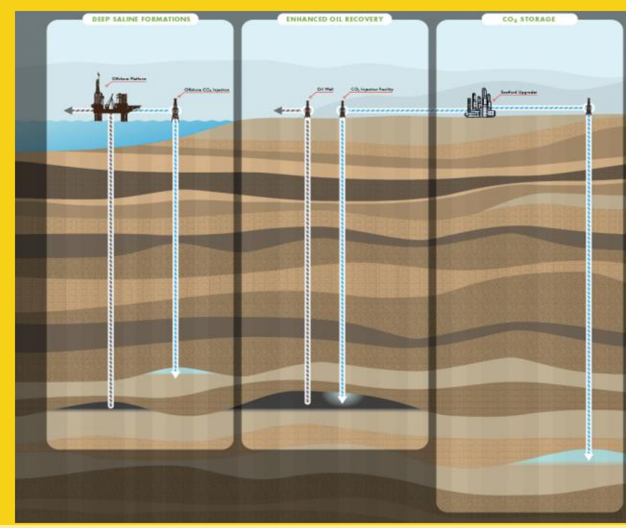
QUEST Carbon Capture and Storage
The Dynamic Aspects Of Formation Storage Use for CO2 Sequestration

CSLF Forum Edmonton

May 2011



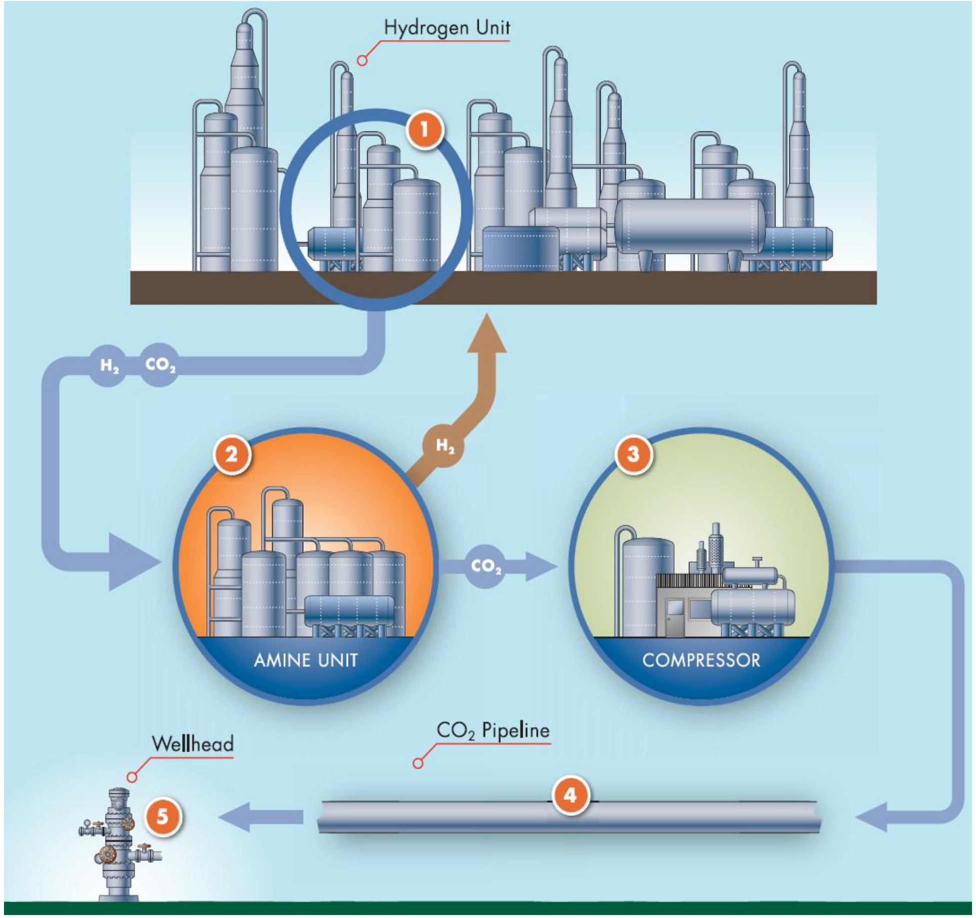
Shell Canada Energy

Syrie Crouch Quest Sequestration Manager:

Hein De Groot, Reda El Mahdy, Mauri Smith, Satinder Malik, Stephen Bourne, Robert Pierpont, Vincent Hugonet, Mario Winkler, Ross Abernethy, Micah Nicolo, Hongmei Huang, Audrey Wang, Shuyu Zhang, Alessandra Simone, Christa Clark, *Shell International Exploration and Production*

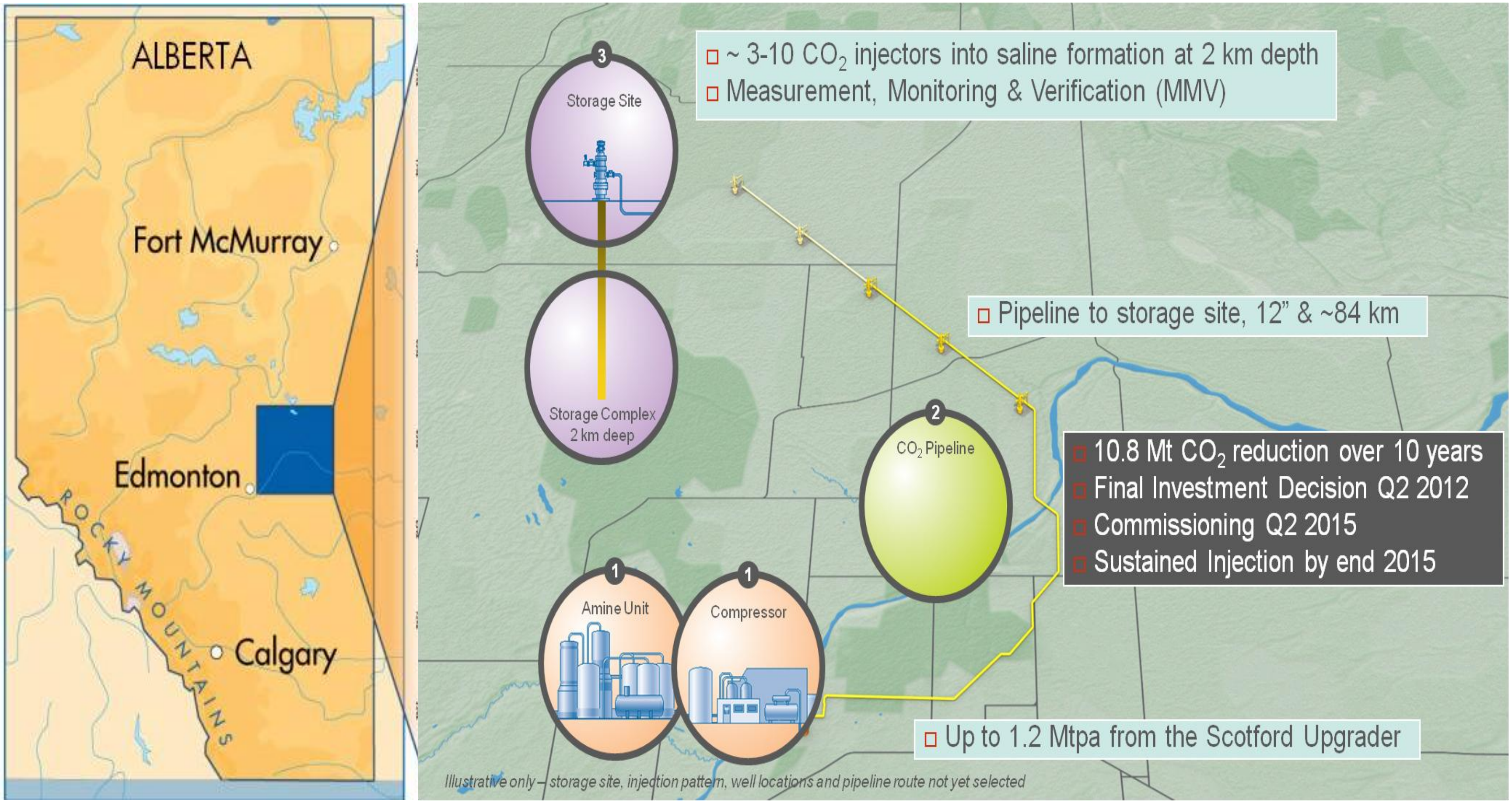
Introduction & Agenda

- Introduction to the Quest Project
- Evolution of Pore Space Evaluation
  - Static
  - Semi-Dynamic
  - Integrated Reservoir Modelling
  - Urban Planning
- Regulatory Submission
- Conclusions
- Aknowledgements



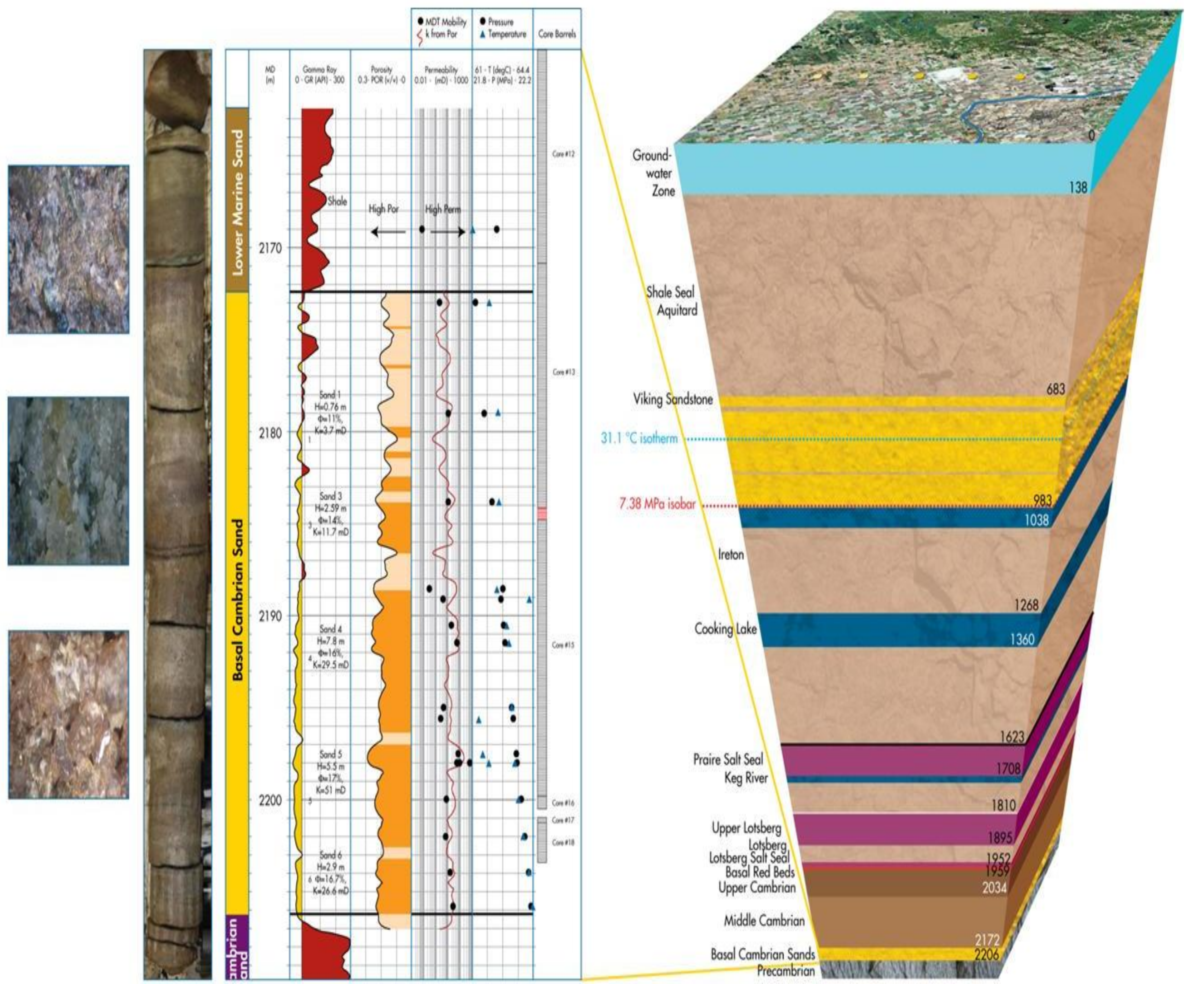
Introduction – The Quest Project

- Quest Project Location and Specification
  - Fully integrated CCS JV of Shell, Chevron and Marathon
  - Capture and storage of 1.1 Mtpa of CO_2 for 25 years from the Scotford heavy oil upgrader (CCS fully operational in 2015)



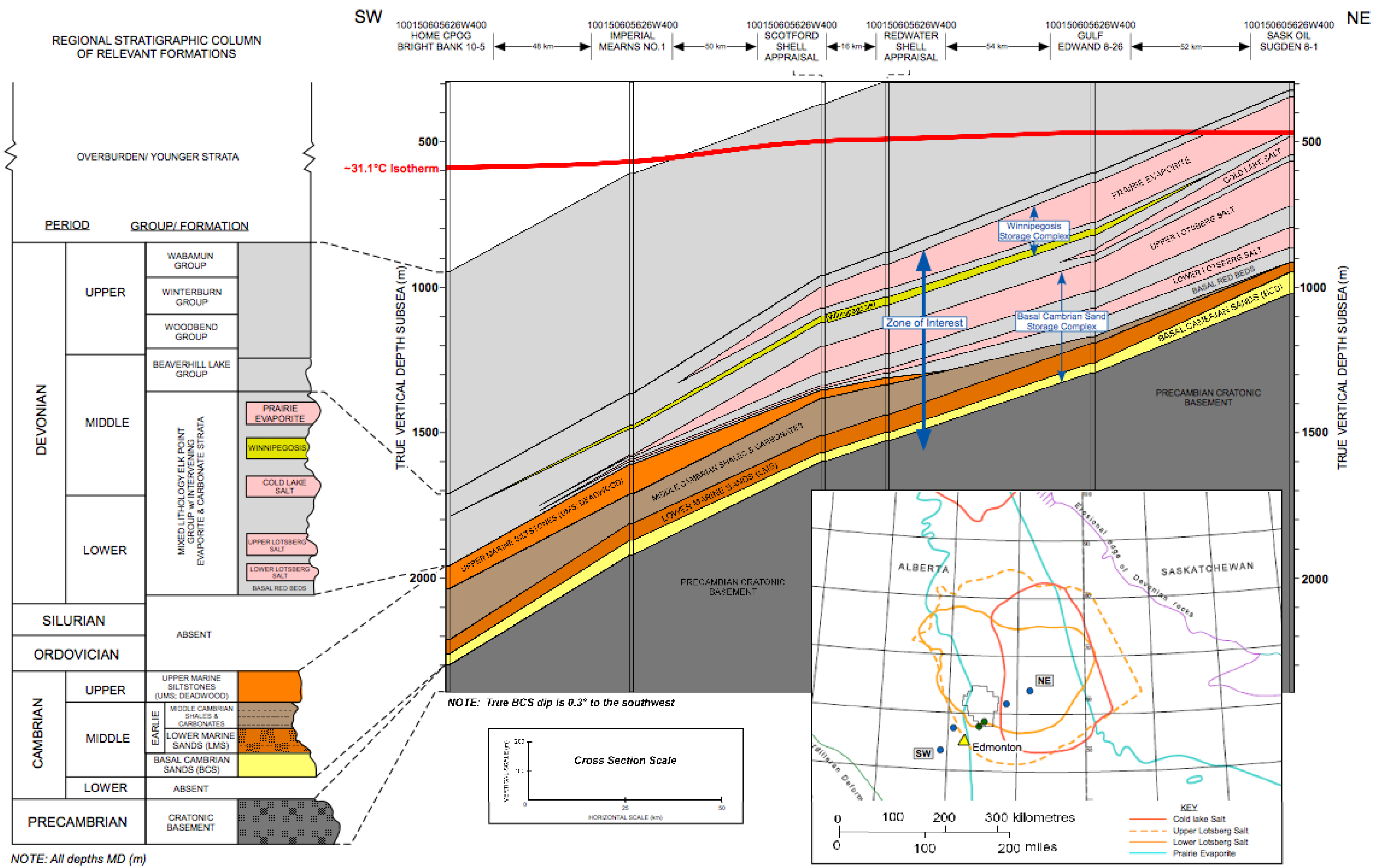
Introduction – The Storage Formation

- A deep saline aquifer more than 2000 m below groundwater
  - Drilled three appraisal wells, Scotford and Redwater (2008/2009) and Radway (2010) ← in the center of the future development
  - Confirmed favorable formation properties and sequence of seals



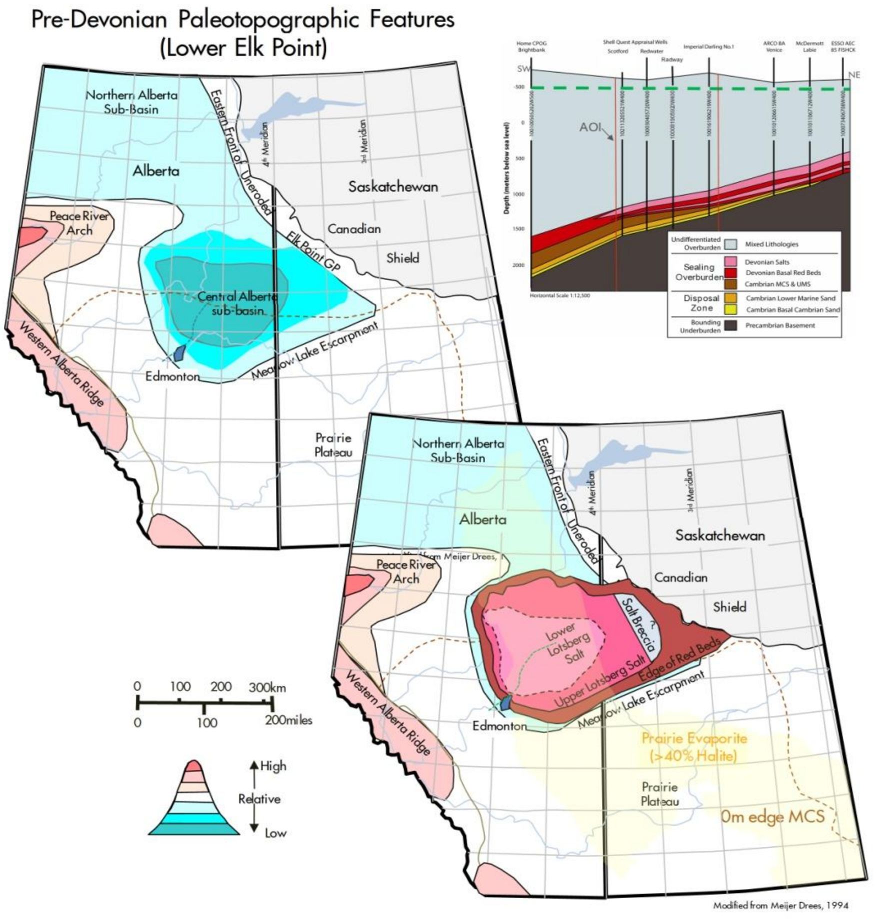
Introduction – The Storage Formation

- Regional stratigraphic column of relevant formations

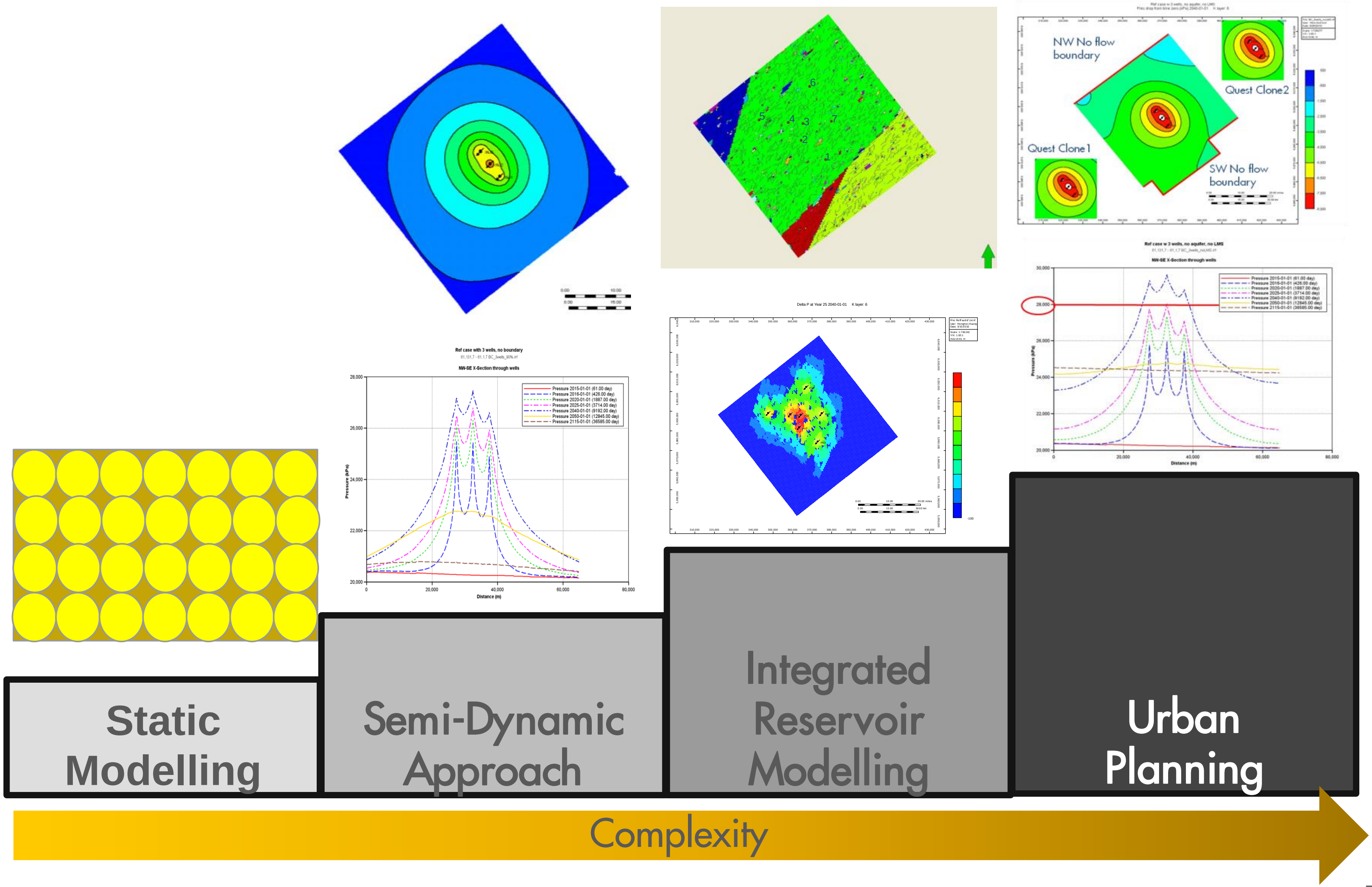


Introduction – Quest Seal Extent

- The Upper and Lower Lotsberg Salts are regional extending halite bodies thickening up-dip towards the NE
  - Seal package able to map from seismic
  - Present in all of the 120+ wells in the region we have evaluated
  - Geophysically “boring” area (no significant faulting)
  - Tectonically quite
  - On a regional scale, an excellent storage complex of 150,000 km^2



Modelling and Pore-Space Evolution



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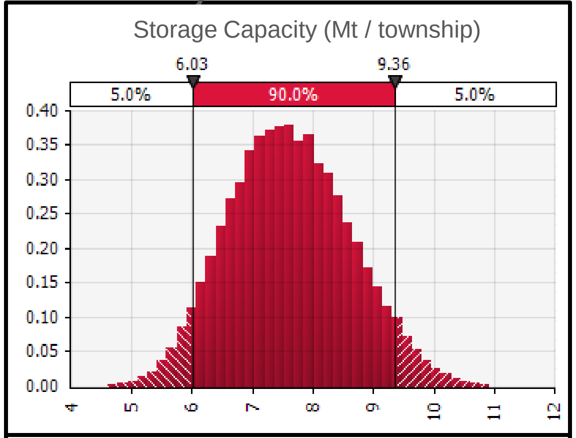
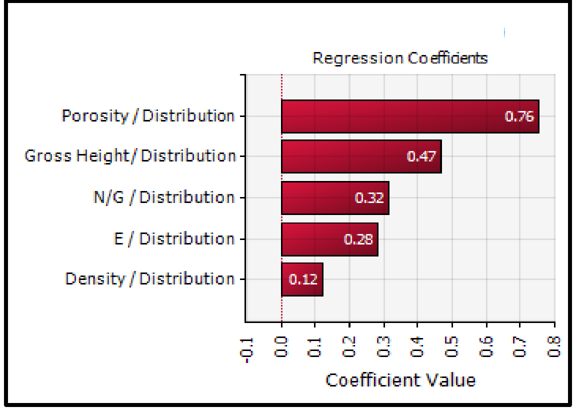
Pore Space Utilization - Static

- Volumetric estimates (material balance) of CO_2 replacing formation brine in a permeable formation with a certain efficiency *E* *

$$G_{CO_2} = A \cdot h_g \cdot \phi_t \cdot \rho \cdot E$$

Parameter	Mid Estimate	Low Estimate	High Estimate	Unit
BCS height	38	28	41	m
BCS porosity	15	11	19	%
BCS NTG	0.90	0.80	1.00	Fraction
Res. Temperature	58	64	55	ºC





- BCS has the potential to store 6-9 Mt of CO_2 per 93.24 km^2
  (1 township = 6 x 6 miles)

* DOE, 2006. Carbon Sequestration Atlas of the United States and Canada: Appendix A – Methodology for Development of Carbon Sequestration Capacity Estimates, National Energy Technology Laboratory, U.S. Department of Energy, 71-81

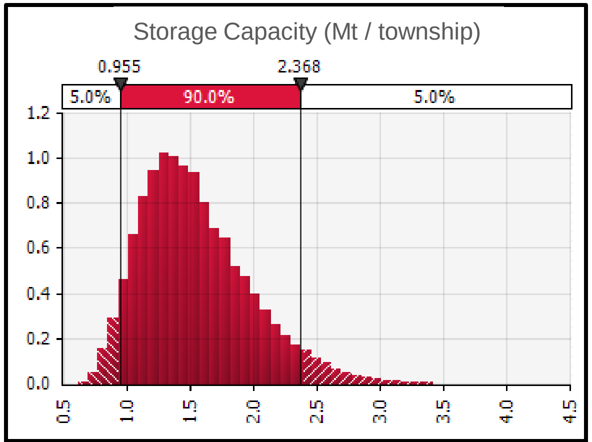
* Bachu, S., Bonijoly, D., Bradshaw, J., Barruss, R., Holloway, S., Christensen, N.P. and Mathiassen, O.M., 2007. CO2 Storage Capacity Estimation: Methodology and Gaps. International Journal of Greenhouse Gas Control, 1(4), 430-443

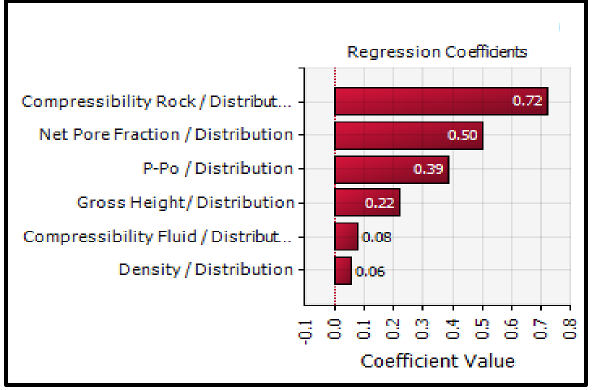
Pore Space Utilization – (Semi)dynamic

- Confined aquifer approach, assuming a compressible net pore volume and matrix under BHP constraint*

$$G_{CO_2} = V_{wo} \cdot c_t \cdot (p - p_0) \cdot \rho \quad c_t = c_p + c_w$$

Parameter	Mid Estimate	Low Estimate	High Estimate	Unit
BCS height	38	28	41	m
BCS porosity	15	11	19	%
BCS NTG	0.90	0.80	1.00	Fraction
Res. Temperature	58	64	55	ºC
Res. Pressure	20.45	20.2	20.7	MPa
Max. Inj. Pressure	28.0	26	31.0	MPa
Rock Compressibility	1.0 E-6	0.5 E-6	5.0 E-6	1/psi
Water Compressibility	2.0 E-6	1.8 E-6	2.2 E-6	1/psi





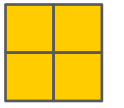
- BCS has the potential to store 1-2.4 Mt of CO_2 per 93.24 km^2 (1 township = 6 x 6 miles)

* DOE, 2008. Methodology for the Development of Geologic Storage Estimates for Carbon, National Energy Technology Laboratory, U.S. Department of Energy, 24-27

* Frailey, S.M., R.J. Finley and Hickman, T.S., 2006, CO2 Sequestration: Storage Capacity Guideline Needed, Oil and Gas Journal, Vol. 104, No. 30, 44-49

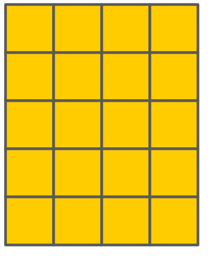
The Required Area - Recap

- The Static Approach and DoE Guidelines
  - Material Balance
  - 6 to 9 Mt/township (at 27 Mt)



4 townships = 373 km^2

- The (Semi)dynamic Approach and DoE Guidelines
  - Static approach at homogeneous pressure limit
  - 1 to 2.4 Mt/township (at 27 Mt)

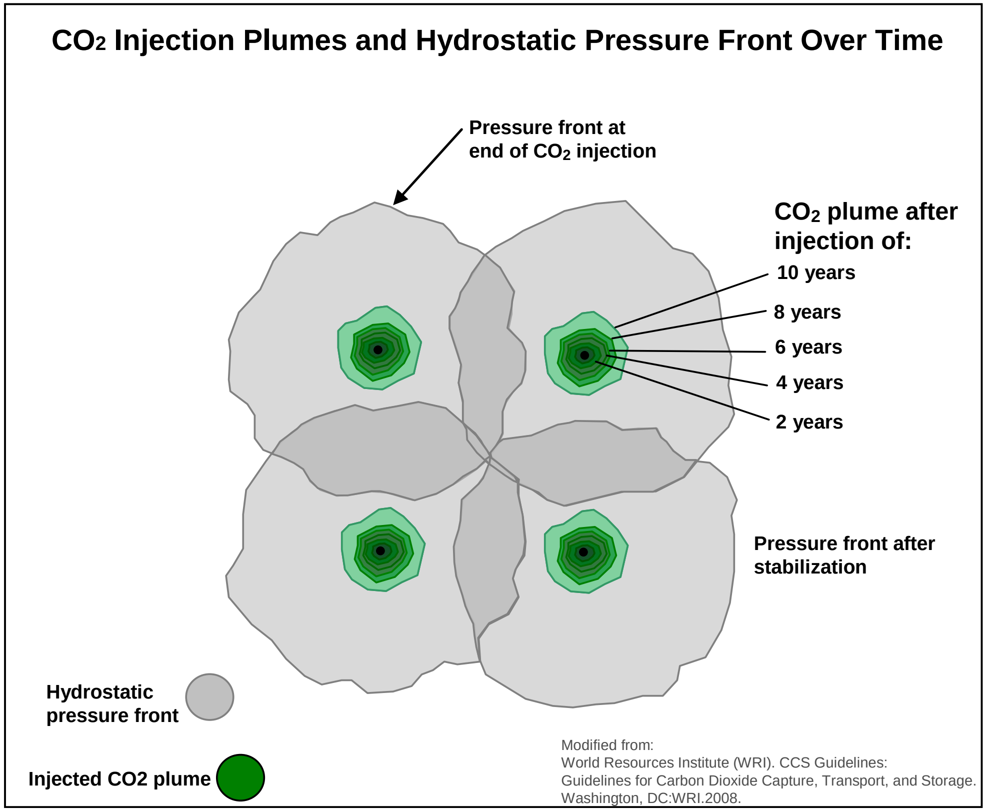


20 townships = 1865 km^2

The Dynamic Aspect of Pore Space Use

- In case of pressure interference (competing wells or competing operators) the ability to maintain injection rate may become a constraint

- Dynamic Reservoir Simulation will enable to:
  - Optimize well spacing
  - Assess the efficient use of pore space
  - Optimize the placement of injection schemes
  - Optimal utilize the pore space for multiple projects at basin scale



Subsurface - Appraisal Strategy

- **Ensure timely demonstration of subsurface containment**
  - **Containment**: Identify any leakage pathways; then avoid or manage using monitoring & control
  - **Injectivity**: Measure injectivity with 3rd appraisal well & retain
  - **Capacity**: Identify any small compartments; then select injector locations
  - **MMV:** Opportunistic baseline

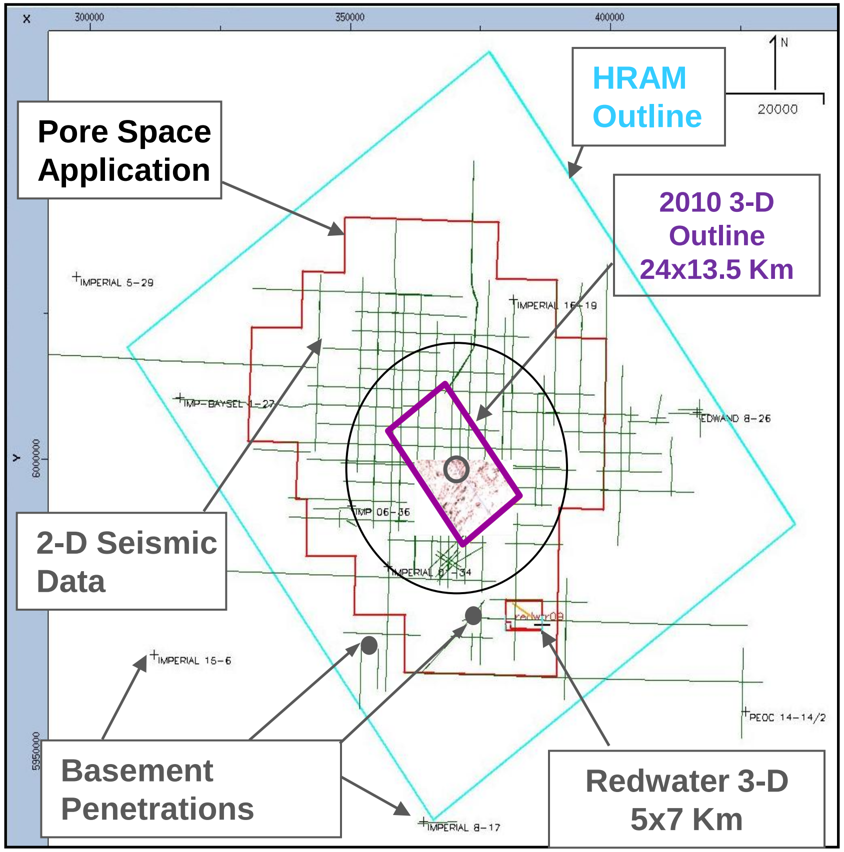
- **2D seismic**
  - Cover pore space application with grid of 55 vintage seismic lines
  - Establish lateral extent of seals

- **3D seismic**
  - Image subsurface development region & validate pipeline route
  - Identify any potential leakage pathways or compartmentalisation
  - De-risk placement of appraisal, injection & monitoring wells

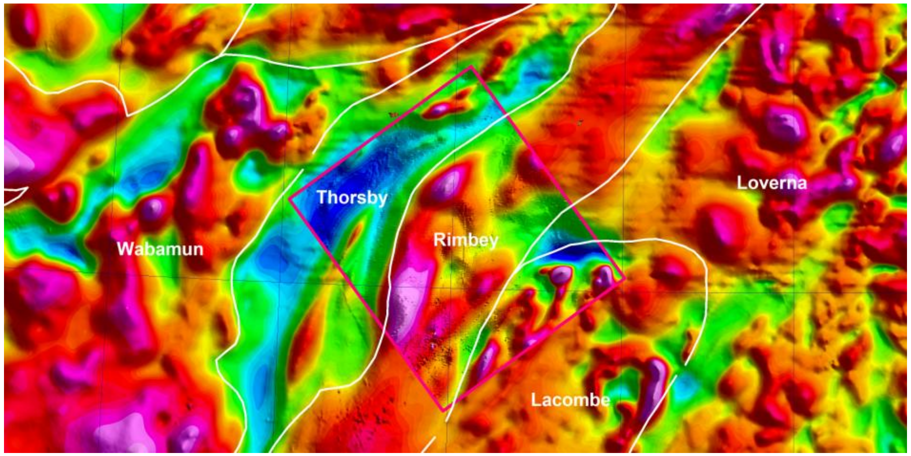
- **High resolution aeromagnetic survey**
  - Wider regional characterisation of pore space area

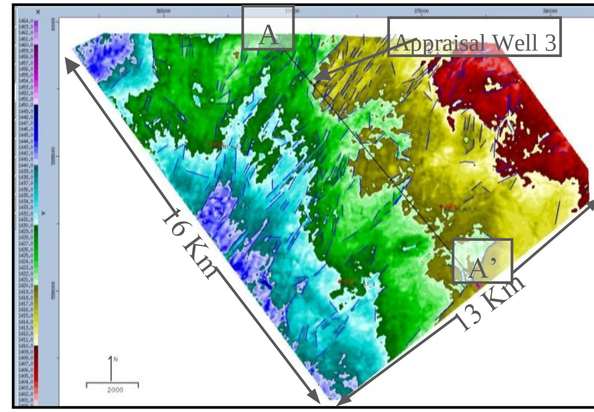
- **Third appraisal well**
  - Acquire data to inform regulatory application & FDP
  - Retain well for injection

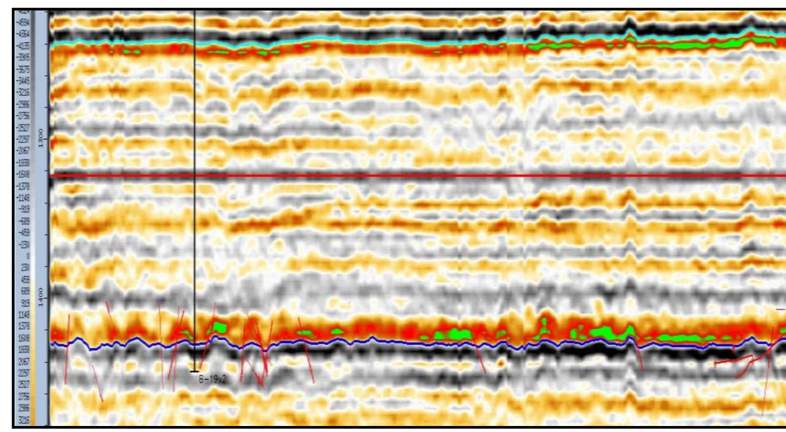
- **Small CO_2 pilot option**
  - Measure CO_2 injectivity only if water injectivity result is marginal



Geophysical Data – AOI derisking

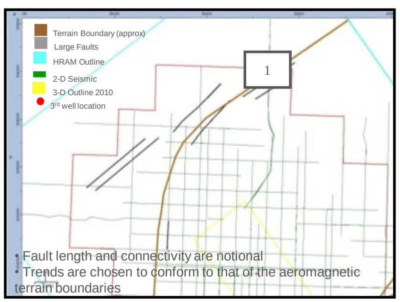


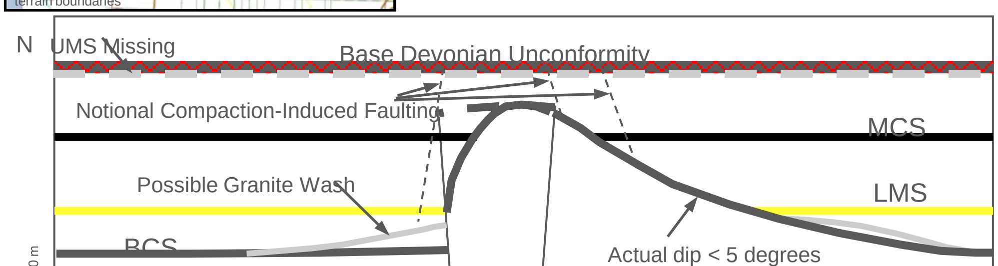




Base Devonian

Top Basement

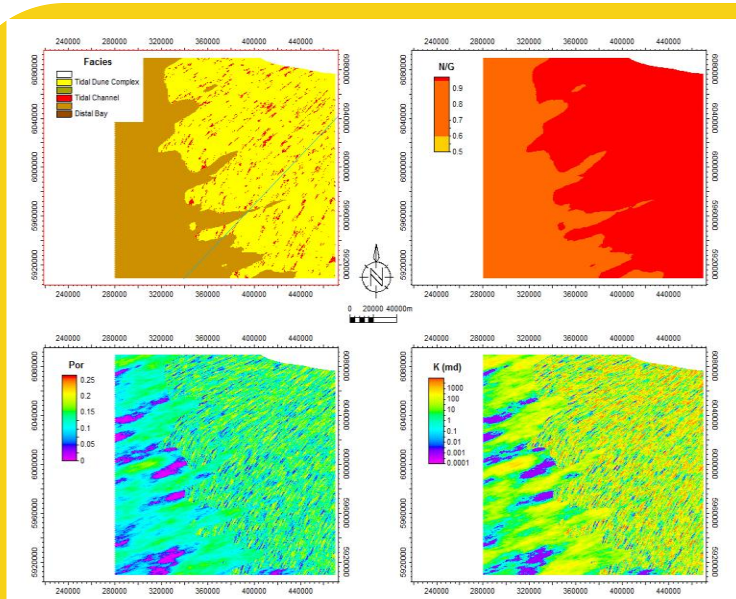


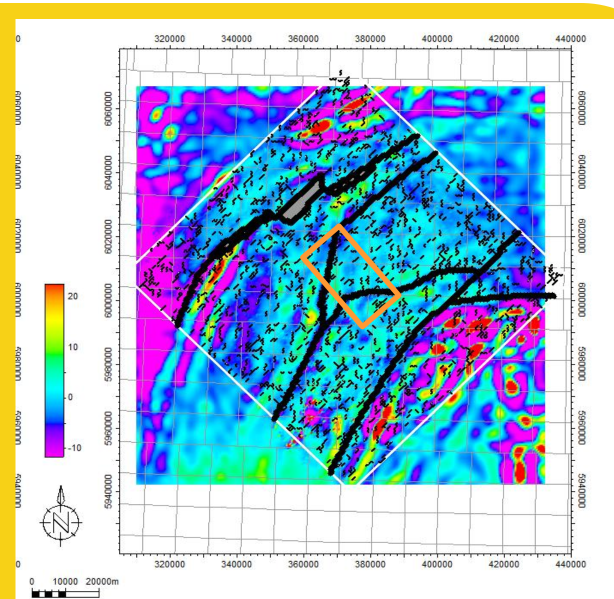


- The Time Structure map shows an overall element of regional dip to the SW
- The map values cover a range of 60 ms (~130 meters), average dip at this level is ~0.5 degrees

Quest Reservoir Models

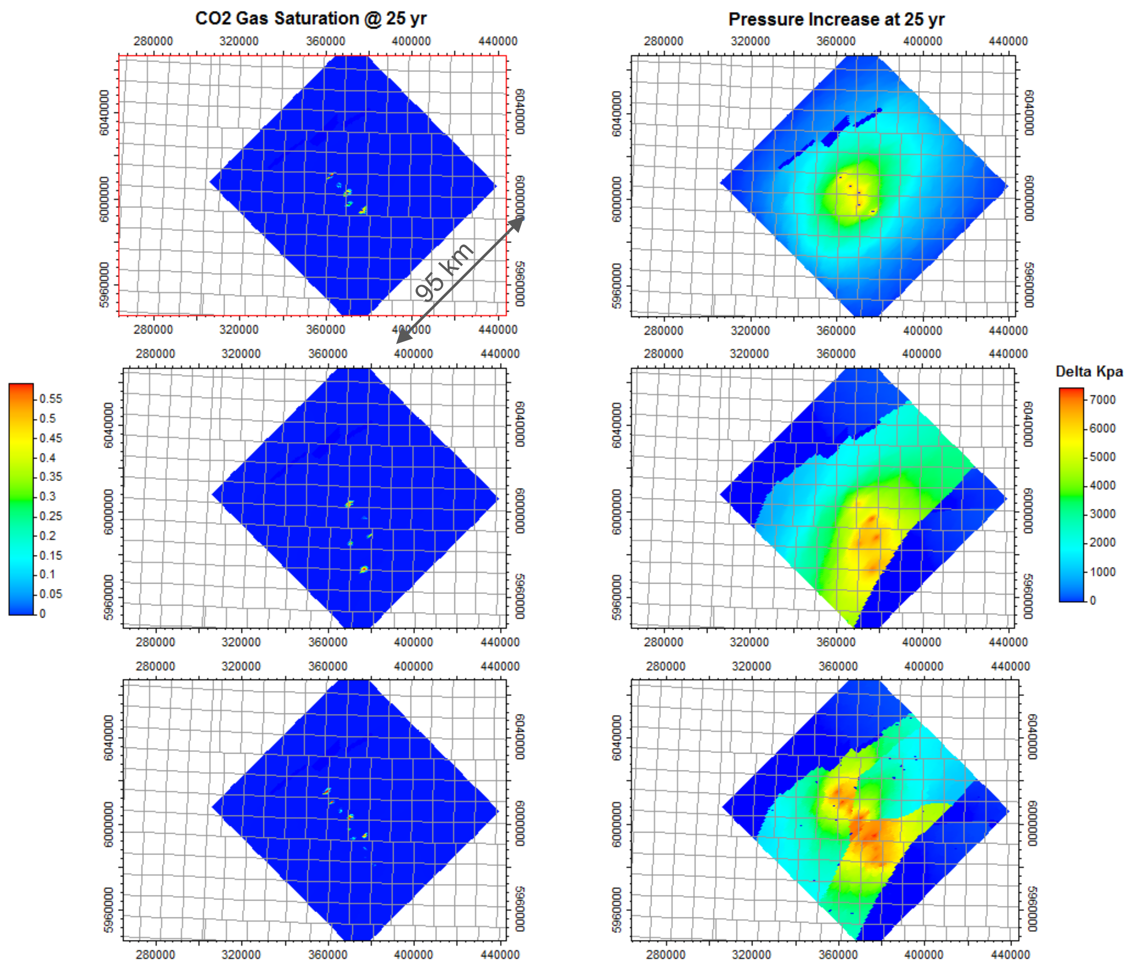
- Conceptual depositional geological model is based on regional core description (tide dominated shallow marine)
- Fully integrated at various scales (GravMag, HRAM, seismic, core, logs, petrography)
- Key drivers / uncertainties:
  - Reservoir quality (n/g, porosity, permeability)
  - Reservoir connectivity (bald highs, flow barriers, connected aquifer size)





CO_2 Footprint and Pore Pressure

- Key outcomes of all potential subsurface realizations are:
  - 2 to 10 vertical injector wells (at 90% of the fracture closure pressure)
  - Well spacing of 5 km is optimal
  - CO_2 footprint around injector wells is a few km's
  - Pore pressure increase in the storage formation extends up to 25 – 40 kilometers



Simple "Urban Planning" 20 MTpa by 2020 or 149 MTpa by 2050

Pressure Map

Pressure Profile

Infinite Aquifer

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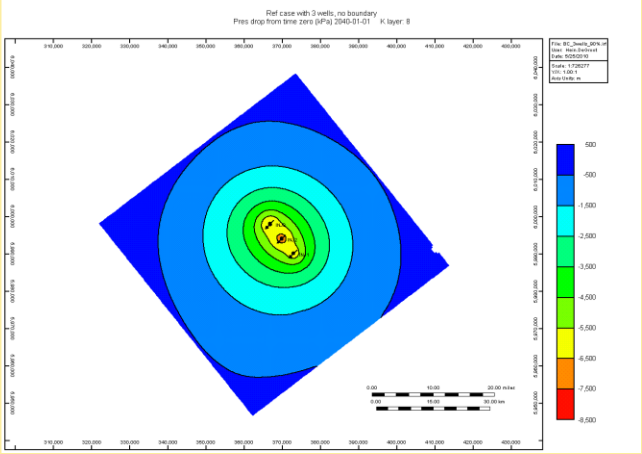
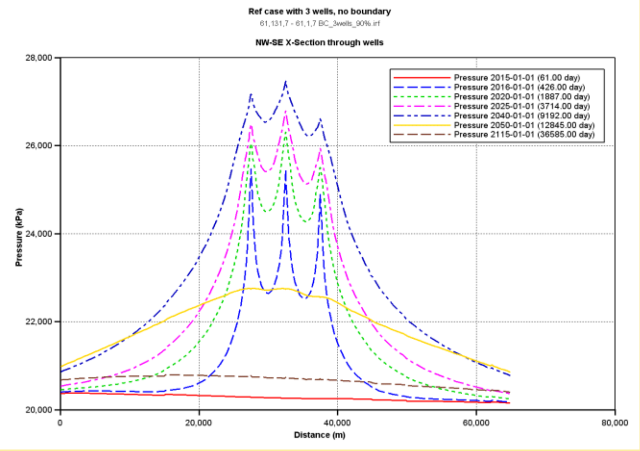
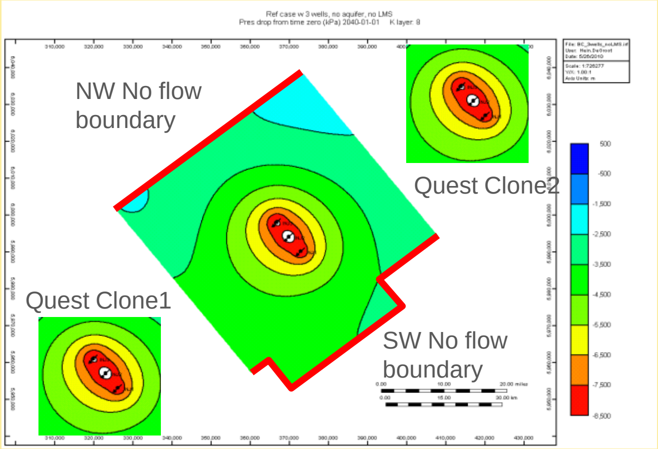
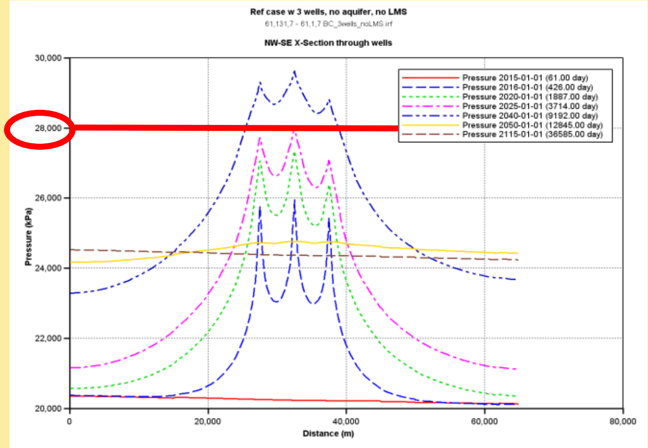




Urban Planning





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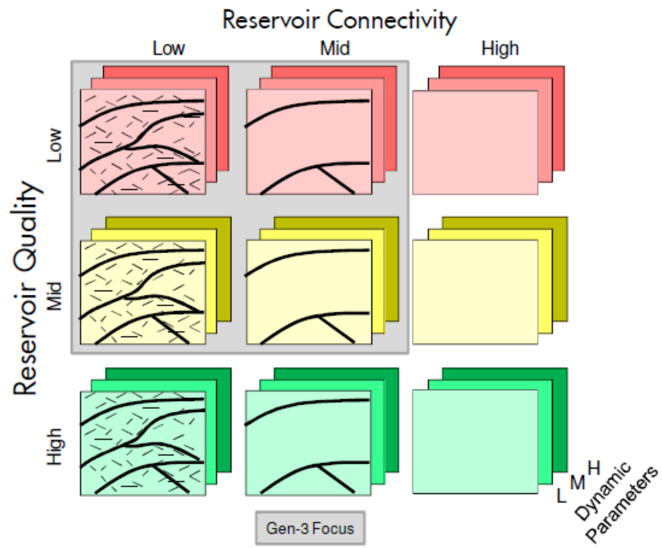
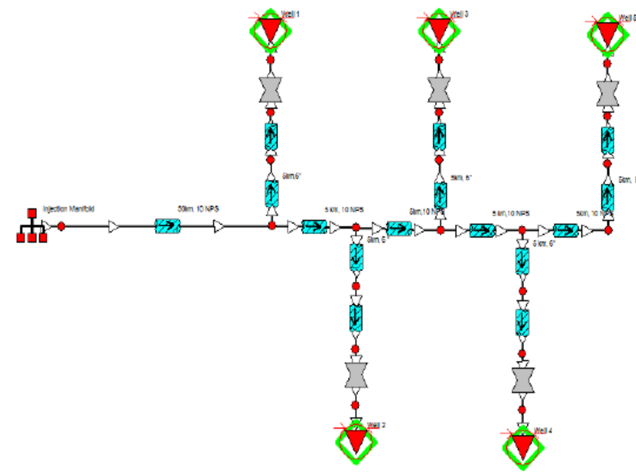
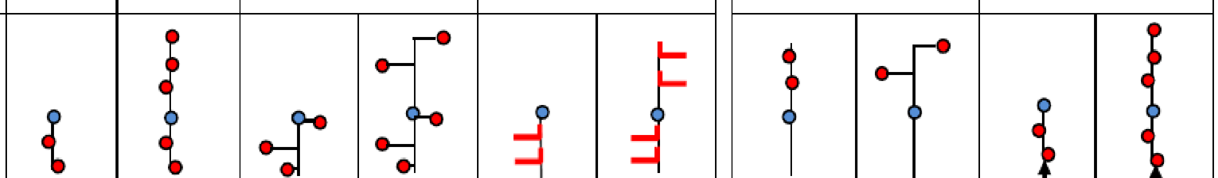
Development Options





	Development Concept Options									
	Key Scenarios						Sensitivities			
							Regulatory		Growth	
	1	2	3	4	5	6	7	8	9	10
Compressor Size (Mpa)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
BHP Constraint (Mpa)	28	28	28	28	28	28	28	28	28	28
Pipeline Size (Inches)	12	12	12	12	12	12	12	12	12	12
Throughput (MM T/yr)	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	2.16	2.16
Well Type	Vertical	Vertical	Vertical	Vertical	Horizontal	Horizontal	Vertical	Vertical	Vertical	Vertical
Main Pipeline Length	Short (To Well 3)	Long (To Point G)	Short (To Well 3)	Long (To Point G)	Short (To Well 3)	Long (To Point G)	Long (To Point G)	Long (To Point G)	Short (To Well 3)	Long (To Point G)
Optimised Well Locations	No	No	Yes	Yes	No	No	No	Yes	No	No
License Size	Full PSA	Full PSA	Full PSA	Full PSA	Full PSA	Full PSA	Limited	Limited	Full PSA	Full PSA
Neighbor Developments?	No	No	No	No	No	No	No	No	No	No
Rationale	Cheapest development closest to SCF Upgrader	Cheapest development utilising full pipeline length with little subsurface guidance on location	Value of Seismic. Can we have get waway with fewwer wells located further from baffles?		Can plausible horizontals offset the impact of poor reservoir quality and connectivty by significantly reducing well count?		If only awarded a smaller area far from Scotford Upgrader can we still make rates? Cost of longer pipe and potetially reduced pore volume access.		Can the world accommodate injection of larger volumes at higher rates?	
Schematic Layout (Blue = RWY 8-19)										

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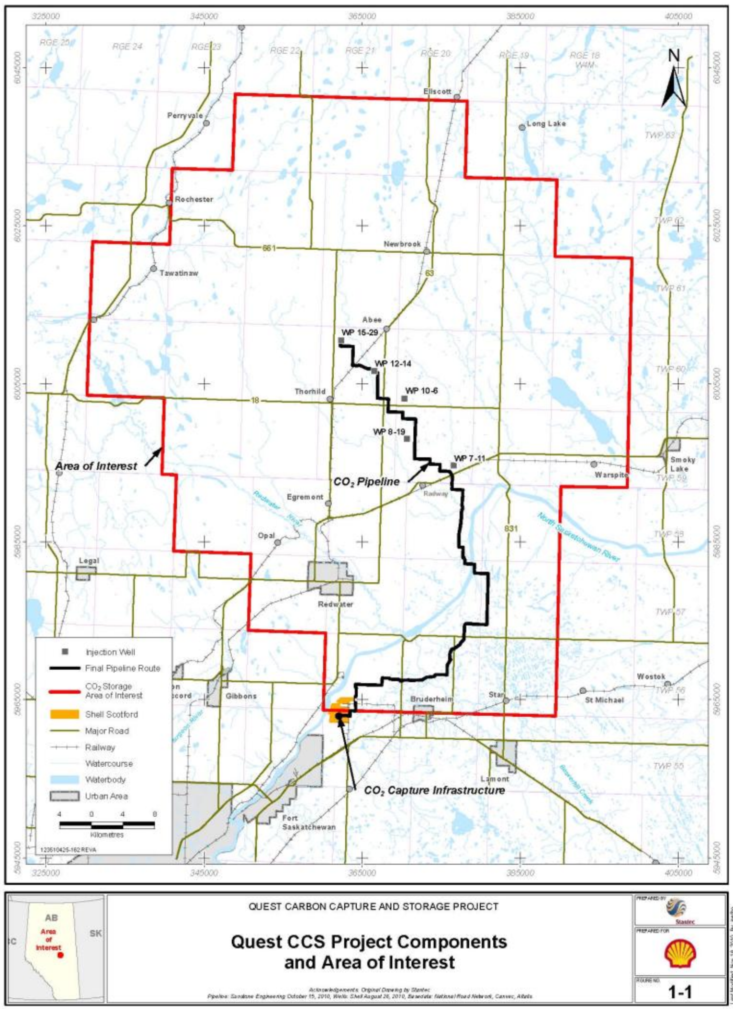
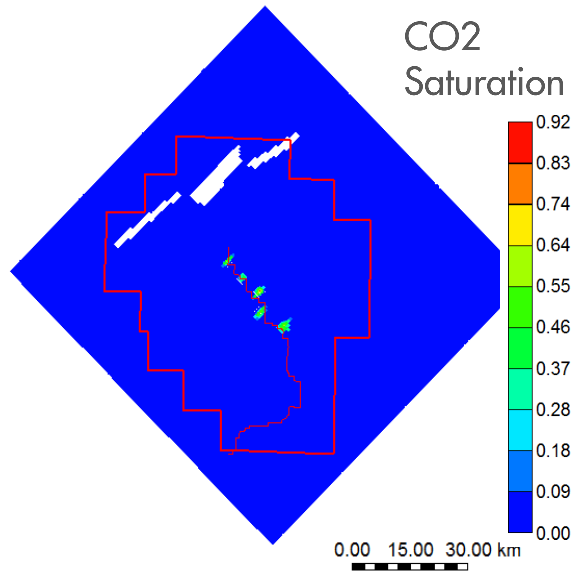
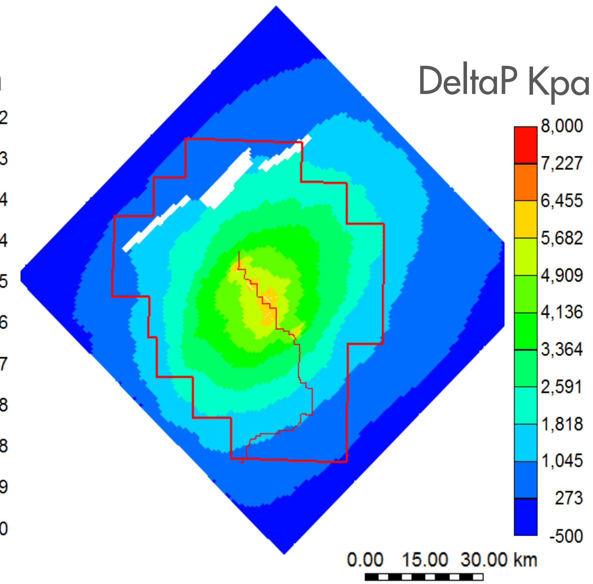
Conceptual Storage Plan
(D65 Regulatory Submission)



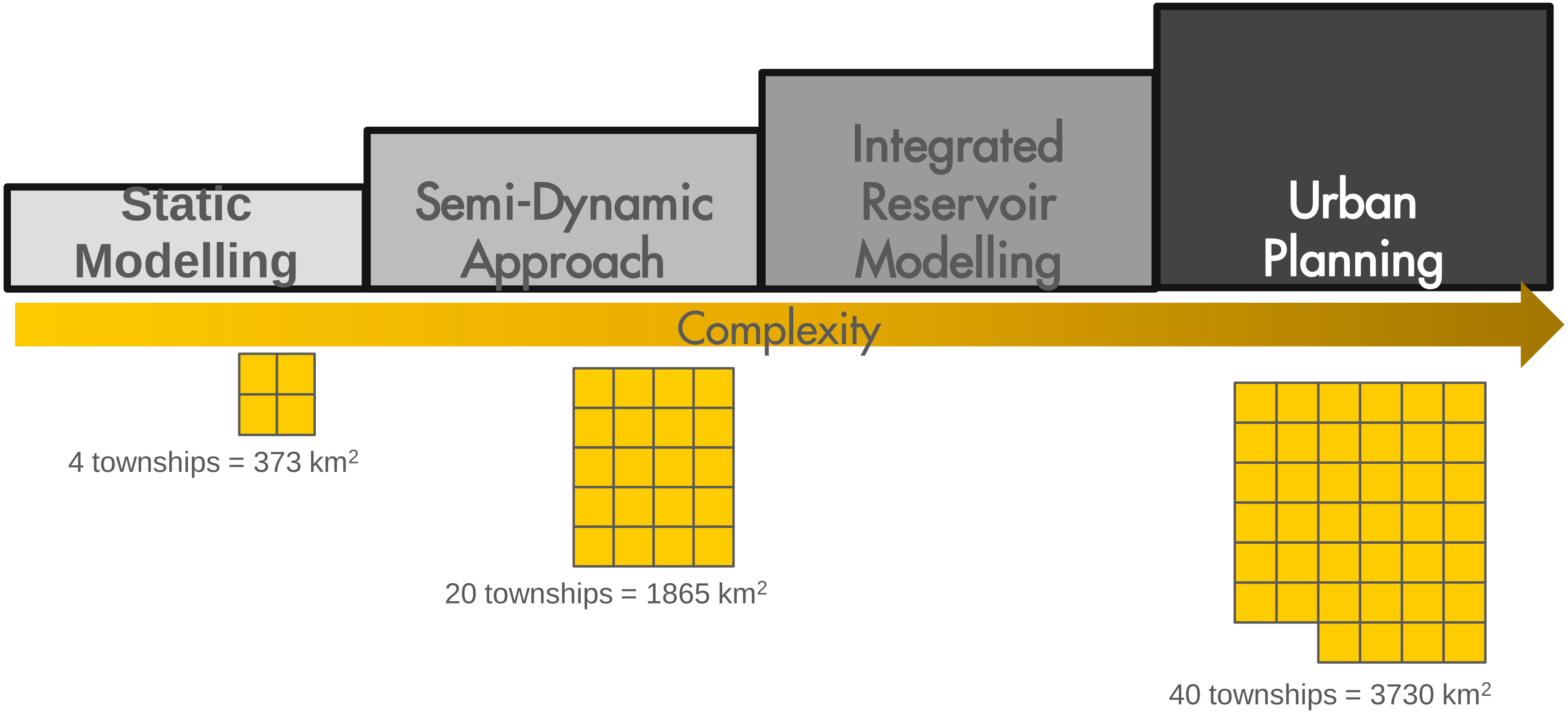




Notional CO2 plume radius based on Reservoir Parameters for Well 8-19

Parameter	Base Case	Promoting Maximum Plume	Promoting Minimum Plume
BCS reservoir height (m)	46	28	43
BCS net-to-gross ratio	0.90	0.80	1.00
BCS porosity	0.16	0.11	0.19
BCS net pore height (m)	6.62	2.46	8.17
Maximum CO_2 saturation	0.60	0.40	0.75
CO_2/brine sweep efficiency	0.80	0.50	0.95
Effective CO_2 saturation	0.48	0.20	0.71
Formation Temperature	60.0	64.0	55.0
Formation Pressure	20.45	20.2	20.7
CO_2 density at Pi, Ti	731	711	761
Injected CO_2 after 25 years (Mt)	27	27	27
Number of wells	5	3	10
Notional CO_2 plume radius (m)	**860**	**2,860**	**440**

The Dynamic Aspect of Pore Space Utilization (Summary)



The Static Approach and DoE Guidelines	The (Semi)dynamic Approach and DoE Guidelines	Integrated Reservoir Modelling Approach
Material balance approach 6 to 9 Mt/township (@ 27Mt)	Static and homogeneous pressure limit 1 to 2.4 MT/Township (@ 27Mt)	Integrated Reservoir Modelling approach at Quest Ave. 0.67 Mt/township (@ 27 Mt) Protects against interference from competing schemes

Acknowledgements

- Partners: Chevron Canada Limited and Marathon Oil Canada
- Government of Alberta, Department of Energy (DOE)
- Government of Canada, Natural Resources Canada (NRCan)
- Government of Alberta, Alberta Innovates

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Back-up

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