QUEST CCS PROJECT

UK-Canada CCS Mission
University of Calgary
August 20, 2012

Anita Spence – Quest Project Manager
Location

Canada

Alberta

Fort McMurray

Fort Saskatchewan

Calgary

Edmonton
General Features

- Quest CCS Project - fully integrated CCS (capture, transport & storage)
- JV among Shell (60%); Chevron (20%); and Marathon (20%)
- Located at Scotford Upgrader Complex
- 35% reduction of Upgrader CO₂ emissions
- Uses existing technology
- Capacity to capture over one million tonnes of CO₂ per year for 25 years
- Equiv to emissions from 175,000 cars
Costs/Revenues and Funding Agreements

- **Total cost of Quest – Cdn$1.4 billion**
  - Includes Pre FID, capital and 10 years opex
  - Capital Ratio: 80% Capture, 10% pipeline, 10% wells

- **Revenues – GHG offsets (credits)**
  - Net amount – stored CO2, less direct and indirect emissions
  - Credits to be used first by Shell’s Alberta assets for regulatory compliance

- **Government Funding Support – Cdn$865 million**
  - Cdn$120 million Canadian Federal Government (Pre FID)
  - Cdn$745 million Alberta Province (Construction, Startup and 10 years operation)
  - Extensive knowledge sharing
  - Stringent monitoring (MMV) plan
  - NPV Zero commitment
Hardware

- Quest CCS Project CO₂ capture plant located in Fort Saskatchewan, approx 50 km N.E. of Edmonton, Alberta
- Capture at the Scotford Upgrader from 3 Hydrogen Units (SMR), Amine system
- CO₂ transported by 12 inch pipeline to storage, with 6 inch laterals
- The pipeline will travel approx. 65 km north of the Scotford Upgrader to the chosen injection locations
- Route selected to meet stakeholder requirements:
  - 28 km follows existing ROW
  - Drilled under North Saskatchewan River
  - 30+ re-routes to accommodate landowner wishes
- 3 injection wells
- Shell ADIP-X Amine process (99%+ pure CO2), 1.2 MTPa capacity
- Multistage centrifugal compressor to 8.5 Mpa (supercritical state)
- TEG dehydration unit
Storage

- Saline aquifer storage
- Basal Cambrian Sands (BCS) selected
  - Storage zone is a formation called Basal Cambrian Sands (BCS) 2,300 m, Prairies deepest sandstone
  - Multiple caprock and salt seal layers, no significant faulting visible from wells or seismic
  - The BCS is well below hydrocarbon bearing formations and potable water zones in the region
  - Relatively few wells drilled into the BCS, none within 10 km of the proposed storage site

- Wells and Drilling
  - 3 well plan, 5 more if required
  - Conventional drilling methods
  - Multiple steel casings for wells, 3 in freshwater zone, all cemented to surface
## BCS Storage Zone Properties

<table>
<thead>
<tr>
<th>Criterion Level</th>
<th>No</th>
<th>Criterion</th>
<th>Unfavourable Condition</th>
<th>Preferred or Favourable Condition</th>
<th>BCS Storage Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical</td>
<td>1</td>
<td>Reservoir-seal pairs; extensive and competent barrier to vertical flow</td>
<td>Poor, discontinuous, faulted and/or breached</td>
<td>Intermediate and excellent; many pairs (multi-layered system)</td>
<td>Three major seals (Middle Cambrian Shale [MCS], Lower Lotsberg and Upper Lotsberg Salts) continuous over entire CO₂ storage AOI. Salt aquicludes thicken up dip to NE.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Pressure regime</td>
<td>Overpressured pressure gradients &gt;14 kPa/m</td>
<td>Pressure gradients less than 12 kPa/m</td>
<td>Normally pressured &lt;12 kPa/m</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Monitoring potential</td>
<td>Absent</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Affecting protected groundwater quality</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Essential</td>
<td>5</td>
<td>Seismicity</td>
<td>High</td>
<td>&lt;=Moderate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Faulting and fracturing intensity</td>
<td>Extensive</td>
<td>Limited to moderate</td>
<td>Limited. No faults penetrating major seal observed on 2D or 3D seismic.</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Hydrogeology</td>
<td>Short flow systems, or compaction flow, Saline aquifers in communication with protected groundwater aquifers</td>
<td>Intermediate and regional-scale flow</td>
<td>Intermediate and regional-scale flow-saline aquifer not in communication with groundwater</td>
</tr>
<tr>
<td>Desirable</td>
<td>8</td>
<td>Depth</td>
<td>&lt;750-800 m</td>
<td>&gt;800 m</td>
<td>&gt;2000 m</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Located within fold belts</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Adverse diagenesis</td>
<td>Significant</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Geothermal regime</td>
<td>Gradients ≥35°C/km and low surface temperature</td>
<td>Gradients &lt;35°C/km and low surface temperature</td>
<td>Gradients &lt;35°C/km and low surface temperature</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Temperature</td>
<td>&lt;35°C</td>
<td>≥35°C</td>
<td>60°C</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Pressure</td>
<td>&lt;7.5 MPa</td>
<td>≥7.5 MPa</td>
<td>20.45 MPa</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Thickness</td>
<td>&lt;20 m</td>
<td>≥20 m</td>
<td>&gt;35 m</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Porosity</td>
<td>&lt;10%</td>
<td>≥10%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Permeability</td>
<td>&lt;20 mD</td>
<td>≥20 mD</td>
<td>Average over AOI 20-500 mD</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Caprock thickness</td>
<td>&lt;10 m</td>
<td>≥10 m</td>
<td>Three caprocks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L. Lotsberg Salt 9-41 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>U. Lotsberg Salt 53-94 m</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Well density</td>
<td>High</td>
<td>Low to moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

Geological Formation Area of Interest (AOI)

- Pore space area required to ensure no pressure for interference
CO2 Containment Loss Risk and Mitigation Diagram

- Bulls-eye hazard assessment diagram – left: possible causes; centre: event; right: consequences
### Measurement, Monitoring and Verification (MMV Plan)

<table>
<thead>
<tr>
<th></th>
<th>Pre-Injection</th>
<th>Injection</th>
<th>Closure</th>
<th>Post-Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atmosphere</strong></td>
<td></td>
<td>Line-of-Sight CO₂ Flux Monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biosphere</strong></td>
<td></td>
<td>Remote sensing, Brine &amp; CO₂ Tracer Monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hydrosphere</strong></td>
<td></td>
<td>Groundwater Monitoring Wells: Water Electrical Conductivity, pH, Brine &amp; CO₂ Tracer Monitoring</td>
<td>Landowner Water Wells: Brine &amp; CO₂ Tracer Monitoring</td>
<td></td>
</tr>
<tr>
<td><strong>Geosphere</strong></td>
<td></td>
<td>Time-Lapse 3D VSP</td>
<td>Time-Lapse 3D Surface Seismic</td>
<td>INSAR</td>
</tr>
<tr>
<td><strong>Wells: Monitors</strong></td>
<td></td>
<td>WPGS Observation Wells: Down-Hole Pressure &amp; Temperature</td>
<td>WPGS Observation Wells: Down-Hole Microseismic Monitoring</td>
<td>BCS Observation Well: Down-Hole Pressure &amp; Temperature</td>
</tr>
<tr>
<td><strong>Wells: Injectors</strong></td>
<td></td>
<td>Injection Rate Metering, Tracer Injection</td>
<td>Down-Hole Pressure &amp; Temperature, Distributed Temperature Sensing, Distributed Acoustic Sensing, Annulus Pressure Monitoring, Wellhead Pressure &amp; Temperature, Wellhead CO₂ sensor, Mechanical Well Integrity Testing, Operational Integrity Assurance</td>
<td>CBL, USIT</td>
</tr>
</tbody>
</table>

- Comprehensive plan developed – entire biosphere and lifecycle
- Independently (DNV) certified MMV and storage plan
Regulatory Framework

- Provincial GHG framework established
  - CCS Act passed in Nov 2010, establishing overall structure
  - Pore space regulations in place with Quest successfully acquiring required area in May 2011
  - Participation in Regulatory Framework Assurance (RFA) process and GHG Offset Protocol revisions
  - No Federal framework to date – possible 2013

- Regulatory approvals near complete
  - Federal compliance achieved – EIA submitted, completed internal and public review
  - Bundled provincial application submitted – Upgrader amendment, Pipeline, Well and Storage
  - 3 rounds of Information Requests (200+) by provincial regulator, the ERCB
  - ERCB public hearing March 2012
  - ERCB Decision Report received July 10th, 2012
  - Upgrader Environmental Plan update approved August, 2012
  - Still waiting on Upgrader Amendment, Pipeline and Storage approvals.
Stakeholder Engagement

- Extensive and continuous public engagement
  - 1st public project disclosure: Oct 2008 (booklet, news release and open house)
  - Stakeholder consultation program initiated Jan 2010
    - All landowners within 450 of either side of pipeline right of way
    - All landowners in storage AOI
    - All Landowners within 5 km of Scotford
    - Municipal districts/local authorities
    - Industry stakeholders
    - Provincial / Federal regulators
    - Aboriginal communities
  - Open Houses: March, November 2010 and September 2011
  - Quest Café’s: June, October 2011
  - Bi-annual County and Town Council updates
  - Quest phone line, e-mail address and web site available for project questions
Stakeholder Engagement Results

- General positive public response
  - Large majority of open house visitors and comment cards positive
  - Minimal public objections to project at ERCB hearing

- Issues management
  - Issues raised by stakeholders:
    - Pipeline / well / storage failure
    - Pipeline routing
    - Containment / leakage
    - Groundwater contamination
    - Perception; relatively new technology, unknown in the area
    - Land use conflicts/ value
    - Incident Management / emergency preparedness and safety
  - Face to face resolution where possible with concerned stakeholders
  - Project adjustments where possible (>30 pipeline re-routes)
  - All issues addressed at ERCB hearing
Timeline

- Regulatory Hearing March 2012
  - Approvals expected Q3 2012
- FID planned Q3 2012
- Well Program Q4 2012
  - 2 additional injection wells
  - Associated deep monitoring and groundwater wells
- Capture & Pipeline in Execute phase
  - Capture at 60% model review stage
  - Early construction Q3 2012
  - Capture construction start May 2013, pipeline Q3 2013
- Operations Handover Q2 2015
  - Full production Q3/4 2015
Next Steps

- Into ‘Execute’ phase to startup in 2015

- 2012 major activities:
  - Secure FID
  - Completion of detailed engineering
  - Continue operations readiness
  - Early Scotford construction fall 2012
  - Begin major construction early 2013 (mod yard work)
  - 2\textsuperscript{nd} and 3\textsuperscript{rd} injection wells drilled - fall 2012
  - MMV baseline data gathering
  - Completion of regulatory applications
  - Ongoing stakeholder management
Thank You!
Opportunity Realization Manual (ORM) Project Management Process

- Quest moved successfully from ‘Define’ to ‘Execute’
- Assurance Review concluded with subsequent Decision Gate 4 approval

No significant deviations from Project Plan

Upcoming focus in Execute (3 year period to 2015):

- Completion of detailed engineering
- Construction
- Operations readiness
Geological Formation – BCS Complex

Basal Cambrian Sand (BCS)

Complex Location
Geological Formation analytical work

- Prime subsurface activities of past period have been validating BCS properties
- Some analysis done using older existing data
  - 2D seismic analysis
  - Vintage well data
  - Earlier Quest test well data
  - Regional reports
- New data and analysis conducted in past period
  - 3\textsuperscript{rd} test well drilled
  - 3D seismic of intended area
  - Reservoir modeling
  - Feasibility studies
Geological Formation Containment Risks

- Extensive investigation into potential containment risks
  - Migration along a legacy well
  - Migration along an MMV well
  - Migration along an injector well
  - Migration along a matrix pathway
  - Migration along a fault pathway
  - Induced stress re-activates a fault
  - Induced stress opens fractures
  - Acidic fluids erode geological seals
  - Third party CO₂ migration

- Potential consequences explored
  - Hydrocarbon resources impacted
  - Groundwater impacted
  - Soil impacted
  - CO₂ released to atmosphere

- Mitigations
  - Each risk and consequence has barriers in place
  - Some barriers are natural (salt seals, etc)
  - Some are project initiated (MMV plan for early warning and correction, etc)
Initial injectivity results positive (one well theoretically feasible)
General Project Assessment

- General Assessment – Very Positive
  - Major project attributes (technical, costs, regulatory, stakeholders) tracking as planned

- Project Successes
  - Government fiscal support
  - Pore space tenure
  - Capture and Pipeline Front End Engineering and Design (FEED) completion and Assurance
  - Test Well and aquifer property verification
  - Stakeholder engagement
  - Pipeline routing finalization
  - DNV certification of the storage development plan
  - Regulatory Hearing

- Challenges
  - Capital Costs
  - Schedule Pressure
  - Regulatory Uncertainty (GHG Protocols, Federal framework)