

SAN JUAN BASIN, SWRPCS

Prepared for:

2008 Regional Carbon Sequestration Partnerships Initiative Review Meeting

Prepared by:

ADVANCED RESOURCES INTERNATIONAL, INC.

October 6-8, 2008
Pittsburgh

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Outline

- Introduction
- Reservoir Characterization and Modeling
- MMV Plan
- Operations
- Results
- Conclusions

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Introduction

- The Southwestern Regional Partnership for Carbon Sequestration (SWP) is one of seven regional partnerships sponsored by the U.S. DOE
- Objective: to determine the most suitable technologies, regulations and infrastructure needs for carbon capture, storage and sequestration in different areas of the country
- One of the demonstration sites is the Pump Canyon site, which is investigating CO_2 injection into a deep unmineable coalbed

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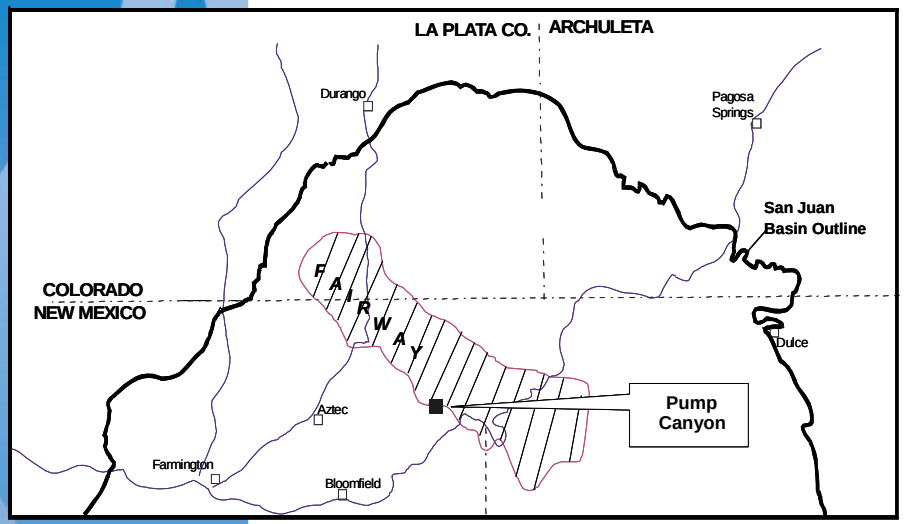
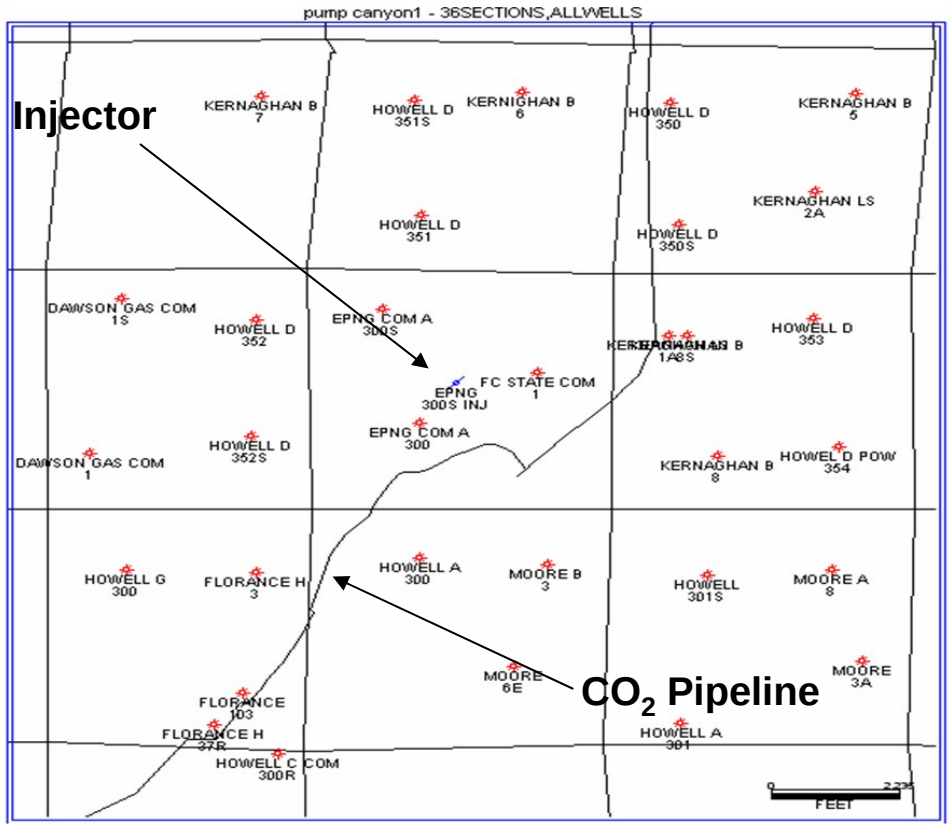
Site Description





31 production wells

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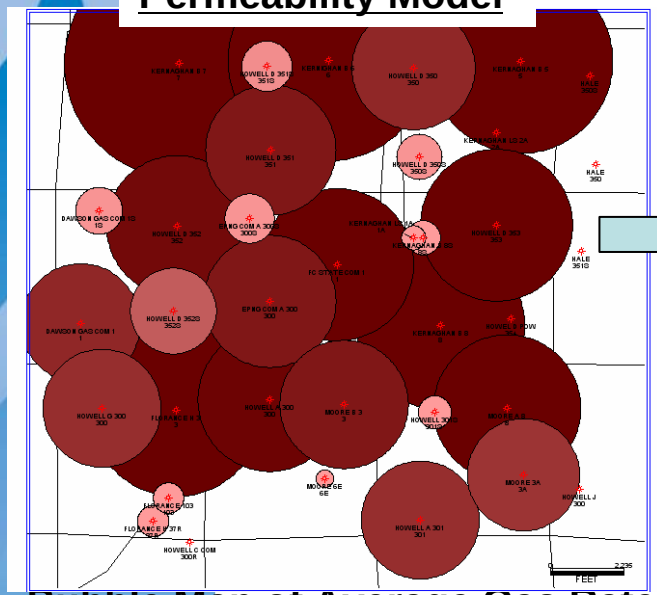
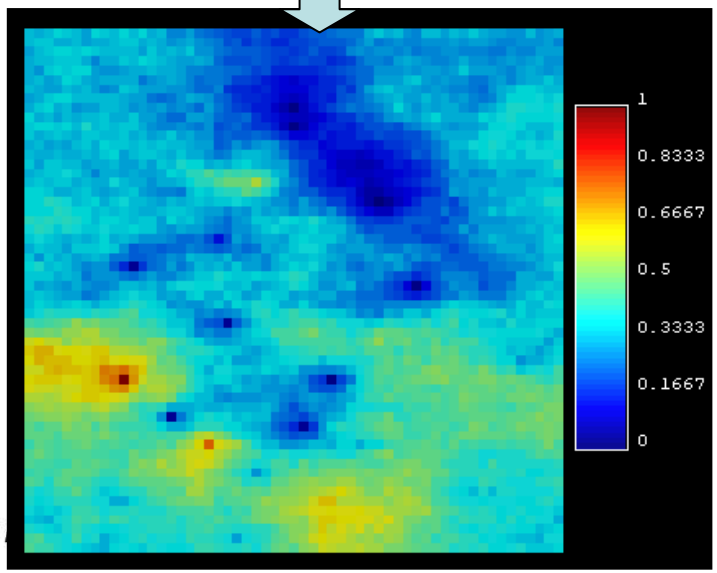
Reservoir Characterization

Permeability Model



Bubble Map of Average Gas Rate

- Gas production used as a loose proxy for coal permeability
- The gas production parameter used was average gas production over the active well life ("production index")
- A sequential Gaussian simulation algorithm was adopted for generating 50 2D realizations of the production index
- The arithmetic average of the 50 different simulated values was selected as a central value for a final characterization
- Index map then multiplied by an average permeability to create a permeability map



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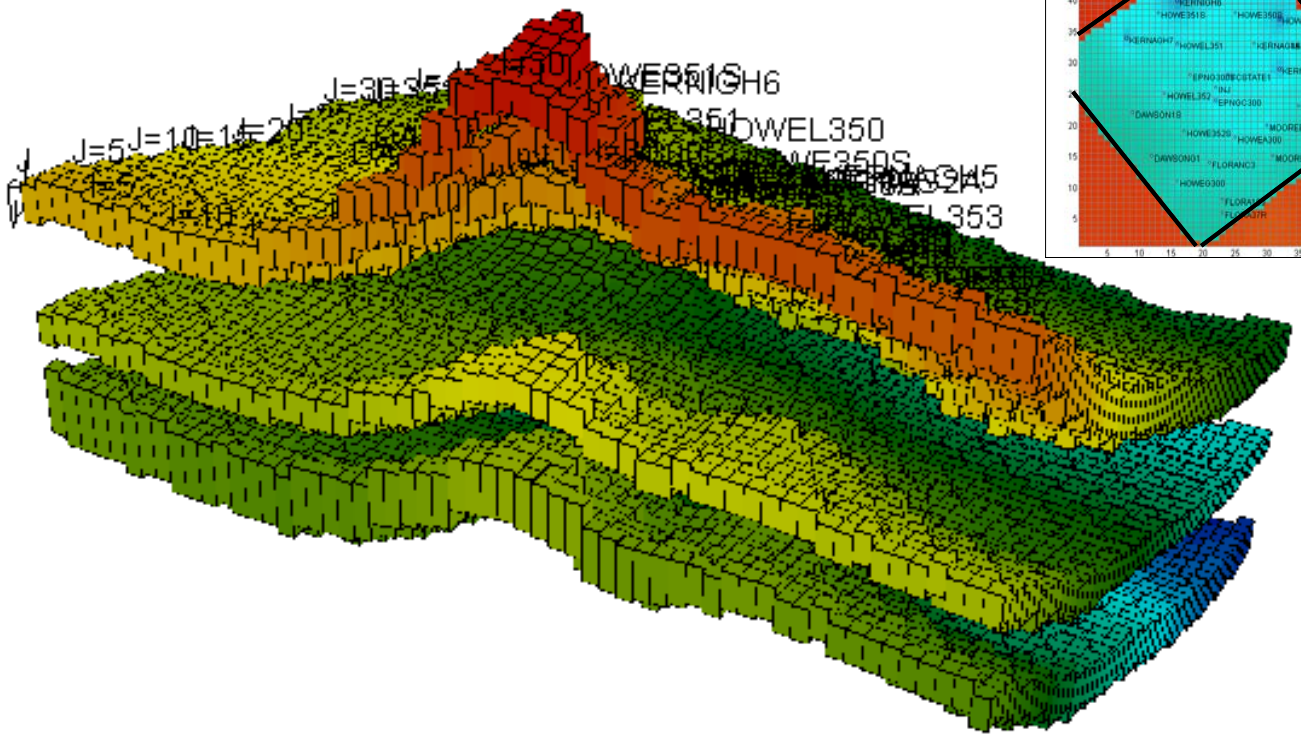
Model Construction



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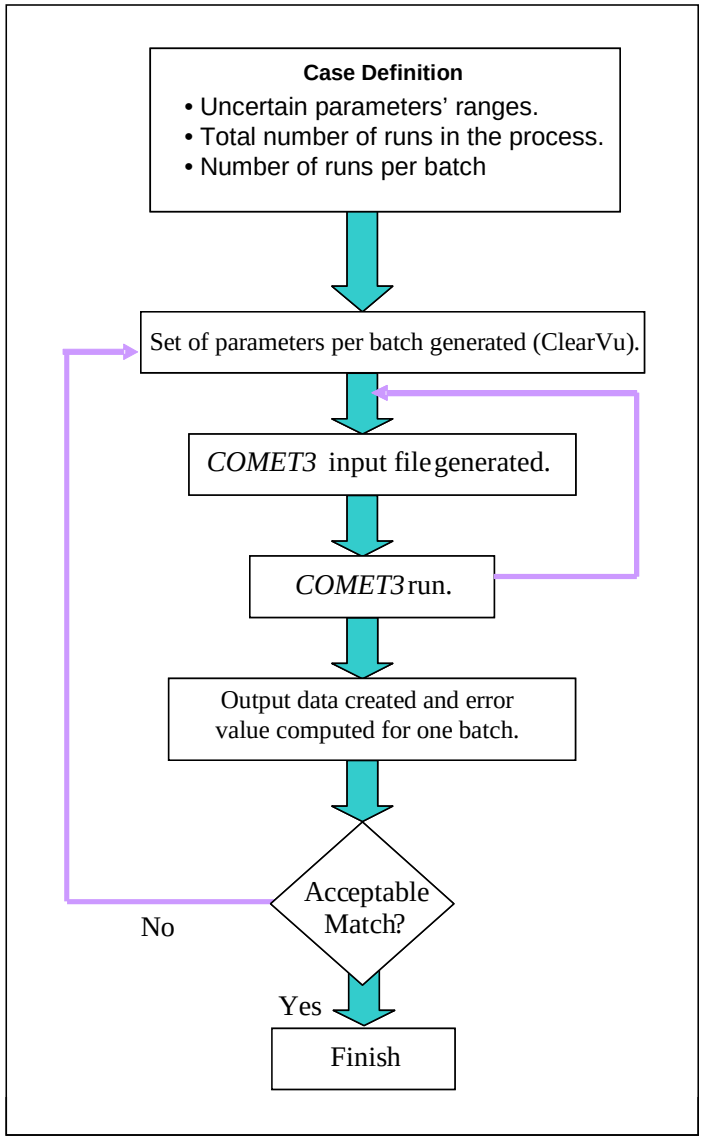
History Matching Process



$$ErrorValue = \frac{\sum \left(\frac{(SimData - ActualData)^2}{2 * Variance} \right)}{NumberofData}$$

Fixed Parameters

Parameters	Units	Value
Formation Properties		
Vertical Permeability	mD	0.0001
In-situ CH4 Langmuir Volume, Layer 1	scf/ton	447
In-situ CH4 Langmuir Volume, Layer 2	scf/ton	436
In-situ CH4 Langmuir Volume, Layer 3	scf/ton	542
CH4 Langmuir Pressure, Layer 1	psi	546
CH4 Langmuir Pressure, Layer 2	psi	606
CH4 Langmuir Pressure, Layer 3	psi	520
Sorption Time, CH4	days	1
In-situ CO2 Langmuir Volume, Layer 1	scf/ton	809
In-situ CO2 Langmuir Volume, Layer 2	scf/ton	766
In-situ CO2 Langmuir Volume, Layer 3	scf/ton	1038
CO2 Langmuir Pressure, Layer 1	psi	317
CO2 Langmuir Pressure, Layer 2	psi	260
CO2 Langmuir Pressure, Layer 3	psi	372
Sorption Time, CO2	days	1
Differential Swelling Factor	-	1.5
Permeability Exponent	-	3
Relative Permeability Relationships		
Maximum Krw	-	1
Irreducible Gas Saturation	-	0

Varied Parameters

Parameters	Units	Min	Max
Formation Properties			
Porosity Factor a	-	0.001	0.0045
Initial Water Saturation	fraction	0.75	1
Average Absolute Permeability	mD	10	1000
Permeability Anisotropy	fraction	1	5
Pore Compressibility	1/psi	1.00E-05	6.00E-04
Matrix Compressibility	1/psi	1.00E-07	5.00E-06
CO2 Content	fraction	0.01	0.25
Relative Permeability Relationships			
Irreducible Water Saturation	-	0.05	0.4
Maximum Krg	-	0.65	0.95
Krw Exponent	-	1	3
Krg Exponent	-	1	3
Well Parameters			
Initial Skin	-	-1	2
Stimulated Skin	-	-5	0

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Core Analysis Program - Overview

CO_2 containment assessment:
Develop methodology for characterizing sealing quality at CO_2 sequestration sites

Approach:
Integrate petrological, petrophysical, geomechanical, isotopic, and geochemical data

Unique research question:
Can natural helium be used to characterize sealing behavior of rock for CO_2 storage?

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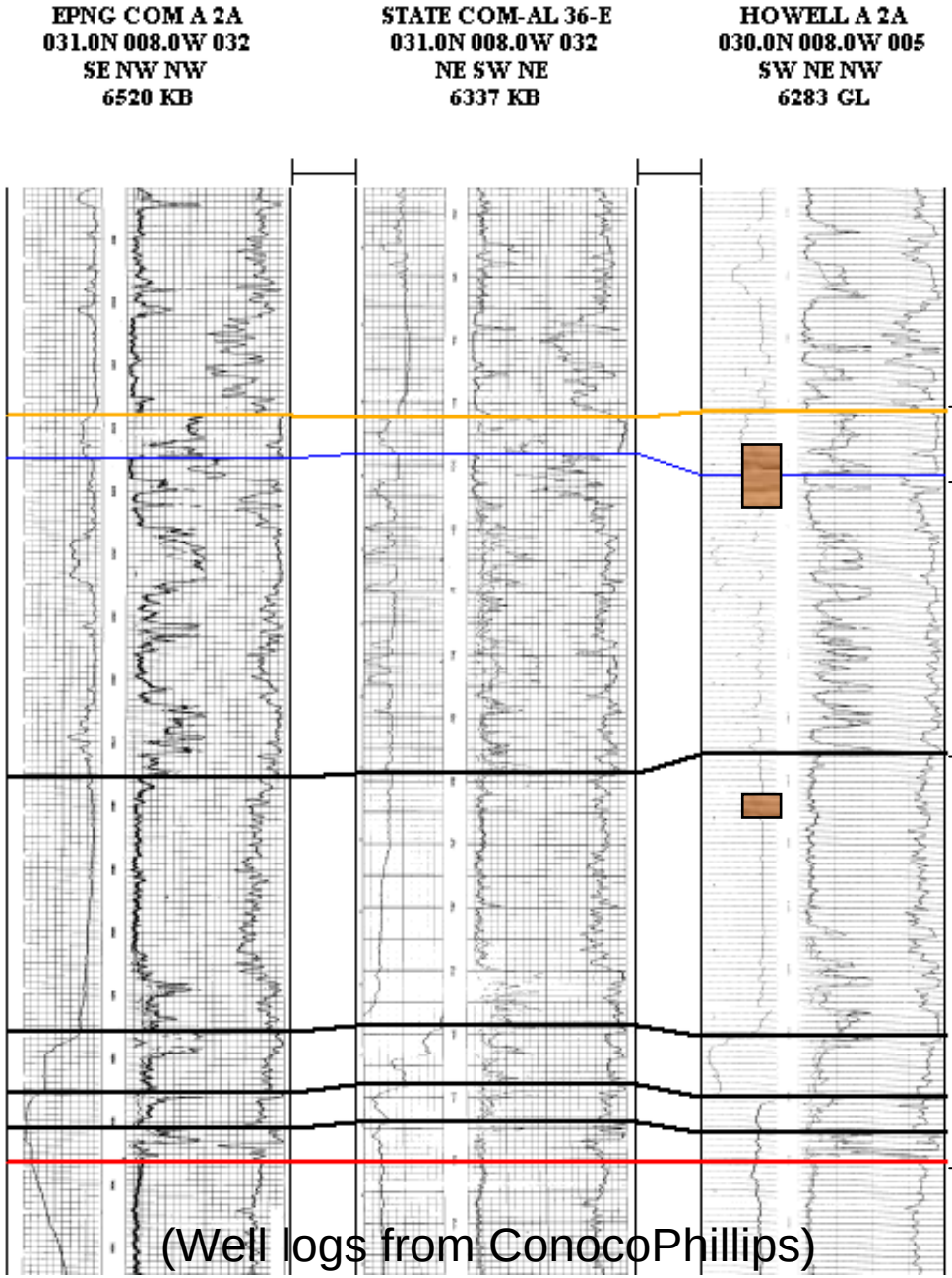
Core Points



(Well logs from ConocoPhillips)

Goal: 120 ft total

Reality: 60 ft total

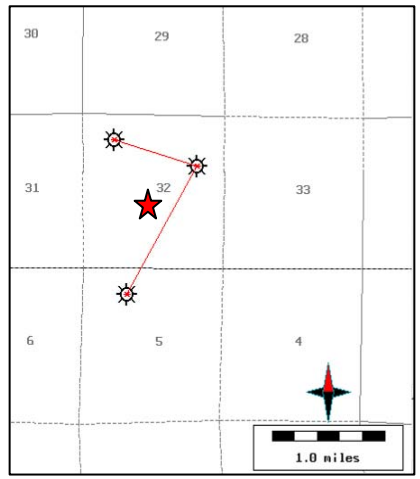
Ojo Alamo

Upper Kirtland and Farmington Sandstone Member

Lower Kirtland Shale

Fruitland

Pictured Cliffs



Core Analysis Program - Methods

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Examine core in field → Cut plugs

Preserve samples with portable vacuum line

Geomechanical properties:

Poisson's ratio, Young's modulus

Multistage compression testing

Core plug preservation in field:

vacuum-tight canisters for preserving noble gases in pore fluids (collection procedure developed by Martin Stute)

Petrological description:

SEM, XRD, TOC

Thin section analysis

Petrophysical properties:

TRA method (Terra Tek)

Permeability, porosity

Fracture analysis:

Fracture type, orientation, dip, mineral fill, assessment of failure potential of natural fractures

Tests with CO_2:

Gas breakthrough pressure

CO_2 adsorption

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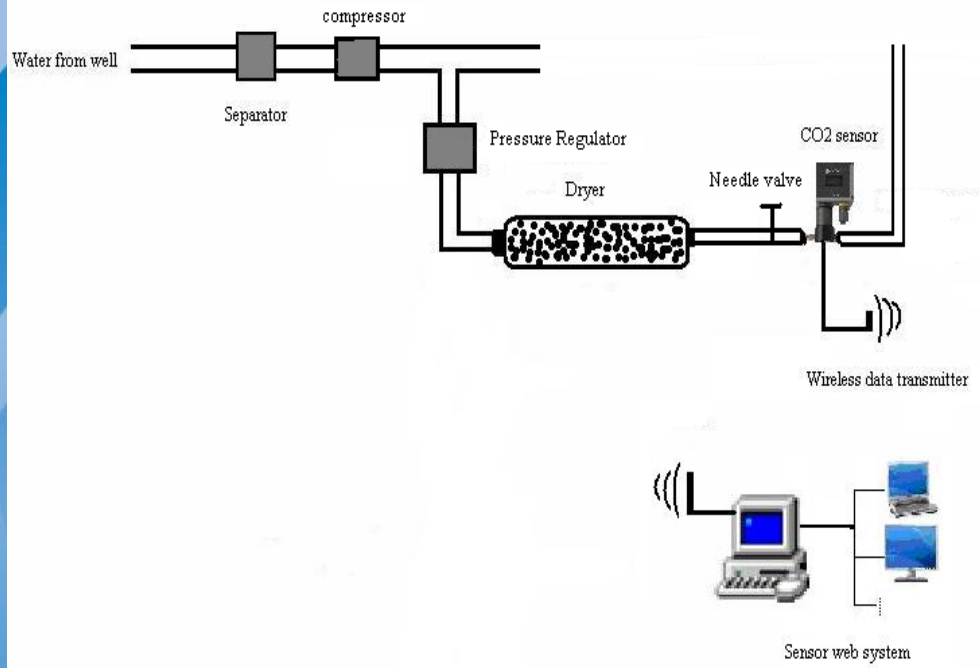
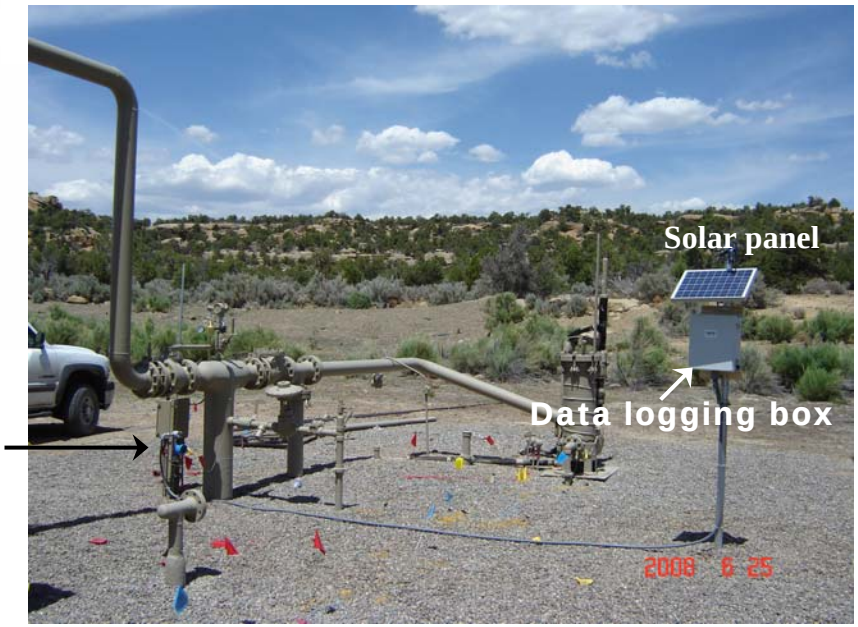
MMV
CO_2 Sensors - Experiment Design





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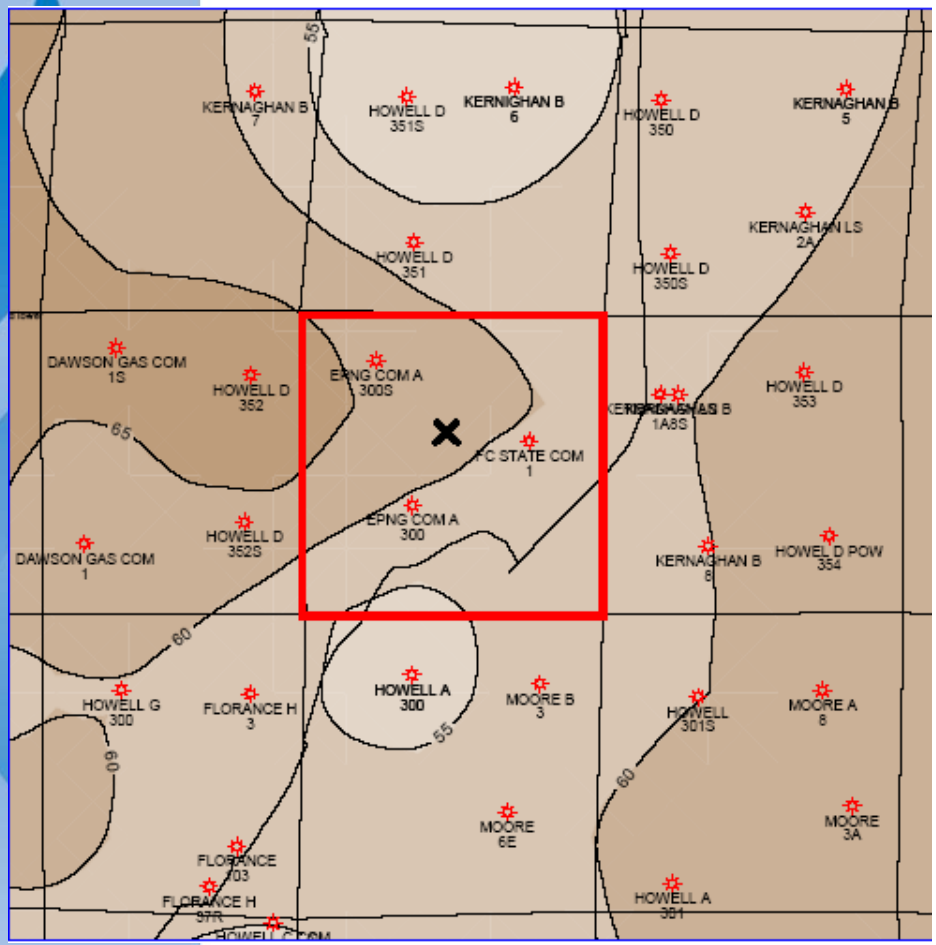
MMV
CO_2 Sensors - Monitoring Wells



×: Injection well

Three wells were selected as monitoring wells. They are:

FC STATE COM (386 m from injection well)

EPNG COM A 300S (547 m from injection well)

EPNG COM A 300 (499 m from injection well)

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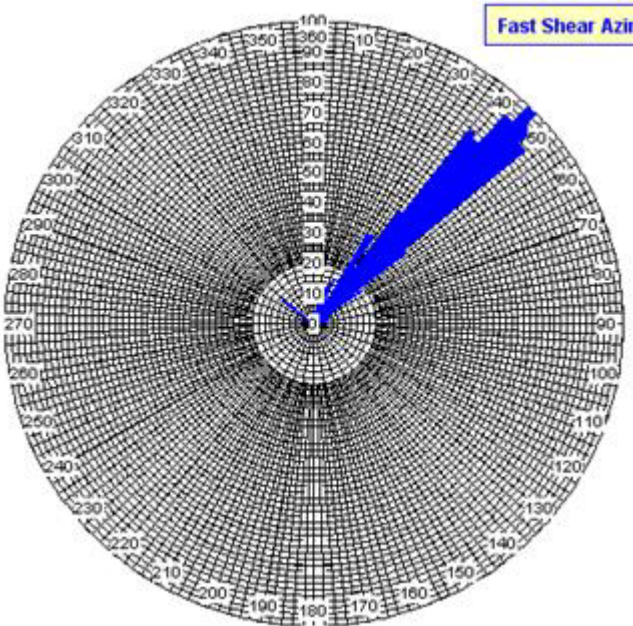
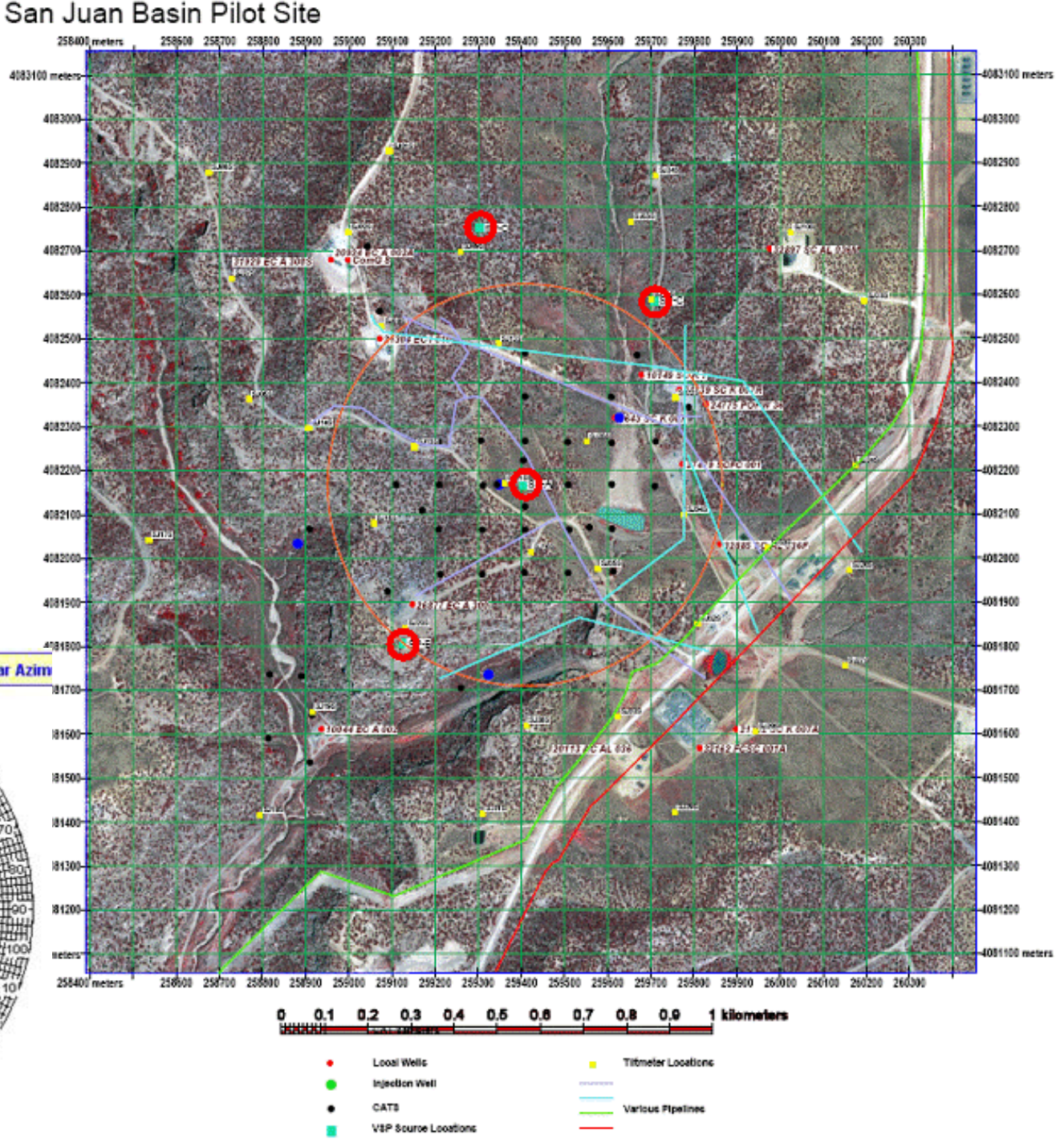
MMV VSP





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Surface Deformation Monitoring (SDM)

- ***Problem:*** Most reservoir monitoring measurements made today only target near wellbore activity. Time lapse seismic offers the ability to image a large volume of the reservoir but is not timely or cost effective for long term containment monitoring.
- ***Solution:*** The technique of measuring and predicting the performance of a reservoir, based on observed surface motion. Ground deformation is observed and run through a geomechanical inversion to identify what reservoir level changes induced the surface deformation.

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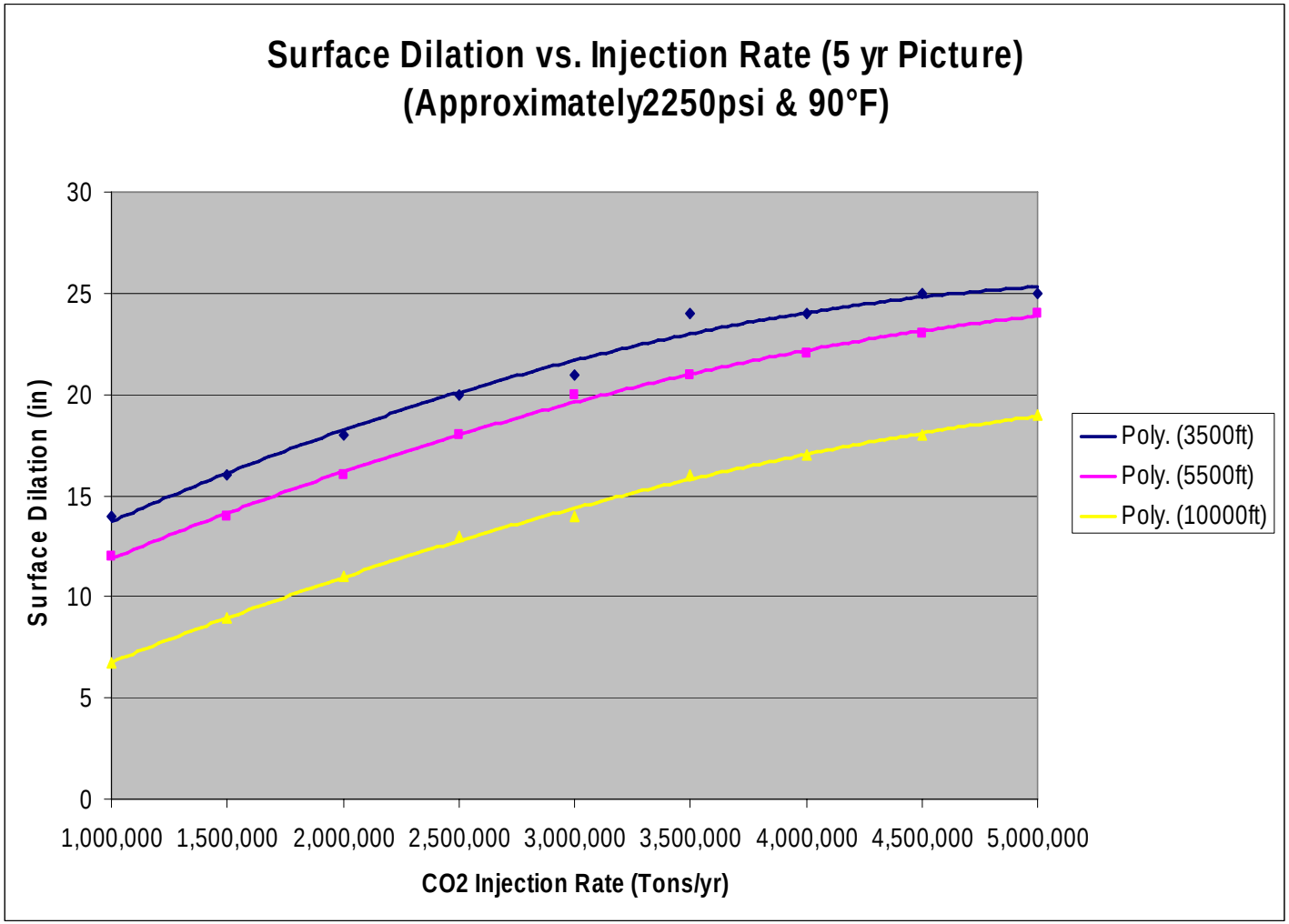
What Does a Large Scale Injection Look Like?



Unconventional Resources • Enhanced Recovery • Carbon Sequestration

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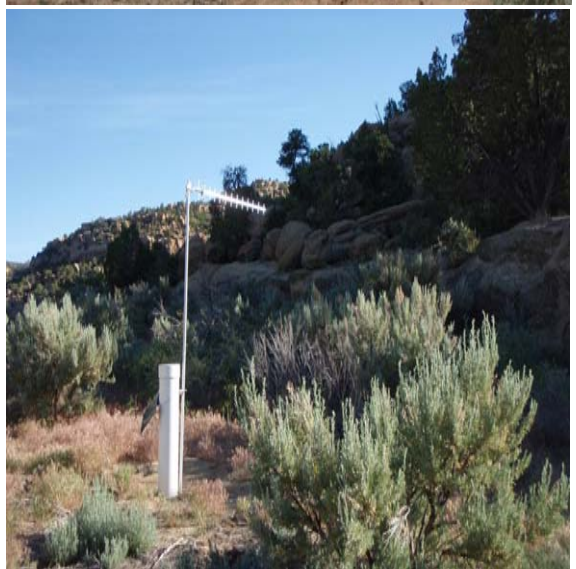
San Juan: Pump Canyon CO_2 Sequestration Project Field Installation



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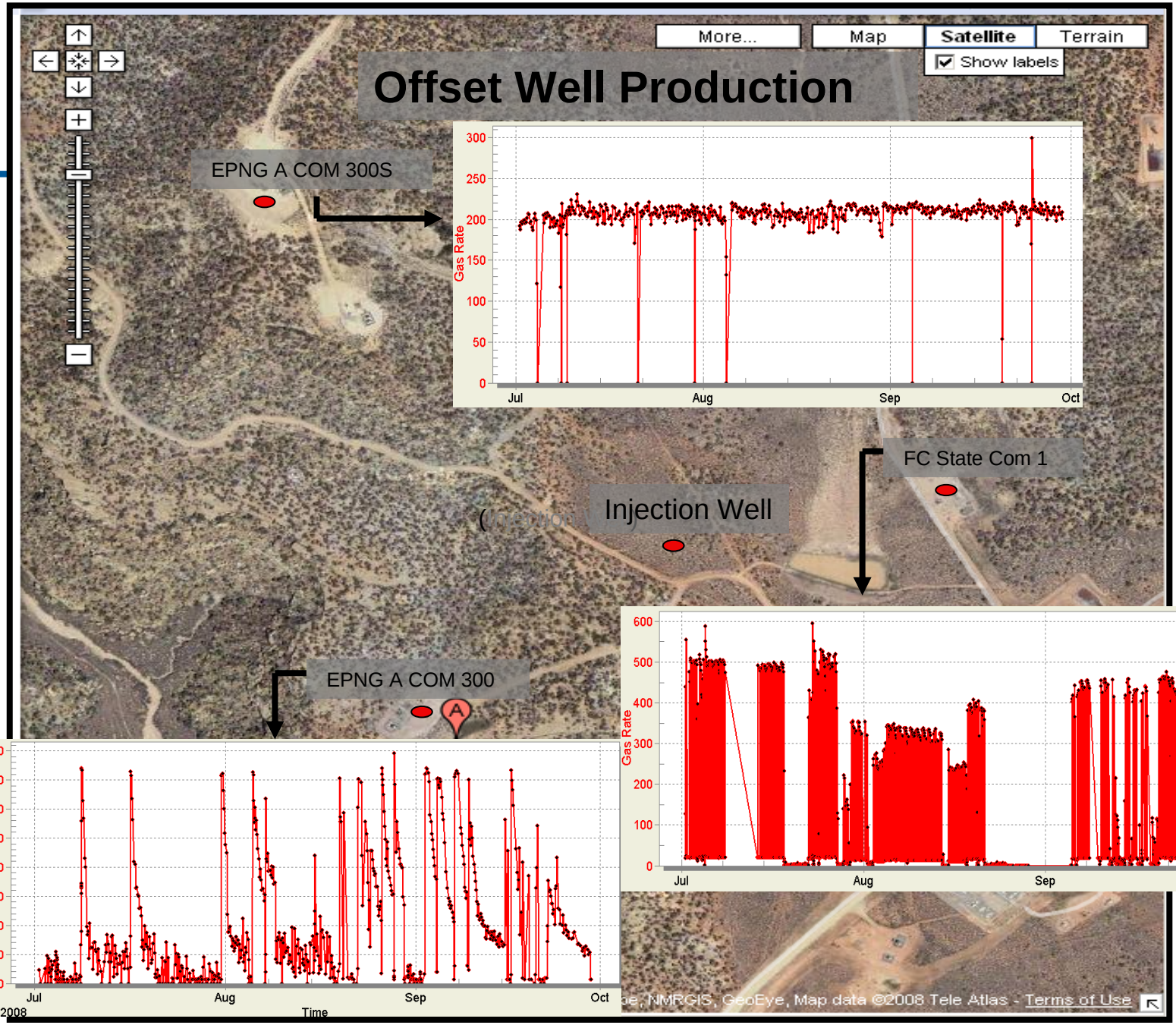
Operations



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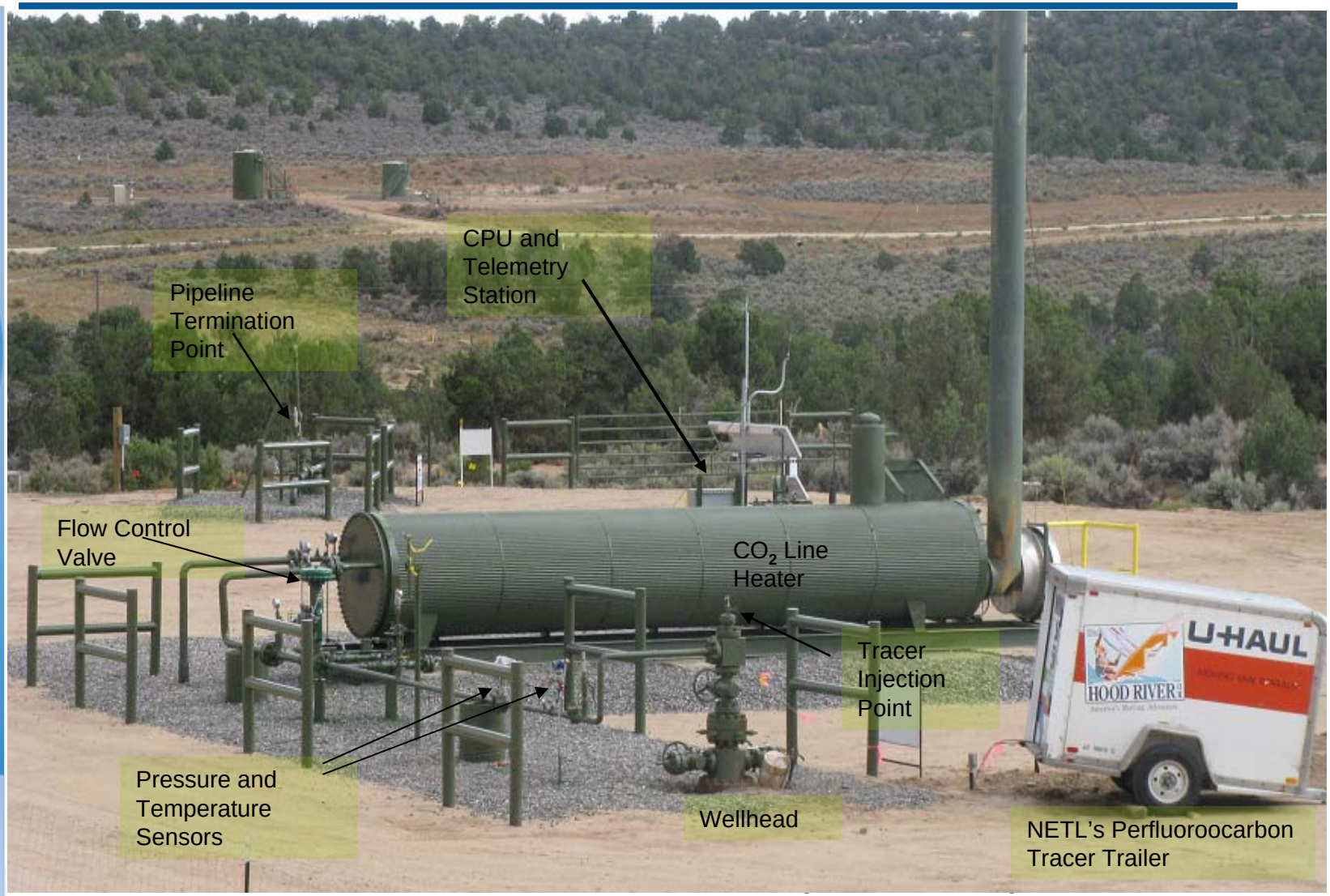
Operations



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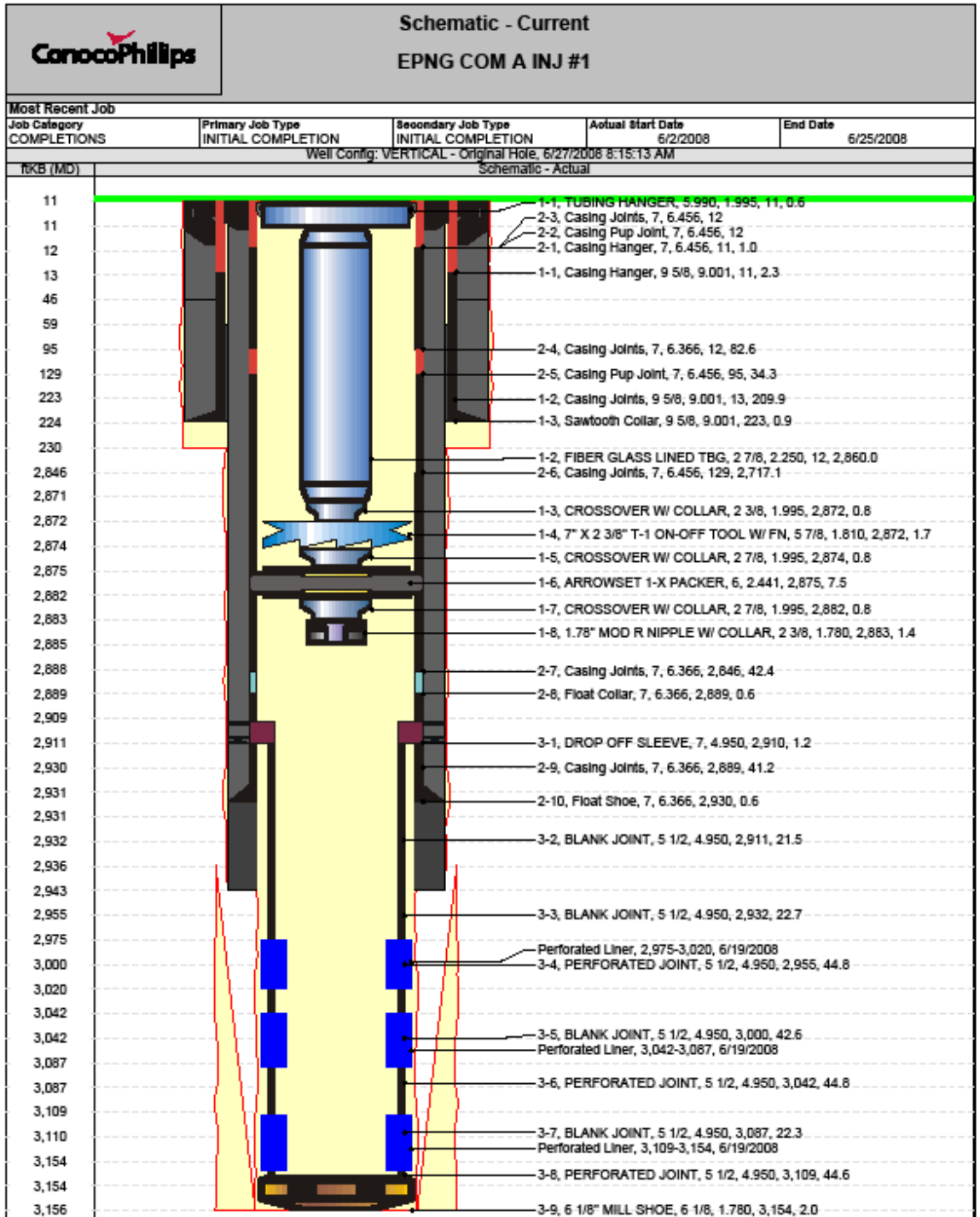
Operations
Injection Well



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Modeling - Results

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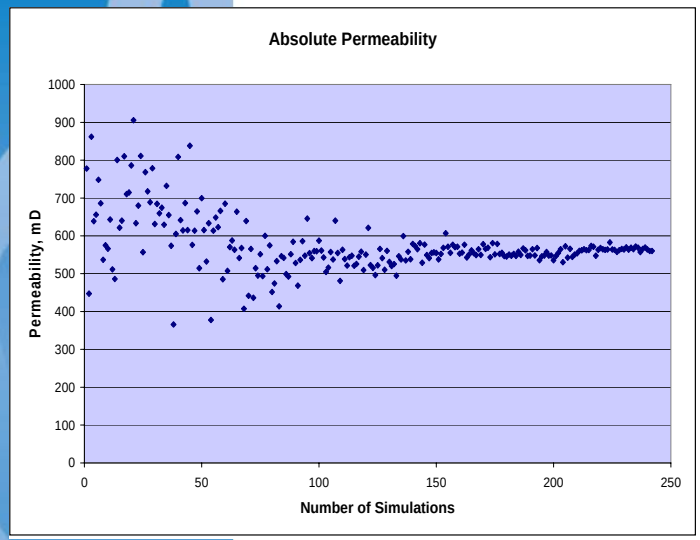
Convergence Plot



Optimized Parameters

Parameters	Units	Min	Max	Optimized
Formation Properties				
Porosity Factor a	-	0.001	0.0045	0.002
Initial Water Saturation	fraction	0.75	1	0.94
Average Absolute Permeability	mD	10	1000	549
Permeability Anisotropy	fraction	1	5	1.8
Pore Compressibility	1/psi	1.00E-05	6.00E-04	3.86E-04
Matrix Compressibility	1/psi	1.00E-07	5.00E-06	3.54E-06
CO2 Content	fraction	0.01	0.25	0.08
Relative Permeability Relationships				
Irreducible Water Saturation	-	0.05	0.4	0.26
Maximum Krg	-	0.65	0.95	0.75
Krw Exponent	-	1	3	2.7
Krg Exponent	-	1	3	2.7
Well Parameters				
Initial Skin	-	-1	2	1.1
Stimulated Skin	-	-5	0	-1.9

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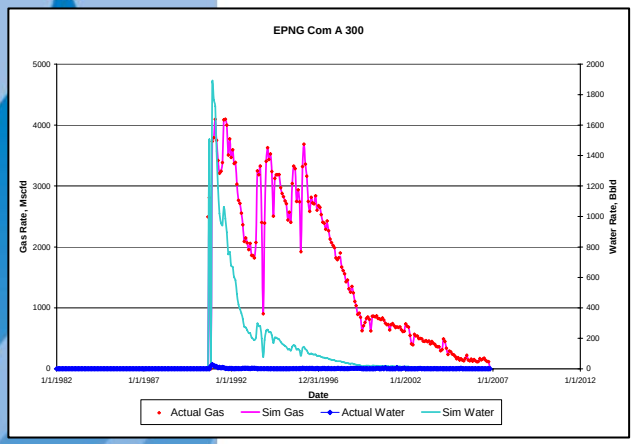
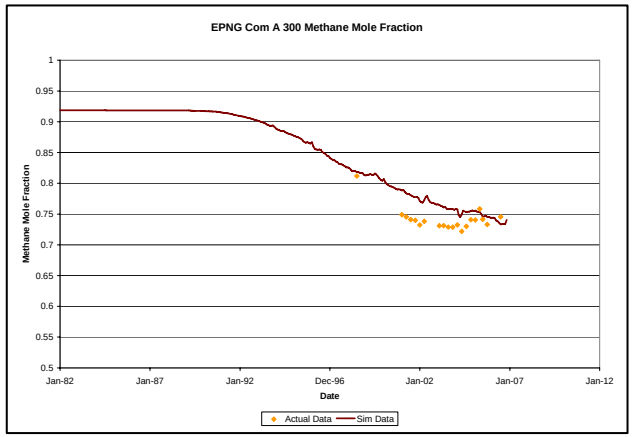
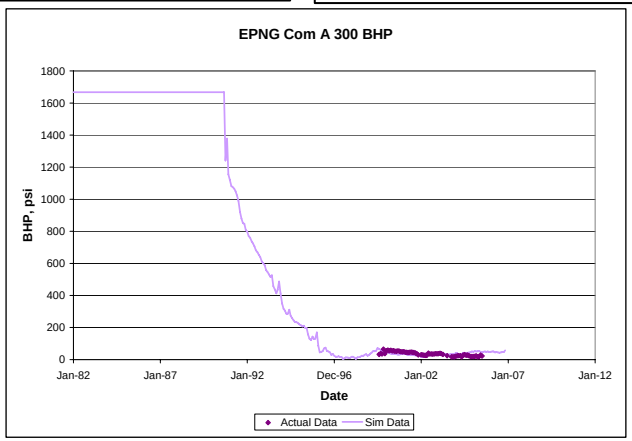
Modeling - Results

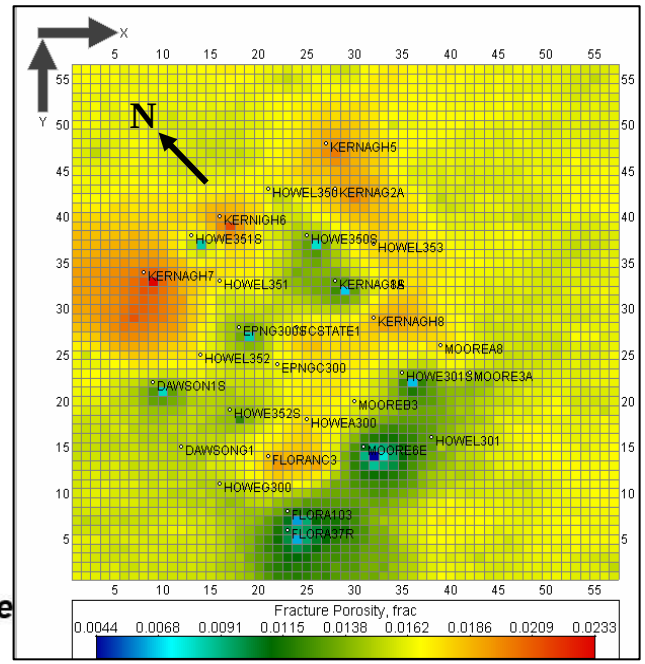






History Match of EPNG Com A 300

Final Porosity Map



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Core Analysis Program – Results to Date

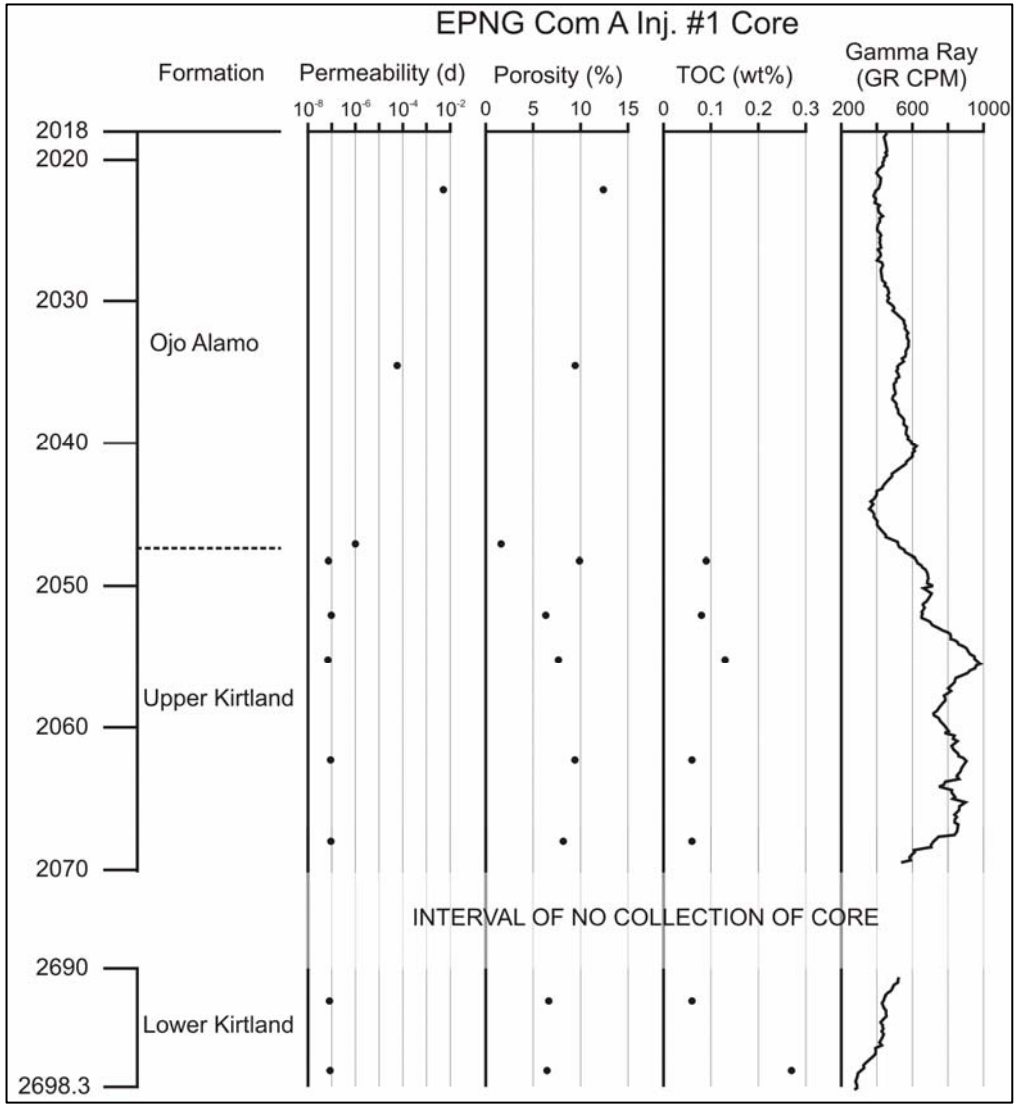
Three conventional plug analyses in Ojo Alamo Sandstone

Seven sets of TRA analyses with XRD, SEM, and thin section work for the Kirtland

Average pressure-decay permeability for Upper Kirtland: 8.4×10^{-5} md

Average pressure-decay permeability for Lower Kirtland: 8.3×10^{-5} md

Smectite varies from 6 to 51% of the whole rock mineralogy in the Kirtland samples



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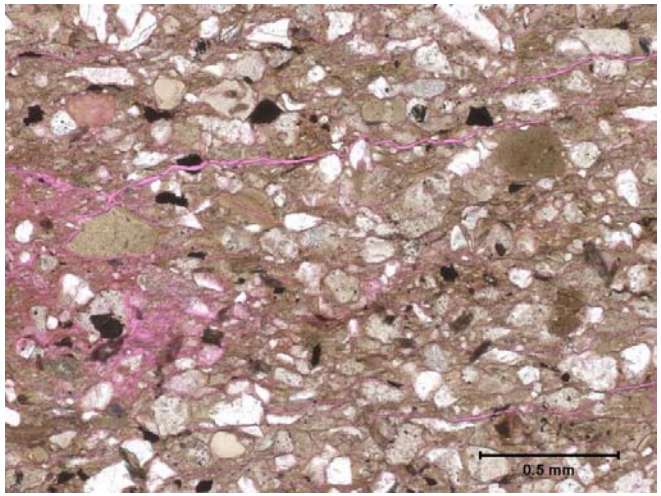
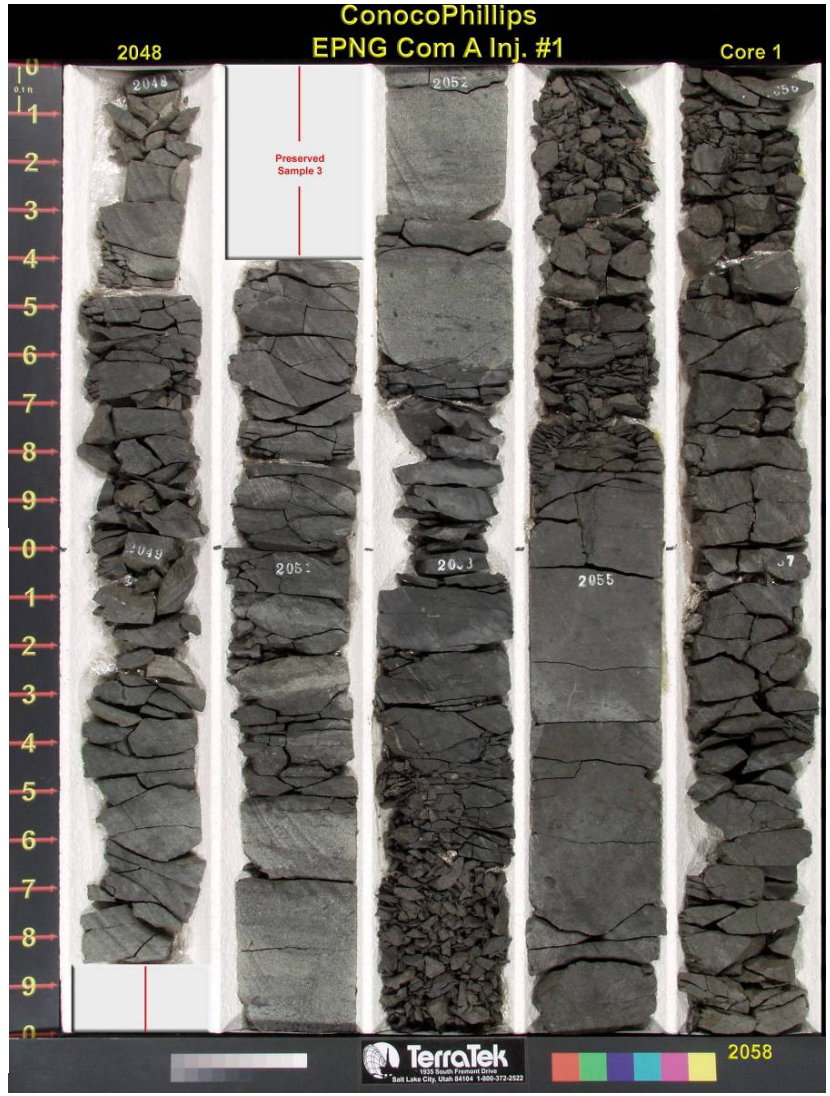
Core Analysis Program - Results to Date





Upper Kirtland:

- Silty argillaceous mudstone
- Clay matrix is illite, smectite, chlorite with minor kaolinite and mixed layer illite-smectite
- Clasts are quartz, feldspar, and volcanic rock fragments
- Fractures are probably pressure-release and dehydration features

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Core Analysis Program
Work in Progress

- Noble gas analysis underway at University of Utah
- Fracture measurement and analysis being done at Sandia
- TOUGH2 simulation work is underway to help interpret the helium data
- Comparison of caprock sealing properties of three different field sites: Kirtland Shale, Gothic Shale, and caprock at the SECARB Plant Daniel site

Acknowledgements

- Core Analysis Program designed by Jason Heath, Brian McPherson, Reid Grigg and Scott Cooper
- TerraTek is performing many tests
- Grant Bromhal and others at NETL are performing geomechanical analyses
- Core-flooding experiments are being conducted by NMT-PRRC

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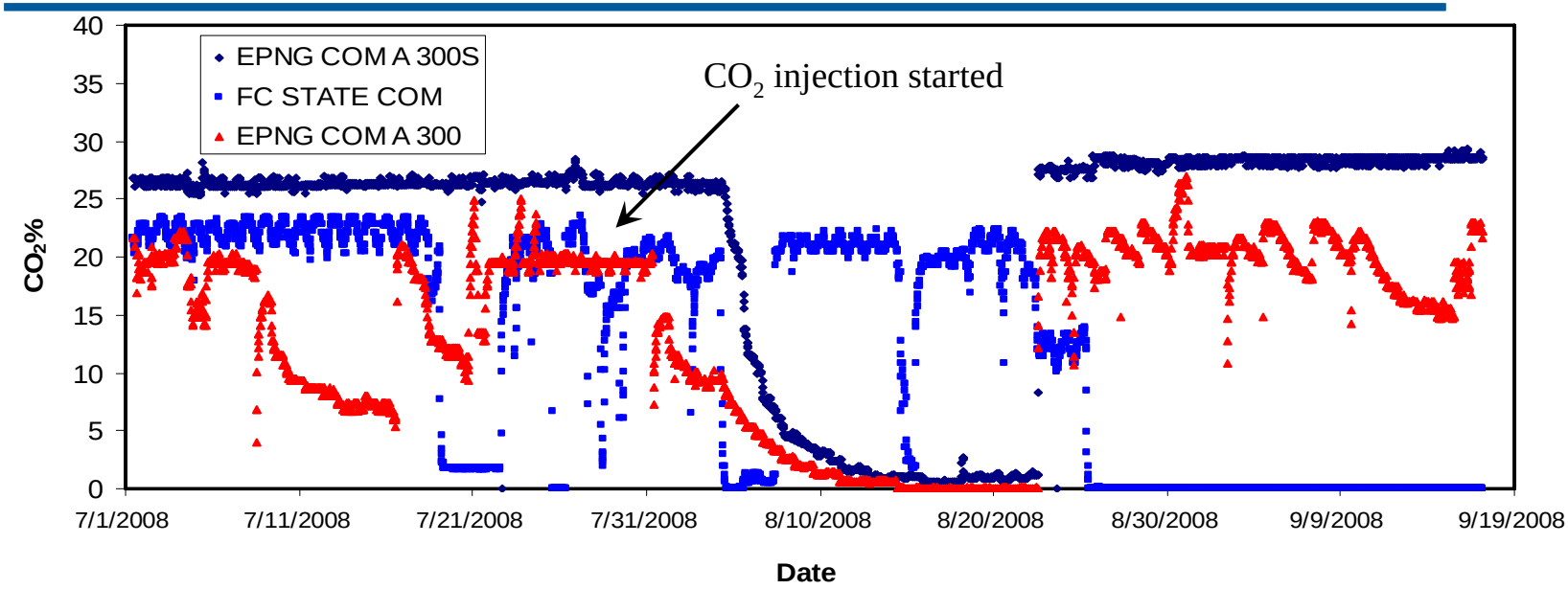
CO_2 Sensors Results



1. CO_2 injection started on July 31. The collected data before July 31 worked as the background data. The background data from the CO_2 sensor are similarly with the gas sample results. They are, 22.2% for FC STATE COM (24.0% from gas sample result on July 26), 20.2% for EPNG COM A 300 (20.6% from gas sample result), 26.8% for EPNG COM A 300S (28.3% from gas sample result)
2. The CO_2 concentration increased to 28.6% for EPNG COM A 300S and 22.5% for EPNG COM A 300, but decreased to 14.3% for FC STATE COM (CO_2 concentration became 0% after Aug. 25 for FC STATE COM due to the well compressor rebuild).

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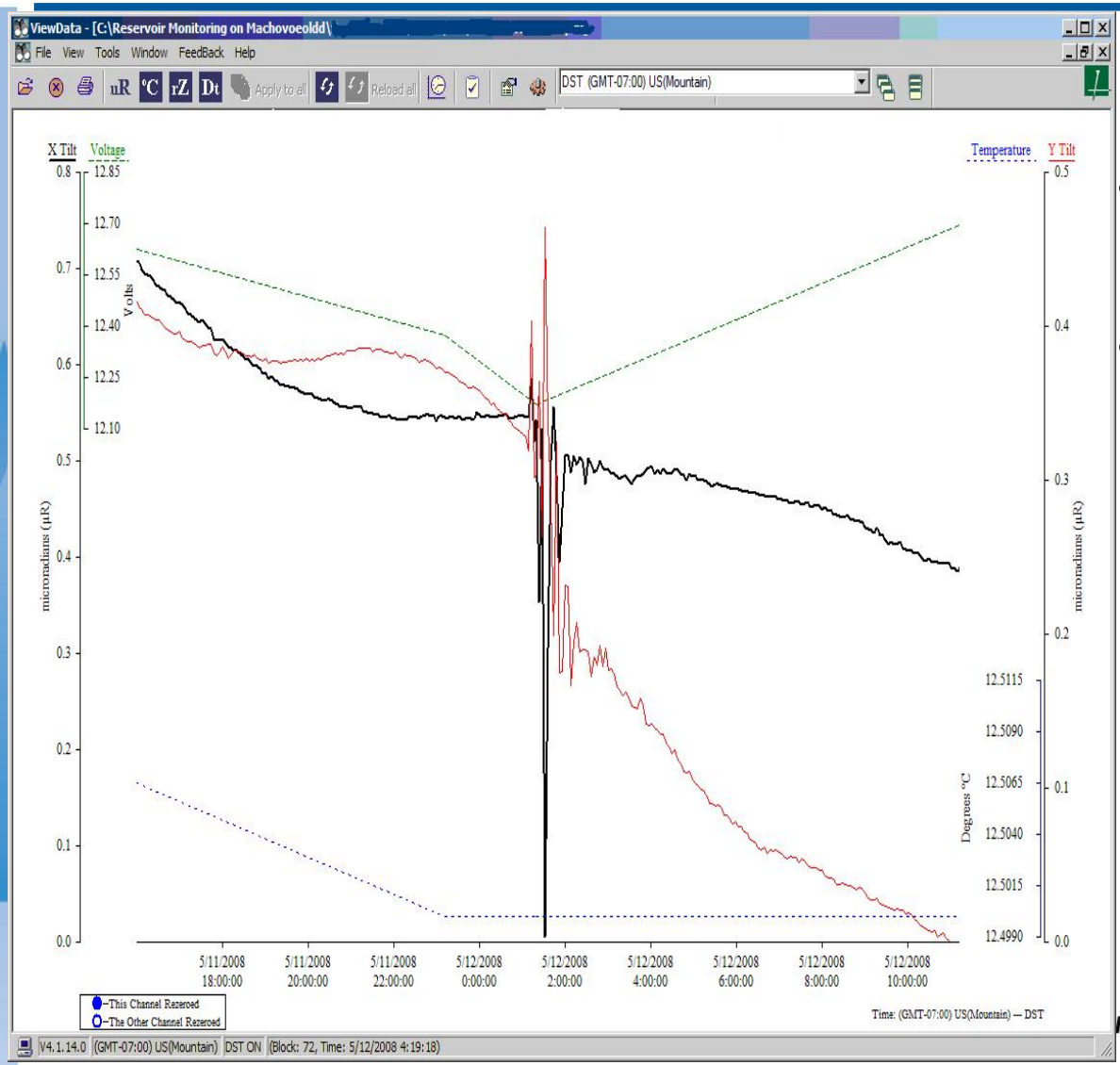
Tiltmeter Results
How Sensitive Is It?



- **2008 Chinese Earthquake**
- **Recorded multiple times at San Juan as shock waves circled the earth**

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Tiltmeter Results
Post Injection Trend Change

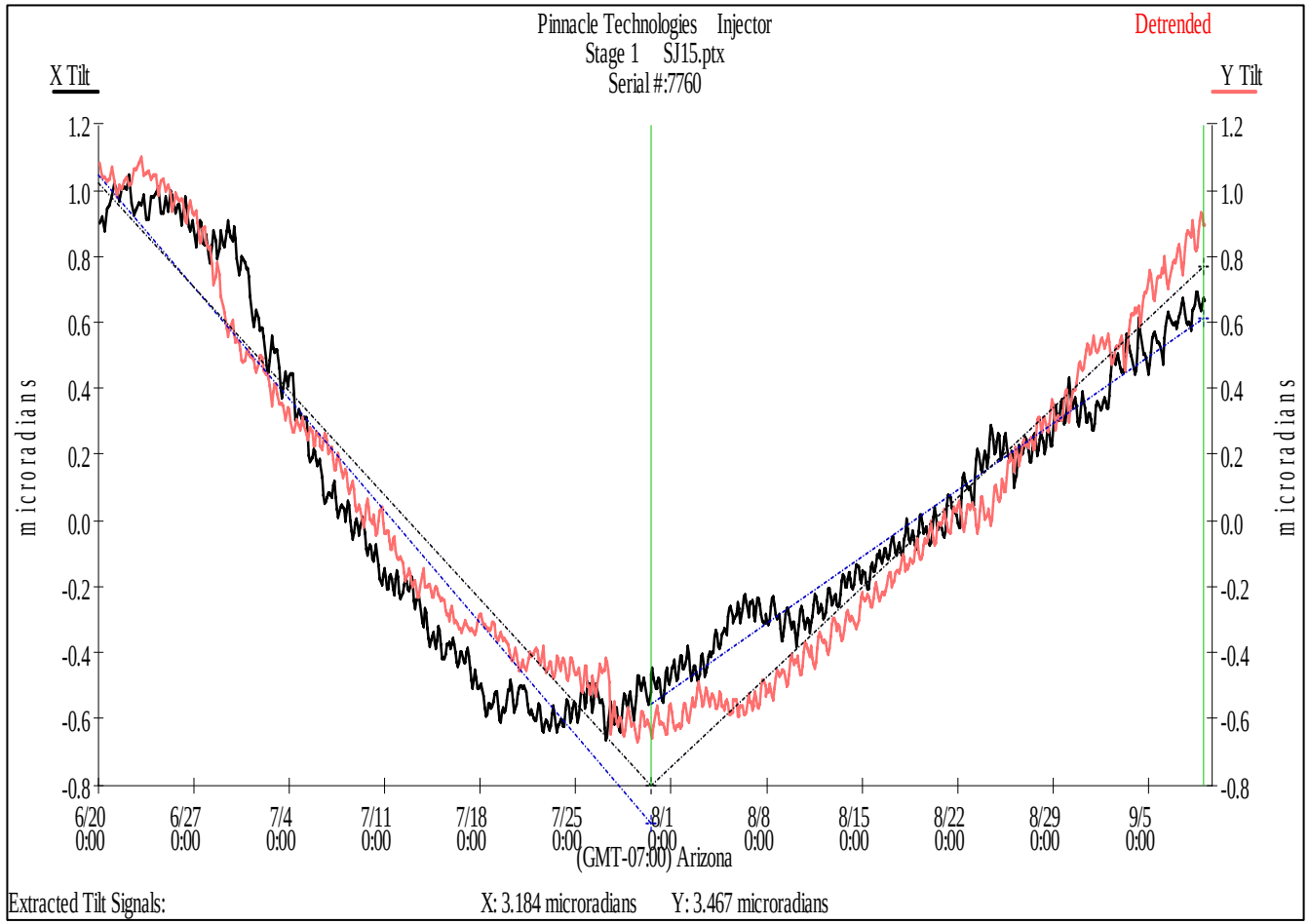

Figure 2: Raw Tilt for site SJ15 – pre and post July 30, 2008

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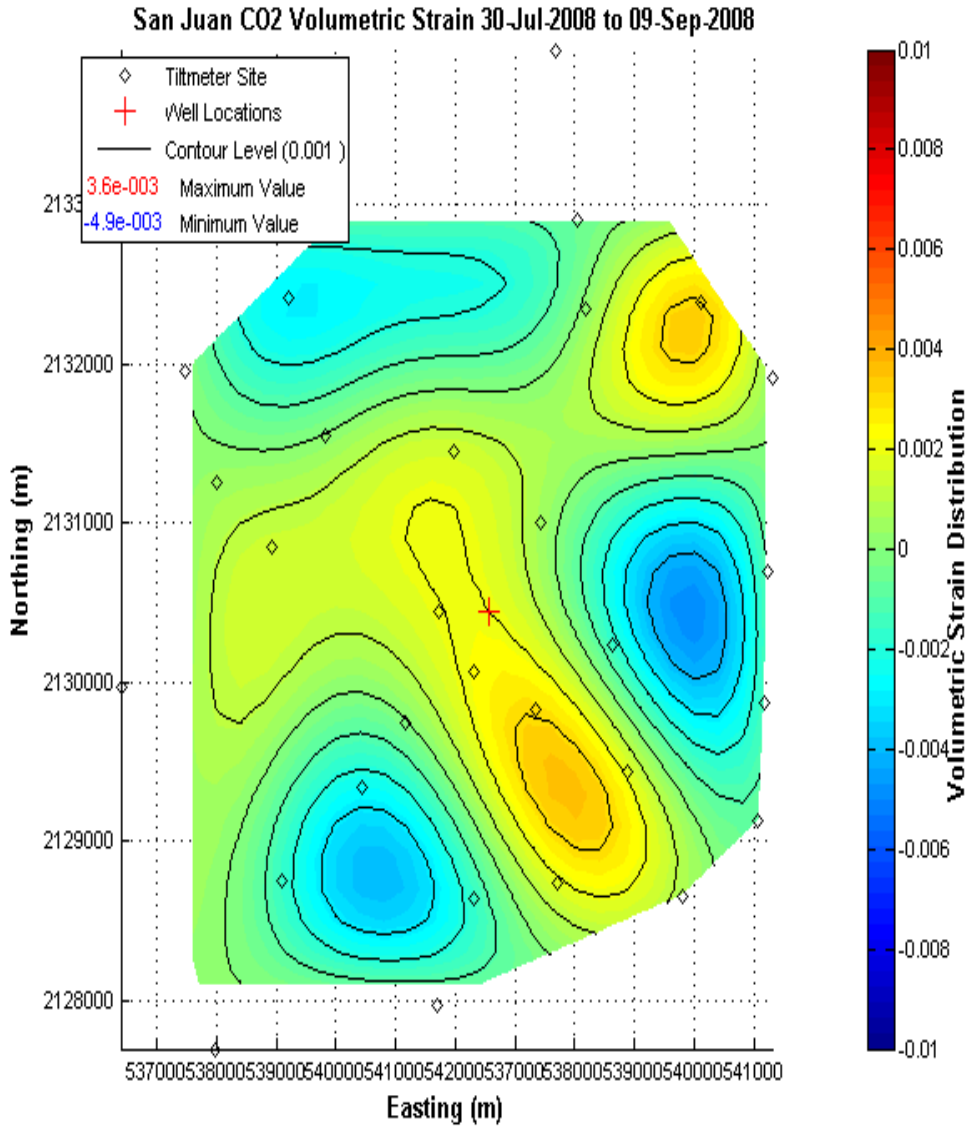
Tiltmeter Results
Volumetric Strain Calculations



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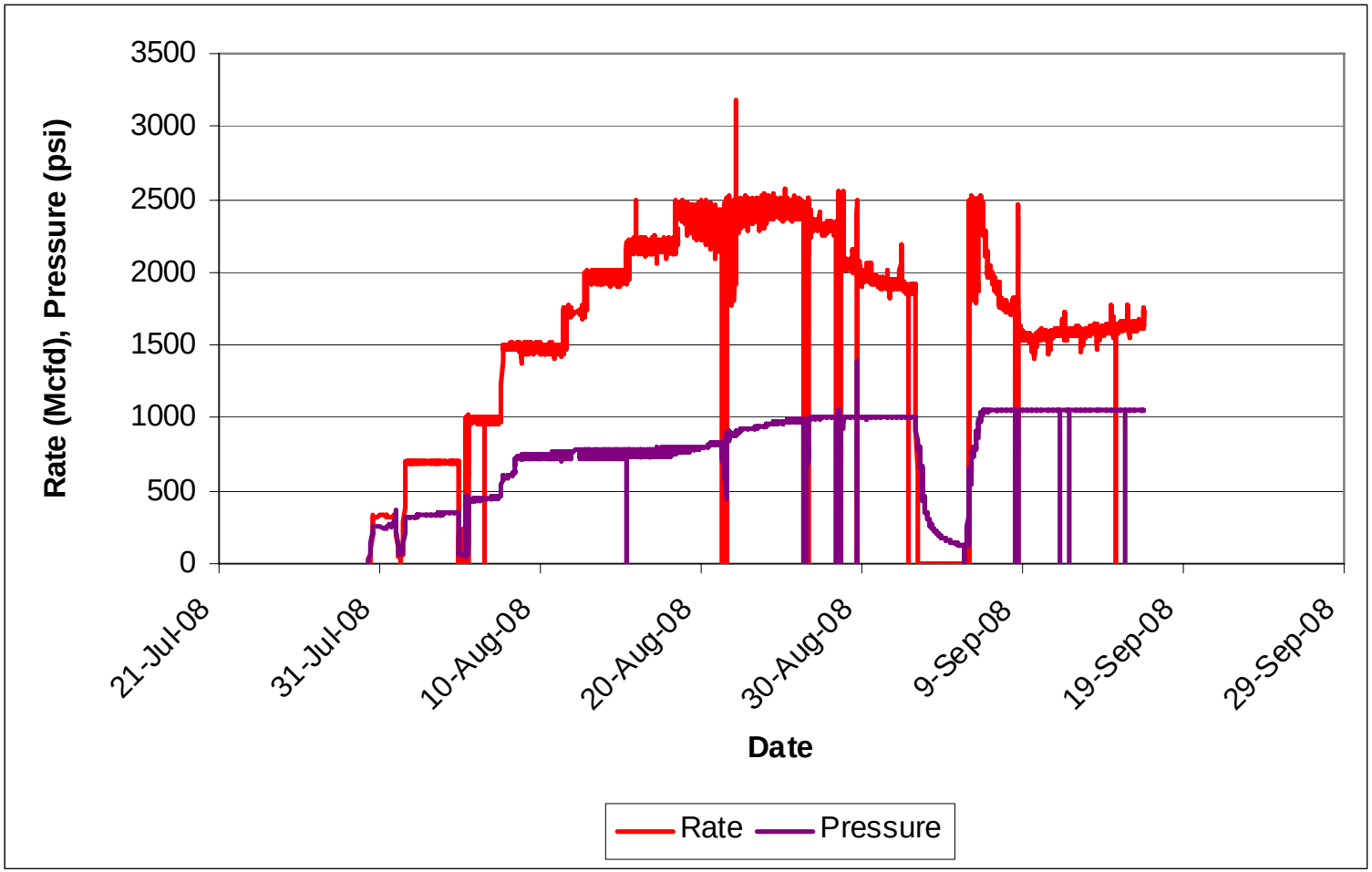
Operations - Injection Plot



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