Simulation Framework for Regional Geologic CO$_2$ Storage Infrastructure Along Arches Province of Midwestern United States

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DOE/EPA Collaborative Review- Tracking Geologically Sequestered CO2: monitoring, Verification, & Accounting
MVA, Simulation, and Risk Assessment

March 24, 2010 Pittsburgh, PA
Introduction

- Widespread deployment of CCS will require an understanding of the regional, basin-scale impacts on groundwater flow, and quality.
- Basin-scale hydrodynamics are controlled by numerous factors, including regional geology, fluid pressure and density, and tectonic history.
- Arches province is important area for CCS due to thick, pervasive nature of Mt. Simon Sandstone and favorable hydrogeologic properties.
Arches Province Simulation Project

- The work will represent the “next step” in simulation of CO₂ storage — the widespread application along a major, regional geologic structure in an area of the country with a dense concentration of large CO₂ sources.
- As such, it will help answer technical and infrastructure questions related to simulation methods and also contribute to research on monitoring options and risk assessment.
Arches Province Simulation Project

- Arches Province is present between the Appalachian, Illinois, and Michigan sedimentary Basins.
- The province includes portions of Indiana, Illinois, Kentucky, Michigan, and Ohio.
- There is a history of wastewater injection operations in Mt. Simon in the region dating back to 1970s.
Conceptual Flow Model Example for Midwest (Gupta and Bair, 1997)

Vertical Exaggeration = 165x

Explanation
- Regional aquifer - highly permeable
- Regional aquifer - moderately permeable
- Regional confining layer
- Jointing-enhanced vertical flow
- Specific gravity
- Direction of flow

DOE/EPA Review- Tracking Geologically Sequestered CO2  March 24, 2010
Arches Province Simulation Project

- Simulation Framework for Regional Geologic CO₂ Storage Infrastructure along Arches Province of Midwestern United States project selected by DOE/NELT under FOA23.
- Three year project through September 2012.
- Significant collaborations with MRCSP, MGSC, and other projects.
**Project Organization**

**Sponsors**
- DOE
- OCDO

**Project Management (Task 1)**
- Battelle
- Principal Investigators: Neeraj Gupta and Joel Sminchak

**Tech. Advisors**
- David Ball (Battelle)
- Mark White (PNWD)
- Larry Wickstrom (ODGS)

**Task 2**
- Comp. of Geologic & Hydraulic and data on Mt. Simon Sandstone
- Chris Perry (ODGS)

**Task 3**
- Model Framework & Parameters
- Joel Sminchak (Battelle)

**Task 4**
- Variable density flow model simulations
- Joel Sminchak (Battelle)

**Task 5**
- Multi-phase model runs of regional storage scenarios
- Diana Bacon (Battelle - PNWD)

**Task 6**
- Implications for Regional Storage Feasibility
- Neeraj Gupta (Battelle)

**Task 7**
- Reporting & Technology Transfer
- Joel Sminchak (Battelle)

State Geological Surveys and WMU will also contribute to Tasks 4-7

- Project will seek collaborations with MRCSP, MGSC, and other projects as viable given project schedule and budget.

DOE/EPA Review - Tracking Geologically Sequestered CO2 March 24, 2010
Task 1: Project Management and Planning

- Project Management Plan
- Reporting and status meetings
Task 2: Compilation of Geologic, Hydraulic, and Injection data on Mt. Simon Sandstone

- Subtask 2.1. Geotechnical Data Compilation
- Subtask 2.2. Mapping and GIS of Mt. Simon
- Subtask 2.3. Eau Claire/Caprock Evaluation
- Subtask 2.4. Class I Data Analysis

Mount Simon Subdivision: Isopach III (Lower Unit)
Task 2: Compilation of Geologic, Hydraulic, and Injection data on Mt. Simon Sandstone

- Facies distribution studies suggest several units with the Mt. Simon Sandstone formation which are important to CO₂ storage potential.

Fining-upward foresets within the facies B3, from granule size to coarse-grained sandstone. (source = Saeed, 2002)
Task 2: Compilation of Geologic, Hydraulic, and Injection data on Mt. Simon Sandstone

- Facies distribution present in recent MRCSP test well at Cincinnati Arch East Bend test site.
Task 2: Compilation of Geologic, Hydraulic, and Injection data on Mt. Simon Sandstone

- Injection data from region is being compiled (operational injection rates, pressures, falloff test data).
- Some injection sites have been operating since 1970s.
- Data will be used for model calibration to injection data and reservoir pressures.

**Cumulative Injection Volume at Lima UIC Site**

![Graph showing cumulative injection volume over time for different wells.](Image)
Task 3: Development of Model Framework and Parameters

- Subtask 3.1. Conceptual Model
- Subtask 3.2. Model Framework/Discretization
- Subtask 3.3. Code Modification & Debugging
- Subtask 3.4. Code Verification/Comparison
Task 3: Development of Model Framework and Parameters

- Model boundary conditions being examined to ensure accurate model solution.
- Facies changes and depth related porosity cutoffs may provide natural boundaries to the model domain.
Task 4: Baseline Variable Density Flow Simulations

- Subtask 4.1. Variable Density Model Setup
- Subtask 4.2. Model Runs
- Subtask 4.3. Flow Analysis
**Task 5: Simulations of Regional CO2 Storage Infrastructure Scenarios**

- Subtask 5.1. Base Simulation
- Subtask 5.2. Model Calibration to Class I/MRCSP Data
- Subtask 5.3. Regional Storage Scenarios
- Subtask 5.4. Data Analysis and Visualization
- Subtask 5.5. Structure Simulations
- Subtask 5.6. Leakage Simulations
- Subtask 5.7. MVA Comparison
Task 6: Infrastructure Analysis

• Subtask 6.1. Infrastructure Analysis
  – Delineate favorable and unfavorable locations for CO2 storage in Arches Province given regional framework.

• Subtask 6.2. Regional Upscaling Analysis
  – Assess regional storage and retention potential, range of capacity estimates for large scale CO2 storage in the Arches Province.
Task 7: Reporting and Tech Transfer

- Subtask 7.1. Project Updates
- Subtask 7.2. Meetings
- Subtask 7.3. Final Reports

<table>
<thead>
<tr>
<th>Deliverable Description</th>
<th>Deliverable Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Updated Project Management Plan as per FOA guidelines</td>
<td>Q1 2010</td>
</tr>
<tr>
<td>Hydrogeologic maps showing depth, thickness, hydraulic parameters, and other data from study region</td>
<td>Q4 2010</td>
</tr>
<tr>
<td>A completed conceptual hydrogeologic framework incorporated into the simulation codes will be presented in a letter report or slide presentation</td>
<td>Q3 2011</td>
</tr>
<tr>
<td>A report on baseline variable density flow model will be submitted</td>
<td>Q4 2011</td>
</tr>
<tr>
<td>A report summarizing key findings of the regional and local scale CO2 injection models</td>
<td>Q3 2012</td>
</tr>
<tr>
<td>Final technical report with detailed outcome of all tasks including implications for regional infrastructure deployment and a simulation framework that can be used to address emerging regulatory, monitoring, site selection, and risk assessment issues.</td>
<td>Q4 2012</td>
</tr>
</tbody>
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## Project Schedule

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Planned Completion Date</th>
<th>Milestone Verification Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revised Project Management Plan</td>
<td>10/23/2009</td>
<td>Submittal of Revised Project Management Plan to DOE/NETL</td>
</tr>
<tr>
<td>Geologic data Compilation</td>
<td>06/30/2010</td>
<td>Submit database of geotechnical data to DOE/NETL</td>
</tr>
<tr>
<td>Mapping and GIS of Mt. Simon</td>
<td>09/30/2010</td>
<td>Submit hydrogeologic maps showing depth, thickness, hydraulic parameters, and other data from study region</td>
</tr>
<tr>
<td>Development of Conceptual Model</td>
<td>06/30/2011</td>
<td>A completed conceptual hydrogeologic framework incorporated into the simulation codes will be presented in a letter report or slide presentation</td>
</tr>
<tr>
<td>Variable-Density Flow Modeling</td>
<td>09/30/2011</td>
<td>A topical report on baseline variable density flow model will be submitted</td>
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<tr>
<td>Multiphase Simulations</td>
<td>03/30/2012</td>
<td>A technical progress report summarizing key findings of the regional and local scale CO\textsubscript{2} injection models</td>
</tr>
<tr>
<td>Regional Storage Simulations</td>
<td>06/30/2012</td>
<td>Confirm regional storage scenarios with DOE/NETL</td>
</tr>
<tr>
<td>Final Technical Report</td>
<td>09/30/2012</td>
<td>Final technical report with detailed outcome of all tasks including implications for regional infrastructure deployment and a simulation framework that can be used to address emerging regulatory, monitoring, site selection, and risk assessment issues.</td>
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Next Steps

• Compile Class I data (in progress)
• Geology team meeting (March 30, 2010)
• Map facies distribution in the Mt. Simon
• Identify additional rock core at state core libraries for testing
• Develop geo-cellular model.