Methodology to Aid In Recognition Of Underperforming Stripper Gas Wells and Remediation Candidates in New York

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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 performed on a field in western New York State.

In this, the most recent project that utilized this SWARM methodology, we studied a Medina / Whirlpool field in western New York. Each well's historical production was compared with that of its offsets which identified 24 underperformers before considering remediation costs, and 20 economically viable candidates based on a range of remediation costs from $2,500 to $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 20 marginal wells to the average of their respective offsets, approximately 185 MMscf of gross incremental gas with a NPV approximating $580,000 after investment, would be made available to the domestic market for an investment of $50,000.

To date, five of these wells have been remediated by installation of a PolyTube completion and have already obtained production increases. At the time of this report, five of these wells had enough post-rework production data available to forecast the incremental gas and verify the project's success. The 20-year forecasted incremental gross production based on a $4,000 capital investment per well is estimated to be 33.3 MMscf. The outcome of the other ten wells can be determined after more post-refrac

production data becomes available. Plans are currently underway for future remediations similar to what has already been done.

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.

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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 used on this project to analyze 99 wells operated by Lenape Resources in Western New York. The intent of the study was to use SWARM to identify underperforming wells in the field and to them propose remediation techniques for these wells.

The study of this area resulted in identifying 24 candidates for remediation. These wells were prioritized based on their expected incrementally recoverable gas and net present value (NPV) based on several scenarios of capital investment ranging from $2,500 to $50,000.

Of the 24 rework candidates, 20 are expected to be economically viable after a $2,500 investment while only four are expected to have a positive NPV with a $50,000 investment. Assuming that successful remediation increased each candidate's production to its offset average, an estimated 180 MMscf of incremental gas with a NPV approximating $580,000 would be accessible. It is likely that the remaining 75 wells have upside potential, but only at lower expenditures.

Suggested remediation techniques considered were hydraulic fracture treatments, re-perforation of the producing zones, matrix acid stimulation, and the running of Poly-Tube technology as a siphon string. To date Lenape has run Poly-tubes in five of the 24 wells with slightly positive results.

Five of these wells have been remediated to date by installation of a PolyTube completion and have already obtained production increases. At the time of this report, five 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 33.3 MMscf that provides a NPV of $91,712 after recovering a total investment of $20,000. Plans are currently underway for future remediations similar to the ones already performed.

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.

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 Lenape's field, which is the primary study area.

Fig. 2.1 – Location map of study area.

The Lower Silurian Whirlpool/Medina Queenston Formation is the major natural gas producing reservoir in this field and is typically encountered at depths of 1,400 to 1,800 feet. The formation consists of interbedded sandstones, siltstones, and shale sequences with the reservoirs being primarily stratigraphic rather than structural. Thicknesses range from 40 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 99 rework candidates, 20 are expected to be economically viable after a $2,500 investment. If all of these wells were successfully reworked, it is estimated that 185 MMscf of incremental gas having a NPV of almost $580,000 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 20 Lenape Candidates Estimated Incremental Production and Net Present Value (Economically Viable After Investment)

Lenape Field	Incremental Gas (Mscf)	Post-Rework Net Present Value (Disc 10%)
Total Candidates (20 wells)	184,770	$577,698

Lenape decided to remediate five wells that were on the list of economically viable candidates by installing Poly-Tube completions. All five have been online long enough to assess their preliminary results. Nevertheless, promising real-world results have already been achieved from the five 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 33.3 MMscf with a NPV = $91,712 based on a total investment of $20,000. Average costs per well are $4,000 per well and average incremental recovery is estimated to be 6,660 Mscf.

An additional interesting point to note is that the W. J. Mcintyre Unit #1 well was one of the four flagged wells that were not expected to be economic after a $4,000 investment. As noted it is the only one of the five wells remediated that had a negative post-work NPV.

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 ($)**
W. J. Reid Unit #1	4,604	25,019
P. Sturm & H. Wilson U#1	10,564	19,034
L. I. Walton #1	4,204	11,544
L. L. Callan #1	16,065	45,879
W. J. Mcintyre Unit #1	-2,134	(9,764)
Total	33,303	91,712

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, the remaining 19 wells may have additional potential at lower expenditures. Some examples of these lower-cost scenarios include optimizing fluid removal, reducing line pressure, or refining well operating 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.

- 24 underperforming wells were identified in the study area.

  - From this list of candidates, 20 are forecasted to be economically viable after expenditures of approximately $2,500 per well while only 4 of these wells are forecasted to have a positive NPV with an investment of $50,000.

  - Assuming that remediation efforts increase production from the 20 wells to the average of their respective offsets, approximately 185 MMscf of gross incremental gas with a NPV approximating $580,000 after investment, would be made available to the domestic market.

  - It is likely that many of the remaining 75 candidates (99 – 24 = 75 wells) would be cost-effective at lower remediation costs.

- Five wells have already been reworked and all have been online long enough to confirm moderate success.

  - Estimated incremental reserves and NPV of these five wells is 33.3 MMscf and $91,712, 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.

- Further consideration should be made to attempt to re-stimulate these wells. The obvious risk associated with this endeavor can be sufficiently reduced by learning more about the effective quality of the original stimulation treatments performed.

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 4,000-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.

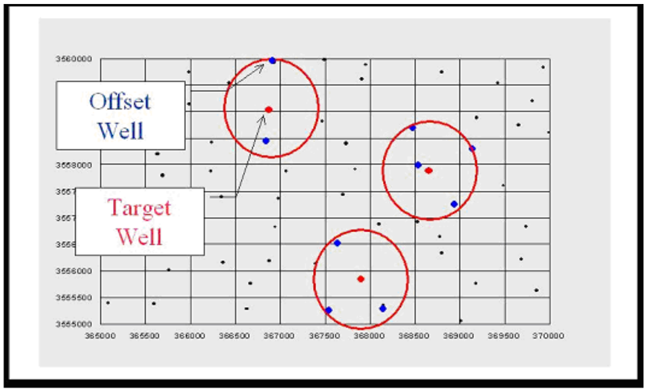

Fig. 5.1 - Example of target and offset wells within three domains.

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 "over performers" by considering targets that have PI's greater than 100% relative to their corresponding offset values.

6 DISCUSSION

6.1 Database Construction

Lenape Resources 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 percentage 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 F.W. Grant #1 has produced 9 MMscf over five years, which is 69% below the offset average of 29 MMscf. This is the first indication that this well may be performing below its potential.

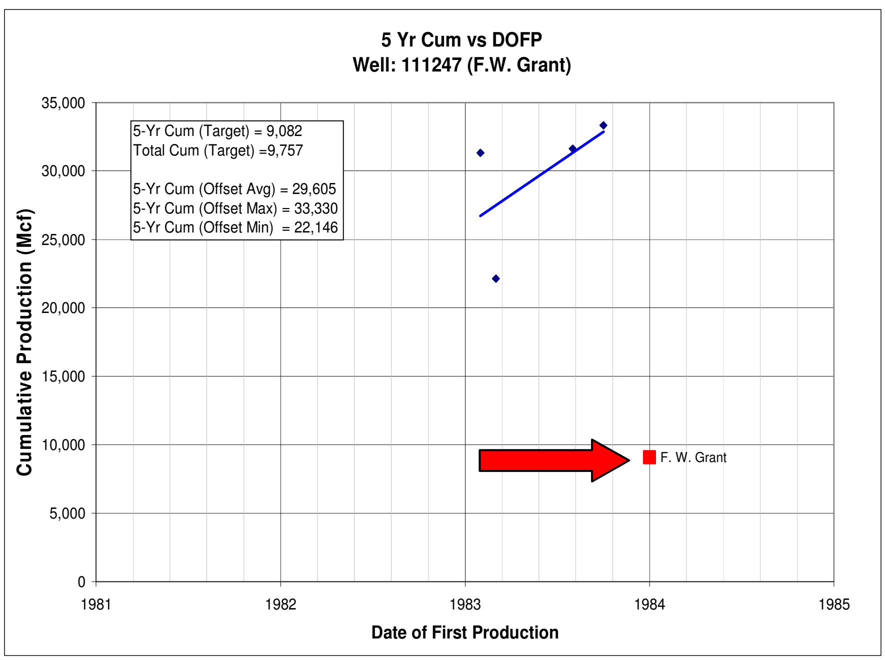

Fig. 6.1 - Plot showing DOFP vs. 5-year cumulative production.

Fig. 6.2 shows that the average monthly production (normalized rate) during Year-5 is 1 Mscf per day, which is 94% lower than the offset average of 16 Mscf per day. This is a second indicator of substandard performance.

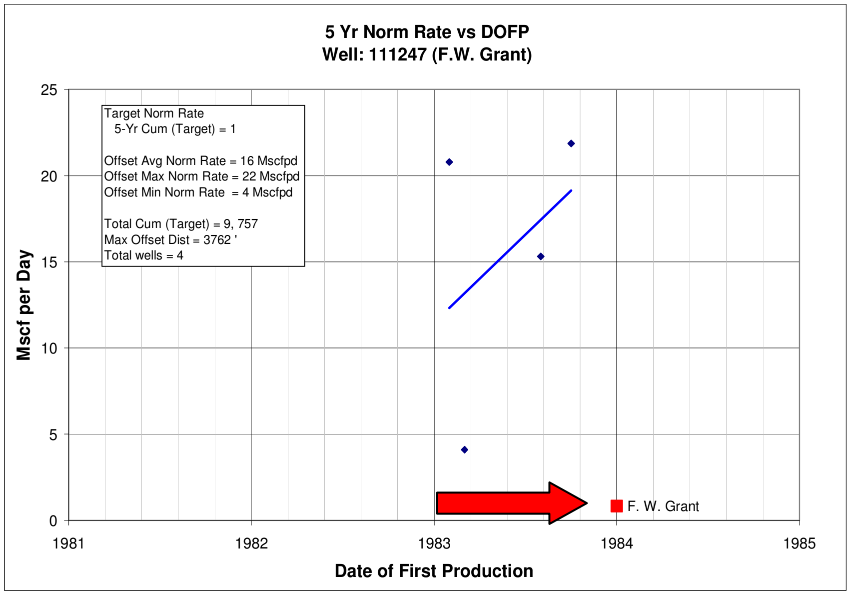

Fig. 6.2 - Plot showing DOFP vs. 5-year normalized rate.

Both of these charts, and the respective PI values of the F.W.Grant #1 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 13 single-case evaluations.

In addition to the two graphs just discussed, a rate-time chart showing the production history of the F.W.Grant #1, 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**.

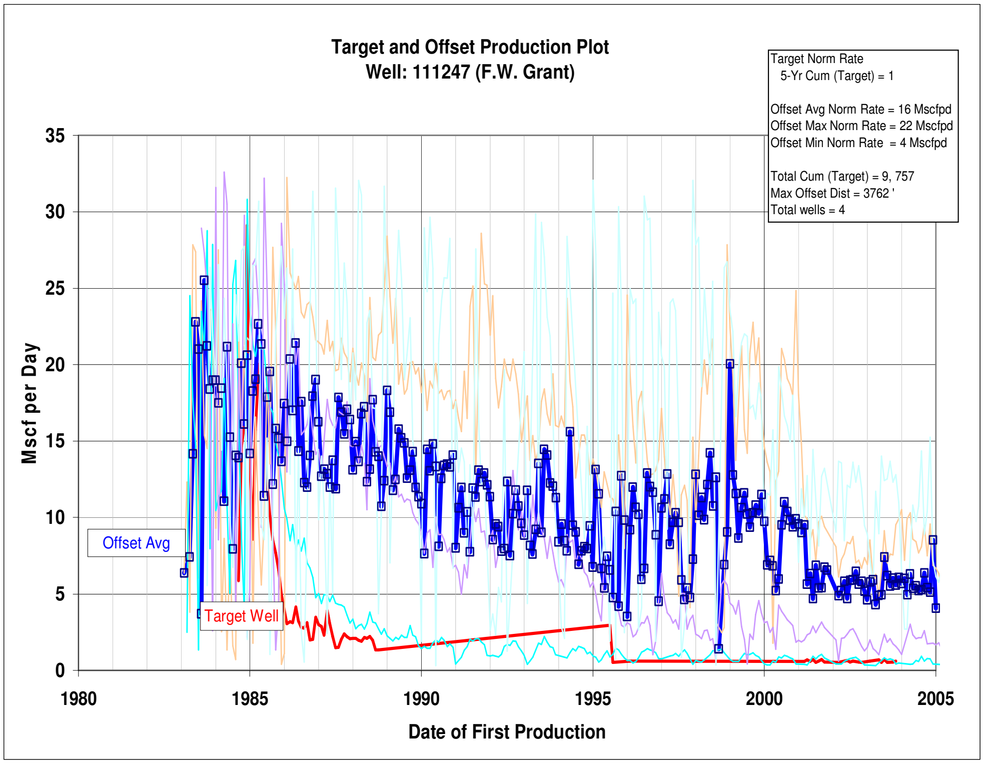

Fig. 6.3 - Rate-time chart showing an underperforming well (F.W. Grant #1) relative to its offsets.

It is apparent upon examination of the above figures that the target well has not performed in the same manner as its offsets.

A rate-time chart showing production before and after remediation for the F.W.Grant #1 is presented in **Fig. 6.4**. It can be seen that the pre-rework production was less than 1 Mscf per day, which increased to ~ 4 Mscf per day after remediation and even though this might not seem to be much results from the analysis from other candidates will show better post remediation production estimates. Incremental reserves were estimated to be 20.9 MMscf and 20 yr incremental NPV of ~ $60 k. 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.

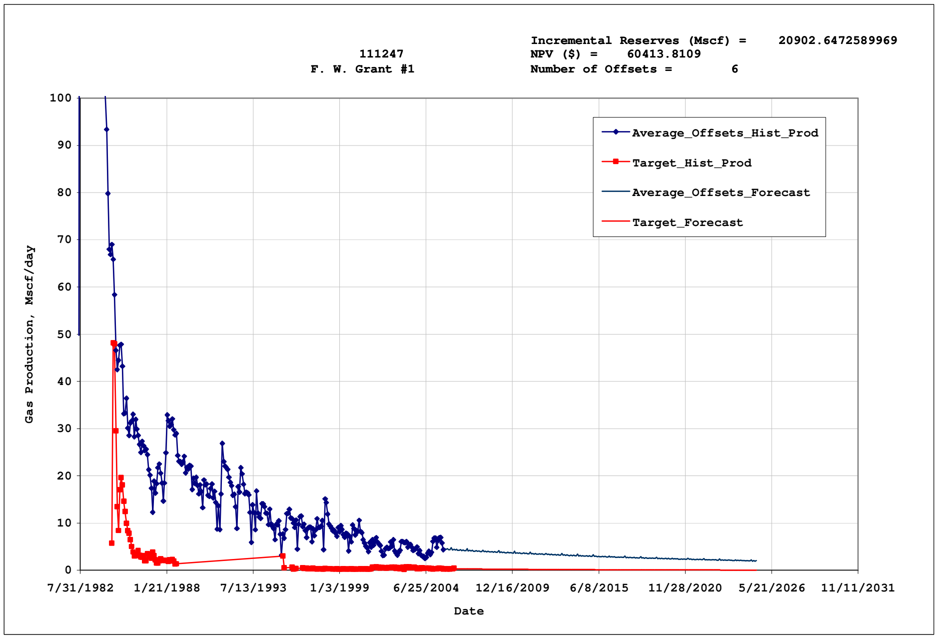

Fig. 6.4 - Rate-time chart of the F.W. Grant #1 showing pre and post-rework production, and their respective forecasts.

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 projections from Aries and economic analysis package. The unimproved forecast was then subtracted from the higher post-rework estimate, which resulted in the incremental gas value. All projections assumed $7.00/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, we will discuss the 24 that were flagged as underperformers and the five wells that the client Lenape Resources ran poly tubings in. A map indicating the locations of all the candidates relative to one another is shown in **Fig 6.5**. The small blue diamonds are the locations of the 100 wells in the field that were studied and the red dots indicate the 24 underperformers. **Table 6.2** lists the 24 wells flagged by SWARM as the underperformers, the number of offsets and the number of filters triggered as part of the analysis.

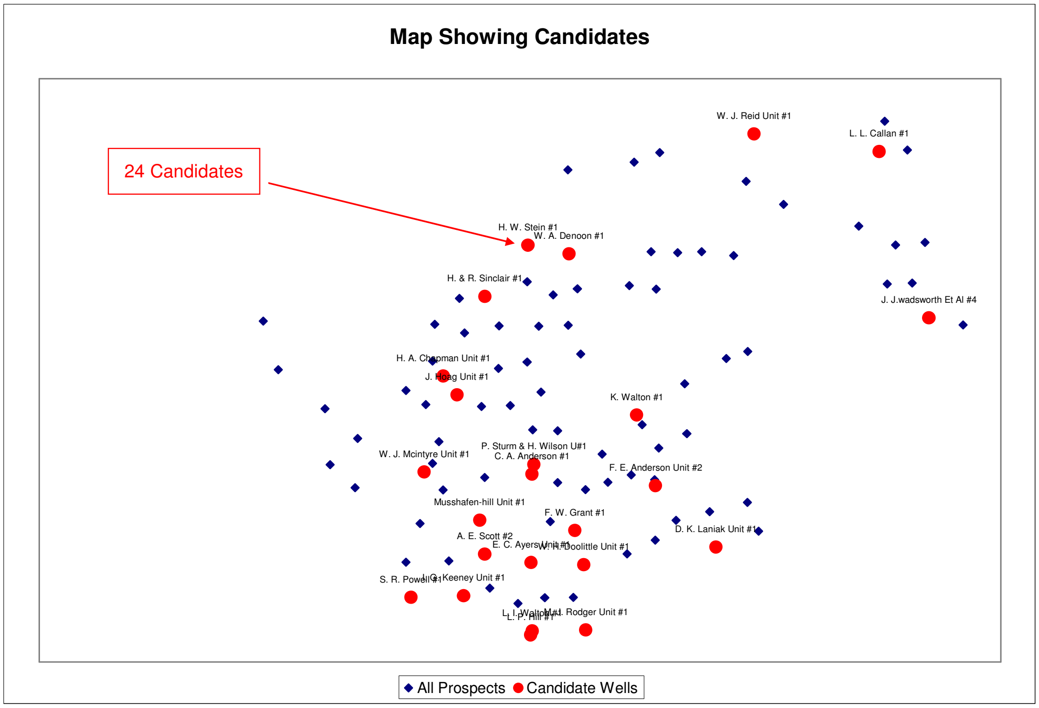

Fig. 6.5 - Map showing location of the 24 underperformers.

Table 6.2 – List of the Under Performing Wells Flagged by SWARM Analysis

	TARGET WELLID	TARGET WELL NAME	NUMBER OF OFFSETS	DATE OF FIRST PRODUCTION	NUMBER OF FILTERS TRIGGERED
1	111066	W. J. Reid Unit #1	1	31-Jul-1982	5
2	111084	H. W. Stein #1	3	31-Jul-1982	12
3	111085	W. A. Denoon #1	4	31-Jul-1982	11
4	111091	H. & R. Sinclair #1	4	31-Jul-1982	12
5	111103	A. E. Scott #2	6	31-Aug-1982	7
6	111105	C. A. Anderson #1	5	31-Aug-1982	5
7	111148	I. G. Keeney Unit #1	3	30-Nov-1983	3
8	111149	H. A. Chapman Unit #1	8	28-Feb-1983	5
9	111153	P. Sturm & H. Wilson U#1	6	31-May-1983	8
10	111154	S. R. Powell #1	2	28-Feb-1983	3
11	111155	E. C. Ayers Unit #1	6	31-Jan-1983	3
12	111165	W. H. Doolittle Unit #1	5	28-Feb-1983	6
13	111167	L. I. Walton #1	5	30-Jun-1983	10
14	111168	L. P. Hill #1	3	31-Jul-1983	5
15	111177	M. J. Rodger Unit #1	3	31-Jul-1983	8
16	111181	K. Walton #1	5	31-Jul-1983	13
17	111185	F. E. Anderson Unit #2	7	30-Sep-1983	7
18	111205	J. Hoag Unit #1	7	30-Nov-1983	3
19	111224	D. K. Laniak Unit #1	4	29-Feb-1984	9
20	111244	Musshafen-hill Unit #1	5	31-Jul-1984	5
21	111247	F. W. Grant #1	6	31-Aug-1984	13
22	111261	W. J. Mcintyre Unit #1	5	30-Sep-1984	4
23	112056	J. J.wadsworth Et Al #4	2	30-Nov-1981	4
24	112061	L. L. Callan #1	2	30-Nov-1981	16

Table 6.3 shows the percent difference in cumulative volumes for the 24 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 will be discussed later in this report. Note that the F.W. Grant #1 well was triggered as an underperformer by six single-case, cumulative production evaluations.

Table 6.3 – Cumulative Production Percent Difference Between Target and Offset Wells

		Percent That Target Well is Below Offset Cumulative Rate							
WellID	Candidate Wells	1 Year	2 Year	3 Year	4 Year	5 Year	10 Year	15 Year	20 Year
111066	W. J. Reid Unit #1								
111084	H. W. Stein #1				54	56	61	61	62
111085	W. A. Denoon #1				51	53	54	53	52
111091	H. & R. Sinclair #1				52	54	57	58	59
111103	A. E. Scott #2							51	56
111105	C. A. Anderson #1							53	57
111148	I. G. Keeney Unit #1								
111149	H. A. Chapman Unit #1								52
111153	P. Sturm & H. Wilson U#1						51	56	58
111154	S. R. Powell #1	51							
111155	E. C. Ayers Unit #1								
111165	W. H. Doolittle Unit #1							57	62
111167	L. I. Walton #1					52	58	100	100
111168	L. P. Hill #1							56	100
111177	M. J. Rodger Unit #1						56	100	100
111181	K. Walton #1			50	54	56	67	70	100
111185	F. E. Anderson Unit #2						50	58	60
111205	J. Hoag Unit #1								
111224	D. K. Laniak Unit #1						53	62	64
111244	Musshafen-hill Unit #1								
111247	F. W. Grant #1			52	59	65	81	100	100
111261	W. J. Mcintyre Unit #1								100
112056	J. J.wadsworth Et Al #4								
112061	L. L. Callan #1	52	59	62	63	64	67	67	68

Tables 6.3 and **6.4** show cumulative quantities (MMscf) from one through twenty years for the 17 reworks and their offsets. As discussed previously, all the 100 wells were evaluated and 24 of these were flagged by SWARM and the economic viability of re-working these wells was analyzed by a sensitivity for capital expenditures of re-stimulation/re-completion ranging from ($2,500 to $50,000). The details of this sensitivity will be discussed later in the report.

The percentages shown above in **Table 6.3** were calculated by dividing the target well's cumulative production figure shown in **Table 6.4**, by the respective PI in **Table 6.5**. 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 three single-case analyses.

Table 6.4 – Cumulative Production (MMscf) – Target Wells Total at Indicated Year

		Target Well Cumulative Production, Mscf							
WellID	Candidate Wells	1 Year	2 Year	3 Year	4 Year	5 Year	10 Year	15 Year	20 Year
111066	W. J. Reid Unit #1	3,317	5,374	7,080	8,700	10,127	16,225	21,500	27,090
111084	H. W. Stein #1	5,094	7,630	9,562	10,948	12,186	16,961	20,368	22,765
111085	W. A. Denoon #1	4,339	7,050	9,336	11,159	12,728	19,352	24,311	27,660
111091	H. & R. Sinclair #1	5,430	7,898	9,894	11,452	12,853	17,922	21,167	23,213
111103	A. E. Scott #2	6,330	10,545	13,085	14,639	15,735	18,791	19,696	20,393
111105	C. A. Anderson #1	5,739	9,624	12,698	14,746	16,304	20,920	23,134	24,397
111148	I. G. Keeney Unit #1	5,020	7,600	9,546	11,641	13,270	19,136	21,925	24,042
111149	H. A. Chapman Unit #1	5,408	11,349	15,206	17,578	19,313	24,430	26,529	27,516
111153	P. Sturm & H. Wilson U#1	6,139	9,903	11,669	13,306	14,610	19,119	21,220	23,202
111154	S. R. Powell #1	2,422	5,351	7,904	10,055	12,174	20,217	25,651	31,039
111155	E. C. Ayers Unit #1	6,844	13,786	18,516	21,786	24,385	31,531	34,782	35,992
111165	W. H. Doolittle Unit #1	5,823	12,014	18,066	20,648	22,146	25,500	27,399	28,624
111167	L. I. Walton #1	5,024	8,618	10,601	11,910	12,926	16,967	0	0
111168	L. P. Hill #1	4,230	9,610	13,136	15,878	18,144	24,457	26,602	0
111177	M. J. Rodger Unit #1	4,355	10,431	13,353	14,569	14,865	15,848	0	0
111181	K. Walton #1	4,466	6,222	7,374	8,209	8,827	10,967	11,723	0
111185	F. E. Anderson Unit #2	4,984	8,024	9,740	11,013	11,988	14,797	16,118	17,163
111205	J. Hoag Unit #1	3,202	7,001	8,831	10,775	13,412	19,334	23,431	26,293
111224	D. K. Laniak Unit #1	5,790	9,514	11,195	12,281	13,108	15,812	16,843	17,574
111244	Musshafen-hill Unit #1	6,555	9,536	11,629	13,034	14,018	18,162	20,431	26,274
111247	F. W. Grant #1	5,434	7,076	8,019	8,788	9,072	9,692	0	0
111261	W. J. Mcintyre Unit #1	7,942	11,926	14,703	17,132	19,142	25,940	29,790	0
112056	J. J.wadsworth Et Al #4	3,719	6,558	8,638	10,328	11,779	17,538	22,360	25,861
112061	L. L. Callan #1	3,318	5,922	7,715	9,174	10,491	15,537	19,998	23,299

Table 6.5 – Cumulative Production (MMscf) – Average Offset Well Total at Indicated Year

		Offset Wells Cumulative Production, Mscf							
WellID	Candidate Wells	1 Year	2 Year	3 Year	4 Year	5 Year	10 Year	15 Year	20 Year
111066	W. J. Reid Unit #1	3,905	7,595	10,482	13,855	16,980	30,147	41,525	49,418
111084	H. W. Stein #1	6,419	11,887	18,180	23,620	27,848	43,379	52,674	59,355
111085	W. A. Denoon #1	5,673	11,626	17,799	22,989	27,149	42,384	51,366	58,073
111091	H. & R. Sinclair #1	6,803	13,645	19,322	24,015	27,705	41,851	49,962	56,388
111103	A. E. Scott #2	6,129	11,906	16,740	20,321	23,431	34,218	40,549	45,922
111105	C. A. Anderson #1	5,861	11,444	15,074	19,025	21,955	39,531	49,001	56,960
111148	I. G. Keeney Unit #1	5,550	11,372	16,507	19,832	22,593	30,498	34,836	38,168
111149	H. A. Chapman Unit #1	5,266	12,009	17,086	21,497	25,259	37,480	46,122	56,917
111153	P. Sturm & H. Wilson U#1	6,072	12,040	16,081	20,050	23,007	39,409	47,986	55,074
111154	S. R. Powell #1	4,974	9,636	15,277	19,243	22,788	33,671	40,528	45,243
111155	E. C. Ayers Unit #1	5,787	11,597	15,793	19,817	23,509	38,002	53,164	62,558
111165	W. H. Doolittle Unit #1	5,615	10,794	14,501	18,511	22,054	35,137	63,518	74,612
111167	L. I. Walton #1	6,228	13,140	18,468	22,745	26,881	40,432	47,917	59,322
111168	L. P. Hill #1	5,815	12,215	16,982	20,648	24,394	37,893	60,226	69,376
111177	M. J. Rodger Unit #1	5,952	12,458	18,146	22,036	25,719	35,966	41,420	44,936
111181	K. Walton #1	5,724	10,923	14,808	17,675	20,008	32,863	39,595	44,039
111185	F. E. Anderson Unit #2	5,753	11,026	14,123	16,099	18,310	29,893	38,099	42,764
111205	J. Hoag Unit #1	5,468	12,216	16,991	21,056	24,475	35,442	42,766	49,086
111224	D. K. Laniak Unit #1	6,850	13,417	18,080	21,423	24,008	33,480	44,165	49,156
111244	Musshafen-hill Unit #1	5,660	12,043	17,296	20,594	23,244	30,676	34,586	35,287
111247	F. W. Grant #1	6,394	11,788	16,644	21,414	25,945	51,189	68,281	81,034
111261	W. J. Mcintyre Unit #1	5,079	12,775	18,874	23,209	26,755	39,126	45,685	50,632
112056	J. J.wadsworth Et Al #4	5,772	11,047	15,323	18,866	21,833	33,772	42,787	49,423
112061	L. L. Callan #1	6,944	14,484	20,282	25,017	29,355	47,229	61,298	72,212

Table 6.6 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 6.7** and **6.8**.

Table 6.6 – Normalized Rate Percent Difference Between Target and Offset Wells

		Percent That Target Well is Below Offset Norm Rate							
WellID	Candidate Wells	1 Year	2 Year	3 Year	4 Year	5 Year	10 Year	15 Year	20 Year
111066	W. J. Reid Unit #1				52	54	54	53	51
111084	H. W. Stein #1		54	69	75	71	70	64	62
111085	W. A. Denoon #1		54	63	65	62	52		56
111091	H. & R. Sinclair #1		64	65	67	62	58	57	69
111103	A. E. Scott #2				57	65	80	85	91
111105	C. A. Anderson #1						70	77	84
111148	I. G. Keeney Unit #1		56	62					73
111149	H. A. Chapman Unit #1					54	70	77	82
111153	P. Sturm & H. Wilson U#1			56	59	56	75	74	
111154	S. R. Powell #1	51		55					
111155	E. C. Ayers Unit #1						59	78	92
111165	W. H. Doolittle Unit #1					58	82	84	88
111167	L. I. Walton #1			63	69	75	70	100	100
111168	L. P. Hill #1						64	91	100
111177	M. J. Rodger Unit #1				69	92	91	100	100
111181	K. Walton #1		66	70	71	74	87	80	100
111185	F. E. Anderson Unit #2					56	68	78	70
111205	J. Hoag Unit #1			62	52		51		
111224	D. K. Laniak Unit #1			64	68	68	74	85	90
111244	Musshafen-hill Unit #1		53	60	57	63	54		
111247	F. W. Grant #1		70	80	84	94	95	100	100
111261	W. J. Mcintyre Unit #1			54			71		100
112056	J. J.wadsworth Et Al #4			51	52	51		52	
112061	L. L. Callan #1	52	65	69	69	70	70	64	68

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. It should be noted that the production data used was updated immediately prior to the writing of this report and was used to analyze the already flagged wells. Re-analysis of all the wells was not performed using data more recent than 2004.

The F.W. Grant #1 was also flagged by seven normalized rate evaluations. This well was recognized as performing below its potential by 13 unique, single-case comparisons.

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

Table 6.7 – Normalized Rate – Target Wells Average Mscf per Day at Indicated Year

		Target Well Normalized Rate, Mscf/Month							
WellID	Candidate Wells	1 Year	2 Year	3 Year	4 Year	5 Year	10 Year	15 Year	20 Year
111066	W. J. Reid Unit #1	276	171	142	135	119	101	78	64
111084	H. W. Stein #1	425	211	161	116	103	74	48	37
111085	W. A. Denoon #1	362	226	191	152	131	109	69	49
111091	H. & R. Sinclair #1	453	206	166	130	117	85	47	24
111103	A. E. Scott #2	528	351	212	130	91	32	14	9
111105	C. A. Anderson #1	478	324	256	171	130	66	26	14
111148	I. G. Keeney Unit #1	418	215	162	175	136	69	39	21
111149	H. A. Chapman Unit #1	451	495	321	198	145	68	21	14
111153	P. Sturm & H. Wilson U#1	512	314	147	136	109	50	28	38
111154	S. R. Powell #1	202	244	213	179	177	125	64	105
111155	E. C. Ayers Unit #1	570	579	394	273	217	88	34	10
111165	W. H. Doolittle Unit #1	485	516	504	215	125	39	27	13
111167	L. I. Walton #1	419	300	165	109	85	59	0	0
111168	L. P. Hill #1	353	448	294	229	189	71	17	0
111177	M. J. Rodger Unit #1	363	506	244	101	25	15	0	0
111181	K. Walton #1	372	146	96	70	52	22	19	0
111185	F. E. Anderson Unit #2	415	253	143	106	81	43	20	19
111205	J. Hoag Unit #1	267	317	153	162	220	95	55	37
111224	D. K. Laniak Unit #1	483	310	140	91	69	33	14	8
111244	Musshafen-hill Unit #1	546	248	174	117	82	50	33	174
111247	F. W. Grant #1	453	137	79	64	24	18	0	0
111261	W. J. Mcintyre Unit #1	662	332	231	202	168	62	87	0
112056	J. J.wadsworth Et Al #4	310	237	173	141	121	97	65	53
112061	L. L. Callan #1	277	217	149	122	110	81	80	52

Table 6.8 – Normalized Rate – Average Offset Average Mscf Per Day at Indicated Year

		Offset Wells Normalized Rate, Mscf/Month							
WellID	Candidate Wells	1 Year	2 Year	3 Year	4 Year	5 Year	10 Year	15 Year	20 Year
111066	W. J. Reid Unit #1	325	308	241	281	260	219	166	129
111084	H. W. Stein #1	535	456	524	453	352	246	131	98
111085	W. A. Denoon #1	473	496	514	432	347	230	122	110
111091	H. & R. Sinclair #1	567	570	473	391	308	204	109	76
111103	A. E. Scott #2	511	481	403	298	259	157	91	103
111105	C. A. Anderson #1	488	465	303	329	244	218	111	85
111148	I. G. Keeney Unit #1	462	485	428	277	230	120	62	77
111149	H. A. Chapman Unit #1	439	562	423	368	314	227	91	77
111153	P. Sturm & H. Wilson U#1	506	497	337	331	246	204	108	72
111154	S. R. Powell #1	414	389	470	331	296	179	92	65
111155	E. C. Ayers Unit #1	482	484	350	335	308	216	152	125
111165	W. H. Doolittle Unit #1	468	432	319	334	295	209	170	108
111167	L. I. Walton #1	519	576	444	356	345	200	101	76
111168	L. P. Hill #1	486	533	397	305	312	198	181	123
111177	M. J. Rodger Unit #1	496	542	474	324	307	158	71	40
111181	K. Walton #1	477	433	324	239	194	176	99	59
111185	F. E. Anderson Unit #2	479	439	258	165	184	135	90	63
111205	J. Hoag Unit #1	456	562	398	339	285	196	74	55
111224	D. K. Laniak Unit #1	571	547	389	279	215	126	90	73
111244	Musshafen-hill Unit #1	472	532	438	275	221	108	56	59
111247	F. W. Grant #1	533	449	388	397	378	362	270	138
111261	W. J. Mcintyre Unit #1	423	641	508	361	296	216	76	67
112056	J. J.wadsworth Et Al #4	481	440	356	295	247	182	136	100
112061	L. L. Callan #1	579	628	483	395	362	272	225	163

An estimated incremental reserves of ~180 MMscf is anticipated if all positive NPV wells were remediated. This would amount to a significant $0.58 Million in net present values (at $7/Mscf gas) for 20-year life as shown in **Table 6.9.** The results in **Table 6.9** also show some of the candidates with negative NPV. For example, one of the wells W.J. Mcintyre Unit #1 had some improvement in production because of poly tubing later in the life of the well. Moreover, this caused it to perform a little better than its offsets.

Table 6.9 – Incremental Reserves and Estimated 20-Year NPV for $4,000 Capital Investment

WellID	WellName	X	Y	NUMBER OF OFFSETS	Incremental Reserves, Mscf	NPV	Candidate/Not Candidate
111066	W. J. Reid Unit #1	758582	4761055	1	4,604	$25,019	Candidate
111084	H. W. Stein #1	752707	4759146	3	3,387	$38,694	Candidate
111085	W. A. Denoon #1	753774	4758999	4	2,967	$37,248	Candidate
111091	H. & R. Sinclair #1	751586	4758265	4	2,037	$33,596	Candidate
111103	A. E. Scott #2	751581	4753847	6	10,976	$19,658	Candidate
111105	C. A. Anderson #1	752812	4755222	5	14,500	$40,194	Candidate
111148	I. G. Keeney Unit #1	751033	4753134	3	1,756	$1,281	Candidate
111149	H. A. Chapman Unit #1	750503	4756904	8	4,826	$11,978	Candidate
111153	P. Sturm & H. Wilson U#1	752859	4755388	6	10,564	$19,034	Candidate
111154	S. R. Powell #1	749667	4753109	2	(8,104)	($27,011)	Not Candidate
111155	E. C. Ayers Unit #1	752788	4753705	6	19,755	$55,086	Candidate
111165	W. H. Doolittle Unit #1	754154	4753666	5	24,446	$66,773	Candidate
111167	L. I. Walton #1	752816	4752534	5	4,204	$11,544	Candidate
111168	L. P. Hill #1	752773	4752465	3	15,885	$44,128	Candidate
111177	M. J. Rodger Unit #1	754209	4752547	3	(2,191)	($3,409)	Not Candidate
111181	K. Walton #1	755536	4756237	5	7,257	$18,235	Candidate
111185	F. E. Anderson Unit #2	756022	4755024	7	4,874	$11,172	Candidate
111205	J. Hoag Unit #1	750863	4756579	7	3,025	$6,260	Candidate
111224	D. K. Laniak Unit #1	757591	4753969	4	6,467	$15,773	Candidate
111244	Musshafen-hill Unit #1	751456	4754432	5	(2,115)	($24,781)	Not Candidate
111247	F. W. Grant #1	753928	4754256	6	20,903	$60,414	Candidate
111261	W. J. Mcintyre Unit #1	750009	4755258	5	(2,134)	($9,764)	Not Candidate
112056	J. J.wadsworth Et Al #4	763133	4757899	2	6,273	$15,732	Candidate
112061	L. L. Callan #1	761838	4760749	2	16,065	$45,879	Candidate
	TOTAL				**170,226**	**$512,732**	

As mentioned earlier **Table 6.10** shows sensitivity of a range of remediation costs/capital investment and estimates of the NPV to expect given the different cost dependent remediation options that the operator might want to embark on.

It is important to notice also from **Fig 6.5** that the 24 underperformers are located in the 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.

Table 6.10 – Incremental Reserves and Estimated 20-Year NPV for Range of Capital Investment

		CAPITAL INVESTMENT FOR REMEDIATION						
		$50,000	*$40,000*	*$30,000*	*$20,000*	*$10,000*	*$5,000*	*$2,500*
		Net Present Value						
111066	W. J. Reid Unit #1	($66,980.51)	($46,980.51)	($26,980.51)	($6,980.51)	$13,019.49	$23,019.49	$28,019
111084	H. W. Stein #1	($7,306.23)	$2,693.77	$12,693.77	$22,693.77	$32,693.77	$37,693.77	$40,194
111085	W. A. Denoon #1	($8,751.89)	$1,248.11	$11,248.11	$21,248.11	$31,248.11	$36,248.11	$38,748
111091	H. & R. Sinclair #1	($12,404.32)	($2,404.32)	$7,595.68	$17,595.68	$27,595.68	$32,595.68	$35,096
111103	A. E. Scott #2	($26,341.80)	($16,341.80)	($6,341.80)	$3,658.20	$13,658.20	$18,658.20	$21,158
111105	C. A. Anderson #1	($5,806.35)	$4,193.65	$14,193.65	$24,193.65	$34,193.65	$39,193.65	$41,694
111148	I. G. Keeney Unit #1	($44,719.02)	($34,719.02)	($24,719.02)	($14,719.02)	($4,719.02)	$280.98	$2,781
111149	H. A. Chapman Unit #1	($34,022.17)	($24,022.17)	($14,022.17)	($4,022.17)	$5,977.83	$10,977.83	$13,478
111153	P. Sturm & H. Wilson U#1	($26,966.34)	($16,966.34)	($6,966.34)	$3,033.66	$13,033.66	$18,033.66	$20,534
111154	S. R. Powell #1	($73,010.92)	($63,010.92)	($53,010.92)	($43,010.92)	($33,010.92)	($28,010.92)	($25,511)
111155	E. C. Ayers Unit #1	$9,086.41	$19,086.41	$29,086.41	$39,086.41	$49,086.41	$54,086.41	$56,586
111165	W. H. Doolittle Unit #1	$20,772.99	$30,772.99	$40,772.99	$50,772.99	$60,772.99	$65,772.99	$68,273
111167	L. I. Walton #1	($34,456.19)	($24,456.19)	($14,456.19)	($4,456.19)	$5,543.81	$10,543.81	$13,044
111168	L. P. Hill #1	($1,872.37)	$8,127.63	$18,127.63	$28,127.63	$38,127.63	$43,127.63	$45,628
111177	M. J. Rodger Unit #1	($49,409.07)	($39,409.07)	($29,409.07)	($19,409.07)	($9,409.07)	($4,409.07)	($1,909)
111181	K. Walton #1	($27,764.72)	($17,764.72)	($7,764.72)	$2,235.28	$12,235.28	$17,235.28	$19,735
111185	F. E. Anderson Unit #2	($34,828.45)	($24,828.45)	($14,828.45)	($4,828.45)	$5,171.55	$10,171.55	$12,672
111205	J. Hoag Unit #1	($39,739.73)	($29,739.73)	($19,739.73)	($9,739.73)	$260.27	$5,260.27	$7,760
111224	D. K. Laniak Unit #1	($30,226.95)	($20,226.95)	($10,226.95)	($226.95)	$9,773.05	$14,773.05	$17,273
111244	Musshafen-hill Unit #1	($70,780.66)	($60,780.66)	($50,780.66)	($40,780.66)	($30,780.66)	($25,780.66)	($23,281)
111247	F. W. Grant #1	$14,413.81	$24,413.81	$34,413.81	$44,413.81	$54,413.81	$59,413.81	$61,914
111261	W. J. Mcintyre Unit #1	($55,764.42)	($45,764.42)	($35,764.42)	($25,764.42)	($15,764.42)	($10,764.42)	($8,264)
112056	J. J.wadsworth Et Al #4	($30,267.71)	($20,267.71)	($10,267.71)	($267.71)	$9,732.29	$14,732.29	$17,232
112061	L. L. Callan #1	($120.99)	$9,879.01	$19,879.01	$29,879.01	$39,879.01	$44,879.01	$47,379

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 B – LIST OF ALL CANDIDATES

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

Well ID	Well Name	Number Of Offsets	Incremental Reserves, Mscf	NPV	# of Filters Triggered
111066	W. J. Reid Unit #1	1	4,963.27	$13,215.70	5
111084	H. W. Stein #1	3	4,871.33	$12,013.32	12
111085	W. A. Denoon #1	4	2,142.04	$3,478.30	11
111091	H. & R. Sinclair #1	4	4,871.33	$12,013.32	12
111103	A. E. Scott #2	6	8,012.01	$20,540.80	7
111105	C. A. Anderson #1	5	15,260.13	$41,550.46	5
111148	I. G. Keeney Unit #1	3	1,858.07	$1,430.93	3
111149	H. A. Chapman Unit #1	8	4,757.54	$11,611.64	5
111153	P. Sturm & H. Wilson U#1	6	11,212.68	$29,970.24	8
111155	E. C. Ayers Unit #1	6	20,066.42	$55,219.14	3
111165	W. H. Doolittle Unit #1	5	24,735.72	$67,298.47	3
111167	L. I. Walton #1	5	4,636.50	$12,783.88	6
111168	L. P. Hill #1	3	16,638.98	$45,543.21	10
111181	K. Walton #1	5	7,525.47	$18,915.68	5
111185	F. E. Anderson Unit #2	7	4,859.22	$11,157.74	7
111205	J. Hoag Unit #1	7	1,453.19	$1,054.80	3
111224	D. K. Laniak Unit #1	4	6,447.96	$15,755.58	9
111247	F. W. Grant #1	6	21,345.36	$61,424.88	13
112056	J. J.wadsworth Et Al #4	2	6,644.71	$16,798.28	4
112061	L. L. Callan #1	2	17,161.88	$48,164.22	16