Calculating Production Rate of each Branch of a Multilateral Well Using Multi-Segment Well Model: Field Example

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ABSTRACT

Multilateral wells require a sophisticated type of well model to be applied in reservoir simulators to represent them. The model must be able to determine the flow rate of each fluid and the pressure throughout the well. The production rate calculations are very important because they give an indication about some main issues associated with multi-lateral wells such as one branch may produce water or gas before others, no production rate from one branch, and selecting the best location of a new branch for development process easily.

This paper states the way to calculate production rate of each branch of a multilateral well-using multi-segment well model. The pressure behaviour of each branch is simulated dependent on knowing its production rate. This model has divided a multi-lateral well into an arbitrary number of segments depending on the required degree of accuracy and run time of the simulator.

The model implemented on a field example (multi-lateral well HF-65ML) in Halfaya Oil Field/Mishrif formation. The production rate and pressure behaviour of each branch are simulated during the producing interval of the multilateral well. The conclusion is that production rate of the main branch is slightly larger than a lateral branch.

Keywords: multilateral well, multi-segment well model, branch, production rate, pressure behavior.

حساب معدل انتاج كل ذراع في بئر متعدد الاذرع باستخدام موديل بئر متعدد الاجزاء :مثال حقلي

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الخلاصة

ابار متعدده الاذرع يتطلب موديل بئر من النوع المتطور متطبق لتمثيلها في برامج المحاكاة المكمنية. الموديل يجب ان يكون قابل لتحديد معدل انتاج كل مائع والضغط خلال البئر. حسابات معدل الانتاج مهمة جدا بسبب انها تعطي مؤشر حول بعض القضايا الرئيسية المتعلقة بالبئر المتعدد الاذرع مثل احد الاذرع ينتج ماء او غاز قبل الاخر، عدم الانتاج من احد الاذرع،وسهوله اختيار افضل موقع الذراع الجديد لغرض عمليلت التطوير.

هذا التقرير يصف الطريقة لحساب معدل انتاج لكل ذراع في بئر متعدد الاذرع باستخدام موديل بئر متعدد الاجزاء. سلوك الضغط لكل ذراع يحسب اعتمادا على معرفة معدل الانتاجه. هذا الموديل يقسم البئر المتعدد الاذرع الى عدد عشوائي من الاجزاء اعتمادا على درجه الدقة المطلوبه و زمن تنفيذ البرنامج المحاكاة.

الموديل طبق على مثال حقلي (بئر متعدد الاذرع حلفايه-65) في حقل الحلفاية\طبقة المشرف. معدل الانتاج وسلوك الضغط لكل ذراع حسب خلال الفتره الانتاجية للبئر المتعدد الاذرع. الاستنتج ان الفرع الرئيسي ينتج بمعدل اكثر قليلا من الفرع الاخر.

الكلمات الرئيسية: بئر متعدد الاذرع، موديل بئر متعدد الاذرع، فرع، معدل الانتاج، سلوك الضغط.

1. INTRODUCTION

A multi-lateral drilling technology is one of the unconventional technologies that play a key role in keeping the development profitable comparison with the conventional technologies today. The multilateral drilling technology increases the production per well and improves the reservoir ultimate recovery factor **Paiaman,** and **Moghadasi, 2009.**

Multilateral wells increase well to reservoir contact by allowing several horizontal/deviated well paths with different orientations from one main wellbore. However, laterals can interfere or compete with one another through both the wellbore and within the reservoir. The corrected modelling of the connection and flow dynamics in the laterals is necessary. This is done by using a multi-segment well model **Wang, et al., 2008**.

A multi-segment well model is represented by a set of segments along the path of the wellbore. This model offers flexibility in the control of appropriate parameters by segment to properly simulate the different issues that arise with multi-lateral wells.

There is a lack in studies about simulated production rate of each branch of a multilateral well. **Chen, et al., 2000** presented a deliverability model to predict the performance of the multilateral well. They constructed a horizontal lateral model first to compute the production rate from each lateral. And, they considered pressure drop along the lateral in the model. Then, they applied the lateral model into the well system with more than one lateral blend to the main wellbore. The production from each lateral, the overall production rate, and the pressure in the good system are predicted by the multilateral deliverability model.

Fahem, et al, 2003 they developed a semi analytical model for a dual lateral well that is drilled into a homogeneous reservoir with a uniform thickness. They used a multi-segment well model to represent the well in the model. They used MATLAB program to solve the linear equations in order to calculate the production rate for each segment that used to calculate pressure drop for each lateral.

Yildiz, 2005 developed a three-dimensional model to predict the productivity of multi-lateral wells and simulated the flow into each branch. The model assumed the reservoir was homogeneous, anisotropic, sealed top and bottom boundaries with impermeable formations, and constant external pressure for four side boundaries. A steady state flow condition was implemented. The fluid was a single phase flow with constant compressibility and viscosity.

Kamkom, 2007 represented the multi-lateral well with the multi-segment well model and calculated the productivity index of each segment in the most bottom lateral from the inflow performance model. The flow rate is computed by multiplying the pressure draw down to the productivity index of each segment.

2. MULTILATERAL WELL

A multilateral well is a well that has two or more drainage holes (branches, secondary laterals, arms or legs) deviated from the main wellbore (trunk, primary well bore, mother bore or back bore), either trunk or branches can be vertical, horizontal, or deviated **Rabia, 2005.**
The junction completion of a multilateral well is the vital step to constructing the well. Multilaterals are divided into six levels according to Technology Advancement of Multilaterals (TAML)

classification on basis junction complexity as shown in **Fig. 1**. Level 1 is the simplest, but level 6 is the most advanced completion (smart well) **Hill, et al., 2008**. The selection of proper completion system depends upon the producing and well intervention requirements during the well's life.

3. MULTI-SEGMENT WELL MODEL

The Multi-segment well model offers a detailed description of fluid flow in the well bore. The facility is designed for horizontal and multi-lateral wells specifically. Also, it can be used to provide a more detailed analysis of fluid flow in inclined and standard vertical wells.

A multi-segment well may be defined as a group of segments arranging in a gathering tree topology. A single well bore comprises a collection of segments arranging along the wellbore serially. A multilateral well has a series of segments along its primary hole, and each lateral branch comprises a set of one or more segments that link at one end to a segment on the main hole as shown in **Fig. 2.**

It can be useful for modelling certain inflow control devices as part of the segments network.

Each segment comprises a node and a flow path to its parent segment's node. A segment s node is positioned at the end that is furthest away from the well head. Each node lies at a specified depth and has a nodal pressure which is estimated by the well model calculation. Also, each segment's flow path is the flow rates of oil, water, and gas which are determined by the well model calculation.

Each segment has completions in one or more reservoir grid blocks, or none at all if there are no perforations in that location **Schlumberger, 2010**.

4. FIELD EXAMPLE

The multilateral well HF065-M65ML is a stacked dual lateral well type and is named as (HF-65ML) in this study. The well HF-65ML is drilled in Halfaya Oil Field/Mishrif formation.

The well has two horizontal sections (Main branch section target depth at 4282m MD and 2987m TVD, and Lateral branch target depth at 4070m MD and 3006.84m TVD). The main branch is cased with 4-1/2-inch perforated liner and the Lateral branch left as open hole **Petro China, 2014**. The completion of the well considers from level 2 as shown in **Fig. 3.**

4.1 Constructing the Reservoir Simulation Model

The completed reservoir model for the drainage area of the well HF-65ML is built using Petrel RE and Eclipse Black Oil Simulator programs. The geological model is constructed from a contour map of the top of Mishrif (only drainage area of the well HF-65ML), CPI for the lateral branch (porosity and water saturation), and permeability. The reservoir model is built from PVT, relative permeability, and capillary pressure. The completed reservoir model is built in order to achieve the history matching between simulated and measured data (production rate and pressure) as shown in **Fig 4.**

4.2 Representing HF-65MLWell Using Multi-Segment Well Model

The HF-65ML well is considered as one of the advanced wells with complex geometry configuration. It has two branches drilled from a primary well bore. The multi-segment well model is used to represent the well in the reservoir simulator as shown in **Figs. 5** and **6.** The primary (mother) well bore is represented as the segment (1) from the surface to 2964 m TVD, the main branch has represented the segments from (2 to 8), and the lateral wellbore represented the segments from (9 to 12).

4.3 History of HF-65ML Well

Monthly oil production rates data is available for the well HF-65ML from August at 2014 until December at 2015. The production history matching of multi-lateral well between the measured and simulated data is made during this period as shown in **Fig. 7.**

HF-65ML well is tested with build up test for 96 hours shut in. The test started on 16 May 2015 and ended on 20 May 2015. The pressure history matching of multi-lateral well between the measured and simulated data is made as shown in **Fig 8.** This figure states that simulated two curves closed from measured curve. One curve is simulated BHP and the other is simulated average BHP (this curve is averaging each four points from BHP). The average BHP is best for matching with measured (observed) pressure.

5. RESULTS AND DISCUSSION

The well HF065ML is produced as commingled production from the branches because of its completion type. Therefore, the total production rate of the multilateral well HF-65ML is known but the production contribution of each branch is not known. The accessible way to calculate the production rate from each branch is by using the multi-segment well model. This stage is applied after the history matching between the simulated and measured data (production rate and build up test) of the multilateral well is achieved.

Oil production rate for the main and lateral branches are simulated from the date opening the well to producing at August 2014 until the end of December 2015

The production rate for the main and lateral branches are approximately close to each other as shown in **Fig. 9.** After knowing the production rate of the main and lateral branches, pressure behaviour is simulated for both branches as shown in **Figs. 10** and **11.**

The production rate of the lateral branch is larger than the main branch about (11 STB/d) at 8th 2014 only. The production rate of the main branch increases continuously than a lateral branch from 9th 2014 to 12th 2015 to reach the difference in flow rates is (75 STB/d) at 12th 2015.This increment in the production rate of the main branch can attribute to larger producing length of the main hole and BHP of the main hole is higher than a lateral branch.

6. CONCLUSIONS

The multi-segment well model is a useful method to calculate the production contribution and pressure behaviour of each branch of a multilateral well which has no advanced completion level and no production log data.

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NOMENCLATURE

BHP = bottom hole pressure.
CPI = computer processed interpretation
HF-65ML = HF065-M65ML well.
MD = measured depth, m.
PVT = pressure volume temperature.
STB/d = stock tank barrel per day.
TAML = technology Advancement of Multilaterals.
TVD = true vertical depth, m.

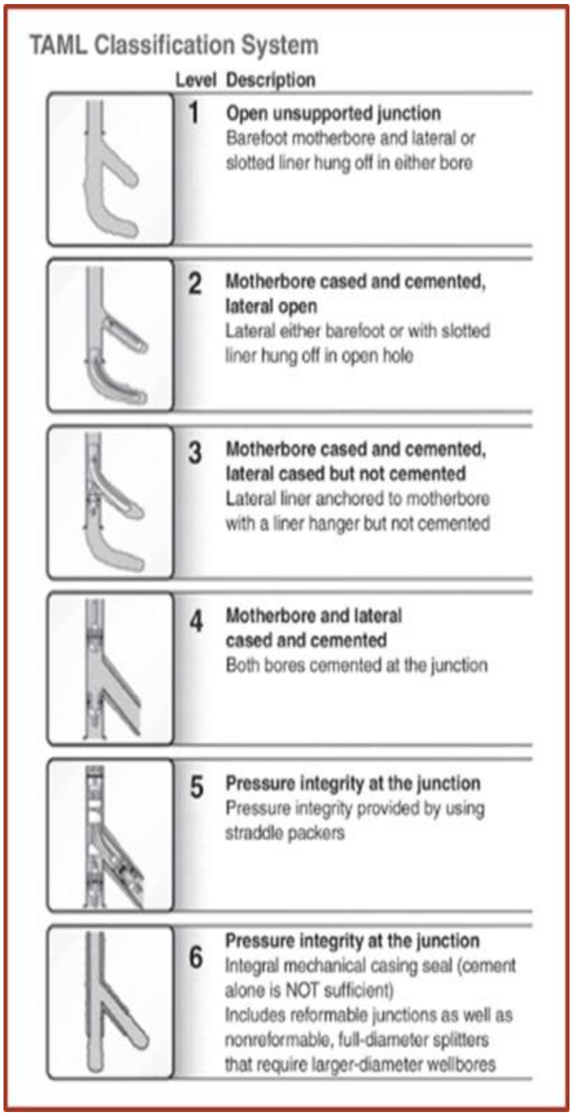

Figure 1. The TAML classification of multilateral completions **Paiaman,** and **Moghadasi, 2009**.

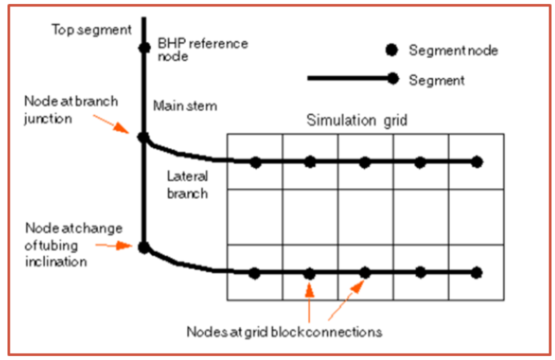

Figure 2. A multilateral, multi-segment well **Schlumberger, 2010**.

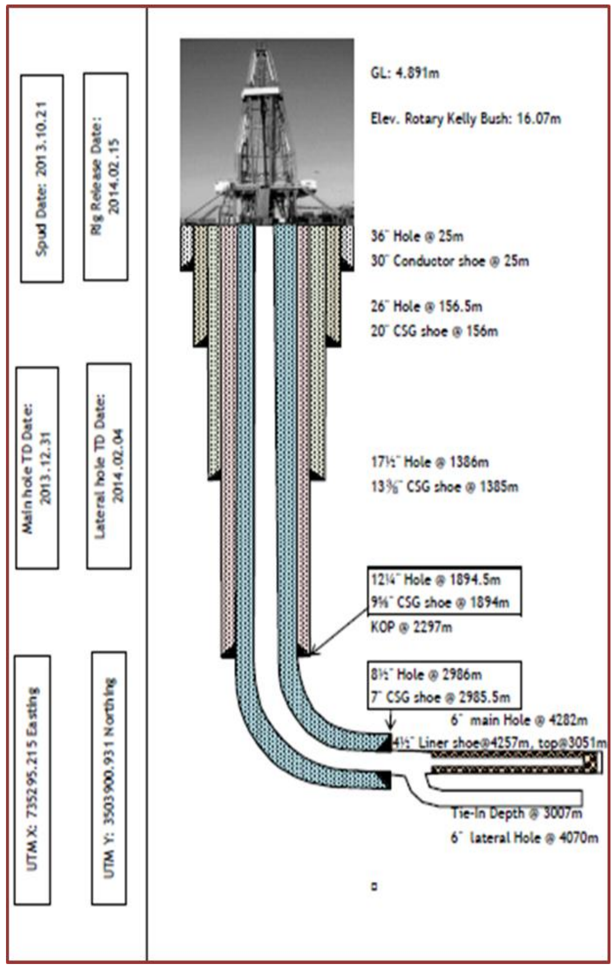

Figure 3. A profile of HF-65ML well **Petro China, 2014.**

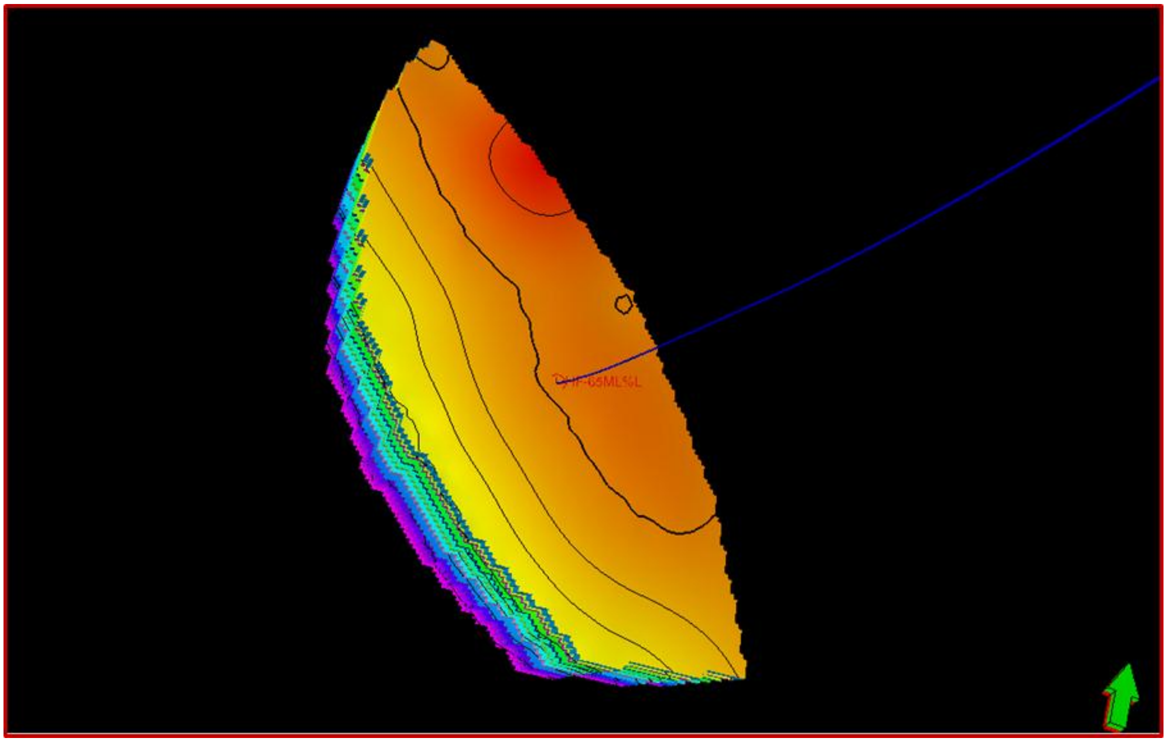

Figure 4. The completed reservoir model of HF-65ML well.

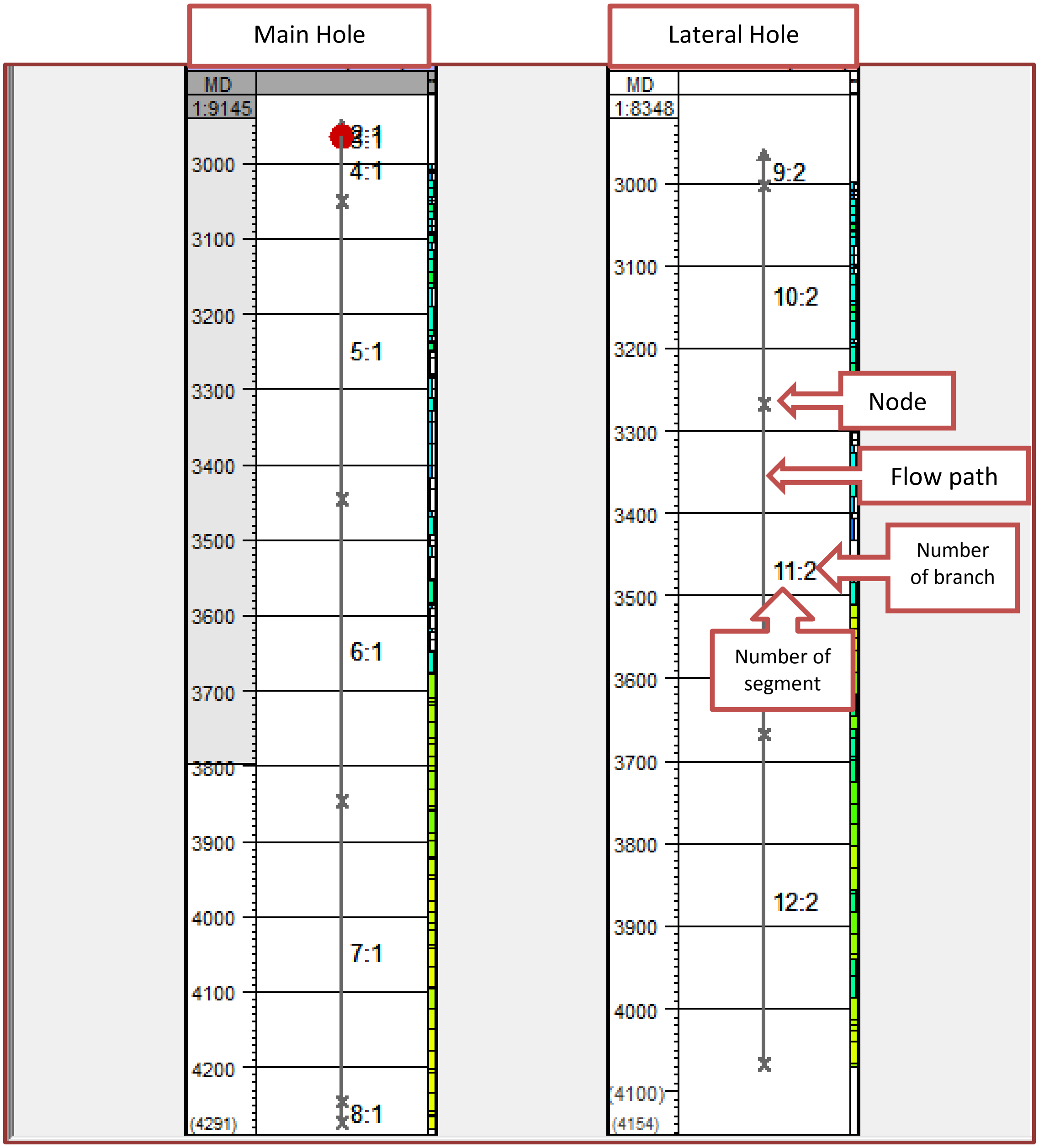

Figure 5. The segment model for the branches.

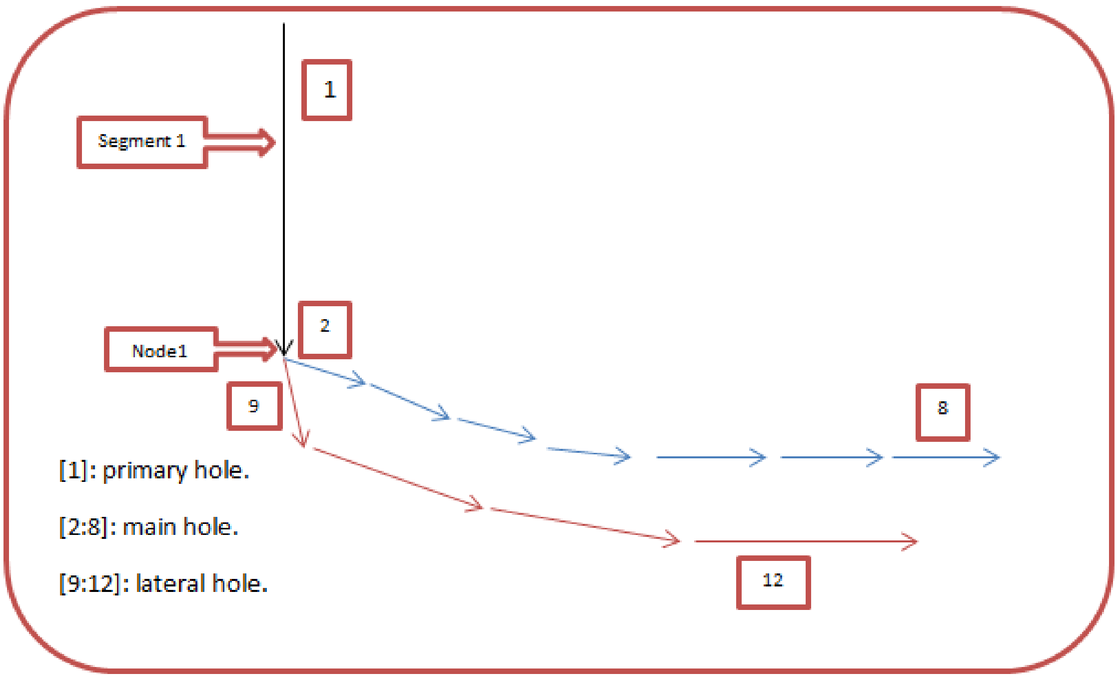

Figure 6. Segment model for the well HF-65ML.

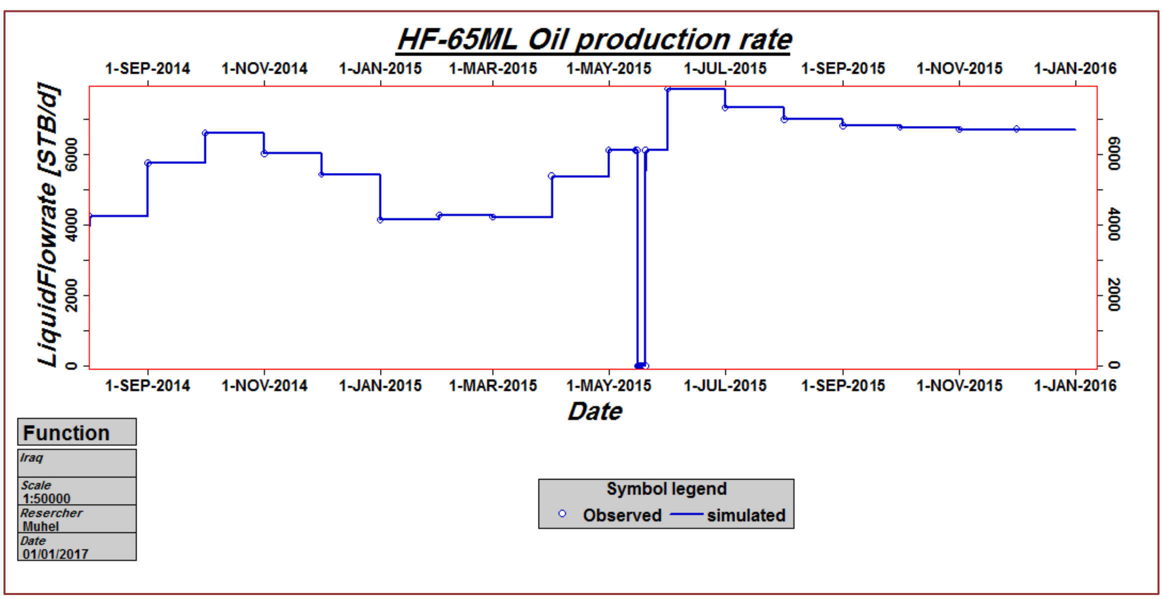

Figure 7. Matching for a production rate of HF-65ML well during the producing period.

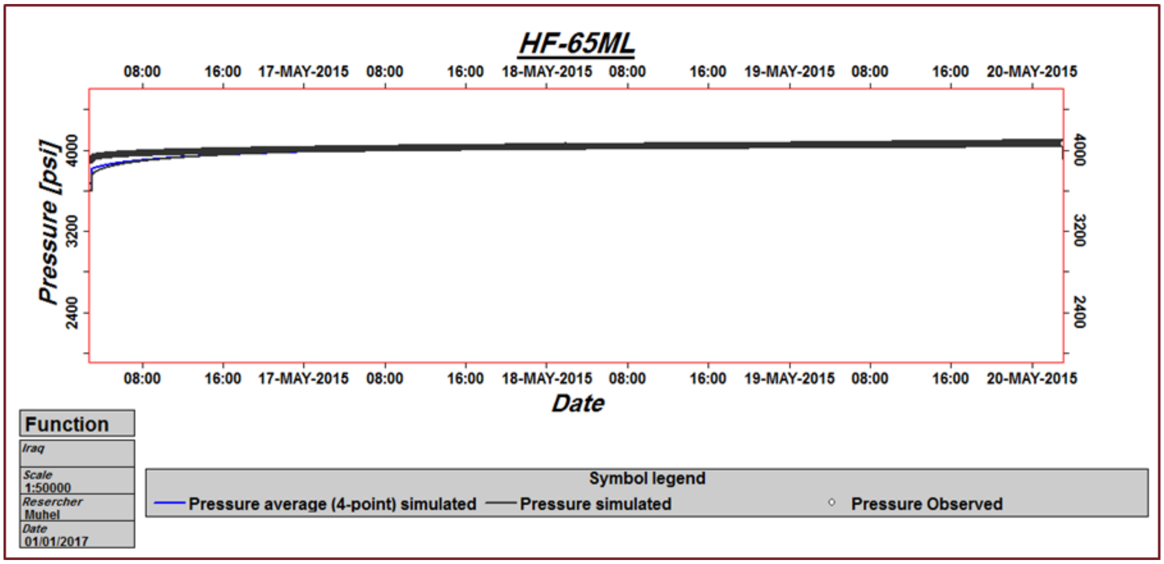

Figure 8. Matching of Buildup Pressure for HF-65MLWell.

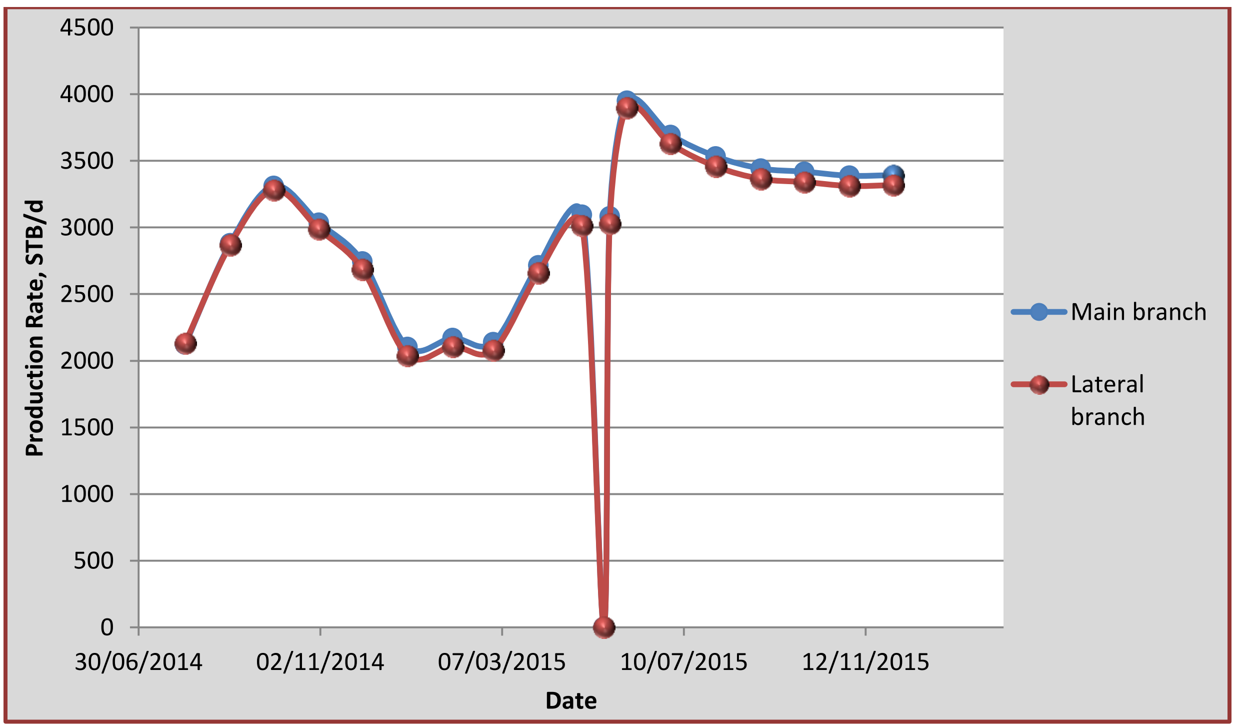

Figure 9. Production rates of the main and lateral branches.

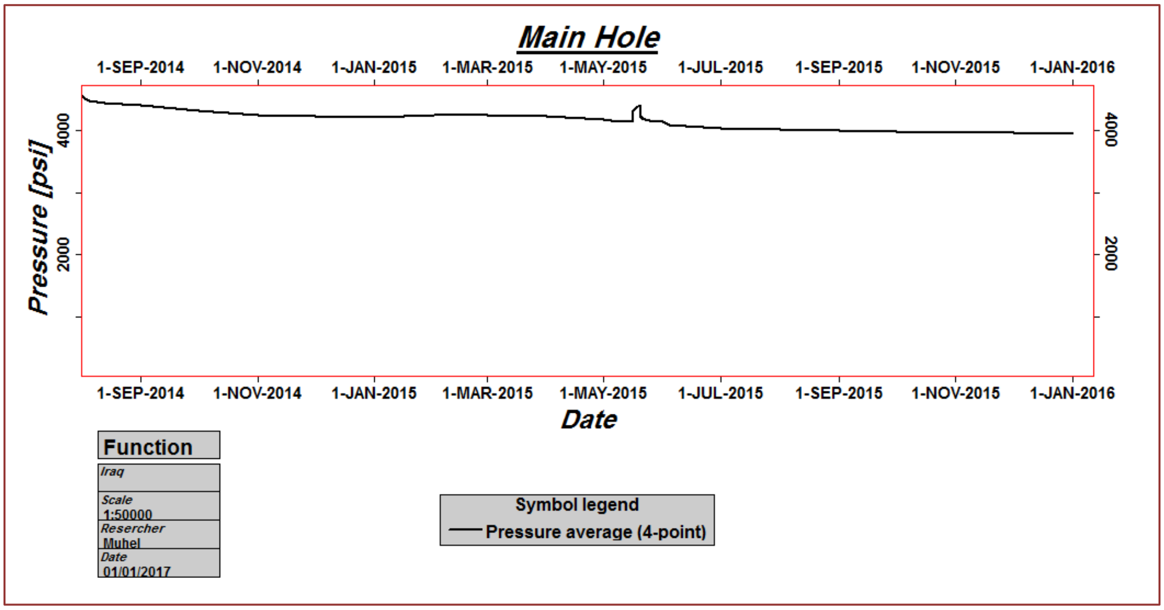

Figure 10. Pressure behaviour of the main branch.

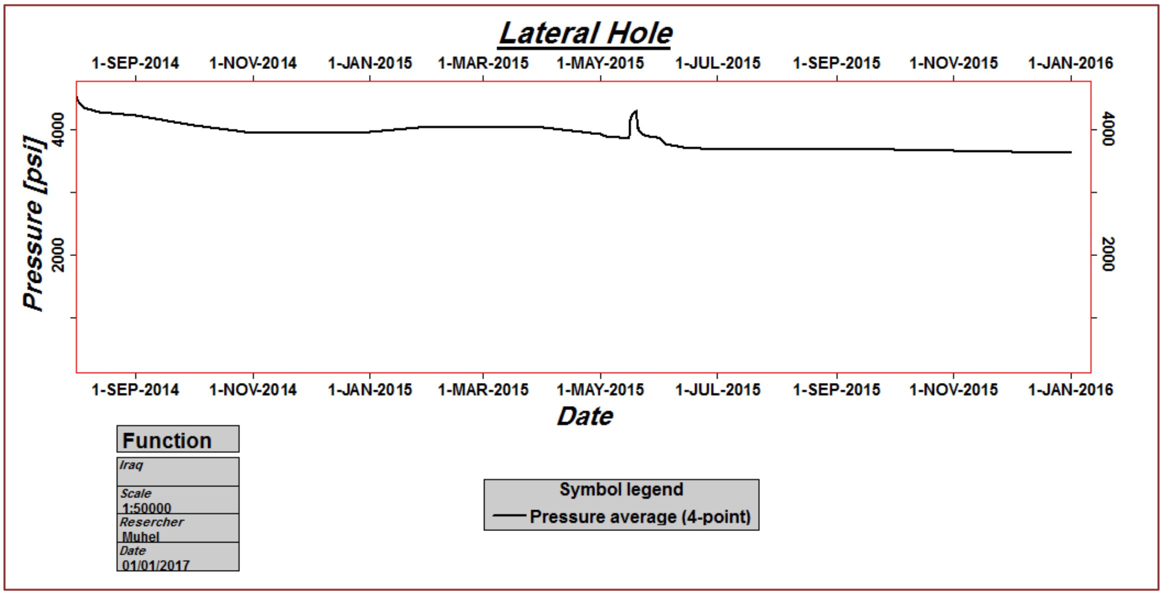

Figure 11. Pressure behavior of the lateral branch.