Weyburn-Midale: Recent Developments and Best Practice Manual

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IEAGHG Weyburn-Midale CO₂ Monitoring & Storage Project (WMP) 2000 to 2012

Commercial EOR operations in Weyburn and Midale oilfields utilise anthropogenic CO₂

Over 20Mt of CO₂ injected and stored since 2000

WMP has used these sites to study technical aspects of CO₂ geological storage
Best Practice Manual

Introduction
  • Purpose, scope, context, background, ...

Characterization
  • Regional geology
  • Regional hydrogeology
  • Containment characterization
  • Geomechanical characterization
  • Geochemical characterization

Performance predictions
  • CO₂ migration
  • Capacity and mass partitioning
  • Containment

Geochemical monitoring
  • Groundwater
  • Soil gas
  • Reservoir fluids
  • Reservoir/caprock core

Geophysical monitoring
  • Geophysical char. of rock-fluid system
  • Feasibility studies
  • Downhole monitoring methods
  • 3D seismic methods

HM and performance validation
  • Prediction/measurement comparison
  • Revision of Geologic Models

Well integrity
  • Integrity assessment
  • Design considerations
  • Remediation and conversion
  • Abandonment considerations
  • Integrity monitoring and field testing

Risk assessment

Community outreach
Integrated technology portfolio for geologic CO₂ storage

Chapter 2
Site Characterization

- Define & boundary conditions
- Initial conditions

Chapter 3
Modeling

- Predict isolation performance

 Chapters 4-5
Monitoring

- Measure isolation performance

Chapter 6
History Match

- Compare results: resolve discrepancies & refine CMM capabilities

- Calibrate predictive models
- Temporal-lapse data for iterative site char & modeling refinement
- Demo regulatory compliance
- Crucial for public acceptance

• Demo site feasibility
• ID screening criteria
• Design site char, injection, & monitoring strategies
• Quantify risk (CFC uncertainty)

Weyburn Flow Unit Model

IEAGHG Weyburn-Midale CO₂ Monitoring and Storage Project

Petroleum Technology Research Centre
Staged Study Areas:

Regional GeoScience Framework Area of Investigation:

- >30,000 wells in study area
- 11,121 drill stem tests
- 6,292 wells with digital core analyses
- 9,207 formation water chemistry samples
Revised Model

Was improved with:

1. More detailed aquitard characterization
2. Larger area
3. More accurate subcrop mapping
4. Increased well density (800 in area)
Slightly leaky wells: 1 micron

**Containment: Jurassic aquifer**

Newcastle: ---
Mannville: ---
Jurassic: 1.4 Mt

Newcastle: ---
Mannville: ---
Jurassic: 20 largest pools, 1.3 Mt

• Jurassic: small pools, migrates NE
Natural Analogue Study
3D Time-Lapse Seismic: CO$_2$ Distribution

Monitoring regional subsurface distribution of CO$_2$:

- Verifying storage conformance
- A primary input for updating reservoir models
- Optimal resolving capability
- Sensitive to low CO$_2$ saturations
- Data repeatability is fundamental
3D Time-Lapse Seismic: Pressure vs. CO₂ Saturation

Inversion of prestack seismic data:

- Semi-quantitative CO₂ saturation and P changes
- Results are model-based
- Characterization of reservoir rock physics is essential
- Monitoring survey design is important as “long offset” data are required
**Interval travel-time changes:**

- Semi-quantitative apportionment of CO₂ within various layers of the storage complex
- Results are model-based
- Characterization of reservoir rock physics is essential
- Data repeatability is essential
Seismic anisotropy as a proxy for vertical fracturing:

- Means of identifying potential fracture zones regionally
- Scale of individual fractures and hydraulic conductivity is not resolved
- “Fracture zones” may warrant subsequent attention
Passive Seismic Monitoring

Documentation of time, magnitude and location of seismicity:
• Public assurance
• Integrity of the sealing units
• Injection control
BPM chapter 4: Geochemical monitoring

4.1 Summary

4.2 Introduction
   4.2.1 Context
   4.2.2 Objectives
   4.2.3 Components

4.3 Soil gas

4.4 Groundwater

4.5 Reservoir fluids
   4.5.1 Produced brines & gases
   4.5.2 Produced hydrocarbons

4.6 Reservoir/caprock core

4.7 Recommendations
Soil gas monitoring: Overview

**Research Providers**
- ✓ Dave Jones et al. (BGS)
- ✓ Dave Risk et al. (StFX)

**Measurements**
- ✓ CO₂, O₂, N₂ conc.
- ✓ CH₄, C₂H₆, C₂H₄ conc.
- ✓ Rn, He conc.
- ✓ CO₂ flux
- ✓ C isotopes

**Methods**
- ✓ Single-depth (BGS), depth-profile (StFX) CO₂
- ✓ CO₂ flux (BGS)
- ✓ Continuous CO₂ (BGS), CO₂ flux (StFX)
- ✓ δ₁³CO₂, δ¹⁴CO₂
Soil Gas Monitoring Data

soil gas CO$_2$ - October, 2011
Carbon Isotopes

Scatter plot of $^{13}$C on CO$_2$ with $^{14}$C on CO$_2$
- Control, Investigation (Event 1 and Event 2)
and Injection Gas samples

- Control Site (Event 1)
- Control Site (Event 2)
- Investigation Site (Event 1)
- Investigation Site (Event 2)
- Injection (DGC)
- Injection (Recycle)
- Literature control site 1
- Literature control site 2
- Teapot Dome oil field
- Rangely CO2-EOR
Chapter 6: History matching & performance validation

6.1 Summary

6.2 Introduction
   6.2.1 Context
   6.2.2 Objectives

6.3 Prediction/measurement comparison
   6.3.1 Core-flood experiments
   6.3.2 Fracture-flow experiments
   6.3.3 Field-scale brine chemistry

6.4 Revision of geological models
   6.4.1 Fracture flow
   6.4.2 Reservoir transport properties
   6.4.3 Reservoir mineralogy

6.5 Recommendations
Well Integrity: Field Testing Program

Modified coring tool: 
→ Direct confirmation of cement
Pressure transient test confirms cement effectiveness
RA and Geological Storage of CO₂

104% Increase

And for just the final? year of each Phase:
2004 – 4 and 2011 – 57

670% Increase

1,325% Increase
Process: Geosphere & Biosphere Risk

Geosphere Risk Assessment

Technical Inputs
- Wellbore integrity research
- Characterisation of reservoir characteristics & transport of CO₂
- Seismicity of area
- Characterisation of CO₂ reactions in reservoir
- Monitoring techniques & effectiveness

Outputs
- CO₂ risk events (initiating event & pathway) & ranking
- Mass of CO₂ released if event occurs
- Likelihood of each event occurring & releasing CO₂

Biosphere Risk Assessment

Other Technical Inputs
- Characterisation of aquifers
- Characterisation of surface water
- Characterisation of soils / sediments
- Behaviour of CO₂ in soils, sediments, groundwater, surface water
- Receptors in environment
- Toxicology (animal, plant, human)

Outputs
- Risks to biosphere assets (ranking & severity)

Stakeholder Engagement
- Stakeholder Values
- Building Capacity to Engage
- Acceptability of Risks

Mitigation Measures
Containment Risk Profile

The storage will retain most of the CO₂ injected

Weyburn - Containment risk profile

No further work would be required to demonstrate containment acceptability.
Identifying Biosphere Assets Most At Risk From Pathways

Initiating Events - Risk to Assets

Risk Level

0.00001  0.0001  0.001  0.01  0.1  1  10  100  1000

- Illness, injury, fatality
- Tourism
- Oil and gas
- Agriculture
- First Nation heritage
- Heritage
- Amenity - sensory, perception
- Amenity - recreation
- Species
- Habitat, communities, assemblages
- Ecosystem function
- Property/infrastructure
- Target Risk Level

EOR Minor faults
EOR Through faults
Nat Seismicity-fault reactivation
Nat Seismicity-new fracs
Nat Seismicity-wells
EOR Induced chem-fracs
EOR Induced P/T-fault reactivation
EOR Induced P/T-new fracs
Wells Micros fracs, annuli
Wells Casing corrosion
Wells cement
Thanks for your attention