An overview of the Wabamun Area CO_2 Sequestration Project (WASP)

David Keith[a], Rob Lavoie[b], Chris Eisinger[a]
[a]Department of Chemical and Petroleum Engineering, University of Calgary, 2500 University Drive, Calgary T2N 1N4, Canada
[b]CalPetra Research and Consulting Inc., 214 – 110, 11th Avenue SW, Calgary T2R 0B8, Canada

Summary

David Keith (PI), Rob Lavoie (Project Manager), Hollie Roberts (Project Secretary), and Stefan Bachu (Project Review Advisor)

The Wabamun Area CO_2 Sequestration (WASP) study is a comprehensive characterization of large-scale CO_2 storage opportunities in the Wabamun Lake area. As a benchmark, the project is examining the feasibility of storing 20 Mt-CO_2/year for a 50 year period. This gigaton-scale storage project is one to two orders of magnitude larger than the commercial projects now under study. It fills a gap between the province-wide capacity estimates (which lack site specific studies of flow and geomechanics etc.) and the detailed commercial studies of small CO_2 storage projects currently underway.

WASP runs from January 2008 to June 2009 with a total budget of ~0.8 $m. We are grateful to our project sponsors: Alberta Energy Research Institute (AERI), Natural Sciences and Engineering Research Council (NSERC), TransAlta, TransCanada, ARC Energy Trust, Penn West Energy Trust, Epcor, Enbridge, ConocoPhillips Canada, Encana, StatOilHydro Canada, Total Canada, Computer Modeling Group and Golder Associates.

Study Area

Possible injection formations within the study area (Fig. 1) were assessed based on storage capacity, ease of injectivity, leakage likelihood, and interference with current petroleum production. Detailed studies are aimed at evaluating how the injected CO_2 moves and reacts within the reservoir, the storage integrity of the over and underlying shaly aquitards (impermeable barrier) formations, leakage risks of CO_2 along existing wells, and preliminary well injection design.

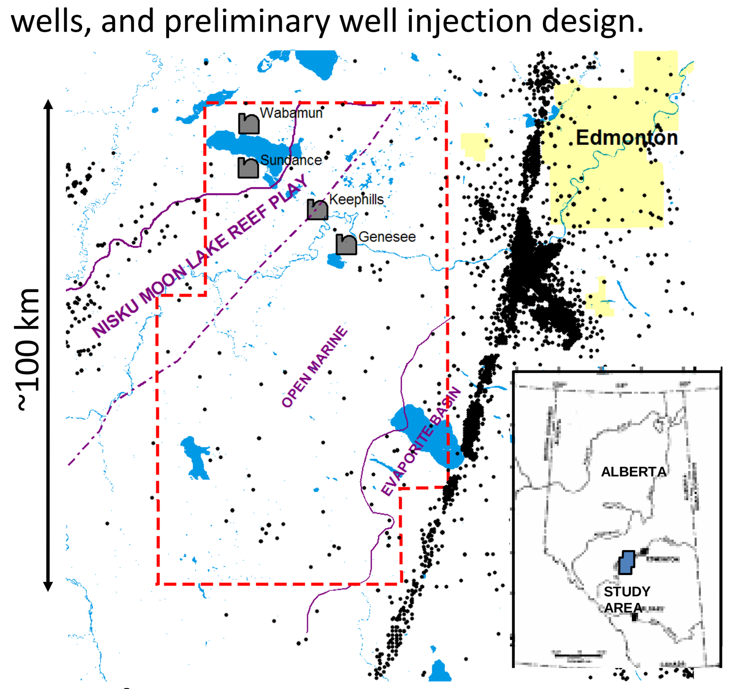


Figure 1. The WASP study area (red outline) and locations of four large power plants. Black circles show wells that penetrate the targeted stratigraphic interval. Purple lines mark important depositional boundaries of the Upper Devonian. The study area has an aerial extent of approximately 5000 km².

Geology

Frank Stoakes and Katrine Foellmer

Sub-Cretaceous carbonates and Pre-Cambrian sandstones are the primary targets of investigation. A saline aquifer, the Devonian Nisku (Fig. 2), is of particular interest as its depth, thickness, and stratigraphic configuration appear to be well suited for CO_2 injection and storage. The targeted facies within the Nisku are dolomitized open marine carbonates that show localized porous zones with 6 to >15% porosity and permeabilities >300 mD. The extent of these zones is not yet well defined however. Work conducted by the Alberta Geological Survey has provided a valuable starting point for this study.

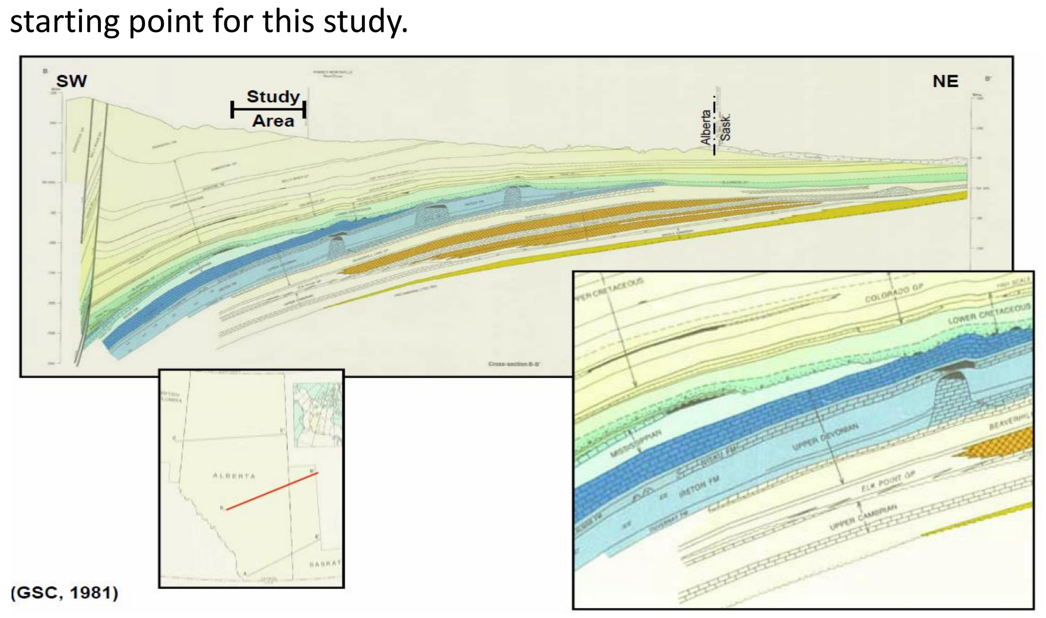


Figure 2. Geologic cross section of the Western Canadian Sedimentary Basin. A target formation is the Upper Devonian Nisku carbonate. WASP study area (Fig. 1) encompasses open marine, inboard margin, and hypersaline basin depositional zones.

Oil companies do not typically collect significant data for areas of limited production potential. Figure 3 illustrates the paucity of data in the WASP project area and how geological experience is required to estimate properties for portions of the target formation(s) that are lacking adequate data coverage.

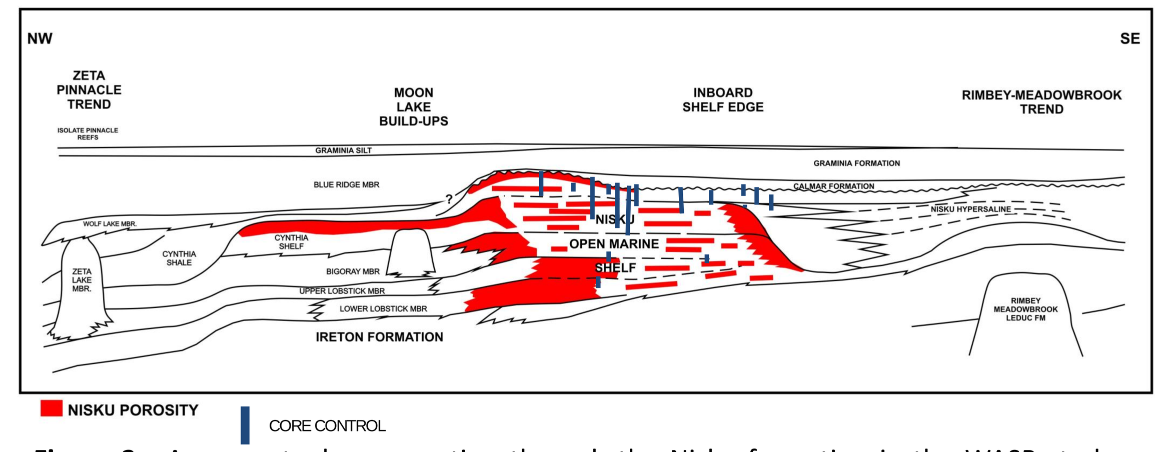


Figure 3. A conceptual cross-section through the Nisku formation in the WASP study area. Red areas indicate higher expected porosity and vertical blue columns represent existing well cores. It appears that most cores are from relatively low porosity regions.

Static Geological Model

Jerry Jensen and Chris Eisinger

A petrophysical model of the cap rock, proposed storage reservoir and underlying seals has been compiled. Information used for creation of the static model includes:

- Electric logs of varying vintage.
- Exisiting routine and special core analysis, lithological descriptions of core, and newly acquired core analysis for 8 wells in the study area.
- Drill stem tests of mixed quality.
- Petrographic studies, both publically available and newly completed for this study.
- Processed and raw geophysical data.

The model provides a means for storing information, integrating diverse measurement types and qualities, and providing estimates of important characteristics in unmeasured regions (Fig. 4). It is the basis for heterogeneous numerical flow simulations.

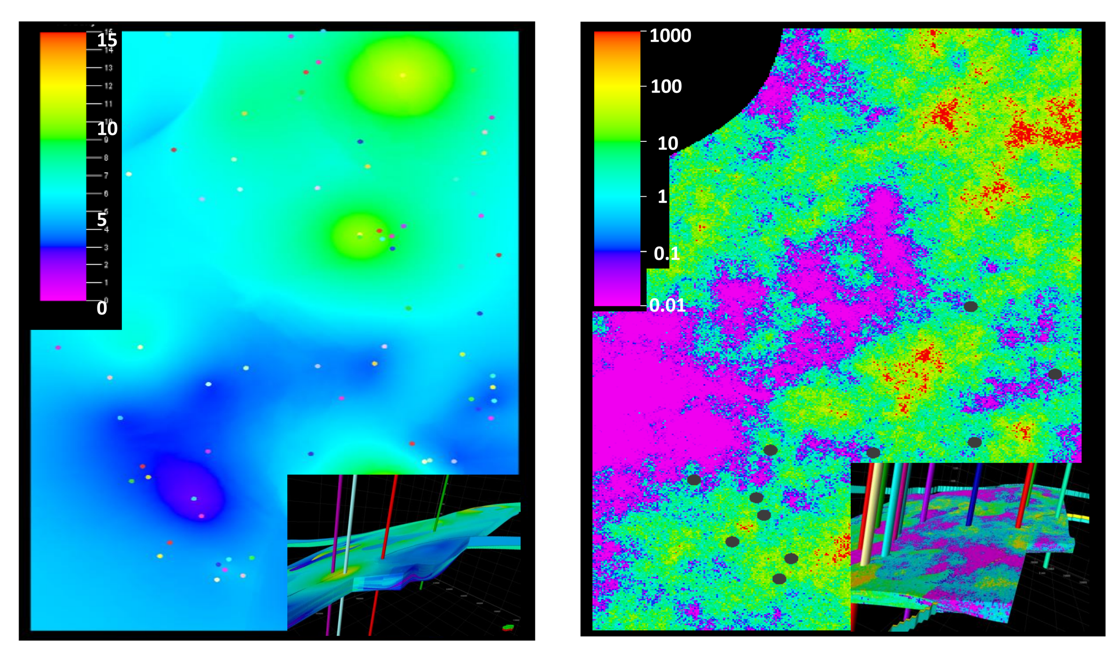


Figure 4. Preliminary modeling of Nisku porosity (%) (left) and permeability (mD) (right).

Geochemistry

Bernhard Mayer and Maurice Shevalier

A complete review and characterization of rock matrix mineralogy and aquifer fluid composition is underway. This work has identified that the formation water in the Nisku aquifer is a Na-Cl brine (Fig. 5) containing significant amounts of H_2S. This complicates and underscores the importance of understanding CO_2 plume movement with regards to cap rock integrity and existing wells in the vicinity of proposed injection sites.

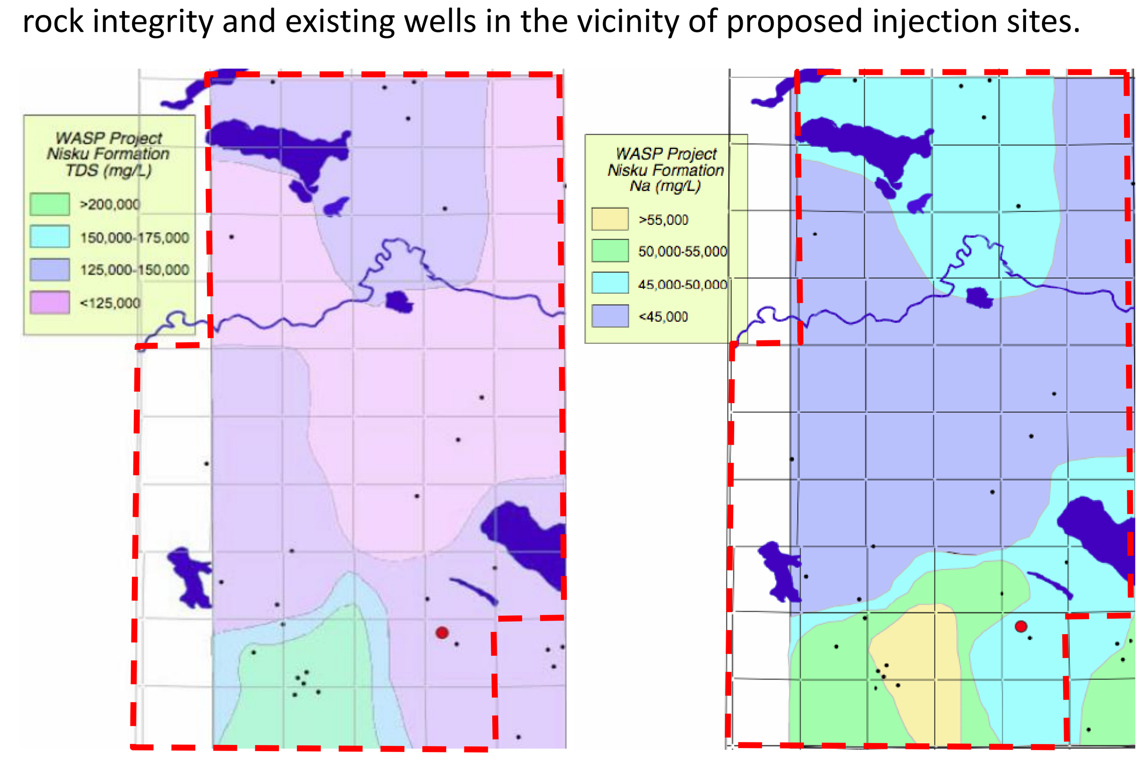


Figure 5. Regional baseline total dissolved solids (left) and Na concentration (right) of the Nisku Na-Cl aquifer brine (WASP area in red).

Geophysics

Don Lawton and Abdullah Alshuhail

Existing 2D seismic data are being compiled for the study area along with Lithoprobe seismic data, which were originally intended to map the earth's crustal thickness. Also, industry sponsors of the project are making processed 2D and 3D data available for interpretation and attribute analysis.

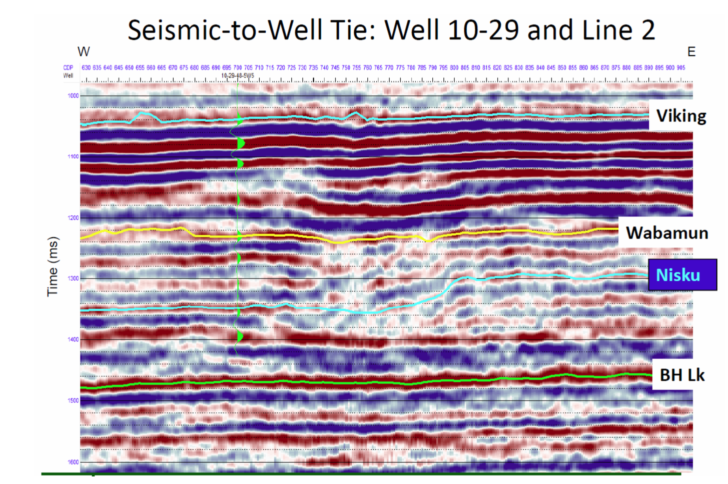
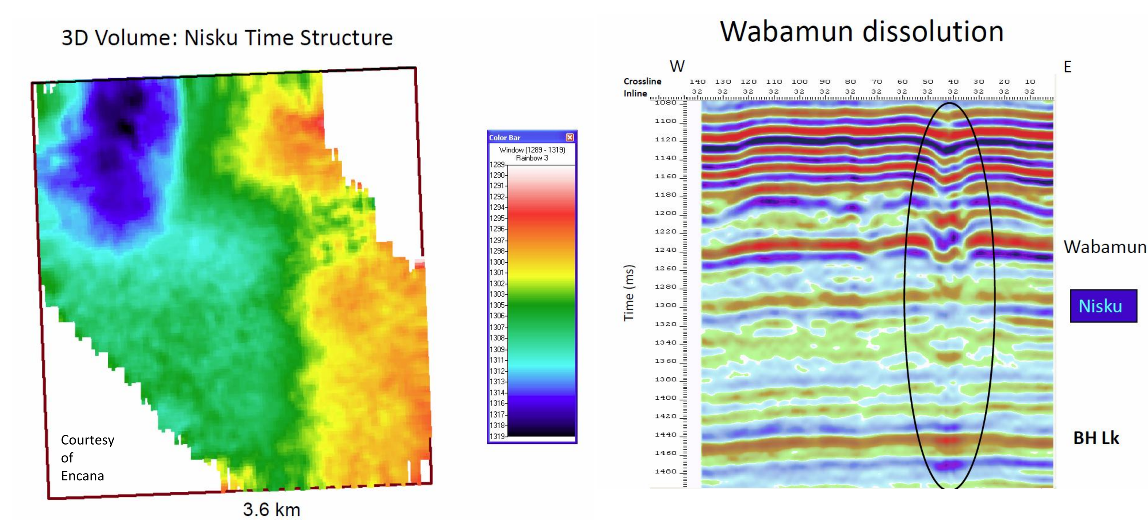


Figure 6. Seismic-based information showing Nisku carbonate structure and associated stratigraphy. Data are valuable for identifying potential flow boundaries and improving accuracy of the static model.



Reservoir Simulation

Seyyed Ghaderi and Yuri Leonenko

Reservoir simulations of CO_2 injection into the Nisku aquifer are providing estimates on how the CO_2 plume expands radially away from the injection well locations over the injection period (Fig. 7).

The rapid expansion of an elevated pressure zone around the injection wells illustrates how significant well spacing of a township or more between wells appears to be optimum.

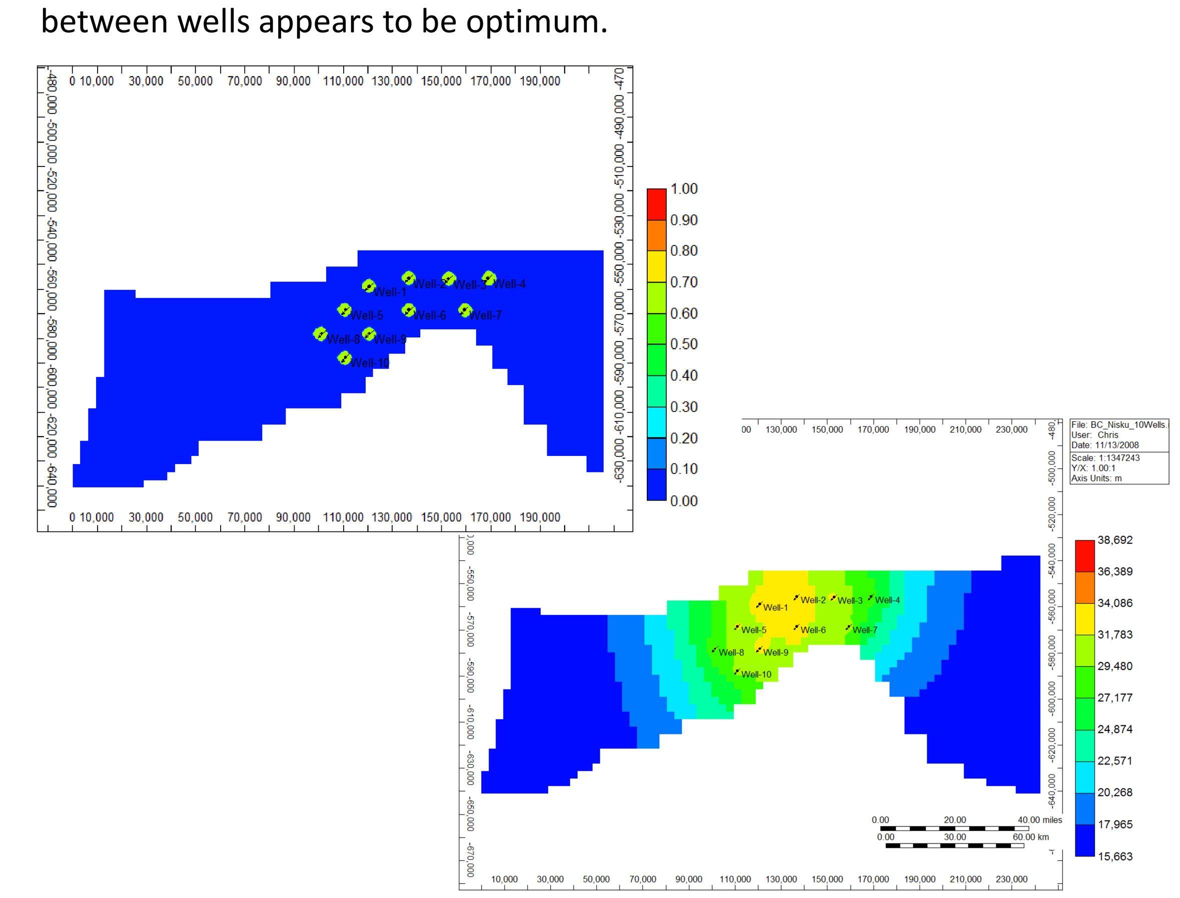


Figure 7. Preliminary reservoir simulations. The upper panel shows distribution of CO_2 saturation while the lower panel shows pressure distribution entities to aquifer after 50 years at total injection rate of 20 Mt-CO_2/yr. Simulations shown are based on homogeneous reservoir properties.

Geomechanical Analysis

Runar Nygaard, Somayeh Goodarzi, and Tony Settari

A geomechanical study of the integrity of the entire geological sequence is underway. The in-situ stresses have been approximated using extrapolation methods based on data available for existing well penetrations. The geomechanical study is evaluating the geomechanical potential for activation of faults and fractures caused by CO_2 injection. Non-destructive core analysis for compressibility and coefficients of thermal expansion provide useful information for geo-mechanical simulations of rock strength (Fig. 8). More comprehensive testing of the cap rock is planned for future wells in the area.

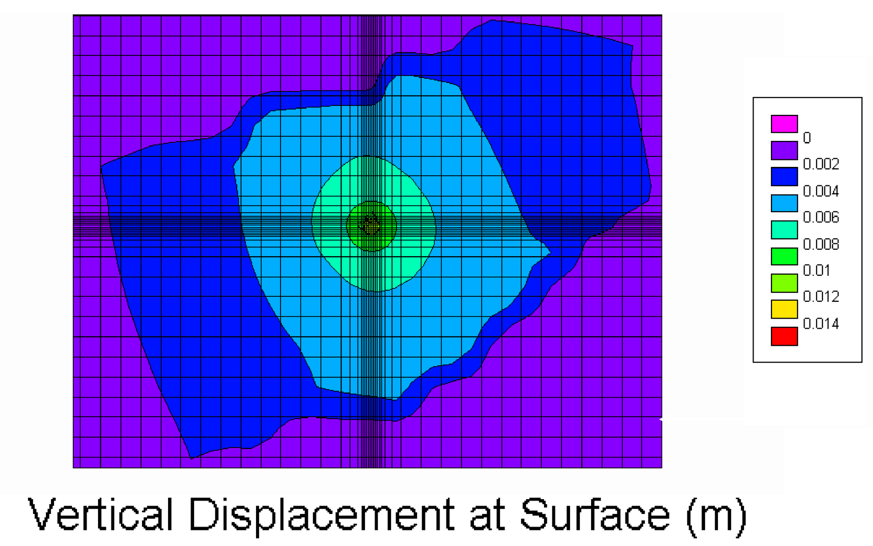


Figure 8. Coupled flow and geomechanical simulations showing vertical displacement at the surface due to CO_2 injection at depth.

Well Integrity

Runar Nygaard

The potential for well leakage is being evaluated through a detailed review of the current conditions of wells that exist in the estimated path of the CO_2 plume. An assessment of the number of wells that may require remediation is being developed. Methods of remediation will also be recommended based on emerging technologies for this purpose. Figure 6 provides some examples of improving well integrity with appropriate cement materials. Likelihood of leakage and severity of leakage will be evaluated based on a probabilistic risk based approach to extend the deterministic analysis currently used for CO_2 leakage projects.

The data and analytical approach will be compared with results from the coupled geomechanical reservoir simulation model. This work is currently planned as a joint effort between the U of C and external researchers.

Monitoring

Don Lawton

Monitoring strategies being examined for Phase II include:

- baseline 3D surface seismic surveys.
- baseline vertical seismic profiles (VSPs).
- baseline geochemical sampling at observation and injection wells, including aquifer fluids, soil and casing gas.
- passive seismic monitoring.
- timelapse surface seismic and VSP surveys.
- timelapse geochemistry surveys to monitor fluid-rock interactions.

In addition, other geophysical methods such as tiltmeter surveys (linked to the geomechanical prediction of surface motion), borehole gravity cross-borehole seismic tomography (depending on well availability), and borehole electromagnetic surveys will be evaluated. Direct monitoring of injection and observation well pressures and temperatures will also be important.

Regulatory & Legal Aspects

Nigel Banks

An accumulation of works on property and liability issues is now available for consideration with large scale CO_2 storage projects. These issues include: (1) ownership of pore space, (2) liability for trespass, (3) access to the surface for CCS, and (4) compulsory acquisition rules.

All of these issues are magnified in importance due to the scale of CO_2 injection volumes being considered for WASP.

Economics

David Keith

A cost model is being developed that includes drilling, completions, tie-in of injection wells, well operating costs, the cost of monitoring equipment, and monitoring programs. It will also include workover costs for CO_2 injectors and possible mitigation workover costs for wells penetrating the injection formation in the vicinity of the plume.