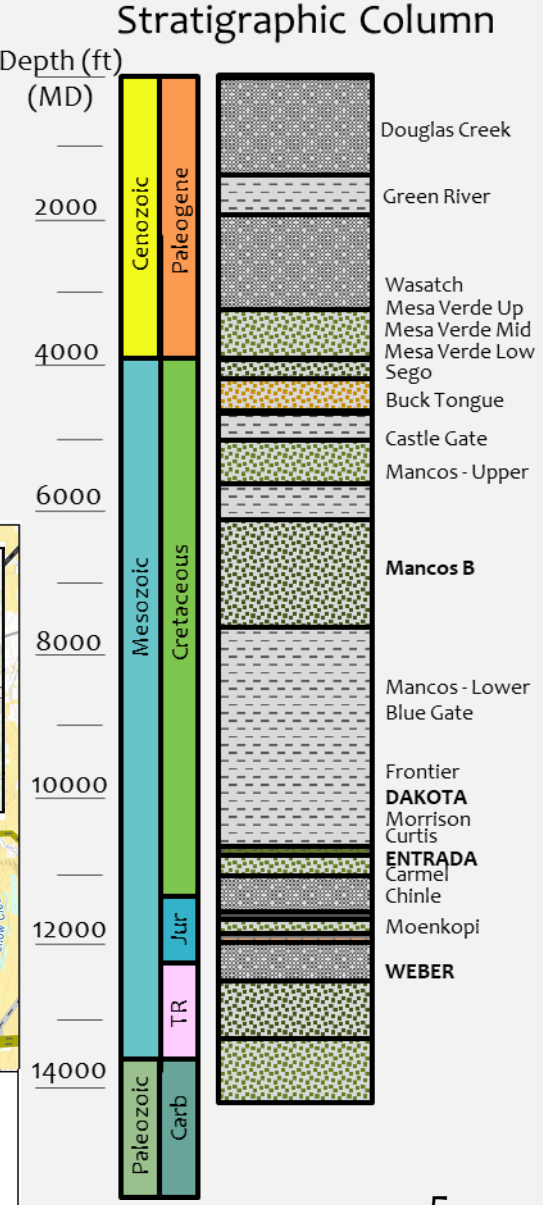
Uinta Basin CarbonSAFE II: Storage Complex Feasibility

To establish the technical and economic feasibility of a commercial-scale CO_2 geological storage complex in the east Uinta Basin, Utah, to securely and economically sequester 50 million metric tons of captured CO_2 over 30 years.

Regional Overview







LEGEND

CarbonSAFE PHASE II Study
- Area of Study
- Proposed Injection Site
- CCS Storage Area
- Proposed Stratigraphic Well

Geological Features and Data
- Wells with Cores / Cuttings / Logs
- Faults
- Legacy 2D Seismic Lines

Oil and Gas Operations
- Oil and Gas Fields
- Enefit Oil Shale Mines
- Enefit Pipeline Right-Of-Way

Utah Land Ownership
- Tribal
- Private
- State (SITLA)
- Federal

Tasks and Leadership

Task 1 Project Management

- Management
- Reporting
- Project Coordination


Ting Xiao

Task 2 Community Benefits Plans

- DEIA
- Justice40
- Public Engagement
- Workforce Engagement


Erin Middleton

Task 3 Site Characterization

- Data Evaluation
- Strat Well Drilling


Michael Vanden Berg


Carlos Vega

Task 4 Modeling & Simulation

- Model Development
- Storage Capacity
- Storage Scenarios
- AoR


Nathan Moodie

Task 5 Risks & Mitigation Plans

- Non-Technical Risks
- Leakage
- Induced Seismicity
- Transportation Risks
- Risk Mitigation Plans


Bailian Chen

Task 6 CO_2 Management & Monitoring Plan

- CO_2 Management Plan
- CO_2 Monitoring Plan


Sai Wang


Maohong Fan

Task 7 Subsequent Characterization & UIC Class VI Permitting Plans

- Site Characterization Plan
- UIC Class VI Permitting Plan

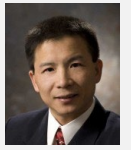

Michael Vanden Berg


Sai Wang

Task 8 Technical & Economic Feasibility Evaluation

- CO_2 Source Viability
- CO_2 Transportation Options
- Economic Feasibility


Richard Middleton


Maohong Fan

Tasks 1. Project Management and Planning

Project Website:

https://egi.utah.edu/uinta-basin-carbonsafe/

Events:

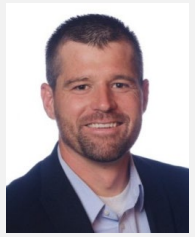
- **Field Trip: January 23rd, Bonanza, Utah**
- **Project Kick-off Meeting: January 24th, Vernal, Utah**

Tasks 1. Project Management and Planning

Advisory Board Members

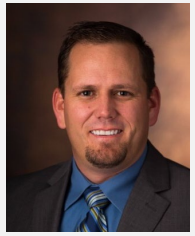
Richard Powell
UIC Program Manager,
Utah Division of OGM

Tyler Esplin
Sr. Engineer,
Deseret Power



Tyson Todd
Area & Lease Manager,
SITLA

Steve Handy
Former State Legislator,
State of Utah



Craig Brown
General Manager,
American Gilsonite

Seth Lyman
Director,
Bingham Research Center

Ryan Clerico
Chief Executive Officer,
Enefit American Oil

Travis Campbell
Director,
Uintah County
Economic Development

Seth Taylor
Director of Energy Services,
Uintah Basin Technical College

Tasks 1. Project Management and Planning

CCS Introduction Video

Publications

- Vega-Ortiz, C., Moodie, N., Vanden Berg, M. D., Xiao, T., McPherson, B., Geological feasibility and volumetric estimation for CCS project in the Uinta Basin, USA. Mitigation and Adaptation Strategies for Global Change, Under review.
- Xiao, T. , McPherson, B., Bakelli, O., Cheng, S., Zhu, D., Xu, L., Middleton, E., A review of public perceptions and engagement for carbon capture, utilization, and storage. Renewable Sustainable Energy Rev., Under review.
- Xiao, T., Vega, C., Moodie, N., Vanden Berg, M. D., Blanchard, F., McPherson, B., Uinta Basin CarbonSAFE Phase II: An overview. AGU Fall Meeting, San Fransisco, December 11-15, 2023.
- Xiao, T., McPherson, B., Tian, H., Early-Stage Risk Assessment for a Potential Commercial-Scale Geological Carbon Storage Site in Utah, USA. The 37th International Geological Congress, Busan, Korea, Aug 25-31, 2024.
- Xiao, T., Birgenheier, L., Vanden Berg, M. D., Vega-Ortiz, C., Moodie, N., Middleton, E., Wang, S., Middleton, R., Fan, M., Chen, B., McPherson, B., Research Overview of the Uinta Basin CarbonSAFE Phase II Project. GSA Annual Meeting, Anaheim, California, Sep 22-25, 2024.
- Melnyk, S., Birgenheier, L., Vanden Berg, M.D., St. Pierre, G., Bailey, N., submitted. Evaluating the CO_2 storage potential of the Entrada Sandstone in the eastern Uinta Basin, Utah. Rocky Mountain Section – American Association of Petroleum Geologists, Park City, Utah, Oct 6 – 8, 2024.

Tasks 2. Community Benefits Plans

Task Progress

CBP component	Activity	Due date	Progress
Community and Labor Engagement	Create an advisory board.	First 90 Days	Advisory board attended the Kick-Off meeting and has on-going consultation with project PI.
	Establish multiple engagement opportunities, including project website, informational videos, engagement with advisory board, and routine outreach events.	End of project	Creating Stakeholder Matrix to inform engagement; Creating student-led information videos; Attending local conferences; Meeting with regional educational orgs
Investing in Job Quality and a Skilled Workforce	Develop a course in CCUS with a focus on geologic sequestration, will be available to students and professionals as part of the development of EGI's new Resilient Energy Certificate program.	End of project	Class completed in Spring 2024; Viability of certificate program in Fall 2025.
Diversity, Equity, Inclusion, and Accessibility	Organize training related to DEIA and principles in community-based research (CBR).	First 60 days	Task leads and students completed Best Practices in Community-Based Research projects training.
	Attend training organized by the UU on working with tribal governments, with special emphasis on long-term planning and energy.	Middle of project	Slated for Fall 2025.
	Employ students or researchers from underrepresented communities/underrepresented groups in the STEM workforce.	End of project	Students are working this summer; helping to create videos.
Justice40 Initiative	Create a geodatabase of stakeholders, physical data, geographic data, and demographic data to facilitate understanding of areas of concern to the community.	60 days before end of project	Collaborating with UGS and UU staff to understand existing and proposed work.

Tasks 2. Community Benefits Plans

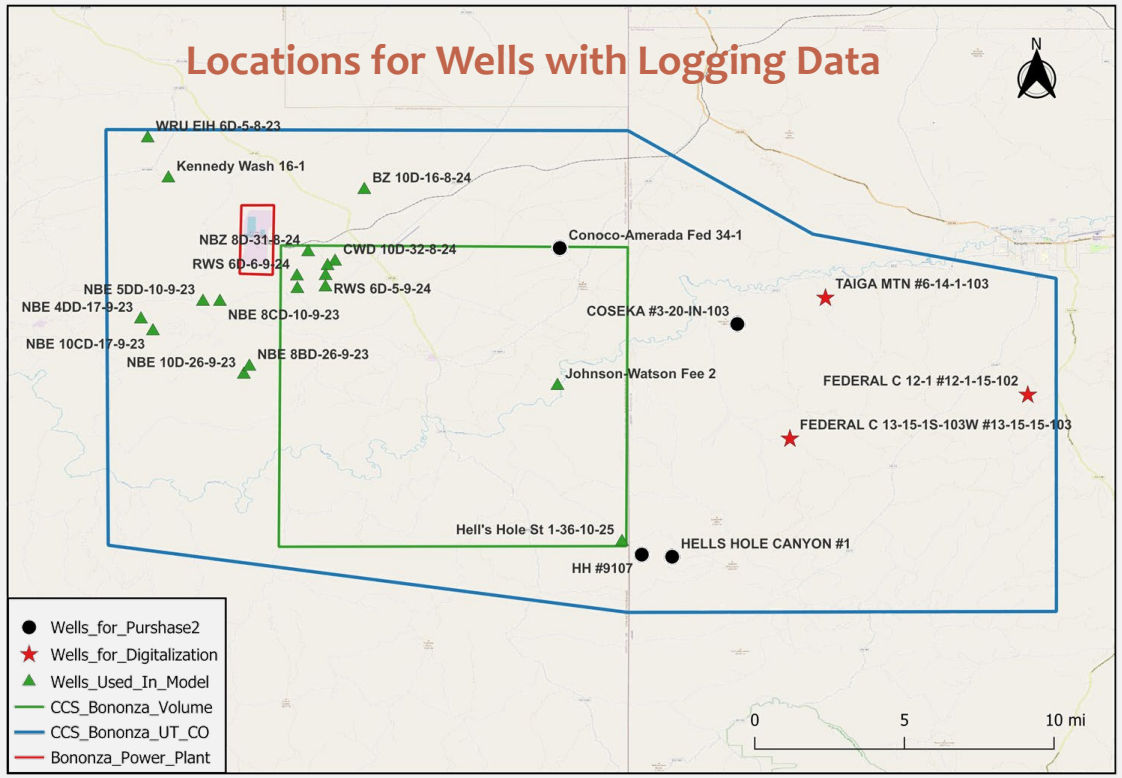
Organization Name	Type of Engagement	Time	Event
Ute Tribe Education Department	Community input/Education	1/18/2024	Office visit and discussion
Uintah Basin Technical College	Community input/Education	1/18/2024	Office visit and discussion
Utah Petroleum Association	Community input	3/12/2024	Attended their conference
Utah Division of Oil, Gas and Mining	Technical assistance	3/21/2024	Uintah Basin Oil & Gas Collaborative - project update
Utah Office of Energy Development	Energy policy developer	5/8/2024	Office visit and discussion
Deseret Power (Bonanza)	Source of CO_2	5/13/2024	Office visit
Utah Division of Multicultural Affairs	Community input	6/12/2024	Office visit and discussion
Utah State Historic Preservation Office	Community input	6/12/2024	Office visit and discussion
Utah Association of Energy Users	Community input	6/18/2024	Discussion
Utah Department of Public Utilities	Community input	6/18/2024	Office visit and discussion
Utah Department of Workforce Services	Community input	6/18/2024	Office visit and discussion
Ute Tribe Employment Rights Office (UTERO)	Community input	7/18/2024	Office visit and discussion
Uintah County	Community-engaged project	7/18/2024	Office visit and discussion
Naples City	Community-engaged project	7/18/2024	Office visit and discussion
Vernal City	Community-engaged project	7/18/2024	Office visit and discussion
Ute Energy	Community input	7/18/2024	Office visit with a flyer

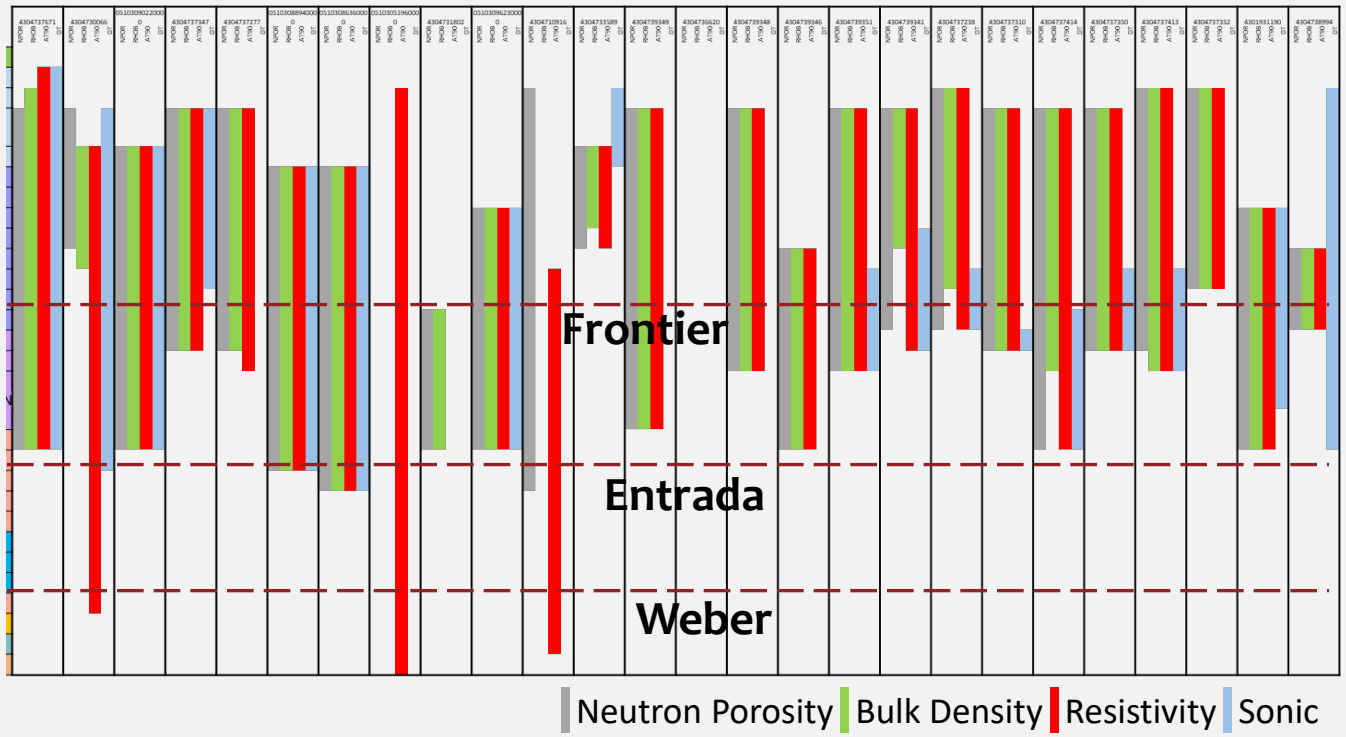
Tasks 3. Storage Complex Characterization

Well Log Data Collection

Sources (26 wells collected):

- Utah Division of Oil, Gas and Mining
- Utah Geological Survey
- Colorado Geological Survey
- Commercial databases

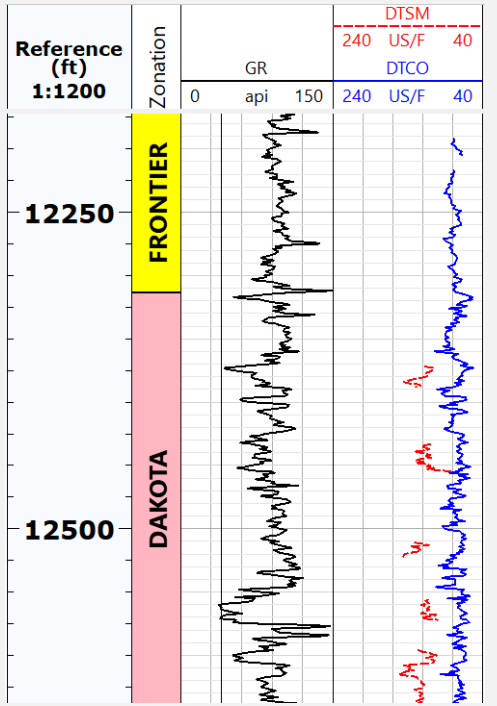




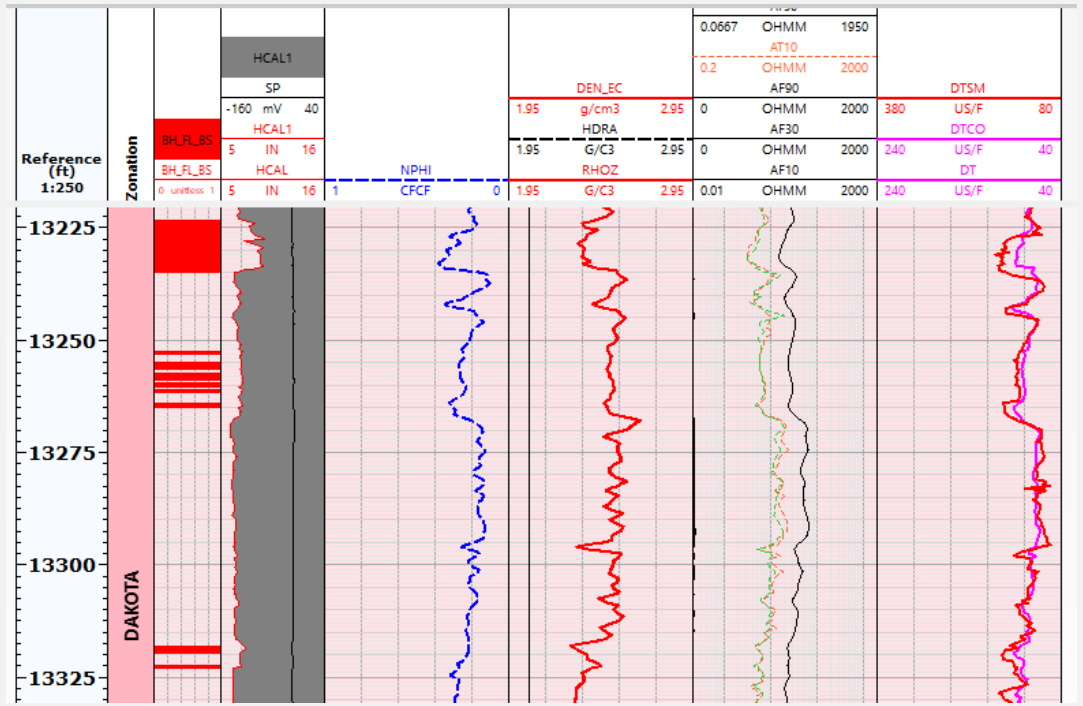
Challenge: limited wells going deep

Tasks 3. Storage Complex Characterization

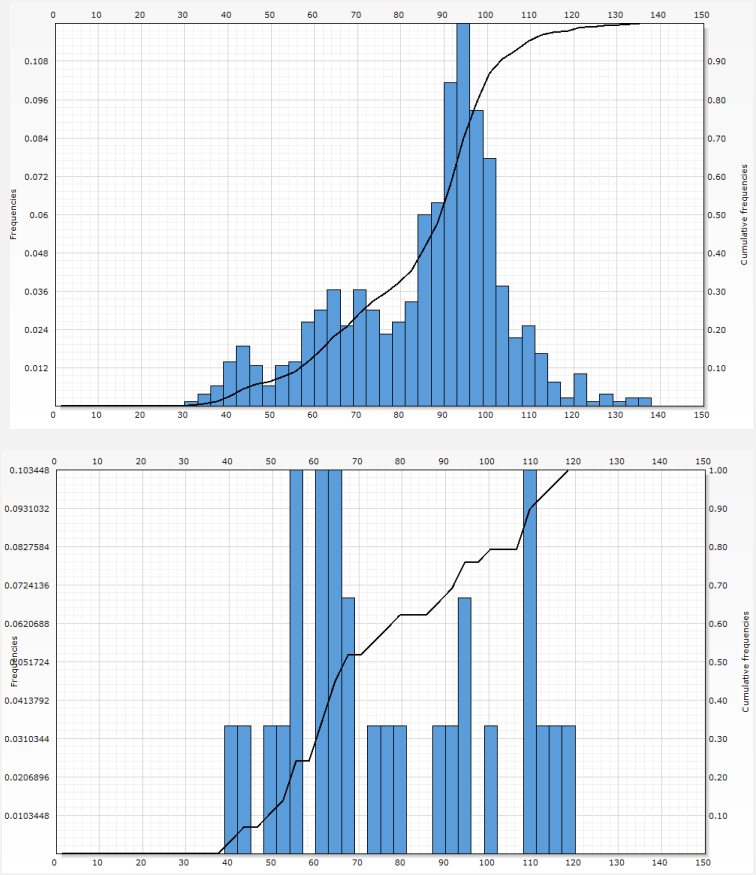
Well Log Data Assessment



Well with Missing Data



Log with Bad Borehole Conditions



Consistent & Inconsistent GR Log Data

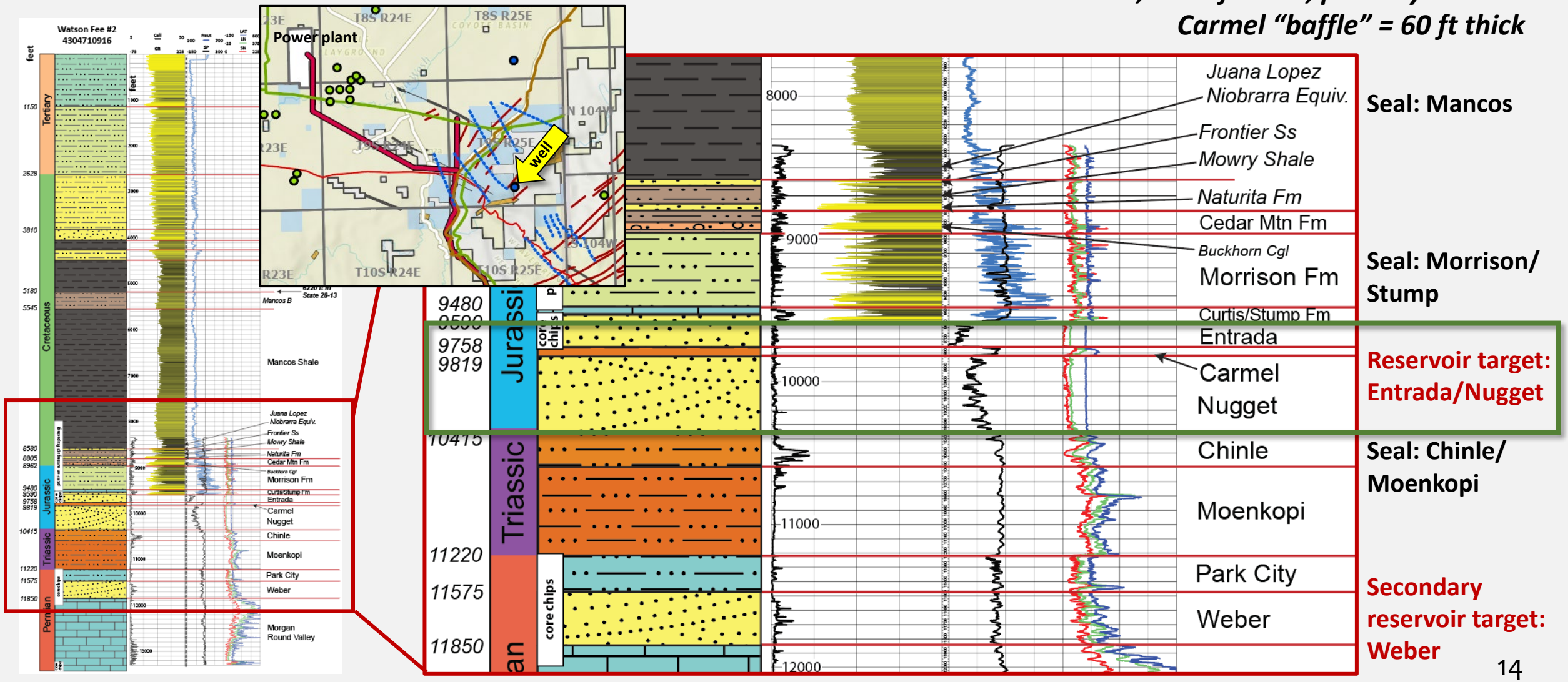
Tasks 3. Storage Complex Characterization

Geology Updates

Primary reservoir target: Jurassic Entrada and Nugget Sandstones

Aeolian sands, ~750 ft thick, porosity 12-18%

Carmel "baffle" = 60 ft thick



Seal: Mancos

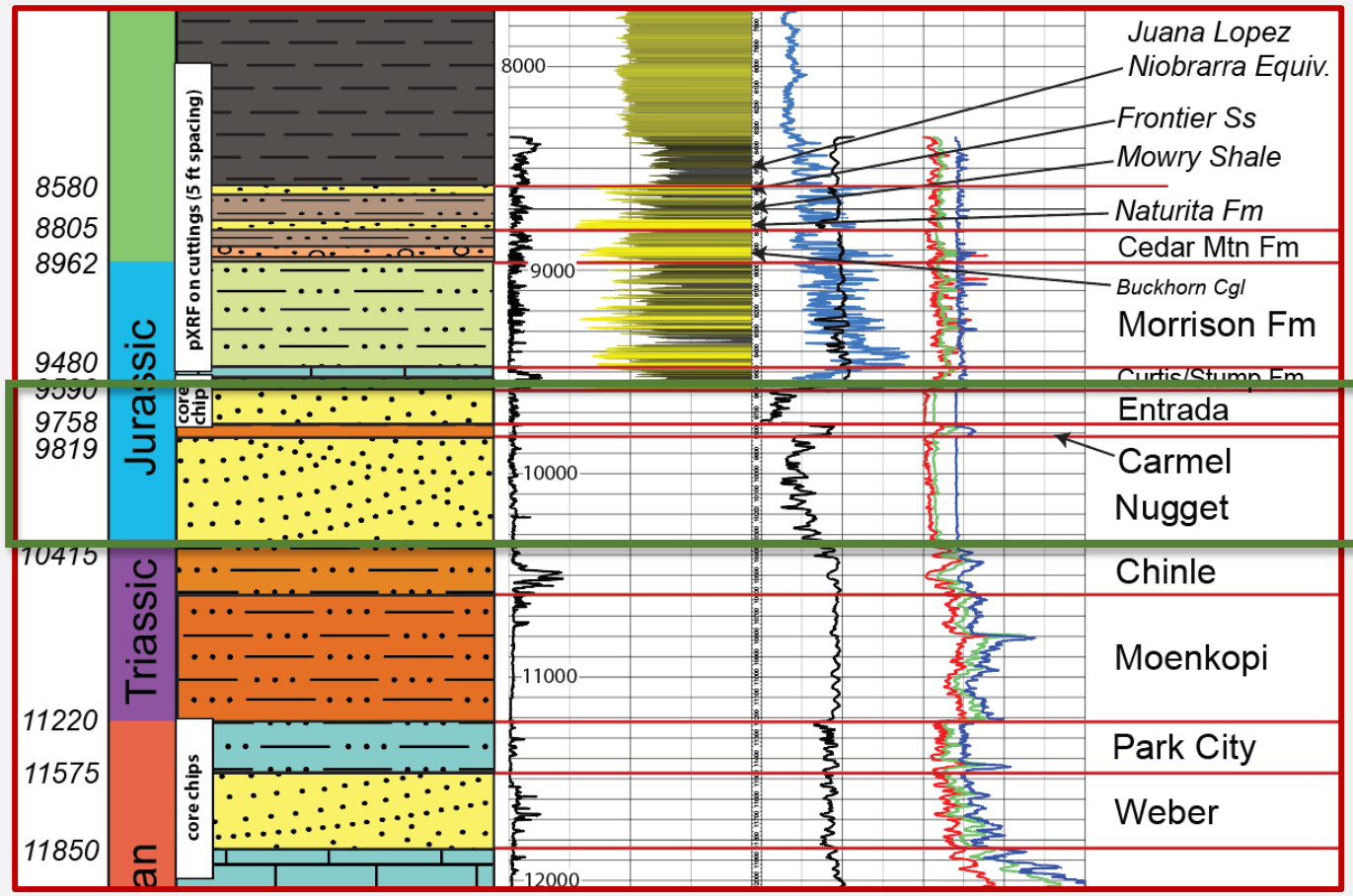
Seal: Morrison/ Stump

Reservoir target: Entrada/Nugget

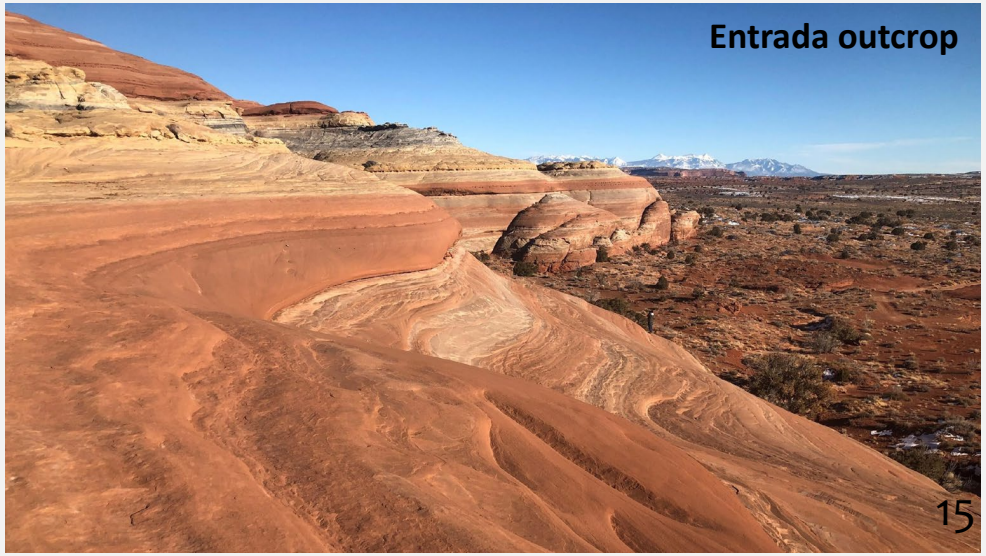
Seal: Chinle/ Moenkopi

Secondary reservoir target: Weber

Tasks 3. Storage Complex Characterization

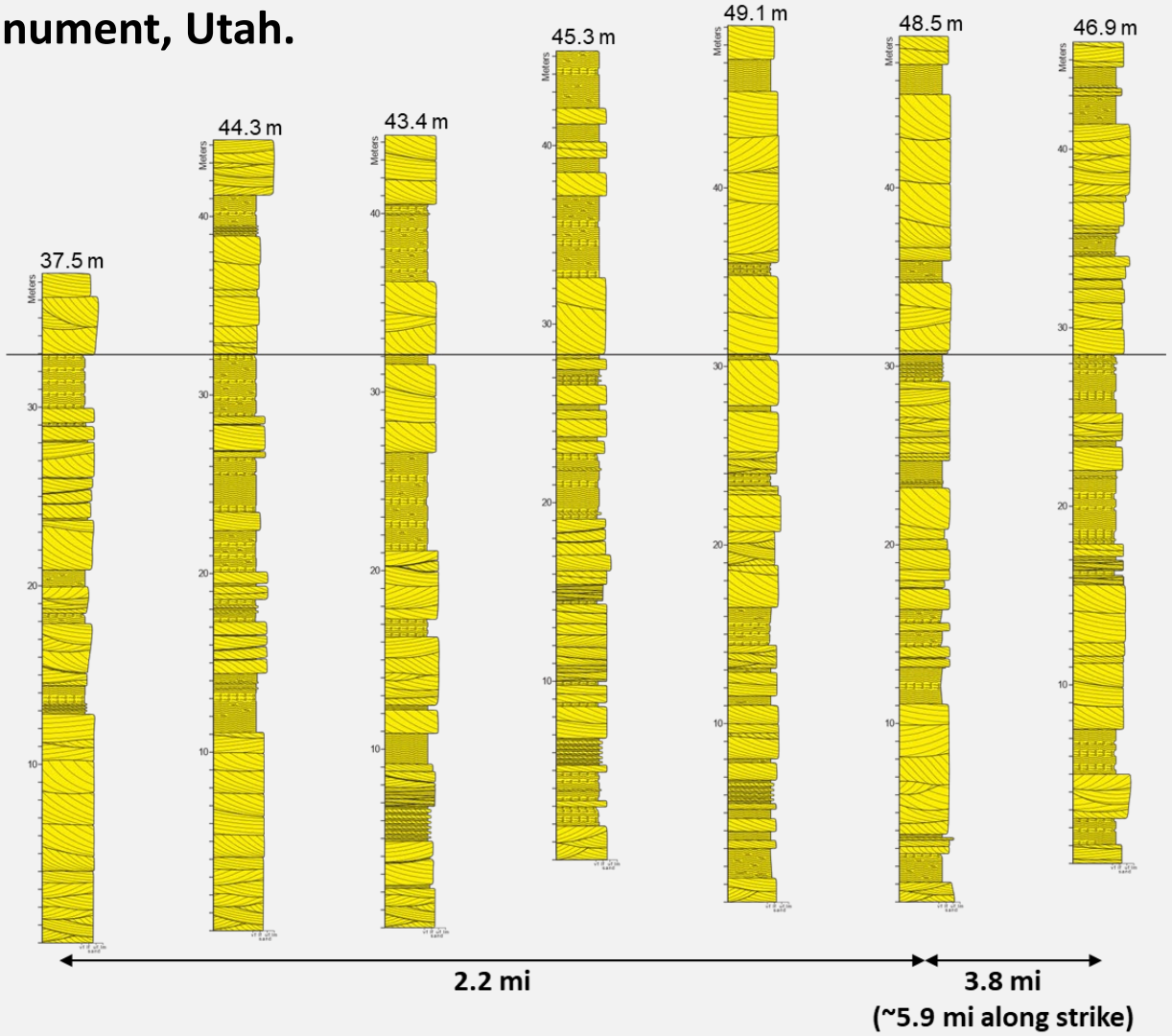


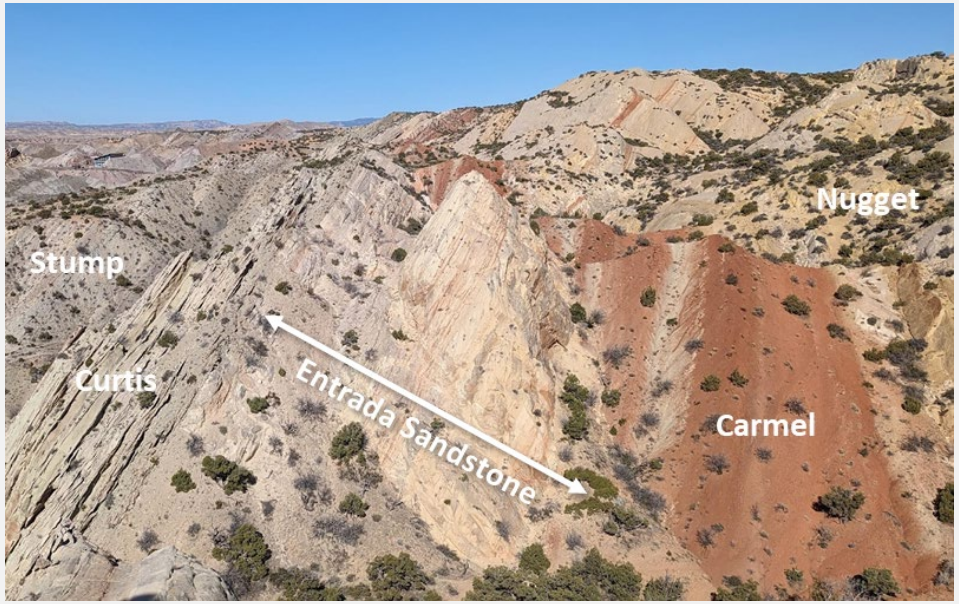
Reservoir target: Entrada/Nugget



Tasks 3. Storage Complex Characterization

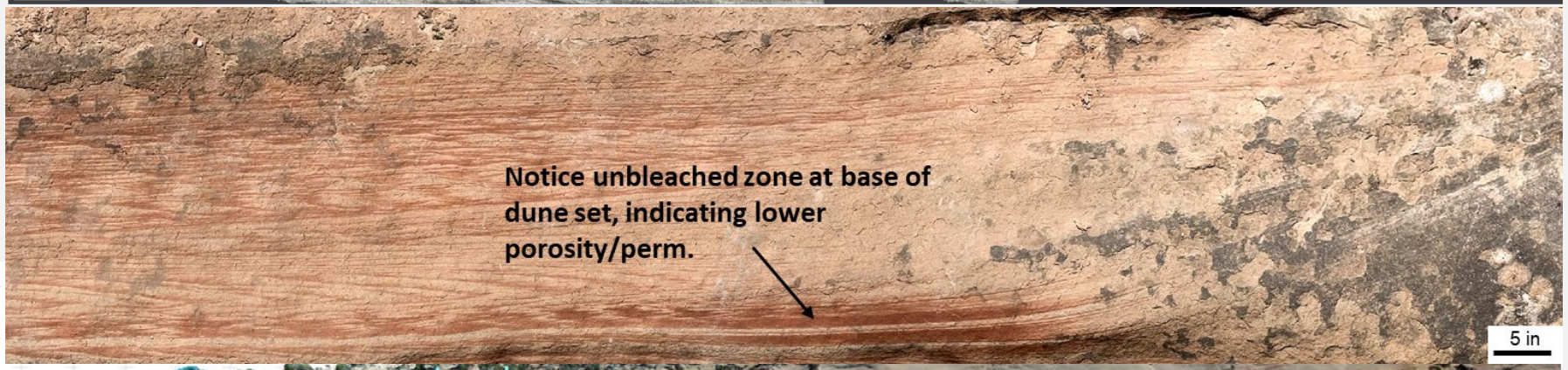
Detailed sedimentological illustrations of the Entrada Sandstone from select sites in the vicinity of Dinosaur National Monument, Utah.

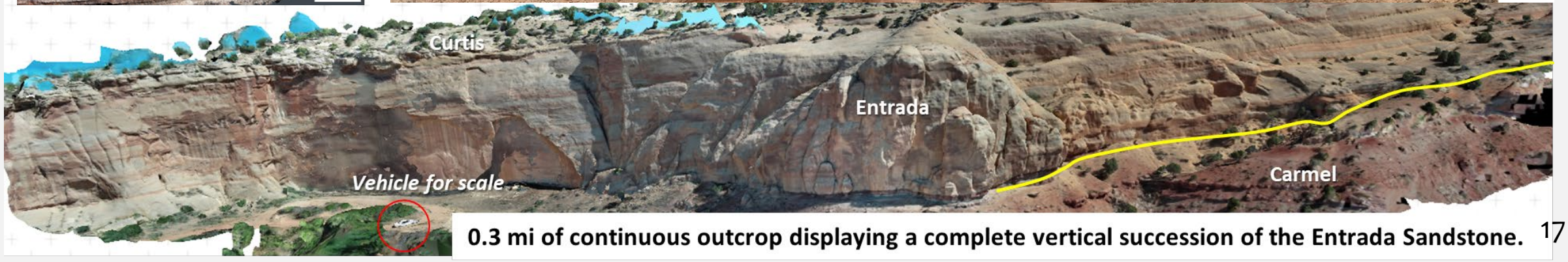




Tasks 3. Storage Complex Characterization

Examples of 3D models used to evaluate reservoir heterogeneity at different spatial scales.





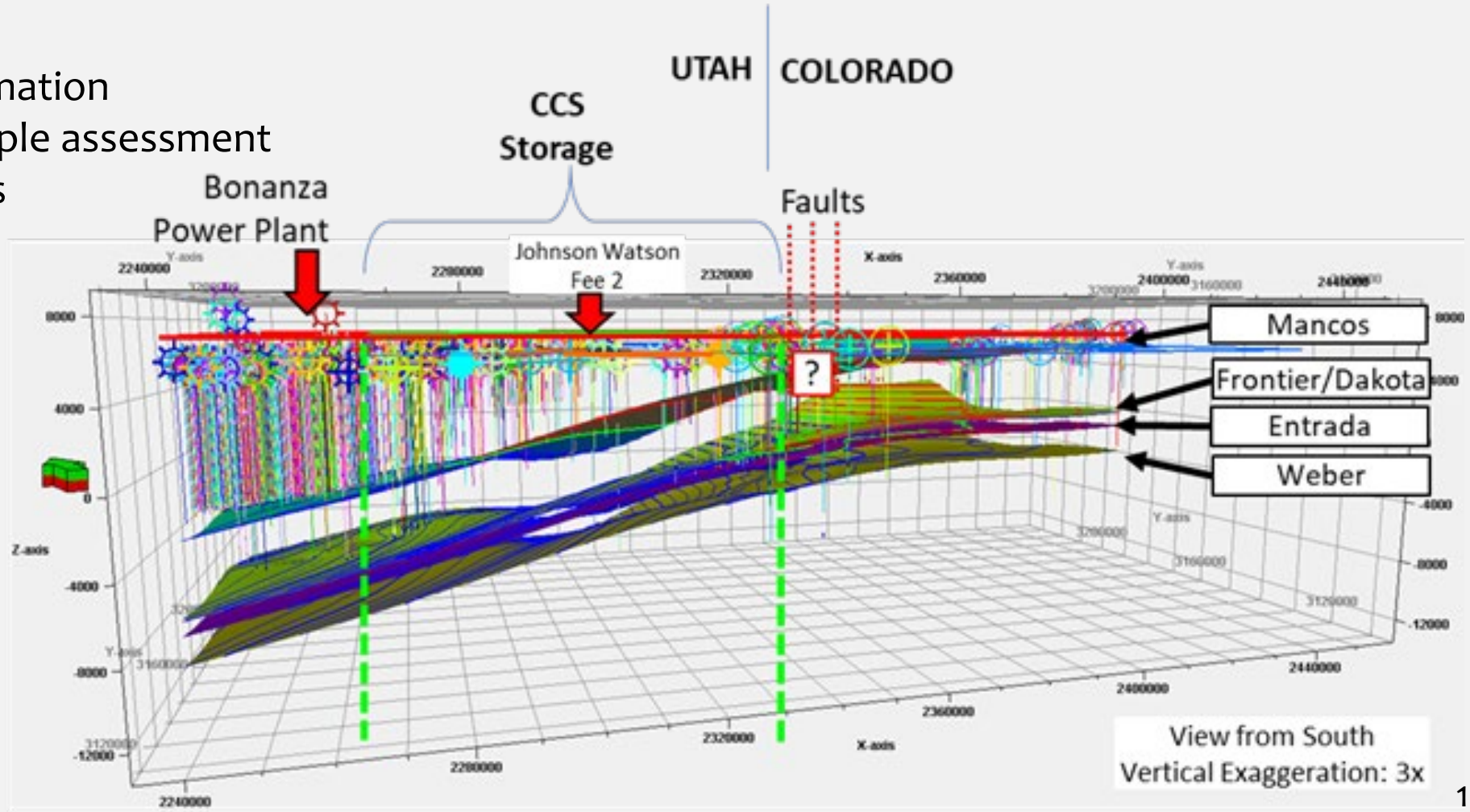
0.3 mi of continuous outcrop displaying a complete vertical succession of the Entrada Sandstone.

Tasks 4. Geologic Modeling and Simulation

Geo Model Updates

The model is updated with information of:

- New well logs
- Outcrop information
- Core/Chip sample assessment
- Seismicity lines



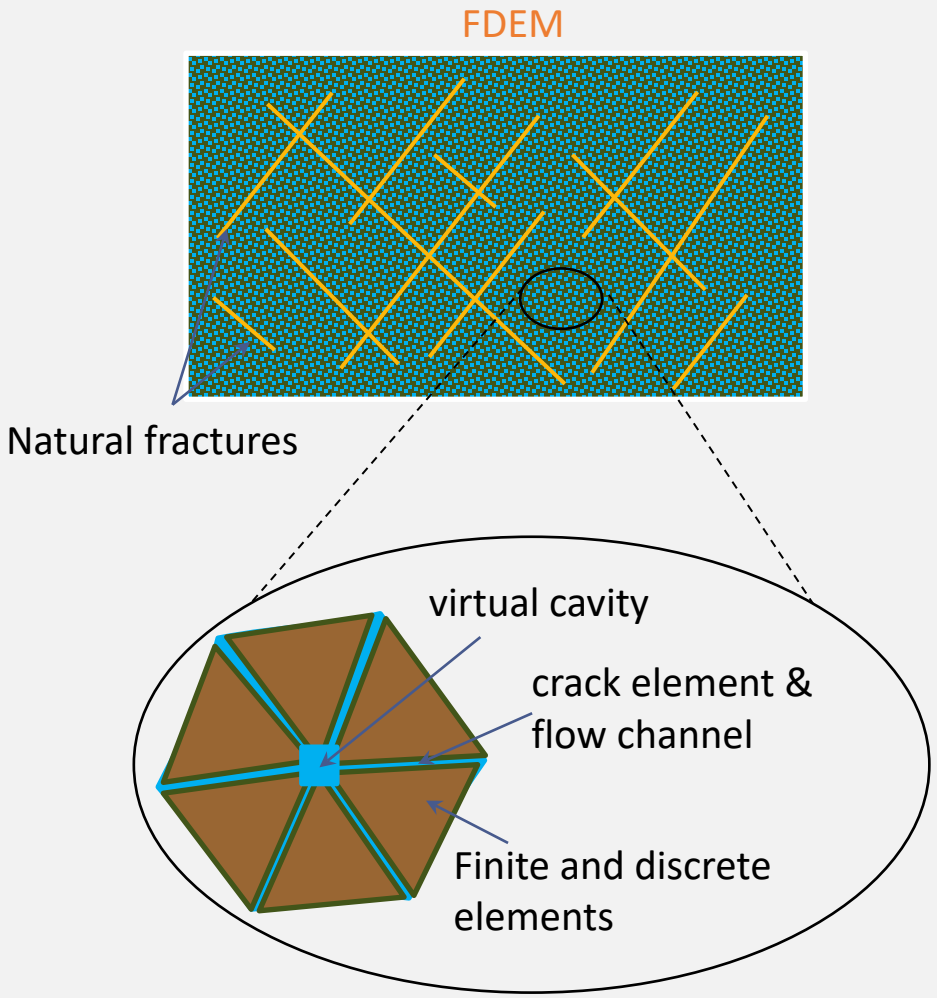
Tasks 4. Geologic Modeling and Simulation

Fluid Injection Induced Micro-Seismicity Simulations

- Formations with different fabrics and boundary conditions can cause different seismic behavior.
- Trends can be formulated when the involved physical processes are understood.

- Using alternative techniques to quantify fluid injection induced micro-seismicity.

- Key parameters:
  - Reservoir rock hydromechanical properties
  - In-situ stress
  - Injection characteristics



Tasks 5. Risk Assessment and Mitigation Plans

Uinta Basin CarbonSAFE

Risk FEP Evaluation - Part 1

Risk FEP Evaluation - Part 2

Qualitative Risk Assessment: A Risk Questionnaire

Use features, events, and processes (FEPs) to identify potential risks.

-25 to -20: Non-operable
-16 to -10: Intolerable
-9 to -5: Undesirable
-4 to -2: Acceptable
-1: Negligible

Categories/Groups:

- Economic
- Environmental
- Legal/Policy
- Social
- Management
- Technical
  - Characterization
  - Monitoring
  - Simulation
  - Operation

MITIGATION
Control Measures
PREVENTION

LIKELIHOOD

SEVERITY

		Improbable 1	Unlikely 2	Possible 3	Likely 4	Probable 5
Light (L)	-1	-1 1L	-2 2L	-3 3L	-4 4L	-5 5L
Serious (S)	-2	-2 1S	-4 2S	-6 3S	-8 4S	-10 5S
Major (M)	-3	-3 1M	-6 2M	-9 3M	-12 4M	-15 5M
Catastrophic (C)	-4	-4 1C	-8 2C	-12 3C	-16 4C	-20 5C
Multi-Catastrophic (MC)	-5	-5 1MC	-10 2MC	-15 3MC	-20 4MC	-25 5MC

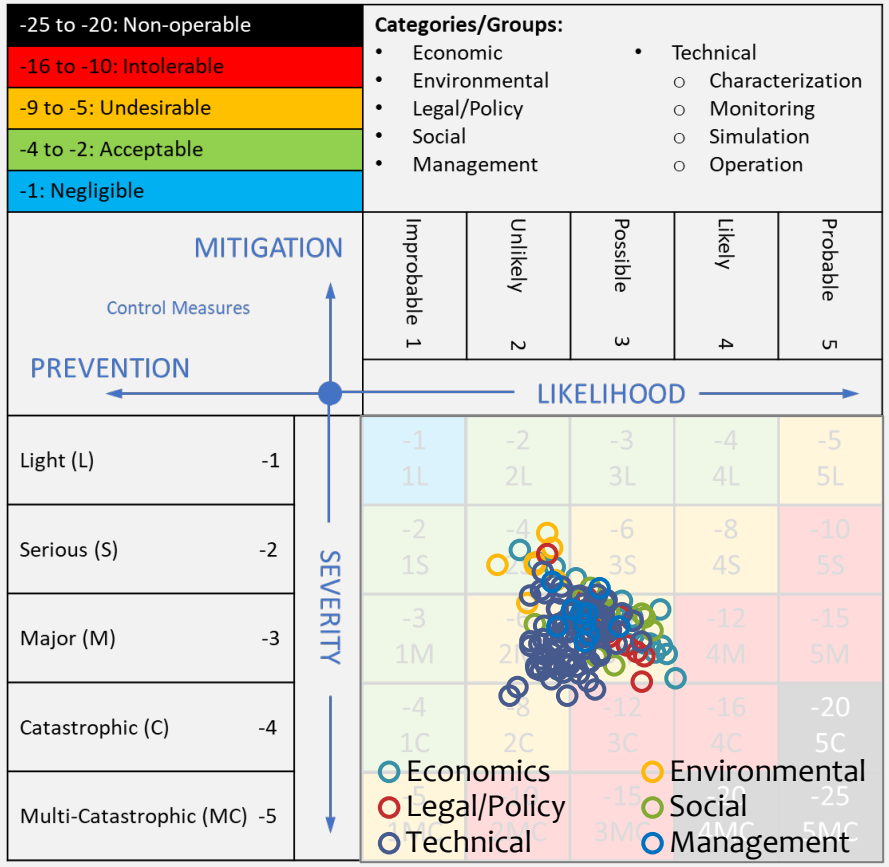
Tasks 5. Risk Assessment and Mitigation Plans

Qualitative Risk Assessment: A Risk Questionnaire

Use features, events, and processes (FEPs) to identify potential risks.

Risk FEP Evaluation - Part 1

Risk FEP Evaluation - Part 2



Ranking	Category	FEP
1	Economics	Financial support from investors and/or government
2	Legal/Policy	Legislation affecting CCUS
3	Economics	Capital cost
4	Economics	Carbon market
5	Legal/Policy	Policies affecting CCUS
6	Economics	CCUS commercialization
7	Economics	Financial viability
8	Characterization	Fractures and faults
9	Social	Low level of trust towards authorities
10	Legal/Policy	Permits (injecting)

Tasks 5. Risk Assessment and Mitigation Plans

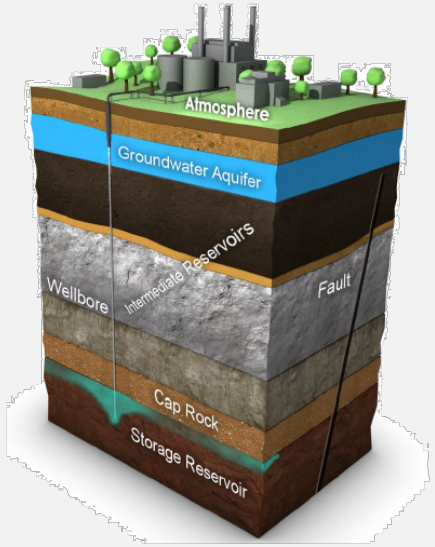
Utah Legislations & Policies

- ❑ Utah State House Bill (H.B.) 244 Geological Carbon Sequestration
  - Provides a policy pathway for Utah Division of Oil, Gas & Mining (DOGM) to establish a permitting program for commercial geologic carbon sequestration projects in Utah
  - Addresses liability, ownership and other critical legal issues
- ❑ H.B. 452 Carbon Capture Amendments
  - Provides additional clarification on addressing liability, including the establishment and funding for the Carbon Dioxide Storage Fund
- ❑ Utah Class VI Permitting Primacy
  - A draft Class VI rule & applying for Class VI regulatory primacy from the U.S. Environmental Protection Agency

Tasks 5. Risk Assessment and Mitigation Plans

Risks of Leakage and Seismicity

'NRAP open IAM' simulates behavior of a CO_2 storage site through an integrated assessment model combining reduced order models for multiple components including reservoir, leakage pathways and receptors (groundwater)

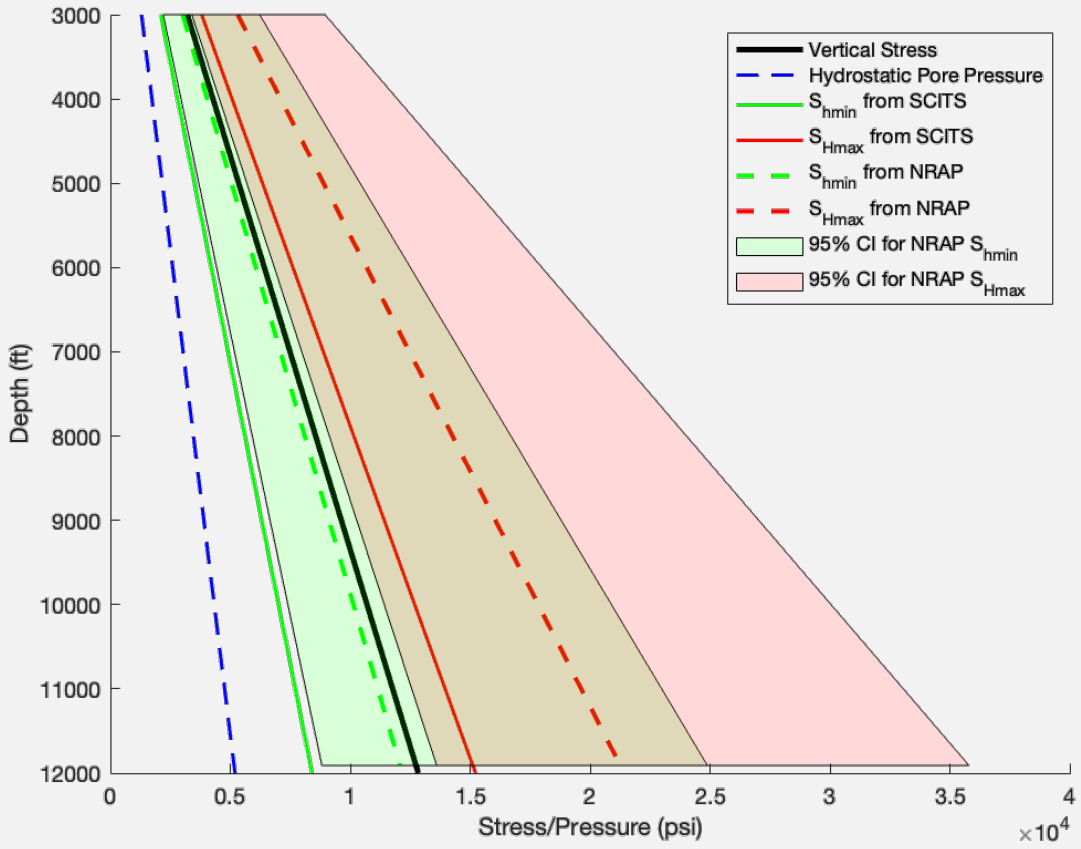


Aquifer ROM → Groundwater Impacts

Wellbore ROM → CO_2/Brine Movement

Reservoir ROM → Reservoir Changes

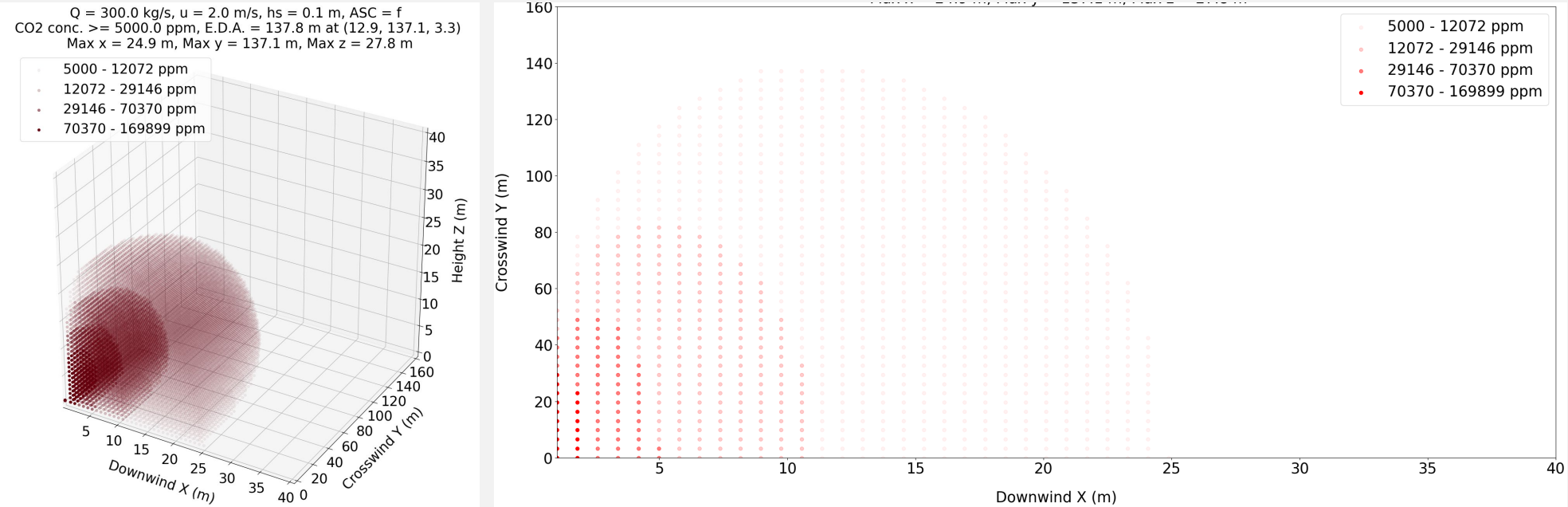
Vasylkivska et al, Env. Mod. Soft., 2021, Pawar et al, IJGGC, 2016



Tasks 5. Risk Assessment and Mitigation Plans

Risks of Transportation

- SimCCS is used to evaluate potential impact radius (PIR) by considering a CO_2 release event.
- Extreme weather/climate changes, seismicity, impurity of CO_2 sources, etc., are considered as key factors.



Example of PIR estimate using SimCCS

Tasks 6. Preliminary CO2 Management and Monitoring Plan

CO2 Source Assessment

CO2 Emission in 2023	CO2 Purity from Flue Gas	CO2 Recovery Rate *	Potential Captured CO2
3,865,499 short tons	12.7%	80-95%	3.09-3.67 million short tons

- Liquid amine sorbent is considered for CO2 capture process.
- Pipeline will be the main option for CO2 transportation.
- Gas separation and purification is required to transport CO_2 effectively.

- HYSYS simulation will be used to estimate the gas composition after the capture process.
- Factors affecting the pipeline and compressor design, including gas composition, pressure conditions, and corrosion will be addressed.
- FECM/NETL CO2 Transport Cost Model ** will be used to optimize the designs.

*. IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B.,O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and NewYork, NY, USA, 442 pp.

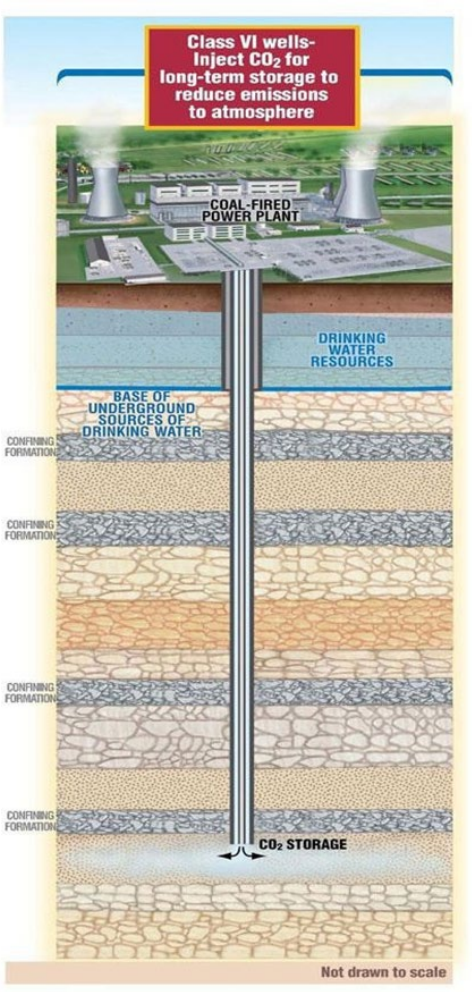
**. Morgan, David, Guinan, Allison, & Sheriff, Alana. FECM/NETL CO2 Transport Cost Model (2022): Description and User's Manual. United States. https://doi.org/10.2172/1856355

Tasks 7. Plans for a Subsequent Complete Site Characterization Effort and UIC Class VI Permitting

The team is interpreting the UIC Class VI regulation (40 CFR 146.82 – 146.95) and preparing the following plans for detailed site characterization:

- Regional geology, and local structural geology,
- Maps and cross-sections of the AoR,
- Faults and fractures,
- Injection and confining zones,
- Geomechanics and petrophysics,
- Seismicity,
- Hydrology and hydrogeology,
- Geochemistry,
- Local climate, weather, air, soil and water information,
- Site suitability.

The project team will coordinate with operators to establish a framework for developing a UIC Class VI permit application for the study area.

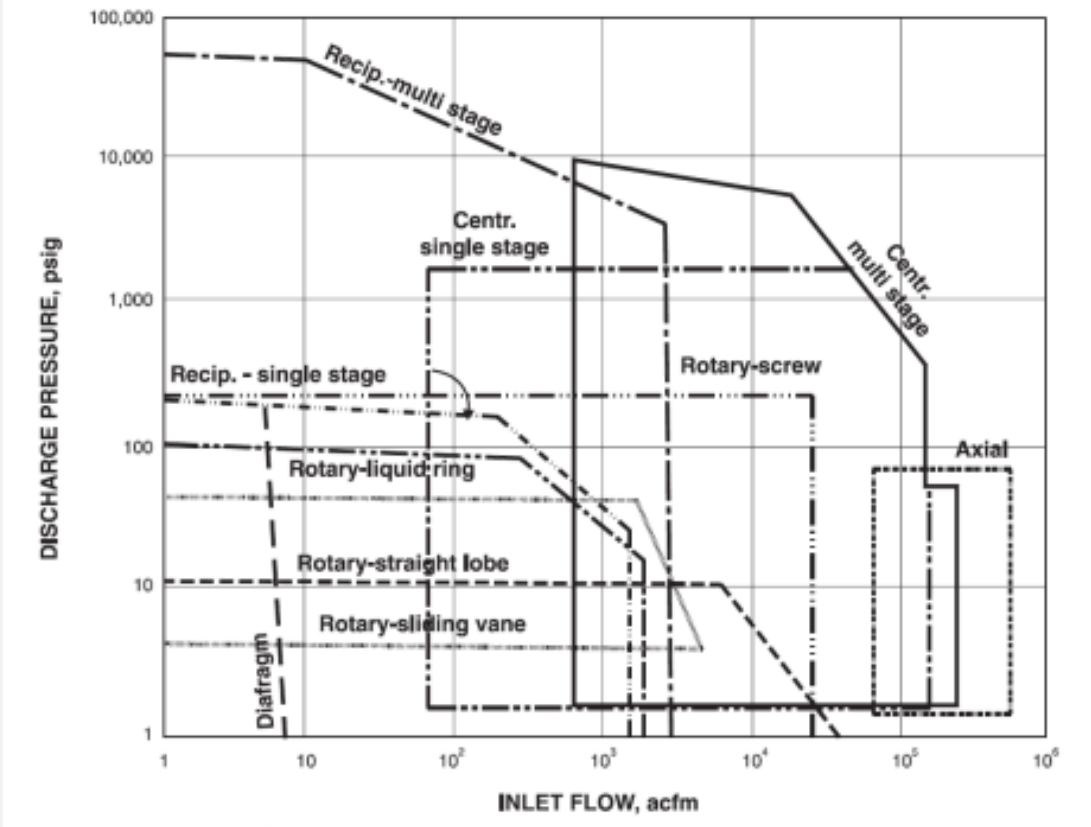


Tasks 8. Technical and Economic Feasibility Evaluation

Natural Gas --> CO2 Pipeline Retrofitting Considerations

- Retrofitting costs are driven by compressor selection, dependent on mass flow rate, existing pipeline length/diameter, and discharge pressure.
- The lower pressure rating of existing natural gas pipelines (ANSI Class 600 vs. 900) means retrofitting is typically not practical for large CO_2 flow rates (1BCSF/d, ~55k t CO_2/d) over distances >100 mi.
  - Feasible if diameters are large enough and throughput volumes are optimized.
  - A few examples of successful retrofits for lower flow rates and/or shorter distances (<100 miles).

Common Compressor Selections for CO_2 Transport



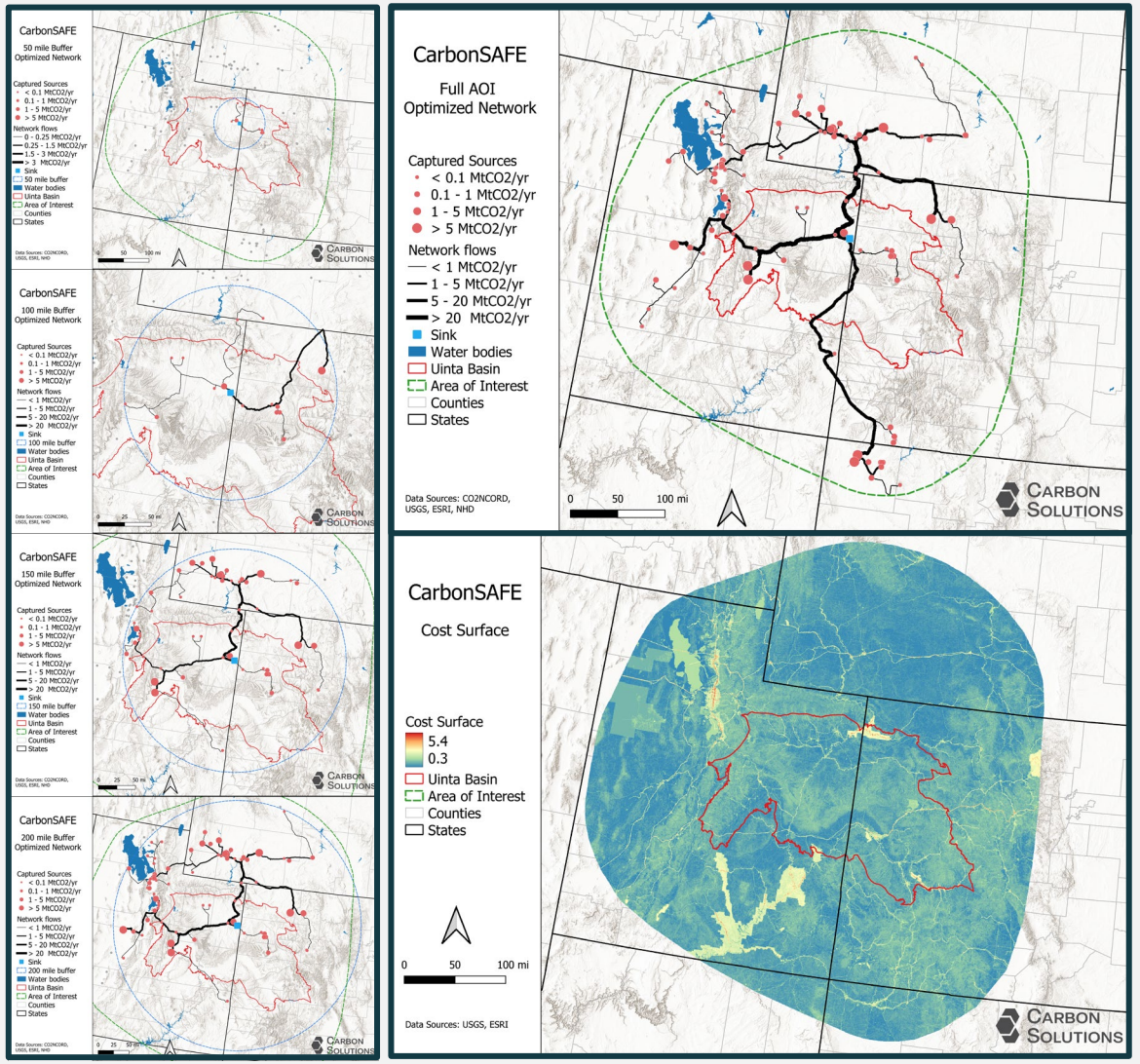
Trimeric Corporation, CO_2 Compression Options for CCUS

Tasks 8. Technical and Economic Feasibility Evaluation

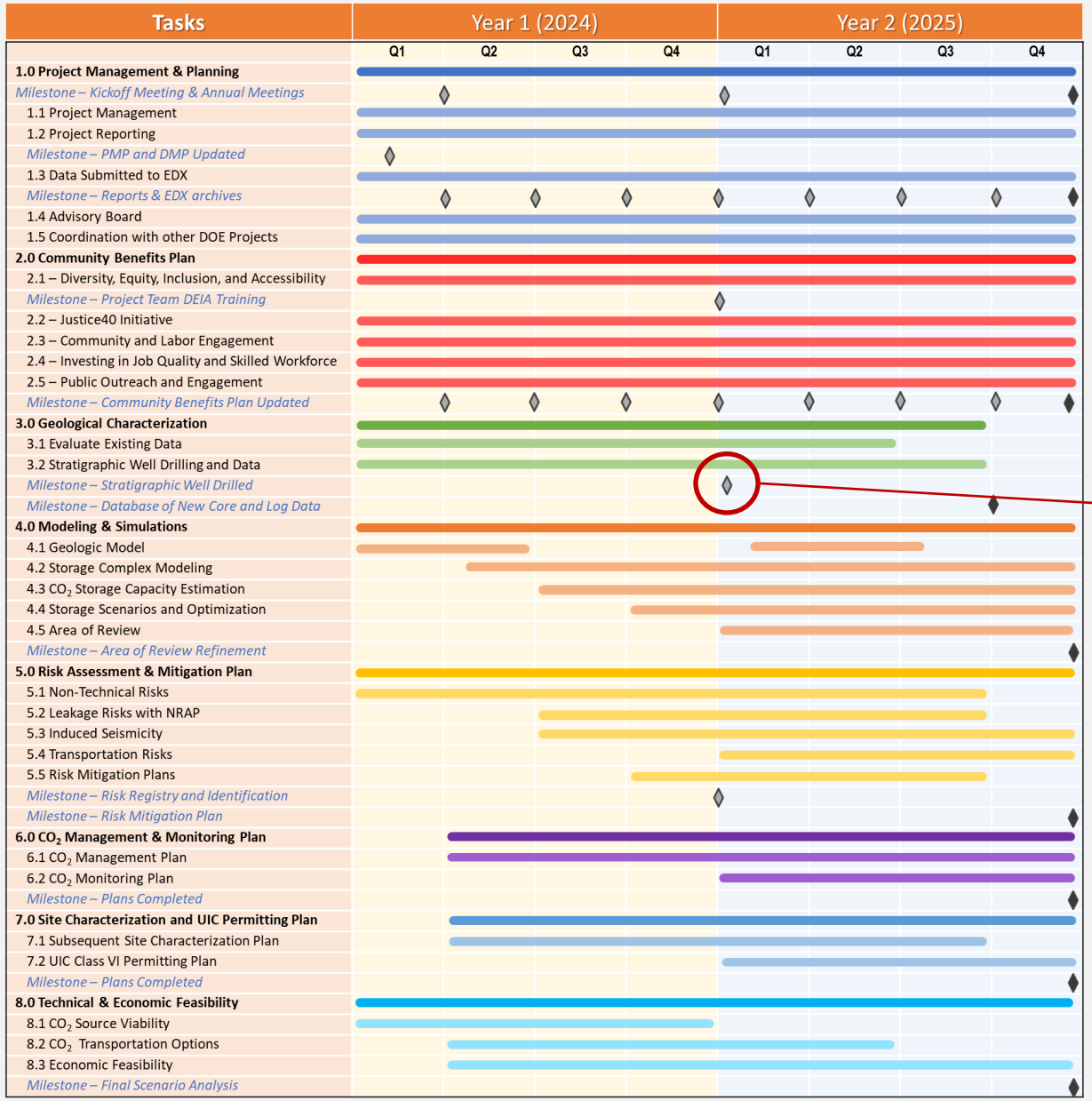
Initial Exploratory Scenarios

- Possible scenarios for CO2 capture, transport, and storage by defining buffers of 50, 100, 150, and 200 miles around the Bonanza's sink.
- Maximum potential of capturing 80.6 MtCO2/yr. within the Area of Interest (AOI).

Sector	Streams	Facilities	Capturable CO2 (MtCO2 per yr)	Average Capture unit cost ($/tCO2)
Power Plants - Coal	14	12	57.81	45.77
Oil & Gas	51	38	8.01	56.39
Mining	13	6	4.33	51.92
Power Plants - Gas	13	13	4.17	64.45
Refineries	11	6	2.38	67.37
Cement	2	2	1.18	74.13
Lime & Gypsum	2	2	0.68	55.69
Chemicals	1	1	0.40	21.90
Metals - Other	1	1	0.23	69.98
Facilities	3	3	0.21	69.98
Natural Gas Processing	4	4	0.19	69.98
Hydrogen	1	1	0.15	71.13
Manufacturing	4	4	0.15	69.98
Power Plants - Other Fossil	1	1	0.15	64.45
Iron & Steel	3	2	0.13	61.30
Power Plants - Biomass	3	3	0.13	63.87
Chemicals - Other	2	2	0.11	69.98
Waste - Landfill	1	1	0.10	69.98
Pulp & Paper	1	1	0.04	69.98
Minerals - Other	1	1	0.03	43.92
Food & Ag	1	1	0.03	69.98
Power Plants - Other	1	1	0.02	64.45
Total	**134**	**106**	**80.63**	**58.67**



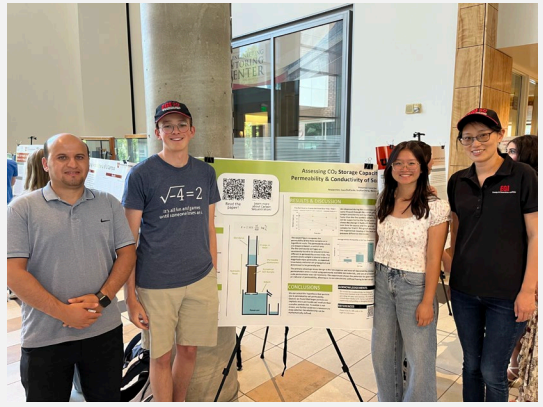
Project Timeline



A delay of the stratigraphic well drilling plan

Project Plans

- Using the geology characterization data, the team will update the geologic model and conduct reservoir simulations to better estimate the storage potential, area of review (AoR), and risks.
- The team will work closely with our field operator to design and drill the stratigraphic well.
- The team will work with local stakeholders for developing a potential CCUS hub in the basin.



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