WHITE PAPER

UNCONVENTIONALS

Using Physics-based Models to Develop Production Forecasts in Unconventional Assets

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PetroVisor™'s completion optimization workflow uses physics-based modeling to optimize completion designs in unconventional formations. Empirical methods may be sufficient if the completion design, including lateral spacings, are within the observed data set. However, a physics-based approach to oil and gas modeling produces superior results when evaluating wells with unknown or unfamiliar lateral spacings, new completion designs or when robust data is not available.

Physics-based modeling can:

- Address transient and bounded multi-phase flow and wellbore hydraulics in horizontal wells with many frac stages and various drainage area sizes
- Efficiently model thousands of completion designs
- Address uncertainty resulting from non-unique history matches
- Quickly produce critical data for operator and investor decisions
- Execute from the cloud or on premise with the appropriate software and computing power

The Benefits of Physics-based Models

Arps decline curve analysis techniques are commonly used for deriving production forecasts. However, Arps equations do not include physics and can often lead to overly optimistic production forecasts. Engineers have struggled to utilize physics-based models when modeling completion designs because models run slow and require extensive manual data manipulation. The PetroVisor solution is a seamless process where automated tasks and accurate physics-based proxy models are employed to deliver results in time frames useful for investment decision.

The automated physics-based modeling in the PetroVisor platform sources many inputs from the data analytics module and delivers ready-to-use production forecasts for a matrix of completion designs.

The PetroVisor completion optimization workflow evaluates a wide range of completion options and uses economic analysis to determine optimal and near-optimal designs. The process allows input from the operations team at an early stage giving multiple stakeholders ownership in the overall optimization strategy.

Understanding the Workflow

The PetroVisor workflow includes a fracture propagation model and a reservoir fluid flow model. The fracture propagation model computes the fracture geometry dimensions based on rock properties and completion design. The reservoir fluid flow model forecasts monthly production volumes based on the fracture geometry and reservoir properties. Both models are calibrated to existing wells in the area of interest with a history-matching phase. The fracture propagation model is calibrated to match fracturing pressures and injection rates for a given set of rock mechanical properties and the reservoir flow model is calibrated to match production data given the calibrated fracture geometry and reservoir flow properties. This iterative process does not require expert human intervention.

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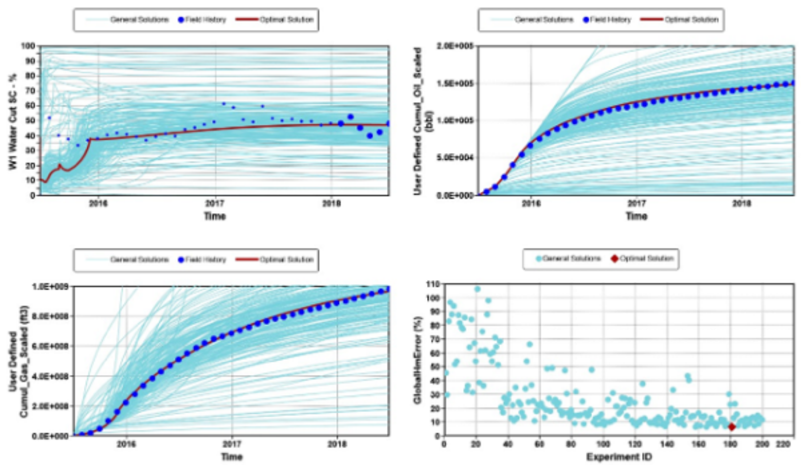
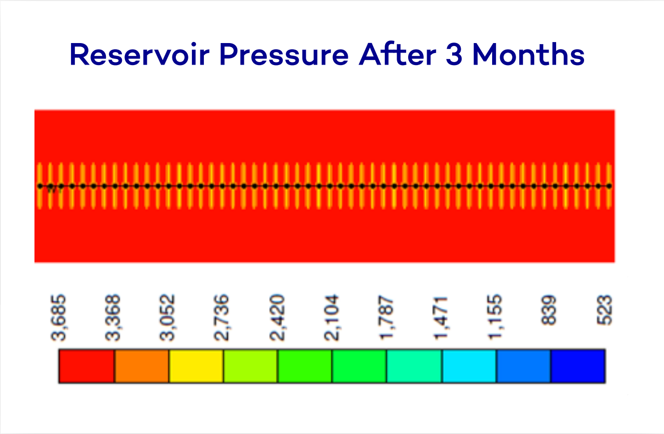


Once calibrated, the models are used to simulate a wide range of completion designs, imposing physics on each. Physics-related data explicitly input with the models include:

- Rock mechanical properties
- Drainage area
- Reservoir fluid properties
- Reservoir fluid flow properties including pressure-dependent permeability
- User-defined surface flow pressures that change over time
- Wellbore hydraulics

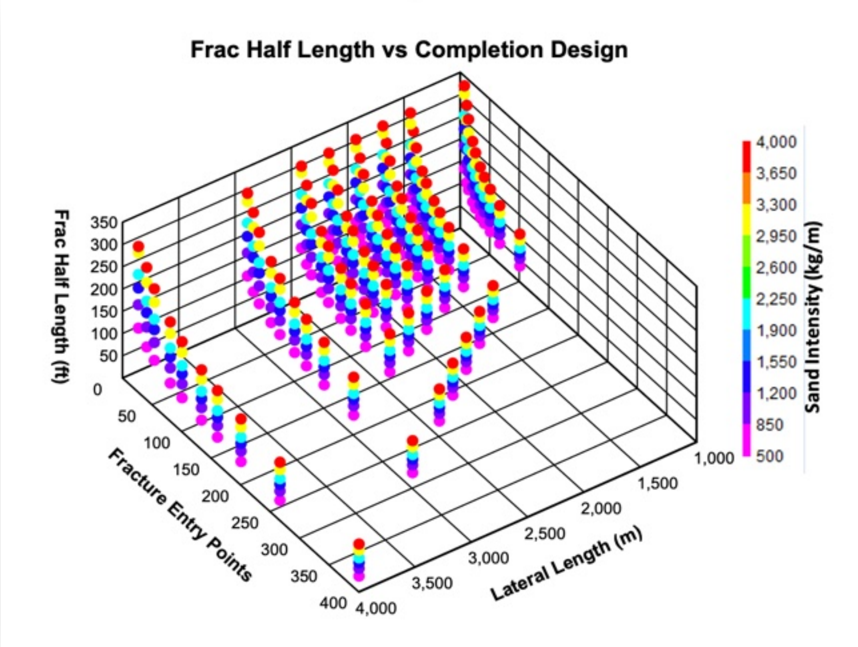


Calibrated models are used to forecast production for a matrix of completion options, often simulating thousands or tens of thousands of potential designs. A 40-year monthly production forecast is generated for each design for use in the follow-on economic optimization. Parameters that are varied in these models include:

- Lateral length and spacing
- Fluid and sand intensity
- Fracture injection rate
- Stage spacing and fracture entry points per stage (perforation clusters or sleeves)
- Reservoir permeability and landing zone

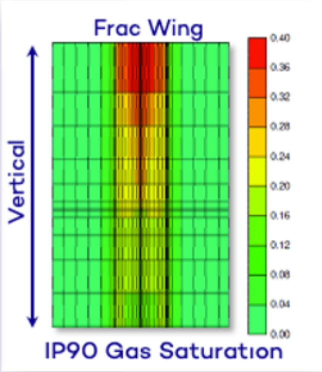
Typically, three to ten values are chosen for each parameter and all permutations are evaluated. Dashboards allow the user to confirm that the simulations were executed properly and quantify how field flowing pressure constraints may impact production volumes.

The physics-based modeling can be completed within a two-week timeframe. A complete workflow from data analytics through development optimization can be completed in 30 days.

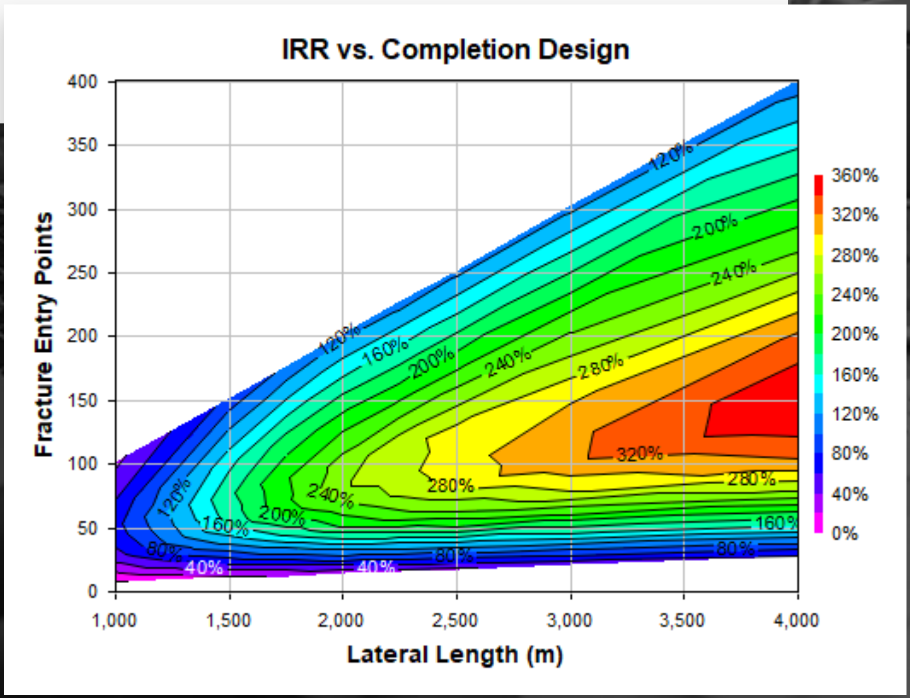


Proxy Model for Faster Results

Physics-based modeling in the completion optimization workflow was designed to suit the often-short timelines required for investment decisions. To achieve fast modeling run times the PetroVisor workflow uses proxy models, which are simplified physics-based models that produce a close approximation to the production forecast generated by a more complex full-wellbore model. The proxy models used in the workflow leverage symmetry when analyzing horizontal completions, model a portion of a single stage and scale up the results to a full wellbore equivalent. This process treats the single stage as the average of all stages in the well and typically delivers results within 5% of a complex full-wellbore model.



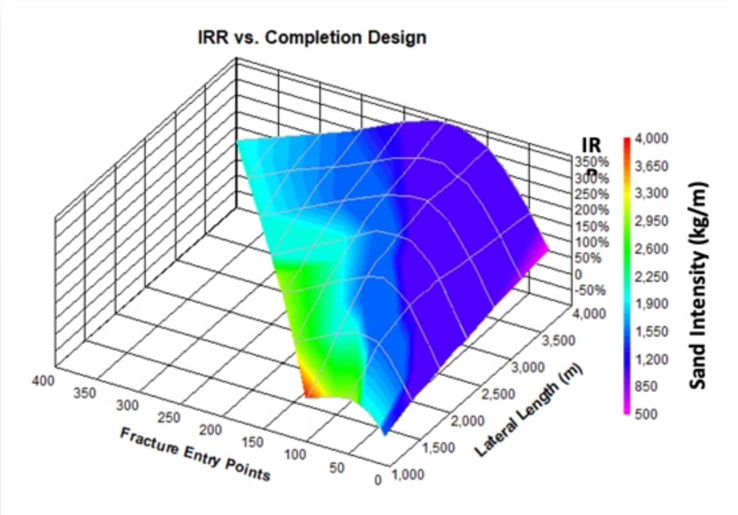
Proxy model optimization does not prevent more complex full-wellbore or multi-wellbore models from being used in future completion designs on individual wells. More complex proxy models can also be used in highly-engineered completions where each stage is modeled. In this situation, run times will be longer but averaging within the wellbore can still be conducted to find a viable proxy model.

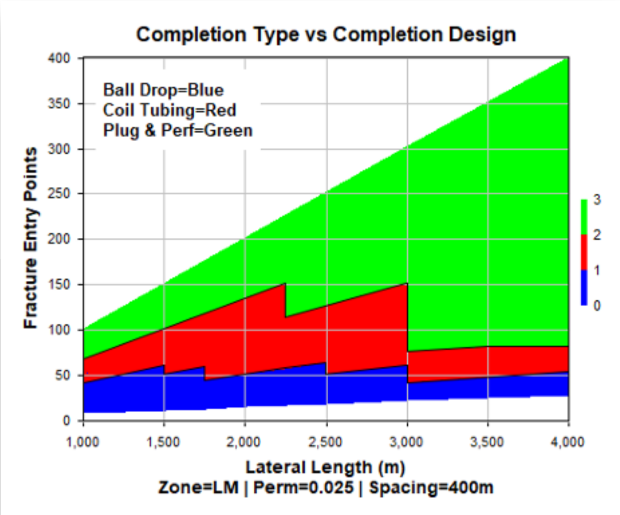


Reducing Complexity for Investment Decisions

While the prevailing mindset may be that more complex models deliver better answers, this proven workflow provides a level of analysis that is usually not achievable in investment-decision timelines. Adding unnecessary complexity to the modeling process can extend timelines past required decision dates and result in using data that is out of date and not reflective of current production parameters.

The PetroVisor completion optimization workflow accommodates physics-based modeling to generate production forecasts for a wide variety of completion designs in unconventional formations. An open and agnostic platform, use the simulator of your choice and integrate emerging technologies. The result is a sound economic assessment, which considers a wide range of technical variables. The workflow offers a marked improvement over computations based on Arps decline curve equations or by running a limited number of physics-based forecasts. The optimized completions are used to guide asset development, allowing both operator and investor to make informed operational and financial decisions in short time frames.





Summary

PetroVisor's completion optimization workflow uses physics-based modeling to optimize completion designs in unconventional formations. When evaluating new completion designs, wells with unknown or unfamiliar lateral spacings or when robust data is not available, a physics-based approach to oil and gas modeling produces superior results. PetroVisor offers an improvement over conventional computations based on Arps decline curve equations or by running a limited number of physics-based forecasts. The resulting completion design provides parameters such as lateral length and spacing that are used in creating the drilling schedule and as inputs to full asset evaluation and development.