A Nonconventional CO_2-EOR Target in the Illinois Basin: Oil Reservoirs of the Thick Cypress Sandstone

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Presentation Outline

- Benefit to DOE Program
- Program and Project Overview
- Methodology
- Expected Outcomes
- Organization Chart and Communication Plan
- Project Tasks
- Deliverable and Milestones
- Risk Matrix
- Proposed Schedule
- Summary
- References

Benefit to DOE Program: Goal and Area of Interest

- Goal: Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness
- Area of Interest: 1A - Opportunities, Knowledge Advancements, and Technology Improvements for CO_2 Storage in Non-Conventional CO_2-EOR Targets – Residual Oil Zones (ROZs)

Benefit to DOE Program: Benefits Statement

- Field development guidelines will be developed to maximize economic oil recovery and CO_2 storage efficiency.
- It is projected that CO_2-EOR is an effective means of recovering additional oil from a formation that has historically low primary production and no waterflooding or EOR attempts. The formation is expected to have a high CO_2 storage (i.e. net utilization) compared to conventional CO_2-EOR.
- Through the application of these techniques, guidelines can be recommended for CO_2-EOR development (e.g., well patterns, spacing, and orientations as well as CO_2 injection profiles) of the thick Cypress (and similar formations) with the end result of maximized incremental recovery and CO_2 storage.

Program and Project Overview: Goals

DOE Program

- Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness
- Develop and advance technologies to significantly improve the effectiveness and reduce the cost of implementing carbon storage
- Adapt and apply existing technologies that can be utilized in the next five years while developing innovative and advanced technologies that will be deployed in the next decade and beyond

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- Identify and quantify nonconventional CO_2 storage and EOR opportunities in the thick Cypress Sandstone in the Illinois Basin
  - Economics/NCNO
  - Field development strategies
  - Near term deployment

Program and Project Overview: Objectives

DOE Program

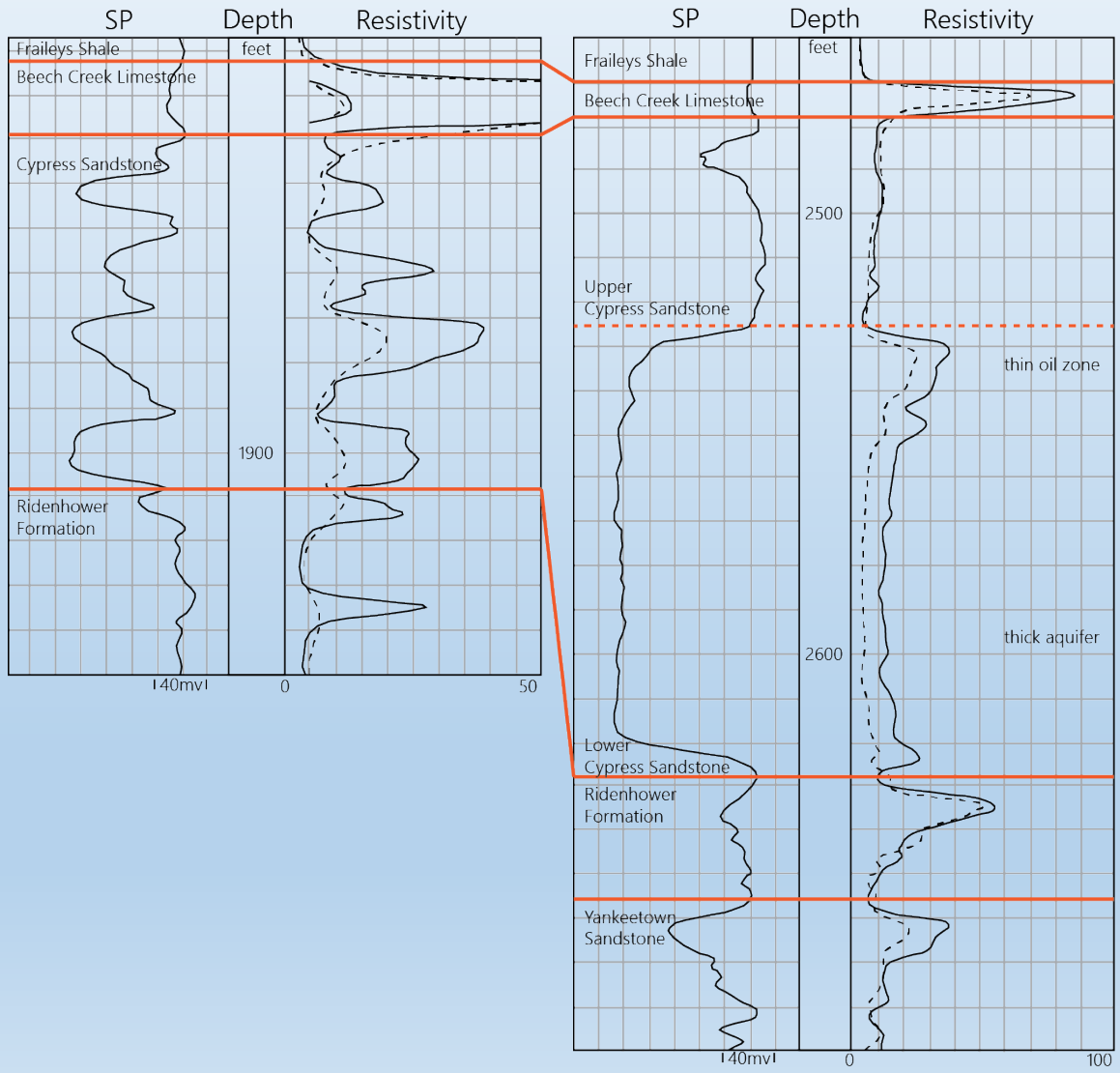
- Detailed characterization
- ROZ fairway locations; CO_2 storage and EOR resource
- Field and lab tests
- Development methods for increasing CO_2 storage and improving oil recovery

ncCO2-EOR TC ILB

- Correlate oil production to key geologic/reservoir properties
- Map CO_2 storage and EOR resource fairway (e.g. oil recovery)
- Obtain and analyze new core, logs, and fluid samples
- Develop screening and selection criteria; full field development strategies; economics and NCNO

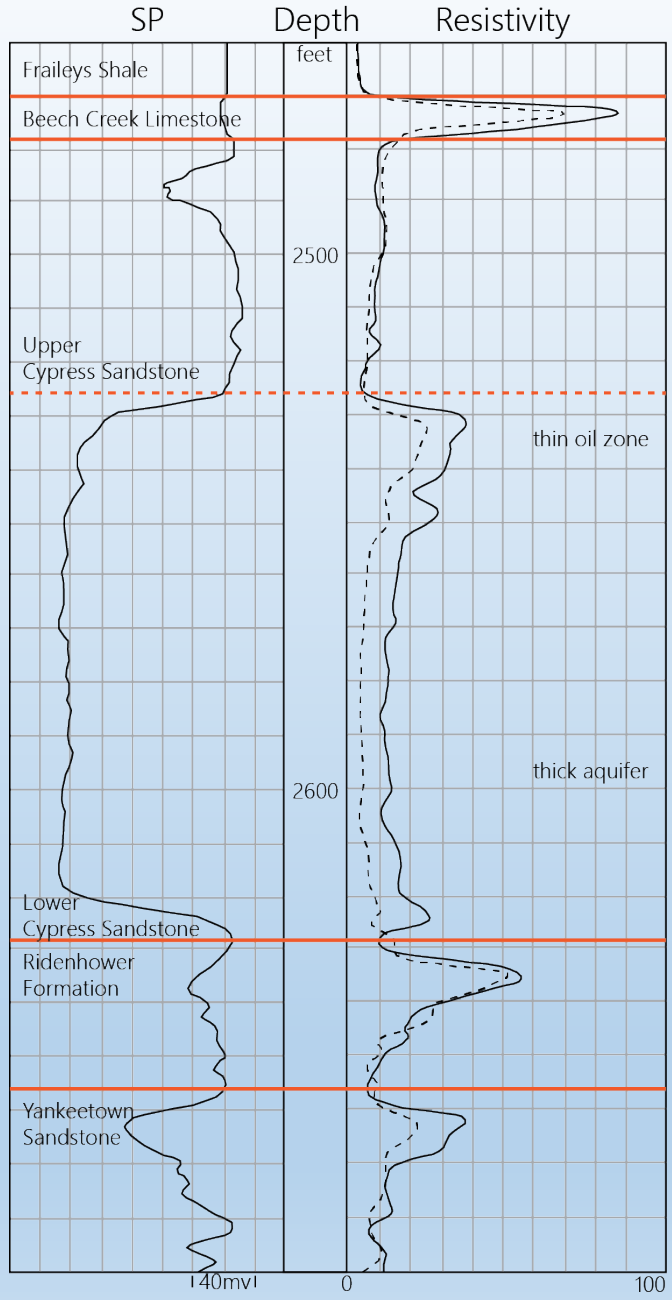
Methodology Background: Cypress Sandstone

- Prolific oil producing zone
- Overlain by an effective seal system
  - Shale (Fraileys Sh)
  - Limestone (Beech Creek Ls)
  - Shaley sandstone (upper Cypress Ss)
- Sandstone lenses vs. thick sandstone



Methodology
Background: Thick Cypress Ss

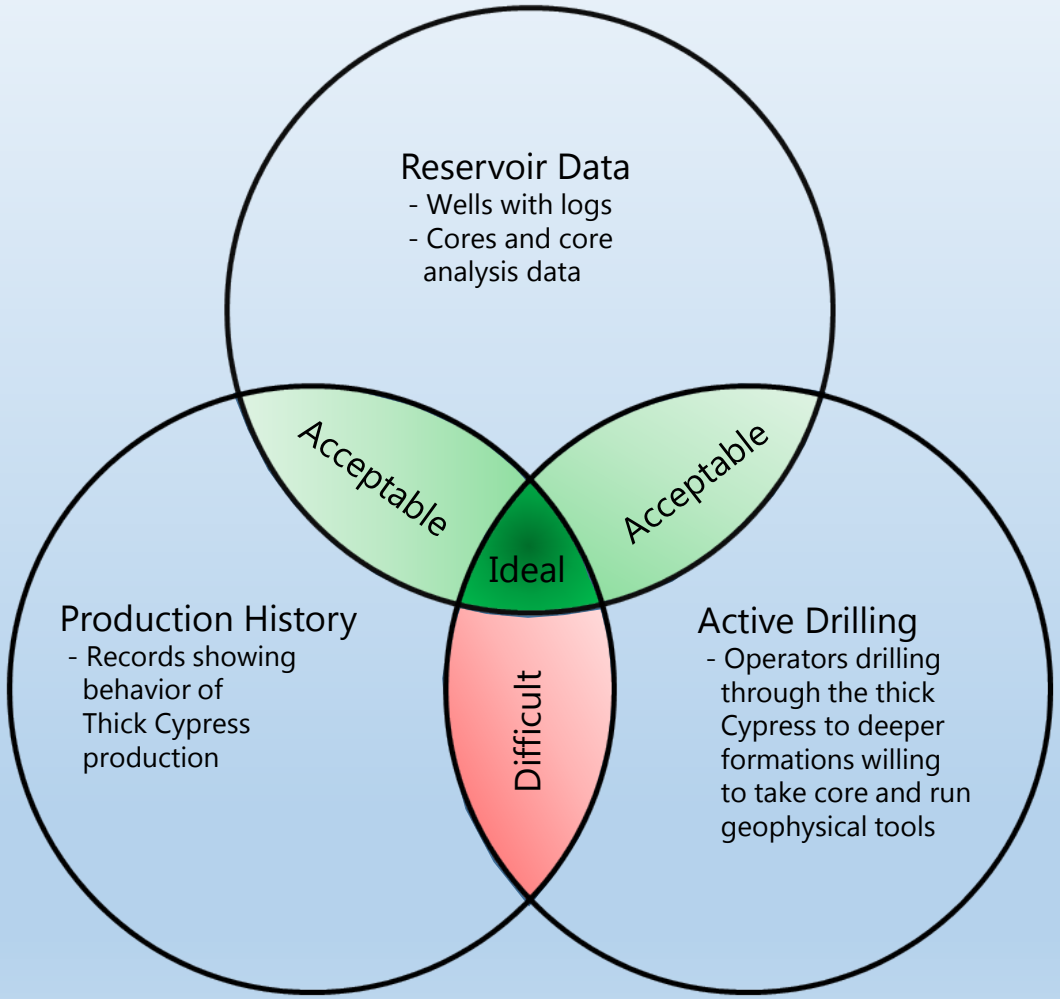
- Thin Oil Zones in Thick Aquifer Sandstones
  - Residual and mobile oil above thick water zone
  - Fining upward (grain size) sequence / increasing permeability with depth
  - Difficult to produce economically due to water coning and water management
- Nonconventional CO_2-EOR
  - Largely bypassed resource due to historical production difficulty
  - Sandstones 30+ meters thick and mostly aquifer
  - Saline storage potential of 0.2 to 2.3 Gt of CO_2 (DOE/MGSC, 2012)



Methodology
Study area selection

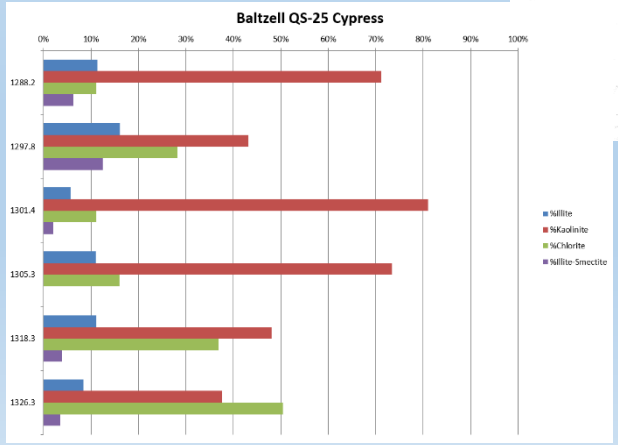
Choose a study area with:

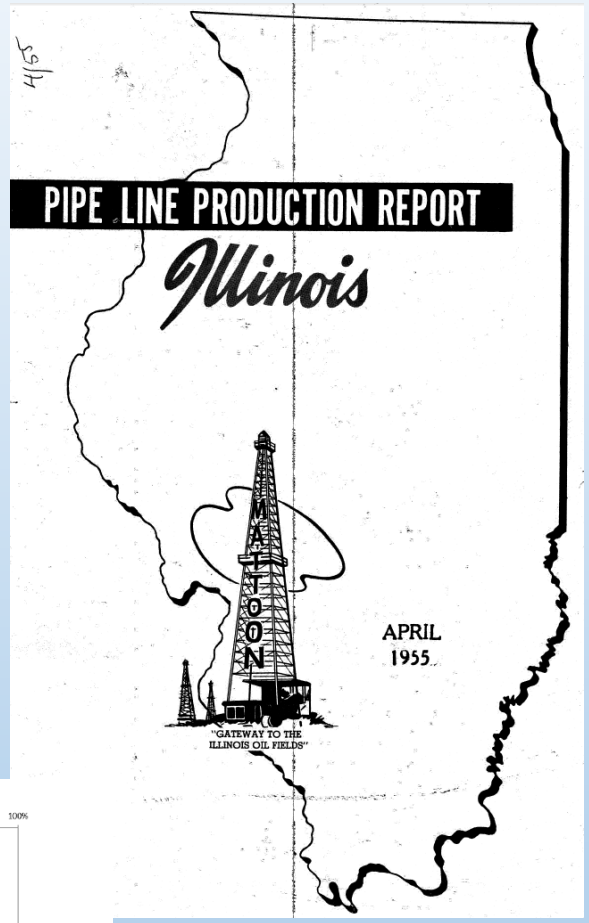
- Reservoir data
  - Necessary for building geologic model and populating geocellular model
- Production history
  - Necessary for establishing typical decline curve for Thick Cypress
- Active drilling
  - Necessary for taking new geophysical logs and core



Methodology
Data synthesis and analysis

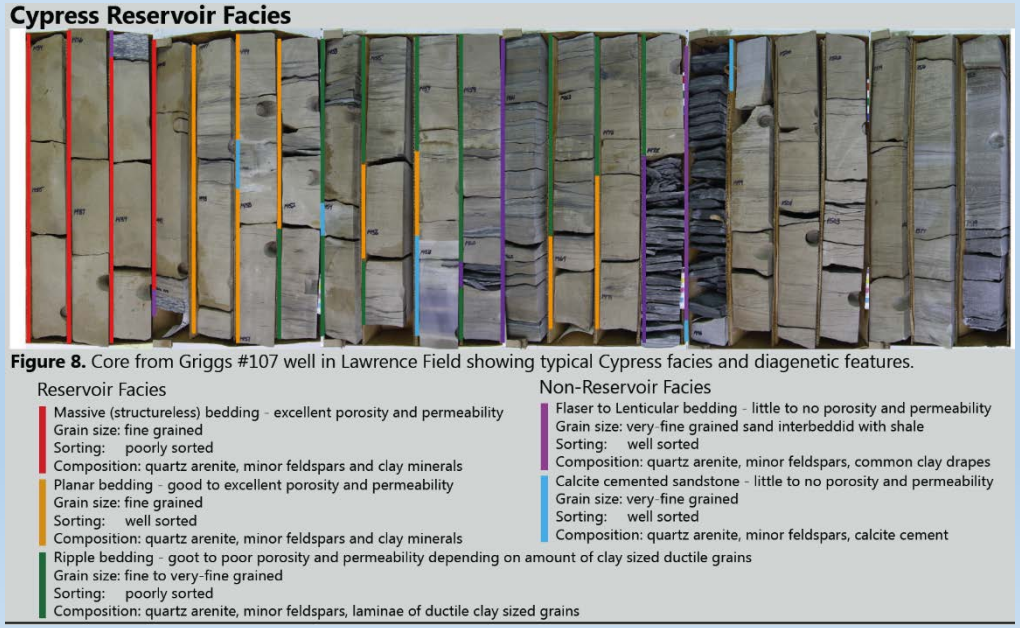
- Assemble comprehensive oil field database:
  - Production history and completion data
  - Petrophysical data
  - Mineralogical data
  - Core analysis data
  - Fluid composition data
  - Cores, core photos, and core descriptions

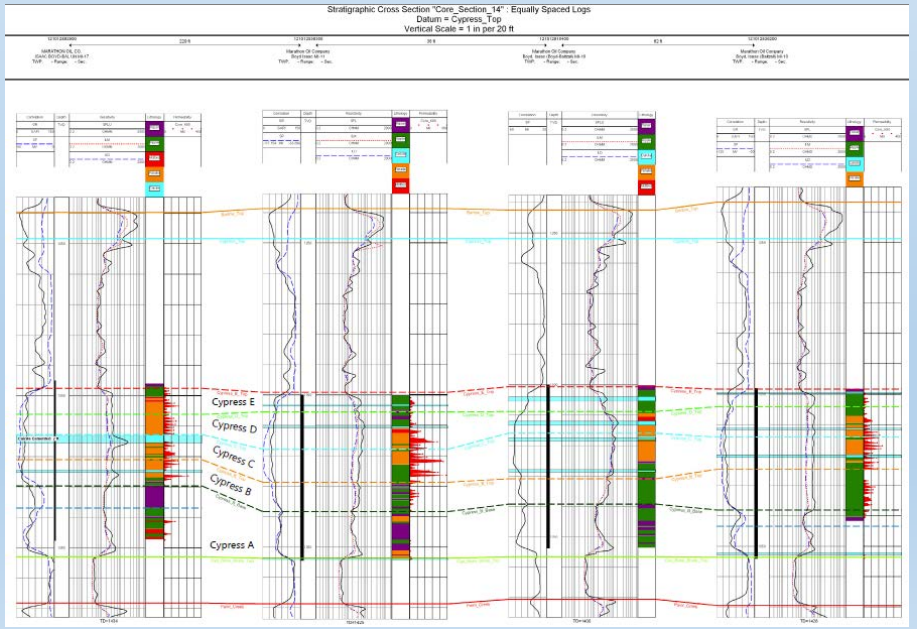


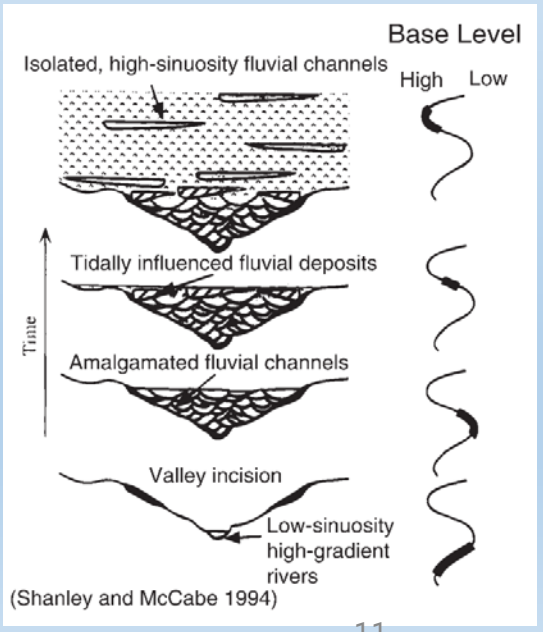


Methodology
Geology and Reservoir Characterization

- Develop geologic conceptual model:
  - Sandstone body geometries will be mapped, facies will be classified, and petrophysical and mineralogical properties will be characterized
  - Sequence stratigraphic, depositional, and diagenetic histories will be interpreted

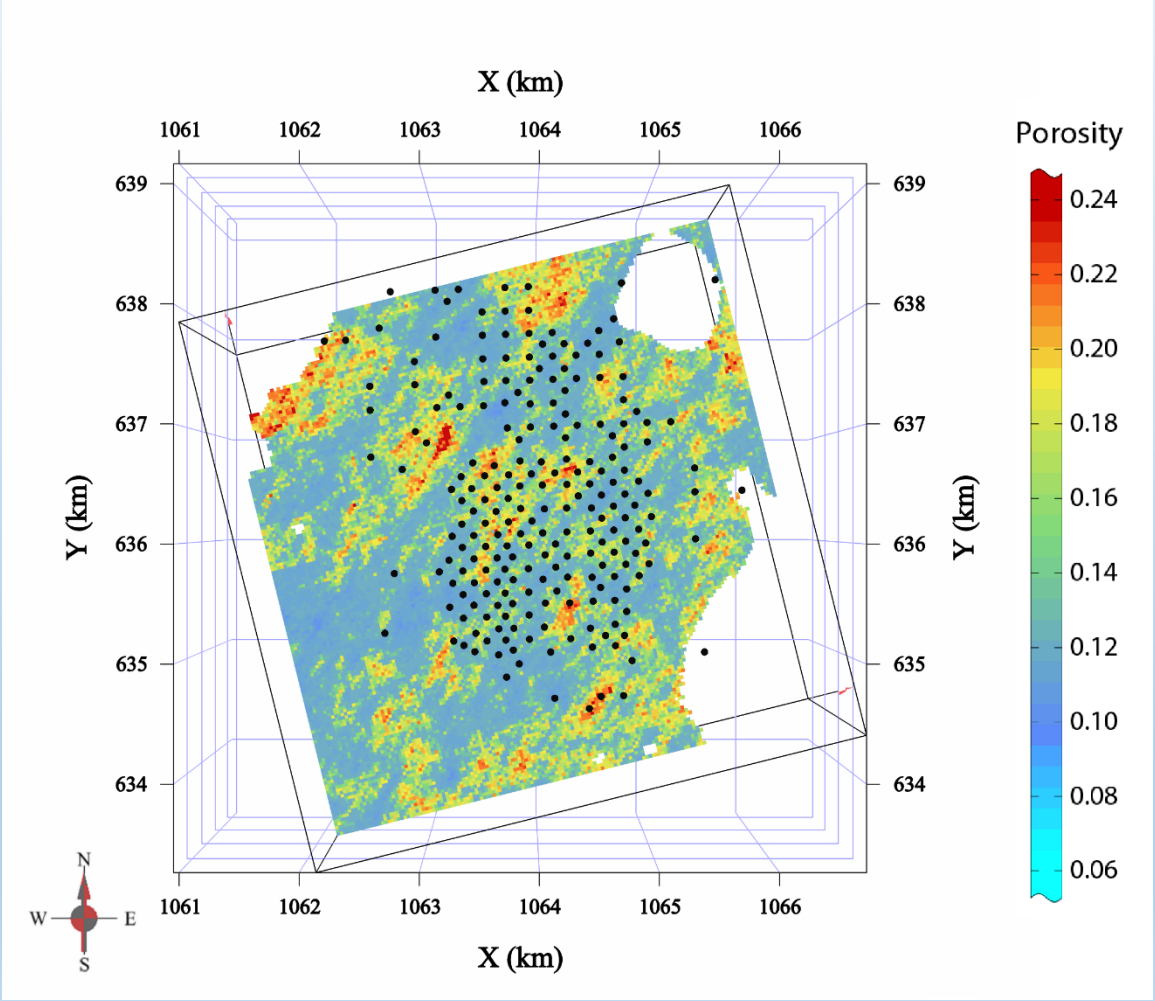






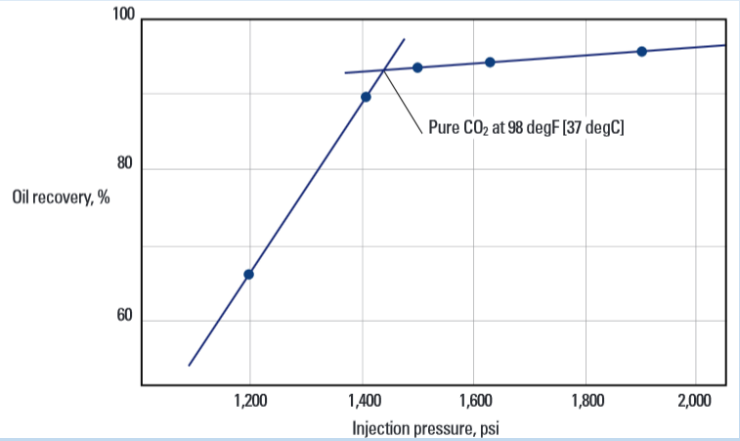
Methodology
Geocellular Modeling

- Build geocellular model that reflects:
  - Petrophysical properties
  - Depositional environment
  - Trends observed in mapping
- Verify model against geologic conceptual model
  - Vetted by geologic staff



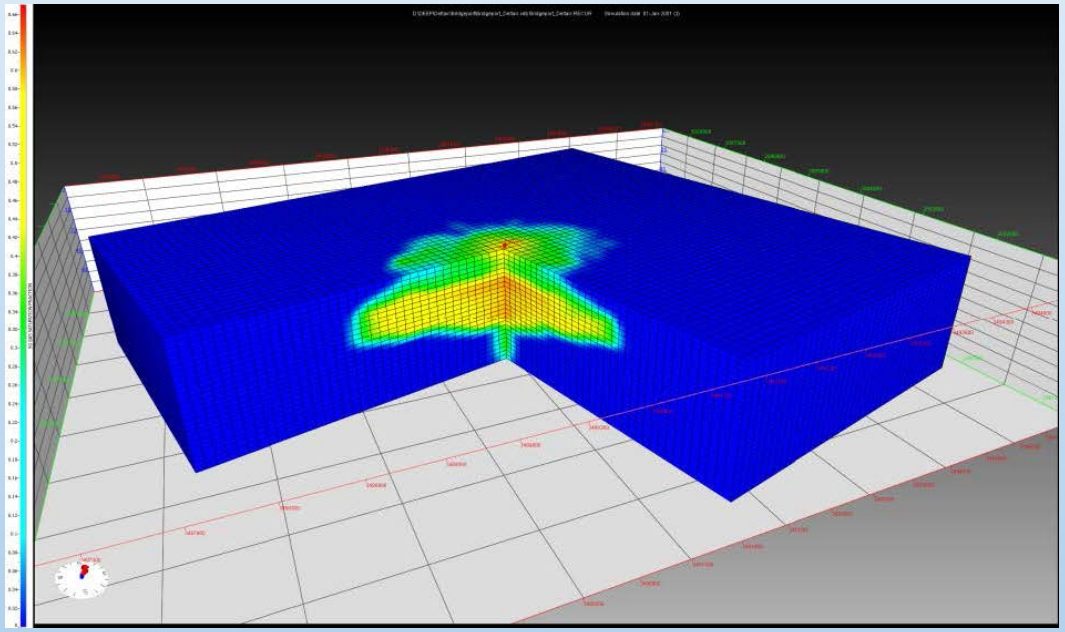
Methodology
Fluid Analysis and Geochemical Modeling

- Fluid Analysis
  - Samples of oil and brine will be collected from the Cypress Sandstone in or near the study area
  - Samples will be analyzed for attributes including: composition, minimum miscibility pressure
- Geochemical Modeling
  - Fluid properties will be modeled to identify potential oil/brine/CO_2 interactions
  - Relative permeability will be determined
  - Reactions with reservoir mineralogy will be investigated



Methodology
Reservoir Simulation

- Simulate injection scenarios using calibrated reservoir models
  - Identify injection scenarios that lead to improvement in CO_2 sweep efficiency
  - Improve understanding of CO_2 storage and water management plans



Methodology
Resource estimate and economics

- Define location of ncCO2-EOR fairways
  - Size of the oil resource and CO_2 storage capacity
    - Revised regional maps
    - Reservoir simulation results
- Analyze economics CO_2-EOR implementation
  - Feasibility of CO_2-EOR
  - Emphasis on Net Carbon Negative Oil

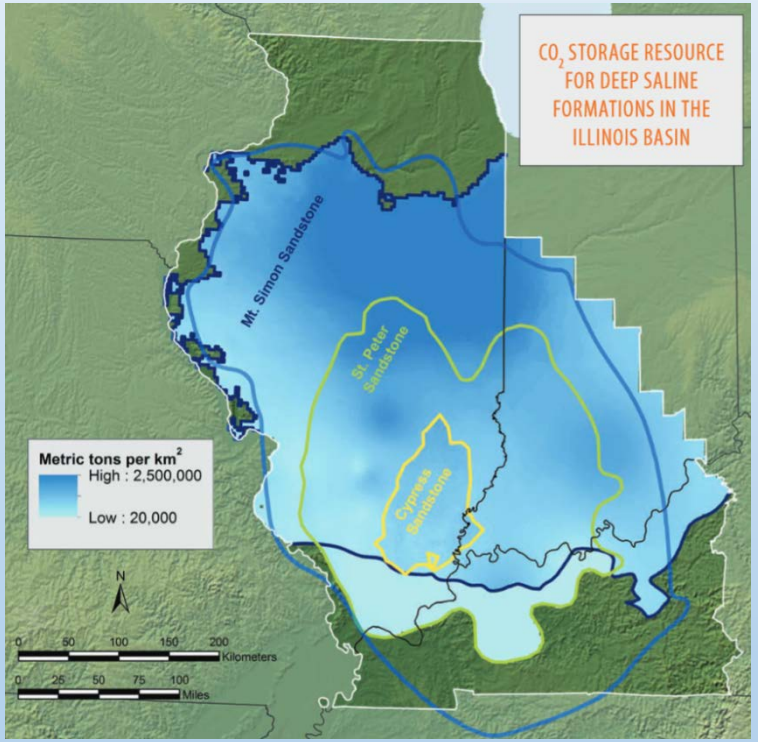


Figure from US DOE, 2012

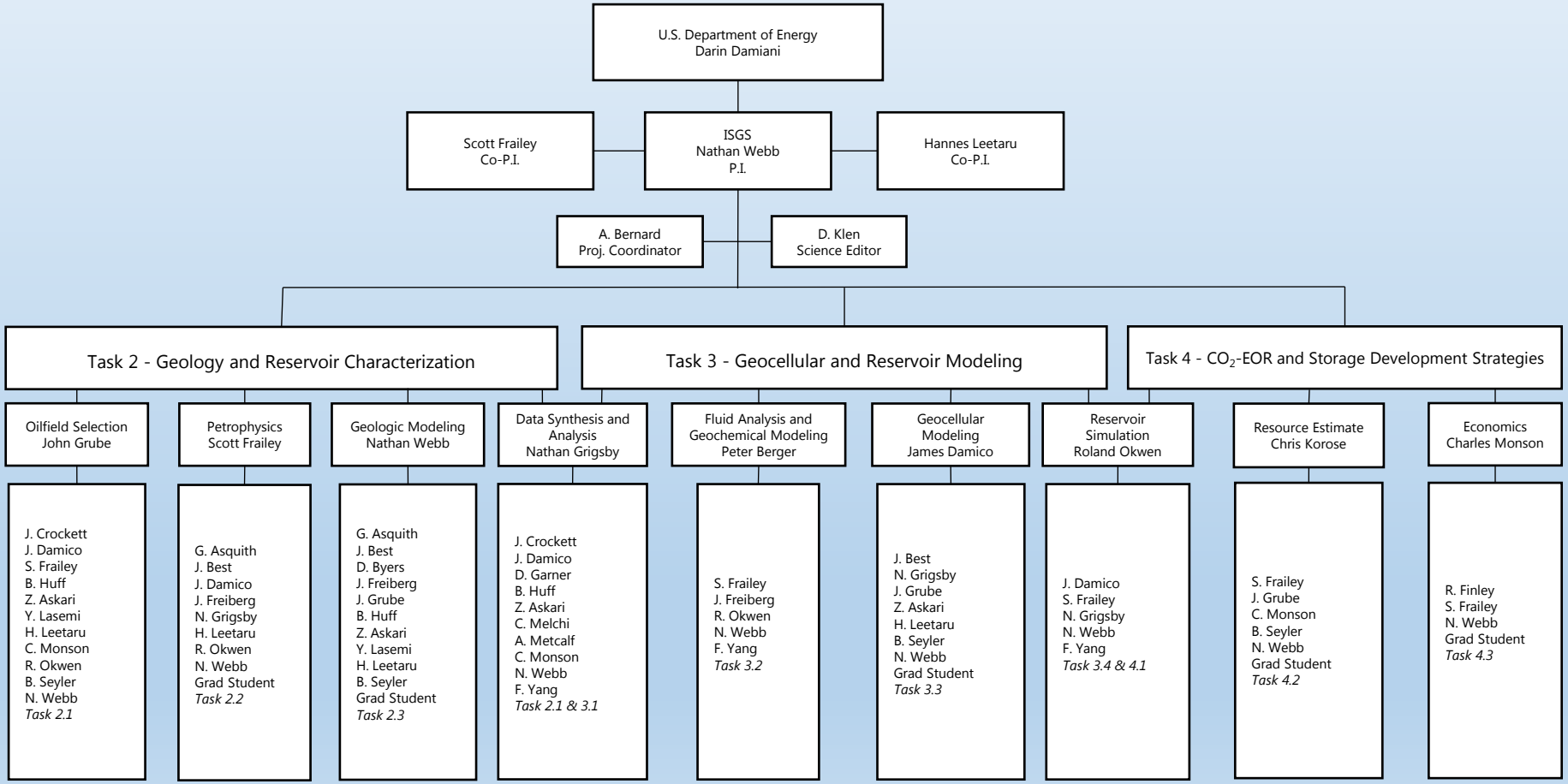
Expected Outcomes

- Identification of effects of geologic attributes on CO_2 storage and EOR in thin oil zone/thick aquifer formations
  - New and existing data synthesis and analysis
  - New interpretation of depositional and diagenetic controls on reservoir, oil production, and storage behavior
- Rigorous geology-based, site-specific geocellular models
  - Include geologic heterogeneity; reflect depositional and diagenetic history
  - Modeling process that emphasizes site specific geologic attributes

Expected Outcomes (continued)

- Full-field development scenarios based on economic analysis and interpretation of reservoir simulation results
- New resource assessment and regional fairway maps of CO_2 storage and EOR
- New assessment of economic viability of CO_2-EOR in the thick Cypress with considerations for NCNO

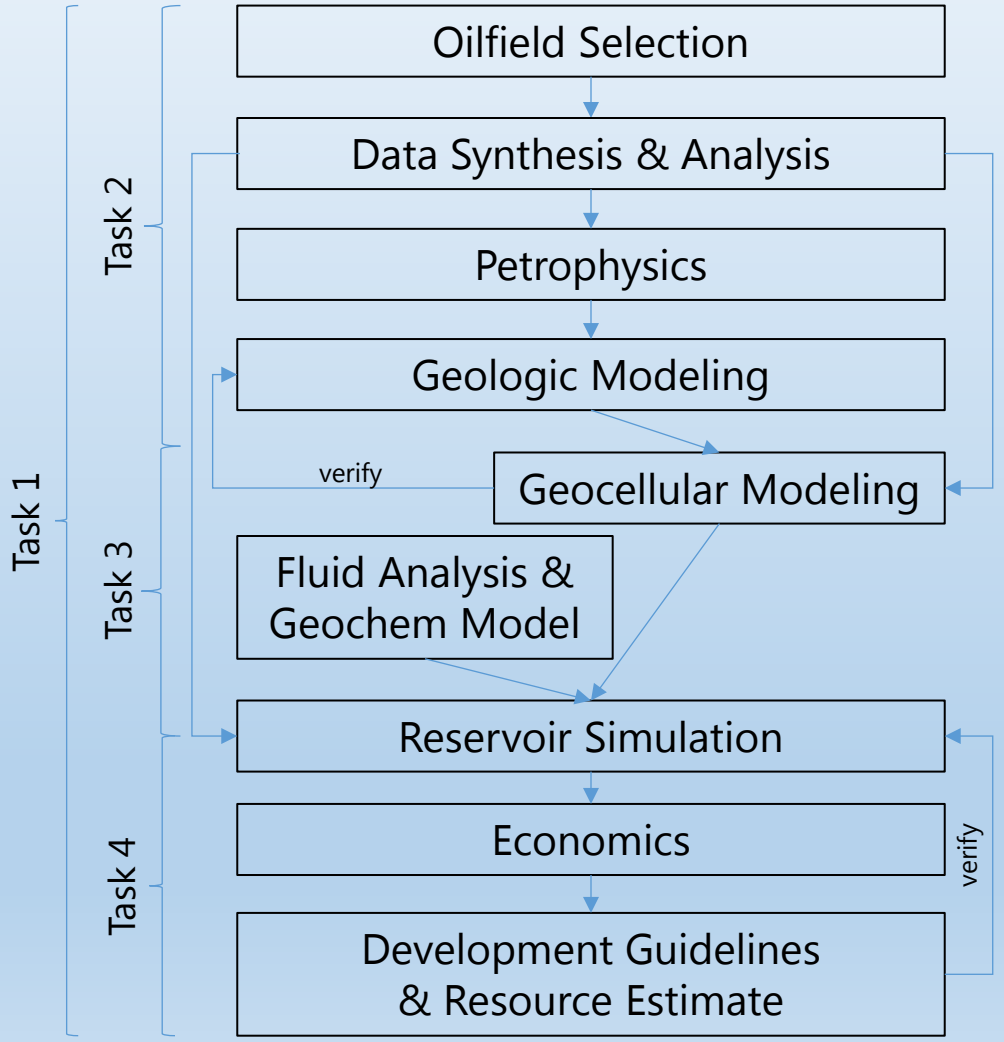
Organization Chart and Communication Plan



- Project management team
  - Weekly update meetings
  - Monthly project plan review meetings
- Subtask leaders
  - Monthly meetings with PI
  - Monthly meetings with staff while task is active

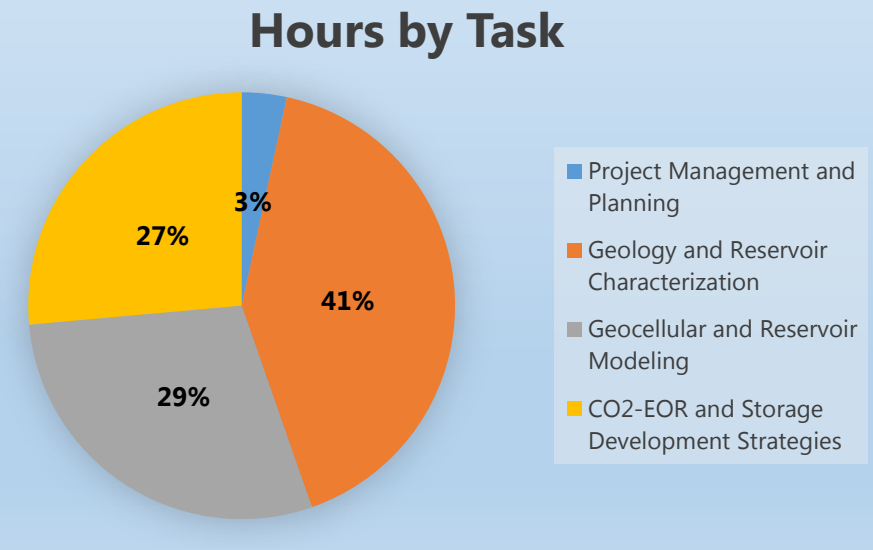
Project Tasks

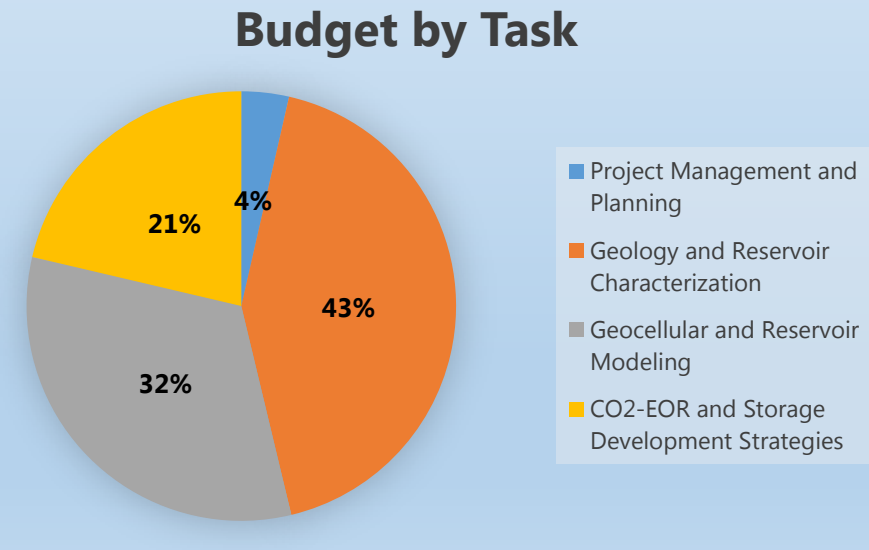
1. Project Management and Planning
2. Geology and Reservoir Characterization
3. Geocellular and Reservoir Modeling
4. CO_2-EOR and Storage Development Strategies



Task 1.
Project Management and Planning

- Largest proportion of effort focuses on geologic characterization task
- Balance of effort roughly split between modeling and development strategies tasks





Task 2.
Geology and Reservoir Characterization

2.1 Oilfield Selection

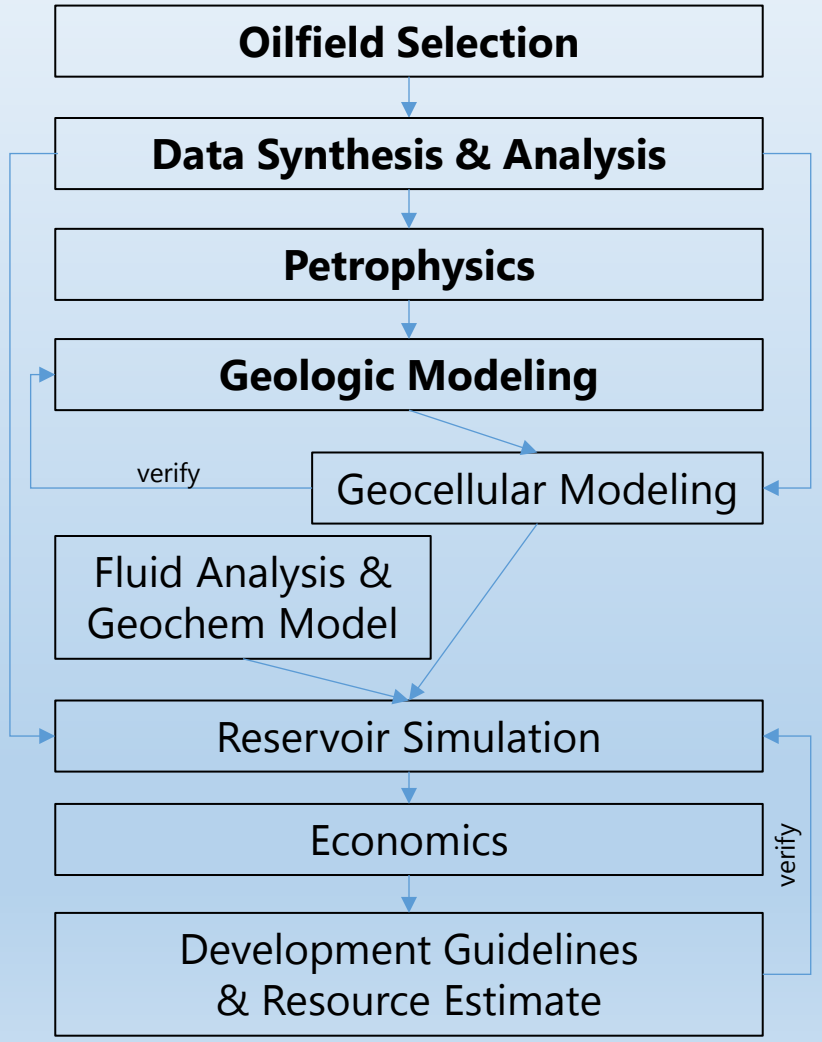
- Review past Illinois Basin studies
- Aggregate, digitize, analyze available data

2.2 Petrophysics

- Collection of new core and geophysical logs
- Analyses of available and newly acquired data

2.3 Geologic Modeling

- Description and analyses of core and outcrop
- Mineralogy and petrography of samples
- Correlations of geophysical logs
- Mapping local and regional geology
- Interpretation of depositional environment



Task 3.
Geocellular and Reservoir Modeling

3.1 Production & Injection Data Analysis

- Analyze decline curves
- Define historical successes and failures

3.2 Fluid Analysis and Geochemical Modeling

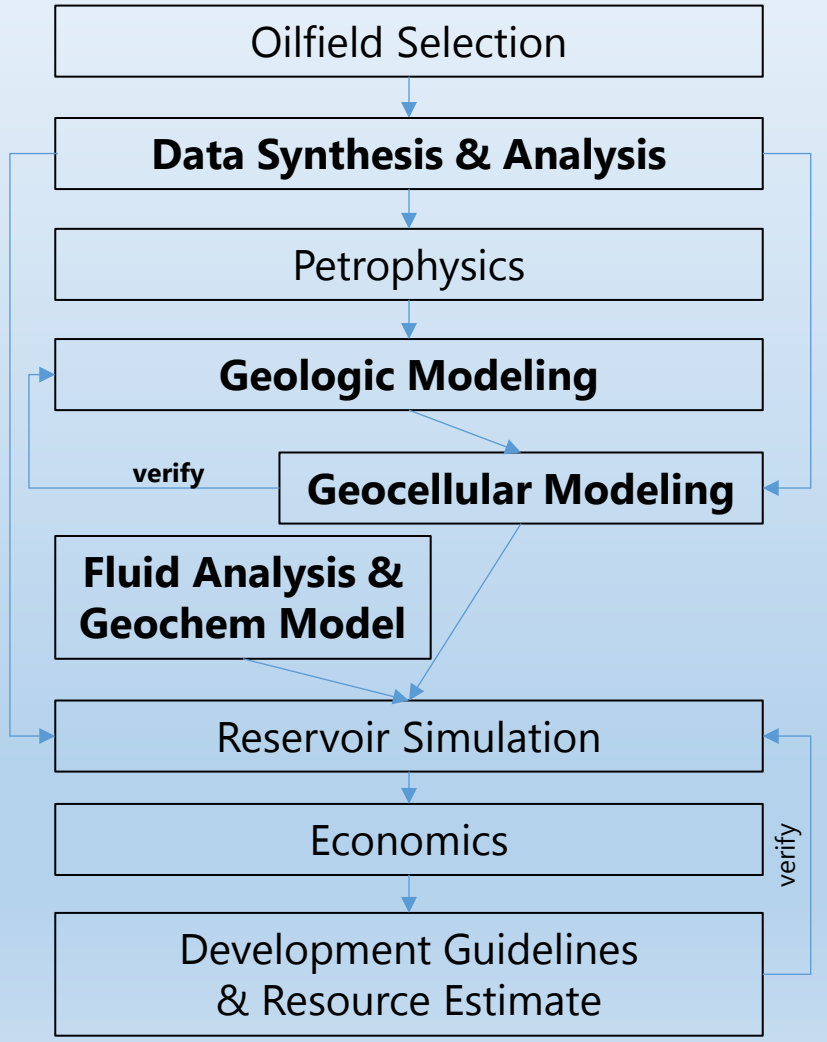
- Sample and analyze reservoir fluids
- Model potential interactions with core

3.3 Geocellular Modeling

- Construct variogram from geostatistical analysis
- Build 3D geocellular model

3.4 Reservoir Modeling

- Set up reservoir modeling files



Task 4.
CO_2-EOR and Storage Development Strategies

4.1 Field Development Guidelines

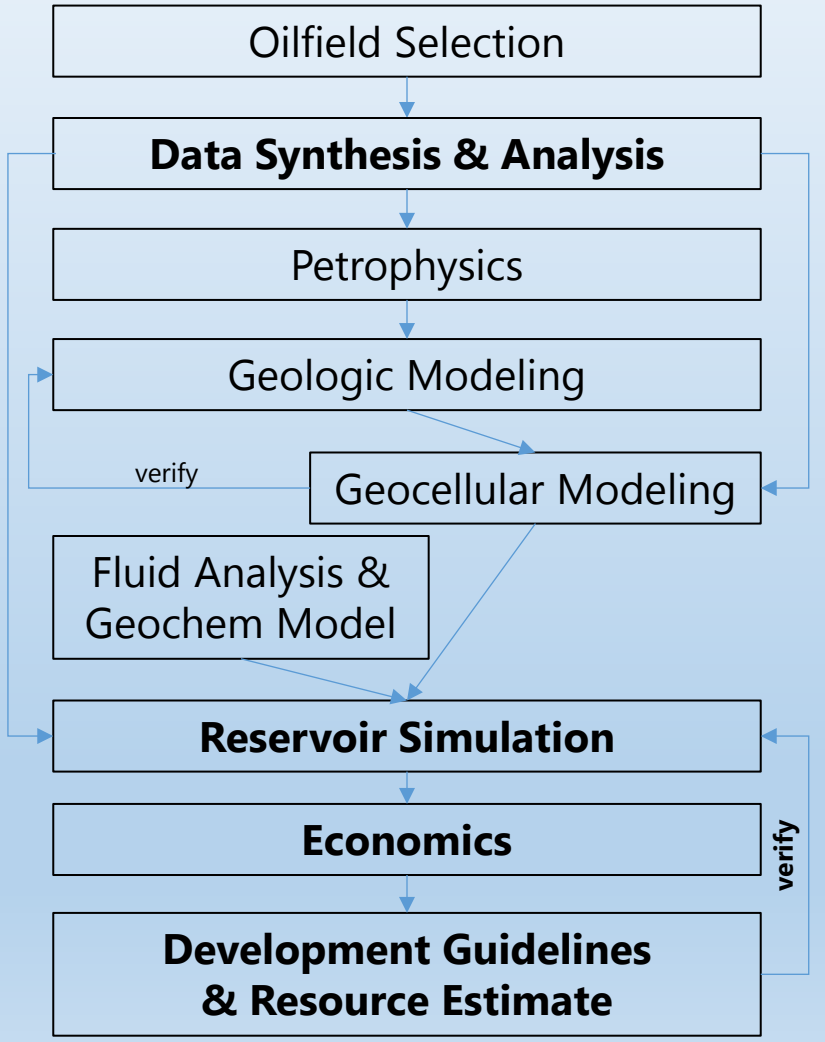
- Simulate:
  - Injection profiles and conformance
  - Well patterns and spacing
  - Vertical vs. horizontal wells

4.2 CO_2-EOR & Storage Resource Assessment

- Calculate volumetrics from regional maps
- Estimate resource using simulation results

4.3 Economics

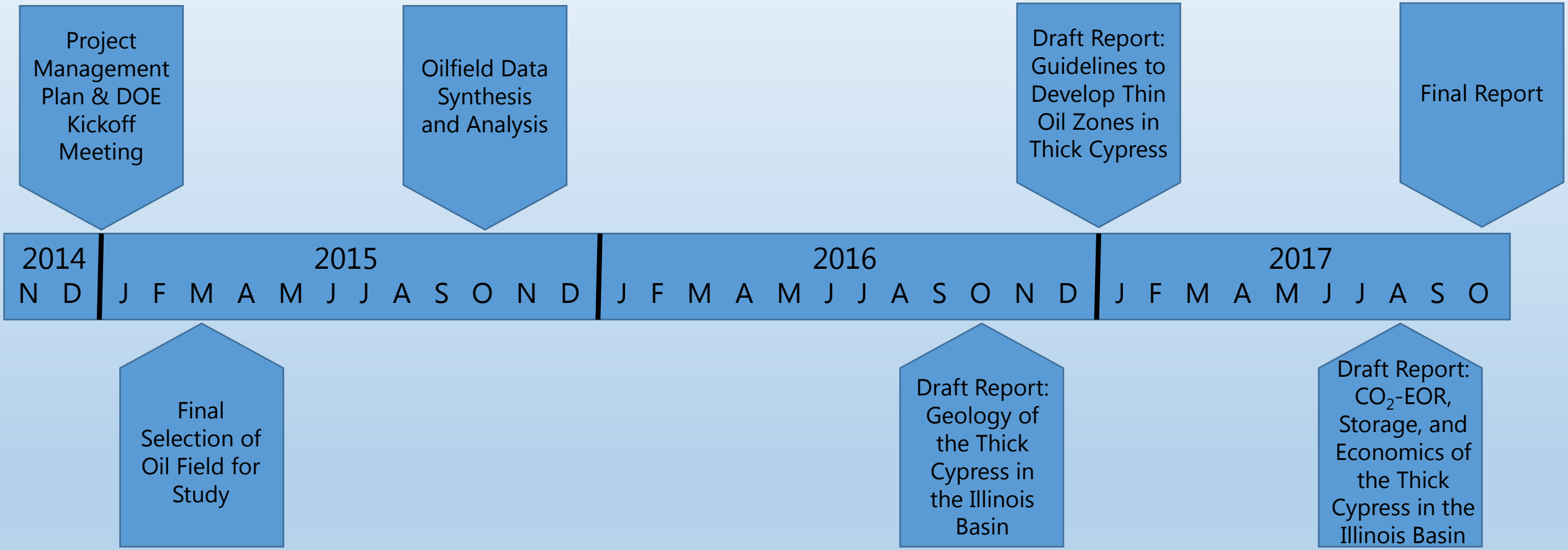
- Demonstrate viability of economic production with CO_2 storage in underlying aquifer
- Determine threshold of NCNO production



Project Deliverables

- Project management plan
- Quarterly progress reports (quarterly)
- Topical reports
  - Geology of Thick Cypress (October, 2016)
  - Guidelines to Develop Thin Oil Zones in the Thick Cypress in the Illinois Basin (December, 2016)
  - CO_2 Storage, EOR, and Economics of the Thick Cypress in the Illinois Basin (August, 2017)
- Final report (October, 2017)
- Website (ongoing)

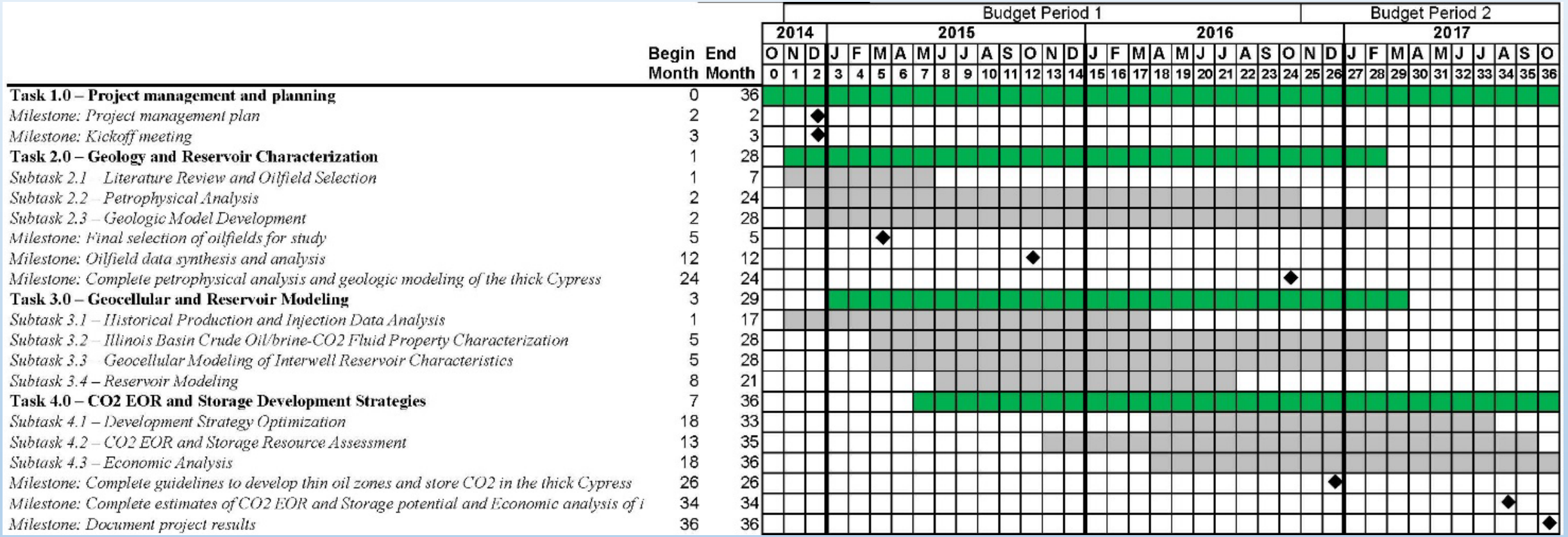
Project Milestones



Risk Matrix

Risk	Description	Likelihood (0-3)	Severity (0-3)	Strategy	Mitigation plan
Data acquisition	Delays in acquiring data can delay the project	1	2	Most data is available at ISGS	Begin assembling and digitizing data immediately
Hiring delays	Delays in hiring key personnel can delay the project	1	2	Most of the staff included on project are current ISGS employees	Eliminate need to hire by utilizing current ISGS staff
Loss of personnel	Interdependencies of tasks require technical deliverables to be completed on time; thus, loss of key staff performing technical tasks may impede progress	2	2	Multiple current ISGS staff on the project are capable of performing the same tasks	Keep technical staff appraised of progress on each task. Distribute critical tasks to two or more staff members
Inability to partner with operator	An operator partner will be needed to facilitate the collection of new geophysical and core data on the thick Cypress; inability to identify such a partner may delay the project	2	2	While not ideal, the thick Cypress is present in shallow areas of the basin at depths that could be cored by ISGS	Make parallel preparations to take core independently of operator

Proposed Schedule



	Begin Month	End Month
Task 1.0 – Project management and planning	0	36
Milestone: Project management plan	2	2
Milestone: Kickoff meeting	3	3
Task 2.0 – Geology and Reservoir Characterization	1	28
Subtask 2.1 – Literature Review and Oilfield Selection	1	7
Subtask 2.2 – Petrophysical Analysis	2	24
Subtask 2.3 – Geologic Model Development	2	28
Milestone: Final selection of oilfields for study	5	5
Milestone: Oilfield data synthesis and analysis	12	12
Milestone: Complete petrophysical analysis and geologic modeling of the thick Cypress	24	24
Task 3.0 – Geocellular and Reservoir Modeling	3	29
Subtask 3.1 – Historical Production and Injection Data Analysis	1	17
Subtask 3.2 – Illinois Basin Crude Oil/brine-CO2 Fluid Property Characterization	5	28
Subtask 3.3 – Geocellular Modeling of Interwell Reservoir Characteristics	5	28
Subtask 3.4 – Reservoir Modeling	8	21
Task 4.0 – CO2 EOR and Storage Development Strategies	7	36
Subtask 4.1 – Development Strategy Optimization	18	33
Subtask 4.2 – CO2 EOR and Storage Resource Assessment	13	35
Subtask 4.3 – Economic Analysis	18	36
Milestone: Complete guidelines to develop thin oil zones and store CO2 in the thick Cypress	26	26
Milestone: Complete estimates of CO2 EOR and Storage potential and Economic analysis of i	34	34
Milestone: Document project results	36	36

Summary

- Three year geologic and reservoir study of the thick Cypress Sandstone in the Illinois Basin
- Site specific oilfield study using newly acquired core, core analyses, and geophysical logs
- CO_2 storage and EOR resource assessment of the thick Cypress Sandstone
- Full-field development guidelines for economic CO_2 storage and EOR

References

- Frailey, S. M., R. J. Finley, and J. A. Rupp, 2013, Illinois basin, Midwest carbon dioxide EOR challenges may be surmountable: Oil and Gas Journal.
- Frailey, S. M., I. G. Krapac, J. R. Damico, R. T. Okwen, and R. W. Mckaskle, 2012, CO2 Storage and Enhanced Oil Recovery: Bald Unit Test Site , Mumford Hills Oil Field, Posey County, Indiana: 172 p.
- Melzer, L. S., 2006, Stranded Oil in the Residual Oil Zone: 35 p.
- Nelson, W. J., L. B. Smith, J. D. Treworgy, L. C. Furer, and B. D. Keith, 2002, Sequence Stratigraphy of the Lower Chesterian (Mississippian) Strata of the Illinois Basin: Illinois State Geological Survey, Bulletin.
- Seyler, B., J. P. Grube, and D. G. Morse, 2000, The Cypress Sandstone in Illinois, in Petroleum Technology Transfer Council Workshop.
- Shanley, K. W., and P. J. McCabe, 1994, Perspectives on the Sequence Stratigraphy of Continental Strata: AAPG Bulletin, v. 78, no. 4, p. 544–568.
- United States Department of Energy (US DOE), 2012, United States Carbon Utilization and Storage Atlas,130 p.
- Webb, N. D., and J. P. Grube, 2014, The Mississippian Cypress Sandstone: Geologic Characteristics of a Potential EOR Target in the Illinois Basin, in North-Central Section - 48th Annual Meeting.