QUEST – MMV OVERVIEW

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Shell
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1) Presumption is zero leakage to atmosphere post-injection
   - Risk-based MMV
   - Good site selection is key
   - Revisit operational plans if migration is detected outside of primary store
   - Best engineering estimate to quantify leakage to atmosphere
   - Surface CO\textsubscript{2} flux can be highly variable (many factors influence) – assurance monitoring

2) Fugitives in dense phase system would be readily visible. GHGRP fugitive emission factors not appropriate for CO\textsubscript{2} systems.
• Capture at the Scotford Upgrader: an Oil Sands facility that upgrades bitumen into synthetic crude

• CO₂ sources are 3 Hydrogen Manufacturing Units, captured using Shell amine technology

• Captures > 1 million tonnes per year (1/3 of the CO₂ emissions from the Upgrader) – equivalent to the emissions of about 250,000 cars

• CO₂ is dehydrated, compressed and transported in dense phase roughly 65 km to three well sites
• **Storage Complex**
  - Carefully selected, characterized and externally assured: complete absence of natural migration pathways
  - Reservoir: High quality sandstone (BCS) at a depth of 2000 m
  - Seals: Multiple shale and salt layers (>200m)

• **Storage Facility consists of 3 well pads:**
  - Each pad has an injection well, a deep monitoring well and multiple shallow ground water wells
  - Conventional drilling methods
  - Multiple redundant engineered barriers: 3 steel casings in injection wells through freshwater zone, all cemented to surface

• **Comprehensive MMV program**
The original Quest MMV plan is publicly available online:
MMV CONSIDERATIONS

• System is designed and engineered not to leak – MMV technologies are not the primary barriers

• Three focus areas:
  • Containment (ensure CO$_2$ stays in zone)
  • Conformance (demonstrate we know where CO$_2$ is now and where it will be in the future)
  • Public/stakeholder confidence

• Timescales for action vary according to risk
  • Geologic movement very slow
  • Wells may potentially provide a faster path to the surface
  • MMV technologies must be appropriate to address the intended risk
BOW-TIE: CCS STORAGE CONTAINMENT RISK EXAMPLE

Legend:
- **Passive safeguards; these are present due to site selection and engineering**
- **Active safeguards, these are only present when a decision to intervene is made triggered by monitoring information**
• Risk-Based
  • Verify geological & engineered safeguards
  • Reduce containment risk to ALARP

• Site-Specific
  • Choose monitoring technologies appropriate for each location
  • Informed by appraisal data

• Adaptive
  • Respond to observed performance
  • Contingency plans in place
• Pressure build-up in the reservoir (BCS) is less than our mid-case forecast
• Reservoir properties appear to be better than expected
• Response at 5-35 to injection at 8-19 within a day or two
• Pressure build-up in the BCS is forecast to be less than 2 MPa ($\Delta P$) by the end of the project life

Can now update our suite of reservoir model forecasts using new data
SEISMIC MONITORING – VERTICAL SEISMIC PROFILE (VSP)

• Design change: from 3D VSP to radial walkaway 2Ds: significant cost savings

• Acquired baseline VSP in Feb, 2015 and the first monitor VSP in Feb, 2016.

• Processing is complete – still evaluating the results, but 4D response is strong
Microseismic array designed to detect events of magnitude -2.0 from a distance of ~840 m.
- The array has been continuously recording since Nov 2014.
- Array is working well: numerous surface (human activity) and regional events triggered.
- No locatable events yet detected.
• Continuous monitoring of Shell project wells (on well pads)
• Extensive field sampling campaign of landowner wells, many measurements taken
• Comprehensive baseline data
• Working with regulator to optimize sampling

Discrete GW well sampling (Landowner & Project Wells)

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Continuous GW well sampling (Project Wells only)

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AITF study

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The high variability of CO₂ levels in the atmosphere makes detecting small emissions difficult.

LightSource system installed and functional at all injection sites.

Release tests demonstrated we can detect and quantify CO₂ emissions on the well site.

Confirmed as technology for atmospheric monitoring at Quest.
Post Injection MMV:

- Complements data collected during baseline and injection periods to demonstrate clear understanding of performance history
- Continues to validate the modelling of future CO₂ behaviour
- Assures decommissioning of the wells
- Facilitates the safe handover of liability, minimize future concerns
- Time frame is determined by assessment of remaining risk: site specific
MMV KEY POINTS

Important considerations for an MMV plan:

• Containment – risk based:
  • Thorough risk assessment required
  • Trigger based – each technology must contribute to specific barriers
  • Wellbore risks prior to abandonment generally higher than geologic risks, hence more intensive monitoring

• Conformance – confidence in storage security:
  • Model driven: need to acquire sufficient data to provide confidence in the model
  • Post-injection monitoring period dependent on site risk and operational performance

• Public/Stakeholder confidence
  • Perceived risks need to be treated seriously

Site selection critical to risk assessment – MMV must be risk-based and site specific
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