Developing the Purbeckian-sourced waxy crudes of the North Celtic Basin, offshore Ireland – A case study from the Barryroe Field

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Agenda

- Brief retrospective overview of the Purbeck-sourced oils of the North Celtic Sea Basin

  John O'Sullivan (Providence Resources)

&

- Developing these oils – A case study of the key technologies and practices to be utilised in the Barryroe First Phase Production System

  Kiran Kamble (CONSUB)

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Purbeck-Sourced Oils

John O'Sullivan

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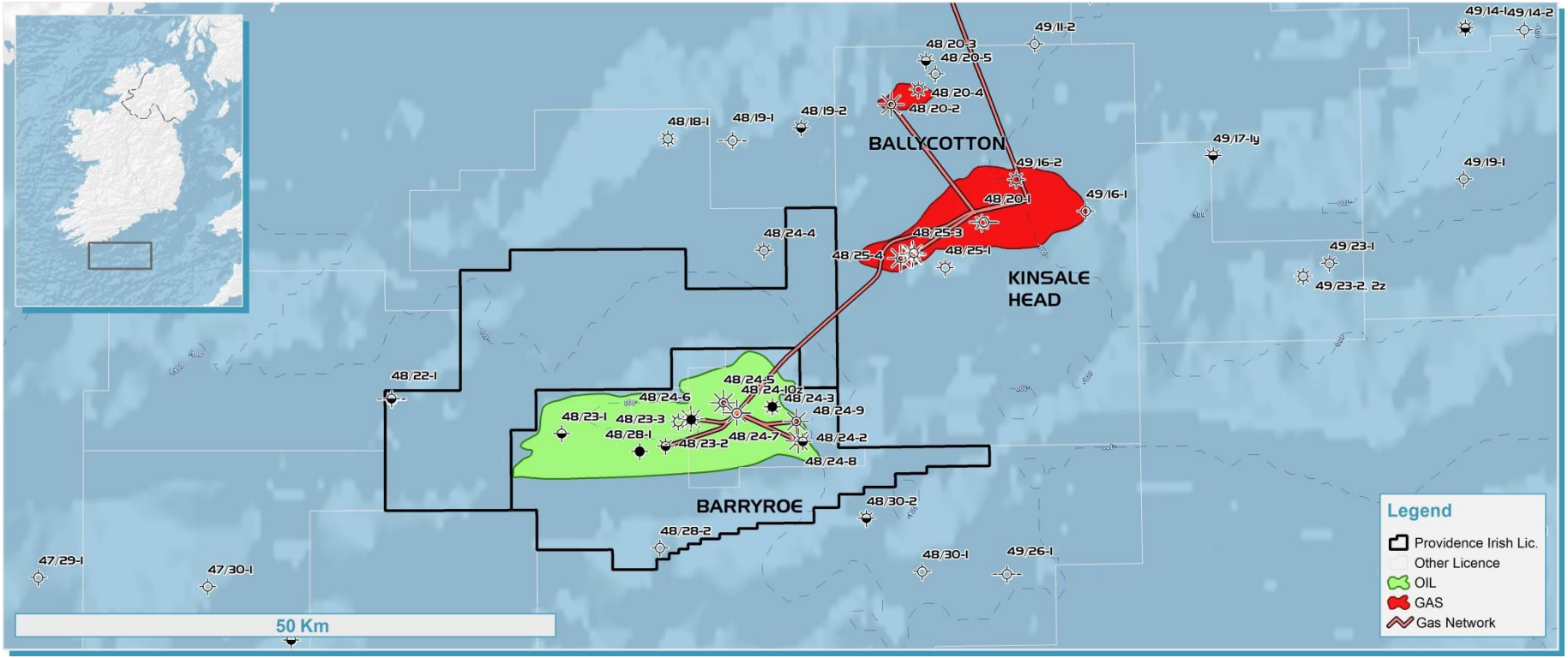
Barryroe Field Location



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Barryroe Waxy Crude

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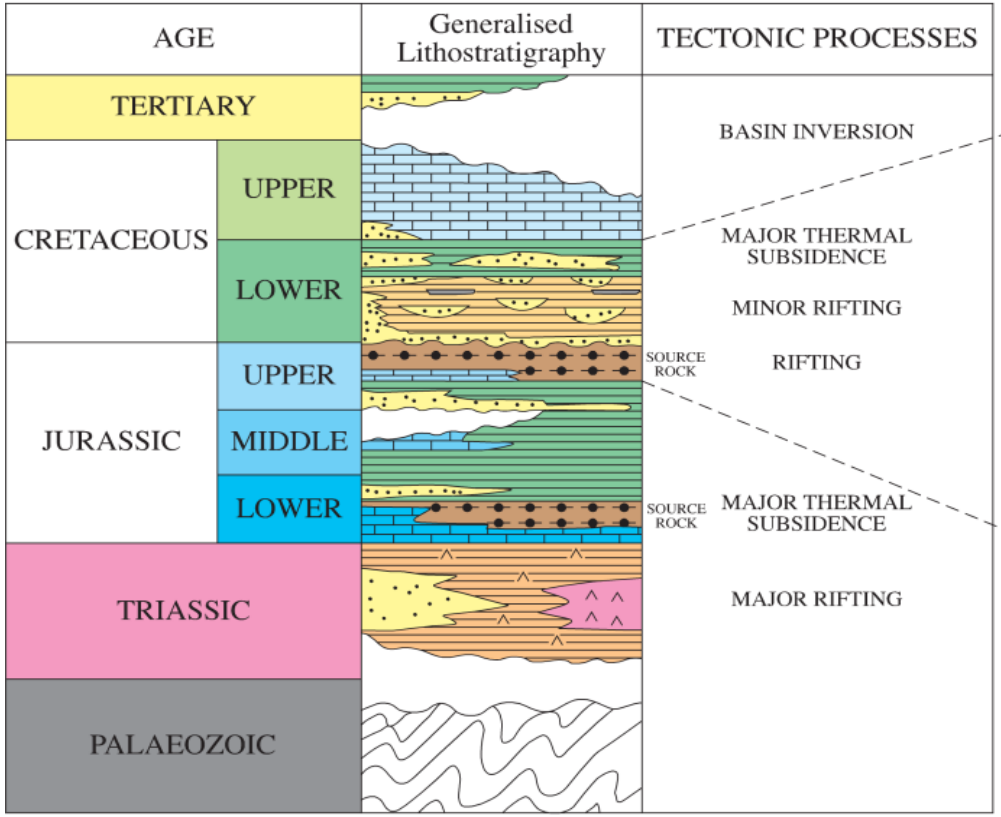
Stratigraphy



After Shannon (1991), Rowell (1995) and O'Sullivan (2001)

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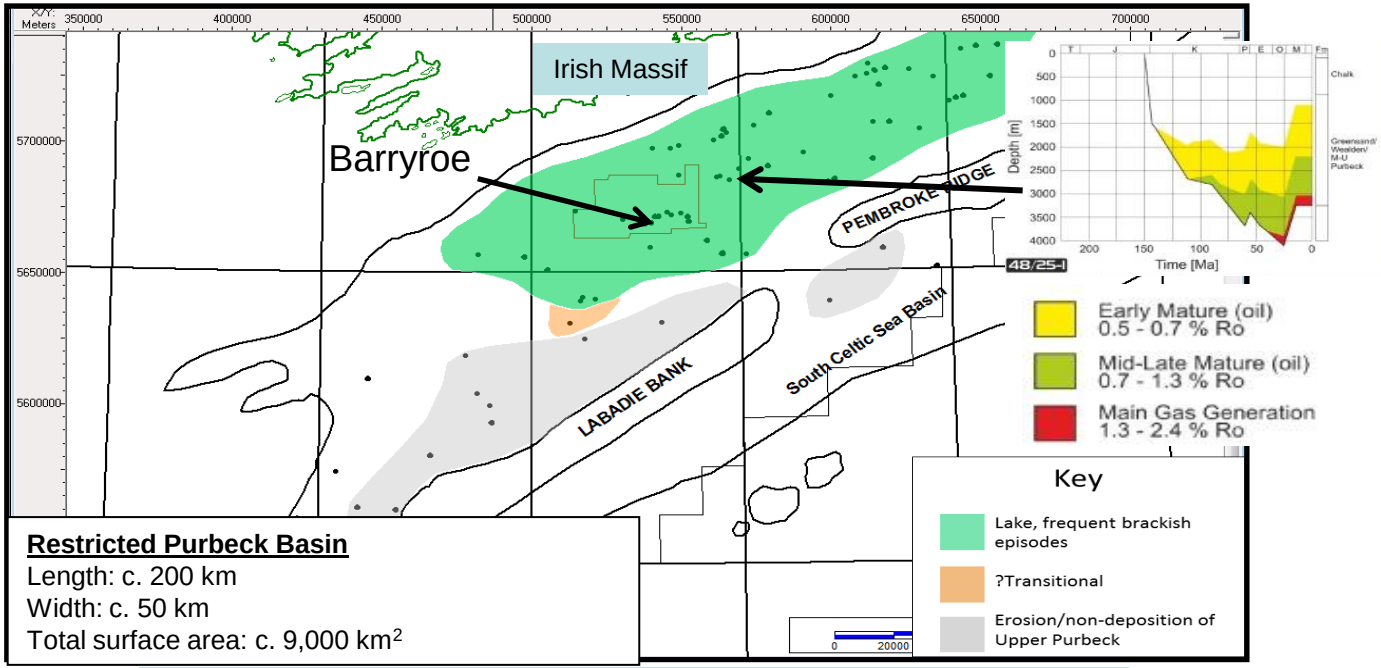
Purbeck Source Paleogeography



Restricted Purbeck Basin
Length: c. 200 km
Width: c. 50 km
Total surface area: c. 9,000 km^2

Age - Tithonian to Berriasian

Lithology - Shale (sl. carbonaceous, occ. Pyritic, non-calcareous) with siltstone, sometimes with sand-prone intervals

Deposition - Freshwater, lacustrine, lagoonal, restricted basin

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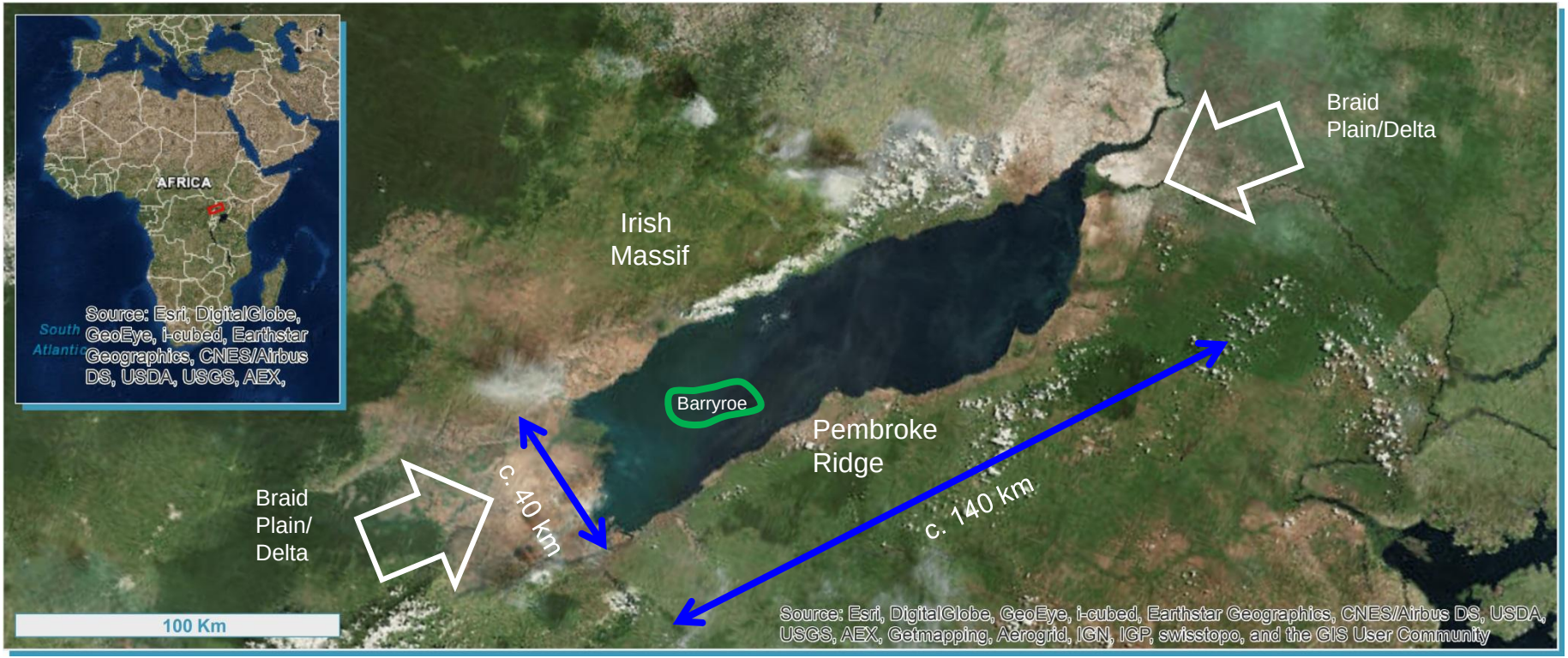
Modern Purbeck Analogue – Lake Albert, East Africa



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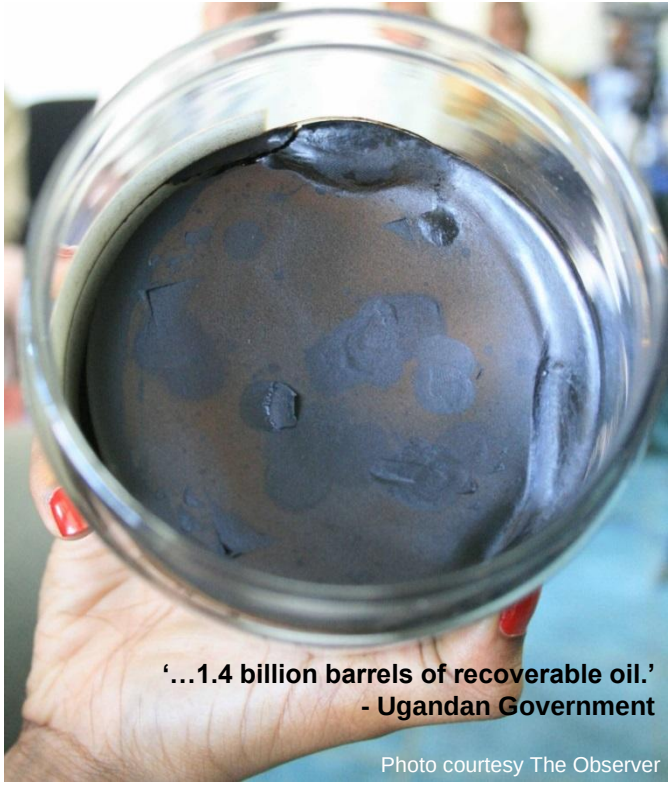
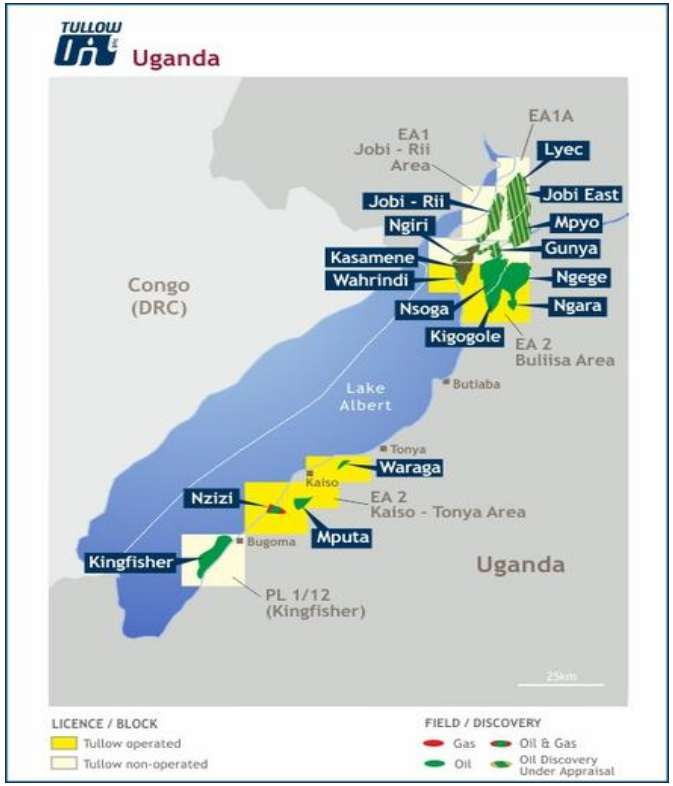
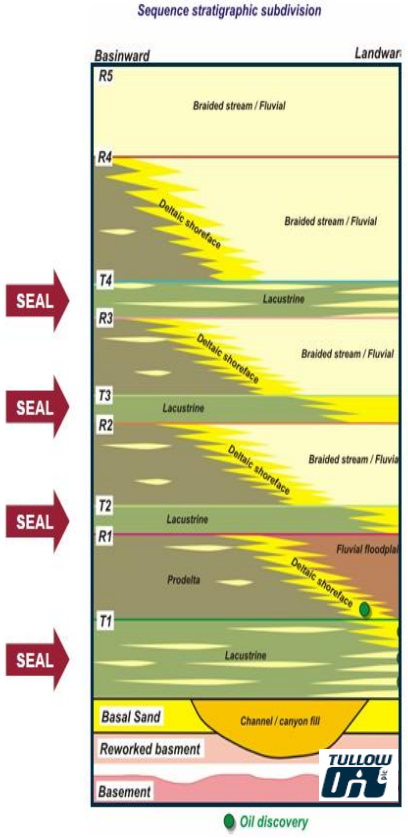
Ugandan Waxy Crude







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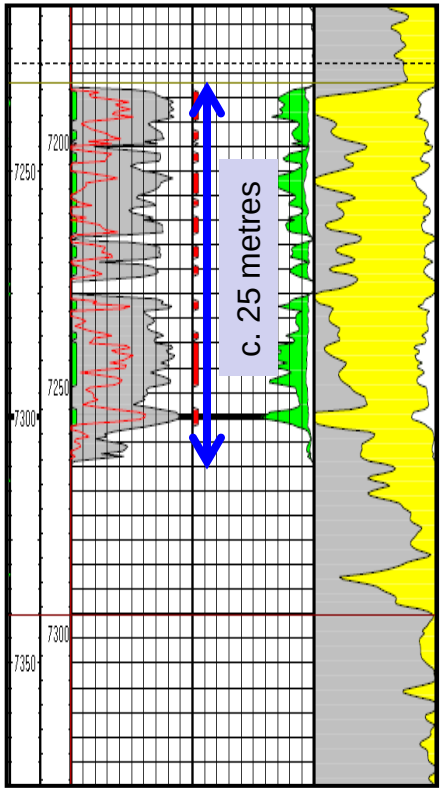
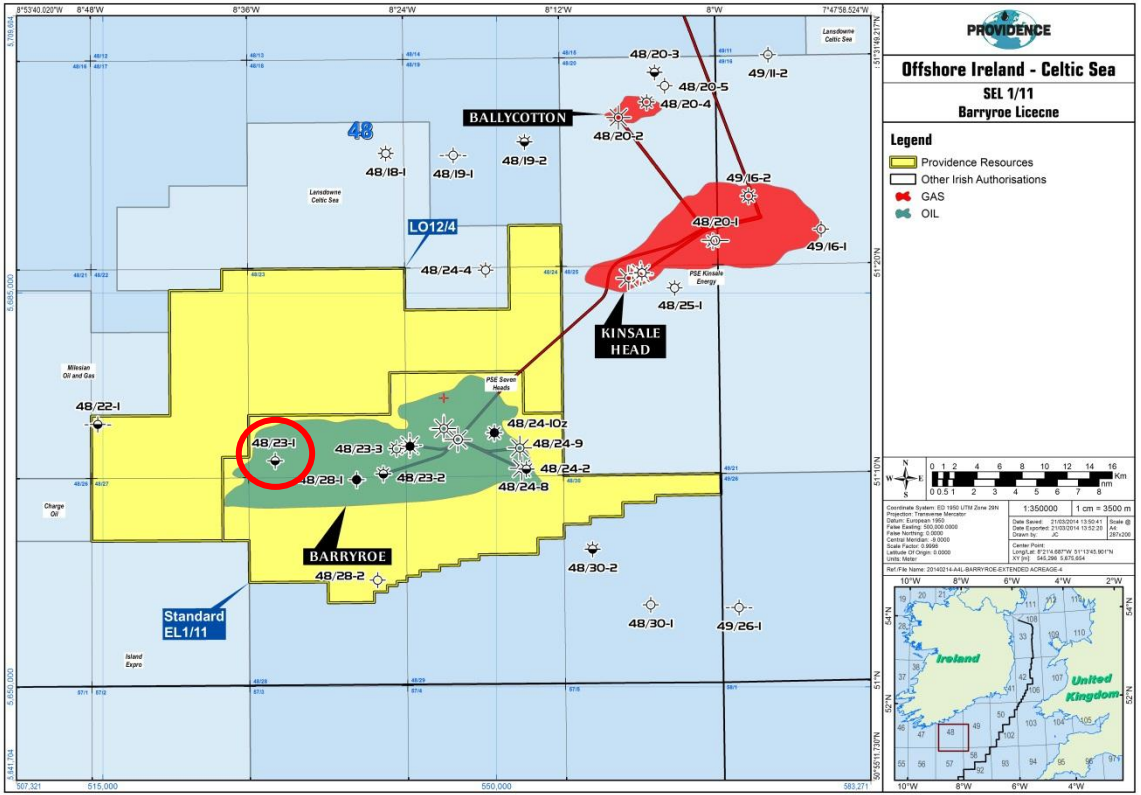
Inter-bedded Lacustrine Reservoir Potential

Well 48/23-1 (Berriasian)





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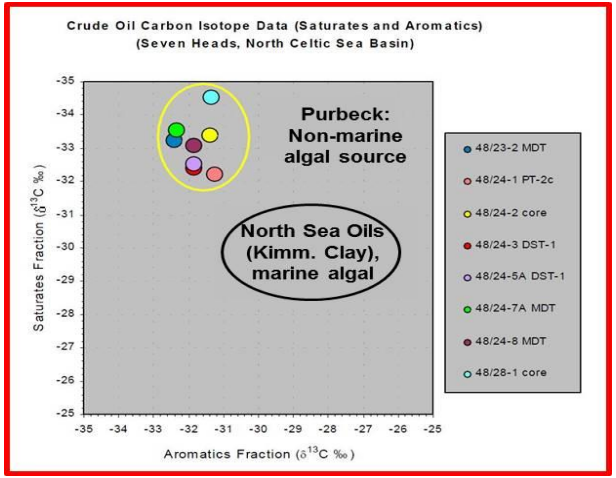
Barryroe Oil 'Family'

- **Light (43° API) sweet Celtic crude oil with high wax content**
  - In-situ viscosity of 0.8 cP
- **Barryroe has similar distillation yields to North Sea grades**
  - Closest comparison to a North Sea crude is Beatrice oil
- **Barryroe is a good cracker feed**
  - Make good diesel product (high cetane number)
- **Maximize value as a blended product (due to high wax content)**
  - Based on market reports for other high paraffin crudes, expecting a **<u>premium to Brent pricing</u>**



Analysis	Test Method	Units	Result
Water	IP 356		
Density at 15.6°C	IP 365		
API Gravity	IP 365		
Molecular weight	Cryoscope		
Salt	UOP 22		
Sediment	ASTM D4807		
Asphaltenes (C5)	CoreLab		
Asphaltenes (C7)	IP 143		
Vanadium	ICP		
Nickel	ICP		
Iron	ICP		
Calcium	ICP		
Mercury	ASTM D6722		
Pour Point (max)	IP 441		
Pour Point (min)	IP 441		
WAT	IP 389		
Wax	BP modified		
Acid number	IP 177		
Sulphur	IP 336	% m/m	
Mercaptans	UOP 163	ppm wt S	
H_2S	UOP 163	ppm wt	

Low sulphur,
Low TAN,
Low asphaltenes
Low mercaptans,
Low metals,
Low salt.

i.e. a sweet light crude oil with no nasty's…

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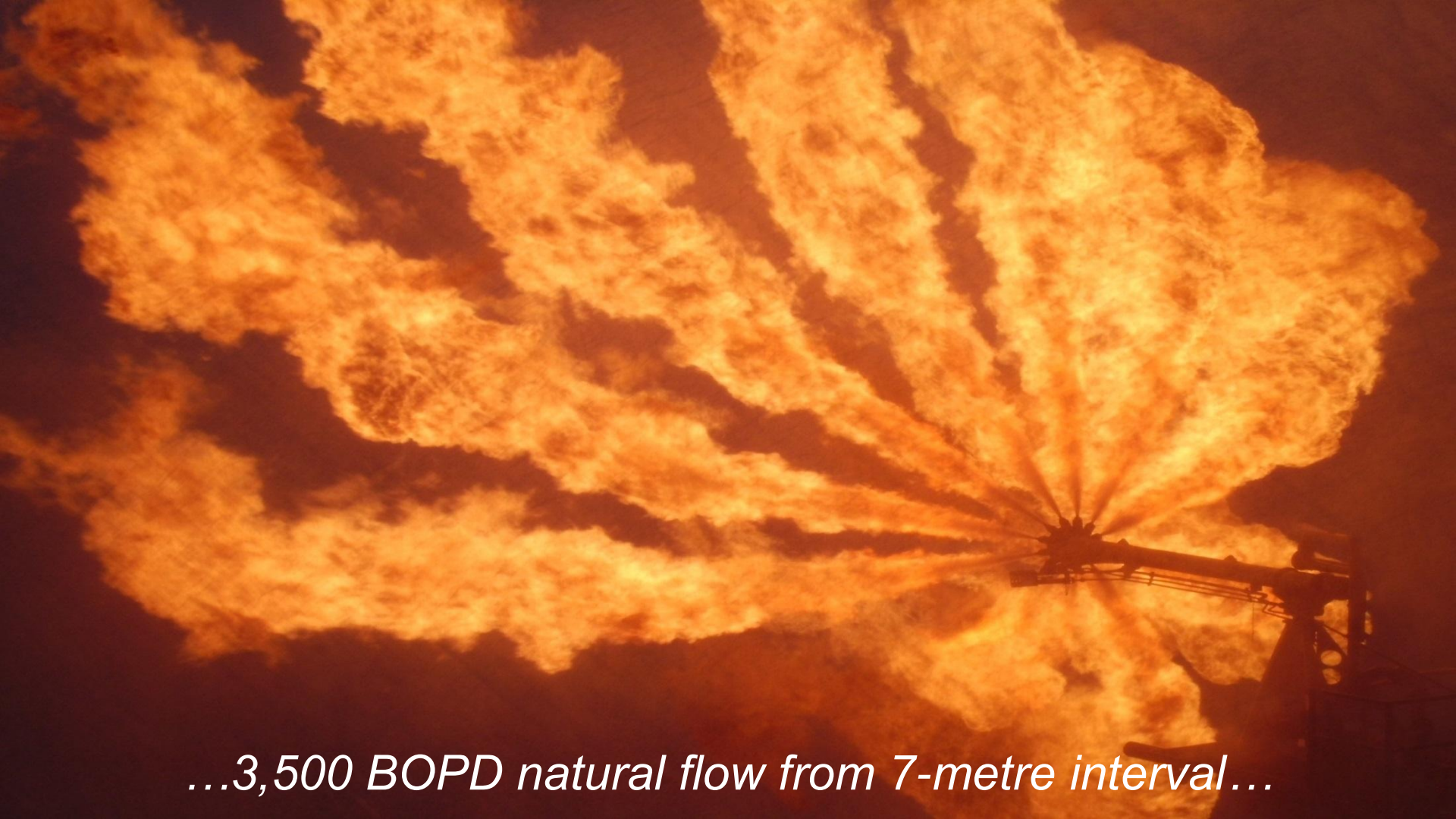

…3,500 BOPD natural flow from 7-metre interval…

Conclusions

- The Late Jurassic/Early Cretaceous Purbeckian lacustrine shales of the North Celtic Sea Basin comprise a regionally significant sequence of mature oil-prone source rocks

- These source rocks have traditionally been overlooked due to the high pour point & waxy nature of the generated crudes

- Recent appraisal drilling on the Barryroe field has demonstrated that these crudes can flow at economically attractive rates which should trade at a premium to the Brent benchmark

- **There is therefore no technical rationale for these waxy premium Celtic crudes to be so unloved….and now for development!**

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Barryroe Field
First Phase Production System (FPPS) Plan

Kiran Kamble

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First Phase Production System (FPPS)

- Basis for FPPS Study
- Technical Challenges
- Conceptual FPPS Layout
- Integrated Production System Modelling (IPSM) Modelling
- Wax Mitigation/Remediation Measures
- Conclusions

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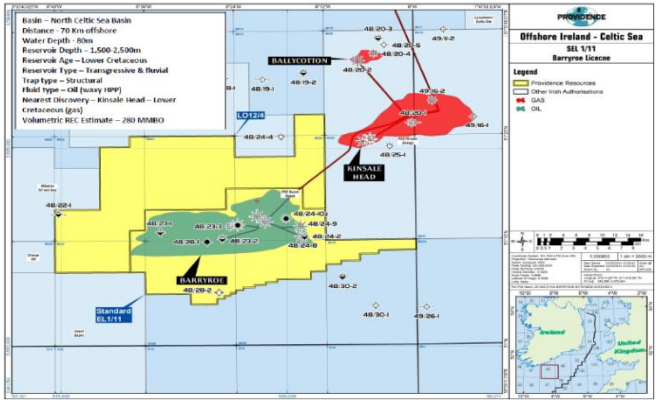
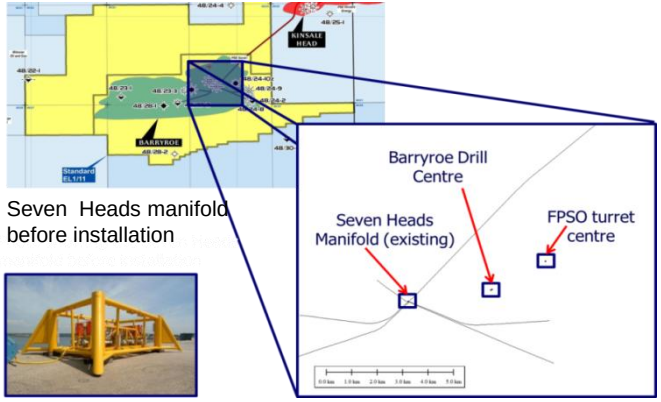
Basis for FPPS Plan

- **FPPS Design life - 5 years**
- **Single Drill Centre**
  - 4 producing wells
  - 2 water injection wells
- **Semi-Submersible Drilling Rig**
- **Floating Production System**
- **Maximum Processing Capacity**
  - Oil : 25,000 BOPD
  - Total Liquids : 30,200 BFPD
  - Produced Water : 8,300 BWPD
  - Water Injection : 50,000 BWPD
  - Produced Gas : 22 MMSCFD
  - Lift Gas : 12 MMSCFD





Seven Heads manifold before installation

Technical Challenges

Crude Characteristics

- The waxy nature of the crude
    - High wax appearance temperature - WAT (46°C)
    - Reservoir temperature (66°C)
    - Pour Point (21°C)
    - Worst Case seabed temperature (5°C)
    - Average seabed temperature (9°C)

Challenges

- Wax deposition risk – design to always operate above WAT
- Wax gelation risk – design to allow cold restart in event of unplanned / emergency shutdown

Heat management of the produced fluids is "Critical"

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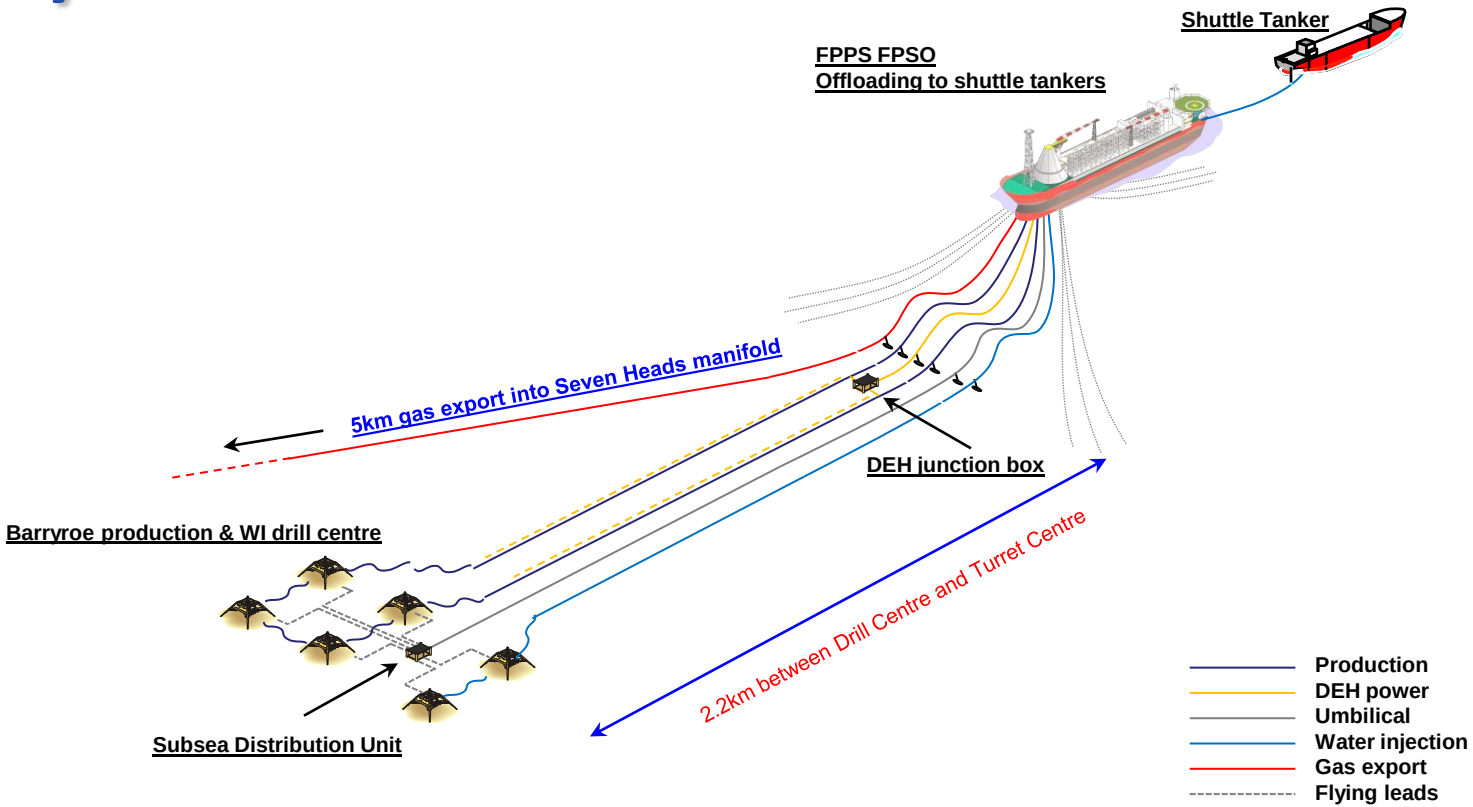
FPPS Layout



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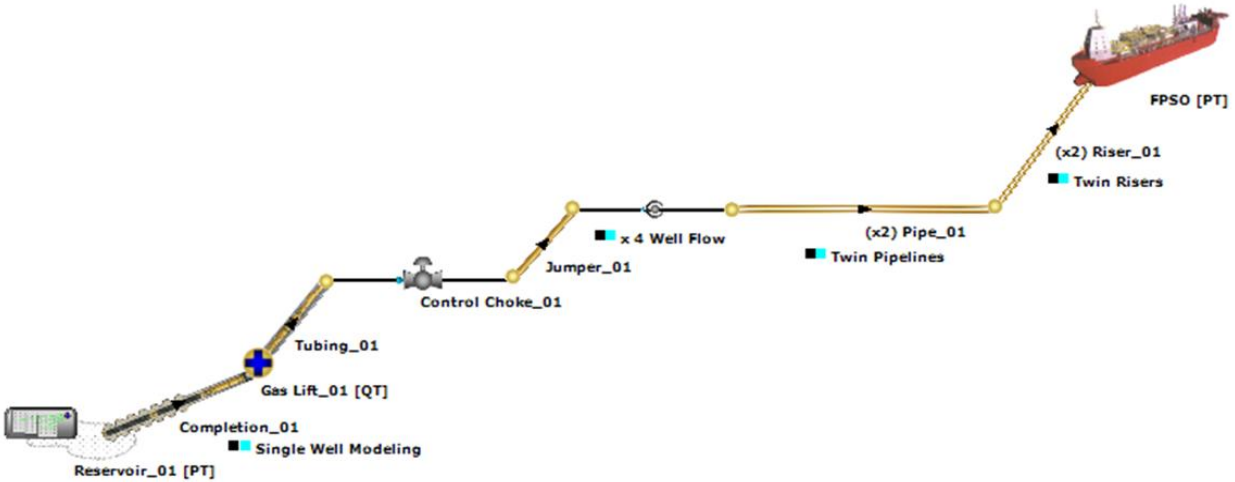
IPSM Modelling

- Thermal hydraulic modelling using IPSM software (Integrated Production System Modelling) for continuous life of field operations
- Multiple variants of well, flowline and riser systems
- Choose proven subsea hardware to maintain **arrival temperature at FPSO > WAT**



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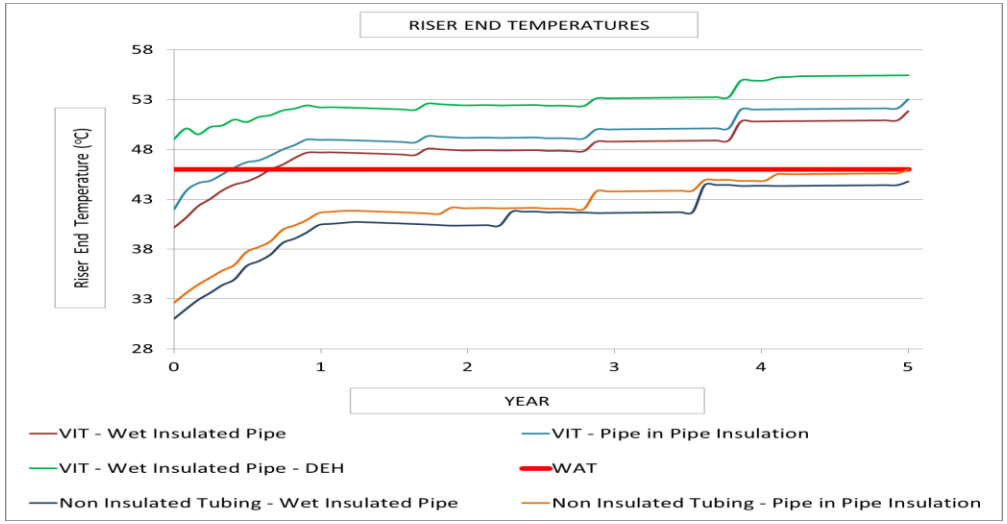
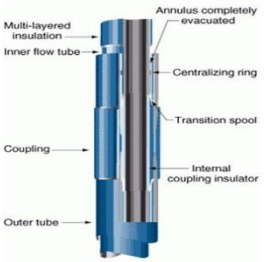
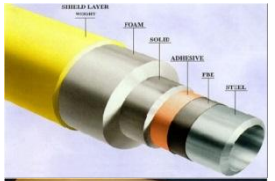
IPSM Modelling - Results

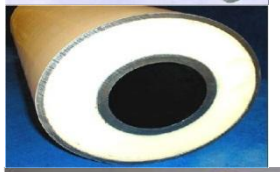




VIT



PUF



PIP

PUF + DEH

Wells

- Conventional tubing < WAT
- **Vacuum Insulated Tubing (VIT)** > WAT

Pipelines

- Insulation (e.g. Polyurethane Foam ,PUF) < WAT
- Pipe in Pipe Insulation < WAT
- **Insulation with Direct Electrical Heating (DEH)** > WAT

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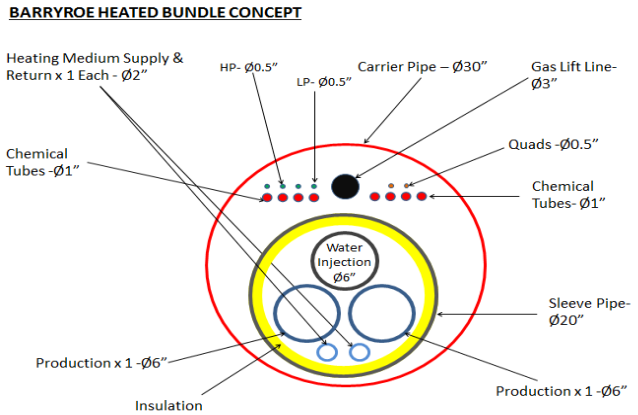
IPSM Modelling – Other Variants

FPSO Offset

- Shorter offset permits high operating pressure/temperature. Allows for possible future optimisation of system.

Heated Pipeline Bundle

- Heated bundle concept is expected to be a feasible alternative to DEH



Wax Mitigation – Continuous Operations

Subsurface

- Inject hot treated sea water into the reservoir

Subsea

- *Producing Wells*
  - VIT to keep tubing temperature > WAT
- *Pipeline*
  - Insulated with DEH > WAT
  - *Alternative* - Heated bundle solution
- *Riser*
  - Unheated dynamic riser (DEH pipeline heating sufficient > WAT)
- *Wax Scraping*
  - Subsea trees on flow base with twin production flowlines allows round trip pigging from FPSO

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Wax Mitigation – Planned Shutdown

Wax Mitigation Measures (Planned Shutdown)

- Hot fluid displacement of riser and flowline contents back to FPSO
- Initiated from a displacement skid on the FPSO

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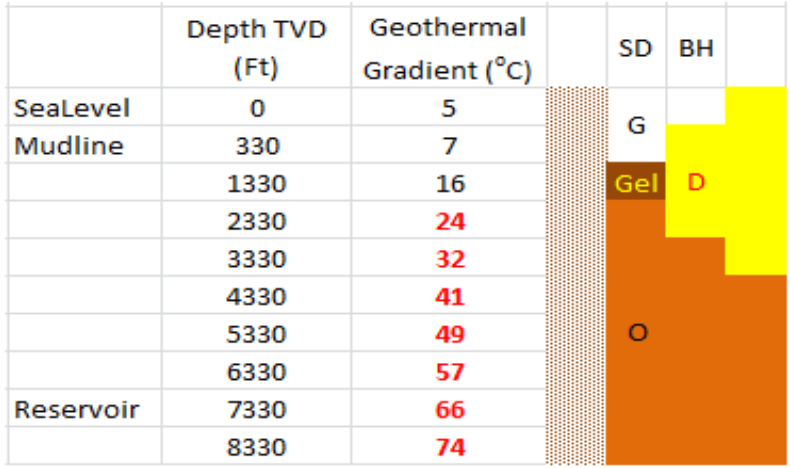
Wax Remediation – Cold Start

Strategy

- Remove all blockages of gels and hydrates present
- Restore conditions to prevent blockage reformation during re-start

	Depth TVD (Ft)	Geothermal Gradient (°C)
SeaLevel	0	5
Mudline	330	7
	1330	16
	2330	24
	3330	32
	4330	41
	5330	49
	6330	57
Reservoir	7330	66
	8330	74



Producer Wells

Strategy - Diesel bullheading

- Push well fluid down tubing
- To depth where T > PP (21°C)
- Slow restart

Alternatives being considered

- Use natural reservoir pressure
- Continuous downhole (PPD)
- Well intervention

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Wax Remediation – Cold Start

Wax Remediation Measures (Cold Start)

Pipeline

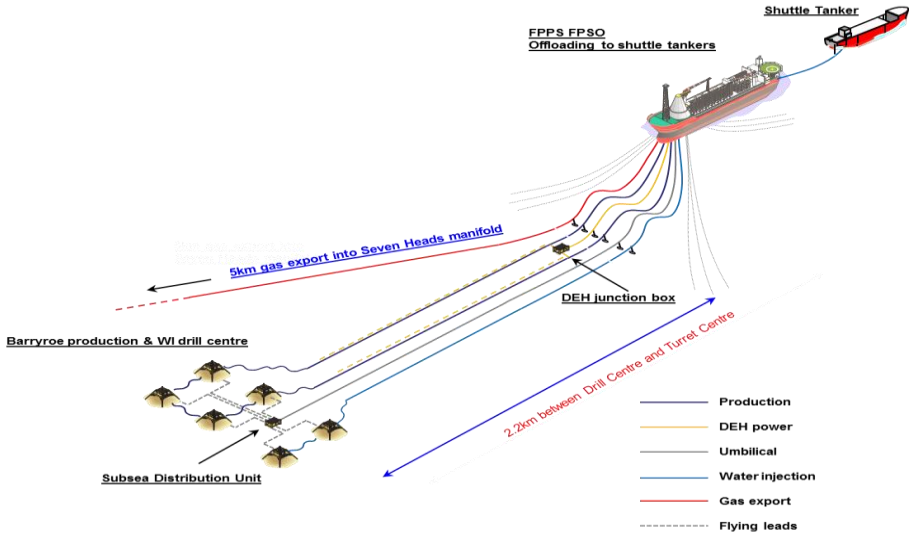
- Insulated with DEH

Risers

- Unheated Riser - Diesel bull-heading
- Coiled tubing interventions
- *Alternative* - Heated dynamic riser - Integrated production bundle (IPB)

Conclusions

- **A feasible First Phase Production System (FPPS) plan for the Barryroe Field has been developed**
  - The use of downhole VIT and Direct Electrical Heating technology can assure flow over the life of the field.
  - Cold start after an unplanned shutdown is a critical operational scenario, however this is considered manageable.

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