# CASE STUDIES

## *CASE STUDY USING THE DIGITAL OILFIELD*

Production Surveillance and Optimisation in a Multi-Zone System

*Introduction*

Production allocation and surveillance are integral parts of any field monitoring process and are imperative steps in ensuring that models are both up to date and robust so that tasks such as production optimisation can be performed. When production occurs from multiple zones or layers, this allocation and surveillance is given an additional level of complexity and the Digital Oil Field (DOF) can play an essential role in this procedure.

This case study details the use of Petroleum Experts' DOF system to allocate production between the different zones of each well and also how the system allows the evolution of water cut to be monitored for each zone without the need to test each zone in isolation.

*Challenges*

It is only possible to optimise production from a multi-zone well if the production conditions of each zone are well understood. Using the available data and models, any changes in the fluid being produced must be diagnosed not only at a well level but also at a zone level. Only with robust zonal surveillance can the optimisation of the field be completed.

While the field is currently very well equipped (with pressure gauges at both sides of each zone's ICV) there is a possibility that some of these gauges may fail over time and therefore contingencies should be put in place to ensure that any solution is still valid if this happens.

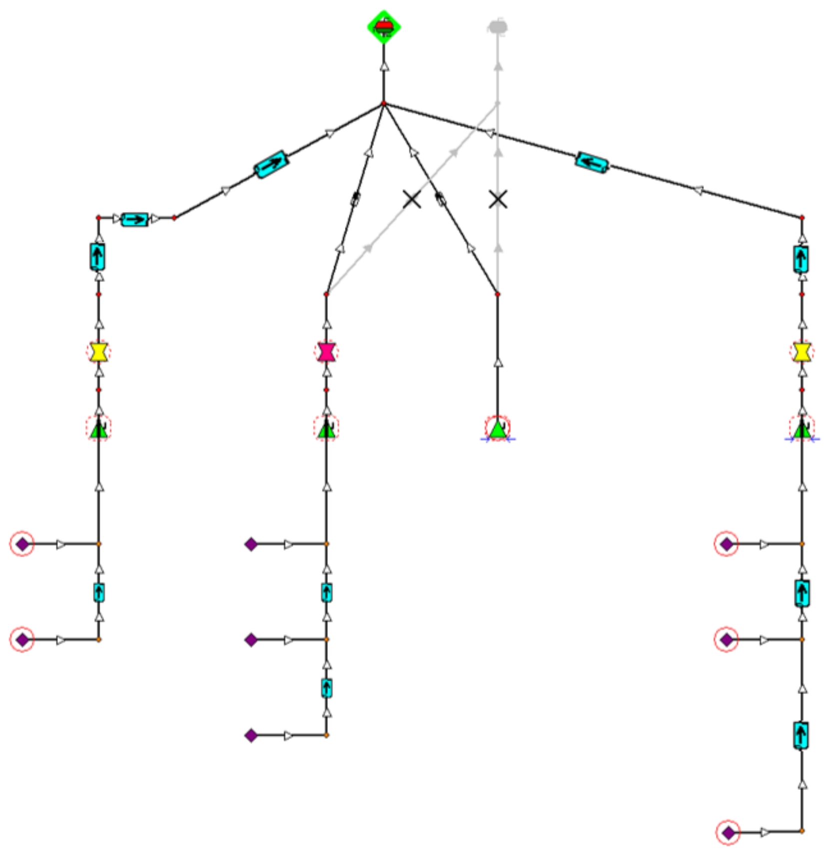
*Field Description*

The field consists of a number of multi-zone wells and some additional single zone wells. These are split between production and water injection systems to allow pressure maintenance with voidage replacement.

The development consists of two reservoirs, with each reservoir having an upper and lower zone. Each of the multi-zone wells is completed in a maximum of three of the four zones and has an ICV to control the flow being produced from each. Each ICV has a pressure gauge located above it which records both the annulus and tubing pressures (upstream and downstream pressures) on a real time basis. Wellhead pressure and top side choke conditions of each well are also known and can be used in any surveillance workflow.

*Objective of Solution*

The overall objective of the project is to provide a system which can optimise production for the total field. To achieve this, the system is required to monitor the production and evolution of water cut and reservoir pressure in each of the wells and zones over time in order to ensure that the physical models (used for the optimisation) are robust and up-to-date.



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*Solution Formulation*

To achieve the overall objective of production optimisation, a number of different steps are required, each utilising different workflows to achieve their requirements:

### Zonal Surveillance

- Using real time data, estimate the production from each zone assuming current base conditions (Water Cut and GOR) for each zone.
- *Workflows Utilised*
  - ◊ MZS - Multi-Zone Surveillance
  - ◊ SQC - System Quality Control

### Well Surveillance

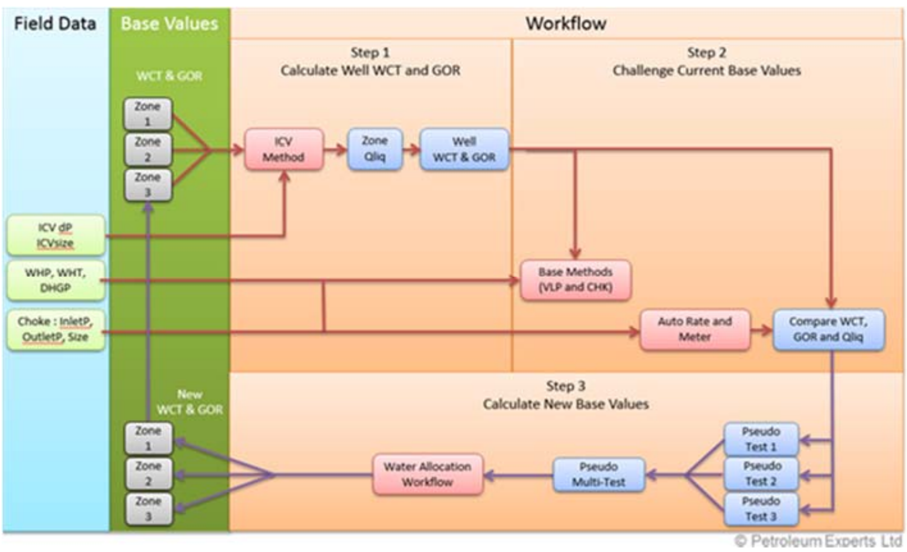
- Using the well water cuts and GORs calculated from the Zonal Surveillance, challenge these conditions using standard well surveillance workflows.
- *Workflows Utilised*
  - ◊ AWS – Advanced Well Surveillance
  - ◊ MWA – Field Wide Multi-Well Allocation

### Zonal Allocation

- Once the current conditions of the zones have been challenged (and have failed) the next step is to understand which of the zones are seeing the changes and which are remaining the same.
- *Workflows Utilised*
  - ◊ IVM Data Management and Pseudo-Test Creation
  - ◊ MZWA – Multi-Zone Water Allocation

### Production Optimisation

- Once the production conditions of each zone are known, the production optimisation workflow can allocate gas lift gas between wells and also find the optimum settings of the ICVs and wellhead chokes.
- *Workflows Utilised*
  - ◊ OPT – Production System Optimisation



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*Solution Implementation*

The following is a list of requirements for the logic to be implemented:

- Access to external data sources (such as real time data from the field)
- Processing and filtering of the data
- Physical models to describe the performance of the different elements of the system
- Workflows to contain and preserve the engineering logic
- An ability to trigger or schedule the workflows when required
- Configuration of the workflows by the engineers
- Visualisation of the external data and workflow results

To achieve these requirements, Petroleum Experts' DOF system contains a number of different elements:

**IPM** – The Integrated Production Modelling (IPM) suite of software packages are the physical models which describe the behaviour of the field. The well models, for example, are built in PROSPER while the surface network model is built in GAP.

**VWF**– Visual Workflows (VWF) are visual representations of engineering (or general) logic which utilise the underlying IPM models to perform calculations in an automated fashion.

**IFM** – Integrated Field Management (IFM) is a package which acts to control the scheduling of workflows and management of the physical models. It is composed of two sub systems; Model Catalogue (which audits the changes and state of each IPM model to ensure that the up to date version is used in any calculation) and the Workflow Manager which triggers and schedules the running of the Visual Workflows.

**IVM** – Integrated Visualisation Management (IVM) is a package which managements the connection and processing of the external data and also allows the data and results to be visualised by the User. Configuration of the engineering workflows can also be setup within this system so that engineers can change the configuration parameters passed into the workflows as required.

With these different elements in place, the formulated solution can be implemented.

*Details of the Solution*

*Zone Surveillance*

The first step of the process is to use the ICV data to calculate the liquid rate being produced from each of the zones.

Two methods are employed to do this; the ICV calculation (which is independent of the IPR) and the SQC. Comparison of these two methods also allows the IPR of each Zone to be estimated.

| | ZONE 1 | | | ZONE 2 | | | ZONE 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Upper | | | Upper | | | Lower | | |
| **PRODUCTION RATES** | | ICV | SQC | | ICV | SQC | | ICV | SQC |
| Oil Rate | | 2,001 | 2,109 | | 2,272 | 2,350 | | 3,160 | 3,242 |
| Water Rate | | 75 | 79 | | 0 | 0 | | 253 | 259 |
| Gas Rate | | 0.486 | 0.513 | | 0.552 | 0.571 | | 0.768 | 0.788 |
| Liquid Rate | | 2,076 | 2,188 | | 2,272 | 2,350 | | 3,412 | 3,502 |
| **BASE VALUES** | | | | | | | | | |
| Water Cut | | 3.60 | 3.60 | | 0.00 | 0.00 | | 7.40 | 7.40 |
| GOR | | 243 | 243 | | 243 | 243 | | 243 | 243 |
| **PRODUCTION CONDITIONS** | | | | | | | | | |
| ICV Annulus Pressure | | 2,084 | 2,067 | | 2,236 | 2,221 | | 2,365 | 2,353 |
| ICV Tubing Pressure | | 2,020 | 2,005 | | 2,160 | 2,146 | | 2,194 | 2,179 |
| ICV Size | | 0.540 | | | 0.540 | | | 0.540 | |
| **RESERVOIR CONDITIONS** | (Reservoir Pressure refers to ICV datum) | | | | | | | | |
| Reservoir Pressure | 2,680 | 2,665 | 2,680 | 2,570 | 2,573 | 2,570 | 2,990 | 2,986 | 2,990 |
| Productivity Index | 3.57 | 3.48 | 3.57 | 6.73 | 6.80 | 6.73 | 5.50 | 5.46 | 5.50 |

Combining the rates of all of the zones together gives an estimation of the total well rates and also the well's water cut and GOR assuming the base conditions (WCT and GOR) of each zone are correct. This method has the advantage that as the fluid is liquid passing through the choke (as the reservoir is maintained above the bubble point) the liquid rate calculated is insensitive to the water cut which is assumed in the calculation.

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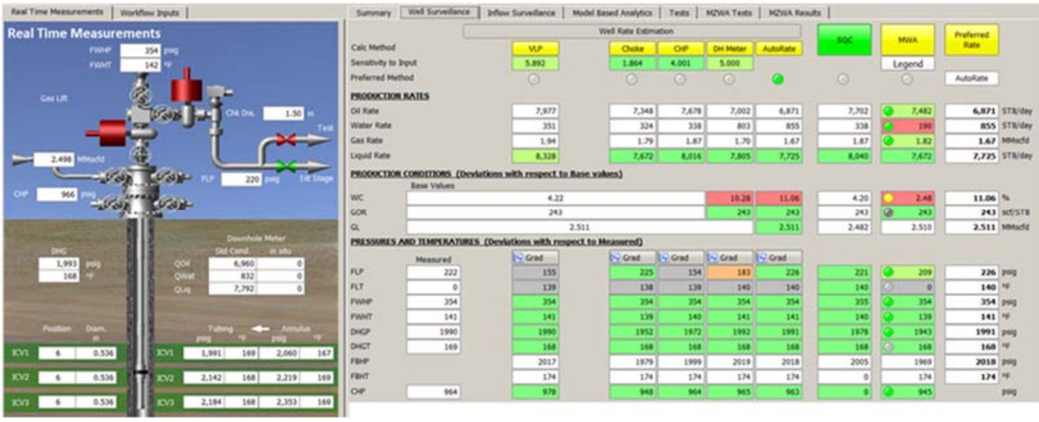
### *Well Surveillance*

For each well, a number of different rate methods can be used to estimate flow rate which is being produced by the well. Using the Water Cut and GOR calculated from the Zone Surveillance we can compare these different methods to see if the calculated inputs are correct. If the different rate methods diverge from each other, then this would suggest that one or more of the zones has had a change in its production conditions.




The Auto-Rate method calculates the Water Cut which would be required to best match all of the different readings in the well. This, along with a metered water cut if present, can be used to challenge the value calculated by the Zone Surveillance and assess if the Zone base values need to be changed.


### *Zonal Allocation*

Once it has been established that the base conditions of the zones has changed, the next step is to find which ones have changed and by how much. This is done by creating a number of 'pseudo' tests which can then be solved to find the water cut of each zone.

The theory behind this approach is the use of simultaneous equations where we need more (or the same number of) equations than we have unknowns. From the Zone Surveillance workflows, we have a good understanding of the liquid rates from each zone through time. Using either the Auto-Rate calculation or a flow meter we also have an estimation of the water rate which the well is producing and so the following equation can be formulated with the only unknowns being the water cut of each zone:

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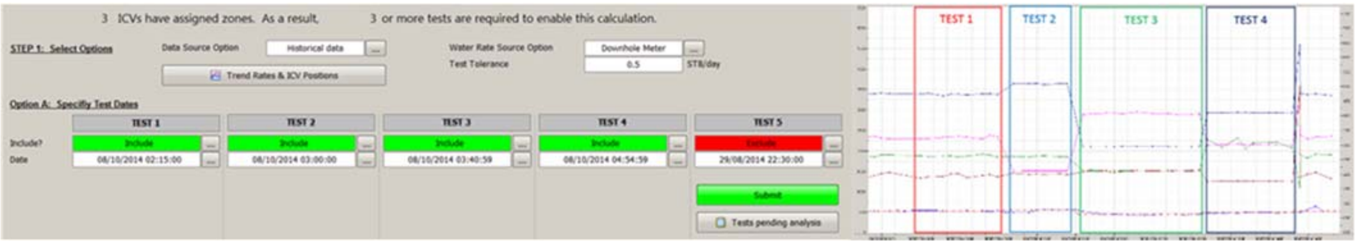
$$Q_{wellwater} = WCT_{Z1}Q_{liq(Z1)} + WCT_{Z2}Q_{liq(Z2)} + WCT_{Z3}Q_{liq(Z3)}$$

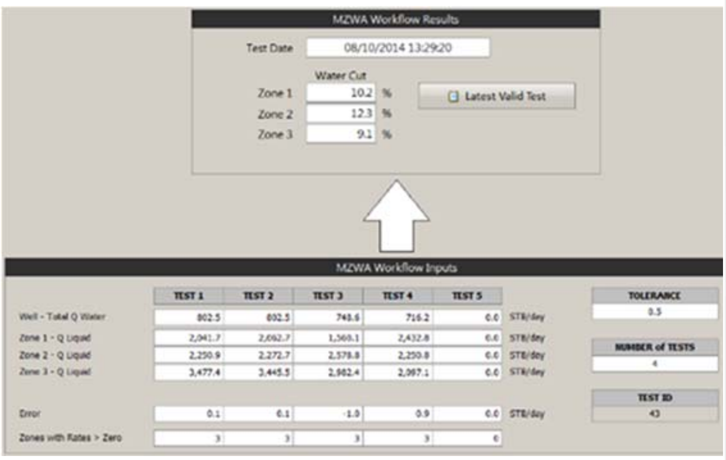
If we have as many of these equations as we have zones then a unique solution can be found. It is important to note, however, that the different equations cannot simply be multipliers of each other and instead need to be different distributions of flow from the zones.




As all of the results are calculated using the real time workflows, the well does not need to be flowing to a test separator. Instead, IVM can be used to select different points in time (which represent different pseudo test periods) and the required data from each time will be automatically picked up and a pseudo test generated for this time period. The tests can also be inserted manually by the User.

The creation of this multiple pseudo-test record will trigger a calculation to find the water cut of each zone which balances all of the tests.

The results of the workflow are then passed back to IVM and can be viewed by the engineer or reports can be generated and sent to the field. Once these have been validated by the User, the models can be updated with these new values.

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*Optimisation*

Once the production conditions have been established for each zone, the production optimisation workflow can be run to find the optimum gas lift injection rate and ICV settings for each well.


The results of the workflow can then be passed back to IVM and visualised alongside the current flowing conditions (calculated by the SQC), so that the engineer can understand how far the current operating conditions are from the optimum and how much benefit can be obtained by changing the production strategy.

*Invalid/Missing Gauge Data*


The logic above assumes that data is readily available for the calculations across the ICVs, but this may not always be the case. In certain conditions, some gauges may be missing or not operating and therefore additional logic is required to handle these conditions.

Within IVM, it is possible to process the real time data to ensure that representative information is always passed to the workflows. In this case, if any of the tubing side gauges are missing or invalid, then other gauges around them can be used to estimate value which would be expected at the depth of the missing gauge. This is done by using other existing gauges to estimate a fluid gradient within the tubing and then applying this gradient to calculate the missing value from one of the existing gauges.

*Conclusions*

Using the DOF system, it is possible to perform both Zonal Surveillance and Allocation to ensure that our understanding of both the well and the different reservoirs feeding into it are well known. These workflows can be used to track how conditions are changing over time and also to validate our current models and understand of the conditions.

Once confidence in the conditions has been established, optimisation calculations can be performed to ensure the field is being run at the best conditions it can be and inform the field engineers if this is not the case.