Accelerated and automated methodology to reduce the time for field development planning

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Artículo recibido en junio de 2022-revisado-evaluado y aceptado en noviembre de 2022-

Summary

The process of field development planning represents a grade of complexity due to the required integration between multiple domains, many scenarios evaluation, and la limited time frame. With the aim to accelerate this task, a methodology is proposed to integrate workflows and technology to fast-track the multiple scenarios evaluation based on subsurface uncertainty and economic evaluation.

The proposed methodology is based on identifying reservoir zones with higher potential to produce hydrocarbons (Al-Khazraji et al 2015), thus, evaluating the multiple development scenarios to define the best well spacing, well trajectory and perforation length. This initial stage allows for technical and economical evaluation of each development scenario using as selection criteria economic indicators such as Net Present Value (NPV). Also, thanks to the Monte-Carlo sampling method is possible to estimate an efficiency frontier of the project (Tonnsen et al 2008).

Once the bests development scenarios are carefully chosen, further simulations were made to assess uncertainty. As a result of integrated analysis, reservoir understanding, and multiple scenarios evaluation the main outcome of the methodology is a “well ranking” associated with a rate of success value which allows the selection of the well location with the lowest associated risk.

As an application example, results showed that only 50% of the wells initially proposed performed above the economic threshold criterion and a similar recovery compared to the reference field development plan. Based on that, new locations were recommended to minimize the CAPEX honoring the target set.

Metodología acelerada y automatizada para reducir el tiempo en la generación de planes de desarrollo de campos

Resumen

El proceso de generación de planes de desarrollo de campos representa un alto grado de complejidad debido a la integración requerida entre múltiples dominios, la evaluación de muchos escenarios y el tiempo limitado. Con el objetivo de acelerar esta tarea, se propone una metodología para integrar flujos de trabajo y tecnología para acelerar la evaluación de escenarios múltiples basados en la incertidumbre del subsuelo y la evaluación económica.

La metodología propuesta se basa en la identificación de zonas de yacimientos con mayor potencial para producir hidrocarburos (Al-Khazraji et al 2015), evaluando así los múltiples escenarios de desarrollo para definir el mejor espaciamiento entre pozos, trayectoria de pozos y longitud de disparos. Esta etapa inicial permite evaluar técnica y económicamente cada escenario de desarrollo utilizando como criterio de selección indicadores económicos como el Valor Presente Neto (VPN). Además, gracias al método de muestreo Monte-Carlo es posible estimar una frontera de eficiencia del proyecto (Tonnsen et al 2008)

Una vez que se eligieron cuidadosamente los mejores escenarios de desarrollo, se realizaron más simulaciones para evaluar la incertidumbre. Como resultado del análisis integrado, la comprensión del yacimiento y la evaluación de múltiples escenarios, el resultado principal de la metodología es una "clasificación de pozos" asociada con un valor de tasa de éxito que permite seleccionar una ubicación de pozo con el menor riesgo asociado.

Como ejemplo de aplicación, los resultados mostraron que solo el 50 % de los pozos propuestos inicialmente superaron el criterio del umbral económico y una recuperación similar en comparación con el plan de desarrollo del campo de referencia. Con base en eso, se recomendaron nuevas ubicaciones para minimizar el CAPEX respetando la meta establecida.

Introduction

As mentioned in many studies, well placement is one of the most complex tasks in the process of creating field development plans, and normally it is performed manually for each simulation case. This activity requires tens, hundreds, or thousands of repetitions to test the spectrum of possible solutions with a lot of options to locate, complete, and schedule the wells, consuming a lot of time from both the human resources and hardware/software viewpoints.

Simulation Opportunity Index (SOI) is one of the methodologies used to help the petrotechnical experts to get the targets but there are a lot of methodologies to calculate this, depending on the specific type of field/reservoir.

This methodology is based on an integrated and automated workflow that allows the sampling of any uncertainty, or optimization variable, such as: Petrophysical variables, natural fracture properties, structural features, horizontal length, well spacing, well orientation, and well trajectory type (horizontal or vertical). Running repeatedly a case for each set of created wells repeatedly and calculating economic variables, for instance: Net present value (NPV), Return of investment (ROI). This allows the team to make decisions, but even better it is a flexible workflow which can be adapted to any condition of reservoir economical constraints, thus reducing the time to generate the Field development plan (FDP) under uncertainty for brown or green field from months to weeks or days.

Methodology & results

This methodology has been tested in theoretical models with a variety of characteristics for clastic or carbonate reservoirs, but also it has been used in different real projects with great results in terms of execution timeframe, uncertainty quantification, and optimization. The description of the methodology and some of these results will be shown below.

Figure 1 describes the eight steps of the methodology, where every step is integrated with the next one for a better understanding of subsurface uncertainty.

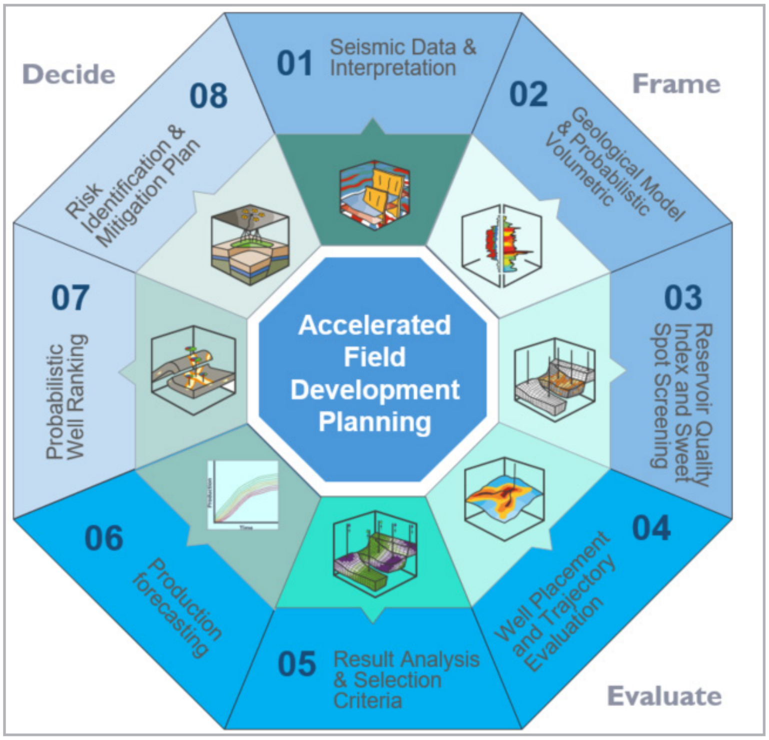


Figure 1. Accelerated Field Development Plan Methodology Scheme.

Seismic data & interpretation

Conventional reservoir characterization begins with the comprehension of seismic data available in the region, where horizons are interpreted, and the reservoir structure is delimited. At this initial stage of structural modeling, the seismic resolution has associated uncertainty. Therefore, the first step in the methodology is to include variation or possible outcomes from more than one interpretation. **Figure 2** illustrates the top, middle, and bottom limits and their range of variation used in the process. This allows capturing one of many key uncertainties during the evaluation process of a well position.

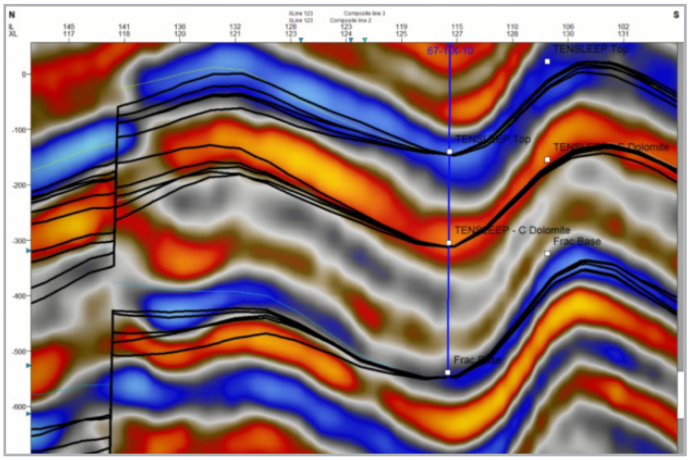


Figure 2. Seismic interpretation ensembles.

The automatization of the methodology gives the opportunity to measure the impact on production forecast and the economic potential of the asset.

Geological model & probabilistic volumetric

A probabilistic approach is a common practice for the estimation of original oil in place (OOIP). The development of multiple static models was connected to simulation models, and associated uncertainties such as porosity, permeability, and oil-water contact were considered. **Figure 3** exemplifies the normal distribution of volumetric calculation.

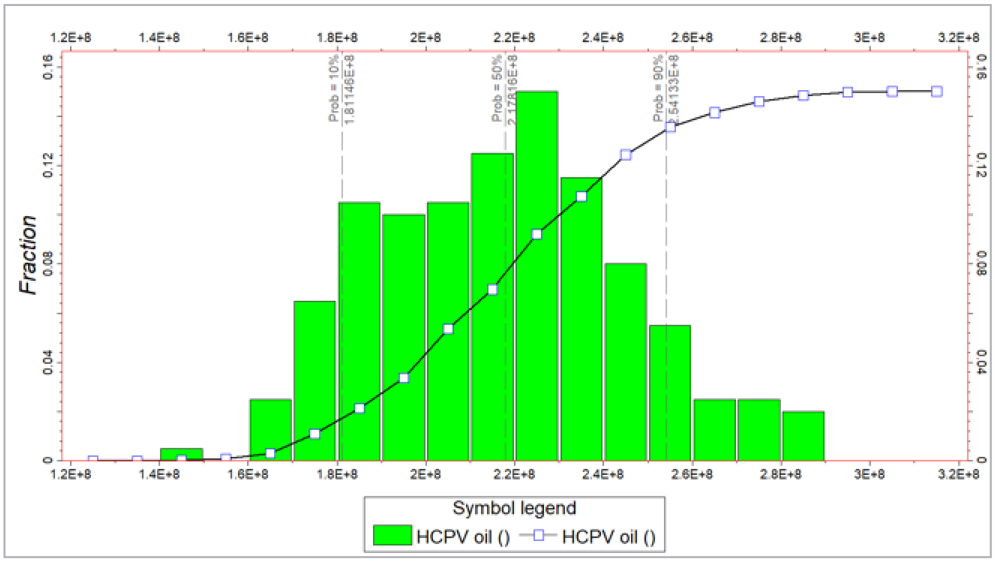


Figure 3. The probabilistic calculation for OOIP.

For carbonate reservoirs, a discrete fracture network had been included in the automated workflow. For instance, fracture aperture (a), sigma (σ), and fracture intensity were also evaluated.

Simulation opportunity index and sweet spot screening

As part of the methodology of this paper, Simulation opportunity index technique (Al-Khazraji et al 2015) has been implemented to identify reservoir potential zones with higher opportunities to maximize oil recovery. This method has been integrated and automated to be applicable for clastic or carbonate reservoirs.

$$SOI = \sqrt[3]{ISO * IHCVP * IKH}$$

SOI = Simulation Opportunity Index

ISO = Oil saturation index

IHCVP = Hydrocarbon volume index

IKH = Flow capacity index

As a result, **Figure 4** shows potential zones identified for one simulation case. Cutoff of 0.3 – 0.4 has been used as a reference. Other considerations for identifying potential zones are connected volumes, distances to faults, and drainage radius of existing wells.

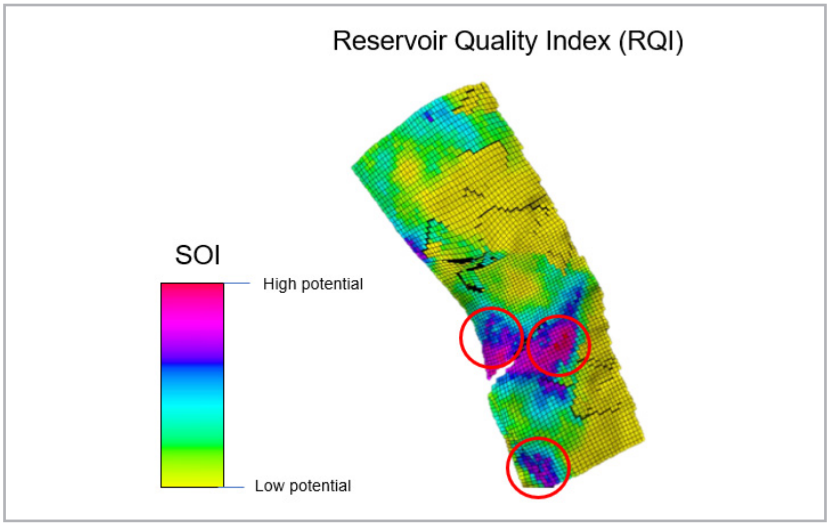


Figure 4. Reservoir sweet spots identification.

Well placement and trajectory evaluation

This is one of the most important stages in the methodology attributable to the well spacing, rig resources, and automatic completion which controls the total well number for each iteration. Consequently, an estimation of CAPEX for each development scenario.

Software automatization and integration allow combining SOI with well-positioning tools easily to switch between vertical, deviated, and horizontal wells to compare multiple FDP concepts, **Figure 5**.

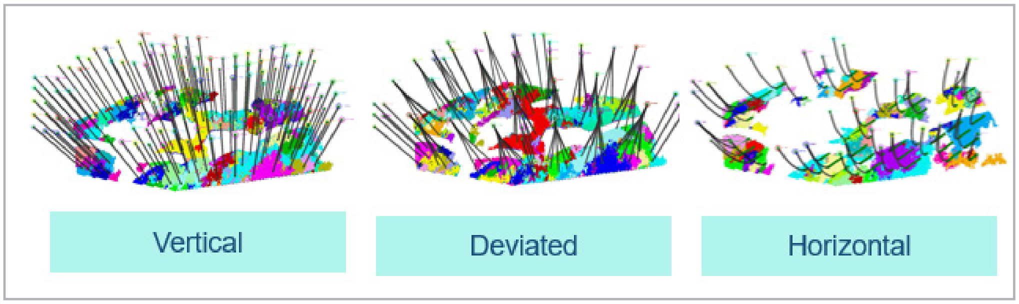


Figure 5. Well placement options for AFP.

Result analysis & selection criteria

Multiple scenarios can be executed in a few hours under uncertainty which allow to use of different selection criteria for each case, with a particular feature or constraint. In **Figures 6** and **7** cumulative production and oil rates for the set of cases are shown; later these values together with economic parameters are used to calculate NPV for all the evaluated scenarios and using a statistical parameters P10, P50, and P90 are calculated, and compared with the same percentiles for the cumulative oil, **Figure 8**.

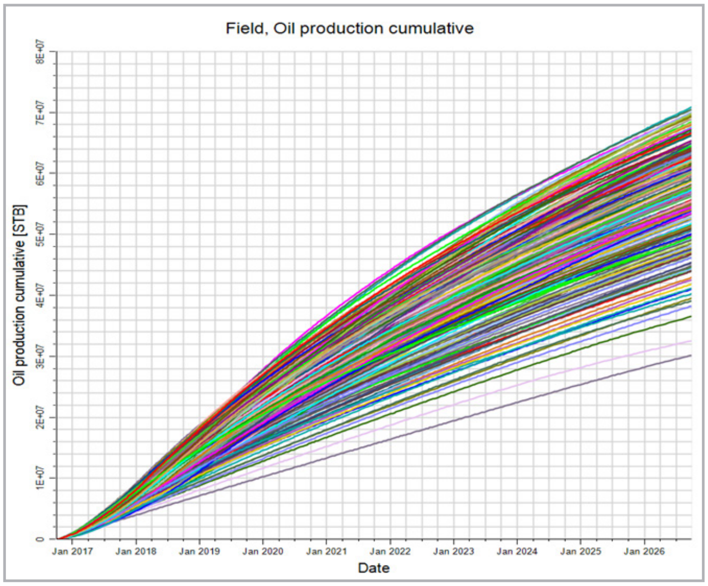


Figure 6. Cumulative oil production for the ensemble of cases.

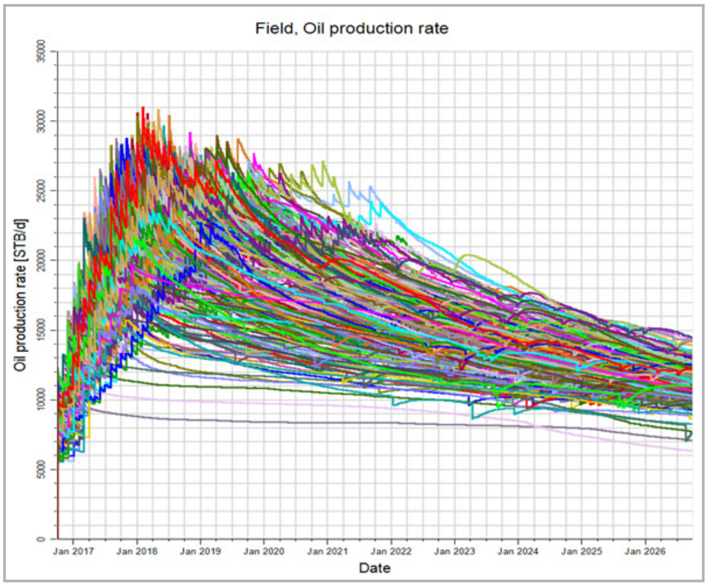


Figure 7. Oil rate for the ensemble of cases.

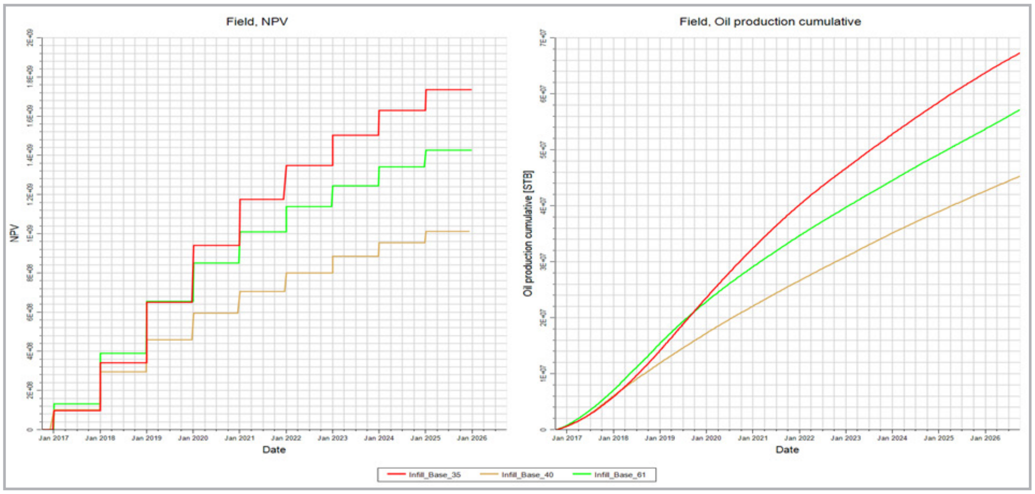


Figure 8. Comparison of NPV and cumulative oil production for P10, P50 and P90.

An additional way to compare results and select the best cases is through complementary economic indicators (i.e., return of investment) and using frontiers of efficient, **Figure 9** it is important to highlight that each point represent one simulation case. in this study two methods were used: first with a cross chart between Net Present Value and Return of Investment and another one with Cumulative Oil Production against Return of Investment, **Figure 10**. Here it is important to highlight that all these graphs and methods could be modified, based on operator or field particularities, adapting the workflow quite simple.

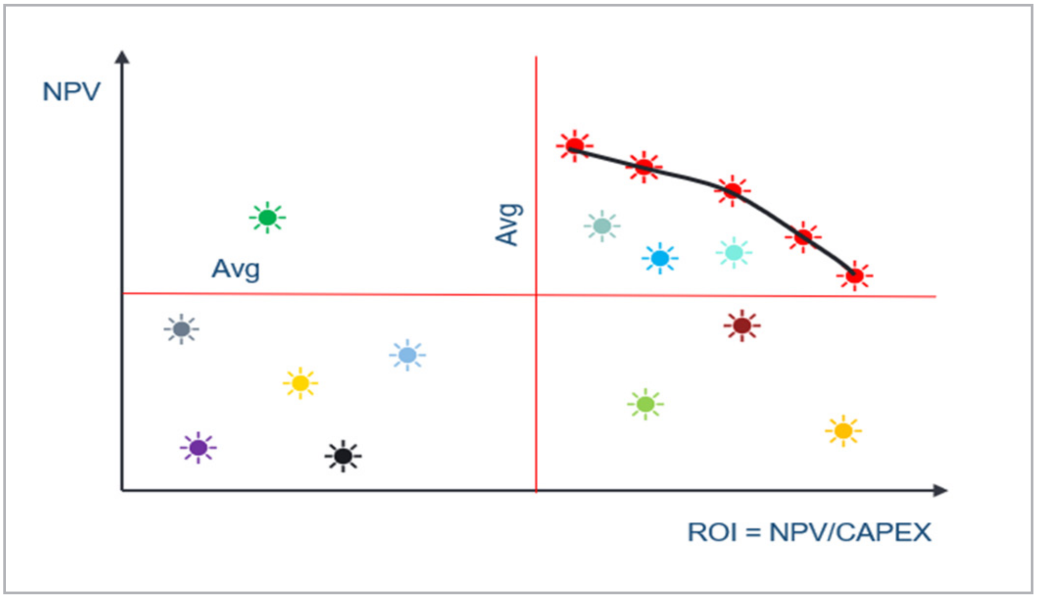


Figure 9. Example for comparison of NPV and ROI and frontiers of efficiency.

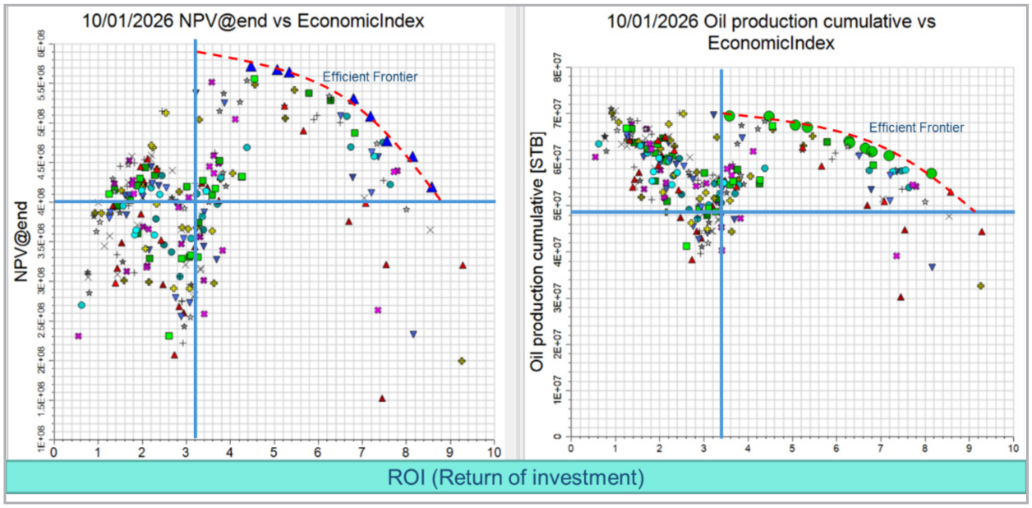


Figure 10. NPV vs ROI and NPV vs Oil cumulative Comparison for all executions.

Production forecasting

From previous results, each selected scenario can be subjected to sensitivity and uncertainty analysis, to investigate the impact of other uncertainty variables in more detail and the subsequent well ranking with probabilities.

For this study, an uncertainty analysis was performed for each percentile previously determined, which allows a later well ranking for each percentile covering the entire uncertainty present. The results of the ensemble of cases are shown in **Figures 11, 12,** and **13**.

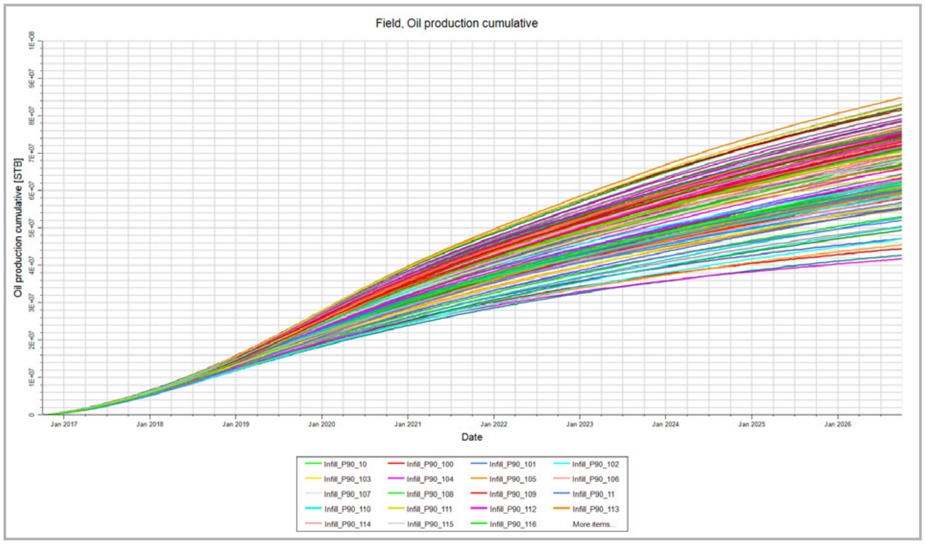


Figure 11. Ensemble of cases from uncertainty for case P10.

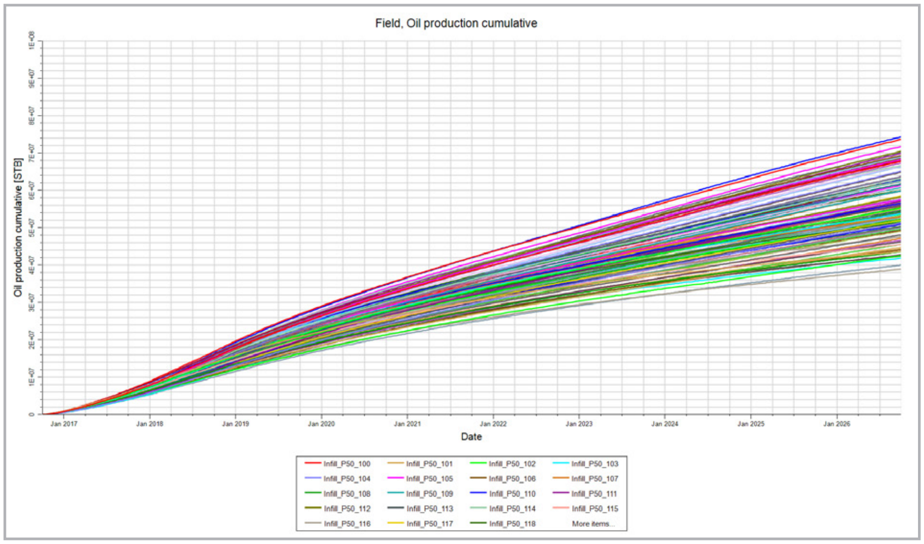


Figure 12. Ensemble of cases from uncertainty for P50.

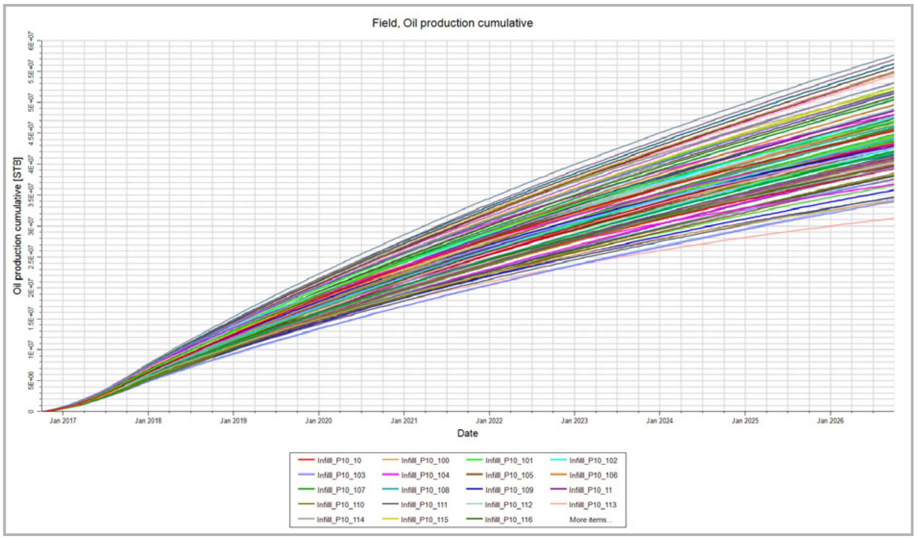


Figure 13. Ensemble of cases from uncertainty for P90.

Probabilistic well ranking

As part of the final stages, all wells for each percentile or ensemble of cases, could be ranked based on the selected success criteria. For this study the success criteria were the well economic demand (Schulze-Riegert et al. 2020); considering the probability of success for all wells in the ensemble of cases from P50. **Figures 14**,**15** and **16**, present the NPV and Np for Well P02 (from P50), It can be seen that the well has a probability of success of 38% and is below the minimum acceptable for this evaluation, (60%).

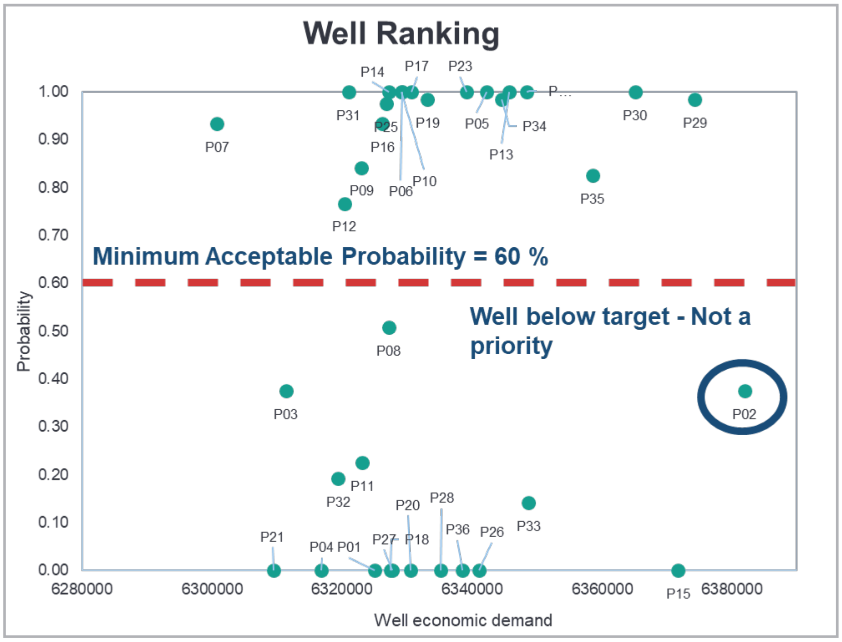


Figure 14. Probability of success for all wells in the Ensemble of cases from P50.

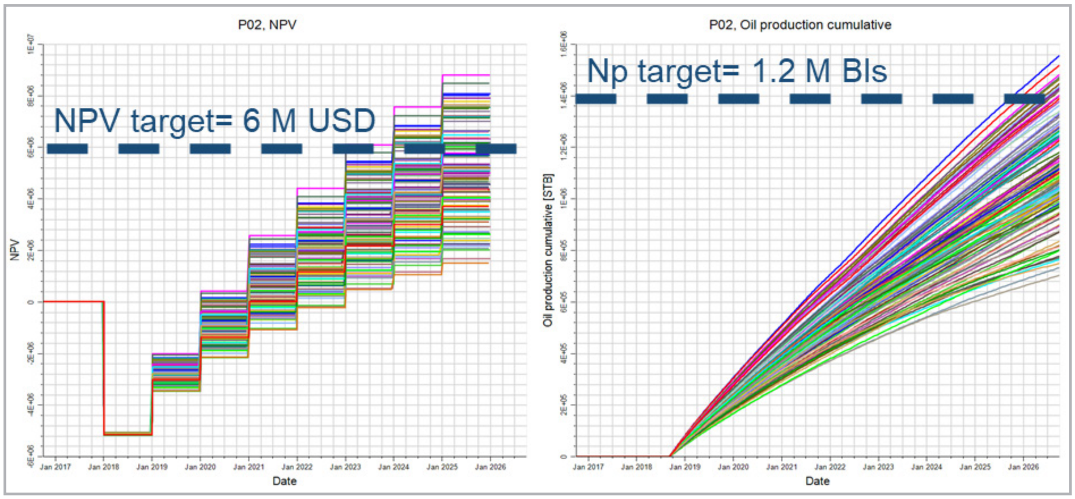


Figure 15. NPV and Np for Well P02 in the ensemble of cases.

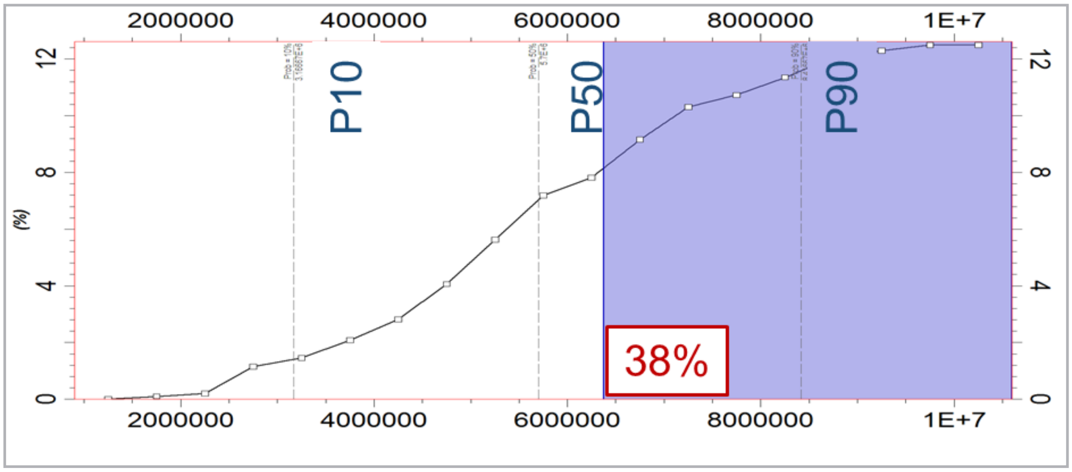


Figure 16. Probability of success for well P02 in the Ensemble of cases from P50.

Risk identification, mitigation plan and reporting

The last step of this methodology is a risk mitigation plan supported by the results of the sensitivity analysis previously performed and the customized reporting. The main idea of the mitigation plan is to invest only where it is necessary. So that data acquisition strategy will be led by those variables with more impact; in this case those parameters are the aquifer, oil water contact, API gravity, initial pressure and relative permeabilities curves, **Figure 17;** and based on that, the acquisition plan comprises MDT/RFT, fluid samples and PVT analysis, core sampling and SCAL.

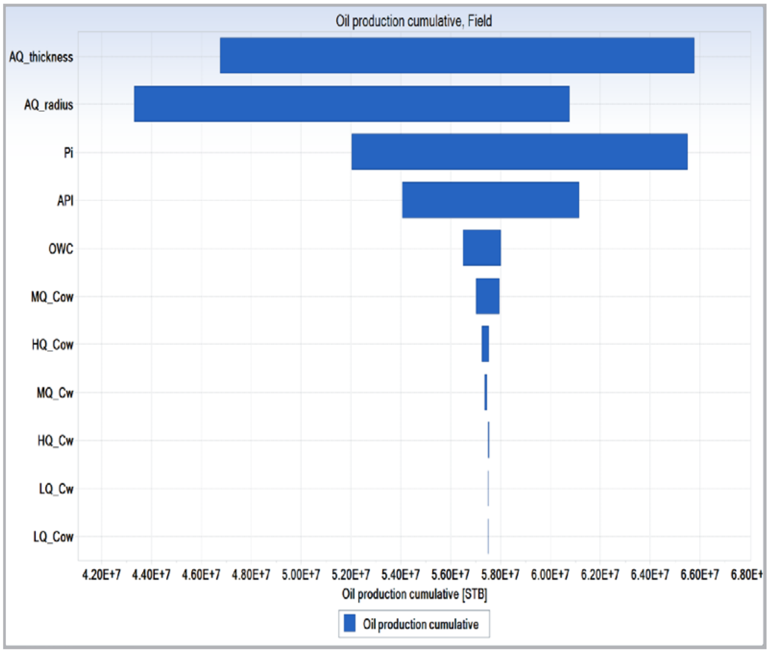


Figure 17. Tornado plot and variables with success for well P02 in the ensemble of cases from P50.

As can be seen in **Figures 18 and 19**, the result reports of this software are automated.

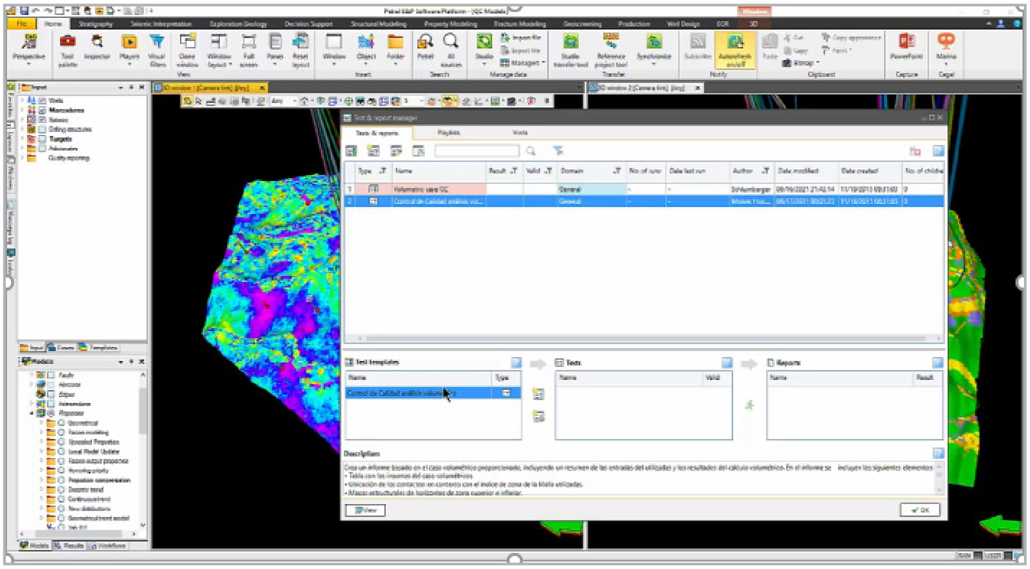
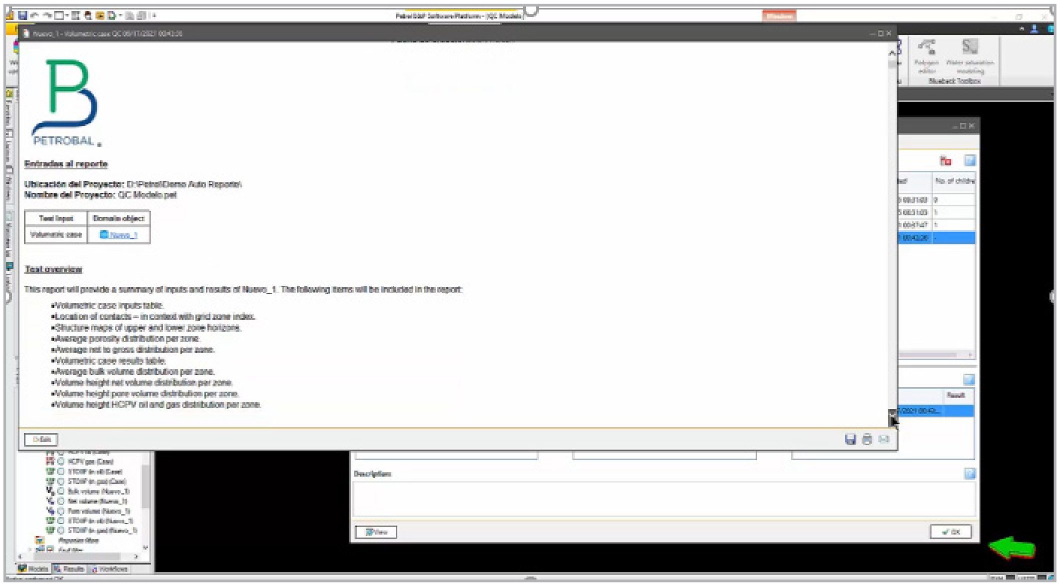


Figure 18. Display for report setup.



PETROBAL

Entradas al reporte

Ubicación del Proyecto: D:\Petrel\Demo Auto Reporte\
Nombre del Proyecto: QC Modelo.pet

Test input	Domain object
Volumetric case	Nuevo_1

Test overview

This report will provide a summary of inputs and results of Nuevo_1. The following items will be included in the report:

- Volumetric case inputs table.
- Location of contacts – in context with grid zone index.
- Structure maps of upper and lower zone horizons.
- Average porosity distribution per zone.
- Average net to gross distribution per zone.
- Volumetric case results table.
- Average bulk volume distribution per zone.
- Volume height net volume distribution per zone.
- Volume height pore volume distribution per zone.
- Volume height HCPV oil and gas distribution per zone.

Figure 19. Example of report header.

Conclusions

We have presented a methodology for evaluation of multiple field development scenarios, that can be carried out in reduced timeframe, thanks to automatization of workflows. The focus of this paper is a flexible and integrated workflow comprising:

- Geological model and probabilistic volumetric
- Reservoir quality evaluation through dynamic modelling
- Well placement and trajectory evaluation
- Probabilistic well ranking and risk identification

This methodology allows the quantification of subsurface uncertainty and support business decisions, with hundreds of executions through a probabilistic approach. The integration with economic indicators (ROI and NPV) strengthens selection of best field development plan concept.

Nomenclature

SOI =	Simulation Opportunity Index
NPV =	Net Present Value
ROI =	Return of Investment
FDP =	Field Development Plan
API =	American Petroleum Institute
SCAL =	Special Core Analysis
a =	fracture aperture
σ =	Sigma
ISO =	Oil saturation index
IHCVP =	Hydrocarbon volume index
IKH =	Flow capacity index

Acknowledgement

The authors of this paper would like to thank the management for permission to publish this work. In particular, authors highly appreciate and respect the technical contributions of all D&I Schlumberger Team.

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