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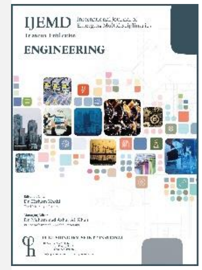

Application of Pressure Transient Analysis in Highly Deviated Reservoir

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Abstract

Conventional pressure transient analysis (PTA) alone may not be a reliable scientific tool for safe oilfield operations and reservoir development, according to earlier studies. The pressure responses were plotted using a skilled simulator in this study to examine the application of PTA and produce an exhaustive analysis. The Nelson oilfield, which is in the UK's North Sea, specifically addressed reservoir characterization and field development in a highly deviated well. The work also used sensitivity analysis and log-log diagnostic plotting to create a model that best matched a short pressure build-up (PBU) test. As a result, reservoir characteristics like permeability, porosity, and reservoir height were modeled, computed, and analyzed alongside wellbore characteristics. For various wells in the Nelson field, averages of core logs, seismic data, and wireline logs were taken to verify the accuracy of these models. Reservoir characterization was accomplished using PTA in conjunction with field data, which improved pre-existing macro and micro datasets. The use of a simulator and such additional data undoubtedly helped to improve field development strategies as well.

Keywords: Log-log Diagnostic; Oilfield Development; Pressure Transient Analysis (PTA); Reservoir Characterization.

1. Introduction

Pressure-transient Analysis (PTA) typically offers a more quantitative understanding of the subsurface characteristics over a comparatively larger area when compared to other subsurface characterization techniques. Improved PTA methodologies can be used to interpret drill stem test (DST) pressure data to learn more about reservoir dynamics. As a result, PTA applications in oilfield studies now have more opportunities. The PTA is a type of well testing that permits a constant flow rate with varying pressure

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responses based on flow and shut-in periods. In contrast, well testing is frequently carried out during exploration and infill drilling. An earlier study made an effort to define condensate banking for gas condensate reservoirs using PTA, and it offers several real-world examples to validate the workflow. Such analysis findings may also help with better reservoir management and quantification of potential well productivity losses. [1] Another analytical solution was proposed to distinguish the pressure signal of leakage, the leakage rate, length of a leaky section of the fault, and relative position of the fault with respect to the location of the monitoring well [2]. It has been proven to be a good practice to comprehend and characterize the reservoir to integrate PTA, material balance, and rate transient analysis (RTA), along with the incorporation of 3–4 years of production and pressure history. [3] An integrated approach involving PTA and quantitative interpretation of time-lapse seismic (4D) was developed. The quantification of the change in porosity and permeability due to a sudden increase in pressure drawdowns can be used where compaction is a significant concern [4]. Thus, the results of the PTA interpretation enabled drilling newer wells away from any geological complexity and achieved the planned target [5]. However, when relying on a single PTA outcome for key subsurface parameters can be demonstrated, the interpreted subsurface properties showed a strong dependence on the input parameter range Abstract Conventional pressure transient analysis (PTA) alone may not be a reliable scientific tool for safe oilfield operations and reservoir development, according to earlier studies. The pressure responses were plotted using a skilled simulator in this study to examine the application of PTA and produce an exhaustive analysis. The Nelson oilfield, which is in the UK's North Sea, specifically addressed reservoir characterization and field development in a highly deviated well. The work also used sensitivity analysis and log-log diagnostic plotting to create a model that best matched a short pressure build-up (PBU) test. As a result, reservoir characteristics like permeability, porosity, and reservoir height were modeled, computed, and analyzed alongside wellbore characteristics. For various wells in the Nelson field, averages of core logs, seismic data, and wireline logs were taken to verify the accuracy of these models. Reservoir characterization was accomplished using PTA in conjunction with field data, which improved pre-existing macro and micro datasets. The use of a simulator and such additional data undoubtedly helped to improve field development strategies as well. Keywords: Pressure Transient Analysis (PTA); Oilfield Development; Log-log Diagnostic; Reservoir Characterization. [6]. An improvement in everyday field operations and better decision making can be achieved through enhanced model predictability, and data readily available can be used for many fields and provides an updated description of oil well behavior and hydraulic reservoir properties. [7] It is emphasized that the conventional PTA which is based on analytical models usually does not work for geothermal datasets; therefore, PTA is under-utilized by the geothermal industry. A framework for numerical modeling is required to promote the comparability of results and increase user-friendliness [8]. A major issue for geothermal PTA should be investigated by further introduced a case study with datasets before and after deflagration of a well. Additionally, the outcome of a geothermal numerical pressure transient analysis was of greatest practical use by indicating the overall shape of the network of flow pathways. [9] On the other hand, a well test model can be proposed and verified by using the stripe-fracture model in KAPPA software and indicates advantages over the stripe-fracture model [10]. In this regard, well testing has been used extensively in old and new oil wells for many years, it allows for undetermined characteristics of the reservoir to become known through disturbing a signal (flow) of hydrocarbons. Thus, monitoring the pressure, trends can be observed, and the calculations can be made to understand the basics of reservoir characteristics such as porosity, permeability, skin, and reservoir height. In addition to understanding these primary characteristics, more information can be obtained by using sensitivity analysis to understand how changing one characteristic effect the well test output. Combining all these data allows an operator to make more clear choices of field development plans.

Methodology

The reservoir and its surroundings, Figure 1, are the subjects of theoretical research in addition to the collection and processing of field data. Along with downhole logs from the well, core samples from the entire Nelson field were also examined. One can make assumptions more confidently than with just test data alone by comparing known core and log data. The goal was to characterize a reservoir by using Kappa Workstation 5.30 with the Saphir Module to analyze transient pressure data, create a case study, and compare it to core data to look for any potential correlations. This research methodology consists of three steps including the analysis process as shown in Figure 2.

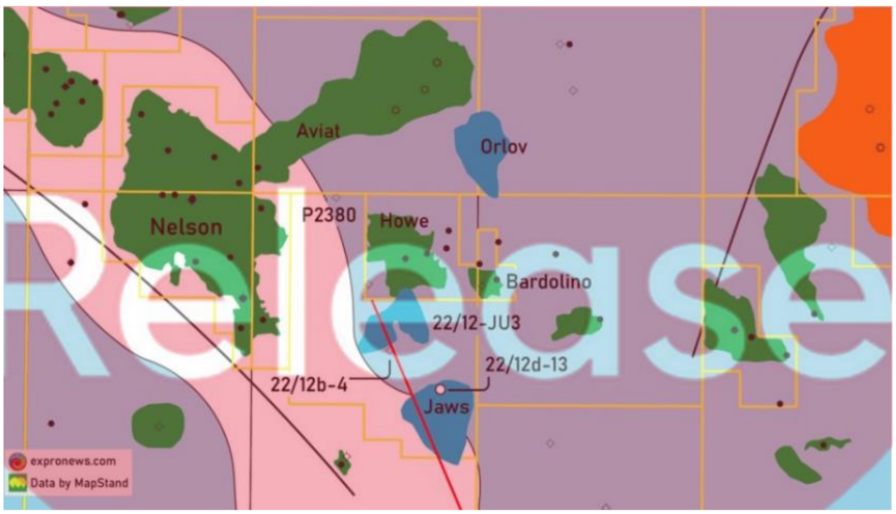

Figure 1 Nelson Oilfield: a conventional oil field in shallow water in the United Kingdom. (Source: expronews.com)

The implementing and analysis steps that conducted in processing of Nelson field data considers the following procedure:

■ Record the dimensions of flowrate information and pressure.

■ Identify the flow regimes via the log-log plot.

■ Verify models by observing the best fit based on the initial flow rate.

■ Based on the empirical data obtained from the N2 core logs, adjust dependant parameters such as the temperature and the pressure to confirm the reservoir model.

■ Conduct sensitivity analysis for horizontal permeability and porosity to check the effects of changing values on the mode.

■ Permeability and porosity can, finally, be analyzed.

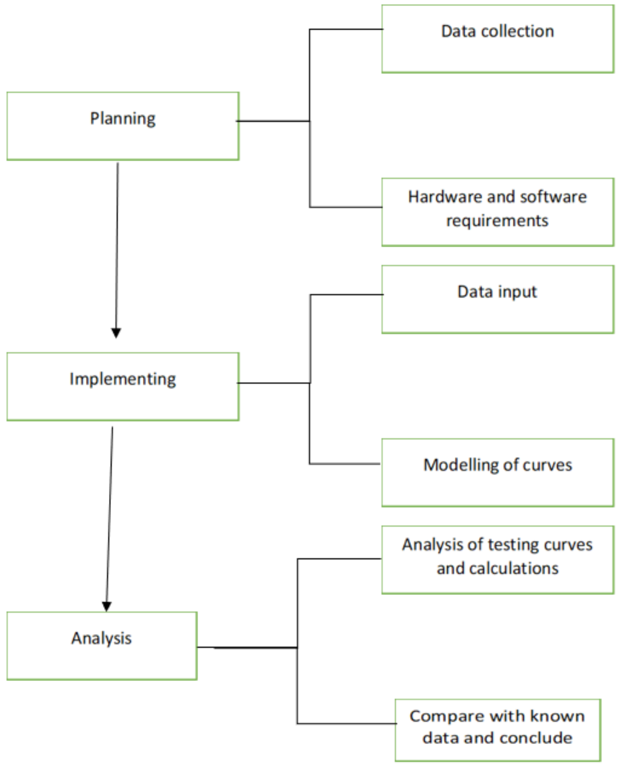

Figure 2 Methodology Steps

Results and Discussion

Data was plotted from the DST test of well N2 in Kappa Saphir using a single-phase model. N2 is a highly deviated (58°) well existing on the west side of the Nelson field; it was selected as it was the only oilfield dataset that had clear and stable flowrate information available. The overall testing regime consisted of an initial flow survey conducted for 34 hours consisting of 3 drawdown periods and 3 subsequent buildup periods, each of them were progressively longer. Based on flow period matching within Kappa Saphir, PBU #3 was chosen for analysis.

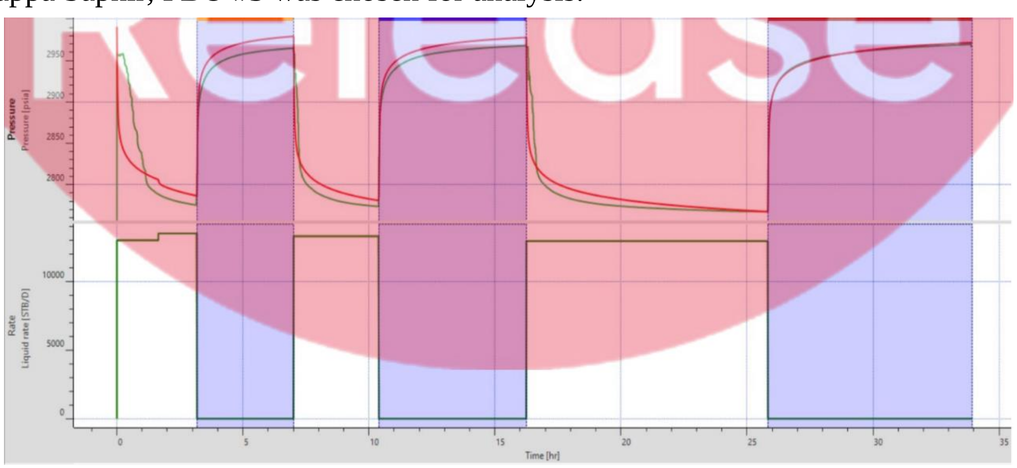

Figure 3 Survey Flow Periods

As can be seen from Figure 3, the second step was to use a log-log diagnostic plot in Saphir to identify the flow regimes during the pressure build-up test. This proved challenging because possible wellbore storage and skin effects could cause values to fluctuate. With a small section at ~2.4hrs into the test being identified as having a slope of 0, radial flow was indicated on a log-log plot [11]. Beyond this radial flow period, an increasing slope may indicate linear channel flow has been achieved; and the core logs from the Nelson field have shown it as a multi-layered reservoir [14].

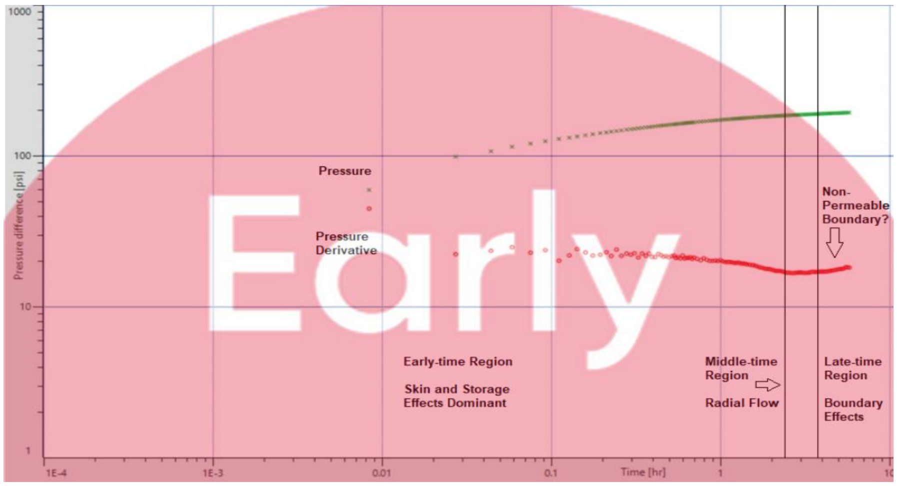

Figure 4 Flow Regime Analysis

To confirm the identification of the flow regimes in the log-log plot, Figure 4 shows a Horner plot of pressure vs. Horner time ratio and a divergence from the main slope was observed, confirming there is a flow regime change at that period [11].

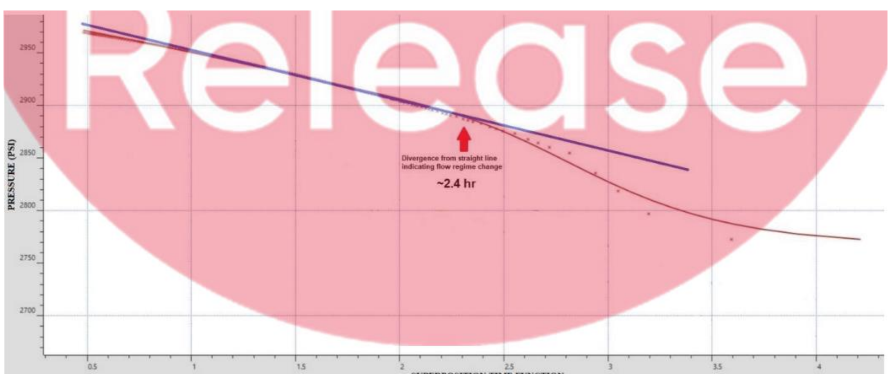

Figure 5 Horner Plot Flow Regime Change

Upon identification of a radial flow section, a model was created to best try and fit the data points. A variety of models were attempted but the best fit was found to be a changing skin model. In figure 5, due to the changing skin that possibly being caused by an insufficient wellbore cleanup period being done before the DST test was conducted [12]. Hence, porosity, permeability, skin, and reservoir height were generated from the model.

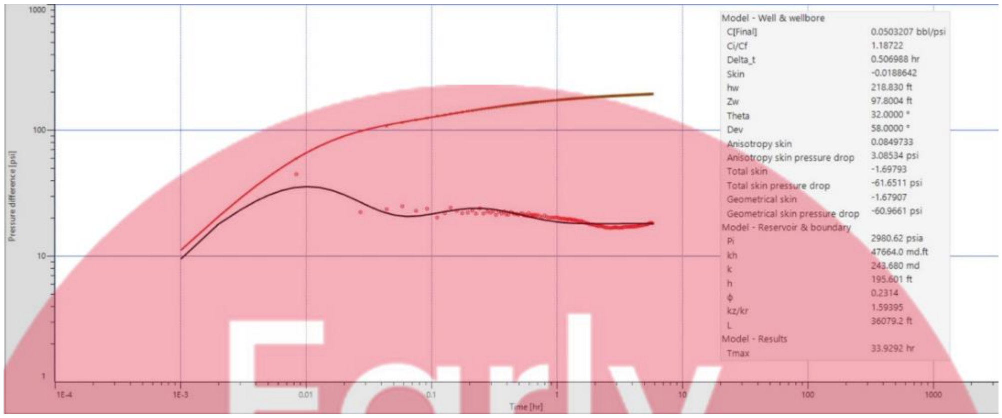

Figure 6 Flow Model - Changing Skin

It's worth mentioning that permeability for flow in a direction that is perpendicular to gravity is horizontal permeability. Vertical permeability, on the other hand, is the permeability for flow in the gravitational direction and can be measured experimentally, and it is approximately one-tenth of horizontal permeability. [13] Hence, to confirm the reservoir model, the necessary empirical data was obtained from the N2 core logs in addition to historical average field data. From figure 6, it is observed that the model closely followed the field average for porosity and permeability that illustrated in table 1, indicating that reservoir characterization is possible in a highly deviated well with complex stratigraphy from a well with differing core values. The results are summarized in table 1.

Table 1 Summary of Reservoir Data [15][18]

Source	Porosity %	Permeability mD	Gross Thickness ft
Model	23.14	243.7	195.6
N2 Core	23.70	340.7	160.5
Field Average	23.60	225.9	128.7

Additionally, sensitivity analysis was conducted for horizontal permeability and porosity to see the effects of changing values on the model, which may indicate how far the core or field average is a better fit for the data points instead of the generated model.

Table 2 Permeability Values [14][17]

Source	Permeability	Difference from model mD	Difference from model %
Model	243.7	-	-
N2 Core	340.7	97	28.5
Field Average	225.9	-17.3	-7.9

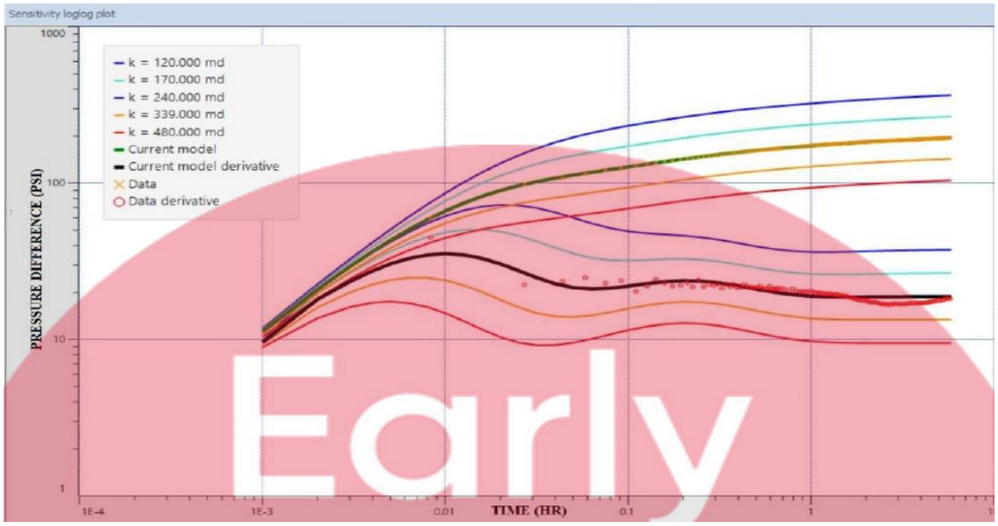

Figure 7 Horizontal Permeability Sensitivity Analysis

With reference to figure 7 and table 2, the permeability can be seen to have a great effect on the model as seen in the sensitivity analysis. Nevertheless, the model is more closely correlated to the field average than that of the N2 core itself, indicating that the surrounding drawdown area shall have permeability values more closely related to the field average. This result could be the average value for permeability in the drawdown area. Or, it could be dependent on near wellbore conditions that can make obvious effects on PTA results [17].

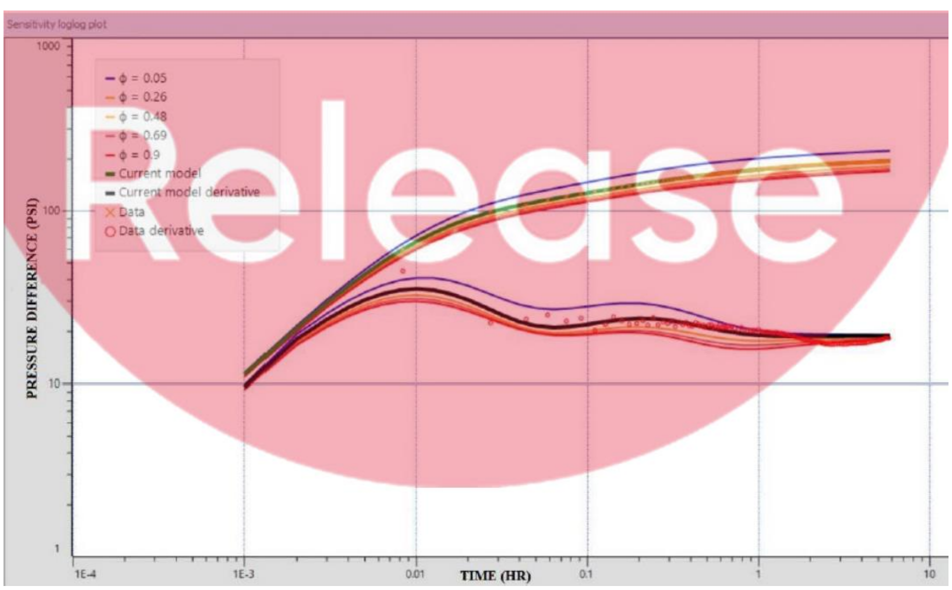

Figure 8 Porosity Sensitivity Analysis

Table 3 Porosity Values [15][18]

Source	Porosity	Difference from model mD	Difference from model %
Model	23.14	-	-
N2 Core	23.70	0.56	2.4
Field Average	23.60	0.46	2.0

Likewise, figure 8 illustrates the porosity which can be analyzed in the same manner and is not seen to have as great effect on the shape of the model as permeability did. Besides, the trend of the values, shown by table 3, is different with the model displaying lower values than that of the field average.

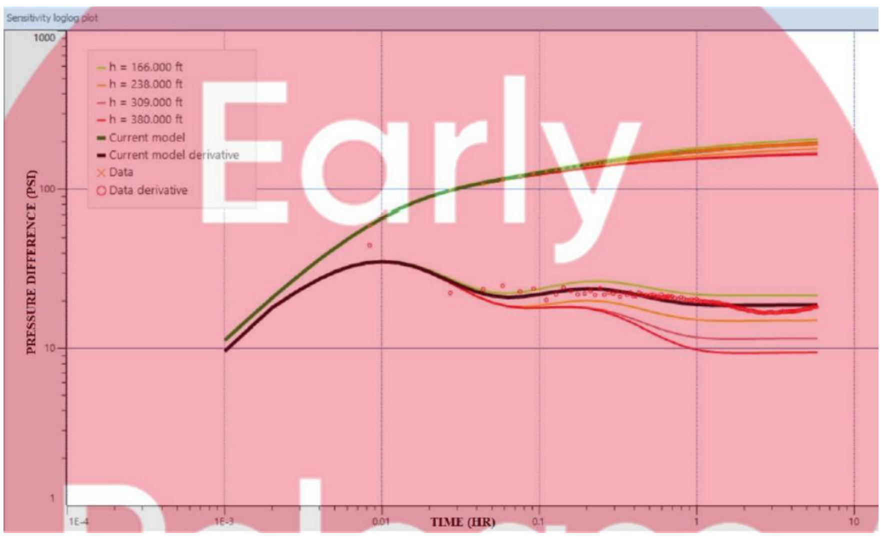

Figure 9 Reservoir Height Sensitivity Analysis

Table 4 Reservoir Height Values [15][18]

Source	Gross Thickness ft	Difference from model ft	Difference from model %
Model	195.6	-	-
N2 Core	160.5	-35.1	17.9
Field Average	128.7	-66.9	34.2

Reservoir thickness can be considered to have a large effect on the later stages of the sensitivity model. In this case, the model predicted a height of 195.6 ft which best fits the data from the DST build-up test. Table 4 shows a poor correlation to the core log and the field average of 128.7ft. From figure 9, it's observed that the reservoir height is especially complicated to confirm with other data sources due to the uneven reservoir thickness throughout the Nelson field, in addition to many impermeable layers that may be impeding flow from sections of the reservoir at this well specifically.

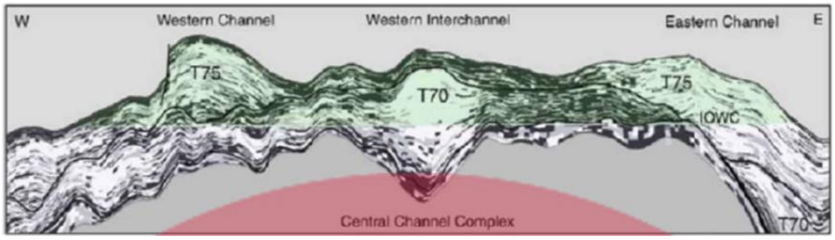

Figure 10 Nelson Channel Complex [16]

Gross thickness and vertical permeability were not able to be predicted accurately using PTA with the current model. Nelson field is characterized as being in a turbidite fan depositional setting with channel sands being highly variable in thickness within the field [14]. Vertical permeability inaccuracies may be due to highly heterogenous permeability values encountered between reservoir layers and complex multiphase flow entering perforations at angle. The highly variable geology poses a challenge to the analysis using core samples only, as each core could have drastically different values for both height and permeability.

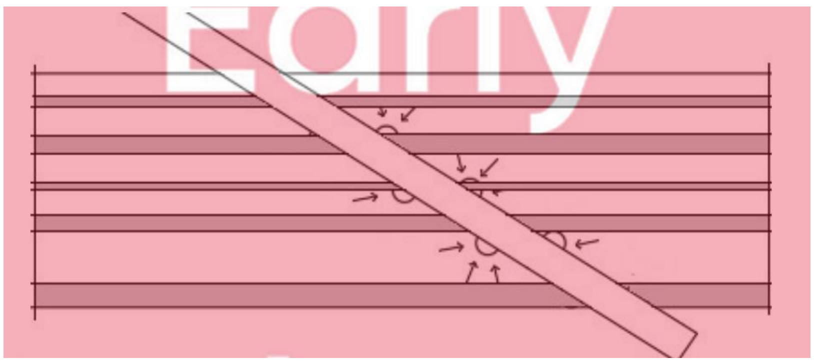

Figure 11 Realistic Deviated Well in Layered Reservoir

PTA modeling allows for a better characterization of the effective values in a reservoir compared to the core log values from the well drilled by positively correlating porosity and permeability values with field average core data. However, despite the Nelson reservoir's high degree of heterogeneity, which makes it challenging to calculate an actionable average, the reservoir height does not exhibit a positive correlation, Figures 10 and 11. By comparing the core values to the effective values determined by PTA modeling, it is possible to confirm drilling success and identify potential damage through the analysis of the drawdown area's effective characteristics.

2. Conclusion

This article has its certain meaning in terms of oilfield production as shown in Figure 12, and its scientific innovation can be outlined in three points as follows:

● PTA and in-depth analysis help guide operational decisions.

● Correlating well test data to core samples and seismic data provide reservoir characterization.

● The PTA is consistent with the oilfield and simulation outcomes. Furthermore, the following are the conclusion of the analysis and discussion:

● Conventional PTA by itself is not a reliable scientific tool because there are numerous geological and result interpretation unknowns in the reservoir. Specifically, a thorough analysis must be carried out by plotting the pressure responses using a variety of different plots using specialized software like Kappa Saphir.

● In highly deviated wells, outputs like permeability, porosity, reservoir height, and skin factor can be precisely predicted for reservoir characterization and field development by correctly identifying IARF and using the right inputs for a model.

● A significant amount of field data, including geological and well data, is required to confirm the PTA results. The field operators can have a better understanding of the reservoir for safe development plans and allowing for more concise operational decisions by correlating well test data to core samples and seismic data. This study discovered that PTA data was consistent with field averages, making it possible to estimate reservoir characteristics more accurately than using just core logs.

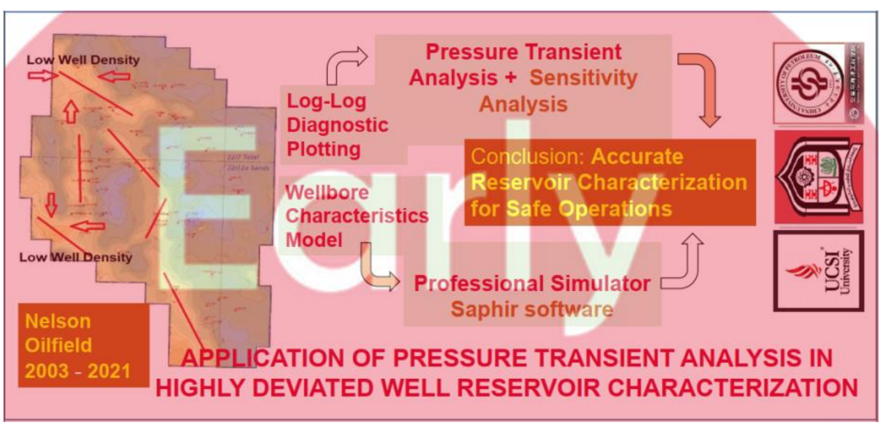

Figure 12 The Graphical Abstract showing the overall specific scheme adopted by the authors

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