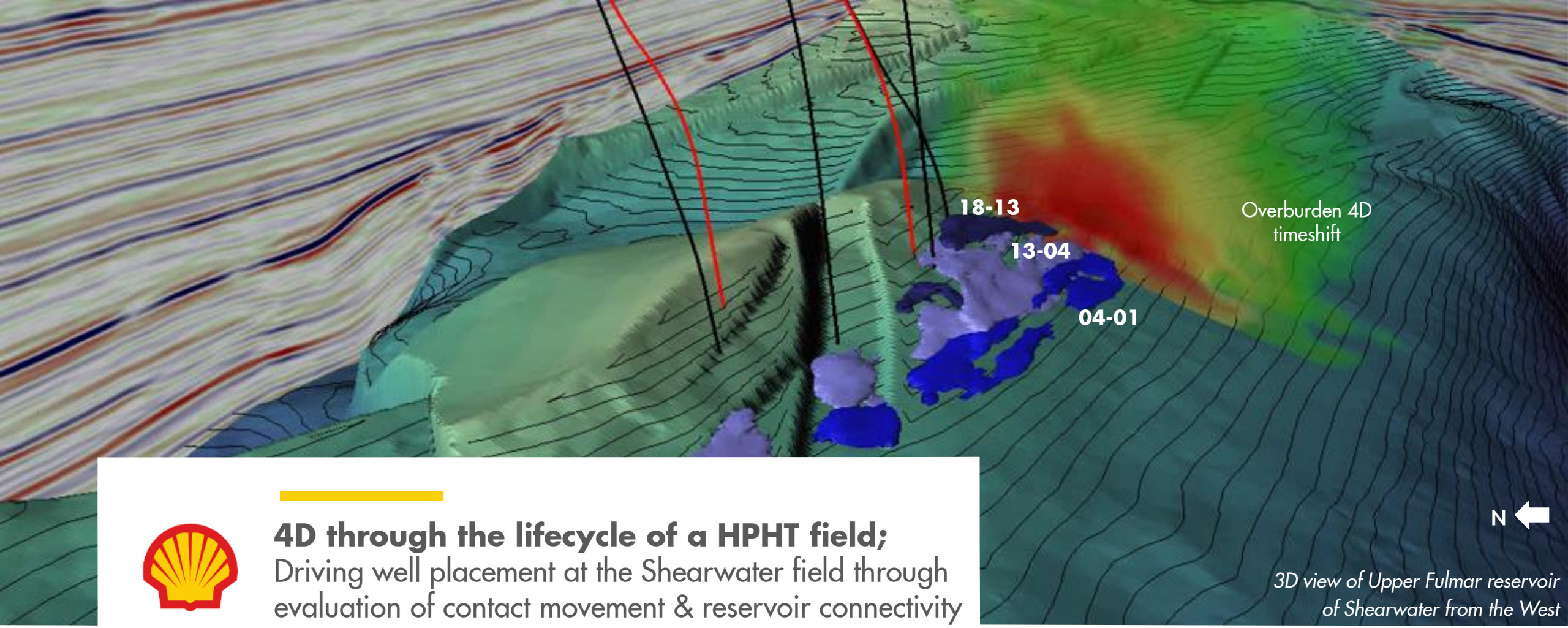

3D view of Upper Fulmar reservoir of Shearwater from the West

4D through the lifecycle of a HPHT field;

Driving well placement at the Shearwater field through evaluation of contact movement & reservoir connectivity

Seismic 2020

Presenter: Alison Ang, Senior Geophysicist

Other Authors: Jonathon Brain, Rebecca Garrard, Jorge de la Torre Guzman, Jack Rushton

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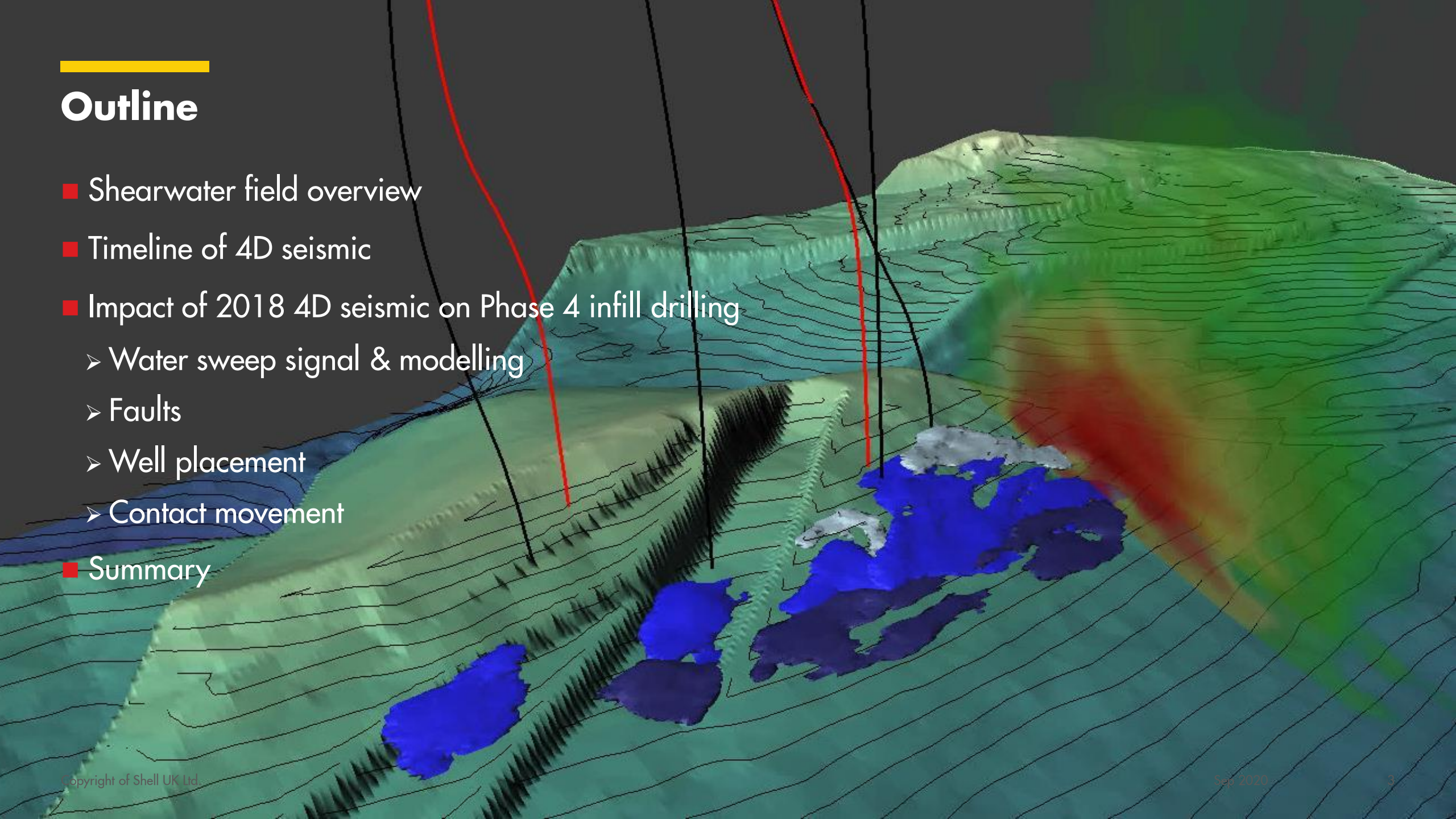
Outline

- Shearwater field overview
- Timeline of 4D seismic
- Impact of 2018 4D seismic on Phase 4 infill drilling
  - Water sweep signal & modelling
  - Faults
  - Well placement
  - Contact movement
- Summary



Shearwater Field overview

- Discovered in 1988
- HPHT gas condensate field in the Central North Sea
- Key reservoirs are Heather Sand, Fulmar & Pentland

Appraisal ('90)

Early producers (Phase 1 & 2)

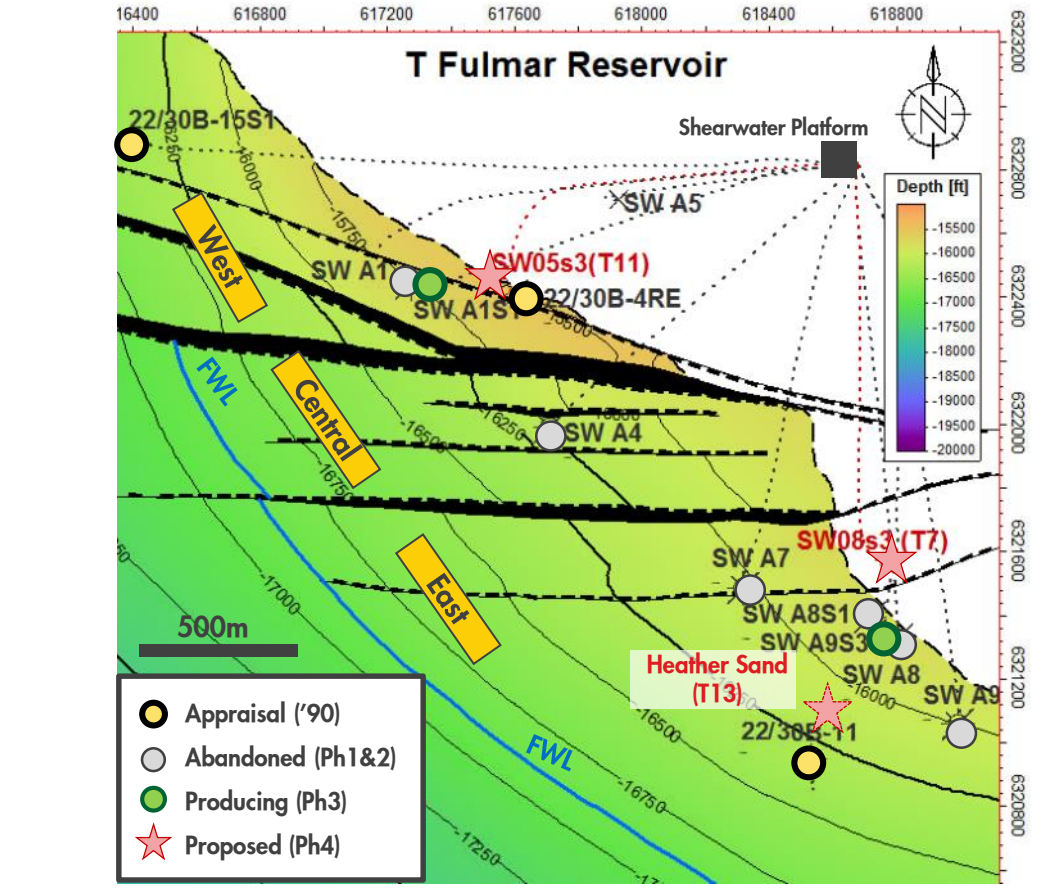
- First production in 2000
- Geomechanical well failures between 2004-2010
- No production from Fulmar reservoir of Shearwater Main Block between 2009 to 2015

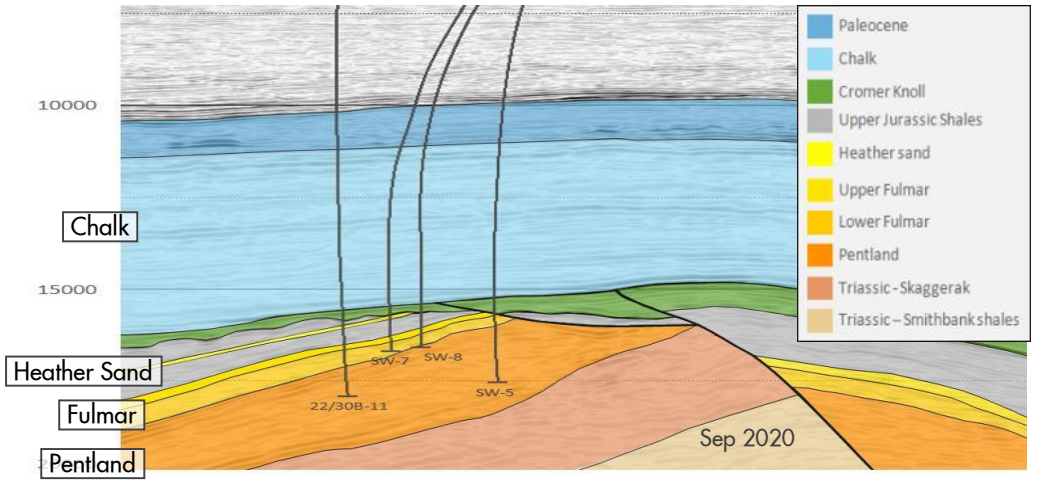
Producing (Phase 3)

- Phase 3 drilling campaign reinstating production in 2015

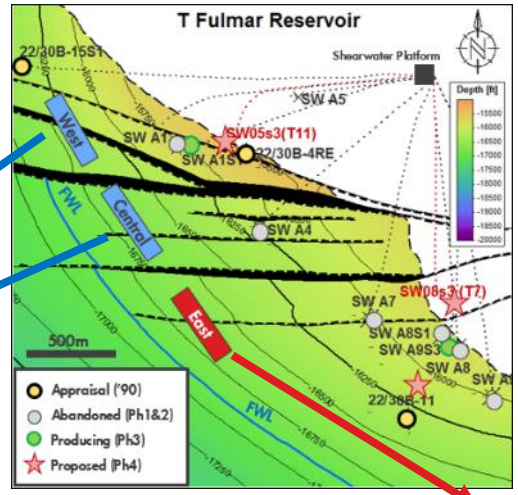
Ongoing Drilling Campaign (Phase 4)

- Phase 4 drilling campaign starting Q1 2020
- 2 x Fulmar infill wells (T11 & T7)
- 1 x Heather Sand well (T13)



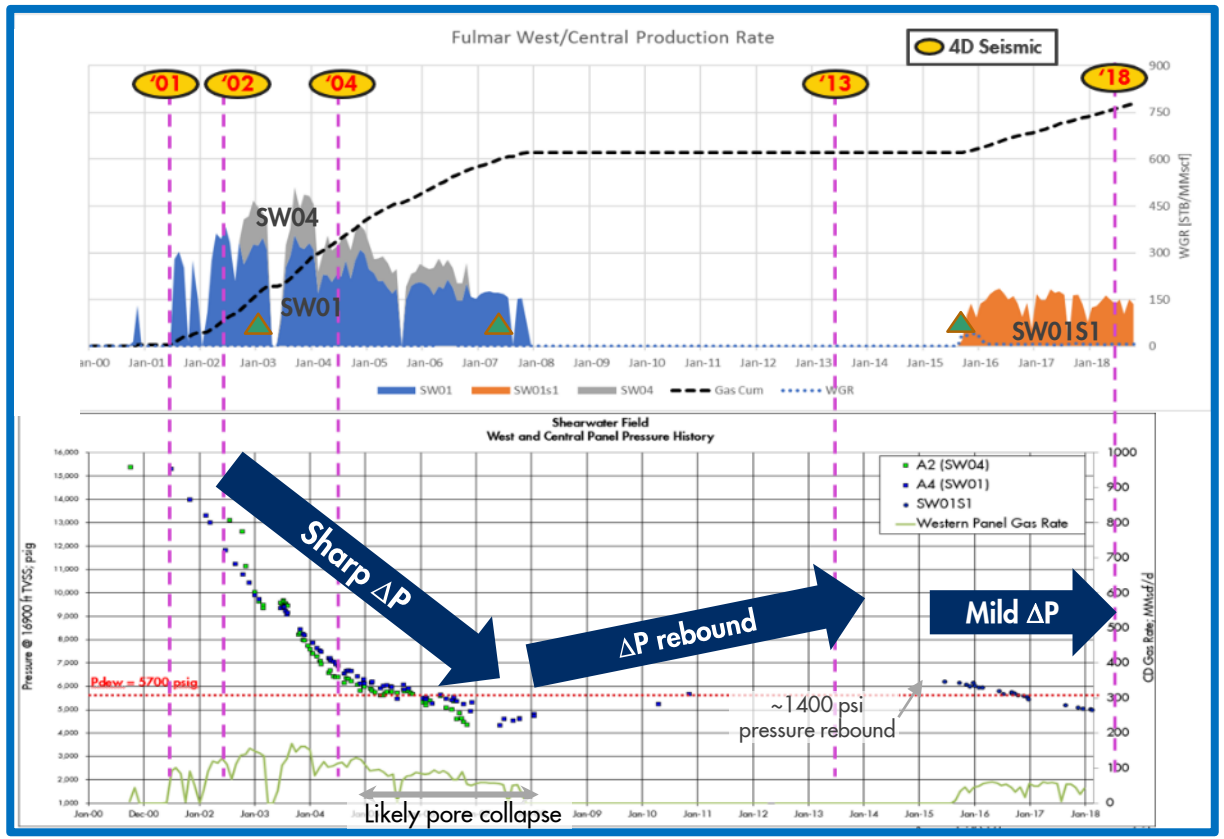


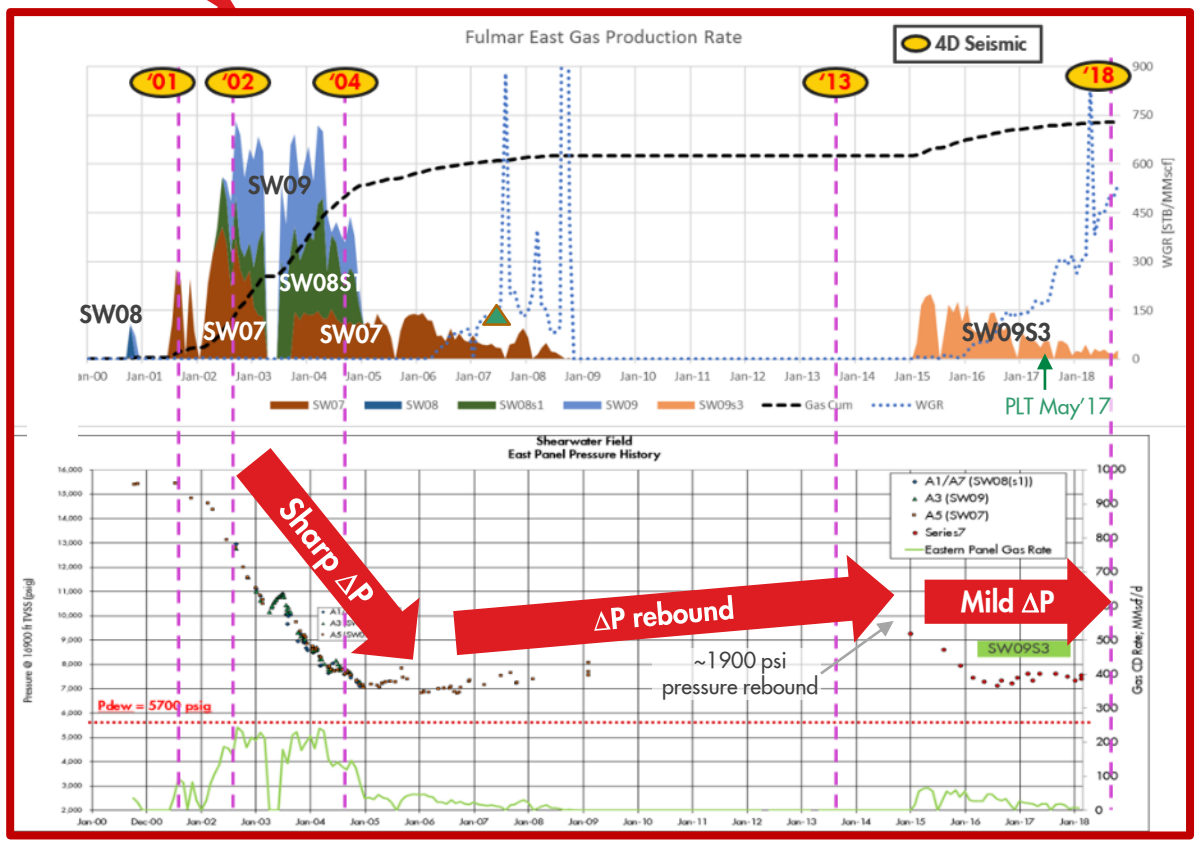
Timeline of 4D seismic & Production History of Fulmar



Streamer seismic data:

- Baseline: 2001
- Monitor: 2002, 2004, 2013 (Ph3), 2018 (Ph4)

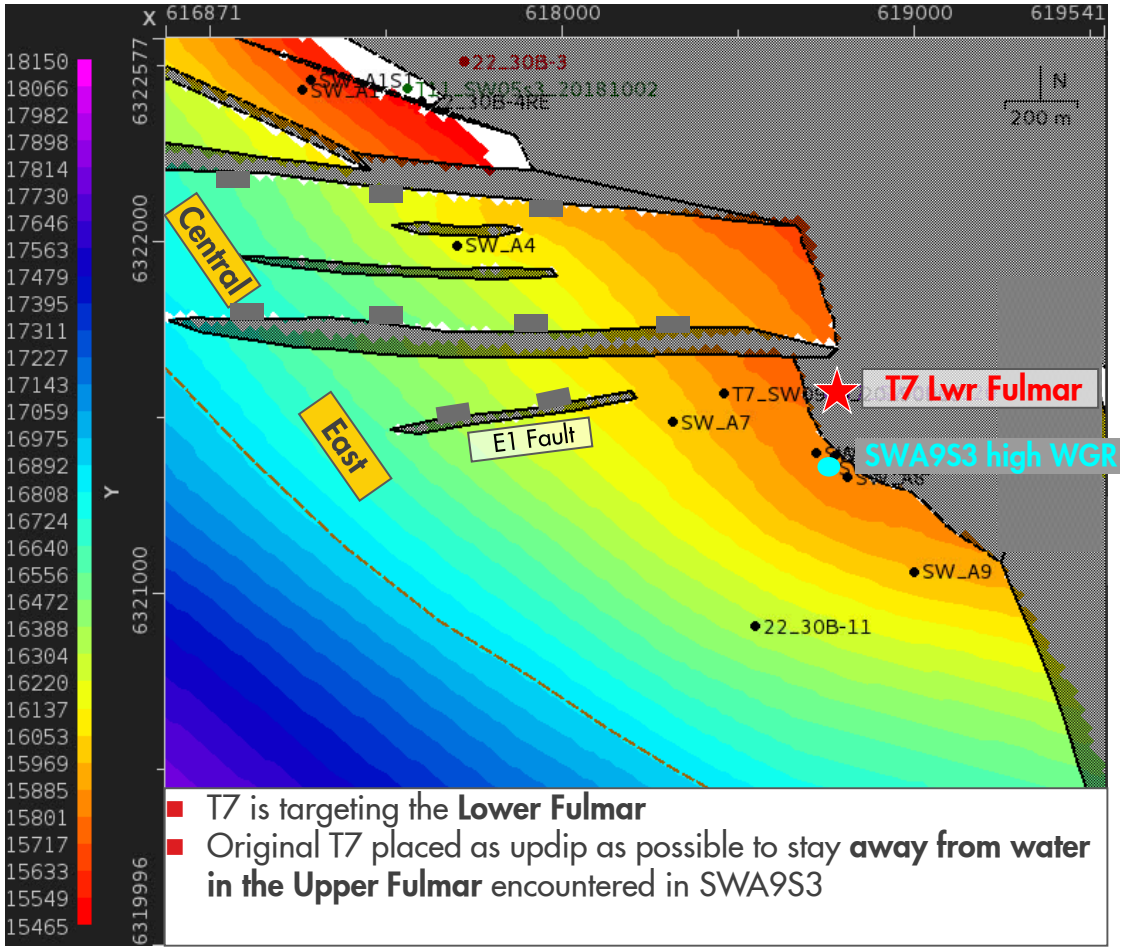




▲ Heather gas seen in Fulmar producer

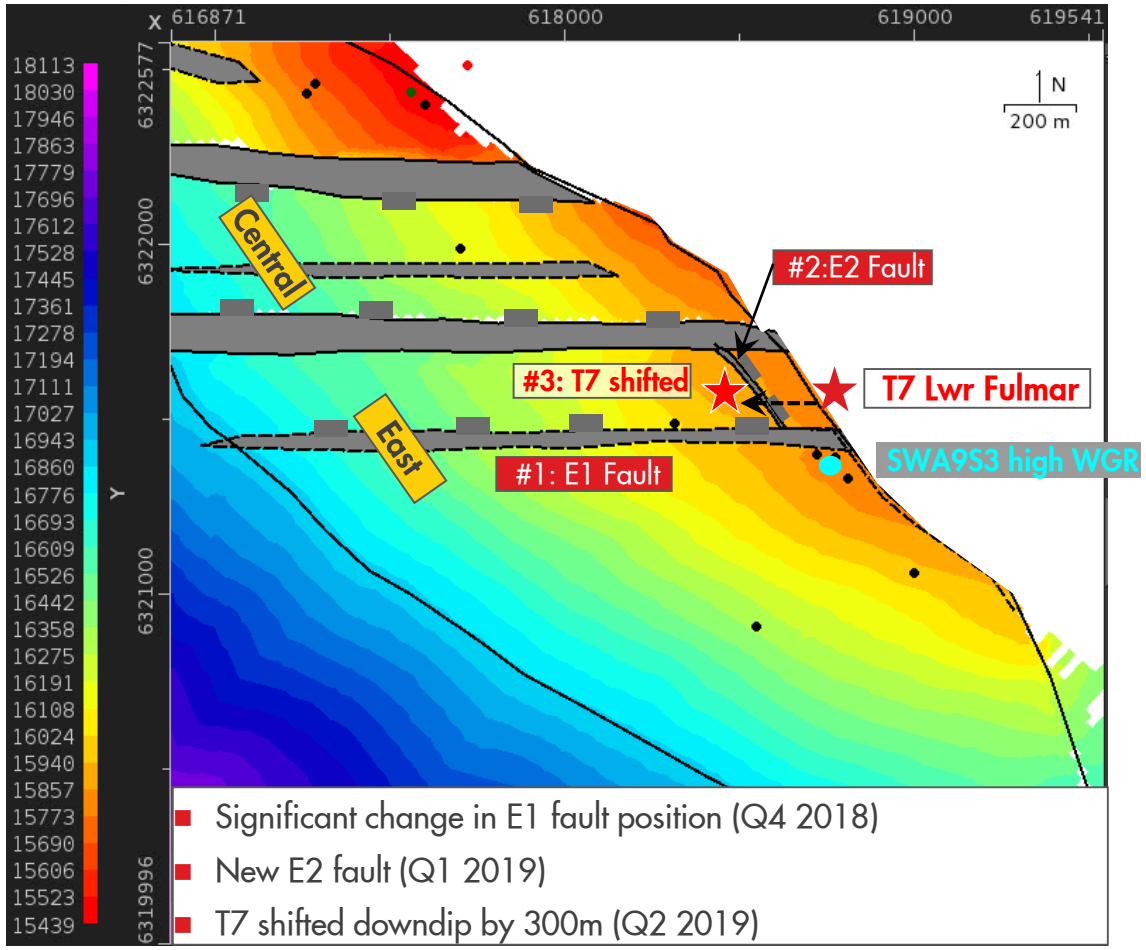
Upper Fulmar maps before and after 2018 4D interpretation

Upper Fulmar Map (BEFORE 2018 4D)



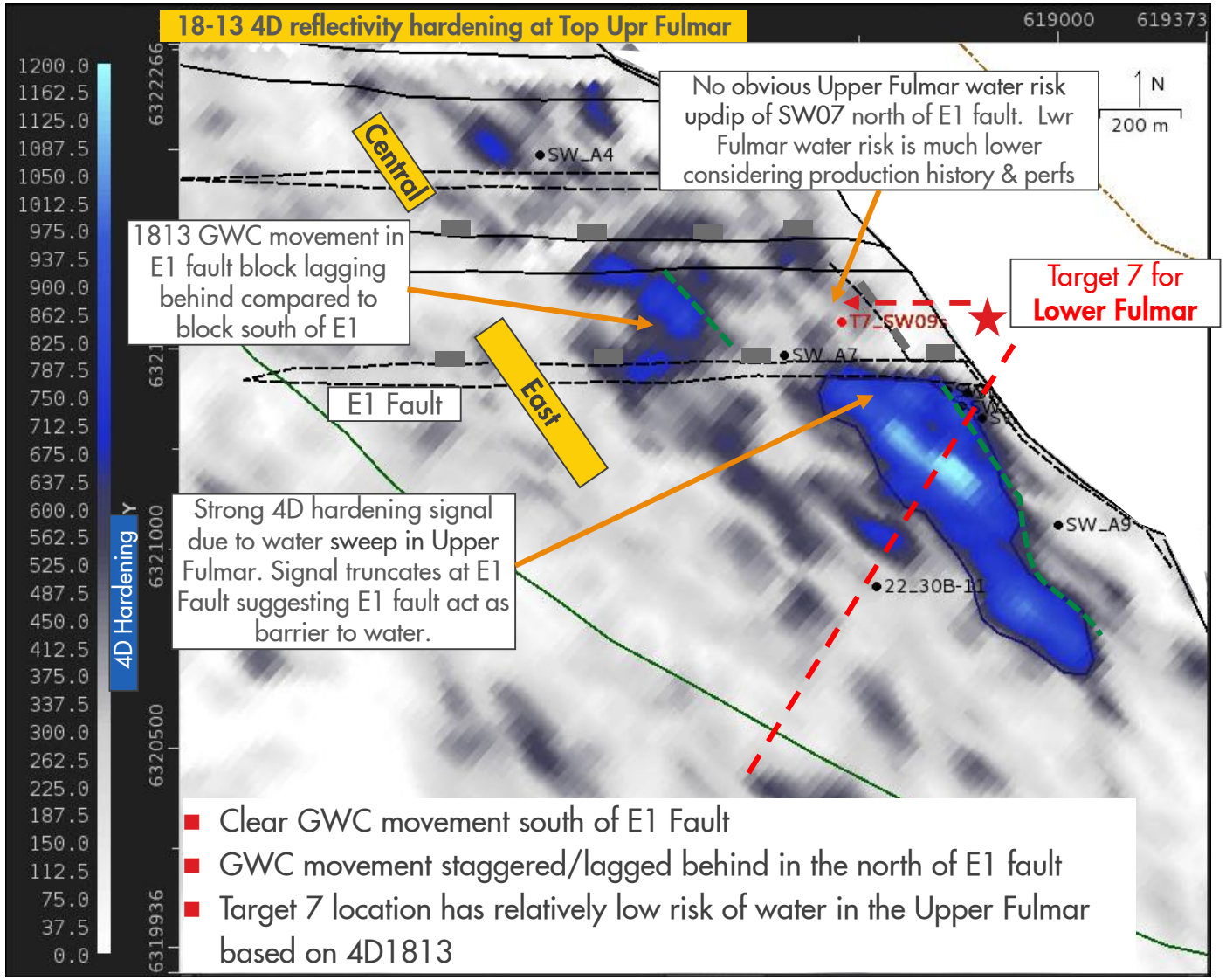
- T7 is targeting the **Lower Fulmar**
- Original T7 placed as updip as possible to stay **away from water in the Upper Fulmar** encountered in SWA9S3

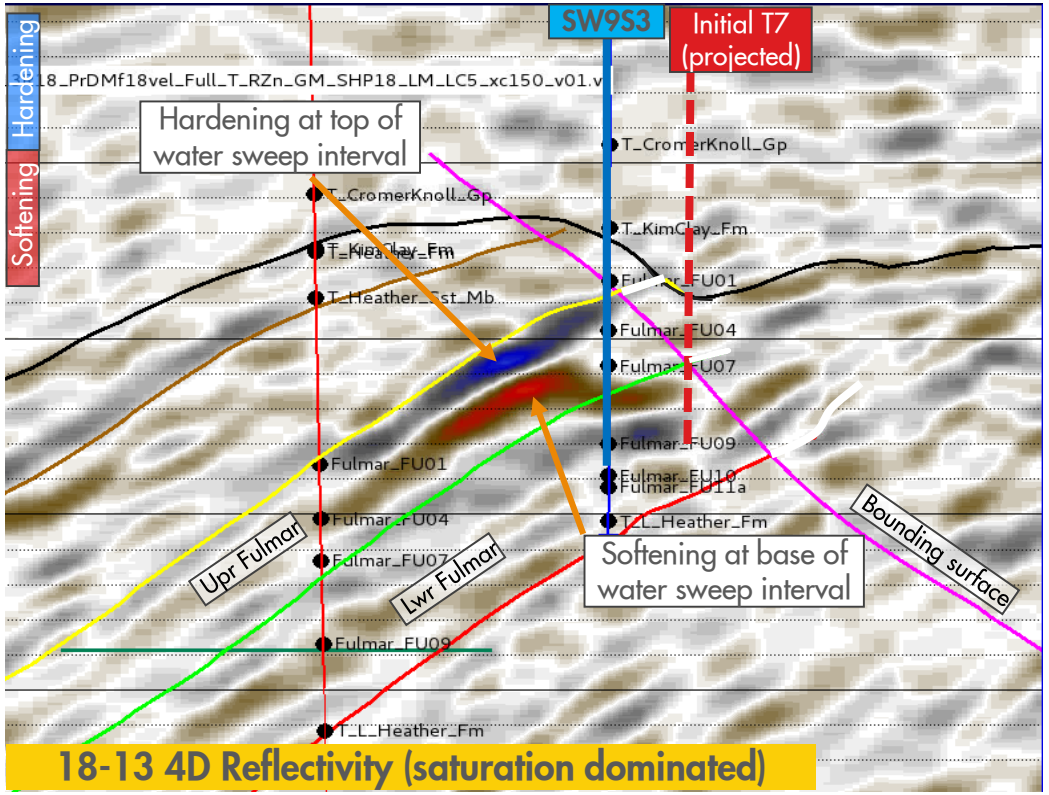
Upper Fulmar Map (AFTER 2018 4D)



- Significant change in E1 fault position (Q4 2018)
- New E2 fault (Q1 2019)
- T7 shifted downdip by 300m (Q2 2019)

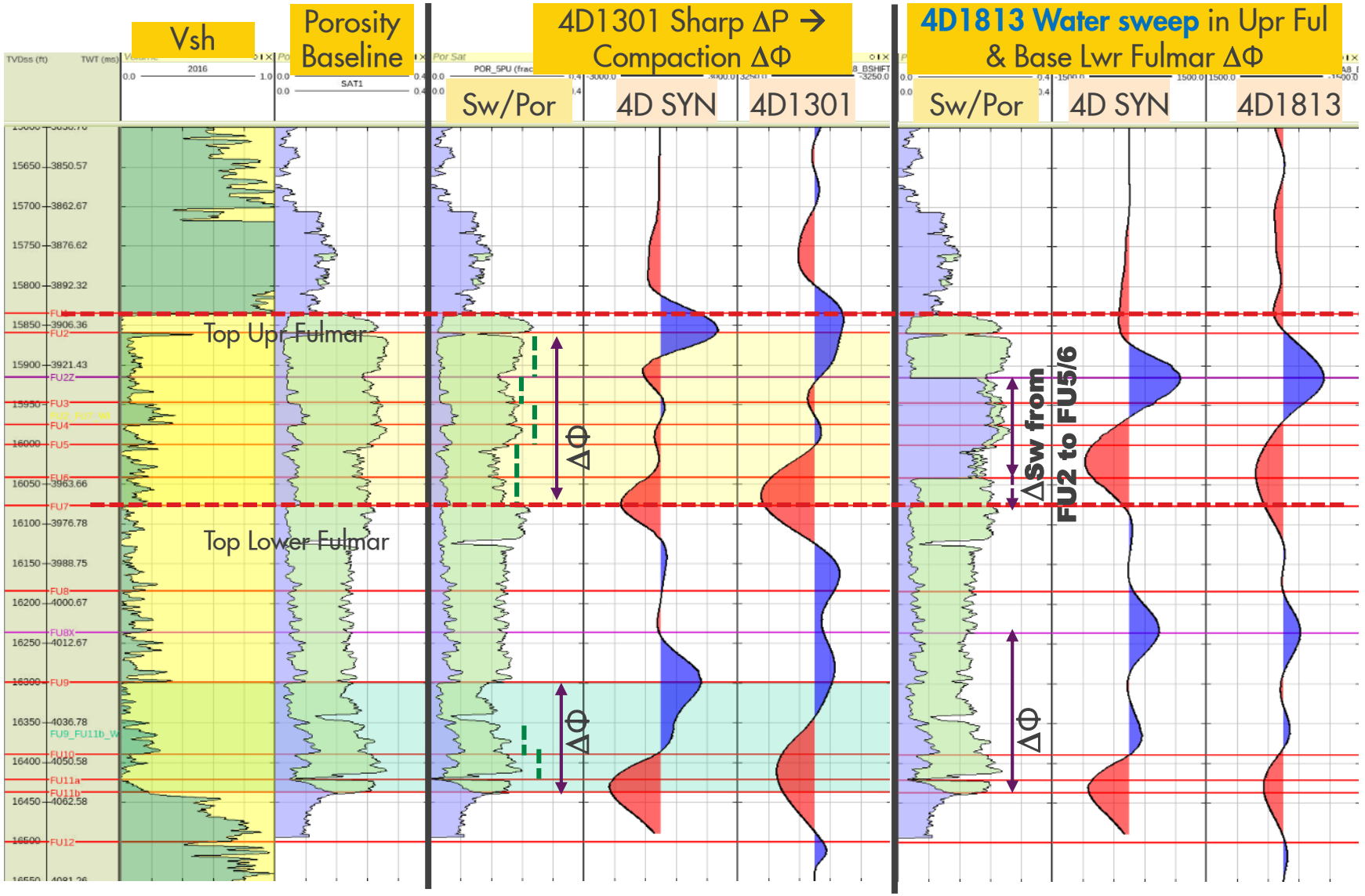
Upper Fulmar 4D – Lateral extent of water sweep

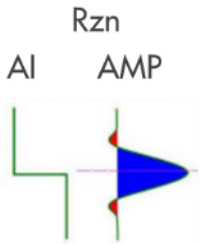




- 4D 18-13 is dominated by **saturation changes**
- Clear 4D **water sweep signal** in Upper Fulmar

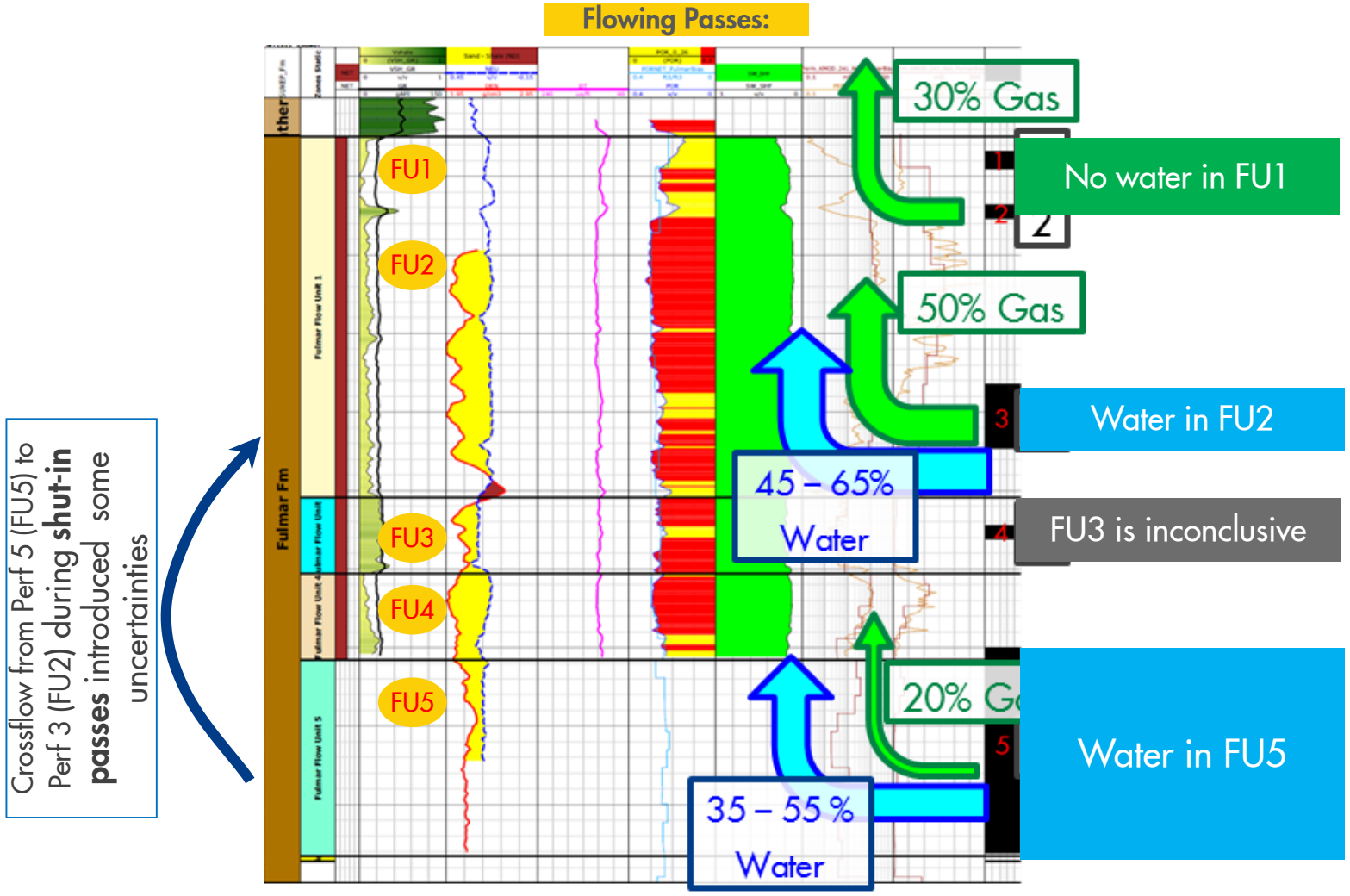
4D Response Modelling at SWA8 - Vertical extent of water





- Modelling shows that the vertical extent of the water sweep is between **FU2 to FU5 of the Upper Fulmar**
- Infill well is targeting the remaining volume in the Lower Fulmar

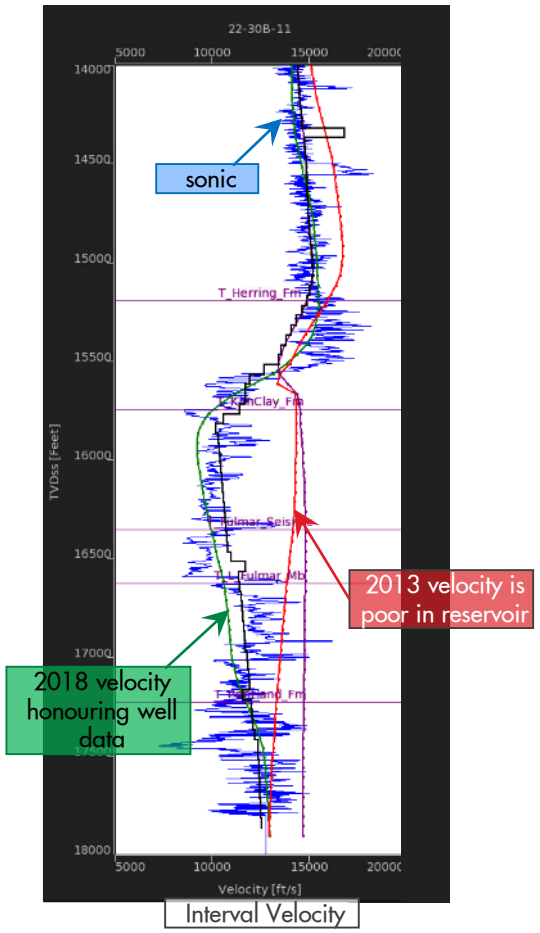
SW09S3 PLT (May 2017) & 2018 4D

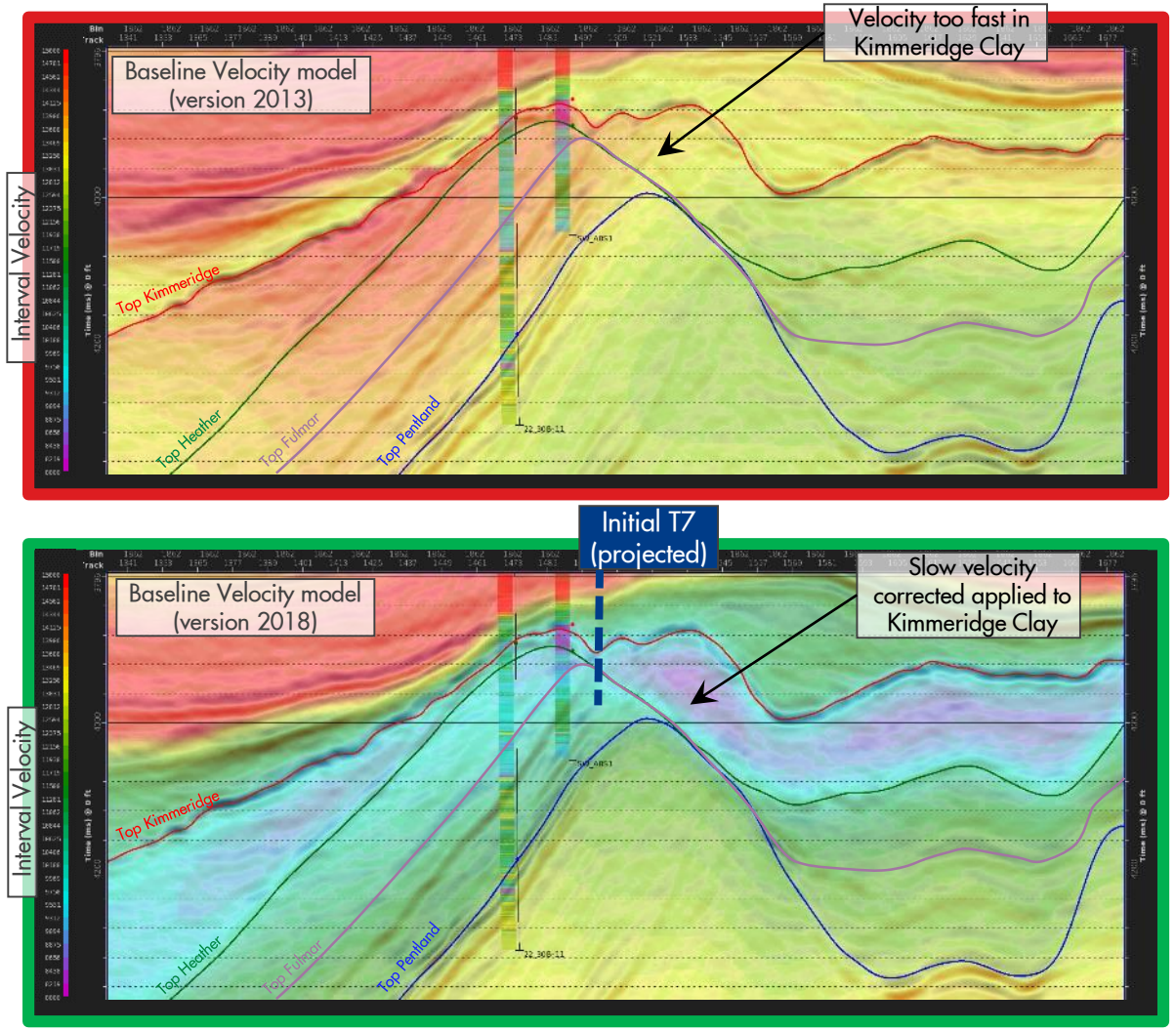


- SW09S3 PLT was acquired ~1 year before 2018 4D seismic
- The PLT and 2018 4D seismic results are in overall **alignment** suggesting water swept zone from **FU2 to FU5 of the Upper Fulmar**

		PLT Interp			PLT Interp after cross flow correction		
Perf	FU	Gas	Water	WGR	Gas	Water	WGR
		%	%	bbl/ MMscf	%	%	bbl/ MMscf
1	1	18	0		18	0	
2	2	16	0	114	16	0	80
3	2	48	64		48	45	
4	3	inconclusive					
5	5	18	36	293	18	55	448

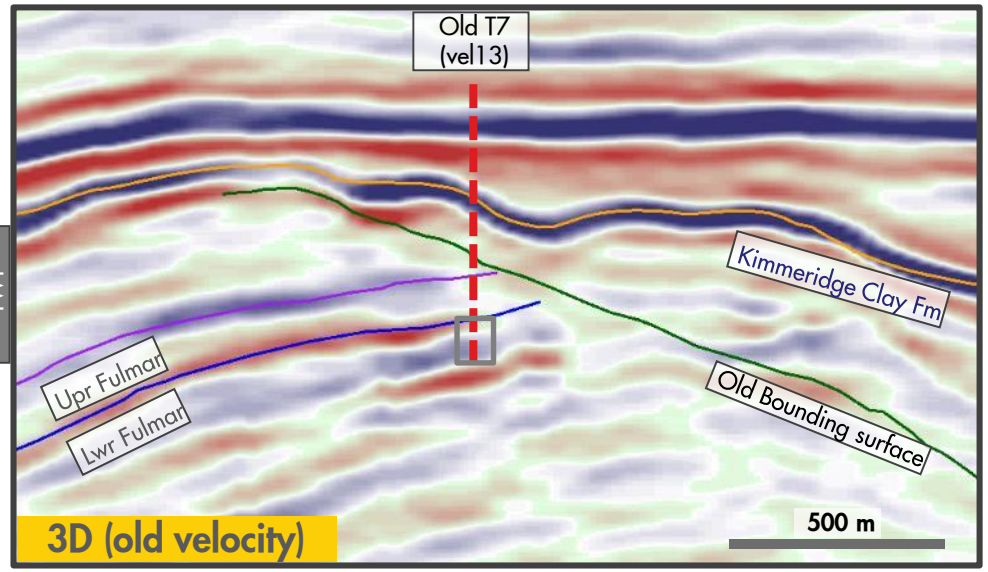
2018 4D migrated with improved baseline velocity model

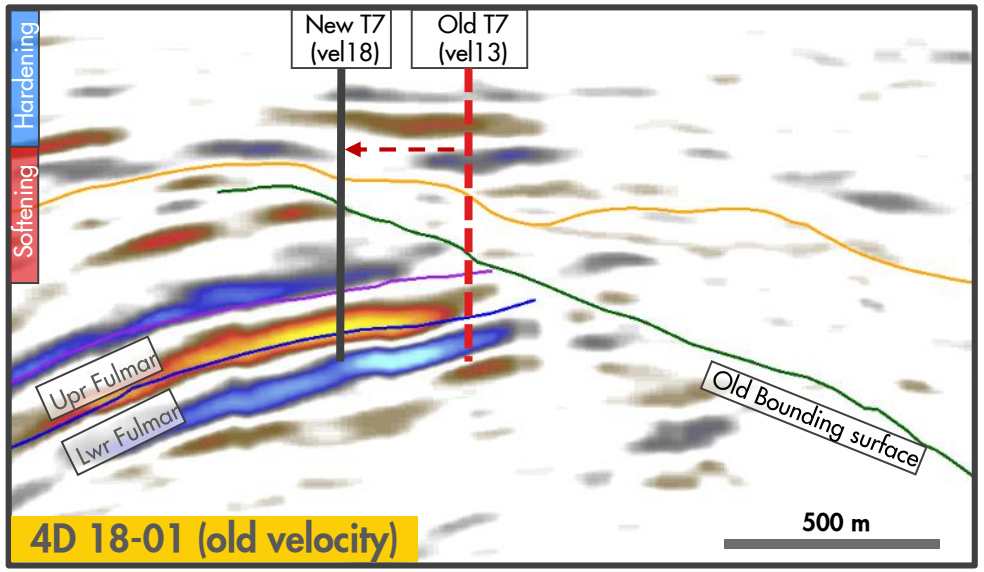


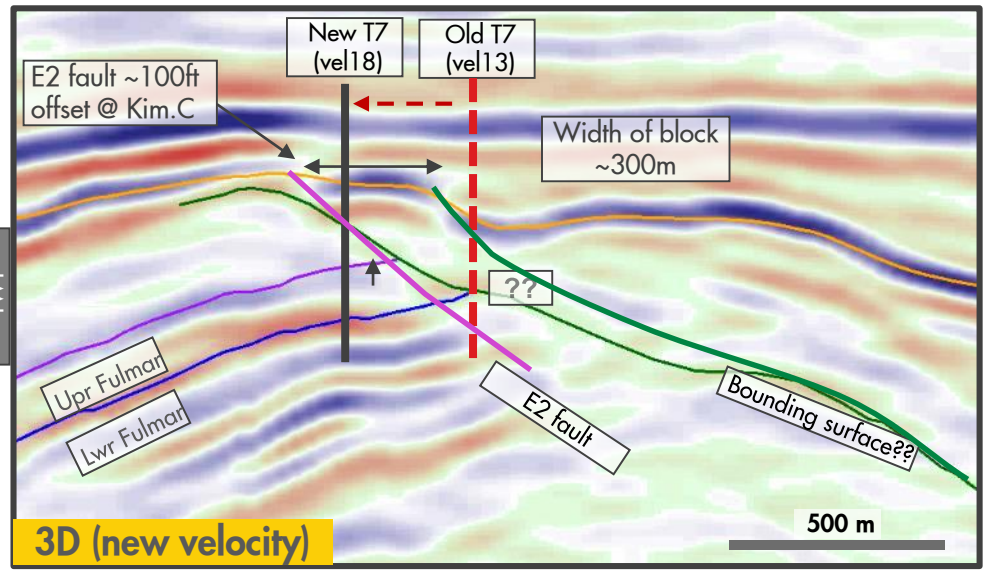


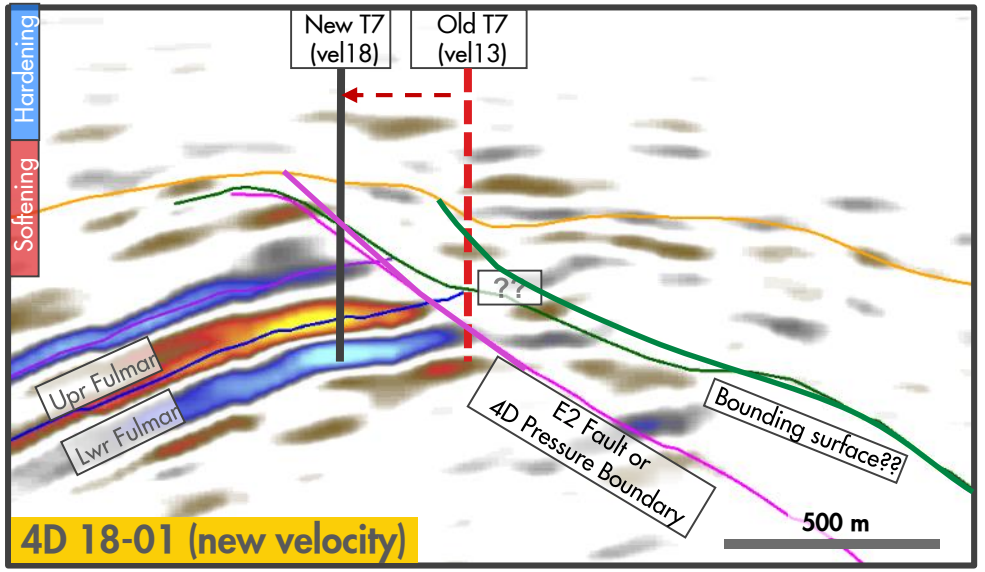
- Lateral velocity variation is critical for imaging (both 3D & 4D)
- Significantly affect the positioning and amplitudes of reflectors near the crestal area
- Better imaging due to improved baseline velocity led to **E2 fault interpretation**

Impact of updated migration velocity & E2 Fault

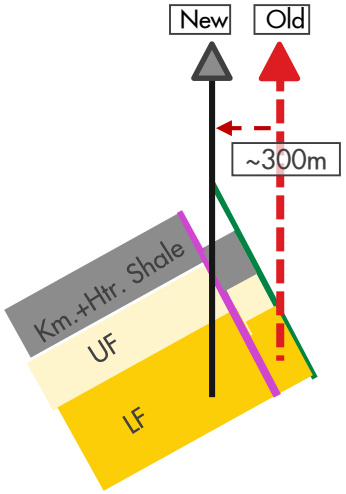




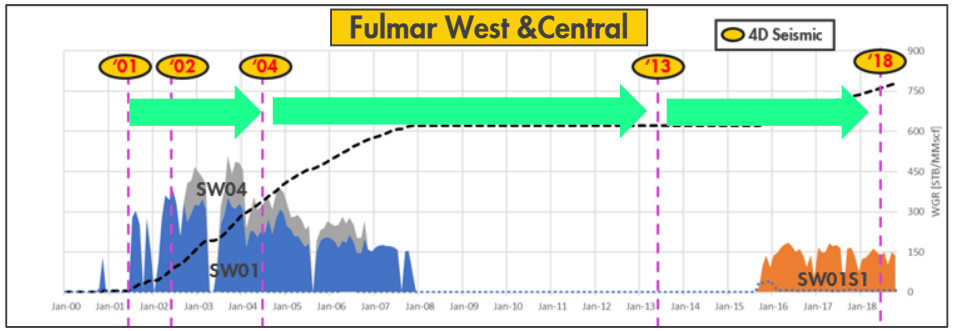


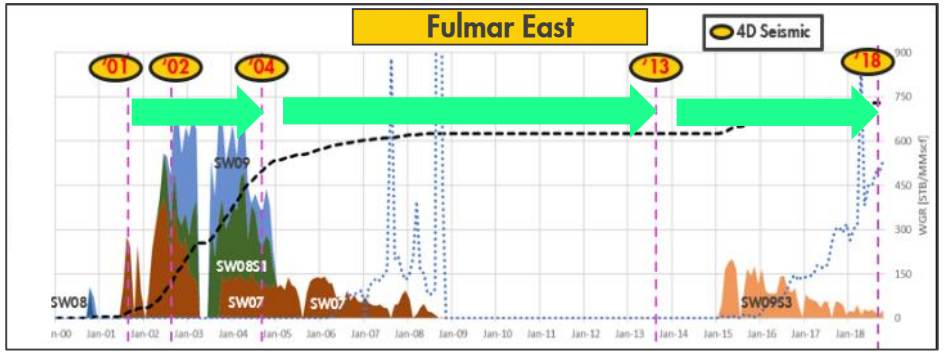


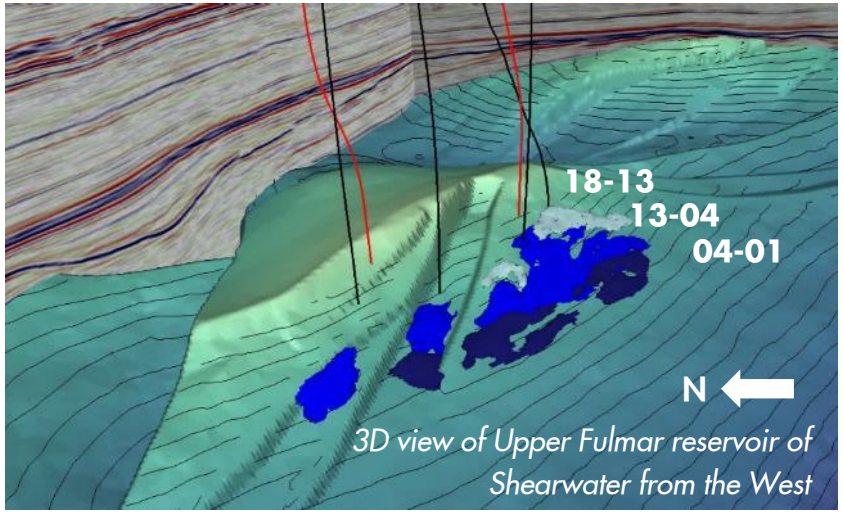
Various geological realizations considered for well planning

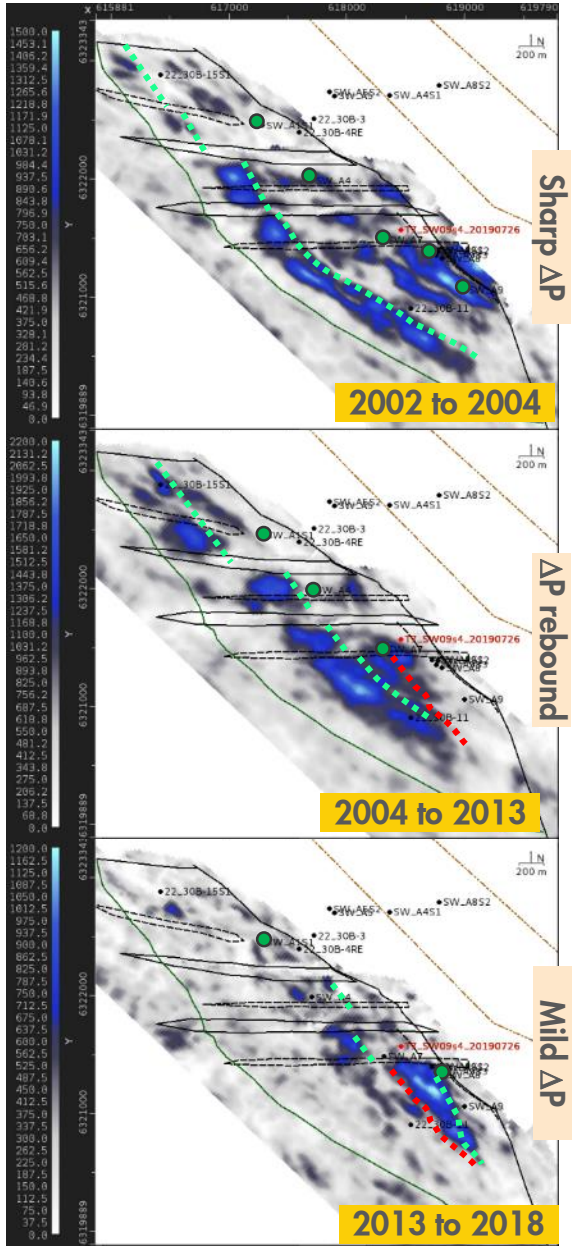


4D interpreted pGWC movement at Top Upper Fulmar









- Joint evaluation of the **spatial position** of the 4D hardening signal of multiple 4D timesteps enable interpretation of producing **GWC movement**.
- The 4D hardening related to water sweep moves **progressively updip** with each 4D timestep
- The 4D hardening signal at the crest in 2002-2004 is dominated by pressure depletion induced **compaction**

Heather Sand 4D: Imaging the invisible

Intro

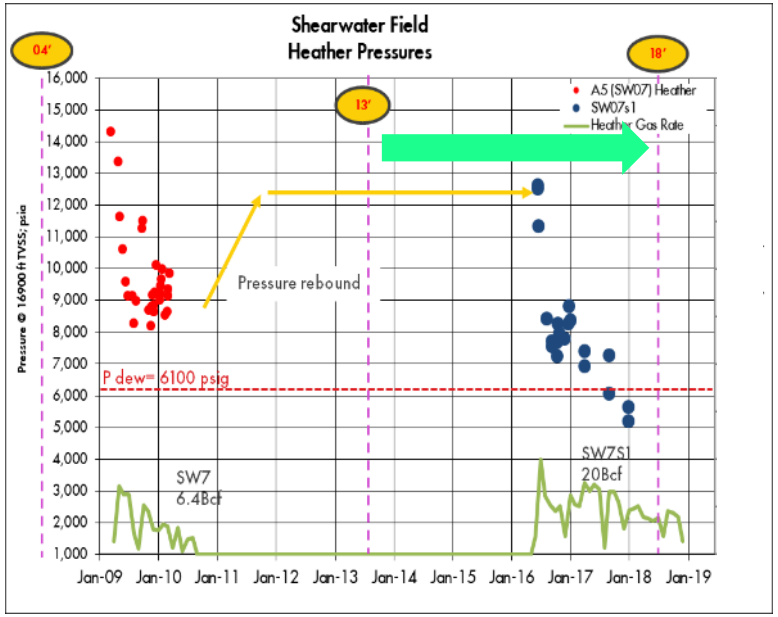
- Heather Sand is ~**48 ft** i.e. **thin and very weak 3D acoustic impedance contrast**
- Turbidite reservoir with 100% NTG and 24% porosity

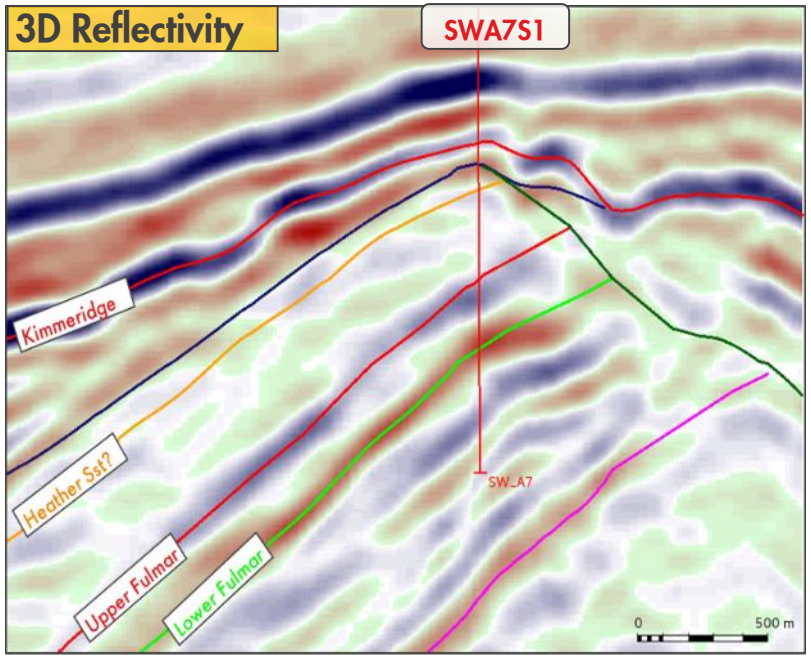
East

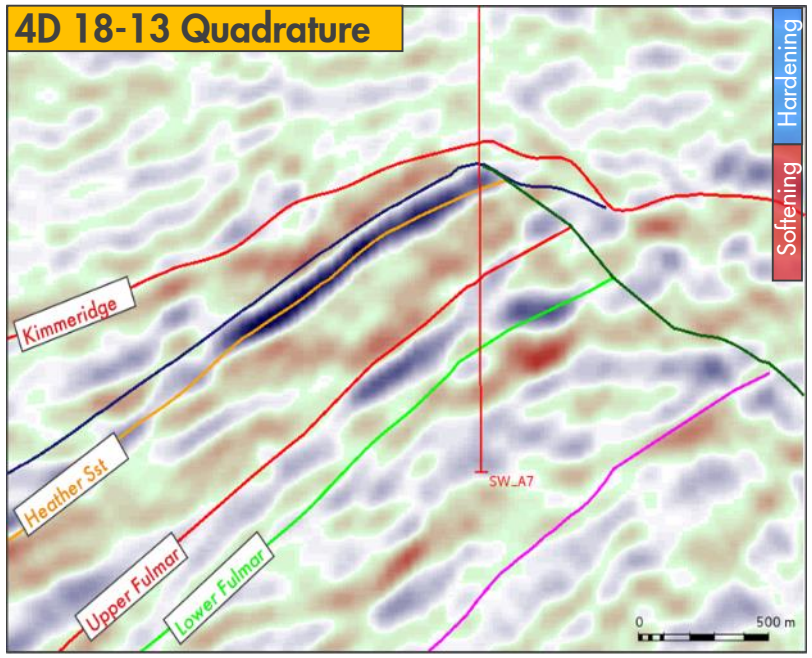
- **SWA7S1** produced ~20Bcf from Heather Sand from 2016 onwards.
- Near / far tank behaviour related to **E1 Fault** (also extend deeper into Fulmar)
- Supported **T13 well placement**

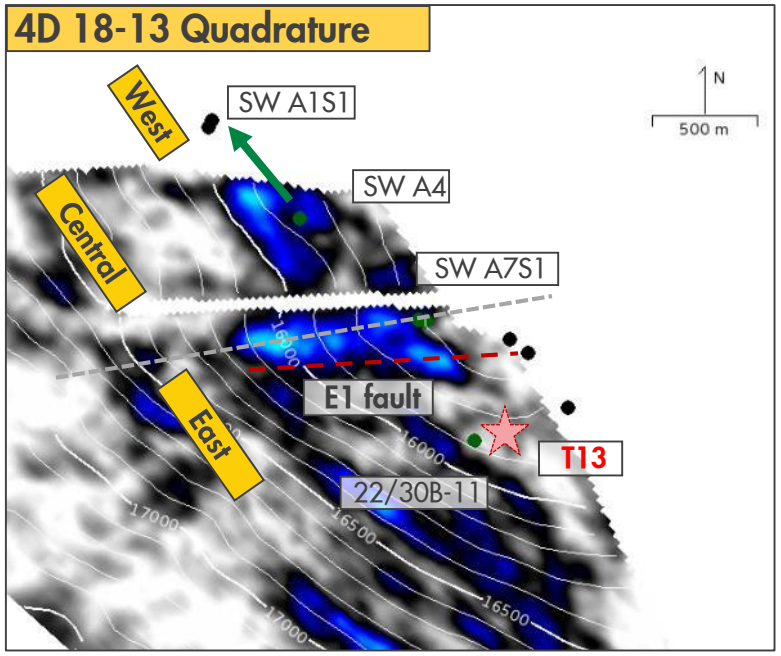
Central

- No direct off-take point in Central Panel
- **SWA1S1 Fulmar producer** is depleting the **Heather Sand** of Central Panel

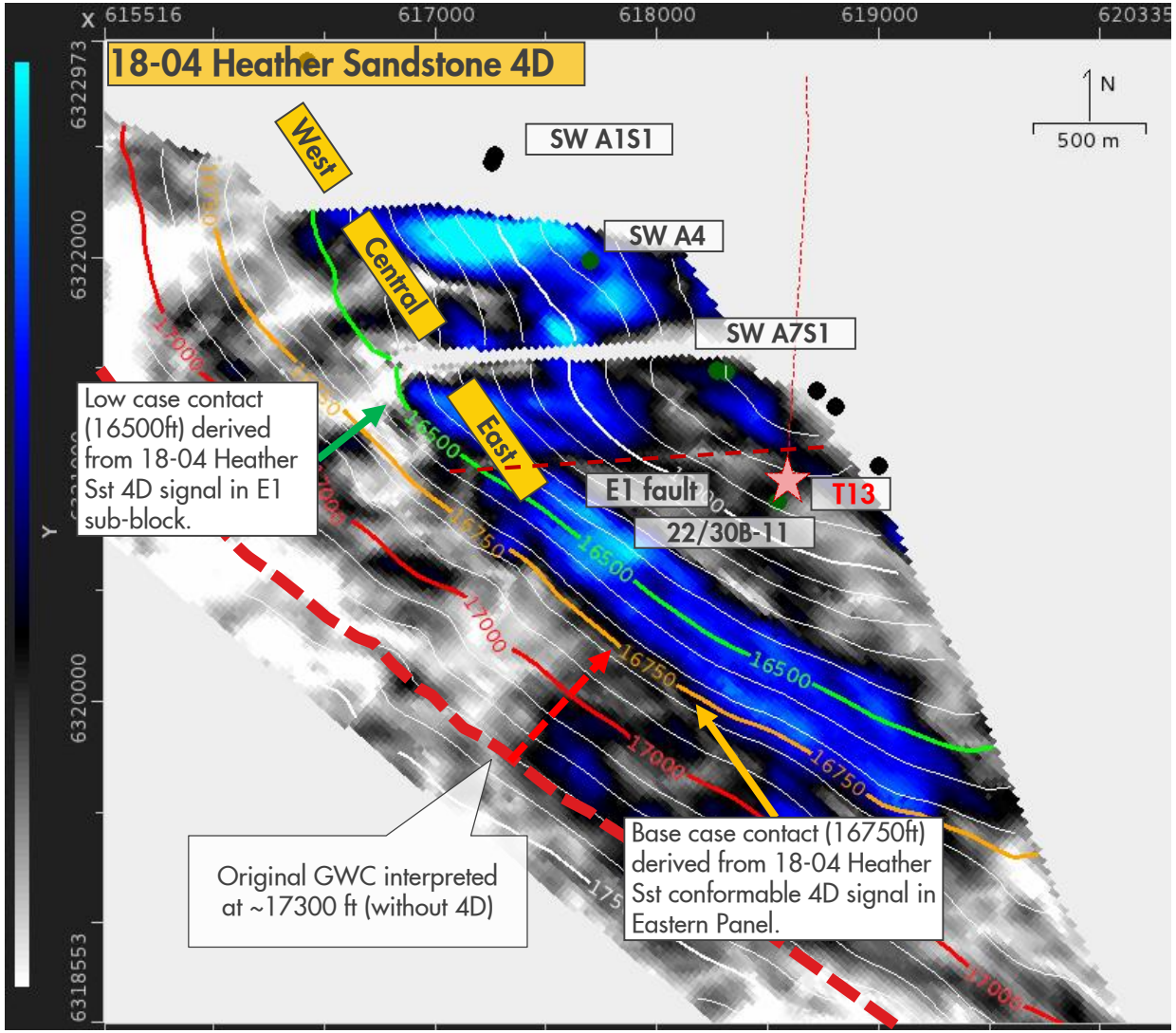








4D indicates original GWC of Heather Sand



- Without aquifer pressure data & without 4D support, previous GWC at 7300 ft has high uncertainties
- With clear 4D signal, the base case for the **original GWC** was revised to16750 ft

Summary

De-risking Phase 4 infill wells

- Supported location of 2 wells
- Shifted location of Fulmar East infill well
- Overburden changes & 4D timeshifts

Connectivity & Compartmentalization

- Identified sub-seismic faults
- Near tank/far tank behaviour of Heather Sand
- Western Panel and Central Panel in communication

Contact

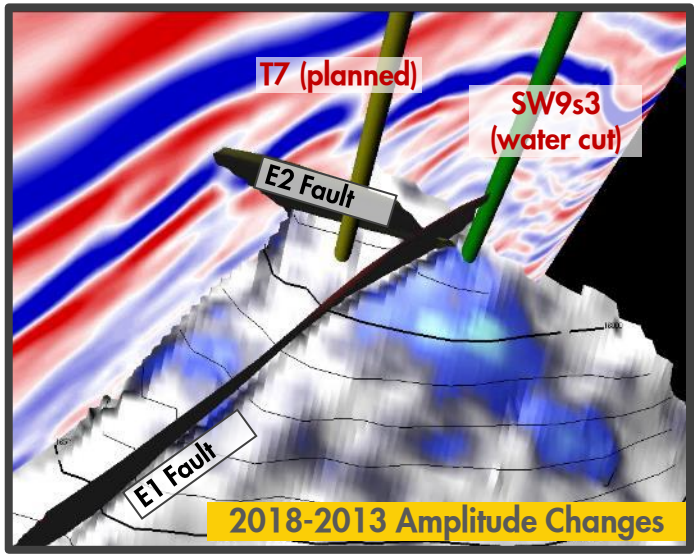
- Producing GWC movement of Fulmar
- Original GWC of Heather Sand

Journey of Continuous improvement

- Integrating production data and analysis at **Flow Unit scale**
- Lateral velocity variation matters for both 3D & 4D data
- Jigsaw puzzle… New 4D data helps to further unravel previous timestep

Raising the bar

- 4D velocity model build per vintage
- Geomechanical model calibration with 4D timeshifts
- Enhanced imaging including least square migration



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Wider team members:

Seismic acquisition, processing team & geophysicists over the last 20 years

We would like to thank the Shearwater co-venturers, Esso Exploration and Production UK Limited and Arco British Limited for their contributions and allowing us to present the data.

Valaris 122 Rig at Shearwater Phase 4 drilling