Development of heavy oil heterogeneous sandstone reservoirs

ANP Workshop
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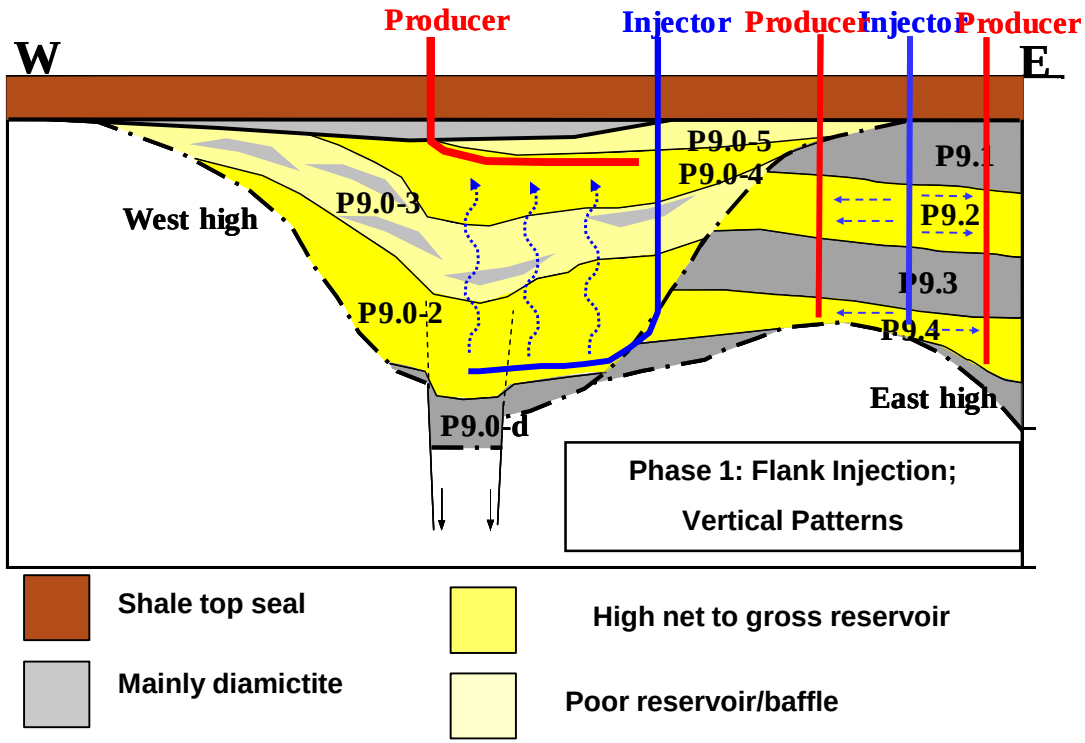
Outline

- Overview of Marmul viscous oilfield
- Journey to large scale polymer flooding
- Creating the future – ASP pilot
- Moving polymer flooding offshore
- Conclusions

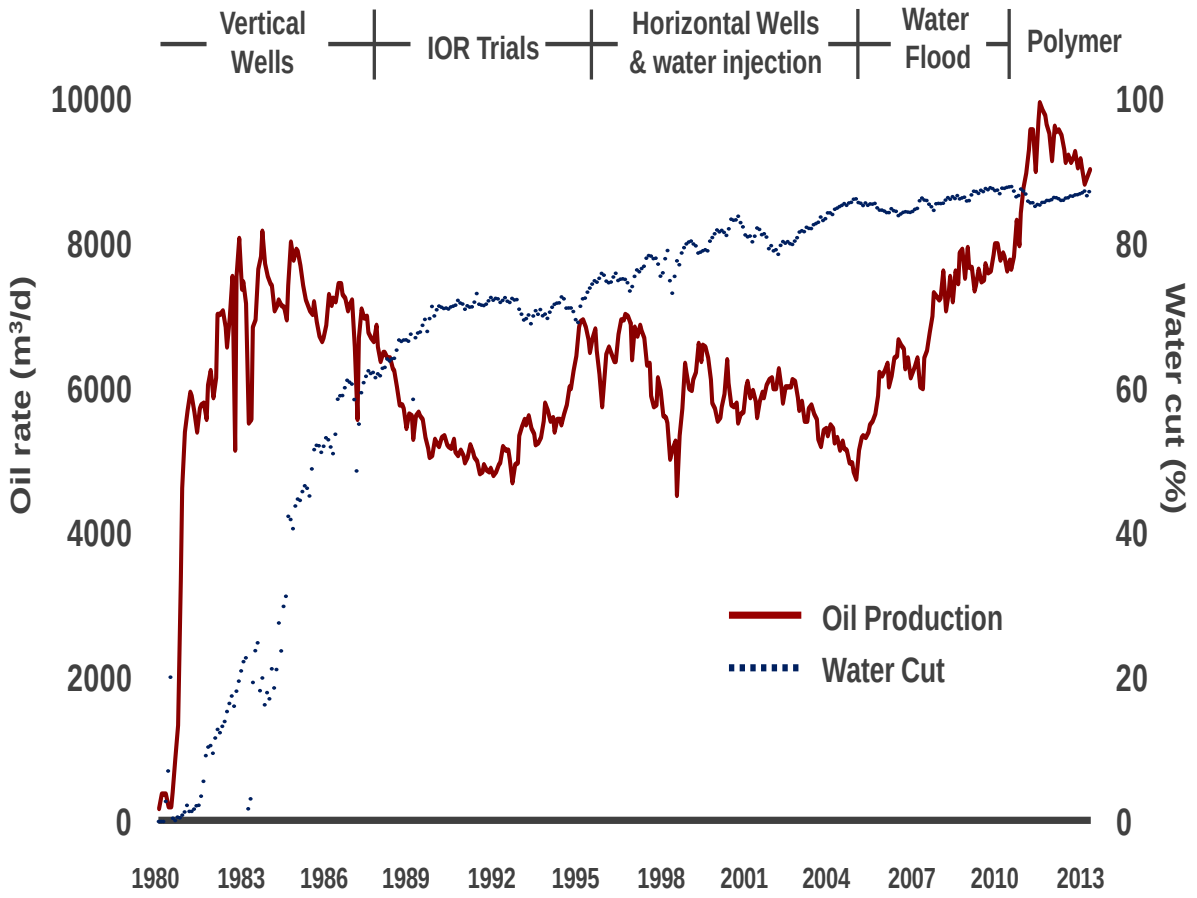
Marmul viscous oil field

Field Characteristics

• Depth	575 – 610m TVDss
• Area	136 km^2 (17*8km)
• Permeability	10 – 5000 mD
• Bubble Point Press.	7600 kPa
• GOR	24m^3/m^3
• Oil Viscosity	90 mPas
• Initial Pressure	9300 kPa @ 610m
• Current Pressure	5000 – 8500 kPa
• Producing since	1980



Marmul production history



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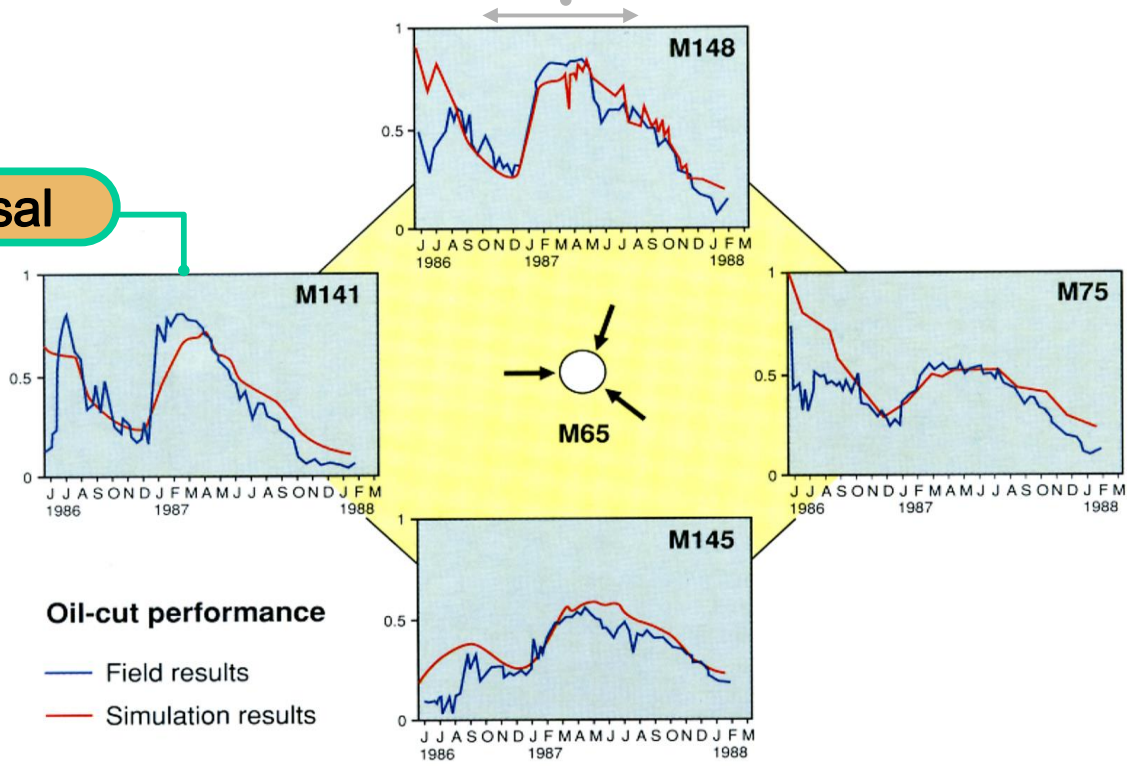
Oman polymer: Piloting

Polymer Pilots
(1986-1988 & 1989-1994)

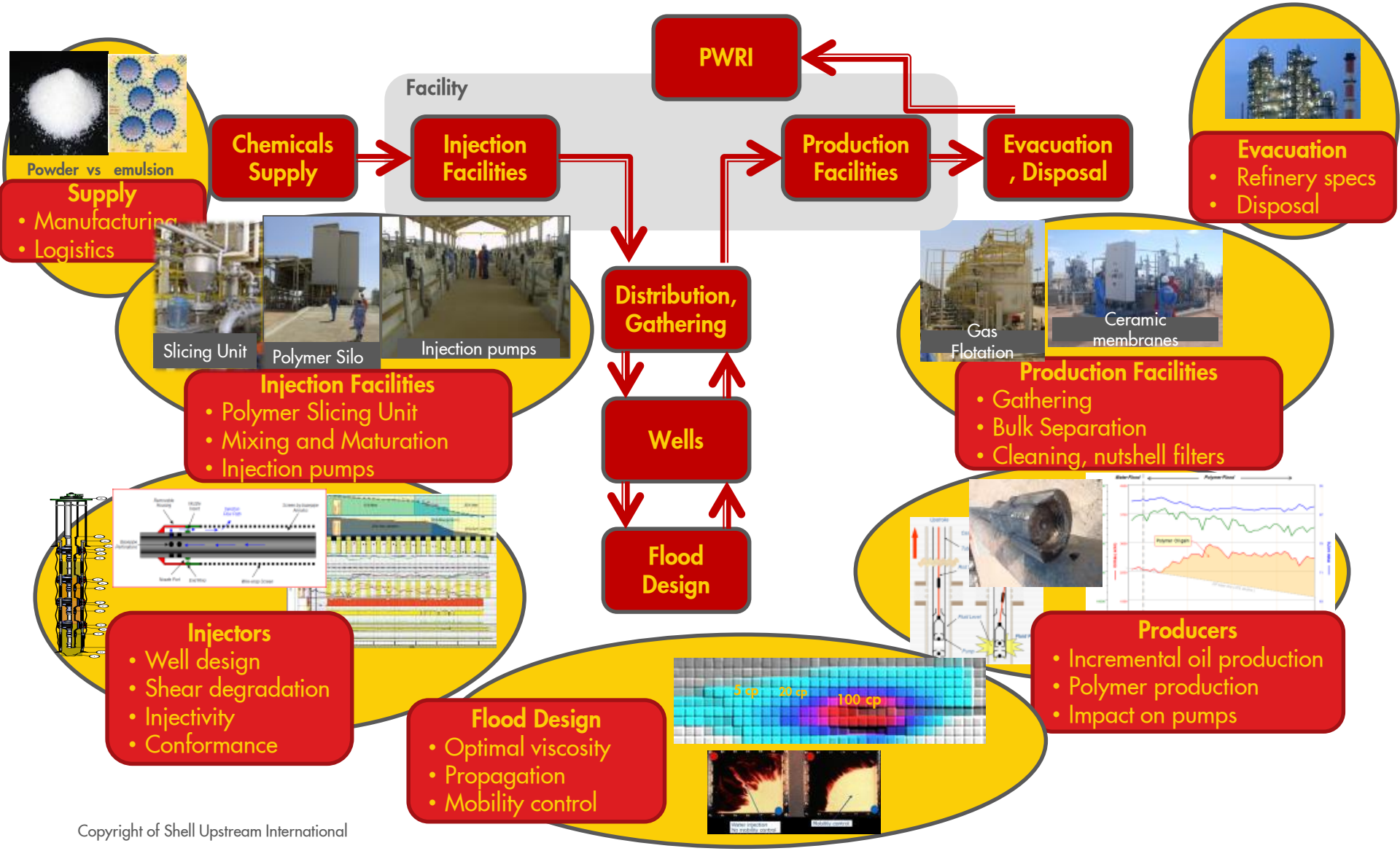
- Pilot testing essential to predict success
- Concept proved in pilots 1986-1988 and 1989-1994

Polymer injection period

Clear oil cut reversal



Polymer Journey – integrated surface & subsurface



Water treatment and polymer plant - Specifications

- Mixing dirty water with the polymer gives high risk of reduced injectivity of the injectors
  - High risk of creating excessive fracture
- Water has to be cleaned to secondary specifications
  - 5 ppm Oil in Water, 2 ppm TSS
- Risk of fracture depend on
  - Cleanness of water
  - Formation property and height
  - Injection rate, viscosity
- Max fracture length 1/3rd of distance to nearest active producer

- Injected Polymer Viscosity is depending on the concentration
- Polymer plant is designed to inject polymer with viscosity 10 cP – 25 cP
- Viscosity can vary per well
- Rate can vary per well

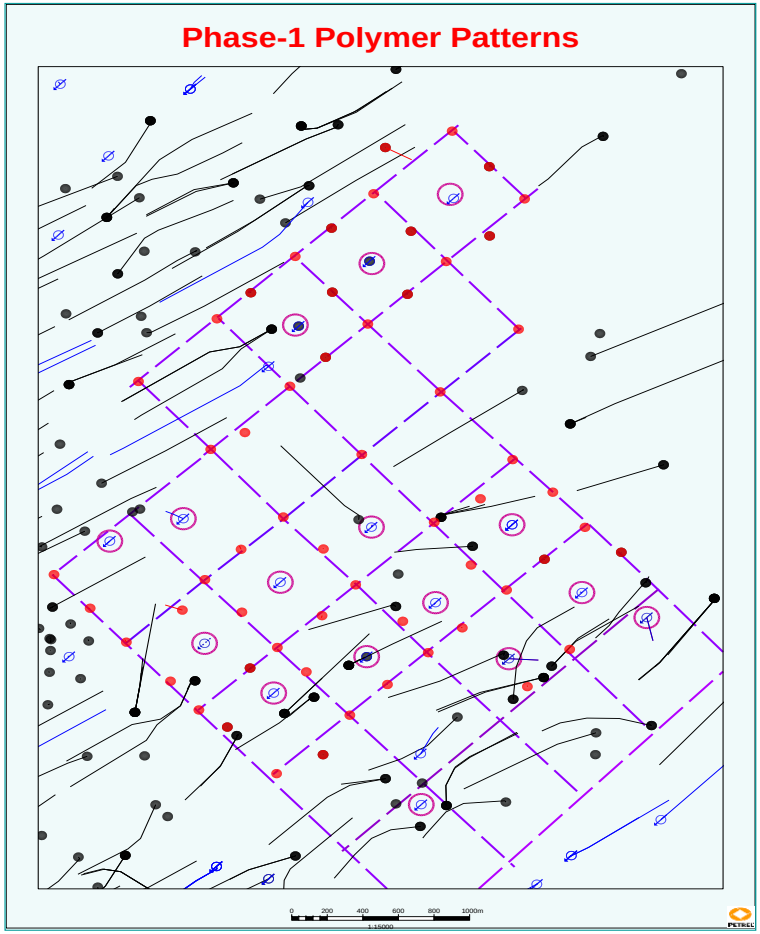
Water Treatment Plant

Polymer Plant

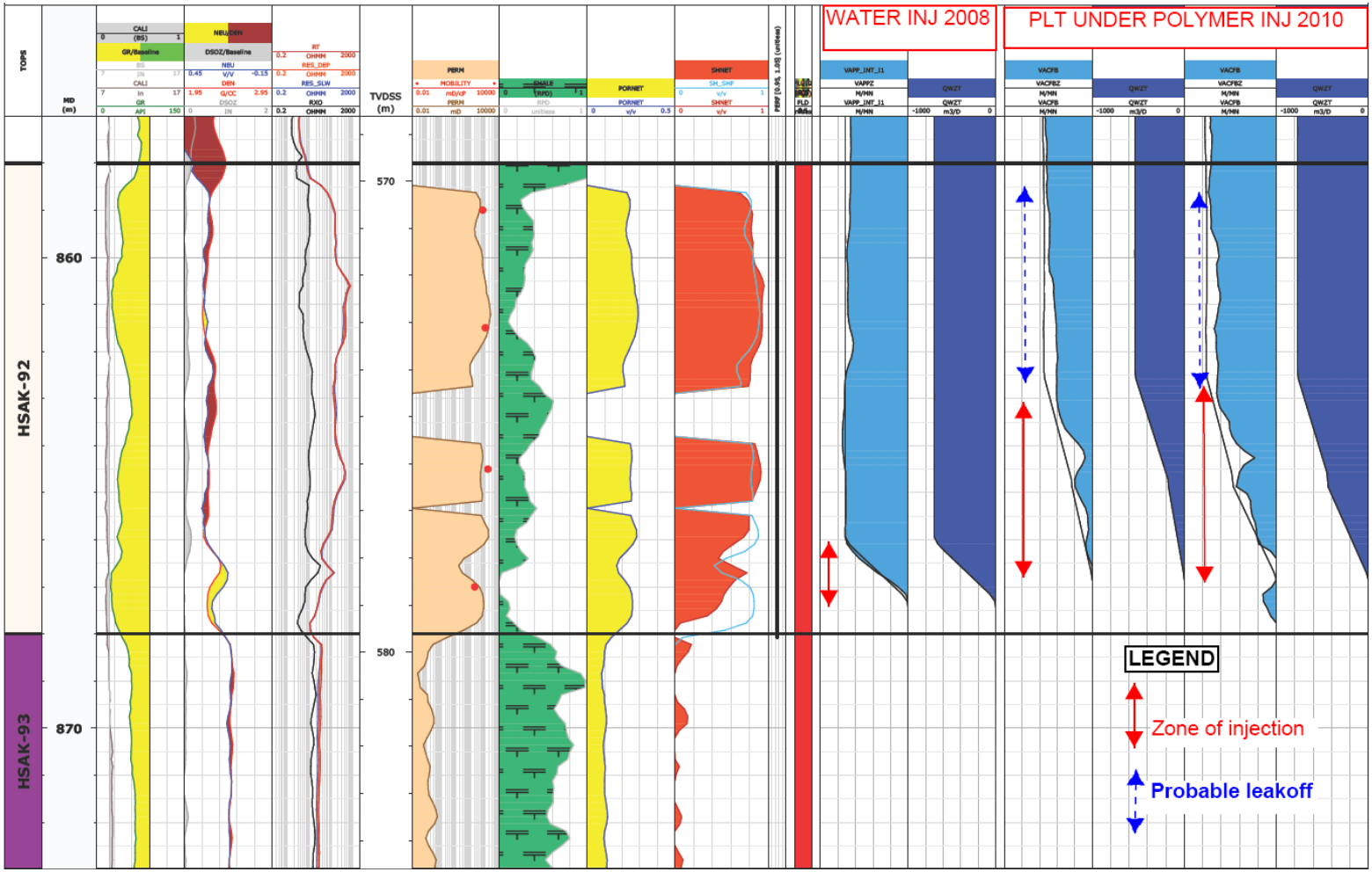
Phase-1 project – Pattern implementation

- Phase 1 - Polymer Injection (27 injectors)
  - 24 Vertical Injectors
  - 3 Horizontal Injectors

- Well spacing 600m inverted 9-spot pattern
- Initial Polymer Injection rate 250 – 500 m^3/d per injector to max. 750 m^3/d
- Expected recovery increase of 10% in targeted area



Surveillance Example - mPLT



- Polymer injection in 2010 has increased the conformance.

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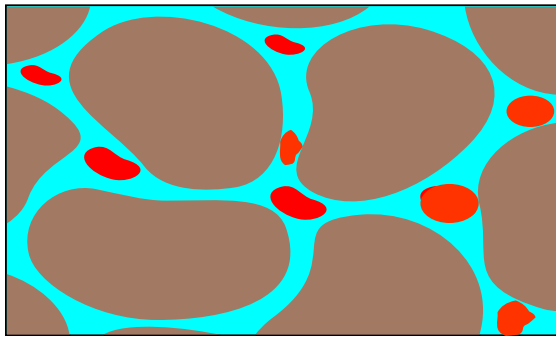
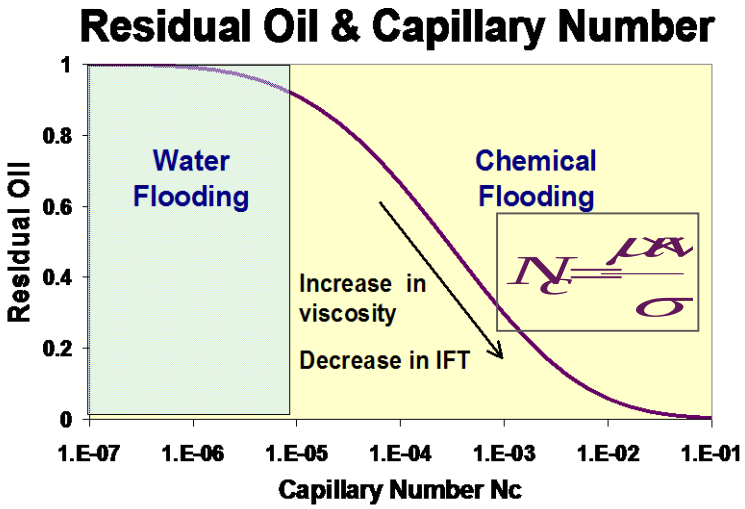
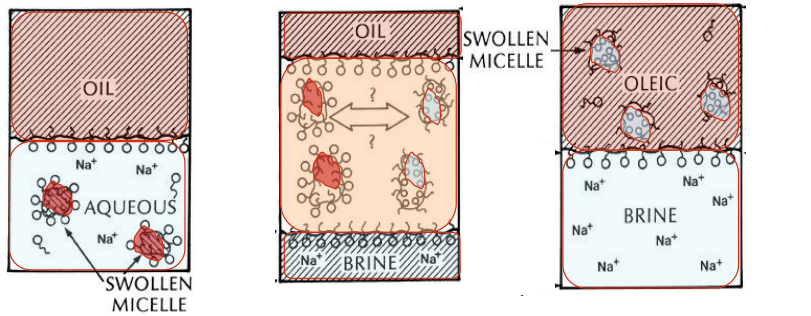
Alkaline-Surfactant-Polymer (ASP) Flooding



During waterflooding residual oil is trapped due to:

- low water viscosity
- high water-oil interfacial tension



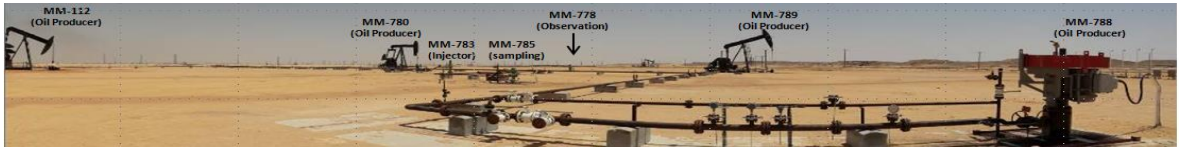


Under-optimum
Low salinity surfactant in water solubilises oil in micelles
IFT ~ 0.1 – 1 mN/m

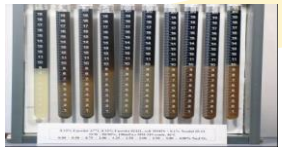
Optimum salinity
middle phase micro-emulsion
IFT ~ 10^{-3} mN/m

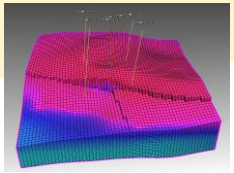
Over-optimum
High salinity surfactant in oil solubilises water in oil
IFT ~ 0.1 – 1 mN/m

Marmul ASP Pilot - Road to operate phase



Phase behaviour
2007 - 2015





Dynamic modelling
2007 - Ongoing

Surfactant Manufacture 2014

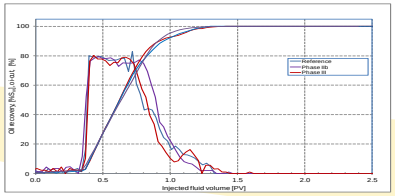
Facilities Construction 2014

2007 | 2010 | 2010 | 2011 | 2015 | 2016

DG1 | DG2 | DG3 | FID

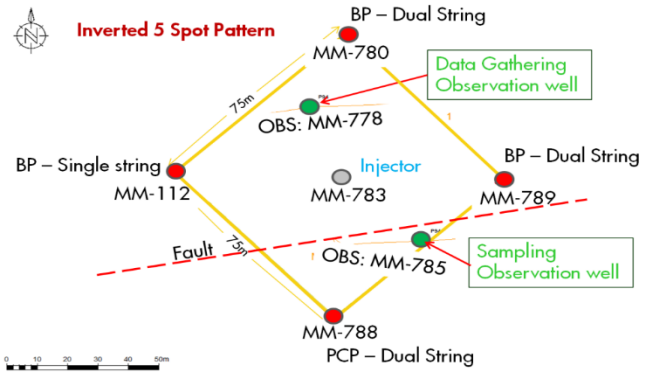
Identify | Assess | Select | Define | Execute | Operate

Core flooding
2007 - 2014



QA/QC of surfactant 2014

Facilities Construction 2014



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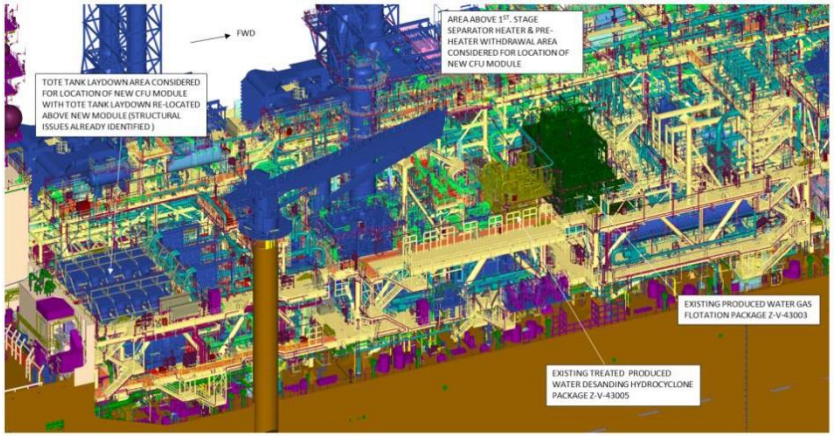
Real estate: Space and weight

South of Oman

Plenty of space available:

- Storage and equipment unlimited
- Separation of O/W no constraints
- Maturation limited constraint
- Build as you go
- Dilution available
- Mitigations can be implemented
  - Expand O/W separation tank
  - Extra filtration

North Sea

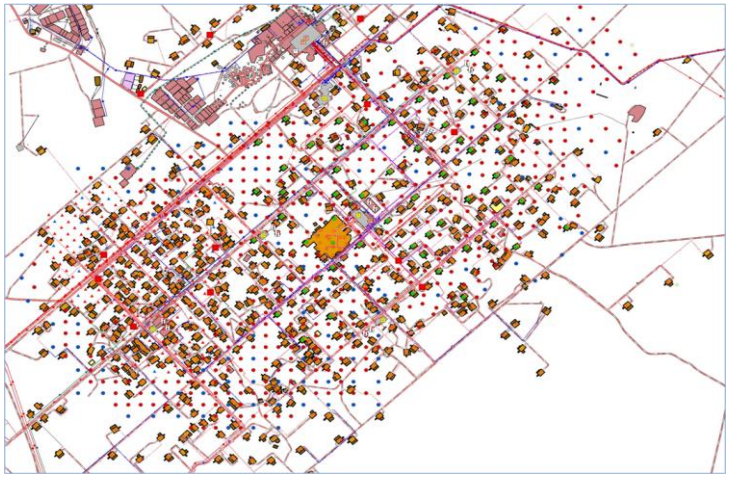


Constraint by space and weight

- Equipment must be nimble
- Storage volume is constraint
- Logistics
- No space to implement mitigations
  - Potentially 3.5 x 2.4 m available for additional equipment

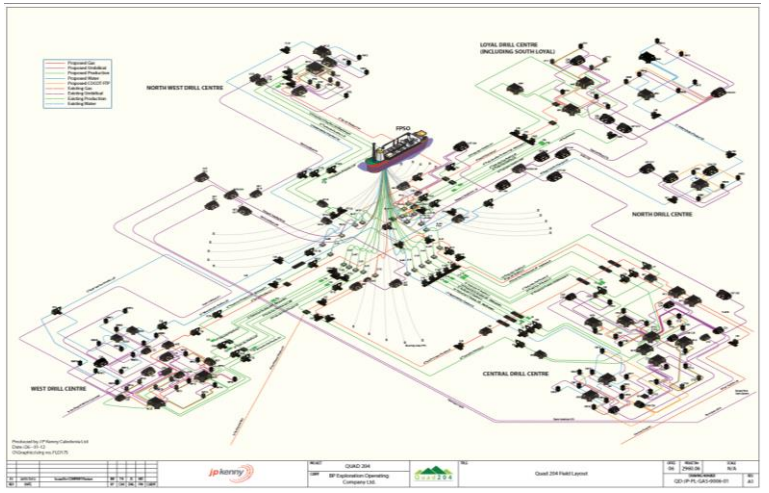
Infrastructure

South of Oman



- Wells are individually accessible
- Infill drilling easy and cheap
- Injector producer distance can be short
- Pilots are easy to implement

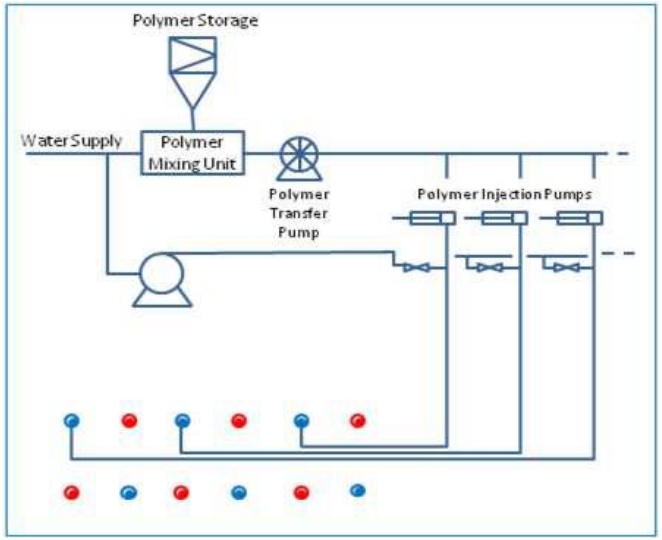
North Sea



- Subsea wells – hard to assess
- Infill drilling is hard and expensive
- Injection producer distance is large
  - no pattern flood
- Pilots are difficult to implement
- Loosing a well is catastrophic

Injection/production

South of Oman



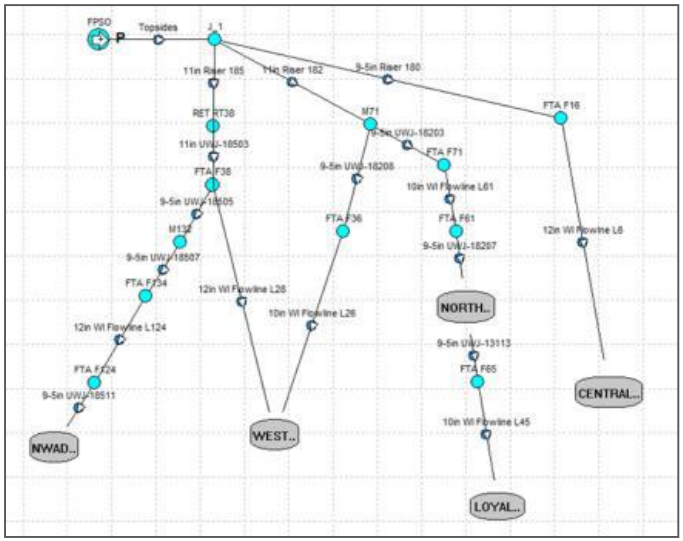
Injectors:

- One pump / one flowline per well
- individually well dosage
- Polymer on/off
- Wellhead sampling

Producers

- Segregated production
- Each well can be tested individually

North Sea



Injectors

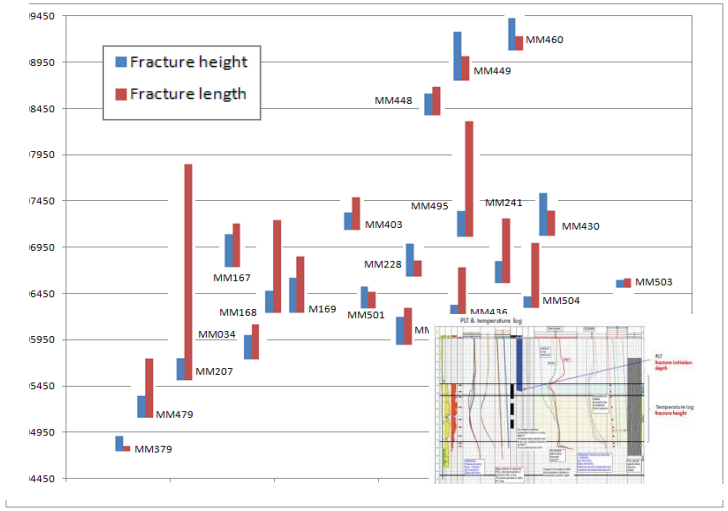
- Combined pump system / 1 riser for 8-12 wells
- Chokes used to distribute flow
- Same concentration every well in riser
- Shear degradation through chokes

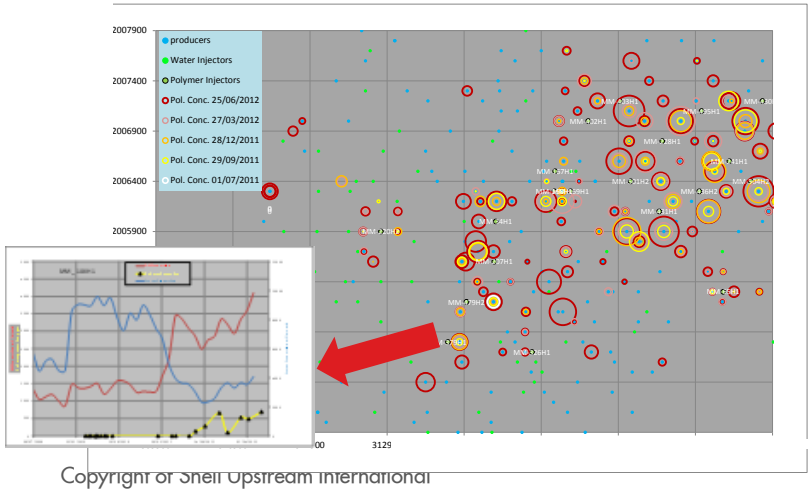
Producers

- Commingled production
- Well testing cumbersome

Reservoir surveillance

South of Oman





North Sea

Sampling per production riser

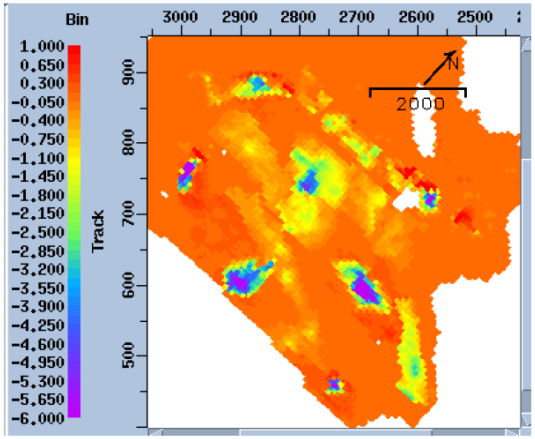
- Commingled production
- Limited individual well information

One PFO and 5 PLTs during field life

- Fracture growth?
- Containment?

4D seismic

- Good enough for surveillance
- Replace PFO



Change in Oil net-column [ft]

Injectivity/Productivity

South of Oman

No injectivity issues Field A

Productivity decline Field A

- Solvent treatments

Poor injectivity Field B

Injectivity issues Field C

- Remediation injectors with foamed acid breaker

North Sea

Injection under fractured conditions

- Some horizontals (partially) matrix

Same polymer injected in all wells

Remediation

- Subsea well connect + stimulation vessel

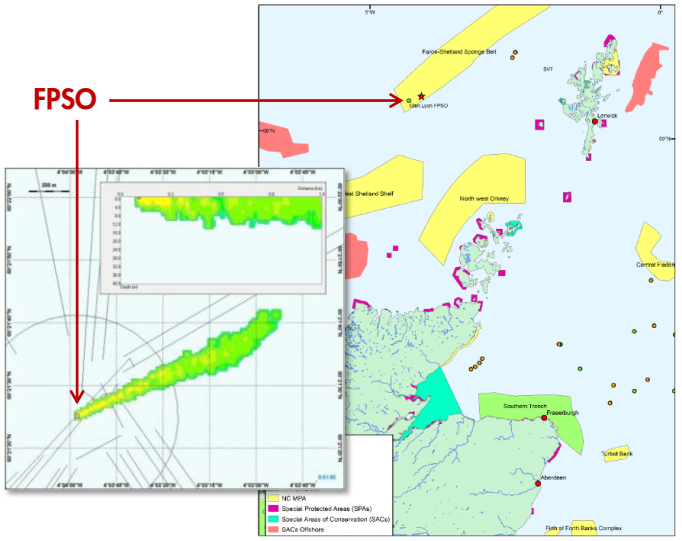
Water treatment, PW sink and polymer disposal

South of Oman

- Dilution by other producers to reduce viscosity produced water
- High PWRI system uptime
- Fall-back PW is well disposal
- Additional filters for water treatment

North Sea

- Water treatment based on hydrocyclones
- No other fields to dilute
- No additional filtration
- 5% on-demand un-availability PWRI system
- 40 ton/year polymer discharge to sea, based on 80 ppm returned polymer (500 ppm injected)
- Fall-back: shut in producers when PWRI is down



Key messages

- Large scale polymer flood deployed onshore Marmul viscous oil field
  - Good response from injection
  - Complex integrated surface and subsurface issues need to be addressed to create EOR system that works
- Pilot testing of ASP to establish additional value and recovery over polymer flooding
- Polymer EOR has potential for application offshore
  - Projects complex and require integrated approach and proper planning
  - Early identification and lifecycle thinking (e.g. injection water quality requirements, deck space and tie in points)
  - Mitigations needed from technology, e.g. shear resistant polymers
- Need to have the right commercial and fiscal environment to make it happen