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Reservoir Quality Function "RQF" for SAGD geo-model ranking and well pair elevation optimization

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Preface:

For reservoir performance prediction usually a large number of realizations may be created quickly to assess uncertainty, but in practice, only a limited number of realizations will be chosen to perform flow simulation because of the computational limitations. The realizations will be selected based on a ranking method.

Ranking methods:

There are a lot ranking methods. The traditional technique such as volumetric "OBIP" does not have a good correlation with reservoir simulation in a SAGD type project. In this paper we are importing some adjustment and correction to the technique developed by the CCG University of Alberta, called Static Quality (See ref 01). Where we are calculating a recovery factor based on vertical permeability, distance and position to the well.

1. OBIP

Summation of all hydrocarbons in place for each realization:

$$OOIP^{l} = \sum_{z=1}^{Z}\sum_{y=1}^{Y}\sum_{x=1}^{X} V_{(x,y,z)} \cdot \left(1 - S^{l}_{(x,y,z)}\right) \cdot \phi^{l}_{(x,y,z)}$$

2. Statistic reservoir quality:

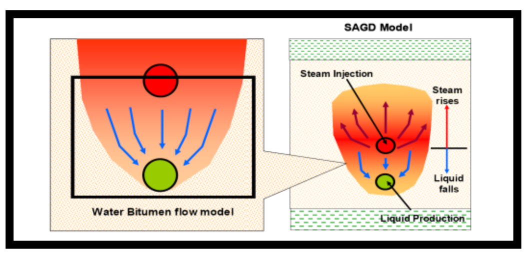
Cell connected to the well are the only one considered (local connectivity approach)

$$Q_s = \sum_{iw}^{nw}\sum_{j=1}^{n_{iw}} V_j \cdot \phi_j \cdot \left(1 - S_{w,j}\right) \cdot \left(\frac{d_{\max}}{d_{j,iw}}\right)^{dw} \cdot \left(\frac{k_{j,iw}}{k_{\max}}\right)^{kw}$$

3. Reservoir quality function (RQF):

Our work consists of calibrating and enhancing the QS ranking method. The below changes were introduced to accommodate for SAGD type project.

A. Oil Flow

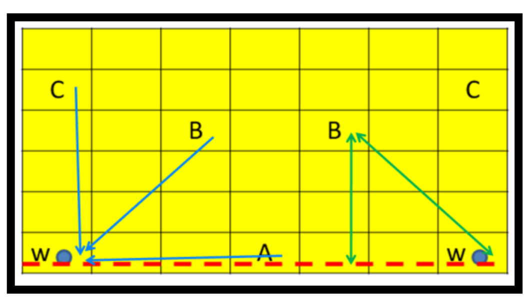


Qs method assumes oil is flowing straight toward the well, SAGD is a gravitational system, where oil flow vertically down till a level, then moves straight toward the well. It has been seen by TOTAL Canada in SPE: 102159 – predicting flow distribution on Joslyn project. In the new method we will focus on the vertical flow as it's the most dominant.

B. Relative position with the well:

In Qs: A, B and C will be considered the same. To handle the difference we introduce the factor "R".

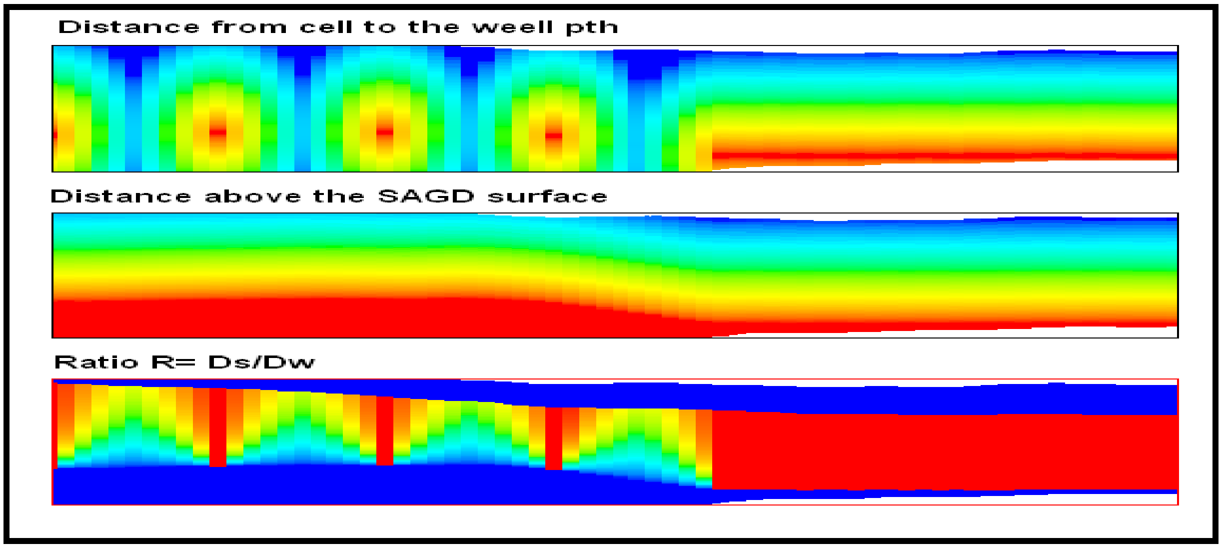
R = Ds/Dw



- S Surface that pass by all SADG wells
- Ds Distance from cells to surface S (above)
- Dw Distance from cell to the well path.

- Cells directly above the well "C" Ds = Dw => R = 1
- Cells same level as the wells "A" Ds = 00 => R = 0

Example: See below cross section from:



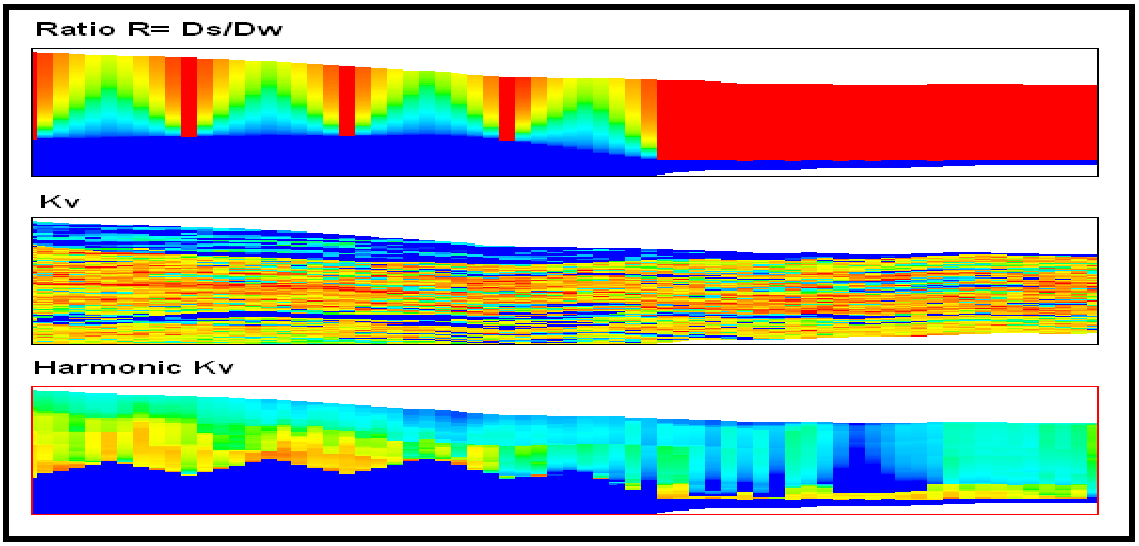
Note: Based on local expertise, the lowest cells to be produced have 10 degree angle with the well path.

- R is the COS of the angle. Cos(10)= 0.17

C. Permeability

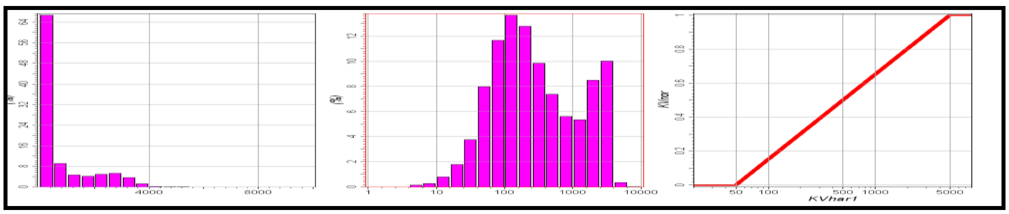
SAGD is mainly gravitational system controlled by the **vertical** permeability. The vertical flow is parallel to Kv. Each cell will be assigned an effective permeability which is the harmonic mean of the Kv for all lower cells (only cell with R> 0.17 will be considered)

$$Hmean = \frac{n}{\sum_{i=1}^{n} \frac{1}{Kv_i}}$$



D. Permeability normalization:

The OBIP value are small compared to KV, lo- normal normalization will be used for the KV values with a cut off 150-5000mD.



Kv-normalized = [Log (kv)-log(150)] / [log(5000) – log (150)

E. Distance to well

Distance to the well is important and need to be included in the equation. Distance is normalized linearly to [0, 1], with 70m as cutoff.

F. Combining all three factors:

We have three factors all with values between [0, 1]

1. Distance to well — Dwnor
2. Position relative to well — R
3. Normalized KV — Kvnor

Because all factors are less than one, the distribution of the product will be pushed towered zero. To be able to distinguish between cells with low factor we lognormal-normalized again this final factor.

- Interval to be normalized — [0.0001, 1]
- Normalization equation — Rec =1+Log(Dwnor * R * Kvnor)/4

RQF

The final RQF equation is:

$$RQF = \sum_{i=1}^{X} \sum_{j=1}^{Y} \sum_{K=1}^{Z} V \cdot (1 - SW) \cdot \phi \cdot \mathrm{Re}\, c$$

- V Cell volume
- SW Water saturation
- Φ Porosity
- Rec 1+Log(Dwnor * R * Kvnor)/4
  - DWnor normalized distance to the well
  - R = Ds/Dw
  - Kvnor normalized harmonic mean of Kv

RQF simulation calibration

The permeability cutoffs are the two values to be calibrated. In our work we start with 50-5000mD. The 150-5000mD gave better calibration to an already producing well pair, with 70% correlation with simulation.

Well elevation

After calibrating the RQF with an already producing well pair the method can be used for model ranking "see above" or well elevation optimization.

In new SAGD project elevation is not known, the RQF will be used to optimize the elevation.

- RQF has a good correlation with simulation.
- P50 from the RQF ranking is the highly probable realization
- The best elevation has the best production rate => best RQF

Workflow steps:

1. Start by the lowest possible elevation
2. Calculate RQF for all realization
3. Determine the P50 RQF
4. Move the well pair up and go back to step1
5. The best elevation is the one with the best P50 RQF

Conclusion

RQF showed a good correlation with simulation results and could be used to solve the time and hardware constraint in any uncertainty analysis. RQF is very fast and can be adjusted quickly.

As example: RQF was performed in 16 hours for:

- 15 million cell model
- 100 realizations (facies, porosity and SW)
- 70 well pairs
- One elevation scenario

Note: This time include all permeability calculations.

Acknowledgements

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