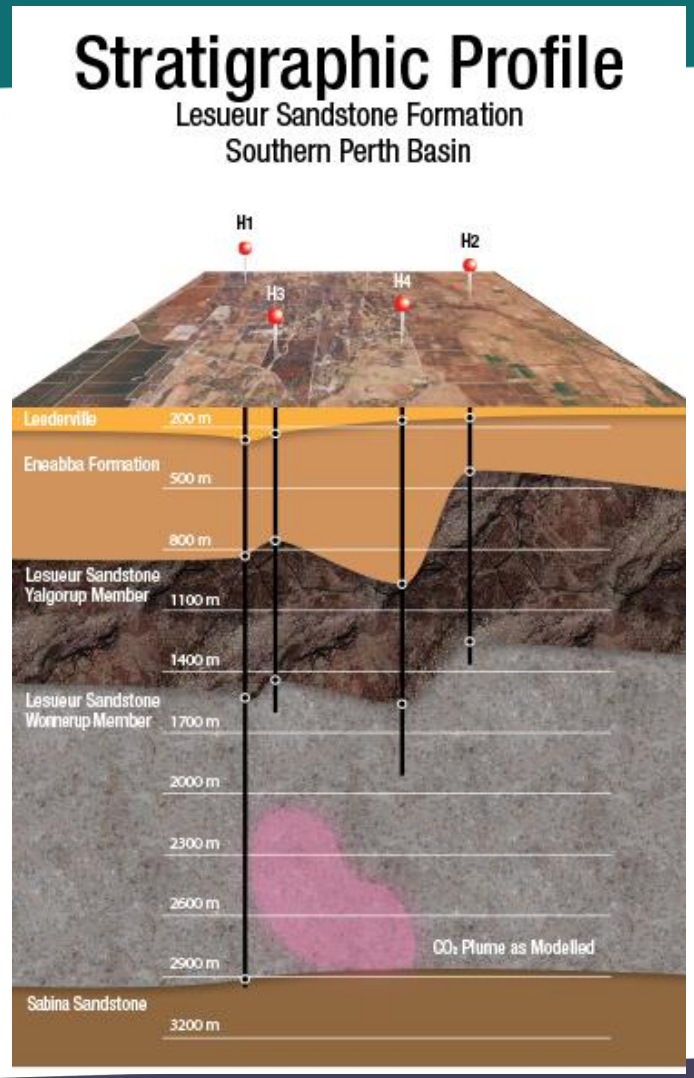
South West Hub Confidence in Carbon Capture and Storage



Presented by

Dominique Van Gent

Coordinator Carbon Strategy

Overview

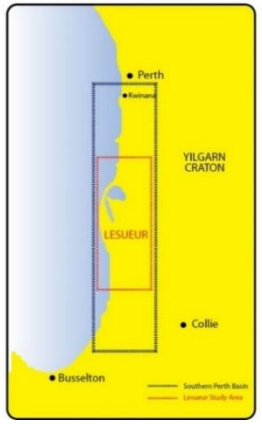
- Location and historical context
- Success criteria
- Process and technical workflows
- Uncertainty mapping and evolution
- Modelling results
- Concluding thoughts

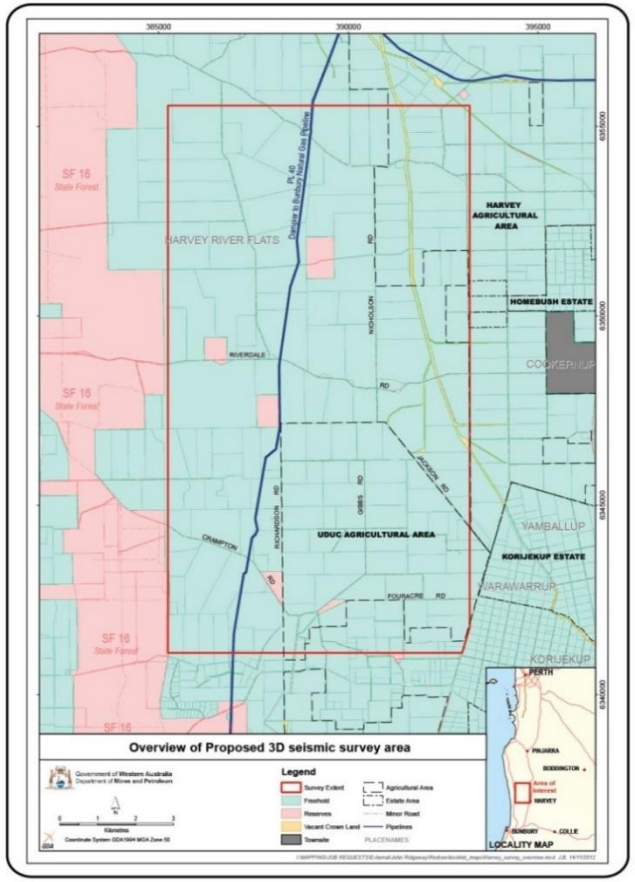
The project is supported through the Australian Commonwealth Government CCS Flagship Program through The Department of Industry, Innovation and Science (DOIIS);
The West Australian State Government through the Department of Mines, Industry Regulation and Safety (DMIRS);
The Australian National Low Emissions Coal R&D Program; and
The local community in the south west of Western Australia.

Australian Government
Department of Industry, Innovation and Science

anlecr&d

LOCATION : Near Industrial Centres

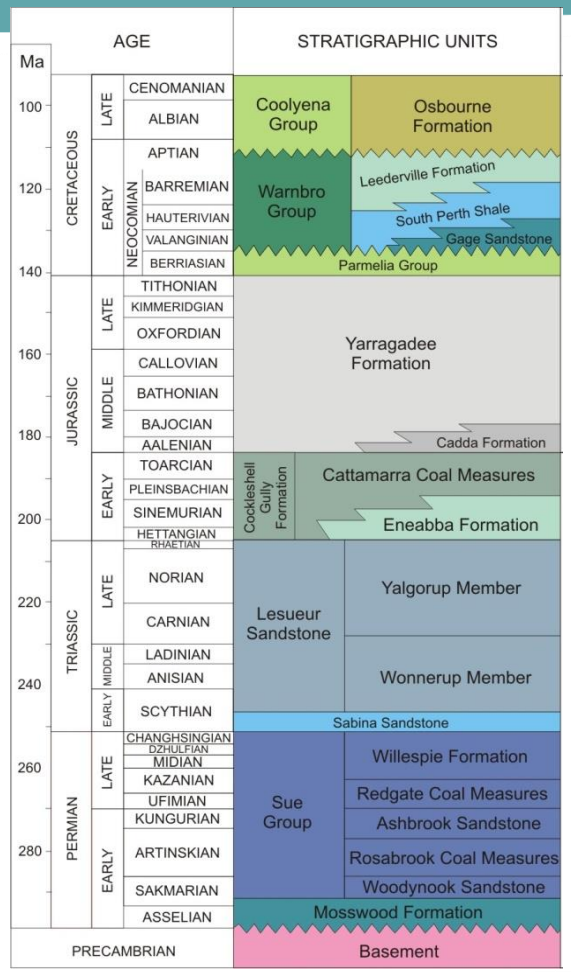




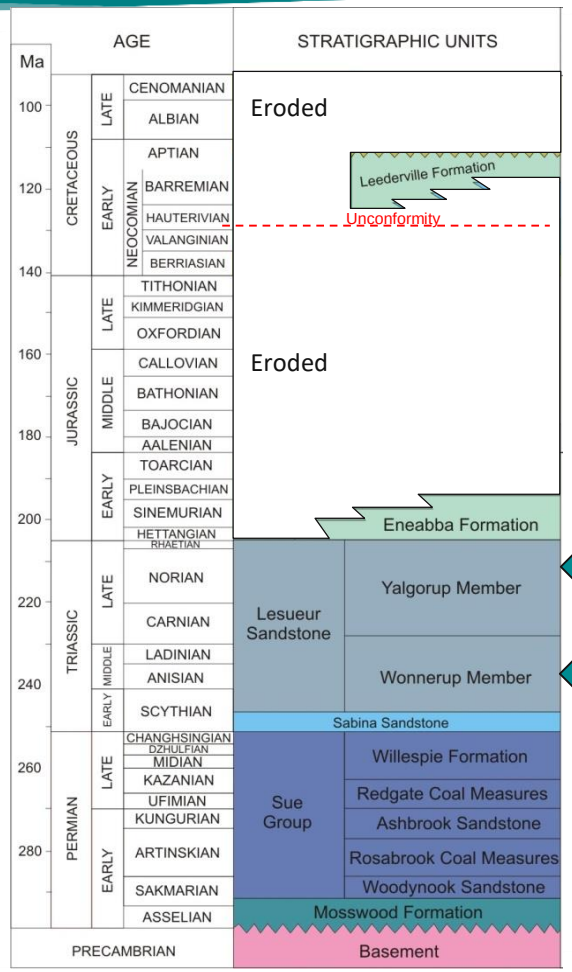
- In the heart of South West industry
- Agricultural and lifestyle area
- Project does not compete with potable water

Stratigraphy: Regional and in the Area of Interest (AOI)

Perth Basin



AOI

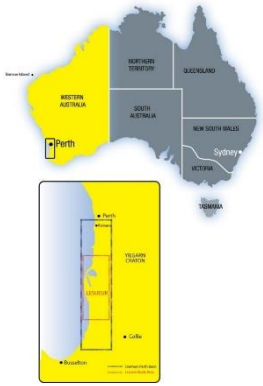


No basin resource conflict – absence of Yarragadee freshwater aquifer is critical to site selection

Lesueur Sandstone

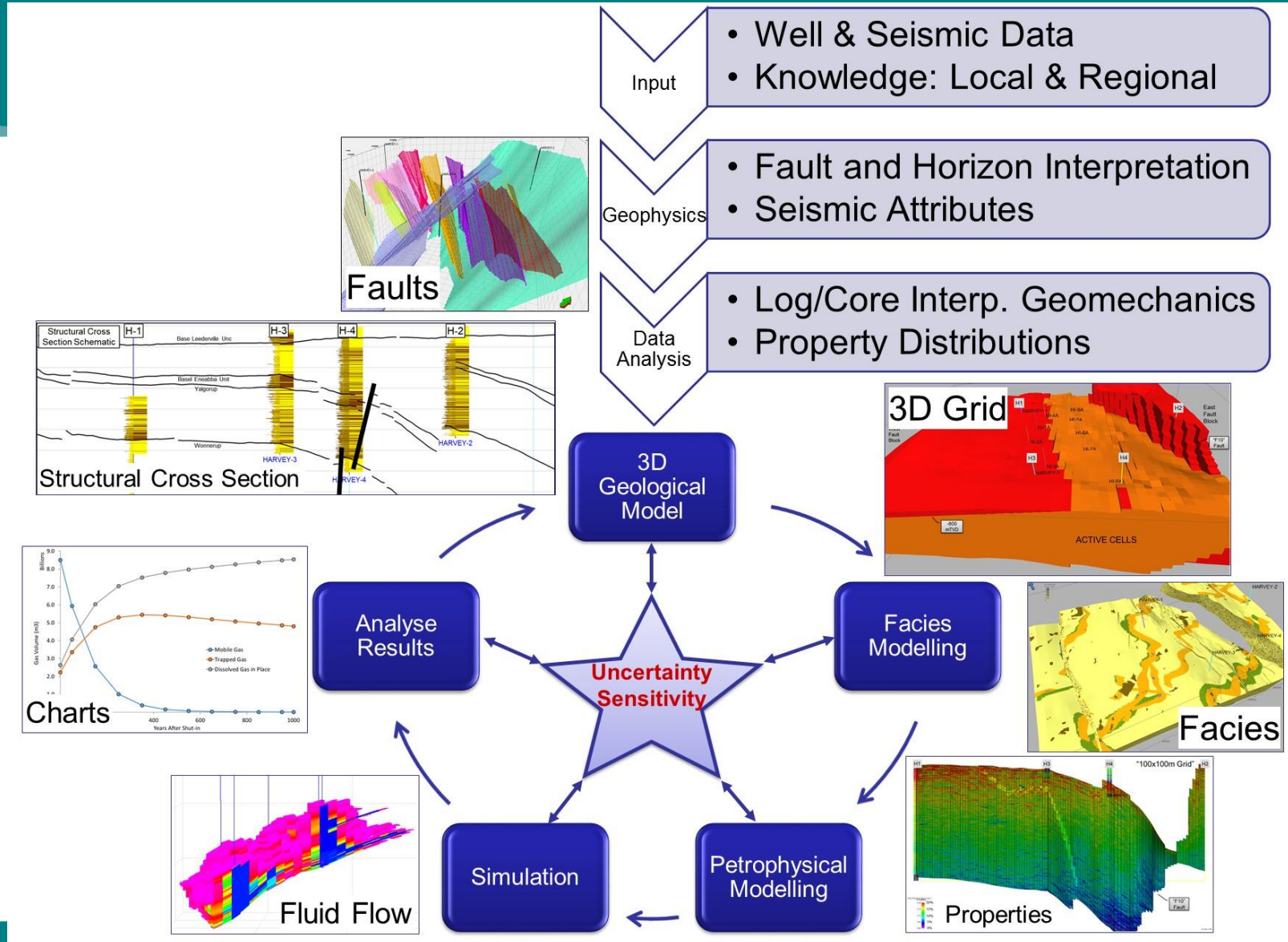
Yalgorup Member
800 metres thick

Wonnerup Member
1500 metres thick



Modelling workflow

- Focus on **uncertainty** impacts on **Performance Factors**
  - Capacity
  - Injectivity
  - Containment
- **Success Criteria**
  - Site can accept **injection rates of 800,000 tpa** of CO_2 **over 30 years** and the plume will remain **contained for 1,000 years**
  - To be achieved through **a well count of 9 or less**



New data acquisition with extensive community consultation

2011 2D Seismic

2012 Harvey-1

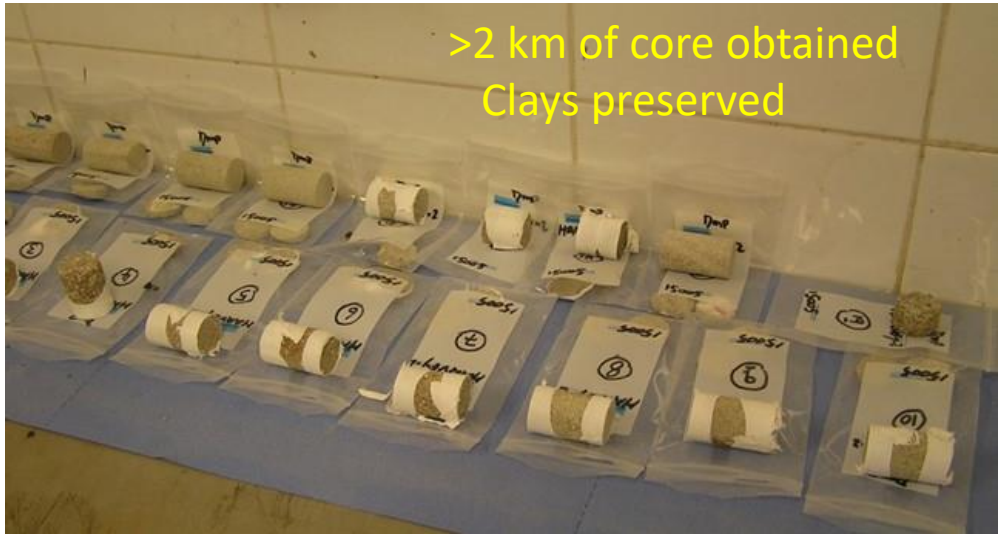
2013 3D Seismic

2015 - Harvey 2, 3 & 4

Extensive core and log data/analyses

- **Routine Core Analysis (RCA)**
  - Grain volume and grain density
  - Porosity and permeability
  - Permeability to brine
  - Threshold pressure to carbon dioxide
- **Special Core Analysis (SCAL)**
  - Flow studies
  - Mercury injection analysis
  - Geomechanical analysis

Well	Run	Services
Harvey-2	1	Gamma-Resistivity-Dipole Sonic
	2	Seismic VSP
Harvey-4	1	Gamma-Resistivity-Dipole Sonic-Neutron-Density
	2	XRMI Image
	1	Gamma-Resistivity-Dipole Sonic-Neutron-Density
	2	XRMI Image
		CSNG Compensated Spectral Gamma
	3	MRIL Nuclear Magnetic Resonance
	4	RDT Reservoir Description Tool
	5	Seismic VSP
Harvey-3	1	Gamma-Resistivity-Sonic-Neutron-Density
	2	Gamma-Resistivity-Sonic-Neutron-Density
	1	Gamma-Resistivity-Sonic-Neutron-Density
	2	HSFT Formation Tester
	3	Seismic VSP



Summary of model development: 2007–2018

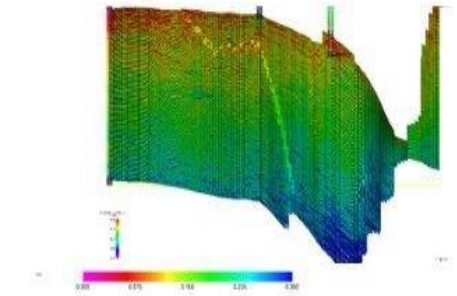
With each iteration more data is acquired and uncertainties reduced

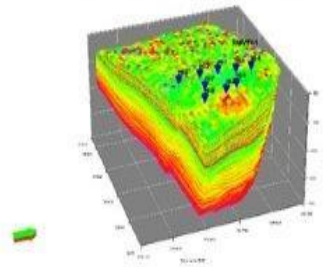
- No show stoppers identified at any stage
- Generation 3 Results show:
  - That it **could be feasible to inject 800,000 tpa** of CO_2 (or more) over 30 years in the Lesueur Formation;
  - There is **scope for some additional work** based on defined uncertainties:
    - Enhanced seismic processing
    - Additional core work
    - Modelling updates and additional scenarios

Four Generations of Models

As more information became available, so did the level of sophistication and intensity of the models:

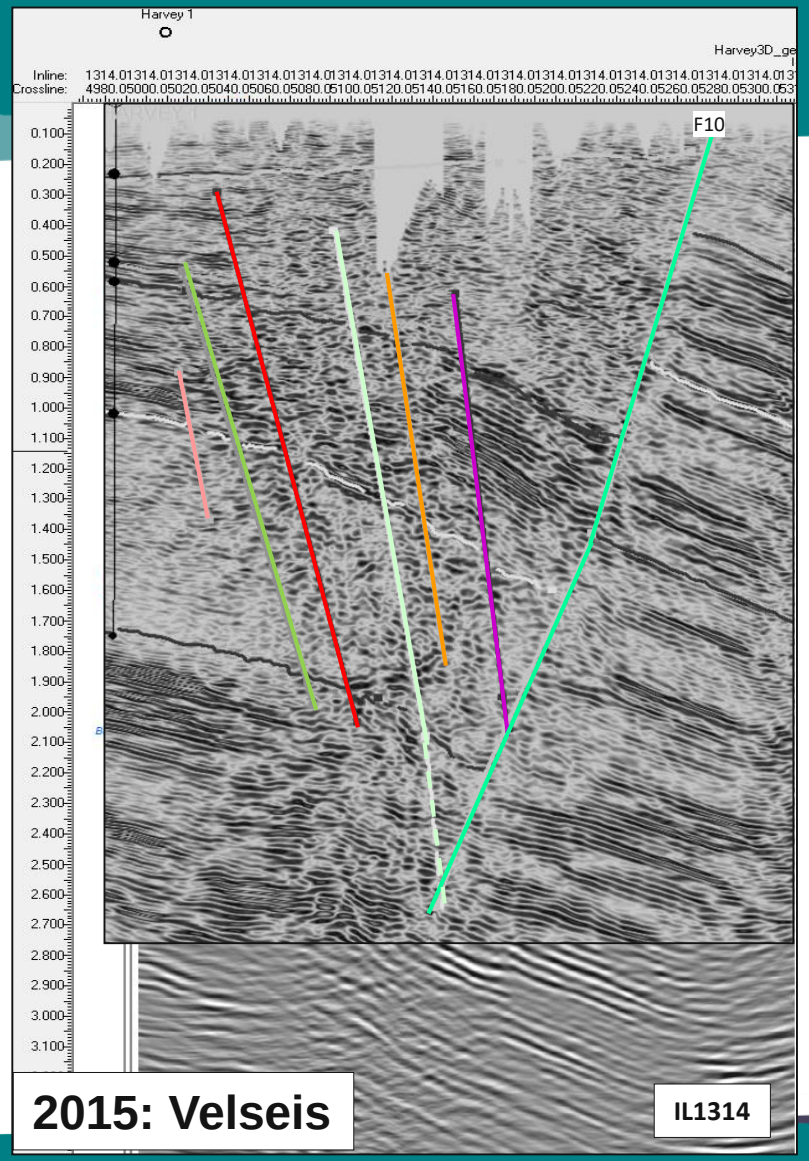
Generation 1 - >100 layers	- 10 million cells
Generation 2 - 357 layers	- 30 million cells
Generation 3 - >1,100 layers	- 214 million cells
Dynamic model	- 1.1 million cells
Generation 4 - current	- 256 million cells
	- 1,100 layers
Dynamic model	- 1.96 million cells



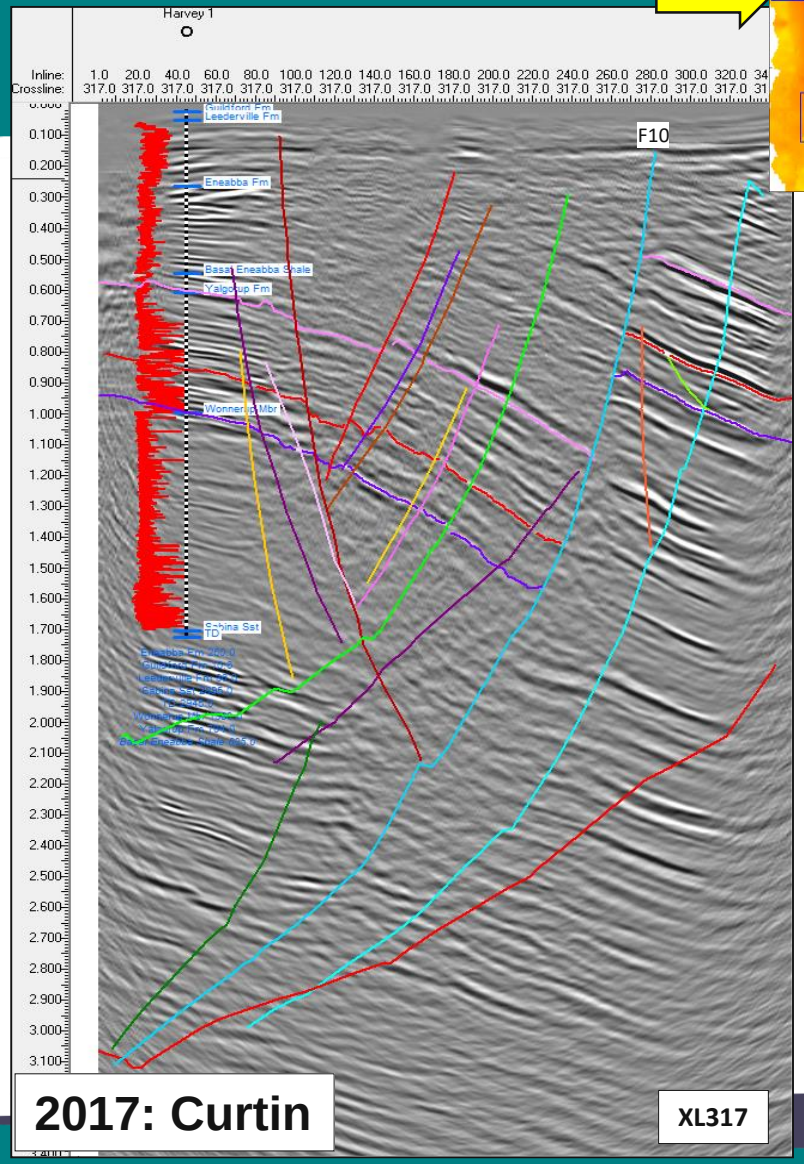


With **each iteration more data** is acquired and **uncertainties reduced**

Exhaustive data processing to improve definition

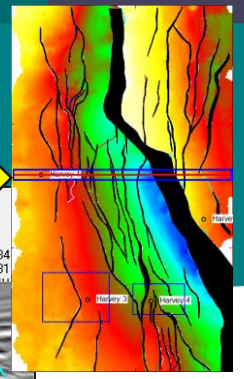


Velseis Proc Datum = 0m

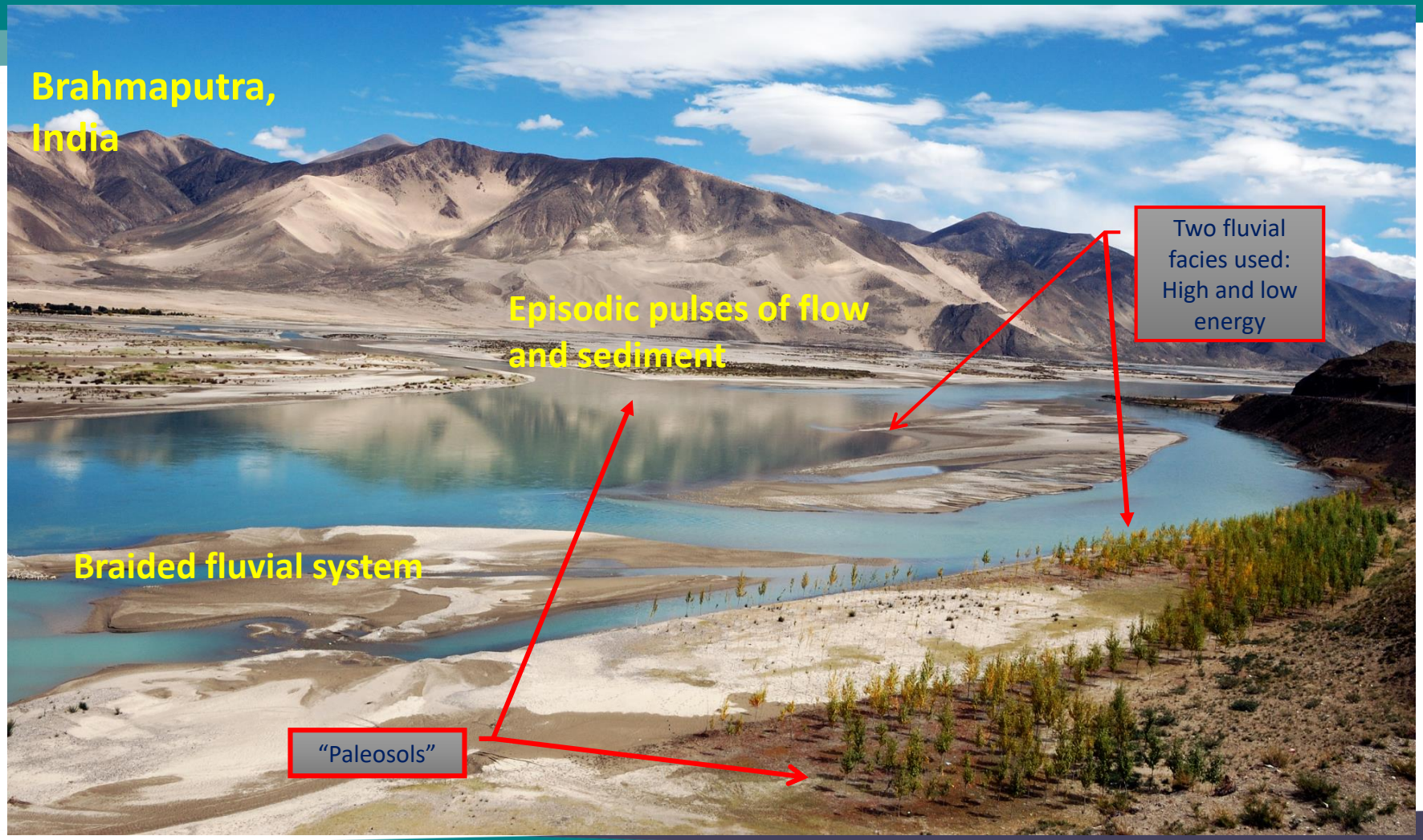


Curtin Proc Datum = 40m

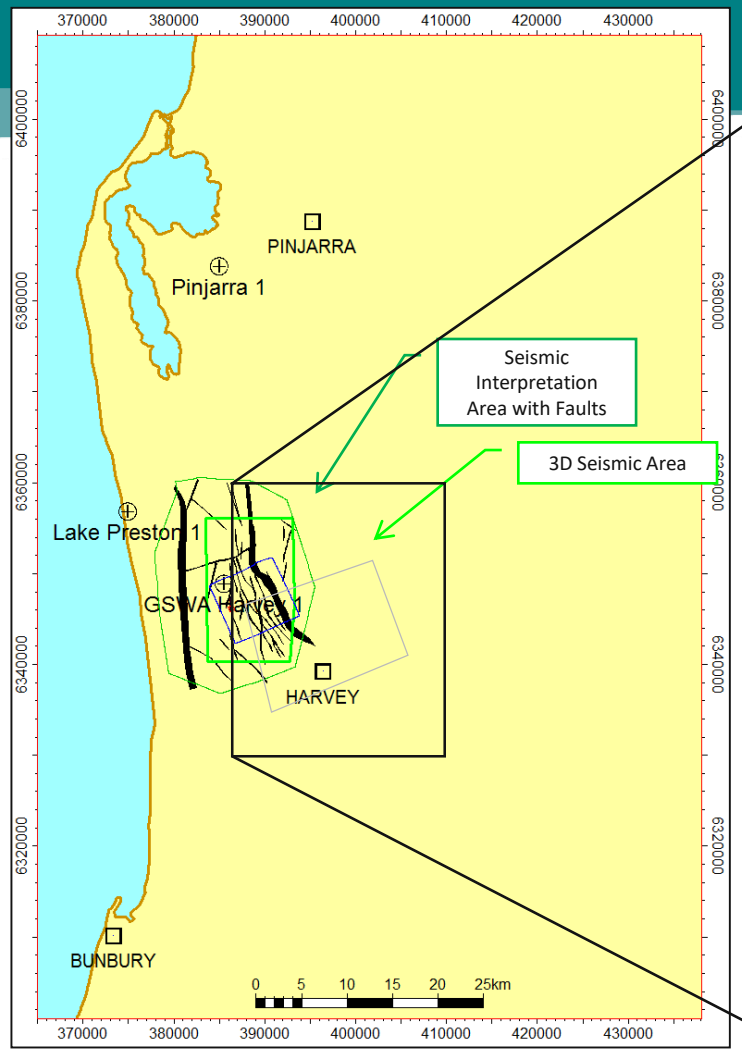
XL and IL reversed cf. Velseis

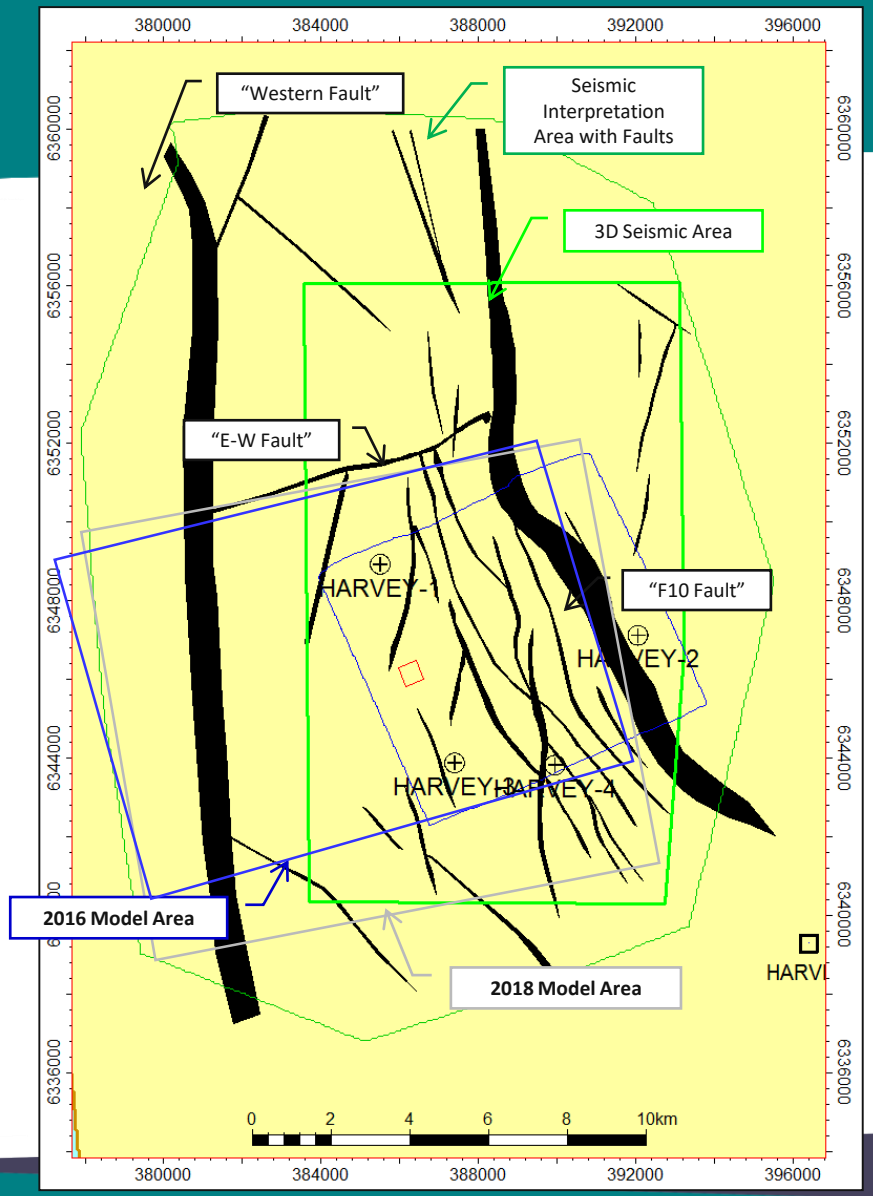


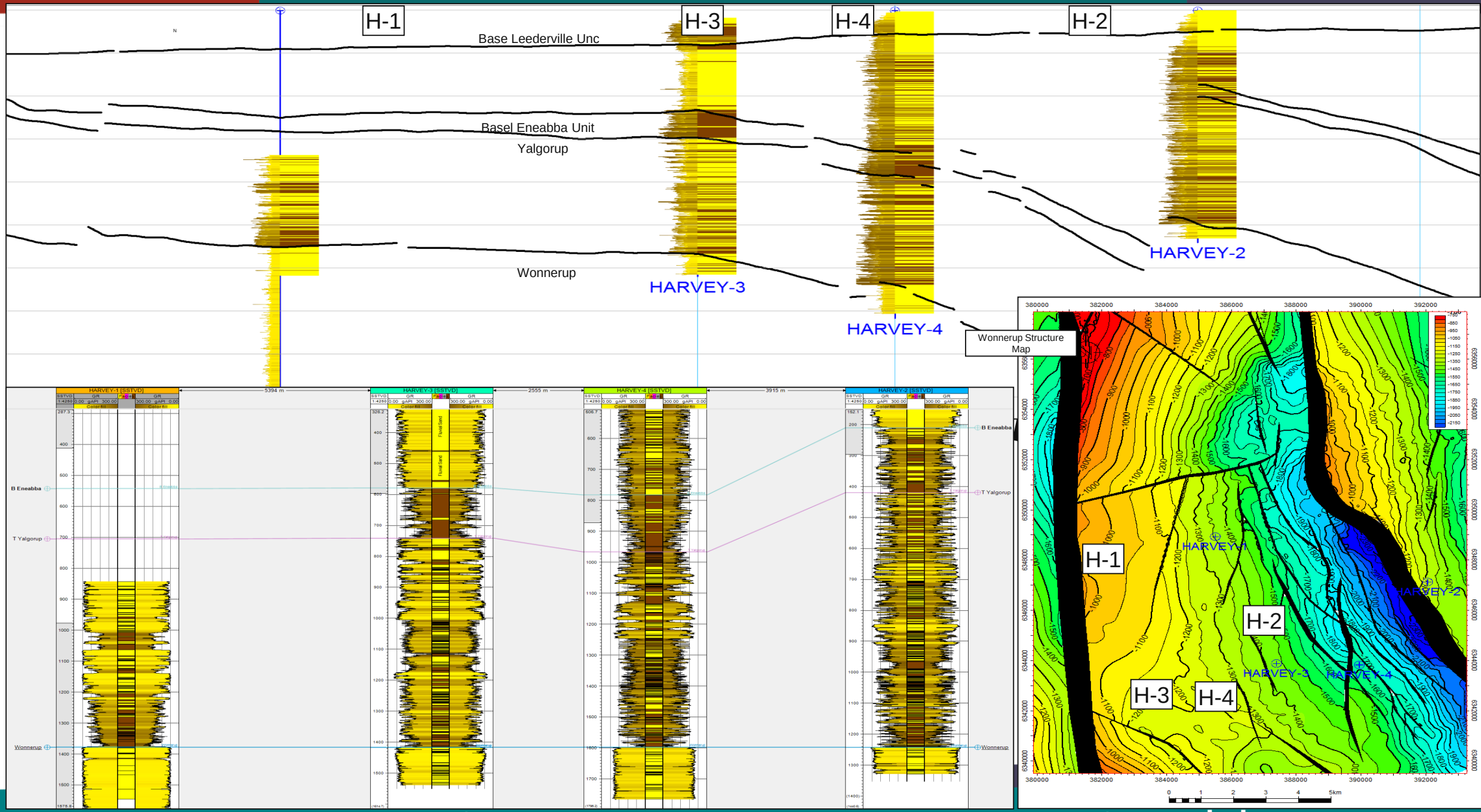
High confidence in depositional environment – analogues



SW Hub : Gen 4 model area





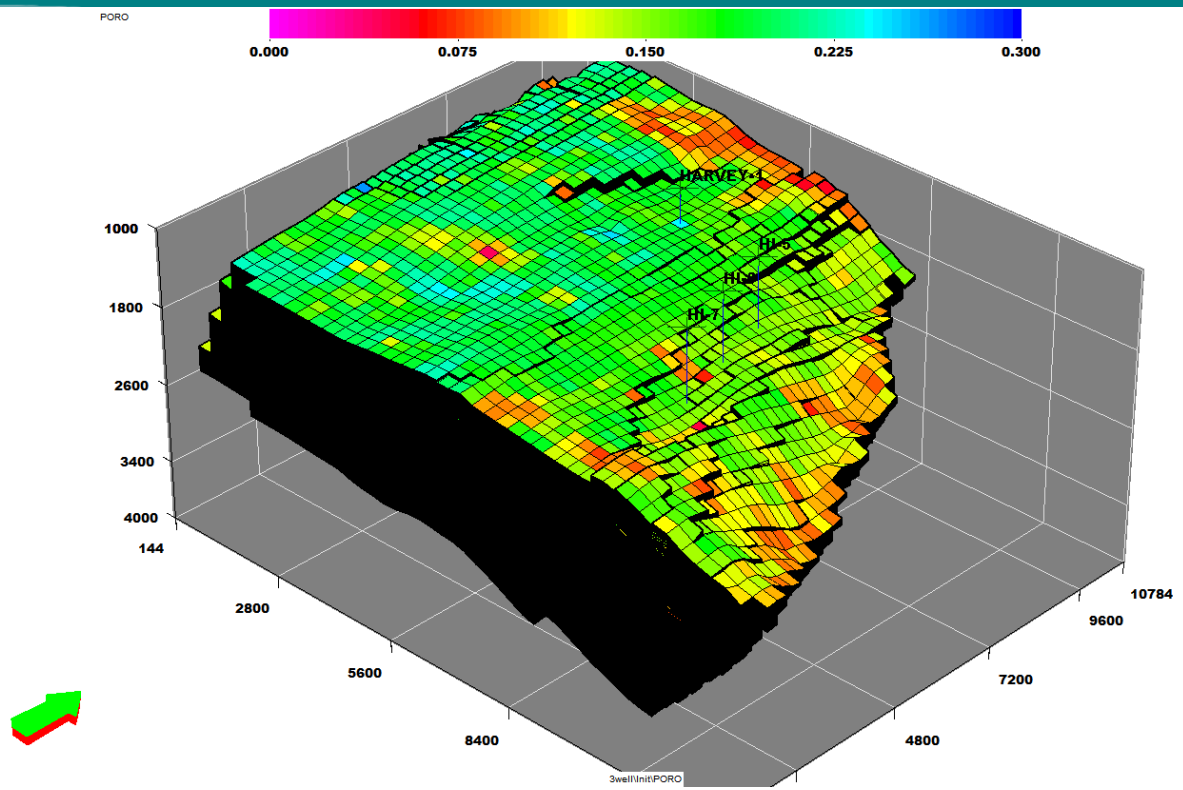


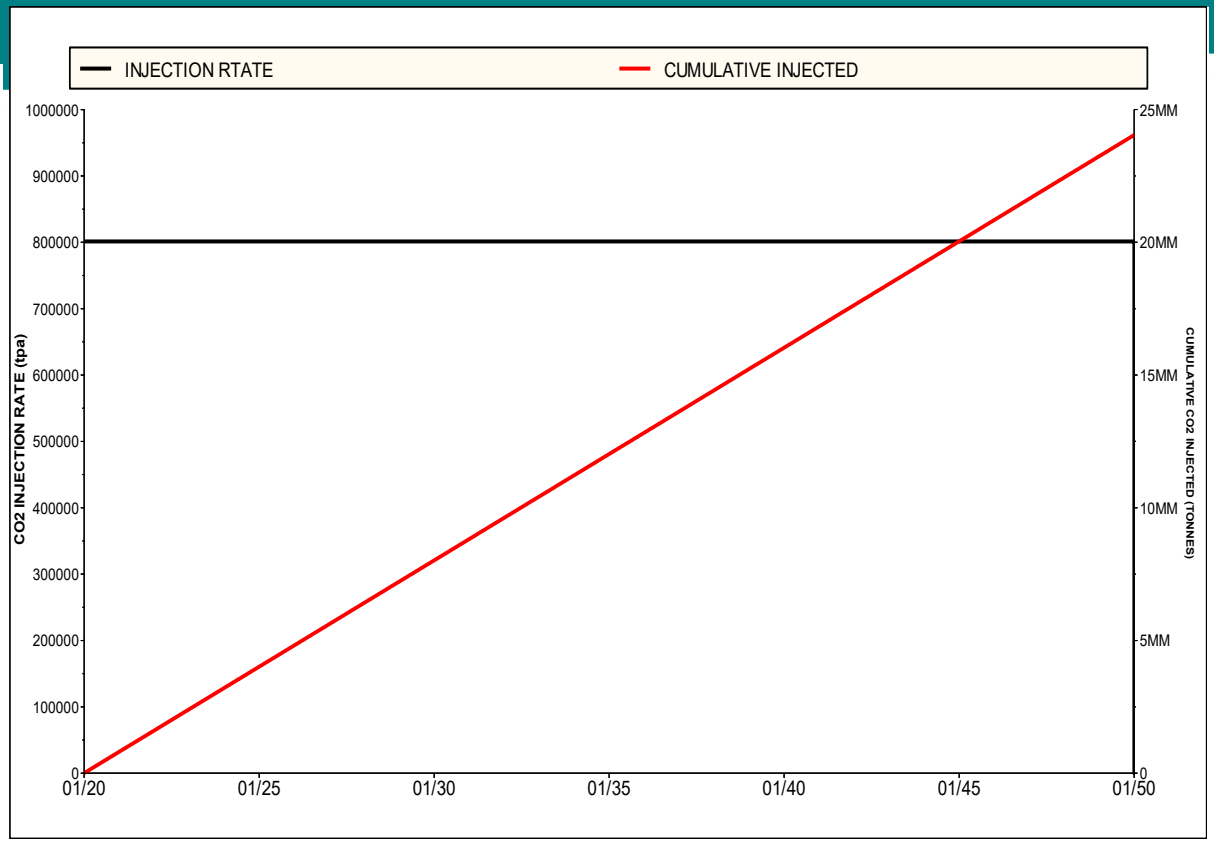
Structural Cross Section

Modelling efficiency: Black Oil and compositional simulation

- Dynamic modelling of the CO_2 sequestration process in the Harvey area was conducted in two ways:
  - ‘Black Oil’ Modelling – A simplified description of the physics of the fluids based on simple interpolation of PVT properties as a function of pressure.
  - Compositional modelling – Using a ‘compositional’ approach based on a thermodynamically consistent model such as a cubic equation of state (EOS).
- Evaluations using Black Oil models can be done, in many instances, a few orders of magnitude faster than compositional models.
- Most cases modelled using the ‘Black Oil’ formulation. Specific cases are tested in a compositional model as a sense check.
- Static model 256 million cells, dynamic model 1.96 million cells

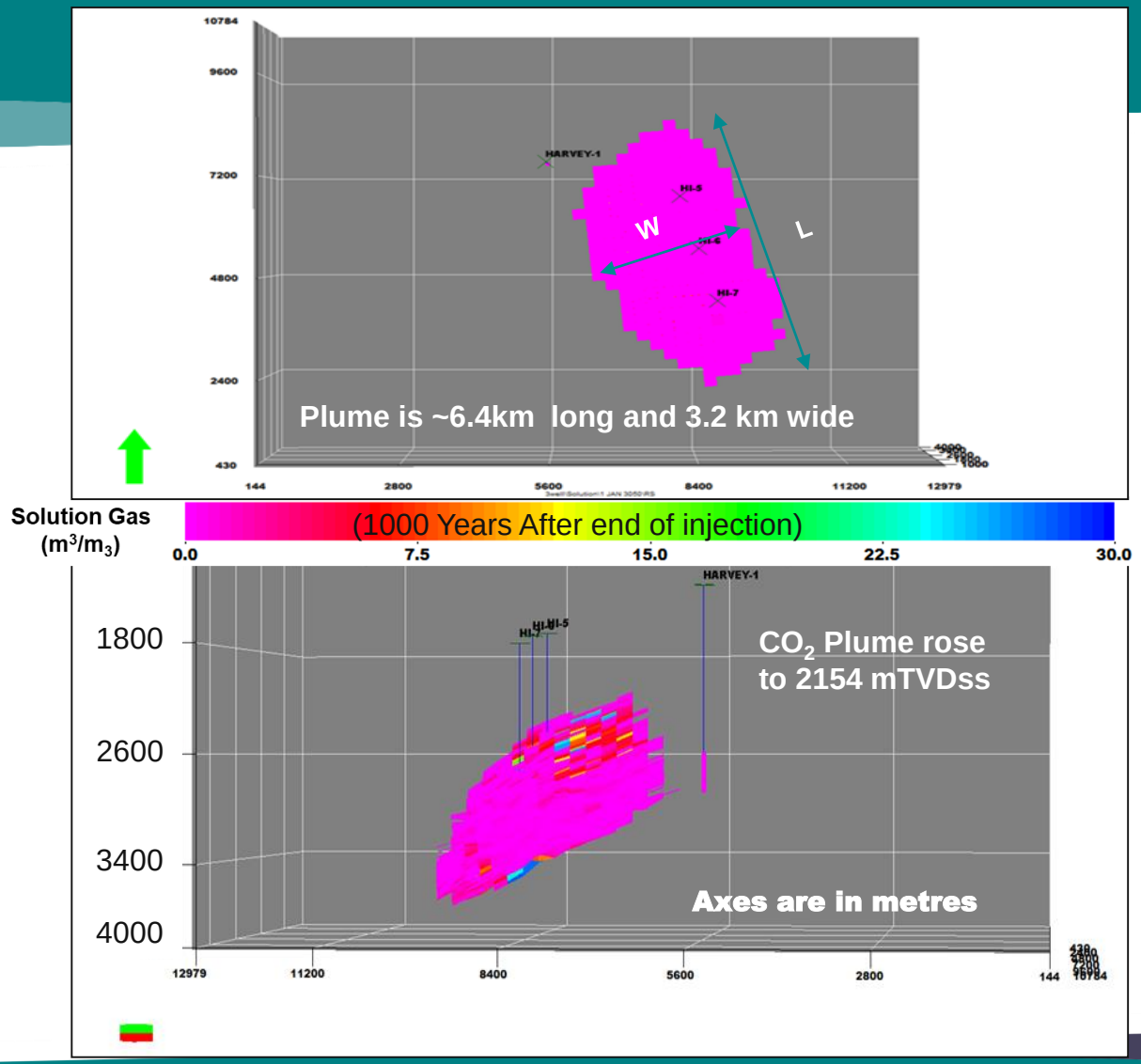
Conceptual development plan and injection profile





- The conceptual plan envisages 3 gas injectors in a line drive configuration. Generation 3 plans had 9 injectors.
- All injectors are completed at depths of almost 3,000 metres in the Wonnerup.

Reference case – Black Oil model

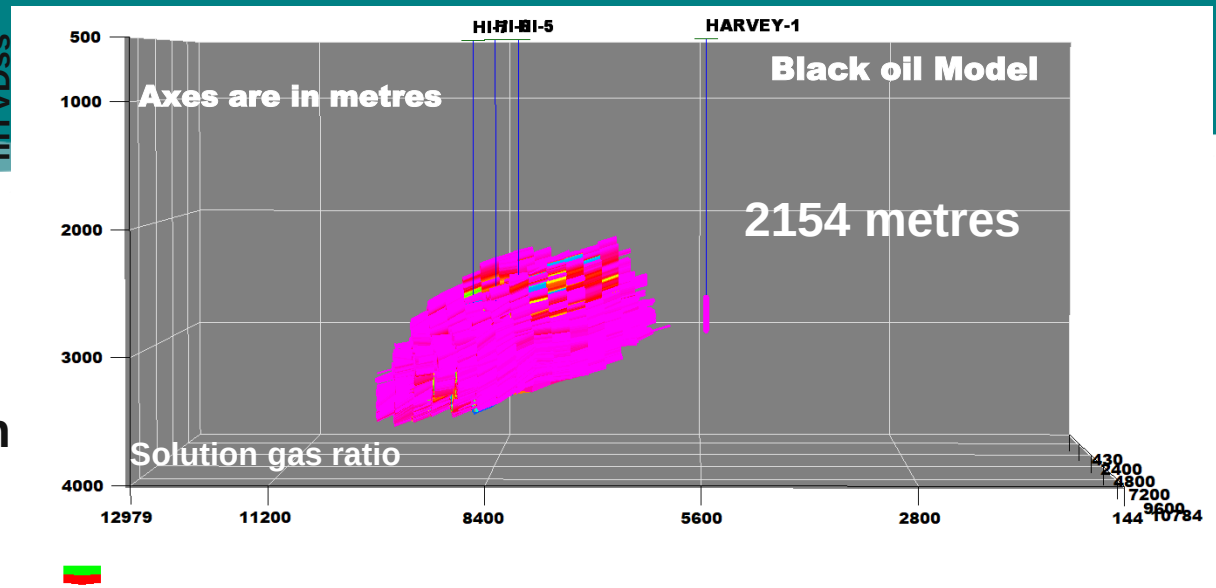


- CO_2 plume is compact and remains within the Area of Interest (AOI).
- The CO_2 stays within the Wonnerup.
- These results are consistent with the Phase 1 studies.
- The CO_2 plume stabilizes about 600 years after the end of injection.

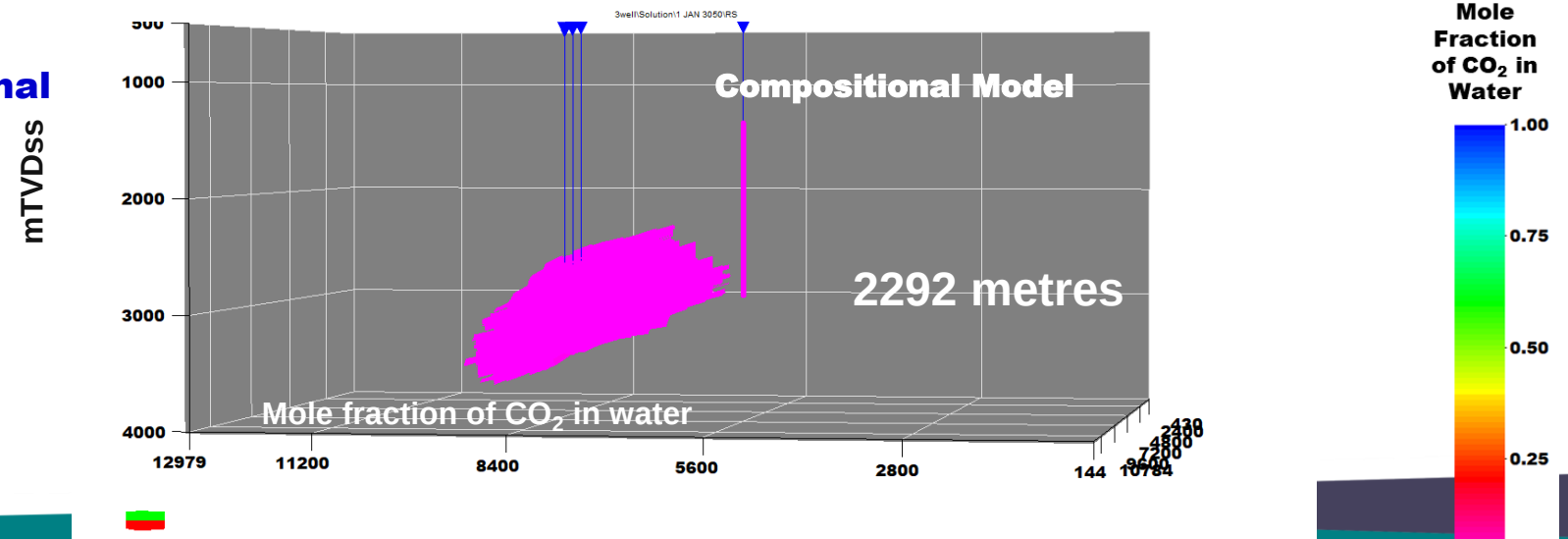
Reference case – comparison of plume shape and movement looking south

Black Oil

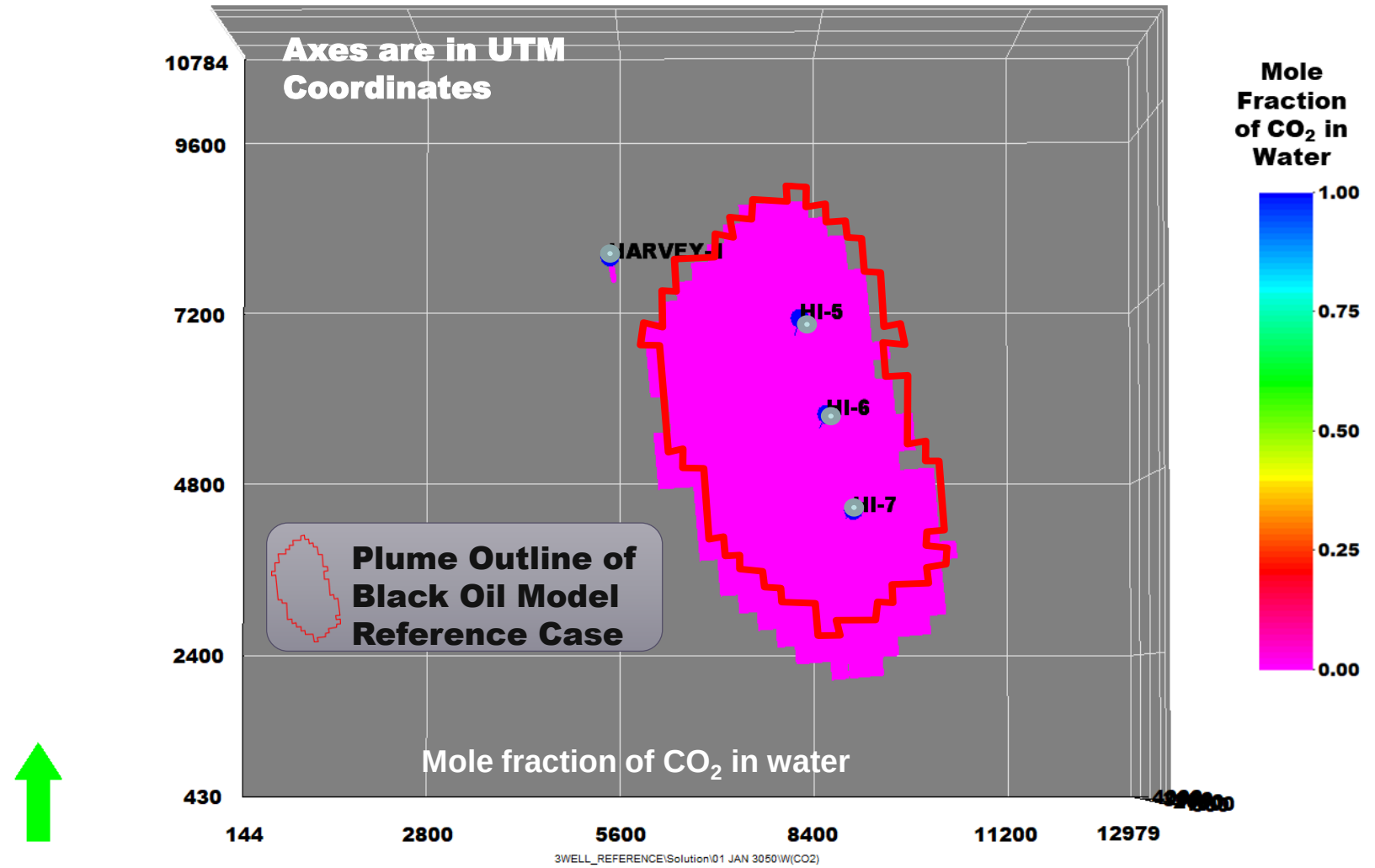
1000 years after injection stops.



Compositional



Reference case – comparison of plume outline (top view) Black Oil and compositional model



CO_2 material balance (1,000 Years after Shut-in)

Reference case : Black Oil model				
	Supercritical CO_2			
	Trapped CO_2 (Sm3)	Mobile CO_2 (Sm3)	Total dissolved CO_2 (Sm3)	Total CO_2 (Sm3)
Gas material balance	5.4E+09	2.0E+07	7.7E+09	1.3E+10
% Injected	40.9%	0.2%	59%	100%
Reference case : Compositional model				
	Trapped CO_2 (moles)	Mobile CO_2 (moles)	Total dissolved CO_2 (moles)	Total CO_2 (moles)
Gas material balance	3.45E+11	2.37E+08	2.13E+11	5.68E+11
% Injected	62.4%	0.0%	37.5%	100%

Modelling – Scenarios to test uncertainty impacts

Objective: To test under what conditions the success criteria can be breached

- Multiple cases (scenarios) modelled
- Ranges of uncertainties considered
- Combination of uncertainties considered as ‘stress’ cases

Uncertainties modelled (examples)

- High mobility upwards
- Poor trapping mechanism
- Low solubility of gas in the water
- Pessimistic scenarios of gas movement in the reservoir
  - Fault baffles
  - Fractures which promote upward movement of gas

Case	Case Name	Geological Model	Description
Reference	3Well	Reference	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
1	3Well_NoPC	Reference	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) No capillary pressures SgT based on Land Correlation C=1.95
2	3Well_highkrg	Reference	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) Krg=0.25 SgT based on Land Correlation C=1.95
3	3Well_bland	Wonneup is homogeneous	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
4	3Well_Hiperm	Permeability in I, J and K directions mulitipled by 1.4	800,000 tpa. Faults not sealing Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
5	3Well_LowSgt	Reference	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=3.2
6	3Well_HighSalt	Reference	800,000 tpa. Faults not sealing Brine salinity=200000 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
7	3Well_highKv	Kv=0.8*K Horizontal	800,000 tpa. Faults not sealing Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
8	3Well_lowKv	Kv=0.1*K Horizontal	800,000 tpa. Faults not sealing Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.96
9	3Well_001Faults	Fault Transmissibility * 0.01	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
10	3WELL_holey_wonnseal	Cells adjacent to faults have the vertical permeability increased by 10 times. Wonnerup and Yalgorup in communication through the faults.	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
11	3WELL_holey	Cells adjacent to faults have the vertical permeability increased by 10 times. Communication between Wonnerup and Yalgorup through faults and sand-on-sand contact.	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
12	3WELL_holey_NoYal	Cells adjacent to faults have the vertical permeability increased by 10 times. No communication between Wonnerup and Yalgorup through faults or sand-on-sand conact.	800,000 tpa. Brine salinity=45600 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95
13	3Well_holey_wonnseal_lowsol	Cells adjacent to faults have the vertical permeability increased by 10 times. Wonnerup and Yalgorup in communication through the faults.	800,000 tpa. Brine salinity=200000 ppm (NaCl Equivalent) SgT based on Land Correlation C=1.95

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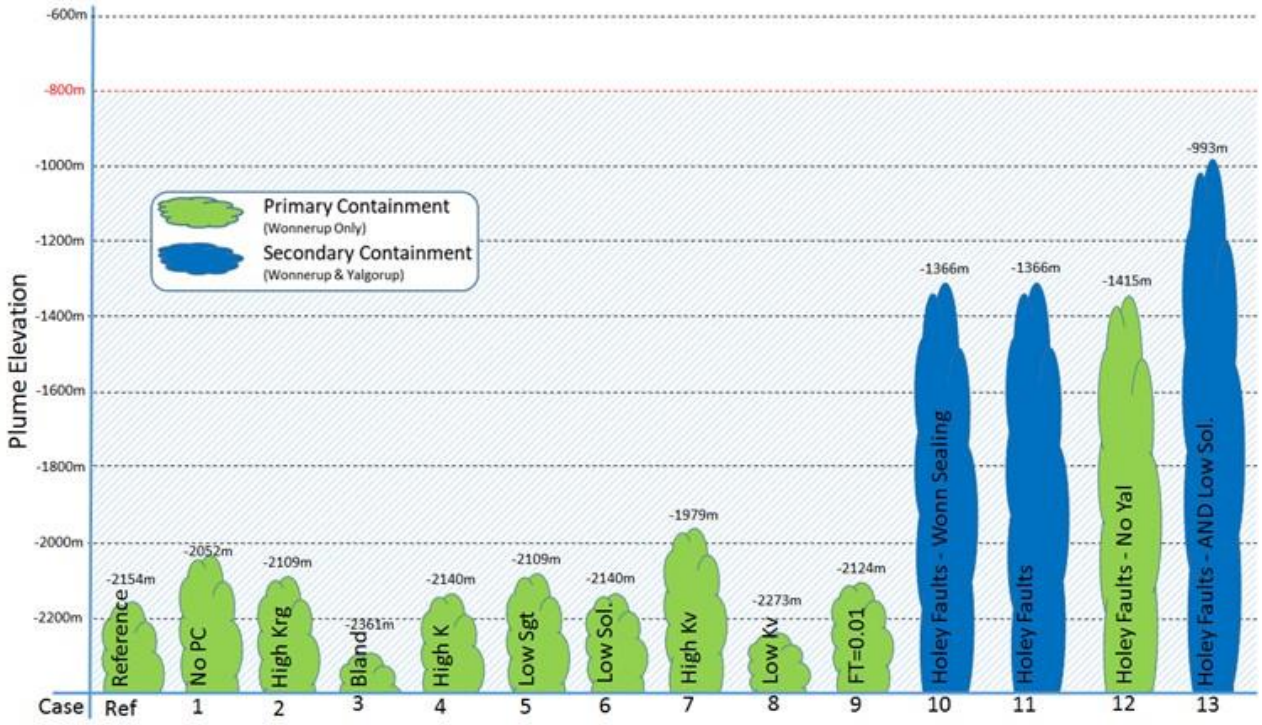
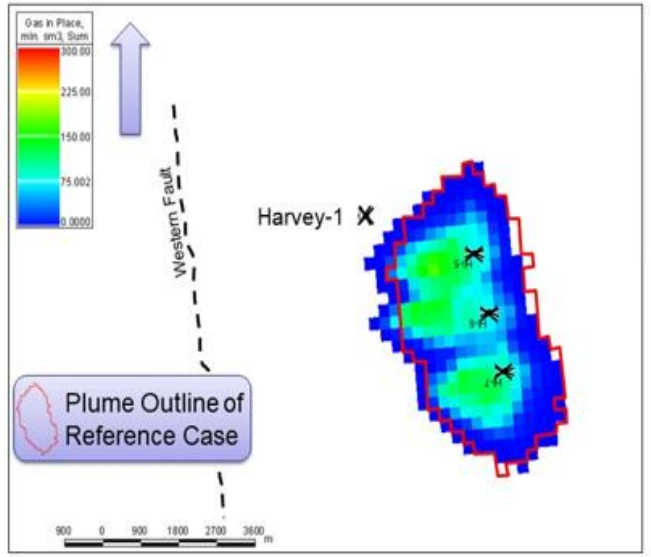
Plume remains inside storage complex in all modelled cases



Only under few conditions the plume (<2%) enters the secondary containment zone



Limited spread of plume compared to reference case: 6.5 km X 3.5 km

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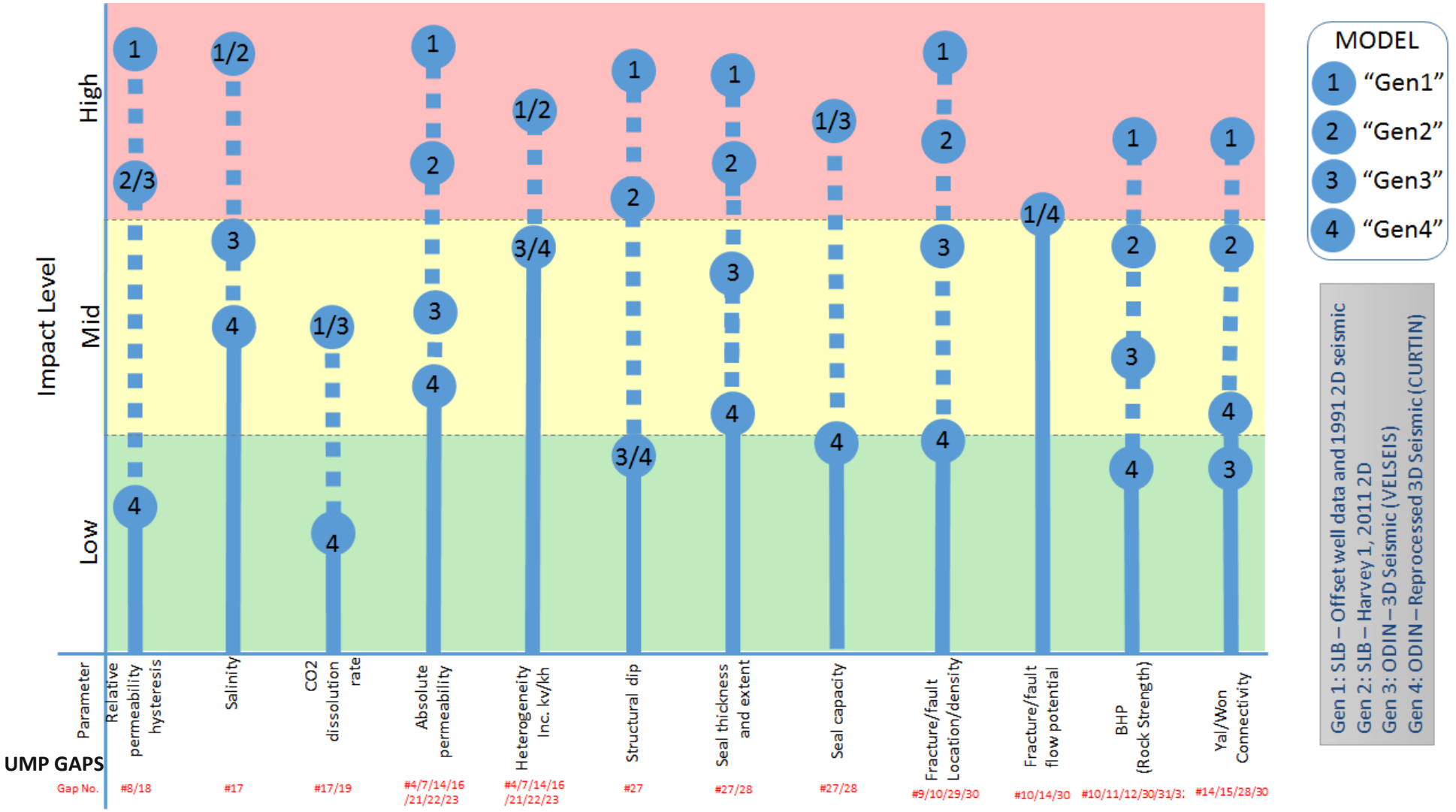
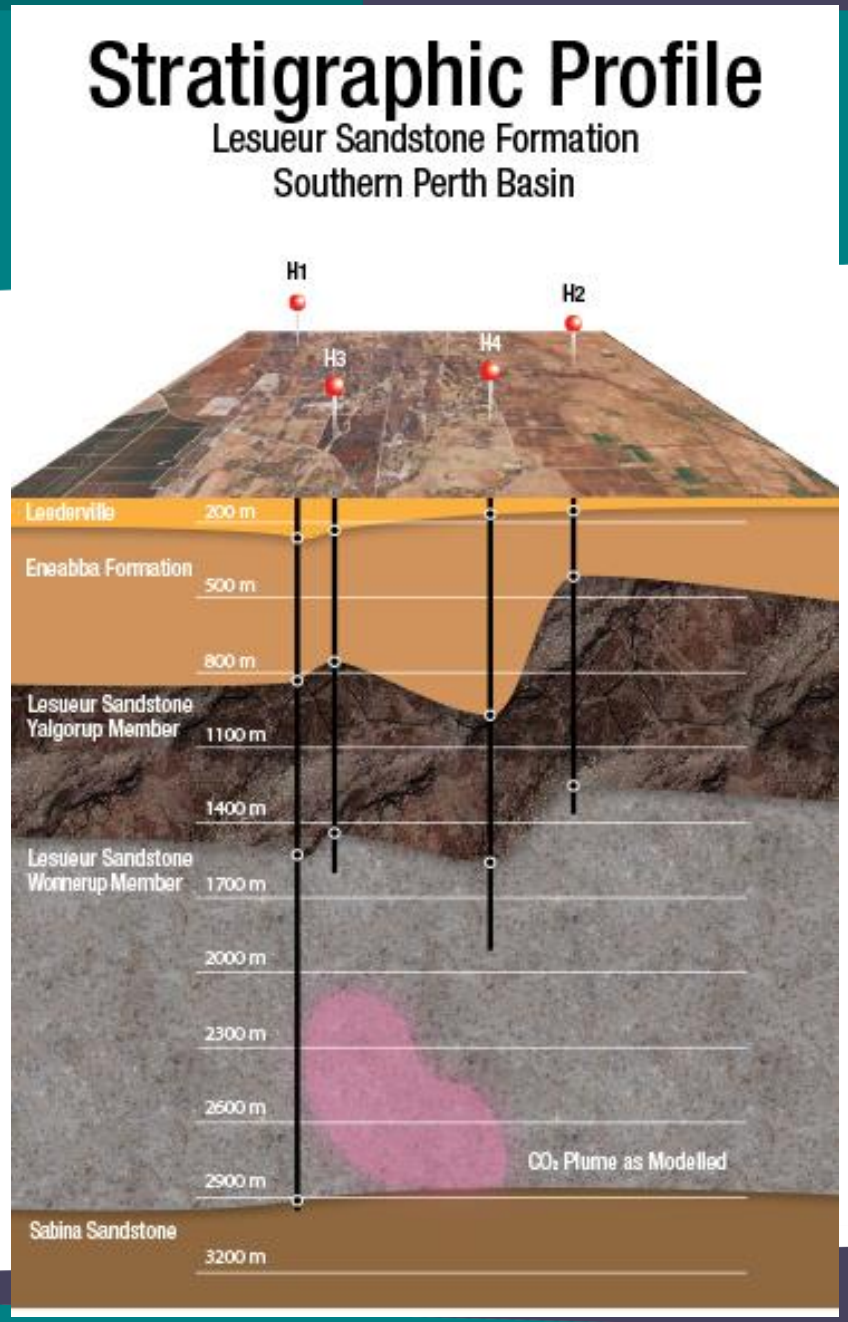
Visualising the key uncertainties over time



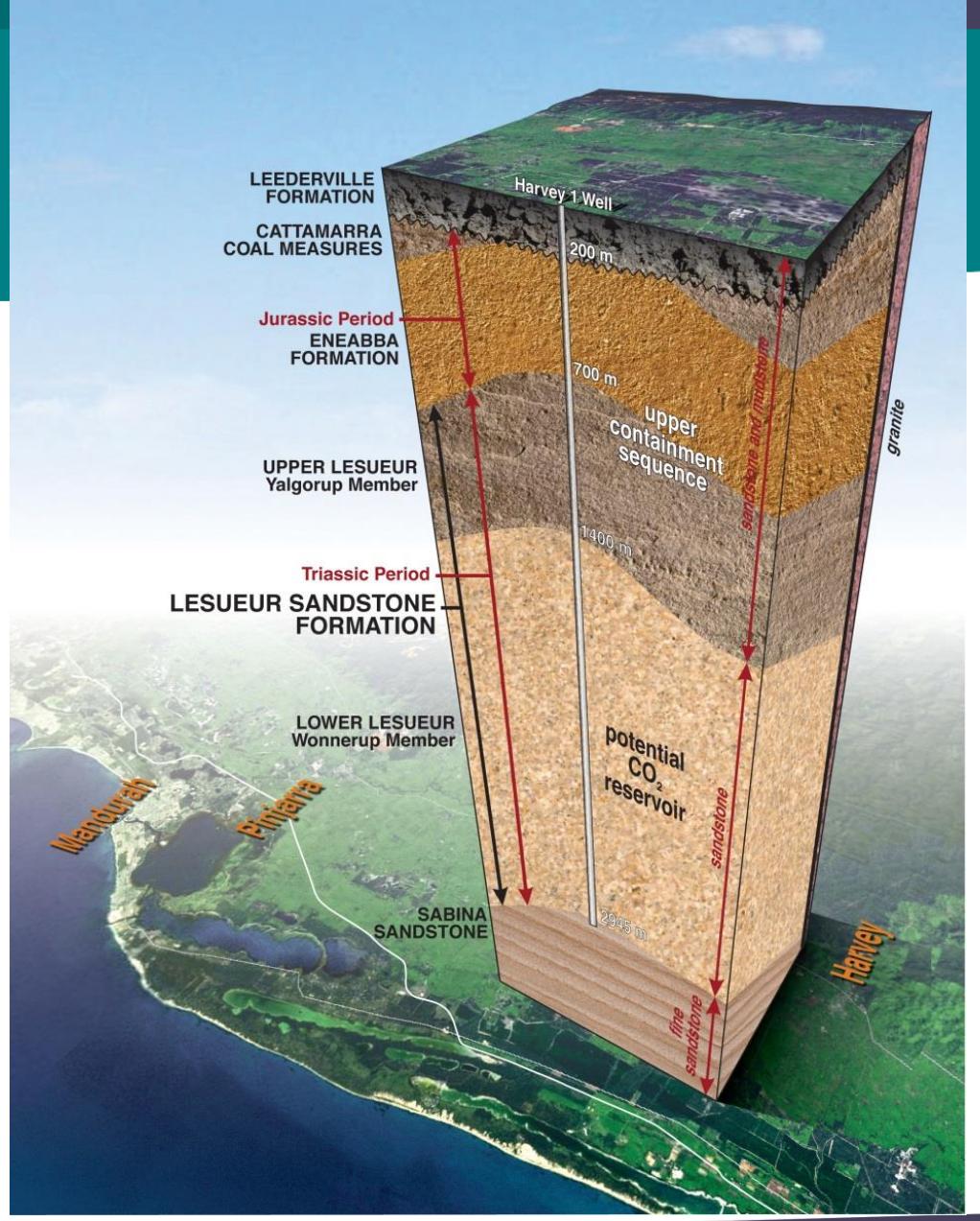
Relevance of the SW Hub

- Our modelling shows that it could be feasible to inject and store **800,000 tpa of CO_2 over 30 years** in the Lesueur formations in the Harvey area.
- Higher volumes can potentially be stored. **3 million tpa for 30 years have been modelled**.
- **Main remaining gaps requires new well and test data**.
- If proven , **absence of a traditional shale cover should not prematurely screen-out** reservoirs for CO_2 storage.
- **SW Hub can widen the available sites for CCS consideration worldwide**.
- **Located in the heart of the S-W industrial belt proximal to multiple emissions sources**.



In the South West

- The Lesueur represents the best opportunity for CCS in the South West
- The absence of the Yarragadee (potable water) is critical



Thank You

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- www.ngl.org.au
- www.anlecrd.com.au

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