Offshore field experience with BrightWater

Presenter: Nancy Lugo
Chevron Upstream Europe

Stavanger 20/01/2010

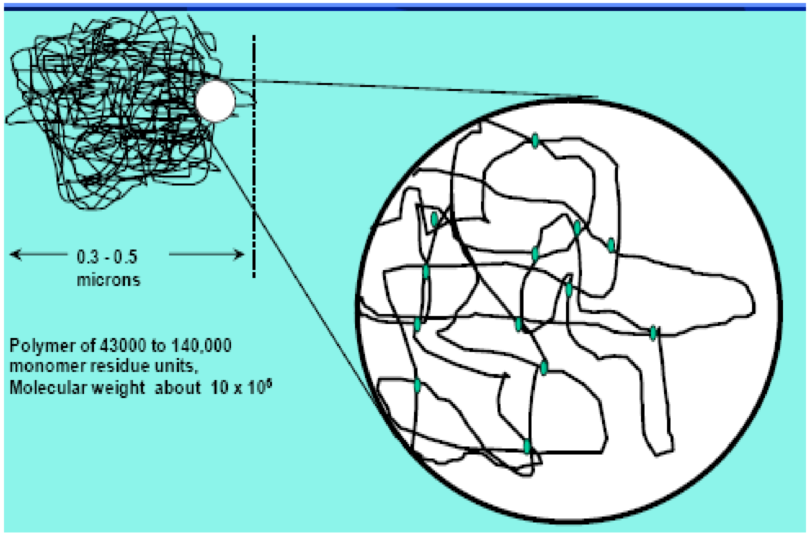
Team Members:
Nancy Lugo, David May, Elaine Campbell – Chevron Upstream Europe, Aberdeen
Rick Ng, Steve Cheung – Energy Technology Company, Houston, Texas

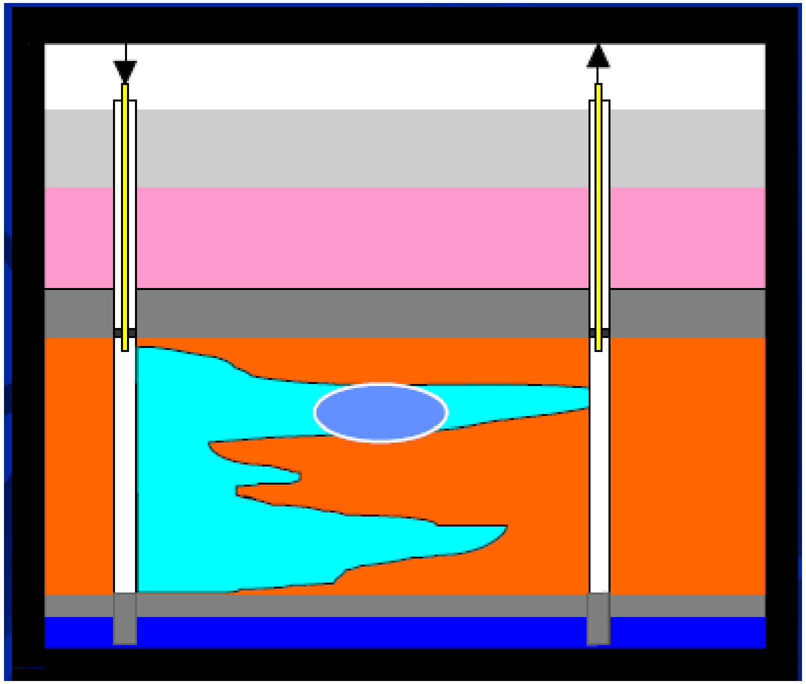
Agenda

- What is BrightWater
- Applications in the world
- BrightWater in Strathspey
    - Strathspey field and geology
    - BrightWater treatment in Strathspey
    - Modeling process
    - Treatment execution
    - Results
- Lessons Learned
- Conclusions

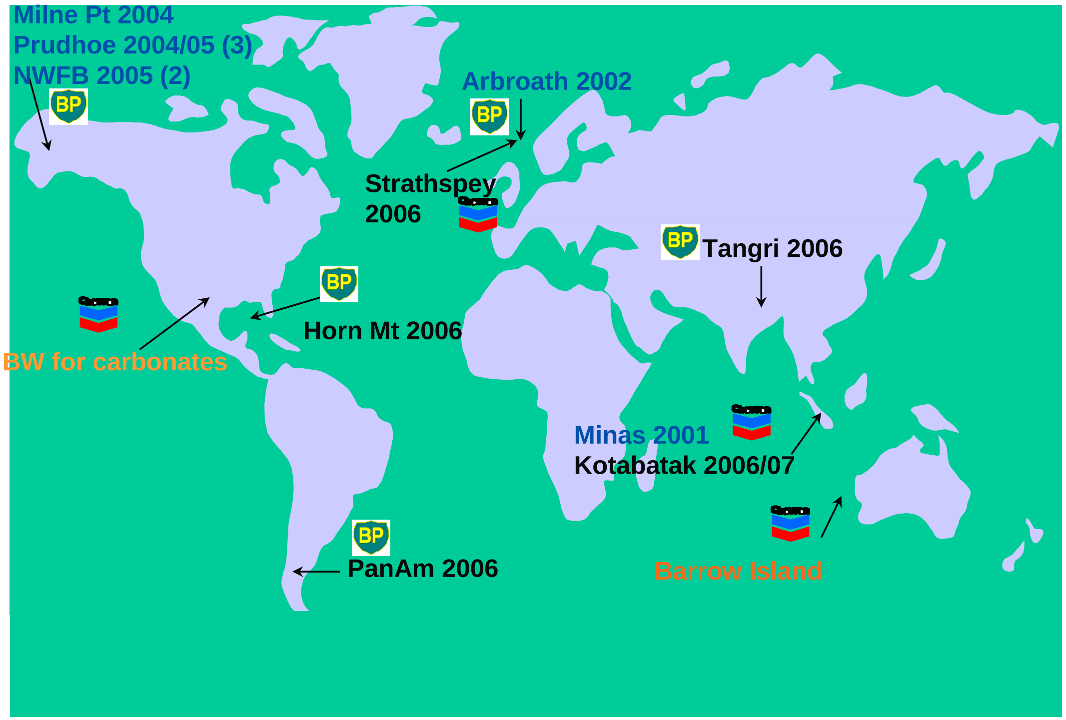
What is BrightWater

- Novel particulate system for in–depth waterflood conformance control
- Co-developed between Chevron, BP and Nalco
- Small cross-linked polymer particles bullheaded into injection well
- Propagate deep into the reservoir
- Once heated polymer expands to block pore throats and prevent further fluid flow through rock
- Injected water diverts into less swept zones





BrightWater applications



- 2001

Minas Field – Indonesia (Chevron operated)

  - Extra oil observed (SPE 84897)

- 2002/03

Arbroath, North Sea (BP)

  - No extra oil. Ownership changes & production issues stopped assessment of field benefit.

- 2004/05

Alaska - Milne Point & Prudhoe Bay (BP)

  - Over half a million extra barrels recovered from four trial wells. Treatment cost of just $3.20 - $3.80 per barrel.

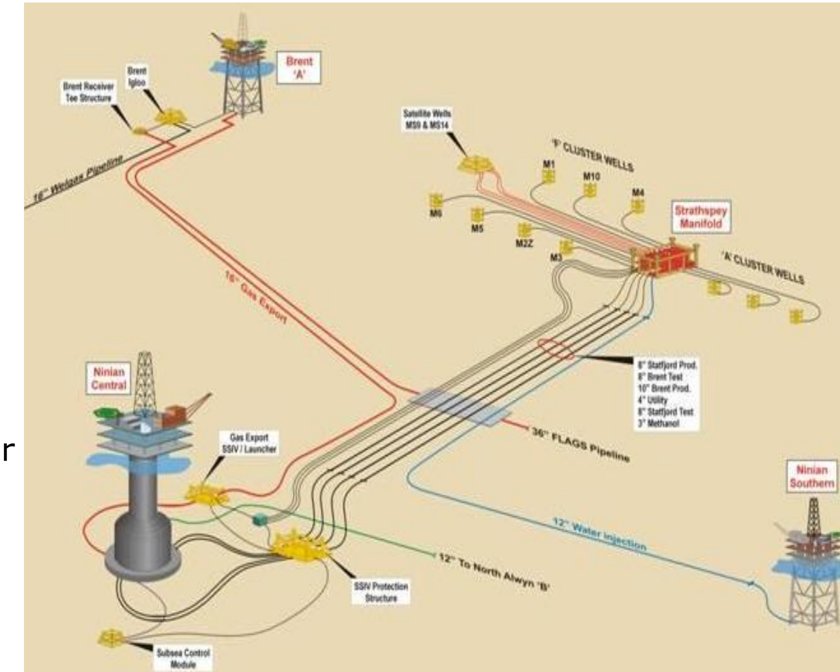
- 2006

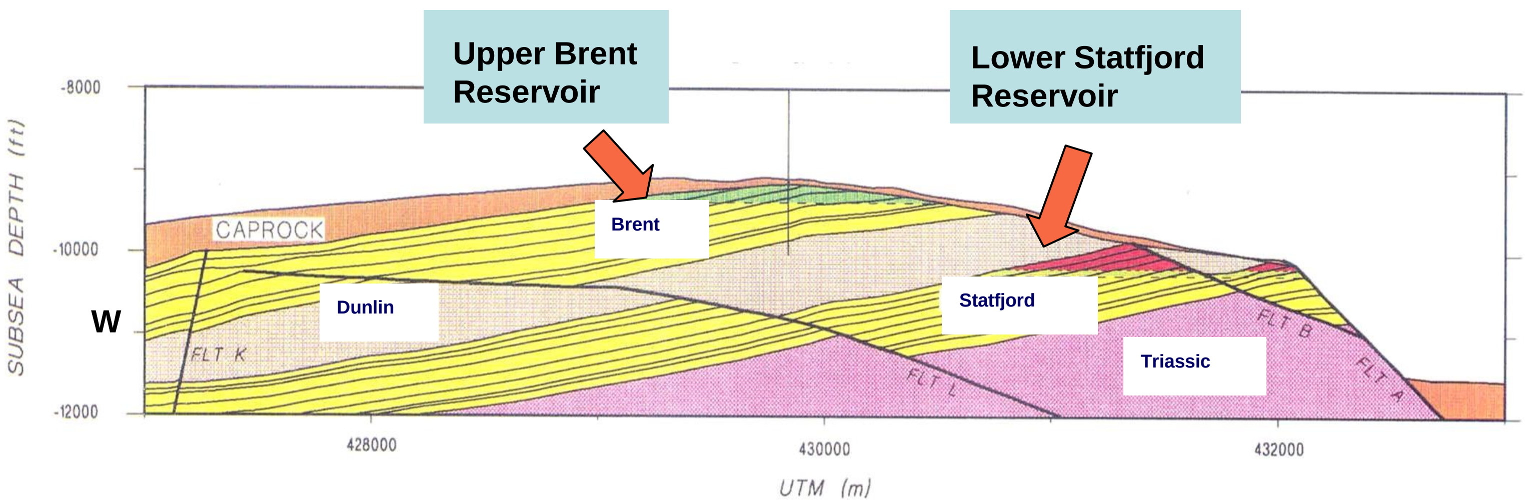
Strathspey

  - Over 130 mboe increase first 12 months. Treatment cost of $3.5 - $4 per boe.

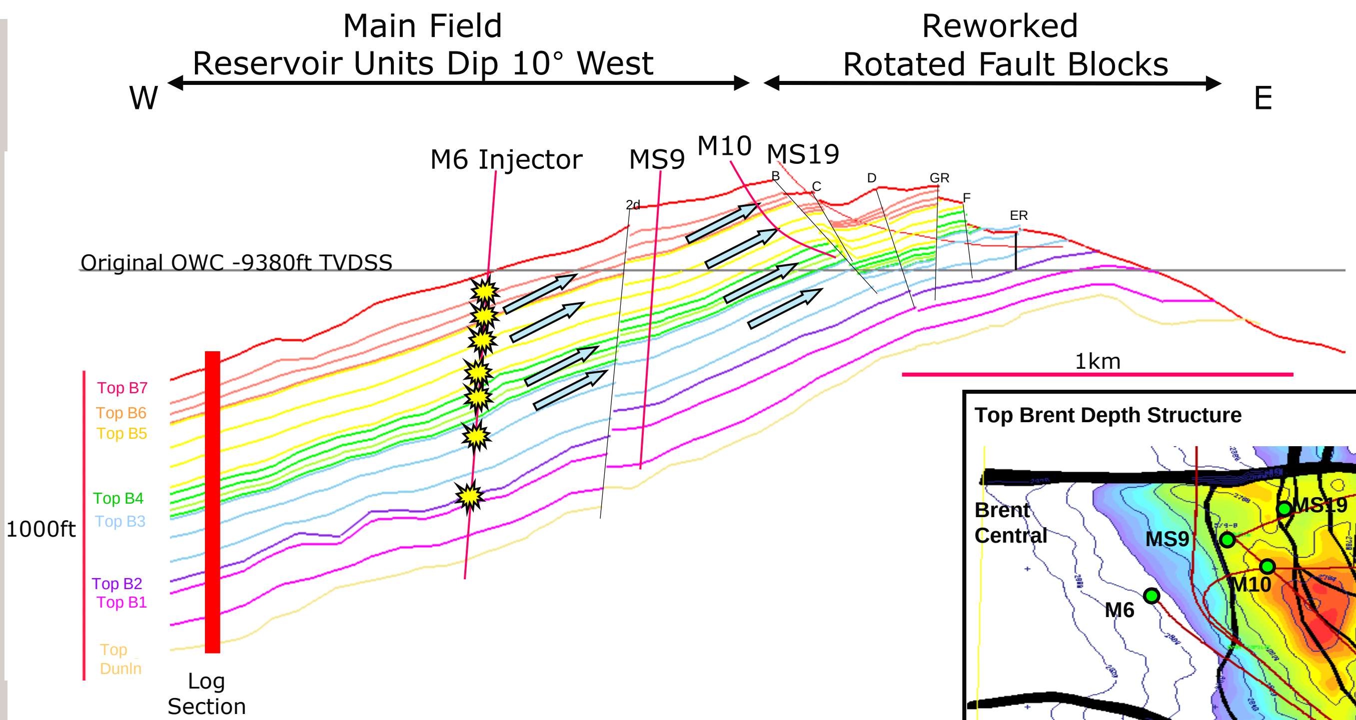
Brightwater treatment in Strathspey Field

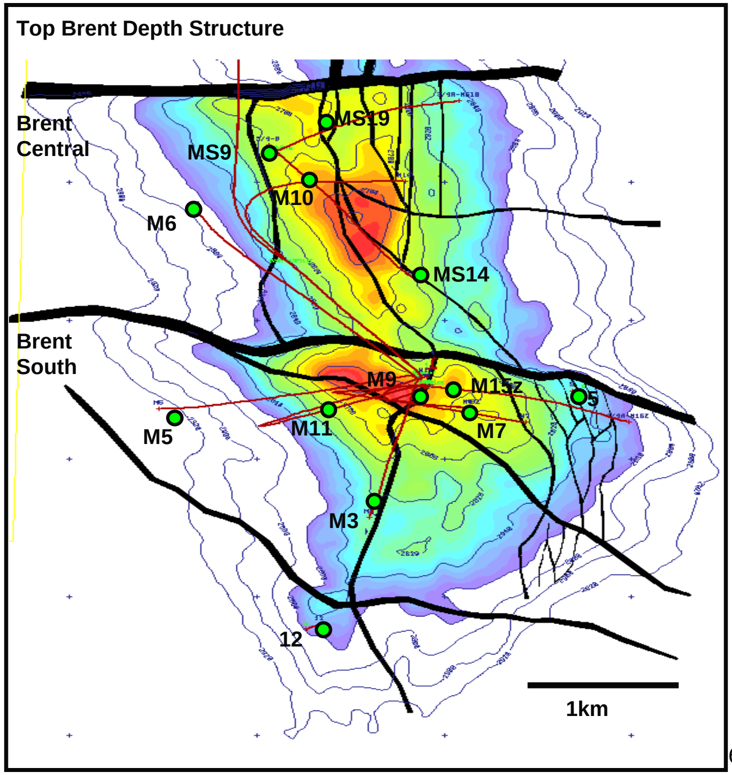
- Subsea development
- Consists of a tilted fault block (10° West)
- Two Reservoirs
  - Brent Group (Black Oil)
  - Banks Group, Statfjord Fm. (Gas Condensate)
- Production Mechanism
  - **Brent**: water flooding, best candidate for BrightWater application
  - **Statfjord:** depletion drive
- Brightwater deployed in Brent reservoir





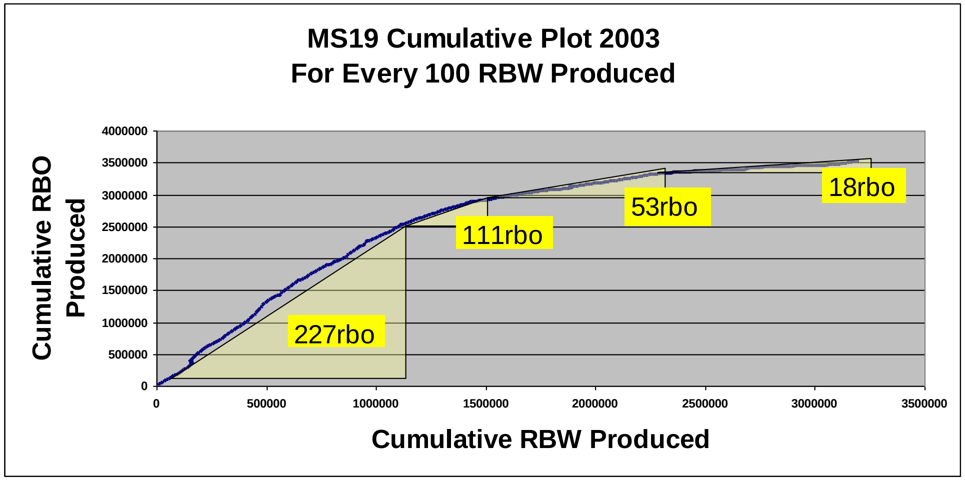
Strathspey Brent Geology

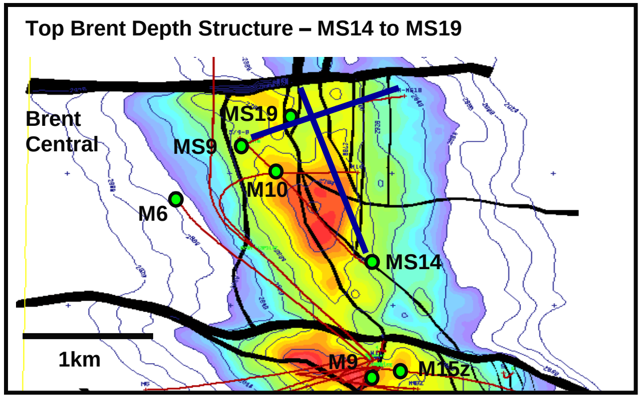


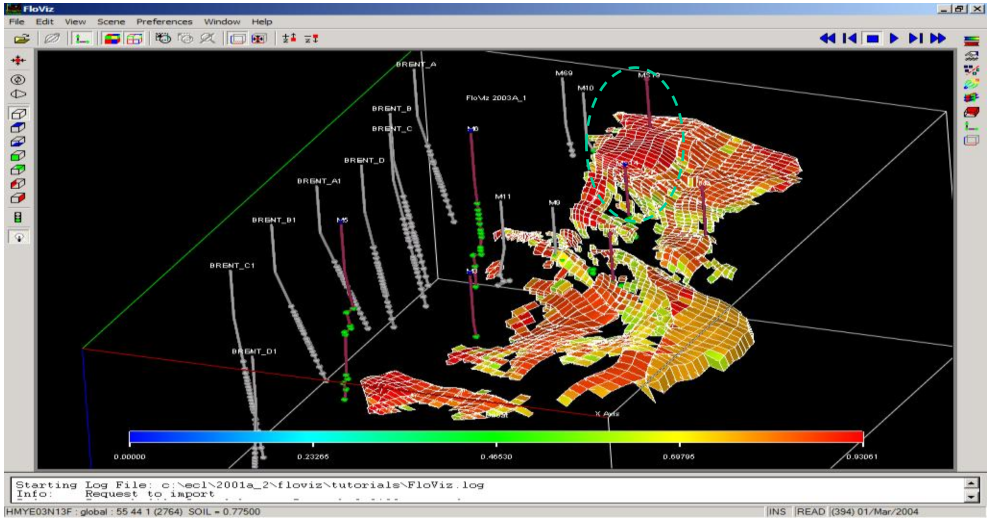


- Favorable mobility ratio has led to efficient sweep in general – Main Field wells
- Geological heterogeneity and complex faulting in the slumped areas has led to localized early water breakthrough and poorer waterflood efficiencies.

MS14 as candidate for BW treatment



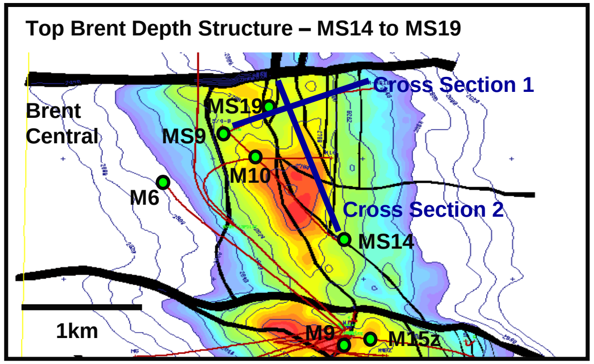




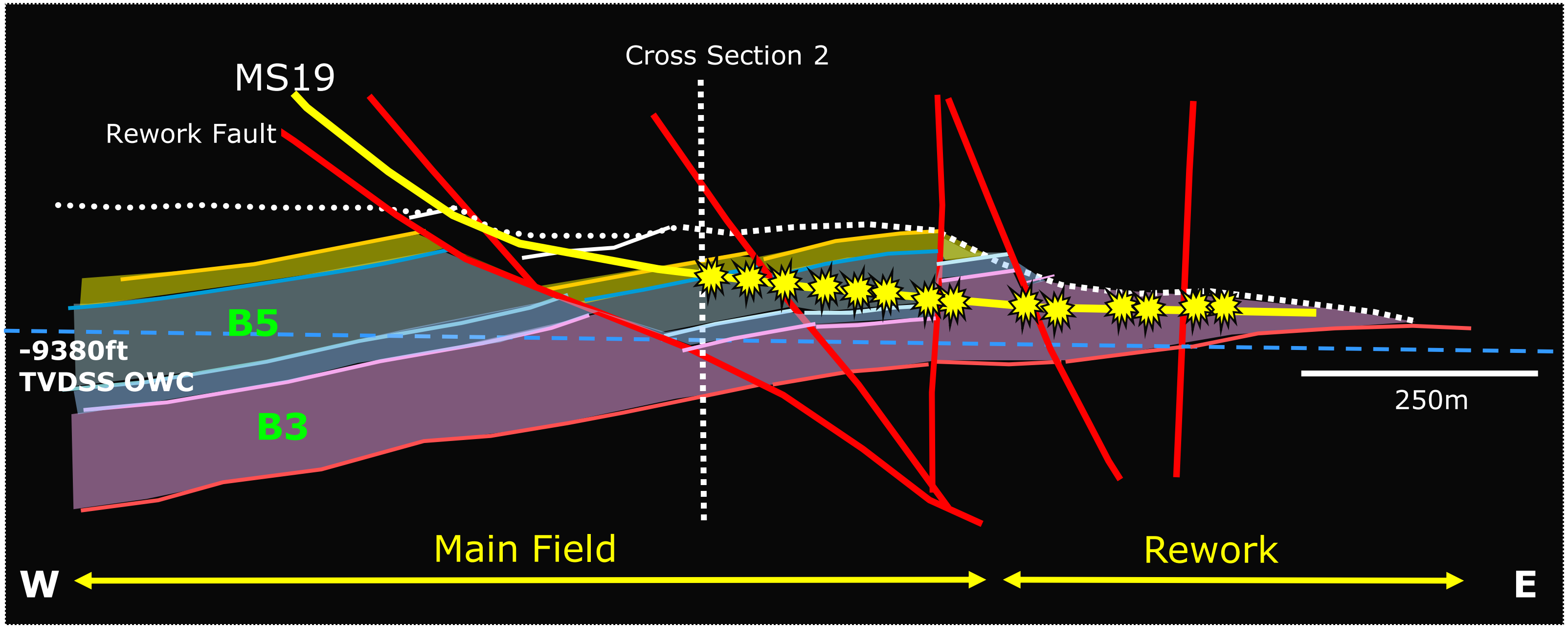
- Fast watercurt development at MS19 after MS14 injection started
- Reservoir simulation indicated high oil saturation around MS19.
- Conventional water shut-off methods require well intervention
  - Cost prohibitive in a subsea environment
- BrightWater treatment recommended for well MS14
  - Treatment deployed in September 2006

Cross Section (W-E) along MS19 well path

- Reworked fault blocks
- Faults act as baffles not sealing
- M6 injector give underlying support but not enough direct support within the fault compartments
- MS14 considered a good injector candidate as it could sweep north towards the faulted compartments
- Hard to get efficient sweep in this area

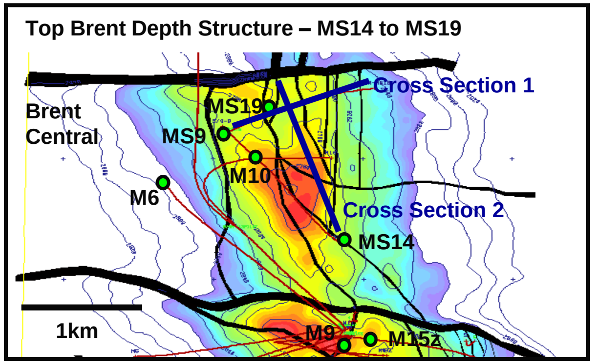


Cross Section 1 - along MS19 Well Path

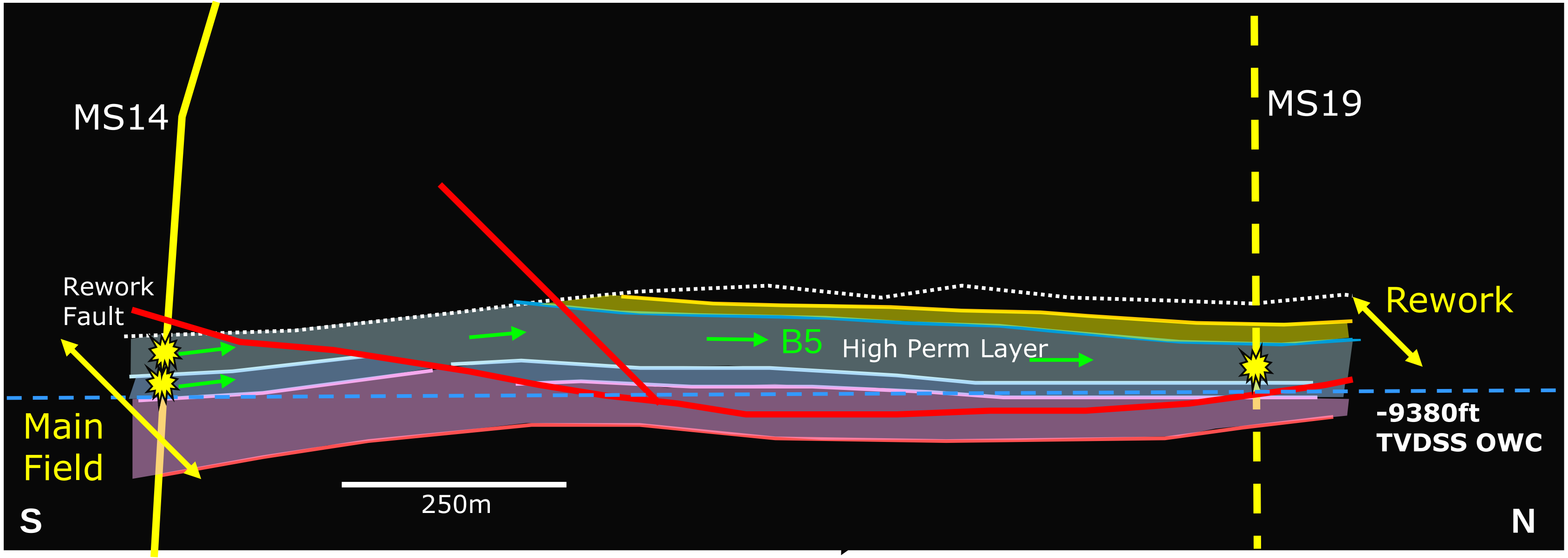


Cross Section MS14 to MS19

- N to S fault structure indicates channeling was likely
- Perm differences between layers indicated thief zones were likely
- Possible improved vertical sweep efficiency was a target
- MS14 was proposed as target for BW



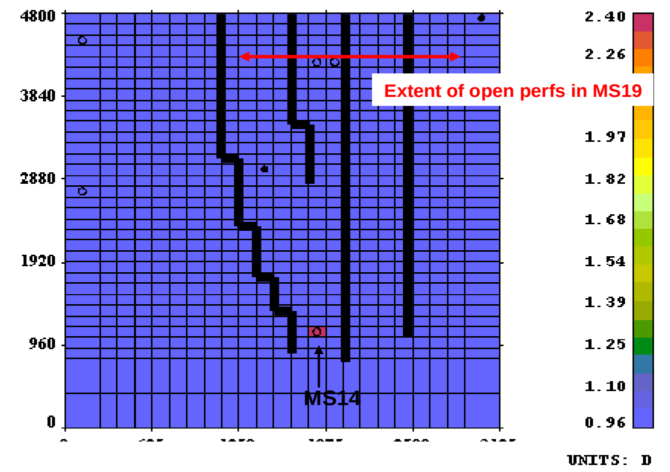
Cross Section 2 - MS14 to MS19



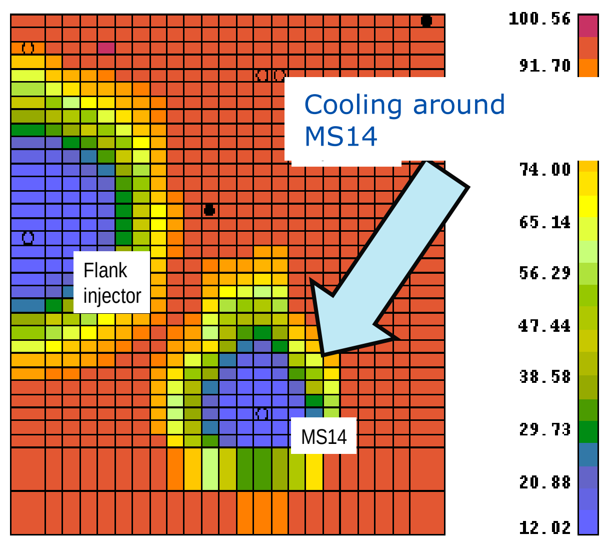
Modeling Process – BrightWater

Temperature regime around injector

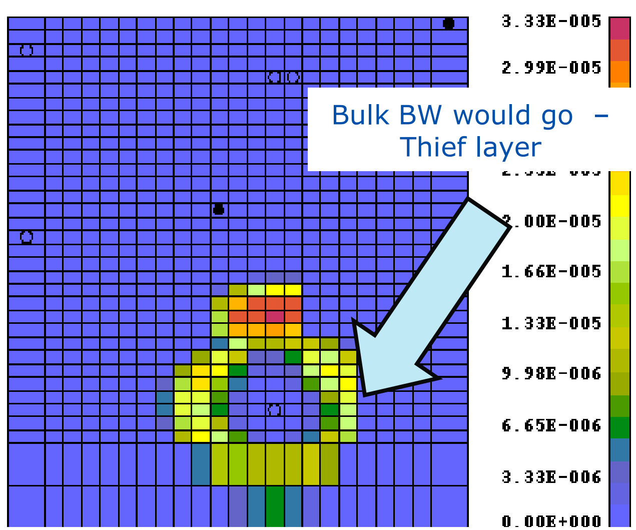
- Use tracer
  - Determine well-well transit time and temp (help select best grade for the application)
  - Look at where the bulk injected BW would go



Temperature Profile



Tracer Concentration



Modeling Process BrightWater (cont…)

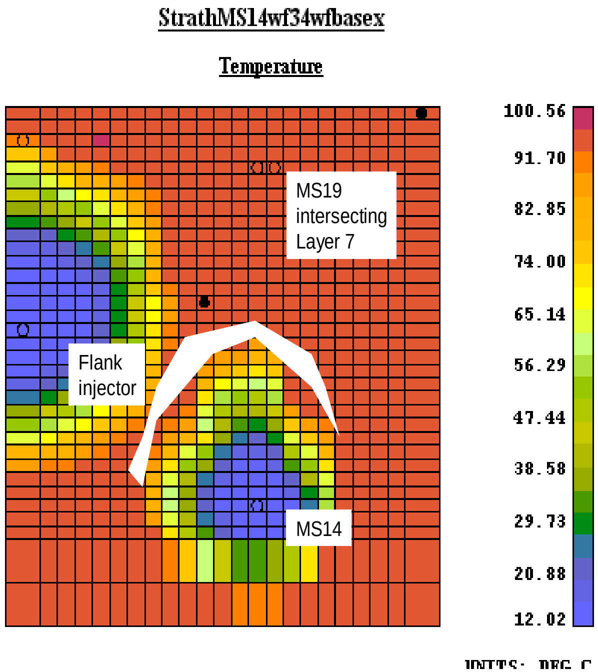
Determine BrightWater Grade using Lab Tests

- Check activation times using bottle tests
- Inject selected BW grade into sand packs to check activation time/strength
- Calculate Resistance Factor
- Reservoir core test to select optimum formulation

Modeling Process BrightWater (cont…)

Predict Incremental Oil

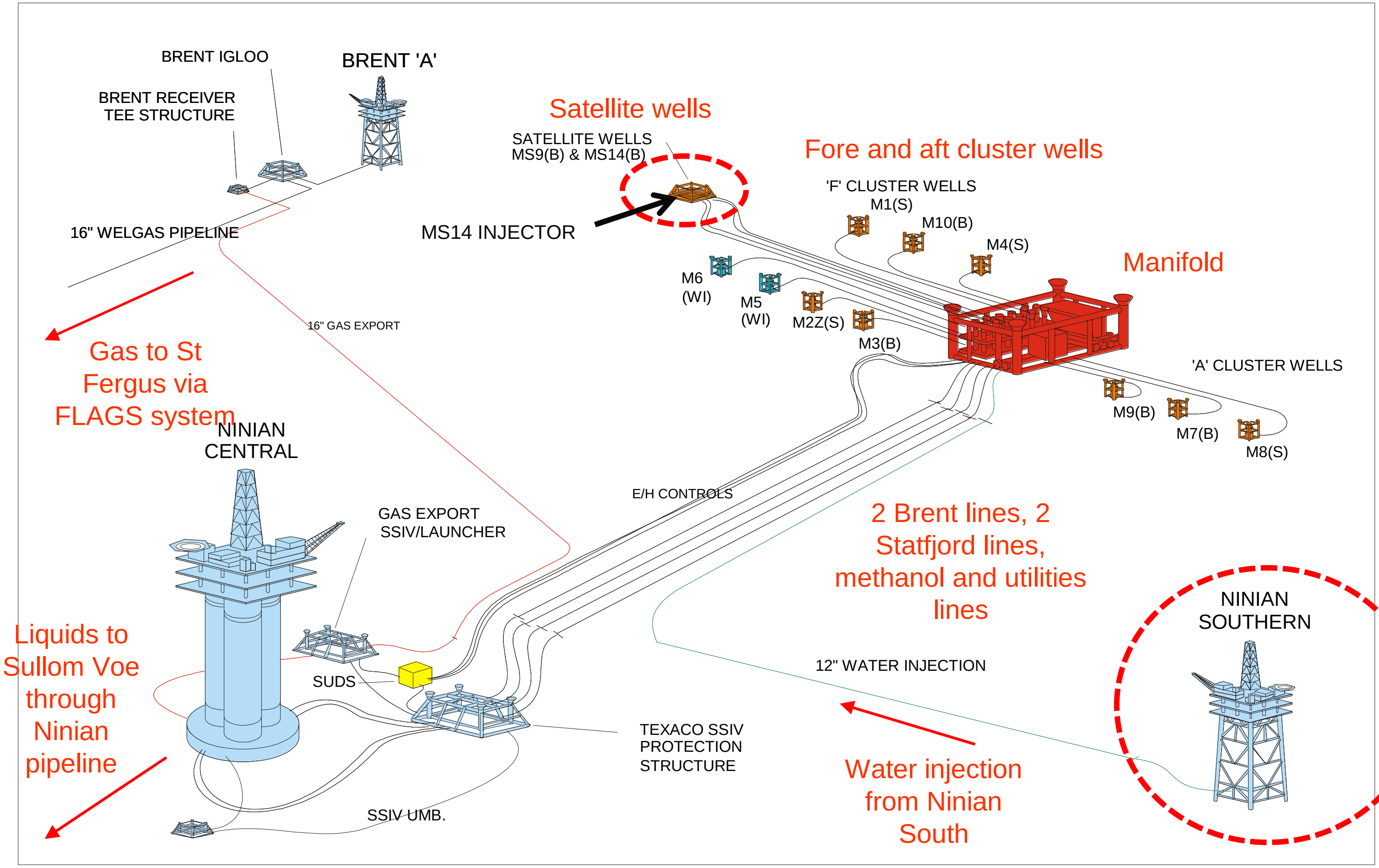
- Run full waterflood history match
- Reduce permeability in the model at the position reached by tracer after heating
- Rerun tracer (assess if water takes a different route)
- Predict oil recovery with and without BW
- Predict incremental oil
- Calculate required treatment quantity



BW - Total Incremental: 250 - 500 mboe

Treatment Execution

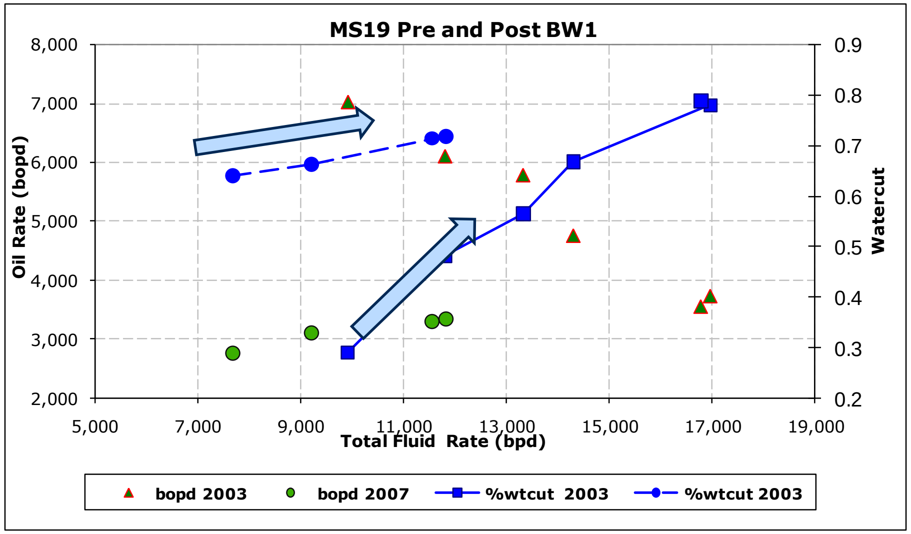
STRATHSPEY SUBSEA LAYOUT

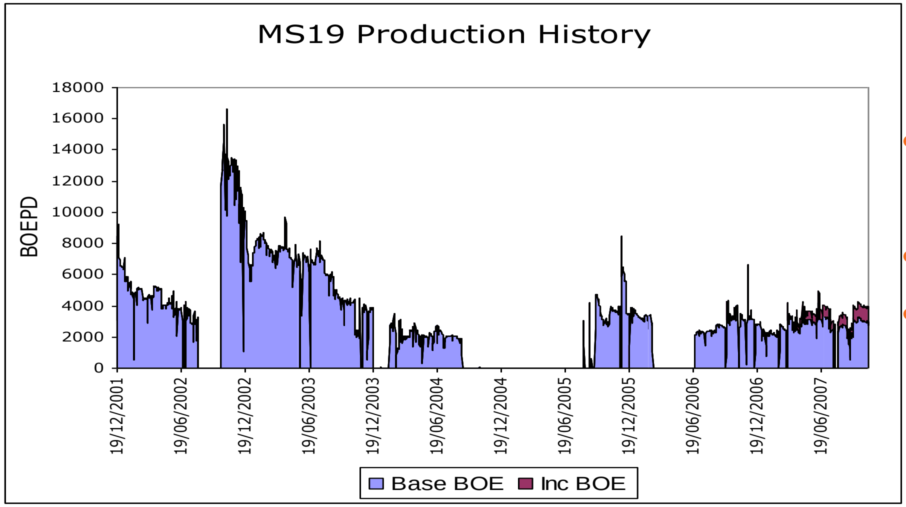


Brightwater Treatment - Logistics

- Planned
  - 140,000 litres Brightwater
  - 70,000 litres BW Surfactant
  - Spiked to 58,000 BBL Injection Water
    - 1.5% Polymer Concentration
  - Pump Time at 22,000 bpd (15bpm)
    - 2.7 DAYS
- Actual
  - Metering Error
    - First Half Of Polymer Treatment At 1%
    - Second Half At 1.5%

Results





- In 2007 the watercut appeared to be more controlled.
- Under similar voidage replacement conditions water cut accelerated to 80% over a matter of nine months in 2003
- BrightWater® slowed down the passage of water considerably between injector and producer.
- Allows MS19 to flow naturally at higher fluid rates with lower water-cut.

- Data indicated oil production rise of 575 boepd.
- Incremental of 130 MBOE first year
- Total incremental hydrocarbon estimated to rise to 317,300 boe

Best Practices and Lessons Learned

Best Practices.

- Committed cooperative efforts among operators, vendors and research insititutes can deliver innovative technologies for enhancing hydrocarbon recovery.
- Investigate all data available to determine transit time between injector and producer. Consider an interwell tracer test first if there is a chance of very rapid connection between wells
- Simple simulation studies add valuable insights to the design and provide useful estimation of incremental oil recovery.

Lessons Learned.

- Long term operator commitment is needed assign resource, monitor results and document.
- Failure of of crucial subsea equipment can make monitoring of well performance very difficult for long periods until opportune availability of vessels is possible.
- More thorough yard trials for pumping Brightwater should be conducted with the vendor and operator personnel present.

Conclusions

- Brightwater was successfully deployed via a 10 mile subsea water injection line from the Ninian South Platform
- The treatment reduced the rate of water injection channeling between injector MS14 and producer MS19.
- The impact on MS19 is that the well can produce at a higher total fluid rate with a lower watercut leading to increased oil production.
- Incremental oil delivered in the first 12 months is 130,000 boe.

Any questions?