

HPT-SNL TECHNOLOGY: REDEFINING PRODUCTION LOGGING

A properly built 3D reservoir model features the areal and vertical matching. The areal is based on well-by-well production history while the vertical flow profile matching is based on perforations and scarce borehole spinner surveys. The existing production logging experience suggests that behind casing flow profiles are often complicated by channeling communication. This eventually results in serious dynamic mismatch in offset wells which is often artificially (and erroneously) compensated by grid permeability distortion in well vicinity.

The simplest example is behind-casing channeling which takes a part of injection volume below the target reservoir. The actual amount of water attributed to the target reservoir becomes less than scheduled in model inputs and results in simulated water propagation evolving faster than the factual. The simulation engineer is naturally tempted to manually decrease the permeability in the vicinity of injector in order to achieve a production match in the offset producer which leads to the wrong flow scenario, material misbalance and poor long-term predictability despite the decent well-by-well history “matching”.

The neutron generator (when applicable) and tracers can be used to match the water breakthrough zones and put the simulated vertical flow profile under a qualitative control. Unfortunately these data are not easily available due to the high cost and logistic complications incurred by pre-survey and post-survey interventions.

Meanwhile the identification of thief injection/production zones is not the only issue. It's very important to assess the volume shares attributed to various zones and then match them carefully to the simulated fluid flux against the corresponding zone. The temperature and noise logging are probably the only quantitative techniques which can be used for the purposes of dynamic profile matching (especially when used as time-lapse monitoring). The actual volumes are fitted during the numeric temperature simulations which also input the data from spectral noise logging.

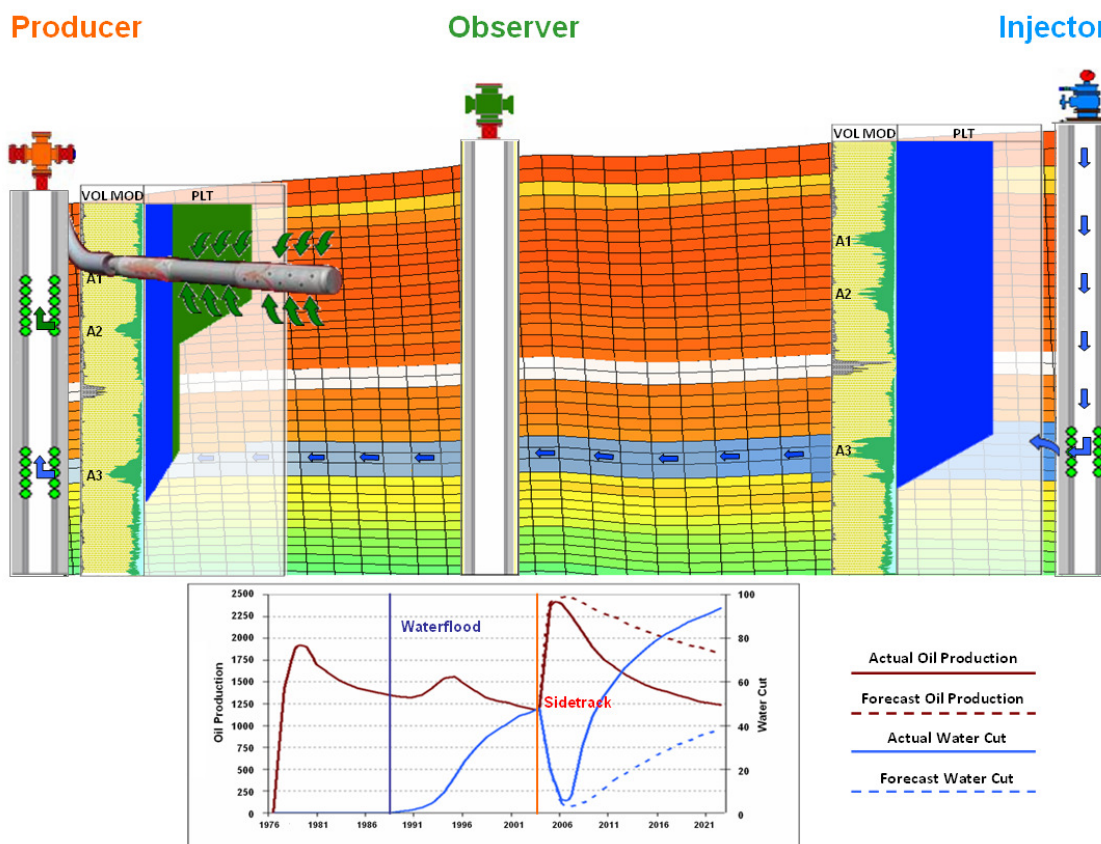
It's worth mentioning that vertical profile matching requires simulation software to provide a comfortable user interface to view the production and simulated flow profile on the screen and some efficient tool for adjustment.

Case 1 – Unsuccessful side-track

Conventional Analysis

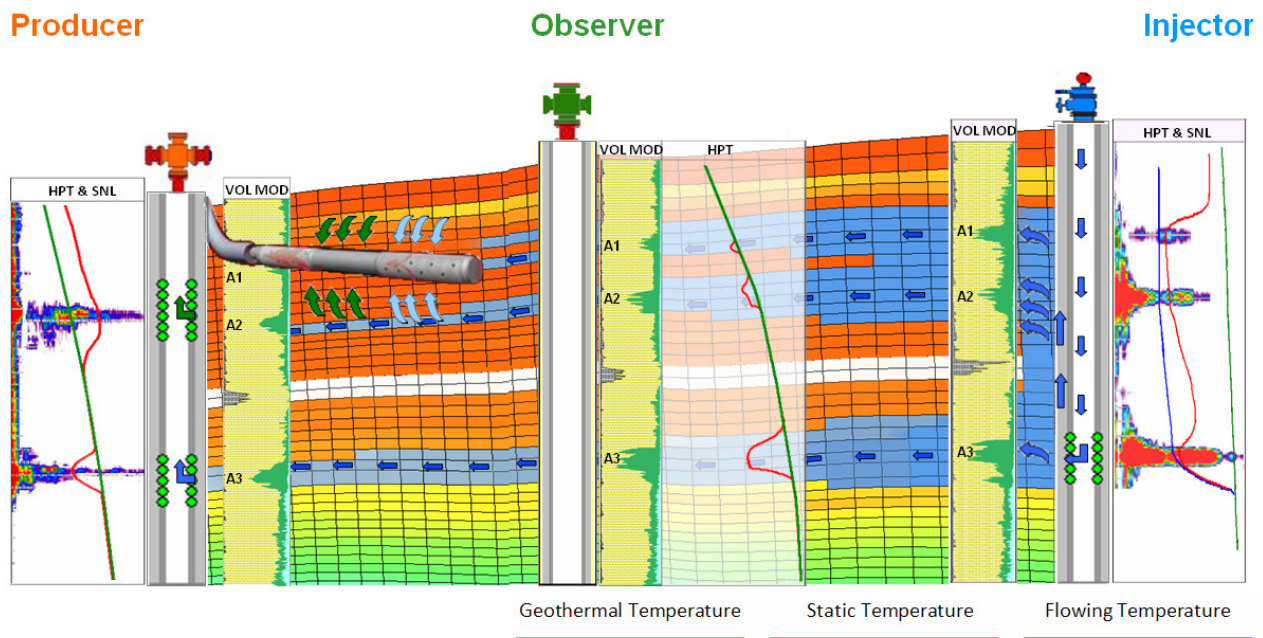
The case is represented by three wells (injector, producer and observer) with three pay formations (A1, A2, A3). The injection profile from spinner readings showed that all injected water was going into the lower, perforated reservoir. The spinner and multiphase logging (PLT) in producer suggested no water was coming from the upper interval while the lower formation is massively watered.

The decision was taken to stop production from lower reservoir and drill a side-track in upper formation. The dash line on the history plot shows a production forecast for the new side-track. However, the newly drilled side-track resulted in substantial water cut increase while oil production has grown up for a very short term and then started declining rapidly.



Advanced Analysis

The frustrating side-track performance suggested the existence of communication between upper and lower formations which built the path for injected water to the upper unit. To check for such a communication the HPT-SNL logging package was performed. High precision temperature (HPT) and spectral noise (SNL) logging are renowned for their ability to capture active flow units behind the casing which is obviously a better judge on reservoir performance than borehole PLT. The survey revealed that injected water was channeling up behind the casing and invading the two upper permeable zones as shown on the figure below. The HPT-SNL in observer has picked up the trace of the water propagation in all three reservoir units. Based on this data, the new vertical schedule has been constructed for injector and 3D model has been re-matched. The renewed dynamic simulations suggested that upper reservoir is broadly flooded by injection water which had not yet reached the vertical producer location. Anyway the new model does not justify drilling a side-track in upper formation.

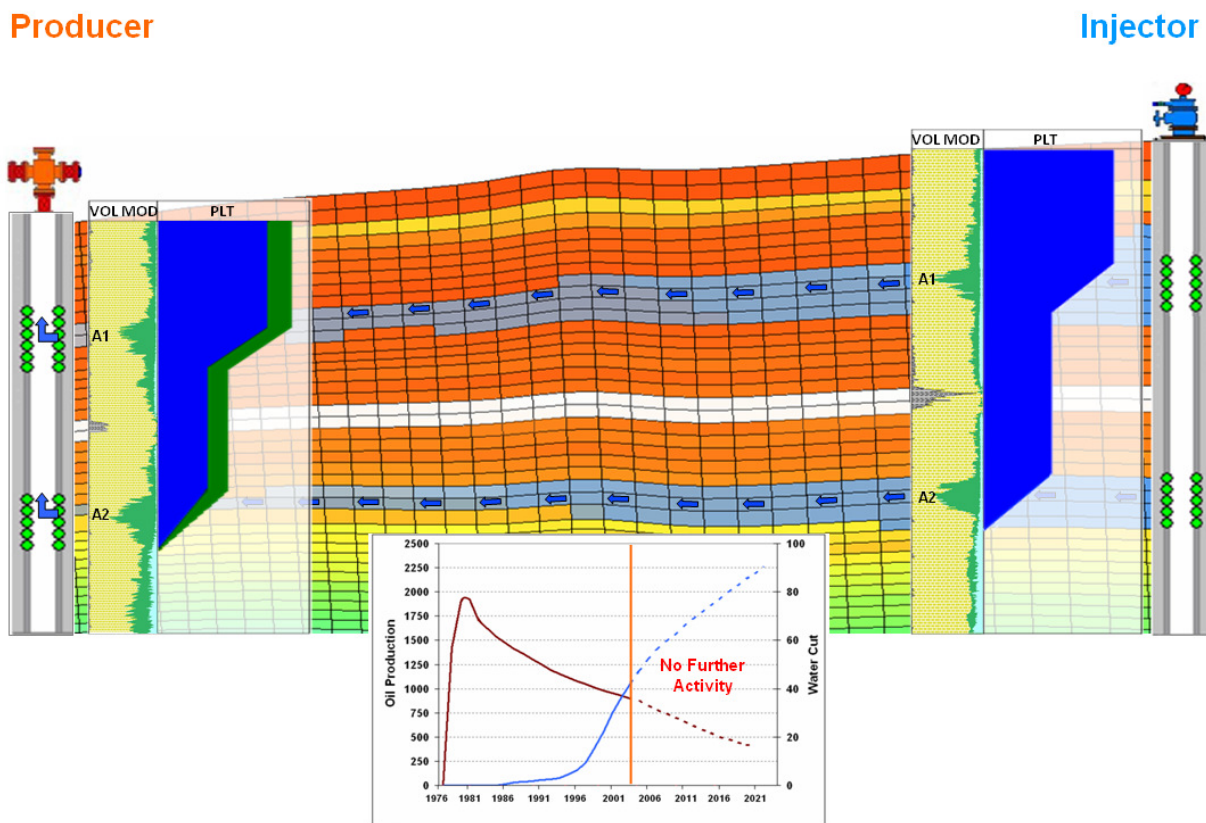


Taking a look behind the casing

Case 2 – Missed opportunity

Conventional Analysis

The case shows injector-producer pair depleting two very similar reservoir units (A1 and A2) separated by dense. The 3D model analysis showed that reservoir in this area is underperforming as the bulk water cut is growing up too high against the cumulative oil production. PLT in injector suggests that injection splits fairly between two perforations. PLT in producer also shows a fair production split with the same water cut against both perforations. From operational point of view there are no clear opportunities to increase the production performance. To adjust for the actual production performance, the 3D model has been set for the lower relative oil permeability than the one gotten from petrophysical study.



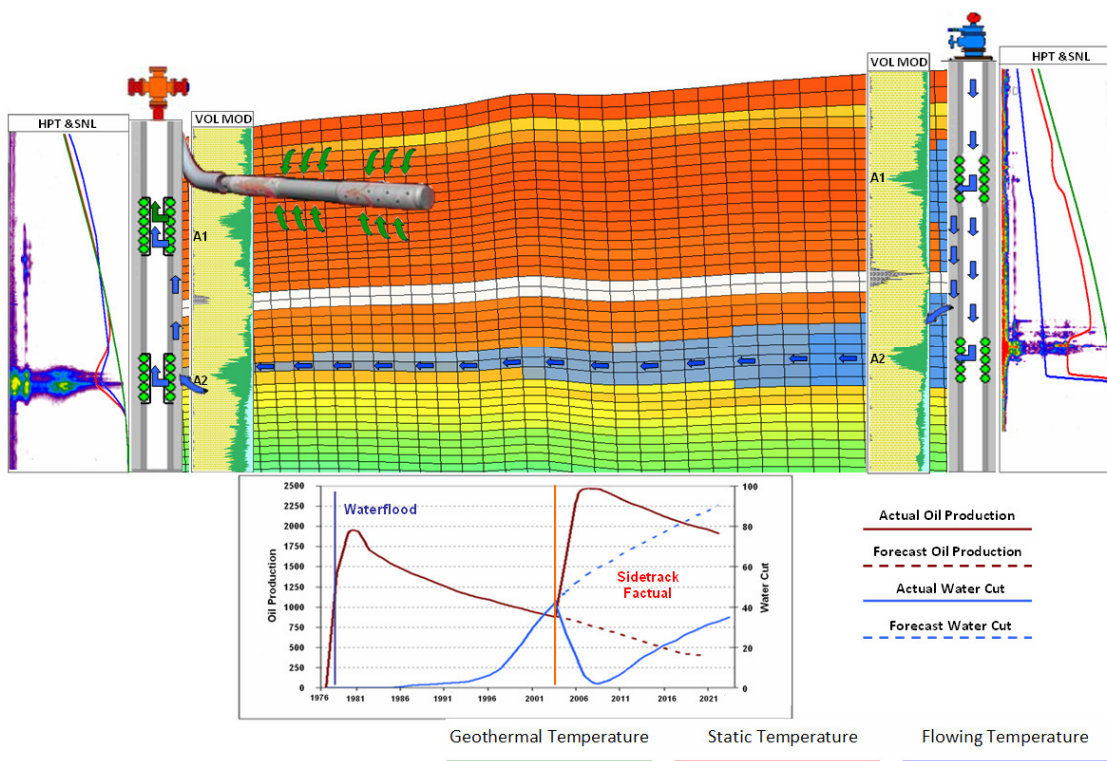
Advanced analysis

As long as the reservoir performance came below the target, it was suggested that a more detailed analysis might shed more light on the origin of this peculiar behaviour. The reservoir-oriented HPT-SNL logging package was performed in both wells. Surprisingly, it has revealed no serious cooling against the upper unit as well as no noise accumulation associated with reservoir flow. At the same time, the SNL shows a clear channeling which takes water from upper perforations down to the bottom reservoir unit. Numeric temperature simulations suggested that more than 95% of injected volumes were going to the bottom reservoir.

The HPT-SNL in producer was showing the similar channeling which takes a part of oil/water from bottom reservoir up to the upper perforations and creating illusion of upper reservoir contribution. This explains why the water cut from both perforations was the same. The reason why upper reservoir was bypassed and didn't take water was initially unclear.

Producer

Injector



The consequent analysis showed that upper reservoir has been depleted in this area before drilling of both wells and possibly has suffered from mud and cement invasion during the drilling and completion. The injection rate was set quite high and this possibly induced a behind-casing channeling. Since that moment the majority of injected water started going into the bottom reservoir. The re-matched model has supported the new flow scenario without any changes in original permeability model from petrophysical study.

The new model has also justified drilling a side-track into upper reservoir once the pressure would be supported. The latter was achieved through the consequent re-perforation and acidization of the upper reservoir unit in injector.