An Assessment of Geological Carbon Sequestration Options in the Illinois Basin

Introduction to Phase II Plans

MGSC Project Team

presented by
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Illinois State Geological Survey

Midwest Geological Sequestration Consortium
www.sequestration.org

MGSC Field Testing: The Heart of Phase II

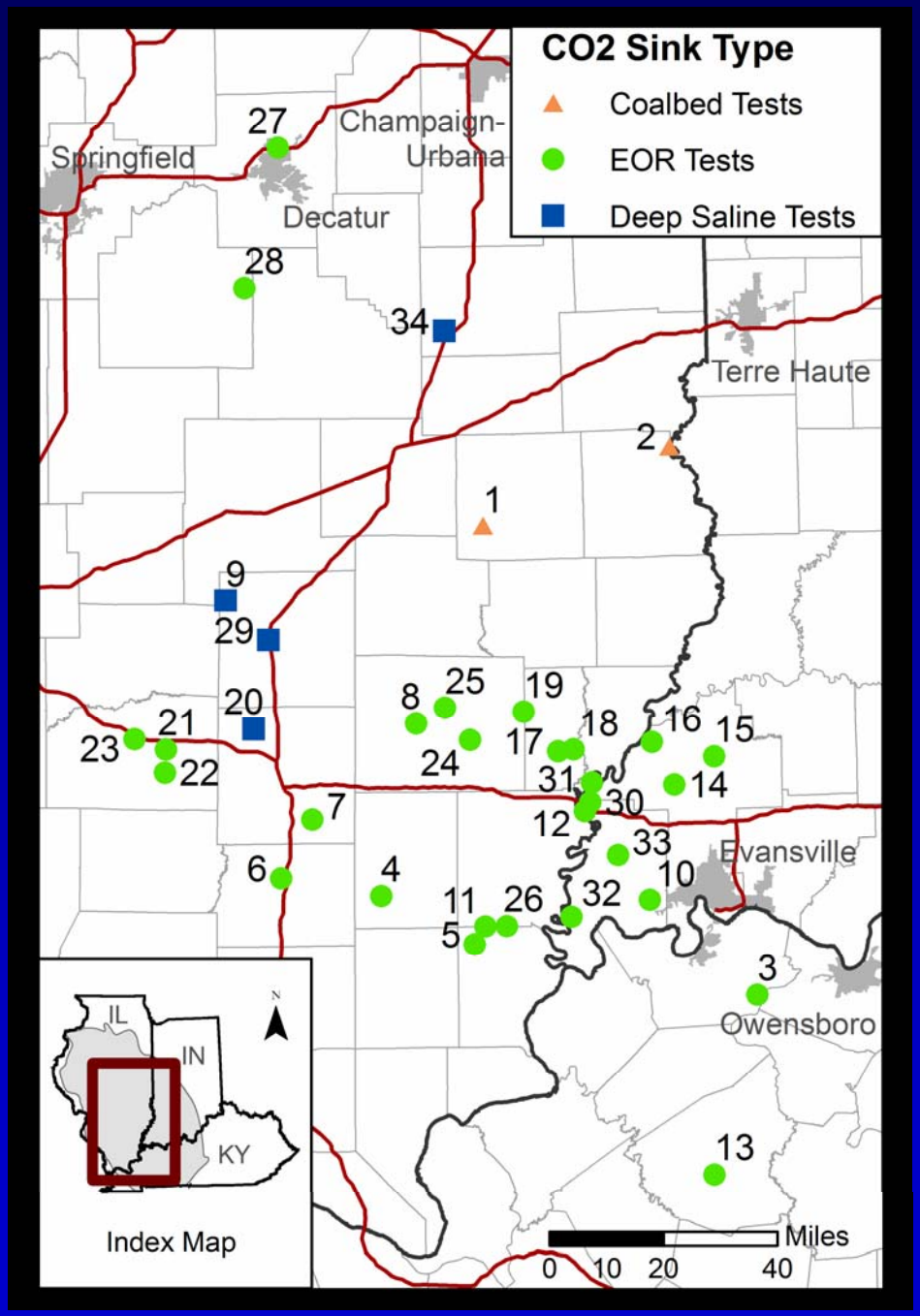
- Six field tests proposed
- CBM at one of two Ameren power plant sites
- Inject/soak/produce (single well), immiscible, and miscible EOR at four sites; new drilling at two of these to optimize CO_2 flooding pattern
- One deep saline reservoir test, the Multi-Opportunity Sequestration Test (MOST) site with two major reservoir targets to 9,400 ft

Phase II Framework

- Total funding provided by DOE of $14.235 million over four years
- Cost share of $1.200 million pledged by Illinois Office of Coal Development, DCEO
- $4.319 million in cost share pledged by the geologic surveys, BYU, SIU, and American Air Liquide
- Additional 20 percent minimum cost share from field test site operators

Phase II Organizational Structure

- Illinois State Geological Survey (ISGS) serves as Lead Technical Contractor
- PI's and co-PI's from the geologic surveys make up the six-member Technical Committee
- Task Coordinators will be assigned to each of 16 Tasks; a total of 81 subtasks are proposed.
- Thirty-one organizations involved: 3 geologic surveys and 28 other subcontractors

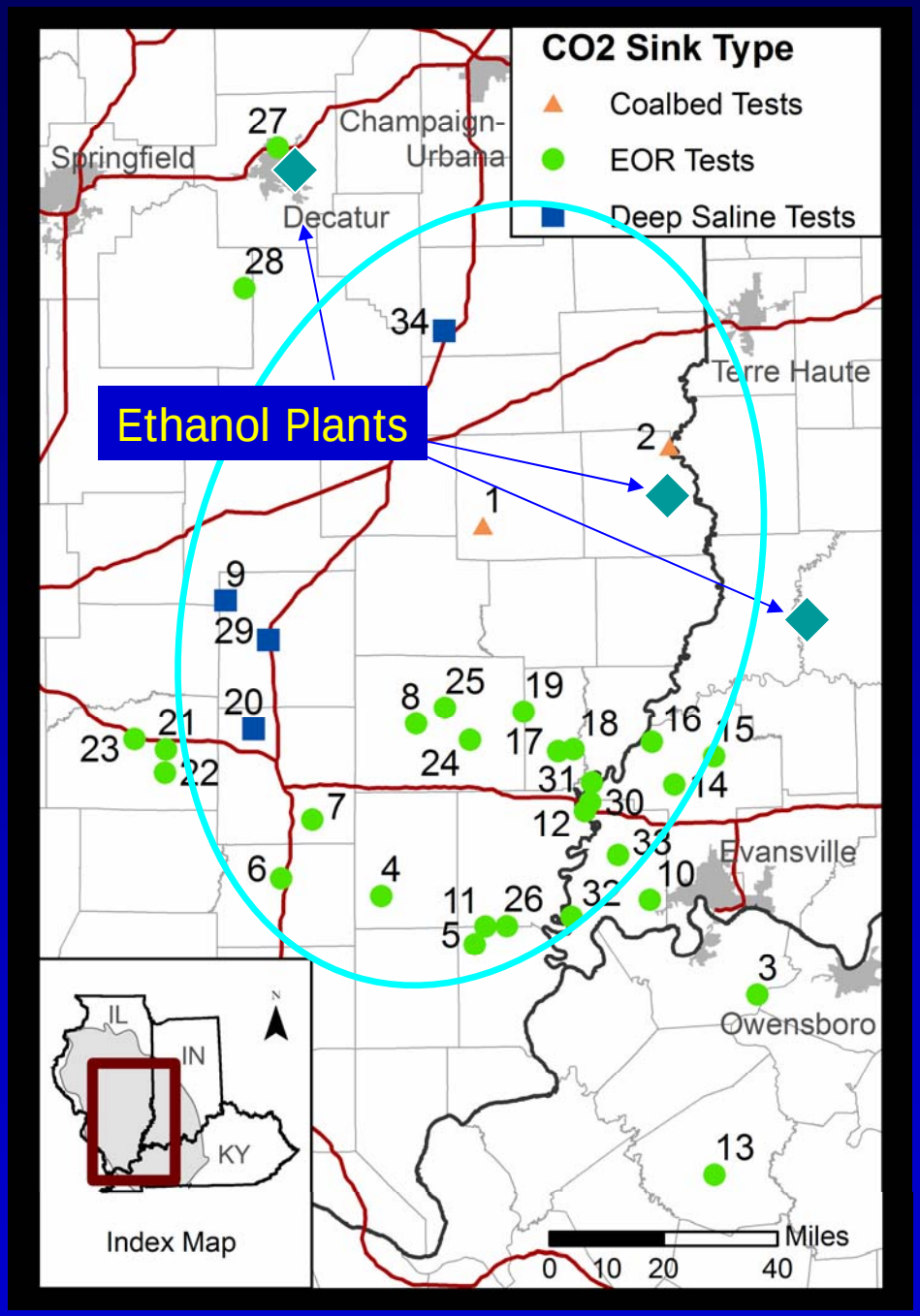


Potential Test Sites

-2 coal seam sites

-28 mature oil field sites for EOR

-4 deep saline reservoir sites



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-2 coal seam sites

-28 mature oil field sites for EOR

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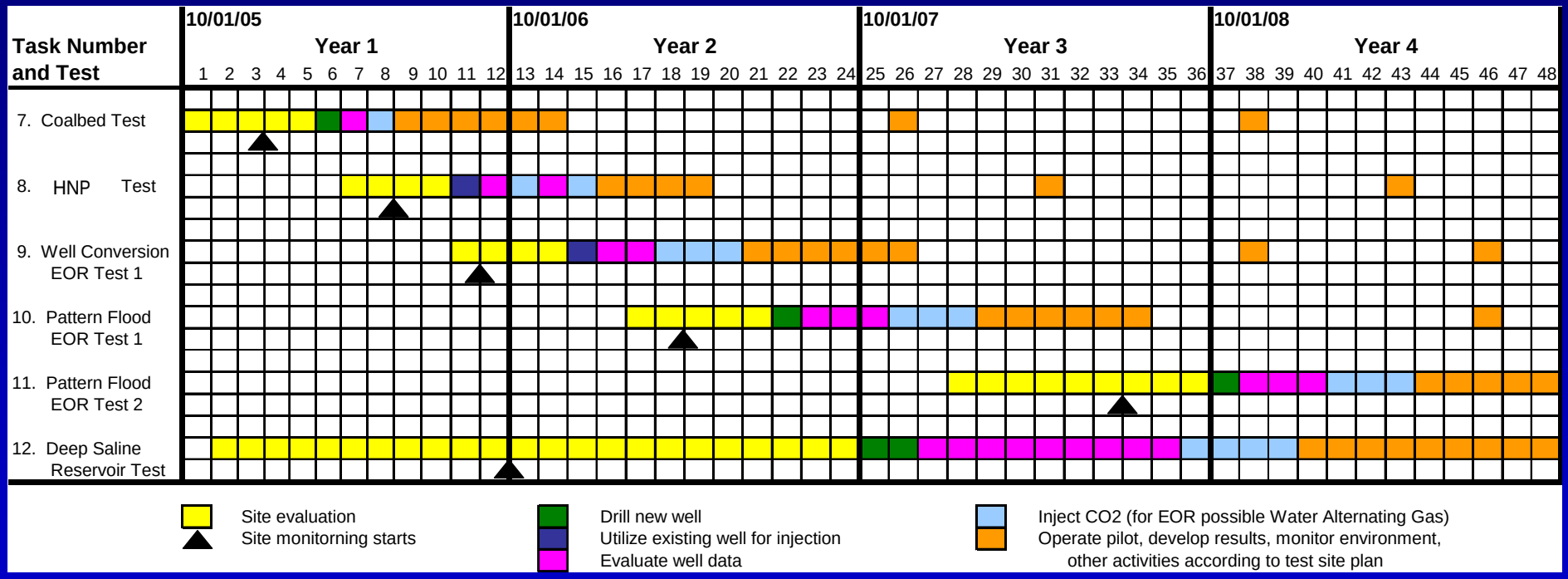
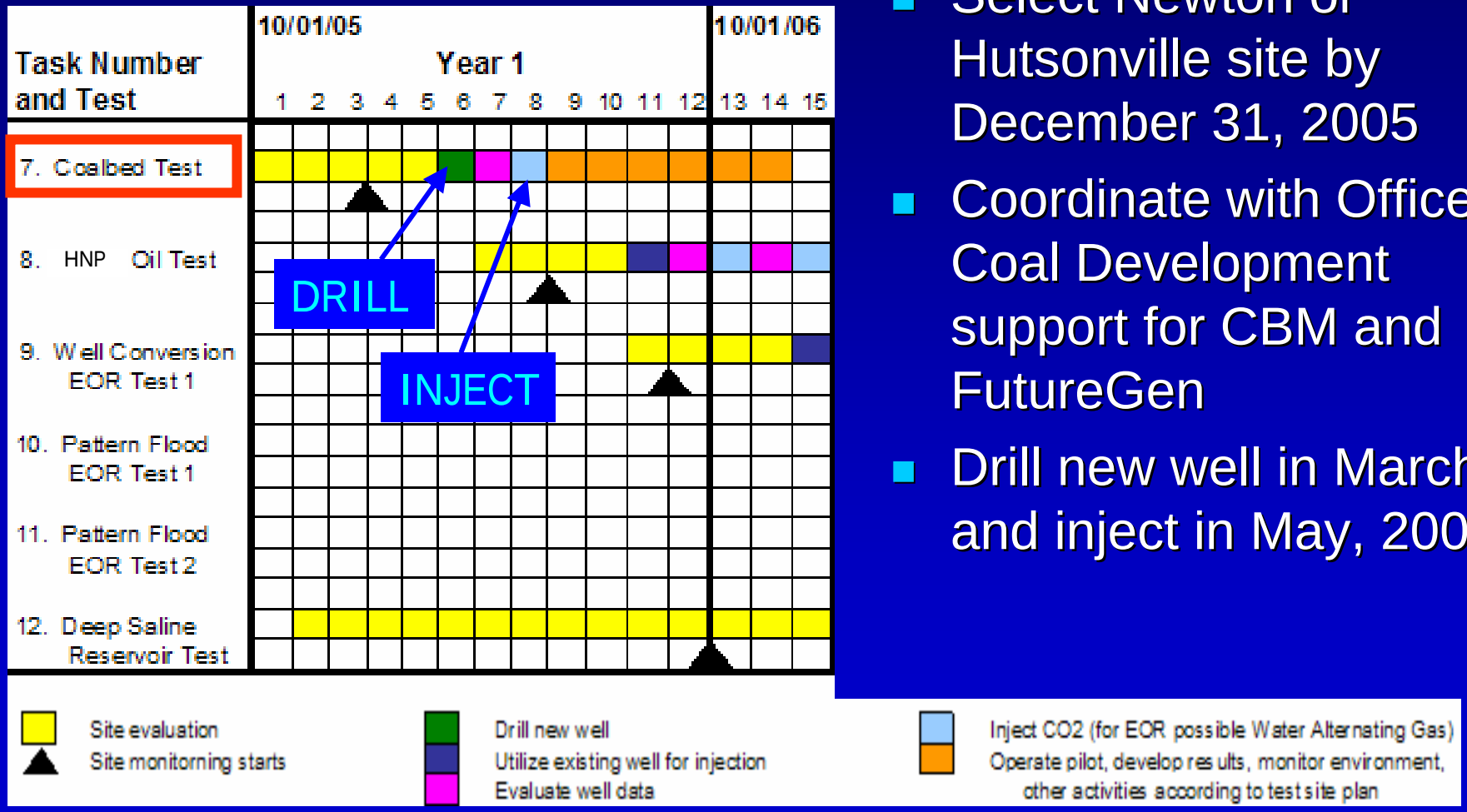
Field Test Site Timeline



Phase II, Year One, Field Activities

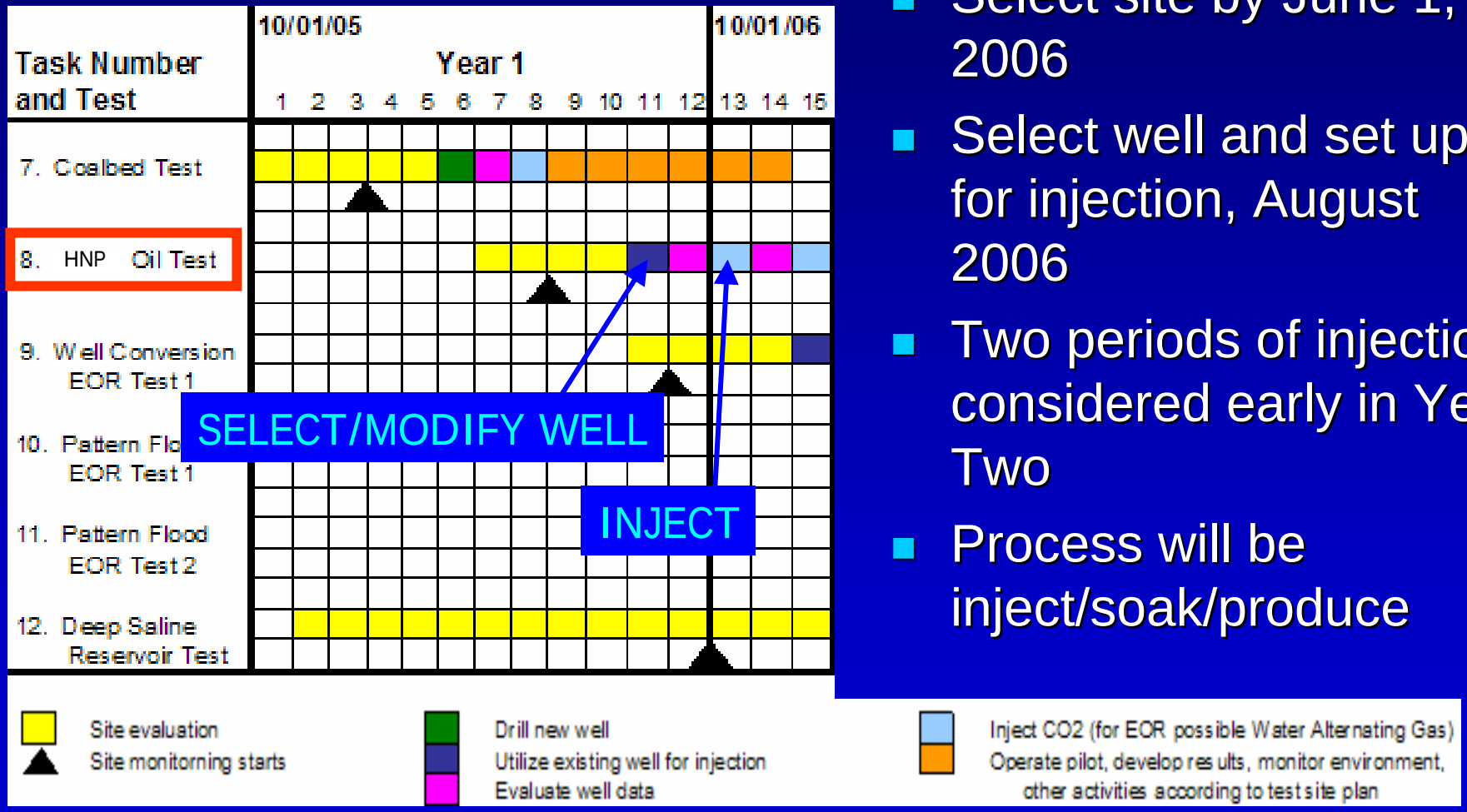
Task 7-Coalbed Site



- Select Newton or Hutsonville site by December 31, 2005
- Coordinate with Office of Coal Development support for CBM and FutureGen
- Drill new well in March and inject in May, 2006

Phase II, Year One, Field Activities

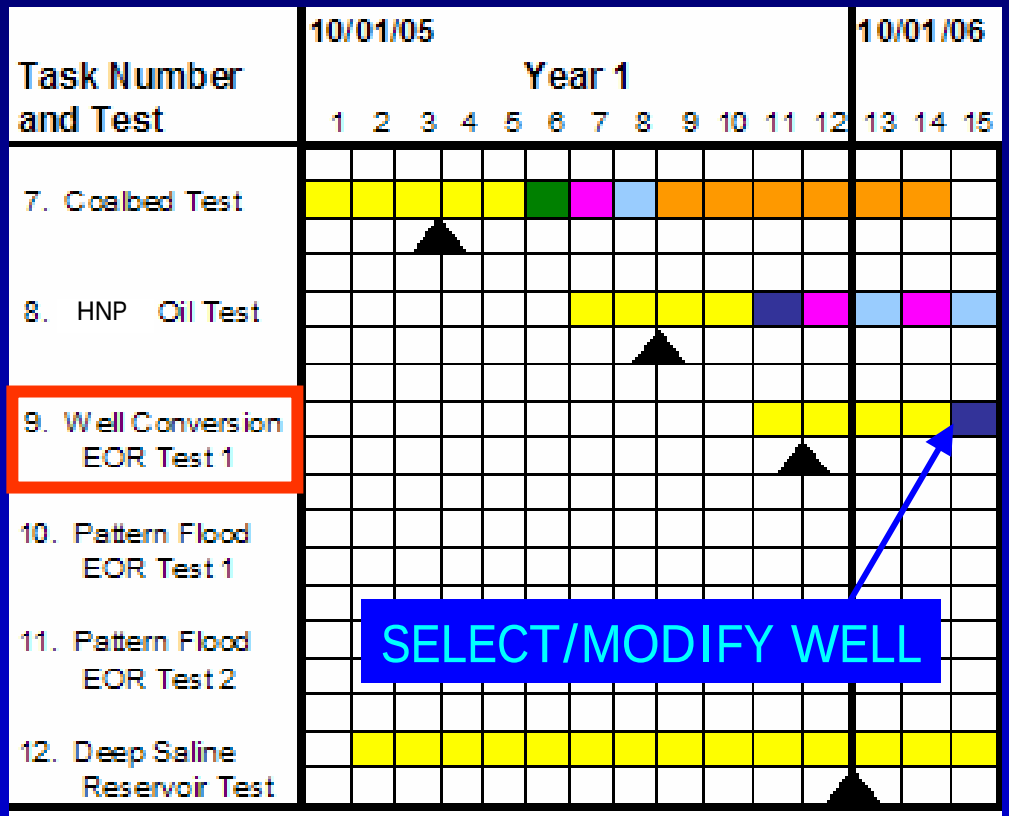
Task 8- Oil Reservoir: Inject/Soak/Produce "Huff & Puff"



- Select site by June 1, 2006
- Select well and set up for injection, August 2006
- Two periods of injection considered early in Year Two
- Process will be inject/soak/produce

Phase II, Year One, Field Activities

Task 9-Well Conversion EOR Test

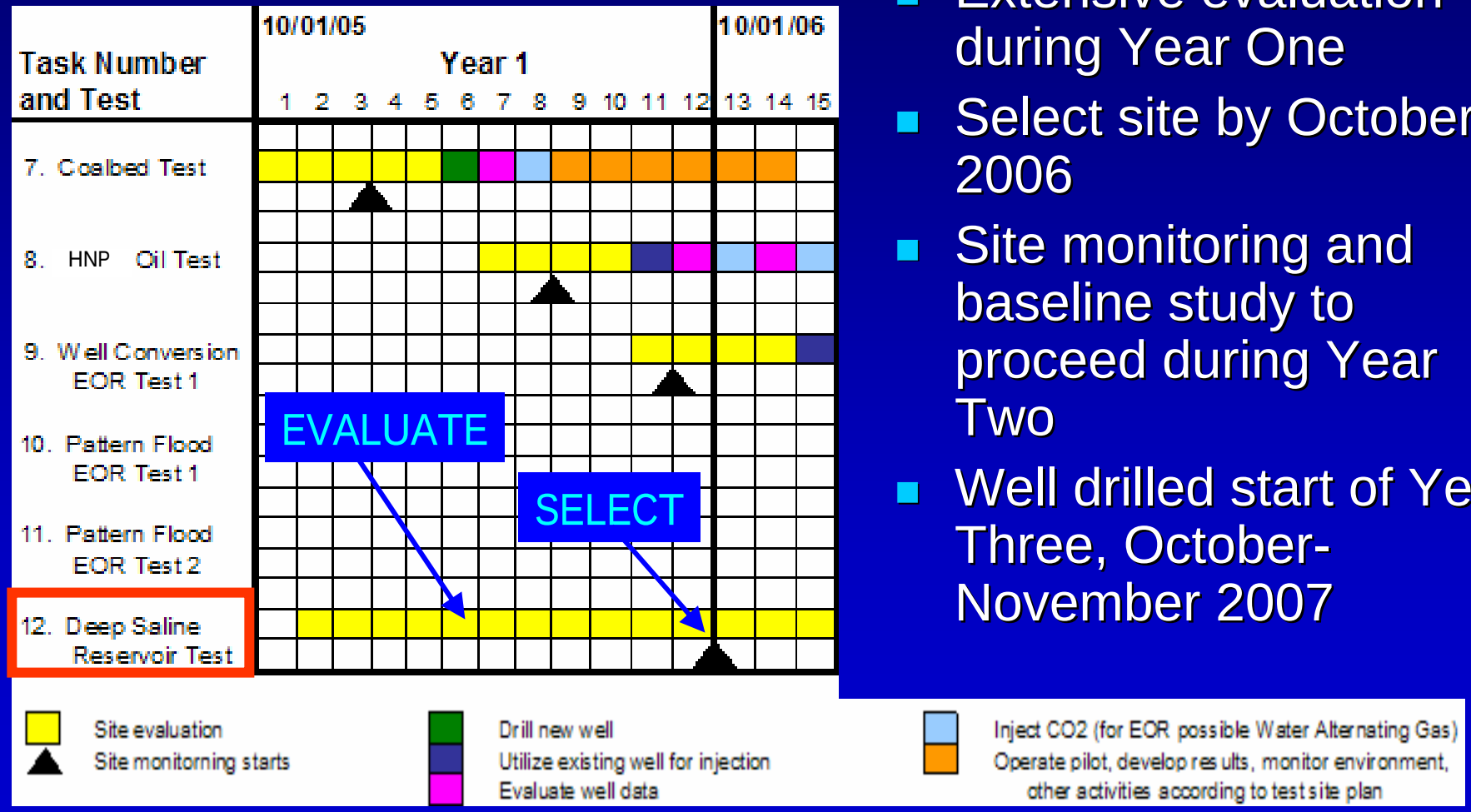


- Site evaluation
- Site monitorning starts
- Drill new well
- Utilize existing well for injection
- Evaluate well data
- Inject CO2 (for EOR possible Water Alternating Gas)
- Operate pilot, develop results, monitor environment, other activities according to test site plan

- Select site by September 1, 2006
- Select well and set up for injection, December, 2006
- Injection to begin March, 2007
- Will be a pattern flood

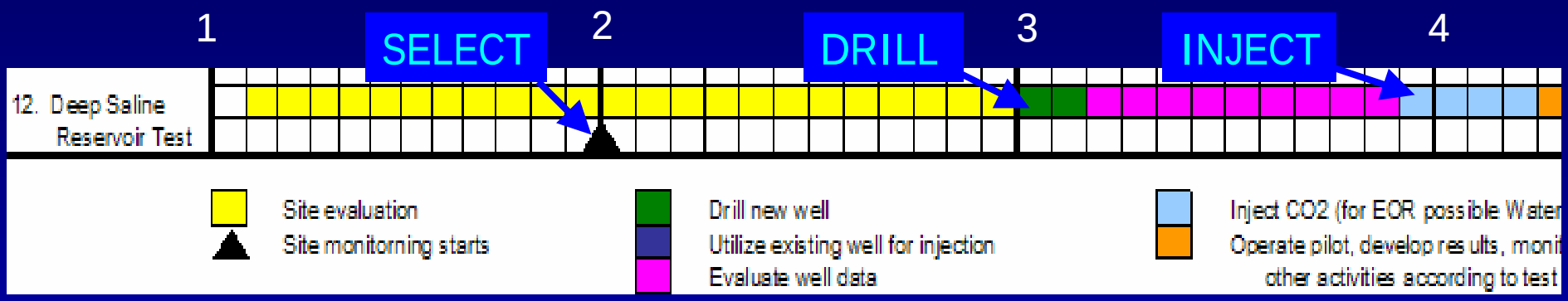
Phase II, Year One, Field Activities

Task 12-Deep Saline Reservoir Test



- Extensive evaluation during Year One
- Select site by October 1, 2006
- Site monitoring and baseline study to proceed during Year Two
- Well drilled start of Year Three, October-November 2007

Task 12-Deep Saline Reservoir Test

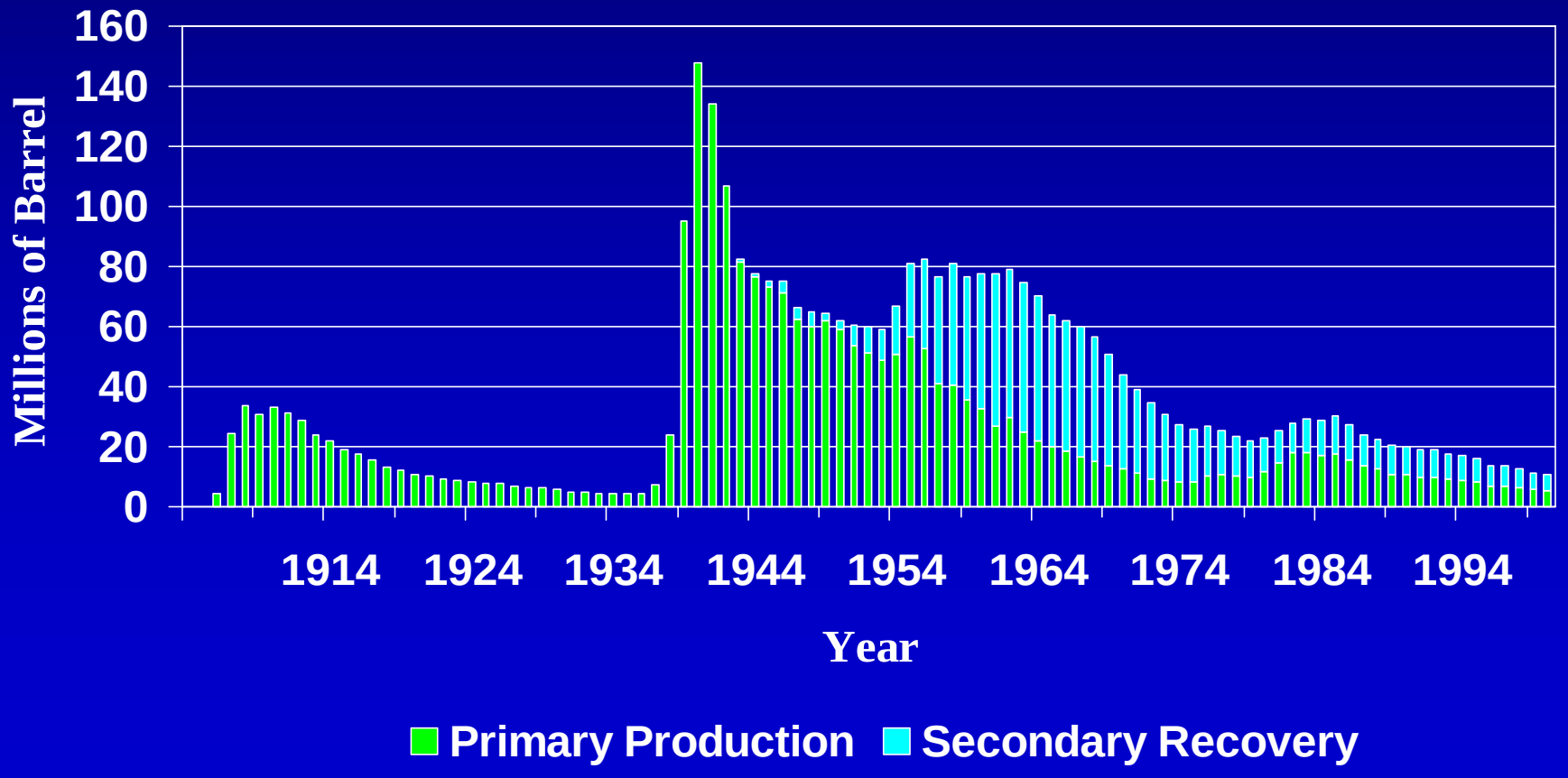


- Extensive cooperation from field operator looked for
- Evaluation will include 2D and 3D seismic
- Deep, expensive (~$1.2 million to drill and complete), and requiring extensive planning and subcontractor collaboration
- Up to 9 months well-data assessment pre-injection
- Injection at end Year 3-early Year 4
- Aiming for a full year of advance site monitoring (MMV)

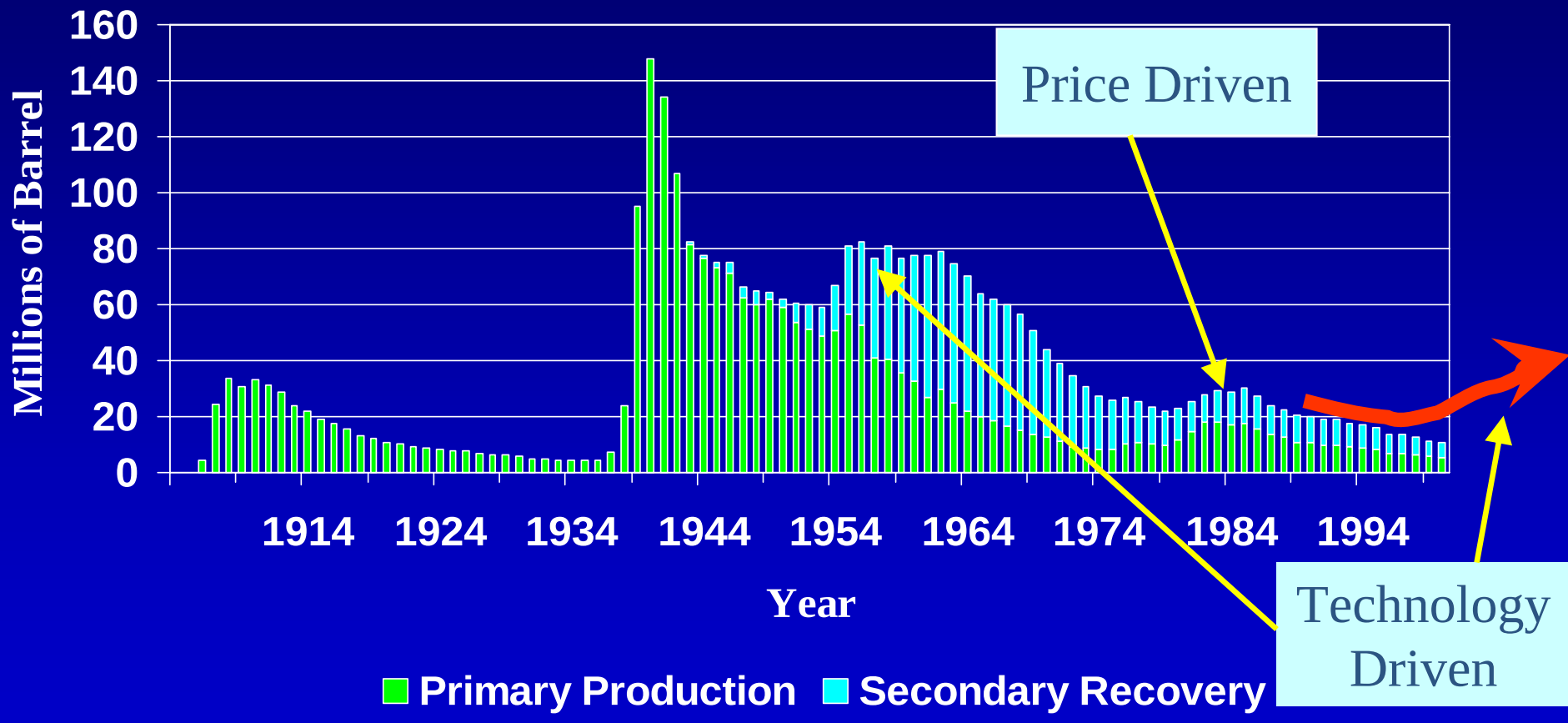
Natural Gas Recovered as Coalbed Methane Using CO_2

- Recoverable resource estimated at 6.7 trillion cubic ft
- 500 wells producing 50,000 cubic ft/day yields $63.9 million annual gross revenue @ $7/mcf
- Economic activity = $141 million/yr (2.2 multiplier)

Illinois Oil Production History



Illinois Oil Production Potential



Incremental Oil Recovered from Mature Reservoirs Using CO_2 EOR

- Recoverable oil target of 860 to 1,300 million bbls
- 500 wells producing 35 bbls/day yields $287.4 million annual gross revenue @$45/bbl
- Economic activity = $632 million

  (2.2 multiplier)

Monitoring, Mitigation, and Verification (largest MGSC budget component)

- "….*the capability to measure the amount of CO_2 stored at a specific sequestration site, monitor the site for leaks or other deterioration of storage integrity over time, and to verify that the CO_2 is stored in a way that is permanent and not harmful to the host ecosystem."*
- *"…capability to respond to CO_2 leakage… in the unlikely event that it should occur."*

--DOE Technology Roadmap and Program Plan, 2005

Education and Outreach

- Building on educational demonstrations of GCCC
- Teacher module developed under Phase I will be further reviewed and presented at 9th Annual Illinois Coal Education Conference (June, 2006)
- New physical benchtop models of CO_2 storage will be developed to improve demonstrations at meetings
- Additional fact sheets and FAQ sheets

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Sequestration Consortium
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Phase II Field Test Implementation Considerations

Scott M. Frailey
Reservoir Engineer
Illinois State Geological Survey

DOE NETL
Phase II Kickoff Meeting
Pittsburgh, PA
October 13, 2005

Pilot Field Test: Developing Ideas

- Proposal Ideas
  - Brainstorming
  - Role Playing
  - Scenario Building
- Objectives
  - Clear, succinct
  - Measurable
  - Achievable
- Test Site Stages
  - Design
  - Implementation
  - Contingencies
  - Results
- Real-time adjustments
- Budget constraint

The Data Acquisition

- Why do we need the proposed tests and data?
- What questions will the data and subsequent analyses allow us to answer?
  - Meet set objective
  - Support field designs
  - Make broader, improved Basin-wide sequestration assessments

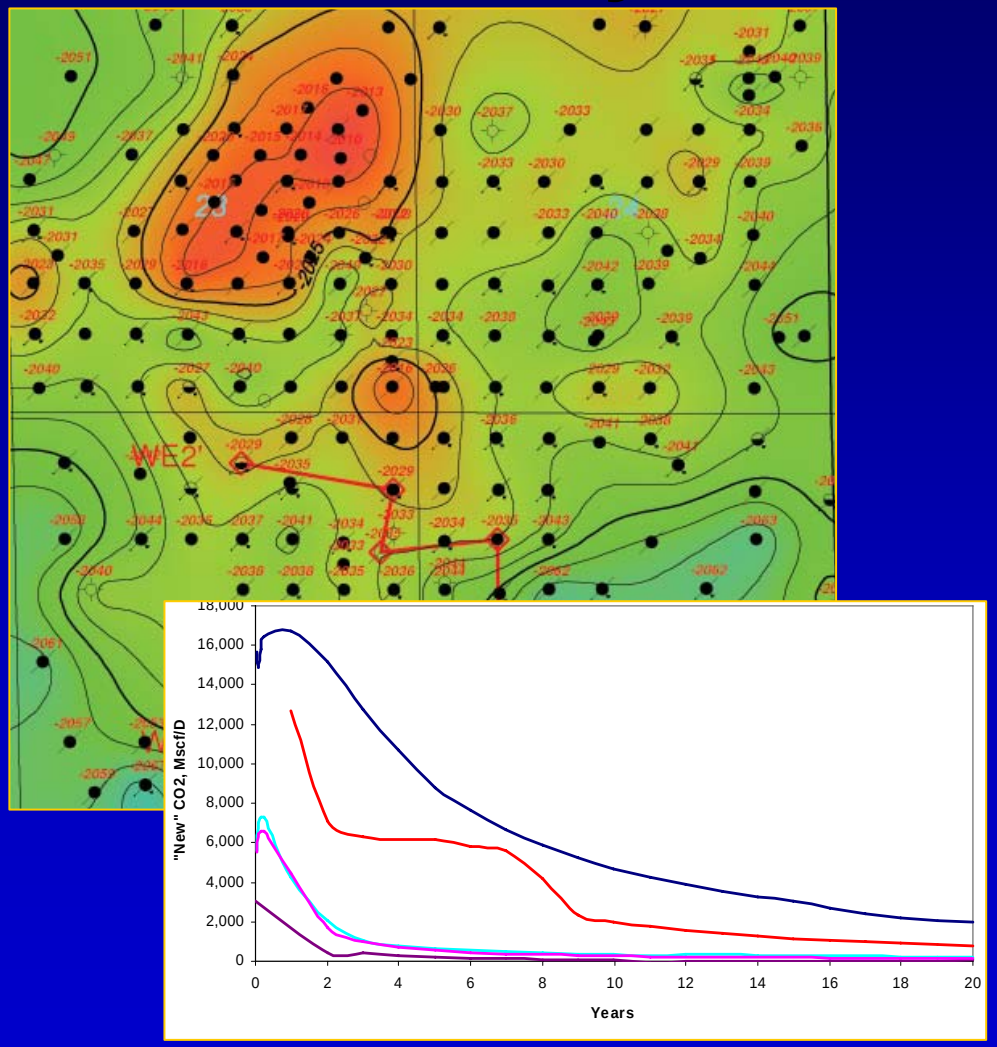
Field Test Scenario

- MMV has been in place and data measurements occurred for 3-12 months
- Operators identified with skilled field-hands to carry out ordinary oilfield operations of production and injection
- Objective set, several field designs made, what-if contingency scenarios developed
- Ready for CO_2 tanker truck to pull-up to location and …

The Truck is Here

- How many trucks do we need?
- How frequently do we need delivery?
- Do we need on-site storage?
- Do we need a pump?
- Do we need a heater?

How many trucks do we need?



- ***Volume*** requirements to meet objective
  - Porosity (ϕ)
  - Net thickness (h)
- Modeling
  - Geologic:
    - Deterministic
    - Geostatistical
  - Reservoir simulation

How frequently do we need delivery? (Injection rate)

- Miscible or Immiscible?
- Continuous or intermittent injection?
- Fracture propagation pressure of formation?
- Caprock failure pressure (fracture or pore pressure)?
- Maximum subsurface rate?

- Pressure transient Analysis
  - Pore pressure
  - Permeability – thickness
  - Near-wellbore flow characteristics (skin)
- Core Analysis
  - Routine: Porosity and Perm
  - Specialized:
    - Caprock capillary pressure and mechanical tests
    - Formation mechanical properties

Do we need on-site storage?

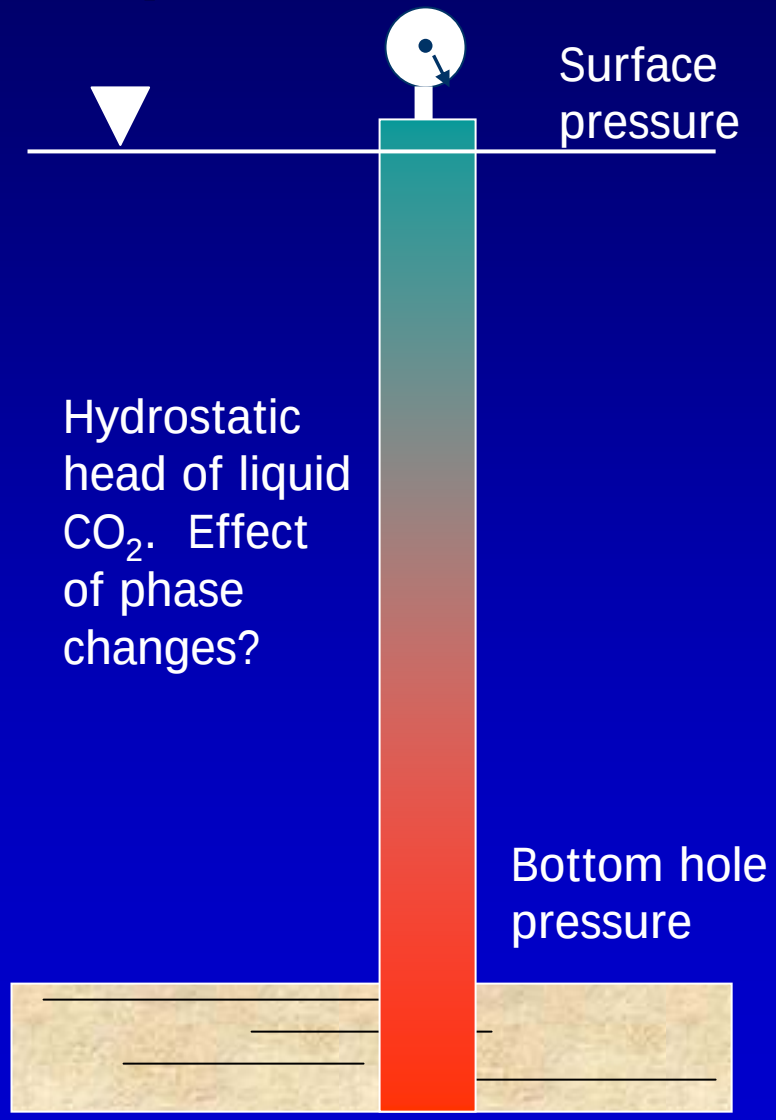
- Volume requirements vs. desired injection rate vs. delivery
- Availability of CO_2
  - 24/7
  - Single source
  - Multi-source
  - Seasonal
  - Road conditions

Do we need a pump?

- Subsurface pressure required?
- Rate of injection required?
- Single phase CO_2 required at perforations?
  - Gas
  - Liquid

Do we need a pump? (contd.)

- Geologic and reservoir modeling
- Nodal Analysis
  - Multiphase flow
  - Pressure drop in well
  - Surface injection pressure required
  - Hydrostatic head of CO_2 gas, liquid, or both



Do we need a heater?

- Temperature effects
  - Formation: thermally induced fractures?
  - Cement bond
    - w/steel casing
    - w/geologic formations
  - Pipe shrinkage
  - Elastomers
- Injection of CO_2: Gas vs. liquid
  - Viscosity and Density

We are injecting (The tanker trailer is draining)

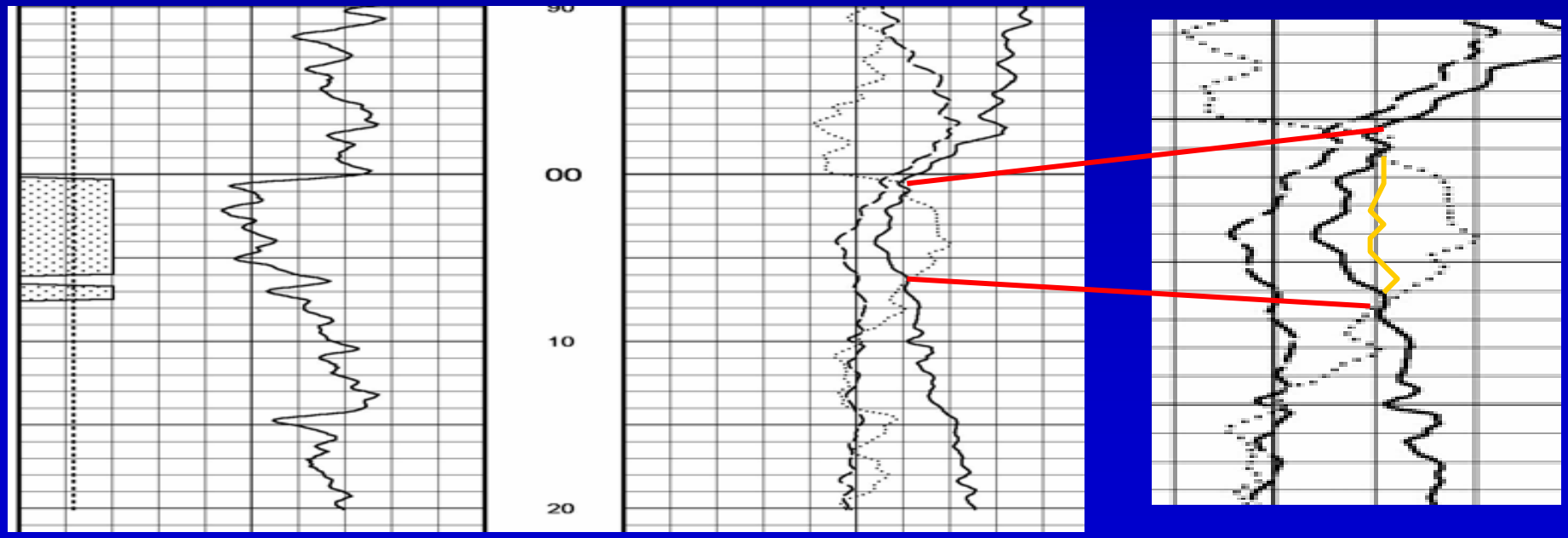
- Are we injecting at the designed rate and wellhead pressure?
- Is CO_2 going into target geologic formation?
- Are injection rate and pressure trends indicative of sub-fracture injection trends?
- For EOR and ECBM, when do we expect a response at producing or observations wells?
- How do we quantify the response?

Are we injecting at the designed rate and wellhead pressure?

- Lower injection pressure than designed?
  - Leak? Surface? Casing? Tubing?
  - Fracture formation? Caprock?
  - Higher formation injectivity?
- Higher injection pressure than designed?
  - Mechanical flow impediment? Hydrate?
  - Phase changes (liquid to gas)? (back pressure)
  - Lower formation injectivity?
- Real-time adjustment to design rate needed?

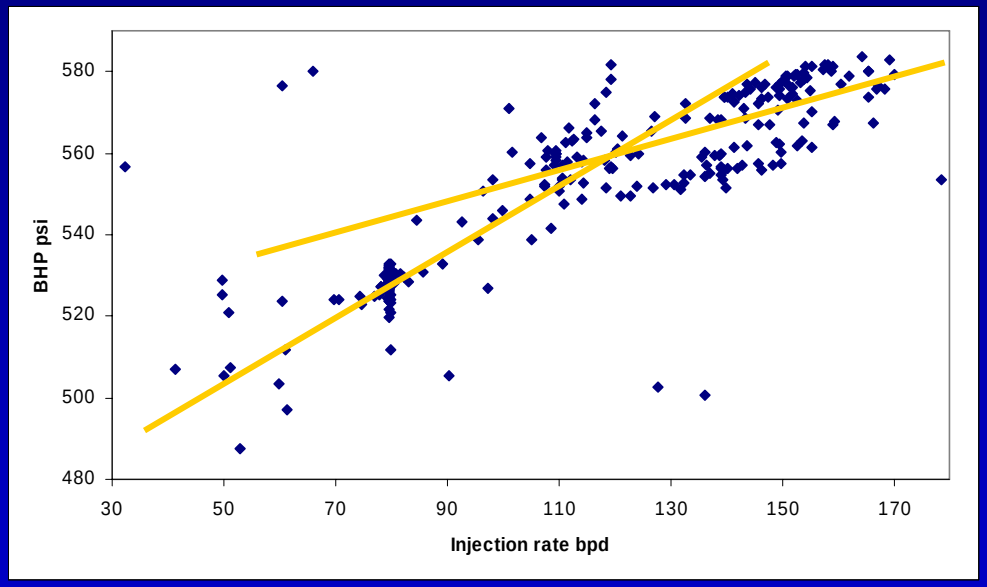
Is CO_2 going into target geologic formation?

- Pre-CO_2 Injection
  - Casing pressure tests
  - Water injection tests
  - Tracer test (EOR)
- Post-CO_2 Injection
  - cased hole logging (temperature and neutron)



Are injection rate and pressure trends indicative of sub-fracture injection trends?

- Constant pressure, rate increasing or decreasing?
- Increasing pressure, rate increasing or decreasing?
- Decreasing pressure, rate increasing or decreasing?

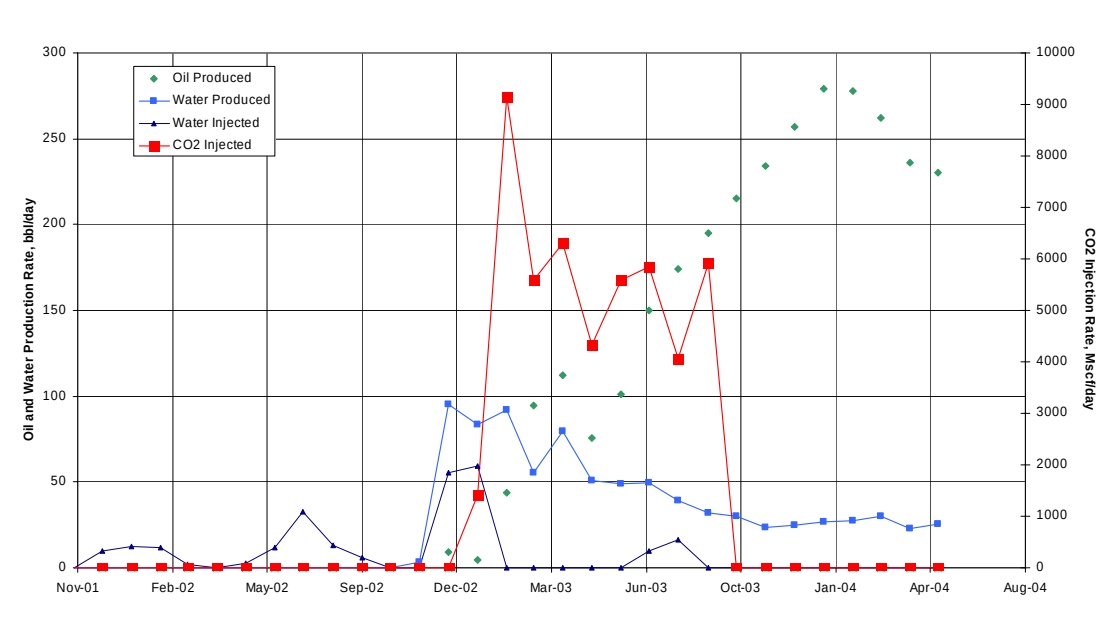


For EOR and ECBM, when do we expect a response and at producing or observations wells?

- How long will it take?
- How large liquid volume?
- How large gas volume?
- Will the gas burn or do we need an incinerator?

For EOR and ECBM, when do we expect a response and at producing or observations wells? (contd.)

- Production History
- Pre-CO_2 tracer tests
  - Water injection
  - Fluorescent dye
- Modeling
  - Geologic
  - Reservoir



For EOR and ECBM, when do we expect a response at producing or observations wells? (contd.)

- Fluid Characterization
  - Composition of crude oil
  - MMP-Slim-tube test
  - PVT
    - Crude oil with associated hydrocarbon gas
    - CO_2 – crude oil

How do we quantify the response?

- Volume measurements at surrounding wells
  - Metering
  - Periodic gauging
- Sampling (composition) of produced fluids at surrounding wells
  - Startup? Frequency?
  - Crude oil, associated gas hydrocarbon composition changing?
- Reservoir Pressure measurement

Post-CO_2 Injection…

- Check that test objectives met
- Assess CO_2 storage, EOR and ECBM for the pilots
- Review/revise Phase I Basin wide assessment with Phase II field test results
- Work with state and federal agencies, oilfield operators and CO_2 suppliers to develop CO_2 EOR and ECBM industry

Additional Expertise Required

ISGS, IGS, KGS: Geologic and reservoir modeling

- Field handling of CO_2 at the wellhead
  - CO_2 injection and production: Trimeric
  - Wellhead injection of CO_2 & EOR (Im): Bernie Miller
  - Wellbore multiphase flow: James F. Lea
  - CO_2 EOR Operations (Mi): Steve Melzer
  - Oil field operators: field hands, engineers, geologists
- Geophysical acquisition and interpretation
  - Bob Hardage and Phil Caserotti
- MMV (and Modeling)
  - Curt Oldenburg

Additional Expertise Required (contd.)

- Formation Evaluation
  - Petrophysics: George Asquith
  - Pressure transient analysis: Gary Crawford
  - Special core analysis: Mihai Vasilache
- Reservoir Characterization and Fluid Flow
  - Geostatistics: Jeff Yarus
  - Geochemical and geophysical modeling: Jim Johnson
  - Basin modeling: Mark Person
  - Deep basin geology: Dennis Kolata
  - Crude oil characterization: Gary Salmon

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Overview
Monitoring, Mitigation, and Verification (MMV) Program

An Assessment of Geological Carbon Sequestration Options in the Illinois Basin: Phase II

Ivan Krapac
Illinois State Geological Survey

Midwest Geological Sequestration Consortium
www.sequestration.org

MMV Goals

- Establish baseline conditions to assess impacts of CO_2 storage.
- Identify location of CO_2 plume.
- Detect and quantify CO_2 seepage to biosphere.
- Reassure public that technology is protective of human health and the environment.

(From Benson et al. 2004)

MMV Goals

- Identify and confirm storage efficiency and processes.
- Evaluate interactions with other geological resources.
- Assess environmental, health, and safety impacts should leakage occur.
- Monitor and evaluate remediation efforts should leakage occur.
- Assist in settling legal disputes due to impacts of technology (groundwater impacts, seismic events, crop or environmental losses due to leakage)

Multidisciplinary Team Effort

- Geologists
- Reservoir Engineers
- Geophysicists
- Geochemists
- Hydrologists
- Statisticians
- Remote Sensing Scientists
- Modelers
- Atmospheric Scientists
- Biologist/Ecologist

Expertise provided by consortium partners and consultants

MMV Approach

- Develop a tailored and dynamic program specific to each site to focus on greatest potential risks for CO_2 leakage from injection formation.
- Use multiple techniques to monitor CO_2 migration.
- Monitor pre-, during, and post- CO_2 injection.
- Develop site specific mitigation plans.
- Extent of MMV program will depend on amount of CO_2 injected, duration of study, potential risks for CO_2 migration (knowledge of site geology), and potential for full-scale injection facility.

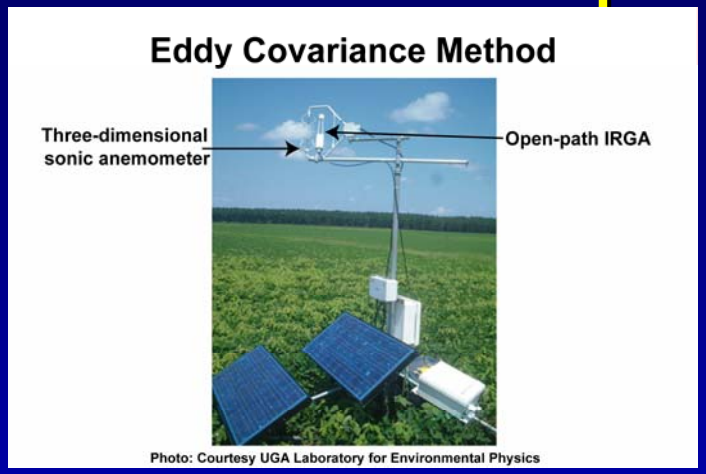
MMV Components

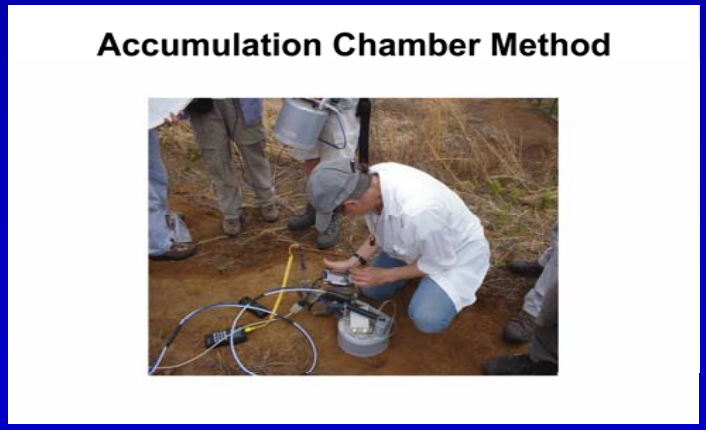
1. Site Assessment
2. Atmospheric monitoring
3. Remote sensing
4. Vadose zone monitoring
5. Shallow geophysical monitoring
6. Shallow groundwater monitoring
7. Injection well monitoring
8. CO_2 monitoring
9. Injection formation monitoring
10. Mitigation plans should CO_2 leakage occur
11. Validation using geochemical, reservoir integrity/gas migration, groundwater flow/contaminant transport, and CO_2 flux model predictions.

Site Assessment

- Determine geology and hydrology.
- Determine location of wells (oil, water, abandoned) and other potential risk areas in vicinity of injection well.
- Construct sampling grid to incorporate various MMV monitoring techniques.

Atmospheric Monitoring





- Measure ambient air quality-to insure worker safety
- Measure net surface CO_2 flux
- Measure soil CO_2 flux

(Oldenburg, LBNL)

Remote Sensing

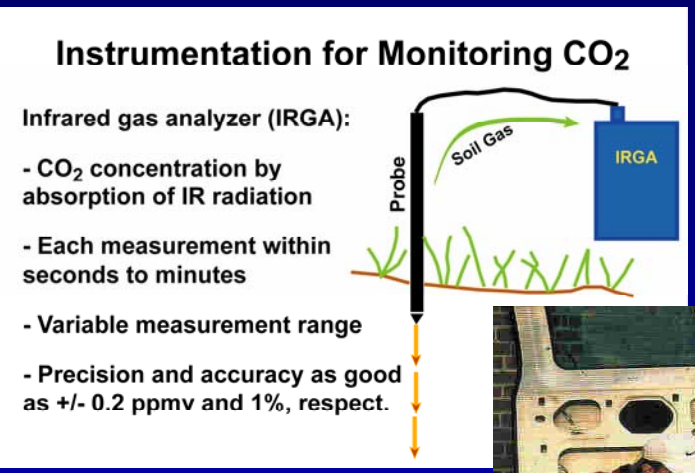
Use color infrared orthoimagery and aerial photography to provide base map & to determine plant stress.

Aerial view of crop stress due to leakage of natural gas

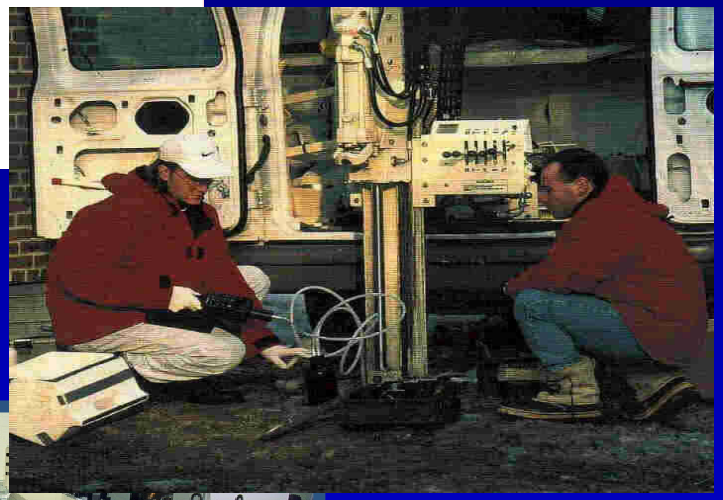
CIR of Potential ECBM Site and Surrounding Area

USDA National Agriculture Imagery Program (NAIP)
September 1, 2004

Monitoring Soil Gas in Vadose Zone



(Oldenburg, LBNL)



ISGS isotope mass spectrometer

- Measure soil pore gas concentrations and isotopic composition using drive points, IR, GC, and mass spectrometry

Shallow Geophysical Monitoring

ISGS conducting EM survey

ISGS conducting resistivity survey

Use Electromagnetic Induction and

High Resolution Electrical Earth Resistivity to:

- Indicate areas that may have increased vapor content in shallow geologic material.

Shallow Groundwater Monitoring

ISGS installing monitoring wells

ISGS collecting groundwater samples

Use existing wells & install monitoring wells to:

- Determine shallow (< 60m) groundwater flow regime.
- Determine water quality with emphasis on carbonate chemistry.

Injection Well Monitoring

Logging test well by ISGS
Capabilities: 1100m, gamma, elogs (resistivity), neutron, acoustic televiewer, fluid sampler

Use down hole logging to:

- Determine geology, casing integrity, mineralogy and measure moisture, density, seismic velocities, and salinity.
- Measure wellhead pressures

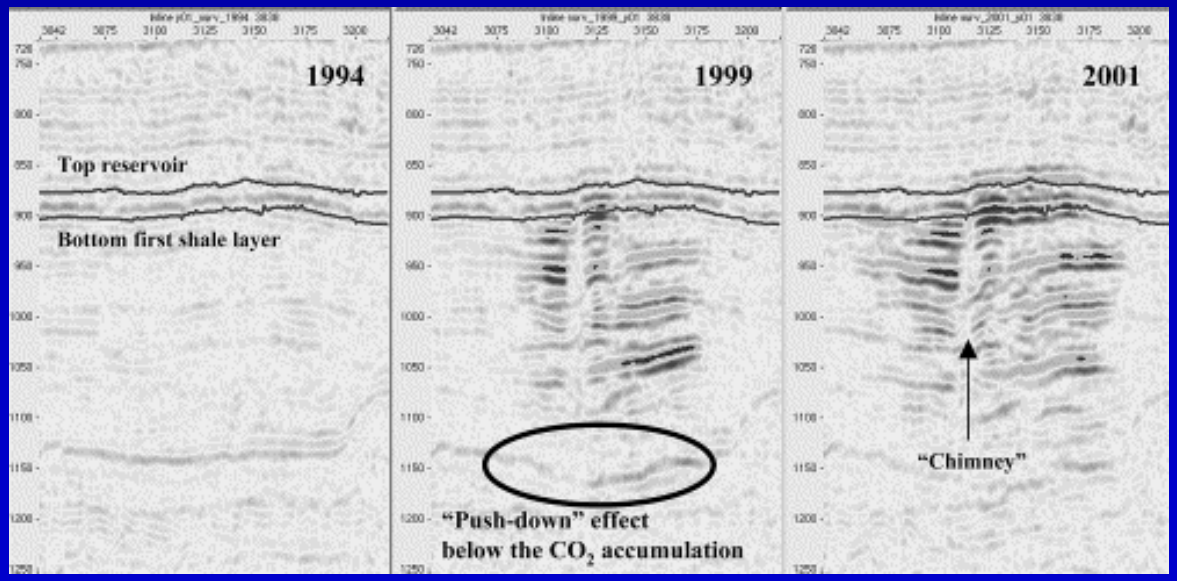
CO_2 Monitoring

- Measure CO_2 injection rate
- Measure CO_2 injection volume
- Determine CO_2 isotopic composition

ISGS staff collecting landfill gas samples for isotopic and chemical composition

Injection Formation Monitoring

- Measure pressure, temperature
- Determine gas concentrations and isotopic signature
- Determine fluid chemistry
- Determine CO_2 migration (3D seismic)

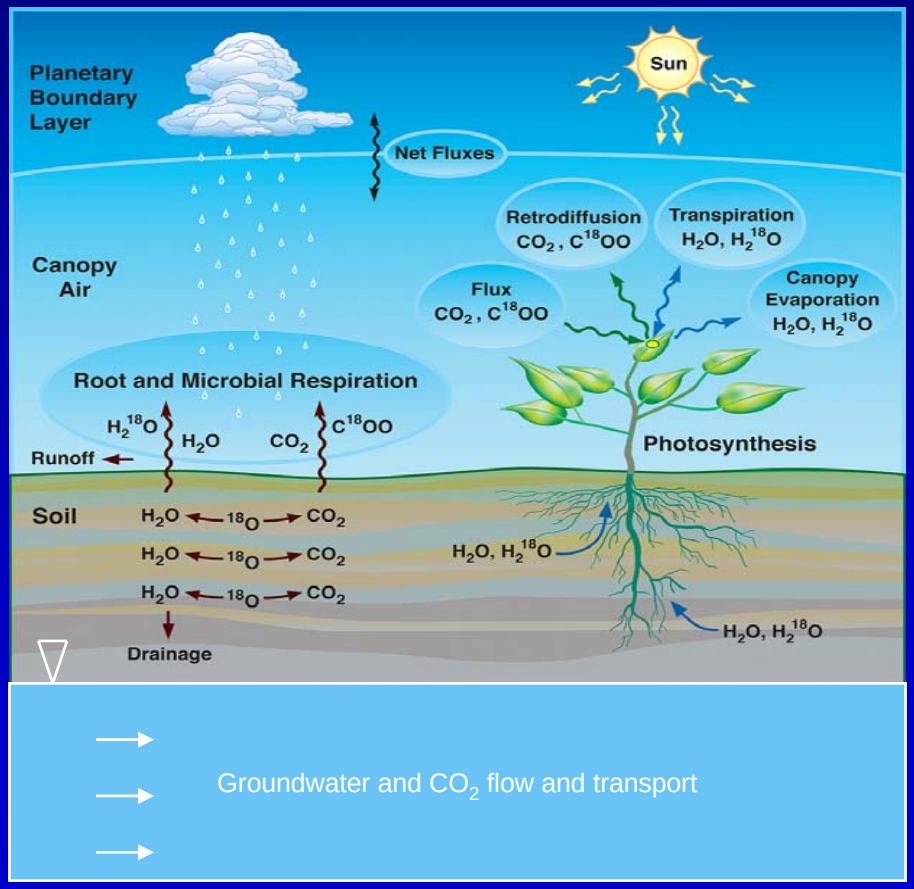


Seismic inline through CO_2 injection area at Sleipner (Arts et al, 2004)

Validation by Modeling

CO_2 migration in vadose zone and atmosphere

(Oldenburg, LBNL)



CLM3

TOUGH2

Validation by Modeling (cont.)

- Thermodynamic geochemical model (MINTEQ, PHREEQE)
- Groundwater flow and contaminant transport (GMS-Modflow/Modem)
- Reservoir engineering models (VIP, COMET)

Mitigation Plans

- Site specific
- Define action trigger criteria
- Define immediate response
- Define long-term response

Current Efforts

- Organize MMV team
- Hire additional MMV personnel
- Develop MMV and mitigation plans for ECBM site
- Purchase equipment for MMV program
- Begin baseline monitoring at ECBM site (Dec./Jan.)

Questions?

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