Results of the Sensitivity Study

We focused the analysis of the sensitivity study simulations on the cumulative oil production (fig.: 6) of the whole sector and the associated plateau duration.
The best case obtained is the case with a connected fracture network, a high fracture conductivity and a small aquifer. Surprisingly, the fracture network has a positive impact on oil production in this sector. The Pareto Diagram confirms this observation (fig.: 7). It indicates that the 3 most influential parameters are in decreasing order:

- The connectivity of the fracture network (Lcon): the more connected the fracture network is, the more oil is produced after 20 years.
- The aquifer volume (Vaq): the smaller the aquifer is, the more oil is produced after 20 years.
- Super-K permeability (Ksk): it has a positive impact on the oil production because it enhances both the pressure support and the well productivity.

Higher connectivity and conductivity of the network enable a better pressure support and therefore improves the pressure support for in-field wells. Generally speaking, a fracture network has both a positive impact on the oil production by improving the pressure maintenance and a negative impact by accelerating the water breakthrough. Here, the positive impact is stronger than the negative one.
Due to the lateral size of the field, a strong injection is needed to support the pressure at producers. In such a case, both of the size and the transmissibility of the aquifer have a major impact since the aquifer absorbs a part of the energy provided by the injection and decreases its efficiency. Therefore, the larger of the aquifer is, the worse the pressure support is. As the consequence, oil production is lower and the plateau life is shorter.

To illustrate the impact of the fracture network properties on oil production and further analyze the sector behavior, we compared two water saturation maps in zone 2A of sector 1 after 20 years, obtained respectively with a connected and conductive fracture network and a poorly connected and poorly conductive one (fig.: 8). Water fingering is more important with the connected and conductive fracture network. This causes wells to intersect the network water out and die prematurely, but even in this case the oil production is

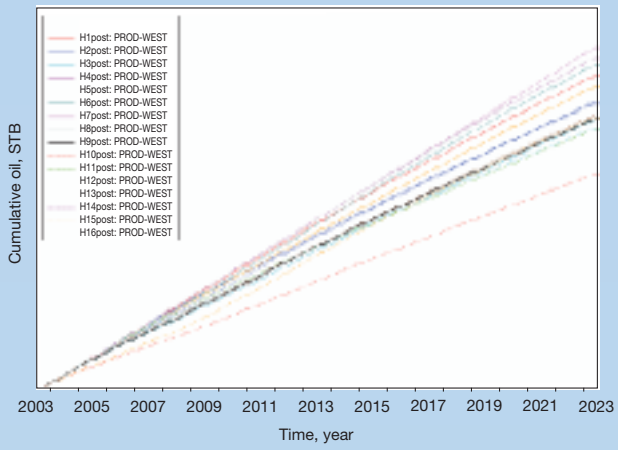

Figure 6: Sector 1 sensitivity study results: cumulative oil vs time

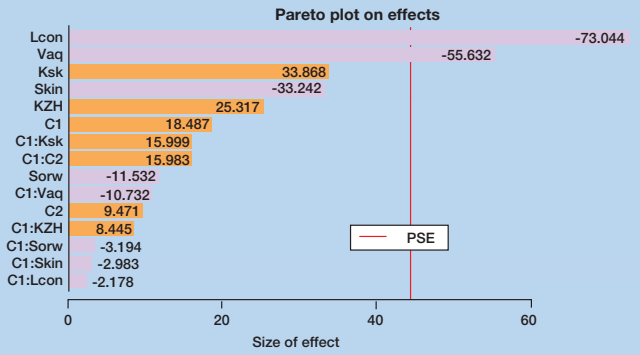

Figure 7: Sensitivity study in sector 1: pareto diagram for the cumulative oil produced

Figure 8: Sector 1 sensitivity study : sw distribution after 20 years of production

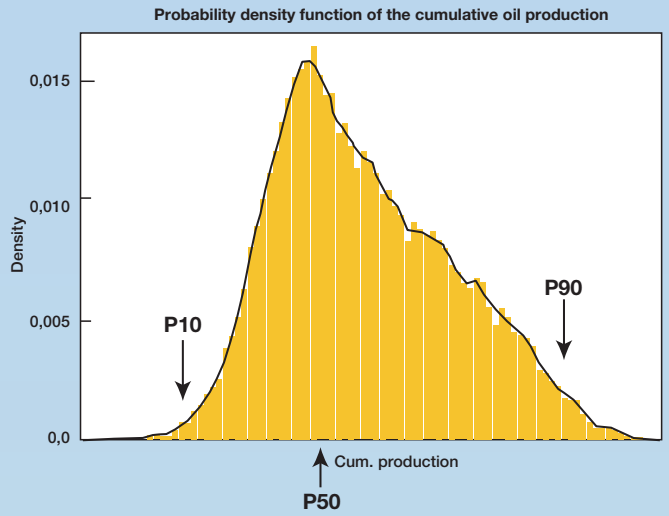

Figure 9: Risk analysis in sector 1: cum. oil produced after 20 years

Impact of the Sensitivity Study and Risk Analysis on Development

The results from sensitivity study and risk analysis clearly impact the way we develop the Increment. From these results we could
a) further optimize the field development by properly formulating the drilling and completion strategy, and
b) re-prioritize the data acquisition and reservoir characterization program to lessen the uncertainties and further minimize the risks.

- *Positive impact of connectivity and conductivity of the fracture networks:*
  - ➔ long horizontal injectors are drilled perpendicular to fracture swarms.
  - ➔ to avoid early water breakthrough, first row hrizontal producers are drilled parallel to the direction of faults and fractures.

- *Positive impact of super-K permeability:*
  - ➔ second row producers are completed through both Zone-2A and 2B.

- *Negative impact of Skin:*
  - ➔ acid jetting.

- *Strong influence of the aquifer size on the field performance:*
  - ➔ design of an injection system with some flexibility for injecting at a higher voidage replacement volume.

In addition, since pressure support is a critical element, we have put together a program to have permanent bottom hole pressure monitoring system in selected wells to make sure that the reservoir is produced at the most optimum condition with respect to rates and recovery.

Model Results Validation

Haradh Increment-2 wells are being drilled with encouraging results. Limited drilling results up to this point have substantiated the validity of the probability approach in developing Haradh Increment-2. Wells drilled outside the window of N70E and EW have much higher percentage of loss circulation through open fractures. So far new wells have been tested dry even though premature water encroachments have been observed in a few existing observation wells through limited production from the Increment.

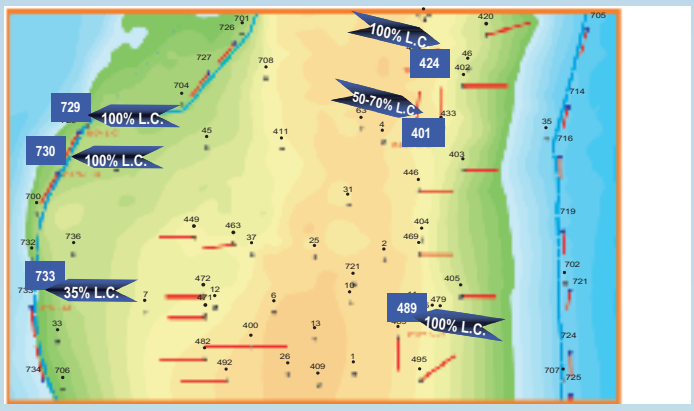

Figure 10: Loss Circulation Map on Recently Drilled Wells in Inc-2

Conclusion

1. Use of experimental design has shortened the number of simulation runs required for sensitive assessment and risk analysis, particularly in large reservoir dual porosity-dual permeability models.

2. Probability analyses identify and rank the most sensitive reservoir parameters that help in field development: maximize the exposure to the reservoir components that bring positive impact and minimize those that have the negative impact on field recovery and economics.

3. Sensitive parameters are on the top priority on the list of data acquisition. This helps put the investment where it matters the most in terms of improved recovery and rate of return.

4. Drilling results up to now have substantiated the validity of the probability approach in developing the reservoir

References

1. *Pham, T. R., Otaibi, U. F., Al-Ali, Z. A., Lawrence, P. , Saudi Aramco, Van Lingen, P. IFP, "Logistic Approach in Using an Array of Reservoir Simulation and Probabilistic Models in Developing a Giant Oil Reservoir with Super-Permeability and Natural Fractures", SPE 77566 presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, 29 September-2 October, 2002.*

2. *Gorell, S., Bassett, R. Landmark Graphics Corporation, "Trends in Reservoir Simulation: Big Models, Scalable Models? Will You Please Make up Your Mind?", SPE 71596 presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 29 September-2 October, 2002.*

3. *Valle, A., Pham, T. R., Hsueh, P. T., Faulhaber, J. "Development and Use of a Finely Gridded Window Model for a Reservoir Containing Super Permeable Channels", paper 25631 presented at the 1993 Middle East Oil Show held in Bahrain, 3-6 April, 1993.*

4. *Cosentino, L., Coury, Y., Daniel, J.M., Manceau, E., Ravenne, C., Van Lingen, P., Cole, J., and Sengul, M., "Integrated Study of a Fractured Middle East Reservoir with Stratiform Super-K Intervals – Part 2 : Upscaling and Dual Media Simulation," SPE paper 68184 presented at the SPE Middle East Oil Show, Bahrain, March 17-20.*

5. *Johnson, N. L. and Leone, F. C., "Statistic and Experimental Design in Engineering and the Physical Sciences", Volume II, John Wiley and Sons, Inc., New York (1964).*

6. *Dejean J.P., and Blanc, G., "Managing Uncertainties on Production Predictions Using Integrated Statistical Methods," SPE 56696 presented at the 1999 SPE Annual Technical Conference and Exhibition, Houston, Texas, 3-6 October.*

7. *Manceau, E., Mezghani, M., Zabalza-Mezghani, I., and Rogerro, F., "Combination of Experimental Design and Joint Modelling Methods for Quantifying the Risk Associated with Deterministic and Stochastic Uncertainties-An Integrated Test Study," SPE 71620 presented at the 2001 SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 30 September-3 October*