

The world's first subsea separator is still performing

20 years of experience of subsea separation and boosting on the Tordis / Vigdis fields

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Technology Day 2026, Norwegian Offshore Directorate, 4th of June 2026

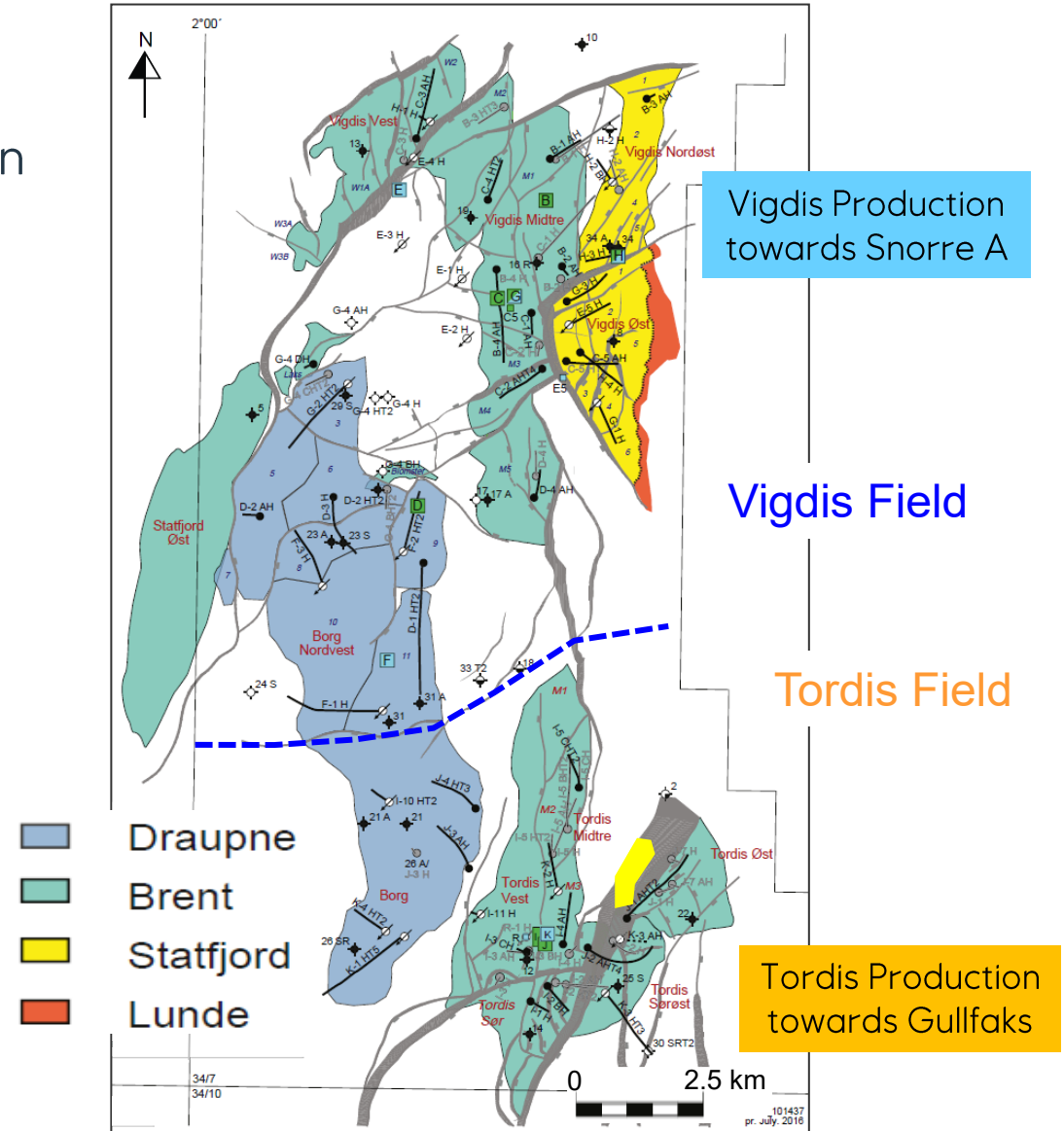
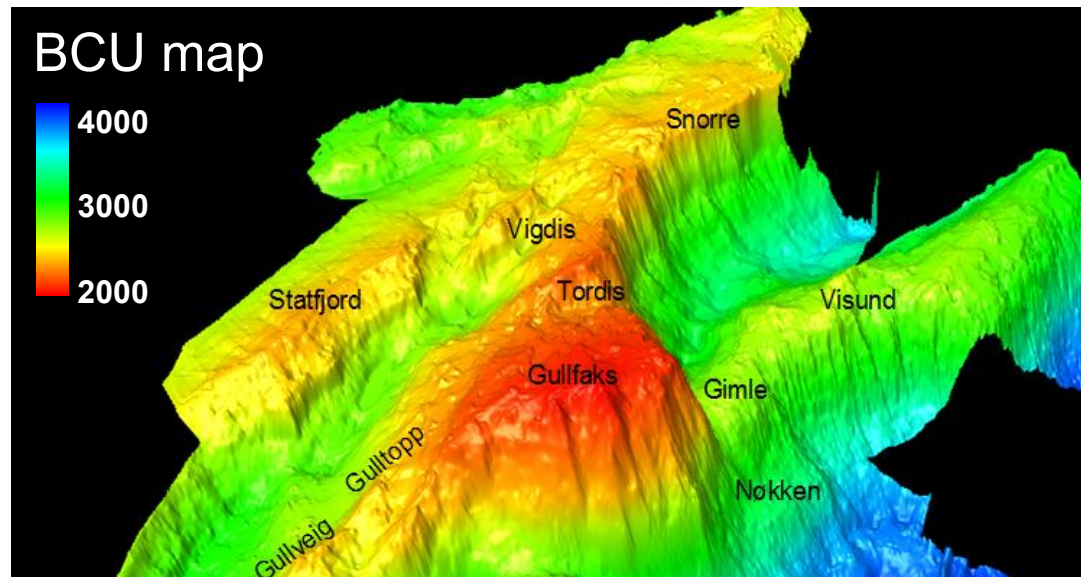


Outline

- Tordis / Vigdis introduction
- Tordis Subsea Separation, Boosting and Injection (SSBI)
 - Objectives
 - First year in operation and water injection fracture to seabed
 - Second operational phase
- Vigdis Boosting Station (VBS)
 - Objectives & Operations
- Conclusion, way forward

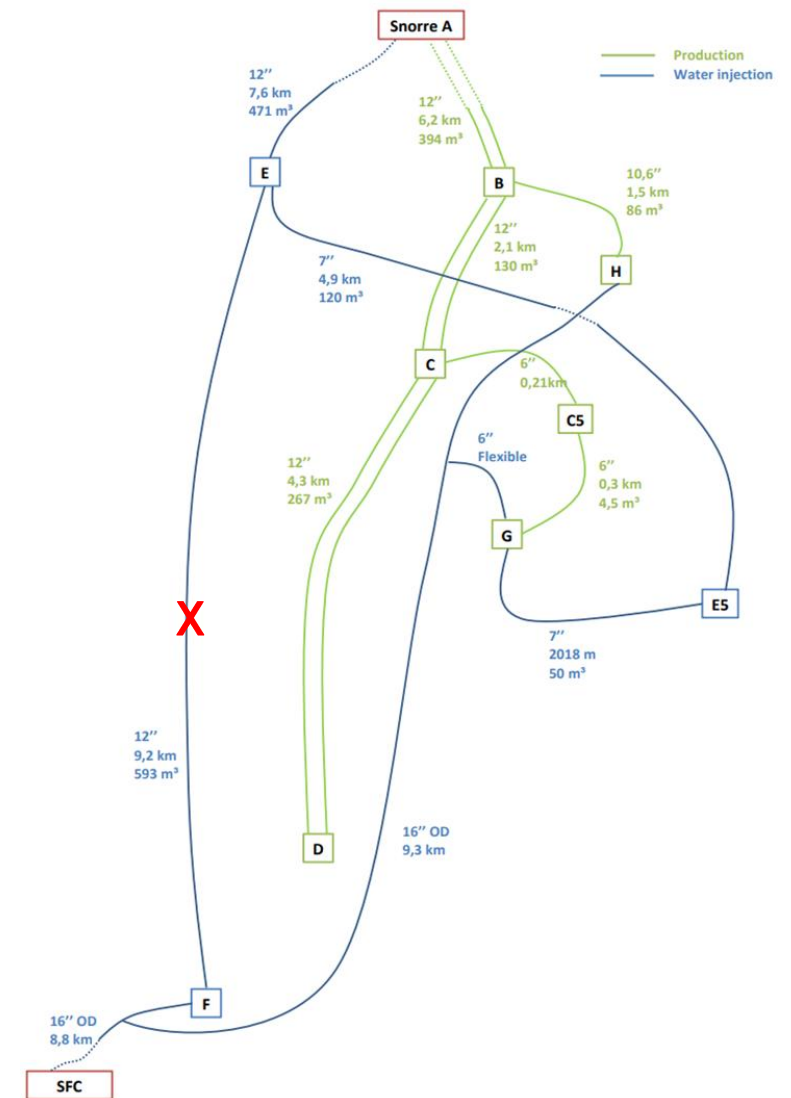
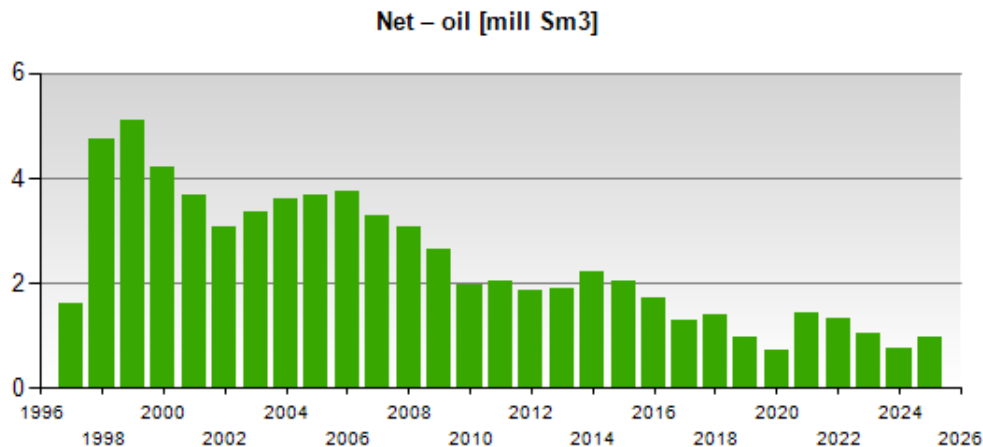
PL089 Tordis / Vigdis Field location

- Block 34/7, located in the Tampen area, in between Snorre, Gullfaks, Statfjord
- Water depth 280 m (Vigdis), 150-220 m (Tordis)
- Reservoir depth 2000- 2600 mTVD



Vigdis: discovery 1986, production start 1997

- Development:
 - 7 subsea templates and 2 satellite wells connected to Snorre A. Oil to Gullfaks A, gas reinjected in Snorre
 - Injection water supplied from Snorre A and Statfjord C
- Recovery:
 - Pressure support by water injection and natural aquifer support. Some reservoirs affected by Statfjord depletion
 - Subsea booster pump to accelerate production
 - 4D seismic every ~4 years

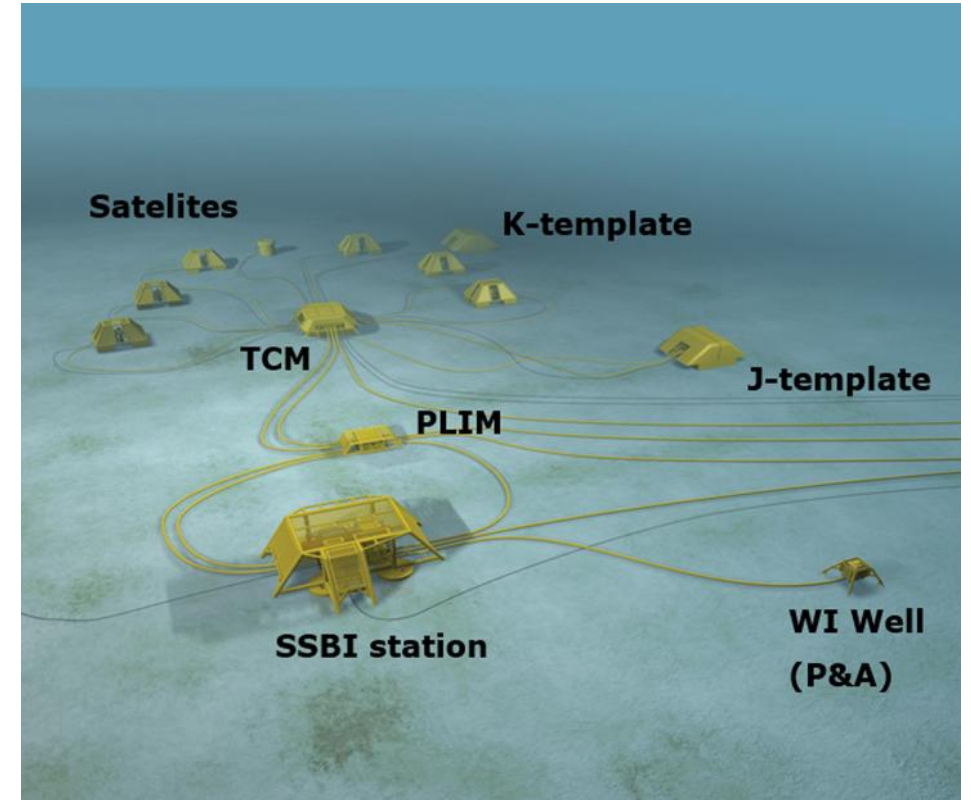


Recoverable oil (RCO-3) [mill Sm ³]	Produced [mill Sm ³]	STOOIP [mill Sm ³]	Recovery Factor Current - Final
76.3	69.4	153.7	45% - 50%

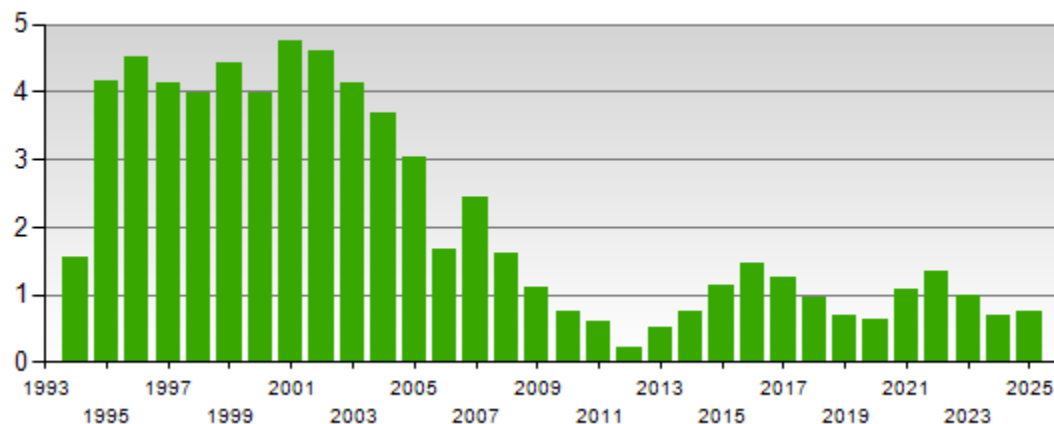
(date: 31.12.2025)

Tordis: discovery 1987, production start 1994

- Development:
 - Central subsea manifold tied-back to Gullfaks C, 7 satellites wells and two 4-slots subsea templates tied-back to the manifold. Oil processed on GFC, gas exported to Kårstø
 - Gullfaks C supplies water for injection
- Recovery:
 - Pressure support by water injection, natural aquifer drive
 - Subsea separation started 2007
 - 4D seismic every ~4 years



Net – oil [mill Sm³]



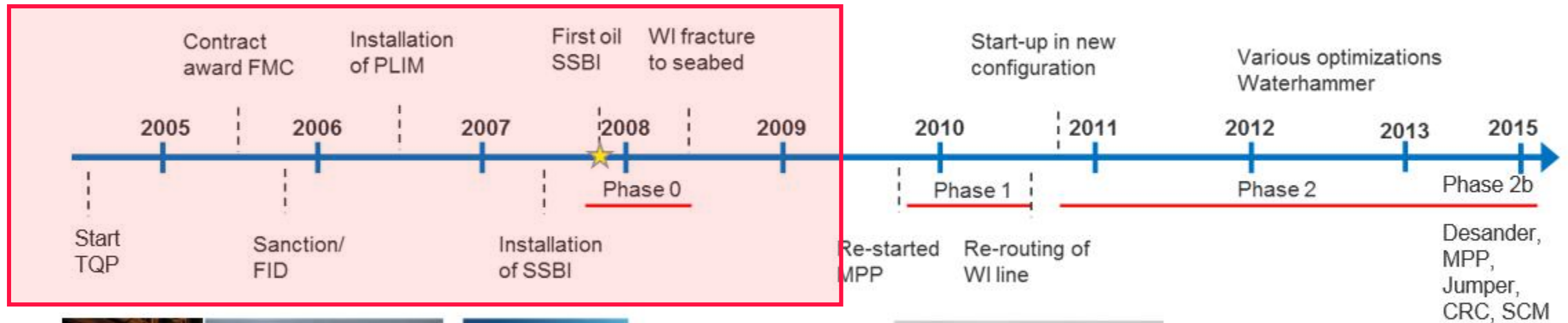
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72.9	67.3	123	55% - 59%

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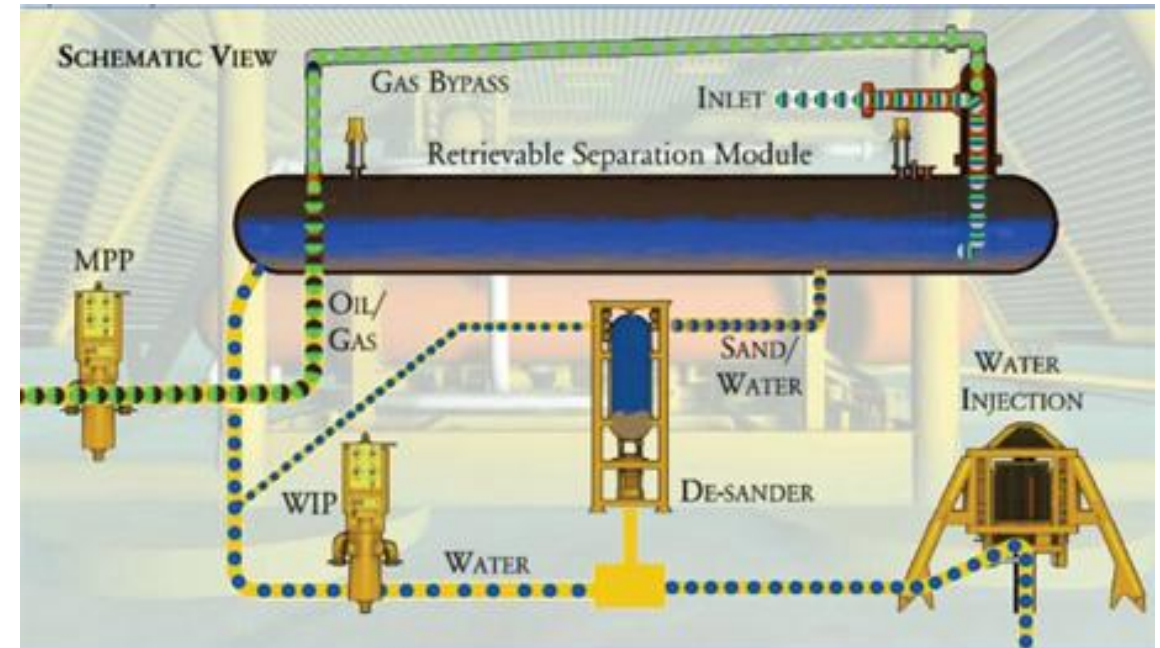
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Timeline: Tordis SSBI (Subsea Separation, Boosting and Injection)



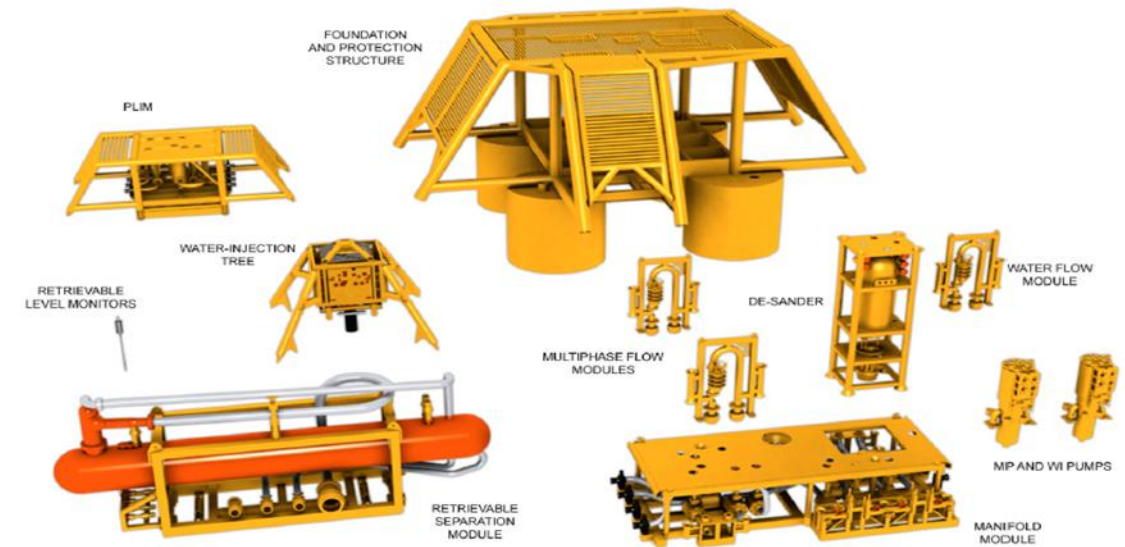
Tordis IOR project: first full-scale subsea separation facility in the world!

- Tordis IOR project initiated in 2005 due to declining production
 - Challenges: pressure support / water handling capacity
- Objectives:
 - Maintain high regularity
 - Increase oil recovery from Tordis field from 49% to 55%, add ca. 5 mill Sm³ of oil
- Original strategy:
 - Reduce production pressure
 - Low pressure production Gullfaks C (GFC)
 - Boosting of HC back to GFC (Multiphase pump / MPP)
 - Increase water handling capacity:
 - Bulk water separation
 - Re-injection of produced water in Utsira



Tordis Subsea Separation, Boosting and Injection (SSBI) – main design requirements

- **Designed for reliable, safe and cost-effective operations:**
 - Modular design – all modules retrievable
 - Sensitive components located on retrievable equipment
 - Spare modules for critical equipment
- **High level of flexibility:**
 - Bypass of SSBI
 - Bypass of Multiphase Pump (MPP)
 - Spare future tie-in points
- **Continuous metering of HC, water and sand**
- **Simplified condition monitoring**





Length 17 m / diameter 2.1 m

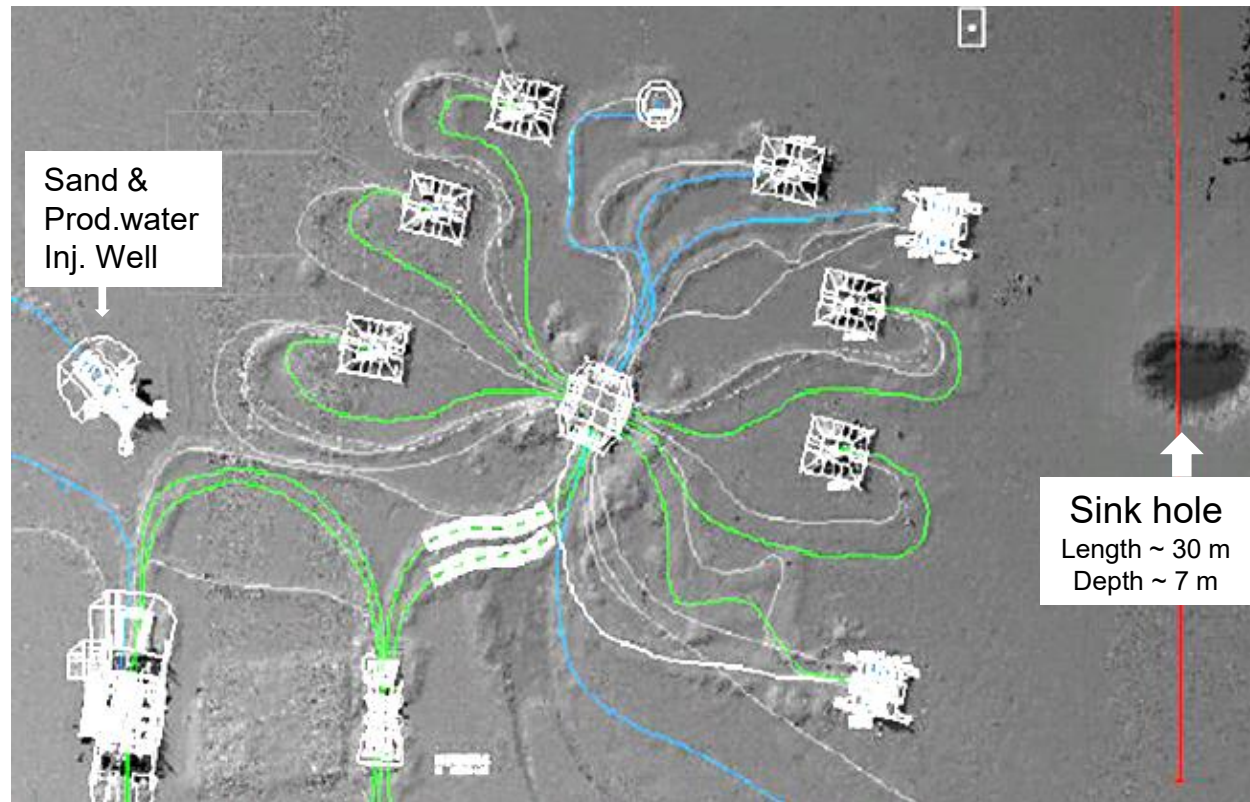
Operational experience: Separation, boosting and injection (~5 months, 2007-2008)

- Multiphase meters have not been performing as expected
 - Back-up calculation based on level changes in the separator proven feasible
- Multiphase and water injection pumps are running as expected
- The oil content in the injected water was less than 500 ppm (reduced rate)
- Sand jetting from the separator and sand injection worked well
- **System is more stable with better slug control and distribution of production**
- **Total liquid production ~doubled, oil uplift +1000 - 1500 Sm³/d (+25%)** – despite lower-than-expected injection in Utsira in the first months

Discharge of oil contaminated water and loss of injection well

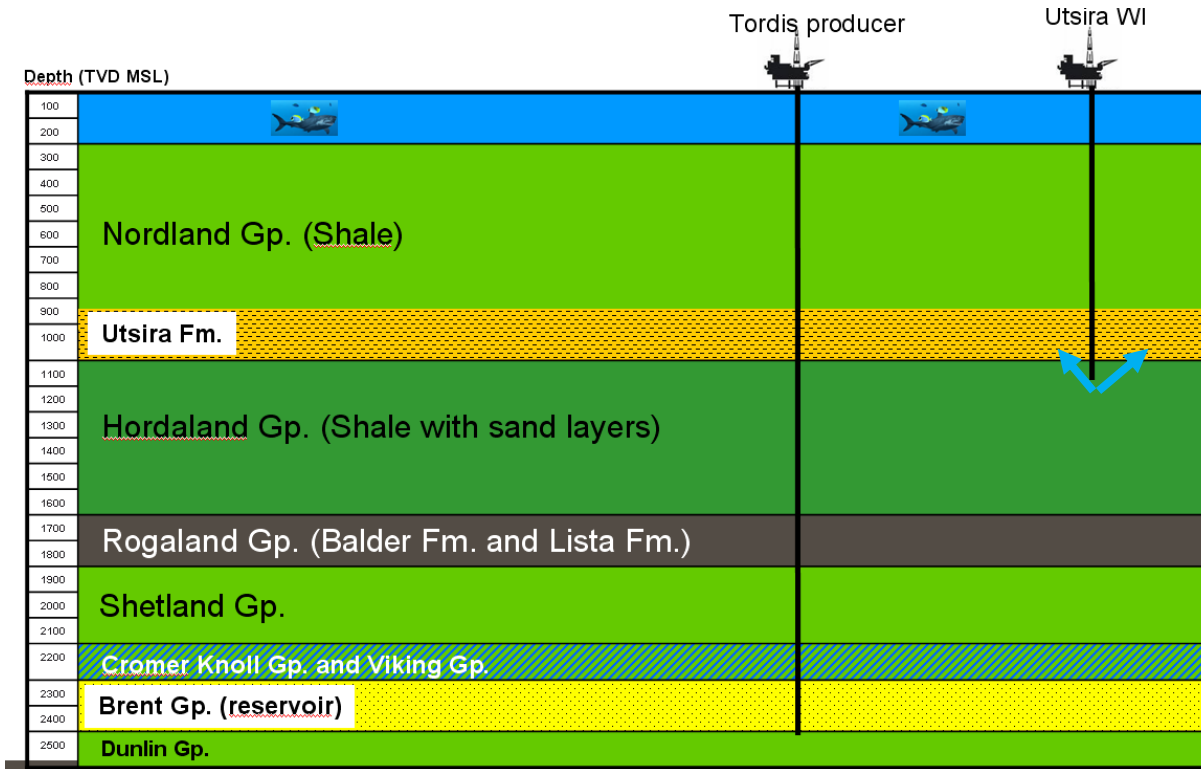
(Reported 30.5.2008. Synergi nr. 1016988. Investigation A-EPN L1 2008-5)

Incident description



Emergency response after observed oil on sea proved a sink hole at the sea floor. The uncontrolled migration of oily water to surface was caused by fracturing through Utsira rock cap and up to the sea bottom.

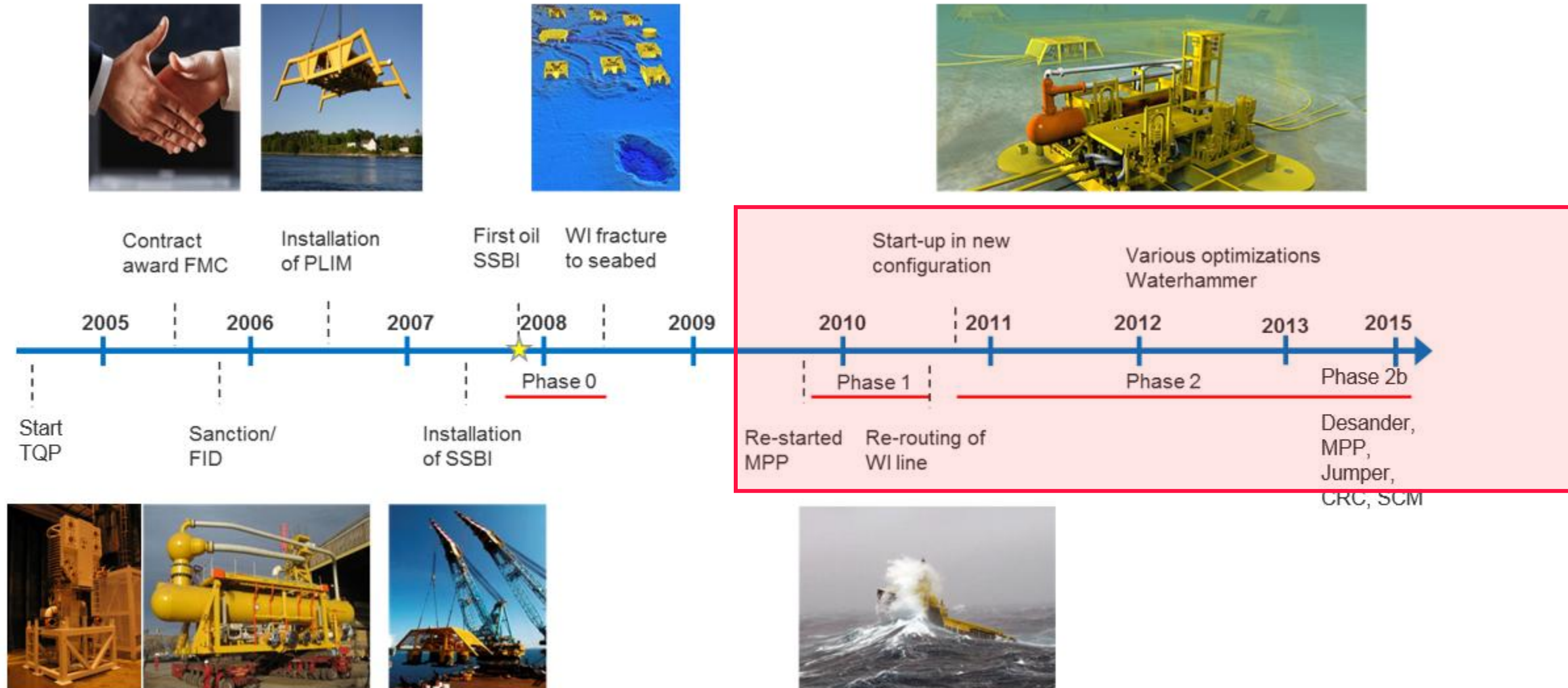
Utsira injector well design and concept



- **Injection concept:** Injection into Hordaland shale and fracture up into Utsira formation
- **Utsira understanding - Before drilling:**
 - Common understanding: Utsira had good distribution, a large volume and good injectivity (reference: CO₂ injector in Sleipner)
 - Discovered too late in the project phase that Utsira below the Tordis area might not be as good as believed
 - Alternative well locations restricted by length of jumper from SSBI to wellhead (140 m) → use planned location
- **After drilling:**
 - Bad quality on Utsira formation
 - Injection operated at pressures and rates larger than the formation capacity
 - **Suboptimal understanding of pressure response during injection**

→ Injection in Utsira stopped!

Timeline: Tordis SSBI (Subsea Separation, Boosting and Injection)



Operational experience: Multiphase boosting only (~1 year, 2009-2010)

- Reduced slugging in production lines
- Separator de-sanding system is performing well
- Production trips in topside facilities gave higher production loss than prior to subsea separation due to more complex start-up
- The availability has been good
- Increase in production (difficult to quantify due to several other facility improvements in same period)

Operational experience: Separation and boosting (from end 2010)

- Subsea separation and boosting
 - Multiphase flow in flowline 1 boosted by Multiphase Pump
 - Water and sand in flowline 2 boosted by Water Injection Pump (which is no longer a water injection pump, but kept its name)
- Optimized water handling topside
- Reduced slugging and more flexibility on the Tordis field
- Reduction in separator pressure (backpressure towards wells) → increase in production

Operational experience: Separation and boosting

- **This is still the current way of operating Tordis!**
 - Oil handling capacity is not an issue anymore
 - Today, water handling capacity on GFC is the main bottleneck when SSBI is bypassed:
 - A-separator can produce $\sim 13000 \text{ Sm}^3/\text{d}$ of water when producing only water, vs $4500 \text{ Sm}^3/\text{d}$ oil + $4500 \text{ Sm}^3/\text{d}$ water when producing a mix of liquids
 - B separator: $4500 \text{ Sm}^3/\text{d}$ oil + $4500 \text{ Sm}^3/\text{d}$ water
- SSBI bypassed: reduced water handling capacity $\sim 9000 \text{ Sm}^3/\text{d}$, prioritize the low watercut wells
 - In 2025 - 2026, low availability of both WIP and MPP (pump or electrical issues): loss estimate $\sim 600 \text{ Sm}^3/\text{d}$ (ca. 30%)

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Vigdis Boosting: objectives

- Effect of boosting pump:
 - Increased and accelerated production from wells with decreasing wellhead pressures (limited pressure support or increased watercut)
 - Overcome pressure losses in the transport systems
- Expected IOR volumes (base case at DG3 - 2018): ~1.7 mill Sm³
 - Upside volumes with more infill drilling and extended lifetime ~1 mill Sm³

Facility Description - Pump Station

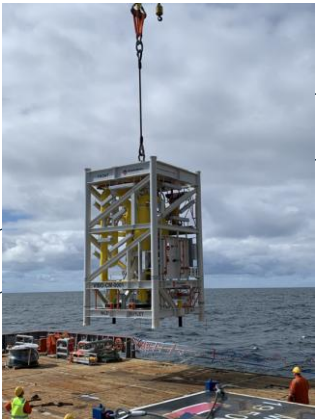
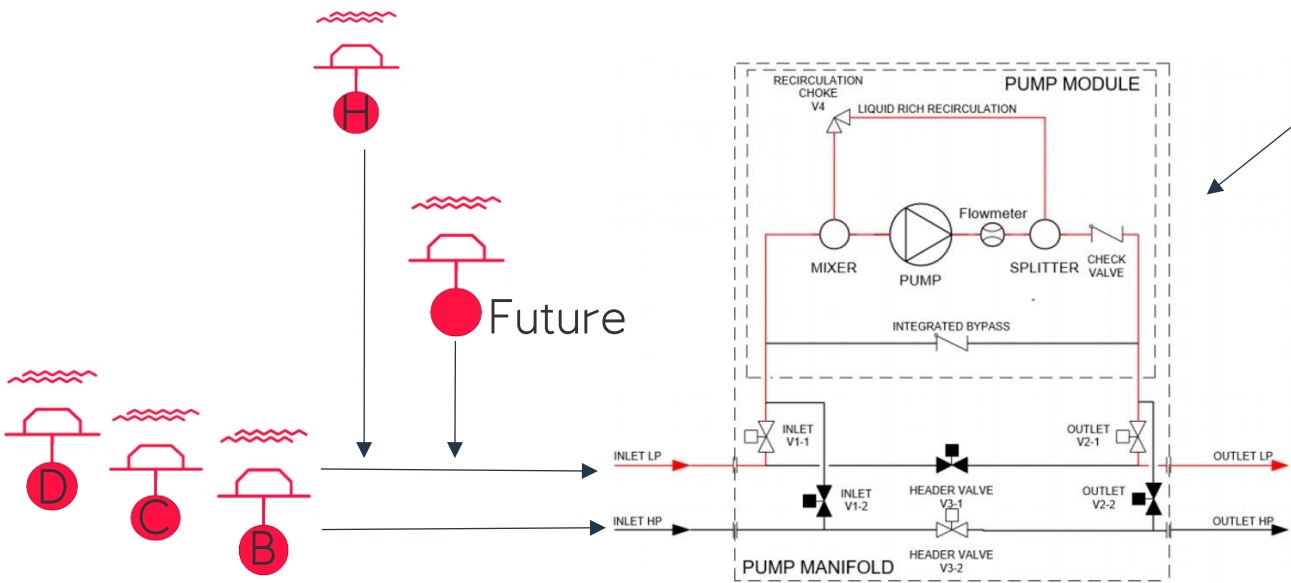


Parameter	Value/Selection Vigdis
Type	Multiphase Hx330 Helico Axial
Number of Pumps	1
Number of Stages	8

Impeller Diameter	330
Pump Maximum Differential Pressure	50 bar
Motor Rating	3,2 MW shaft power @ 70 Hz
Operating Speed Range	1500 – 4600
Axial Thrust	Thrust Bearing + Balance Piston
Design Pressure	230 barg
Design Temperature Pump	121 deg. C

Snorre B,
operates topside
equipment

Snorre A,
operates subsea
equipment

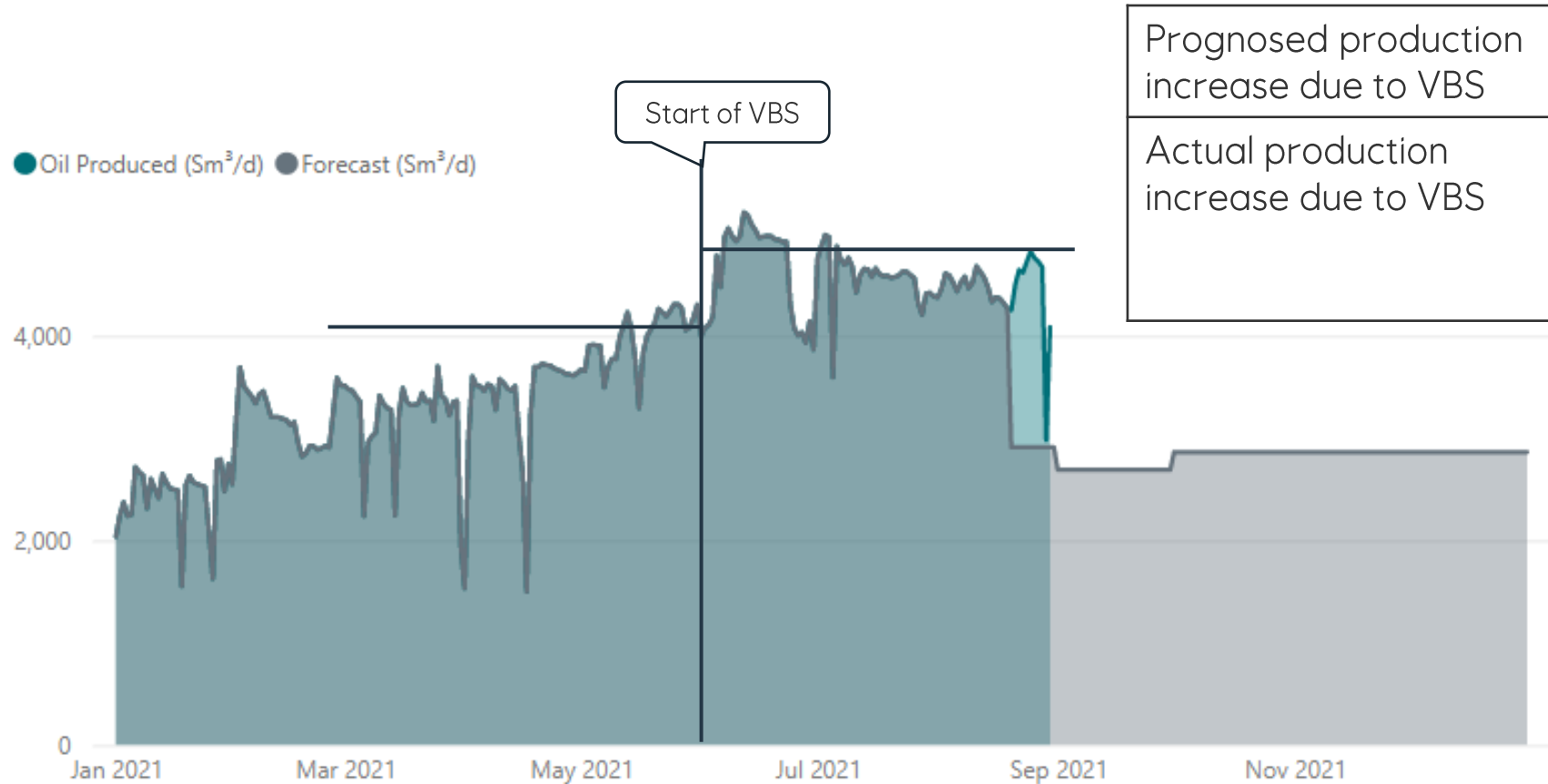


Line B (1) LP

Line A (2) HP

Pump capacity:
400-1400 Am3/h

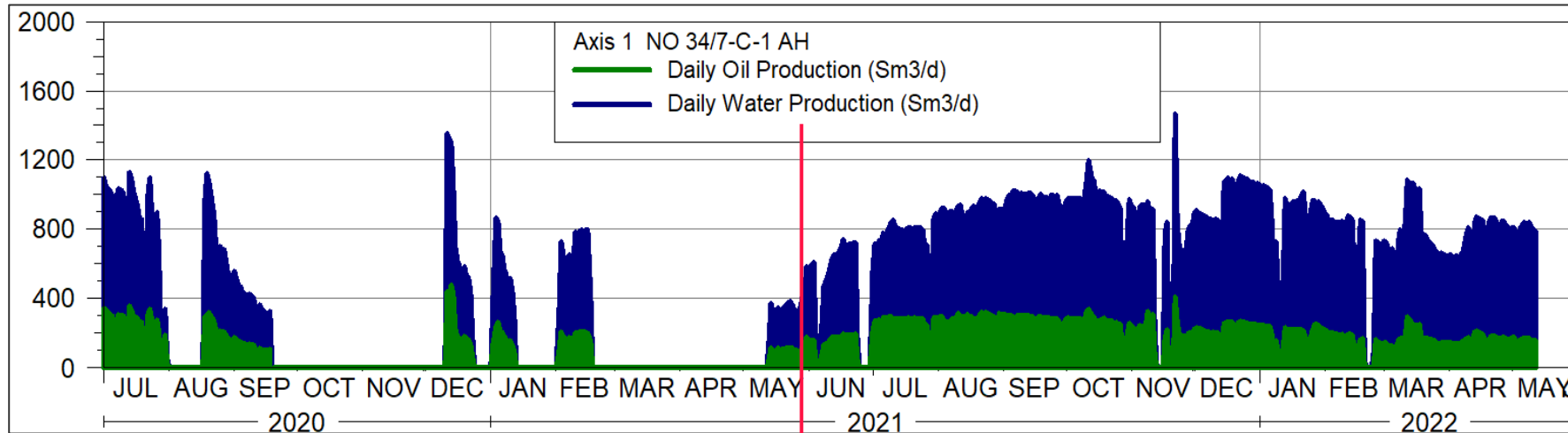
VBS Production experience – first months



Prognosed production increase due to VBS	First year: 400 -500 Sm ³ /d
Actual production increase due to VBS	Not easy to quantify, due to many changes at same time, but at least as prognosed

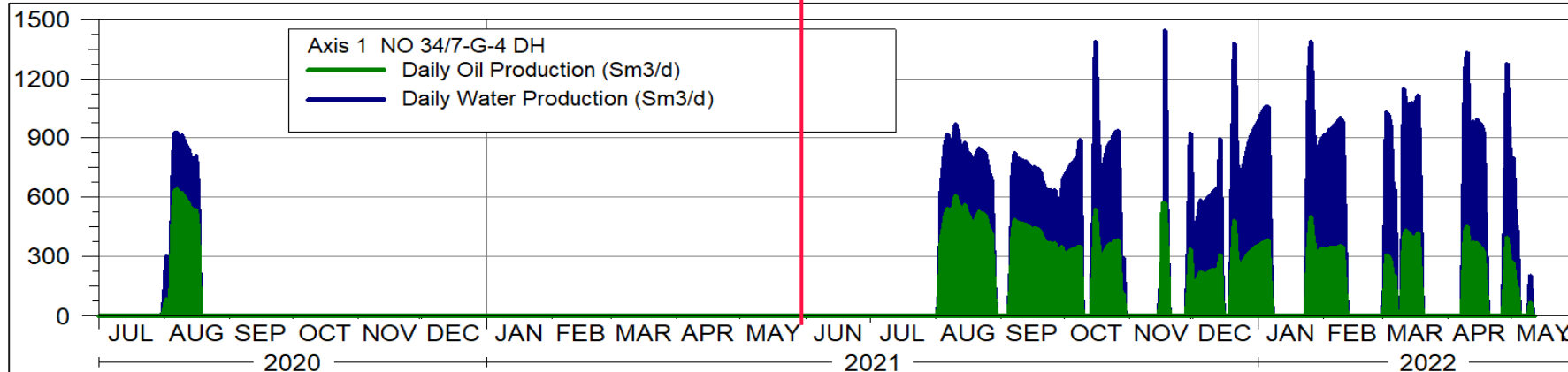
Field	YTD Oil (Sm ³)	YTD Oil vs. Forecast (%)	Annual Forecast (Sm ³)	Annual (YTD + Forecast) (Sm ³)
VIG	904,243	1.6 %	1,234,369	1,248,242
Total	904,243	1.6 %	1,234,369	1,248,242

Examples of VBS effect on well performance



Start of VBS

- After the start of VBS C-1 AH became a continuous producer with higher liquid rate



- G-4 increasing up-time, but still a swing producer due to limited pressure support

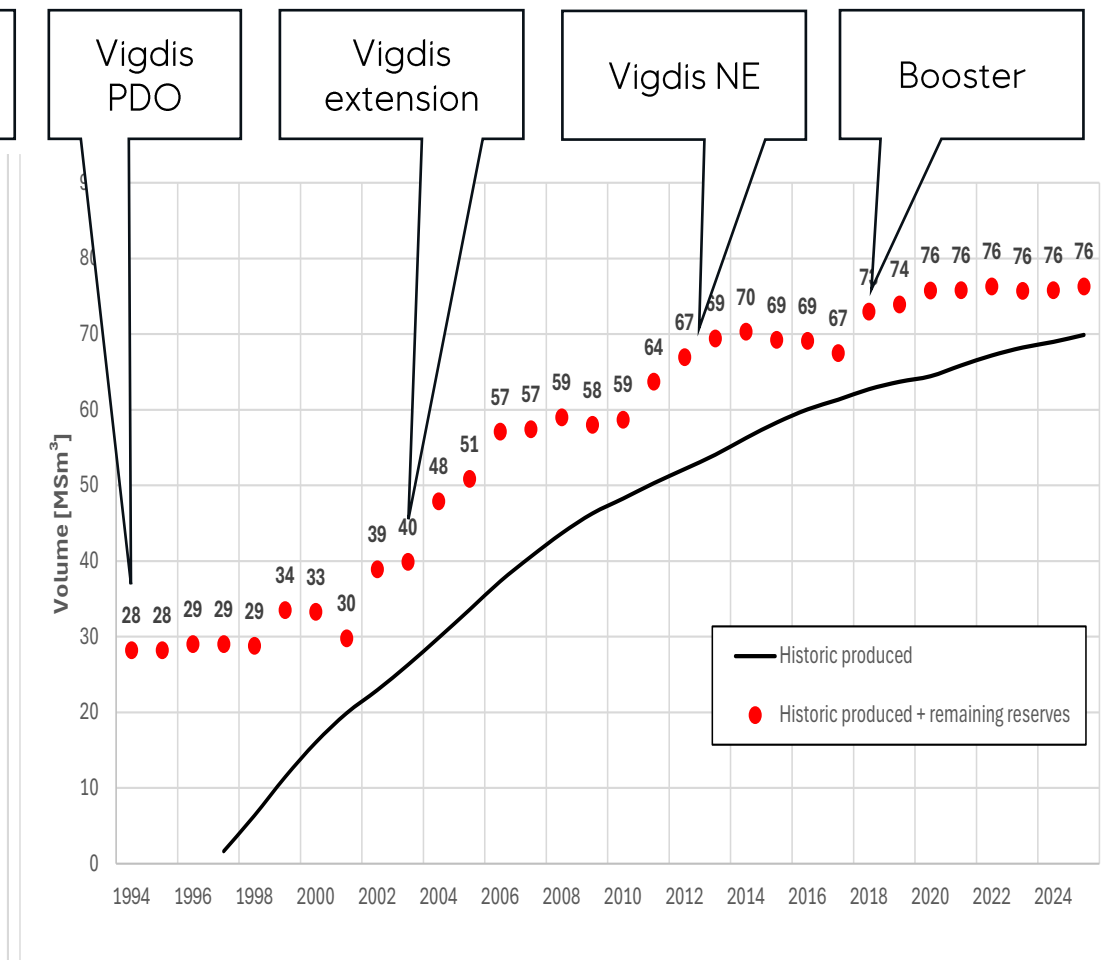
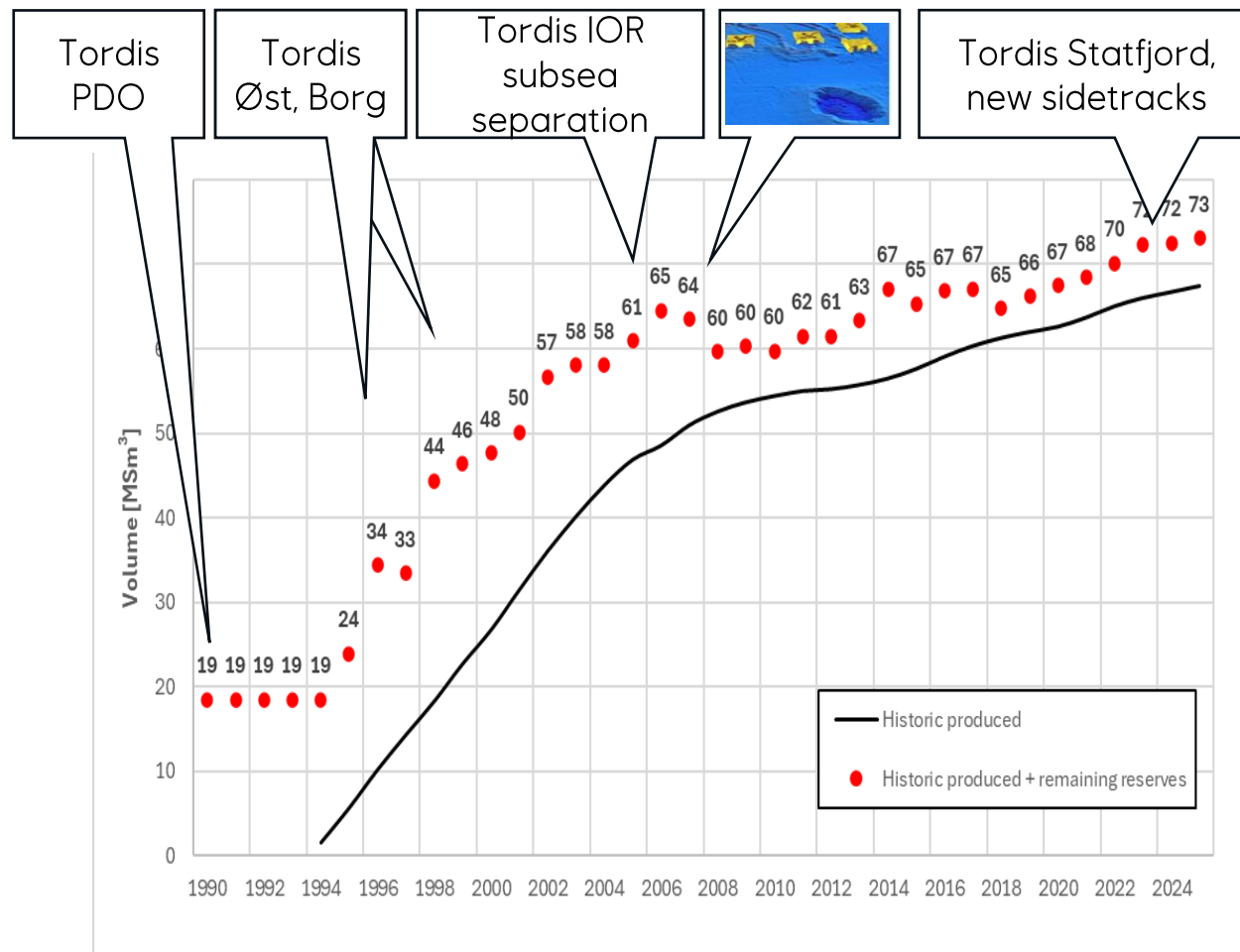
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Conclusions – would we do it again?

- Tordis SSBI and Vigdis VBS still delivering ca. 1300 Sm³/d of oil (out of ca. 5000 Sm³/d)
- Total benefit from SSBI and VBS difficult to estimate accurately – many IOR measures implemented between 2005 and now – mainly infill drilling – however:
 - SSBI: start 1500 Sm³/d uplift in 2008, now over 600 Sm³/d. Most likely exceeded the expected 5 mill Sm³ total despite the failure of the Utsira injector – but over a longer time.
 - VBS: delivering according to expectations, AND will realize the upside with new infill wells – VBS essential to produce parts of Vigdis that are affected by the Statfjord blowdown
- Challenges:
 - Multiphase metering, ejector damage on de-sanding unit in 2014, MPP breakdown in 2015, WIP breakdown in 2025, high consumption of barrier fluid in the Vigdis pump indicates breakdown soon
 - But still quite reliable considering the age and technology!
- If we could go back to the 90s and start from scratch, knowing what we know now... we would probably build a Snorre C platform!

Tordis & Vigdis reserves evolution (oil only)



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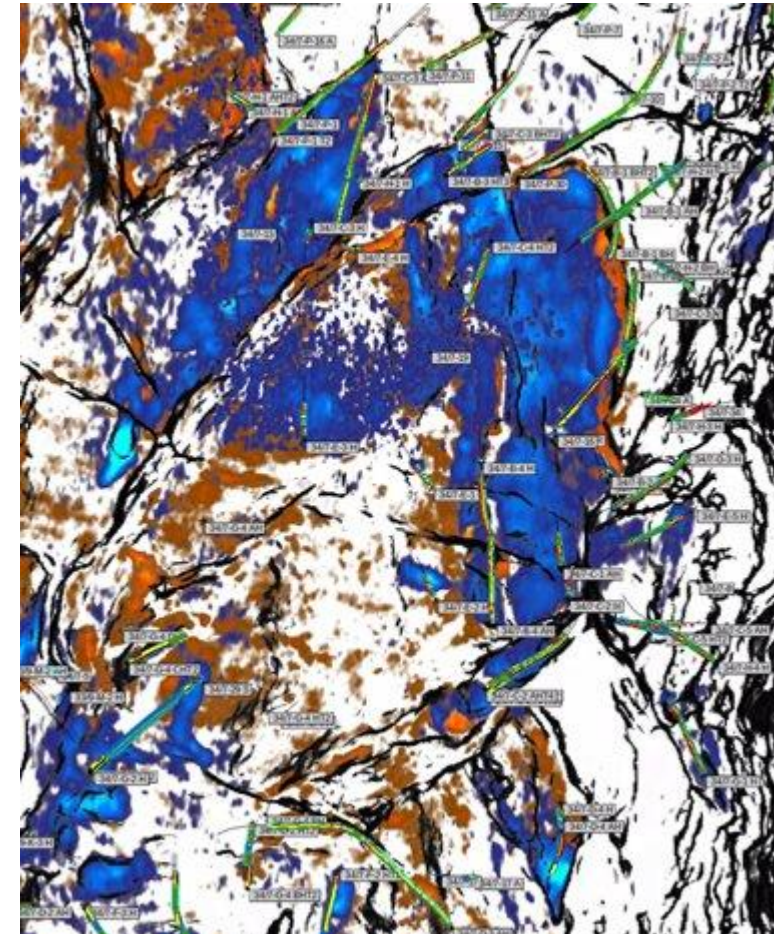
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Now and way forward

- Vigdis and Tordis have more than tripled their initial reserves estimates, from ~300 mmboe to more than a billion boe
- The PDOs for Tordis and Vigdis anticipated a cessation of production in 2006 and 2008 respectively, we are now considering 2040
- What's next?
 - ▼ Ageing infrastructures and wellhead fatigue issues, concerns on future production efficiency.
 - ▼ 4D data show a very effective waterflood (▲ excellent job by the T/V team! ▲). Remaining oil in the edges → challenging well placement.
 - ▲ Remaining reserves around 90 mmboe, identified upside around 60 mmboe - remaining potential larger than initial recoverable resources of dozens of fields on the Norwegian Continental Shelf.
 - ▲ IOR funnel including new infill drilling, a ditch well, coil tubing drilling, development of low permeability sands in Lista...



4D analysis, Vigdis Brent

And probably more to come, thanks to a dedicated team and a very supportive partnership!

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- Vår Energi ASA
- INPEX Idemitsu Norge AS
- Harbour Energy Norge AS

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