Southwest Regional Partnership on Carbon Sequestration

Phase III Field Test Overview and Summary

Presented by
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New Mexico Tech

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Acknowledgements

- Many thanks to the U.S. Department of Energy and NETL for supporting this project

- We express our gratitude also to our many industry partners, who have committed a great deal of time, funding and other general support for these projects

- The work presented today is co-authored by all partners in the Southwest Partnership

Presentation Outline

- **Phase II - Phase III Integration**
- Summary of Phase III Project
  - location
  - site characterization
  - injection plans
  - baseline analysis to date
- Monitoring and Mitigation Planning
- Summary

Southwest Partnership Objectives

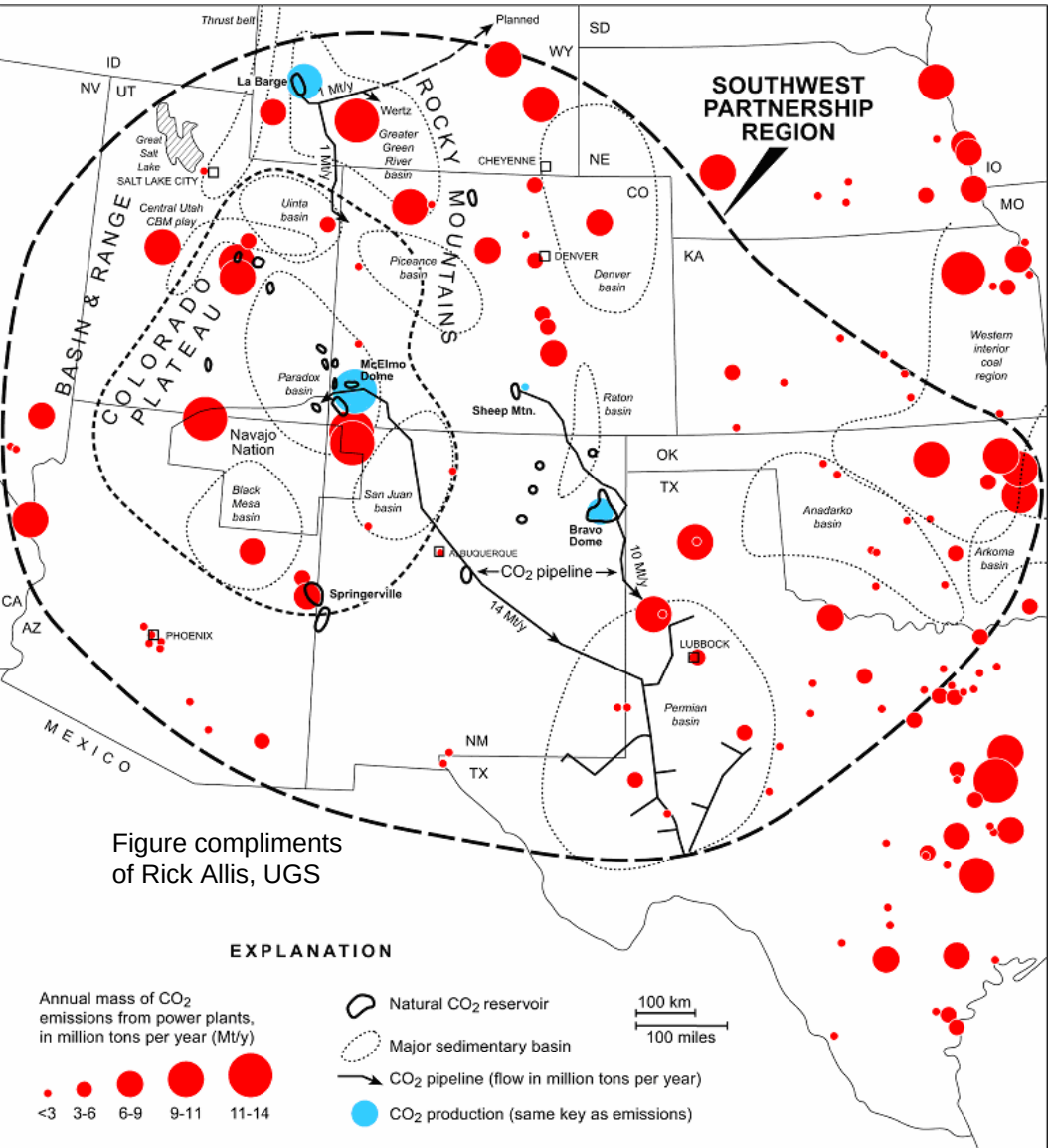


Figure compliments of Rick Allis, UGS

Phase I - Characterization:

- **Characterize SW region carbon sources and sinks**
- **Identify the best options by linking carbon sources to carbon sinks**

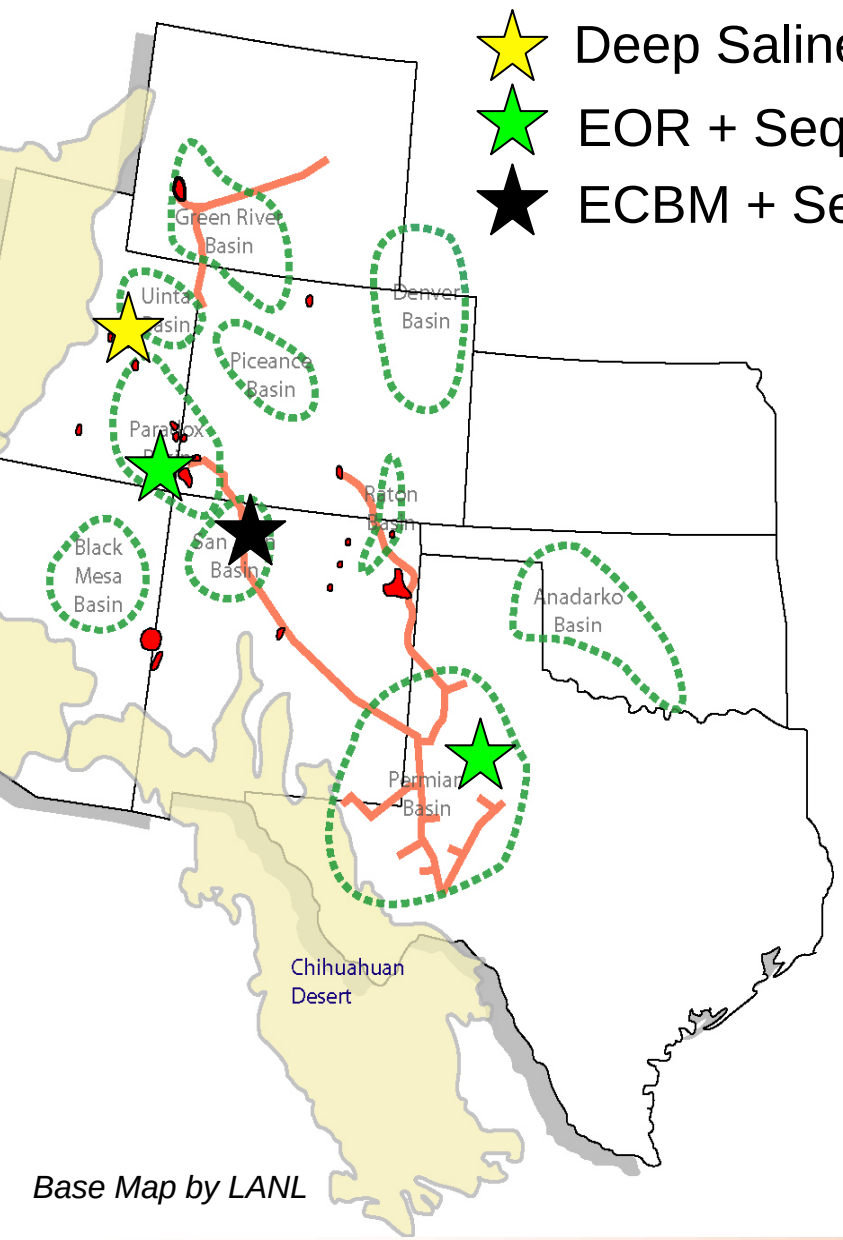
Phase II - Validation:

- **Demonstrate these options with medium-scale field tests**

Phase III - Deployment:

- **Deploy commercial-scale sequestration demonstration**

SWP Phase II - Phase III Integration



Base Map by LANL

<u>Integrated Goals</u>:

Based on common themes in the results and "lessons learned":

(1) Develop a "template" or "blueprint" for future commercial-scale sequestration.

(2) Evaluate "portability" or transferability of results, from formation-to-formation or site-to-site. This includes monitoring, risk assessment, and mitigation planning.

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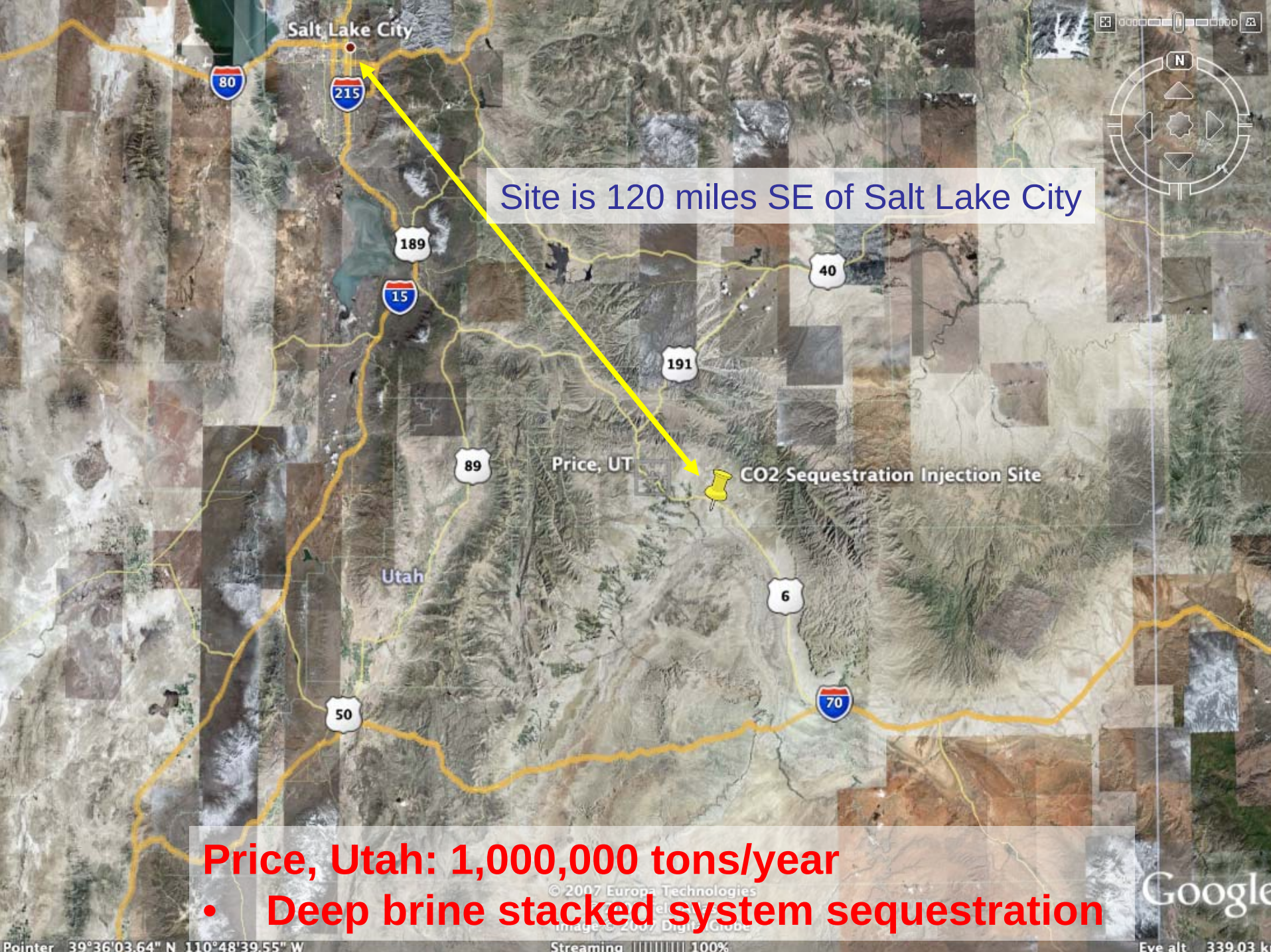

Salt Lake City
80
215
189
15
40
191
89
Price, UT
CO2 Sequestration Injection Site
Utah
6
50
70
Site is 120 miles SE of Salt Lake City
Price, UT: 1,000,000 tons/year
• Deep brine stacked system sequestration
© 2007 Europa Technologies
Image © 2007 DigitalGlobe
Google
Pointer 39°36'03.64" N 110°48'39.55" W
Streaming 100%
Eye alt 339.03 k

Price, Utah: 1,000,000 tons/year

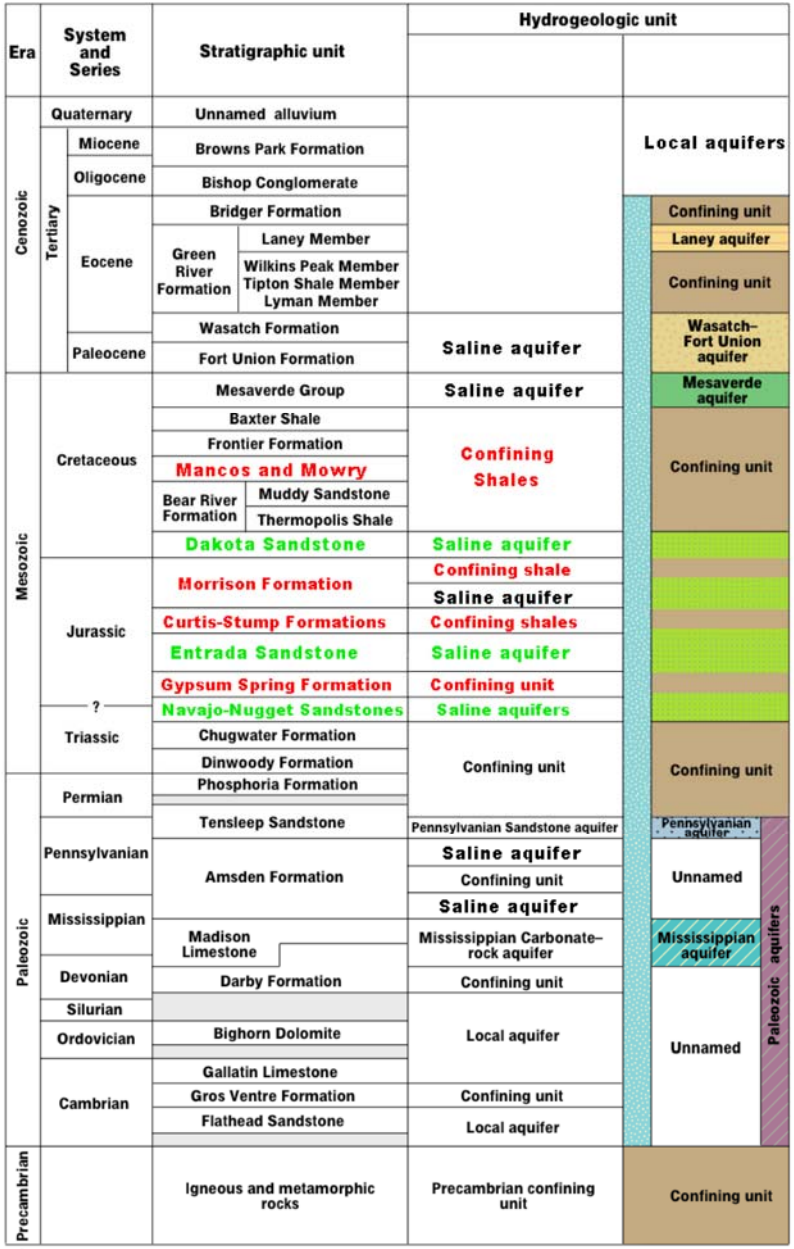
- **Deep brine stacked system sequestration**

Phase III Farnham Dome Site Characterization

- Farnham Dome Data
  - Farnham Dome producing food-grade CO_2 for greater than 80 years
  - >20 wells on and in vicinity yield formation depth and thickness
  - Available well logs being digitized to database

- Farnham Dome Reservoirs of Interest
  - 2 target formations identified: **Wingate** and **White Rim Ss**
  - Both aquifers are capped by low permeability formations
  - Both aquifers are further topped by the Navajo sandstone (CO_2 source) and its seal, the Carmel formation

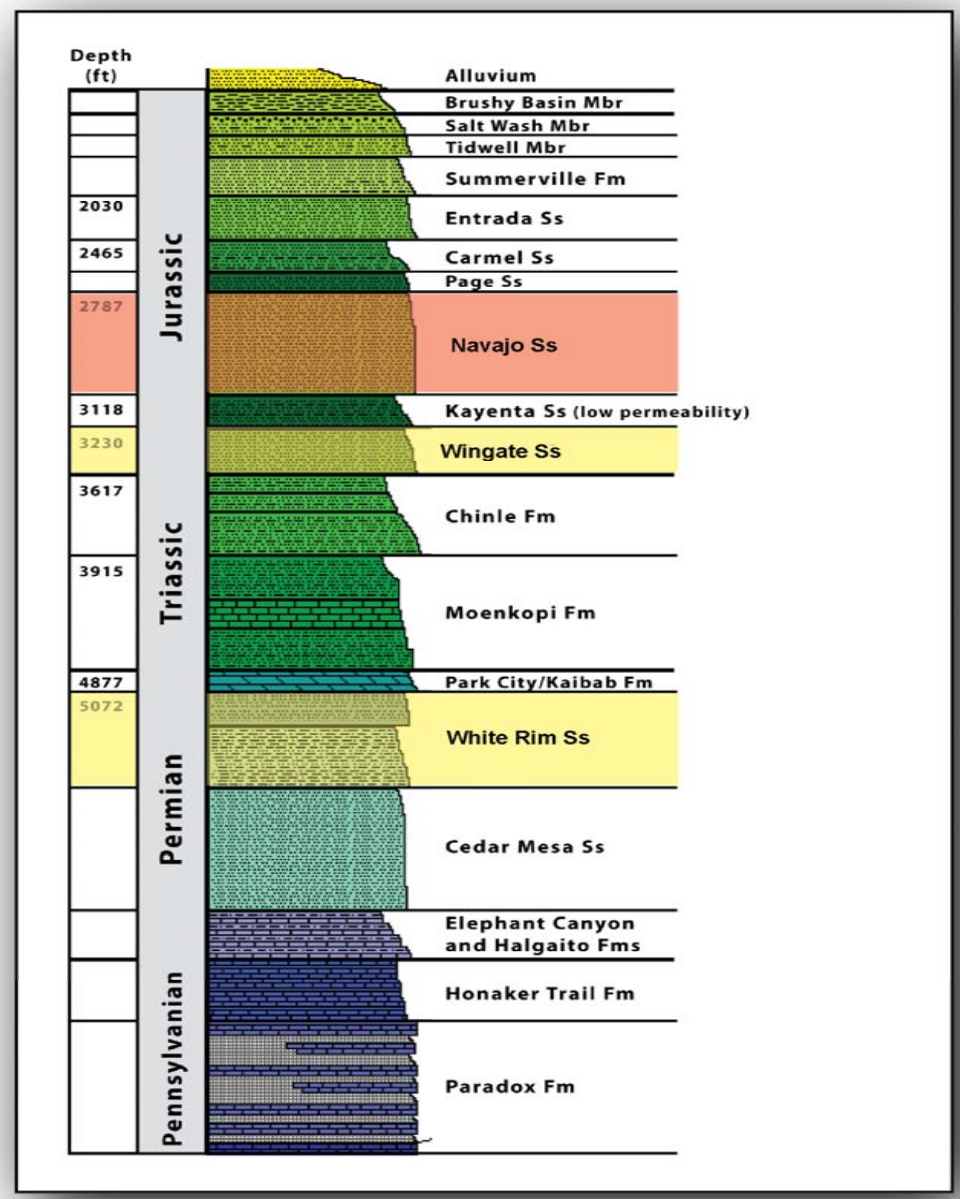
Phase III Regional Characterization



This stratigraphy is representative of the entire Southwest region, and surrounding areas.

A critical point: this "stacked system" of alternating reservoirs and seals is present throughout the region!

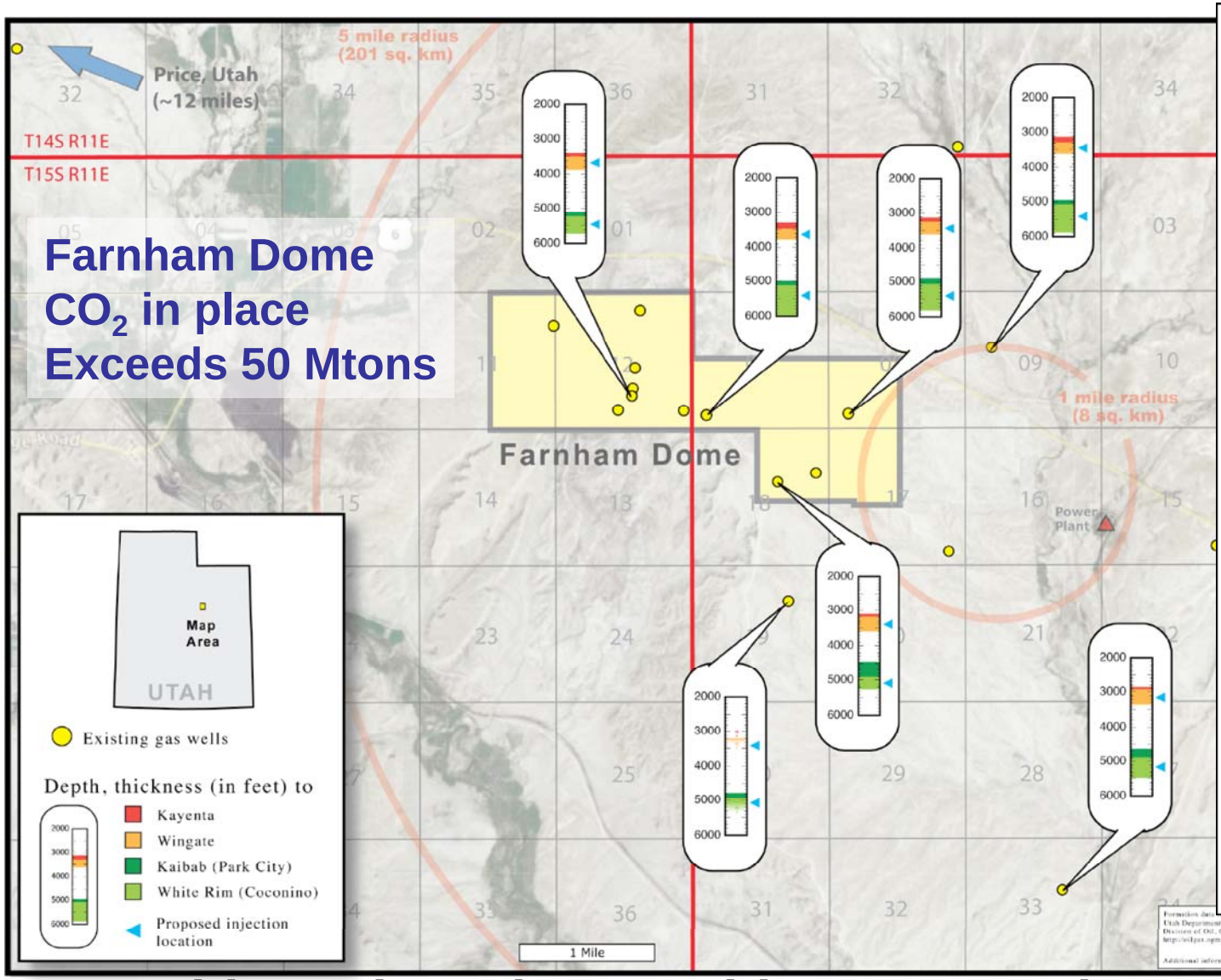
Phase III Site Characterization



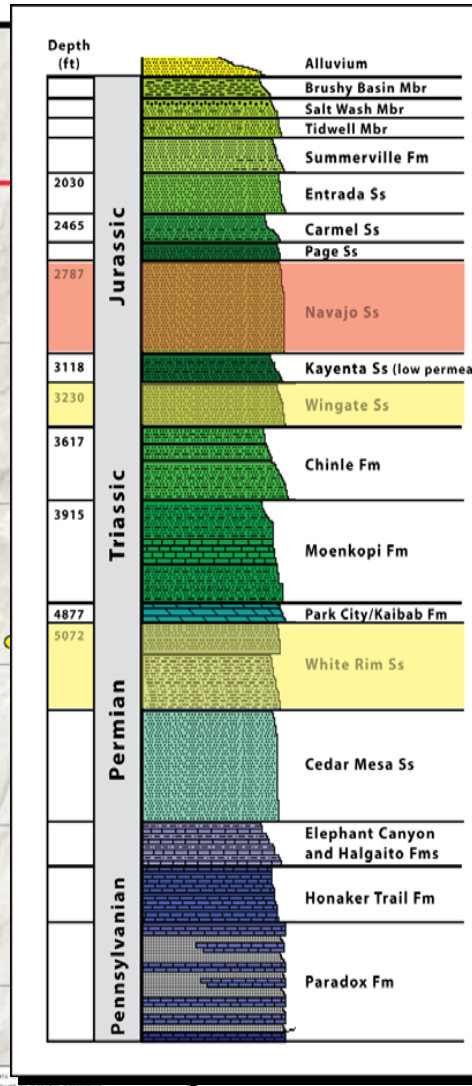
Focusing in on the deep strata:

Our target geological sequestration formations are Jurassic and older formations. The proposed units of interest for Phase III deployment testing are the Navajo, Wingate, and White Rim.

Phase III Site Characterization



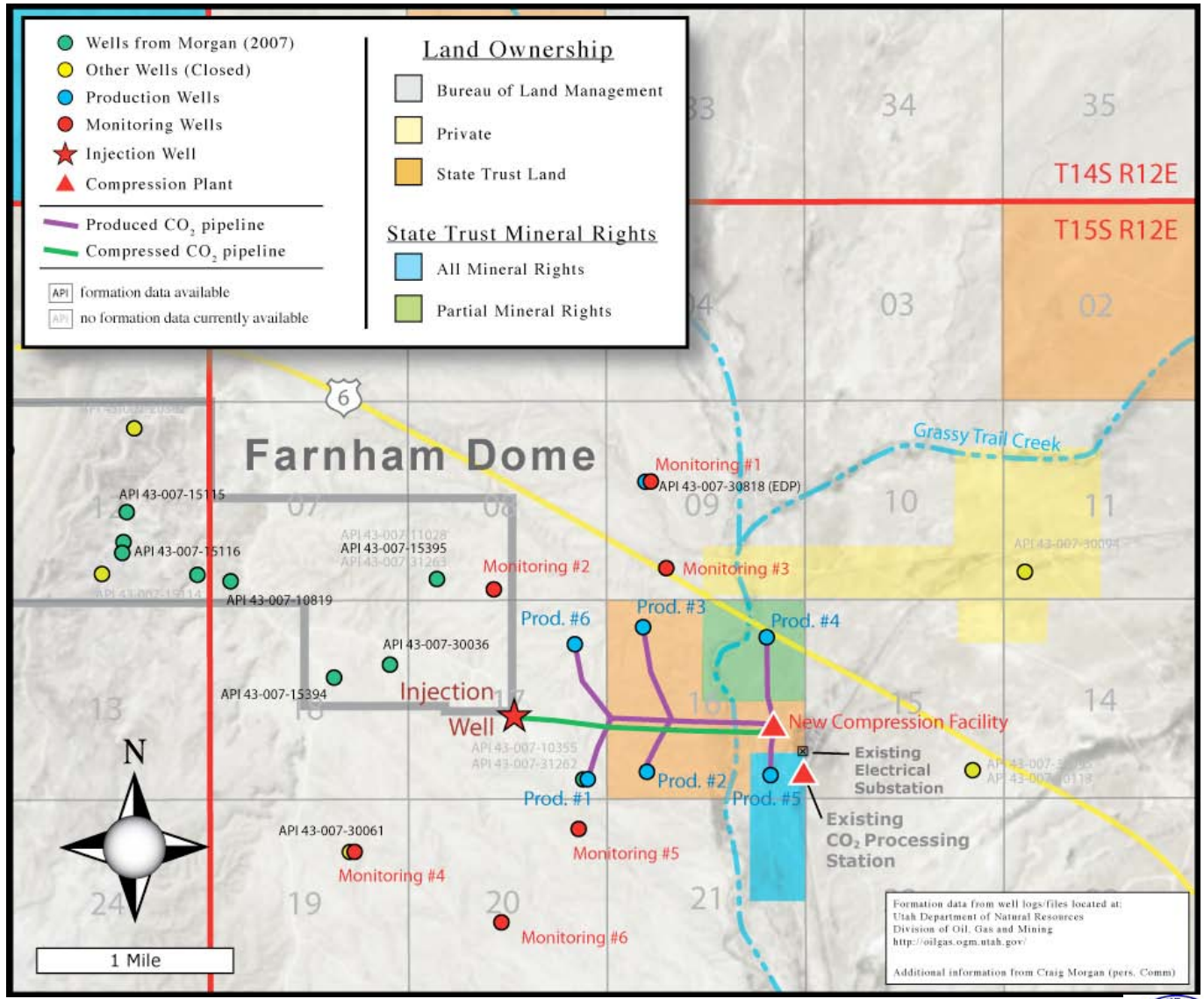
Farnham Dome
CO_2 in place
Exceeds 50 Mtons



Note: this project also provides unprecedented opportunity for very detailed study of a natural analogue.

Construction & Drilling

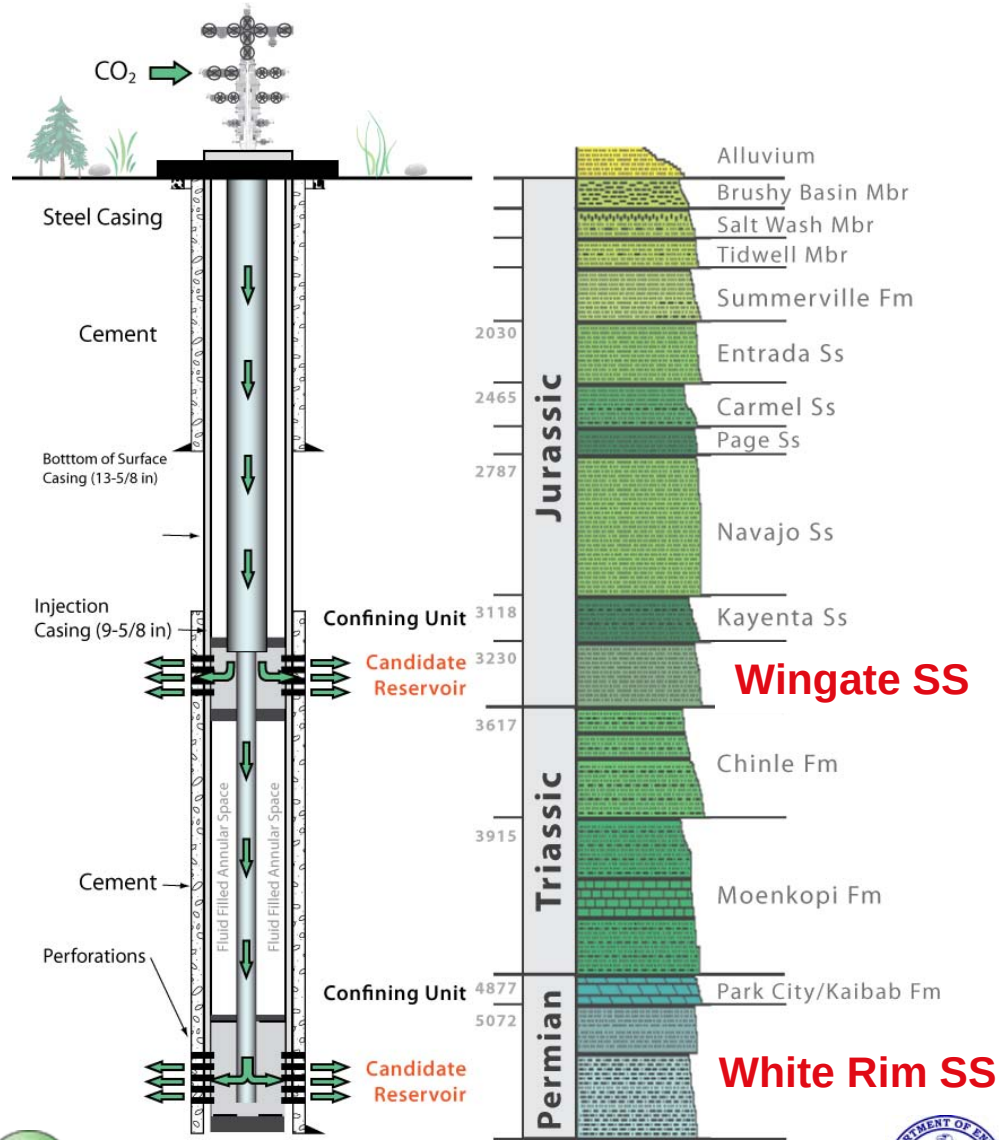
- Up to 6 production wells
- Up to 6 monitoring wells
- 1 injection well
- Stacked injection (multiple completion)
- CO_2 compression facility
- Pipeline
- Electrical substation
- Improved roads/ trails
- GPS/Seismometer stations



Construction & Drilling

Schematic of injection well design

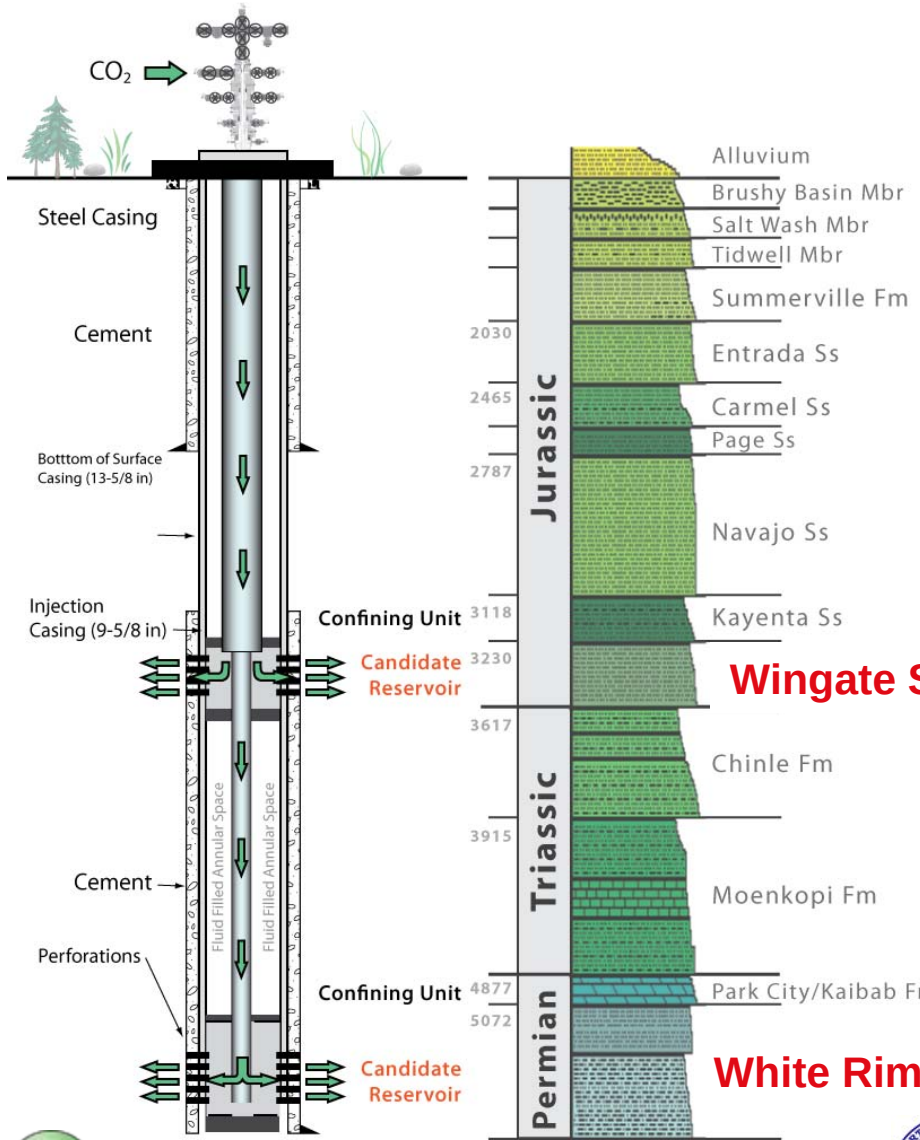
- Note relative locations of candidate sequestration targets and seals
- a “stacked system” of reservoirs/seals present throughout the SW region
- We are engineering a “dual-injection” zone to maximize capacity and mitigation plans or
  stacked storage test
- Monitoring technologies will focus on effective imaging of double- and triple-zones of CO_2 storage



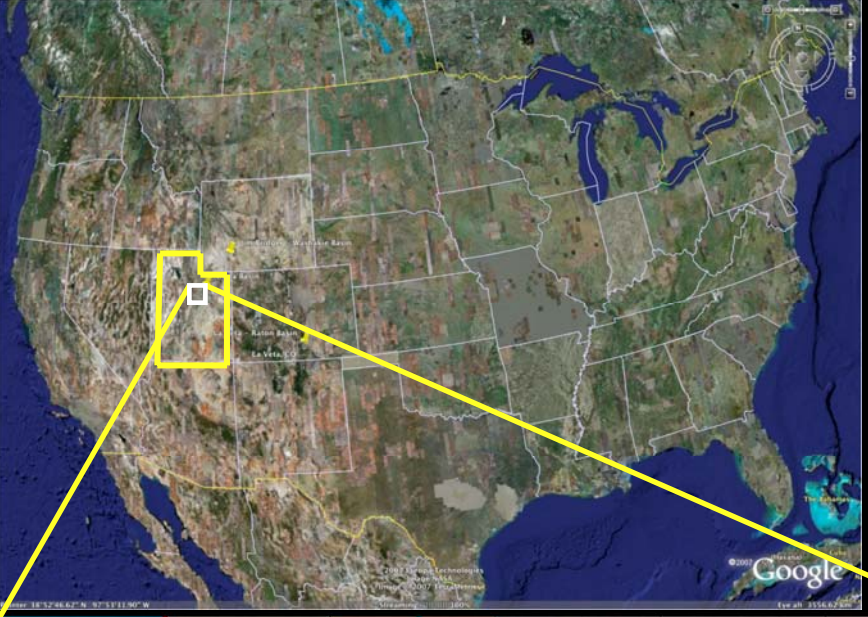
CO_2 Production & Injection

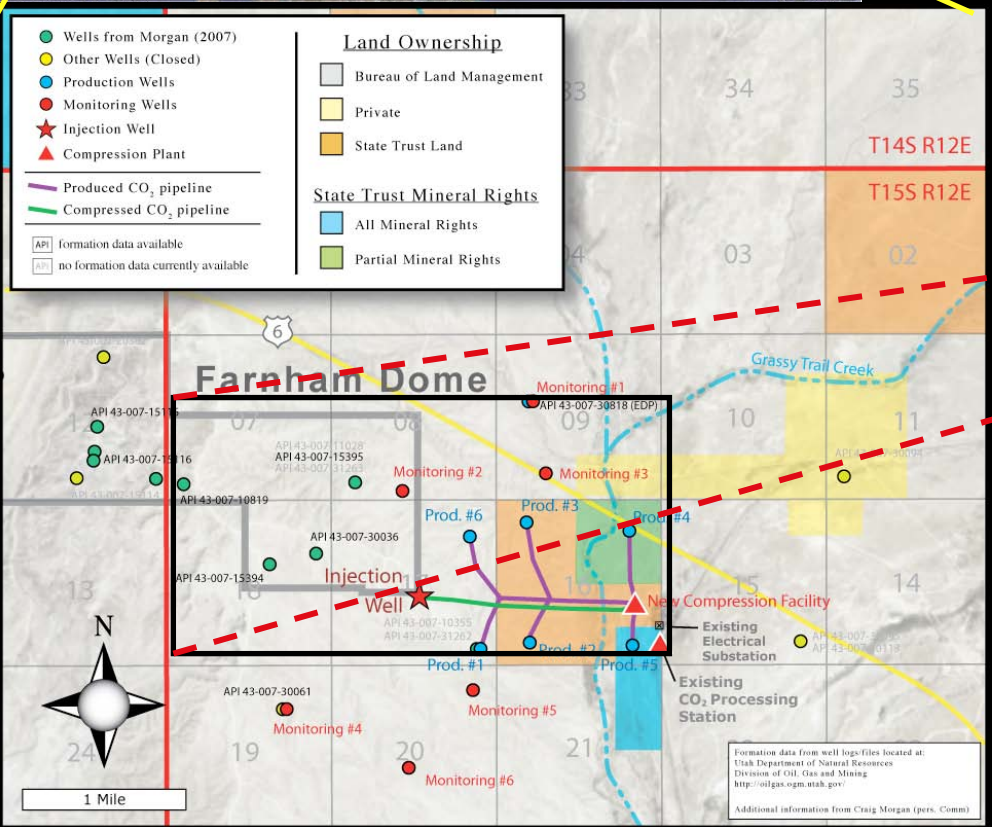
- Drilling of injection, production and monitoring wells will begin April, 2009 (following NEPA and permitting)

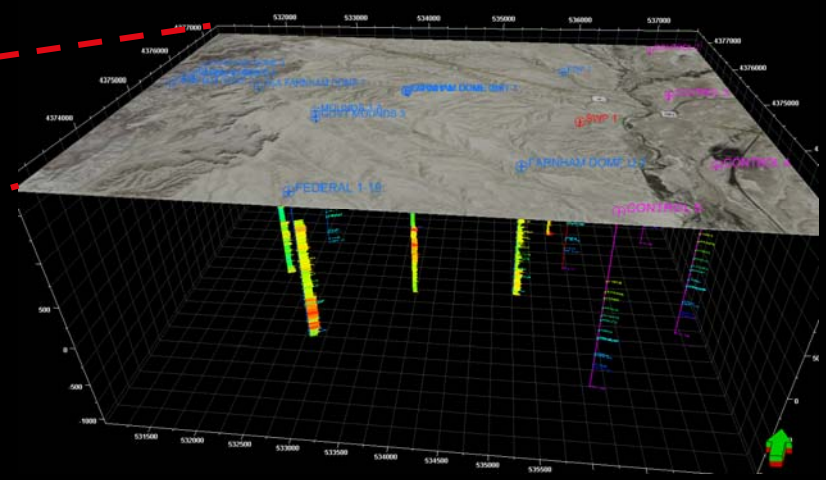
Injection July, 2009:
- 300,000 tons year 1
- 600,000 tons year 2
- 1,000,000 tons year 3
- 1,000,000 tons year 4



Baseline Site Model: Development

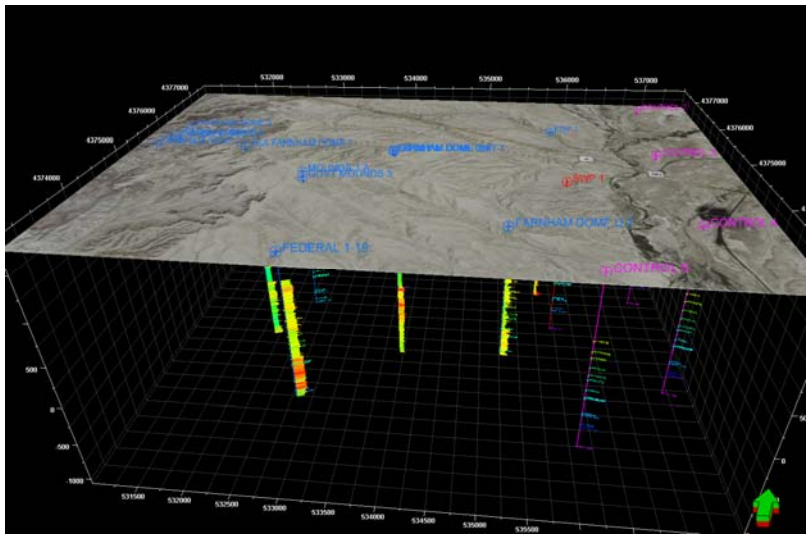




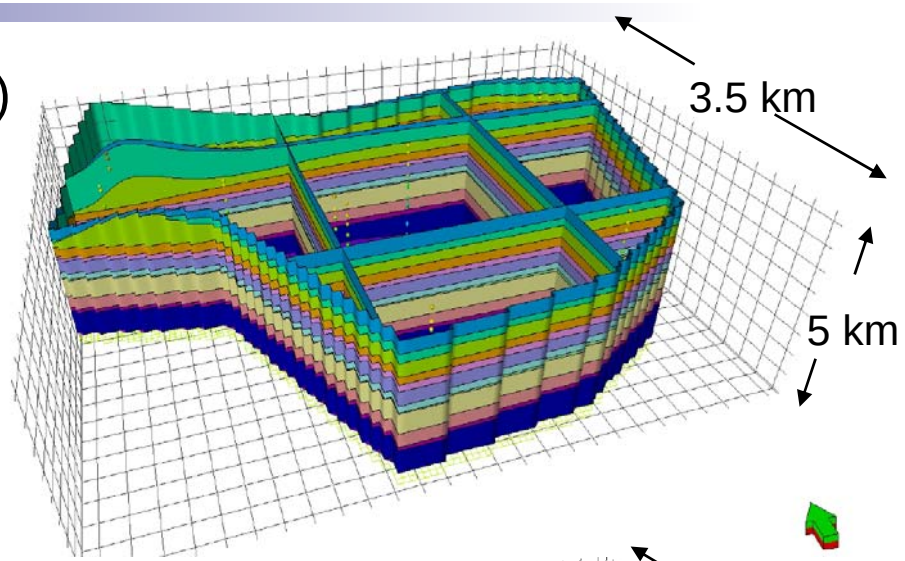


Baseline Site Model: Development

(1)



(2)



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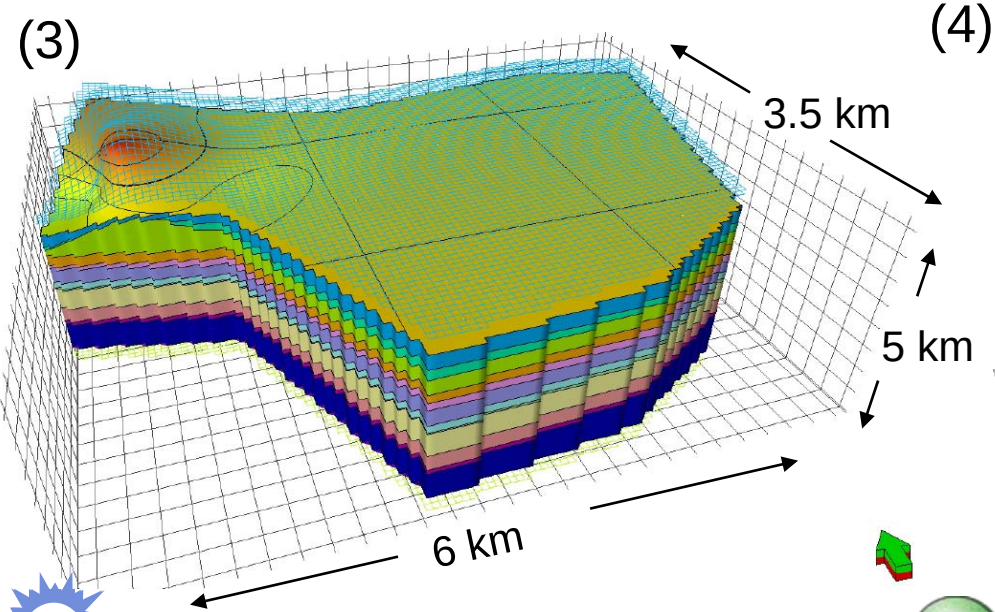

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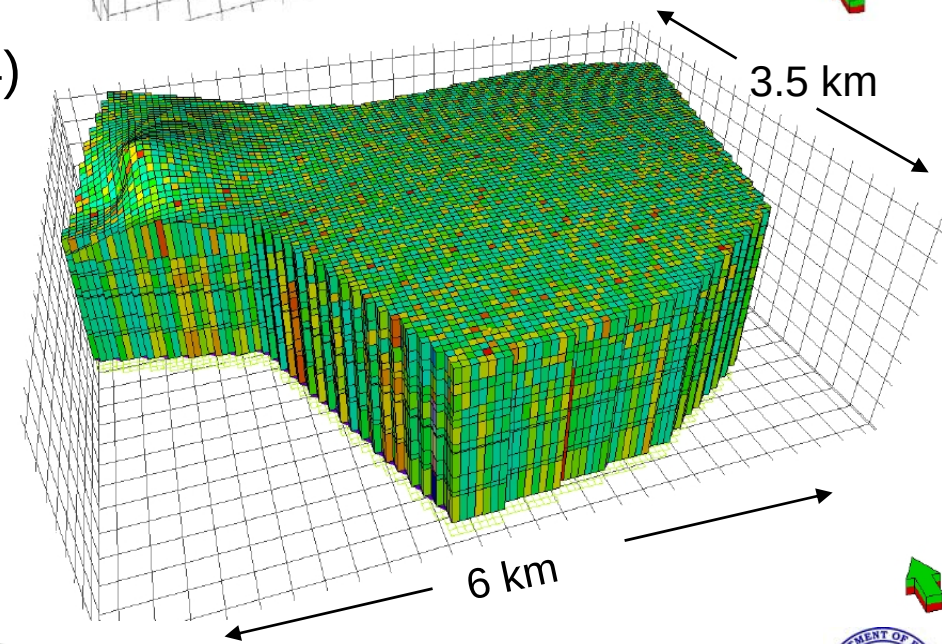
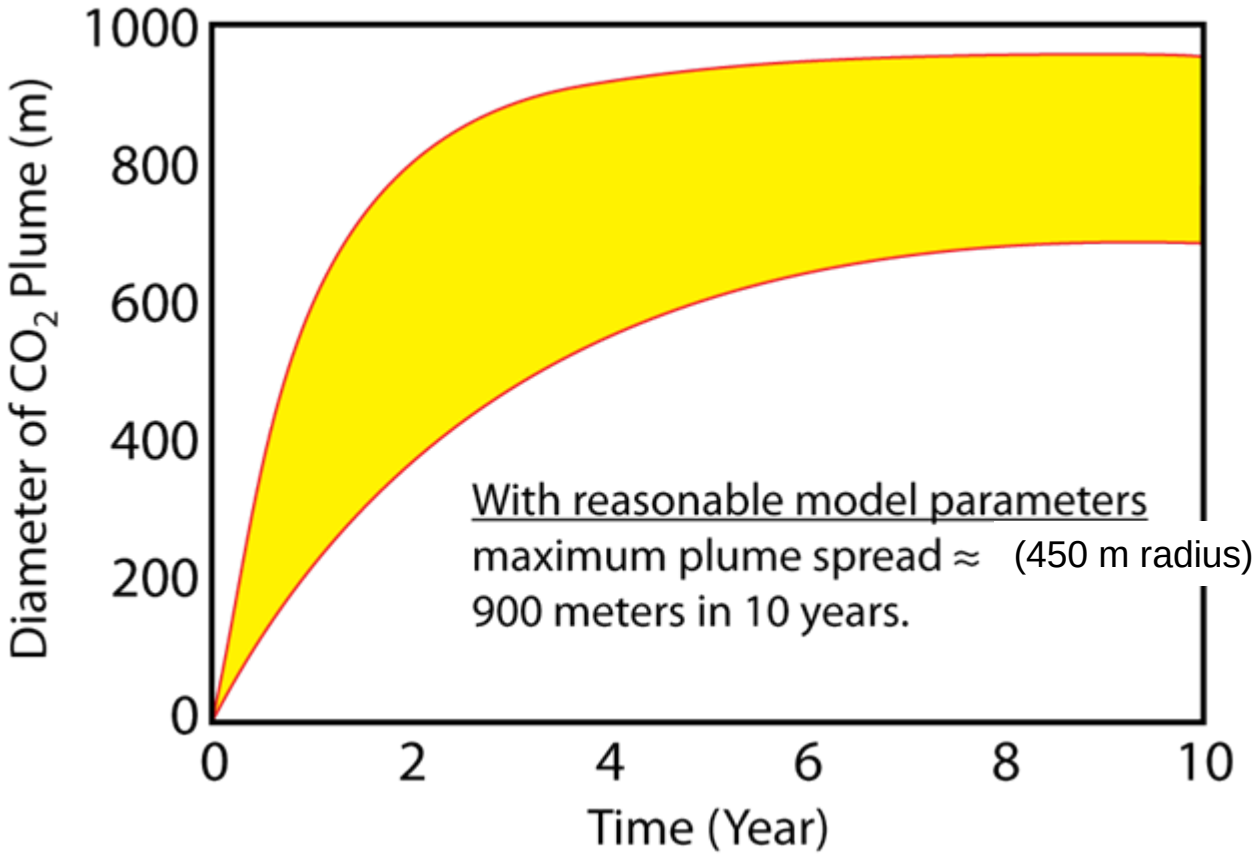


Baseline Site Model: Results

Single-year Injection of 1M tons

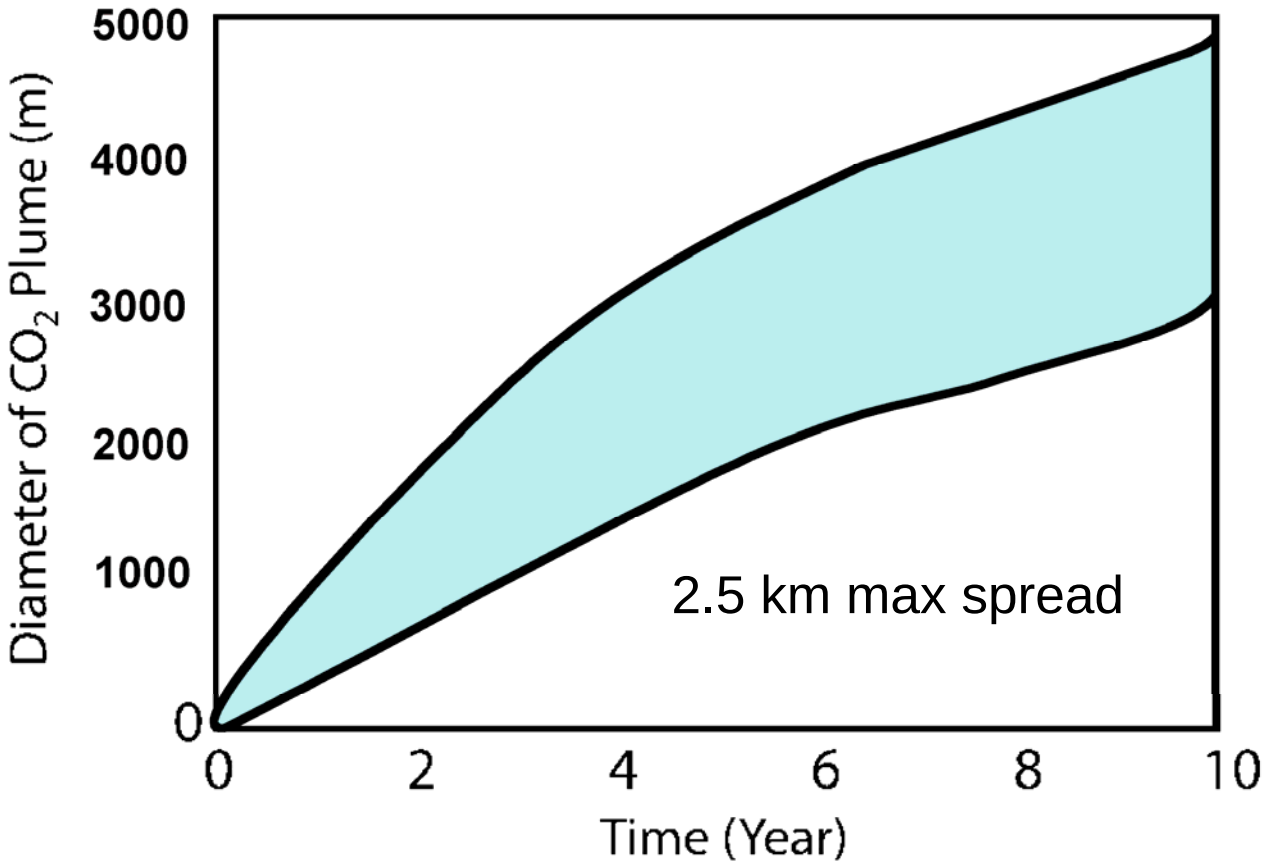


Sensitivity analysis: CO_2 plume expansion versus time

- Additional data anticipated…
  - More detailed analysis of existing Farnham Dome wells (UGS)
  - Core from target and seal formations
  - High Resolution 3D seismic

Baseline Site Model: Results

10-year Injection of 2M tons/year



Sensitivity analysis: CO_2 plume expansion versus time

- Additional data anticipated…
  - More detailed analysis of existing Farnham Dome wells (UGS)
  - Core from target and seal formations
  - High Resolution 3D seismic

Baseline Site Model: Results

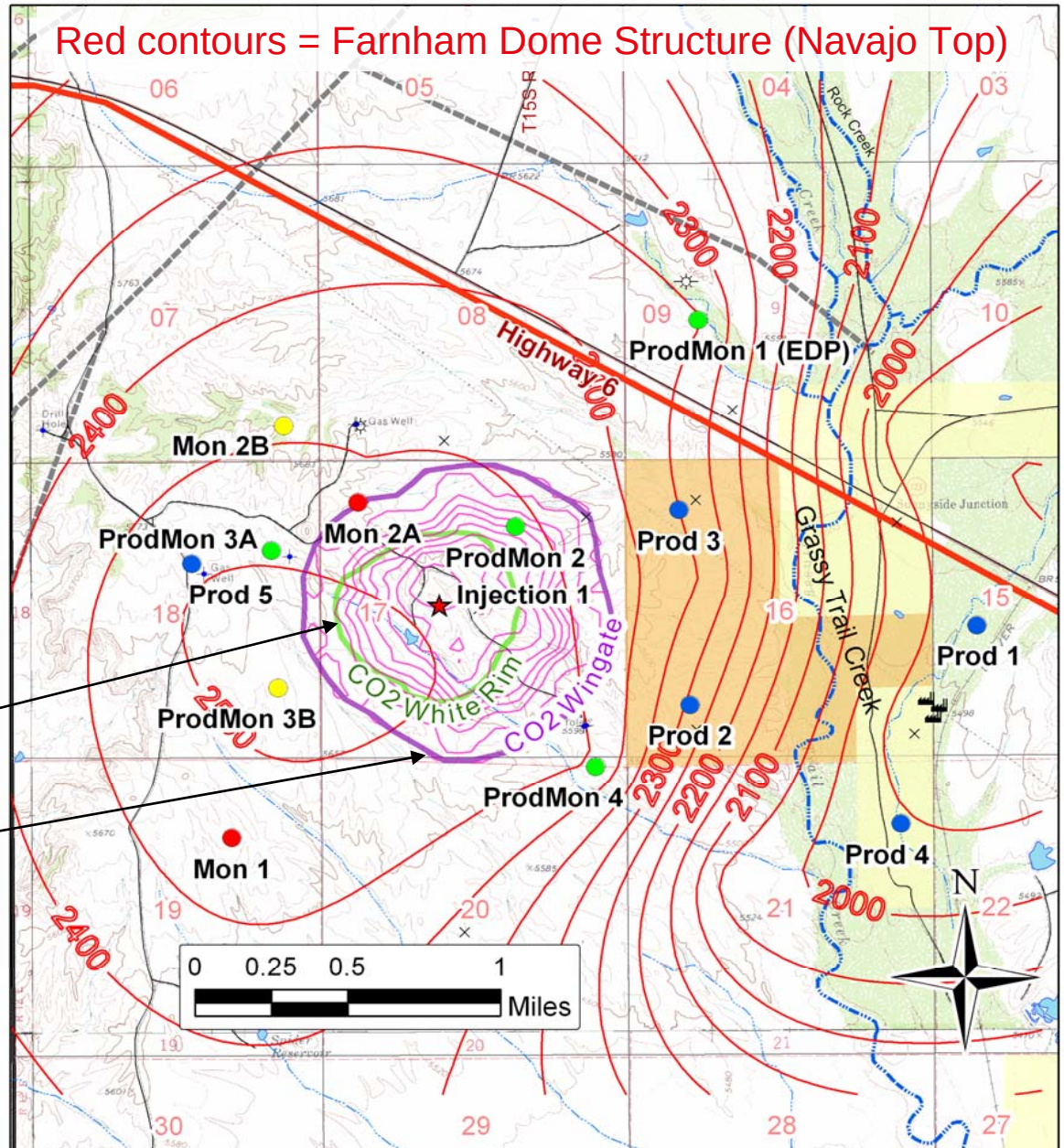
Simulation:
mimic the Phase III demonstration test injection schedule

300,000 tons Year 1
600,000 tons Year 2
1,000,000 tons Year 3
1,000,000 tons Year 4
10 Years total
(6 yr post MMV)

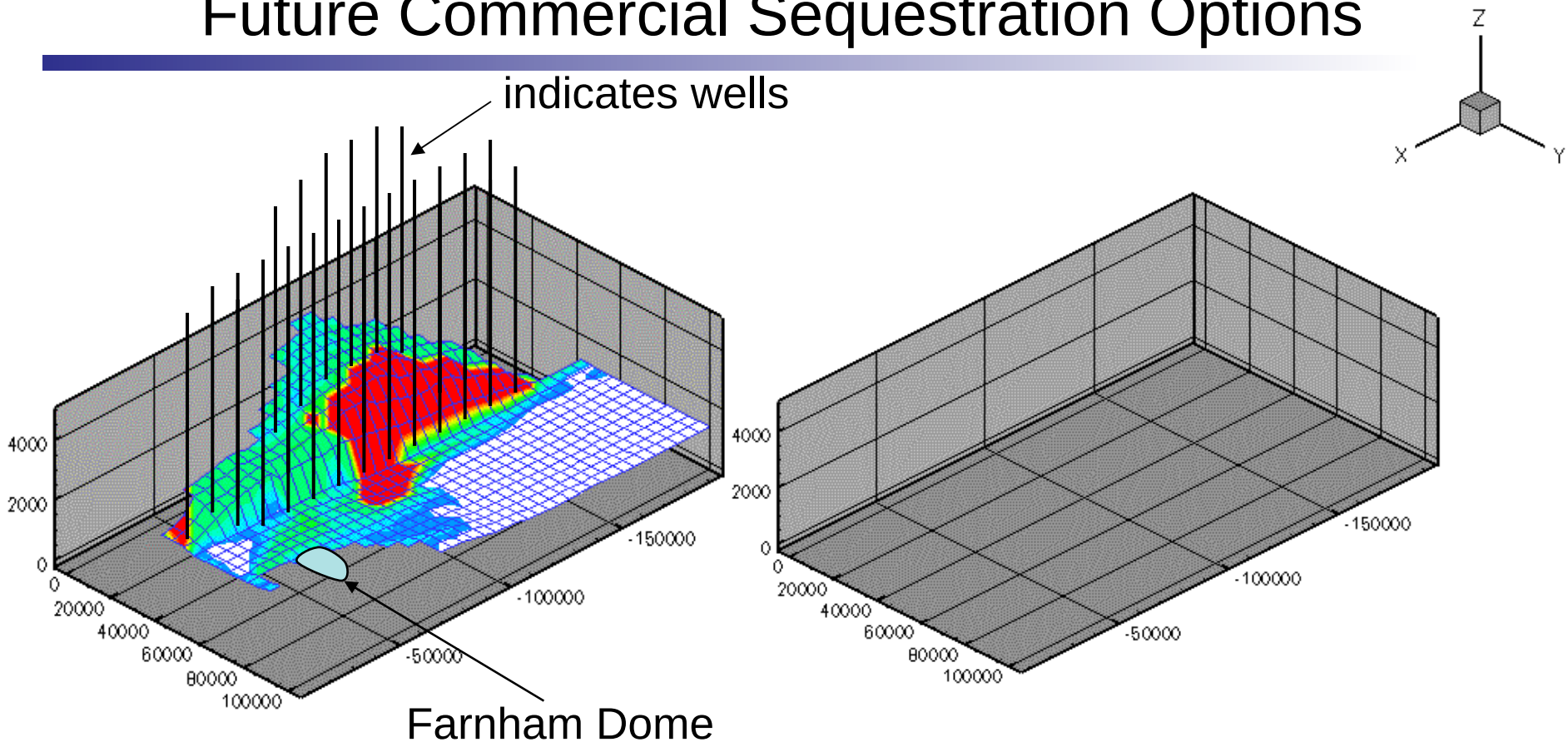
White Rim Plume

Wingate Plume

We are using simulation results to guide well placements.

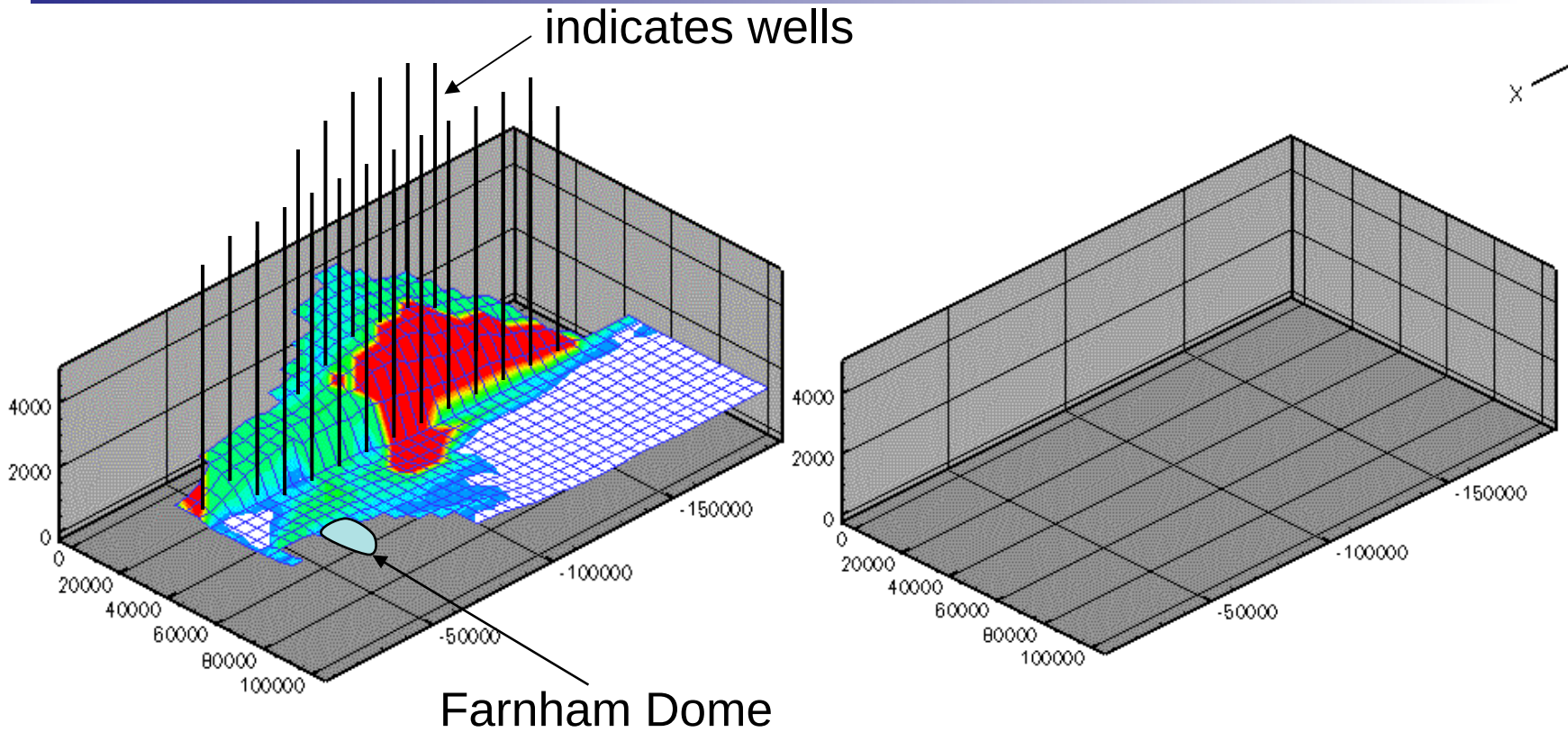


Basin-Scale Scoping Model: Future Commercial Sequestration Options



- **40 CO_2 injection wells penetrating the Green River Fm**
- **no production wells**
- **dissolved phase shown here (follows separate phase, for most part)**

Basin-Scale Scoping Model: Future Commercial Sequestration Options

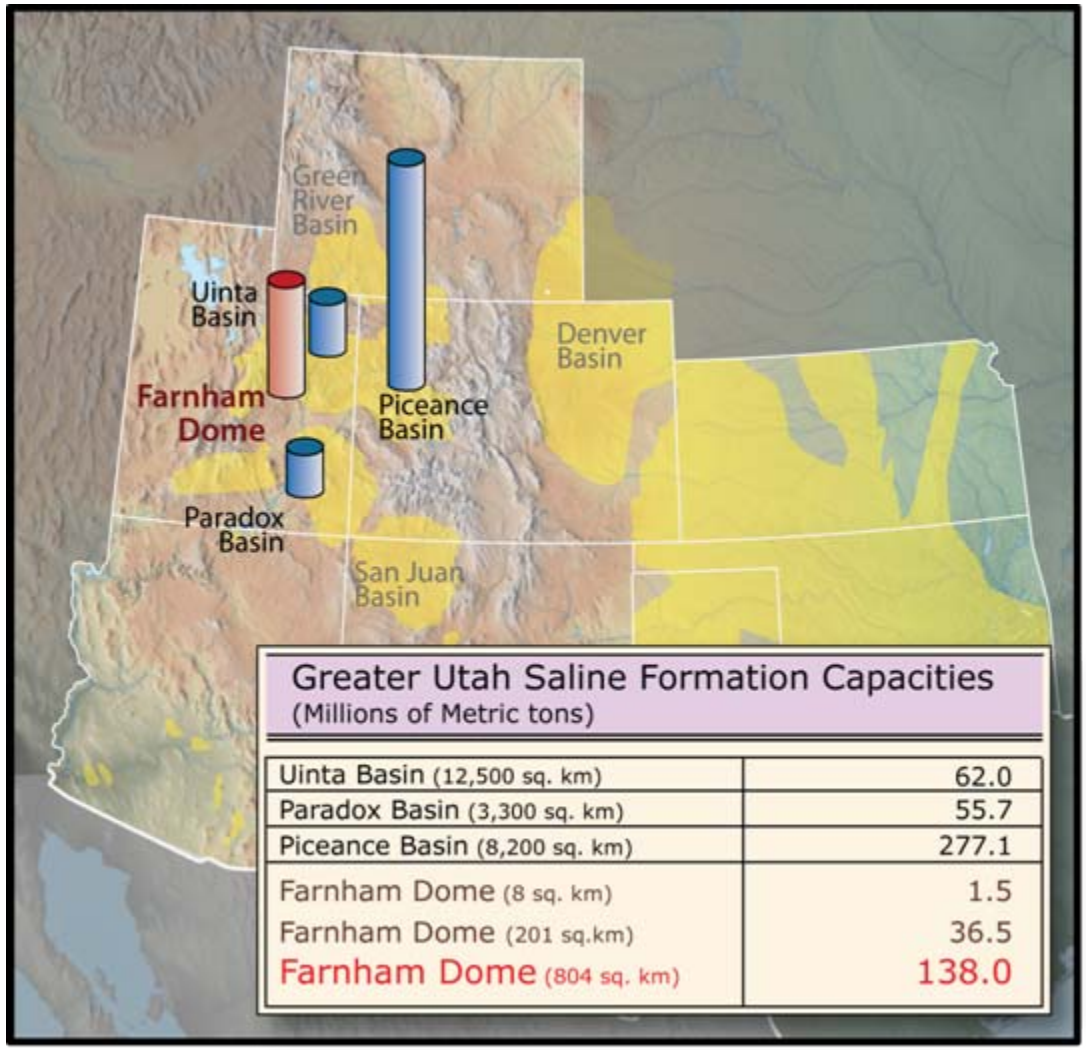


- **induced pressure not permitted to exceed 90% of fracture pressure (in this case, 80% of lithostatic, as measured in a previous study)**
- **overpressures develop in lower perm marginal lacustrine facies**
- **overpressures terminate at higher perm open lacustrine facies**
- **CO_2 migrates more freely in higher perm open lacustrine facies**

Comparison to Regional Capacity

Calculated CO_2 capacity of Farnham Dome target units approach those of much larger basins:

Wingate Ss : > 40 MMT
White Rim Ss : > 98 MMT



Greater Utah Saline Formation Capacities
(Millions of Metric tons)

Uinta Basin (12,500 sq. km)	62.0
Paradox Basin (3,300 sq. km)	55.7
Piceance Basin (8,200 sq. km)	277.1
Farnham Dome (8 sq. km)	1.5
Farnham Dome (201 sq.km)	36.5
Farnham Dome (804 sq. km)	138.0

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Roles of Modeling and Monitoring

Phase II

- Small- to medium-scale testing (validation)
- Intra-region technical options
- Risk assessment
- Mitigation plans

Phase III

- Larger-scale for commercial evaluation (deployment)
- Inter-region (national) technical options
- Inter-region (national) variability that industry must consider for commercial deployment
- Risk assessment
- Mitigation plans

Farnham Dome Monitoring Plans

(1) Methods for Detecting CO_2 in non-Target Reservoirs:

- Groundwater chemistry (non-target reservoirs)
- Surface CO_2 chamber flux
- Shallow CO_2 “piezometers” for sub-bio flux
- Remote sensing / LandSat Imaging
- Coupled process reservoir modeling

(2) Methods for Tracking CO_2 Migration and Fate

- 2-D and/or 3-D seismic reflection imaging surveys
- Vertical seismic profiles (VSP)
- Crosswell seismic imaging
- Passive seismic monitoring/imaging
- Groundwater chemistry
- In situ pressure, temperature measurements
- In situ bicarbonate detection
- Coupled process reservoir modeling
- Production wells will be used for monitoring

General Mitigation Planning

The basis of ongoing mitigation plans involve:

(1) integration of monitoring technologies at appropriate scales in reservoir models, for optimized design of monitoring deployments

(2) integration of unique or site-specific risk elements (e.g., FEPs) in reservoir models, for optimized calculation of risk probabilities

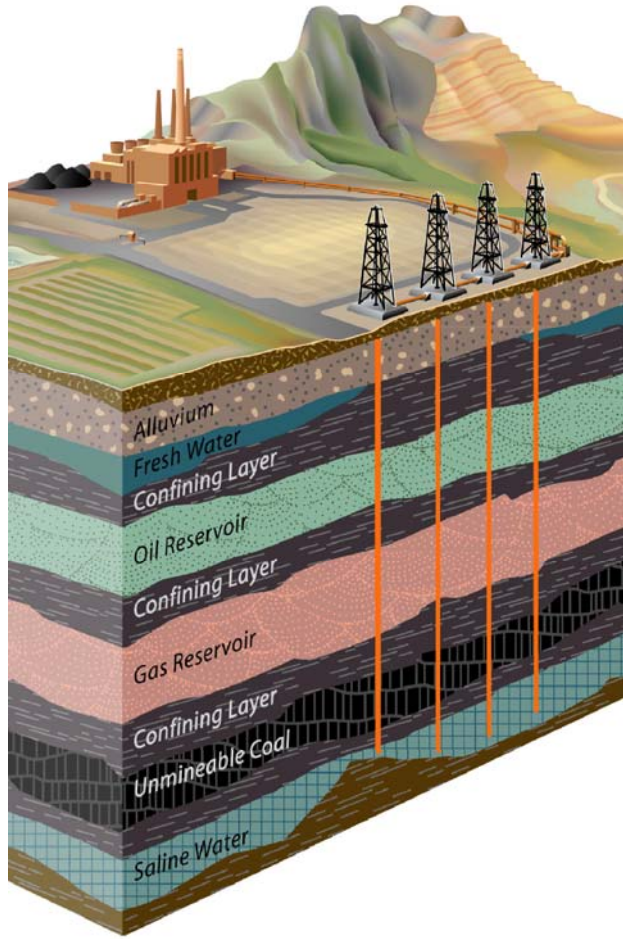
Reservoir models that include (1) and (2) are more adept at formulating mitigation plans.

Pressure Reduction for Mitigation

Farnham models are now being used to forecast optimum array of wells used both for observation and production, as needed -- **O**bservation**/P**ressure **R**eduction wells **(OPR wells).**

Reservoir models suggest that immediate pressure reduction may:

- Stem geomechanical deformation
- Stem and/or close crack/fracture growths
- Shut down “piston-flow” displacement of brines into unintended reservoirs
- Slow leakage through wellbores
- Slow leakage through faults and even induce closure of faults



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Summary

(1) Deep saline stacked storage demonstration ~ 1M tons per year

(2) Goal: Develop a “template” or “blueprint” for future commercial-scale sequestration. Integration of Phase II and Phase III results (“lessons learned”) are critical to this goal

(3) Goal: Evaluate “portability” or transferability of results, from formation-to-formation or site-to-site.