

**INJECTING CARBON DIOXIDE INTO
UNCONVENTIONAL STORAGE RESERVOIRS IN
THE CENTRAL APPALACHIAN BASIN WITH AN
EMPHASIS ON ENHANCED COALBED
METHANE RECOVERY**

Nino Ripepi
Virginia Center for Coal and Energy Research,
Virginia Tech

DOE Annual Review Meeting
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Purpose, Objectives & Duration

★ Purpose:

- ★ Test the injectivity of CO₂ into unmineable coal seams and the potential for ECBM.
- ★ The results of the injection and monitoring will help to better understand the effect of matrix swelling on injectivity and ECBM.
- ★ Provide much needed information on unconventional stacked storage options.

★ Objectives:

- ★ Inject 20,000 metric tons of CO₂ into **CBM wells** over a one-year period
- ★ Perform a small Huff and Puff test in a **Devonian shale gas well**

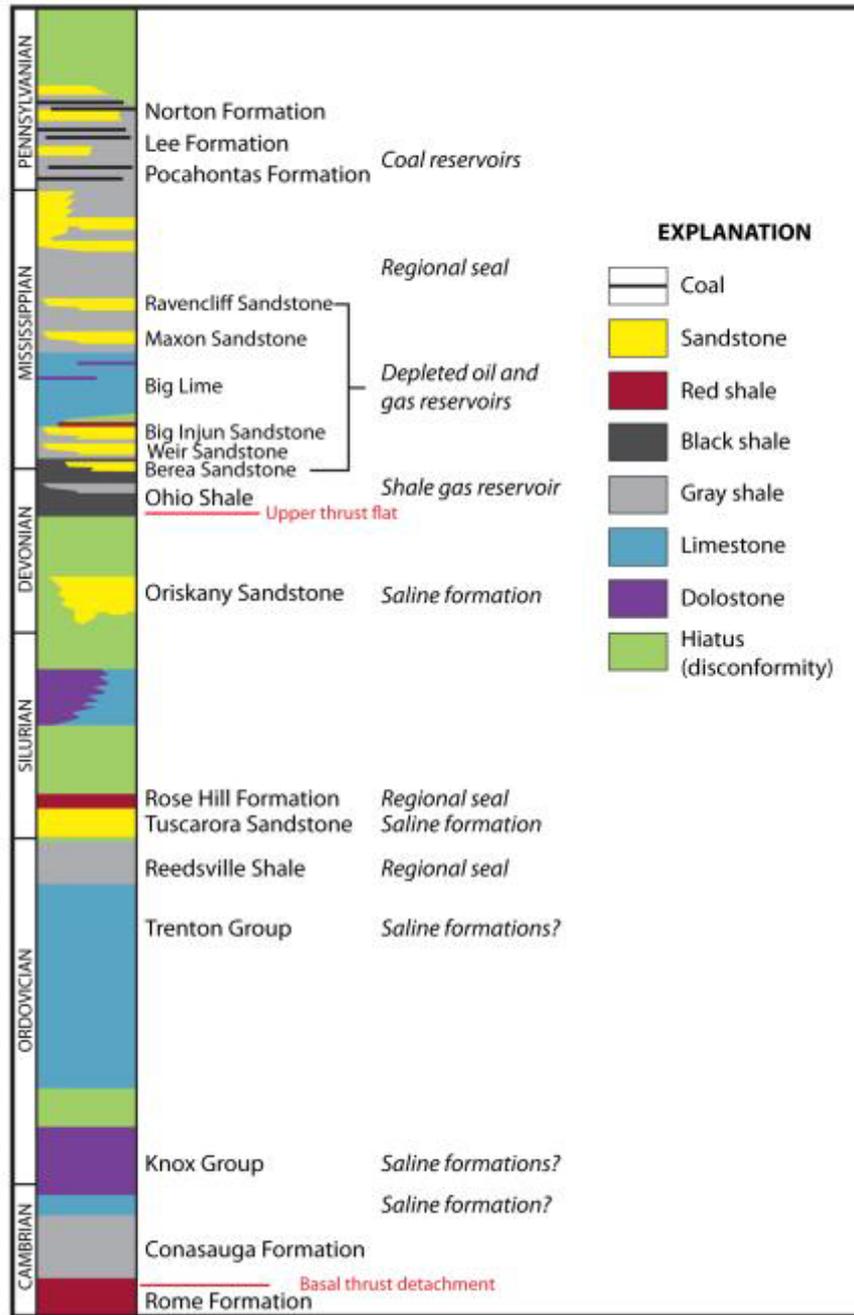
- ★ **Duration:** 4 years (October 1, 2011 – September 30, 2015)

Research Partners

- Virginia Center for Coal and Energy Research (Virginia Tech)
- Marshall Miller & Associates
- Jerry Hill & Southern States Energy Board
- Virginia Department of Mines, Minerals and Energy
- Geological Survey of Alabama
- Sandia Technologies
- Det Norske Veritas (DNV)
- CONSOL Energy

Industrial Partners

- CNX Gas (CONSOL)
- Alpha Natural Resources
- Dominion Energy



Generalized stratigraphic column showing potential carbon sinks for the Central Appalachian Basin

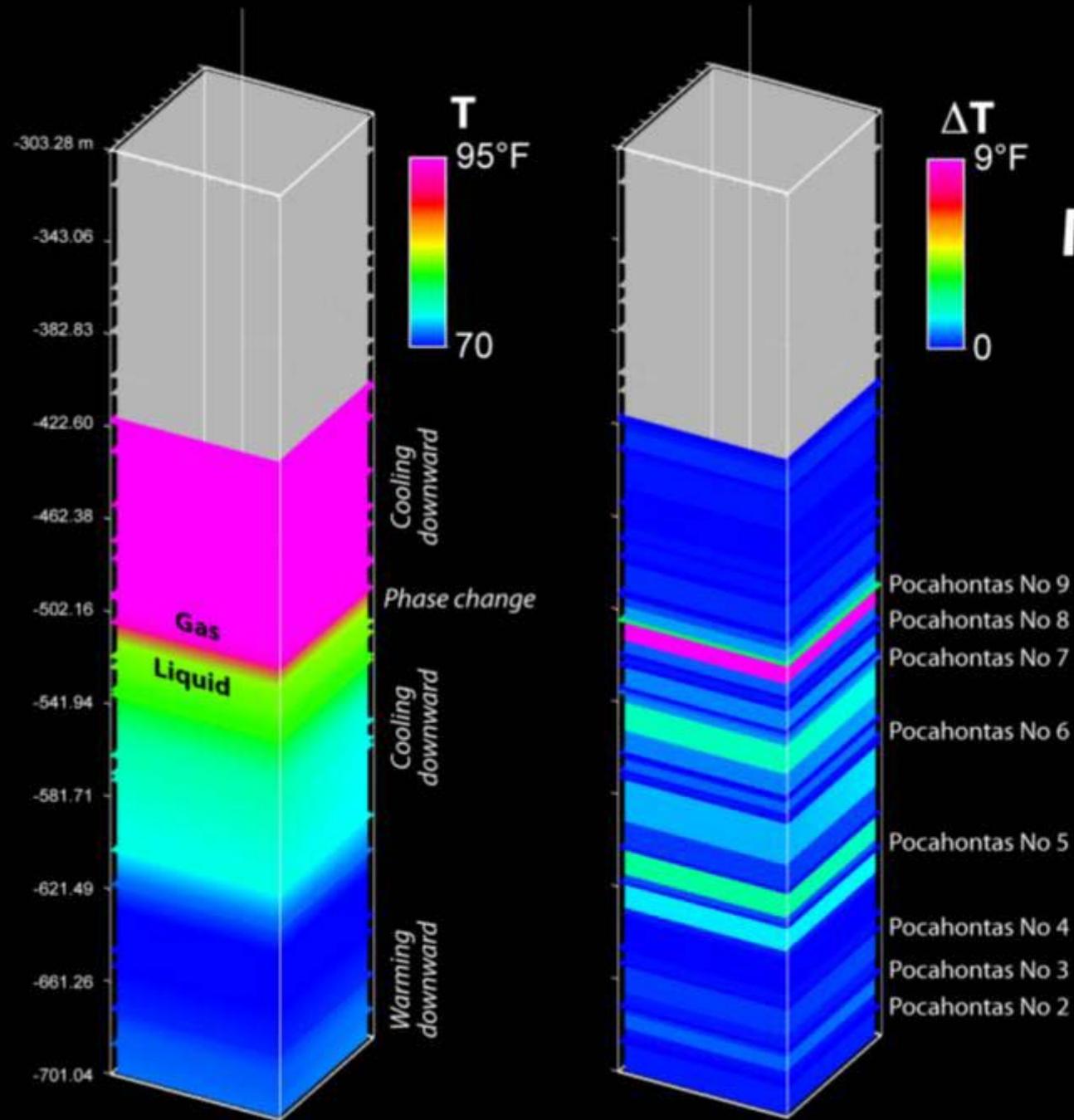
SECARB Phase II Task 2 – 1,000 Ton CO₂ Injection



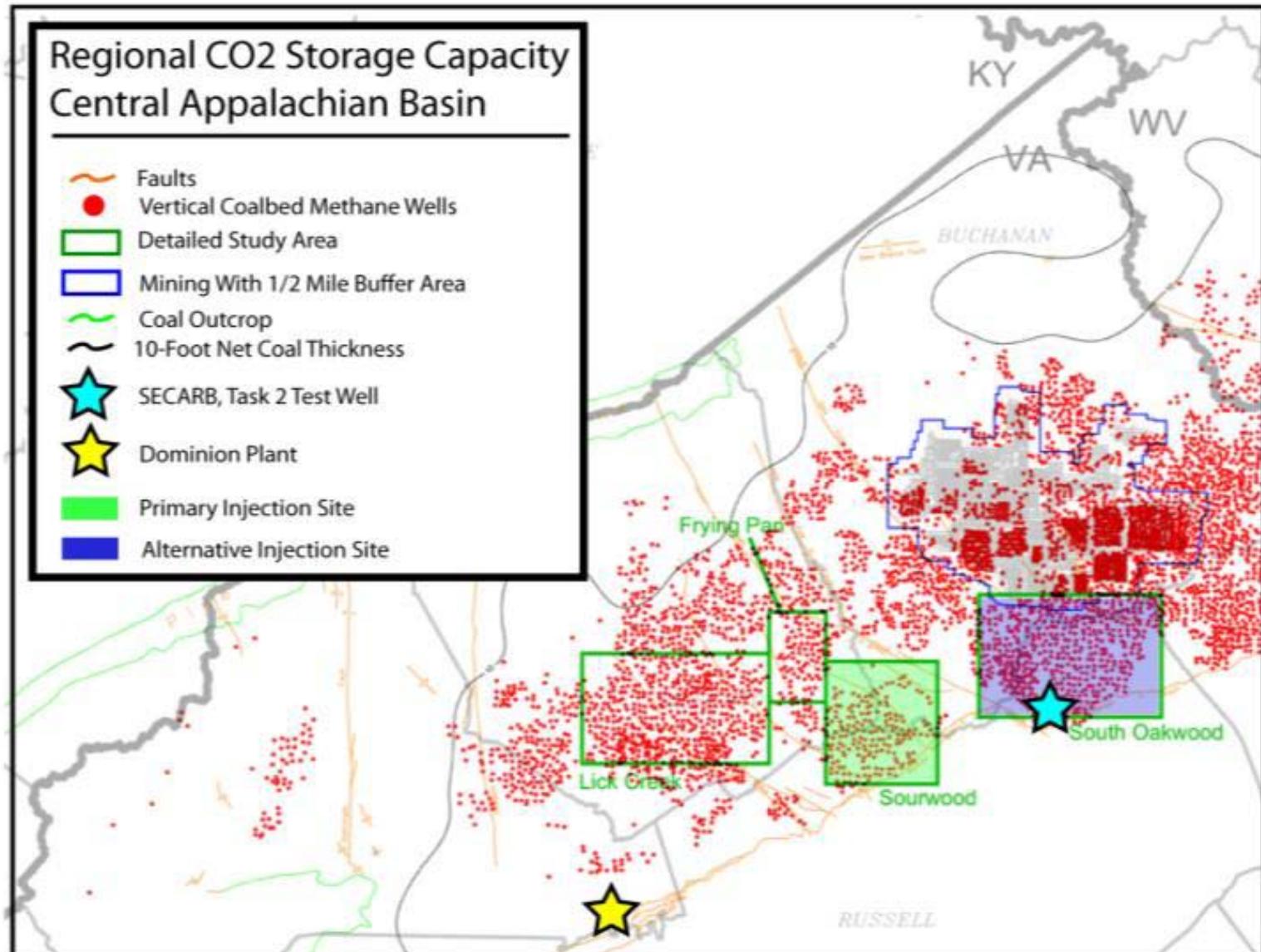
Phase II Injection

- 1,000 tons injected into stacked coals in January 2009
- Higher than anticipated Injection Rate (>40 tons per day)
- Decrease in Injection Rate (<20 tons per day)
- Flowback
 - Production returned to greater than pre-injection rates
 - N₂-CH₄-CO₂ Desorption confirmed
 - 20% of injected CO₂ produced to date
 - Significant Tracer concentrations detected in Flowback
- Need Longer Term/Higher Capacity injection to better understand
 - Injectivity,
 - ECBM logistics,
 - coal swelling, and
 - plume dimensions (image) in stacked coals.

TEMP. MODELS



Southwest Virginia Characterization/Study Area – SECARB Phase II Task 10



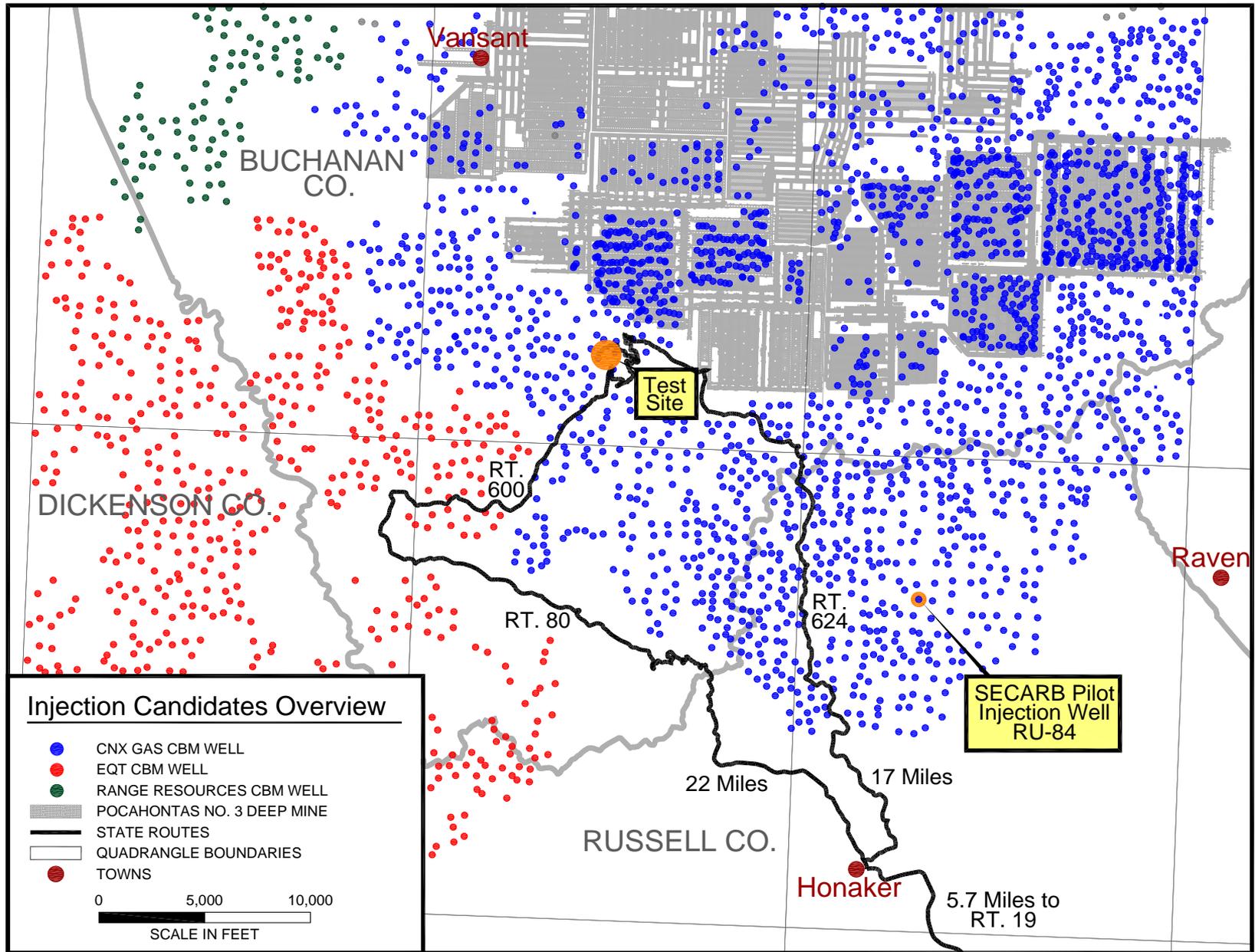
CO2 Storage Capacity by CBM Field

Field Name	State	Cumulative Production (Bcf)	Ultimate Recovery (Bcf)	Current State of Depletion (%)	Current Storage Capacity (tonnes)	Total Storage Capacity (tonnes)
Frying Pan	VA	17.1	35.6	48%	1,613,000	3,360,000
Sourwood	VA	18.8	55.3	34%	1,772,000	5,209,000
Lick Creek	VA	80.8	231.1	35%	7,616,000	21,783,000
South Oakwood	VA	90.6	321.9	28%	8,535,000	30,345,000
Loup Creek	WV	30.1	47.4	64%	2,835,000	4,464,000
Totals	--	237.3	691.3	--	22,371,000	65,161,000

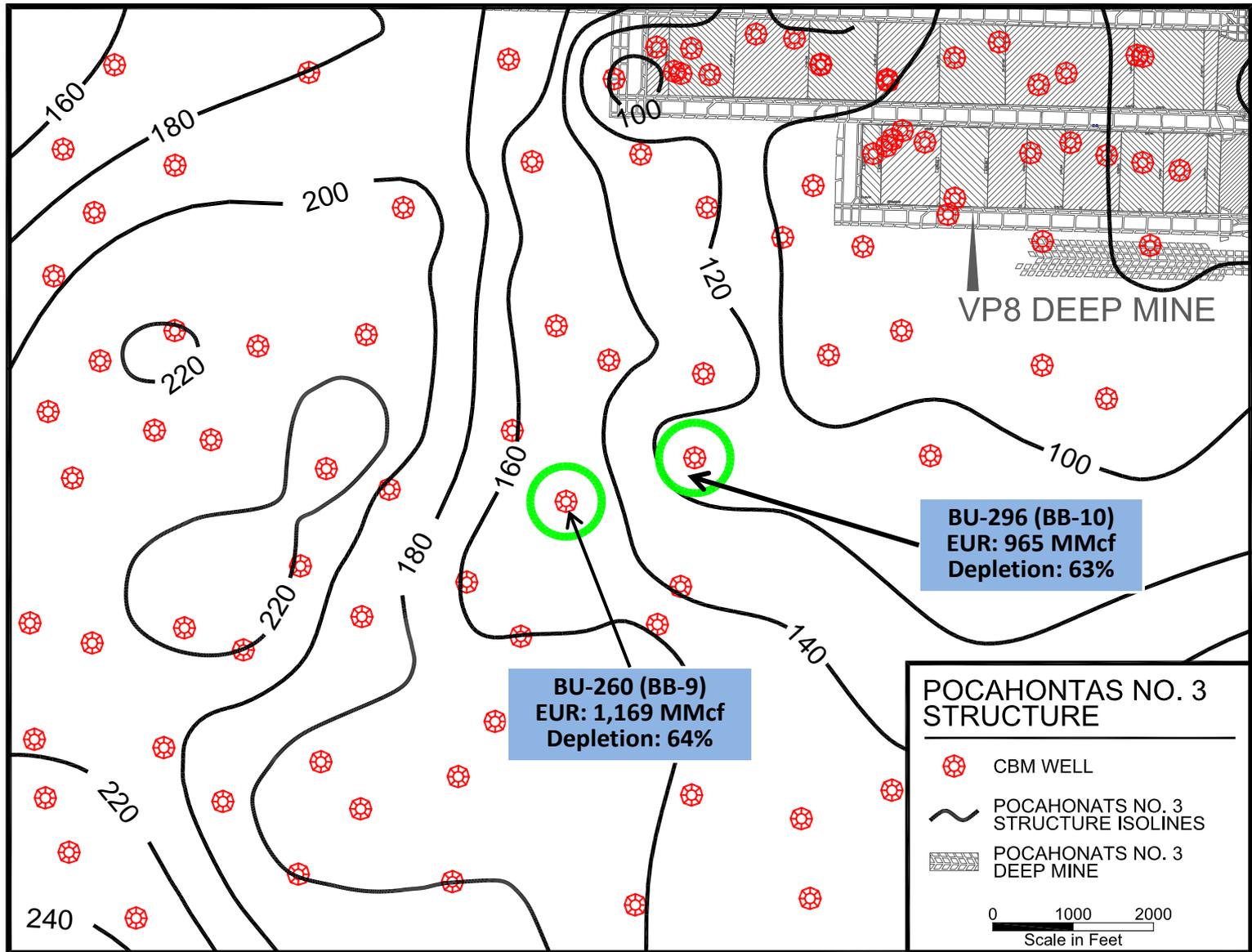
Current Project Status

- Virginia Tech and DOE/NETL are currently in contract negotiations – anticipate contract soon.
 - 10/1/2011 Expected Start Date
- CNX Gas (CONSOL) has recommended:
 - Potential CBM wells that can be utilized for CO₂ injection
 - Available vertical shale gas wells for CO₂ injection
- Research team is currently evaluating well options and access agreements

Potential CBM Injection Site



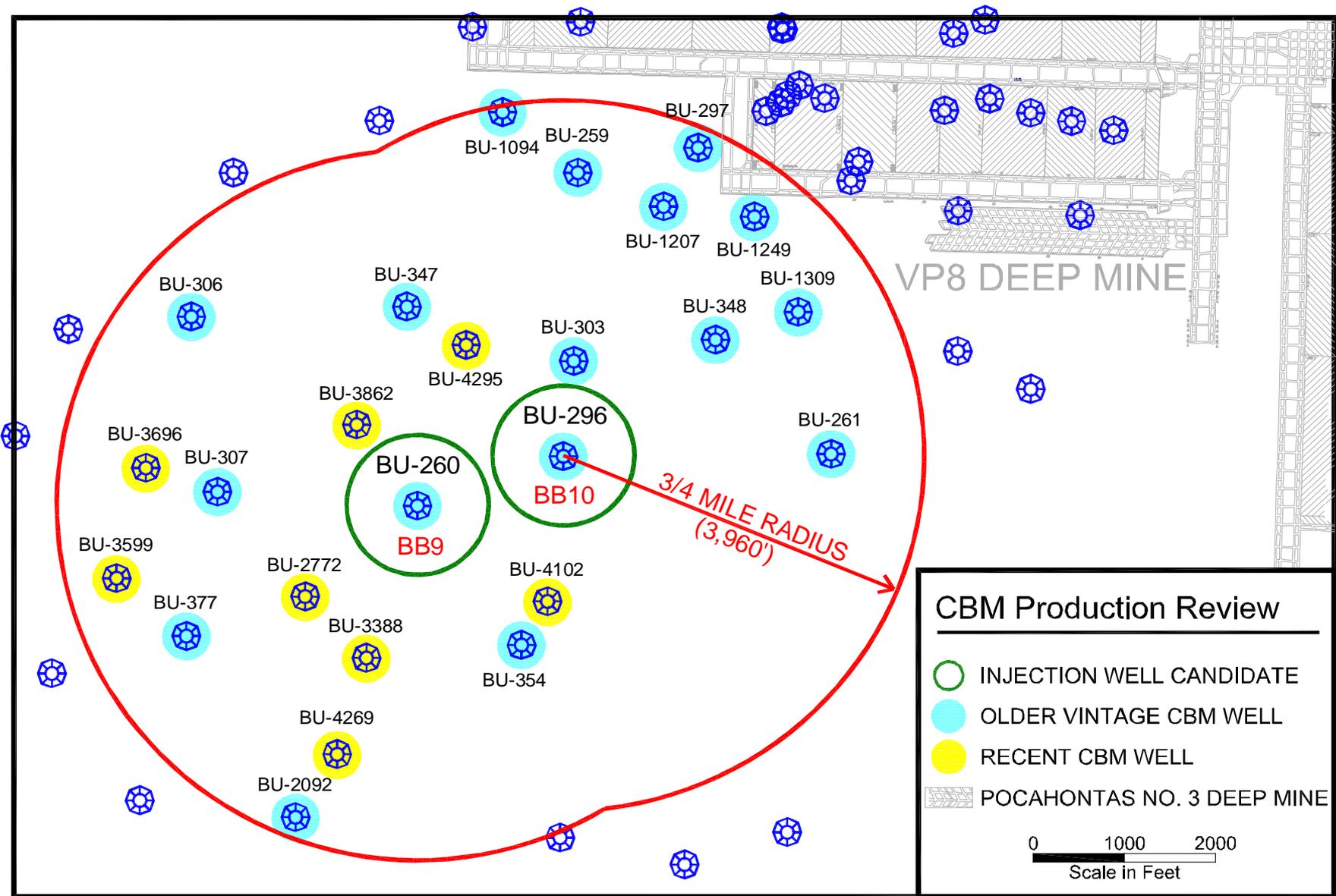
Pocahontas No. 3 Structure with Injection Well Candidates



Completion Reports

BU-260				BU-296			
zone	coal seam	coal depth	coal thickness	coal seam	coal depth	coal thickness	zone
stim. Notes (psig)							stim. Notes
Zone 1	Poc. 3-30	2252.9, 2252.25	0.900	Poc. 3-40	2327.8	0.4	Zone 1
ISIP: 1450, AVG: 1900	Poc. 3-20	2244.55, 2243.25	1.650	Poc. 3-30	2321.25	0.95	ISIP: 1300, AVG: 1769
MIN: 1230, BRKDWN: 1460	Poc. 3-10	2242.250	1.350	Poc. 3-20	2309.65	1.8	MIN: 1126, BRKDWN: 1070
2358 bbls gelled water				Poc. 3-10	2307.6	1.5	2284 BFW
31,000# 20/40 sand							30,600# 20/40 sand
27,000# 12/20 sand							13,425# 12/20 sand
Zone 2	Poc. 4-10	2171.2, 2169.5	1.700	Poc. 4-10	2232.5	0.5	Zone 2
ISIP: 1480, AVG: 2300	Poc. 5-20	2133.9	1.9	Poc. 5-20	2191.5	1.5	ISIP: 1244, AVG: 2550
MIN: 1250, BRKDWN: 3450	Poc. 5-10	2110.35, 2107.6	2.7	Poc. 5-10	2147	0.5	MIN: 1130, BRKDWN: 2990
1809 BFW							2344 BFW
51,400# 20/40 sand							25,300# 20/40 sand
55,100# 12/20 sand							19,900# 12/20 sand
Zone 3	Poc. 7-10	1931.5	1	Poc. 7-10	1989	2	Zone 3
ISIP: 3850, AVG: 3980		1810.5, 1810.2, 1809.85,					ISIP: 1660, AVG: 2872
MIN: 2000, BRKDWN: 3800	Poc. 9-10	1809.75, 1809.35, 1809.1	2.2	Poc. 9-10	1887.25, 1885.5	2.25	MIN: 1254, BRKDWN: 3500
354 BFW							1066 BFW
500# 20/40 sand							36,000# 20/40 sand
							40,000# 12/20 sand
Zone 4	WRC 20	1709	1	Low HP 10	1762	1	Zone 4
ISIP: 2360, AVG: 3300	WRC 10	1671.8, 1671.0, 1670.3	1.8	WRC 10	1737	2	ISIP: 1300, AVG: 2776
MIN: 1350, BRKDWN: 3600							MIN: 926, BRKDWN: 3600
1081 BFW							960 BFW
30,351# 20/40 sand							30,000# 20/40 sand
28,931# 12/20 sand							28,000# 12/20 sand
Zone 5	Mid HP 10	1524.3	1.6				
ISIP: N/A, AVG: N/A	Up HP 20	1507.7	0.7				
MIN: N/A, BRKDWN: N/A	Up HP 10	1482	1				
"treatment pending"							
			19.500				14.400

CBM Production Review

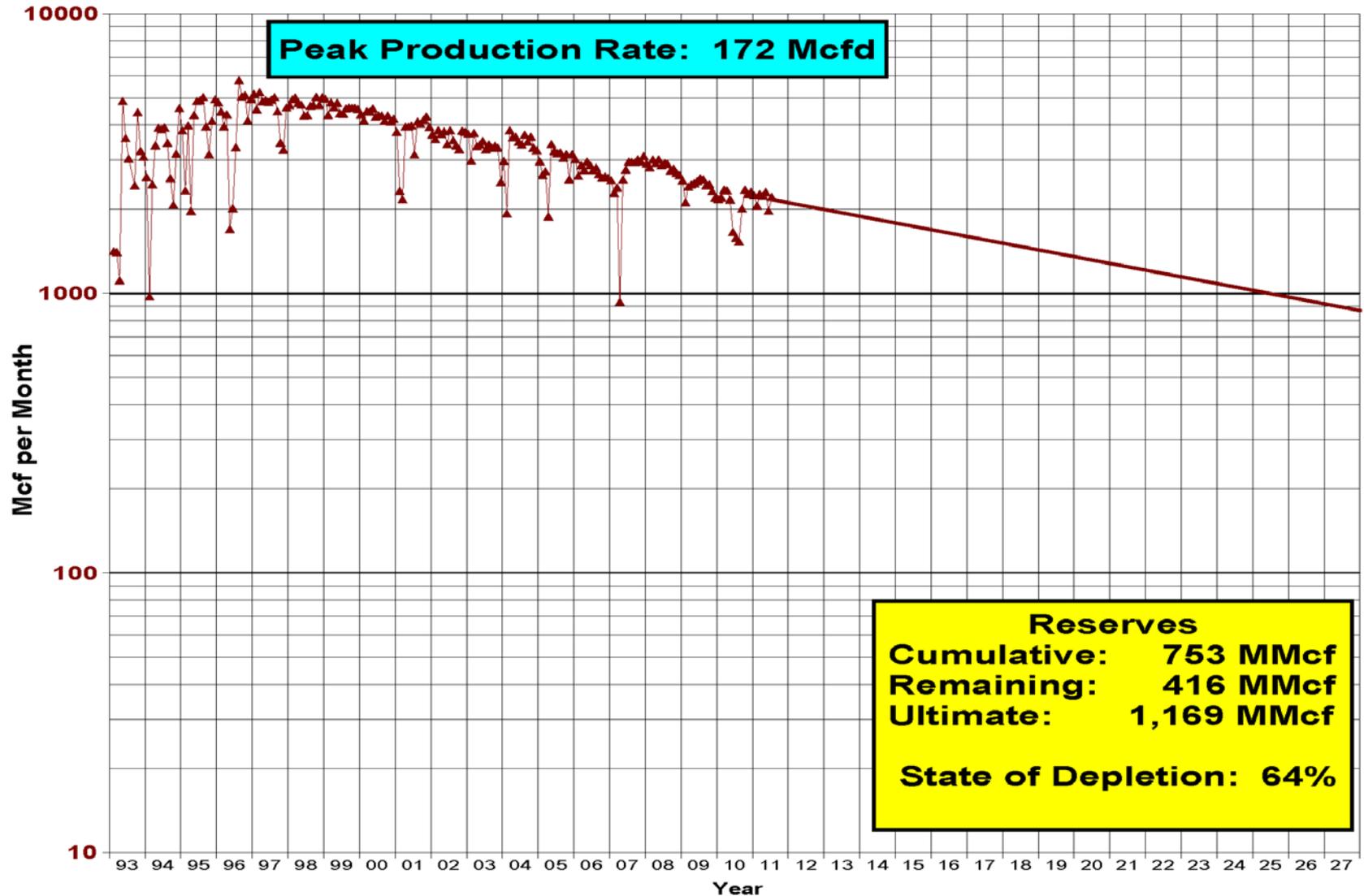


CBM Production Summary

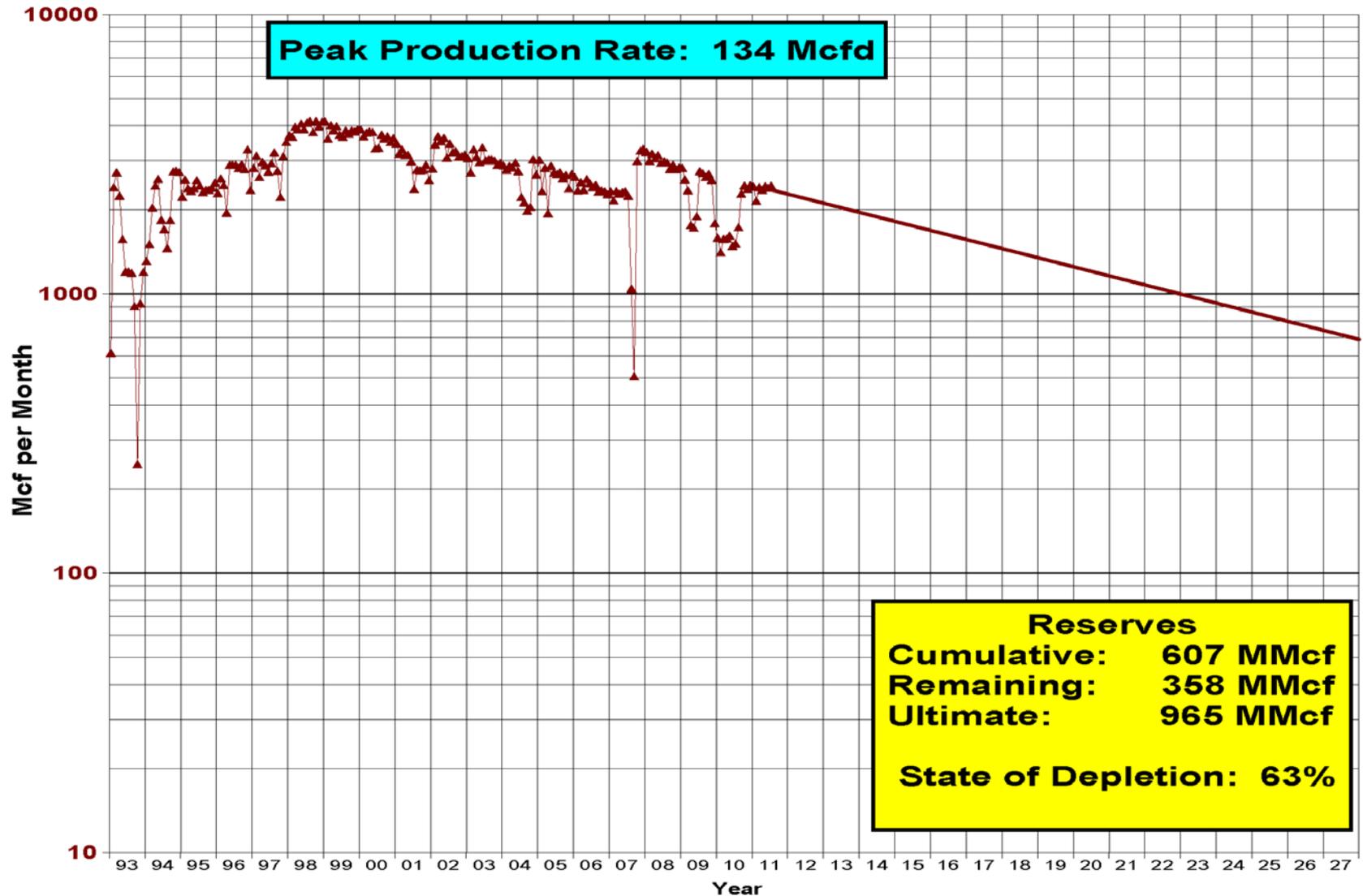
Well	Cumulative Reserves (MMcf)	Remaining Reserves (MMcf)	Ultimate Reserves (MMcf)	State of Depletion (%)
BU-0259	705	166	871	81%
BU-0260	753	416	1,169	64%
BU-0261	431	561	991	43%
BU-0296	607	358	965	63%
BU-0297	743	127	870	85%
BU-0303	619	353	972	64%
BU-0306	877	326	1,203	73%
BU-0307	818	324	1,142	72%
BU-0347	497	319	816	61%
BU-0348	509	193	702	73%
BU-0354	619	641	1,260	49%
BU-0377	517	307	824	63%
BU-1094	284	59	343	83%
BU-1207	343	135	478	72%
BU-1249	324	105	429	75%
BU-1309	790	472	1,262	63%
BU-2092	363	652	1,015	36%
Average	576	324	901	64%

Production and Reserve Summary

BU-0260 (BB-9)



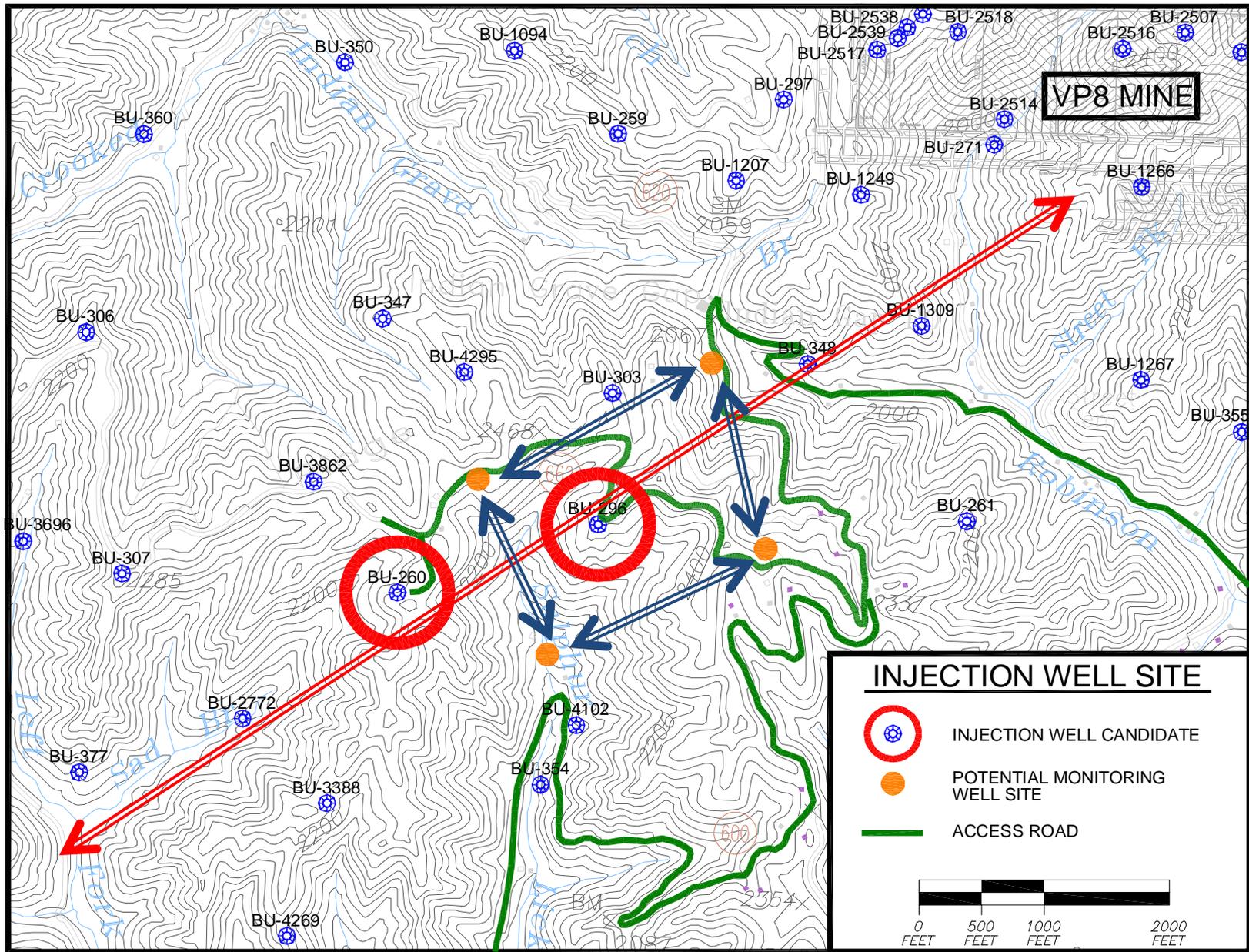
Production and Reserve Summary BU-0296 (BB-10)



Monitoring, Verification and Accounting (MVA) Plan

<i>WELL MONITORING</i>	<i>SURFACE AND NEAR SURFACE MONITORING</i>
Geophysical logs	Soil Gas Composition
Vertical Seismic Profiles (VSPs)	Soil CO ₂ Flux
Cross-Well Seismic	Soil CH ₄ Flux
Gas Pressure and Composition	Soil Moisture And Temperature
Gas Desorption	Geo-Microbiology
CO ₂ -CH ₄ -N ₂ Adsorption Isotherms	Ambient CO ₂ Concentrations
Porosity, Permeability, Stress and Strain	Ambient CH ₄ Concentrations
Proximate, Ultimate and Petrographic Analysis	Meteorological Data
Gas Composition, Gas and Water Production at Off-set CBM Wells	Water Quality
	Introduced Tracers
	Carbon Isotopes
	Vegetative Stress

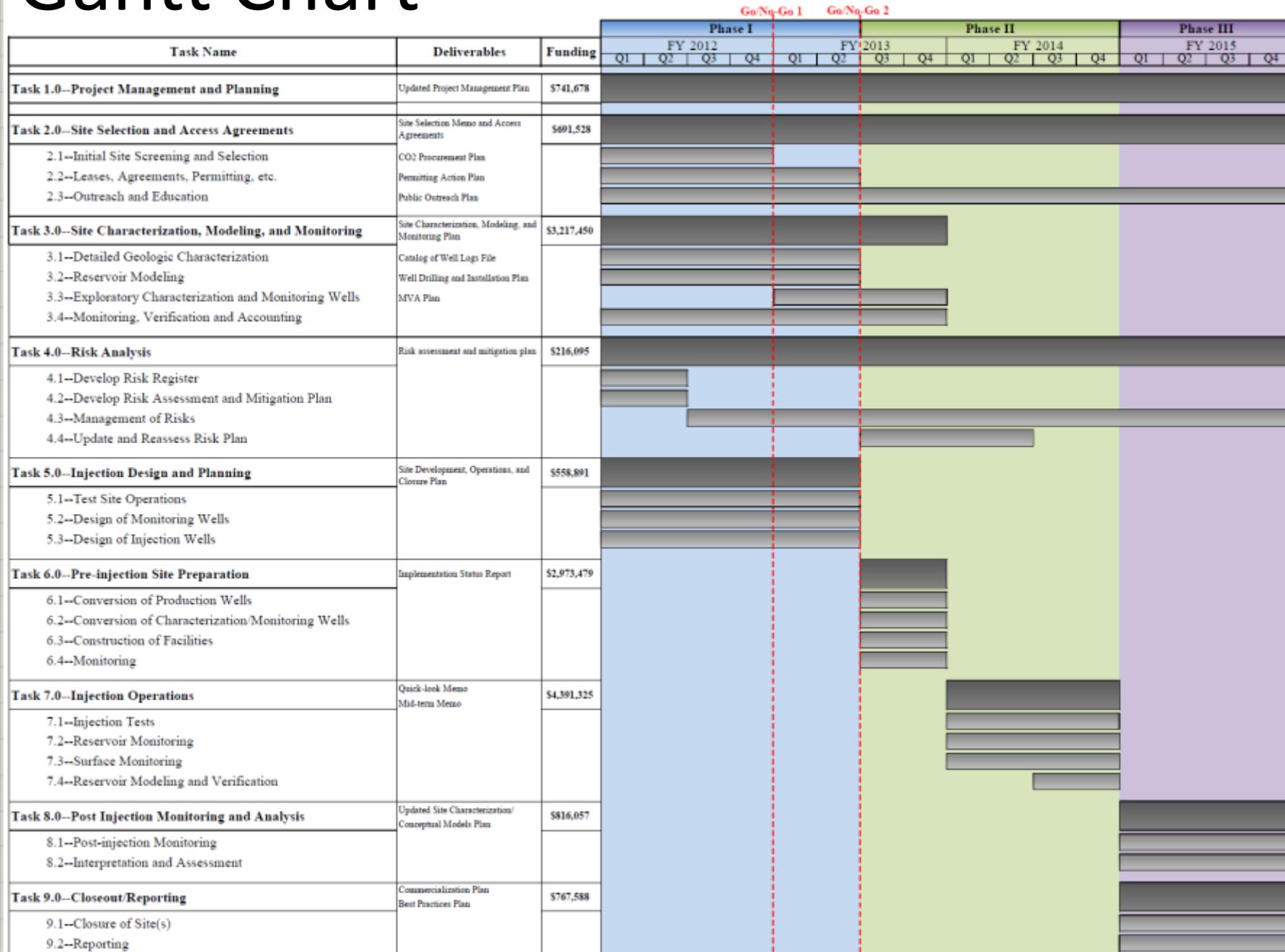
Topographic Setting and Monitoring Options



Reservoir Modeling (CBM & Shale)

- Different Reservoir Models
- Post-Production History Matching
 - Gas and Water Production
- Pre-Injection Simulation
 - Injectivity
 - Plum Dimensions
- Post-Injection History Matching
- Predictive Modeling

Gantt Chart



Budget Periods, Go/No-Go, Tasks

- ★ BP1 – 18 months; BP2 – 18 months; BP3 – 12 months
- ★ Go/No-Go decisions: 12 months and 18 months
 - ★ #1 is for Access Agreements
 - ★ #2 is for Injection Plan and Feasibility
- ★ Injection Timeframe: 10/1/2013 – 9/30/2014 (start in 2 years)

Task	Task Name	Begin	End
1	Project Management and Planning	10/1/2011	9/30/2015
2	Site Selection and Access Agreements	10/1/2011	9/30/2015
3	Site Characterization, Modeling, and Monitoring	10/1/2011	9/30/2013
4	Risk Analysis	10/1/2011	9/30/2015
5	Injection Design and Planning	10/1/2011	3/31/2013
6	Pre-injection Site Preparation	4/1/2013	9/30/2013
7	Injection Operations	10/1/2013	9/30/2014
8	Post Injection Monitoring and Analysis	10/1/2014	9/30/2015
9	Closeout/Reporting	10/1/2014	9/30/2015