OIL & GAS RESERVES

IN NONTECHNICAL LANGUAGE

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Preface

Petroleum reserves represent the amount of oil, gas, and natural gas liquids that can be recovered over a period of time. For this reason, the importance of reserves to the entire oil & gas industry cannot be overestimated. Companies use reserve forecasts for planning, budgeting, and capital allocation. Energy lenders and investors make significant financial decisions based on reserve estimates and valuations. Government agencies and various organizations use resource estimates and reserve forecasts to make policy decisions, often with significant economic and worldwide consequences. Yet very few outside the reservoir engineering profession truly understand how oil & gas reserves are calculated and reported. Even fewer understand the inherent limitations involved with the estimation and reporting of reserves—even though most reserve reports include a warning along the lines of:

> ***It is not possible to measure underground accumulations of oil and natural gas in an exact way. Oil and natural gas reserve engineering is complex, requiring subjective estimates of underground accumulations of hydrocarbons and assumptions concerning future oil and natural gas prices, future production levels and operating and development costs. As a result, estimated quantities of proved reserves, projections of future production rates and the timing of development expenditures may prove inaccurate.***

Despite this clearly written caveat, many involved with the oil & gas industry, including engineers, finance professionals, investors, and even governments, continue to make important decisions that assume the quantities and values contained within a reserve report are unassailable. The results of this assumption are all too apparent—squandered investments, unsupportable debt, an inability to create value, and even outright bankruptcy—although many of these investments and companies reported significant and profitable reserves just prior to collapse.

So why does this happen? Why do important decision-makers continue to be surprised by poor results based on reserve reports they thought were strong enough to validate their decision? The answer is unfamiliarity with the fundamentals of oil & gas reserve reporting and a general acceptance, even unquestioned assumption, of the validity of a reserve report. Fortunately, a basic working knowledge of the fundamentals of oil & gas reserves and reserve reporting can overcome these

limitations. Knowing what reserves are and what information a reserve report contains—or, more importantly, what a reserve report does not contain or imply—can make a tremendous difference in the quality of reserve-based decision-making.

The goal of this book is to provide the reader with an easily readable yet thorough examination of the important fundamentals and concepts of oil & gas reserves and reserve reporting. Using clear, nontechnical language, this book will introduce the reader to the basic reservoir and geological principles of oil & gas reserves, discuss how these reserves are classified and reported, how an actual reserve report is prepared, and, perhaps most importantly, how to validate a reserve report.

While the book's goal is clear, it is not without limitations. The world of reserves estimation is very technical, even within the petroleum engineering community. The knowledge and experience required to be a qualified reserves estimator are significant. Furthermore, since no two reservoirs are alike, the nuances and definitions used in estimating reserves can be very technical and specific. For every example used in this book, an experienced reservoir engineer or reserves evaluator can easily find an exception. The sources summarized in this book, like the SPE's Petroleum Resources Management System (PRMS), are extensive, detailed, 200-plus-page documents and are updated on a regular basis. Trying to capture the details of these in a nontechnical book is all but impossible.

So, given these limitations, it is hoped that the reader will gain a solid working knowledge and understanding of oil & gas reserves and reserve reporting, which in turn will lead to better and more realistic decision-making—and fewer unpleasant surprises.

Introduction

In the simplest of terms, petroleum reserves represent the amount of oil, gas, and natural gas liquids that can be recovered over a period of time. For this reason, many consider the calculation and reporting of petroleum reserves—from an individual well to an entire prospective region—to be the foundation of the oil & gas industry. Oil & gas companies typically calculate and report reserve forecasts on an annual basis. These forecasts are used for various purposes, including budgeting, production forecasting, capital allocation, exploration initiatives, and internal valuation and benchmarking. Outside of the industry, reserve reports are used extensively by investors and energy finance professionals to quantify the intrinsic value of a company, its overall potential for growth, and whether an oil & gas asset or company merits a financial investment. On a much larger scale, governments and associated agencies use reserve estimates and calculations to form energy policy, levy taxes, and promote capital investment. However, and despite the incredible importance of reserve estimates and reports to an exceptionally broad and diverse base of stakeholders, very few outside of the reservoir engineering profession truly understand what it takes to calculate oil & gas reserves and prepare the associated reserve report. In fact, far too many take a reserve report and the information contained within as fact upon which sound decisions can be made. For this very reason, the oil & gas industry is littered with squandered investments and failed companies that still managed to post significant and profitable reserves just prior to collapse.

This is most unfortunate and is generally quite avoidable. In fact, the oil & gas industry and the engineers who calculate reserves go out of their way to warn all who rely upon a reserve report of the inherent risks associated with reserve calculations. They do so by including language similar to the following as a preface to any published reserve report:

> ***It is not possible to measure underground accumulations of oil and natural gas in an exact way. Oil and natural gas reserve engineering is complex, requiring subjective estimates of underground accumulations of hydrocarbons and assumptions concerning future oil and natural gas prices, future production levels, and operating and development costs. As a result, estimated quantities of proved reserves, projections of future production rates, and the timing of development expenditures may prove inaccurate.***

And just like the small print found on many product warranties, this language is often ignored. Fortunately, the oil & gas industry goes out of its way to ensure oil & gas reserves are calculated and reported in the most accurate way possible. In fact, the calculation and definition of oil & gas reserves is perhaps the most studied and documented subgroup of the entire petroleum engineering profession. Since the beginning of the oil & gas industry, some of the most brilliant minds have worked diligently to refine the techniques used to calculate oil & gas reserves and to create a standardized measure of reserve reporting. This work continues today as new resources are found and new exploitation and production technologies become available.

Despite the meticulous work, thorough research, and diligence employed by reserve engineers and auditors—as well as the aforementioned caveats—oil & gas executives, seasoned energy finance professionals, and investors often find themselves surprised when a reserve estimate proves to be overstated or fails to materialize. So, why does this happen? The reasons are numerous, but the foremost is the fact that many fail to grasp the true nature of a reserve report and its intended purpose. A reserve report is not designed to guarantee the ability to produce projected reserves; rather, its primary function is to quantify them accurately. For example, a company might accurately estimate and disclose significant reserves, both in quantity and value, associated with a new play. However, if oil & gas prices decline, the ability to fund this forecasted growth may diminish. In some cases, unforeseen geological or reservoir constraints may come into play, especially with new discoveries. As more production and reservoir data becomes available, initial reserve estimates may be modified and, in some cases, reduced. Finally, external factors totally unrelated to a reserve estimate may hinder or reduce projected production and cash flow. Poor management and risky financial decisions, such as taking on excessive debt to fund new acquisitions, can lead to failure and bankruptcy despite having verified robust and profitable reserves.

Fortunately, the most effective way to avoid surprises related to reserve calculations and reporting is through knowledge. While the mathematics and methodologies used in calculating reserves can be daunting, obtaining a basic understanding of oil & gas reserves and reporting does not necessitate a technical background. Many of the concepts are easily comprehensible and grounded in common sense. However, there is a notable dearth of materials and publications covering the fundamentals of oil & gas reserves, with existing resources often heavily focused on the reservoir engineering aspects of reserve calculations. Moreover, when it comes to comprehending and utilizing a reserve report for decision-making, materials are limited, leaving on-the-job training as the primary means of gaining experience. Hence, it is of utmost importance that everyone relying on a reserve report—be it oil & gas industry personnel or energy finance professionals—grasps the fundamentals of oil & gas reserves and their reporting methodologies. This, of course, requires a working knowledge of the geological

principles of hydrocarbon accumulations, the definitions used in reserve reporting, the standards and methods used to prepare and present a reserve report, and how a reserve report can be used to analyze the ability to add and monetize reserves profitably.

1

PETROLEUM GEOLOGY

An oil & gas reserve report is, in summary, an "estimation of the amount of oil, gas, and natural gas liquids that can be recovered over a period of time from a known accumulation of hydrocarbons." There are two key concepts contained within this definition. The first and foremost is the term "accumulation." Without a basic knowledge of how and under what conditions hydrocarbons can accumulate and create a reservoir, it is almost impossible to understand how the volumes and value of these accumulations are estimated. This leads us to the second key concept, which involves the term "estimation." As one can imagine, it is impossible to physically and precisely measure the oil & gas contained within a reservoir found miles below the surface of the earth.

Understanding how oil & gas reservoirs are formed and how it is possible to estimate the quantities of hydrocarbons located far below the earth's surface requires knowledge of petroleum geology. Petroleum geology is a broad science that seeks to answer questions like: How do hydrocarbon accumulations form? Where did the organic material that eventually became oil & gas originate? What geological processes facilitated the accumulation of oil & gas in economically significant quantities? What are the characteristics of the rock hosting the oil & gas reservoirs, and how are they determined? These questions, when answered, can provide the information necessary to begin the reserves estimation process.

Today, advancements in petroleum geology, particularly in technologies like reflection seismology (seismic) and borehole evaluation, coupled with modern computing capabilities, have enhanced our ability to identify hydrocarbon accumulations and estimate their potential reserves with increasing precision. However, despite these strides, significant uncertainties persist, particularly with novel hydrocarbon plays. New reservoir types, structural settings, extreme depths, and other geological complexities can introduce unforeseen challenges to reserves estimation.

The Rock Cycle

To understand the more complex geological forces that create hydrocarbon reservoirs, it is necessary to begin with a fundamental geological concept known as

Conventional Reservoirs

Conventional oil & gas reservoirs are formed through a complex interplay of geological processes spanning millions of years. They are characterized by their high porosity and permeability, which allows hydrocarbons to migrate from the original source rock and accumulate within the reservoir rock. The formation of a conventional reservoir requires six key conditions: a source rock, migration pathways, a reservoir rock, a trap, a seal, and an energy source to mobilize the hydrocarbons. Figure 2.1 depicts a simplified schematic of a conventional reservoir, illustrating how various geological components, from source rock to sealing rock, work together to form and maintain the reservoir.

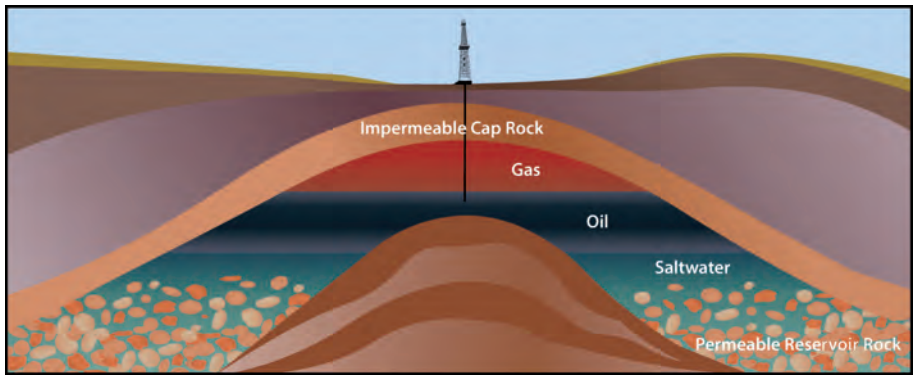

Figure 2.1. Basic Characteristics of a Conventional Reservoir

Source Rock

One of the key elements in the formation of a conventional reservoir is the source rock, the original sedimentary formation where oil & gas originate and the thermal maturation process occurs. Petroleum source rocks are typically organic-rich shales or limestones that have become oil- and gas-bearing through the transformation of organic matter. These fine-grained sediments contain sufficient organic material to generate and release enough hydrocarbons to form commercial accumulations of oil or gas. Due to the low permeability of most source rocks, oil & gas tend to remain trapped within the rock for long geological periods, requiring significant pressure and time to force the hydrocarbons through the dense rock matrix.

Migration

Oil & gas migration is the process by which hydrocarbons move out of the original source rock. This migration is driven by pressure differentials and

Hydrocarbon Classifications and Reserves

In reservoir engineering, reservoirs can be further defined based on the physical properties of the hydrocarbons found within the reservoir. These physical properties include color, gravity, and hydrocarbon weight (Figure 3.1). Based on these properties, oil, natural gas, and natural gas liquids are typically categorized into five reservoir types:

- Black Oil
- Volatile Oil
- Gas Condensate
- Wet Gas
- Dry Gas

Understanding these classifications helps users of reserve reports contextualize and understand reserve estimates and values for various reservoirs and fields. Each of these categories requires different production methods, which impact operating expenses. They also receive different market pricing, affecting revenues. How these fluids interact within a reservoir and are produced can significantly influence ultimate recoveries, impacting both volume and value. While this gets into a level of detail beyond a nontechnical book, a brief overview of these classifications and their impact on reserves follows.

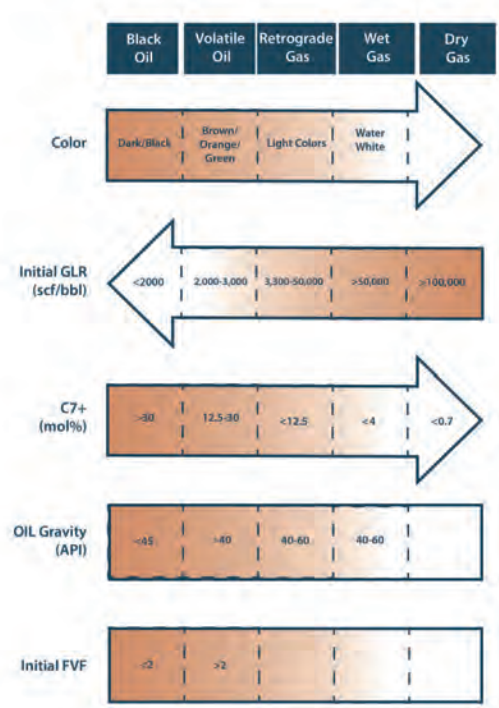

Figure 3.1. The Physical Properties of Hydrocarbon Classifications

Black Oil

Black oil is a type of crude oil characterized by its dark color and relatively low gas-oil ratio (GOR). The GOR for black oil typically ranges from 100 to 800 standard cubic feet per barrel (scf/bbl), indicating that it releases smaller quantities of gas when brought to surface conditions from the reservoir. The API gravity of black oil ranges from 9 to 45, and below an API of 9, it becomes tarry and is generally referred to as bitumen.

Proved Reserves can be further classified as "developed" or "undeveloped." These terms are significant, especially within the energy lending and finance space.

Proved Developed Reserves

Proved Developed Reserves are defined as "*those Proved Reserves that can be expected to be recovered through existing wells and facilities and by existing operating methods.*" The SPE then goes on to define several categories of Proved Developed Reserves including Proved Developed Producing (PDP) and Proved Developed Nonproducing (PDNP). The SPE defines Proved Developed Producing Reserves (PDP) as reserves that can be recovered from completion intervals that are open and producing at the time of the estimate. Proved Developed Nonproducing Reserves (PDNP) are defined by the SPE to include shut-in and behind-pipe reserves. Shut-in reserves are reserves that are not producing for known reasons, such as recently completed wells that have not started producing, wells that were shut in for market conditions or pipeline connections, and/or wells not capable of production for mechanical reasons. Proved Developed Behind-pipe Reserves (PDBP) are reserves that can be recovered from zones in existing wells that are currently not open and require additional completion work or future re-completion prior to the start of production.

Proved Undeveloped Reserves

Proved Undeveloped Reserves (PUD) are commonly associated with new wells that will be drilled in to known accumulation of oil & gas. The SPE defines Proved Undeveloped Reserves as "*those Proved Reserves that are expected to be recovered from future wells and facilities, including future improved recovery projects which are anticipated with a high degree of certainty in reservoirs which have previously shown a favorable response to improved recovery projects.*"

The SPE and SEC have further refined the definition to include only offset wells drilled within a known field boundary and/or reservoir. Thus, on only a rare occasion would an exploration well ever be classified as a PUD. That said, overbooking of reserves classified as PUD does occur. For this reason, both reserve auditors and the SEC take a very close look at the reserves categorized as PUD.

Of all the terms and definitions presented above, Proved Reserves are the most important, especially when it comes to reserve reporting. Very few reserve reports contain detailed information on anything other than Proved Reserves, and as far as the SEC and many financial institutions are concerned, Probable and Possible Reserves are irrelevant, although having a large amount of Probable and Possible Reserves can provide an element of comfort to a potential lender.

Table 6.1. Example Lease Operating Statement (LOS)

JRT RESOURCES

NET LOS

Field: TEXAS (ALL)	1st Quarter Actual	2nd Quarter Feb	3rd Quarter Mar	4th Quarter Apr	12 MONTH TOTAL
-- SALES VOLUMES --			Volume Data		
-- 100 % / 8/8'S --					
CRUDE OIL (BBLS)	37,650	42,598	41,230	48,543	170,021
NATURAL GAS (MCF)	45,144	35,658	42,144	55,356	178,302
NGL's (BBLS)	497	392	464	609	1,961
NET PROD SALES BOE (6:1)	45,671	48,933	48,718	58,378	201,699
DAILY BOE	*502*	*538*	*535*	*642*	*553*
-- NET VOLUMES --					
Crude Oil (BBLS)	28,238	31,949	30,923	36,407	127,516
Natural Gas (MCF)	33,858	26,744	31,608	41,517	133,727
NET PROD SALES BOE (6:1)	34,253	36,700	36,538	43,783	154,979
DAILY BOE	*255*	*218*	*164*	*156*	*425*
-- NET PRICES --					
Oil	$72.34	$75.33	$78.10	$73.24	$74.74
Gas	$3.49	$3.76	$3.25	$2.75	$3.26
-- REVENUES --					
OIL REVENUES	$2,042,701	$2,406,681	$2,415,047	$2,666,467	$9,530,895
GAS REVENUES	$118,010	$100,444	$102,726	$114,172	$435,352
TOTAL OIL & GAS REVENUE	**$2,160,711**	**$2,507,125**	**$2,517,773**	**$2,780,639**	**$9,966,248**
TAXES					
SEVERANCE TAX EXPENSE	$97,232	$112,821	$113,300	$125,129	$448,481
AD VALOREM TAX EXPENSE	$43,214	$50,142	$50,355	$55,613	$199,325
TOTAL TAX EXPENSE	$140,446	$162,963	$163,655	$180,742	$647,806
-- TOTAL NET REVENUES --	**$2,020,265**	**$2,344,162**	**$2,354,118**	**$2,599,897**	**$9,318,442**
LEASE OPERATING EXPENSE					
COMPANY LABOR	$42,816	$68,629	$45,673	$54,729	$211,847
CONTRACT LABOR	$42,816	$45,875	$66,500	$43,783	$198,974
MAINTENANCE & REPAIR	$83,920	$89,915	$82,211	$107,269	$363,315
COMPRESSORS	$18,839	$20,185	$20,096	$24,081	$83,201
PULLING UNIT / WELL SERVICE	$196,954	$211,025	$210,095	$251,755	$869,828
EQUIPMENT RENTALS	$71,931	$77,070	$76,730	$91,945	$317,676
SALT WATER DISPOSAL	$111,322	$130,285	$118,749	$142,296	$502,652
CHEMICAL TREATMENT	$37,678	$40,370	$40,192	$48,162	$166,402
MATERIAL & SUPPLIES	$56,517	$104,595	$60,288	$72,243	$293,643
TRANSPORTATION	$8,563	$9,175	$9,135	$10,946	$37,819
MISC / OTHER	$38,363	$41,104	$40,923	$49,037	$169,427
TOTAL LEASE OPERATING EXPENSES	**$709,721**	**$838,226**	**$770,590**	**$896,247**	**$3,214,785**
$/BOE	*$15.54*	*$17.13*	*$15.82*	*$15.35*	*$15.94*
WORKOVER EXPENSE	$124,233	$25,413	$87,315	$187,210	$424,171
TOTAL OPERATING EXPENSES	**$833,954**	**$863,639**	**$857,905**	**$1,083,457**	**$3,638,956**
PLUG & ABANDON	$0	$0	$55,715	$0	$3,638,956
-- NET LEASE OPERATING INCOME --	**$833,954**	**$863,639**	**$802,190**	**$1,083,457**	**$5,679,486**
CAPITAL EXPENDITURES					
DRILLING_TANGIBLE	$0	$0	$0	$0	$0
DRILLING-INTANGIBLE	$0	$0	$0	$0	$0
EQUIPMENT	$0	$78,235	$0	$14,875	$0
FACILITY	$0	$0	$276,908	$0	$276,908
TOTAL CAPITAL COSTS	**$0**	**$78,235**	**$276,908**	**$14,875**	**$370,018**
-- NET LEASE CASH FLOW --	**$833,954**	**$785,404**	**$525,282**	**$1,068,582**	**$5,309,468**

Table 10.1. Gross/Net One-Line Report

Lease Summary

Project Name: JRT Resources - SEC **As of Date: 1/1/2023**

Lease Name *Risked / UnRisked*	Gross Reserves Oil (MBBL)	Gross Reserves Gas (MMCF)	Net Reserves Oil (MBBL)	Net Reserves Gas (MMCF)	Net Revenue Oil ($)	Net Revenue Gas ($)	Net Revenue Other ($)	Expense & Tax ($)	Invest. ($)	Cash Flow Non-Disc. ($)	Cash Flow Disc. CF ($)
Grand Total	**1,433.45**	**1,588.50**	**1,197.51**	**1,375.60**	**109,746.51**	**10,760.23**	**0.00**	**58,451.03**	**8,210.00**	**53,845.71**	**27,869.88**
Proved Rsv Class	**1,433.45**	**1,588.50**	**1,197.51**	**1,375.60**	**109,746.51**	**10,760.23**	**0.00**	**58,451.03**	**8,210.00**	**53,845.71**	**27,869.88**
Proved Rsv Class											
Proved Producing Rsv Class & Category	**892.68**	**227.57**	**740.05**	**191.58**	**67,821.74**	**1,591.29**	**0.00**	**39,727.55**	**3,935.00**	**25,750.48**	**14,258.38**
Proved Rsv Class											
Proved Producing Rsv Class & Category											
ALBANY Field	**892.68**	**227.57**	**740.05**	**191.58**	**67,821.74**	**1,591.29**	**0.00**	**39,727.55**	**3,935.00**	**25,750.48**	**14,258.38**
HARTFORD 1	60.05	0.00	45.85	0.00	4,202.08	0.00	0.00	3,292.39	1,175.00	-265.31	216.57
HARTFORD 2A	285.48	98.01	229.72	78.87	21,053.11	718.47	0.00	12,188.08	870.00	8,713.50	4,380.61
REED STUART	104.73	0.00	84.82	0.00	7,773.32	0.00	0.00	4,759.72	510.00	2,503.60	1,465.28
WRIGHT A	43.80	0.00	32.85	0.00	3,010.50	0.00	0.00	1,899.13	180.00	931.37	516.66
WRIGHT B	398.62	129.55	346.80	112.71	31,782.73	872.82	0.00	17,588.22	1,200.00	13,867.33	7,679.25
Proved Rsv Class											
Proved Shut-In Rsv Class & Category	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Proved Rsv Class											
Proved Shut-In Rsv Class & Category											
ALBANY Field	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
WRIGHT P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Proved Rsv Class											
Proved Non-Producing Rsv Class & Category	**378.68**	**100.43**	**316.46**	**87.37**	**29,001.79**	**676.61**	**0.00**	**11,455.11**	**275.00**	**17,948.29**	**7,982.33**
Proved Rsv Class											
Proved Non-Producing Rsv Class & Category											
ALBANY Field	**378.68**	**100.43**	**316.46**	**87.37**	**29,001.79**	**676.61**	**0.00**	**11,455.11**	**275.00**	**17,948.29**	**7,982.33**
HARTFORD #6	59.66	0.00	44.75	0.00	4,100.96	0.00	0.00	1,363.90	25.00	2,712.06	1,086.24
REED #28 P1	7.77	100.43	6.76	87.37	619.31	676.61	0.00	99.90	35.00	1,161.03	665.27
REED B 10A	55.47	0.00	48.26	0.00	4,422.90	0.00	0.00	2,180.68	25.00	2,217.25	1,045.29
REED B 17A	55.47	0.00	48.26	0.00	4,422.90	0.00	0.00	2,180.12	25.00	2,217.78	1,071.96
REED B 41	55.47	0.00	48.26	0.00	4,422.90	0.00	0.00	2,180.22	25.00	2,217.68	1,080.69
REED B 9A	55.47	0.00	48.26	0.00	4,422.90	0.00	0.00	2,180.18	25.00	2,217.72	1,089.94
WRIGHT #11	29.83	0.00	24.01	0.00	2,199.99	0.00	0.00	424.02	25.00	1,750.97	671.60
WRIGHT #12	29.78	0.00	23.95	0.00	2,194.95	0.00	0.00	423.05	45.00	1,726.90	635.67
WRIGHT #27	29.76	0.00	23.95	0.00	2,194.95	0.00	0.00	423.05	45.00	1,726.90	635.67
Proved Rsv Class											
Proved Undeveloped Rsv Class & Category	**162.08**	**1,260.51**	**141.01**	**1,096.64**	**12,922.99**	**8,492.32**	**0.00**	**7,268.37**	**4,000.00**	**10,146.95**	**5,629.17**
Proved Rsv Class											
Proved Undeveloped Rsv Class & Category											
ALBANY Field	**162.08**	**1,260.51**	**141.01**	**1,096.64**	**12,922.99**	**8,492.32**	**0.00**	**7,268.37**	**4,000.00**	**10,146.95**	**5,629.17**
HARTFORD PUD #1	35.03	352.91	30.48	307.03	2,793.16	2,377.66	0.00	1,810.78	1,000.00	2,360.03	1,286.74
HARTFORD PUD #2	32.77	194.83	28.51	169.50	2,612.40	1,312.62	0.00	1,484.55	1,000.00	1,440.48	792.63
REED B PUD #1	47.14	356.38	41.01	310.05	3,758.71	2,401.02	0.00	1,986.57	1,000.00	3,173.16	1,782.15
REED B PUD #2	47.14	356.38	41.01	310.05	3,758.71	2,401.02	0.00	1,986.46	1,000.00	3,173.27	1,767.65

The gross/net one-liner is designed to give the users of a reserve report a quick snapshot of the reserve situation. Common elements of a gross/net one-liner include:

- **Title, Date, and Timing**—Gross/net one-liners will include a title and both the "as-of" date and the date the report was generated.
- **Gross Reserves**—This column provides the total volume of reserves associated with the property or project. It includes all reserves, regardless of ownership interests.