NGMS–105

A Forecast of Marginal Natural Gas and Oil Well Data

Topical Report

By:

Don J. Remson

June, 2005

FOR

U. S. DEPARTMENT OF ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Work Performed Under Contract No. DE-AD26-01NT00612

Northrop Grumman Mission Systems
Information & Technical Services Division
Tulsa, Oklahoma

NGMS–105

A Forecast of Marginal Natural Gas and Oil Well Data

Topical Report

By

Don J. Remson

June, 2005

Prepared For
U.S. Department of Energy
National Energy Technology Laboratory

Work Performed under Contract No.
DE-AD26-00NT00612

Northrop Grumman Mission Systems
Information &Technical Services Division
Tulsa, Oklahoma

Table of Contents

Table of Contents **1**
1 Executive Summary **2**
2 Introduction to Marginal Wells **6**
2.1 What is a Marginal well? 6
2.2 Why are Marginal Wells important? 7
2.3 What is being done to help Marginal Well Producers? 8
3 Background of Marginal Well Analysis **11**
3.1 Reasons for Developing the Forecasts 11
3.2 Goals and Objectives 11
4 Data Sources Used in Analysis **13**
4.1 EIA 2005 Annual Energy Outlook (AEO2005) 13
4.2 IOGCC Marginal Oil and Gas: Fuel for Economic Growth 14
4.3 2002-2003 Oil and Gas Producing Industry in Your State (Website) 14
4.4 EIA Natural Gas Annual 15
4.5 EIA Petroleum Supply Annual 15
5 Methodology Used to Predict Marginal Oil and Natural Gas Data **16**
5.1 Using Regression Analysis to Forecast Marginal Well Data 16
5.2 Limitations of Current method 20
6 History Match **23**
6.1 Lower 48 history match results 25
7 Marginal Well Forecasts **27**
7.1 Quality Assurance Procedure 27
7.2 Sample Quality Assurance Modifications 28
7.2.1 New York Marginal Natural Gas Forecasts 28
7.2.2 Utah Marginal Oil Forecasts 30
7.2.3 New Mexico Marginal Oil Forecasts 33
8 Conclusions and Recommendations **36**
Bibliography **41**
Appendix A: Description of Files Generated **42**
Appendix B: Secondary Methodology Considered for Marginal Well and Production Forecasting **46**
Appendix C: Supply Region History Match Results **48**
Appendix D: State Level History Match Data **61**
Appendix E: Aggregated Onshore Lower 48 Marginal Forecasts **63**
Appendix F: Aggregated Supply Region Marginal Forecasts **66**

1 Executive Summary

This document presents the methodology and results of an analysis conducted by Northrop Grumman Mission Systems for the Strategic Center for Natural Gas and Oil (SCNGO) of the U.S Department of Energy's National Energy Technology Laboratory (NETL). The goal of this analysis was to develop a forecast of marginal oil and natural gas production and well counts through the year 2025. NETL has an important ongoing research and development program involving marginal wells. Support and planning for this program requires the development of these forecasts. An approach was developed which ties these forecasts to two important publicly available and reliable data sources; the *Annual Energy Outlook (AEO)* published annually by the Energy Information Agency (EIA) and the *Marginal Oil and Gas: Fuel for Economic Growth* annual publication of the Interstate Oil and Gas Compact Commission (IOGCC).

The forecast of production and well count generated by the analysis is best displayed graphically. Figure 1-1 displays historical oil production (total and marginal) as well as forecasts of total oil production reported by the AEO and a marginal oil production forecast generated as a result of this analysis. Figure 1-2 displays the same set of results for natural gas.

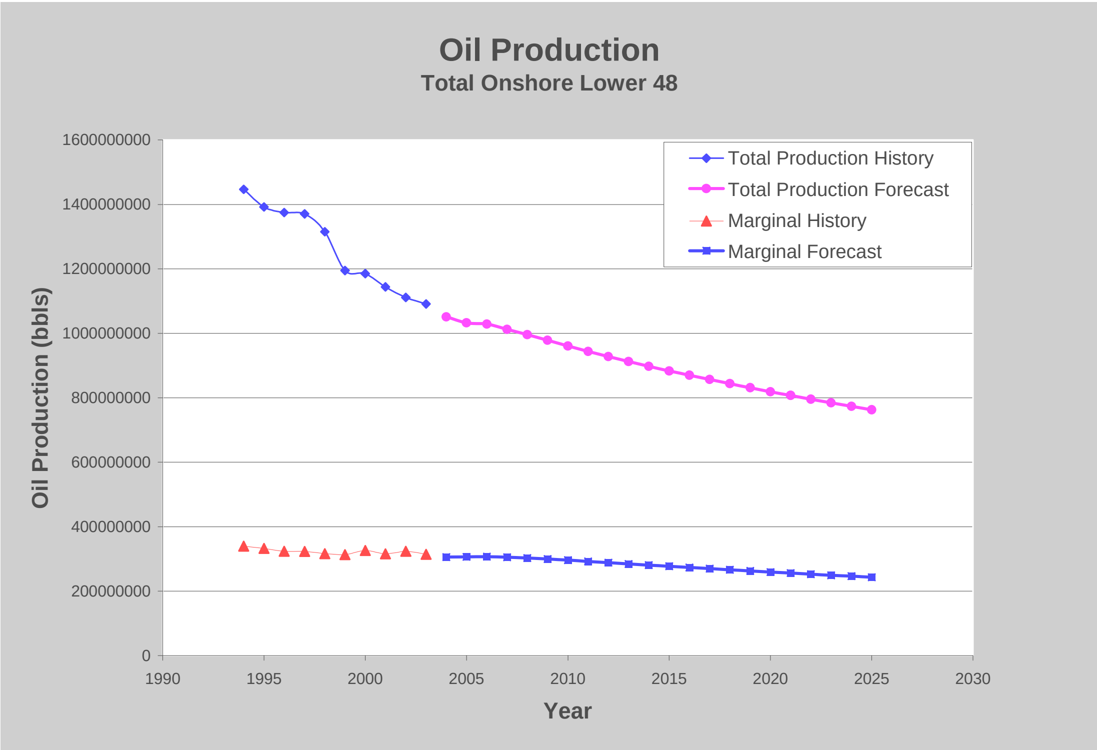


Figure 1-1 Onshore Lower 48 Oil Production History + Forecast

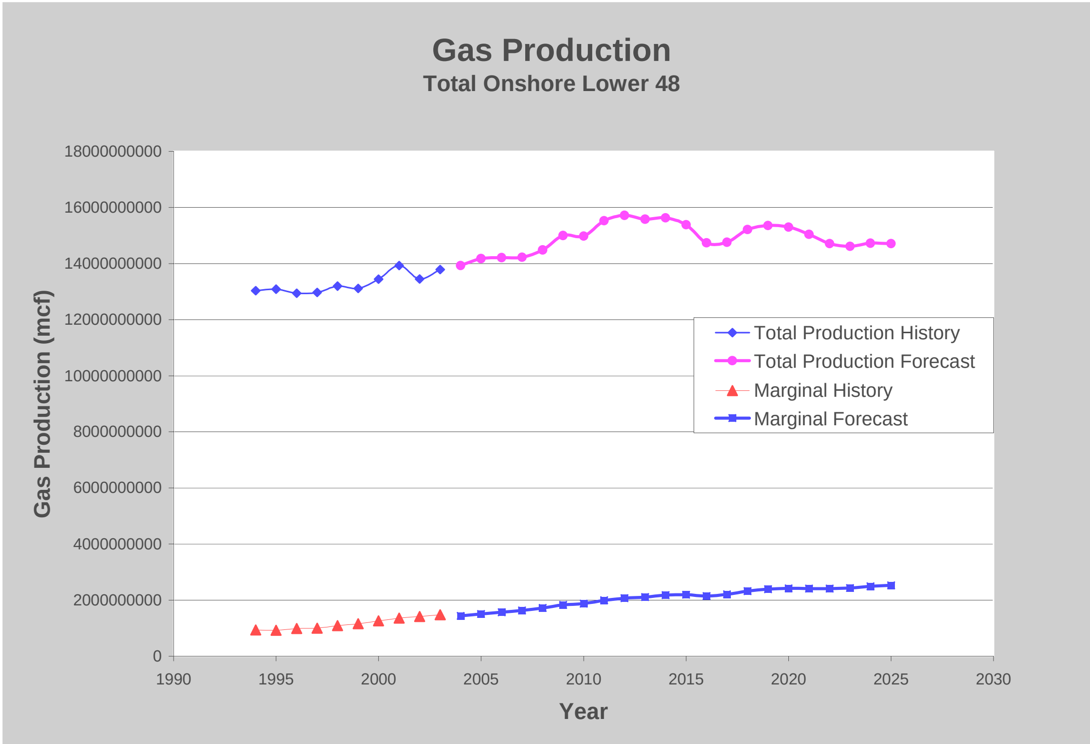


Figure 1-2 Onshore Lower 48 Natural Gas Production History + Forecast

A forecast of marginal well count was generated for both oil and natural gas through the year 2025. These results along with historical well count data are presented in Figure 1-3.

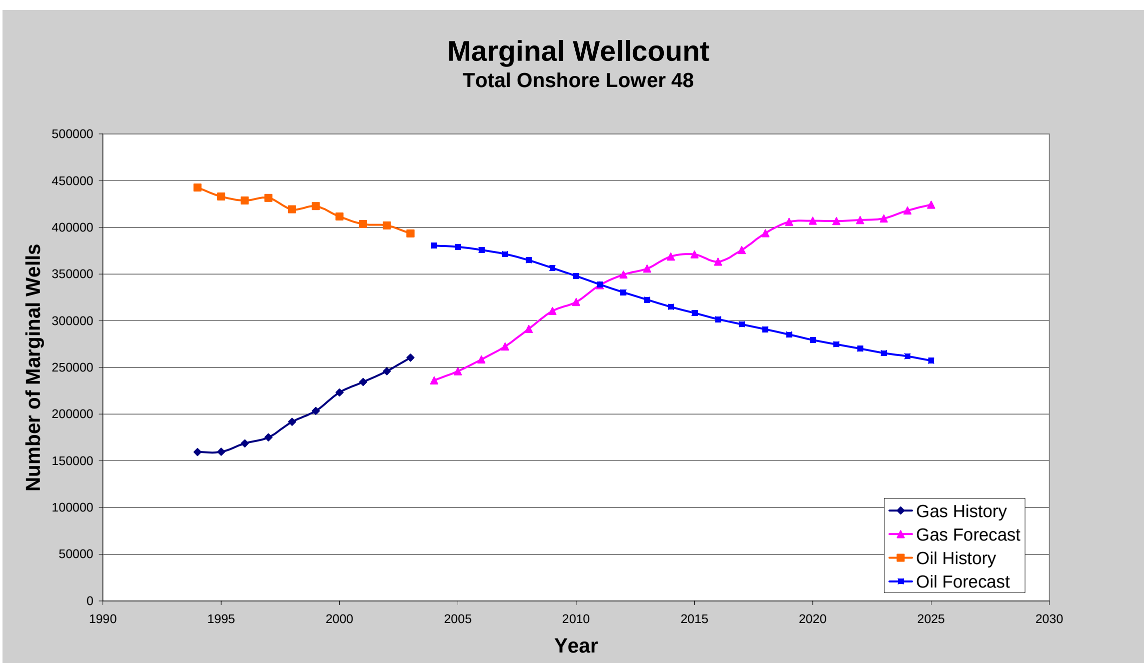


Figure 1-3 Onshore Lower 48 Marginal Well Count History + Forecast

Regional forecasts which are displayed in detail as an Appendix of this report are summarized here as a set tables displaying production and well count data for three distinct years in the forecast.

	Marginal Oil Production (Mbbls)			**Marginal Natural Gas Production (BCF)**		
	2005	**2015**	**2025**	**2005**	**2015**	**2025**
Northeast	26,156	15,464	11,108	506	680	699
Gulf Coast	50,351	33,454	23,975	247	333	389
Mid-Continent	77,575	74,621	66,419	350	437	408
Southwest	99,256	95,827	86,687	103	160	168
Rocky Mountain	20,131	28,910	28,627	298	582	867
West Coast	32,567	28,711	26,218	2	1	0
Total U.S Lower 48	306,036	276,987	243,034	1,507	2,193	2,531

Table 1-1*

Table 1-1 presents marginal production for six supply regions. A map showing the location of the six regions is graphically displayed as Figure 5-1. Table 1-2 presents the forecast values of marginal well count for the same regions.

	Marginal Oil Well Count			**Marginal Natural Gas Well Count**		
	2005	**2015**	**2025**	**2005**	**2015**	**2025**
Northeast	99,492	54,230	36,151	130,938	202,274	225,671
Gulf Coast	49,369	27,693	17,721	34,769	41,136	43,936
Mid-Continent	92,512	86,209	74,347	36,623	49,992	48,309
Southwest	95,380	91,711	82,536	12,167	18,264	18,536
Rocky Mountain	19,069	26,575	25,161	31,183	59,279	87,717
West Coast	23,303	21,849	21,305	303	169	69
Total U.S Lower 48	379,125	308,267	257,221	245,984	371,115	424,238

Table 1-2

Analysis of the summary results presented here as well as the detailed results provided in the Appendix of the report result in the following list of conclusions:

- Near term forecasts of production and well count generated by the method used are reasonable at national and regional levels of detail.
- Relative importance of natural gas marginal wells will increase over time while oil will decrease†.
- The marginal fraction of total onshore production will continue to increase for both oil and natural gas.

* Significant digits not considered in the data throughout this report
† assumes no significant technological breakthroughs

- Focus of marginal oil production will shift more and more to the central and western regions of the country.
- Significant increases in marginal natural gas wells in the Rocky Mountain region are forecast.

An approach was developed and implemented to generate these forecasts. The method can be considered a "current trend analysis". It is performed on a state by state basis for both oil and natural gas separately. It involves three separate linear regression analyses. The three sets of data for which linear regression analysis is performed in order to develop equations to estimate future annual values are:

- State fraction of production from a supply region
- Fraction of state-wide production that is marginal
- Average production rate of marginal wells.

Forecasts of these three values along with total production forecasts from each supply region provided by the AEO forecast provide all of the detail necessary to estimate values for total production, marginal production, and marginal well count. The methodology may be summarized in the nine steps. These steps are explained in greater detail within the main body of the report.

Generation of Marginal Production and Well Count Forecasts Based on 2005 AEO Production Forecast

1. Acquire state historical oil and natural gas production data for years 1994-2003
2. Determine fraction of regional production produced by state for years 1994-2003
3. Regress year vs. state fraction of region production data to derive linear function in order to project fraction of regional production produced annually by the state.
4. Calculate annual future production forecast for the state
5. Calculate historical state annual marginal to total production ratios
6. Regress year vs. state marginal to total production ratios to derive a linear function in order to predict annual state future marginal to total production ratios. These ratios are multiplied by production of step 4 to determine forecast of state marginal production.
7. Generate state annual average marginal production rate for historical years 1994-2003.
8. Regress year vs. state average marginal production rate to derive a linear function for projecting future state average stripper production rates.
9. Generate state well count forecast by annually dividing state marginal production forecast by projection of state average stripper production rate.

The results of this procedure are then subjected to a "Quality Assurance" check which compares the forecast of marginal well count to an estimate of total available wells in the state.

As an initial test of the procedure, a history match was performed by using the first 8 years (1994-2001) as history, performing the regressions to project marginal production and well counts for years 2002 and 2003, and comparing these results to history. The complete method and results of this procedure are detailed later in the report.

2 Introduction to Marginal Wells

2.1 What is a Marginal well?

A producing oil or natural gas well is considered to be "marginal" if it is producing at such a rate that it is at the margin of profitability. Of course this rate varies depending upon many factors such as operating costs, product prices, tax liability of the operator, capital recovery costs, environmental costs, and plugging and abandonment liability to name a few. A well may produce at relatively high rates but still be considered marginal due to factors such as high water cut and heavy oil production which contribute to much higher than normal operating costs. Marginal wells and production are commonly referred to as stripper wells and stripper production. Throughout this report the words "stripper" and "marginal" will be used interchangeably.

One definition of a marginal well may be construed from the federal government. The Internal Revenue Code (1986, Title 26,Subtitle A, Chapter 1, Subchapter 1, Part 1, Section 613A) defines a marginal well for the purpose of enacting special percentage depletion provisions for marginal production. This code defines the term "marginal production" as a domestic crude oil or natural gas produced from a property which is either a "stripper" well property or a property from which substantially all of the production is from heavy oil. Heavy oil is defined as oil having a gravity of less than or equal to 20 degrees API at surface conditions. A property is considered a stripper well property if it produces a daily average of 15 or less equivalent barrels of oil and natural gas per producing oil or natural gas well. In determining equivalent barrels, 6 Mcf of natural gas is considered to be 1 barrel of oil equivalent. Therefore, the government definition of marginal well is an average daily production rate of less than or equal to 15 barrels of oil equivalent per day or heavy oil production.

The Interstate Oil and Gas Compact Commission (IOGCC) has been documenting production annually from low volume stripper wells for over 50 years. The IOGCC defines low volume stripper wells as oil wells producing 10 barrels of oil per day or less and natural gas wells producing 60 Mcf per day or less. Production from these wells will definitely be at the lower edge of profitability and their production is considered to be marginal. The IOGCC elected to not distinguish between light and heavy oil in their annual survey of marginal wells. Since this study will be primarily using data from the IOGCC annual surveys of marginal production, their definition of marginal wells will be used from this point onward.

Definition of Stripper or Marginal Production

- **Marginal oil is produced by oil wells which produce less than or equal to 10 barrels of oil per day on average.**
- **Marginal natural gas is produced by natural gas wells which produce less than or equal to 60 Mcf of natural gas per day on average.**

2.2 Why are Marginal Wells important?

Based on data collected as part of this analysis, approximately 80 percent of the oil wells and 67 percent of the natural gas wells producing in the U.S. are considered to be marginal. Note – for the purpose of this report, the term U.S production refers only to onshore lower 48 state production. The reason for this is that due to the high cost of producing wells offshore and Alaska, there are very few if any stripper wells in these regions. These marginal wells produced about 29 percent of the oil and 11 percent of the natural gas produced in the U.S. during 2003. This is not an insignificant amount of production and the fraction of marginal production relative to total production is increasing with time. Figure 2-1 illustrates how the marginal fraction of oil and natural gas has been increasing over the last 10 years.

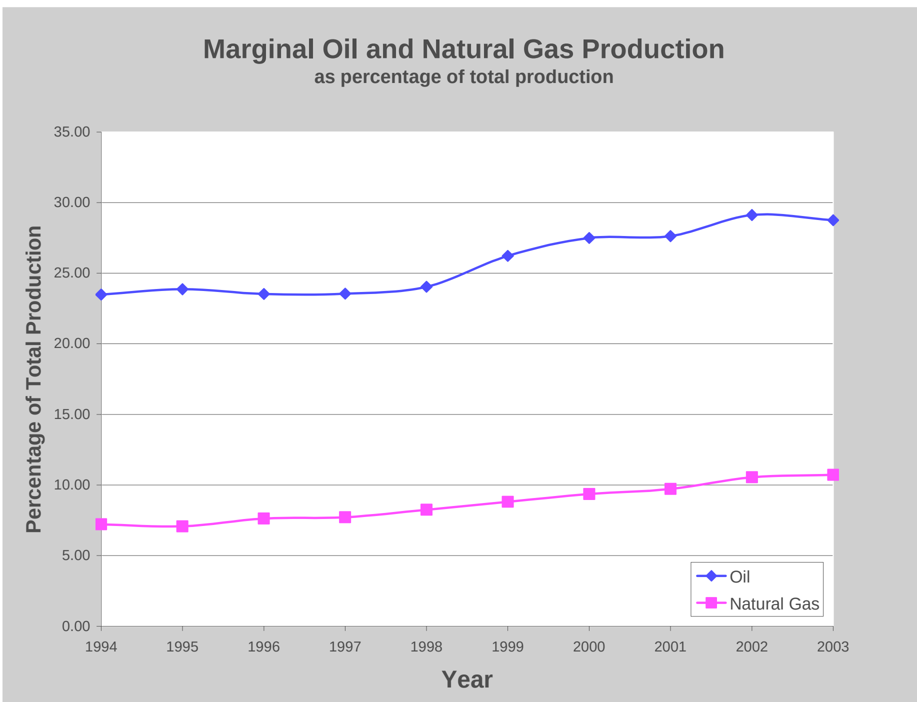


Figure 2-1 Marginal Natural Gas and Oil Production as Fraction of Total Production

Due to the largely mature nature of our resource, the U.S. is fairly unique in that so much of its resource is produced by such low volume wells. The majority of these wells are owned, maintained, and produced by independent operators as opposed to the large globally operating integrated E&P firms. On an individual basis these wells are relatively insignificant, however, collectively they account for a large proportion of the jobs and the corresponding economic growth associated with the petroleum industry in this country. Another reason these wells are so important is that they serve as access to much of the remaining oil and natural gas resource. There is always the potential for new technologies to enhance the production of some of the residual and bypassed oil and natural gas in these reservoirs. If these wells are shut-in and then plugged and abandoned, it becomes much more unlikely these remaining reserves will ever be produced due to the increased cost of drilling new wells.

If there was no longer any production from marginal wells, the impact on our economy would be noticeable. According to data published in the 2004 IOGCC: *Marginal Oil and Gas: Fuel for Economic Growth* report, if the reduction in supply was made up through an increase in imports, we would have to increase oil imports by about 7 percent and natural gas imports by almost 38 percent based on 2003 numbers. This would have a severe impact on our balance of trade. Economic calculations show that the theoretical abandonment of all stripper oil and natural gas wells would cost the U.S about $32.4 billion dollars in economic output, earnings and wages would decrease about $6.6 billion and almost 160,000 jobs would be lost. There would also be an impact on state and local government in that an estimated $697 million dollars in severance taxes were paid by producers of marginal wells.

2.3 What is being done to help Marginal Well Producers?

The importance of marginal wells has not been lost on industry and government. The greatest threat to marginal wells is low product prices and the best way to offset this effect is through cost reduction. Federal and state governments have both provided help in reducing cost to marginal producers through reduced severance tax programs, tax credits, and royalty relief programs. Another way to prolong the operational life of marginal wells is research dedicated to fulfilling the specific requirements of these low producing rate wells. Again, both federal and state governments as well as industry have supported consortiums and associations dedicated to helping operators of marginal wells and have provided direct funding for research and tech transfer designed to improve the viability of marginal wells. A list of some of the current marginal well “supports” or incentives programs follows:

Federal Incentives

- The Countercyclical Marginal Well Tax Credit – This credit recently passed by the congress and signed into law applies to marginal wells and high water cut wells. High water cut wells are defined as those producing 25 barrels or less of oil equivalent per day and produce 95 % water. The credit applies to the first three barrels/day of production. The credit is a maximum of $3.00 per barrel ($0.50 per Mcf) applied proportionately as the price falls below the trigger point. It begins when the annual domestic first purchase price of oil falls below $18.00 per barrel ($2.00 per Mcf) and is fully applied if this price falls below $15.00 per barrel

($1.67 per Mcf). This credit provides a safety net for marginal producers and was originally recommended in the 1994 National Petroleum Council *Marginal Wells* study.

- Increased Percentage Depletion Allowance – Federal tax law allows an increase in the percentage depletion rate for marginal properties owned by independent operators. The normal percentage depletion allowance for an independent operator is 15% of gross production. Marginal property owners are allowed an extra percent for each whole dollar by which the reference price is less than $20 for the preceding year.

- Stripper Oil Royalty Rate Reduction Program – This rule published by the U.S Department of the Interior and the Bureau of Land Management in 1992 grants a reduction in the royalty paid for oil produced by verified stripper properties on federal lands. The rule was subjected to review in 1997, found to successfully accomplishing its goals, and extended indefinitely.

State Incentives

- Alabama – reduction in privilege tax from 8% to 6%
- Arizona – reduction in severance tax from 5% to 4%
- Colorado – exempt from severance tax, tax credit for 87.5% of ad valorem tax
- Florida – reduction in severance tax from 8% to 5% for oil, stripper natural gas taxed at $0.12 per Mcf
- Kansas – exemptions from severance tax, the amount of oil exempted is subject to a complex list of rules which depend on well depth and oil price.
- Louisiana – total exemption from severance tax for oil if oil price is below $20. Above $20 the severance tax is reduced by 50%
- Michigan – reduction in severance from 6.6% to 4% for oil and from 5% to 4% for natural gas
- Mississippi – refund of two thirds of severance tax if price of oil is less than $12
- Montana – reduction in severance from 10.5% to 5.5% if price of oil is below $30
- Nebraska – reduction in severance from 3% to 2%
- New Mexico – severance reduction 3.75% to as low as 1.875% and emergency school tax is reduced from 4% to as low as 2% for natural gas and from 3.15% to as low as 1.58% for oil. Reduction begins as price falls below $18 for oil and $1.35 for natural gas. Maximum reduction at $15 for oil and $1.15 for natural gas
- North Dakota- exempt from severance tax
- Texas – reduced royalty for two years for marginally economic state leases
- Utah – exemption from severance tax
- West Virginia – exemption from severance tax
- Wyoming – if oil price is less than $20, wells producing less than 15 barrels/day receive 2% reduction in severance. If oil price is greater than $20, wells producing less than 10 barrels/day receive 2% reduction in severance rate

Industry and Government Consortia and Associations

- Oklahoma Marginal Well Commission – The Marginal Well Commission is an Oklahoma state agency, funded by the oil and natural gas industry through a small tax on oil and natural gas produced in the state, with a purpose of protecting and promoting oil and natural gas production in Oklahoma. It sponsors technology transfer programs to help operators of marginal wells.

- National Stripper Well Association – A lobbying group which operates in conjunction with the Independent Petroleum Association of America (IPAA) to insure that the voices of independent producers and stripper well operators are heard by lawmakers in Washington D.C and state capitols.

- Stripper Well Consortium – an industry driven research consortium primarily funded by the U.S Department of Energy (DOE). This consortium was established in 2000 by a cooperative agreement between DOE and Penn State University, and is managed by the NETL. It was set up to assist small and independent operators who own the vast majority of the nation's stripper wells in the development, demonstration, and commercialization of technologies to improve production performance from stripper wells. The roughly 50 or so members coordinate research projects in three broad areas: reservoir remediation, wellbore clean-up, and surface system optimization. Projects are developed by consortium members and require a minimum 30% cost share for the participant.

3 Background of Marginal Well Analysis

3.1 Reasons for Developing the Forecasts

The key to the survival of marginal oil and natural gas wells is and always has been incentive programs and research. The typical operators of these wells do not have the means to conduct their own research, therefore Federal and state research money must provide a crucial part in developing the new technologies to keep these low rate wells producing. In keeping with this need of the smaller operators, the SCNGO manages an important ongoing research and development program on marginal wells.

In order to make informed decisions regarding the long-range focus and direction of this research effort, managers require timely data on which to base their planning and help support their programs. As part of this effort, the Petroleum Systems Analysis and Planning Division (PSAP) saw the need for and sought to develop forecasts related to marginal oil and natural gas wells and the production from these wells. These forecasts will provide policy makers with important information as to where marginal production and well count are headed in the future at national, regional, and state levels of detail. By knowing where the majority of these stripper wells are located and most likely will be in the future, research funding and incentive programs designed to help marginal well operators will be directed where they will do the most good.

3.2 Goals and Objectives

The primary goal of this marginal well analysis is a set of forecasts of various parameters pertaining to marginal oil and natural gas. In accomplishing this goal, one of the primary objectives is to tie these forecasts to two very important data sources.

- *The Annual Energy Outlook (AEO)* published annually by Energy Information Agency (EIA) , used most recent version which was 2005

- *Marginal Oil and Gas: Fuel for Economic Growth* published annually by IOGCC, data in this study came from 1997,1999,2000,and most recent 2004 editions

It is critical that any forecasting of marginal well activity must be tied to the 2005 AEO. The AEO is a de facto standard by which other projections and forecasts of petroleum supply and demand are often compared. It has the advantage of being well supported and documented. The AEO is updated annually. It provides a forecast through year 2025 of total oil and natural gas production on a supply region basis. Forecasts of new wells drilled are also provided along with the production. While oil and conventional natural gas data are provided only at the supply region level, unconventional natural gas resources (tight gas, coal bed methane, gas shale) data are reported at a play level.

Since EIA's forecast is frequently referred to by both industry and government entities, it makes sense that any forecast of marginal activity is tied to these results. In this way the marginal well forecasts will be inextricably linked to the technology assumptions and product prices and cost assumptions made by the EIA in their annual production forecast.

A meaningful forecast should also replicate past history. If an algorithm is used to forecast marginal production and well count for a period of time for which historical data are available, the forecast should reasonably match the history. This is referred to as "history matching" and is used as a means of validating the forecasting methodology. It is obvious that the forecast methodology will need to make use of historical marginal well data. A quick literature search showed that the IOGCC's annual projections of marginal production and well counts are constantly quoted throughout the oil industry and have a lot of credibility. This resource is published annually and contains other information such as annual well abandonment and estimates of lost revenue due to actual and potential abandonment.

After careful study of the information contained in these two resources, a method was developed to specifically yield the following (intermediate and final) information:

- State and supply region forecasts (2004-2025) of total oil and natural gas production from EIA's 2005 AEO forecast
- State and supply region forecasts (2004-2025) of marginal oil and natural gas production
- State and supply region forecasts (2004-2025) of marginal oil and natural gas well counts. This information along with the marginal production would give an average stripper well rate on an annual basis.

The method developed employs a linear "trend analysis" approach and works well in meeting the goals and objectives of this forecasting task. The methodology will be explained in greater detail in chapter 5 of this report.

4 Data Sources Used in Analysis

There were five major data sources used in performing the marginal well analysis and creating this report. They are all publicly available at no or nominal cost. In this chapter these data sources will be described in detail.

4.1 EIA 2005 Annual Energy Outlook (AEO2005)

This publication presents midterm forecasts of energy supply, demand, and prices through 2025 prepared by the Energy Information Administration. The projections are based on results from EIA's National Energy Modeling System (NEMS). The forecasts in AEO2005 focus primarily on a reference case, a lower and a higher economic growth case, and four alternative oil price cases. The alternative oil price cases are a low world oil price case, an October oil futures case, and two high world oil price cases. The projections used in this marginal well analysis are from the AEO2005 reference case.

The projections in the Annual Energy Outlook are not statements of what will happen but of what might happen, given the assumption and methodologies used. They are basically business as usual trend forecasts, given known technology, technological and demographic trends and current laws and regulations. As such they provide a policy-neutral reference case that can be used to analyze policy initiatives.

Federal, State, and local governments, trade associations, and other planners and decision makers in the public and private sectors use the AEO2005 projections. They are published in accordance with Section 205c of the Department of Energy Organization Act of 1977 (Public Law 95-91), which requires the EIA Administrator to prepare annual reports on trends and projections for energy use and supply.

The data used in this marginal well analysis was generated by the NEMS Oil and Gas Supply Model (OGSM). Results from the lower 48 conventional oil and natural gas modules along with the lower 48 unconventional natural gas module were used. Results from the offshore and Alaska modules of OGSM were not used as there is little or no marginal well production in these regions. The projections used in the analysis consisted of annual numbers for conventional crude oil in Mbbls/day by EIA supply region. Natural gas results were presented in BCF/year. The natural gas results were separated into the product types of conventional non-associated gas, conventional associated-dissolved gas, tight sands, gas shales, and coalbed methane. The unconventional natural gas results were further broken down into individual play. Also used in this analysis were projections of "successful" new wells drilled during this analysis. These numbers were reported for the same categories as were the production numbers. Projections were provided for years 2004 through 2025. The historical year 2003 was also provided. In general, the historical data for 2003 are based on EIA's *Annual Energy Review 2003*, published in September 2004; however, data are taken from multiple sources.

4.2 IOGCC Marginal Oil and Gas: Fuel for Economic Growth

This document is published on an annual basis and made available to the general public for a very nominal fee. It surveys production from the preceding year and reports back both marginal production and marginal well counts. The Interstate Oil and Gas Commission (IOGCC) has been documenting stripper well production since 1941. The goal is to help draw attention to the importance of the contribution provided by marginal wells.

These reports made a very important contribution to this marginal well study in that they supplied the following data. For oil, the report provides the number of stripper wells along with total production from these stripper wells by state. Also included is the number of oil wells plugged and abandoned in the previous year and a calculation of the average daily production per stripper well. Again these data are provided on a state basis. The same information is also provided separately for marginal natural gas wells.

Each report contains data coverage of the current and three years preceding. By collecting IOGCC reports for the years 1997, 1999, 2000, and 2004, complete data coverage was acquired for 10 years of historical production (1994-2003). Ten years of history should be a long enough sample for the type of trend analysis being performed in this study. This data became the focus of a regression analysis to predict future marginal production.

In addition to the survey results on marginal production, marginal well count, and P&A data, the IOGCC provides as part of the report a calculation of the impact of stripper wells on the economy of the United States. They calculate the impact on the economy both of the P&A wells and the impact on the economy of the current marginal wells. This is done using the Regional Input-Output Modeling System (RIMS II) developed by the Bureau of Economic Analysis (BEA). RIMS II contains a set of multipliers which are used along with other assumptions to calculate variables such as gross receipts or sales, earnings income such as wages, and employment levels in a given region due to the effect of production from marginal wells.

4.3 2002-2003 Oil and Gas Producing Industry in Your State (Website)

The Independent Petroleum Association of America (IPAA) provides in its website www.ipaa.org a unique look at the oil and natural gas industry in each of the 33 producing states. The publication details all information covering the upstream side of the industry, including prices, production, severance taxes, industry employment, and drilling. Of special interest to this marginal well study were drilling statistics provided for each state for the year 2001. This is the only year for which drilling data were available in this publication. The data used was the total number of successful oil wells and natural gas wells drilled in each state. The data were used to determine the fraction of the total regional drilling done in each state. This information was used to split the regional drilling forecast provided by the AEO2005 into the various state figures.

4.4 EIA Natural Gas Annual

The *Natural Gas Annual (NGA)* is a publication which provides information on the supply and disposition of natural gas to a wide audience including Congress, Federal and State agencies, industry analysts, consumers, and education institutions. The data of interest for the marginal well study were state level total natural gas production and natural gas well count information. Having total natural gas production information along with marginal natural gas production information from the IOGCC report, allows calculation of the fraction of total natural gas production which is marginal on a state by state and year by year basis. This is an integral part of the methodology used to project future marginal natural gas production.

The data of interest found in the *Natural Gas Annual* are basically obtained from two surveys conducted by the EIA. The mandatory Form EIA-176. "Annual Report of Natural and Supplemental Gas Supply and Disposition," and the voluntary Form EIA-895, "Monthly Quantity and Value of Natural Gas Report" provide most of the production and well count information. Form EIA-176 was submitted to operators of fields, wells, or natural gas processing plants who distribute natural gas to end users or transport natural gas by pipeline; or operate underground natural gas storage facilities. Form EIA-895 was sent by the appropriate agencies of 32 natural gas producing states.

4.5 EIA Petroleum Supply Annual

The *Petroleum Supply Annual (PSA)* contains information on the supply and disposition of crude oil and petroleum products. The data found in this annual publication are collected from the petroleum industry through annual and monthly surveys. Detailed information is provided on imports, exports, refinery operations, stocks, production, and transportation of both crude oil and many petroleum products. The data of interest for the marginal well study were state level total oil production. Total oil production information along with marginal oil production information from the IOGCC report, allows calculation of the fraction of oil production which is marginal on a state by state and year by year basis. This is an integral part of the methodology used to predict future marginal oil production.

The data of interest found in the *Petroleum Supply Annual* are obtained from several sources. Information is obtained from State government agencies, U.S. Department of the Interior, Minerals Management Service (MMS), and EIA Reserves and Production Division estimates base on Form EIA-182, "Domestic Crude Oil First Purchase Report" data.

5 Methodology Used to Predict Marginal Oil and Natural Gas Data

A method of forecasting marginal production and well count using linear regression analysis of state level data was adapted for this study. A second approach which considered decline analysis of either well or reservoir data was considered but dropped in favor of the aforementioned approach. For reference, a discussion of this second approach appears in Appendix B of this report. The remainder of this chapter will fully explain the state level linear regression approach which was utilized in this study. There is also a discussion of the limitations involved with this approach.

5.1 Using Regression Analysis to Forecast Marginal Well Data

As stated earlier, two important drivers for this analysis are the following:

- Provide results based on 2005 AEO forecasts
- Be able to show reconciliation with IOGCC survey data

In order to do this a methodology was designed which used these two data sources directly. AEO results are reported at the supply region level.

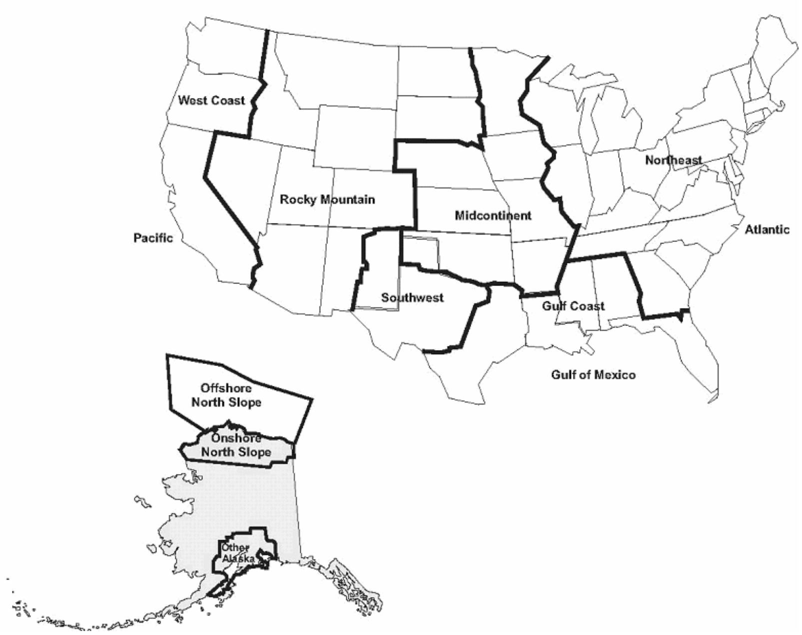


Figure 5-1 AEO Supply Regions

Since Alaska and offshore regions do not contain marginal wells, there are six supply regions considered for which forecasts were made; Northeast, Gulf Coast, Mid-continent, Southwest, Rocky Mountain, and West Coast. Figure 5-1 displays the boundaries of these regions. The IOGCC data on marginal production and well count are provided at the state level of detail. In order to make use of state level IOGCC data, the AEO forecast was disaggregated into state level data. The approach taken to disaggregate the regional AEO forecast into state level data was to use the historical breakdown of each regions production into its member states. Using state production data for oil and natural for years 1994-2003 captured from the *Natural Gas Annual* and the *Petroleum Supply Annual*, it was possible to calculate data for each region which showed the fraction of the region's production produced by each state for each year of historical production. Observations of this data showed that as a general rule most states have not produced a constant fraction of the region's production. Generally the fraction of production has either tended to trend slightly upward or downward in a linear manner. This justifies our planned use of linear regression to forecast this production trend into the future. This regression created a forecast for each state of the fraction of the regional total production, provided by the 2005 AEO report, which would be produced by that state.

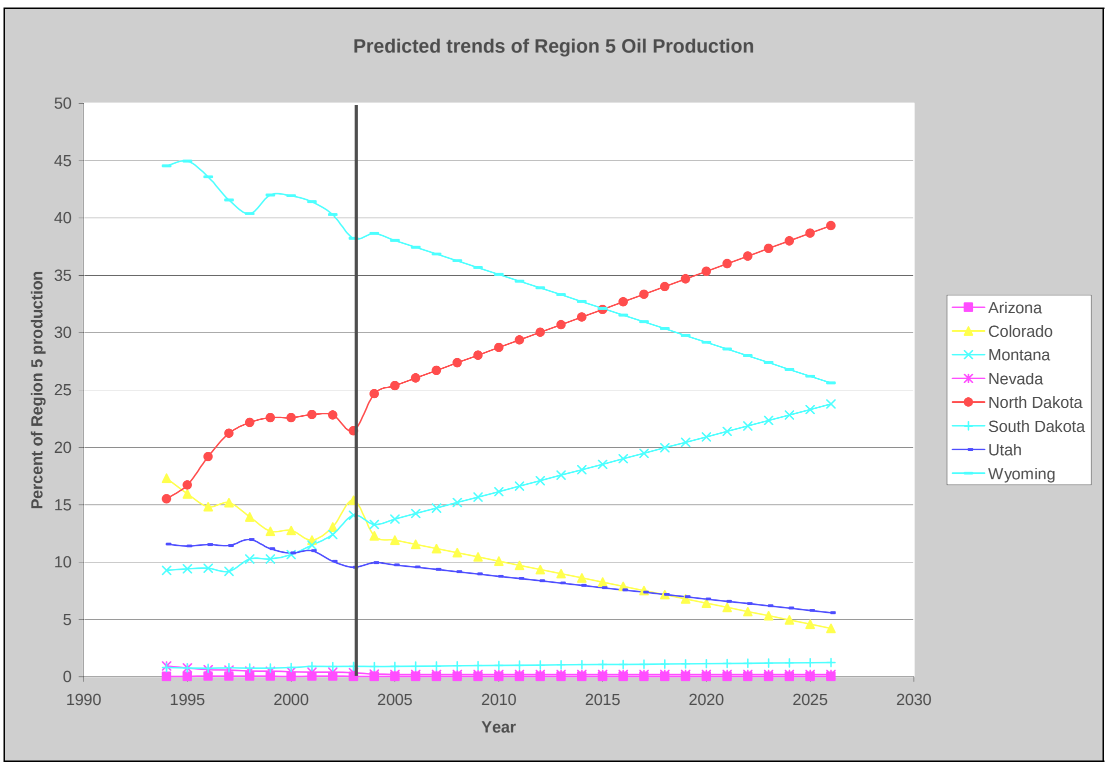


Figure 5-2 Percent of Rocky Mountain Region Production in Member States, History + Forecast

This analysis was performed for each of the six supply regions and separately for oil and natural gas. Figure 5-2 shows an example of historical and predicted percentage of region 5 (Rocky Mountain) oil production for the 8 states located in the region. It is observed in this example that Wyoming's oil production trended downward over the last 10 years from about 45% of the region total to about 38%. Linear projection of this trend to year 2025 says that Wyoming will be producing about 25% of the regions oil in that year. At the same time North Dakota's contribution went from about 15% of the region's production to about 22% during the historical period. Linear projection of this trend to 2025 suggests that North Dakota's percentage of the region's production will increase even further.

With an estimate of future oil and natural production in each state provided by application of the projected percentage of regional production to the 2005 AEO regional estimates, the next step is to forecast the volume of marginal production in each state. Using IOGCC state historical marginal production along with historical total state production, the fraction of total production which is marginal for each year of the history was calculated. Plotting this marginal to total ratio over time showed that in most cases this ratio follows a linear trend. Linear regression of this data to project forward into the future is considered a viable means of estimating the future trend of this data.

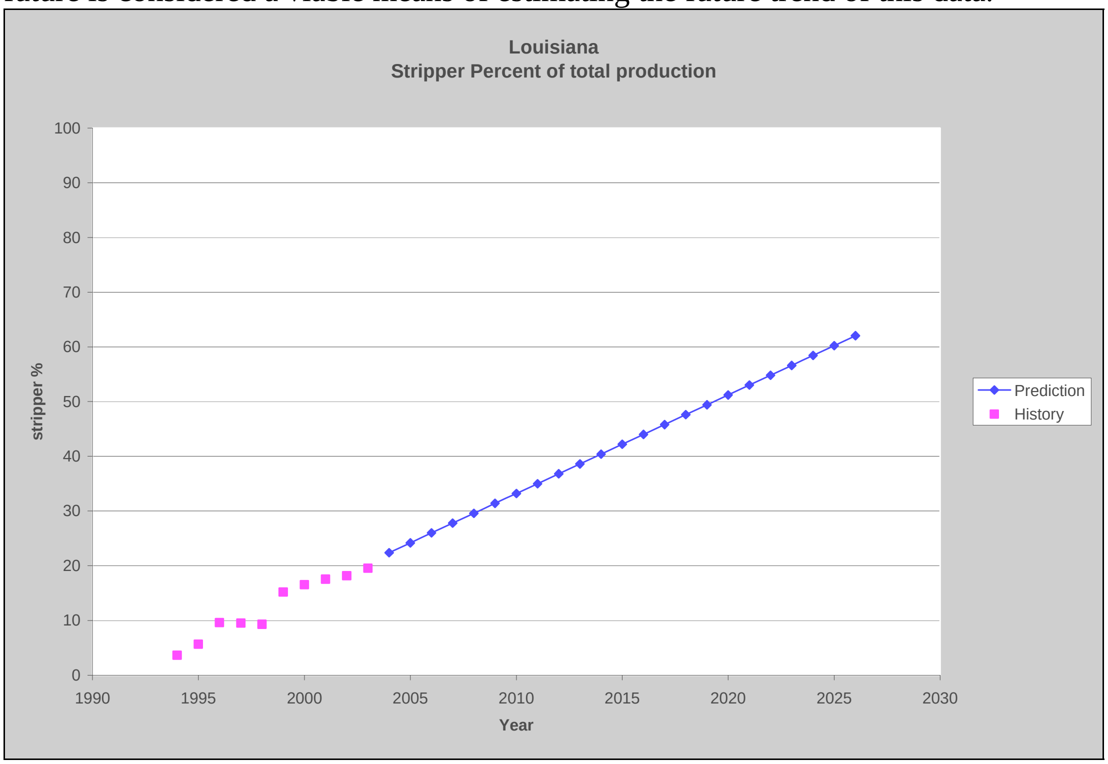


Figure 5-3 Louisiana Stripper Percent of Total Production, History + Forecast

This regression was performed for each state and for each product, oil and natural gas. Figure 5-3 shows an example of this regression performed for oil production in the state of Louisiana. This is an example where the stripper percentage of Louisiana's oil production has gone from about 3% to 20% over the 10 years of historical production. Regression of this data and extrapolation if the resulting linear equation to 2025 suggests that a majority percentage of Louisiana's oil production will be from wells producing less than 10 barrels per day at this time.

The next challenge is to somehow translate the future forecasts of marginal production obtained from the first two regressions into a forecast of stripper well count. Using IOGCC data for state historical marginal well count and state marginal production, it was possible to calculate historical marginal well rate for each state and each product, oil and natural gas. Once again the majority of these plots tended to show a trend of either decreasing or increasing marginal well rate with time.

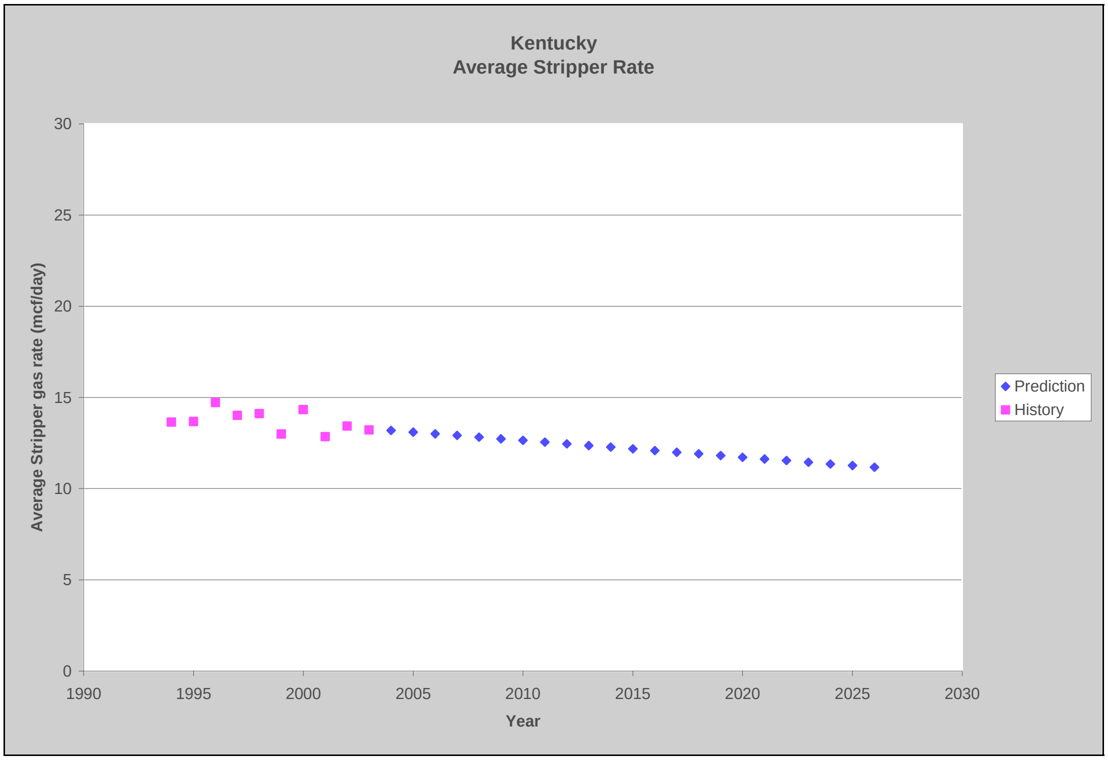


Figure 5-4 Kentucky Average Stripper Rate, History + Forecast

A linear regression fit was applied to the data in order to estimate a linear function for determining future average stripper well rates for each state. Figure 5-4 shows the regression fit for marginal natural production in the state of Kentucky. Average marginal well rate is decreasing in a trend that will reach about 11 Mcf/day in year 2025, down from the current average rate of about 13 Mcf/day.

Now that there is an estimate of marginal production for all forecast years from the second regression and an estimate of average marginal rate from the third set of regressions, the estimated number of marginal wells is simply a matter of dividing the marginal production by the average marginal rate. This approach estimates both marginal production and well count, is directly tied into 2005 AEO projections, and uses historical numbers from IOGCC's marginal well reports as a primary source of data. This algorithm is summarized in the following sequence of steps.

Generation of State Marginal Wells Forecast Based on 2005 AEO

1. Acquire historical oil and natural gas total production data for each state for years 1994-2003. The sources of data used which seem to match up well with AEO forecasts were the EIA publications *Natural Gas Annual* and the *Petroleum Supply Annual*.

2. For the years 1994-2003, divide the annual state total production acquired in step 1 by the annual region total production for the region containing the state in order to determine the fraction of regional production produced annually by the state.

3. Regress the year vs. fraction of region production data to derive a linear function for forecasting future fraction of regional production produced by the state.

4. Calculate the future total production forecasts for the state by multiplying the 2005 AEO annual supply region production forecast by the forecast fraction of regional production produced by the state

5. Divide IOGCC marginal well production data by the data acquired in step 1 in order to come up with an annual ratio of marginal well production to total production for both oil and natural gas in the state.

6. Regress the year vs. stripper well ratio data to derive a linear function for forecasting future ratios of marginal production to total production. Multiply these forecast ratios by total production forecasts of step 4 to come up with a forecast of marginal production.

7. Using marginal production and well count data for years 1994-2003 from IOGCC marginal well reports calculate historical annual average stripper production rates for the state.

8. Regress the year vs. historical average stripper production rate data to derive a linear function for forecasting future average stripper production rates.

9. For each year of the forecast, divide the marginal production forecast of step 6 by the predicted average stripper production rate from step 8 to determine the marginal well count forecast.

5.2 Limitations of Current method

The method presented in chapter 5.1 has some limitations which the reader must keep in mind when using the results. The most important thing to remember is that the forecast generated by this method is not guaranteed to correctly replicate future marginal well data. The results represent a scenario which may happen if current trends should continue into the future. The forecasting method used is a “trend” analysis. It is simply a progression of past trends relating to marginal well production and does not incorporate any major new oil discoveries or changes in the oil and natural gas markets which might significantly change the relative amount of stripper to non-stripper production. Since most changes do not happen rapidly, as can be seen by observing plots of the 10 years of historical data, it is likely that the early year projections will give an accurate representation of production and well count. This is verified to some degree by the history match performed on this data which is discussed in the next chapter. What happens later on depends on how much future trends deviate from those seen in the last ten years.

Another important point is that the ratio of marginal to total production projected by this approach does not change with forecast product price. For example, if the AEO included a new run assuming lower oil and natural prices and the total oil and natural gas forecast was cut in half, the amount of marginal production might be expected to be cut in half also. One may expect the marginal production to be less than half of its previous value because the marginal production would probably be shut in first. However, if you look at historical product price and marginal well count data, there is not an obvious connection between marginal production and product prices. This indicates that the lack of product price sensitivity displayed by the forecasting methodology is not a major problem. Figures 5-5 and 5-6 display historical and AEO projected oil and natural gas prices respectively. The prices are compared to the historical and projected well count data. These figures show that in general the marginal well counts do not respond to the up and down nature of the product prices during the ten year historical data period. Apparently price changes must be maintained for a longer period of time to have effect. Notice that the AEO forecast prices do not change rapidly in either direction.

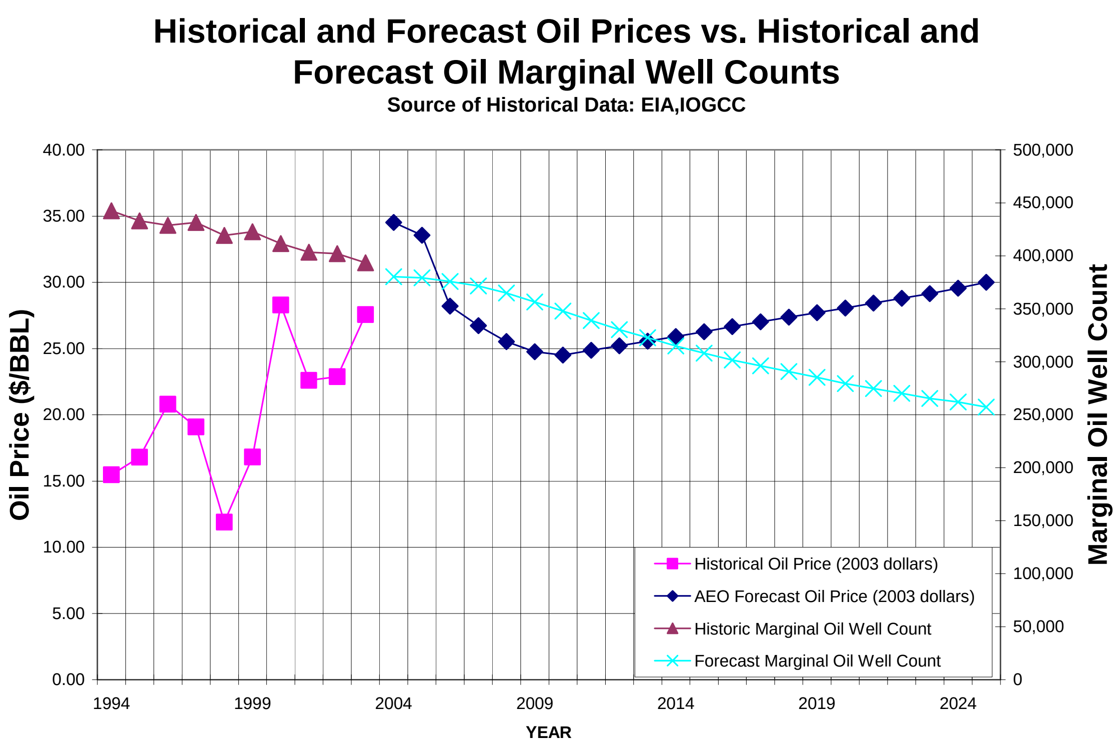


Figure 5-5 Oil Prices vs. Marginal Oil Well Count, History + Forecast

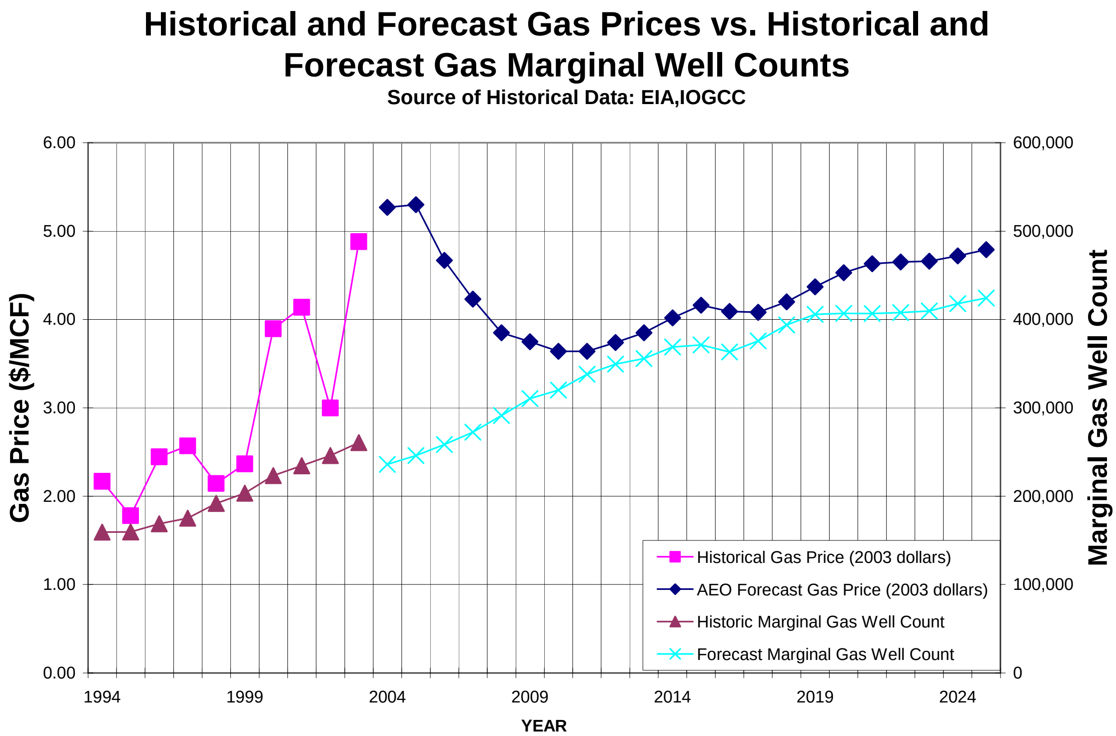


Figure 5-6 Natural Gas Prices vs. Marginal Natural Gas Well Count, History + Forecast

6 History Match

As a test of the method for forecasting marginal production and well count which was introduced in the previous chapter, a history match was performed on two years of historical data. The goal of this test was to validate the methodology used and to confirm the accuracy of forecasts using the linear regression approach.
This section describes the approach used to perform the history match and presents the highlights of the results.

As mentioned previously, historical data for marginal well production and well count was acquired from the IOGCC for years 1994-2003. The 2005 AEO report contains total production forecasts for years 2004-2025. Historical results are also given in the AEO report for year 2003. Using this data, a history match was performed in the following manner.

Approach for Performing History Match

1. For total production forecasts, use historical data for 2002, for 2003-2025 use 2005 AEO projections.

2. For each state, apply regression methodology to historical IOGCC data from 1994-2001 along with total production data from 1994-2001 to generate linear functions for predicting fraction of regional production, percent marginal production, and average marginal rate as described in section 5-2.

3. Use the equations developed in step 2 to estimate total production, marginal production, and marginal well count for the years 2002 and 2003.

4. Compare the forecasts made for years 2002 and 2003 to the actual data published by IOGCC for these two years.

The history match was performed strictly as a test of the regression method and as part of this test the results of these regressions were not subject to the “quality assurance” step of the procedure which is always applied when making actual forecasts. The “quality assurance” procedure looks for and addresses inconsistencies in data and results, and will be detailed in the next chapter of the report.

The remainder of this chapter presents national level history match results for both oil and natural gas. These results are displayed in Figures 6-1 through 6-4. Results for the national level match were very good with annual oil production forecasts within 2% of actual historical values and natural gas production forecasts within 5% of actual historical values. Annual marginal well count forecasts were within 3.5% of actual historical values for both oil and natural gas.

Appendix C contains graphical results of both marginal production and marginal well count history matches for each of the six supply regions. Tabular history match results are also presented for each of the oil and natural gas producing states as Appendix D.

6.1 Lower 48 history match results

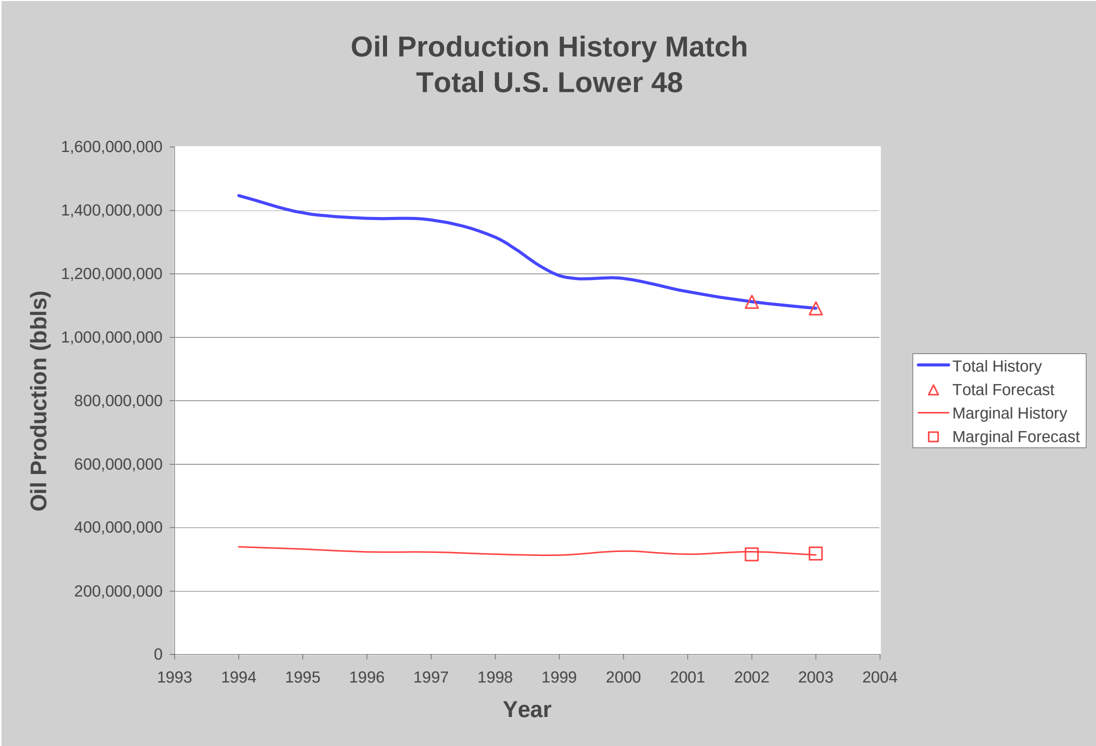


Figure 6-1 Onshore Lower 48 Marginal Oil Production History Match

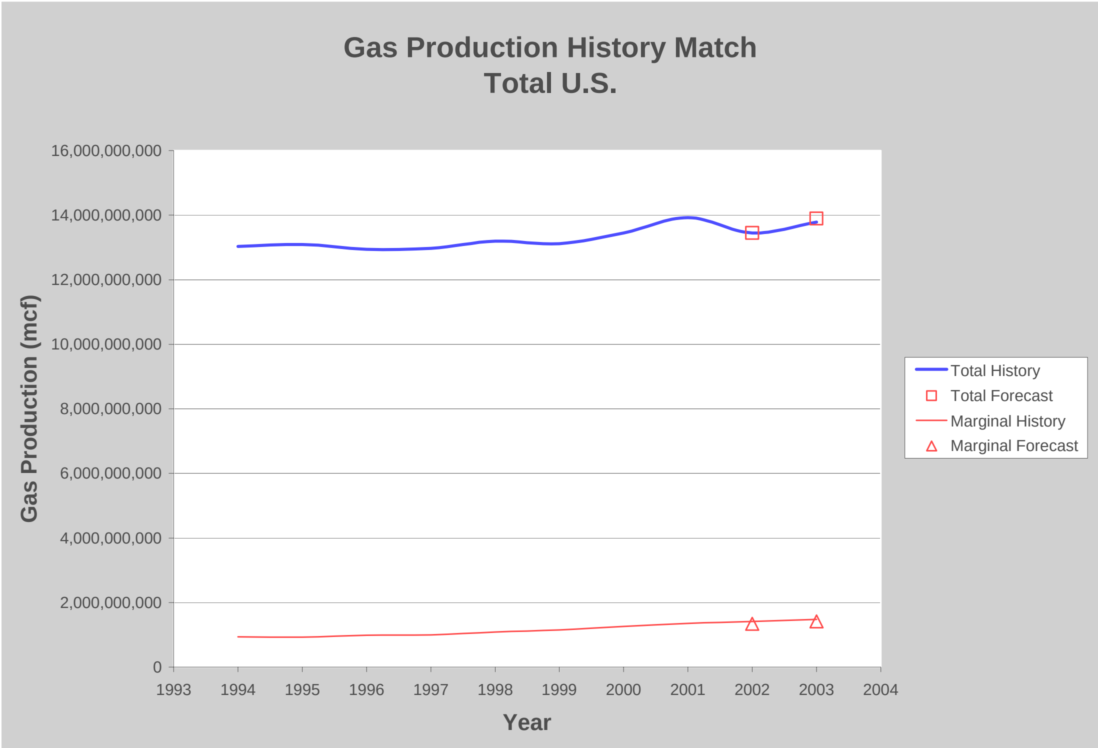


Figure 6-2 Onshore Lower 48 Marginal Natural Gas Production History Match

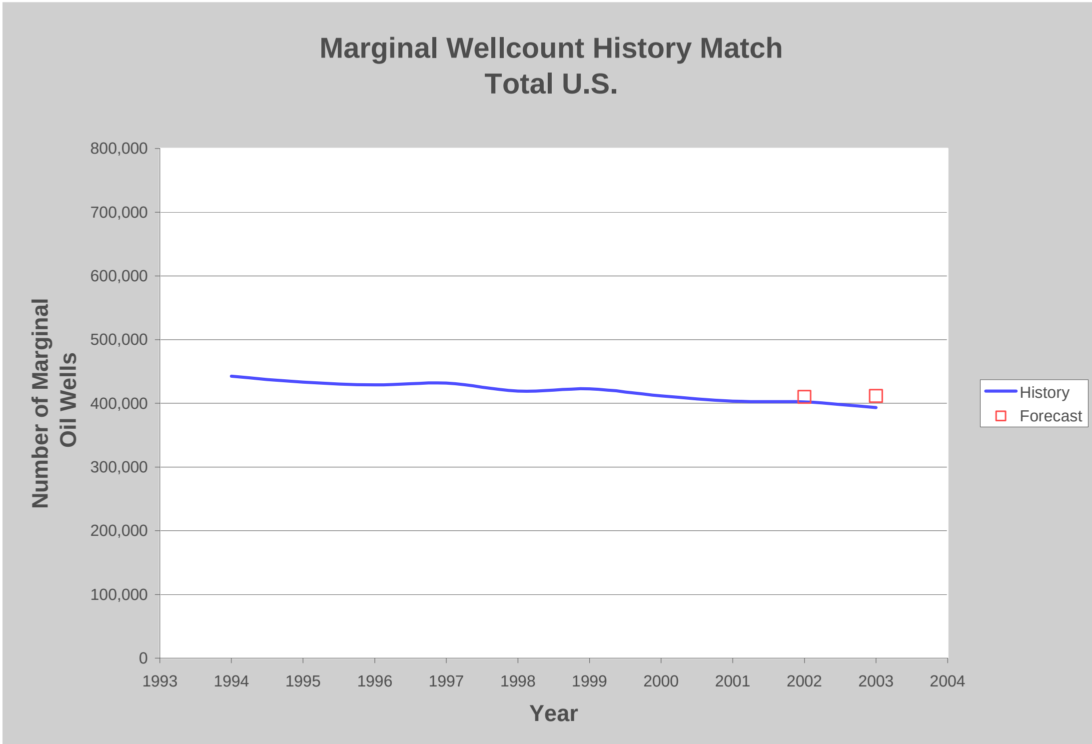


Figure 6-3 Onshore Lower 48 Marginal Oil Well Count History Match

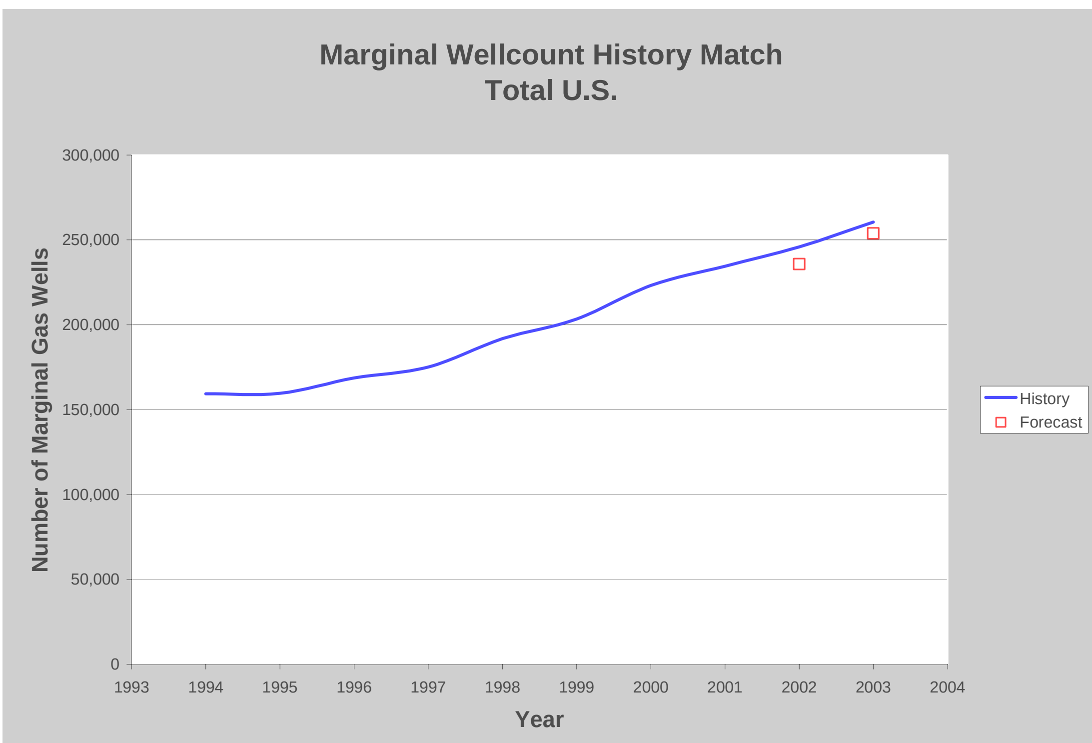


Figure 6-4 Onshore Lower 48 Marginal Gas Well Count History Match

7 Marginal Well Forecasts

After qualifying the forecasting methodology by performing a history match comparison on two years of historical data as described in the previous chapter, the next step was to re-apply the methodology to all 10 years of historical data in order to base the final forecasts on the most complete set of data possible. After performing the regression analysis, a "quality assurance" procedure was applied to the results resulting in some modifications to the equations created by the linear regression. In this chapter the "quality assurance" procedure will be explained and some examples of modifications made as a result of this check will be discussed. The final forecasts made using this methodology are presented as the Appendix of the report.

One modification to the linear regression results was applied automatically in all cases. This modification involves setting a lower limit to the average stripper rate equation. During the history match procedure, it was noted that forecasts created for several of the states showed abnormally large increases in the number of marginal wells over a very short period of time. This anomaly was determined to result from lack of a reasonable lower limit for the forecast of marginal well rate. Suppose, for example, that the best regression fit for a set of state average stripper rate vs. year data has a slope of -2 bbl/day/year. If the current average stripper rate is 10 bbl/day and the stripper production is expected to remain constant, we would expect a 25% increase in the number of stripper wells. This is because the number of wells is calculated by dividing the expected production by the average stripper rate. Three years down the road when average stripper rate is 4 bbl/day, the number of stripper wells will increase 100% that year as the average production rate goes from 4 bbl/day to 2 bbl/day. As the marginal rate numbers get smaller and smaller the calculated number of marginal wells becomes extremely large. This is avoided by setting a reasonable lower production limit to the calculated average stripper rate. This is a reasonable assumption as all wells have some economic limit of production below which the well will be shut in. The problem is that we have no way of knowing this exact limit for a given state. Each state's marginal well population is comprised of many different types of marginal wells operated by many different types of operators. Rates of 1 bbl/day for oil and 6 Mcf/day for natural gas were selected as lower limits for the purpose of marginal well forecasting. Several states in the Northeast region have average stripper well rates already below this level. In most of these states the rates seem to be fairly constant and have been for the last 10 years. The approach taken in these cases was to assume a constant stripper well rate for the forecast period equal to the current year stripper rate. The addition of these rules to the regression methodology helped increase the "soundness" of the marginal well forecasting.

7.1 Quality Assurance Procedure

Due to various data anomalies, it was known from the beginning that some of the marginal well count projections from the regression analysis would be unreasonable when compared to the total number of existing wells and the future drilling projections for the region. The method used to adjust for this behavior was to derive an estimate for the “maximum” oil and natural gas wells existing in a given state at any time during the forecast period. In cases where the forecast number of marginal wells exceeded the estimated maximum number of wells in a state, the historical data were carefully scrutinized to see if there was a logical explanation which would result in an assumption which would give more reasonable results.

The most reliable source of data for total number of wells came from sources within EIA. Totals for 2004 oil producing wells were acquired from EIA’s state petroleum profile data. For natural gas, the most recent well count data found was from the *Natural Gas Annual* publication. Forecasts for successful wells drilled in the future came directly from the 2005 AEO. These were reported on an annual basis by supply region. A method was developed to pro-rate this drilling forecast from the supply region to the individual state using 2001 drilling data reported by the IPAA in the state level data section of their website. The pro-rata method was to assume that regional drilling would continue in the same proportions by state for all years into the future. The combination of these data sources allowed an estimate of all new and existing wells within a given state for all years into the future. This number was then reduced by the average well abandonment count per year for that state. The average well abandonment number was determined by averaging abandonment data for years 1998, 1999, and 2003. In this manner data were developed allowing comparisons of historical and predicted marginal well counts with projections of future “possible” well activity based on the “quality assurance” methodology described.

7.2 Sample Quality Assurance Modifications

The types of modifications made to the original regression analysis by the “quality assurance” procedure can be illustrated using a couple of actual examples.

7.2.1 New York Marginal Natural Gas Forecasts

Figure 7.1 presents a plot generated as part of the quality assurance for natural gas marginal well count forecasts. This plot shows historical marginal well count from 1994 through 2003. Also shown are estimates for total wells from 2004 through 2025. Remember that these estimates were derived by adding the 2005 AEO projections for year 2004 to 2025 successful natural gas well drilling to the 2004 value of total wells from the *Natural Gas Annual.* A total of 22 wells per year were subtracted from these projections to represent the average New York natural gas well abandonment rate. The original regression forecast of marginal natural gas well count is also displayed and shows a trend which deviates from the behavior of the historical well count data. In 2003 there was a historical report of 5,723 marginal wells out of a total of 5,878 total natural gas wells in New York. That means that over 97% of the natural gas wells in New York are stripper. The original forecast based on the regression of 10 years of data projects that the number of marginal wells will drop precipitously and fall to zero by 2010. Meanwhile the total number of wells is estimated to increase by almost 100 wells per year.

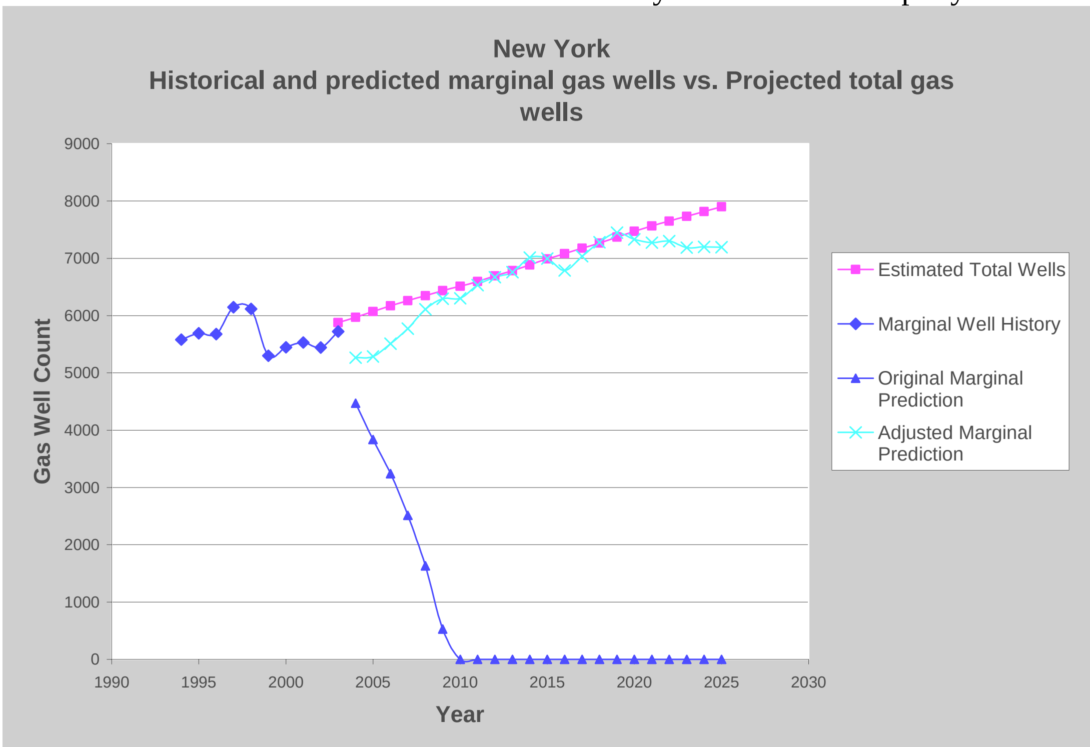


Figure 7-1 New York Marginal Natural Gas Well Count vs. Forecast Total Natural Gas Well Count

This behavior points to some type of anomaly with some of the historical data involved in the three regression analyses which make up the marginal well forecasting algorithm. The purpose of the "quality assurance" procedure is to identify this problem and come up with a reasonable solution.

Examination of the regression analysis for percentage of New York natural gas production which is stripper (Figure 7-2) exposes the problem with this forecast. Notice that for the first 5 years of history, the percentage of New York natural gas production which is stripper averages around 75 percent. Over the next 3 years, this percentage drops all of the way down to about 30 percent where it seems to have stabilized. Closer examination reveals that this behavior is due to the discovery in year 2000 of the Trenton-Black River deep gas play. New York was able to double natural gas production with the addition of only 20 new wells. Since the nature of natural gas production was so drastically changed by these discoveries, it is reasonable to disregard the 10 years of history and come up with an alternate method of forecasting future stripper percent of total natural gas production in New York.

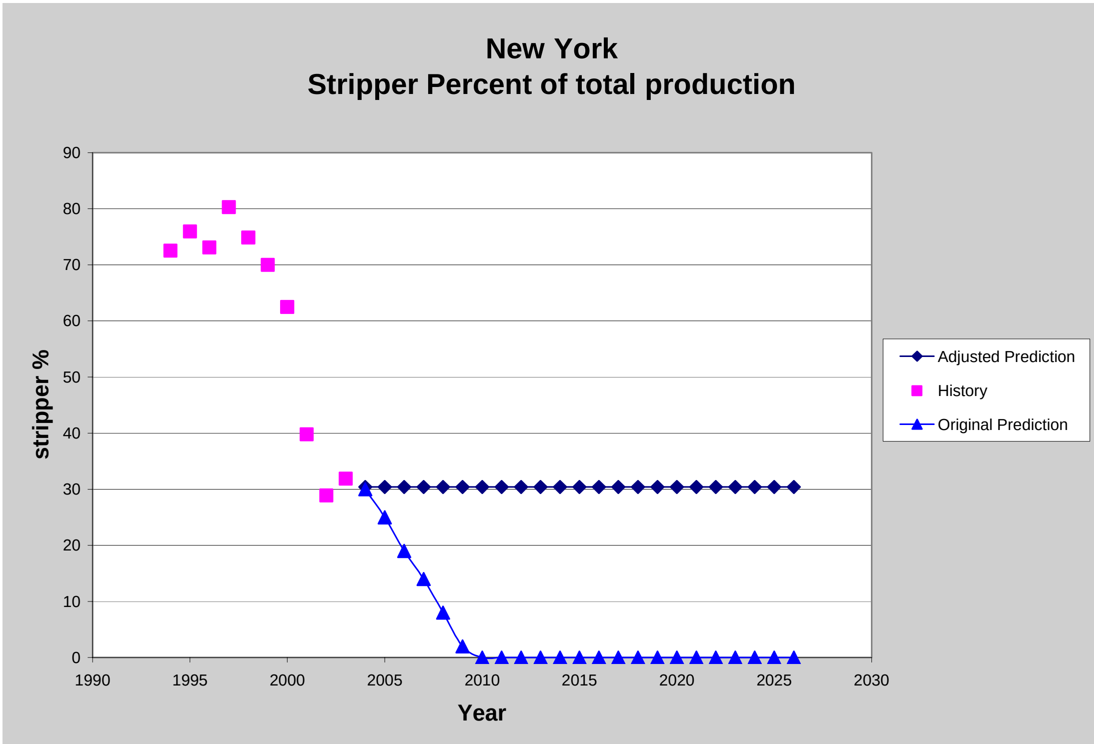


Figure 7-2 New York Stripper Percent of Total Production (Original and Adjusted)

Figure 7-2 shows the new function for percent of New York natural gas production which is stripper. The decision was made to hold the percentage of production which is stripper constant at 30.38 percent which is the average of the last two data points. It was determined that this was an accurate representation of the future and would result in a more reasonable forecast of natural gas marginal wells than regressing all of the data which results in a very steep decline of stripper percentage into the future even though the percentage seems to have stabilized to some degree in the years after the discovery of the prolific gas trend.

After performing this modification to the forecast equation for percentage of New York production which is stripper, the forecast for number of marginal wells is recalculated. The results can be seen in Figure 7-1. Based on the historical numbers of marginal wells and the historical abandonment rate, the new forecast of marginal natural gas wells seems to reflect a plausible scenario.

7.2.2 Utah Marginal Oil Forecasts

A similar type of problem was observed in making marginal oil well forecasts for the state of Utah. Figure 7-3 shows the original marginal well count forecasts compared to the estimated number of total wells.

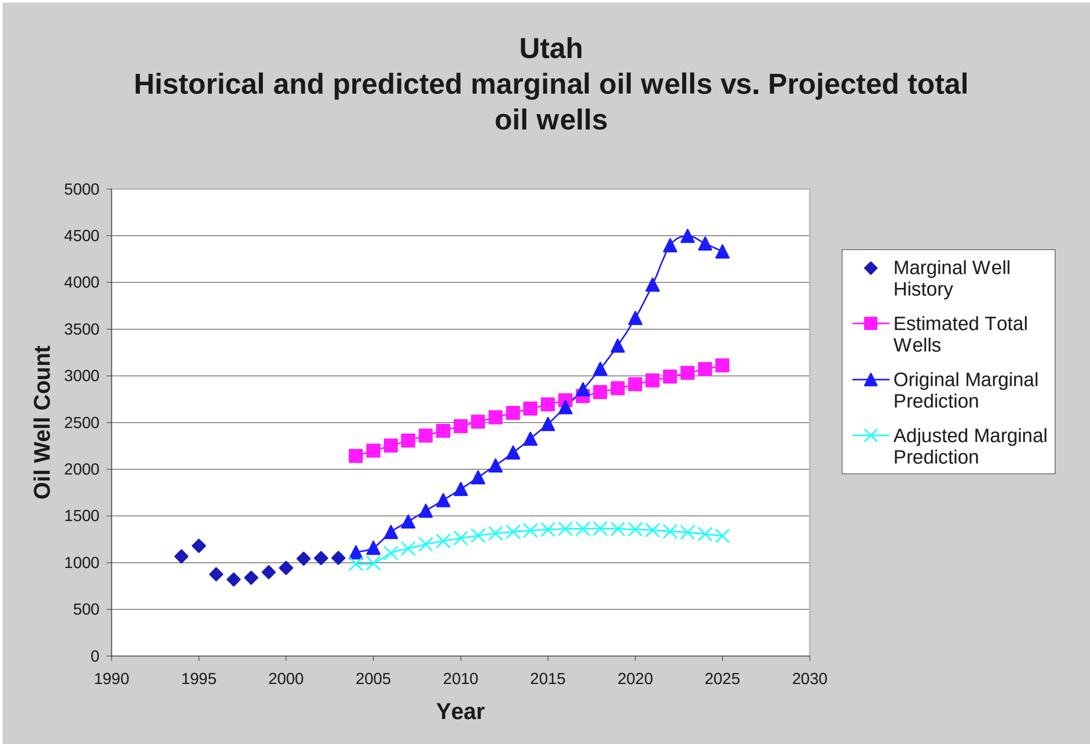


Figure 7-3 Utah Marginal Oil Well Count vs. Forecast Total Oil Well Count

The original forecast of marginal well count is not reasonable when comparing to historical marginal well count. During the historical time frame the number of marginal wells stayed fairly constant at about 1000. The forecast shows this number increasing about 100 wells per year. It is the function of the "quality assurance" procedure to decide if this forecast behavior is justified. Figure 7-3 shows that this increase could not be justified by the estimated number of total wells for the state of Utah. Historically, less than half of the oil wells in Utah were marginal. All of a sudden the marginal forecast actually surpassed the estimated number of wells around 2017 and continued rising steadily. The quality assurance procedure required that the regression analyses be carefully examined to see if anything in the data appeared to be causing a problem. Examination showed that the average oil stripper rate regression (Figure 7-4) appeared to be skewed by a data anomaly in the first two years of historical production. Due to the abnormally high value of the 1994 data point, the regression fit predicted a rather steep decline in average stripper production rate which has not been observed in the remaining years of history.

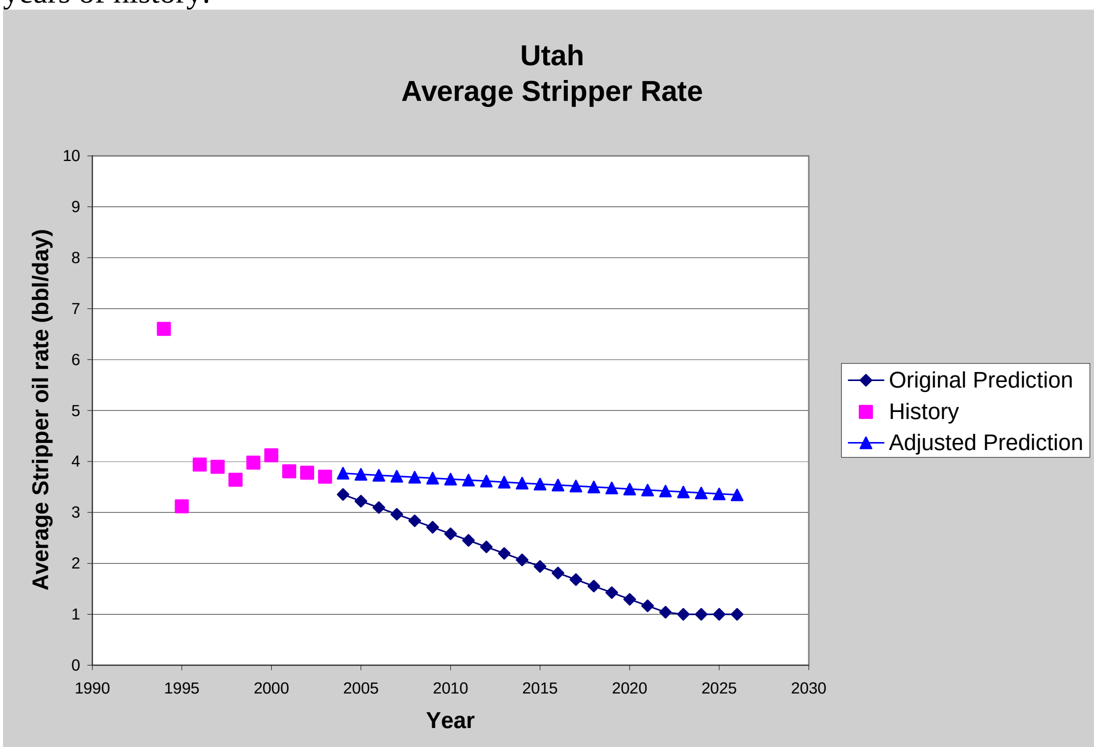


Figure 7-4 Utah Average Stripper Rate (Original + Adjusted)

In order to address this anomaly, the regression analysis was re-run after removing the first two anomalous years of data. The new regression fit is also displayed in Figure 7-4. When the new average stripper rate regression formula is used to make forecasts of marginal well counts, the results seem to follow what has been historically happening in Utah. These results are displayed in Figure 7-3.

7.2.3 New Mexico Marginal Oil Forecasts

This marginal oil well count forecast for New Mexico is presented as an example of a case in which no anomalies were observed during the "quality assurance" procedure and the regression forecast is accepted with no modifications. Figures 7-5 through 7-7 show results of the three regression analyses performed to determine future forecasts of marginal oil production and marginal well count. Figure 7-5 shows the projection of fraction of region 4 production. Texas and New Mexico share Region 4 production. New Mexico appears to gaining an increased fraction of the region's oil production over time while Texas is losing its share. Both seem to follow a linear trend. Figure 7-6 shows a regression fit on the percentage of New Mexico oil production which is stripper. Again we see a linear trend over the 10 years of history. The same applies for New Mexico average oil stripper rate which is displayed in Figure 7-7. After reviewing these trends, there is little problem with accepting the projections displayed in Figure 7-8, especially since the marginal well projections fall well below the estimated total number of oil wells in New Mexico.

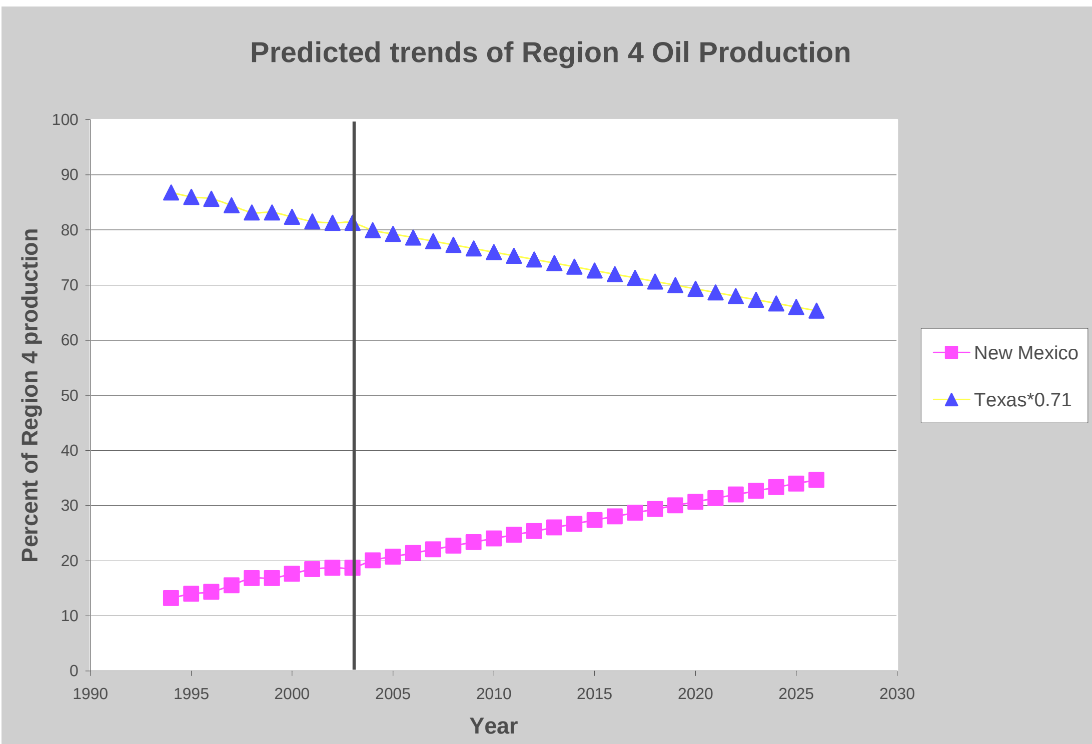


Figure 7-5 Percent of Southwest Region Production in Member States (History + Forecast) Note: Texas*071 in the legend refers to fact that 71% of Texas production is in region 4.

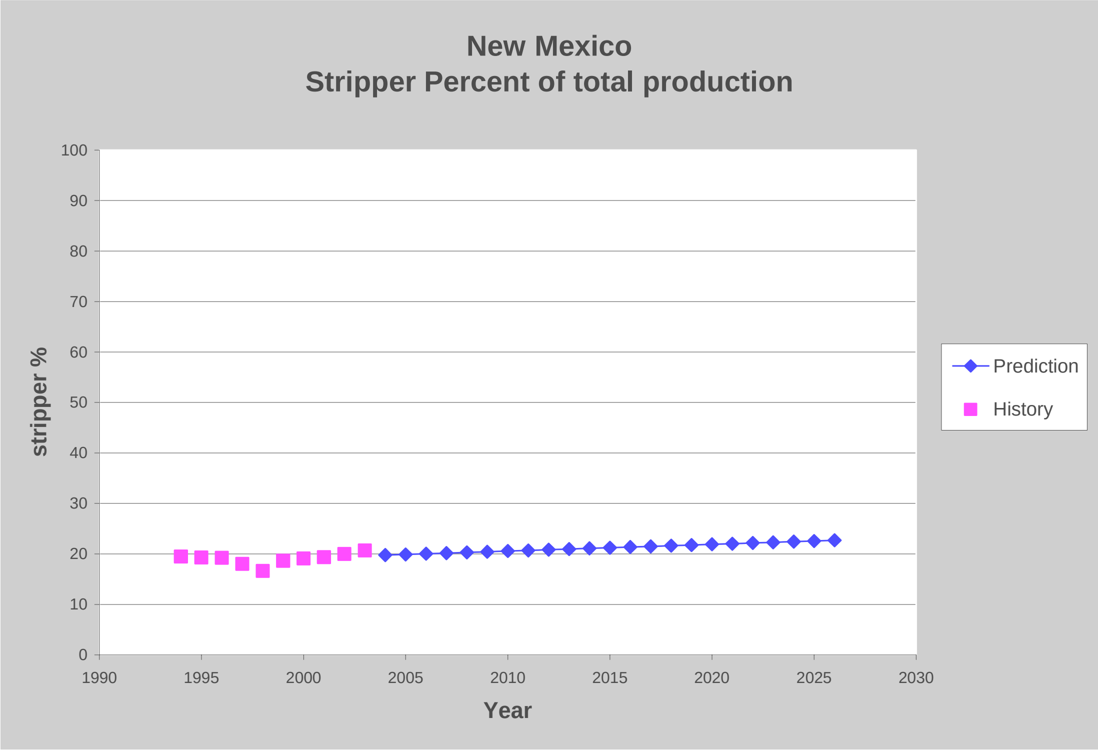


Figure 7-6 New Mexico Stripper Percent of Total Production (History + Forecast)

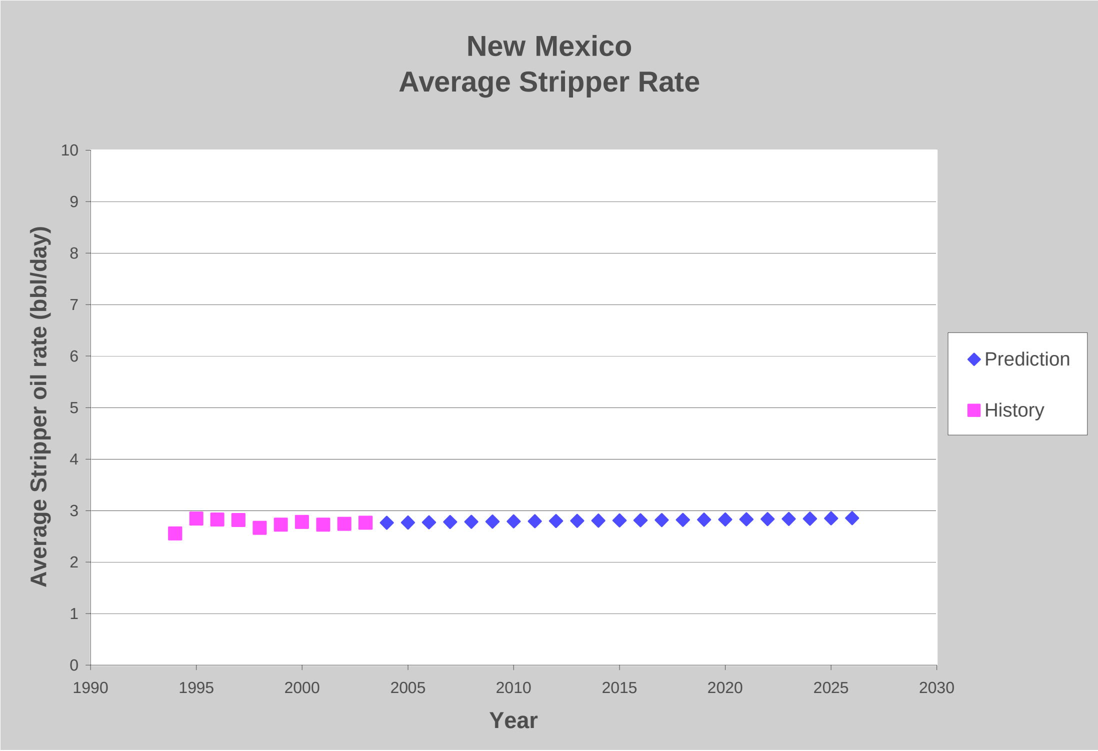


Figure 7-7 New Mexico Average Stripper Rate (History + Forecast)

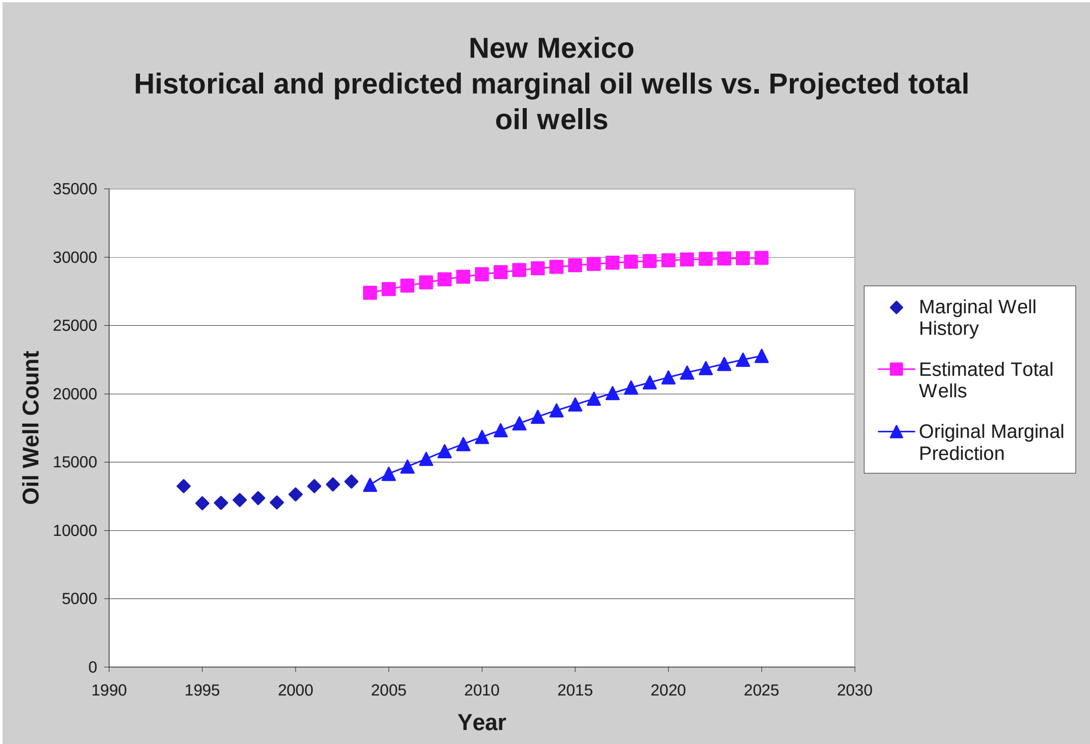


Figure 7-8 New Mexico Marginal Oil Wells vs. Forecast Total Oil Wells

8 Conclusions and Recommendations

Figures 1-1 and 1-2 graphically present the forecasts of marginal oil and marginal natural gas production generated by the regression methodology. These are forecasts of marginal production for the entire onshore lower 48. Figure 1-3 presents onshore lower 48 forecasts of marginal well count for both oil and natural gas. These same forecasts also are presented as Appendix E. The regional level [AEO supply region] forecasts are presented in Appendix F.

A series of summary graphs are presented in this chapter in order to aid the reader in making observations involving the forecasts which were generated. Figure 8-1 uses bar graphs for each of the AEO supply regions to represent the percentage of lower 48 marginal production produced in each of the regions for three separate years (2003, 2015, and 2025). Both oil and natural gas production are shown on the same plot (solid green bars represent oil and red cross-hatched bars represent natural gas). Figure 8-2 is plotted in exactly the same format except that it represents marginal well counts instead of production. The plots show that over time an increasing share of marginal production and well count is forecast from the western regions and a decreasing share is forecast from the eastern regions.

It is forecast that marginal oil production and well counts will decline in all but a couple of states like Wyoming and New Mexico. The majority of marginal production and well count is forecast to remain in Midwestern states like Texas, Oklahoma, and Kansas.

These graphs show generally increasing marginal natural gas production and well count with time throughout almost all of the states. Exceptionally large increases in marginal natural gas production and well count are noted in Wyoming, Colorado, Oklahoma, Texas, and Michigan. The forecast shows large increases in marginal natural gas wells for the states of Pennsylvania and West Virginia without a correspondingly large increase in marginal natural gas production due to the very low average rates of these wells.

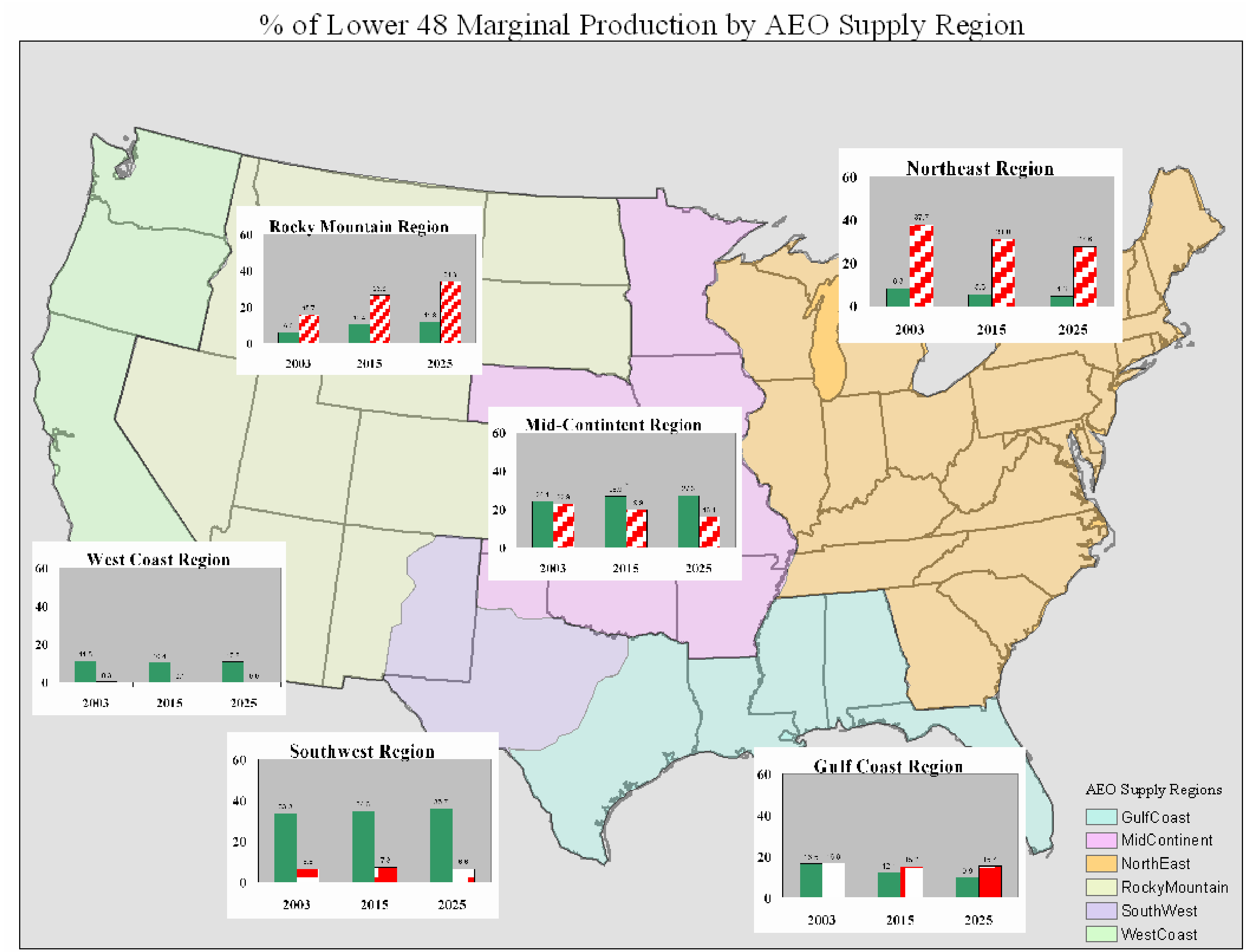


Figure 8-1 Percent Onshore Lower 48 Marginal Production by AEO Supply Region

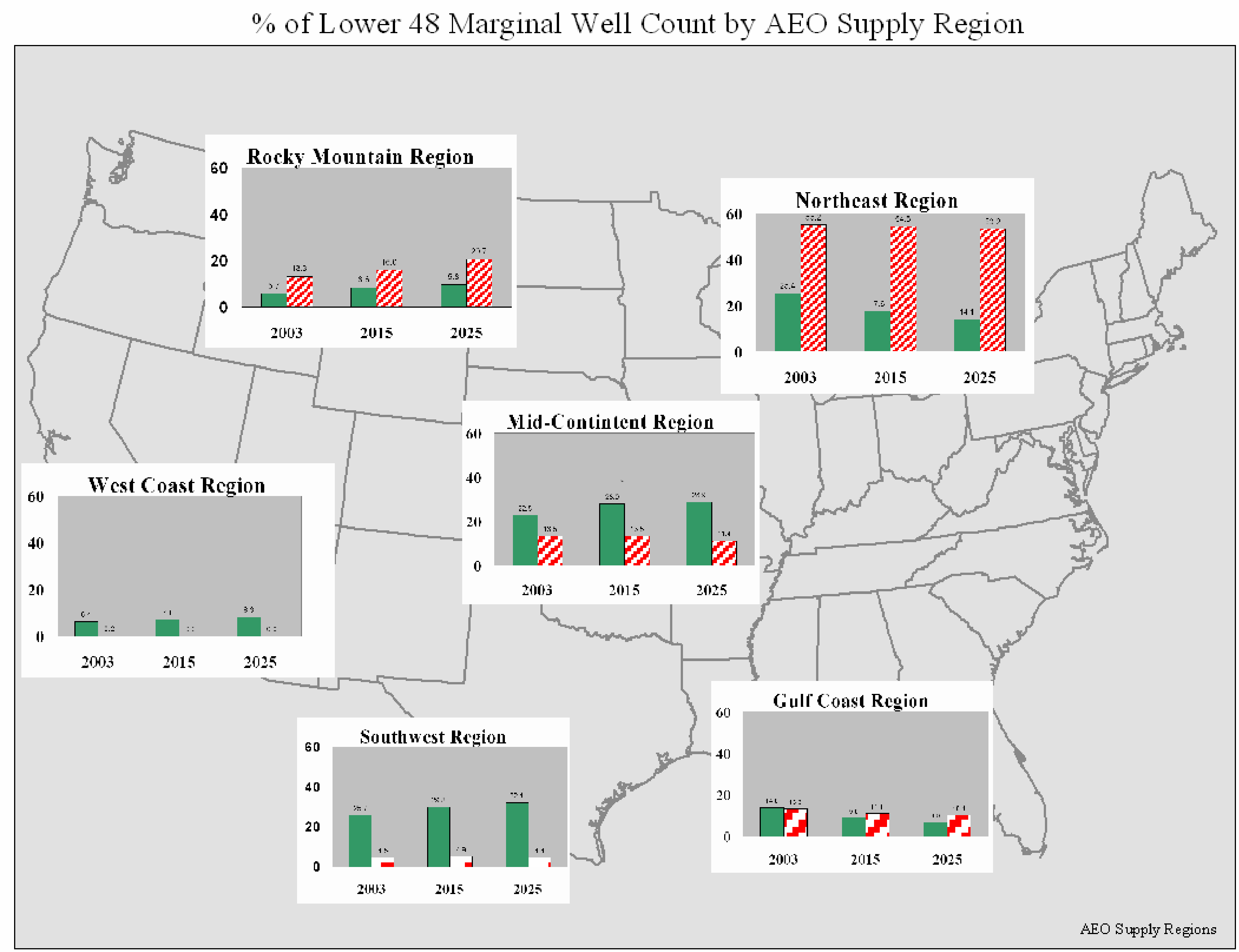


Figure 8-2 Percent Onshore Lower 48 Marginal Well Count by AEO Supply Region

Based on the analysis described herein, the following may be concluded:

1. Near term forecasts using the method are reasonable for their intended application A history match was performed in order to estimate marginal production and marginal well count for years 2002 and 2003. These estimates were then compared to the actual historical results. The national results turned out very close with the production matching historical production within 2.0% for oil and 4.7% for natural gas each year on average. The well count was within 3.3% each year on average for both oil and natural gas. These comparisons were based on a test which used straight regression results without any attempt to improve the forecasts using the "quality assurance" procedure specified in this report. The actual forecasts are expected to be much better as some of the problems due to anomalous data are corrected by the procedure.

2. Importance of natural gas marginal wells will increase while that of oil marginal wells will decrease over time – At the start of 2004 there were about 393,000 marginal oil wells and about 260,00 marginal natural gas wells. According to the forecasts made using this methodology, the number of marginal oil wells will continue to steadily decline due to increasing abandonment while the number of marginal natural gas wells will steadily increase due to increased natural gas well drilling. The number of natural gas stripper wells will surpass the number of oil stripper wells sometime around 2011. By 2025 the number of natural gas stripper wells will be about 1-1/2 times the number of stripper oil wells. In the absence of significant technological breakthroughs, this fact is not likely to change much as the oil resource is very mature and has been in a fairly steady decline for several decades.

3. Stripper Fraction of Production will continue to increase for both oil and natural gas – According to the model results, the percentage of oil production which is stripper will increase from about 28% of production today to about 32 % in 2025. Stripper natural gas wells are forecast to produce over 17% of total natural gas production in 2025. This is up significantly from the 11% of production today.

4. Focus of Marginal Oil wells to shift more and more to the central and western regions over time – Currently, about 40% of the marginal oil wells are located in the Northeast and Gulf Coast regions. By 2025 the model forecasts that only 21% of marginal oil wells will be located in these two regions. The four western supply regions mid-continent, southwest, rocky mountain, and west coast will all increase their relative fraction of the total number of stripper wells with the largest increases coming in the southwest (Permian basin) and the mid-continent regions. The southwest region will increase its share from 25.7% to 32.1% of oil stripper wells in the lower 48 states while the mid-continent region will go from 22.8% to 28.9%. All of the regions are forecast to suffer large decreases in the number of marginal oil wells with the exception of the rocky mountain region in

which the number of stripper wells is projected to increase about 12% over the next 20 years.

5. <u>Expect significant increases in marginal natural gas wells in Rocky Mountain region</u> – At this time, the Northeast region is home to about 55% of all lower 48 natural gas stripper wells. The west coast has a negligible number of natural gas stripper wells; the Permian basin contains about 4% of all natural gas strippers while the remaining three regions each contain about 13.5% of the lower 48 natural gas stripper wells. According to the model, by 2025 the Rocky Mountain region will have about 21% of all natural gas stripper wells. This can be attributed to a large amount of drilling for unconventional natural gas expected in this region. The model is forecasting about a three fold increase in the number of natural gas strippers in this region. The remaining regions will all have a reduced share of the total number of natural gas stripper wells in the U.S lower 48. The Northeast region will fall to about 53% of the total share. In 2025 it is expected that 74% of all natural gas stripper wells will be found in either the Northeast or Rocky Mountain regions. With the exception of the West Coast region, all of the natural gas supply regions are expected to have large increases in the number of marginal wells over the next 20 years.

6. <u>A consistent method of predicting marginal production and well data has been developed and implemented</u> – A method for predicting future marginal oil and natural gas production as well as future marginal well counts has been developed. The method is a simple "trend analysis" which relies on linear regression of historical data. The method is directly tied to historical data from the IOGCC annual publication *Marginal Oil and Gas: Fuel for Economic Growth* and future forecasts of oil and natural gas production from the EIA publication *The Annual Energy Outlook (AEO)*. An updated forecast of marginal production and well count could easily be generated each year as annual updates are made available to these data sources.

It is recommended that any future effort spent to improve these forecasts be directed towards more detailed analysis of stripper natural gas production in the Northeast and Rocky Mountain regions. These two areas appear to be in the greatest state of flux as far as natural gas production is concerned over the last few years. Improvements in the accuracy of the forecast could be made by developing a greater and more detailed understanding of precisely when and where drilling is likely to occur in these regions. Based on the forecasts of this model, by 2025 the majority of stripper wells in the lower 48 states will be natural gas wells located in these two regions.

Alternatively, if the desire should be to focus attention on marginal wells in greatest danger of abandonment, stripper oil wells in the Northeast and Gulf Coast regions would be the primary focus according to the results of this analysis. Stripper wells in the Northeast region are especially at risk because most of the stripper wells in this region produce at a fraction of a barrel of oil per day, most of the wells in the region are stripper, and the AEO forecast predicts strong declines in oil production in these regions.

Bibliography

1. Energy Information Administration, “Annual Energy Outlook 2005 – With Projections to 2025”, February, 2005.
2. Interstate Oil and Gas Compact Commission, “Investments in Energy Security, State Incentives to Maximize Oil and Gas Recovery”, December, 1999.
3. Interstate Oil and Gas Compact Commission, “Marginal Oil and Gas: Fuel for Economic Growth”, (1997, 1999, 2000, and 2004 editions).
4. Energy Information Administration, “Natural Gas Annual (NGA)”, various editions 1994-2004.
5. Energy Information Administration, “Petroleum Supply Annual”, various editions 1994-2004.
6. National Petroleum Council, “Marginal Wells, A Report of the National Petroleum Council”, July, 1994.

Appendix A: Description of Files Generated

This appendix contains a listing of the files provided to the Department of Energy (DOE) as a stipulation of the statement of work for this project. These files are stored in folders and are listed by folder. A brief description is attached to each file in the listing.

Folder: Reports

Description: This folder contains reports, outlines, and progress reports generated in the course of this project

> **Final_report.doc –** MS Word copy of final report
> **Report_outline.doc –** MS Word copy of outline of final report
> **Marginal Well_progress.doc –** MS Word copy of 1/31/05 progress report
> **Marginal Well_progress2.doc –** MS Word copy of 2/22/05 progress report
> **Marginal Well_progress3.doc –** MS Word copy of 3/3/05 progress report
> **Marginal Well_progress4.doc –** MS Word copy of 4/15/05 progress report

Folder: EIA-AEO05

Description: This folder contains the data files containing the 2005 AEO projections

> **AEO2005_production.xls –** Excel spreadsheet containing oil and gas production by supply region and play (unconventional gas).
> **AEO2005_new wells.xls –** Excel spreadsheet containing estimates of new oil and gas wells by region and play (unconventional gas)

Folder: IOGCC_data

Description: This folder contains data from IOGCC reports

> **2000 IOGCC Report.pd**f **–** PDF file containing IOGCC 2000 Marginal Oil and Gas Report
> **IOGCC 1997 Marginal Oil and Gas Book.pdf –** PDF file containing IOGCC 1997 Marginal Oil and Gas Report
> **Marginal wells_IOGCC 2004.pdf –** PDF file containing IOGCC 2004 Marginal Oil and Gas Report
> **Stripper_stats.xls –** Excel spreadsheet containing comprehensive collection of historical data used for this project -- contains by state things such as total production, stripper production, and stripper well counts.

Folder: History_Match

Description: This folder contains files created during the initial history match regression runs where data were run on 8 years of history and results compared to 2002 and 2003 history

Reg1_oil.xls – spreadsheet containing oil regression data and plots for Northeast Region
Reg1_gas.xls – spreadsheet containing gas regression data and plots for Northeast Region
Reg2_oil.xls – spreadsheet containing oil regression data and plots for Gulf Coast Region
Reg2_gas.xls – spreadsheet containing gas regression data and plots for Gulf Coast Region
Reg3_oil.xls – spreadsheet containing oil regression data and plots for Mid-continent Region
Reg3_gas.xls – spreadsheet containing gas regression data and plots for Mid-continent Region
Reg4_oil.xls – spreadsheet containing oil regression data and plots for Southwest Region
Reg4_gas.xls – spreadsheet containing gas regression data and plots for Southwest Region
Reg5_oil.xls – spreadsheet containing oil regression data and plots for Rocky Mountain Region
Reg5_gas.xls – spreadsheet containing gas regression data and plots for Rocky Mountain Region
Reg6_oil.xls – spreadsheet containing oil regression data and plots for West Coast Region
Reg6_gas.xls – spreadsheet containing gas regression data and plots for West Coast Region
Results_oil.xls – Excel spreadsheet containing plots of marginal oil production and well count results by supply regions and total U.S. along with a table containing a comparison of predicted values vs. actual values for year 2002 and 2003 by state.
Results_gas.xls – Excel spreadsheet containing plots of marginal gas production and well count results by supply regions and total U.S. along with a table containing a comparison of predicted values vs. actual values for year 2002 and 2003 by state.
Reconcile_2003.xls – Excel spreadsheet containing reconciliation data for 2003 used to determine fraction of contribution in each region for states whose production is split into 2 or more regions.
St_reg_translation.xls – Excel spreadsheet showing state composition of regions for both oil and gas

Folder: Full_History_Regression

Description: This folder contains files created during the regression analysis which used the full 10 years of historical data (1994-2003). These files contain the straight regression run with no "quality assurance" modifications.

Reg1_oil.xls – spreadsheet containing oil regression data and plots for Northeast Region
Reg1_gas.xls – spreadsheet containing gas regression data and plots for Northeast Region
Reg2_oil.xls – spreadsheet containing oil regression data and plots for Gulf Coast Region
Reg2_gas.xls – spreadsheet containing gas regression data and plots for Gulf Coast Region
Reg3_oil.xls – spreadsheet containing oil regression data and plots for Mid-continent Region
Reg3_gas.xls – spreadsheet containing gas regression data and plots for Mid-continent Region
Reg4_oil.xls – spreadsheet containing oil regression data and plots for Southwest Region
Reg4_gas.xls – spreadsheet containing gas regression data and plots for Southwest Region
Reg5_oil.xls – spreadsheet containing oil regression data and plots for Rocky Mountain Region
Reg5_gas.xls – spreadsheet containing gas regression data and plots for Rocky Mountain Region
Reg6_oil.xls – spreadsheet containing oil regression data and plots for West Coast Region
Reg6_gas.xls – spreadsheet containing gas regression data and plots for West Coast Region
Results_oil.xls – Excel spreadsheet containing plots of marginal oil production and well count results by supply regions and total U.S. along with a table containing a comparison of predicted values vs. actual values for year 2002 and 2003 by state.
Results_gas.xls – Excel spreadsheet containing plots of marginal gas production and well count results by supply regions and total U.S. along with a table containing a comparison of predicted values vs. actual values for year 2002 and 2003 by state.
WC_check_oil.xls – Excel spreadsheet containing data and plots used for "quality assurance" of oil regression data. Contains data necessary to calculate estimated number of total wells.
WC_check_gas.xls – Excel spreadsheet containing data and plots used for "quality assurance" of gas regression data. Contains data necessary to calculate estimated number of total wells.

Folder: “Corrected”_Projections

Description: This folder contains files created during the regression analysis which used the full 10 years of historical data (1994-2003). These files contain the straight regression run with “quality assurance” modifications.

Reg1_oil.xls – spreadsheet containing oil regression data and plots for Northeast Region
Reg1_gas.xls – spreadsheet containing gas regression data and plots for Northeast Region
Reg2_oil.xls – spreadsheet containing oil regression data and plots for Gulf Coast Region
Reg2_gas.xls – spreadsheet containing gas regression data and plots for Gulf Coast Region
Reg3_oil.xls – spreadsheet containing oil regression data and plots for Mid-continent Region
Reg3_gas.xls – spreadsheet containing gas regression data and plots for Mid-continent Region
Reg4_oil.xls – spreadsheet containing oil regression data and plots for Southwest Region
Reg4_gas.xls – spreadsheet containing gas regression data and plots for Southwest Region
Reg5_oil.xls – spreadsheet containing oil regression data and plots for Rocky Mountain Region
Reg5_gas.xls – spreadsheet containing gas regression data and plots for Rocky Mountain Region
Reg6_oil.xls – spreadsheet containing oil regression data and plots for West Coast Region
Reg6_gas.xls – spreadsheet containing gas regression data and plots for West Coast Region
Results_oil.xls – Excel spreadsheet containing plots of marginal oil production and well count results by supply regions and total U.S. along with a table containing a comparison of predicted values vs. actual values for year 2002 and 2003 by state.
Results_gas.xls – Excel spreadsheet containing plots of marginal gas production and well count results by supply regions and total U.S. along with a table containing a comparison of predicted values vs. actual values for year 2002 and 2003 by state.
Oil_productions.xls – Excel spreadsheet containing plots of history + prediction for total U.S., supply regions, and states. Plots are of total oil production, marginal oil production, and marginal oil well count.
Gas_productions.xls – Excel spreadsheet containing plots of history + prediction for total U.S., supply regions, and states. Plots are of total natural gas production, marginal natural gas production, and marginal natural gas well count.

Appendix B: Secondary Methodology Considered for Marginal Well and Production Forecasting

An approach considered in the early phases of this project involved making projections of future marginal well activity by estimating production from individual wells and then running this forecast through an economic model which would predict the abandonment of each well individually. The basic idea was that a projection of future production could be made for each well either through decline curve analysis of historical data or a type curve approach. This production stream could then be evaluated with a detailed cash flow model which would determine the economic limit of the well for each year in order to determine when the well would be shut-in. Since one would know the rate of every well each year of the forecast, it is a simple matter to aggregate marginal production and well count at any level desired; reservoir, play, state, Total U.S. etc.

The most attractive feature of this method is that one could run the economics model at various product price tracks and be able to determine easily the effect of increases or decreases in price on the amount of marginal production. One could adjust tax laws or operating costs in the same manner in order to measure their effect. Once work began on this approach it became apparent very quick that this approach had serious problems with data availability. Here is a list of a few of the obstacles which stand in the way of an individual well approach.

1. Well Data Coverage - This would be the major obstacle. In researching the overall availability of data, it was discovered that consistency of marginal well data is at times, questionable. That is, some discrepancies in well count data exist across the different reporting agencies. It would be a very difficult task to come up with reconciled meaningful data for these wells if we were to attempt the individual well method.

2. Decline Curve Predictions – While hyperbolic decline predictions work well with certain well types, especially oil wells under primary or secondary recovery, this method of forecasting production becomes problematic with natural gas wells. Gas well production data does not usually follow a normal hyperbolic decline. Since natural gas wells are easily shut-in or curtailed and production rate easily adjusted by an adjustable choke to maintain a fairly constant rate or even an increased rate as reservoir pressure declines, a decline fit may have no relevance to the actual amount of natural gas available for production. Many natural gas wells are producing at a constant or even increasing rate. Fitting a decline curve to historical production requires several years of production data which in many cases would be difficult to acquire.

3. Type Curve Predictions – Type curve predictions would be more appropriate for natural gas wells, however, a substantial amount of data is required in order to use a type curve method to predict future production. The major data elements which would be required are pressures, permeability, porosity, and volume of reservoir

directly affected by the well. Coverage of these data elements would be very poor at best even if any historical production data were available for the well.

4. Lack of Appropriate Economic Model – Determining the economic limit of marginal wells would require a very formation specific complex model requiring a high level of very difficult to acquire data. Since some marginal wells continue to operate at very low flow rates (often less than 0.5 barrels of oil equivalent per day), and since the production rates for these wells often vary very little over time, the resulting forecasts would be very sensitive to very small changes in cost or tax structure. Things such as the financial status of the operator would have a large bearing on the economic limit predicted for a given well. Creation of such a highly detailed model and the extensive database required would be a very time intensive endeavor.

5. Lack of correlation with AEO forecasts – One of the objectives of this analysis was that the results tie to the 2005 AEO projections. It is plain to see that even if work was undertaken to create appropriate models and databases, it is very unlikely that if the same price scenario was applied to the models as the AEO reference case that we would achieve forecasts which have any relation to the results forecast by the AEO. This is due to the very different types of models used by the NEMS system and the huge number of assumptions which would have to be made to attempt the well level method.

6. Future Exploration and Drilling model – Another problem with using either the decline curve or type curve approach is that it would only work on existing wells. A model would have to be developed which would predict not only the future amount of exploration and development, but would also have to predict future production streams from these undiscovered wells. Assumptions would have to be made as to the reservoir properties of these undiscovered wells as well as the economic parameters. Again adding a very large degree of uncertainty to a very sensitive model.

After spending time evaluating the problems mentioned, a decision was made to go with the state level linear regression model in order to make the forecasts. While the decline method would allow forecasting of marginal well statistics under various price and cost scenarios, it will be a difficult problem requiring a substantially larger level of effort.

Appendix C: Supply Region History Match Results

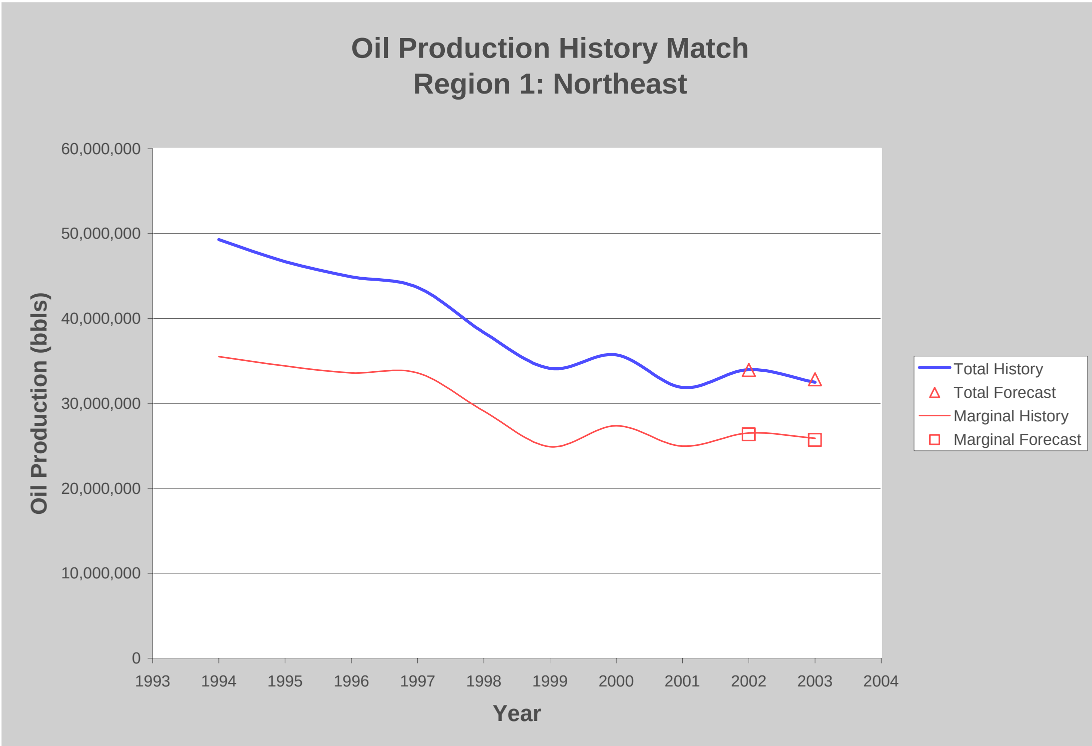


Figure C-1 Northeast Region Oil Production History Match

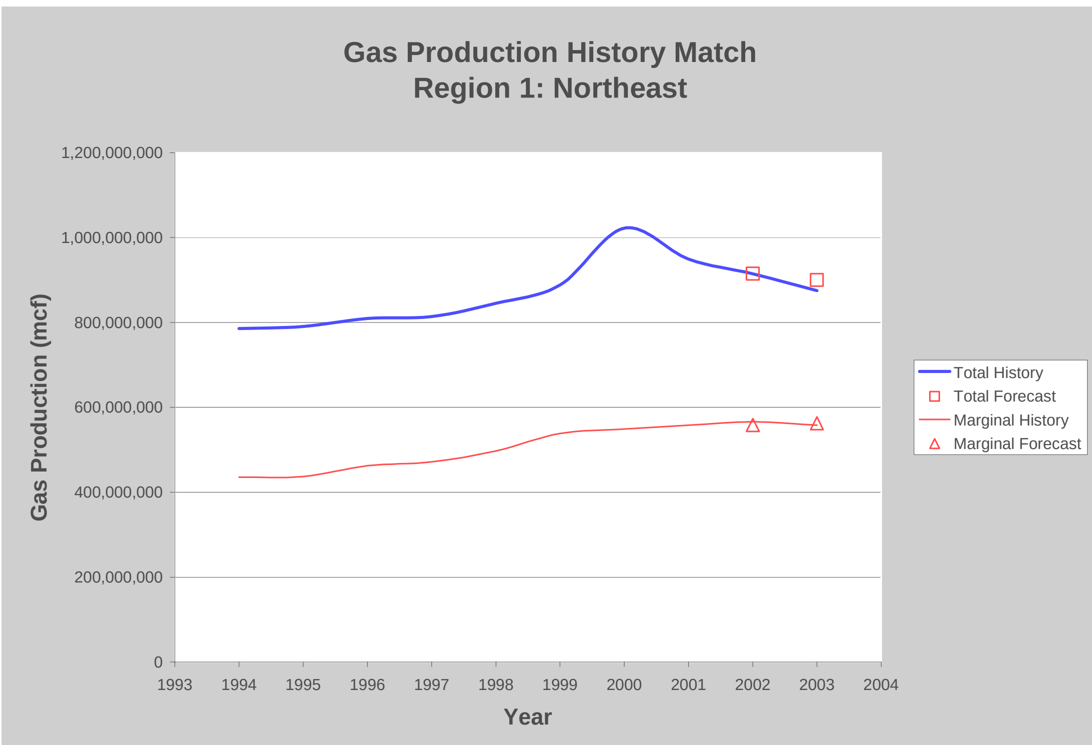


Figure C-2 Northeast Region Natural Gas Production History Match

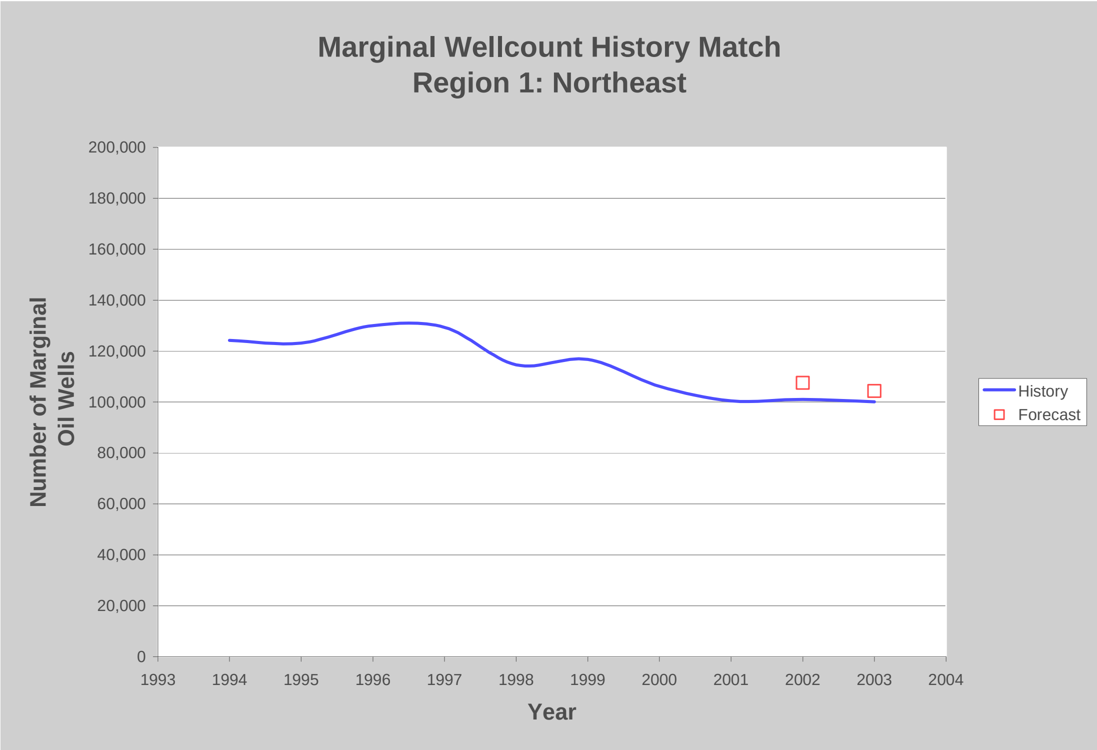


Figure C-3 Northeast Region Marginal Oil Well Count History Match

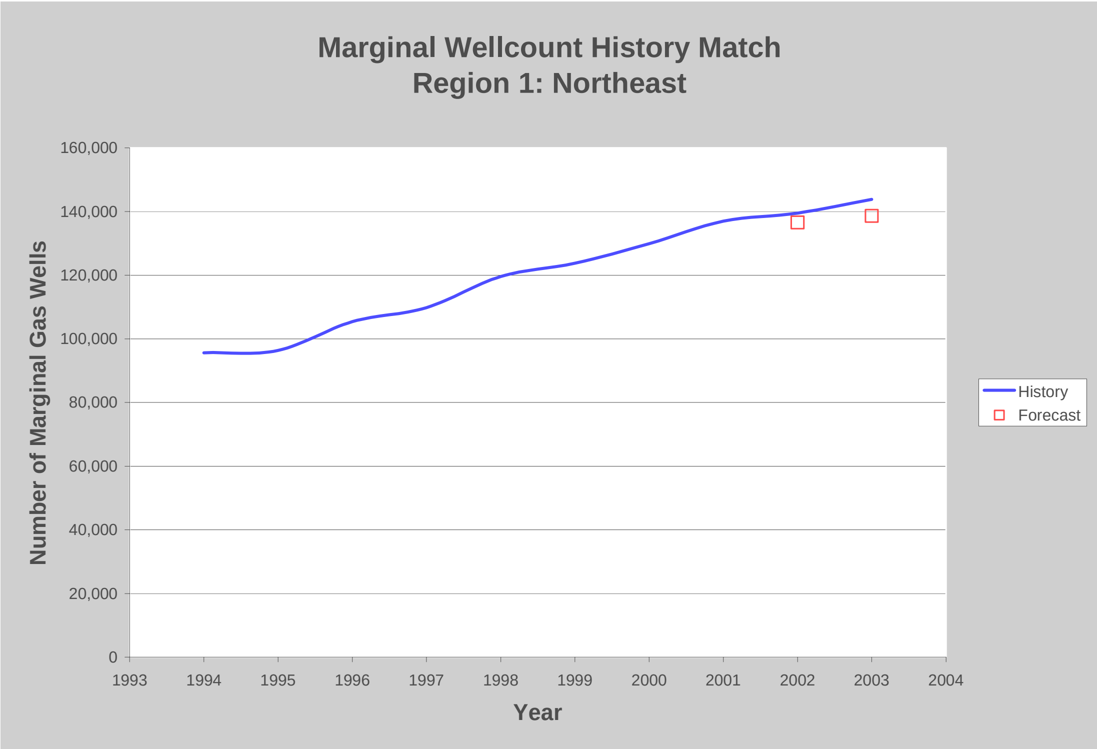


Figure C-4 Northeast Region Marginal Natural Gas Well Count History Match

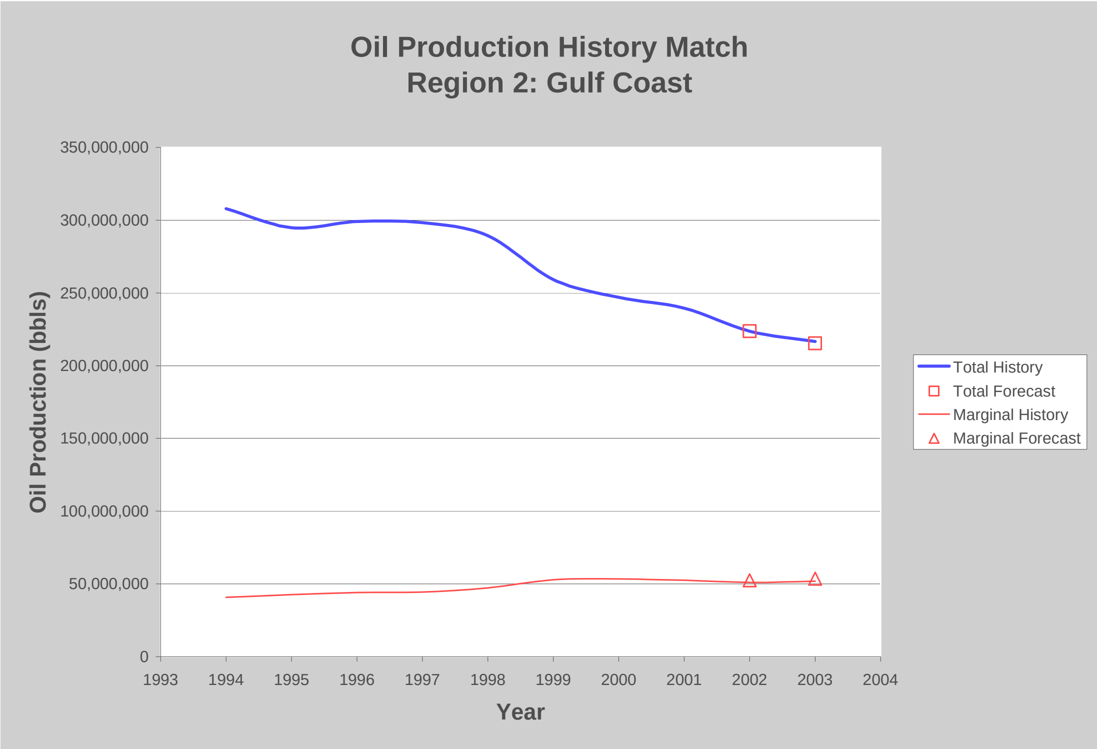


Figure C-5 Gulf Coast Region Oil Production History Match

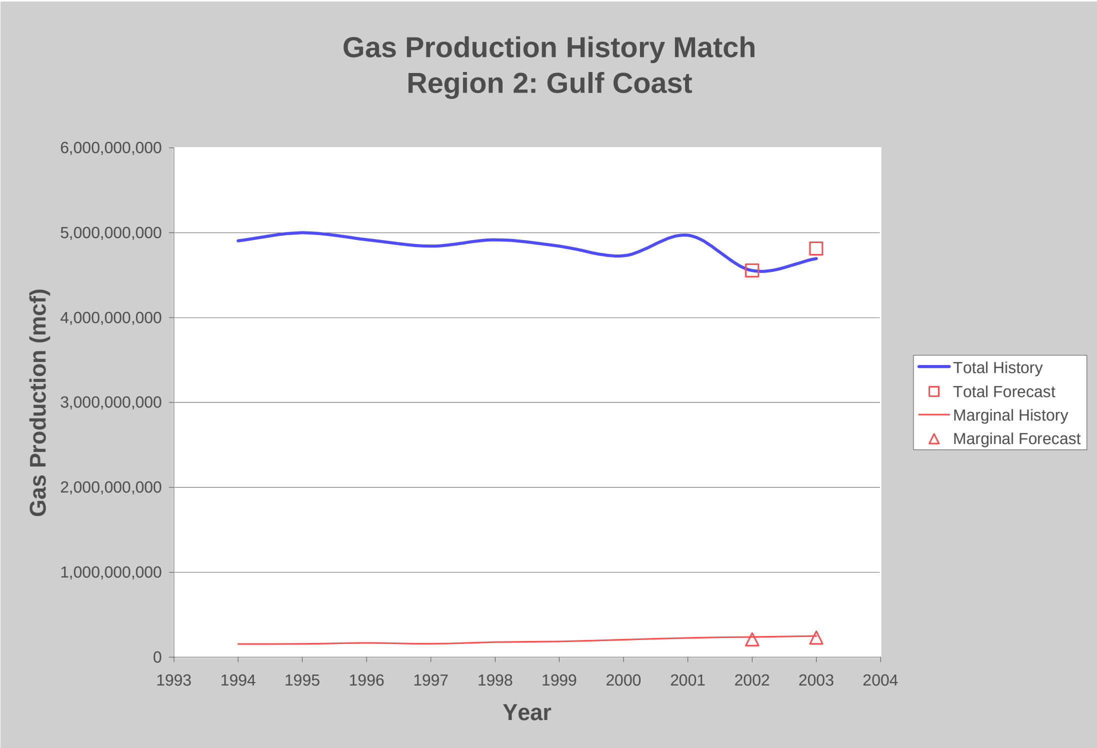


Figure C-6 Gulf Coast Region Natural Gas Production History Match

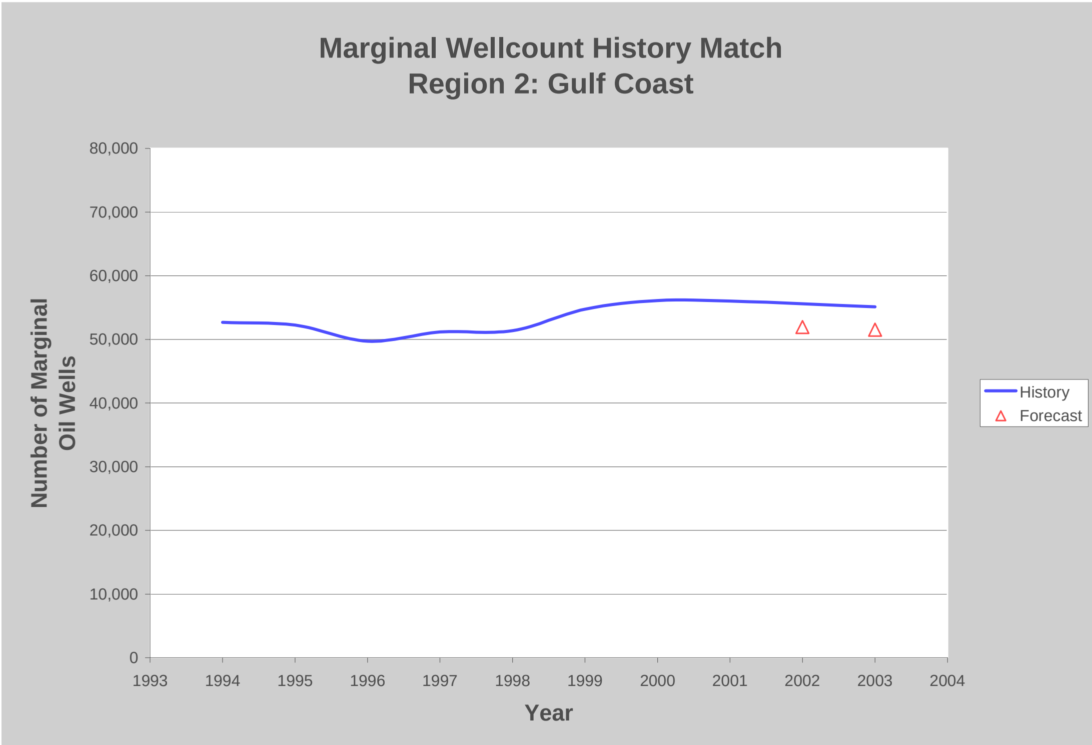


Figure C-7 Gulf Coast Region Marginal Oil Well Count History Match

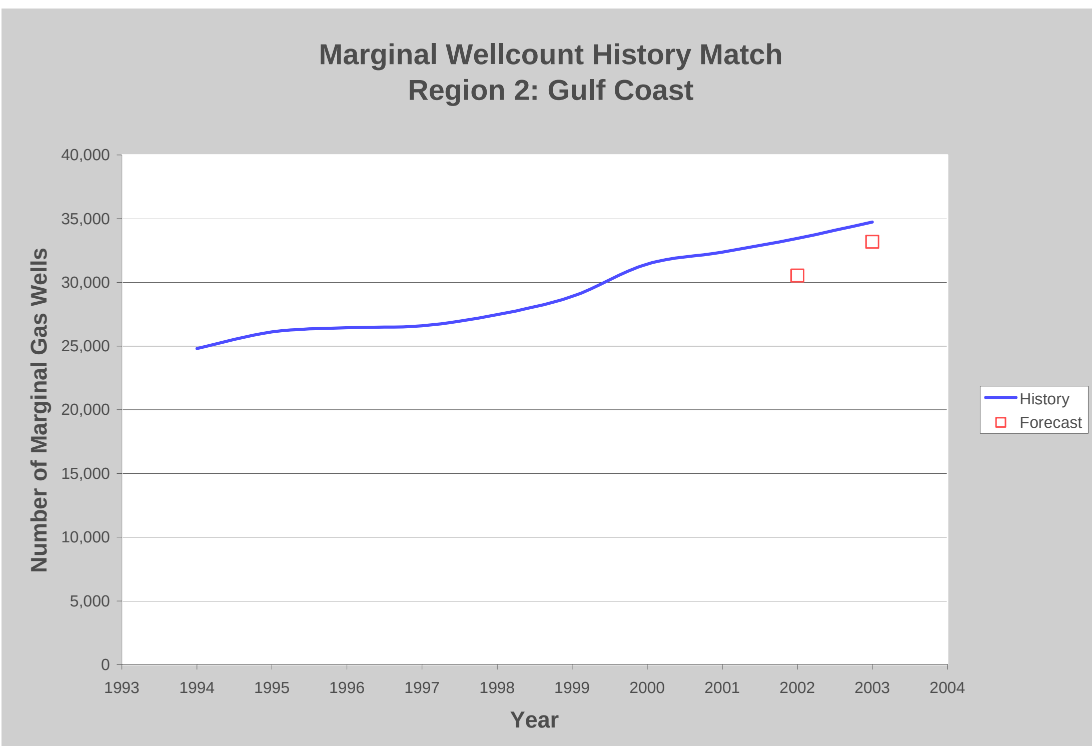


Figure C-8 Gulf Coast Region Marginal Natural Gas Well Count History Match

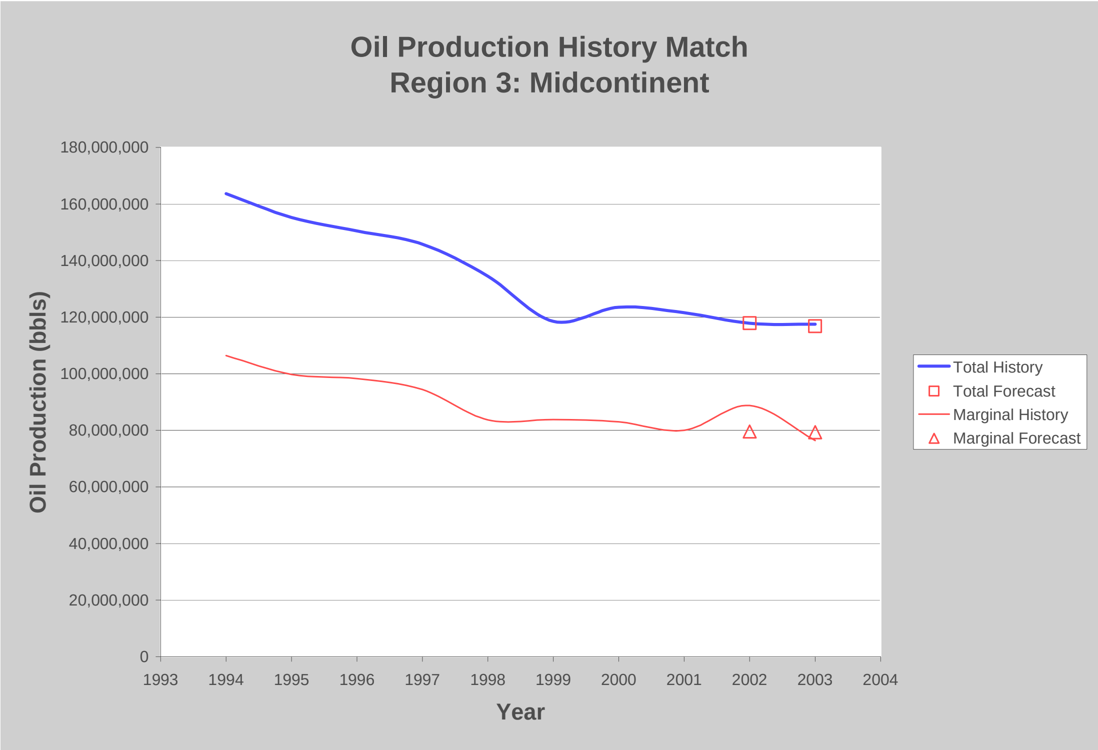


Figure C-9 Mid-Continent Region Oil Production History Match

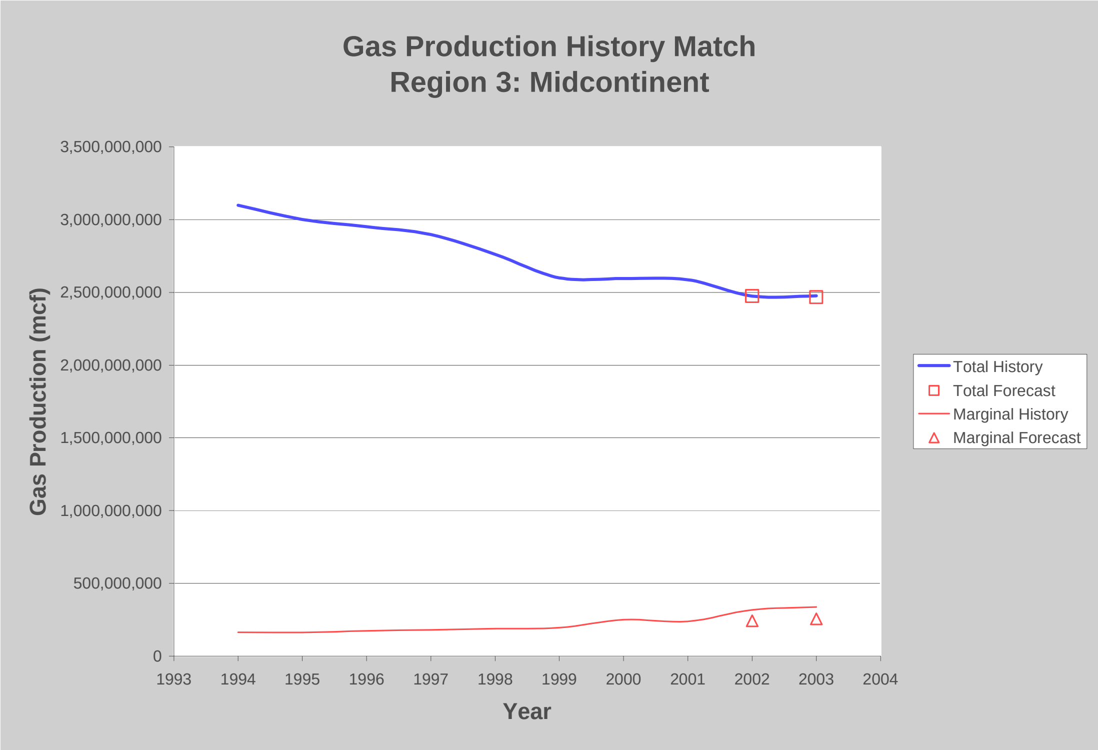


Figure C-10 Mid-Continent Region Natural Gas Production History Match

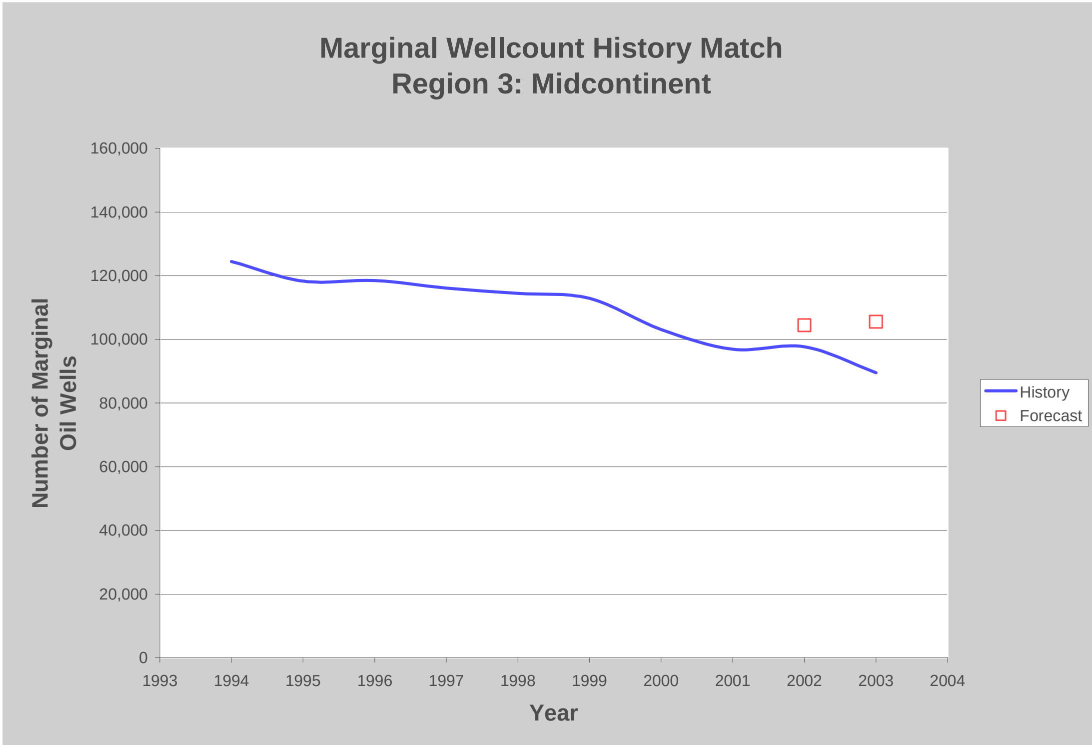


Figure C-11 Mid-Continent Region Marginal Oil Well Count History Match

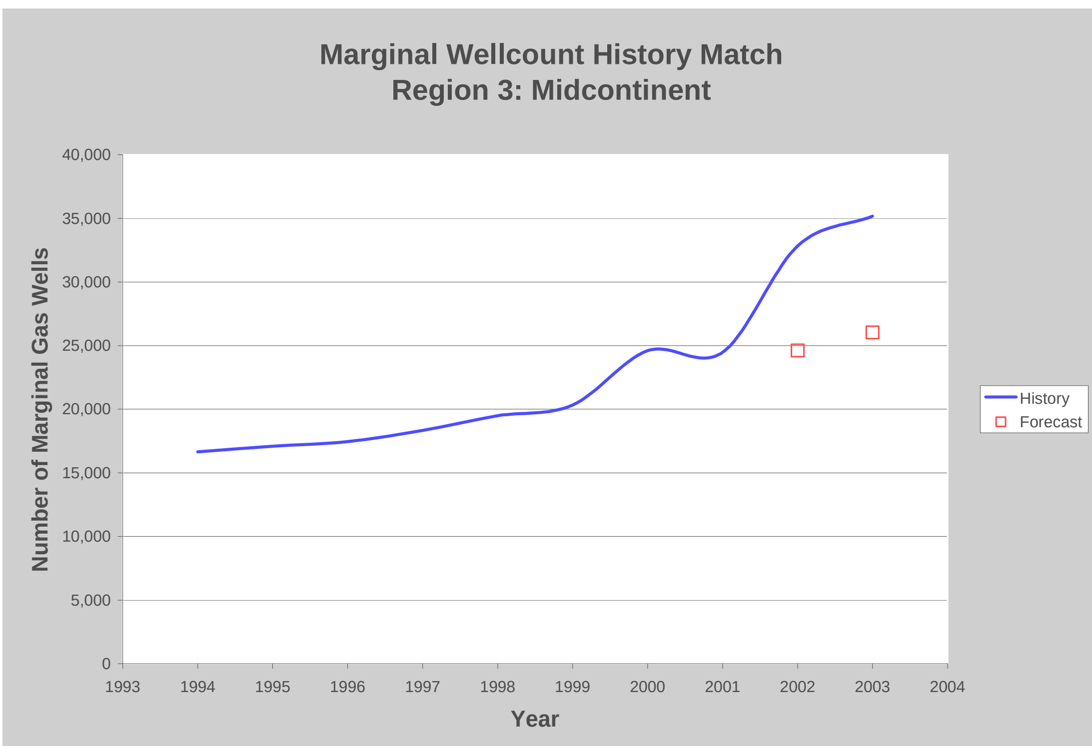
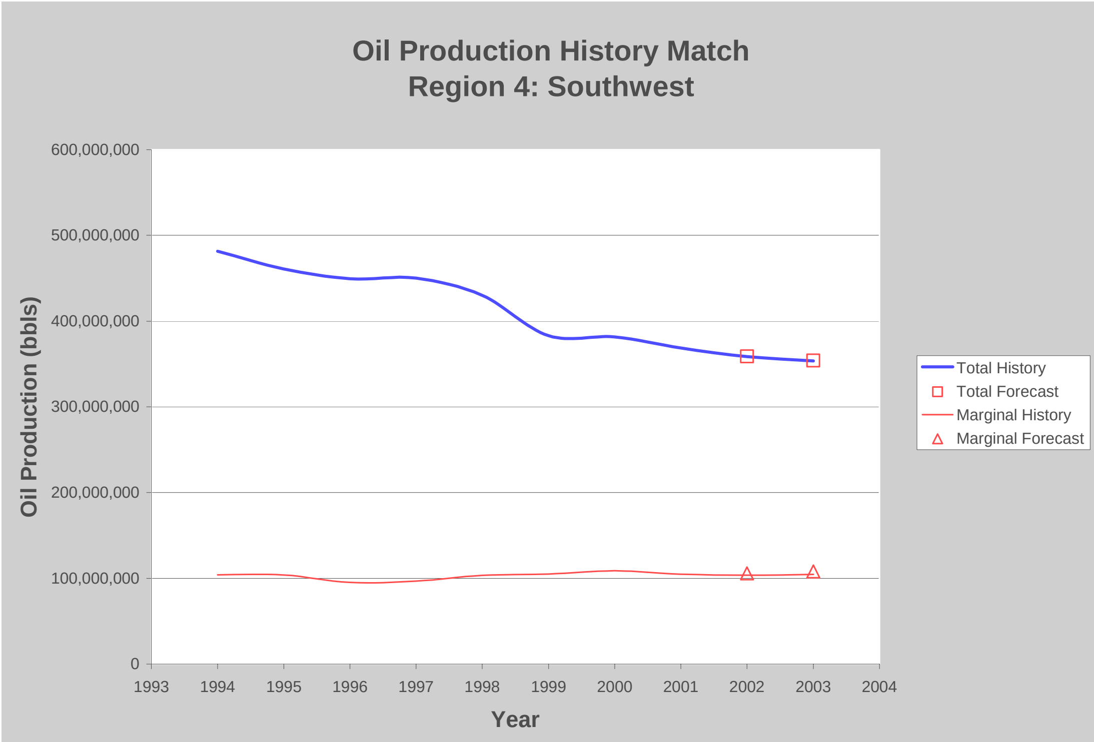


Figure C-12 Mid-Continent Region Marginal Natural Gas Well Count History Match



FigureC-13 Southwest Region Oil Production History Match

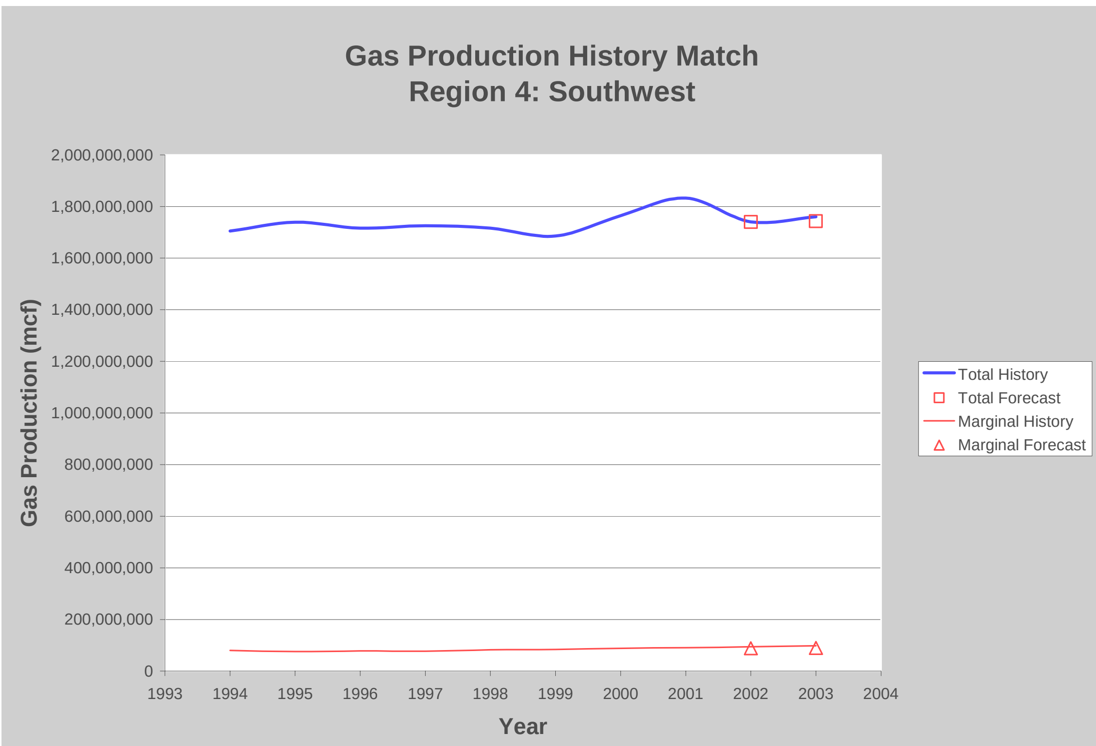


Figure C-14 Southwest Region Natural Gas Production History Match

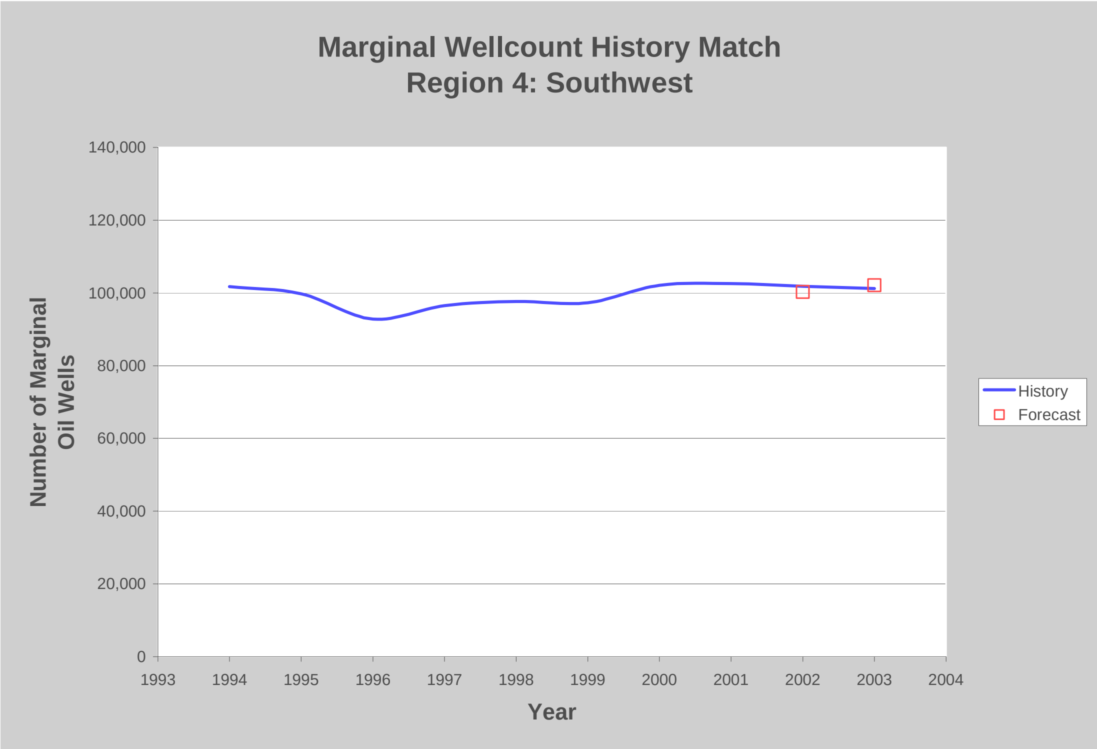


Figure C-15 Southwest Region Marginal Oil Well Count History Match

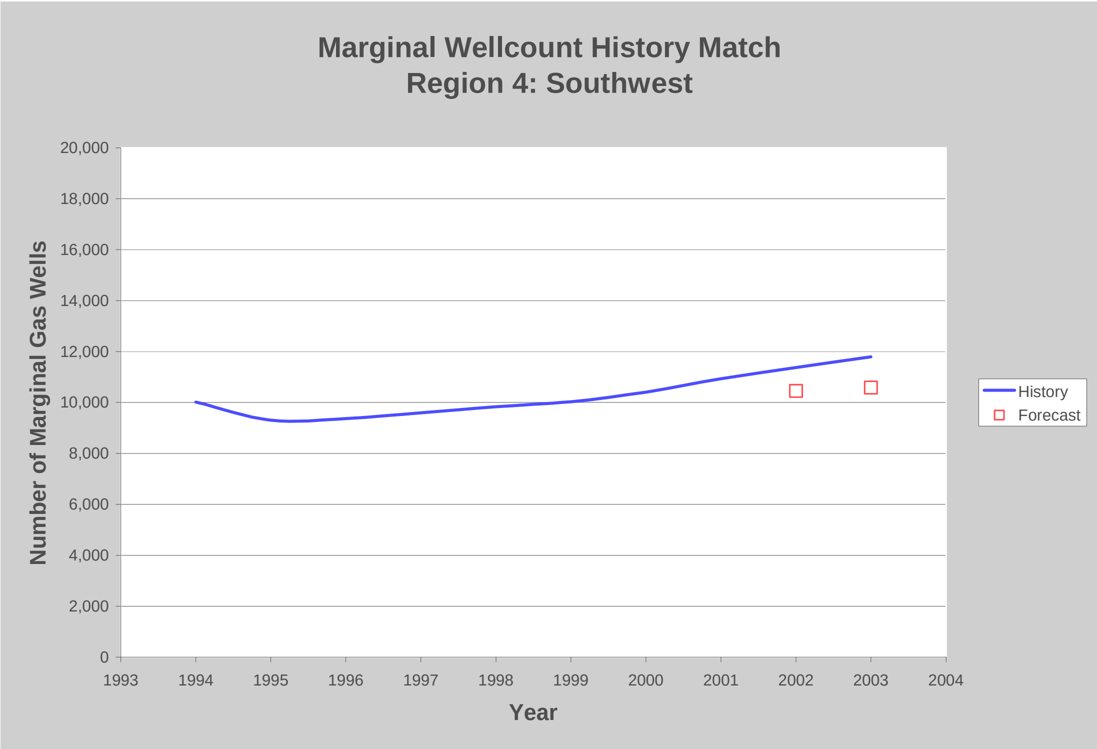


Figure C-16 Southwest Region Marginal Natural Gas Well Count History Match

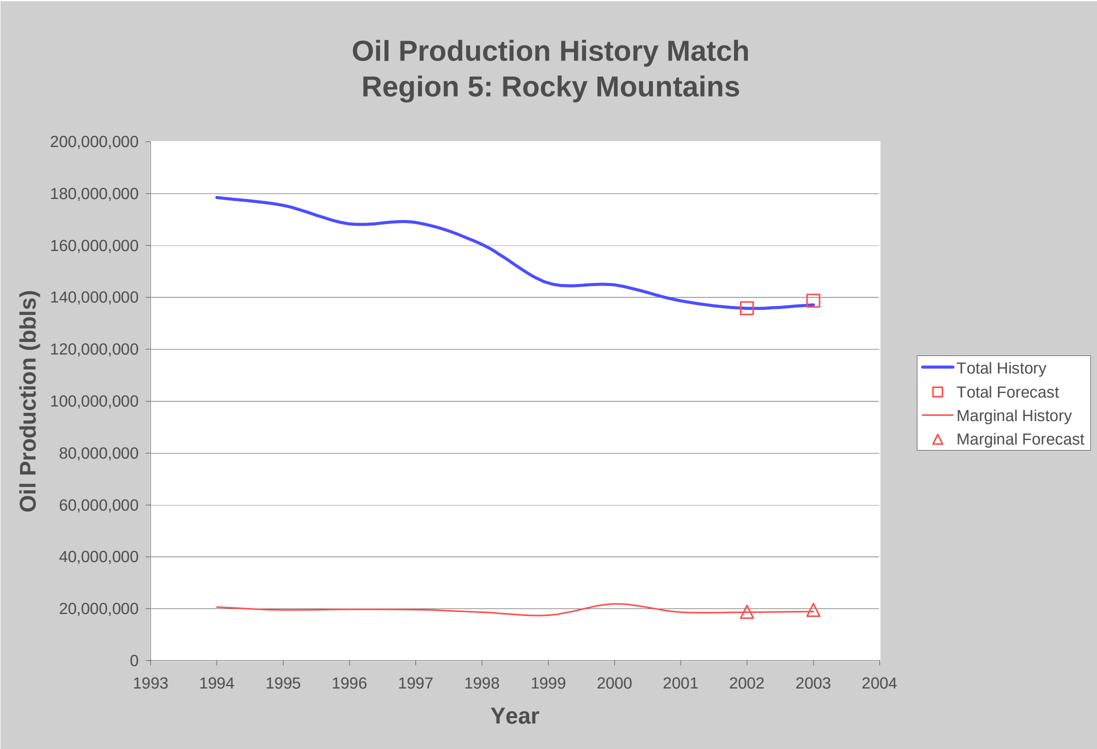


Figure C-17 Rocky Mountain Region Oil Production History Match

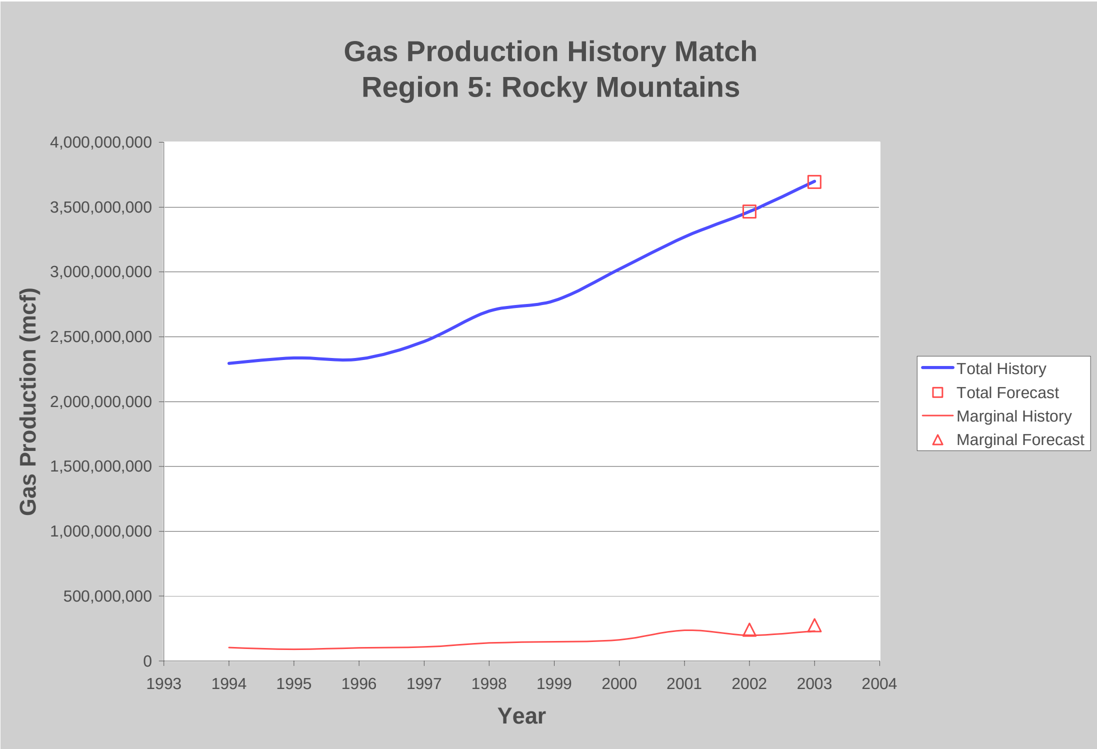


Figure C-18 Rocky Mountain Region Natural Gas Production History Match

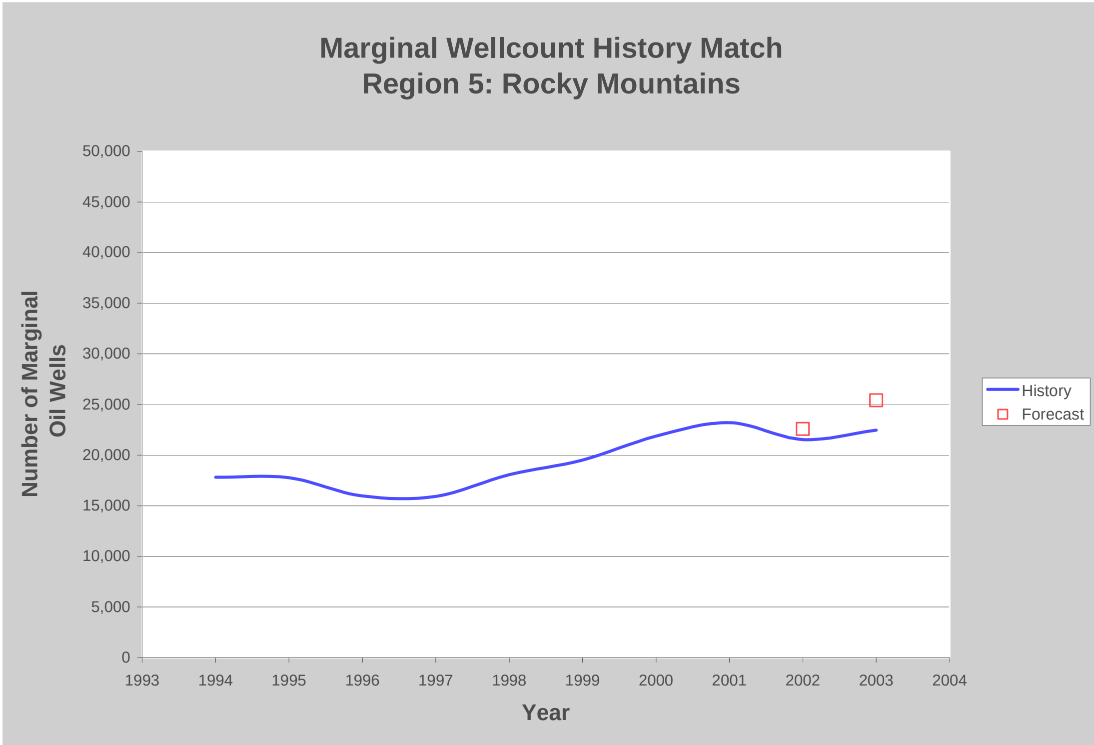


Figure C-19 Rocky Mountain Region Marginal Oil Well Count History Match

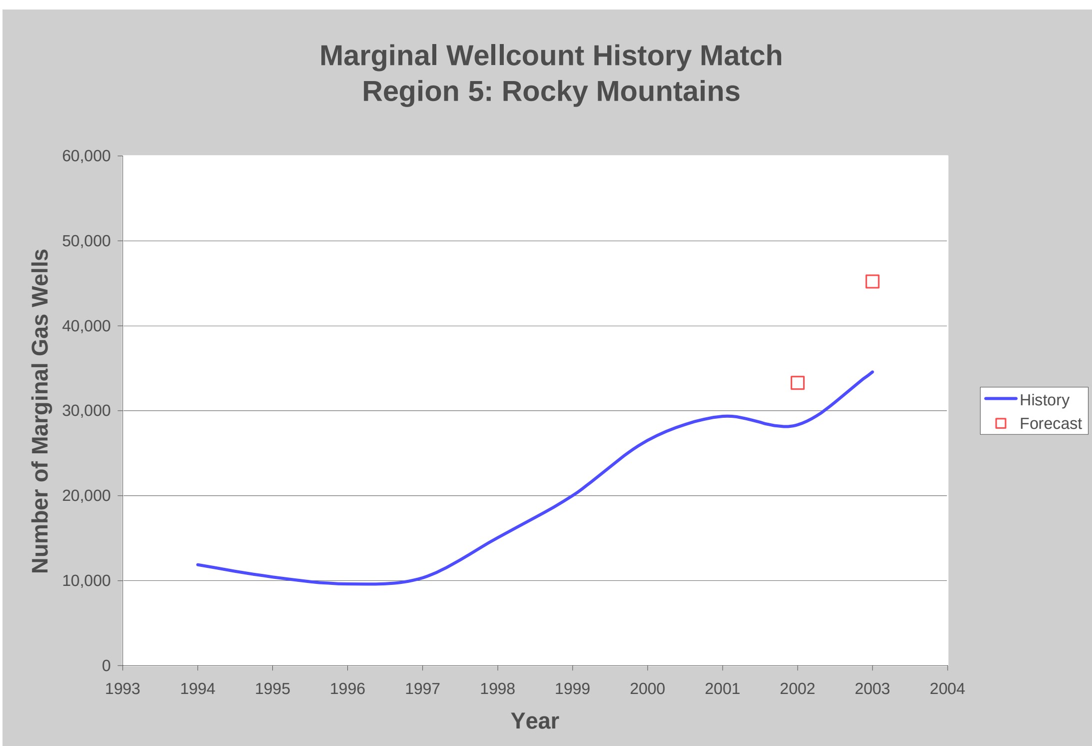


Figure C-20 Rocky Mountain Region Marginal Natural Gas Well Count History Match

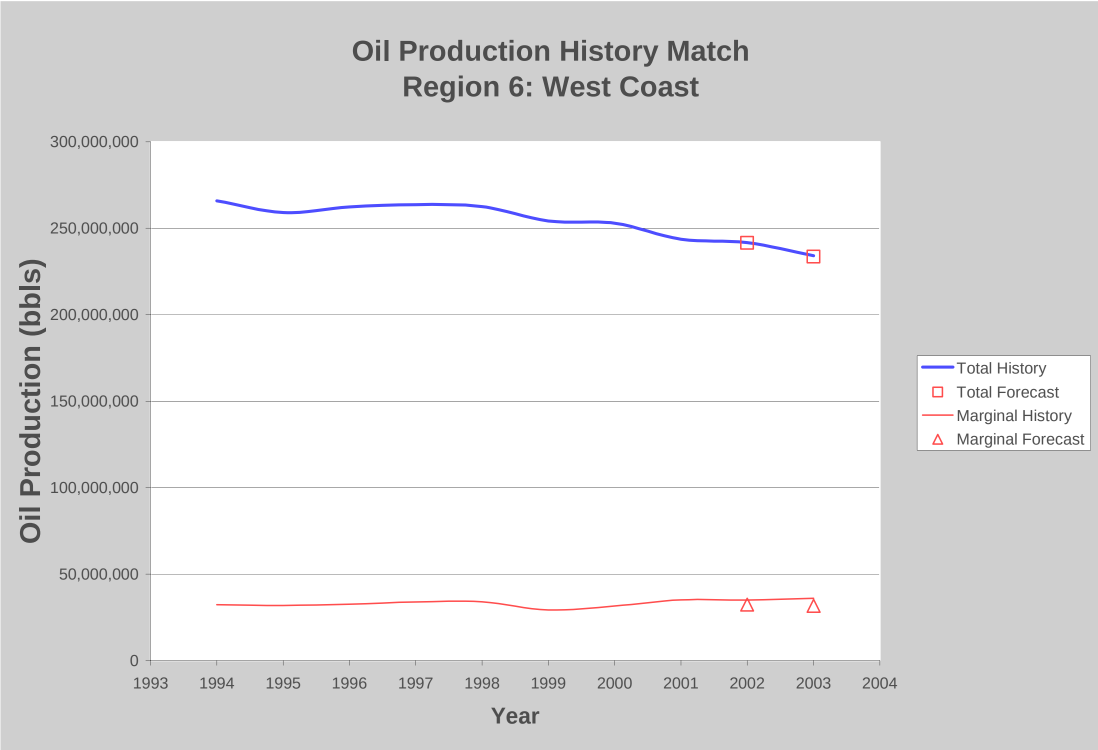


Figure C-21 West Coast Region Oil Production History Match

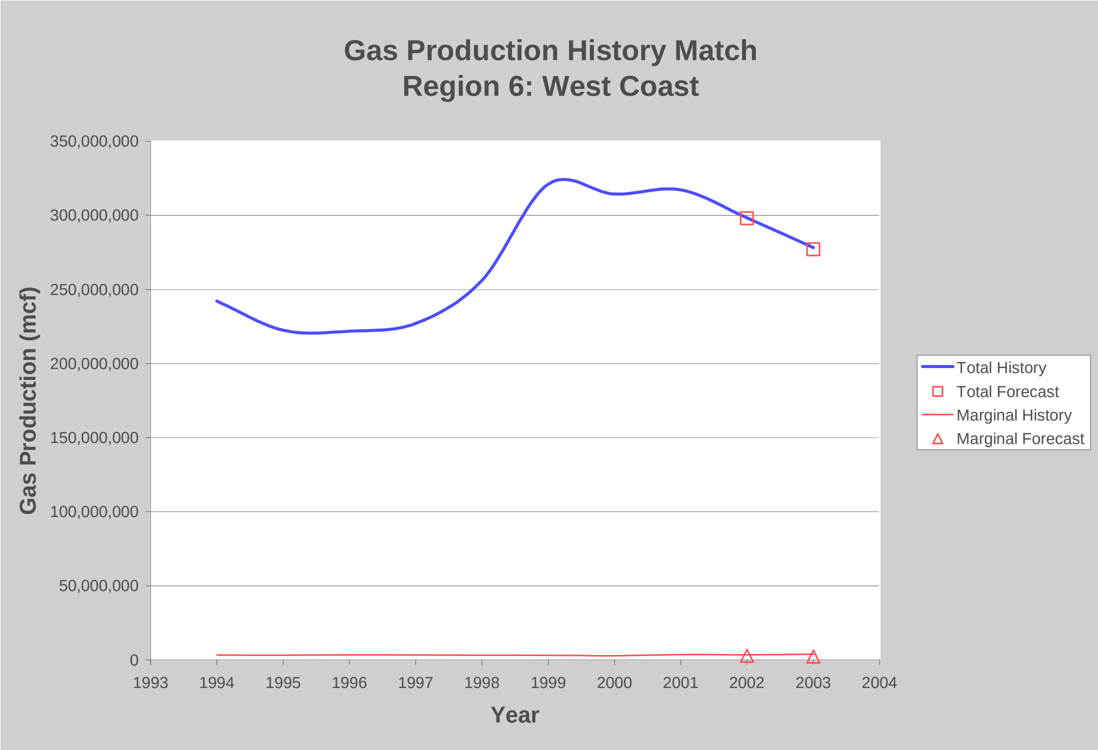


Figure C-23 West Coast Region Natural Gas Production History Match

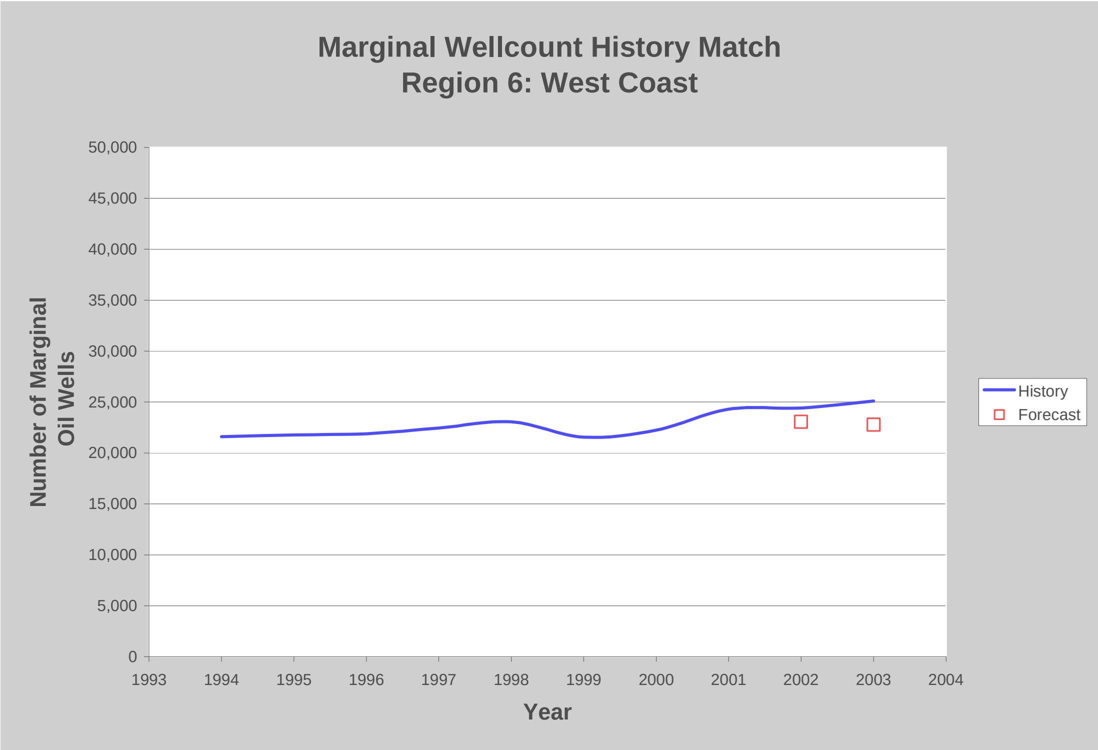


Figure C-23 West Coast Region Marginal Oil Well Count History Match

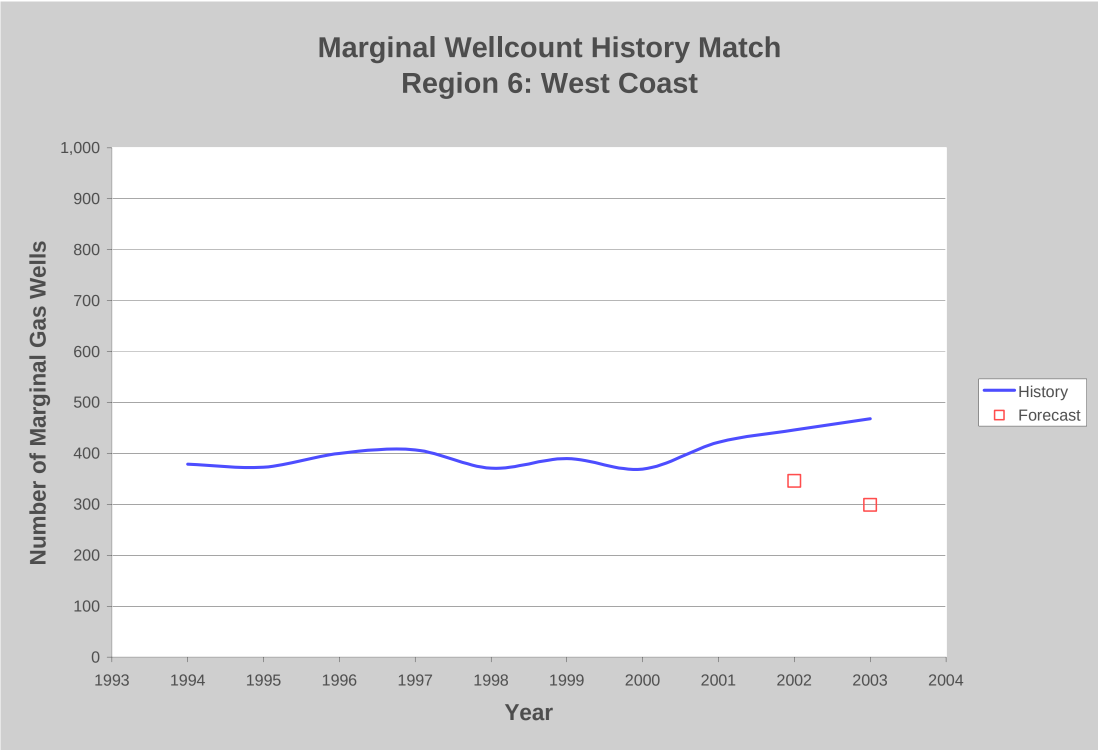


Figure C-24 West Coast Region Marginal Natural Gas Well Count History Match

Discussion of Regional History Match Results

Oil

Forecasts of marginal oil production at the regional level were very good. The percentage error of the forecast marginal production relative to the actual marginal production was calculated for each of the two history match years for each of the regions. The northeast region was very predictable with an average error of only 0.72 percent in the forecast of the two years. The west coast region had the worst forecast results, but was still only 10 percent off from the actual production data. The average error of the six regions was slightly over 4 percent.

Forecasts of marginal oil well count were also very good, although not quite as accurate as the production. The southwest region was very easy to forecast with an average error of 1.2 percent. The mid-continent was the hardest with an average error of 12.4%. The average error of the six regions was almost 7 %. These results were considered to be excellent, especially since the history match was only a test of the regression method and there was no "quality assurance" procedure applied at this time in the analysis in order to investigate and clean up potential problems with raw data.

Natural Gas

History matching forecasts of marginal natural gas production were very good on a percentage basis for three of the six regions. Average error was 1.1 percent for the Northeast region, 9.4 percent for the gulf coast region, and 7.2 percent for the southwest region. Some problems were observed in the remaining regions. Average forecast error was 23.8 percent for the mid-continent and 20.0 percent for the Rocky Mountains. An average error of 29.3 percent was observed for the West Coast region; however, this error is more a function of the very small population of marginal gas wells and production in this region. Recall, these "errors" reflect results from the initial regressions and not from the final quality-assured application of the model. The quality assurance steps led to much improved results. Any small non-linearity in the behavior of the data will result in a large percentage error although we are talking about a small number of wells.
The error in the mid-continent can be attributed solely to the forecasts for Oklahoma and Kansas. What happened was that a nice linear historical trend of marginal natural gas production in these states was interrupted by a huge amount of shallow, low rate, coalbed methane wells coming on line during the two years we were attempting to match. The rate of marginal production which had been almost flat for eight years suddenly almost doubled in these two states. These types of abrupt trend changes are fairly rare.
The forecast error for the Rocky Mountain region was attributed to the state of Colorado. There was a large anomaly in a single data point for stripper production which was causing an over prediction of marginal production and well count. In the process of doing the final forecast, this anomaly was spotted by the "quality assurance" procedure and corrected. Error rates for the natural gas marginal well count forecast were similar to the production forecast and for the very same reasons.

Appendix D: State Level History Match Data

Oil Reservoirs

History vs. Prediction for years 2002 and 2003

	Stripper Oil Production				Stripper Oil Well Count			
	IOGCC		PREDICTION		IOGCC		PREDICTION	
STATE	2002	2003	2002	2003	2002	2003	2002	2003
Alabama	1,141,083	1,152,351	915,444	825,713	639	632	578	559
Arizona	23,951	23,303	25,035	26,259	17	18	23	25
Arkansas	3,087,798	3,302,376	2,787,738	2,802,620	3,362	3,615	3,048	2,979
California	35,030,269	36,015,129	32,292,775	31,601,893	24,420	25,089	23,062	22,771
Colorado	4,643,717	5,442,974	3,985,678	3,948,193	5,384	5,334	8,421	9,912
Florida	0	0	0	0	0	0	0	0
Illinois	10,720,000	10,600,000	11,283,894	10,974,173	17,466	17,154	18,093	17,103
Indiana	1,962,078	1,864,883	2,018,171	1,969,240	4,956	5,049	5,302	5,379
Kansas	25,002,372	25,103,681	25,237,763	25,130,987	33,317	32,883	36,282	36,514
Kentucky	2,049,971	1,942,879	2,011,188	1,915,159	19,462	19,272	22,118	21,062
Louisiana	14,999,393	15,567,256	17,964,193	19,371,897	20,891	20,722	19,789	19,694
Maryland	0	0	0	0	0	0	0	0
Michigan	3,397,608	2,500,500	2,269,994	2,170,928	3,428	2,578	2,282	2,204
Mississippi	562,190	604,800	455,305	438,182	442	437	357	346
Missouri	95,071	86,133	88,191	87,164	364	489	294	290
Montana	1,842,960	1,830,410	1,764,436	1,826,269	2,274	2,291	2,183	2,245
Nebraska	1,717,983	1,651,923	1,871,866	1,889,357	1,451	1,423	1,881	2,126
New Mexico	13,386,587	13,693,595	12,752,724	13,039,831	13,379	13,577	12,633	12,892
Nevada	0	0	0	0	0	0	0	0
New York	174,766	152,967	168,832	156,891	2,758	2,763	2,842	2,641
North Dakota	2,263,059	2,288,191	2,000,071	2,082,009	1,384	1,394	1,317	1,375
Ohio	4,398,074	4,696,636	5,047,535	4,974,616	28,850	28,911	30,092	29,658
Oklahoma	56,299,808	43,703,475	46,905,067	46,587,346	56,673	48,657	60,362	60,960
Pennsylvania	2,324,000	2,466,000	2,032,320	2,080,570	15,470	15,758	17,927	17,742
South Dakota	27,345	51,461	17,062	15,412	22	24	18	19
Tennessee	246,026	270,827	205,603	202,545	424	385	256	236
Texas	127,252,695	128,058,395	129,132,426	131,071,208	124,551	123,402	121,409	122,791
Utah	1,445,945	1,418,563	1,154,913	1,161,860	1,049	1,051	945	1,003
Virginia	3,428	2,502	6,466	6,612	13	7	20	20
West Virginia	1,248,000	1,400,000	1,302,736	1,249,068	8,210	8,200	8,600	8,246
Wyoming	8,430,429	7,856,791	9,857,522	10,499,298	11,416	12,348	9,670	10,822
Total	323,776,606	313,748,001	315,554,948	318,105,300	402,072	393,463	409,804	411,614

Table D-1 State Level Marginal Oil History Match Results

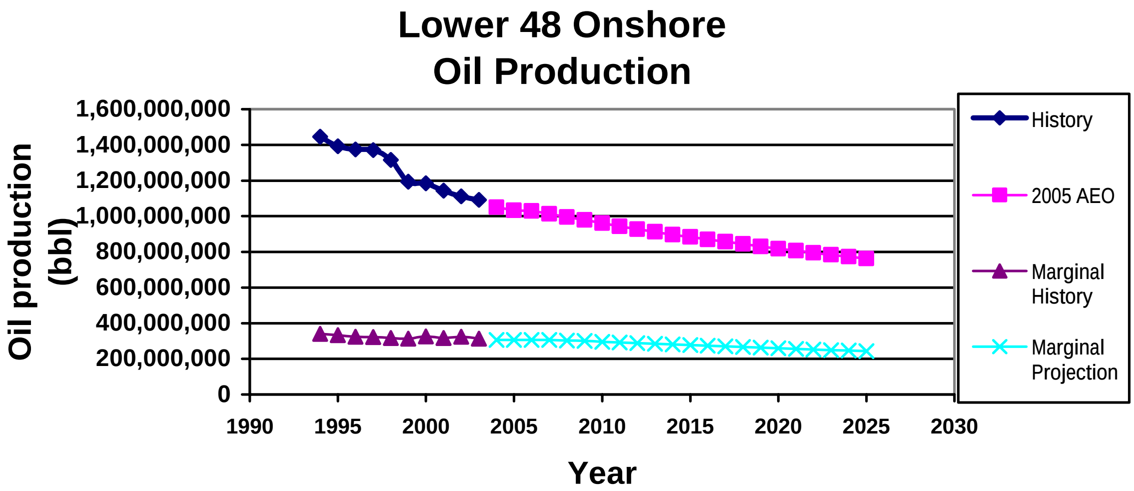
Gas Reservoirs
History vs. Prediction for years 2002 and 2003

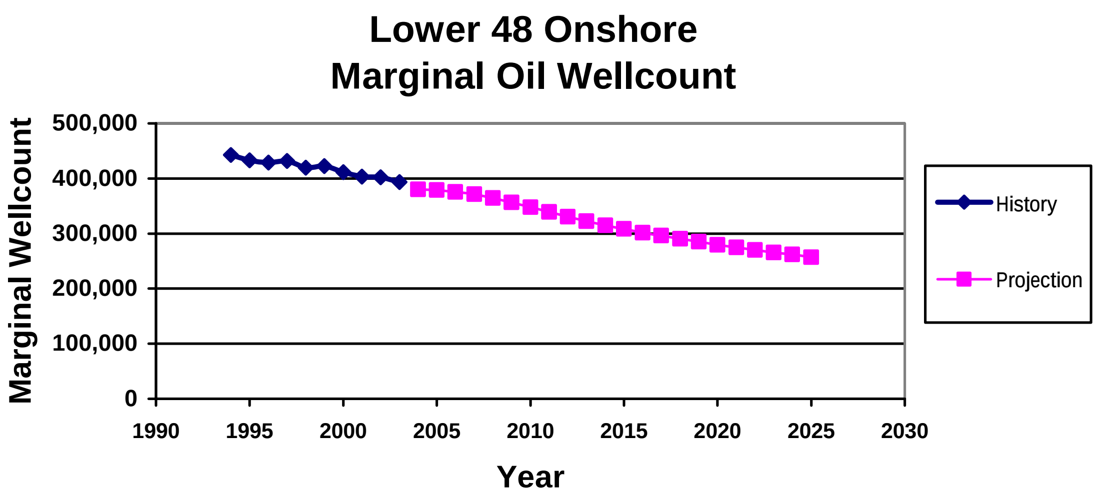
	Stripper Gas Production				Stripper Gas Well Count			
	IOGCC		PREDICTION		IOGCC		PREDICTION	
STATE	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**
Alabama	18,139,406	20,885,970	13,627,630	16,344,908	1,696	1,931	1,337	1,613
Arizona	3,387	1,177	14,826	10,042	4	1	3	2
Arkansas	15,574,407	16,252,825	15,226,783	16,035,779	1,719	1,847	1,644	1,737
California	3,506,947	3,855,523	2,789,475	2,380,240	446	468	346	299
Colorado	60,945,434	73,077,507	118,934,512	141,306,989	6,701	7,342	14,322	18,350
Florida	0	0	0	0	0	0	0	0
Illinois	184,860	184,860	58,928	37,157	172	209	85	54
Indiana	1,309,120	1,464,372	1,118,919	1,212,453	1,545	2,291	1,451	1,417
Kansas	124,877,543	118,418,079	75,994,686	79,991,208	10,437	9,906	6,902	7,498
Kentucky	78,444,980	77,865,801	67,487,552	64,815,974	16,010	16,139	13,803	13,344
Louisiana	40,835,950	40,329,957	30,984,468	33,993,361	9,595	9,772	8,849	9,365
Maryland	13,446	34,943	37,667	31,922	6	7	7	5
Michigan	55,623,429	66,782,258	46,059,918	48,469,236	4,100	4,950	3,550	3,777
Mississippi	2,718,961	4,477,027	1,824,010	2,032,665	260	387	272	313
Missouri	0	0	0	0	0	0	0	0
Montana	25,286,348	26,158,548	25,550,623	26,293,657	3,533	3,754	3,599	3,747
Nebraska	750,809	833,513	737,155	680,726	99	99	107	110
New Mexico	81,059,390	84,488,076	75,030,251	74,434,929	9,232	9,616	8,175	8,053
Nevada	0	0	0	0	0	0	0	0
New York	10,637,283	11,518,289	9,955,424	8,990,196	5,442	5,723	5,206	4,701
North Dakota	449,971	762,017	365,044	357,321	55	67	65	64
Ohio	75,993,000	75,109,000	58,296,630	51,164,374	33,345	33,367	28,045	24,614
Oklahoma	153,207,218	178,200,970	128,605,758	135,298,831	17,676	20,321	13,156	13,727
Pennsylvania	131,800,000	133,455,545	157,319,592	170,389,112	40,830	42,437	46,330	52,134
South Dakota	396,482	415,523	555,782	577,289	56	56	74	81
Tennessee	1,586,127	1,411,060	860,214	727,714	401	310	174	147
Texas	258,983,600	268,891,682	243,017,953	261,952,716	32,200	33,312	29,912	32,059
Utah	9,359,853	11,928,457	8,351,805	9,333,455	929	1,099	778	836
Virginia	1,807,834	2,042,666	2,377,417	2,399,710	127	150	145	145
West Virginia	208,775,000	188,000,000	214,589,205	214,344,721	37,528	38,240	37,708	38,255
Wyoming	56,002,994	71,259,878	43,808,779	53,859,333	11,817	16,762	9,677	17,433
Total	1,418,273,779	1,478,105,523	1,343,581,006	1,417,466,018	245,961	260,563	235,722	253,880

Table D-2 State Level Marginal Natural Gas History Match Results

Appendix E: Aggregated Onshore Lower 48 Marginal Forecasts

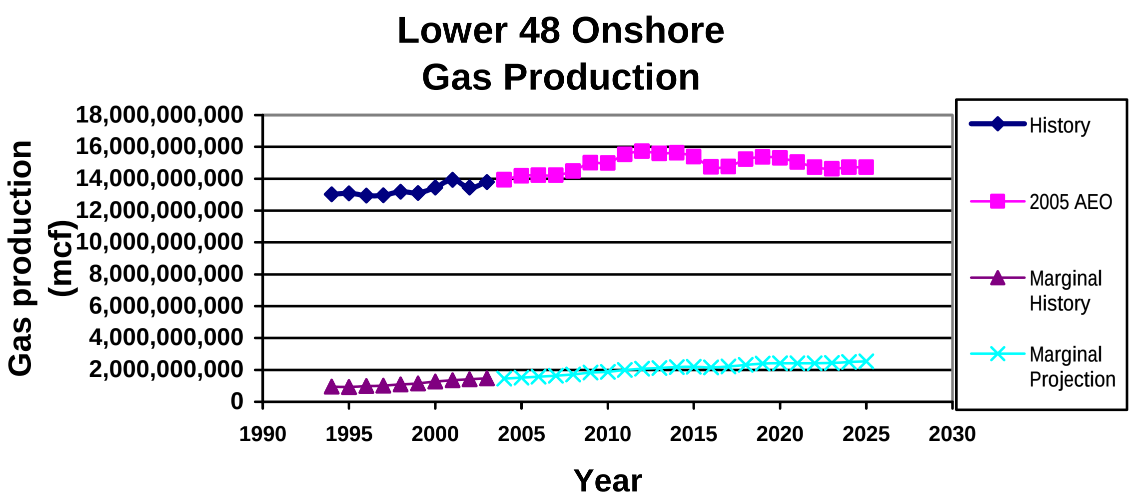
Lower 48 Onshore Marginal Oil Forecasts

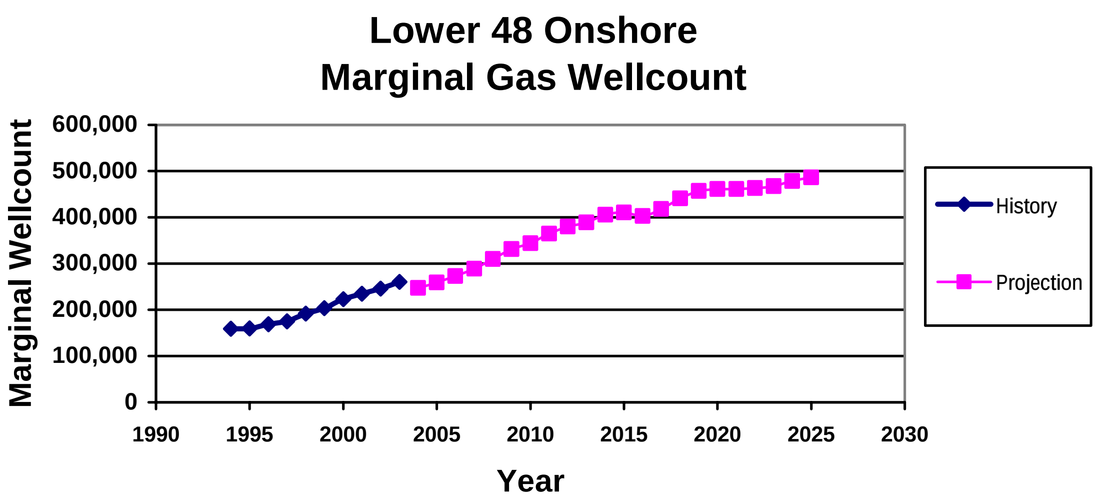




Year	1995	2000	2005	2010	2015	2020	2025
Total Oil Production (bbl)	1,392,249,000	1,185,402,000	1,032,950,000	960,680,000	883,300,000	818,695,000	762,485,000
Marginal Oil Production (bbl)	332,288,089	325,947,181	306,035,548	296,132,980	276,987,064	259,248,067	243,034,074
Percent Marginal Production	23.87	27.50	29.63	30.83	31.36	31.67	31.87
Number of Marginal Oil Wells	433,047	411,630	379,125	347,832	308,267	279,383	257,221
Average Marginal Well Rate (bbl/day)	2.10	2.17	2.21	2.33	2.46	2.54	2.59

Lower 48 Onshore Marginal Gas Forecasts

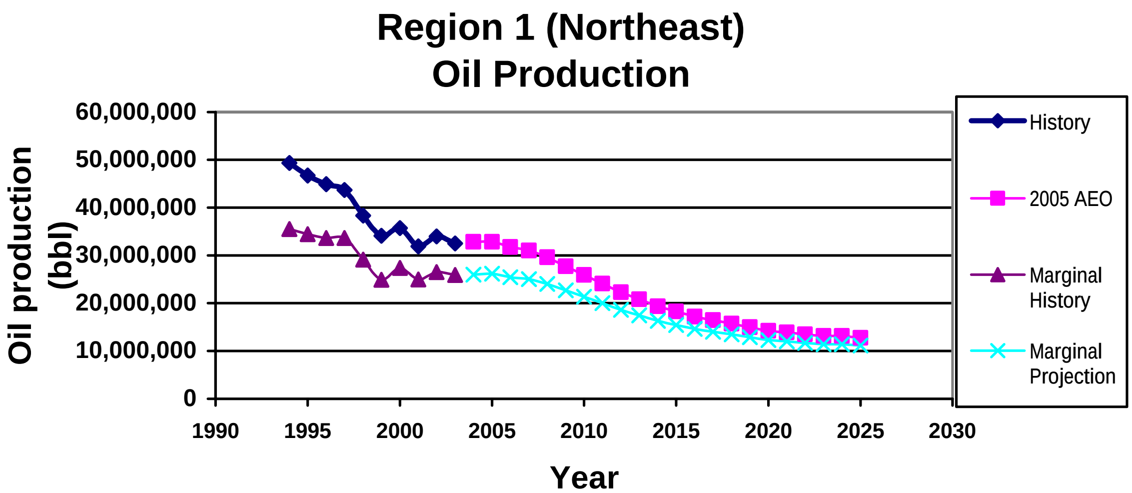


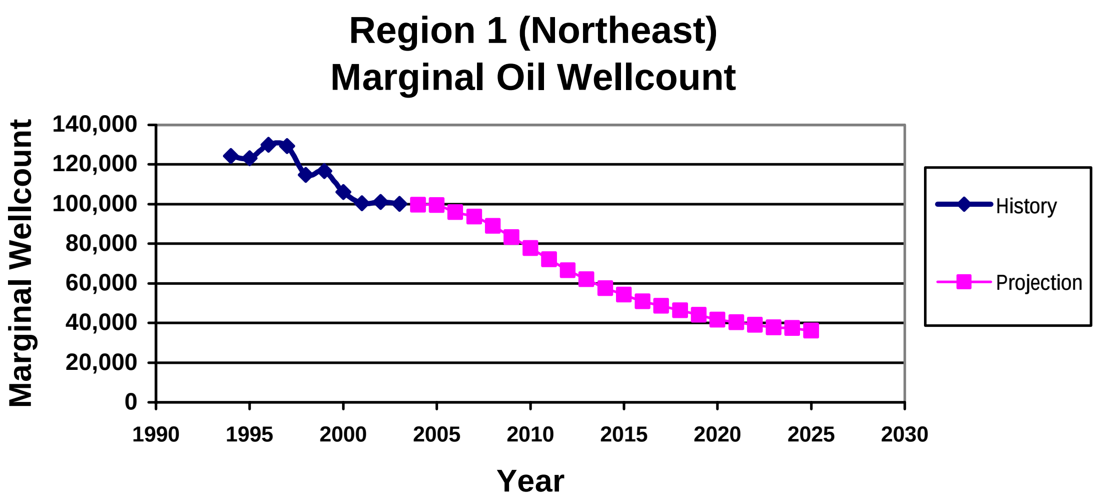


Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	13,089,720	13,445,852	14,177,006	14,978,014	15,382,021	15,300,026	14,709,030
Marginal Gas Production (MMcf)	925,563	1,258,727	1,507,268	1,875,890	2,193,320	2,416,486	2,530,881
Per cent Marginal Production	7.07	9.36	10.63	12.52	14.26	15.79	17.21
Number of Marginal Gas Wells	159,369	223,221	258,792	343,845	410,326	460,807	486,180
Average Marginal Well Rate (Mcf/day)	15.91	15.45	15.96	14.95	14.64	14.37	14.26

Appendix F: Aggregated Supply Region Marginal Forecasts

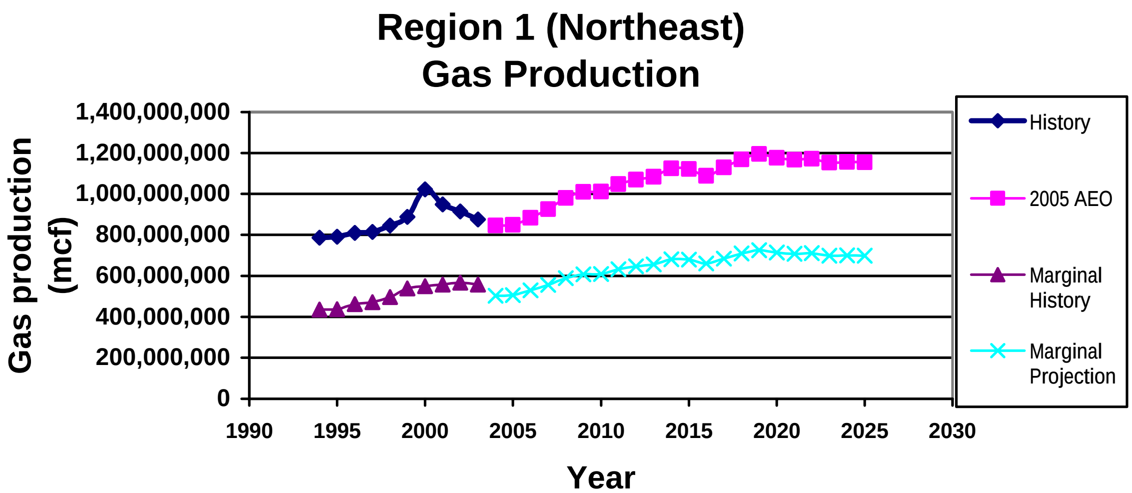
Northeast Region Marginal Oil Forecasts

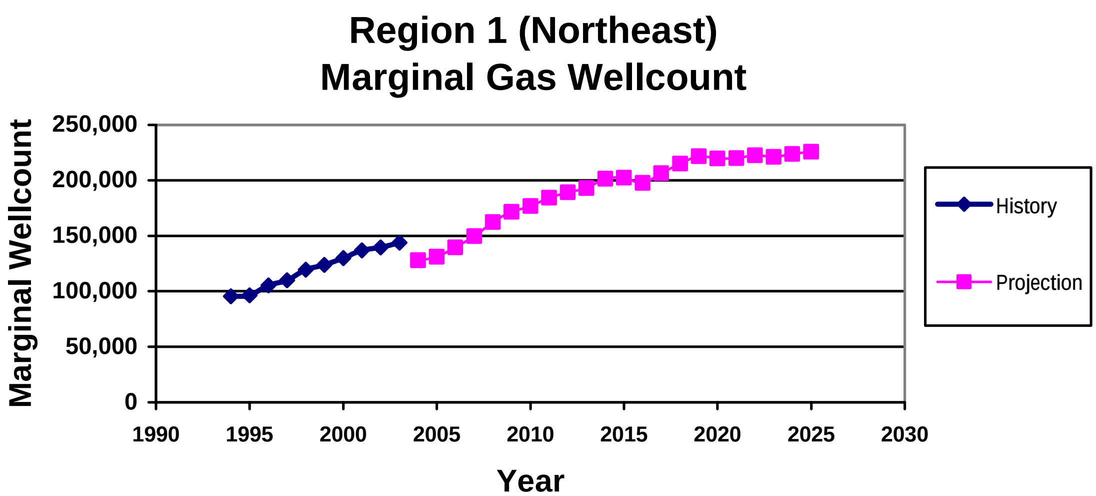




Year	1995	2000	2005	2010	2015	2020	2025
Total Oil Production (bbl)	46,686,000	35,716,000	32,850,000	25,915,000	18,250,000	14,235,000	12,775,000
Marginal Oil Production (bbl)	34,419,136	27,364,381	26,155,735	21,354,345	15,463,939	12,302,856	11,108,271
Percent Marginal Production	73.72	76.62	79.62	82.40	84.73	86.43	86.95
Number of Marginal Oil Wells	123,186	106,167	99,492	77,740	54,230	41,670	36,151
Average Marginal Well Rate (bbl/day)	0.77	0.71	0.72	0.75	0.78	0.81	0.84

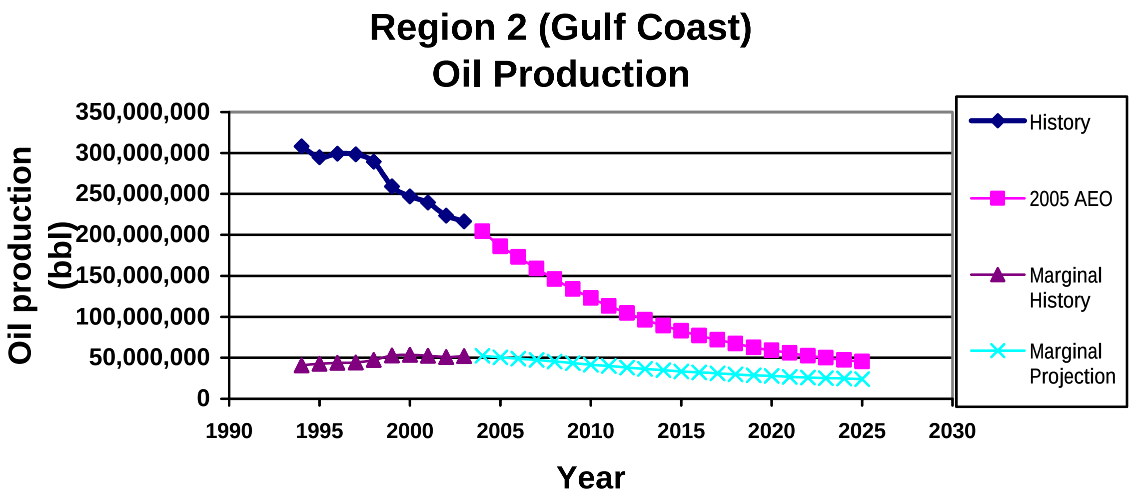
Northeast Region Marginal Gas Forecasts

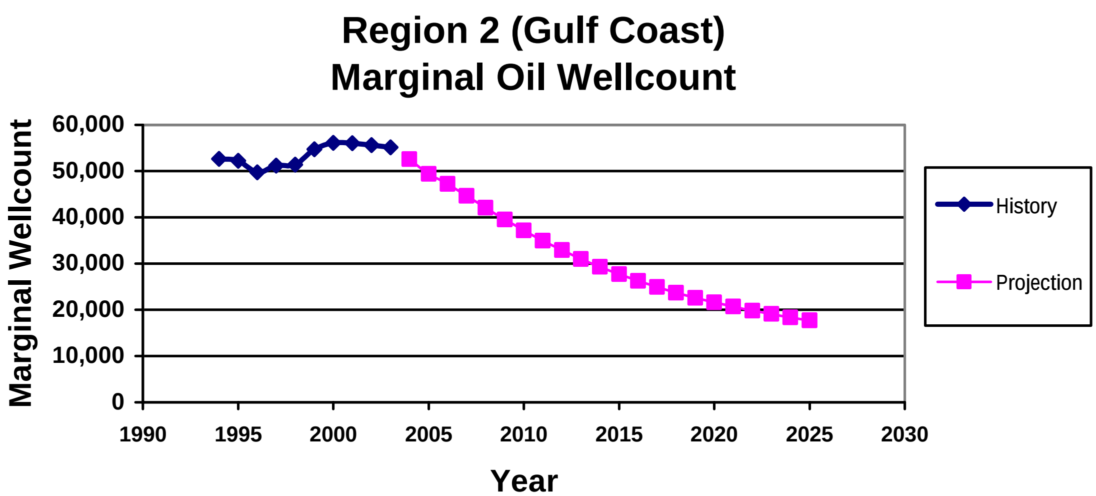




Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	790,388	1,022,004	848,000	1,011,000	1,122,000	1,176,000	1,154,000
Marginal Gas Production (MMcf)	436,887	548,901	506,364	609,335	679,866	713,614	698,543
Per cent Marginal Production	55.28	53.71	59.71	60.27	60.59	60.68	60.53
Number of Marginal Gas Wells	95,619	129,905	130,938	176,774	202,274	219,744	225,671
Average Marginal Well Rate (Mcf/day)	12.52	11.58	10.60	9.44	9.21	8.90	8.48

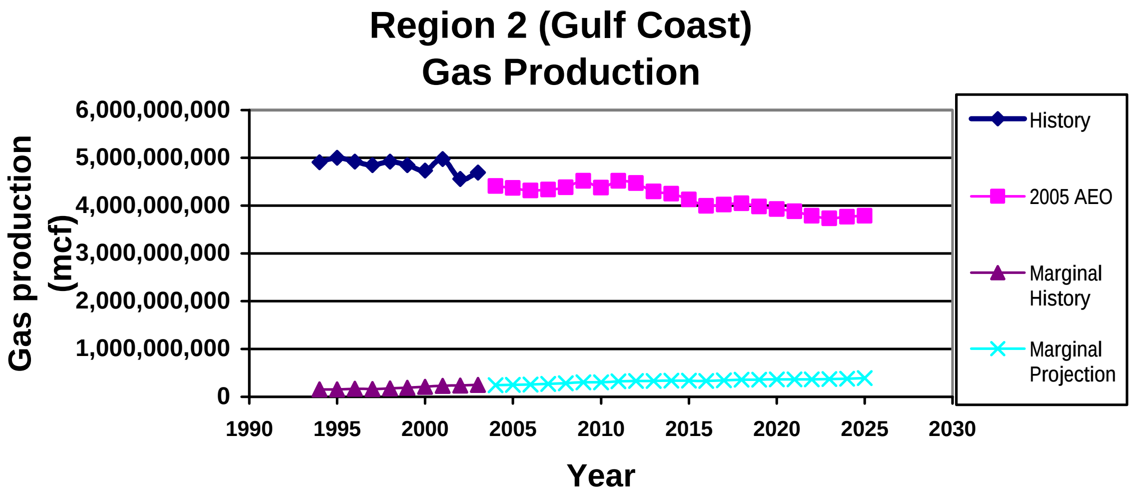
Gulf Coast Region Marginal Oil Forecasts

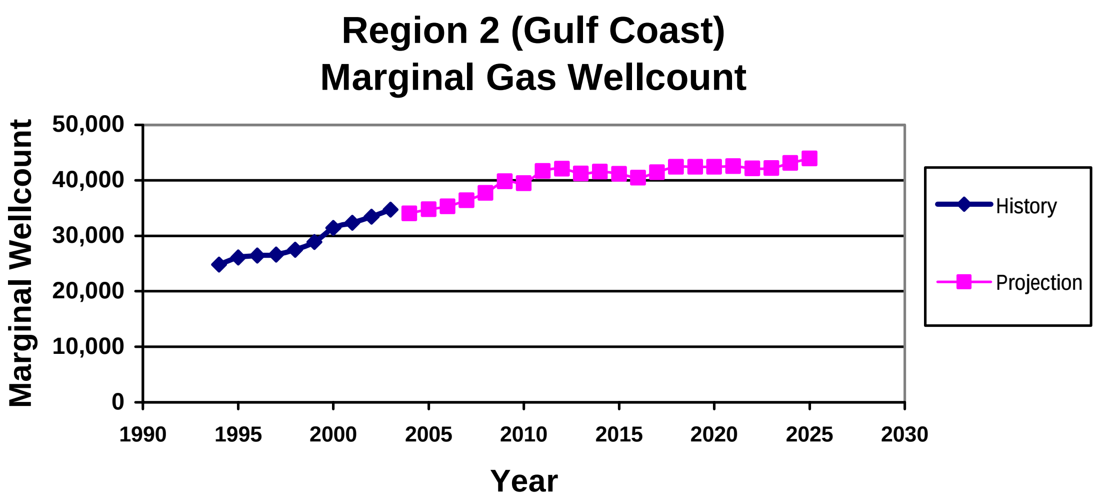




Year	1995	2000	2005	2010	2015	2020	2025
Total Oil Production (bbl)	294,846,830	246,879,840	186,150,000	123,005,000	82,855,000	59,130,000	45,260,000
Marginal Oil Production (bbl)	42,686,273	53,497,015	50,351,228	41,559,689	33,454,153	27,637,997	23,974,958
Percent Marginal Production	14.48	21.67	27.05	33.79	40.38	46.74	52.97
Number of Marginal Oil Wells	52,235	56,122	49,369	37,170	27,693	21,605	17,721
Average Marginal Well Rate (bbl/day)	2.24	2.61	2.79	3.06	3.31	3.50	3.71

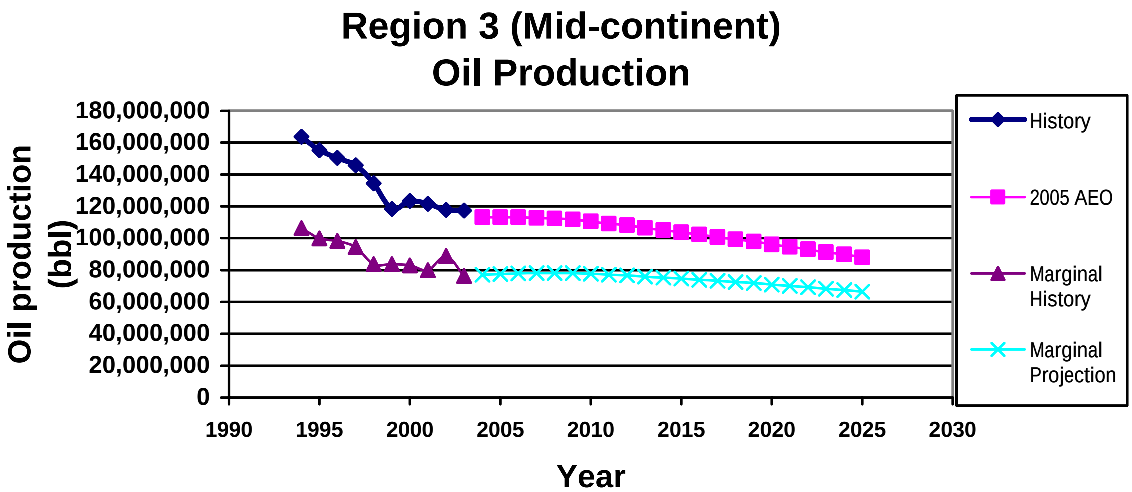
Gulf Coast Region Marginal Gas Forecasts

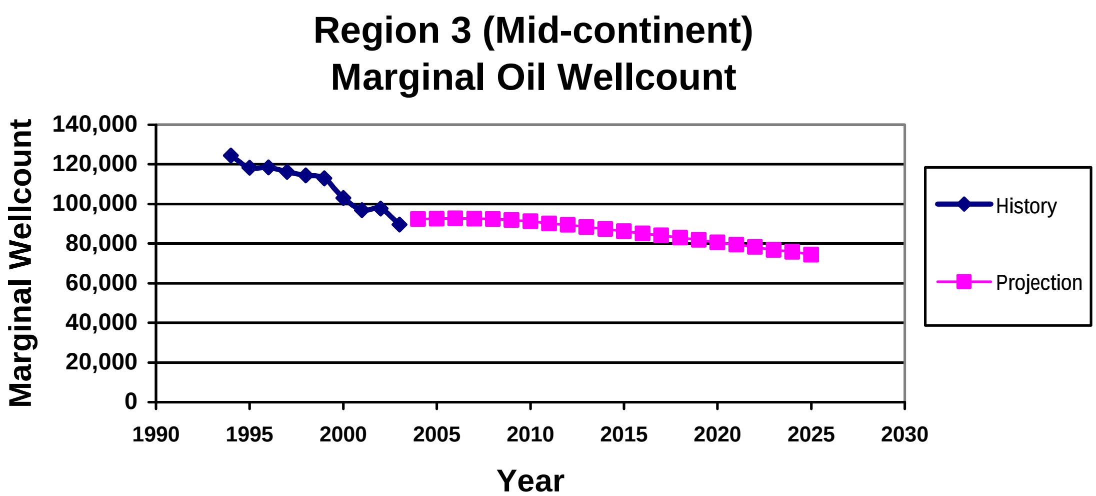




Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	4,999,567	4,729,391	4,372,000	4,374,000	4,129,000	3,924,000	3,782,000
Marginal Gas Production (MMcf)	156,565	205,020	247,434	301,310	333,208	361,070	388,962
Per cent Marginal Production	3.13	4.34	5.66	6.89	8.07	9.20	10.28
Number of Marginal Gas Wells	24,815	31,435	34,769	39,468	41,136	42,447	43,936
Average Marginal Well Rate (Mcf/day)	17.29	17.87	19.50	20.92	22.19	23.31	24.25

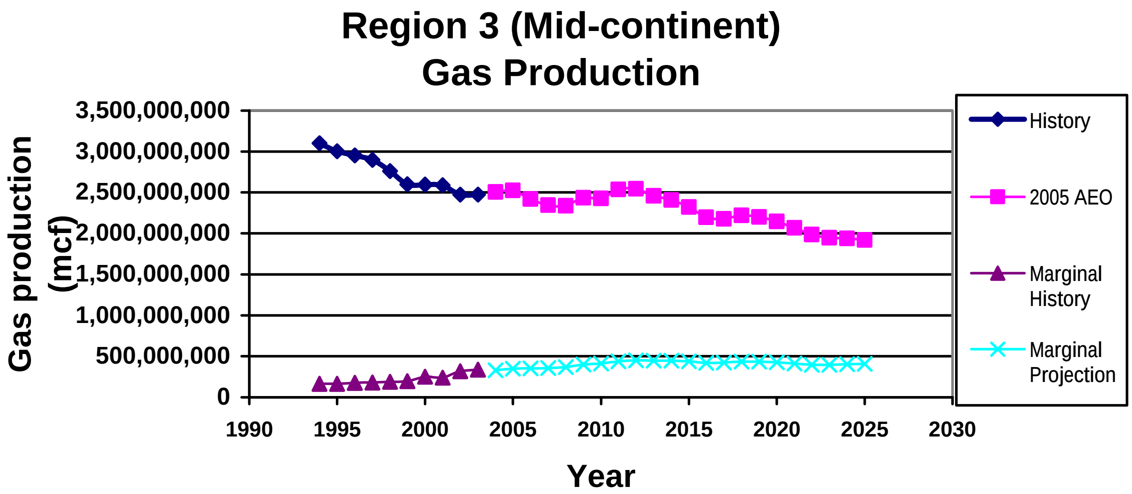
Mid-Continent Region Marginal Oil Forecasts

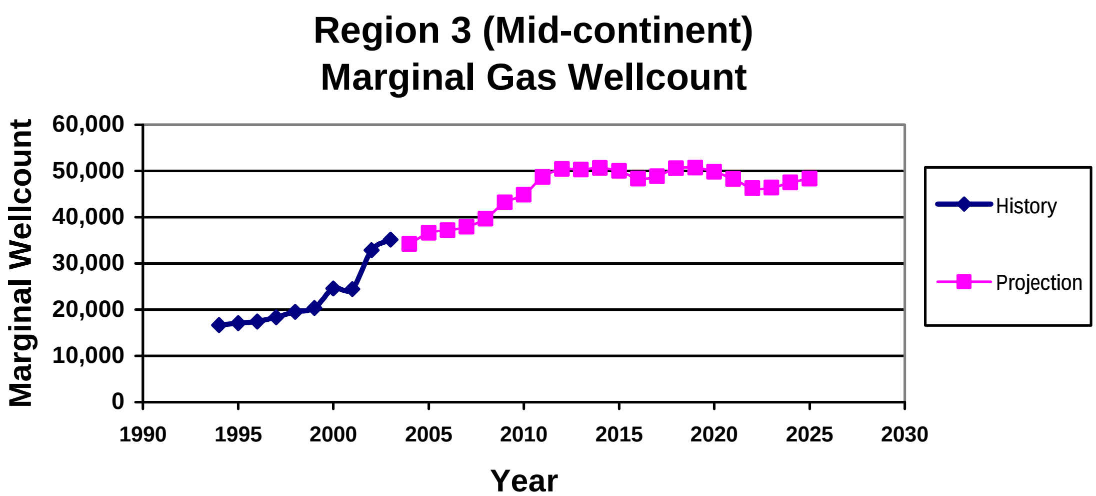




Year	1995	2000	2005	2010	2015	2020	2025
Total Oil Production (bbl)	155,248,580	123,497,840	113,150,000	110,595,000	103,660,000	95,995,000	87,965,000
Marginal Oil Production (bbl)	99,803,390	82,983,208	77,574,616	77,705,337	74,620,981	70,781,380	66,418,546
Percent Marginal Production	64.29	67.19	68.56	70.26	71.99	73.73	75.51
Number of Marginal Oil Wells	118,327	103,096	92,512	91,206	86,209	80,491	74,347
Average Marginal Well Rate (bbl/day)	2.31	2.21	2.30	2.33	2.37	2.41	2.45

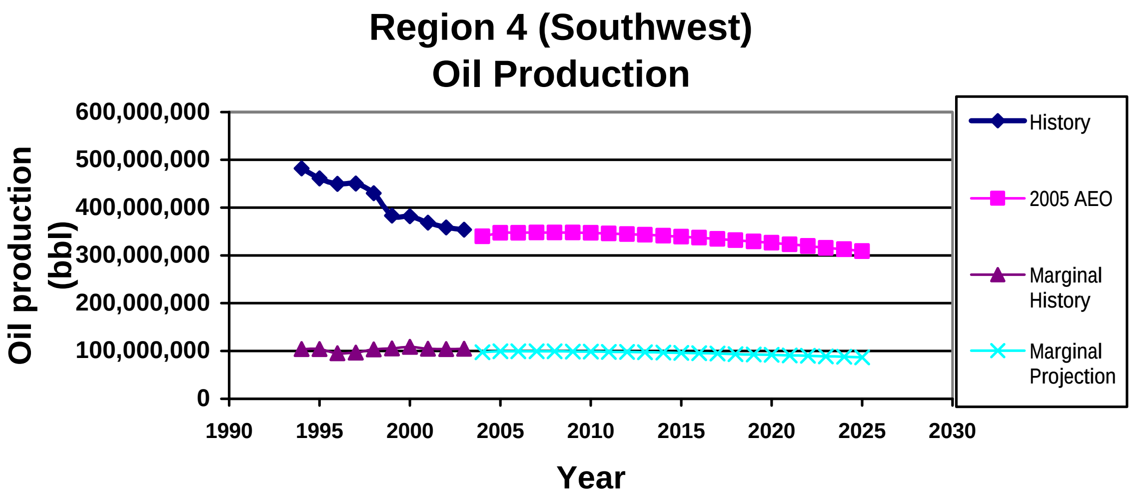
Mid-Continent Region Marginal Gas Forecasts

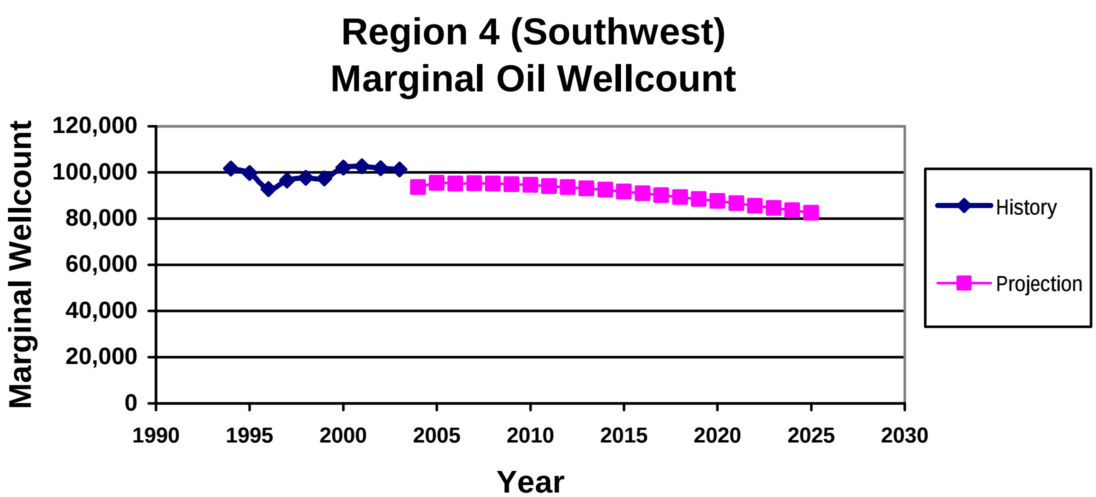




Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	3,001,266	2,595,162	2,525,006	2,428,014	2,320,021	2,146,026	1,917,030
Marginal Gas Production (MMcf)	162,843	251,287	349,944	409,175	436,830	424,951	407,704
Per cent Marginal Production	5.43	9.68	13.86	16.85	18.83	19.80	21.27
Number of Marginal Gas Wells	16,655	24,595	36,623	44,861	49,992	49,825	48,309
Average Marginal Well Rate (Mcf/day)	26.79	27.99	26.18	24.99	23.94	23.37	23.12

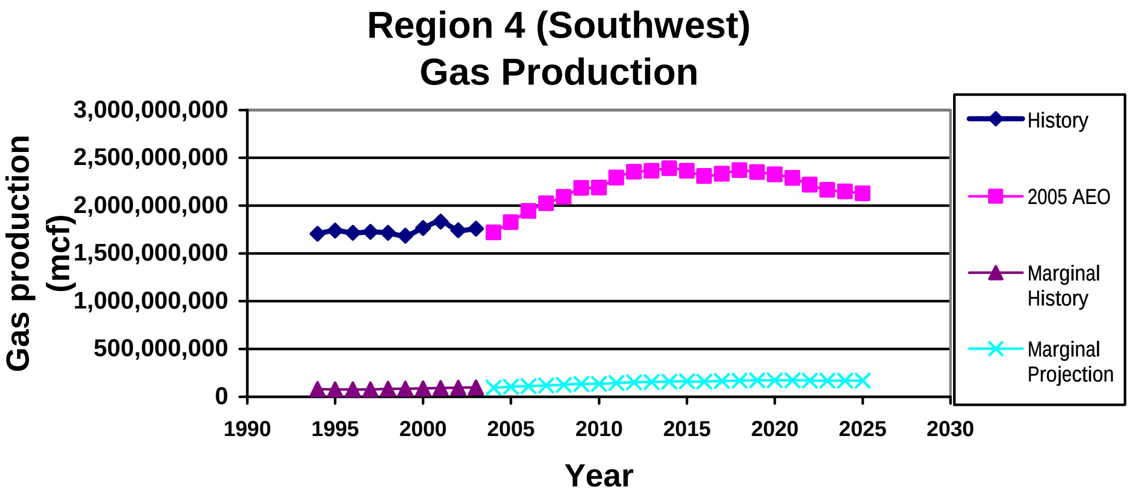
Southwest Region Marginal Oil Forecasts

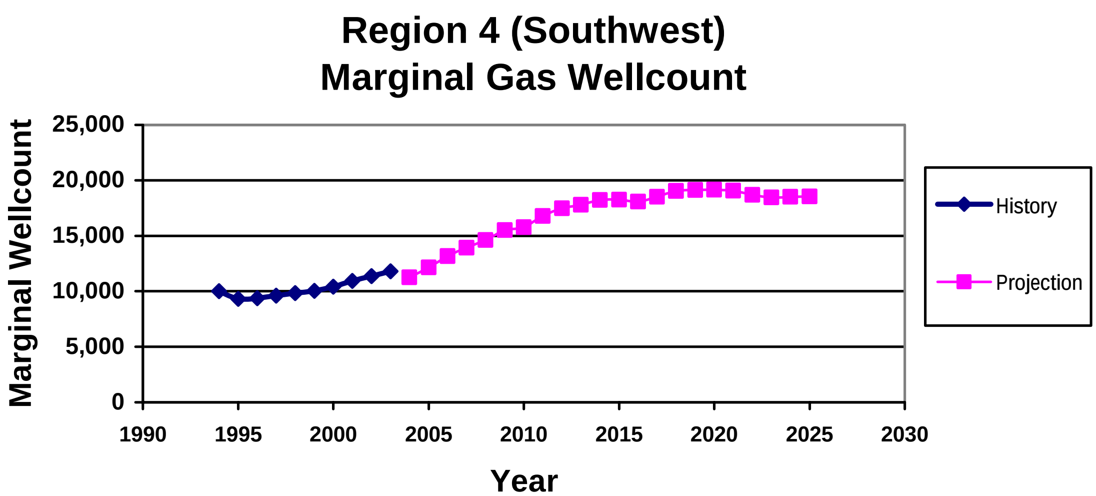




Year	1995	2000	2005	2010	2015	2020	2025
Total Oil Production (bbl)	460,921,590	381,580,320	346,750,000	346,750,000	339,085,000	325,945,000	308,790,000
Marginal Oil Production (bbl)	103,986,508	108,780,657	99,255,914	98,547,823	95,826,868	91,736,042	86,686,803
Percent Marginal Production	22.56	28.51	28.62	28.42	28.26	28.14	28.07
Number of Marginal Oil Wells	99,759	102,122	95,380	94,519	91,711	87,582	82,536
Average Marginal Well Rate (bbl/day)	2.86	2.92	2.85	2.86	2.86	2.87	2.88

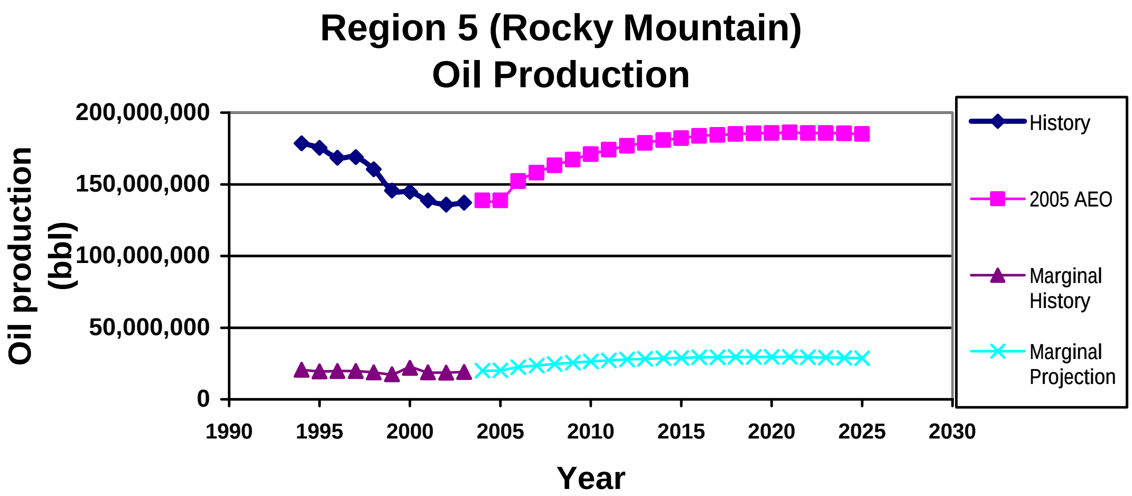
Southwest Region Marginal Gas Forecasts

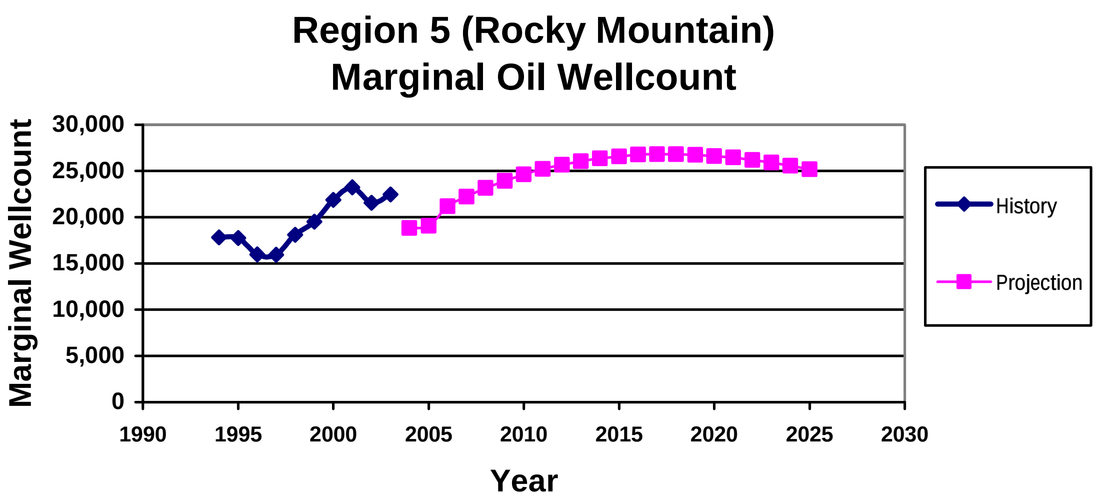




Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	1,739,332	1,764,343	1,826,000	2,187,000	2,361,000	2,325,000	2,128,000
Marginal Gas Production (MMcf)	76,040	88,220	102,885	135,660	159,841	170,550	168,098
Per cent Marginal Production	4.37	5.00	5.63	6.20	6.77	7.34	7.90
Number of Marginal Gas Wells	10,014	10,409	12,167	15,774	18,264	19,145	18,536
Average Marginal Well Rate (Mcf/day)	20.80	23.22	23.17	23.56	23.98	24.41	24.85

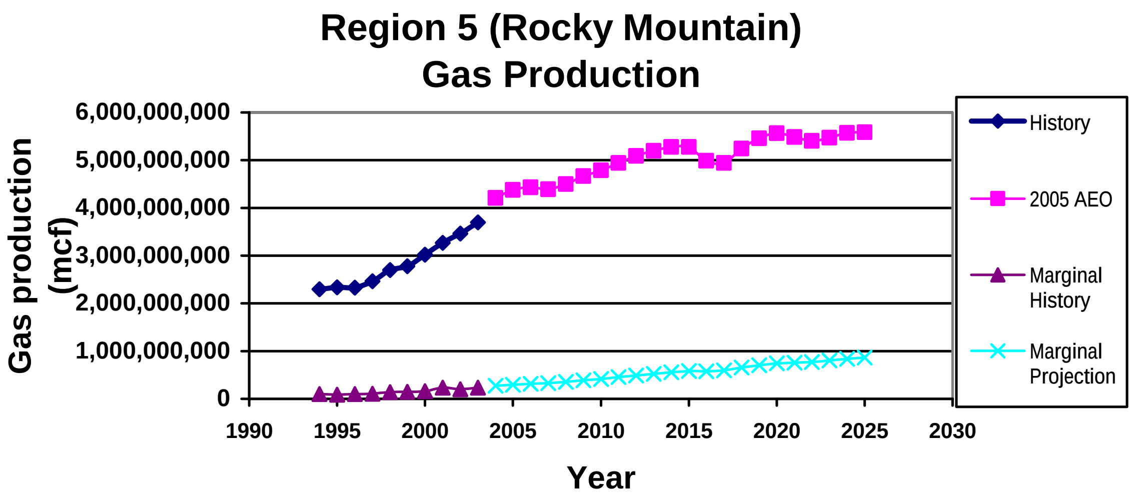
Rocky Mountain Region Marginal Oil Forecasts

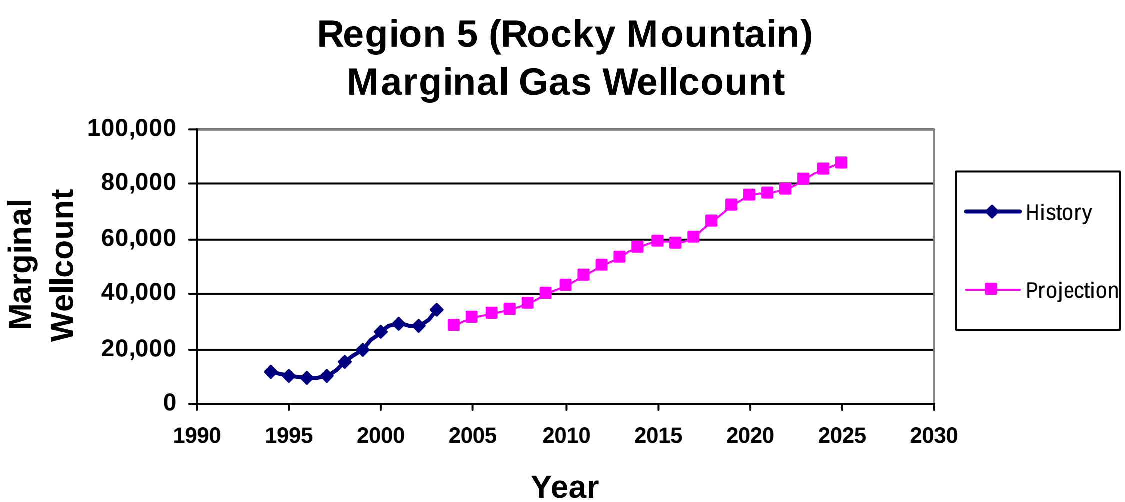




Year	1995	2000	2005	2010	2015	2020	2025
Total Oil Production (bbl)	175,469,000	144,834,000	138,700,000	170,820,000	182,135,000	185,785,000	185,055,000
Marginal Oil Production (bbl)	19,481,804	21,822,350	20,130,561	26,329,652	28,910,268	29,524,324	28,627,456
Percent Marginal Production	11.10	15.07	14.51	15.41	15.87	15.89	15.47
Number of Marginal Oil Wells	17,757	21,879	19,069	24,601	26,575	26,606	25,161
Average Marginal Well Rate (bbl/day)	3.01	2.73	2.89	2.93	2.98	3.04	3.12

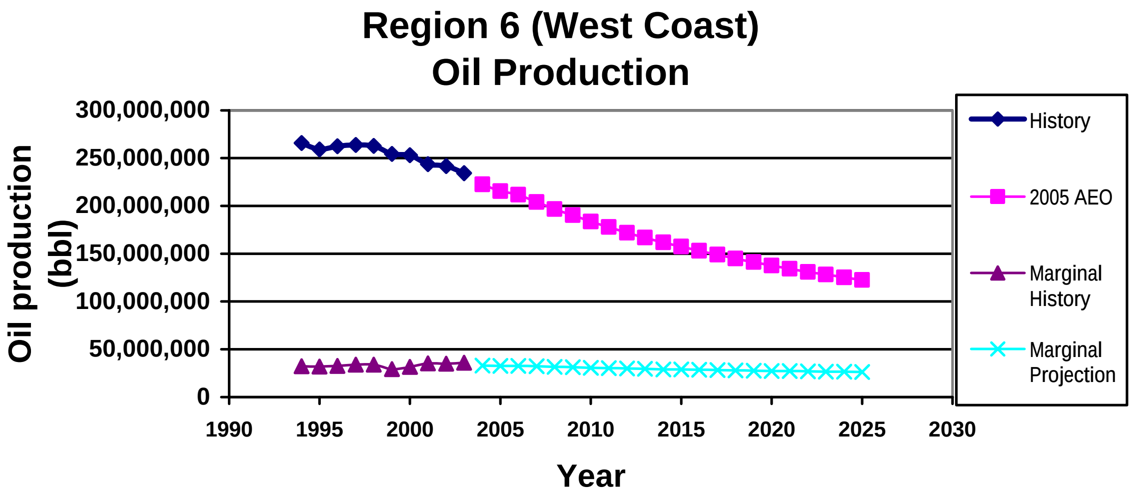
Rocky Mountain Region Marginal Gas Forecasts

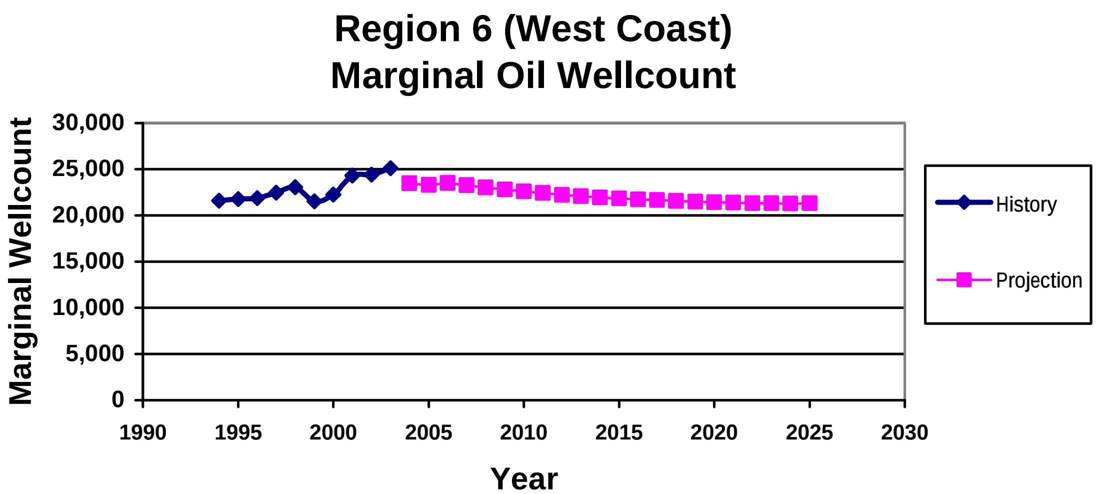




Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	2,336,714	3,020,602	4,378,000	4,788,000	5,274,000	5,564,000	5,582,000
Marginal Gas Production (MMcf)	89,927	162,465	298,281	418,803	582,419	745,530	867,168
Per cent Marginal Production	3.85	5.38	6.81	8.75	11.04	13.40	15.54
Number of Marginal Gas Wells	11,887	26,508	31,184	42,998	59,280	75,752	87,717
Average Marginal Well Rate (Mcf/day)	20.73	16.79	26.20	26.68	26.91	26.96	27.08

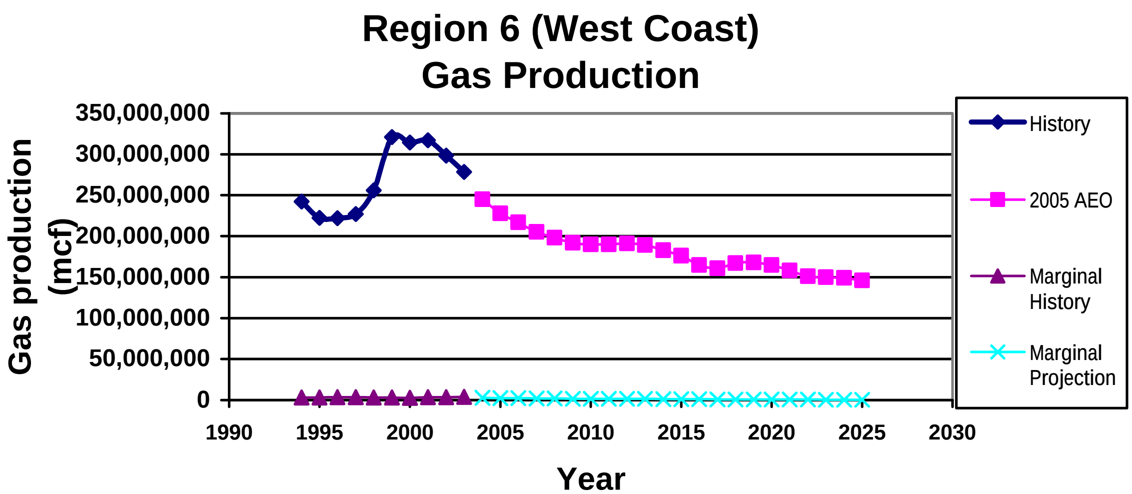
West Coast Region Marginal Oil Forecasts

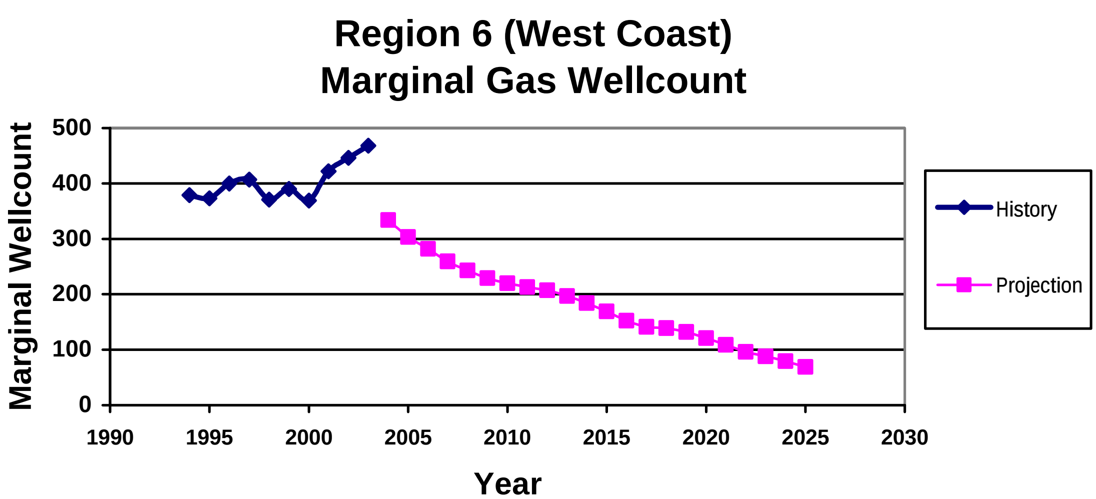




Year	1995	2000	2005	2010	2015	2020	2025
Total Oil Production (bbl)	259,077,000	252,894,000	215,350,000	183,595,000	157,315,000	137,605,000	122,640,000
Marginal Oil Production (bbl)	31,910,978	31,499,570	32,567,494	30,636,134	28,710,855	27,265,468	26,218,040
Percent Marginal Production	12.32	12.46	15.12	16.69	18.25	19.81	21.38
Number of Marginal Oil Wells	21,783	22,244	23,303	22,596	21,849	21,429	21,305
Average Marginal Well Rate (bbl/day)	4.01	3.88	3.83	3.71	3.60	3.49	3.37

West Coast Region Marginal Gas Forecasts





Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	222,453	314,350	228,000	190,000	176,000	165,000	146,000
Marginal Gas Production (MMcf)	3,301	2,833	2,360	1,607	1,155	771	406
Per cent Marginal Production	1.48	0.90	1.04	0.85	0.66	0.47	0.28
Number of Marginal Gas Wells	379	369	303	220	169	121	69
Average Marginal Well Rate (Mcf/day)	23.86	21.03	21.34	20.01	18.73	17.45	16.10