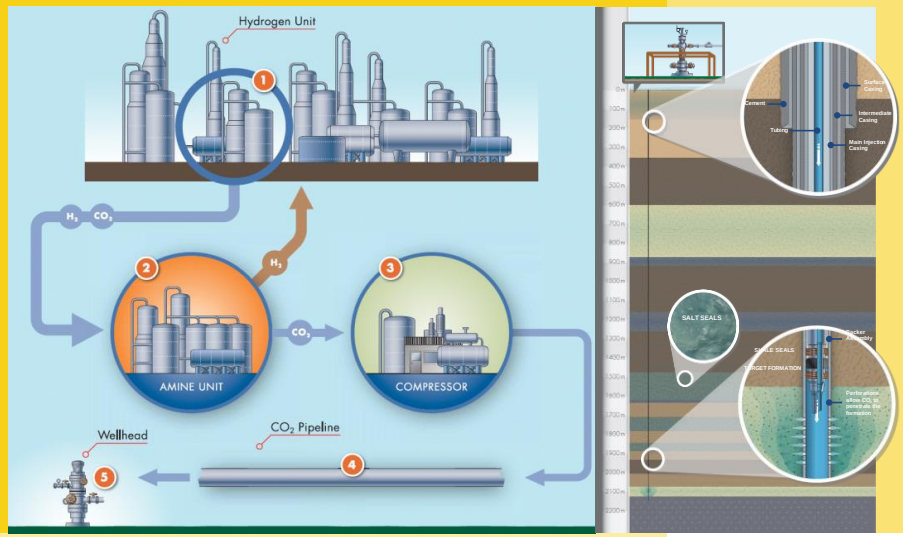
# QUEST – YEAR 1 OF COMMERCIAL OPERATIONS

IEAGHG Monitoring and Modelling Networks Meeting

Edinburgh – July, 2016

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Shell Canada Limited

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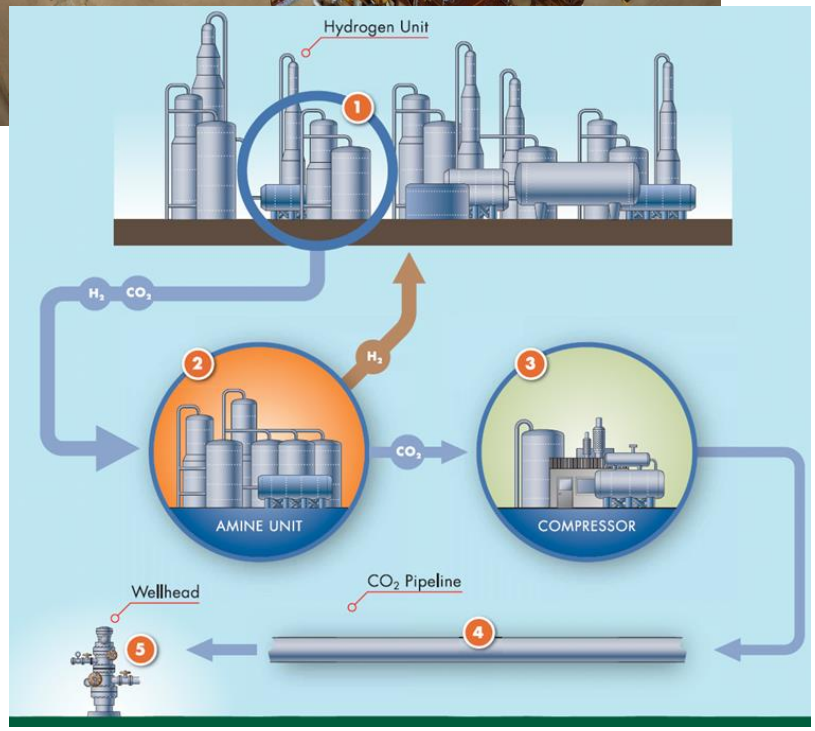
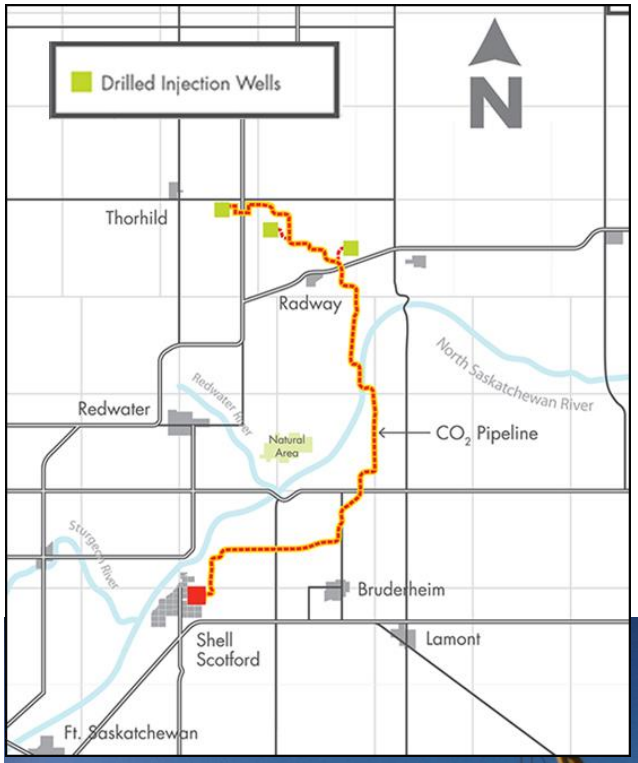
# QUEST – $CO_2$ CAPTURE




- $CO_2$ Source is the Scotford Upgrader – an Oil Sands facility that upgrades bitumen to synthetic crude
- 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
- Captures 1 million tonnes per year (1/3 of the $CO_2$ emissions from the Upgrader)

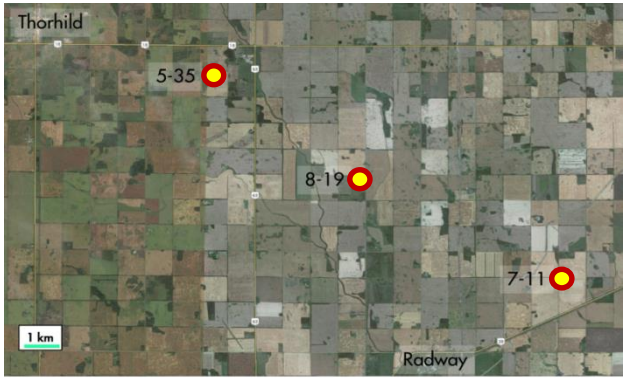
# QUEST – TRANSPORT

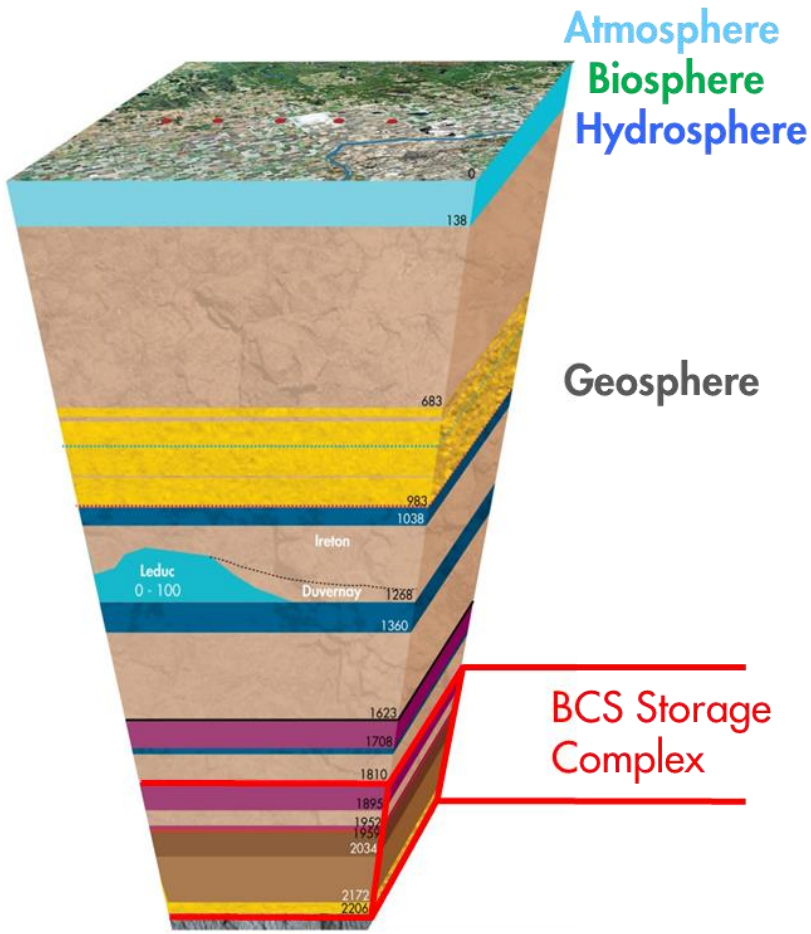
- The compressor includes a TEG unit for dehydration to ensure minimal water in the pipeline
- $CO_2$ inlet pressure >10 MPa to keep the $CO_2$ in dense phase through entire pipeline
- 65 km pipeline with 6 block valves (between 4-15 km spacing)
- Considerable stakeholder interaction
- Pipeline construction Oct 2013 –Aug 2014
- Cleaning and preserved with nitrogen by October 2014



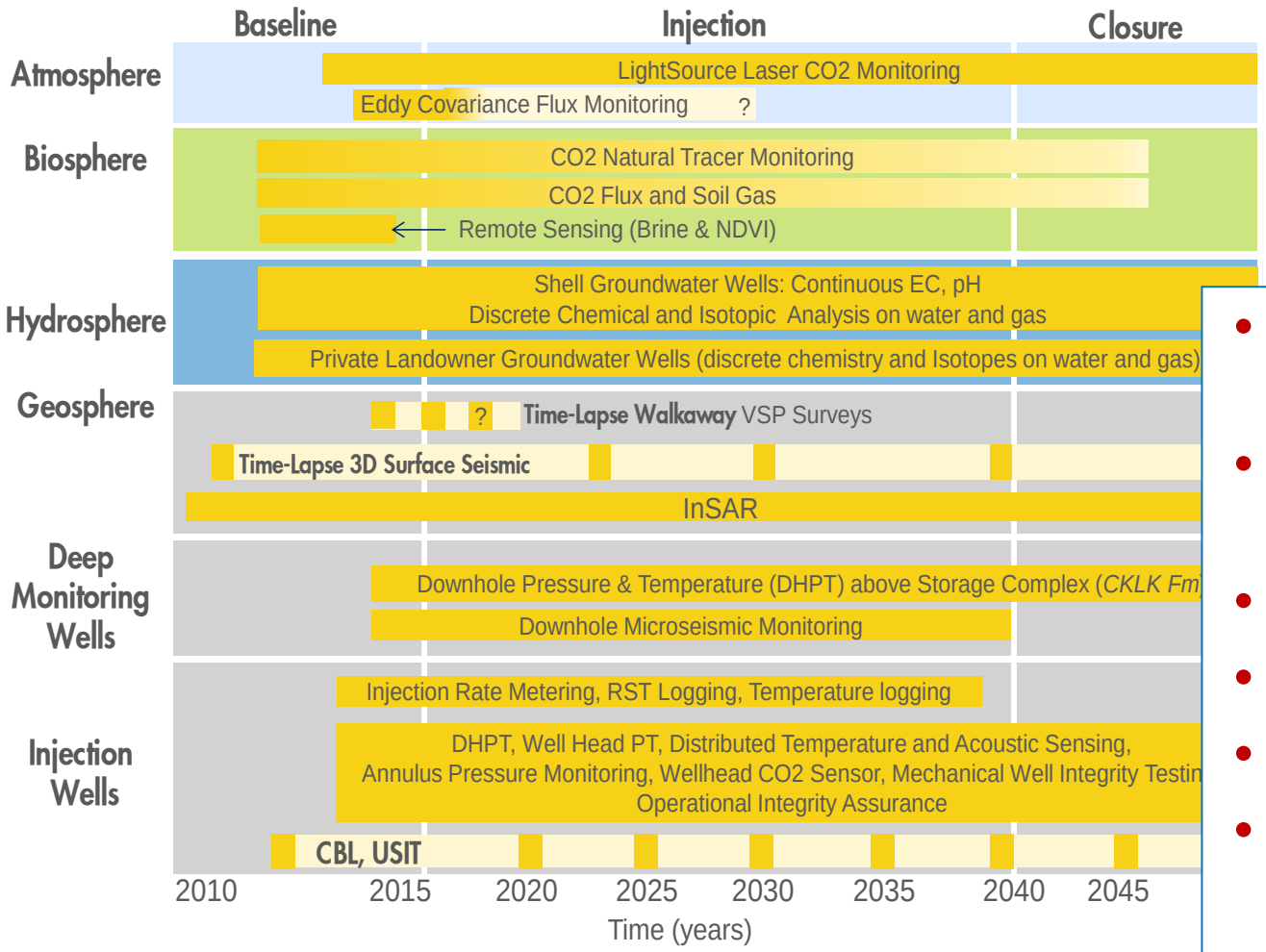

# QUEST – STORAGE

- **Storage Complex**
  - Reservoir: Basal Cambrian Sands (17% porosity, 1000 mD permeability) at a depth of 2000 m
  - Seals: Middle Cambrian Shale and Lotsberg Salts
- **Storage Facility consists of 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 MMV program**



# MMV (MEASURE, MONITOR AND VERIFY) PLAN

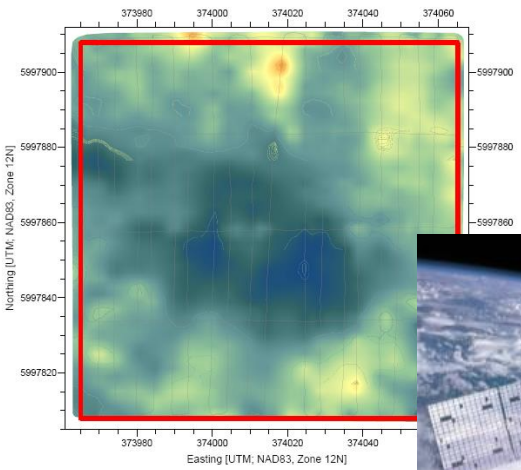



- First of a kind – conservative approach
- Comprehensive: from atmosphere to geosphere
- Risk-based
- Site-specific
- Independently reviewed
- Combination of new and traditional technologies
- Baseline data collected before start-up

# REMOTE SENSING

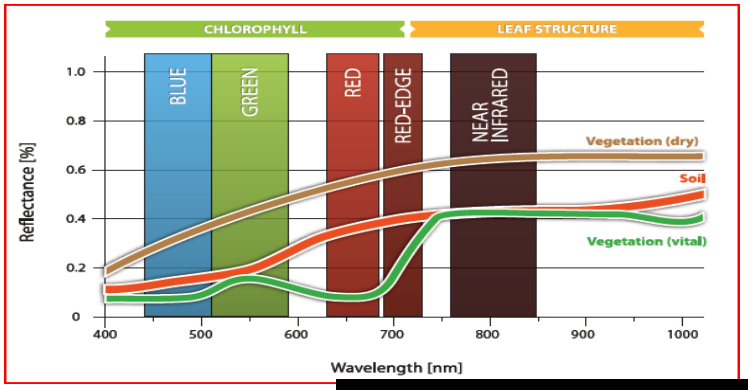
## Radar Image Analysis (RIA)

- Assessed for brine leakage
- Poor correlations (field vs radar derived data)
- No risk of saline brine leakage into BGPZ



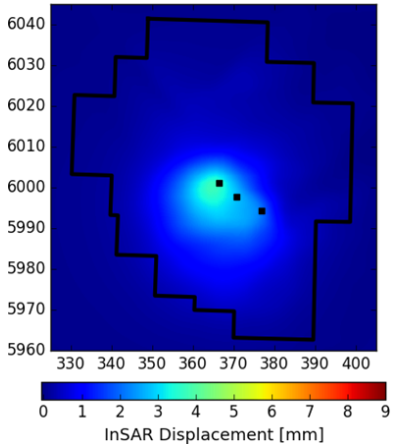

## Multispectral Satellite Imagery (MIA)

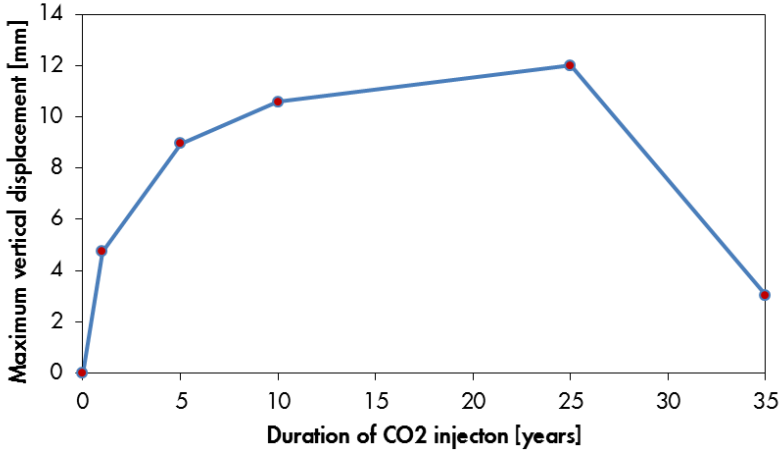
- Assessed for $CO_2$ release / impact
- Lack of spectral and spatial resolution of available sensors




➡ **Removed from monitoring program**

# REMOTE SENSING - INSAR



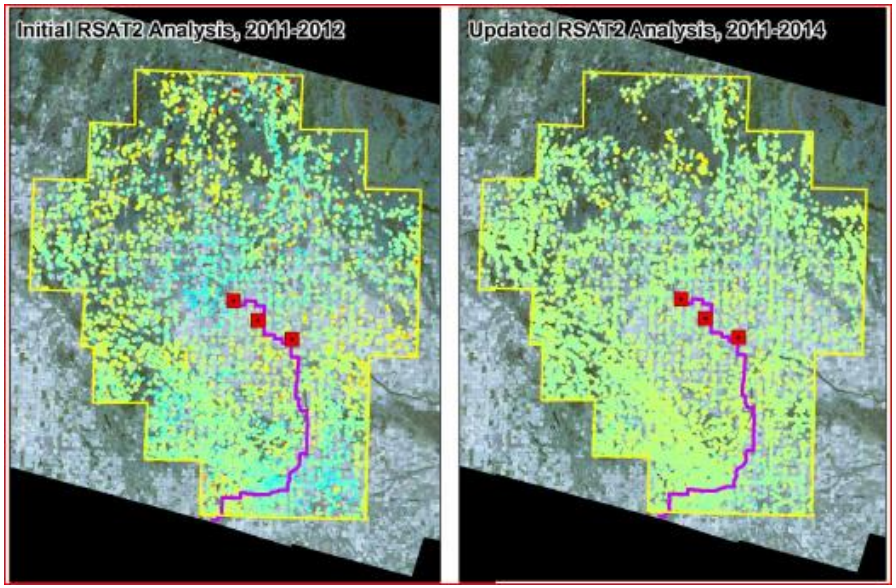




## Surface Deformation Model Update

- High case shows detectable deformation about one year post injection
- Factor of 10 uncertainty

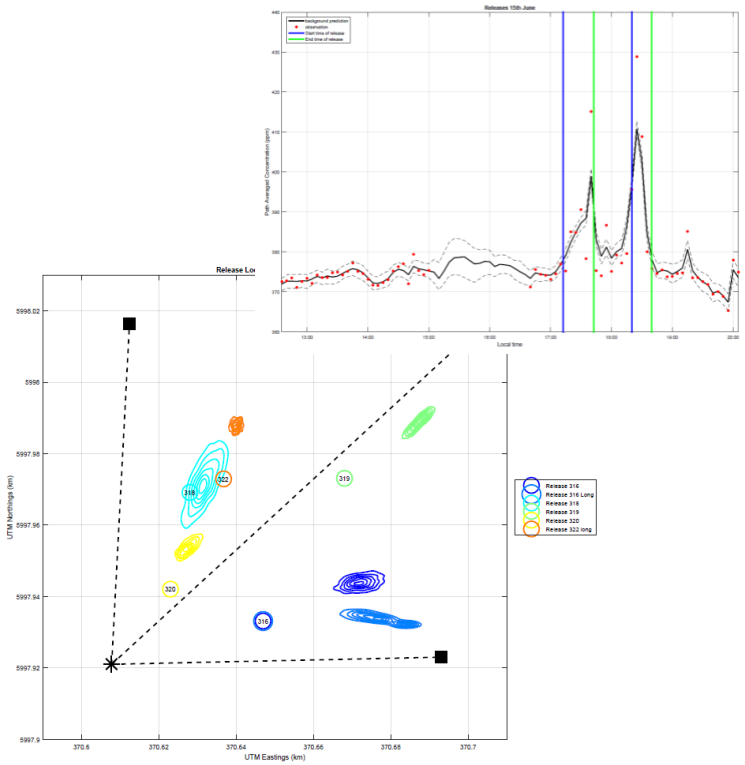
## InSAR

- Updated processing of natural reflectors
- Measurement point density increased
- Average displacement rate detection sensitivity of 0.87 mm/year
- **Currently evaluating the data**

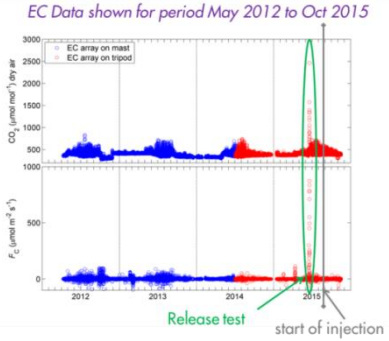


# ATMOSPHERIC MONITORING

from Hirst et al. 2015

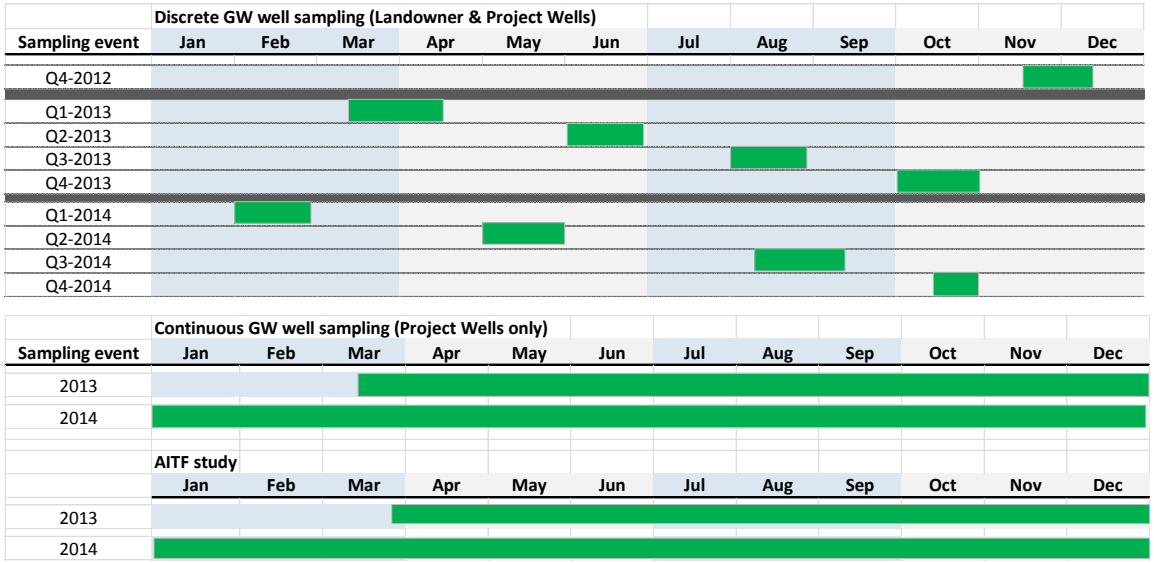


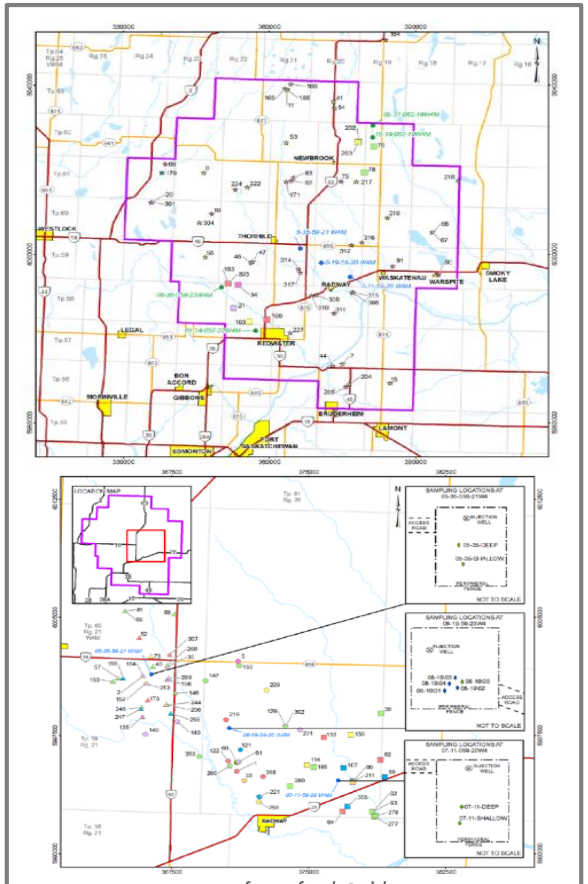

- LightSource system installed and functional at all injection sites
- Release testing very successful
- **Confirmed as technology for atmospheric monitoring at Quest**




- Eddy Covariance system maintained at 8-19 site until end of 2015
- $CO_2$ release tests also clearly detected

# GROUNDWATER



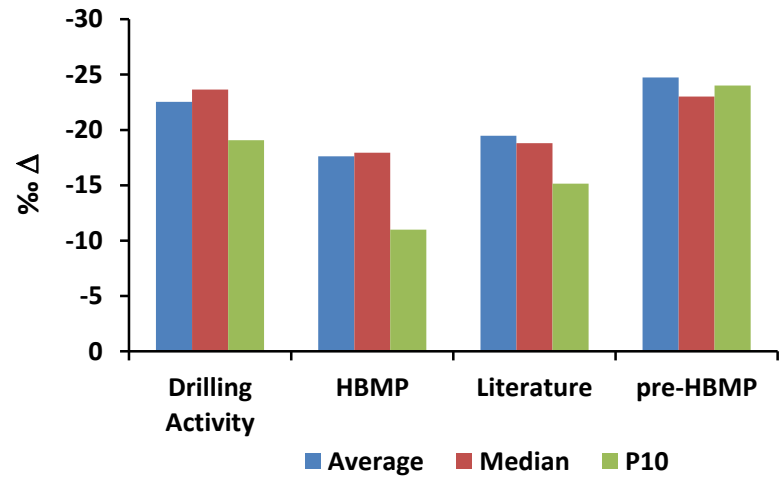



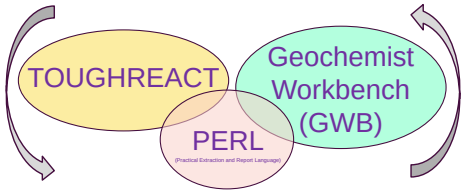

from final Golder report

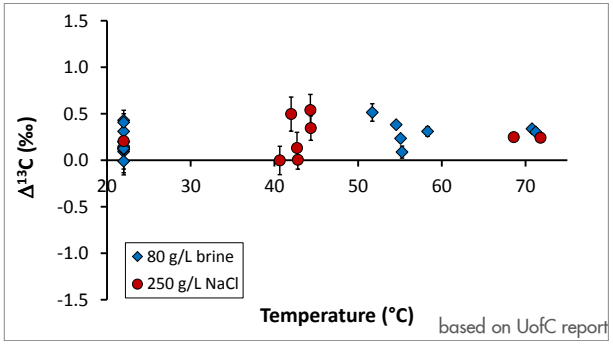
- Continuous monitoring of Shell project wells (on well pads), some issues with sensor maintenance
- Extensive field sampling campaign of landowner wells, many measurements taken
- Comprehensive baseline data
- **Working with regulator to optimize sampling**

# TRACER ASSESSMENT

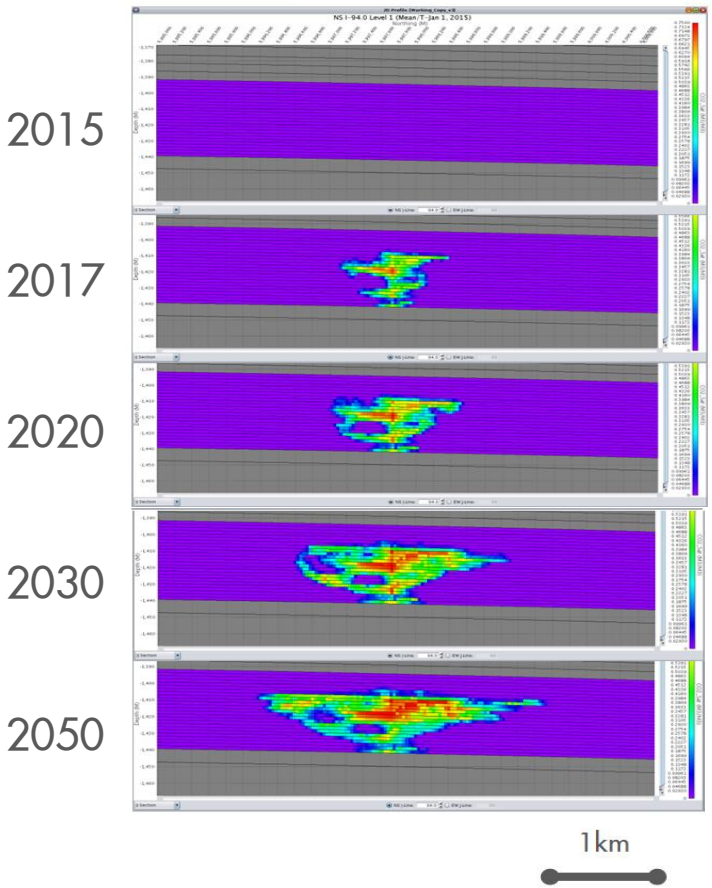
- Assessed artificial & natural tracers
- Determined $\delta^{13}C$ for various $CO_2$ sources within Quest SLA
- Samples taken from sampling point at Scotford Upgrader near output from compressor
- Laboratory work and modelling studies
- **Expect injection gas to be distinct from background $CO_2$ sources in Quest SLA**



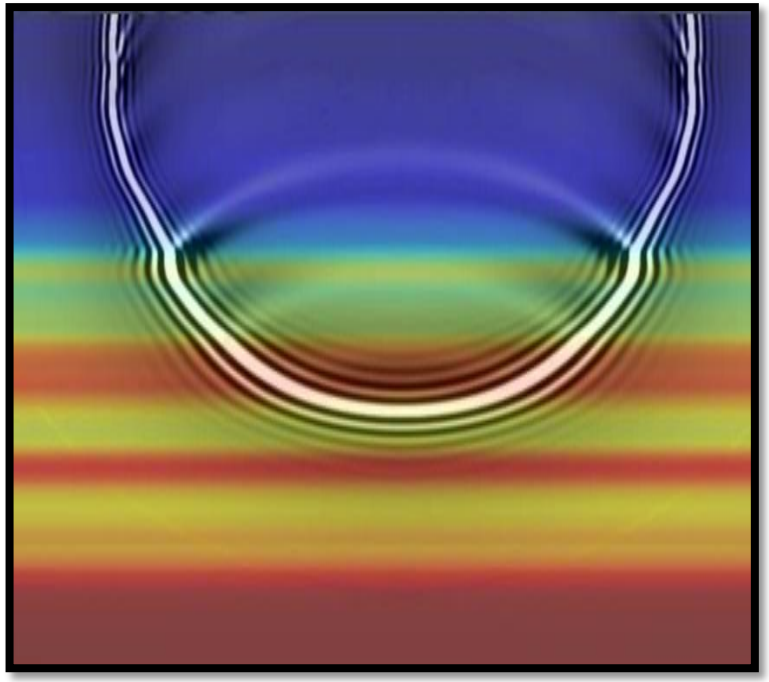



# GEOPHYSICS – VSP MODELLING



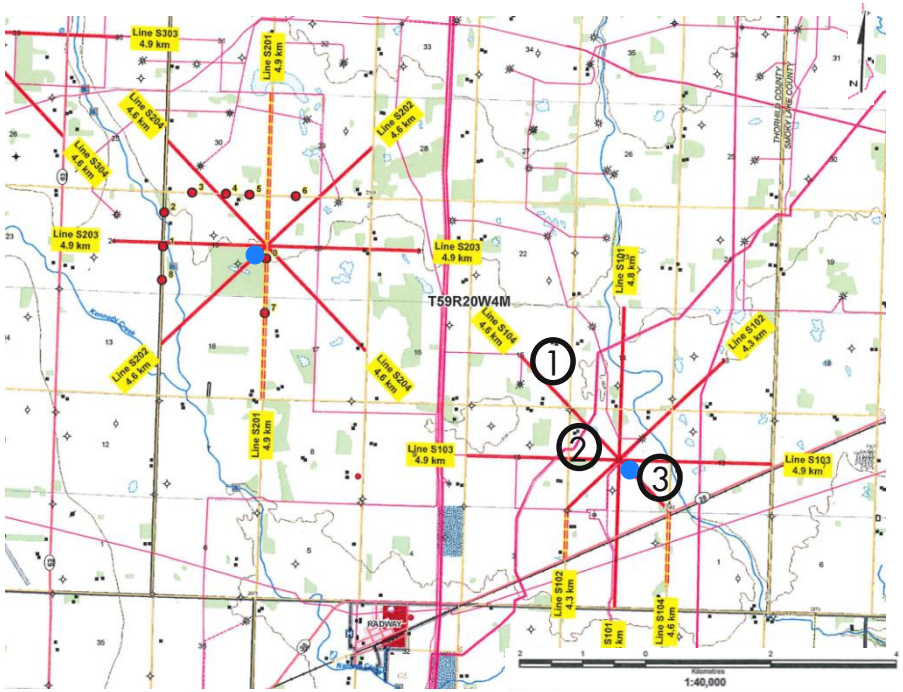

Development through time of a $CO_2$ plume injected into the BCS using our current reservoir model



Wave equation synthetics used to predict the seismic response of $CO_2$ in the reservoir

# VSP ACQUISITION



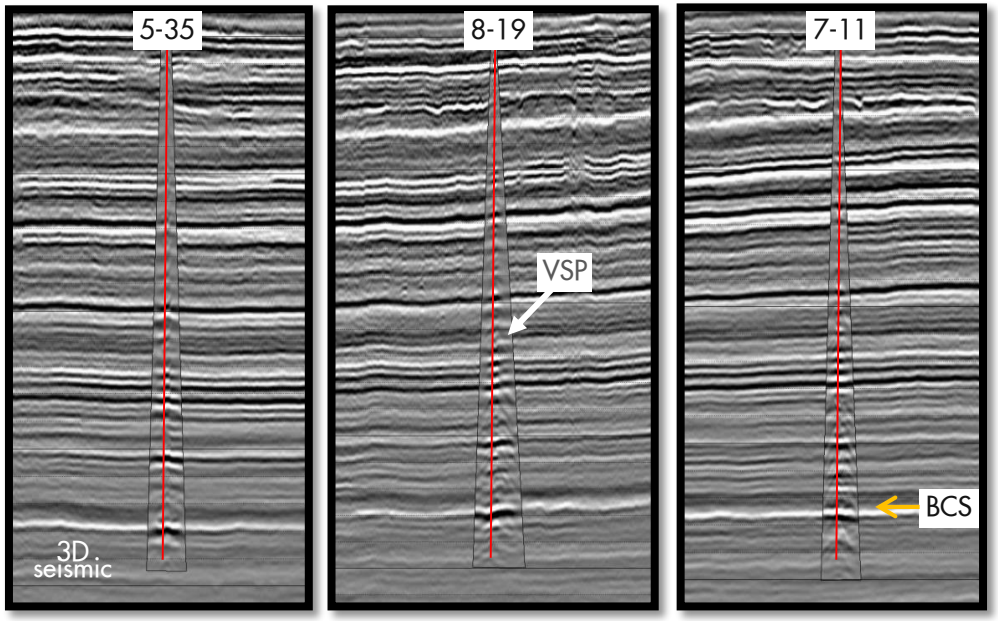

- Design change: from 3D VSP to radial walkaway 2Ds
- Acquired baseline VSP in Feb, 2015 and the first monitor VSP in Feb, 2016.
- Processing is complete – still evaluating the results, but 4D response is strong

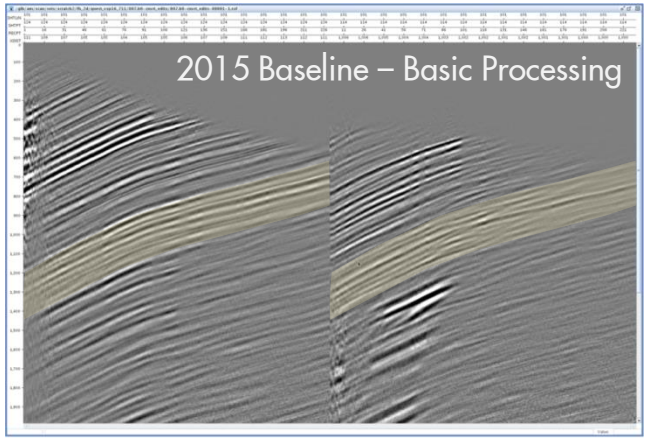
# VSP RESULTS

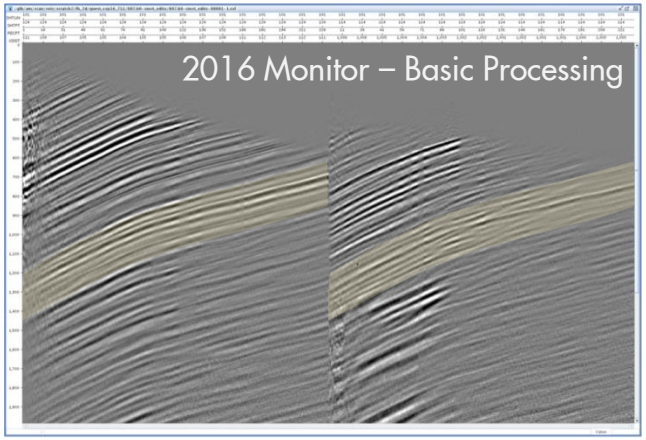
## Baseline work:

- VSP processing was challenging: anisotropy, strong multiples
- VSP Results contributed to the re-processing of the existing 3D
- Good tie between the VSP and the 3D seismic

VSP vs 3D seismic for 2015 baseline survey



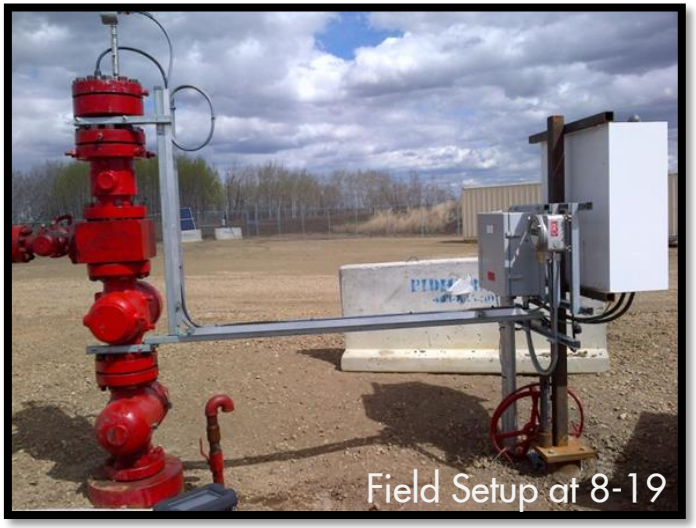



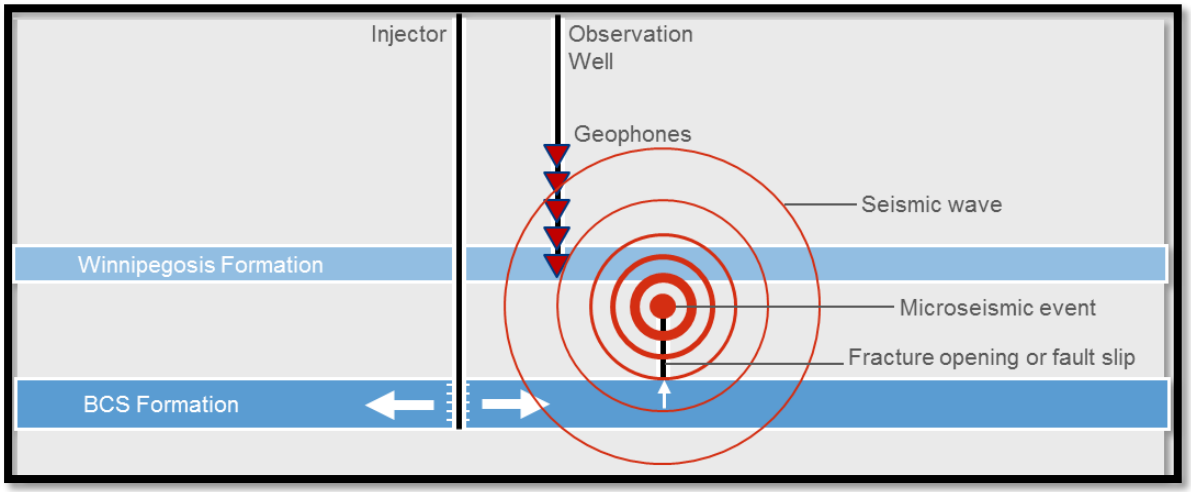



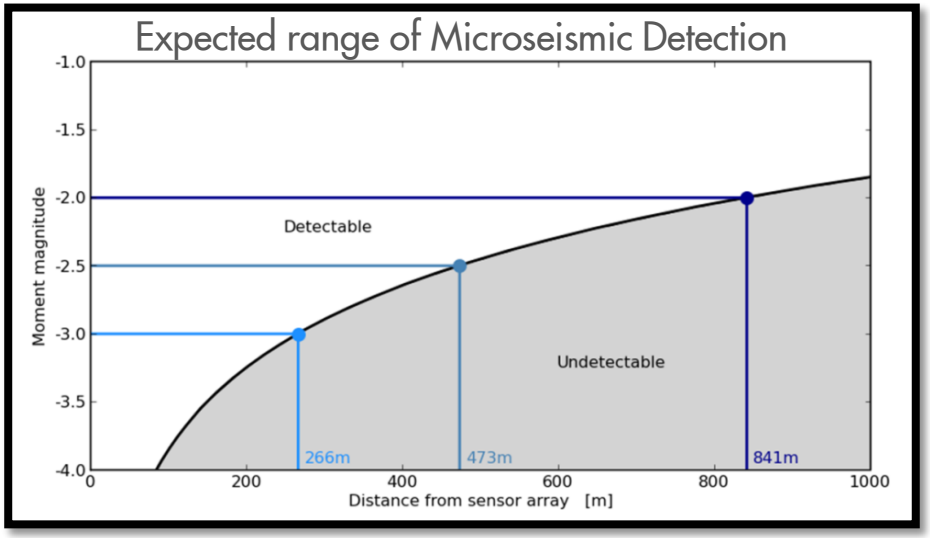

## Early time lapse results:

- Good quality DAS data
- Excellent repeatability
- **Strong time lapse response**

# MICROSEISMIC

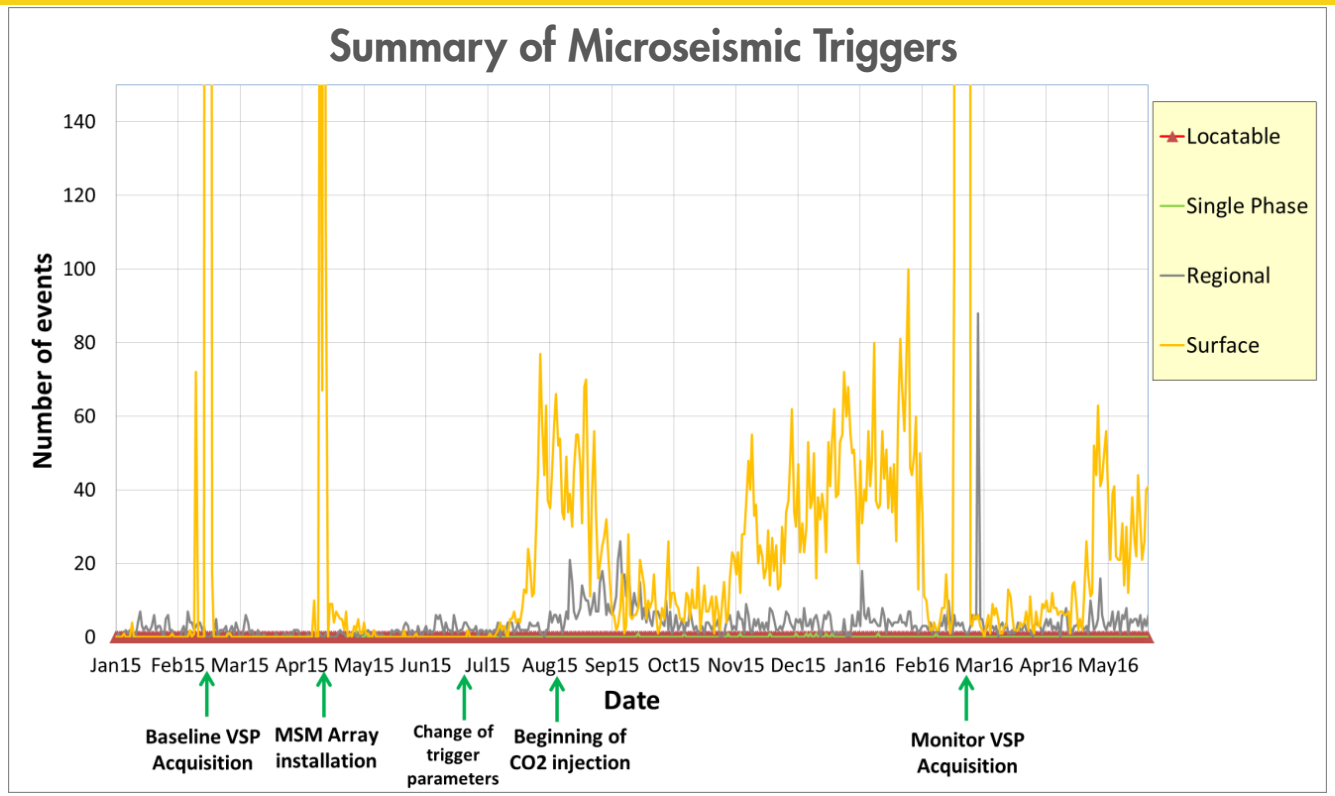



- Microseismic array has been continuously recording since Nov 2014.
- The array is expected to detect events of magnitude -2.0 from a distance of ~840 m

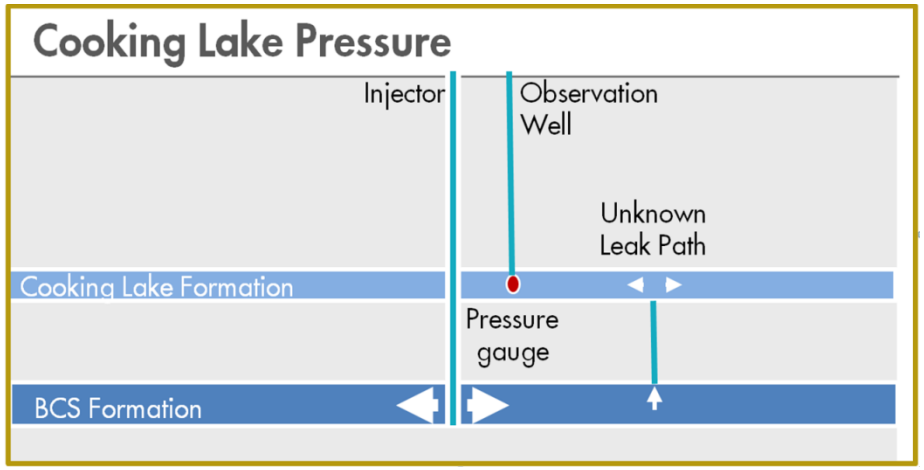
# MICROSEISMIC – QUEST DATA

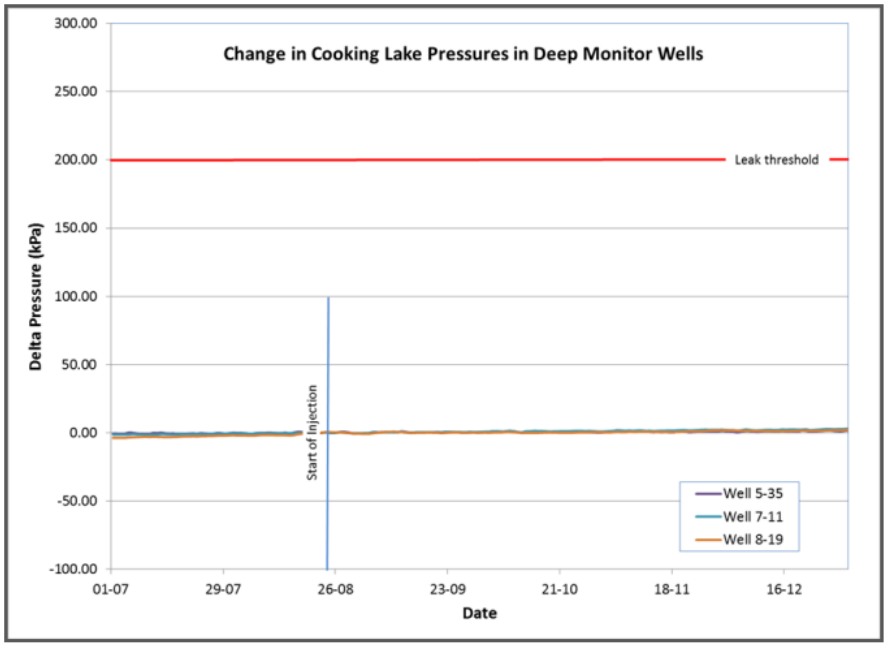



- Array working correctly. Surface and regional triggers are constantly recorded.
- High number of surface events are related to well or seismic work.
- Earthquakes and regional human (eg. mining, industrial, military) activity are recorded as regional events.

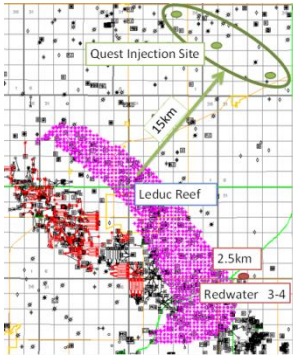
➡ **No locatable events yet detected**

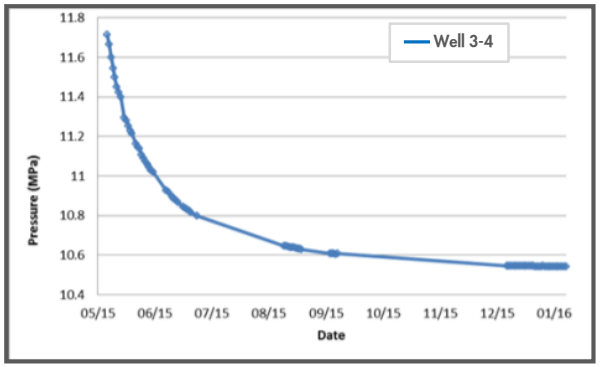
# DEEP MONITORING WELLS



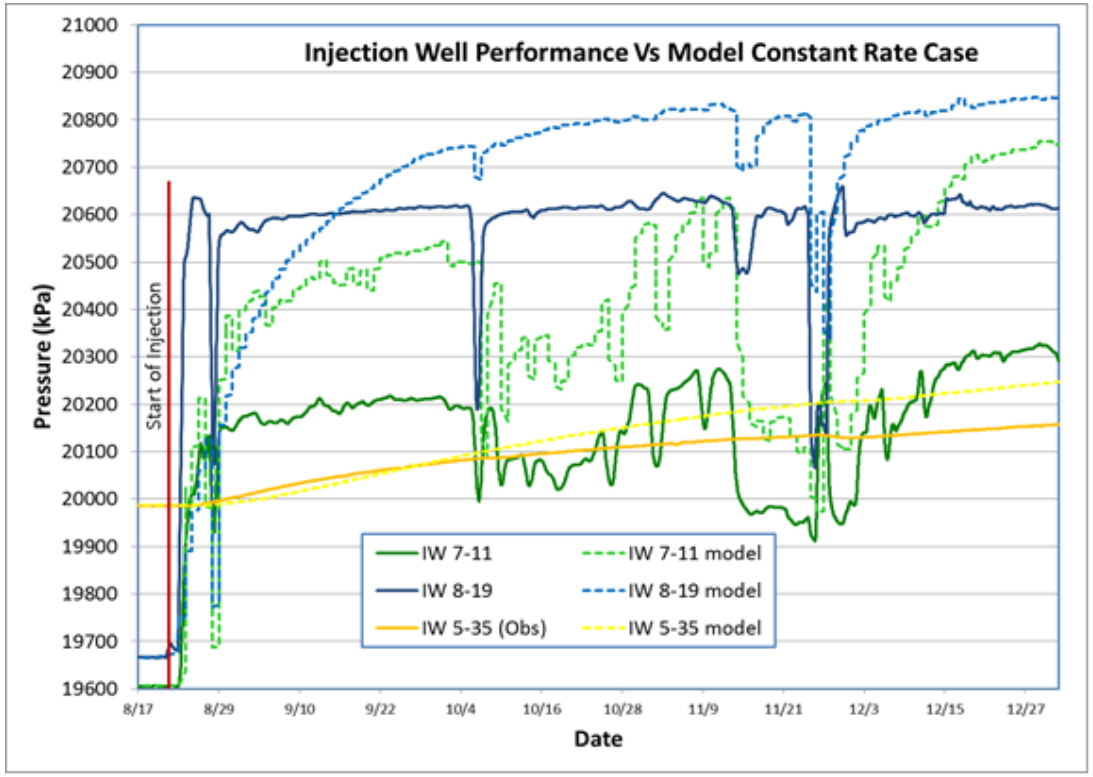

- Steady DMW pressure data in CKLK provides reasonable evidence of the absence of a leak path into the CKLK.
- Pressure fluctuation > 200 kPa is the threshold indication of a leak
- The 3-4 well is closer to the Redwater Field – used as a proxy for Leduc response



# RESERVOIR MODEL – PRESSURE RESPONSE

- Pressure build-up in the reservoir (BCS) is less than predicted
- 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 (ΔP) by the end of the project life



# MMV UPDATE SUMMARY

## Key Update to MMV plan:

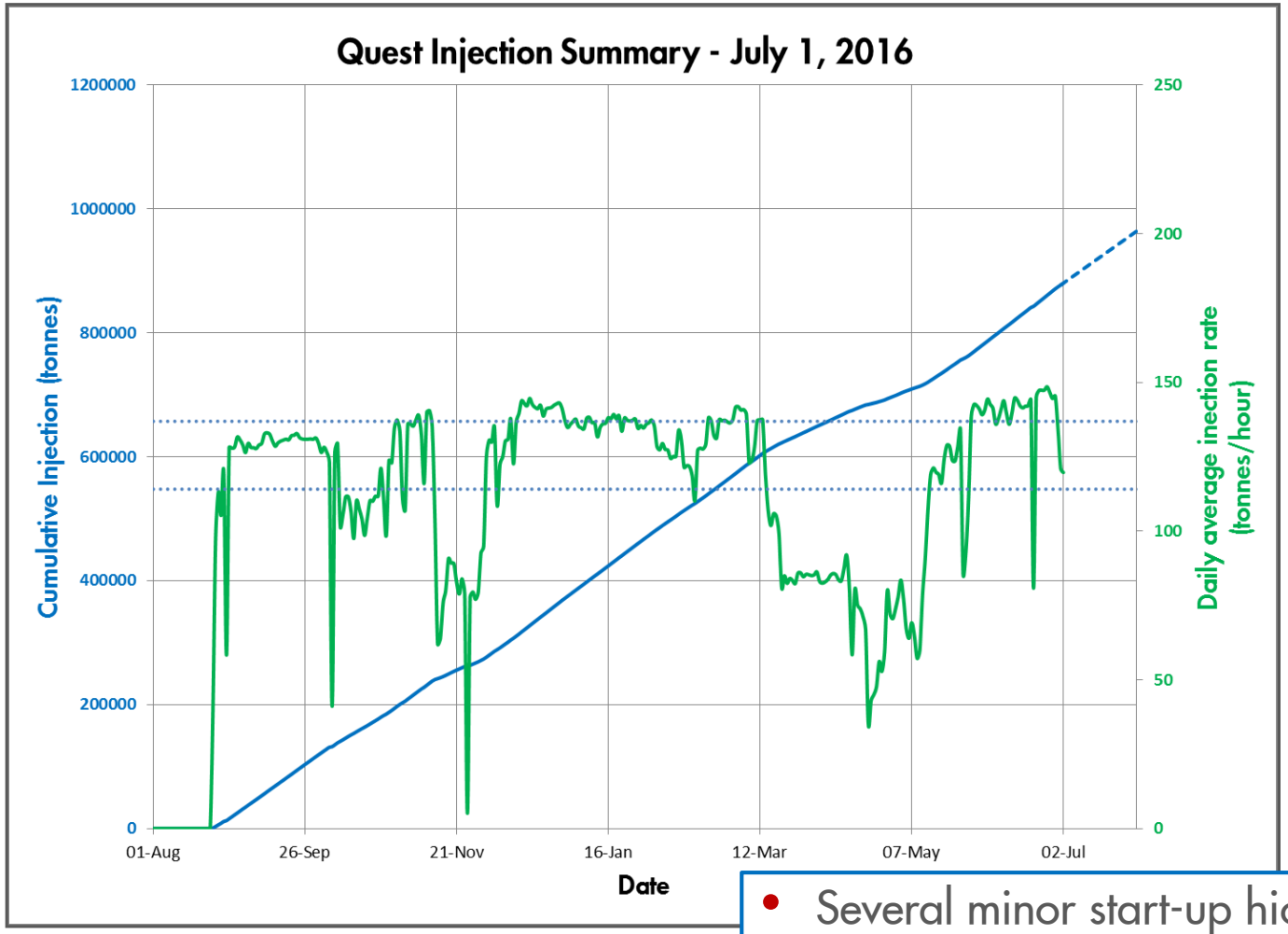
- Removed RIA & MIA
- LightSource functionality confirmed
- Revised GW well sampling strategy
- Change in VSP survey design

| Domain | Technology | Trigger Event | 23 Aug to 31 Dec 2015 | Comment |
|---|---|---|---|---|
| Atmosphere | LightSource | Sustained locatable anomaly above background levels | | Impact of inclement weather on system response being investigated |
| Bio-sphere | Soil Gas | Outside established baseline range | | |
| Bio-sphere | Surface CO2 Flux | Outside established baseline range | | |
| Hydro-sphere | Tracer | Outside established baseline range | | |
| Hydro-sphere | WPH | Sustained decrease in baseline pH values | | |
| Hydro-sphere | WEC | Sustained increase in baseline WEC values | | |
| Hydro-sphere | Geochemical Analyses | Outside established baseline range | | |
| Geopshere | DHPT CKLK | Pressure increase 200 Kpa above background levels | | |
| Geopshere | DHMS | Sustained clustering of events with a spatial pattern indicative of fracturing upwards | | |
| Geopshere | DTS | Sustained temperature anomaly outside casing | | Move to automatic data retrieval |
| Geopshere | VSP2D | ID coherent and continuous amplitude anomaly above the storage complex | | 1st Monitor Q1/2016 |
| Geopshere | SEIS3D | ID coherent and continuous amplitude anomaly above the storage complex | | N/A |
| Geopshere | InSAR | Unexpected localized surface heave | | assessment after ~ 1 year of injection |

## Operations:

- Still evaluating InSAR, other technologies
- Microseismic completely silent
- No valid triggers yet recorded
- **Reservoir quality better than expected – excellent injection performance to date!**

# QUEST – FIRST (ALMOST) YEAR OF OPERATION




- Several minor start-up hiccups
- Remarkably stable injection
- On target for a million tonnes in first year

# ACKNOWLEDGEMENTS


- Government of Alberta, Department of Energy (DOE)
- Government of Canada, Natural Resources Canada (NRCan)
- Shell staff (Calgary, Houston, EU, Scotford and in the field)
- 3rd Party Contractors: Fluor, Golder Assoc., ESG, Boreal, Air Liquide, U. of C., U.B.C., U. Vic., et al.
- Partners: Chevron Canada Ltd & Marathon Oil Canada