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Protecting Return on Investment through Automated Ensemble-based Quantification of Risk - Norwegian Offshore Field Case Study

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Summary

This abstracts illustrates how integrating different uncertainties at different reservoir modeling stages produces geologically consistent models, increases reservoir model reliability and generates more reliable prediction estimates. Using an integrated reservoir modeling and reservoir engineering workflow, the Big Loop and its ensemble-statistics based approach can generate crucial information to reduce risk and support decision-making - on determining reservoir uncertainties and their ranges, in planning future field development, and in guiding well placement using multiple history match models.

Introduction

The sharp oil price decline is pushing exploration and production companies to revise future investment plans and ensure investment decisions come with positive returns. Reservoir modeling is a key tool in such evaluations, as it explores different development scenarios to optimize field performance and get the most value out of the reservoir. Traditional reservoir modeling, however, relies on a single or small number of scenarios (base, high and low cases) and introduces deterministic prediction profiles for future field performance that don't fit with modern reservoir management guidelines. Such a modeling approach also fails to integrate the impact of uncertainties at the different reservoir modeling stages - from seismic interpretation through to dynamic simulation. In this abstract, the Big Loop™ methodology from Emerson Automation Solutions has been applied to a field offshore Norway to quantify the risk within the model due to different reservoir uncertainties, and evaluate the risk of installing an additional subsea production template in the field. The abstract will illustrate how the automated workflow produces geologically consistent history matched ensembles that lead to optimized production and a better quantification of the impact of combined uncertainties on current and future investment decisions.

Method

The geological and dynamic models are constructed and the uncertainties at each stage of reservoir modeling incorporated. Uncertainty ranges and prior distribution are defined, creating the prior multi-dimensional uncertainty solution space.

The Big Loop workflow starts by submitting a batch of simulation cases where the uncertainty solution space is sampled to validate the workflow settings, with the simulation results of these sampling runs used to build the initial proxy model. The second workflow step consists of submitting further simulation runs to refine the proxy model and enhance the history match. Consideration is given to the available observed data and its allowable history match tolerances. This is until multiple history matched models are achieved that reflect the probabilistic posterior distribution of the identified uncertainty parameters.

The final workflow step is to use the proxy model to sample this multi-dimensional posterior solution space through an ensemble-based prediction workflow. Predictions are generated with and without including the proposed additional subsea production template. The delta ensemble between both scenarios is subsequently calculated to evaluate the probability distributions of incremental recoverable oil as a result of this investment.

Implementation

The field in study comprises three oil reservoirs in a sandstones deposition environment and laterally sub-divided into four regions - from region one in the north to region four in the south with region one the primary target area for wells feeding into the planned new subsea template. The field comprises 17 drilled wells, where eight are producer wells and nine are water /gas injector wells. Based on sand volume fractions calculated from drilled wells of different zones, the channel belt and channels facies are populated, with crevasse and floodplain as a background.

Based on data analysis and previous history matching exercises, the following uncertainties were identified – all of which can have a major impact on calculating the reserves in place. These were: i) Facies Volume Fractions (VF): how much Channel (or Channel Belt) & Crevasse and their geometries. Also widths/thickness/azimuth/sinuosity as this impacts connectivity; ii) Facies Petrophysical Net Properties: Within the modeled channel (or channel belt)/crevasse, how much is net quality sand? iii) Water Saturation (OWC and SW equations); iv) Fault transmissibility to address the communication between the different reservoirs and different field regions; and v) Gas-oil relative permeability, oil-water relative permeability (LET correlations), saturation table end point scaling, vertical to horizontal permeability ratios, and analytical aquifer properties.

After defining uncertainty modifiers, the model's validity can be analyzed by comparing scoping runs results with the observed history data and investigating if the scoping runs bracket the history and whether the shapes of the simulator responses are similar to the observations or not. After completing the validation process, history match criteria and allowable tolerances were specified and refinement runs launched in batches. As more and more refinement runs are submitted, the proxy model gets updated and gradually improved until multiple good history match cases were achieved.

Figure 1 shows the improvement in quality during the process of refinement (red dots). Two different sets of posterior ensembles (100 simulation cases each) were submitted and investigated (green dots). In this case, most of the posterior ensemble runs had a good history match, indicating that the current proxy model is reliable enough and can be used for analyzing the model uncertainties.

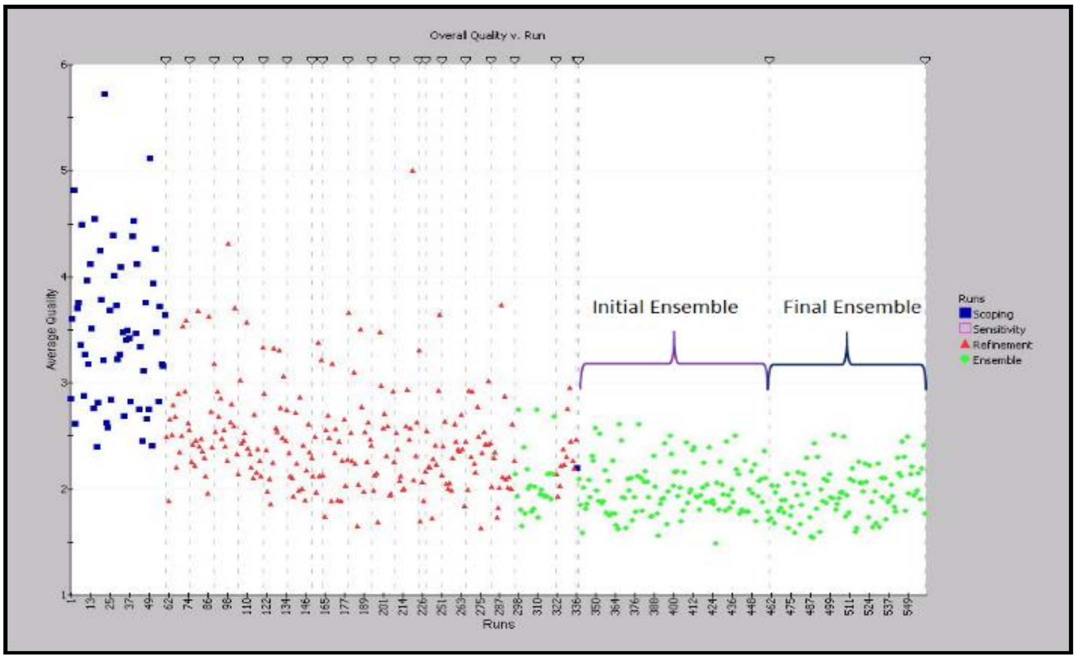

Figure 1 - Average overall quality plot after two posterior ensemble sets.

Results –History Matched Models and Uncertainty Analysis

Multiple geologically consistent history matched models were achieved using the Big Loop workflow with the models having different facies distribution. Figure 2 displays the history match results for different wells and figure 3 the geological models for three different acceptable history match cases along with the base model showing the consistency between the history match model and the static geology model. Big Loop prediction ensembles will integrate the effect of these different acceptable facies models on future field performance and optimization. The detailed uncertainty analysis and sensitivity tornado plots also highlight the fluid contacts, sand volume fractions, and the water saturation as the most influential history match parameters, with these main uncertainties having a significant impact on reserves calculations when compared with other identified uncertainties (figure 4).

Results – Prediction and Risk Evaluation

Once multiple history match cases were achieved, the proxy model was used to determine the posterior uncertainty solution space and the Markov Chain Monte Carlo sampling technique was used to create a set of parameter values for the prediction ensemble sets (100 cases for each set). These take into account the posterior knowledge gained during the history matching process. Two different ensemble sets were submitted to confirm a stable confidence interval for both ensemble sets.

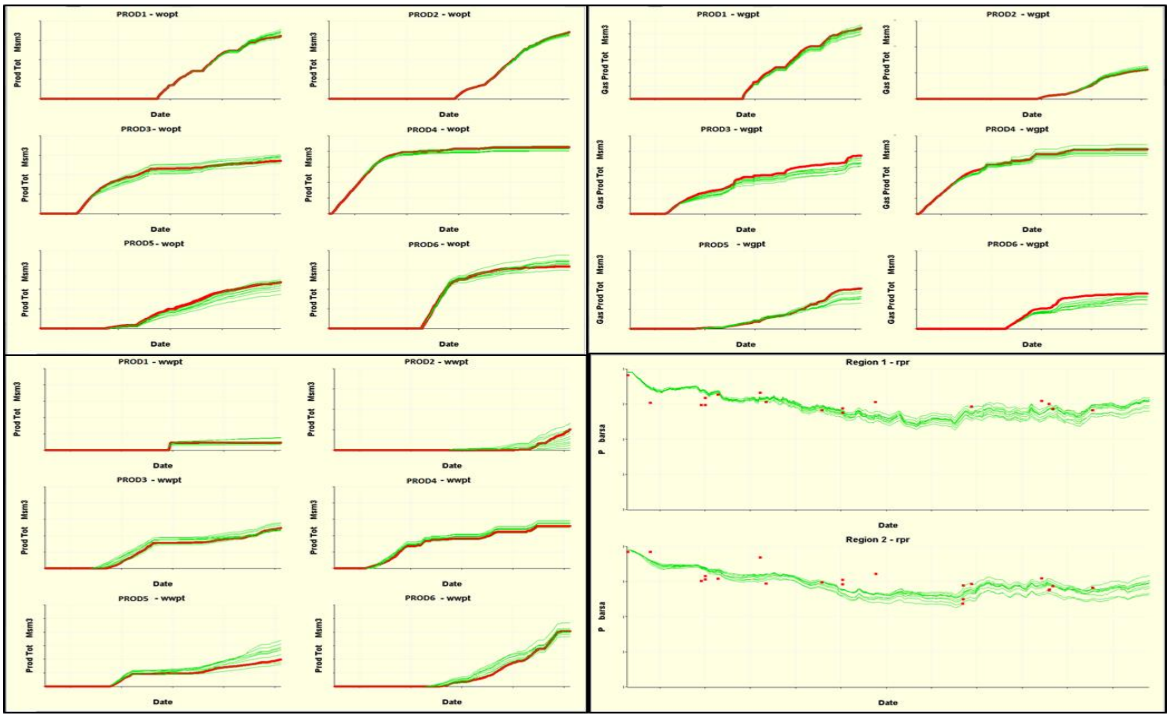

Figure 2 – History match results for different wells and regional pressure

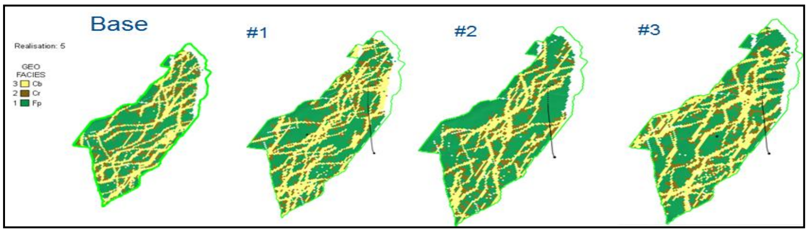

Figure 3 – Facies distribution for different history match models

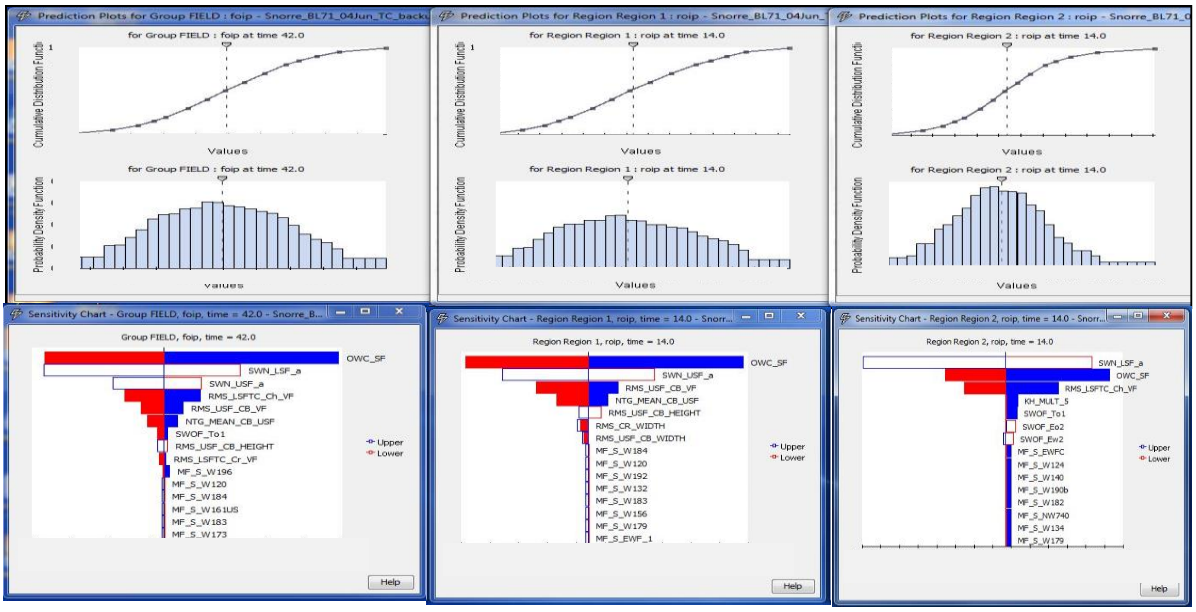

Figure 4 – STOIIP probability distributions and sensitivity tornado plots

As the main study objective is to evaluate the probability distribution of incremental oil recovery resulting from installing an additional subsea production template in the northern part of the field, the second ensemble set was used for two different prediction scenarios with and without installing the additional subsea template. The scenario without installing the additional subsea template was used as a reference case. Figures 5 shows the total field oil production for both prediction scenarios (reference scenario in green and subsea scenario in blue).

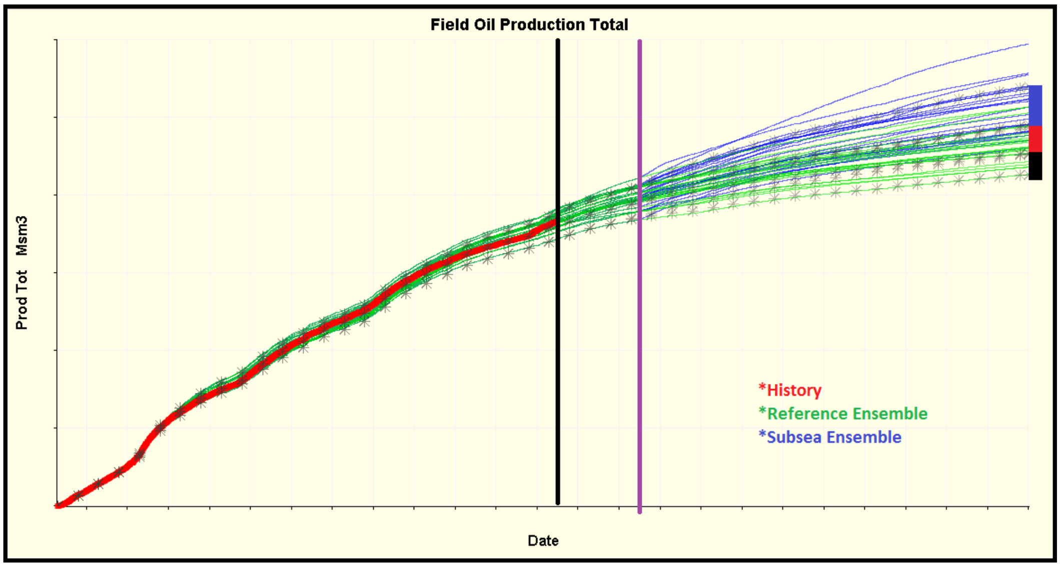

Figure 5 – Field oil production total for reference and subsea ensembles

For evaluating such investment decisions, the probability and cumulative distribution function of oil recovery at the end of the predicted time for both prediction scenarios were calculated. The cumulative distribution function for the difference between both scenarios (delta ensemble) was also calculated to represent the probability of incremental oil recovery as a result of the subsea template installation.

Conclusions

This abstract illustrates how integrating different uncertainties at different reservoir modeling stages produces geologically consistent models, increases reservoir model reliability and generates more reliable prediction estimates. Using an integrated reservoir modeling and reservoir engineering workflow, the Big Loop and its ensemble-statistics based approach can generate crucial information to reduce risk and support decision-making - on determining reservoir uncertainties and their ranges, in planning future field development, and in guiding well placement using multiple history match models.

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