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# Production Optimization of Beani Bazar Gas Field of Bangladesh Through Simulation Run

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**MASTER'S THESIS**

# "PRODUCTION OPTIMIZATION OF BEANI BAZAR GAS FIELD IN BANGLADESH THROUGH SIMULATION RUN"

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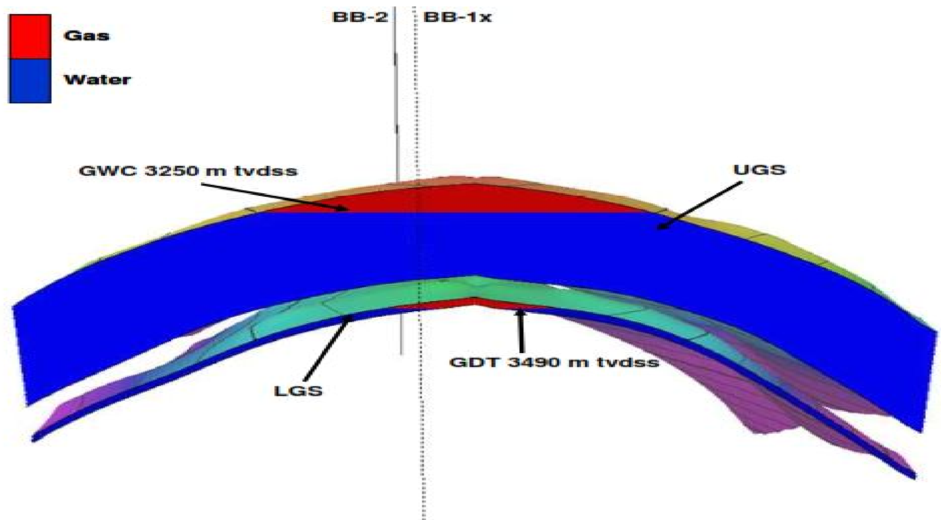
# MASTER'S THESIS

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**DEPARTMENT OF PETROLEUM ENGINEERING AND APPLIED GEOPHYSICS**

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# ABSTRACT

This paper presents the production optimization of Beani Bazar gas field in Bangladesh through simulation run. Beani Bazar gas field is one of the four gas fields of Sylhet Gas Fields Limited (SGFL), a company of Bangladesh Oil, Gas and Mineral Corporation (Petrobangla). The field is governed under the Ministry of Energy, Bangladesh. This is one of the condensate rich gas fields in Bangladesh. From the previous reports, it was observed that the total proven gas reserve of this field is 230.8 Bcf. The total gas produced till December, 2011 was 75.65 Bcf. That is one-third reserve had already been finished. The remaining reserve of 155.15 Bcf of gas is required to recover from the wells by predicting the present well and reservoir performance for a certain time based on the current production data. This is why the task was liked by me when the authority proposed me.

Beani Bazar gas field has two wells namely BB-1 and BB-2. Also, the wells encountered two gas sands named as Upper Gas Sand (UGS) and Lower Gas Sand (LGS) from depths 3230 - 3278m and 3451 - 3465m respectively. Both sands flowed gas during drill-stem testing. The upper zone produced gas as well as condensate at a rate ranging of 16 - 19 bbl/MMscf. For the Lower Gas Sand, the condensate rate was 14 - 16 bbl/MMscf. The well BB-1 was completed as a selective dual producer. For the gas demand of the country, BB-1 started production since 12th May 1999. The other well BB-2 produced gas since January, 2002. The gas produced from these wells is being supplied to the power plants, industries, tea estates and houses through N/S pipe line whereas the condensate is being sold to the marketing companies of the country after it is fractioned into petrol and diesel.

The grid dimensions of the geological model in this study was 50 x 75 x 62 to represent the main horizons encountered in the field with layers 1-20 for the upper gas sand and layers 57-62 for the lower gas sand. The parameters used in this study

had been mostly taken from the report “Simulation Study of Beani Bazar Gas Field” by RPS Energy, U.K, 2009 which were mostly assumed parameters. But the field production rates in different stages were more practical. Parameters such as absolute permeability, porosity, initial water saturation, residual gas saturations were assumed and corresponding relative permeability and capillary pressures were made for the simulation of Beani Bazar gas field by RPS Energy. These were kept the same in the thesis study.

Using all these geological and latest production data, a dynamic simulation model was developed for Beani Bazar gas field. Twenty years of gas, water and liquid rate and pressure history were matched with the simulated rate and pressure data to examine the accuracy of the simulation model. Input of Vertical Flow Performance (VFP) for well BB-1 and BB-2, change of aquifer angle, change of transmissibility etc. improved the history matching. The simulation model which yields the best history matching can be said the representative of the actual field. The simulation model was then run to forecast the future field performance and find out an optimal development plan for the field and to determine the reserve estimation.

The field is produced by water drive. A huge amount of water is produced from both sand zones. But fortunately, the tubing pressure is still above the 2500 psig. An aquifer is considered to control the pressure fluctuation and quick gas production. The water limit was used while simulation was run. For all cases, gas production rate in simulation was considered equivalent to actual field production rate to compare the results of other parameters like well bottom hole pressure, water production rate and water-gas ratio. The sensitivity of gas production rate showed excellent recovery results. Therefore, the change in the flow rate affects the performance of the wells a bit.

To compare the different recoveries for the remaining reserves of the field, simulation run was made by considering the drilling of one well BB-3 in upper gas sand in the southern flank of the reservoir and BB-4 in upper gas sand in the western flank of the reservoir. It was observed that the maximum gas recovery was found when two new wells BB-3 and BB-4 were proposed for different cases. The optimum gas recovery found between the periods of 15 years to 20 years. These cases were considered the best cases here. The squeezing of completion interval or perforation depth for both upper and lower sand groups were also the factors to optimize the production.  The simulation results showed that a remarkable gas recovery was obtained when we considered the squeezing of perforation depth in upper and lower gas sand plus change in the gas flow rate.

Simulation results showed that the remaining production life of this field lies between 15 to 25 years for different cases. The ultimate recovery is very high in drilling wells but it involves a lot of cost. But there is no way out. By decreasing the limitations of bottom hole pressure, the remaining production life of the field can also be increased. Therefore, the final recommendation for future work on Beani Bazar simulation model is that the water rise must be controlled. It can be done by drilling a new well in the present reservoir a few km away from the existing wells. The quick gas production can bring huge water which should be handled by re-installing the plant infra-structure.

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I acknowledge my heartfelt gratitude to the Chairman of Petrobangla, Dhaka, Bangladesh to give me the permission to use the necessary data of Beani Bazar gas field.

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Finally, I would like to extend my thanks to all staffs of Reservoir and Data Management Division, Petrobangla, Dhaka, Bangladesh for their loyal support in conducting the different tasks associated with this thesis work.

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# DEDICATION

My great thanks go to my respected parents, brothers, sisters and my wife for their moral support during the course of my entire master program. I love all very much. May Almighty bless all.

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# CHAPTER 1

## INTRODUCTION

## 1.1 OBJECTIVE

The main objective of this thesis is to optimize the production of Beani Bazar gas field in Bangladesh through simulation. To perform this thesis work, a reservoir simulator has been used to model the reservoir fluid systems by using the physical properties of the reservoir fluid (black oil). The "black oil" approach is normally used for reservoir fluids which have low shrinkage and where the compositional changes are constant over the life of the reservoir. The gas reservoirs which have gas and condensate are usually simulated by using the physical properties of the gas. The thesis work consists of two parts - theory and technical. The theory contains an insight into reservoir simulation, general field information, geological study, reservoir study, literature review and other relevant theories. The technical part consists of the following steps:

i. Collection of required data of Beani Bazar gas field from Petrobangla.
ii. Review of previous works on reservoir studies by different companies.
iii. Review of static model (PETREL geo-model) by RPS Energy.
iv. Construction of dynamic model based on the latest production data.
v. History matching of observed behavior.
vi. Prediction of future field performance to find out an optimal development plan for the field.
vii. Review of previous works on GIIP estimation and re-estimate it by simulation.

## 1.2 RESERVOIR SIMULATION

### 1.2.1 SIMULATION

Reservoir simulation is a commonly used tool in the gas and oil field development. It helps engineers to simulate their recovery techniques before implementing them on the original field. It is multi-disciplinary and incorporates effort from geophysics, petro physics, reservoir, production and facilities engineering.

Basically, simulation is a computer programming which allows the users to divide the entire reservoir into discrete grid blocks. Each grid block is represented by different reservoir properties. The principle of mass conservation and Darcy's law are used for the flow of fluids from block to block. Large sets of second order differential equations for the simultaneous flow of oil, gas and water in three dimensions can easily be solved by the simulators. The effects of water influx, fluid compressibility, mass transfer between the gas and liquid phases and variation of porosity and permeability as a function of pressure are modeled. The differential equations themselves are generally formulated using the finite difference analogue for first and second order differentials and solved simultaneously using numerical techniques with some acceptable, small error attached to each solution. In brief, the reservoir simulation is the sets of grid block averaged data concentrated at each node and since these are the discrete points in space, it has the effect of reducing the flow description to one dimension.

To solve the complex reservoir problems, engineers must resort to the numerical simulation methods and displacement process which determines the aerial distribution of fluids in the reservoir resulting from flooding. For this reason, to find out the recovery of gas for different predictive cases on the basis of latest production data, simulation is used.

### 1.2.2 GEOLOGICAL MODEL

Geological model is a static numerical representation of a gas or oil reservoir. It supplies the seismic structural interpretations and well petrophysical data in a numerically consistent way along with known depositional characteristics. Petrophysical properties such as porosity, permeability, and water saturation are distributed throughout the inter-well 2D or 3D volume using various techniques, many of which rely on geostatistics.

### 1.2.3 SIMULATION MODEL

The geological model is used as input for the simulation model. Required production data, completion data, vertical flow performance of the wells, perforation data etc are initialized for the dynamic reservoir model. The model is run to get the production rate and pressure history matching. This result then is used to find out the field reserve, forecast and optimize the production to augment the gas recovery which is vital for the field development

### 1.2.4 HISTORY MATCHING

After the completion of simulation model development, the validity of the model is checked by simulating under past operating conditions. If there is major difference between the simulated and observed well/reservoir performance, the adjustments to the simulation model are made in order to minimize the difference. The process is known as history matching.

History Matching involves making a number of runs off the initialized model to attempt to match historical performance of the reservoir/s and performance data of individual wells. For oil wells, oil rates are normally specified and reservoir pressure, GOR, and water-cut are computed and compared with measured data. Gas rates are normally entered for gas wells. Production periods should correspond to periods of time during which production rates changes are relatively minor. Matching is accomplished by altering reservoir or aquifer data which are the least reliable; permeability and relative permeability fall into this category. There are no formal standards for determining how closely measured data should be matched or exactly what constitutes a "good" history match.

The adjustments consist of adjusting model parameters that have the highest degree of uncertainty. The adjustments should be done in a geological consistent manner. Well productivity and flowing bottom hole pressure should also be closely matched. This is usually done on the later runs after reservoir adjustments have been made to match reservoir pressure, GOR, etc. If the simulator has the facility for simulating vertical flow, wellhead pressures can also be matched.

No history match is perfect nor unique and an acceptable match is often a function of time, budget, and quality of data.

## 1.2.5 PREDICTION OF WELLS/RESERVOIRS

Once a history match is obtained, predictions or forecasts of future well/reservoir performance under various operation schemes are made. Any number of production forecasts can be made from a file created during the final history match run. A greater number of possible development and forecast cases should be investigated. Examples are:

- Minimum water production limit
- Maximum water production limit
- Squeezing off of bottom perforations in various layers
- Drilling new wells on the present reservoir
- Infill wells on regular or irregular patterns
- Water injection using various well arrangements.
- Gas injection.
- Horizontal well bores.
- Combinations of two or more of the cases.
- Effect of start-up time for various recovery methods

Generally models of multiphase flow in the wellbore and production lines are used to constrain the production rate. These models may include subsea completions with very long gathering lines or complex surface facilities with reinjection of produced fluids. Because of the uncertainty in the geological and reservoir simulation models for new fields, often multiple forecasts with different reservoir parameters are made to determine the uncertainty in the forecasts. Multiple history matched models based on multiple geological models and experimental design may also be used to characterize the uncertainty in production forecast.

Data input files for making predictive runs or forecasts include:

- Well grid block locations
- Well specifications such as the layers to be open and well productivity
- Desired rates of production and injection
- Time periods, and criteria for opening, closing or re-completing of wells.

**WELL GRID BLOCK LOCATION**

Wells that were present during history matching need not be re-specified; new wells do. One of three different means of selecting new well locations can be applied. One method is to locate and "drill" wells according to some anticipated drilling schedule. Another is to select well locations bases on saturation and pressures at the end of history. A third method is to "test" a large number of locations by making a short run of perhaps only one day, review results and then select the best locations.

**WELL SPECIFICATIONS**

Information for new wells such as the layers open for production or injection, type of well (oil, gas, or water), well bore size and well productivity among other things need to be specified.

**PRODUCTION RATES**

Desired maximum and minimum production and injection rates as well as either minimum flowing bottom hole pressure or surface pressures must also be set out.

**WELL AND RESERVOIR SHUTIN LIMITS**

Minimum production rates and maximum GOR and WC limits are generally specified to set criteria for either closing in or re-completion of individual wells, closing of groups of wells or the reservoir.

**TIME PERIODS**

Time periods must also be specified. Oftentimes, one year periods are used. The total length of the forecast period also needs to be examined. Many forecasts are made for up to 10 or 20 years. Other times, the forecast is made to some predetermined field or reservoir economic limit. In this case, the run should be carried out past a time when this might be determined from an economic evaluation or a restart can be made to run for a few more years.

# CHAPTER 2

## BEANI BAZAR GAS FIELD

## 2.1 GENERAL FIELD INFORMATION

Beani Bazar gas field, an onshore gas field, is located near the town of Beani Bazar, Sylhet and some 220 km north-east of Dhaka, Bangladesh. It lies in the south eastern part of Surma Basin and in the western margin of Tripura High. This is one of the condensate rich fields in Bangladesh. The well Beanibazar-1 is located at $92^0$10′18″ N and $24^0$97′33″E and Beanibazar-2 is located at $92^0$10′9.99″ N and $24^0$ 48′ 24.99″E.

Beani Bazar field is an elongated anticline with a simple four way dip closure. On the surface, the structure is represented by low hills. The structural alignment is slightly north-south with asymmetrical east-west orientation and a deep plunging northern flank. The structure lies on the western margin of Chittagong-Tripura folded belt and in the south central part of Surma Basin. A narrow syncline to the east separates Beani Bazar structure from the huge Patharia anticlinal trend. Beani Bazar structure is bounded by Hakaluki syncline in the west, Latu syncline in the east, Hararganj feature to the south and Kushiara trough in the north-east.

## 2.2 DEVELOPMENT

Beani Bazar structure was first identified by Pakistan Shell Oil Company (PSOC) in early 1960s after recording a single-fold seismic survey on the shallow depth of 1750m corresponding to the R phantom horizon and was later defined 12 fold seismic survey in the frontal folded belt more precisely by a 1979-80 survey conducted by Prakla Seismos, a company of Federal Republic of Germany. This company conducted the acquisition data on Beani Bazar area that resulted in the structural delineation of the Beani Bazar anticline. The field was discovered by this company with drilling of Beani Bazar-1 under the project ''Multi-well Drilling Programme'' in 1980-81. But the field was not developed till April, 1999. The initial production started from this well from $12^{th}$ May, 1999. The field is governed by Sylhet Gas Fields Limited (SGFL), a company of Bangladesh Oil, Gas and Mineral Resources Corporation (Petrobangla) under the Ministry of Energy, Bangladesh since 1999.

There are two wells penetrating the Beani Bazar structure. These are named as BB-1 (BB-1x) and BB-2. The wells encountered two gas sands namely Upper Gas Sand (UGS) and Lower Gas Sand (LGS) from depths 3230 – 3278m and 3451 – 3465m respectively. Both sands flowed gas during drill-stem testing. The well BB-1 is a vertical well. It was drilled in lower gas sand in 1980-1981 by a German company, Prakla Seismos. It was perforated from 3452m to 3466m. The well was completed as a selective dual producer. Due to the increasing gas demand of the country, BB-1 started production since 12th May 1999. At present, the well is producing gas at a rate of 2000 Mscf/d and condensate at a rate of 17-19 bbl/MMscfd. On the other hand, Beani Bazar -2 (BB-2) is a deviated well. It was drilled in upper gas sand in 1988 under the Second Gas Development Project of Project Implementation Unit (PIU) of Petrobangla, Bangladesh. The perforation interval was from 3286m to 3297m, 3301m to 3303m and 3305m to 3310m respectively. Now, the well is producing gas at a rate of 12000 Mscf/d and condensate at a rate of 16 -17 bbl/MMscfd.

There are mainly two sand zones – upper and lower. BB-1 was completed in the lower sand whereas BB-2 was completed in the upper sand. These two sand groups are separated by a field-wide shale interval. The majority of the GIIP lies in the upper gas sand, with the lower gas sand contributing only a minor amount of the Gas Initially In place (GIIP). Initially the total gas production was 30,000 Mscf/d from both the wells. Due to increasing water production, the daily average production has dropped to 10,000 Mscf/d. The general tendency is an increase in water produced and this has been difficult to control. Probable causes could be water coning from an underlying aquifer in both the wells, which might need to be controlled or mitigated. Currently, about 9,400 Mscf/d gas is being produced from the two gas wells of this field. The produced gas is supplied to the North-South pipeline and the condensate (by-product of gas) is sold to the local marketing companies.

Beani Bazar gas field has already produced 75.65 Bcf gas till December, 2011 and on that month, the gas production rate from the field was 9,000 Mscf/d. In its

10-year producing life, the field seems to have a number of complexities, both reservoir and surface facility related. As per previous reservoir engineering reports, the proven Gas Initially In Place (GIIP) in 2011 was 163.5 Bcf and 67.3 Bcf respectively for the upper and lower gas sand. Total gas production from May 1999 to December, 2011 was 38.71 Bcf from the lower gas sand and 36.94 Bcf from the upper gas sand.

Thus, it is clear that after 10-12 year production history, 30% recoverable reserves has already been produced from this field. The current production data shows that the water-gas ratio has increased rapidly while the wellhead pressure lies in the range of 2400-2500 psig. Present interest is the remaining recoverable reserves. Hence, it is required to predict the performance of the reservoir for remaining reserves on the basis of latest production data. Also, in order to meet the gas demand of the country, it is needed to take some feasible development works in the gas field. That is why, it is important to re-estimate the reserves on the basis of latest production data.

## 2.3 LOCATION MAP

The location maps of Beani Bazar gas field are shown in figure-1 and figure-2:


**Figure 1: Location Map of Beani Bazar Field**

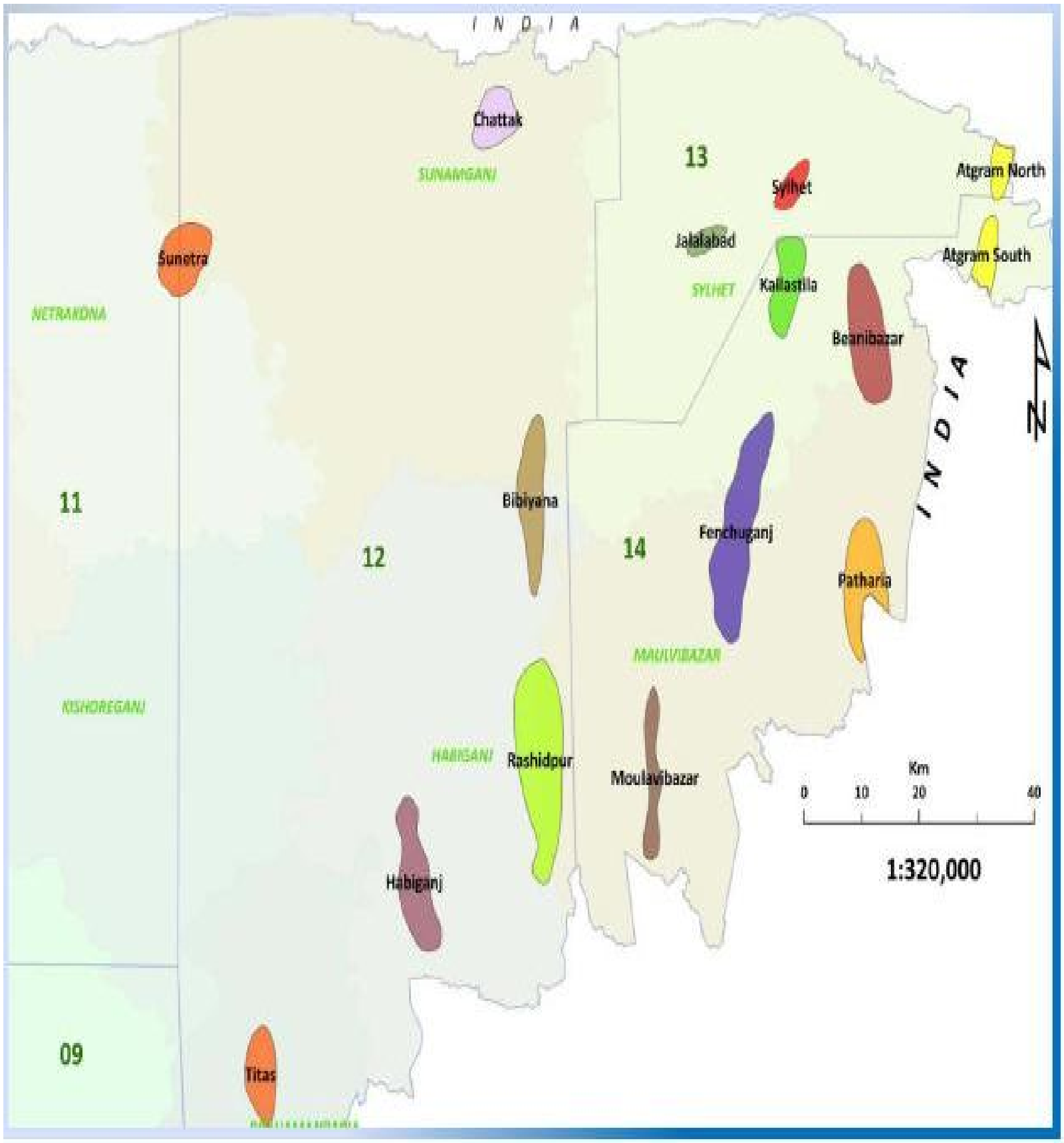


**Figure 2: Location Map of Beani Bazar Field with Structure**

## 2.4 GEOLOGICAL STUDY

### 2.4.1 GENERAL GEOLOGY

In relation to regional tectonic history, the Beani Bazar structure has developed in the fore deep located west and south of massive orogenic uplifts. It is a north-south trending elongated anticline with the axis on the north swinging gently towards the west like other structures in this Fold Belt. The Beani Bazar structure is considered to be quite young and formed during Late Pliocene – Early Pleistocene time.

The depositional environments of these fields was one of prolific, younger, Tertiary clastics accumulation along a mobile delta front, developing in a sinking basin, which effected the lower reaches of the continental slope. However, these main directions of sedimentary flow are not always reflected in the local thickness trends encountered in the Beani Bazar succession.

The sediments making up the reservoirs are composed of sandstone and shale and considered to have been deposited in the delta or delta front environment. These sediments were subjected to the later phases of the Himalayan / Arakan orogeny, resulting in the formation of the relatively gentle folds of the frontal folded belt

The stratigraphy of the Beani Bazar area is related to the stratigraphy of the Surma Basin and is based on lithological correlation with rocks in the Asam oil fields. The formations that have been reached by wells in the Surma Basin are the Dupi Tila, Tipam, Boka Bil and Bhuban. Sediments deposited in the later stages of the Indian Plate collision include the Upper Bhuban and Boka Bil units and are overlain by the Tipam and Dupi Tila. This stage is represented by sedimentation contemporaneous with the major phase of continental collision (Late Miocene – Recent), when the main uplift of the Himalayan and Indo-Burma ranges occurred. Deposition occurred in fluvial-deltaic to estuarine environments during the Miocene- Pliocene, accompanied by extensive channeling and sediment reworking.

### 2.4.2 **STRUCTURE**

Beani Bazar gas field is an elongated anticline with a simple four way dip closure. On the surface the structure is represented by low hills. The structural alignment is slightly North–South with asymmetrical East–West orientation and a deep plunging northern flank. The structure lies on the western margin of the Chittagong-Tripura folded belt in the south central part of the Surma Basin. It was first mapped by Shell in 1960 with a single fold seismic grid and was later defined more precisely by a 1979-80 survey conducted by Prakla Seismos. The first discovery well was only drilled in 1979/1980. The structural dip of the Beani Bazar closure is estimated to be about 7 degrees. A narrow syncline to the east separates the Beani Bazar structure from the huge Patharia anticlinal trend.

No faults were observed from the 2D seismic data over the Beani Bazar structure or its vicinity. This is probably due to the low resolution of the variable quality 2D seismic data and probably more faults can be expected to be seen in a higher resolution 3D seismic dataset.

### 2.4.3 **STRATIGRAPHY**

The sedimentary sequence encountered during the drilling of the Beani Bazar structure is listed below:

**ALLUVIUM**

This surface formation is entirely made up of loose sand.

**DUPI TILA (Plio-Pleistocene)**

This is composed of medium grained sandstone that is poorly consolidated, containing lignite and wood fragments.

**TIPAM GROUP**

The Tipam Group consists of the Girujan Clay and Tipam Sandstone. The Tipam Sandstone is the lower member of the Tipam Group and is predominately an arenaceous sequence with clay pebble beds at its base. It is characterized by highly cross-bedded, very coarse grained sands with pebbles, mica granules, and fossil wood as common constituents. The environment of deposition is fluvial. Although the Tipam Sandstone has excellent reservoir characteristics and is a producing interval in the Assam Valley of India, it is not productive anywhere In Bangladesh. This is probably due to the lack of a consistent regional seal.

**BOKABIL FORMATION (Middle – Late Miocene)**

This formation mainly consists of sandstones, shales and siltstones. The shales are light to medium grey, occasionally dark grey with minor coal inclusions, soft, silty, micromicaceous and calcareous. The sandstone are light grey, very fine to fine grained and generally calcareous. The siltstone is light to medium grey with thin argillaceous lamination, slightly calcareous and sandy. The depositional environment is interpreted as being a lower delta plain.

**BHUBAN FORMATION (Middle Miocene)**

This zone mainly consists of very fine to medium grained, well sorted, sub-angular to subrounded, calcareous sandstone. Interbedded grey shales are common with laminations of siltstone. The palaeo- environment seems to be one of persistent marine influence.

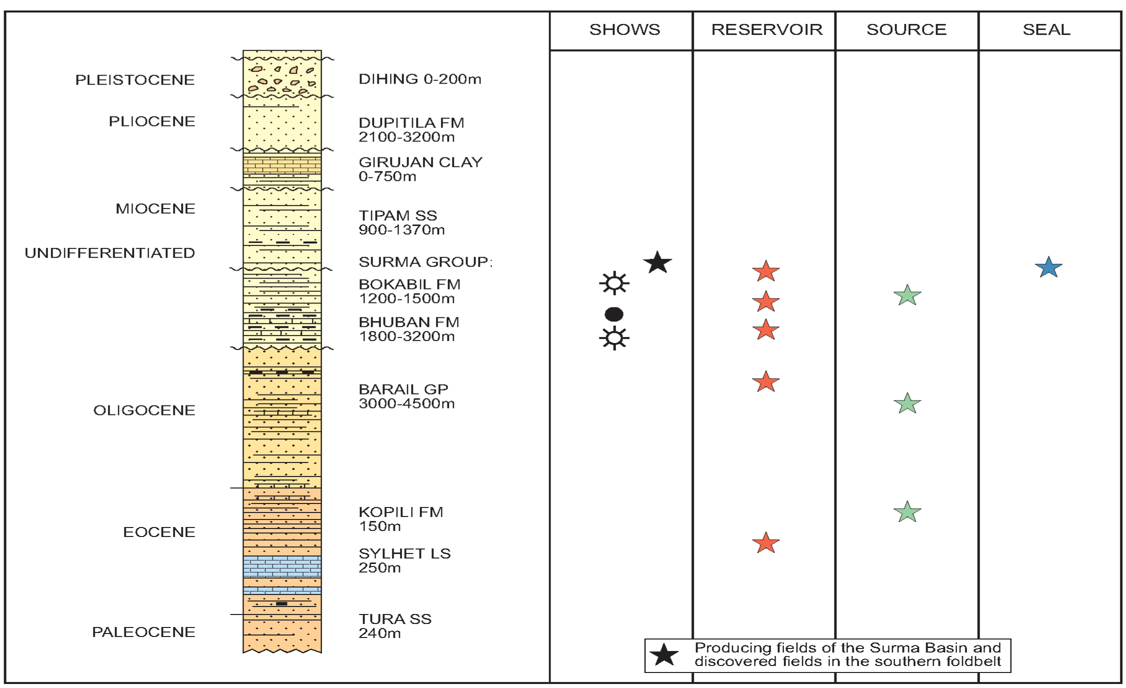


**Figure 3: General Stratigraphy and Petroleum System of Bangladesh**

## 2.5 PETROLEUM SYSTEM

Regionally, the Beani Bazar area is a part of the Hatia Petroleum System that is located in the south of the Tangail-Tripura High. The hydrocarbon system is characterized by Plio-Pleistocene traps in sandstone reservoirs of Upper Miocene to Pliocene age. Gas with little or no condensate is produced. The hydrocarbon source is probably from Miocene Bhuban shales, which have generated primarily natural gas with minimal condensate.

### TRAP

A low-angle anticline structure trending almost North–South is the trap type for the Beani Bazar Gas Field. This compressional structuring took place from Miocene to Recent.

### SOURCE ROCKS

The Miocene Bhuban Shale is widely developed over the Bengal Basin, including the Eastern Fold Belt, and is probably the youngest source rock unit capable of generating gas. The formation, deposited under a wide range of environmental regimes, from shallow marine deltaic to fluvio-deltaic, has been characterized by different proportions of alternating shales, silts and sands, with an overall increase of shale content southwards. The sequence is poor to lean in terms of source rock potential, with TOC values averaging from 0.2 to 0.7 %.

### VERTICAL SEAL

The Upper Marine Shale (late Miocene-early Pliocene) is clearly recognized from seismic and supposed to be a regional vertical seal in the Beani Bazar area. Intra-formational seals are also recognized both from well data and seismic sections.

### TIMING AND MIGRATION

In Beani Bazar, as part of the Hatia area, the rapid sedimentation rates during the Miocene pushed the Oligocene and earlier source rocks through the oil and gas windows well before the formation of the structural traps in the Pliocene to Recent.

The most likely gas source is in shaly sections of the middle to lower Miocene. The migration pathway is probably a combination of vertical migration from earlier Miocene through flanking faults and lateral migration form upper Miocene in basinal, "kitchen" areas.

## 2.6 TECTONIC AND GEOLOGIC MAP OF BANGLADESH

The tectonic and geologic map of Bangladesh and adjacent areas are shown in the following figure (Figure 4):

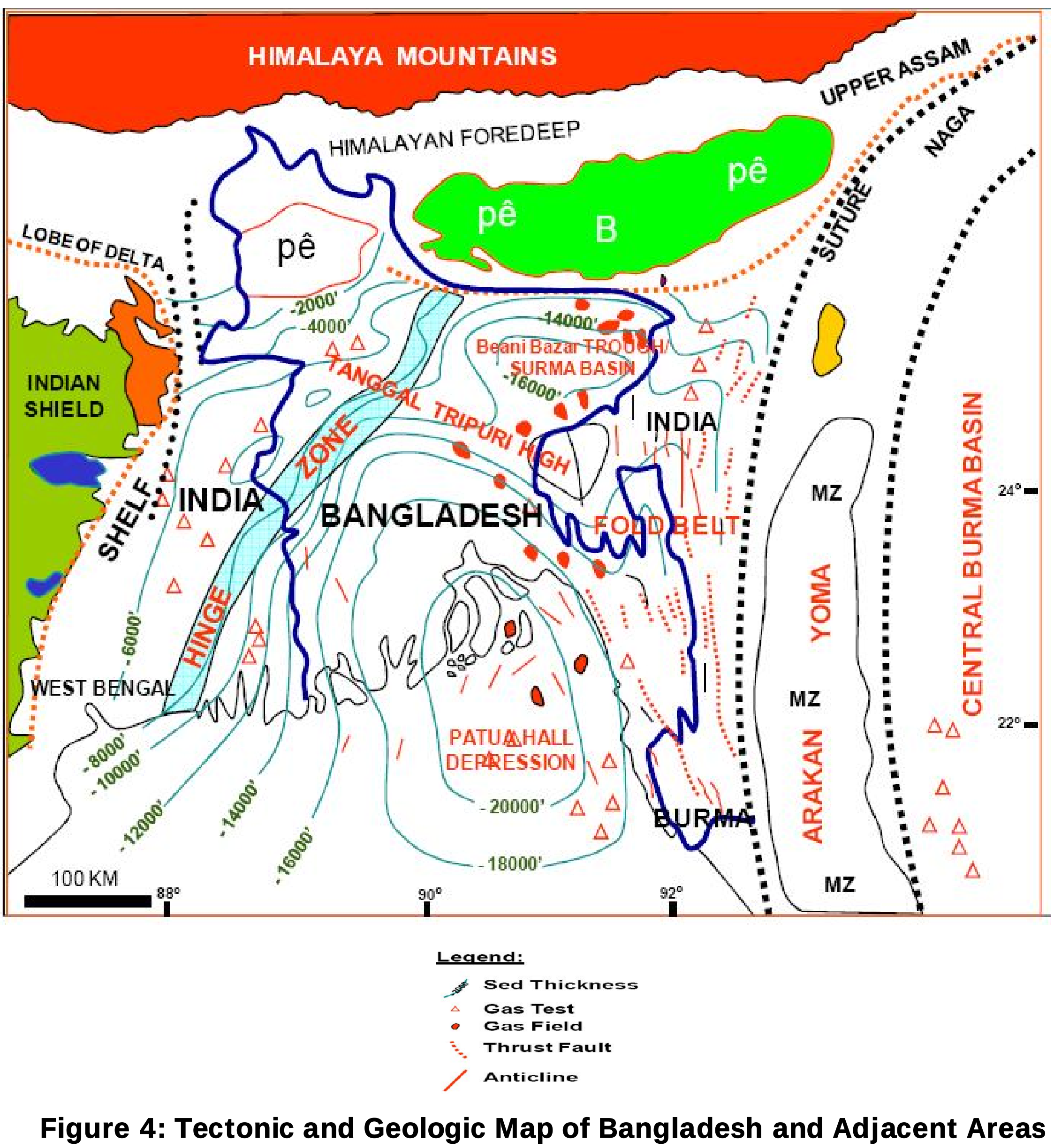


**Figure 4: Tectonic and Geologic Map of Bangladesh and Adjacent Areas**

# CHAPTER 3

## PREVIOUS WORKS ON RESERVOIR STUDIES

## 3.1 WORKS DURING THE PERIOD OF 1988-1989

Intercomp-Kanata Management (IKM), a Canadian company retained by the Canadian International Development Agent (CIDA), was the first company who worked on the geological, geophysical and petrophysical survey of six reservoirs including Beani Bazar gas field in Bangladesh under the Second Gas Development Project (SGDP), Project Implementation Unit (PIU) of Petrobangla, After constructing the contour map and geological model and other works, the company showed the delineation of areas of proved, probable and possible reserves of six reservoirs, both laterally and vertically. The company submitted a report on June, 1989.

## 3.2 WORKS DURING THE PERIOD OF 1990-1991

The British company Well drill Limited reviewed the recoverable gas reserves of seven gas fields including Beani Bazar gas field in Bangladesh. They submitted their report on November, 1991. It showed that available known seven fields reserves varied greatly from a low of 4 Tcf to a high of 25 Tcf due to several factors including differing reserve definitions such as in place reserves versus standard recoverable developed reserves, differences in the estimated physical volume of gas in place and differing development programs which result in different recovery factors.

## 3.3 WORKS DURING THE PERIOD OF 2007

Al Mansoori, a wireline service company of U.A.E conducted a pressure transient analysis on November, 2007 on the individual sands of Beani Bazar gas field.

### LOWER SAND GROUP:

A flow after flow survey was conducted in the lower sand of well BB-1 on October, 2007. The survey was done by using quartz memory gauges which were hanged at a depth of 11300ft. The gauges recorded the survey data successfully and the data quality was excellent. The flow-after-flow test involved 4 periods of increasing draw-down followed by a build-up. The production test was carried out by Al Mansoori Production Services. The well was flowed for approximately 8hrs in different chokes and shut in for approximately 33hrs. The

Test Summary was based on the average on specified choke during the test. Before starting the production test the well was shut in for 8hrs.

According to the analysis, the pressure transient response of the lower sand displayed the characteristics of the wellbore storage and skin in a homogeneous reservoir. The results showed that the initial reservoir pressure for the lower sand was 4645 psia at the gauge depth (11300ft) and the reservoir capacity was 2570 mD-ft. The well skin was determined to be 63.6 which was excessive.

### UPPER SAND GROUP:

As per the analysis, the pressure transient response of the upper sand displayed the characteristics of the wellbore storage and skin in a homogeneous reservoir which is similar to the lower sand. The initial reservoir pressure of the upper sand was determined to be 4546.97 psia. The reservoir capacity was 5580 mD-ft. The well skin was determined to be 20.9.

## 3.4 WORKS DURING THE PERIOD OF 2004-2009

The Exploration Company Limited (ECL), presently merged with RPS Energy, a British company, conducted a reservoir study on 14 gas fields of Petrobangla located in Bangladesh from 2004 to 2009 under the Reservoir Management Project (RMP) of Petrobangla. Beani Bazar gas field was one of those fourteen fields.

RPS Energy constructed a geological model in Schlumberger Petrel$^{TM}$ 2008.1 software. The structural model was constructed by using the top and base seismic input surfaces. Following the structural modeling, a facies model was created and petrophysical reservoir properties were populated within these facies using a stochastic method to create a P50 model. A full Monte Carlo probabilistic volumetric analysis was undertaken using REP$^{TM}$ to determine P10, P50 and P90 GIIP estimates based upon GRV, net-to-gross, porosity and water saturation values from Petrel$^{TM}$.

Then the simulation study of Beani Bazar gas field was done compared with the results of the Petrel™ geo-modeling work. The Gas Initially I n Place (GIIP) estimated from volumetric calculations and as per the ECLIPSE™ model were 163.4 Bcf and 163.5 Bcf for upper gas sand and 67.5 Bcf and 67.2 Bcf respectively.

Finally, a number of predictive cases were run from a “Do Nothing” case to cases with squeezed perforations, new wells, and cases which test the water-handling limits of the facilities. The Do Nothing case yielded a recovery factor of 62% (UGS) and 98% (LGS) (FGPT = 167 Bcf), while the best case (with one new well) yielded a total recovery of 203.0 Bcf.

# CHAPTER 4

## LITERATURE REVIEW

## 4.1 TO ESTIMATE GAS INITIALLY IN PLACE (GIIP) BY P/Z METHOD USING MATERIAL BALANCE EQUATION FOR WATER DRIVE GAS RESERVOIR

The general form of material balance equation was first presented by Schilthis in 1941. The material balance equation is an expression of the law of the conservation of mass, which is commonly used in reservoir engineering. This equation is derived as a volume balance which equates the cumulative observed production, expressed as an underground withdrawal, to the expansion of the fluids in the reservoir resulting from a finite pressure drop. A straight-line plot of p/z vs Gp (cumulative gas Production) is widely used to estimate the original gas in Place. It is known as the "P/Z Plot Technique". The linearity of that plot has been historically known to be a unique feature of a volumetric (closed) reservoir.

For a gas reservoir without water influx and without water encroachment, the material balance equation will have the following form

$$GB_g = \left(G - G_p\right)B_g \qquad \text{..........1}$$

With neglect formation and water compressibility, material balance equation can also be written as

$$\frac{p}{z} = \frac{p_i}{z_i}\left(1 - \frac{G_p}{G}\right) \qquad \text{..........2}$$

If we plot p/z Vs Gp which is the graphical solution of the gas material balance for volumetric depletion reservoir from which we can get the original gas in place, but every reservoir has a different driving mechanism in which reservoir fluid are caused to flow out of the reservoir rock and into a well bore by natural energy. Water drive reservoir depends on water pressure to force the Hydrocarbons out of the reservoir and in the wellbore. For gas reservoir, which is water drive with water influx, including all forces, the material balance equation will be;

Commutative Gas Production = Original Gas in Place – Gas remaining in the reservoir

$$Gp = G\left[\frac{G}{Ei} - \frac{G}{E_i}\frac{\left(c_w S_{wc} + c_f\right)}{1 - S_{wc}}\Delta p - W_e B_g\right]E \text{ ...............................3}$$

In which Ei and $E_i$ are the gas expansion factors at the initial and reduced average pressure. G/$E_i$ in the original HCPV and the second term within the brackets takes carve for expansion of the connate water and reduction of pore volume resulting from compaction. The term $W_e$ represents the commutative net water influx, if we neglects water and pore compressibility and the second term within the brackets can be omitted, the equation (3) will be following

$$\frac{G_p}{G} = 1 - \frac{E}{E_i}\left[1 - \frac{W_e B_w E_i}{G}\right] \text{ .......................................................4}$$

If the reservoir temperature remains constant, the gas expansion factor can be replaced by the corresponding values of P/Z and the equation (4) will be following (Dake, 1978);

$$\frac{P}{Z} = \frac{P_i}{Z_i}\frac{\left(1 - \frac{G_p}{G}\right)}{\left(1 - \frac{W_e B_w E_i}{G}\right)} \text{ ..........................................................5}$$

We can re-write equation (2) to be simplified in the following form

$$\frac{p}{z} = \frac{p_i}{z_i} - CG_p \text{ ...................................................................6}$$

Where the constant,

$$C = \frac{p_i}{z_i G} \text{ ..........................................................................7}$$

Now, equation (6) states that, there is a linear relationship between p/z and the cumulative volume of produced gas $G_p$ as shown by the solid line in Figure 5. If the trend of this straight-line is extrapolated to p/z =0, then we can obtain an estimate of the **Original Gas in Place, G,** since when

$$p/z = 0, 1 - \frac{G_p}{G} = 0, G_p = G$$

But for a water drive reservoir, the performance plots behavior can not exist on plot area as shown in Figure 1, in this case we have to use equation (5) instead of equation (2) where the term $W_e$ is introduced that accounts for the cumulative water influx that encroached into the reservoir at a specific time (EL-Ahmady, *et. al.*, 2001 and EL-Ahmady *et. al.*, 2000).

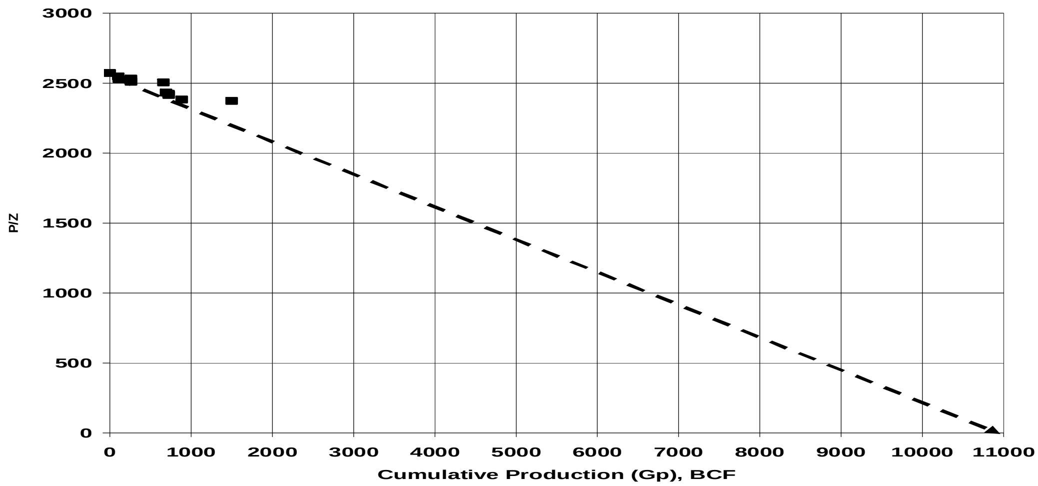


**Figure 5: P/Z plot for gas expansion drive reservoir**

In the above figure, we see that the data point for water drive gas reservoir can lay on straight-line (the dashed line), which can be falsely interpreted in the field to be of a volumetric reservoir. This line extrapolated will lead to obtain an overestimated Original Gas in Place (G')

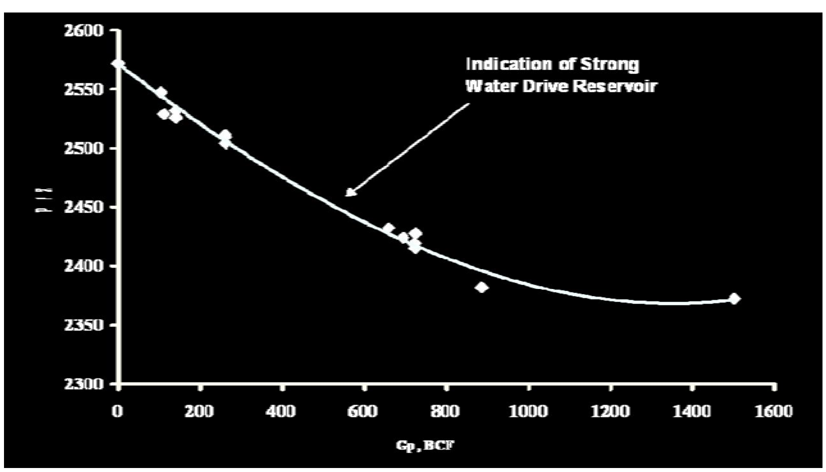


**Figure 6: Non linear P/Z plot for Water Drive Reservoir**

Initially this field has been considered as a volumetric depletion type reservoir, but after observing long production history it appears that p/z plot is non linear and curve behavior indicating water drive mechanism as shown in Figure 6.

## 4.2 TO ESTIMATE GAS INITIALY IN PLACE (GIIP) BY WATER INFLUX USING MATERIAL BALANCE EQUATION FOR WATER DRIVE GAS RESERVOIR

To estimate GIIP by material balance analysis for water drive reservoir, we have to calculate water influx. There are different methods to calculate water influx such as Case-1 for Allard-Chen method and Case-2 for Carter-Tracy method for Havelena-Odeh interpretation technique. The material balance is expressed in reservoir volume of production, expansion and water influx as (Craft, *et. al.*, 1991)

$$G_p B_g + W_p B_w = G(B_g - B_{gi}) + GB_{gi} \frac{(c_w S_{wc} + c_f)}{1 - S_{wc}} \Delta p + W_p B_w$$

$$\begin{aligned} &Gas\ production + Water\ production = \\ &Gas\exp ansion\ (rcf) + Water\exp ansion / pore\,compaction(rcf) + Water\inf lux \end{aligned}$$

$$F = G(E_g + E_{fw}) + W_e B_w \ldots\ldots 8$$

Where F is the total gas & water production (rcf),

$Eg = B_g - B_{gi} = undergroun\,d\ gas \exp ansion\ (rcf\ / scf)$ and

$$E_{fw} = B_{gi} \frac{(c_w S_{wc} + c_f)}{1 - S_{wc}} \Delta p =$$

$Expansion\,of\ connet\,water\ and\ reduction\,of\ the\ pore\,space(rcf / scf)$

In most practical cases $E_{fw} << E_g$ and may be omitted but not before checking that this is a valid neglect of the term across the entire range of pressure depletion. The material balance then become (Craft, *et. al.*, 1991 and Irby, *et. al.*, 1962);

$$F = GE_g + W_e B_w$$

$$\frac{F}{E_g} = G + \frac{W_e B_w}{E_g} \quad \text{.........................................................................9}$$

Using the production, pressure and PVT data, the left hand side of equation (9) expression can be plotted as a function of the cumulative gas production, $G_p$ to inspect variation during depletion shown in Figure 5.

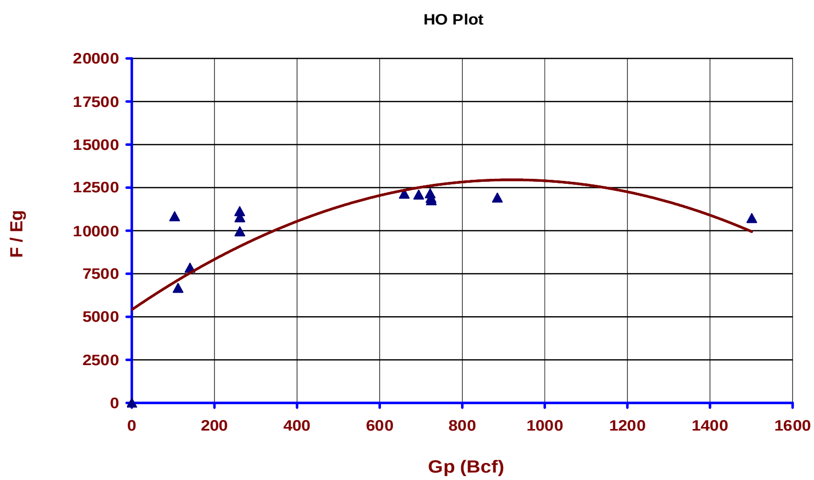


**Figure 7: Reservoir depletion vs Cumulative Gas Production**

**Case 1: Estimate water influx using Allard and Chen Method** (Craft, *et. al.*, 1991)

The equation is $W_{e(t_{Dn})} = U \times \sum_{i=1}^{n} \Delta p_i W_{eD} \left(t_n - t_{i-1}\right)_D$ ..................................10

Where $U = 1.119 \phi c_t h r_R{}^2 \left(\frac{\theta}{360}\right)$ and Dimensionless time $t_D = \frac{.00634kt}{\phi \mu c_t r_R{}^2}$

Where t is in days

**Case 2: Estimate Water Influx using Carter – Tracy Method**

The equation is $W_{en} = W_{en-1} + \left(t_{Dn} - t_{Dn-1}\right)\left[\frac{U\Delta p_n - W_{en-1} p_D^{'}\left(t_{Dn}\right)}{P_{D\left(t_{Dn}\right)} - t_{Dn-1} P_D^{'}\left(t_{Dn}\right)}\right]$ ........11

Where $U = 1.119\phi c_t h r_R^2 \left(\frac{\theta}{360}\right)$ in RB/psi, $\Delta p_n = p_{aq,i} - p_n$ , $t_D = \frac{.006kt}{\phi \mu c_t r_R^2}$

Where, t is in days.

## 4.3 IMPORTANCE OF WATER INFLUX IN WATER DRIVE GAS RESERVOIR

We know that the gas recovery of water drive gas reservoir depends on the following factors:

(1) The production rate and manner of production;

(2) The residual gas saturation.

(3) Aquifer properties.

(4) The volumetric displacement of water invading the gas reservoir.

In certain cases, it appears that the gas recovery can be increased significantly by controlling the production rate and the manner of production. For this reason, the potential importance of water influx in particular gas reservoir should be investigated early to permit adequate planning to optimize the gas reservation.

A considerable portion of the initial gas in place might be trapped in a water drive gas reservoir as residual gas at high pressure. A full water drive would result in loss of residual gas trapped at initial reservoir pressure. Another factor worth consideration in the water-drive gas reservoir is interruption of production. Shutting in gas production will result in reservoir pressure build-up.

There are available methods for estimating the water influx which can be applied to the water-drive gas reservoir problem. The steady state methods include Hurst modified steady state method and various unsteady state methods include Van Everdingen-Hurst unsteady state method, Hurst and Carter-Tracy unsteady state method.

# CHAPTER 5

## FIELD CASE STUDY

## 5.1 GEOLOGICAL MODEL

The input data to build the geological model involves integrating seismic interpretation, geological correlation of the wells and petrophysical data. This process was made of the Beani Bazar Field to estimate the reserves and to prepare the inputs required for reservoir simulation for the reservoir management plan.

In 2009, RPS Energy, U.K constructed a geological model of Beani Bazar field to conduct a simulation study for the first time. The thesis work was carried out based on this geological model. According to the report of Simulation Study of Beani Bazar Gas Field by RPS Energy, U.K, 2009, the grid was 100 m by 100 m grid cell size in XY direction to incorporate the full extent of the seismic surface data. The input seismic surface data were tied to the well tops. The facies model was developed with the vertical proportion curves to maintain a more accurate relationship between the log data and the modeled property. The generation of property was updated by using the Sequential Gaussian Simulation (SGS) method linked to the facies model. Fluid contacts were also determined based upon the available log data. The seismic base map of Beani Bazar field is shown in the figure 8.

Petrophysical properties modeled across the field were net-to-gross, as a binary property, effective porosity, permeability and water saturation. These were modeled using the Sequential Gaussian Simulation (SGS) algorithm within Petrel™ and all properties were modeled within facies. Shales were given a porosity and permeability value of zero and water saturation of one.

The figures of porosity model and permeability distribution model for Beani Bazar field are also shown.

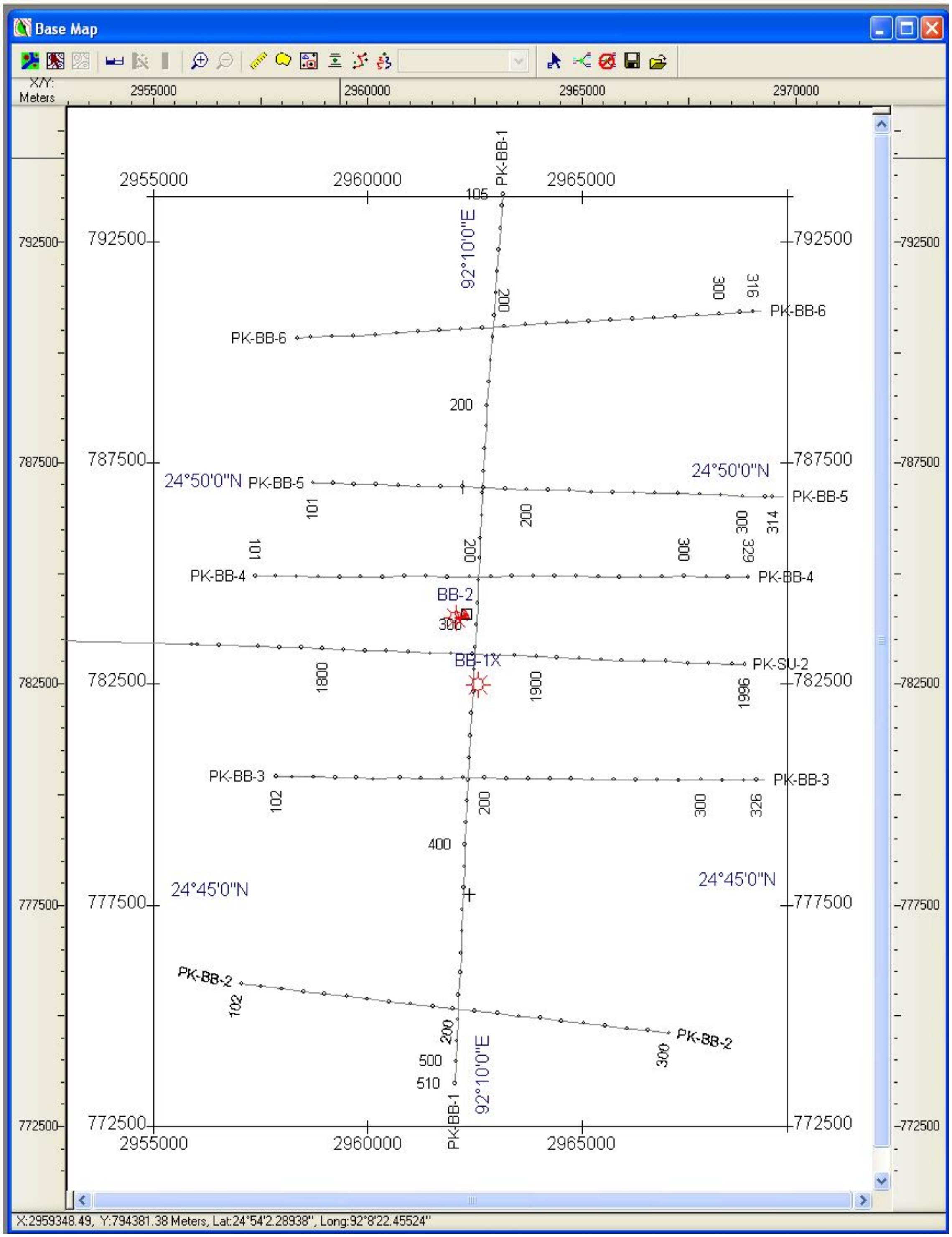


**Figure 8: Seismic Base Map of Beani Bazar Field**

The grid dimensions of the static model was 50 x 75 x 62 to represent the main horizons encountered in the field, with layers 1-20 for the upper gas sand and layers 57-62 for the lower gas sand i.e

| | |
|---|---|
| Grid Dimension | 50 x 75 x 62 |
| Upper Gas Sand | 1 - 20 |
| Lower Gas Sand | 57 - 62 |

**Table 1: Grid Dimension and Layer Distribution**

The parameters used in this study are mostly taken from the report "Simulation Study of Beani Bazar Gas Field" by RPS Energy, U.K, 2009 which were mostly assumed parameters. But the field production rates in different stages were more practical. Absolute permeability, porosity, initial water saturation, residual gas saturations were assumed and corresponding relative permeability and capillary pressures were made for the simulation.

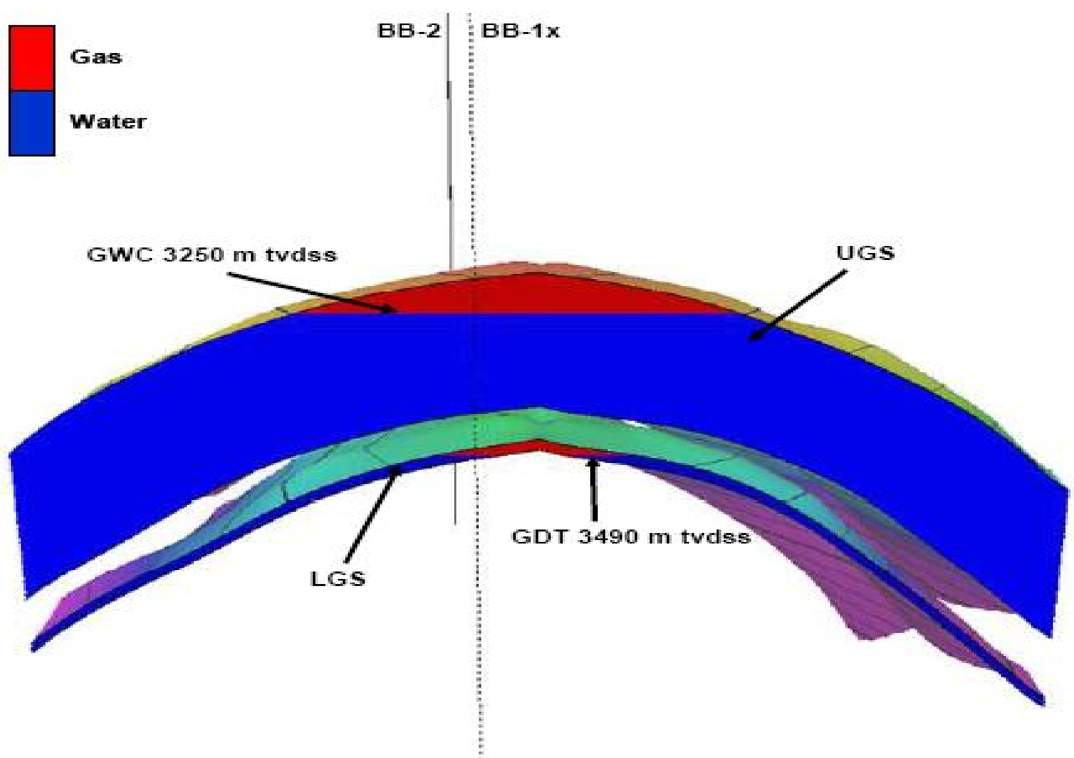


**Figure 9: Structural Cross-Section through Beani Bazar Anticline**

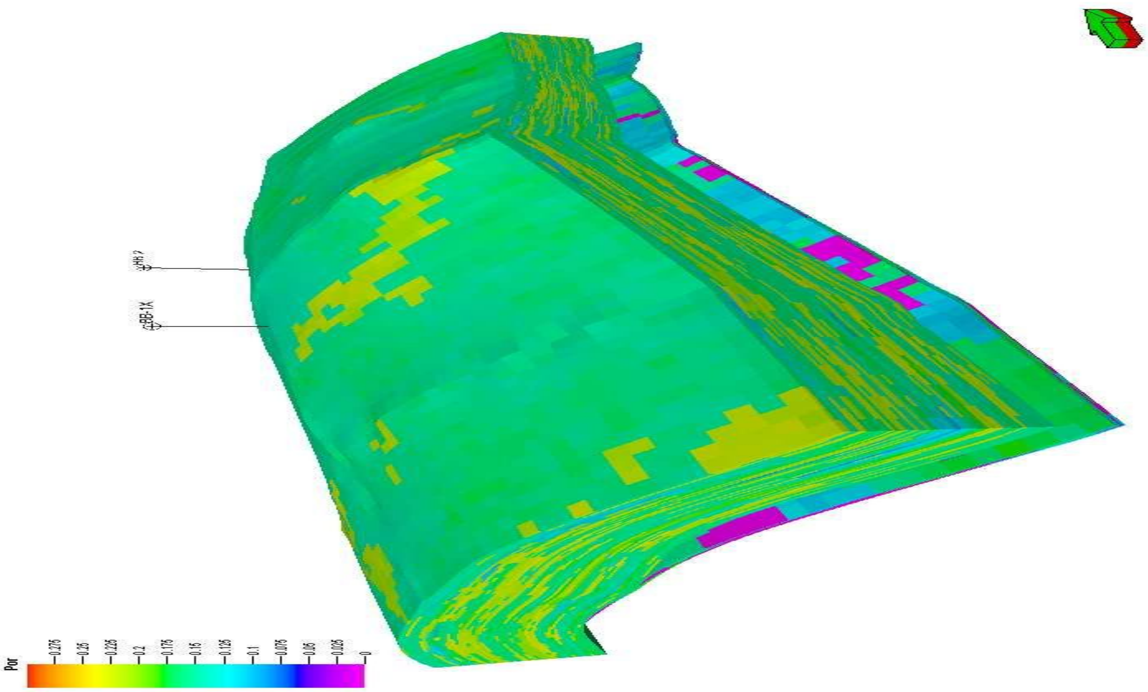

**Figure 10: Porosity Distribution of Reservoir Zones in Beani Bazar Model**

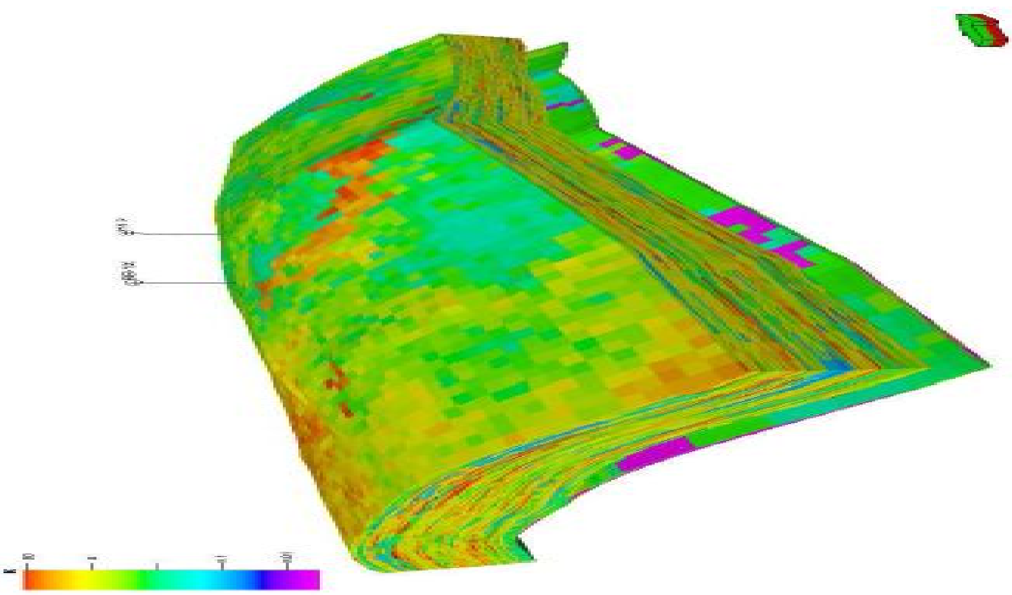

**Figure 11: Permeability Distribution of Reservoir Zones in Beani Bazar Model**

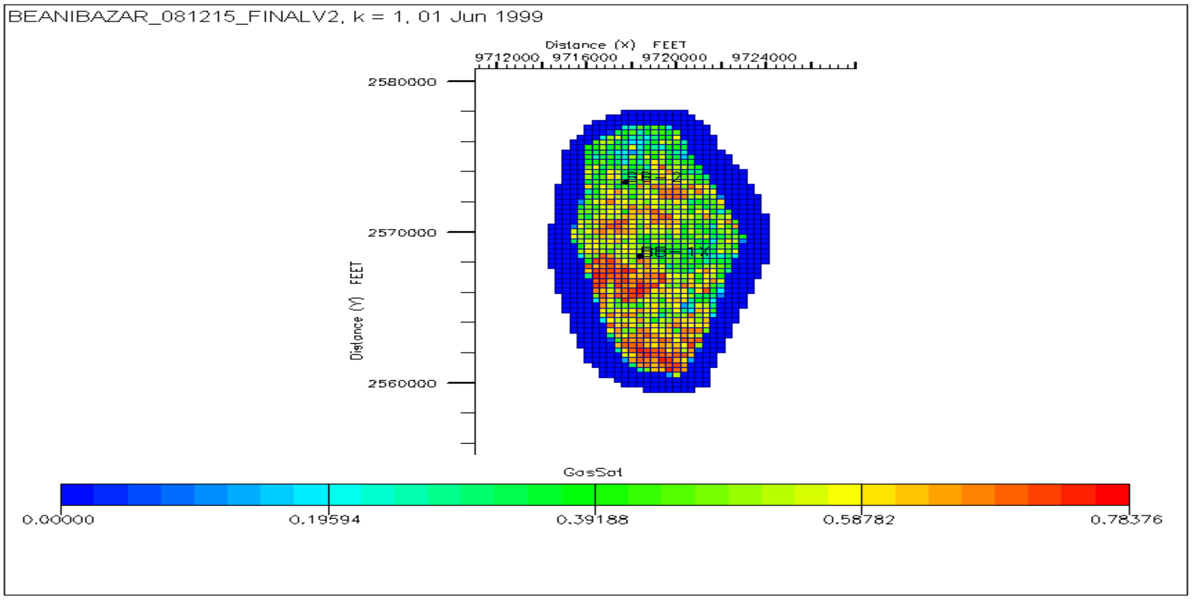


**Figure 12: Initial Gas Saturation on Top Layer (Layer-1)**

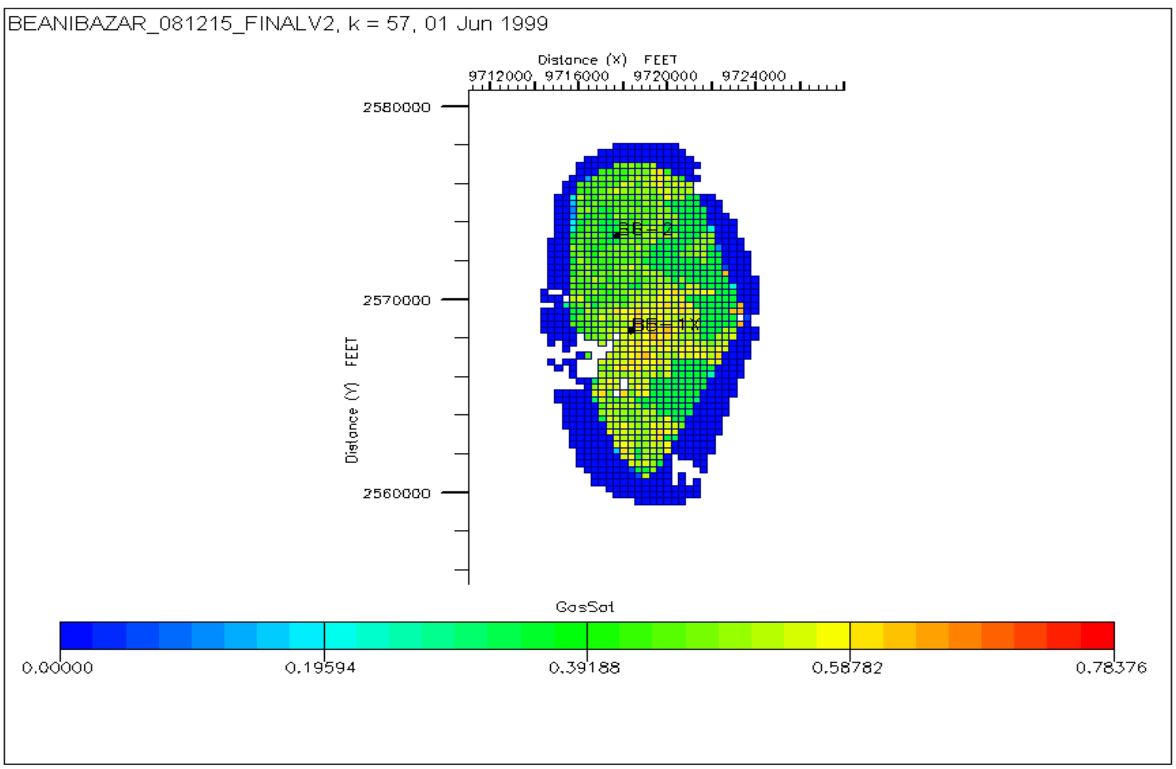


**Figure 13: Initial Gas Saturation on Bottom Layer (Layer-57)**

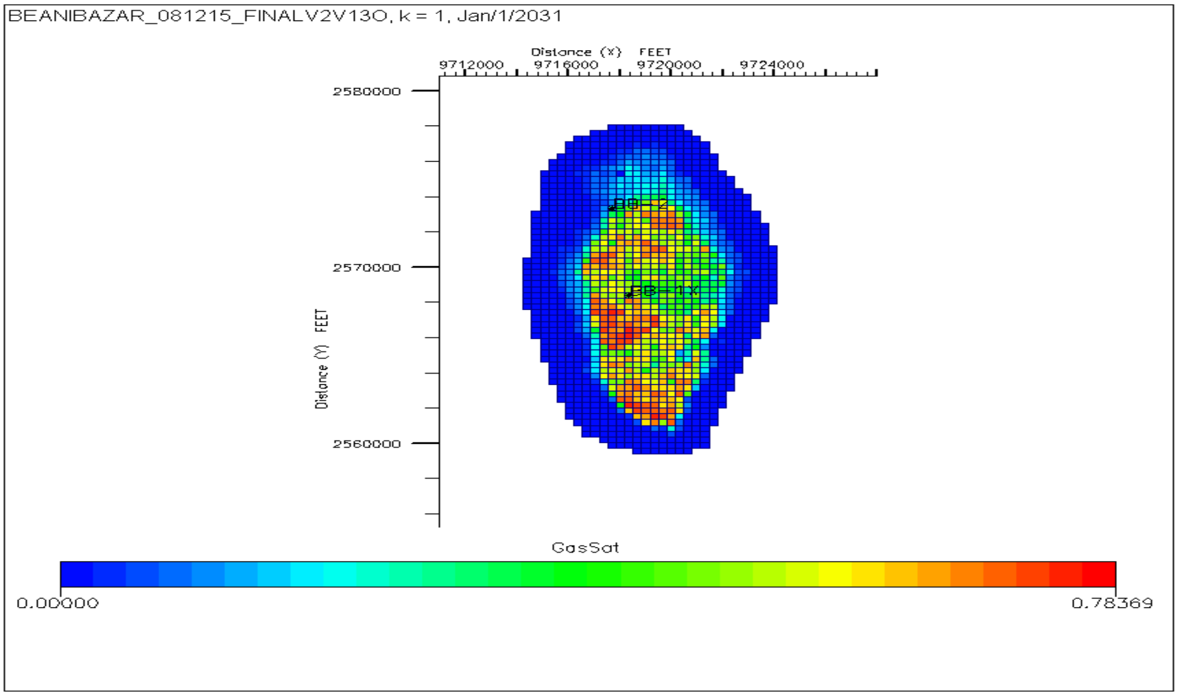


**Figure 14: Final Gas Saturation on Top Layer (Layer-1)**

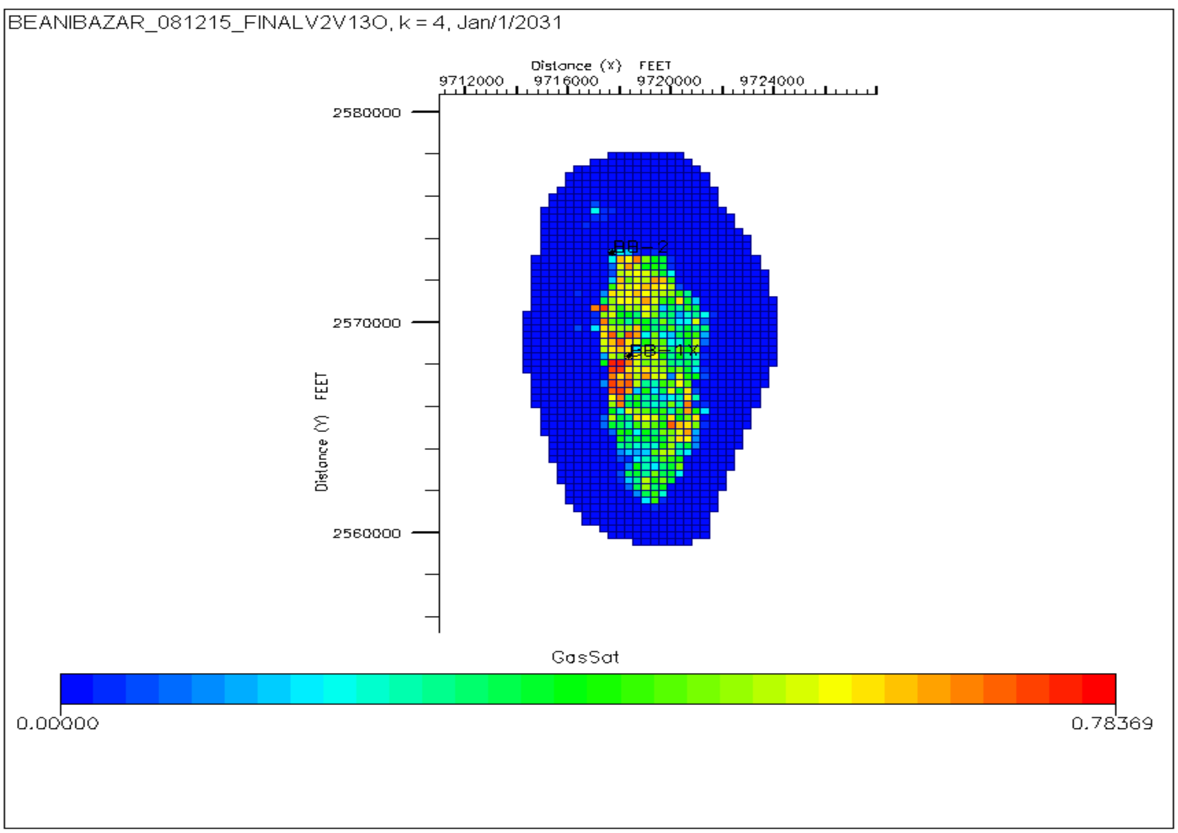


**Figure 15: Final Gas Saturation on Bottom Layer (Layer-57)**

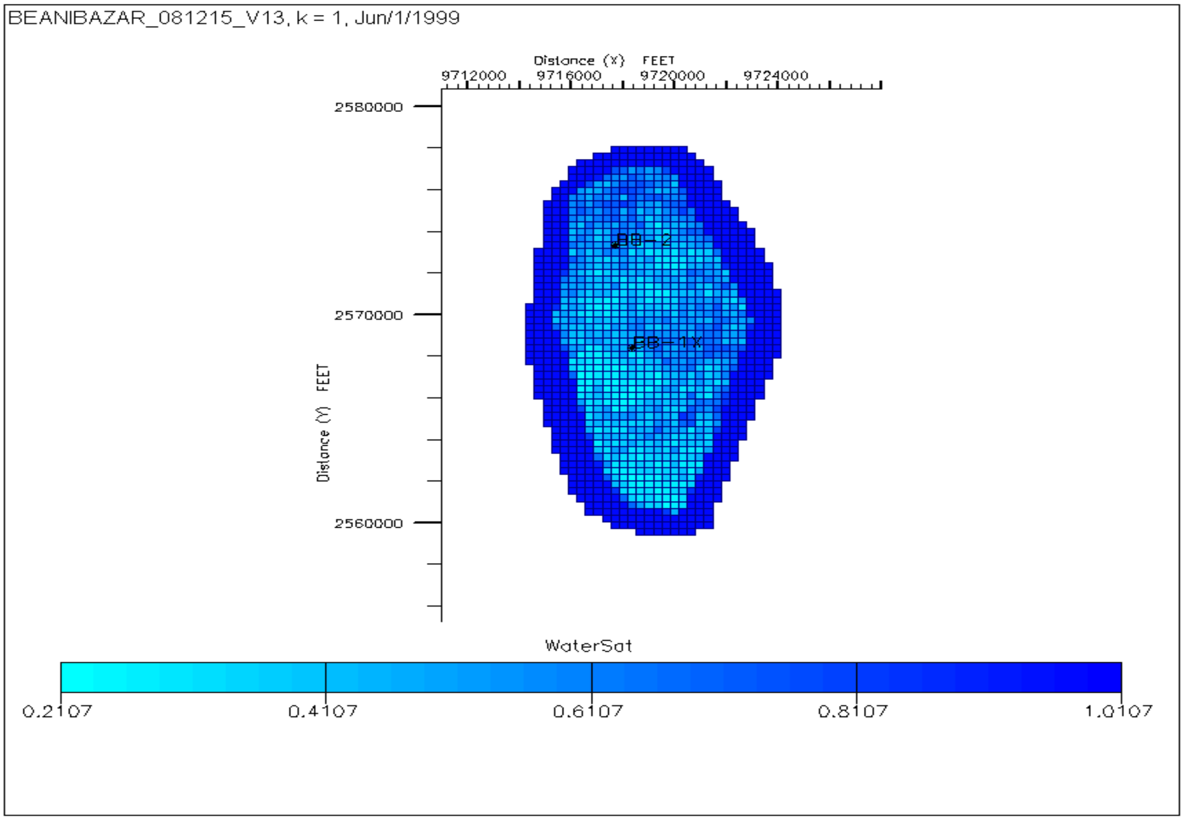


**Figure 16: Initial Water Saturation on Top Layer (Layer-1)**

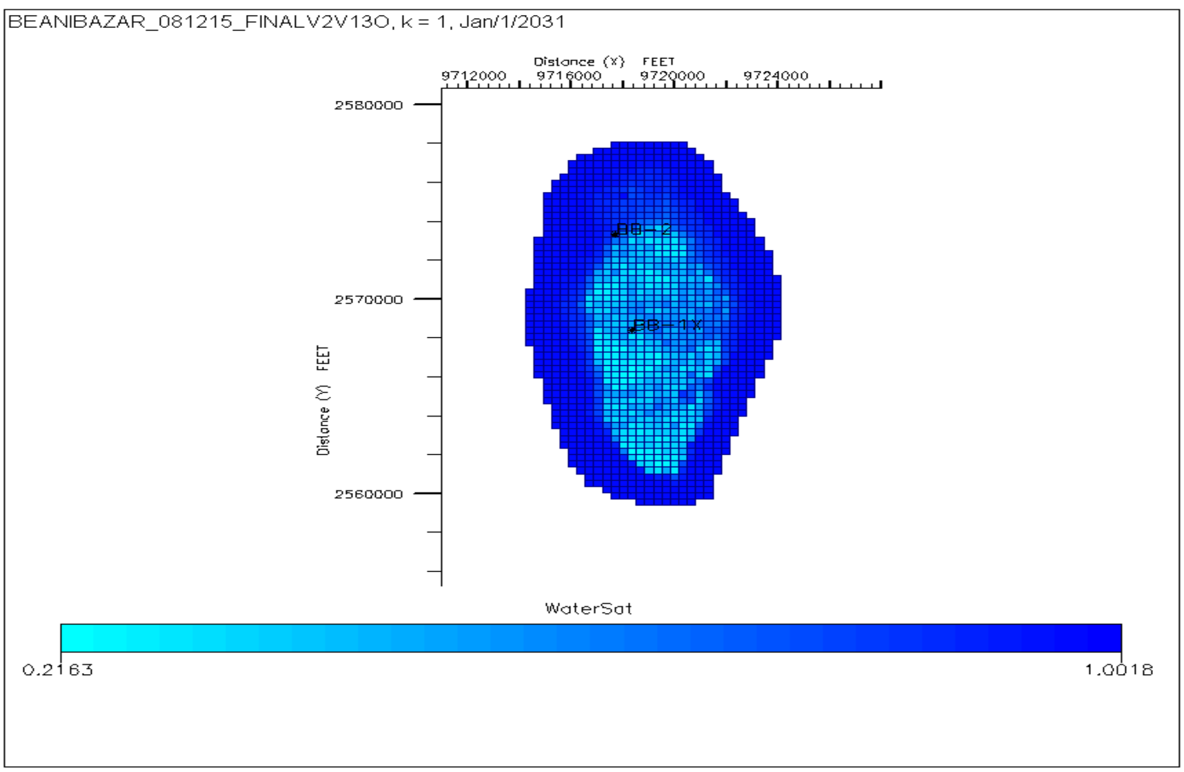


**Figure 17: Final Water Saturation on Top Layer (Layer-1)**

## 5.2 SIMULATION MODEL

A dynamic reservoir simulation model was built on a grid of 50 x 75 x 62 cells and used to perform a history match with cumulative gas production at 53.2 Bscf as of 31 December, 2011. Different matching parameters were used to calibrate the reservoir model, including gas rate, condensate rate, and water-gas ratio. The production data and the three pressure measurements were used for a period of May, 1999 to December, 2011.

There was a few Bottom Hole Pressure (BHP) data of the field which created some problems to understand the lateral continuity and dynamic behavior of the reservoir. The reservoir fluid was modeled as a dry gas with a small constant Condensate-Gas-Ratio (CGR) to account for condensing liquids.

Before simulation model, a material balance analysis was checked out using P/Z plot to estimate the Gas Initially In Place (GIIP) and also to identify the presence of aquifer support.

## 5.3 HISTORY MATCHING OF OBSERVED BEHAVIOR

This section showed the history matching of the simulation model with the aims of confirming the initial reservoir conditions and obtaining an acceptable match of the observed reservoir behavior. To achieve the accurate history matching results, the simulation model was run based on the available data (Upto December 2011). It was observed that the gas production rate match was excellent for wells BB-1X and BB-2. Field water production rate match was moderate good. Bottom hole pressure measurements were very few. There was a good agreement on BHPH measurement for well BB-1X.

The set of graphs comparing the simulation model results with measured data were presented as follows:

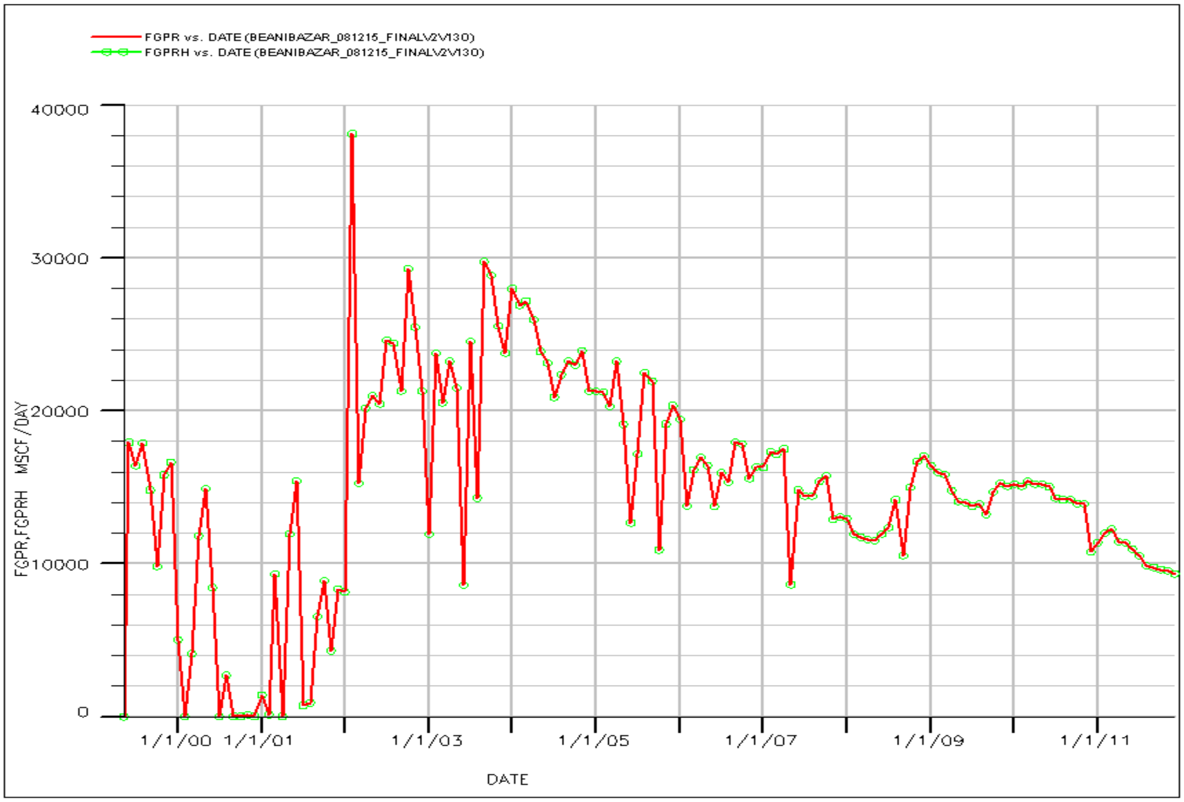


**Figure 18: Field Gas Production History Match**

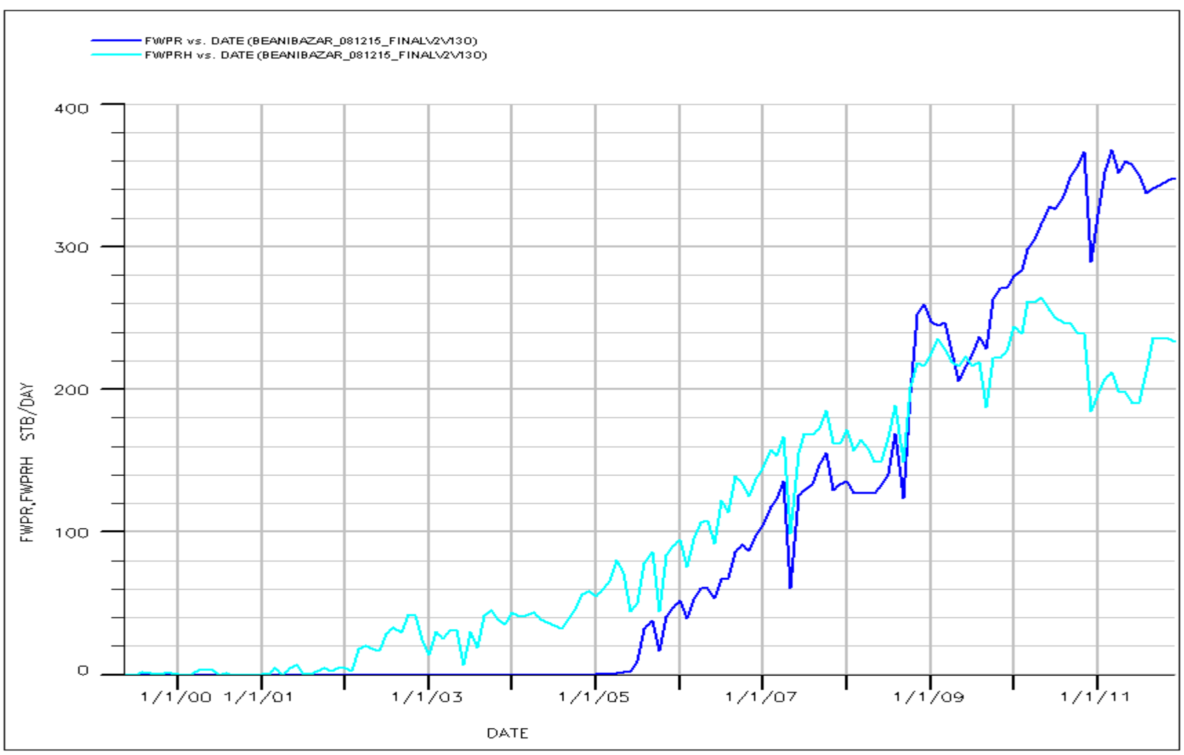


**Figure 19: Field Water Production History Match**

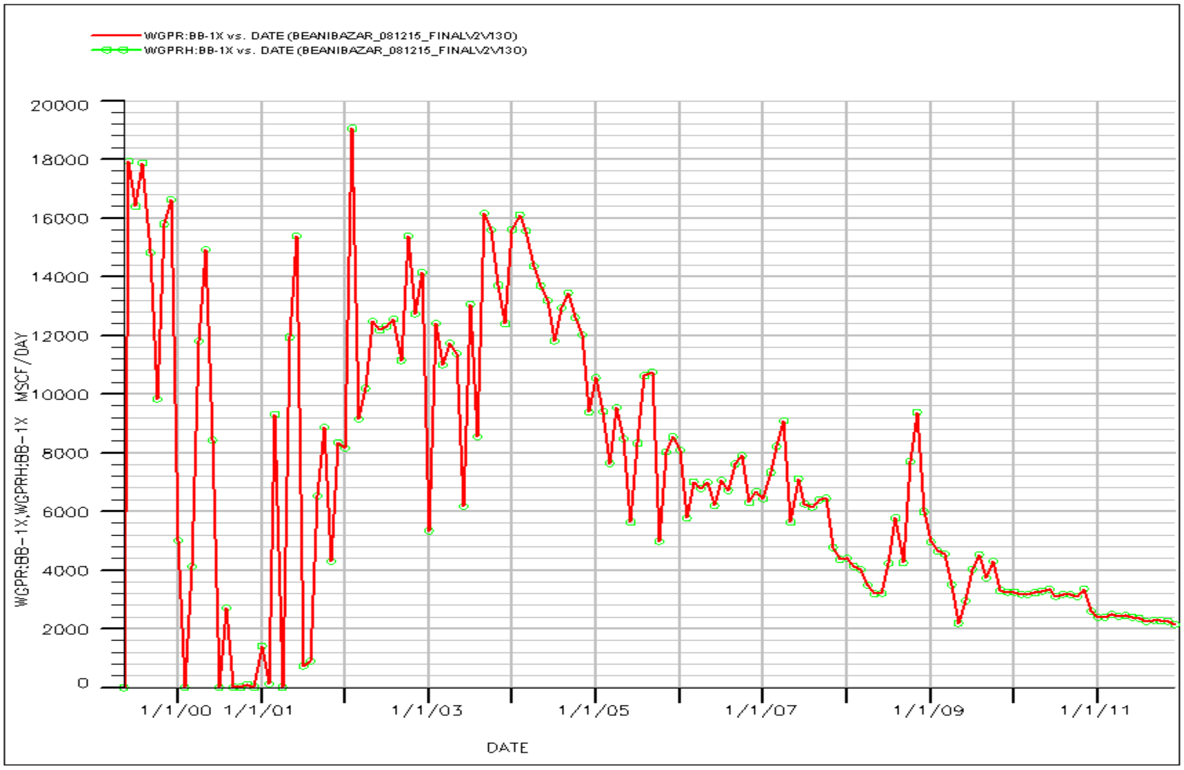


**Figure 20: BB-1x Gas Rate History Match**

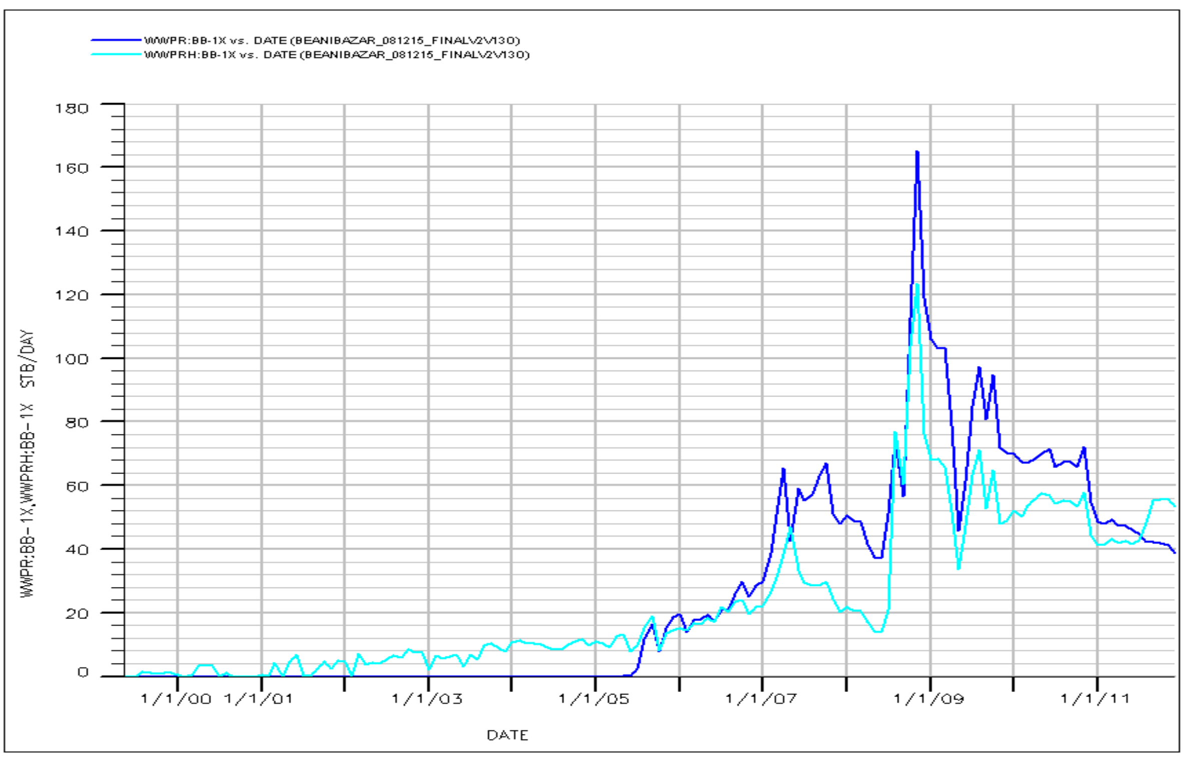


**Figure 21: BB-1x Water Rate History Match**

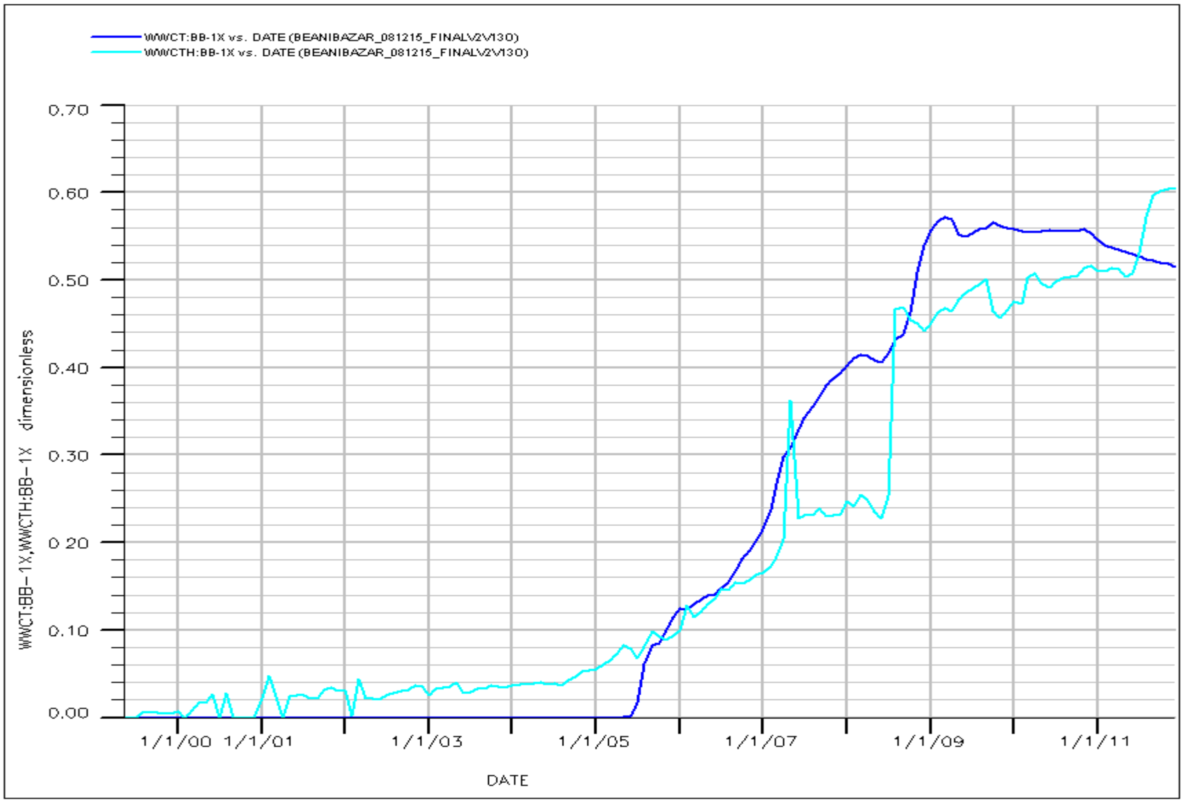


**Figure 22: BB-1x Water Cut History Match**

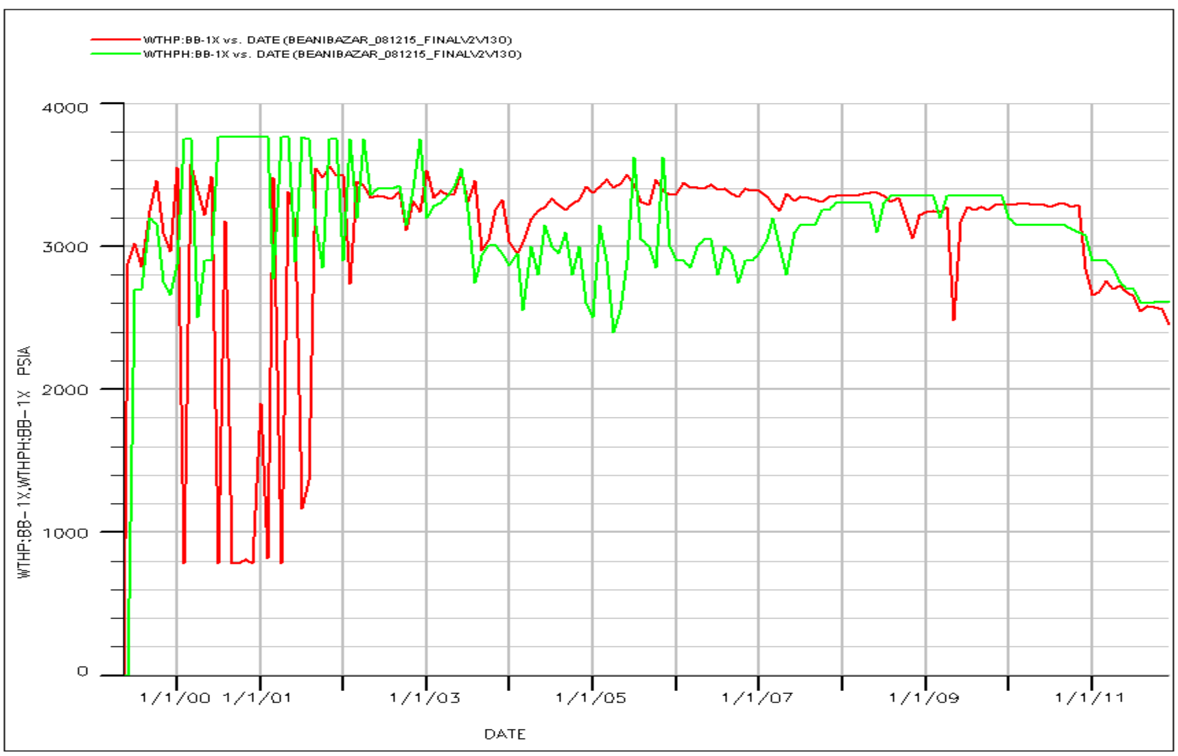


**Figure 23: BB-1x THP History Match**

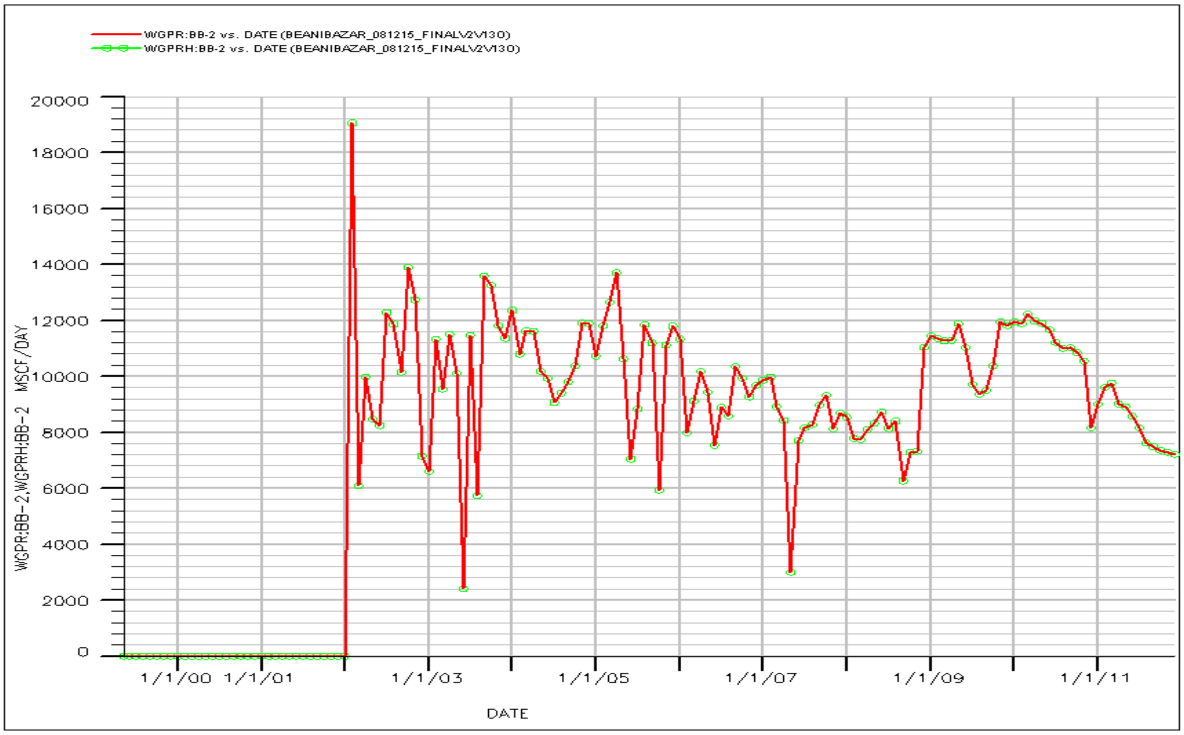


**Figure 24: BB-2 Gas Rate History Match**

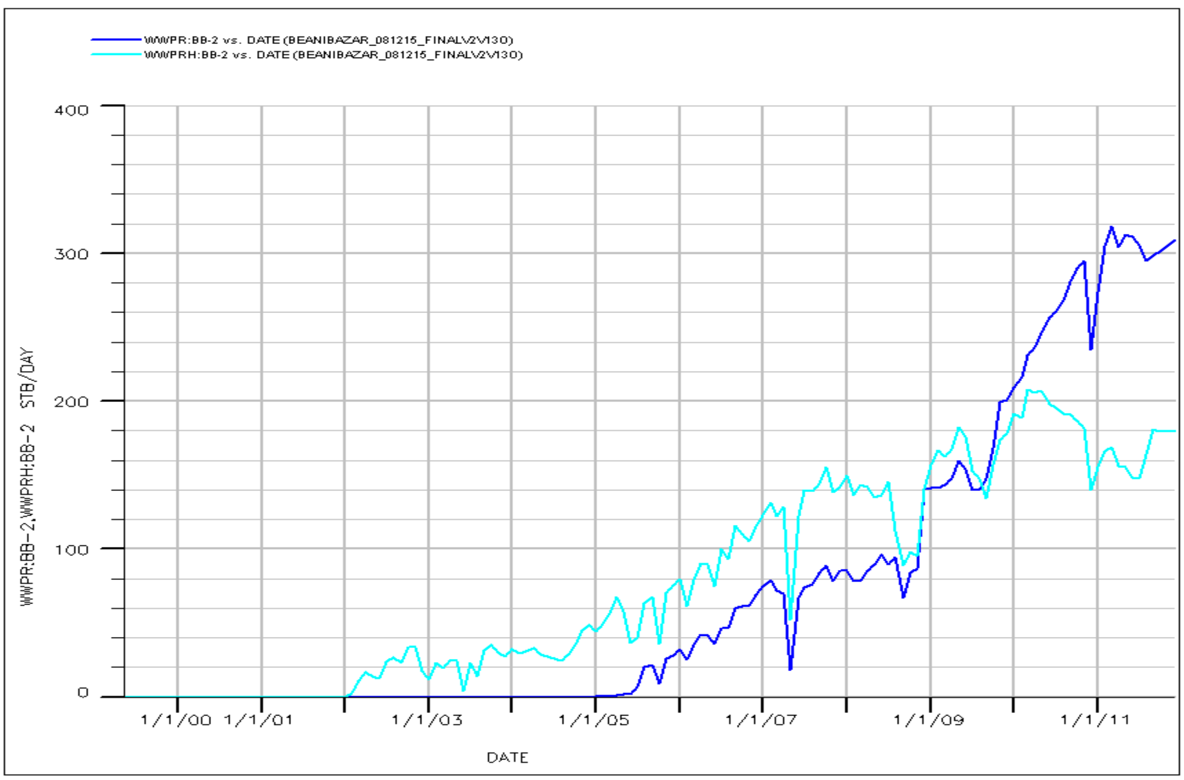


**Figure 25: BB-2 Water Rate History Match**

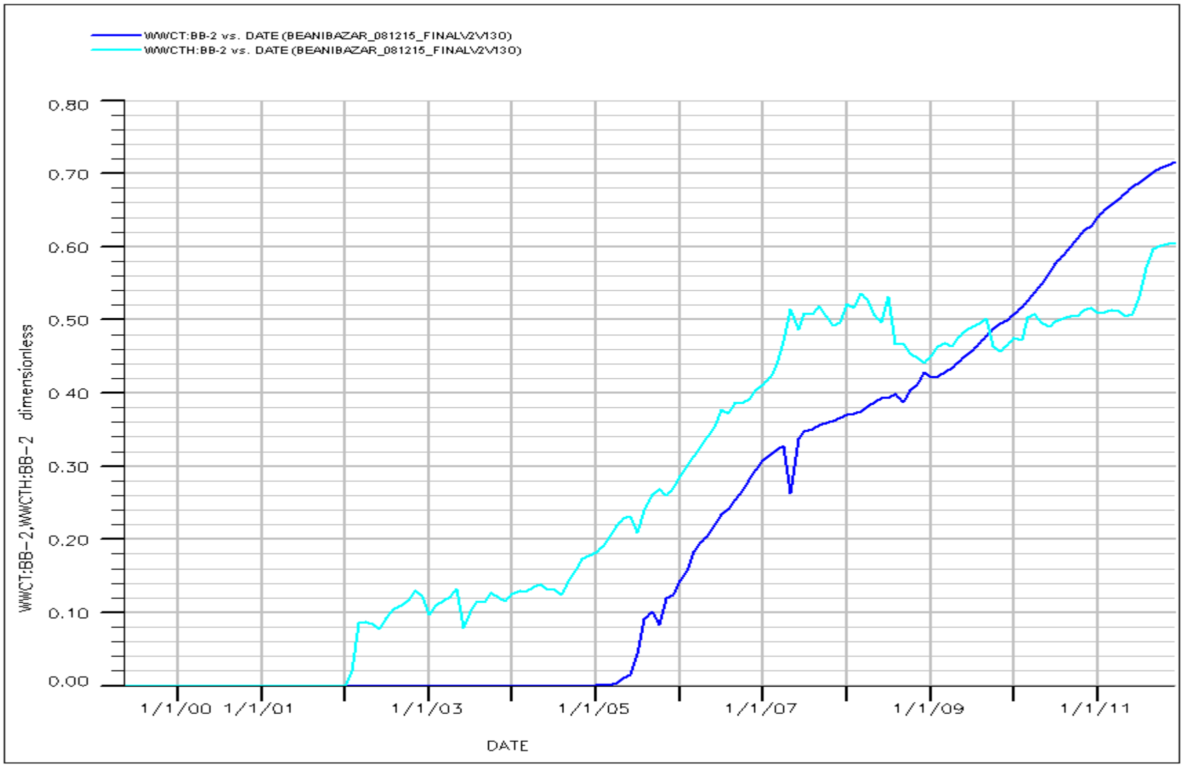


**Figure 26: BB-2 Water Cut History Match**

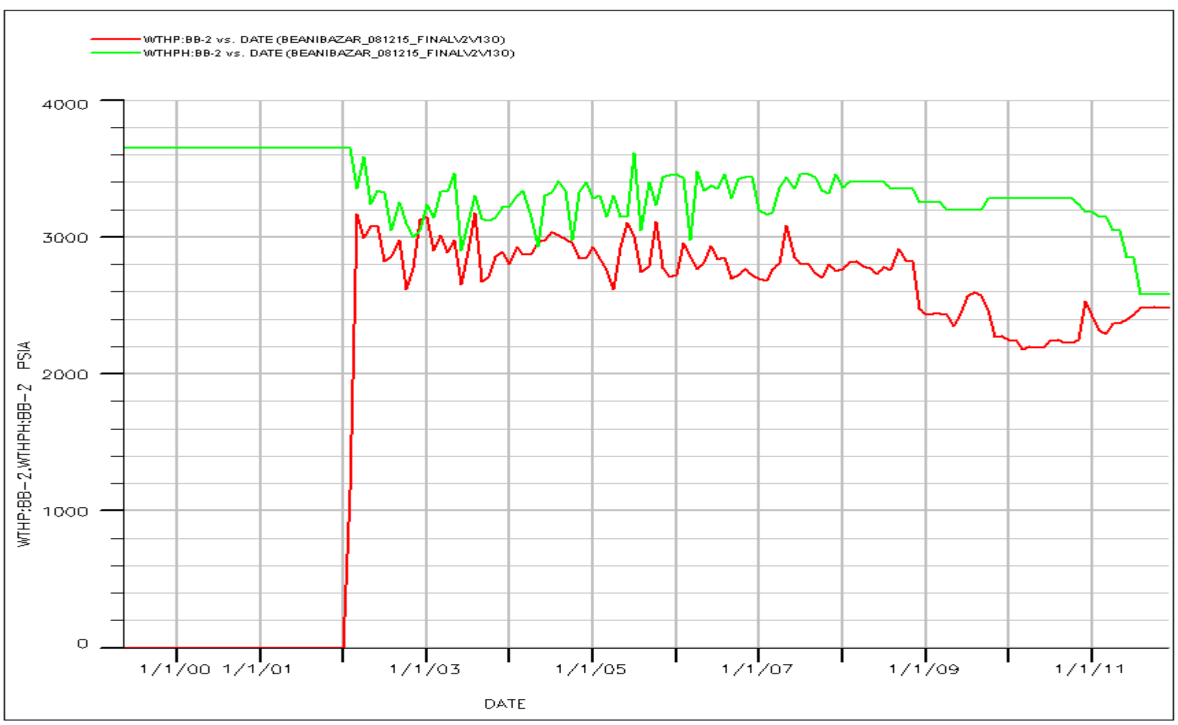


**Figure 27: BB-2 THP History Matc**

## 5.4 PREDICTION OF FUTURE FIELD PERFORMANCE

This section focused the prediction of the future well/reservoir performance. To obtain the perfect scenario, a total number of 11 (Eleven) different forecast cases were run up to 2031. It was observed that a huge amount of water was produced while the prediction cases were run. To prevent excessive water, different water production limits were applied in such a way that the field facilities can handle maximum 750 stb/d per well.

The forecast cases considered were as follows:

1. Case 1: Do nothing case
2. Case 2 : Impact of water production limit 300 stb/d
3. Case 3 : Impact of water production limit 500 stb/d
4. Case 4 : Impact of water production limit 750 stb/d
5. Case 5 : Impact of water production limit 750 stb/d + 50 ft squeezed off in upper sand
6. Case 6 : Impact of water production limit 750 stb/d + 50 ft squeezed off in upper sand + 80 ft squeezed off in lower sand.
7. Case 7 : Impact of drilling one additional well BB-3 in UGS in southern flank.
8. Case 8 : Impact of drilling one additional well BB-4 in UGS in western flank.
9. Case 9 : Impact of rate sensitivity for 10000 mscf/d for both wells in base case.
10. Case 10: Impact of rate sensitivity for 15000 mscf/d for both wells in base case.
11. Case 11: Impact of rate sensitivity for 15000 mscf/d for both wells in base case + 50 ft squeezed off in upper sand + 80 ft squeezed off in lower sand.

## 5.5 RESULTS AND DISCUSSION

The results of the above cases were shown in the following table:

| Predictive Cases | Sand Zones | GIIP Bcf | WGPT Bcf | RF % | BHP Psia | Simulation up to | End of Simulation |
|---|---|---|---|---|---|---|---|
| Case 1 | UGS | 163.5 | 84.4 | 51.62 | 3314 | 2031 | Gas & water limits |
| | LGS | 67.3 | 47.5 | 70.58 | 4547 | 2031 | Gas & water limits |
| Case 2 | UGS | 163.5 | 54.0 | 33.03 | 4533 | 2031 | Gas & water limits |
| | LGS | 67.3 | 47.1 | 70.00 | 4627 | 2031 | Gas & water limits |
| Case 3 | UGS | 163.5 | 58.4 | 35.72 | 4499 | 2031 | Gas & water limits |
| | LGS | 67.3 | 47.5 | 70.58 | 4548 | 2031 | Gas & water limits |
| Case 4 | UGS | 163.5 | 61.8 | 37.80 | 4462 | 2031 | Gas & water limits |
| | LGS | 67.3 | 47.5 | 70.58 | 4548 | 2031 | Gas & water limits |
| Case 5 | UGS | 163.5 | 60.4 | 36.94 | 4454 | 2031 | Gas & water limits |
| | LGS | 67.3 | 47.5 | 70.58 | 4548 | 2031 | Gas & water limits |
| Case 6 | UGS | 163.5 | 61.3 | 37.49 | 4448 | 2031 | Gas & water limits |
| | LGS | 67.3 | 47.5 | 70.58 | 4531 | 2031 | Gas & water limits |
| Case 7 | UGS | 163.5 | 143.63 | 87.85 | 3352 | 2031 | Gas & water |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | limits |
| | LGS | 67.3 | 47.51 | 70.58 | 4127 | 2031 | Gas & water limits |
| Case 8 | UGS | 163.5 | 134.38 | 82.19 | 3655 | 2031 | Gas & water limits |
| | LGS | 67.3 | 47.51 | 70.58 | 4395 | 2031 | Gas & water limits |
| Case 9 | UGS | 163.5 | 102.0 | 62.39 | 4446 | 2031 | Gas & water limits |
| | LGS | 67.3 | 66.1 | 98.21 | 4086 | 2031 | Gas & water limits |
| Case 10 | UGS | 163.5 | 126.0 | 77.06 | 4443 | 2031 | Gas & water limits |
| | LGS | 67.3 | 66.1 | 98.21 | 4088 | 2031 | Gas & water limits |
| Case 11 | UGS | 163.5 | 126.0 | 77.06 | 4443 | 2031 | Gas & water limits |
| | LGS | 67.3 | 66.1 | 98.21 | 4088 | 2031 | Gas & water limits |

**Table 2: Results of Different Predictive Cases**

From the above table, the proven recoverable reserve was 163.5 Bcf in upper gas sand and 67.3 Bcf in lower gas sand. Total cumulative gas production of 75.65 Bcf (36.94 Bcf from upper gas sand and 38.71 Bcf from lower gas sand) was produced upto December, 2011 which is 22.59 % of GIIP from Upper Gas Sand and 57.51 % of GIIP from Lower Gas Sand.

The simulation cases were run up to 2031 to prevent the huge water which was hard to handle for the operators in the surface facilities premises. Therefore, a minimum gas production rate of 1000 Mscf/d and a maximum water production limit of 750 stb/d per well were applied. The limit of water production rates considered were 300 stb/d, 500 stb/d and 750 stb/d per well to study the effect on recovery.

The squeezing of bottom perforation in upper and lower gas sand was also investigated to prevent huge water. This job was done in higher limit of water production rate (750 stb/d).

To optimize the gas recovery, two new wells were introduced, one in the southern flank and the other in the western flank. It was realized that new well BB-3 yielded 5.67 % more recovery from Upper Gas Sand compared to new well BB-4. On the other hand, there is no effect in recovery factor for lower gas sand for both wells BB-3 and BB-4.

### 5.5.1 CASE 1: DO NOTHING CASE

Do nothing case showed the gas recovery of 51.62 % in upper gas sand at the end of simulation run in 2031. In this case, the total gas production was 84.4 Bcf. From the production profile of the field for do nothing case, it was observed that the maximum water production limit of 750 stb/d would be reached in June 2014. The plots of field gas production rate, well water production rate and well total gas produced were shown in the figure 28-29.

### 5.5.2 CASE 2: IMPACT OF WATER PRODUCTION LIMIT 300 STB/D

In this case, the water production limit of 300 stb/d was applied. The recovery factor of 33.03% was achieved from upper gas sand and 70% from lower gas sand.

### 5.5.3 CASE 3: IMPACT OF WATER PRODUCTION LIMIT 500 STB/D

By increasing the water production limit from 300 stb/d to 500 stb/d, there was an increase in recovery factor by 2.69 % for the upper gas sand and an increase of 0.58 % in lower gas sand. The plots of field gas production rate, well water production rate and well total gas produced were shown in the figure 34-36.

### 5.5.4 CASE 4: IMPACT OF WATER PRODUCTION LIMIT 750 STB/D

The maximum water production limit of 750 stb/d/well showed an increase in recovery factor by 4.78% for upper gas sand and 0.58% for lower gas sand. The plots of field gas production rate, well water production rate and well total gas produced were shown in the figure 37-39.

### 5.5.5 CASE 5: IMPACT OF WATER PRODUCTION LIMIT 750 STB/D AND 50 FT SQUEEZED OFF IN THE UPPER SAND

By squeezing the bottom perforations by 50 feet in the upper gas sand while keeping the water production limit as 750 stb/d, there was 0.86 % decrease from the case where there was no squeeze (FCCase3) for the upper gas sand. There was no change in recovery factor for lower gas sand. The plots of field gas production rate, well water production rate and well total gas produced were shown in the figure 40-42.

### 5.5.6 CASE 6: IMPACT OF WATER PRODUCTION LIMIT 750 STB/D AND 50 FT SQUEEZED OFF IN THE UPPER SAND AND 80 FT SQUEEZED OFF IN THE LOWER SAND

By keeping the water production limit of 750 stb/d and the bottom perforation squeezed by 50 ft in upper gas sand 80 ft in lower gas sand, there was a little bit increase in recovery factor compared to previous case (FC Case 5). It was observed that lower gas sand was insensitive to squeeze job. The plots of field gas production rate, well water production and well total gas produced were shown in the figure 43-45.

### 5.5.7 CASE 7: IMPACT OF DRILLING ONE ADDITIONAL WELL BB-3 IN UGS IN SOUTHERN FLANK

To optimize the production, a new well was introduced in the southern flank with completion in upper gas sand. The new well was introduced to **Do Nothing** case.

The results showed that sudden water production for the field starts to jump high after 2020. The new well BB-3 maintained a plateau rate of production 8 MMscf/d. Production from three wells, including new well BB-3 remained constant at 22 MMscf/d. Selective top 12 layers were assigned to the new well BB-3 in upper gas sand, because lower 8 layers were not so promising for this new location. BB-3 well is about 3000 ft south of well BB-1X. A recovery factor of 87.85 % was observed in upper gas sand in this case.

### 5.5.8 CASE 8: IMPACT OF DRILLING ONE ADDITIONAL WELL BB-4 IN UGS IN WESTERN FLANK

By introducing another new well BB-4 in the western flank of the reservoir, the effect of new well location optimization was investigated. The new well was also applied to the Do Nothing case with completion in upper gas sand. The selective layers available to this well were assigned from 1 – 5. The new well BB-4 was about 3880 ft south east existing well BB-1X. A lower recovery factor of 82.19 % was achieved from BB-4 well compared to 87.85 % from BB-3 well. Gas production rate started from year 2013 as shown in figure 47. The reservoir pressure at the end of simulation from well BB-4 was 3655 psia compared to 3352 psia from BB-3 well.

### 5.5.9 CASE 9: IMPACT OF RATE SENSITIVITY FOR 10000 MSCF/D FOR BOTH WELLS IN BASE CASE

By increasing the production rate of 10000 Mscf/d for both wells BB-1 and BB-2 in base case , there was an increasing trend of recovery factor. The enhanced gas production rate accelerated the recovery factor to 62.3% which was moderate for upper gas sand.

### 5.5.10 CASE 10: IMPACT OF RATE SENSITIVITY FOR 15000 MSCF/D FOR BOTH WELLS IN BASE CASE

Like FC Case 10, the production rate of 15000 Mscf/d for both wells BB-1 and BB-2 in base case was applied and found that there was no change in recovery factor.

The enhanced gas production rate accelerated the recovery factor to 77.06% which was similar to the previous case for upper gas sand. The plots of field gas production rate, well water production and well total gas produced were shown in the figure 49.

### 5.5.11 CASE 11: IMPACT OF RATE SENSITIVITY FOR 15000 MSCF/D BOTH WELLS IN BASE CASE AND 50 FT SQUEEZED OFF IN UPPER SAND AND 80 FT SQUEEZED OFF IN LOWER SAND

Keeping the production rate of 15000 Mscf/d from each well, the bottom perforation squeezed by 50 ft in upper gas sand and 80 ft in lower gas sand were applied and found that the recovery factor was the same as that of FC Case 10 in upper gas sand. Similarly, lower gas sand showed the same recovery factor to that of the previous case. The recovery factor was 77.06% for upper gas sand and 98.21% for lower gas sand which was excellent.

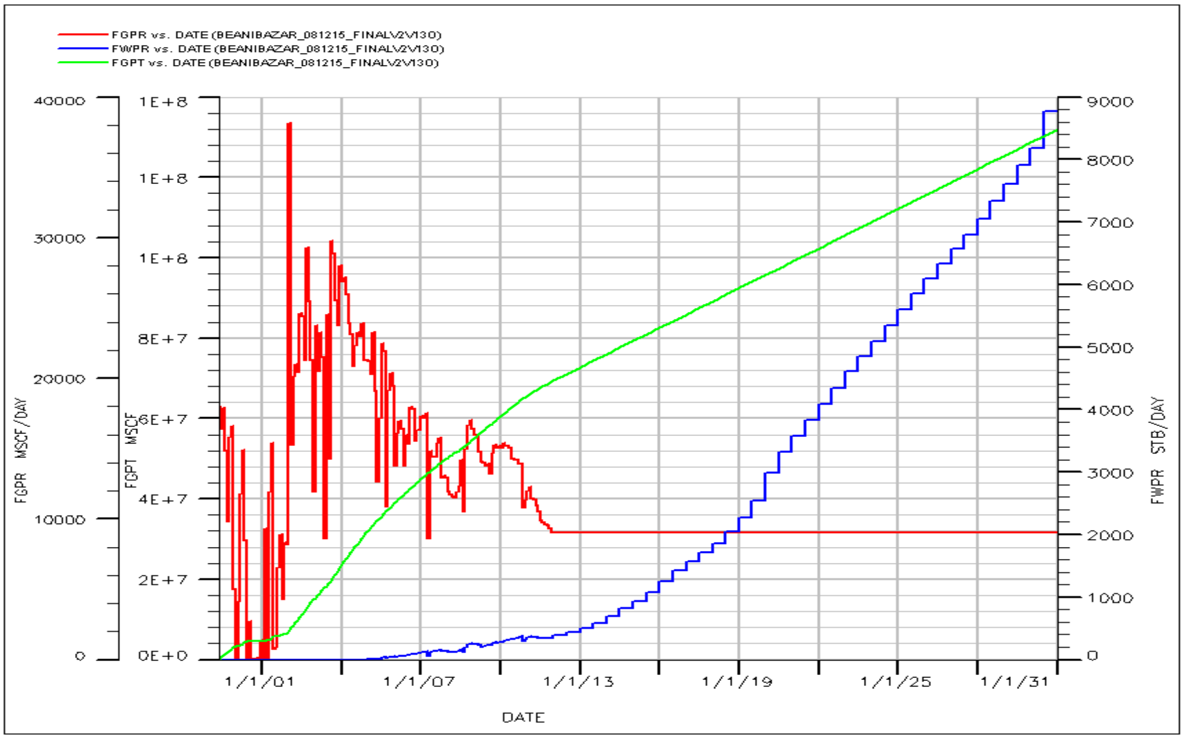


**Figure 28: Field Production Profile of Forecast Case 1: Do Nothing Case**

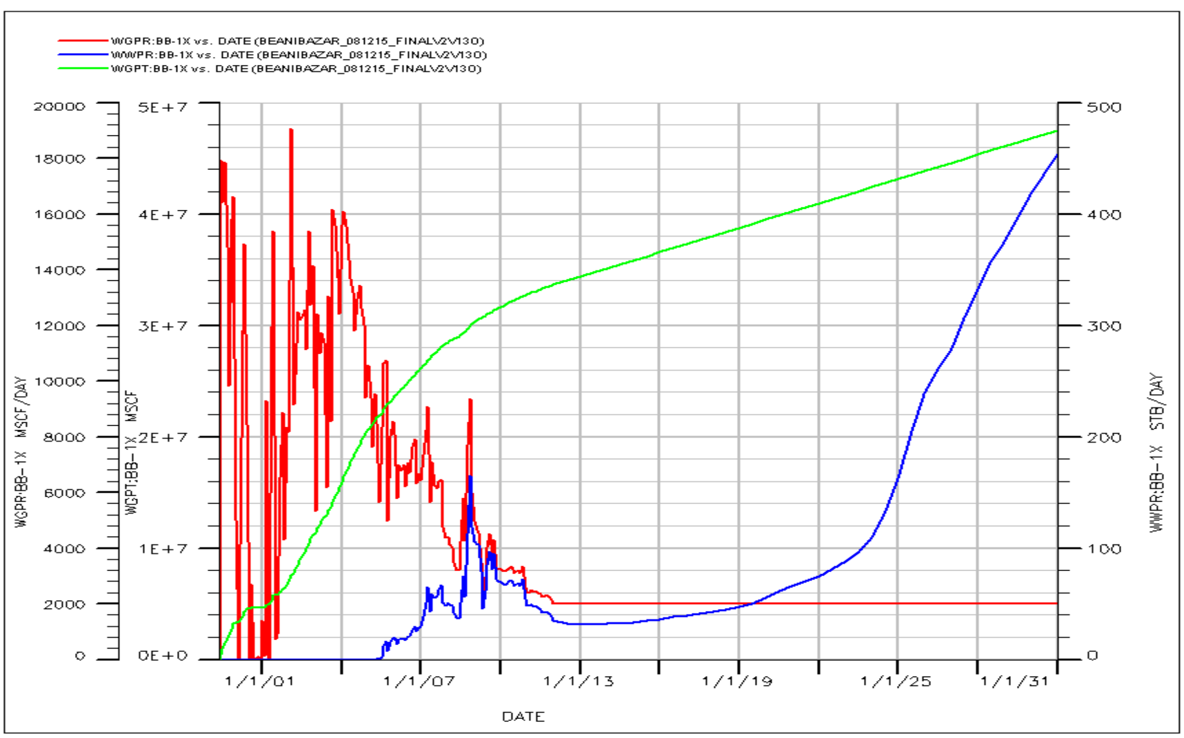

**Figure 29: BB-1 Production Profile of Forecast Case 1: Do Nothing Case**

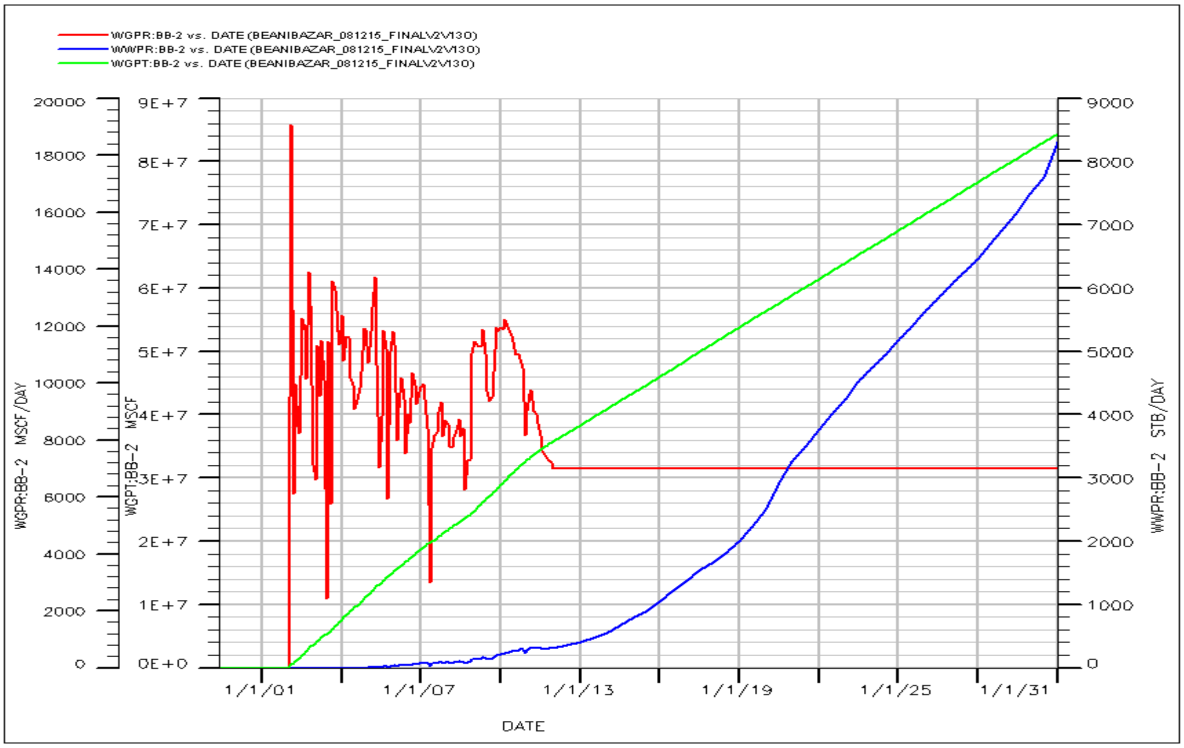


**Figure 30: BB-2 Production Profile of Forecast Case 1: Do Nothing Case**

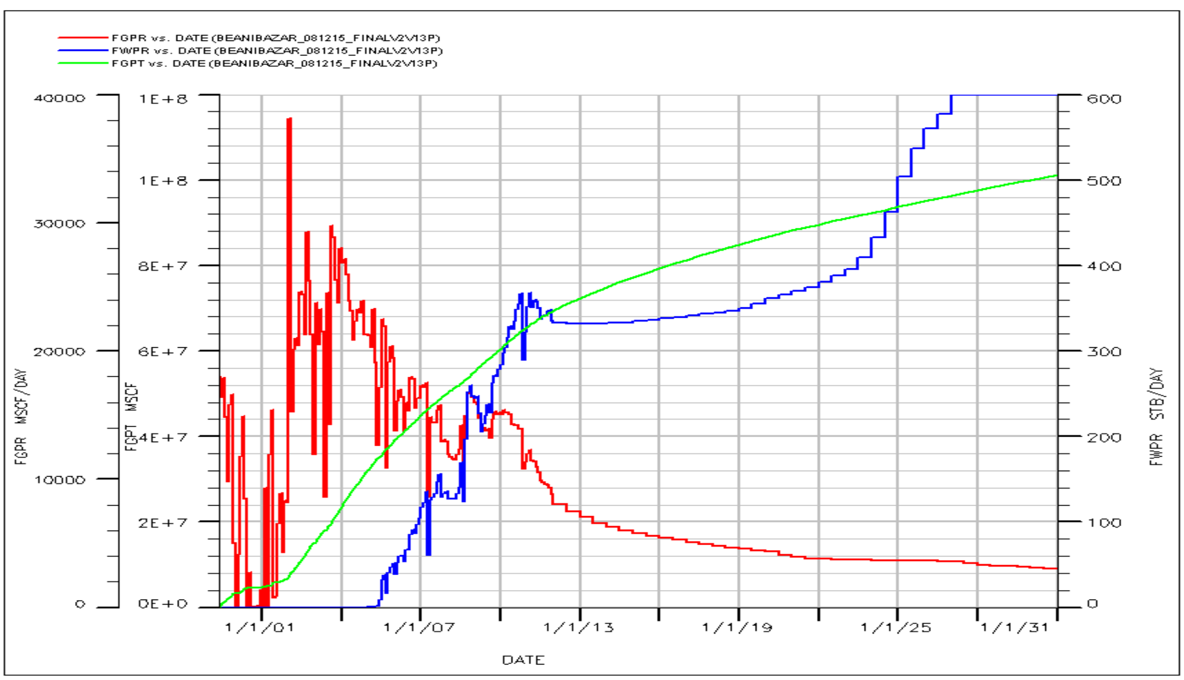


**Figure 31: Field Gas Production Profile of Forecast Case 2: Impact of Water Production limit 300 stb/d/well**

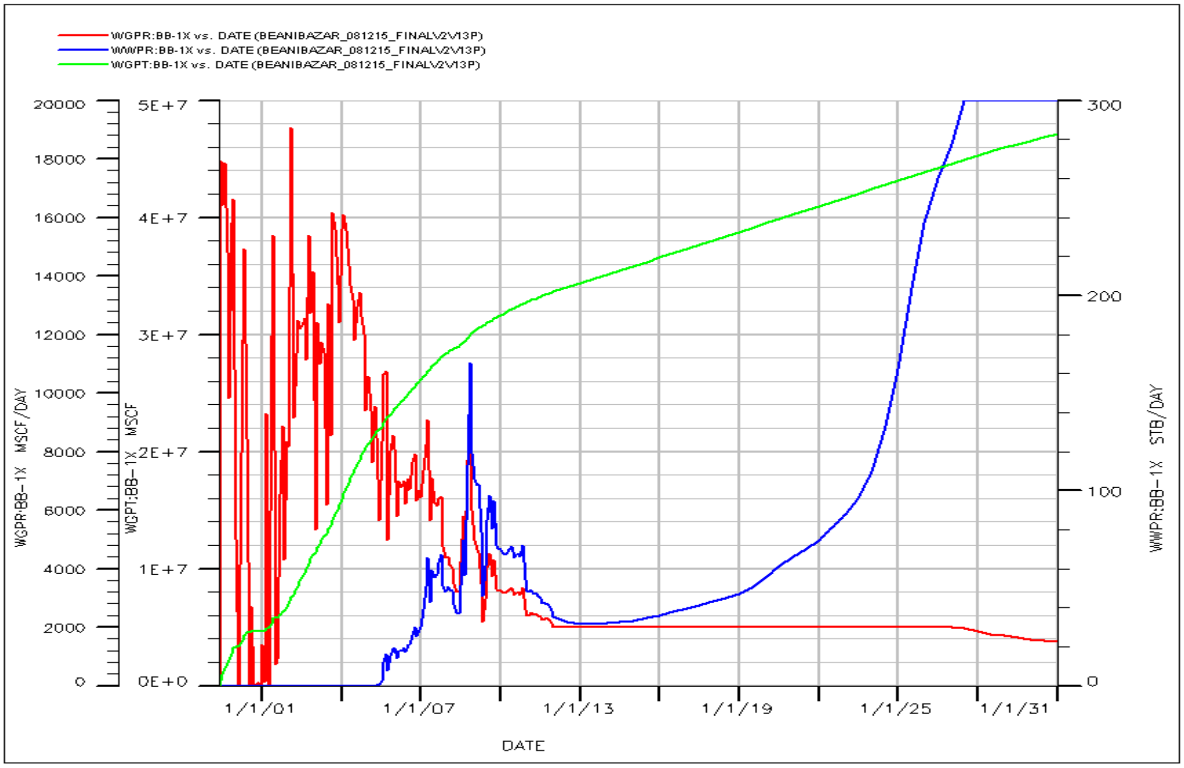


**Figure 32: BB-1Production Profile of Forecast Case 2: Impact of Water Production Limit 300 stb/d/well**

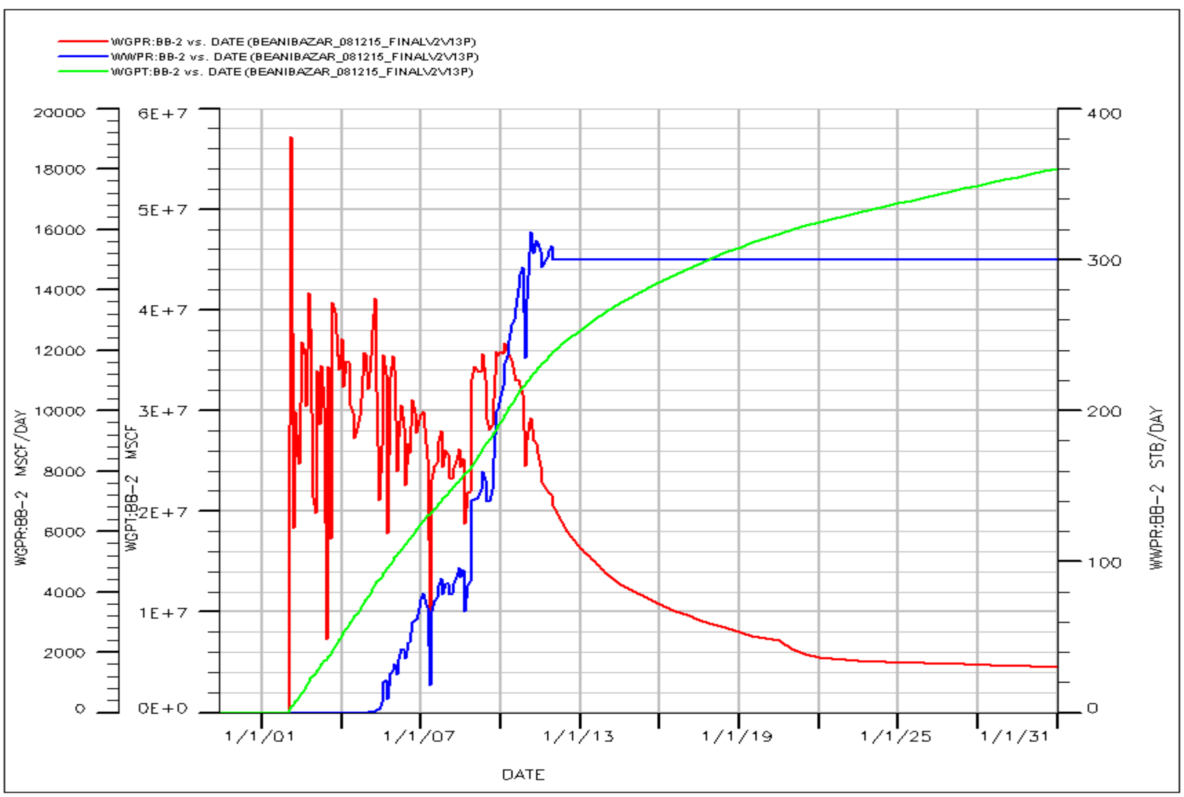


**Figure 33: BB-2 Production Profile of Forecast Case 2: Impact of Water Production Limit 300 stb/d/well**

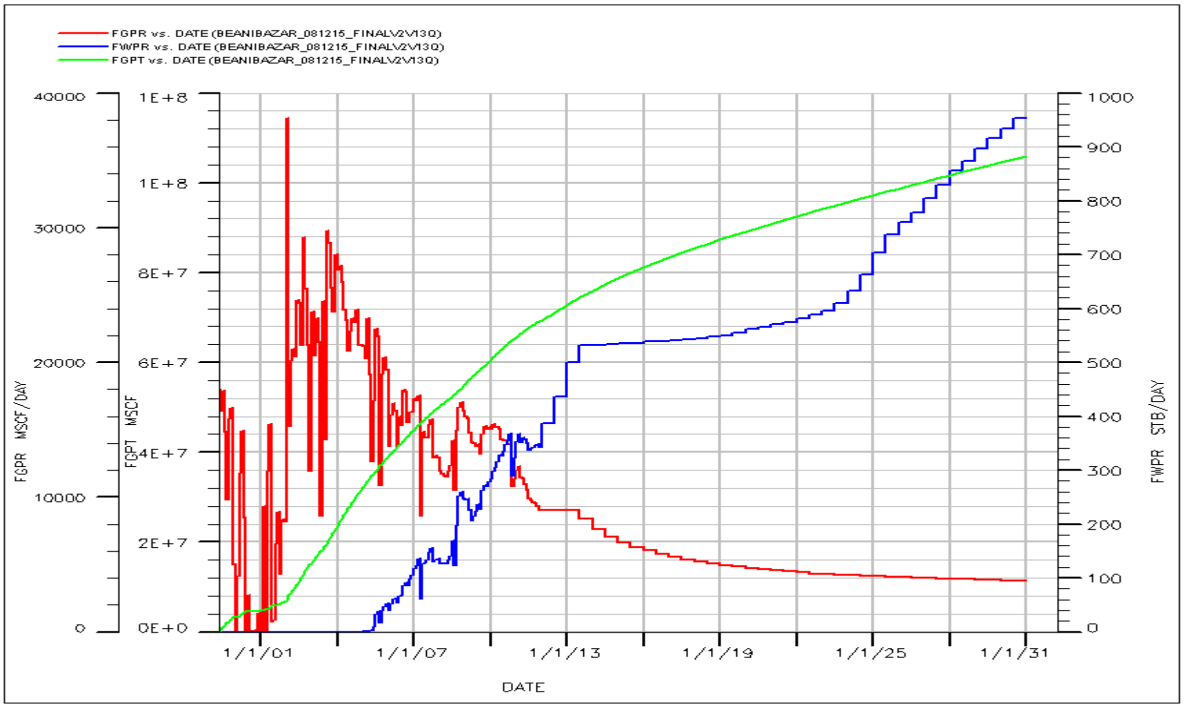


**Figure 34: Field Production Profile of Forecast Case 3: Impact of Water Production Limit 500 stb/d/well**

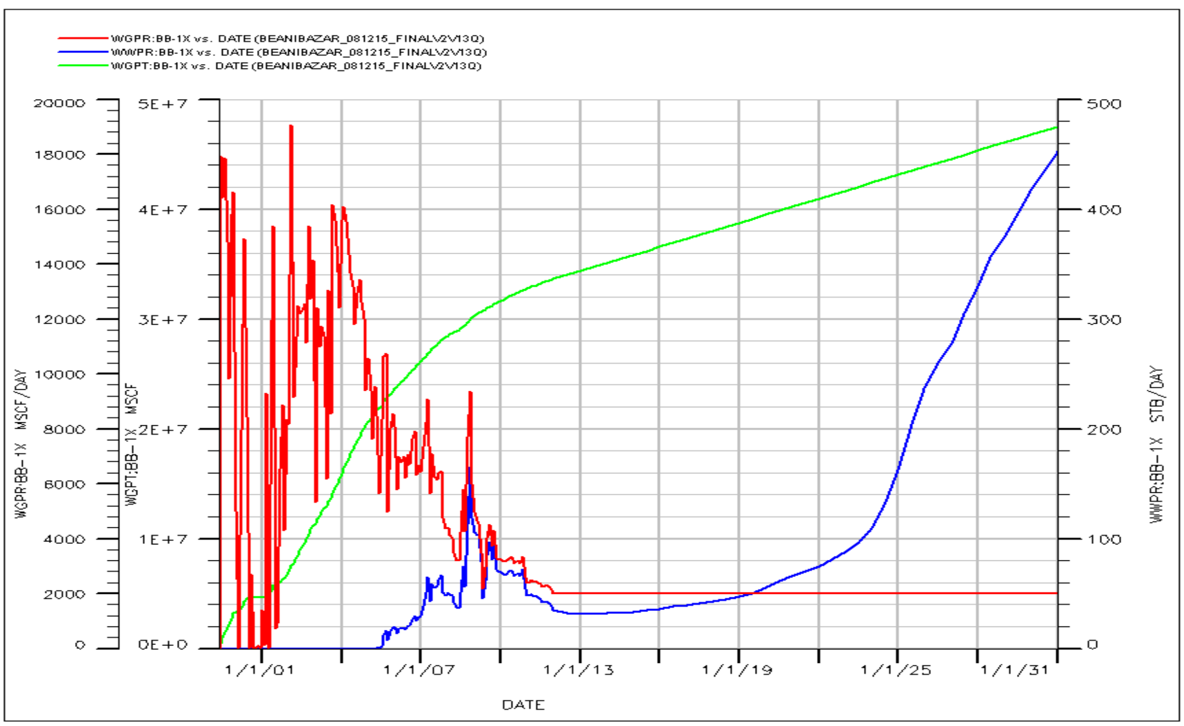


**Figure 35: BB-1 Production Profile of Forecast Case 3: Impact of Water Production Limit 500 stb/d/well**

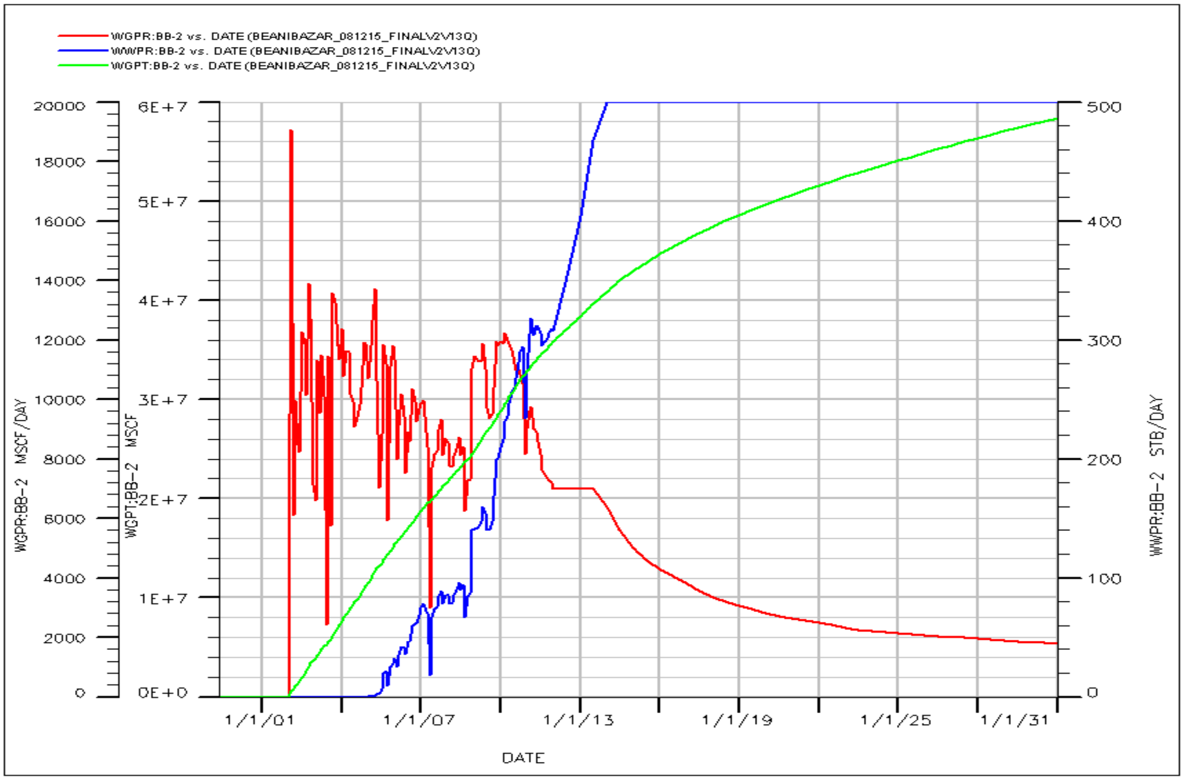


**Figure 36: BB-2 Production Profile of Forecast Case 3: Impact of Water Production Limit 500 stb/d/well**

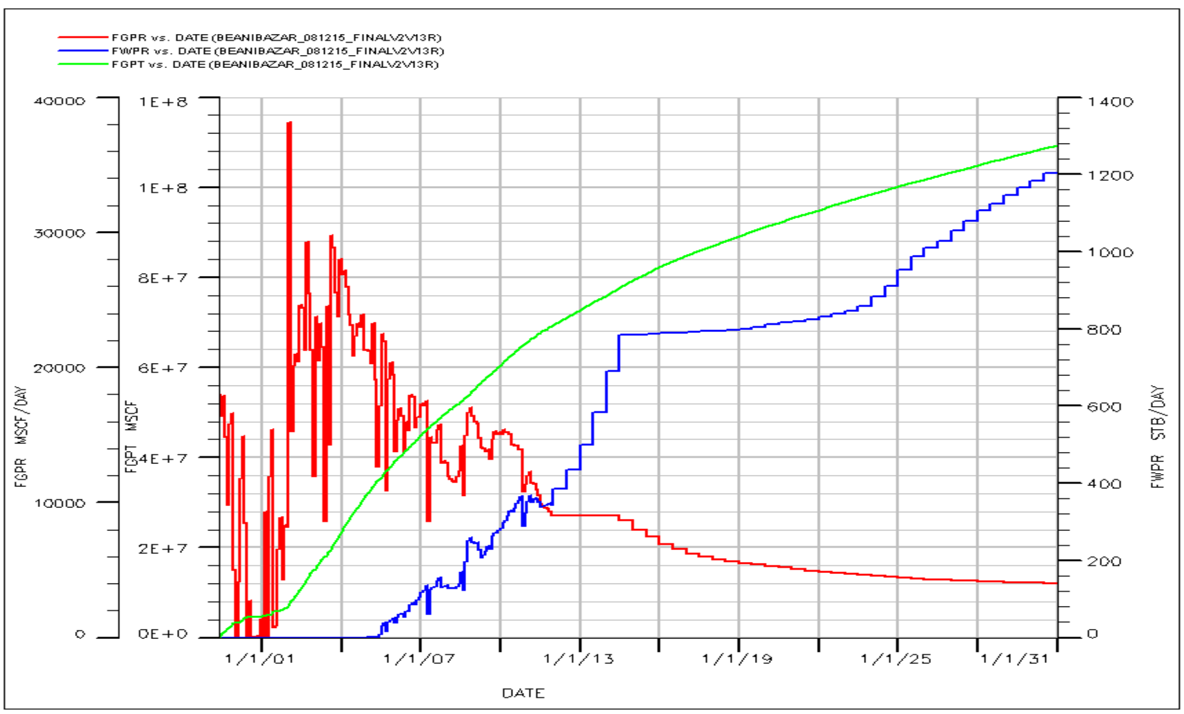


**Figure 37: Field Production Profile of Forecast Case 4: Impact of Water Production Limit 750 stb/d/well**

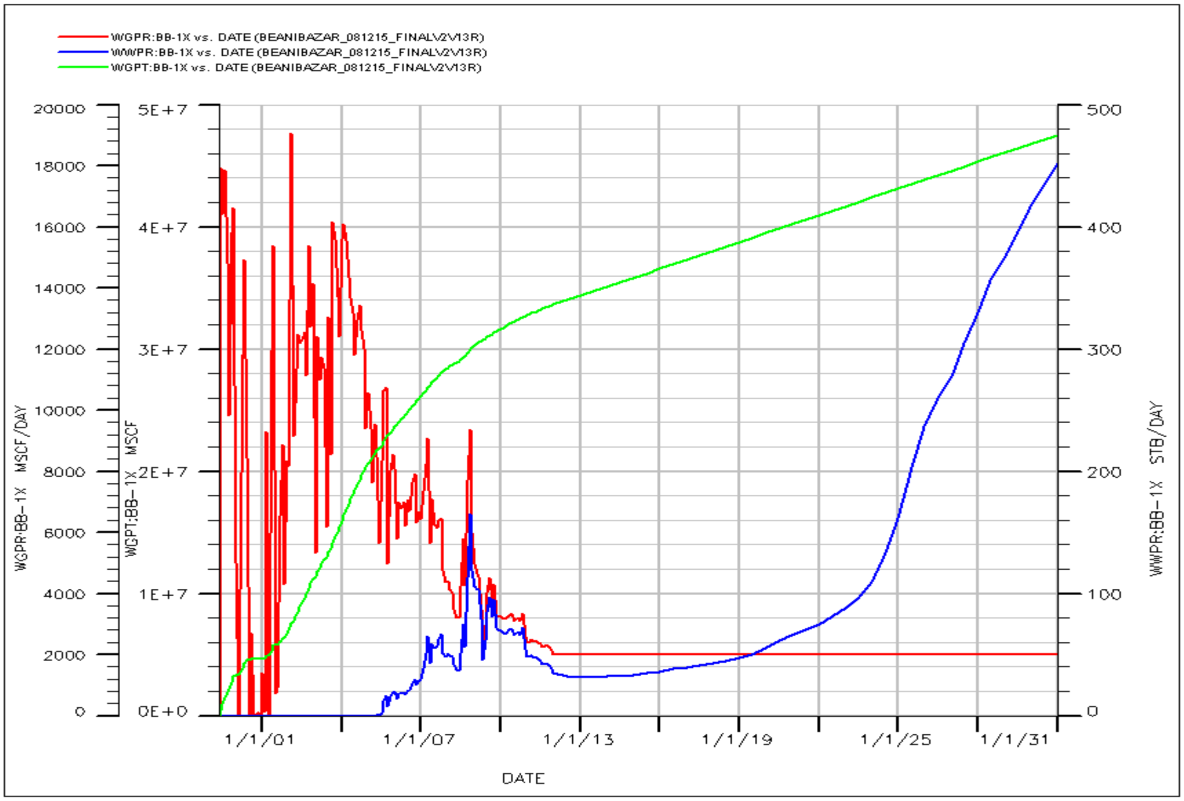


**Figure 38: BB-1 Production Profile of Forecast Case 4: Impact of Water Production Limit 750 stb/d/well**

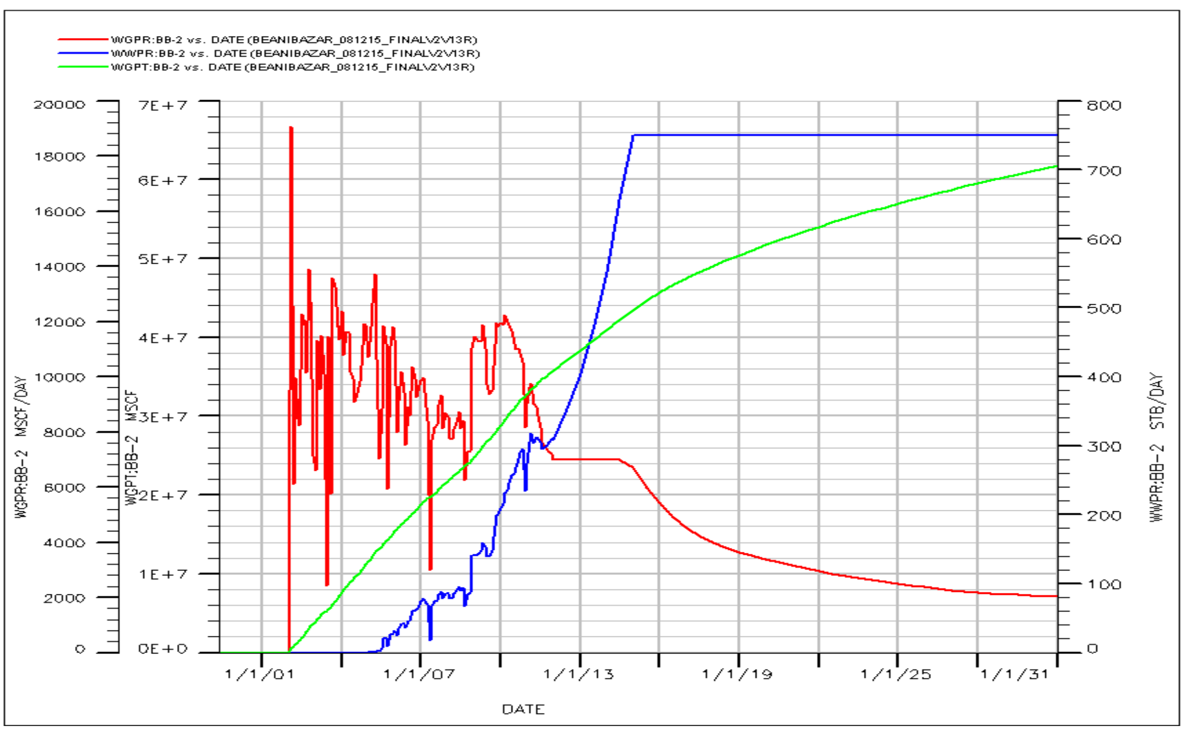


**Figure 39: BB.2 Production Profile of Forecast Case 4: Impact of Water Production Limit 750 stb/d/well**

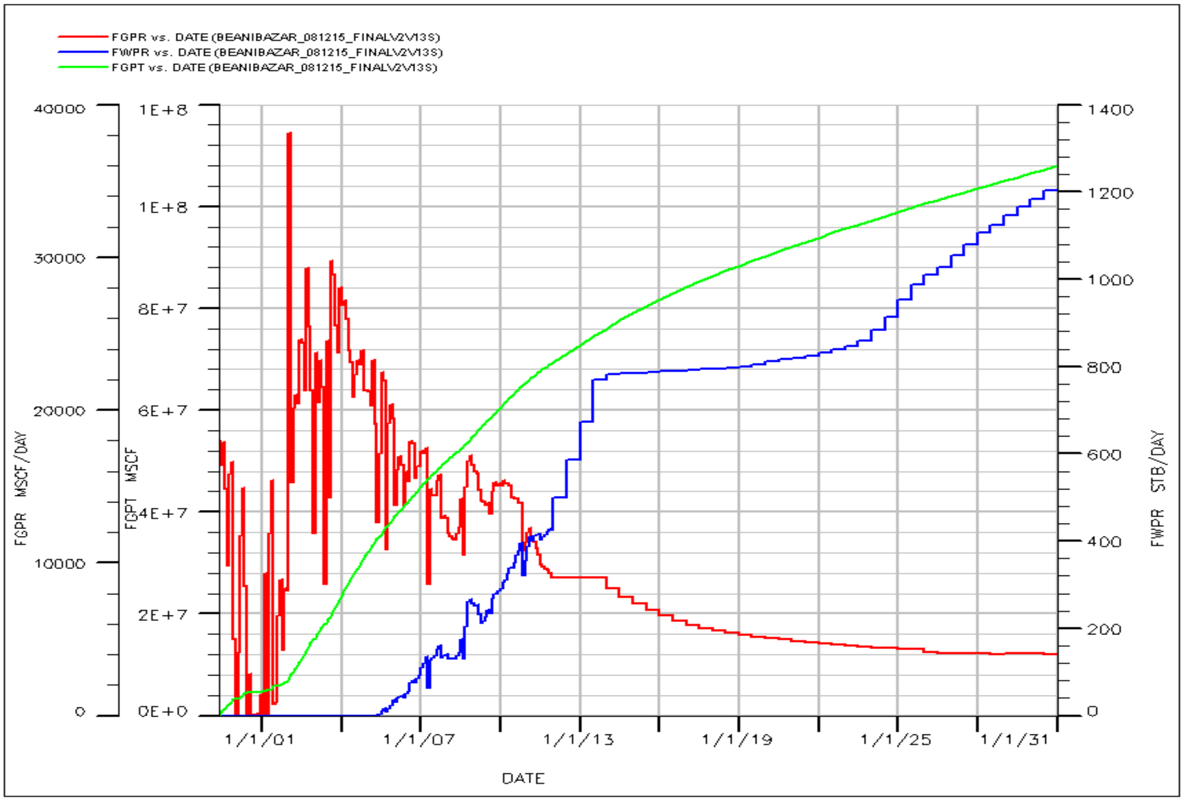


**Figure 40: Field Production Profile of Forecast Case 5: Impact of Water Production Limit 750 stb/d/well + 50 ft Squeezed off in Upper Sand**

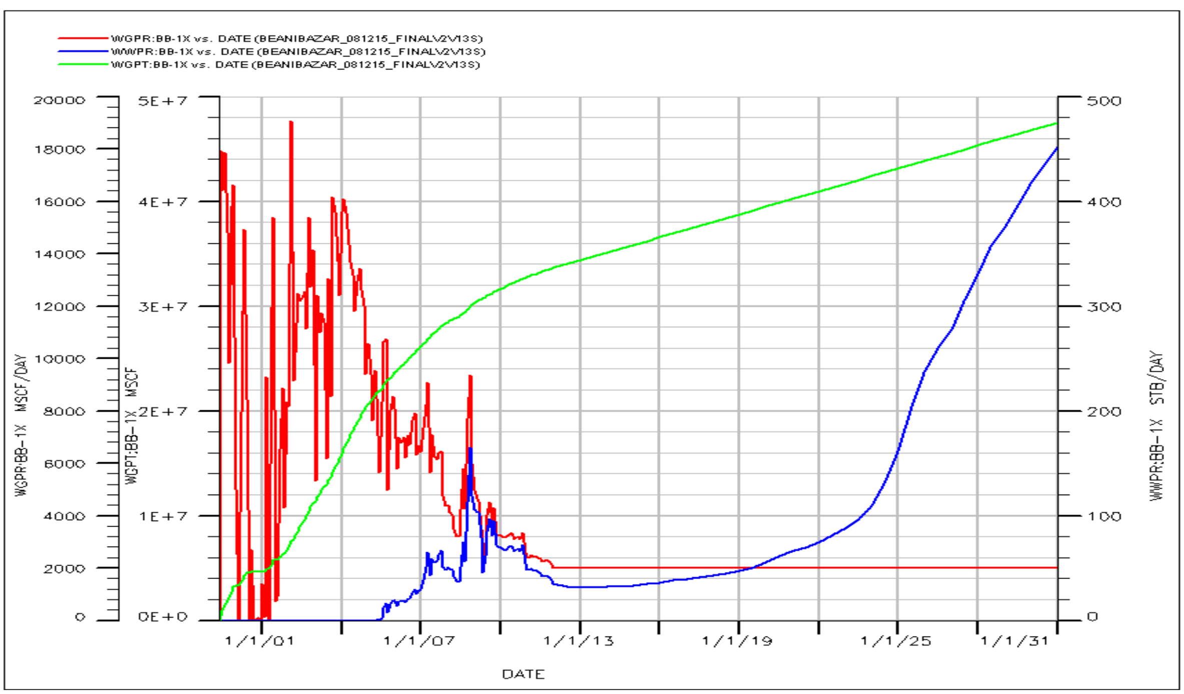


**Figure 41: BB-1 Production Profile of Forecast Case 5: Impact of Water Production Limit 750 stb/d/well + 50 ft Squeezed off in Upper Sand**

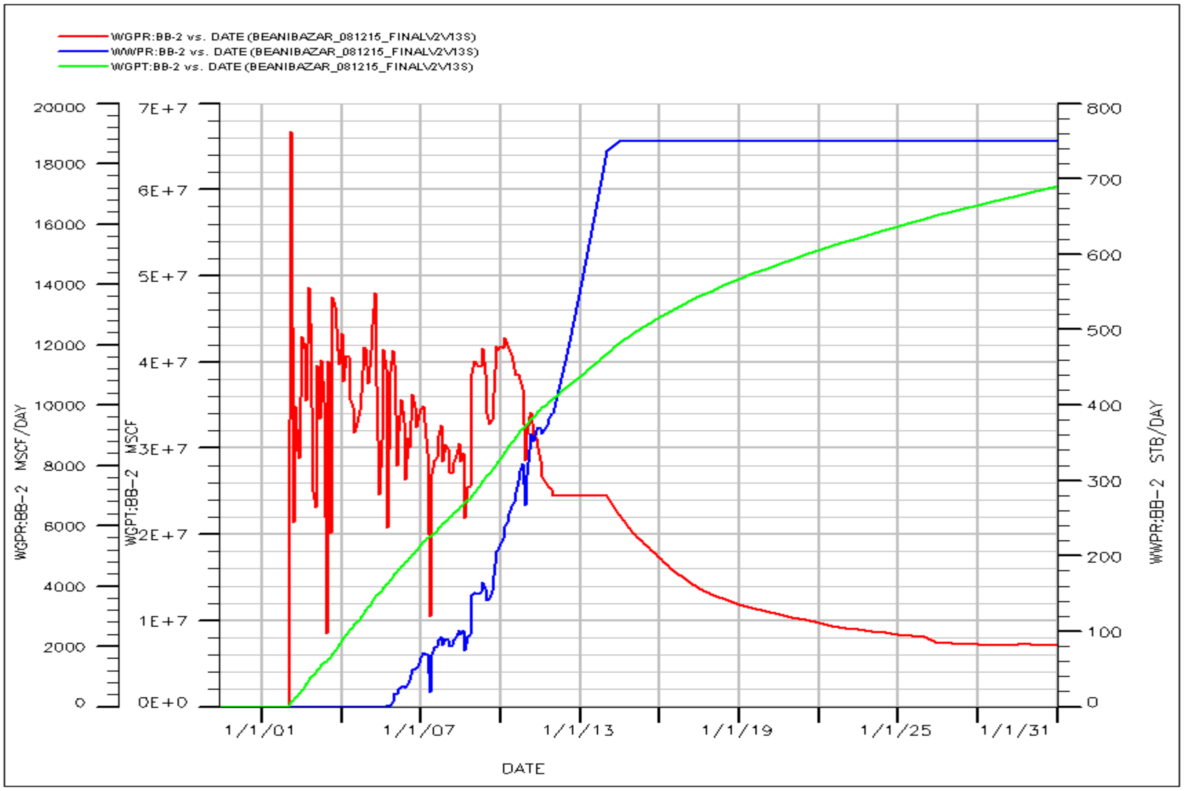


**Figure 42: BB-2 Production Profile of Forecast Case 5: Impact of Water Production Limit 750 stb/d/well + 50 ft Squeezed off in Upper Sand**

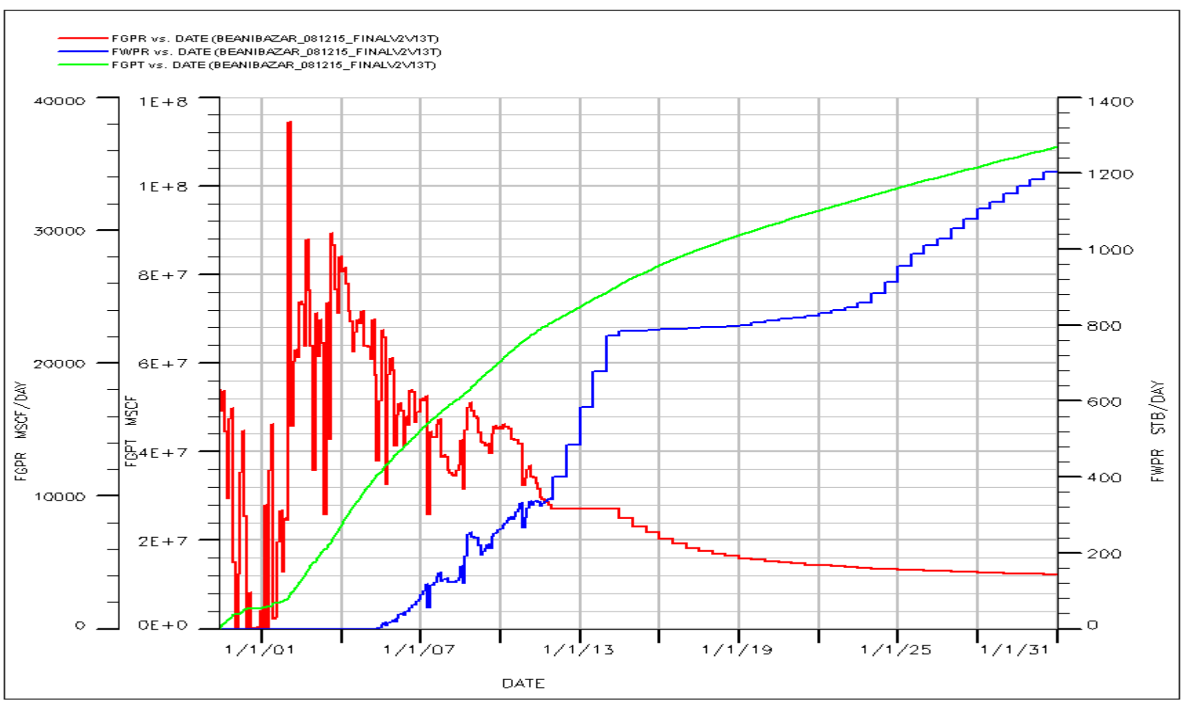


**Figure 43: Field Production Profile of Forecast Case 6: Impact of Water Production Limit 750 stb/d/well + 50 ft Squeezed off in Upper Sand + 80 ft Squeezed off in Lower Sand**

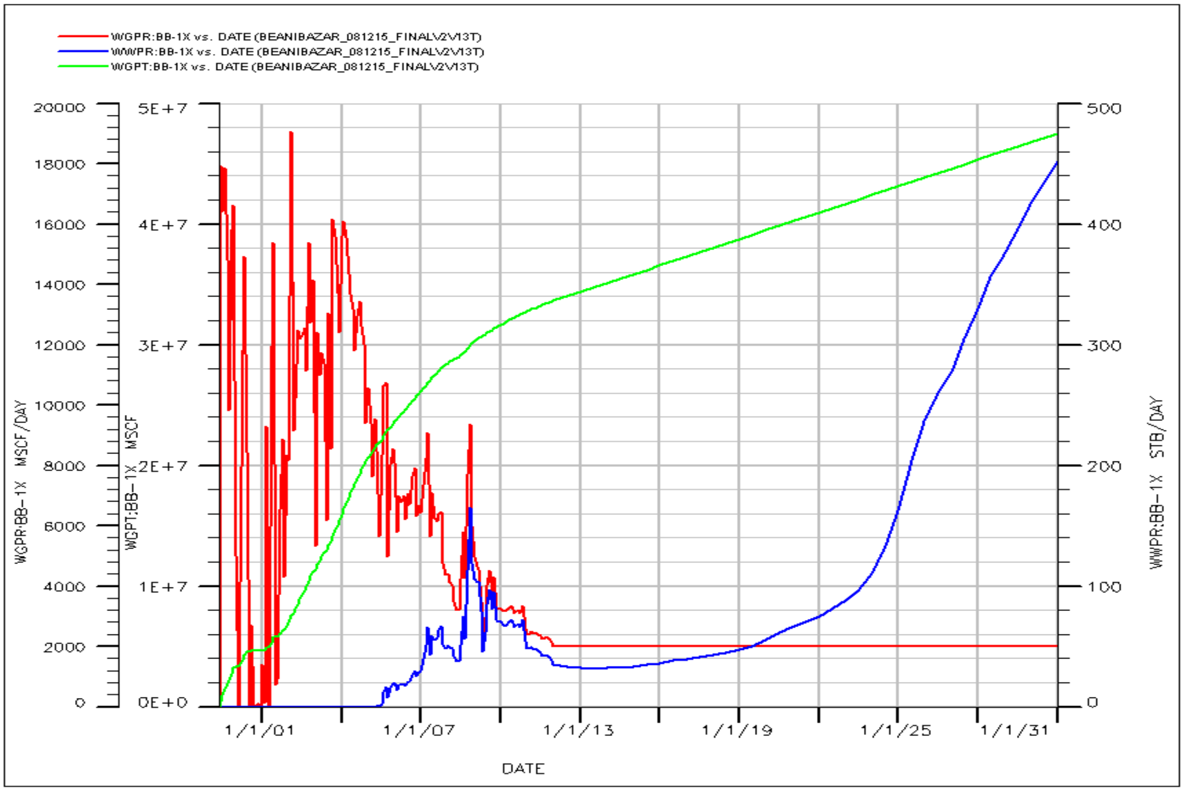


**Figure 44: BB-1 Production Profile of Forecast Case 6: Impact of Water Production Limit 750 stb/d/well + 50 ft Squeezed off in Upper Sand + 80 ft Squeezed off in Lower Sand**

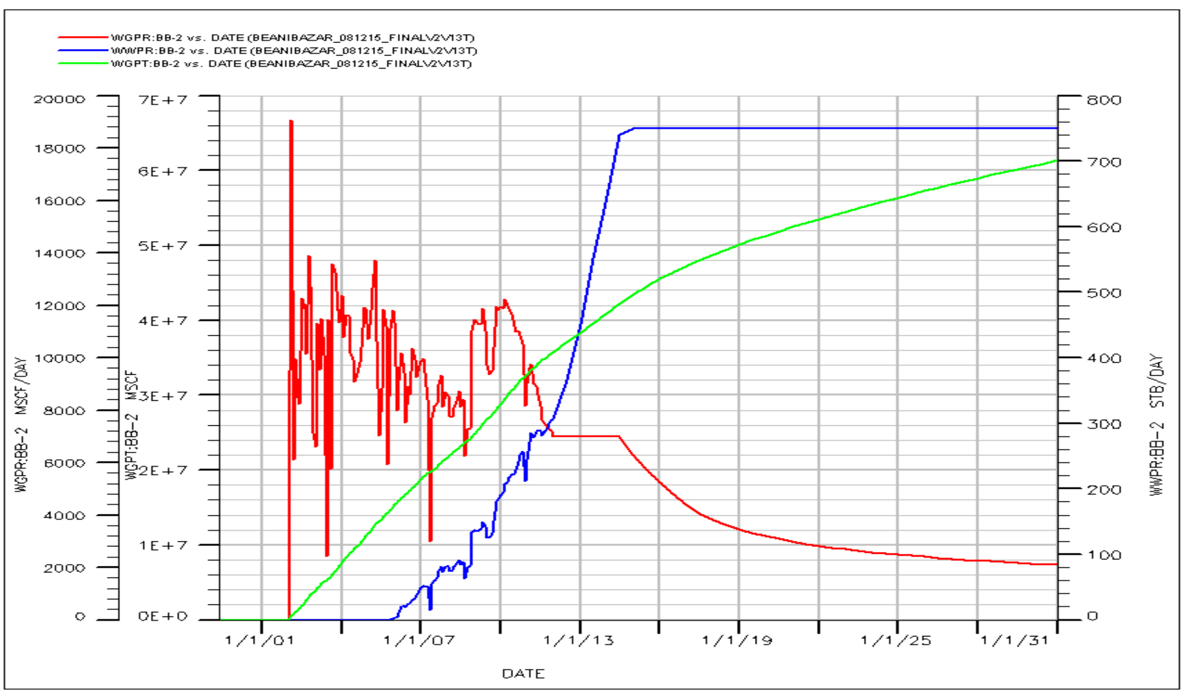


**Figure 45: BB-2 Production Profile of Forecast Case 6: Impact of Water Production Limit 750 stb/d/well + 50 ft Squeezed off in Upper Sand + 80 ft Squeezed off in Lower Sand**

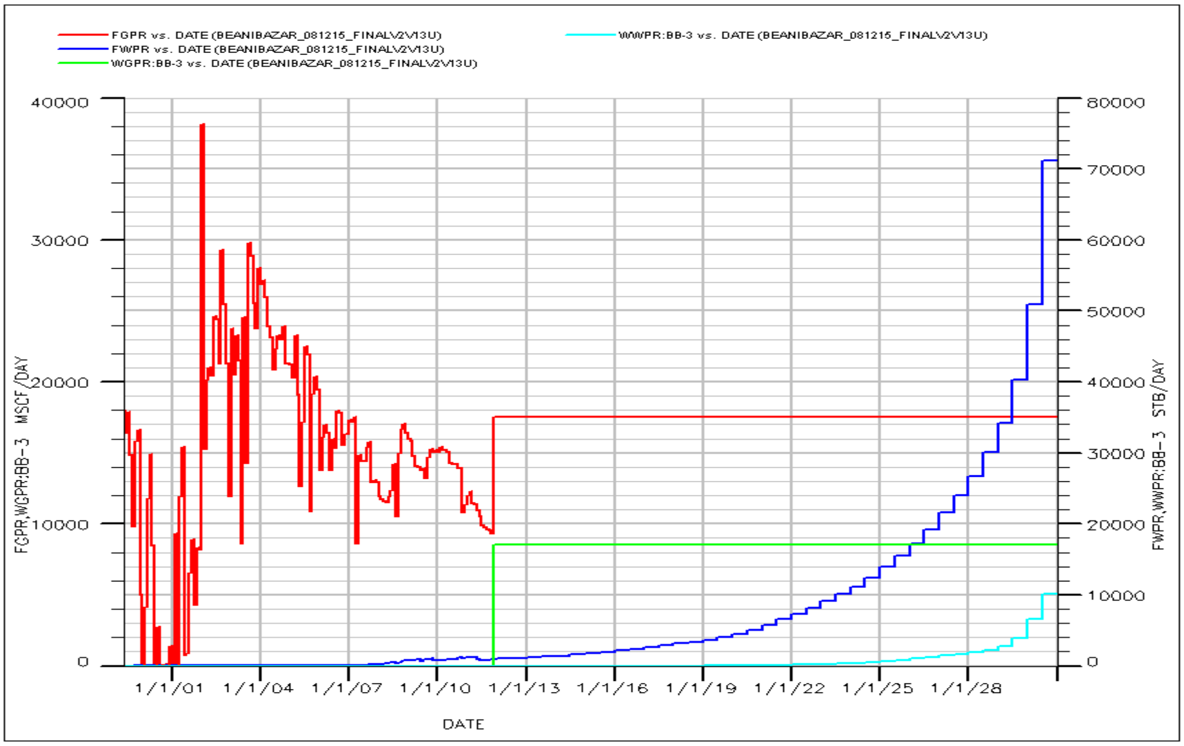


**Figure 46: Field and BB-3 Production Profile of Forecast Case 7: Impact of Drilling One Additional Well BB-3 in Southern Flank**

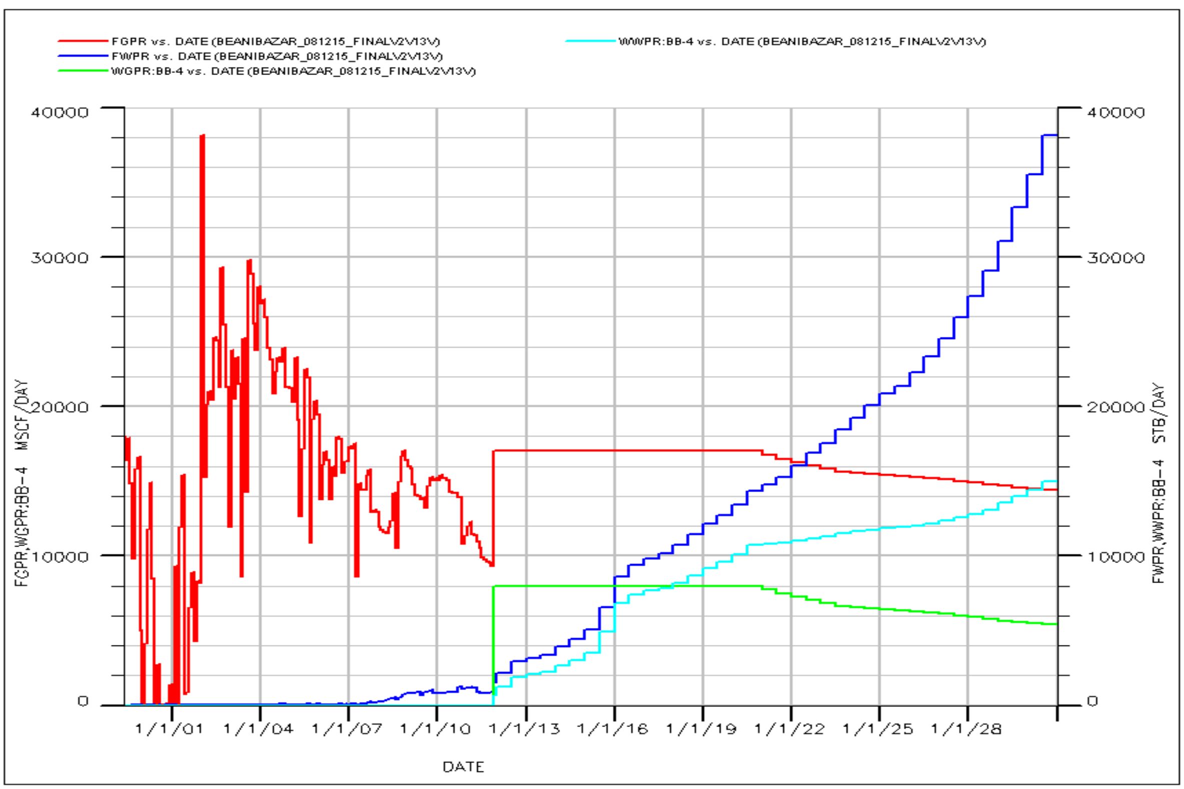


**Figure 47: Field and BB-4 Production Profile of Forecast Case 8: Impact of Drilling One Additional Well BB-4 in Western Flank**

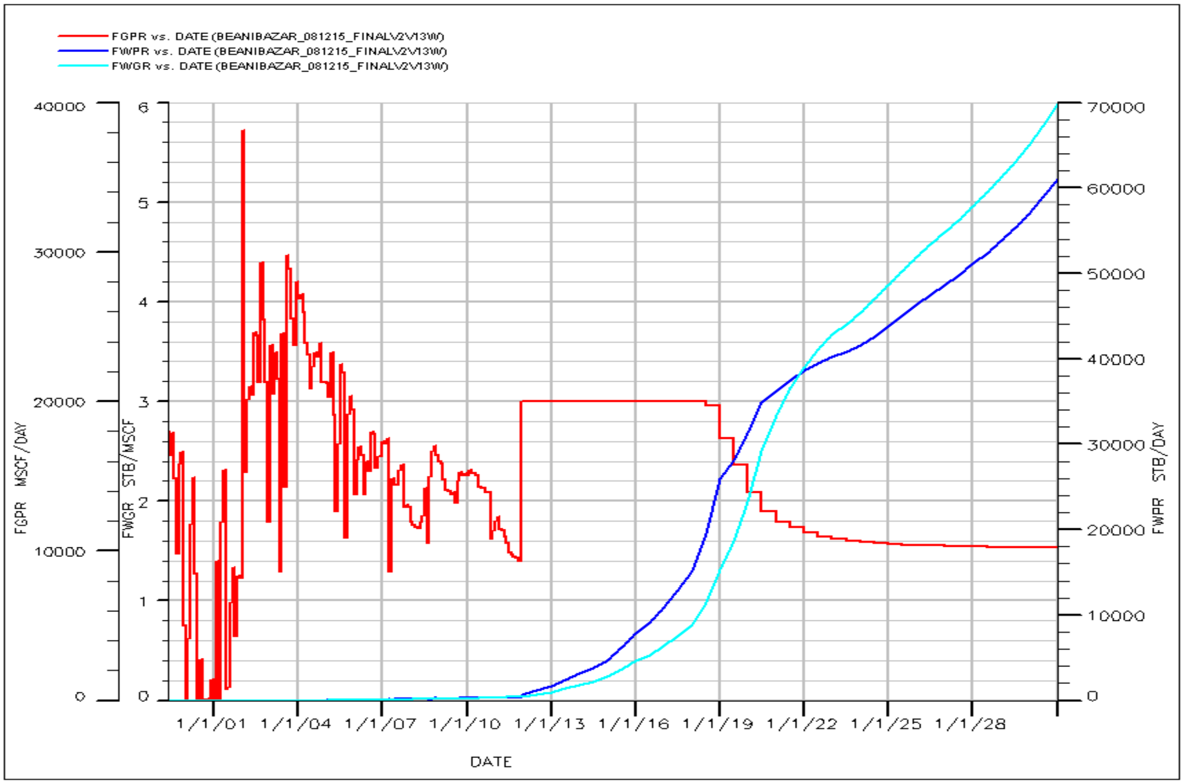


**Figure 48: Field Production Profile of Forecast Case 9: Rate Sensitivity 10000 Mscf/d for both wells**

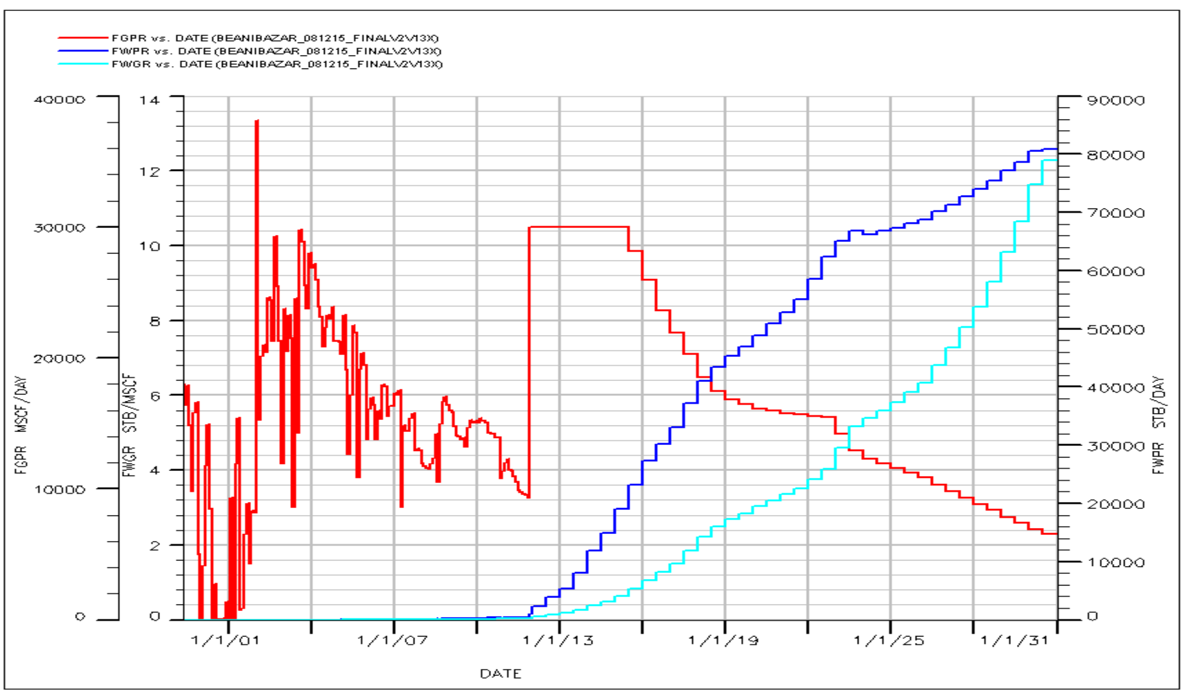


**Figure 49: Field Production Profile of Forecast Case 10: Rate Sensitivity 15000 Mscf/d for both wells**

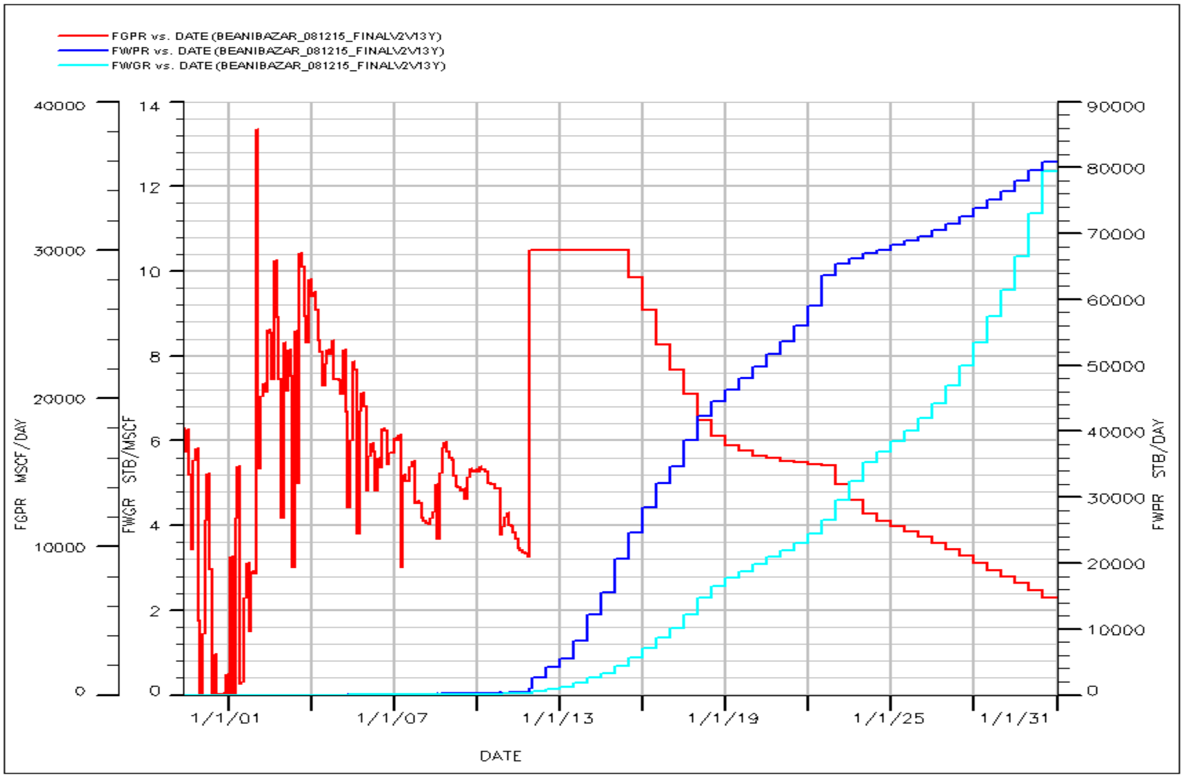


**Figure 50: Field Production Profile of Forecast Case 11: Rate Sensitivity 15000 Mscf/d for both wells + 50 ft Squeezed off in Upper Sand and 80 ft Squeezed off in Lower Sand**

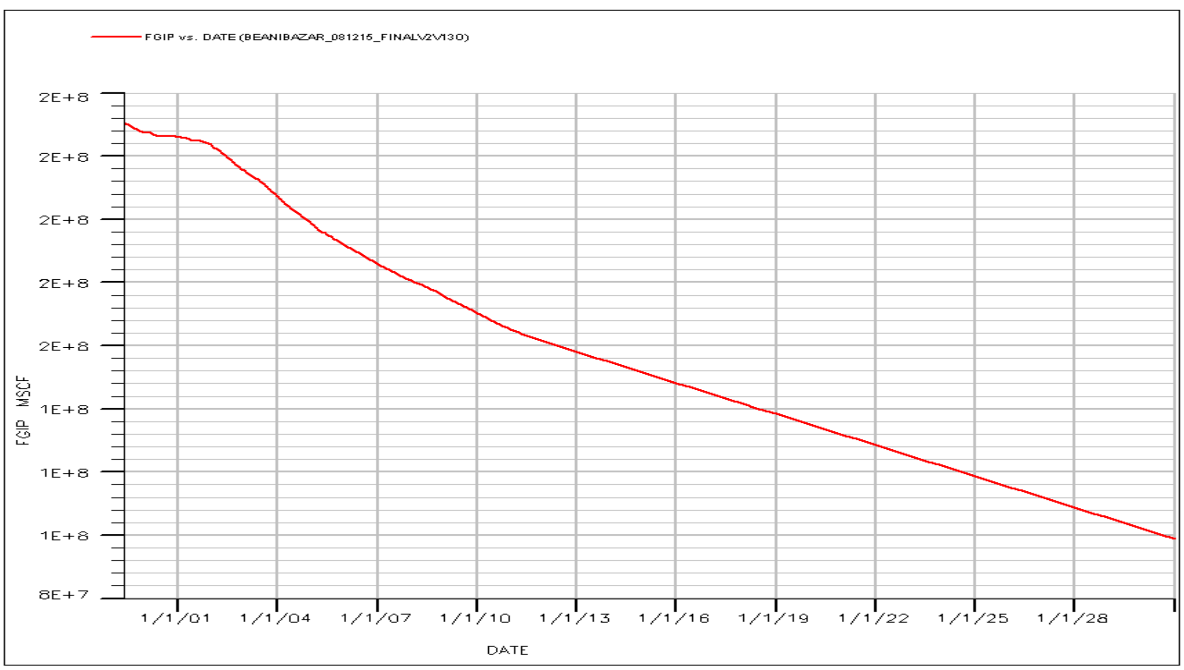


**Figure 51: Field Gas Initially In Place (GIIP) for Forecast Case 1: Do Nothing Case**

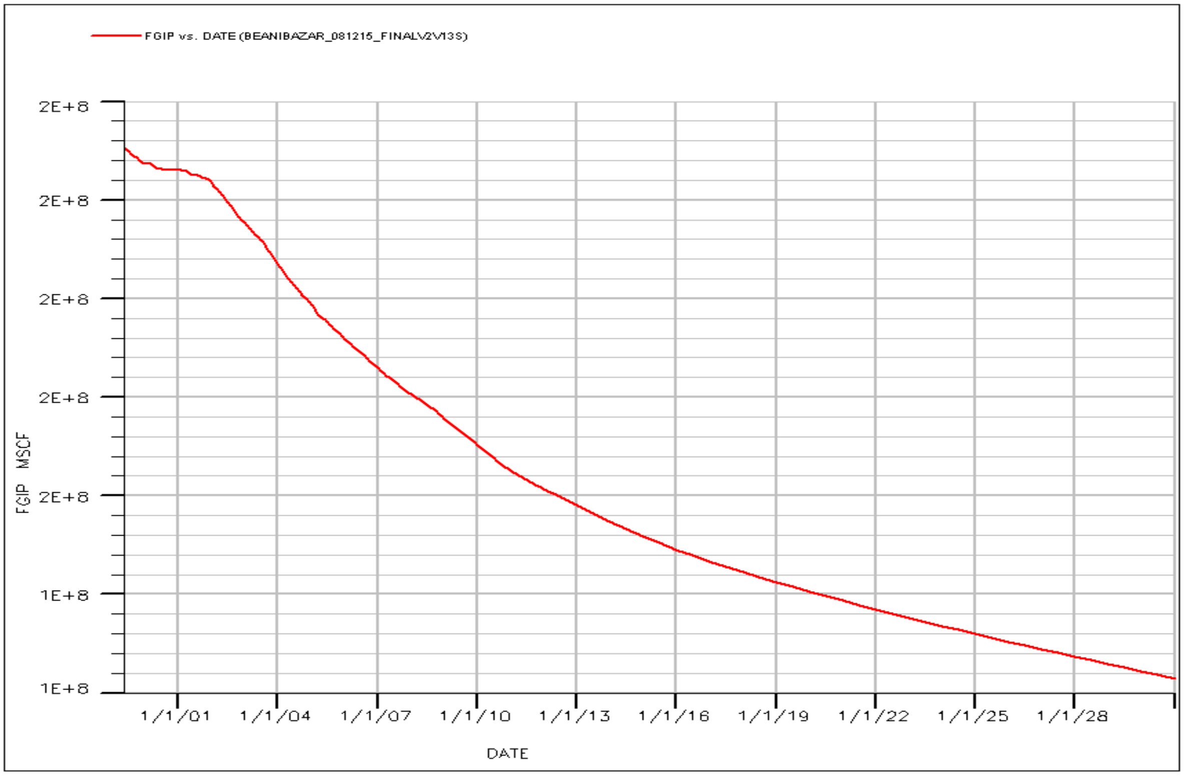


**Figure 52: Field Gas Initially In Place (GIIP) for Forecast Case 5**

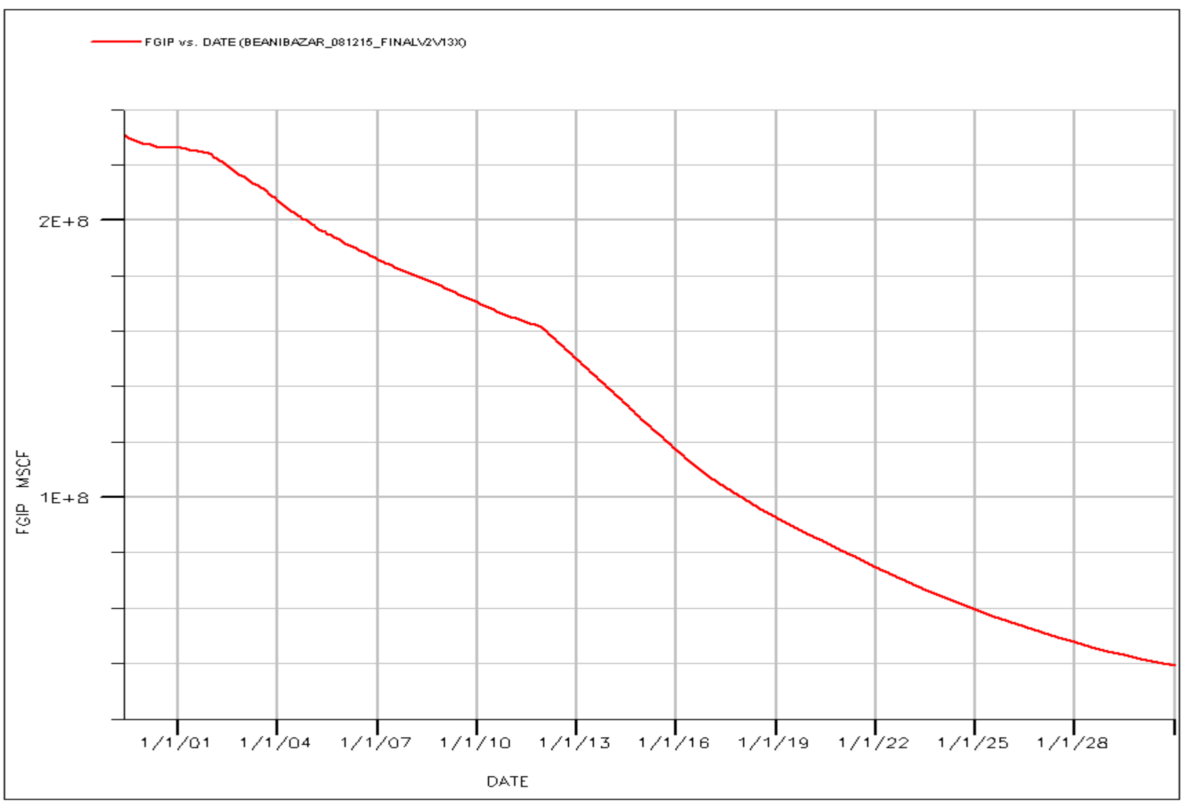


**Figure 53: Field Gas Initially In Place (GIIP) for Forecast Case 11**

# CHAPTER 6

## RESERVE ESTIMATION

## 6.1 PREVIOUS WORKS ON RESERVE ESTIMATION

### 6.1.1 RESERVE ESTIMATES BY IKM:

Intercomp-Kanata Management (IKM) worked on the geological, geophysical and petrophysical survey of six reservoirs including Beani Bazar gas field in Bangladesh under the Second Gas Development Project (SGDP), Project Implementation Unit (PIU) of Petrobangla, After constructing the contour map and geological model and other works, the company showed the delineation of areas of proved, probable and possible reserves of six reservoirs, both laterally and vertically. As per Intercomp-Kanata Management (IKM), the reserve estimation of Beani Bazar gas field was as follows:

| Sand | GIIP by Volumetric Calculations by IKM |
|---|---|
| Upper Sand | 187.0 |
| Lower Sand | 56.1 |
| **Total** | **243.1** |

**Table 3: GIIP Estimates by IKM**

### 6.1.2 RESERVE ESTIMATES BY ECL/RPS ENERGY:

The Exploration Company Limited (ECL), presently merged with RPS Energy, a British company, conducted a reservoir study on 14 gas fields of Petrobangla located in Bangladesh from 2004 to 2009 under the Reservoir Management Project (RMP) of Petrobangla. Beani Bazar gas field was one of those 14 fields.

**1**. RPS Energy constructed a geological model of Beani Bazar field using Petrel software based on the top and base seismic input surfaces. Following the structural modeling, a facies model was created and petrophysical reservoir properties were populated within these facies using a stochastic method to create a P50 model.

**2.** Also, probabilistic volumetric analysis (Monte Carlo) was undertaken using REP software to determine P10, P50 and P90 GIIP estimates based upon the input values such as GRV, net-to-gross, porosity and water saturation of the Petrel Model.for this field.

**3.** RPS Energy constructed a simulation model of Beani Bazar gas field using Eclipse simulator. They applied the simulation study of Beani Bazar field to determine the GIIP compared with the results of the REP work, Petrel Geo-modeling work. The Gas Initially I n-Place (GIIP) estimated from volumetric calculations and as per the ECLIPSE™ model was as follows:

## Result:

| Sand | GIIP by Volumetric Analysis using Petrel Software, Bcf, P50 (2009) | GIIP by Volumetric Analysis using REP Software, Bcf, P50 (2009) | GIIP by Simulation Method using Eclipse Software, Bcf (2009) |
|---|---|---|---|
| Upper Sand | 163.4 | 133.0 | 163.5 |
| Lower Sand | 67.5 | 34.9 | 67.2 |
| **Total** | **230.9** | **167.9** | **230.7** |

**Table 4: GIIP Estimates by RPS Energy**

## 6.2 RESERVE FROM PRESENT STUDY:

After the simulation model was run based on the latest production data till December, 2011, the following GIIP was achieved:

| Sand | GIIP by Simulation Method using Eclipse Simulator, Bcf, (2011) |
|---|---|
| Upper Sand | 163.5 |
| Lower Sand | 67.3 |
| **Total** | **230.8** |

**Table 5: GIIP Estimates in 2011**

From above table, it can be said that the main reserve of Beani Bazar field lies in the upper gas sand with very little gas being contributed from the lower gas sand. The proved Gas Initially In Place (GIIP) in 2011 was 163.5 Bcf and 67.3 Bcf respectively for the upper and lower gas sand. Total gas production from May 1999 to December, 2011 was 38.71 Bcf from the lower gas sand and 36.94 Bcf from the upper gas sand which is 22.59 % of GIIP from Upper Gas Sand and 57.51 % of GIIP from Lower Gas Sand.

# CHAPTER 7

## CONCLUSION AND RECOMMENDATIONS

Based on the result of simulation and literature review, the following conclusions and recommendations can be made:

## 7.1 CONCLUSION

1. The production optimization of Beani Bazar gas field can be achieved by using the simulation method. In this thesis work, 11 (Eleven) different prediction cases were run up to 2031 to increase the recovery factor. The best case can be chosen after analyzing the recovery results.
2. The parameters that affected the recovery factor for production optimization were gas production rate, water production rate, well location, squeezing of perforation, change of well bore diameter, different bottom hole pressures etc. The simulation method was used to investigate the relationship between these parameters and to determine how they could be controlled in order to achieve the production optimization.
3. There was no effect of relative permeability, capillary pressure, residual gas saturation on field production in natural drive case and also no effect for aquifer size.
4. From the simulation results, it was found that the remaining production life of this field lies between 12 to 31 years for different conditions of run. But huge water was coming. In spite of taking measures to prevent excessive water such as, water production limit 300 stb/d, 500 stb/d, 750 stb/d, the recovery factor found was less than 50% which was not satisfactory. For different gas rate (10000 Mscf/d, 15000 Mscf/d), the recovery factor was high enough for upper gas sand than other cases. On the other hand, lower gas sand was insensitive to the gas rate sensitivity. These cases can be considered for the future field development.
5. Gas recovery was more and quicker in enhanced gas production rate (15000 Mscf/d) cases. By keeping the water production limit of 750 stb/d and the bottom perforation squeezed by 50 ft in upper gas sand 80 ft in lower gas sand, there was a satisfactory recovery factor. The recovery factor was

77.06% for upper gas sand and 98.21% for lower gas sand. But there would be the question of cost involvement to handle the huge water.

6. It was observed that large amount of water produced during the simulation run. May be, there was a large aquifer from which encroachment of water was occurring. The water production may be happened by the expansion of connate water.

7. The most effective result was found from the cases of drilling of new wells in two different well locations – southern and western flank. The recovery factor for southern flank was 87.85% which was higher than that of western flank (82.19%). These cases can be considered for the future development of the field.

## 7.2 RECOMMENDATIONS

1. To achieve high gas recovery, one well should be drilled in southern or western flank of the reservoir. It would be economically feasible for the development of Beani Bazar field.
2. The surface facilities must be required to change to handle the huge water
3. Pressure survey for Beani Bazar gas field should be carried out to re-estimate the reserves, because it may be changed for the time being. Accordingly new well can be drilled as per the report to augment the production.
4. During the simulation run, minimum BHP was considered as 1000 psia. By decreasing this value, the ultimate recovery and plateau period can be increased. For this case, the re-selection of consumers would be required. Because one of the most important condition of agreement with the consumer was minimum supplying pressure 1000 psia.
5. Last but not least, the production optimization of a field largely depends on the construction of geological and simulation model. Even after these models are constructed, improper geological data or prediction can affect the gas recovery. Moreover, different gas rates or water rates, or other parameters can achieve the similar recoveries but the best case should be chosen from them.

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# NOMENCLATURE

| | |
|---|---|
| AQR | Aquifer Influx Rate |
| AQT | Total Aquifer Influx |
| BB | Beani Bazar |
| Bcf | Billion Cubic Feet |
| Bg | Gas Formation Volume Factor |
| bbl(s) | Barrels |
| bbl/MMscf | Barrels per Million Standard Cubic Feet |
| BHP | Bottom Hole (Static) Pressure |
| Condensate | Liquid Hydrocarbons which are sometimes produced with natural gas and liquids derived from natural gas |
| CGR | Condensate-Gas-Ratio |
| CGRH | Condensate-Gas-Ratio History |
| FVF | Formation Volume Factor |
| FWH | Flowing Well Head |
| FBHP | Flowing Bottom Hole Pressure |
| FTHP | Flowing Tubing Head Pressure |
| FGPR | Field Gas Production Rate |
| FGPRH | Field Gas Production Rate History |
| ft | Feet |
| ftss | Depth in Feet Below Sea Level |
| Gp | Cumulative Gas Production |
| GDT | Gas Down To |
| GIIP | Gas Initially In Place |
| GPR | Gas Production Rate |
| GPRH | Gas Production Rate History |
| GOC | Gas Oil Contact |
| GWC | Gas Water Contact |
| GOR | Gas Oil Ratio |
| HCPV | Hydro Carbon Pore Volume |
| IKM | Intercom Kanata Management |
| $K_r$ | Relative Permeability |

| | |
|---|---|
| Krg | Relative Permeability of Gas |
| $K_v$ | Vertical Permeability |
| Krw | Relative Permeability of Water |
| M | Thousand |
| MM | Million |
| MD | Measured Depth |
| mD | Permeability in millidarcies |
| Mscf/day | Thousands of Standard Cubic Feet per Day |
| MMscf/day | Millions of Standard Cubic Feet per Day |
| NTG | Net to Gross Ratio |
| OGIP | Original Gas In Place |
| OOIP | Original Oil In Place |
| phi | Porosity Fraction |
| $p_i$ | Initial Reservoir Pressure |
| psia | Pounds Per Square Inch Absolute |
| PVT | Pressure Volume Temperature |
| rb | Barrel(s) at Reservoir Conditions |
| rb/Mscf | Barrel(s) at Reservoir Conditions per Thousand Standard Cubic Feet |
| RF | Recovery Factor |
| REP | Reserve Evaluation Program |
| Tx | Transmissibility |
| scf | Standard Cubic Feet Measured at 14.7 Pounds per Square Inch and 60°F |
| scf/d | Standard Cubic Feet per Day |
| scf/stb | Standard Cubic Feet per Stock Tank Barrel |
| $S_{wc}$ | Connate Water Saturation |
| stb | Stock Tank Barrels Measured at 14.7 Pounds Per Square Inch and 60° F |
| stb/d | Stock Tank Barrels per day |
| Sg | Gas Saturation |
| $S_w$ | Water saturation |

| | |
|---|---|
| THP | Tubing head pressure |
| THPH | Tubing pressure history |
| TVDSS | True Vertical Depth (Sub-Sea) |
| WBHPH | Well Bottom Hole Pressure History Match |
| WBP9 | Pressure Average for 9 Neighboring Inner Grid Cells |
| WGR | Water-Gas-Ratio |
| WGRH | Water-Gas-Ratio History |
| WCGR | Well Condensate-Gas-Ratio |
| WCGRH | Well Condensate-Gas-Ratio History |
| WGPR | Well Gas Production Rate |
| WGPRH | Well Gas Production Rate History |
| WWGR | Well Water-Gas-Ratio |
| WWGRH | Well Water-Gas-Ratio History |
| WTHP | Well Tubing Head Pressure |
| WTHPH | Well Tubing Pressure History |
| Z | Compressibility Factor |

# CHAPTER 8

## APPENDICES

## APPENDIX – A (DATA, DIAGRAM AND THEORY)

### 8.1 SUMMARY DATA

The summary data of Beani Bazar wells are shown in the the following table:

| | | |
|---|---|---|
| Well Name | : | **Beani Bazar-1 or BB-1X** |
| | | |
| Well Type | : | Vertical |
| | | |
| Location | : | Beani Bazar Town of Sylhet District, Bangladesh |
| | | |
| Location Type | : | Onshore |
| | | |
| Coordinates | : | Longitude: 2962199 meter, Lattitude: 782818 meter |
| | | |
| Geological Structure | : | Bhuban |
| | | |
| Company | : | Sylhet Gas Fields Limited Company (SGFL) |
| | | |
| Corporation | : | Bangladesh Oil, Gas and Mineral Corporation (Petrobangla) |
| | | |
| Ministry | : | Bangladesh Oil, Gas and Mineral Resources |
| | | |
| Drilling Depth (TVD) | : | 4109 meter |
| | | |
| Perforation Depth | : | 3452m – 3457m and 3460m – 3466m |
| | | |
| Sand Zone | : | Lower |
| | | |
| Spudd in Date | : | 20.11.1980 |
| | | |
| Completion date | : | 12.05.1981 |
| | | |
| Status | : | Gas Producing |

**Table 6: Summary Data of Well BB-1**

| | | |
|---|---|---|
| Well Name | : | **Beani Bazar-2 or BB-2** |
| | | |
| Well Type | : | Deviated |
| | | |
| Location | : | Beani Bazar Town of Sylhet District, Bangladesh |
| | | |
| Location Type | : | Onshore |
| | | |
| Coordinates | : | Longitude: 2962254 meter, Latitude: 784387 meter |
| | | |
| Geological Structure | : | Bhuban |
| | | |
| Company | : | Sylhet Gas Fields Limited Company (SGFL) |
| | | |
| Corporation | : | Bangladesh Oil, Gas and Mineral Corporation (Petrobangla) |
| | | |
| Ministry | : | Bangladesh Oil, Gas and Mineral Resources |
| | | |
| True Vertical Depth (TVD) | : | 3628 meter |
| | | |
| Perforation Depth | : | 3287m – 3298m and 3302m – 3303m |
| | | |
| Sand Zone | : | Upper |
| | | |
| Spudd in Date | : | 21.03.1988 |
| | | |
| Completion date | : | 16.07.1988 |
| | | |
| Status | : | Gas Producing |

**Table 7: Summary Data of Well BB-2**

## 8.2 WELL COMPLTION DIAGRAM

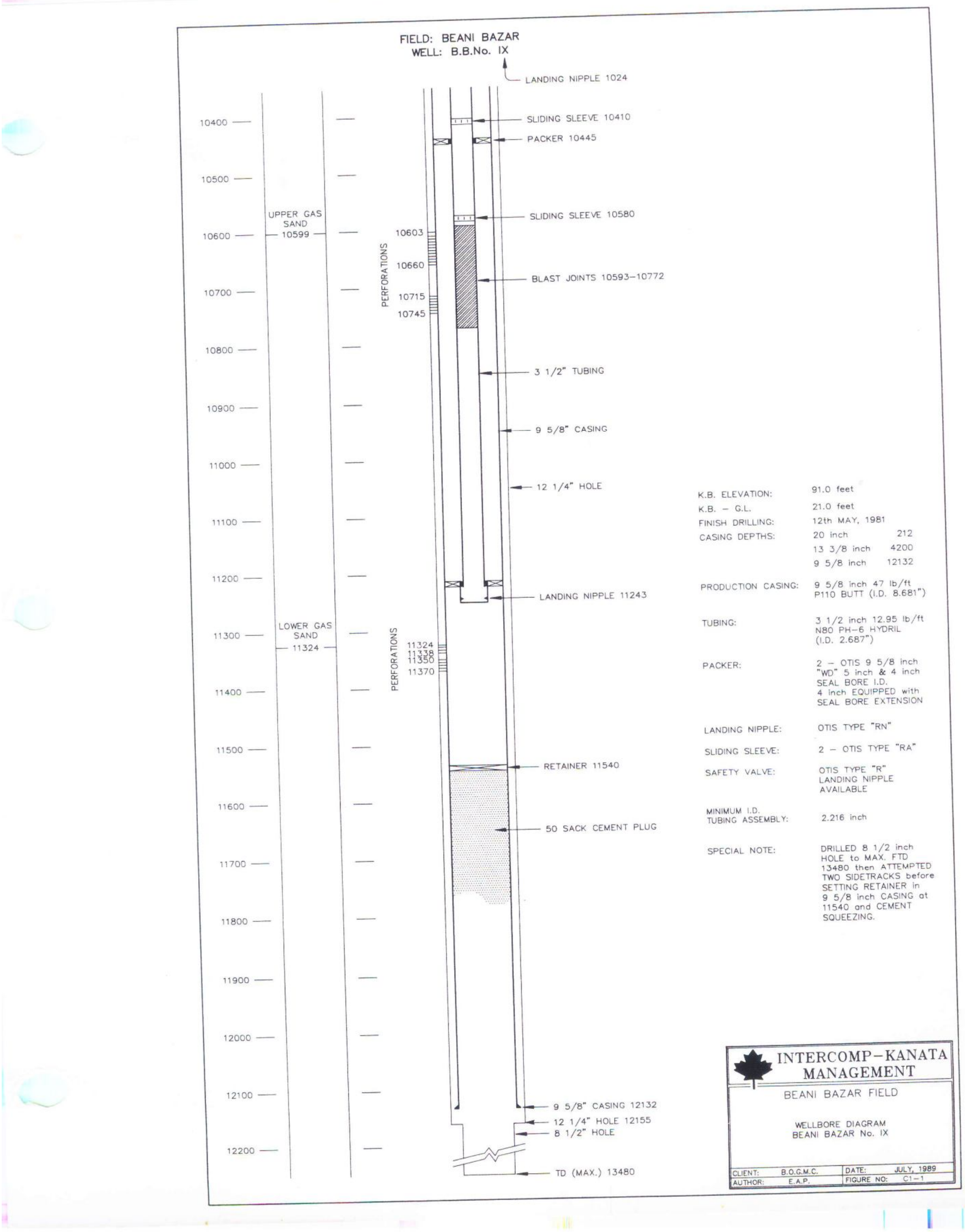


**Figure 54: Well Completion Diagram of BB-1X**

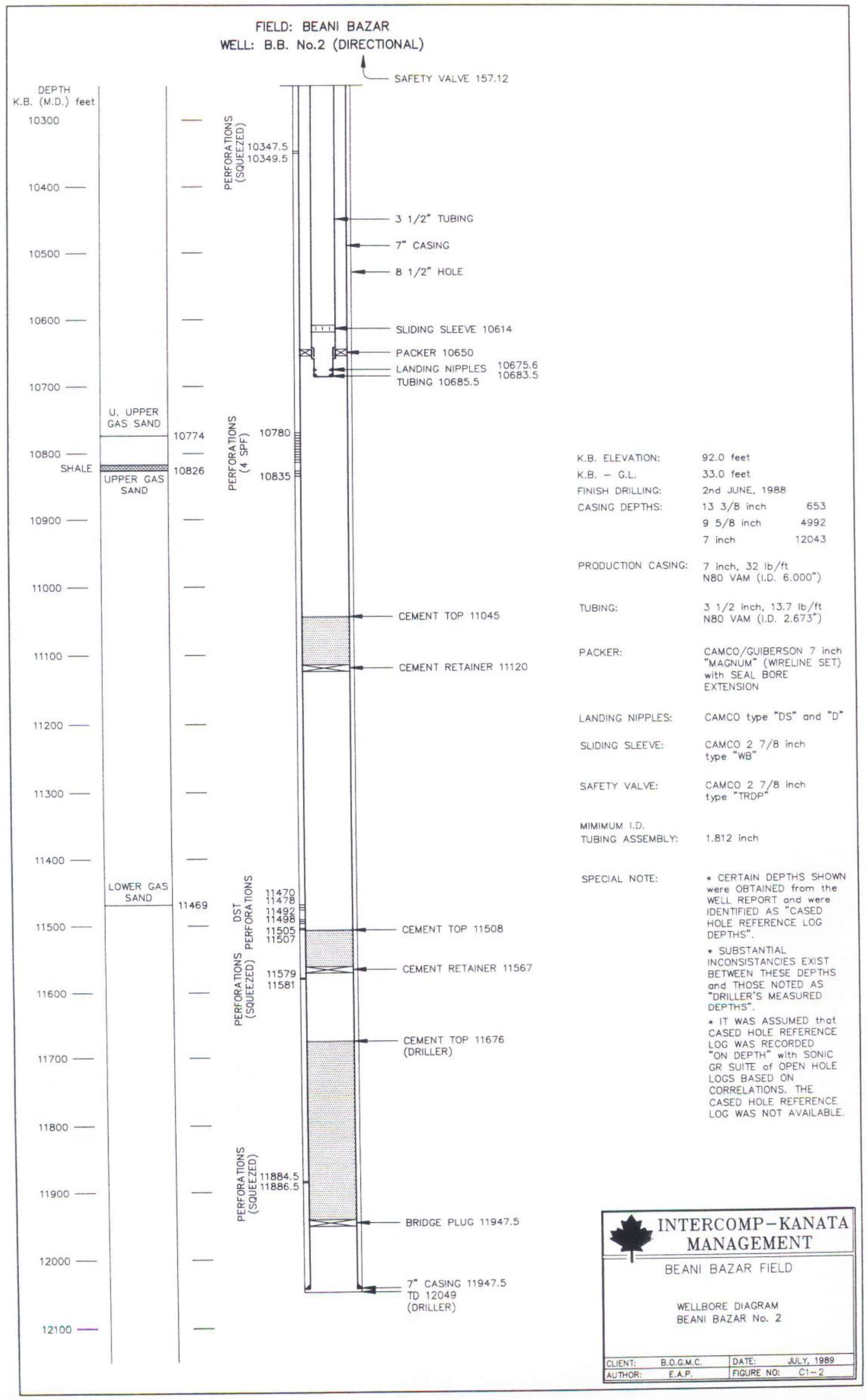


**Figure 55: Well Completion Diagram of BB-2**

## 8.3 RESERVOIR DRIVE MECHANISMS

Producing oil and gas needs energy. Usually some of this required energy is supplied by nature. The hydrocarbon fluids are under pressure because of their depth. The gas and water in petroleum reservoirs under pressure are the two main sources that help move the oil to the well bore and sometimes up to the surface. Depending on the original characteristics of hydrocarbon reservoirs, the type of driving energy is different.

### SOLUTION GAS DRIVE MECHANISM

When a newly discovered reservoir is below the bubble point pressure, there will be free gas as bubbles within the oil phase in reservoir. The reservoir pressure decreases as production goes on and this causes emerging and expansion of gas bubbles creating extra energy in the reservoir. These kinds of reservoirs are called as solution gas drive reservoirs. Crude oil under high pressure may contain large amounts of dissolved gas. When the reservoir pressure is reduced as fluids are withdrawn, gas comes out of the solution and displaces oil from the reservoir to the producing wells. The efficiency of solution gas drive depends on the amount of gas in solution, the rock and fluid properties and the geological structure of the reservoir. Recoveries are low, on the order of 10-15 % of the original oil in place (OOIP). Recovery is low, because the gas phase is more mobile than the oil phase in the reservoir. Solution gas drive reservoirs are usually good candidates fro water-flooding

### GAS CAP DRIVE RESERVOIRS

Sometimes, the pressure in the reservoir is below the bubble point initially, so there is more gas in the reservoir than the oilcan retain in solution. This extra gas, because of density difference, accumulates at the top pf the reservoir and forms a cap. These kinds of reservoirs are called a gas cap drive reservoir. In gas cap drive reservoirs, wells are drilled into the crude oil producing layer of the formation. As oil production causes a reduction in pressure, the gas in gas cap expands and pushes oil into the well bores. Expansion the gas cap is limited by the desired pressure level in the reservoir and by gas production after gas comes into production wells. Figure 5-1 Schematic of a Typical Gas Cap Reservoir

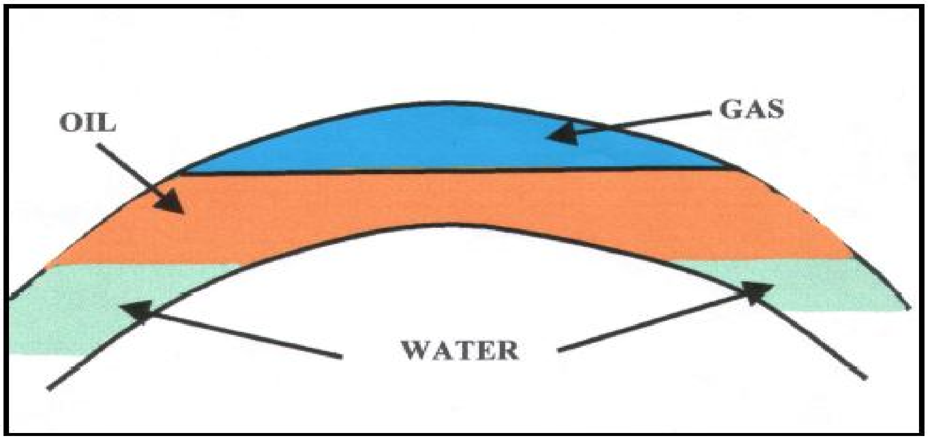


**Figure 56: Schematic of a Typical Gas Cap Reservoir**

## WATER DRIVE RESERVOIRS

Most oil or gas reservoirs have water aquifers. When this water aquifer is an active one, continuously fed by incoming water, then this bottom water will expand as pressure of the oil/gas zone is reduced because of production causing an extra driving energy. This kind of reservoir is called water drive reservoirs. The expanding water also moves and displaces oil or gas in an upward direction from lower parts of the reservoir, so the pore spaces vacated by oil or gas produced are filled by water. The oil and gas are progressively pushed towards the well bore. Recovery efficiencies of 70 to 80 % of the original oil in place (OOIP) are possible in some water drive reservoirs. 46 Figure 5-2 Schematic of a Typical Water Drive Reservoir.

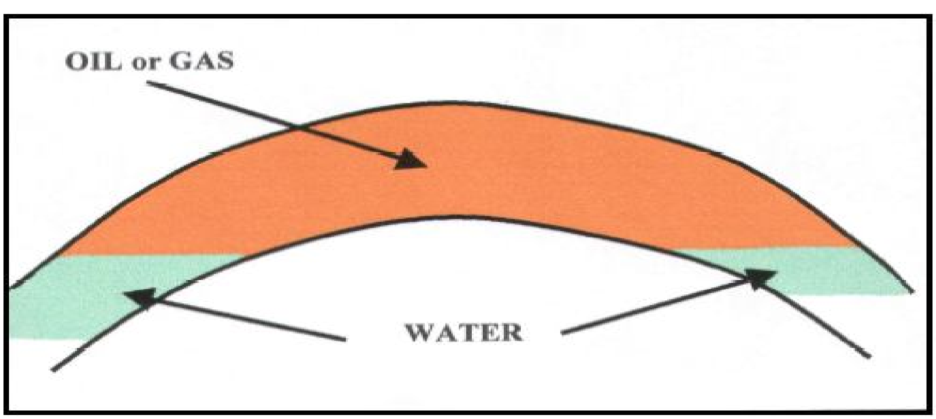


**Figure 57: Schematic of a Typical Water Drive Reservoir**

## GRAVITY DRAINAGE RESERVOIRS

Gravity drainage may be a primary producing mechanism in thick reservoirs that have a good vertical communication or in steeply dipping reservoirs. Gravity drainage is a slow process because gas must migrate up structure or to the top of the formation to fill the space formerly occupied by oil. Gas migration is fast relative to oil drainage so those oil rates are controlled by the rate of oil drainage.

## UNDER SATURATED RESERVOIRS

A crude oil is under-saturated when it contains less gas than is required to saturate the oil at the pressure and temperature of the reservoir. When the oil is highly under-saturated much of the reservoir energy is stored in the form of fluid and rock compressibility. Pressure declines rapidly as fluids are withdrawn from the under-saturated reservoir until the bubble point is reached. Then, solution gas drive becomes the source of energy for fluid displacement. Reservoir fluid analysis, PVT behavior and the pressure data will identify an under-saturated reservoir. Those reservoirs are good candidates for water injection to maintain a high pressure to increase oil recovery.

## 8.4 PETROLEUM RESERVE ESTIMATION METHODS

The process of estimating oil and gas reserves for a producing field continues throughout the life of the field. There is always uncertainty in making such estimates. The level of uncertainty is affected by the following factors:

1. Reservoir type,
2. Source of reservoir energy,
3. Quantity and quality of the geological, engineering, and geophysical data,
4. Assumptions adopted when making the estimate,
5. Available technology, and
6. Experience and knowledge of the evaluator.

The magnitude of uncertainty, however, decreases with time until the economic limit is reached and the ultimate recovery is realized, see Figure 1. Figure 1: Magnitude of uncertainty in reserves estimates

The oil and gas reserves estimation methods can be grouped into the following categories:

1. Analogy
2. Volumetric
3. Decline analysis
4. Material balance calculations for oil reservoirs
5. Material balance calculations for gas reservoirs and
6. Reservoir simulation

### ANALOGY METHOD

In the early stages of development, reserves estimates are restricted to the analogy calculations. The analogy method is applied by comparing factors for the analogous and current fields or wells. A close-to-abandonment analogous field is taken as an approximate to the current field. This method is most useful when running the economics on the current field; which is supposed to be an exploratory field.

## VOLUMETRIC METHOD

Like analogy method, the reserves estimates are also restricted to the volumetric calculations in the early stages of development. The volumetric method entails determining the aerial extent of the reservoir, the rock pore volume, and the fluid content within the pore volume. This provides an estimate of the amount of hydrocarbons-in-place. The ultimate recovery, then, can be estimated by using an appropriate recovery factor. Each of the factors used in the calculation above have inherent uncertainties that, when combined, cause significant uncertainties in the reserves estimate.

## DECLINE ANALYSIS METHOD

As production and pressure data from a field become available, decline analysis method becomes the predominant method of calculating reserves. This method greatly reduces the uncertainty in reserves estimates; however, during early depletion, caution should be exercised in using them. Decline curve relationships are empirical, and rely on uniform, lengthy production periods. It is more suited to oil wells, which are usually produced against fixed bottom-hole pressures. In gas wells, however, wellhead back-pressures usually fluctuate, causing varying production trends and therefore, not as reliable.

The most common decline curve relationship is the **constant percentage decline (exponential).** With more and more low productivity wells coming on stream, there is currently a swing toward decline rates proportional to production rates (hyperbolic and harmonic). Although some wells exhibit these trends, hyperbolic or harmonic decline extrapolations should only be used for these specific cases. Over exuberance in the use of hyperbolic or harmonic relationships can result in excessive reserves estimates.

## MATERIAL BALANCE METHOD

Like decline analysis method, material balance calculations, become the predominant methods of calculating reserves if production and pressure data from a field become available. This method also greatly reduces the uncertainty in reserves estimates However, during early depletion, caution should be exercised in using it. Material balance calculation is an excellent tool for estimating gas reserves. If a reservoir comprises a closed system and contains single-phase gas, the pressure in the reservoir will decline proportionately to the amount of gas produced. Unfortunately, sometimes bottom water drive in gas reservoirs contributes to the depletion mechanism, altering the performance of the non-ideal gas law in the reservoir. Under these conditions, optimistic reserves estimates can result.

## 8.5 CALACULATION PROCEDURES OF RESERVE ESTIMATION

When calculating reserves using any of the mentioned methods, the following two calculation procedures may be used:

1. Deterministic method
2. Probabilistic method

### DETERMINISTIC METHOD

The deterministic method is by far the most common. The procedure is to select a single value for each parameter to input into an appropriate equation, to obtain a single answer.

The deterministic methods calculate reserve values that are more tangible and explainable. In these methods, all input parameters are exactly known; however, they may sometimes ignore the variability and uncertainty in the input data compared to the probabilistic methods which allow the incorporation of more variance in the data.

### PROBABILISTIC METHOD

The probabilistic method is more rigorous and less commonly used. This method utilizes a distribution curve for each parameter and, through the use of Monte Carlo Simulation; a distribution curve for the answer can be developed. Assuming good data, a lot of qualifying information can be derived from the resulting statistical calculations, such as the minimum and maximum values, the mean (average value), the median (middle value), the mode (most likely value), the standard deviation and the percentiles.

The probabilistic methods have several inherent problems. They are affected by all input parameters, including the most likely and maximum values for the parameters. In such methods, one can not back calculate the input parameters associated with reserves. Only the end result is known but not the exact value of any input parameter.

## COMPARISON BETWEEN DETERMINISTIC AND PROBABILISTIC METHODS

A comparison of deterministic and probabilistic methods can provide the quality assurance for estimating hydrocarbon reserves; i.e. reserves are calculated both deterministically and probabilistically and the two values are compared. If the two values agree, then confidence on the calculated reserves is increased. If the two values are away different, the assumptions need to be re-examined.

## APPENDIX B: ECLIPSE INPUT DATA (CASE 1)

```
-- Upper layer = 1
-- Lower layer = 2

---------------------------------------------------------------------------------------------------
RUNSPEC
---------------------------------------------------------------------------------------------------
TITLE
   Production Optimization of Beani Bazar Gas Field by Simulation

FIELD

DIMENS
   50 75 62 /

REGDIMS
  2 /
EQLDIMS
  2 /
--EQLOPTS
--QUIESC /

--NOSIM

WATER
GAS

TABDIMS
-- NTSFUN  NTPVT NSSFUN NPPVT NTFIP
      2      2     40    100    4    /

WELLDIMS
   10     62      1      10  /

VFPPDIMS
----  MXMFLO  MXMTHP  MXMWFR  MXMGFR  MXMALQ  NMMVF
     20      15       10       10      10       3 /
VFPIDIMS
  20  20  20 /

ENDSCALE
/

-- check
START
  09 'May' 1999 /
```

```
AQUDIMS
--MxnAqn  MxnAqc  Niftbl  Nriftb  Nanaqu  NcaMax
  0       0       3       30      4       70713  /

UNIFIN

UNIFOUT

----------------------------------------------------------------------------------------------------
GRID
----------------------------------------------------------------------------------------------------

INIT
GRIDFILE
2/
include
  'BeaniBazar_Dec08.GRDECL' /
include
  'BeaniBazar_Dec08.actnum' /
equals
  'actnum' 0 4*  21  56 /
--  'actnum' 0 4*  56  62 /
/
multiply
  permx  10 4*  1 20 /
  permx 100 4* 57 62 /
/
COPY
'PERMX' 'PERMY' /
'PERMX' 'PERMZ' /
/
MULTIPLY
'PERMZ' 0.1 /
/
equals
multpv .96 4* 57 62 /
/

----------------------------------------------------------------------------------------------------
EDIT
----------------------------------------------------------------------------------------------------
-- Change of Transmissibilities near BB_2

BOX
18 18 17 26 1 20 /
TRANX
200*0.25 /
ENDBOX
```

```
BOX
18 18 17 26 1 20 /
TRANY
200*0.25 /
ENDBOX

-----------------------------------------------------------------------------------------------------
-
PROPS
-----------------------------------------------------------------------------------------------------
--
RVCONSTT
--stb/Mscf
 0.017  14.7 /
 0.017  14.7 /


DENSITY
-- Upper Beanibazar
--          Oil          Water          Gas
--        LB/FT3         LB/FT3         LB/FT3
         32.345         62.366        0.04571 /
-- Lower Beanibazar
--          Stock tank densities
         32.000         62.366        0.04833 /


ROCK
  4000.0  0.30E-05 /
  4000.0  0.30E-05 /

--NB: from RPS techPVT analysis

PVDG
-- Beani_Bazar_upper
-- Pressure  Gas FVF   Gas Vis
-- psia      rb/Mscf     cp
     14.7  214.0486    0.0128
     50.0   65.8611    0.0129
    100.0   32.9306    0.0129
    230.0   14.2699    0.0130
    460.0    6.9609    0.0132
    690.0    4.5542    0.0134
    920.0    3.3708    0.0137
   1150.0    2.6508    0.0141
   1380.0    2.1842    0.0146
   1610.0    1.8573    0.0151
```

```
   1840.0    1.6155    0.0157
   2070.0    1.4294    0.0163
   2300.0    1.2856    0.0170
   2372.0    1.2463    0.0173
   2530.0    1.1697    0.0178
   2760.0    1.0743    0.0186
   2990.0    0.9967    0.0194
   3220.0    0.9306    0.0203
   3450.0    0.8755    0.0212
   4500.0    0.7041    0.0252
   6000.0    0.5754    0.0307
/
-- Beani_Bazar_lower
-- Pressure  Gas FVF   Gas Vis
-- psia      rb/Mscf     cp
     14.7  221.6932    0.0128
     50.0   68.2133    0.0128
    100.0   34.1066    0.0128
    230.0   14.5373    0.0129
    460.0    7.1514    0.0131
    690.0    4.6672    0.0134
    920.0    3.4505    0.0138
   1150.0    2.7202    0.0142
   1380.0    2.2450    0.0147
   1610.0    1.9070    0.0152
   1840.0    1.6606    0.0159
   2070.0    1.4706    0.0166
   2300.0    1.3235    0.0173
   2372.0    1.2833    0.0176
   2530.0    1.2065    0.0181
   2760.0    1.1099    0.0190
   2990.0    1.0311    0.0199
   3220.0    0.9639    0.0208
   3450.0    0.9076    0.0217
   4500.0    0.7341    0.0260
   6000.0    0.6037    0.0316
/

-- WATER DATA--

PVTW

-- Ref Pres Bw  cw  uw  viscosibility
-- psia   rb/stb  1/psi cP  1/psi
  2000    1.0229     3.07e-06  0.381       0.45e-05/
  2000    1.0229     3.07e-06  0.381       0.45e-05/

sgwfn
```

```
  0.0 0.0000  1.0000 0.0
  0.1 0.0019  0.6561 0.0
  0.2 0.0144  0.4096 0.0
  0.3 0.0459  0.2401 0.0
  0.4 0.1024  0.1296 0.0
  0.5 0.1875  0.0625 0.0
  0.6 0.3024  0.0256 0.0
  0.7 0.4459  0.0081 0.0
  0.8 0.6144  0.0016 0.0
  0.9 0.8019  0.0001 0.0
  1.0 1.0000  0.0000 0.0
/
  0.0 0.0000  1.0000 0.0
  0.1 0.0019  0.6561 0.0
  0.2 0.0144  0.4096 0.0
  0.3 0.0459  0.2401 0.0
  0.4 0.1024  0.1296 0.0
  0.5 0.1875  0.0625 0.0
  0.6 0.3024  0.0256 0.0
  0.7 0.4459  0.0081 0.0
  0.8 0.6144  0.0016 0.0
  0.9 0.8019  0.0001 0.0
  1.0 1.0000  0.0000 0.0
/

equals
  krw 0.5 4* 1 20 /
/
include
 'BeaniBazar_Dec08.sw' /
copy
  swl swcr /
/
equals
  swu 1.0 /
/
add
  swcr 0.15 /
/
maxvalue
  swcr 1.0 /
/

----------------------------------------------------------------------------------------------------
REGIONS
----------------------------------------------------------------------------------------------------
-- check
EQUALS
```

```
FIPNUM 1  4*  1 20 / Upper Sand
FIPNUM 2  4* 57 62 / Lower Sand
/

copy
  fipnum eqlnum /
/

-----------------------------------------------------------------------------------------------
SOLUTION
-----------------------------------------------------------------------------------------------
EQUIL
-- check
-- datum(x)  datum(x)    WGC     Pc   GOC      Pcgoc
-- depth     pressure    depth        depth
   10575     4601        10663   0    10663    0      0  1  / Upper sand observed GWC
   11256     4831        11450   0    11450    0      0  1  / Lower sand GDT in BB-1

----Carter Tracy Aquifer Setup
AQUCT
--AQ#   Datum  Pi      Perm    Poro          Comp                    Re       Thick     Angle     WaterTab
InfluenceTab
 1      10663     -1       995      0.2  1.00000060266128e-005      5000      600        360        1         1    1* /
 2      10663     -1       995      0.2  1.00000060266128e-005      5000      600        360        1         1    1* /
 3      11256     -1        10      0.2  1.00000060266128e-005      5000      600        360        1         1    1* /
 4      11256     -1        10      0.2  1.00000060266128e-005      5000      600        360        1         1    1* /

--Aquifer Connections

AQUANCON
--AQ#   I-    I+    J-    J+    Z-    Z+    Face
  1    26   50    1  63   1    20   'I+' 2* 'NO' /
  2     1   25    1  63   1    20   'I-' 2* 'NO' /
  3    26   50    1  63  57    62   'I+' 2* 'NO' /
  4     1   25    1  63  57    62   'I-' 2* 'NO' /
/

-----------------------------------------------------------------------------------------------
SUMMARY
-----------------------------------------------------------------------------------------------

--Summary Reporting Controls
RPTSMRY
1 /

runsum

include
 'SMRY.INC' /
```

```
-------------------------------------------------------------------------------------------------
SCHEDULE
------------------------------------------------------------------------------------------------
-- SCHEDULE

RPTSCHED
--Report switches for simulation results
   'SUMMARY=2' 'RESTART=2' 'WELSPECS' 'FIP=2'  'CPU=1' /

RPTRST
--Controls data written to the restart file
  'BASIC=5' 'FREQ=1'  /

-- VFP TABLE
INCLUDE
'VFP_BB_1.inc'  / VFP Table1 (BB-1 Lower Gas Sand)/

INCLUDE
'VFP_BB_2.inc'  / VFP Table2 (BB-2 Upper Gas Sand)/

WELSPECS
-- check
-- Well     Group  X    Y   bhp_depth(x) Pref_phase
   'BB-1X'  'g'    22   37  11256        'gas'  /
   'BB-2'   'g'    20   22  10575        'gas'  /
/

-- VFP DATA
VFPCHK
  1.0E5 /
VFPTABL
2  /

include
'BeaniBazar_Dec08.compdat'
/
include
'BBazar_production.inc'
/

DATES
  1 'Dec' 2011 /
/
END
```

BBazar_production.inc

```
WCONHIST
'BB-1X' open GRAT 319.3 0 17925.9 1 1*  0 4898 /
'BB-2' open GRAT 0 0 0 2 1* 3650 4574 /
/
DATES
  1 'Jun' 1999 /
/
WCONHIST
'BB-1X' open GRAT 240.4 0 16390.7 1 1* 2697 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
 1 'Jul' 1999 /
/
WCONHIST
'BB-1X' open GRAT 256.4 1.5 17871.9 1 1* 2699 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
 1 'Aug' 1999 /
/
WCONHIST
'BB-1X' open GRAT 208.1 1.2 14809.9 1 1* 3200 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
 1 'Sep' 1999 /
/
WCONHIST
'BB-1X' open GRAT 138.4 0.7 9817 1 1* 3152 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
```

```
/
DATES
  1 'Oct' 1999 /
/
WCONHIST
'BB-1X' open GRAT 227.5 1.1 15789.5 1 1* 2748 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Nov' 1999 /
/
WCONHIST
'BB-1X' open GRAT 245.7 1.2 16623.3 1 1* 2657 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Dec' 1999 /
/
WCONHIST
'BB-1X' open GRAT 72.6 0.5 5016 1 1* 2871 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jan' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3750 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Feb' 2000 /
/
```

```
WCONHIST
'BB-1X' open GRAT 58.9 0.5 4121.4 1 1* 3750 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Mar' 2000 /
/
WCONHIST
'BB-1X' open GRAT 188.5 3.2 11811.1 1 1* 2505 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Apr' 2000 /
/
WCONHIST
'BB-1X' open GRAT 199.8 3.4 14912.4 1 1* 2900 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'May' 2000 /
/
WCONHIST
'BB-1X' open GRAT 129.3 3.5 8425.9 1 1* 2896 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jun' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
```

```
DATES
  1 'Jul' 2000 /
/
WCONHIST
'BB-1X' open GRAT 42 1.2 2700.8 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Aug' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Sep' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Oct' 2000 /
/
WCONHIST
'BB-1X' open GRAT 1.2 0 102.9 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Nov' 2000 /
/
WCONHIST
```

```
'BB-1X' open GRAT 0 0 4.9 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Dec' 2000 /
/
WCONHIST
'BB-1X' open GRAT 22.9 0.5 1411.7 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jan' 2001 /
/
WCONHIST
'BB-1X' open GRAT 2 0.1 129 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Feb' 2001 /
/
WCONHIST
'BB-1X' open GRAT 140.6 4.3 9308.1 1 1* 2773 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Mar' 2001 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
```

```
  1 'Apr' 2001 /
/
WCONHIST
'BB-1X' open GRAT 192.4 4.7 11936 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'May' 2001 /
/
WCONHIST
'BB-1X' open GRAT 257.5 6.7 15380.6 1 1* 2891 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jun' 2001 /
/
WCONHIST
'BB-1X' open GRAT 11.7 0.3 722.1 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jul' 2001 /
/
WCONHIST
'BB-1X' open GRAT 13.2 0.3 910.5 1 1* 3751 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Aug' 2001 /
/
WCONHIST
'BB-1X' open GRAT 105.9 2.4 6537 1 1* 3150 0 /
```

```
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Sep' 2001 /
/
WCONHIST
'BB-1X' open GRAT 138.8 4.6 8872.6 1 1* 2850 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Oct' 2001 /
/
WCONHIST
'BB-1X' open GRAT 66.8 2.4 4301.4 1 1* 3751 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Nov' 2001 /
/
WCONHIST
'BB-1X' open GRAT 152 4.8 8352.2 1 1* 3751 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Dec' 2001 /
/
WCONHIST
'BB-1X' open GRAT 137.9 4.5 8152.1 1 1* 2900 0 /
'BB-2' open GRAT 0 0 0  2 1* 3650 0 /
/
DATES
  1 'Jan' 2002 /
```

```
/
WCONHIST
'BB-1X' open GRAT 199.7 0.3 19049.9 1 1* 3748 4744 /
'BB-2' open GRAT 115.3 2.3 19049.9 2 1* 3650 0 /
/
DATES
  1 'Feb' 2002 /
/
WCONHIST
'BB-1X' open GRAT 155.2 7.2 9154.7 1 1* 3200 0 /
'BB-2' open GRAT 113.5 10.7 6089.1 2 1* 3350 0 /
/
DATES
  1 'Mar' 2002 /
/
WCONHIST
'BB-1X' open GRAT 168.3 3.8 10195.3 1 1* 3752 0 /
'BB-2' open GRAT 175.3 16.6 9976 2 1* 3586 0 /
/
DATES
  1 'Apr' 2002 /
/
WCONHIST
'BB-1X' open GRAT 202.9 4.4 12482.3 1 1* 3360 0 /
'BB-2' open GRAT 149.1 13.7 8484.5 2 1* 3240 0 /
/
DATES
  1 'May' 2002 /
/
WCONHIST
'BB-1X' open GRAT 195.9 4.1 12185 1 1* 3400 0 /
'BB-2' open GRAT 146.2 12.3 8246.6 2 1* 3340 0 /
```

```
/
DATES
  1 'Jun' 2002 /
/
WCONHIST
'BB-1X' open GRAT 208.7 5.4 12317.9 1 1* 3400 0 /
'BB-2' open GRAT 227.5 23.4 12281.6 2 1* 3325 0 /
/
DATES
  1 'Jul' 2002 /
/
WCONHIST
'BB-1X' open GRAT 219.9 6.4 12542.5 1 1* 3400 0 /
'BB-2' open GRAT 225.6 26.4 11860.6 2 1* 3050 0 /
/
DATES
  1 'Aug' 2002 /
/
WCONHIST
'BB-1X' open GRAT 191.1 5.9 11145.7 1 1* 3420 0 /
'BB-2' open GRAT 188.6 23.2 10133.8 2 1* 3250 0 /
/
DATES
  1 'Sep' 2002 /
/
WCONHIST
'BB-1X' open GRAT 257.8 8.5 15374.7 1 1* 3150 0 /
'BB-2' open GRAT 256 33.8 13893.8 2 1* 3100 0 /
/
DATES
  1 'Oct' 2002 /
/
```

```
WCONHIST
'BB-1X' open GRAT 198.4 7.6 12717.3 1 1* 3400 0 /
'BB-2' open GRAT 226.1 33.6 12735.4 2 1* 3000 0 /
/
DATES
  1 'Nov' 2002 /
/
WCONHIST
'BB-1X' open GRAT 204.8 7.5 14137.3 1 1* 3752 0 /
'BB-2' open GRAT 123.6 17.2 7142.6 2 1* 3050 0 /
/
DATES
  1 'Dec' 2002 /
/
WCONHIST
'BB-1X' open GRAT 77.1 2 5337.4 1 1* 3200 0 /
'BB-2' open GRAT 112.1 12 6602.7 2 1* 3240 0 /
/
DATES
  1 'Jan' 2003 /
/
WCONHIST
'BB-1X' open GRAT 190.9 6.6 12410.2 1 1* 3282 0 /
'BB-2' open GRAT 187.2 23.2 11326.3 2 1* 3139 0 /
/
DATES
  1 'Feb' 2003 /
/
WCONHIST
'BB-1X' open GRAT 161.4 5.7 10992.5 1 1* 3302 0 /
'BB-2' open GRAT 150.8 19.6 9536.2 2 1* 3330 0 /
/
```

```
DATES
  1 'Mar' 2003 /
/
WCONHIST
'BB-1X' open GRAT 169 6.2 11731.1 1 1* 3349 0 /
'BB-2' open GRAT 178.9 24.6 11504.3 2 1* 3330 0 /
/
DATES
  1 'Apr' 2003 /
/
WCONHIST
'BB-1X' open GRAT 166 7 11380.8 1 1* 3414 0 /
'BB-2' open GRAT 158 24.2 10106.4 2 1* 3462 0 /
/
DATES
  1 'May' 2003 /
/
WCONHIST
'BB-1X' open GRAT 103.3 2.9 6176.2 1 1* 3541 0 /
'BB-2' open GRAT 44.2 3.8 2411.3 2 1* 2900 0 /
/
DATES
  1 'Jun' 2003 /
/
WCONHIST
'BB-1X' open GRAT 228 6.8 13056.4 1 1* 3245 0 /
'BB-2' open GRAT 204.9 23.2 11465.7 2 1* 3103 0 /
/
DATES
  1 'Jul' 2003 /
/
WCONHIST
```

```
'BB-1X' open GRAT 148.7 5.1 8557 1 1* 2745 0 /
'BB-2' open GRAT 104 13.5 5740.5 2 1* 3301 0 /
/
DATES
  1 'Aug' 2003 /
/
WCONHIST
'BB-1X' open GRAT 285.2 9.7 16154.4 1 1* 2935 0 /
'BB-2' open GRAT 245.9 31.5 13587.5 2 1* 3136 0 /
/
DATES
  1 'Sep' 2003 /
/
WCONHIST
'BB-1X' open GRAT 275.5 10.5 15594.6 1 1* 3008 0 /
'BB-2' open GRAT 240.2 34.7 13265 2 1* 3121 0 /
/
DATES
  1 'Oct' 2003 /
/
WCONHIST
'BB-1X' open GRAT 245.5 9 13705.4 1 1* 3004 0 /
'BB-2' open GRAT 216.8 29.9 11806.9 2 1* 3140 0 /
/
DATES
  1 'Nov' 2003 /
/
WCONHIST
'BB-1X' open GRAT 223.6 7.8 12396.8 1 1* 2949 0 /
'BB-2' open GRAT 209.8 27.5 11356.5 2 1* 3216 0 /
/
DATES
```

```
  1 'Dec' 2003 /
/
WCONHIST
'BB-1X' open GRAT 280.6 10.7 15609 1 1* 2865 0 /
'BB-2' open GRAT 226.7 32.5 12359.3 2 1* 3224 0 /
/
DATES
  1 'Jan' 2004 /
/
WCONHIST
'BB-1X' open GRAT 285.7 11.2 16105.1 1 1* 2950 0 /
'BB-2' open GRAT 197.5 29.4 10791.9 2 1* 3300 0 /
/
DATES
  1 'Feb' 2004 /
/
WCONHIST
'BB-1X' open GRAT 271.2 10.5 15559.6 1 1* 2550 0 /
'BB-2' open GRAT 208.9 30.8 11612.3 2 1* 3340 0 /
/
DATES
  1 'Mar' 2004 /
/
WCONHIST
'BB-1X' open GRAT 254 10.4 14352.3 1 1* 3000 0 /
'BB-2' open GRAT 211.8 33.2 11602.6 2 1* 3150 0 /
/
DATES
  1 'Apr' 2004 /
/
WCONHIST
'BB-1X' open GRAT 233 9.9 13693.5 1 1* 2800 0 /
```

```
'BB-2' open GRAT 179.8 28.7 10178.3 2 1* 2925 0 /
/
DATES
  1 'May' 2004 /
/
WCONHIST
'BB-1X' open GRAT 233.6 9.2 13177.1 1 1* 3150 0 /
'BB-2' open GRAT 183.6 27.6 9932.2 2 1* 3300 0 /
/
DATES
  1 'Jun' 2004 /
/
WCONHIST
'BB-1X' open GRAT 214.6 8.6 11812.8 1 1* 3000 0 /
'BB-2' open GRAT 171.8 25.9 9065.5 2 1* 3325 0 /
/
DATES
  1 'Jul' 2004 /
/
WCONHIST
'BB-1X' open GRAT 224.2 8.4 12946.1 1 1* 2950 0 /
'BB-2' open GRAT 171.4 24.1 9415.2 2 1* 3410 0 /
/
DATES
  1 'Aug' 2004 /
/
WCONHIST
'BB-1X' open GRAT 224.5 10 13449.6 1 1* 3100 0 /
'BB-2' open GRAT 172 28.7 9811 2 1* 3335 0 /
/
DATES
  1 'Sep' 2004 /
```

```
/
WCONHIST
'BB-1X' open GRAT 221.2 10.9 12610.4 1 1* 2800 0 /
'BB-2' open GRAT 190 35.1 10372.5 2 1* 2975 0 /
/
DATES
 1 'Oct' 2004 /
/
WCONHIST
'BB-1X' open GRAT 206 11.5 12021.4 1 1* 3000 0 /
'BB-2' open GRAT 212.7 44.8 11900.7 2 1* 3325 0 /
/
DATES
 1 'Nov' 2004 /
/
WCONHIST
'BB-1X' open GRAT 170 9.7 9383.7 1 1* 2600 0 /
'BB-2' open GRAT 224.3 48.4 11888.3 2 1* 3400 0 /
/
DATES
 1 'Dec' 2004 /
/
WCONHIST
'BB-1X' open GRAT 187.4 11 10555.1 1 1* 2500 0 /
'BB-2' open GRAT 198.2 44 10720.2 2 1* 3280 0 /
/
DATES
 1 'Jan' 2005 /
/
WCONHIST
'BB-1X' open GRAT 162.7 10.5 9402 1 1* 3150 0 /
'BB-2' open GRAT 210.6 49.4 11811.3 2 1* 3300 0 /
```

```
/
DATES
  1 'Feb' 2005 /
/
WCONHIST
'BB-1X' open GRAT 130.3 9 7640.8 1 1* 2900 0 /
'BB-2' open GRAT 222 56.4 12654.2 2 1* 3150 0 /
/
DATES
  1 'Mar' 2005 /
/
WCONHIST
'BB-1X' open GRAT 163.9 12.7 9531.9 1 1* 2400 0 /
'BB-2' open GRAT 242.1 67.8 13702.6 2 1* 3300 0 /
/
DATES
  1 'Apr' 2005 /
/
WCONHIST
'BB-1X' open GRAT 148.4 13.3 8474.6 1 1* 2550 4619 /
'BB-2' open GRAT 194.7 57.7 10624.7 2 1* 3150 4556 /
/
DATES
  1 'May' 2005 /
/
WCONHIST
'BB-1X' open GRAT 92.9 7.9 5628.8 1 1* 2900 0 /
'BB-2' open GRAT 120.6 36.3 7042 2 1* 3150 0 /
/
DATES
  1 'Jun' 2005 /
/
```

```
WCONHIST
'BB-1X' open GRAT 136.4 9.8 8321.4 1 1* 3624 0 /
'BB-2' open GRAT 151.7 40.2 8833.1 2 1* 3616 0 /
/
DATES
  1 'Jul' 2005 /
/
WCONHIST
'BB-1X' open GRAT 172.4 15.1 10621.9 1 1* 3050 0 /
'BB-2' open GRAT 199.7 63.2 11842.7 2 1* 3050 0 /
/
DATES
  1 'Aug' 2005 /
/
WCONHIST
'BB-1X' open GRAT 174.3 19 10741.9 1 1* 3000 0 /
'BB-2' open GRAT 190.9 67.3 11187.7 2 1* 3400 0 /
/
DATES
  1 'Sep' 2005 /
/
WCONHIST
'BB-1X' open GRAT 78.5 8 4976.2 1 1* 2850 0 /
'BB-2' open GRAT 98.4 36 5921.6 2 1* 3233 0 /
/
DATES
  1 'Oct' 2005 /
/
WCONHIST
'BB-1X' open GRAT 138.6 13.5 8012.9 1 1* 3624 0 /
'BB-2' open GRAT 199.3 70.2 11108.8 2 1* 3440 0 /
/
```

```
DATES
  1 'Nov' 2005 /
/
WCONHIST
'BB-1X' open GRAT 142 14.6 8536.3 1 1* 3000 0 /
'BB-2' open GRAT 203.9 75.5 11791.8 2 1* 3450 0 /
/
DATES
  1 'Dec' 2005 /
/
WCONHIST
'BB-1X' open GRAT 136.6 15.1 8091.9 1 1* 2900 0 /
'BB-2' open GRAT 198.7 79.6 11335.8 2 1* 3460 0 /
/
DATES
  1 'Jan' 2006 /
/
WCONHIST
'BB-1X' open GRAT 99 14.6 5775.7 1 1* 2900 0 /
'BB-2' open GRAT 142.4 61 7983.3 2 1* 3430 0 /
/
DATES
  1 'Feb' 2006 /
/
WCONHIST
'BB-1X' open GRAT 128.3 16.6 7008 1 1* 2850 0 /
'BB-2' open GRAT 172.4 78.6 9120.7 2 1* 2975 0 /
/
DATES
  1 'Mar' 2006 /
/
WCONHIST
```

```
'BB-1X' open GRAT 119.4 16.5 6775.5 1 1* 3000 0 /
'BB-2' open GRAT 186 90.3 10177.5 2 1* 3480 0 /
/
DATES
  1 'Apr' 2006 /
/
WCONHIST
'BB-1X' open GRAT 123.7 18.3 6992 1 1* 3050 0 /
'BB-2' open GRAT 173.2 89.5 9426.2 2 1* 3340 0 /
/
DATES
  1 'May' 2006 /
/
WCONHIST
'BB-1X' open GRAT 108.1 16.9 6197.3 1 1* 3050 0 /
'BB-2' open GRAT 136.6 74.5 7538.9 2 1* 3370 0 /
/
DATES
  1 'Jun' 2006 /
/
WCONHIST
'BB-1X' open GRAT 126.6 21.8 7059.8 1 1* 2800 0 /
'BB-2' open GRAT 165.5 100.1 8886.9 2 1* 3350 0 /
/
DATES
  1 'Jul' 2006 /
/
WCONHIST
'BB-1X' open GRAT 118.2 20.1 6724 1 1* 3000 0 /
'BB-2' open GRAT 157.4 93.3 8586.5 2 1* 3460 0 /
/
DATES
```

```
  1 'Aug' 2006 /
/
WCONHIST
'BB-1X' open GRAT 128.7 23.4 7610.7 1 1* 2950 0 /
'BB-2' open GRAT 183 115.8 10352.7 2 1* 3280 0 /
/
DATES
  1 'Sep' 2006 /
/
WCONHIST
'BB-1X' open GRAT 133.2 24 7900.4 1 1* 2740 0 /
'BB-2' open GRAT 175.3 110.1 9930.1 2 1* 3425 0 /
/
DATES
  1 'Oct' 2006 /
/
WCONHIST
'BB-1X' open GRAT 105.7 19.7 6300.9 1 1* 2900 0 /
'BB-2' open GRAT 163 105.1 9269.4 2 1* 3440 0 /
/
DATES
  1 'Nov' 2006 /
/
WCONHIST
'BB-1X' open GRAT 112.3 21.8 6656.6 1 1* 2900 0 /
'BB-2' open GRAT 170.4 115.3 9673.4 2 1* 3440 0 /
/
DATES
  1 'Dec' 2006 /
/
WCONHIST
'BB-1X' open GRAT 111.1 22.1 6425.6 1 1* 2950 0 /
```

```
'BB-2' open GRAT 176.5 123 9869.3 2 1* 3200 0 /
/
DATES
  1 'Jan' 2007 /
/
WCONHIST
'BB-1X' open GRAT 127.5 26.6 7336.2 1 1* 3050 0 /
'BB-2' open GRAT 178.8 131.1 9973.9 2 1* 3160 0 /
/
DATES
  1 'Feb' 2007 /
/
WCONHIST
'BB-1X' open GRAT 138.8 31.2 8220.3 1 1* 3200 0 /
'BB-2' open GRAT 156.8 122.2 8918.5 2 1* 3180 0 /
/
DATES
  1 'Mar' 2007 /
/
WCONHIST
'BB-1X' open GRAT 149.5 38.3 9075.4 1 1* 3000 0 /
'BB-2' open GRAT 144.5 128.7 8423.1 2 1* 3360 0 /
/
DATES
  1 'Apr' 2007 /
/
WCONHIST
'BB-1X' open GRAT 82.4 46.9 5632.5 1 1* 2800 0 /
'BB-2' open GRAT 48.8 51.8 2995.4 2 1* 3440 0 /
/
DATES
  1 'May' 2007 /
```

```
/
WCONHIST
'BB-1X' open GRAT 112.9 33.2 7106.6 1 1* 3100 0 /
'BB-2' open GRAT 129 122 7693.6 2 1* 3350 0 /
/
DATES
  1 'Jun' 2007 /
/
WCONHIST
'BB-1X' open GRAT 97.6 29.4 6241.6 1 1* 3150 0 /
'BB-2' open GRAT 134.9 139.8 8155.7 2 1* 3455 0 /
/
DATES
  1 'Jul' 2007 /
/
WCONHIST
'BB-1X' open GRAT 94.8 28.5 6139.7 1 1* 3150 0 /
'BB-2' open GRAT 135 139.4 8269.4 2 1* 3460 0 /
/
DATES
  1 'Aug' 2007 /
/
WCONHIST
'BB-1X' open GRAT 91.3 28.6 6400.6 1 1* 3150 0 /
'BB-2' open GRAT 133.1 143.8 8977.5 2 1* 3440 0 /
/
DATES
  1 'Sep' 2007 /
/
WCONHIST
'BB-1X' open GRAT 99.3 29.7 6442.6 1 1* 3250 0 /
'BB-2' open GRAT 152.2 155.5 9325.8 2 1* 3340 0 /
```

```
/
DATES
  1 'Oct' 2007 /
/
WCONHIST
'BB-1X' open GRAT 80.9 24.3 4774.3 1 1* 3250 0 /
'BB-2' open GRAT 142.5 138.1 8122.4 2 1* 3320 0 /
/
DATES
  1 'Nov' 2007 /
/
WCONHIST
'BB-1X' open GRAT 67.4 20.2 4362.2 1 1* 3300 4592 /
'BB-2' open GRAT 143.6 141.6 8695.9 2 1* 3460 4546 /
/
DATES
  1 'Dec' 2007 /
/
WCONHIST
'BB-1X' open GRAT 66.9 21.9 4414.4 1 1* 3300 0 /
'BB-2' open GRAT 137.2 149.5 8539.3 2 1* 3360 0 /
/
DATES
  1 'Jan' 2008 /
/
WCONHIST
'BB-1X' open GRAT 64.4 20.4 4134.5 1 1* 3300 0 /
'BB-2' open GRAT 127.7 136.5 7779.7 2 1* 3400 0 /
/
DATES
  1 'Feb' 2008 /
/
```

```
WCONHIST
'BB-1X' open GRAT 60.8 20.7 4021.3 1 1* 3300 0 /
'BB-2' open GRAT 124.2 143.7 7726.4 2 1* 3400 0 /
/
DATES
  1 'Mar' 2008 /
/
WCONHIST
'BB-1X' open GRAT 51 16.9 3487.4 1 1* 3300 0 /
'BB-2' open GRAT 127.6 142.1 8101.5 2 1* 3400 0 /
/
DATES
  1 'Apr' 2008 /
/
WCONHIST
'BB-1X' open GRAT 46.7 14.3 3192.5 1 1* 3300 0 /
'BB-2' open GRAT 131.3 134.9 8325.9 2 1* 3400 0 /
/
DATES
  1 'May' 2008 /
/
WCONHIST
'BB-1X' open GRAT 46.8 13.8 3198 1 1* 3100 0 /
'BB-2' open GRAT 137.9 136 8734.4 2 1* 3400 0 /
/
DATES
  1 'Jun' 2008 /
/
WCONHIST
'BB-1X' open GRAT 61.7 21 4228.1 1 1* 3300 0 /
'BB-2' open GRAT 127.9 145.2 8132.9 2 1* 3400 0 /
/
```

```
DATES
  1 'Jul' 2008 /
/
WCONHIST
'BB-1X' open GRAT 88.27 77.01 5770 1 1* 3350 0 /
'BB-2' open GRAT 128.00   111.97          8390.00 2 1* 3350 0 /
/
DATES
  1 'Aug' 2008 /
/
WCONHIST
'BB-1X' open GRAT 68.27 60.41 4250.0 1 1* 3350 0 /
'BB-2'  open GRAT 101.00 88.83  6260.00 2 1* 3350 0 /
/
DATES
  1 'Sep' 2008 /
/
WCONHIST
'BB-1X' open GRAT 124.58 103.72 7700.00 1 1* 3350 0 /
'BB-2'  open GRAT 117.71 98.00  7280.00         2 1* 3350 0 /
/
DATES
  1 'Oct' 2008 /
/
WCONHIST
'BB-1X' open GRAT 150.67 123.31 9380.00 1 1* 3350 0 /
'BB-2'  open GRAT 117.41 95.31  7310.00        2 1* 3350 0 /
/
DATES
  1 'Nov' 2008 /
/
WCONHIST
```

```
'BB-1X' open GRAT 96.42 76.25 5990.00 1 1* 3350 0 /
'BB-2'  open GRAT 177.29 140.22 11030.00 2 1* 3250 0 /
/
DATES
  1 'Dec' 2008 /
/
WCONHIST
'BB-1X' open GRAT 83.16 67.98 4960.00 1 1* 3351 0 /
'BB-2'  open GRAT 191.33 156.91 11450.00 2 1* 3250 0 /
/
DATES
  1 'Jan' 2009 /
/
WCONHIST
'BB-1X' open GRAT 79.21 68.30 4640.00 1 1* 3351 0 /
'BB-2'  open GRAT  193.49 166.84 11340.00 2 1* 3250 0 /
/
DATES
  1 'Feb' 2009 /
/
WCONHIST
'BB-1X' open GRAT 74.74 65.68 4550.00 1 1* 3200 0 /
'BB-2' open GRAT 184.98 162.57  11260.00 2 1* 3250 0 /
/
DATES
  1 'Mar' 2009 /
/
WCONHIST
'BB-1X' open GRAT 60.06 51.86 3500.00 1 1* 3351 0 /
'BB-2'  open GRAT 193.71 167.28 11290.00 2 1* 3200 0 /
/
DATES
```

```
  1 'Apr' 2009 /
/
WCONHIST
'BB-1X' open GRAT 36.90 33.66 2189.00 1 1* 3350 0 /
'BB-2'  open GRAT 200.09 182.49 11872.15 2 1* 3200 0 /
/
DATES
  1 'May' 2009 /
/
WCONHIST
'BB-1X' open GRAT 50.08 47.27 2964.05 1 1* 3351 0 /
'BB-2'  open GRAT 186.15 175.70 11018.23 2 1* 3200 0 /
/
DATES
  1 'Jun' 2009 /
/
WCONHIST
'BB-1X' open GRAT 65.90 63.36 4032.19 1 1* 3350 0 /
'BB-2'  open GRAT 158.80 152.67 9715.65      2 1* 3200 0 /
/
DATES
  1 'Jul' 2009 /
/
WCONHIST
'BB-1X' open GRAT 72.75 71.32 4525.76 1 1* 3350 0 /
'BB-2'  open GRAT 150.59 147.64 9368.46      2 1* 3200 0 /
/
DATES
  1 'Aug' 2009 /
/
WCONHIST
'BB-1X' open GRAT 52.55 52.87 3736.90 1 1* 3350 0 /
```

```
'BB-2'  open GRAT 133.59 134.39 9498.85     2 1* 3200 0 /
/
DATES
  1 'Sep' 2009 /
/
WCONHIST
'BB-1X' open GRAT 74.94 64.98 4296.68 1 1* 3350 0 /
'BB-2'  open GRAT 181.05 156.98 10379.99 2 1* 3280 0 /
/
DATES
  1 'Oct' 2009 /
/
WCONHIST
'BB-1X' open GRAT 57.05 47.95 3292.92 1 1* 3351 0 /
'BB-2'  open GRAT 207.01 173.98 11948.00 2 1* 3280 0 /
/
DATES
  1 'Nov' 2009 /
/
WCONHIST
'BB-1X' open GRAT 56.09 48.79 3240.79 1 1* 3350 0 /
'BB-2'  open GRAT 204.42 177.83 11811.16 2 1* 3280 0 /
/
DATES
  1 'Dec' 2009 /
/
WCONHIST
'BB-1X' open GRAT 57.84 52.24 3254.30 1 1* 3200 0 /
'BB-2'  open GRAT 212.11 191.56 11933.82 2 1* 3280 0 /
/
DATES
  1 'Jan' 2010 /
```

```
/
WCONHIST
'BB-1X' open GRAT 56.03 50.26 3169.30 1 1* 3150 0 /
'BB-2'  open GRAT 209.98 188.37 11878.13 2 1* 3280 0 /
/
DATES
  1 'Feb' 2010 /
/
WCONHIST
'BB-1X' open GRAT 53.20 53.78 3169.30 1 1* 3150 0 /
'BB-2'  open GRAT 205.46 207.69 12238.93 2 1* 3280 0 /
/
DATES
  1 'Mar' 2010 /
/
WCONHIST
'BB-1X' open GRAT 53.90 55.51 3230.08 1 1* 3150 0 /
'BB-2'  open GRAT 199.68 205.64 11965.85 2 1* 3280 0 /
/
DATES
  1 'Apr' 2010 /
/
WCONHIST
'BB-1X' open GRAT 58.36 57.35 3291.48 1 1* 3150 0 /
'BB-2'  open GRAT 210.81 207.14 11888.98 2 1* 3280 0 /
/
DATES
  1 'May' 2010 /
/
WCONHIST
'BB-1X' open GRAT 59.12 56.95 3353.03 1 1* 3150 0 /
'BB-2'  open GRAT 205.63 198.10 11662.88 2 1* 3280 0 /
```

```
/
DATES
  1 'Jun' 2010 /
/
WCONHIST
'BB-1X' open GRAT 54.78 54.21 3097.62 1 1* 3150 0 /
'BB-2'  open GRAT 198.04 195.95 11197.84 2 1* 3280 0 /
/
DATES
  1 'Jul' 2010 /
/
WCONHIST
'BB-1X' open GRAT 54.70 55.23 3167.36 1 1* 3150 0 /
'BB-2'  open GRAT  189.92 191.78 10997.84 2 1* 3280 0 /
/
DATES
  1 'Aug' 2010 /
/
WCONHIST
'BB-1X' open GRAT 54.02 54.92 3166.08 1 1* 3150 0 /
'BB-2'  open GRAT 188.00 191.12 11018.16 2 1* 3280 0 /
/
DATES
  1 'Sep' 2010 /
/
WCONHIST
'BB-1X' open GRAT 52.19 53.32 3098.93 1 1* 3120 0 /
'BB-2'  open GRAT 182.49 186.46 10836.46 2 1* 3280 0 /
/
DATES
  1 'Oct' 2010 /
/
```

```
WCONHIST
'BB-1X' open GRAT 54.58 57.70 3354.31 1 1* 3100 0 /
'BB-2'  open GRAT 171.54 181.34 10541.85 2 1* 3240 0 /
/
DATES
  1 'Nov' 2010 /
/
WCONHIST
'BB-1X' open GRAT 41.58 44.44 2596.00 1 1* 3075 0 /
'BB-2'  open GRAT 130.80 139.80 8166.90       2 1* 3180 0 /
/
DATES
  1 'Dec' 2010 /
/
WCONHIST
'BB-1X' open GRAT 39.60 41.14 2381.68 1 1* 2900 0 /
'BB-2'  open GRAT 149.72 155.54 9005.46       2 1* 3180 0 /
/
DATES
  1 'Jan' 2011 /
/
WCONHIST
'BB-1X' open GRAT 39.74 41.42 2399.49 1 1* 2900 0 /
'BB-2'  open GRAT 159.17 165.92 9610.87 2 1* 3150 0 /
/
DATES
  1 'Feb' 2011 /
/
WCONHIST
'BB-1X' open GRAT 40.81 43.04 2490.96 1 1* 2900 0 /
'BB-2'  open GRAT 160.03 168.77 9768.17 2 1* 3150 0 /
/
```

```
DATES
  1 'Mar' 2011 /
/
WCONHIST
'BB-1X' open GRAT 40.02 41.96 2422.28 1 1* 2850 0 /
'BB-2'  open GRAT 149.08 156.30 9023.95 2 1* 3050 0 /
/
DATES
  1 'Apr' 2011 /
/
WCONHIST
'BB-1X' open GRAT 41.95 42.65 2447.70 1 1* 2750 0 /
'BB-2'  open GRAT 152.88 155.41 8919.95 2 1* 3050 0 /
/
DATES
  1 'May' 2011 /
/
WCONHIST
'BB-1X' open GRAT 40.52 41.73 2402.72 1 1* 2700 0 /
'BB-2'  open GRAT 144.00 148.31 8569.71 2 1* 2850 0 /
/
DATES
  1 'Jun' 2011 /
/
WCONHIST
'BB-1X' open GRAT 37.83 42.88 2364.16 1 1* 2700 0 /
'BB-2'  open GRAT 130.48 147.88 8153.24 2 1* 2850 0 /
/
DATES
  1 'Jul' 2011 /
/
WCONHIST
```

```
'BB-1X' open GRAT 36.23 48.36 2249.88 1 1* 2610 0 /
'BB-2'  open GRAT  122.62 163.66 7614.47 2 1* 2578 0 /
/
DATES
  1 'Aug' 2011 /
/
WCONHIST
'BB-1X' open GRAT 37.38 55.30 2284.33 1 1* 2600 0 /
'BB-2'  open GRAT  122.30 180.92 7473.25 2 1* 2578 0 /
/
DATES
  1 'Sep' 2011 /
/
WCONHIST
'BB-1X' open GRAT 36.87 55.62 2273.99 1 1* 2610 0 /
'BB-2'  open GRAT  119.02 179.54 7340.79 2 1* 2578 0 /
/
DATES
  1 'Oct' 2011 /
/
WCONHIST
'BB-1X' open GRAT 36.56 55.74 2260.40 1 1* 2610 0 /
'BB-2'  open GRAT  117.64 179.34 7273.21 2 1* 2578 0 /
/
DATES
  1 'Nov' 2011 /
/
WCONHIST
'BB-1X' open GRAT 34.76 53.38 2138.37 1 1* 2610 0 /
'BB-2'  open GRAT  117.02 179.77 7201.94 2 1* 2578 0 /
/
DATES
```

```
  1 'Dec' 2011 /
/
WCONHIST
'BB-1X' open GRAT 34.29 53.57 2118.76 1 1* 2610 0 /
'BB-2'  open GRAT  117.62 183.76 7267.44 2 1* 2578 0 /
/
END
```

## APPENDIX C: PREDICTION INPUT DATA (CASE 11)

```
-- Upper layer = 1
-- Lower layer = 2
-- Gas Production Limit=15000 mscf/d for both BB-1X and BB-2 and
-- 50ft sueezed off in the Upeer sand and 80ft in the Lower sand
```

```
----------------------------------------------------------------------------------------------------
RUNSPEC
----------------------------------------------------------------------------------------------------
TITLE
   Production Optimization of Beanibazar Gas Field by Simulation

FIELD

DIMENS
   50 75 62 /

REGDIMS
  2 /
EQLDIMS
  2 /
--EQLOPTS
--QUIESC /

--NOSIM

WATER
GAS

TABDIMS
-- NTSFUN  NTPVT NSSFUN NPPVT NTFIP
      2      2     40    100    4    /

WELLDIMS
   10     62      1      10  /

VFPPDIMS
----  MXMFLO  MXMTHP  MXMWFR  MXMGFR  MXMALQ  NMMVF
     20      15       10       10      10       3 /

VFPIDIMS
  20  20  20 /

ENDSCALE
/

-- check
START
  09 'May' 1999 /

AQUDIMS
--MxnAqn  MxnAqc  Niftbl  Nriftb  Nanaqu  NcaMax
  0       0       3       30      4       70713  /
```

```
UNIFIN
UNIFOUT

-----------------------------------------------------------------------------------------------
GRID
-----------------------------------------------------------------------------------------------

INIT

GRIDFILE
2/
include
  'BeaniBazar_Dec08.GRDECL' /
include
  'BeaniBazar_Dec08.actnum' /
equals
  'actnum' 0 4*  21  56 /
--  'actnum' 0 4*  56  62 /
/
multiply
  permx  10 4*  1 20 /
  permx 100 4* 57 62 /
/
COPY
'PERMX' 'PERMY' /
'PERMX' 'PERMZ' /
/
MULTIPLY
'PERMZ' 0.1 /
/
equals
multpv .96 4* 57 62 /
/

-----------------------------------------------------------------------------------------------
EDIT
-----------------------------------------------------------------------------------------------
-- Change of Transmissibilities near BB_2

BOX
18 18 17 26 1 20 /
TRANX
200*0.25 /
ENDBOX

BOX
18 18 17 26 1 20 /
```

```
TRANY
200*0.25 /
ENDBOX

-----------------------------------------------------------------------------------------------
PROPS
-----------------------------------------------------------------------------------------------
RVCONSTT
--stb/Mscf
 0.017  14.7 /
 0.017  14.7 /

DENSITY
-- Upper Beanibazar
--          Oil          Water          Gas
--        LB/FT3         LB/FT3         LB/FT3
         32.345         62.366         0.04571 /
-- Lower Beanibazar
--          Stock tank densities
         32.000         62.366         0.04833 /

ROCK
  4000.0  0.30E-05 /
  4000.0  0.30E-05 /

--NB: from RPS techPVT analysis

PVDG
-- Beani_Bazar_upper
-- Pressure  Gas FVF   Gas Vis
-- psia      rb/Mscf     cp
     14.7  214.0486    0.0128
     50.0   65.8611    0.0129
    100.0   32.9306    0.0129
    230.0   14.2699    0.0130
    460.0    6.9609    0.0132
    690.0    4.5542    0.0134
    920.0    3.3708    0.0137
   1150.0    2.6508    0.0141
   1380.0    2.1842    0.0146
   1610.0    1.8573    0.0151
   1840.0    1.6155    0.0157
   2070.0    1.4294    0.0163
   2300.0    1.2856    0.0170
   2372.0    1.2463    0.0173
   2530.0    1.1697    0.0178
   2760.0    1.0743    0.0186
   2990.0    0.9967    0.0194
```

```
   3220.0    0.9306    0.0203
   3450.0    0.8755    0.0212
   4500.0    0.7041    0.0252
   6000.0    0.5754    0.0307
/
-- Beani_Bazar_lower
-- Pressure  Gas FVF   Gas Vis
-- psia      rb/Mscf     cp
     14.7  221.6932    0.0128
     50.0   68.2133    0.0128
    100.0   34.1066    0.0128
    230.0   14.5373    0.0129
    460.0    7.1514    0.0131
    690.0    4.6672    0.0134
    920.0    3.4505    0.0138
   1150.0    2.7202    0.0142
   1380.0    2.2450    0.0147
   1610.0    1.9070    0.0152
   1840.0    1.6606    0.0159
   2070.0    1.4706    0.0166
   2300.0    1.3235    0.0173
   2372.0    1.2833    0.0176
   2530.0    1.2065    0.0181
   2760.0    1.1099    0.0190
   2990.0    1.0311    0.0199
   3220.0    0.9639    0.0208
   3450.0    0.9076    0.0217
   4500.0    0.7341    0.0260
   6000.0    0.6037    0.0316
/

-- WATER DATA---

PVTW

-- Ref Pres Bw  cw  uw  viscosibility
-- psia   rb/stb  1/psi cP  1/psi
  2000    1.0229     3.07e-06  0.381       0.45e-05/
  2000    1.0229     3.07e-06  0.381       0.45e-05/

sgwfn
  0.0 0.0000  1.0000 0.0
  0.1 0.0019  0.6561 0.0
  0.2 0.0144  0.4096 0.0
  0.3 0.0459  0.2401 0.0
  0.4 0.1024  0.1296 0.0
  0.5 0.1875  0.0625 0.0
  0.6 0.3024  0.0256 0.0
```

```
  0.7 0.4459  0.0081 0.0
  0.8 0.6144  0.0016 0.0
  0.9 0.8019  0.0001 0.0
  1.0 1.0000  0.0000 0.0
/
  0.0 0.0000  1.0000 0.0
  0.1 0.0019  0.6561 0.0
  0.2 0.0144  0.4096 0.0
  0.3 0.0459  0.2401 0.0
  0.4 0.1024  0.1296 0.0
  0.5 0.1875  0.0625 0.0
  0.6 0.3024  0.0256 0.0
  0.7 0.4459  0.0081 0.0
  0.8 0.6144  0.0016 0.0
  0.9 0.8019  0.0001 0.0
  1.0 1.0000  0.0000 0.0
/

equals
  krw 0.5 4* 1 20 /
/
include
 'BeaniBazar_Dec08.sw' /
copy
  swl swcr /
/
equals
  swu 1.0 /
/
add
  swcr 0.15 /
/
maxvalue
  swcr 1.0 /
/

-----------------------------------------------------------------------------------------------
REGIONS
-----------------------------------------------------------------------------------------------
-- check
EQUALS
FIPNUM 1  4*  1 20 / Upper Sand
FIPNUM 2  4* 57 62 / Lower Sand
/

copy
  fipnum eqlnum /
/
```

```
-----------------------------------------------------------------------------------------------
SOLUTION
-----------------------------------------------------------------------------------------------
EQUIL
-- check
-- datum(x)  datum(x)    WGC     Pc   GOC      Pcgoc
-- depth     pressure    depth        depth
   10575     4601        10663   0    10663    0      0  1  / Upper sand observed GWC
   11256     4831        11450   0    11450    0      0  1  / Lower sand GDT in BB-1

--Carter Tracy Aquifer Setup
AQUCT
--AQ#   Datum    Pi     Perm    Poro Comp                 Re      Thick    Angle    WaterTab
InfluenceTab
 1     10663     -1      995     0.2  1.00000060266128e-005     5000     600      360     1      1    1* /
 2     10663     -1      995     0.2  1.00000060266128e-005     5000     600      360     1      1    1* /
 3     11256     -1      10      0.2  1.00000060266128e-005     5000     600      360     1      1    1* /
 4     11256     -1      10      0.2  1.00000060266128e-005     5000     600      360     1      1    1* /

--Aquifer Connections
AQUANCON
--AQ#  I-   I+   J-   J+   Z-   Z+   Face
  1   26   50   1  63   1   20   'I+' 2* 'NO' /
  2    1   25   1  63   1   20   'I-' 2* 'NO' /
  3   26   50   1  63  57   62   'I+' 2* 'NO' /
  4    1   25   1  63  57   62   'I-' 2* 'NO' /
/

-----------------------------------------------------------------------------------------------
SUMMARY
-----------------------------------------------------------------------------------------------

--Summary Reporting Controls
RPTSMRY
1 /

runsum

include
 'SMRY.INC' /


-----------------------------------------------------------------------------------------------
SCHEDULE
-----------------------------------------------------------------------------------------------
-- SCHEDULE

RPTSCHED
```

```
--Report switches for simulation results
   'SUMMARY=2' 'RESTART=2' 'WELSPECS' 'FIP=2'  'CPU=1' /

RPTRST
--Controls data written to the restart file
  'BASIC=5' 'FREQ=1'  /


-- VFP table
INCLUDE
'VFP_BB_1.inc'  / VFP Table1 (BB-1 Lower Gas Sand)/

INCLUDE
'VFP_BB_2.inc'  / VFP Table2 (BB-2 Upper Gas Sand)/

WELSPECS
-- check
-- Well     Group  X    Y   bhp_depth(x) Pref_phase
   'BB-1X'  'g'    22   37   11176        'gas'  /
   'BB-2'   'g'    20   22   10525        'gas'  /
/

-- VFP Data
VFPCHK
  1.0E5 /
VFPTABL
2  /

include
'BeaniBazar_Dec08.compdat'
/

include
'BBazar_FCCase11.inc'
/

DATES
  1 'Dec' 2011 /
/

END
```

## BBazar_FCCase11.inc

```
-- This information was generated from the daily production database
-- From the file "Production Analysis of Beanibazar.xls"
-- Gas Production Limit = 15000 mscf/d for both BB-1X and BB-2 and
```

```
-- 50ft squuezed off in the Upper sand and 80ft in the Lower sand

WCONHIST
'BB-1X' open GRAT 319.3 0 17925.9 1 1*  0 4898 /
'BB-2' open GRAT 0 0 0 2 1* 3650 4574 /
/
DATES
  1 'Jun' 1999 /
/
WCONHIST
'BB-1X' open GRAT 240.4 0 16390.7 1 1* 2697 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jul' 1999 /
/
WCONHIST
'BB-1X' open GRAT 256.4 1.5 17871.9 1 1* 2699 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Aug' 1999 /
/
WCONHIST
'BB-1X' open GRAT 208.1 1.2 14809.9 1 1* 3200 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Sep' 1999 /
/
WCONHIST
'BB-1X' open GRAT 138.4 0.7 9817 1 1* 3152 0 /
```

```
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Oct' 1999 /
/
WCONHIST
'BB-1X' open GRAT 227.5 1.1 15789.5 1 1* 2748 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Nov' 1999 /
/
WCONHIST
'BB-1X' open GRAT 245.7 1.2 16623.3 1 1* 2657 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Dec' 1999 /
/
WCONHIST
'BB-1X' open GRAT 72.6 0.5 5016 1 1* 2871 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jan' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3750 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Feb' 2000 /
```

```
/
WCONHIST
'BB-1X' open GRAT 58.9 0.5 4121.4 1 1* 3750 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Mar' 2000 /
/
WCONHIST
'BB-1X' open GRAT 188.5 3.2 11811.1 1 1* 2505 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Apr' 2000 /
/
WCONHIST
'BB-1X' open GRAT 199.8 3.4 14912.4 1 1* 2900 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'May' 2000 /
/
WCONHIST
'BB-1X' open GRAT 129.3 3.5 8425.9 1 1* 2896 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jun' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
```

```
/
DATES
  1 'Jul' 2000 /
/
WCONHIST
'BB-1X' open GRAT 42 1.2 2700.8 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Aug' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Sep' 2000 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Oct' 2000 /
/
WCONHIST
'BB-1X' open GRAT 1.2 0 102.9 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Nov' 2000 /
/
```

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WCONHIST
'BB-1X' open GRAT 0 0 4.9 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Dec' 2000 /
/
WCONHIST
'BB-1X' open GRAT 22.9 0.5 1411.7 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jan' 2001 /
/
WCONHIST
'BB-1X' open GRAT 2 0.1 129 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Feb' 2001 /
/
WCONHIST
'BB-1X' open GRAT 140.6 4.3 9308.1 1 1* 2773 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Mar' 2001 /
/
WCONHIST
'BB-1X' open GRAT 0 0 5 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
```

```
DATES
  1 'Apr' 2001 /
/
WCONHIST
'BB-1X' open GRAT 192.4 4.7 11936 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'May' 2001 /
/
WCONHIST
'BB-1X' open GRAT 257.5 6.7 15380.6 1 1* 2891 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jun' 2001 /
/
WCONHIST
'BB-1X' open GRAT 11.7 0.3 722.1 1 1* 3760 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Jul' 2001 /
/
WCONHIST
'BB-1X' open GRAT 13.2 0.3 910.5 1 1* 3751 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Aug' 2001 /
/
WCONHIST
```

```
'BB-1X' open GRAT 105.9 2.4 6537 1 1* 3150 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Sep' 2001 /
/
WCONHIST
'BB-1X' open GRAT 138.8 4.6 8872.6 1 1* 2850 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Oct' 2001 /
/
WCONHIST
'BB-1X' open GRAT 66.8 2.4 4301.4 1 1* 3751 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Nov' 2001 /
/
WCONHIST
'BB-1X' open GRAT 152 4.8 8352.2 1 1* 3751 0 /
'BB-2' open GRAT 0 0 0 2 1* 3650 0 /
/
DATES
  1 'Dec' 2001 /
/
WCONHIST
'BB-1X' open GRAT 137.9 4.5 8152.1 1 1* 2900 0 /
'BB-2' open GRAT 0 0 0  2 1* 3650 0 /
/
DATES
```

```
  1 'Jan' 2002 /
/
WCONHIST
'BB-1X' open GRAT 199.7 0.3 19049.9 1 1* 3748 4744 /
'BB-2' open GRAT 115.3 2.3 19049.9 2 1* 3650 0 /
/
DATES
  1 'Feb' 2002 /
/
WCONHIST
'BB-1X' open GRAT 155.2 7.2 9154.7 1 1* 3200 0 /
'BB-2' open GRAT 113.5 10.7 6089.1 2 1* 3350 0 /
/
DATES
  1 'Mar' 2002 /
/
WCONHIST
'BB-1X' open GRAT 168.3 3.8 10195.3 1 1* 3752 0 /
'BB-2' open GRAT 175.3 16.6 9976 2 1* 3586 0 /
/
DATES
  1 'Apr' 2002 /
/
WCONHIST
'BB-1X' open GRAT 202.9 4.4 12482.3 1 1* 3360 0 /
'BB-2' open GRAT 149.1 13.7 8484.5 2 1* 3240 0 /
/
DATES
  1 'May' 2002 /
/
WCONHIST
'BB-1X' open GRAT 195.9 4.1 12185 1 1* 3400 0 /
```

```
'BB-2' open GRAT 146.2 12.3 8246.6 2 1* 3340 0 /
/
DATES
  1 'Jun' 2002 /
/
WCONHIST
'BB-1X' open GRAT 208.7 5.4 12317.9 1 1* 3400 0 /
'BB-2' open GRAT 227.5 23.4 12281.6 2 1* 3325 0 /
/
DATES
  1 'Jul' 2002 /
/
WCONHIST
'BB-1X' open GRAT 219.9 6.4 12542.5 1 1* 3400 0 /
'BB-2' open GRAT 225.6 26.4 11860.6 2 1* 3050 0 /
/
DATES
  1 'Aug' 2002 /
/
WCONHIST
'BB-1X' open GRAT 191.1 5.9 11145.7 1 1* 3420 0 /
'BB-2' open GRAT 188.6 23.2 10133.8 2 1* 3250 0 /
/
DATES
  1 'Sep' 2002 /
/
WCONHIST
'BB-1X' open GRAT 257.8 8.5 15374.7 1 1* 3150 0 /
'BB-2' open GRAT 256 33.8 13893.8 2 1* 3100 0 /
/
DATES
  1 'Oct' 2002 /
```

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/
WCONHIST
'BB-1X' open GRAT 198.4 7.6 12717.3 1 1* 3400 0 /
'BB-2' open GRAT 226.1 33.6 12735.4 2 1* 3000 0 /
/
DATES
  1 'Nov' 2002 /
/
WCONHIST
'BB-1X' open GRAT 204.8 7.5 14137.3 1 1* 3752 0 /
'BB-2' open GRAT 123.6 17.2 7142.6 2 1* 3050 0 /
/
DATES
  1 'Dec' 2002 /
/
WCONHIST
'BB-1X' open GRAT 77.1 2 5337.4 1 1* 3200 0 /
'BB-2' open GRAT 112.1 12 6602.7 2 1* 3240 0 /
/
DATES
  1 'Jan' 2003 /
/
WCONHIST
'BB-1X' open GRAT 190.9 6.6 12410.2 1 1* 3282 0 /
'BB-2' open GRAT 187.2 23.2 11326.3 2 1* 3139 0 /
/
DATES
  1 'Feb' 2003 /
/
WCONHIST
'BB-1X' open GRAT 161.4 5.7 10992.5 1 1* 3302 0 /
'BB-2' open GRAT 150.8 19.6 9536.2 2 1* 3330 0 /
```

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/
DATES
  1 'Mar' 2003 /
/
WCONHIST
'BB-1X' open GRAT 169 6.2 11731.1 1 1* 3349 0 /
'BB-2' open GRAT 178.9 24.6 11504.3 2 1* 3330 0 /
/
DATES
  1 'Apr' 2003 /
/
WCONHIST
'BB-1X' open GRAT 166 7 11380.8 1 1* 3414 0 /
'BB-2' open GRAT 158 24.2 10106.4 2 1* 3462 0 /
/
DATES
  1 'May' 2003 /
/
WCONHIST
'BB-1X' open GRAT 103.3 2.9 6176.2 1 1* 3541 0 /
'BB-2' open GRAT 44.2 3.8 2411.3 2 1* 2900 0 /
/
DATES
  1 'Jun' 2003 /
/
WCONHIST
'BB-1X' open GRAT 228 6.8 13056.4 1 1* 3245 0 /
'BB-2' open GRAT 204.9 23.2 11465.7 2 1* 3103 0 /
/
DATES
  1 'Jul' 2003 /
/
```

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WCONHIST
'BB-1X' open GRAT 148.7 5.1 8557 1 1* 2745 0 /
'BB-2' open GRAT 104 13.5 5740.5 2 1* 3301 0 /
/
DATES
  1 'Aug' 2003 /
/
WCONHIST
'BB-1X' open GRAT 285.2 9.7 16154.4 1 1* 2935 0 /
'BB-2' open GRAT 245.9 31.5 13587.5 2 1* 3136 0 /
/
DATES
  1 'Sep' 2003 /
/
WCONHIST
'BB-1X' open GRAT 275.5 10.5 15594.6 1 1* 3008 0 /
'BB-2' open GRAT 240.2 34.7 13265 2 1* 3121 0 /
/
DATES
  1 'Oct' 2003 /
/
WCONHIST
'BB-1X' open GRAT 245.5 9 13705.4 1 1* 3004 0 /
'BB-2' open GRAT 216.8 29.9 11806.9 2 1* 3140 0 /
/
DATES
  1 'Nov' 2003 /
/
WCONHIST
'BB-1X' open GRAT 223.6 7.8 12396.8 1 1* 2949 0 /
'BB-2' open GRAT 209.8 27.5 11356.5 2 1* 3216 0 /
/
```

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DATES
  1 'Dec' 2003 /
/
WCONHIST
'BB-1X' open GRAT 280.6 10.7 15609 1 1* 2865 0 /
'BB-2' open GRAT 226.7 32.5 12359.3 2 1* 3224 0 /
/
DATES
  1 'Jan' 2004 /
/
WCONHIST
'BB-1X' open GRAT 285.7 11.2 16105.1 1 1* 2950 0 /
'BB-2' open GRAT 197.5 29.4 10791.9 2 1* 3300 0 /
/
DATES
  1 'Feb' 2004 /
/
WCONHIST
'BB-1X' open GRAT 271.2 10.5 15559.6 1 1* 2550 0 /
'BB-2' open GRAT 208.9 30.8 11612.3 2 1* 3340 0 /
/
DATES
  1 'Mar' 2004 /
/
WCONHIST
'BB-1X' open GRAT 254 10.4 14352.3 1 1* 3000 0 /
'BB-2' open GRAT 211.8 33.2 11602.6 2 1* 3150 0 /
/
DATES
  1 'Apr' 2004 /
/
WCONHIST
```

```
'BB-1X' open GRAT 233 9.9 13693.5 1 1* 2800 0 /
'BB-2' open GRAT 179.8 28.7 10178.3 2 1* 2925 0 /
/
DATES
  1 'May' 2004 /
/
WCONHIST
'BB-1X' open GRAT 233.6 9.2 13177.1 1 1* 3150 0 /
'BB-2' open GRAT 183.6 27.6 9932.2 2 1* 3300 0 /
/
DATES
  1 'Jun' 2004 /
/
WCONHIST
'BB-1X' open GRAT 214.6 8.6 11812.8 1 1* 3000 0 /
'BB-2' open GRAT 171.8 25.9 9065.5 2 1* 3325 0 /
/
DATES
  1 'Jul' 2004 /
/
WCONHIST
'BB-1X' open GRAT 224.2 8.4 12946.1 1 1* 2950 0 /
'BB-2' open GRAT 171.4 24.1 9415.2 2 1* 3410 0 /
/
DATES
  1 'Aug' 2004 /
/
WCONHIST
'BB-1X' open GRAT 224.5 10 13449.6 1 1* 3100 0 /
'BB-2' open GRAT 172 28.7 9811 2 1* 3335 0 /
/
DATES
```

```
  1 'Sep' 2004 /
/
WCONHIST
'BB-1X' open GRAT 221.2 10.9 12610.4 1 1* 2800 0 /
'BB-2' open GRAT 190 35.1 10372.5 2 1* 2975 0 /
/
DATES
  1 'Oct' 2004 /
/
WCONHIST
'BB-1X' open GRAT 206 11.5 12021.4 1 1* 3000 0 /
'BB-2' open GRAT 212.7 44.8 11900.7 2 1* 3325 0 /
/
DATES
  1 'Nov' 2004 /
/
WCONHIST
'BB-1X' open GRAT 170 9.7 9383.7 1 1* 2600 0 /
'BB-2' open GRAT 224.3 48.4 11888.3 2 1* 3400 0 /
/
DATES
  1 'Dec' 2004 /
/
WCONHIST
'BB-1X' open GRAT 187.4 11 10555.1 1 1* 2500 0 /
'BB-2' open GRAT 198.2 44 10720.2 2 1* 3280 0 /
/
DATES
  1 'Jan' 2005 /
/
WCONHIST
'BB-1X' open GRAT 162.7 10.5 9402 1 1* 3150 0 /
```

```
'BB-2' open GRAT 210.6 49.4 11811.3 2 1* 3300 0 /
/
DATES
  1 'Feb' 2005 /
/
WCONHIST
'BB-1X' open GRAT 130.3 9 7640.8 1 1* 2900 0 /
'BB-2' open GRAT 222 56.4 12654.2 2 1* 3150 0 /
/
DATES
  1 'Mar' 2005 /
/
WCONHIST
'BB-1X' open GRAT 163.9 12.7 9531.9 1 1* 2400 0 /
'BB-2' open GRAT 242.1 67.8 13702.6 2 1* 3300 0 /
/
DATES
  1 'Apr' 2005 /
/
WCONHIST
'BB-1X' open GRAT 148.4 13.3 8474.6 1 1* 2550 4619 /
'BB-2' open GRAT 194.7 57.7 10624.7 2 1* 3150 4556 /
/
DATES
  1 'May' 2005 /
/
WCONHIST
'BB-1X' open GRAT 92.9 7.9 5628.8 1 1* 2900 0 /
'BB-2' open GRAT 120.6 36.3 7042 2 1* 3150 0 /
/
DATES
  1 'Jun' 2005 /
```

```
/
WCONHIST
'BB-1X' open GRAT 136.4 9.8 8321.4 1 1* 3624 0 /
'BB-2' open GRAT 151.7 40.2 8833.1 2 1* 3616 0 /
/
DATES
  1 'Jul' 2005 /
/
WCONHIST
'BB-1X' open GRAT 172.4 15.1 10621.9 1 1* 3050 0 /
'BB-2' open GRAT 199.7 63.2 11842.7 2 1* 3050 0 /
/
DATES
  1 'Aug' 2005 /
/
WCONHIST
'BB-1X' open GRAT 174.3 19 10741.9 1 1* 3000 0 /
'BB-2' open GRAT 190.9 67.3 11187.7 2 1* 3400 0 /
/
DATES
  1 'Sep' 2005 /
/
WCONHIST
'BB-1X' open GRAT 78.5 8 4976.2 1 1* 2850 0 /
'BB-2' open GRAT 98.4 36 5921.6 2 1* 3233 0 /
/
DATES
  1 'Oct' 2005 /
/
WCONHIST
'BB-1X' open GRAT 138.6 13.5 8012.9 1 1* 3624 0 /
'BB-2' open GRAT 199.3 70.2 11108.8 2 1* 3440 0 /
```

```
/
DATES
  1 'Nov' 2005 /
/
WCONHIST
'BB-1X' open GRAT 142 14.6 8536.3 1 1* 3000 0 /
'BB-2' open GRAT 203.9 75.5 11791.8 2 1* 3450 0 /
/
DATES
  1 'Dec' 2005 /
/
WCONHIST
'BB-1X' open GRAT 136.6 15.1 8091.9 1 1* 2900 0 /
'BB-2' open GRAT 198.7 79.6 11335.8 2 1* 3460 0 /
/
DATES
  1 'Jan' 2006 /
/
WCONHIST
'BB-1X' open GRAT 99 14.6 5775.7 1 1* 2900 0 /
'BB-2' open GRAT 142.4 61 7983.3 2 1* 3430 0 /
/
DATES
  1 'Feb' 2006 /
/
WCONHIST
'BB-1X' open GRAT 128.3 16.6 7008 1 1* 2850 0 /
'BB-2' open GRAT 172.4 78.6 9120.7 2 1* 2975 0 /
/
DATES
  1 'Mar' 2006 /
/
```

```
WCONHIST
'BB-1X' open GRAT 119.4 16.5 6775.5 1 1* 3000 0 /
'BB-2' open GRAT 186 90.3 10177.5 2 1* 3480 0 /
/
DATES
  1 'Apr' 2006 /
/
WCONHIST
'BB-1X' open GRAT 123.7 18.3 6992 1 1* 3050 0 /
'BB-2' open GRAT 173.2 89.5 9426.2 2 1* 3340 0 /
/
DATES
  1 'May' 2006 /
/
WCONHIST
'BB-1X' open GRAT 108.1 16.9 6197.3 1 1* 3050 0 /
'BB-2' open GRAT 136.6 74.5 7538.9 2 1* 3370 0 /
/
DATES
  1 'Jun' 2006 /
/
WCONHIST
'BB-1X' open GRAT 126.6 21.8 7059.8 1 1* 2800 0 /
'BB-2' open GRAT 165.5 100.1 8886.9 2 1* 3350 0 /
/
DATES
  1 'Jul' 2006 /
/
WCONHIST
'BB-1X' open GRAT 118.2 20.1 6724 1 1* 3000 0 /
'BB-2' open GRAT 157.4 93.3 8586.5 2 1* 3460 0 /
/
```

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DATES
  1 'Aug' 2006 /
/
WCONHIST
'BB-1X' open GRAT 128.7 23.4 7610.7 1 1* 2950 0 /
'BB-2' open GRAT 183 115.8 10352.7 2 1* 3280 0 /
/
DATES
  1 'Sep' 2006 /
/
WCONHIST
'BB-1X' open GRAT 133.2 24 7900.4 1 1* 2740 0 /
'BB-2' open GRAT 175.3 110.1 9930.1 2 1* 3425 0 /
/
DATES
  1 'Oct' 2006 /
/
WCONHIST
'BB-1X' open GRAT 105.7 19.7 6300.9 1 1* 2900 0 /
'BB-2' open GRAT 163 105.1 9269.4 2 1* 3440 0 /
/
DATES
  1 'Nov' 2006 /
/
WCONHIST
'BB-1X' open GRAT 112.3 21.8 6656.6 1 1* 2900 0 /
'BB-2' open GRAT 170.4 115.3 9673.4 2 1* 3440 0 /
/
DATES
  1 'Dec' 2006 /
/
WCONHIST
```

```
'BB-1X' open GRAT 111.1 22.1 6425.6 1 1* 2950 0 /
'BB-2' open GRAT 176.5 123 9869.3 2 1* 3200 0 /
/
DATES
  1 'Jan' 2007 /
/
WCONHIST
'BB-1X' open GRAT 127.5 26.6 7336.2 1 1* 3050 0 /
'BB-2' open GRAT 178.8 131.1 9973.9 2 1* 3160 0 /
/
DATES
  1 'Feb' 2007 /
/
WCONHIST
'BB-1X' open GRAT 138.8 31.2 8220.3 1 1* 3200 0 /
'BB-2' open GRAT 156.8 122.2 8918.5 2 1* 3180 0 /
/
DATES
  1 'Mar' 2007 /
/
WCONHIST
'BB-1X' open GRAT 149.5 38.3 9075.4 1 1* 3000 0 /
'BB-2' open GRAT 144.5 128.7 8423.1 2 1* 3360 0 /
/
DATES
  1 'Apr' 2007 /
/
WCONHIST
'BB-1X' open GRAT 82.4 46.9 5632.5 1 1* 2800 0 /
'BB-2' open GRAT 48.8 51.8 2995.4 2 1* 3440 0 /
/
DATES
```

```
  1 'May' 2007 /
/
WCONHIST
'BB-1X' open GRAT 112.9 33.2 7106.6 1 1* 3100 0 /
'BB-2' open GRAT 129 122 7693.6 2 1* 3350 0 /
/
DATES
  1 'Jun' 2007 /
/
WCONHIST
'BB-1X' open GRAT 97.6 29.4 6241.6 1 1* 3150 0 /
'BB-2' open GRAT 134.9 139.8 8155.7 2 1* 3455 0 /
/
DATES
  1 'Jul' 2007 /
/
WCONHIST
'BB-1X' open GRAT 94.8 28.5 6139.7 1 1* 3150 0 /
'BB-2' open GRAT 135 139.4 8269.4 2 1* 3460 0 /
/
DATES
  1 'Aug' 2007 /
/
WCONHIST
'BB-1X' open GRAT 91.3 28.6 6400.6 1 1* 3150 0 /
'BB-2' open GRAT 133.1 143.8 8977.5 2 1* 3440 0 /
/
DATES
  1 'Sep' 2007 /
/
WCONHIST
'BB-1X' open GRAT 99.3 29.7 6442.6 1 1* 3250 0 /
```

```
'BB-2' open GRAT 152.2 155.5 9325.8 2 1* 3340 0 /
/
DATES
  1 'Oct' 2007 /
/
WCONHIST
'BB-1X' open GRAT 80.9 24.3 4774.3 1 1* 3250 0 /
'BB-2' open GRAT 142.5 138.1 8122.4 2 1* 3320 0 /
/
DATES
  1 'Nov' 2007 /
/
WCONHIST
'BB-1X' open GRAT 67.4 20.2 4362.2 1 1* 3300 4592 /
'BB-2' open GRAT 143.6 141.6 8695.9 2 1* 3460 4546 /
/
DATES
  1 'Dec' 2007 /
/
WCONHIST
'BB-1X' open GRAT 66.9 21.9 4414.4 1 1* 3300 0 /
'BB-2' open GRAT 137.2 149.5 8539.3 2 1* 3360 0 /
/
DATES
  1 'Jan' 2008 /
/
WCONHIST
'BB-1X' open GRAT 64.4 20.4 4134.5 1 1* 3300 0 /
'BB-2' open GRAT 127.7 136.5 7779.7 2 1* 3400 0 /
/
DATES
  1 'Feb' 2008 /
```

```
/
WCONHIST
'BB-1X' open GRAT 60.8 20.7 4021.3 1 1* 3300 0 /
'BB-2' open GRAT 124.2 143.7 7726.4 2 1* 3400 0 /
/
DATES
  1 'Mar' 2008 /
/
WCONHIST
'BB-1X' open GRAT 51 16.9 3487.4 1 1* 3300 0 /
'BB-2' open GRAT 127.6 142.1 8101.5 2 1* 3400 0 /
/
DATES
  1 'Apr' 2008 /
/
WCONHIST
'BB-1X' open GRAT 46.7 14.3 3192.5 1 1* 3300 0 /
'BB-2' open GRAT 131.3 134.9 8325.9 2 1* 3400 0 /
/
DATES
  1 'May' 2008 /
/
WCONHIST
'BB-1X' open GRAT 46.8 13.8 3198 1 1* 3100 0 /
'BB-2' open GRAT 137.9 136 8734.4 2 1* 3400 0 /
/
DATES
  1 'Jun' 2008 /
/
WCONHIST
'BB-1X' open GRAT 61.7 21 4228.1 1 1* 3300 0 /
'BB-2' open GRAT 127.9 145.2 8132.9 2 1* 3400 0 /
```

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/
DATES
  1 'Jul' 2008 /
/
WCONHIST
'BB-1X' open GRAT 88.27 77.01 5770 1 1* 3350 0 /
'BB-2' open GRAT 128.00   111.97          8390.00 2 1* 3350 0 /
/
DATES
  1 'Aug' 2008 /
/
WCONHIST
'BB-1X' open GRAT 68.27 60.41 4250.0 1 1* 3350 0 /
'BB-2'  open GRAT 101.00 88.83  6260.00 2 1* 3350 0 /
/
DATES
  1 'Sep' 2008 /
/
WCONHIST
'BB-1X' open GRAT 124.58 103.72 7700.00 1 1* 3350 0 /
'BB-2'  open GRAT 117.71 98.00  7280.00         2 1* 3350 0 /
/
DATES
  1 'Oct' 2008 /
/
WCONHIST
'BB-1X' open GRAT 150.67 123.31 9380.00 1 1* 3350 0 /
'BB-2'  open GRAT 117.41 95.31  7310.00        2 1* 3350 0 /
/
DATES
  1 'Nov' 2008 /
/
```

```
WCONHIST
'BB-1X' open GRAT 96.42 76.25 5990.00 1 1* 3350 0 /
'BB-2'  open GRAT 177.29 140.22 11030.00 2 1* 3250 0 /
/
DATES
  1 'Dec' 2008 /
/
WCONHIST
'BB-1X' open GRAT 83.16 67.98 4960.00 1 1* 3351 0 /
'BB-2'  open GRAT 191.33 156.91 11450.00 2 1* 3250 0 /
/
DATES
  1 'Jan' 2009 /
/
WCONHIST
'BB-1X' open GRAT 79.21 68.30 4640.00 1 1* 3351 0 /
'BB-2'  open GRAT  193.49 166.84 11340.00 2 1* 3250 0 /
/
DATES
  1 'Feb' 2009 /
/
WCONHIST
'BB-1X' open GRAT 74.74 65.68 4550.00 1 1* 3200 0 /
'BB-2'  open GRAT 184.98 162.57 11260.00 2 1* 3250 0 /
/
DATES
  1 'Mar' 2009 /
/
WCONHIST
'BB-1X' open GRAT 60.06 51.86 3500.00 1 1* 3351 0 /
'BB-2'  open GRAT 193.71 167.28 11290.00 2 1* 3200 0 /
/
```

```
DATES
  1 'Apr' 2009 /
/
WCONHIST
'BB-1X' open GRAT 36.90 33.66 2189.00 1 1* 3350 0 /
'BB-2'  open GRAT 200.09 182.49 11872.15 2 1* 3200 0 /
/
DATES
  1 'May' 2009 /
/
WCONHIST
'BB-1X' open GRAT 50.08 47.27 2964.05 1 1* 3351 0 /
'BB-2'  open GRAT 186.15 175.70 11018.23 2 1* 3200 0 /
/
DATES
  1 'Jun' 2009 /
/
WCONHIST
'BB-1X' open GRAT 65.90 63.36 4032.19 1 1* 3350 0 /
'BB-2'  open GRAT 158.80 152.67 9715.65      2 1* 3200 0 /
/
DATES
  1 'Jul' 2009 /
/
WCONHIST
'BB-1X' open GRAT 72.75 71.32 4525.76 1 1* 3350 0 /
'BB-2'  open GRAT 150.59 147.64 9368.46      2 1* 3200 0 /
/
DATES
  1 'Aug' 2009 /
/
WCONHIST
```

```
'BB-1X' open GRAT 52.55 52.87 3736.90 1 1* 3350 0 /
'BB-2'  open GRAT 133.59 134.39 9498.85        2 1* 3200 0 /
/
DATES
  1 'Sep' 2009 /
/
WCONHIST
'BB-1X' open GRAT 74.94 64.98 4296.68 1 1* 3350 0 /
'BB-2'  open GRAT 181.05 156.98 10379.99 2 1* 3280 0 /
/
DATES
  1 'Oct' 2009 /
/
WCONHIST
'BB-1X' open GRAT 57.05 47.95 3292.92 1 1* 3351 0 /
'BB-2'  open GRAT 207.01 173.98 11948.00 2 1* 3280 0 /
/
DATES
  1 'Nov' 2009 /
/
WCONHIST
'BB-1X' open GRAT 56.09 48.79 3240.79 1 1* 3350 0 /
'BB-2'  open GRAT 204.42 177.83 11811.16 2 1* 3280 0 /
/
DATES
  1 'Dec' 2009 /
/
WCONHIST
'BB-1X' open GRAT 57.84 52.24 3254.30 1 1* 3200 0 /
'BB-2'  open GRAT 212.11 191.56 11933.82 2 1* 3280 0 /
/
DATES
```

```
  1 'Jan' 2010 /
/
WCONHIST
'BB-1X' open GRAT 56.03 50.26 3169.30 1 1* 3150 0 /
'BB-2'  open GRAT 209.98 188.37 11878.13 2 1* 3280 0 /
/
DATES
  1 'Feb' 2010 /
/
WCONHIST
'BB-1X' open GRAT 53.20 53.78 3169.30 1 1* 3150 0 /
'BB-2'  open GRAT 205.46 207.69 12238.93 2 1* 3280 0 /
/
DATES
  1 'Mar' 2010 /
/
WCONHIST
'BB-1X' open GRAT 53.90 55.51 3230.08 1 1* 3150 0 /
'BB-2'  open GRAT 199.68 205.64 11965.85 2 1* 3280 0 /
/
DATES
  1 'Apr' 2010 /
/
WCONHIST
'BB-1X' open GRAT 58.36 57.35 3291.48 1 1* 3150 0 /
'BB-2'  open GRAT 210.81 207.14 11888.98 2 1* 3280 0 /
/
DATES
  1 'May' 2010 /
/
WCONHIST
'BB-1X' open GRAT 59.12 56.95 3353.03 1 1* 3150 0 /
```

```
'BB-2'  open GRAT 205.63 198.10 11662.88 2 1* 3280 0 /
/
DATES
  1 'Jun' 2010 /
/
WCONHIST
'BB-1X' open GRAT 54.78 54.21 3097.62 1 1* 3150 0 /
'BB-2'  open GRAT 198.04 195.95 11197.84 2 1* 3280 0 /
/
DATES
  1 'Jul' 2010 /
/
WCONHIST
'BB-1X' open GRAT 54.70 55.23 3167.36 1 1* 3150 0 /
'BB-2'  open GRAT  189.92 191.78 10997.84 2 1* 3280 0 /
/
DATES
  1 'Aug' 2010 /
/
WCONHIST
'BB-1X' open GRAT 54.02 54.92 3166.08 1 1* 3150 0 /
'BB-2'  open GRAT 188.00 191.12 11018.16 2 1* 3280 0 /
/
DATES
  1 'Sep' 2010 /
/
WCONHIST
'BB-1X' open GRAT 52.19 53.32 3098.93 1 1* 3120 0 /
'BB-2'  open GRAT 182.49 186.46 10836.46 2 1* 3280 0 /
/
DATES
  1 'Oct' 2010 /
```

```
/
WCONHIST
'BB-1X' open GRAT 54.58 57.70 3354.31 1 1* 3100 0 /
'BB-2'  open GRAT 171.54 181.34 10541.85 2 1* 3240 0 /
/
DATES
  1 'Nov' 2010 /
/
WCONHIST
'BB-1X' open GRAT 41.58 44.44 2596.00 1 1* 3075 0 /
'BB-2'  open GRAT 130.80 139.80 8166.90        2 1* 3180 0 /
/
DATES
  1 'Dec' 2010 /
/
WCONHIST
'BB-1X' open GRAT 39.60 41.14 2381.68 1 1* 2900 0 /
'BB-2'  open GRAT 149.72 155.54 9005.46        2 1* 3180 0 /
/
DATES
  1 'Jan' 2011 /
/
WCONHIST
'BB-1X' open GRAT 39.74 41.42 2399.49 1 1* 2900 0 /
'BB-2'  open GRAT 159.17 165.92 9610.87 2 1* 3150 0 /
/
DATES
  1 'Feb' 2011 /
/
WCONHIST
'BB-1X' open GRAT 40.81 43.04 2490.96 1 1* 2900 0 /
'BB-2'  open GRAT 160.03 168.77 9768.17 2 1* 3150 0 /
```

```
/
DATES
  1 'Mar' 2011 /
/
WCONHIST
'BB-1X' open GRAT 40.02 41.96 2422.28 1 1* 2850 0 /
'BB-2'  open GRAT 149.08 156.30 9023.95 2 1* 3050 0 /
/
DATES
  1 'Apr' 2011 /
/
WCONHIST
'BB-1X' open GRAT 41.95 42.65 2447.70 1 1* 2750 0 /
'BB-2'  open GRAT 152.88 155.41 8919.95 2 1* 3050 0 /
/
DATES
  1 'May' 2011 /
/
WCONHIST
'BB-1X' open GRAT 40.52 41.73 2402.72 1 1* 2700 0 /
'BB-2'  open GRAT 144.00 148.31 8569.71 2 1* 2850 0 /
/
DATES
  1 'Jun' 2011 /
/
WCONHIST
'BB-1X' open GRAT 37.83 42.88 2364.16 1 1* 2700 0 /
'BB-2'  open GRAT 130.48 147.88 8153.24 2 1* 2850 0 /
/
DATES
  1 'Jul' 2011 /
/
```

```
WCONHIST
'BB-1X' open GRAT 36.23 48.36 2249.88 1 1* 2610 0 /
'BB-2'  open GRAT  122.62 163.66 7614.47 2 1* 2578 0 /
/
DATES
  1 'Aug' 2011 /
/
WCONHIST
'BB-1X' open GRAT 37.38 55.30 2284.33 1 1* 2600 0 /
'BB-2'  open GRAT  122.30 180.92 7473.25 2 1* 2578 0 /
/
DATES
  1 'Sep' 2011 /
/
WCONHIST
'BB-1X' open GRAT 36.87 55.62 2273.99 1 1* 2610 0 /
'BB-2'  open GRAT  119.02 179.54 7340.79 2 1* 2578 0 /
/
DATES
  1 'Oct' 2011 /
/
WCONHIST
'BB-1X' open GRAT 36.56 55.74 2260.40 1 1* 2610 0 /
'BB-2'  open GRAT  117.64 179.34 7273.21 2 1* 2578 0 /
/
DATES
  1 'Nov' 2011 /
/
WCONHIST
'BB-1X' open GRAT 34.76 53.38 2138.37 1 1* 2610 0 /
'BB-2'  open GRAT  117.02 179.77 7201.94 2 1* 2578 0 /
/
```

```
DATES
  1 'Dec' 2011 /
/
WCONHIST
'BB-1X' open GRAT 34.29 53.57 2118.76 1 1* 2610 0 /
'BB-2'  open GRAT  117.62 183.76 7267.44 2 1* 2578 0 /
/
WCONPROD
'BB-1X'  OPEN   GRAT   2*  15000  3*  0 / Wellhead requirement = 0 psia
'BB-2'   OPEN   GRAT   2*  15000  3*  0 / Wellhead requirement = 0 psia
/
--WEFAC
-- Working assumption for downtime i.e. 5%
-- 'BB-1X'  0.95  /
-- 'BB-2'  0.95  /
/
-- Well prod rates threshold based on VFP analysis
--WECON
--'BB-1X' 1* 100  3* NONE NO  /
--'BB-2' 1* 100  3* NONE NO  /
DATES
1 JAN 2012 /
1 JUL 2012 /
1 JAN 2013 /
1 JUL 2013 /
1 JAN 2014 /
1 JUL 2014 /
1 JAN 2015 /
1 JUL 2015 /
1 JAN 2016 /
1 JUL 2016 /
1 JAN 2017 /
```

1 JUL 2017 /

1 JAN 2018 /

1 JUL 2018 /

1 JAN 2019 /

1 JUL 2019 /

1 JAN 2020 /

1 JUL 2020 /

1 JAN 2021 /

1 JUL 2021 /

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1 JUL 2030 /

1 JAN 2031 /

/

END

# APPENDIX D: SUMMARIZED PREDICTION RESULTS (CASE 11)

**PREDICTION CASE11**

**RESULTS OF PREDICTION RUN**

| DATE | BB-1 PRODUCTION PROFILE | | | | BB-2 PRODUCTION PROFILE | | | | FGPT | FWPT |
|---|---|---|---|---|---|---|---|---|---|---|
| | WGPR | WWPR | WGPT | WWGR | WGPR | WWPR | WGPT | WWGR | | |
| | (MSCF/DAY) | (STB/DAY) | (MSCF) | (STB/MSCF) | (MSCF/DAY) | (STB/DAY) | (MSCF) | (STB/MSCF) | (MSCF) | (STB) |
| 9-May-99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-Jun-99 | 17925.9 | 0 | 412295.72 | 0 | 0 | 0 | 0 | 0 | 412295.72 | 0 |
| 1-Jul-99 | 16390.699 | 0 | 904016.69 | 0 | 0 | 0 | 0 | 0 | 904016.69 | 0 |
| 1-Aug-99 | 17871.9 | 0 | 1458045.6 | 0 | 0 | 0 | 0 | 0 | 1458045.6 | 0 |
| 1-Sep-99 | 14809.9 | 0 | 1917152.5 | 0 | 0 | 0 | 0 | 0 | 1917152.5 | 0 |
| 1-Oct-99 | 9817 | 0 | 2211662.5 | 0 | 0 | 0 | 0 | 0 | 2211662.5 | 0 |
| 1-Nov-99 | 15789.5 | 0 | 2701137 | 0 | 0 | 0 | 0 | 0 | 2701137 | 0 |
| 1-Dec-99 | 16623.301 | 0 | 3199836 | 0 | 0 | 0 | 0 | 0 | 3199836 | 0 |
| 1-Jan-00 | 5016 | 0 | 3355332 | 0 | 0 | 0 | 0 | 0 | 3355332 | 0 |
| 1-Feb-00 | 5 | 0 | 3355487 | 0 | 0 | 0 | 0 | 0 | 3355487 | 0 |
| 1-Mar-00 | 4121.3999 | 0 | 3475007.8 | 0 | 0 | 0 | 0 | 0 | 3475007.8 | 0 |
| 1-Apr-00 | 11811.1 | 0 | 3841151.8 | 0 | 0 | 0 | 0 | 0 | 3841151.8 | 0 |
| 1-May-00 | 14912.4 | 0 | 4288523.5 | 0 | 0 | 0 | 0 | 0 | 4288523.5 | 0 |
| 1-Jun-00 | 8425.9004 | 0 | 4549726.5 | 0 | 0 | 0 | 0 | 0 | 4549726.5 | 0 |
| 1-Jul-00 | 5 | 0 | 4549876.5 | 0 | 0 | 0 | 0 | 0 | 4549876.5 | 0 |
| 1-Aug-00 | 2700.8 | 0 | 4633601.5 | 0 | 0 | 0 | 0 | 0 | 4633601.5 | 0 |
| 1-Sep-00 | 5 | 0 | 4633756.5 | 0 | 0 | 0 | 0 | 0 | 4633756.5 | 0 |
| 1-Oct-00 | 5 | 0 | 4633906.5 | 0 | 0 | 0 | 0 | 0 | 4633906.5 | 0 |
| 1-Nov-00 | 102.9 | 0 | 4637096.5 | 0 | 0 | 0 | 0 | 0 | 4637096.5 | 0 |
| 1-Dec-00 | 4.9000001 | 0 | 4637243.5 | 0 | 0 | 0 | 0 | 0 | 4637243.5 | 0 |
| 1-Jan-01 | 1411.7 | 0 | 4681006 | 0 | 0 | 0 | 0 | 0 | 4681006 | 0 |
| 1-Feb-01 | 129 | 0 | 4685005 | 0 | 0 | 0 | 0 | 0 | 4685005 | 0 |
| 1-Mar-01 | 9308.0996 | 0 | 4945632 | 0 | 0 | 0 | 0 | 0 | 4945632 | 0 |
| 1-Apr-01 | 5 | 0 | 4945787 | 0 | 0 | 0 | 0 | 0 | 4945787 | 0 |
| 1-May-01 | 11936 | 0 | 5303867 | 0 | 0 | 0 | 0 | 0 | 5303867 | 0 |
| 1-Jun-01 | 15380.6 | 0 | 5780665.5 | 0 | 0 | 0 | 0 | 0 | 5780665.5 | 0 |
| 1-Jul-01 | 722.09998 | 0 | 5802328.5 | 0 | 0 | 0 | 0 | 0 | 5802328.5 | 0 |
| 1-Aug-01 | 910.5 | 0 | 5830554 | 0 | 0 | 0 | 0 | 0 | 5830554 | 0 |
| 1-Sep-01 | 6537 | 0 | 6033201 | 0 | 0 | 0 | 0 | 0 | 6033201 | 0 |
| 1-Oct-01 | 8872.5996 | 0 | 6299379 | 0 | 0 | 0 | 0 | 0 | 6299379 | 0 |
| 1-Nov-01 | 4301.3999 | 0 | 6432722.5 | 0 | 0 | 0 | 0 | 0 | 6432722.5 | 0 |
| 1-Dec-01 | 8352.2002 | 0 | 6683288.5 | 0 | 0 | 0 | 0 | 0 | 6683288.5 | 0 |
| 1-Jan-02 | 8152.1001 | 0 | 6936003.5 | 0 | 0 | 0 | 0 | 0 | 6936003.5 | 0 |
| 1-Feb-02 | 19049.9 | 0 | 7526550.5 | 0 | 19049.9 | 0 | 590546.94 | 0 | 8117097 | 0 |
| 1-Mar-02 | 9154.7002 | 0 | 7782882 | 0 | 6089.1001 | 0 | 761041.69 | 0 | 8543924 | 0 |
| 1-Apr-02 | 10195.3 | 0 | 8098936 | 0 | 9976 | 0 | 1070297.8 | 0 | 9169234 | 0 |
| 1-May-02 | 12482.3 | 0 | 8473405 | 0 | 8484.5 | 0 | 1324832.7 | 0 | 9798238 | 0 |
| 1-Jun-02 | 12185 | 0 | 8851140 | 0 | 8246.5996 | 0 | 1580477.3 | 0 | 10431618 | 0 |
| 1-Jul-02 | 12317.9 | 0 | 9220677 | 0 | 12281.6 | 0 | 1948925.3 | 0 | 11169603 | 0 |
| 1-Aug-02 | 12542.5 | 0 | 9609495 | 0 | 11860.6 | 0 | 2316604 | 0 | 11926099 | 0 |
| 1-Sep-02 | 11145.7 | 0 | 9955011 | 0 | 10133.8 | 0 | 2630751.8 | 0 | 12585763 | 0 |
| 1-Oct-02 | 15374.7 | 0 | 10416252 | 0 | 13893.8 | 0 | 3047565.8 | 0 | 13463818 | 0 |
| 1-Nov-02 | 12717.3 | 0 | 10810489 | 0 | 12735.4 | 0 | 3442363 | 0 | 14252852 | 0 |
| 1-Dec-02 | 14137.3 | 0 | 11234608 | 0 | 7142.6001 | 0 | 3656641 | 0 | 14891249 | 0 |
| 1-Jan-03 | 5337.3999 | 0 | 11400067 | 0 | 6602.7002 | 0 | 3861324.8 | 0 | 15261392 | 0 |
| 1-Feb-03 | 12410.2 | 0 | 11784783 | 0 | 11326.3 | 0 | 4212440 | 0 | 15997223 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-Mar-03 | 10992.5 | 0 | 12092573 | 0 | 9536.2002 | 0 | 4479453.5 | 0 | 16572027 | 0 |
| 1-Apr-03 | 11731.1 | 0 | 12456237 | 0 | 11504.3 | 0 | 4836087 | 0 | 17292324 | 0 |
| 1-May-03 | 11380.8 | 0 | 12797661 | 0 | 10106.4 | 0 | 5139279 | 0 | 17936940 | 0 |
| 1-Jun-03 | 6176.2002 | 0 | 12989124 | 0 | 2411.3 | 0 | 5214029.5 | 0 | 18203152 | 0 |
| 1-Jul-03 | 13056.4 | 0 | 13380816 | 0 | 11465.7 | 0 | 5558000.5 | 0 | 18938816 | 0 |
| 1-Aug-03 | 8557 | 0 | 13646083 | 0 | 5740.5 | 0 | 5735956 | 0 | 19382038 | 0 |
| 1-Sep-03 | 16154.4 | 0 | 14146869 | 0 | 13587.5 | 0 | 6157168.5 | 0 | 20304038 | 0 |
| 1-Oct-03 | 15594.6 | 0 | 14614707 | 0 | 13265 | 0 | 6555118.5 | 0 | 21169826 | 0 |
| 1-Nov-03 | 13705.4 | 0 | 15039574 | 0 | 11806.9 | 0 | 6921132 | 0 | 21960706 | 0 |
| 1-Dec-03 | 12396.8 | 0 | 15411478 | 0 | 11356.5 | 0 | 7261827 | 0 | 22673306 | 0 |
| 1-Jan-04 | 15609 | 0 | 15895357 | 0 | 12359.3 | 0 | 7644965.5 | 0 | 23540322 | 0 |
| 1-Feb-04 | 16105.1 | 0 | 16394616 | 0 | 10791.9 | 0 | 7979514.5 | 0 | 24374130 | 0 |
| 1-Mar-04 | 15559.6 | 0 | 16845844 | 0 | 11612.3 | 0 | 8316271 | 0 | 25162116 | 0 |
| 1-Apr-04 | 14352.3 | 0 | 17290766 | 0 | 11602.6 | 0 | 8675952 | 0 | 25966716 | 0 |
| 1-May-04 | 13693.5 | 0 | 17701570 | 0 | 10178.3 | 0 | 8981301 | 0 | 26682870 | 0 |
| 1-Jun-04 | 13177.1 | 0 | 18110060 | 0 | 9932.2002 | 0 | 9289199 | 0 | 27399260 | 0 |
| 1-Jul-04 | 11812.8 | 0 | 18464444 | 0 | 9065.5 | 0 | 9561164 | 0 | 28025608 | 0 |
| 1-Aug-04 | 12946.1 | 0 | 18865774 | 0 | 9415.2002 | 0 | 9853035 | 0 | 28718808 | 0 |
| 1-Sep-04 | 13449.6 | 0 | 19282710 | 0 | 9811 | 0 | 10157176 | 0 | 29439888 | 0 |
| 1-Oct-04 | 12610.4 | 0 | 19661022 | 0 | 10372.5 | 0 | 10468351 | 0 | 30129374 | 0 |
| 1-Nov-04 | 12021.4 | 0 | 20033686 | 0 | 11900.7 | 0 | 10837273 | 0 | 30870960 | 0 |
| 1-Dec-04 | 9383.7002 | 0 | 20315198 | 0 | 11888.3 | 0 | 11193922 | 0 | 31509120 | 0 |
| 1-Jan-05 | 10555.1 | 0 | 20642406 | 0 | 10720.2 | 0 | 11526248 | 0 | 32168654 | 0 |
| 1-Feb-05 | 9402 | 0 | 20933868 | 0 | 11811.3 | 0 | 11892398 | 0 | 32826266 | 0 |
| 1-Mar-05 | 7640.7998 | 0 | 21147810 | 0 | 12654.2 | 0 | 12246716 | 0 | 33394526 | 0 |
| 1-Apr-05 | 9531.9004 | 0 | 21443298 | 0 | 13702.6 | 0 | 12671497 | 0 | 34114796 | 0 |
| 1-May-05 | 8474.5996 | 0.010127584 | 21697536 | 1.20E-06 | 10624.7 | 0 | 12990238 | 0 | 34687776 | 0.03106272 |
| 1-Jun-05 | 5628.7998 | 0.12678769 | 21872030 | 2.25E-05 | 7042 | 0 | 13208540 | 0 | 35080568 | 1.119647 |
| 1-Jul-05 | 8321.4004 | 2.6080377 | 22121672 | 0.000313413 | 8833.0996 | 0 | 13473532 | 0 | 35595204 | 33.998386 |
| 1-Aug-05 | 10621.9 | 11.839538 | 22450950 | 0.001114635 | 11842.7 | 0 | 13840656 | 0 | 36291608 | 273.45972 |
| 1-Sep-05 | 10741.9 | 16.399986 | 22783950 | 0.001526731 | 11187.7 | 0 | 14187475 | 0 | 36971424 | 721.71405 |
| 1-Oct-05 | 4976.2002 | 7.8306789 | 22933236 | 0.001573626 | 5921.6001 | 0 | 14365123 | 0 | 37298360 | 952.97864 |
| 1-Nov-05 | 8012.8999 | 15.200112 | 23181636 | 0.001896955 | 11108.8 | 0.033175666 | 14709496 | 2.99E-06 | 37891132 | 1384.6338 |
| 1-Dec-05 | 8536.2998 | 18.742212 | 23437724 | 0.00219559 | 11791.8 | 0.71454167 | 15063250 | 6.06E-05 | 38500976 | 1919.1758 |
| 1-Jan-06 | 8091.8999 | 19.519165 | 23688574 | 0.002412186 | 11335.8 | 3.3276672 | 15414659 | 0.000293554 | 39103232 | 2552.7432 |
| 1-Feb-06 | 5775.7002 | 13.833347 | 23867620 | 0.002395094 | 7983.2998 | 3.8430583 | 15662142 | 0.000481387 | 39529760 | 3069.5549 |
| 1-Mar-06 | 7008 | 17.766819 | 24063844 | 0.00253522 | 9120.7002 | 10.886916 | 15917521 | 0.001193649 | 39981364 | 3766.1255 |
| 1-Apr-06 | 6775.5 | 17.936062 | 24273884 | 0.002647194 | 10177.5 | 20.472975 | 16233024 | 0.002011592 | 40506908 | 4855.8081 |
| 1-May-06 | 6992 | 19.274452 | 24483644 | 0.002756644 | 9426.2002 | 21.172535 | 16515810 | 0.002246137 | 40999456 | 6025.5532 |
| 1-Jun-06 | 6197.2998 | 17.337799 | 24675760 | 0.002797638 | 7538.8999 | 19.737488 | 16749516 | 0.002618086 | 41425276 | 7117.9463 |
| 1-Jul-06 | 7059.7998 | 20.873793 | 24887554 | 0.002956712 | 8886.9004 | 24.155243 | 17016122 | 0.002718073 | 41903676 | 8452.1582 |
| 1-Aug-06 | 6724 | 20.955418 | 25095998 | 0.003116511 | 8586.5 | 24.428638 | 17282304 | 0.002845005 | 42378304 | 9821.8545 |
| 1-Sep-06 | 7610.7002 | 26.00775 | 25331930 | 0.003417261 | 10352.7 | 30.220573 | 17603238 | 0.002919101 | 42935168 | 11520.186 |
| 1-Oct-06 | 7900.3999 | 29.80818 | 25568942 | 0.003772996 | 9930.0996 | 33.340229 | 17901142 | 0.003357492 | 43470084 | 13296.835 |
| 1-Nov-06 | 6300.8999 | 25.177614 | 25764270 | 0.003995876 | 9269.4004 | 37.170387 | 18188492 | 0.00401001 | 43952764 | 15116.096 |
| 1-Dec-06 | 6656.6001 | 28.68861 | 25963968 | 0.004309799 | 9673.4004 | 44.068024 | 18478694 | 0.004555588 | 44442664 | 17204.238 |
| 1-Jan-07 | 6425.6001 | 29.950104 | 26163162 | 0.00466106 | 9869.2998 | 48.315487 | 18784642 | 0.004895533 | 44947804 | 19547.949 |
| 1-Feb-07 | 7336.2002 | 38.977001 | 26390584 | 0.005312969 | 9973.9004 | 52.136539 | 19093834 | 0.005227297 | 45484416 | 22242.809 |
| 1-Mar-07 | 8220.2998 | 50.916092 | 26620752 | 0.006193946 | 8918.5 | 50.353832 | 19343552 | 0.005645998 | 45964304 | 24914.787 |
| 1-Apr-07 | 9075.4004 | 65.522476 | 26902090 | 0.007219789 | 8423.0996 | 52.074299 | 19604668 | 0.00618232 | 46506756 | 28361.934 |
| 1-May-07 | 5632.5 | 42.741074 | 27071064 | 0.007588295 | 2995.3999 | 14.211037 | 19694530 | 0.004744287 | 46765596 | 30077.145 |
| 1-Jun-07 | 7106.6001 | 59.20816 | 27291370 | 0.008331433 | 7693.6001 | 55.067978 | 19933032 | 0.007157635 | 47224400 | 33412.027 |
| 1-Jul-07 | 6241.6001 | 55.524788 | 27478618 | 0.008895922 | 8155.7002 | 60.032768 | 20177702 | 0.007360836 | 47656320 | 36797.719 |
| 1-Aug-07 | 6139.7002 | 57.395874 | 27668948 | 0.009348319 | 8269.4004 | 64.376793 | 20434054 | 0.00778494 | 48103000 | 40477.801 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-Sep-07 | 6400.6001 | 62.896961 | 27867366 | 0.009826729 | 8977.5 | 74.299896 | 20712356 | 0.008276234 | 48579724 | 44624.277 |
| 1-Oct-07 | 6442.6001 | 67.111298 | 28060644 | 0.010416803 | 9325.7998 | 81.431458 | 20992130 | 0.008731847 | 49052776 | 48969.676 |
| 1-Nov-07 | 4774.2998 | 51.364902 | 28208648 | 0.010758625 | 8122.3999 | 73.007935 | 21243924 | 0.008988469 | 49452572 | 52751.027 |
| 1-Dec-07 | 4362.2002 | 48.16724 | 28339514 | 0.01104196 | 8695.9004 | 80.878654 | 21504802 | 0.00930078 | 49844316 | 56570.969 |
| 1-Jan-08 | 4414.3999 | 50.786011 | 28476360 | 0.011504624 | 8539.2998 | 81.174149 | 21769520 | 0.009505949 | 50245880 | 60600.211 |
| 1-Feb-08 | 4134.5 | 49.089043 | 28604530 | 0.01187303 | 7779.7002 | 74.637665 | 22010690 | 0.0095939 | 50615220 | 64397.141 |
| 1-Mar-08 | 4021.3 | 48.598148 | 28721148 | 0.012085184 | 7726.3999 | 75.249496 | 22234756 | 0.00973927 | 50955904 | 67960.156 |
| 1-Apr-08 | 3487.3999 | 41.793514 | 28829258 | 0.011984147 | 8101.5 | 81.273064 | 22485902 | 0.010031854 | 51315160 | 71748.594 |
| 1-May-08 | 3192.5 | 37.55793 | 28925032 | 0.011764427 | 8325.9004 | 85.085152 | 22735680 | 0.010219333 | 51660712 | 75417.477 |
| 1-Jun-08 | 3198 | 37.226955 | 29024170 | 0.0116407 | 8734.4004 | 91.060394 | 23006446 | 0.010425488 | 52030616 | 79380.75 |
| 1-Jul-08 | 4228.1001 | 51.316898 | 29151014 | 0.012137106 | 8132.8999 | 84.432289 | 23250434 | 0.010381572 | 52401448 | 83429.773 |
| 1-Aug-08 | 5770 | 74.6008 | 29329884 | 0.012929081 | 8390 | 88.948036 | 23510524 | 0.010601673 | 52840408 | 88413.461 |
| 1-Sep-08 | 4250 | 56.501556 | 29461634 | 0.013294484 | 6260 | 63.715302 | 23704584 | 0.010178163 | 53166216 | 92123.734 |
| 1-Oct-08 | 7700 | 112.94252 | 29692634 | 0.014667859 | 7280 | 79.497879 | 23922984 | 0.010920038 | 53615616 | 97681.063 |
| 1-Nov-08 | 9380 | 165.48587 | 29983414 | 0.017642418 | 7310 | 82.372101 | 24149594 | 0.011268414 | 54133008 | 104885.73 |
| 1-Dec-08 | 5990 | 119.28844 | 30163114 | 0.019914597 | 11030 | 133.69681 | 24480494 | 0.012121197 | 54643608 | 112220.87 |
| 1-Jan-09 | 4960 | 106.03015 | 30316874 | 0.021377048 | 11450 | 136.21021 | 24835444 | 0.011896089 | 55152316 | 119680.53 |
| 1-Feb-09 | 4640 | 103.15617 | 30460714 | 0.022231931 | 11340 | 134.81398 | 25186984 | 0.011888359 | 55647696 | 126990.05 |
| 1-Mar-09 | 4550 | 103.70731 | 30588114 | 0.022792814 | 11260 | 135.9801 | 25502264 | 0.012076386 | 56090376 | 133635.03 |
| 1-Apr-09 | 3500 | 78.969025 | 30696614 | 0.022562578 | 11290 | 139.29434 | 25852254 | 0.012337852 | 56548868 | 140364.38 |
| 1-May-09 | 2189 | 45.888374 | 30762284 | 0.020963168 | 11872.15 | 149.2654 | 26208418 | 0.012572735 | 56970700 | 146218.98 |
| 1-Jun-09 | 2964.05 | 61.440403 | 30854168 | 0.02072853 | 11018.23 | 141.82697 | 26549982 | 0.012872027 | 57404152 | 152487.41 |
| 1-Jul-09 | 4032.1899 | 84.856705 | 30975134 | 0.021044819 | 9715.6504 | 125.90286 | 26841452 | 0.012958768 | 57816588 | 158777.52 |
| 1-Aug-09 | 4525.7598 | 97.328217 | 31115432 | 0.021505387 | 9368.46 | 125.11739 | 27131874 | 0.013355172 | 58247308 | 165582.56 |
| 1-Sep-09 | 3736.8999 | 80.694519 | 31231276 | 0.021593975 | 9498.8496 | 131.87733 | 27426338 | 0.013883505 | 58657616 | 172087.23 |
| 1-Oct-09 | 4296.6802 | 95.000298 | 31360178 | 0.022110162 | 10379.99 | 150.26971 | 27737738 | 0.014476866 | 59097916 | 179346.02 |
| 1-Nov-09 | 3292.9199 | 71.984131 | 31462258 | 0.021860274 | 11948 | 180.39722 | 28108126 | 0.015098528 | 59570384 | 187089.13 |
| 1-Dec-09 | 3240.79 | 70.133766 | 31559482 | 0.021640947 | 11811.16 | 183.11787 | 28462462 | 0.0155038 | 60021944 | 194622.61 |
| 1-Jan-10 | 3254.3 | 69.940666 | 31660364 | 0.02149177 | 11933.82 | 190.63486 | 28832410 | 0.015974335 | 60492776 | 202627.11 |
| 1-Feb-10 | 3169.3 | 67.562172 | 31758614 | 0.021317694 | 11878.13 | 195.36382 | 29200632 | 0.016447354 | 60959244 | 210694.53 |
| 1-Mar-10 | 3169.3 | 67.232346 | 31847354 | 0.021213625 | 12238.93 | 207.53928 | 29543322 | 0.016957305 | 61390676 | 218307.55 |
| 1-Apr-10 | 3230.0801 | 68.484222 | 31947486 | 0.02120202 | 11965.85 | 210.60596 | 29914264 | 0.017600585 | 61861748 | 226843.73 |
| 1-May-10 | 3291.48 | 69.995651 | 32046230 | 0.021265708 | 11888.98 | 217.14223 | 30270932 | 0.01826416 | 62317164 | 235338.17 |
| 1-Jun-10 | 3353.03 | 71.696968 | 32150174 | 0.02138274 | 11662.88 | 222.21577 | 30632482 | 0.019053251 | 62782656 | 244305.81 |
| 1-Jul-10 | 3097.6201 | 65.868919 | 32243102 | 0.021264363 | 11197.84 | 222.57381 | 30968418 | 0.019876495 | 63211520 | 252825.41 |
| 1-Aug-10 | 3167.3601 | 67.352913 | 32341292 | 0.021264685 | 10997.84 | 229.33339 | 31309350 | 0.020852584 | 63650640 | 261849.87 |
| 1-Sep-10 | 3166.0801 | 67.373215 | 32439440 | 0.021279693 | 11018.16 | 241.08173 | 31650914 | 0.021880398 | 64090352 | 271239.13 |
| 1-Oct-10 | 3098.9299 | 65.888718 | 32532408 | 0.021261765 | 10836.46 | 250.86179 | 31976006 | 0.02314979 | 64508416 | 280538.78 |
| 1-Nov-10 | 3354.3101 | 72.112907 | 32636392 | 0.021498581 | 10541.85 | 257.67175 | 32302804 | 0.024442747 | 64939196 | 290545.56 |
| 1-Dec-10 | 2596 | 54.5961 | 32714272 | 0.021030854 | 8166.8999 | 211.4496 | 32547812 | 0.025891049 | 65262084 | 298351.94 |
| 1-Jan-11 | 2381.6799 | 48.652828 | 32788104 | 0.020427946 | 9005.46 | 244.69995 | 32826980 | 0.0271724 | 65615084 | 307301.44 |
| 1-Feb-11 | 2399.49 | 47.912331 | 32862488 | 0.019967714 | 9610.8701 | 270.65152 | 33124918 | 0.02816098 | 65987404 | 317047.75 |
| 1-Mar-11 | 2490.96 | 49.268616 | 32932234 | 0.019778967 | 9768.1699 | 285.49341 | 33398426 | 0.029226908 | 66330660 | 326282.31 |
| 1-Apr-11 | 2422.28 | 47.279213 | 33007324 | 0.019518474 | 9023.9502 | 277.94528 | 33678168 | 0.030800844 | 66685492 | 336156.81 |
| 1-May-11 | 2447.7 | 47.424171 | 33080756 | 0.019374995 | 8919.9502 | 287.23145 | 33945768 | 0.032201014 | 67026524 | 346021.75 |
| 1-Jun-11 | 2402.72 | 46.113991 | 33155240 | 0.019192411 | 8569.71 | 288.93814 | 34211428 | 0.033716209 | 67366672 | 356218.31 |
| 1-Jul-11 | 2364.1599 | 44.937996 | 33226164 | 0.019008018 | 8153.2402 | 287.61243 | 34456024 | 0.035275843 | 67682192 | 366018.59 |
| 1-Aug-11 | 2249.8799 | 42.08144 | 33295912 | 0.018703861 | 7614.4702 | 281.44604 | 34692076 | 0.036961999 | 67987984 | 375869.25 |
| 1-Sep-11 | 2284.3301 | 42.393303 | 33366726 | 0.018558308 | 7473.25 | 287.74515 | 34923744 | 0.038503349 | 68290472 | 385939.66 |
| 1-Oct-11 | 2273.99 | 41.878998 | 33434946 | 0.018416528 | 7340.79 | 292.67804 | 35143968 | 0.039870102 | 68578912 | 395843.88 |
| 1-Nov-11 | 2260.3999 | 41.332291 | 33505018 | 0.018285388 | 7273.21 | 299.12674 | 35369436 | 0.041127197 | 68874456 | 406267.34 |
| 1-Dec-11 | 2138.3701 | 38.644962 | 33569168 | 0.018072158 | 7201.9399 | 304.99396 | 35585496 | 0.042348862 | 69154664 | 416455.13 |
| 1-Jan-12 | 15000 | 338.54938 | 34034168 | 0.022569958 | 15000 | 618.99078 | 36050496 | 0.041266054 | 70084664 | 444834.72 |
| 1-Jul-12 | 15000 | 1312.9413 | 36764168 | 0.087529421 | 15000 | 1269.292 | 38780496 | 0.08461947 | 75544664 | 774313.31 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-Jan-13 | 15000 | 2447.2529 | 39524168 | 0.16315019 | 15000 | 1755.6844 | 41540496 | 0.11704563 | 81064664 | 1376905 |
| 1-Jul-13 | 15000 | 3237.2849 | 42239168 | 0.21581899 | 15000 | 2265.4348 | 44255496 | 0.15102899 | 86494664 | 2270282.5 |
| 1-Jan-14 | 15000 | 5193.5317 | 44999168 | 0.34623545 | 15000 | 3084.967 | 47015496 | 0.20566446 | 92014664 | 3494952.5 |
| 1-Jul-14 | 15000 | 8125.1099 | 47714168 | 0.54167396 | 15000 | 4057.7483 | 49730496 | 0.27051654 | 97444664 | 5388041.5 |
| 1-Jan-15 | 15000 | 10317.458 | 50474168 | 0.68783051 | 15000 | 5261.7832 | 52490496 | 0.35078555 | 1.03E+08 | 7892116 |
| 1-Jul-15 | 15000 | 12779.763 | 53189168 | 0.85198414 | 15000 | 7831.7964 | 55205496 | 0.52211976 | 1.08E+08 | 11125907 |
| 1-Jan-16 | 13113.776 | 15141.831 | 55865832 | 1.1546507 | 15000 | 9510.3408 | 57965496 | 0.63402271 | 1.14E+08 | 15345819 |
| 1-Jul-16 | 10954.577 | 17539.207 | 58017816 | 1.6010848 | 15000 | 10815.249 | 60695496 | 0.72101665 | 1.19E+08 | 20118482 |
| 1-Jan-17 | 8626.4521 | 20116.676 | 59799628 | 2.3319757 | 15000 | 11963.226 | 63455496 | 0.79754841 | 1.23E+08 | 25739444 |
| 1-Jul-17 | 6918.1958 | 21787.592 | 61206856 | 3.149317 | 15000 | 12869.354 | 66170496 | 0.85795689 | 1.27E+08 | 31762812 |
| 1-Jan-18 | 5271.9517 | 24949.398 | 62325964 | 4.7324781 | 15000 | 13706.742 | 68930496 | 0.91378284 | 1.31E+08 | 38489820 |
| 1-Jul-18 | 3536.6072 | 27703.436 | 63119060 | 7.8333368 | 15000 | 14612.177 | 71645496 | 0.97414511 | 1.35E+08 | 45872912 |
| 1-Jan-19 | 2439.5063 | 28853.209 | 63659868 | 11.827479 | 15000 | 15665.076 | 74405496 | 1.0443383 | 1.38E+08 | 53863500 |
| 1-Jul-19 | 1842.4532 | 29564.268 | 64042500 | 16.046143 | 15000 | 16780.01 | 77120496 | 1.1186674 | 1.41E+08 | 62090376 |
| 1-Jan-20 | 1480.8839 | 30032.404 | 64346412 | 20.280054 | 15000 | 18063.559 | 79880496 | 1.2042373 | 1.44E+08 | 70778848 |
| 1-Jul-20 | 1141.1163 | 30357.256 | 64584760 | 26.603121 | 15000 | 19430.021 | 82610496 | 1.2953348 | 1.47E+08 | 79690904 |
| 1-Jan-21 | 933.49402 | 30624.111 | 64773700 | 32.805901 | 15000 | 21110.385 | 85370496 | 1.407359 | 1.50E+08 | 89029928 |
| 1-Jul-21 | 786.8736 | 30816.281 | 64929276 | 39.162937 | 15000 | 22861.533 | 88085496 | 1.5241022 | 1.53E+08 | 98565384 |
| 1-Jan-22 | 657.28412 | 31027.553 | 65061916 | 47.205692 | 15000 | 24996.477 | 90845496 | 1.6664318 | 1.56E+08 | 1.09E+08 |
| 1-Jul-22 | 570.16663 | 31598.541 | 65172820 | 55.419834 | 15000 | 27437.213 | 93560496 | 1.8291475 | 1.59E+08 | 1.19E+08 |
| 1-Jan-23 | 499.76062 | 32120.385 | 65270772 | 64.271538 | 14970.735 | 31560.52 | 96320448 | 2.1081474 | 1.62E+08 | 1.30E+08 |
| 1-Jul-23 | 450.83249 | 32488.621 | 65356788 | 72.063614 | 13740.274 | 32870.867 | 98906104 | 2.3923006 | 1.64E+08 | 1.42E+08 |
| 1-Jan-24 | 407.02826 | 32850.98 | 65435544 | 80.709343 | 12754.557 | 33376.988 | 1.01E+08 | 2.6168678 | 1.67E+08 | 1.54E+08 |
| 1-Jul-24 | 372.39536 | 33116.465 | 65506200 | 88.928246 | 11827.576 | 33906.469 | 1.04E+08 | 2.86673 | 1.69E+08 | 1.66E+08 |
| 1-Jan-25 | 346.51538 | 33376.699 | 65572296 | 96.320984 | 11399.052 | 34075.621 | 1.06E+08 | 2.9893384 | 1.71E+08 | 1.79E+08 |
| 1-Jul-25 | 323.32211 | 33612.492 | 65632864 | 103.95977 | 11065.97 | 34578.727 | 1.08E+08 | 3.1247804 | 1.73E+08 | 1.91E+08 |
| 1-Jan-26 | 303.23672 | 33846.141 | 65690456 | 111.61623 | 10736.094 | 35016.277 | 1.10E+08 | 3.2615471 | 1.75E+08 | 2.04E+08 |
| 1-Jul-26 | 285.17752 | 34079.34 | 65743680 | 119.50219 | 10385.214 | 35472.305 | 1.12E+08 | 3.4156549 | 1.77E+08 | 2.16E+08 |
| 1-Jan-27 | 268.0719 | 34300.617 | 65794580 | 127.95305 | 9965.8701 | 36181.289 | 1.14E+08 | 3.6305199 | 1.79E+08 | 2.29E+08 |
| 1-Jul-27 | 251.91133 | 34509.32 | 65841620 | 136.98994 | 9538.2852 | 36927.055 | 1.15E+08 | 3.8714564 | 1.81E+08 | 2.42E+08 |
| 1-Jan-28 | 236.75522 | 34704.125 | 65886552 | 146.58231 | 9110.3975 | 37816.602 | 1.17E+08 | 4.1509275 | 1.83E+08 | 2.55E+08 |
| 1-Jul-28 | 223.95035 | 34867.527 | 65928436 | 155.69312 | 8657.6787 | 38897.387 | 1.19E+08 | 4.4928193 | 1.85E+08 | 2.68E+08 |
| 1-Jan-29 | 213.06387 | 35005.641 | 65968620 | 164.29646 | 8201.1748 | 40133.313 | 1.20E+08 | 4.8936052 | 1.86E+08 | 2.82E+08 |
| 1-Jul-29 | 203.37791 | 35127.828 | 66006296 | 172.72194 | 7794.2207 | 41291.945 | 1.22E+08 | 5.2977643 | 1.88E+08 | 2.96E+08 |
| 1-Jan-30 | 194.25238 | 35242.293 | 66042884 | 181.42528 | 7332.3862 | 42699.988 | 1.23E+08 | 5.8234773 | 1.89E+08 | 3.10E+08 |
| 1-Jul-30 | 185.37482 | 35353.102 | 66077232 | 190.71146 | 6831.7075 | 44284.691 | 1.24E+08 | 6.4822288 | 1.90E+08 | 3.24E+08 |
| 1-Jan-31 | 176.98679 | 35460.383 | 66110556 | 200.35611 | 6379.4106 | 45459.148 | 1.26E+08 | 7.1259165 | 1.92E+08 | 3.39E+08 |

**Table 8: Results of Prediction Case 11**