LTRO Workflow for Fast Turnaround Field-Optimisation Studies and Efficient Development Decisions*

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Search and Discovery Article #42190 (2018)**
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Abstract

Getting the most out of existing assets and optimizing production can be a time-consuming and technically complex exercise when using traditional static and dynamic modelling workflows, which hampers fast and cost effective decision making. This article presents a case study of an alternative approach using LTRO (Locate-the-Remaining-Oil) technique that identifies potential drilling opportunities in a fraction of the time with the same confidence level as the traditional dynamic modelling approach.

The study, conducted on the Marmul GNR Field located in the South of Oman, used an efficient ROCM (remaining oil-compliant mapping) workflow within an advanced LTRO software package. The goal of the study was to perform an evaluation of quantified and risked remaining oil for infill drilling. This assessment was then combined with the forecast for the various infill scenarios using predictive analytics approach driven by neural network engine coupled with ROCM. To benchmark the results of the study against 3D reservoir simulation, a dynamic sector model was created and history matched.

From LTRO perspective, Marmul GNR has a number of challenges starting from the fact that for the last 25 years the field has been developed by radial horizontal producers. The geological challenges are related to the high degree of reservoir heterogeneity, which, combined with high oil viscosity, leads to water-fingering effects.

In this article we present an overall workflow to determine risked remaining oil distribution, along with the results of ROCM and a full-field forecast for infill development scenarios by using neural network predictive analytics. The applied innovative workflow provides a breakthrough in reservoir management. This methodology has a potential to become a reliable alternative approach to be used over the conventional reservoir modelling, providing equivalent results in a fraction of the time and thus allowing for efficient decision making in mature oil field redevelopment.

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APACHE
NEURAL NETWORK PREDICTIVE ANALYTICS
A PART OF POSEIDON SUITE

POSEIDON

LTRO WORKFLOW FOR FAST TURNAROUND FIELD OPTIMISATION STUDIES AND EFFICIENT DEVELOPMENT DECISIONS

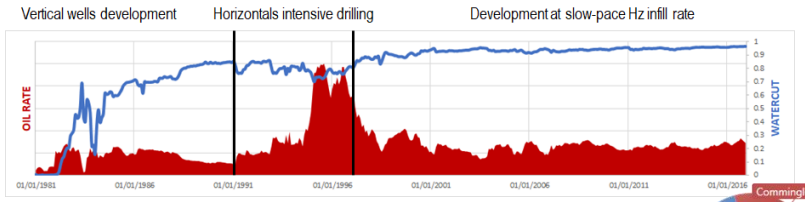
Delivering value-driven solutions for the Upstream Oil&Gas industry

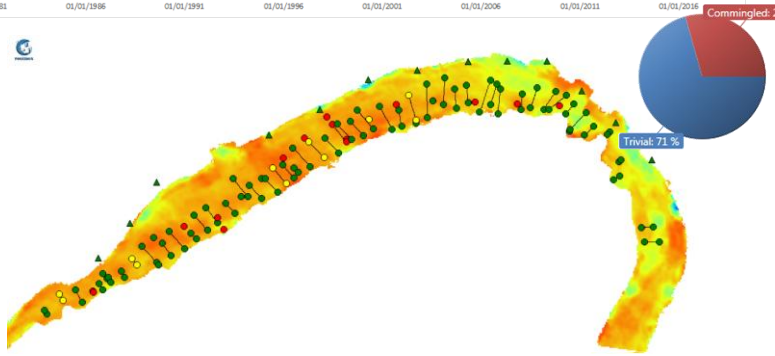
- RESERVOIR MANAGEMENT SOLUTION
- ADVANCED PRODUCTION ALLOCATION
- INFILL DRILLING IDENTIFICATION CAPTURING SUBSURFACE UNCERTAINTIES
- MACHINE LEARNING QUANTIFICATION FOR DEVELOPMENT SCENARIOS (1000+ well in total)

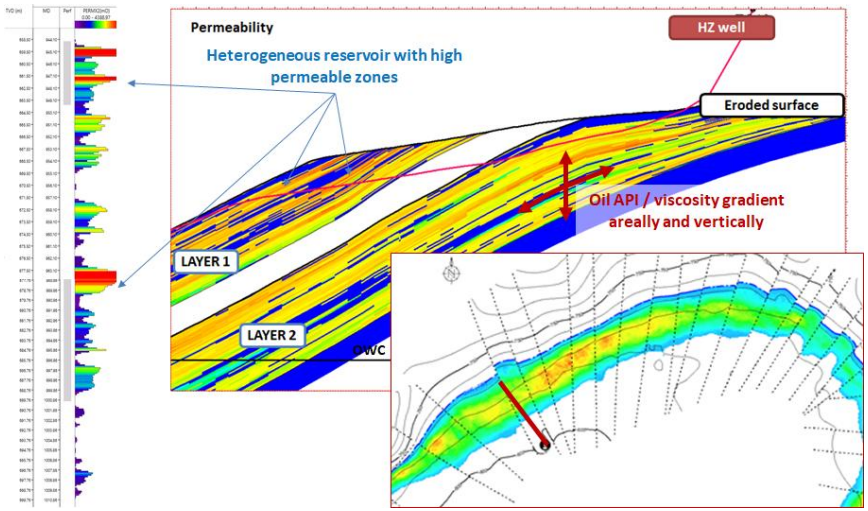
LEAP Energy
TARGET
شركة تنمية نفط عمان
Petroleum Development Oman

MARMUL GNR

- Accelerated Mature Field Further Development assessment
  - **3 months end-to-end project**
  - Delivered infill drilling locations, EUR/well
  - ROCM technology & machine learning
  - Subsurface uncertainty assessment
  - Setting a new standard for mature fields







- The asset complexities
  - 30+ years producing
  - 100's horizontal + 10's vertical wells
  - Two main producing zones
  - Recent WI implementation
  - Heavy Oil, API = 20, Visc = 100-1000 cP
  - High water cut >96%

A SIGNIFICANT ACCELERATION VS. TRADITIONAL WORKFLOWS

The Opportunity… A mature field with low recovery factor and potentially significant undrained volumes; can more be economically recovered ?

Operator dilemma… the long road of reservoir simulation with uncertain results vs. traditional analytical methods with limited quantitative capability

Straight into full field static & dynamic modelling
Long process (8-12 months), Large resource loading; History-matching unlikely to be fully well-compliant… problematic for infill decisions

Revert to 'simple' traditional analytical workflows (OFM maps, MBAL)
Simpler and faster, but historically proven not to be sufficiently quantitative: how to estimate confidently and consistently incremental reserves from infill wells ?

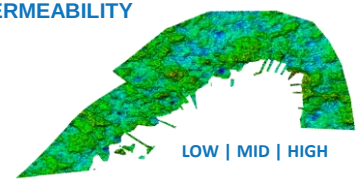
The Innovative LTRO workflow: 3 months end-to-end comprehensive assessment
Delivered high-graded infill locations, risk assessment, EUR/ well and production forecast for each well location with uncertainty assessment (P90/P50/P10). Predictions validated by full physics simulation sector model

RAPID ANALYSIS	RESERVOIR DECISIONS
• Feasibility of alternative development schemes	Understanding of flow pattern and infill scenarios economical viability analysis. Full-field predictions
• Infill locations	Infill locations identification, quantification, prioritization and risking
• Water shutoff opportunities	Wells screening and prioritization

KEY UNCERTAINTIES FOR THE FIELD

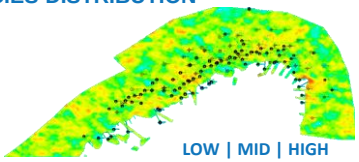
SUBSURFACE UNCERTAINTIES

PERMEABILITY



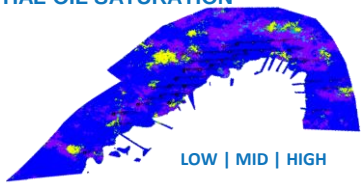
Limited and/or unreliable core data hence poro-perm uncertainty
SCAL dataset incomplete

FACIES DISTRIBUTION



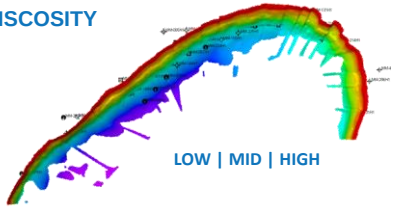
Limited constraining of facies and reservoir quality distribution possible from seismic due to old vintage & low resolution

INIITIAL OIL SATURATION



Complex facies assemblage resulting in difficulty in estimating initial oil saturation (many wells drilled post-production, and Hz)
Poor coverage from early vertical wells (log vintage)

VISCOSITY



Evidence from sampling that API & viscosity varies, both areal and depth-trends present; significant fluid PVT uncertainty

PRODUCTION ALLOCATION UNCERTAINTIES

Commingling occurring in ~30% of the production total

Both vertical and horizontal wells have been commingled

Limited PLT dataset and pressure data

Combined with uncertainty on reservoir pressure, oil API/viscosity distribution and permeability estimation in wellbore

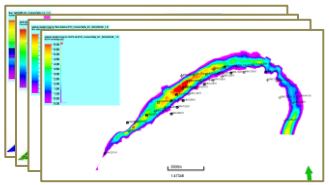
SIGNIFICANT CHALLENGES TO ADDRESS

LIMITED TIME AND RESOURCES AVAILABLE

FULL-CYCLE LTRO & FORECAST WORKFLOW

1 Inputs QC and Deck Setup

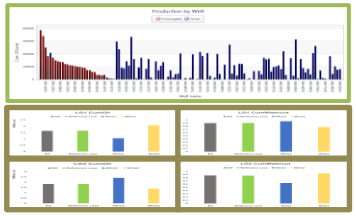
- Static properties definition using direct export from Petrel in maps format
- General properties import – PVT, RelPerms, Reservoir Pressure, etc.
- LOW / MID / HIGH realisations to capture subsurface uncertainties



LOW | MID | HIGH

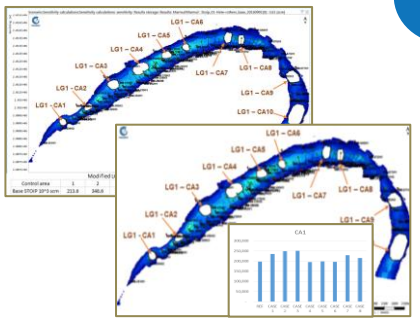
2 Allocation

- **Commingling analysis** per well / production volume
- Generating **alternative allocation cases** (LOW / MID / HIGH) to capture allocation uncertainty



3★ Remaining Oil Compliant Mapping (ROCM)

- **SENSITIVITY** cases runs (varying one uncertainty parameter) - **to classify key parameters for further runs**
- **COMBINED** cases runs (varying few selected uncertainty parameters) - basis **for opportunities screening and risking criteria**

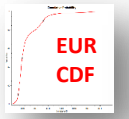


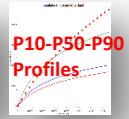
6★ Machine Learning Full-Field Forecast (ANN-based)

Neural Network Inputs:

- **Static properties** @ well location (depth, net pay, porosity)
- **Well performance type-curve fit**
- **ROCM-derived Dynamic properties** @ well location (OIP at drilling time, ΔSw over time, effective well spacing)

Trained POSEIDON APACHE Neural Network model to predict new wells type-curves at any given location



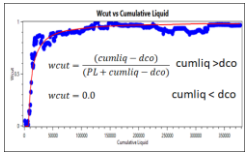


Forecast scenarios

- Individual targets
- Full-field development scenario with various wellspacing 150m / 75m / 50m

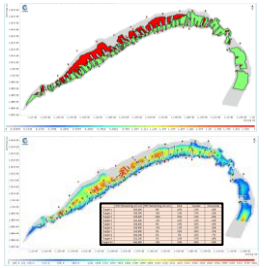
5 Predictive Analytics – History

Fit wells historical performance with type curves for a further POSEIDON APACHE neural network "learning"



4 Opportunities Framing

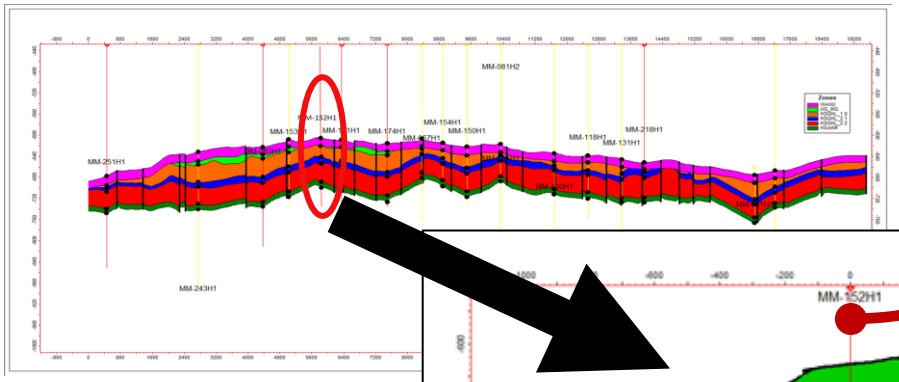
- **Water shutoff** candidates
- **Infill targets** with quantified remaining oil volume, risk and upside / downside potential
- Zonation for well placement within low Sw areas

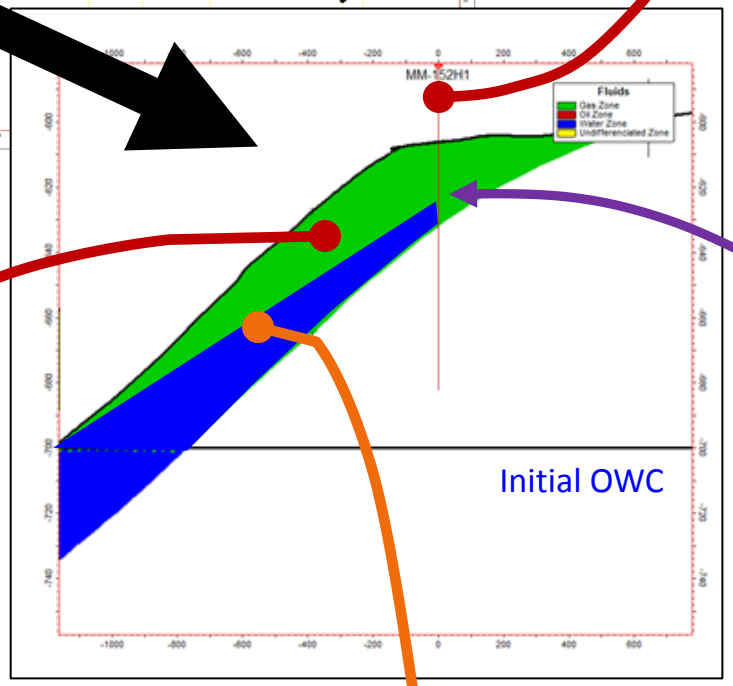


Experience. Expertise. Technology

★ **Benchmarked versus simulator (dynamic sector model)**

REMAINING OIL-COMPLIANT MAPPING (ROCM)
Algorithm description – iterative time-stepping





Well:

- Production (allocated)
- Logs
  - Zone properties
  - Sw if measured
- Completion / perf
- Well events

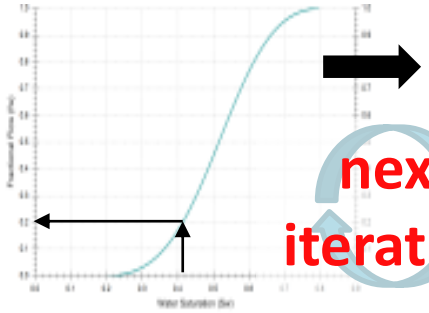
AT TIMESTEP

Iteration 1

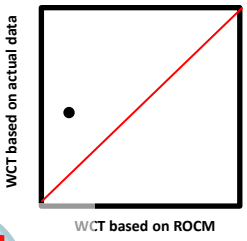
Reservoir:

- Original Sw => In-place HC
- Res. properties distribution
- OWC

Construct Fractional Flow to convert WCT ⇔ Sw at the well

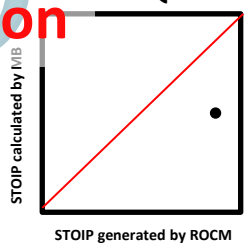


WCT QC Plot



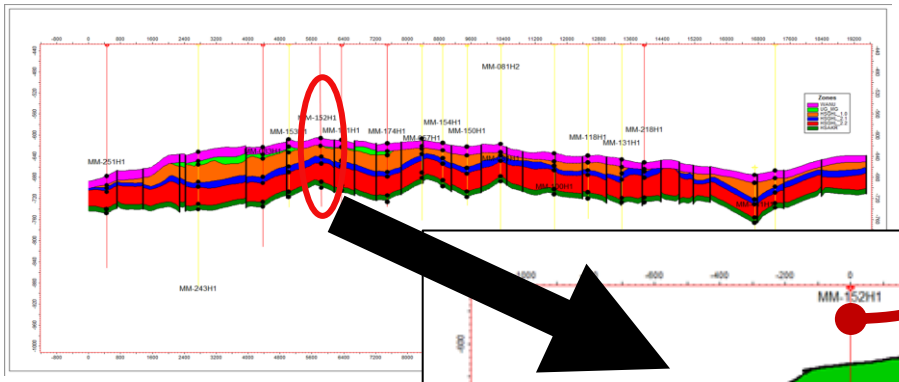
next iteration

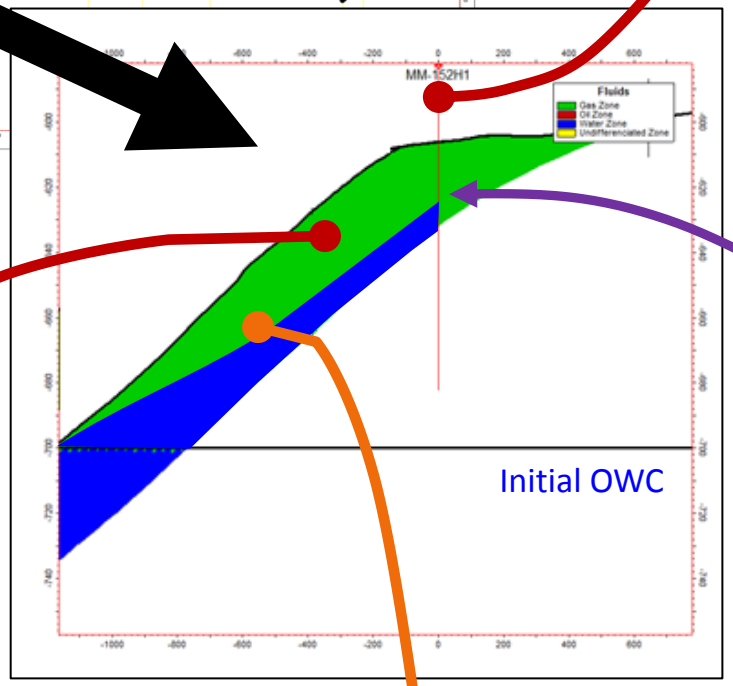
STOIP QC Plot



POSEIDON generates parametrized front-shape and calculates material balance

REMAINING OIL-COMPLIANT MAPPING (ROCM)
Algorithm description – iterative time-stepping





Well:

- Production (allocated)
- Logs
  - Zone properties
  - Sw if measured
- Completion / perf
- Well events

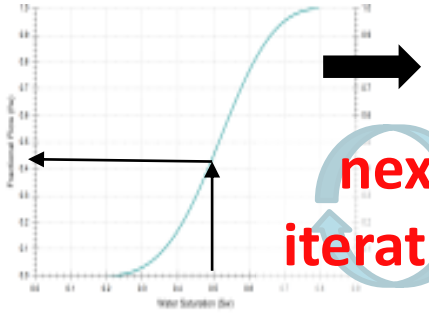
AT TIMESTEP

Iteration 2

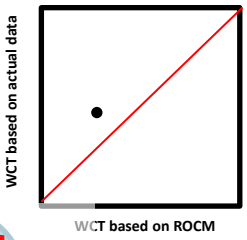
Reservoir:

- Original Sw => In-place HC
- Res. properties distribution
- OWC

Construct Fractional Flow to convert WCT ⇔ Sw at the well

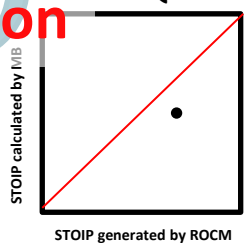


WCT QC Plot



next iteration

STOIP QC Plot



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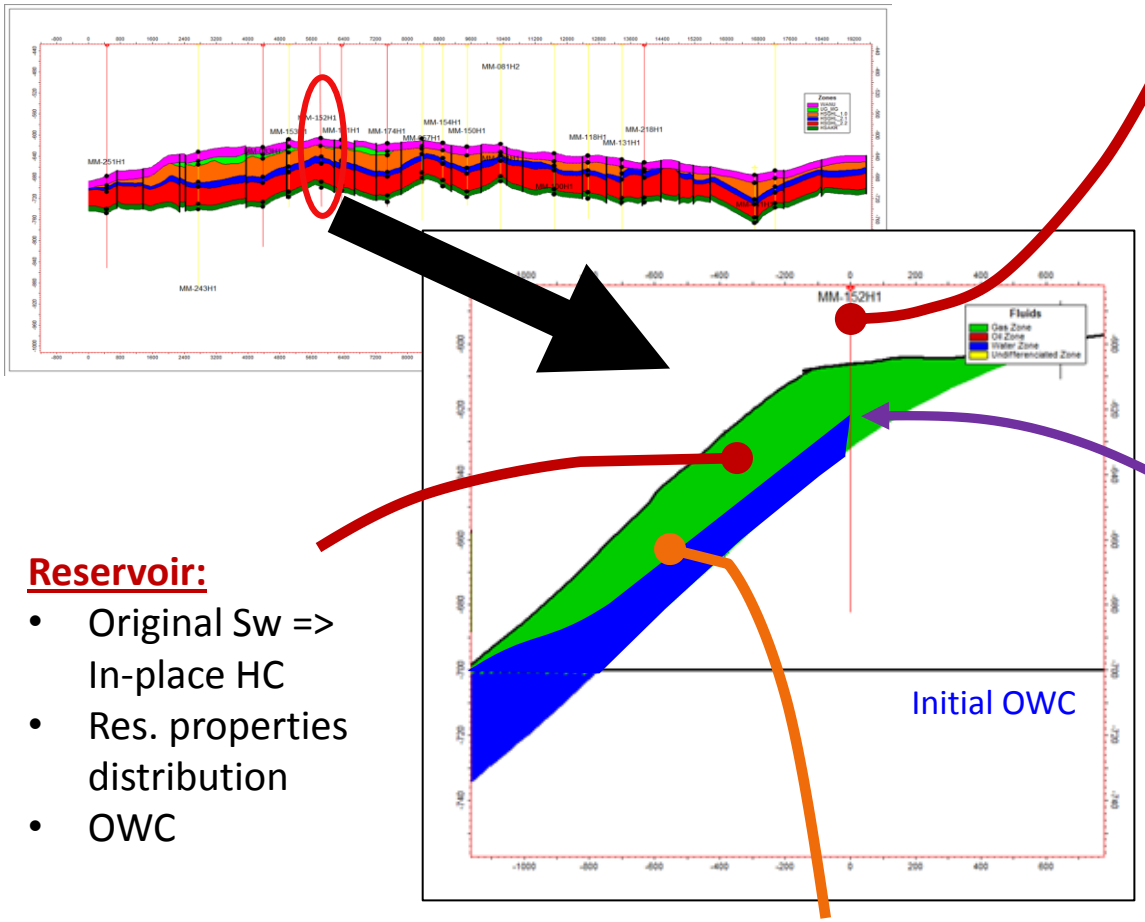
REMAINING OIL-COMPLIANT MAPPING (ROCM)
Algorithm description – iterative time-stepping



Well:

- Production (allocated)
- Logs
  - Zone properties
  - Sw if measured
- Completion / perf
- Well events

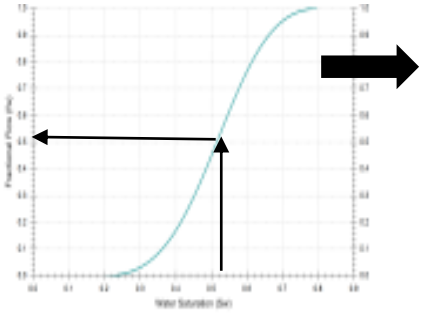
AT TIMESTEP

Iteration 3

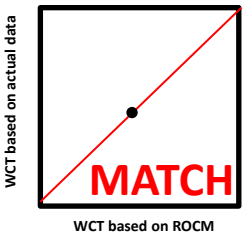
Reservoir:

- Original Sw => In-place HC
- Res. properties distribution
- OWC

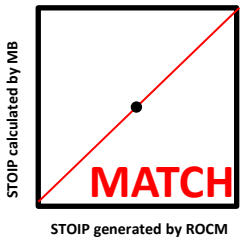
Construct Fractional Flow to convert WCT ⇔ Sw at the well



WCT QC Plot



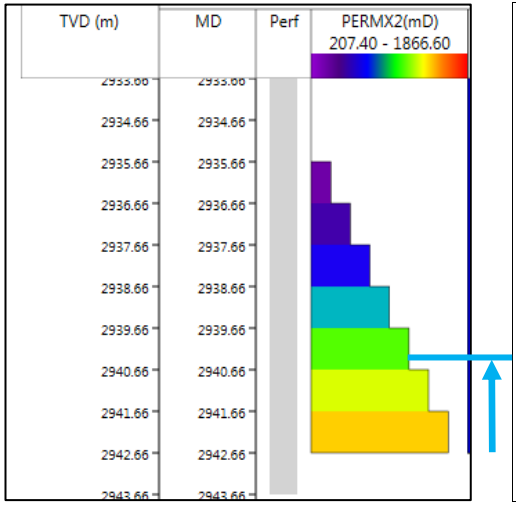
STOIP QC Plot

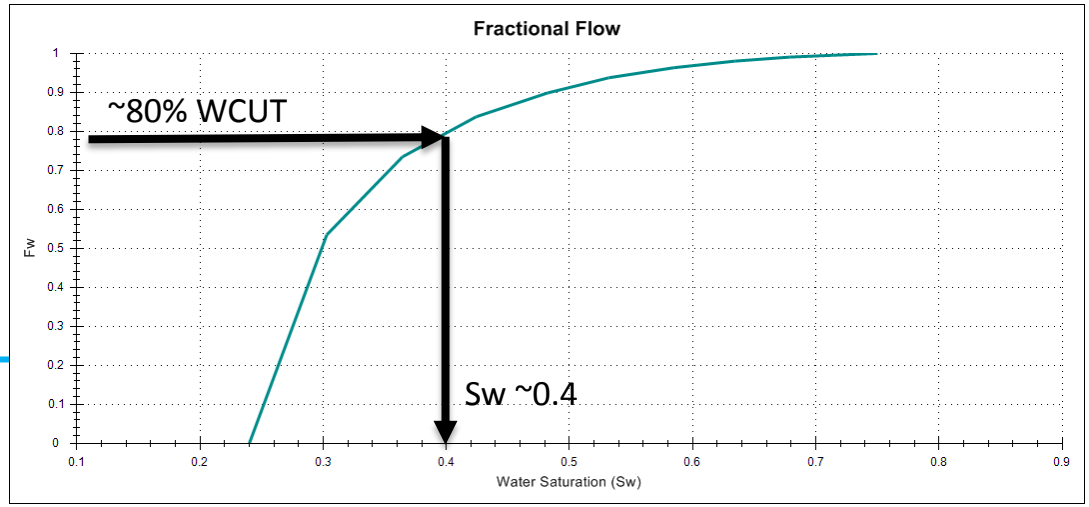


POSEIDON generates parametrized front-shape and calculates material balance

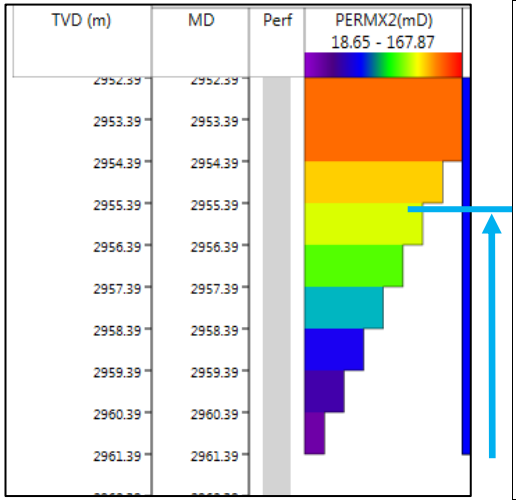
A 2D approach but taking into account the vertical heterogeneity as part of FF modelling

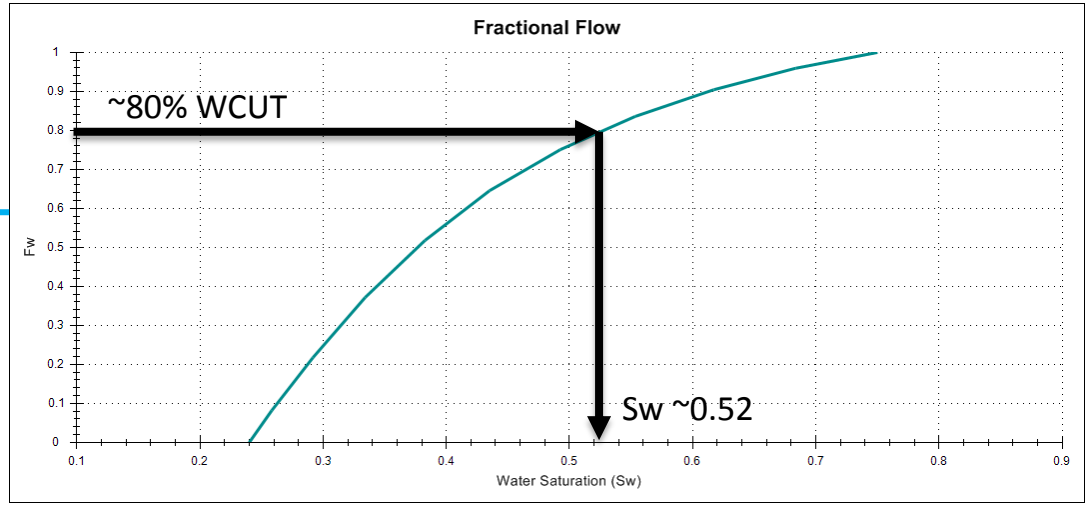
VERTICAL HETEROGENEITY & FRACTIONAL FLOW





PROD 3

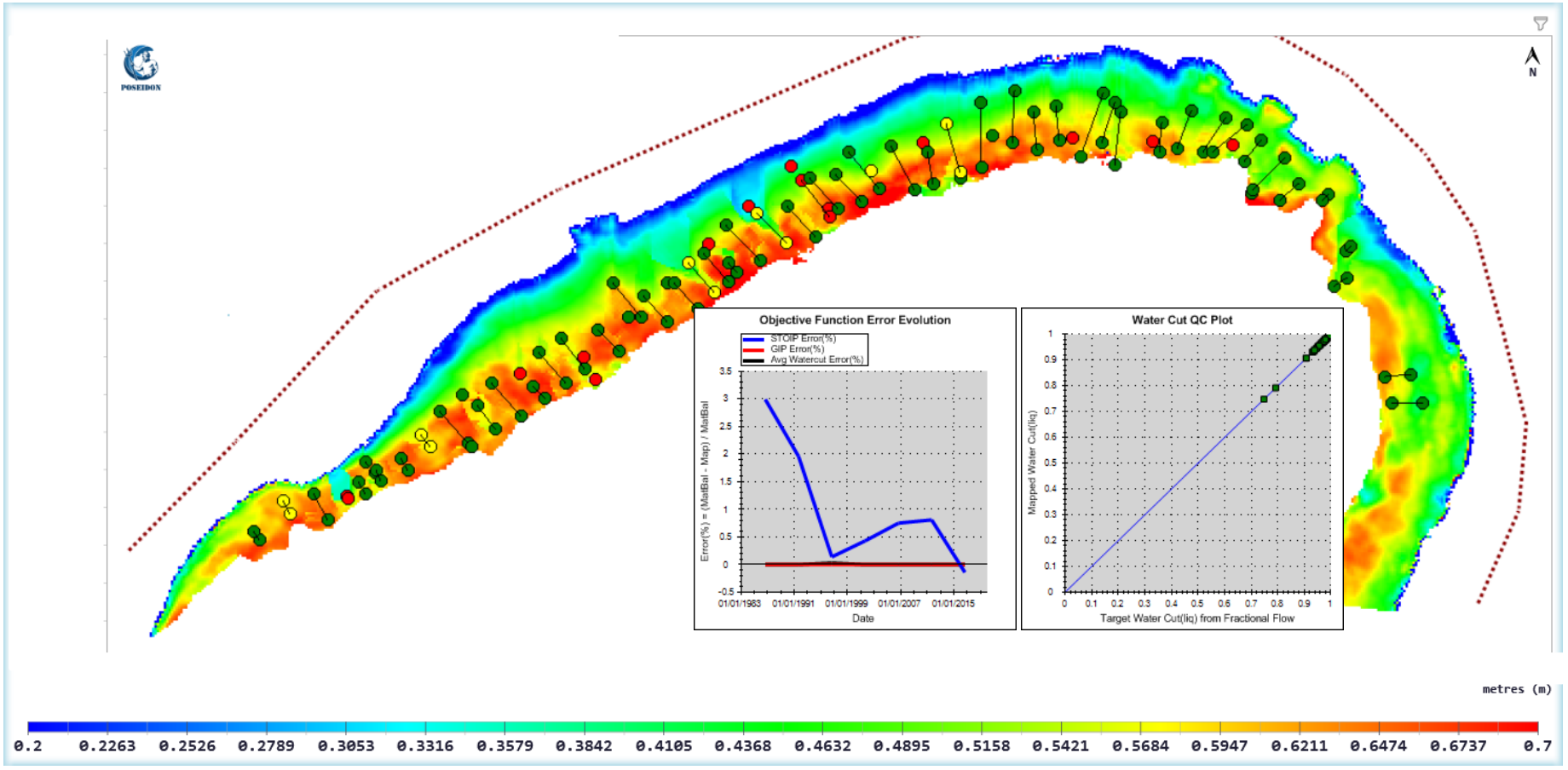




PROD 6

Example of ROCM map – Oil Saturation evolution versus time

Layer 1 – Selected Allocation/Static/PVT Realisation



This process is repeated for all identified key uncertainties, combined into realisations:

Allocation | viscosity distribution | SCAL

3 MONTHS END-TO-END QUANTITATIVE PRODUCT

Study initiation

Study Completion

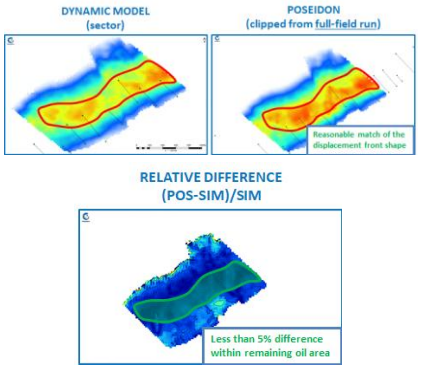
DELIVERY PACKAGE:
- Slidepacks
- Report
- Remaining oil / saturation maps in Petrel format
- Wells profiles
- Other digital data

1 — 2 — 3 months

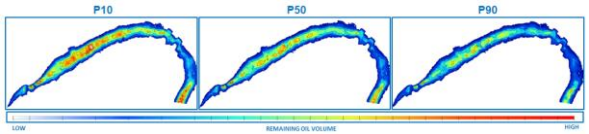
PRODUCTION ALLOCATION
Data QA/QC, commingling analysis, Alternative reservoir allocation scenarios

REMAINING OIL SENSITIVITY CASES
Testing impact of subsurface uncertainties on by-passed oil

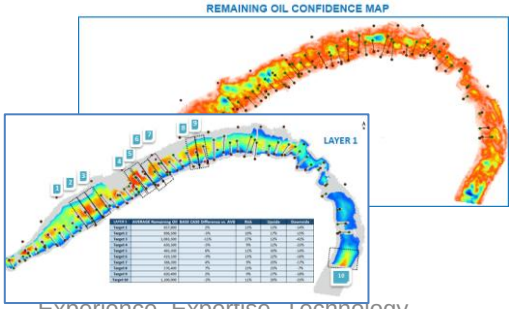
SECTOR MODEL BENCHMARK
Validation of ROCM maps to sector models



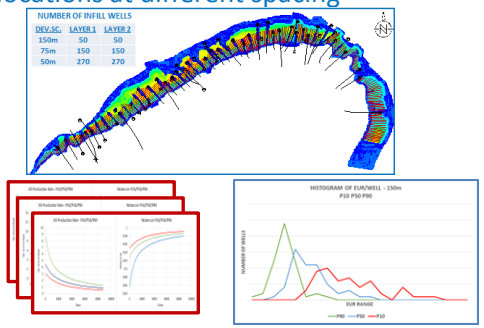
REMAINING OIL MAPPING ANALYSIS
By-passed oil analysis and identification of Water shutoff and Infill Opportunities



REMAINING OIL RISKING
Incorporation of subsurface uncertainties into a set of combined scenarios and delivery of P10/50/90 remaining oil maps with risk map associated



DEVELOPMENT SCENARIOS FORECAST
Screen 100's of well locations and generate forecasts for infill drilling locations at different spacing



SECTOR MODEL BENCHMARK
Benchmarked machine learning outcomes to sector models