MATERIAL BALANCE ANALYSIS OF A SATURATED OIL RESERVOIR IN AN ONSHORE NIGER DELTA FIELD

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A PROJECT REPORT SUBMITED TO THE DEPARTMENT OF PETROLEUM ENGINEERING
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CERTIFICATION

This is to certify that the project contained herein is the original work of **Egbagbeolomo Monday Amos** with matriculation number **ENG2006419** of the department of Petroleum Engineering, University of Benin, Edo State, Nigeria.

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DEDICATION

This work is dedicated to God Almighty for His infinite mercies, love, guidance, knowledge and strength in carrying out this work.

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I wish to first and foremost acknowledge God Almighty for His divine protection, guidance, and countless blessings throughout my life and during the course of my academic pursuit.

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I remain deeply grateful to the Nigerian National Petroleum Company (NNPC) for providing access to the relevant field data used in this study. The data obtained from NNPC formed a vital part of this research and made it possible to carry out a realistic material balance analysis in an onshore Niger Delta Field.

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ABSTRACT

In the petroleum industry, the accurate determination of hydrocarbons initially in place is critical for effective reservoir management and the formulation of efficient production strategies. This research focuses on the evaluation of a saturated oil reservoir in an onshore Niger Delta field through the application of Material Balance Analysis (MBA). The objectives of the study include estimating the initial oil in place, evaluating the presence and strength of an underlying aquifer, identifying the dominant reservoir drive mechanism, and recommending an optimal production scheme capable of maximizing economic recovery. For this research, the majority of the reservoir and production data were obtained from Nigerian National Petroleum Company (NNPC), which also provided access to the MBAL simulation software. MBAL is a simplified yet powerful analytical tool that applies the concept of material balance to characterize reservoir behavior. The program models the reservoir using a zero-dimensional (tank) approach, which does not explicitly account for geometry, drainage area, or well orientation, but provides valuable insights into fluid distribution and drive mechanisms by analyzing production and pressure performance. The results from the MBAL analysis indicate that the reservoir contains an estimated 250.258 MMSTB of oil initially in place, and the predicted volume of water in place to be 99788.4 MMft^3. Furthermore, the aquifer's influence on reservoir pressure performance demonstrates that water drive is the predominant drive mechanism sustaining production. These findings provide a reliable basis for planning production strategies that optimize reservoir performance while enhancing ultimate recovery.

In carrying out this research, valuable hands-on experience was gained in data handling, diagnostic plotting, and MBAL simulation. The work strengthened descriptive, technical and analytical competence in reservoir evaluation and provided deeper insight into the importance of accurate data interpretation for sustainable hydrocarbon recovery in the Niger Delta basin.

CHAPTER ONE

INTRODUCTION

Brief Overview

A petroleum reservoir is a geological sub-surface formation consisting of porous and permeable rock structures that are saturated with hydrocarbons under distinct pressure and temperature conditions. These accumulations are considered recoverable when they exist in commercial quantities and can be exploited using scientific and engineering methods.

To a non-specialist, a hydrocarbon reservoir can be likened to a foam-like medium saturated with fluid, which when subjected to specific pressure and temperature conditions, begins to release fluids. The study of fluid flow in porous media is a complex subject that involves an understanding of multiphase flow dynamics, capillary pressure, and relative permeability.

Material Balance Analysis is one of the oldest and most fundamental methods used to evaluate reservoir performance. It is an analytical approach that applies the law of conservation of mass to determine the amount of hydrocarbons initially in place and the production potential over time. This method utilizes physical and thermodynamic properties such as specific gravity, viscosity and compressibility, or relies on empirical correlations and field data to estimate and predict reservoir behavior.

1.1 Background Study

Reservoir Simulation is the process of modelling the behavior of fluid flow in a petroleum reservoir system through the use of either physical or mathematical models (Chevron, 2006). It can simply be considering as the process of mimicking the behavior of fluid flow in a petroleum reservoir system (including reservoir rocks and fluids, aquifer, surface and subsurface facilities) through the use of either physical or mathematical models. It’s a valuable tool to understand the oil and gas reservoir performance under various operating strategies.

Basically, reservoir simulation is used to optimize development plans for new fields and to assist with operational and investment decisions. Reservoir simulation can also be used to obtain insights into the dynamic behavior of a recovery process or mechanism. Reservoir simulation make use of tools (SIMULATOR) to carry out these process. In this study, MBal software will be the simulator tool to be used.

1.1.1 Material Balance

Material balance is a volumetric balance which states that since the volume of a reservoir is a constant the cumulative observed production expressed as an underground withdrawal must be equal to the expansion of fluids in the reservoir with a finite pressure drop. It is the application of law of conservation of mass to petroleum reservoirs. It provides a dynamic measure of hydrocarbon volumes. To a lay man, material balance is likened to be an inventory of the reservoir. It was developed by Schilthius in 1936, it covers area that contributes to the pressure production. history.

Basically, material balance equation is based on the conservation of mass which states that mass can neither be created nor destroyed but only changes from one form to another to petroleum reservoir for the purpose of making quantitative deduction. It can simply be expressed as follows according to the volume of fluids.

IN - OUT = ACCUMULATION

IN → Amount of fluids present in the reservoir initially (vol)

OUT→ Amount of fluids produced (vol)

ACCUMULATION → Amount of fluids remaining in the reservoir finally (vol)

The material balance uses a model that is existing as imagination of reservoir to actually or forecast the behavior of the reservoir established on the effects of production of fluid from the oil pool and injection of gas and water. The material balance equation considers the reservoir to be a tank, thereby eliminating the dynamicity of the reservoir and not taking note of the various changes in permeability and porosity occurring in the reservoir but yet it is still used by the Reservoir Engineers as a tool for interpreting and predicting reservoir performance.

In the cause of this study, to illustrate the method, only sections specifically dealing with the material balance principles are included. Additional geologic information and basic data are reported to better acquire an understanding of the cases and thus to better follow the reasoning that suggested the successful application of the straight-line method of solving the MBE.

Table 1. 2: Data Required For MBE

i. Data Source.
ii. PVT Data from PVT reports, correlations.
iii. Production data Well and reservoir records.
iv. Ratio of gas cap volume to oil volume from wireline log, reservoir modeling (M).
v. Oil and gas in place from volumetric estimate and geological model.
vi. Connate water saturation from petro-physics (core and log).
vii. Water compressibility from correlation or measured.
viii. Pore compressibility from correlation or measured.
ix. Reservoir pressures from pressure survey.
x. Water influx Calculation or history.

The accuracy of material balance is based on the consistency of results when applied at successive intervals and agreement of the Material balance equation (MBE) result with result gotten from volumetric technique. It is applied at later stage of development (after 20% of initial oil/gas is produced, or 10% of initial reservoir pressure has declined). It uses the reservoir pressure measurements to determine estimates of oil in place and gas in place, and develop an understanding of the reservoir's drive mechanisms. The Material balance equation relies on the assumption that as oil, gas and water are produced from the reservoir; there will be corresponding change in the reservoir pressure and the expansion of oil, gas, water, and rock.

The Material Balance procedure describes the expansion of oil, gas, water, and rock over time as a pool is produced. When fluid is removed from a reservoir, reservoir pressure tends to decrease and the remaining fluids expand to fill the original space. Injection situations such as water flooding or gas storage, are handled by treating the injection volumes as negative production. The material balance equation may be expressed in a number of different forms and the general form of the equation applies to a reservoir containing a gas cap, gas saturated oil and connate water, producing under a combination of primary drive mechanisms.

In the cause of this study, to illustrate the method, only sections specifically dealing with the material balance principles are included. Additional geologic information and basic data are reported to better acquire an understanding of the cases and thus to better follow the reasoning that suggested the successful application of the straight-line method of solving the MBE.

1.1.2 Basic Material Balance Assumptions

Some of the assumptions employed in the material balance equation are:

i. Reservoir is considered to be a single tank.
ii. Pressure, temperature, rock and fluid properties are not space dependent.
iii. Thermodynamic equilibrium always attained.
iv. Production data are reliable.

1.2 Problem Statement

In the oil and gas industry, the accurate determination of oil and gas initially in place and the prediction of the future reservoir performance are of vital importance to it. Also, an accurate and reliable production data directly impacts the accuracy of the estimate and future performance.

Some drawbacks may occur if the wells drilled in the reservoir are not accounted for, if the knowledge of the geologic trend is lacking, when the individual saturations for each fluid is not accounted for but only an average saturation is shown and also if the representation of variations in fluids or gas properties can't be represented. By integrating geological, petrophysical, and PVT data into software, material balance analysis (MBAL), errors from missing wells, poor saturation data, and fluid variability are minimized. This enhances the accuracy of reservoir performance prediction and recovery forecasting.

1.3 Objectives of The Study

The main objectives of this study is material balance analysis of a saturated oil reservoir in an onshore Niger Delta field. While the specific objectives are as follows:

1. To estimate the initial oil in place.
2. To verify a suitable drive mechanism.
3. To determine the presence of an aquifer and the strength of the aquifer.
4. To deduce the best operational production scheme that would economize maximum recovery.
5. To ascertain the ultimate hydrocarbon recovered using various types of primary driving mechanism

1.4 Justification of the Study

This study is justified by the need to apply practical and analytical reservoir engineering principles to evaluate the performance of mature oil fields in the Niger Delta. Material balance analysis provides a cost-effective and reliable method for estimating reserves, identifying drive mechanisms, and forecasting production performance without extensive field testing.

During the course of this project, the study proved significant in bridging theoretical knowledge with real industry applications through the use of MBAL software and NNPC field data. It enhanced practical understanding of data integration, pressure–production evaluation, and decision-making processes in field development planning.

The research contributes to improving recovery efficiency, optimizing reservoir management, and supporting sustainable hydrocarbon production within the Niger Delta basin.

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1.5 Scope and Limitations of Study

1.5.1 Scope:

This study focuses on applying material balance analysis to evaluate the performance of a saturated oil reservoir in an onshore Niger Delta field. It covers the estimation of OOIP, identification of drive mechanisms, and prediction of reservoir performance using MBAL software. The analysis utilizes production, pressure, and PVT data from NNPC, considering aquifer and compaction effects.

During the research, practical experience was gained in handling real field data, performing reservoir diagnostic plots, and integrating analytical results with practical petroleum judgment. The study also enhanced proficiency in using reservoir engineering tools and interpreting results for improved field development planning and recovery optimization.

1.5.2 Limitations:

During the course of this project, several challenges were encountered that influenced the depth and pace of analysis. The primary limitation was the restricted availability and completeness of field data from NNPC, which required careful estimation and interpolation of missing parameters such as PVT and aquifer properties. Time constraints and limited computational resources also restricted the number of MBAL simulation runs for pressure matching. Additionally, the lack of direct field validation and core analysis due to logistical and cost limitations hindered experimental calibration of rock and fluid properties. Variations in data quality and format demanded extensive preprocessing to ensure accuracy. Despite these challenges, the research provided valuable experience in data handling, analytical reasoning, and reservoir evaluation using MBAL software, enhancing practical petroleum engineering competence

CHAPTER TWO

LITERATURE REVIEW

Introduction

Tarek (2010) stated that in reservoir engineering calculations, material balance equation, MBE plays a key role in most of the useful applications requiring the concurrent use of fluid flow equations such as Darcy's equation. Reservoir engineers constantly look for ways to improve or optimize hydrocarbon recovery by predicting the future performance of the reservoir which is the direction of the study to develop a tool using Tarner's method, a simple MBE concept that will perform such task whenever the required data are available. The MBE simply makes use of the average reservoir pressure for performance evaluation without the inclusion of fluid flow concepts.

Therefore, when we combine the MBE and fluid flow equations would assist engineers to make use of time function in predicting the reservoir future production performance. Material balance analysis implies "integration", the reservoir is assumed to be a tank model and treated as a zero dimensional "black box". The result obtain from the material balance analysis may contain so many of complications such as heterogeneity, fractures, horizontal wells, etc. all of which are sublimated to the overall balance which, once an average pressure decline has been defined for the system, relies solely on the production, pressure and PVT data. It is not uncommon for engineers to attempt to add sophistication to their calculations by subdividing a reservoir into two or three grid blocks and applying material balance to each. This practice, however, should be treated with caution, because it requires the handling of fluid fluxes between the blocks which raises the same problems as described above for numerical simulation.

Bui et al. (2006) used the material balance analysis to determine the mature Samarang field's reservoir compartmentalization. A workflow for material balance analysis was proposed and the effects of the relative permeability curves on the history match effectiveness were investigated.

According to Mazloom et al., (2007) compared the material balance prognosis results from both single- and multi-tank models against a fine grid simulation model, and concluded that the single tank overestimates recovery factor. The authors also concluded that the single-tank model was unable to capture the reservoir heterogeneities for the condensate field which they investigated, whereas the multi-tank model results were in an acceptable range when compared with the simulation results.

Moreover, several studies have been performed on fluids migration examining the transmissibility parameter. For example, (Vera et al. 2008) analyzed an uncertain transmissibility parameter using single- and multi-tank models and summarized that the multi-tank material balance technique was an effective method for examining fluids migration.

While Amudo et al., (2011) and Esor et al., (2004) addressed the application and methodology of the MBAL tool on establishing connected hydrocarbon volume in place and drive mechanisms.

Cole (1969) points out that the control of the gas-cap size is very often a reliable guide to the efficiency of reservoir operations. A shrinking gas cap will cause the loss of a substantial amount of oil, which might otherwise be recovered. Normally, there is little or no oil saturation in the gas cap, and if the oil migrates into the original gas zone, there will necessarily be some residual oil saturation remaining in this portion of the gas cap at abandonment. The magnitude of this loss may be quite large, depending upon the: Area of the gas-oil contact, Rate of gas-cap shrinkage, Relative permeability characteristics, Vertical permeability.

Garcia et al. (2007) proposed the methodology to assess the most significant parameter that affects material balance computation. His work showed that OOIP estimation is very sensitive to reservoir pressure and PVT data.

Hyne, Norman J. (2001) stated that the amount of oil in a subsurface reservoir is called "Oil in Place (OIP)" and only a fraction of this oil can be recovered from a reservoir. This fraction is called the recovery factor. The portion that can be recovered is considered to be a reserve. The portion that is not recoverable is not included unless and until methods are implemented to produce it.

There are a number of methods of calculating oil reserves. These methods can be grouped into three general categories: "Volumetric", "Material Balance", and "Decline Curve Analysis (DCA)". Each method has its advantages and drawbacks. (Lyons, William C. et al. 2005).

The Decline Curve Analysis (DCA) method uses production data to fit a decline curve and estimate future oil production. The three most common forms of decline curves are exponential, hyperbolic, and harmonic. It is assumed that the production will decline on a reasonably smooth curve. This method requires a sufficient history to establish a statistically significant trend, ideally when production is not curtailed by regulatory or other artificial conditions. (Lyons, William C. 2005).

Volumetric method attempts to determine the amount of oil in place by using the size of the reservoir and as well as the physical properties of its rocks and fluids. Then a recovery factor is assumed, using assumptions from fields with similar characteristics. OIP is multiplied by the recovery factor to arrive at a reserve number. Current recovery factors for oil fields around the world typically range between 10 and 60 percent; some are over 80 percent. The wide variance is due largely to the diversity of fluid and reservoir characteristics for different deposits. E.Tzimas, (2005). The method is most useful early in the life of the reservoir, before significant production has occurred.

Schilthius (1938) developed one of the first useful oil and gas reservoir Material Balance equations. The use of Schilthius equation in predicting future reservoir performance has proved to be laborious, and one generally must take several estimates at each step of its trial and error calculation before arriving at a check of the oil in place. Basically, it is a statement of "conservation of mass and is a method of accounting for the volumes and quantities of fluids produced from injected fluids and remaining oil in the reservoir at any state of depletion."

Havlena and Odeh (1963) developed a useful graphical procedure for estimating the volume of oil initially in place for a solution gas drive reservoir, by rearranging the materials equation so that the total withdrawals from the reservoir are grouped onto the y-axis while all the expansion terms are grouped on x-axis.

For a reservoir under water drive, the volume of the water which encroaches into the reservoir also enters into the material balance equation. Schilthius presented a method for calculating water encroaching by using the material balance equation.

It was left for Hurst and later Van Everdingen (1949) to develop methods for calculating the water encroachment independent of material balance equation, which appears to aquifer of either limited or infinite extent in either steady or unsteady state. Later Fetkovich simplified the calculations of Van Everdigen and Hurst.

The material balance equation had improved by various modifications for the prediction of the reservoir performance by using time function, which was presented by Tarner, Muskat and Tracy method. These enable the reservoir engineer to history match and predict the performance of the reservoir. In these prediction methods, the following assumptions are generally made: uniformity of the reservoir at all times regarding porosity, fluid saturations, relative permeabilities; uniform pressure throughout the reservoir in both the gas and oil zones (which means the gas and oil volume factors, the gas and oil viscosities, and the solution gas will be the same throughout the reservoir); negligible gravity segregation forces; equilibrium at all times between the gas and the oil phases; a gas liberation mechanism which is the same as that used to determine the fluid properties, and no water encroachment and negligible water production. Hence, this thesis uses the approach by Tarner's in prediction.

All the techniques that are used to predict the future performance of a reservoir are based on combining the appropriate MBE with the instantaneous GOR using the proper saturation equation. The calculations are repeated at a series of assumed reservoir pressure drops. These calculations are usually based on one stock-tank barrel of oil-in-place at the bubble-point pressure.

Tarner (1944) and Muskat (1945) proposed methods to predict the performance of depletion (solution-gas)-drive reservoirs under internal gas drive mechanism, using rock and fluid properties. The assumptions of both methods include negligible gravity segregation forces. Thus, these authors considered only thin, horizontal reservoirs. Both methods use the material balance principle (static) and a producing gas-oil ratio equation (dynamic) to predict reservoir performance at pressures, where gas saturation exceeds the critical value. A more detailed description of both methods appears in (Craft and Hawkins 1991).

Tracy (1955) In the model developed for reservoir performance prediction, the model did not consider oil reservoirs above the bubble-point pressure (undersaturated reservoir) but the computation starts at pressures below or at the bubble-point pressure. To use this method for predicting future performance, it is pertinent therefore to select future pressures at desired performance. This means that we need to select the pressure step to be used. Hence, Tracy's calculations are performed in series of pressure drops that proceed from a known reservoir condition at the previous reservoir pressure p* to the new assumed lower pressure p. The calculated results at the new reservoir pressure become "known" at the next assumed lower pressure.

Tarner (1944) suggested an iterative technique for predicting cumulative oil production (N_P) and cumulative gas production (G_P) as a function of reservoir pressure. The method is based on solving the MBE and the instantaneous GOR equation simultaneously for a given reservoir pressure drop from a known pressure **(P)** to an assumed (new) pressure p. It is accordingly assumed that the cumulative oil and gas production has increased from known values of N_P and G_P at reservoir pressure **P** to future values of N_P and G_P at the assumed pressure p. To simplify the description of the proposed iterative procedure, the stepwise calculation is illustrated for a volumetric saturated oil reservoir; however, the method can be used to predict the volumetric behavior of reservoirs under different driving mechanisms.

Laurie Dake (1978) quoted from the practice of reservoir engineering - Elsevier "that it seems no longer fashionable to apply the concept of the material balance to oilfields, the belief that it is now superceded by the application of modern numerical simulation. Acceptance of this idea is a tragedy and has robbed engineers of their most powerful tool for investigating reservoirs and understanding their performance rather than imposing their wills upon them, as is often the case when applying numerical simulation directly in history matching. Thus, there should be no competition between MB and simulation instead they must be supportive of one another: the former defining the system which is used as input to the model. Material balance is excellent at history matching production performance but has considerable disadvantages when it comes to prediction, which is the domain of numerical simulation".

Muskatt (1945) the material balance equation method is by no means a universal tool for estimating reserves. In some cases, it is excellent. In others it may be grossly misleading. It is always instructive to try it, if only to find out that it does not work, and why. It should be a part of the stock in trade of all reservoir engineers.

Material balance method has some limitations though it can be used as a pre-processing tool to infer fluid in place, drive mechanisms and identify aquifer for a more sophisticated tool "reservoir simulation" which gives insight into the rock and fluid properties dynamically for evaluation of historic performance of the reservoir, future prediction of reservoir performance, and reserve estimation (Warner et al., 1979, Harris, 1975). It should be noted that we cannot enter into the reservoir to see enough of the reservoir to enable us describe it accurately, it therefore implies that reservoir simulation cannot be relied on completely. Since we cannot get into the reservoir, it will be absolutely difficult to explain the physics of processes in the reservoir system and develop an accurate mathematics that will represent the physics of the system with a degree of certainty. Besides, having developed an adequate mathematical model of the reservoir, solving for the numbers of unknown becomes a challenge because of the much mathematical equations to handle it. (Dake 2001). Several authors have carried a reservoir study on various field around the world and some of them are presented below.

Mattax et al. (1990) stated that performance prediction of large complex reservoirs might be possible by the use of method of reservoir simulation. Furthermore, with the incorporation of 3-D seismic time-lapse results, the result from simulation form a monitoring tool for the reservoir when mapping changes associated with production used to comprehend the historical behavior to predict the future (Landro et al., 1999; Johnston et al., 2000). With the concepts and developments by various authors on the Material Balance Equation, during the 1960s, the term reservoir simulation and reservoir mathematical modeling became popular. Thus material balance which uses the single tank model and as modified by various authors to time function and other useful modification was imbedded into simulation with the ability of predicting the performance of the reservoir and also solving drainage problems arising during production and development of oil and gas reservoir in order to obtain high economic recovery.

Agarwal et al. (1965) noted that high rate production was a requirement to ensure high gas during depletion, residual-gas saturation plays an important role, particularly at low rates. Agarwal et al. also found the Carter-Tracy (1960) aquifer model to be quite effective in modelling water influx. Bruns et al. (1965) also performed forward modelling to capture various water drive signatures in pav/z vs. G, plot, using Scilthuis (1936), Hurst simplified (1943), and Van Everdingen and Hurst (1949) aquifer models. Because the aquifer size vis-à-vis its influx plays a major role in the performance response, the use of the P_{av}/Z method can potentially lead to over 100% error in original gas-in-place (OGIP) estimates, if proper care is not taken. Similar to Agarwal et al, findings, Bruns et al, also recommended accelerated production 'to get a better understanding of OGIP in early production life.

Chierici (1967) noted that unique determination of OGIP may be elusive. They argued that the internal structure of a coupled system (gas and associated water) cannot be uniquely determined from its external behavior. They suggested that large fluctuations in production rates can induce large perturbations in the system, thereby minimizing the uncertainty range in OGIP estimation. The notion that large perturbations improve signal quality is analogous to ideas prompted by transient-pressure testing.

Warner et al. (1979) stated that the material balance method has some limitations, though it can be used as a pre-processing tool to infer fluid in place, drive mechanisms and identify aquifer for a more sophisticated tool "reservoir simulation". This sophisticated tool gives an insight into dynamic rock and fluid properties for evaluation of past reservoir performance, prediction of future reservoir performance, and reserves estimation.

Payne (1996) applied the multi-compartment reservoir model to single, tight gas reservoirs. Payne's method is a simple and straight forward method and ignores the changes in the flow across the boundaries and gas properties during a time step. Haggort and Hoogstra (1999) presented another simple but rigorous numerical method for the solution of material balance equations for compartmented gas reservoirs. Their method employs an implicit calculation scheme for calculation of the pressures of individual tanks during a time step.

Over pressure reservoirs within creasing drilling depth added another level of complexity because the P_{av}/Z plot generates a quadratic signature, (Gonzalez, 2008). Roach (1981) reformulated the material balance equation to incorporate rock and water compressibility because the rock compressibility becomes comparable to that of gas in overpressure systems. Ambastha (1993) pointed out issues with the Roach formulation because of the method's reliance on high quality data. Furthermore, he illuminated the uniqueness issue by studying challenges in decoupling effective compressibility and initial in-place gas volume in overpressure reservoirs. Subsequently, water influx was incorporated implicitly into the analysis with studies by (Poston, 1994 and Fetkovich, 1998), among others. In particular, Fetkovich incorporated an effective pressure dependent compressibility term in their reformulation of the material balance equation. This compressibility term accounts for pore volume, water saturation, gas solubility, and aquifer associated with the gas. Although this approach is comprehensive, Walsh (1998) showed that a simpler straight line method can provide an equally robust solution with the F vs Et plot, where F represents total fluid withdrawal and Et the total net expansitivity. This approach mimicks the straight-line method of Havlena and Odeh (1963), but necessitates a trial-and-error solution. The pot aquifer model is implicit in this formulation.

More recently, Yildiz (2008) showed a hybrid approach for handling MB in water drive gas reservoirs to minimize the range of uncertainty in OGIP estimation. Yildiz argued that multiple combinations of OGIP and aquifer parameters can match the same field data, thereby suggesting a range of possible solutions. He offered modifications to Roach (1981), Haviena-Odeh (1963), and McEwen (1962) plots.

The reformulation of the McEwen plot involved the use of the Van Everdingen and Hurst (1949) unsteady-state aquifer model. The key to minimizing the OGIP uncertainty range in the McEwen plot is that a time-invariant horizontal response exists for the estimated OGIP trend with increased producing time. Other notable papers in this area include those of Gonzalez (2008) and Mogadham (2011), among others.

Harville and Hawkins and Hammerlindi attribute the concave downward shape of P/Z vs G_p. Curves obtained in abnormally pressured gas reservoirs entirely to pore collapse, but a plot of back calculated PV change indicated a system compressibility change from 28 x 10^{-6} psi at initial pressure to about 6 x 10^{-6} psi at low pressures. This magnitude of PV change implies associated water volume. The decreasing "system" compressibility is expected for an over pressured reservoir with pressures-dependent PV compressibility.

King (1993) suggested that the material balance equation can be expressed in general terms as

$G_p = G - G_r$

The material balance proposed by King (1993) is the most comprehensive, and considers gas adsorbed in the coal matrix, gas contained in the cleats (fracture system) and water compressibility with respect to the gas material balance equation.

Seidle (1999) suggested using a similar material balance as that developed by King, but with the simplifying assumption that the water saturation is constant. This simplification is justified by the assumption that the water saturation in the CBM reservoirs have little impact on the calculations as the term in which it appears is small in comparison to the one in which it is added to. For much of the producing life a well, the expression for $\mathbf{Z^*}$ is dominated by the ratio of sorbed to free gas in the denominator. Formation and water compressibility is also assumed to be negligible.

Jensen and Smith (1997) method assumes that the gas stored in the cleat space is negligible (1 – 2%), resulting in the complete omission of water saturation effects. In this case, the gas content is described solely by the adsorbed volume.

2.1 Data Analysis

The basic workflow for carrying out a simulation using MBAL (Petroleum Experts, User Manual, IPM MBAL Version 14, February 2018) Follows:

1. Setting Modeling Options.
2. Entering PVT Properties and Performing a correlation Match.
3. Entering reservoir and aquifer properties.
4. Entering production history data.
5. Performing a history match.
6. Using regression to improve the match.

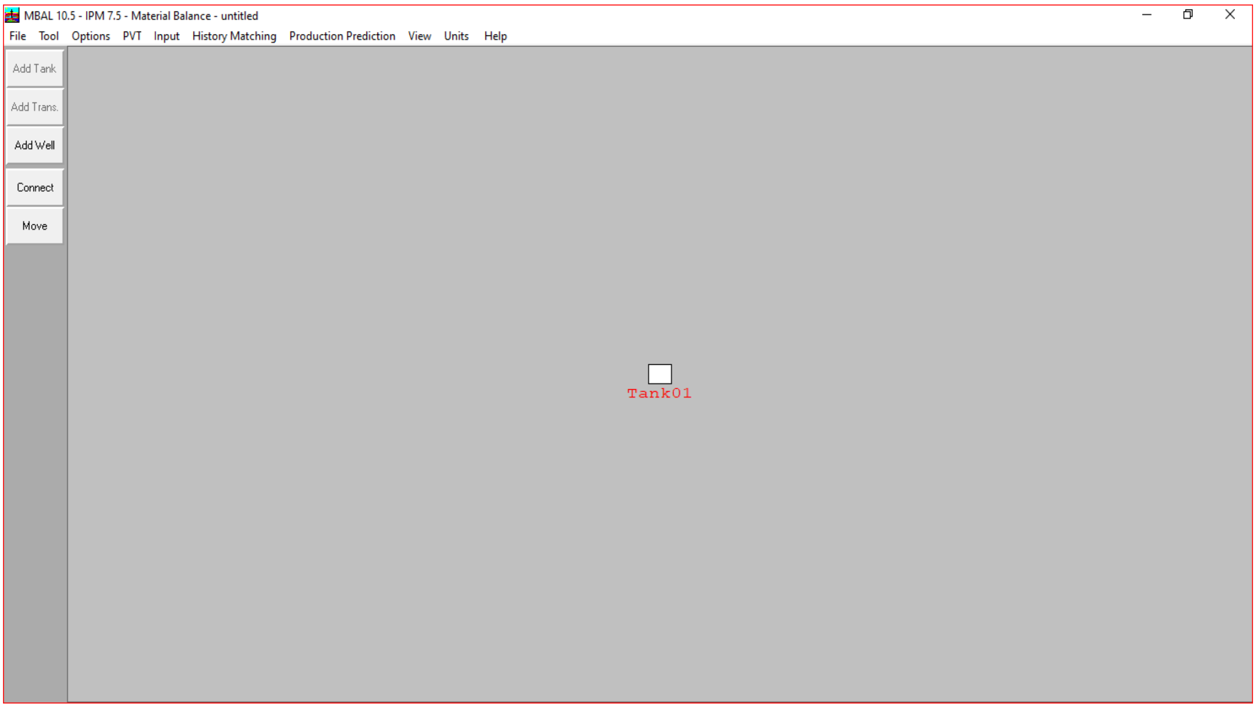


Figure 2. 2: Start Up Menu of Material Balance (MBAL)

Source: (Petroleum Experts, User Manual, IPM MBAL Version 14, February 2018).

2.1.1 Setting Up the Model

To initialize or start, click File/New, it automatically calibrates the MBAL interface to start a new project. Then select Material Balance from the Tool menu. And click option to setup the system properly and click done. The system has been setup.

2.1.2 PVT

Click fluid properties from the PVT Menu and the PVT screen displays. Enter the required PVT data. Select the "Match Button" as soon as it selects, click it and it prompts the regression screen. In order to match the data to the correlation, click "calc. button" as soon as the calculation is finished the "Match parameter" screen displays and allow the selection of the correlation that best fit matches the data. Click on the "Match Parameter" to establish the correlation among whom to be selected. And then it displays the black oil correlations. And the best correlation is selected for the fluid properties. Click Done to finish the PVT section.

2.1.3 Reservoir Input

Click Tank Input from the INPUT menu. Enter the required data by navigating to the tabs, the Tank Parameters, Water Influx, Pore Volume, Relative Permeability, and Production History. Enter the tank parameter, and Production history import from excel file.

2.1.4 History Matching

All the reservoir input is used at this point for the history matching. From the history match, select; All and the history match plots displays.

The graphical plots are based on the basic material balance equation. $F = NE_t$

Where;

F = Total production

E_t = Total expansion

W_e = Water influx

N = Original oil in place

The Campbell displays by default. It suggests:

Theoretically the data would be expected to fit to a horizontal line whose intersection with the y-axis gives the OIIP. The increasing trend of the data in the Campbell plots suggests that an aquifer source of energy. In this case, an aquifer needs to be added to the model. Hence go back to the Tank input data and navigate to the aquifer influx tab, enter the necessary parameters and then select the model, for this work, it is Hurst Van-Everdingen Modified. Click done and return to the history match Analytical Plot. Click the regression menu on the screen, and on the regression screen select at least two variables, click on the regression button to do the regression. And then click done. It automatically transfers all the calculated data on the model and that makes the necessary updates. To verify, click the simulation from the History Match. It displays the plots relationships.

2.1.5 Production Prediction

To establish future production, go to the production prediction menu, ensure the prediction setup, constraints and make the necessary prediction. That completes the process.

CHAPTER THREE

METHODOLOGY

3.1 Research Methodology

In this research, both descriptive and analytical approaches were utilized, and the study explained the methods of data collection, presentation and analysis adopted. The various sections of the chapters include:

- Research Design
- Method of Data Collection
- Data Analysis

3.2 Research Design

The research design approaches

- Descriptive Approach
- Analytical Approach

Descriptive Approach:

This approach involves a detailed evaluation of the reservoir's geological and production characteristics to understand its behavior under natural depletion. It includes:

- Review of field pressure and production data
- Description of reservoir drive mechanisms
- Identification of production trends and performance indicators
- Correlation between pressure decline and cumulative production

This approach provides a conceptual understanding of the reservoir's response to production and serves as the basis for analytical evaluation.

Analytical Approach:

The analytical approach utilizes material balance analysis to quantitatively determine reservoir performance. Using the general material balance equation, the study evaluates reservoir pressure depletion and fluid withdrawal over time to estimate the Original Oil in Place (OOIP) and recovery factor.

Key computational tools such as Havlena–Odeh graphical method and data regression analysis were employed to interpret the relationship between cumulative production and pressure drop, ensuring accurate assessment of reservoir energy and production efficiency.

3.3 Method of Data Collection

The data used in this study were obtained from an onshore Niger Delta oil field through field production reports and reservoir engineering records. The dataset includes pressure, production, and PVT data necessary for material balance analysis.

3.4 Material Balance Evaluation and Analysis

MBAL (MBAL user manual, 2011) is a simplified analytical tool used to identify reservoir characteristics using the concept of material balance. The MBAL software due to its simplified nature, is governed by the following assumptions:

i. Homogenous reservoir tanks.
ii. Constant tank pressure.
iii. Uniform pressure and hydrocarbon saturation distributions in the tank.
iv. Instantaneous transmission of pressure changes throughout the system.

The material balance program uses a model of the reservoir to predict the reservoir behavior based on the effect of the reservoir fluids production and gas to water injection. The material balance is zero dimensional, meaning that it is based on a tank model and does not take into account the geometry of the reservoir, the drainage area, the position and orientation of the wells etc. Petroleum experts MBAL, is a reservoir modelling tool belonging to the integrated production model (IPM) suite. This tool was designed to allow for greater understanding of the current reservoir behavior and perform predictions while determining its depletion.

The objective of this software (MBAL) is to demonstrate the basic functionality of MBAL in terms of history matching options and performing predictions.

The list of objectives for using the material balance tool are:

i. Quality-checking the data that is available. This quality checking is based on what is physically possible and focused towards determining inconsistencies between data and physical reality.

ii. History matching procedure to determine the OOIP and possible aquifer size.

iii. Prepare the history matched model for forecast (Fractional flow matching).

iv. Creating a well model in MBAL upon which the forecast can be based.

v. OOIP is obtained from geology.

vi. History match model is done in terms of identifying and quantifying its various drive mechanism and determining the OOIP and aquifer support.

The three plots available are:

I. Energy plot: Showing the relative importance of each drive mechanism currently in the model.

II. Graphical method: Where the diagnostics in terms of drives can be done.

III. Analytical method plots: Shows the reservoir pressure vs. cumulative production from the historical data and the model.

The three main subgroups for an oil system are:

i. Profile from production schedule (No wells).

ii. Production profile using well models.

iii. Calculate number of wells to achieve target rate. The first allows forecast without a well, while the second requires forecast with a well model. The production is kept constant throughout the prediction, until the reservoir does not have enough energy to support it.

3.5 Mathematical Concept of MBE Programmed into MBAL

As stated in the definition earlier, material balance is basically a balancing between volumes (i.e. volume produced = expansion of fluids). The material balance still works on the basic conservation of mass principle which states that mass can neither be created nor destroyed but only changes from one form to another.

Total underground withdrawal (rb) = Expansion of primary Gas Cap Gas (rb) + Expansion of Oil + Originally Dissolved Gas (rb) + Expansion of Connate water (rb) + Decrease in (Rock) pore volume (rb).

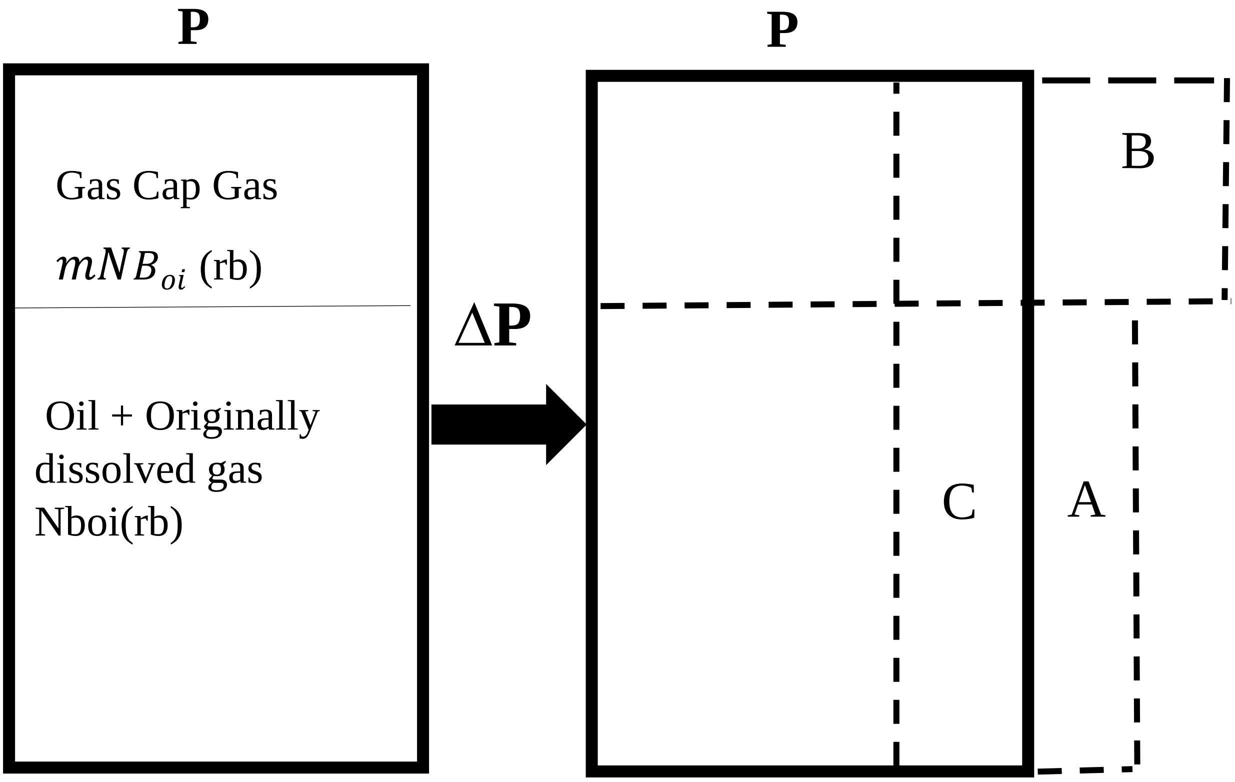


Figure 3. 4: Pictorial Description of the Material Balance Theory

Cumulative Production = Expansion = A + B + C

Where;

A = Expansion of the oil + originally dissolved gas (rb)

B = Expansion of the gas cap gas (rb)

C = Reduction in the Hydrocarbon Pore Volume due to connate water expansion and decrease in the pore volume (rb).

N = Initial oil in place in stock tank barrels (rb) = $V\Phi(1-S_{wc}) / B_{oi}$ (stb).

$m = \frac{\text{Initial hydrocarbon volume of the gas cap gas}}{\text{Initial hydrocarbon volume of the oil}}$

The expansion terms in the material balance equation can be expressed as follows;

a) Expansion of oil plus originally dissolved gas.

There are two components in this term:

i. Liquid expansion

The N stb will occupy at a reservoir volume of NB_{oi} (rb), at the initial pressure, while at the lower pressure **P**, the reservoir volume occupied by the N stb will be NBo, where Bo is the oil formation volume factor at the lower pressure. The difference gives the liquid expansion.

$N (B_o - B_{oi})$ (rb)....…..........(i)

ii. Liberated gas expansion

Since the initial oil is in equilibrium with a gas cap, the oil must be at saturation or bubble point pressure. Reducing the pressure below P_i will result in the liberation of solution gas. The total amount of solution gas in the oil is NR_{si} scf. The amount still dissolved in the N stb of oil at the reduced pressure is NR_s (scf). Therefore, the gas volume liberated during the pressure drop ΔP, expressed in reservoir barrels at the lower pressure, is;

$N (R_{si} - R_s) B_g$ (rb)..................... (ii)

b) Expansion of the gas cap gas

The total volume of gas cap gas is mNB_{oi} (rb), which is in scf may be expressed as;

$G = \frac{mNB_{oi}}{B_{gi}}$ (scf) .... (iii)

At reduced pressure it becomes;

$mNB_{oi} \frac{B_g}{B_{gi}}$ ....(iv)

Therefore, the expansion of the gas cap gas is

$mNB_{oi} \frac{B_g}{B_{gi}} - 1$ (rb) .... (v)

c) Reduction in the hydrocarbon pore volume due to connate water expansion and pore volume reduction.

$d(HCPV) = dV_w + dV_f$ .... (vi)

OR

$d(HCPV) = (C_w V_w + C_f V_f)$ .... (vii)

where;

V_f (total pore volume) = HCPV / $((1 - S_{wc})$

V_w (connate water volume) = V_f x S_{wc} = (HCPV) S_{wc} / $(1-S_{wc})$

The total HCPV is $(1 + m)NB_{oi}$, then the HCPV reduction can be expressed as;

$d(HCPV) = (1 + m)NB_{oi} \frac{C_w S_w}{1 - S_{wc}} + (C_f)\,\Delta P$

d) Underground Withdrawal

This is the observed surface production during the pressure drop occurring in the reservoir and the equation is expressed as below:

$N_p\,[B_o + (R_p - R_s)]\,B_g + W_p B_o$ (rb)............... (ix)

Equating underground withdrawal = Expansion of primary gas cap + Expansion oil + originally dissolved gas + Expansion of connate water + Decrease in pore volume.

$N_p\,[B_o + (R_p - R_s)]\,B_g = NB_{oi}\{[(B_o - B_{oi}) + (R_{si} - R_s)\,B_g] / B_{oi} + m(B_g B_{gi} - 1) + (1+ m)\,[(C_w S_{wc} + C_f) / (1 - S_{wc})]\,\Delta P\} + (W_e - W_p)\,B_w$ ....(x)

Material Balance Expressed as a Linear Equation

$F = N_p\,[B_o + (R_p - R_s)]\,B_g + W_p B_w$ ....(production) .... (xi)

$E_o = (B_o - B_{oi}) + (R_{si} - R_s)\,B_g$ .... (oil gas expansion) ....(xii)

$E_g = (B_g / B_{gi} - 1)\,B_{oi}$................ (free gas expansion) .... (xiii)

$E_{fw} = B_{oi}\,(C_w S_{wc} + C_f)\,\Delta P / (1 - S_{wc})$ …... (connate water of rock) .... (xiv)

Furthermore, equating and simplifying the equations together, the equation becomes:

F = N (E_o+ mE_g + (1 + m) E_{fw}] + W_eB_w.............(xv)

3.6 Analysis of Various Drive Mechanism Using MBE

If none of the terms in the material balance equation can be neglected, then the reservoir can be described as having a combination drive in which all possible sources of energy contribute a significant part in producing the reservoir fluids and determining the primary recovery factor. In many cases, however, reservoirs can be singled out as having predominantly one main type of drive mechanism in compares to which all other mechanisms have a negligible effect. The following are the various reservoir drive mechanisms;

a. Solution gas drive
b. Gas cap drive
c. Natural water drive
d. Compaction drive

The individual drive mechanisms can be investigated in terms of:

a. Determining the main producing characteristics, the producing gas oil ratio and water cut
b. Determining the pressure decline in the reservoir
c. Estimating the primary recovery factor
d. Investigating the possibilities of increasing the primary recovery

Solution Gas Drive

A solution gas drive reservoir is one in which the principal drive mechanism is the expansion of the oil and its originally dissolved gas. The increase in fluid volumes during the process is equivalent to the production. It comprises of two phases which are:

When the reservoir oil is under-saturated and when the pressure has fallen below bubble point and a free gas phase exist in the reservoir

Above bubble point pressure (under-saturated oil): For a solution drive, it is assumed that the initial gas-cap is not present so m=0, the aquifer is relatively small in volume and the water influx is negligible.

N_pB_o = NB_{oi} [B_o- B_{oi} / B_{oi} + [$(C_wS_{wc} + C_f)$ / $((1 - S_{wc})$] ΔP ....(xvi)

Below bubble point pressure (saturated oil): Below the bubble point pressure gas will be liberated saturated oil and a free gas saturation will develop in the reservoir. There is absence of gas cap. m = 0, water influx is negligible and N_pB_o = NB_{oi} [$(C_wS_{wc} + C_f)$ / $((1 - S_{wc})$] ΔP is also negligible once a free gas saturation develops in the reservoir.

The material balance equation is:

N_p [B_o $(R_p$-$R_s)$ B_g] = N [(B_o - B_{oi}) + (R_{si} - R_s) B_g ....(xvii)

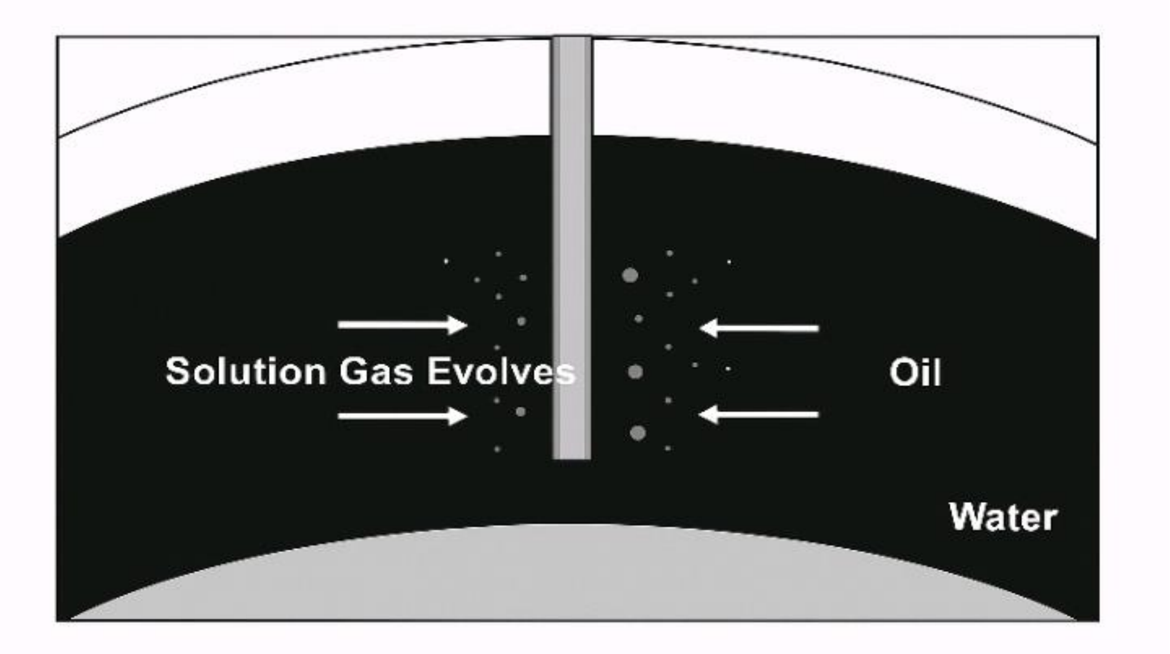


Figure 3. 5:Pictorial Description of Solution Gas Drive Mechanism.

Gas-Cap Drive

In the gas-cap under initial condition, the oil in the gas oil contact must be saturated or at bubble point pressure. The oil further down dip becomes progressively less saturated at the higher pressure and temperature. For a reservoir in which gas-cap drive is the predominant mechanism it is still assumed that the natural water influx is negligible (We =0) and, in the presence of so much high compressibility gas, that the effect of water and pore compressibility is also negligible. Under these circumstances, the material balance equation can be written as:

$N_p\ (B_o\ (R_p - R_s)\ B_g) = N\ [(B_o - B_{oi}) + (R_{si} - R_s)\ {}^{B_g}\!/_{B_{oi}} + m\ ({}^{B_g}\!/_{B_{gi}} - 1)]$ ....(xviii)

because of the gas cap expansion, the pressure decline is less severe than that of the solution gas drive reservoir and the oil recovery is greater.

Natural Water Drive

A drop in reservoir pressure due to the production of fluids causes the aquifer water to expand and flow into the reservoir. Applying the compressibility definition to the aquifer then

Water influx = Aquifer compressibility × Initial volume × Pressure drop or

$W_e = (C_w + C_f)\ W_i \Delta P$ .... (xix)

In the total aquifer compressibility is the direct sum of the water and pore compressibility since the pore space is entirely saturated with water. The sum of C_w andC_f is usually very small, say 10^{-5}/psi, therefore, unless the volume of water **w**, is very large the influx into the reservoir will be relatively small and its influence as a drive mechanism will be negligible. If the aquifer is large, however, equation will be inadequate to describe the water influx. This is because the equation implies that the pressure drop Δp, which is in fact the pressure drop at the reservoir boundary is instantaneously transmitted throughout the aquifer. This will be a reasonable assumption only if the dimensions of the aquifer are of the same order of magnitude as the reservoir itself. For every large aquifer there will be a time lag between the pressure change in the reservoir and the full response of the aquifer. In this respect natural water drive is time dependent. If the reservoir fluids are produced too quickly, the aquifer will never have a chance to catch up" and therefore the water influx, and hence the degree of pressure maintenance, will be smaller than if the reservoir were produced at a lower rate.

Compaction Drive

The withdrawal of liquid or gas from a reservoir results in a reduction in the fluid pressure and an increase in the effective or grain pressure. The increased pressure between the grains will cause the reservoir to compact and this in turn can lead to subsidence at the surface.

Compaction drive is the expulsion of reservoir fluids due to dynamic reduction of the pore volume and will only be significant as a drive mechanism if the pore compressibility C_f is large.

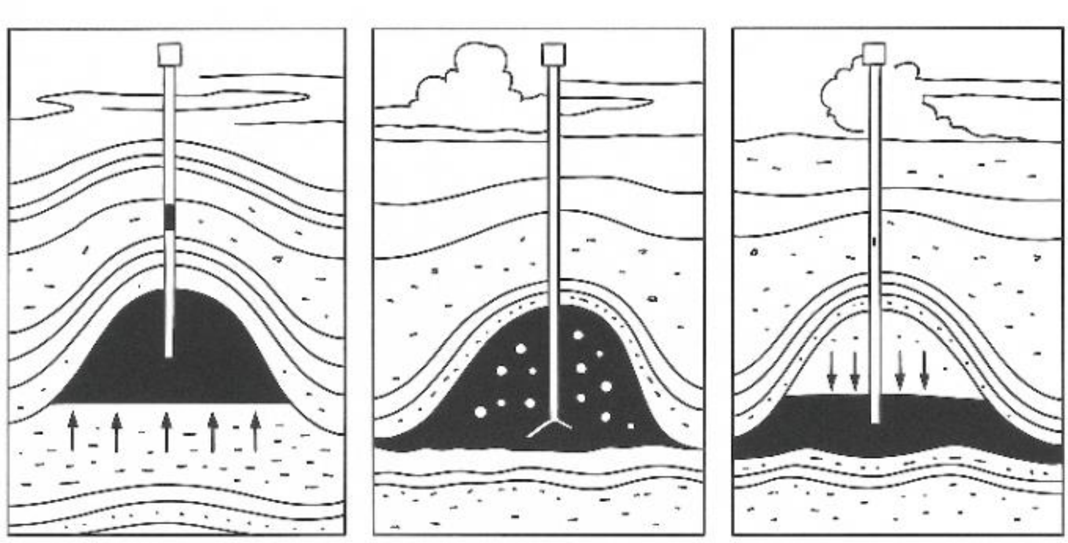


Figure 3. 6: Pictorial Description of Compaction Drive Mechanism.

3.5 **Reservoir Drive Indices Evaluation**

Pirson arranged the material balance equation as to obtain three fractions; whose sum is one which is called the depletion drive index (DDI), the segregation gas cap index (SDI) and the water drive index (WDI), Compaction Drive Index (CDI) and sometime injection drive (IDI).

Reservoir Drive Mechanism

$= \frac{\text{Individual Production Contribution}}{\text{Total Underground HC Production}}$ ....(xx)

Depletion Drive Index (DDI) = $\frac{N[(B_o - B_{oi}) + (R_{si} - R_s)B_g]}{N_p[B_o + (R_p - R_s)B_g]}$ ....(xxi)

Gas-cap Drive Index (SDI)

$= \frac{mNB_{oi}\frac{B_g}{B_{gi}} - 1}{N_p[B_o + (R_p - R_s)B_g]}$ ....(xxii)

Compaction Drive Index (CDRI)

$$= \frac{(1+m)NB_{oi}\frac{c_w S_w + c_f}{(1-S_{wc})}}{N_p[B_o + (R_p - R_s)B_g]} \text{ ....(xxiii)}$$

Water Drive Index (WDI)

$$= \frac{(W_e - W_p)B_w}{N_p[B_o + (R_p - R_s)B_g]} \text{ .... (xxiv)}$$

Injection Drive Index (IDI)

$$= \frac{W_i B_w + G_i B_g}{N_p[B_o + (R_p - R_s)B_g]} \text{ ....(xxv)}$$

DDI + SDI + CRDI + WDI + IDI = 1 ....(xxvi)

CHAPTER FOUR

DATA PRESENTATION, RESULT AND DISCUSSION

4.1 Data Presentation

In this chapter, the information of the field is presented, the field properties data, the production data, the relative permeability data and the reservoir data. The results are further presented for analysis.

Table 4. 6: PVT Data for the field.

Separator	Single Tank
Formation GOR (scf/stb)	800
Oil Gravity (API)	35
Gas Gravity	0.78
Water Salinity	80,000
Mole Percent of H_2S	0
Mole Percent of CO_2	0
Mole Percent of NO_2	0

Table 4. 7: Tank Parameter.

Tank Type	Oil
Temperature (F)	250
Initial Pressure (psig)	5215
Porosity	0.23
Connate Water Saturation	0.15
Initial Gas Cap	0
Original Oil in Place (MMSTB)	250.258
Start of Production	2/1/2000

Table 4. 8: Water Influx Data.

Model	Hurst-Van Everdingen Model
System	Radial Aquifer
Reservoir Thickness (Ft.)	100
Reservoir Radius (Ft.)	2844.09
Outer/Inner Radius Ratio (Ft.)	6.70973
Encroachment Angle (Deg)	151.402
Aquifer Permeability (md)	54.7773

Table 4. 9:Relative Permeability Data.

Relative Permeability	Residual Saturation	Endpoint	Exponential
K_{rw}	0.15	0.9	1.23
K_{ro}	0.15	0.3	3.5
K_{rg}	0.05	0.7	2

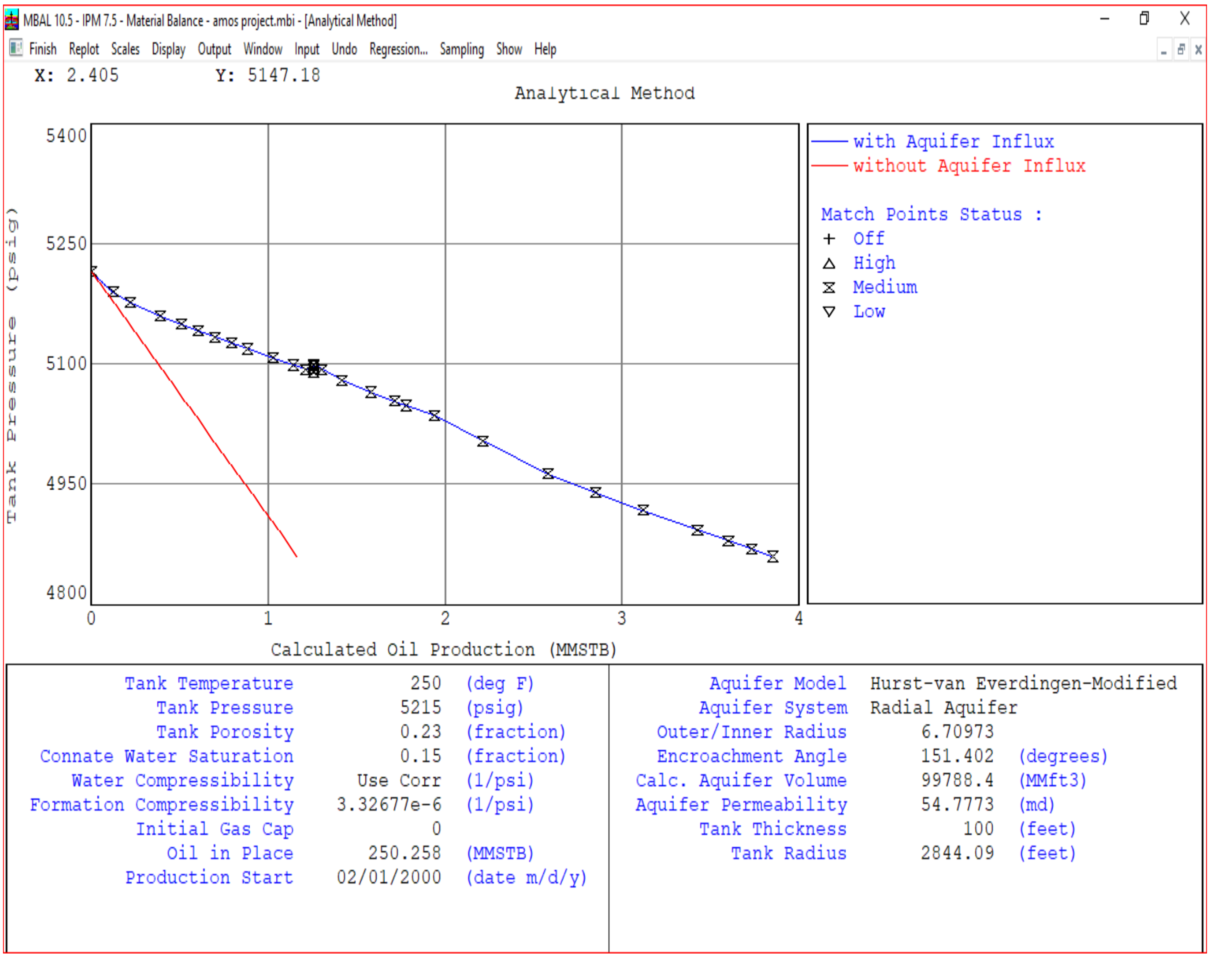
Table 4. 10: The PVT lab report of the reservoir fluid under study

Temp	Press (Psia)	Pb	Rs (Scf/STB)	Oil FVF (bbl/STB)	Gas FVF
250	3600	3600	800	1.456	0.31

The production data of the field can be gotten from Table 1. in the appendix.

4.2 Result

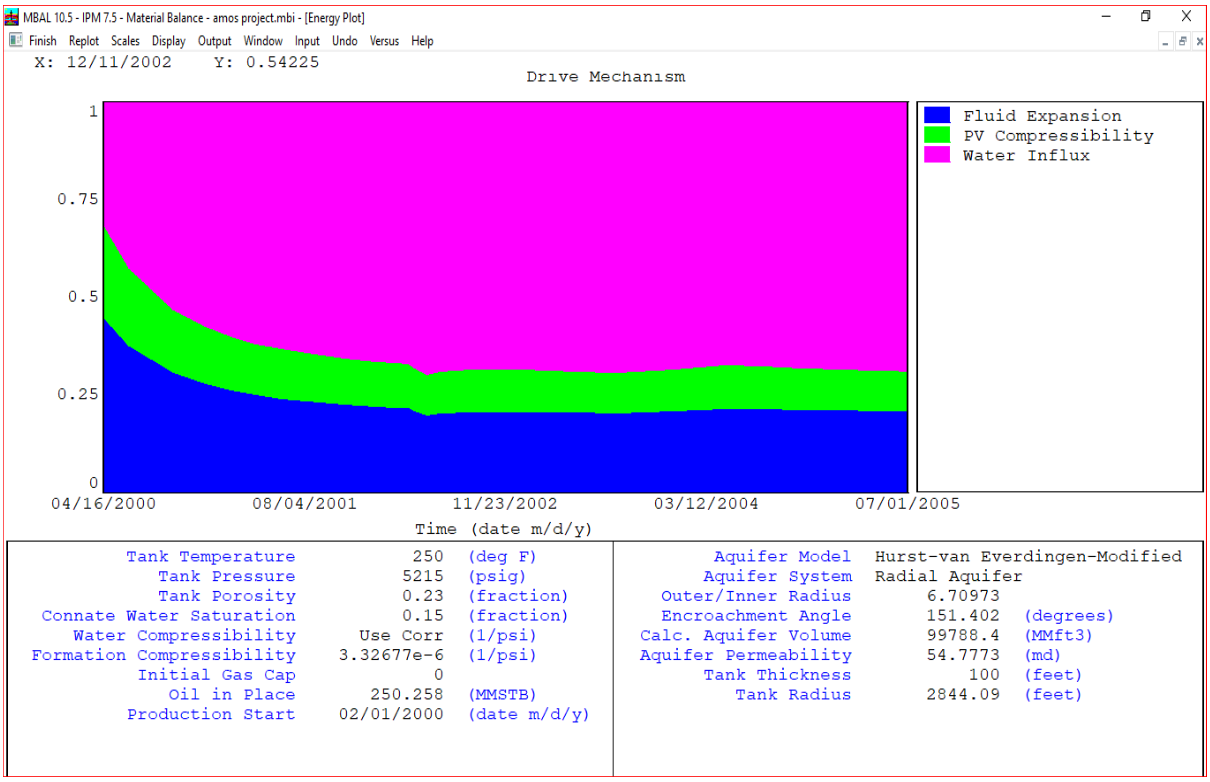
Material balance analysis has been carried out on the field and the objectivity of the project which was to estimate the initial oil in place, predict the future reservoir performance and the determination of the drive mechanism have been met and the result would be shown subsequently.



Tank Temperature	250	(deg F)
Tank Pressure	5215	(psig)
Tank Porosity	0.23	(fraction)
Connate Water Saturation	0.15	(fraction)
Water Compressibility	Use Corr	(1/psi)
Formation Compressibility	3.32677e-6	(1/psi)
Initial Gas Cap	0	
Oil in Place	250.258	(MMSTB)
Production Start	02/01/2000	(date m/d/y)

Aquifer Model	Hurst-van Everdingen-Modified	
Aquifer System	Radial Aquifer	
Outer/Inner Radius	6.70973	
Encroachment Angle	151.402	(degrees)
Calc. Aquifer Volume	99788.4	(MMft3)
Aquifer Permeability	54.7773	(md)
Tank Thickness	100	(feet)
Tank Radius	2844.09	(feet)

Figure 4. 8: Analytical Plot.



X: 12/11/2002 Y: 0.54225

Tank Temperature	250	(deg F)
Tank Pressure	5215	(psig)
Tank Porosity	0.23	(fraction)
Connate Water Saturation	0.15	(fraction)
Water Compressibility	Use Corr	(1/psi)
Formation Compressibility	3.32677e-6	(1/psi)
Initial Gas Cap	0	
Oil in Place	250.258	(MMSTB)
Production Start	02/01/2000	(date m/d/y)

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Calc. Aquifer Volume	99788.4	(MMft3)
Aquifer Permeability	54.7773	(md)
Tank Thickness	100	(feet)
Tank Radius	2844.09	(feet)

Figure 4. 9: Energy Plot.

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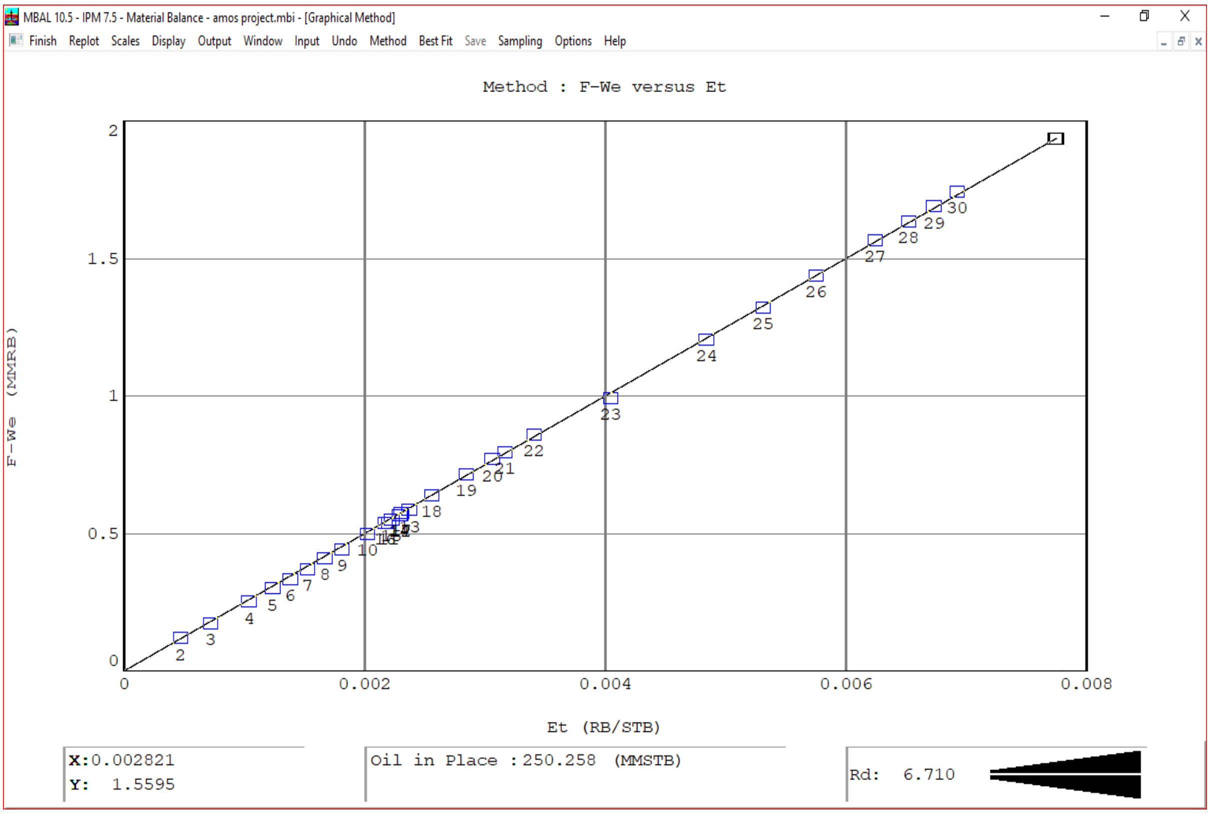
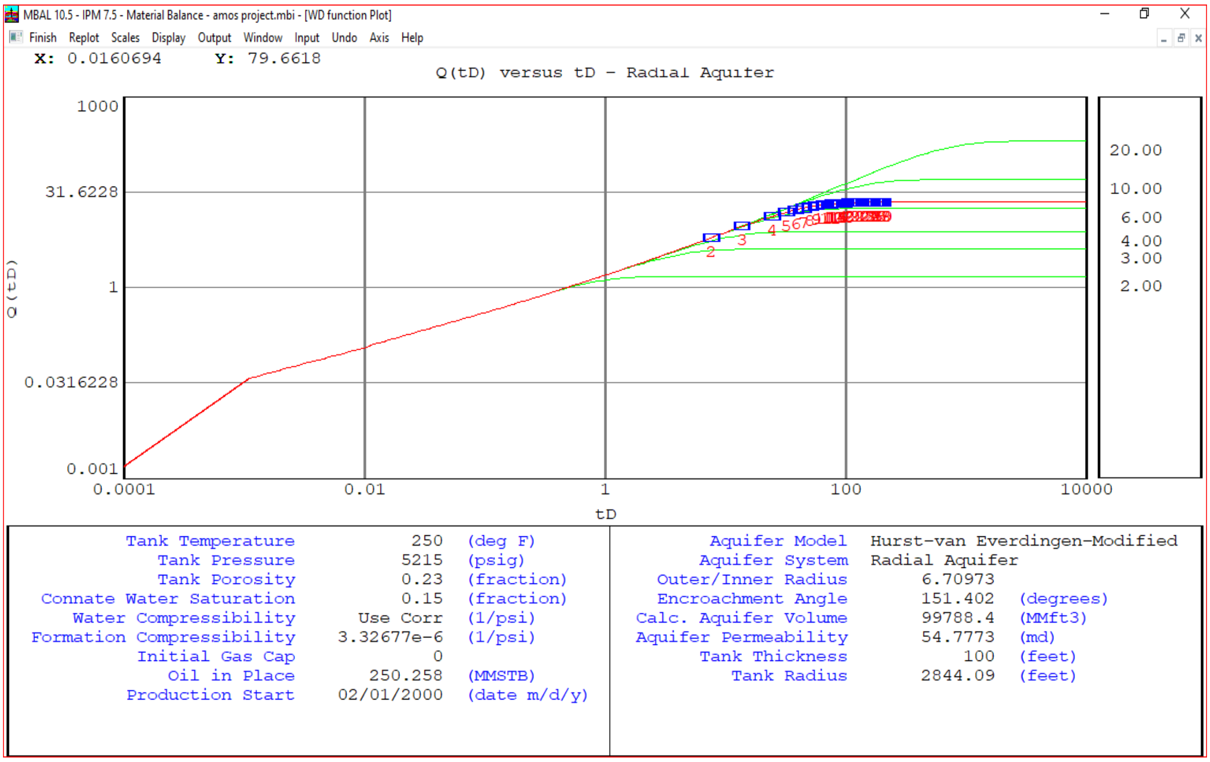


X:0.002821
Y: 1.5595

Oil in Place : 250.258 (MMSTB)

Rd: 6.710

Figure 4. 10: Graphical Plot.



Tank Temperature	250	(deg F)
Tank Pressure	5215	(psig)
Tank Porosity	0.23	(fraction)
Connate Water Saturation	0.15	(fraction)
Water Compressibility	Use Corr	(1/psi)
Formation Compressibility	3.32677e-6	(1/psi)
Initial Gas Cap	0	
Oil in Place	250.258	(MMSTB)
Production Start	02/01/2000	(date m/d/y)

Aquifer Model	Hurst-van Everdingen-Modified	
Aquifer System	Radial Aquifer	
Outer/Inner Radius	6.70973	
Encroachment Angle	151.402	(degrees)
Calc. Aquifer Volume	99788.4	(MMft3)
Aquifer Permeability	54.7773	(md)
Tank Thickness	100	(feet)
Tank Radius	2844.09	(feet)

Figure 4. 11: Aquifer Plot.

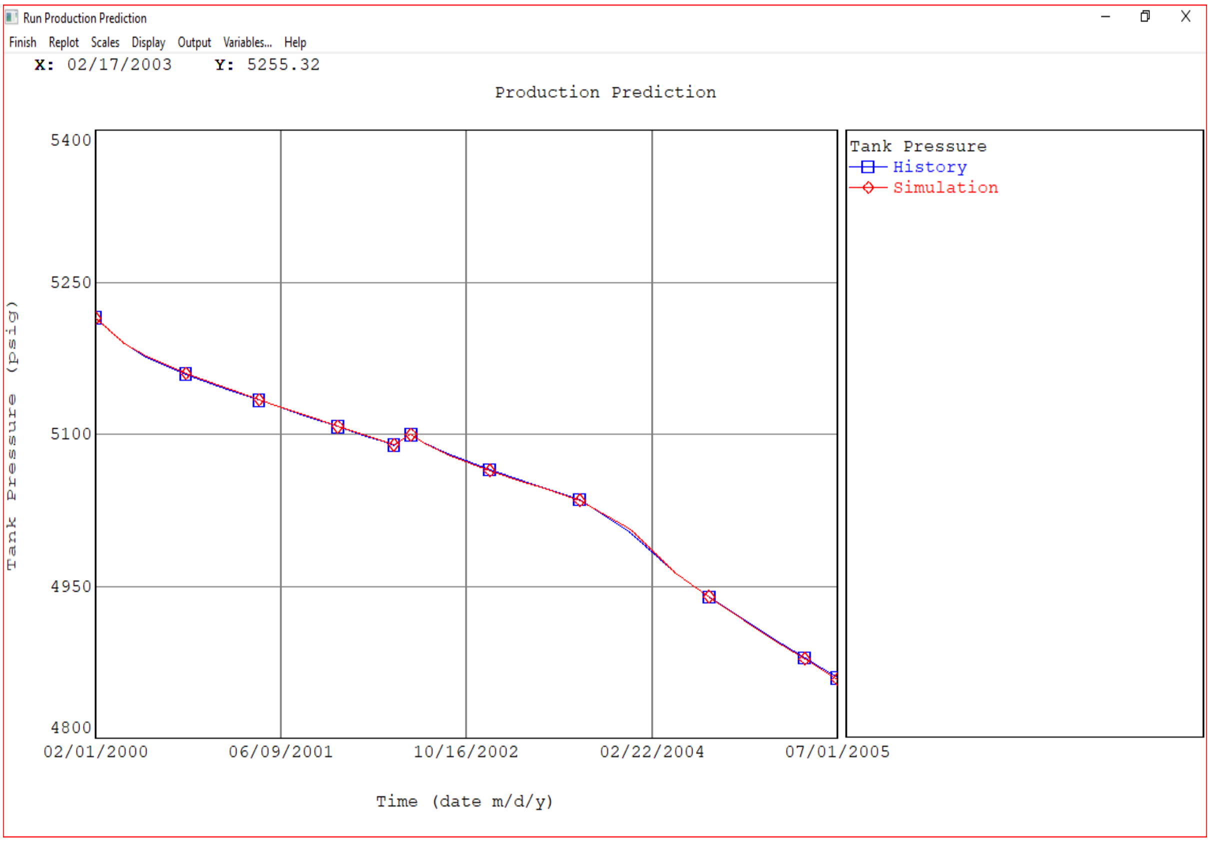


Figure 4. 12: Simulated production history Vs actual production history plot

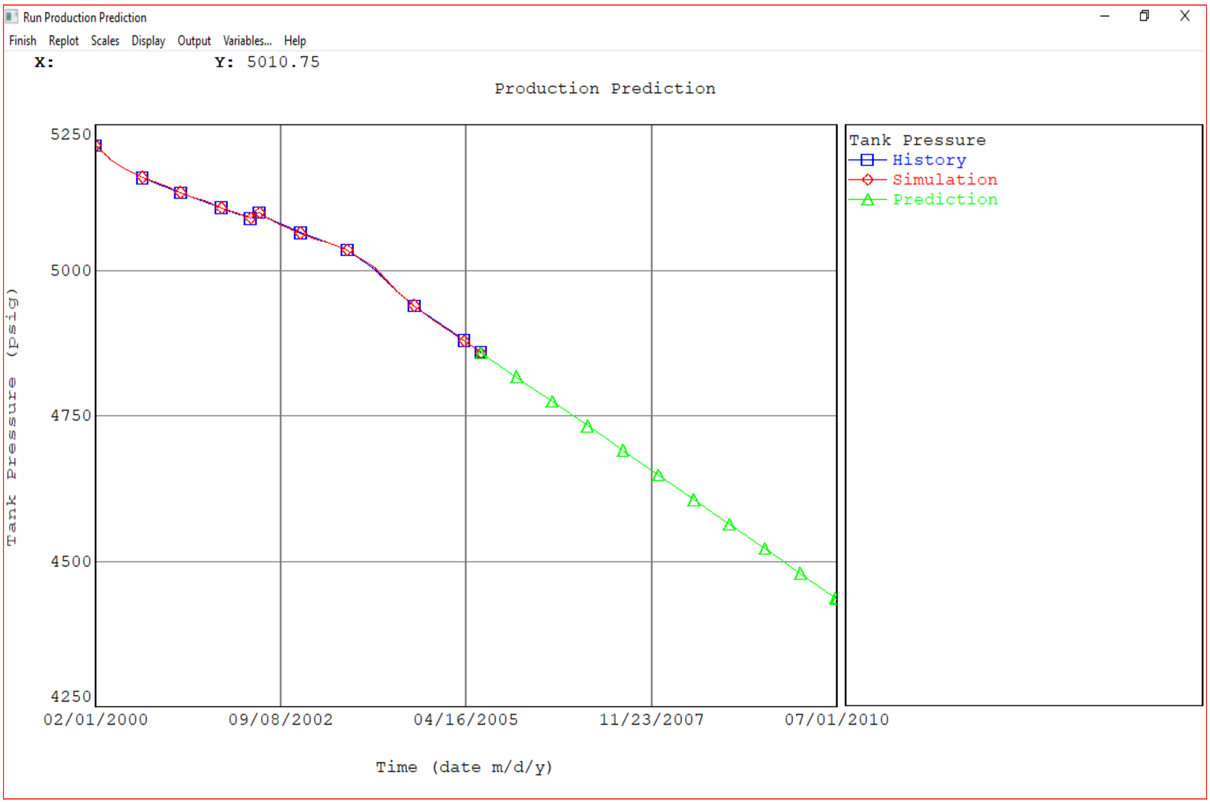


Figure 4. 13: Pressure drop prediction after 5 years (Green line)

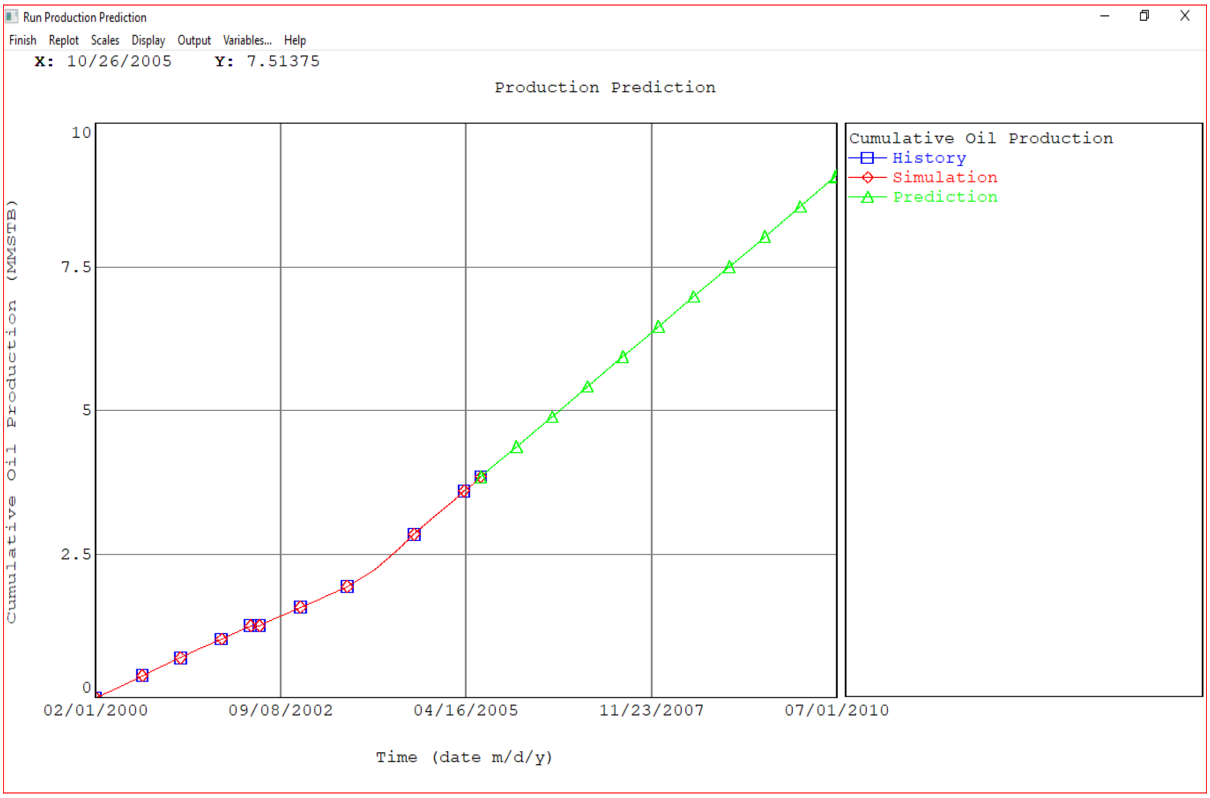


Figure 4. 14: Expected cumulative oil production after 5 years

4.3 Discussion

The Hurst-Van Everdingen was selected as the most likely case for the reservoir. The parameters used to obtain the history match and STOIIP from Hurst-Van Everdingen radial aquifer compare favorably with the expected values. The Inferences from the Material Balance analysis are as follows:

i. The stock thank oil initial in place (STOIIP) was predicted by MBAL Software to be 250.258 MMSTB as shown in fig 4.2. From the graph it can be seen that the STOIIP is constant at 250.258 MMSTB, with an aquifer present in the reservoir with the aquifer system being a radial aquifer.

ii. Fig 4.4 shows the WD function plot which shows the dimensionless aquifer function versus the dimensionless time curves. This point also indicates the location of the history data points in dimensionless co-ordinates.

iii. Fig 4.1 shows the analytical plot which shows the effect of the aquifer on the pressure of the reservoir. From the graph, the aquifer volume was predicted to be 99788.4 MMft^3.

iv. Fig 4.2 shows the energy plot which shows the various energy contributors present in the reservoir with the energy contributors being fluid expansion, PV compressibility and water influx. The predominant drive mechanism from the graph is seen to be water drive with the rest being secondary.

v. Fig 4.5 shows the plot of simulated production and actual production history match

vi. Fig 4.6 shows the Pressure drop prediction after 5 years (Green line). This plot shows that after a period of five years, the reservoir pressure is expected to drop to 4420.1 psia if we maintain production as the last rate

vii. Fig 4.7 shows the expected cumulative oil production after 5 years.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the analysis carried out on the field using the MBAL software, it can be drawn that the Hurst-Van Everdingen model was selected as the most likely case for the reservoir reason being that the parameters used to obtain the history match and STOIIP from Hurst-Van Everdingen radial aquifer compare favorably with the expected values. It is also seen that the reservoir supports water drive and the use of the MBAL software would save a reasonable amount of time in evaluating the reservoir before a more compositional approach is used to study the reservoir.

The material balance model is effective at history matching the production performance but has substantial drawbacks when it comes to field predictions. One of the limitations of the MBAL tool is that it cannot be used for the estimation of trapped gas. The reason is that the MBAL tool is not able to deal with the task, in other words, it is out of the MBAL's scope.

5.2 Recommendations

From this case study used, the management should bear in mind that any recovery operation rather than the primary recovery process at the early stage of the reservoir is unnecessary and not economically feasible.

Further study should be conducted on the reservoir in reasonable time before abandonment so as to develop an economically viable production schemes (probably water injection) to reduce the residual oil.

I recommend the use of other simulation tool like Eclipse to carry out further studies on reservoir due to the limitation of MBAL as stated in this project. In addition, students should be informed on project at the fourth (4) year of their program, in order to prevent constrains in doing effective research work with the available time.

Contribution to Knowledge

In the process of conducting this research, the following contributions were recorded:

Full history matching was performed to validate the reservoir behaviors, identify the dominant water drive mechanism, and evaluate aquifer effect, which lingered into predicting future pressure decline.

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APPENDIX

Table 2: Production Data of the Field.

Time	Pressure (Psia)	Cum. Oil (mmstb)	Cum. Gas (mmscf)	Cum. Water (mmstb)
2/1/2000	5215.0	0	0	0
4/16/2000	5189.6	0.1215	97.2268	0.000022
6/15/2000	5176.5	0.2181	174.4480	0.000102
9/28/2000	5159.4	0.3859	308.6930	0.000422
12/12/2000	5149.1	0.5050	403.9860	0.000804
2/10/2001	5141.3	0.5999	479.8880	0.001204
4/11/2001	5133.7	0.6944	555.5030	0.001689
6/10/2001	5126.2	0.7885	630.8350	0.002258
8/9/2001	5118.7	0.8824	705.8880	0.002911
11/7/2001	5107.7	1.0224	817.9460	0.004045
1/21/2002	5098.5	1.1386	910.8550	0.005132
3/7/2002	5093.1	1.2080	966.3940	0.005844
4/6/2002	5089.4	1.2542	1003.3400	0.006344
4/21/2002	5093.7	1.2542	1003.3400	0.0063441
5/6/2002	5097.1	1.2542	1003.3400	0.0063441
5/21/2002	5099.9	1.2542	1003.3400	0.0063441
6/20/2002	5092.9	1.3004	1040.3100	0.00688304
9/3/2002	5079.8	1.4154	1132.3400	0.00829563
12/17/2002	5065.0	1.5754	1260.3600	0.0104555
3/17/2003	5053.7	1.7117	1369.3900	0.0124862
5/1/2003	5048.2	1.7796	1423.6700	0.0135643
8/14/2003	5035.7	1.9372	1549.7600	0.0162417
12/27/2003	5003.2	2.2109	1768.7100	0.021429
4/25/2004	4963.0	2.5773	2061.8600	0.029275
7/24/2004	4939.3	2.8481	2278.4400	0.0358439
10/22/2004	4917.5	3.1156	2492.5000	0.0430237
2/4/2005	4893.1	3.4240	2739.2200	0.0521613
4/5/2005	4879.4	3.5985	2878.7700	0.0577414
5/20/2005	4869.2	3.7285	2982.7600	0.0620932
7/1/2005	4859.8	3.8491	3079.3100	0.0662827