CASE STUDY

HALLIBURTON

Waterflood optimization: maximized economic benefits

Evaluation and optimization of waterflood projects: new approaches and technologies to revitalize a classic method

Challenge

More than half of the world's oil is produced through waterflooding. Though waterfloods have been applied in oilfields for several decades, there are many challenges to both further improving project performance and avoiding project failure. These include scenarios such as early water breakthrough, very high water cuts, mature reservoirs needing revitalization, low recovery, and sub-optimal infrastructure.

A typical field development design approach involves a small number of standalone solutions that are not designed to achieve a common objective. Decisions are often made reactively, on a day-to-day basis, rather than on a proactive planning basis. This approach does not take into account the complexity of upstream or downstream consequences of operational decisions.

Field development plans involve screening a multitude of operational options and decisions that can easily lead to hundreds or thousands of developmental scenarios. The main challenge is designing operational parameters such as injection rate, position of injection wells, and surface facilities such that they optimize the most desirable business objective.

Benefits

Quick assessment of current exploitation scheme performance:

- **Maximize waterflood oil production and economics** (net present value (NPV), rate of return, and so on); increments of up to 400% of base-case NPV have been obtained in real cases
- **Lower risk of waterflood under-performance or failure**
- **Higher accuracy on key decision variables** such as injection rate, number and location of wells, and drilling and workover schedules considering multiple constraints
- **Precise short-term planning with a robust long-term visualization**
- **Real-time monitoring and control of project performance**
- **Full complement of Halliburton's product service lines to execute optimized designs**

Solution

Halliburton's proven workflow ensures not only a good waterflood solution but an optimal one. Our process starts with a comprehensive evaluation of current exploitation methods whether for primary recovery or already exisiting waterfloods. Based on the status of the field, we offer flexible solutions that can be tailored to data availability, desired time frames, preferred functionality, and a target injection-production forecast accuracy.

These solutions can vary from classical reservoir engineering-based methods using analytical models up to the use of fully integrated numerical models. Additionally, models can be optimized through simple pattern balancing and diagnostic techniques or with high-end global optimizers and digital oilfield real-time monitoring and control systems. In effect, our approach takes into consideration a holistic view of the asset and provides an optimum solution accordingly—regardless of the recovery methods, reservoir life, or level of modeling sophistication.

A centerpiece of this approach is the use of a smart algorithm to evaluate key field design and operational parameters based solely on their effectiveness at reaching the optimum value of the desired business objective function.

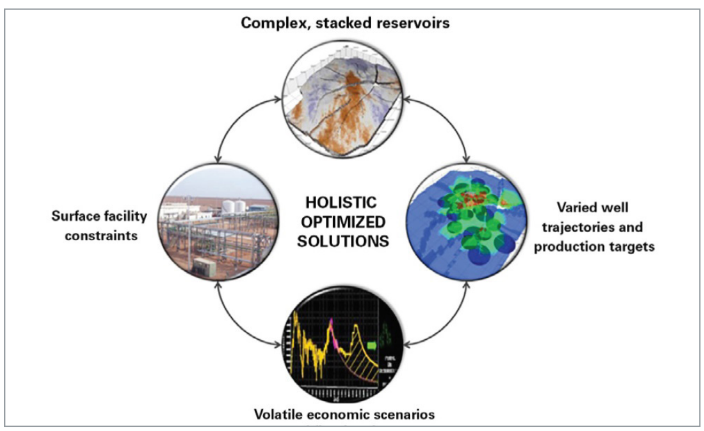

Figure 1: Holistic approach to waterflood optimization

Solution (Continued)

Multiple objective functions can be evaluated according to the needs of the asset, such as maximum net present value (NPV), maximum cumulative oil, and minimum water cut. By incorporating all decision variables and their constraints, we can develop an optimal waterflood design solution that decreases risk and can significantly increase project profitability.

Our approach is completely compatible with full-scale numerical modeling software as well as with analytical modeling spreadsheets. It also extends seamlessly to large-scale integrated waterflood projects that use state-of-the-art, real-time, and digital monitoring and data gathering through the use of our proprietary workflows on digital oilfield technology.

Finally, no waterflood designs can realize their potential without best-in-class field implementation. We also bring to bear our multiple product service lines to ensure error-free implementation of optimized designs. Our product service lines are able to tackle common issues associated with waterflood field operations such as injection water treatment for comparability with the reservoir, water shut-off, sand and fines migration prevention, and flow assurance and control, to name a few.

Case study

A South American NOC wanted to revitalize an important mature field with most of its 1100 MMSTB original oil in place (OOIP) already produced. A revitalization plan using a minimum capital investment was urgently needed. The operator requested the work to be done on-site to assure knowledge transfer and that the model would be in place and ready for further update after the study concluded.

In order to keep the time to accomplish the work using the operator hardware to less than 2 1/2 months, Halliburton tailored the methodology, dividing it into three simulation stages. Each stage evaluated the effect of short periods of operational action on cumulative productions, made decisions, and then further optimized the coming years. A fourth stage targeted maximizing net present value (NPV) by deciding well type (i.e., injector-producer), location of the wellsite, drilling sequence, and water injection rate.

Through the use of the reservoir numerical model, coupled with an optimizer-stochastic machine, Halliburton's team was able to analyze 880 scenarios generated using the constraint of existing infrastructure systems and rig availability. Production increases at an NPV of 400% greater than the operator's existing plans were forecasted. A detailed five-year implementation plan with a risk analysis detailing injection rate by well, location and schedule of workovers, drilling and conversion of wells, and surface facilities revamp was provided.

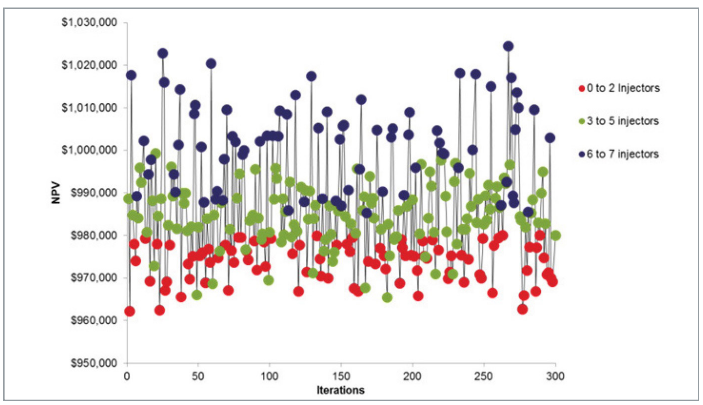

Figure 2: Selection of variables by optimized objective function

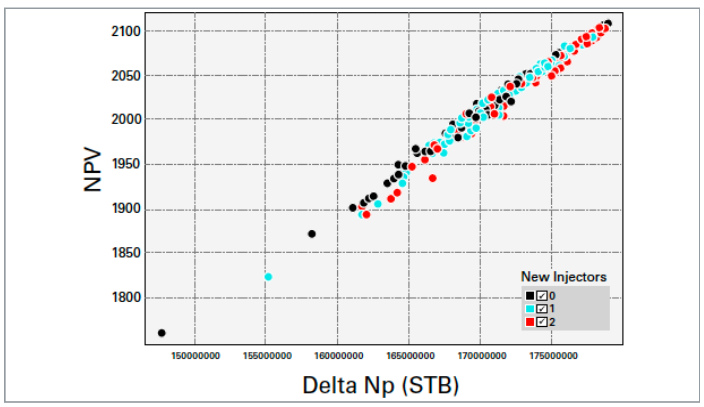

Figure 3: Cycle 4 optimization

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