Quest CCS Project

Learnings from the First Year of Operations

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Shell's Response to the CO_2 Challenge

Shell's CCS/CCUS Project Portfolio

Quest

Boundary Dam

TCM

Gorgon

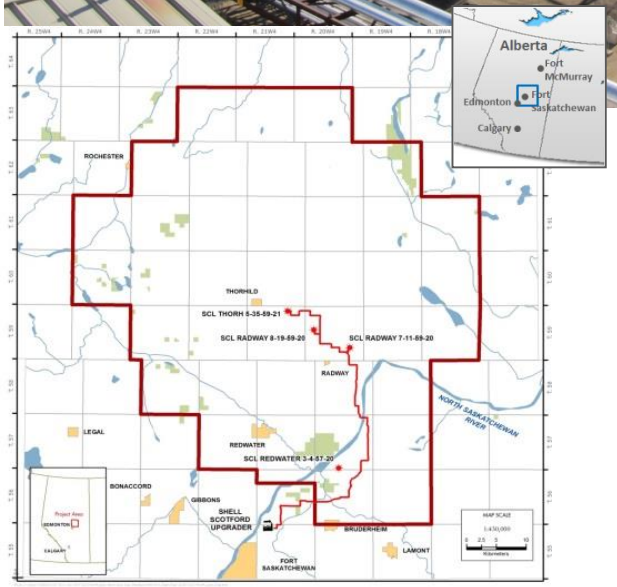
Lula CCUS

- Industrial scale projects in operation
- Industrial scale projects in construction
- Involvement through Shell Cansolv Technology

Quest Overview

Quest Project at a Glance

- **World First** – the first full-scale CCS project for oil sands
- **Who** – joint venture between Shell, Chevron and Marathon
- **Where** – capture at Scotford Upgrader; storage in saline aquifer: the Basal Cambrian Sands (at a depth of 2000m)
- **Impact** – 25 million tonnes of CO_2 captured over a 25 year period (1/3 of CO_2 from the Upgrader) – equivalent to the emissions of 250,000 cars
- **Technology** – syngas capture using amines



The Athabasca Oil Sands Project (AOSP)

MUSKEG RIVER MINE

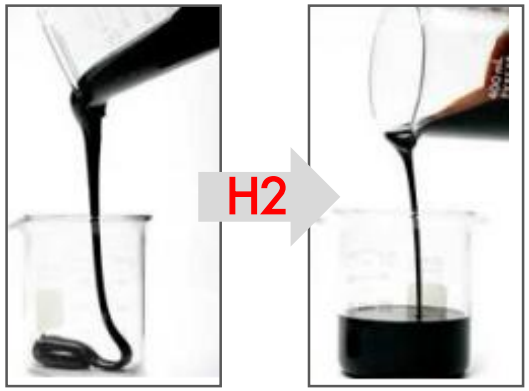
CORRIDOR PIPELINE

SCOTFORD UPGRADER

SCOTFORD REFINERY (SHELL ONLY)

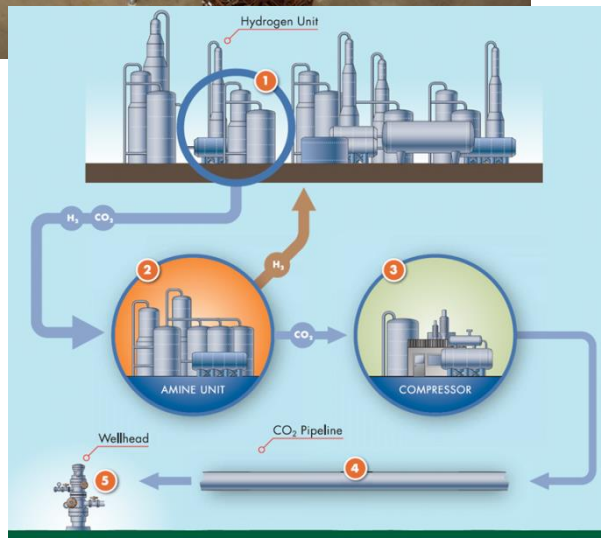
QUEST: CO_2 CAPTURE FROM 3 HMUs

Bitumen



Bitumen to Synthetic crude (255,000 bpd)

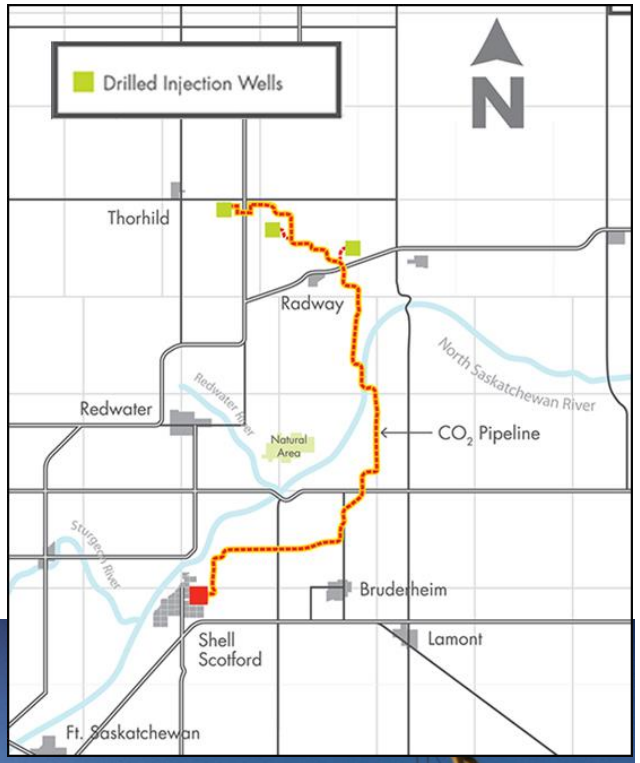
CO_2 Capture



- The Hydrogen Unit combines steam and natural gas to produce high pressure steam and H_2 for use in the upgrader
- The Amine Unit uses Shell technology to capture the CO_2 directly from the process
- The process produces a 99% pure CO_2 output
- Award winning integrated, modular construction (Fluor)

Transport

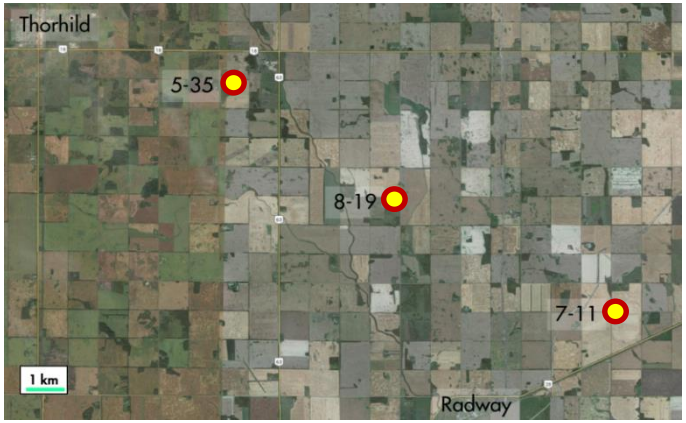
- CO_2 dehydrated and compressed to >10 MPa to keep the CO_2 in dense phase through entire pipeline
- 65 km pipeline with 6 block valves (every 4-15 km)
- Pipeline construction Oct 2013 – Aug 2014, with considerable stakeholder interaction
- Cleaning and preserved with nitrogen by October 2014
- First CO_2 into pipeline August 2015

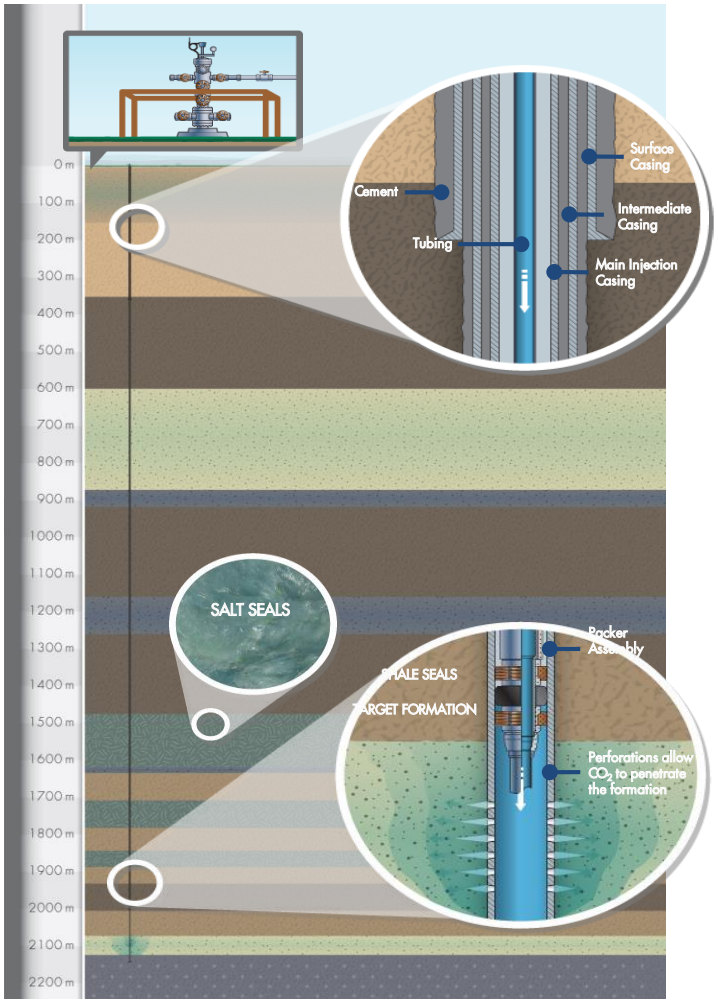


Storage

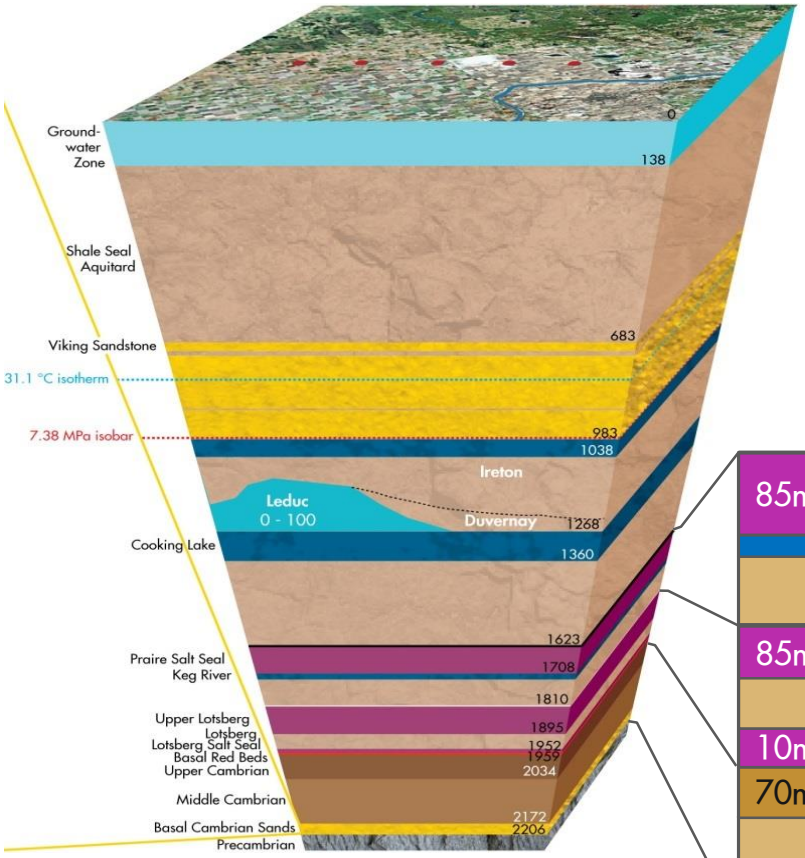
3 well pads:

- Each pad has 1 injection well, 1 deep monitoring well and multiple shallow ground water wells
- Conventional drilling methods
- Multiple steel casings for injection wells, 3 in freshwater zone, all cemented to surface
- Comprehensive Measurement, Monitoring and Verification program





The Storage Complex



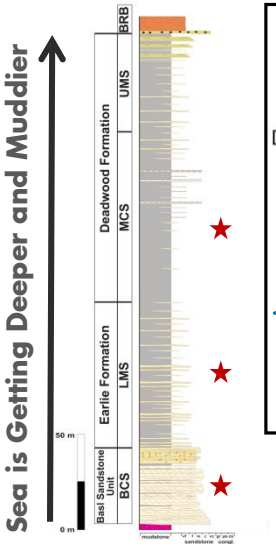
BCS Storage Complex

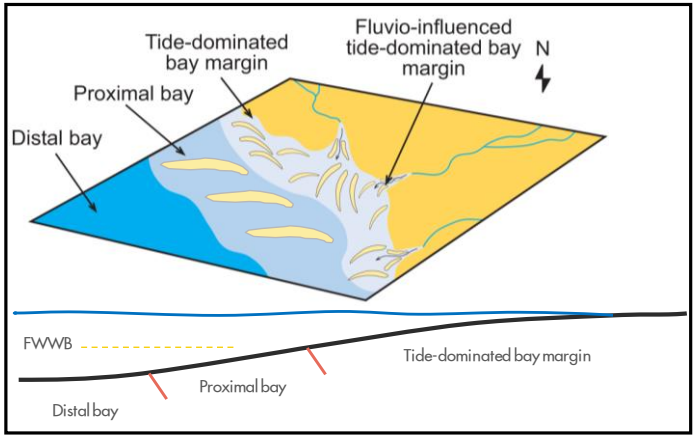
- Deep (~2km) saline aquifer
- Below potable water zones, zones with hydrocarbon potential
- Multiple thick, continuous seals (>150m within the complex)
- High quality (~17% porosity) sandstone reservoir
- Excellent permeability (~1000mD)

85m	Prairie Evaporite	– Additional Seal	
85m	Upper Lotsberg Salt	– Ultimate Seal	BCS Storage Complex
10m	Lower Lotsberg Salt	– Secondary Seal	
70m	Middle Cambrian Shale	– Primary Seal	
40m	Basal Cambrian Sand	– Storage Reservoir	
	PreCambrian Shield		

Geology and Wells

Storage Complex Geology

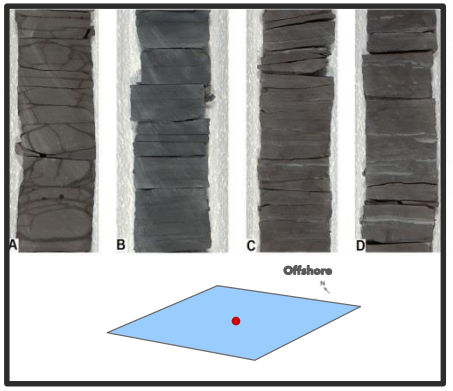


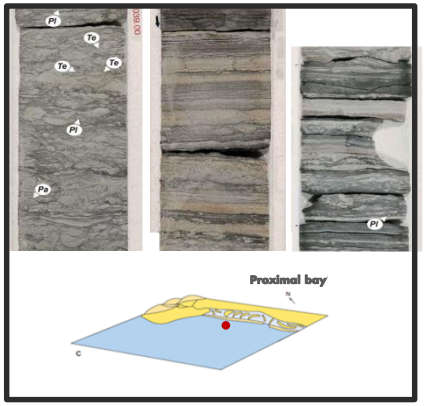


Middle Cambrian Shale (MCS) – The Primary Seal
Predominantly shale.

Deposited in an offshore environment as sea got deeper

Schematic of the Core



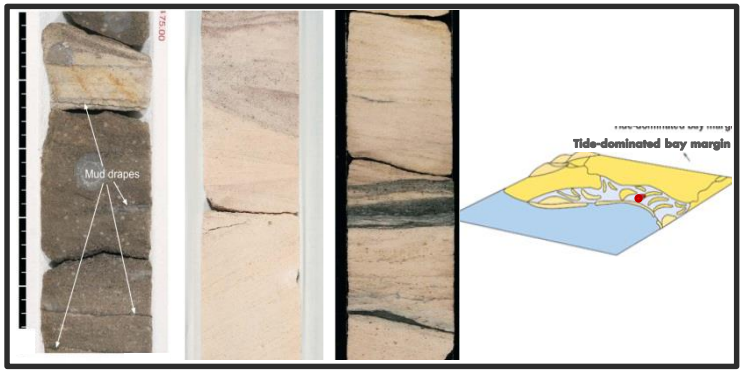


Lower Marine Siltstone (LMS) – Impedes CO_2 migration.

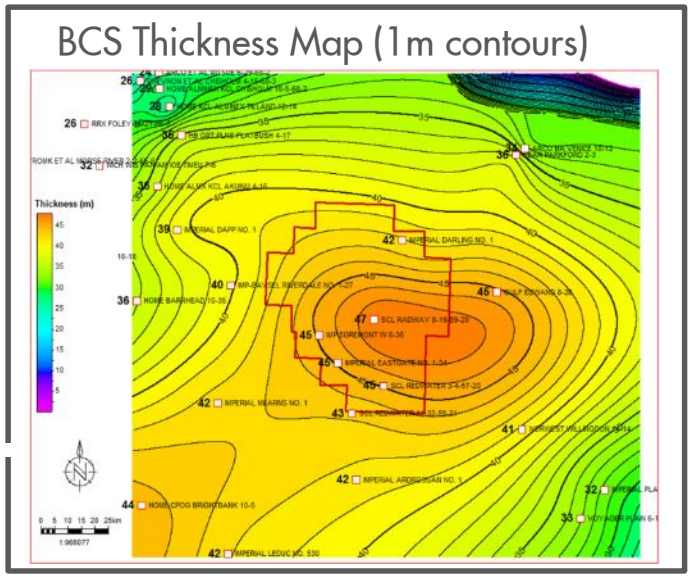
Intermixed mudstones and sandstones

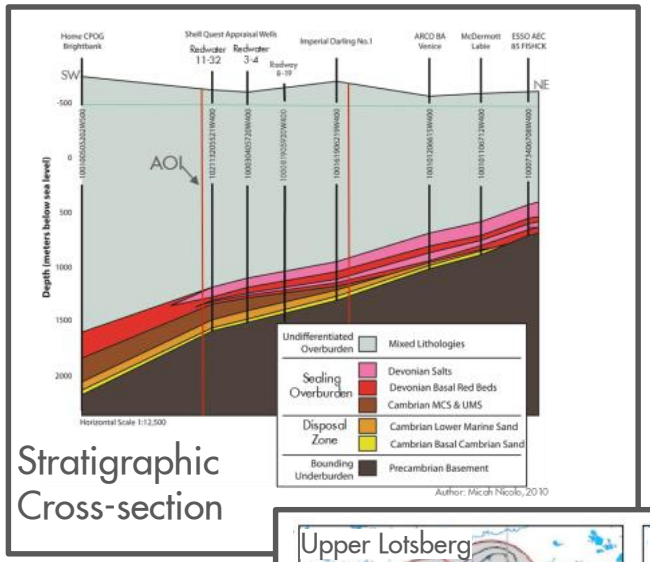
Basal Cambrian Sandstone (BCS) – The injection zone.

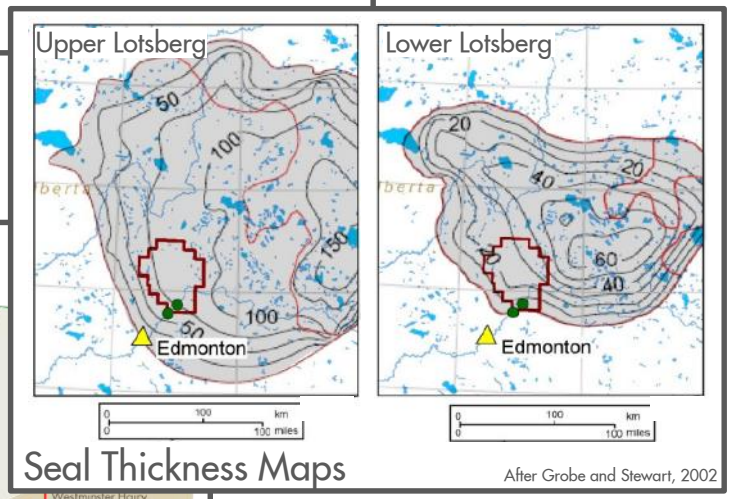
Dominantly sandstones, with local thin - to very thin-bedded mudstones

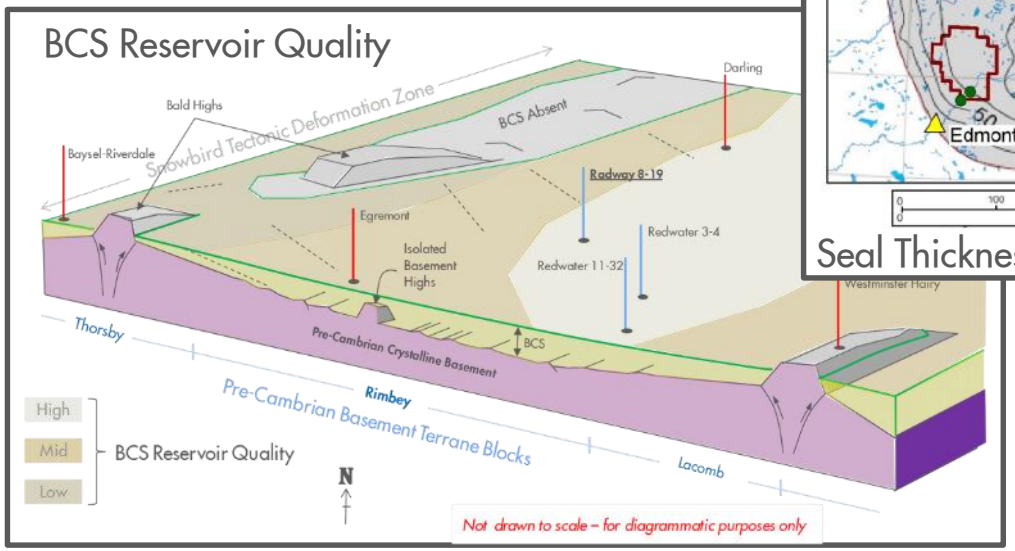


Reservoir Screening

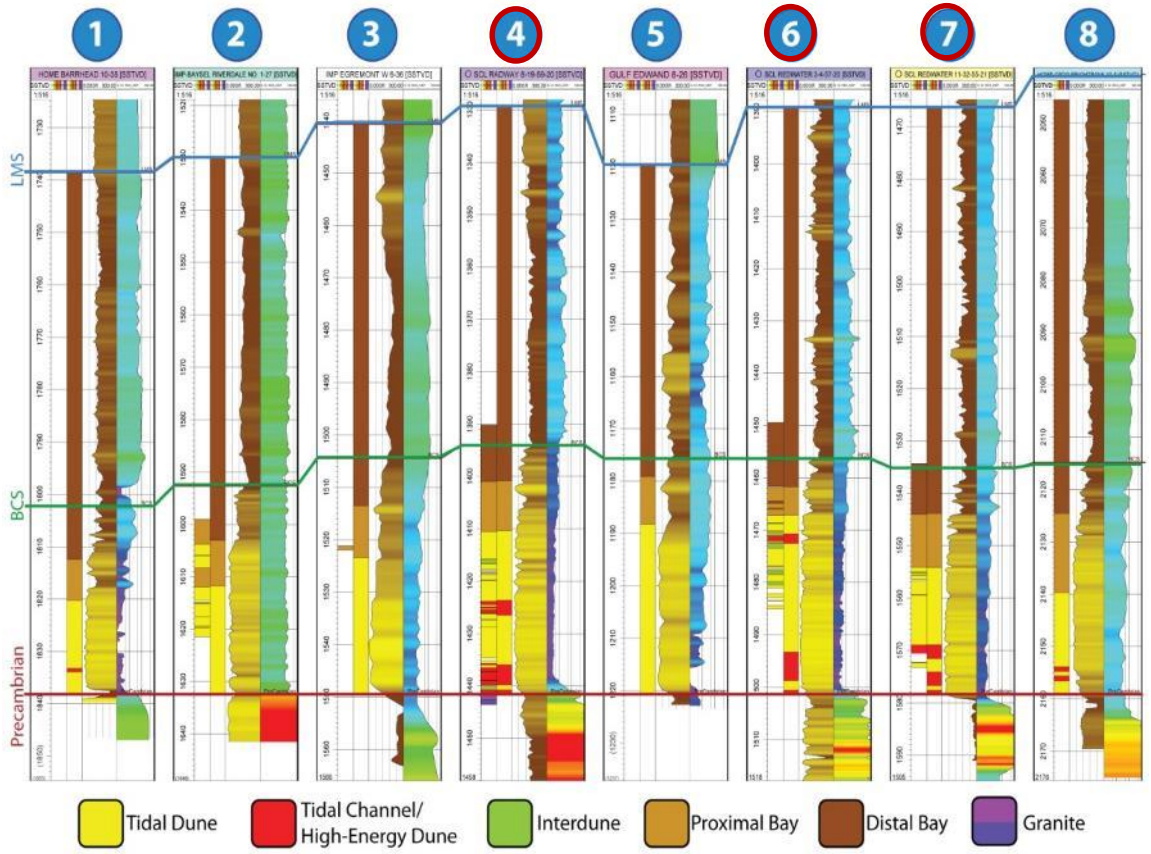


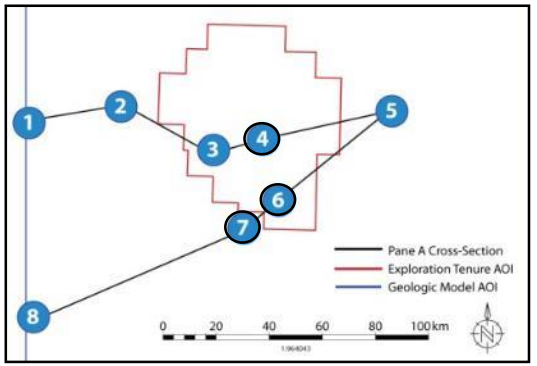






Regional Correlations

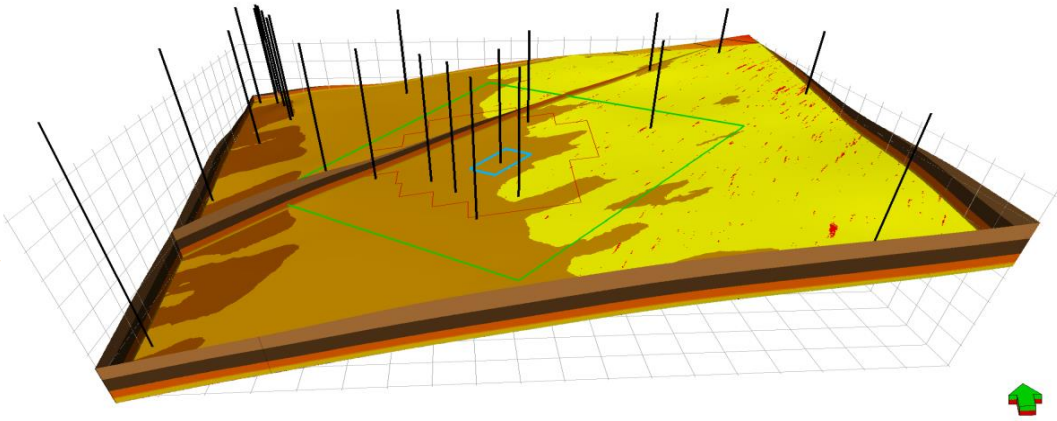


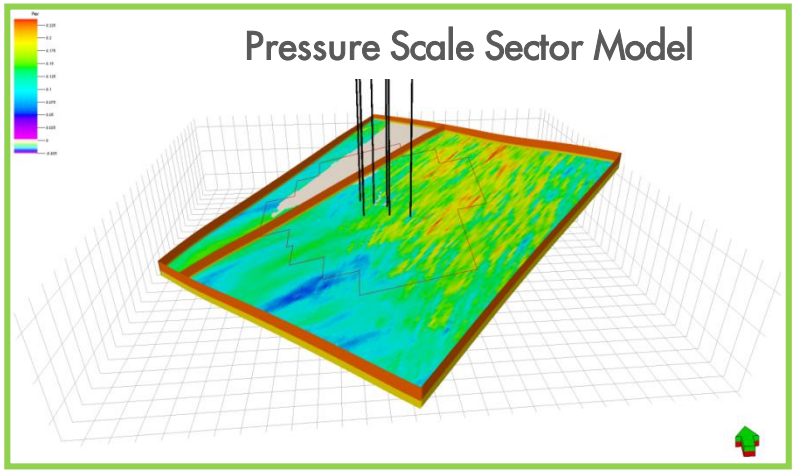


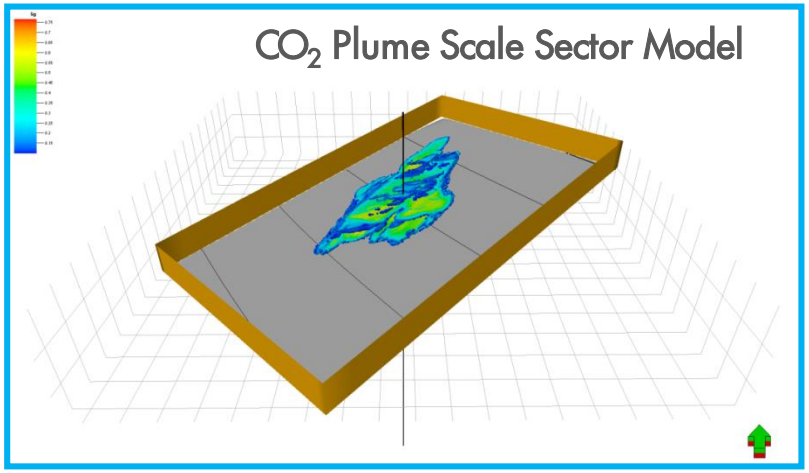
Regional correlation of well data provides confidence in our depositional model and helps us predict how the reservoir will respond to CO_2

Reservoir Modeling (Static, Dynamic)

- Well Correlations
- Structural Framework
- Facies Interpretation
- Regional Property Trends
- Upscaled Well Logs

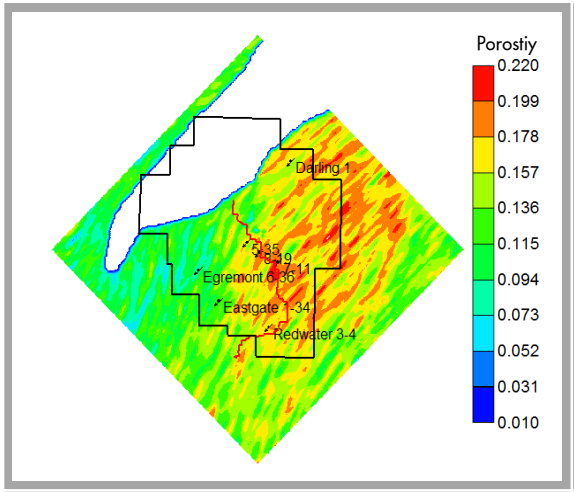


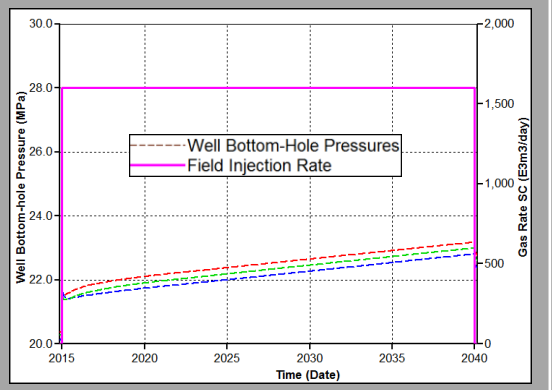




Development Scenario Modelling

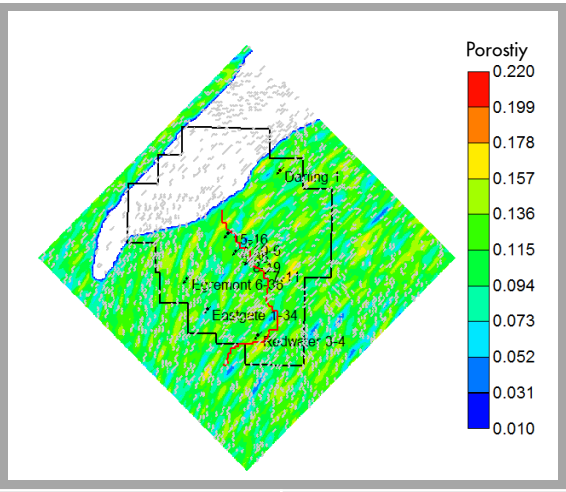
Expectation Case

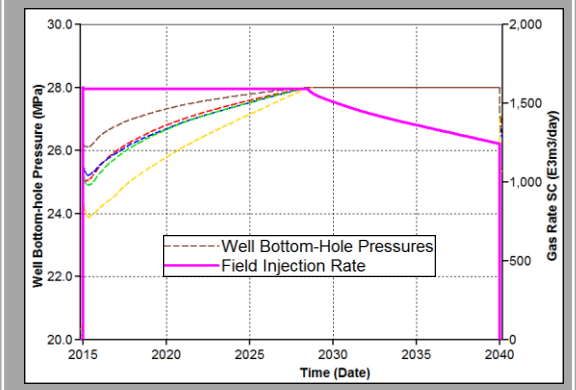




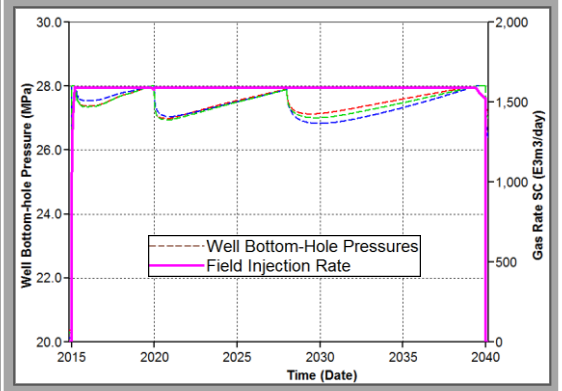
3 wells

Low Case



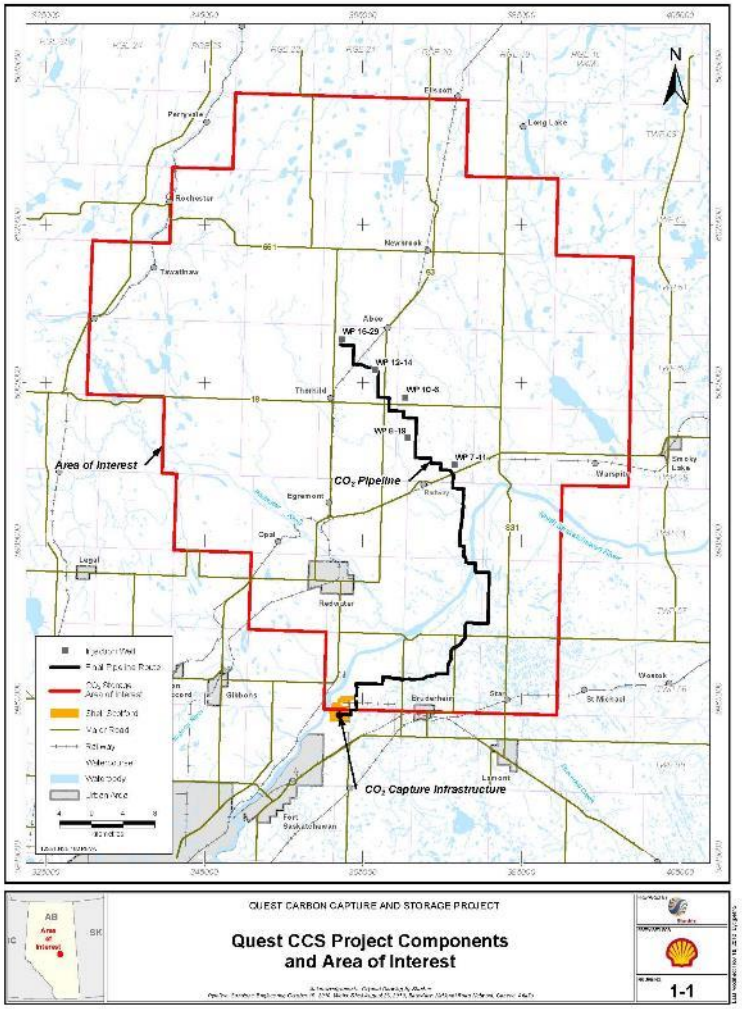


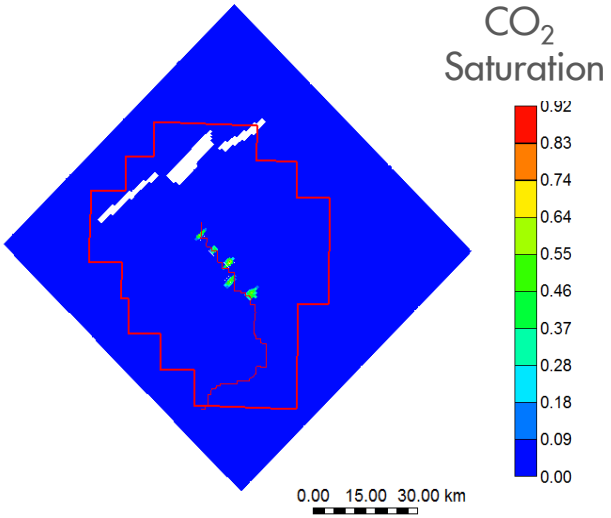
5+3 wells

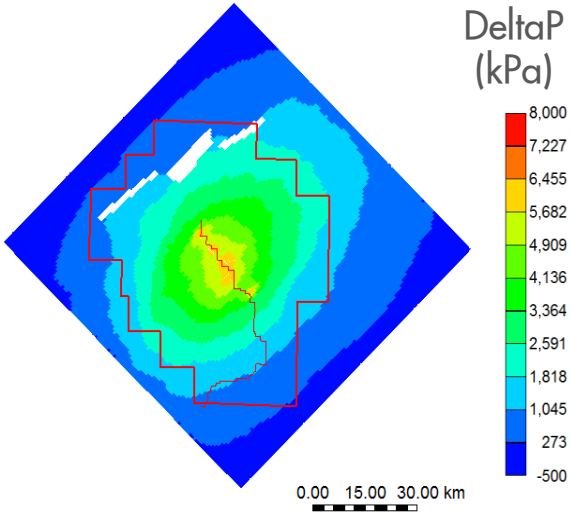


3+2+3 wells

Conceptual Storage Plan

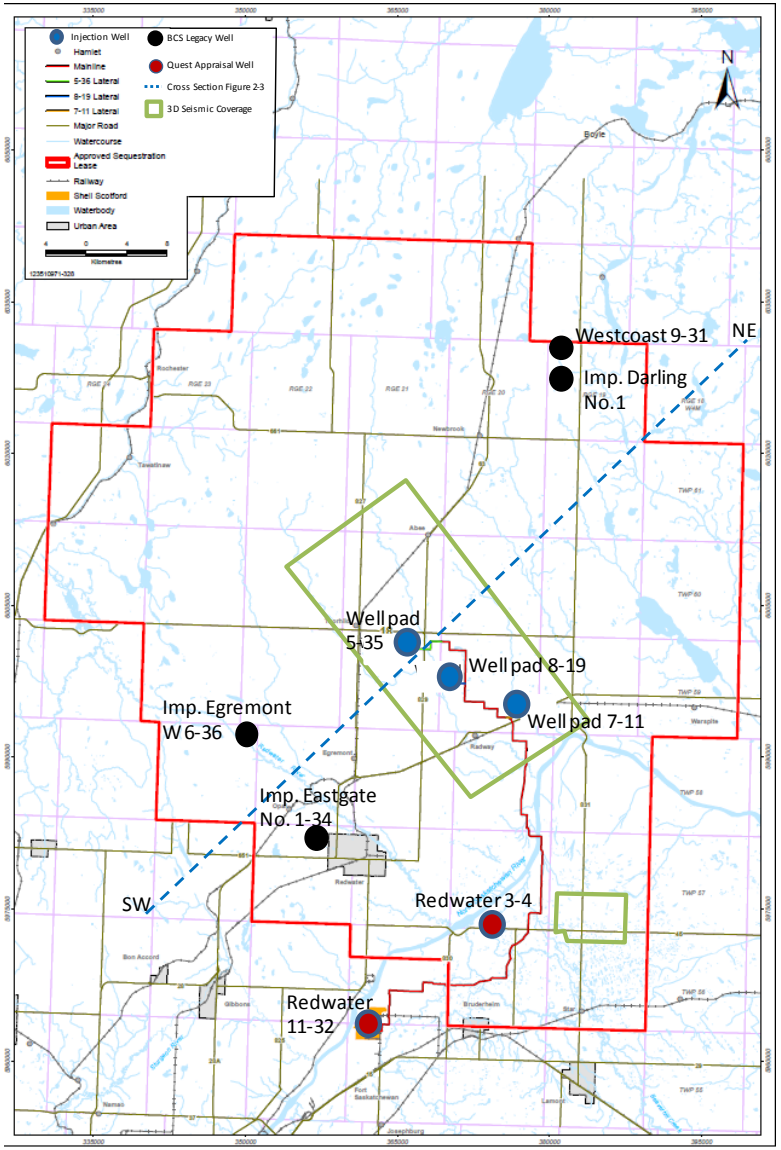




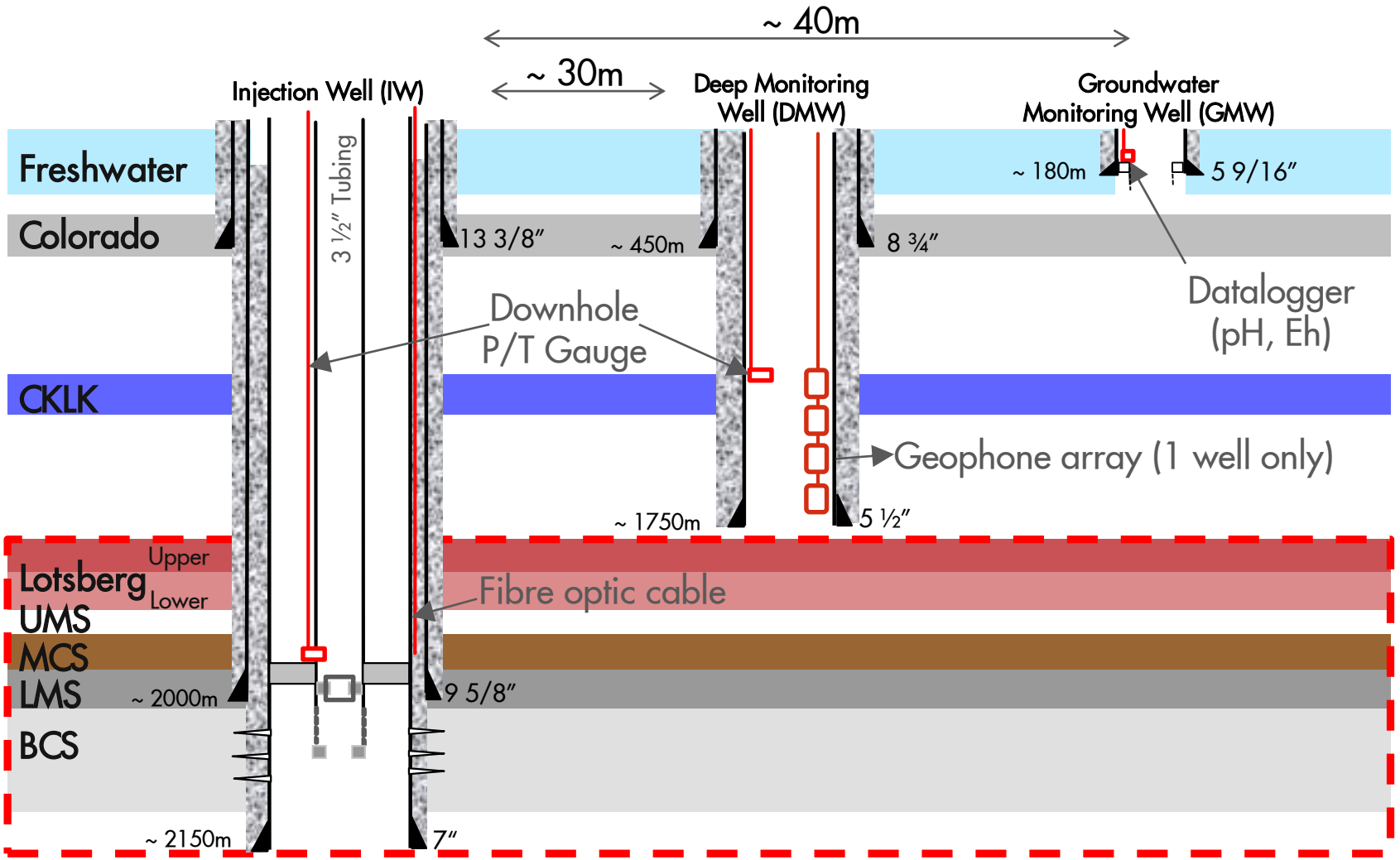


Drilling Campaign

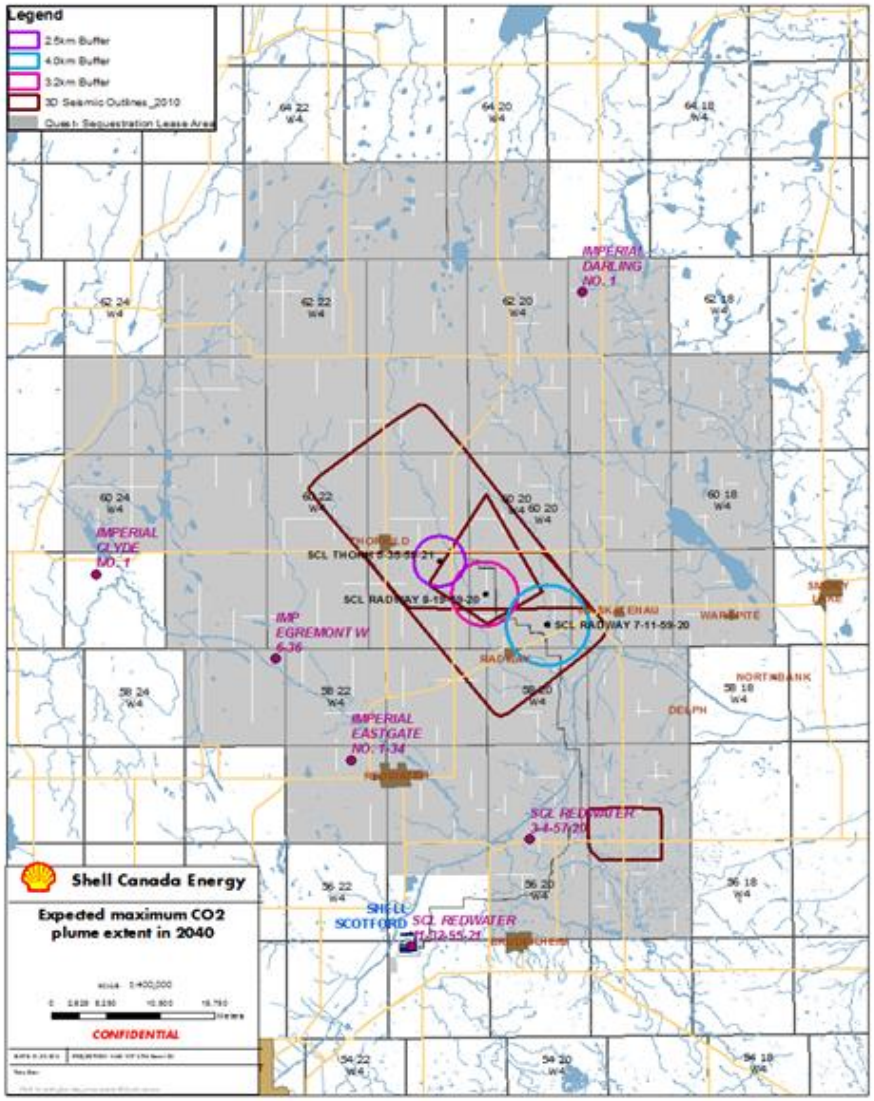
- 2 appraisal wells
  (~ 2 km MD, to BCS)
- 3 injection wells
  (~ 2 km MD, to BCS)
- 3 deep monitoring wells
  (~ 1.7 km MD, to top of seal)
- 9 groundwater monitoring wells
  (< 0.2 km MD, in GWP zone)

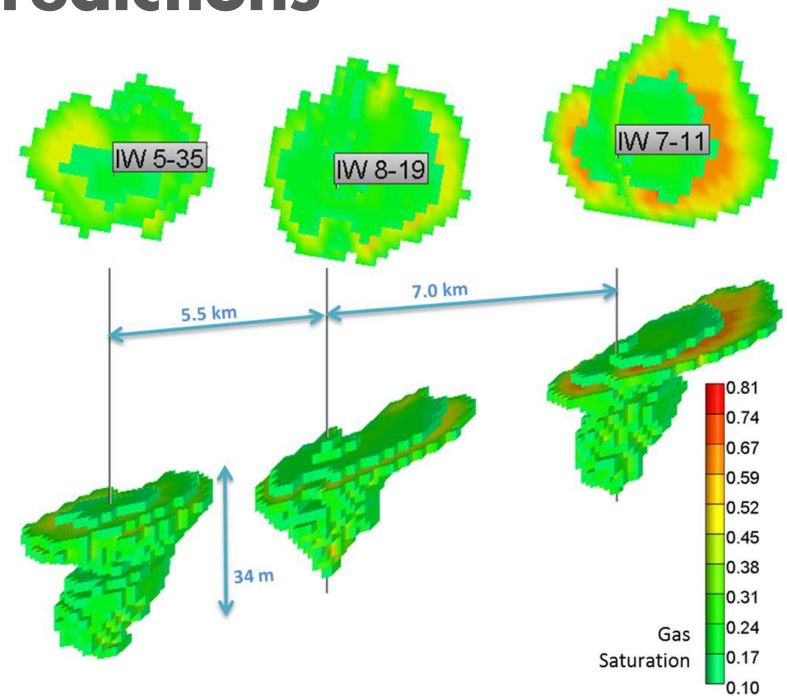


Well Pad Schematic



Reservoir Model – Plume Predictions

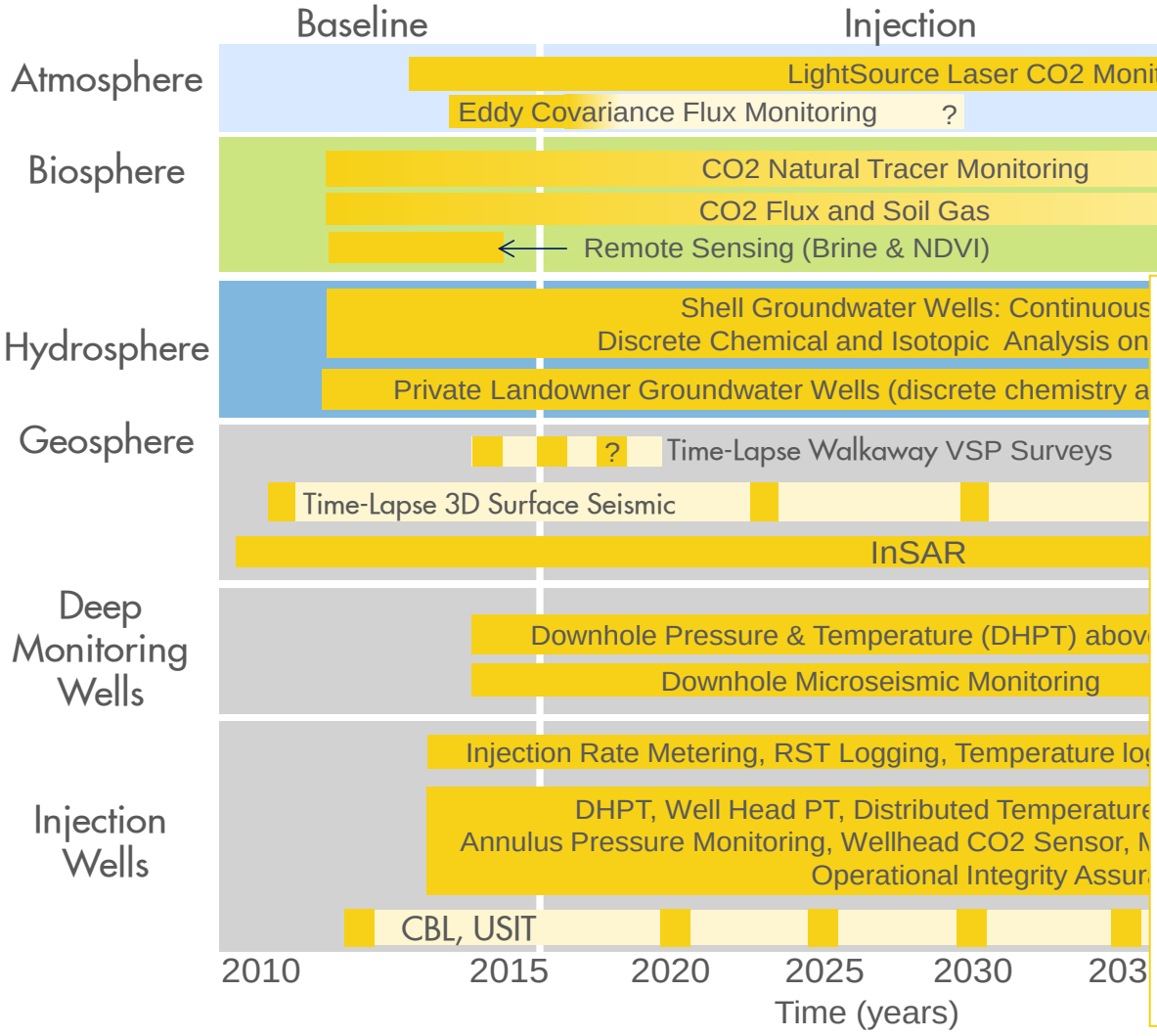




- Based on pre-injection model
- Remaining uncertainty on relative permeability of CO_2 reduced in 2016 with model update and tuning to performance data.
- Current estimate of max plume lengths: 2.5 to 4.2 km

Measure, Monitor and Verify (MMV)

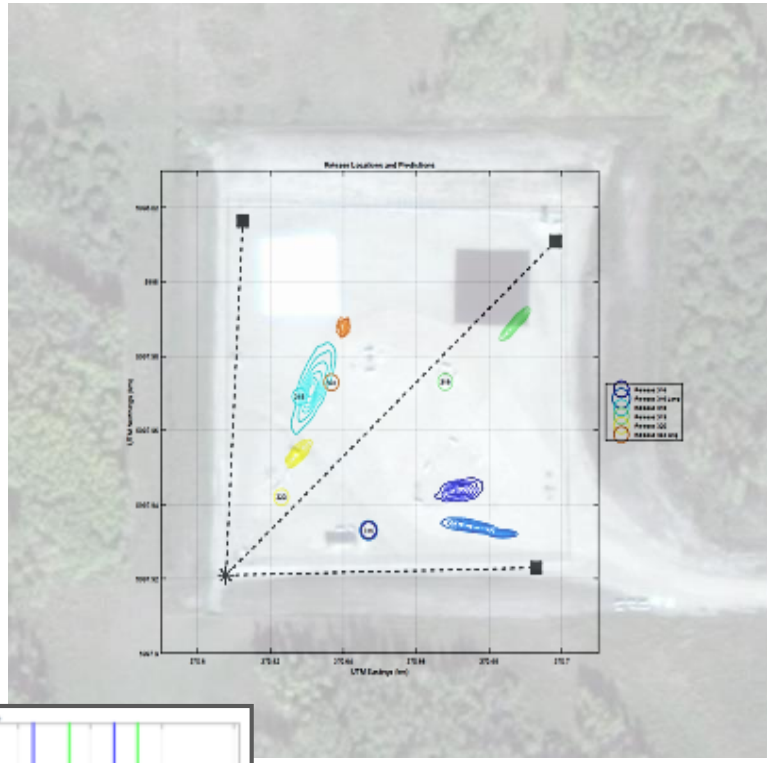
Quest MMV Plan 2015



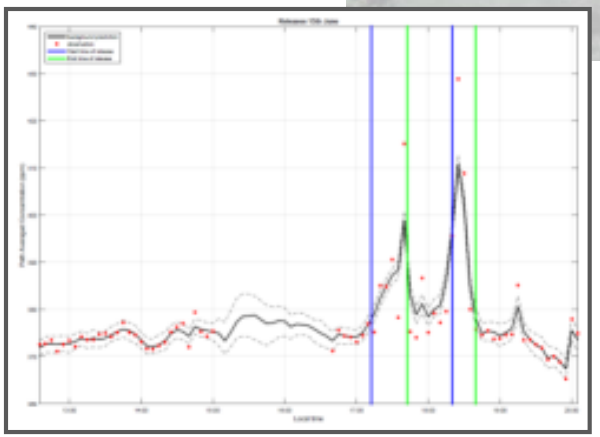
- First of a kind – conservative approach
- Comprehensive: from atmosphere to geosphere
- Risk-based
- Site-specific
- Independently reviewed
- Combination of new and traditional technologies
- Baseline data collected before start-up

Atmosphere: LightSource

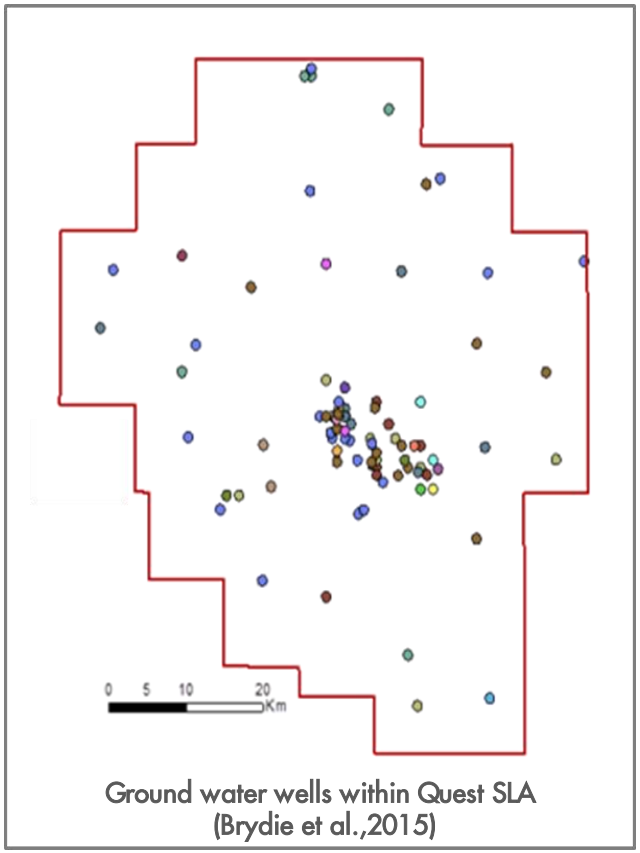
from Hirst et al. 2015



- LightSource system installed and functional at all injection sites prior to CO_2 injection
- Release testing very successful – all releases detected, quantified and located
- Confirmed as the technology for atmospheric monitoring at Quest



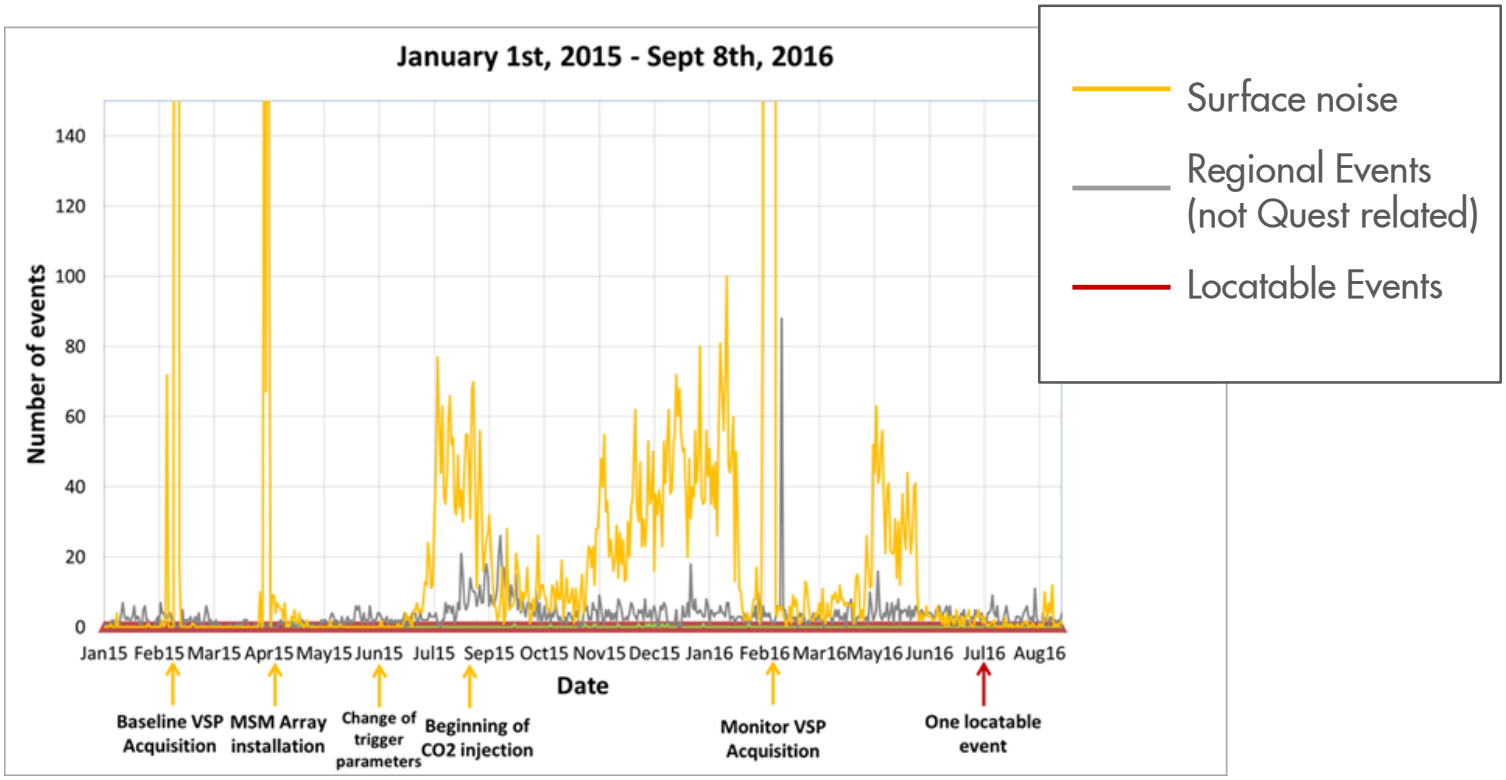
Hydrosphere: Groundwater Monitoring



Ground water wells within Quest SLA
(Brydie et al.,2015)

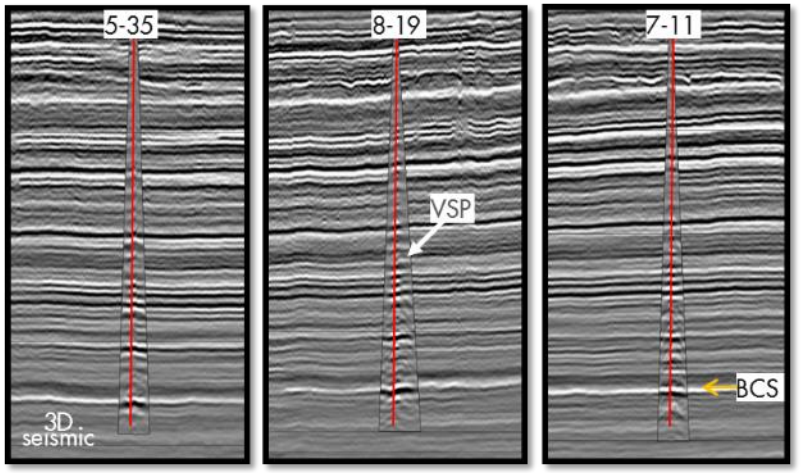
- Continuous monitoring of Shell project wells (on well pads) – recently changed sensors to improve reliability
- Extensive field sampling campaign of landowner wells, many measurements taken
- Comprehensive baseline data

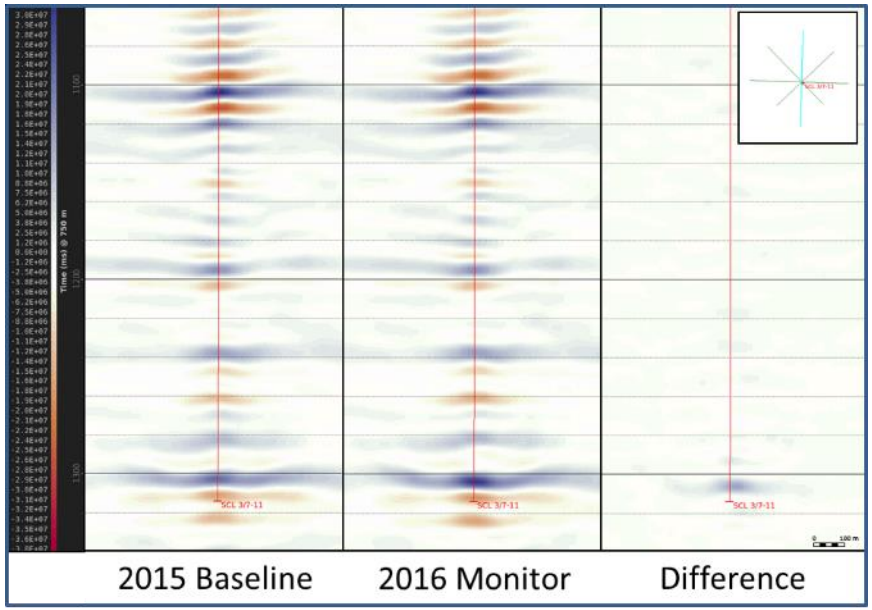
Geosphere: Microseismic



- Microseismic array installed in DMW 8-19 recording baseline MS activity in November 2014 – re-installed in April 2015.
- Three small (M < -1) locatable events have been detected through the end of 2016

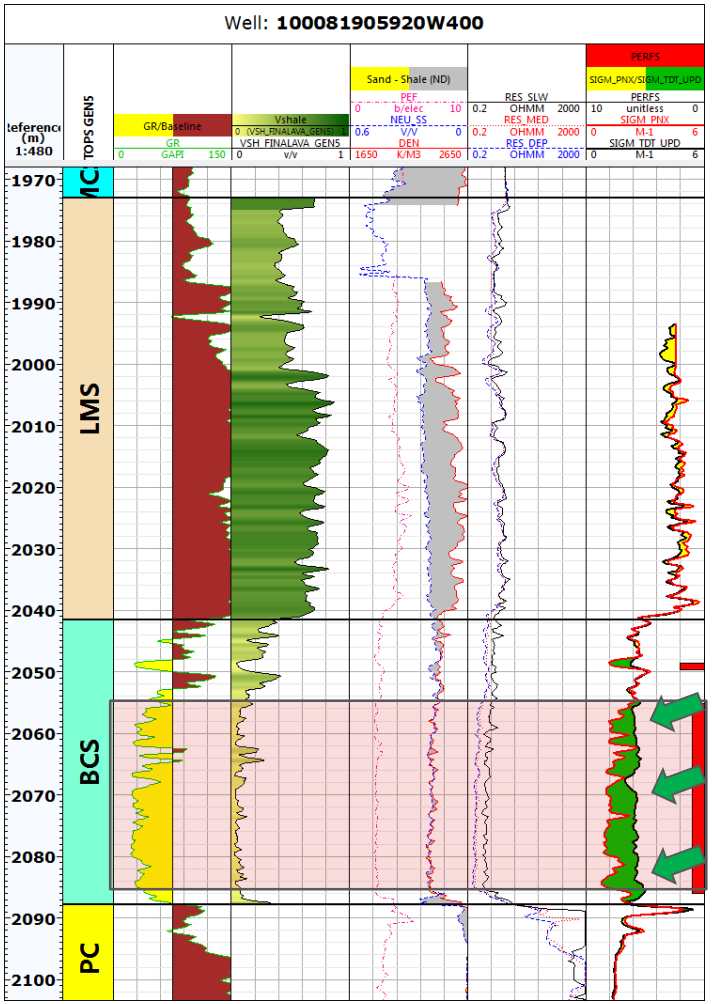
Geosphere: Time Lapse VSPs





- Baseline VSP acquired pre-injection in April, 2015 (no CO_2 is present in the reservoir).
- The first monitor VSP was recorded in March, 2016.
- Time lapse signal quite strong, consistent with modelled plume

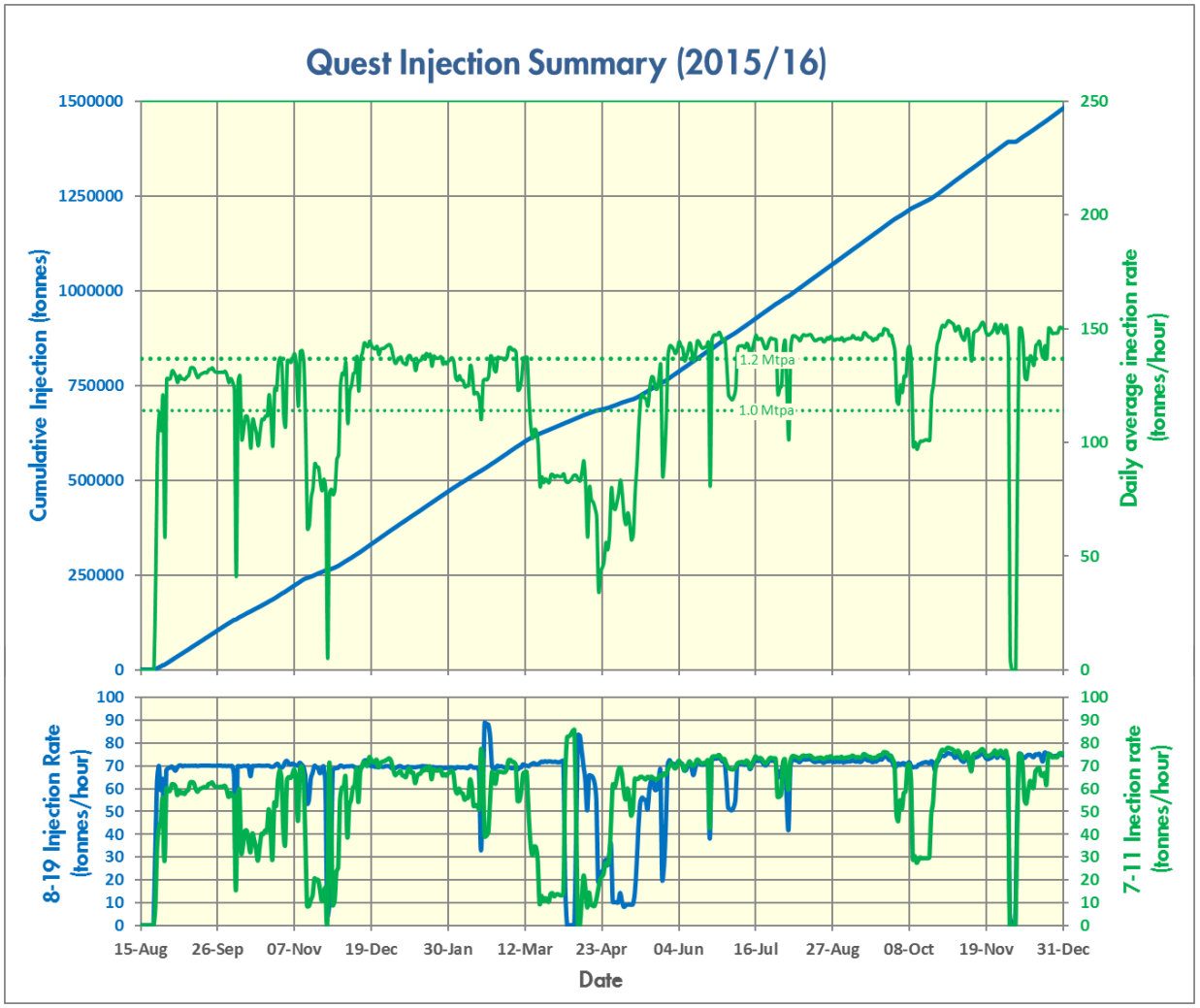
Geosphere: Pulsed Neutron Logging



- Pulsed Neutron log was run in May 2015 prior to injection (Black line), and a repeat was run after 6 months of CO_2 injection. (Red line)
- Initial Observations
  - Change in the pulsed neutron response over the perforated (Red rectangle).
  - No change in log response above or below the perforated interval or through the LMS member.
- Conclusions:
  - CO_2 is contained within the perforated interval and the BCS reservoir. (Red rectangle).
  - The injected CO_2 is mainly within the high permeability streaks (Green Arrows).

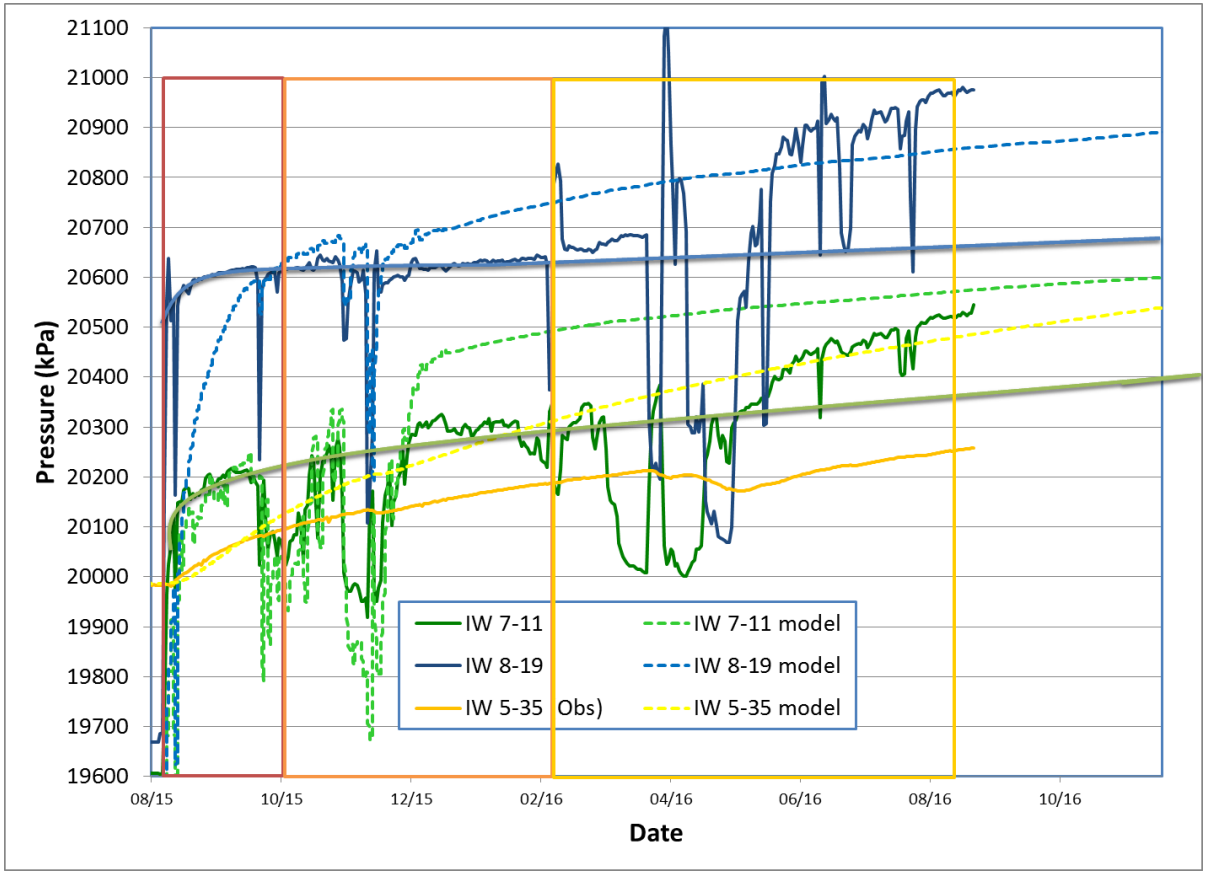
Storage Operations

Quest – First 16 Months' Performance



- Kept 8-19 steady initially to simplify pressure data at 5-35
- Capacity testing in February
- Well logging runs during Turn Around
- First million tonnes captured and stored by August, 2016
- Wells have not been a limiting factor

Reservoir Model – Pressure Forecasting



- Still too early for reliable history matching
- Reservoir properties looking more like our modelled high case scenarios
- (Far field) data from 5-35 considerably better than expected
- Pressure build-up in the BCS is still forecast to be less than 2 MPa (ΔP) by the end of the project life

Quest Storage Learnings

MMV:

- MMV systems working well – no triggers
- Microseismic array has been very quiet
- VSPs can image CO_2 in the BCS, DAS working very well

Wells:

- Only 2 wells active – contributing to significant wells and MMV savings
- Pulse neutron logging confirmed that CO_2 is where it is supposed to be
- Important to keep water out of the wells, even the small amounts routinely used during logging

Reservoir:

- Excellent injectivity – comparable to high case scenarios
- After 25 years, we expect to use 5-7% of the available pore space
- Current estimate is that the ΔP at the end of the project may only be 2 MPa.

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