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Sensitivity study and Assisted History Matching in a shale gas reservoir

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- Overview of workflow
- Results
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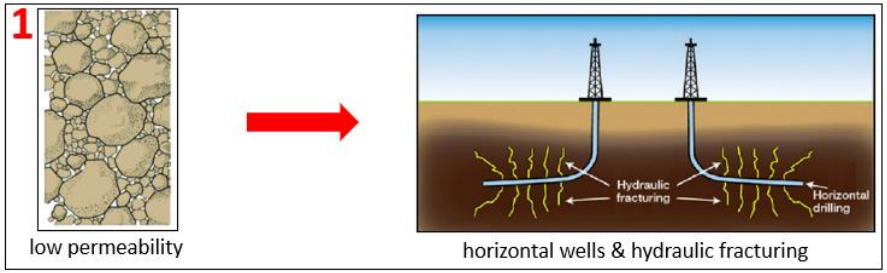
Problem statement

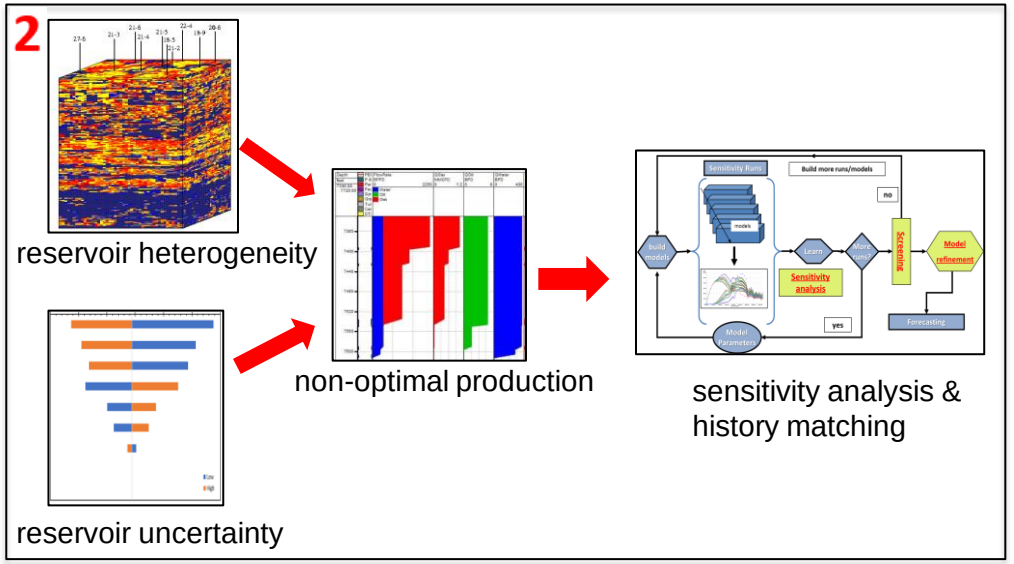
1. Problem:
- low permeability in unconventional reservoirs & unknown physics

Solution:
- horizontal wells & hydraulic fracturing

2. New problems:
- non-optimal production and non-reliable predictive models due to a lot of uncertainty in reservoir, fracture geometry and properties

Potential solution(s):
- Targeted data acquisition, systematic reservoir modeling, sensitivity analysis and history matching





Sensitivity analysis and History matching basics

Sensitivity analysis -

- Study of how the **uncertainty** in the **output of a mathematical model** can be divided and allocated to **different sources of uncertainty** in its inputs (Wikipedia)
- Determines **which parameters** have an effect on results and **how much**
- **Single** variable (one parameter at a time) and **multivariate** (multiple parameters) approaches

History matching

- The act of **adjusting a reservoir model** until it closely **reproduces** the **past behavior** of a reservoir (SLB oilfield glossary)
- The **accuracy** of the history matching depends on the **quality of the reservoir model** and the **quality and quantity** of field data.
- Once a model has been **history matched**, it can be **used to simulate future** reservoir behavior with a higher degree of confidence
- A **range of approaches** (manual, assisted, automated), still an open **research area**

Workflow overview

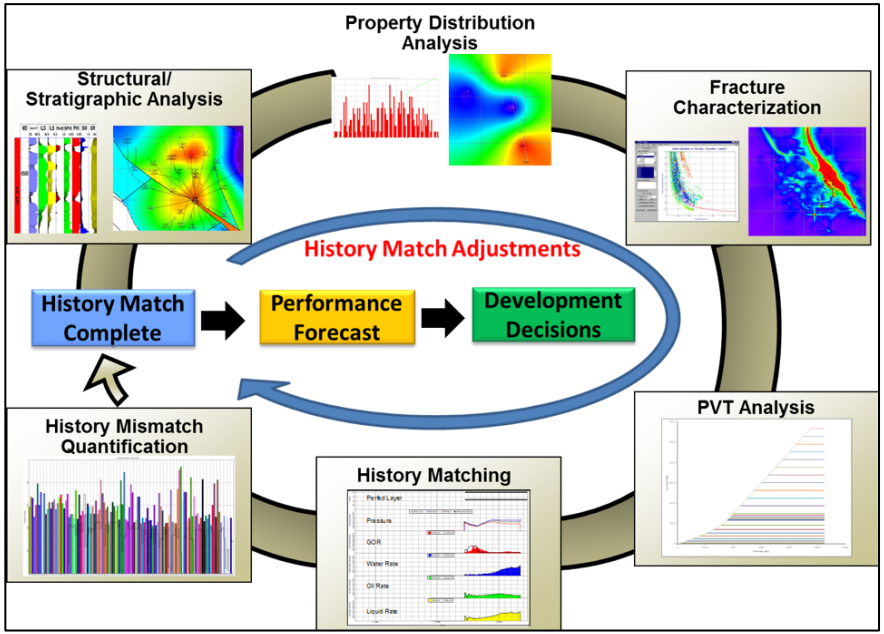
Reservoir modeling
rock, fluid, rock-fluid properties, reservoir geometry and reservoir initialization

Well modeling
horizontal well and completion modeling

Fracture modeling
modeling of 2 fracture distribution scenarios

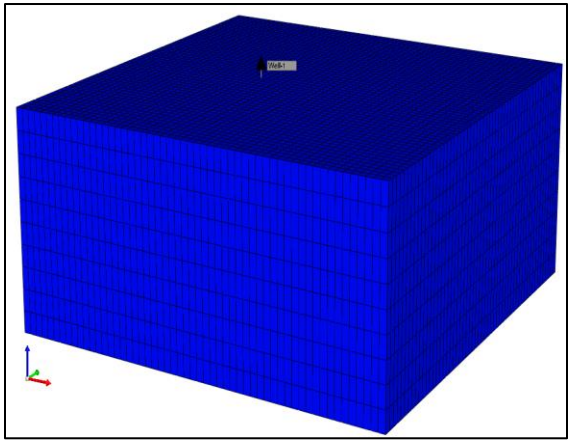
Sensitivity analysis
sensitivity analysis for the model that has the best match for historical data

History Matching
history matching of the most representative model against historical flow data

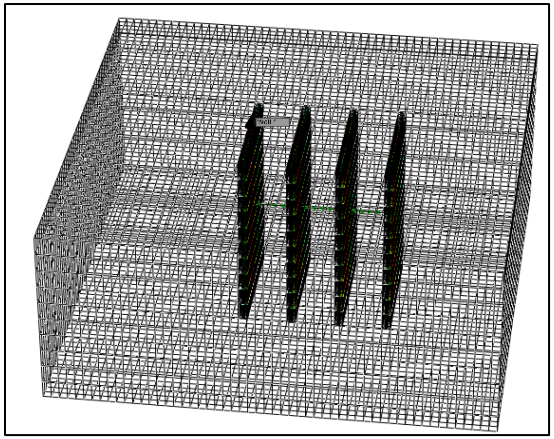


Results

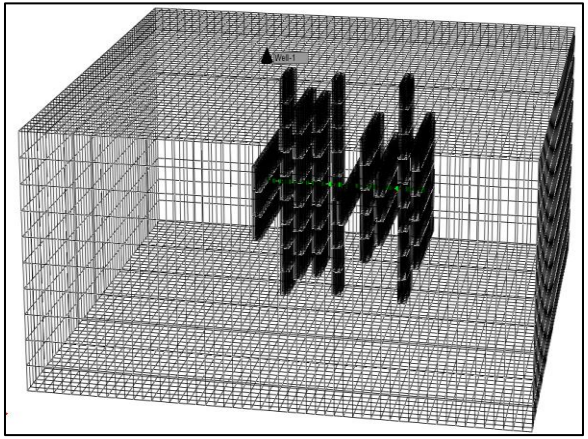
- Fracture modeling scenarios for Cartesian 55x55x10 shale gas (CH4 gas, 2-phase, GEM, CMG) model, penetrated by single horizonal well



Base case: No fractures



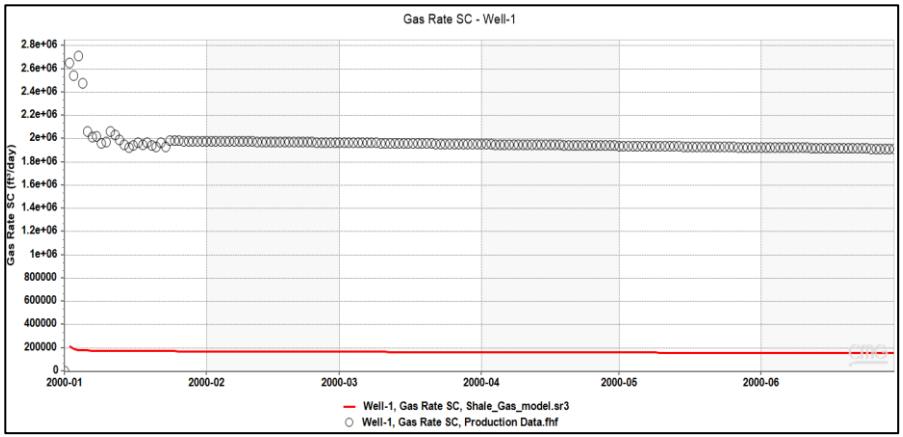
2nd scenario: 4 equally sized and spaced planar fractures



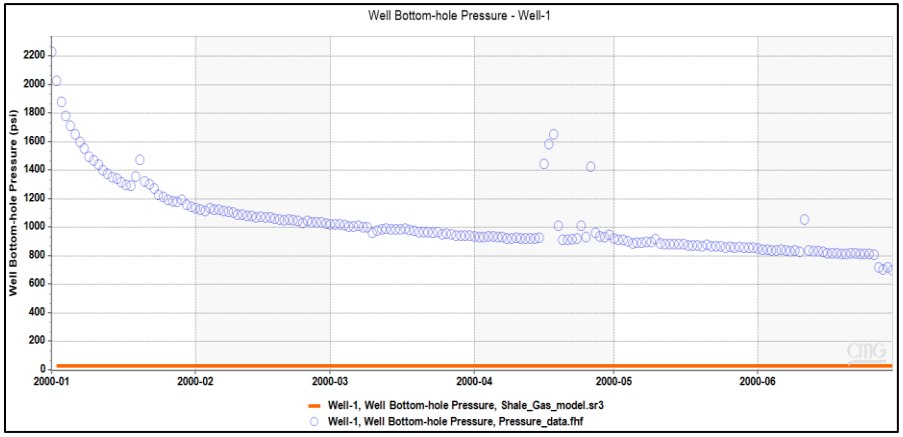
3rd scenario: 10 equally spaced but differently sized fractures

Results

- Simulated and observed flow data for the base case (no fractures)



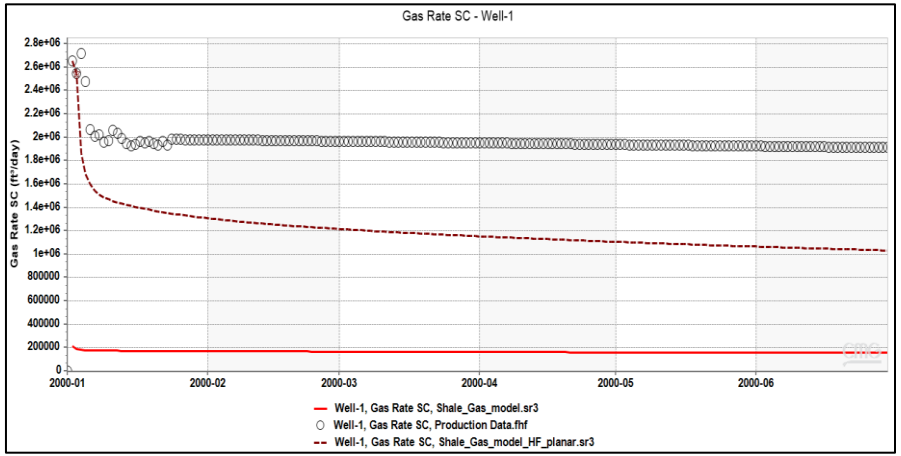
Simulated and observed gas production rates for the base case



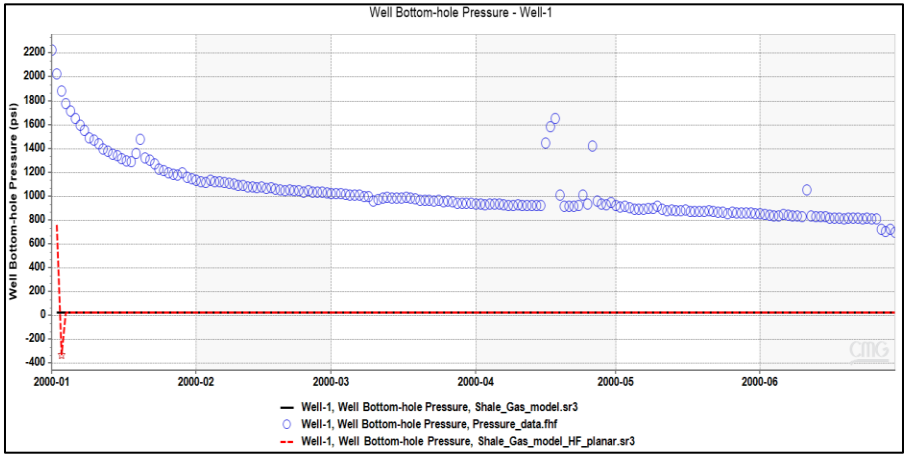
Simulated and observed well bottomhole pressure data for the base case

Results

- Simulated and observed flow data for the 2nd scenario (4 planar fractures)



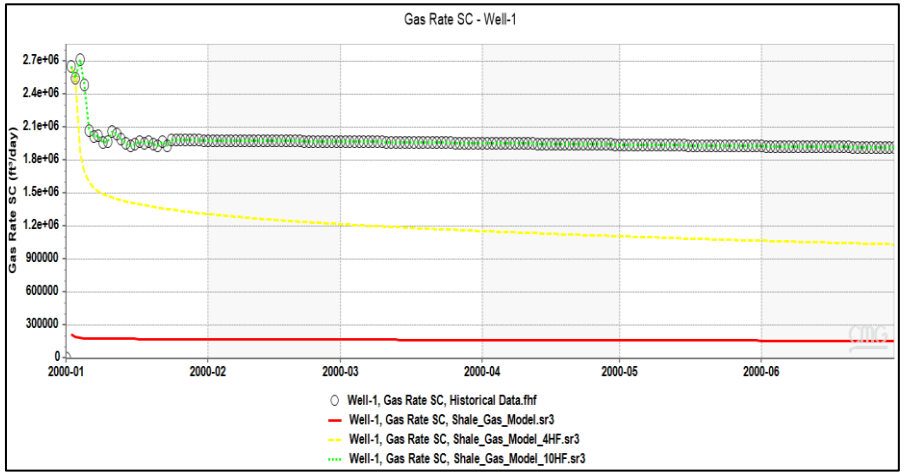
Simulated and observed gas production rates for the base case and 2nd scenario



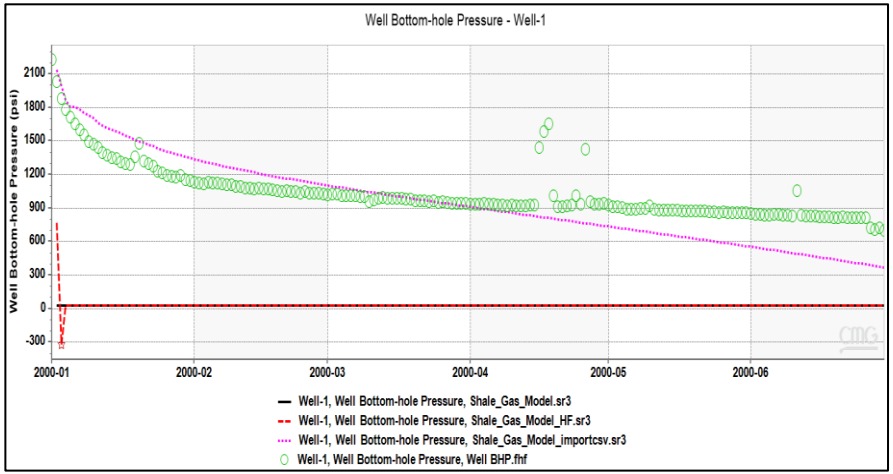
Simulated and observed well bottomhole pressure data for the base case and 3rd scenario

Results

- Simulated and observed flow data for the 3rd scenario (10 planar fractures)



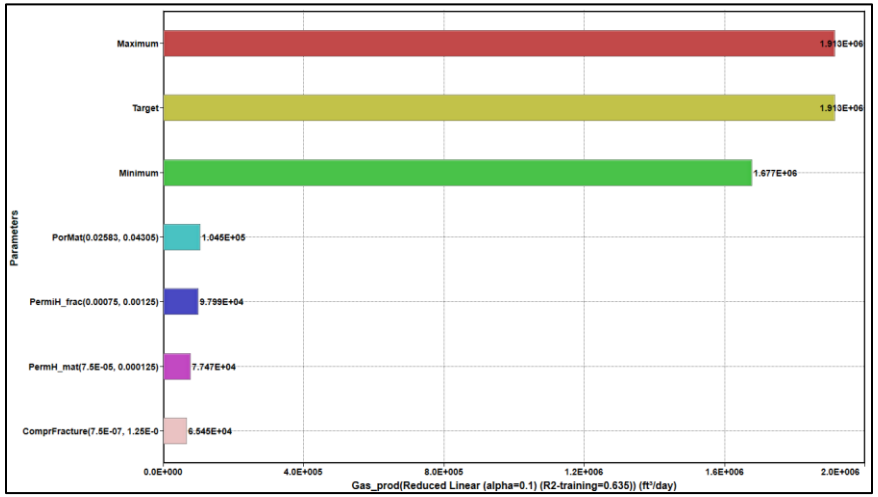
Simulated and observed gas production rates for the base case and 3rd scenario



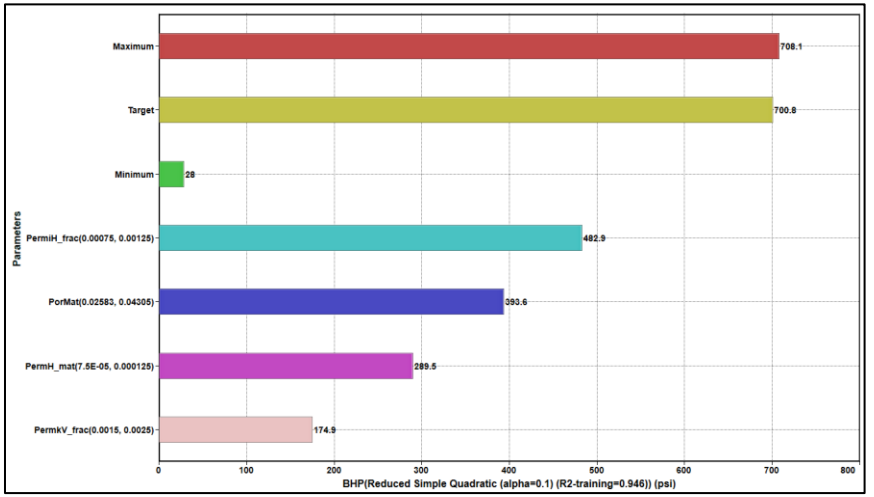
Simulated and observed well bottomhole pressure data for the base case and 3rd scenario

Results

- Sensitivity analysis (both independent single variable and multivariate variation) study of the effect of rock and fracture parameters on gas production and well bottomhole pressure for 2nd scenario (most representative scenario in terms of field data match)



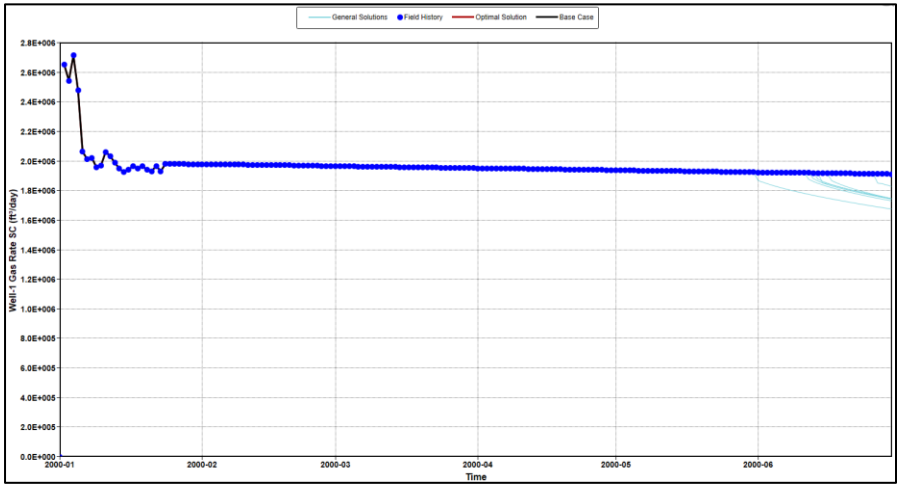
Sensitivity analysis outcome for gas production rate



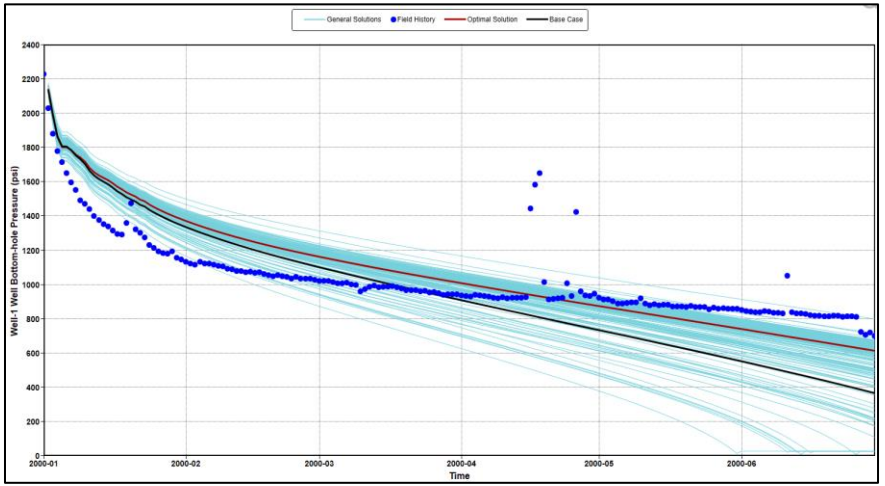
Sensitivity analysis outcome for bottomhole pressure data

Results

- Having identified the most sensitive parameters to production performance data from sensitivity analysis, the history matching workflow, has been applied to a 3rd scenario (most representative scenario in terms of field data match)



History matching realizations for the gas production rate



History matching realizations for the well bottomhole pressure

Discussion and conclusion

- Structured workflow for reservoir, well, fracture modeling, sensitivity analysis and history matching for a shale gas reservoir has been presented
- Almost perfect matches for the gas production rate, but not quite a perfect one for bottomhole pressure have been obtained.
- To further increase the quality of match we can do one or combination of the following:

1. Build a new fracture model, possibly with different number of fracture or more complex fracture network
2. Select different or more reservoir and fracture parameters with possibly larger range of values to sample from
3. Run history matching algorithm for large number of cases with different optimization algorithms/approaches

Thank You

Questions???

Appendix

- Model inputs

Table 1. Parameters and their values for reservoir geometry and rock properties

Grid type, number, size of each grid	Cartesian, 55x55x10, 50 ft x 50 ft x 30 ft
Units	field
Matrix porosity	0.0344
Fracture porosity	0.001
Fracture spacing: x, y, z directions	50 ft x 0 ft x30 ft
Matrix permeability: x, y, z directions	0.0001 md, 0.0001 md, 0.00001 md
Fracture permeability: x, y, z direction	0.001 md, 0.001 md, 0.002 md
Rock compressibility	10^{-6} $1/psi$

Table 2. Relative permeability model input parameters and their values

SWCON	0.2
SWCRIT	0.2
SOIRW	0.2
SORW	0.2
SOIRG	0.05
SORG	0.05
SGCON	0.05
SGCRIT	0.05
KROCW	0.8
KRWIRO	0.8
KRGCL	0.8
Exponent for Krw	2.0
Exponent for Krow	2.0
Exponent for Krog	2.0
Exponent for Krgcl	2.0

Appendix

- Model inputs

Table 3. Reservoir initiliazation data

Reference pressure	2500 psi
Depth	1050 ft
Water-gas contact	1500 ft

Table 4. Well data

Well type	Horizontal
Penetration/completion length	200 ft (horizontal section)
Well radius	0.25 ft

Table 5. Fracture properties

Fracture width	0.001 ft
Fracture permeability	10000 md
Orientation	Y axis
Number of refinements in x, y, z directions	7, 7, 1
Fracture half length	350 ft
Fracture height	150 ft
Fracture depth	180 ft