



Weatherford®

ReO™ Production Simulation and Optimization Software



Software products for simulating and optimizing upstream hydrocarbon production systems.

ReO Production Simulation and Optimization Software

Weatherford International's production optimization division offers the most complete and robust suite of software tools in the industry for petroleum engineering and production optimization. *ReO* software is a part of Weatherford's **Field Office™** suite and is recognized to be the preeminent software product for simulating and optimizing production networks.



Introduction

ReO software provides simulation and optimization solutions for surface networks incorporating practically every piece of equipment from wellhead to the processing plant. The application simulates the total production system behavior and concurrently optimizes the production honoring the user-defined economic model which typically results in substantial production increases and/or reductions in operating costs.

Typical pay back times for investments in *ReO* software can vary from as little as two weeks to a few months—depending on operating conditions and production parameters.

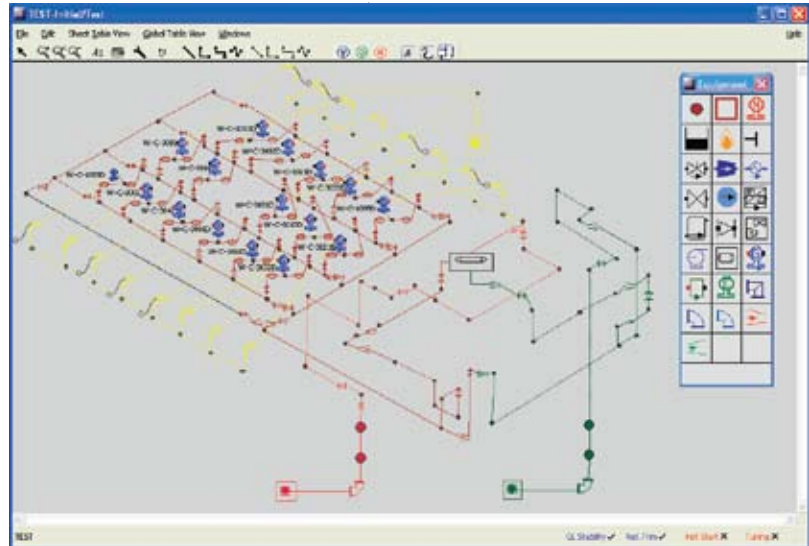
The program is based on leading technology in the areas of fluid modeling, process simulation, optimization and software design to provide the most accurate engineering and economic solutions. Its flexibility enables engineers to build complicated network models very efficiently. The applications unique integrated simulation and optimization approach allows users to handle large and complex networks with ease.

The program was developed using technology that allows integration with Weatherford's current and future production optimization software solutions. **ReO Forecast™** software, a powerful companion program, allows users to couple *ReO* data with sub-surface modeling applications such as material balance or reservoir simulators. This integrated solution enables the operator to make accurate production predictions over the life of the asset. The software offers unprecedented flexibility and powerful tools to analyze and optimize production and perform business planning in the design, operations and forecast phases. Being part of Weatherford's *Field Office* suite means *ReO*'s data and results are seamlessly integrated with **WellFlo™** and **MatBal™** applications.

ReO Production Simulation and Optimization Software

Typical Applications

- **Production facility optimization:** Using available production equipment more effectively increases hydrocarbon production. After optimization, the application returns new settings for various equipment in the field that provide increased hydrocarbon production. Production facility optimization could achieve production gains up to five percent without any capital expenditure.
- **Production system optimization:** Increase hydrocarbon production by re-routing fluids making better use of the existing production system. ReO optimization gains of this type typically depend on capacity of the flow lines.
- **Asset-based gas-lift optimization:** Optimization of hydrocarbon production of a gas-lifted field including injection and production system pressure constraints and allocation of lift gas to gas-lifted wells. The gas-lift optimization algorithm computes the injection rates for each of the wells and these rates are based on the available injection pressure in the network.
- **Production allocation:** The sophisticated simulation and reporting functionality allows users to translate the measured field production rates into individual well and reservoir off-takes which are an essential input for asset and reservoir development planning.
- **Artificial-lift design:** Evaluate whether the selected means of artificial lift (gas lift or electric submersible pump (ESP)) and its design will provide the expected production gains—especially after taking into account production and processing system constraints.
- **De-bottlenecking:** State-of-the-art mathematical models coupled with detailed flow and equipment related results provide sufficient information to the user to identify bottlenecks in production systems in the most cost-effective way.
- **Process equipment design:** The flexibility of modeling the process equipment in multiple ways allows users to run various what-if scenarios for different configurations of process equipment.



Surface network model.

ReO Production Simulation and Optimization Software

Why ReO Software?

Robust, Reliable and Versatile

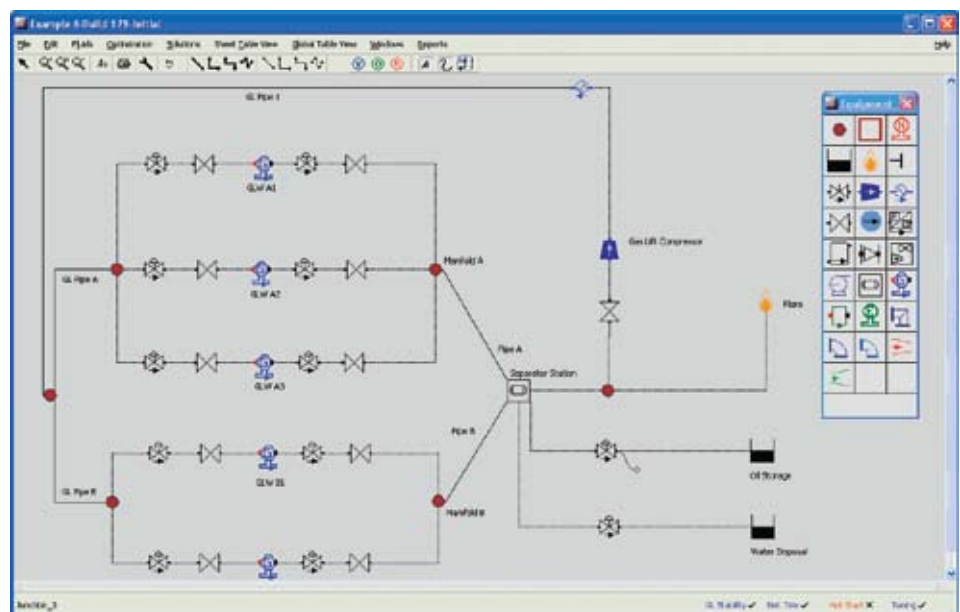
- Highly sophisticated engineering mathematical models coupled with the optimizer ensures that the process physics, in every component of process equipment, is honored during the optimization calculations.
- ReO models have been built for various assets with varying degrees of complexity—many with hundreds of gas-lifted wells and thousands of pipes. The software has an unrivaled track record for robustness both in terms of reliability and solution time for even the most complicated assets.
- ReO models have been stress tested in online systems running four different scenarios four times a day for more than a year without a significant failure rate.

Efficient, Fast and Easy to Use

- The novel solver approach makes it applicable to a large variety of advanced production and asset management problems.
- The program's drag and drop user interface is highly intuitive. Bulk data entry and edit facilities allow fast and efficient model building. Results plotting and visualization aid effective outcome interpretation.
- The ReO solver has been designed for speed and efficiency. In contrast to many other available software packages, the program solution times stay acceptable as problem complexity increases.

Open Interface

- The well documented COM interface allows user to integrate ReO software with third party well modeling software, downstream process simulators or even Excel™.



Excel is a trademark of Microsoft®.

ReO Production Simulation and Optimization Software

Key Features

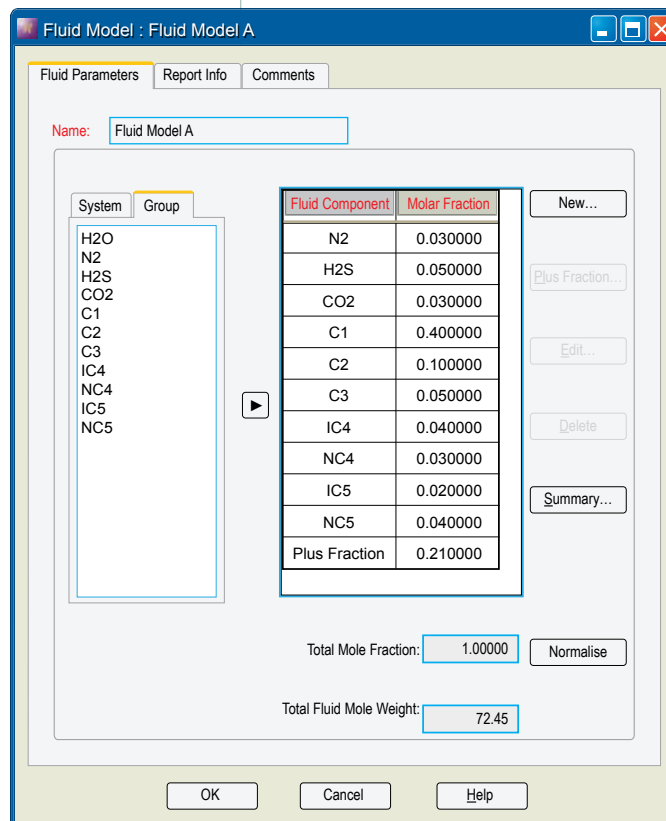
Fluid Modeling

ReO software offers both black oil and compositional pressure/volume/temperature (PVT) models for accurate phase behavior predictions of gas-oil-water systems at a wide range of temperatures and pressures which are commonly encountered in production networks. For black oil PVT, a range of industry standard correlations (Standing, Glaso, Petrosky-Farshad, etc) are available. The compositional PVT is based on equation of state. Six equations of state—including Peng-Robinson and Soave Redlich Kwong are incorporated in ReO software. The fluid data library supplied with the application has component properties up to C45 including many commonly found inorganic components. This allows users to enter the compositional PVT data quickly.

Mixing of fluids plays an important role in the surface production network and ReO software handles the mixing of fluids of different compositions efficiently. For compositional PVT, the application uses the common fluid description approach which enables the accurate mixing of fluids without affecting the CPU time of flash calculations.

The novel black oil to compositional translating algorithm allows users to mix black and compositional PVT data sets and use the sophisticated equation of state calculation engine for optimization.

ReO software reports fluid composition at all nodes in the network. This is highly valuable in tracking the composition of key inorganic components like CO₂ or H₂S. This reporting also helps in monitoring the composition of injected gas, especially in water alternating gas (WAG) processes.



Fluid component modeling example.

ReO Production Simulation and Optimization Software



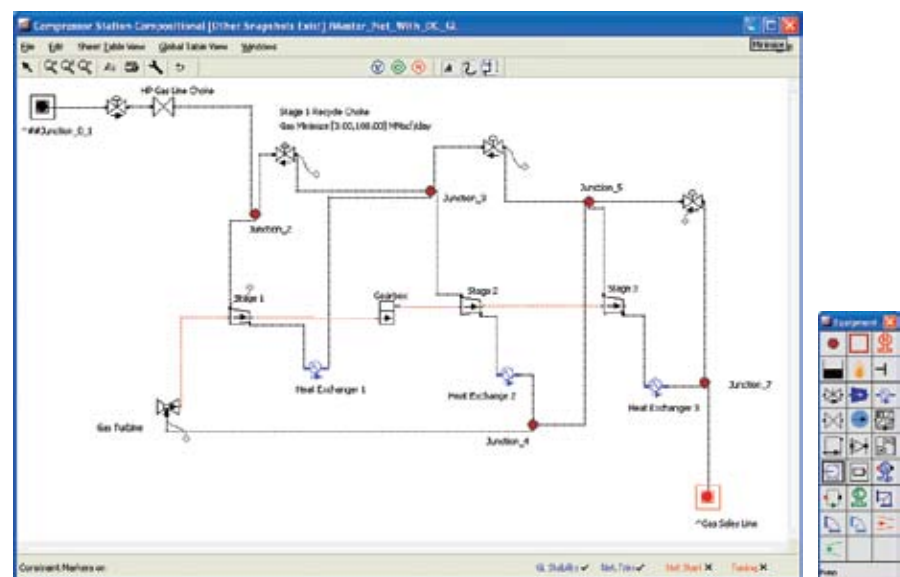
Key Features (continued)

Process Modeling

The software supports all key equipment used in typical gas and oil production systems—namely chokes, flow lines, risers, downcomers, pipe fittings, manifolds, multiphase separators, heat exchangers, gas compressors, pumps, H₂S and CO₂ removal scrubbers, etc.

For each type of equipment, a range of industry standard correlations are offered to meet the assets' degree of complexity. The mathematical models are presented to users in various ways to allow them to focus on key objectives of their study without investing too much time in the area which will have small or no effect on the overall optimization calculations.

- **Chokes:** Both critical and sub-critical correlations (Sachdeva and Gilbert type) are available to accurately model the critical flow rate and pressure drop in a choke.
- **Compressors:** The simple gas compressor option is ideal when users are interested in running quick and simple what-if scenarios. The detailed gas compressor option is available to model the entire compressor station which is comprised of a turbine, compressor stages, gear boxes, heat exchangers, etc. Users are given an opportunity to enter the manufacturer's data-head coefficient and efficiency curves for compressor stages, power and speed data for turbine, etc.



Process modeling example.

ReO Production Simulation and Optimization Software

Process Modeling (continued)

- **Flow lines, risers and downcomers:** ReO software offers a range of industry standard flow correlations to predict the pressure drop namely–Beggs and Brill, Dukler-Eaton-Flanigan, etc. The coupled fluid flow and heat transfer models facilitate accurate modeling of temperature changes. The application also allows users to specify tuning factors to augment the accuracy of the predictions.
- **H₂S and CO₂ removal:** The gas purifier object enables users to simulate the H₂S and CO₂ processing facility. Users can specify the efficiency and capacity of the processing plant.
- **Heat exchangers:** The simple heat exchanger option in the ReO application allows users to simulate the temperature change in the process stream quickly and efficiently. If users are interested in modeling the heat transfer processes in detail, a detailed heat exchanger model is also available which offers many heat exchanger types including the most commonly used shell and tube.
- **Pipe fittings:** The contribution of various pipe fittings in the overall pressure drop of the surface network could be significant. The application offers all commonly used pipe fittings namely–bends, contraction, enlargement and elbows. The industry standard equivalent length concept is used to calculate the pressure drops. Users can always specify the tuning factors to match the observed pressure drop.
- **Pumps:** Both centrifugal and reciprocating pump options are supported. Users can enter the pump performance data supplied by the manufacturer. This information along with the cost of compression is used by the optimizer to find the optimum speed along with the maximum possible efficiency.
- **Separators:** ReO software is capable of optimizing a multi-stage separator train on both gas and oil streams. For each separator stage, users can simulate field separations by specifying the entrainment factors for each stream.

For large network models, users can modify data for all the equipment quickly through global or sheet table view functionality. ReO's sub-sheet feature helps users manage huge amounts of data and provides better visualization of the network.



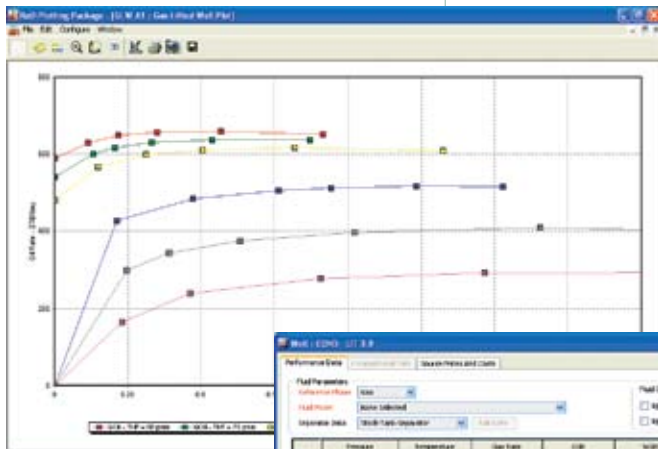
ReO Production Simulation and Optimization Software

Key Features (continued)

Well Modeling

ReO software is seamlessly integrated with *Field Office* suite's well modeling application, *WellFlo* software. This provides detailed well performance data which plays a pivotal role in optimization calculations. This functionality is available for both production as well as injection wells.

For naturally flowing wells ReO software uses the performance curve at wellhead based on wellhead pressure, temperature and gas, oil and water rates. For gas-lifted wells a two dimensional tabulation is generated using gas-lift injection rate and tubing head pressure against well head temperature, fluids produced and casing head pressure. *WellFlo* advanced gas valve modeling (AGVM) functionality is used to compute the correct casing head pressure for the specified injection rate.



Plotting package.

Production	Temperature	Gas Rate	COP	WOB
1	200.00	0.00	0.00	0.00
2	200.00	0.00	0.00	0.00
3	200.00	0.00	0.00	0.00
4	200.00	0.00	0.00	0.00
5	200.00	0.00	0.00	0.00
6	200.00	0.00	0.00	0.00
7	200.00	0.00	0.00	0.00
8	200.00	0.00	0.00	0.00
9	200.00	0.00	0.00	0.00
10	200.00	0.00	0.00	0.00

Well modeling example.

For ESP wells, the power data corresponding to the given production rate is also used during the calculations. During optimization, ReO software honors the manufacturer's recommended flow-rate range for the selected frequency.

The application allows users to import well performance data from Prosper™ software using its OpenServer™ feature or copy and paste well performance data generated by any other well modeling program. For gas-lifted wells, the user could use the externally generated PCD file for importing data into the ReO application.

ReO Production Simulation and Optimization Software

Solver Technology

ReO's optimizer technology is based on sequential linear programming. Unlike many surface production network software products, it simulates and optimizes the network simultaneously. Simulation determines the pressures, temperatures and flow rates within the production system while optimization determines the most economic production strategy subject to engineering and economic constraints. The economic modeling capability inherent within the program takes into account revenues from hydrocarbon sales in conjunction with production costs to optimize the net revenue from the field.

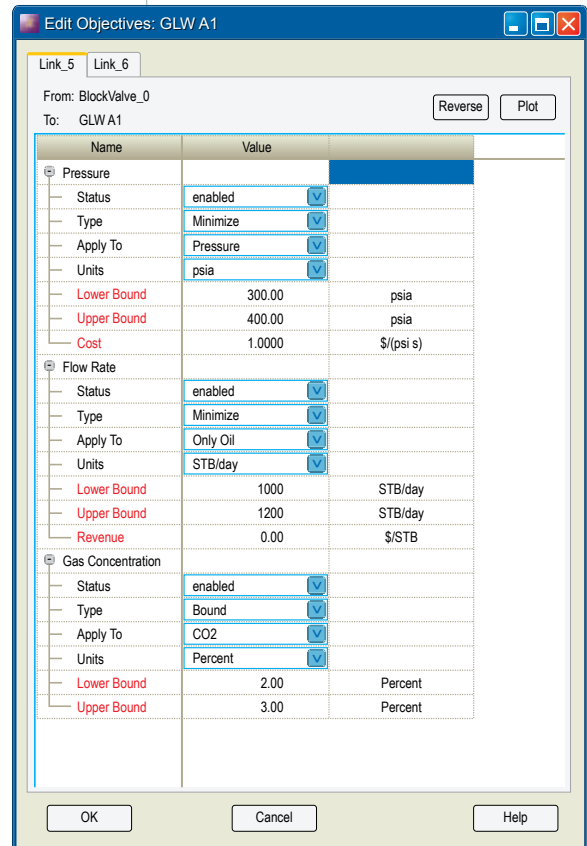
ReO software offers a wide variety of objectives—maximize, minimize, bounds and target, for pressure, flow rate and H₂S and CO₂ concentrations. Users can set these objectives at practically any point in the network. Even when operational constraints and user-defined targets conflict, the optimized solution will honor the operational constraints as far as physically possible (i.e. if required the optimizer breaks the user-defined objectives and warns user accordingly; however, the algorithm always honors the physics of the process).

Scalability—ReO software can optimize networks of thousands of wells in a robust and efficient manner.

Topological complexity—any degree of complexity can be handled by the software including loops and branches as well as distribution and injection networks.

Total system modeling—injection and production networks can be solved and optimized simultaneously.

The unique network trimming functionality aids users in focusing the prime part of the network. The intelligent scanning algorithm identifies sections of the network which are not accessible due to blocking of various valves and disables these sections for optimization calculations. The hot start feature allows users to start optimization calculations using the results of the previously optimized solution.



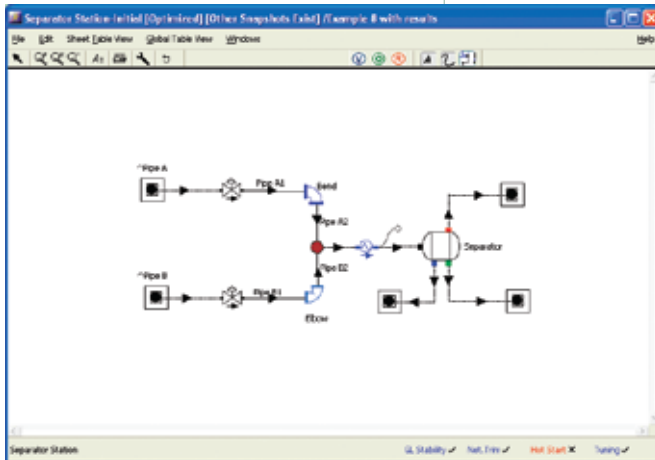
Solver technology.

ReO Production Simulation and Optimization Software

Key Features (continued)

Software Architecture

The program has been developed using object-oriented technologies. The integral object-oriented ObjectStore® database, stores all production system and network configuration data along with computed results. It enables different scenarios to be created, evaluated and easily compared. All modeling and analysis is carried out through a GUI with drag and drop capability allowing easy construction of production networks.



Software architecture.

A nested sub-sheet facility helps engineers to drill down to greater levels of detail to avoid excessive on-screen complexity for large production systems.

Units can be selected and changed as required. Maps or other diagrams may be imported to allow production models to be correctly and swiftly laid out.

The program imposes no restrictions on the complexity of the production system other than physical and logical consistency. A complex network including loops, branches, cross-overs, parallel flowlines and recycle loops can be modeled without constraints or excessive computational time overheads.

ReO Forecast Module

The *ReO Forecast* module extends *ReO* software's capabilities to include the ability to time-step the production system model for short or long term production forecasting. This module allows users to build an integrated sub-surface and surface network model for accurate forecasting. It links *ReO* software with the sub-surface model via *WellFlo* software. The sub-surface model can be Weatherford's material balance application, *Matbal* software, or other commercial reservoir simulators. This is an ideal tool for production forecasting, facilities design and sizing and reservoir development planning.

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ReO Forecast Module (continued)

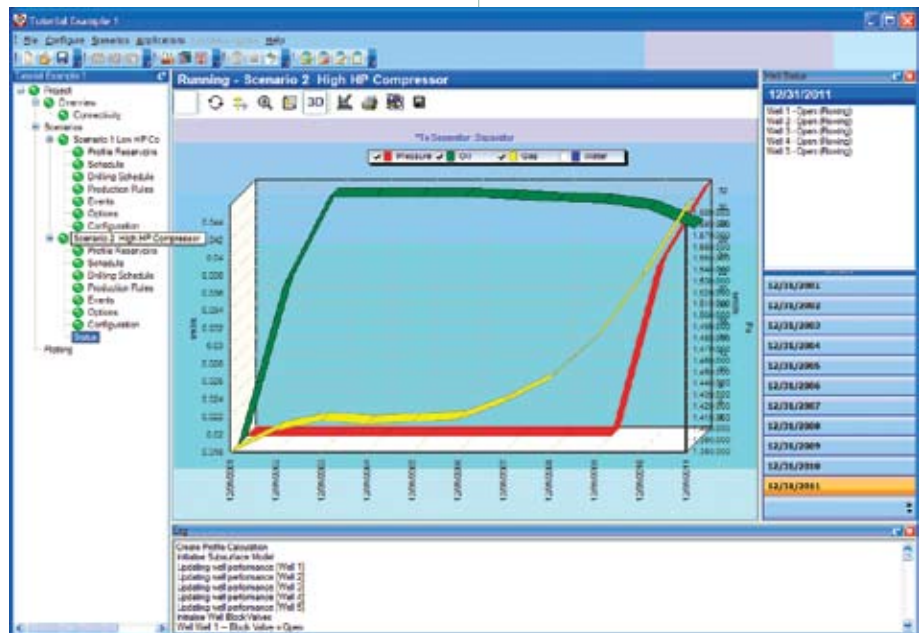
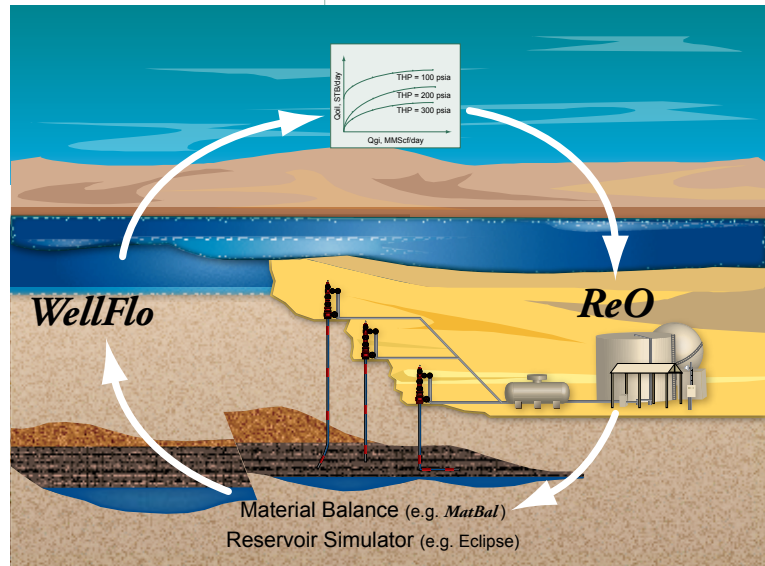
Both static and dynamic links are available for reservoir simulators. For static link, the forecasting results of the reservoir simulator or material balance application forms an input to the integrated *WellFlo*/*ReO* model at the reservoir/well connection level. In the case of dynamic link (available for Eclipse™ 100 and 300), the reservoir/well/surface network models are run dynamically (in series) with seamless data communication between these applications. An iteration algorithm is incorporated to resolve discrepancies in the predictions between the reservoir simulator and *ReO* software.

The two main forecasting options offered in the module are:

- Production profile
- Gas contract

Flexible event-based scheduling allows users to modify any constraint in the surface network as well as open or close the wells. Built-in production rules ensure that production from every well is optimized in the best possible way for the given asset. Manual and automatic drilling options offer full flexibility to users in managing the forecasting calculations.

For gas contract, users can specify daily contract quantity (DCQ) and swing factor to simulate seasonal changes in gas demands.



ReO Forecast example.

ReO Production Simulation and Optimization Software

Conclusion

ReO and *Reo Forecast* software packages provide simulation, optimization and forecasting for surface networks incorporating practically every piece of equipment from wellhead to the processing plant.

The software is part of Weatherford's suite of production optimization software that includes:

- **DynaLift™** dynamic gas-lift simulator
- *Field Office* real-time production optimization software suite
- Intelligent daily operations (**i-DO™**) system
- **LOWIS™** life of well information software
- *MatBal* reservoir analysis and production forecasting software
- **PanSystem™** well test analysis software
- **PanManager™** multiple well testing software
- **PanMesh™** numerical simulator for well test analysis
- **RigPlan™** resource scheduling software
- **Verge™** production surveillance software
- **Well Service Manager™** production optimization software
- *WellFlo* petroleum engineering software
- **WellScribe™** mobile data collection software



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