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SPE workshop

IOR/EOR Practices for Enhanced Efficiency in the Evolving Carbon-Conscious Environment

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Immiscible Water Alternate Gas (iWAG) EOR Field Development in Mature Offshore Reservoirs: Planning, Execution, and Surveillance

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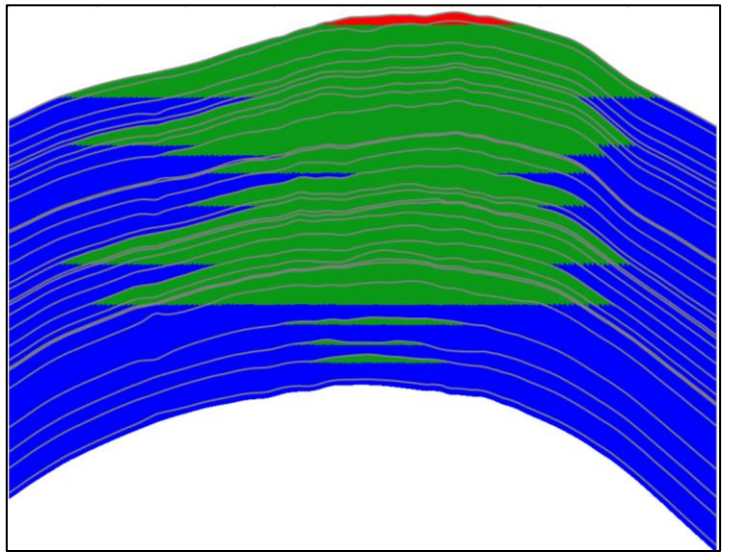
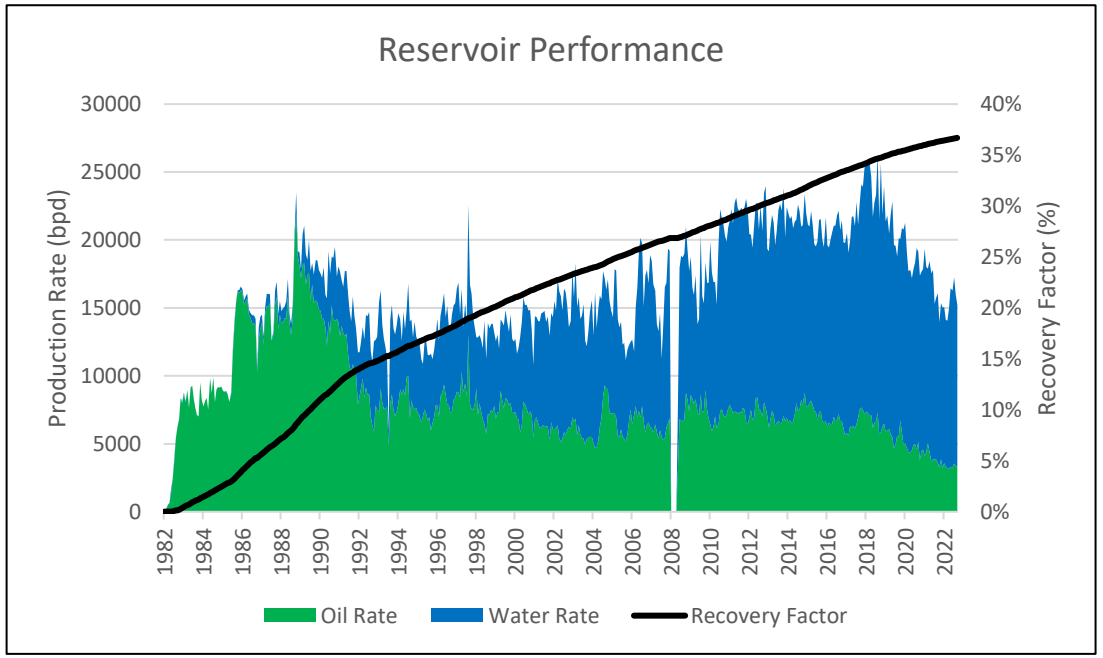
Presentation Outline

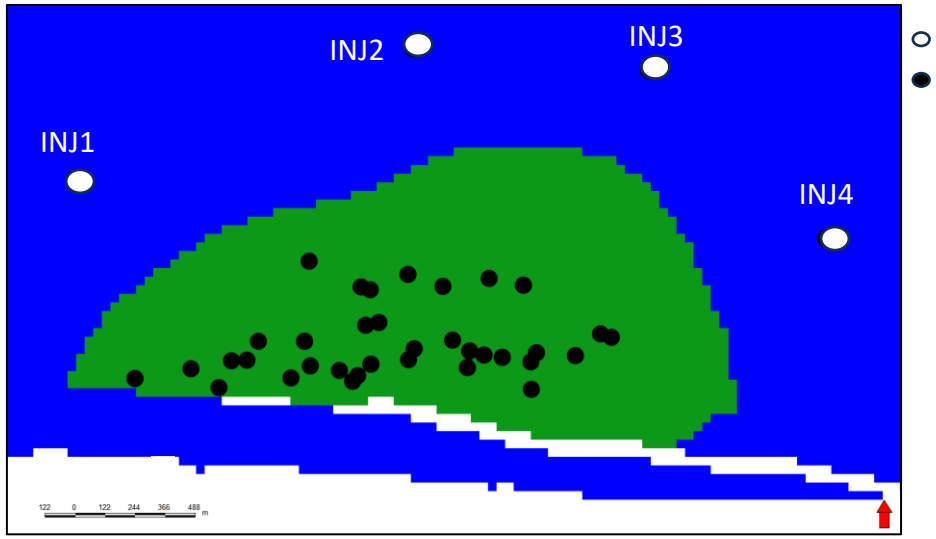
- Field Background
- iWAG Reservoir Management Plan
- iWAG Surveillance Plan
- iWAG Execution Challenges
- Conclusion

Field Introduction

- Field B is located 40km offshore Sarawak
- Major reservoir A is a multistacked reservoir group with heavy oil and strong water drive at 37 per cent current RF
- Further development with new infill and implementation of Tertiary EOR : iWAG Injection through drilling of four (4) deviated wells, and development of new CPP for injection facilities
- Implementation of EOR and infill project to improve UR to close to 50 per cent RF.



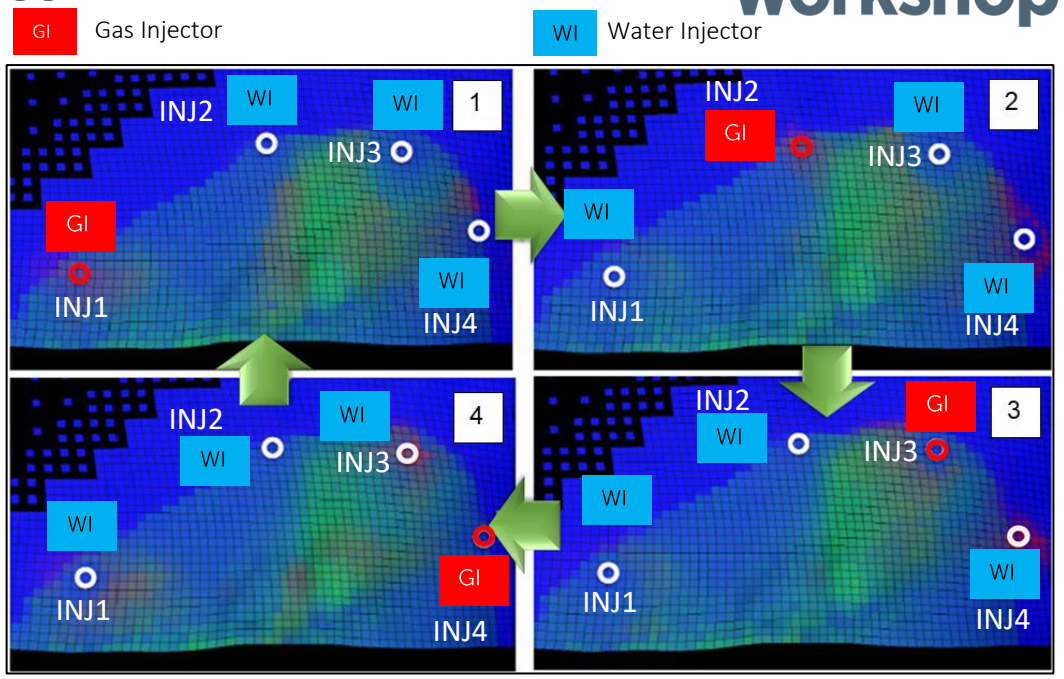




Reservoir unit A7 top view map with initial fluid contact

iWAG RMP - Formulation

	Criteria
Well location and number of wells	• Areal sweep • Well creaming
Target IWAG Ratio	• Optimum recovery • Flood front
Cycle Period	• Shorter cycle • Practicality
Injection rate	• Optimum recovery • Sufficient injection source
Injection Profiling	• Vertical sweep • Permeability variation

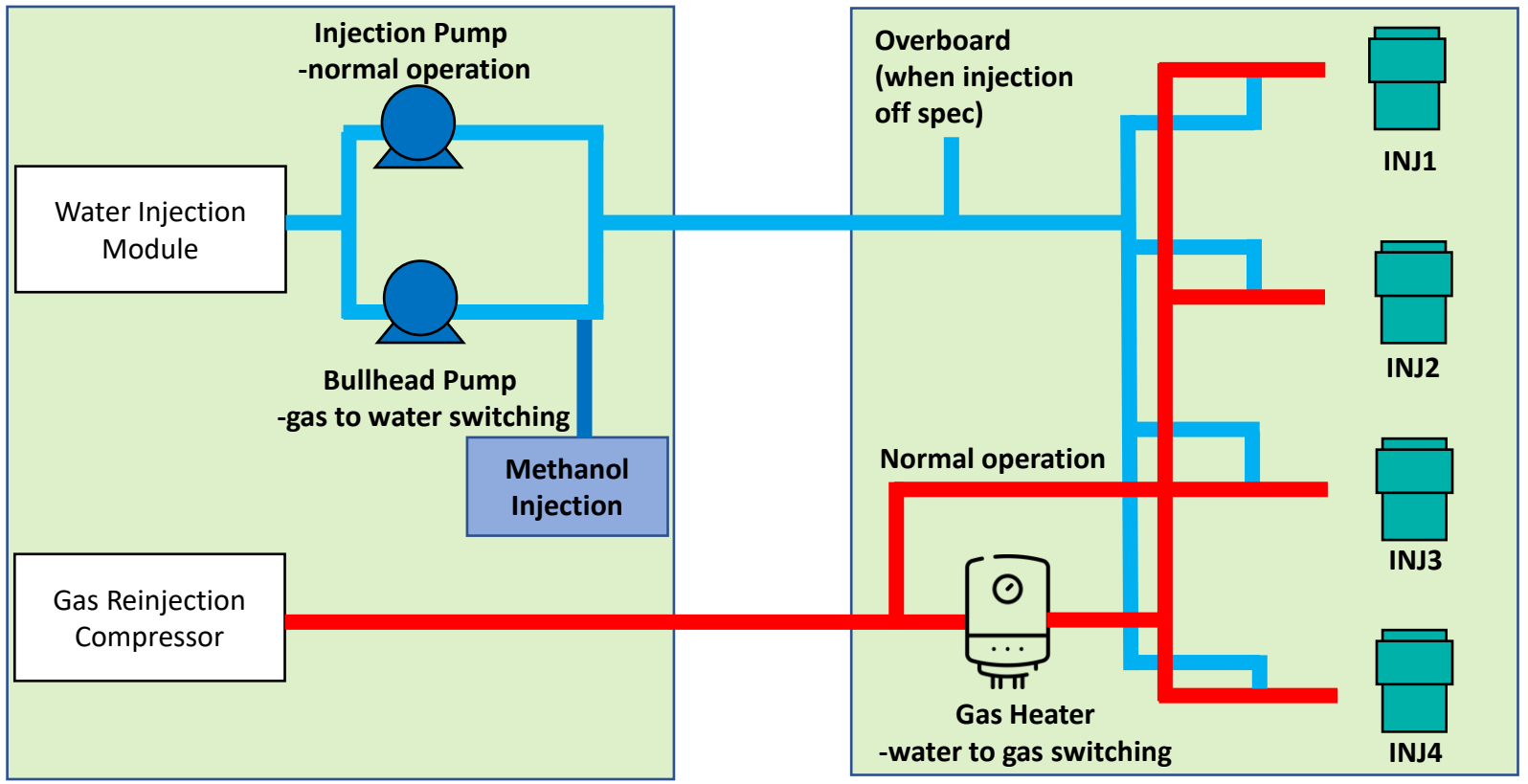


Map showing alternating injector phase during each 120 days cycle

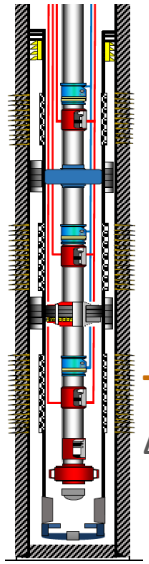
Parameter	Gas Injection Scheme	Water Injection Scheme
No of Wells	1	3
iWAG Ratio	~1:1	
Injection Rates	18 MMscfd	33 kbwpd
Cycle Period	120 days	
Injection Pattern	Peripheral (water leg)	
Injection Profiling	Three (3) major injection zones split using ICV for selective injectivity	

iWAG RMP - Execution

New injectors and facilities are designed to allow continuous gas and water injection, smooth injection phase switching and zonal injection to reservoir group



Injector Downhole



PDG
Fracture pressure monitoring

ICV
Rate control of 3 zonal injection

Tubing-Annulus PDG
ΔP for zonal rate estimation

Cycle (Every 120 days)	INJ1	INJ2	INJ3	INJ4
Cycle 1	Gas	Water	Water	Water
Cycle 2	Water	Gas	Water	Water
Cycle 3	Water	Water	Gas	Water
Cycle 4	Water	Water	Water	Gas

iWAG Surveillance Plan (1/2)

Nine (9) critical focus area for surveillance were identified and implemented to ensure thorough data gathering and effective well and reservoir monitoring for iWAG strategy optimisation.

Benefiter Performance

Real-time monitoring through digital platform

- Baseline production performance
- Post injection production performance

Pressure

Utilisation of **Permanent Downhole Gauge** installed in eight (8) benefiters and all injectors for continuous monitoring

Saturation Distribution

Pre and post injection saturation monitoring through conventional data acquisition

Breakthrough

Permanent DFOS in four (4) wells key wells for monitoring coupled with routine surveillance: Well test, wellhead sampling, produced water analysis.

Injectivity / Injection Profiling

Pre and periodic injectivity testing, diagnostic plots and advance profiling ie. HPT-SNL

Production Profiling

Permanent Distributed Fiber Optic (DFOS) and periodic conventional data acquisition ie. PLT/RFA

Connectivity between Wells

Reservoir interference testing, tracers, multiwell retrospective testing

Wellbore Integrity

Injection wells wellbore integrity through baseline and post injection data acquisition

Production Chemistry

Daily monitoring of the injected water and gas specifications and continuous monitoring on reservoir souring

iWAG Surveillance Plan (2/2)

Real-time monitoring via a digital platform has revolutionised Well and Reservoir Surveillance for the iWAG operations.

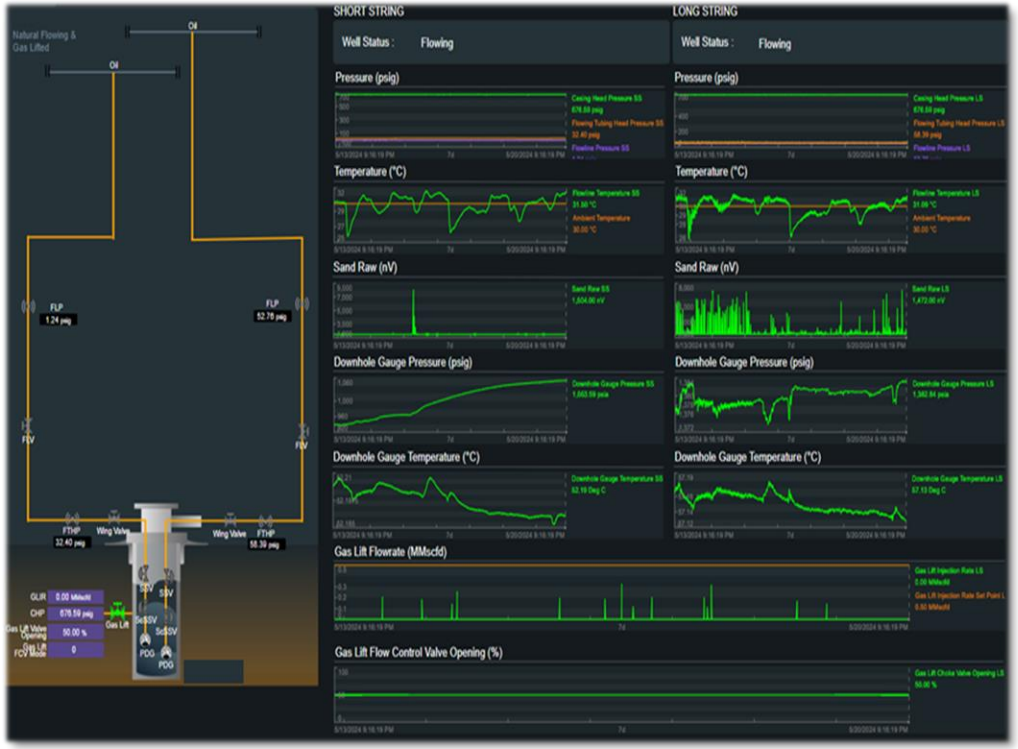
(1) Injector Wells Key Parameters Monitoring

Daily Well Parameter

- ✓ ITHP/FTHP
- ✓ BHP
- ✓ Injection Rate
- ✓ Temperature

Monthly Parameter

- ✓ Injection volume
- ✓ iWAG Ratio
- ✓ Reservoir pressure



(2) Benefiter Wells Key Parameters Monitoring

iWAG Execution Challenges

Continuous improvement is in place to address challenges throughout the implementation phase to ensure continuous iWAG injection.

01 – Water Injection Module

- Reliability and recurring issues particularly on the Ultra Filtration system

02 – Gas Injection Compressor

- Reliability and recurring issues which hinder continuous gas injection

03 – Measurement Inaccuracies

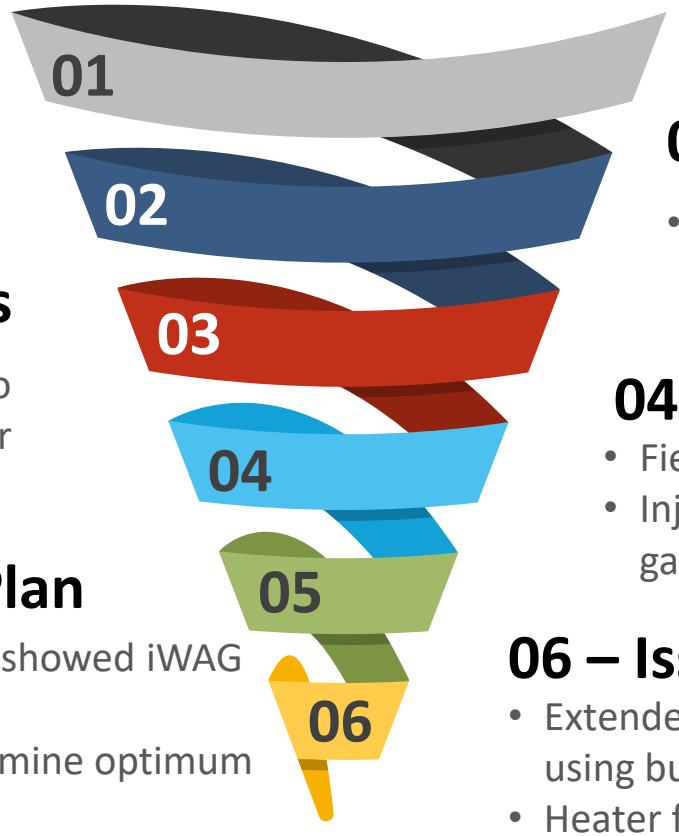
- Meter calibration through clamp-on meter to validate inconsistencies in well vs compressor measurement

04 – Gas Injection Supply

- Field B has low GOR
- Injection sources relied heavily on produced gas from neighbouring field

05 – Poorer Injectivity vs Plan

- Post drilled result with injectivity test showed iWAG injectors has poorer water injectivity.
- Ongoing zonal injectivity test to determine optimum RMP



06 – Issues during Switching

- Extended flushing to meet water injection specification using bullhead pump
- Heater failure which might cause hydrate formation

iWAG Journey in Field B

RMP Formulation

- Optimum areal sweep through 4 peripheral injectors
- Maximise recovery through iWAG ratio ~1:1 with 120 days cycle
- Injector profiling at multistacked reservoir through ICV controlled zonal injection

Fit for Purpose Facilities Design

- Optimally designed equipment capacity to deliver target injection rate
- Bullhead pump and heater for hydrate free phase switching process
- Stable and continuous injection through continuous collaboration

Proactive Surveillance

- Digital field as enabler for proactive well monitoring
- Flood front monitoring through saturation logging
- RMP optimisation through data acquisition and reservoir monitoring

Additional oil production

Improved RF

Thank You / Questions

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