NEW TECHNOLOGIES GUIDE STRATEGIC CHANGES IN A LOW OIL PRICE ENVIRONMENT

SPEEDWISE DIAGNOSTICS®

SPEEDWISE® WATERFLOOD

A QRI white paper
The current low oil price environment presents a distinct challenge to the field development planning and reserves estimation process. Operating companies around the world, of all shapes and sizes, have been left with large portfolios of mature assets whose field development plans (FDPs) and associated reserves are no longer economically feasible. These plans must be retooled away from capital intensive investments toward reservoir management and field optimization.

Reservoir management of mature assets is inherently complex. The FDP process typically takes many months, involving a large team of experts and the construction of sophisticated full-field simulation models. In this low price environment, the large teams necessary for reservoir studies and development planning are often no longer available, as companies have been forced to downsize their organizations. The sad result of this reality is that the bulk of the world’s mature assets are currently operating on autopilot, with little active investment, and with a reserves base that is not accurately quantified.

This poses two challenges to oil and gas companies without the time and/or resources to devote to a large technical team working for many months:

1. How can new field development plans be created to actively manage and optimize mature oil fields, without an up-to-date model?
2. How can reserves estimates be updated to accurately evaluate assets, without an up-to-date model?

Changing Strategies

A large North American operator recently addressed this problem by relying on SpeedWise Diagnostics®, a new technology that accelerates the FDP workflow. For a large mature asset under waterflood, a vintage 2014 FDP was found to be no longer feasible, requiring a new FDP and reserves estimate.

Using SpeedWise Diagnostics, within three weeks Quantum Reservoir Impact® (QRI®) delivered a new FDP, grounded by the current oil price, including technical due diligence and economic validation. The new plan included cycling or shut-in of marginal producers, along with restoration of production from offline wells; artificial lift upgrades or up sizing; recompletions; waterflood pattern optimization and expansion; and new drilling.

SpeedWise Diagnostics has an established track record worldwide of assisting companies in meeting two objectives:

1. Rapidly preparing FDPs that increase production and optimize current operations.
2. Rapidly estimating asset value as part of acquisition analysis.

Rapid Analysis of Reservoir Performance

SpeedWise Diagnostics leverages a big-data analytics platform and an array of analytical, numerical, and empirical models combined through experience-tested workflows to deliver a catalog of actionable opportunities for an asset. The entire historical set of well, field, and reservoir data is processed and input into this platform. Each opportunity is quantified in terms of its expected value under uncertainty. The field development opportunities are highly specific, uniquely tailored for the challenges of each asset, and typically include waterflood optimization actions (close uneconomic wells, optimize producer/injector rates, etc.), pump optimization and upsizing, reperforations and recompletions, new well locations, and waterflood expansions.

Specifically, the objectives of this tool are:

- Diagnose the current state of reservoir performance by instantly processing and analyzing well and reservoir data.
- Couple automated analytics with engineering wisdom.
- Translate diagnostics into detailed action plans in the field to capture increases in production, reserves or capital efficiency improvements.
Combining the power of automation and diagnostics, the process is designed to move fast, arming engineers with the analytics needed to increase the performance of a given asset.

Comprehensive analytics are grouped into four categories, with action plans to increase production and reserves resulting from each category. The categories are:

1. **Performance:** Captures performance at the field and well level, focusing on observed trends in all wells, including producers and injectors, active and inactive, and lays the foundation for the diagnostics in subsequent sections.

2. **Reservoir Contact:** Integrates completion data, geologic data, and petrophysical data to analyze all aspects of reservoir contact for all wells, over the entire producing history of the field.

3. **Pressure and Voidage:** Examines reservoir fundamentals by analyzing trends in the reservoir pressure. The foundation for this analysis is QRI’s stochastic material balance history matching*, which accounts for multiple realizations and scenarios that could yield the observed trends in pressure.

4. **Sweep Efficiency and Fractional Flow:** Integrates the findings of the prior sections into an analysis of fluid movement through the reservoir.

Analytics are integrated, allowing deep, multifaceted investigation of reservoir conditions. All well and reservoir data is processed nearly instantly, allowing engineers to focus on solutions in the field.

This course of action typically requires only three weeks (Figure 1), beginning with data processing (typically one week), and including roughly two hours of computation time once the data set is prepared. The final two weeks involve technical due diligence by subject matter experts to mature the opportunities that were identified by the algorithm. Opportunities that are not technically feasible are discarded; opportunities that are not economically feasible are kept in the backlog of the portfolio, and a break-even oil price is provided. Those actionable opportunities that are both technically and economically feasible provide the basis of a new FDP and associated production forecasts and reserves estimates, and work proposals are prepared for each opportunity that can be used to justify the cost of the work.

Each potential action is identified through a classic workflow that has been accelerated or automated through technology. For example, an empirical method is used to identify pump upsizing opportunities: the wells are filtered based on their apparent flow upside potential, wellbore diagram and current pump and operational parameters.

For reperforations, a data-driven machine-learning algorithm is used. First, each historical perforation is described in terms of a series of attributes: log signature, distance to nearby geologic features, characteristics of offset production and injection data. The performance of each perforation is then summarized in a few key metrics: initial rate, maximum rate, expected ultimate recovery, etc. A machine-learning algorithm then determines a relationship between the historical perforation attributes and their performance. This model can now be used to identify all current behind pipe opportunities and quantify each opportunity based on chance of success and estimated production parameters. Proceeding similarly for various kinds of opportunities, SpeedWise Diagnostics thus delivered a portfolio of economic actions on a field and redefined the development strategy going forward.

**Case Study: Accelerated Field Development Planning**

The subject of this case study is a large mature oil field, with over 19 stacked reservoirs under waterflood. The oilfield data set is exceptionally large, due to more than 3,000 wells that have been on production for more than 100 years. The vintage 2014 FDP, found to be mostly unfeasible at the current oil prices, focused on new drilling and waterflood expansions.
Following the conventional FDP workflow, a multidisciplinary technical team would have required many months to prepare a new FDP with associated production forecasts.

In particular, the stratigraphic complexity of this reservoir presented a daunting challenge to the technical team. Almost all wells have historically commingled production and injection from numerous layers simultaneously, resulting in uncertainty around the recovery factor of each layer, and the drainage radius of each well. This common reservoir management problem is often unaddressed, or is indirectly addressed through reservoir simulation history matching. However, the SpeedWise Diagnostics algorithm includes a module designed to allocate production and injection by flow unit for all commingled wells. This module incorporates any and all relevant data which is available, including flowmeter results, permeability and thickness at each location, relative zonal pressures, and a water influx model to allocate water appropriately (and re-allocate remaining fluids). By estimating the production and injection of each well from each flow unit, during each month of operation, estimates of recovery factor and drainage allowed new opportunities to be identified.

The FDP prepared for this field relied on five pillars. A summary of these results (Figure 2) includes a field map showing each well location, risked production forecasts, and economic indicators for each pillar.

1. **Operate the Right Wells**
   - Shutting wells that are currently below their economic limit, and re-activating offline wells that may have potential.

2. **Lift Optimization**
   - Upgrading from rod to ESP, or upsizing existing ESPs.

3. **Recompletion**
   - Restoring production from offline wells by recompleting to target new pay (Figure 3).

4. **Waterflood Expansion and Optimization**
   - Expanding current waterflood areally into new patterns, and vertically into new formations.
   - Optimizing current waterflood patterns by recompleting injectors to target new layers, or shutting in injectors without remaining potential and using the water in other patterns.

5. **New Drilling**
   - New well locations.

**Figure 2: Summary of Field Development Opportunities in Five Categories.**

<table>
<thead>
<tr>
<th>PILLAR</th>
<th># Wells / Patterns</th>
<th>CAPEX per Well (M$)</th>
<th>Min. Incr. Oil Rate (bpd)</th>
<th>Ave. Incr. Oil</th>
<th>Total Incr. Oil</th>
<th>Ave. Cost</th>
<th>Ave. Payout (months)</th>
<th>Ave. NPV (M$)</th>
</tr>
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<tbody>
<tr>
<td>I.</td>
<td>Operate the right wells</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>II.</td>
<td>Lift optimization</td>
<td>25</td>
<td>2.10</td>
<td>7.0</td>
<td>18 bopd</td>
<td>84%</td>
<td>16</td>
<td>3.1</td>
</tr>
<tr>
<td>III.</td>
<td>Recompletion</td>
<td>12</td>
<td>177</td>
<td>7.5</td>
<td>7.5 Mboe</td>
<td>91 Mboe</td>
<td>18%</td>
<td>14.3</td>
</tr>
<tr>
<td>IV.</td>
<td>Waterflood</td>
<td>49</td>
<td>618</td>
<td>9 (plateau)</td>
<td>12.2 Mboe</td>
<td>5945 Mboe</td>
<td>73%</td>
<td>13 (Top 5 Plates)</td>
</tr>
<tr>
<td>V.</td>
<td>New Drills</td>
<td>7</td>
<td>2,006</td>
<td>62</td>
<td>38 bopd</td>
<td>17b bopd</td>
<td>54%</td>
<td>2,243</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td></td>
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**New Technology for Waterflood Optimization**

SpeedWise® Waterflood Management (SWM™) is a second piece of technology currently being deployed in the same asset. For a mature waterflood, SWM contains a reduced-physics data-driven model that quantifies each connection between an injector and a producer in terms of strength and efficiency (Figure 4).

To quantify the strength of each interwell connection, the stationary pressure equation is solved and the solution is post-processed using the tracer equation to estimate well-allocation factors. The efficiency of each connection is determined by an empirical fractional flow model calibrated to production data at each connection. This information is then fed to an optimization engine that takes into account the connection parameters, the various existing operational constraints at the field and well level and the general objective of the strategy to propose a rebalancing of the producer and injector. Target rates are defined that will help strengthen efficient connection and weaken connection associated with swept areas.
Specifically, the objectives of SWM are:

- **Determine the strength and efficiency of well interactions.**
- **Continually optimize of operational decisions to maximize performance of existing waterfloods.**

The SWM methodology offers features that are critical for the reservoir under study: an improved modeling strategy, an advanced optimization engine and a new uncertainty analysis methodology.

The workflow contains four steps:

1. **Data Processing:** Two types of data, geological data and operational data, are required to maximize this technology. Geological data of the reservoir is used to create a reservoir grid where the connectivity analysis will be applied, and operational data of each well is used to calculate the strength and efficiency of the connections between injectors and producers as well as aquifers.

2. **Reservoir Surveillance:** The reservoir grid that is created based on the geological data loaded during the data processing step is essential. The reservoir model has similarities to other surveillance models but differs in two important aspects: the inter-well allocation factors are computed through the solution of a tracer equation rather than through streamline computations, and the fractional flow analysis is performed per connection rather than per well. The tracer method is much more computational efficient than other methods. Using the tracer also allows an improved treatment of dual-porosity systems.

3. **Well Control Optimization:** After the surveillance analysis, an automatic optimization on the rate controls of the existing wells is performed. The optimization is based on the inter-well and well-aquifer connectivity information obtained in the surveillance step.

4. **Visualization:** The user receives an interactive, portable, cross-platform, user-friendly graphic interface to present the surveillance analysis and operational recommendations. The interface enables users to interactively view the pre-analyzed results by SWM and also performs real-time cloud computing. The user interface allows users to input their own well controls for future and get instantaneous forecast results on the reservoir response.

**Case Study: Optimizing Field Development Planning**

The new technology was also used for management of a large Middle East carbonate waterflood, where it maintained the target oil production rate of the field while minimizing water production for cost and maximizing water injection for pressure support. It was able to integrate all relevant facility, well group, individual well and reservoir constraints but remained fast enough to run daily analysis as new data became available.

One of the main advantages to this waterflood management technology is providing engineers key information that can guide operations quickly and provide more controllable uncertainty. In waterfloods where the main drive mechanism is the replacement of oil by injected water, understanding the connectivity between wells helps engineers
identify insufficient pressure support and water cycling. This new technology reduces the amount of time spent building subsurface models and focuses the asset team on the tactical reservoir management decisions to be made to improve the waterflood.

The common thread between these technologies is that they are guided by experience-based workflows and leveraging simplified physics and data-driven models that allow them to deliver insights extremely quickly. They are used to determine what well to recomplete, what pump to upgrade or how to adjust the production/injection strategy for complex and very mature fields. These diagnostics can be run quickly to update the strategy as oil prices are changing, and requires very little resources to identify the top opportunities to focus on.

Conclusion

Simulation studies or field development plans are examples of work efforts that often take months to complete. These efforts are not cost effective in the current downturn, as resources may not be available. The ability to accelerate that work dramatically through workflows leveraging automated or at least assisted components lead to significant and timely value creation opportunities even at low oil prices. These experience-guided and technology-driven solutions help operators adapt quickly to the volatile prices. The asset team can focus on planning and executing the right solutions rather than being paralyzed in the analysis stage.

To learn more about how these solutions are being used to help companies perform technical due diligence for better field development planning, for acquisition and divestitures, and for finding new opportunities in mature fields, contact info@qrigroup.com, or visit www.qrigroup.com.