RESMAN®

WIRELESS RESERVOIR SURVEILLANCE

New Approach to well design, completion, surveillance and modelling

UK North Sea Operator

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Sr Well Technology Engineer
24th of January 2017

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Passive ICD Field Application • Introduction

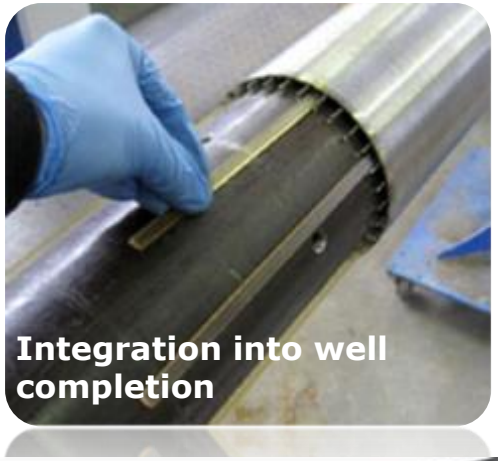
- First passive ICD field trial for UK operator
  - Verify claims from vendor
    - Balance inflow
    - Delays water breakthrough
- Using interventionless PLT information
  - Heel to toe performance (Transient/Steady-State)
  - Model calibration
- Developed new ICD monitoring workflow

How it Works • Inflow Tracer Systems

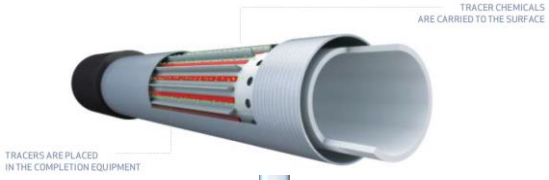
Unique tracer molecule

Engineered Polymer Matrix

Tracer Systems
Up to 160 (80 RES•Oil + 80 RES•H20)
unique intelligent molecule IDs

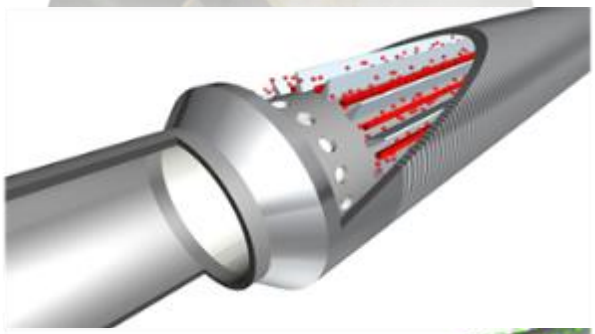


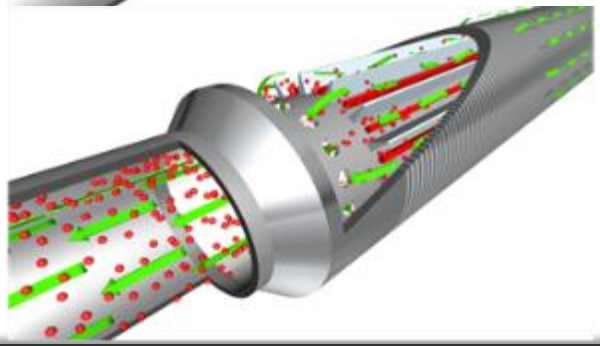
RIH



FLUID CONTACT DETECTION
Oil **or** Water

Molecule Release
Constant release rate
(Flow rate independent)





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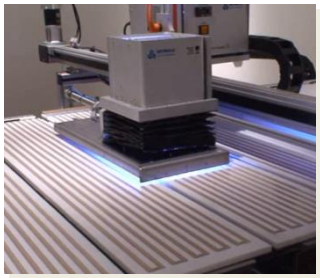
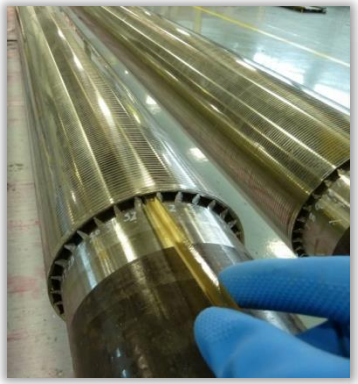
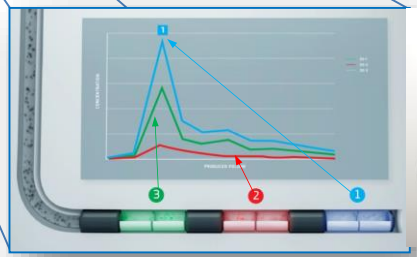
How it Works • Acquisition & Interpretation Process

Design and manufacturing → System integration → Well completion → Sampling → Lab analysis & interpretation





Polymer Matrix
80 oil
&
80 water
unique signatures



RESMAN Project Management procedure is based upon Project Management Methodology set out in the ANSI standard PMBOK® (Project Management Body of Knowledge) created by PMI (Project Management Institute).

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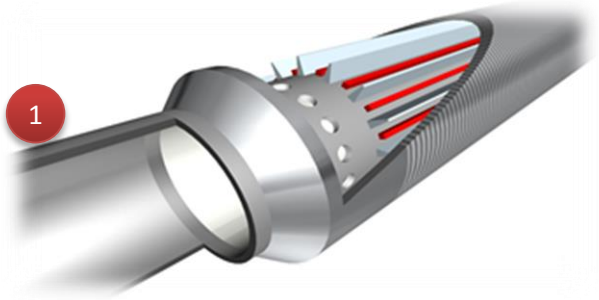
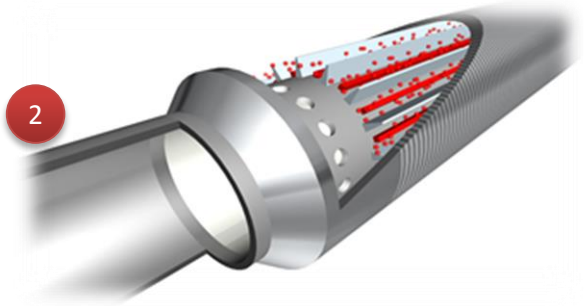
Quantification • Creating a Transient

1. RESMAN integrated into completion

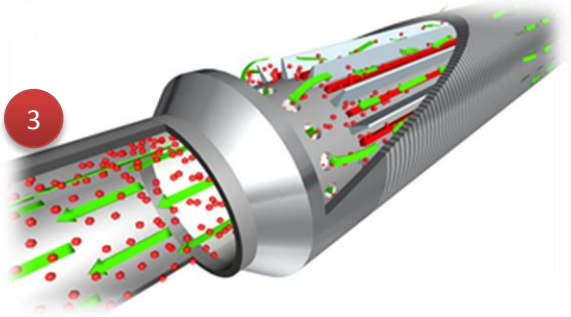
   Completion RIH



2. Static flow periods:
   Intelligent molecule's concentration builds up
   (release is ''rate independent")



3. Start up = concentration is Flushed Out



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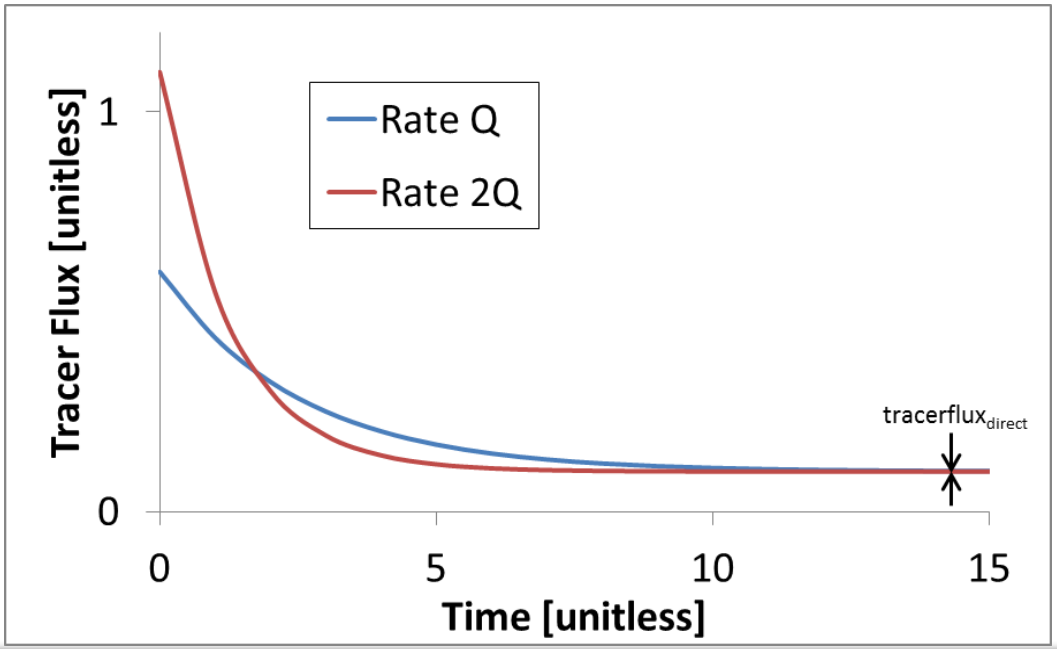
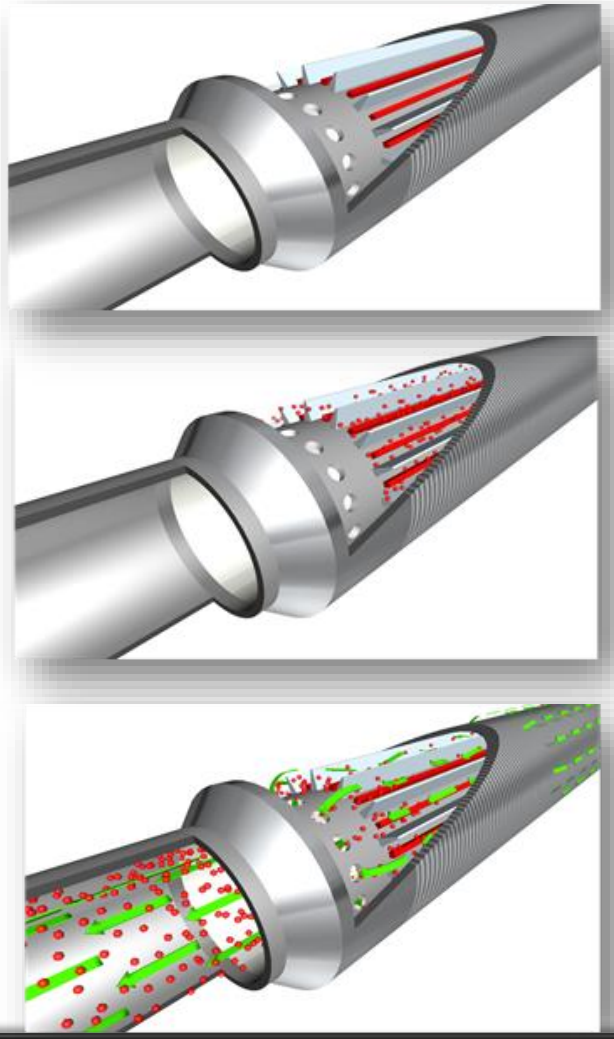
Quantification • Flush Out Model

Shut-in generates locally high concentration *tracer shot*

- Displacing tracer shot during re-start; *flush out*
  - Steep decay curve = high production rate
- Model matching by tuning flow dependent parameter *k*
- ***Patent granted in 2013***





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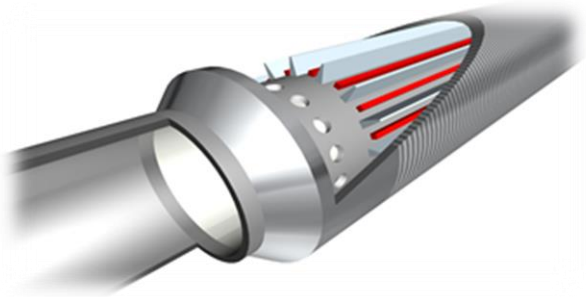
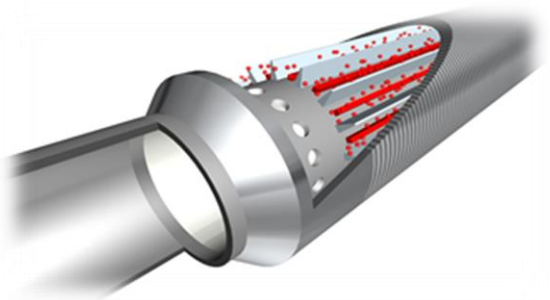
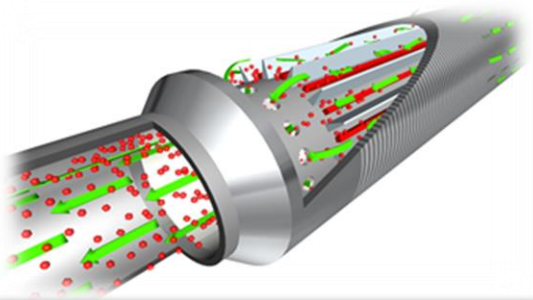
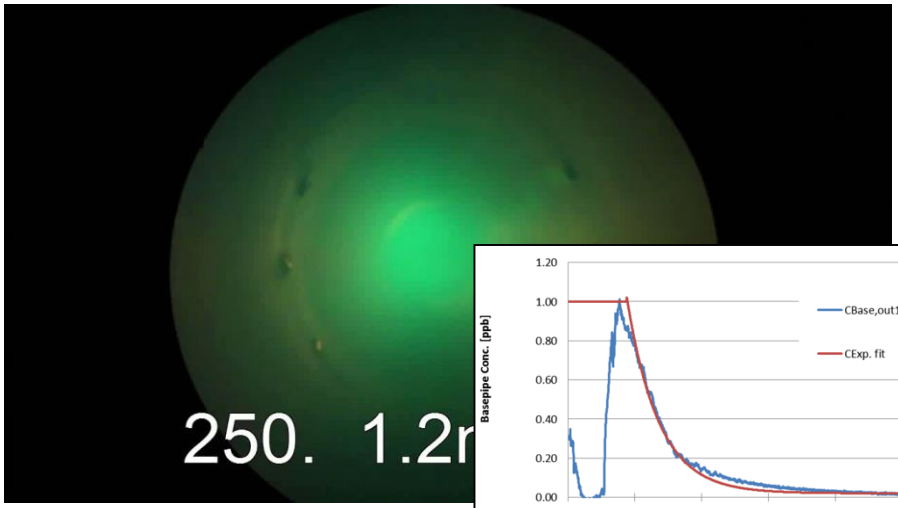
Quantification• Flow Loop Verification









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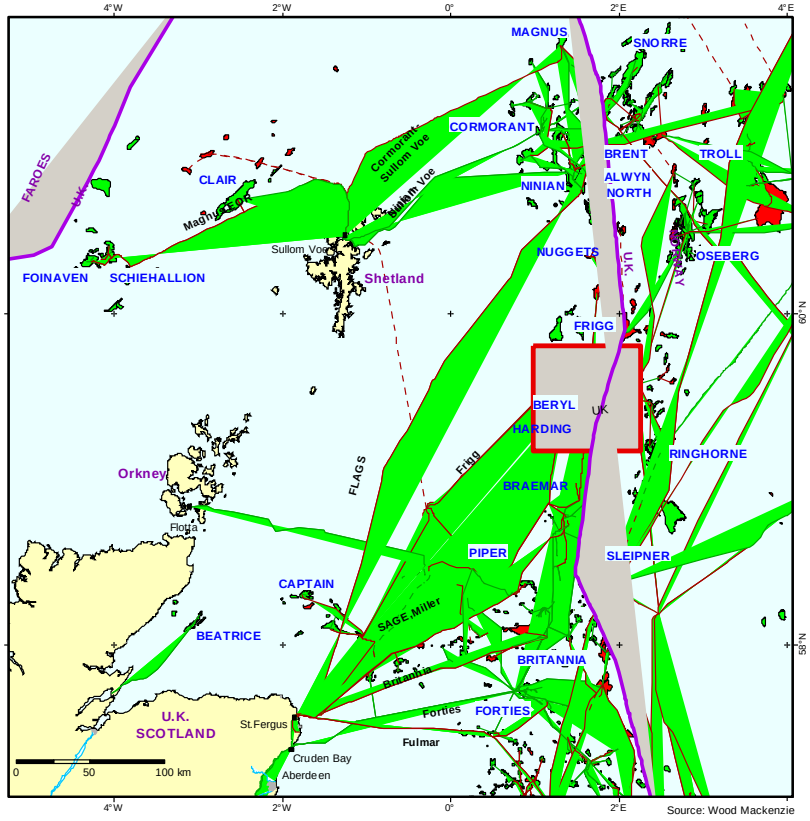
UK Case Study• Field Description

- Field located in UK block 9
- Subsea wells and a FPSO
  - First Oil October 1993
- Current average production
  - 12,000 bopd
  - BSW = 80%
  - GOR = 300 SCF/STB



UK Case Study• Challenge & New Technologies

Challenge

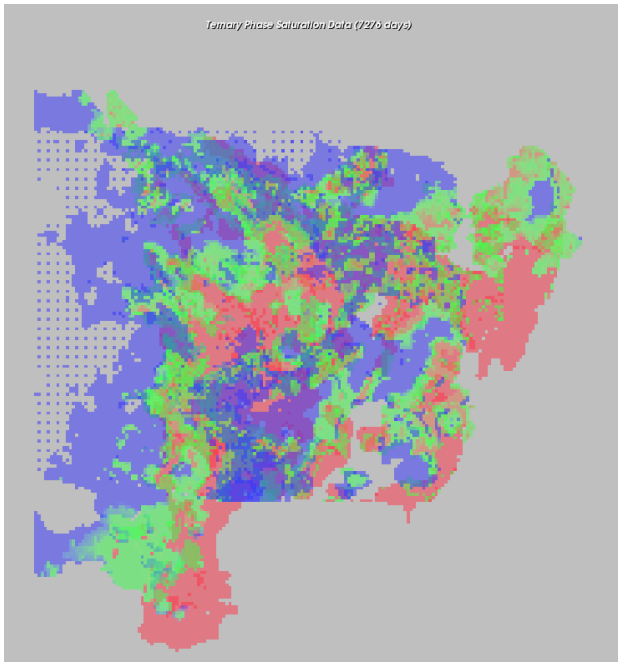
- Very mature field
  - Narrow window of success for new in fill wells
  - Remaining reserves located in injectite type reservoir sections.
  - Production from the toe is key to guarantee an economical success from this well.
  - Subsea development, PLT prohibited expensive and operationally risky.

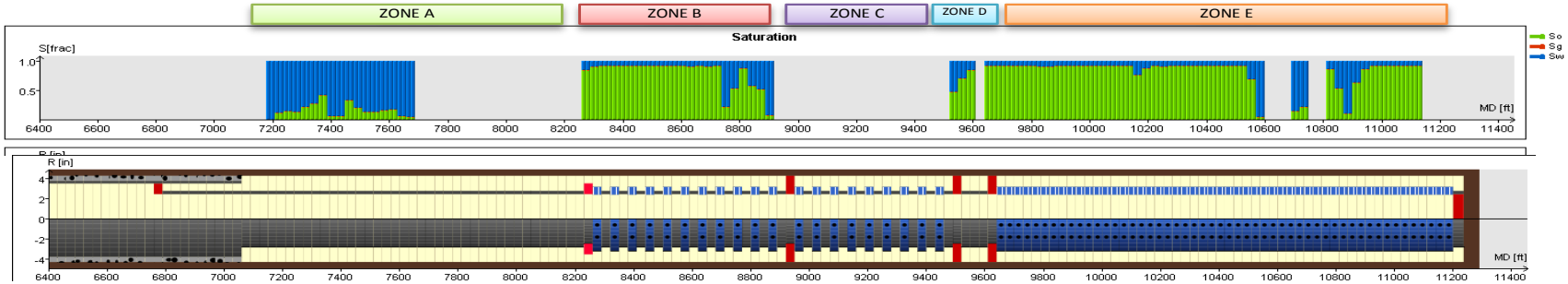
Solution

- Pilot new technologies
  - Passive inflow control devices to delay water breakthrough and balance inflow
  - Inflow tracers for downhole surveillance from heel to toe
  - Near wellbore modelling software

UK Case Study• Pilot Well

- Based on LWD interpretation, completion is partly
  - Passive ICD
  - SAS
  - Blanks
- Inflow tracers indicated flow from heel to toe
- Inflow tracers results used to match production from the detailed well design





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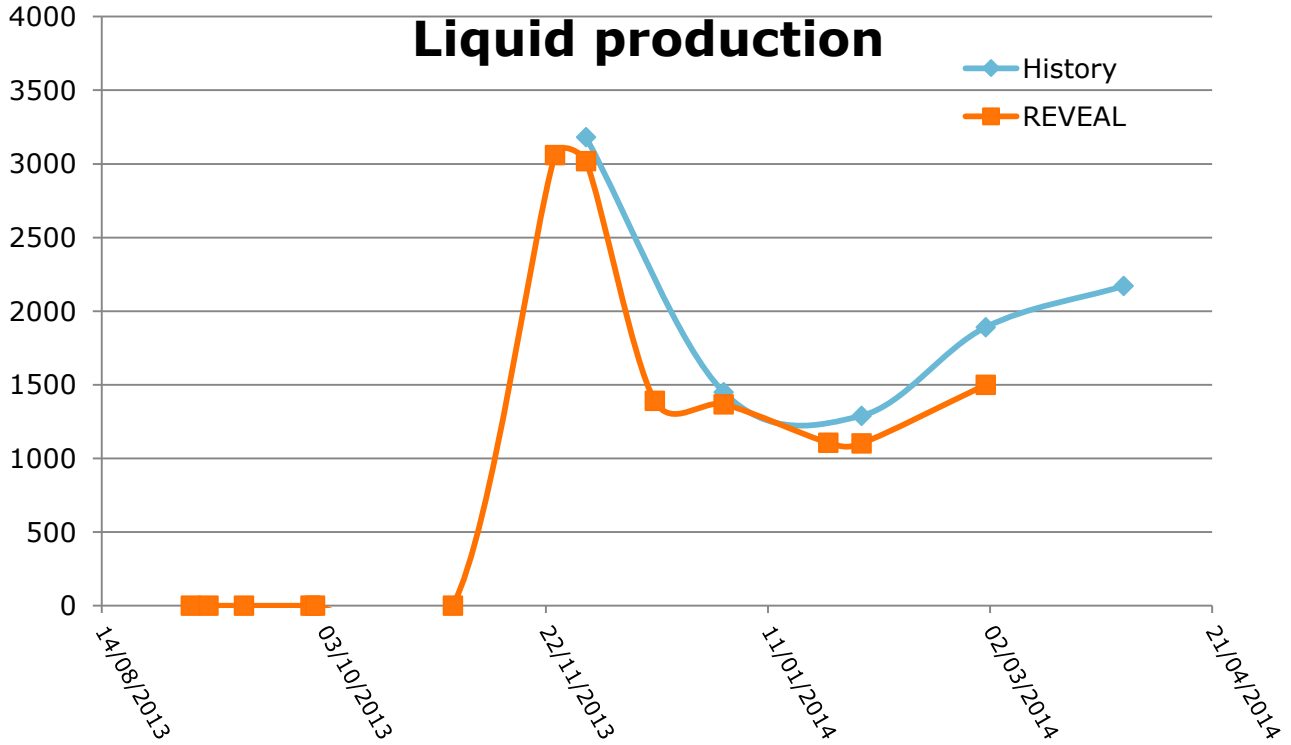
UK Case Study• History Match

- ECLIPSE unable to forecast ICD production accurately
  - First water breakthrough predicted ~5 month
- After 8 months of actual production
  - No water breakthrough and REVEAL matched this behaviour



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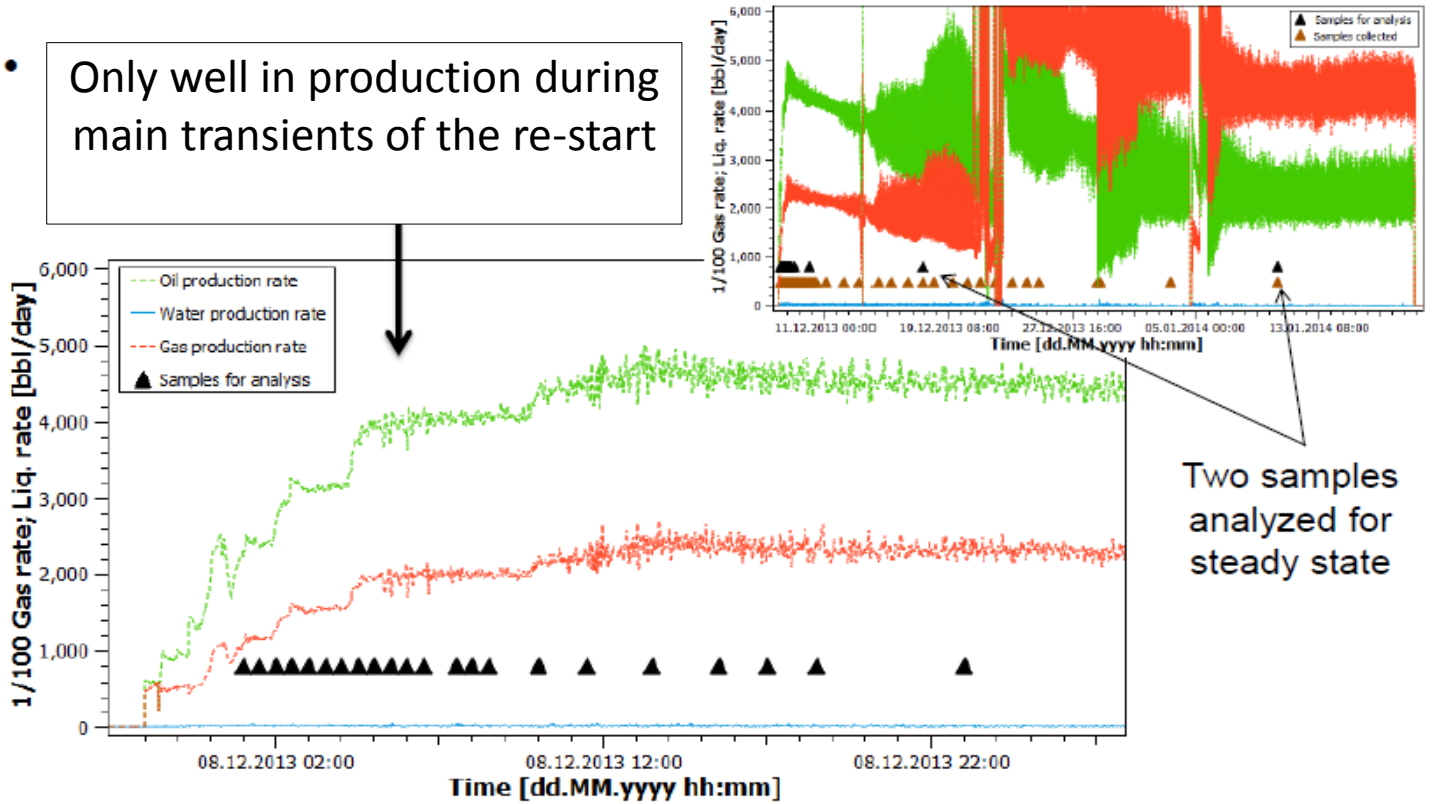
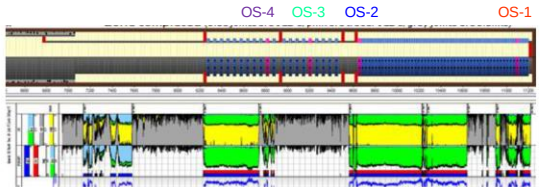
UK Case Study• History Match

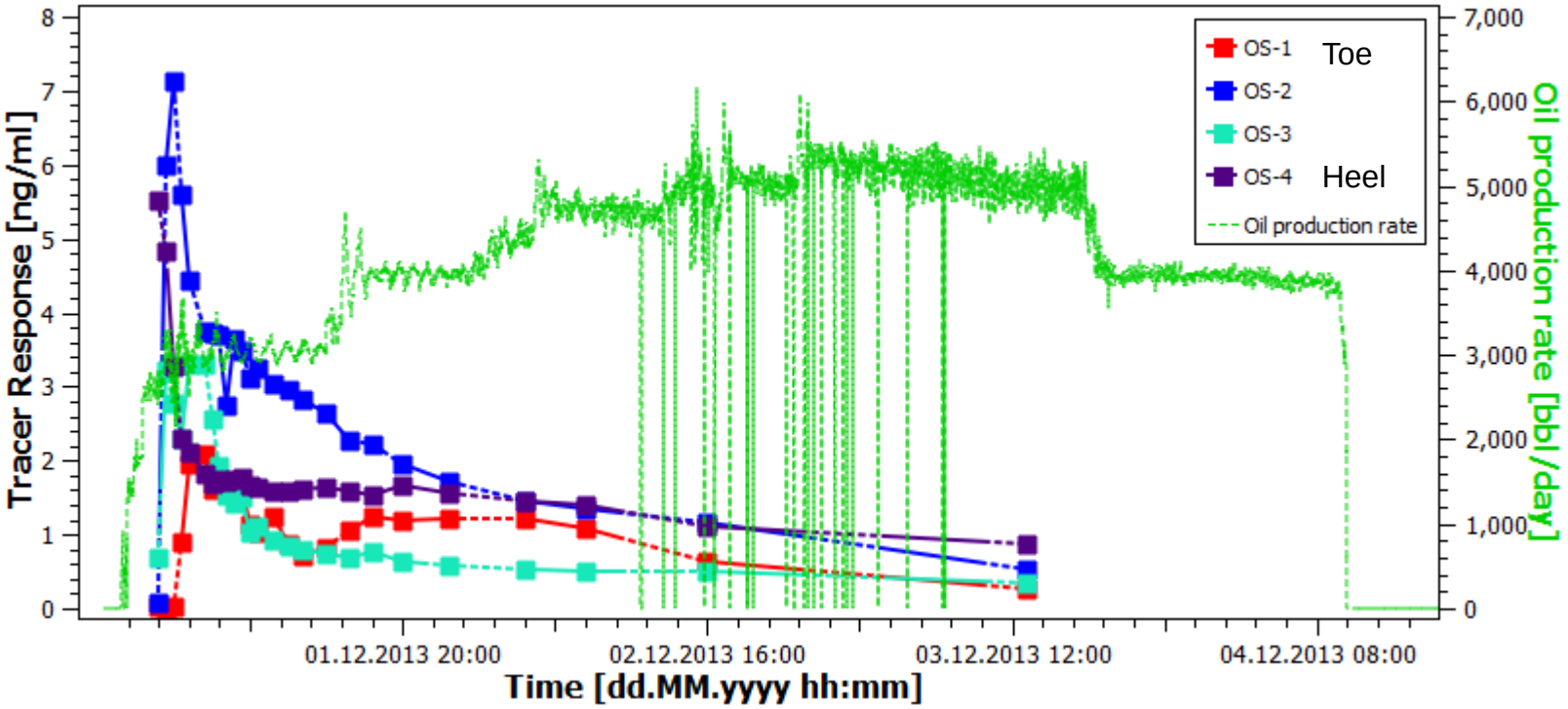
- Samples captured to obtain Chemical PLT ®well restart in December 2013
  - Dry well at the time



Re-start 1 Tracer Signals



- Robust oil tracer (OS) responses from all tracer locations
  - Eligible for inflow distribution by flush-out modeling
  - Indications of productivity improvement for OS-1 (toe)



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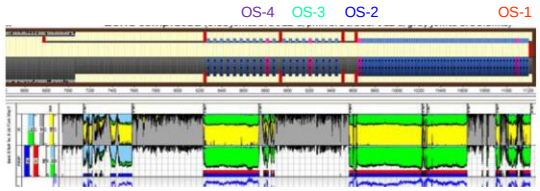
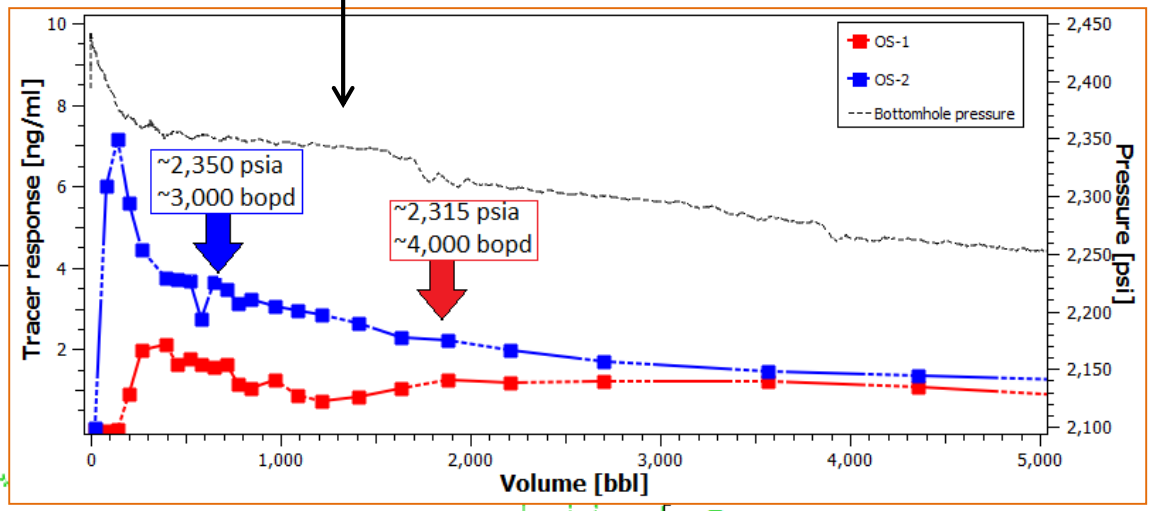
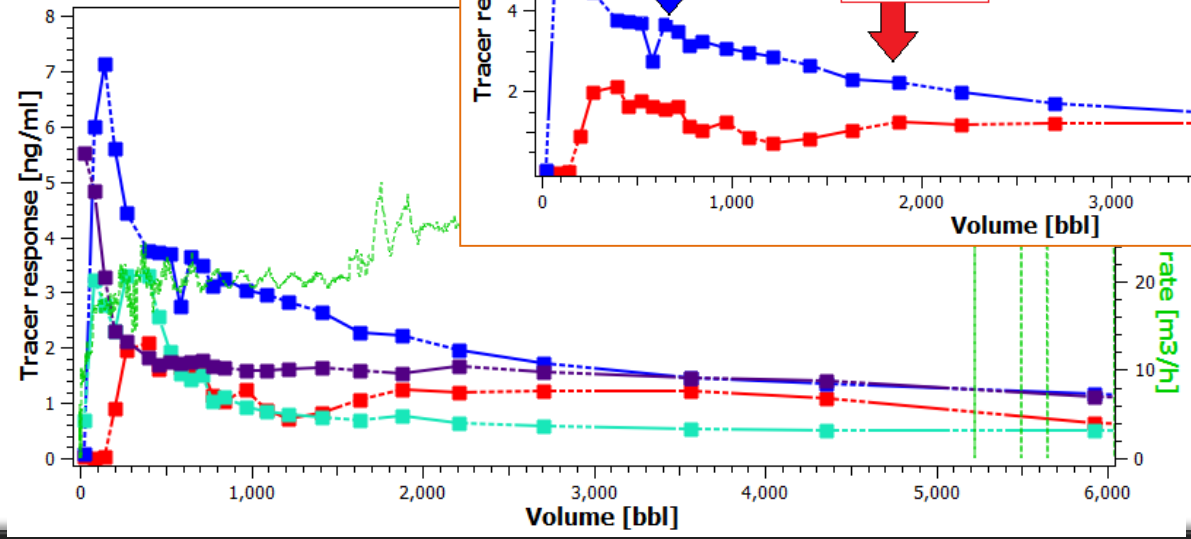
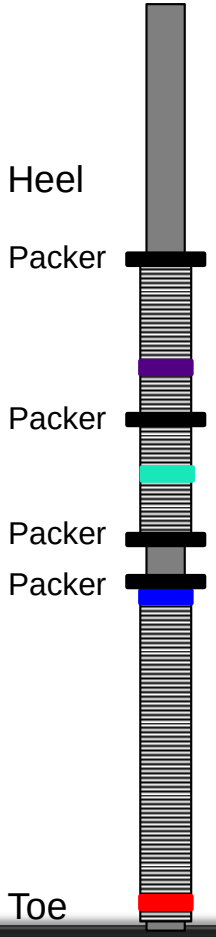
Qualitative Interpretation



- Strong response from **OS-4**, **OS-3** and **OS-2**
- Ongoing clean-up / improvement in lower zone (**OS-2** & **OS-1**)
  - Increased tracer response indicates different lift-off pressures







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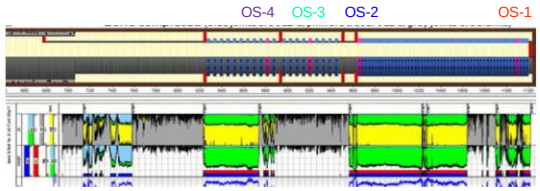
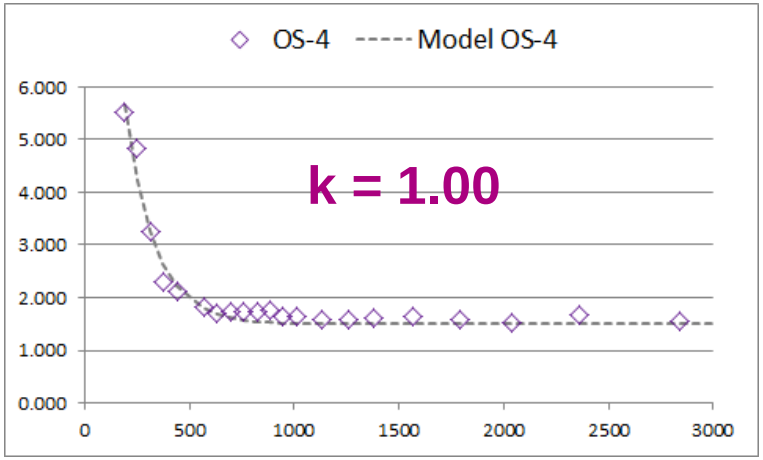
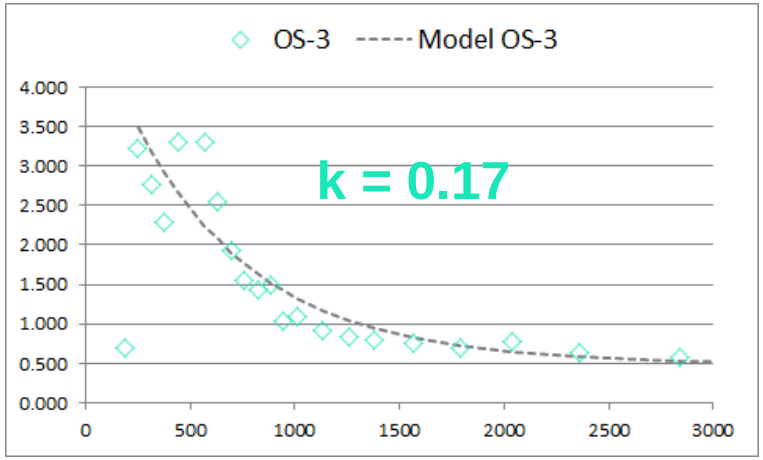
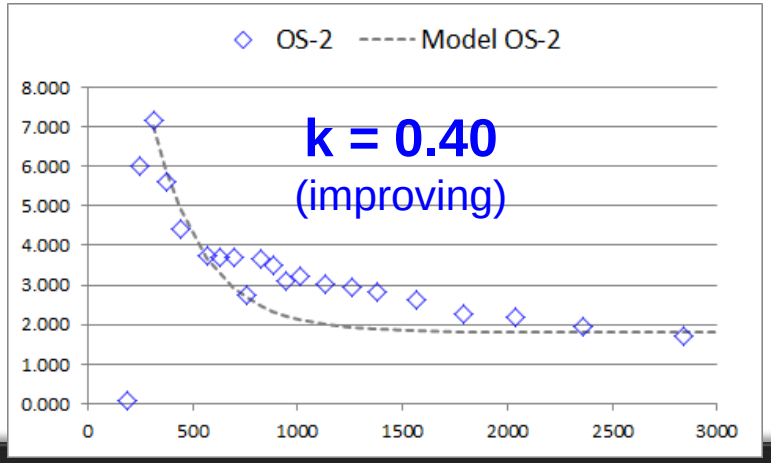
RE1 Flush-out Interpretation

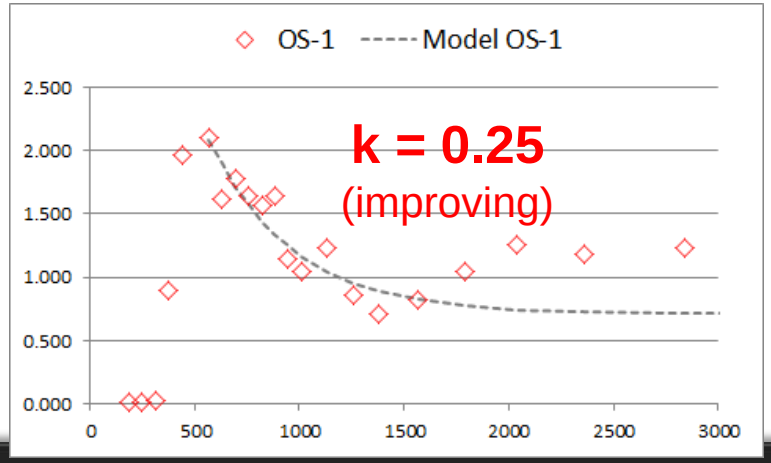


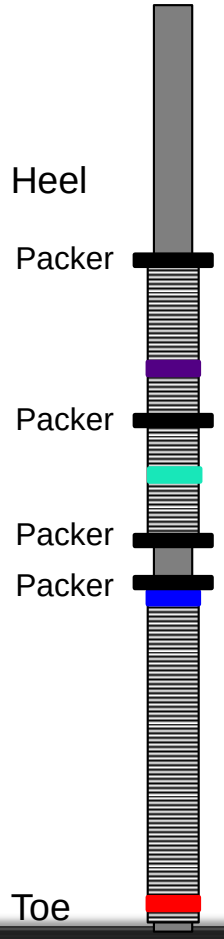
- Dominating heel (**OS-4**). On-going clean-up in lower zone (**OS-1** & **OS-2**)











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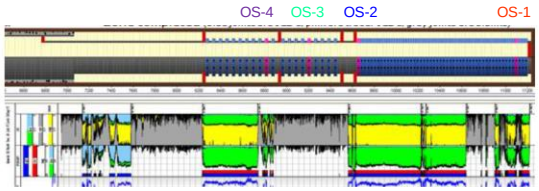
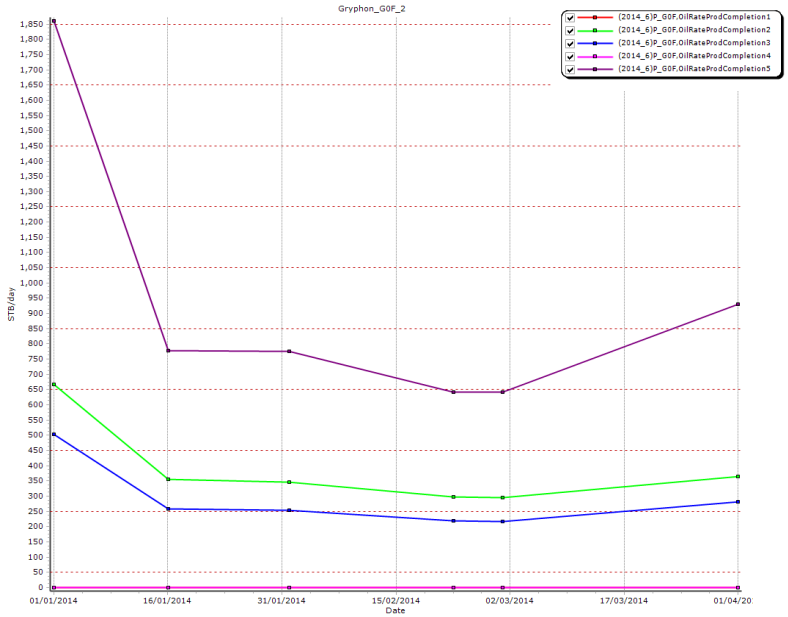
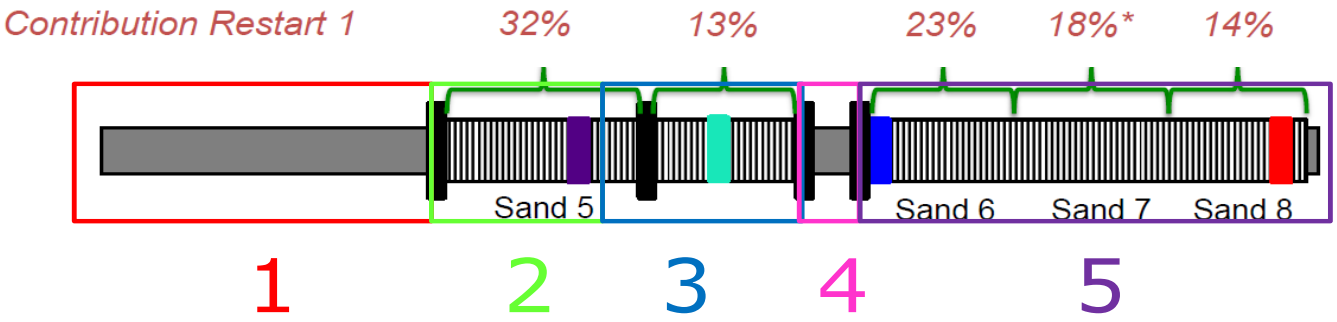
History Match

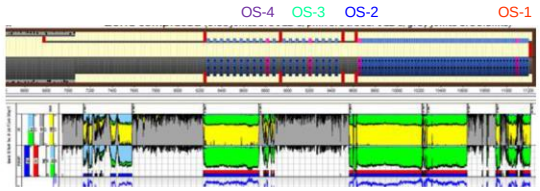


- Tracers placed to monitor
  - Well and reservoir barriers
- REVEAL split the completion zones with numbered rectangles in illustration below
- REVEAL quantifies 55% of the production came from zone 5

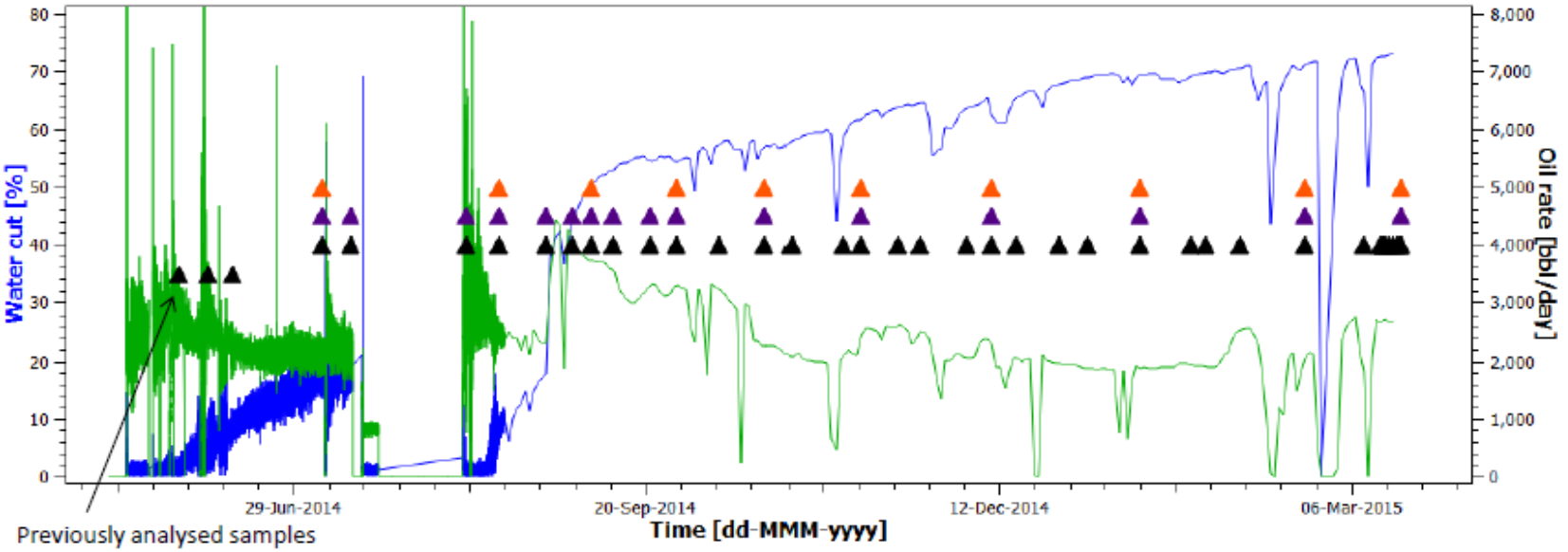




Water Breakthrough



- May 2014 first water breakthrough observed and stabilising in June 2014
- Large increase in August-September
  - Water cut > 70%



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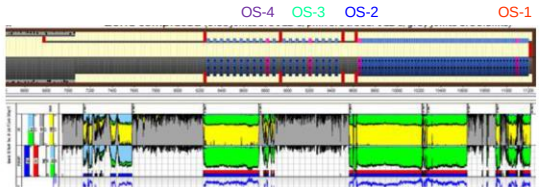
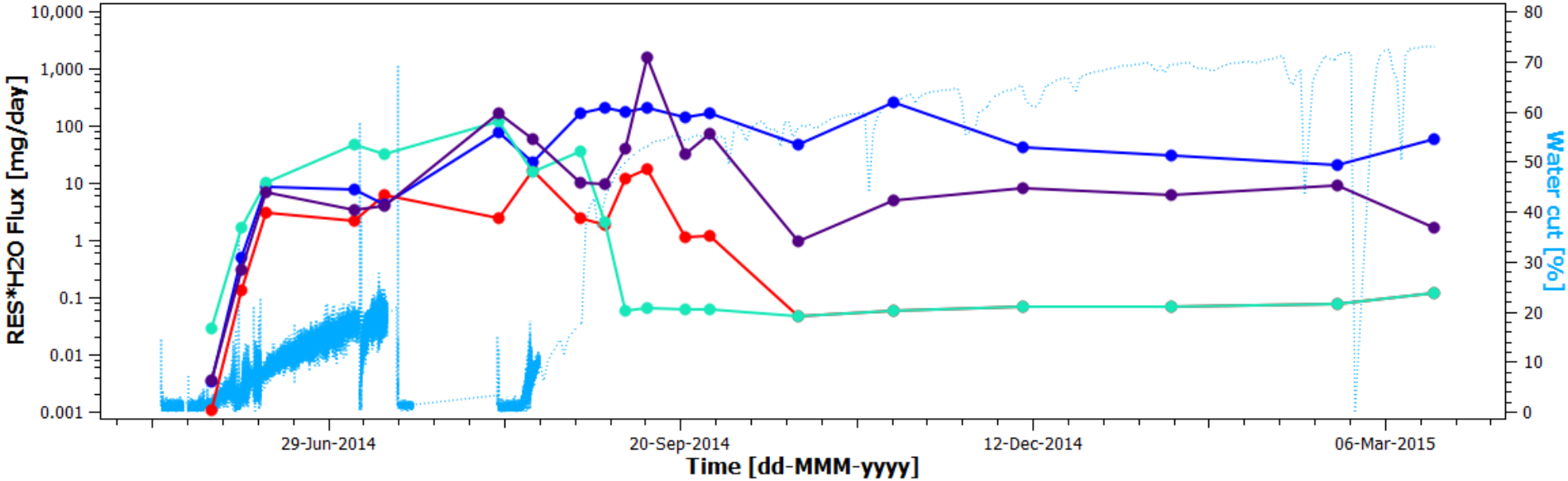
RES•H2O Flux 1

Steady State 2014-15



- All systems respond across WBT
  - Main water production from around 9,641’ MD (**2**) and heel (**4**)
  - Toe (WS-1) with least water production, dropping out from OCT 2014
  - Mid (WS-3) water loading response, dropping out in SEP 2014



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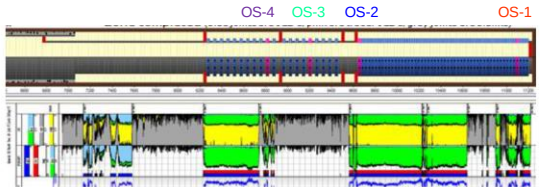
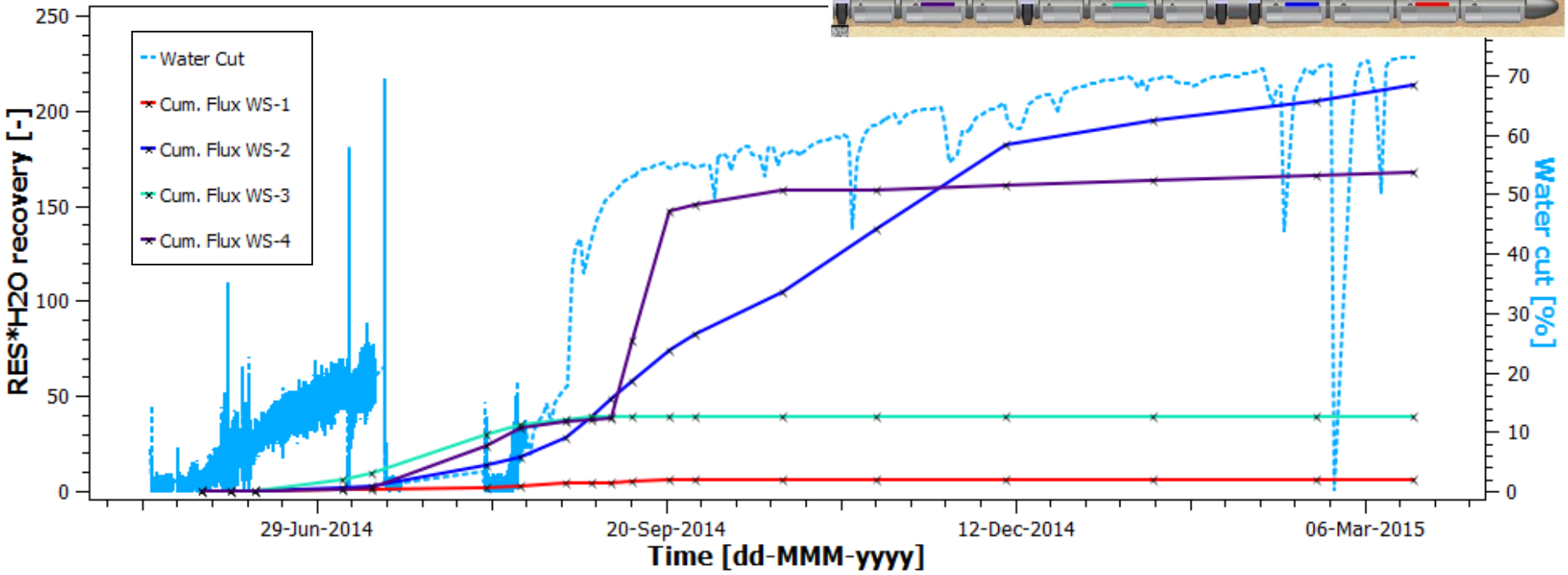
RES•H2O Cumulative Flux 1

Steady state 2014-15



- Gradually increasing water contribution from Sand 6 (WS-2)
  - Consistenly increasing throughout, probably main water source
- Massive water contribution from Sand 5 (WS-4) when WC goes fom 15 to 55%
- Little or no water from Sand 8 (WS-1)



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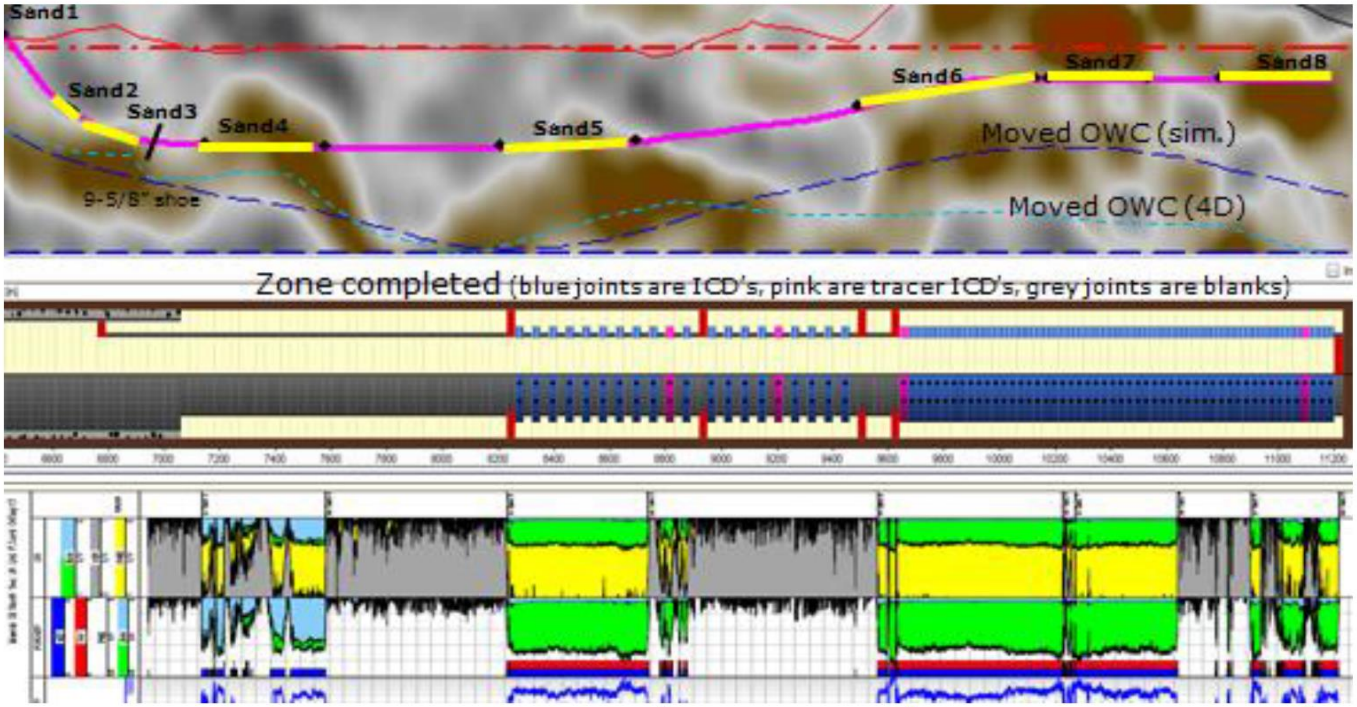
UK Case Study• Water breakthrough Monitoring



- Shale between Sands 5 and 6: Responses seen sporadically, and both oil and water responses drop out from SEP/OCT 2014.

- Oil production confirmed and stable.
- Cutting water and contributing to the largest water production increase, going from 15 to 55% WC.

- Oil production confirmed and stable.
- Main source of water production and continuously adding to climbing water cut.

- Oil production confirmed and stable.
- Little or insignificant contribution to water production

UK Case Study• Conclusion

- Applying appropriate modelling tools and incorporating inflow tracer data can improve the well construction process from design to forecasting

- The operator used ECLIPSE **without** Multi-Segmented Well option
  - Matched bulk well rates only with pressure and near wellbore saturations,
  - Friction not modelled
  - ICD not modelled
  - No zonal isolation

- REVEAL modelled the ICD/SAS completion with zonal isolation
  - Forecast predicted water breakthrough was imminent

- Inflow tracers results allocate voidage per sand in model
  - successfully forecasting water breakthrough

- The voidage per sand was extrapolated to offset wells and utilized as new input for new well location and completion design

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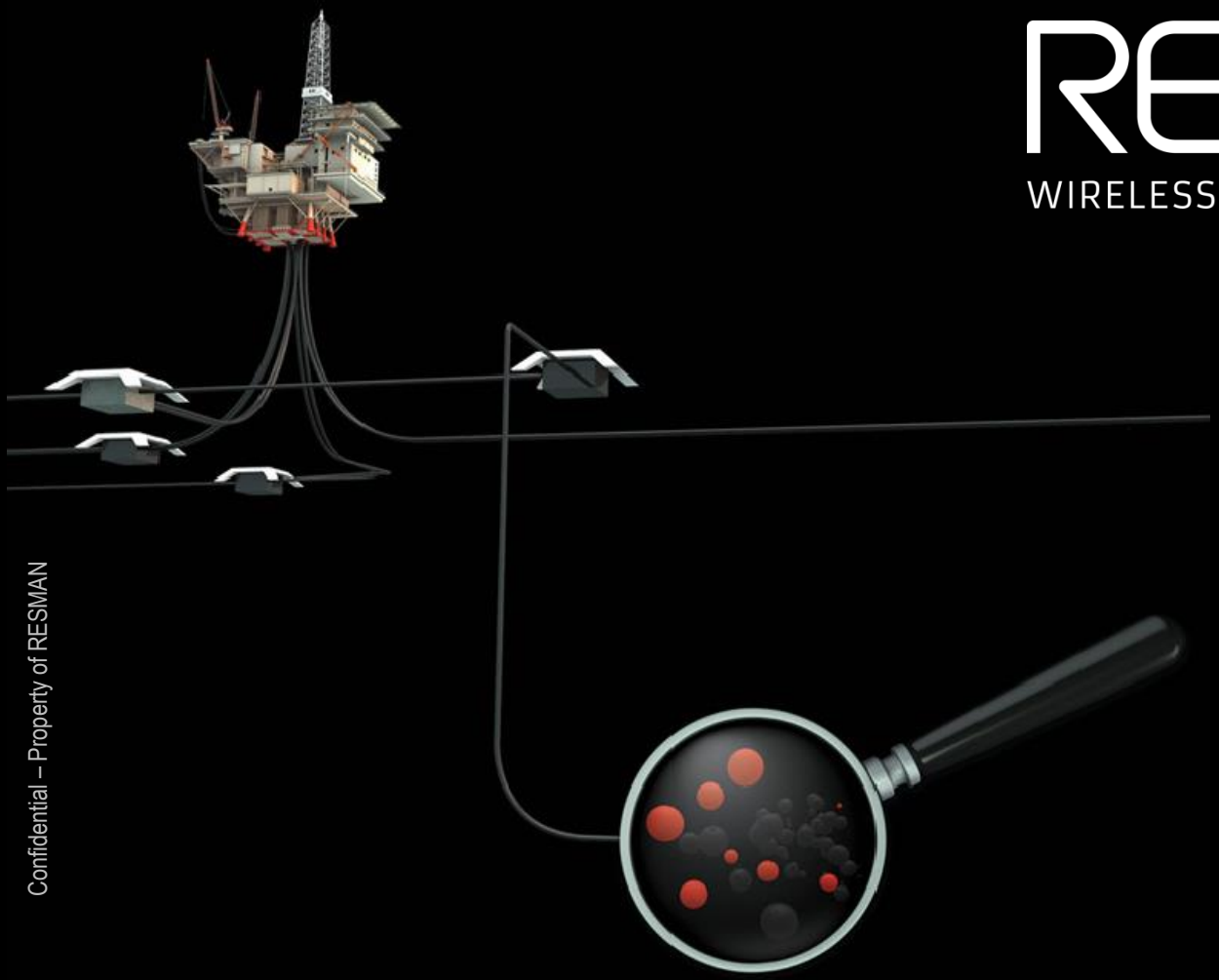

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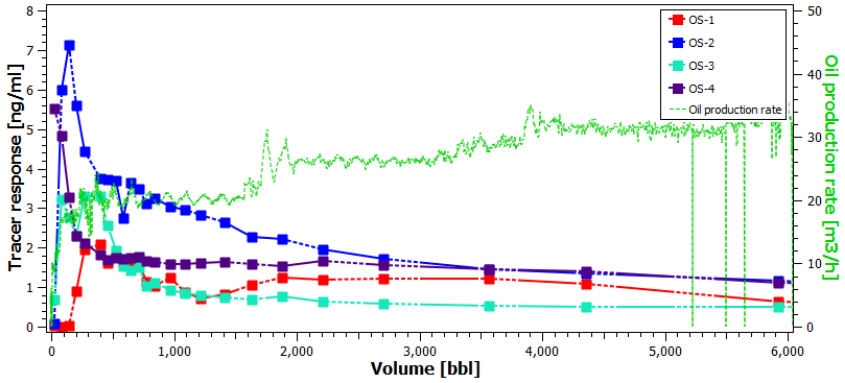
UK Case Study• RESMAN as input for well modelling

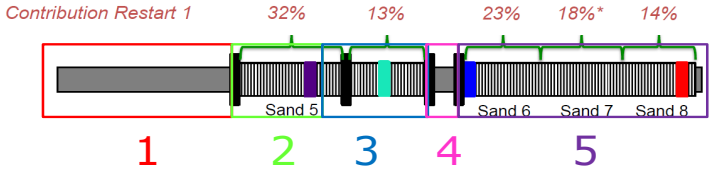
- Quantitative data obtained from a well restart was used as input for detailed well modelling.

Qualitative Results

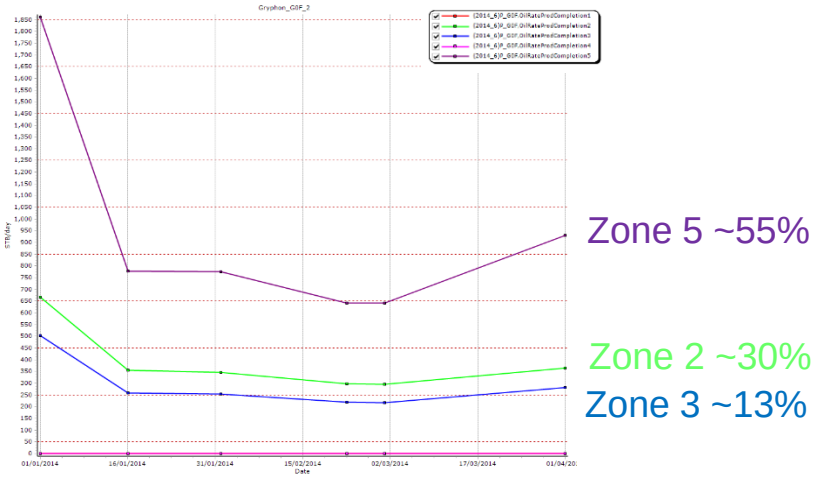


The dynamic model was updated with the detailed completion well design and production history, matching the well sections contribution with RESMAN results, ***successfully forecasting water breakthrough***

Quantitative Results



Well / reservoir simulation Results



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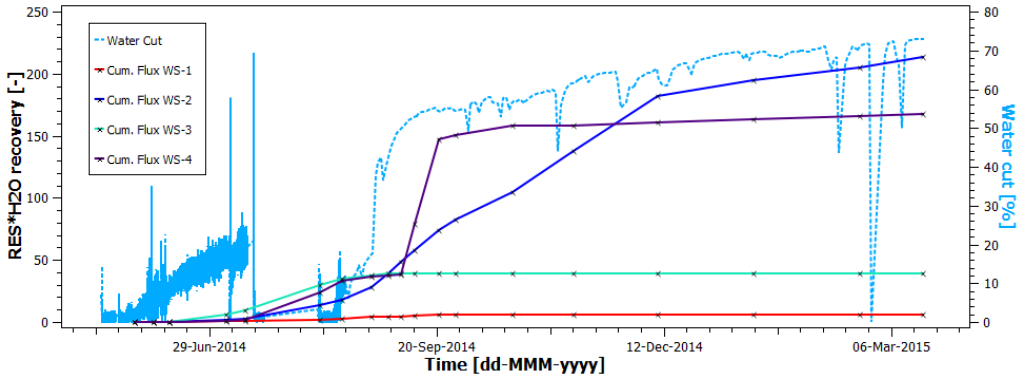
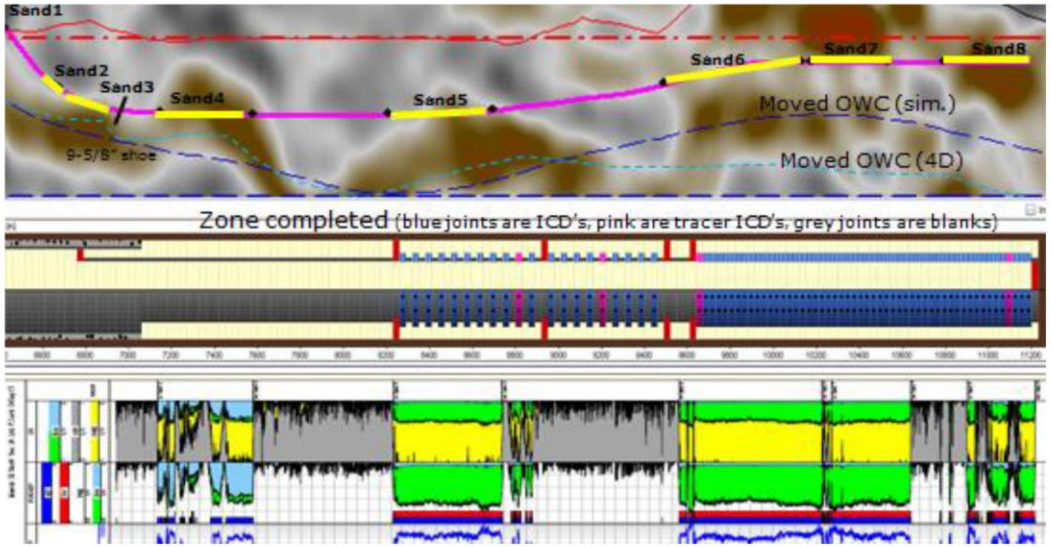
UK Case Study• Water breakthrough monitoring

Cumulative tracer flux was plotted against water cut



Combining tracer results with completion and reservoir information, it was possibly to identify two WBT events that happens during the Steady State monitoring.



- Shale between Sands 5 and 6: Responses seen sporadically, and both oil and water responses drop out from SEP/OCT 2014.

- Oil production confirmed and stable.
- Cutting water and contributing to the largest water production increase, going from 15 to 55% WC.

- Oil production confirmed and stable.
- Main source of water production and continuously adding to climbing water cut.

- Oil production confirmed and stable.
- Little or insignificant contribution to water production