Advanced Technologies
For
Stripper Gas Well Enhancement

FINAL REPORT
July 1999 to April 2005

Prepared for

U.S. Department of Energy
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

DOE Award No. DE-FG26-99FT40700

Prepared by

Schlumberger Data & Consulting Services

Ronald J. MacDonald, P.G.
Charles M. Boyer II, P.G.
Joseph H. Frantz, Jr., P.E.
Paul A. Zyglowicz

April 2005

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warrant, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinion of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ABSTRACT

Stripper gas and oil well operators frequently face a dilemma regarding maximizing production from low-productivity wells. With thousands of stripper wells in the United States covering extensive acreage, it is difficult to identify easily and efficiently marginal or underperforming wells. In addition, the magnitude of reviewing vast amounts of data places a strain on an operator's work force and financial resources.

Schlumberger DCS, in cooperation with the National Energy Technology Laboratory (NETL) and the U.S. Department of Energy (DOE), has created software and developed in-house analysis methods to identify remediation potential in stripper wells relatively easily. This software is referred to as Stripper Well Analysis Remediation Methodology (SWARM).

SWARM was beta-tested with data pertaining to two gas fields located in northwestern Pennsylvania and had notable results. Great Lakes Energy Partners, LLC (Great Lakes) and Belden & Blake Corporation (B&B) both operate wells in the first field studied. They provided data for 729 wells, and we estimated that 41 wells were candidates for remediation. However, for reasons unbeknownst to Schlumberger these wells were not budgeted for rework by the operators.

The second field (Cooperstown) is located in Crawford, Venango, and Warren counties, Pa and has more than 2,200 wells operated by Great Lakes. This paper discusses in depth the successful results of a candidate recognition study of this area.

We compared each well's historical production with that of its offsets and identified 339 underperformers before considering remediation costs, and 168 economically viable candidates based on restimulation costs of $50,000 per well. From this data, we prioritized a list based on the expected incremental recoverable gas and 10% discounted net present value (NPV). For this study, we calculated the incremental gas by subtracting the volumes forecasted after remediation from the production projected at its current configuration.

Assuming that remediation efforts increased production from the 168 marginal wells to the average of their respective offsets, approximately 6.4 Bscf of gross incremental gas with a NPV approximating $4.9 million after investment, would be made available to the domestic market.

Seventeen wells have successfully been restimulated to date and have already obtained significant production increases. At the time of this report, eight of these wells had enough post-rework production data available to forecast the incremental gas and verify the project's success. This incremental gas is estimated at 615 MMscf. The outcome of the other ten wells will be determined after more post-refrac production data becomes available. Plans are currently underway for future restimulations.

The success of this project has shown the value of this methodology to recognize underperforming wells quickly and efficiently in fields containing hundreds or

thousands of wells. This contributes considerably to corporate net income and domestic natural gas and/or oil reserves.

Table of Contents

1 EXECUTIVE SUMMARY 1

2 INTRODUCTION 3

3 CONCLUSIONS 6

4 RECOMMENDATIONS 7

5 STATEMENT OF THEORY 8

6 DISCUSSION 9

6.1 DATABASE CONSTRUCTION 9
6.2 METHODOLOGY 9
6.3 RESULTS 12

7 USING THE SWARM SOFTWARE 18

8 APPENDIX A – INSTRUCTIONS FOR USING THE SWARM SOFTWARE 19

9 APPENDIX 2 – LIST OF ALL CANDIDATES 26

List of Tables

Table 2.1 All 168 Cooperstown Candidates Estimated Incremental Production and Net Present Value (Economically Viable After Investment) 4
Table 2.2 Reworked Wells with Sufficient Production Data for Post-Refrac Analysis Estimated Incremental Production and Net Present Value 5
Table 6.1 Thirty-Two Single-Case Evaluations..... 9
Table 6.2 Cumulative Production Percent Difference between Target and Offset Wells 13
Table 6.3 Cumulative Production (MMscf) - Target Wells Total at Indicated Year..... 14
Table 6.4 Cumulative Production (MMscf) - Average Offset Well Total at Indicated Year . 14
Table 6.5 Normalized Rate Percent Difference between Target and Offset Wells 15
Table 6.6 Normalized Rate - Target Wells Average Mscf per Day at Inidicated Year..... 15
Table 6.7 Normalized Rate - Average Offset Average Mscf per Day at Indicated Year 16

List of Figures

Fig. 2.1 – Location map of study area (courtesy Pennsylvania Geological Survey). 3
Fig. 5.1 – Example of target and offset wells within three domains. 8
Fig. 6.1 – Plot showing DOFP vs. 5-Year cumulative production. 10
Fig. 6.2 – Plot showing DOFP vs. 5-year normalized rate. 11
Fig. 6.3 – Rate-time chart showing an underperforming well (Armstrong, D 1) relative to its offsets. 11
Fig. 6.4 – Rate-time chart of the Armstrong D1 showing pre and post-rework production, and their respective forecasts. 12
Fig. 6.5 – Map showing 168 candidates and 17 reworked wells. Names indicate wells with sufficient post-rework data for evaluation..... 16

1 EXECUTIVE SUMMARY

Schlumberger DCS, in cooperation with the National Energy Technology Laboratory (NETL) and the U.S. Department of Energy (DOE), has created software and developed in-house analysis methods to identify remediation potential in stripper wells relatively easily. This study was performed under Contract No. DE-FG26-99FT40700.

Stripper well operators frequently face a dilemma regarding maximizing production from low-productivity wells. With thousands of stripper wells in the United States covering extensive acreage, it is difficult to easily and efficiently identify marginal or underperforming wells. In addition, the magnitude of reviewing vast amounts of data frequently places a strain on the available work force and its financial resources.

In any stripper gas field, there are often wells that do not perform as expected. Though this may be due to reservoir characteristics, it also frequently results from inadequate completions, operational constraints, or mechanical problems. Regardless of the cause of underperformance, the first step for any operator is to identify these suspect wells. Because of these factors, it was recognized that operators could use a timely and straightforward method to screen the wells and spot candidates potentially in need remediation.

One approach to assist with this process was through the development of a user-friendly, PC-based program named Stripper Well Analysis Remediation Methodology (SWARM). This software utilizes production indicators (PI), which are short-term gauges that aid in comparing each well's historical production with its offsets. Examples of production indicators include cumulative production and average monthly rate (i.e. normalized rate) over a chosen period.

SWARM was beta-tested with data pertaining to two gas fields located in northwestern Pennsylvania and had notable results. Great Lakes Energy Partners, LLC (Great Lakes) and Belden & Blake Corporation (B&B) both operate wells in the first field studied and they provided data for 729 wells. A study of this area resulted in identifying 41 candidates for remediation. However, for reasons unbeknownst to Schlumberger these wells were not budgeted for rework by the operators.

The second field (Cooperstown) is situated in Crawford, Venango, and Warren Counties, Pa and has more than 2,200 wells currently operated by Great Lakes.

As a result of studying the second field, 339 remediation candidates were recognized as significant underperformers. These were prioritized based on their expected incrementally recoverable gas and net present value (NPV).

Of the 339 rework candidates, 168 are expected to be economically viable after a $50,000 investment. Assuming that successful remediation increased each candidate's production to its offset average, an estimated 6.4 Bscf of incremental gas with a NPV

approximating $4.9 million would be accessible. It is likely that the remaining 171 wells have upside potential, but only at lower expenditures.

Seventeen wells have been refraced by Great Lakes and sufficient post-rework production data was available from eight of these wells to evaluate their success. The incremental recovery from these wells is forecasted to be 615 MMscf, which provides a NPV of $628,025 after recovering a total investment of $400,000 ($50,000/well * eight wells).

2 INTRODUCTION

Because of the enormous effort required to evaluate and compare each well's production with its offsets, a primary objective was to develop an easier way to screen the stripper wells and spot underperformers. To accomplish this, each well's cumulative production and average inline rates were compared with the equivalent values of offsetting wells for various 12-month periods. These values are referred to as production indicators (PI), which are short-term gauges of performance that facilitate in comparing historical profiles. Any well that had a PI lower than a previously selected percentage (e.g. 50%, 70%) relative to the offset average, was flagged as a potential remediation candidate warranting further study.

Fig. 2.1 highlights the location of the Cooperstown field, which is the primary study area.

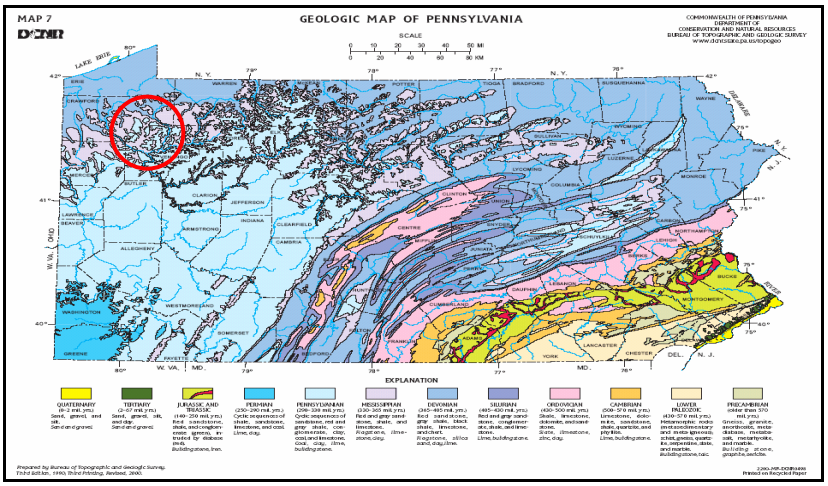

Fig. 2.1 – Location map of study area (courtesy Pennsylvania Geological Survey).

The Lower Silurian Whirlpool/Medina Queenston Formation is the major natural gas producing reservoir in this field and is typically encountered at depths of 5,000 to 5,500 ft. The formation consists of interbedded sandstones, siltstones, and shale sequences with the reservoirs being primarily stratigraphic rather than structural. Thicknesses range from 100 to 225 feet and natural gas production is related to zones of higher porosity and permeability. Approximately 298 Bscf have been produced here and most wells were drilled after 1986. The average cumulative production per well is 150 MMscf; however these values range from zero to one Bscf.

It was mentioned earlier that of the 339 rework candidates, 168 are expected to be economically viable after a $50,000 investment. If all of these wells were successfully reworked, it is estimated that 6.4 Bscf of incremental gas having a NPV of almost $4.9 million would be accessible. These figures can be seen in **Table 2.1**. As a refresher, the NPV considers time value of money and essentially adjusts the worth of future cash flows to present-day dollars by means of a discount rate, which is commonly 10% in the oil and gas industry.

Table 2.1
All 168 Cooperstown Candidates
Estimated Incremental Production and Net Present Value
(Economically Viable After Investment)

Cooperstown Field	Incremental Gas (Mscf)	Post-Rework Net Present Value (Disc 10%)
Total Candidates (168 wells)	6,385,300	$4,864,954

Great Lakes decided to remediate 17 wells that were on the list of economically viable candidates after reviewing their stimulation and operational history. Eight of these have been online long enough to assess their preliminary results, however the rework/online dates of the other nine wells were too recent, and production data too limited, to effectively calculate their incremental gas and NPV. Nevertheless, promising real-world results have already been achieved from the eight remediated wells, which can be seen below in **Table 2.2**. Note that this table indicates that the incremental gas from these wells is forecasted to be 615 MMscf with a NPV = $928,025 based on a total investment of $400,000. Average costs per well are $50,000 per well and average incremental recovery is estimated to be 76.9 MMscf.

Table 2.2
Reworked Wells with Sufficient Production Data for Post-Refrac Analysis Estimated Incremental Production and Net Present Value

Well	Incremental Mscf	Post-Rework Net Present Value ($)
Armstrong D 1 North	30,335	16,544
Dunegan Unit 1	34,657	25,531
Fleming G 1	414,259	831,228
Giovengo Unit 1	42,166	33,258
Lowry Realty Unit 1	37,892	42,161
Staub E 2	31,014	26,362
Way G 3	5,650	(39,110)
Willis-Tracey Unit 1	19,494	(7,949)
Total	615,467	928,025

An important outcome of this methodology is that it highlights many substandard wells that may need only minimal and low-cost remediation efforts to improve productivity. As previously discussed, 171 wells may have additional potential at lower expenditures. Some examples of these lower-cost scenarios include optimizing fluid removal, reducing line pressure, or improving well tending practices.

The above factors substantiate the viability of this project's evaluation methods.

3 CONCLUSIONS

The following conclusions are provided:

- A PC-based software package called Stripper Well Analysis Remediation Methodology (SWARM) was created and is capable of quickly and easily identifying underperforming gas stripper wells. This software has been designed, built, tested, and used with the in-house interpretation procedures.

- Forty-one (41) remediation candidates were identified by the software in the first field operated by Great Lakes and Belden & Blake. However, no candidates from this area were reworked.

- Cooperstown field was the second field studied and 339 underperformers were identified in this area.

    - From this list of candidates, 168 are forecasted to be economically viable after expenditures of approximately $50,000 per well.

    - Assuming that remediation efforts increase production from the 168 wells to the average of their respective offsets, approximately 6.4 Bscf of gross incremental gas with a NPV approximating $4.9 million after investment, would be made available to the domestic market.

    - It is likely that many of the remaining 171 candidates (339-168=171 wells) would be cost-effective at lower remediation costs.

- Seventeen wells have already been reworked and eight of these have been online long enough to confirm their success.

    - Estimated incremental reserves and NPV of these eight wells is 615 MMscf and $928,025, respectively.

- SWARM also identified numerous wells that are not rework candidates.

- The methodology discussed is also capable of recognizing high performing wells, which may aid in field optimization insight.

4 RECOMMENDATIONS

The following recommendations are provided:

- The remaining candidates on the list should continue to be evaluated for geologic and operational factors, and then high-graded for remediation based on economic viability.

- It is important to continue monitoring the production and pressure data from the wells that have been reworked. This will aid in estimating their incremental reserves and provide understanding into future candidate selection.

- Future restimulations should be based upon a priority list ranked by anticipated incremental recovery and NPV.

5 STATEMENT OF THEORY

It was assumed that general, localized production trends exist within a field and that any persistently low or abrupt drop in a well's performance, relative to an established trend qualified that well as a potential remediation candidate warranting further review. Each of the 2,213 wells was compared with offsets within a 5,000-foot radius (domain). An example of three domains containing target and offset wells is shown in **Fig. 5.1**. Note that the target well is the unit being evaluated. During the analysis, each well became a target well and its PI was compared with the corresponding PI of the offsets within its domain.

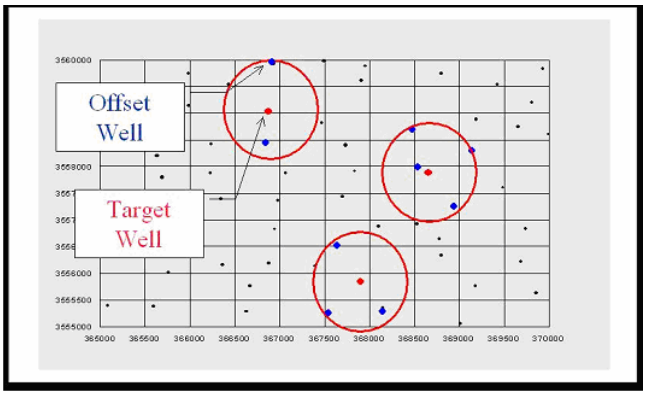

Fig. 5.1 – Example of target and offset wells within three domains.

The process focused on three types of information: 1) the magnitude of production performance, 2) the location of that performance, and 3) the date when this performance occurred. A basic principle was that a target well's expected production can be based on the profile of its offsets, considering the date when the production took place.

To facilitate this process, PI's were derived by calculating the cumulative production and normalized rates over various years. Cumulative production includes the sum of all volumes from online date through the end of the chosen year. Normalized rate is defined as the average monthly or daily rate for any selected consecutive twelve months. For this study, the procedure selected targets that had cumulative production and/or normalized rates, less than 50% or 70% relative to their offsets. All the wells were processed and a list was created for those that met the conditions of substandard performance.

Although the primary objective of this process was to screen for underperformers, it is important to note that this technique can also distinguish "overperformers" by considering targets that have PI's greater than 100% relative to their corresponding offset values.

6 DISCUSSION

6.1 Database Construction

Great Lakes and B&B provided most of the data used in this study, which consisted of individual-well monthly production, location coordinates, and well identifier. Any additional information, such as stratigraphy and lithology, originated from public geological and reservoir engineering sources. This information was populated into various Microsoft ACCESS™ databases and EXCEL™ spreadsheets designed to facilitate the analyses.

6.2 Methodology

The process used in the study is efficient and only a minimal amount of information was essential for the analysis. The data requirements included just monthly production history, well location coordinates (latitude and longitude, or x and y), and well identifier.

The SWARM software analyzes the production data and performs a quick, first-pass search to identify wells performing notably worse than their offsets. To begin the process, a PI representative of a target well's cumulative production history, or its average monthly production rate, over a chosen time "x" interval is calculated. This PI is compared with those of the average of the offsets located within its domain. During the analysis procedure, plots of "x-year" Cumulative Production vs. Date of First Production (DOFP) and Normalized Rate vs. DOFP are generated in addition to rate-time plots, a list of candidates, and location maps. As previously mentioned, a normalized rate is defined as the average monthly production during any chosen twelve consecutive months. Wells that perform significantly lower than adjacent wells are identified.

To maximize the accuracy of the candidate recognition procedure and minimize false identification, we made 32 single-case comparisons using a variety of PI's (see **Table 6.1**).

Table 6.1
Thirty-Two Single-Case Evaluations

	Cumulative Production		Normalized Rate	
Years	Target >=50% Below Offset Average	Target >=70% Below Offset Average	Target >=50% Below Offset Average	Target >=70% Below Offset Average
1	Run 1	Run 9	Run 17	Run 25
2	Run 2	Run 10	Run 18	Run 26
3	Run 3	Run 11	Run 19	Run 27
4	Run 4	Run 12	Run 20	Run 28
5	Run 5	Run 13	Run 21	Run 29
10	Run 6	Run 14	Run 22	Run 30
15	Run 7	Run 15	Run 23	Run 31
20	Run 8	Run 16	Run 24	Run 32

The 32 analyses ranged from one through 20 years filtered at 50% and 70%. To be flagged as a potential candidate during any single-case evaluation, the percentages stipulated that a target's PI had to be at least this percentages below its offsets. These filters provided a benchmark for selecting only candidates that had a cumulative production, or a normalized rate, less than these fractions.

In addition to the above single-case criteria, it was decided that a target well had to be flagged by at least four single-case evaluations before being placed on the final list for additional investigation. This minimized false positives due to a temporary drop in production, and validated sustained substandard performance rather than only short-term.

The following figures help to clarify the methods of comparing production indicators. **Figs. 6.1** and **6.2** are example graphs of Cumulative Production vs. Date of First Production (DOFP), and Normalized Rate vs. DOFP correspondingly, of a target well performing significantly less than its offsets. Note in **Fig. 6.1** that the Armstrong D1 has produced 35 MMscf over five years, which is 57% below the offset average of 82 MMscf. This is the first indication that this well may be performing below its potential.

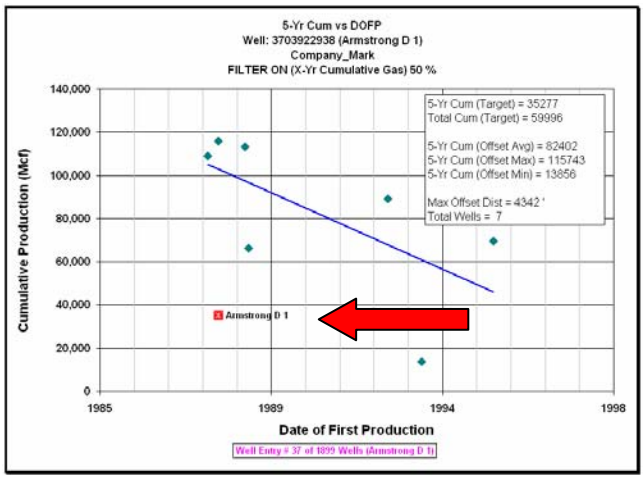

Fig. 6.1 – Plot showing DOFP vs. 5-Year cumulative production.

Fig. 6.2 shows that the average monthly production (normalized rate) during Year-5 is eight Mscf per day, which is 71% lower than the offset average of 28 Mscf per day. This is a second indicator of substandard performance.

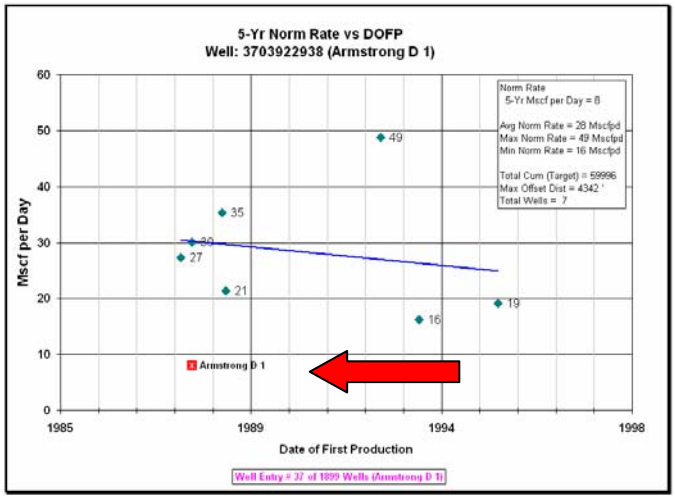

Fig. 6.2 – Plot showing DOFP vs. 5-year normalized rate.

Both of these charts, and the respective PI values of the Armstrong relative to its offsets, indicate the likelihood that it is an underperformer. Later in this report, it will be shown that this well was flagged as producing below its capability by 12 single-case evaluations.

In addition to the two graphs just discussed, a rate-time chart showing the production history of the Armstrong D1, relative to each individual offset and their average, is shown below for visual comparison. Note its long-term underperformance as revealed in **Fig. 6.3**.

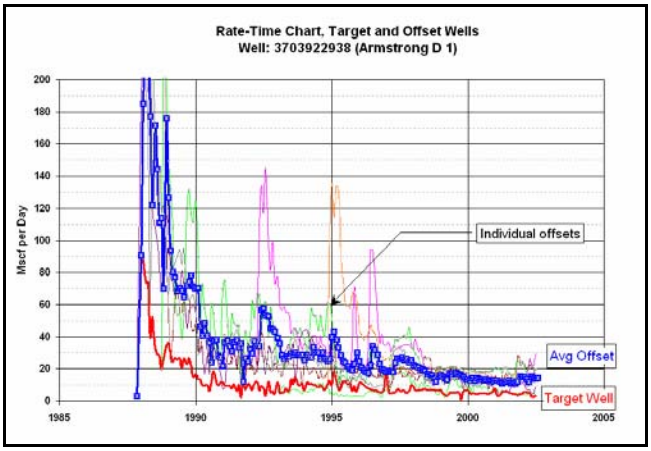

Fig. 6.3 – Rate-time chart showing an underperforming well (Armstrong, D 1) relative to its offsets.

It is apparent upon examination of the above figures that the target well has not performed in the same manner as its offsets. From additional study of the operational, completion, and geologic information pertaining to this well it was determined that the initial frac treatment was inadequate.

A rate-time chart showing production before and after remediation for the Armstrong D1 is presented in **Fig. 6.4**. It can be seen that the pre-rework production was about 4 Mscf per day, which increased to ~15 Mscf per day after remediation. Incremental reserves were estimated to be 20.9 MMscf. Though SWARM does not create a before and after graph similar to that shown below, it is offered as confirmation of the viability of the analysis procedure.

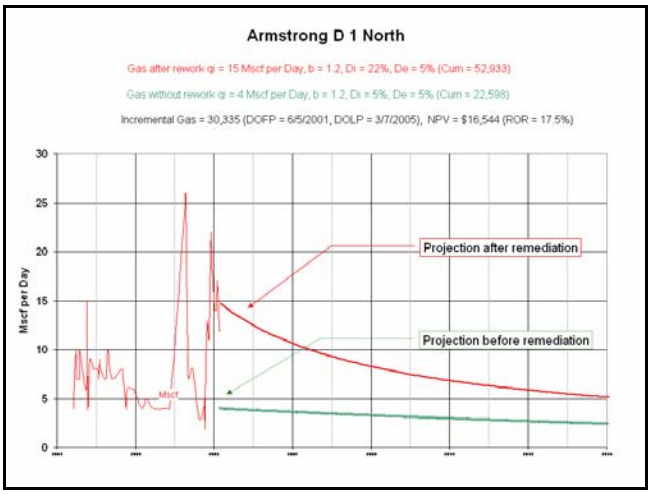

Fig. 6.4 – Rate-time chart of the Armstrong D1 showing pre and post-rework production, and their respective forecasts.

To determine the incremental gas, an estimate was calculated of the higher post-rework volumes that would be obtained by increasing the target well's production to the current average rate of the offsets. This projection was based on an initial hyperbolic decline that reverted to a minimum 5% exponential. The unimproved forecast was then subtracted from the higher post-rework estimate, which resulted in the incremental gas value. All projections assumed $5.00/Mscf and a 20-year life unless the well reached an earlier economic limit.

This methodology efficiently and rapidly identified viable restimulation candidates.

6.3 Results

Making the most of the above methods was fundamental to the successful detection of underperforming wells. In this section, the 17 reworked wells will be discussed and afterwards the outcome of the eight wells that had enough preliminary information to enable post-remediation analysis. Though the methodology recognized 168 candidates,

this narrative will now concentrate on the wells that went through the entire systematic selection process from start to finish.

Table 6.2 shows the percent difference in cumulative volumes for the 17 reworked wells vs. their offsets during various years. The target well's PI was compared only with the PI of the offsets that produced for an equivalent number of years. Note that the difference in these percentages is always greater than 50% based on the decision to single out only wells underperforming to this extent. Though this table pertains to cumulative production, normalized rates are discussed later in this report. Note that the Armstrong D1 well was triggered as an underperformer by six single-case, cumulative production evaluations.

Table 6.2
Cumulative Production
Percent Difference between Target and Offset Wells

		Percent that Target Well is Below Offset Cum Prod					
Wells Identified by Cum Analysis	Count	1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
Armstrong D 1	6	51%	52%	53%	55%	57%	63%
Dunegan U #1	2	90%	89%				
Fleming G #1	4	86%	86%	86%	87%		
Giovengo U 1	6	88%	88%	88%	88%	87%	83%
Lowry Realty No 1	4	58%	65%	68%	68%		
Staub Edgar 2 Mv495	6	79%	81%	81%	81%	82%	82%
Way George 3 Mv327	6	69%	71%	70%	71%	71%	73%
Willis Tracy U 1	5	93%	90%	90%	89%	84%	
Burkhardt #2	2	88%	89%				
Dennis Helen 3 Mv814	5	75%	77%	77%	78%	79%	
Koger 2	6	72%	73%	72%	71%	70%	67%
Lee #2	4	63%	64%	63%	64%		
Lindsey #1	3	63%	64%	66%			
Oil Creek St Park 808 #2	3	58%	56%	57%			
Resinger U 1	6	59%	63%	67%	67%	64%	64%
Rung Vance 4 Mv800	5	73%	72%	70%	69%	63%	
Rynd #6	4	84%	86%	87%	87%		

Tables 6.2 and **6.3** show cumulative quantities (MMscf) from one through ten years for the 17 reworks and their offsets. As discussed previously, all the wells were evaluated (~2,200) and 168 economically viable candidates were identified assuming capital expenditures of $50,000 per well. However, this selection process recognized 340 candidates before considering investment costs.

The percentages shown above in **Table 6.2** were calculated by dividing the target well's cumulative production figure shown in **Table 6.3**, by the respective PI in **Table 6.4**. Note that many wells have entries for a number of years indicating an ongoing history of underperformance. As mentioned before, a final rework candidate required recognition by at least four single-case analyses.

Table 6.3
Cumulative Production (MMscf) - Target Wells
Total at Indicated Year

Wells Identified by Cum Analysis	Count	Target Well Cumulative Production (MMscf)					
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
Armstrong D 1	6	16.3	24.9	29.1	32.3	35.3	51.5
Dunegan U #1	2	2.1	3.7				
Fleming G #1	4	5.0	8.3	10.9	12.5		
Giovengo U 1	6	7.9	11.4	14.2	17.0	19.4	31.2
Lowry Realty No 1	4	15.0	21.7	26.4	30.3		
Staub Edgar 2 Mv495	6	16.9	22.3	27.0	30.6	33.2	46.0
Way George 3 Mv327	6	21.9	30.2	37.6	41.1	44.0	58.7
Willis Tracy U 1	5	2.3	5.1	6.3	8.0	13.9	
Burkhardt #2	2	4.7	6.6				
Dennis Helen 3 Mv814	5	15.7	21.8	25.9	29.0	31.7	
Koger 2	6	11.9	16.7	21.9	25.5	28.9	42.1
Lee #2	4	11.1	19.1	26.3	30.3		
Lindsey #1	3	9.3	15.3	18.8			
Oil Creek St Park 808 #2	3	7.0	13.6	18.3			
Resinger U 1	6	8.8	11.9	14.5	17.0	21.2	30.2
Rung Vance 4 Mv800	5	8.9	15.2	21.1	27.7	38.6	
Rynd #6	4	8.1	10.9	12.6	14.2		

Table 6.4
Cumulative Production (MMscf) - Average Offset Well
Total at Indicated Year

Wells Identified by Cum Analysis	Count	Average Offset Cumulative Production (MMscf)					
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
Armstrong D 1	6	33.2	52.2	62.5	72.1	82.4	139.9
Dunegan U #1	2	22.1	35.1				
Fleming G #1	4	35.6	59.3	78.4	93.0		
Giovengo U 1	6	65.0	95.1	114.5	136.6	148.6	187.5
Lowry Realty No 1	4	35.3	61.7	81.2	95.2		
Staub Edgar 2 Mv495	6	82.6	119.4	145.3	164.7	181.0	249.7
Way George 3 Mv327	6	71.4	103.4	124.9	140.6	153.6	218.9
Willis Tracy U 1	5	31.9	51.1	63.7	74.2	84.0	
Burkhardt #2	2	39.0	58.7				
Dennis Helen 3 Mv814	5	62.3	93.4	114.0	132.7	147.9	
Koger 2	6	42.6	62.9	77.0	87.7	96.9	128.9
Lee #2	4	30.1	53.1	70.8	84.9		
Lindsey #1	3	25.0	42.2	55.5			
Oil Creek St Park 808 #2	3	16.7	31.1	42.3			
Resinger U 1	6	21.1	32.0	43.8	51.4	58.7	83.3
Rung Vance 4 Mv800	5	33.5	54.4	71.6	89.4	102.8	
Rynd #6	4	50.5	76.1	97.1	111.6		

Table 6.5 lists the percent difference in normalized rates for these wells and it is again apparent that the variation in these percentages is greater than 50%. The actual normalized rates (Mscf per day) for the target and offsets are listed in **Tables 6.6** and **6.7**.

Table 6.5
Normalized Rate
Percent Difference between Target and Offset Wells

		Percent that Target Well is Below Offset Norm Rate					
Wells Identified by Norm Rate Analysis	Count	1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
Armstrong D 1	6	51%	55%	59%	66%	72%	68%
Dunegan U #1	2	90%	88%				
Fleming G #1	4	86%	86%	86%	89%		
Giovengo U 1	6	88%	88%	85%	82%	80%	60%
Lowry Realty No 1	4	58%	71%	74%	72%		
Staub Edgar 2 Mv495	6	80%	86%	82%	81%	84%	82%
Way George 3 Mv327	6	69%	74%	66%	78%	77%	63%
Willis Tracy U 1	4	93%	86%	91%	84%		
Burkhardt #2	2	88%	90%				
Dennis Helen 3 Mv814	5	75%	80%	80%	83%	82%	
Koger 2	6	72%	76%	64%	66%	63%	63%
Lee #2	4	63%	65%	59%	72%		
Lindsey #1	3	63%	64%	74%			
Oil Creek St Park 808 #2	3	58%	55%	58%			
Resinger U 1	5	59%	71%	70%	67%		67%
Rung Vance 4 Mv800	4	73%	70%	65%	59%		
Rynd #6	4	84%	87%	92%	89%		

Tables 6.6 and **6.7** show the normalized rates for these wells. During the analysis, we compared the average daily production of the targets with their associated offsets for the indicated year. We flagged these candidates based on rate differences larger than 50% similar to the cumulative production comparison.

As in the single-case cumulative production analyses, the Armstrong D1 was also flagged by six normalized rate evaluations. This well was recognized as performing below its potential by 12 unique, single-case comparisons.

Table 6.6
Normalized Rate - Target Wells
Average Mscf per Day at Indicated Year

		Target Well Norm Rate (Mscf per Day)					
Wells Identified by Norm Rate Analysis Only	Count	1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
Armstrong D 1	6	44.7	23.7	11.5	8.8	8.1	6.5
Dunegan U #1	2	5.9	4.2				
Fleming G #1	4	13.6	9.2	7.1	4.4		
Giovengo U 1	6	21.7	9.5	7.8	7.6	6.5	6.3
Lowry Realty No 1	4	41.0	18.6	12.7	10.9		
Staub Edgar 2 Mv495	6	46.4	14.6	12.9	10.0	7.2	4.6
Way George 3 Mv327	6	59.9	23.0	20.2	9.6	8.1	8.0
Willis Tracy U 1	4	6.4	7.5	3.3	4.6		
Burkhardt #2	2	12.8	5.3				
Dennis Helen 3 Mv814	5	43.0	16.8	11.1	8.5	7.4	
Koger 2	6	32.7	13.2	14.0	10.0	9.3	5.3
Lee #2	4	30.6	21.9	19.8	10.9		
Lindsey #1	3	25.5	16.4	9.6			
Oil Creek St Park 808 #2	3	19.3	17.9	13.0			
Resinger U 1	5	24.0	8.6	7.2	6.9		4.1
Rung Vance 4 Mv800	4	24.3	17.4	16.3	18.0		
Rynd #6	4	22.1	7.7	4.7	4.4		

Table 6.7
Normalized Rate - Average Offset
Average Mscf per Day at Indicated Year

		Average Offset Norm Rate (Mscf per Day)					
Wells Identified by Cum Analysis	Count	1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
Armstrong D 1	6	91.0	52.2	28.2	26.2	28.3	20.2
Dunegan U #1	2	60.7	35.5				
Fleming G #1	4	97.7	64.8	52.6	39.8		
Giovengo U 1	6	178.3	82.5	53.1	42.6	33.1	15.8
Lowry Realty No 1	4	96.9	65.0	48.3	38.5		
Staub Edgar 2 Mv495	6	226.3	101.1	70.8	53.2	44.6	25.7
Way George 3 Mv327	6	195.6	87.8	59.0	43.1	35.4	21.5
Willis Tracy U 1	4	87.4	52.8	34.5	28.5		
Burkhardt #2	2	106.8	54.1				
Dennis Helen 3 Mv814	5	170.7	85.4	56.3	51.3	41.7	
Koger 2	6	116.8	55.6	38.7	29.3	25.3	14.4
Lee #2	4	82.5	63.2	48.3	38.8		
Lindsey #1	3	68.4	45.1	36.4			
Oil Creek St Park 808 #2	3	45.7	39.7	30.7			
Resinger U 1	5	57.9	29.9	23.6	20.8		12.4
Rung Vance 4 Mv800	4	91.7	57.5	47.1	43.7		
Rynd #6	4	138.5	60.7	57.5	39.8		

The previous discussion supports that this is an effective method for recognizing underperforming wells.

A map indicating the location of all candidates relative to one another is shown in **Fig. 6.5**. Small black dots are the locations of the 2,213 wells in the field that were studied. Both the open and solid blue circles indicate the 339 candidates, but the 168 solid ones are the wells forecasted to be economically viable after a $50,000 investment. The remaining 171 open blue circles are underperforming candidates, but do not appear to be viable at this level of expenditure.

The 17 reworked wells are presented by solid red triangles, and the red boxes with well names highlight the eight that had enough data for post-remediation analysis. This can be clarified by viewing the legend.

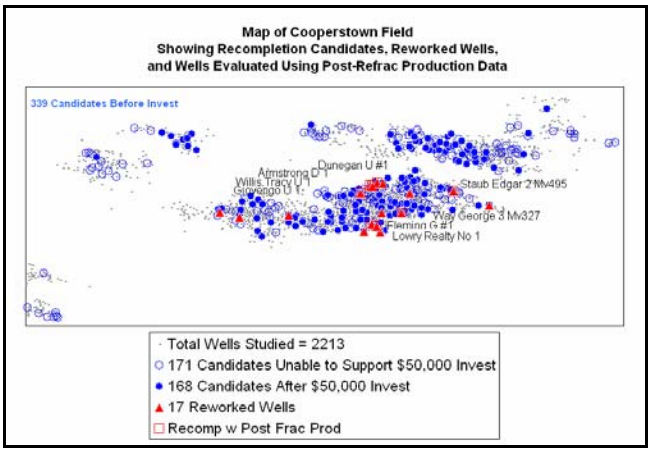

Fig. 6.5 – Map showing 168 candidates and 17 reworked wells. Names indicate wells with sufficient post-rework data for evaluation.

Notice that the 168 economically viable candidates tend to be located in the heart of the various groups of wells. This may be indicative of a historical, field-wide stimulation method that did not optimally access the reservoirs in this area. In this case, the potential exists that stimulation methods can be optimized using today's technology. For example, many of these wells were stimulated with nitrogen using little, or zero proppant. Stimulation methods that can carry greater quantities of proppant may enable production of significant levels of additional gas.

7 USING THE SWARM SOFTWARE

The user selects the PI to be evaluated within a chosen radius of investigation (domain). SWARM then calculates this PI for every well and then compares the "target" well with each of its offsets. Utilizing SWARM, an operator is able to contrast cumulative production or normalized rates over various chosen time intervals.

Additionally, the user chooses a minimum percentage below which a target well must perform relative to its offsets in order to be flagged as a candidate. For example, SWARM contrasts the PI of a target well with the average value of its offsets and if it is lower than the user-defined percentage (e.g. 50%, 70%) it is listed for additional review. As a clarification, to be flagged as a potential candidate this percentage requires that a target well performed at least this amount below the offset average during the chosen period. Although the primary objective of the program is to screen for underperformers, it is important to note that this methodology can distinguish "overperformers" by selecting a percentage greater than 100%.

This is an efficient and rapid method to identify potential restimulation candidates. After this first phase is completed, a review of each candidate's completion data, geologic information, production history, and operating environment should be conducted to determine the most likely cause for poorer performance. The appropriate remediation treatment can be considered based on corporate business plans.

Please refer to Appendix A for instructions on using the SWARM software.

8 APPENDIX A – INSTRUCTIONS FOR USING THE SWARM SOFTWARE

Schlumberger

APPENDIX A

Instructions for Using SWARM Software

(Stripper Well Analysis Remediation Methodology)

PART I – PRODUCTION DATABASE

Software Requirements

Microsoft Access 2000™ and Excel™ 2000 are required to operate the SWARM software.

Opening the Database

To open the database, first open Windows Explorer and go the working directory where the SWARM software resides. *Double-click on Swarm_Final_DOE.mdb in the working directory*. This will open Access and a window will appear that lists the Table objects within the database. You will see four tables listed as follows:

1) Offsets

2) Production

3) Statistics

4) Wells

Populating the Database

Swarm_Final_DOE.mdb is a template Access database included with a distribution CD. In order to use the SWARM software for a specific gas field, this template database must be replaced by real production data. In order to accomplish this, two tables must be populated.

The first table that must be populated is the Wells table, which has the format shown in **Table 1**. The software is designed to accommodate a maximum of 10,000 wells.

Table 1
Description of Wells Table

Column	Field Name	Description
1	Well ID	API well number
2	Well name	Well name
3	X	x-distance, ft
4	Y	y-distance, ft
5	Misc. info	Operator name or other identifier

A Production table is associated with the Wells table that consists of monthly production data. The format of the Production table is presented in **Table 2**.

Table 2
Description of Production Table

Column	Field Name	Description
1	Well ID	API well number
2	Date	Calendar date (mm/dd/yyyy)
3	Production	Monthly production, Mscf
* Up to 1,000 months of data may be input for each well.		

Generating the Statistics and Offsets Tables

After populating the Wells and Production tables with actual data, two additional tables (Statistics and Offsets) must be created before operating SWARM with its Excel spreadsheet. These two tables are created utilizing a macro that will be discussed later. The Statistics table consists of cumulative production, normalized rate, and other information for each well. Table 3 gives a detailed description of the statistics table.

Table 3
Description of Statistics Table

Column	Field Name	Description
1	Well ID	API well number
2	X_Yr_Cum	Cumulative production after X-years
3	X_Cum Time	Number of years selected for X_yr_cum
4	Total_Cum	Total well cumulative production, Mscf
5	Months_Produced	Number of months well has produced
6	Normalized Rate	Average monthly production rate
7	DOFP	Calendar date of first production (mm/dd/yyyy)
8	DOLP	Calendar data of last production (mm/dd/yyyy)

The Offsets table consists of multiple records for each well as illustrated in **Table 4**.

Table 4
Offsets Table

Column	Field Name	Description
1	WellID	API number of current well
2	OffsetID	API number of offset well
3	OffsetDist	Distance of offset well from current well, ft
4	OffsetRank	Distance rank of offset well from current well

Both the Statistics and Offset tables may be generated by clicking on the Macros button in the upper left corner of the main Access screen. Then click on "Offset Calculations" and enter a desired maximum offset radius in feet and a cumulative time-period in years. Then click "Run" to create the Statistics and Offset tables.

The four tables are now fully populated and the database is complete. At this time, the Access database may be left open or closed (by closing Access). You are now ready to open the Swarm spreadsheet.

PART II – SPREADSHEET OPERATION

Spreadsheet Operation

To open the spreadsheet, double-click (from Windows Explorer) on SWARM_Final_DOE.xls in the working directory. This will open the spreadsheet module of SWARM using Excel and display the Well List worksheet. In Cell E7, enter the complete path to the SWARM Access database (SWARM_Final_DOE.mdb) in the box indicated. This enables linking Excel file to the Access database. Now click the Update Well List button (located in the top left of the screen) to import appropriate well data. Cell B16 shows the number of wells imported from the database. It is important to note that this value will frequently be less than the total number of wells in the database. This is because some wells have less than the required number of months of production specified as "cumulative time" when you ran the database macro.

The next step is to choose a filter based on either cumulative production or normalized rate. Normalized rate is defined as the average monthly rate for X-year. For example, if you specified 5 years when you ran the database macro, then the normalized rate is the average rate for the 5th year.

Use the drop-down menu (located near Cell E9) and select the desired filter type. Then use the small drop-down box positioned below Cell E9 to select a percentage. For example, if the filter type is cumulative and you select 70, then you are looking for wells that had cumulative production 70% less than any of their offsets during the first X-years, as specified in the database macro.

The Batch Process button may be used to view graphical output for each well that meets the filter criteria. You may obtain 1, 2 or 3 plots for each well that meets the filter criteria, depending on your selection. The graphics consist of (1) cumulative production vs DOFP, (2) normalized rate vs DOFP, and (3) production rate vs time for each well. The cumulative production and normalized rate plots are for the time selected in the database (see X_Yr_Cum and X_Cum_time in the statistics table). The production rate vs time plot includes all production for each of the filtered wells. Choosing the option in the clickbox "Send results to printer" will print all appropriate charts and maps. Location maps showing all wells and identified candidates are also created in addition to candidate lists.

Note that lists and maps for All Operators, Operator 1, and Operator 2 are created. The term "Operator" can be replaced with any miscellaneous identifier, if desired, that has been loaded into the Access database.

To see a map of all well locations, click on the Well_Map worksheet tab at the bottom of the screen. The first time the spreadsheet is opened after a new set of wells is entered into the database, the map scales will need to be set appropriately. To do this, double click on the x- or y-axis and change the scales appropriately.

Clicking the Next Well or Previous Well button on the Well_Map graph will update the map and identify the location of the current target well with a red dot. The well name and sequence number of the current well are printed at the top of the screen below the graph title.

In addition to the basic use of the spreadsheet discussed above, there are other options available. For example, the user may manually enter a well index in cell B12 and click on "Update Current Well." This will update each of the three plots and the field map of well locations. Any of the plots may be viewed by clicking on the appropriate button on the Well List worksheet.

The Sample Data worksheet contains tabular information about the target well and its associated offset wells. First, there is a table of X-year cumulative production and offset distance for each of the offset wells for the current target well. Then there is a summary table in columns J and K that gives the number of offset wells and the minimum, maximum, and average cumulative production and normalized rate for the group of offset wells. Further to the right is a normalized rate table for the offset wells. Finally, there is a complete table of the monthly production for the current target well.

It is important that no information be changed directly in Excel since various Visual Basic routines and/or range names could be adversely affected.

PART III – IDENTIFYING CANDIDATE WELLS FOR REMEDIATION

It is important that both filters are used and that different time-periods be selected in the database macro. The following are general guidelines, based on the dataset used during development and testing of the SWARM software.

Step 1: Run the database macro with an appropriate offset distance (e.g. 4000 ft) and a time of 3 years.

Step 2: Click on Update Well List on the Well List worksheet.

Step 3: Select the cumulative filter with 70 percent reduction.

Step 4: Go to the cumulative plot and use the Next Well button to advance through all of the filtered wells. For each filtered well, also look at the normalized rate plot and the production plot. Use File Print from the Menu Bar if you wish to print any of the three graphs for each of the filtered wells. For convenience, a rate-time plot showing a target wells production profile overlain by rates of its offsets has been provided.

Alternatively, you may click on Batch Process from the Well List worksheet after activating the "print" clickbox, and review the filtered wells from hard copy plots.

Step 5: Change the filter to normalized rate.

Step 6: Go to the normalized rate plot and use the Next Well button to advance through the filtered wells. For each well, also look at the cumulative and production plots. Print as desired by well.

Alternatively, you may click on Batch Process after activating the "print" clickbox, from the Well List worksheet and review the rate-filtered wells from hard copy plots.

Step 7: Repeat steps 1 through 6 for time-periods of 5 and 10 years.

This process will systematically identify wells that are under performing, relative to their offsets. It is important that different time-periods be used, as appropriate for the field under study. There may be periods when many of the wells in the field were not producing for several months. For example, if there are many wells that are non producing wells during their 5th year, then the wells filtered using normalized rate based on a 5 year time period will include many of these non producing wells. These wells, may, in fact be very good wells that would not be "filtered" if a 4 year or 6-year time period had been used. Hence, it is very important to use different time-periods.

In addition, both the cumulative and rate filters must be sequentially applied in order to be certain that candidate wells are in need of remediation. A common occurrence in some fields is for wells to be very good for 3 to 5 years and then remain on a steep exponential decline. In these cases, the cumulative filter based on 5 years might not identify wells in need of remediation. However, a 10-year timeframe and the normalized rate filter would identify wells that are dramatically under performing after 10 years.

In summary, judicious use of the time-period and the two filters will positively identify wells that are potential candidates for remediation.

9 APPENDIX 2 – LIST OF ALL CANDIDATES

Appendix 2 is a list of candidates sorted by well name. The Number of Filters triggered column indicates the total number, out of 32 analyses, that the well met the criteria for underperformance. A column showing the number of offsetting wells and producing from the same formation within a 5,000 ft. radius is also shown.

Appendix 2
List of Candidates
Showing Number of Offsets, Filters Triggered, and Incremental Forecast

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
1	Abbott Lawrence 1 Mv00			9	13	Mar-1981	21	54,749
2	Abmyr U #4			5	10	Jul-1998	4	9,330
3	Adams James 1 Mv767			14	10	Nov-1993	9	4,135
4	Alderfer D 1			6	14	Oct-1993	9	56,566
5	Allen 1			9	20	Jul-1981	21	35,699
6	Armstrong D 1	Yes	Yes	6	13	Jan-1988	14	56,850
7	Armstrong Larry 1 Mv52			8	16	Nov-1990	12	25,750
8	Arthurs Nancy 1 Mv409			22	18	Dec-1986	16	10,442
9	Ashworth U 1			10	7	Jan-1992	10	11,662
10	Aversa 1 W 057			7	20	Oct-1980	22	43,647

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
11	Bailly Floyd 1 Mv007			6	8	Apr-1982	20	3,272
12	Ballog 1 W 084			3	27	Nov-1981	21	16,793
13	Bangs G 1 W 026			12	10	Mar-1982	20	25,811
14	Beals Norman Iii 1 Mv2			19	6	Oct-1990	12	15,852
15	Bean William 2 A Mv203			14	9	Dec-1985	17	22,007
16	Beightolu #5			21	5	Jul-1998	4	44,990
17	Bell 2			19	17	Feb-1988	14	10,967
18	Bell Deliah 1 Mv615			13	12	Nov-1981	21	32,649
19	Bellu #7			9	7	Sep-1998	4	13,785
20	Benson Don 2 Mv209			18	17	Dec-1987	15	34,632
21	Bish Charles 1 Mv616			4	14	Dec-1981	21	25,441
22	Blakeslee R 1 Ds 24			9	6	Jul-1987	15	18,029
23	Bleicher U 1			5	7	Jun-1982	20	24,954
24	Bogardus 1			18	13	Feb-1991	11	20,675
25	Bogardus 4 W 021			4	26	Apr-1980	22	51,290
26	Bogardus 5 W 027			8	19	Apr-1980	22	30,240

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
27	Boggs U 1			13	20	Feb-1991	11	3,135
28	Bonner 2			21	23	Mar-1990	11	44,240
29	Boy Scouts Of America 2			7	20	Sep-1984	18	54,927
30	Bradford J 1 Ds 67			4	5	Feb-1988	14	28,068
31	Brenner A 2 Ds 58			8	10	Dec-1987	14	31,917
32	Brown 1			21	18	Oct-1989	13	8,964
33	Brown 617 01			5	14	Jan-1983	19	10,566
34	Brown Jf 1			14	9	Nov-1994	8	22,610
35	Brown Martha 1 A Mv412			14	12	Sep-1989	13	38,828
36	Brown Mu2			13	12	Oct-1998	4	14,789
37	Brunst E 1 W 132a			9	20	Jan-1995	7	50,166
38	Bunting 680 01			7	20	Sep-1983	19	11,141
39	Burchfield 1b			22	10	Feb-1985	17	20,831
40	Burk 2			22	14	Oct-1989	13	25,433
41	Burk J J 1			21	11	Jan-1986	16	4,749
42	Burkhardt #2		Yes	4	8	Jun-2000	2	121,657
43	Burleigh H 1 Ds 32			15	13	Dec-1986	15	10,218
44	Burleigh H 2 Ds 54			17	9	Dec-1987	14	7,895

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
45	Burleigh H 3 Ds 55			17	12	Jan-1988	14	3,581
46	Byler J 1 Ds 46			9	24	Dec-1987	14	28,878
47	Byler N 1 W 160			12	20	Jan-1983	18	19,085
48	Byler S U #2			13	8	Dec-1999	2	4,496
49	Byler Sj 1 W 023			10	25	Apr-1980	22	36,524
50	Caldwell M #1			20	12	Dec-1998	3	24,071
51	Caldwell Nophia 1 Mv41			4	7	Dec-1990	12	18,625
52	Campgrounds 1			3	9	Apr-1991	11	7,920
53	Cannon North U 1			20	19	Oct-1988	13	19,558
54	Canon U 2			8	11	Apr-1992	6	3,960
55	Carroll's Nursery 1 Mv2			9	9	Jan-1982	20	44,474
56	Carroll's Nursery 3 Mv6			15	12	Nov-1984	18	33,809
57	Cerro 2			13	8	Sep-1991	11	10,353
58	Chitester Eliza 1 Mv22			7	14	Apr-1982	20	16,469
59	Conaway R U 1			14	6	Jun-1993	9	12,801
60	Condrasyu1			8	17	Mar-1997	5	25,176
61	Conn U #7			11	11	Jul-1998	4	35,650

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
62	Conn William 8 Mv793			8	20	Aug-1994	8	34,344
63	Country Royals 1 W 147			12	21	Sep-1983	19	36,145
64	Coyne Slagle U 3			17	20	Aug-1991	11	31,644
65	Cubbon Lumber Co 1			13	14	Mar-1990	12	21,538
66	Cummings William 2 Mv0			15	14	Dec-1985	17	24,871
67	Darwinbellu #5			9	10	Sep-1998	4	58,476
68	Dean James 1 Mv352			11	11	Nov-1982	20	70,094
69	Dearment R 1			6	9	May-1993	9	44,253
70	Deeter #2a			20	16	Dec-1997	4	13,892
71	Deeter Pe 3			24	19	Aug-1984	18	73,698
72	Deissu #3 Geneva29			10	11	Jul-1998	4	17,687
73	Dennis Helen 3 Mv814		Yes	15	20	Aug-1996	6	16,574
74	Desarro 208 01			7	9	Oct-1985	17	12,805
75	Dewey U 1			12	8	Nov-1989	13	36,724
76	Dewey U 2			11	5	Nov-1991	11	35,858
77	Dietz Edward 1 Mv037			19	8	Dec-1985	17	27,087

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
78	Dittman Howard 1			6	18	Jan-1997	5	31,497
79	Dorn 1			9	21	Jul-1981	21	20,143
80	Douthitt Roy 1 Mv627			5	12	Oct-1981	21	30,605
81	Drake 2			19	5	Jan-1985	17	42,485
82	Drda R U 3			5	11	Jul-1985	17	12,135
83	Dunegan U #1	Yes	Yes	6	8	Jan-1998	4	56,955
84	Dunkleu #4			20	8	Nov-1998	4	1,745
85	Dunn Construction #5			11	11	Mar-1984	18	23,829
86	Dunn David 6 Mv785			18	8	Jun-1994	8	8,352
87	Dunn Richard 1 Mv629			6	8	Oct-1981	21	17,564
88	Dyda 4			6	10	Feb-1995	7	4,323
89	Eddy #1			7	5	May-1998	4	48,388
90	Ellen Elizabeth 3 Mv42			5	6	Jan-1990	12	12,757
91	Elliot U 1			12	24	Feb-1991	11	27,701
92	Engelskirger Eugene 4			9	10	May-1996	6	3,021
93	Evans 1 W 048			11	24	Jul-1980	22	33,738
94	Farley H U 2			3	12	Feb-1985	17	3,907
95	Feevey 4			15	14	Sep-1991	11	2,924

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
96	Feevey T & C 1			17	11	Sep-1990	12	4,865
97	Fennell 1			18	7	Dec-1989	13	14,796
98	Ferris 614 01			9	14	Jan-1983	19	9,018
99	Fike Dempsey U 1			17	8	Oct-1985	17	13,429
100	Fink Eg 1 W 176			5	6	Jan-1983	19	26,640
101	Firth 1 Ds 07			7	11	Dec-1986	15	23,250
102	Fisher & Young 1 Cb078			3	13	Apr-1991	11	14,223
103	Fisher Frank 1 Mv047			11	10	Nov-1984	18	20,543
104	Fleming G #1	Yes	Yes	15	16	May-1998	4	42,769
105	Ford Dean 2 Mv542			14	11	Feb-1988	14	15,849
106	Foster 1			21	6	Sep-1988	14	7,919
107	Foster U 3			11	10	Oct-1994	8	7,914
108	Foster U 4			8	12	Nov-1994	8	11,416
109	Fox Dale 2 Mv544			8	13	Jan-1990	12	39,633
110	Fox Ward U 3			16	8	Oct-1992	10	7,416
111	Franke Floyd 1 Mv433			16	22	Nov-1988	14	21,075
112	Fritz William 1a Mv244			18	6	Nov-1991	11	33,151
113	Fruehauff #3			7	13	Jun-1998	4	111,102

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
114	Fry R U 1			5	5	Sep-1984	18	12,398
115	Gallaher A U 2			6	20	Sep-1992	10	5,241
116	Gettig Eugene 1 Mv437			6	12	Dec-1988	14	22,311
117	Gifford U 2			20	12	Aug-1989	13	15,072
118	Gingerich 1 W 070			8	26	May-1981	21	26,858
119	Giovengo U 1	Yes	Yes	16	23	May-1991	11	22,779
120	Glover L 946 04			7	8	Apr-1988	14	3,091
121	Glover Williard #2			19	24	Sep-1987	15	58,887
122	Gonzalez Mcclintock U			11	9	Oct-1989	13	17,644
123	Gordon Floyd 1 Mv186			10	12	Dec-1985	17	41,789
124	Graham U 1			16	8	Feb-1991	11	12,186
125	Halfast D 1 Ds 89			4	20	Apr-1988	14	18,352
126	Hamilton Marion 1 Mv05			12	7	Jun-1981	21	12,415
127	Hammermill Pr Co 2 Mv445			10	11	Feb-1989	13	21,086
128	Hamrick 1 W 177			5	23	Nov-1983	19	30,931
129	Handelman U 3			10	20	Aug-1993	7	15,437
130	Harris Ames U 3			12	17	Dec-1994	8	38,716

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
131	Harris Wladzia 2 Mv808			20	17	May-1996	6	24,923
132	Harter U #3			17	12	Aug-1998	4	11,293
133	Hasbrouck 2 W 253			14	21	Nov-1989	13	13,027
134	Hasbrouck G 3 Ds 64			11	13	Aug-1987	15	26,965
135	Hauck William 1 Mv715			4	18	Oct-1992	10	56,323
136	Hauser Merle 1 Mv643			6	15	Feb-1982	20	5,721
137	Hazlett 1			19	10	Sep-1985	17	17,884
138	Himes U 1			6	6	Dec-1995	6	26,516
139	Hines 3 W 251			10	11	Nov-1989	13	24,856
140	Hinestarr U 1			15	8	Feb-1984	18	82,966
141	Hoffman L 1			7	6	May-1986	16	79,307
142	Holman 1			15	9	Jul-1989	13	13,049
143	Holmes Robert 2 Mv453			17	9	Dec-1985	17	33,214
144	Hritzay 3 97			6	16	Jul-1997	5	39,585
145	Hummer 1 W 168			11	8	Feb-1983	19	22,250
146	Hummer R 2 Ds 57			12	8	Dec-1987	14	26,858
147	Hutchinson 1 W 133			12	17	Dec-1983	18	24,552
148	Huya 176			8	7	Apr-1982	20	747

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
149	Huya 3			9	19	Sep-1996	6	31,591
150	Hyde Kenneth 1 Mv556			11	16	Nov-1988	14	42,555
151	International Paper Co 2			4	10	Sep-1993	9	20,392
152	Izbicki I W 085			4	28	Nov-1981	21	17,310
153	Jacoby 2			19	12	Nov-1984	18	28,776
154	James William 1 Mv759			12	10	Oct-1993	9	28,811
155	Janoski 2			6	11	Apr-1992	10	13,474
156	Johnson 1 W 139			15	6	Jan-1983	19	10,733
157	Johnson Oil Co #1			12	12	Aug-1998	4	24,793
158	Jones E 1			16	9	Dec-1988	14	31,894
159	Jones Spangler 1			21	23	Jun-1988	14	26,104
160	Karns U 1			25	5	Apr-1986	16	24,524
161	Kerr Ja 1 W 179			8	5	Dec-1983	18	21,861
162	King 1 W 216			3	26	Dec-1983	18	21,017
163	Klein 3			17	19	Feb-1991	11	25,813
164	Klein 4			17	19	Sep-1991	11	23,931
165	Kleinsmith U 1			18	6	Nov-1991	11	6,957
166	Knapp C 1 Ds 36			5	8	Feb-1987	15	51,833
167	Koger 2		Yes	14	19	Dec-1988	14	21,825
168	Kohl 7			17	13	Mar-1987	15	42,158

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
169	Kolaja L Et Al 1 W 247a			7	6	Mar-1990	12	6,933
170	Kozik 1 W 090			9	22	Nov-1981	21	27,660
171	Kozik F 2 W 227			9	14	Sep-1987	15	18,269
172	Krantz 1			6	17	May-1990	12	12,550
173	Kuhn U 758 02			10	10	Jan-1988	14	6,122
174	Kunz M 1 W 131			6	5	Jan-1983	19	10,882
175	Lamberson #1			18	6	Oct-1997	5	25,489
176	Lane Development 1 Kp156			8	8	Sep-1987	14	22,997
177	Lane Development 2 Kp174			8	10	Jan-1988	14	19,400
178	Lee #2		Yes	18	9	Jul-1998	4	13,338
179	Lee Oil & Gas			10	17	Jan-1988	14	10,834
180	Lee Oil & Gas 11a Cb065			9	14	Jan-1991	11	23,792
181	Lee Oil & Gas 14 Cb098			9	5	Oct-1991	11	11,380
182	Lee Oil & Gas 16 Cb133			8	20	Jul-1993	9	25,020
183	Lefes 1			5	5	Sep-1991	11	17,875
184	Leofsky James 5 Cb136			10	17	Mar-1993	9	10,290

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
185	Lewis 1 W 114			6	20	Jan-1982	20	23,953
186	Lindsey #1		Yes	5	7	Sep-1998	4	25,924
187	Lorenz L 1 W 029			9	6	Apr-1980	22	10,684
188	Lowry Realty No 1	Yes	Yes	18	11	Aug-1997	5	13,465
189	Lowry Robert 1 Mv459			9	6	Nov-1988	14	13,589
190	Lubach P 1 W 228			8	7	Nov-1989	13	70,682
191	Luchansky 1			3	12	Oct-1995	7	24,800
192	Lyons John 1 Cb044			4	8	Oct-1990	12	25,386
193	Manson U #2			17	7	Dec-1998	3	3,003
194	Marleygarczek 1			3	12	Oct-1984	18	6,431
195	Matt Frank 1 Mv373			15	6	Oct-1982	20	32,828
196	Matt Frank 2 Mv374			15	11	Oct-1982	20	35,802
197	Matteson 1 W 125			6	11	Jan-1983	19	11,421
198	Matteson Equipment Co #			7	14	Oct-1989	13	32,302
199	Matteson U #1			6	13	Jun-1997	5	27,768
200	Mccoy R 1 Ds 14			6	13	Dec-1986	15	65,629

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
201	Mcelhaney Pj 2			23	15	Sep-1985	16	58,056
202	Mcfall 2			4	17	Aug-1991	11	6,935
203	Mcfall 3			3	19	Apr-1992	10	7,667
204	Mcfall 4			4	10	Apr-1992	10	2,632
205	Mcguire #3 052 03			3	8	Jan-1998	4	10,607
206	Mciver U 1			16	15	Oct-1986	16	51,962
207	Mckuhn 3 W 241			10	5	Nov-1988	14	30,075
208	Merry #1			8	8	Jan-2000	2	4,736
209	Merry 4 W 207			11	5	Nov-1983	19	16,184
210	Miehl D U 1			3	10	May-1985	17	23,588
211	Mika Chester 1 Mv516			12	9	Nov-1989	13	29,500
212	Miller Gravatt 1			16	10	Mar-1985	12	39,419
213	Miller J 1 W 050			5	26	Dec-1981	20	18,693
214	Mills 1 W 019			3	31	Apr-1980	22	54,231
215	Minnamon Virgina 1 Mv4			19	6	Dec-1987	15	24,463
216	Morrell Robert 1 Mv666			9	9	Nov-1981	21	42,145
217	Morris Cw 2 W 127			13	28	Jan-1983	19	26,943
218	Morris F 5 W 238			13	8	Mar-1990	12	12,402

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
219	Motter 2			13	12	Dec-1988	14	13,942
220	Moyer U 1			18	12	Sep-1988	11	38,375
221	Mueller John 1 Mv470			17	10	Jan-1988	14	31,756
222	Mullen 1 W 222			13	10	Nov-1985	17	5,637
223	Mumford James 4 Mv806			17	10	Apr-1996	6	11,949
224	Myers U #2			10	8	Aug-1998	4	49,160
225	Nadolny R 2 Ds 59			13	13	Sep-1987	15	13,925
226	Neiport Matthew 1 Mv51			18	10	Oct-1988	14	35,692
227	Newton Charles 1 Mv287			16	14	Jan-1987	15	33,432
228	Nichols James 1 Mv729			10	17	Mar-1993	9	33,760
229	Nichols P 8			4	16	Apr-1992	10	9,865
230	Niknar 166 01			4	6	Jun-1984	18	29,245
231	Noel 3			23	12	Aug-1985	12	1,488
232	Noel 4			22	10	Oct-1985	17	27,467
233	Noel J 1			10	21	Mar-1991	11	32,441
234	Obrien Francis 2 Mv38			10	21	Nov-1990	12	14,578

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
235	Oehmler Herman 2 Mv519			11	24	Sep-1989	13	37,699
236	Oil Creek St Park 808 #2		Yes	3	6	Jul-1998	4	13,423
237	Omiecinski Walter 1a M			13	14	Oct-1985	17	18,757
238	Painter 3			22	10	Feb-1994	8	29,129
239	Pape 2			20	6	Jan-1993	9	32,472
240	Pardee Ernest 2 Mv290			16	5	Feb-1988	14	27,881
241	Paul M 1 W 152			11	15	Jan-1983	19	18,137
242	Paul P 1 W 028			6	23	May-1982	20	33,492
243	Pennzoil A 3 Kp205			3	14	Jul-1988	14	15,394
244	Pennzoil C 7 Cb077			12	12	Mar-1991	11	17,798
245	Peterson Hugh 1 Mv135			19	11	Jan-1981	21	60,428
246	Petrow U #6			11	12	Jul-1998	4	16,074
247	Pettigrew U 1			3	21	Oct-1990	12	36,756
248	Plyler H U 2			4	18	Mar-1985	17	1,475
249	Plyler U 1			13	8	Jul-1989	13	9,587
250	Podojil 1			19	7	Oct-1988	14	6,637
251	Powell Abagail 1 Mv802			13	11	Mar-1996	6	27,090

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
252	Prather William 1 Mv67			11	11	Nov-1981	21	50,171
253	Proper H Unit #2			17	8	Jul-2000	2	2,800
254	Quick 1n			18	11	Dec-1988	14	6,601
255	Quick 3			15	19	Nov-1992	10	51,748
256	Quiring 694 01			7	21	Jan-1988	14	12,958
257	Rankin #1			23	13	Jul-1984	18	45,190
258	Reese 2			4	9	Dec-1990	12	3,735
259	Reese Lillian 1 Mv674			7	11	Dec-1981	20	1,647
260	Reese U 1			11	17	Nov-1990	12	9,512
261	Reitz Lester #1			19	5	Dec-1987	15	27,636
262	Rensma Cobb 4 Cb028			4	12	Aug-1990	12	24,789
263	Resinger U 1		Yes	9	12	Jan-1991	11	35,784
264	Rigas Crawford 1			4	24	May-1989	12	48,884
265	Rogers M Jr 1 Ds 86			4	22	May-1988	14	24,476
266	Root Betty 1 Mv598			18	16	Sep-1988	14	35,405
267	Rung Vance 4 Mv800		Yes	16	13	Mar-1996	6	
268	Rynd #6		Yes	9	16	Jul-1998	4	39,056

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
269	Ryznar Theodore 1 Mv60			17	7	Dec-1988	14	36,965
270	S G L 199 A #01			8	12	Dec-1997	4	2,089
271	S G L 199 A #03			7	16	Dec-1997	4	37,952
272	S G L 96 A #14			14	15	Jan-1995	7	26,398
273	S G L 96 B #3			14	18	Sep-1996	6	38,025
274	Saeger U 3			9	11	Oct-1994	8	45,439
275	Sanborn 2 W 258			12	8	Nov-1988	14	13,101
276	Sandor 1			7	13	Aug-1982	20	13,982
277	Say U 2			21	9	Apr-1988	14	35,984
278	Say U 3			20	18	Jun-1993	9	16,783
279	Schlosser 3			13	16	Jul-1997	5	30,868
280	Scouten 2 W 255			6	23	Nov-1988	14	25,977
281	Seigworth William 1a Kp11			6	14	Jun-1987	15	42,101
282	Shay Milbert 1 Mv487e			20	6	Oct-1985	10	8,003
283	Shevchik Michael 2 Mv4			16	10	Aug-1988	14	17,834
284	Shrock Plum 1			15	19	Oct-1990	10	17,547
285	Shuda A 1 Ds 34			4	7	Jul-1987	15	2,993
286	Shuffstall U #4			11	8	Jul-1998	4	30,149

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
287	Smith Ila 2 Mv741			3	7	Mar-1993	9	21,610
288	Smith Merle 1 Mv684			8	5	Dec-1981	21	18,999
289	Smith Ut No 6 3			13	16	Feb-1998	4	31,982
290	Snyder Jeannette 1 Mv7			8	12	Jan-1993	9	6,686
291	Sojack M U 1			6	6	Jan-1986	11	141
292	Spangler G U 4			19	10	Jun-1993	9	25,303
293	Speck J U 4			3	11	Aug-1994	8	39,960
294	Staley H U 1			3	5	Jul-1984	18	9,337
295	Stapf 1 W 104			5	19	Dec-1981	20	30,311
296	Staub Edgar 2 Mv495	Yes	Yes	9	24	Jan-1989	13	57,308
297	Stec Tony 3 Cb053			7	9	Nov-1990	12	8,875
298	Stewart U 1			20	6	Nov-1989	13	14,802
299	Strawbridge 2			15	10	Dec-1988	14	18,903
300	Sutton U 1			11	20	Aug-1993	9	44,259
301	Threlfall Edward 1 Mv5			11	11	Jan-1989	13	30,402
302	Tidioute Water Co 4 M Cb			5	6	Sep-1992	10	15,426
303	Trimble Arthur 3 Mv801			18	12	Mar-1996	6	40,658

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
304	Troyer M 1 W 159			10	10	Jan-1983	18	43,230
305	Turner Harold 1 Mv323			6	13	Nov-1990	12	24,713
306	Upton Lumber U 1 Cb110			7	20	May-1992	10	6,551
307	Upton Robert 1 Cb024			10	11	Apr-1990	12	15,128
308	Van Tassel 1 W 099			7	10	Jun-1982	20	462
309	Vanderhoff 2 W 250			8	10	Oct-1988	14	13,626
310	Wagner David 3 Mv396			16	10	Feb-1988	14	16,960
311	Wagnercrest Farms 3 Mv1			10	9	Oct-1990	12	54,859
312	Wallace Baird 3 Mv705			9	23	Nov-1990	12	39,559
313	Way George 3 Mv327	Yes	Yes	20	19	Dec-1987	15	47,980
314	Weathers U 1			6	11	Jan-1990	12	18,214
315	Weddell 761 02			6	12	Oct-1984	18	7,635
316	Westfall 167			3	11	Apr-1982	20	11,969
317	White 286			5	10	Aug-1994	8	59,037
318	Whitebarger U 2			17	5	Oct-1992	10	30,678

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
319	Whitman 1			19	12	Dec-1985	17	49,248
320	Whitman Mailliard 1			14	8	Nov-1990	12	21,221
321	Williams A U 1			21	18	Jun-1993	9	6,891
322	Williams John 1 Mv337			8	10	Jul-1986	16	10,207
323	Willis Tracy U 1	Yes	Yes	10	18	Jan-1993	9	41,638
324	Winton 1 W 004			7	12	Apr-1980	22	26,410
325	Wissler 1			15	19	Mar-1990	12	8,556
326	Wolski 1			17	10	Dec-1988	14	15,808
327	Wood Curtis 5s Mv772			7	7	Jan-1994	8	96,858
328	Wood John U 2 Kp201			7	15	Jul-1988	14	17,586
329	Woodring U 3			13	9	Aug-1997	5	9,410
330	Woods 1			22	11	Jun-1988	13	31,886
331	Woods 2			19	6	Oct-1988	14	34,732
332	Woodworth Paul 1 Mv179			14	11	May-1984	18	11,687
333	Worley 177			4	13	Apr-1982	20	36,156
334	Wright Alan 1 Kp241			3	7	Feb-1989	13	8,908
335	Wright U 2			10	13	Nov-1991	11	31,978
336	Wright U 3			12	20	Nov-1994	8	40,579

	Well	Recompleted With Sufficient Post-Rework Prod Data For Analysis (8 Total)	Recompleted (17 Total)	Number Of Offsets	Number Of Filters Triggered	DOFP	Total Years of Production	Incremental Forecast (Mscf)
337	Young David 1 Mv728			20	10	Dec-1992	10	45,838
338	Young Emmit 1 Kp252			6	7	Dec-1989	12	21,324
339	Zilhaver 503 01			13	10	Apr-1981	21	11,499