

Illinois Basin - EOR Sequestration Tests

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Regional Carbon Sequestration Partnership
Initiative Review Meeting
October 6-8, 2008



Midwest Geological
Sequestration Consortium
www.sequestration.org



Objectives

- Estimate injectivity
- Validate Phase I CO₂ storage estimates
- Estimate Enhanced Oil Recovery
- Provide input to Basin sequestration model to include added value benefit EOR

EOR I: Huff n Puff Pilot Test Objective

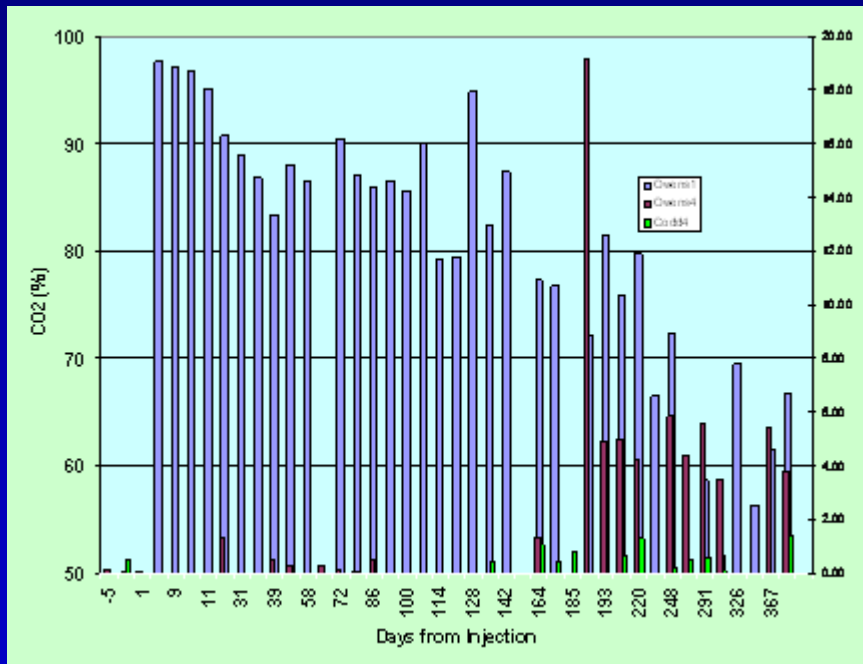
- To conduct small scale CO₂ injection pilot
 - Single well,
 - Inject CO₂
 - Produce oil, gas, water)



EOR I Summary: CO₂ Sequestered and EOR

- 43 tons CO₂ injected in 5 days
 - 33 tons of CO₂ produced
- Reduction of water production
 - Initially fell 33%
 - 2 months back to nearly pre-injection rates (94%)
- EOR 95 bbls oil (2 months)
 - Peak 8x base rate
 - Decrease quickly to stable near stable rate

EOR I Update



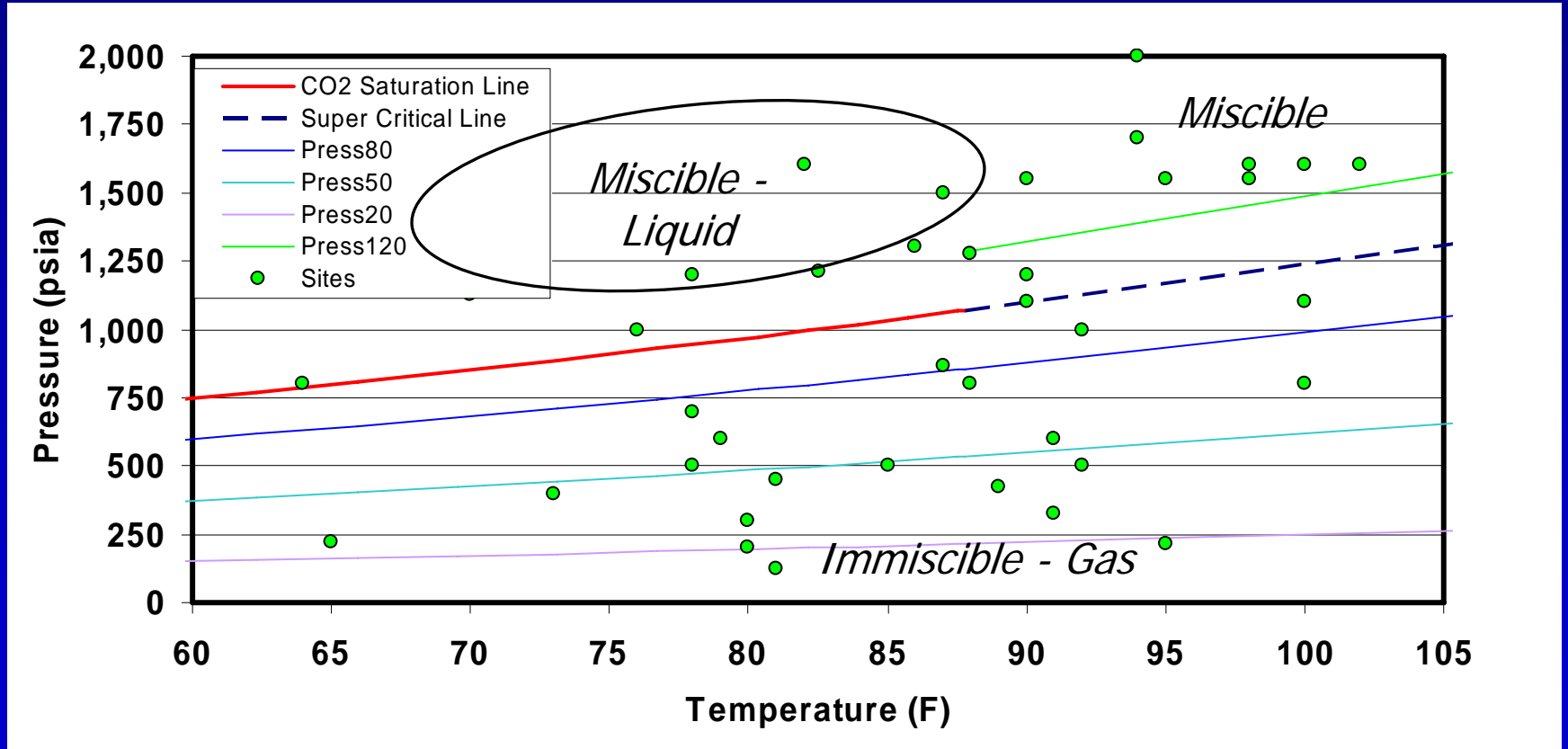
- Continue to produce low pressure casing gas with 50-60% CO₂
- No indication of corrosion
- Well continues to produce slightly higher oil rate than pre-CO₂ injection rate

EOR II: Liquid CO₂ Flood

- Liquid CO₂ flood
 - Low temperature 70° F ($< T_{cCO_2}$)
 - High fracture pressure (1 psi/ft)
- Water flood pattern reservoir pressure 1200-1500 psi
- Conditions to have miscible, liquid CO₂ flood

EOR II: Liquid CO₂ Classification

Comparison of current reservoir pressure and temperature to the saturation p-T line and critical point of pure CO₂



EOR II Screening

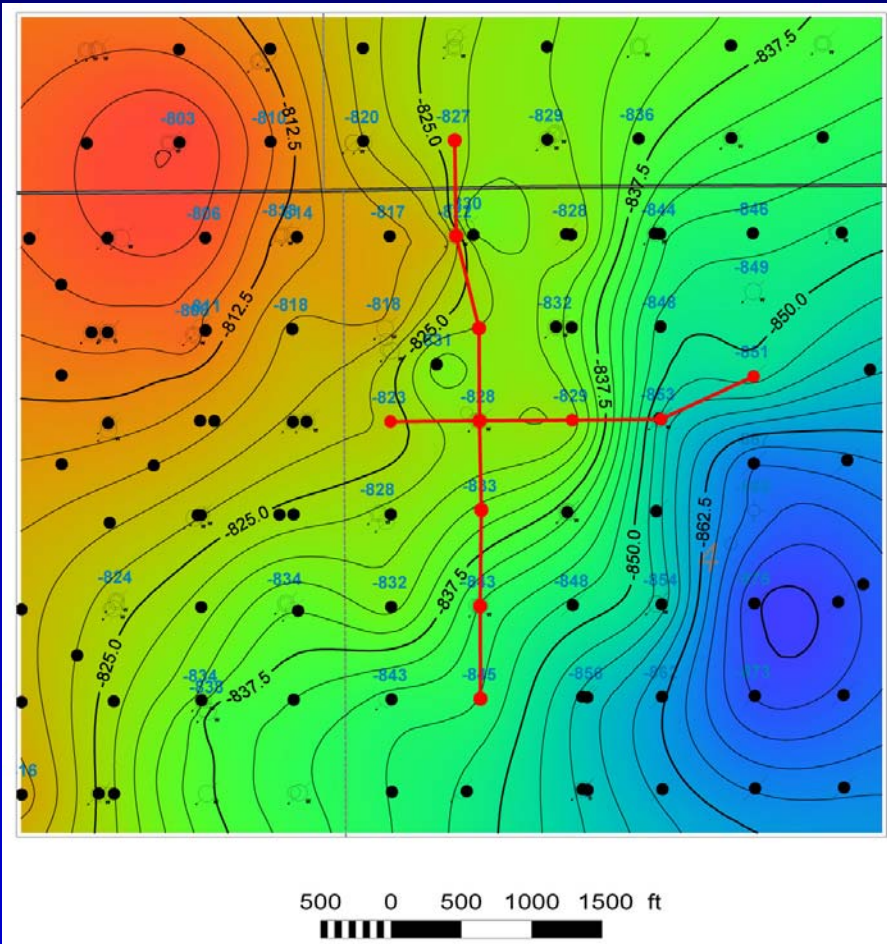
- Over 100 injection wells screened for pattern size and shape, injection pressure and rate, and completion zone(s)
- 32 site visits for surface criteria: flood plain, houses, ponds and streams and CO₂ delivery access
- 10 injection well files reviewed
- 5 geologic and reservoir models developed

EOR II Selection Issues for Loudon

- 4" liner inside 6" casing surface to above formations
- Proximity of wells to
 - flood plains
 - major roads
 - homes
 - private ponds



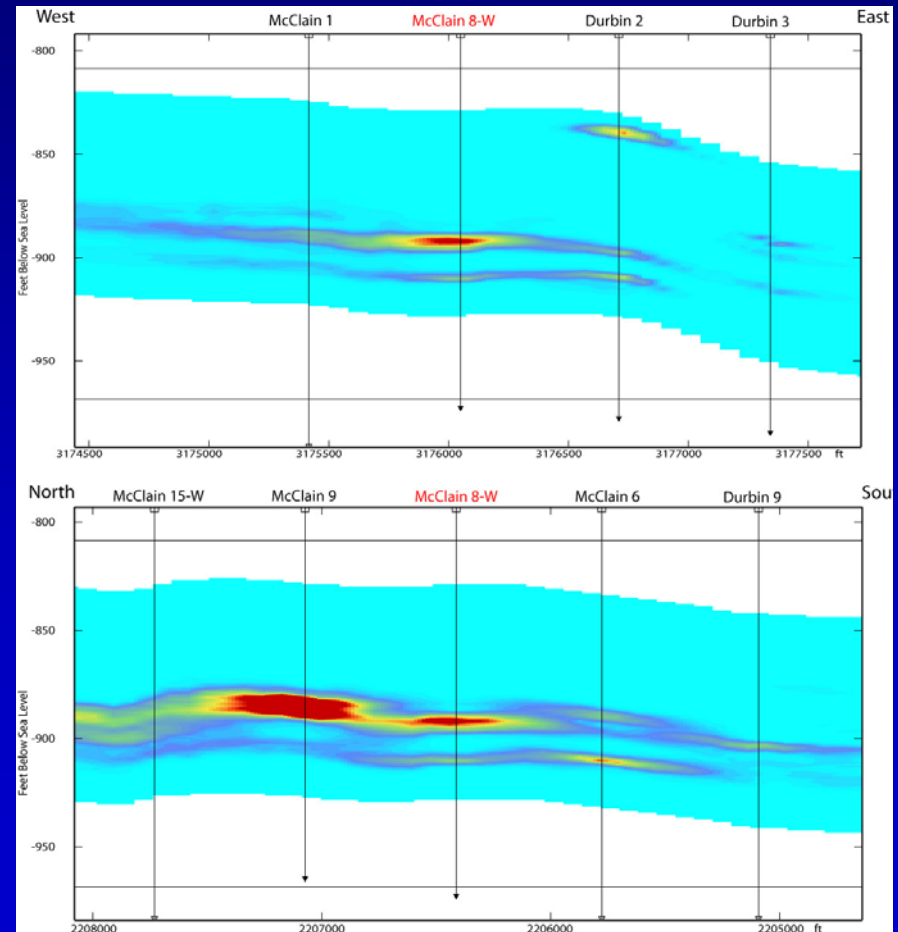
EOR II Model Results



- Five geologic/reservoir models developed for five water injection well locations
- Variations in geologic models included
 - Thickness 10-30 ft
 - Multiple zones open to injection
 - Permeability 50-150 md

EOR II Model Results

- VIP reservoir models project 6000-8000 tons required to have measureable oil response
- Requires 6-8 months of continuous CO₂ injection, followed by 3-5 months of water injection



EOR II: UIC II Permit

- Multiple iterations with IDNR O&G Division, USEPA Region 5, and Petco (operator)
- Initially triple permit required
 - (1) existing water injection permit
 - (2) CO₂ injection permit
 - (3) water injection permit (back to pre-CO₂ operations)
- DNR and USEPA 5 agree to an amendment to existing permit to change injection fluid from water to CO₂ without issuing a permit
- HOWEVER...

EOR II: UIC II Permit

- ...an AOR of a $\frac{1}{4}$ mile radius of the injector was required
 - All wells within this radius must have well records available to show that cement is in place to protect USDW
 - One well in AOR at exactly $\frac{1}{4}$ mile did not have records available...
- So an exemption was requested and written case developed for exemption...

EOR II: UIC II Permit...Latest

- Application in operator's possession, but wants written assurance that IDNR will allow well to return to water injection...
- ...IDNR may not want to provide hypothetical assurance until a permit application is received...
- Overall IDNR O&G Division and USEPA 5 cooperative and agreeable to consider new ideas and requests for CO₂ sequestration project.

EOR II Remaining

- Contract with operator (pending issuance of permit)
- Potential winter road restrictions for CO₂ delivery
- Anticipate establish production baseline and inject November/December 2008

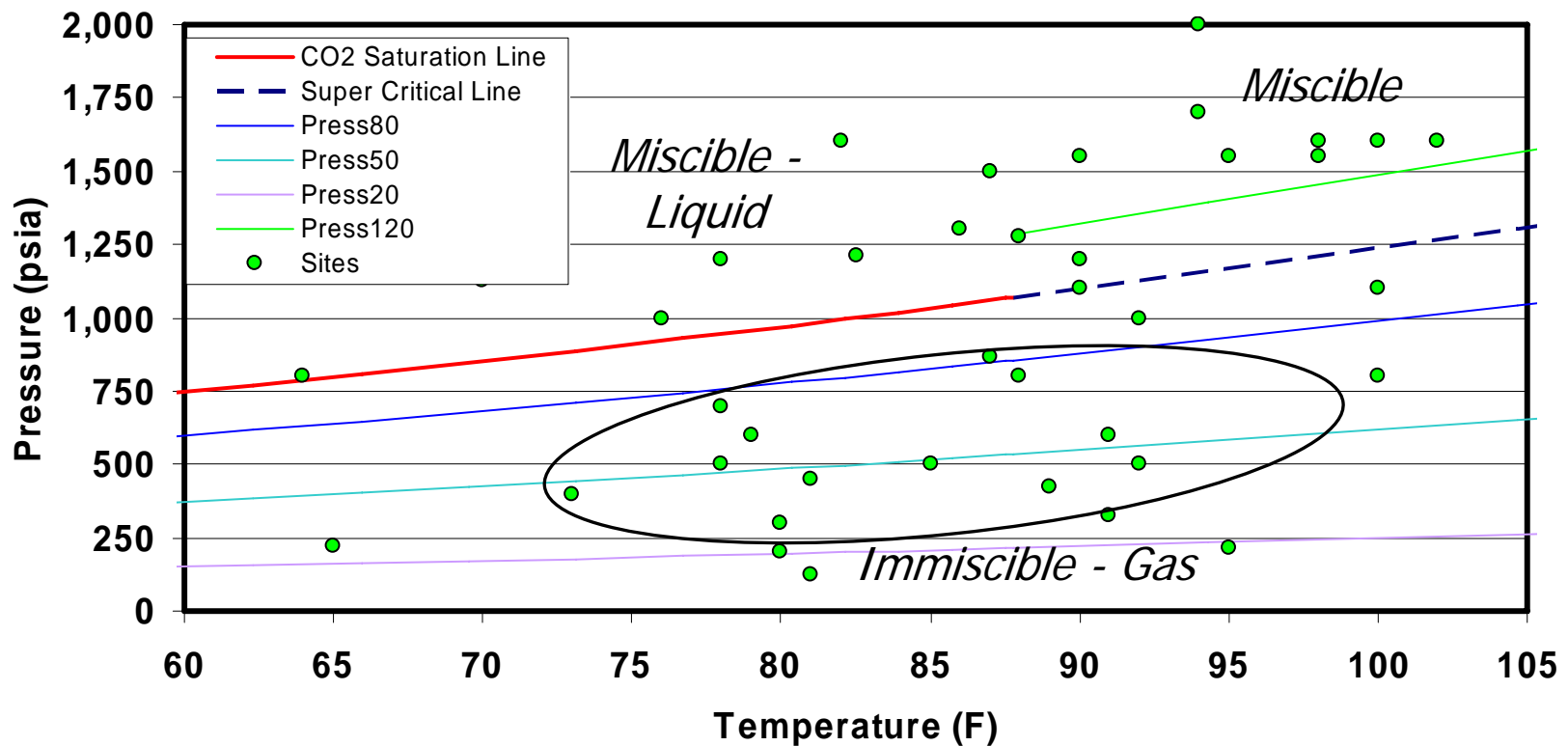
EOR II Backups

- Two contingent operators and fields have been pursued
- Decision will be made in next two weeks depending on IDNR response to hypothetical application

EOR III: Immiscible (Gas) CO₂ Flood

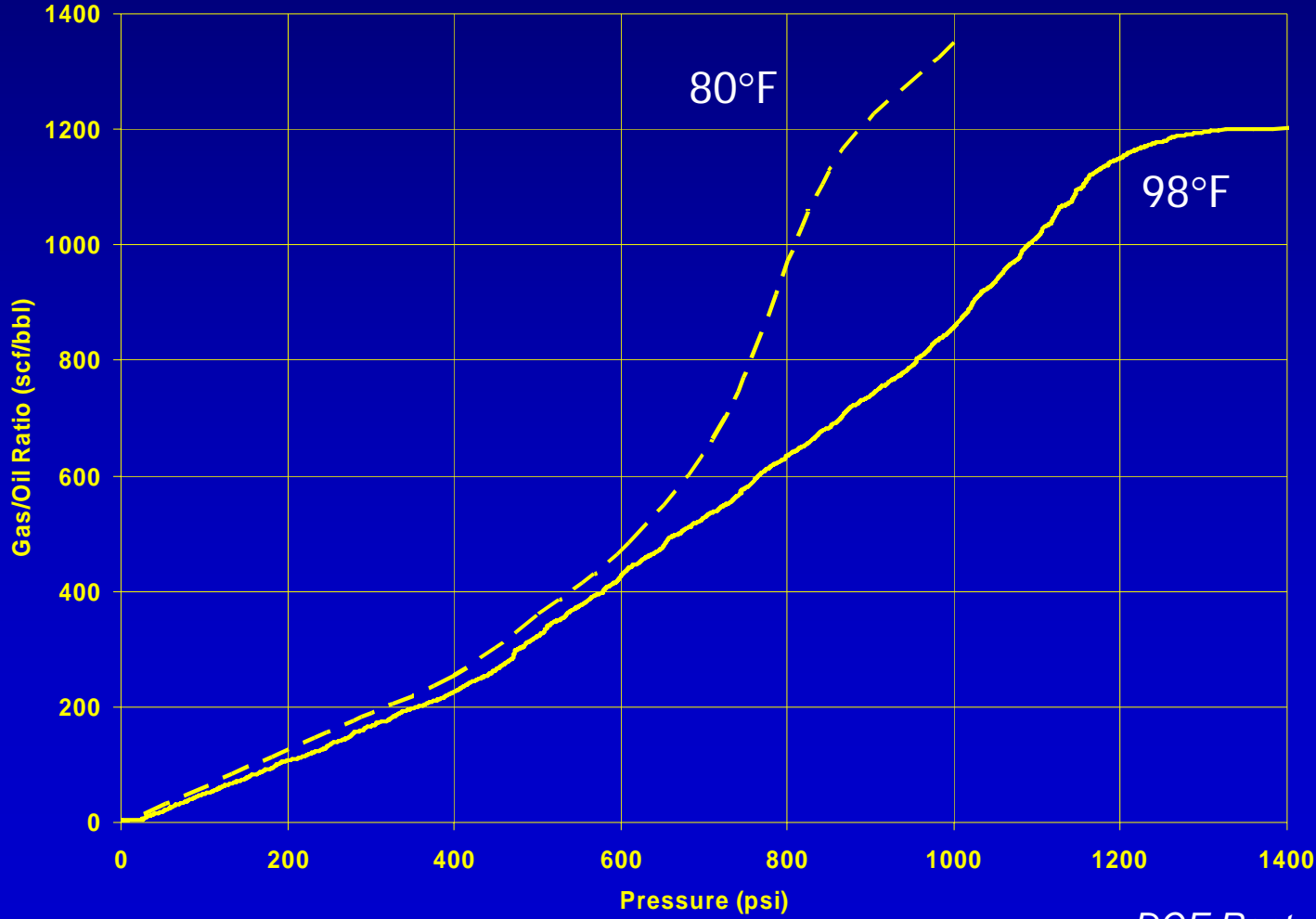
- Pressure below CO₂ vapor pressure line
- However, too low of pressure has too little dissolution of CO₂ in oil
- Lower temperature greater dissolution of CO₂ in oil.

EOR III Immiscible (Gas) CO₂ Classification



CO₂ Solubility in Illinois Crude Oil

In situ CO₂ solubility w/oil higher for low temperature Illinois Basin Oil fields



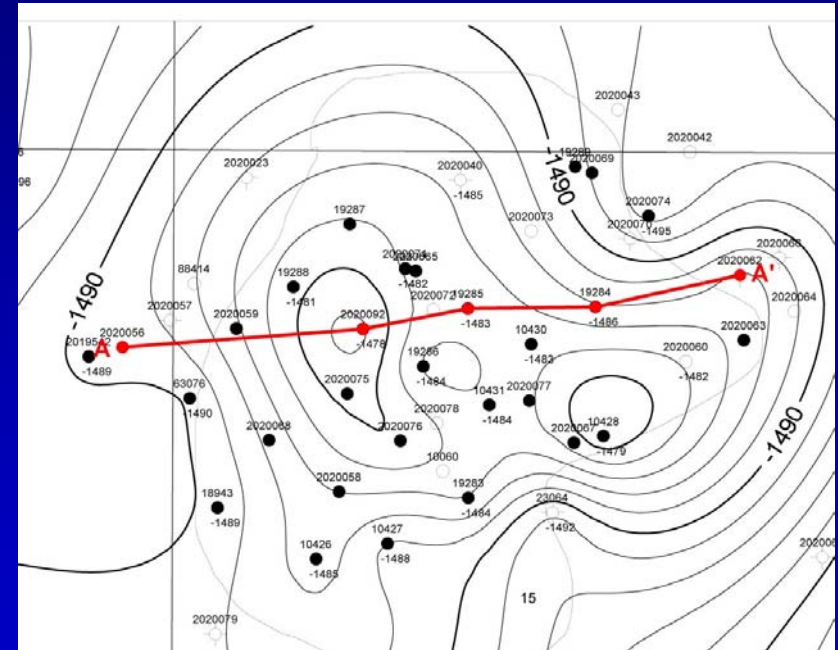
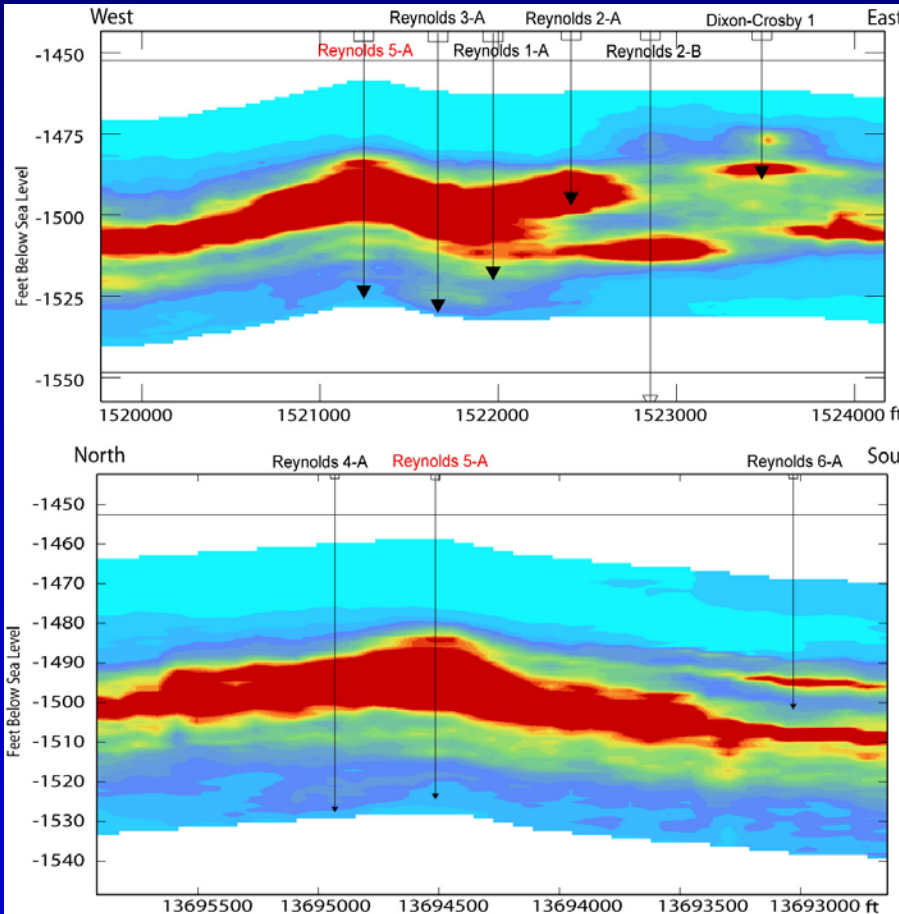
Cypress
(1750-1830 ft)
Mattoon Field
Coles Cty IL

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

EOR III Candidate-1

- Immiscible gas CO₂ flood
 - Low temperature 70° F ($< T_{cCO_2}$)
 - Strong bottom-drive water aquifer 500-600 psi
- Modest geologic structure present
 - Water injector up-dip in center of structure
 - Structure and natural pressure will control CO₂ migration in the case of intermittent CO₂ availability.
- Good permeability: 2-3 months injection

EOR III Candidate-1, contd.



EOR III Candidate-1, contd.

■ Disadvantages

- CO₂ may be lost to aquifer instead of oil zone
- Flood plain
- Several well workovers prior to injection
- Winter months road restrictions
- Long CO₂ pipeline to well head

EOR III Candidate-1, contd.

- Joint project between KGS and MGSC
- May 2008 contracts negotiated and sent to operator
- Operator and interest owners decided to look at horizontal well option
- So search continued for another immiscible site

EOR III Candidate-2

- Immiscible gas CO₂ flood
 - Low temperature 70° F ($< T_{cCO_2}$)
 - Current single well water injection 500-600 psi
- Stratigraphic trap
- Water injector near end of unit
- Wells' condition good
- Good surface access

EOR III Candidate-2

- Disadvantage
 - Low perm...6-8 months of injection
 - Low injection may not support pressure for significant mixing of CO₂ with oil

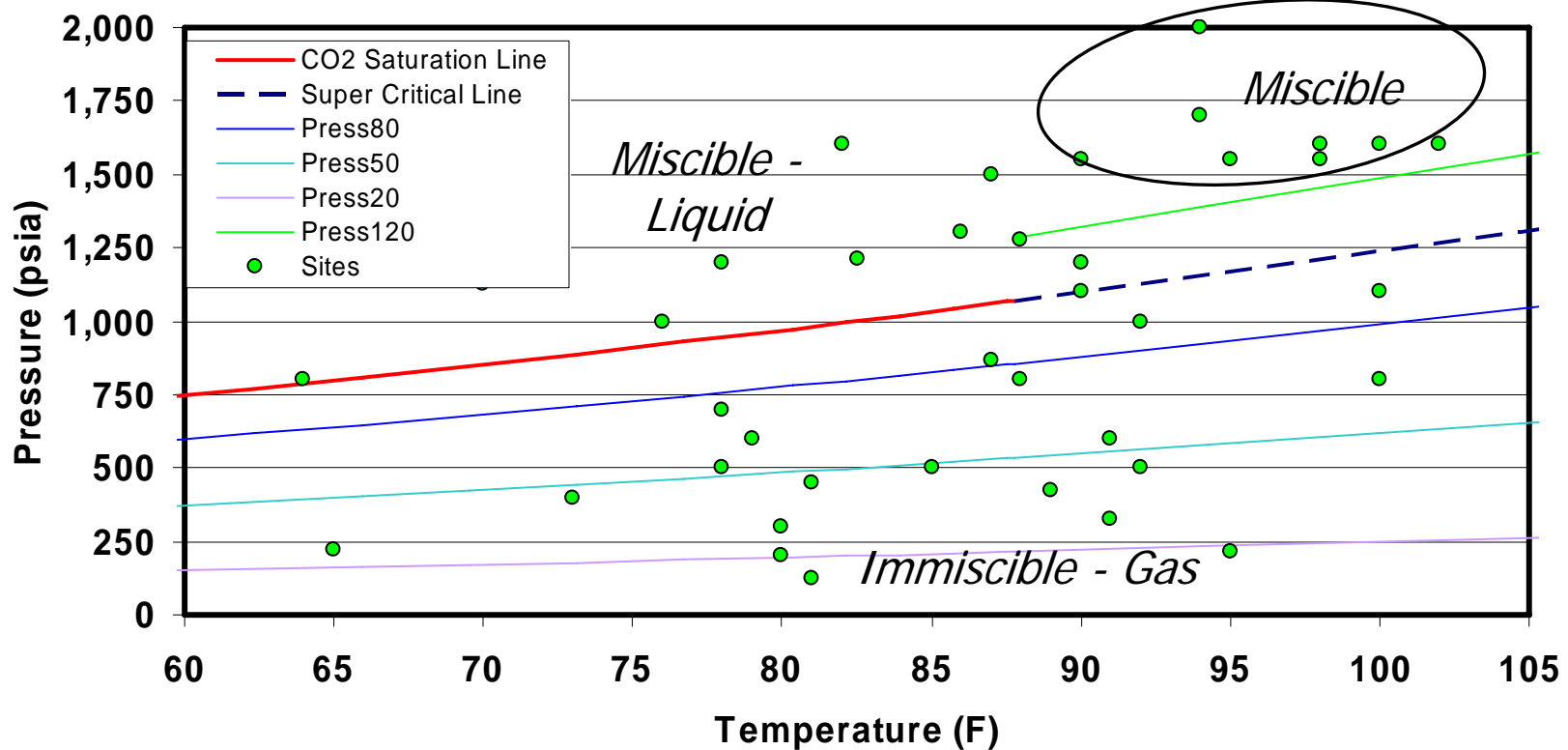
EOR III Status

- Candidate I operator and interest owners are now interested in CO₂ again
- Joint project between KGS and MGSC
- Presently:
 - objectively reviewing the two oilfield options based on oilfield logistics and geology
 - Complete modeling to project reservoir responses that can be measured with scope of the research timeline and budget

EOR IV: Miscible

- Relatively deeper formation
 - Higher temperature ($>T_{cCO_2}$)
 - Pressure exceed Miscibility Pressure
- Due to time and budget, looking for 5 acre spacing injection pattern
- Schedule for late spring 2009

EOR IV Miscible CO₂ Classification



EOR IV: Candidate



- Site selected
- Easy access from state road
- Injection well “on” lease road
- Injection pad built on open, untilled river bottom
- Disadvantage
 - Flood plain

EOR IV: Status

- Discussions with operators in progress
- Operator scheduled to drill injection well this year to complete 5 acre spacing
- Schedule for late spring 2009



EOR IV: Status, contd.

- Contract with operator to be completed
- NEPA to be completed



Site Selection Staff

- John Grube: geologic modeling, operator negotiations, permitting
- James Damico: geologic and geostatistical modeling
- Kevin Wolfe: reservoir model input data, site logistics, data acquisition setup
- Jim Kirksey: site logistics, operator discussions, equipment selection

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