

Title: **“Improved Miscible Nitrogen Flood Performance Utilizing  
Advanced Reservoir Characterization and Horizontal Laterals  
in a Class I Reservoir – East Binger (Marchand) Unit”**

Type of Report: **Quarterly Technical Progress (Report No. 15121R21)**

Reporting Period Start: **April 1, 2005**

Reporting Period End: **June 30, 2005**

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Report Date: **September 15, 2005**

Cooperative Agreement No: **DE-FC26-00BC15121**

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## **Abstract**

A significant work program was implemented from 2002 to 2004 in the East Binger Unit (“EBU”) miscible nitrogen injection project in an effort to reduce gas cycling and economically increase ultimate oil recovery. This work included the drilling of new wells, both horizontal and vertical, as well as pattern realignment through producer-to-injector conversions.

Monitoring of overall performance of the pilot area continues. Response to the various projects continues to be very favorable. Injection into the pilot area, though limited at times by problems in the Air Separation Unit of the Nitrogen Management Facility, and has increased 70% over levels prior to the project. Meanwhile, gas production and nitrogen content of produced gas have both decreased. Nitrogen recycle within the pilot area is now only about 32%, far below the 72% recycle prior to initiation of the project.

Poor areal sweep efficiency appears to be the primary cause of nitrogen cycling. Four vertical and three horizontal wells have been drilled in the pilot area throughout the project, and most have had initial produced gas oil ratios and gas nitrogen contents significantly below the field averages. Additional vertical well drilling is planned due to the success of wells drilled to date.

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## **Quarterly Technical Progress Report – 2<sup>nd</sup> Quarter 2005**

### **Introduction**

A significant work program was implemented from 2002 to 2004 in the East Binger Unit (“EBU”) miscible nitrogen injection project in an effort to reduce gas cycling and economically increase ultimate oil recovery. Horizontal and vertical infill wells were drilled and existing producers were converted to injection. Although overall project results have been encouraging, with reductions in nitrogen production and cycling as desired, horizontal wells have been disappointing relative to their vertical counterparts. The DOE-sponsored project is now in Phase 3, the monitoring phase of the program. Data gathering will continue throughout this Budget Period.

### **Executive Summary**

A significant work program was implemented from 2002 to 2004 in the East Binger Unit (“EBU”) miscible nitrogen injection project in an effort to reduce gas cycling and economically increase ultimate oil recovery. This work included the drilling of new wells, both horizontal and vertical, as well as pattern realignment through producer-to-injector conversions.

Monitoring of overall performance of the pilot area continues. Response to the various projects continues to be very favorable. Injection into the pilot area, though limited at times by problems in the Air Separation Unit of the Nitrogen Management Facility, and has increased 70% over levels prior to the project. Meanwhile, gas production and nitrogen content of produced gas have both decreased. Nitrogen recycle within the pilot area is now only about 32%, far below the 72% recycle prior to initiation of the project.

Poor areal sweep efficiency appears to be the primary cause of nitrogen cycling. Four vertical and three horizontal wells have been drilled in the pilot area throughout the project, and most have had initial produced gas oil ratios and gas nitrogen contents significantly below the field averages. Additional vertical well drilling is planned due to the success of wells drilled to date.

### **Experimental**

There were no experimental methods used in the work completed during this reporting period.

### **Results and Discussion**

The following is a detailed review of the work conducted in this reporting period.

### *Task 1.3.1 – Continue Monitoring Program*

Binger Operations, LLC continues to monitor new well and overall pilot area performance. Figure 1 shows the well work implemented during the project, plus additional drilling locations planned for 2005 (initiated in June 2005). Overall, for the second quarter of 2005, pilot area production averaged 419 bopd, a net increase of 161 bopd over the projected current rate without development. Production from new wells added 221 bopd but was offset by the loss of 60 bopd from wells converted to injection. See Figures 2 (all wells in pilot area), 3 (pre-existing wells), and 4 (new wells).

The reduction in gas cycling continues to be significant, as shown in Figure 2. Injection has returned to normal levels following extensive problems with the Air Separation Unit (“ASU”) of the Gas Plant from November 2004 through February 2005. The ASU provides make-up nitrogen for the miscible nitrogen flood. Compared to pre-project levels, total nitrogen produced from the pilot area has declined from 2.9 MMscf/d (4.2 MMscf/d total gas with a nitrogen content of 69%) to 2.2 MMscf/d (3.7 MMscf/d total gas with a nitrogen content of 60%). Over the same time period, total nitrogen injection has increased from 4 MMscf/d to 6.8 MMscf/d. As shown in the table below, this represents a total change in gas recycle from 72% prior to development to 32% in the first quarter. Injection, production, and gas nitrogen content will continue to change and stabilize as rate impacts from new wells and conversions level off. Benefits to this work program will continue to be monitored as the flood progresses.

#### **Pilot Area Gas Recycle**

	[A] Total Gas Production Rate (MMscf/d)	[B] Percent Nitrogen (%)	[C] = [A]*[B] Nitrogen Production Rate (MMscf/d)	[D] Nitrogen Injection Rate (MMscf/d)	[C] / [D] Percent Recycle (%)
Pre-Development Baseline (1H 2001)	4.2	69	2.9	4.0	72
Third Quarter 2004	3.6	54	1.9	7.0	28
Fourth Quarter 2004	3.7	56	2.1	5.1 *	40
First Quarter 2005	3.4	58	2.0	4.4 *	46
Second Quarter 2005	3.7	60	2.2	6.8	32

\* Plant problems limited the supply of nitrogen for injection from November 2004 through February 2005.

A secondary aspect of Pilot Area performance monitoring is the comparison of the performances of horizontal wells to vertical wells. Figure 5 is a plot of the rate performances of the new wells drilled in the project, excluding EBU 37-3H, the horizontal well drilled in Budget Period 1. As discussed previously, EBU 37-3H was drilled in an area that, as expected, had much higher gas saturation. Overall, with the exception of EBU 65-2, the vertical wells have performed nearly as well as the horizontal wells. Figure 6 shows the averages of these wells, with EBU 65-2 also excluded due to its lower than expected pay.

Most of the new wells have low GORs and nitrogen contents in produced gas. As shown in Figure 7, nitrogen contents in the produced gas of all of the new wells are far below the field average of about 70%. The relative lack of nitrogen at the infill well locations indicates poor areal sweep. Trends for most of the new wells suggest it will be years before the nitrogen contents in their produced gas approach the current field average. One new well that has seen higher nitrogen content is EBU 67-2. It is not shown in the table because it is outside the pilot area, though it is close, as shown in Figure 1. EBU 67-2 appears to have penetrated an area that was partially swept; it has a GOR of about 15 Mscf/bbl (see Figure 5) and about 50% nitrogen in its produced gas.

Gas sampling also continues at other pilot area wells. As previously reported, the most significant changes have occurred around EBU 37-3H. After 37-3H was brought on production in late 2001 (with a gas nitrogen content of 68%), the nitrogen content in the produced gas at surrounding producers 36-1, 37-2, and 44-1 all decreased – see Figure 8. Since 37-3H was converted to injection service in October 2003, additional changes have been observed. As expected, the nitrogen content at 37-2 returned to its previous levels and trend, and the nitrogen content at 36-1 increased significantly: after decreasing from 65% nitrogen to 44%, it has now risen to 86%. As shown in Figure 1, well 36-1 is due east of the heel of the horizontal section of well 37-3H, which in turn is due east of injection well 38G-1. Less expected were the observed changes at producers 43-1 and 44-1. The nitrogen content at 43-1 (also shown in Figure 8) was unchanged for about nine months following 37-3H's conversion to injection, and then began to rise rapidly. At 44-1, the nitrogen content has remained relatively flat – and not rising on its prior trend – since 37-3H was first brought on production. Its conversion to injection has not impacted 44-1's nitrogen content.

Monitoring of pilot area performance will continue throughout the project.

#### *Task 1.3.3 – Technology Transfer Activities – Continue Updating Web Site*

Additional technical progress reports have been posted on the project web site, [www.eastbingerunit.com](http://www.eastbingerunit.com).

#### *Task 1.3.7 – Drill New Wells*

Originally, Binger Operations intended to drill only two wells in this Budget Period – EBU 65-2 and EBU 67-2. Based on the performance of the wells to date, additional drilling is planned for the area in 2005. As shown in Figure 1, three additional wells are planned: EBU 43-2, EBU 47-2, and EBU 60-2. EBU 47-2 was drilled in June of this year and brought on line at the end of this reporting period. Early production performance data from all of these wells will be included in future reports.



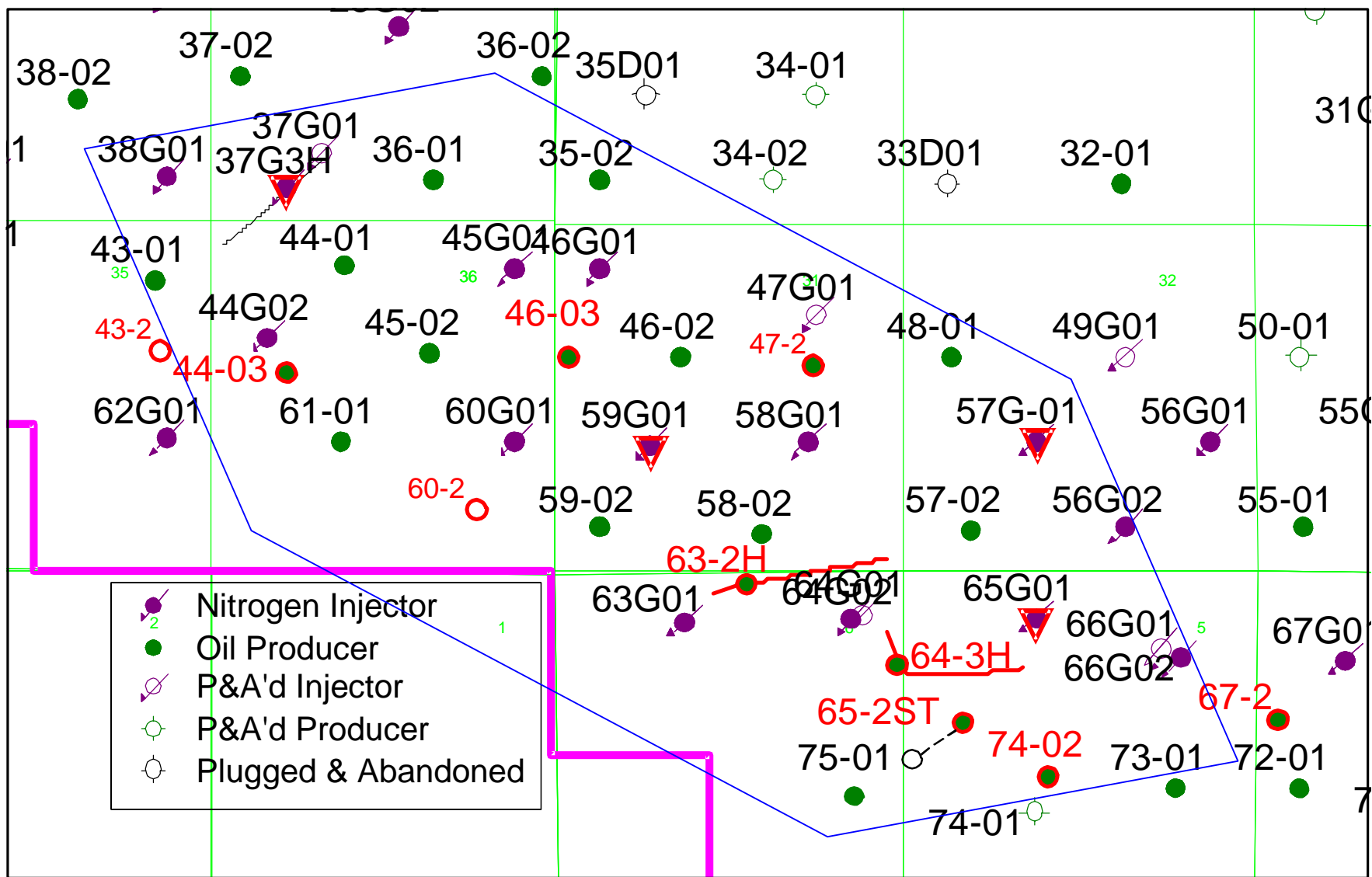
## **Conclusion**

Monitoring of overall performance of the pilot area continues. Response to the various projects continues to be very favorable. Injection into the pilot area, though limited at times by problems in the Air Separation Unit of the Nitrogen Management Facility, and has increased 70% over levels prior to the project. Meanwhile, gas production and nitrogen content of produced gas have both decreased. Nitrogen recycle within the pilot area has decreased from about 72% recycle prior to initiation of the project to about 32% today.

It appears from the production data of new infill wells that poor areal sweep efficiency is the primary factor causing nitrogen cycling and limiting oil recovery. Most new infill wells have had initial produced gas oil ratios and gas nitrogen contents significantly below the field averages. Four vertical and three horizontal wells have been drilled in the pilot area throughout the project. Additional vertical well drilling is planned due to the success of wells drilled to date.

## **References**

There are no references for this report.



**Figure 1. Map of the central portion of the East Binger Unit. The Pilot Area is indicated by the blue polygon. Well work implemented in the Project is highlighted in red; wells 47-2 (first), 43-2, and 60-2 will be drilled in 2005.**

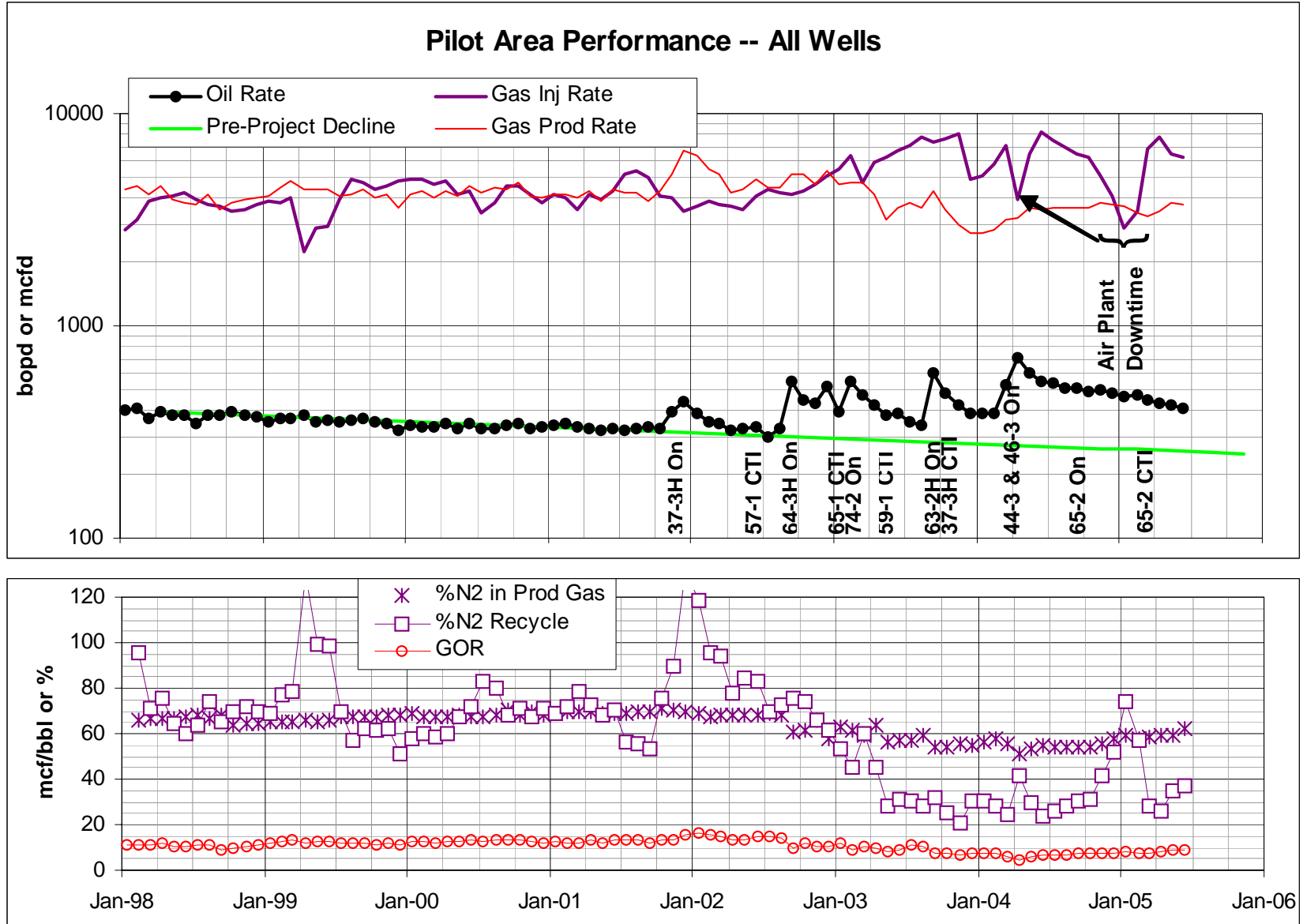
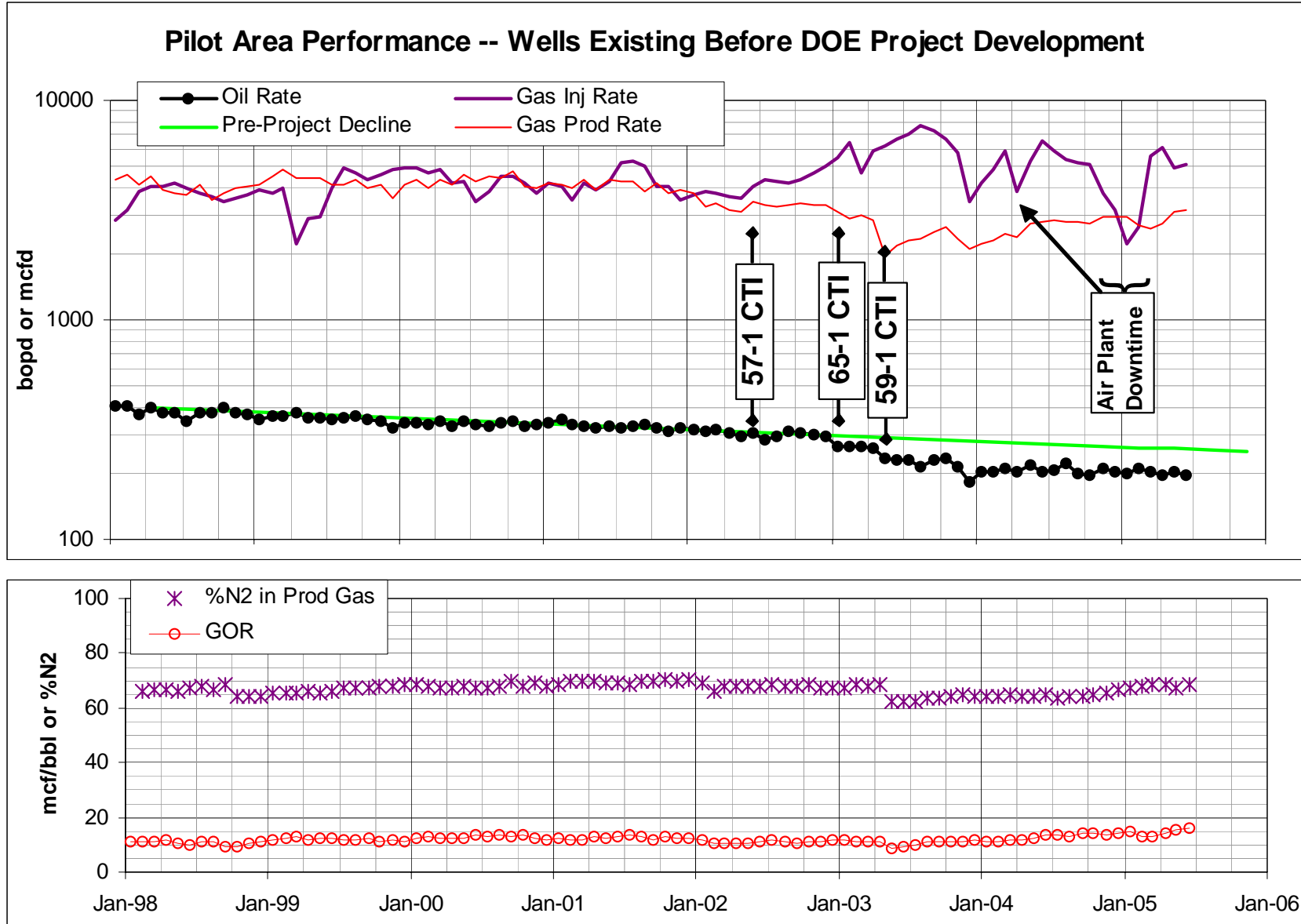
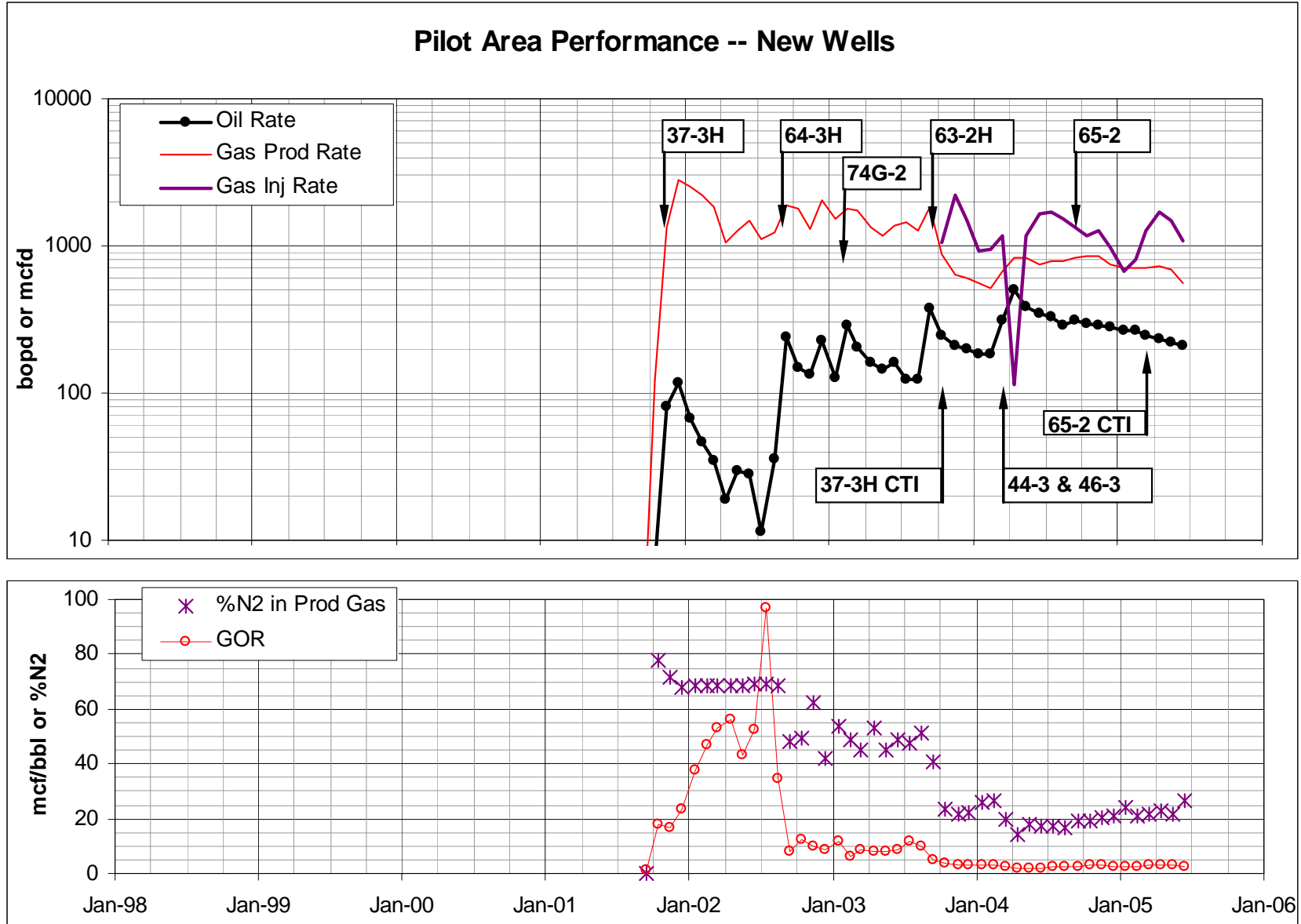


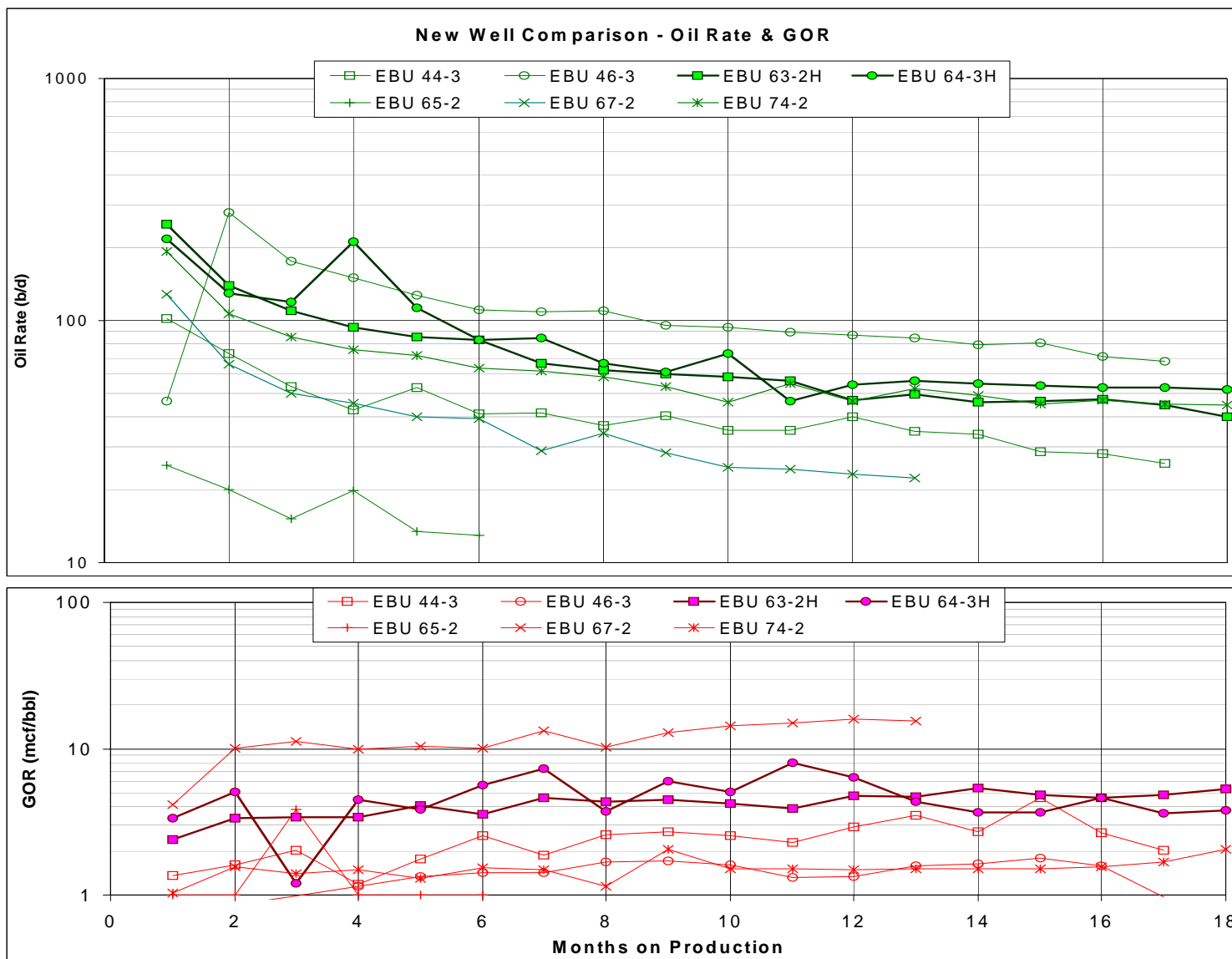
Figure 2. Production data for all wells in the pilot area.



**Figure 3. Production data for wells in the pilot area that existed before DOE Project development.**



**Figure 4. Production data for new wells in the pilot area.**



**Figure 5. Comparison of production data for recent horizontal and vertical wells in or near the Pilot Area. Horizontal wells are designated with an “H” in their names.**

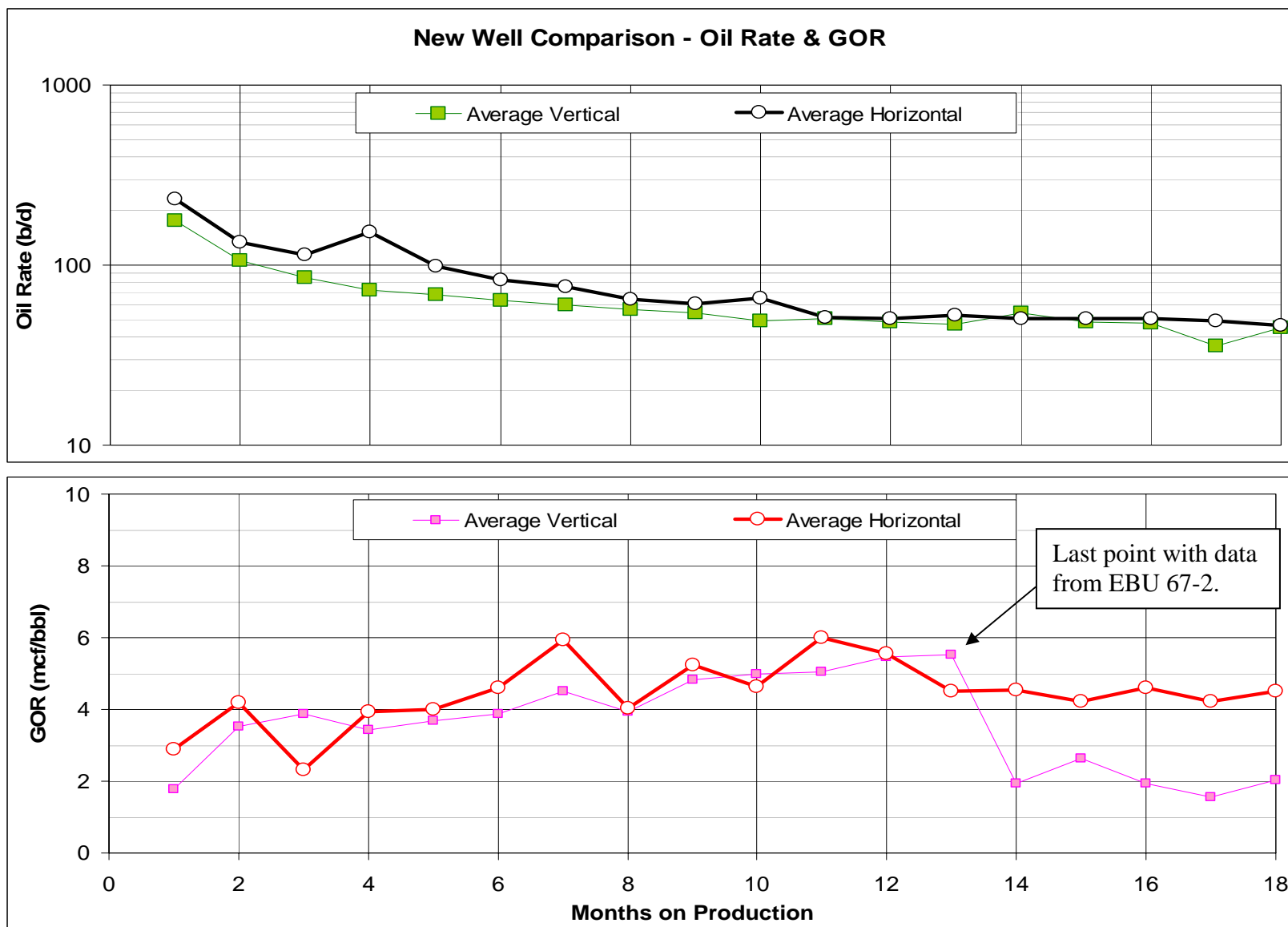


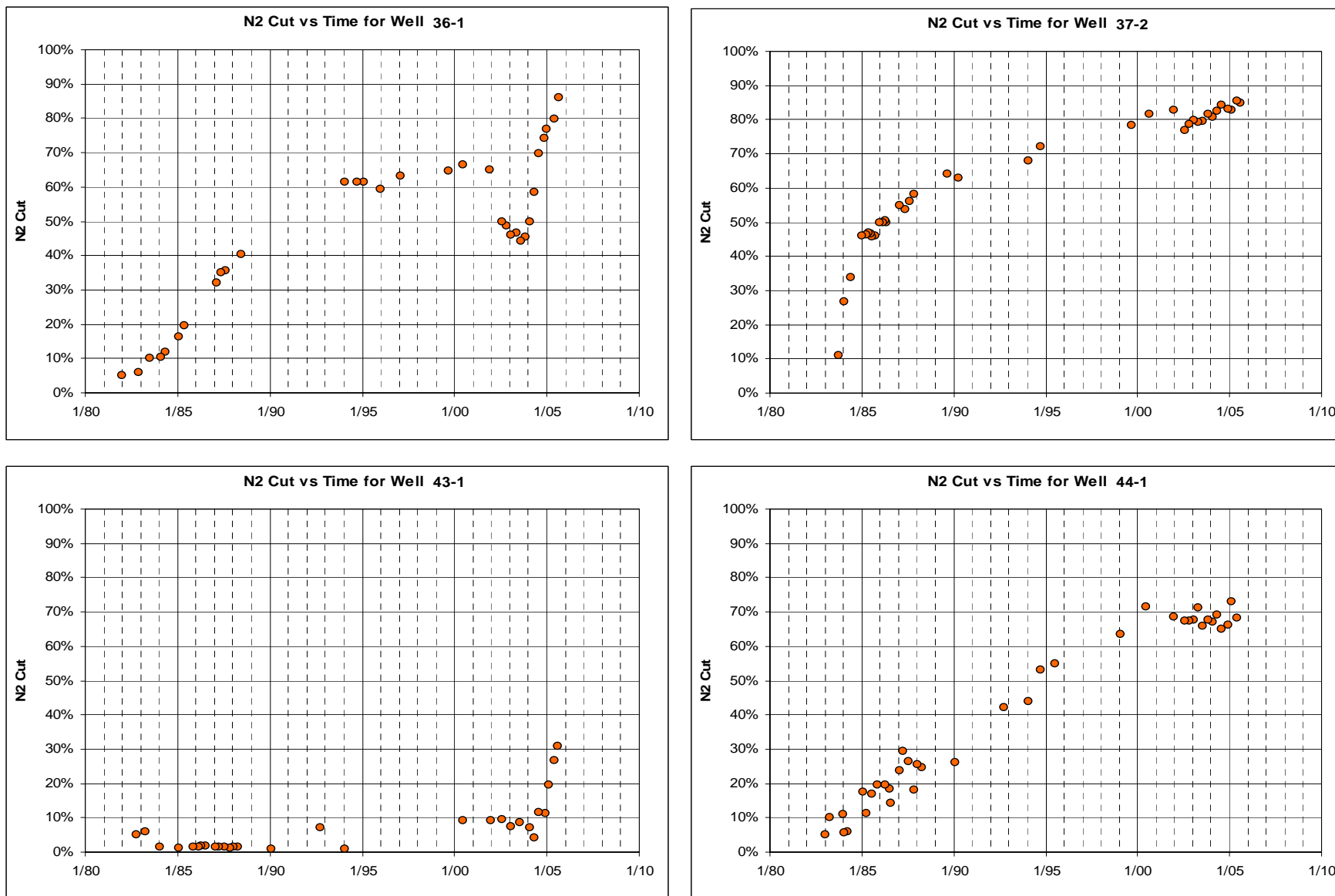
Figure 6. Comparison of average production data for recent horizontal and vertical wells in or near the Pilot Area, excluding EBU 65-2.

**East Binger Unit Pilot Area  
Nitrogen Content in Produced Gas  
Pilot Area Sample Data**

<u>Well</u>	<b>4th Qtr 2001</b>	<u>3rd Qtr 2002</u>	<u>4th Qtr 2002</u>	<u>1st Qtr 2003</u>	<u>2nd Qtr 2003</u>	<u>3rd Qtr 2003</u>	<u>4th Qtr 2003</u>	<u>1st Qtr 2004</u>	<u>2nd Qtr 2004</u>	<u>3rd Qtr 2004</u>	<u>4th Qtr 2004</u>	<u>1st Qtr 2005</u>	<u>2nd Qtr 2005</u>
35-2	<b>58%</b>	-	61%	-	63%	67%	63%	-	66%	-	67%	-	<b>70%</b>
36-1	<b>65%</b>	50%	49%	46%	47%	44%	45%	50%	58%	70%	74%	77%	<b>80%</b>
36-2	<b>25%</b>	-	29%	-	20%	-	18%	-	22%	-	18%	-	<b>20%</b>
37-2	<b>83%</b>	77%	79%	80%	79%	80%	81%	81%	83%	84%	83%	83%	<b>85%</b>
43-1	<b>9%</b>	10%	-	7%	-	6%	-	4%	4%	12%	11%	20%	<b>27%</b>
44-1	<b>69%</b>	67%	67%	68%	71%	66%	68%	67%	69%	65%	66%	73%	<b>68%</b>
44-3	-	-	-	-	-	-	-	4%	3%	3%	3%	4%	4%
45-2	<b>56%</b>	58%	-	57%	59%	60%	61%	62%	64%	64%	65%	64%	<b>67%</b>
46-2	<b>62%</b>	-	-	68%	64%	61%	62%	64%	62%	62%	61%	63%	<b>66%</b>
46-3	-	-	-	-	-	-	-	-	2%	3%	4%	4%	-
48-1	<b>83%</b>	83%	84%	84%	85%	86%	87%	87%	87%	87%	87%	87%	<b>87%</b>
57-2	<b>37%</b>	41%	39%	41%	45%	47%	40%	37%	39%	40%	43%	45%	<b>45%</b>
58-2	<b>8%</b>	5%	-	6%	5%	-	-	12%	6%	6%	17%	5%	<b>5%</b>
59-2	<b>44%</b>	-	-	48%	45%	43%	39%	45%	48%	49%	52%	54%	<b>55%</b>
61-1	<b>56%</b>	-	-	-	56%	-	59%	-	63%	61%	-	60%	-
63-2H	-	-	-	-	-	16%	19%	22%	20%	19%	23%	26%	20%
64-3H	-	23%	18%	17%	16%	23%	25%	36%	36%	30%	43%	45%	-
65-2	-	-	-	-	-	-	-	-	-	25%	22%	CTI	-
73-1	<b>13%</b>	21%	-	21%	-	21%	-	19%	-	24%	-	18%	-
74-2	-	-	-	6 - 10%	10%	10%	10%	19%	16%	16%	18%	24%	25%

**Figure 7. Pilot Area gas sample data – percent nitrogen in produced gas. New wells are shown in blue.**





**Figure 8. Percent nitrogen in produced gas for four wells near EBU 37-3H.**