Gas Storage Field Deliverability Enhancement and Maintenance: An Intelligent Portfolio Management Approach.

Final Report

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ABSTRACT

Portfolio management, a common practice in the financial market, is essentially an optimization problem that attempts to increase return on investment. The objective of this project is to apply the state-of-the-art in optimum portfolio management to the gas storage field in order to optimize the return on investment associated with well remedial operations.

Each year gas storage operators spend hundreds of thousands of dollars on workovers, re-completions, and re-stimulations of storage wells in order to battle the decline in deliverability due to well damage with time. A typical storage field has tens if not hundreds of production wells. Each well will respond to remedial operations in its own unique way. The well's response to the remedial operation is a function of a set of uncontrollable reservoir characteristics such as porosity and permeability and a set of controllable parameters such as completion and stimulation practices.

The objective of this project is to identify the combination of best candidate wells for the remedial operations that will result in the most successful program each year, and consequently provides the highest return on investment. The project deliverable is a Windows-based software application that would perform the analysis and provide the list of wells and their corresponding remedial operation for each year based on the budget constraints identified by the user.

The state-of-the-art in intelligent systems application that is currently being used extensively in the Wall Street is the methodology to achieve the objectives of this proposed project. This methodology includes a hybrid form of artificial neural networks, genetic algorithms and fuzzy logic. Columbia Gas Transmission Corporation is the industry partner of this project and cooperated with the research and development team in order to ensure successful completion of the project.

The software application that is the deliverable of this project and is explained in much detail in this report is available to public free of charge. One important note about the software is that the current, publicly available version of the software includes a neural network model that has been developed for our industry partner based on the data that they made available. Once a storage operator decides to implement this software, they should contact the principal investigator of this project *(Shahab D. Mohaghegh, Professor, Petroleum & Natural Gas Engineering, West Virginia University, Email: shahab@wvu.edu - Tel; 304-293-7682 ext. 3405 – Web Site: http://shahab.pe.wvu.edu)* and arrange for development of a neural network model for their specific storage field. In order to make the best use of capabilities of the software package, it is recommended that the storage filed have a minimum of 75 wells (wells with data that can be used for analysis).

TABLE OF CONTENTS

Abstract 3
Table of Content 4
List of Figures 5
List of Figures 7
Introduction 8
Executive Summary 9
Experimental 10
Results & Discussions 11
Conclusions 102
References 103

LIST OF FIGURES

Figure 1. Well-bore data retrieved from a file 14
Figure 2. Correction of Wrong API number in data 15
Figure 3. Data addition and refinement for Well-bore Data 16
Figure 4. Multiple Data Entries in Completion Table 18
Figure 5. Well-bore data retrieved from a file 20
Figure 6. Data addition and refinement for Completion Data 19
Figure 7. Perforation data retrieved from a file 22
Figure 8. Data addition and refinement for Perforation Data 23
Figure 9. Perforation data retrieved from a file 25
Figure 10. Microfiche to Database process 26
Figure 11. Different formats of Nitrogen Amount 27
Figure 12. Data addition and refinement for Stimulation Data 29
Figure 13. Tubing head pressure profile for multi-point test 33
Figure 14. Bottom-hole pressure profile for multi-point test 33
Figure 15. Flow test 1 – Delta pressure squared vs. time 34
Figure 16. Flow test 2 – Delta pressure squared vs. time 34
Figure 17. Extended flow test – Delta pressure squared vs. time 35
Figure 18. Log-log graph 35
Figure 19. Gas properties simulator 36
Figure 20. Calculation of true skin 37
Figure 21. Calculation of true skin from build up test 38
Figure 22. Retrieving flow rate of an open flow test 40
Figure 23. Flow Diagram of Well Test Analysis procedure 42
Figure 24. Neural Network Inputs and their source 44
Figure 25. Accuracy of training data for the Neural Net 45
Figure 26. Accuracy of calibration data for the Neural Net 45
Figure 27. Accuracy of verification data for the Neural Net 46
Figure 28. Different option in the software that make it versatile 48
Figure 29. Data addition and refinement for well test data 49
Figure 30. Screen shot of database showing different tables 50
Figure 31. Main Screen of software 51
Figure 32. File Main options 52
Figure 33. Screen shot of Template file 53
Figure 34. Comment that shows format of some cells in Template Excel file........... 53
Figure 35. Import data from filled-out Template 54
Figure 36. Remove all data from database.. 54
Figure 37. Exit from file menu.................. 55
Figure 38. Help menu options.................. 55
Figure 39. “about” screen from help menu....... 56
Figure 40. Browsing through the well-bore data 57
Figure 41. Well-bore tab 59
Figure 42. Completion tab 60
Figure 43. Perforation tab 61
Figure 44. Stimulation tab 62
Figure 45. Well-test tab 63
Figure 46. Adding a complete new Well – well-bore tab 64
Figure 47. Adding a complete new Well - completion tab.............................. 65
Figure 48. Adding a complete new Well – entering data for wellbore 66

Figure 49. Adding a complete new Well – entering data for perforation …………… 66
Figure 50. Adding a complete new Well – entering data for stimulation …………… 67
Figure 51. Adding a complete new Well – entering data for well test …………… 67
Figure 52. Result of adding a complete new well ……………………………………. 68
Figure 53. Editing well data ………………………………………………………. 71
Figure 54. Editing completion data …………………………………………… 72
Figure 55. Saving completion data …………………………………………… 73
Figure 56. Saved completion data …………………………………………… 74
Figure 57. Deleting perforation record ……………………………………………. 75
Figure 58. Finding a well …………………………………………………… 76
Figure 59. Well-test Analysis Option in well-test tab ………………… 77
Figure 60. Show Chart – Peak Day Rate ………………………………………….. 77
Figure 61. Show Chart – Absolute Open Flow …………………………………. 78
Figure 62. Show Chart – Skin …………………………………………………… 78
Figure 63. Show Chart – All Well Tests …………………………………………… 79
Figure 64. Well Test Analysis button …………………………………………… 80
Figure 65. Well Test Analysis module …………………………………………… 80
Figure 66. Well Test Analysis tool …………………………………………… 82
Figure 67. Draw a line and calculate the slope …………………………………… 83
Figure 68. Simplified well test analysis tool …………………………………… 83
Figure 69. Simplified well test with one well test before or after stimulation………… 84
Figure 70. LIT well test analysis………………………………………….………… 85
Figure 71. Multi point well test analysis ………………………………………….. 86
Figure 72. Well extended pressure profile …………………………………… 87
Figure 73. Selecting the build-up selection from pressure profile …………………… 89
Figure 74. Diagnostic plot analysis ……………….…………………………… 90
Figure 75. Calculating skin from Hornet plot …………………………………… 91
Figure 76. Selecting Ohio County …………….………………………………. 91
Figure 77. Selecting wells according to stimulation year ………………………… 92
Figure 78. Offset wells ……….………………………………………….. 92
Figure 79. Selecting Well Parameters …………………………………………… 93
Figure 80. Result of the wells & parameters selected ………………………...… 94
Figure 81. Start Candidate Selection from main screen …………………………..… 95
Figure 82. Candidate Selection main screen …………………….…………..… 95
Figure 83. Selecting a well for candidate selection ……………………..…… 99
Figure 84. Options to control Candidate Selection process …………………… 97
Figure 85. Cost analysis Module……………………………………..…………… 99
Figure 86. Inputs that used to train the Neural Network ……………………….…… 99
Figure 87. Select the controllable parameters in optimization process …………… 100
Figure 88. Setup GA parameters……………………………………………………. 100
Figure 89. If one of the Neural Net input is well test before stimulation it could setup here. 100
Figure 90. Optimization process for one well……………………………………… 101
Figure 91. Optimization result for selected wells…………………………………… 101
Figure 92. Rank the optimization result based on delta skin in order to find the best candidate 101

LIST OF TABLES

Table 1. Draw down Test Results ………………………………………… 37
Table 2. Build-up test results ……………………………..…………….... 39
Table 3. Average Results ……………………………………………………………… 39
Table 4. Calculation to determine the length of chromosome …………………………. 47
Table 5. CA characteristic ………………………………………………………….. 47

INTRODUCTION

Each year Gas Storage operators spend hundreds of thousands of dollars to combat the inevitable decline in the deliverability of their production wells. The decline in deliverability with time has two major contributors. The first contributor is geology and reservoir characteristics that are uncontrollable parameters. The second sets of parameters that contribute to the decline are associated with well damage that is addressed by well remedial operations such as workovers, re-completions, and re-stimulation of the producing wells. The parameters associated with these remedial operations can be controlled by the operator.

It is a fact that every well will respond to a specific remedial operation in a unique way. For example, the deliverability of well "A" will increase two folds if a proper restimulation is performed on it while the same operation performed on well "B" will result in little or no deliverability enhancement. Same is true for workovers. Finding the best candidate for restimulation or workover, each year, among the tens or hundreds of wells is a challenging task. Consider another situation where well "C" will have a 70% increase if a restimulation is performed but it would have a 65% increase if a far less expensive workover is performed. Obviously performing a workover instead of a restimulation on well "C" would be more economical this year.

EXECUTIVE SUMMARY

Portfolio management, a common practice in the financial market, is essentially an optimization problem that attempts to increase return on investment. The objective of this project is to apply the state-of-the-art in optimum portfolio management to the gas storage field in order to optimize the return on investment associated with well remedial operations.

Each year gas storage operators spend hundreds of thousands of dollars on workovers, re-completions, and re-stimulations of storage wells in order to battle the decline in deliverability due to well damage with time. A typical storage field has tens if not hundreds of production wells. Each well will respond to remedial operations in its own unique way. The well's response to the remedial operation is a function of a set of uncontrollable reservoir characteristics such as porosity and permeability and a set of controllable parameters such as completion and stimulation practices.

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EXPERIMENTAL

No experimental work was performed during this project.

RESULTS & DISCUSSIONS

This is the detail report of the progress made so far in the above mentioned project, which consists of following components:

1- Project Overview
2- Data made available and its format
3- Neural Network Model
4- Genetic Optimization Model
5- Database & Software

PROJECT OVERVIEW

The objective of this project is to apply state-of-the-art intelligent, optimum portfolio management to the gas storage field in order to optimize the return on investment associated with well remedial operations. Columbia Gas Transmission Corporation is the industry partner in this project and provided us with very valuable data and in-depth knowledge about their gas storage field operations.

The data in very crude form was provided to the research and development team in the last week of March, 2005. The team extracted valuable data and organized it in a form of database, with generic make up in order to be reusable. Windows-based software was developed which can help the user in viewing and later populating the data with easy to use interface. One of its modules provides the user with all the valid stimulations required as an input for Neural Network. A Neural Network was trained in order to predict skin for different stimulation parameters. A Genetic Optimization tool was developed and associated with the trained Neural Network in order to find the optimum stimulation parameters. The software ranks the well according to maximum change in skin value or/and stimulation cost for a well. Then a decision is made to re-stimulate a well or not accordingly.

DATA MADE AVAILABLE AND ITS FORMAT

The research and development (R & D) team was initially provided data in MS excel worksheets. On further request, some pdf files with well schematics, well test files and well summary files were provided but still the required data especially relating to stimulations and well-tests was so scarce that the team in July, 2005 went to the Columbia Transmission Corporation Office in Charleston, WV to get more information. Retrieval of data from different files and thousands of microfiche was taking so long at the office that it was decided that West Virginia University lab facilities will be used to read thousands of microfiche. So, for the next few weeks the team concentrated its efforts on data collection. That data could be segregated into five main tables, each relating to specific characteristic features of the gas storage wells. The five characteristic features are as below:

1- Well-bore data
2- Completion Data
3- Perforation Data
4- Stimulation Data
5- Well-Test Data
6- Reservoir Characteristic Data

WELL BORE DATA

It includes basic features of the well like location, depth, well name … etc. Data about well-bore was retrieved mostly from well schematics and well summary reports. The data already provided by Columbia Transmission Corporation was also verified. The complete list of the data type retrieved is as below:

1. API Number
2. Field Name
3. Well
4. Lease Name
5. Classification
6. Latitude (Lat)
7. Longitude (Long)
8. Section
9. Township
10. County
11. State
12. Operator
13. Total Vertical Depth
14. Formation

Picture of one of the forms from which this data was retrieved is on next page

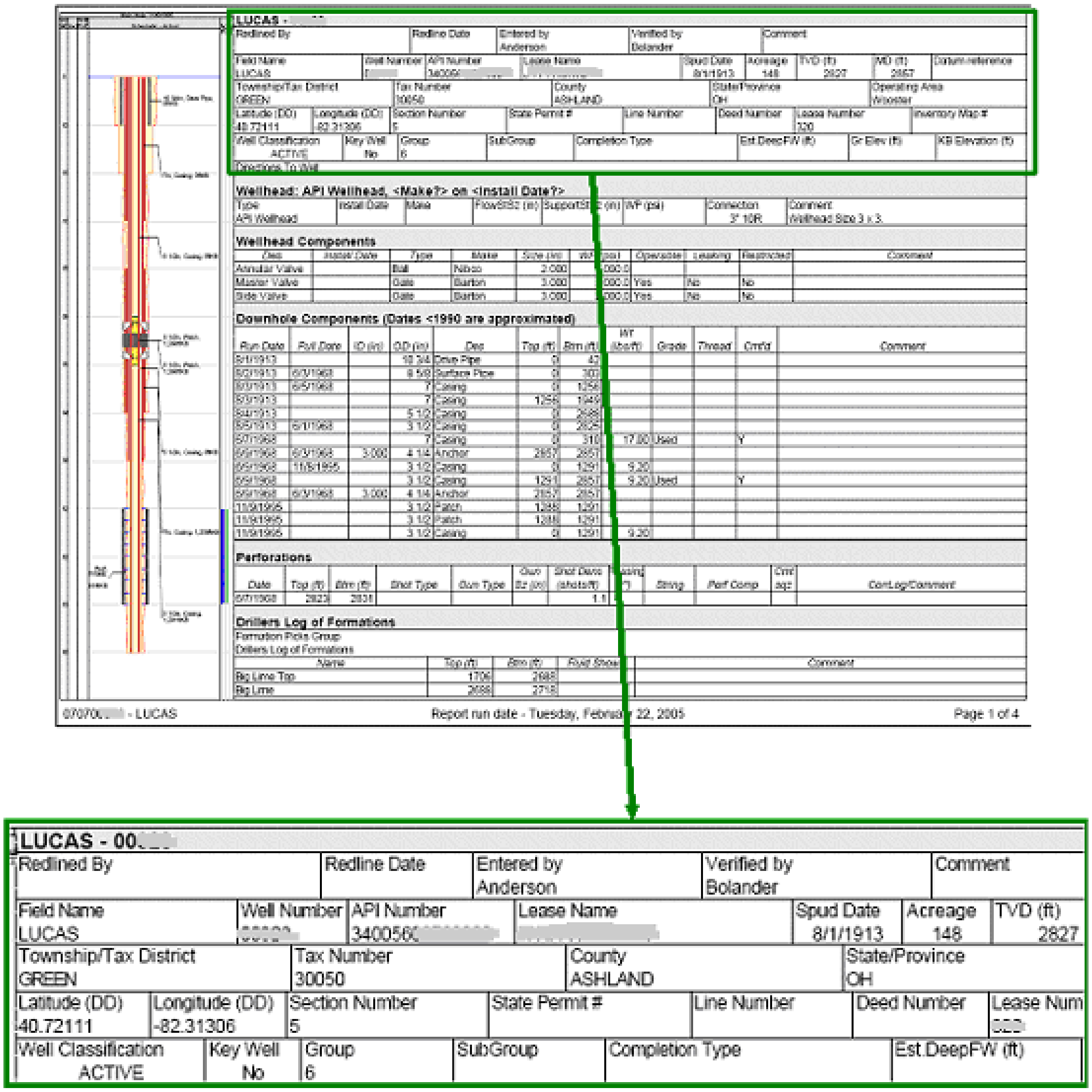


Fig1. Well-bore data retrieved from a file

The tables contained many minor mistakes like wrong Well API number, length, and many spelling mistakes. A picture of this correction is shown below:

	A	B	C	D	E	F	G	H	I	J	K
1	Field Name	Well	Lease Name	API	Classification	Latitude	Longitude	Section	Township	County	State
32	LUCAS	03897	"SYLVIA C. KROUT, ET AL"	34-005-93897	ACTIVE	40.6961	-82.3058	17	GREEN	ASHLAND	OH
33	LUCAS	03912	P. SHAFFER #1	34-005-602660000	SPECIAL	40.7133	-82.24	1	GREEN	ASHLAND	OH
34	LUCAS	03921	G. W. HINER #2	34-005-93921	ACTIVE	40.7383	-82.2719	34	VERMILLION	ASHLAND	OH
35	LUCAS	03926	JOHN BUSLER #1	34-005-602650000	ACTIVE	40.7106	-82.2358	12	GREEN	ASHLAND	OH
36	LUCAS	03929	D. KICK #1	34-005-93929	ACTIVE	40.7103	-82.2611	10	GREEN	ASHLAND	OH
37	LUCAS	03931	W. E. GUTHRIE #1	34-005-93931	ACTIVE	40.6889	-82.3047	17	GREEN	ASHLAND	OH
38	LUCAS	03932	H. J. TRUMPOWER #1	34139601180000	ACTIVE				MONROE	RICHLAND	OH
39	LUCAS	03935	J. O. ANDREWS #2	34-005-93935	ACTIVE				GREEN	ASHLAND	OH
40	LUCAS	03939	M. A. MAURER #1	34-005-93939	ACTIVE				VERMILLION	ASHLAND	OH
41	LUCAS	03945	"RUSSEL J. LIFER, ET UX"	34-005-93945	ACTIVE				GREEN	ASHLAND	OH
42	LUCAS	03946	C. SMITH #1	34005602420000	ACTIVE	40.6703	-82.3339	19	GREEN	ASHLAND	OH
43	LUCAS	03950	G. W. PURVINE #1	34139601230000	active	40.6736	-82.3453	24	MONROE	RICHLAND	OH
44	LUCAS	03953	J. H. ROWE #1	34139201590000	ACTIVE	40.6761	-82.3417	24	MONROE	RICHLAND	OH
45	LUCAS	03963	WM. & MARY BRENNSTUHL #1	34-005-93963	ACTIVE	40.6228	-82.2925	9	HANOVER	ASHLAND	OH
46	LUCAS	03967	J. F. MANG #1	34005602590000	ACTIVE	40.6983	-82.3061	8	GREEN	ASHLAND	OH
47	LUCAS	03969	J. & E. PARR #1	34-005-93969	ACTIVE	40.6739	-82.3375	19	GREEN	ASHLAND	OH
48	LUCAS	03972	J. H. ROWE #2	34-139-93972	ACTIVE	40.6797	-82.3408	24	MONROE	RICHLAND	OH
49	LUCAS	03976	W. & M. APPLEGATE #1	34-139-93976	ACTIVE	40.6836	-82.3494	13	MONROE	RICHLAND	OH
50	LUCAS	03978	A. & C. GUTHRIE #1	34-005-93978	ACTIVE	40.6806	-82.3356	19	GREEN	ASHLAND	OH
51	LUCAS	03983	E. & M. OSWALD #1	34139601590000	ACTIVE	40.6836	-82.345	13	MONROE	RICHLAND	OH
52	LUCAS	03995	S. E. MCKENLEY #1	34-005-93995	ACTIVE	40.7378	-82.2231	36	VERMILLION	ASHLAND	OH
53	LUCAS	03997	W. & M. APPLEGATE #2	34-139-93997	ACTIVE	40.6856	-82.3536	13	MONROE	RICHLAND	OH
54	LUCAS	04008	H. & M. MCGUIRE #1	34005216200000	ACTIVE	40.6983	-82.2614	10	GREEN	ASHLAND	OH

Wrong API Number length

1	Field Nan	We	API	Classificatior	Latituc	Longitu	Secti	Township	County	Sta	Operator
32	LUCAS	03897	34-005-93897	ACTIVE	40.6961	-82.3058	17	GREEN	ASHLAND	OH	Columbia Gas Transmissi
33	LUCAS	03912	34-005-60266	SPECIAL	40.7133	-82.24	1	GREEN	ASHLAND	OH	Columbia Gas Transmissi
34	LUCAS	03921	34-005-93921	ACTIVE	40.7383	-82.2719	34	VERMILLION	ASHLAND	OH	Columbia Gas Transmissi
35	LUCAS	03926	34-005-60265	ACTIVE	40.7106	-82.2358	12	GREEN	ASHLAND	OH	Columbia Gas Transmissi
36	LUCAS	03929	34-005-93929	ACTIVE	40.7103	-82.2611	10	GREEN	ASHLAND	OH	Columbia Gas Transmissi
37	LUCAS	03931	34-005-93931	ACTIVE	40.6889	-82.3047	17	GREEN	ASHLAND	OH	Columbia Gas Transmissi
38	LUCAS	03932	34-139-60118	ACTIVE		-82.3478	24	MONROE	RICHLAND	OH	Columbia Gas Transmissi
39	LUCAS	03935	34-005-93935			-82.247	2	GREEN	ASHLAND	OH	Columbia Gas Transmissi
40	LUCAS	03939	34-005-93939			-82.2375	25	VERMILLION	ASHLAND	OH	Columbia Gas Transmissi
41	LUCAS	03945	34-005-93945			-82.3017	17	GREEN	ASHLAND	OH	Columbia Gas Transmissi
42	LUCAS	03946	34-005-60242	ACTIVE		-82.3339	19	GREEN	ASHLAND	OH	Columbia Gas Transmissi
43	LUCAS	03950	34-139-60123	Active	40.6736	-82.3453	24	MONROE	RICHLAND	OH	Columbia Gas Transmissi
44	LUCAS	03953	34-139-20159	ACTIVE	40.6761	-82.3417	24	MONROE	RICHLAND	OH	Columbia Gas Transmissi
45	LUCAS	03963	34-005-93963	ACTIVE	40.6228	-82.2925	9	HANOVER	ASHLAND	OH	Columbia Gas Transmissi
46	LUCAS	03967	34-005-60259	ACTIVE	40.6983	-82.3061	8	GREEN	ASHLAND	OH	Columbia Gas Transmissi
47	LUCAS	03969	34-005-93969	ACTIVE	40.6739	-82.3375	19	GREEN	ASHLAND	OH	Columbia Gas Transmissi
48	LUCAS	03972	34-139-93972	ACTIVE	40.6797	-82.3408	24	MONROE	RICHLAND	OH	Columbia Gas Transmissi
49	LUCAS	03976	34-139-93976	ACTIVE	40.6836	-82.3494	13	MONROE	RICHLAND	OH	Columbia Gas Transmissi
50	LUCAS	03978	34-005-93978	ACTIVE	40.6806	-82.3356	19	GREEN	ASHLAND	OH	Columbia Gas Transmissi
51	LUCAS	03983	34-139-60159	ACTIVE	40.6836	-82.345	13	MONROE	RICHLAND	OH	Columbia Gas Transmissi
52	LUCAS	03995	34-005-93995	ACTIVE	40.7378	-82.2231	36	VERMILLION	ASHLAND	OH	Columbia Gas Transmissi
53	LUCAS	03997	34-139-93997	ACTIVE	40.6856	-82.3536	13	MONROE	RICHLAND	OH	Columbia Gas Transmissi
54	LUCAS	04008	34-005-21620	ACTIVE	40.6983	-82.2614	10	GREEN	ASHLAND	OH	Columbia Gas Transmissi

Corrected API Number

Fig2. Correction of Wrong API number in data

Analysis of raw data vs. refined data:

WELLBORE DATA														
DATA FIELDS	API Number	Field Name	Well	Lease Name	Classification	Lat	Long	Section	Township	County	State	Operator	Total Vertical Depth	Formation
INITIIAL DATA AVAILABLE	430	427	430	430	427	429	430	430	430	430	430	430	425	430
FINAL DATA AVAILABLE	430	430	430	430	430	430	430	430	430	430	430	430	430	430

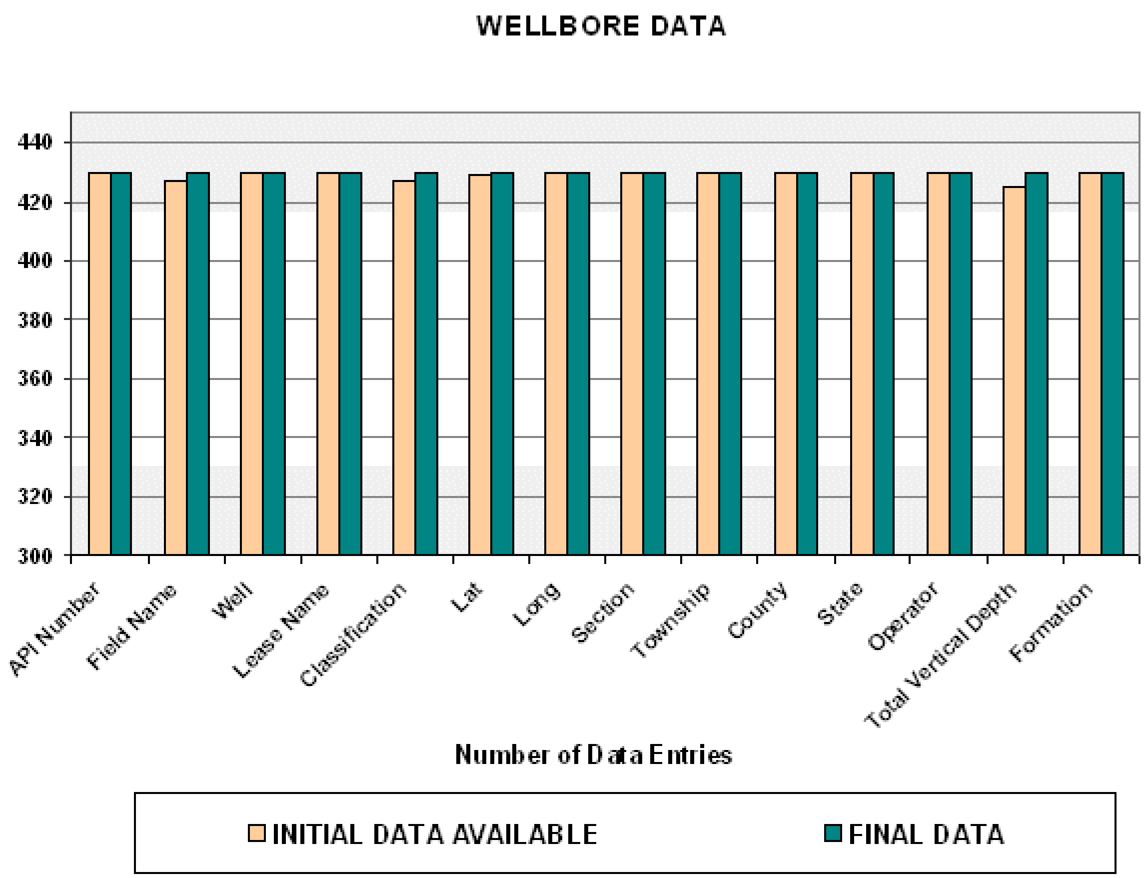


Fig3. Data addition and refinement for Well-bore Data

COMPLETION DATA

Completion data mostly relates to the type and depth of casing/liner/tubing run in the gas storage wells. The data type retained for the database includes the following:

1. API Number
2. Field Name
3. Well Name (Well)
4. Completion Description (Des)
5. Date Tubing Run (Dt Tm Rn)
6. Outer Diameter (OD)
7. Top of Casing
8. Bottom of Casing(Bot)
9. Casing Weight (Weight)
10. Casing Grade (Grade)

Unfortunately the data was mostly in an excel file and had to be verified with well schematic drawings. This led to the most unusual step in this project as it lead to reduction of valuable data available to us. This was due to the erroneous and multiple data entry originally in the completion table. Identification of the multiple entries and their removal from table was the most focused act of cleaning the data, as omission of desirable records was unacceptable. Following pictures show one of such flawed multiple data entries which were removed.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Field Name	Well	API	Des	DtTmRun	OD	Top	Bot	Weight	Grade		
71	LUCAS	00873	34-005-90873	Casing	03-Oct-17	7.00	0	2043	20.00			
72	LUCAS	00873	34-005-90873	Casing	02-Mar-64	5.50	0	2908	17.00	Seamless		
73	LUCAS	01981	34-005-91981	Drive Pipe	01-Nov-24	10.75	0	33	40.00			
74	LUCAS	01981	34-005-91981	Surface Pipe	02-Nov-24	8.63	0	299	24.00			
75	LUCAS	01981	34-005-91981	Casing	03-Nov-24	7.00	1893	1931	20.00			
76	LUCAS	01981	34-005-91981	Casing	04-Nov-24	5.50	0	2681	17.00			
77	LUCAS	01981	34-005-91981	Casing	02-Nov-63	3.50	0	2694	9.20	Used		
78	LUCAS	01981	34-005-91981	Packer	03-Nov-63	5.50	2694	2694		Straight Anchor		
79	LUCAS	01981	34-005-91981	Packer	03-Nov							
80	LUCAS	01981	34-005-91981		03-Nov					Straight Anchor		
81	LUCAS	02008	34-005-92008	Drive Pipe	01-Jul				.00			
82	LUCAS	02008	34-005-92008	Surface Pipe	02-Jul				.00			
83	LUCAS	02008	34-005-92008	Packer	03-Jul-25	8.63	1829	1839		Larkin Lead B.H.		
84	LUCAS	02008	34-005-92008	Packer	03-Jul-25	8.63	1829	1839				
85	LUCAS	02008	34-005-92008	Casing	03-Jul-25	7.00	1793	1839	20.00			
86	LUCAS	02008	34-005-92008	Packer	04-Jul-25	7.00	2500	2510				
87	LUCAS	02008	34-005-92008	Packer	04-Jul-25	7.00	2500	2510		OWS Midget		
88	LUCAS	02008	34-005-92008	Casing	04-Jul-25	5.50	0	2510	17.00			
89	LUCAS	02008	34-005-92008	Casing	02-Oct-63	5.50	0	2654				
90	LUCAS	02008	34-005-92008	Packer	02-Oct-63	5.50	2561	2561				
91	LUCAS	02008	34-005-92008	Anchor	02-Oct-63	5.50	2561	2571				
92	LUCAS	02008	34-005-92008	Packer	02-Oct-63	5.50	2561	2561				
93	LUCAS	02008	34-005-92008	Anchor	02-Oct-63	5.50	2561	2571				
94	LUCAS	02060	34-005-92060	Casing	01-Oct-25	10.75	0	64	40.00			

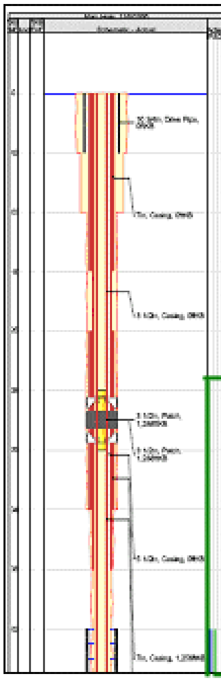
Multiple Data Entry

Fig4. Multiple Data Entries in Completion Table

In the completion table, the following notations used as casing description were replaced in place of different notations being used to have a standard definition

NOTATION KEPT IN DATABASE	Surface casing
NOTATIONS DISCARDED	Drive pipe
	Driver Pipe
	Swedge Two stage

Completion data was mostly re- checked for accuracy from the documents, picture of which is shown below for a Well.



LUCAS - [illegible]

Redlined By	Redline Date	Entered by	Verified by	Comment
		Anderson	Bolander	

Field Name	Well Number	API Number	Lease Name	Spud Date	Acreage	TVD (ft)	MD (ft)	Datum reference
LUCAS	0[illegible]	340056[illegible]	[illegible]	8/1/1913	148	2827	2857	

Township/Tax District	Tax Number	County	State/Province	Operating Area
GREEN	30050	ASHLAND	OH	Wooster

Latitude (DD)	Longitude (DD)	Section Number	State Permit #	Line Number	Deed Number	Lease Number	Inventory Map #
[illegible]72111	[illegible]31306	5				[illegible]	

Well Classification	Key Well	Group	SubGroup	Completion Type	Est.DeepFW (ft)	Gr Elev (ft)	KB Elevation (ft)
ACTIVE	No	6					

Directions To Well

Wellhead: API Wellhead, <Make?> on <Install Date?>

Type	Install Date	Make	FlowStSz (in)	SupportStSz (in)	WP (psi)	Connection	Comment
API Wellhead						3" 10R	Wellhead Size 3 x 3.

Wellhead Components

Des	Install Date	Type	Make	Size (in)	WP (psi)	Operable	Leaking	Restricted	Comment
Annular Valve		Ball	Nibco	2.000	2,000.0				
Master Valve		Gate	Barton	3.000	2,000.0	Yes	No	No	
Side Valve		Gate	Barton	3.000	2,000.0	Yes	No	No	

Downhole Components (Dates <1990 are approximated)

Run Date	Pull Date	ID (in)	OD (in)	Des	Top (ft)	Btm (ft)	Wt (lbs/ft)	Grade	Thread	Cmt'd	Comment
8/1/1913			10 3/4	Drive Pipe	0	42					
8/2/1913	6/3/1968		8 5/8	Surface Pipe	0	303					
8/3/1913	6/5/1968		7	Casing	0	1256					
8/3/1913			7	Casing	1256	1949					
8/4/1913			5 1/2	Casing	0	2688					
8/5/1913	6/1/1968		3 1/2	Casing	0	2825					
6/7/1968			7	Casing	0	310	17.00	Used		Y	
6/9/1968	6/3/1968	3.000	4 1/4	Anchor	2857	2857					
6/9/1968	11/8/1995		3 1/2	Casing	0	1291	9.20				
6/9/1968			3 1/2	Casing	1291	2857	9.20	Used		Y	
6/9/1968	6/3/1968	3.000	4 1/4	Anchor	2857	2857					
11/9/1995			3 1/2	Patch	1288	1291					
11/9/1995			3 1/2	Patch	1288	1291					
11/9/1995			3 1/2	Casing	0	1291	9.20				

Downhole Components (Dates <1990 are approximated)

Run Date	Pull Date	ID (in)	OD (in)	Des	Top (ft)	Btm (ft)	Wt (lbs/ft)	Grade
8/1/1913			10 3/4	Drive Pipe	0	42		
8/2/1913	6/3/1968		8 5/8	Surface Pipe	0	303		
8/3/1913	6/5/1968		7	Casing	0	1256		
8/3/1913			7	Casing	1256	1949		
8/4/1913			5 1/2	Casing	0	2688		
8/5/1913	6/1/1968		3 1/2	Casing	0	2825		
6/7/1968			7	Casing	0	310	17.00	Used
6/9/1968	6/3/1968	3.000	4 1/4	Anchor	2857	2857		
6/9/1968	11/8/1995		3 1/2	Casing	0	1291	9.20	
6/9/1968			3 1/2	Casing	1291	2857	9.20	Used
6/9/1968	6/3/1968	3.000	4 1/4	Anchor	2857	2857		
11/9/1995			3 1/2	Patch	1288	1291		
11/9/1995			3 1/2	Patch	1288	1291		
11/9/1995			3 1/2	Casing	0	1291	9.20	

Fig5. Well-bore data retrieved from a file

Analysis of raw data vs. refined data:

Please note that multiple data entry was the major reason for the reduction in the refined data from the initial data.

COMPLETION DATA											
DATA FIELDS	Total Completions Run	API Number	Field Name	Well	Description	Date Tubing Run	OD	Top Casing	Bot	Weight	Grade
INITIIAL DATA AVAILABLE	2910	431	431	431	2909	2909	2909	2909	2909	1781	1607
FINAL DATA AVAILABLE	2413	430	431	431	2413	2413	2413	2413	2413	1723	1607

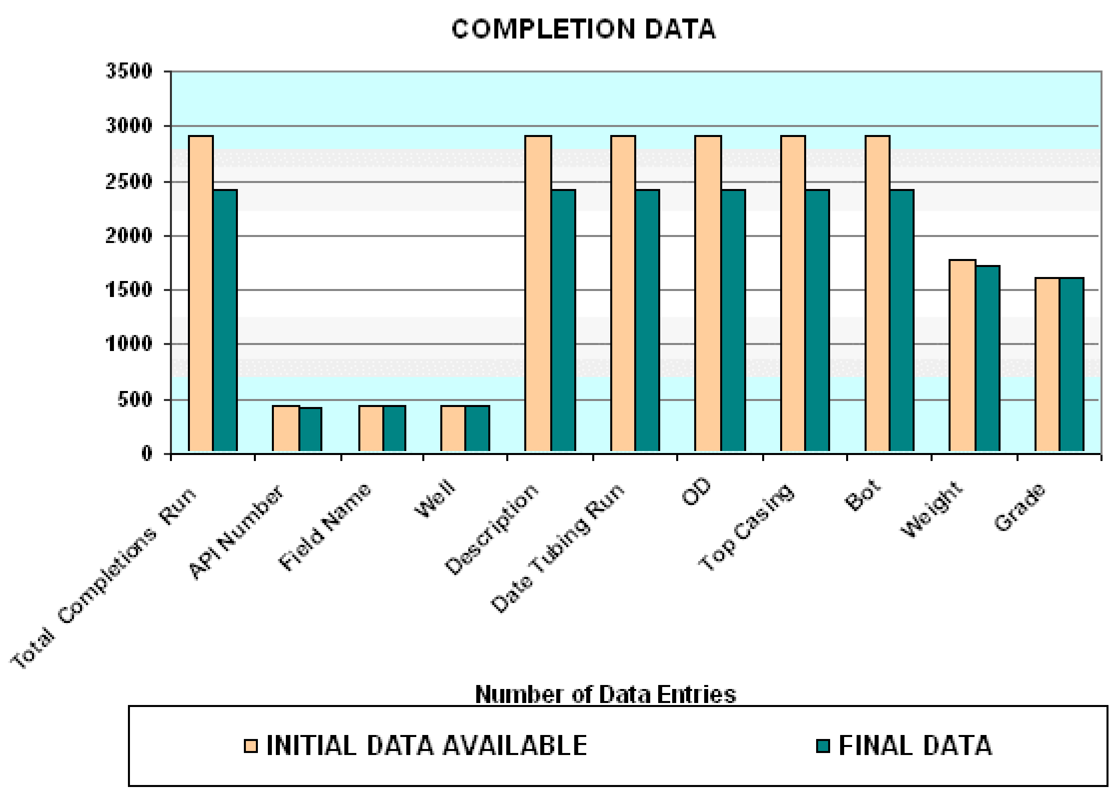


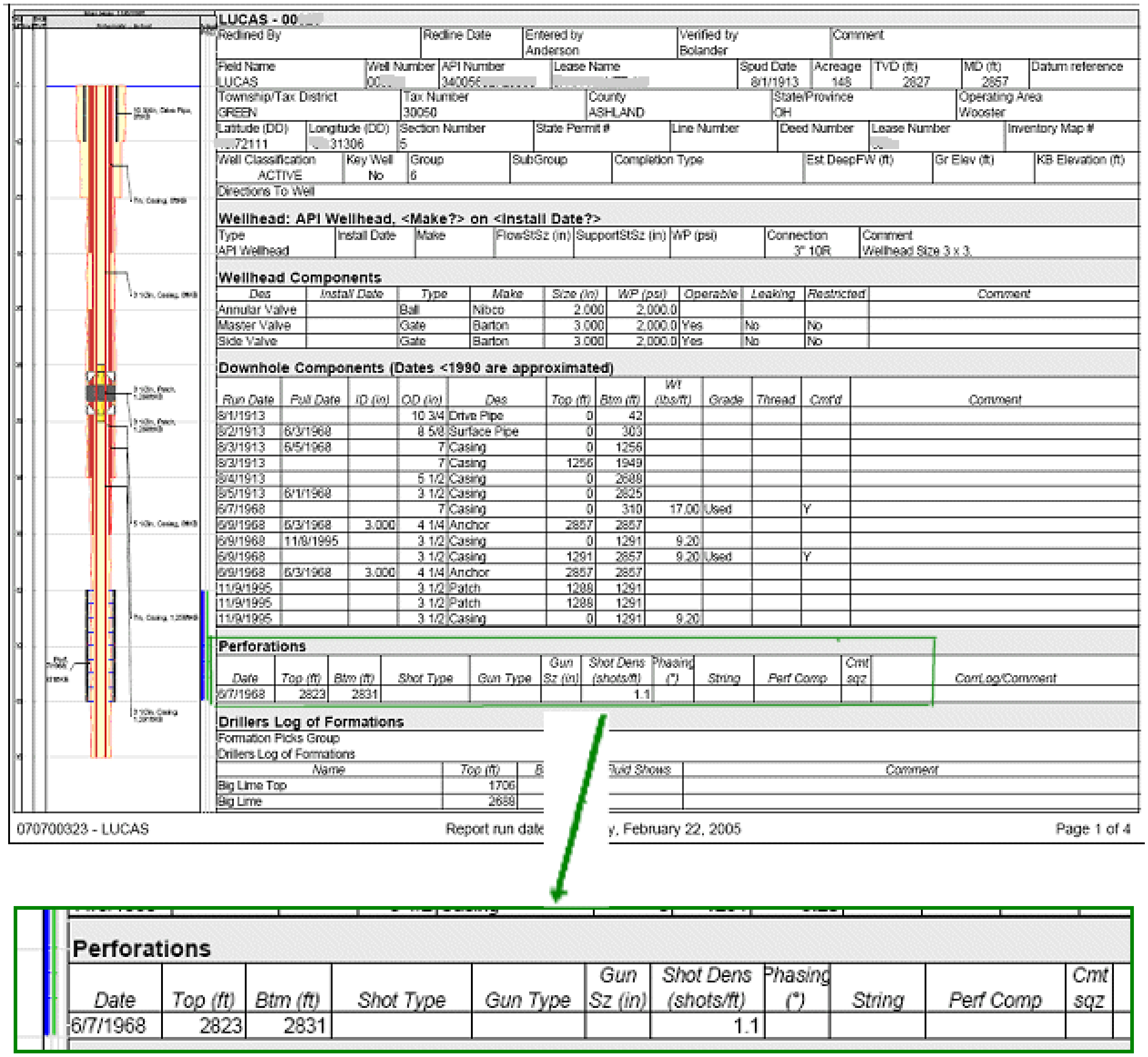
Fig6. Data addition and refinement for Completion Data

PERFORATION DATA

This data set contains all the information relating to the perforations done on the gas storage well like perforation top & bottom depth and shots per foot. Following are the data types included in this type of data set:

1. Well API Number
2. Field Name
3. Well Name
4. Completion Type
5. Perforation Date (Perf Date)
6. Perforation Top (Perf Top)
7. Perforation Bottom (Perf Btm)
8. Shot Type
9. Shot Per foot (Shot Per ft)

The picture of a document showing this information is shown below.



LUCAS - 00

Redlined By	Redline Date	Entered by	Verified by	Comment
		Anderson	Bolander	

Field Name	Well Number	API Number	Lease Name	Spud Date	Acreage	TVD (ft)	MD (ft)	Datum reference
LUCAS	00	340056		8/1/1913	148	2827	2857	

Township/Tax District	Tax Number	County	State/Province	Operating Area
GREEN	30050	ASHLAND	OH	Wooster

Latitude (DD)	Longitude (DD)	Section Number	State Permit #	Line Number	Deed Number	Lease Number	Inventory Map #
.72111	.31306	5					

Well Classification	Key Well	Group	SubGroup	Completion Type	Est DeepFW (ft)	Gr Elev (ft)	KB Elevation (ft)
ACTIVE	No	6					

Directions To Well

Wellhead: API Wellhead, <Make?> on <Install Date?>

Type	Install Date	Make	FlowStSz (in)	SupportStSz (in)	WP (psi)	Connection	Comment
API Wellhead						3" 10R	Wellhead Size 3 x 3.

Wellhead Components

Des	Install Date	Type	Make	Size (in)	WP (psi)	Operable	Leaking	Restricted	Comment
Annular Valve		Ball	Nibco	2.000	2,000.0				
Master Valve		Gate	Barton	3.000	2,000.0	Yes	No	No	
Side Valve		Gate	Barton	3.000	2,000.0	Yes	No	No	

Downhole Components (Dates <1980 are approximated)

Run Date	Pull Date	ID (in)	OD (in)	Des	Top (ft)	Btm (ft)	Wt (lbs/ft)	Grade	Thread	Cmt'd	Comment
8/1/1913			10 3/4	Drive Pipe	0	42					
8/2/1913	6/3/1968		8 5/8	Surface Pipe	0	303					
8/3/1913	6/5/1968		7	Casing	0	1256					
8/3/1913			7	Casing	1256	1949					
8/4/1913			5 1/2	Casing	0	2688					
8/5/1913	6/1/1968		3 1/2	Casing	0	2825					
6/7/1968			7	Casing	0	310	17.00	Used		Y	
6/9/1968	6/3/1968	3.000	4 1/4	Anchor	2857	2857					
6/9/1968	11/9/1995		3 1/2	Casing	0	1291	9.20				
6/9/1968			3 1/2	Casing	1291	2857	9.20	Used		Y	
6/9/1968	6/3/1968	3.000	4 1/4	Anchor	2857	2857					
11/9/1995			3 1/2	Patch	1288	1291					
11/9/1995			3 1/2	Patch	1288	1291					
11/9/1995			3 1/2	Casing	0	1291	9.20				

Perforations

Date	Top (ft)	Btm (ft)	Shot Type	Gun Type	Gun Sz (in)	Shot Dens (shots/ft)	Phasing (°)	String	Perf Comp	Cmt sqz	Corr.Log/Comment
6/7/1968	2823	2831				1.1					

Drillers Log of Formations

Formation Picks Group

Drillers Log of Formations

Name	Top (ft)	B	Fluid Shows	Comment
Big Lime Top	1706			
Big Lime	2688			

070700323 - LUCAS Report run date y, February 22, 2005 Page 1 of 4

Perforations

Date	Top (ft)	Btm (ft)	Shot Type	Gun Type	Gun Sz (in)	Shot Dens (shots/ft)	Phasing (°)	String	Perf Comp	Cmt sqz
6/7/1968	2823	2831				1.1				

Fig7. Perforation data retrieved from a file

Analysis of raw data vs. refined data:

PERFORATION DATA										
DATA FIELDS	Total Perforations	API Number	Field Name	Well Name	Completion Type	Perf Date	Perf Top	Perf Bottom	Shot Type	Shot Per ft
INITIIAL DATA AVAILABLE	392	57	57	57	48	392	392	392	209	383
FINAL DATA AVAILABLE	392	57	57	57	48	392	392	392	209	383

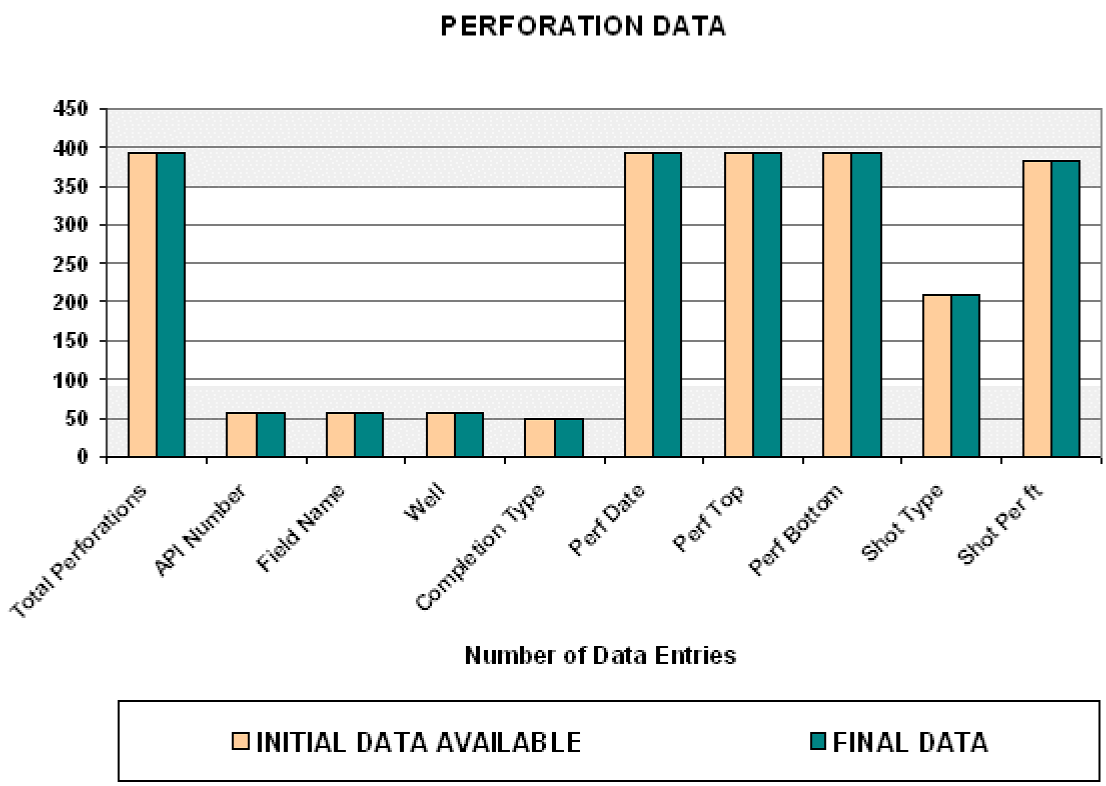


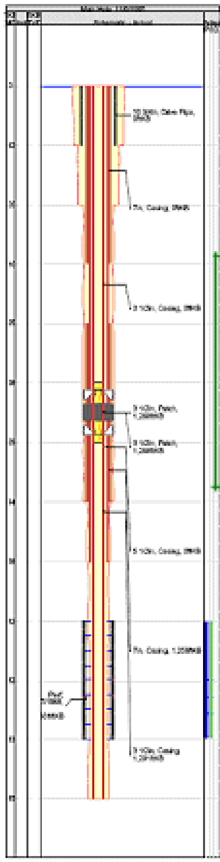
Fig8. Data addition and refinement for Perforation Data

STIMULATION DATA

Stimulation data is one of the most significant datasets about the storage wells. Because of this, it was very important that we have maximum records of valid stimulations. Following data type is used to represent stimulation:

1. API Well Number
2. Well Name
3. Size of String
4. Stimulation From
5. Stimulation To
6. No Of Shots
7. Fractured by
8. Stimulation Type
9. Stimulation Date
10. Water
11. Acid
12. Gel
13. Foam
14. Nitrogen
15. Alcohol
16. Cushion
17. Flush
18. Sand Quantity
19. Sand Type
20. Injection Rate
21. Total Fluid
22. Breakdown Pressure
23. ISIP

Unfortunately, initially we didn't have much data about the stimulations being done in this Lucas field. With this in mind, every record with Columbia Transmission Corporation was carefully examined. The largest source of stimulation data came from the thousands of microfiche with some data being found in well summary reports. Following is a picture of data in well summary reports.



LUCAS - [illegible]

Name	Top (ft)	Btm (ft)	Fluid Shows	Comment
Clinton Sand	2817	2827		
TD	2827	2827		
DDTD	2857	2857		

ELog Formations(Record Log & Date in Comments)

Formation Picks Group
ELog Formations(Record Log & Date in Comments)

Name	Top (ft)	Btm (ft)	Fluid Shows	Comment
Big Lime				
Clinton Sand				
DDTD				
Logger's TD				
Big Lime Top				

Stimulations: Water Fracture on 7/1/1968

Date	Stim Type	Stim/Treat Company	Stim Trade Name	
7/1/1968	Water Fracture			
Zone	**Top (ft)**	**Bottom (ft)**	**Est. Pore Press (psig) (psi)**	
	2823	2831		
Breakdown Pressure (psi)	**Avg Treat Press (psi)**	**Avg BH rate (bpm)**	**Instant. Shut-in Pressure (psi)**	**Flush Fluid Density (ppg)**
Fluid Volume Pumped (bbl)	**Nitrogen Amount (mcf)**	**Proppant Type & Mesh**	**Proppant Amount (lb)**	**Max BH sand conc.(lb/gal)**

Comment
Clinton

breakdown 2500 #, ave press 2434 #, ISIP 1000 #, 10,500 lb. sand.

Build-Up Tests

Start Date	Type	c	n	kh	Skin	True Skin	DDRate (mcf/day)	AOF (mcf/day)	Comment
8/1/1913	Open-Flow								
4/13/1964	Open-Flow								
9/21/1966	Open-Flow								
4/5/1967	Open-Flow								
9/7/1967	Open-Flow								
7/29/1968	Open-Flow								
10/9/1968	Open-Flow								
4/8/1969	Open-Flow								
10/2/1969	Open-Flow								
4/1/1970	Open-Flow								
10/7/1970	Open-Flow	0.454	0.750				4765.96	18054.40	
4/2/1973	Open-Flow								
5/13/1981	Open-Flow								
6/14/1993	Multi-Point	0.047	0.750				497.89	1886.94	Repair casing / wellhead as necessary, re-perforate and frac.Historical comparison of BP curve indicates significant loss of delivery. Analysis of flow test not possible, very ambiguous.Fill in well.Coiled tubing cleanout to original TD. Reperf and frac well.

070700323 - LUCAS   Report run date - Tuesday, February 22, 2005   Page 2 of 4

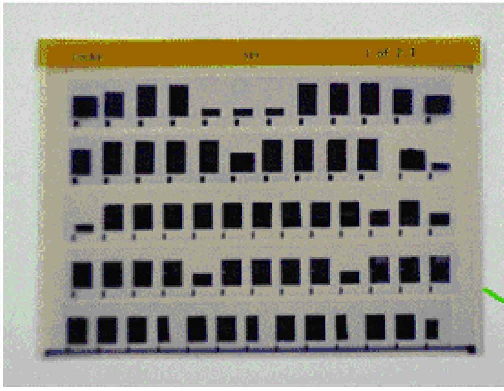
Stimulations: Water Fracture on 7/1/1968

Date	Stim Type	Stim/Treat Company	Stim Trade Name	
7/1/1968	Water Fracture			
Zone	**Top (ft)**	**Bottom (ft)**	**Est. Pore Press (psig) (psi)**	
	2823	2831		
Breakdown Pressure (psi)	**Avg Treat Press (psi)**	**Avg BH rate (bpm)**	**Instant. Shut-in Pressure (psi)**	**Flush Fluid Density (ppg)**
Fluid Volume Pumped (bbl)	**Nitrogen Amount (mcf)**	**Proppant Type & Mesh**	**Proppant Amount (lb)**	**Max BH sand conc.(lb/gal)**

Comment
Clinton

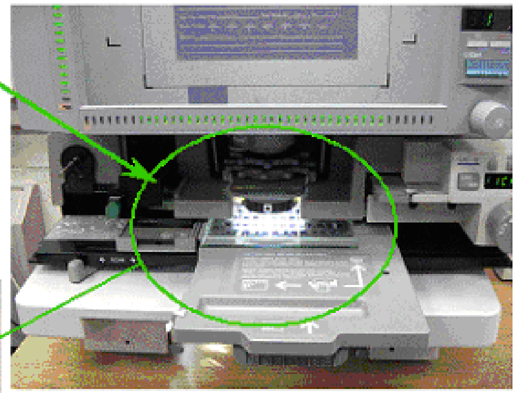
breakdown 2500 #, ave press 2434 #, ISIP 1000 #, 10,500 lb. sand.

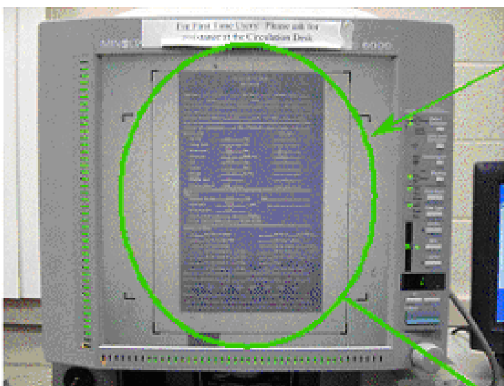
Fig9. Stimulation data retrieved from a file



Each Microfiche contained dozens of documents from invoices to valuable stimulation and well-test data

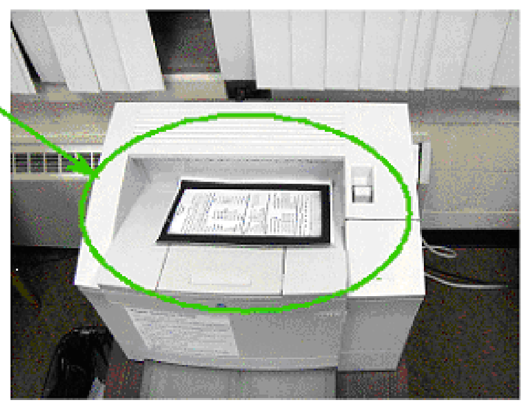
Microfiche were read by digital Microfilm scanners





Each scanned image of the microfiche was searched and read for valuable data

Prints were taken of the documents containing data



Stimulation_Data : Table

API_Number	SizeOfString	StimFrom	StimTo	NoOfShots	Fracturedby	Type	St
34-005-01272	4.5	2882	2906	8	Dowell Inc.	Water-Gel	11/
34-005-02420	4.5	2758	2764	11	Dowell Inc.	Water-Gel	12/
34-005-02887	4.5	2804	2810	13	Dowell Inc.	Water-N2	6
34-005-02889	4.5	2838	2845	12	Dowell Inc.	Water-N2	7
34-005-02899	4.5	2820	2828	10	Dowell Inc.	Water-N2	6/
34-005-02897	4.5	2853	2860	12	Halliburton Co.	Water-Gel	7/
34-005-02901	4.5	2723	2748	12	Halliburton Co.	Water-Gel	6/
34-005-02907	3.5	2823	2845	13	Halliburton Co.	Water-Gel	7
34-005-02909	4.5	2796	2814	5	Halliburton Co.	Water-Gel	7/
34-005-02909	4.5	2809	2814	6	Halliburton Co.	Water-Gel	7/
34-005-02911	4.5	2786	2806	13	Halliburton Co.	Water-Gel	9/
34-005-02980	4.5	2911	2921	13	Dowell Inc.	Water-Gel	10/
34-005-10516	5.5	2588	2608		Halliburton Co.	Visco-Frac	12/
34-005-10517	5.5	2588	2590		Dowell Inc.	Water-N2	5/
34-005-10518	5.5	2580	2622		Dowell Inc.	Petro-Gel	12/
34-005-10519	5.5	2874	2882		Halliburton Co.	Water-N2	9/
34-005-10520	5.0	2926	2964		Dowell Inc.	Water-Gel	1/
34-005-10527	5.5	2886	2901		Dowell Inc.	Water-N2	8
34-005-10533	5.5	2827	2853		Dowell Inc.	Petro-Gel	1
34-005-10538	5.5	2804	2844		Dowell Inc.	Petro-Gel	12/
34-005-10540	5.5	2860	2906		Dowell Inc.	Water-N2	6/

Data was entered in the database

Fig10. Microfiche to Database process

Following are pictures of some types of data formats for fracture jobs found in the records

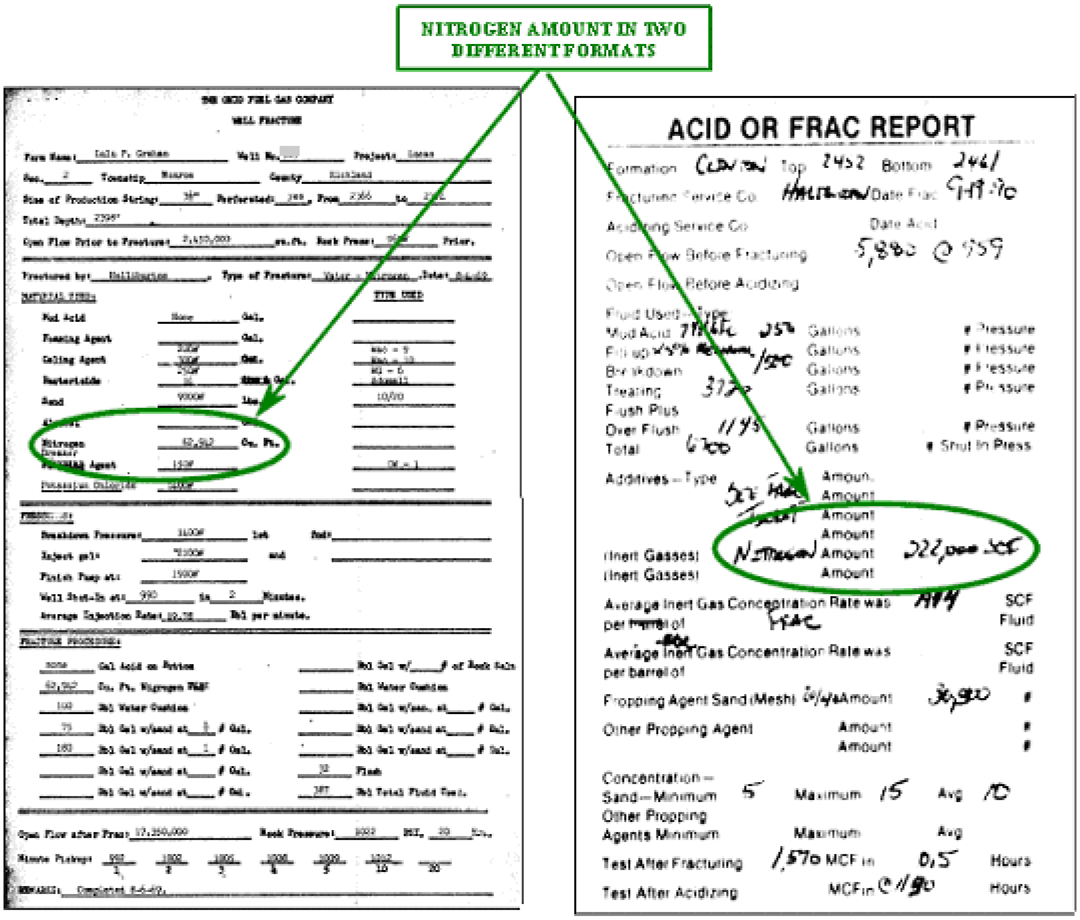


Fig11. Different formats of Nitrogen Amount

During the data entry different sign conventions and unit conversions were carried out as follows:

MEASURED QUANTITY	UNITS IN RECORDS	UNITS USED IN DATABASE
SAND	1 sack 1 sks	100 lbs
NITROGEN	52M	52,000 SCF
LIQUID	1 bbl	42 gal
PERFORATIONS	2000-2005 ft, 10 shots 10/5	2 shots /ft

The following notations were used in place of different notations being used in the tables:

NOTATIONS USED IN DATABASE	WATER GEL FRAC	PETRO GEL FRAC	FOAM FRAC	NITRO SHOT	WATER/N2 FRAC	WATER FRAC	10/20 SAND
NOTATIONS THAT WERE REPLACED	Gelled water frac	Petrl gel	Foam	Shot	Water / N2	water	10/20
	Water Gel	Petro Gel Petro gel fracture	foam Frac foam fracture		Water N2 Fracture Water nitrogen		Sand 10/20
					Water/N2 assist Water Fracture w/N2 assist		

All records of Nitro-shots were discarded for this database as they have no stimulation parameters on record and are part of history now plus they also damage the well. Above all, they will tend to degrade the Neural Network.

Analysis of raw data vs. refined data:

STIMULATION DATA																								
DATA FIELDS	Total Stimulations	API Number	Well	Size Of String	Stim From	Stim To	No Of Shots	Fractured by	Type	Stim Date	Water	Acid	Gel	Foam	N2	Alcohol	Cushion	Flush	Sand Quantity	Sand Type	Injection Rate	Total Fluid	Breakdown Pressure	ISIP
INITIIAL DATA AVAILABLE	32	32	32	32	32	32	32	32	32	32	0	0	0	0	0	0	0	0	32	32	25	0	27	24
FINAL DATA AVAILABLE	390	430	430	308	388	388	156	354	370	391	85	293	294	157	249	21	277	302	368	266	263	317	181	345

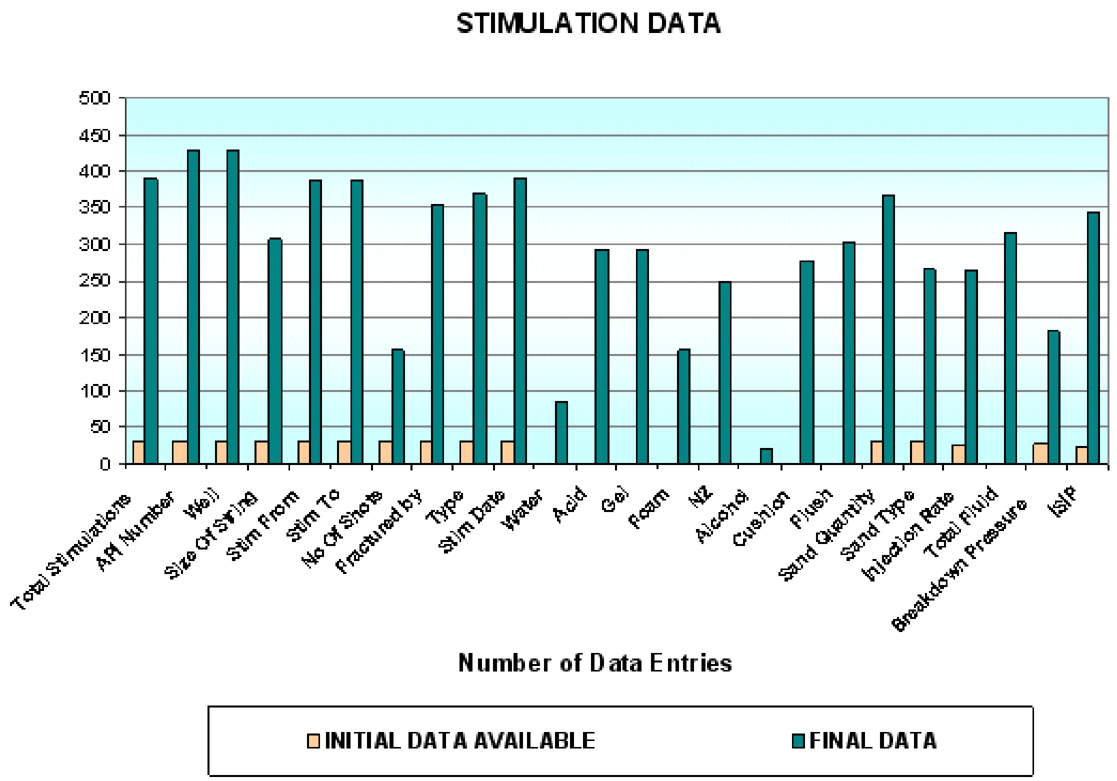


Fig12. Data addition and refinement for Stimulation Data.

WELL TEST DATA

Well-test data is the most extensive dataset that our R & D team worked on. It has the maximum amount of records nearly 3365 and 29 data types that control every aspect of a well-test. The data type selected for a well-test representation consists of following:

1. Well API Number
2. Field Name
3. Test Date
4. Test Type
5. Time 1
6. Field Pressure 1
7. Flowing Pressure 1
8. Rate 1
9. Time 2
10. Field Pressure 2
11. Flowing Pressure 2
12. Rate 2
13. Time 3
14. Field Pressure 3
15. Flowing Pressure 3
16. Rate 3
17. Time Extended
18. Field Pressure Extended
19. Flowing Pressure Extended
20. Rate Extended
21. kh
22. Skin
23. True Skin
24. Non Darcy Co-efficient
25. n Value
26. C Value
27. Delta Pressure Squared
28. Peak Day Rate
29. Absolute Open Flow

Estimation of n, C, peak day rate & absolute open flow

Single/Open flow Tests:

The values used for point 1 and 2 are from different well-tests

1- Find ΔP^2

3- $\frac{1}{n} = \frac{\log(\overline{p}^2 - p_{wf}^{\ 2})_2 - \log(\overline{p}^2 - p_{wf}^{\ 2})_1}{\log q_2 - \log q_1}$ (Where q is in MMcfD)

4- $C = \frac{q_g}{(\overline{p}^2 - p_{wf}^{\ 2})^n}$ (Where q is in McfD)

5- $AOF = C(1150^2 - 0^2)^n$ McfD

6- $PDRate = (C \times 250,000)^n$ McfD

Multi-Point Tests:

Estimation of n, C, PD rate & AOF:

Same as above except that the points used are from the same test

NOTE: The n, C, PD rate & AOF values for more than 400 well-tests were manually calculated

Estimation of kh, skin, true skin, non--darcy coefficient

1- From extended draw-down test plot (P_i-P_{wf}) vs. time on log-log paper. Draw unit-line for un-stimulated wells and half-slope line for Stimulated wells. Find end of well-bore storage effects after 1-1/2 log time cycle

2- Find values of viscosity, z-factor, compressibility of storage gas at different pressure assuming Gas gravity = 0.585 & temperature = 75 F = 535 R

Draw-Down Test:

1- Plot P_{wf}^2 vs. time
2- Draw straight line after pseudo-steady state starts
3- Find slope *m* and $P^2$1hr
4- $kh = \dfrac{1637qTzu}{m}$
5- $S = 1.151\left[\dfrac{p^2 - p^2_{1hr}}{m} - \log\left(\dfrac{k}{\phi\mu c r_w^2}\right) + 3.23\right]$
6- Plot skin vs. flow-rate. It should be a straight line
7- Slope of this line is D
8- Find True Skin (S') at q=0.

Build-Up Test:

1- Plot P_{wf}^2 vs. (tp+dt)/dt on semi-log paper
2- Draw straight line after well-bore storage effects diminishes
3- Find slope *m* and $P^2$1hr
4- $kh = \dfrac{1637qTzu}{m}$
5- $S = 1.151\left[\dfrac{p^2_{1hr} - p^2}{m} - \log\left(\dfrac{k}{\phi\mu c r_w^2}\right) + 3.23\right]$
6- Plot skin vs. flow-rate. It should be a straight line
7- Slope of this line is D
8- Find True Skin (S') at q=0.

We require time, flow-rate & Bottom hole pressure from the data which are present in two txt files as bottom hole & surface recording files. The flow rates are at Wellhead so we match the BHP & THP with time.

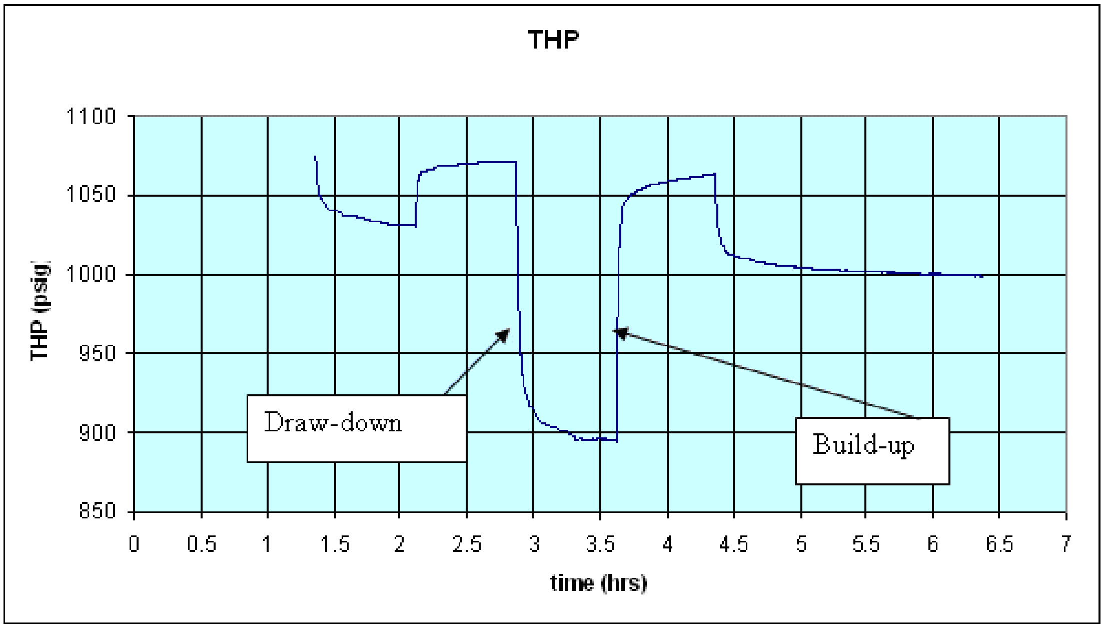


Fig13. Tubing Head Pressure profile for Multi-Point test

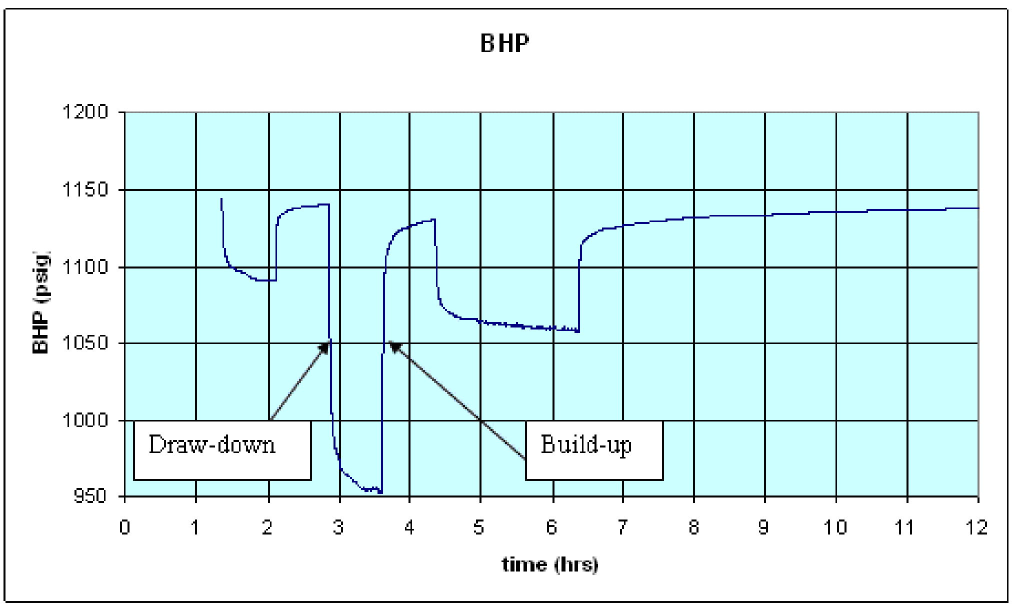


Fig14. Bottom Hole Pressure profile for Multi-Point test

The multipoint-test data is divided into Draw-down & build-up test and each one is analyzed separately.

Draw-down test

Analysis of drawdown tests was done as described above and following graphs were obtained

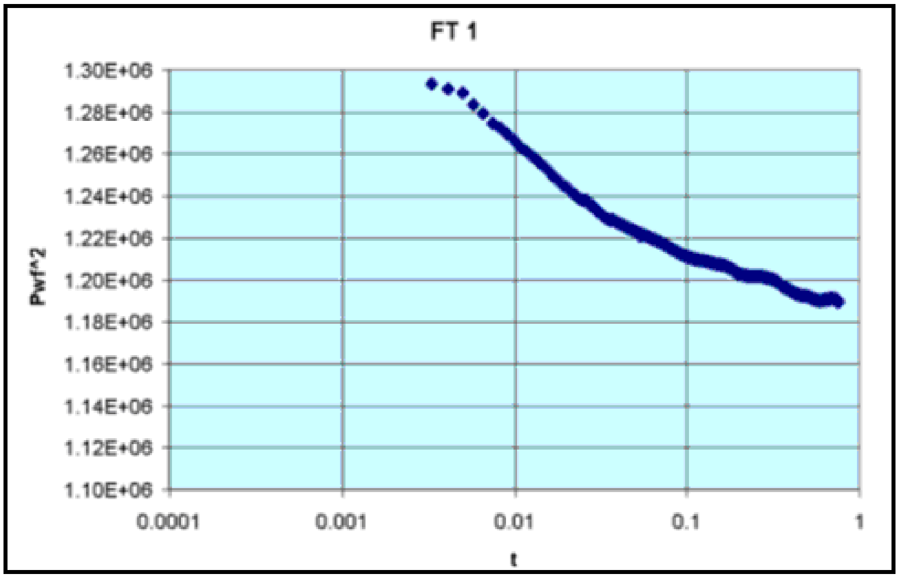


Fig15. Flow Test 1 – Delta pressure squared vs. time

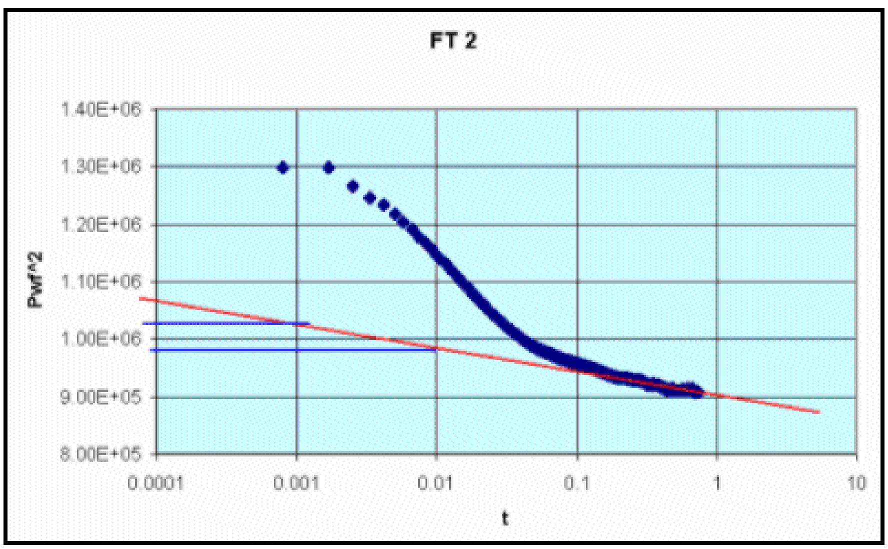


Fig16. Flow Test 2 – Delta pressure squared vs. time

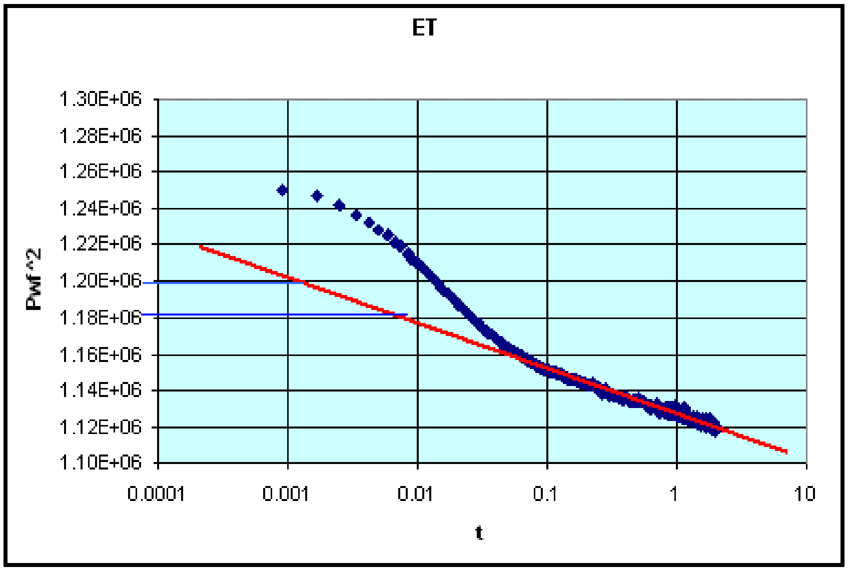


Fig17. Extended Flow Test – Delta pressure squared vs. time

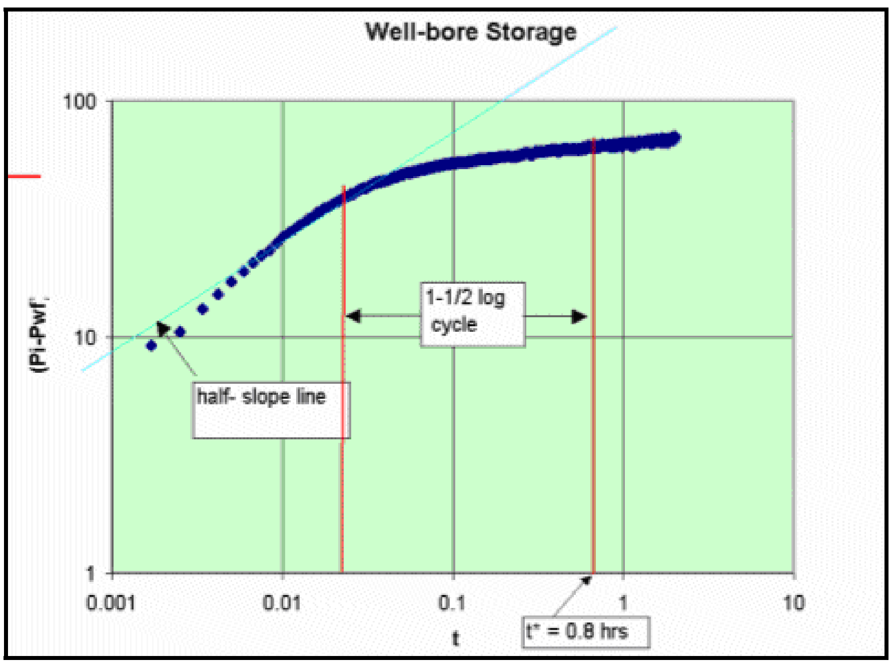


Fig18. Log-log graph

For well-tests after fracture half-slope line is drawn and for un-simulated wells unit slope line is drawn to find end of well-bore effects and start of pseudo-steady state.
Gas production Simulator was used to find the values of viscosity, z-factor and compressibility of storage gas at different pressure assuming Gas gravity = 0.585 & Temperature = 75 F = 535 R that are also used by Columbia Trans.

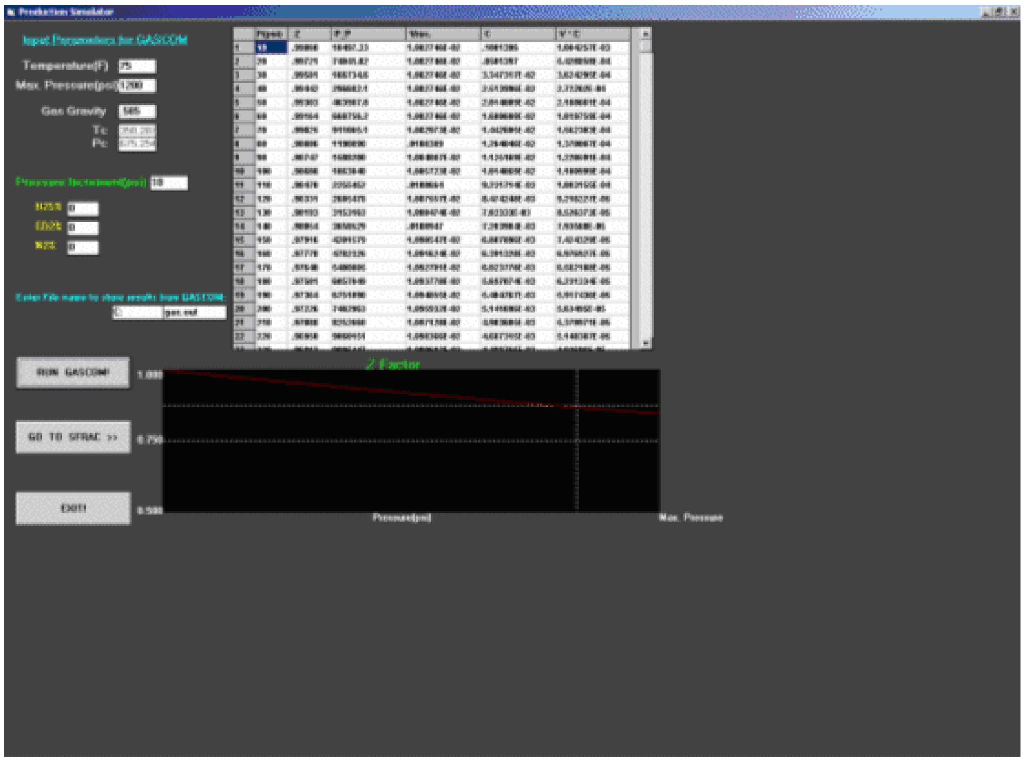


Fig19. Gas Properties Simulator

The slope from Pwf^2 vs. time on semi-log graph was used to find kh & then skin. The three values of skin were plotted on Q vs. S graph and extrapolated to Q = 0 to get True skin (S').

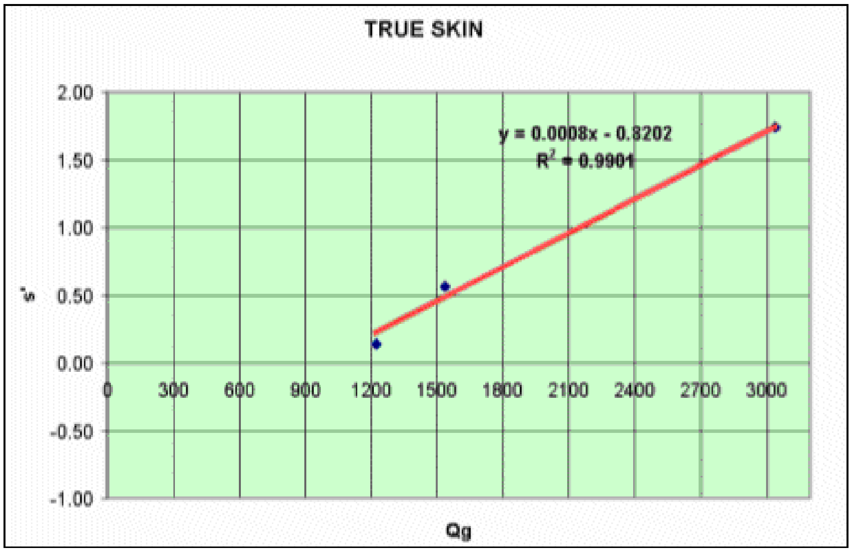


Fig20. Calculation of True skin

	FLOW TEST 1	FLOW TEST T2	EXTENDED TEST
porosity	0.14	0.14	0.14
rw	0.1458333	0.1458333	0.1458333
Ct	1.02E-03	1.08E-03	1.04E-03
Uav	1.28E-02	1.26E-02	1.27E-02
Zav	0.8558691	0.8635354	0.859119
P	1143	1140	1127.3
Qav	1223.8668	3038.7039	1536.1134
Tav	533	533	533
h	10	10	10
m	2.00E+04	5.40E+04	2.20E+04
kh	5.86E+02	5.36E+02	6.67E+02
k	5.86E+01	5.36E+01	6.67E+01
p1hr^2	1.185E+06	9.000E+05	1.128E+06
S	0.14	1.74	0.57
S'	-0.8202		
D	0.0008		

Table 1. Draw down Test Results

Build-up test

In build-up tests, the slope drawn for Horner plot is after the time when well-bore storage effects were found to be minimizing from previous draw-down test. This slope is then used to find the values of kh & skin. The True skin is found the similar way as in draw-down test.

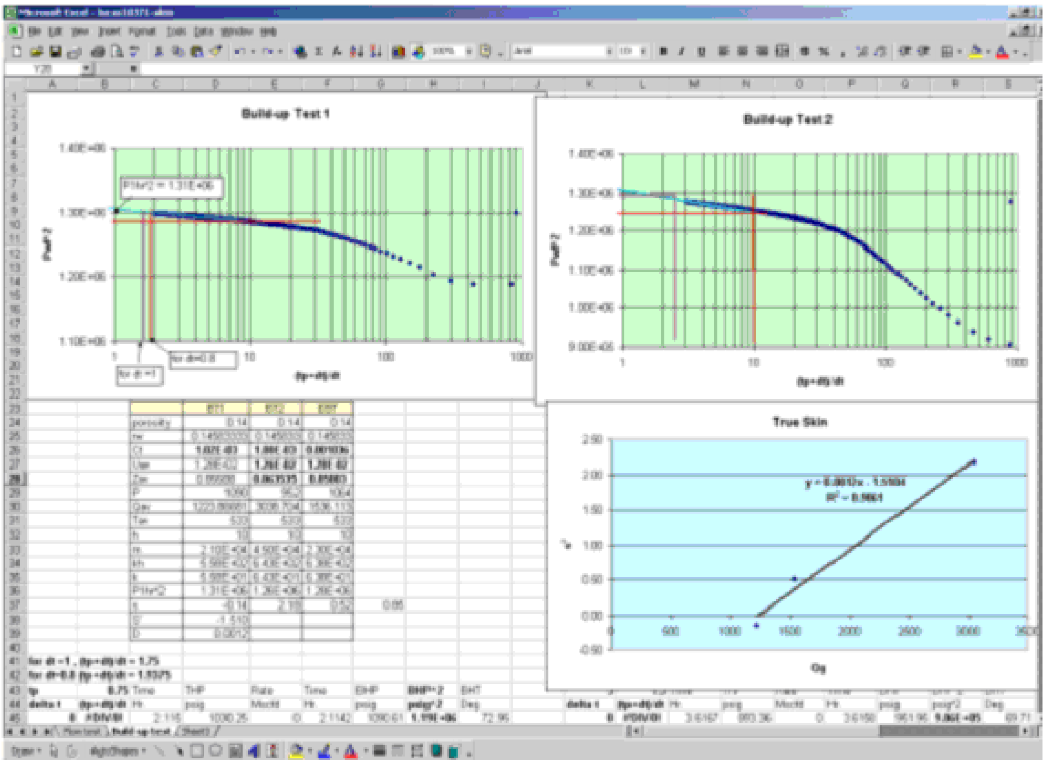


Fig21. Calculation of True skin Build-up test

	BUILD-UP TEST 1	BUILD-UP TEST 2	EXTENDED BUILD-UP TEST
porosity	0.14	0.14	0.14
rw	0.14583333	0.145833	0.145833
Ct	1.02E-03	1.08E-03	0.001036
Uav	1.28E-02	1.26E-02	1.28E-02
Zav	0.85588	0.863535	0.85803
P	1090	952	1064
Qav	1223.86681	3038.704	1536.113
Tav	533	533	533
h	10	10	10
m	2.10E+04	4.50E+04	2.30E+04
kh	5.58E+02	6.43E+02	6.38E+02
k	5.58E+01	6.43E+01	6.38E+01
P1hr^2	1.31E+06	1.26E+06	1.28E+06
s	-0.14	2.18	0.52
S'	-1.510		
D	0.0012		

Table 2. Build-up test results

	DRAW-DOWN	BUILD-UP	AVERAGE	ACTUAL
S'	-0.8202	-1.510	-1.165	-1.17
D	0.0008	0.0012	0.0010	.00126

Table 3. Average Results

Due to large errors corresponding to estimating skin and kh values manually, it was decided that for time being these values will not be entered in the database.

Following are some pictures of the documents to show the different format in which the data was presented in files and microfiche.

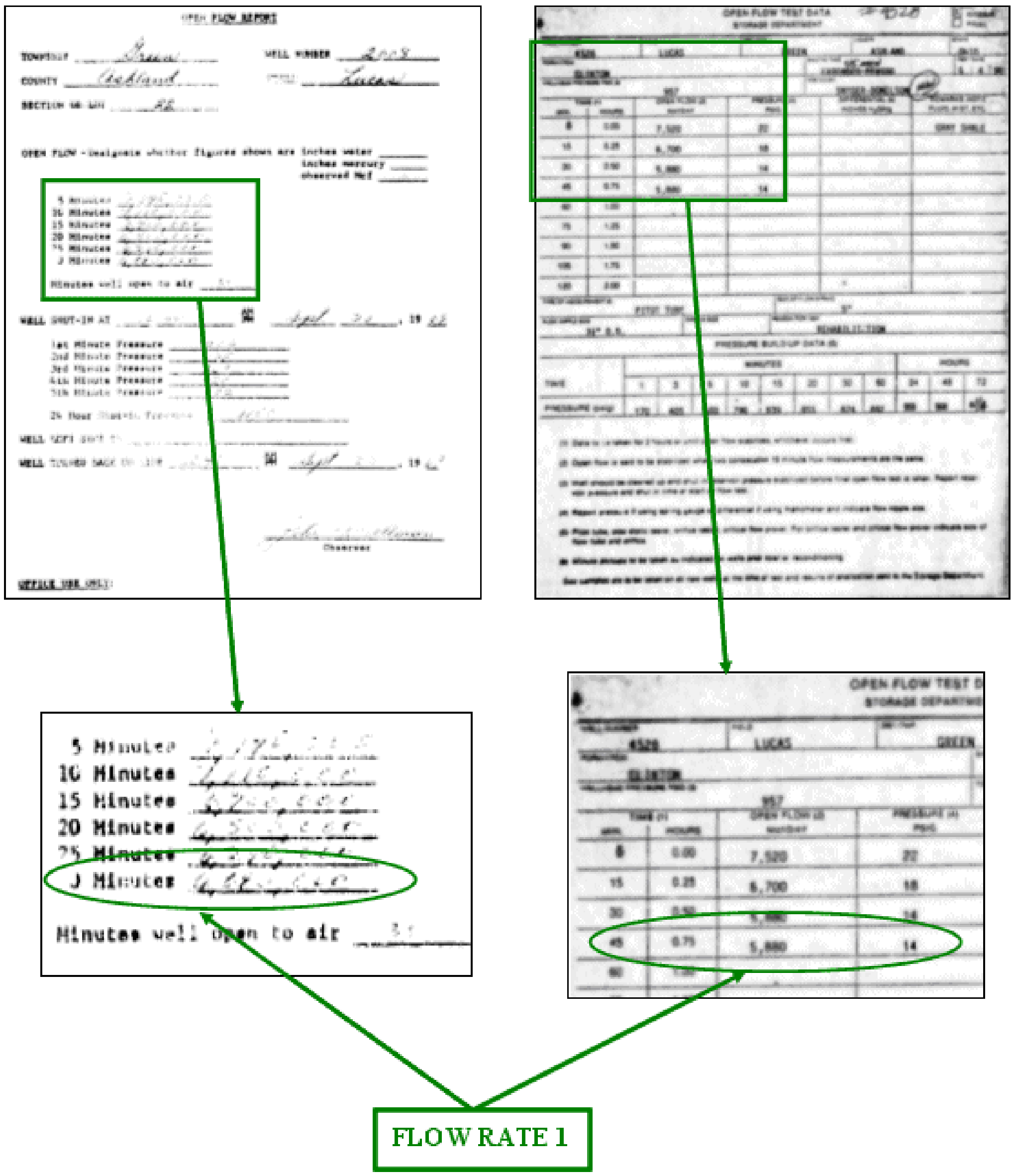


Fig22. Retrieving flow-rate of an open-flow test

Laminar Inertial Turbulent (LIT) Test

Analysis of data from isochronal type test using Laminar Inertial Turbulent (LIT) flow equation will yield considerable data. This method can also be used to find skin of a well from single-point test when the value of permeability of reservoir is known from prior multi-point test. The LIT equation is written as:

$$\Delta\psi = \overline{\psi}_R - \psi_{wf} = \underbrace{a_t q_{sc}}_{\text{Pressure drop due to laminar flow and well conditions}} + \underbrace{b q_{sc}^2}_{\text{Pressure drop due to inertial-turbulent flow}}$$

Procedure for calculating Skin from LIT analysis for known permeability (k) value is as shown below:

1. Calculate a_t and b from equations below:

$$a_t = \frac{\sum \frac{\Delta\Psi}{q_{sc}} \sum q_{sc}^2 - \sum q_{sc} \sum \Delta\Psi}{N \sum q_{sc}^2 - \sum q_{sc} \sum q_{sc}}$$

N= Number of data points

$$b = \frac{N \sum \Delta\Psi - \sum q_{sc} \sum \frac{\Delta\Psi}{q_{sc}}}{N \sum q_{sc}^2 - \sum q_{sc} \sum q_{sc}}$$

2. Plot $\left(\Delta\Psi - b q_{sc}^2\right) vs. q_{sc}$ on a logarithmic scale. The transient data points should form a straight line. If they don't form a straight line, calculate a_t and b again with the data which forms the straight line.
3. Calculate Skin (S) with the formula.

$$S = \frac{1}{0.869}\left[a_t \times 10^6 \frac{kh}{1.632 \times 10^6 T} - \log\left(\frac{kt}{\phi \mu_i c_i r_w^{\,2}}\right) + 3.23\right]$$

Where:

$\Delta\Psi$: Delta Pseudo Pressure
k : Effective permeability to gas, md
h : Net pay thickness, ft
t : Flow time, hrs
φ : Porosity, %
u_i : Initial Viscosity, cp
c_i : Initial compressibility, psi-1
T : Temperature of the reservoir, ^{o}R
r_w : Well-bore radius, ft
S : Skin, dimensionless

Flow Diagram of Well Test Analysis procedure

Following is the flow diagram of the well test analysis procedure and the type of values that we get from the data.

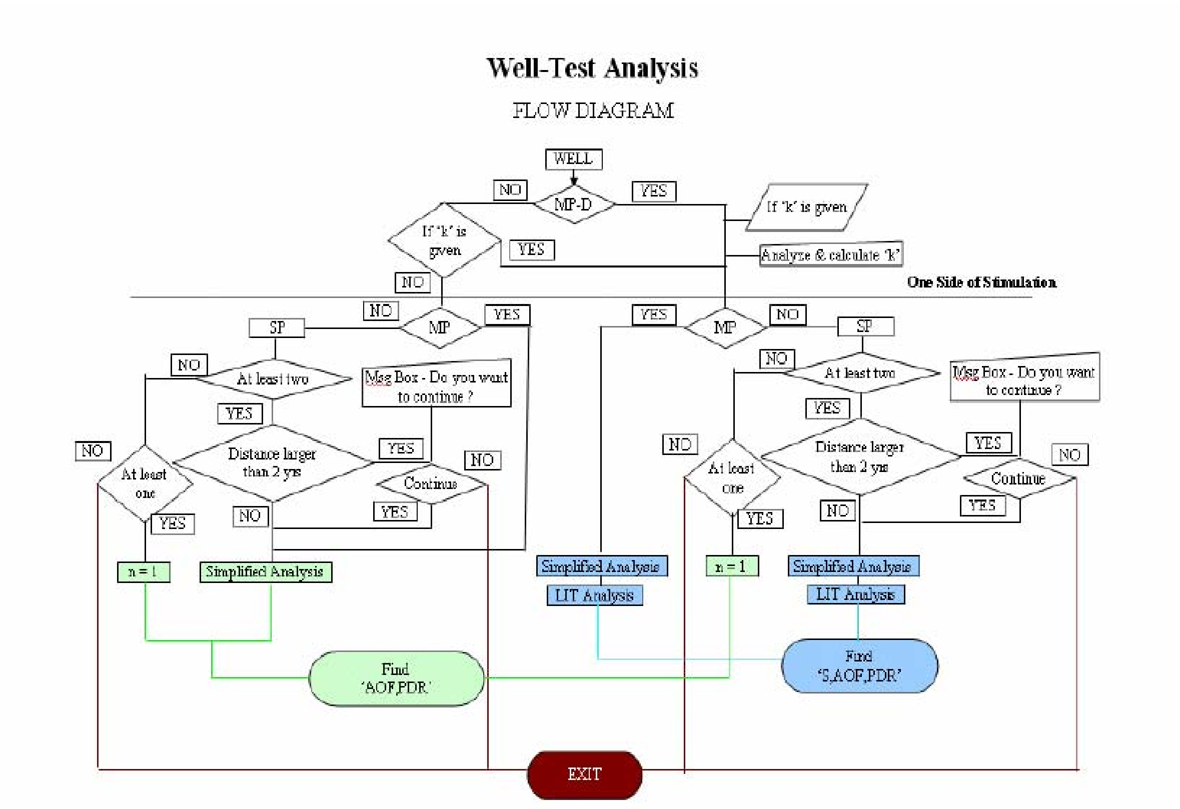


Fig23. Flow Diagram of Well Test Analysis procedure

RESERVIOR CHARACTERISTIC

It includes some reservoir properties. The complete list of the data type retrieved is shown below:

1. API Number
2. Well Radius
3. Reservoir Porosity
4. Reservoir Temperature
5. Gas Specific Gravity
6. Reservoir Thickness

NEURAL NETWORK MODULE

The Neural nets are very powerful in predicting non-linear relationships. As the relationship between skin and stimulation parameters is non-linear and very complicated, thus neural nets are used which are very good at it. With skin values before and after the stimulation calculated and stimulation parameters known, we can now use these valid stimulations to train the Neural Network to use it as a prediction tool. Intelligent Data Evaluation and Artificial Network IDEA® software by Intelligent Solutions Inc. was used to design the neural network. This software is very versatile in making different nets with different training algorithms. Generalized Regression Neural Net (GRNN) was used to train the neural net. The net had 11 inputs and 1 output as skin. The source of data for the neural net is given in Figure 24.

	Inputs	Source
1	Lat	Database
2	Long	Database
3	Sum Fluids	Sum of item 5,6,7,8
4	Prior-kh	Database
5	Water (bbls)	GA
6	Acid (bbls)	GA
7	Gel (bbls)	GA
8	Foam (bbls)	GA
9	N2 (Mcf)	GA
10	Sand Quantity (lbs)	GA
11	After-Test Type 3- Multi-Point 2- Single-Point 1- Open-Flow	GA

Fig24. Neural Network Inputs and their source

Out of the 78 valid stimulations available, the Neural net was trained on 60 data items while 14 were used as calibration data and 4 as verification data. The Neural network showed very good results for all three types of data. The screen shot taken from the IDEA software for training of the neural net is shown in Figure 25.

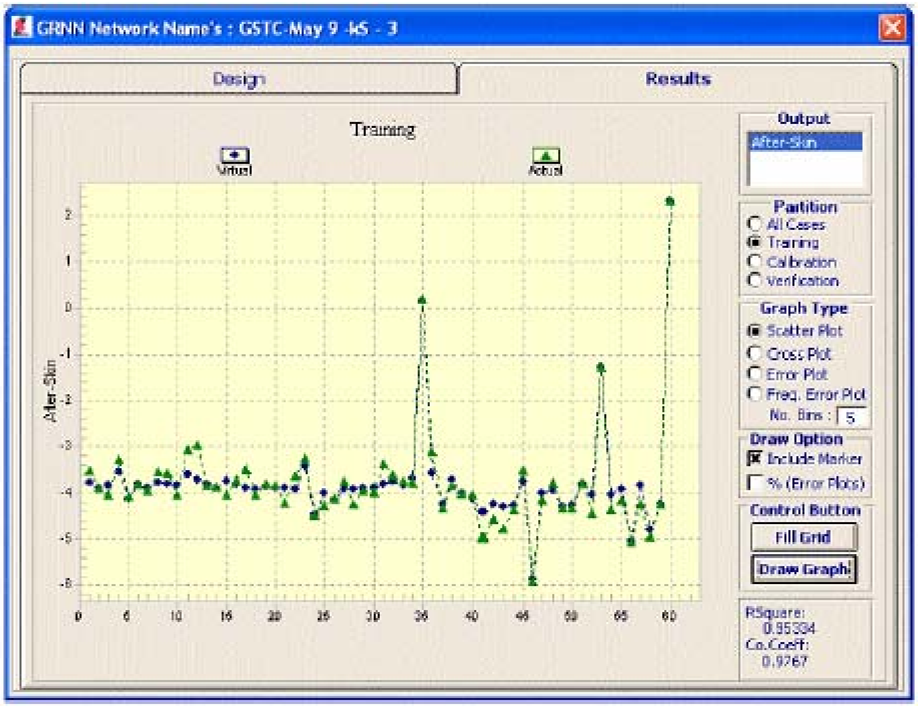


Fig25. Accuracy of training data for the Neural Net

The calibration and verification of the Neural net is shown in Figure 26 and Figure 27 respectively. After the accurate results of this GRNN, the software was updated to use the GRNN generated files to be used in the Genetic algorithm.

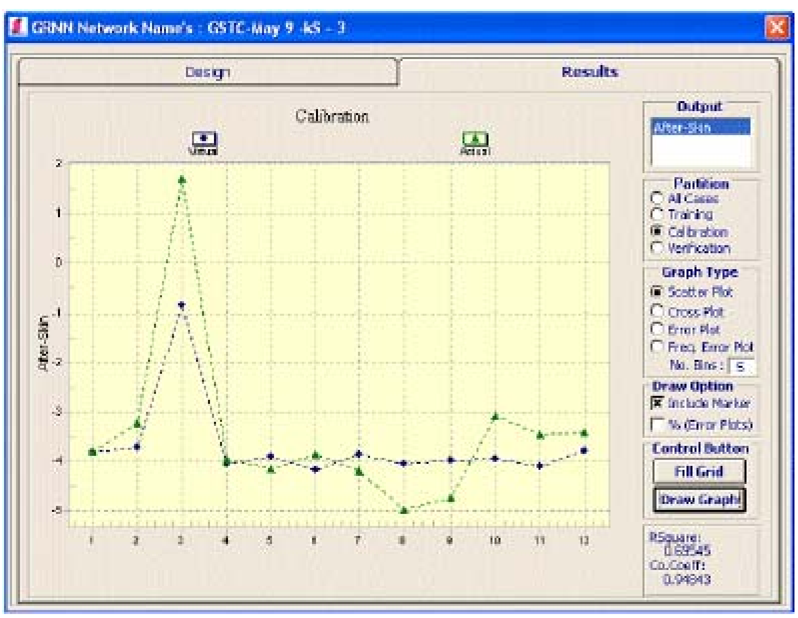


Fig26. Accuracy of calibration data for the Neural net

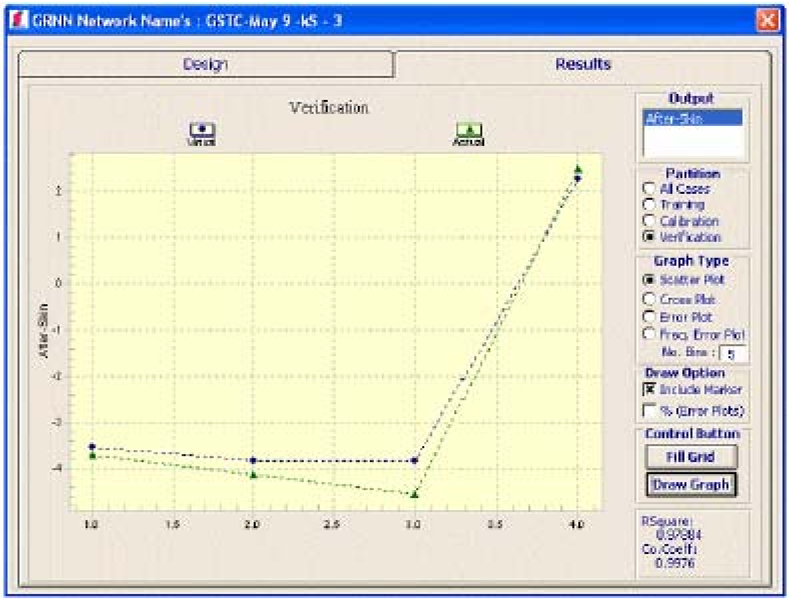


Fig27. Accuracy of verification data for the Neural net

GENETIC OPTIMIZATION MODEL

Genetic Algorithm was written to optimize the stimulation parameters used in the neural net. Out of the 11 input parameters, 7 can be varied to obtain optimum skin. The range of these variables was calculated and accuracy desired was determined to design the length of the chromosome of Genetic Algorithm (GA) that will be required. The calculation is shown in the table 4. for the chromosome length if all the parameters are selected.

	GA Input Parameter	Min	Max	Range	Accuracy Required	Accuracy Size	Range Size	Chromosome Size	Min Byte size	Max Byte size
1	Water (bbls)	0	345	345	1	1	345	9	2^8 =256	2^9=512
2	Acid (bbls)	0	11.9	11.9	0.01	100	1190	11	2^10 =1024	2^11=2048
3	Gel (bbls)	0	535	535	1	1	535	10	2^9=512	2^10=1024
4	Foam (bbls)	0	1.7	1.7	0.01	100	170	8	2^7 =128	2^8=256
5	N2(Mcf)	0	368	368	1	1	368	9	2^8 =256	2^9=512
6	Sand Quantity (lbs)	0	30000	30000	100	0.01	300	9	2^8 =256	2^9=512
7	After-Test Type 3- Multi-Point 2- Single-Point 1- Open-Flow	1	3	3	1	1	3	2	2^1=2	2^2 =4

Table 4. Calculation to determine the length of chromosome

The length of chromosome came out to be 9 + 11 +10 + 8 + 9 + 9 + 2 = 58.
The GA characteristics that were used are shown in Table 5. These were the best but can be changed as desired to suit other neural nets in the future.

GA CHARACTERISTICS	VALUE
Crossover rate	60 %
Mutation rate	10 %
Population size	500
No of Generations	10
Next Generation criteria	Top 30 % ranked from previous generation
Crossover criteria	Top 25 % has 75 % chance of Crossover

Table 5. CA characteristic

There are two optimization methods made available in this software. One is optimization just based on skin and other, based on both skin and cost. The optimization objective function is calculated using the following formula and GA minimizes this optimization objective function.

$$Optimization\ Objective\ Function = \frac{Skin - Skin_{min}}{Skin_{max} - Skin_{min}} \times Skin\ weight + \frac{Cost - Cost_{min}}{Cost_{max} - Cost_{min}} \times Cost\ weight$$

Software compatibility and variability:

In the software user has been given many options to accommodate the particular situation that he has and data availability if different from the data that we have used to verify the results from this software.

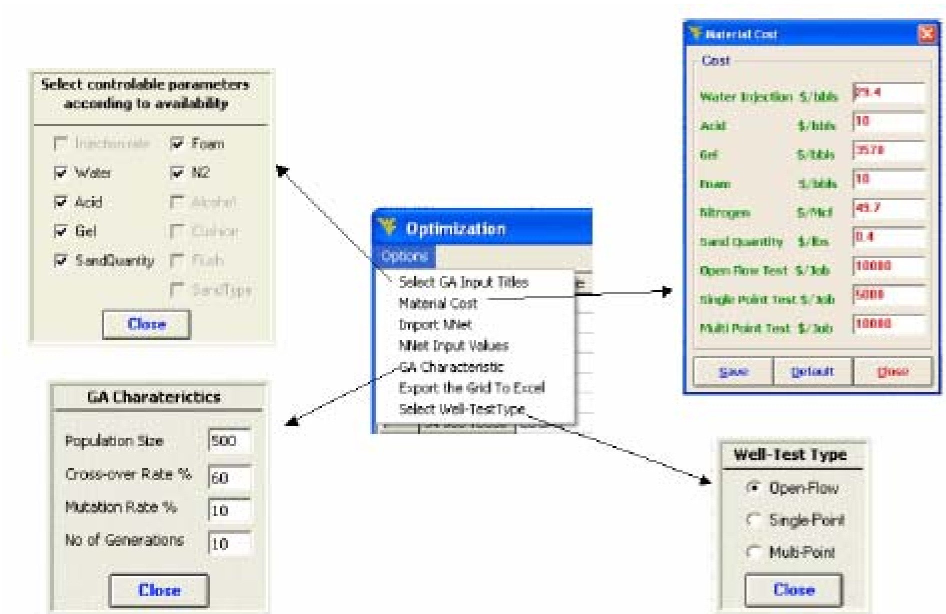


Fig28. Different options in the software that makes it versatile.

One of such variability introduced is that the software can use any other neural net if it is required. The option menu of the optimization screen has the option to import any other neural network. Plus, there is an option to select the available controllable parameters for the GA. For example, if the user does not want to use or does not have foam and nitrogen, then he can unselect them as shown in Figure 3.18. The length of GA will change according to the selection.

As the Neural Net has ‘Well-Test Type’ as its input, so the ‘Select Well-Test Type’ menu option gives the user an option to choose the test the user wants the neural net to interpret the well-test. With changing price of hydro-carbons, the petroleum industry is going through fluctuating material cost. The stimulation material prices change frequently and are a factor of demand and supply in that region. The software has the option to change the price of the stimulation material before applying the GA to the available data.

Analysis of raw data vs. refined data:

WELL TEST DATA																															
DATA FIELDS	Total Well-Tests	API Number	Field Name	Well	Test Date	Test Type	Time1	FieldPress1	FlowingPress1	Rate1	Time2	FieldPress2	FlowingPress2	Rate2	Time3	FieldPress3	FlowingPress3	Rate3	Time Extended	Field Pressure Ext	Flowing Pressure Ext	Rate Ext	kh	Skin	True Skin	Non Darcy Coefficient	n-Value	C-Value	Delta P Squared	Peak Day Rate	Absolute Open Flow
INITIAL DATA AVAILABLE	3223	431	431	431	3223	3223	3223	3223	3223	3223	347	347	347	347	292	292	292	292	345	345	345	345	191	182	163	163	916	916	916	916	916
FINAL DATA AVAILABLE	3365	431	431	431	3365	3365	3365	3365	3365	3365	347	347	347	347	292	292	292	292	345	345	345	345	194	185	166	166	1362	1362	1362	1362	1362

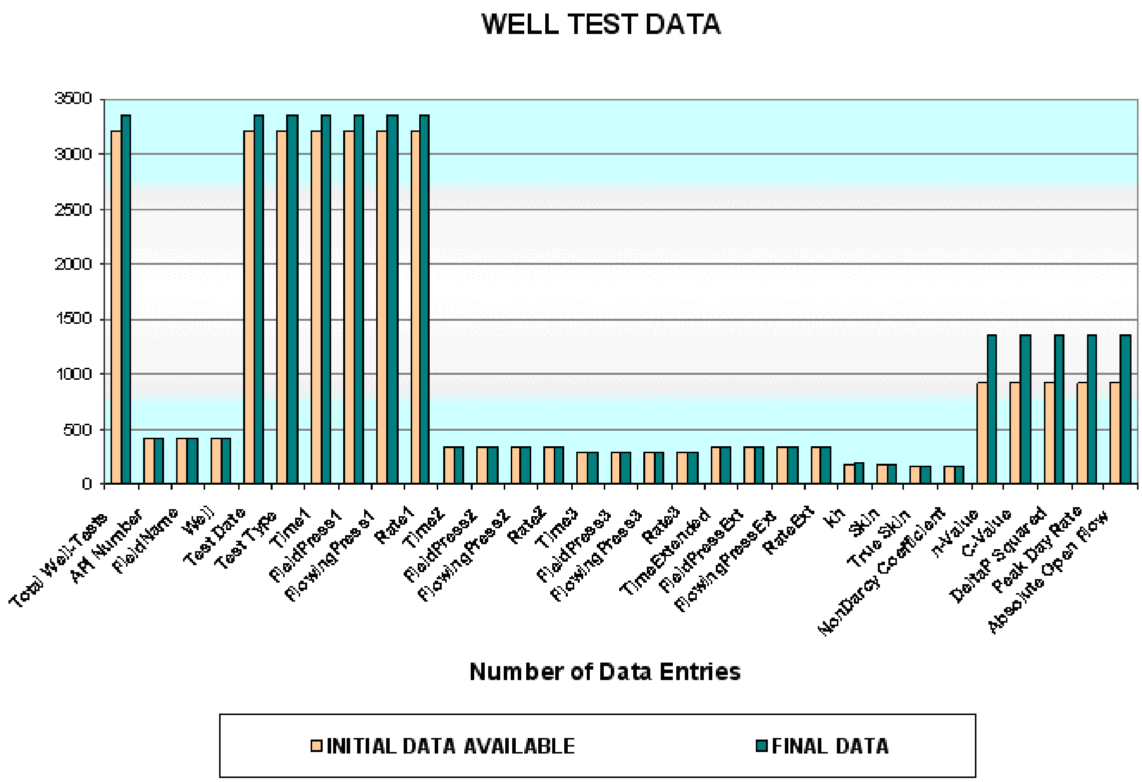


Fig29. Data addition and refinement for well test data

SOFTWARE BASICS

This software allows you to add/edit well data in the database and choose the data that you want to look at, for a selected well. It also has a Well Test Analysis tool which calculates the well deliverability parameters like n, C, Peak Day rate & Absolute Open Flow

The database for this software consists of five main tables

1. Well bore Data
2. Completion Data
3. Perforation Data
4. Stimulation Data
5. Well Test Data
6. Reservoir Characteristic Data

The **API number** of a well is the primary key in this database so it must be known before adding a record and cannot be duplicated

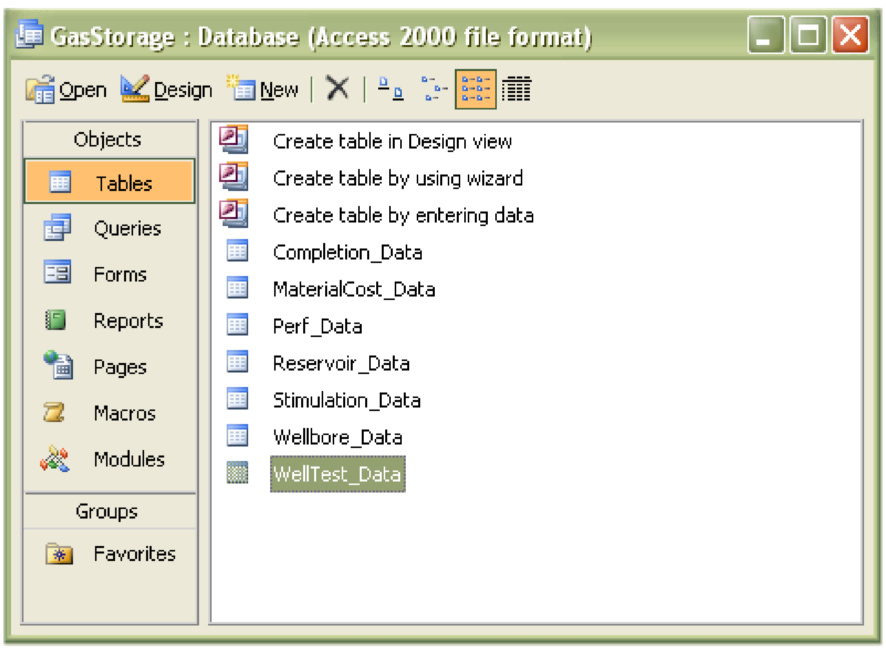


Fig30. Screen shot of database showing different tables

The software starts with the main menu screen with six options

Fig31. Main Screen of software

Complete list of items and sub-items in the above command buttons is shown below:
File
- o Create Template
- o Import Data from filled-out Template
- o Remove all data from database
- o Exit

Help
- o User Manual
- o Formulas
- o About

Edit Well Data
- o Well bore
- o Completion
- o Stimulation
- o Perforation
- o Stimulation
- o Well Test
    - Well Test Analysis Tool
- o Reservoir
- o Find a Well

View Well Data

- o Select State & county
- o Select Wells
- o Selection Options
- o Select Well Data

Candidate Selection

File

The file menu can be accessed from the top left corner of menu bar. It contains four options.

- o Create Template
- o Import Data from filled-out Template
- o Remove all data from database
- o Exit

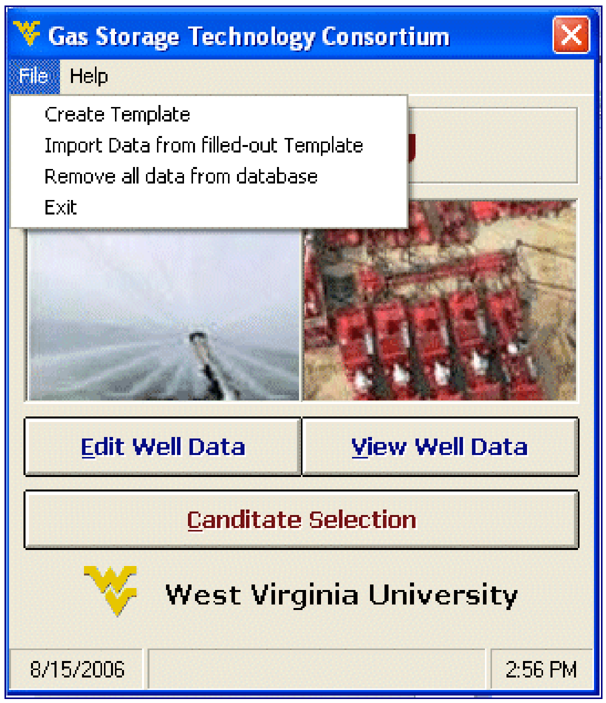


Fig32. File Menu options

Create Template

By executing this option first the user need to select a location in hard drive in order to save Template file.

Once the Template is successfully created in the hard drive, a message will appear indicating the user that the template file has been created.

Following is the screen shot of the Template file showing the Well bore data.

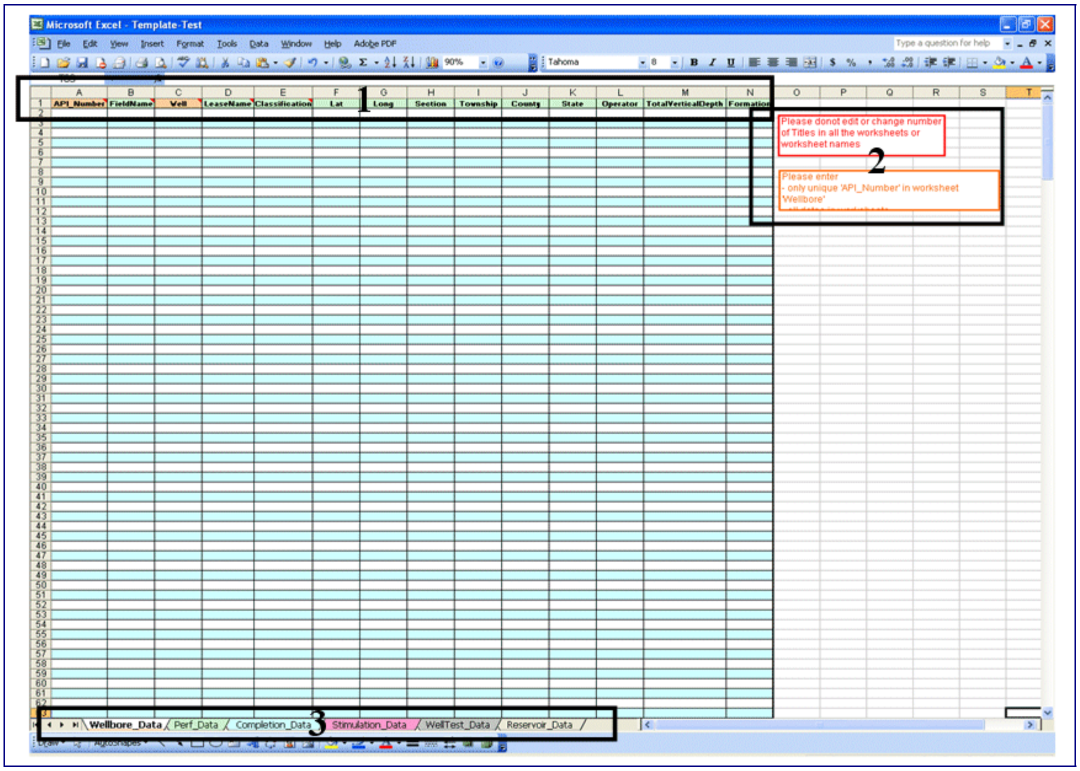


Fig33. Screen shot of Template file

It has six worksheets, each representing the table in the database of the software.

- Well bore Data
- Completion Data
- Stimulation Data
- Perforation Data
- Stimulation Data
- Well Test Data
- Reservoir Characteristic

1. These are the fields of the table. Each field represents one characteristic of the table and each row is one record. If the user is not clear about any field, then he/she can drag the screen cursor to that field name and the comment will appear like in the picture below where it will give a little explanation, its format and an example so that the user understands what sort of data to enter in each field

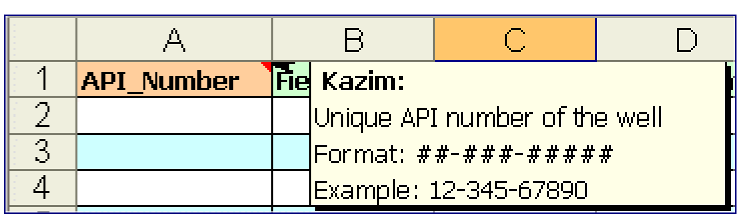


Fig34. Comments that shows format of some cells in Template Excel file

2. This section has two sets of warnings for the user entering data. One is to not edit or change number of Titles in all the worksheets or worksheet names and the other is to add only unique 'API Number' in worksheet 'Well bore Data' and all dates in worksheets where required.
   This has been done as the data is retrieved from the template according to some specific format and non presence of any data in elementary field might stop program from using that record. All the elementary fields' background is orange/red while others are in green.

3. This section shows all the worksheets in the Template file.

Import Data from filled-out Template

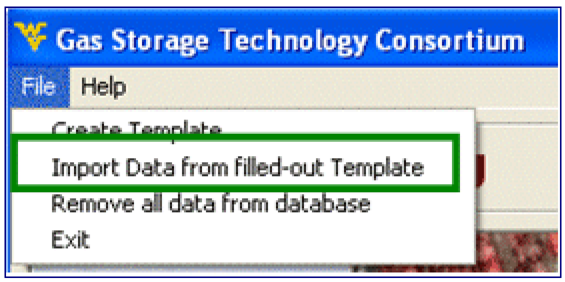


Fig35. Import data from filled-out Template

If this option is selected from the file menu, then the program will ask the user to select the filled Template file from the location. The new data will be appended to the existing data.

Remove all data from database

If the user doesn't want to append the data to the previous database but instead wants to up-load a whole new data, then there is an option in file menu as highlighted in the snapshot below. This option will remove all data in the previous database. After removing the data from previous database, the user can up-load the updated data from the template or enter it in the software.

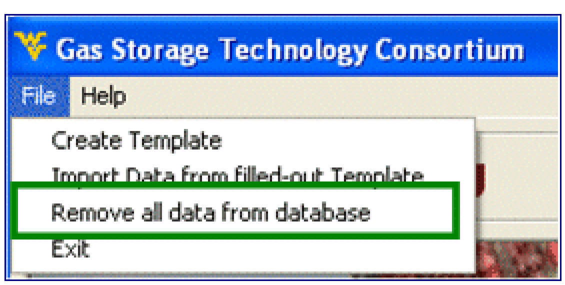


Fig36. Remove all data from database

Exit

The program can be exited by two options. One is to exit by using the file menu and selecting 'Exit' while the other is to select the cross on the top right corner as in normal windows based applications.

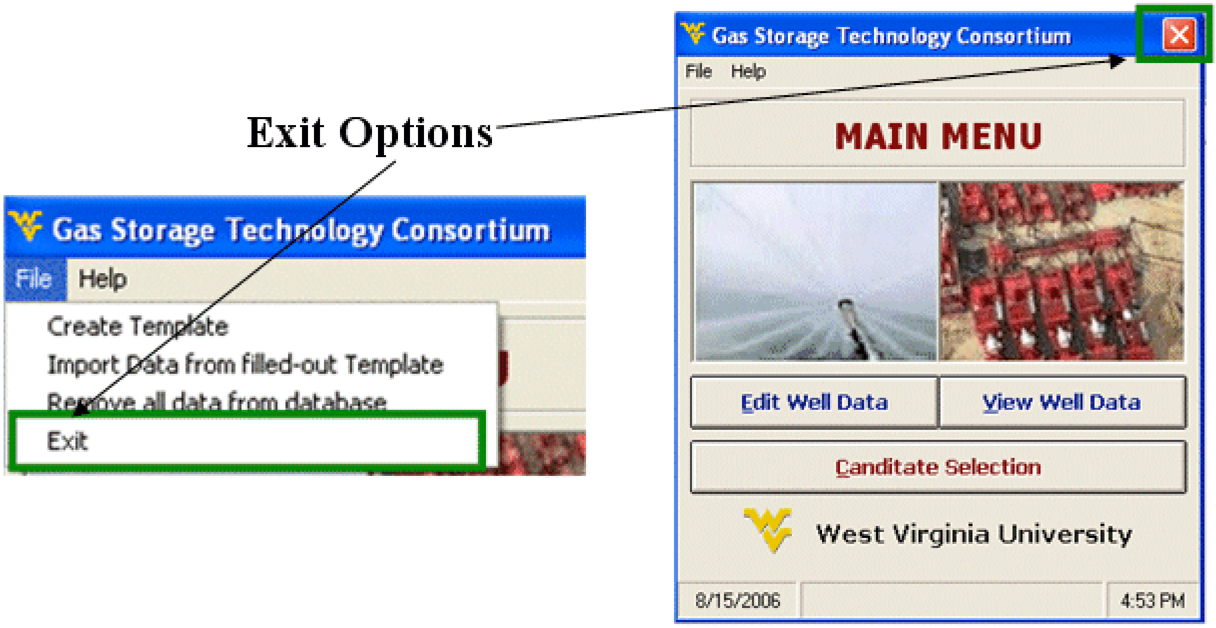


Fig37. Exit form file menu

Help
Another option that can be accessed from the menu bar on top of the main menu screen is the Help menu option.

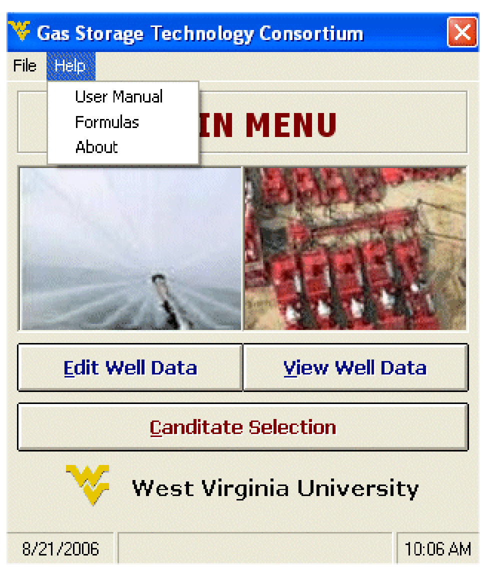


Fig38. Help menu options

It contains three types of information one is the User Manual for this software and second is the Formulas used in this software and third 'About' form which shows the system information and software contributors.

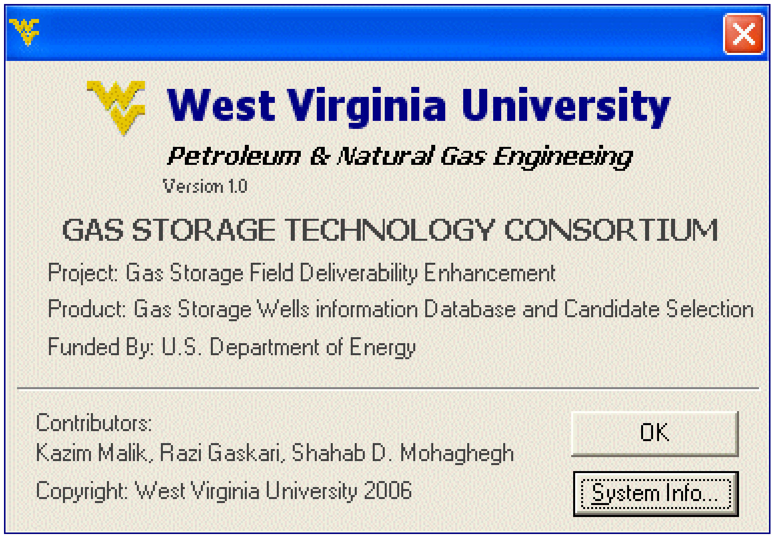


Fig39. "about" screen form help menu

Edit/View Well Data

This screen has all the well data in the form of five tabs (for five database tables) that can be edited / viewed or a Well Test Analysis can be performed in the Well Test tab.

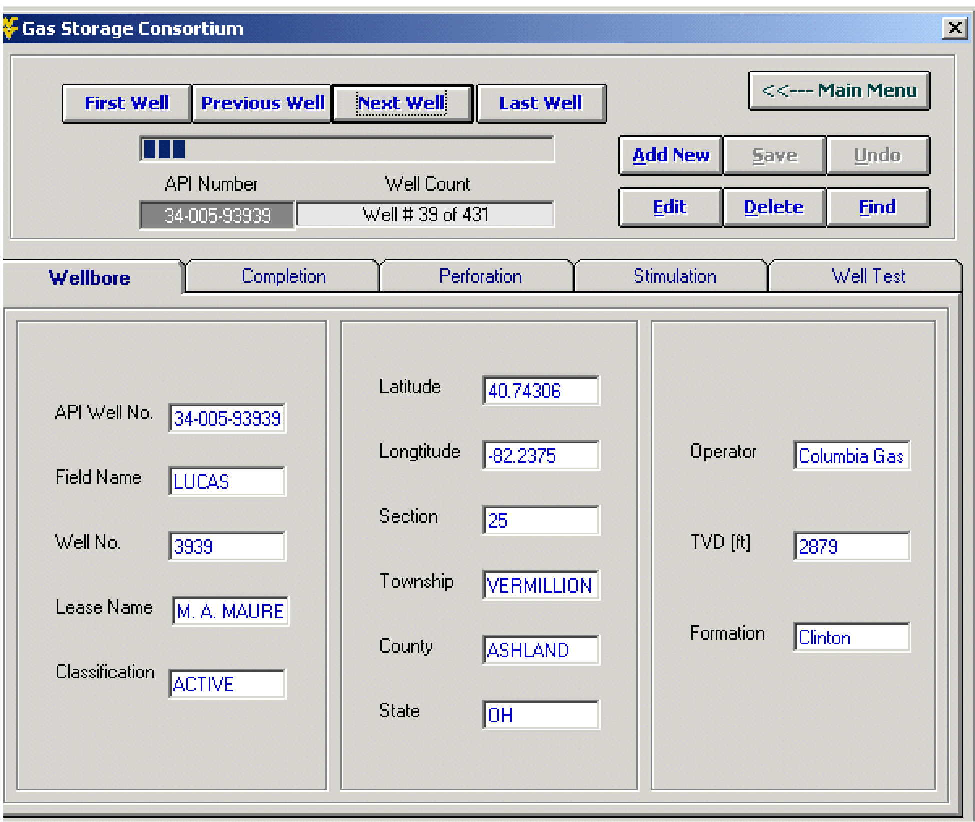
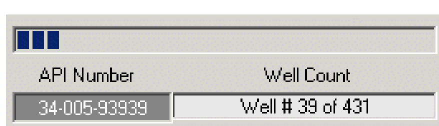


Fig40. Browsing through the well-bore data

To browse between different wells

To move to the first well, previous well, next well & the last well in the record, click on the button assigned to it. The records are sorted in ascending order according to well number

API Number & Well Count



The progress bar shows the relative position of the record and well count shows the current well position in the well bore database out of the total records. The API number of the current well is also displayed

Back to main menu

Takes you back to the very first screen of the program

Editing Tools

These buttons will help you to add a new record, edit or delete it or find a well for which you want the data to be retrieved if you know its API number.

Different Tabs

WELL BORE:

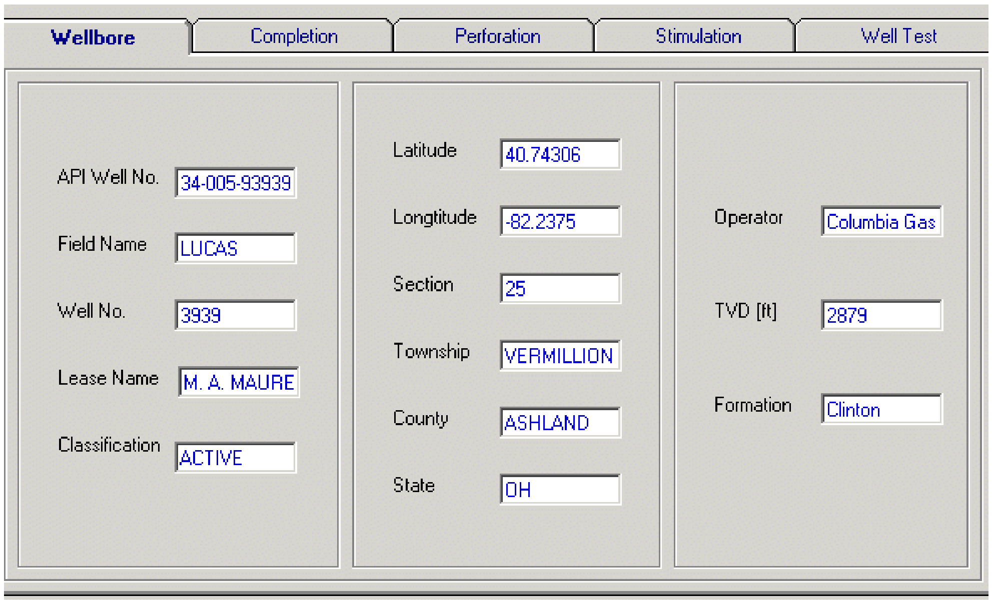


Fig41. Well-bore tab

This tab contains all the data pertaining to the name, location & some main features of the current well.

COMPLETION:

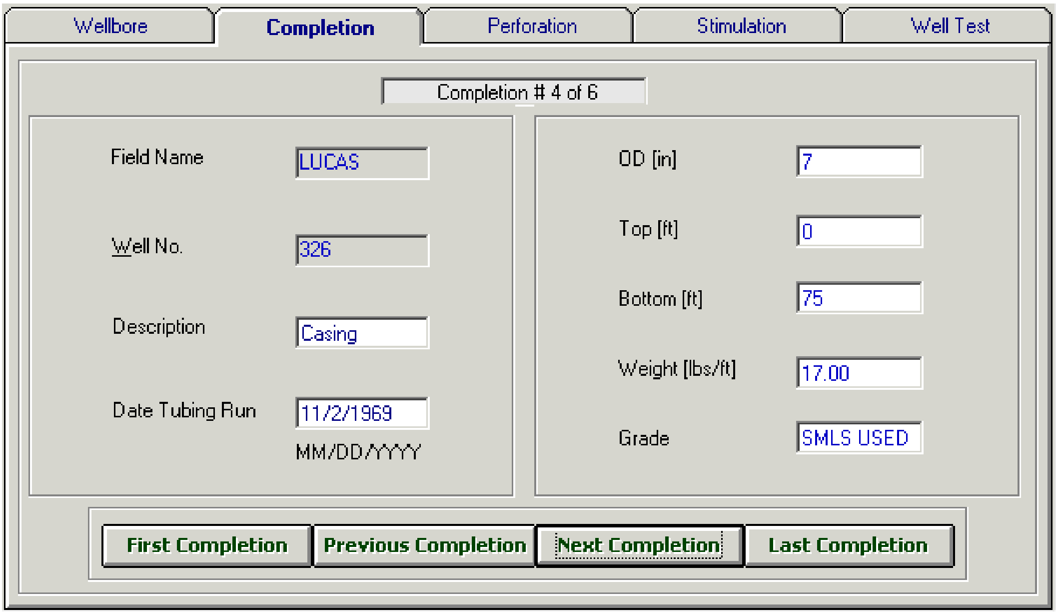
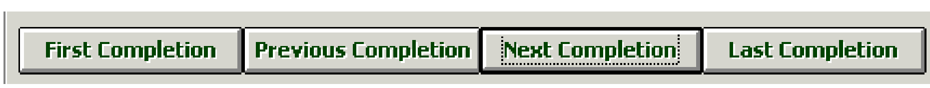


Fig42. Completion tab

This tab contains all the data relating to different completion run in the well.

To browse between different Completions



To move to the first completion, previous completion, next completion & the last completion in the record, click on the button assigned to it. The completions are assorted in ascending order according to date tubing run for current well.

PERFORATION:

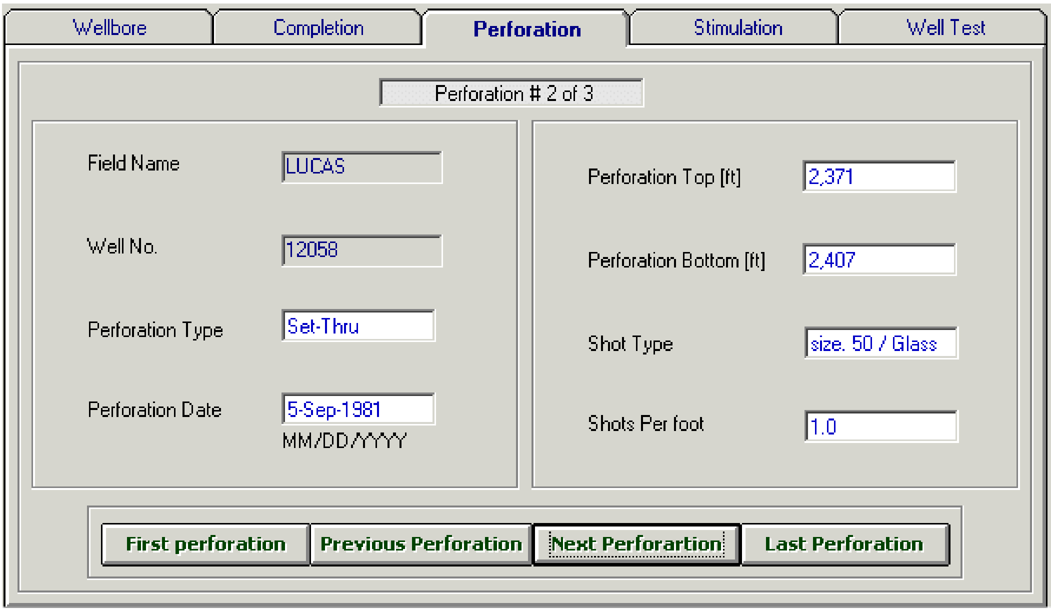
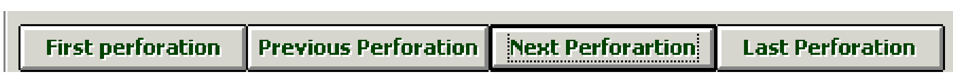


Fig43. Perforation tab

To browse between different Perforations



To move to the first perforation, previous perforation, next perforation & the last perforation in the record, click on the button assigned to it. The perforations are sorted in ascending order according to perforation date for current well.

STIMULATION:

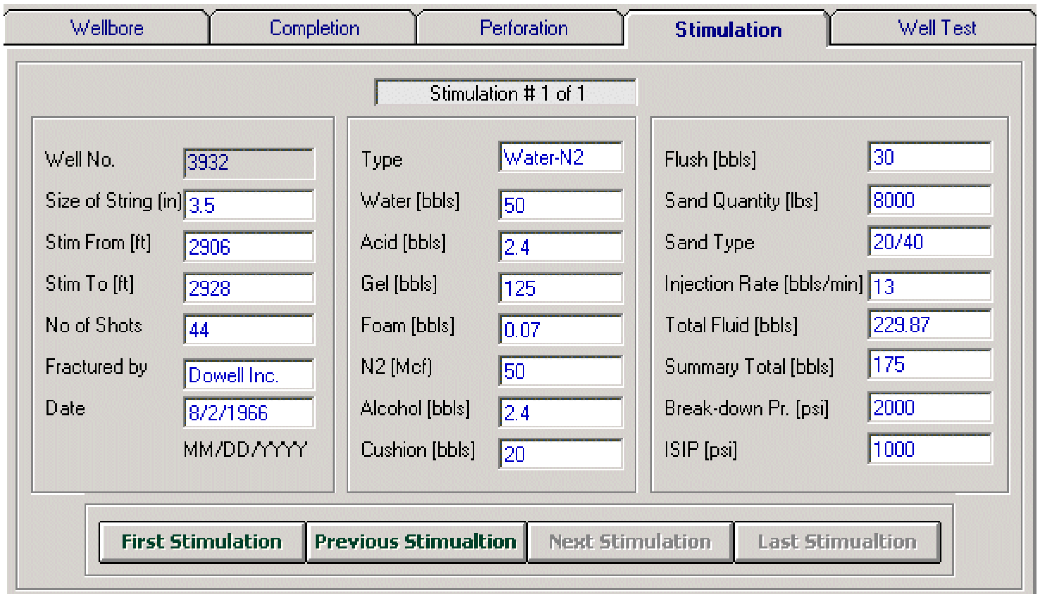


Fig44. Stimulation tab

To browse between different Stimulations

To move to the first stimulation, previous stimulation, next stimulation & the last stimulation in the record, click on the button assigned to it. The stimulations are sorted in ascending order according to stimulation date for current well.

WELL TEST:

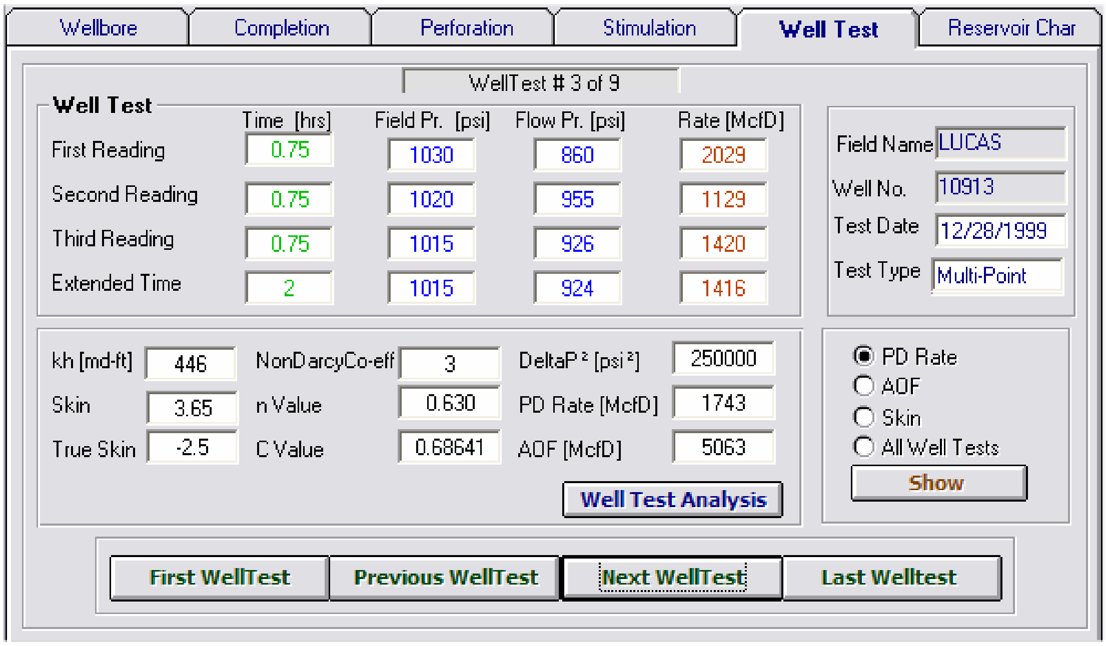


Fig45. Well-test tab

To browse between different Well Tests

To move to the first well test, previous well test, next well test & the last well test in the record, click on the button assigned to it. The well tests are sorted in ascending order according to well test date for current well.

Adding a new data

One can add a complete new well or just only a new well-bore/completion/perforation/ stimulation/well-test data by following method

Adding a complete new well data

1- Click on the Add New button  while keeping your well bore tab as active.

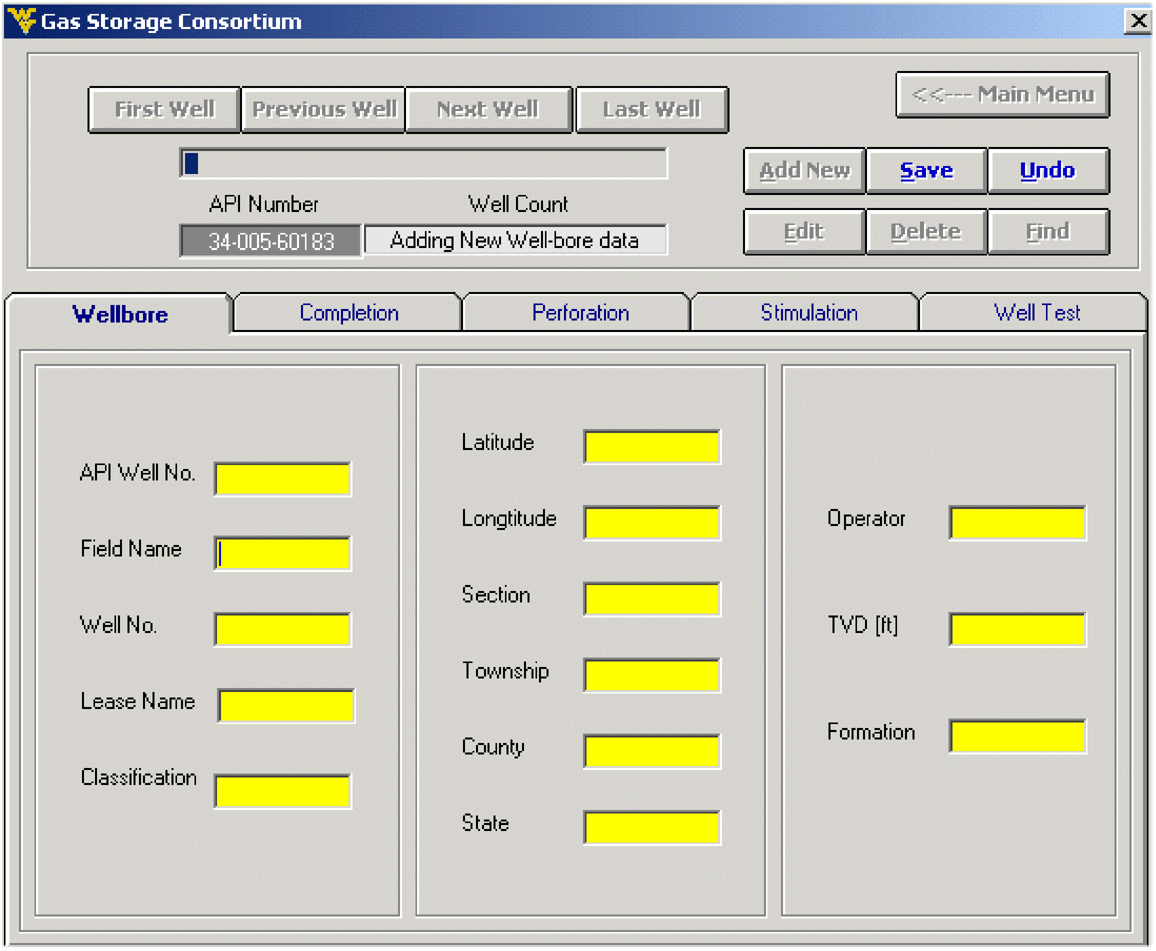
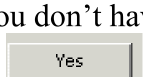


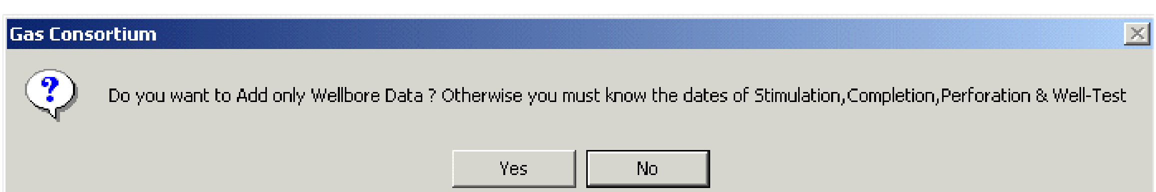
Fig46. Adding a complete new Well – well-bore tab

The following messages will pop-up. If you want to add the complete new well-bore data then click No button 

.

If you don't have the dates of Stimulation, Completion, Perforation & Well-Test data, then click Yes 

and then add them one-by one.



Following screen appears if No is clicked:

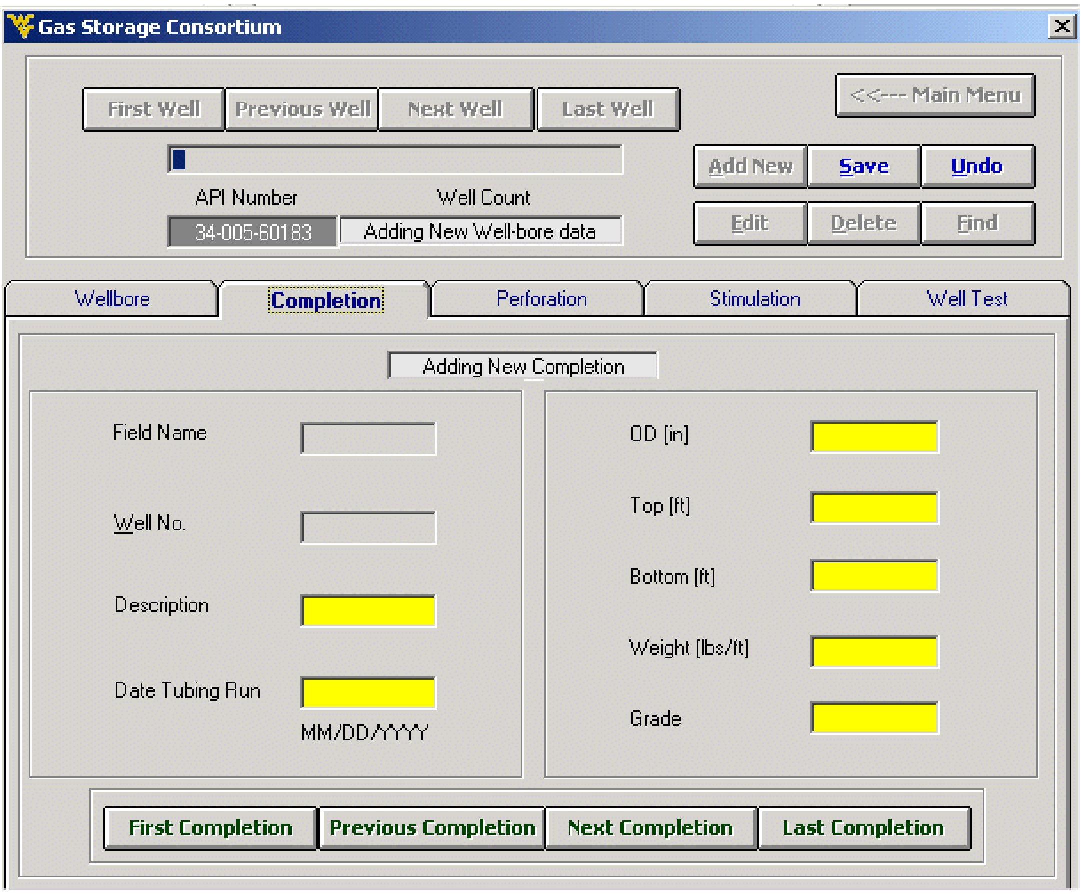


Fig47. Adding a complete new Well - completion tab

The background color of text boxes of all tabs including well-bore tab will be yellow indicating that they are ready for entering data.

2- Enter the data in all the tabs. The dates for completion, perforation, stimulation & well test job should be known.

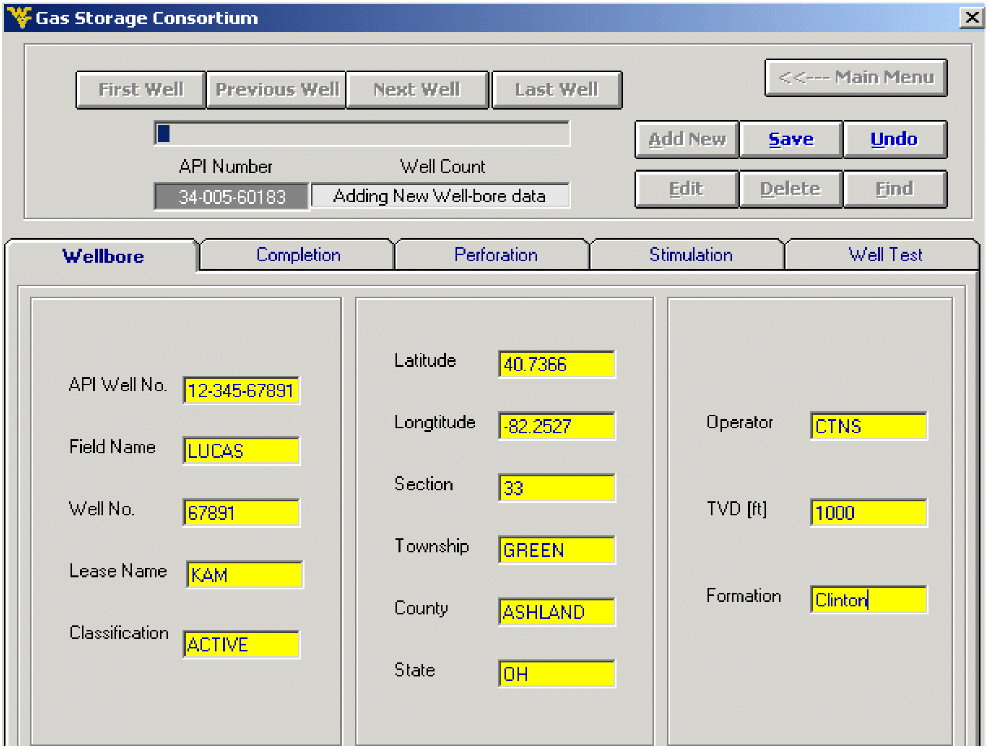


Fig48. Adding a complete new Well – entering data for wellbore

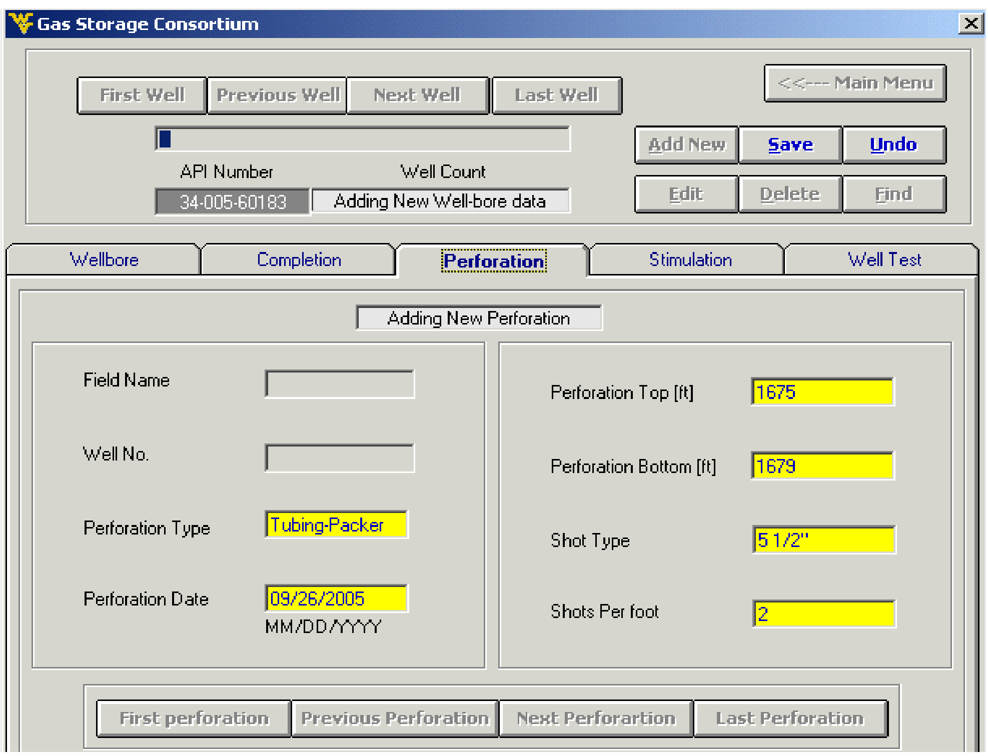


Fig49. Adding a complete new Well – entering data for perforation

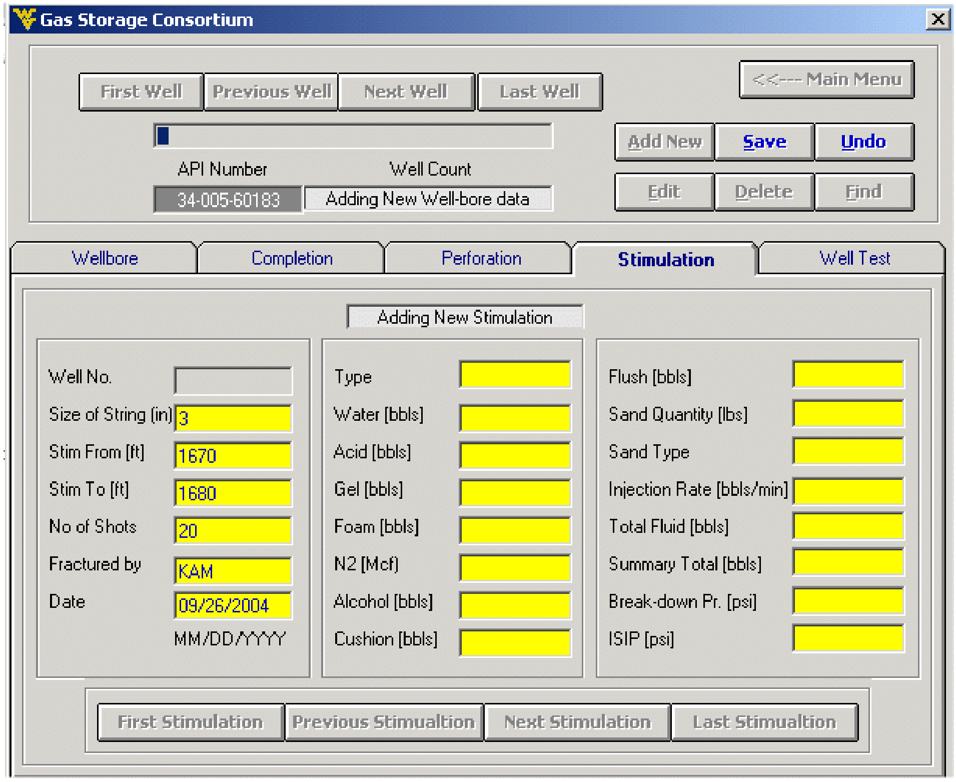


Fig50. Adding a complete new Well – entering data for stimulation

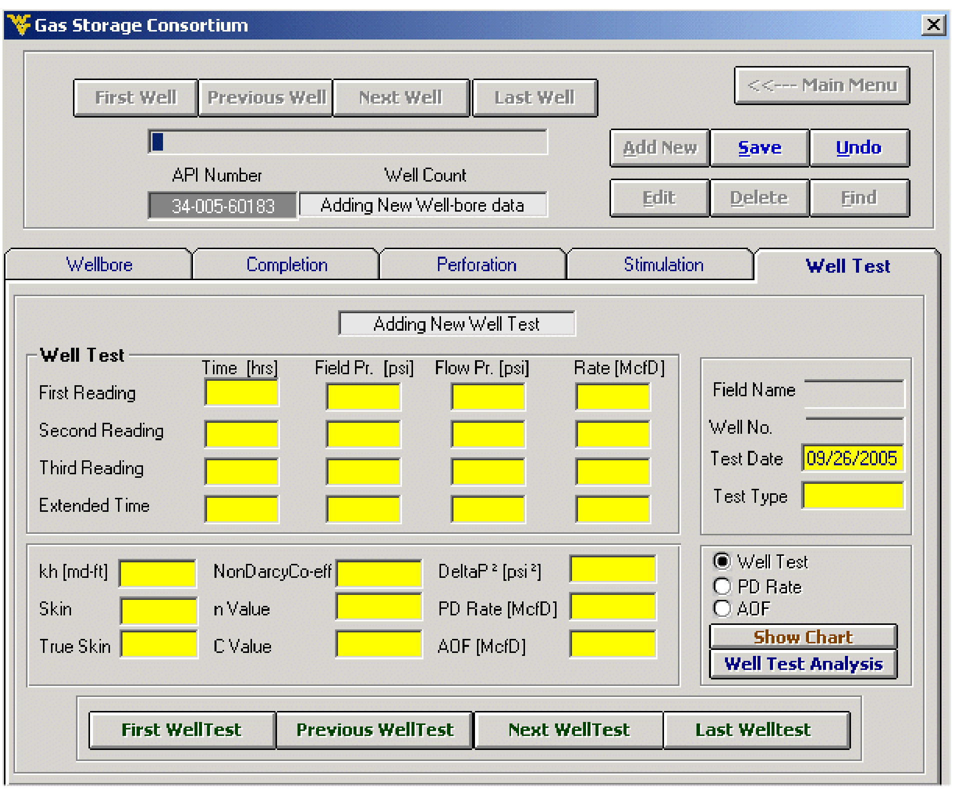


Fig51. Adding a complete new Well – entering data for well test

3- Click the Save button 

Result of adding of complete well data

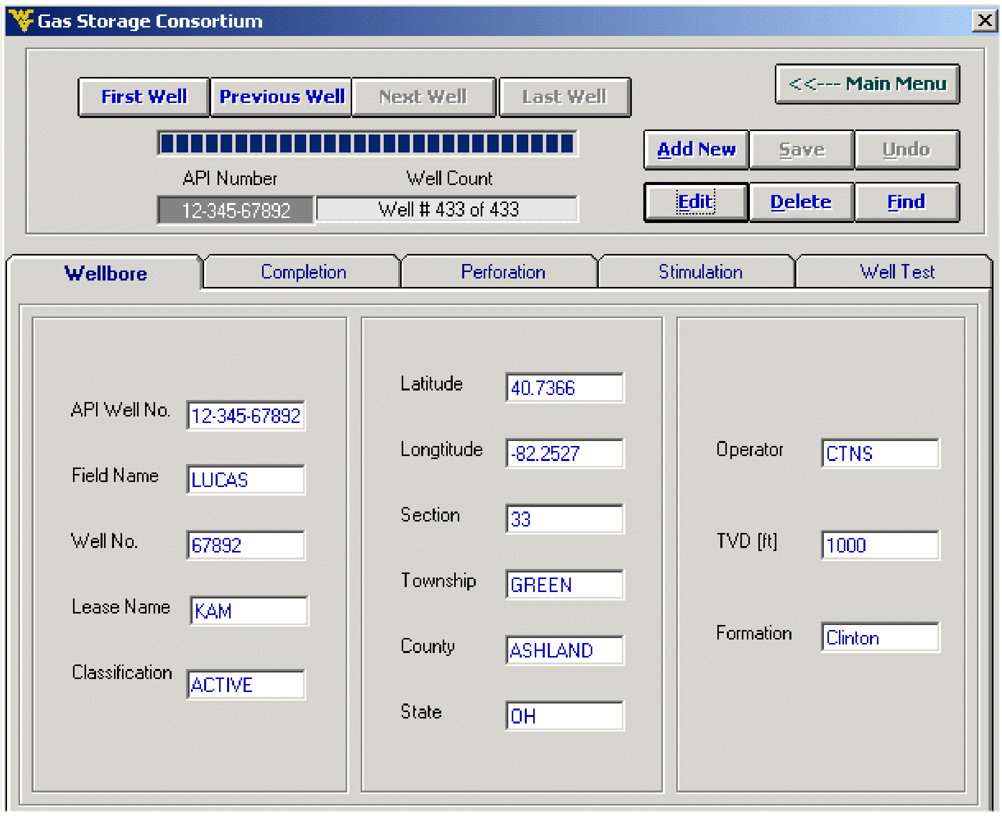
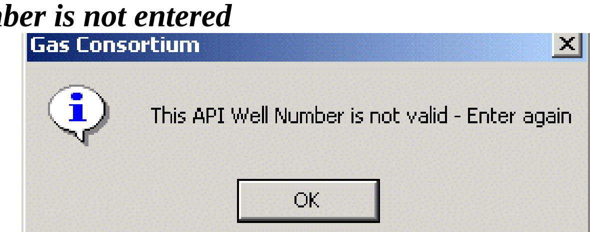


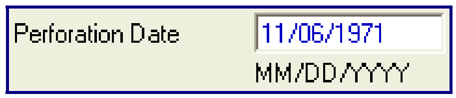
Fig52. Result of adding a complete new well

Warnings – If API Number is not entered

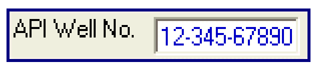


Warnings – If API Number entered is already in the database

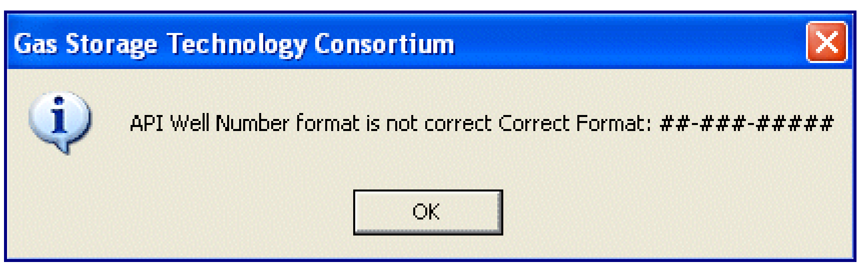
Note: The dates for completion, perforation, stimulation & well test should always be entered as the output of the software is directly dependent on the chronology of events. The format of date is also specified for the user where required. A close picture of that format is below:



You need to enter API well number only once in the well-bore tab and it will be automatically copied in the rest of tabs and procedure is the same for editing. The format for entering well API Number is:



If wrong format or well API number is entered for a new well, then you will be greeted with the following message

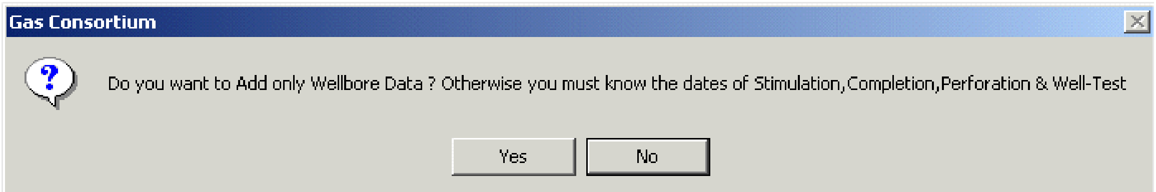


Adding only well-bore/completion/perforation/stimulation/well-test data

1- Click on the Add New button 

while keeping that tab active for which you want to add the data.

Only for well-bore tab following message pops up:

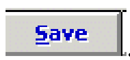


Click Yes 

button to add only Well-bore data.

The background color of all text boxes of that tab will be yellow indicating that they are ready for entering data.

2- Enter the data. The dates for completion, perforation, stimulation & well test job should be known.

3- Click the Save button 

.

Editing data

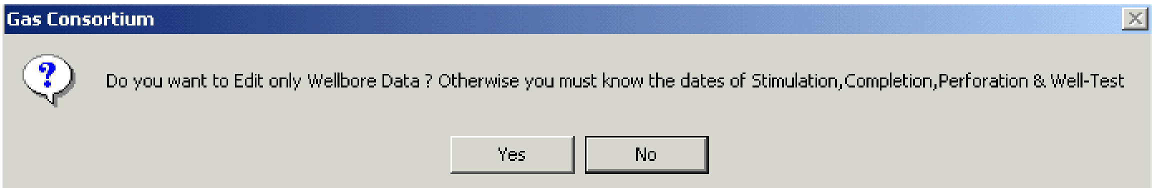
One can edit complete well or just only a new well-bore/completion/perforation/ stimulation/well-test data by following methods:

Editing a complete well data

1- Click on the Edit button 

while keeping your well bore tab as active.

Following screen pops up:



Select accordingly.

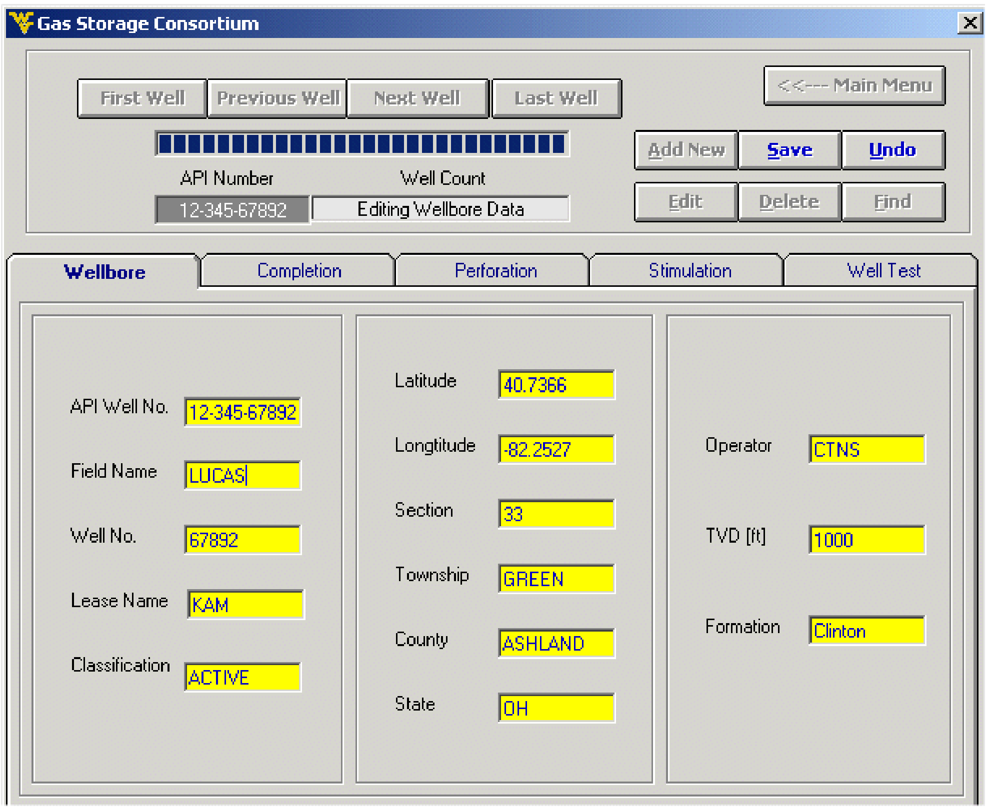


Fig53. Editing well data

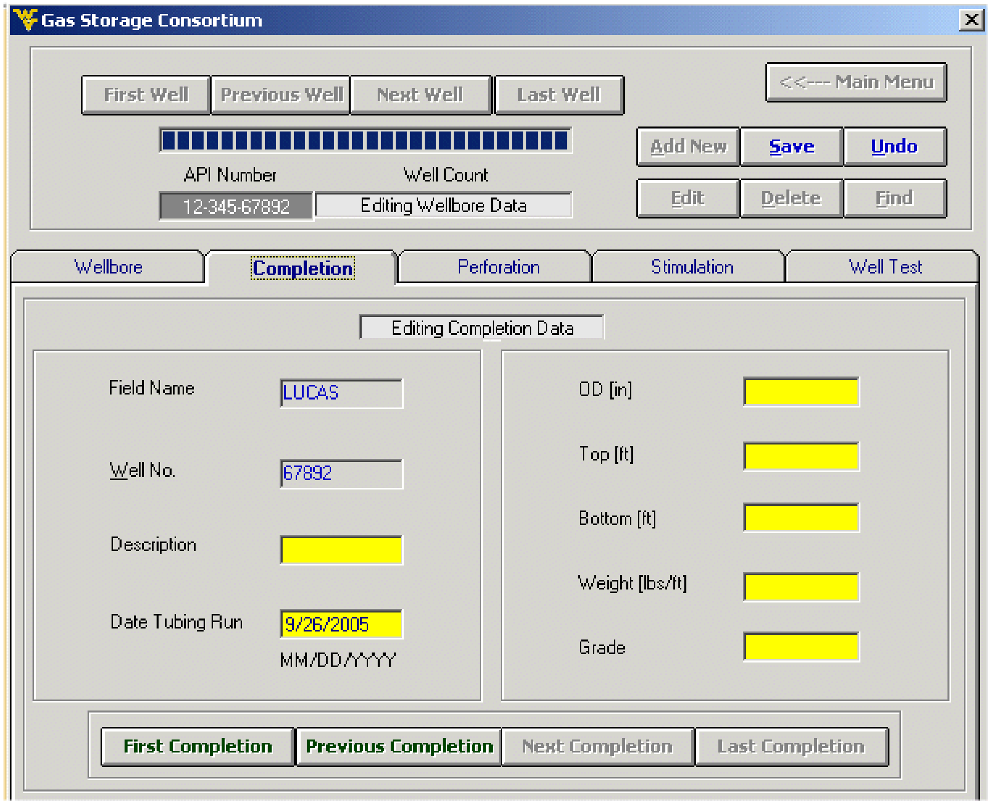


Fig54. Editing completion data

The background color of text boxes of all tabs including well-bore tab will be yellow indicating that they are ready for entering data.

2- Enter the data in all the active tabs. The dates for completion, perforation, stimulation & well test job should be known.

3- Click the Save button 

.

Editing only completion/perforation/stimulation/well-test data

1- Click on the Edit button 

while keeping that tab active for which you want to edit the data except well bore tab.

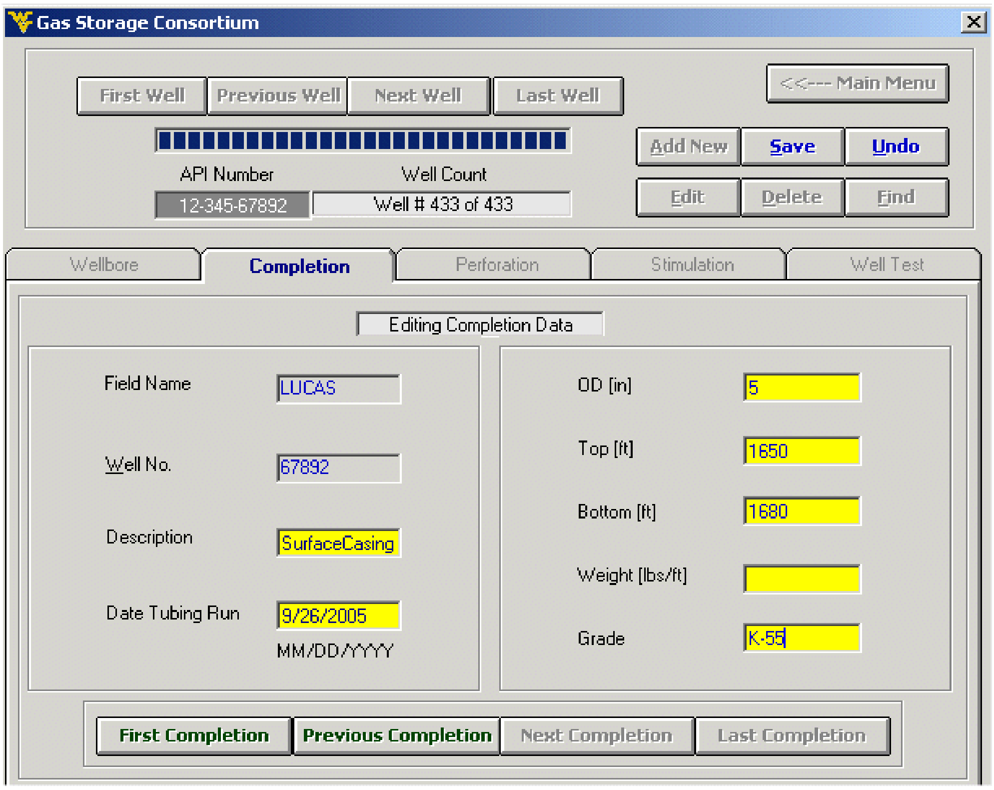
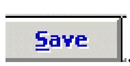


Fig55. Saving completion data

The background color of all text boxes of that tab will be yellow indicating that they are ready for entering data.

Enter the data. The dates for completion, perforation, stimulation & well test job should be known.

Click the Save button 

.

Result of editing only completion data

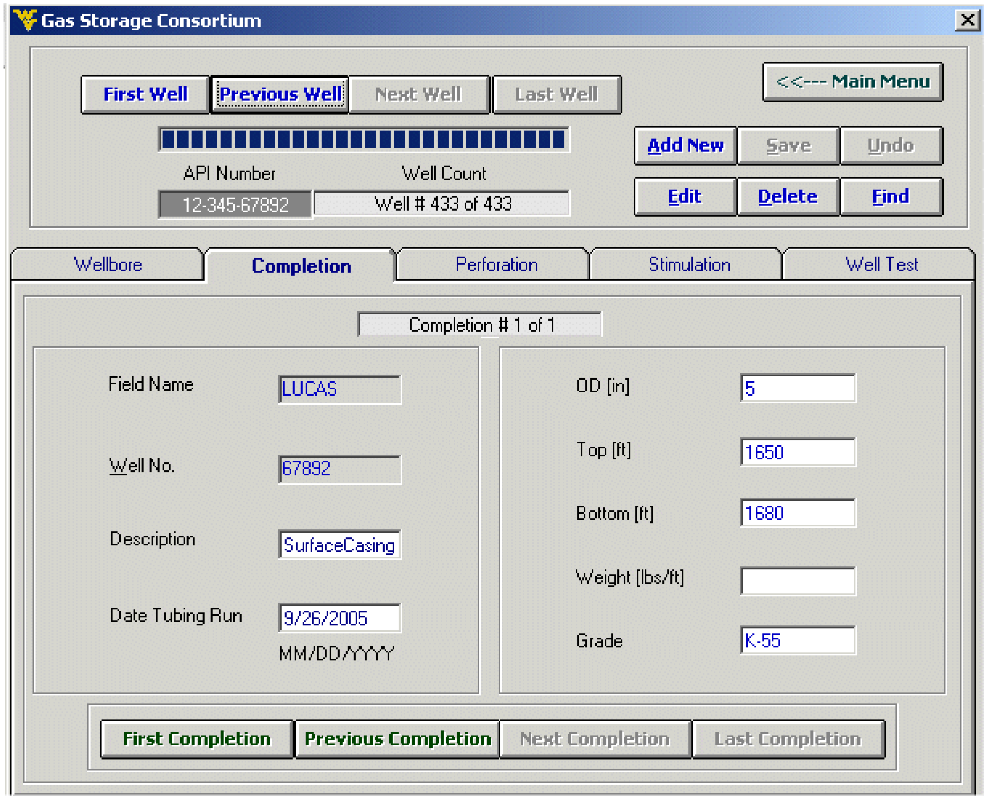


Fig56. Saved completion data

Deleting data

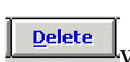
One can delete complete well or just only delete completion/perforation/ stimulation/well-test data by following methods:

Deleting a complete well data

1- Click on Delete button 

while keeping your well bore tab as active

Editing only completion/perforation/ stimulation/well-test data

1- Click on Delete button 

while keeping that tab active of which you want to delete the data except well bore tab.

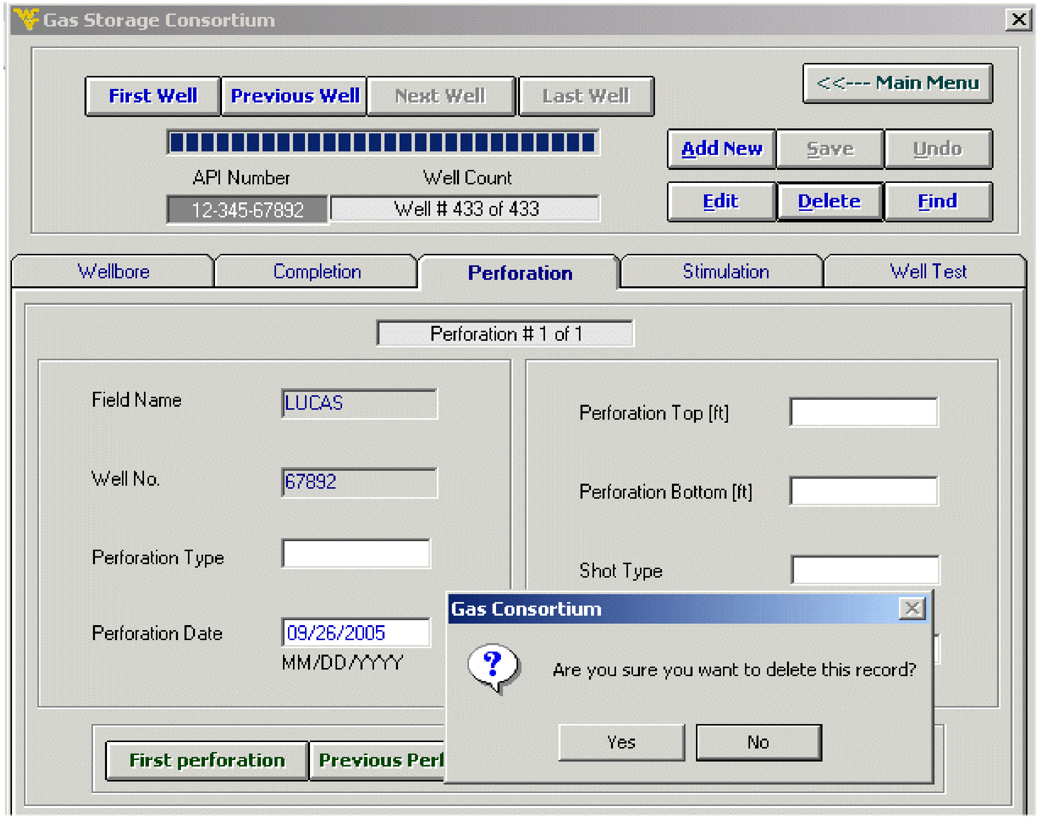
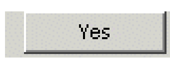


Fig57. Deleting perforation record

You will be greeted with the above message to make sure that delete button is not accidentally pressed.

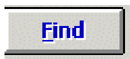
2- Click on yes  if you want the selected record to be deleted.

Undo the edit/add operation:

To undo the edit or add operation before they can be saved click undo button 

Finding a well

Follow the following procedure to find a well for which you have some idea of its API well number:

Click on Find button 

The following screen is displayed:

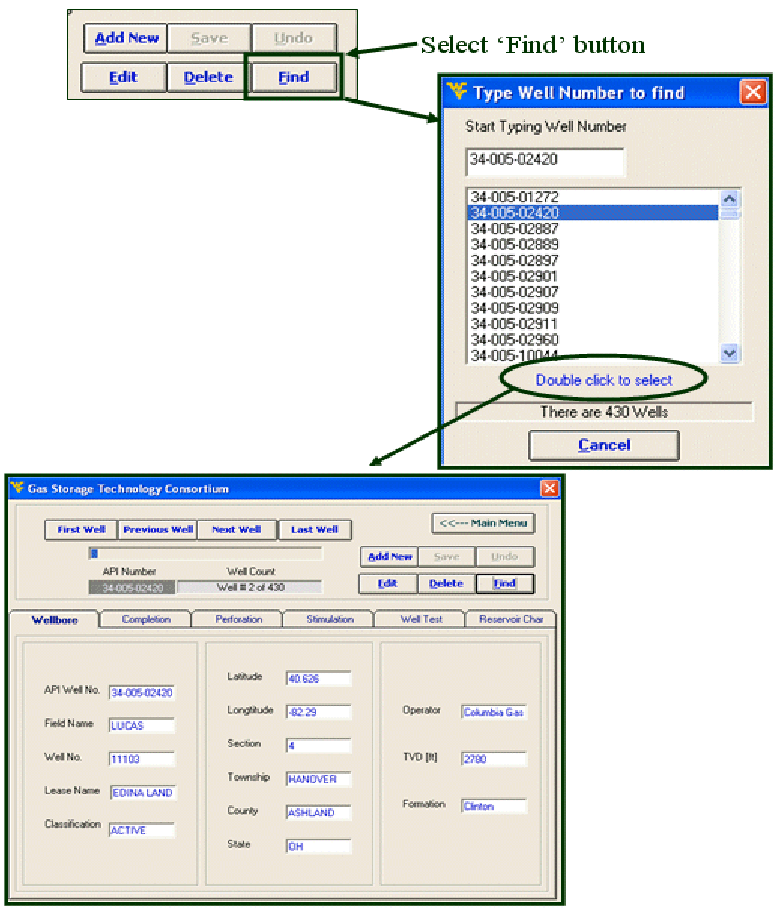


Fig58. Finding a well

WELL TEST ANALYSIS

To perform well test analysis on a well and draw graph of Peak day rate and Absolute open flow, use the option / command buttons below:

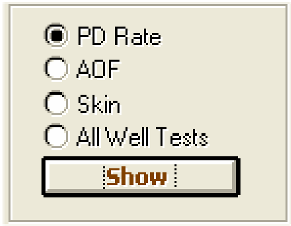


Fig59. Well-test Analysis Option in well-test tab

Peak day, AOF, Skin, and all well test graph

Select ***PD rate*** , ***AOF, Skin or All well Tests*** option button and then click on the **Show** button 

. The following screens will appear according to the option selected:

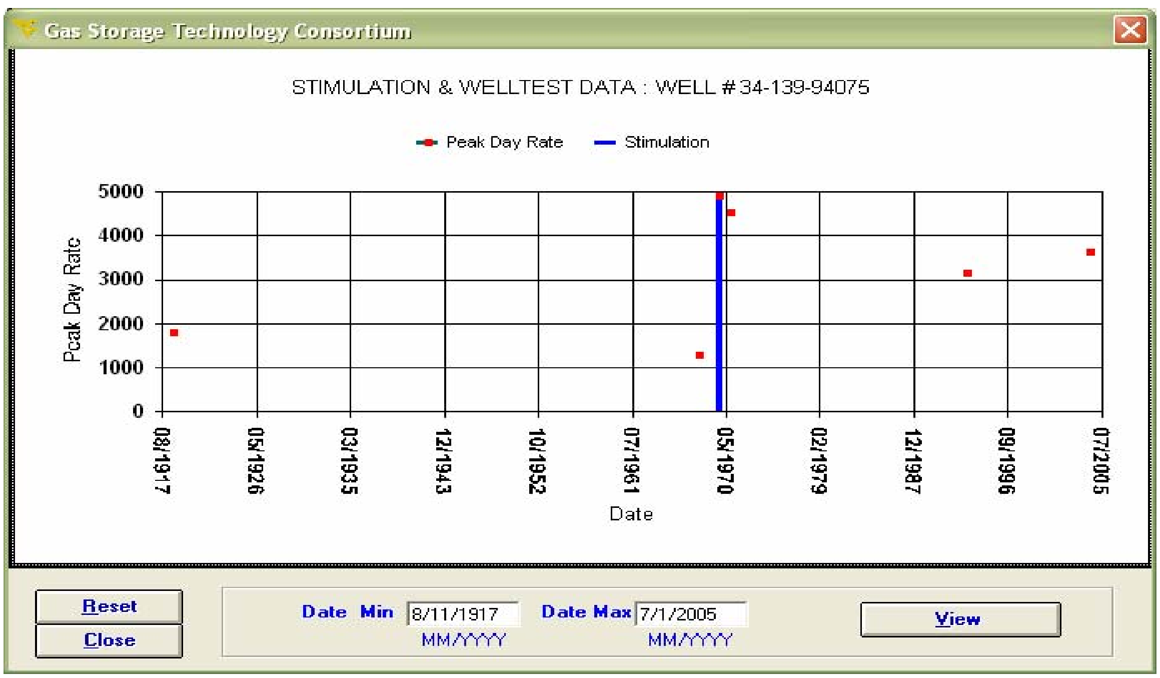


Fig60. Show Chart – Peak Day Rate

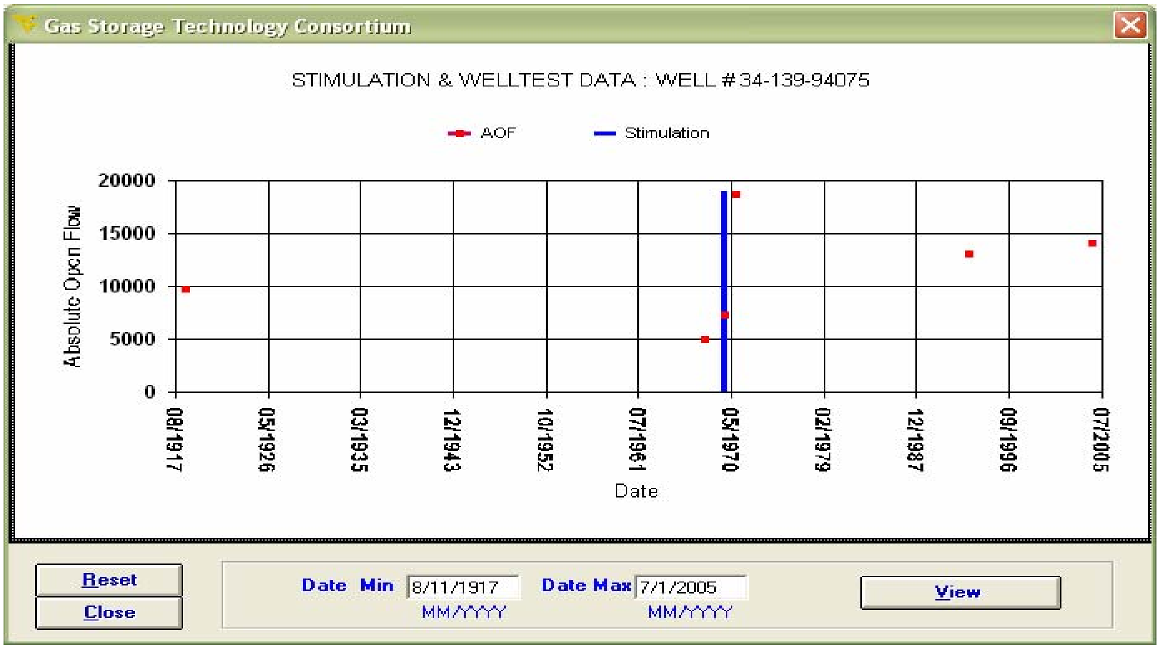


Fig61. Show Chart – Absolute Open Flow

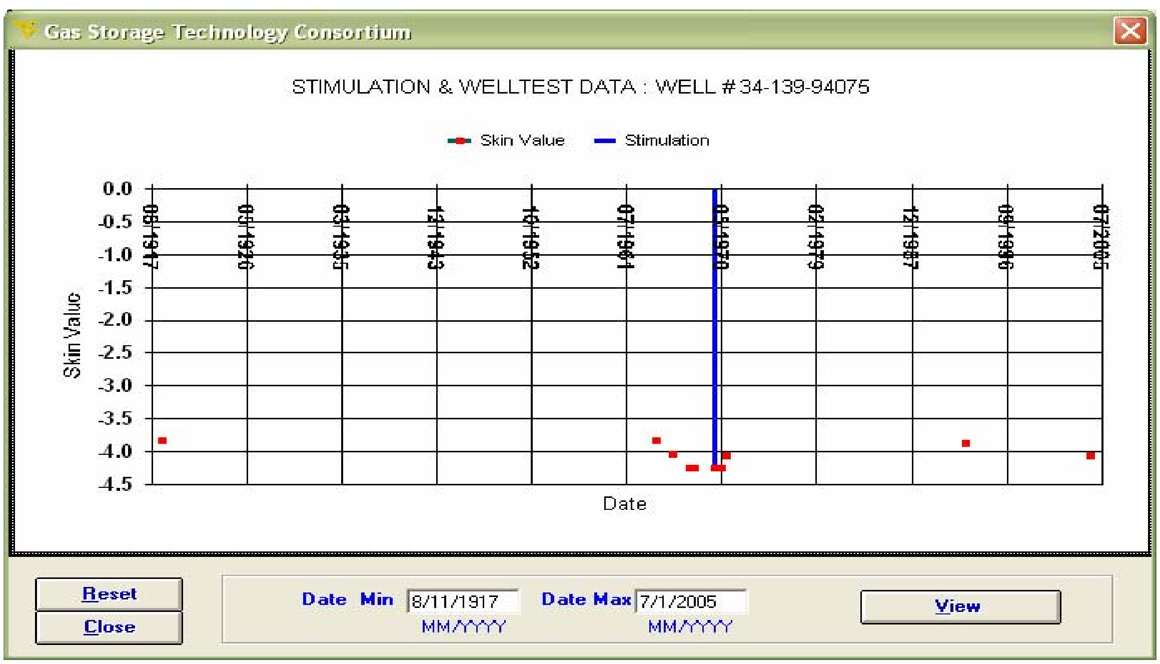


Fig62. Show Chart – Skin

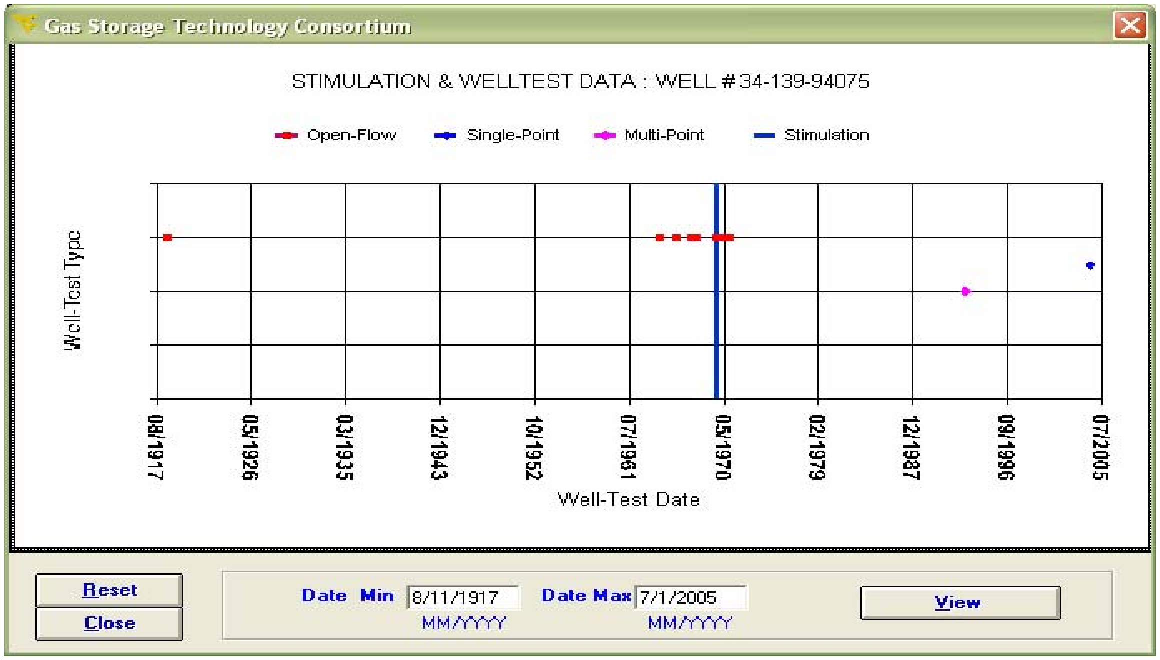


Fig63. Show Chart – All Well Tests

WELL TEST ANALYSIS TOOL

The user can do three types of Well Test Analysis in this software:

1- Simplified Analysis (for calculating n, C, PD rate & AOF)
2- LIT Analysis (for calculating Skin if ‘k’ is known)
3- Build-up Test Analysis (If Detailed Multi-Point Test data is available)

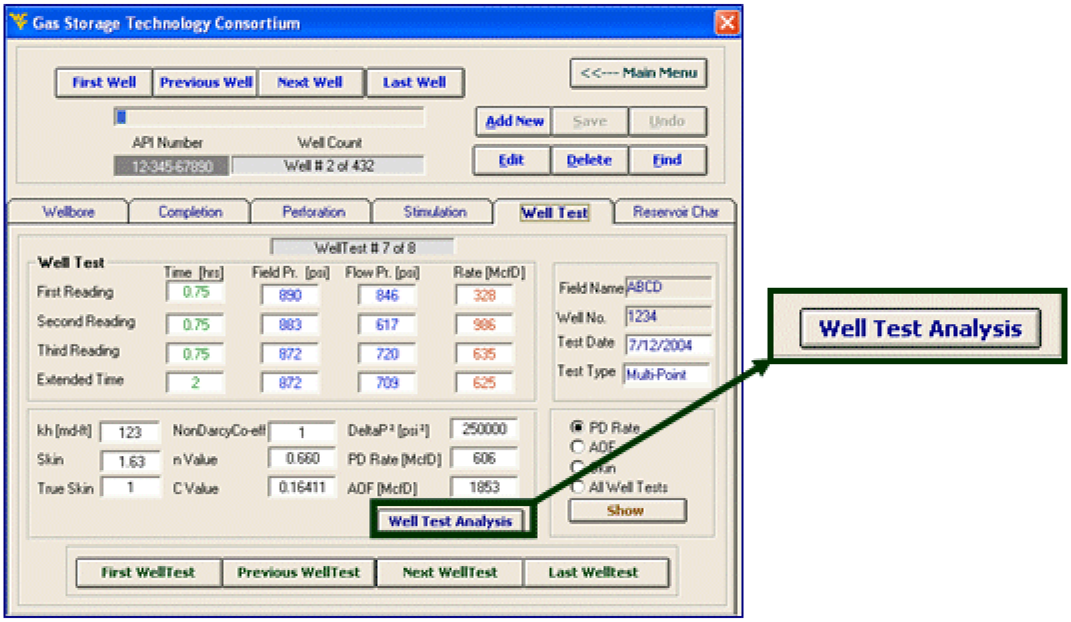


Fig64. Well Test Analysis button

The analysis tools are very similar for Simplified and LIT Analysis except where mentioned. The interface below will appear when you select 'Well Test Analysis' button. It will give you a glimpse of what has happened on the well since it was drilled.

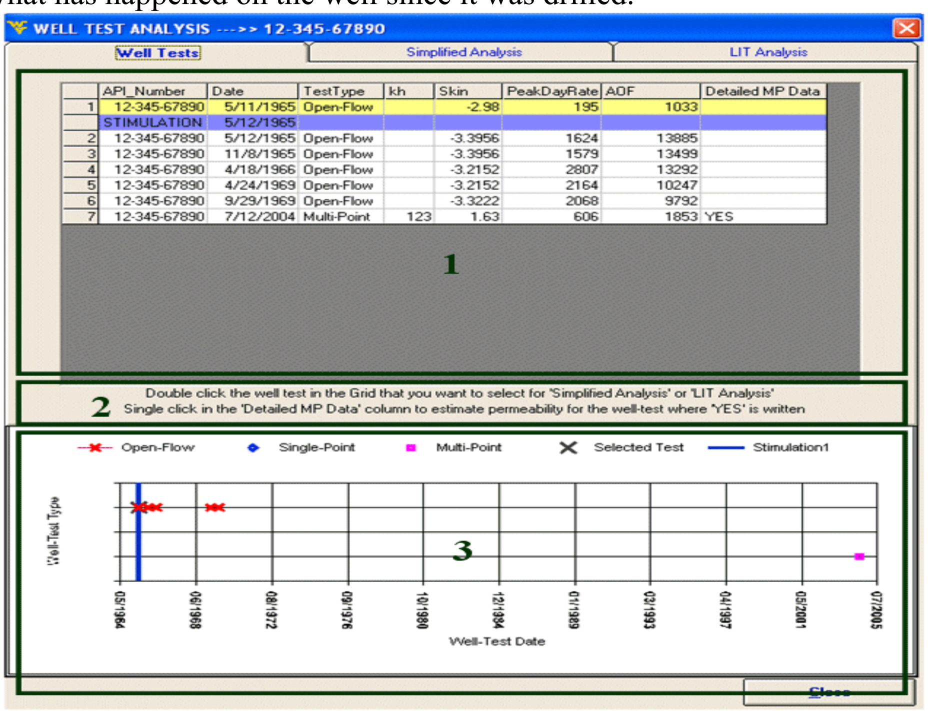


Fig65. Well Test Analysis Module

1. This section contains all the data in a grid form API Number, Date of well test, Test Type, kh value, Skin value, Peak Day rate, Absolute Open Flow and information in 'YES' or 'NO' form if the Detailed Multi-point data (Pressure profile & flow-rate vs.

time) is available for a given test or not. The back color of selected well-test is yellow while of stimulation is purple. The first well-test is selected by default.

2. This section contains instructions as how to select well-tests for analysis. Single click on any well-test will make it the current well-test with background changed to yellow and by double click; it will be selected for Simplified and LIT Analysis. If the Detailed MP Data for a well-test is given, then it can be selected for permeability analysis (build-up test) by single click on the cell where 'YES' is written. This way the build-up test analysis module will show up.

3. This section shows the time of different well tests which are indicated by three types of markers and stimulations on a well which are represented by straight blue vertical lines. The selected well have the similar marker according to its test-type but its color is dark green.

Once any well-test is double clicked, it is selected and added in the list box of simplified and LIT Analysis.

Simplified Analysis:

The screen shot of Simplified Analysis tab is below with Well-test # 2 to # 7 selected for analysis.

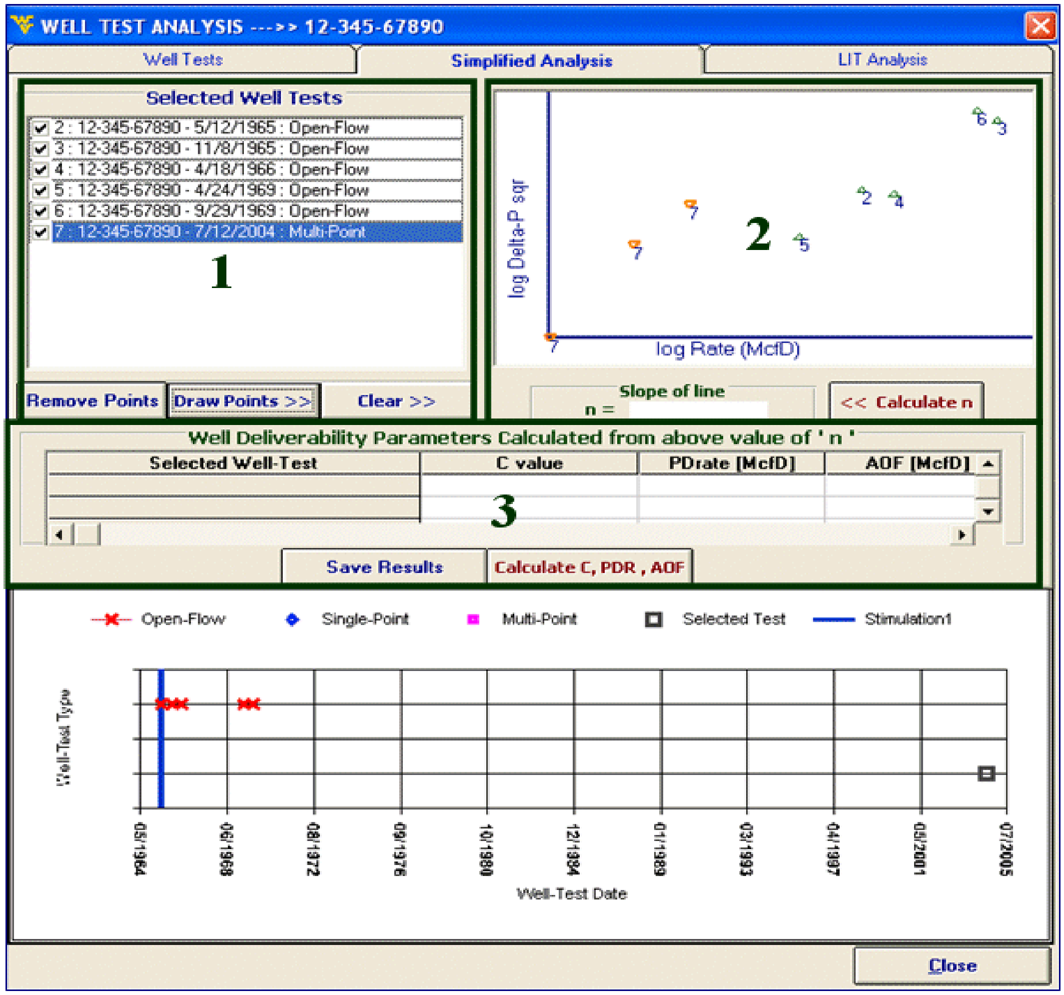


Fig66. Well Test analysis tool

1. This section contains the list box which has the entire well-tests selected for an analysis. Any test now again can be selected or de-selected by using the check-box in front of it. Once the well-tests are selected, then they can be drawn on log-log graph of Flow-rate (McfD) vs. Delta Pressure Square (Delta P sqr) by selecting the ‘Draw Points’ button. This graph can be cleared by selecting the ‘Clear>>’ button also if the well-tests drawn need to be changed.

2. Once the data points have been drawn, the user can draw a line in the picture box keeping left mouse button held down like shown below:

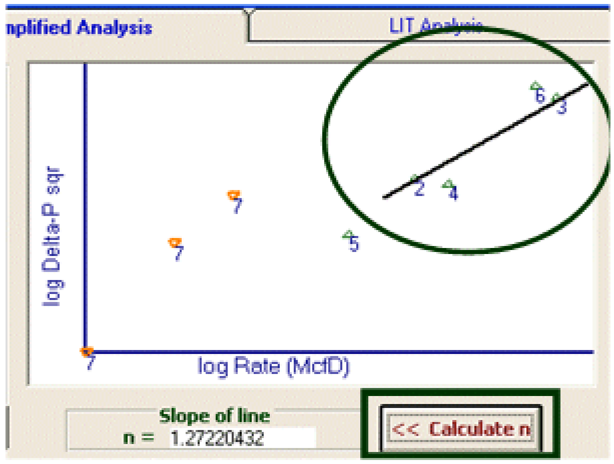


Fig67. Draw a line and calculate the slope

Select 'Calculate n' button to find the slope of the drawn line. The slope will be calculated in front of 'n' text box.

1. Now the user can select the well-tests that he/she intended to the simplified analysis on them. Then a line should draw based on the selected well tests in the picture box (Figure 68). The slop (n) will be calculated by mouse clicking on the "Calculate n" Button. The values of C, Peak Day Rate and Absolute Open Flow will be calculated and shown in the grid as shown in the picture shot on next page. These results can be saved in the database by selecting the 'Save' button.

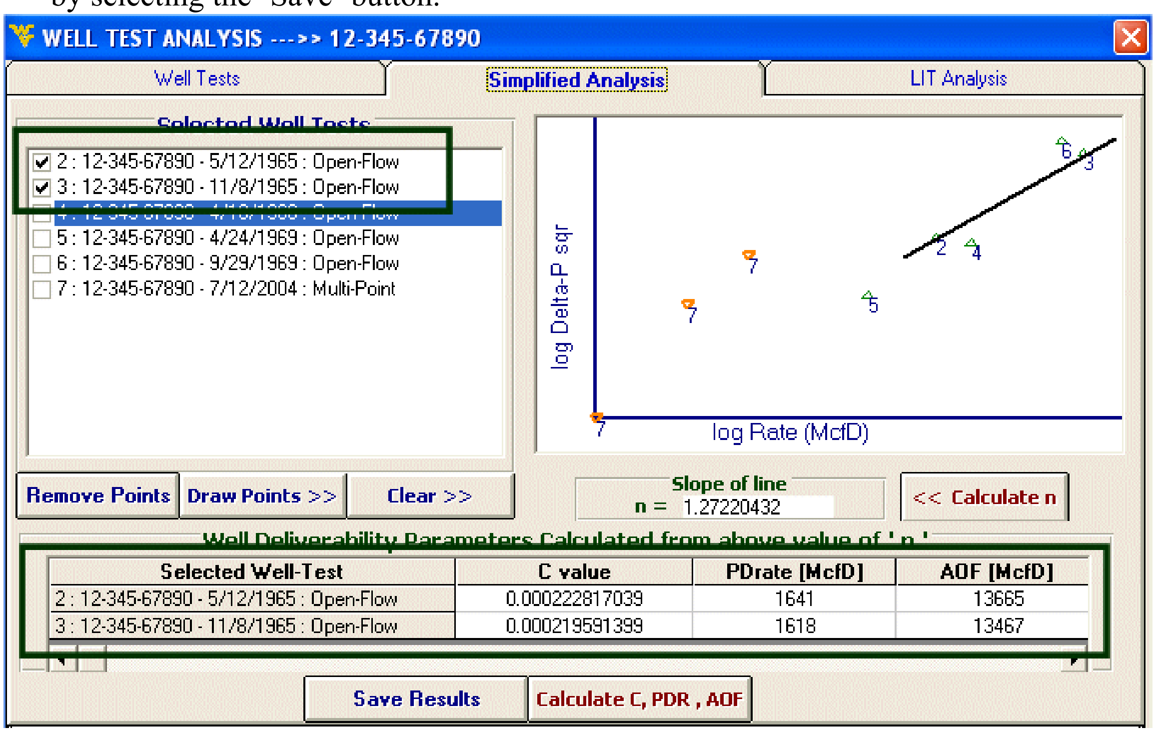


Fig68. Simplified well test analysis tool

Note: If there is only one well-test before or after the stimulation, then the value of *n* can be assumed and written in the textbox in front of label 'n' as shown in the picture below. The value of 'n' cannot be assumed for more than one well at a time so if there is more than one well-test for which the value of 'n' has to be assumed, then they should be selected one by one.

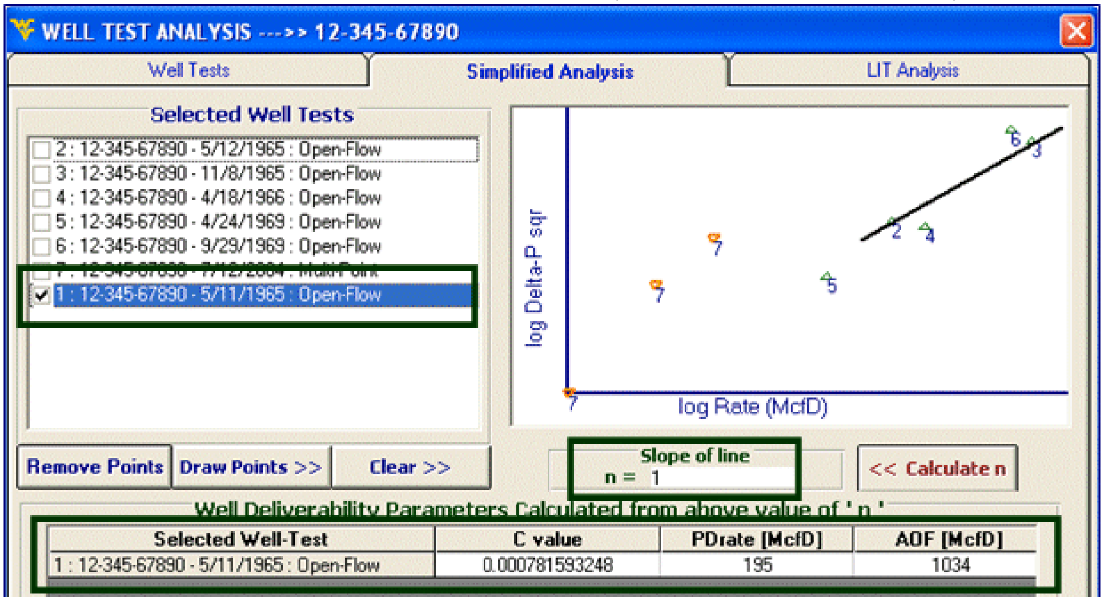


Fig69. Simplified well test with one well test before or after stimulation

Laminar Inertial Turbulent (LIT) test Analysis:

The screen shot of the LIT analysis is below:

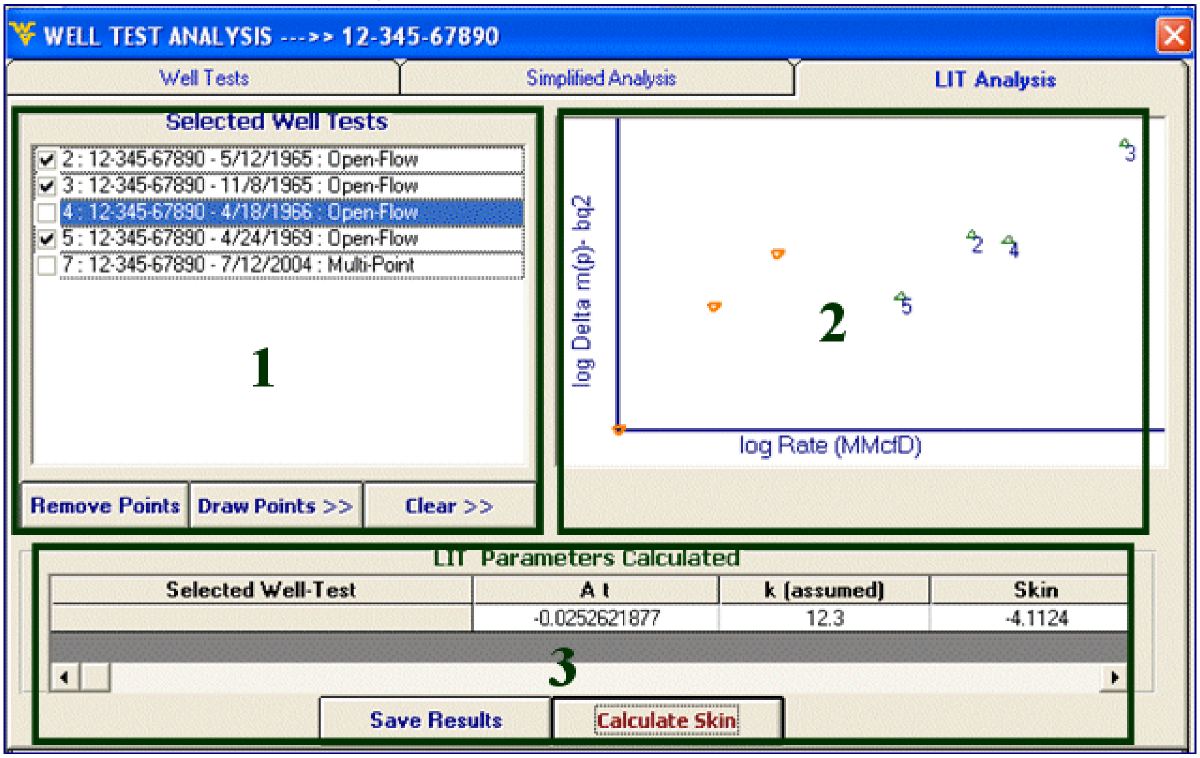


Fig70. LIT well test analysis

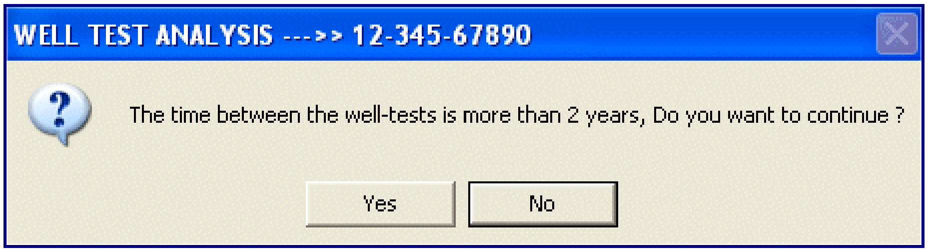
1. This section is the same as for Simplified Analysis.

2. In this section, the well-test points are drawn on log – log plot of 'Flow rate (MMcfD) vs. Delta pseudo pressure – bq^2' . There is no need to draw a slope line in this plot. Instead, the points can be selected by visual inspection that they form a straight line and that they were conducted preferably within 2 years. In the snapshot above, well test points 2,3 and 5 have been selected to calculate Skin.

3. When the 'Calculate' button is pressed, the program uses the permeability value 'k' from the nearest well-test and calculates skin. The new value of skin can be saved in the database by selecting 'Save Results' button.

Note: Multi-point test points give erroneous calculations if selected with other well-tests as they are recorded one flow after another simultaneously, not like Open Flow and single point tests, which are recorded once a year.

If the selected well-tests are not within 2 years, then the following message will appear giving the user choice either to select other well-tests or continue with the well-tests selected.



Build-up test Analysis:

If any Multi-point well test has a detailed data (pressure and flow-rate profile vs. time), then the 'Detailed MP Data' column in front of that test will show 'YES'. It means that the data for this well-test can be analyzed to estimate a value of permeability.

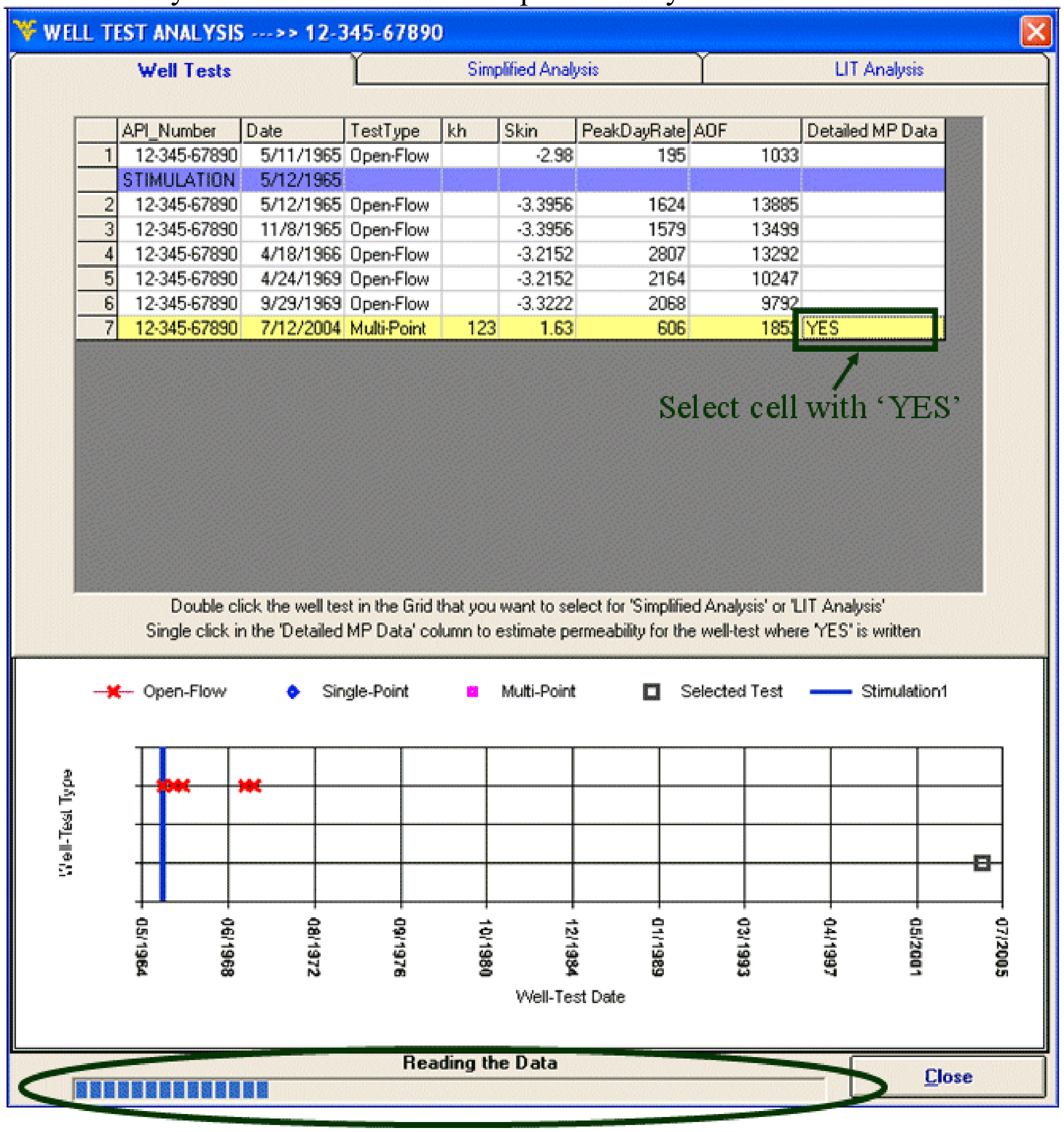


Fig71. Multi point well test analysis

If the cell with value 'YES' is selected the software will read the data from the excel file and progress bar will become visible like in the picture shot above showing that the data is being read.

After the complete data has been read by the software, the following screen will appear showing the pressure profile of the well-test.

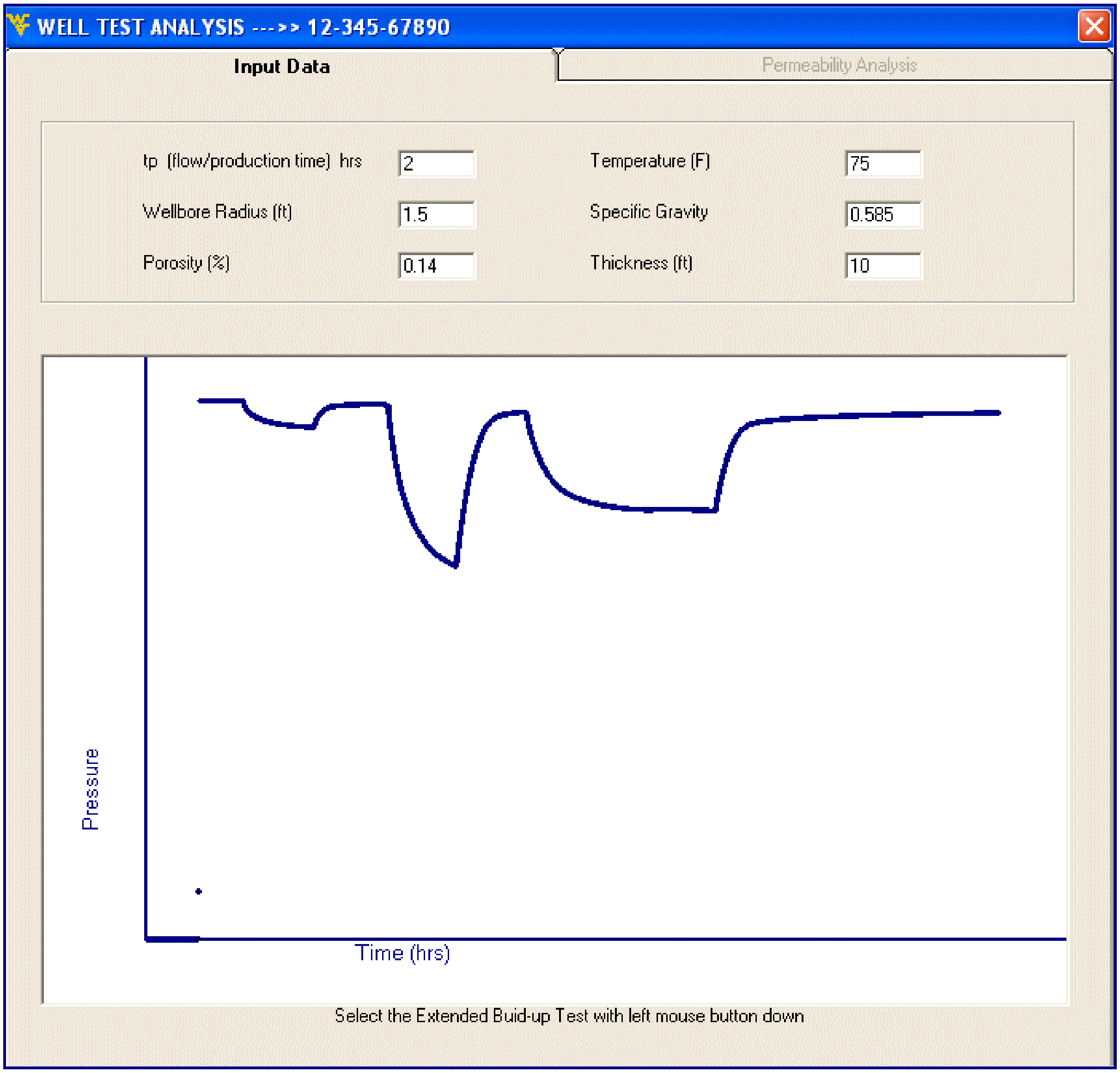


Fig72. Well extended pressure profile

All the Input data is retrieved from the database and if it is not found, then default values are inserted. The value 'tp (flow/production time' is 2 hrs by default but can be changed by the user. The Extended build-up test for 2 or more hours should be selected by keeping the left mouse button down. The green lines will indicate portion of build-up test selected.

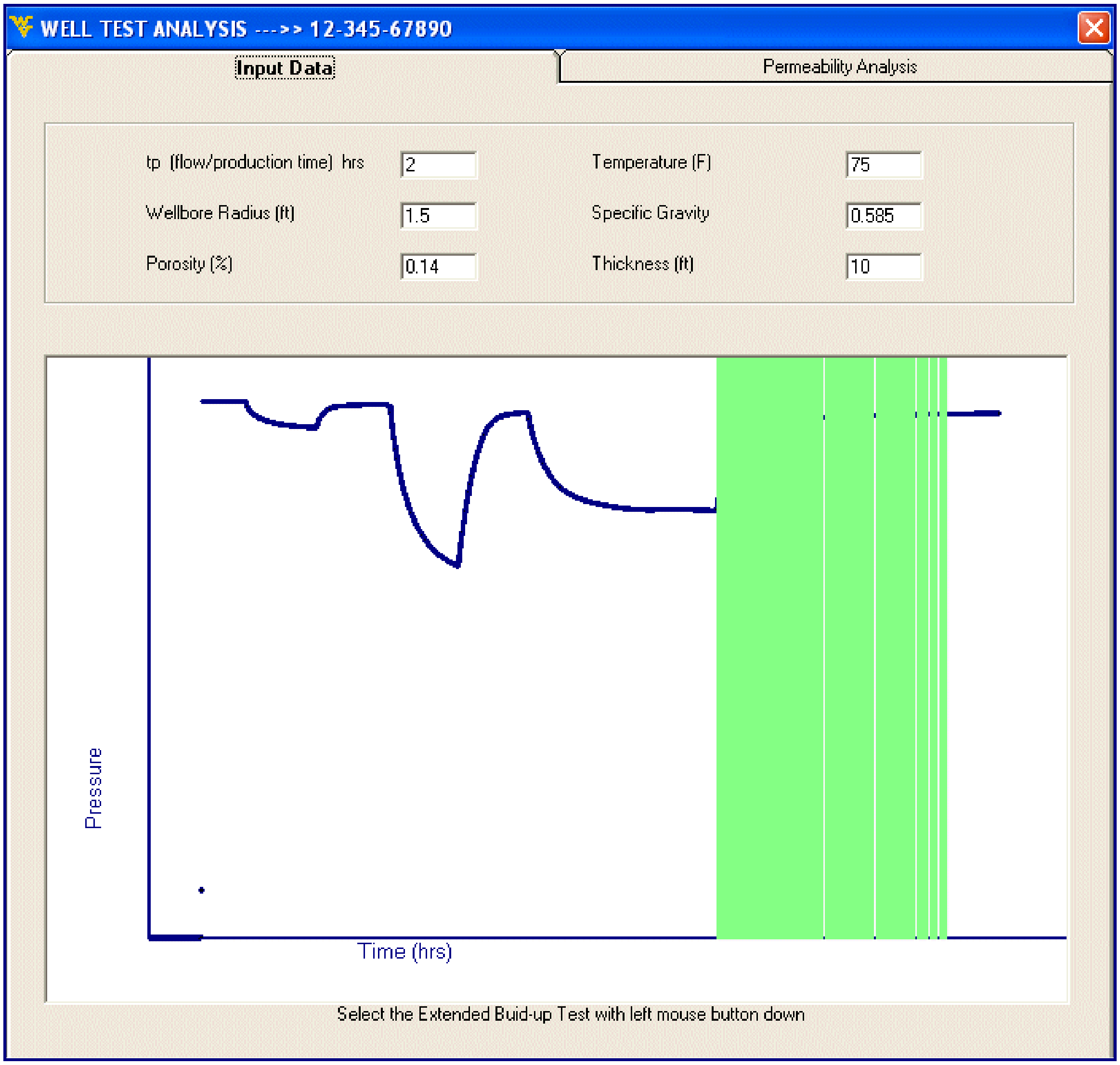
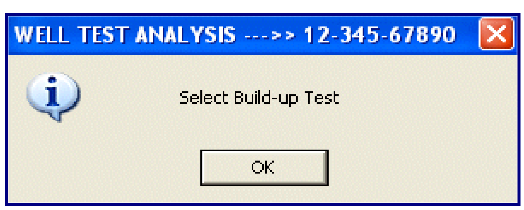


Fig73. Selecting the build-up section from pressure profile

If by mistake draw-down data is selected, then the following message will appear informing the user to select build-up data again.



After the portion of build-up data has been correctly selected, the permeability analysis tab will show following graphs. The first one is the log-log diagnostic plot between 'Del Pressure' and 'Del Time'. The user should select the first point which does not fall on the unit slope line drawn by holding the left mouse button down. The initial pressure 'Pi' and flow rate text box values will be selected from the build-up portion of the extended well-test selected. The graphs will be drawn again with a green line drawn on the Horner plot indicating The End of Well-Bore Storage (tewbs).

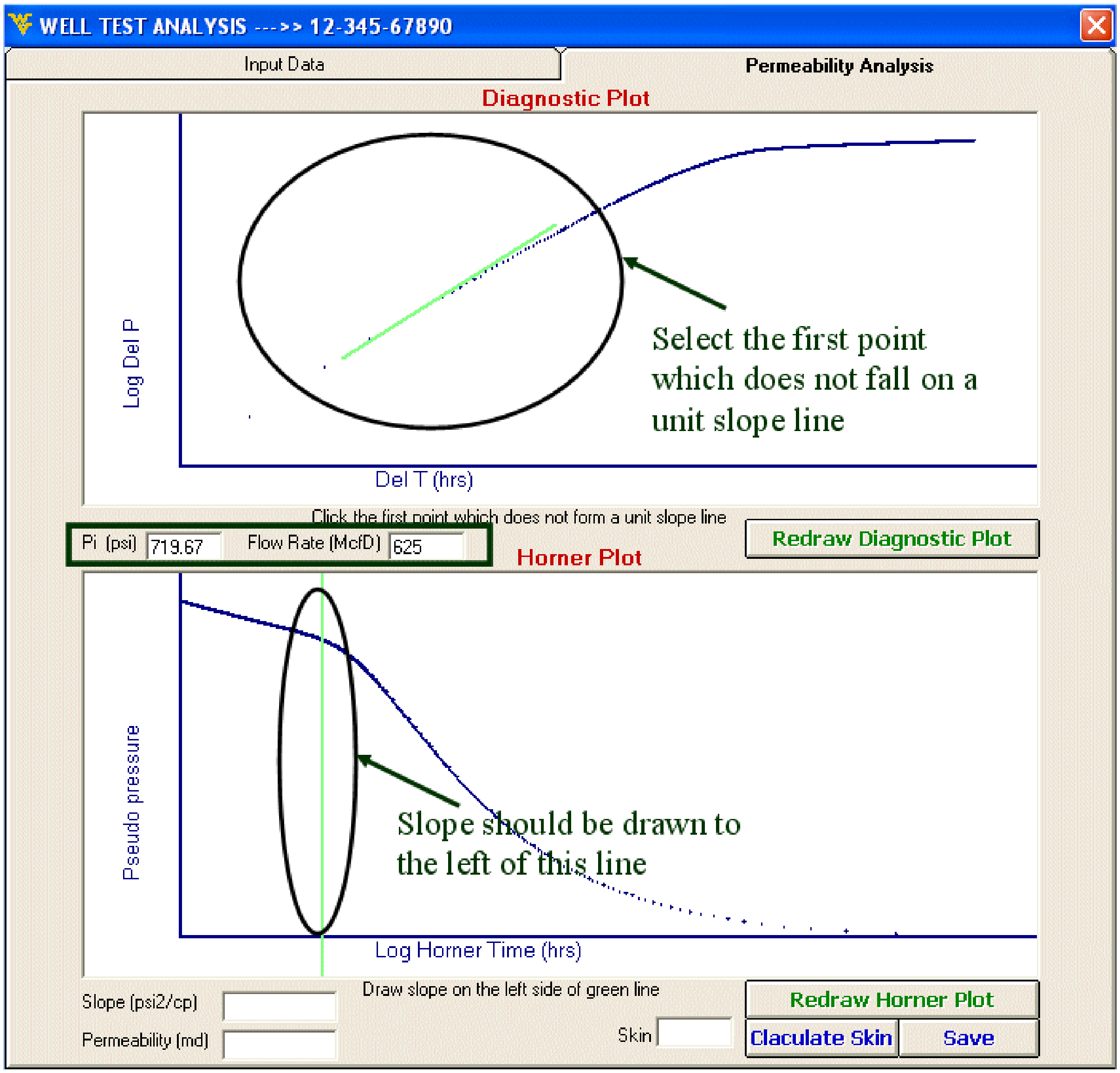


Fig74. Diagnostic plot analysis

The slope should be drawn on the Horner plot on the left side of the end of well bore storage line shown in green on Horner plot.

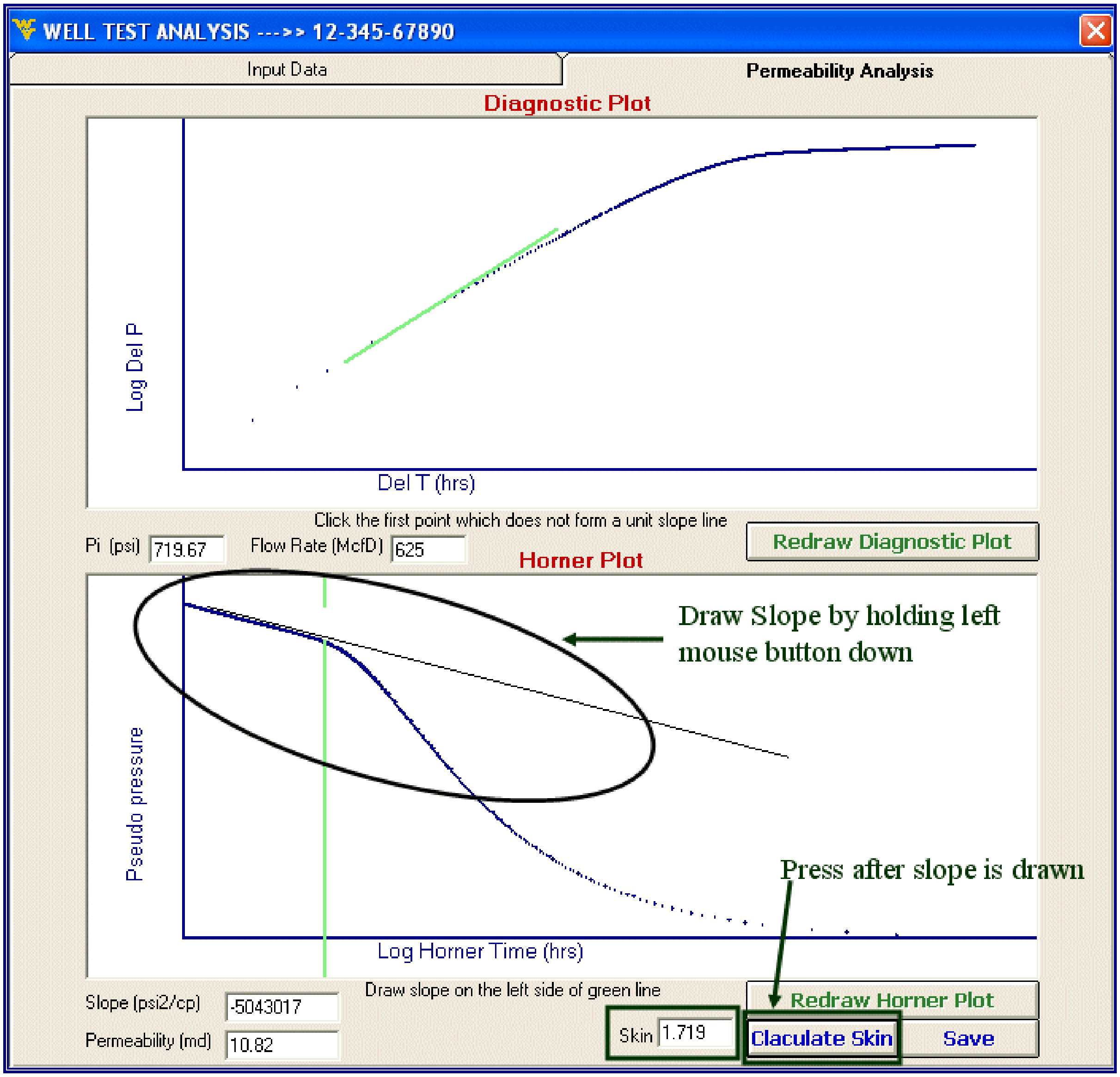


Fig75. Calculating skin from Hornet plot

After the slope is drawn, the user can select 'Calculate Skin' button to find the skin of the well. The respective graphs can be redrawn any time by selecting the 'Redraw Diagnostic Plot' or 'Redraw Horner Plot'.
The value of permeability and Skin can be saved in the database by selecting 'Save' button.

SELECT WELL DATA

In this form the user can choose to select the data of the wells that he wants to look at. Following are a few ways he can choose the data:

Selecting a well by State/County:

The user selects the state first and then the county. All the wells will be selected for that county in the selected wells list box:

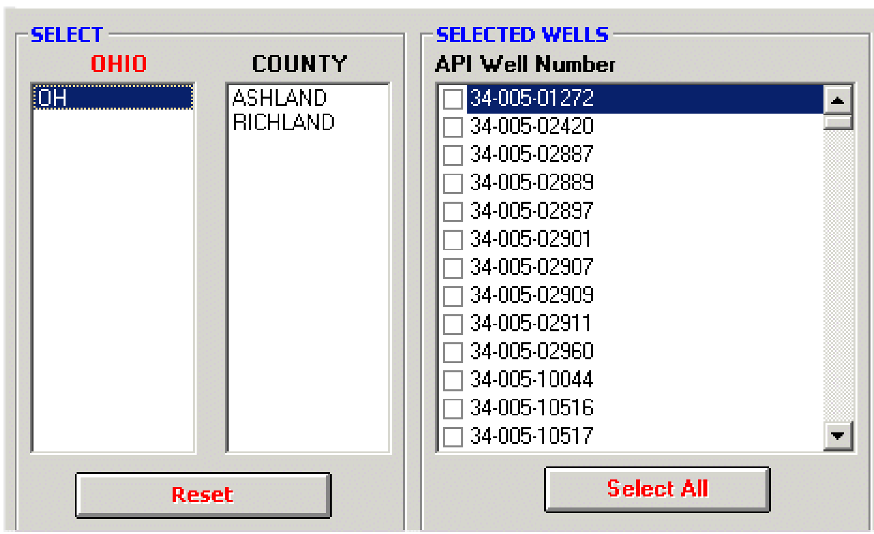
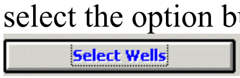


Fig76. Selecting Ohio County

Selecting wells by stimulation year:

The user can select the option button for stimulated year and input the year values. If Select Wells button 

is clicked, then all the wells that have been stimulated between these years will be shown in the selected wells list box

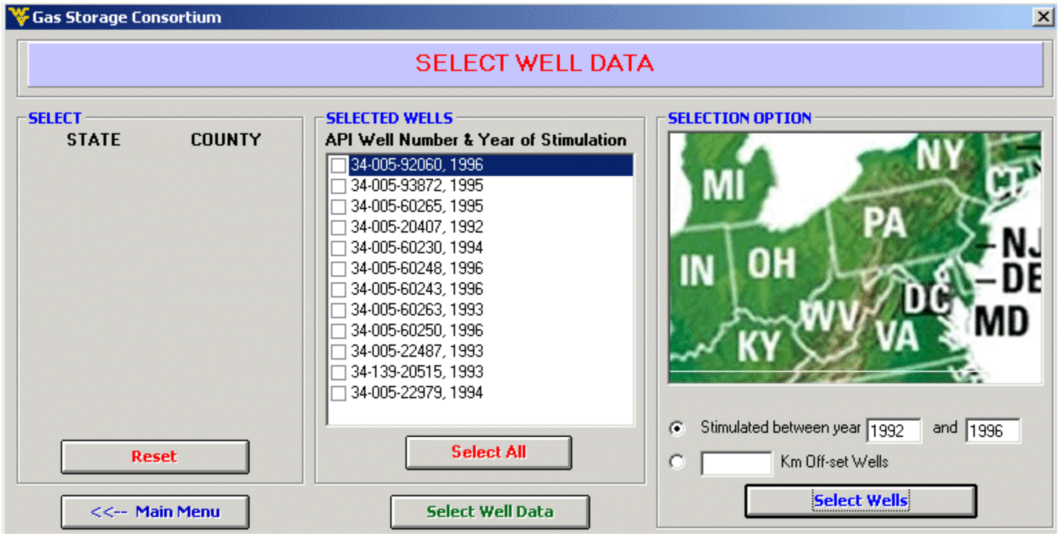


Fig77. Selecting wells according to stimulation year

Selecting offsets wells form a well:

The user selects the offset option and the well near which he wants to find the off-set wells, and then enters the distance of off-set in kilometers. If Select Wells button is clicked, then all the wells that are off-set of the selected well will be shown in the selected wells list box

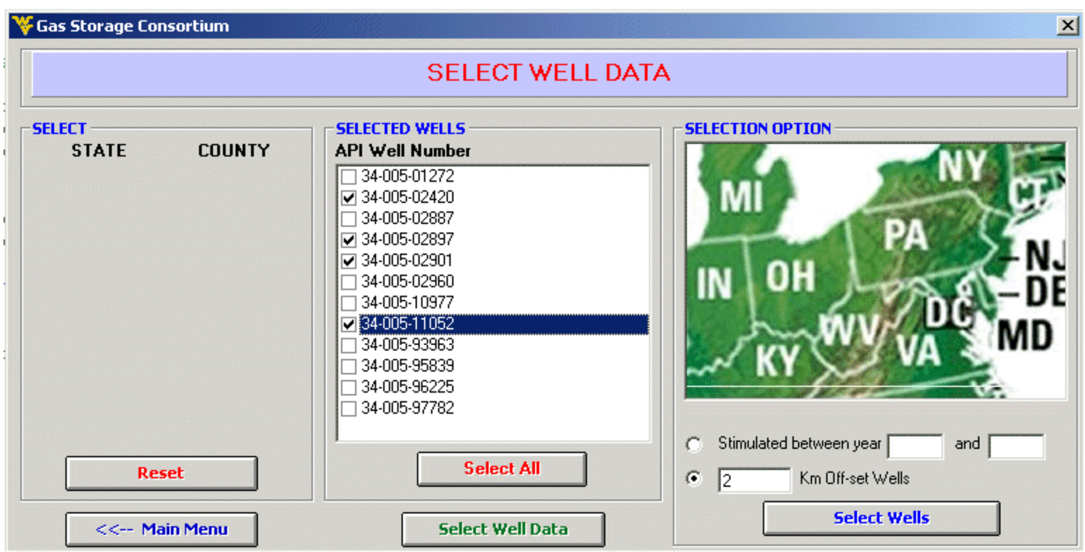


Fig78. Offset wells

Display the selected wells data:

When the wells for which the user want the data to be retrieved have been selected, click the Select Well Data button 

and select the parameters.

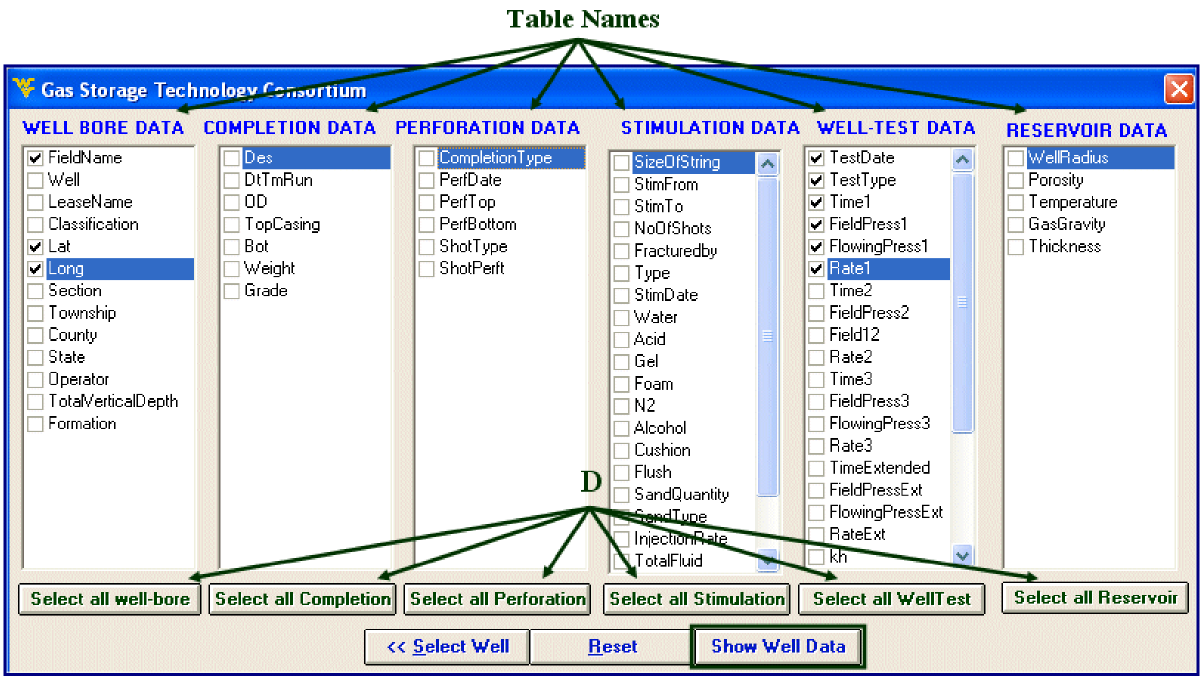
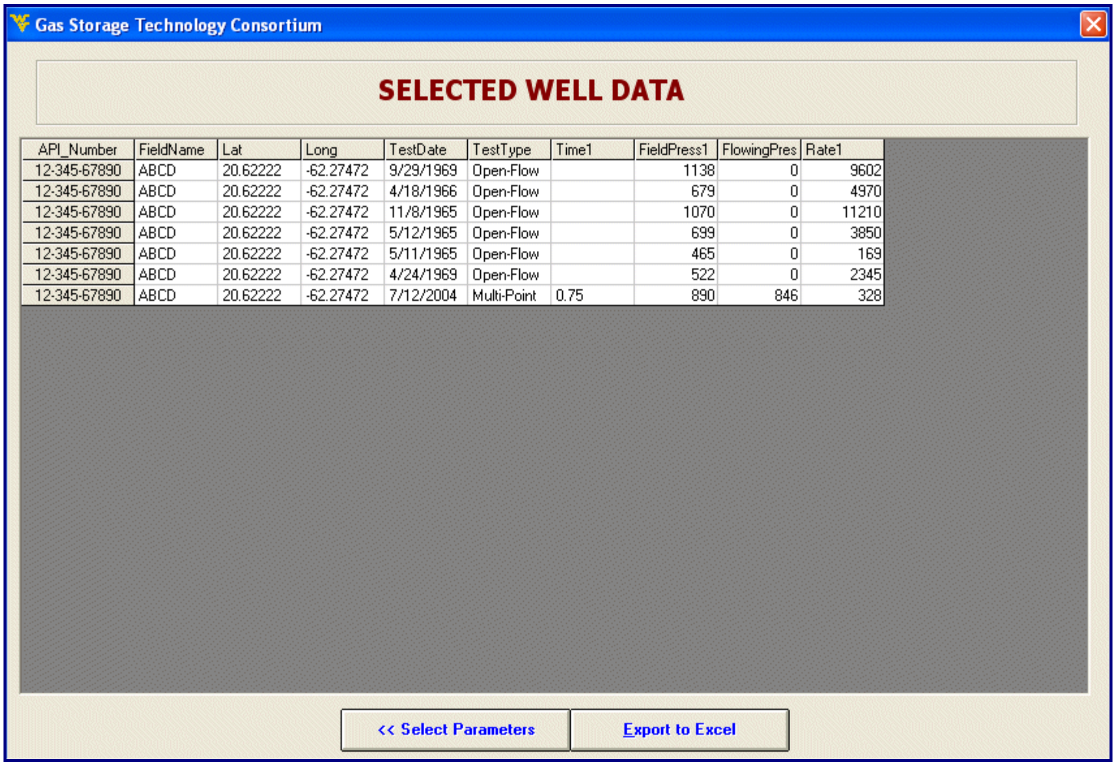


Fig79. Selecting Well Parameters

Click Show Well Data 

to retrieve the data.



API_Number	FieldName	Lat	Long	TestDate	TestType	Time1	FieldPress1	FlowingPres	Rate1
12-345-67890	ABCD	20.62222	-62.27472	9/29/1969	Open-Flow		1138	0	9602
12-345-67890	ABCD	20.62222	-62.27472	4/18/1966	Open-Flow		679	0	4970
12-345-67890	ABCD	20.62222	-62.27472	11/8/1965	Open-Flow		1070	0	11210
12-345-67890	ABCD	20.62222	-62.27472	5/12/1965	Open-Flow		699	0	3850
12-345-67890	ABCD	20.62222	-62.27472	5/11/1965	Open-Flow		465	0	169
12-345-67890	ABCD	20.62222	-62.27472	4/24/1969	Open-Flow		522	0	2345
12-345-67890	ABCD	20.62222	-62.27472	7/12/2004	Multi-Point	0.75	890	846	328

Fig80. Result of the wells & parameters selected

CANDIDATE SELECTION

This module will appear on selecting the 'Candidate Selection' button from Main Menu.

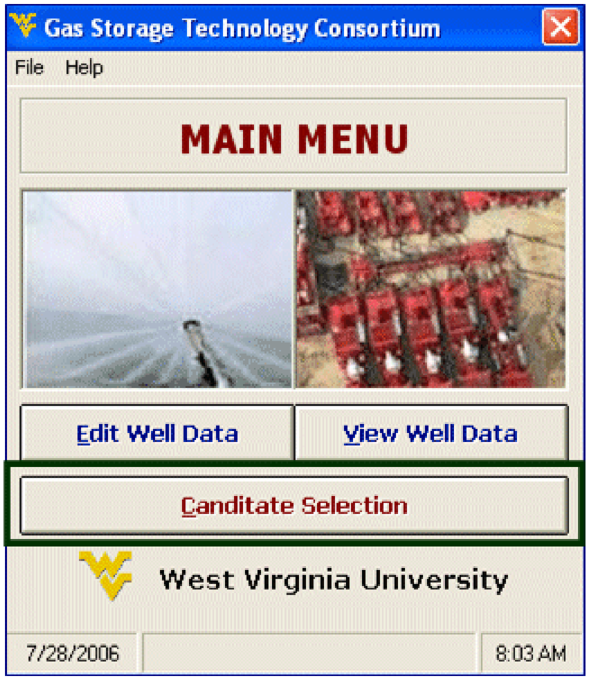


Fig81. Start Candidate Selection form main screen

For intelligent candidate selection of wells, it is very important that only valid data is given to the Neural Network (NN) for training. Valid data is one which will not degrade the performance of the NN and is useful in NN training.

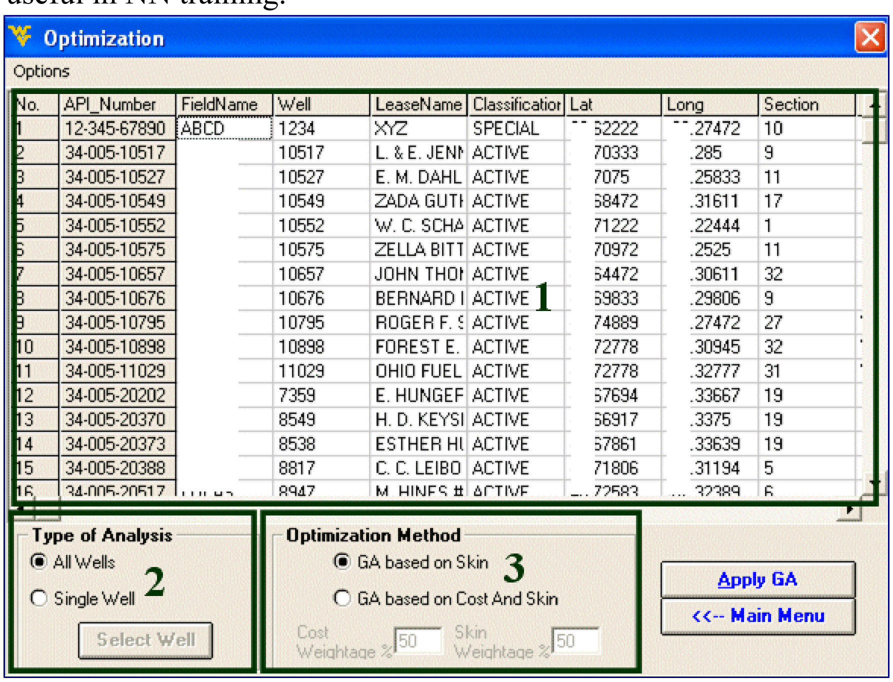


Fig82. Candidate Selection main screen

1. When this module is loaded, each row in this section of the grid represents a valid stimulation as shown in figure above. Following, is the criteria for valid stimulation selection:

   Valid Stimulation – It should have skin value before & after stimulation.
   Valid Perforation – Perforation just before the stimulation.
   Valid Completion – The smallest size completion run before stimulation.
   Valid Well-test – Well-test having skin value just before or after the well-test.

2. Two types of analysis can be done on the wells: One option is to apply Genetic optimization on wells one at a time and the other is to apply it on all wells. If the 'All Wells' option is selected, then the 'Select Well' button will be enabled and the user can select the well the same way as shown in the previous section of the user Manual for – Find a well.

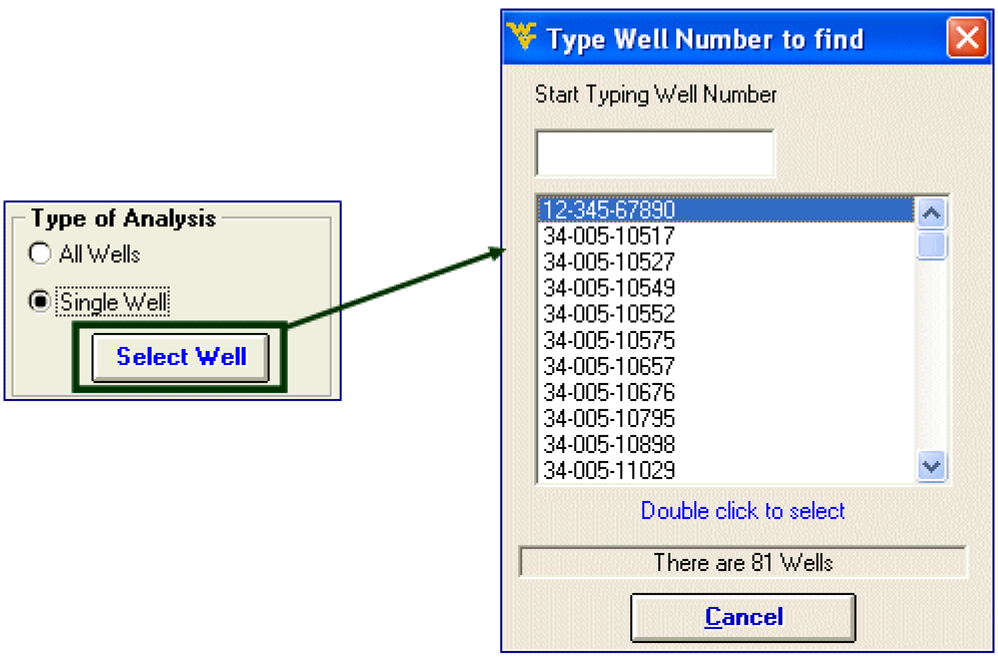
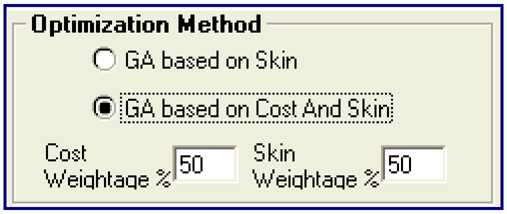


Fig83. Selecting a well for candidate selection process

3. This section of module relates to the Optimization methods available. User can optimize the stimulations according to only change in skin criteria or may choose to select the 'GA based on cost and skin' option where he/she can give different weight ages to cost and skin.



Options Menu:

This software can cater for many varied situations. These options can be selected from the 'options' menu bar on the top of the form. It contains following items:

- Select controllable parameters
- Material cost
- Import NNet
- NNet Input values
- GA characteristic
- Export the Grid to Excel
- Select Well-Test Type

Following is a screen shot of the items in the Options menu tool bar.

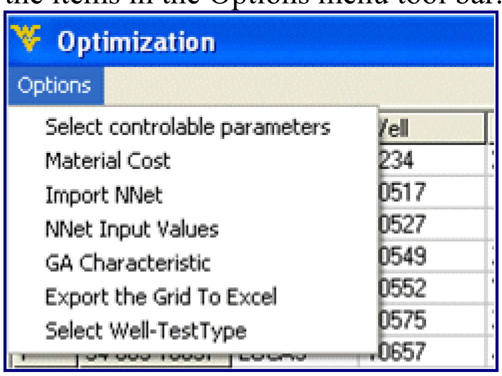


Fig84. Options to control Candidate Selection process

Material cost can be changed by the user as the prices fluctuate. These prices can be saved in the database by selecting 'Save' button and Default values can be retrieved by selecting ' Default' button. The screen shot of material cost is shown below and price is just an estimate and can be changed by user.

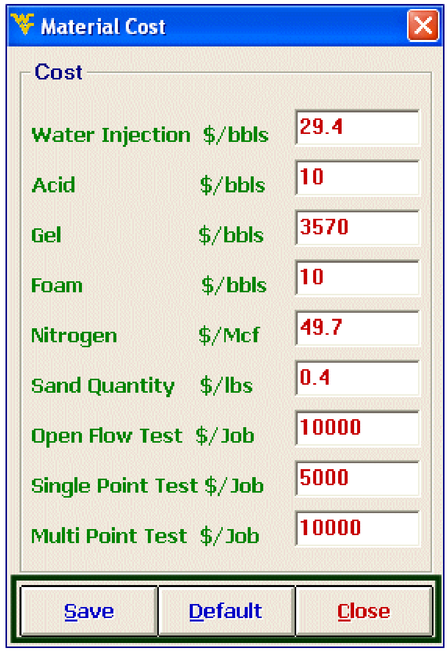
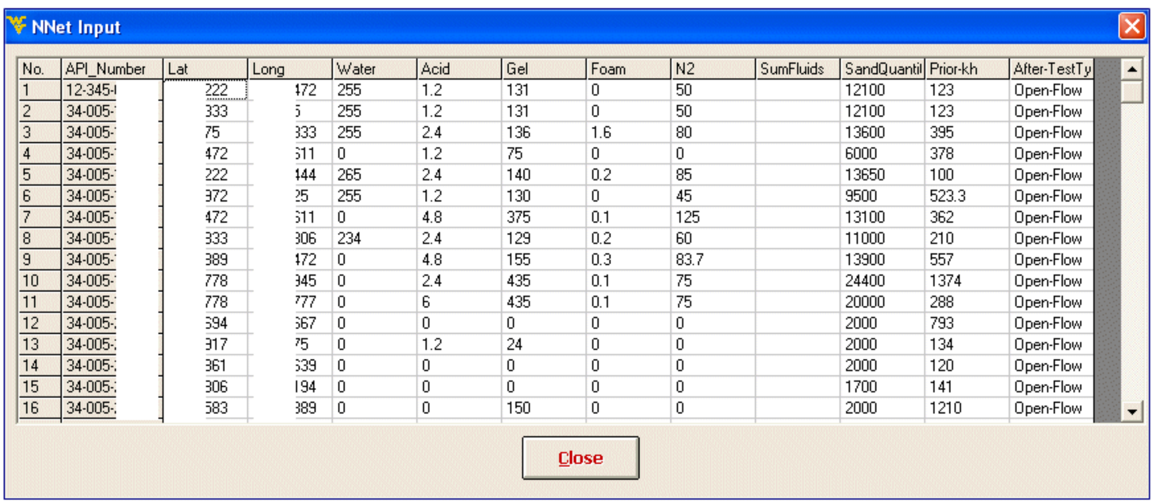


Fig85. Cost analysis module



No.	API_Number	Lat	Long	Water	Acid	Gel	Foam	N2	SumFluids	SandQuanti	Prior-kh	After-TestTy
1	12-345-	222	472	255	1.2	131	0	50		12100	123	Open-Flow
2	34-005-	333	5	255	1.2	131	0	50		12100	123	Open-Flow
3	34-005-	75	333	255	2.4	136	1.6	80		13600	395	Open-Flow
4	34-005-	472	511	0	1.2	75	0	0		6000	378	Open-Flow
5	34-005-	222	444	265	2.4	140	0.2	85		13650	100	Open-Flow
6	34-005-	372	25	255	1.2	130	0	45		9500	523.3	Open-Flow
7	34-005-	472	511	0	4.8	375	0.1	125		13100	362	Open-Flow
8	34-005-	333	306	234	2.4	129	0.2	60		11000	210	Open-Flow
9	34-005-	389	472	0	4.8	155	0.3	83.7		13900	557	Open-Flow
10	34-005-	778	345	0	2.4	435	0.1	75		24400	1374	Open-Flow
11	34-005-	778	777	0	6	435	0.1	75		20000	288	Open-Flow
12	34-005-	594	567	0	0	0	0	0		2000	793	Open-Flow
13	34-005-	317	75	0	1.2	24	0	0		2000	134	Open-Flow
14	34-005-	361	539	0	0	0	0	0		2000	120	Open-Flow
15	34-005-	306	194	0	0	0	0	0		1700	141	Open-Flow
16	34-005-	583	389	0	0	150	0	0		2000	1210	Open-Flow

Fig86.Inpurs that used to train the Neural Network

If the user wants to look at the Neural Network inputs being used, then 'NNet Input' option will take the user to a new form as shown above where all the inputs are shown. Keep in mind that this grid can only be seen once and that only after the Genetic optimization has been applied.

If some material is not available for stimulation, then still the user can optimize the stimulation by de-selecting that material from the 'Select controllable parameters' option. The materials not enabled are the ones that are not being used by the Neural Network in use.

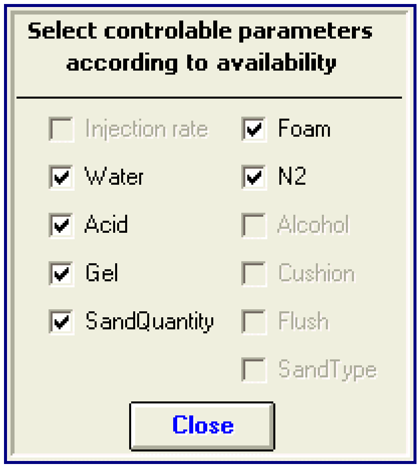


Fig87. Select the controllable parameters in optimization process

A new Neural Network can be used if the data is changed or appended by importing its 'ida' file. When a new Neural Network is imported, it might change the optimum GA parameters. The user can change them from 'GA characteristic' option. The default values are always loaded at startup as shown in figure below but can be changed by user.

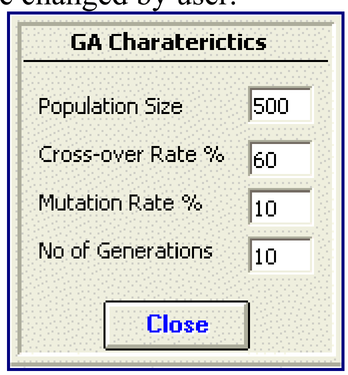


Fig88. Setup GA pentameters

If one of the Neural Net inputs is well test before stimulation, the type of the wells test in optimization process should specify here.

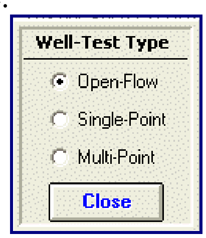


Fig89. Type of the wells test in optimization process.

When all the parameters for GA have been selected and user selects the 'Apply GA'

button, then the screen below will appear showing the values of optimized stimulation slurry and change in skin due to this stimulation. The picture below shows the GA optimization done on well # 12-345-67890.

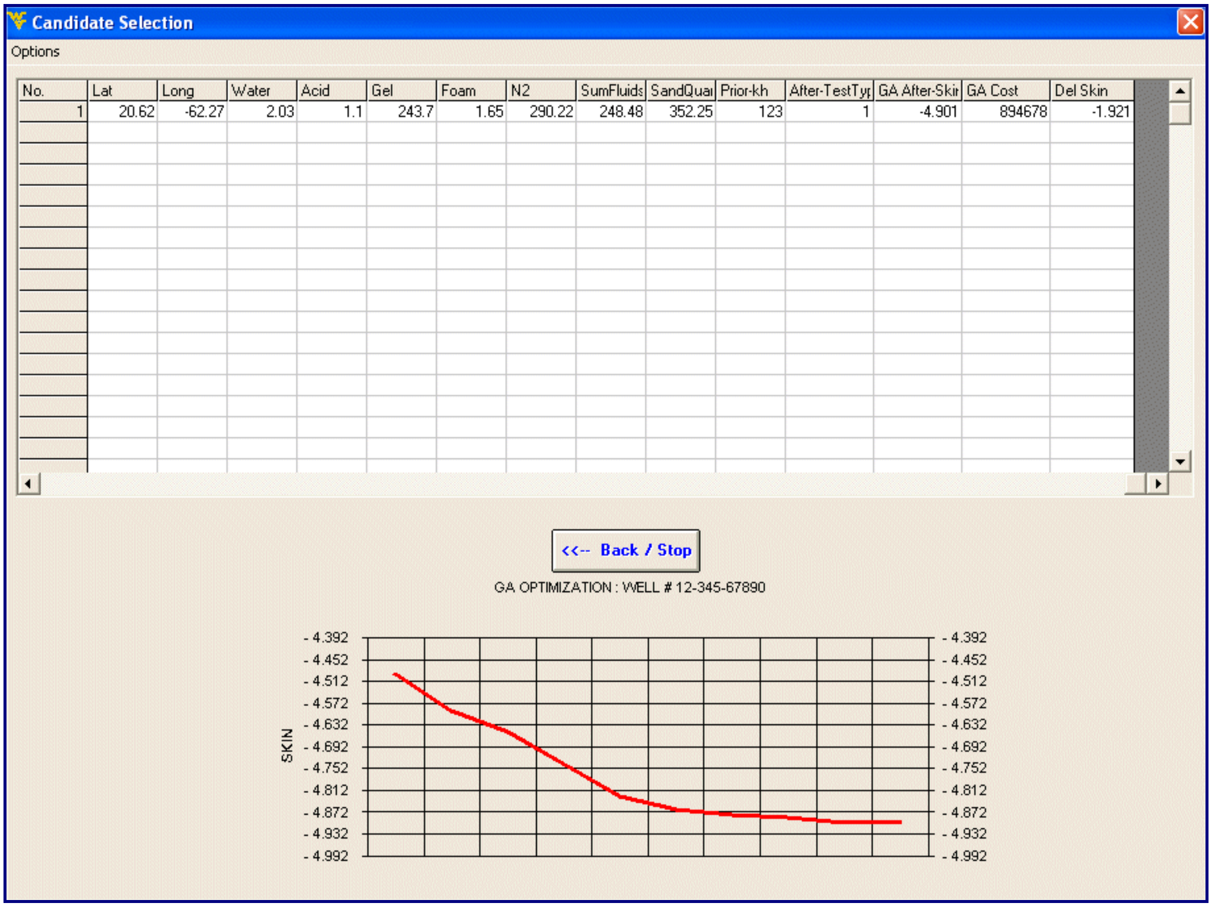
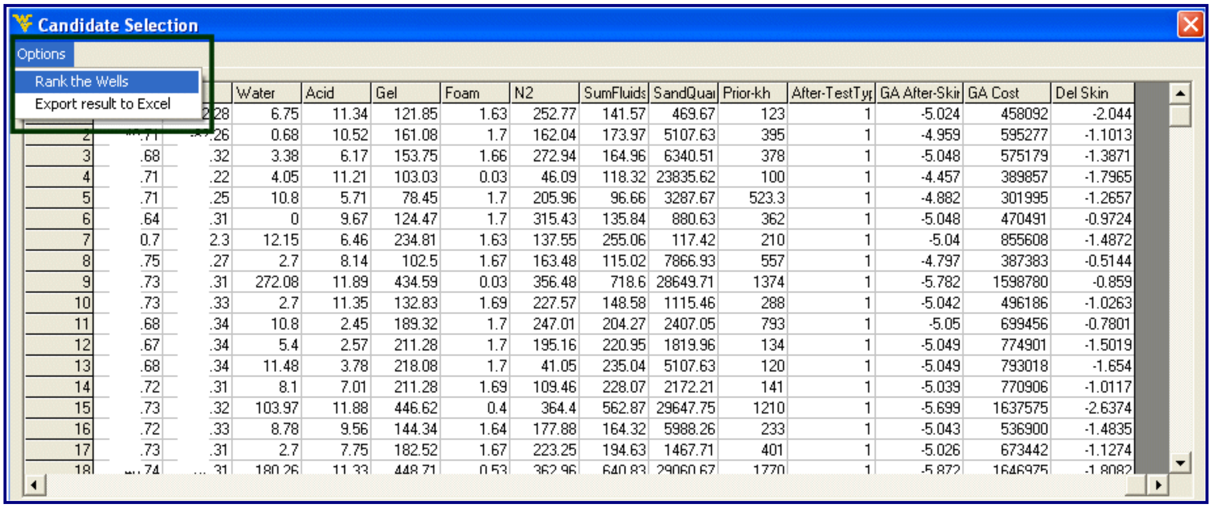


Fig90. Optimization process for one well

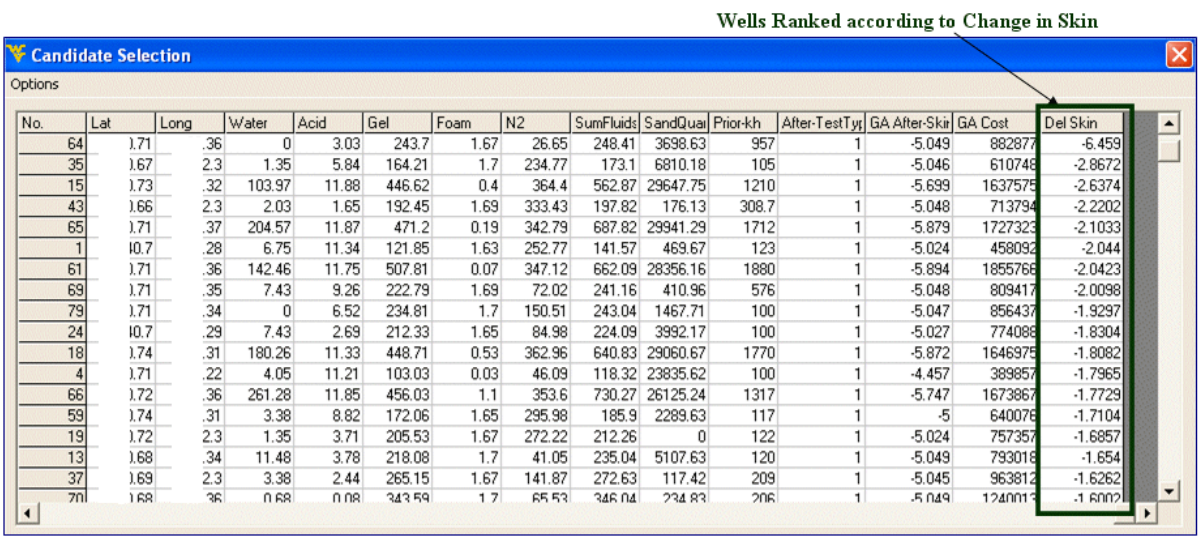
If the optimization is applied to all the wells, then we can rank the wells according to the change in skin by selecting 'Rank the wells' from Options menu bar on the top left corner of the form as shown in snapshot below.



No.	Lat	Long	Water	Acid	Gel	Foam	N2	SumFluids	SandQuai	Prior-kh	After-TestTy	GA After-Skin	GA Cost	Del Skin
		.28	6.75	11.34	121.85	1.63	252.77	141.57	469.67	123	1	-5.024	458092	-2.044
2	.71	.26	0.68	10.52	161.08	1.7	162.04	173.97	5107.63	395	1	-4.959	595277	-1.1013
3	.68	.32	3.38	6.17	153.75	1.66	272.94	164.96	6340.51	378	1	-5.048	575179	-1.3871
4	.71	.22	4.05	11.21	103.03	0.03	46.09	118.32	23835.62	100	1	-4.457	389857	-1.7965
5	.71	.25	10.8	5.71	78.45	1.7	205.96	96.66	3287.67	523.3	1	-4.882	301995	-1.2657
6	.64	.31	0	9.67	124.47	1.7	315.43	135.84	880.63	362	1	-5.048	470491	-0.9724
7	0.7	2.3	12.15	6.46	234.81	1.63	137.55	255.06	117.42	210	1	-5.04	855608	-1.4872
8	.75	.27	2.7	8.14	102.5	1.67	163.48	115.02	7866.93	557	1	-4.797	387383	-0.5144
9	.73	.31	272.08	11.89	434.59	0.03	356.48	718.6	28649.71	1374	1	-5.782	1598780	-0.859
10	.73	.33	2.7	11.35	132.83	1.69	227.57	148.58	1115.46	288	1	-5.042	496186	-1.0263
11	.68	.34	10.8	2.45	189.32	1.7	247.01	204.27	2407.05	793	1	-5.05	699456	-0.7801
12	.67	.34	5.4	2.57	211.28	1.7	195.16	220.95	1819.96	134	1	-5.049	774901	-1.5019
13	.68	.34	11.48	3.78	218.08	1.7	41.05	235.04	5107.63	120	1	-5.049	793018	-1.654
14	.72	.31	8.1	7.01	211.28	1.69	109.46	228.07	2172.21	141	1	-5.039	770906	-1.0117
15	.73	.32	103.97	11.88	446.62	0.4	364.4	562.87	29647.75	1210	1	-5.699	1637575	-2.6374
16	.72	.33	8.78	9.56	144.34	1.64	177.88	164.32	5988.26	233	1	-5.043	536900	-1.4835
17	.73	.31	2.7	7.75	182.52	1.67	223.25	194.63	1467.71	401	1	-5.026	673442	-1.1274
18	.74	.31	180.26	11.33	448.71	0.53	362.96	640.83	29060.67	1770	1	-5.872	1646975	-1.8082

Fig91. Optimization result for selected wells

The wells are ranked according to change in skin as shown in the figure below. These ranked wells and the optimized stimulation data now can be exported to excel by selecting 'Export to Excel' in the Option menu of Candidate Selection module.



No.	Lat	Long	Water	Acid	Gel	Foam	N2	SumFluids	SandQuai	Prior-kh	After-TestTy	GA After-Skin	GA Cost	Del Skin
64	).71	.36	0	3.03	243.7	1.67	26.65	248.41	3698.63	957	1	-5.049	882877	-6.459
35	).67	2.3	1.35	5.84	164.21	1.7	234.77	173.1	6810.18	105	1	-5.046	610748	-2.8672
15	).73	.32	103.97	11.88	446.62	0.4	364.4	562.87	29647.75	1210	1	-5.699	1637575	-2.6374
43	).66	2.3	2.03	1.65	192.45	1.69	333.43	197.82	176.13	308.7	1	-5.048	713794	-2.2202
65	).71	.37	204.57	11.87	471.2	0.19	342.79	687.82	29941.29	1712	1	-5.879	1727323	-2.1033
1	)0.7	.28	6.75	11.34	121.85	1.63	252.77	141.57	469.67	123	1	-5.024	458092	-2.044
61	).71	.36	142.46	11.75	507.81	0.07	347.12	662.09	28356.16	1880	1	-5.894	1855766	-2.0423
69	).71	.35	7.43	9.26	222.79	1.69	72.02	241.16	410.96	576	1	-5.048	809417	-2.0098
79	).71	.34	0	6.52	234.81	1.7	150.51	243.04	1467.71	100	1	-5.047	856437	-1.9297
24	)0.7	.29	7.43	2.69	212.33	1.65	84.98	224.09	3992.17	100	1	-5.027	774088	-1.8304
18	).74	.31	180.26	11.33	448.71	0.53	362.96	640.83	29060.67	1770	1	-5.872	1646975	-1.8082
4	).71	.22	4.05	11.21	103.03	0.03	46.09	118.32	23835.62	100	1	-4.457	389857	-1.7965
66	).72	.36	261.28	11.85	456.03	1.1	353.6	730.27	26125.24	1317	1	-5.747	1673867	-1.7729
59	).74	.31	3.38	8.82	172.06	1.65	295.98	185.9	2289.63	117	1	-5	640076	-1.7104
19	).72	2.3	1.35	3.71	205.53	1.67	272.22	212.26	0	122	1	-5.024	757357	-1.6857
13	).68	.34	11.48	3.78	218.08	1.7	41.05	235.04	5107.63	120	1	-5.049	793018	-1.654
37	).69	2.3	3.38	2.44	265.15	1.67	141.87	272.63	117.42	209	1	-5.045	963812	-1.6262
70	).68	.36	0.68	0.08	343.59	1.7	65.53	346.04	234.83	206	1	-5.049	1240013	-1.6002

Fig92.Rank the optimization result based on delta skin in order to find the best candidates

CONCLUSION

The main aim of this study was to find the re-stimulation candidate wells with the given data without trying to spend thousands of dollars on well-test and gas reservoir simulators. Detailed analysis of well-tests performed on the storage field was done and intelligent tools like Neural networks to predict the Skin and Genetic Algorithms were used to optimize the stimulation and to select the best stimulations for a well. The following conclusions can be drawn from this research:

1. The Artificial Intelligence Tool can predict Skin with high degree of confidence.

2. The Portfolio Management for re-stimulation candidate selection provides a cost effective method for taking full advantage of annual budget for remedial operations.

3. This software is the first successful attempt to combine Data editing, Well-Test analysis and Artificial Intelligence in one software package.

REFERENCES

NONE