Update on Results of SECARB “Early” Test of Monitoring Large Volume Injection at Cranfield

Mississippi River

Natchez
Mississippi

Illustration by Tip Meckel
Gulf Coast Carbon Center (GCCC)

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Collaborators
BEG- CEE
LBNL
LLNL
ORNL
USGS
New Mexico Tech
Mississippi State U
U of Mississippi
BP
ARI
SECARB
SWP
UT-PGE
UT- CCEP
UT- DGS
Univ Edinburgh

NETL: Bruce Brown
SSEB: Jerry Hill

IA sponsors
bp
Chevron
Marathon
Kinder Morgan
ConocoPhillips
ExxonMobil
Luminant
Entergy
EDF
LCRA

New 2011
GE BG group
Early Test Organization Chart

**Gulf Coast Carbon Center**
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

**Federal collaborators**
- LBNL
  - Well-based geophysics, U-tube and lab design and fabrication
- LLNL
  - ERT
- USGS
  - Geochemistry

**UT DGS**
Anchor QEA
Core Laboratory

**Environmental Information Volumes**
Walden Consulting

**Vendors**
e.g. equipment

**Separately funded groups**
- ORNL
  - PFT, Stable isotopes
- NRAP
  - VSP
- NETL
  - Rock-water interaction
  - Stanford, Princeton, U Edinburgh, UT PGE & ICES (CFSES), U. Tennessee, USGS RITE, BP

**Denbury Resources**
Field owner and injection system design, management, 4-D survey, HS&E

**Sandia Technologies**
Monitoring Systems Design, Installation, HS&E

**50 Vendors**
e.g. Schlumberger

**MSU, Univ Miss**
Hydro & hydrochem
Early Test Workflow and Presentations

Reservoir characterization;
production history;
Existing cores and logs;
Existing aquifer data

2008 Sue

GEM and TOUGH2 models for experiment design

Well construction;
Cross well seismic,
Multi-well hydro tests,
Logging, coring,
Petrography,
petrophysics
Soil gas recon,
Groundwater surveillance

2009 David

Bold=topics discussed

GEM, TOUGH2
Geochemist workbench models for operations

2010 Tom

Time-lapse cross well;
VSP, repeat 3-D,
Groundwater Surveillance, P-site measurements

U-tube geochemistry,
P-site measurements
BHP BHT DTS ERT, RST, Measurement
Groundwater Surveillance

2009-2010 Jiemin

GEM, TOUGH2
Geochemist workbench models for assessment

2011 Seyyed

+ Reservoir characterization; production history; Existing cores and logs; Existing aquifer data
+ GEM and TOUGH2 models for experiment design
+ Well construction; Cross well seismic, Multi-well hydro tests, Logging, coring, Petrography, petrophysics Soil gas recon, Groundwater surveillance
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Source of CO₂ for Early Test

Phase 1
36 MMBbls

Phase 2
31 MMBbls

Phase 3
77 MMBbls

Phase 4
41 MMBbls

Phase 5
82 MMBbls

Phase 6
50 - 90 MMBbls

Phase 7
Seabreeze Complex
30 - 40 MMBbls

Phase 8
Hastings Field
190 - 225 MMcfd of CO₂

Faustina Project

Cranfield

Courtesy of Denbury Resources, Inc.
Regionally significant sequestration target for Early Test: Gulf Coast Wedge

Repetitive depositional units
• Results transferable to:
  • older and younger units
  • other parts of region
Geologic Setting of Early Test Site at Cranfield

**Phase II**
- Middle Tuscaloosa confining System
- Oil-water contact
- Cross section from 3-D seismic survey
- 3,000 m depth
- Gas cap, oil ring, downdip water leg
- Shut in since 1965
- Strong water drive
- Returned to near initial pressure

**Phase III**
- Tip Meckel
Geologic Characteristics of Injection Zone

![Diagram showing channel erosion and point bars.](image)

Stratal slicing of 3-D volume
Hongliu Zeng

Galloway 1983

Meander fluvial model
Interim Conclusions of Early Test

- Injection start July 2008
- 2.8 Million metric tons stored
- 1 million metric ton/year rate achieved Dec 2009
- Monitored with standard and novel approaches
  - History match pressure response
  - Above-Zone Monitoring Interval (AZMI)
  - Fluid flow measured/monitored with multiple tools in complex flow field
  - Quantification of dissolution
  - Knowledge sharing, outreach, risk assessment
- Export to commercial EOR/sequestration projects
(1) RCSP Program Goal

Predict storage capacities within +/- 30%

- Capacity and injectivity well known at project start.
- Advance understanding of efficiency of pore-volume occupancy (E factor).
- Measure saturation during multiphase plume evolution (completed).
- Increase predictive capabilities (underway through modeling).
(2) RCSP Program Goal

Evaluate protocols to demonstrate 99% CO$_2$ retained

- Permanence of geologic system well understood prior to test. Assess methods for documenting well performance.
- Measure changes above the injection zone along well, above zone monitoring interval (AZMI), and at surface (P site) over long times (underway).
- Plume confined by 4-way closure. Uncertainty – amount of radial flow (down dip/out of pattern).
- Completed certification framework assessment of leakage risk. Confirmed well performance as highest uncertainty and focus of monitoring research.
Contribute Technical Expertise and Lessons Learned, Development of Best Practices Manuals

- Participated in developing BPMs for MVA, characterization, risk and reservoir modeling
- O&E in public and technical arenas.
- Hosted site visits, responses to local and trade media, Fact Sheets, website postings of project information.
Five Study Areas

- Injector
- Producer (monitoring point)
- Observation Well

Key:
- Structure Contour
- Access roads
- Tuscaloosa Wells

GIS base Tip Meckel

Five Study Areas

- High Volume Injection Test (HiVIT)
- Pipeline head & Separation facility
- Study DAS
- GMT
- Observation Well
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GIS base Tip Meckel

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## Early Test MVA Design

<table>
<thead>
<tr>
<th>Area tested</th>
<th>Whole plume</th>
<th>Focus study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>Soil gas</td>
<td>Time-lapse surveys at active and P&amp;A well pads</td>
<td>“P site” methodology assessment</td>
</tr>
<tr>
<td>Groundwater</td>
<td>Monitoring well at each injector</td>
<td>EGL-7 UM cored test well. Push-pull test</td>
</tr>
<tr>
<td>Shallow production</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>AZMI</td>
<td>Not tested</td>
<td>DAS pressure and EGL 7 pressure + fluids</td>
</tr>
<tr>
<td>Geo Mechanical test</td>
<td>Not tested</td>
<td>GMT-failed</td>
</tr>
<tr>
<td>Injection zone</td>
<td>Geochemistry breakthrough</td>
<td>DAS multi-well multi tool array</td>
</tr>
</tbody>
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