Southwest Regional Partnership on Carbon Sequestration

DE-FC26-05NT42591

Phase III – Deployment Phase

Gordon Creek Field

Wasatch Plateau, Utah

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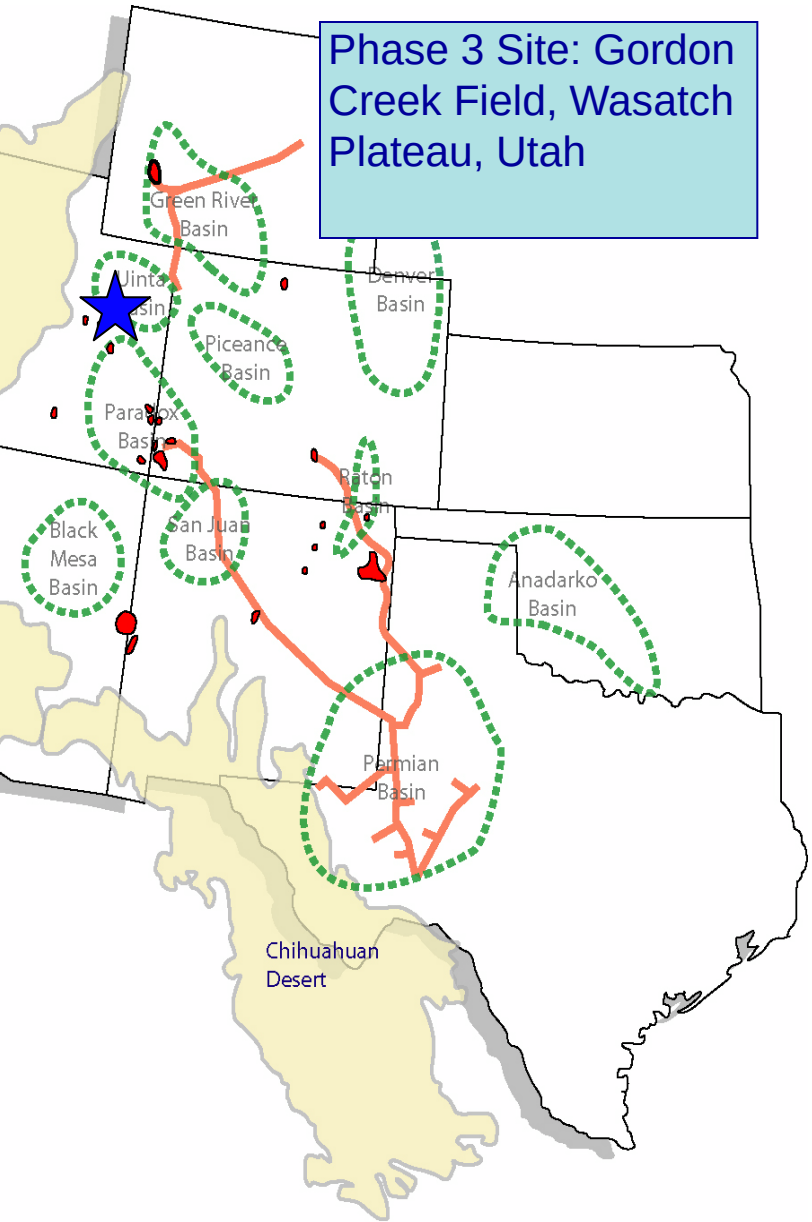
New Mexico Institute of Mining and Technology

Introduction



Large-Scale Deep Saline Sequestration Test (Phase 3)

- site suitability evaluation completed;
- geologic characterization ongoing;
- site proposal submitted to NETL;
- cost-price (budget) evaluation beginning;
- baseline simulation models designed;
- baseline monitoring designed.

SWP Presentation Outline

- SWP Phase III Goals
- Project Overview and Scope of Work
- Schedule, Costs and Milestones
- Technical Plan
- Summary (Wrap-up)

SWP Phase III Goals

- Storage Capacity Verification
  - The SWP is developing technologies that will support our industry partner's ability to confirm CO_2 storage capacity in geologic formations
  - The uncertainty or tolerance planned is ±30 % (target is ±10 %)

- Verification of Containment
  - The SWP is refining a technological approach to confirm that 99 % of injected CO_2 remains in the injection zones
  - From Phase II project results, we find that the most effective approach are geophysical (VSP) surveys, tracer monitoring, pressure and geochemical monitoring, and detailed numerical modeling.

- Best Practices
  - The SWP continues to emphasize technology transfer in the form of Best Practice Manuals (BPMs) development
  - SWP personnel have already contributed much to several BPMs, including: *Simulation and Risk Assessment, Site Selection and Characterization, MVA,* and *Public Education and Outreach.*

SWP Phase III Goals

- **Injectivity and Capacity**
  - Injectivity determined from wellbore simulation models calibrated with produced water disposal (injection) data from existing wells, laboratory analysis of existing field cores, and future core acquisition and well-testing via the first characterization well to be drilled in fall of 2011, which will verify injectivity.
  - Capacity verification via 3-D simulation models and direct data—repeat 2-D VSP plus tracers, pH, pressure and other indicators from wells and the surface.
  - Finally, direct determination on injection well.
- **Storage Permanence**
  - Storage permanence confirmed, including geophysical (VSP) surveys , tracer monitoring, pressure and geochemical monitoring, and detailed numerical modeling calibrated by these data.
  - Direct testing to validate that there is no impact on USDWs. Also: identify risks specific to USDWs and develop associated Probability Density Functions (PDFs); quantify risks to USDWs by pressure/brine/CO2 migration through seals; or by lateral migration of pressure/brine/CO2; and determine conditions that minimize (or eliminate) the risks to USDWs.

SWP Phase III Goals

• Plume Extent and Potential Leakage Pathways

•The SWP will characterize and forecast potential plume extent and potential leakage pathways via geophysical (VSP) surveys, tracer monitoring, pressure and geochemical monitoring, and detailed numerical modeling.

•We will also confirm the forecasts through continuous monitoring and measurements during- and post-injection.

• Risk Assessment

•The SWP has developed a comprehensive risk assessment strategy which is "Adaptive"— iterative modeling-monitoring approach for assessment of uncertainty and performance assessment: healthy/safety risks, economic and programmatic risks, and otherwise.

•Best Practices

•Adopting the main programmatic goals for developing Best Practices Manuals (BPMs) of geologic CCS, the SWP will continue present BPM efforts and will focus much of its BPM efforts on NETL's Risk Assessment and Simulation.

SWP Phase III Goals

- Outreach and Education
- The SWP will continue successful outreach and education methods, including: focus groups with opinion leaders and decision-makers in the communities; quarterly press releases about the SWP's field progress; and collaboration with the Southwest CCS Training Center's efforts developing K-12 and University curricula, as well as professional short courses for industry and other entities.
- Permitting Approach
- Regulatory efforts activities have three complementary objectives: ascertain and monitor permitting requirements as they evolve; secure permits for the Gordon Creek project; and Manual of Best Practices.

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Project Overview and Scope of Work

The SWP project will be a deep saline sequestration deployment with

- Injection into one well;
- injection rates at up to ~ 1 million tons per year for multiple years;
- injection in a truly stacked system with multiple reservoirs and seals;
- the stacked system includes a producing natural gas zone, at least three saline aquifers—each representative of potential regional carbon sequestration targets—and two CO_2 reservoirs with seals above each of those reservoirs.

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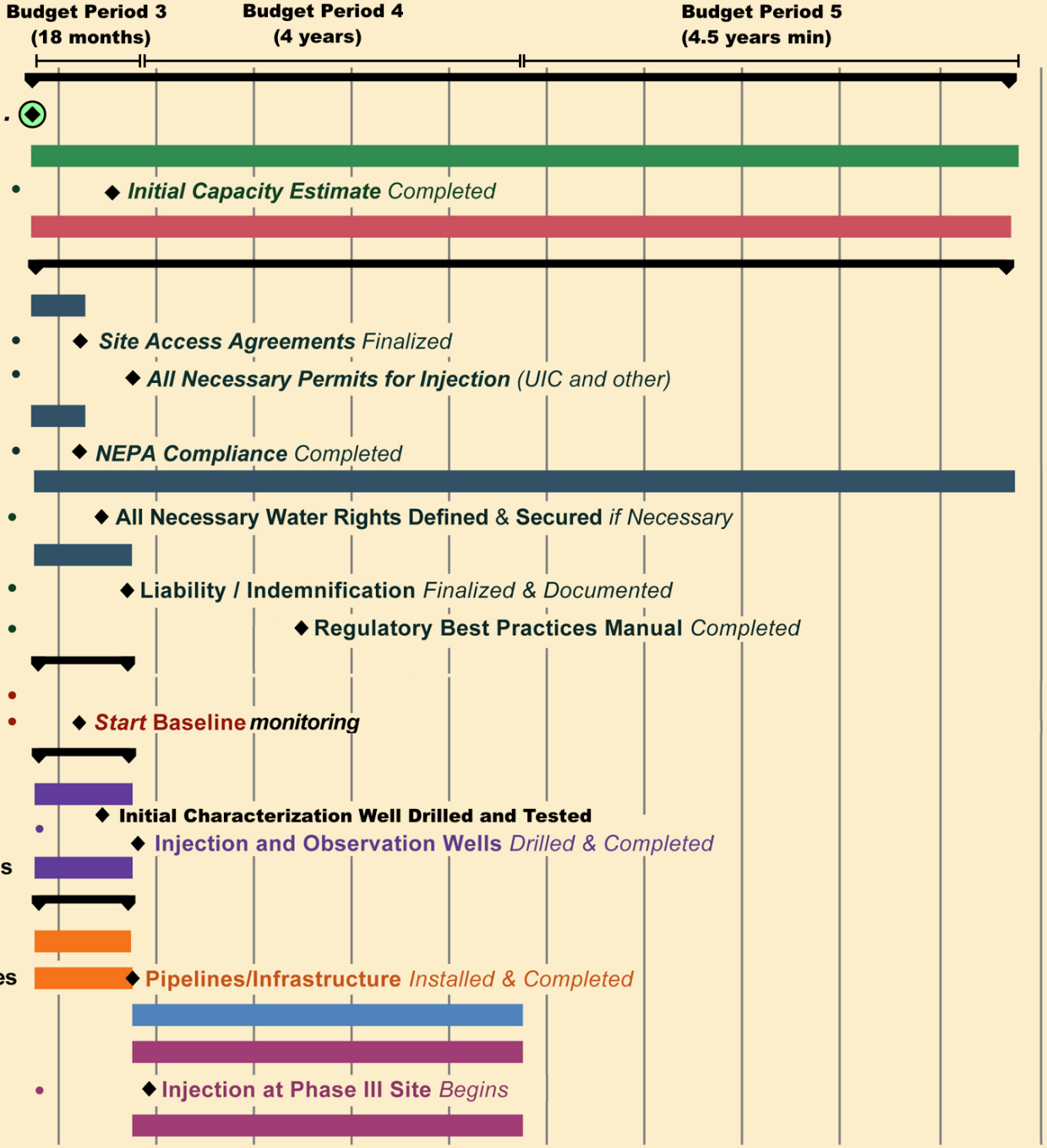
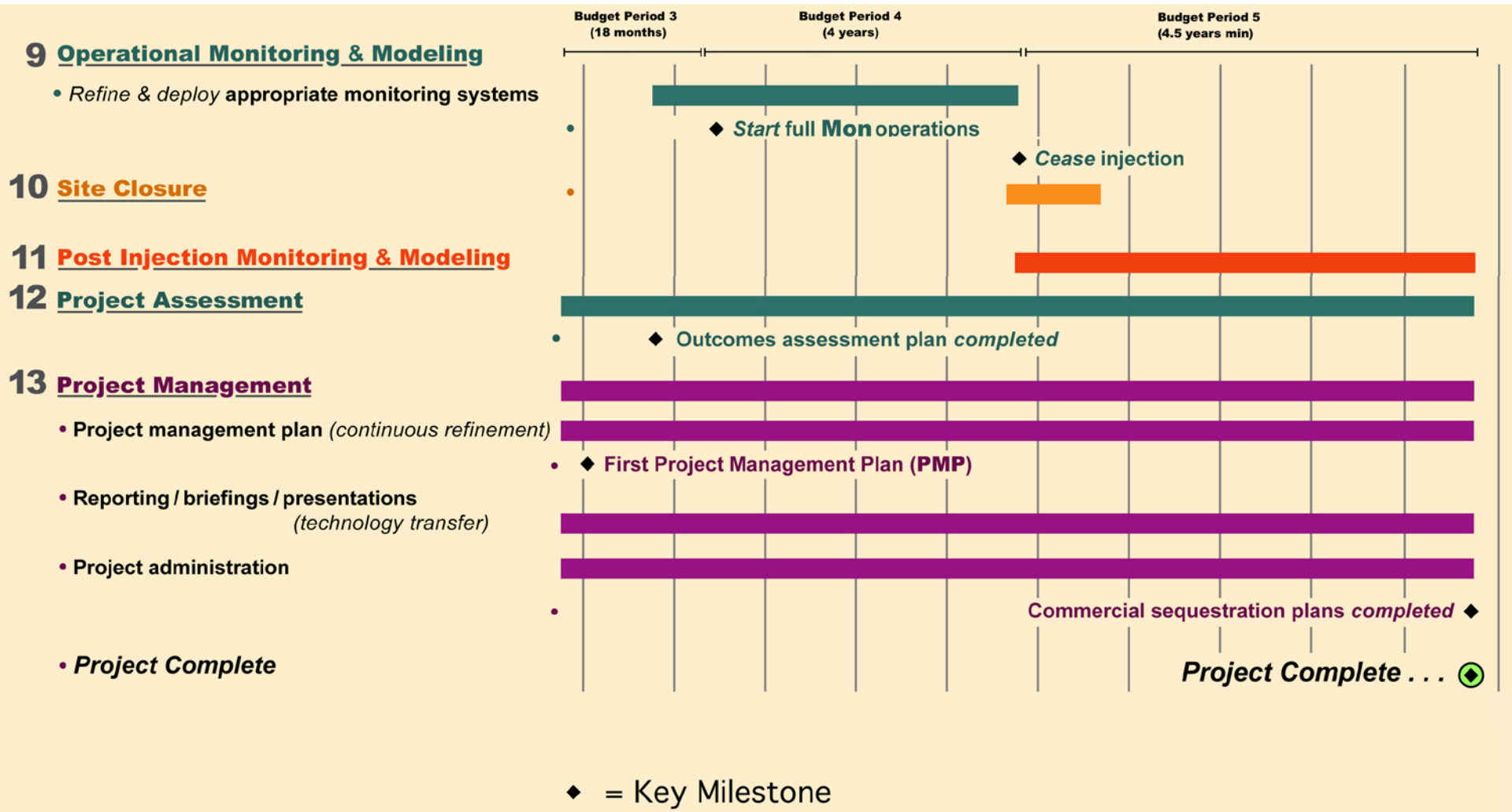
Project Overview:
Schedule, Cost and Milestones

- Project Schedule
  - No cost overruns
  - Major delay in site selection
    - Site #1: withdrawn just after Phase III was approved.
    - Site #2: abandoned for technical (faults) and financial concerns (cost share and operator issues)
    - Site #3: Gordon Creek is the third site, which received DOE approval August 2011. The site liability has been obtained through:
      - Public indemnification: Utah Risk Division
      - Private issuance
      - Site Operator taking the remaining unconditional liability
- Project Cost:
  - DOE ~$65,500,000 (~$25,331,000 BP3)
  - non-DOE/cost shares ~$25,285,000 (~$9,380,000 BP3)
  - Expended amount through the end of FY11Q1 (12/31/10) DOE~$1,537,000.

Southwest Partnership
Phase III Deployment



◆ = Key Milestone



◆ = Key Milestone

Feasibility of Approach and Schedule

Major Project Elements, Schedule and Success Factors:

BP 3 (first 18 months)

- Indemnification finalized - done
- Start baseline monitoring design and deployment
- Injection well recompleted - spring, 2012 (Nov 2011)
- Characterization/1st Production well tested and CO_2 source verified - summer, 2012
- UIC well permit in 2012
- Injection and observation wells, and facilities completed – fall 2012

BP 4 (next 4 years)

- Injection begins
- Full-time monitoring begins
- Successful engineering of stacked injection
- No significant risk events induced
- Successful monitoring of stacked storage

BP 5 (remaining 4 years)

- Injection ceases
- Post-Injection monitoring begins
- Project complete

* items in red font denote critical project success factors

Critical Milestones

Selected Critical Milestones: Budget Period 3:

- Site Approval from the DOE
- Initial Capacity Estimate Completed
- Site Access Agreements Finalized
- All Necessary Permits Acquired
- NEPA Compliance Completed
- All Necessary Water and Mineral Rights Secured
- Indemnification Finalized
- Start Baseline Monitoring
- 1st Production, Injection and Observation Wells Completed/Recompleted
- Infrastructure (pipelines, compressors etc) Completed

Selected Critical Milestones: Budget Period 4:

- Injection Begins
- Full-time Monitoring Begins
- If required additional Production wells completed
- Updated Risk Management Framework Complete
- Regulatory Best Practices Manual Complete

Selected Critical Milestones: Budget Period 5:

- Injection Ceases
- Post-Injection Monitoring Begins
- History Match Modeling Completed
- Project Complete

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  - What and why
  - Project site
  - Project risks and mitigation plans
  - Baseline modeling
  - Baseline monitoring design
  - Project engineering design
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SWP Phase 3: What and Why

- **<u>What</u> is the SWP and its partners planning for 2010?**
  - 1,000,000 tons per year for multiple years
  - “blueprint” for future commercial sequestration

- **<u>Why</u> are we conducting this testing?**
  - many deep saline formations common to all basins
  - deep Jurassic- and older “clean” sandstones in all states
  - representative commercial sites

- **<u>How</u> are we carrying out this testing?**
  - Close collaboration among Partnership and industry
  - Concerted coordination with regulatory agencies

SWP Phase 3: What and Why

- Validate Geologic Storage
  - Injectivity
  - Capacity
  - Permanence
- Develop Monitoring Methodologies
  - Areal Extent of Plume
- Develop from Experience
  - Risk Assessment Strategies
  - Best Practices for Industry
- Support Regulatory Development
- Engage in Public Outreach and Education

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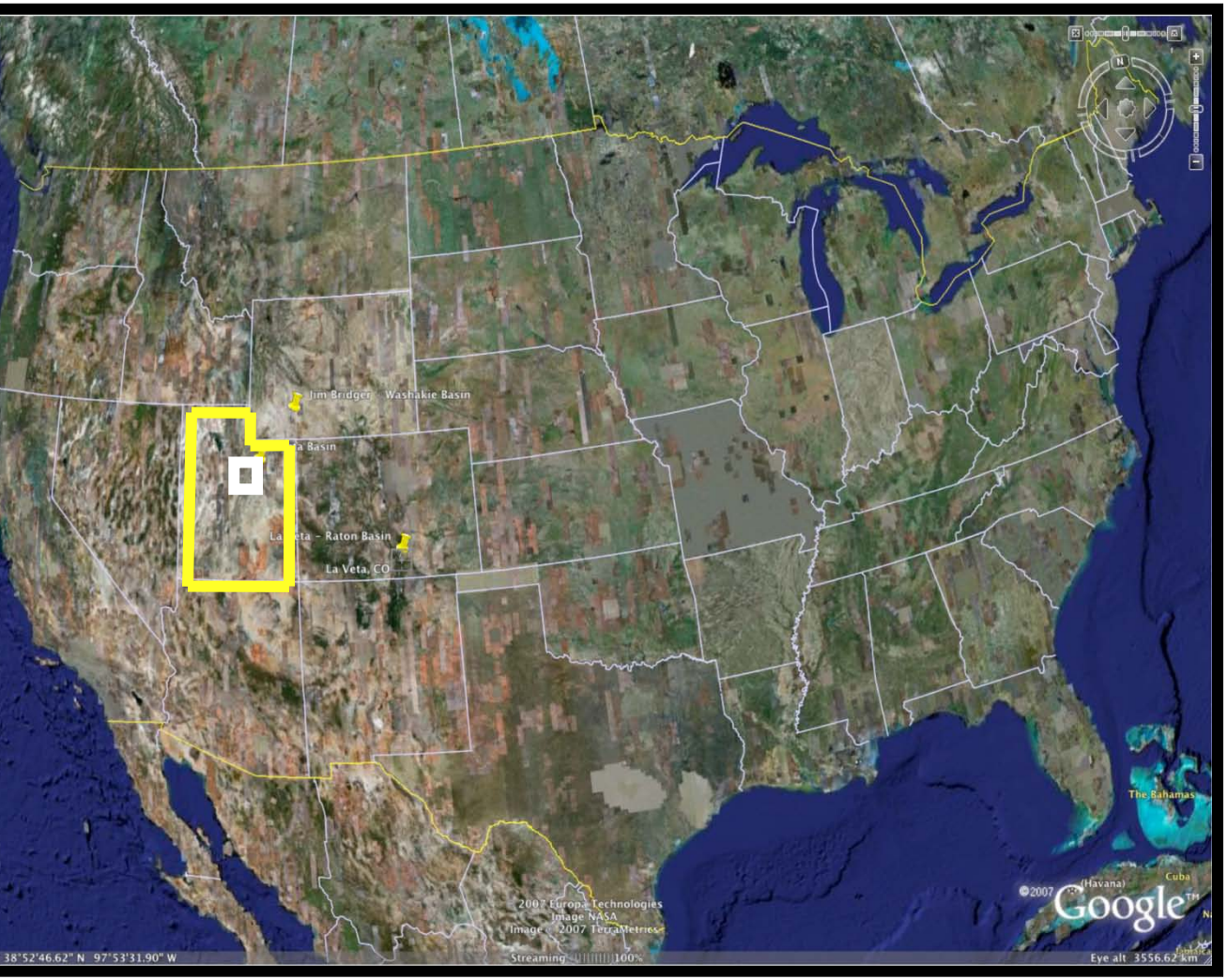
SWP Phase III: Project Site

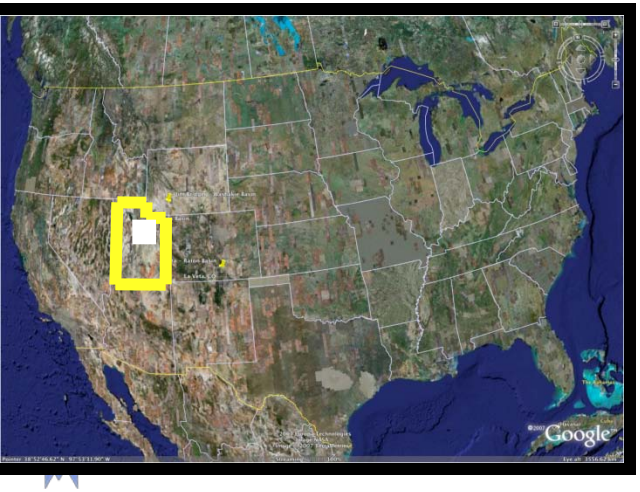


Details:

- Gordon Creek Field (active gas field)
- 3,000,000 tons (goal)
- 3-4 year injection
- focus on transferability of results (site-to-site)
- target injection start date: **2012**

Commercial-Scale Project Location:
Wasatch Plateau, Utah
CO_2 Source = White Rim Formation (natural)

SWP Phase III: Project Site



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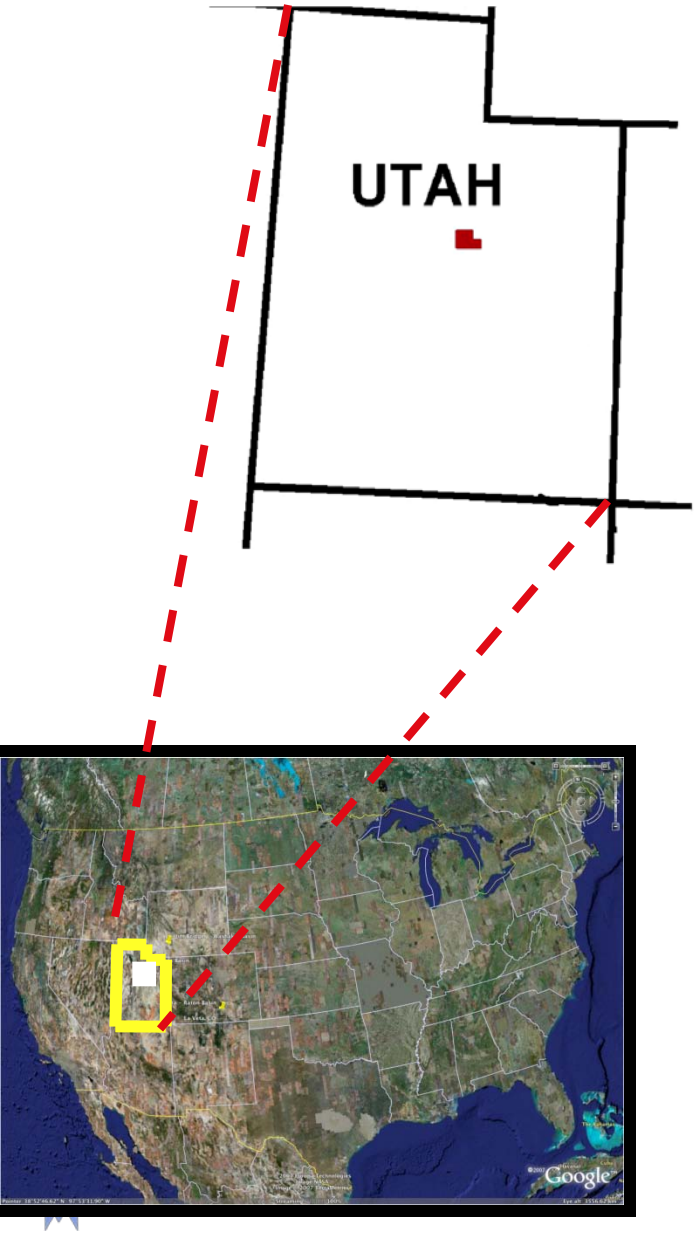
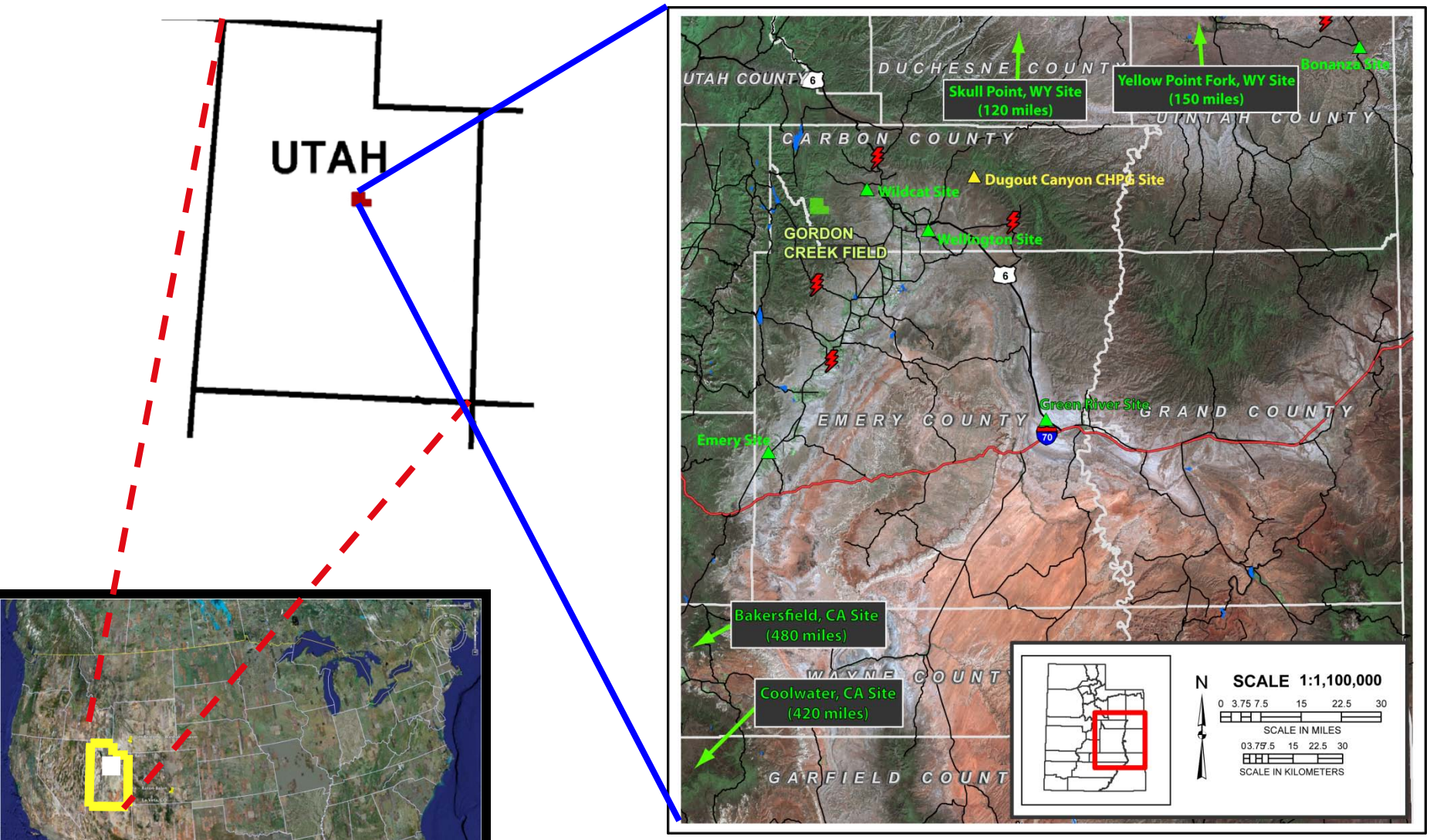


SWP Phase III: Project Site



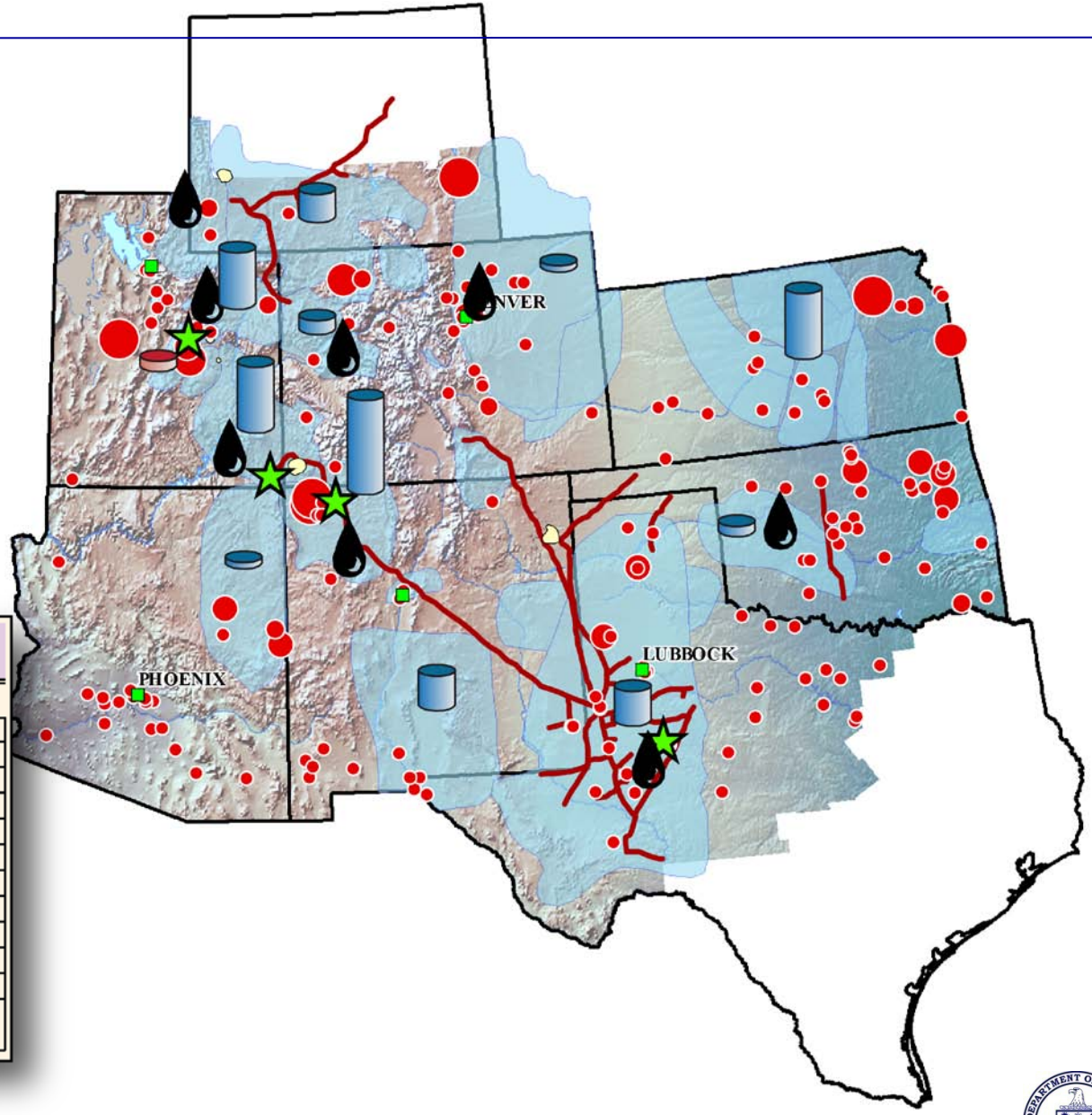
Gordon Creek Field

Looking east near the well head at the flatter land.

Looking west at the Manti Lasal National Forest on the north end of the project.

Looks great, but not the easiest terrain for seismic surveys.

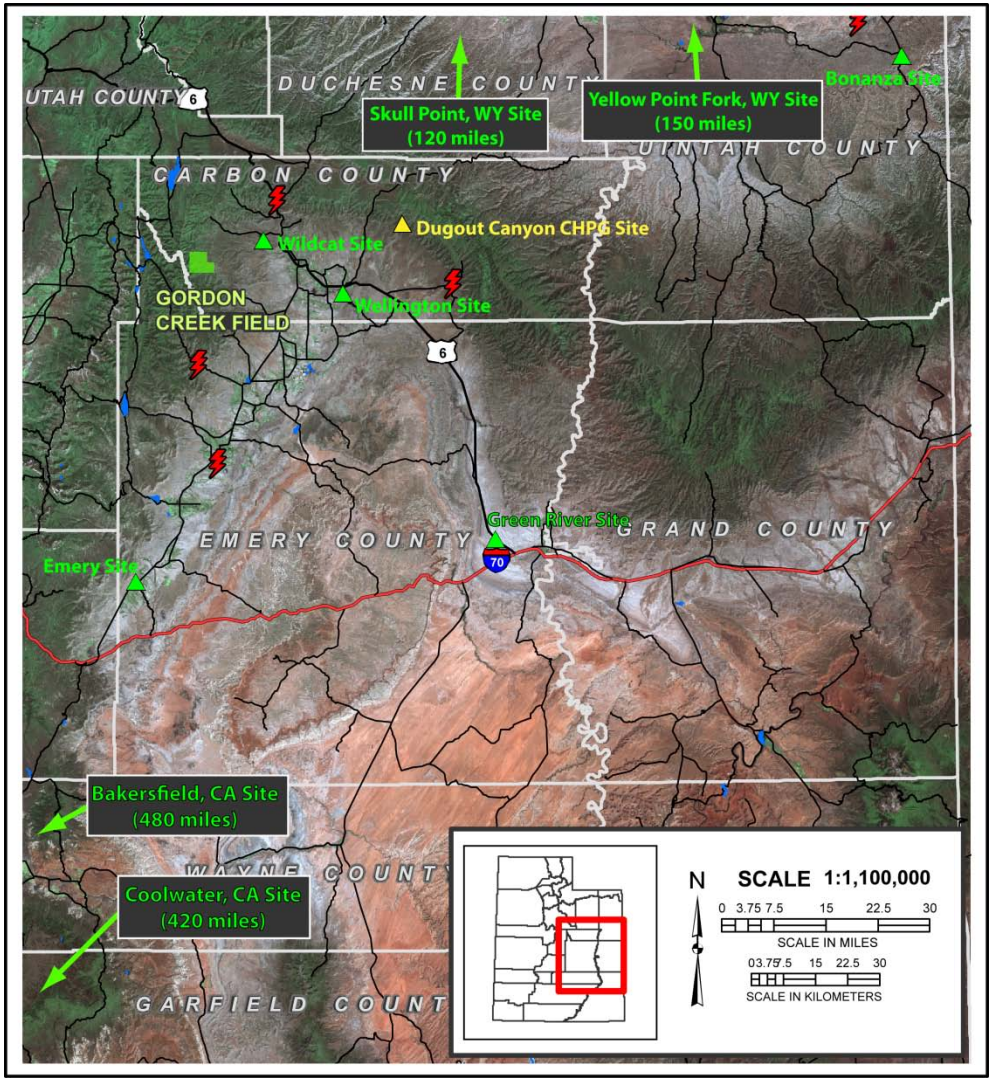
SWP Phase III: Regional Significance



Greater SWP Saline Formation Capacities
(Millions of Metric tons CO_2)

Sequestration Target	Capacity
Uinta Basin	12,436
Paradox Basin	14,901
Piceance Basin	3,370
Anadarko Basin	2,319
Denver Basin	357
Green River Basin	6,387
NM & TX Permian Basins	8,399
KS & eastern CO Basins	13,329
Arizona Basins	19
San Juan Basin	20,624
Total	82,141
Gordon Creek Field	~50

SWP Phase III: Project Site Geology



Period	Symb.	Formation / Member		Thickness (feet)	Depth (feet)*	Lith.
CRET	Km	Mancos Shale	Emery Ss Mbr		0	
			Blue Gate Sh Mbr	<250	**3115**	
			Ferron Ss Mbr	10-110	**3250**	
			Tununk Sh Mbr	200-300	**4000**	
	Kd	Dakota Sandstone		0-30	**4025**	
	Kcm	Cedar Mtn Fm	Upper member	150-750	**4120**	
			Buckhorn Cg Mbr	0-50		
JURASSIC	Jm	Morrison Formation		800±	**4460**	
	Js	Summerville Formation		120-180	**5895**	
	Jct	Curtis Formation		140-180	**6275**	
	Je	Entrada Formation		150-950	**6585**	
	Jc	Carmel Formation		300-700	**7650**	
	Jc	Page Sandstone		<70		
	Jgc	Navajo Sandstone		150-300	**8400**	
		Kayenta Formation		120-200	**8750**	
		Wingate Sandstone		300-400	**8885**	
TRIASSIC	Trc	Chinle Fm	Upper member	200-300	**9225**	
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	Trmt	Moenkopi Fm	Upper member	550-700	**9520**	
	Trms		Sinbad Ls Mbr	50	**10460**	
	Trmbd		Black Dragon Mbr	250-350		
PERM	Ppc	Kaibab/Park City Fm		170	**10890**	
	Pwr	White Rim Sandstone		500-700	**11135**	

CO_2 Source
CO_2 Sink
Methane Producer
Seal

Stacked System

SWP Phase III: Project Site Geology

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CO_2 Source

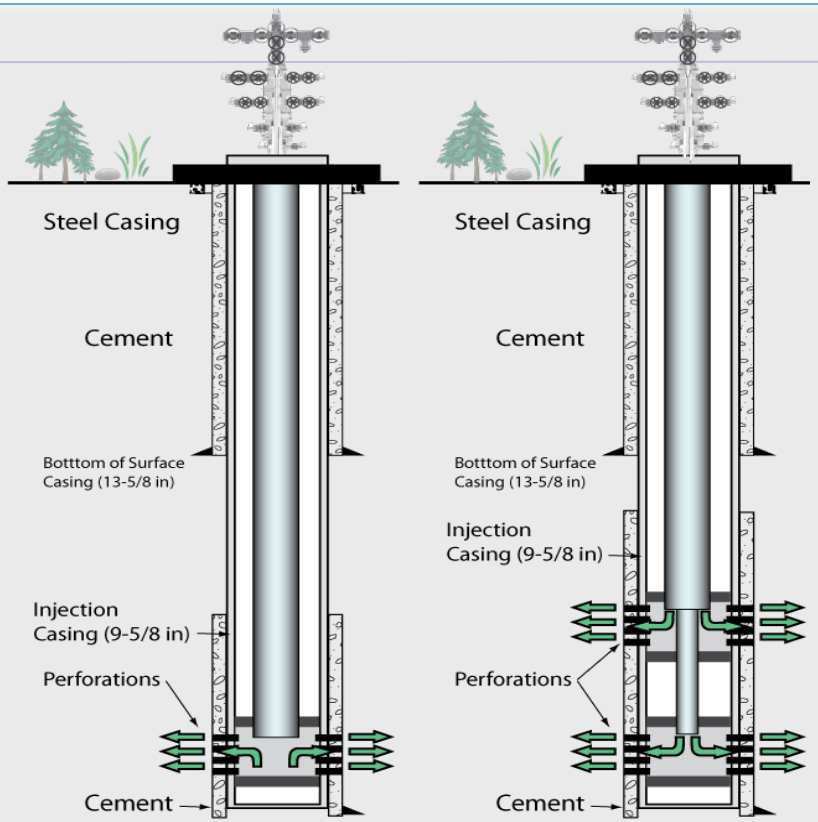
CO_2 Sink

Methane Producer

Seal

† Geologic symbols for correlation to units in Morgan (2007)

Modified from Hintze (1992)



Single zone Injection (Navajo Fm):

Dual zone Injection (Entrada & Navajo Fm)

Multiple-Zone Injection and Storage Assessment

SWP Phase III: Storage Formations

Period	Symb †	Formation / Member		Thickness (feet)	Depth (feet)*	Lith.
CRET	Km	Mancos Shale	Emery Ss Mbr		0	
			Blue Gate Sh Mbr	<250	3115	
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CO_2 Source — CO_2 Sink

Methane Producer — Seal

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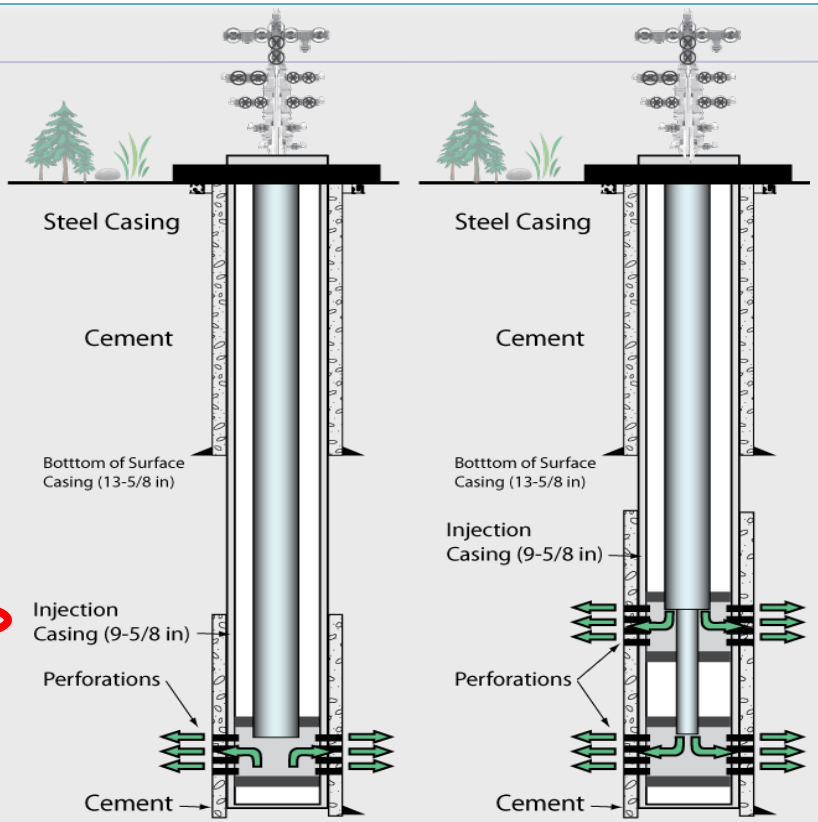

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Multiple-Zone Injection and Storage Assessment

SWP Phase III: CO_2 Source

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CO_2 Source
CO_2 Sink
Methane Producer
Seal

Natural CO_2 Reservoir

Advantages:
- FREE

- still facilitates goals:
- MVA efficacy
- injectivity design
- risk asssessment
- mitigation design
- water management
- CCUS in form of EGR?

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Critical Project Risks and Mitigation Plan

Verification of CO_2 Source:

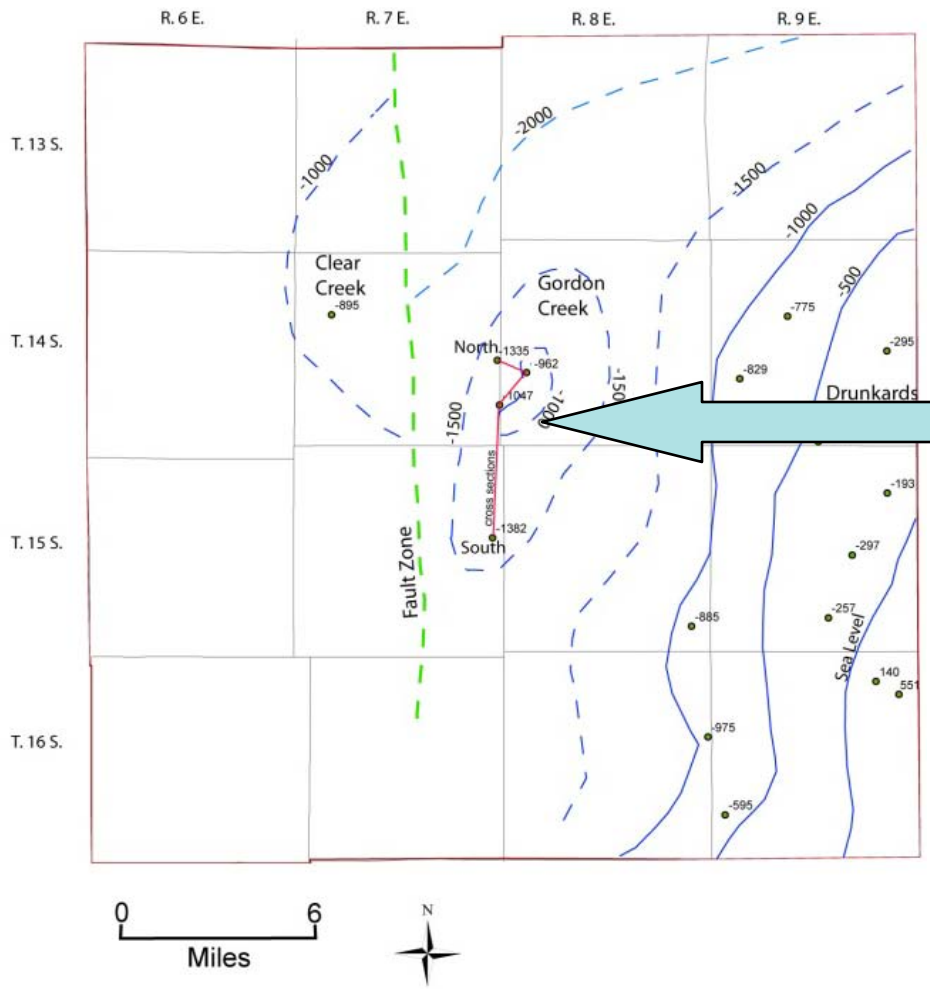
- three wells drilled to the White Rim in the 50's and 70's found CO_2;

- estimates are that each well has a reserve of about 140 BCF of gas or ~8 million tons;

- the White Rim structure at ~12,000 ft is mapped as an anticline similar to the 3500 ft Ferron Formation with the highest and thickest portion near planned production wells

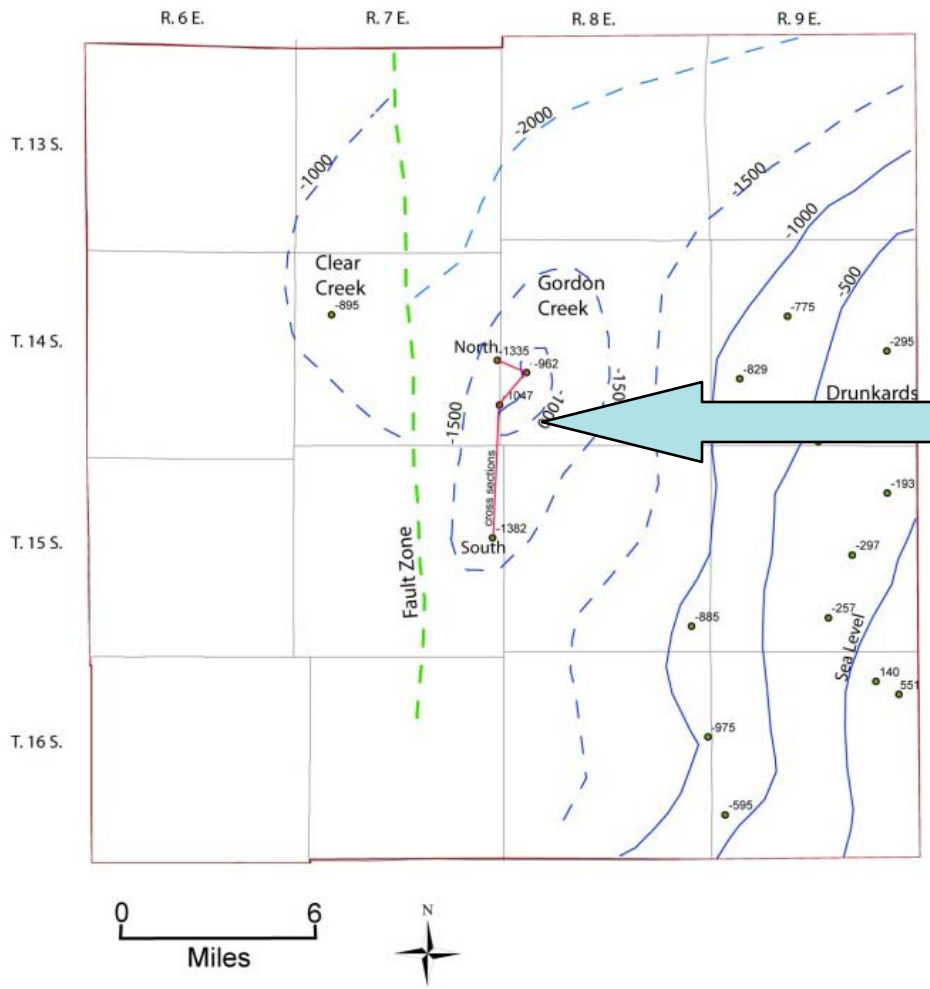
- seismic data and initial production will confirm CO2 source

Critical Project Risks and Mitigation Plan



Some uncertainty regarding structural high at center of the field

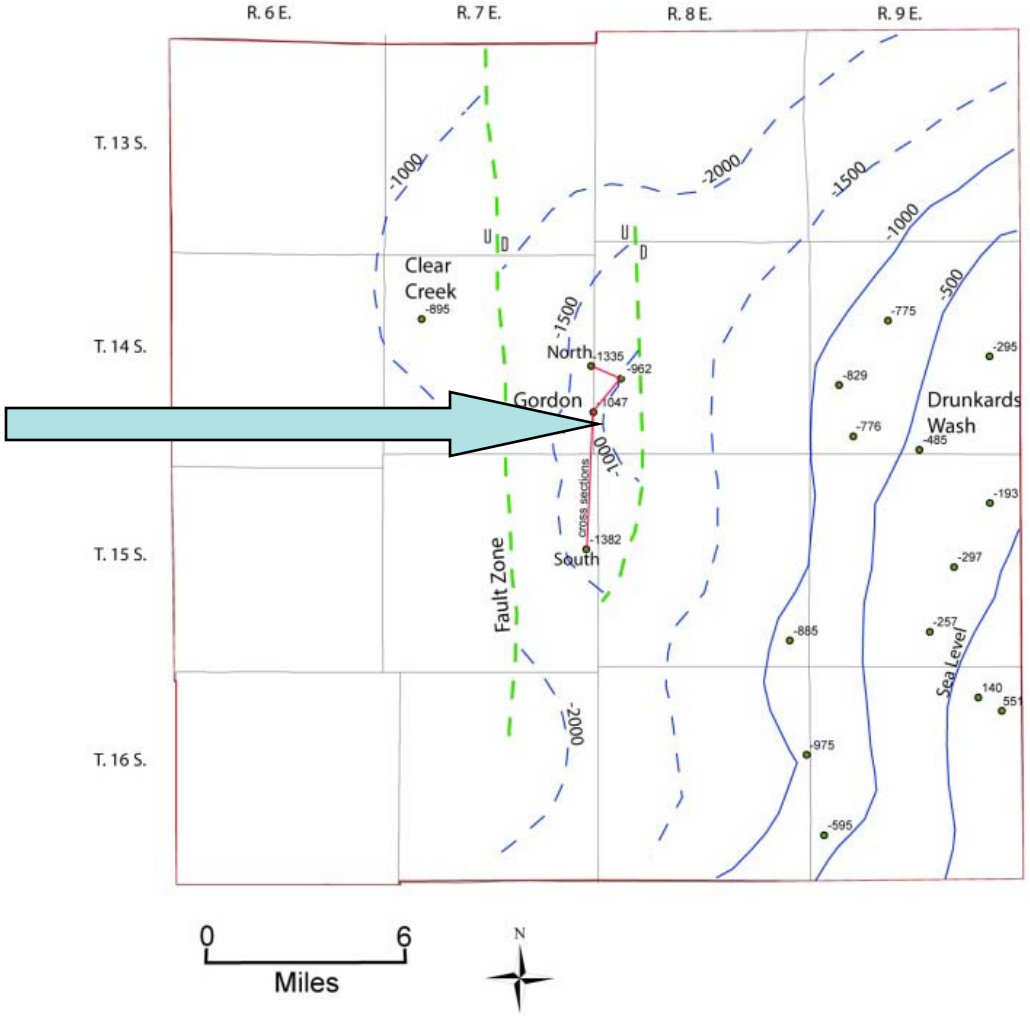
Critical Project Risks and Mitigation Plan



(1) Interpreted as an anticline

Critical Project Risks and Mitigation Plan

(2) But a small fault is evident adjacent to the apex



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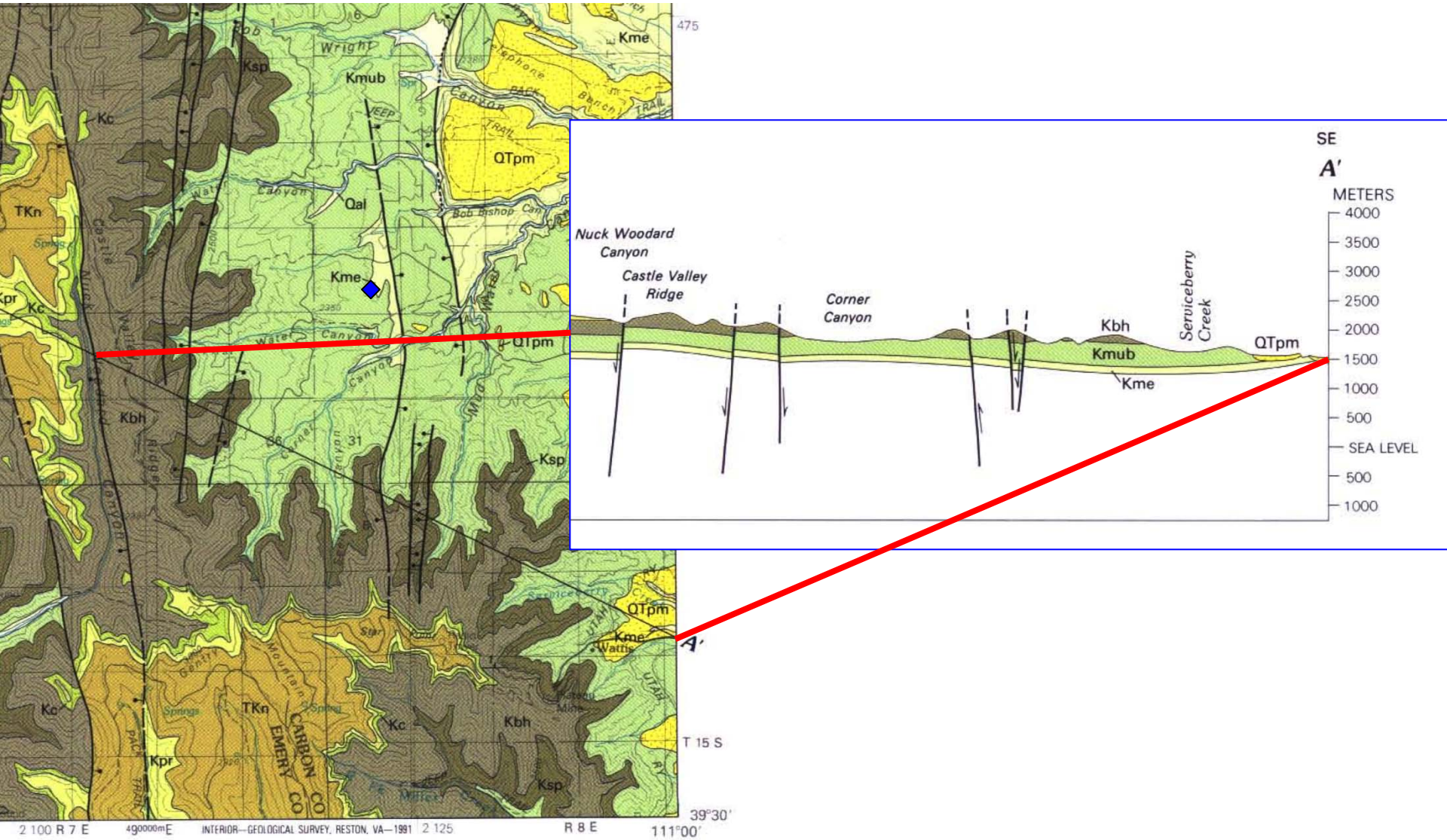
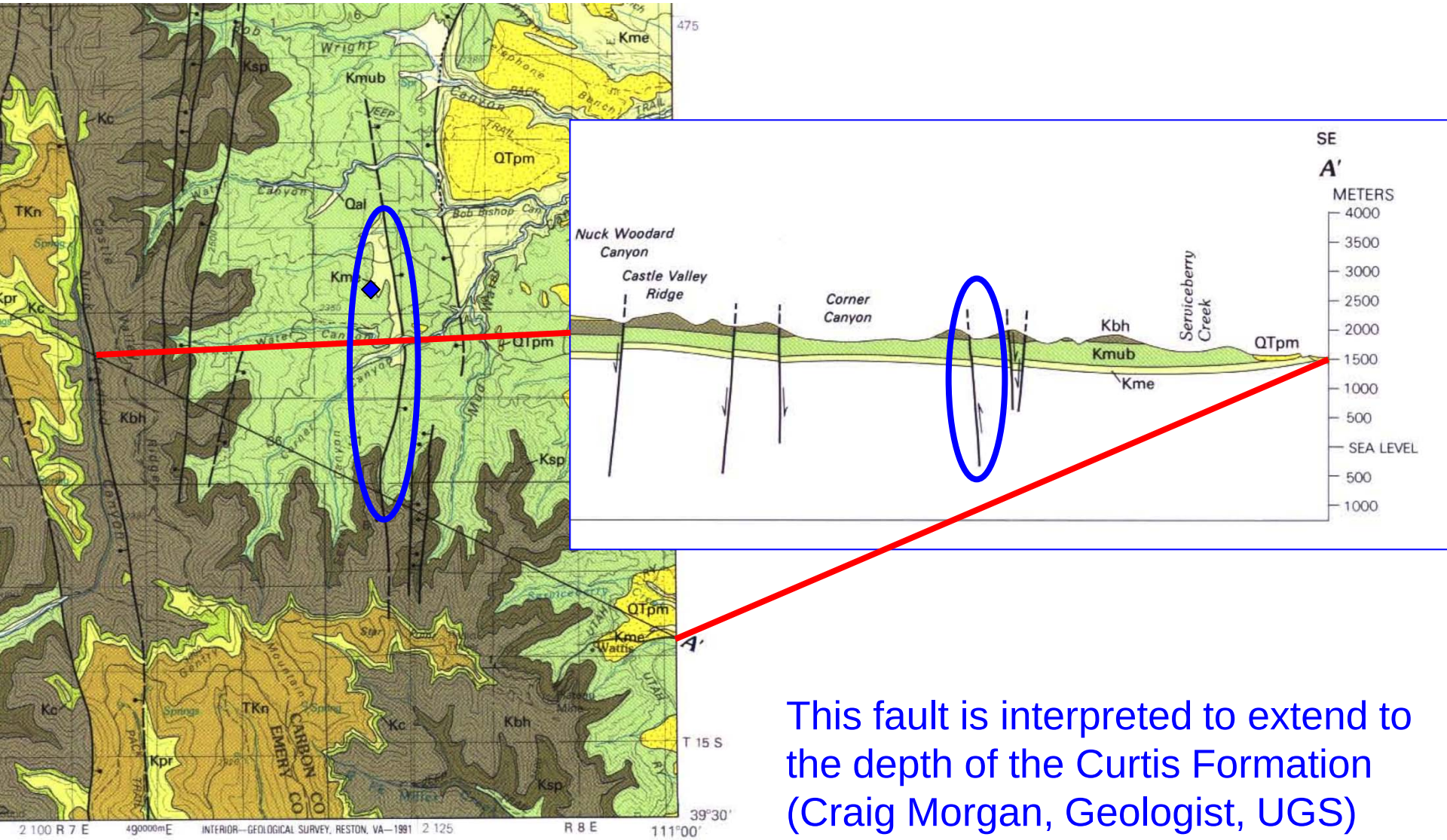


Critical Project Risks and Mitigation Plan



This fault is interpreted to extend to the depth of the Curtis Formation (Craig Morgan, Geologist, UGS)

Critical Project Risks and Mitigation Plan

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CO_2 Sink
Methane Producer
Seal

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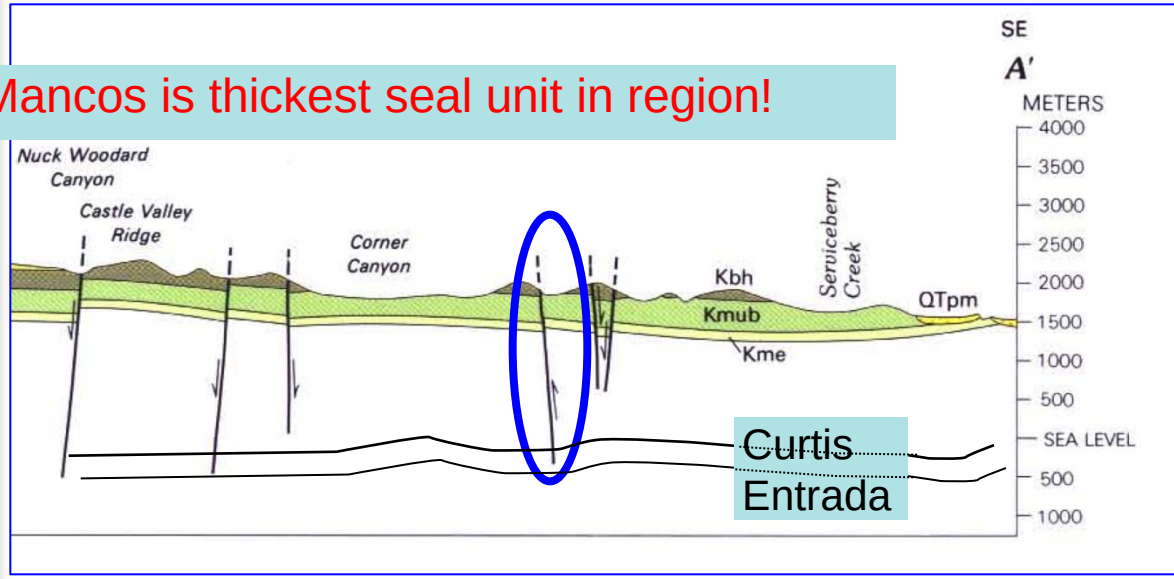
Modified from Hintze (1992)

Mancos is thickest seal unit in region!



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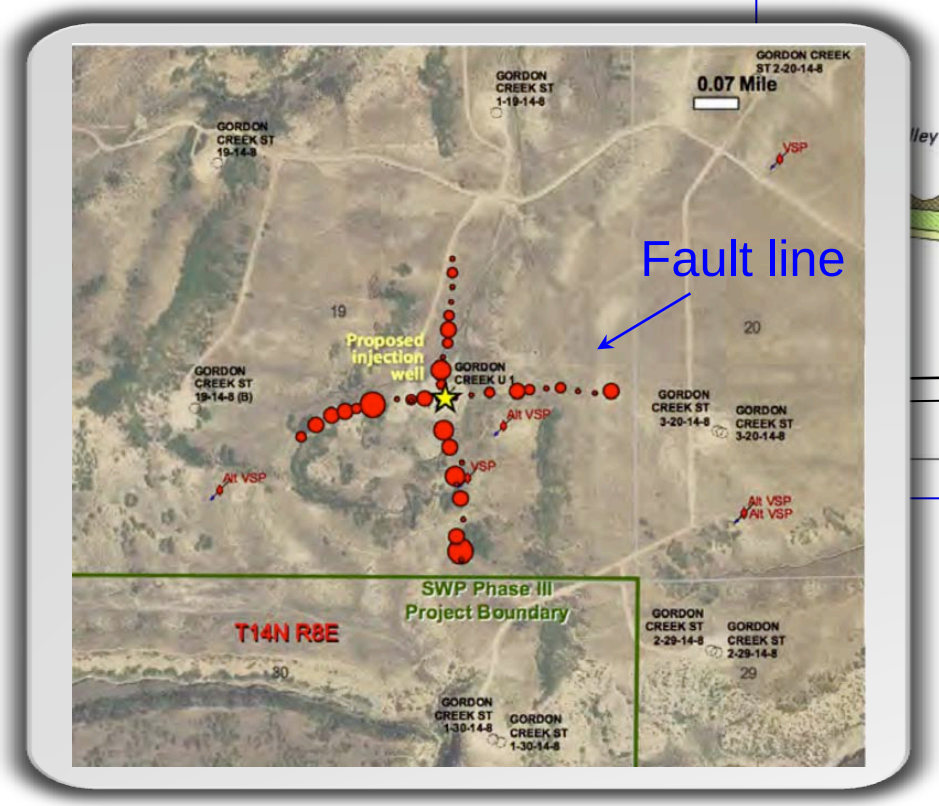
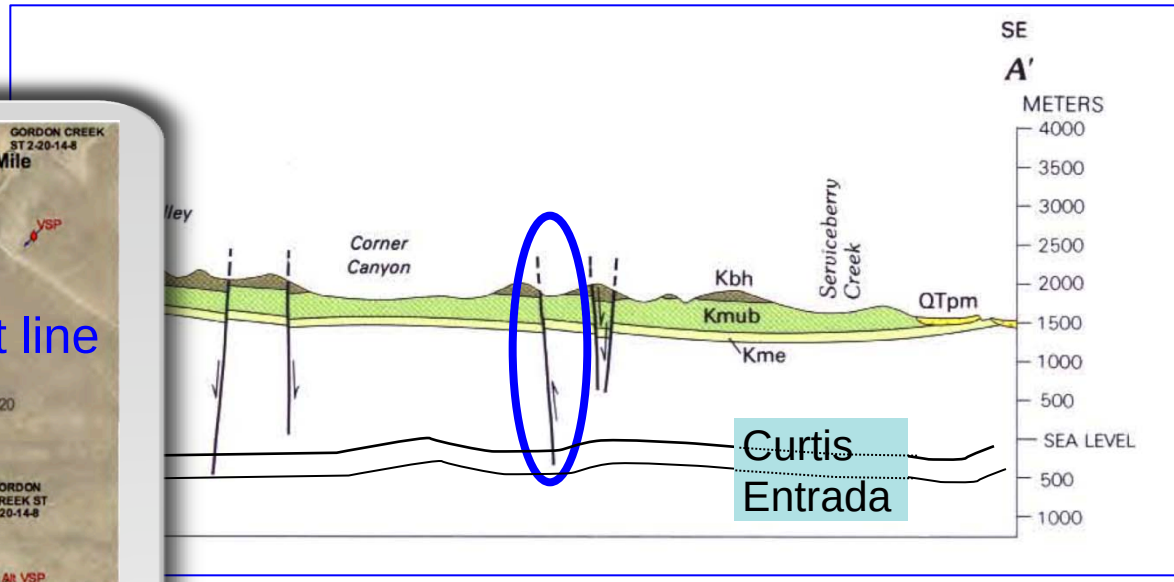
Critical Project Risks and Mitigation Plan





This fault is interpreted to extend to the depth of the Curtis Fm. (Craig Morgan, Geologist, UGS)

Critical Project Risks and Mitigation Plan

Our mitigation plans are not finalized (see poster session), but we forecast reliance on well-shutdown and, potentially, production. We are designing and simulating pressure-reduction scenarios for the following purposes:

- **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**

Preliminary simulation results suggest that diffusivity is a critical component for pressure reduction, and that high pumping (production) rate scenarios may lead to premature pore-collapse and formation damage for some rock types.

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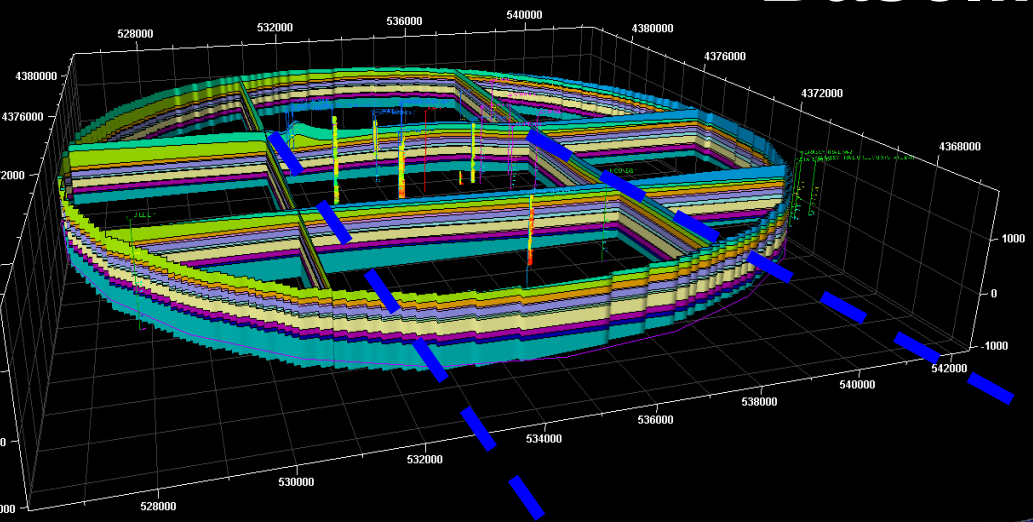
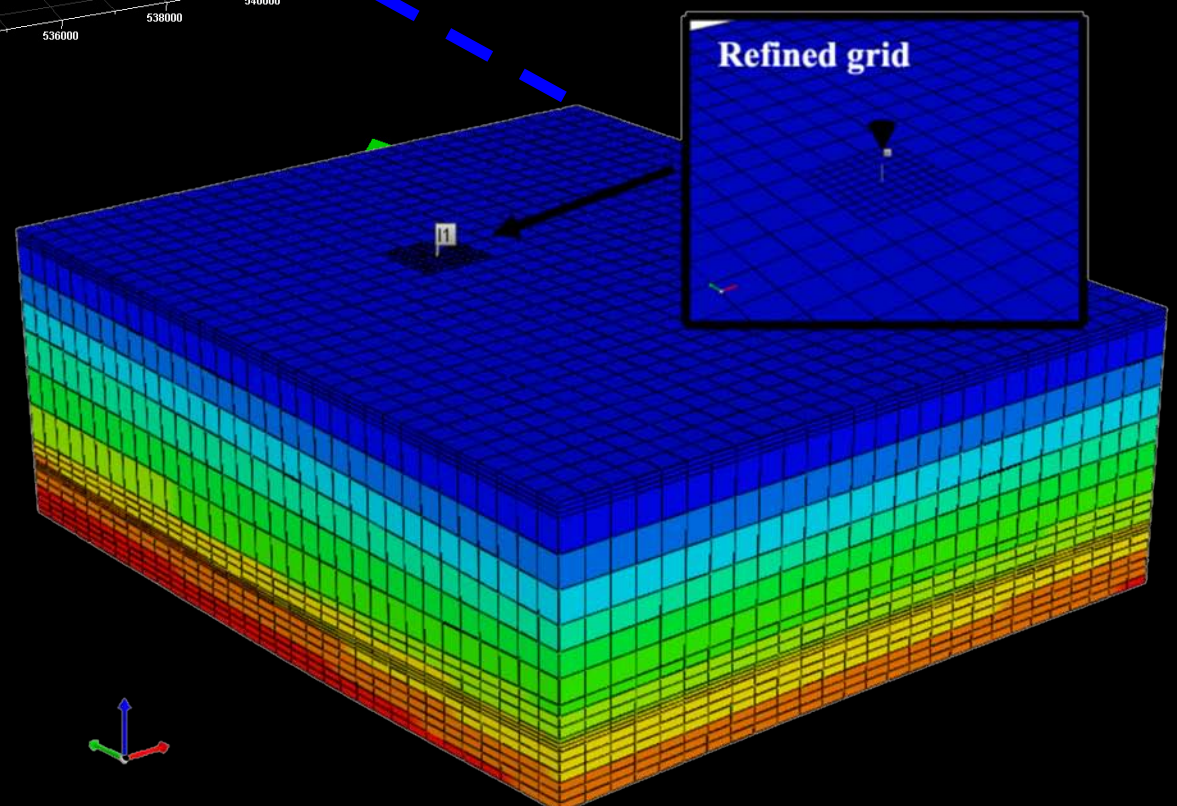
SWP Phase III: Baseline Modeling for MVA

5 Mile Radius

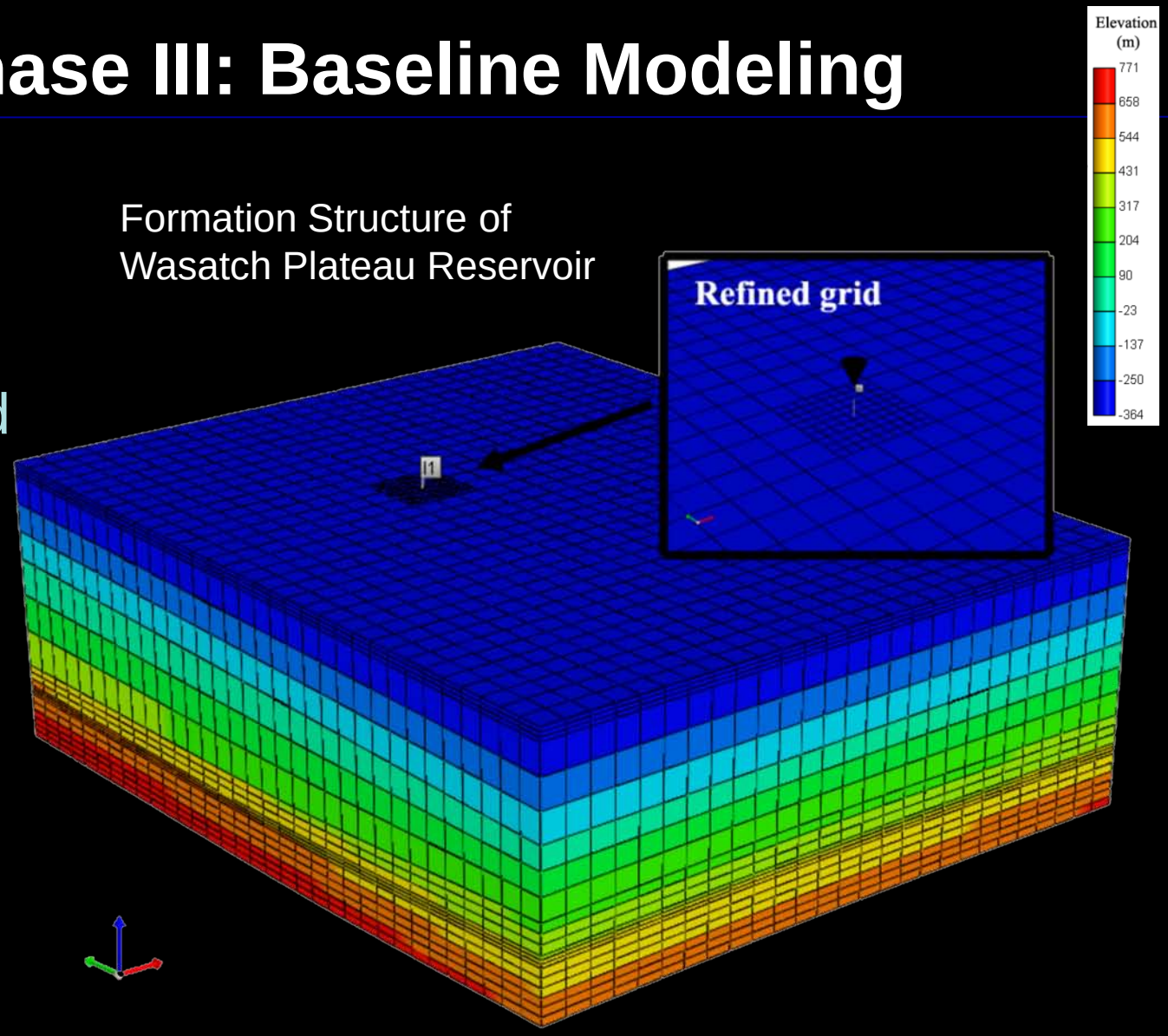




SWP Phase III: Baseline Modeling

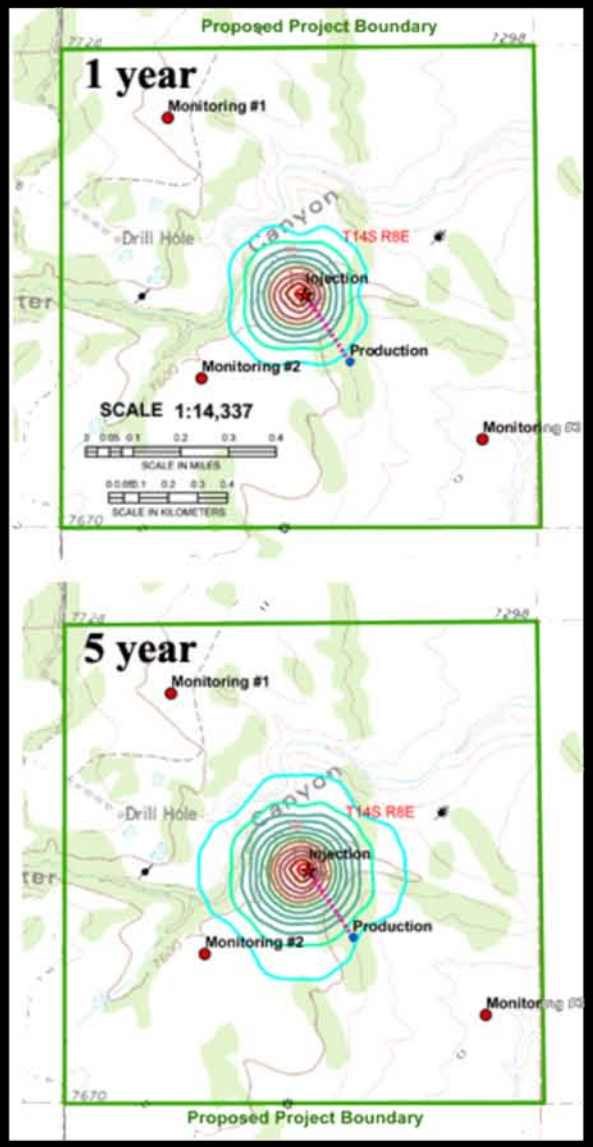
Formation Structure of
Wasatch Plateau Reservoir

Well logs used to construct initial general model of Wasatch Plateau site



SWP Phase III: Baseline Modeling

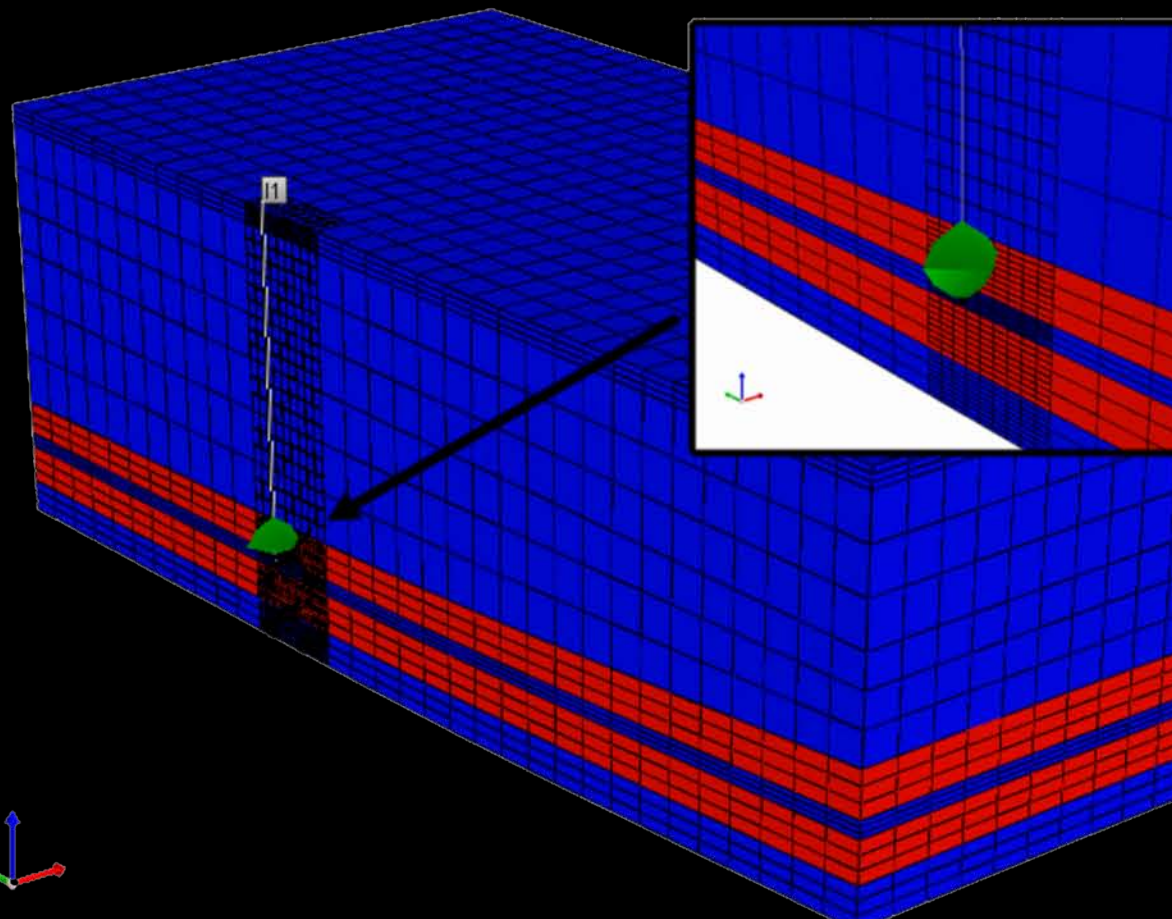
Plume-spreading "footprint" is less than a half-mile for a small-scale injection demonstration.



Legend

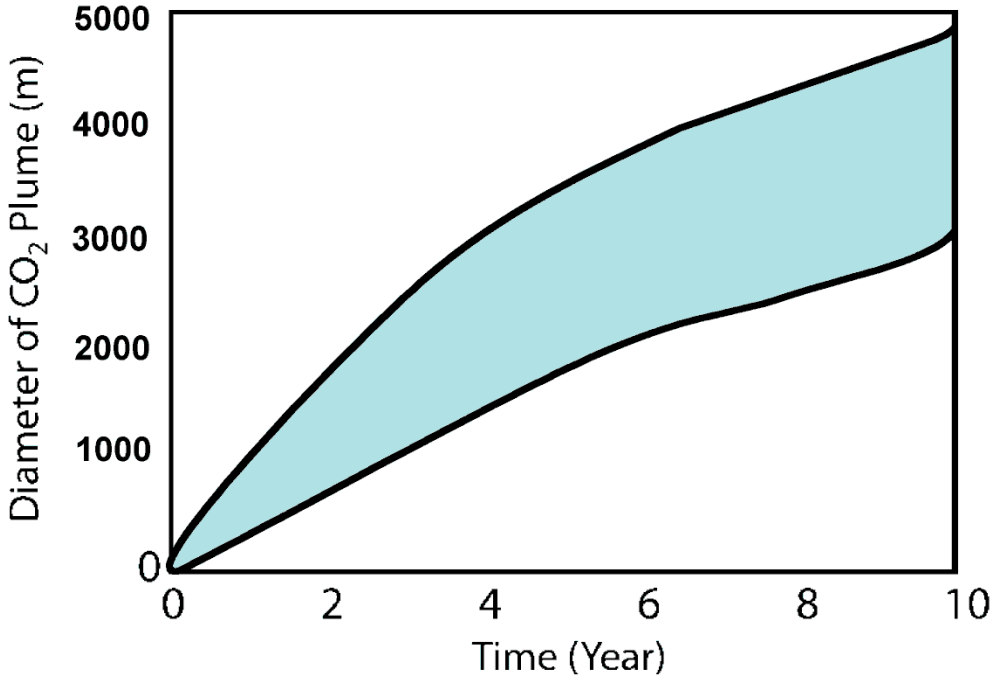
CO2 Saturation after 5 years of injection (100,000 metric tons per year)

- <1%
- 6%
- 15%
- 24%
- 33%



SWP Phase III: Baseline Modeling

10-year Injection of 2M tons/year



- Wasatch Plateau, Utah

Initial modeling of capacity and stability

- Additional data anticipated…
  - Core from target and seal formations
  - Accurate logs from injection well
  - High Resolution 3D seismic

SWP Phase III: Basic Capacity Data

	NAVAJO	CARMEL	ENTRADA	CURTIS / SUMMERVILLE
FUNCTION	1° Reservoir	1° Seal	2° Reservoir	2° Seal
Storage Capacity/1.0 mi^2 (million tons) 0.01 to 0.05 efficiency	**up to 50 Mtons**	NA	**Up to 10 Mtons**	NA
Depth (ft)	8400	7650	6585	5895
Thickness (ft)	350	650	1065	690
Temperature (°F)	149	144	131	127
Pressure (psi)	4050	3600	3050	2750
~Permeability (mD)	10	0.001	5	0.001
~Porosity	10%	2%	10%	2%
Lithology	Eolian Sandstone	Interbedded limestone, shale, siltstone, sandstone, evaporites	Eolian Sandstone	Interbedded shale, siltstone, sandstone
Mineralogy/ Chemical Composition	quartz with feldspar and minor clay	Silicates (quartz, feldspar) carbonates, phosphorites (carbonate-fluorapatite) and sulfides	quartz with feldspar and minor clay	illite, chloaite, quartz, calcite, dolomite, plagioclase, authigenic pyrite and trace amounts of other minerals

NA = Not Applicable

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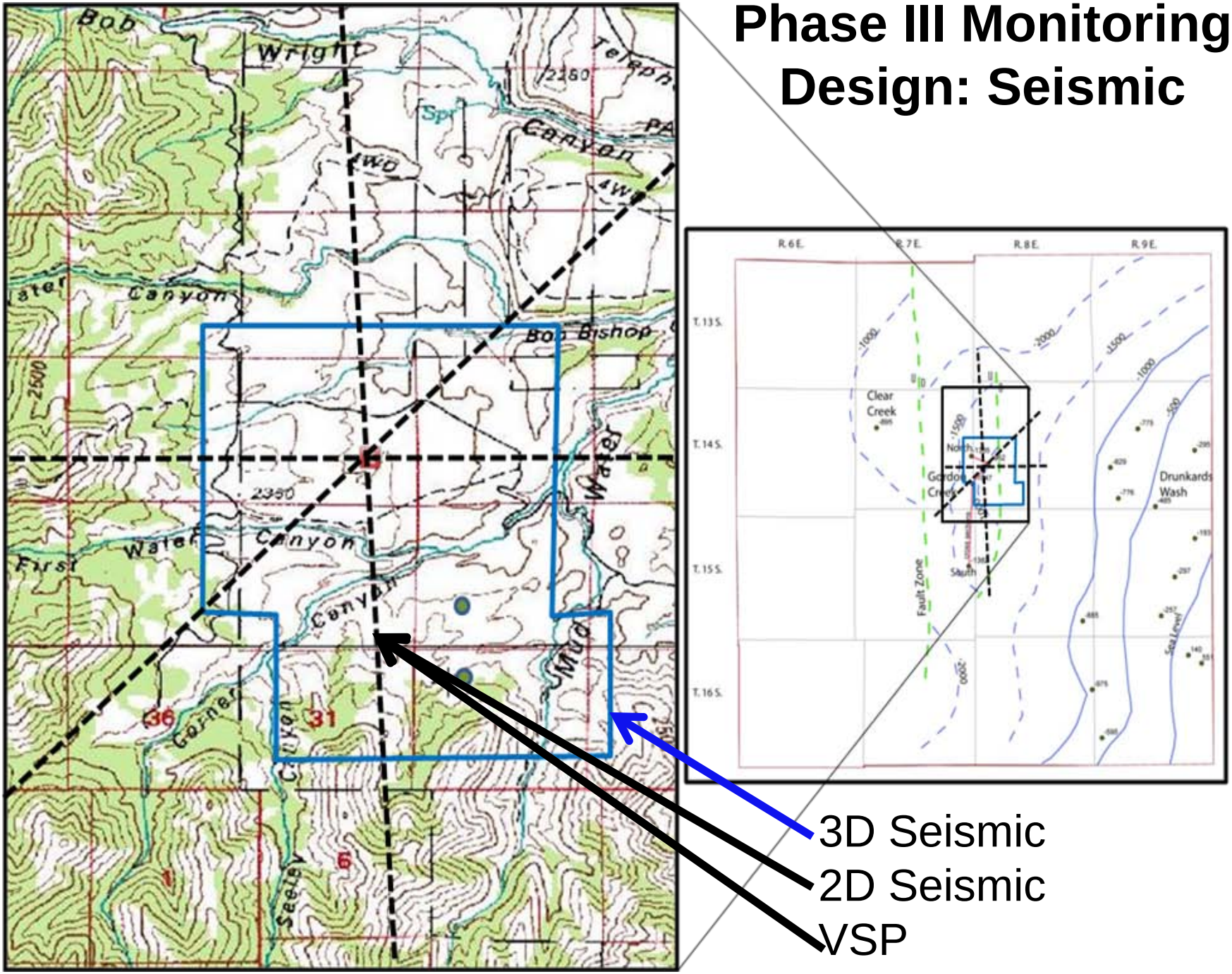
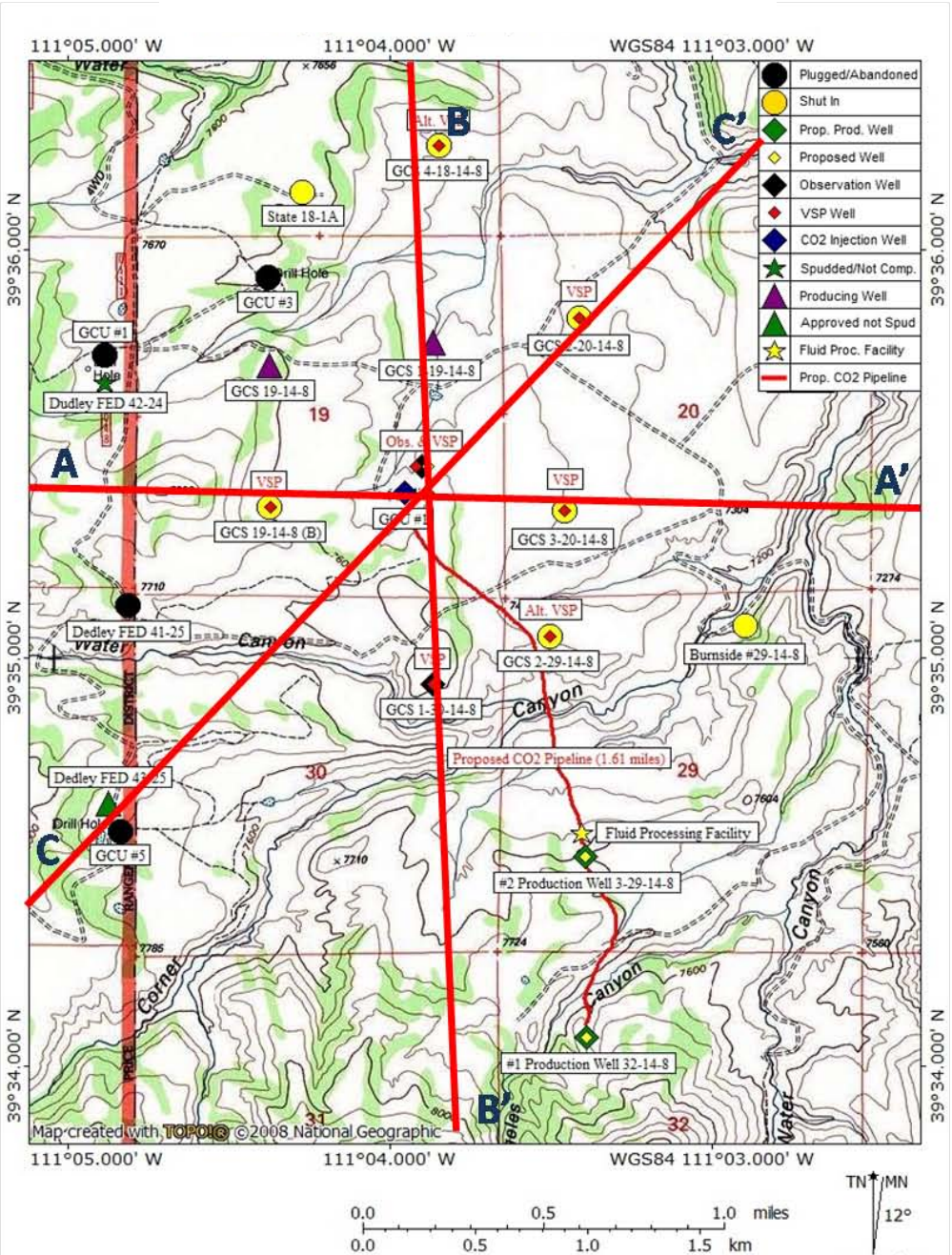
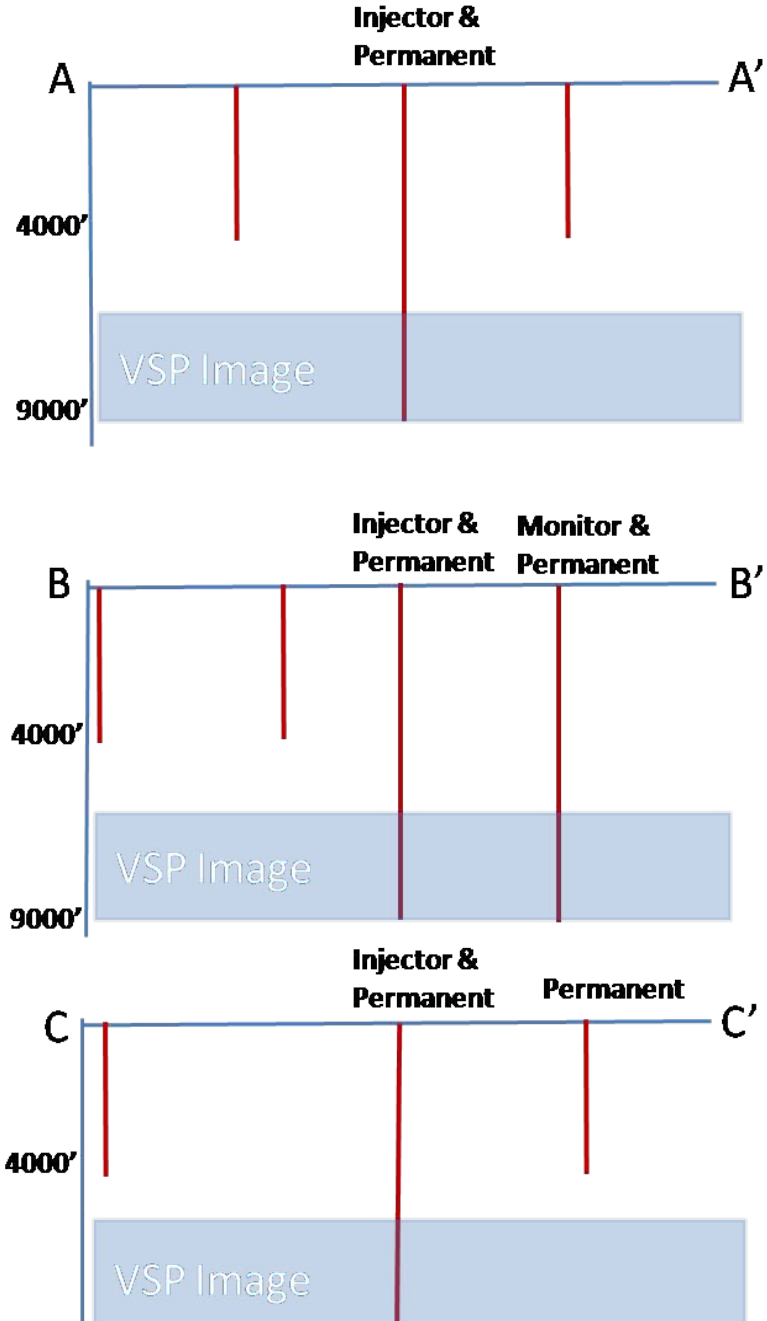
Phase III Monitoring Design: Seismic



Phase III Monitoring Design: Seismic





Big Game Winter Closure
(delay seismic survey till Spring)

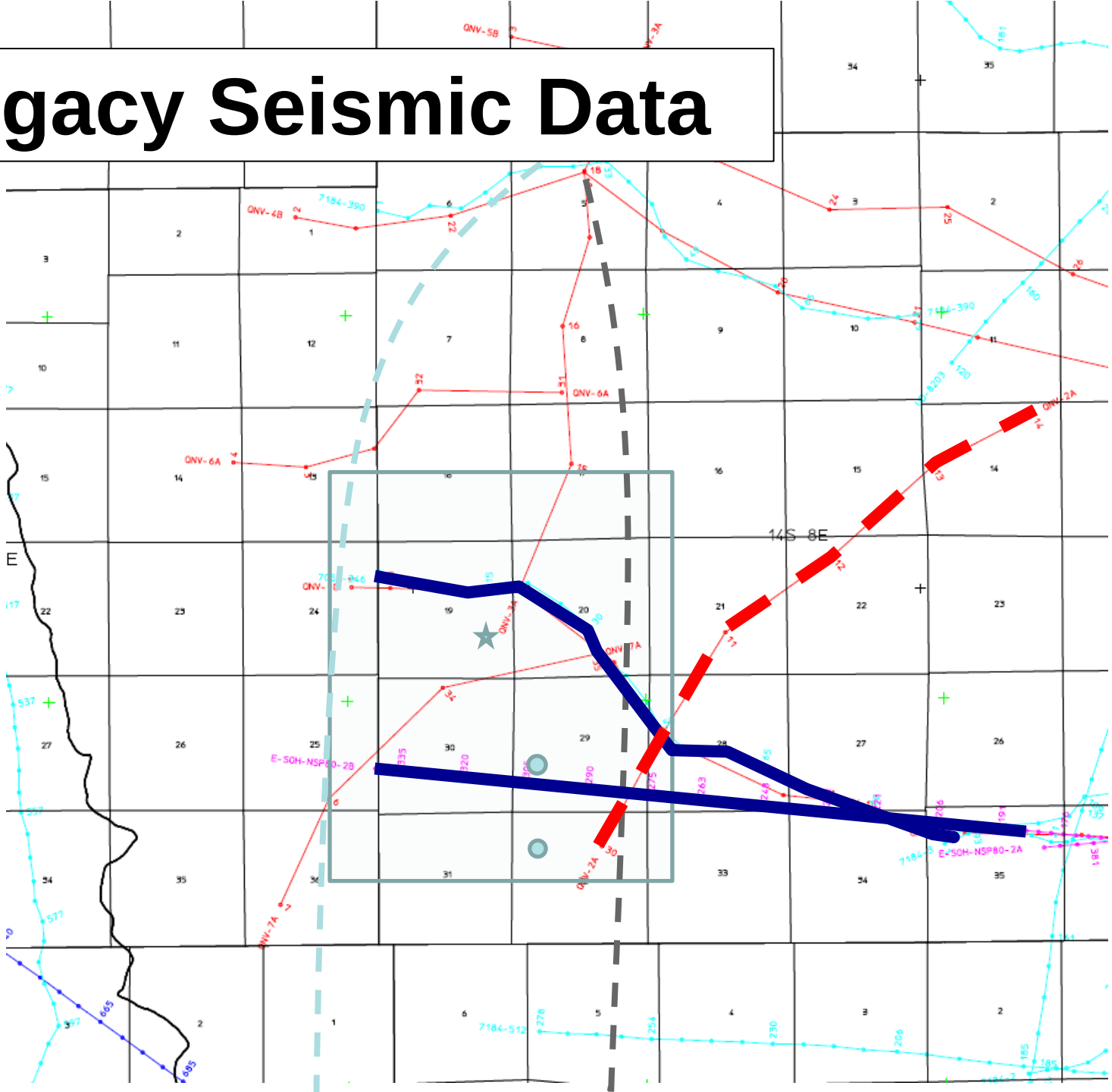
Existing 2D Data

- Exploration in the area in the 1960's and 1980's resulted in some legacy data:
  - 1 fold 2D lines – 1960's
  - Multifold 2D lines – 1980's
- We have acquired several lines in the area to see if any preliminary structural confirmation can be made

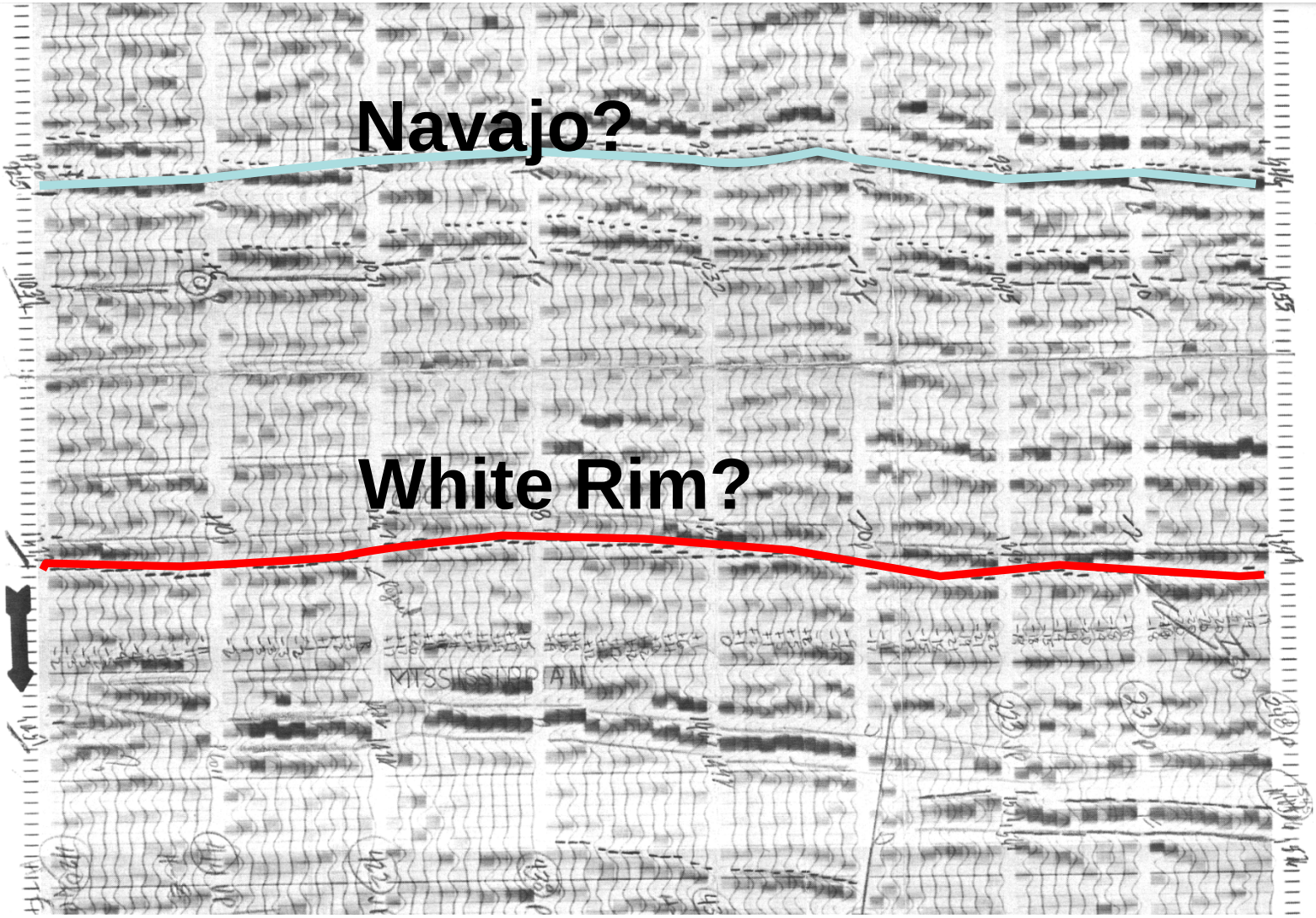
Current Status

- Examining Legacy 2D data
  - Re-processing digital data
  - Is it enough to define structure?
    - No obvious faults…
- Prepare for Seismic NEPA
  - Prepare an acquisition plan that minimizes off-road activities
    - Simpler NEPA
    - Reduces acquisition cost

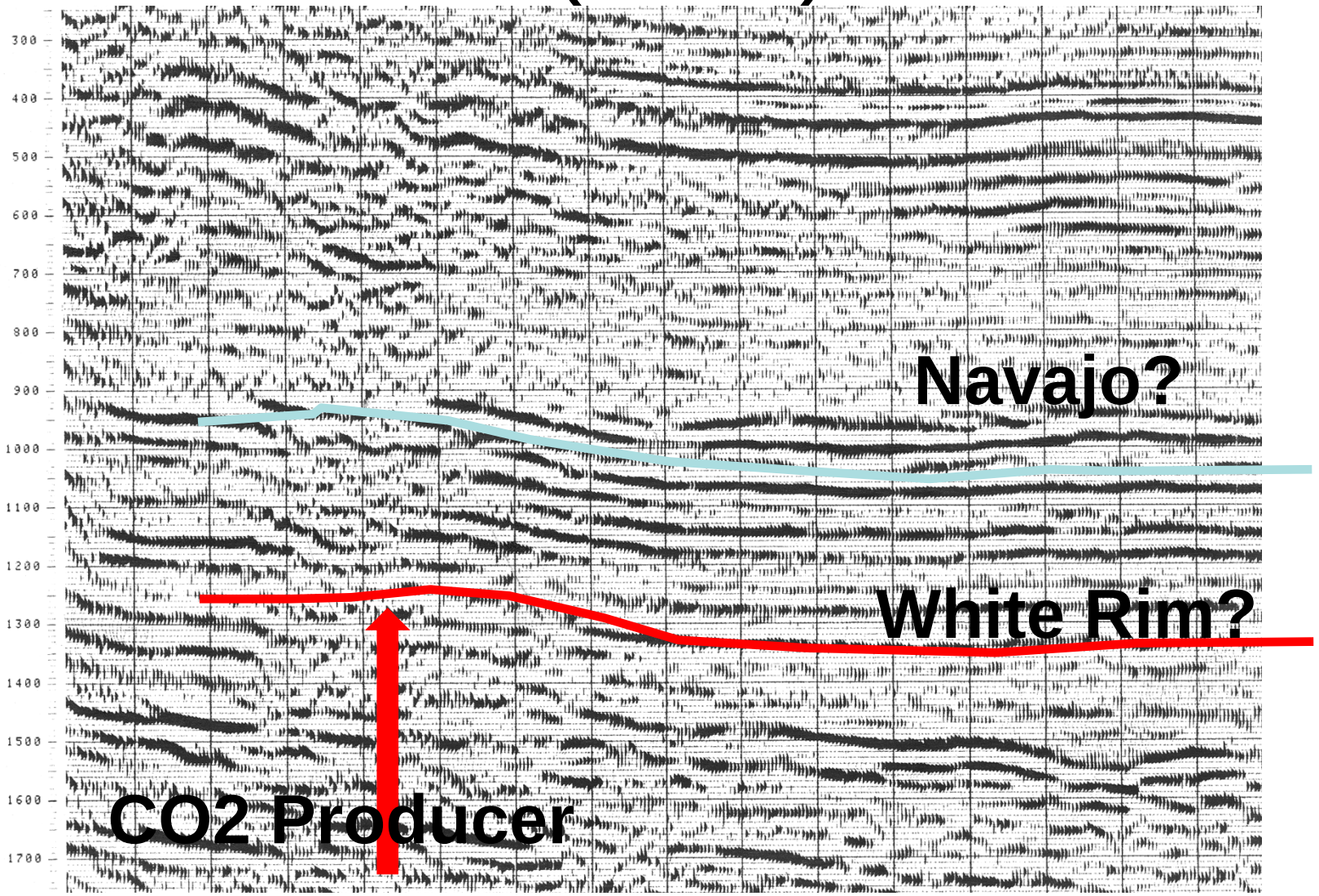
Legacy Seismic Data



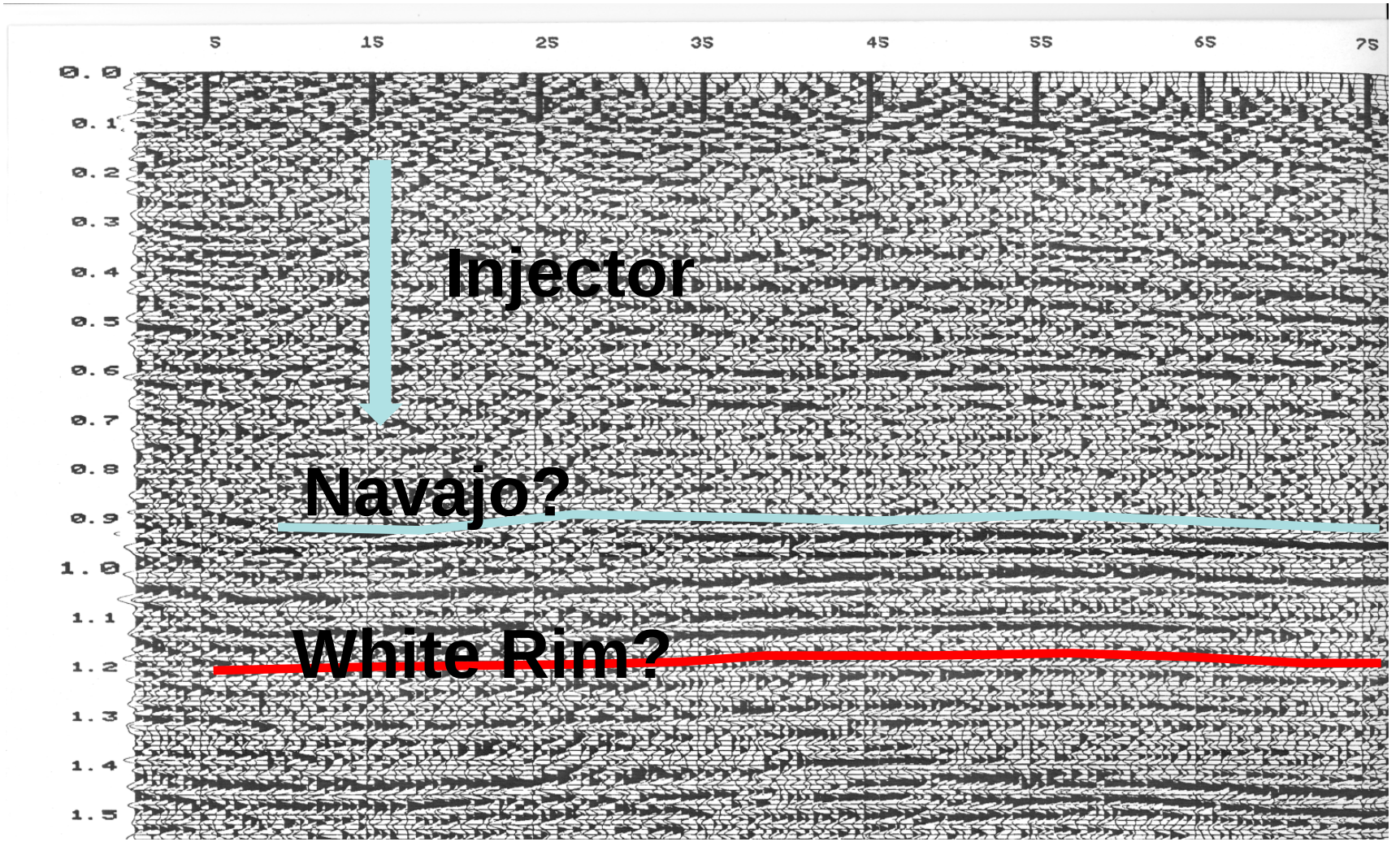
QNV-2A 1-fold line (1962)



E-SOH-NSP80-2B 10-fold (1981)



7052-346 10-fold (1981)



Phase III Monitoring Design: Surface

Surface and near-surface gas flux monitoring

Monitoring	Objectives	Equipment
Soil gas flux (CH_4, CO2, O2, N2, Hydrocarbons) Nobel gas analysis Isotope analysis	➢ CO_2 leakage; ➢ Compositional and isotopic fluxes; ➢ Vertical flux of isotopes to resolve diurnal variations of caused by natural sources and isotopic shifts between natural and fossil sources; ➢ Thief zone monitoring	▪ Gas chromatograph (GC); ▪ Eddy-flux tower for evaluating not only CO_2, but also CH_4

Shallow groundwater quality monitoring wells

Existing wells New drilling wells	➢ CO_2 leakage ➢ Identification of ground water contamination	▪ Ion chromatograph (IC) ▪ Inductively coupled plasma - mass spectrometer (ICPMS)

Phase III Monitoring Design: Wells

Monitoring well

❑ Downhole P,T monitoring Chemical sensor (pH) Downhole water sampling Tracers Permanent geophone array for passive seismic monitoring and VSP	➢ CO_2 plume tracking ➢ Impact of CO_2 on receiving aquifer	▪ Pressure, temperature sensor ▪ Chemical sensor ▪ Ion chromatograph (IC) ▪ Inductively coupled plasma - mass spectrometer (ICPMS) ▪ Total organic carbon analyzer (TOC) ▪ Picarro isotope analyzer

Active methane production wells

Isotope analysis of CH_4 and CO_2 Compositional analysis of produced gases	➢ Caprock integrity ➢ Leakage; use isotopic mixing methods to characterize mixing & transport processes in the reservoir	▪ Picarro isotope analyzer in the field

Phase III Monitoring Design: Wells

CO_2 production well

Isotope analysis Downhole P,T monitoring at different formations Wellhead pressure	➢ CO_2 source analysis ➢ CO_2 supply ➢ CO_2 plume tracking	Picarro isotope analyzer

Injection well

Downhole P,T monitoring Wellhead pressure Injection volume/rate Pump testing	➢ Injectivity monitoring ➢ Operating adjustment ➢ Reservoir diagnostics to characterize boundary conditions; obtain permeability	▪ Pressure sensor ▪ Temperature sensor ▪ Pressure gauge ▪ Flow meter

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SWP Phase III: Deployment Design

Period	Symb †	Formation / Member		Thickness (feet)	Depth (feet)*	Lith.
CRET	Km	Mancos Shale	Emery Ss Mbr		0	
			Blue Gate Sh Mbr	<250	**3115**	
			Ferron Ss Mbr	10-110	**3250**	
			Tununk Sh Mbr	200-300	**4000**	
	Kd	Dakota Sandstone		0-30	**4025**	
	Kcm	Cedar Mtn Fm	Upper member	150-750	**4120**	
			Buckhorn Cg Mbr	0-50		
JURASSIC	Jm	Morrison Formation		800±	**4460**	
	Js	Summerville Formation		120-180	**5895**	
	Jct	Curtis Formation		140-180	**6275**	
	Je	Entrada Formation		150-950	**6585**	
	Jc	Carmel Formation		300-700	**7650**	
	Jc	Page Sandstone		<70		
	Jgc	Navajo Sandstone		150-300	**8400**	
		Kayenta Formation		120-200	**8750**	
		Wingate Sandstone		300-400	**8885**	
TRIASSIC	Trc	Chinle Fm	Upper member	200-300	**9225**	
			Moss Back Mbr	20-60		
	Trmt	Moenkopi Fm	Upper member	550-700	**9520**	
	Trms		Sinbad Ls Mbr	50	**10460**	
	Trmbd		Black Dragon Mbr	250-350		
PERM	Ppc	Kaibab/Park City Fm		170	**10890**	
	Pwr	White Rim Sandstone		500-700	**11135**	

CO_2 Source

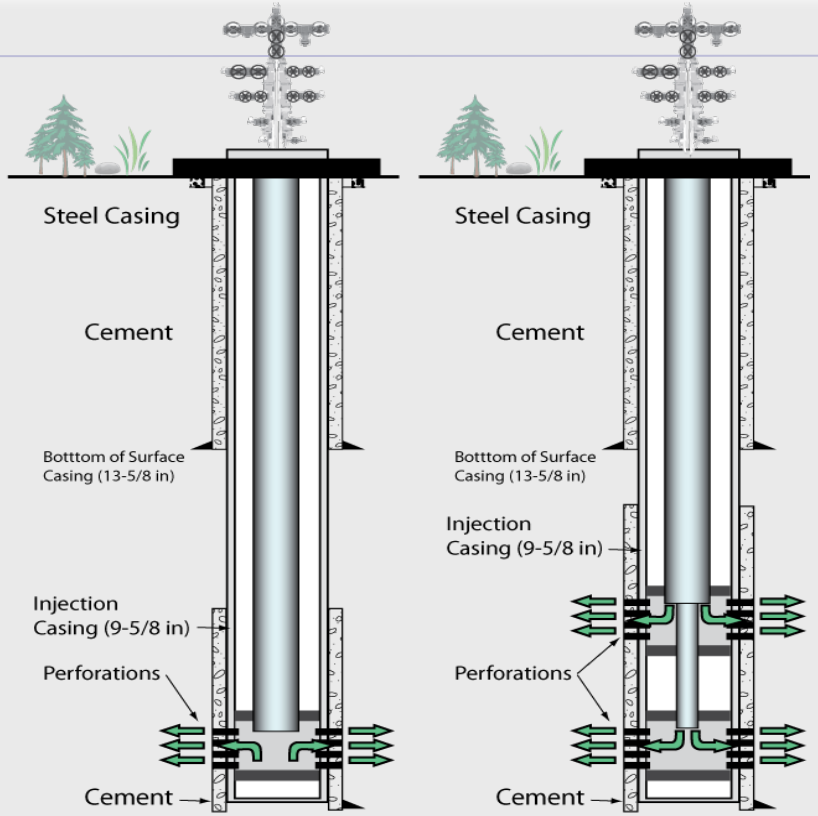
CO_2 Sink

Methane Producer

Seal

† Geologic symbols for correlation to units in Morgan (2007)

Modified from Hintze (1992)

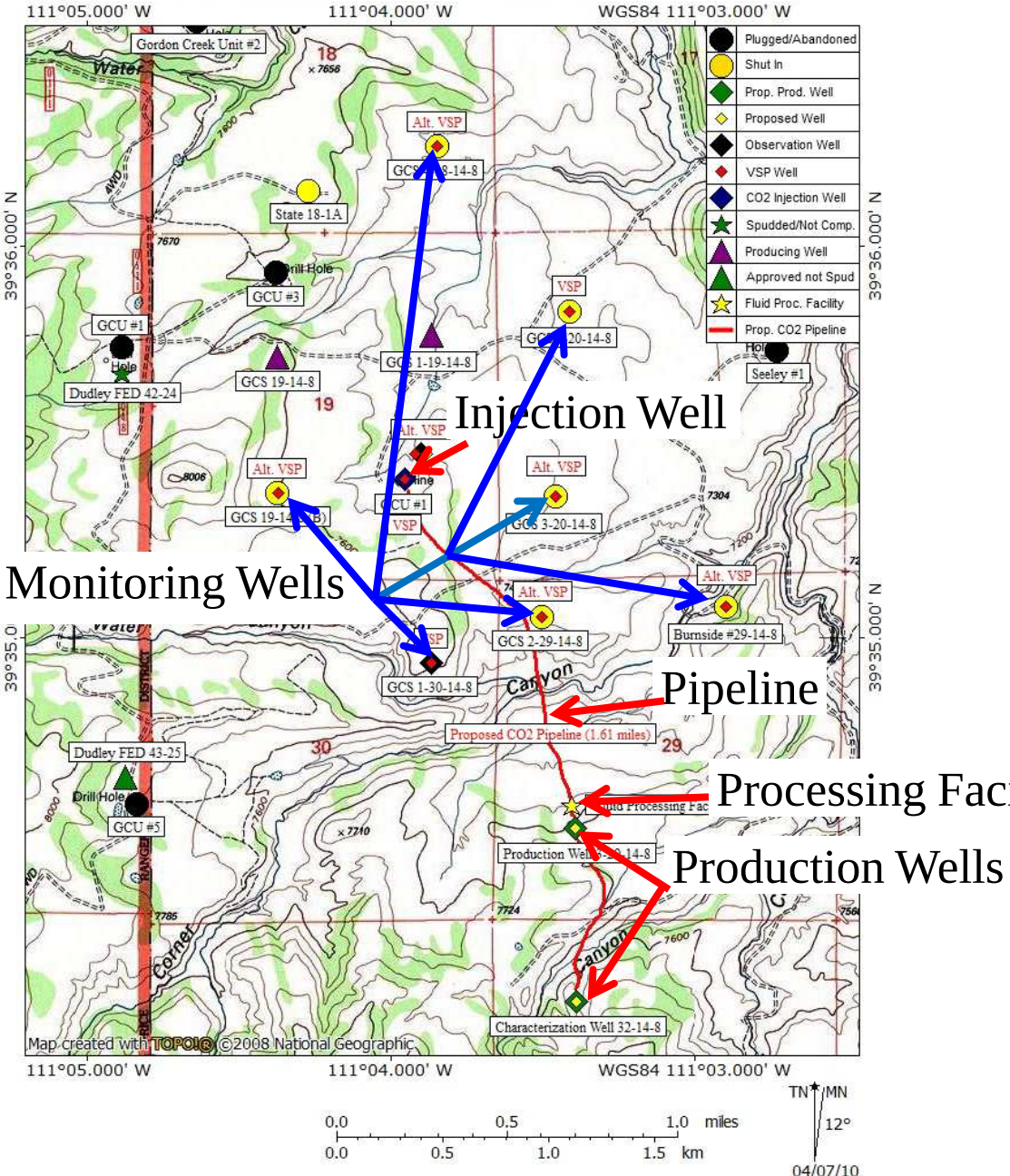


Single zone Injection (Navajo Fm):

Dual zone Injection (Entrada & Navajo Fm)

Multiple-Zone Injection and Storage Assessment

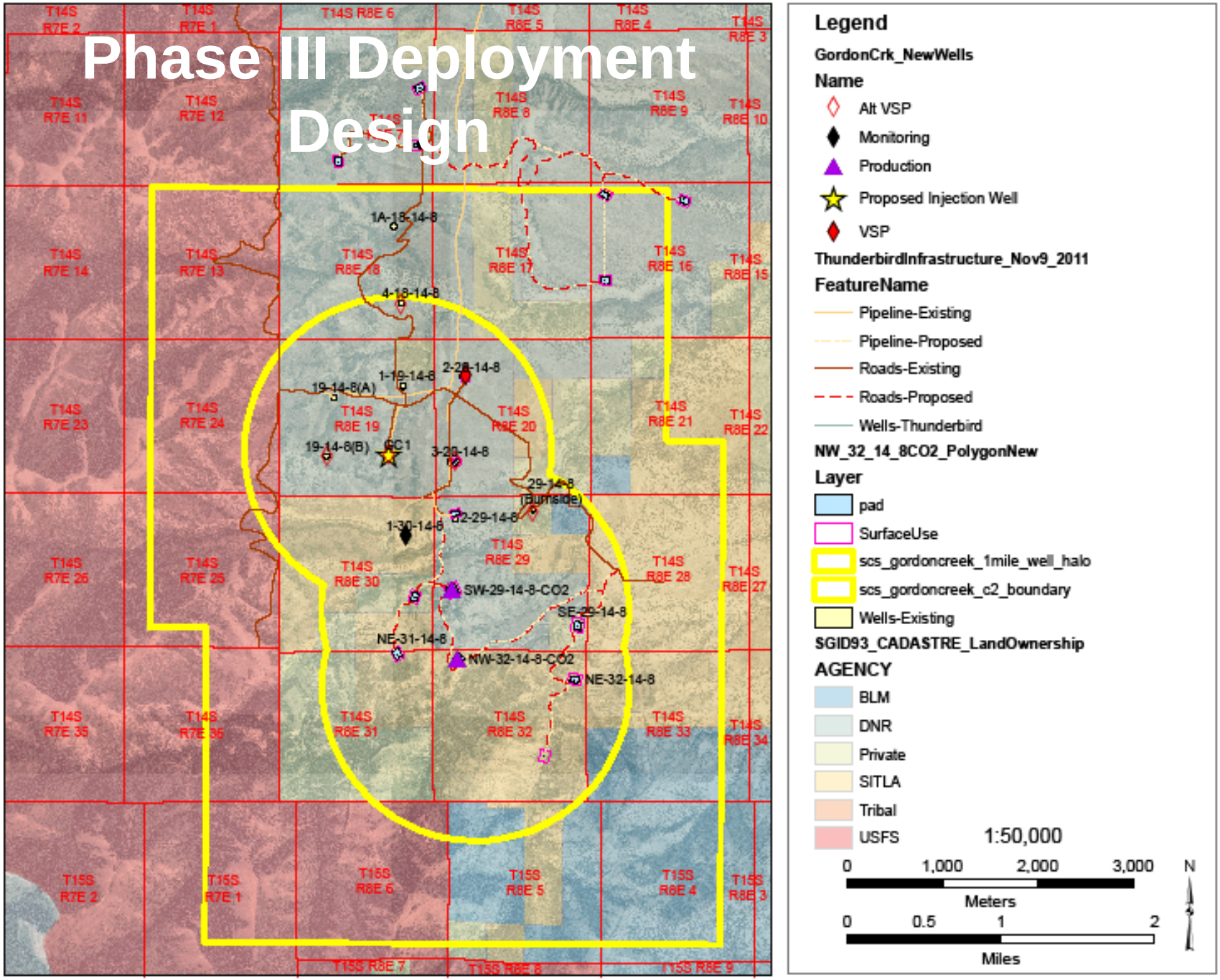
SWP Phase III: Deployment Design



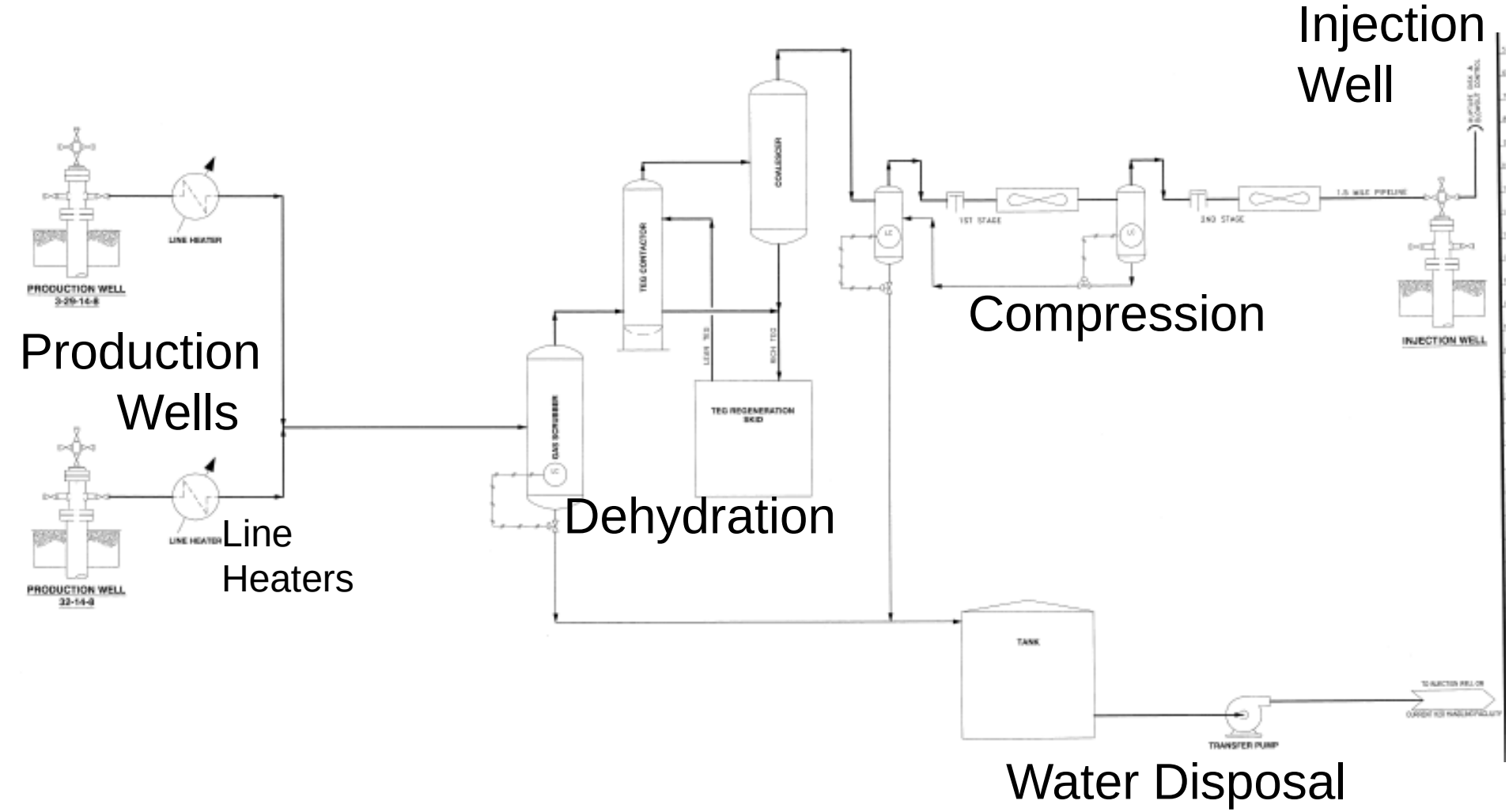
Initial Field Engineering Design:

Site map including existing and projected wells, CO_2 pipeline, and CO_2 processing facilities.

Phase III Deployment Design



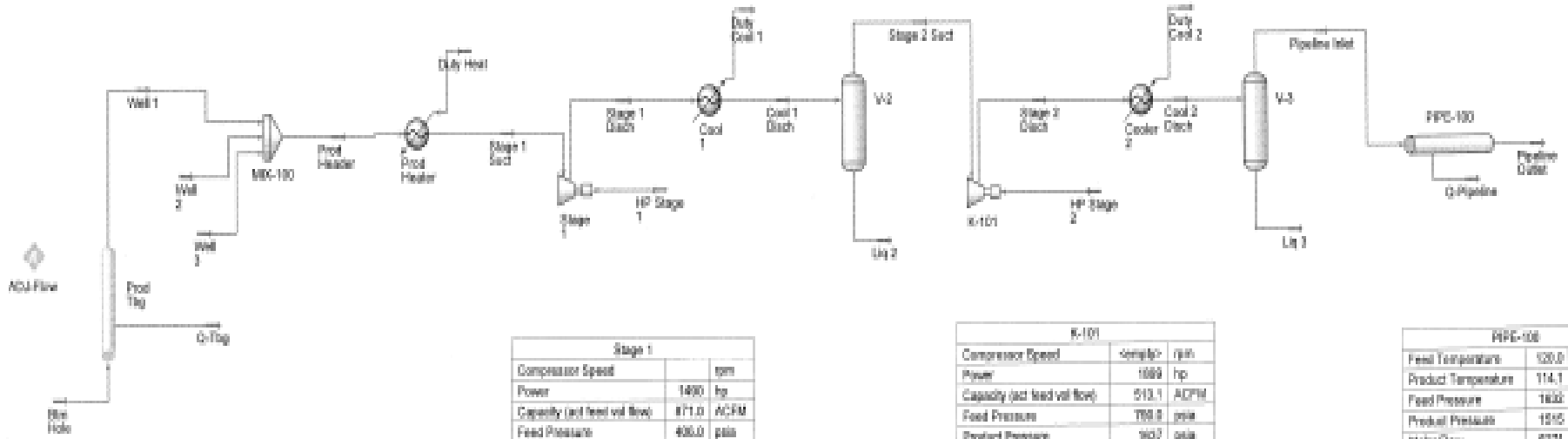
Phase III Deployment Design: Surface Facilities



Phase III Deployment Design: Surface Facilities

2-3 Stage Compression

200-400 psia production
1800-2000 psia injection



Stage 1		
Compressor Speed		rpm
Power	1490	hp
Capacity (act feed vol flow)	871.0	ACFM
Feed Pressure	400.0	psia
Product Pressure	795.0	psia
Product Temperature	136.0	F
Surge Flow Rate		ACFM

K-101		
Compressor Speed	<empty>	rpm
Power	1089	hp
Capacity (act feed vol flow)	513.1	ACFM
Feed Pressure	795.0	psia
Product Pressure	1803	psia
Product Temperature	248.8	F
Surge Flow Rate	<empty>	ACFM

PIPE-100		
Feed Temperature	120.0	F
Product Temperature	114.1	F
Feed Pressure	1803	psia
Product Pressure	1515	psia
Molar Flow	5271	lbmole/hr

Support of Local Politicians and Long-Term Liability

- Because Gordon Creek is in an area of active hydrocarbon production, public perception tends to be very positive and supportive

- Local politicians, however, are not always supportive, especially those in Salt Lake City (the closest metropolitan area)

- Perhaps the greatest obstacles to commercial-CCS are lack of a liability framework and lack of financial incentives; public outreach has not been helpful for addressing these issues to date

- Through state bonding and private insurance, we have secured liability for this project, although UIC issues are inducing a bit of uncertainty

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Project Wrap-up

- Overall Accomplishments
- Key Findings
- Lessons Learned
- Future Plans

Wrap-up: Key Findings and Lessons Learned (Phase II)

Too many specific lessons to list. A specific sub-list, for sake of example, focuses on microseismicity:

- Microseismicity - both natural and induced - occurs just about everywhere

- Most seismic/microseismic events are associated with:
- pre-existing faults
- low permeability zones

(3) Microseismicity can aid in identifying geologic features like “critically-stressed” faults

(4) Induced seismicity can be controlled through effective reservoir/injection engineering

(5) Careful and effective site characterization and selection are keys to successful microseismicity management

Wrap-up: Key Findings and Lessons Learned (Phase II)

- **Oil/gas fields can play an important monitoring role in deep saline sequestration ops**
- **In all cases, it is difficult to predict geomechanical processes**
- **In all cases, it is difficult to predict induced or triggered seismicity**
- **CO_2 Diffusivity not = Hydraulic Diffusivity**

Wrap-up: Future Plans

- **Confirm the CO_2 source as soon as feasible**
- **Confirm injectivity and capacity of injection zone(s)**
- **Refine design of stacked storage monitoring**
- **Continue baseline monitoring and characterization**
- **Measure baseline CH_4 fluxes (if any) in the field, as a means of evaluating hydraulic communication of faults with the Ferron Sandstone**
- **Continue simulation development and increase resolution of risk assessment**

The End

Phase III Deployment Design: MVA

Measurement Technique	Monitoring Level	Measurement Parameters	Application (frequency)
Introduced and natural tracers	Subsurface	Travel time	Tracing movement of CO_2 in the storage formation (quarterly-annually)
		Partitioning of CO_2 into brine	Quantifying solubility trapping
		Identification sources of CO_2	Tracing leakage
Water composition	Subsurface	CO_2, HCO_3, CO_3^2	Quantifying solubility and mineral trapping (quarterly)
		Major ions	Quantifying CO_2-water-rock interactions (quarterly)
		Trace elements	Detecting leakage into shallow groundwater aquifers (quarterly)
		Salinity	(quarterly)
Subsurface pressure and temperature	Subsurface	Formation P & T	Control of formation pressure below fracture gradient and track temperature (constant)
		Annulus P & T	Wellbore and injection tubing condition (constant)
		Potable water aquifer pressure	Leakage out of the storage formation (constant)

Phase III Deployment Design: MVA

Measurement Technique	Monitoring Level	Measurement Parameters	Application (frequency)
Well logs	Subsurface	Brine salinity	Tracking CO_2 movement in and above storage formation (2-4 years)
		Sonic velocity	Tracing migration of brine into shallow aquifers (2-4 years)
		CO_2 saturation	Calibrating seismic velocities for 3D seismic surveys (once or twice)
3D & 2D seismic imaging	Surface	P and S wave velocity Reflection horizons Seismic amplitude attenuation	Mainly for characterization (One repeat if VSP warrant and funding available)
Vertical seismic profiling (VSP)	Subsurface	P and S wave velocity Reflection horizons Seismic amplitude attenuation	Detecting detailed distribution of CO_2 in the storage formation (1-2 year interval) Detection of leakage through faults and fractures (1-2 year interval)
Passive seismic monitoring	Subsurface /Surface	Location, magnitude and source characteristics of seismic events	Development of microfractures in formation or caprock (constant)
			CO_2 migration pathways (constant)

Phase III Deployment Design: MVA

Measurement Technique	Monitoring Level	Measurement Parameters	Application (frequency)
Soil gas sampling	Surface	Soil gas composition Isotopic analysis of CO_2	Soil gas composition (quarterly) Isotopic analysis of CO_2 (semiannually)
Electrical techniques	Subsurface	Formation conductivity	Tracking movement of CO_2 in and above the storage formation (quarterly to annually)
Land surface deformation	Surface	Vertical and horizontal displacement using InSAR and GPS monuments	Detect geomechanical effects on storage formation and caprock (InSAR: quarterly; GPS: constant)
			Locate CO_2 migration pathways (InSAR: quarterly; GPS: constant)
CO_2 land surface flux monitoring	Surface	CO_2 fluxes between the land surface and atmosphere	CO_2 fluxes between the land surface and atmosphere (quarterly if used)
		Atmosphere	(depending on instrumentation: quarterly or constant)