# Illinois Basin – Sugar Creek and Mumford Hills EOR Test (Reservoir Engineering and Geology)

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Regional Carbon Sequestration Partnerships Annual Review Meeting

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Midwest Geological Sequestration Consortium
www.sequestration.org

# Acknowledgements


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- The MGSC is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky

# Sequestration EOR Pilot Objectives

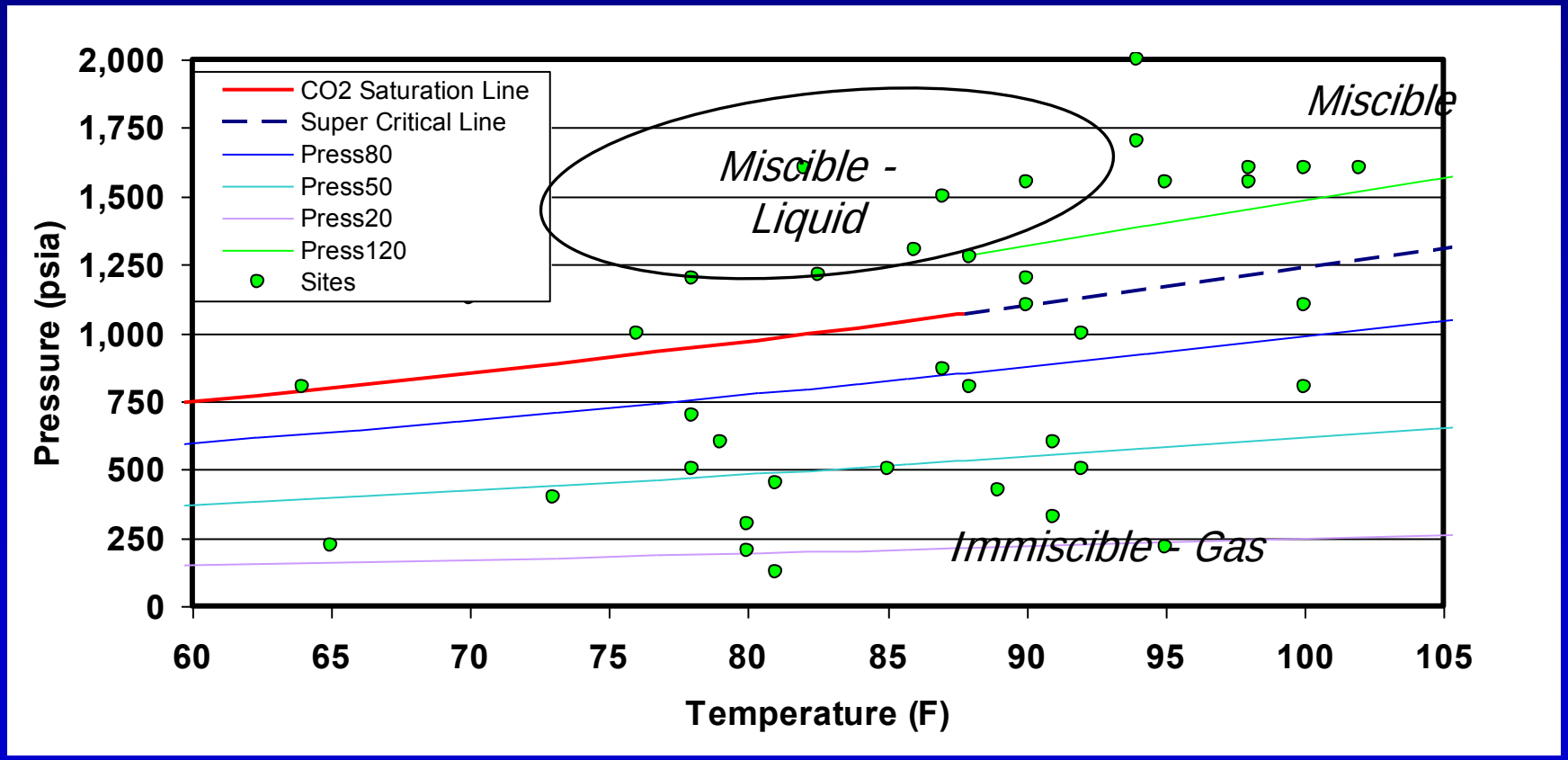
- Estimate $CO_2$ injectivity
- Validate Phase I $CO_2$ storage estimates
- Identify barriers to commercialization of sequestration EOR

# EOR II: Miscible (Liquid) $CO_2$ Flood (Mumford Hills Field, Indiana)

- Field History
  - Discovered 1974; OOIP 2,100,000 bbl
  - Edgewater injection 1976
  - Pre-$CO_2$, one water injector; two active oil producers on pump
- Production History
  - Primary oil production 41,000 bbl
  - Waterflood oil production 794,000 bbl
  - Total 835,000 bbl; 40% oil recovery
- Injection zone
  - Reservoir pressure 1,200-1,500 psi; wells can flow to surface
  - 1,000 bbl/day water injection; 3-5 bopd

# EOR II: Liquid $CO_2$ Classification

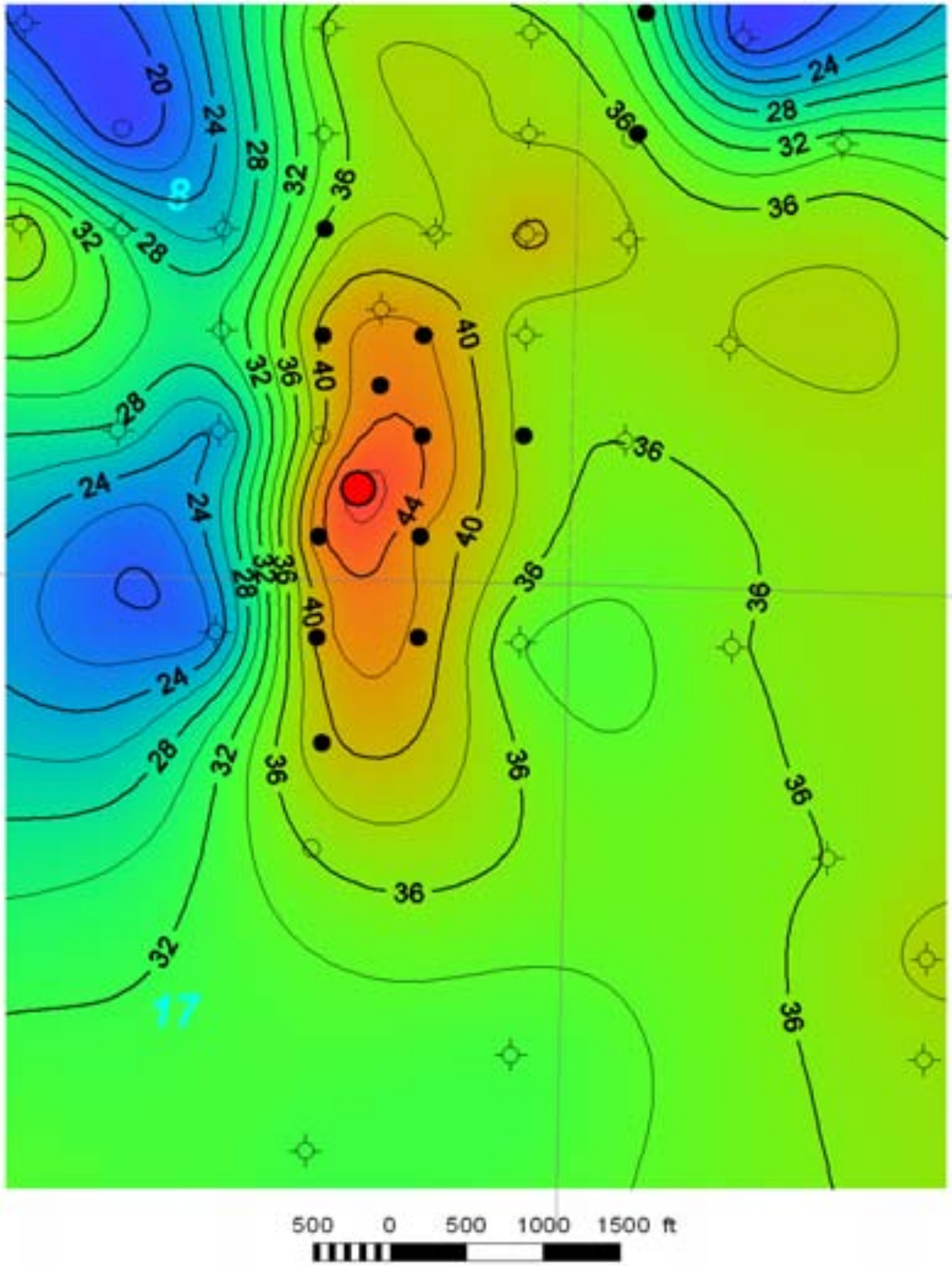
- Conditions to have miscible, liquid $CO_2$ flood
  - Low temperature 80°F (< $T_{cCO2}$)
  - High fracture pressure (1 psi/ft)



# EOR II: Geology

- Depth 1,900 ft
- Reservoir is a thick, elongated body of sandstone with good communication.
- Channel sandstone body; thickness 10 to 40 feet
- At this pilot site, sandstone about 30 ft thick
  - 20 ft oil column
  - Small structure with stratigraphic pinchout
  - Small underlying aquifer
- Porosity 19%; Permeability 155 md

Isopach Map
2 foot
contour
interval

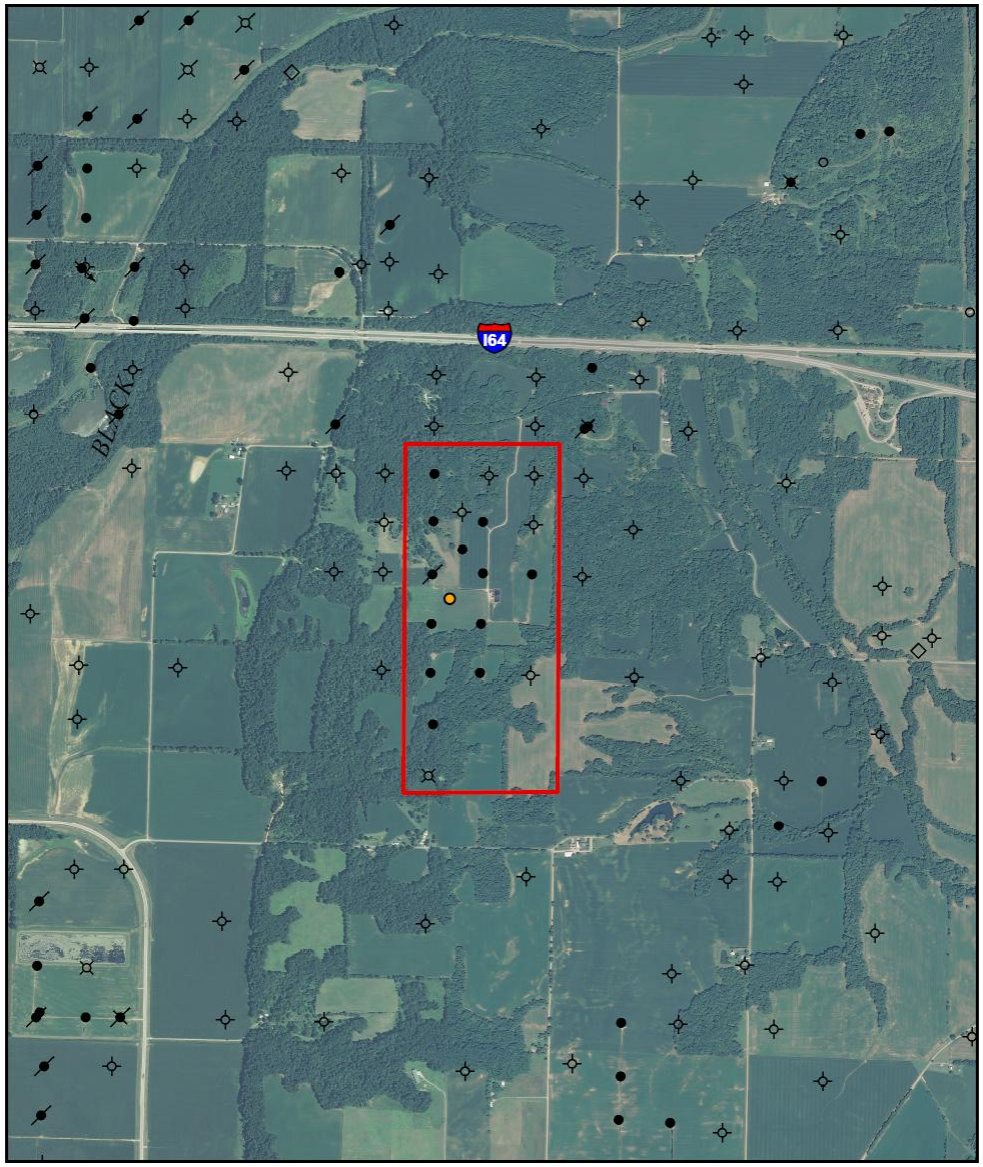


# EOR II Model Results

- VIP Models project 6,000-8,000 tons required to have measureable oil response
- Requires 6-8 months of continuous injection, followed by 3-5 months of water injection
- Project oil increase of 4-8 times current rate

# EOR II Pilot Design

- Inverted 5-spot $CO_2$ injection pattern
  - Four flowing wells (through tubing) in pattern
  - Central $CO_2$ injection well converted from producer
  - Edge water injector: 1,000 bbl/day
- 6-8 months of continuous injection, followed by 3-5 months of water injection
- Winter road restriction may require shut-down or return to water injection



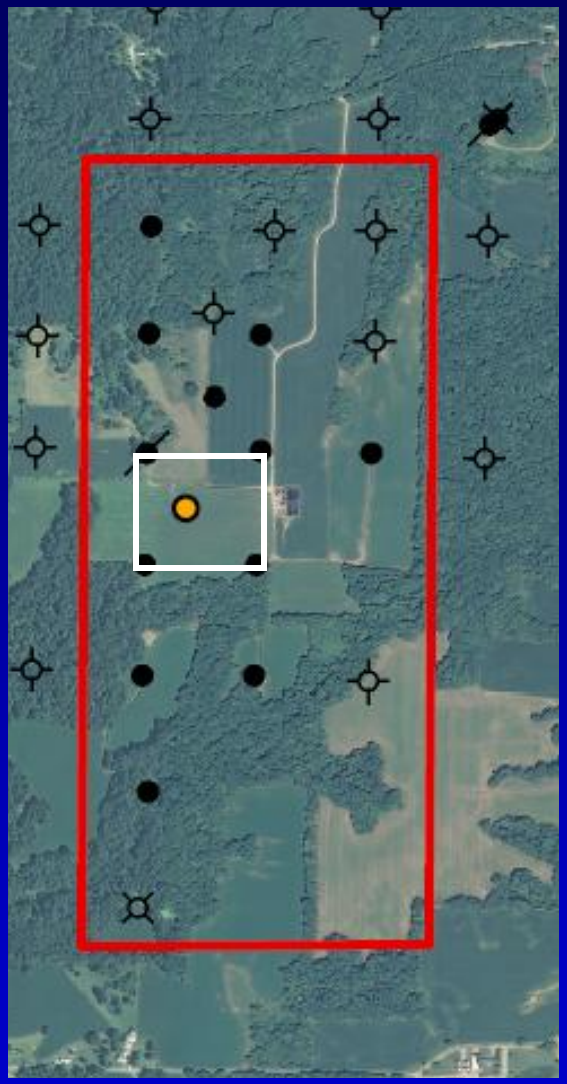

Mumford Hills Site, Posey County, IN

Data from IndianaMap, Indiana Geological Survey, Midwest Geological Sequestration Consortium, 2008 NAIP digital orthophoto imagery

- Oil Well
- Bald Unit #1 well
- Abandoned Oil Well
- Abandoned Oil and Water Injection Well
- Dry and Abandoned Oil Well

N

0 0.5 1 Miles



# EOR II MVA

- Residential water well sampling planned
- 3 shallow groundwater monitoring wells installed, developed and instrumented
- Weekly gas reading
  - Observation well and separator
- Monthly brine sampling schedule
- Cased hole logging

# Data Acquisition Equipment

- Bottomhole and surface pressure in flowing producing and injection wells. (5 wells)
- Pressure monitoring two wells:
  - out of pattern
  - nearest $CO_2$ injection well
  - downstream of general pressure gradient

# Injection Equipment

- Injection pump and booster pump
- Two, 60 ton storage tanks
- Inline propane-fired heater

# EOR II Status

- Injection started September 3, 2009
- Cumulative injection 1,550 tons (11/16/09)
  - Currently 30-35 tons/day
- Portable test separator optimization
- History matching production and pressure responses

# EOR II Observations to Date

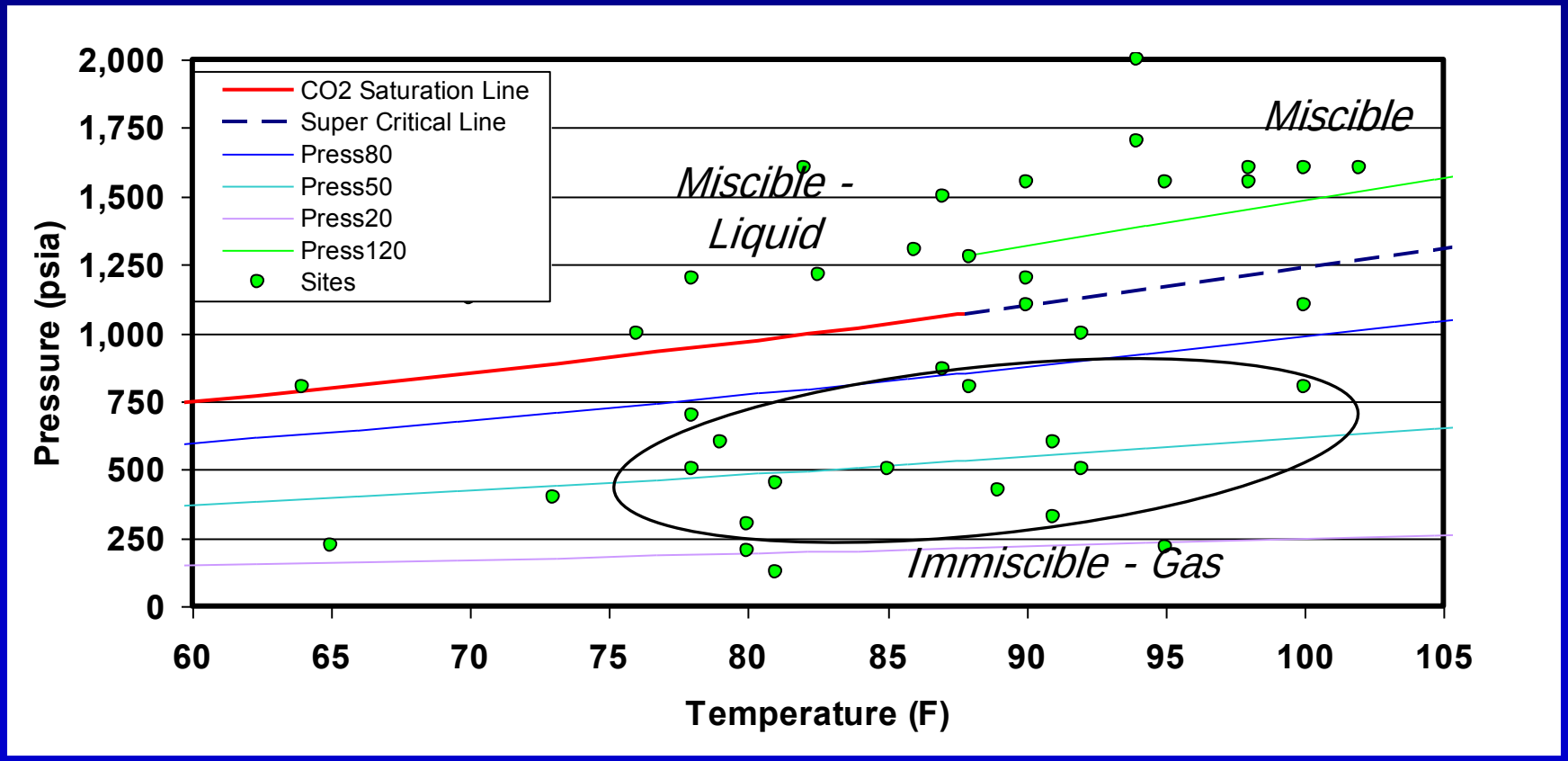
- Flowing production wells eliminates electrical costs of pumping wells
- Demonstration of opening an abandoned well to increase oil production
- No increase in oil production
- No out-of-zone indication of $CO_2$

# EOR III: Immiscible (Gas) $CO_2$ Flood (Sugar Creek Field, Kentucky)

- Field History
  - Discovered 1963; OOIP 2,410,000 bbl
  - Waterflood 1993
- Production History
  - Primary oil production 475,000 bbl
  - Waterflood oil production 314,000 bbl
  - Total 793,000 bbl; 33% oil recovery
- Water injection
  - Low water injectivity and low injector/producer ratio; low reservoir pressure, not depleted (500-600 psi)
  - 100 bbl/day water injection; 36-42 bopd

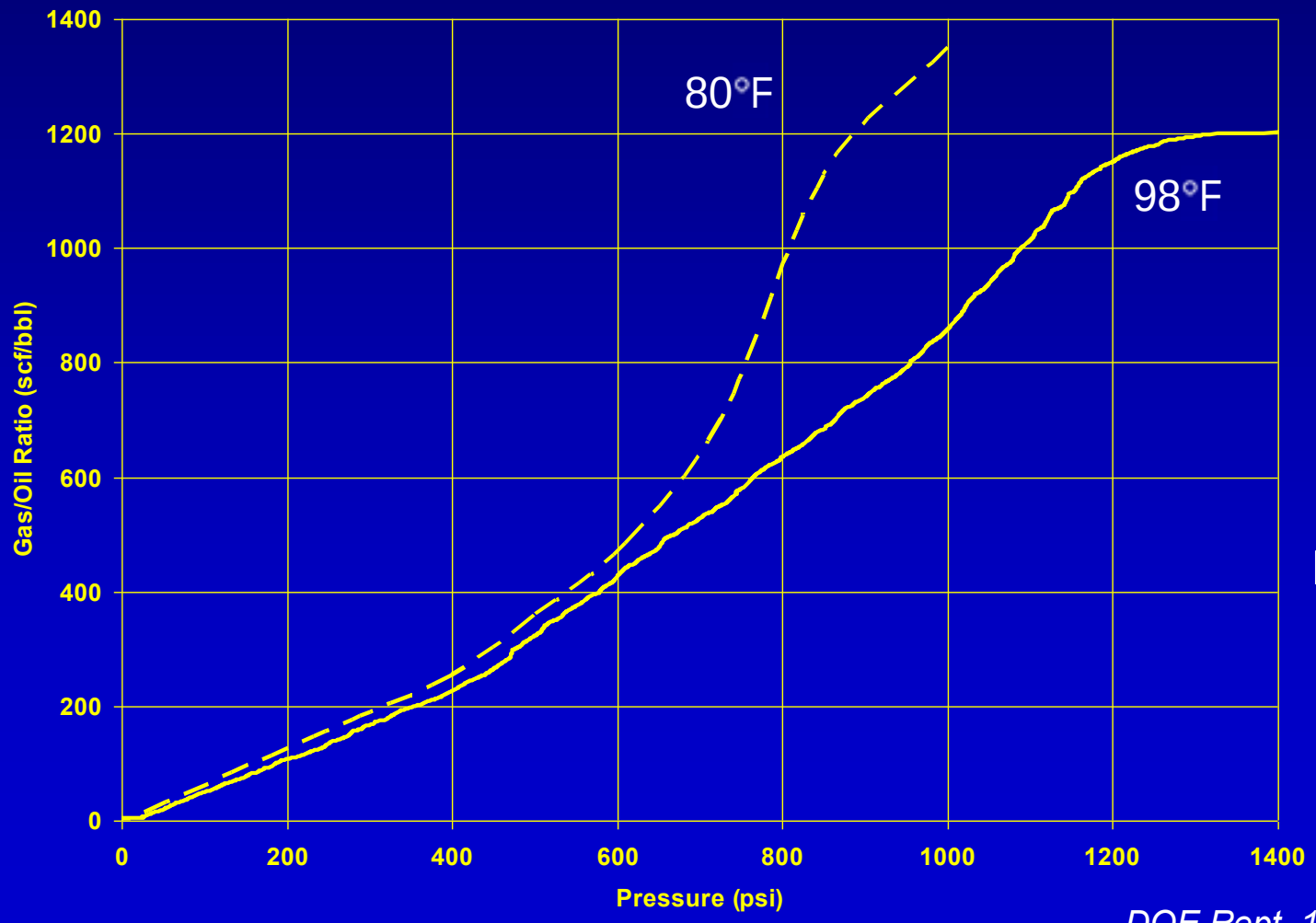
# EOR III Immiscible (Gas) $CO_2$ Classification

- 80°F (< $T_{cCO2}$); pressure 500-600 psi



# $CO_2$ Solubility in Illinois Crude Oil

In situ $CO_2$ solubility w/oil higher for low temperature Illinois Basin Oil fields

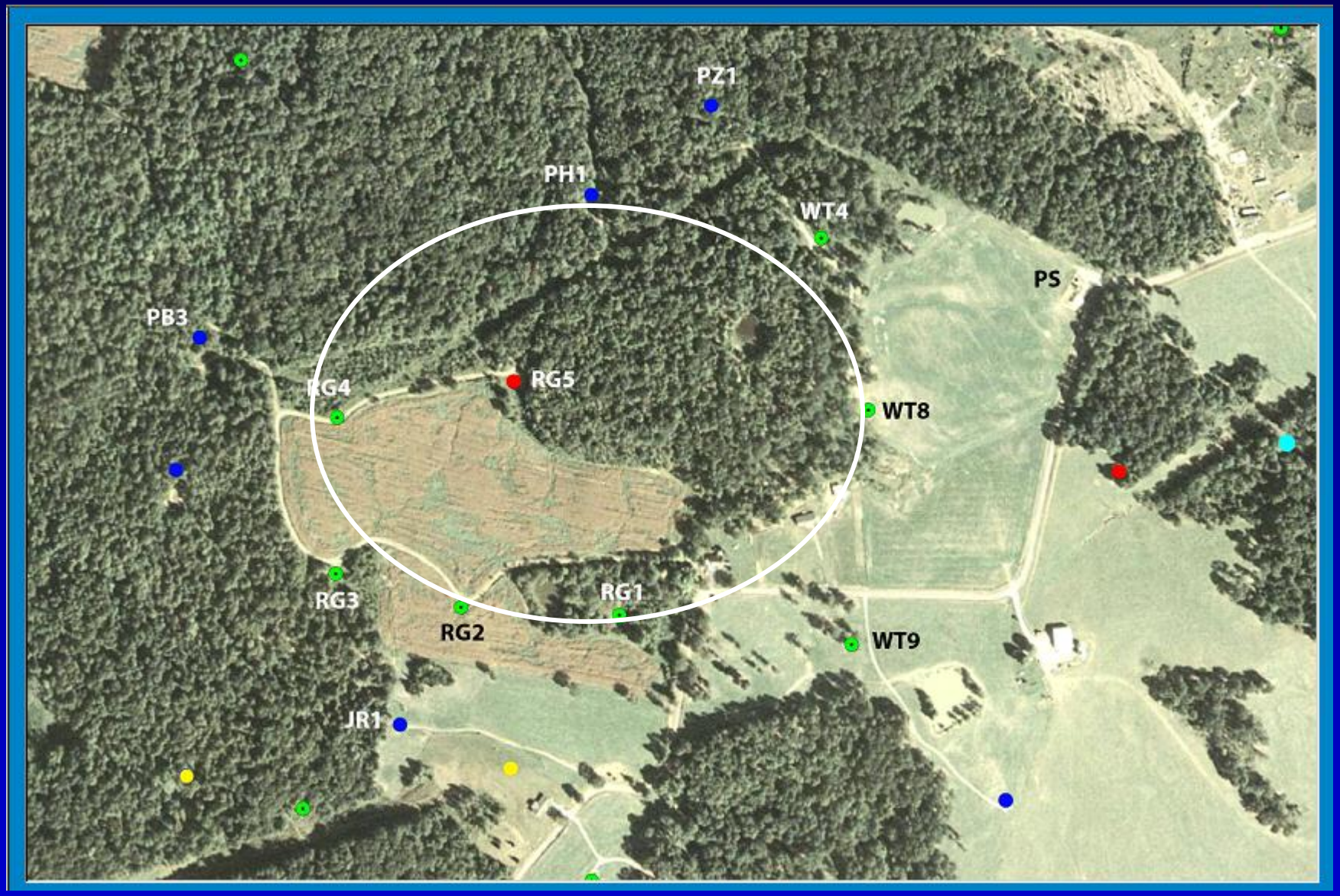



Cypress
(1750-1830 ft)
Mattoon Field
Coles Cty IL

Aux Vases
(3158-3176 ft)
Dale Consolidated
Franklin County

ISGS IP 140

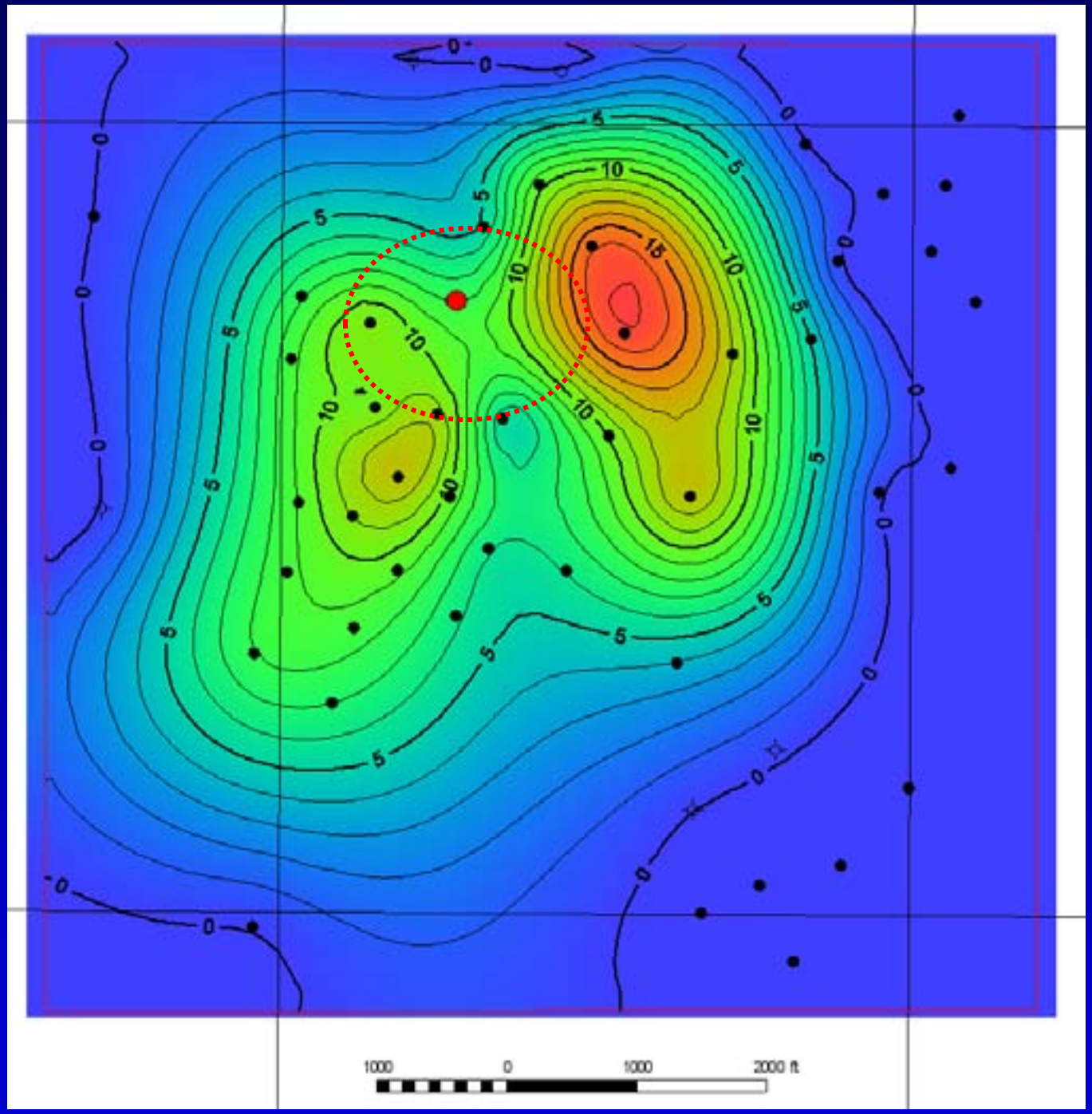
*DOE Rept, 1995 DE-FC22-93BC 14955*


PZ1
PH1
WT4
PS
PB3
RG4
RG5
WT8
RG3
RG1
RG2
WT9
JR1

# EOR III Geology

- Depth:  1,900 ft
- Modest geologic structure present
- Lenticular reservoir sandstone bodies, likely a shallow marine environment.
- Porosity 15%; permeability 15 md
- Thicknesses ranging from 5 - 20 feet; fair to poor communication.  Site 12 ft thick

Isopach Map
1 foot
contour
interval



# EOR III Model Results

- VIP Models project 6,000-8,000 tons required to have measureable oil response
- Requires 6-8 months of continuous injection, followed by 3-5 months of water injection
- Project oil increase of 2-3 times current rate

# EOR III Pilot Design

- Central $CO_2$ injection pattern
  - Eight oil producing wells on pumping units
  - 20-30 tons/day
- Low injection rate may lead to 1-3 injection wells
- 6-8 months of continuous injection, followed by 3-5 months of water injection

# Injection Equipment

# EOR III MVA

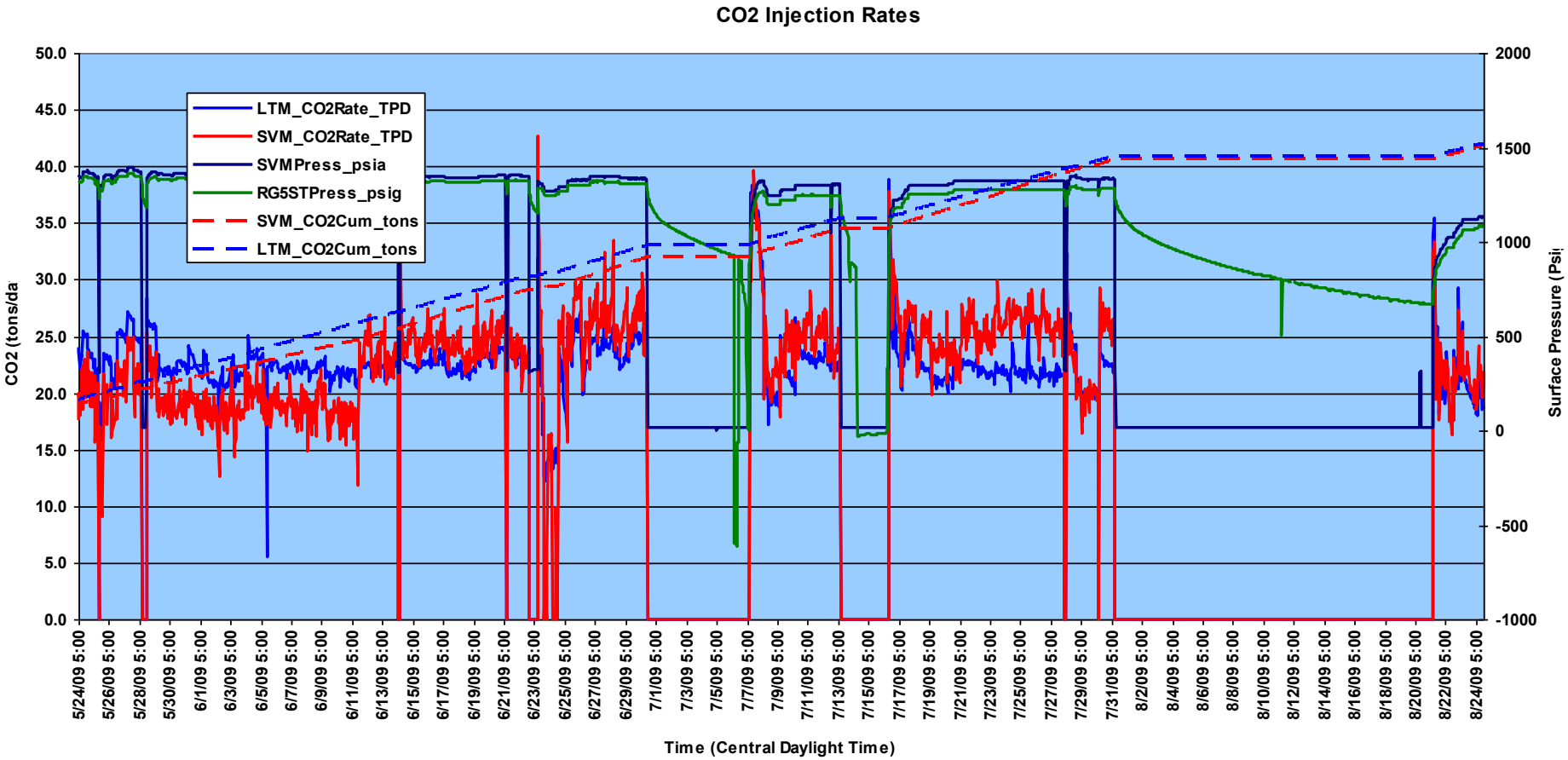
- 3 shallow groundwater monitoring wells
- Quarterly residential well sampling
- Cased hole logging (RST, CBL)
- Injection Zone:
  - weekly gas readings (IRGA)
  - monthly gas and brine samples taken

# Data Acquisition Equipment

- Surface casing pressure in producing wells (8 wells)
- Surface and bottomhole pressure in injection well
- Injection zone monitoring wells (3 outside of area)
  - Combination of surface and subsurface pressure

# Wellhead and MVA Well

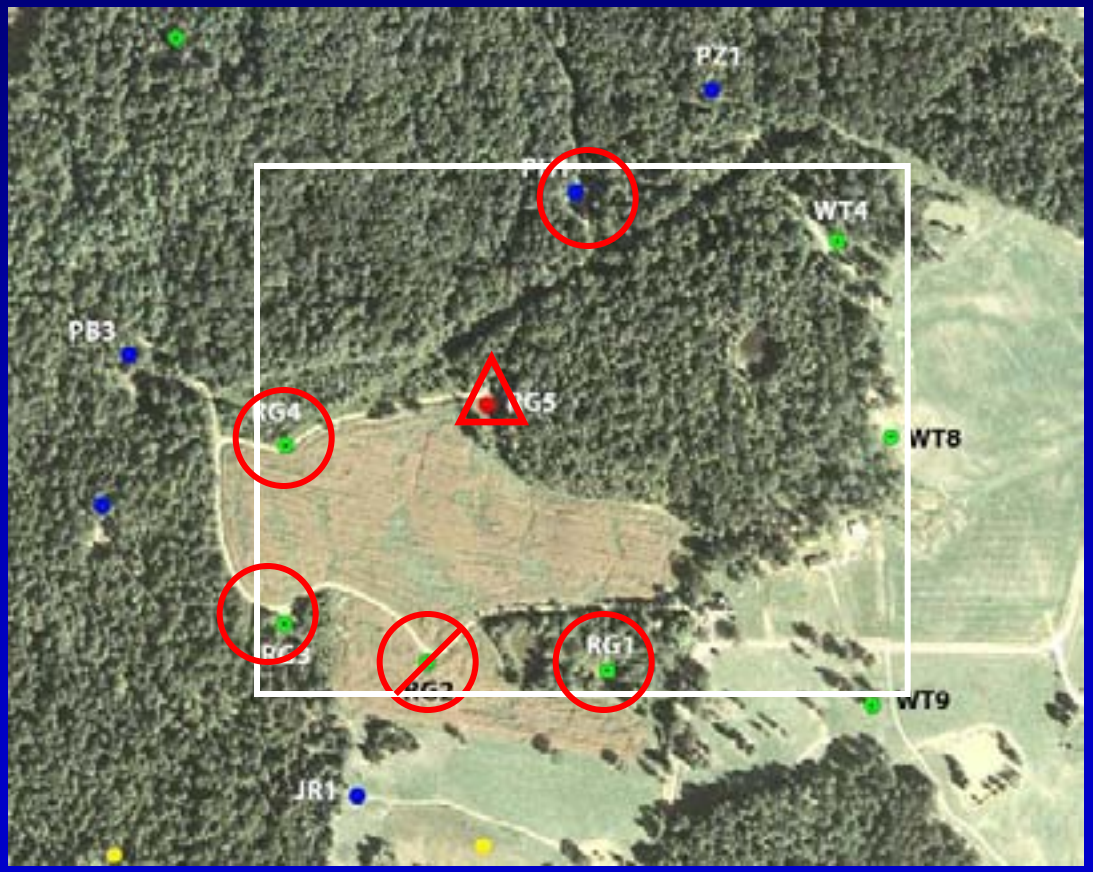
# $CO_2$ Injection Rate



# Very Early $CO_2$ Breakthrough (two weeks after injection startup)

Detected via pressure and gas sampling

# Presently $CO_2$ and Pressure Detected at Additional Wells




| Well | $CO_2$ | Press |
|---|---|---|
| RG2 | 5/20 | 5/19 |
| RG3 | 6/29 | 9/8 |
| RG1 | 9/15 | 9/12 |
| RG4 | 9/15 | 9/25 |
| PH1 | 10/7 | 10/6 |

# EOR III Status

- 3,450 tons injected (11/16/09); 25-30 tons per day injection
- Produced approximately 2% of injected $CO_2$; 55% from RG2.
- Target 6,000-8,000 tons
- Schedule to inject through early winter followed by water injection

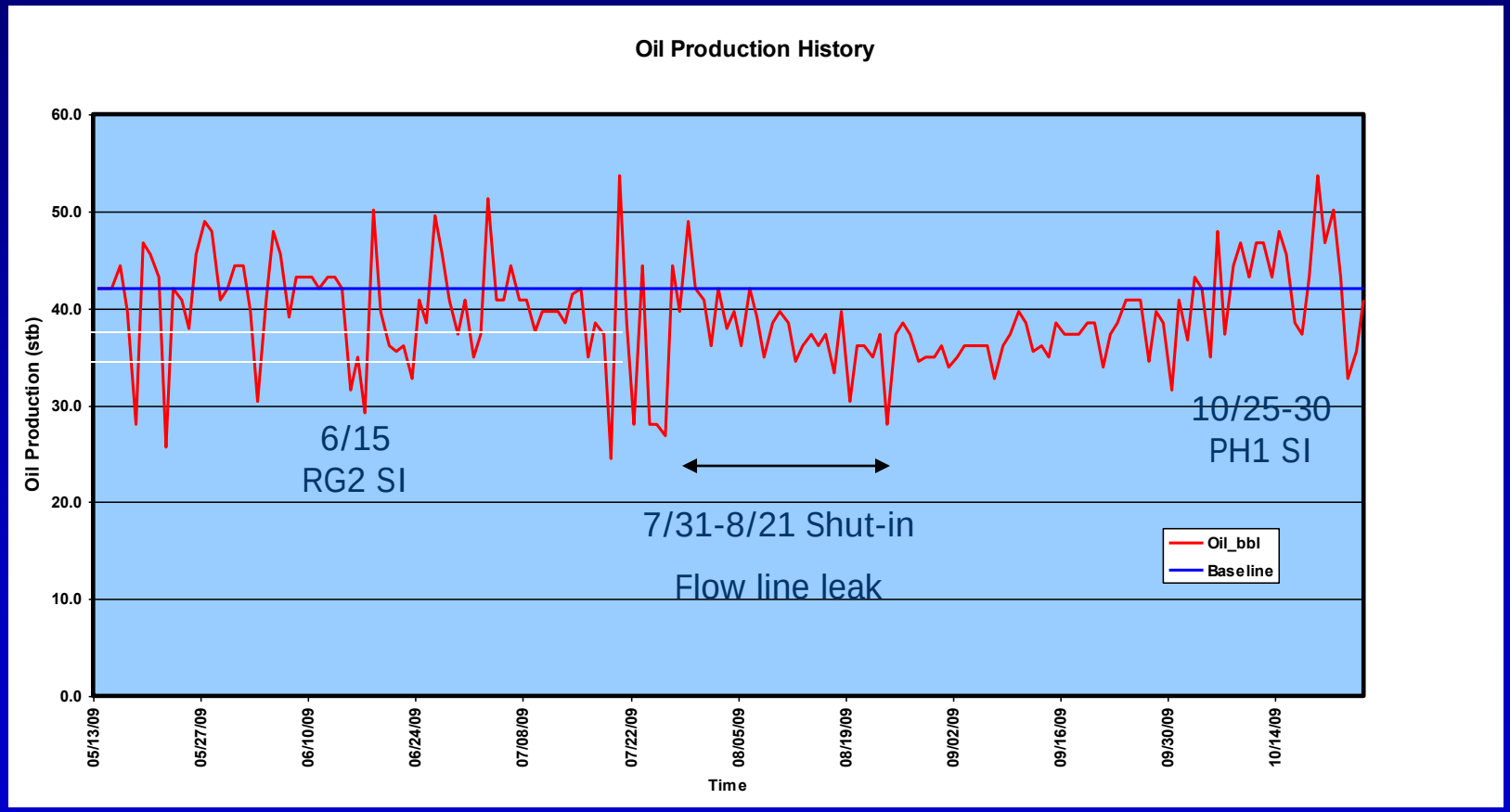
# EOR III Observations to Date

- Operational problems
  - Early breakthrough at offset well (RG2)
  - Injection flowline leak (RG5)
  - Producing well packer failure (RG2)
  - Paraffin deposition (PH1)
    - Downhole pump failure
    - Production flowline restriction

# EOR III Observations to Date, contd.

- RG2
  - Oil rate increased with early $CO_2$ breakthrough, but short duration
  - Subsequent to shut-in, oil production decreased
- RG5 (Injector)
  - Flow line leak:  SI 3 weeks
  - Noticeable loss in oil production
- PH1
  - Substantial oil increase (0.5 up to 8 bopd)
  - Paraffin deposition; xylene treatment in progress

# Oil Production



# Incremental Oil Production

| Month | Jan | Feb | Mar | Apr | May |
|---|---|---|---|---|---|
| bopd | 37 | 13 | 37 | 42 | 43 |

4.5 month average 33 bopd

| Base Oil Rate bopd | 36 | 38 | 40 | 42 |
|---|---|---|---|---|
| Incr. Oil Prod stb | 549 | 218 | -114 | -446 |

Cumulative Oil Production: 6520 bbl

# Staff

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  - John Rupp, IGS
- HASP:
  - William Roy, ISGS
  - Jim Kirksey, SCS

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  - SCS:  Jim Kirksey
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  - John Grube and James Damico, ISGS

# Illinois Basin – Sugar Creek and Mumford Hills EOR Test (Reservoir Engineering and Geology)

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