Reservoir Surveillance: Wireless Solutions for Mozambique Deepwater

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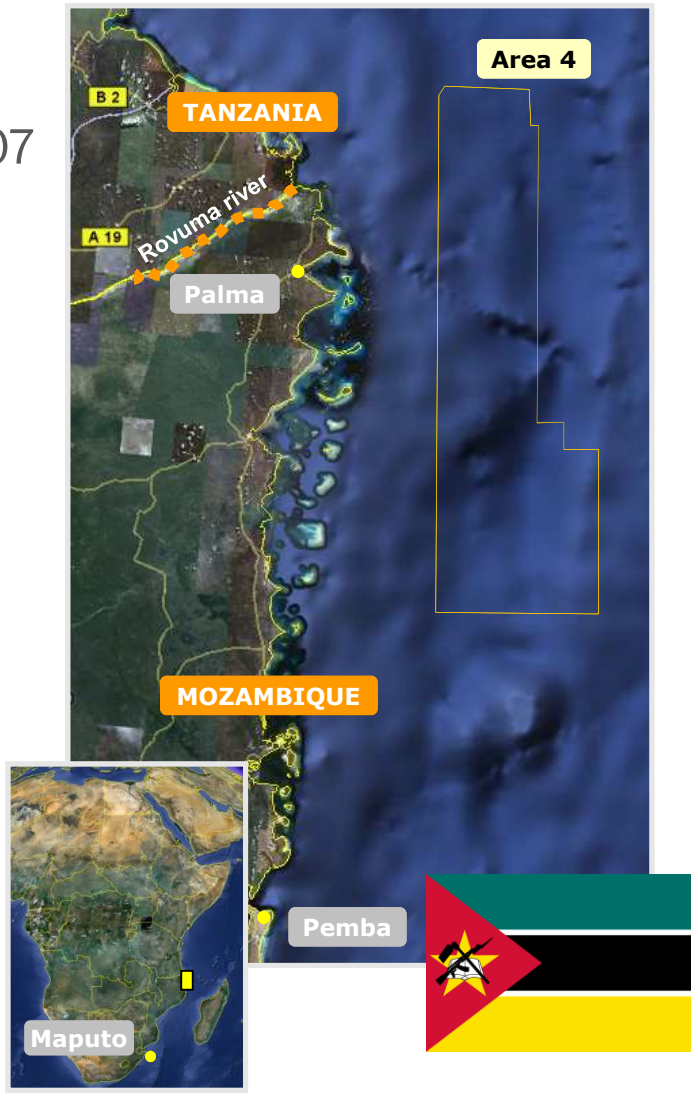
DEEPWATER DEVELOPMENT

Area 4 Project – General Overview

- Area 4, a 10,207 sqkm exploratory block, awarded in February 2007 and located in the deep waters of the Rovuma Basin, near Mozambique's Northern border with Tanzania
- Area 4 is situated approximately 200 km northeast of Pemba and 50 km from the coastline, measured from the western limit of the concession; the Block is about 70 km wide and 200 km long.
- Area 4 consists of 9 different pools aged between Paleocene and Oligocene.
- 5 reservoirs cross the license boundary with Area 1 (straddling resources)
- 4 reservoir do not cross the licence boundary (non straddling resources)



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Area 4 Project - Drilling & Completion Basis of Design

- Clusterisation scenario and deviated wells
- Water depth range: 1570m - 2150m
- Strong marine currents
- Targets depth range: 3500m - 4600m TVD
- Average well productivity: 150 MMscf/d
- Dynamic positioning rig
- Normal pore pressure gradient
- Dry gas with traces of water and condensate
- Sandstone as reservoir lithology
- Sand control technology (Open Hole Gravel Packing)

Challenges in Deepwater Reservoir Surveillance

- Deepwater environment
- Remote location

Minimal intervention philosophy due to high cost/complexity

Challenge 1

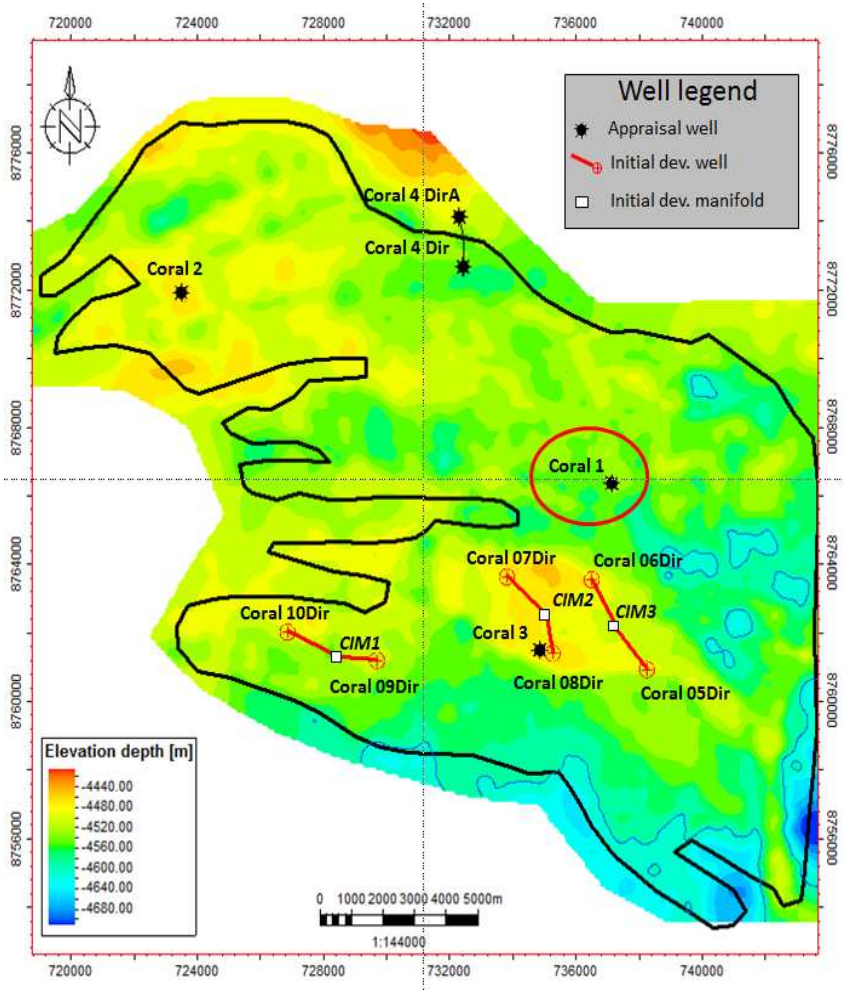
- Reservoir pressure monitoring at field scale

Challenge 2

- Detection of water breakthrough

Challenge 1: Reservoir pressure monitoring

- Even though each development well will be equipped with DHPT, during production it is required to monitor reservoir pressure at “field scale” in the southern area through a monitoring well.
  - To allow the evaluation of the reservoir connectivity between the southern and northern portion of the field
  - To give more confidence for the subsequent North development



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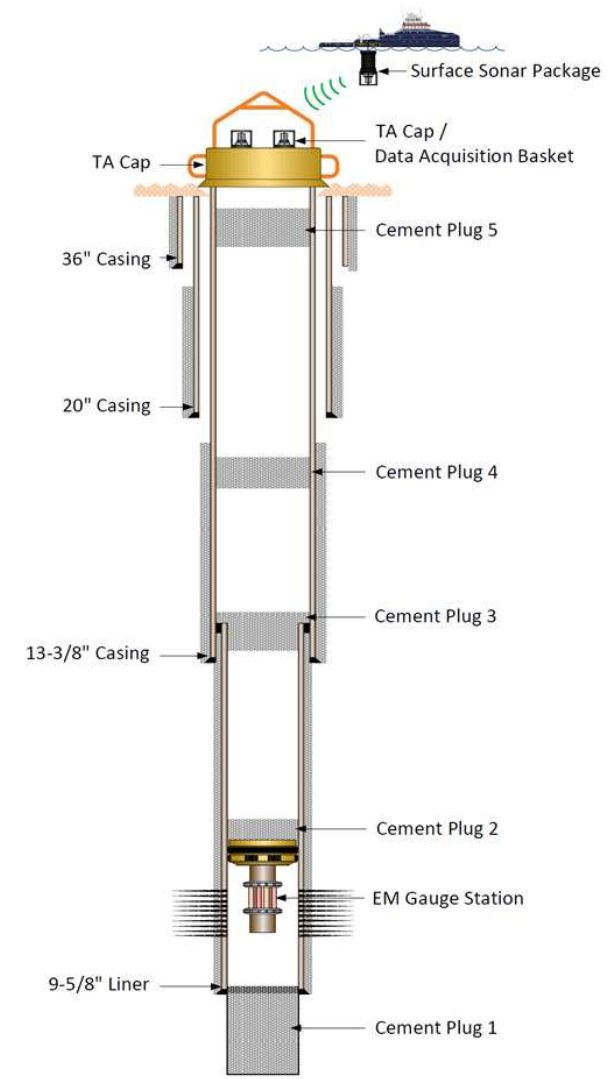
Technology Selection: Wireless Monitoring System

- Field scale Reservoir pressure Monitoring will be implemented by deploying a wireless monitoring system in a previously abandoned Exploration Well in the northern part of the field.

- This technology has been deployed successfully by Eni Ghana in the past.

  - Operations sequence will consist in:
    - Well re-entering
    - Installation of a wireless monitoring system
    - Well abandonment
    - Installation of a subsea acoustic logger unit
    - Wireless Data Retrieving



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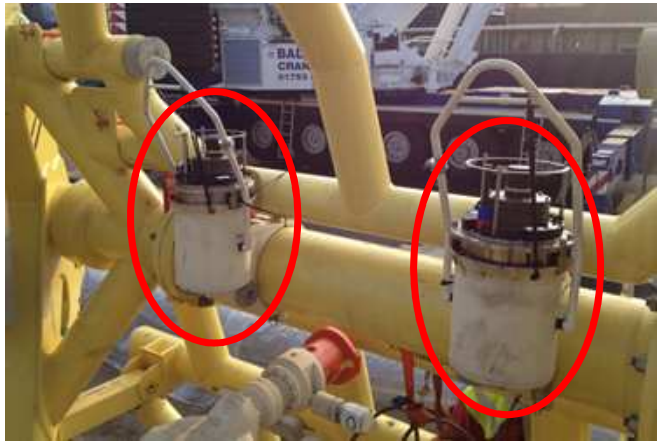
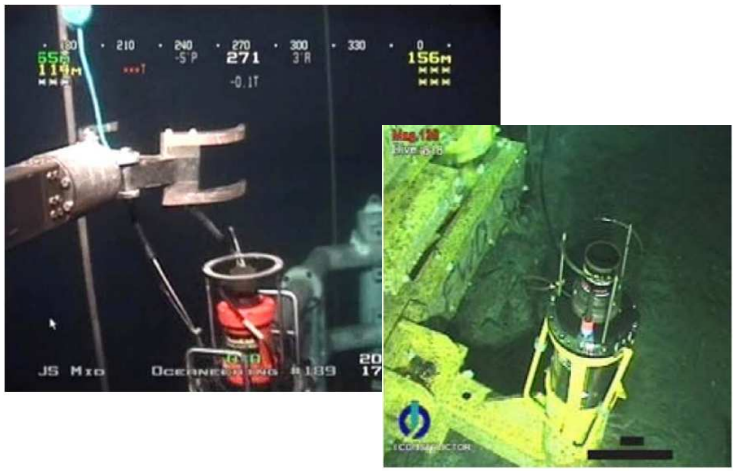
Wireless Monitoring System

- Temperature and pressure gauges are installed in the bottom part of the well set on a predefined and adjustable data sampling rate.
- Gauges and wireless processors store all data to memory using an autonomous downhole battery supply.
- Well is abandoned after technology installation.
- Data is remotely transmitted to surface using:
  - Electro-magnetic signals (from DH to subsea WH)
  - Hydro-acoustic signals (from subsea WH to surface)
- Data retrieved at surface directly from Coral FLNG or from a supply vessel equipped with geophones.





Wireless Monitoring System - Technical Benefits

- No cabled connection required to DH or surface system
- All high-res data stored to DH memory, available for download in case of future well intervention.
- System capable of retrieving historic data at any time.
- Technology based on acoustic and electromagnetic technologies. Both can are combined in a *hybrid system*.
- Very good volume of transmitted data: up to 12000 data points possible, over the life of a system, under ideal conditions.

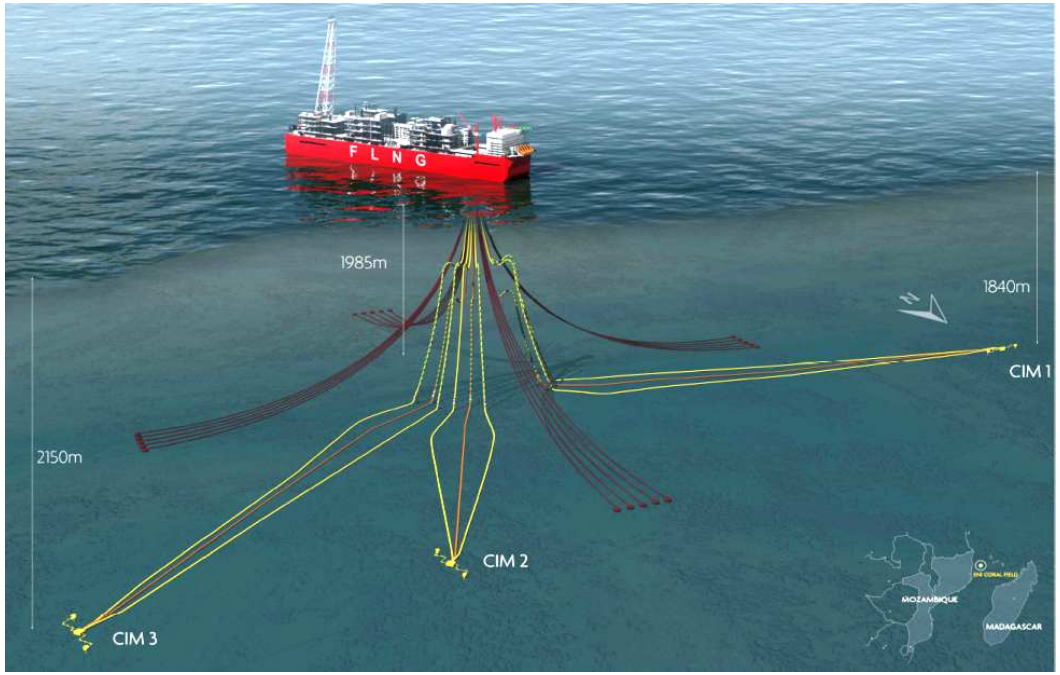
Wireless Monitoring System - Technical Benefits

- Good reliability of the technology due to system redundancy.
- High degree of wirelessly controllable downhole gauges, from surface, including adjustable data sample rate and gauge resolution.
- Good proven track record for the wireless technology in the oil and gas industry.

The main technical constraint is represented by the battery life of the equipment: strategy for data acquisition must be the optimal compromise between sampling frequency and system longevity

Challenge 2: Detection of Water Breakthrough

- FLNG will be able to handle only a limited rate of production water due to MEG injection capacity.
- It is of paramount importance for the company to be able to detect any water breakthrough that may occur in the wells of the field in order to shut them down.
- Due to well clusterisation, the challenge is to identify exactly which well is producing water.



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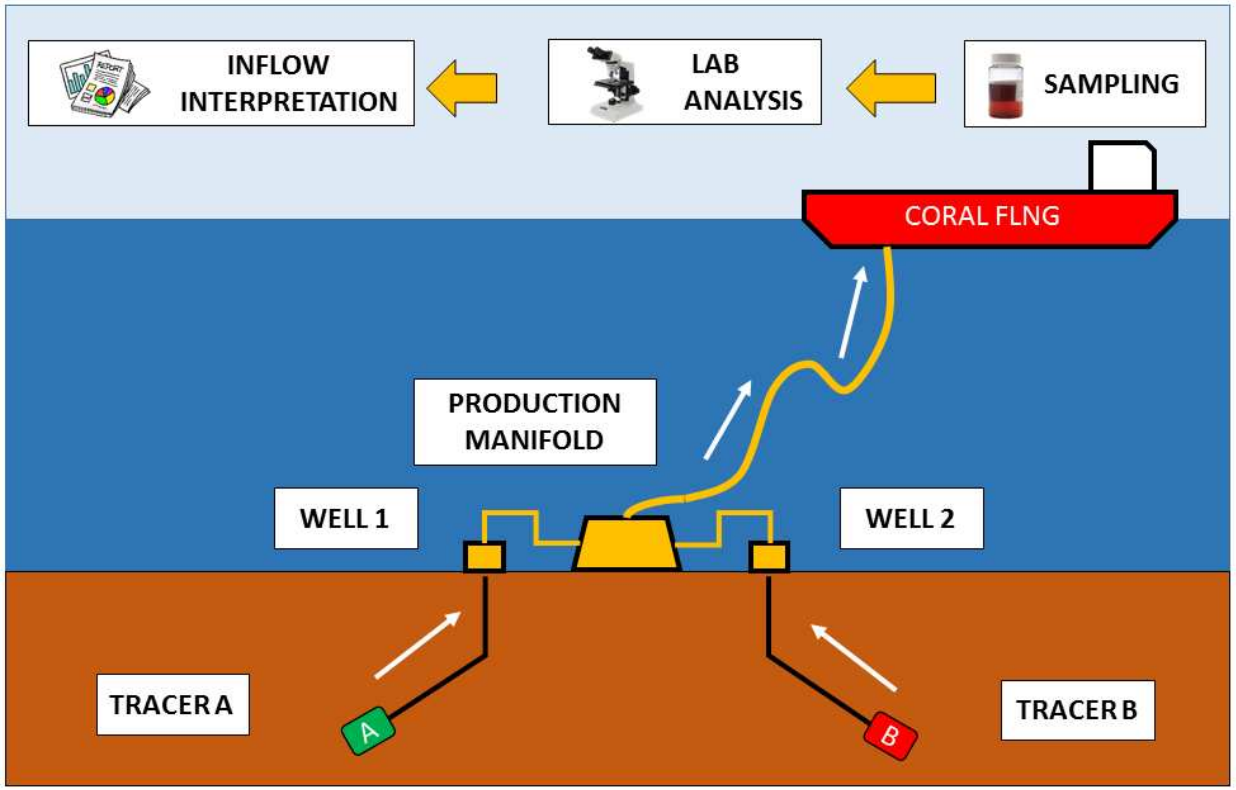
Technology Selection – Downhole Chemical Tracers

- As soon as water will be detected on the FLNG, it will be possible to identify exactly in which well the water breakthrough occurred by using Downhole Chemical Tracers.

- Tracer system is designed to mark the target fluids (water, in this case) to create topside detectable tracer levels.

- Tracers can be detected by performing a lab test on a water sample directly on the FLNG



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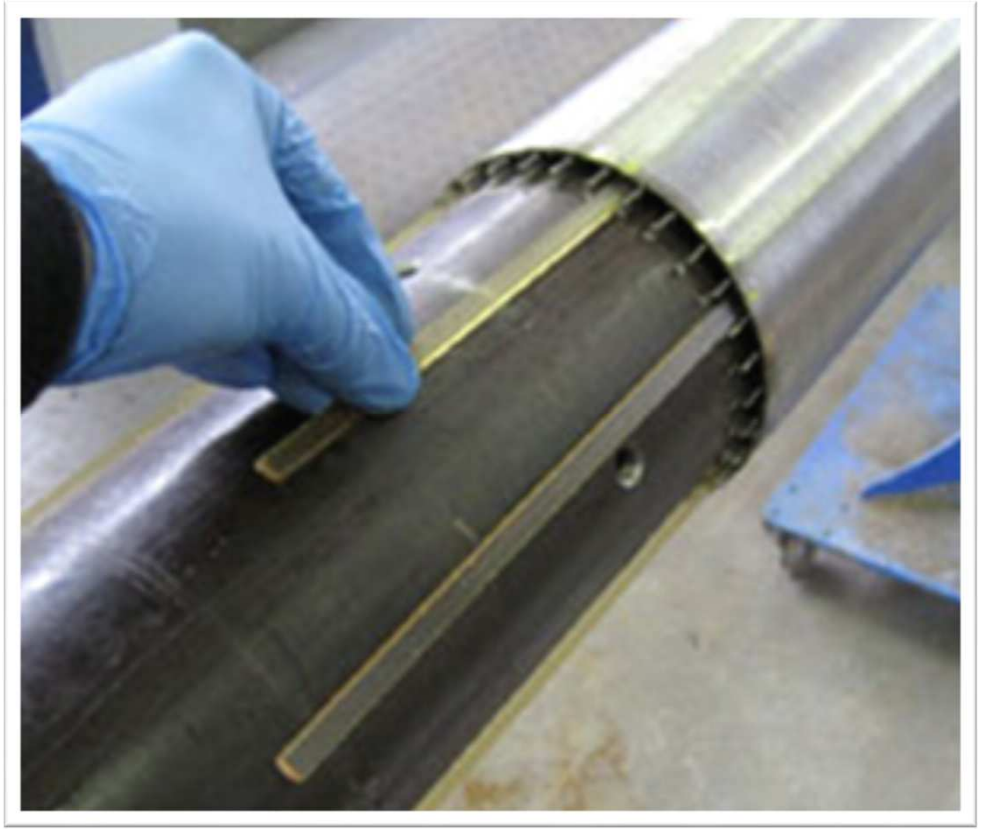
Downhole Chemical Tracers

- The tracer compound is encapsulated/ embedded in polymer matrix (rods or filaments)
- The rods are installed into the lower completion screen joint
- When the water flows through screen and contacts the matrix, the molecule is released from the matrix into the production fluid



Downhole Chemical Tracers

- Water tracer for Mozambique application:
  - Water tracers dormant in pure gas phase
  - 25 years dormant life
  - 3 years monitoring time
  - At least 32 different types of tracers to have a unique one for each well application

Downhole Chemical Tracers – Technical Benefits

- No cables, no connections, no intervention, and no major changes to completion design.
- No additional rig time, no expensive completion hardware, and no extra personnel required at the well site.
- Downhole chemicals are used in extremely low concentrations (down to parts per trillion) and are compatible for water discharge. No radiation is used.

- This technology has been used successfully by Eni in:
  - Italy
  - Republic of Congo
  - Norway
  - USA

Acknowledgements

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