Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 1 (2009) 2817–2824
Energy Procedia
www.elsevier.com/locate/procedia

GHGT-9

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

David Keith[a] Rob Lavoie[b]

[a]University of Calgary

[b]CalPetra Research and Consulting Inc.

Abstract

Large stationary CO2 emitters are located in central Alberta with cumulative annual emissions in the order of 30 Mt CO2. This includes four coal-fired power plants in the Wabamun Lake area, southwest of Edmonton with emissions between 3 to 6 Mt/year each. The study will perform a comprehensive characterization of large-scale CO2 storage opportunities in the Wabamun area and analyze any potential risks. As a benchmark, the project will examine the feasibility of storing 20 Mt-CO2/year for 50 years within 30 km of Wabamun. This gigaton-scale storage assessment project is one to two orders of magnitude larger than the commercial projects now under study. It will fill a gap between Canadian province-wide capacity estimates (which do not involve site specific studies of flow and geomechanics etc.) and the detailed commercial studies of small CO2 storage projects currently underway. Unlike the commercial projects, this project is planned as a public non-confidential project lead by the University of Calgary (U of C).

The study will first assess the possible injection formations within the area based on storage capacity, ease of injectivity, leakage likelihood, and interference with current petroleum production. Then a few (1-3) specific targets will be selected for more detailed studies. The detailed studies will evaluate how the injected CO2 moves and reacts within the reservoir, the storage integrity of the over and underlying shaly aquitard, leakage risks of CO2 along existing wells and a preliminary well injection design. Finally, the study will do a preliminary assessment of currently available options for monitoring such large scale injection of CO2. Since the project is planned to develop a realistic scenario we will add an economic evaluation of the total project costs downstream of the capture and pipeline transportation components. Furthermore, the study will outline the necessary next steps to close any remaining knowledge gaps before planning and conducting the actual injection phase of the project.

Keywords: Type your keywords here, separated by semicolons ; Carbon Capture and Sequestration, Saline Aquifer CO_2 Sequestration, Climate Change Mitigation

Note: Due to the time constraints between the second WASP sponsors meeting and production of this paper, we were unable allow a thorough review by sponsors, therefore dispersion the paper contains a limited set of results.

doi:10.1016/j.egypro.2009.02.054

We will anticipate updating this paper prior to the GHGT-9 conference with more complete results once we have obtained permission from sponsors. Please visit www.ucalgary.ca/~keith/wasp.html for the most up-to-date version of this paper.

1. Introduction

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.

2. Study Description

The possible injection formations within the study area (Figure 1) were assessed based on storage capacity, ease of injectivity, leakage likelihood and interference with current petroleum production. A few (3) specific targets have been selected for more detailed studies. The 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 a preliminary well injection designs.

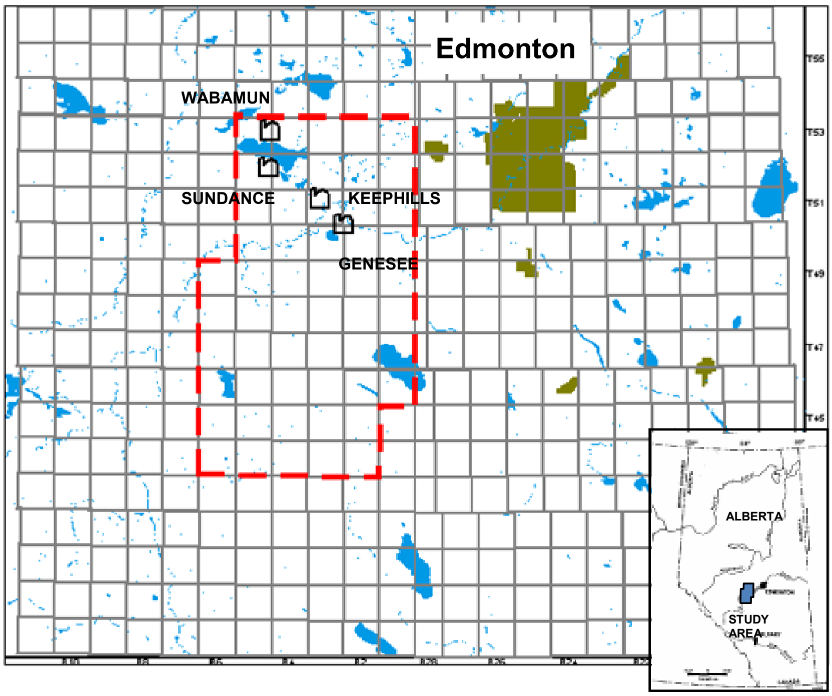


Figure 1. The WASP study area. The location of four large power plants is noted. The squares show township boundaries, each township is six statute miles (9.7 KM) on a side. The WASP study area has an aerial extent of approximately 5000 km2.

This paper describes the various components of the study and some early findings.

3. Geology and Static Geological Modeling - Dr. Jerry Jensen, Dr. Frank Stoakes, and Chris Eisinger

The project builds upon previous geological and geochemical studies conducted by the U of C and government based research. However, additional work, including an expansion of the geographical study area and acquiring additional details relating to variations in rock properties for specific formations was necessary.

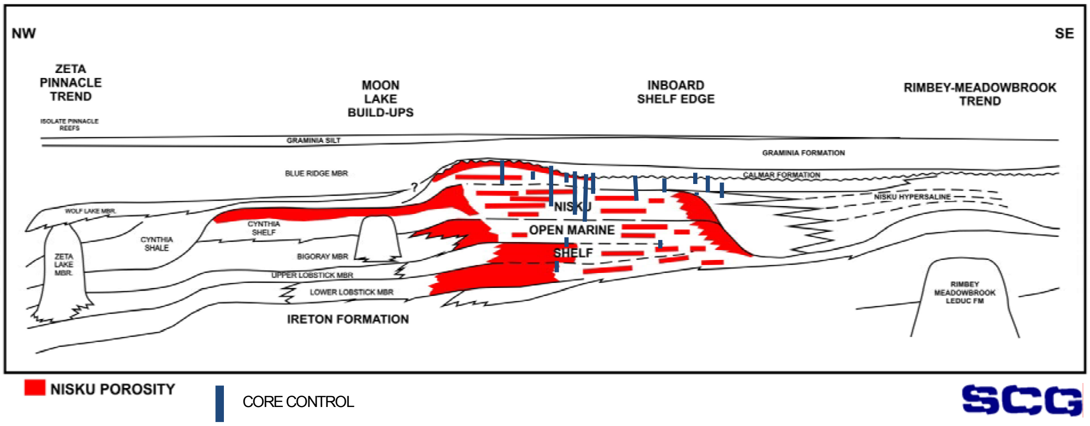
A geo-statistical model of the cap rock, the proposed storage reservoir and underlying seals has been compiled. The model currently contains geological, geophysical, and petrophysical characterizations of the system. The model provides a means for storing information, integrating the diversity of measurement types and qualities, and providing estimates of important characteristics in unmeasured regions. This static geological model is the basis for homogeneous project specific numerical reservoir simulations.

Information used for creation of the geological model include:

1. Electronic logs from wells drilled and logged through the zones of interest. Most of these were available from public domain information sources.
2. Routine and special core analysis and lithological descriptions of core. Again, most of this information was available from public sources, but permission to perform additional routine core analysis on 8 wells in the study area was obtained and the results of this analysis are incorporated.
3. Drill Stem Tests (DSTs), if they were conducted over the zone of interest, have been included in the model. Many of these available DSTs were quite old and of poor quality, however, and only the higher quality tests could be included.
4. Very little water analysis information was recorded in the public domain data. Testing of one currently producing water source well was possible (more on this in the geochemistry section of this paper).
5. Petrographical studies that were available in the pubic domain.
6. Processed and raw geophysical data.

The work conducted by the Alberta Geological Survey (AGS), Reference 1. provided an excellent starting point for the study. However, the current study required a doubling of the study area size to accommodate the necessary scale for a 20 Mt/yr CO_2 injection objective.

The availability of data is quite sporadic as a result of the way oil companies do not collect significant data from aquifers once it has been determined that oil or gas production is unlikely. Figure 2 illustrates how sporadic the data is and how significant geological experience is required to estimate properties for portions of the target formation(s) that are lacking adequate data coverage.



After Dr. Frank Stoakes

Figure 2. A schematic cross-section through the Nisku formation in the WASP study area. Red areas indicate locations where porosity is expected to be high, vertical blue columns are present areas where core is available, note that it appears that most core is from relatively low porosity regions.

4. Geochemical Analysis - Dr. Bernhard Mayer

Since CO_2 may act as a cap rock dissolving agent over time, this will need to be better understood and quantified before such large scale sequestration can be justified. To this end, a complete review and characterization of rock matrix mineralogy and aquifer fluid composition is underway. This work has identified that the formation brine in the Nisku aquifer may be saturated with H_2S, further complicating and underscoring the importance of understanding CO_2 plume movement and the integrity of the cap rock and existing wells in the vicinity of proposed injection sites. A thorough modeling effort on the geochemical aspects of CO_2 storage over the long term is planned.

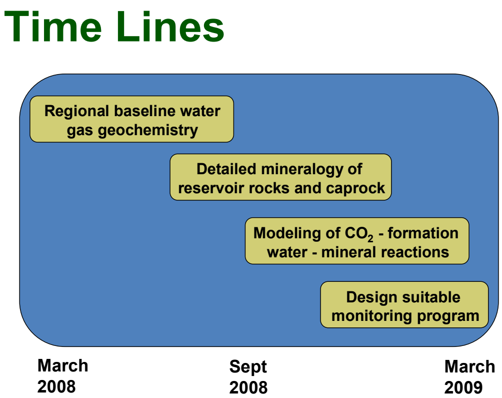


Figure 3. WASP project timeline.

5. Geophysics - Dr. Don Lawton, Abdullah Alshuhail

Pre-processed and raw seismic data are being compiled for the study area. A set of Geological Survey of Canada Litho-Prob lines which where originally intended to map the earth's crust thickness are available in the study area. Also, industry sponsors of the project are making both processed and raw geophysical data available for interpretation.

6. Reservoir Simulation - Dr. Yuri Leonenko and Seyyed Ghaderi

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, See Figure 4.

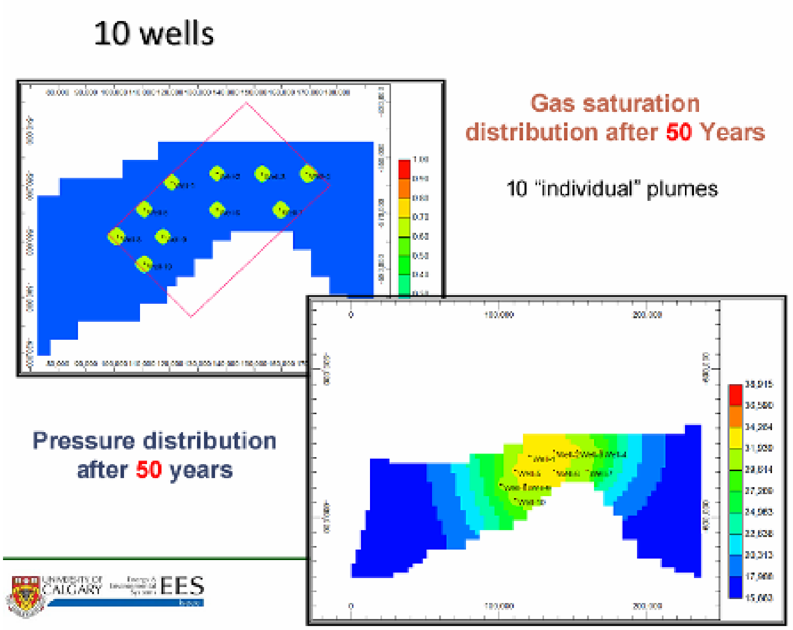


Figure 4. Preliminary reservoir simulations. The upper panel shows distribution of CO2 saturation while the lower panel shows pressure distribution entities to aquifer after 50 years at total injection rate of 20 Mt-CO2/yr. Note that these simulations are based on homogeneous reservoir properties rather than the geostatistical model.

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. Simulations will be repeated for the other 2 candidate horizons, the overlying Wabamun formation and the deepest formation in the stratigraphic sequence, the Basal Cambrian Sands.

A companion paper to this poster presentation provides further details about the simulation results for the Nisku formation cases.

7. Geomechanical Analysis - Dr. Runar Nygaard, Dr. Tony Settari, Somayeh Goodarzi

To evaluate the long term storage safety of the project, 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 drilling 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. Some non-destructive core analysis of compressibility and coefficients of thermal expansion are providing useful information for geo-mechanical simulations of rock strength. However, collection of fresh core for more comprehensive testing of the cap rock is planned for future wells in the area. Figure 5 illustrates early numerical results of a coupled flow and geomechancial simulation.

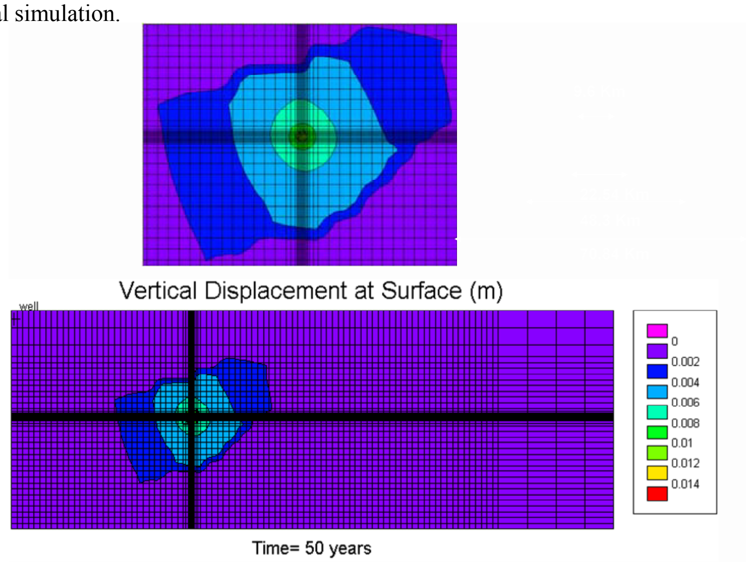


Figure 5. Coupled flow and geomechanical simulations. These results show vertical displacement at the surface produced using a the geomechanical call a model and the Geosim coupled flow-geomechanical simulator.

8. Well Integrity - Dr. 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.

Integrated risk assessment may include such components as:

- Stochastic geological models of a large area
- More detailed stochastic geological models of selected injection sites
- Numerous detailed reservoir numerical models coupled to geomechanical numerical models to identify rate of plume expansion and reservoir pressure fields over time during and post injection
- Assessment of existing wells penetrating the proposed injection formation and located withing the vicinity of the estimate range of the outer edge of the CO_2 plume
- Quantative Expert risk assessment of well leakage probabilities and mitigation plans
- Risk management matrix identifying as many possible technical, safety, and environmental risks of this magnitude of CO_2 sequestration.

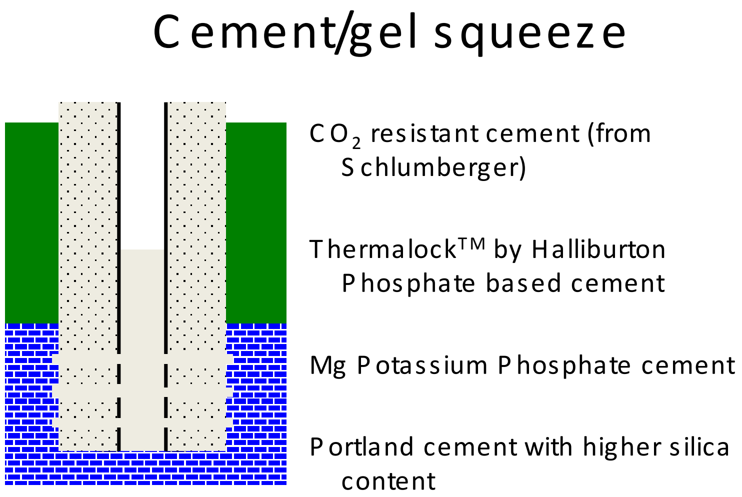


Figure 6. Schematic illustration of possible options for CO2 storage well completion and abandonment.

9. Monitoring - Dr. Don Lawton

Monitoring the CO_2 plume and detecting possible eventual leakage will be an important future activity once actual CO_2 injection begins. The current project scope will include identifing necessary pre-injection baseline studies, reviewing currently available monitoring techniques, and scoping future monitoring activities. As part of this we will build on the seismic expertise at the University of Calgary (U of C). Monitoring strategies will include:

- baseline 3D surface seismic surveys, to characterise the site at a local scale (4 sq miles)
- baseline vertical seismic profiles (VSPs) recorded in an observation well at the the proposed site.
- baseline geochemical sampling at observation and injection wells, including aquifer fluids, soil and casing gas.
- passive seismic monitoring within the observation well, Figure 7.
- timelapse surface seismic and VSP surveys to track the CO2 plume within the aquifer.
- timelapse geochemistry surveys to monitor fluid-rock interactions.

In addition, other geophysical methods such as, tiltmeter surveys, borehole gravity cross-borehole seismic tomography (depending on well availability) and borehole electromagnetic surveys will be evaluated as well as directly monitoring injection and observation well pressures and temperatures.

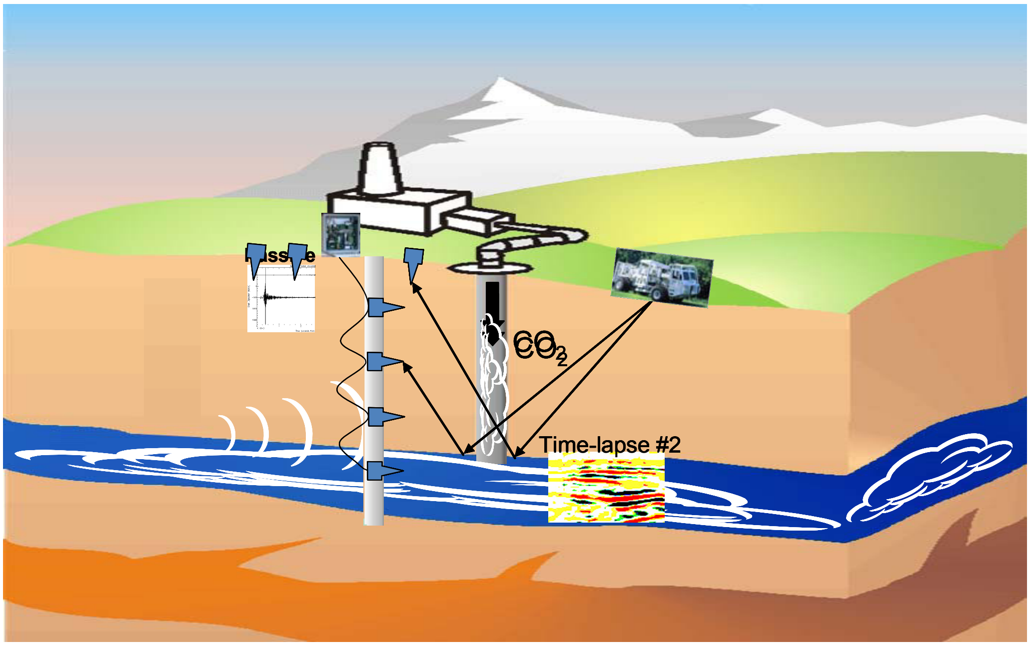


Figure 7. Schematic illustration of possible geophysical monitoring methods at the WASP site.

10. Regulatory and Legal Review - Dr. Nigel Banks

A accumulation of works on property, and liability issues is now available for consideration with large scale CO_2 storage projects. These issues include:

- Ownership of pore space
- Liability for trespass
- Access to the surface for CCS
- Compulsory acquisition rules

All of these issues are magnified in importance due to the scale of CO_2 injection volumes being considered. As an illustration, a plume radius of 4.5 km at the end of a 50 year injection project is possible. Injection wells may need to be spaced at greater than a township apart, but a total of 10 to 20 wells is likely to be the maximum requirement (based on early simulation results) in the area being considered.

11. Economics - Dr. David Keith

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

References:

1. Test Case for Comparative Modelling of CO2 Injection, Migration and Possible Leakage - Wabamun Lake Area, Alberta, Canada: http://www.ags.gov.ab.ca/co2_h2s/wabamun/Wabamun_base.html