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Department of Petroleum and Natural Gas Engineering

Production Data Analysis in a Developed Field in Carthage, Texas

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1. Executive Summary

Intelligent Production Data Analysis (IPDA), is capable of tracking the sweet spots in the field with time in order to allocate the most probable locations that may still have reserves. The Production data used in this project is from twenty wells in a field located in the north-east of Texas.

In this project three major steps have been completed. First, the application of conventional production data analysis such as “Decline Curve” and “Type Curve Matching” followed by using intelligent systems “Fuzzy Pattern Recognition” in order to classify the field based on potential sweet spots for infill drilling and to identify the underperformer wells to be recommended for workover or stimulation.

After the analysis is completed three locations are recommended for infill drillings. Cesarito, Camilito and Yasito are the proposed names of the wells.

Five wells are proposed for stimulation and four for workover. The criteria behind this selection are based on relative values of permeability and Reserves. Low permeability and high Reserves for stimulation and high permeability and low reserves for work over.

After performing economical analysis based on all above considerations the overall value of the asset is estimated to be $ 48,381,470

A model in CMG is built based on the available data from the field and the analysis. A sensitivity analysis is conducted to evaluate the reserves of some parameters changes on the production.

2. Introduction

The only type of data that can be easily found in many of the mature fields is production rate data.

Oil and Gas Production started at a time when reservoir characterization was not a priority. At the time being, better recovery of the fields requires reservoir characterization.

The method used in IPDA for characterization of mature fields is only based on production rate data. This methodology integrates conventional production data analysis like “Decline Curve Analysis”, “Type Curve Matching”, with techniques developed based on intelligent systems such as neural networks, genetic algorithms and fuzzy logic in order to model the fluid flow in the reservoir as a function of time.

2.1 Project Objective

1. Application of Intelligent Production Data analysis (IPDA) to a mature field in order to estimate the Recoverable Reserves.
2. Recommend infill drilling locations and possibly remedial operations on existing wells based on the economical analysis.
3. Obtain the overall value of the asset.

3. Theoretical Background

The Application of Intelligent Production Data Analysis requires having a theoretical background of the methods. In this chapter a summary of these concepts provides some information that would be beneficial to easily follow the methodology.

3.1 Decline Curve Analysis

Production Prediction and Reserve Estimation of a reservoir are two of the most important challenges we have in Oil and Gas Industry. Several methods have been developed during years. Decline Curve Analysis is introduced as one of the less demanding approaches. In this method only production history is needed. The very first development of this method is based on the empirical Arps exponential, hyperbolic, and harmonic equations. The empirical Arps decline equation represents the relationship between production rate and time for oil wells during pseudo steady state period and is shown as follows

$$q_t = \frac{q_i}{\left(1 + bD_i t\right)^{\frac{1}{b}}} \tag{3-1}$$

In which

q_t = Oil Production rate at time *t* and

q_i = Initial Oil Production rate.

b = Hyperbolic Exponent

D_i = Initial Decline Rate

When $b=0$, the decline is exponential, $b=1$, the decline is harmonic and for $0 < b < 1$, the decline is said to be hyperbolic. The method is still being used because it is very simple and it doesn't need any reservoir or well's data.

Although the Arps decline curve analysis approach was proposed around sixty years ago a large number of studies on production decline analysis are still using this method. A lot of attempts have been taken to interpret the Arps decline equation theoretically. Many derivations are based on a single phase flow which applies only to under saturated oil wells.

Later Fetkovich recommended fitting Arps equation only to the pseudo steady state (non-transient) portion of the rate time data. He combined the transient rate and the pseudo steady-state decline curves in a single graph. Also he related the Arps empirical equations to the single-phase flow solutions and tried to provide a theoretical basis for the Arps equations.

3.2 Type Curve Matching

In 1973, Fetkovich proposed a dimensionless rate-time type curve for decline curve analysis of wells producing at constant bottomhole pressure. These type curves were developed for slightly compressible liquids. These type curves combined analytical solutions to the flow equation in the transient region with empirical decline curve equations in the pseudo-steady state region.

The analysis procedure provided estimates of formation permeability, *k*, and drainage radius, r_e, instead of the traditional decline curve analysis parameters q_i and D_i. This approach to decline curve analysis, now commonly referred to as "advanced decline curve analysis", has become widely used as a tool for formation evaluation and reserves estimation.

Basically, production decline type curve is a log-log plot of a family of production decline curves with the dimensionless flow rate q_d showing on ordinate and the dimensionless time t_d showing on abscissa.

One should try to match the real data plotted on a log-log paper with the same scale as the type curve with one of the type curves. Having the best fit a match point can be selected to dimensionalize the dimensionless values.

The matched type curve and the match point let one to estimate the future production rates in case the data match the empirical part of the type curve. If the data matches the analytical part of the type curve it results in estimating the reservoir’s characteristics.

Among the literature, most of the type curves available are for oil wells and are not directly applicable to gas wells. Intelligent Production Data Analysis provides an environment to do type curve matching for both oil and gas wells.

3.3 History Matching and Reservoir Simulation

History matching is adjusting a model of a reservoir so it closely reproduces the past behavior of that reservoir. Production rates and pressure data are matched as closely as possible. The accuracy of the history matching depends on the quality of the reservoir model and the quality and quantity of pressure and production data. Once a model has been history matched, it can be used to simulate future reservoir behavior with a higher degree of confidence. This confidence can be improved by adjusting the model's constraints to the known geological properties of the reservoir.

3.4 Fuzzy Pattern Recognition

This Process uses Fuzzy Pattern Recognition (***FPR***). This routine integrates the information obtained from all wells in order to track Field-Wide behavior. The characterization of reservoir allows for the identification of sweet spots and to forecast remaining reserves.

FPR uses intelligent systems to deduce patterns when the available data apparently does not show any relationship between input and output. This capability distinguishes IPDA from conventional Production Data Analysis.

4. Methodology

Different steps are taking place in order to achieve the project objectives. Main steps are illustrated briefly in Fig. 4-1.

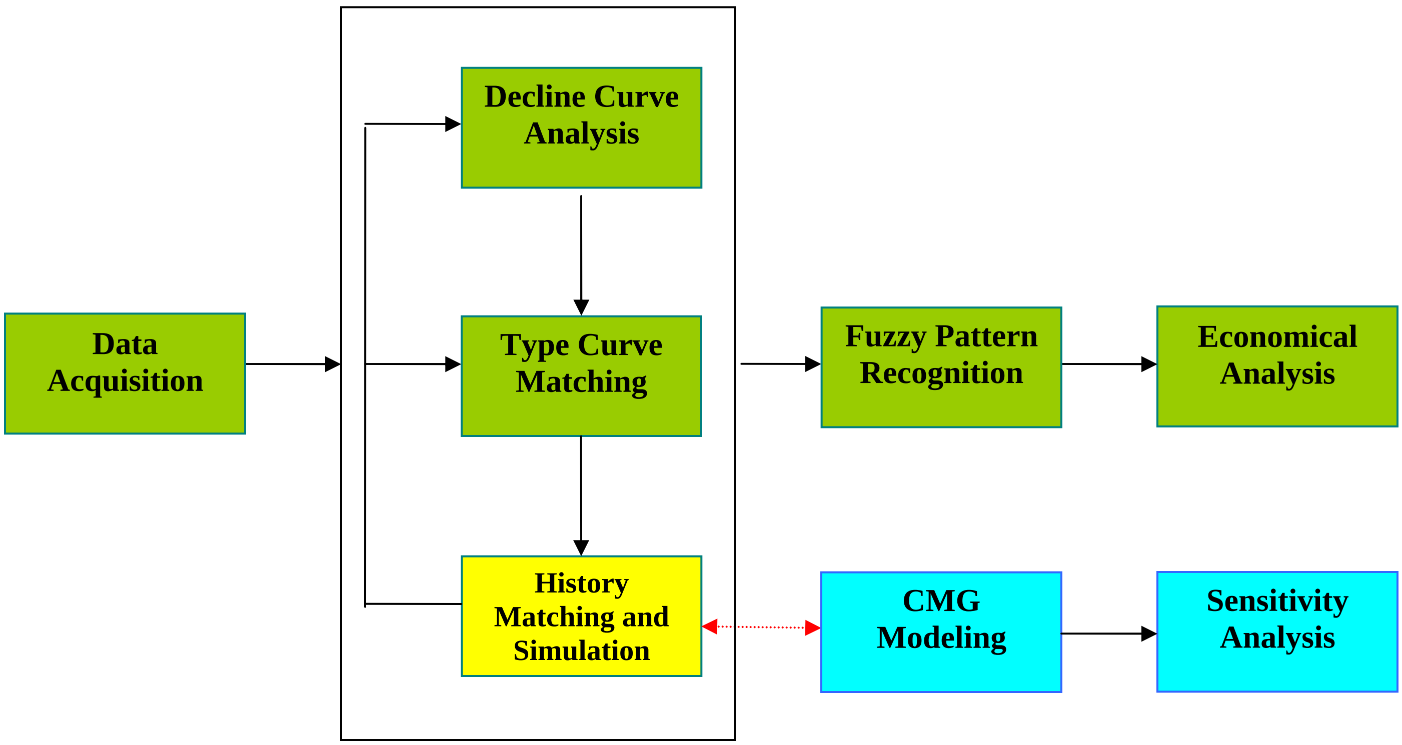


Fig. 4-1 Methodology Flow Chart

Detail of these steps will be discussed in the appropriate section.

4.1 Data Acquisition

Almost nineteen years of monthly production rate data is available for number of twenty wells in a mature Gas field. Importing these data into IPDA is done by using the data import section.

Reservoir characteristics such as porosity, pay thickness and initial water saturation are given in contour maps as shown below.

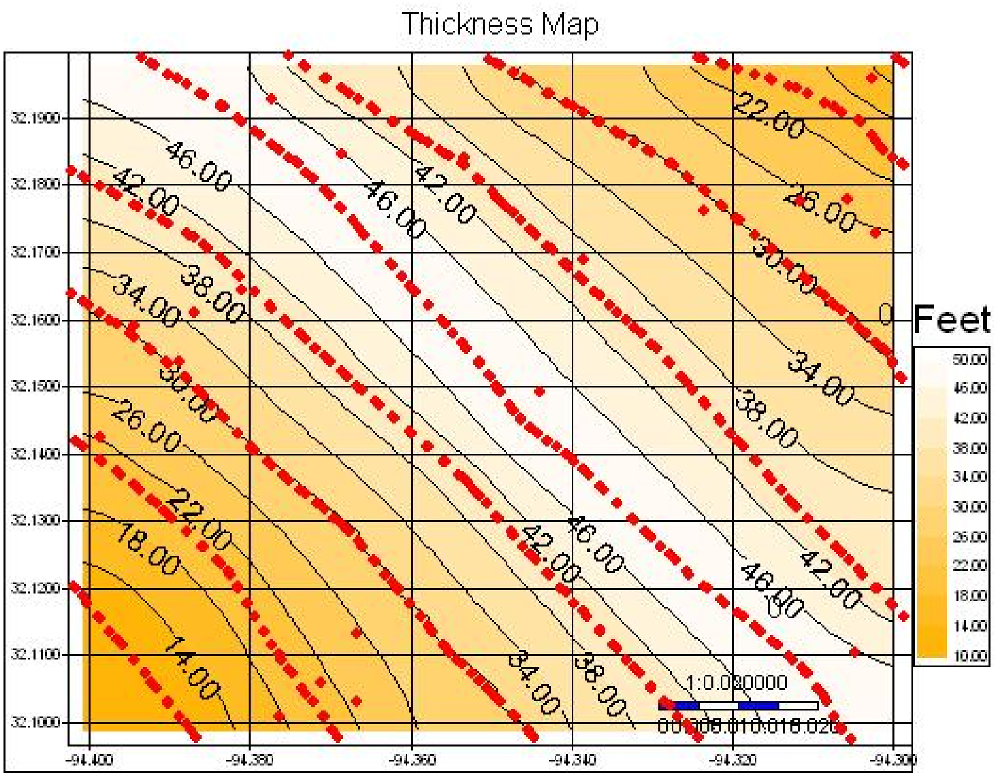


Fig 4-2. Thickness Contours

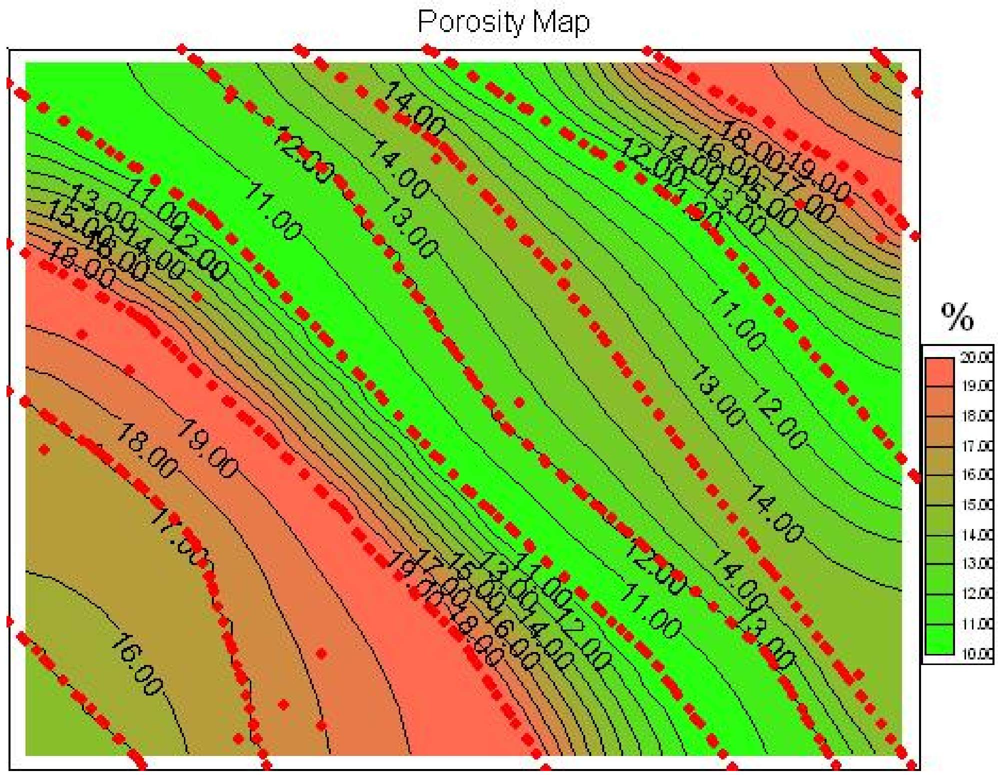


Fig 4-3 Porosity Contour

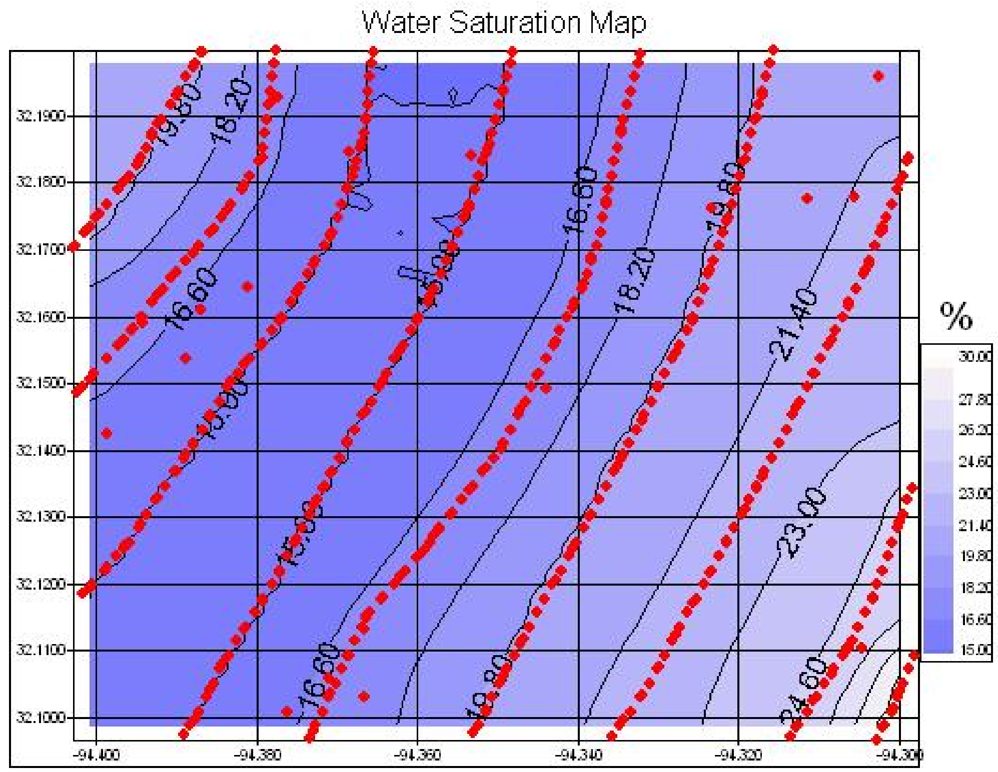


Fig 4-4 Water Saturation Map

Production data is imported to the IPDA using the import data file interface.

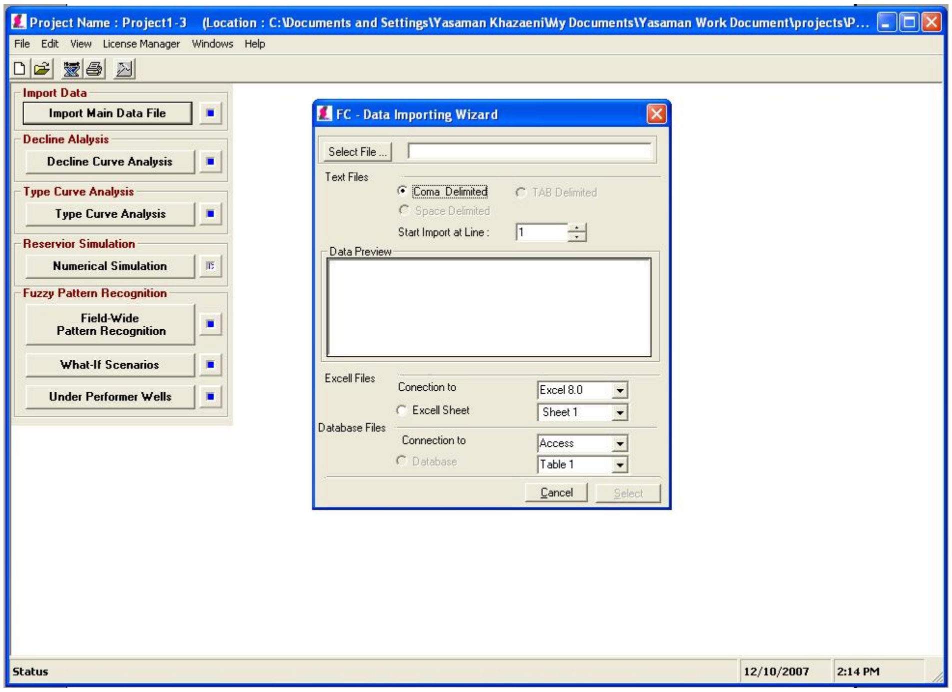


Fig 4-5 Import Data Interface

An example of the production data for one well is presented in Fig 4-6.

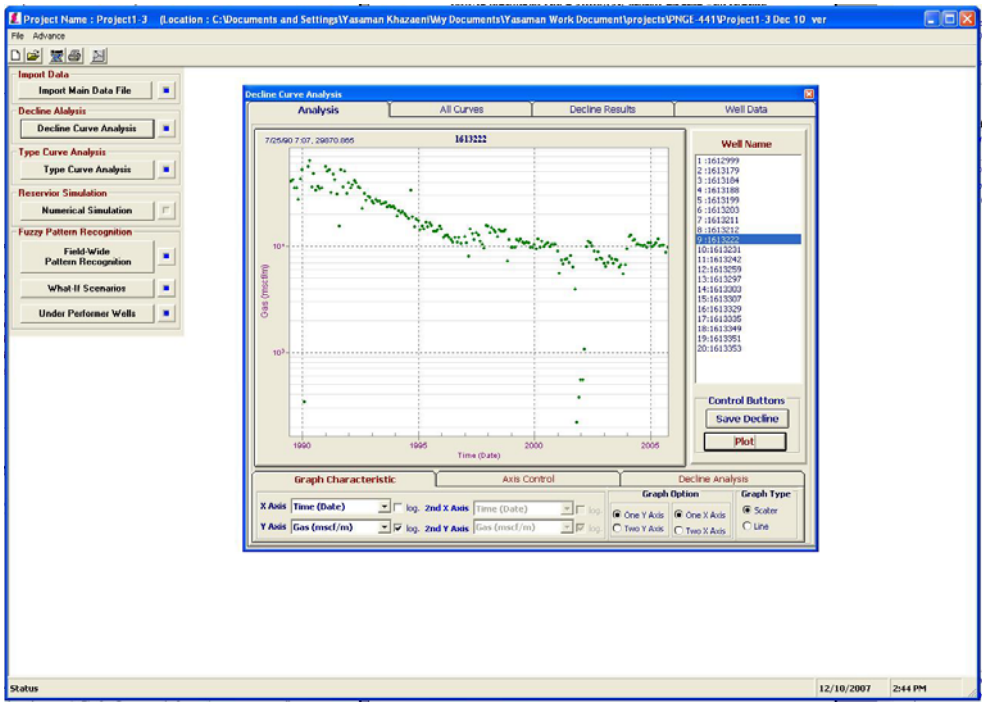


Fig 4-6 - Example of Production Data for well 9

<u>*4.2 Decline Curve Analysis*</u>

The plot of Flow Rate vs. Time. is generated in this section. An autogenerated decline curve can be fitted to the data using the “Auto Decline” feature in the software. This fitted curve can be improved by changing the values of q_i , D_i and b. because of normally having anomalies and outliers in the production data adjusting the decline curve with eye is normally generating a better result than any least mean square error method.

Many equations might be used to model a Decline Curve, in IPDA three sets of equations which were described in the theoretical background section are supported. These three are Hyperbolic, Exponential, and Harmonic decline equations. The DCA used in this project are hyperbolic and harmonic decline curves with b values between 0 and 2.

A sample decline curve is shown on fig 4-7 .

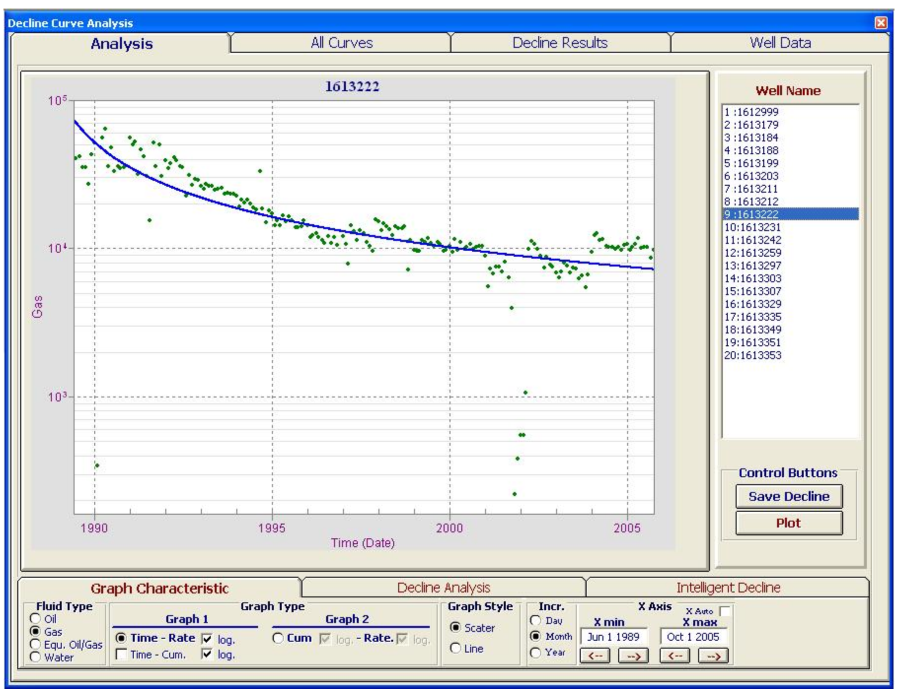


Fig 4-7. Production Rate Decline Curve for well 9

In the decline curve section it's possible to get the cumulative data simultaneously in the same plot so the validity of the match can be verified based on the cumulative data.

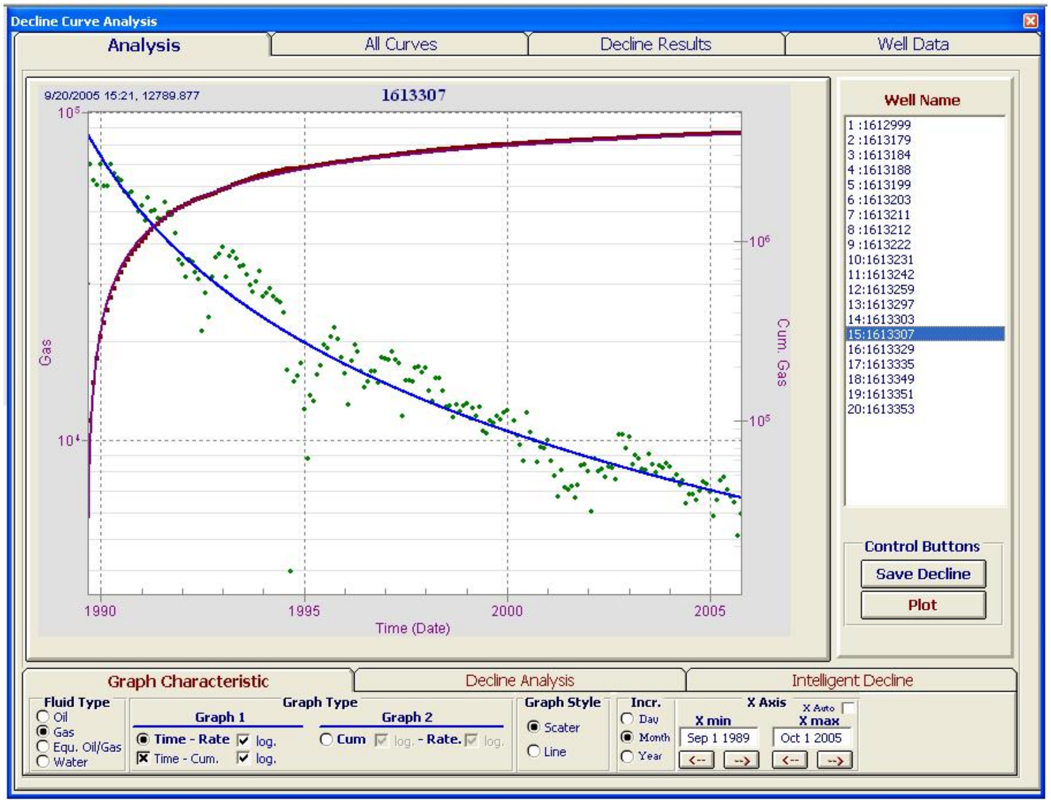


Fig 4-8. Production rate and Cumulative vs time for well 15

In the DCA interface one can calculate the EUR for a specific number of years (50 years in this case) and an abandonment rate of 5 MCFD.

4.3 Type Curve Matching

Type Curve Matching, TCM, uses Cox approach, Cox Type curves are specifically designed for low permeability Gas reservoirs. In this part reservoir's parameters like EUR, permeability, drainage area and fracture half length are calculated on a per well basis. In order to calculate these values the reservoir's parameters should be imported to the program.

This can be done using two different buttons in the Type curve Matching Interface as “Default All Wells” and “Specific Well Input”. These dialogs have the same data but the first one assign the inputs to all the wells as default and the second is for a particular well. There was a problem in the program that once you set a special data if you open the default dialogue again it will assign the default value to that well and ignore the special value assigned previously.

The dialogue is illustrated in Fig 4-9 .

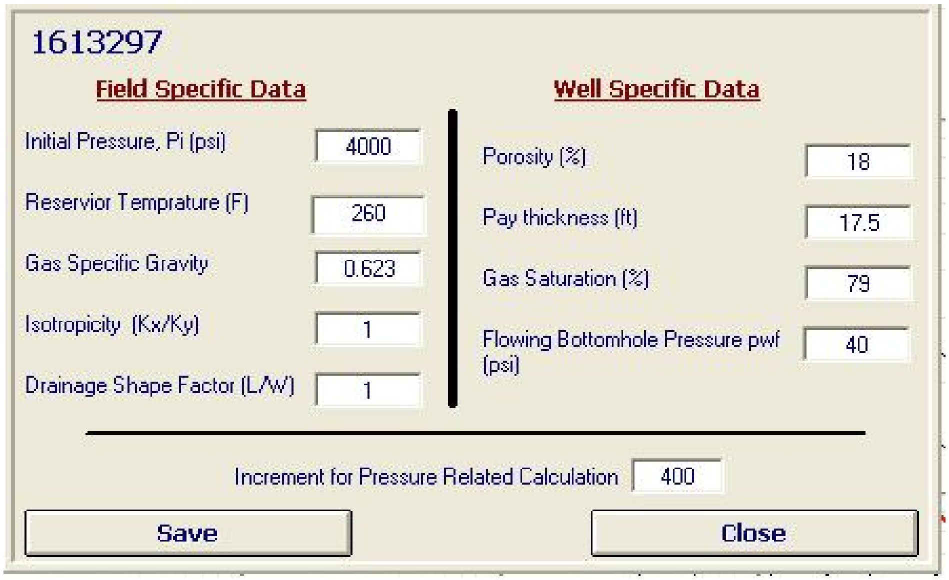


Fig 4-9. Special Well Input Dialogue

Software gets the *b* value for the type curves from the DCM and produce a set of type curves for different values of $\frac{X_e}{X_f}$. Once a match is found the red curve should be set to the particular match so the correct value of $\frac{X_e}{X_f}$ is calculated.

The EUR value calculated from DCM can be validated in the Type Curve Matching procedure. Once you save the type curve the EUR is calculated and can be found under the Type Curve Results tab.

A sample set of Type Curves are shown in Fig 4-10 .

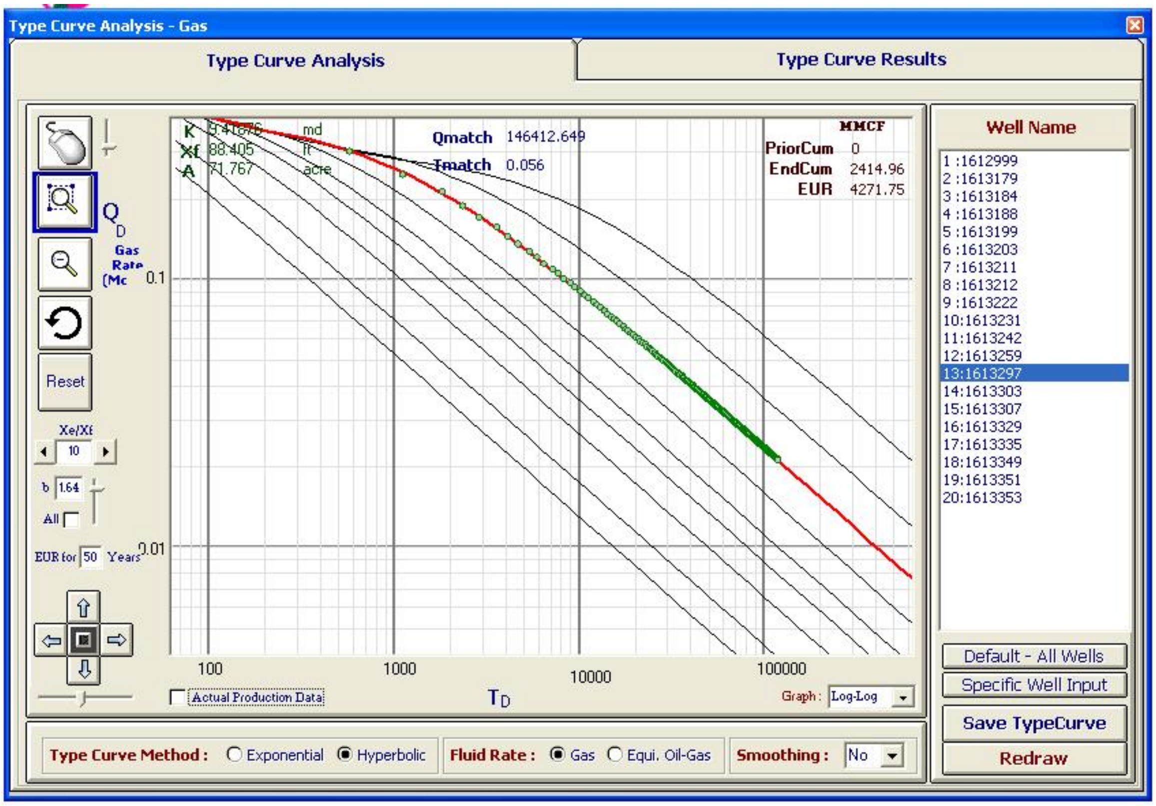


Fig 4-10 . Type curves for well Number 13

4.4 History Matching

Under the Numerical Simulation tab a single well simulation model for each well can be performed. By History Matching (HM) the reservoir's characteristics are adjusted in such a way so the model has the same behavior as the Production Data History.

There might be several reservoirs set of parameters that will experience similar behavior. Therefore, a qualitative and quantitative comparison between HM, DCA and TCM results will lead to the best possible model.

Fig 4-11 . Describes the algorithm followed in the software.

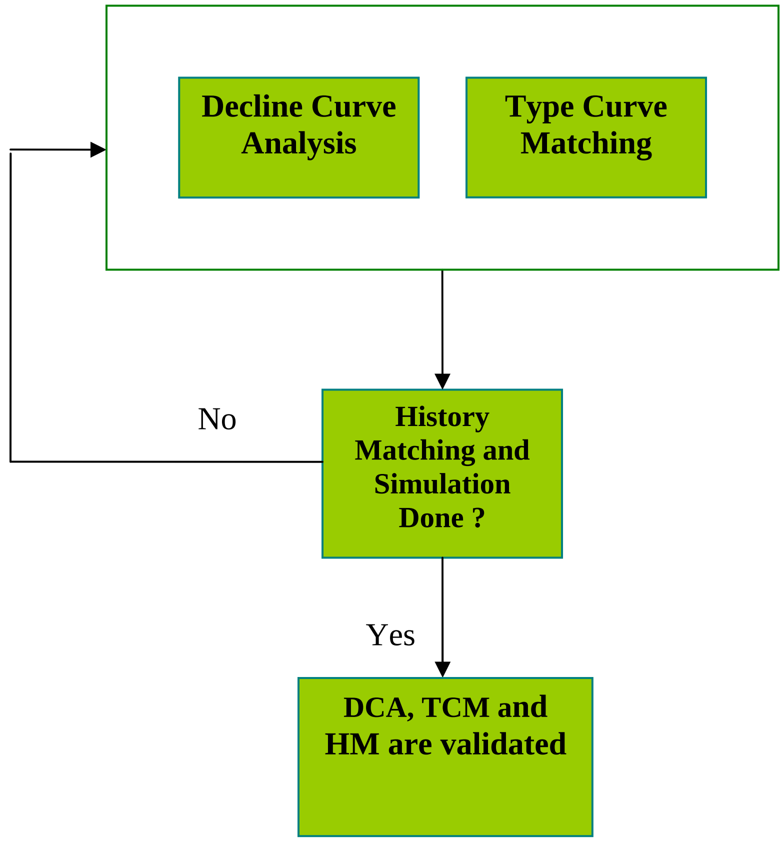


Fig 4-11 . Algorithms followed for History Matching.

History matching process can be started using the values taken from the TCM. These values are changed until the simulation behavior is matching with the data. A sample simulation result is given in Fig 4-12.

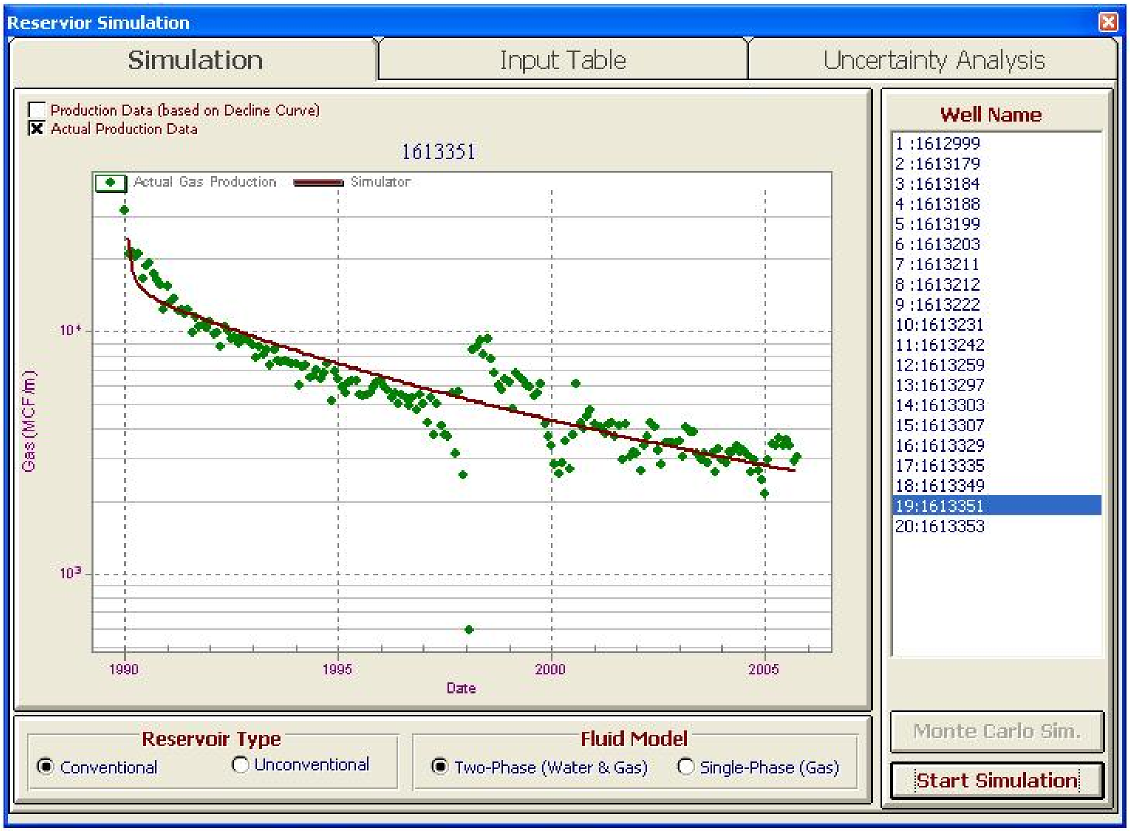


Fig 4-12 .– History Match of Well number 19

4.5 DCA TCM and HM validation

DCA, TCM and HM are compared through a back and forth procedure. For this comparison the value for EUR is used to evaluate the consistency of these three methods.

4.6 Fuzzy Pattern Recognition

Results from FPR allow the identification of the sweet spots for drilling locations and recognition of under performer wells by tracking particular productivity indices.

Also other deliverables are available upon completion of the analysis. Some of them are:

1. Initial Gas in Place
2. Cumulative Production
3. Remaining Reserves
4. Permeability
5. Drainage Area
6. Fracture Half Length
7. Under-Performer Wells

4.7 CMG Modeling

4.7.1 Preliminary Field Model:

Using CMG, a reservoir simulator package, a preliminary field model is built. This approach is taken in order to perform a sensitivity analysis on the data to understand the effects that some reservoir characteristics may have on the behavior of the field. This study can be taken as a preliminary sensitivity analysis for future History Matching approach.

Building the Model:

The data and assumptions entered in the simulator are as follow:

Provided:

- Thickness Map: Iso-pach Map (Provided. See Figure)

- Porosity: Iso-Porosity Map (Provided. See Figure)
- Water Saturation Map (Provided. See Figure)
- Reservoir Pressure: 4000 psi
- Temperature: 260 °F

From History Matching (IPDA):

- Permeability. (See Table)

Assumed:

- Depth: 1000 ft
- Grid Top elevation: 500 ft
- Two-Phase Model (Gas – Water). As History Matching in IPDA
- Grid System: 81x48x1. Cell size: 120x120 ft
- Kx=ky and kz=kx*0.1

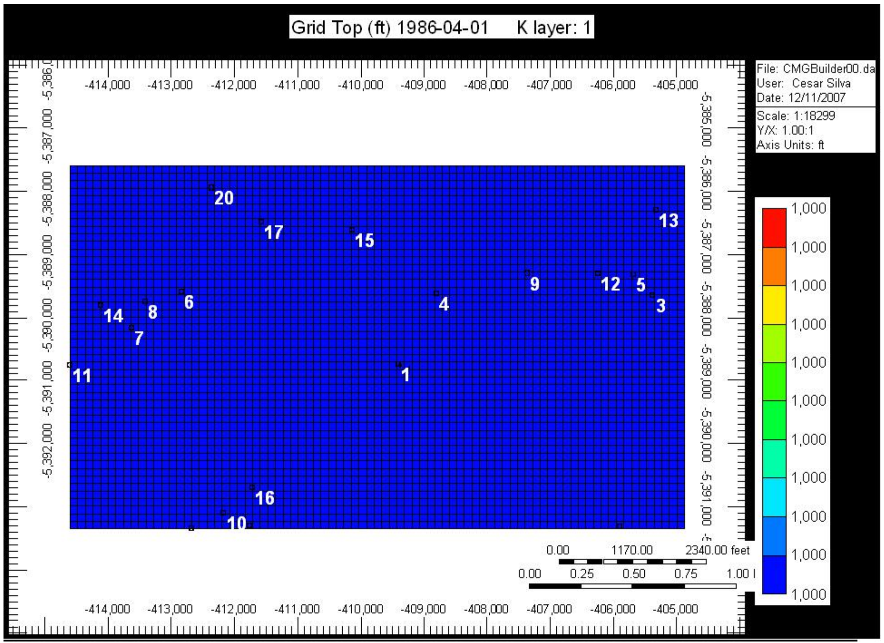


Fig 4-13 Field Map

The following is showing a 3D view of the field, also showing thickness distribution:

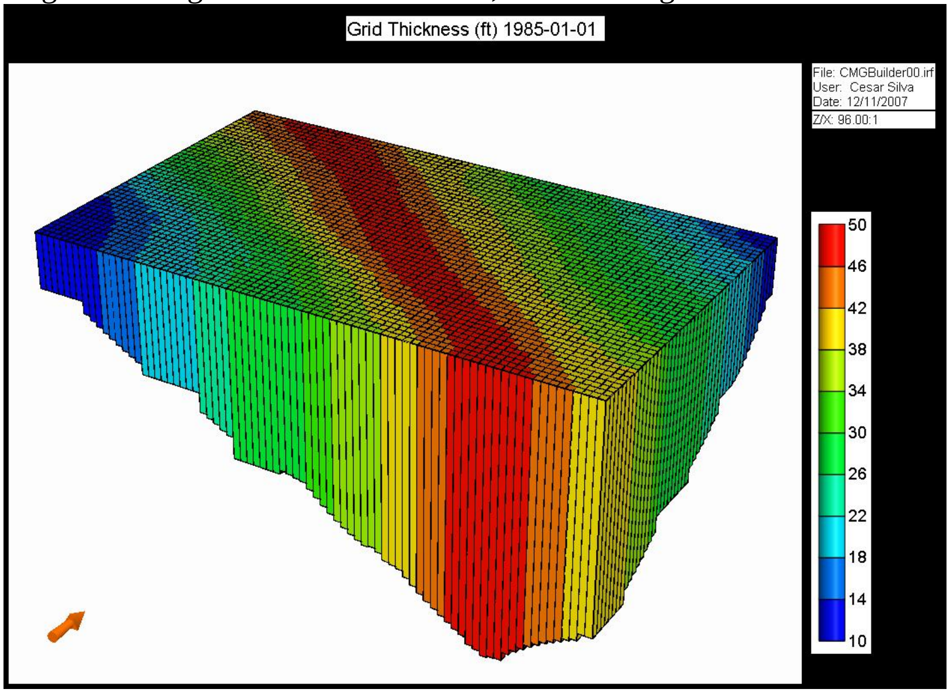


Fig 4-14. 3D View of the Field with thickness distribution

The following Figure shows the Permeability values from History Matching performed in IPDA, also its distribution along the field using Sequential Gaussian Simulation.

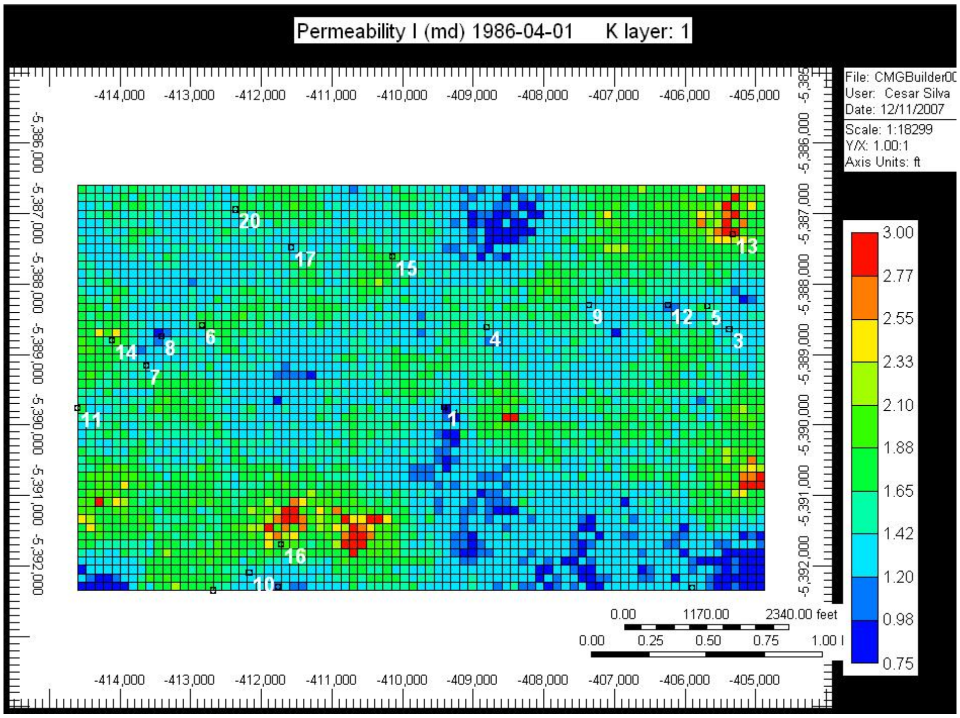


Fig. 4-15 Permeability Distribution

The following Figure shows the Porosity Map input using the provided Iso-Porosity:

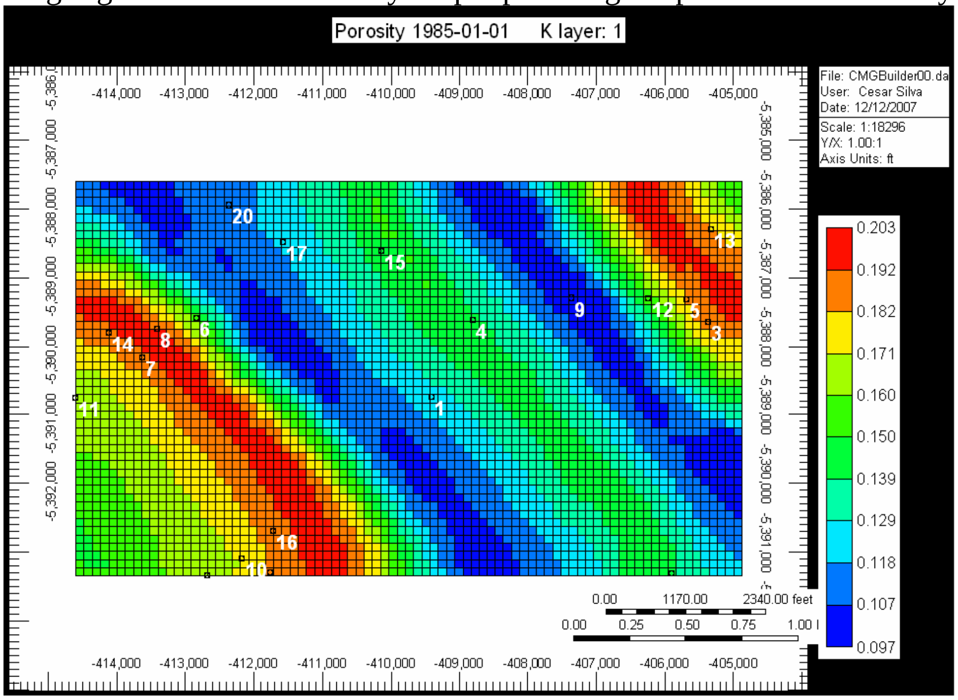


Fig. 4-16 Porosity Distribution

The following Figure shows the Water Saturation Map input using the provided Iso-Saturation:

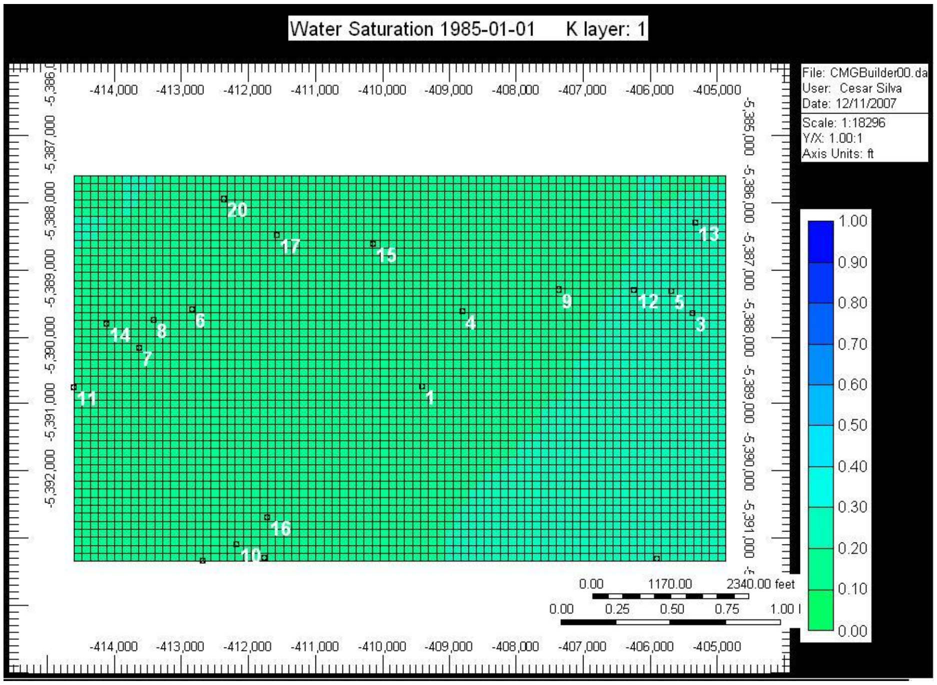


Fig. 4-17 Water Saturation Distribution

4.7.2 Sensitivity Analysis:

Values for permeability, porosity, and Thickness were changed in order to perform the analysis.

In the following tables, Permeability values are from History Matching performed in IPDA, porosity and thicknesses values are from the provided Iso-Porosity and Iso-Pach respectively since those values were not changed during the History Matching stage.

In order to change the parameters, they were multiplied by a factor as is shown in Table 4-1.

<table>
<tr><th>Permeability</th><th>Porosity</th><th>Thickness</th></tr>
<tr><td>0.5 * k from HM</td><td rowspan="4">Iso-Porosity</td><td rowspan="4">Iso-Pach</td></tr>
<tr><td>k from HM</td></tr>
<tr><td>1.5 * k from HM</td></tr>
<tr><td>2.5 * k from HM</td></tr>
</table>

<table>
<tr><th>Permeability</th><th>Porosity</th><th>Thickness</th></tr>
<tr><td rowspan="4">k History Matching</td><td>0.5 x Iso-Porosity</td><td rowspan="4">Iso-Pach</td></tr>
<tr><td>Iso-Porosity</td></tr>
<tr><td>0.5 x Iso-Porosity</td></tr>
<tr><td>0.5 x Iso-Porosity</td></tr>
</table>

<table>
<tr><th>Permeability</th><th>Porosity</th><th>Thickness</th></tr>
<tr><td rowspan="4">k History Matching</td><td rowspan="4">Iso-Porosity</td><td>0.5 * Iso-Pach</td></tr>
<tr><td>0.7 * Iso-Pach</td></tr>
<tr><td>Iso-Pach</td></tr>
<tr><td>1.5 * Iso-Pach</td></tr>
</table>

Table 4-1

5. Results and Discussion

5.1 Conventional Data Analysis Techniques and Numerical Simulation

In the Appendix A all the results for Decline Curve Analysis, Type Curve Method and Numerical Simulation are summarized. These results have been validated based on the EUR calculation as mentioned in the methodology. The outcome of this validation is illustrated in Table 5-1.and Fig 5-1 .

Well ID	Well Number	EUR DC	EUR TC	EUR FP
1612999	1	4053.14	4035.21	3886.3
1613179	2	4636.5	4596.838	4404.4
1613184	3	2224.59	2231.35	1833
1613188	4	3860.56	3846.77	3493.6
1613199	5	3089.55	3088.883	2601.8
1613203	6	4417.72	4399.387	4040.4
1613211	7	1663.09	1701.157	1677.7
1613212	8	2559.78	2554.141	2289.8
1613222	9	5188.2	5191.85	4985.25
1613231	10	1738.46	1775.627	1531.3
1613242	11	1642.18	1636.039	1521.3
1613259	12	2402.78	2406.843	2146.8
1613297	13	4264.17	4271.75	3779.3
1613303	14	3821.66	3805.132	3549.4
1613307	15	5382.98	5355.697	5009.2
1613329	16	2677.03	2662.646	2222
1613335	17	5886.07	5843.667	5140.5
1613349	18	2689.05	2669.127	2320
1613351	19	2053.14	2043.736	1708.4
1613353	20	4479.29	4463.137	4349

Table 5-1 – Verification of EUR values

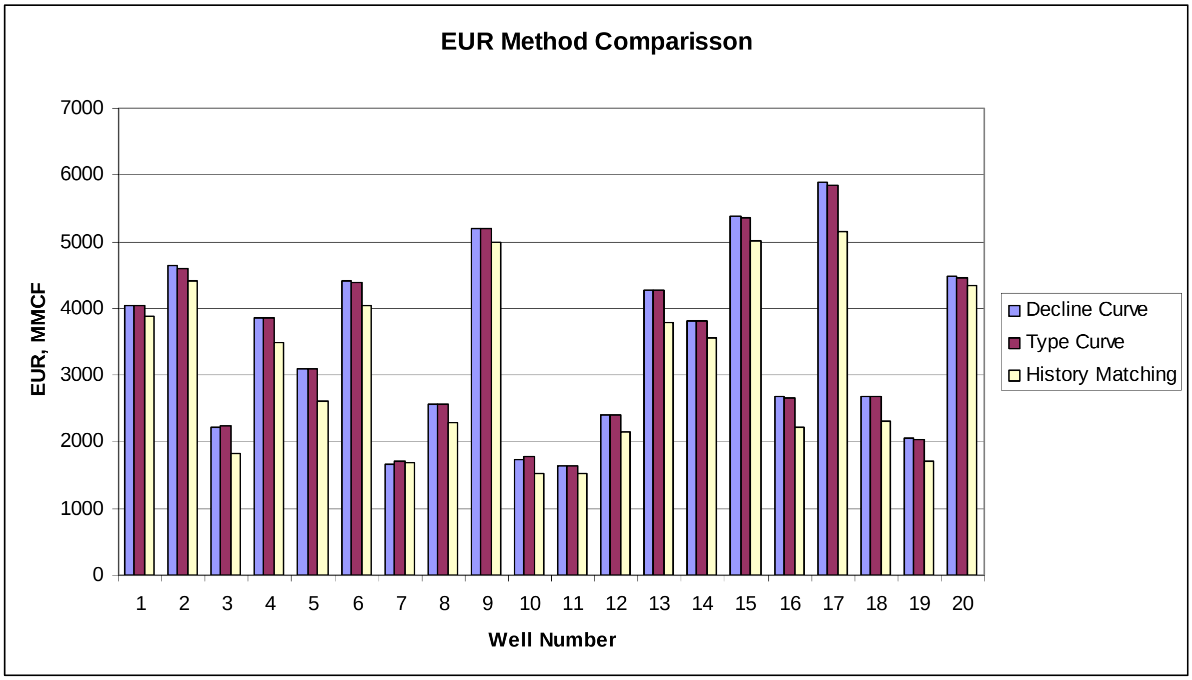


Fig 5-1. EUR Value Validation

5.2 Fuzzy Patter Recognition Results

Using the deliverables such as Remaining Reserves, EUR, Permeability and Drainage area from the analysis, some recommendations should be made. These recommendations will be based on the comparison of the trends among these Productivity Indices (PI) mentioned above.

Based on each PI the whole reservoir is partitioned so each part has a ranking which is called the Quality Index. These QI let us to evaluate the reservoir's area based on that particular PI.

Results for each indicator have been shown and analyzed in this chapter. These trends help us to find sweet spots along the field. Also they play a role on the identification of underperformer wells and potential drilling locations in order to increase the productivity and efficiency of the reservoir by adjusting some variables.

5.1 Results for Initial Gas in Place

Fig. shows the reservoir's partitioning based in the Initial Gas In Place (IGIP). Also a surface map illustrates the distribution of the IGIP along the reservoir. This surface map allows the identification of the higher quality indices (QI) zones.

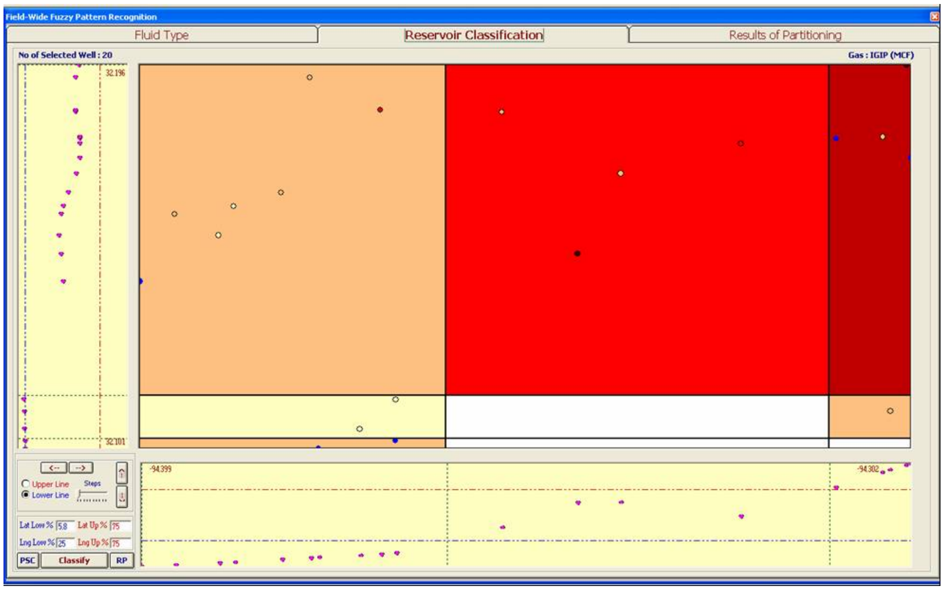


Fig 5-2 – Initial Gas in Place, Reservoir Partitioning

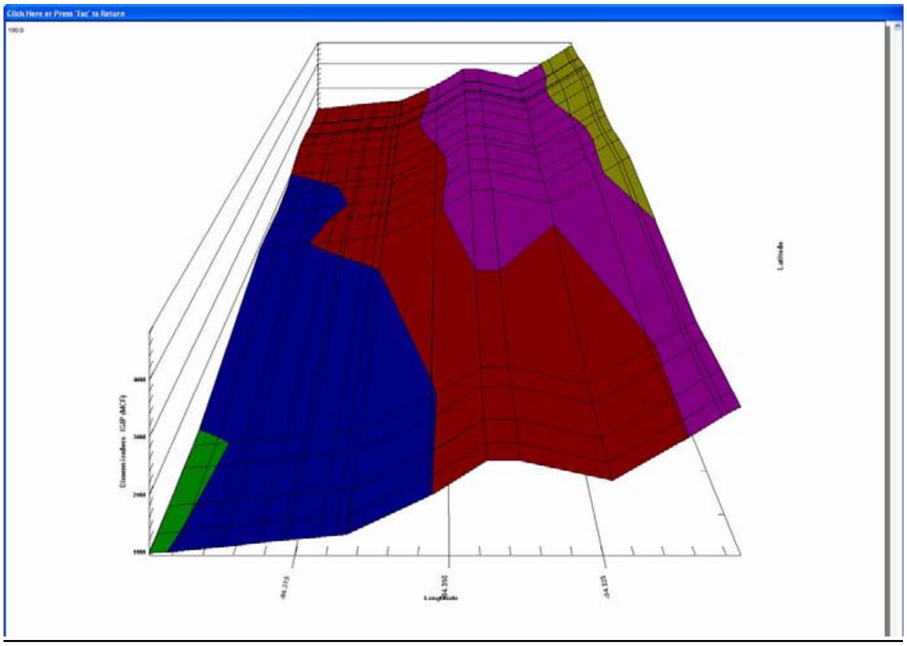
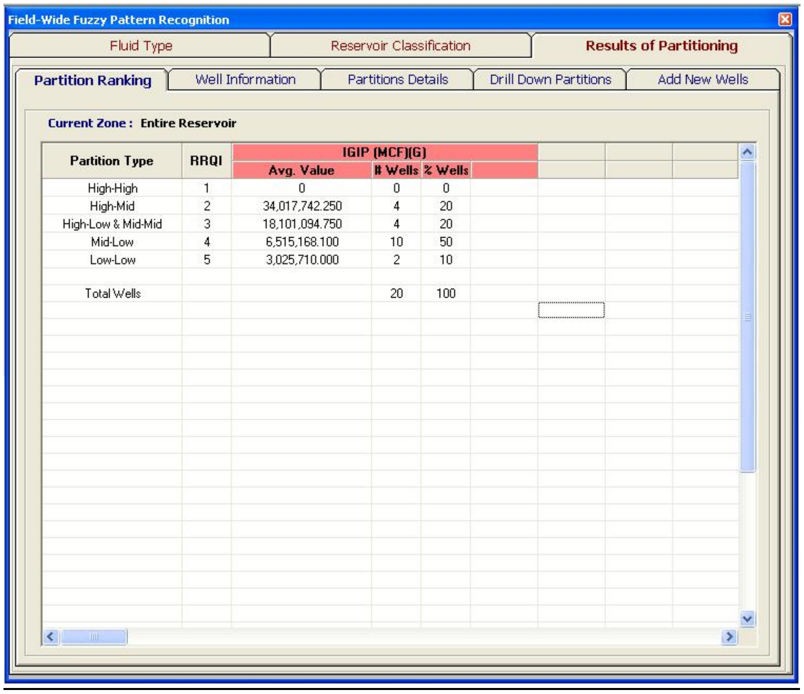


Fig 5-3. Initial Gas In_Place- Surface Map



Partition Type	RRQI	IGIP (MCF)(G) Avg. Value	# Wells	% Wells
High-High	1	0	0	0
High-Mid	2	34,017,742.250	4	20
High-Low & Mid-Mid	3	18,101,094.750	4	20
Mid-Low	4	6,515,168.100	10	50
Low-Low	5	3,025,710.000	2	10
Total Wells			20	100

Fig 5-3. Initial Gas In_Place- Data

5.2 Results for Remaining Reserves

Fig. shows the reservoir's partitioning based in the Remaining Reserve. Also a surface map illustrates the distribution of the Remaining Reserve along the reservoir. This surface map allows the identification of the higher quality indices (QI) zones.

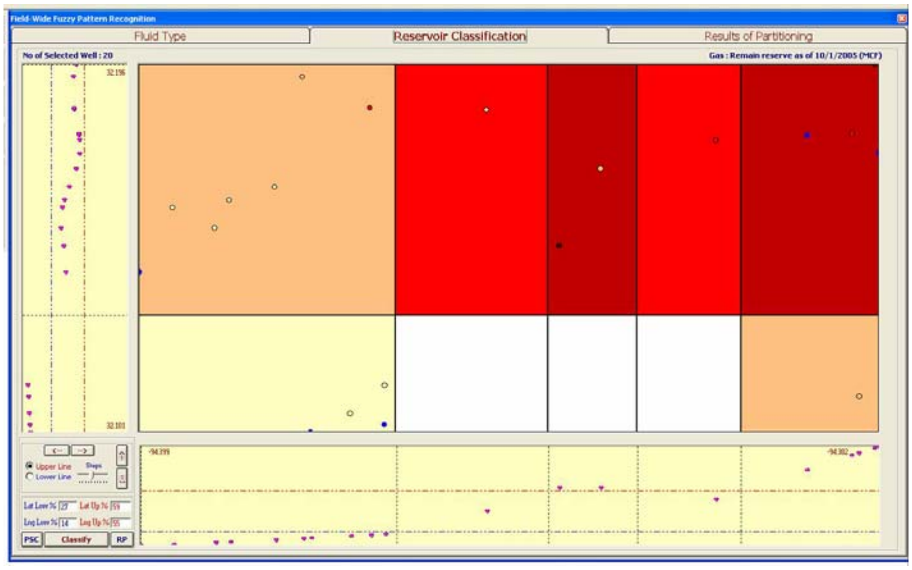


Fig. 5-5 – Remaining Reserves – Reservoir Partitioning

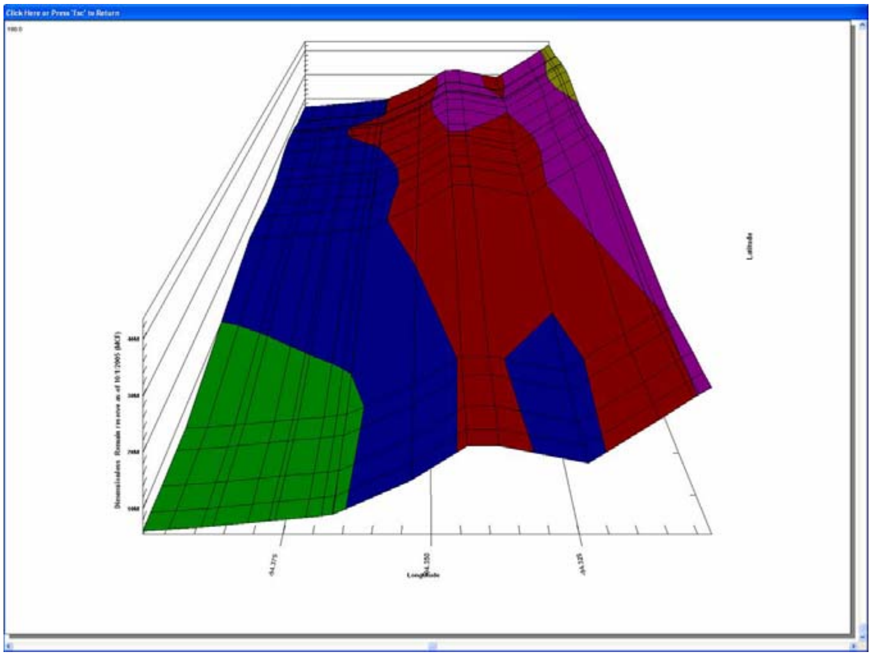
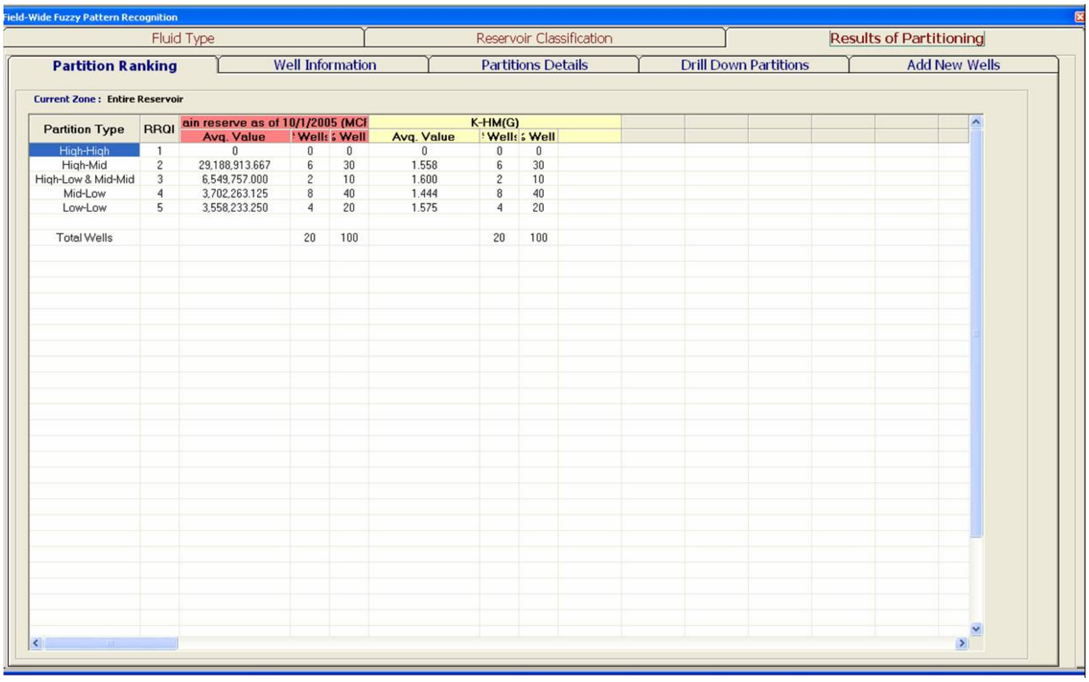


Fig. 5-6 Remaining Reserves- Surface Map



Partition Type	RRQI	ain reserve as of 10/1/2005 (MCF			K-HM(G)		
		Avg. Value	Wells	Well	Avg. Value	Wells	Well
High-High	1	0	0	0	0	0	0
High-Mid	2	29,188,913.667	6	30	1.558	6	30
High-Low & Mid-Mid	3	6,549,757.000	2	10	1.600	2	10
Mid-Low	4	3,702,263.125	8	40	1.444	8	40
Low-Low	5	3,558,233.250	4	20	1.575	4	20
Total Wells			20	100		20	100

Fig. 5-7 Remaining Reserves Attribute Data

While Remaining Reserve was used as an output in FPR, the same pattern with the permeability was tried to found which is shown in Fig. . these two PI's Patterns do not match each other very well.

5.3 Results for Permeability

Fig. shows the reservoir's partitioning based on the Permeability. Also a surface map illustrates the distribution of the Permeability along the reservoir. This surface map allows the identification of the higher quality indices (QI) zones.

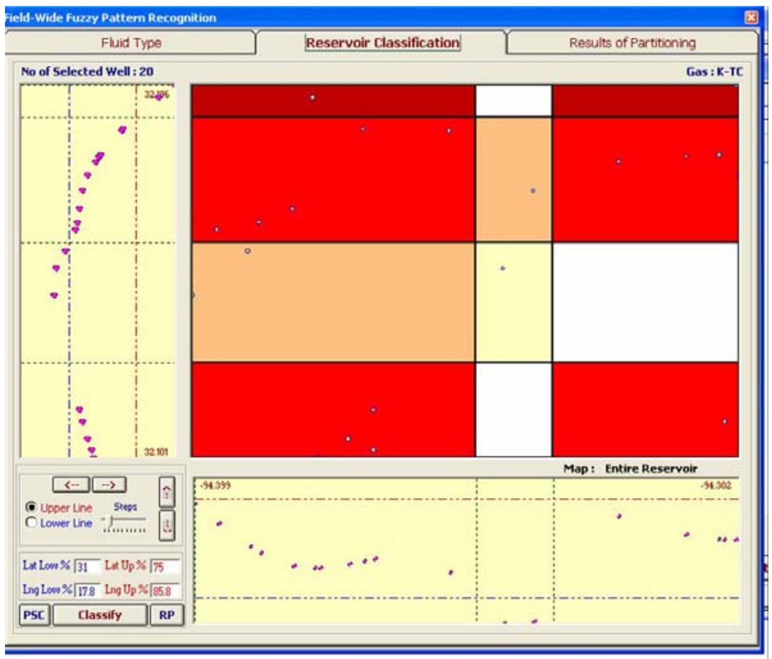


Fig.5-8 Permeability – Reservoir Partitioning

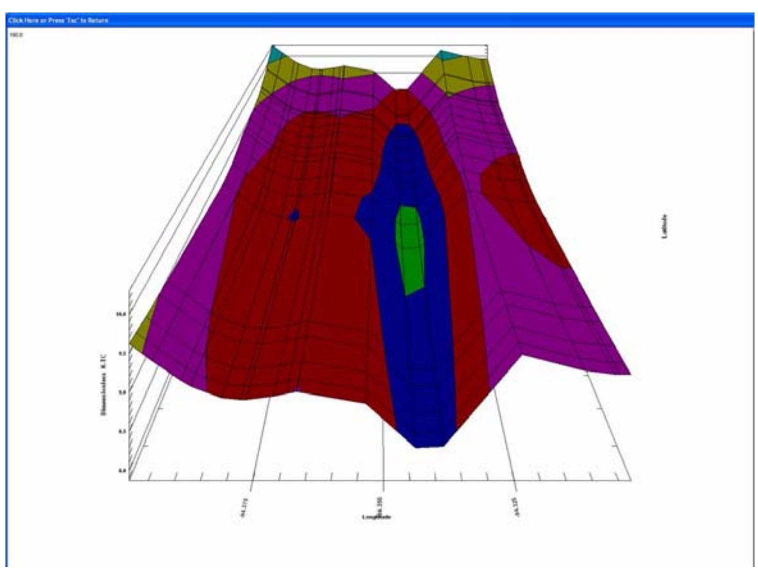


Fig. 5-9 Permeability – Surface Map

Observing above graphs we can see that the low permeability areas which have a good reserve will e good selections for our stimulation candidates among the underperformer wells. This problem will be addressed in the under performer wells' section.

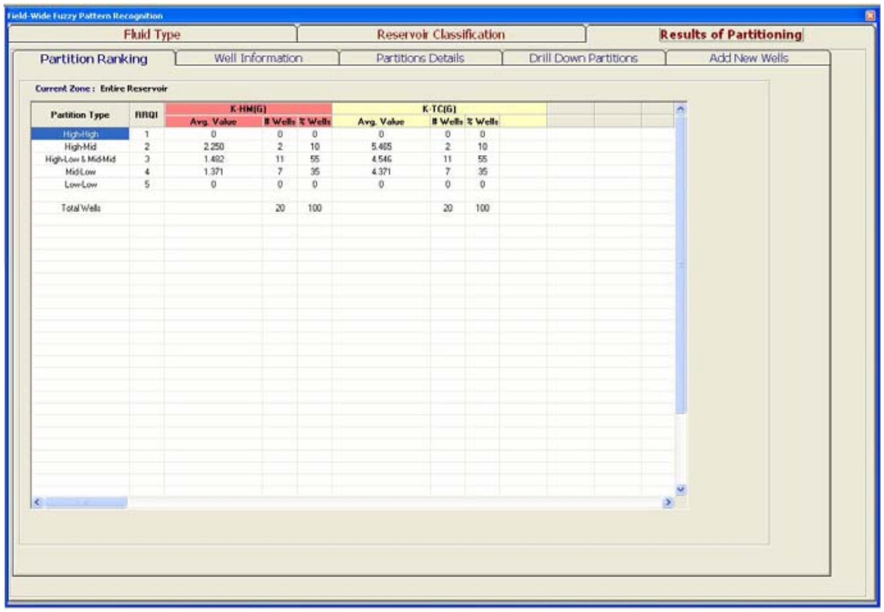


Fig. 5-10 Permeability , Attribute's data

5.4 Results for Drainage Area

Fig. shows the reservoir's partitioning based on the Drainage Area. Also a surface map illustrates the distribution of the Drainage Area along the reservoir. This surface map allows the identification of the higher quality indices (QI) zones.

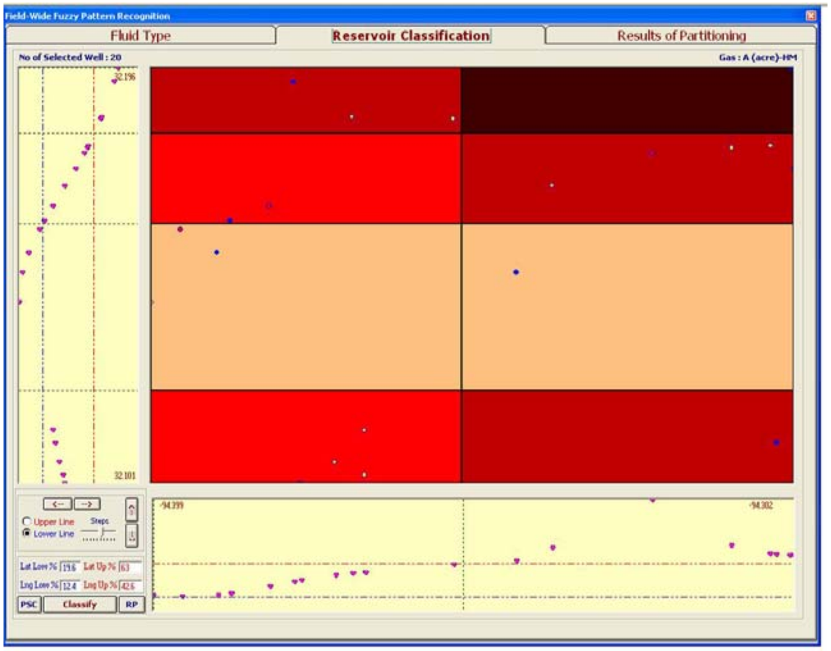


Fig. 5-11 Drainage Area , Reservoir Partitioning

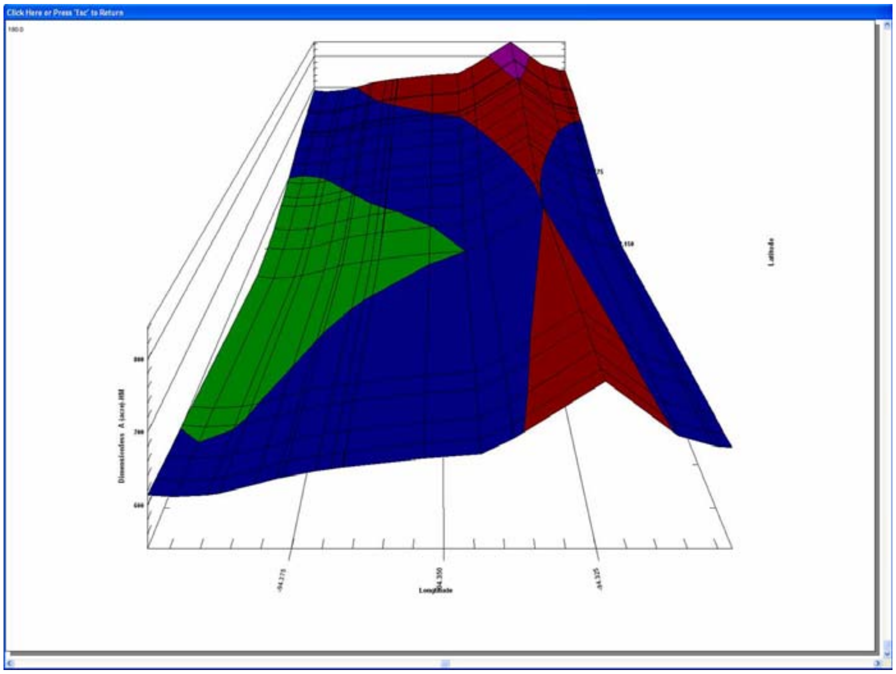
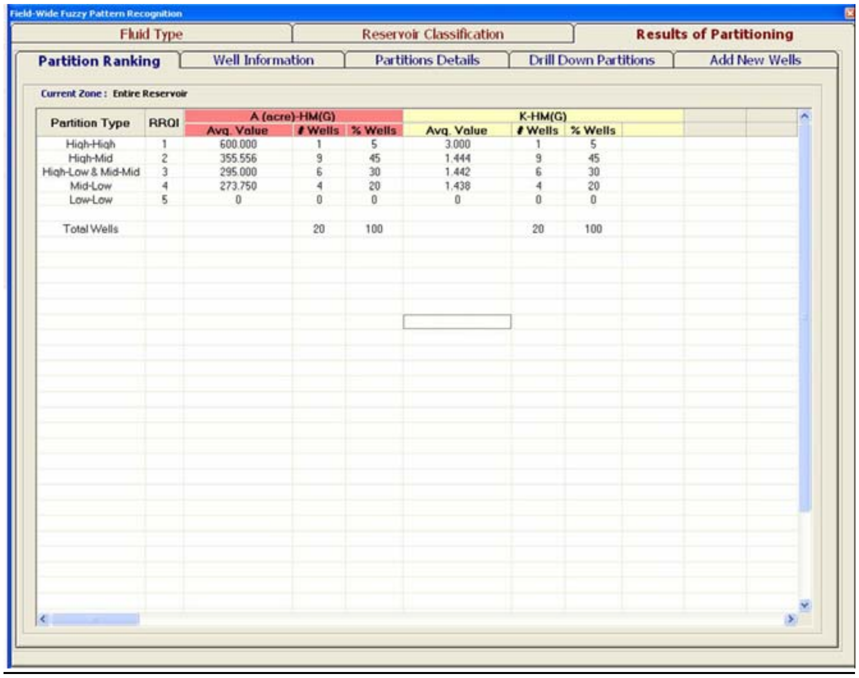


Fig. 5-12 Drainage Area – Surface Map



Partition Type	RRQI	A (acre)-HM(G)			K-HM(G)		
		Avg. Value	# Wells	% Wells	Avg. Value	# Wells	% Wells
High-High	1	600.000	1	5	3.000	1	5
High-Mid	2	355.556	9	45	1.444	9	45
High-Low & Mid-Mid	3	295.000	6	30	1.442	6	30
Mid-Low	4	273.750	4	20	1.438	4	20
Low-Low	5	0	0	0	0	0	0
Total Wells			20	100		20	100

Fig. 5-13 Drainage Area – Attribute’s Data

5.5 Results for the Best 3 Months Cumulative Production

Fig. shows the reservoir’s partitioning based on the best three months of cumulative production. Also a surface map illustrates the distribution of this PI along the reservoir. This surface map allows the identification of the higher quality indices (QI) zones.

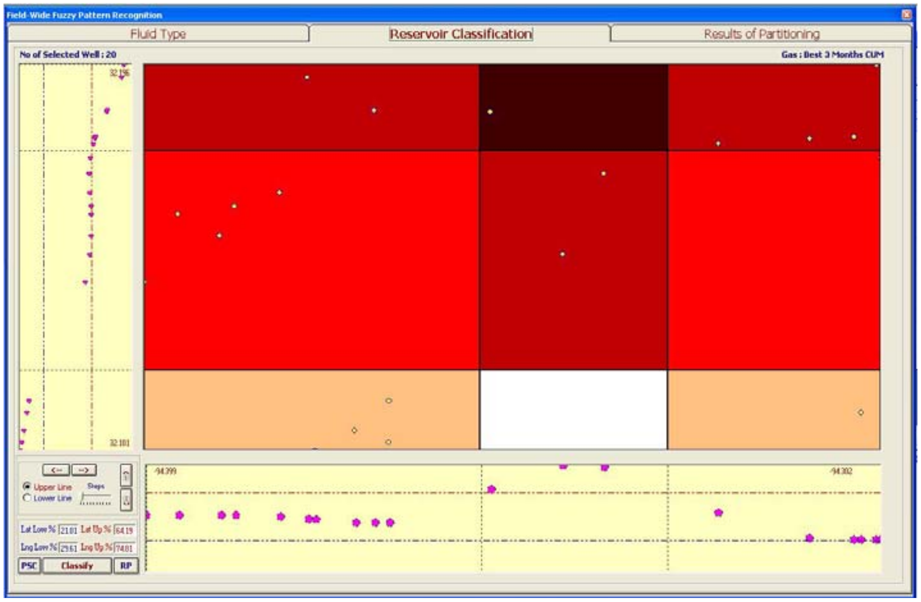


Fig. 5-14 Best Three Months Cum Prod.

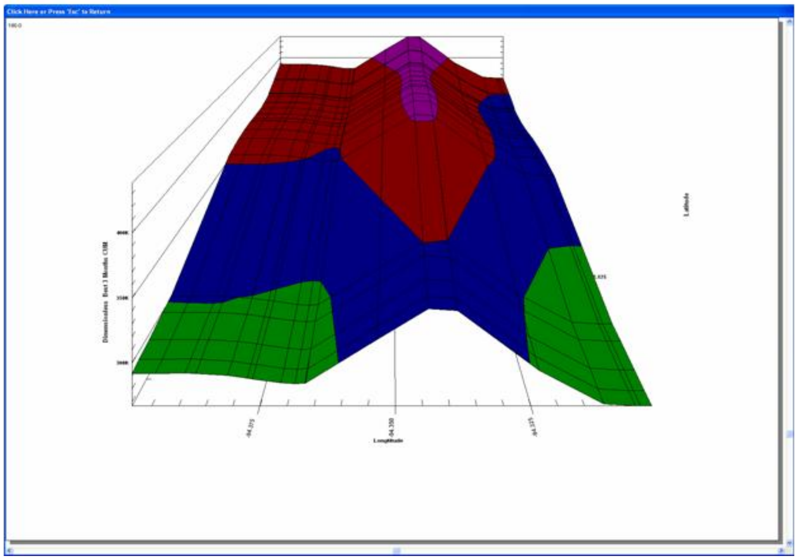


Fig. 5-15 Best Three Months Cum Prod. Surface Map

5.6 Results for the first one year Cumulative Production

Fig. 5-15 shows the reservoir's partitioning based on the first one year cumulative production. Also a surface map illustrates the distribution of this PI along the reservoir. This surface map allows the identification of the higher quality indices (QI) zones.

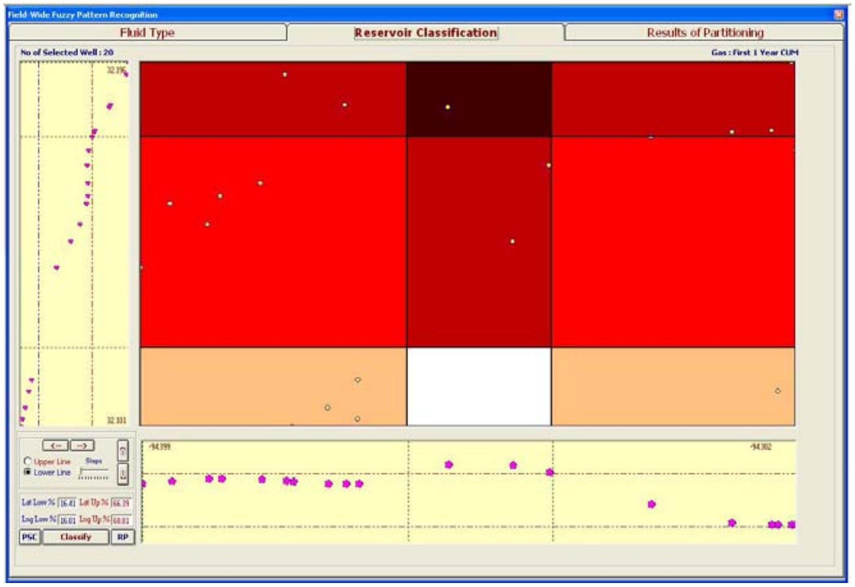


Fig.5-16 First one year cumulative production

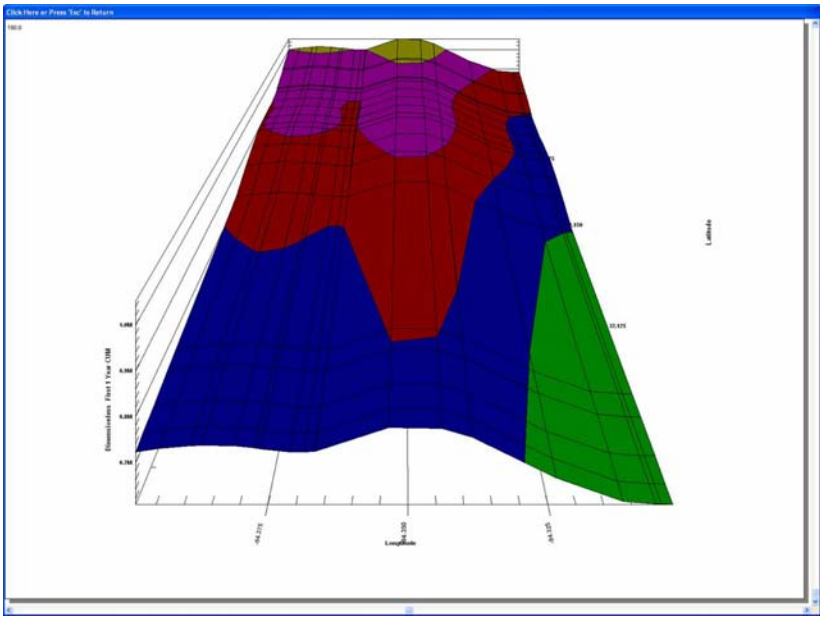
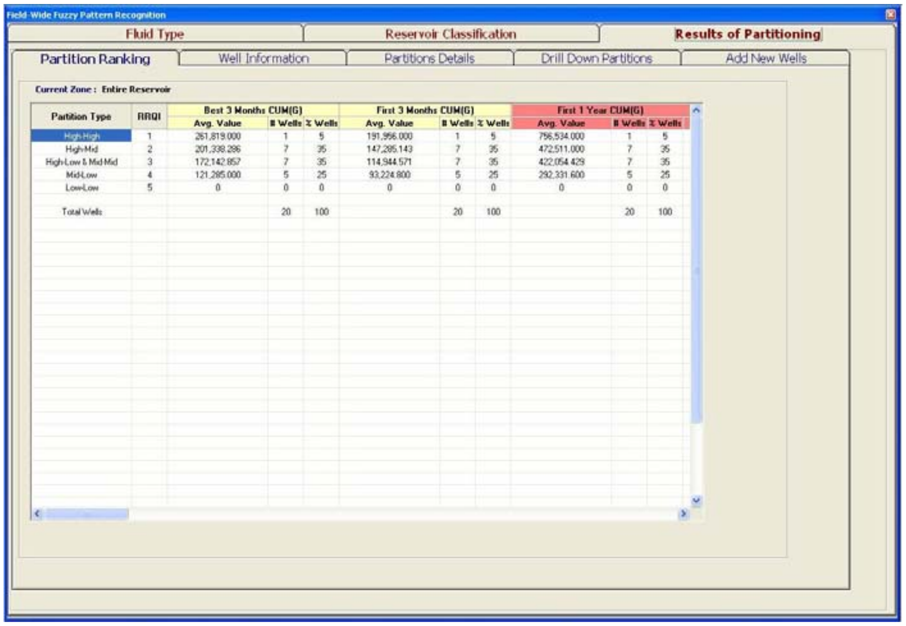


Fig.5-17 First one year cumulative production, Surface Map



Partition Type	RRQI	Best 3 Months CUM(G)			First 3 Months CUM(G)			First 1 Year CUM(G)		
		Avg. Value	# Wells	% Wells	Avg. Value	# Wells	% Wells	Avg. Value	# Wells	% Wells
High-High	1	261,819.000	1	5	191,956.000	1	5	756,534.000	1	5
High-Mid	2	201,338.286	7	35	147,285.143	7	35	472,511.000	7	35
High-Low & Mid-Mid	3	172,142.857	7	35	114,944.571	7	35	422,054.429	7	35
Mid-Low	4	121,285.000	5	25	93,224.800	5	25	292,331.600	5	25
Low-Low	5	0	0	0	0	0	0	0	0	0
Total Wells			20	100		20	100		20	100

Fig. 5-18 First one year cumulative production Attribute's Data

5.7 Results for EUR

Fig. 5-18 shows the reservoir's partitioning based on the EUR calculated with Type Curves. Also a surface map illustrates the distribution of this PI along the reservoir. This surface map allows the identification of the higher quality indices (QI) zones.

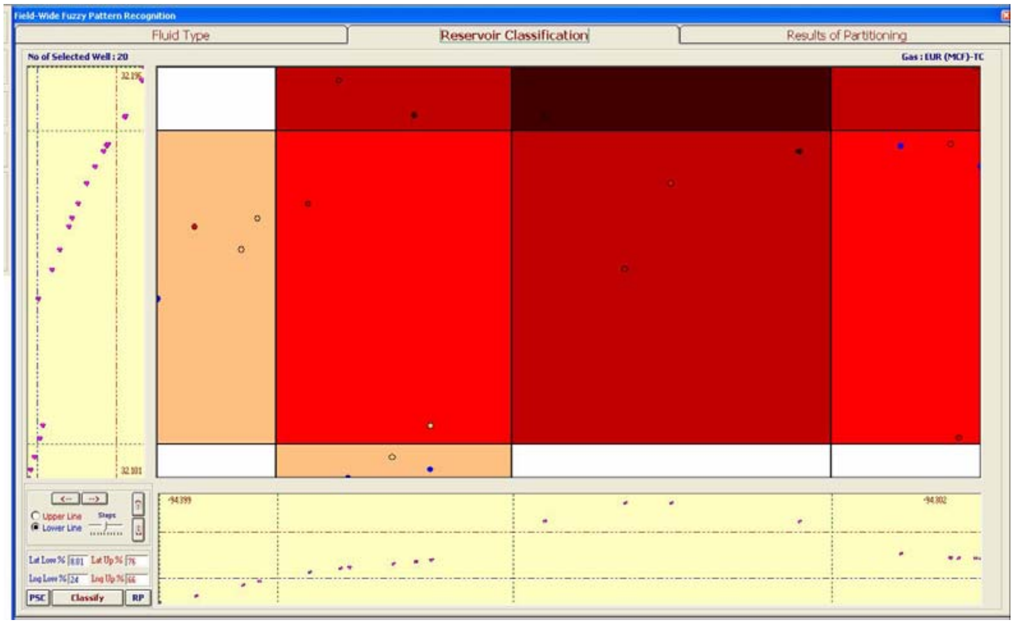


Fig.5-19. EUR reservoir Partitioning

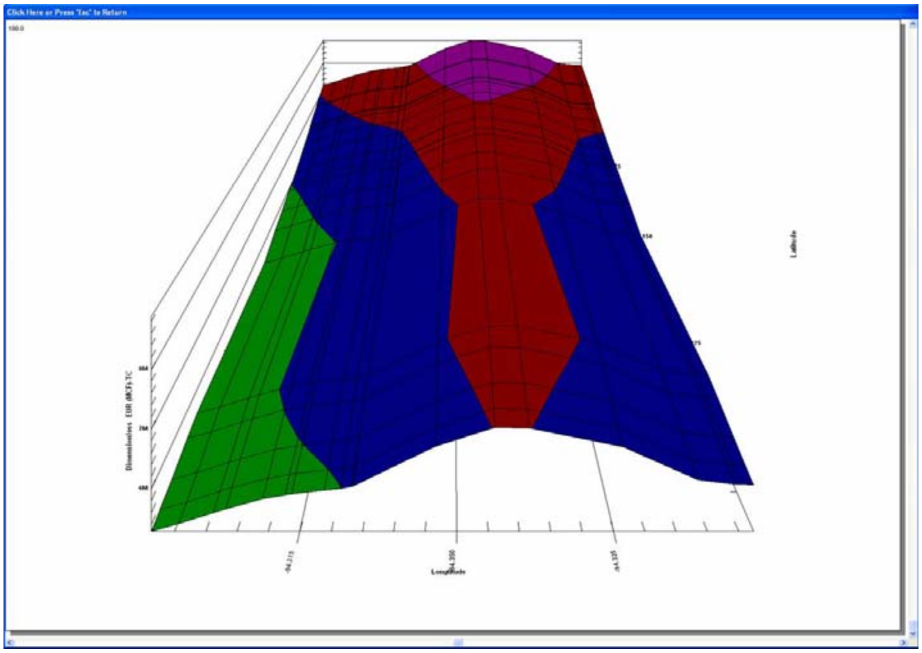
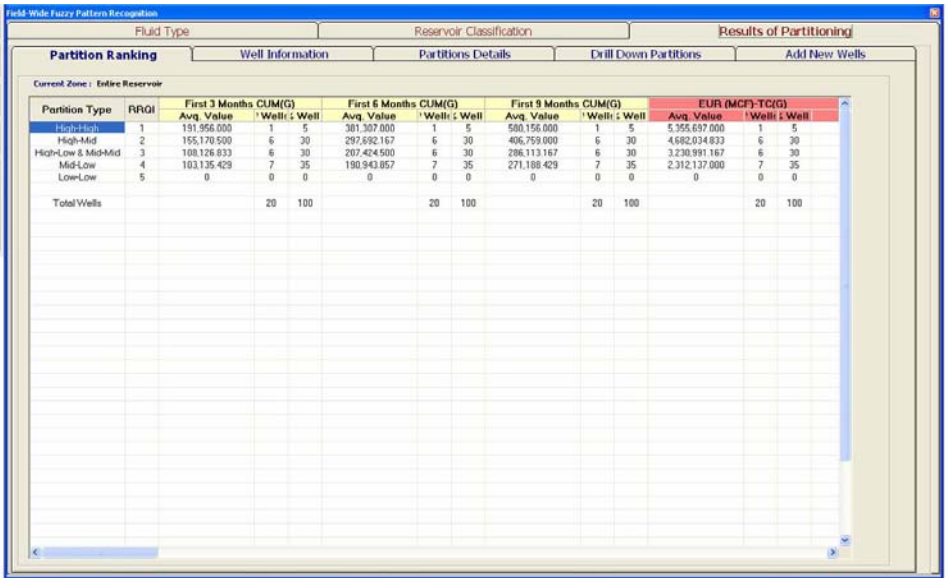


Fig. 5-20 EUR Surface Map



Partition Type	RRQI	First 3 Months CUM(G)			First 6 Months CUM(G)			First 9 Months CUM(G)			EUR (MCF)-TC(G)		
		Avg. Value	Well	Well	Avg. Value	Well	Well	Avg. Value	Well	Well	Avg. Value	Well	Well
High-High	1	191,956.000	1	5	381,307.000	1	5	580,156.000	1	5	5,355,697.000	1	5
High-Mid	2	155,170.500	6	30	297,692.167	6	30	406,759.000	6	30	4,682,034.833	6	30
High-Low & Mid-Mid	3	108,126.833	6	30	207,424.500	6	30	286,113.167	6	30	3,230,991.167	6	30
Mid-Low	4	103,135.429	7	35	190,943.857	7	35	271,188.429	7	35	2,312,137.000	7	35
Low-Low	5	0	0	0	0	0	0	0	0	0	0	0	0
Total Wells			20	100		20	100		20	100		20	100

Fig. 5-21 EUR Attribute's Data

In this Fuzzy Pattern Analysis taking EUR as output and First 3, 6 and 9 months production as an attributes a consistent pattern for all of them can be seen.

5.8 Recoverable Reserves for the asset

Assuming a Recovery Factor of 68% and using the Remaining Reserves calculated in the Fuzzy Pattern Recognition Section, the recoverable reserves on a per well basis is shown in Table. 5-2 .

Well Number	Well ID	Remaining Reserves MCF	Recoverable reserves BCF
1	1612999	41910723	28.50
2	1613179	4092143	2.78
3	1613184	77918770	52.98
4	1613188	4286898	2.91
5	1613199	8227316	5.59
6	1613203	3286166	2.24
7	1613211	193120	0.13
8	1613212	2949778	2.01
9	1613222	9957949	6.77
10	1613231	1034749	0.70
11	1613242	734160	0.50
12	1613259	8838468	6.01
13	1613297	33951307	23.09
14	1613303	3507023	2.39
15	1613307	3141565	2.14
16	1613329	1853268	1.26
17	1613335	10540251	7.17
18	1613349	5022005	3.42
19	1613351	6322911	4.30
20	1613353	4315464	2.94

Table 5-2 Recoverable Reserve

5.8 Under Performer wells

Using the under performer well tab in the IPDA a list of under performing wells appear in 3 different tables. Two criteria is applied to find the underperforming wells the first one is the first three month cumulative production and the second is the first three years cumulative production. Based on these two and the definition in the software number of wells will be subject to performing less than expected. These wells based on their location will be the best candidates to do workover and stimulation processes.

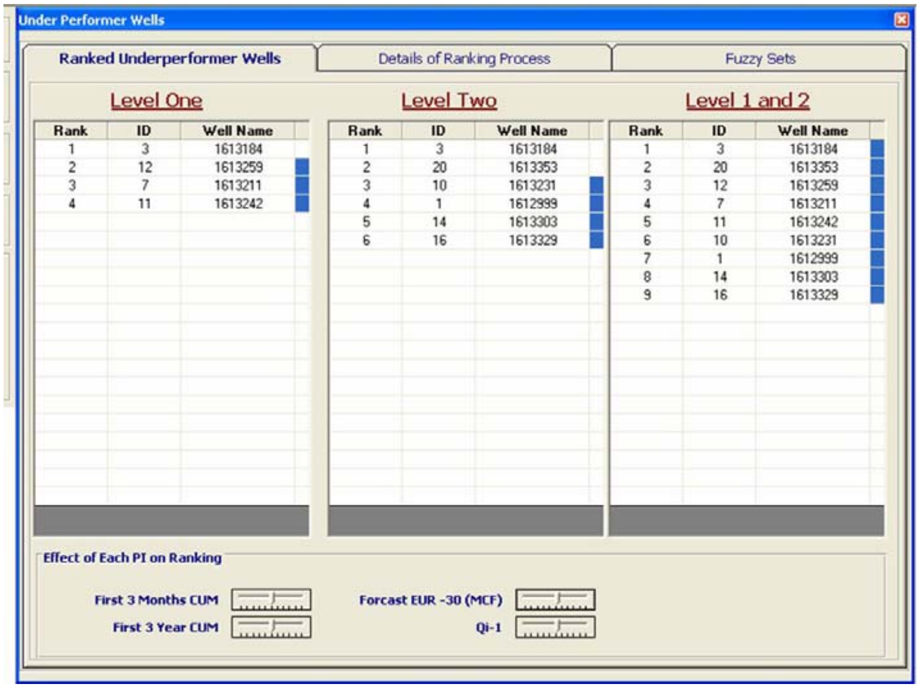


Fig. 5-22 . List of Underperformer wells

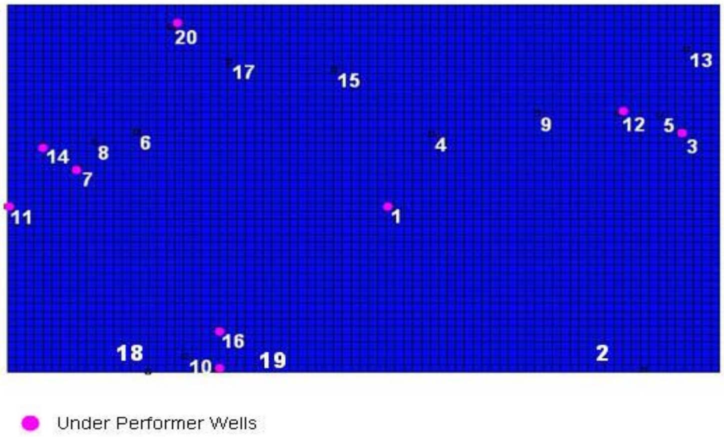


Fig.5-23 . Under Performer Wells

Based on where the well is and how the permeability and remaining reserve are at that part a remedial process is chosen. For instance when the permeability is relatively low but the reserve is good, there is a good spot for stimulation process. These decisions are illustrated in Table.

Under Performer Wells	K Permeability	Remaining Reserves	Remedial Method
1	Low	High Mid	Stimulation
20	High Mid	Low Mid	Work Over
12	High Mid	High Mid	Stimulation
3	High Mid	High Mid	Stimulation
7	Mid Low	Low Mid	Work Over
11	Mid Low	Mid Low	Stimulation
10	High Mid	Low	Work Over
14	High Mid	Low Mid	Work Over
16	High Mid	Low	Work Over

Table 5-3 . Underperformer well's remedial decision

Well number 1 is in a Low permeability but is having a mid-high reserve. In this case stimulation is chosen to overcome the low permeability of the reservoir.

Well number 20 is located in a mid high permeability but it doesn’t show a very good reserve. The investment for stimulation doesn’t seem approachable instead work over remedial solution is proposed.

Well number 3 and 12 were selected for stimulation based on having a good reserve and Mid-High permeability.

Well number 7 and 10 were selected for work over based on having a Low and Mid-Low reserve.

5.9 Recommendation for infill drilling

Infill drilling recommendations are made based on the fuzzy pattern of the permeability and the Remaining Reserve in the reservoir. These two parameters provide the storage and conductivity (to flow) at that specific spot.

Three new wells are proposed to be drilled. These wells are allocated in upper part of the map where most of the reserves are located.

The well's allocation and economical analysis have been performed in the What-If Scenario tab in IPDA. Under this tab by selecting a new well and entering appropriate economical parameters the Net Present Value (NPV) for the new well is calculated. The more NPV, the better the well's influence on the package.

These three wells' locations and economical analysis are shown in figures in the next three pages.

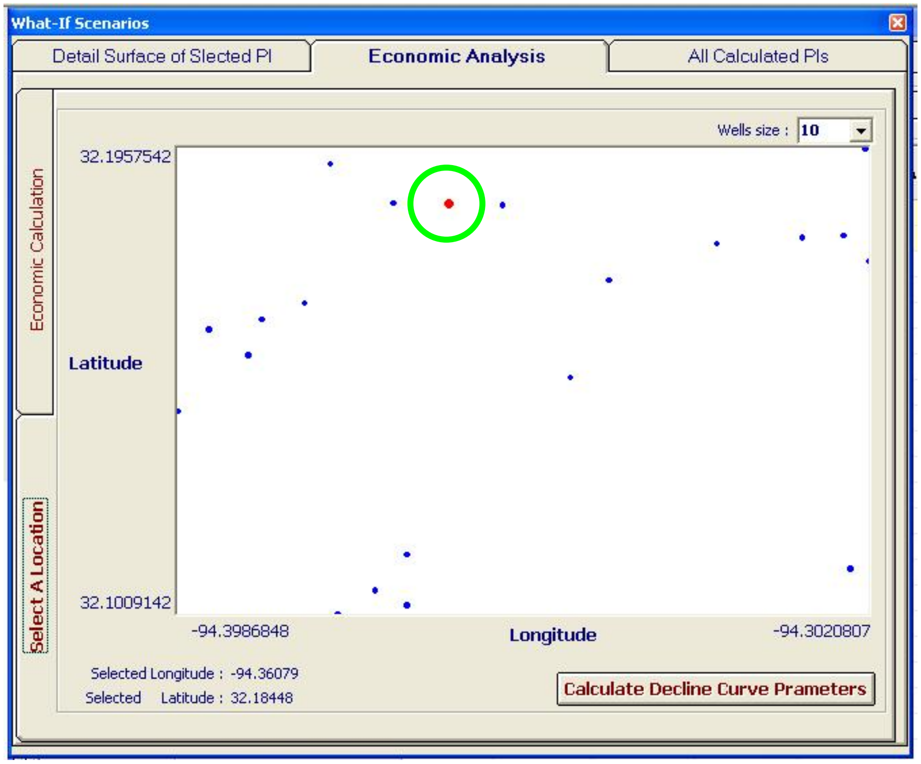


Fig.5-24 . Cesarito well position

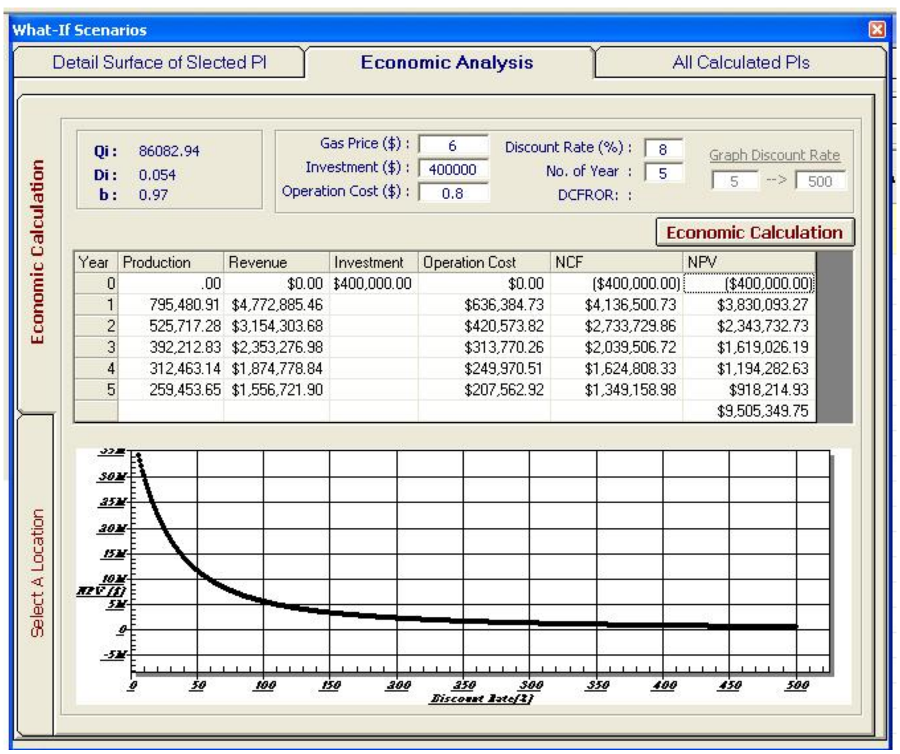


Fig 5.25 Economic Analysis of Cesarito well

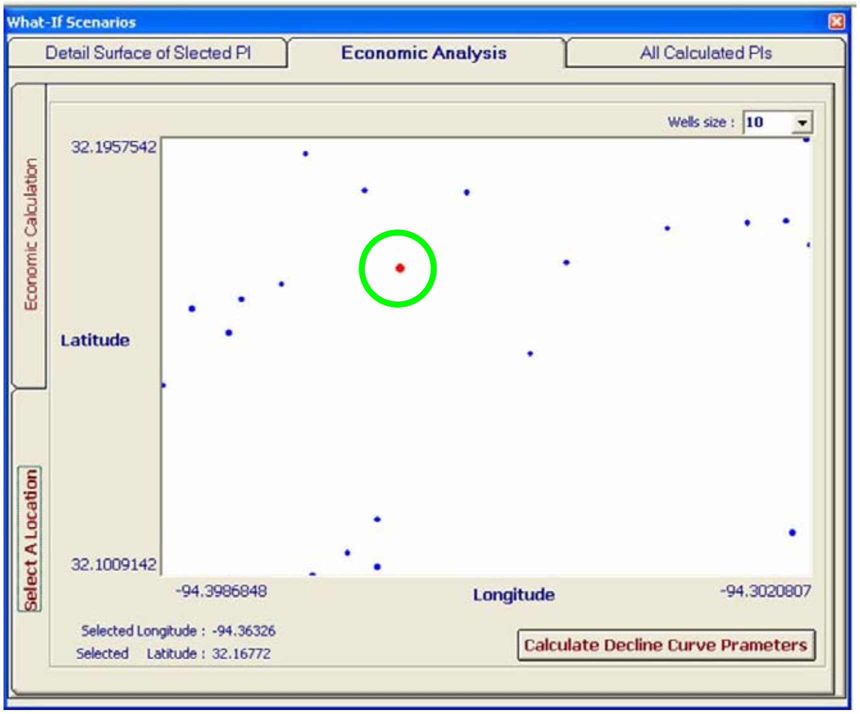


Fig 5-26 Yasita well location

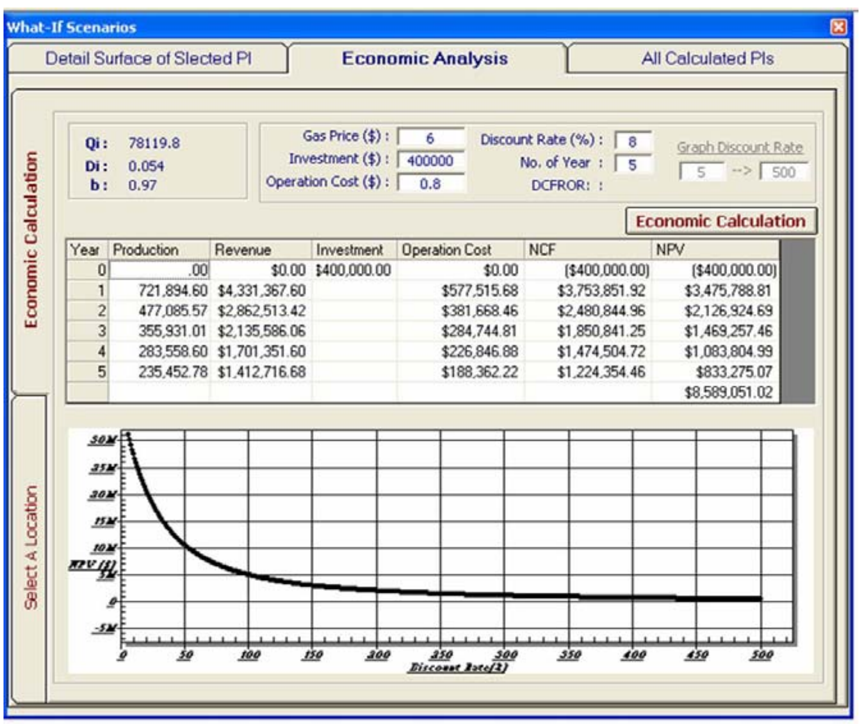


Fig 5-27 Economic Analysis of Camilito well

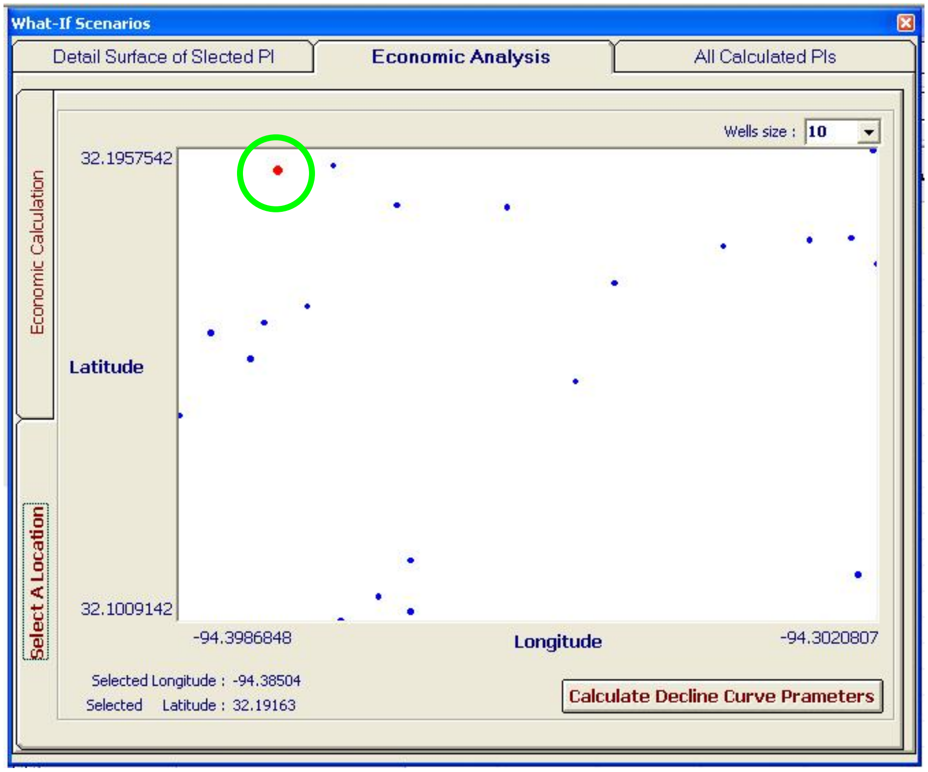
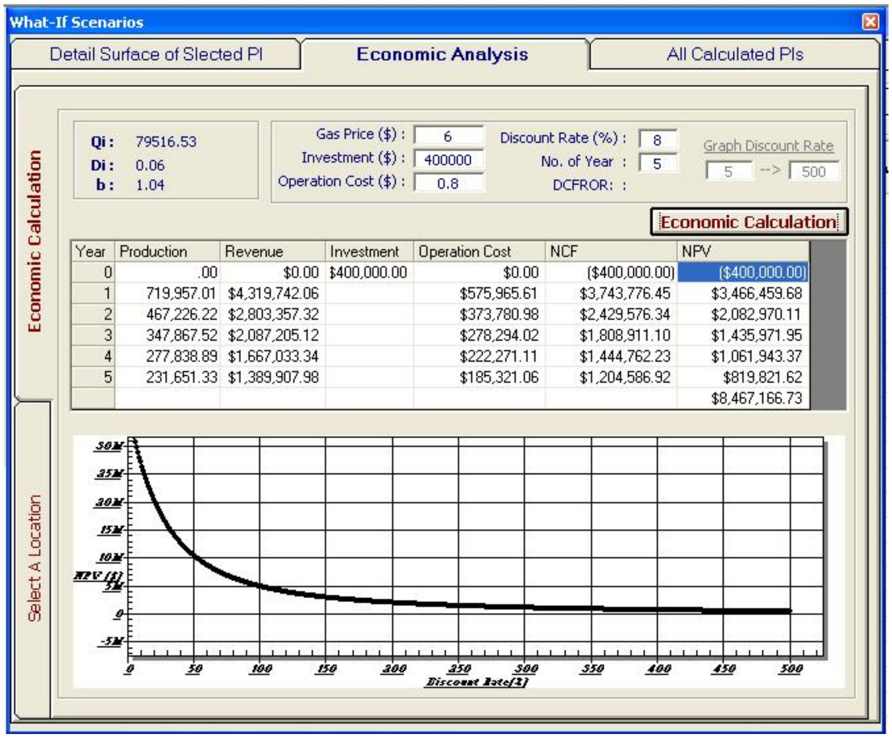


Fig 5-28 Camilito well location



Year	Production	Revenue	Investment	Operation Cost	NCF	NPV
0	.00	$0.00	$400,000.00	$0.00	($400,000.00)	($400,000.00)
1	719,957.01	$4,319,742.06		$575,965.61	$3,743,776.45	$3,466,459.68
2	467,226.22	$2,803,357.32		$373,780.98	$2,429,576.34	$2,082,970.11
3	347,867.52	$2,087,205.12		$278,294.02	$1,808,911.10	$1,435,971.95
4	277,838.89	$1,667,033.34		$222,271.11	$1,444,762.23	$1,061,943.37
5	231,651.33	$1,389,907.98		$185,321.06	$1,204,586.92	$819,821.62
						$8,467,166.73

Fig 5-29 Economic Analysis of Yasita well

5.10. Economical Analysis

The Forecast Incremental Production is calculated in the Fuzzy Pattern Recognition Section Forecast Tab. To get the yearly cumulative production these incremental values were calculated for each year. Yearly cumulative production will be the difference of each pair of consecutive values.

Economical Analysis at the discount rate of 8% was performed. Value of the asset is first obtained without any investment and compared with the scenario including the three new wells, Cesarito, Camilito and Yasita, and the remedial operations which are five stimulations and four work overs. The cost of each of these operations is included in the investment.

Drilling a New Well	**$400,000.00**
Stimulation of a Well	**$125,000.00**
Work Over of a Well	**$25,000.00**

Table 5-4 Operation's Cost

Overall Value of the Asset Before Investment	**$20,768,811.00**
Overall Value of the Asset After Investment	**$48,381,470.00**.
Discount rate of Return	**908.20%**

Table 5-5 Analysis Results

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All well's yearly production are shown in Table 5-6 the Net Cash Flow analysis is done based on a $1,925,000 investment and it is compared to a Net Cash Flow Analysis of the asset without any investment.

The increment of the Value of the asset can justify the proposed investment. The Net Cash Flow profile and Net Present Value Profile are shown in Figures. 5-29 and 5-30.

	Well Name	Latitude	Longitude	DOFP	DOLP	Forecast Incr -1 (MCF)	Forecast Incr -2 (MCF)	Forecast Incr -3 (MCF)	Forecast Incr -4 (MCF)	Forecast Incr -5 (MCF)
1	1612999	32.149108	-94.343847	4/1/1986	10/1/2005	85012.05	166628.2	245434.25	321311.3	394742.2
2	**1613179**	32.110235	-94.304697	2/1/1989	10/1/2005	78121	152128	222592	289463	353229
3	**1613184**	32.172833	-94.302081	4/1/1989	10/1/2005	77488	149758.9	218053.9	282736.95	344540.3
4	**1613188**	32.168929	-94.338448	6/1/1989	10/1/2005	60545	118055	172972	225247	275255
5	**1613199**	32.178007	-94.305637	7/1/1989	10/1/2005	52500	102908	151540	198294	243445
6	**1613203**	32.16428	-94.381007	3/1/1989	10/1/2005	63768	123978	181143	235259	286752
7	1613211	32.153669	-94.388843	12/1/1989	10/1/2005	16676.15	31779.1	39616	50537	60558
8	**1613212**	32.160925	-94.386909	6/1/1989	10/1/2005	39654	77419	113572	148072	181155
9	**1613222**	32.176326	-94.323418	6/1/1989	10/1/2005	84698	165591	243240	317528	388936
10	**1613231**	32.105816	-94.371123	8/1/1989	4/1/2003	43072.25	83228.55	120922.75	156430.35	190073.25
11	**1613242**	32.142295	-94.398685	5/1/1989	9/1/2005	30155.65	58542.3	85418.05	110797.4	134890.6
12	**1613259**	32.177616	-94.31146	10/1/1989	10/1/2005	60862.3	119487.25	176221.4	230929.9	283915.8
13	**1613297**	32.195754	-94.302669	1/1/1990	10/1/2005	78454	154175	227597	298526	367345
14	**1613303**	32.158959	-94.394324	7/1/1989	10/1/2005	65121.05	126793.25	161322	209807	256076
15	**1613307**	32.184176	-94.353343	9/1/1989	10/1/2005	77566	150302	218907	283446	344489
16	**1613329**	32.113135	-94.36664	11/1/1989	10/1/2005	48818.65	94820.95	120360	156181	190210
17	**1613335**	32.184587	-94.368552	10/1/1989	10/1/2005	96313	188105	276043	360019	440602
18	**1613349**	32.100914	-94.376329	10/1/1989	10/1/2005	46667	91312	134235	175363	214956
19	**1613351**	32.102895	-94.366675	1/1/1990	10/1/2005	35583	69828	102941	134847	165728
20	**1613353**	32.192661	-94.377361	11/1/1989	10/1/2005	71490.9	136862.65	171624	220426	266110
21	**Cesarito**	32.18448	-94.36079	10/1/2005		795480.91	525717.28	392212.83	312463.14	259453.65
22	**Camilito**	32.18696	-94.33598	10/1/2005		719957.01	467226.22	347867.52	277838.89	231651.33
23	**Yasita**	32.16772	-94.36326	10/1/2005		721895.6	477085.57	355931.01	283558.6	235452.78

	work over
	Stimulation
	New Well

Table 5-6 Forecast Results after Remedial Operations

Year	Investment $	Production Mcf	Revenue, $	Op Cost, $	Net Cash Flow	NPV (8%)
0	0.00				0.00	0.00
1		1,094,159.00	6,564,954.00	875,327.20	5,689,626.80	5,268,172.96
2		1,037,371.00	6,224,226.00	829,896.80	5,394,329.20	4,624,767.83
3		989,657.00	5,937,942.00	791,725.60	5,146,216.40	4,085,232.50
4		941,970.00	5,651,820.00	753,576.00	4,898,244.00	3,600,355.57
5		901,456.00	5,408,736.00	721,164.80	4,687,571.20	3,190,282.19
					Total NPV, $	20,768,811.05

Table 5-7 Economical Results Analysis without Investment

Year	Investment $	Production Mcf	Revenue, $	Op Cost, $	Net Cash Flow $	NPV (8%) $	NPV (20%) $	NPV (50%) $	NPV (100%) $	NPV (200%) $	NPV (DCFROR=908.2%) $
0	1,925,000				-1,925,000	-1,925,000	-1,925,000	-1,925,000	-1,925,000	-1,925,000	-1,925,000
1		3,449,900	20,699,397	2,759,920	17,939,478	16,610,627	14,949,565	11,959,652	8,969,739	5,979,826	1,779,243
2		2,619,165	15,714,991	2,095,332	13,619,659	11,676,663	9,458,097	6,053,182	3,404,915	1,513,295	133,973
3		2,118,064	12,708,381	1,694,451	11,013,931	8,743,213	6,373,802	3,263,387	1,376,741	407,923	10,745
4		1,895,327	11,371,963	1,516,262	9,855,701	7,244,235	4,752,942	1,946,805	615,981	121,675	954
5		1,704,345	10,226,070	1,363,476	8,862,594	6,031,733	3,561,678	1,167,091	276,956	36,472	85
						48,381,470	37,171,084	22,465,116	12,719,332	6,134,192	0

Table 5-8 Economical Analysis Results with Investment

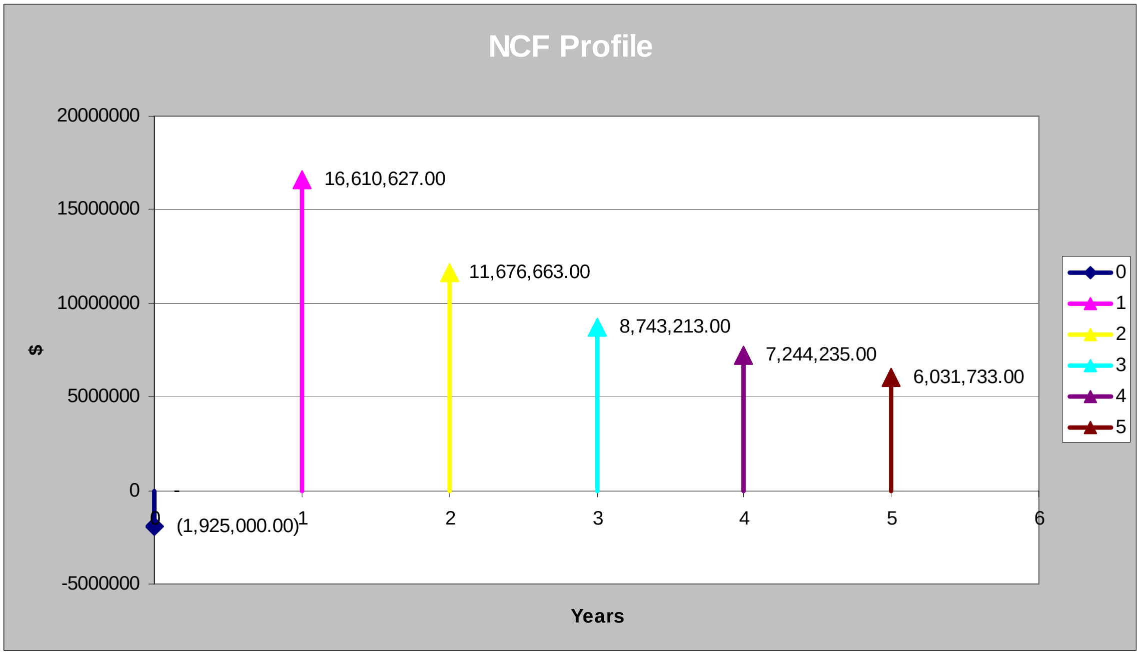


Fig. 5-30 Net Cash Flow Diagram

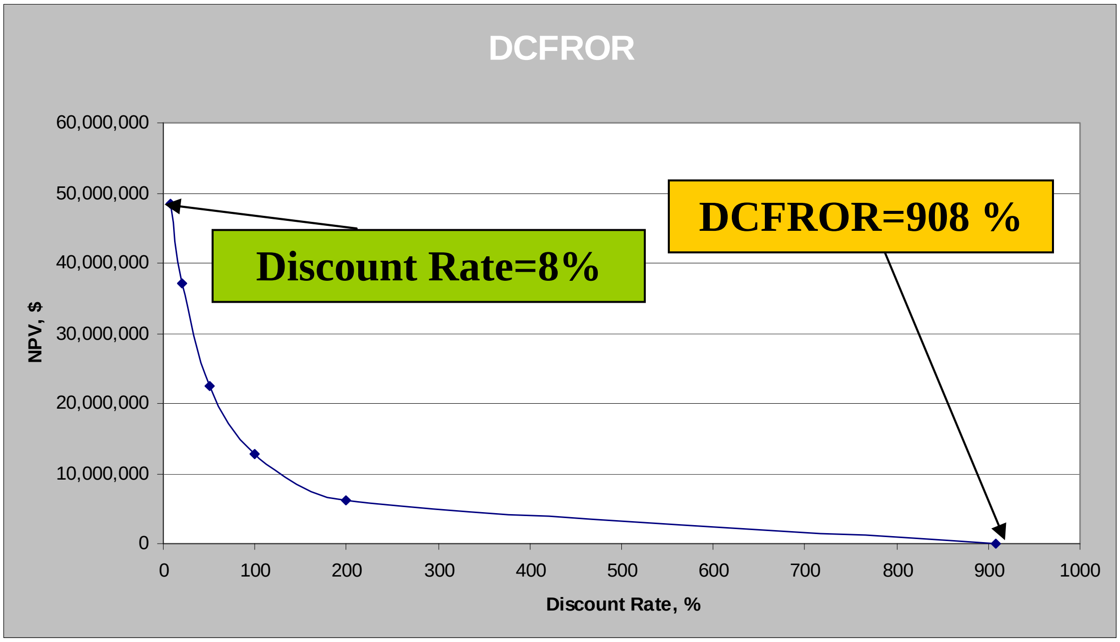
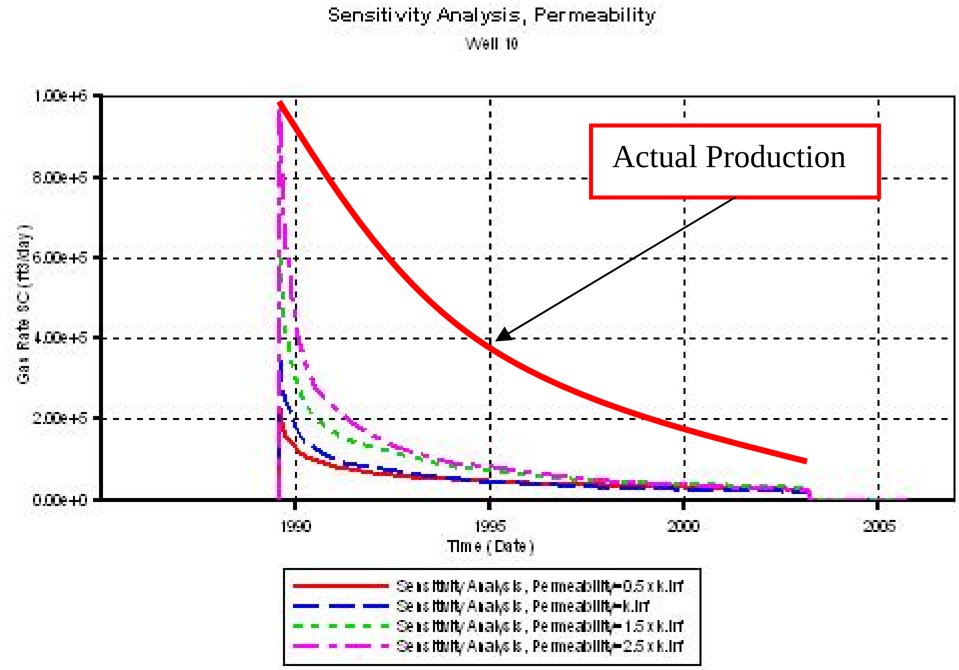


Fig. 5-31 NPV Profile

<u>*5.11. CMG Modeling Results*</u>

The model in CMG has been successfully built, also the sensitivity analysis. The results of this analysis are as follow; also the results were compared with the actual data.

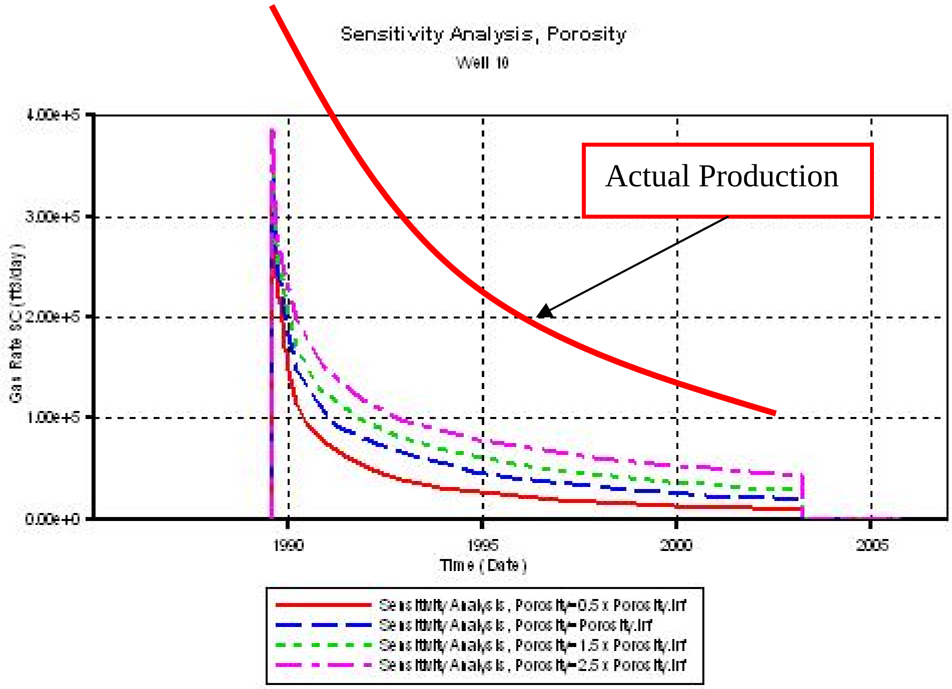
Permeability Changes: **As Permeability increases, Gas Rate Increases**



Source: C.Y.C. Field Consulting Services, Inc

As we went over all the wells the same trend was found, except for some well which show abnormal behaviors due to being close to the boundaries. The results for the other wells are shown in the Appendix B.

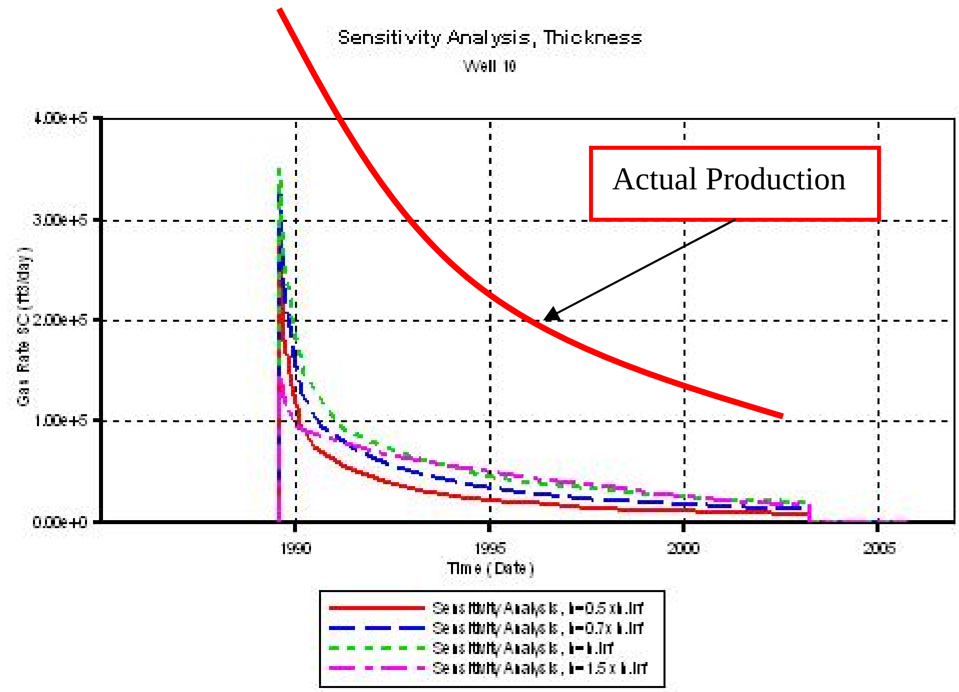
Porosity Changes: **As Porosity increases, Gas Rate Increases**



Source: C.Y.C. Field Consulting Services, Inc

As we went over all the wells the same trend was found, except for some well which show abnormal behaviors due to being close to the boundaries. The results for the other wells are shown in the Appendix B.

Thickness Changes: **At early time as Thickness increases, Gas Rate decrease, and as the life of the well goes on the behavior become inversely proportional**



Source: C.Y.C. Field Consulting Services, Inc

As we went over all the wells the same trend was found, except for some well which show abnormal behaviors due to being close to the boundaries. The results for the other wells are shown in the Appendix B.

6. Conclusions and Recommendations

1. The field has been studied and its recoverable reserve identified also in the performer wells bases.
2. Several locations for potential infill drills have been evaluated based on the results of Fuzzy Pattern Recognition (FPR), Decline Curves (DC) and Type Curve (TC).
3. Nine underperformer wells have been identified and evaluated as candidates for work over or stimulation. These wells are 1, 20, 12, 3, 7, 11, 10, 14 and16.
4. Five wells have been recommended for Stimulation, these are as follows: 1, 12, 3 and 11.
5. Wells 20, 7, 10, 14 and 16 are recommended for work over base on the fact they have high relative values of K and low relative values in the reserves.
6. The total investment is $1,925,000.00 to drill 3 wells and perform 5 Stimulations and 4 Work Over remedial operations on the existing wells.
7. Three new wells, Cesarito, Yasita and Camilito are recommended to be drilled based on the capacity of the location to deliver gas and the economics without interfering the estimated drainage area at the surroundings wells.
8. An integrated complete analysis has been completed. As a result the overall value of the asset is $ 48,381,470
9. Preliminary field model has been used as CMG software and a sensitivity analysis.
10. Total Production gas before the investment within the next 5 years is estimated as 4,964,613 Mcf and after is 11,786,801 Mcf.

11. A Base Field Model has been built using CMG and a preliminary Sensitivity Analysis performed. The results from this study can be used for future evaluations of the reservoir including the History Matching of the whole field rather than on the per well basis. The real data was compared with the simulation outcome and they did not match. At this point no further analysis has been done.

7. References

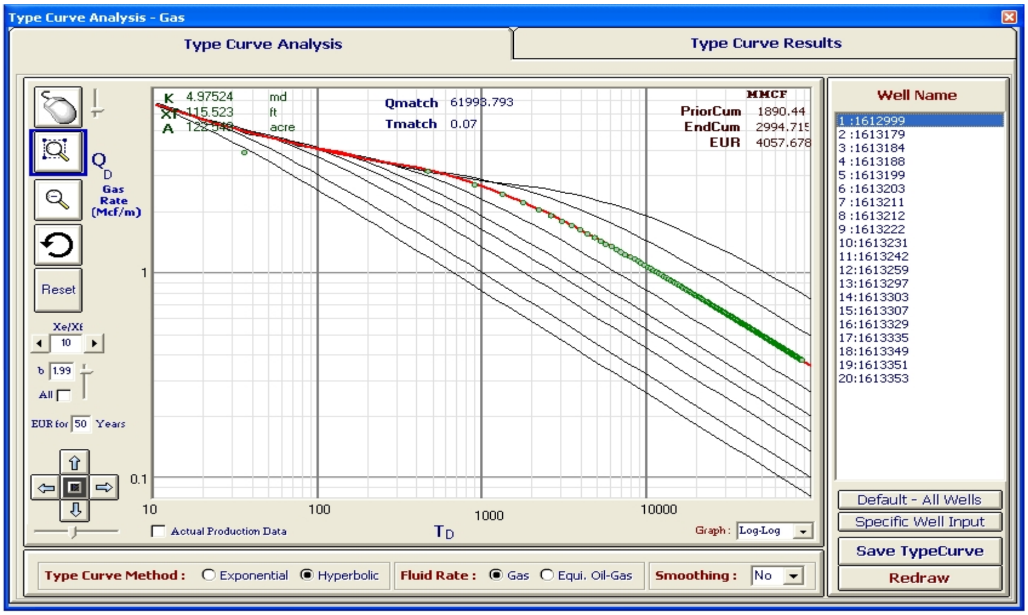
1. Intelligent Solutions Production Data Analysis. (IPDA) Software Manual
2. Jalali, Mohaghegh and Gaskari. *Identifying Infill Locations and Underperformer Wells in Mature Fields using Monthly Production Rate Data.* SPE paper 104554. 2006
3. Gaskari, Mohaghegh, Jalali. *An Integrated Technique for Production Data Analysis with Application to Mature Fields.* SPE paper 100562. 2006.
4. Mohaghegh, Gaskari, Jalali. *New Methods for Production Data Analysis to Identify New Opportunities in Mature Fields: Methodology and Application.* SPE paper 98010. 2005.
5. Schlumberger Oilfield Glossary.
   Available at:: http://www.glossary.oilfield.slb.com/default.cfm
6. Thompson R.S. Wright J.D. *Oil Property Evaluation*. 1984

Appendix A

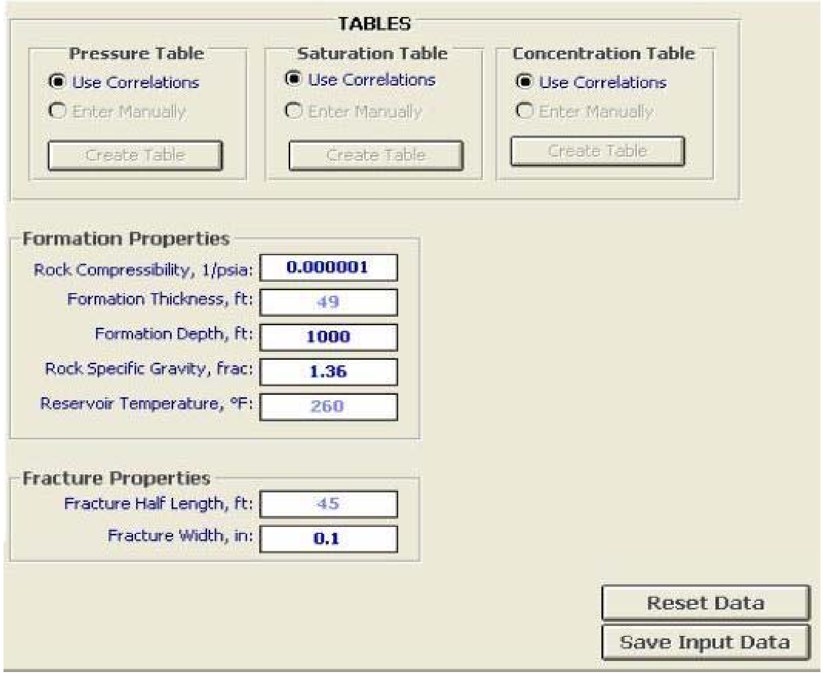
WELL 1

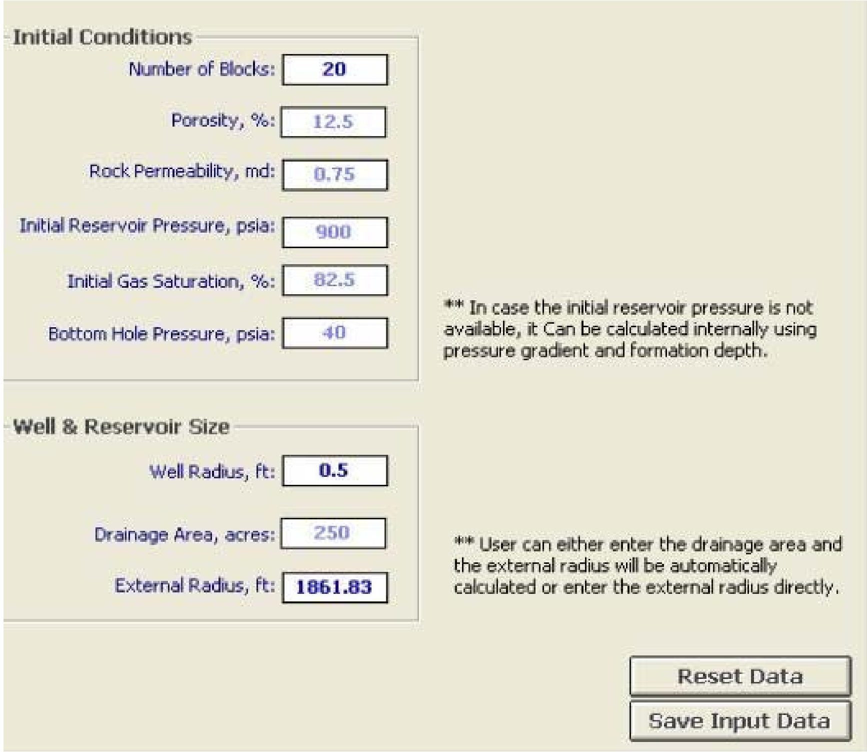
Decline Curve Analysis

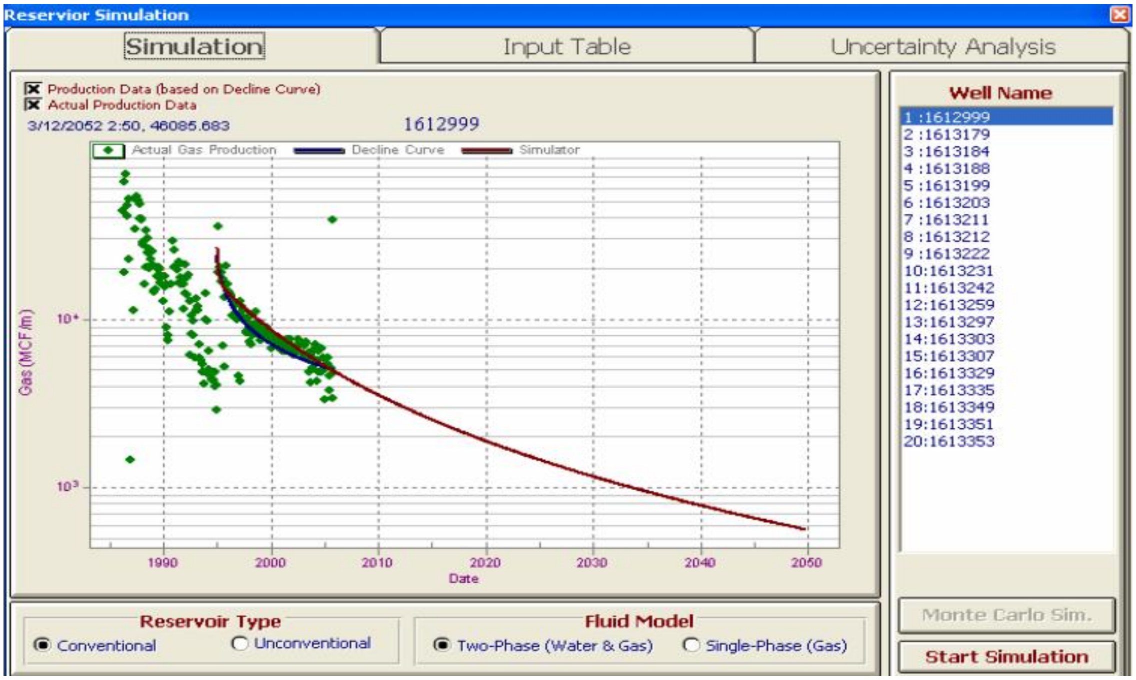
Type Curve Matching



Numerical Simulation Results:

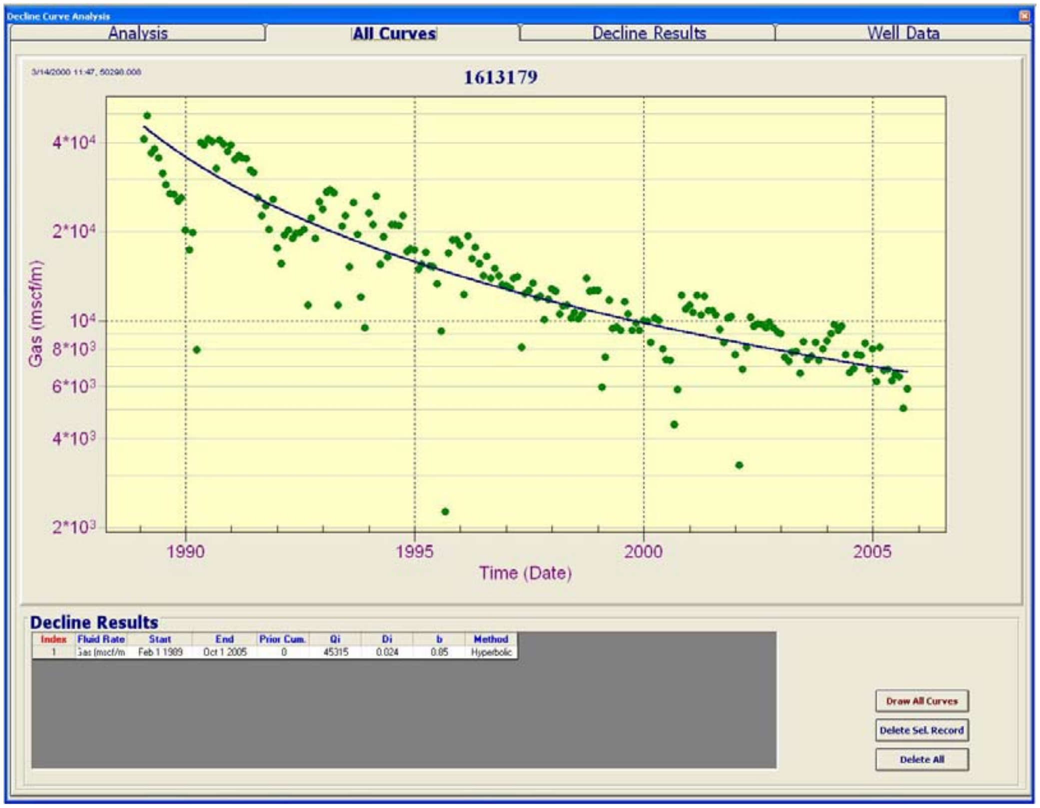




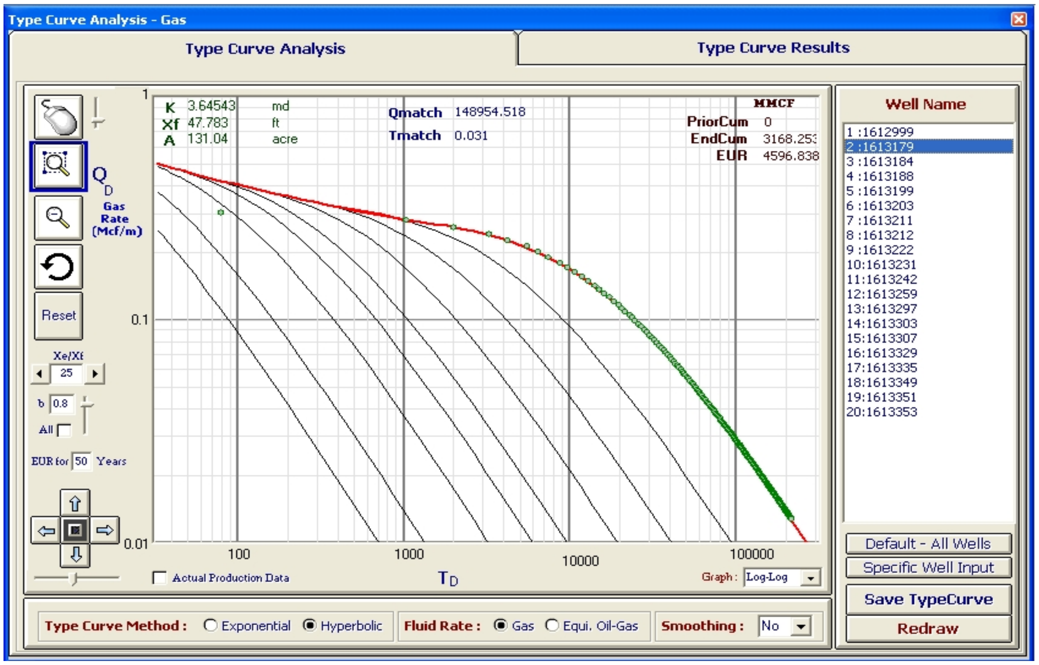

Reservior Simulation
Simulation
Input Table
Uncertainty Analysis
Production Data (based on Decline Curve)
Actual Production Data
3/12/2052 2:50, 46085.683
1612999
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 2

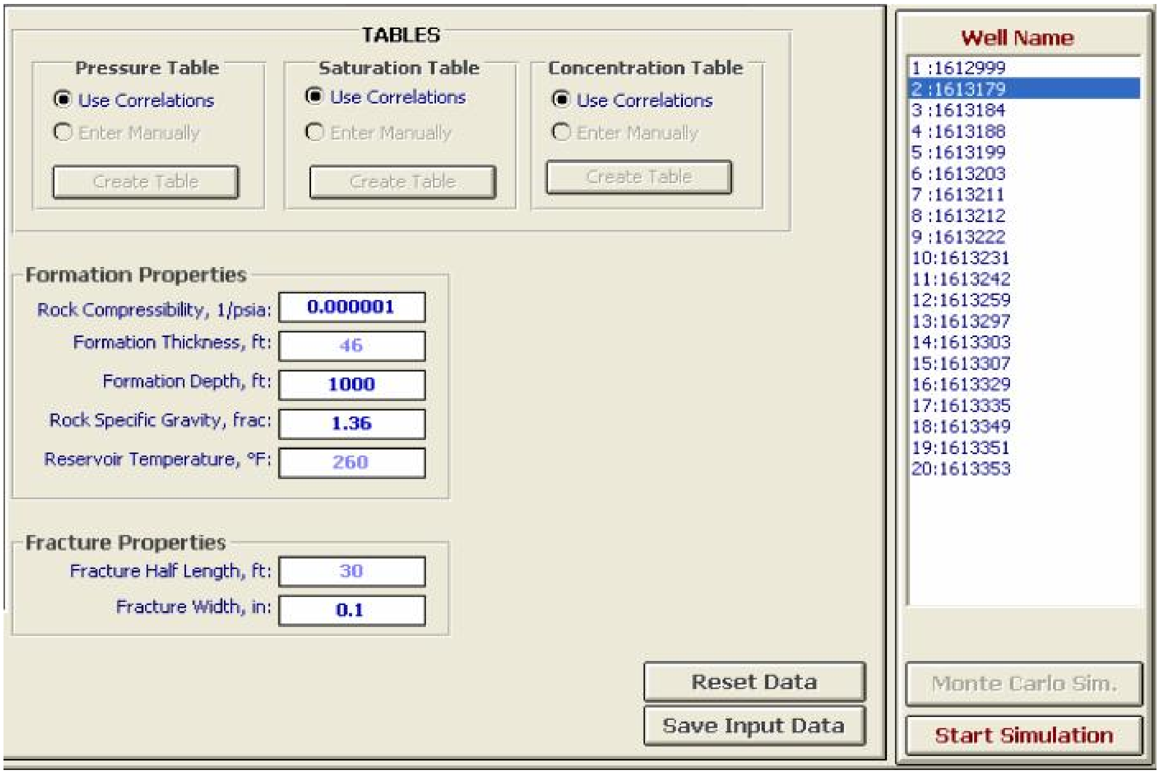
Decline Curve Analysis:

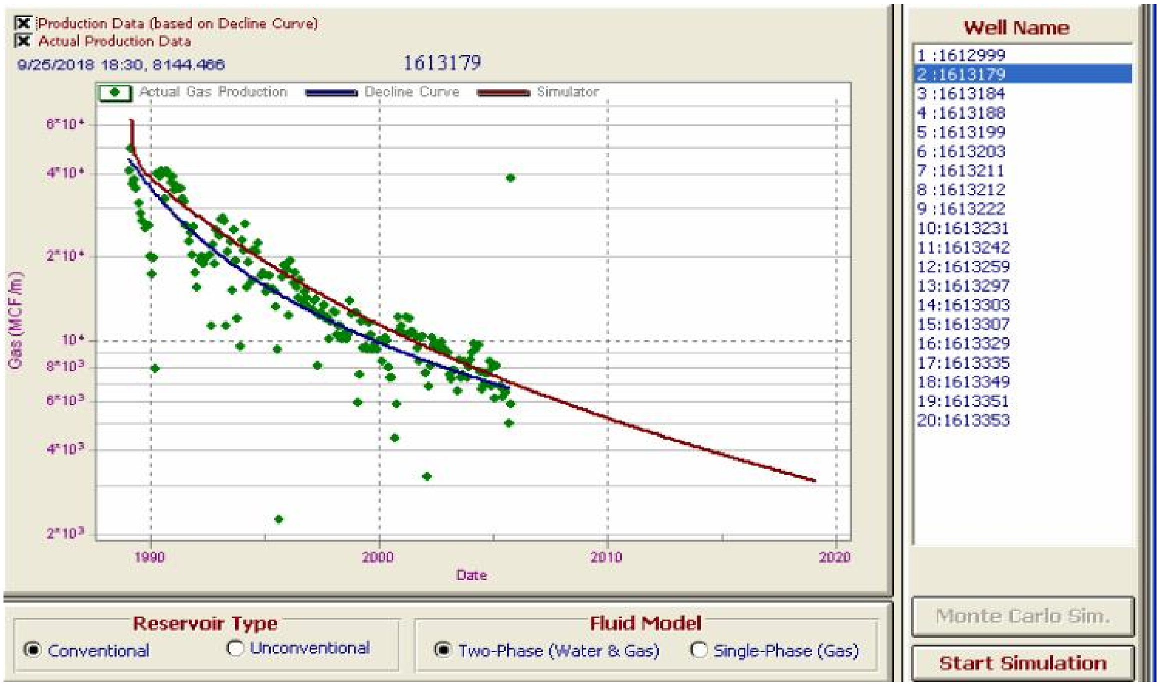


Type Curve Analysis



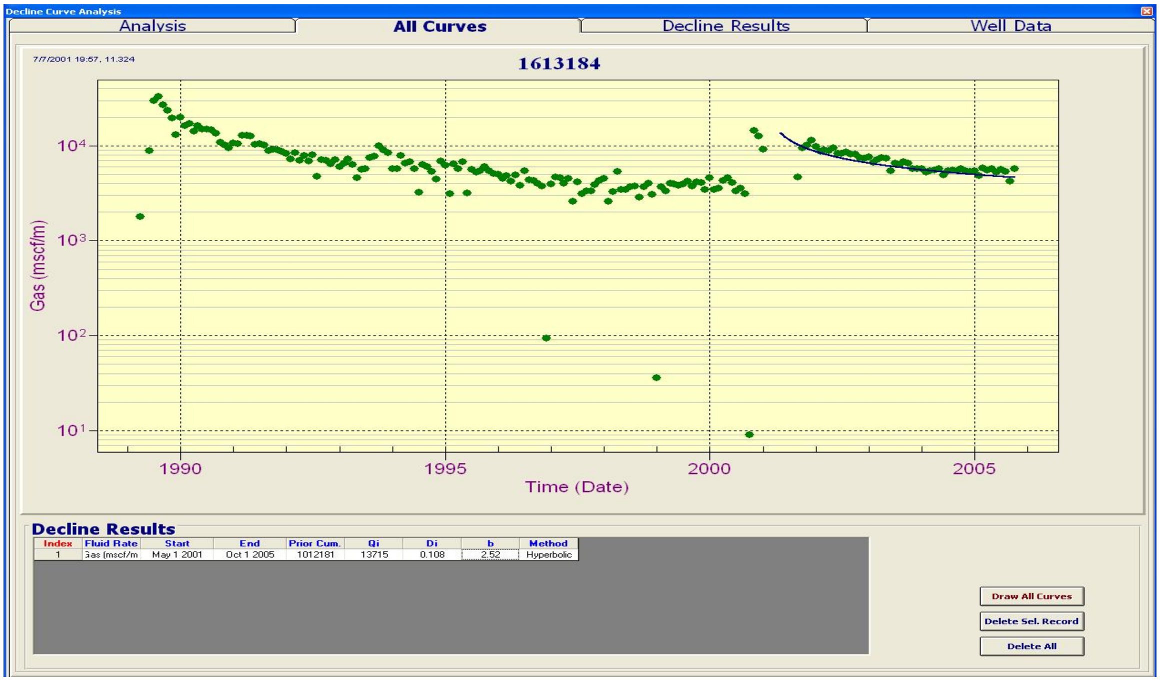
Numerical Simulation Results



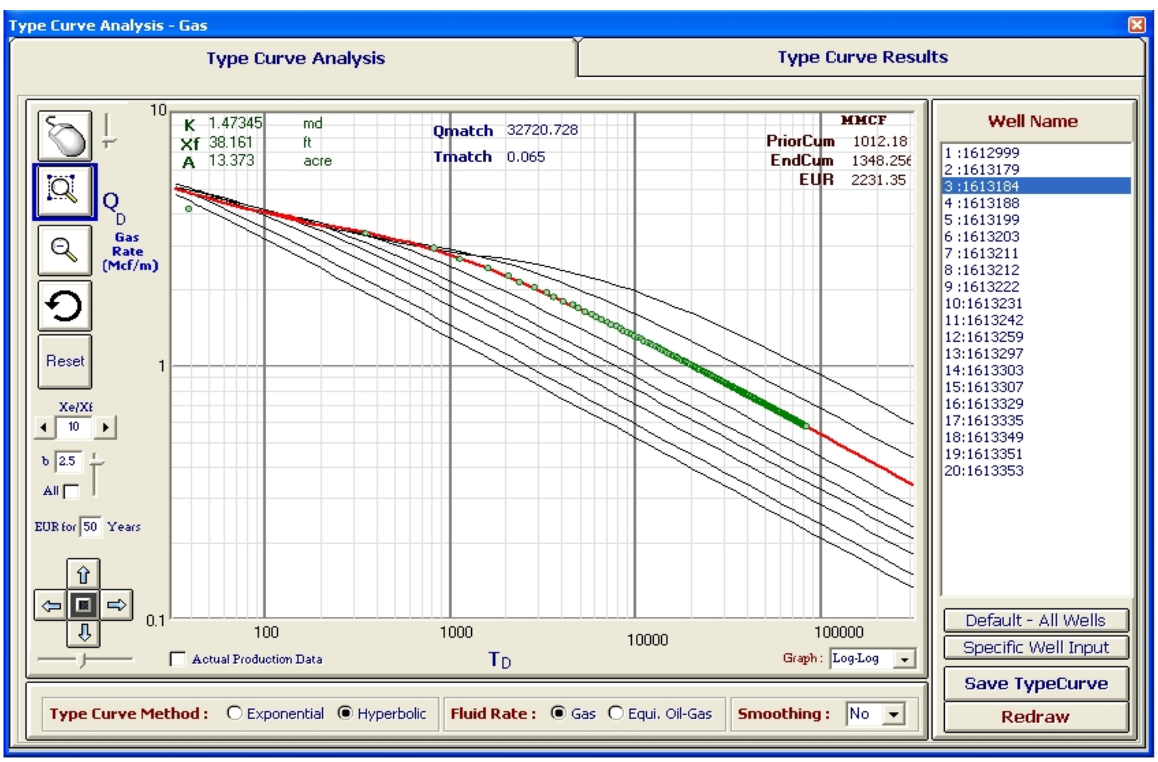

Production Data (based on Decline Curve)
Actual Production Data
9/26/2018 18:30, 8144.466
1613179
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 3

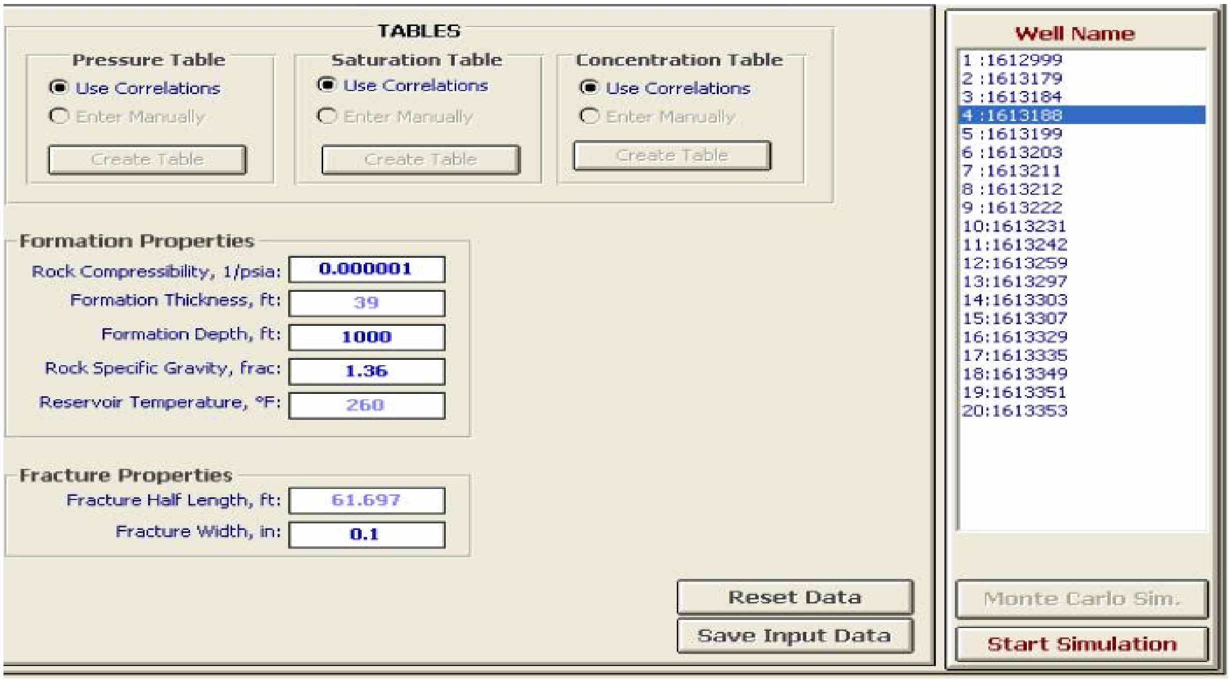
Decline Curve Analysis

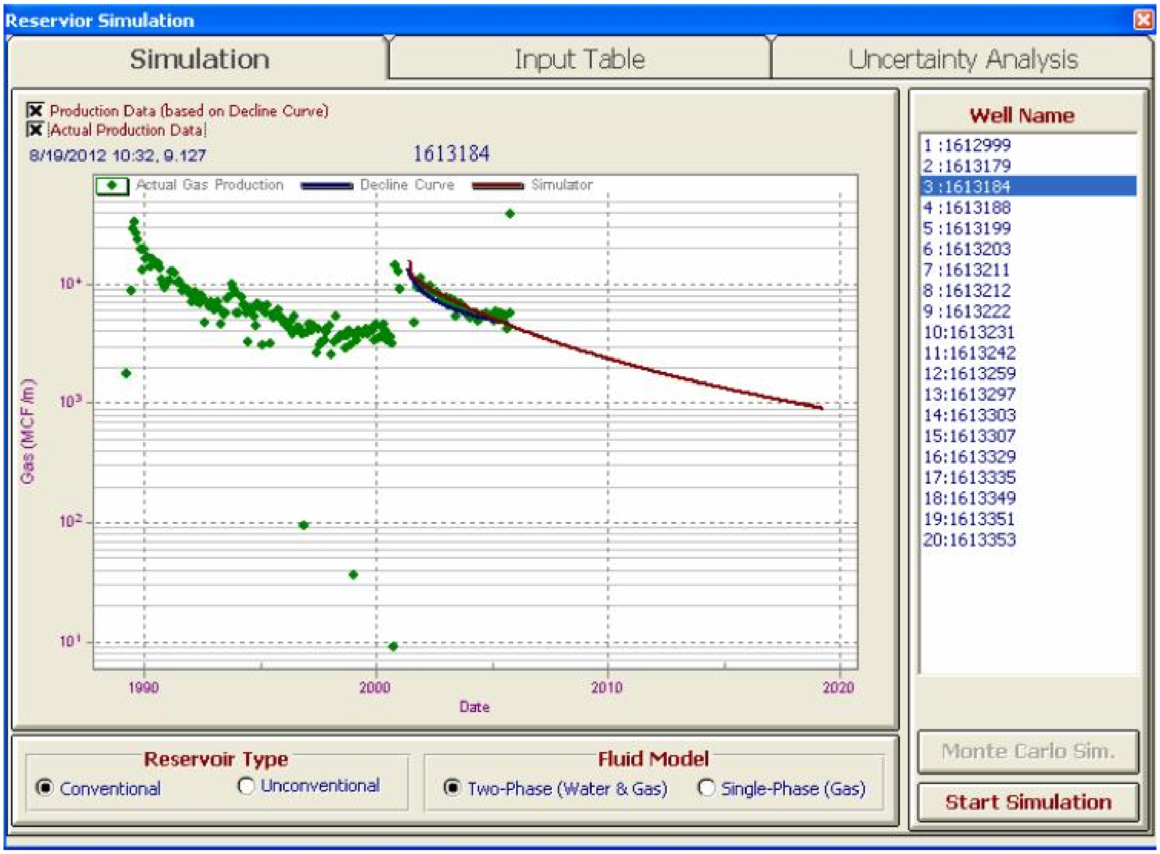


Type Curve Matching:



Numerical Simulation Results

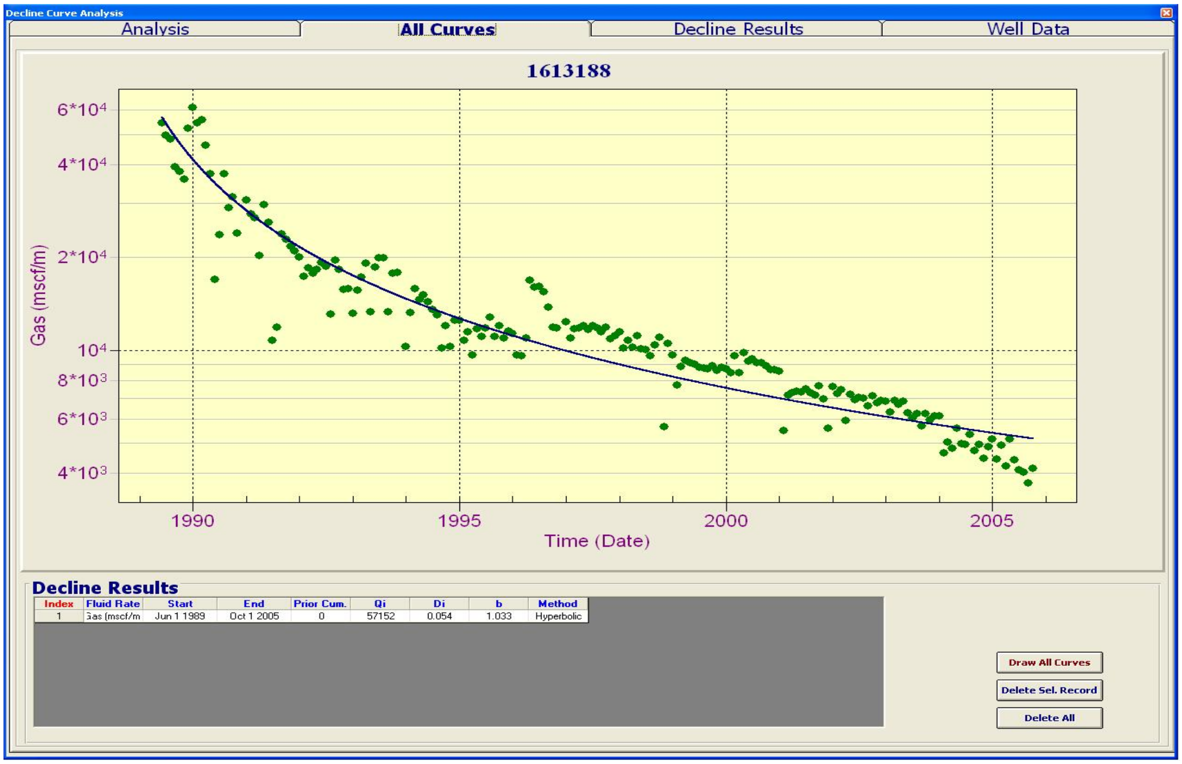




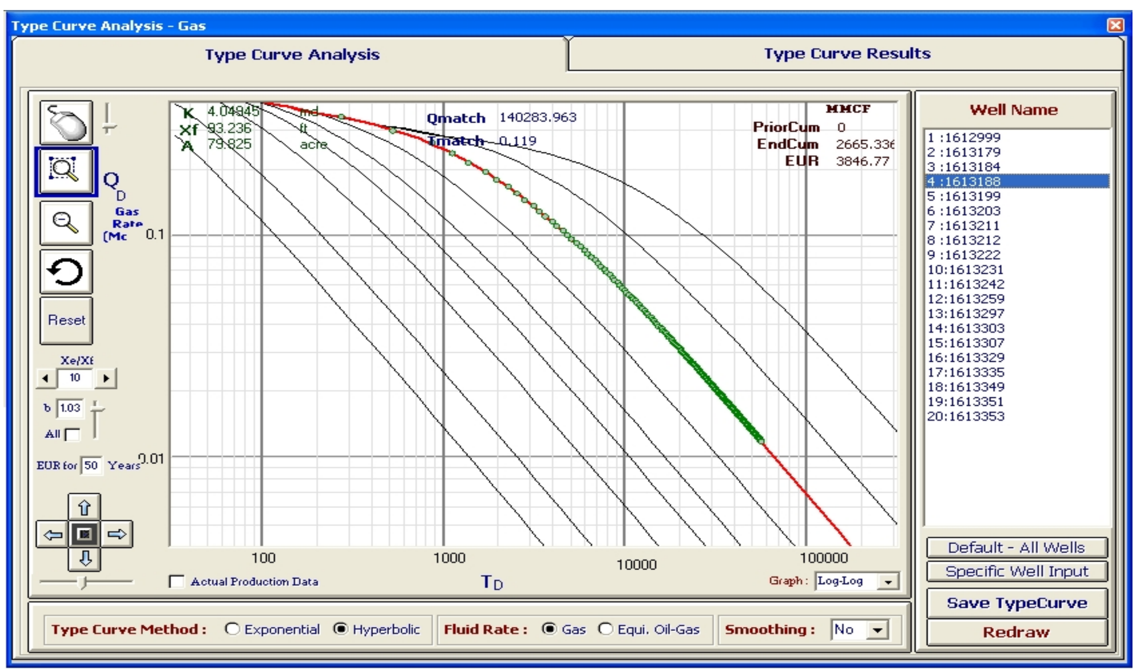
Reservior Simulation
Simulation
Input Table
Uncertainty Analysis
Production Data (based on Decline Curve)
Actual Production Data
8/19/2012 10:32, 9.127
1613184
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Monte Carlo Sim.
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Start Simulation

WELL 4

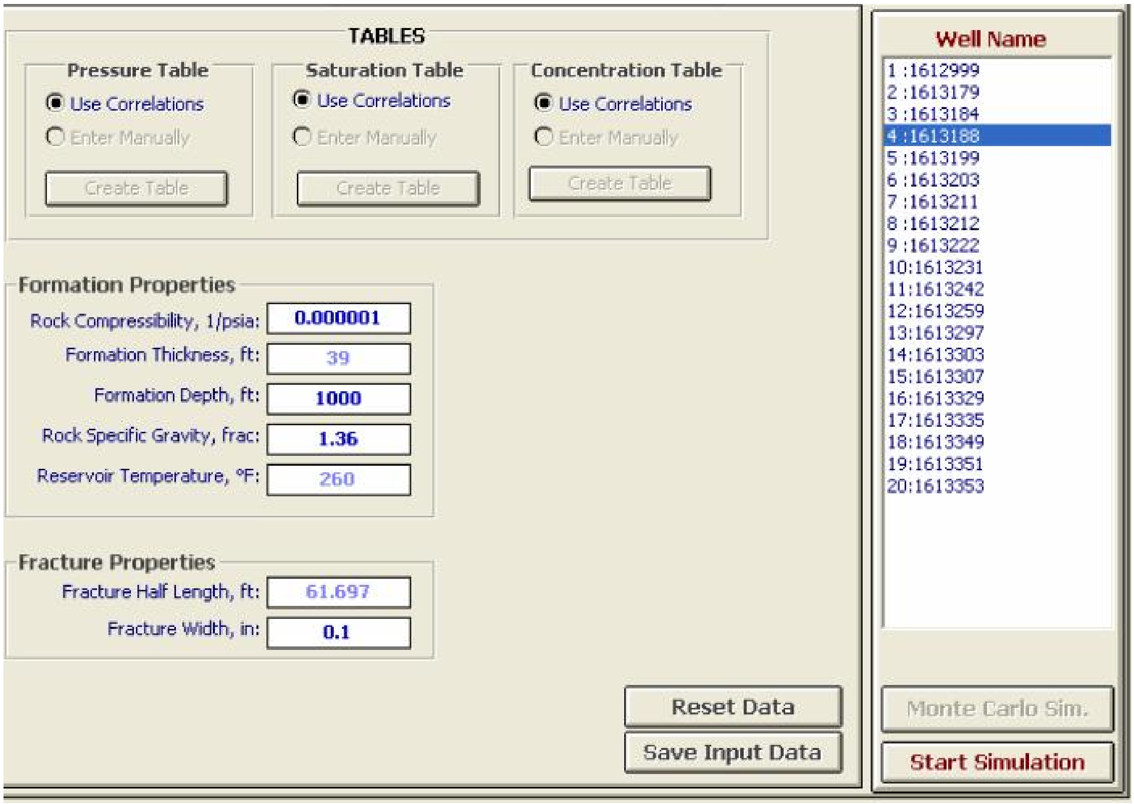
Decline Curve Analysis

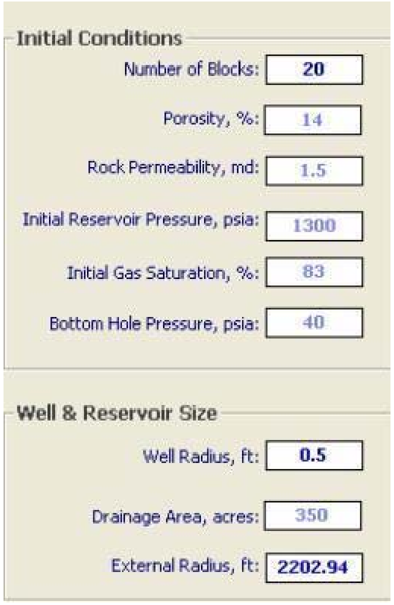


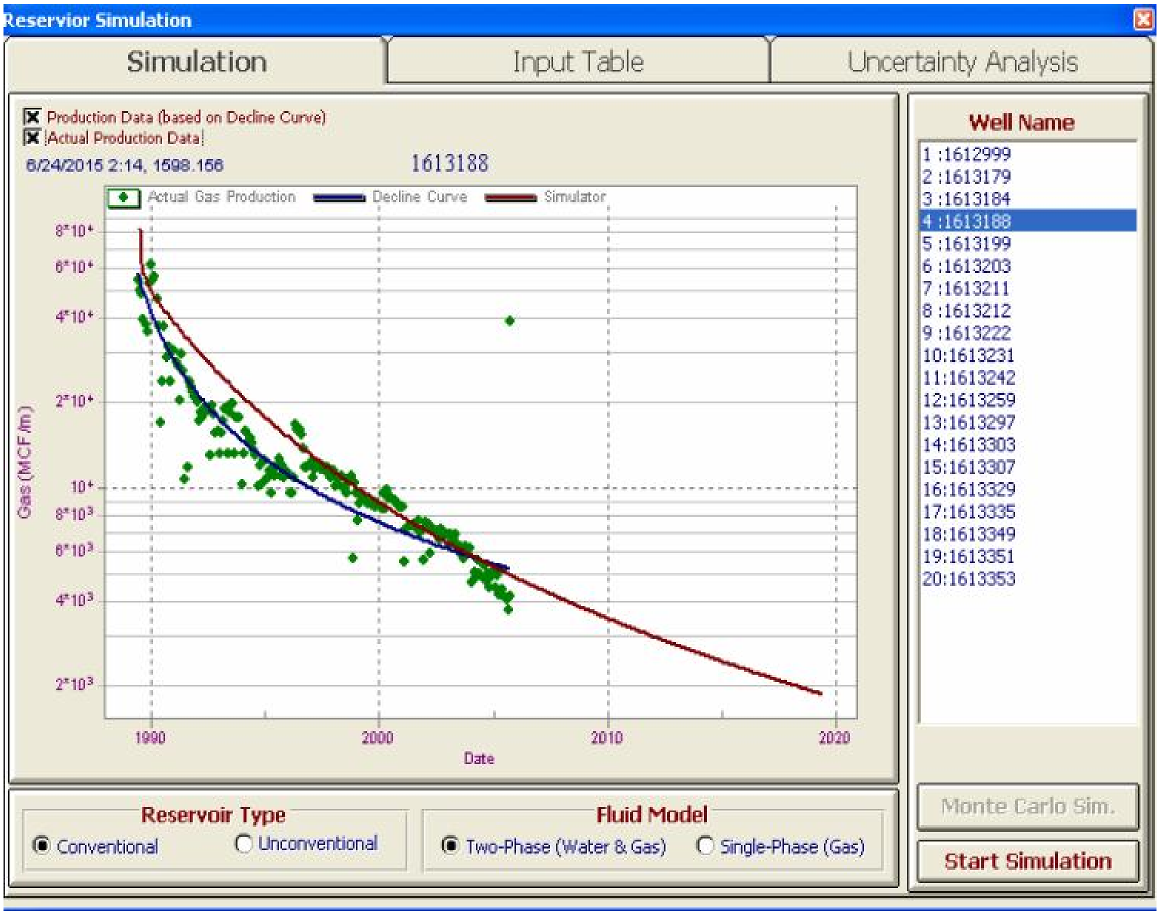
Type Curve Matching



Numerical Simulation Results

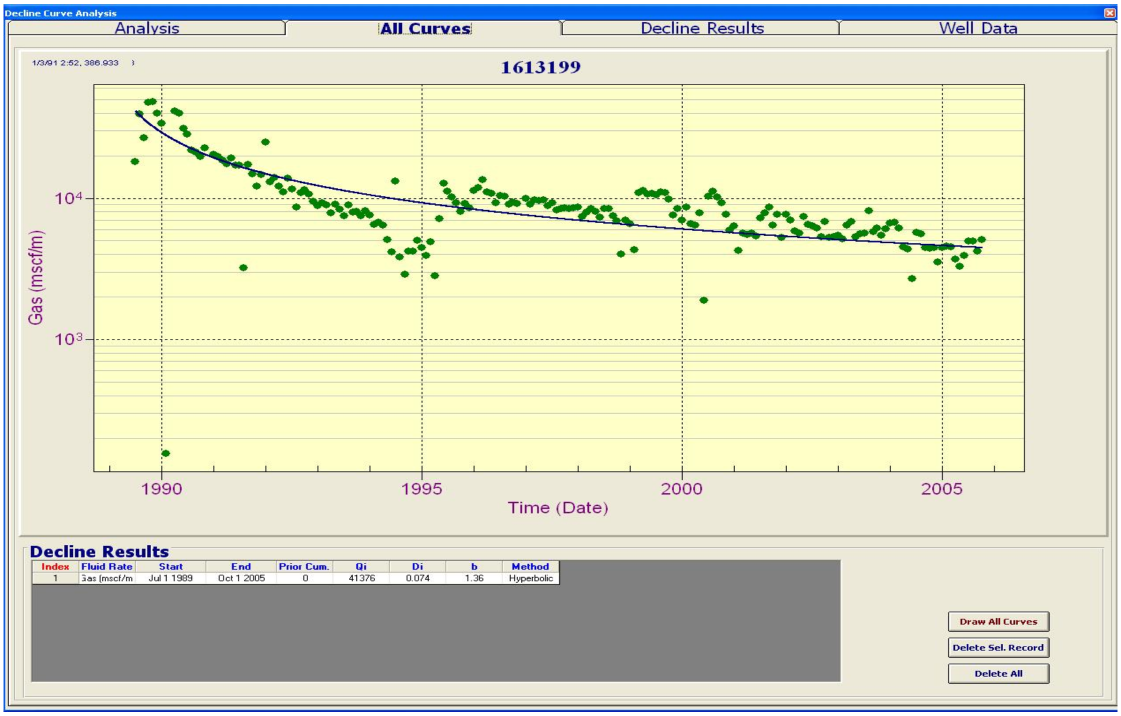




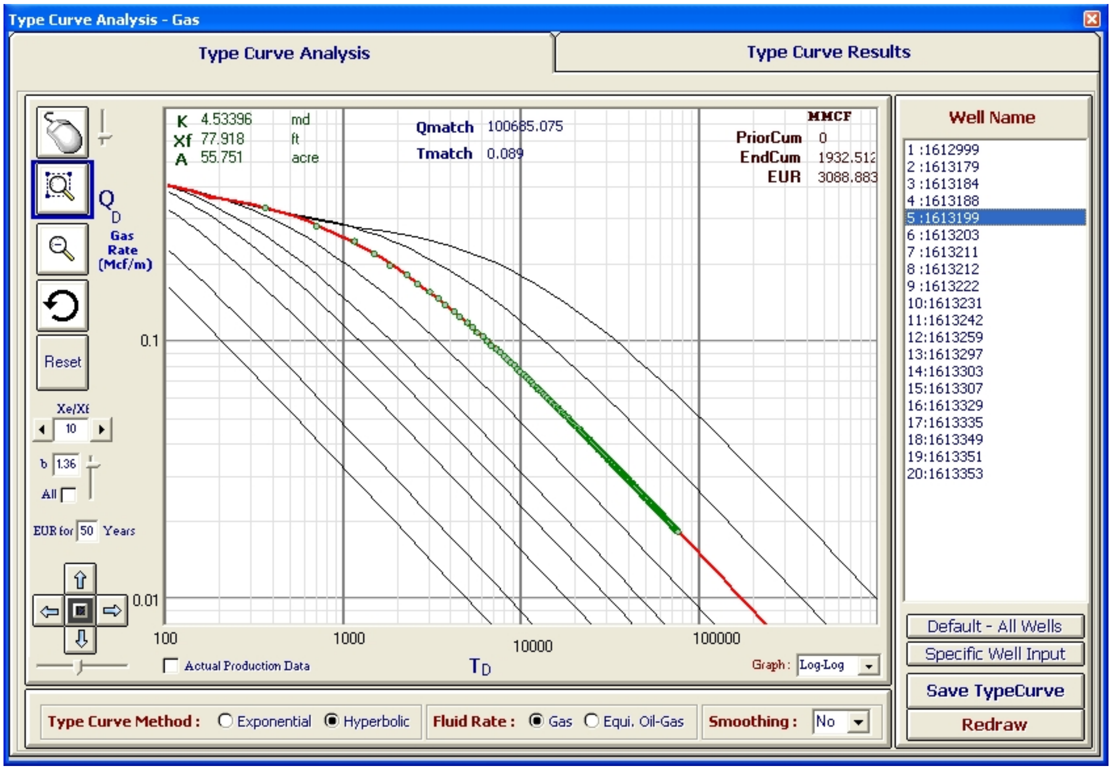

Reservior Simulation
Simulation
Input Table
Uncertainty Analysis
Production Data (based on Decline Curve)
Actual Production Data
6/24/2015 2:14, 1598.156
1613188
Actual Gas Production
Decline Curve
Simulator
8*10⁴
6*10⁴
4*10⁴
2*10⁴
10⁴
8*10³
6*10³
4*10³
2*10³
Gas (MCF/m)
1990
2000
2010
2020
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 5

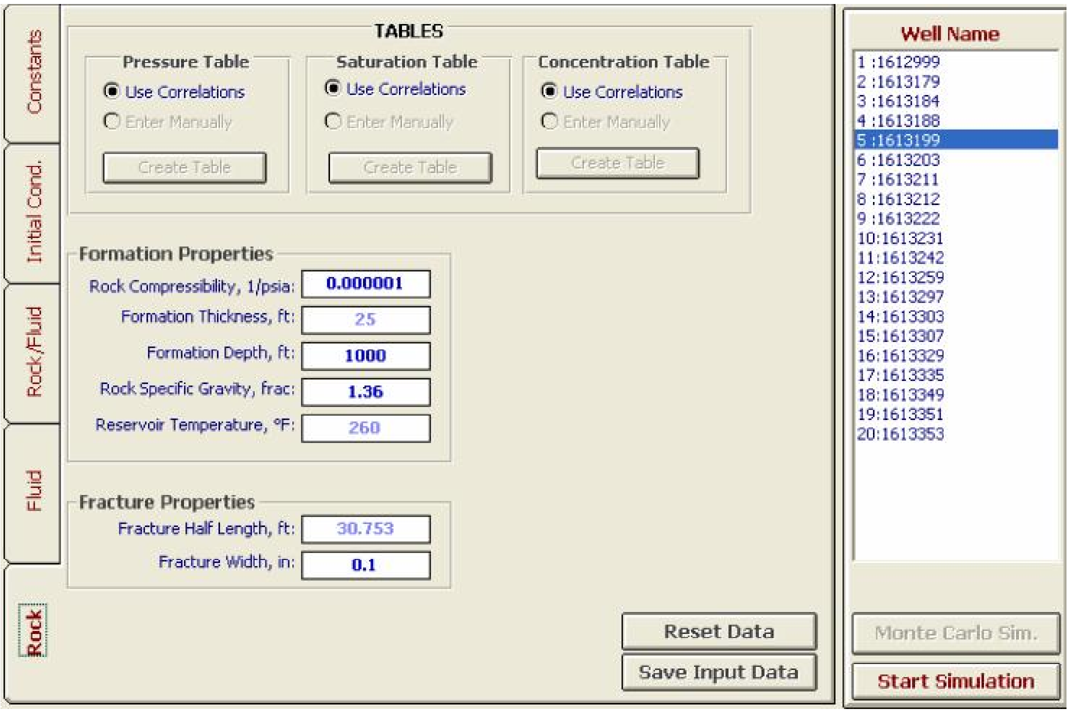
Decline Curve Analysis

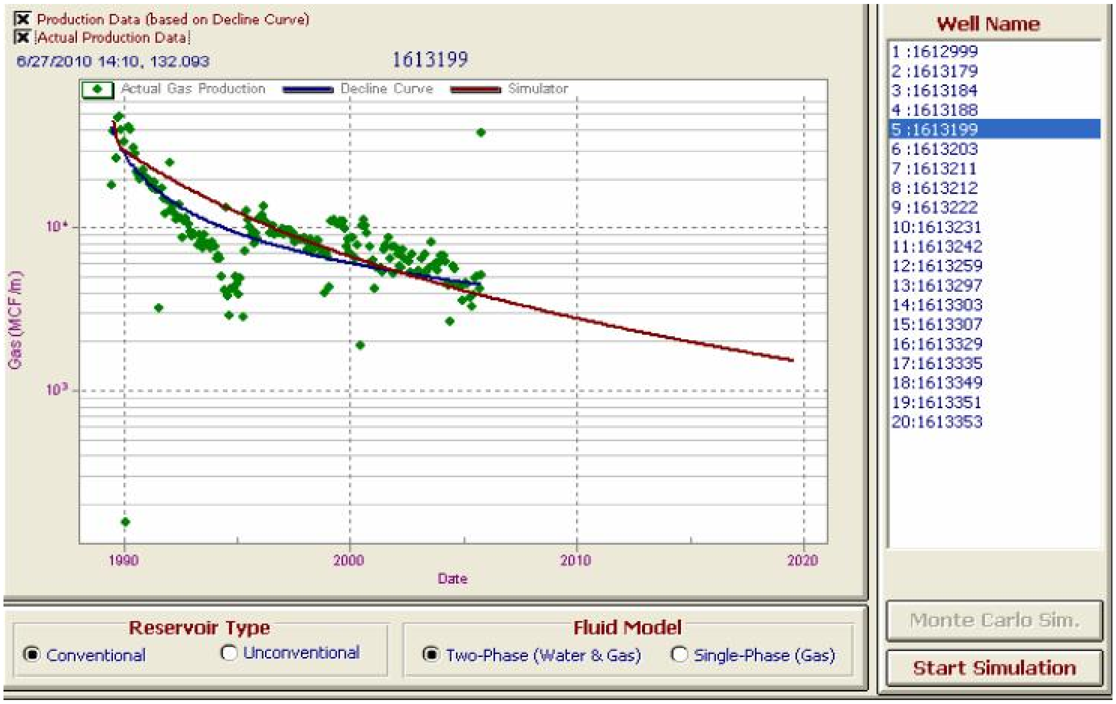


Type Curves Matching



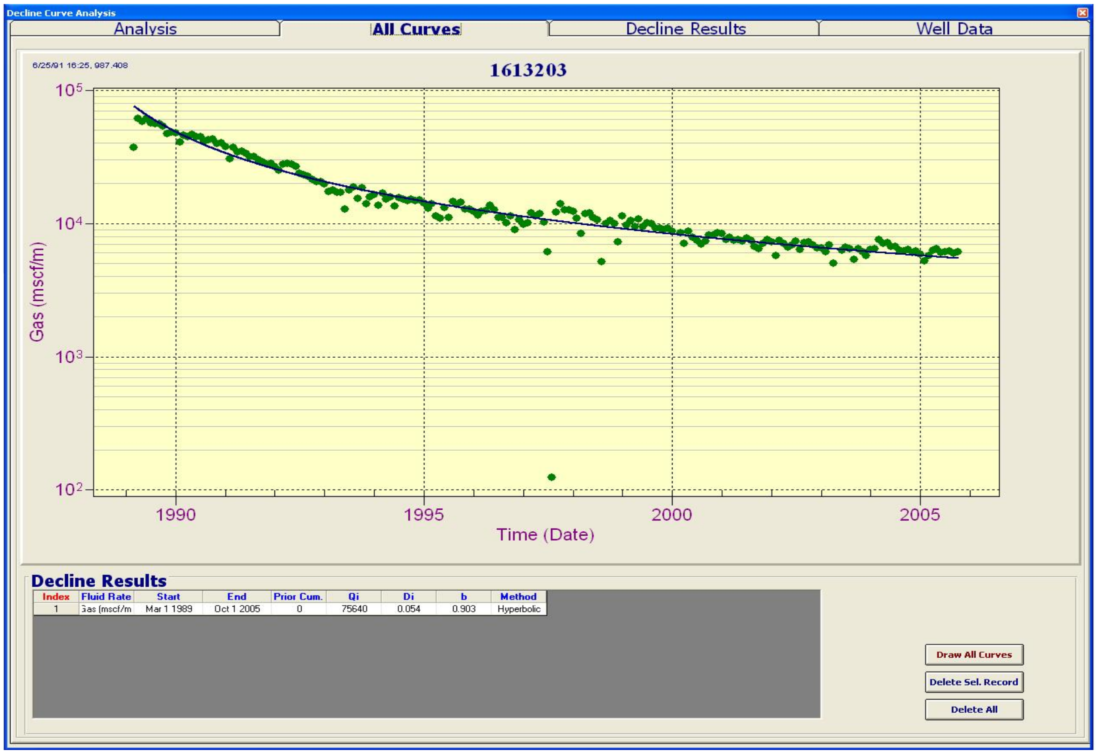
Numerical Simulation Results



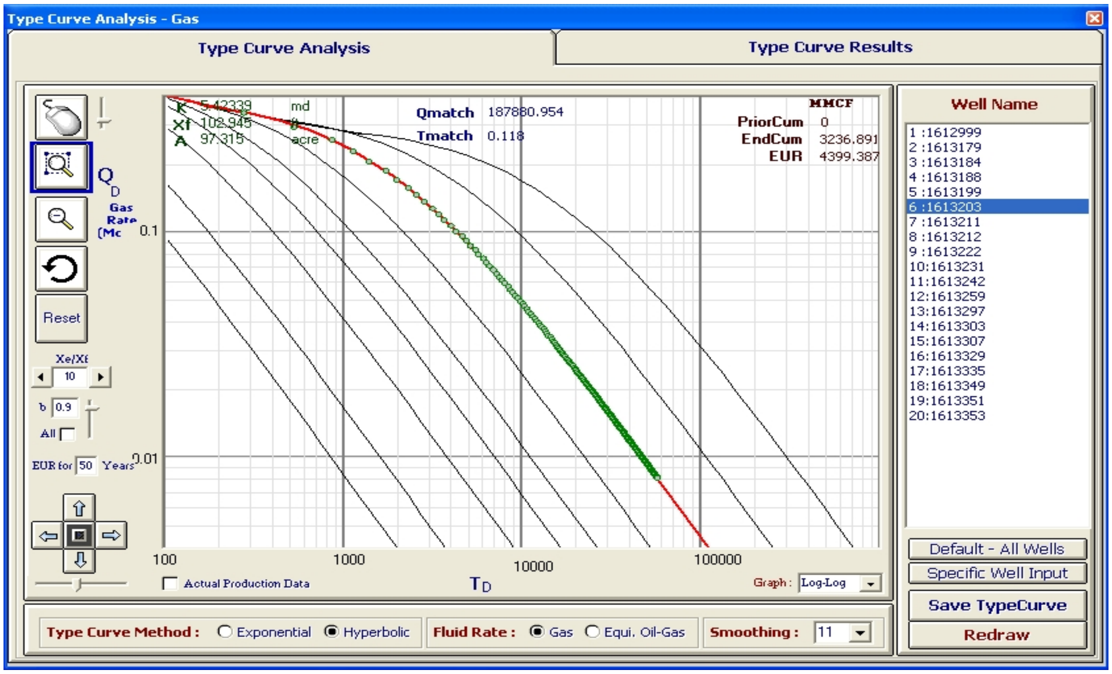

Production Data (based on Decline Curve)
Actual Production Data
6/27/2010 14:10, 132.093
1613199
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 6

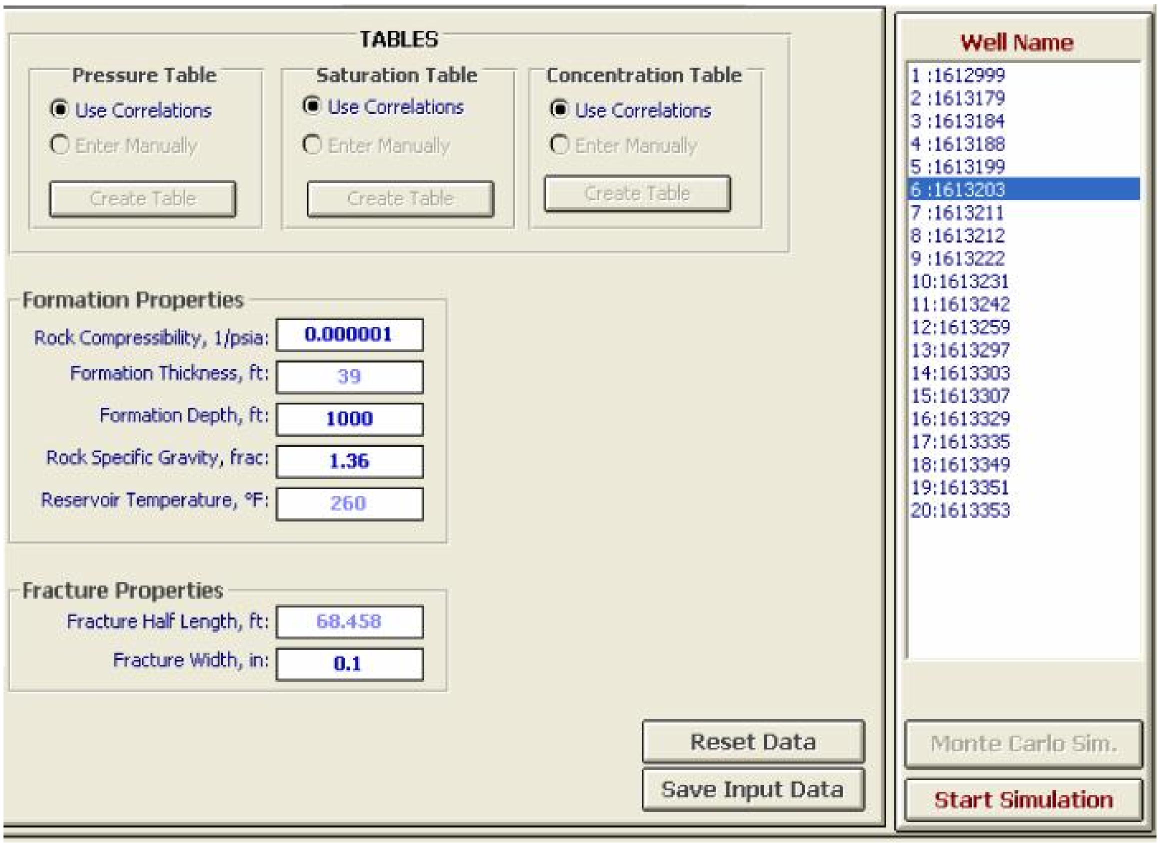
Decline Curve Analysis

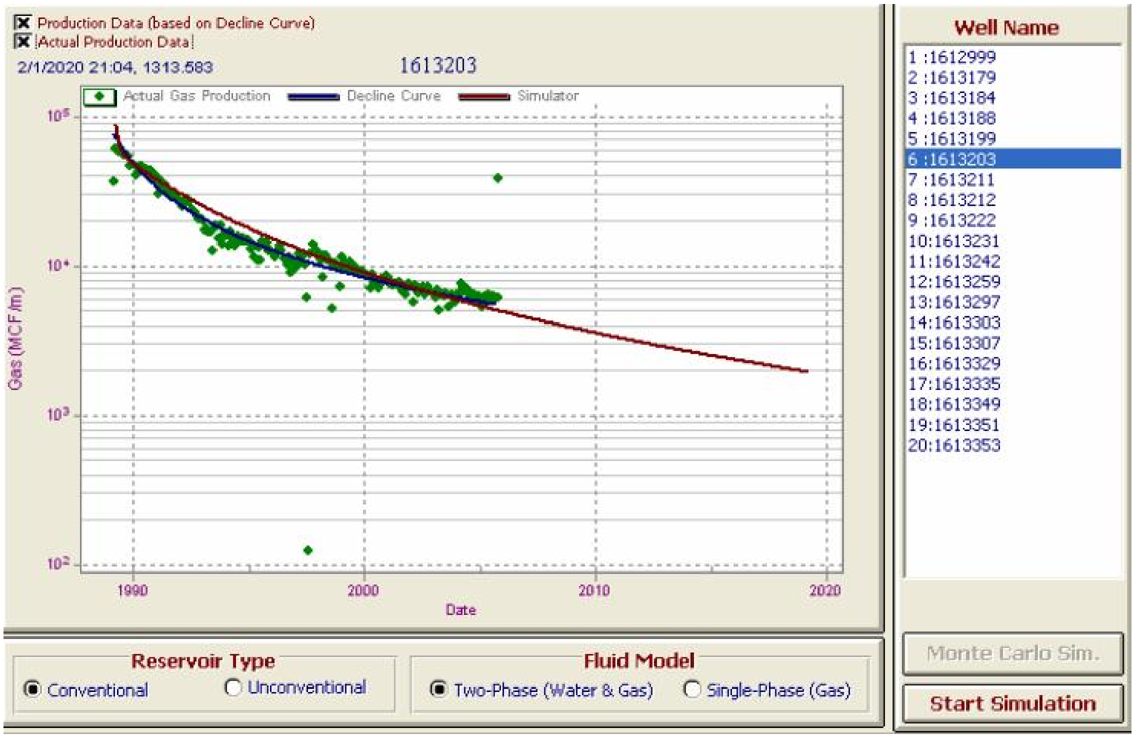


Type Curve Matching



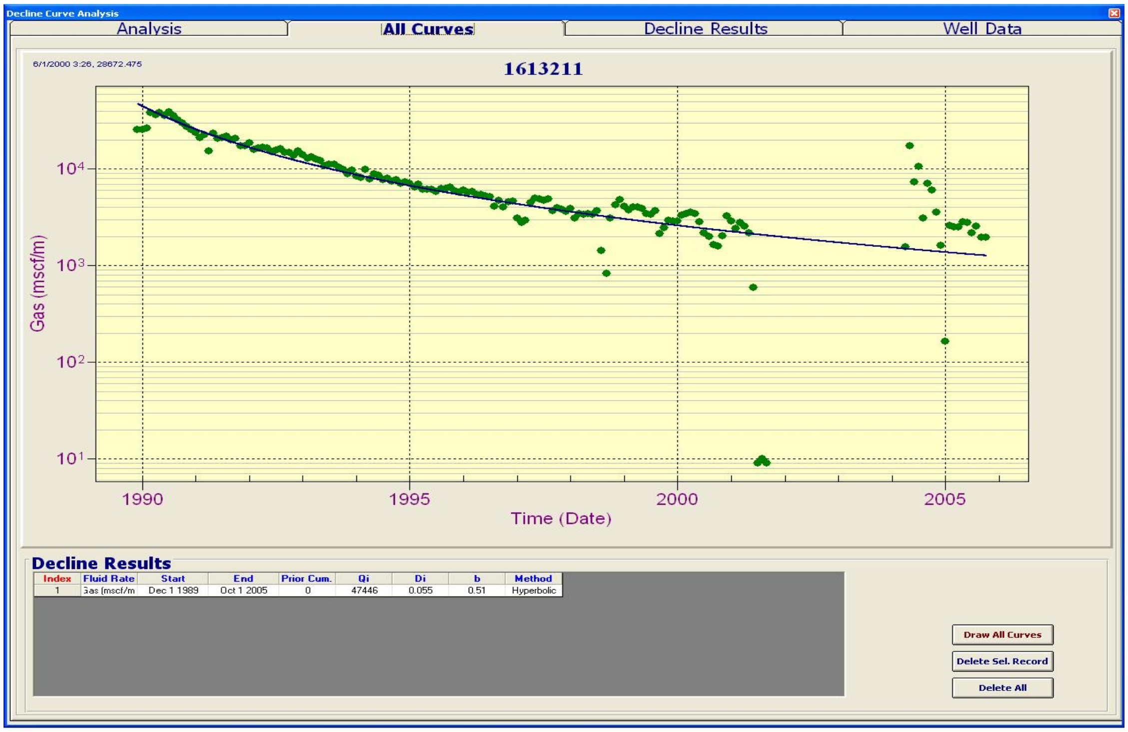
Numerical Simulation Results



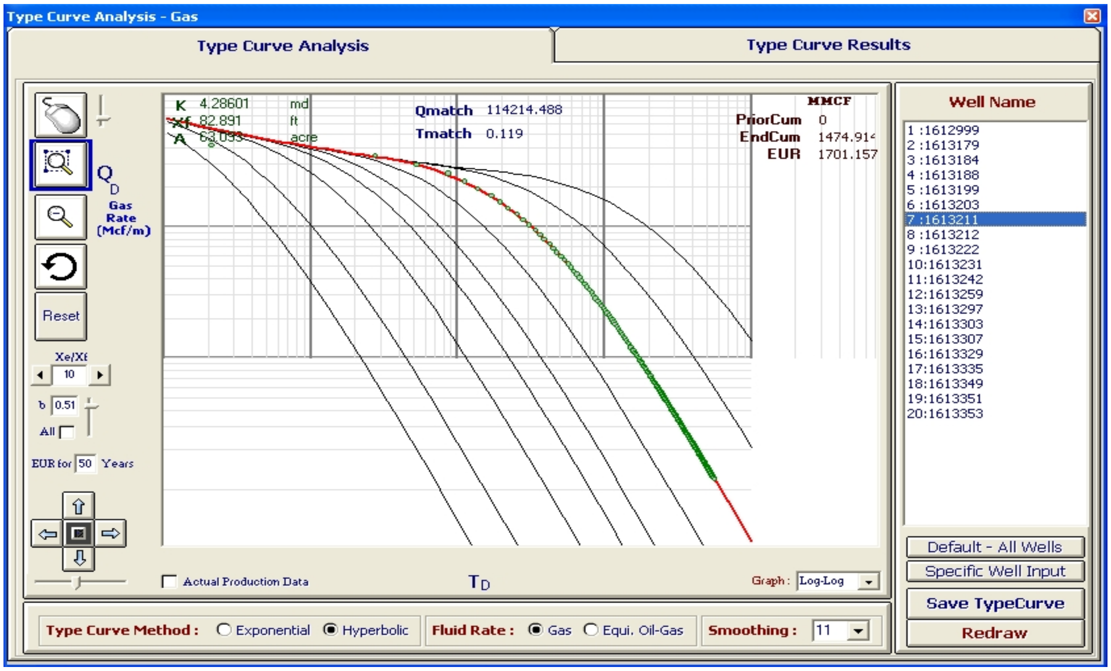

Production Data (based on Decline Curve)
Actual Production Data
2/1/2020 21:04, 1313.583
1613203
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 7

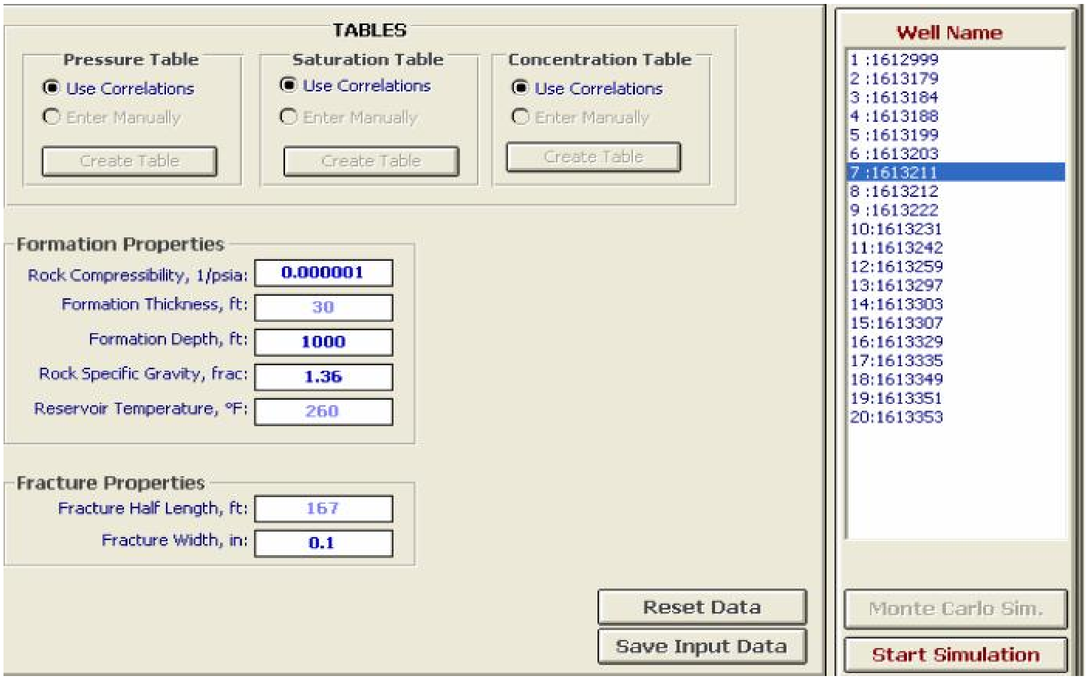
Decline Curve Analysis

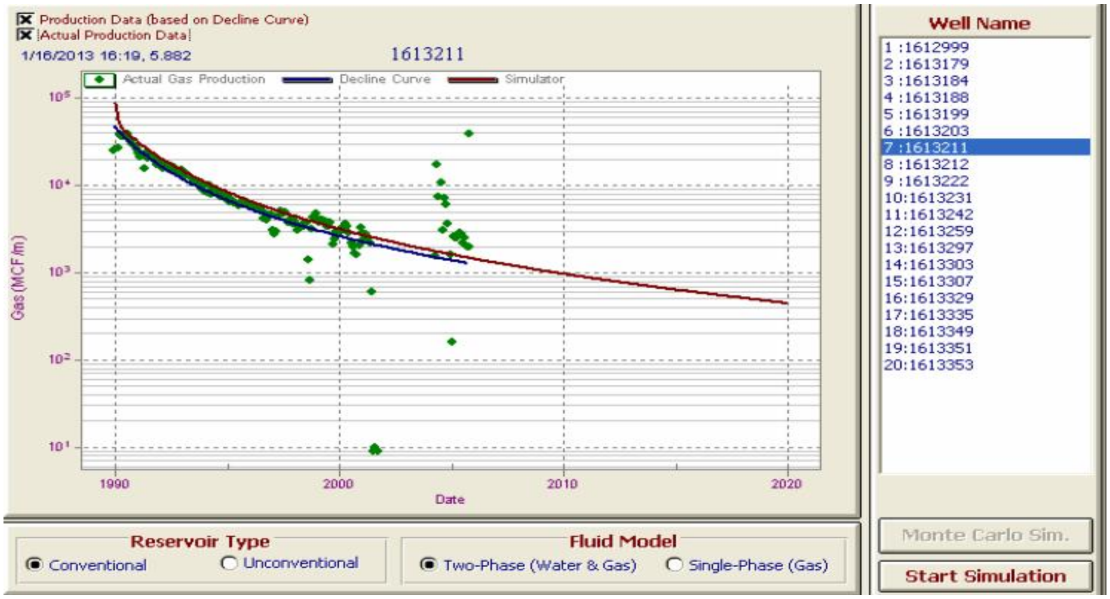


Type Curve Matching



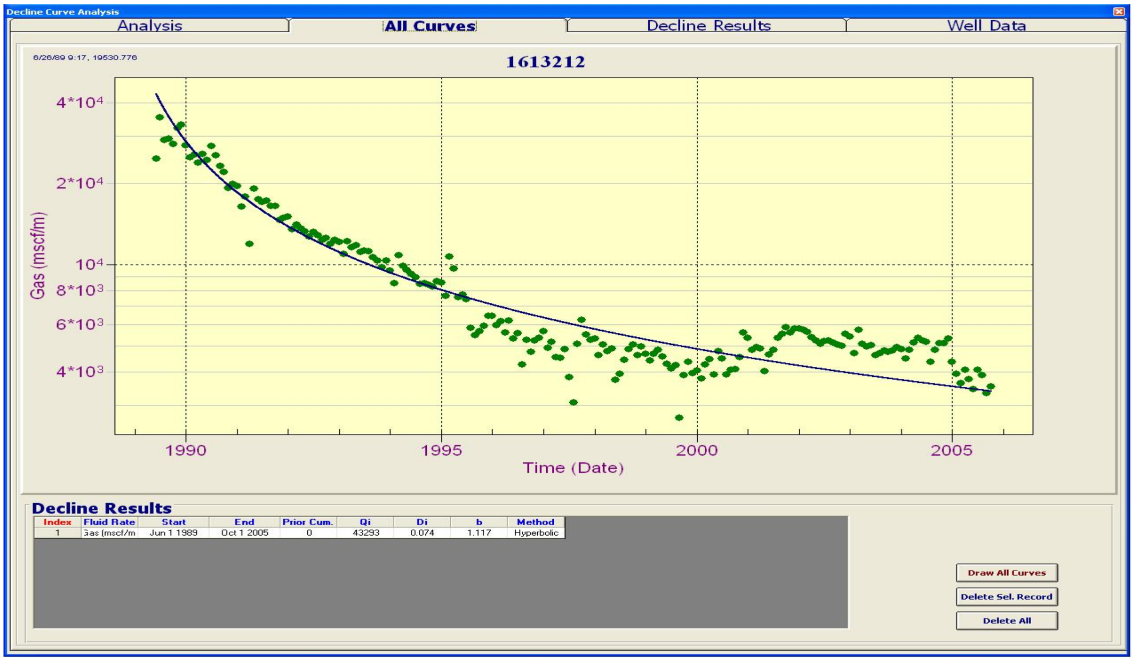
Numerical Simulation Results



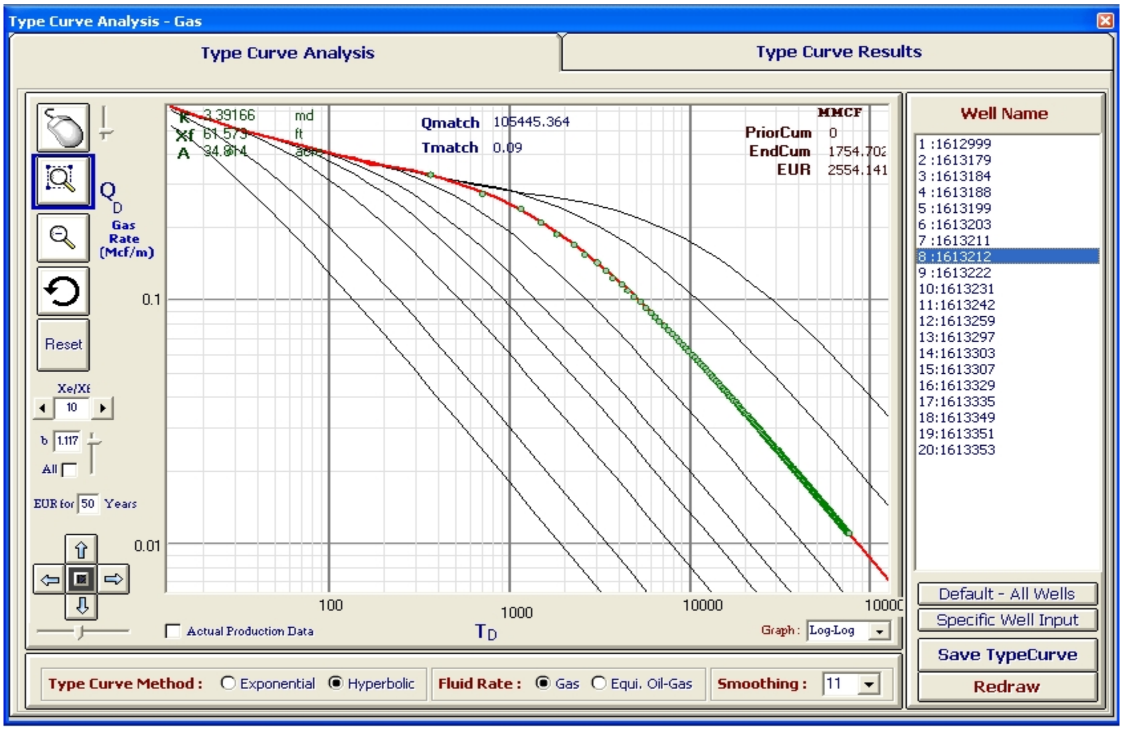

Production Data (based on Decline Curve)
Actual Production Data
1/16/2013 16:19, 5.882
1613211
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 8

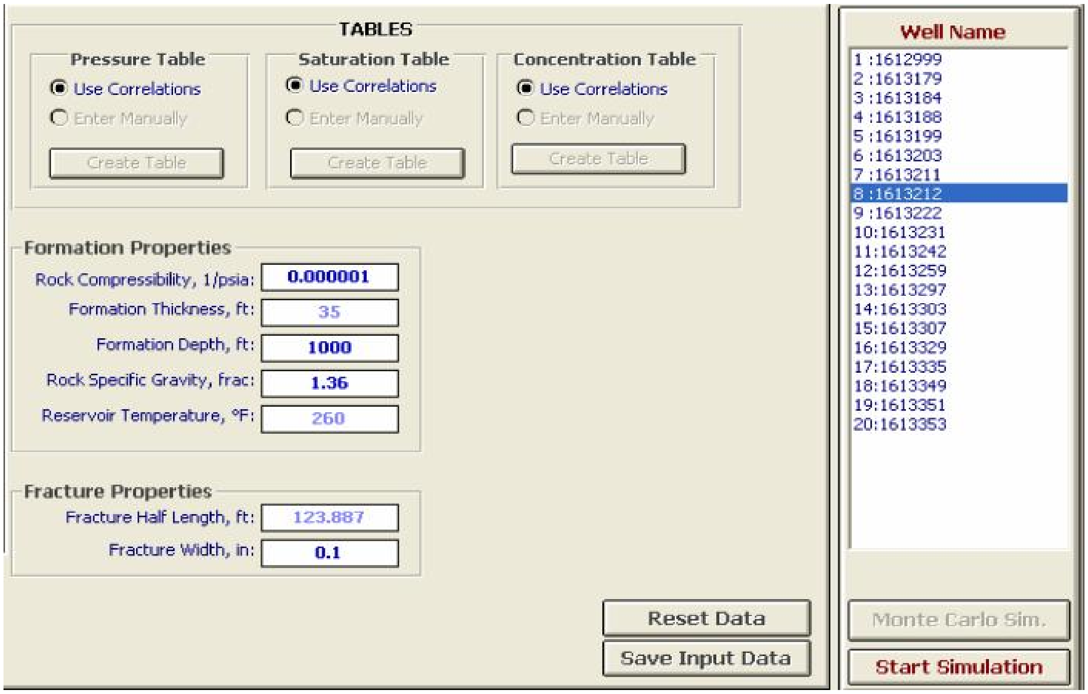
Decline Curve Analysis

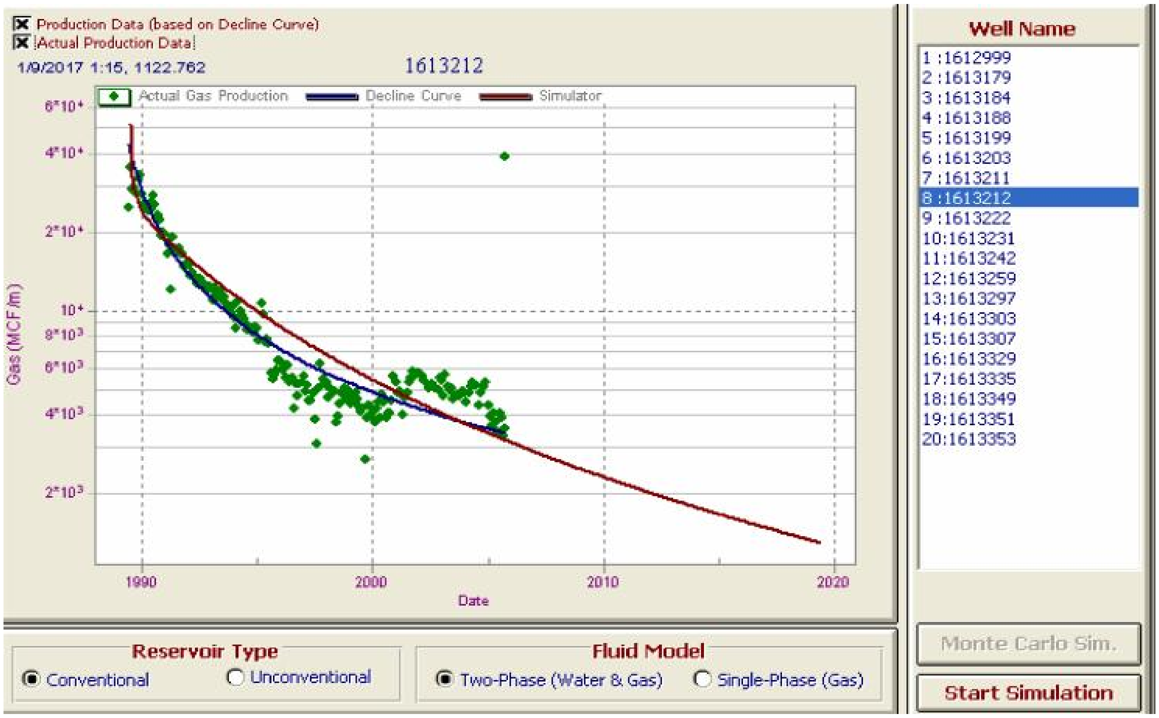


Type Curve Matching



Numerical Simulation Results



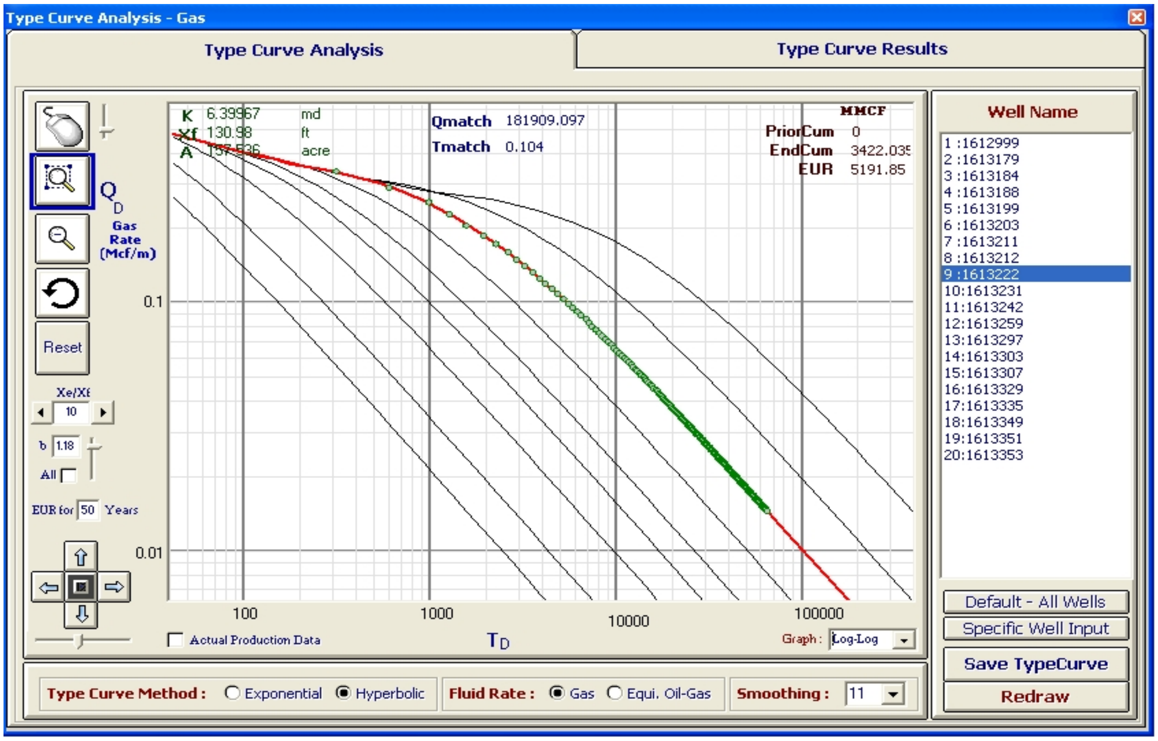


Production Data (based on Decline Curve)
Actual Production Data
1/9/2017 1:15, 1122.762
1613212
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
6*10⁴
4*10⁴
2*10⁴
10⁴
8*10³
6*10³
4*10³
2*10³
1990
2000
2010
2020
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

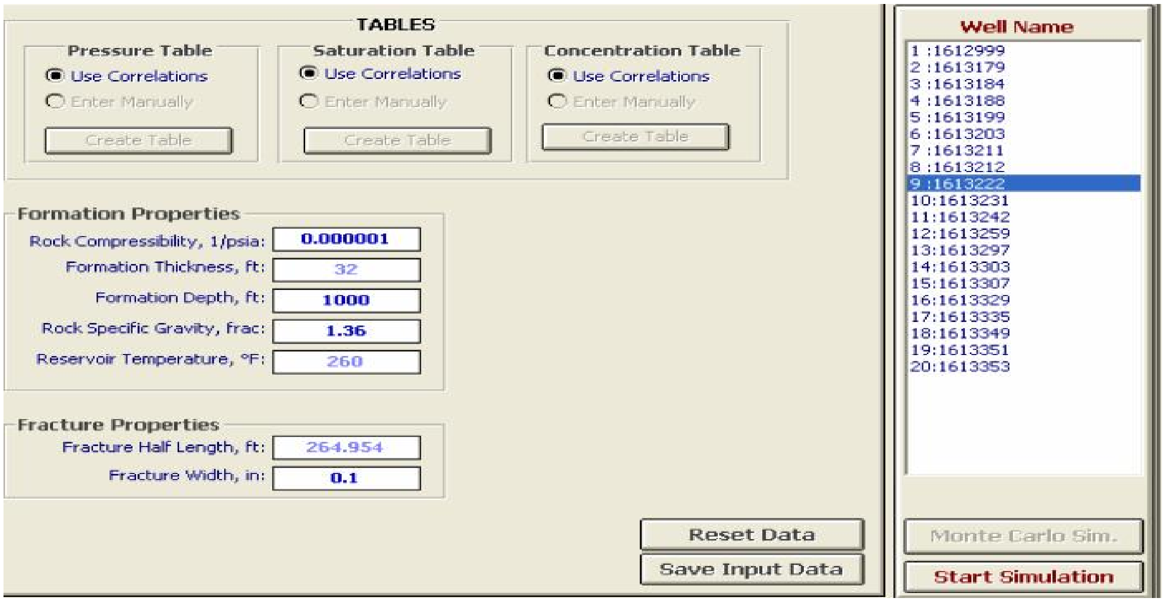
WELL 9

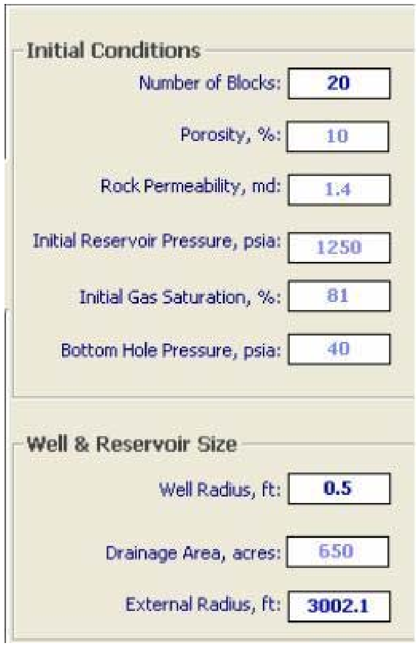
Decline Curve Analysis

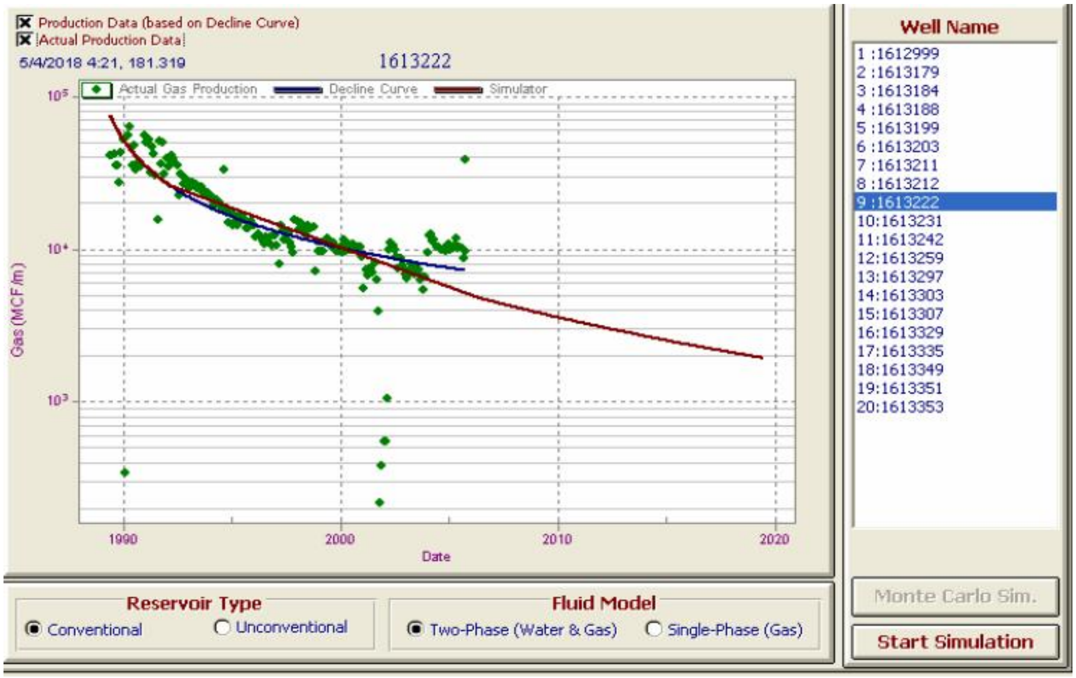
Type Curves Matching



Numerical Simulation Results

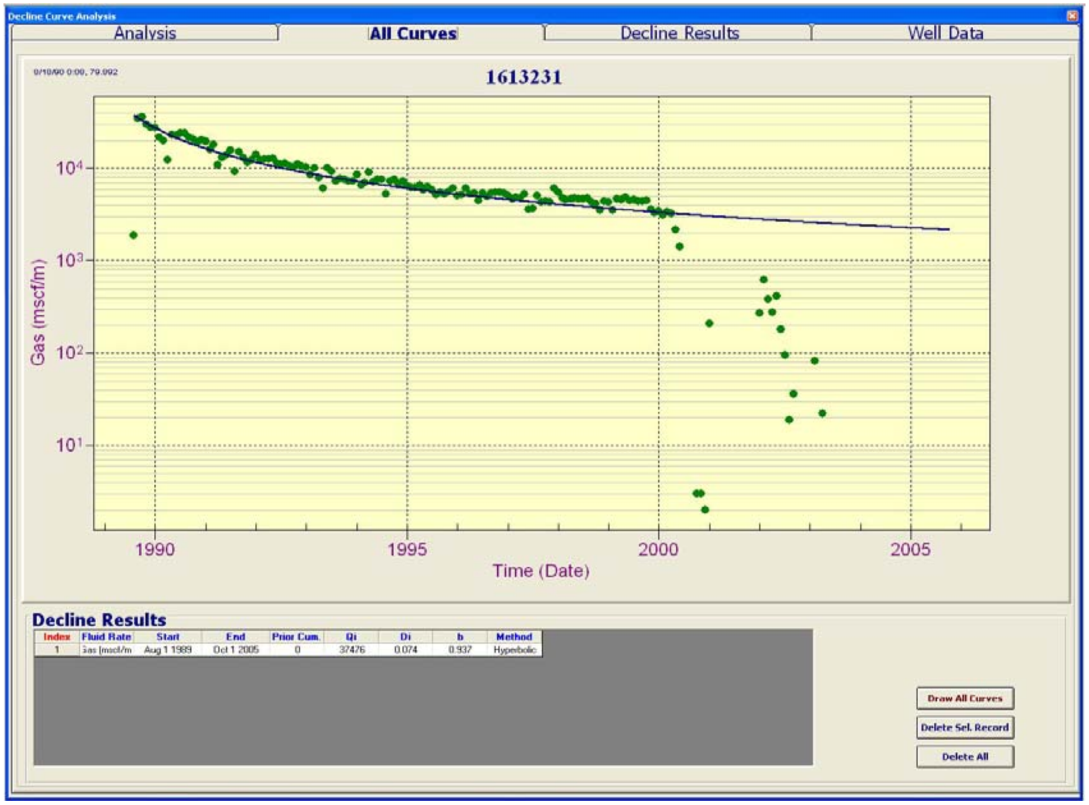




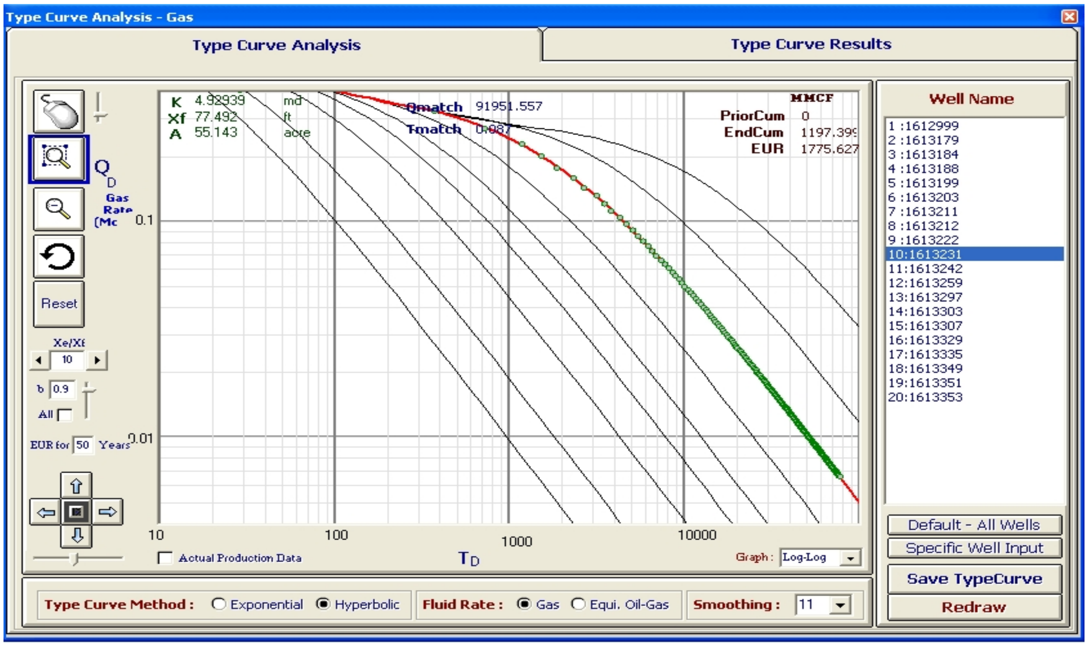

Production Data (based on Decline Curve)
Actual Production Data
5/4/2018 4:21, 181.319
1613222
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
1990
2000
2010
2020
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 10

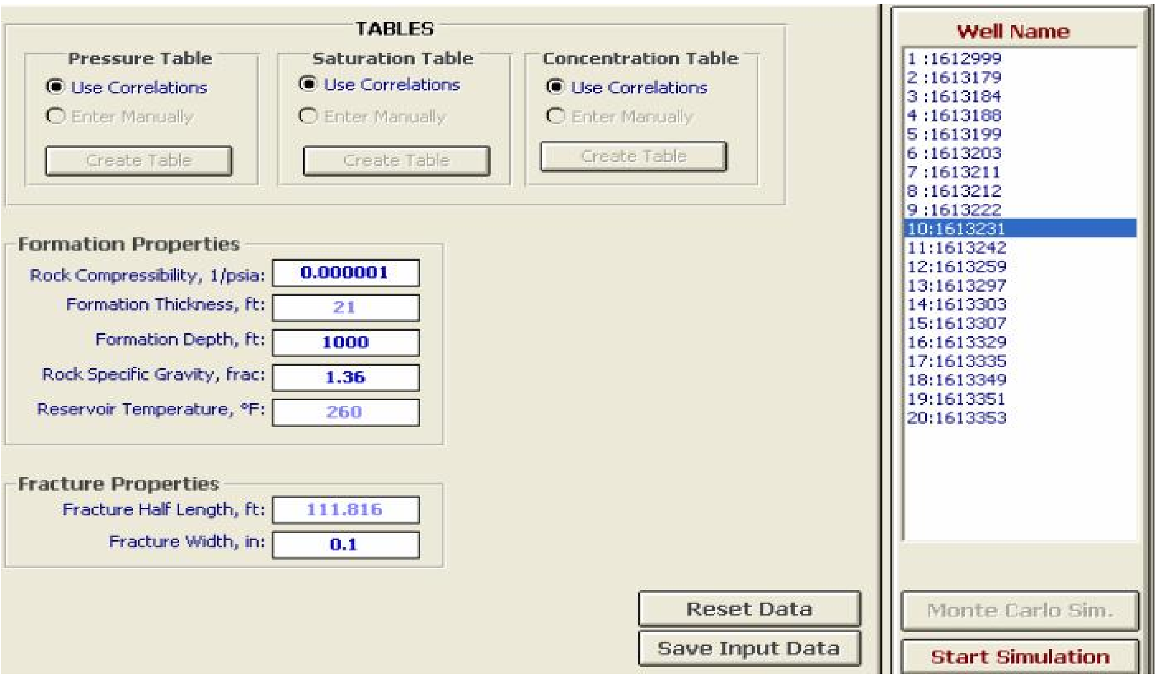
Decline Curve Analysis

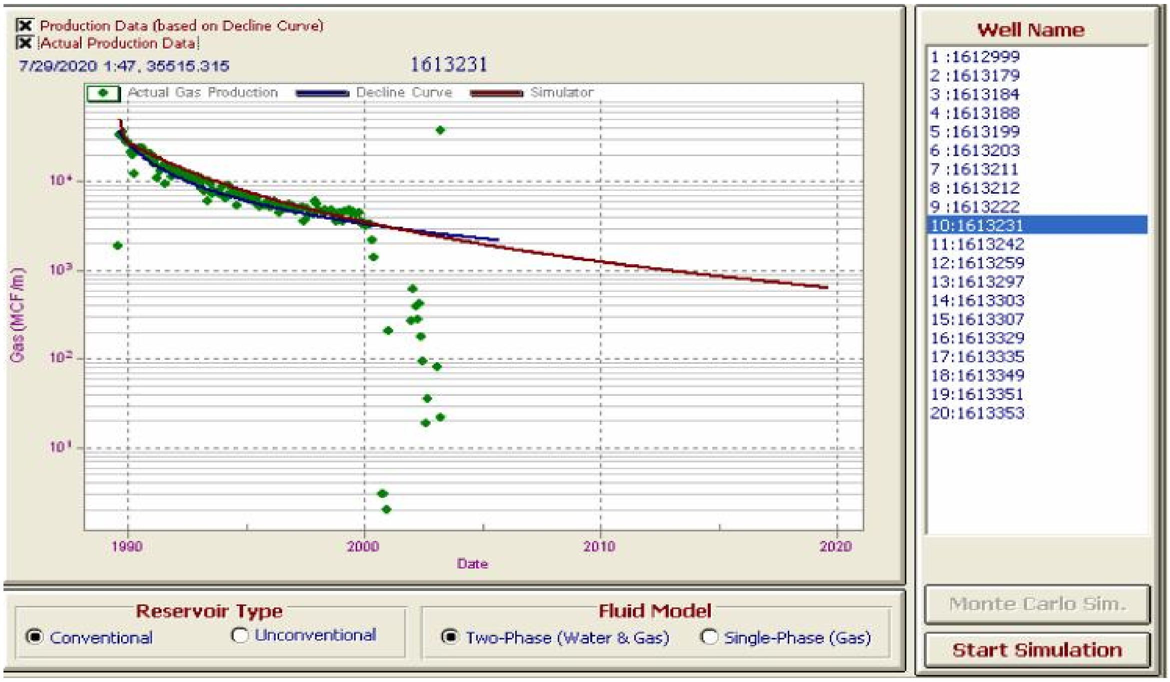


Type Curves Matching



Numerical Simulation Results

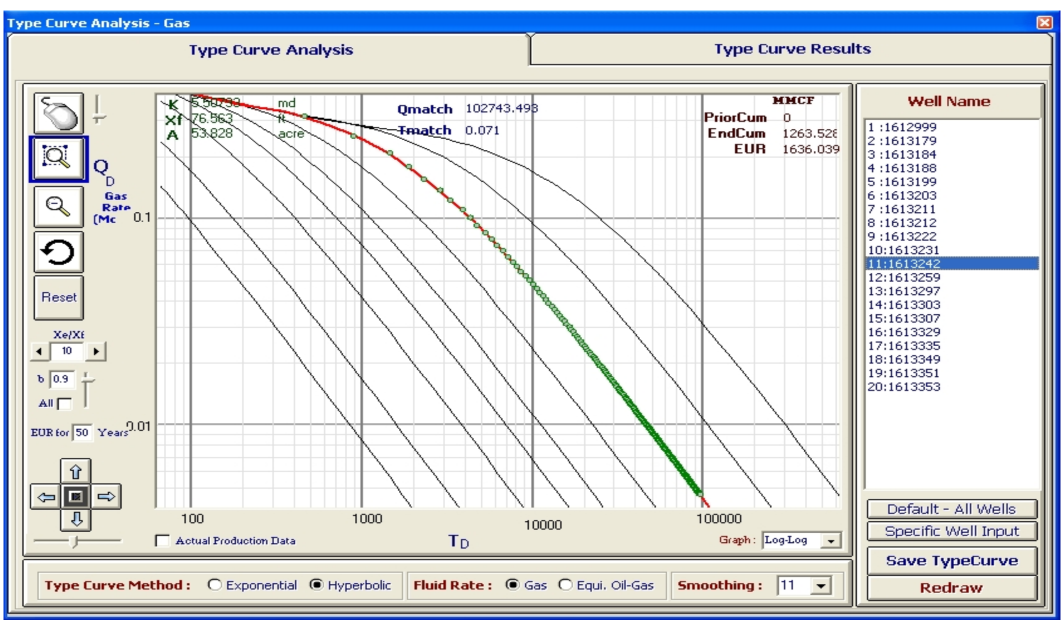




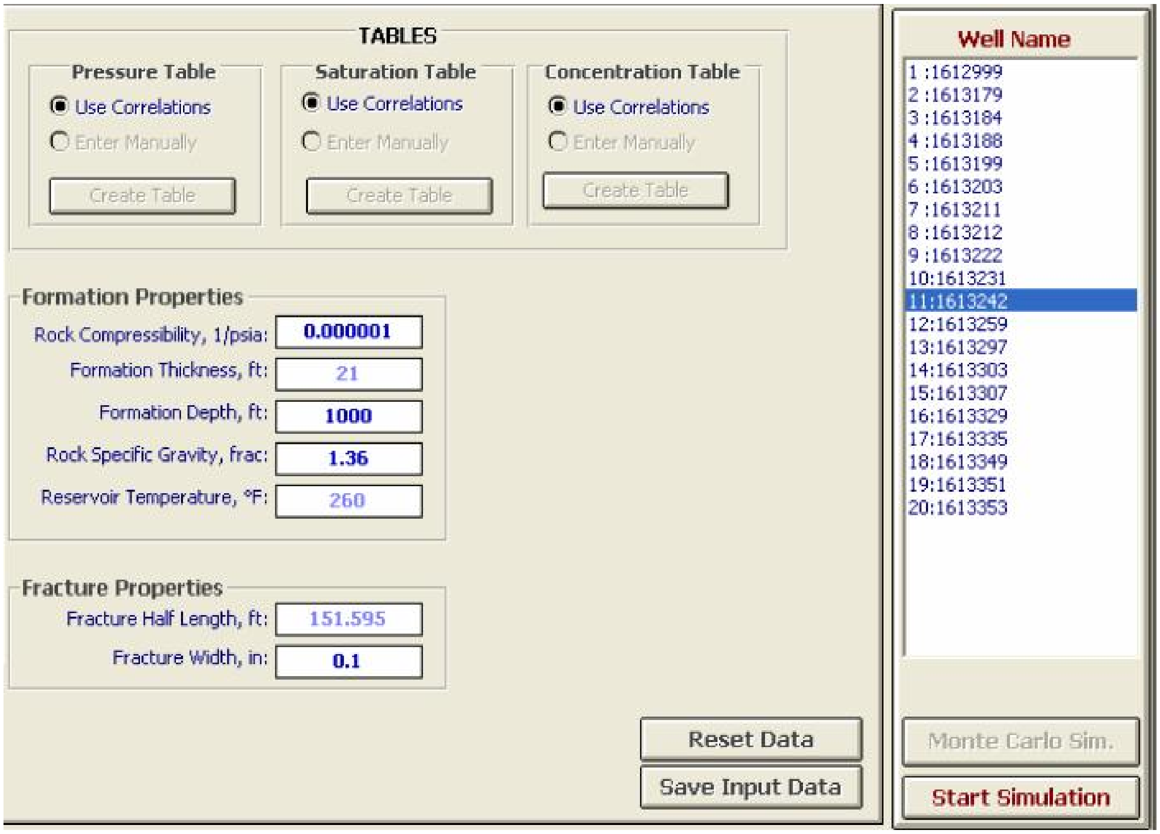
WELL 11

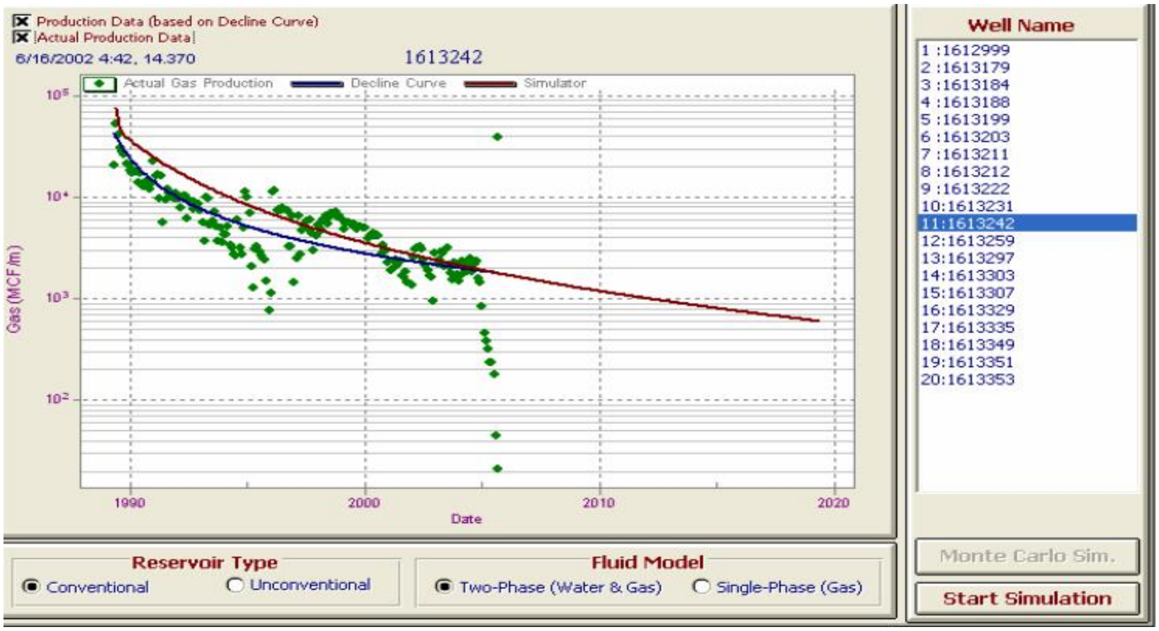
Decline Curve Analysis

Type Curve Matching



Numerical Simulation Results

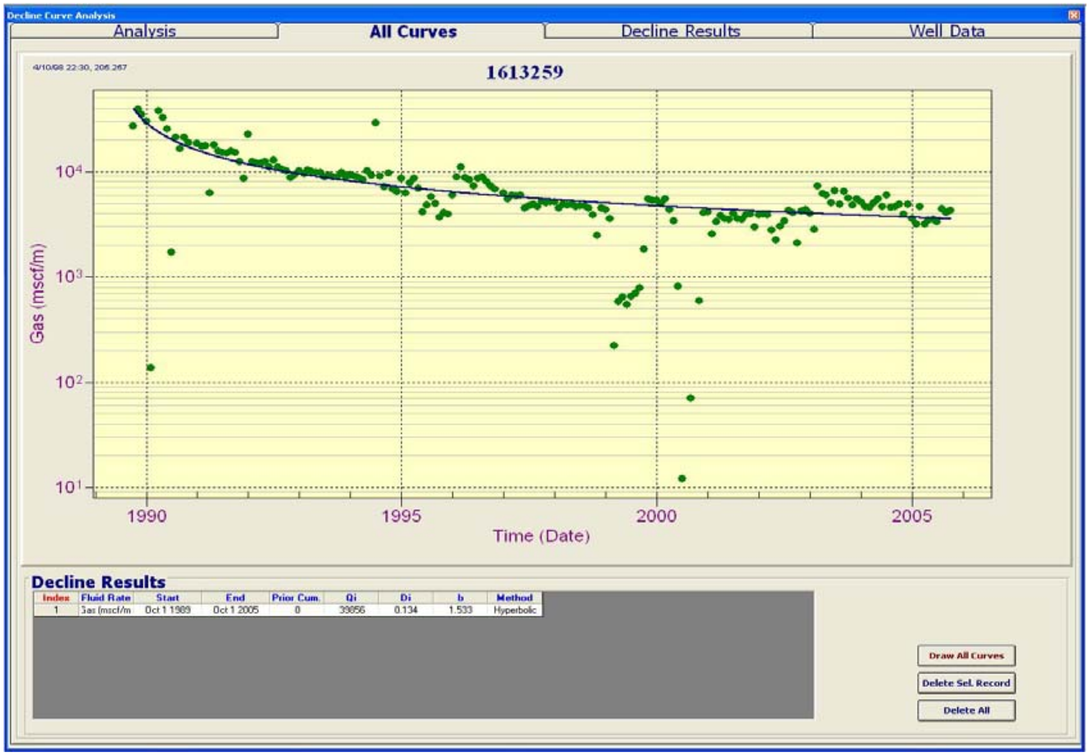




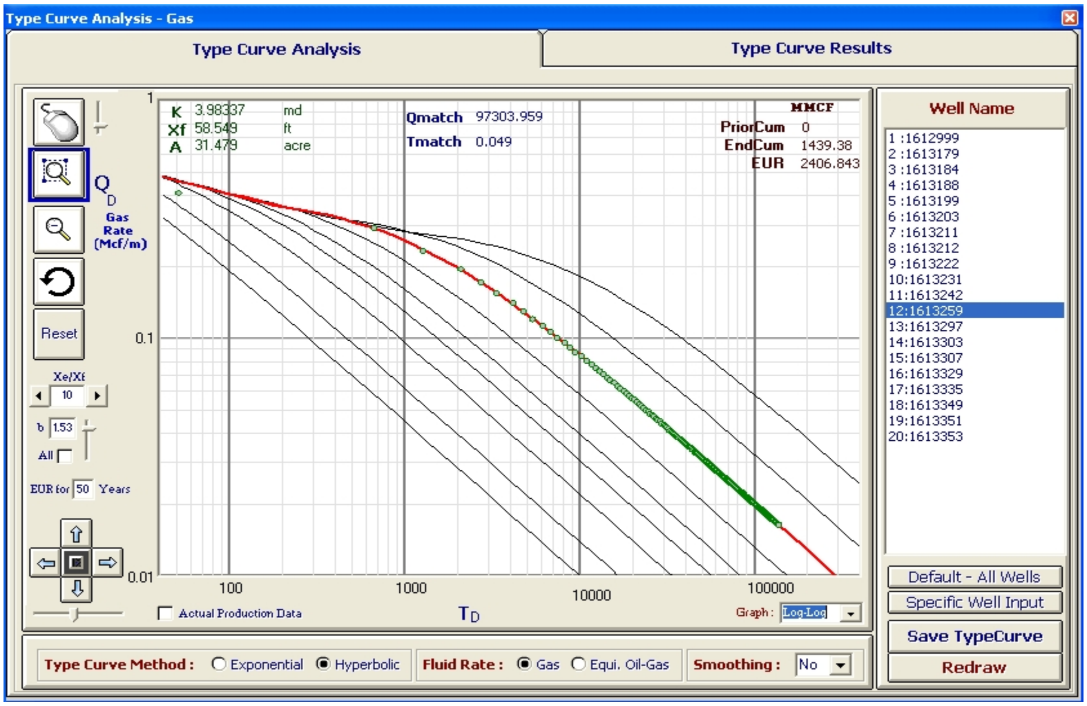
Production Data (based on Decline Curve)
Actual Production Data
6/16/2002 4:42, 14.370
1613242
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
1990
2000
2010
2020
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 12

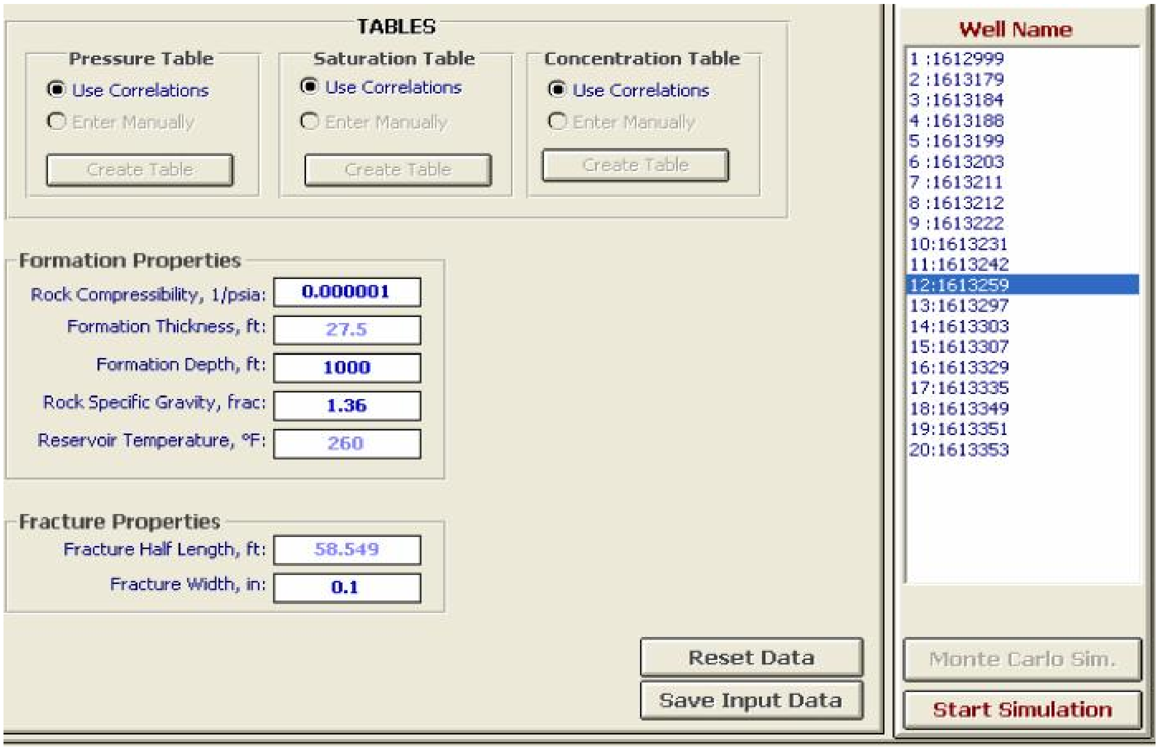
Decline Curve Analysis:

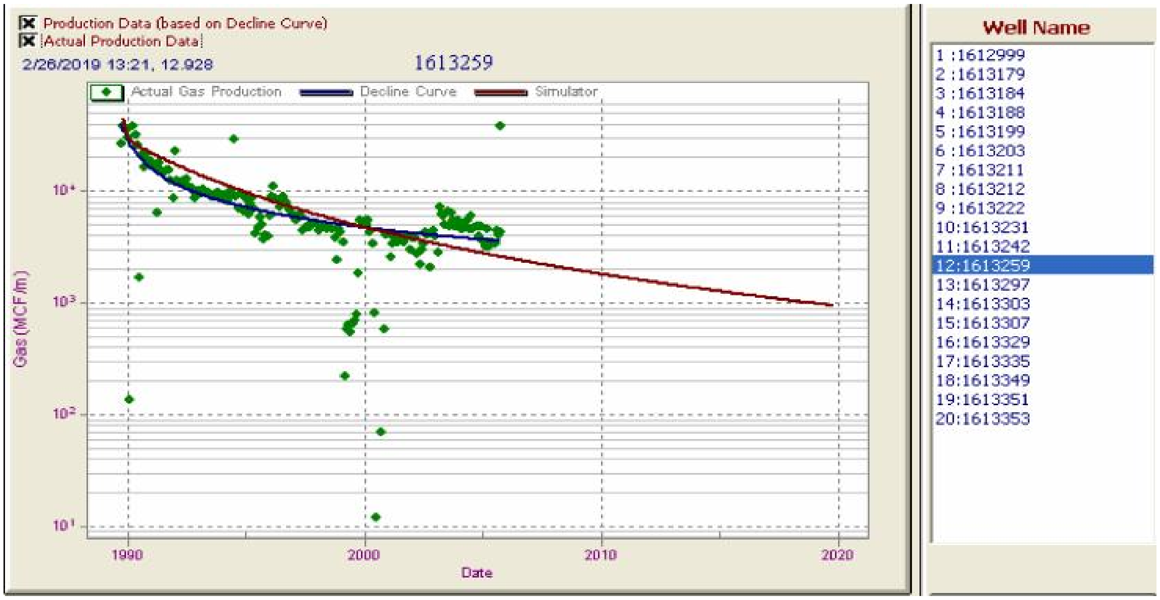


Type Curve Matching



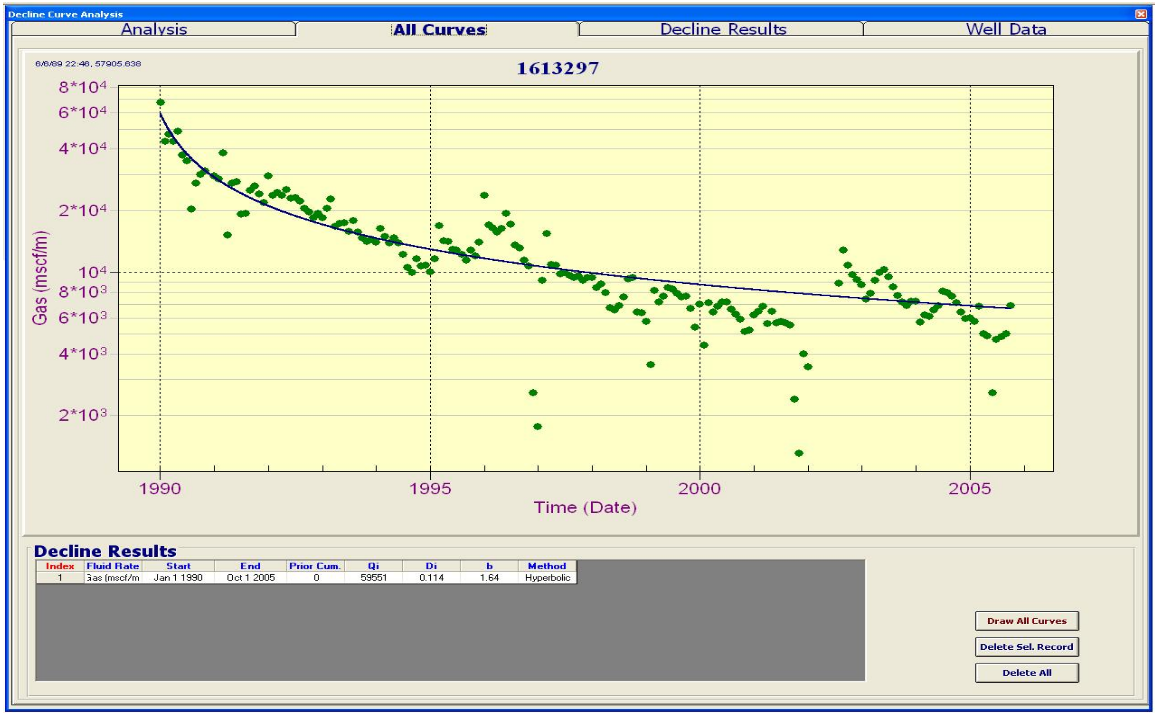
Numerical Simulation Results:




Production Data (based on Decline Curve)
Actual Production Data
2/26/2019 13:21, 12.928
1613259
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353

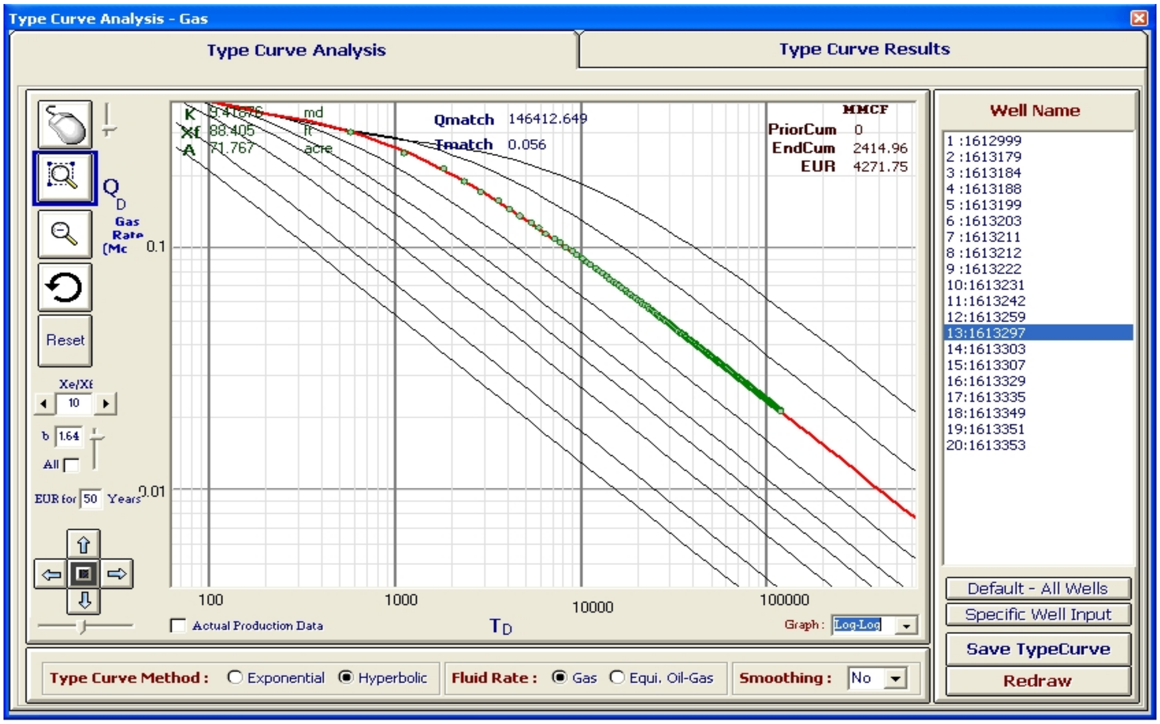
WELL 13

Decline Curve Analysis

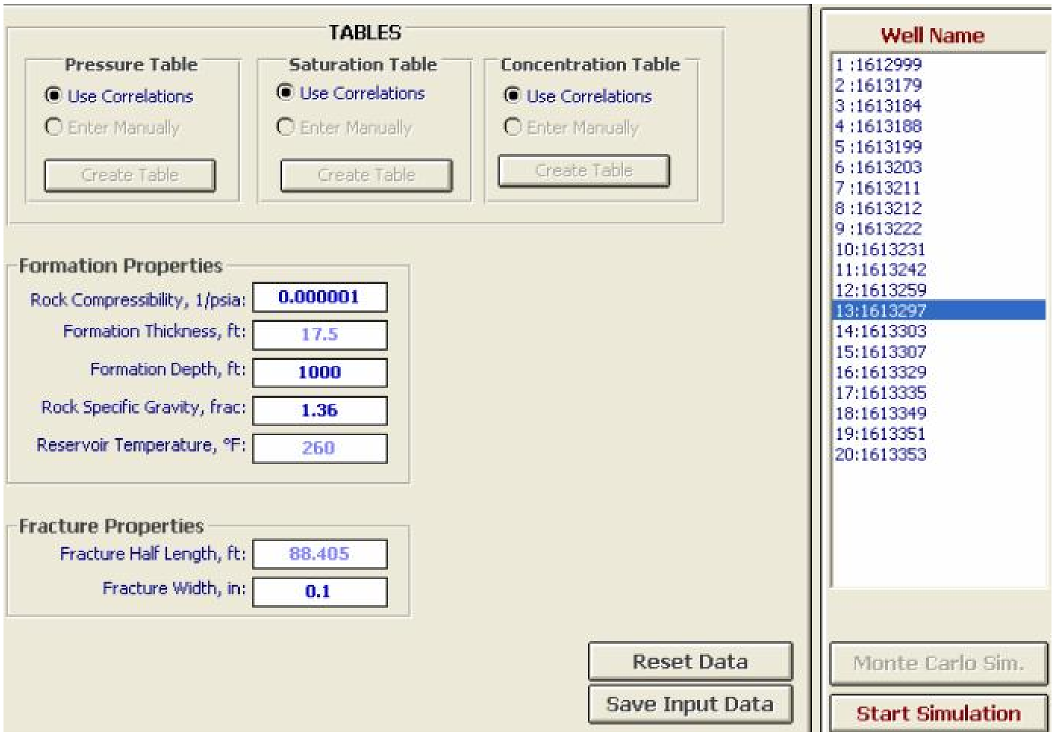


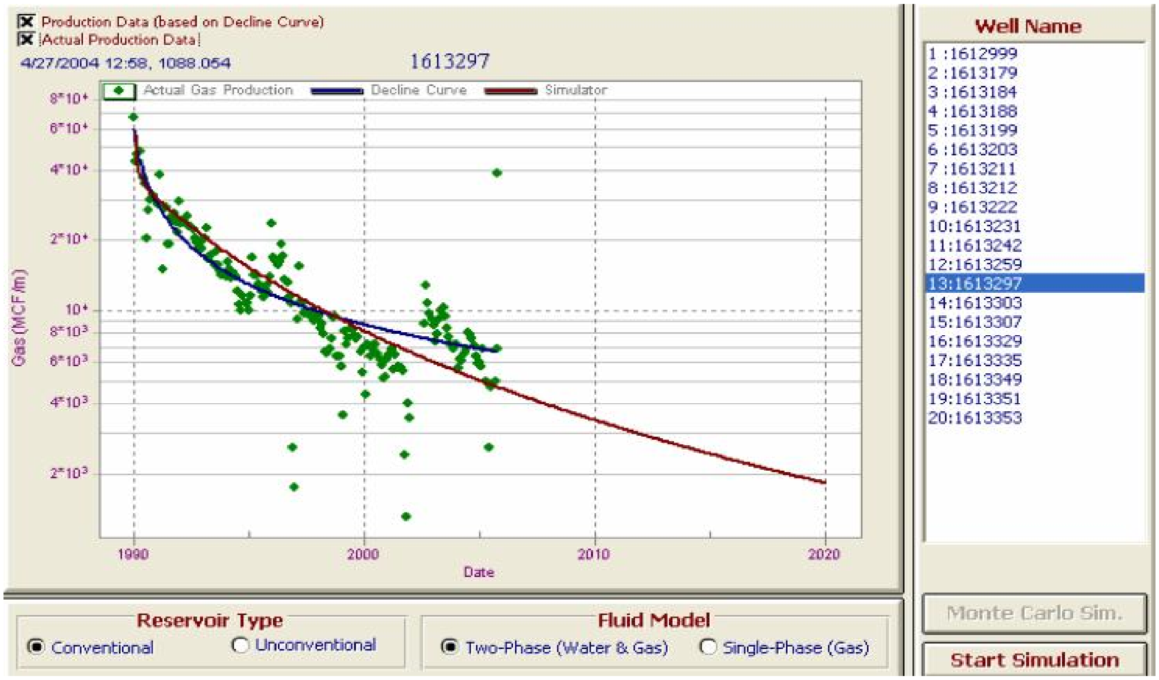
Index	Fluid Rate	Start	End	Prior Cum.	Qi	Di	b	Method
1	Gas (mscf/m	Jan 1 1990	Oct 1 2005	0	59551	0.114	1.64	Hyperbolic

Type Curve Matching



Numerical Simulation Results

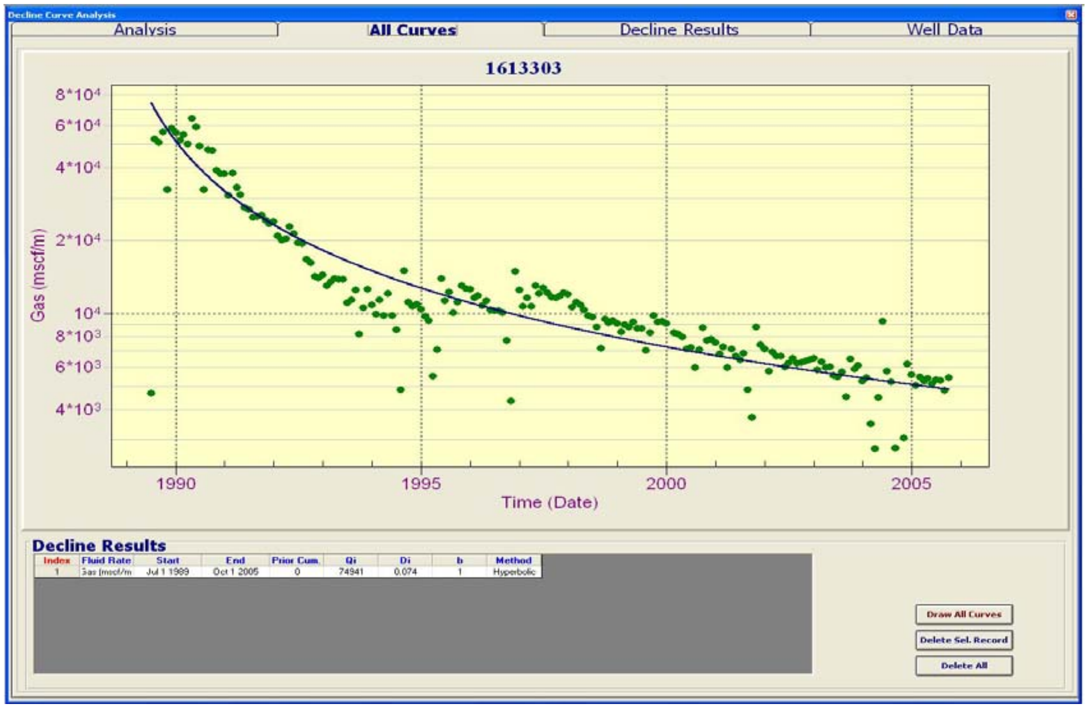




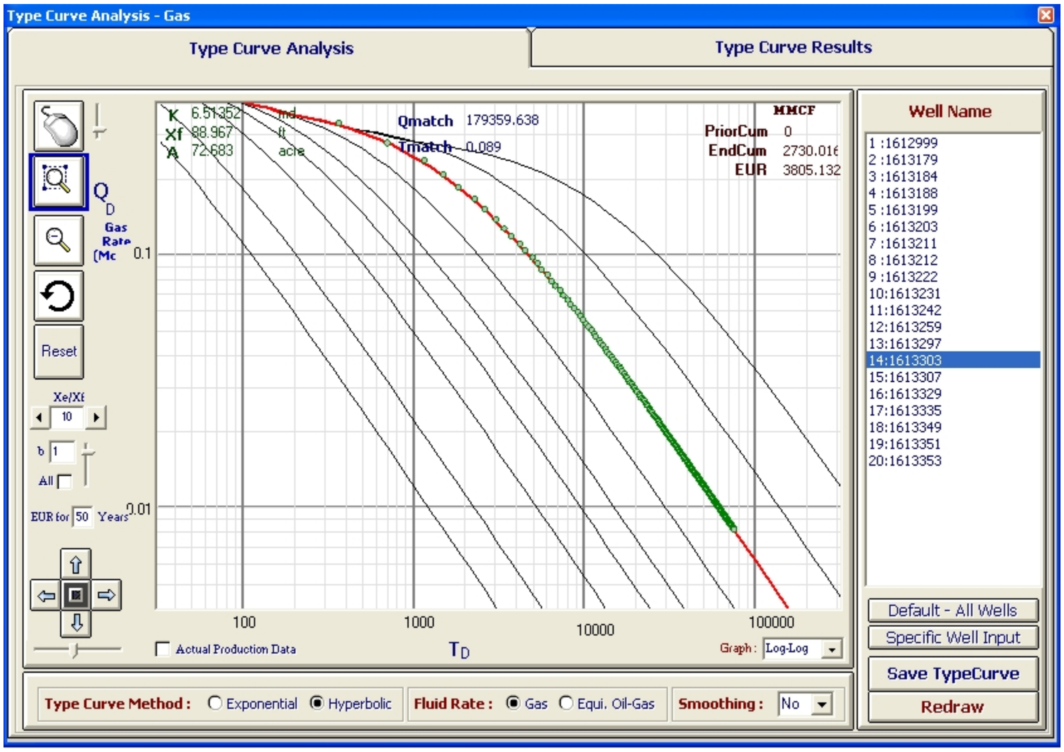
Production Data (based on Decline Curve)
Actual Production Data
4/27/2004 12:58, 1088.054
1613297
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 14

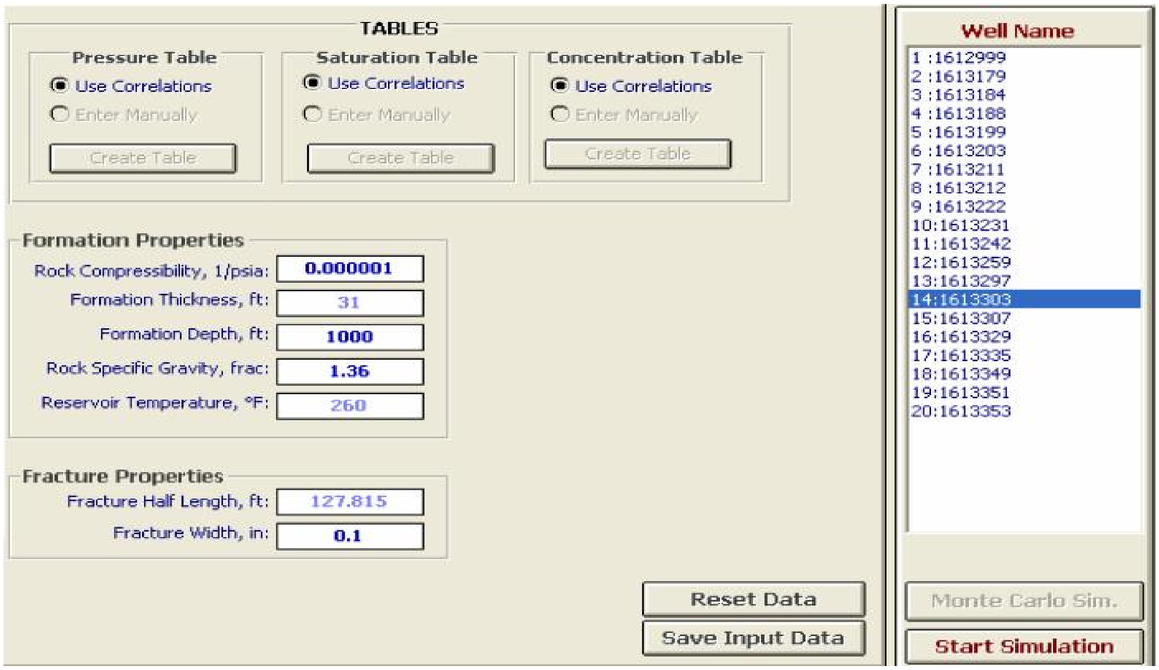
Decline Curve Analysis

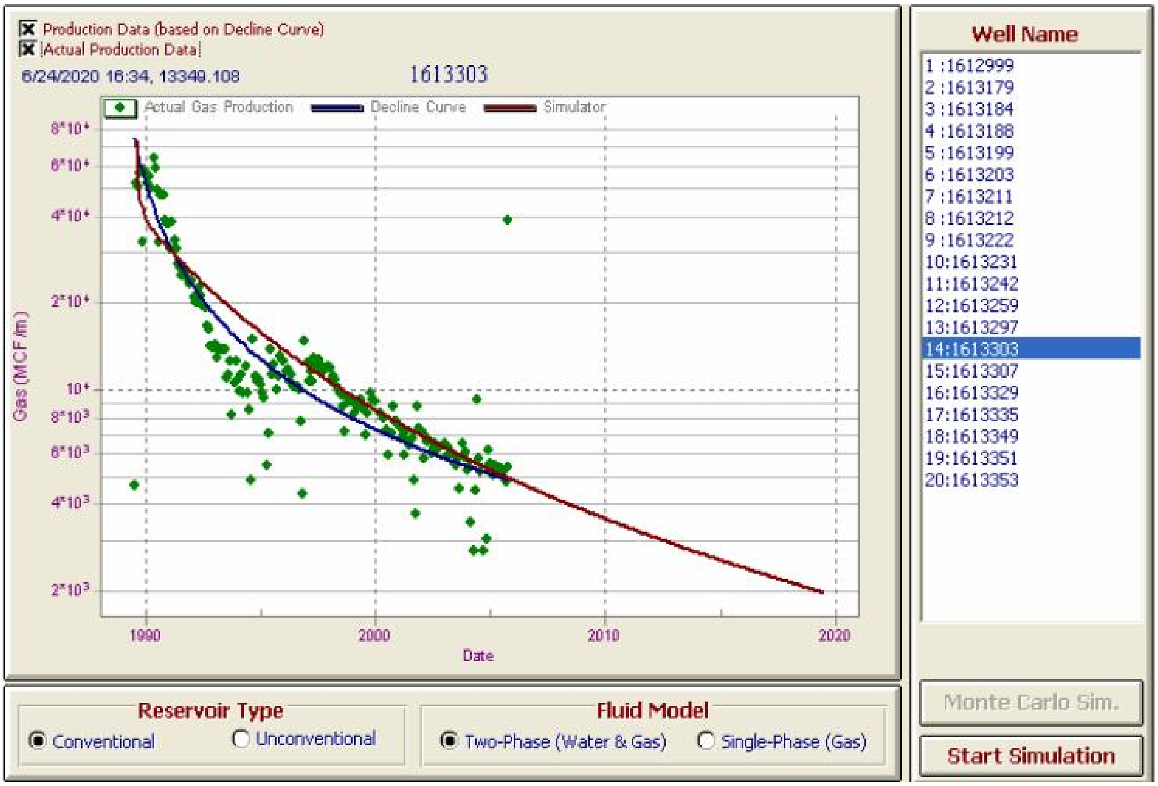


Type Curve Matching



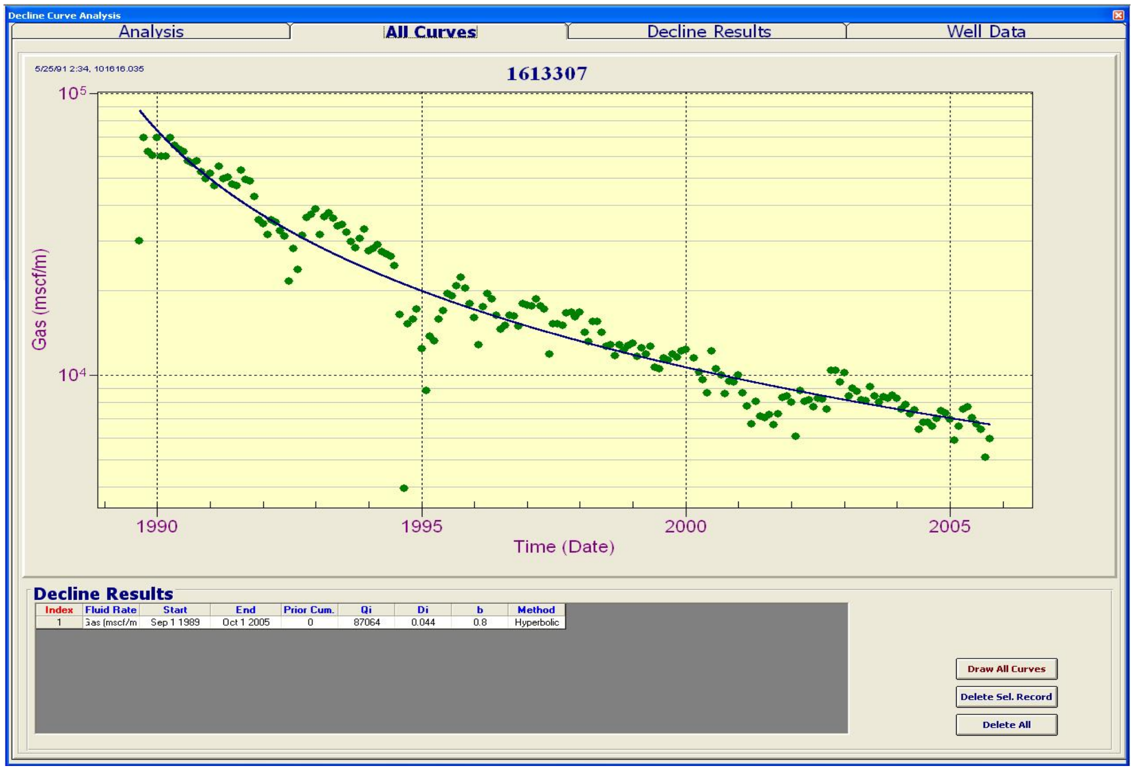
Numerical Simulation Results



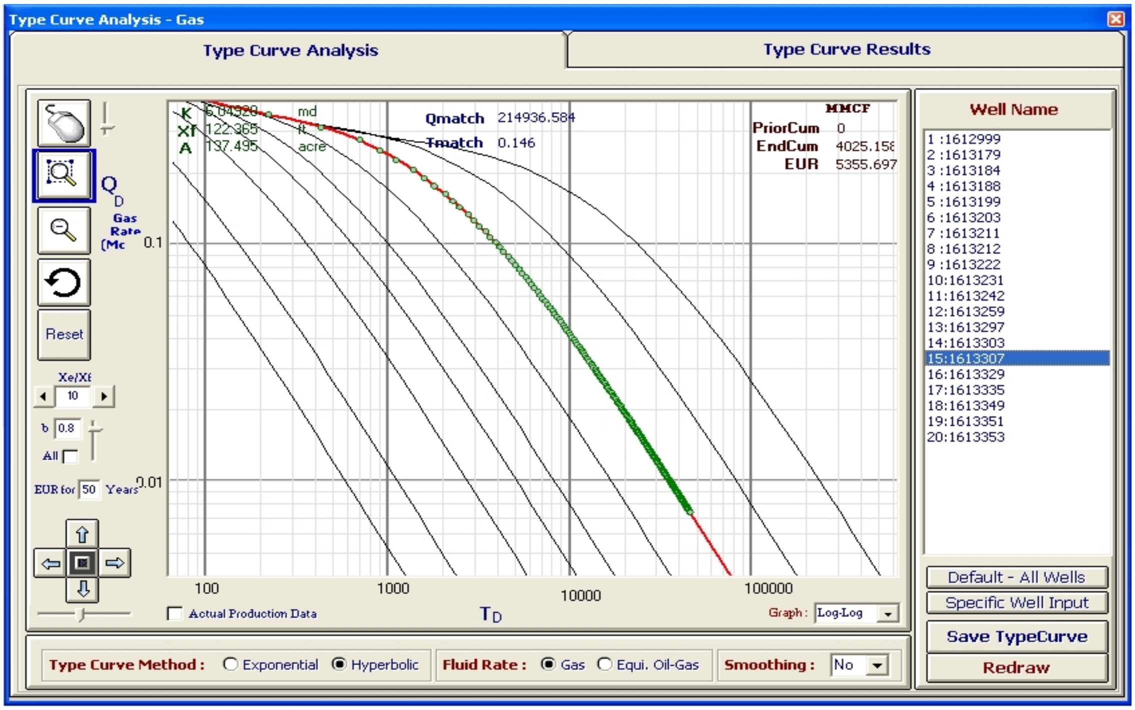

Production Data (based on Decline Curve)
Actual Production Data
6/24/2020 16:34, 13349.108
1613303
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
1990
2000
2010
2020
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 15

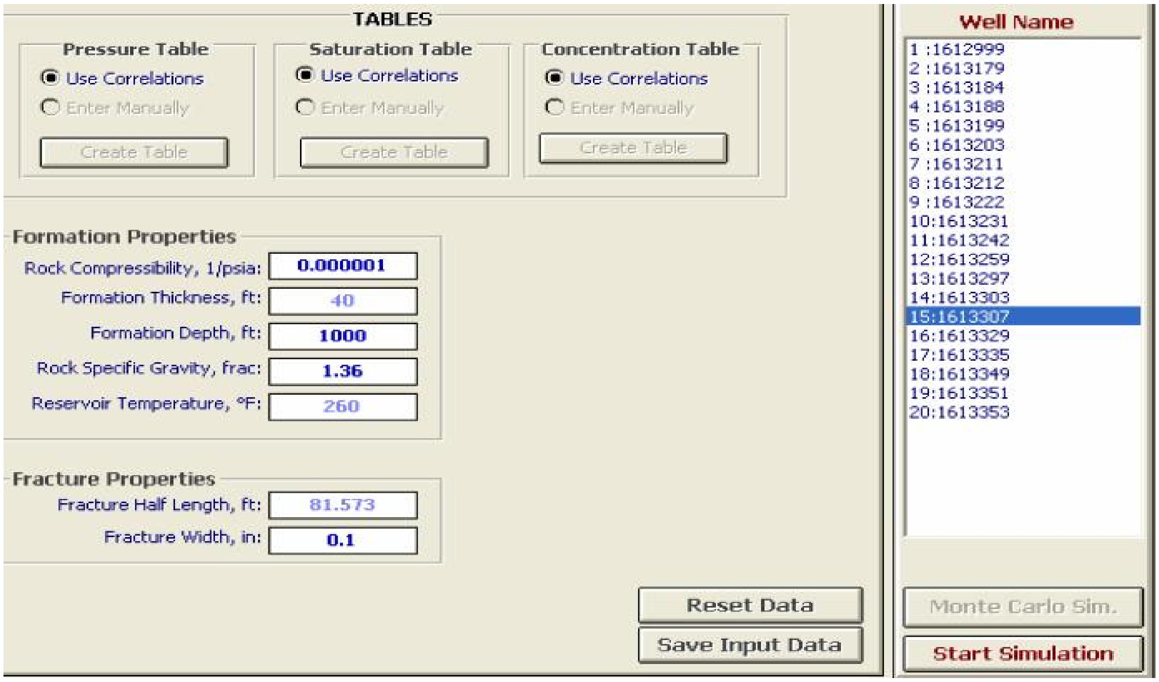
Decline Curve Analysis

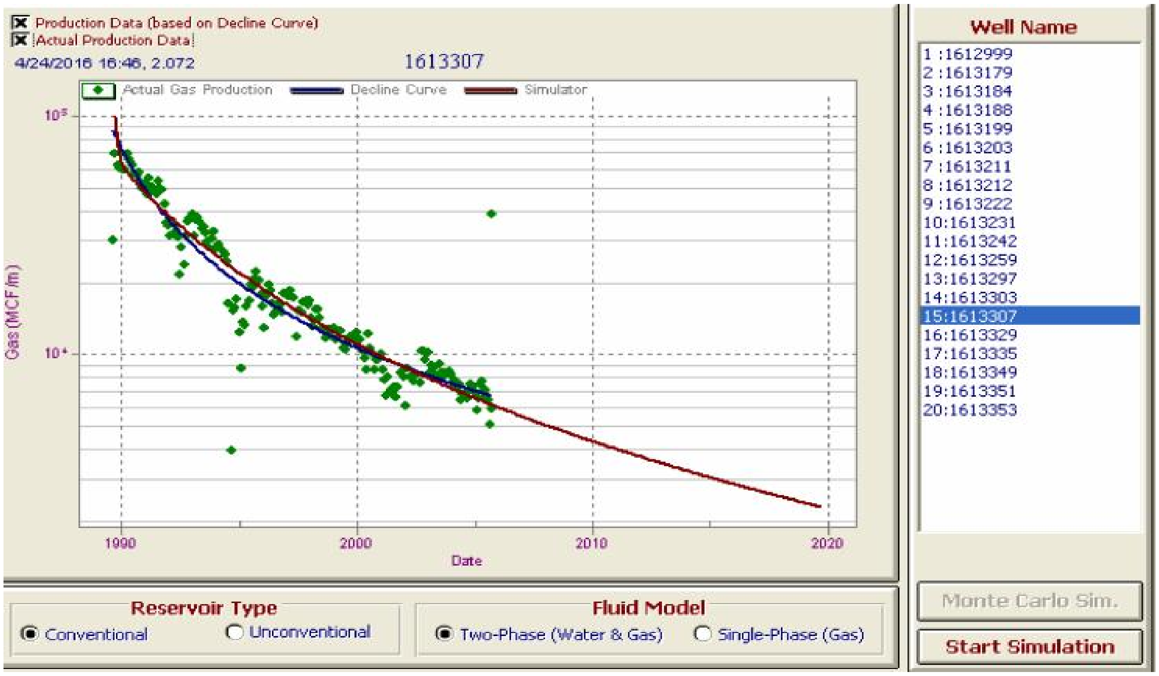


Type Curve Matching



Numerical Simulation Results

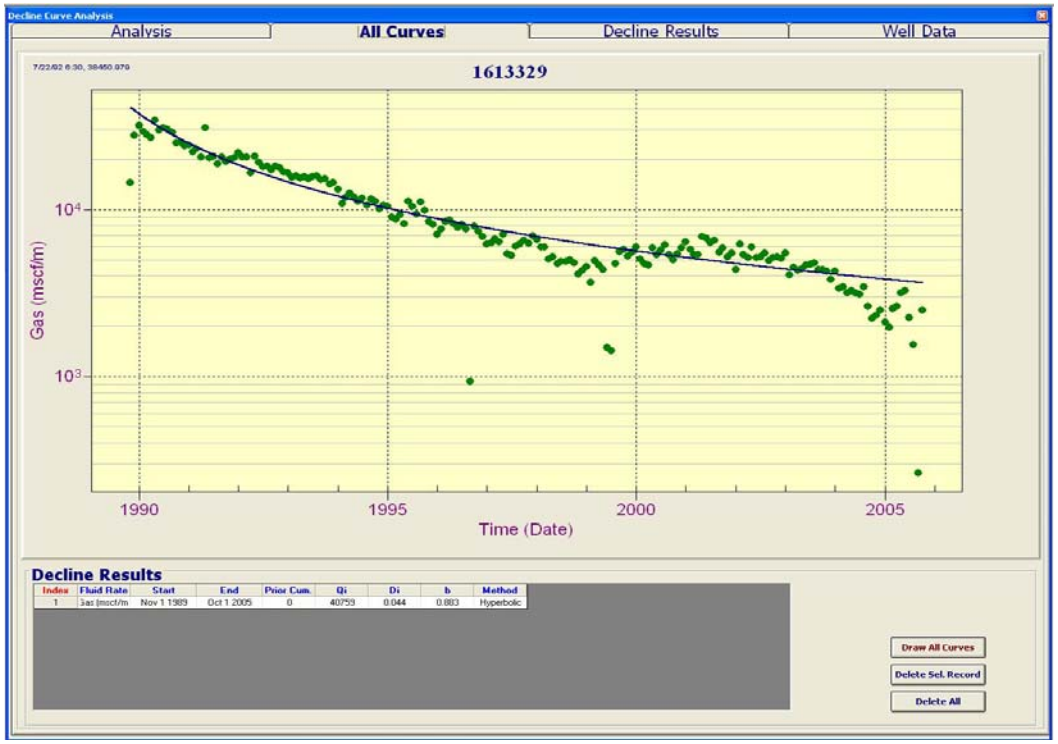




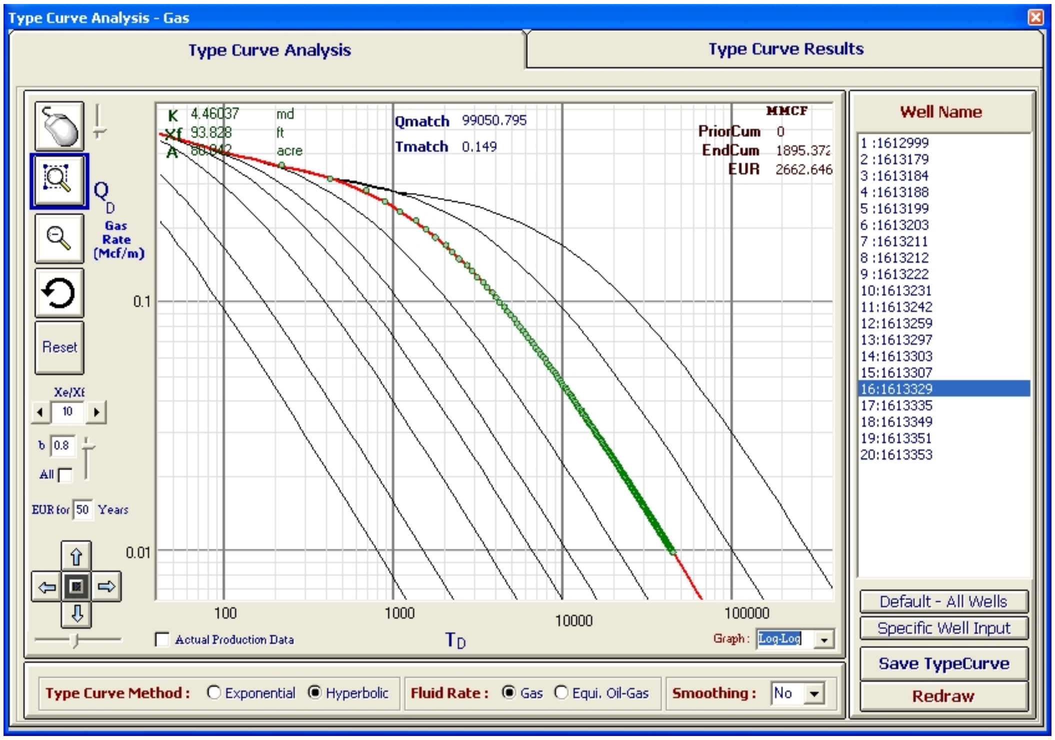
Production Data (based on Decline Curve)
Actual Production Data
4/24/2016 16:46, 2.072
1613307
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
1990
2000
2010
2020
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 16

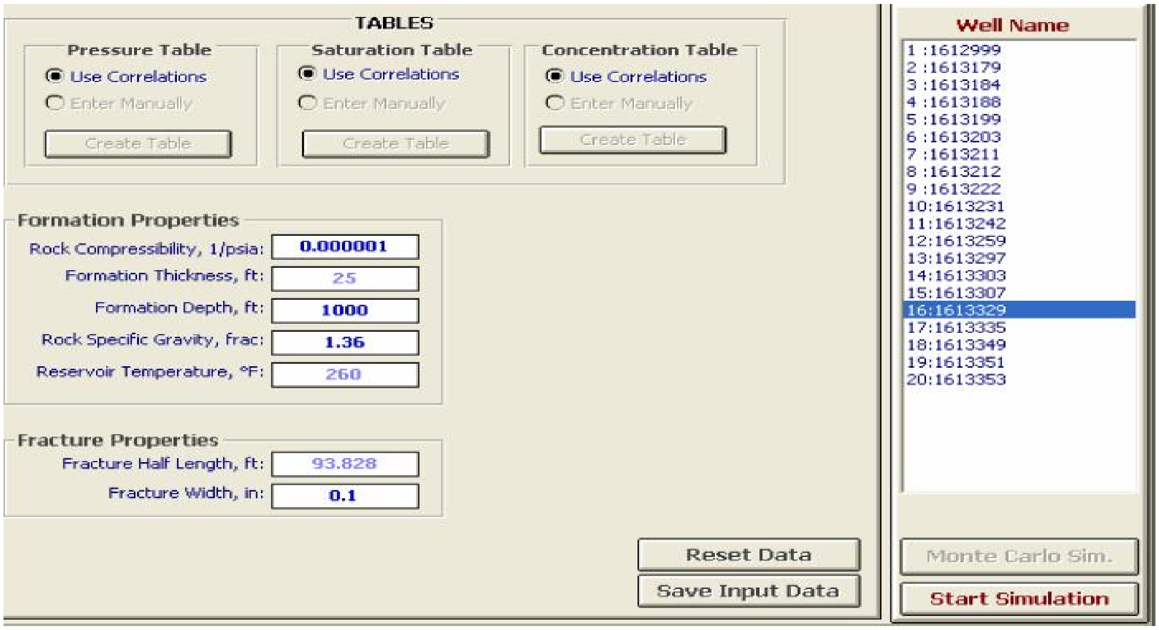
Decline Curve Analysis

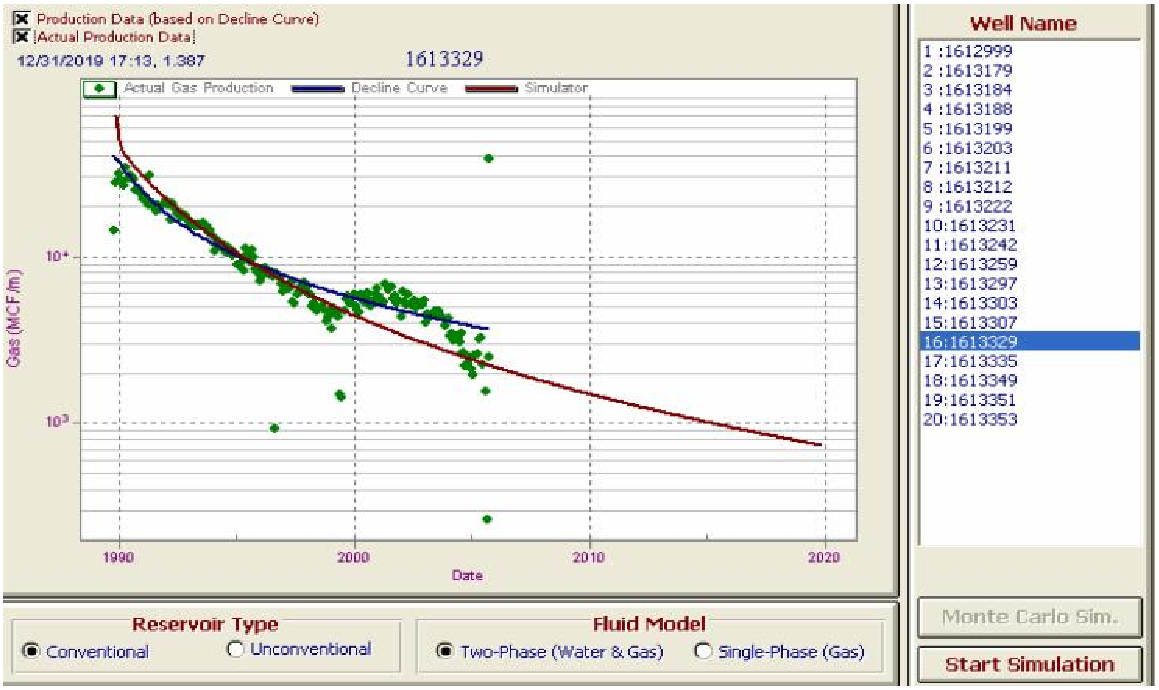


Type Curve Matching



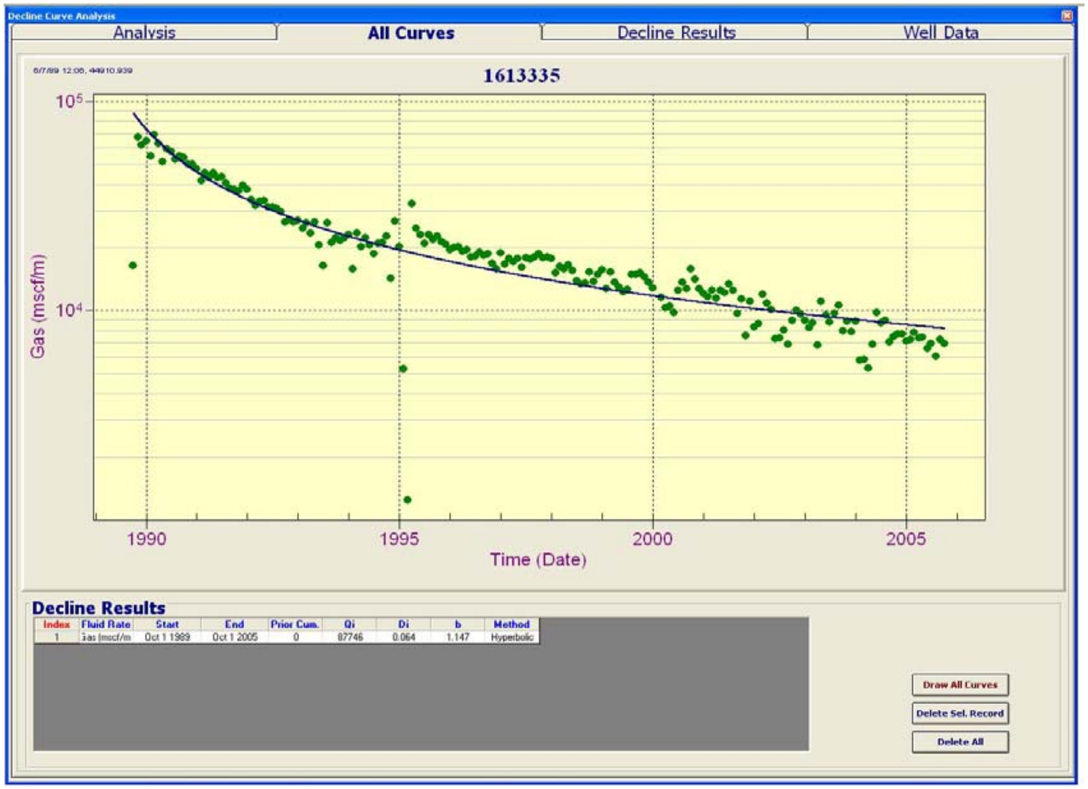
Numerical Simulation Results



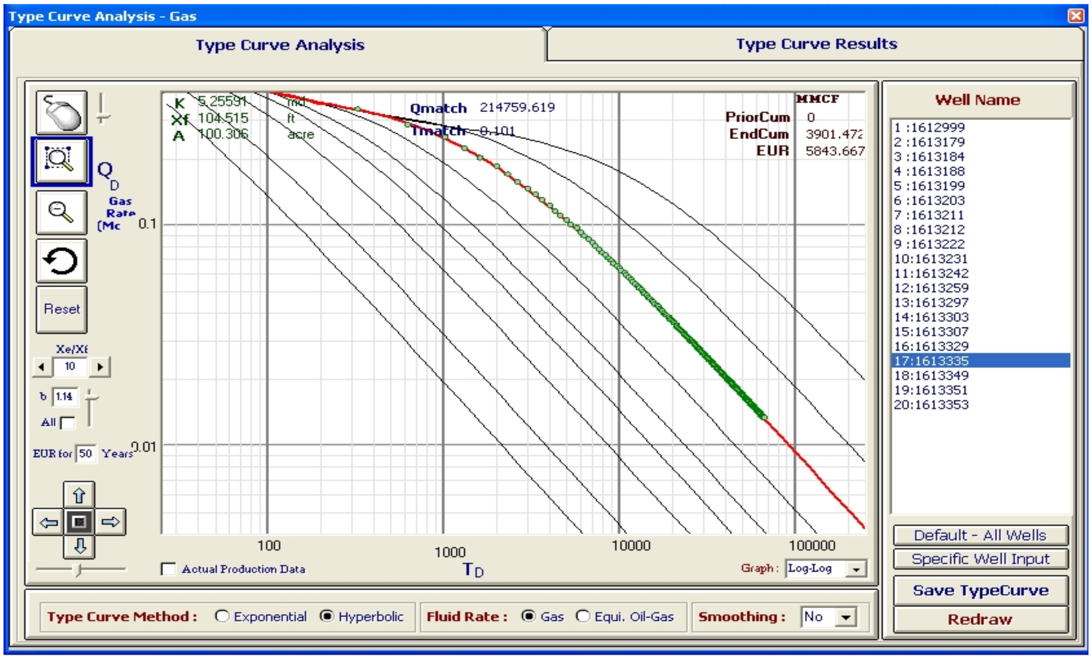

Production Data (based on Decline Curve)
Actual Production Data
12/31/2019 17:13, 1.387
1613329
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
10⁴
10³
1990
2000
2010
2020
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 17

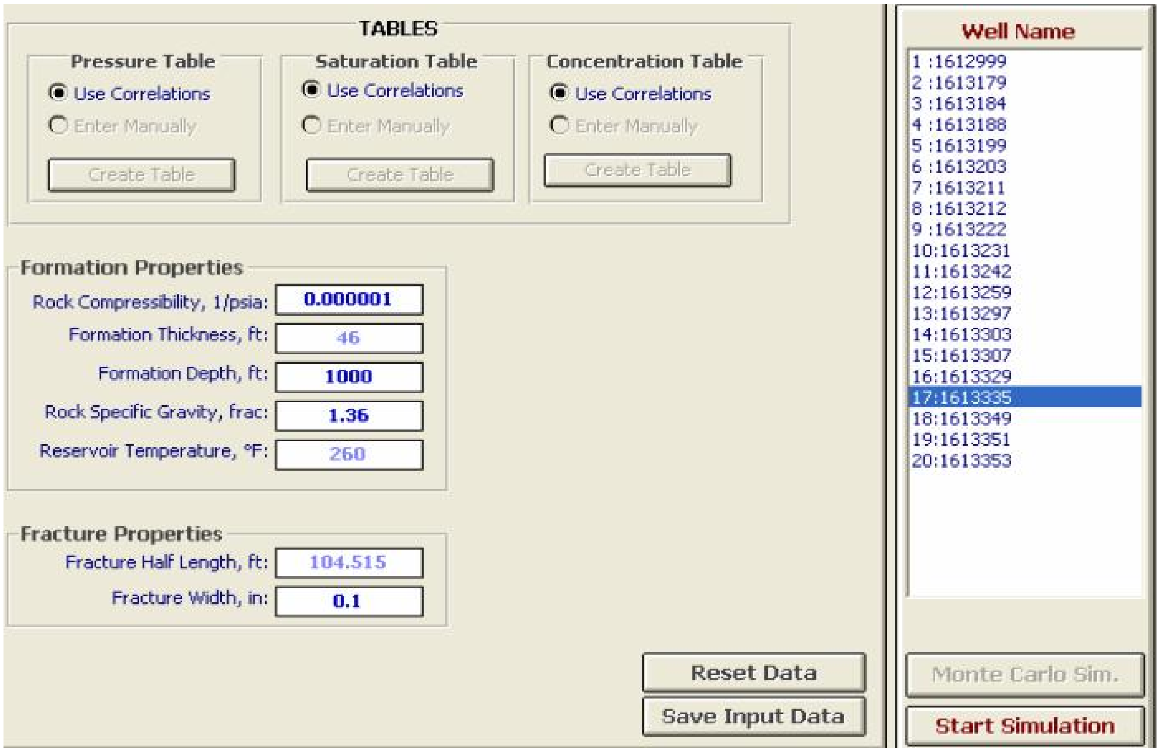
Decline Curve Analysis

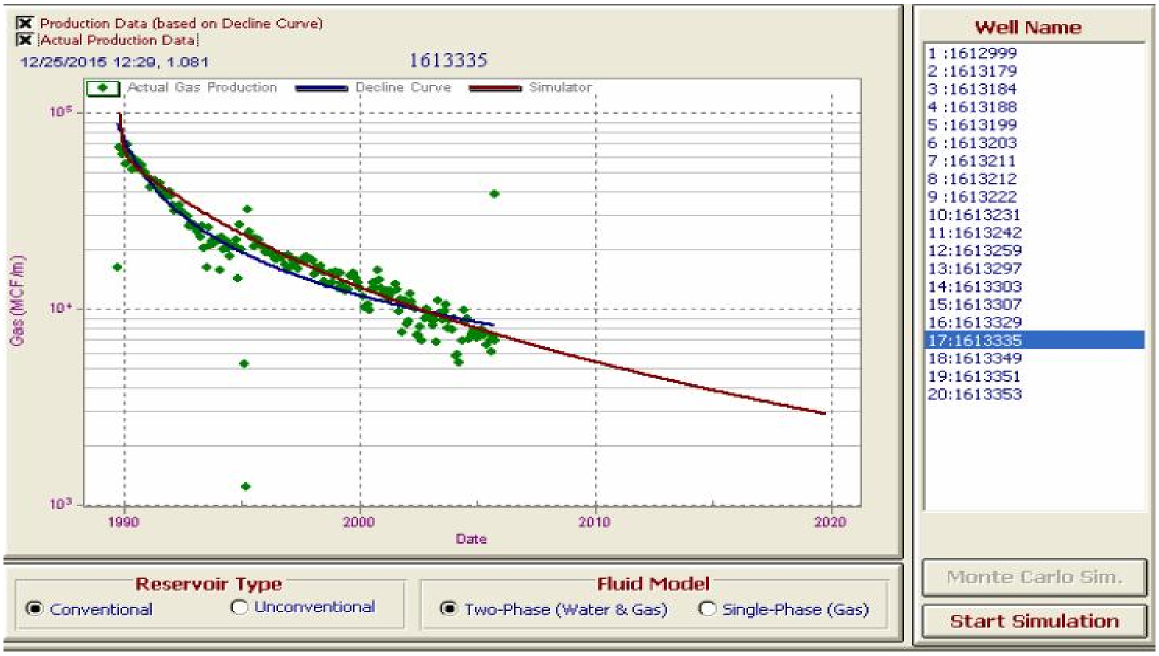


Type Curve Matching



Numerical Simulation Results

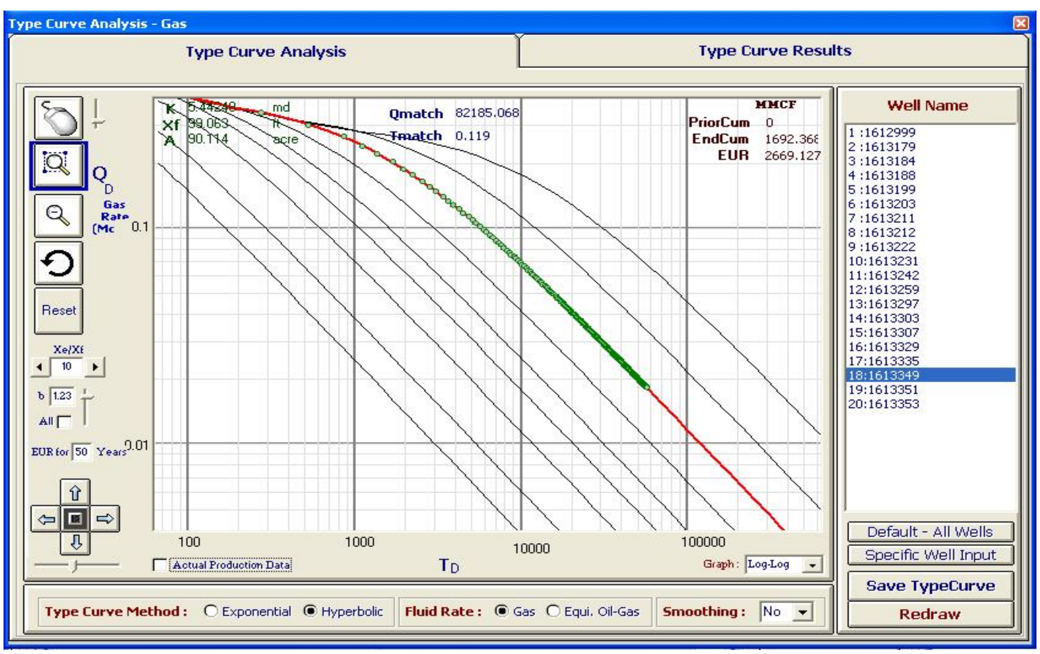



Production Data (based on Decline Curve)
Actual Production Data
12/25/2015 12:29, 1.081
1613335
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

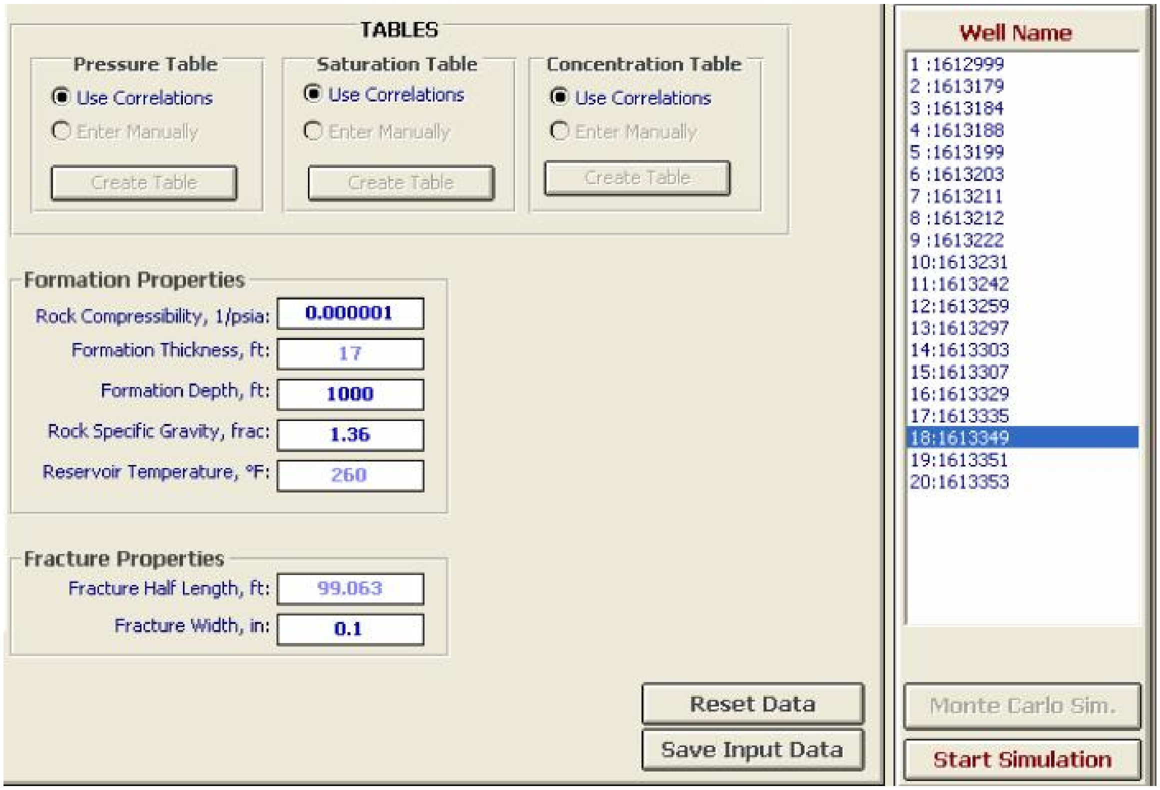
WELL 18

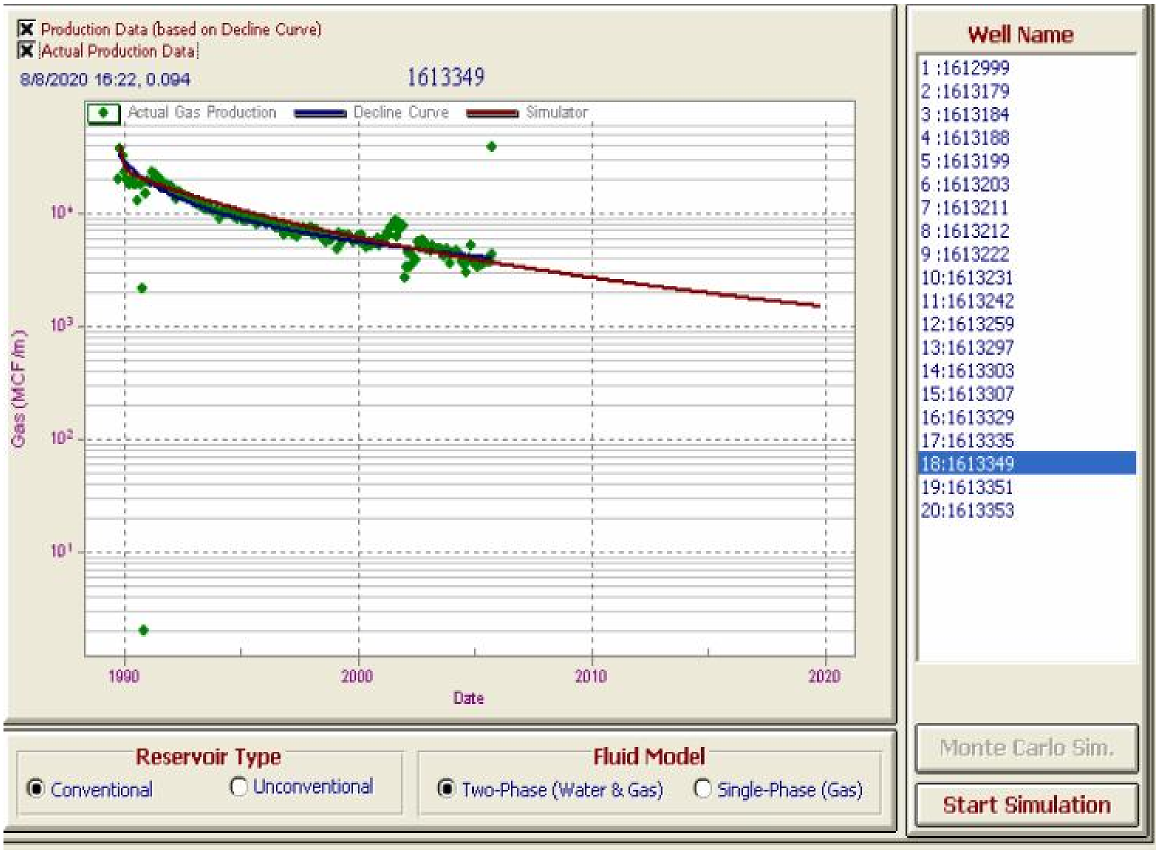
Decline Curve Analysis

Type Curve Matching



Numerical Simulation Results

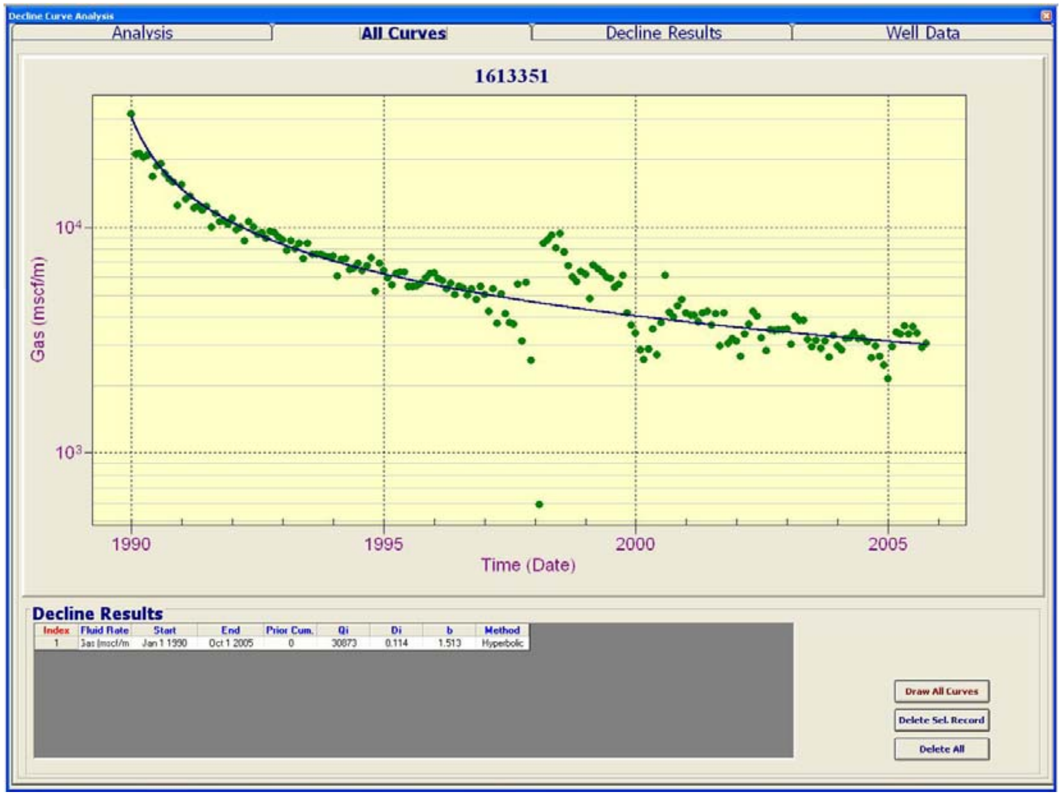




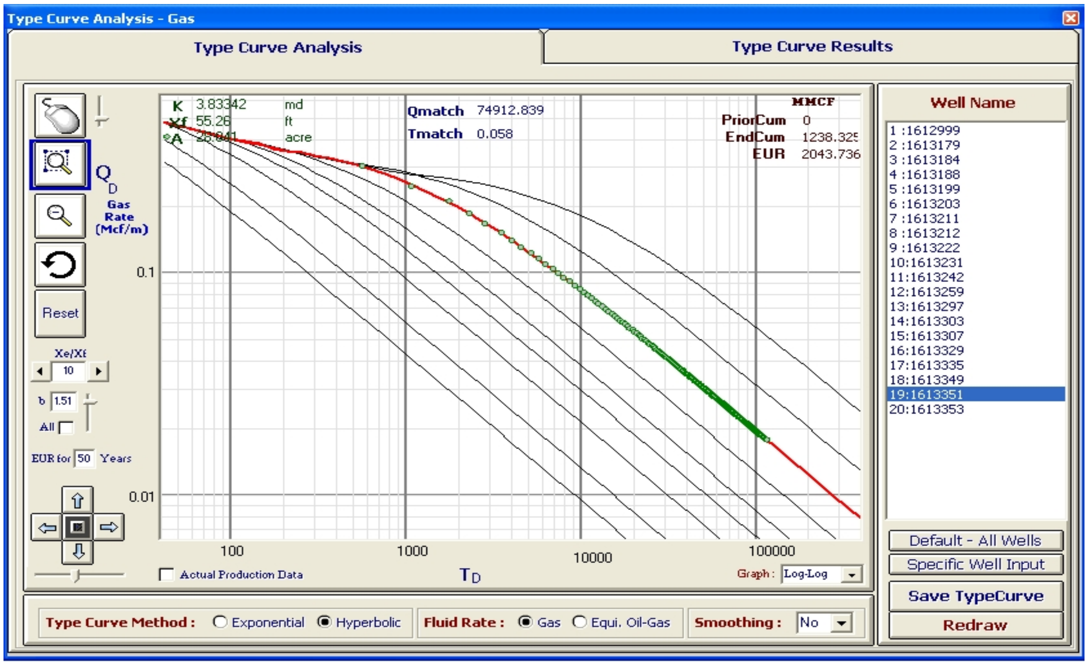
Production Data (based on Decline Curve)
Actual Production Data
8/8/2020 16:22, 0.094
1613349
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
Date
1990
2000
2010
2020
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 19

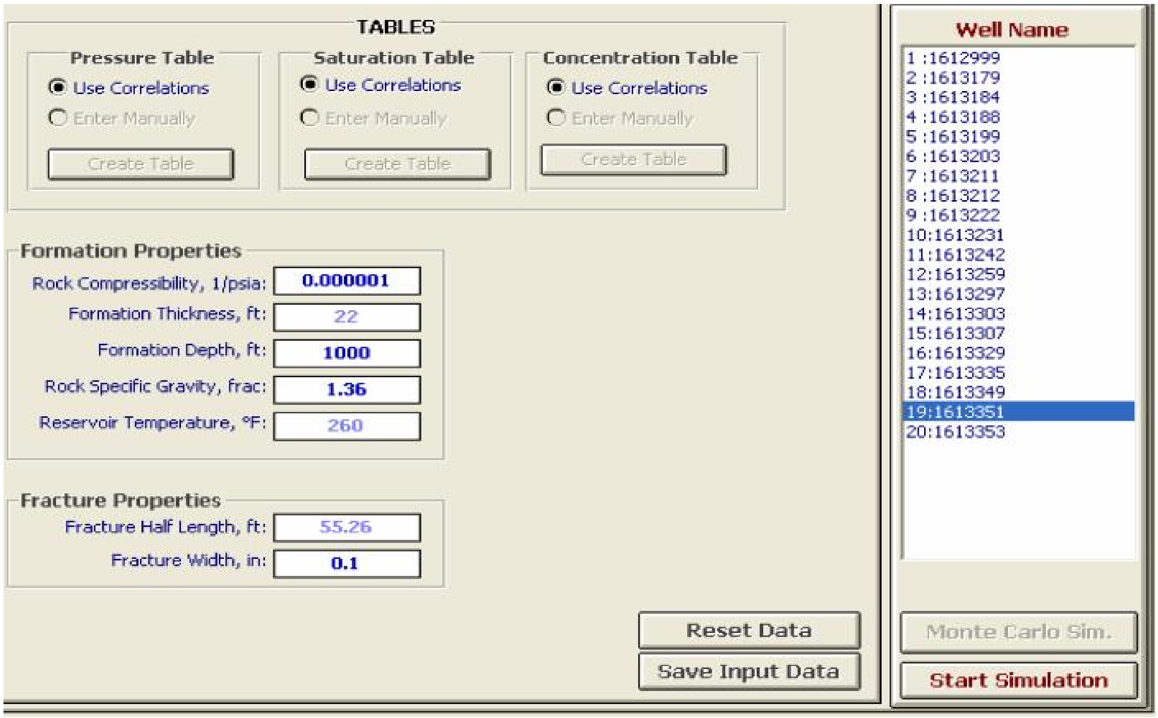
Decline Curve Analysis

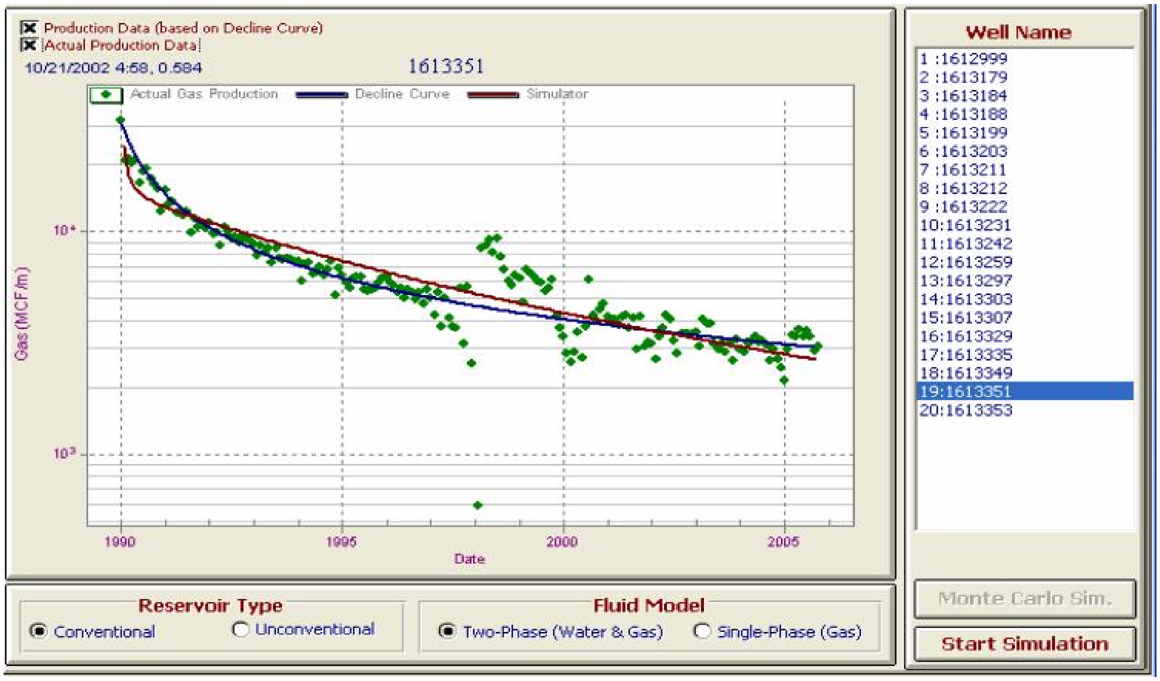


Type Curve Matching



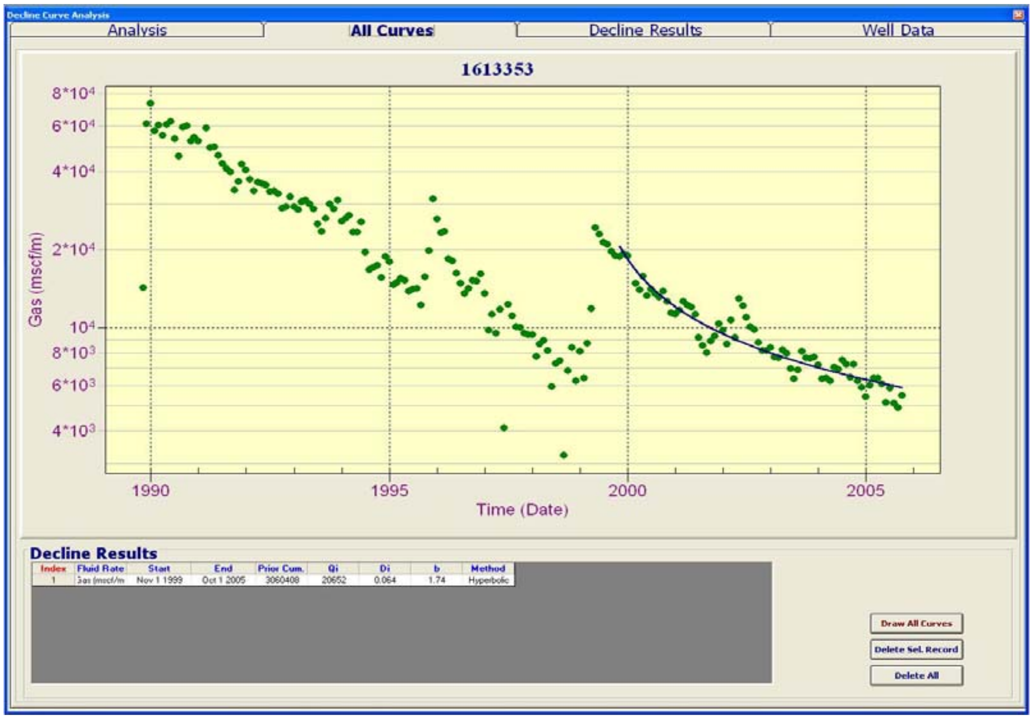
Numerical Simulation Results



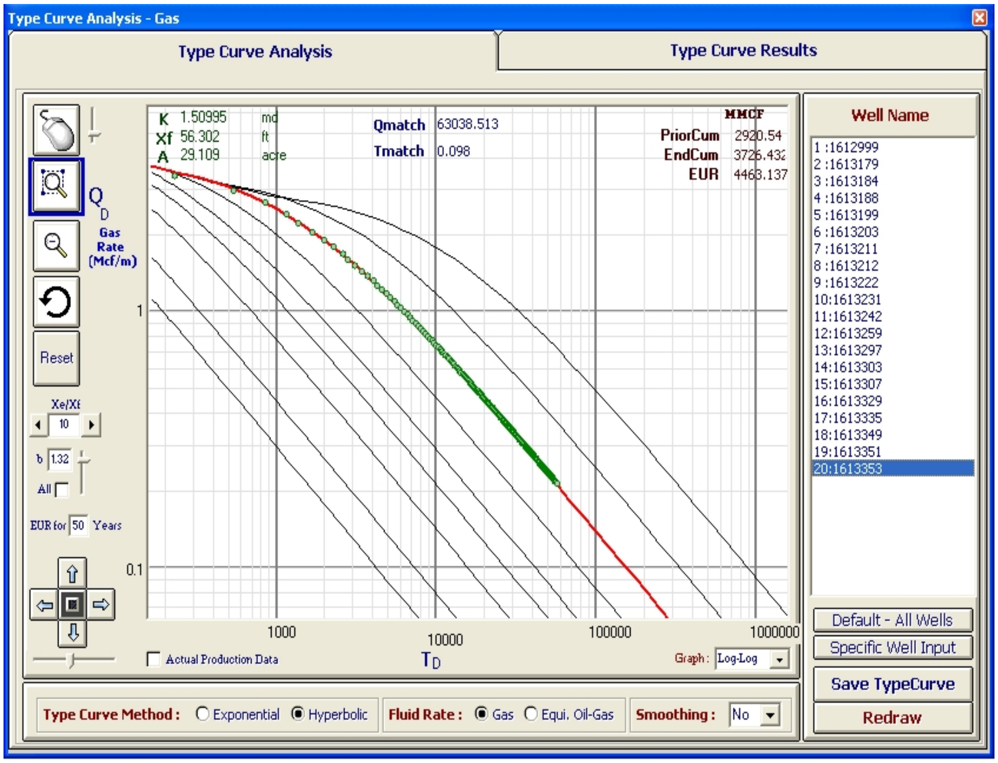

Production Data (based on Decline Curve)
Actual Production Data
10/21/2002 4:58, 0.584
1613351
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
10⁴
10³
1990
1995
2000
2005
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

WELL 20

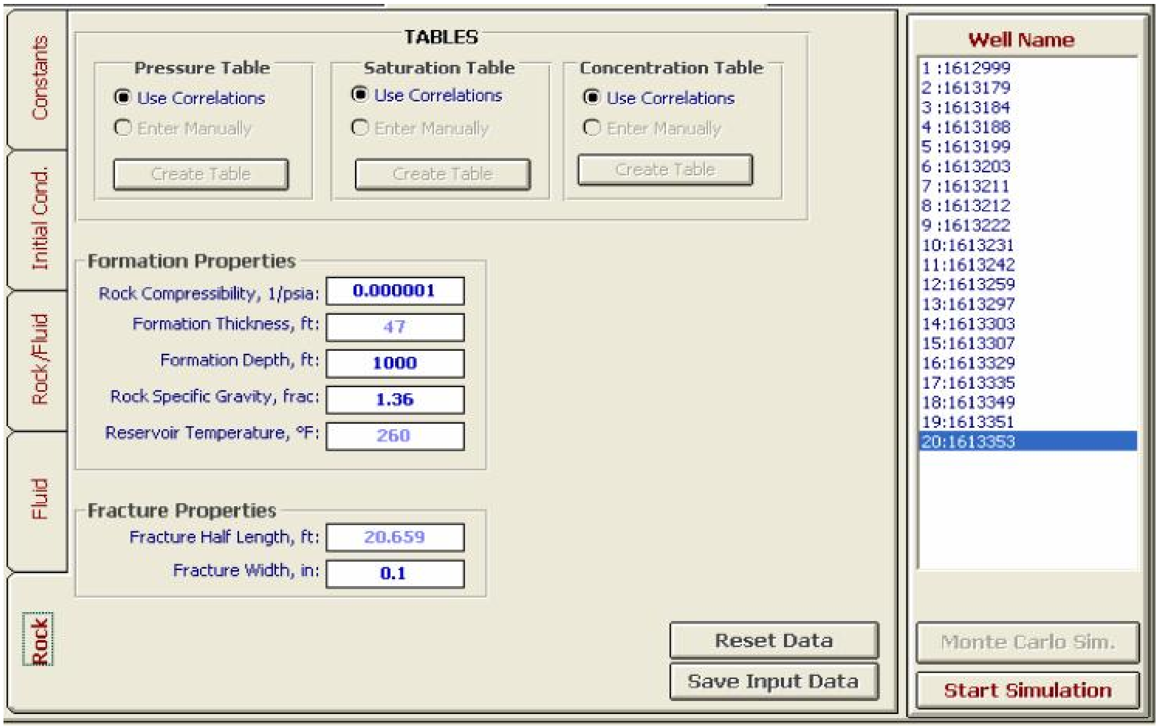
Decline Curve Analysis

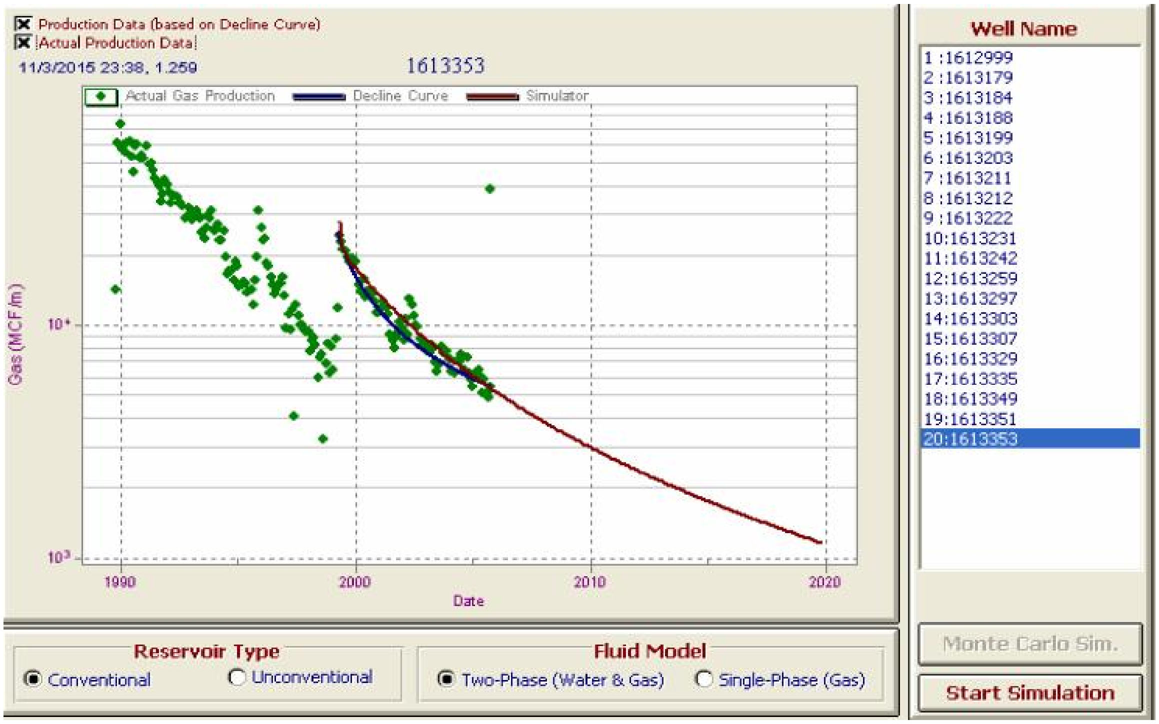


Type Curve Matching



Numerical Simulation Results

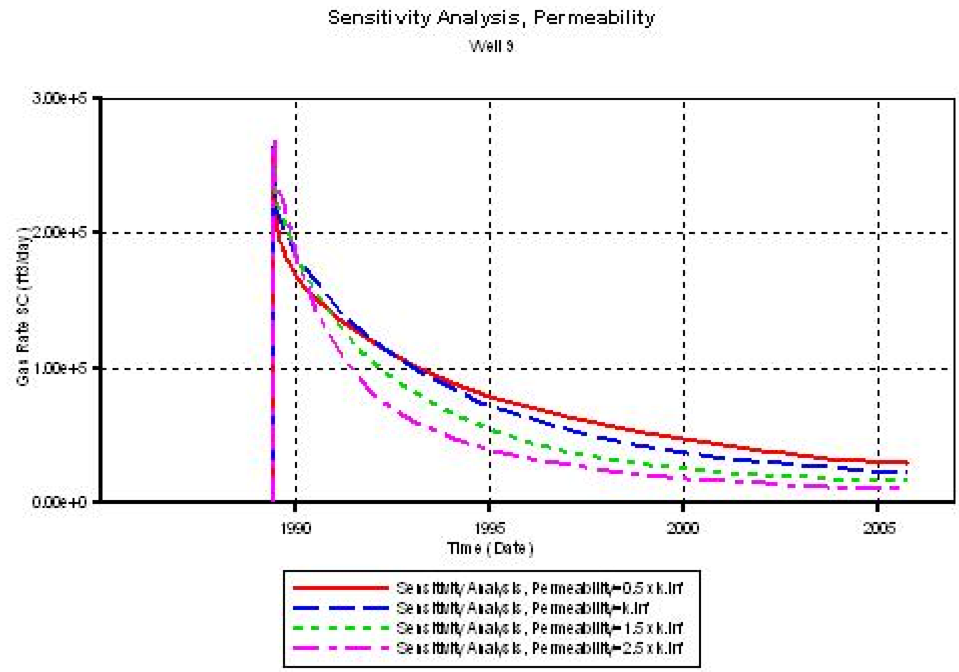




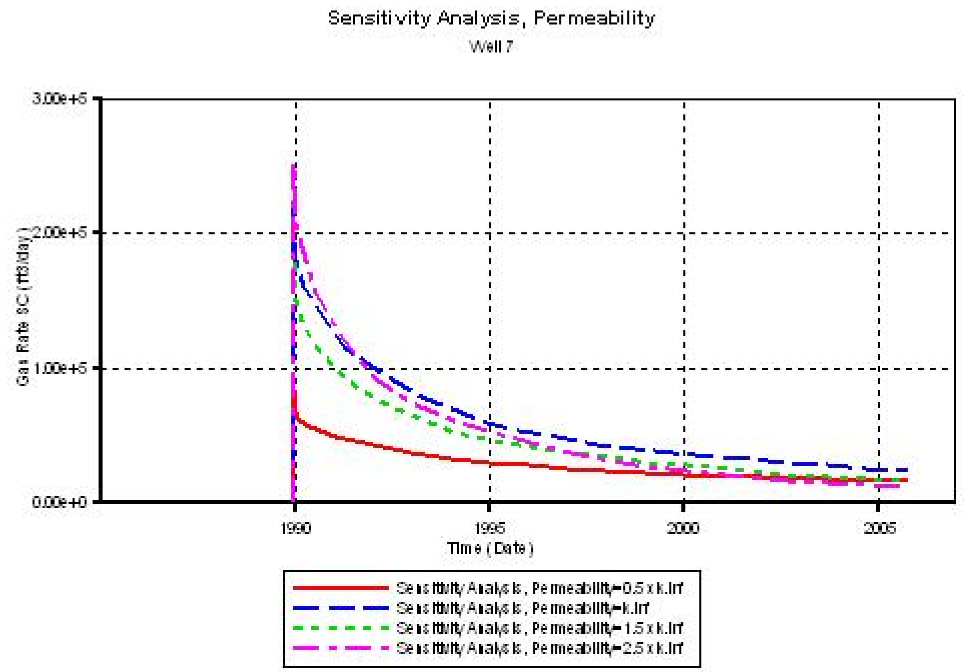
Production Data (based on Decline Curve)
Actual Production Data
11/3/2015 23:38, 1.259
1613353
Actual Gas Production
Decline Curve
Simulator
Gas (MCF/m)
10⁴
10³
1990
2000
2010
2020
Date
Well Name
1 :1612999
2 :1613179
3 :1613184
4 :1613188
5 :1613199
6 :1613203
7 :1613211
8 :1613212
9 :1613222
10:1613231
11:1613242
12:1613259
13:1613297
14:1613303
15:1613307
16:1613329
17:1613335
18:1613349
19:1613351
20:1613353
Reservoir Type
Conventional
Unconventional
Fluid Model
Two-Phase (Water & Gas)
Single-Phase (Gas)
Monte Carlo Sim.
Start Simulation

Appendix B

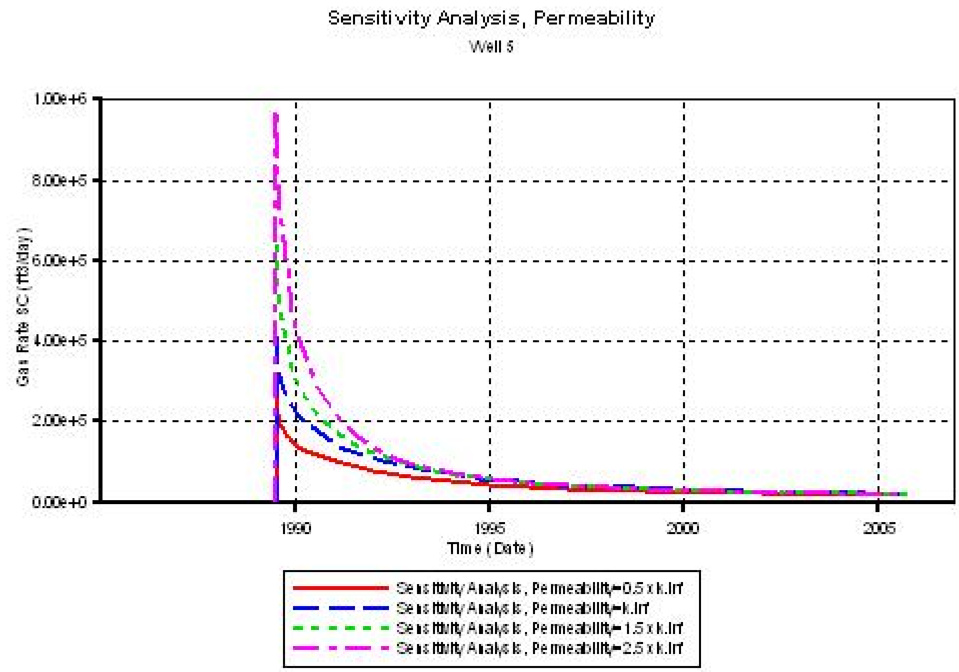
Sensitivity Analysis Permeability Results



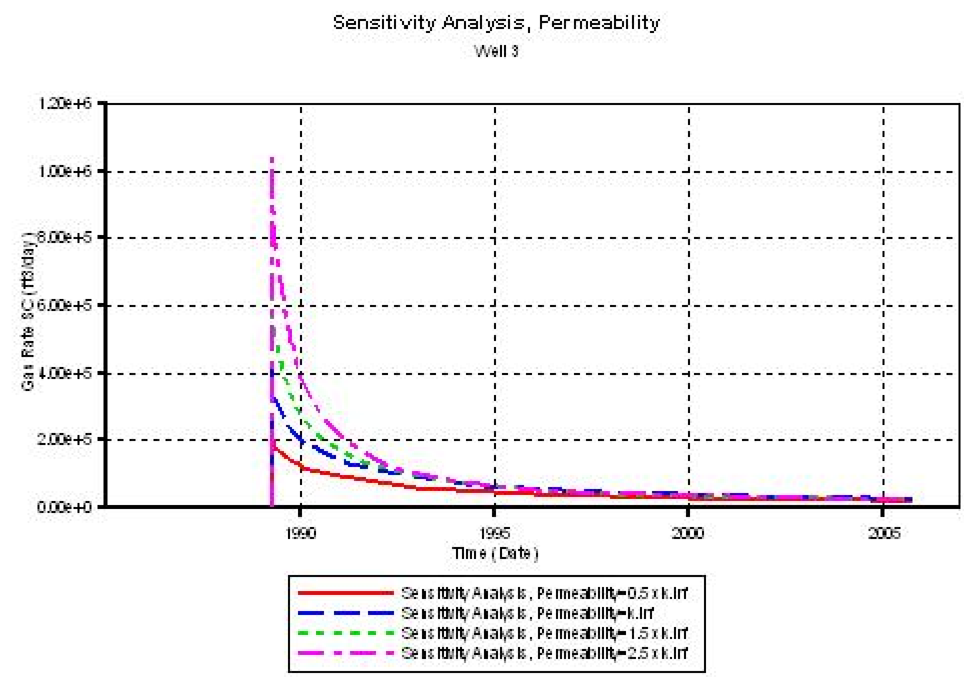
Source: C.Y.C. Field Consulting Services, Inc



Source: C.Y.C. Field Consulting Services, Inc

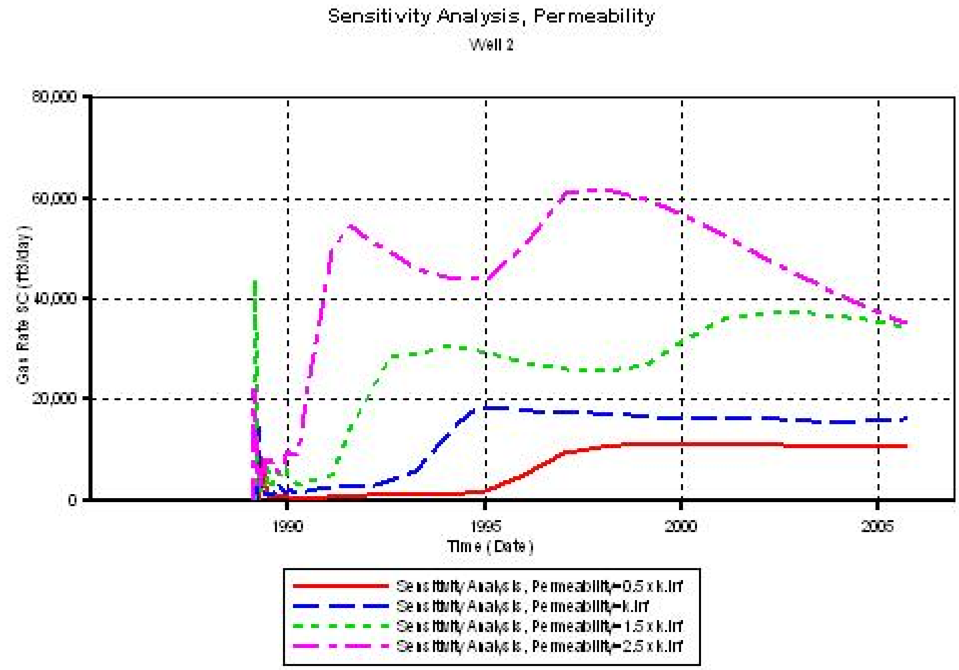


Source: C.Y.C. Field Consulting Services, Inc



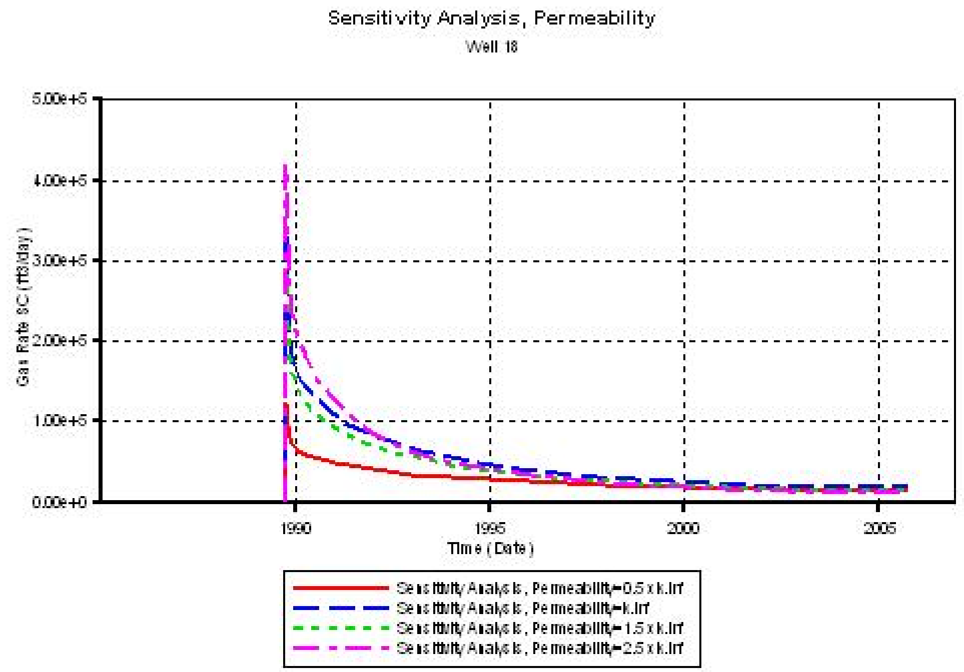
Source: C.Y.C. Field Consulting Services, Inc

[redacted]



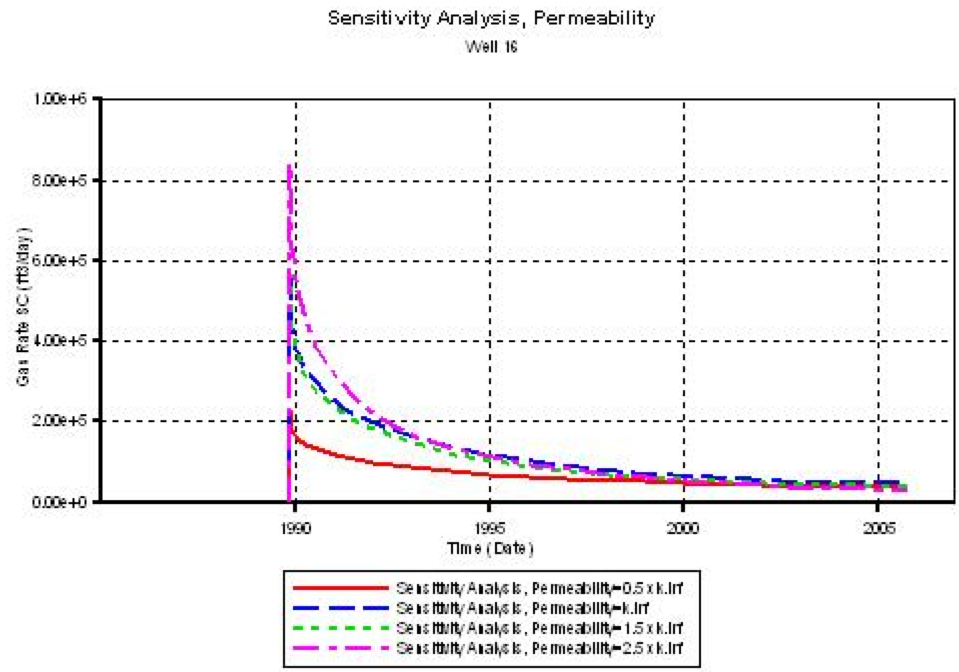
Source: C.Y.C. Field Consulting Services, Inc

[redacted]



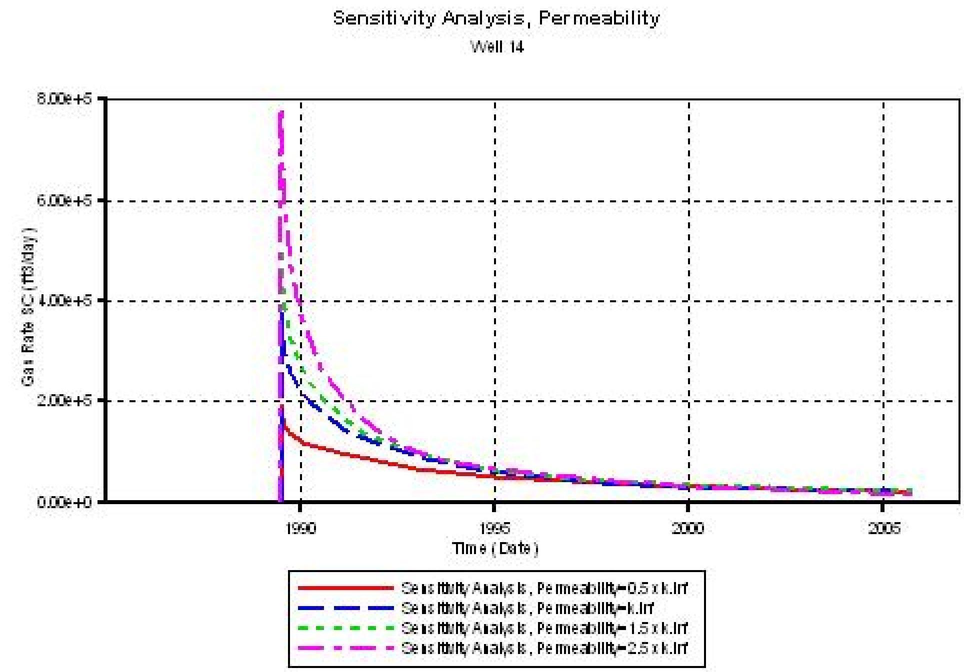
Source: C.Y.C. Field Consulting Services, Inc

[redacted]

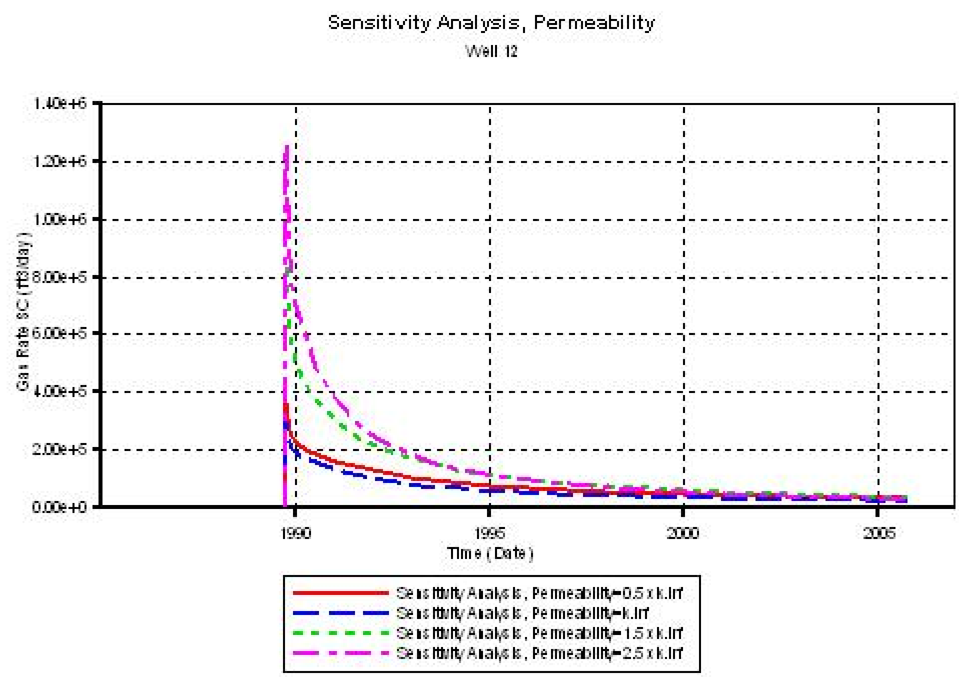


Source: C.Y.C. Field Consulting Services, Inc

[redacted]

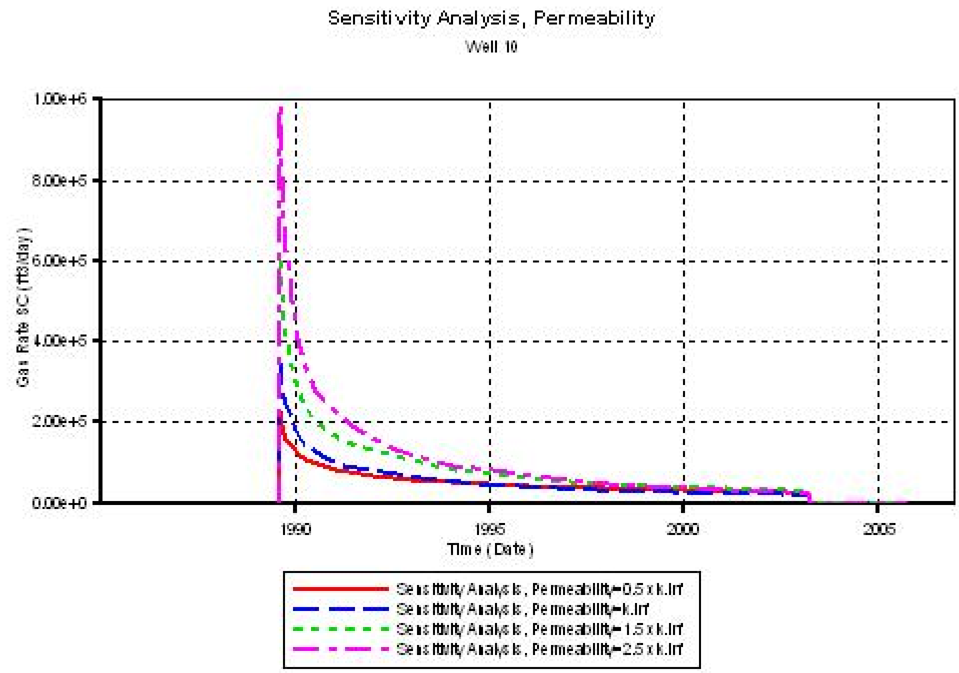


Source: C.Y.C. Field Consulting Services, Inc

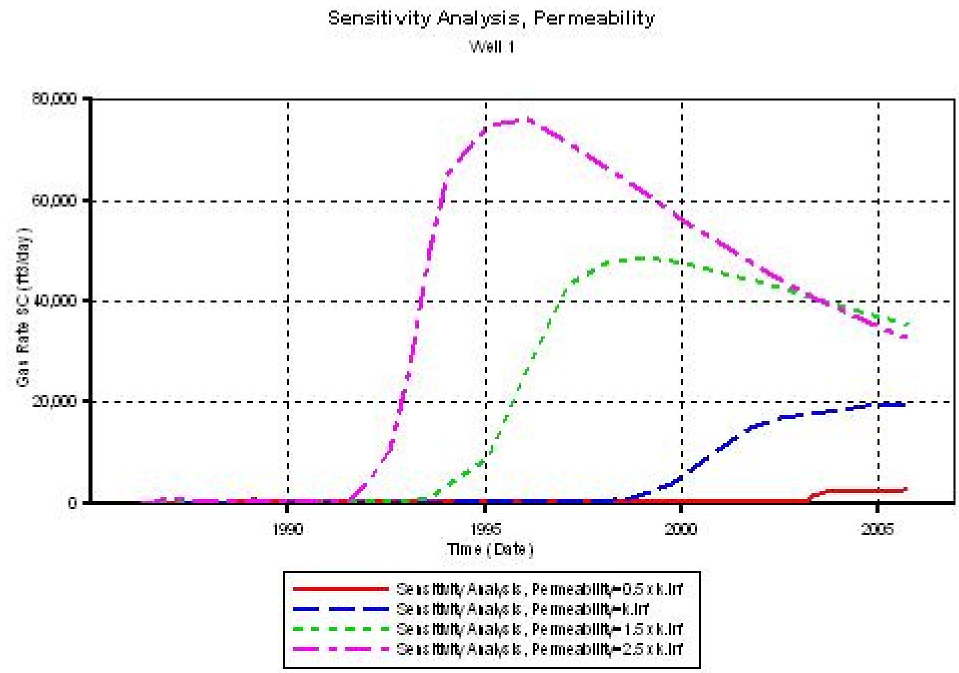


Source: C.Y.C. Field Consulting Services, Inc

[redacted]

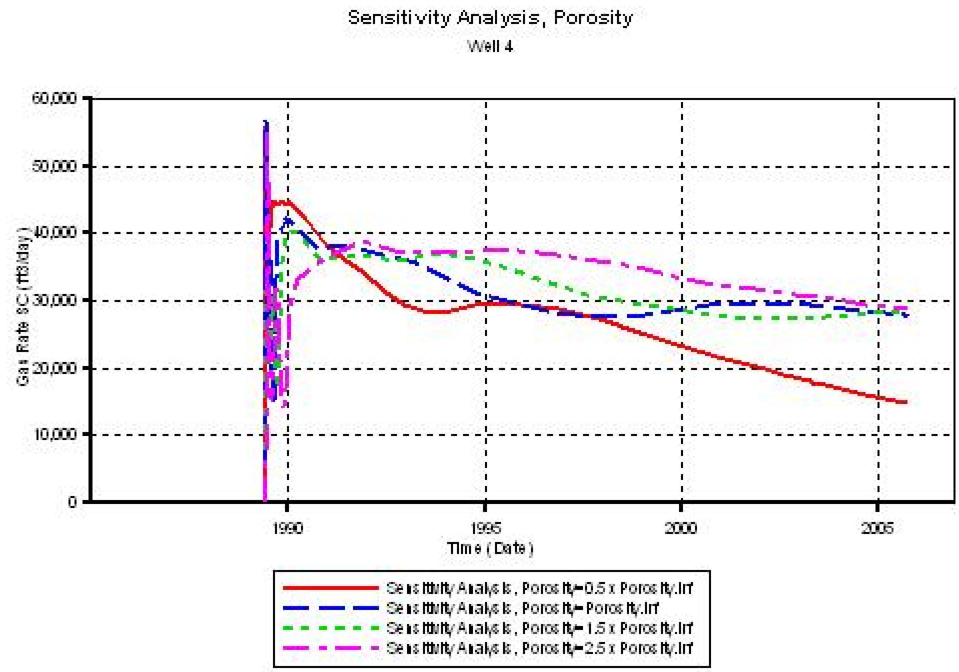


Source: C.Y.C. Field Consulting Services, Inc



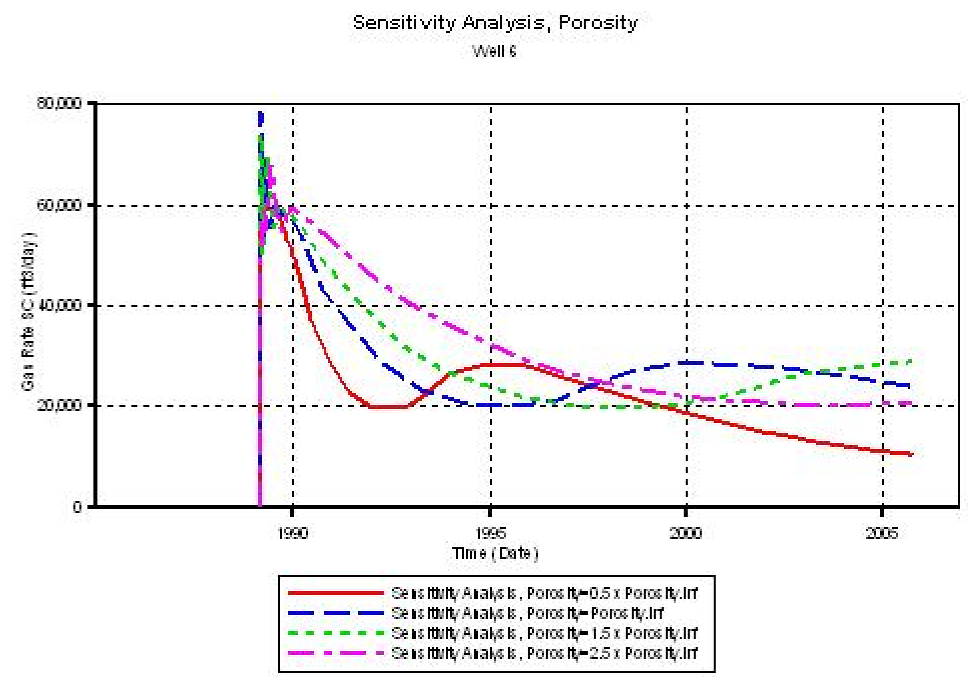
Source: C.Y.C. Field Consulting Services, Inc

Sensitivity Analysis Porosity Results



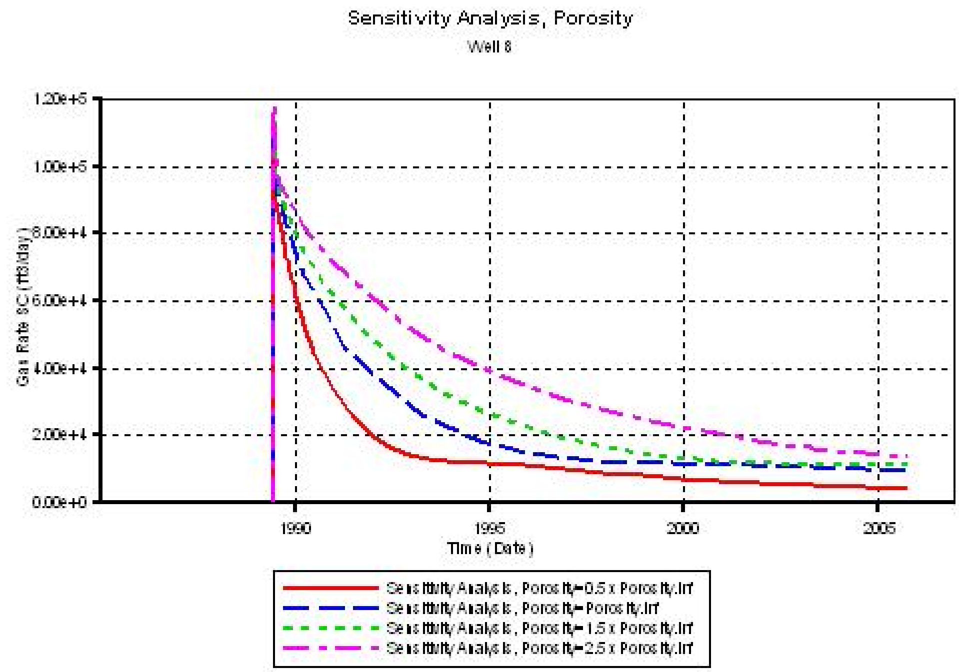
Source: C.Y.C. Field Consulting Services, Inc

[redacted]

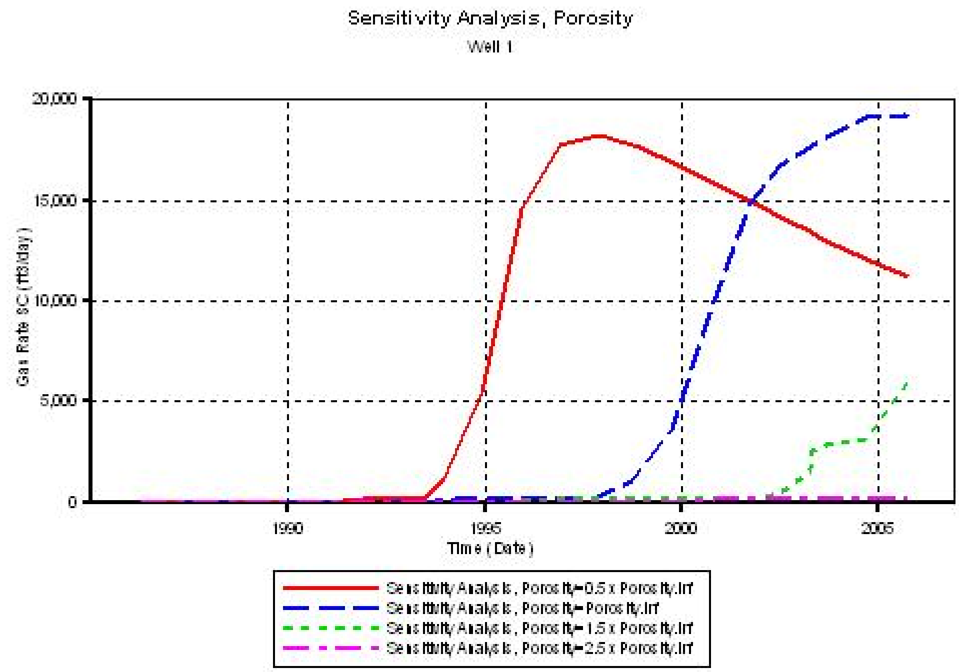


Source: C.Y.C. Field Consulting Services, Inc

[redacted]



Source: C.Y.C. Field Consulting Services, Inc



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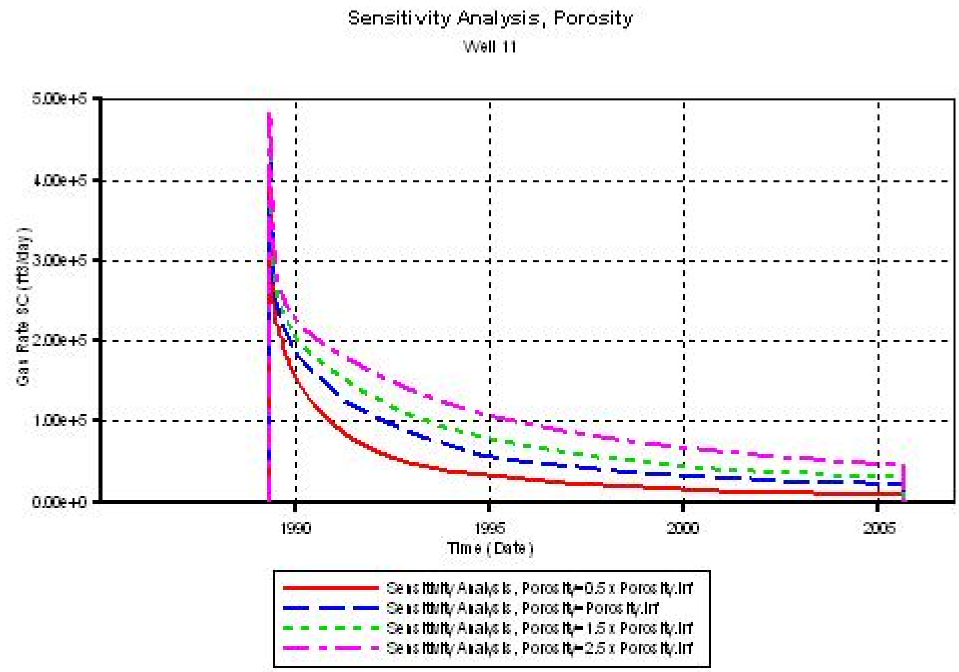

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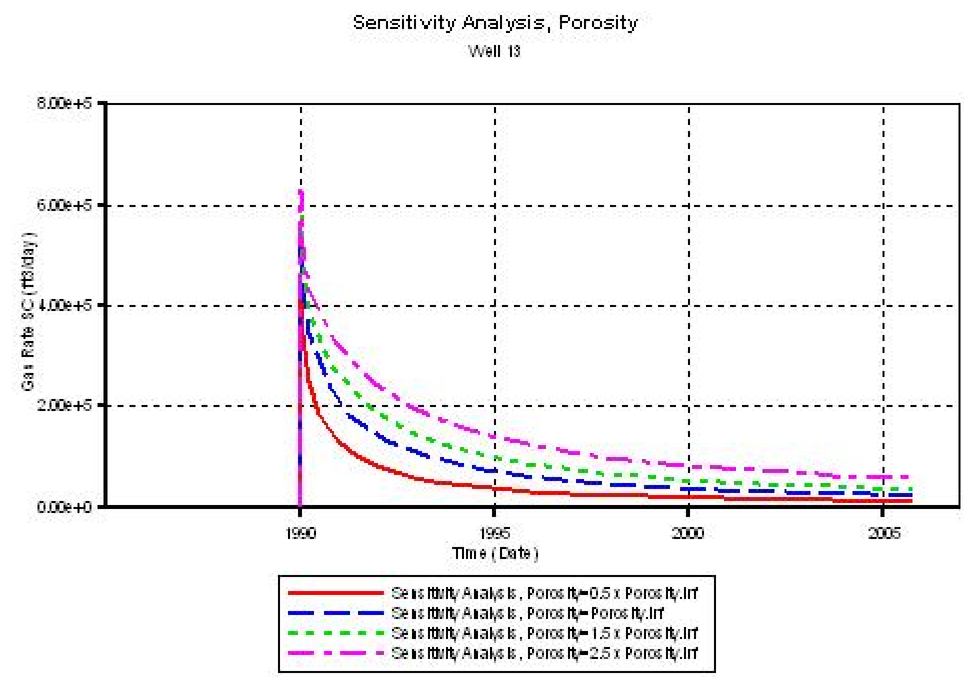

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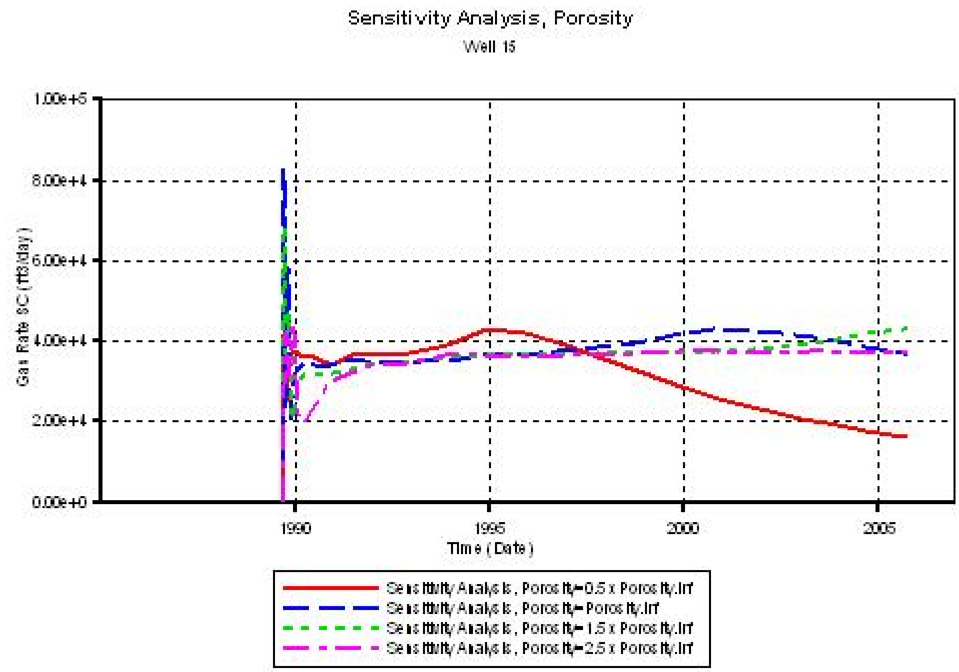

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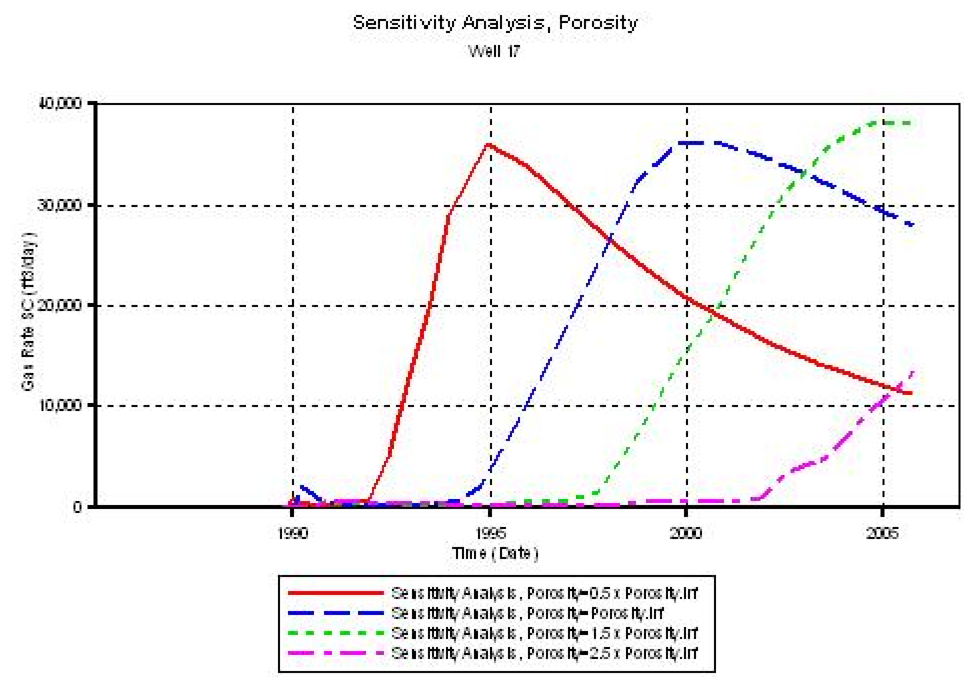

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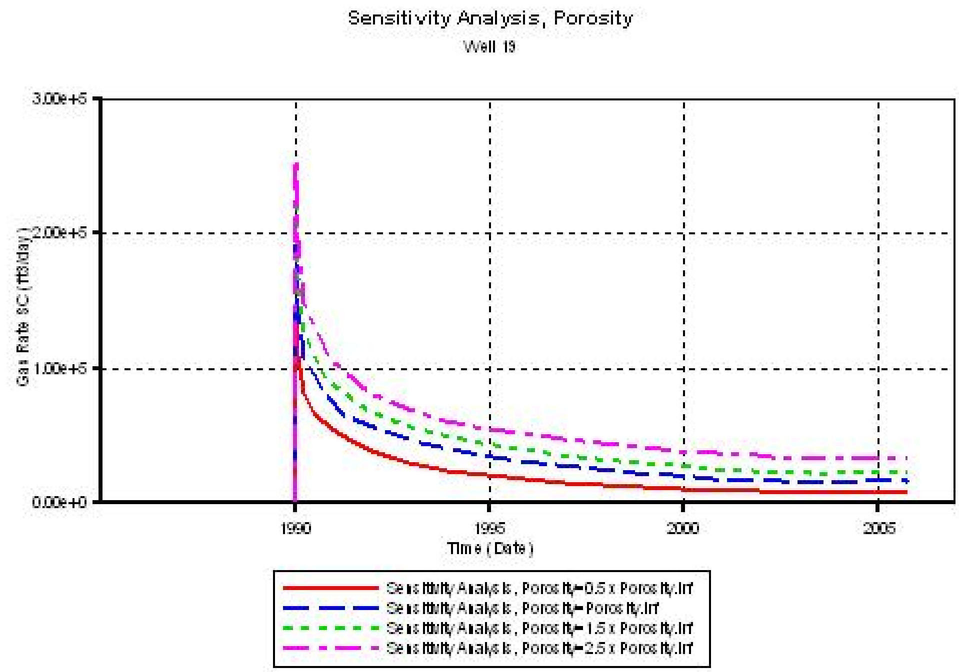

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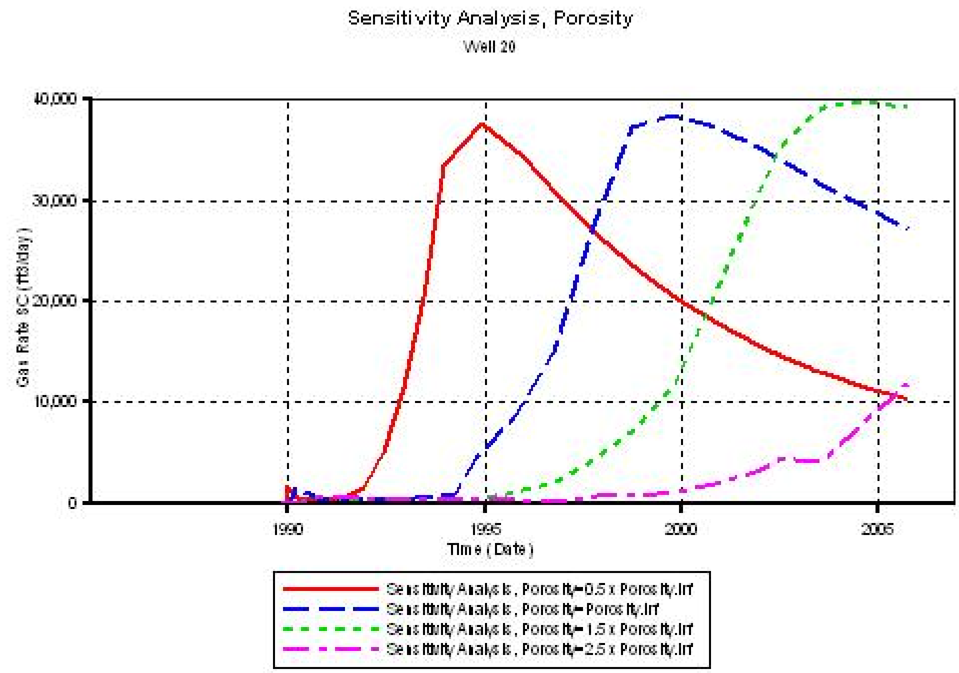

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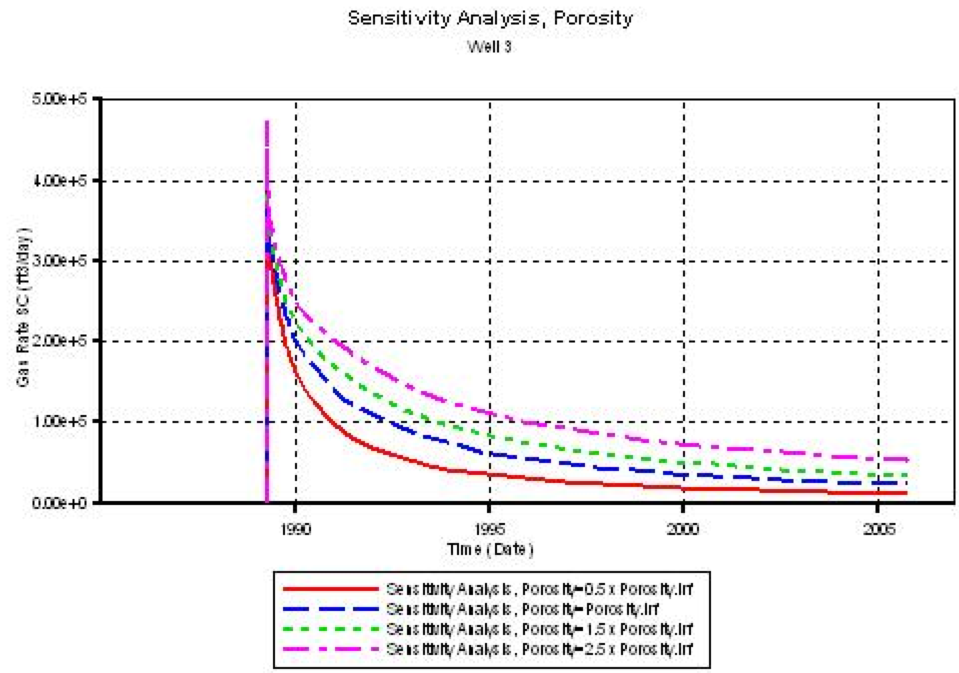

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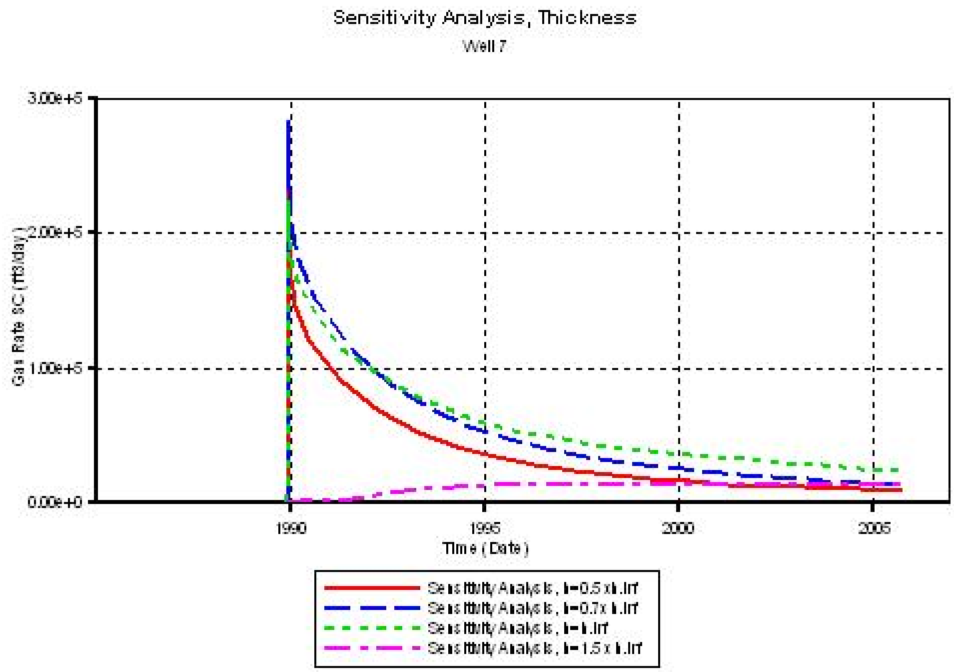
Sensitivity Analysis Thickness Results



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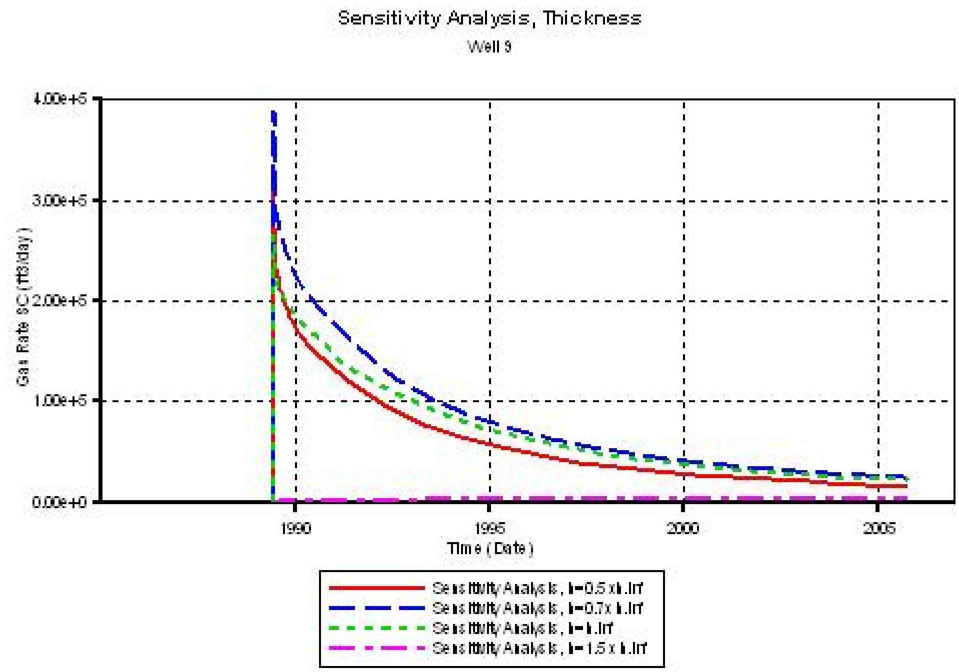

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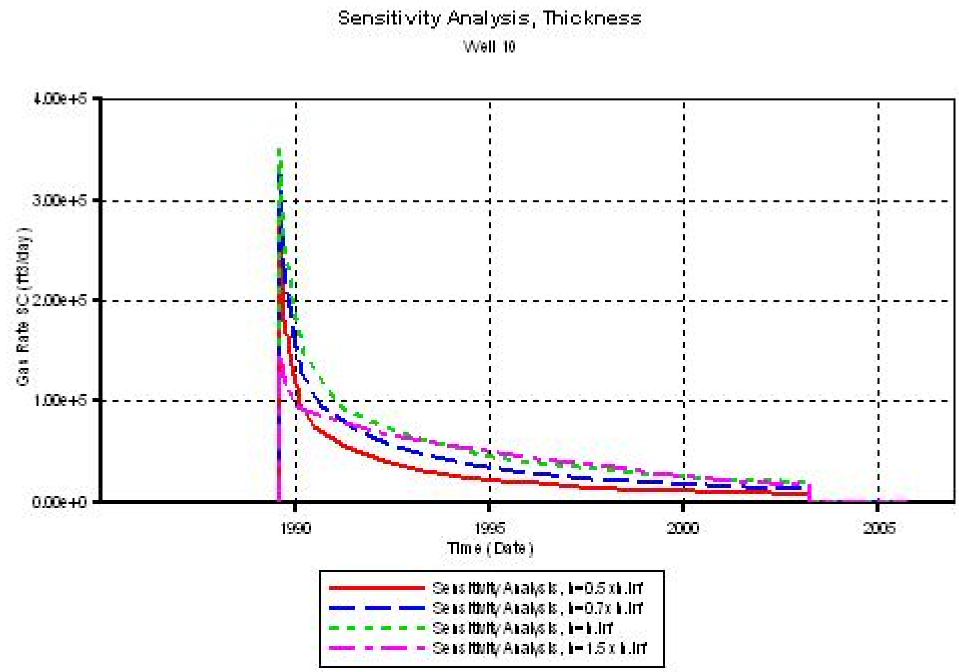

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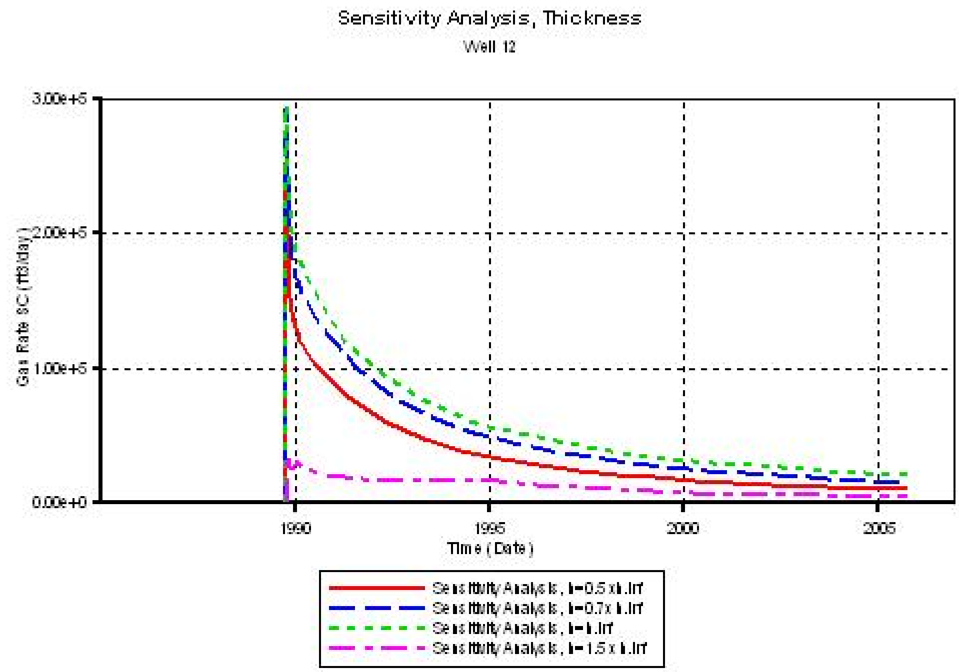

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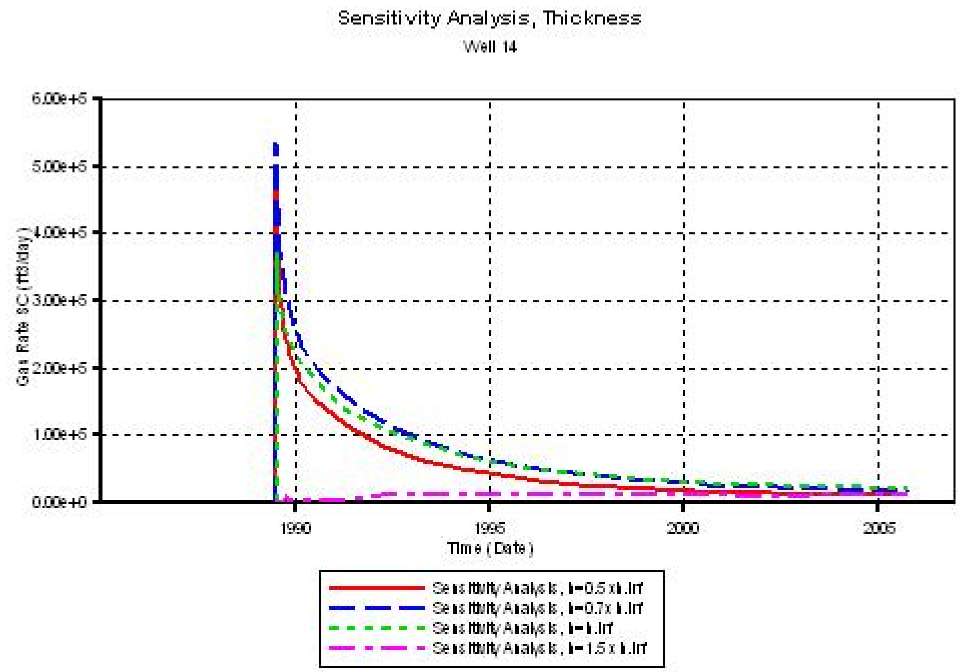

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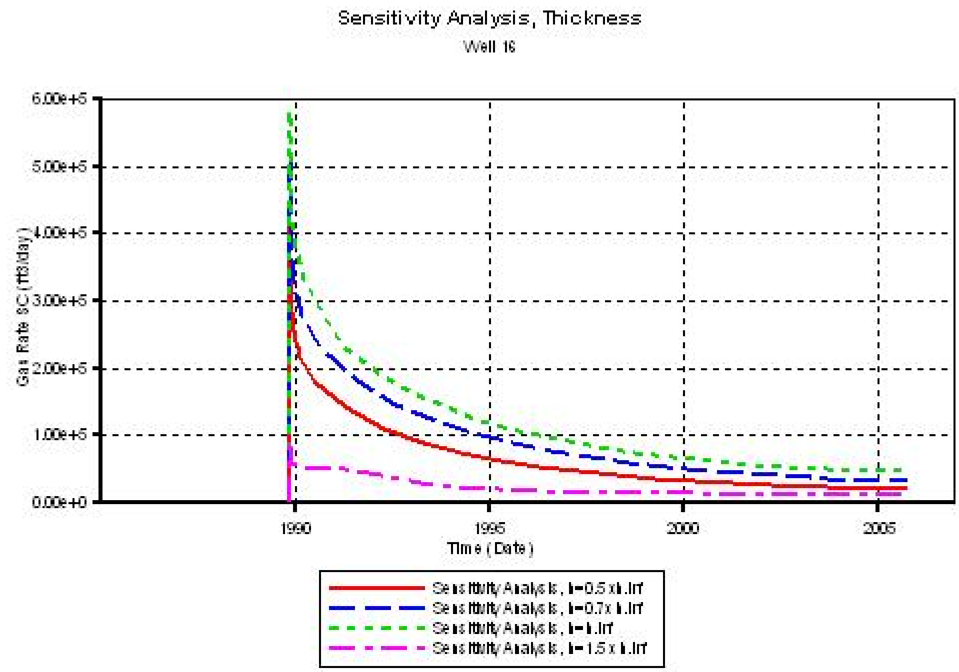

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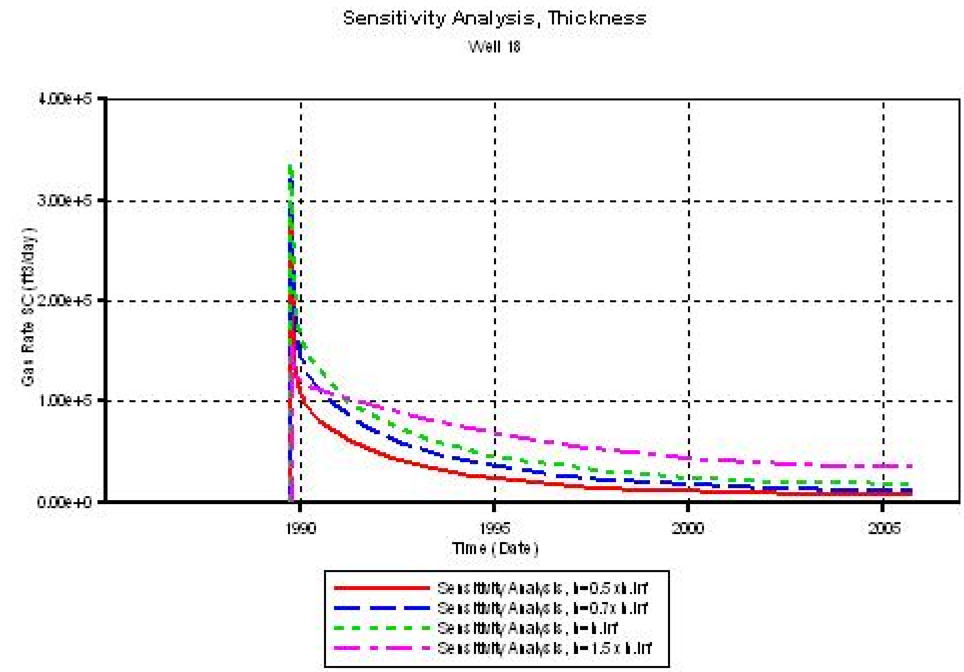

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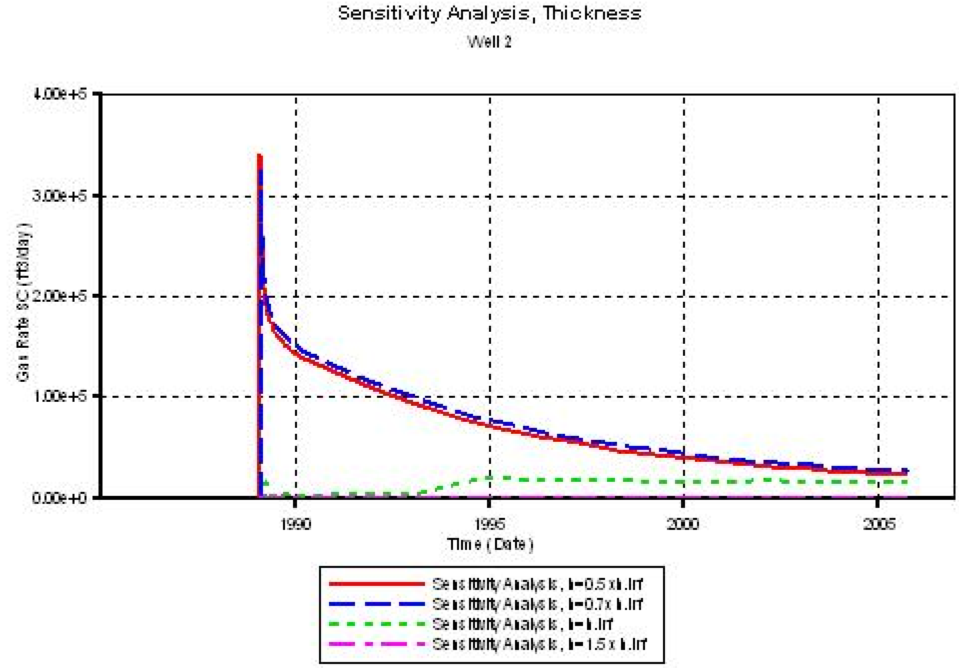

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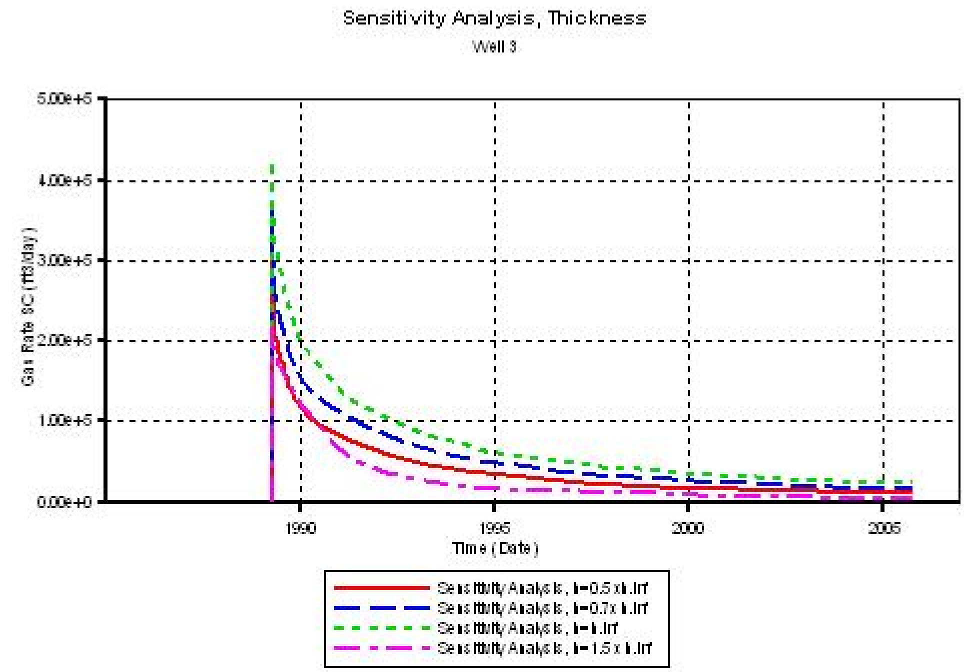

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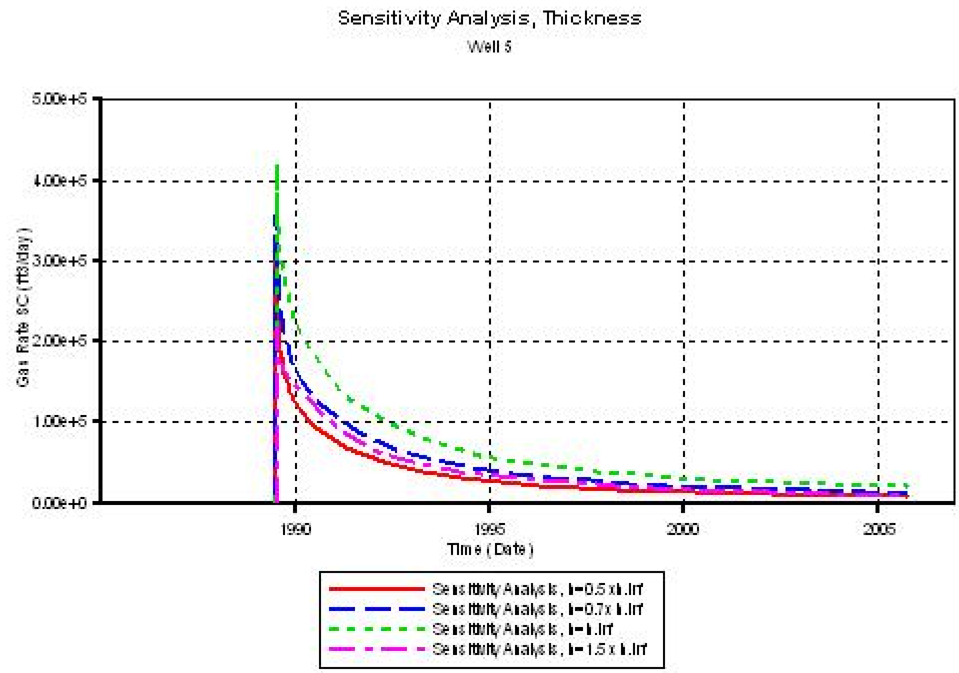

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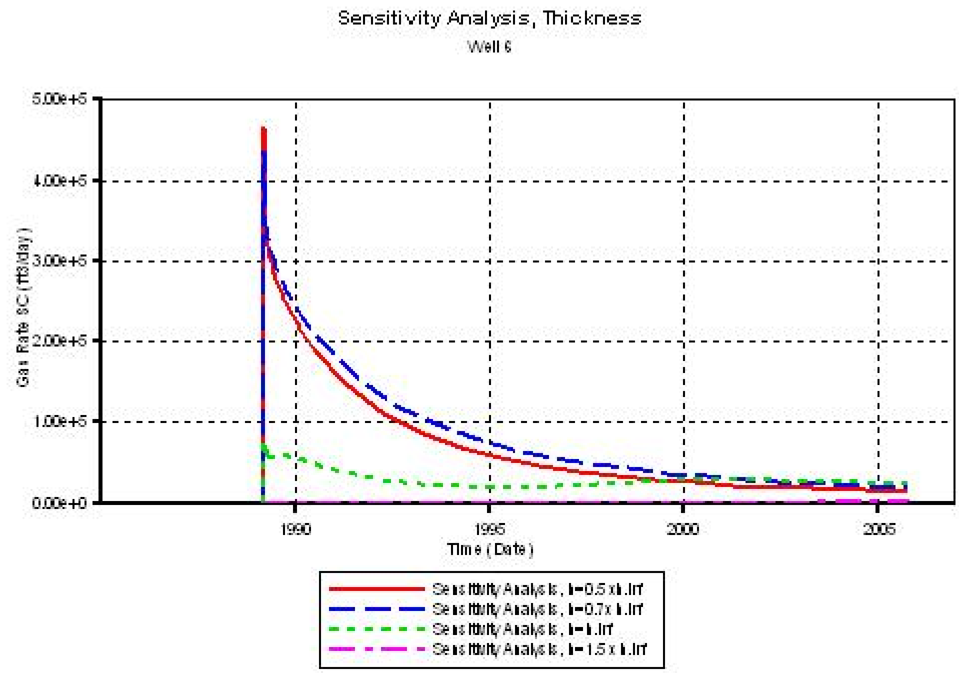

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