

Future Oil Production for the Alaska North Slope

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Preface

Future Oil Production for the Alaska North Slope, a product of the Energy Information Administration's (EIA) Office of Oil and Gas, Reserves and Production Division, provides a range of plausible production scenarios for the North Slope area of Alaska based on the decline of existing production, the anticipated start-up of identified field development projects, and future discovery and development of the remaining undiscovered oil resources estimated for the area by the U.S. Geological Survey (USGS), the Bureau of Land Management (BLM), and the Minerals Management Service (MMS).

Because EIA is a policy-neutral agency, this report focuses on those portions of the North Slope not presently subject to exploration and development restrictions. The production potential associated with currently withdrawn or prohibited areas of the National Petroleum Reserve-Alaska (NPR-A) and the Arctic National Wildlife Refuge (ANWR) is not considered here. Also not considered in this report are heavy (viscous) oil production and the conversion of natural gas to liquid.

The estimates of undiscovered resources of the Northeast National Petroleum Reserve-Alaska (NE NPR-A) used herein were taken from the Integrated Activity Plan/Environmental Impact Study (IAP/EIS) prepared for the May 1999 lease sale by the U.S. Department of Interior's Bureau of Land Management in cooperation with the Minerals Management Service. The estimates of undiscovered resources used for the area between ANWR and NPR-A and for the area west of the NE NPR-A were based on the latest USGS estimates adjusted to correspond to the areal divisions used herein.

Readers should be aware of the limitations of the projections presented in this report. The USGS resource estimates, on which the presented production estimates are based, encompass a sizeable range of uncertainty. Further, there are

many underlying energy market-affecting forces that cannot now be known with certainty such as the future rate of technological development, the impact of future variations in oil prices, future legislative and regulatory changes, and impacts of the future state of the general economy on supply and demand.

Simplifying assumptions were made which also add to the uncertainty of the projections. For example, production schedules were postulated without specific reference to the effects of prices and technology advancements. Oil price is, of course, a key factor in determining when production becomes economic. Rapid technology growth can yield lower costs and faster development, or the reverse can happen given slower technology growth.

General information about this publication may be obtained from John Wood, Director of the Reserves and Production Division, (214) 720-6150. Specific information regarding the content or preparation of this report may be obtained from Floyd Wiesepape, (214) 720-6166, fax (214) 720-6155, or e-mail Floyd.Wiesepape@eia.doe.gov.

A glossary of frequently used acronyms and technical terms is included.

As an adjunct to this report, Senator Frank H. Murkowski, Chairman of the Senate Committee on Energy and Natural Resources, requested that EIA prepare a special report presenting plausible scenarios for Arctic National Wildlife Refuge (ANWR) development. EIA submitted that study, [*Potential Oil Production from the Coastal Plain of the Arctic National Wildlife Refuge: Updated Assessment*](#), to the Committee in May 2000. It is available on the EIA website.

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Executive Summary

Future Oil Production for the Alaska North Slope was prepared by the Reserves and Production Division, Office of Oil and Gas, Energy Information Administration (EIA) as part of the Domestic Oil and Gas Technical Support Program. The report presents a range of plausible production scenarios of combined crude oil, condensate, and natural gas liquids (NGL) *hereafter jointly referred to as oil*, for the Alaska North Slope (North Slope or ANS).

Production of oil (total liquids) from the ANS has declined from the 1988 peak rate of over 2.0 million barrels per day (MMbbl/d). As of this writing, the rate of production is about 1.1 MMbbl/d, accounting for 16 percent of total domestic production in 2000. Cumulative production through 2000 was 13.306 billion barrels (Bbbls).

In the absence of additional development 3.707 Bbbls remain to be produced from the currently on-stream fields. The inclusion of identified development, defined for the purposes of this report as projects to develop additional resources in discovered fields located near the existing production and transportation infrastructure, increases the ANS remaining recovery potential to 5.126 Bbbls.

Beyond identified development, exploration for and subsequent development of as-yet undiscovered ANS resources could add significant volumes to ultimate recovery. Three estimates of undiscovered technically recoverable resources that are representative of the range of uncertainty associated with the resource estimation process are used herein to provide a range of production scenarios for each of the ANS sub-areas analyzed. These estimates are based on the U.S. Geological Survey's (USGS) 95 percent probability (19 in 20 chance) of occurrence, mean (expected value), and 5 percent probability (1 in 20 chance) of occurrence values.

The production projections presented here were constructed in three layers beginning with the anticipated future production from currently on-

stream fields. The second layer adds production from the anticipated development of identified fields and projects. The third layer adds projected volumes of production from technically recoverable undiscovered resources. The projections are based on historical performance, the reported anticipated performance of projects in the identified development category, and the application of current performance parameters to estimates of undiscovered resources.

The assumed minimum and maximum operating capacities of the Trans Alaska Pipeline System (TAPS) were limiting factors in determining minimum and peak production rates. Production projections based on performance history such as those presented in this report inherently embody past rates of technology improvement. The production possibilities associated with potential future gas-to-liquid conversion, gas liquefaction, and high viscosity crude production projects were not considered in this analysis.

The range of remaining and undiscovered Alaska North Slope oil is 6.1 to 13.3 billion barrels with a mean (expected) value of approximately 8.9 billion barrels. Ultimate recovery will range from 19.4 to 26.6 billion barrels. The mean ultimate recovery is approximately 22.2 billion barrels. **Figure ES1** shows the production schedule for the mean estimates of undiscovered resources layered on the projected production of the currently producing and anticipated new development fields.

Identified development will stabilize ANS production at approximately 1.0 MMbbl/d until 2005, at which point decline resumes in the absence of new discoveries. If the identified development is delayed by factors such as low oil prices or environmental issues, production will begin declining before the year 2005.

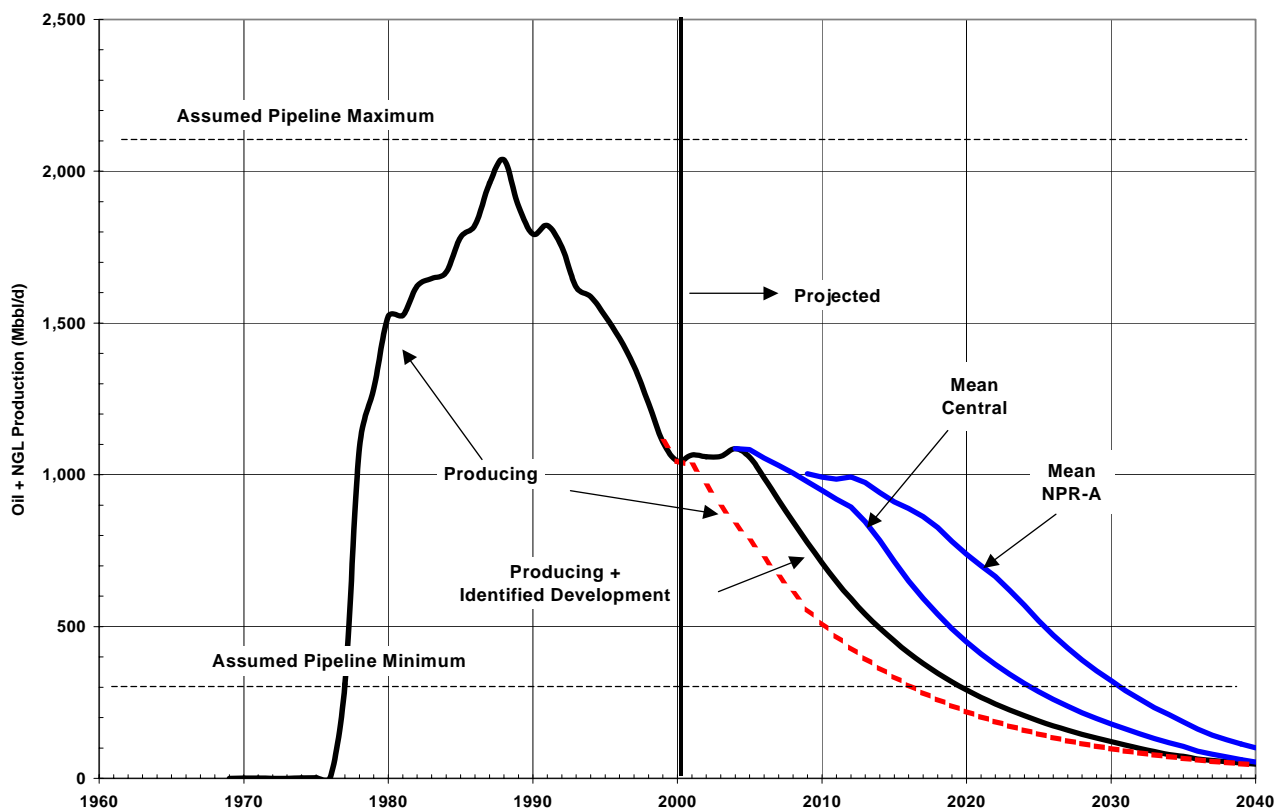
Finding and developing the estimated mean volume of undiscovered resources in the ANS areas that are presently open to exploration and development activity maintains the production

rate at approximately 1.0 million barrels per day until 2010. Production from the development of undiscovered resources in the National Petroleum Reserve-Alaska (NPR-A) is assumed to begin in 2010, causing production to remain close to 1.0 million barrels per day for another 5 years. The development of the estimated mean volume of resources increases the productive life of the ANS by approximately 10 years. Development of volumes larger than the mean estimate could increase production to approximately 1.4 million barrels per day.

Continued exploration for and development of undiscovered ANS resources is necessary to make a significant impact on production decline. Since minimum ANS production is not based on

the minimum economic limits of individual fields, but rather on the sum of production from all producing fields compared to the assumed minimum pipeline operating limit, the timing of the future development will become critical as production declines to approach that limit. To the extent that development is delayed, technically recoverable oil resources in known fields will not be recovered. Further, when new development is added late in the producing life of the area, it might not be possible to produce the newest fields to their economic abandonment rate before the pipeline reaches its minimum operating limit and is shut down, in which event the remaining reserves in these fields also would not be recovered.

Figure ES1. Alaska North Slope Production History with Production Projections of Fields Producing, Producing plus Identified Development, and Mean Estimates of Undiscovered Resources (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

1. Overview of the Alaska North Slope

Background

The Alaska North Slope (North Slope or ANS) is the source of approximately 15 percent of United States oil production. It also contains the largest estimated volume of undiscovered petroleum resources of any domestic onshore sedimentary basin. What happens on the ANS thus has the potential to significantly affect the future domestic supply of oil and natural gas liquids (NGL). This study assesses the plausible range of future production potential of the ANS via projections based on a combination of undiscovered technically recoverable resource estimates, reserve estimates, production data, and publicly announced industry plans obtained from a variety of sources.

An oil and gas resource assessment of the entire North Slope area was completed in 1995 by the U. S. Geological Survey (USGS). A study of the eastern portion of the National Petroleum Reserve-Alaska (NPR-A), by the Alaska Department of Natural Resources Division of Oil and Gas, was completed in 1997. In 1998, the Bureau of Land Management published the Northeast National Petroleum Reserve-Alaska (NPR-A) Final Integrated Activity Plan/Environmental Impact Statement (IAP/EIS) which included a resource assessment prepared by the Minerals Management Service. The Alaska Division of Oil and Gas annually publishes a report prepared for the Alaska Legislature on the production and reserves of the producing fields in the State. This information, along with information gathered from press releases and published articles, provides the basis for this analysis of the production potential of the ANS.

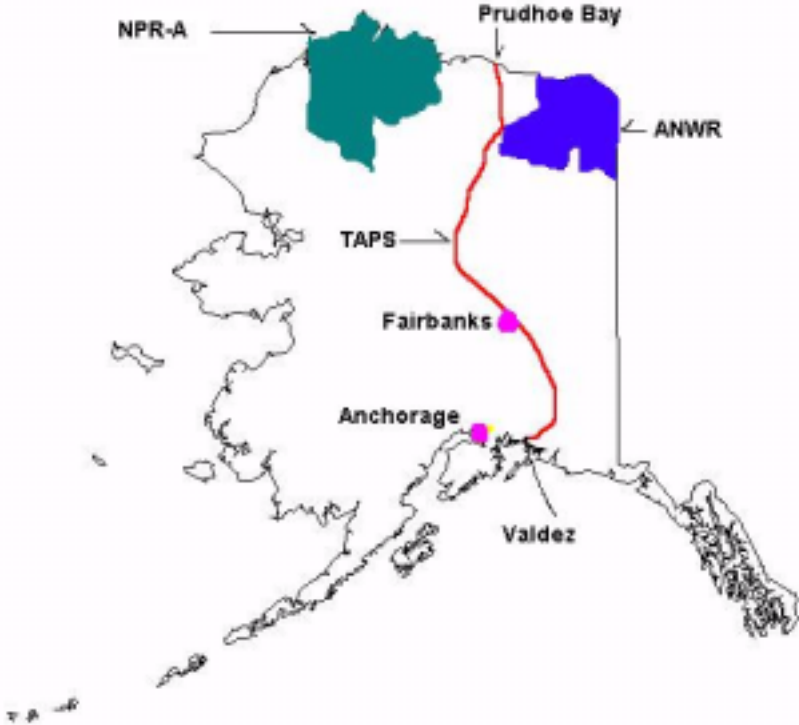
The projections presented here provide a view of the future production that could plausibly be expected from that part of the ANS located between ANWR and NPR-A (central area), from the Northeast NPR-A planning area, and from the remainder of NPR-A (west of the current planning area). The projections are based on three layers of estimated production. The first layer projects the current performance of producing fields. The second layer incrementally adds production from identified development (developing fields) to the current production. The third layer incrementally adds production from undiscovered technically recoverable resources, which are estimated at the 95 percent (19 in 20 chance), mean (expected value), and 5 percent (1 in 20 chance) probabilities of occurrence.

Geographic Setting

The ANS is the area north of the Brooks Range of mountains between the foothills and the Chukchi and Beaufort Seas, extending approximately 700 miles westward from the Canadian border to Point Hope. The coastal plain portion is an arctic desert receiving only 10 inches of precipitation annually. The average temperature ranges from 40° Fahrenheit in the summer to -20° Fahrenheit in the winter. Permafrost extends to a depth of approximately 2000 feet beneath the land surface. The barren, almost flat coastal plain gives way to treeless rolling hills as it extends southward toward the foothills of the Brooks Range.

The National Petroleum Reserve-Alaska (NPR-A) is an area of special interest on the ANS set aside by Congress. (**Figure 1**)

Figure 1. Map of the State of Alaska Locating the NPR-A, ANWR, Trans Alaska Pipeline System (TAPS), and Prudhoe Bay on the North Slope



Source: State of Alaska Department of Natural Resources Division of Oil and Gas.

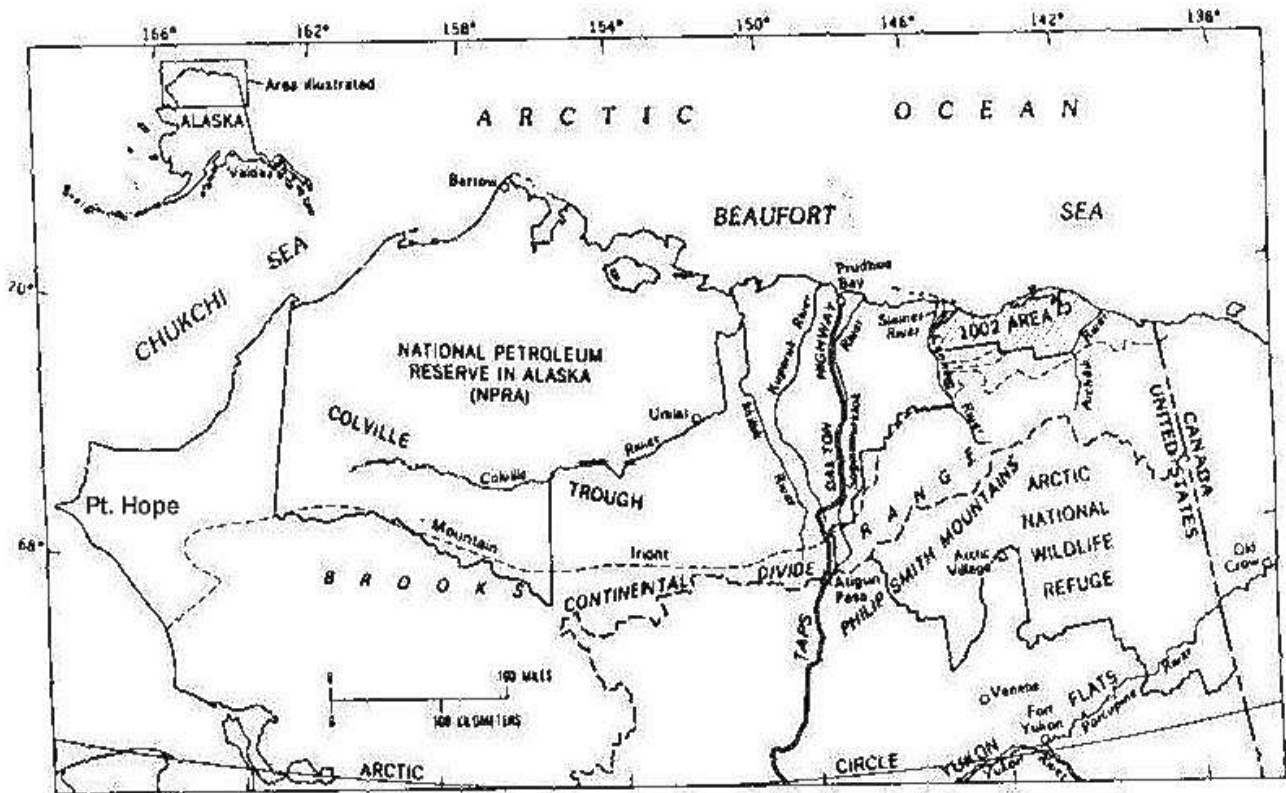
It was initially established as Naval Petroleum Reserve No. 4 (PET-4) by President Warren Harding in 1923. In 1976, Congress passed the Naval Petroleum Reserve Production Act which transferred responsibility for PET-4 from the Navy to the Department of Interior, and the 23.5-million-acre area was renamed the National Petroleum Reserve-Alaska. NPR-A extends westward from the Colville River, located 55 miles west of Prudhoe Bay, to Icy Cape at 162° West Longitude. The southern boundary is the Brooks Range. The northern boundary follows the coastline of the Beaufort and Chukchi Seas. NPR-A is larger than ANWR and approximately the size of the state of Indiana (Figures 1 and 2).

The BLM completed the Northeast National Petroleum Reserve-Alaska Integrated Activity Plan/Environmental Impact Statement (IAP/EIS)

in August 1998 to determine the appropriate use and management of 4.6 million acres of the NPR-A located closest to the existing petroleum infrastructure clustered about the Prudhoe Bay Field. A lease sale was held May 5, 1999.

The area between ANWR on the east and NPR-A on the west is primarily State-owned land extending from the Brooks Range to the Beaufort Sea. Encompassing approximately 12–14 million acres, this area forms a 100-mile-wide corridor between the two Federal reserves. State lease sales in the area in 1964 and 1965 led to the discovery of the Prudhoe Bay Field in 1968. Some of the other discoveries in the area near the Prudhoe Bay Field area are producing and some of them are not yet producing owing to poor economics and/or the distance to the Trans Alaska Pipeline System.

Figure 2. Map of Northern Alaska Showing the Location of North Slope Features



Source: U.S. Department of the Interior, April 1987. "Arctic National Wildlife Refuge, Alaska, Coastal Plain Resource Assessment." Chapter I, Figure I-1, p. 2.

Geology

The subsurface of the North Slope comprises a sedimentary basin containing a thick sequence of porous and permeable rocks, some of which serve as reservoirs for oil and gas, others of which are source rocks. The Colville sedimentary basin contains a sediment column tens of thousands of feet thick. Early deposition during the Paleozoic and Mesozoic was from a northerly source (in present-day orientation). The sediment source was reversed during the Mesozoic; deposition during the remainder of the Mesozoic and the Cenozoic was from a southerly source (the Brooks Range).

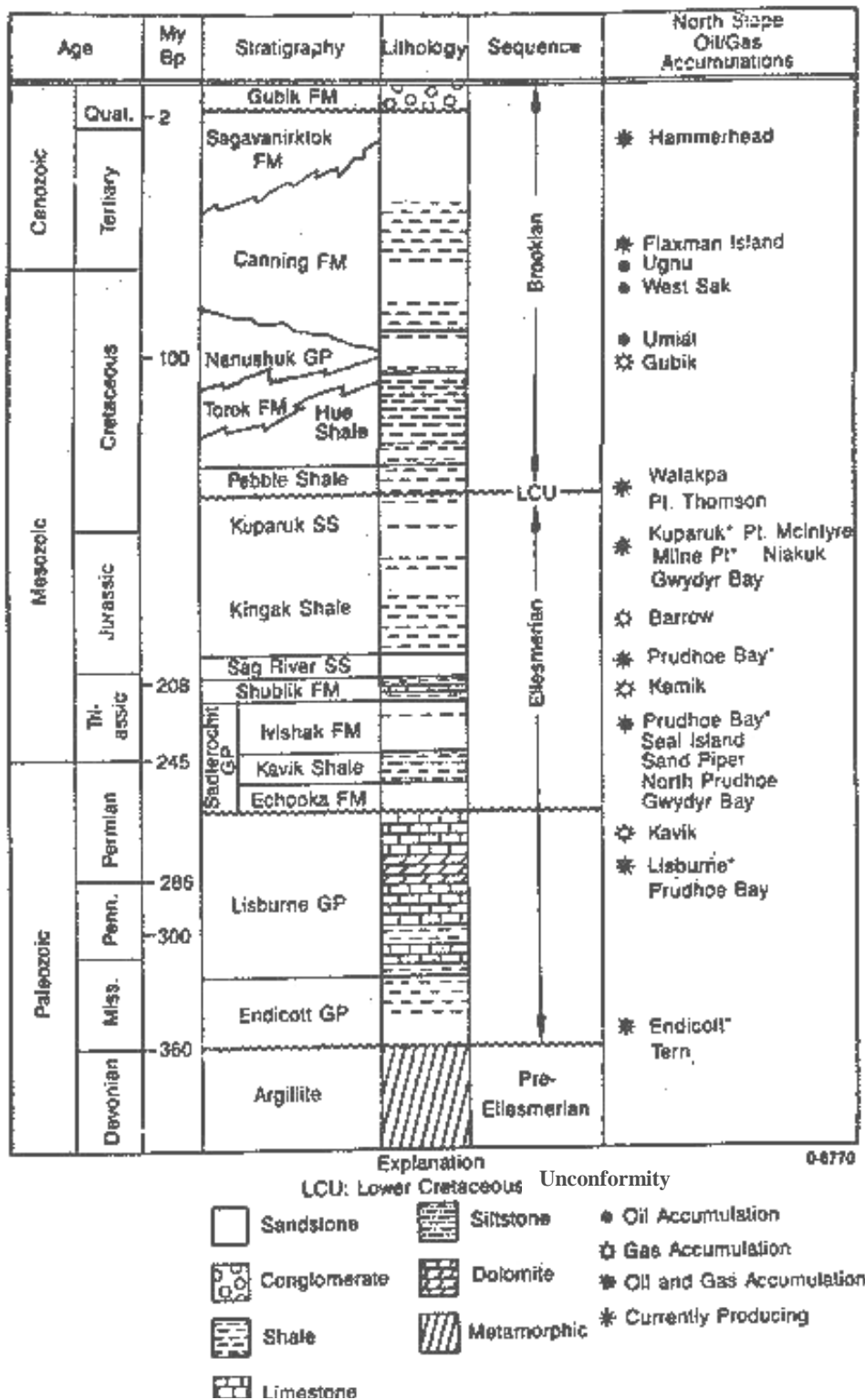
Petroleum potential occurs in both depositional sequences. The older Ellesmerian sequence (Mississippian-to-Lower Cretaceous) consists of clastic and carbonate rocks. The younger Brookian sequence (Lower Cretaceous through the Tertiary) is clastic sediment. The reservoir fluid properties of the contents of Ellesmerian sandstone provide better production characteristics than the fluid properties of the Brookian sandstone sequences (**Figure 3**).

The major structural elements are the folds and thrusts of the Brooks Range, the Colville

Trough, and the Barrow Arch. Structural relief and fold complexity increase southward toward the Brooks Range. The Colville Trough, located north of and parallel to the mountain front, contains over 20,000 feet of sediment in its deepest portion. The Barrow Arch, a broad structural high in the basement rocks that has elevated all successive strata, parallels the coast between Point Barrow and the Canning River, offshore to onshore, for 375 miles from the northwest to the southeast. It plunges to the east. North of and parallel to the Barrow Arch lies a down-faulted hinge line which approximately marks the edge of the continental shelf (**Figure 4**).

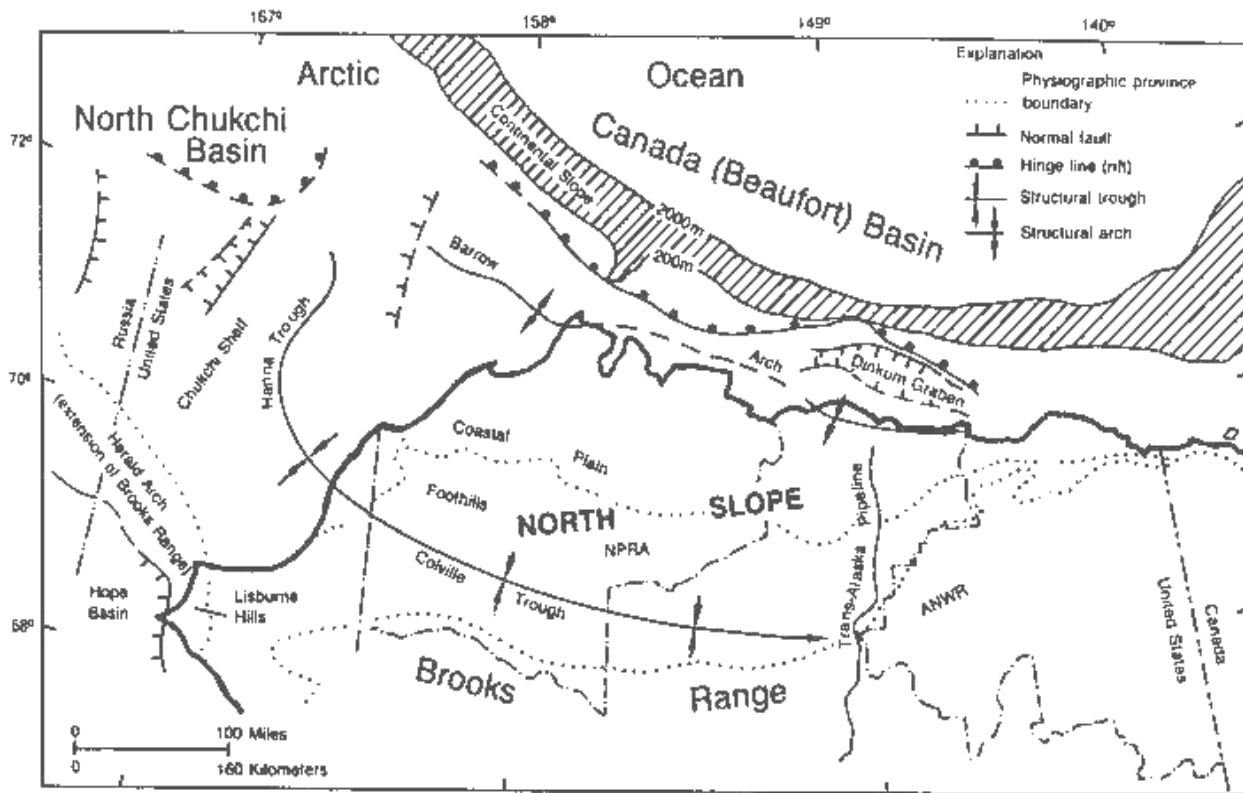
Source rocks in the Ellesmerian sequence, the Pebble Shale, the Kingak Shale, and the Shublik Formation, are composed of shale, siltstone, and fossiliferous limestone. The Brookian sequence source rocks are the Canning Formation, a portion of which is composed of shales, and the Lower Hue Shale. Traps and seals are formed by shales, facies changes, asphalt layers, simple arches, and complex folds and faults. The potential exists for production from several reservoir horizons within productive areas.

Figure 3. Generalized Stratigraphic Columnar Section for the Alaska North Slope



Source: U. S. Department of Energy. "Alaska Oil and Gas, Energy Wealth or Vanishing Opportunity?" Figure 2-3, p. 2-4.

Figure 4. Generalized Structural Features and Geologic Framework of Onshore and Offshore Northern Alaska



Source: U. S. Department of Energy. 'Alaska Oil and Gas, Energy Wealth or Vanishing Opportunity?' Figure 2-4. p. 2-5.

Production History

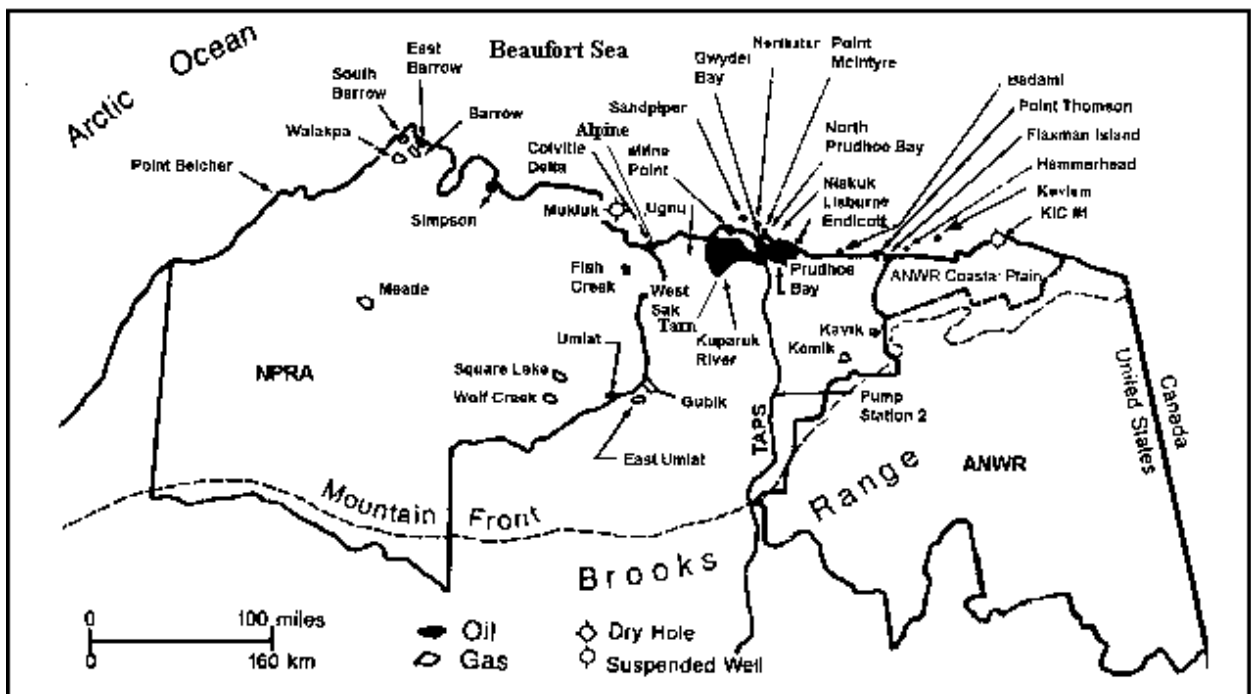
The USGS initiated petroleum exploration on the ANS in the early 1900's. The United States Navy, as operator of the NPR-A, conducted exploration activities there from 1944 to 1952. The first wells were drilled near natural oil seeps and on anticlines expressed at the surface. Several discoveries were made. Umiat, the first oil field, was discovered in 1946. It remains undeveloped. The Fish Creek and Cape Simpson oil fields were discovered in 1949 and 1950, respectively. The first gas field, South Barrow, was discovered in 1949 and then developed in 1958 to supply fuel to the village of Barrow. A total of six gas discoveries were made in the 1940's and 1950's including the Gubik, Meade, Square Lake, Titaluk, and Wolf Creek fields.

Exploration of the State-land area between ANWR and NPR-A was conducted in 1959.

State and Federal lease sales in the area were held in 1958, 1964, 1965, and 1966. The Prudhoe Bay Field was discovered in 1968 as a result. Several other large fields were also discovered in the area including the Kuparuk River, Milne Point, Endicott-Duck Island, and Point McIntyre fields. Construction began on the Trans Alaska Pipeline System (TAPS) in 1974 to transport ANS oil to market. The first oil flowed to the port of Valdez, Alaska, in 1977. (Figure 5)

Cumulative ANS oil production through 2000 was 12.941 billion barrels (Bbbl) of oil and condensate and 0.378 Bbbl of natural gas liquids (NGL) for a total liquids production of 13.319 Bbbl. Net production of 13.306 Bbbl resulted from the injection of 0.013 Bbbl of liquid.

Figure 5. Location of Oil and Gas Fields of the Alaska North Slope



Source: Idaho National Engineering Laboratory *Economics of the Alaska North Slope Gas Utilization Options*, INEL-98/0322, DOE Idaho Operations Office, August 1996.

Cumulative gas production was 42.069 trillion cubic feet (Tcf) with 38.040 Tcf injected, yielding a net production of 4.029 Tcf. Approximately 78 percent of the cumulative oil, condensate, and NGL and 88 percent of the cumulative gas production came from the Prudhoe Bay Field. Fifty-seven percent of current oil production is from the Prudhoe Bay Field. Peak ANS production occurred in 1988 when the production rate averaged 2.038 million barrels per day (MMbbl/d). Since then, production has been declining. In 2000, the average production was 1.045 MMbbl/d.. The North Slope currently accounts for 16 percent of United States oil production. Gas production averaged 9.132 billion cubic feet per day (Bcf/d) in 2000 but in the absence of a market 8.430 Bcf/d of that was injected, while the remaining 0.702 Bcf/d was used locally

Resource Assessments

The Department of the Interior has the responsibility of assessing the Nation's undiscovered oil and gas resources. The USGS's responsibility covers the onshore and State waters, while the MMS is responsible for Federal offshore assessments. Several assessments of the undiscovered technically recoverable oil of the Alaska North Slope have been completed over the years with revisions being made as more data became available and improved assessment techniques were adopted. Studies assessed the entire North Slope area in 1995 and the eastern portion of the National Petroleum Reserve-Alaska (NPR-A) in 1997.

The USGS assessments are developed at the geologic play level. For each play, statistical distributions of the number and size of potential petroleum accumulations are estimated utilizing geologic, geophysical, and engineering data and probabilistic estimation techniques. The uncertainty of hydrocarbon accumulation is assessed by applying the probabilities of occurrence of petroleum, favorable reservoir characteristics, and the presence of a trapping

mechanism. An appropriate recovery factor is applied to the estimate of initial oil-in-place to derive an estimate of the technically recoverable resources. The volumetric estimates provided from the resulting distributions of technically recoverable resources are reported at the 95 percent (19 in 20 chance of occurrence), mean (expected value), and 5 percent (1 in 20 chance of occurrence) probability levels.

The USGS geologic play volumes allocated to this report's study areas were based on the areal percentage of each play located within the study area. Environmentally sensitive restricted areas were excluded from the study area.

Production Projections

The production projections shown hereafter combine estimates of future production from currently producing fields, identified development, and undiscovered resources. *The volumes of all liquids produced on the ANS, oil, condensate, and NGL, are combined in the projections shown in this report.* The time lag from discovery of undiscovered resources to first production was not a variable considered in making the projections. Instead, an average time to the start of production was based on operator estimates. Production from each area and scenario is reported separately so that changes in the timing of first production can be easily evaluated by shifting production modules. The production of gas was not considered in this study because many problems require resolution before the marketing of ANS gas can begin. Potential marketing of ANS gas using gas-to-liquid technology, liquified natural gas, or a gas pipeline from the area would entail a long lead-time. Any gas production projection made at the current time would therefore be highly speculative. Gas production associated with the oil production is assumed to be injected. Natural gas liquids (NGL) recovered from the produced gas are included with the crude oil volumes.

2. Analysis Discussion

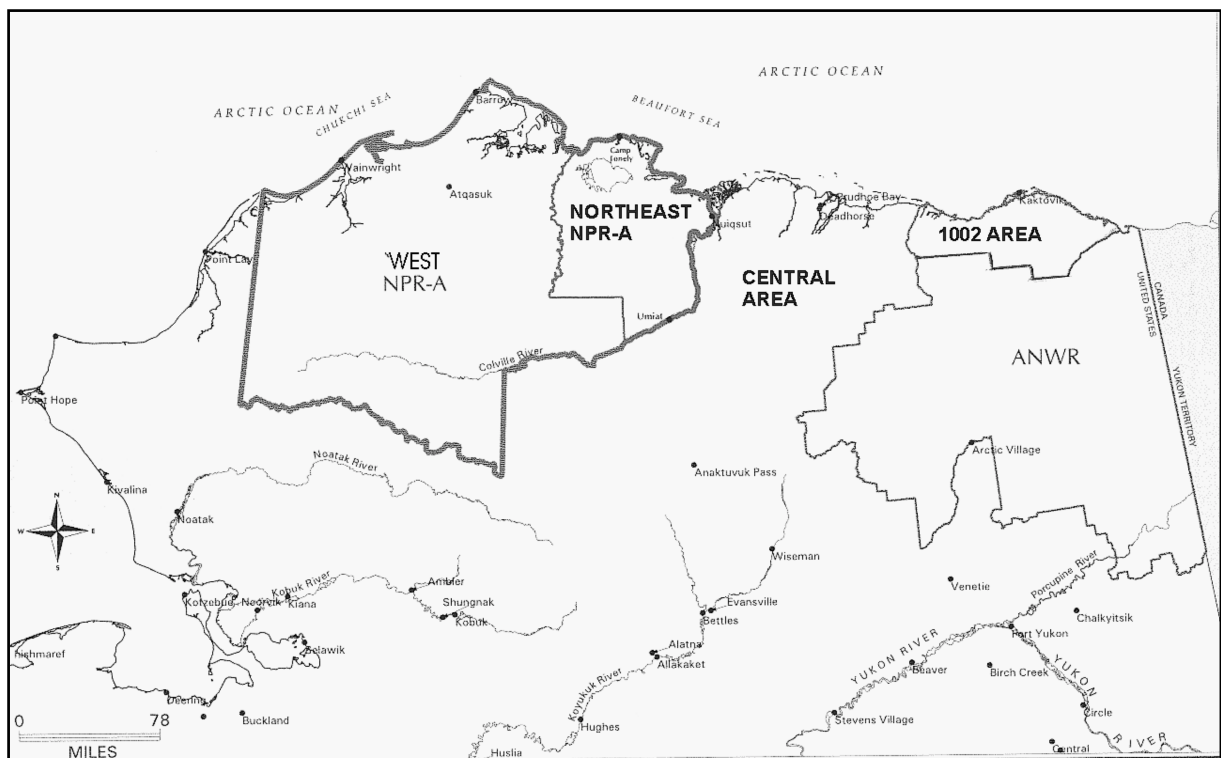
Method of Analysis

The future ANS oil production scenarios presented here are based on three alternative projections of production from undiscovered resources added to projected production from developed fields and projected production from identified development. The developed production is from fields that were producing in 2000. The production from identified development includes several projects reported in press releases and trade journals as planned or under active development. Production projections based on performance history such as those presented here inherently embody past rates of technological improvement. Potential production from gas-to-liquid conversion

technology, gas liquifaction, and high viscosity crude projects is not considered in the analysis.

To accommodate the element of development scheduling in the analysis, the ANS was divided into three study areas. The Central Area is the area between ANWR and NPR-A. The Northeast NPR-A (NE NPR-A) is the portion of NPR-A that was made available for leasing in May 1999. The remainder of NPR-A is referred to as West NPR-A. **(Figure 6)** Production from the discovery and development of undiscovered resources was scheduled to begin in 2005 in the Central Area, in 2010 in NE NPR-A, and in 2015 in West NPR-A. Production schedules are reported as individual layers so that production can be shifted to accommodate different start of production dates.

Figure 6. Alaska North Slope Study Areas Assigned for Analysis



Source: U.S. Department of Interior, Bureau of Land Management, Minerals Management Service. *Northeast National Petroleum Reserve – Alaska Final Integrated Activity Plan / Environmental Impact Statement*, Anchorage, Alaska, August 1998. P. I-6. Edited by Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Treatment of Operating Limit

A minimum operating volume (throughput lower limit) of 300,000 barrels per day for the Trans Alaska Pipeline System (TAPS) is assumed in this analysis. This throughput limit was also assumed and discussed in the Department of Energy report *Alaska Oil and Gas: Energy Wealth or Vanishing Opportunity?* Another report from the Idaho National Engineering Laboratory, *Economics of Alaska North Slope Gas Utilization Options*, discusses a range of minimum throughput volumes of 200,000 to 400,000 barrels per day based on the Department of Energy report *Alaska North Slope National Energy Strategy Initiative*. The latter report highlights the possible loss of ultimate recovery from ANS fields that are still producing above their individual economic limits owing to the shut down of TAPS at its lower throughput limit.

In the present study, the sum of projected production for each field and resource area is compared to the assumed TAPS lower operating limit to determine an abandonment date for each projection. The timing of future development will become critical as production declines and approaches the minimum pipeline operating limit. As development starts later, ultimate recovery from the ANS will be reduced. Further, when new development is added late in the producing life of the area it may not produce to its economic abandonment rate before the pipeline is shut down. Another way of saying this is that the remaining reserves of the fields then producing above their economic limit will not be recovered when the pipeline is shut down. The pipeline maximum capacity of 2.2 million barrels per day does not become a factor in the future producing life of the ANS.

Treatment of Producing Fields

The currently producing fields include those fields with production reported to the State of Alaska Oil and Gas Division in 2000. **Appendix A, Tables A1 and A2** show the production history of the ANS and the annual production for these fields.

Oil, condensate, and natural gas liquids (NGL) production in 2000 was 381.5 MMbbl with cumulative net production of 13.306 billion barrels. Gas production in 2000 was 3,333 Bcf. Gas injection was 3,077 Bcf resulting in net gas production of 256 Bcf. Cumulative gas production through 2000 was 42,069 Bcf with injection of 38,040 Bcf. The amount of fuel or lease use gas was 4,029 Bcf.

The production performance of each field was used to make the production projections that are shown in **Appendix A, Table A3**. The production of all of the fields that are declining exhibit an exponential decline. Therefore, all ANS production is assumed to decline exponentially.

Historically, most oil fields exhibit hyperbolic decline of oil production, but none of the ANS fields has a sufficient production history to determine hyperbolic decline rates. Production for fields that do not have sufficient history to indicate a decline rate is based on the average decline performance of ANS fields. While use of an exponential decline might be expected to provide conservative estimates of future performance, the difference between the future performance of exponential and hyperbolic projections may actually be small owing to relatively high producing rates at abandonment.

Technology advancements are reflected in the past performance of the producing fields and in the historically progressively reduced size of fields that can be economically developed. The increased estimated ultimate recovery from the Prudhoe Bay Field is an example of increased recovery that has resulted from improvements in technology since the field was discovered.

The producing field projections made here are compared with forecasts made by the State of Alaska Division of Oil and Gas in the graphs of **Appendix B**.

ANS ultimate oil recovery to the assumed minimum economic pipeline operating rate of 300 Mbbl/d is projected to be 17.013 billion barrels for the producing fields. Cumulative production to December 31, 2000, was 13.306 billion barrels. Remaining recoverable oil from producing fields is estimated to be 3.707 billion barrels. It is projected that the production rate will fall below the assumed pipeline minimum operating rate in the year 2017. Therefore, in the absence of new development, the remaining economic producing life for the currently producing ANS fields is estimated to be 17 years. (**Figure 7**)

Treatment of Identified Development

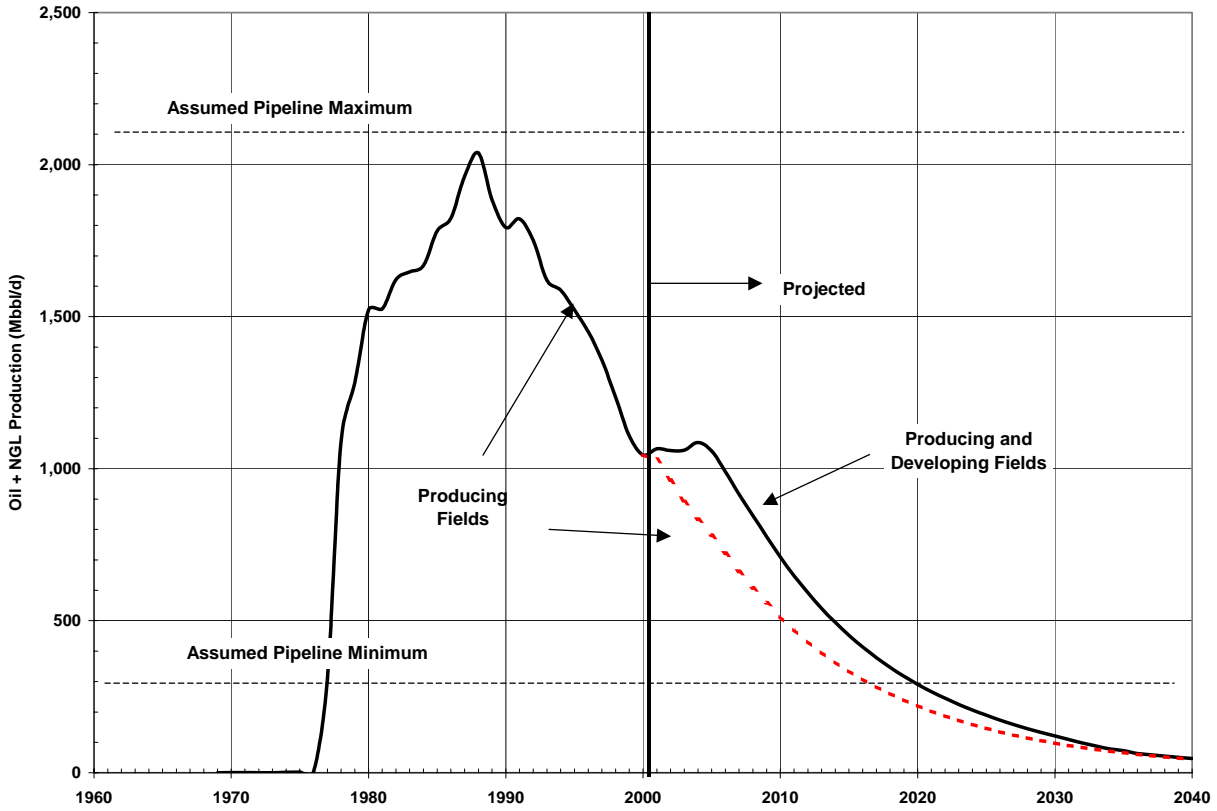
Several field development projects are in progress or have been identified by the operators for development within the next several years. Most of these projects are located near the current producing infrastructure. Development of these smaller fields is possible because of technology improvements, cost reductions, and existence of the infrastructure. Fields that share existing production facilities or that require short extensions of the oil gathering pipelines are also being developed. The development of these fields is expected to stabilize production for approximately 5 years before the ANS production decline resumes. Continued discovery and development is necessary to

maintain the producing rate over a longer period of time.

The West Sak and Schrader Bluff fields which produce heavy, viscous oil are being developed in stages. Development is expected to continue as technology and economic conditions improve. An example of current small field development is Tarn Field. Located southwest of Kuparuk Field, Tarn was put on production in late 1998. The short time (16 months) from discovery to first production demonstrates the effect of advancements in technology, operational efficiency, and facility sharing that have been occurring on the ANS. Not only is the field on production within a relatively short time after discovery, the associated environmental impact has also been minimized by use of a small drilling and production pad area and provision for zero emissions to the atmosphere. As of this writing, other ANS fields being developed include Alpine, Northstar, Liberty, Badami, Eider, Midnight Sun, Meltwater, Tabasco, and several additional satellite fields that have been identified for development. The State includes oil production forecasts for approximately 600 million barrels from fields identified as “other onshore” and “satellites” in the Prudhoe Bay and Kuparuk field areas. In addition to the satellite fields reported by the State, an additional 300 million barrels have been added in this report to cover other satellite fields reported in news releases.

If no additional development occurs beyond the identified development, ultimate ANS recovery will be 18.432 Bbbls of oil to the assumed pipeline operating limit. The incremental oil production from identified development is approximately 1.156 billion barrels. Remaining recovery from December 31, 2000, is estimated to be 5.126 Bbbls to the year 2020 for producing fields plus identified development. Of the additional recovery, 264,000 barrels results from extension of the producing life of fields as total production remains above the assumed minimum economic operating limit of TAPS. (**Figure 7**)

Figure 7. Alaska North Slope Production History and Projection of Producing and Developing Fields (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Treatment of Undiscovered Resources

Three levels of estimates of undiscovered technically recoverable resources were used to bound the range of potential production from each study area. There is a 95 percent probability (19 in 20 chance) that the recovery of the lower resource volume of each study area will be exceeded. The mean volume is the statistical average of all values in the estimated resource distribution. It is therefore also the expected recovery volume for the area. The highest volume resource estimates have only a 5 percent probability (1 chance in 20) of being exceeded. For each area evaluated, a production rate for each of the three resource occurrence levels was calculated. The rates for the individual study areas were then summed by occurrence level to provide the total ANS production projection from undiscovered technically recoverable resources at each of the three resource occurrence levels.

The method used to calculate the production schedule was a simplified approach which assumes a constant annual development volume, a peak rate of 10 percent of the annual development volume, and an exponential decline rate. The development rates were selected as volumes that could be developed within practical drilling and operational limits. The annual development is not associated with field size, but rather is an amount attributed to the number of wells drilled each year. Several large fields may be discovered in a year, but only a portion is scheduled for production. The assumed parameters are based on historical development in the area and on engineering evaluation of the past performance and operational activities in the area.

The production schedule for each annual development volume was based on increasing

production in the first 2 years to a peak production rate in the third year of approximately 10 percent of the development volume. Beginning in the fourth year, production was assumed to begin declining exponentially at a 10 percent annual rate until the total amount of oil developed was recovered. The production schedules of the annual development volumes were then summed to obtain a production rate schedule that recovers the estimated technically recoverable oil. Note that the actual development in early years might exceed that in later years, but a constant rate of development was assumed in this study. Also note that production schedules were postulated without specifying the effects of various levels of oil prices or technological advancement. That is, they are based on basic engineering estimates and current technology. Rapid technological growth could yield lower costs and therefore faster development, as could the advent of substantially higher oil prices.

An example of the method is presented for the 7-year 140 million barrel per year development of the 1.0 billion-barrel mean value NE NPR-A case in **Table 1**. The increasing production phase in the first and second years is scheduled at 12,500 and 25,000 barrels per day, respectively. Peak production of 10 percent of the annual development rate, approximately 35,000 barrels per day, is scheduled in the third year of production. Beginning in the fourth year production declines at an exponential rate of 10 percent per year, ending after 32 years. This 32-year production schedule is replicated each year for 7 years, yielding a total productive life of 38 years. **Table 1** shows a portion of the full table constructed to schedule the rate of production. The total production for a given year is the sum of the rates of production started that year and the production for that year which started in all prior years, as shown in the last column.

Table 1. Example of Production Schedule Projection for 1.0 Billion Barrels Developed at 140 Million Barrels per Year for the NE NPR-A

Year	Producing Rate for Each Year of Development (Mbbls/day)						Total
	1	2	3	4	-----	7	
1	12.5	--	--	--	-----	--	12.5
2	25.0	12.5	--	--	-----	--	37.5
3	35.0	25.0	12.5	--	-----	--	72.5
4	31.7	35.0	25.0	12.5	-----	--	104.2
5	28.7	31.7	35.0	25.0	-----	--	132.8
6	25.9	28.7	31.7	35.0	-----	--	158.8
-	-	-	-	-	-----	-	---
38	-	-	-	-	-----	1.9	1.9

Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Development of Undiscovered Resources

Three scenarios are presented here to show the range of production potential associated with inclusion of the undiscovered resources in each ANS study area. All are based on the undiscovered resource estimates of the USGS. The key assumptions associated with each projection are the discovery rate, number of years necessary to develop the estimated resources, time to the start of production, and the beginning year. **(Table 2)**

Explicit economic considerations were not included in the estimates of undiscovered technically recoverable resources. The USGS and BLM have estimated the resource volumes that can be developed at given prices in reports listed in the Bibliography. For example, the Environmental Impact Statement for the NE NPR-A provides an estimate that between 0.2 and 1.0 billion barrels of resources could be economically developed and produced at an oil price of \$18 per barrel. The estimated range of undiscovered resources for the NE NPR-A is 0.6 to 1.6 billion barrels of technically recoverable oil. These volumes are clearly indicative of the potential that exists for economic production from the ANS.

Table 2. Parameters Used to Schedule the Development of Undiscovered Oil Resources of the Alaska North Slope

	Central	Northeast NPR-A	West NPR-A
Years Delay from 1-1-00 Begin Production (Year)	5 2005	10 2010	15 2015
Low (95 % Probability of Occurrence) Volume Case			
Years of Development	1	7	1
Developed per Year (MMbbl)	120	90	40
Undiscovered Resources (Bbbl)	0.1	0.6	0.04
Mean (Expected) Volume Case			
Years of Development	8	7	8
Developed per Year (MMbbl)	200	140	100
Undiscovered Resources (Bbbl)	1.6	1.0	0.8
High (5% Probability of Occurrence) Volume Case			
Years of Development	13	8	10
Developed per Year (MMbbl)	300	200	200
Undiscovered Resources (Bbbl)	3.9	1.6	2.0

Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Central Area Undiscovered Resources

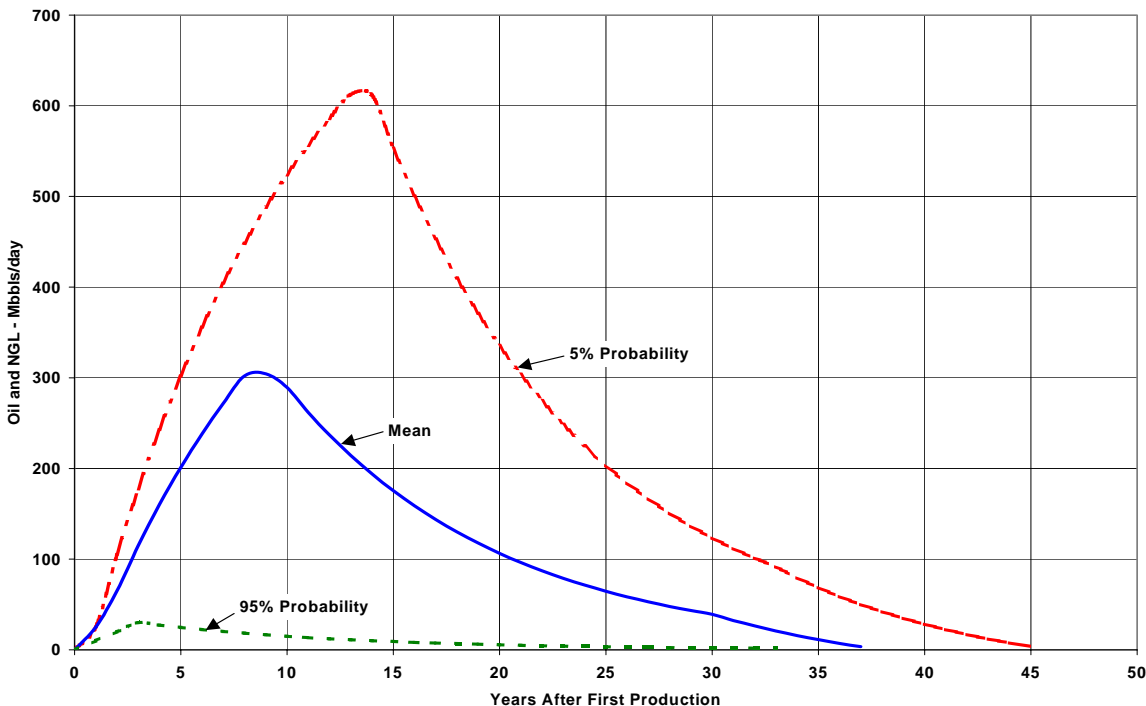
The Central Area (**Figure 6**) lies between ANWR and NPR-A. All current ANS production is from the Central Area. The most recent USGS study that included the Central Area was completed in 1995. In it the ANS was divided into play areas that overlap the study areas used in the present analysis. The estimated undiscovered resources were therefore allocated to the Central Area based on the area of each geologic play that was located within the Central Area. The reserves of producing and developing fields discovered after completion of the 1995 study were subtracted from the undiscovered volume.

It is assumed that the development of undiscovered resources in the Central Area will follow development of the identified development planned for the next several years.

The development of undiscovered resources is therefore scheduled to begin in this area in the year 2005. There is a 95 percent probability of developing more than 0.1 billion barrels and a 5 percent probability of developing more than 3.8 billion barrels of undiscovered resources. The estimated mean is 1.6 billion barrels.

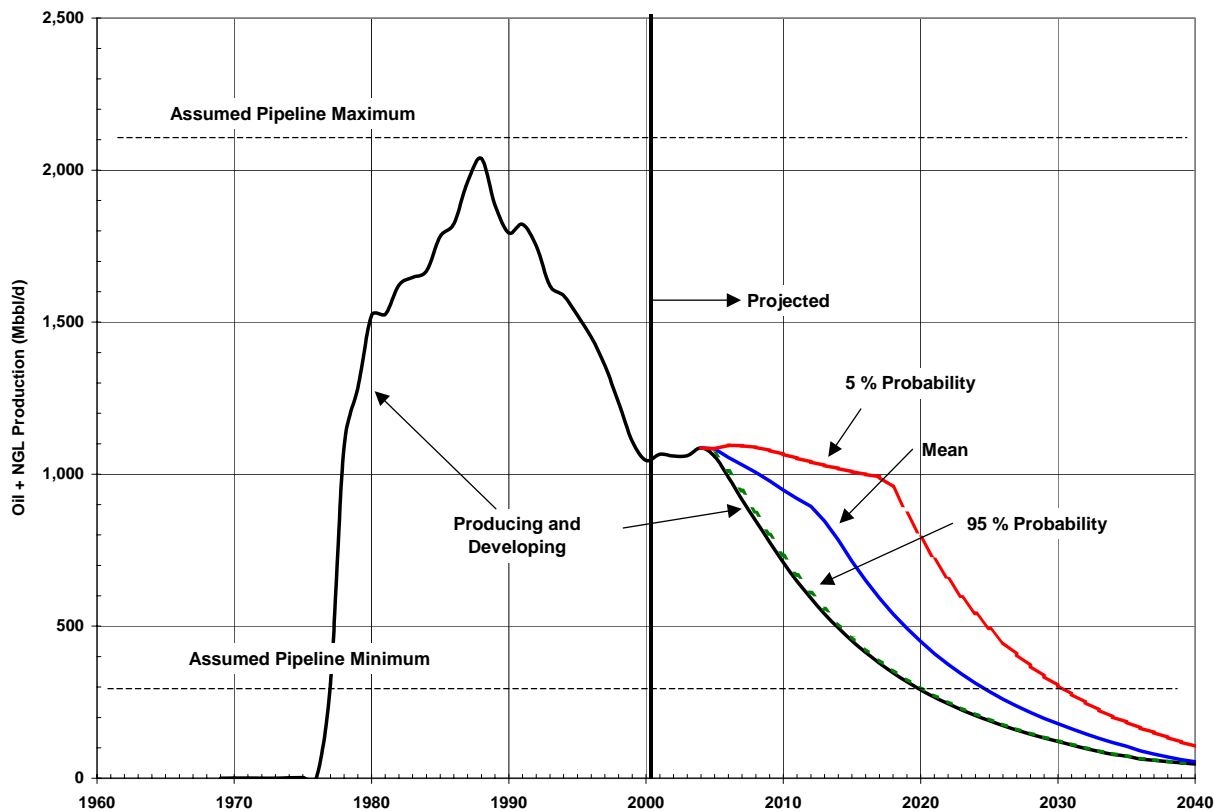
The associated additional production from the Central Area is projected to peak at between 30,000 and 600,000 barrels per day. The mean production projection peaks at approximately 300,000 barrels per day. (**Figure 8**) The range of projected production from undiscovered resources is added to the projected production from producing fields and identified development in **Figure 9**. The production for the mean projection remains near 1.0 million barrels per day until approximately 2010, when continued decline causes production to fall below 1.0 million barrels per day.

Figure 8. Alaska North Slope Central Area Projected Oil and NGL Production Rates in Years After Development of Undiscovered Resources for 95 Percent, Mean, and 5 Percent Probability of Occurrence (Mbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure 9. Alaska North Slope Oil and NGL Production of Producing Fields and Identified Development with Central Area Projected Production for 95 Percent, Mean, and 5 Percent Cases Added (Mbbbls/day)



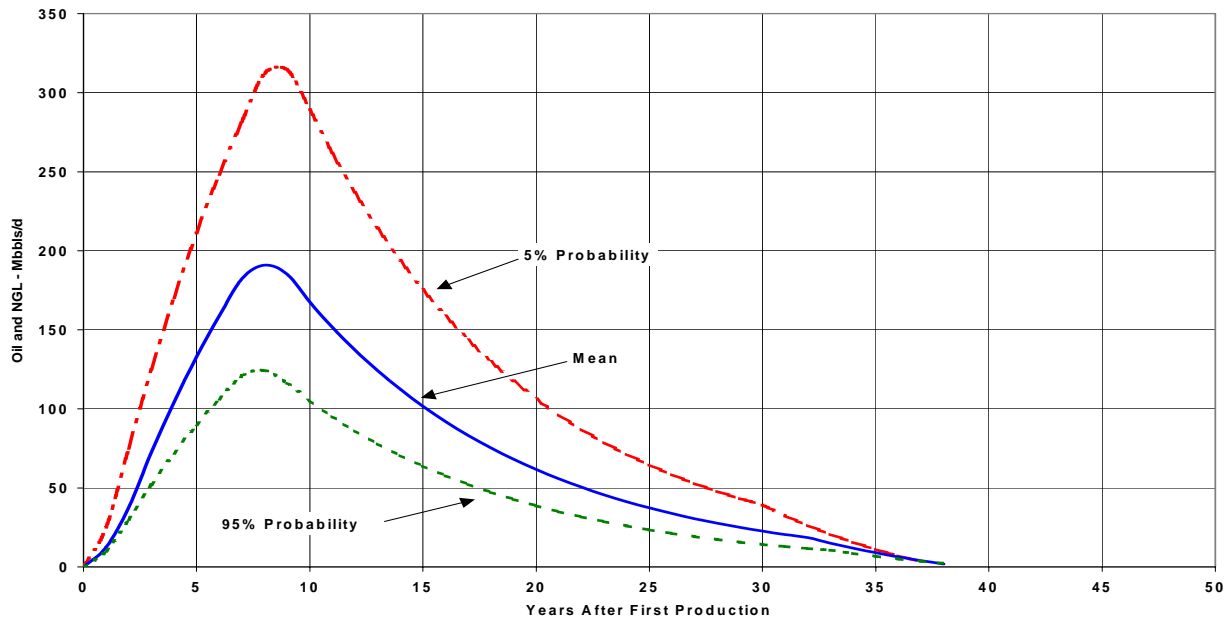
Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Northeast NPR-A Area Undiscovered Resources

On the northeastern 4.6 million acres of NE-NPR-A (Figure 6) leased in May 1999, only 34.5 percent of the technically recoverable oil resources are available for development based on the Integrated Action Plan/Environmental Impact Statement (IAP/EIS). The technically recoverable amount of undiscovered resources available not including the protected areas is therefore between 0.6 and 1.6 billion barrels. There is a 95 percent probability that the undiscovered resources will be greater than the 0.6 billion barrel projection and a 5 percent chance that the amount will be greater than 1.6 billion barrels. The estimated mean resource is 1.0 billion barrels. The area is adjacent to the developed infrastructure and could contribute production by the year 2010.

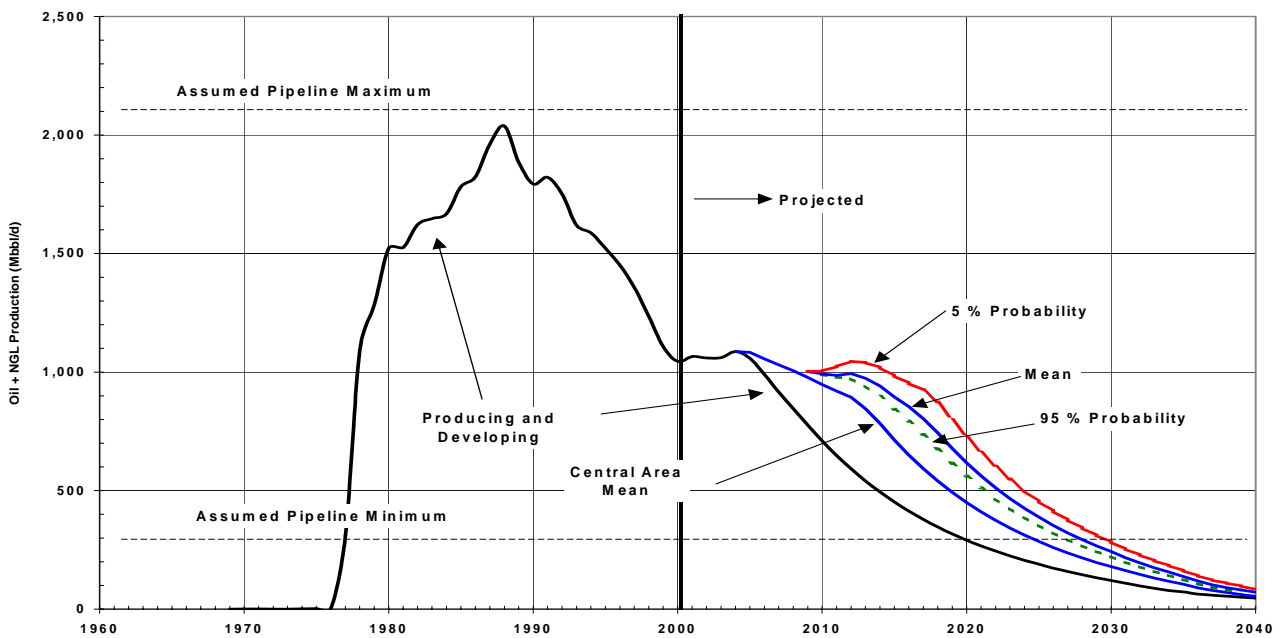
Peak production from the NE NPR-A is projected to range from 130,000 to 315,000 barrels per day. Production in the mean case is expected to peak at 190,000 barrels per day. (Figure 10) Adding the production from the three cases to the production from the Central Area mean case, the producing fields, and identified development results in the production projection shown in Figure 11. With production beginning at approximately 1.0 million barrels per day in 2010, in the 5 percent probability case production increases slightly to approximately 1.05 million barrels per day and then declines below 1.0 million barrels per day after 2014. The mean case maintains production at 1.0 million barrels per day for approximately 2 years before depletion causes decline to begin.

Figure 10. Alaska North Slope NE NPR-A Area Projected Oil and NGL Production Rates in Years After Development of Undiscovered Resources for 95 Percent, Mean, and 5 Percent Probability of Occurrence (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure 11. Alaska North Slope Oil and NGL Production of Producing Fields, Identified Development, and Central Area Mean with NE NPR-A Area Projected Production Added for 95 Percent, Mean, and 5 Percent Probability Cases (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

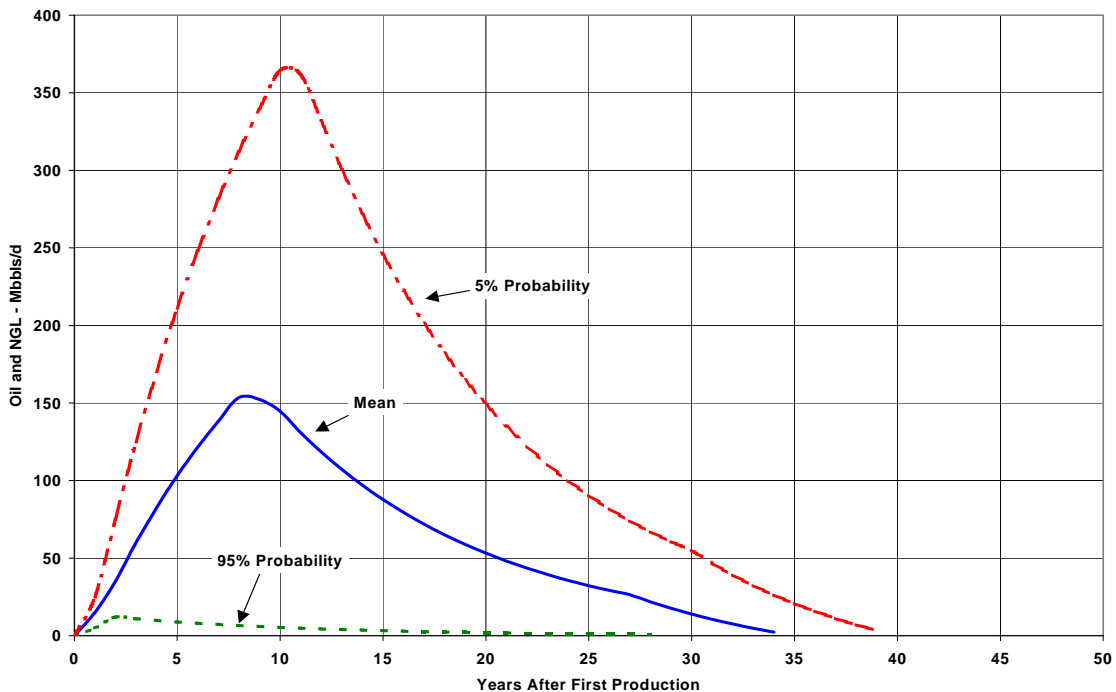
West NPR-A Area Undiscovered Resources

The West NPR-A Area is identified on the map in **Figure 6**. The remaining 18.9 million acres of NPR-A contain similar environmental features as those excluded from development in NE NPR-A IAP/EIS. For example, the Utukok River Uplands Special Area and an extension of the Colville River Special Area are similar to areas excluded from leasing in NE NPR-A. Five and one-half million acres of the West NPR-A area were therefore excluded in this analysis. Reducing the amount of resources in proportion to the area available for development leaves an available technically recoverable oil resource of 0.04 to 1.9 billion barrels for the 95 percent and 5 percent probabilities of occurrence,

respectively. The mean of the available technically recoverable undiscovered resource is 0.6 billion barrels.

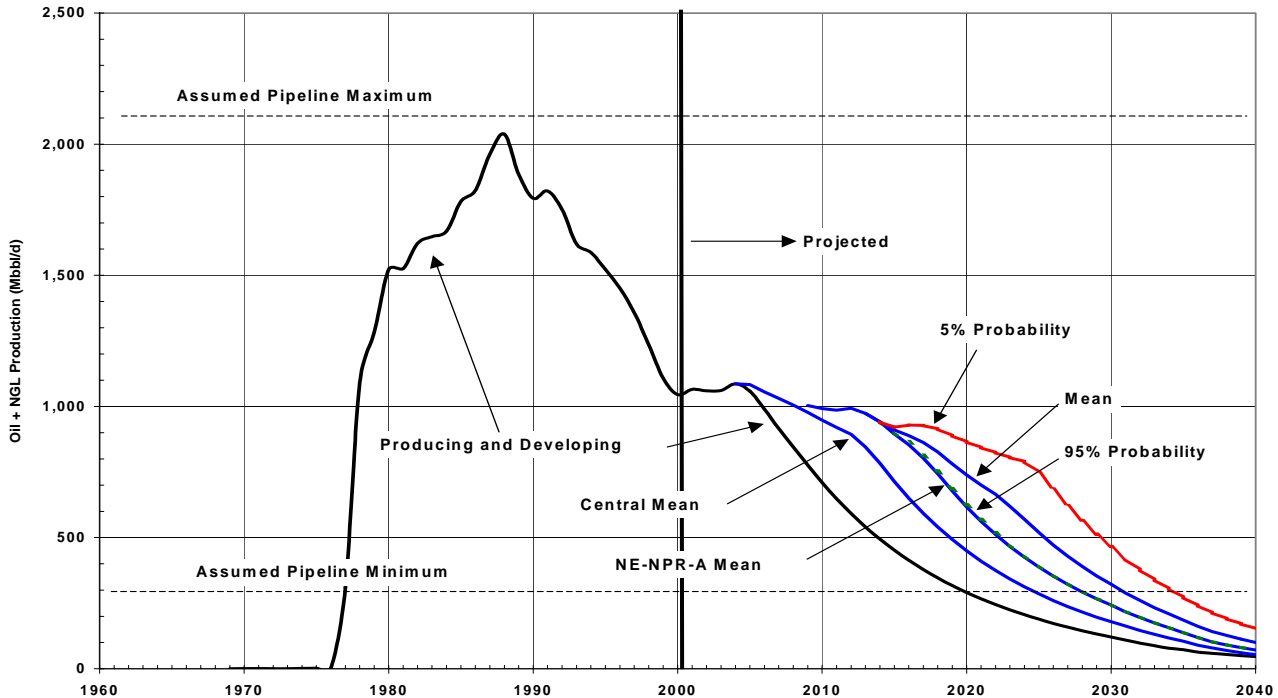
Production is assumed to begin in 2015. Peak projected production rates for this range of resources are from less than 20,000 to 360,000 barrels per day. The peak mean case production rate is projected to be 150,000 barrels per day. **(Figure 12)** The three production scenarios for the West NPR-A Area are added to the projections of production from existing fields, identified development, the Central Area mean, and the NE NPR-A mean cases and shown in **Figure 13**. Projected production from the 5 percent probability is sufficient to arrest the decline for 1 year, but in all other cases production continues to decline.

Figure 12. Alaska North Slope West NPR-A Area Projected Oil and NGL Production Rates in Years After Development of Undiscovered Resources for 95 Percent, Mean, and 5 Percent Probability of Occurrence (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure 13. Alaska North Slope Oil and NGL Production of Producing Fields, Identified Development, Central Area Mean, NE NPR-A Mean, and West NPR-A Projected Production Added for 95 Percent, Mean, and 5 Percent Probability Cases (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division

Summary of Expected Alaska North Slope Production

The mean projected ultimate recovery from producing fields, identified development, and development of undiscovered resources on the ANS is 22.173 billion barrels. Remaining recovery from January 1, 2001, to the assumed

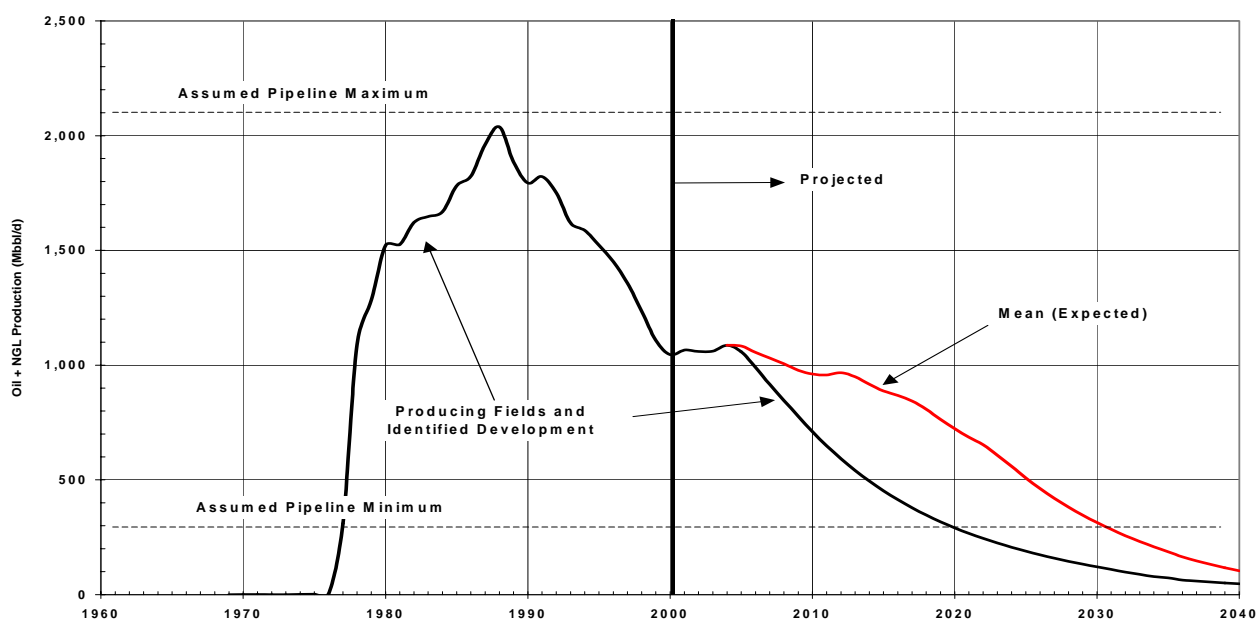
minimum pipeline operating limit which would be reached in 2031 (mean case) is expected to be 8.867 billion barrels. The results of the summation of the mean (expected value) cases are summarized in **Table 3**. **Figure 14** shows the projected production rate of the producing fields and identified development along with the projected production rate from the development of the mean (expected) undiscovered ANS resource.

Table 3. Summary of Mean Estimated Oil Resources and Ultimate Recovery to Abandonment Year for the Alaska North Slope (Billions of barrels)

	Alaska North Slope
Oil Produced to 12-31-00	13.306
Remaining Discovered Oil	
Producing Fields	4.532
Identified Developing Fields	1.314
Undiscovered Oil Resources	
Central Area	1.541
Northeast NPR-A	0.860
West NPR-A	0.620
Total	3.021
Ultimate Recovery	22.173
Abandonment Year (300 Mbbbl/d)	2031

Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure 14. Alaska North Slope Oil and NGL History and Projected Production of Producing Fields and Identified Development with Production of Mean (Expected) Undiscovered Resources Added (Mbbbl/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division

Projected Production Range

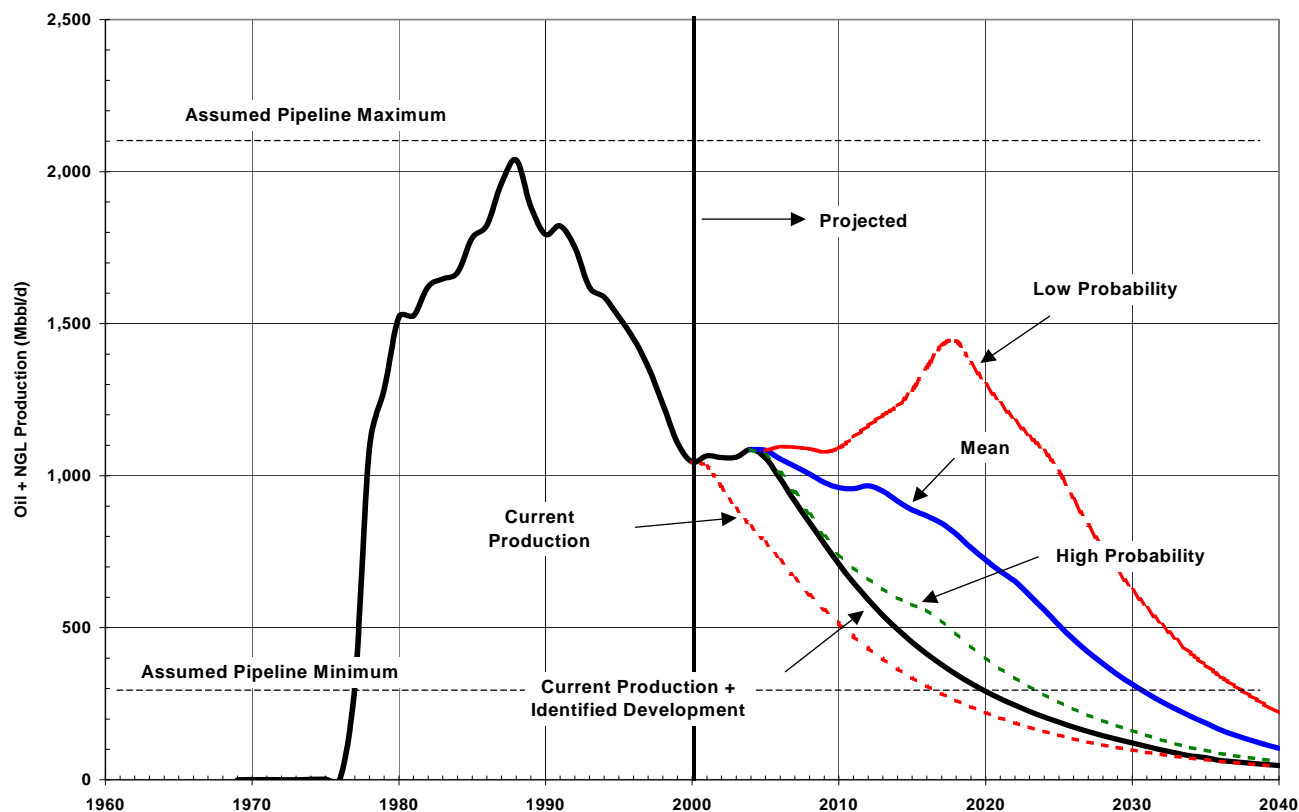
Figure 15 shows the range of the projected production estimates for the ANS. The production projections associated with the high (95 percent) and low (5 percent) probabilities of undiscovered resource occurrence are added to the projections for production from the producing fields and identified development to establish the high and low production cases.

The case involving the high probability resource estimate temporarily lessens, but does not arrest, the present ANS production decline. Production declines to below the assumed TAPS operating limit of 300,000 barrels per day in 2024, having extended the producing life of the ANS by only 3 years, with an ultimate ANS recovery of approximately 19.356 billion barrels.

Production in the case involving the low probability resource estimate remains between 1.0 and 1.1 million barrels per day until production from NE-NPR-A begins in 2010. Production then increases to 1.4 million barrels per day in 2017 and 2018 before declining below the assumed TAPS operating limit in 2038. The producing life of the ANS is extended for 11 years to an ultimate ANS recovery of 26.604 billion barrels.

The overall range of projected ANS ultimate recovery is therefore 19.4 to 26.6 billion barrels, with a mean (expected) value of 22.2 billion barrels. Remaining recovery from January 1, 2001, is estimated to range from 6.1 to 13.3 billion barrels, with an expected value of 8.9 billion barrels.

Figure 15. Range of Projected Production from the Alaska North Slope (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Additional Potential

As noted earlier, there are several sources of future ANS production potential that were not considered in the present projection. The heavy, viscous oil recovery potential associated with the Ugnu and West Sak formations, discussed at a Department of Energy/industry workshop in 1998, could range from 3 to 6 billion barrels assuming the advent of improved development and production economics and technology.

A sizeable natural gas potential also exists in both discovered and undiscovered ANS resources. Gas-to-liquid (GTL) conversion

technology could recover from 2 to 4 billion barrels of liquids from the 43 to 54 trillion cubic feet of identified natural gas resources based on the range of anticipated recovery and plant efficiencies from GTL technical reports. Significant liquids volumes could also be derived from the approximately 65 trillion cubic feet from undiscovered technically recoverable gas resources, should they and the technology for their conversion become available. Pilot plants are being constructed now to develop and test the technology needed to make the GTL process economically and technically feasible for the North Slope.

3. Summary

Combined crude oil, condensate, and NGL production from the Alaska North Slope reached a peak in 1988 when production averaged 2.038 million barrels per day (MMbbl/d). By 2000 production had declined to an average rate of 1.045 MMbbl/d, and the decline continues today. Gas production in 2000 averaged 9.132 Bcf/d. Gas injection averaged 8.429 Bcf/d in 2000. The development of new and satellite fields in the area between NPR-A and the ANWR 1002 Area has added reserves and production and promises to add more reserves and production over the next several years. Without the currently planned development, the fields that were on production in 2000 would recover 17.013 Bbbls of oil, condensate, and NGL. Cumulative production to December 31, 2000 was 13.306 Bbbls with 3.707 Bbbls remaining. The remaining ANS life would be 17 years (to the year 2017) assuming exponential production to the assumed minimum operating limit of TAPS of 300,000 barrels per day.

Adding new projects being developed or planned for development (identified development) to the producing fields is projected to increase ANS ultimate recovery by approximately 1.156 billion barrels and to extend the lifespan of ANS operations by 3 years. In this case the ultimate recovery is projected to be 18.432 Bbbls with 5.126 Bbbls remaining to be recovered after 2000, of which approximately 4.0 billion barrels will come from the fields that are currently producing. The production rate is anticipated to stabilize at approximately 1.0 MMbbl/d until decline resumes after the year 2004, with the assumed TAPS minimum operating limit of 300,000 barrels per day being reached in 2020.

The ANS production projections summarized here assume that production from NE NPR-A will begin in 2010. The assumed beginning of production from the remainder of the NPR-A is 2015. It is assumed that leasing and exploration of the western area of NPR-A will occur during the time prior to the assumed start of production.

Projected production from each area is reported separately so that the production can be shifted to different start-of-production dates if desired.

Because of the remote location, severe weather conditions and the limited number of operators in the area, the amount of development and new production will be limited as compared to development that would occur if the area were in the contiguous States. Potential heavy, viscous oil production in excess of current West Sak and Schrader Bluff production, potential gas-to-liquid conversion volumes, and volumes from improvements in technology or recovery efficiency which might occur at rates exceeding those historically observed, are not reflected in the current resource estimates and are not included in the production projections.

Adding three estimates of future producing rates that correspond to three levels of USGS estimates of technically recoverable undiscovered ANS resources to the projections of production from currently producing fields and from identified development yields a range of estimates of future ANS production. The low end of the range is based on the estimated 95 percent probable technically recoverable resource volume and the high end of the range is based on the 5 percent probability estimate. A case corresponding to the statistical mean resource volume (the expected value) is also included.

Adding the remaining discovered volume of 5.5 billion barrels (Bbbls) to the low resource estimate of 0.6 Bbbls yields 6.1 Bbbls remaining to be produced from the ANS, with a 19.4 Bbbls ultimate ANS recovery to the year 2024. The remaining discovered volume increases from 5.1 to 5.5 Bbbls because the producing life of the fields is extended when total ANS production remains above the assumed minimum operating limit of the pipeline. The high estimate of remaining oil to be produced is approximately 13.3 billion barrels with projected ultimate recovery of 26.6 billion barrels. In the mean resource estimate case, the remaining ANS

production from January 1, 2001, is 8.9 Bbbls, yielding an ultimate ANS recovery of 22.2 Bbbls. **Figure 16** shows the incremental production from the identified development, Central Area, and NPR-A Areas mean case..

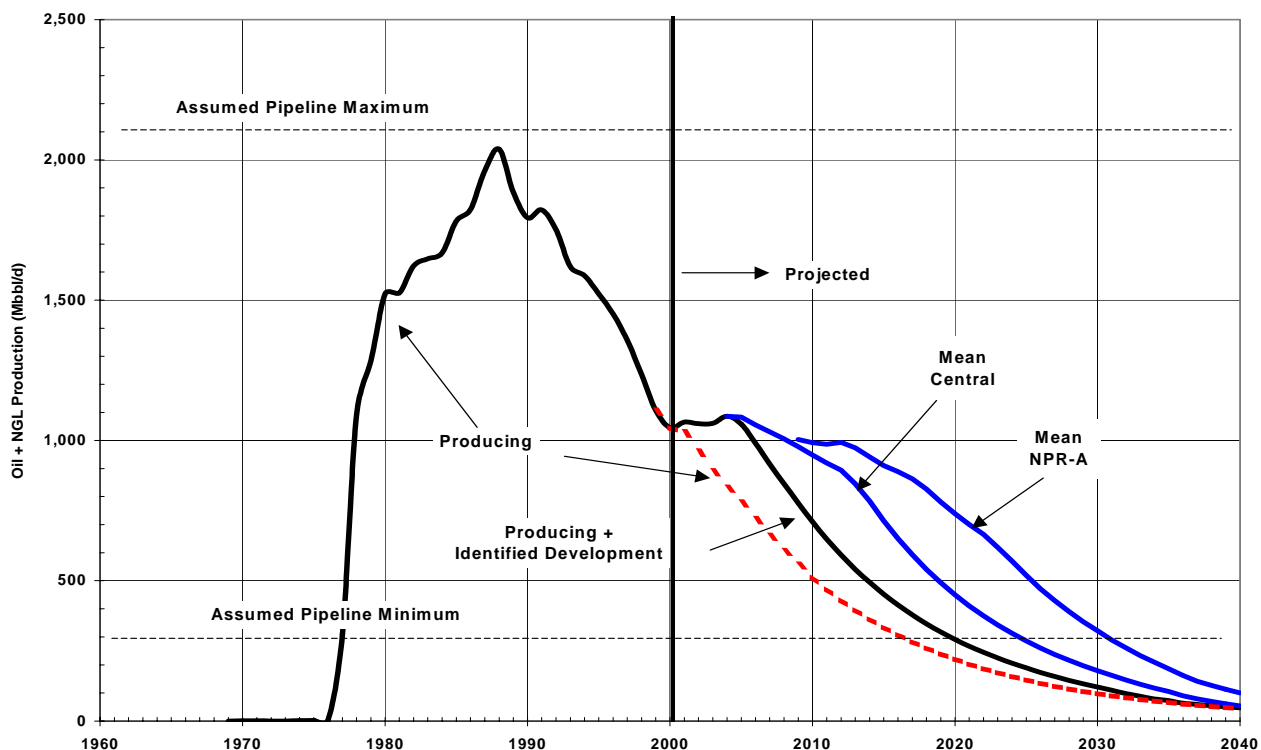
Delay of development or restrictions on development will cause reduced ultimate ANS recovery because the assumed TAPS minimum operating limit determines the future minimum producing limit of the entire ANS. Extending the life of ANS production may increase the cost or increase the minimum throughput of the aging TAPS.

This study of the future production potential for the ANS shows that as current production declines, ANS resources will not be produced as development is delayed owing to the TAPS limit. Sufficient undiscovered resources are available to at least stabilize production, and perhaps have a chance of increasing production,

if all estimated undiscovered resources exist and they are developed within a time frame coincident with TAPS operation. Maximum pipeline limitations will not be a problem. Potential sources to maintain production in the future are the significant deposits of heavy, viscous oil, and liquids obtainable from the conversion of natural gas resources. Exploration, development, and technology advancement must continue to arrest the ANS production decline and thereby minimize U.S. dependence on imported oil.

The **Appendices** provide in full detail the production rate projections for currently producing fields, currently producing fields plus identified development, and currently producing fields plus identified development plus the three undiscovered resource scenarios. A **Glossary** of frequently used acronyms and technical terms is also provided.

Figure 16. Alaska North Slope Production History with Production Projections of Fields Producing, Identified Development, and Mean Estimates of Undiscovered Resources (Mbbbls/day)



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Bibliography

Anadarko Petroleum Corporation, Third Quarter 1996, "Alaska's Alpine Field Announced Commercial," Anadarko Third Quarter 1996.

Crow, Patrick. "Alaskan Opportunity," *Oil & Gas Journal* (January 20, 1997) p. 33.

Crow, Patrick. "GTL Research," *Oil & Gas Journal* (August 4, 1997) p.33.

Energy Information Administration. *Annual Energy Outlook*, Market Trends, Washington, DC.

Energy Information Administration. *Potential Oil Production from the Coastal Plain of the Arctic National Wildlife Refuge*, SR/RNGD/87-01. (Washington, DC, September 1987).

Energy Information Administration. *Potential Oil Production from the Coastal Plain of the Arctic National Wildlife Refuge: Updated Assessment*, SR/O&G/2000-02. (Washington, DC, May 2000).

Foerster, Cathy P. and others. "West Sak Field Development: Analysis of a Marginal Project," *The Society of Petroleum Engineers* SPE 37946, 1997.

Idaho National Energy Laboratory, Advanced Engineering Development Laboratory. *Economics of the Alaska North Slope Gas Utilization Options*, INEL – 96/0322, DOE Idaho Operations Office, August 1996.

Minerals Management Service. "BP Submits Development and Production Plan for Liberty," March 5, 1998.

Minerals Management Service, "BP Confirms Oil Discovery at Liberty Prospect," May 5, 1997.

Oglethorpe, Kim. "Oil Companies May Develop Alaska Field," *Dallas Morning News* (March 14, 1997).

Oil & Gas Journal, 1997. "North Slope Satellite Projects Spark Alaska Exploration," (May 26, 1997), pp 51-58.

Oil & Gas Journal, 1997. "North Slope Producers See Alaska Renaissance as TAPS Reaches 20," (June 16, 1997) pp. 22-27.

Oil On Line, "ARCO, Exxon, BP Exploration Make 'Double Discovery' Adjacent to Prudhoe Bay," February 13, 1998.

Oil On Line, "Chevron Becomes Operator of Alaska's Kuvlum and Hammerhead Units," January 19, 1998.

Oil On Line, "Construction Begins on Alpine Oil Field," February 24, 1998.

Oil On Line, "Prudhoe Bay Owners to Build Production Module," April 30, 1998.

PIW, "No Decline After '99 May Come True in Alaska Upstream," (August 25, 1997) p. 5.

PR Newswire / NewsEdge Corporation, “Anadarko Petroleum Corporation Announces Exploration Agreement.” Anadarko Petroleum Corporation, Anchorage, Alaska, August 13, 1998.

PR Newswire, “Alpine, Other ARCO-Managed Projects Will Mean \$850 Million Boost to Alaska Economy, \$2.5 Billion in New State Revenue,” Anchorage, Alaska, October 13, 1997.

PR Newswire, “Tarn Oil Field Production.” ARCO Alaska, August 24, 1998.

Reuters, “ARCO Seeks Extra \$500 Million for Alaska Projects,” December 5, 1996.

Reuters, “BP to Boost Alaska Investment by \$1 Billion” Anchorage, Alaska, December 16, 1996.

Reuters, “Prudhoe Oil Partners to Share Processing Facilities,” Anchorage, Alaska, December 15, 1997.

Rosen, Yereth. “Quest to Wring More Oil from Alaska North Slope,” *The Christian Science Monitor* (October 8, 1996) p. 1.

Sanders, Jack. “Estimate of Undiscovered Oil Resources in Arctic National Wildlife Refuge Coastal Plain (ANWR 1002 Area, an Undeveloped Part of the Alaska North Slope),” Review Notes (August 1, 1995) to John Wood, EIA, Dallas.

Shirley, Kathy. “Discoveries Brighten Slope Future,” *AAPG Explorer*, (July 1997), p. 10.

Simon, Andrew D. and Eric J. Petersen. “Reservoir Management of the Prudhoe Bay Field,” *The Society of Petroleum Engineers* SPE 38847, 1997.

Stanley, M.J. and D.S. Stoltz. “The Evaluation of Profitable Development Drilling in Prudhoe Bay: A Case of Adapting to Survive,” paper presented at the 1997 SPE/IADC Drilling Conference (Amsterdam, March 1997).

State of Alaska, Department of Natural Resources, Division of Oil and Gas. *Petroleum Potential of the Eastern National Petroleum Reserve – Alaska*. Washington, DC, 1997.

State of Alaska, Department of Natural Resources, Division of Oil and Gas. *Oil and Gas Annual Report - 2000*. Anchorage, Alaska, August 2000.

U. S. Department of Energy in Cooperation with the State of Alaska. *Alaska Oil and Gas, Energy Wealth or Vanishing Opportunity?*, DOE/ID/01570-H1, Washington DC, January 1991.

U.S. Department of Energy, *Alaska North Slope National Energy Strategy Initiative*, DOE/ID/01570-T164, Washington DC, May 1993.

U.S. Department of the Interior, Bureau of Land Management. Minerals Management Service. *Northeast National Petroleum Reserve – Alaska Final Integrated Activity Plan / Environmental Impact Statement*, Anchorage, Alaska, August 1998.

U.S. Geological Survey. *1995 National Assessment of United States Oil and Gas Resources*, U.S. Geological Survey Circular 1118. Washington, DC, 1995.

U. S. Department of Interior, U. S. Geological Survey, Minerals Management Service. *Estimates of Undiscovered Conventional Oil and Gas Resources in the United States – A Part of the Nation's Energy Endowment*. United States Government Printing Office, Washington, DC, 1989.

U. S. Department of Interior, U. S. Geological Survey. *Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998*, USGS Fact Sheet FS-040-98, Washington, DC, May 1998.

U. S. Department of Interior, U. S. Geological Survey. *Economics and Undiscovered Oil and Gas Accumulations in the 1995 National Assessment*, U.S. Geological Survey Open-File Report 95-751, Washington, DC.

U. S. Department of Interior, U. S. Geological Survey. *Economics of Undiscovered Oil in the 1002 Area of the Arctic National Wildlife Refuge*, U.S. Geological Survey Open-File Report 98-34, Washington, DC, June 1998.

U. S. Department of Interior, U. S. Geological Survey. *The 1995 National Assessment of United States Oil and Gas Resources – The Economic Component*, USGS Fact Sheet FS 024-98, Washington, DC, March 1998.

Appendix A

Field Production Summaries

Appendix A

Field Production Summaries

The oil and natural gas liquid production history for the Alaska North Slope is tabulated from 1969 through 2000 in **Table A1**. Daily production rates, annual production, and cumulative production are reported.

Production through 2000 for each field as reported by the Alaska Department of Natural Resources, Division of Oil and Gas in “Annual Report 2000,” and in State monthly reports for 2000 is tabulated in **Table A2**. The production

is reported in thousands of barrels per day (Mbbbl/d) and is the sum of crude oil, condensate, and natural gas liquids (NGL) recovered from the associated gas that is produced.

Production projections through 2039 for the currently producing fields, fields being developed, and fields that have been identified for development are reported in **Table A3**.

Table A1. Alaska North Slope Oil and Natural Gas Liquid Production History.

Year	Average Rate Mbbbls/d	Annual Production MMbbbls	Cumulative Production Bbbbls
1969	0.164	0.060	0.000
1970	0.877	0.320	0.000
1971	0.888	0.324	0.001
1972	0.356	0.130	0.001
1973	0.348	0.127	0.001
1974	1.452	0.530	0.001
1975	1.981	0.723	0.002
1976	2.721	0.993	0.003
1977	310	113.183	0.116
1978	1,090	397.679	0.514
1979	1,283	468.412	0.982
1980	1,522	555.648	1.538
1981	1,525	556.714	2.095
1982	1,622	592.003	2.687
1983	1,647	601.117	3.288
1984	1,668	608.771	3.897
1985	1,782	650.430	4.547
1986	1,823	665.347	5.213
1987	1,961	715.842	5.928
1988	2,038	743.869	6.672
1989	1,885	688.123	7.360
1990	1,793	654.537	8.015
1991	1,822	664.910	8.680
1992	1,751	639.007	9.319
1993	1,619	590.921	9.910
1994	1,587	579.269	10.489
1995	1,523	555.733	11.045
1996	1,450	529.395	11.574
1997	1,358	495.564	12.070
1998	1,235	450.803	12.520
1999	1,108	404.288	12.925
2000	1,045	381.500	13.306

Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Table A2. Alaska North Slope Oil, Condensate, and NGL Production History and Cumulative Production
(Thousand barrels per day for field level; other units shown)

Fields	1969	1970	1971	1972	1973	1974	1975	1976
Alpine	--	--	--	--	--	--	--	--
Endicott	--	--	--	--	--	--	--	--
Sag Delta North	--	--	--	--	--	--	--	--
Point McIntyre	--	--	--	--	--	--	--	--
Other Point McIntyre	--	--	--	--	--	--	--	--
Lisburne (Pt. McIntyre)	--	--	--	--	--	--	--	--
Niakuk (Pt. McIntyre)	--	--	--	--	--	--	--	--
Kuparuk River	--	0.016	--	--	--	--	--	--
West Sak	--	--	--	--	--	--	--	--
Milne Point	--	--	--	--	--	--	--	--
Sag River	--	--	--	--	--	--	--	--
Schrader Bluff	--	--	--	--	--	--	--	--
Tarn	--	--	--	--	--	--	--	--
Badami	--	--	--	--	--	--	--	--
Tabasco	--	--	--	--	--	--	--	--
Eider	--	--	--	--	--	--	--	--
Midnight Sun	--	--	--	--	--	--	--	--
Prudhoe Bay Unit	0.2	0.9	0.9	0.4	0.3	1.5	2.0	2.7
Polaris	--	--	--	--	--	--	--	--
Aurora	--	--	--	--	--	--	--	--
Total Daily Rate - Mbb/d	0.2	0.9	0.9	0.4	0.3	1.5	2.0	2.7
Annual Production - MMbbl	0.1	0.3	0.3	0.1	0.1	0.5	0.7	1.0
Cumulative Production - MMbbl	0.1	0.4	0.7	0.8	1.0	1.5	2.2	3.2

See footnotes at end of table

Table A2. Alaska North Slope Oil, Condensate, and NGL Production History and Cumulative Production
 (Thousand barrels per day for field level; other units shown) (continued)

1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	0.011
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	0.005	0.6	0.2	0.8	3.1	9.8
--	--	--	--	--	--	--	--	--	--
--	--	--	--	3.0	88.8	109.2	126.3	218.3	260.2
--	--	--	--	--	--	0.016	0.3	0.9	0.8
--	--	--	--	--	--	--	--	1.9	12.9
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
310.1	1089.5	1283.3	1522.3	1522.2	1532.6	1537.4	1540.5	1557.8	1539.1
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
310.1	1089.5	1283.3	1522.3	1525.2	1621.9	1646.9	1667.9	1782.0	1822.9
113.2	397.7	468.4	555.6	556.7	592.0	601.1	608.8	650.4	665.3
116.4	514.1	982.5	1538.1	2094.8	2686.8	3288.0	3896.7	4547.2	5212.5

See footnotes at end of table

Table A2. Alaska North Slope Oil, Condensate, and NGL Production History and Cumulative Production
(Thousand barrels per day for field level; other units shown) (continued)

Fields	1987	1988	1989	1990	1991	1992	1993
Alpine	--	--	--	--	--	--	--
Endicott	24.1	103.9	100.2	101.4	110.0	115.3	109.5
Sag Delta North	--	--	1.0	4.3	6.5	2.8	2.1
Point McIntyre	--	--	--	--	--	--	20.9
Other Point McIntyre	--	--	--	--	--	--	3.2
Lisburne (Pt. McIntyre)	45.6	44.1	40.6	43.5	40.1	38.3	26.7
Niakuk (Pt. McIntyre)	--	--	--	--	--	--	--
Kuparuk River	284.1	304.5	300.7	293.7	311.2	324.7	315.5
West Sak	--	--	--	--	--	--	--
Milne Point	0.1	0.0	10.2	18.1	18.4	15.9	15.6
Sag River	--	--	--	--	--	--	--
Schrader Bluff	--	--	0.003	0.011	2.1	3.1	2.9
Tarn	--	--	--	--	--	--	--
Badami	--	--	--	--	--	--	--
Tabasco	--	--	--	--	--	--	--
Eider	--	--	--	--	--	--	--
Midnight Sun	--	--	--	--	--	--	--
Prudhoe Bay Unit	1607.3	1585.4	1432.5	1332.1	1333.4	1250.7	1122.4
Polaris	--	--	--	--	--	--	--
Aurora	--	--	--	--	--	--	--
Total Daily Rate - Mbb/d	1961.2	2038.0	1885.3	1793.3	1821.7	1750.7	1619.0
Annual Production - MMbbl	715.8	743.9	688.1	654.5	664.9	639.0	590.9
Cumulative Production - MMbbl	5928.4	6672.2	7360.3	8014.9	8679.8	9318.8	9909.7

See footnotes at end of table

Table A2. Alaska North Slope Oil, Condensate, and NGL Production History and Cumulative Production
(Thousand barrels per day for field level; other units shown) (continued)

1994	1995	1996	1997	1998	1999	2000	Cumulative MMbbl
--	--	--	--	--	--	6.1	2.2
97.0	93.7	75.2	62.1	49.4	41.7	35.8	408.6
1.0	0.6	0.5	0.7	0.5	0.0	0.0	7.3
104.7	139.5	161.0	163.1	133.0	93.9	78.5	326.5
3.5	2.5	1.7	0.9	0.3	1.8	1.2	5.5
21.3	17.2	14.1	9.4	7.7	6.9	10.4	138.9
9.3	19.4	30.3	28.5	28.7	27.4	20.4	59.9
306.3	293.1	272.5	262.9	251.2	225.7	203.1	1735.6
--	--	--	0.003	1.5	3.3	4.2	4.0
15.5	20.1	34.7	46.7	50.2	47.7	45.6	129.1
--	0.5	0.9	1.0	0.4	0.0	0.0	1.0
2.8	3.2	3.0	4.2	5.3	6.0	6.8	14.4
--	--	--	--	9.7	26.1	23.7	21.7
--	--	--	--	2.0	3.2	2.5	2.8
--	--	--	--	1.3	5.3	5.2	4.3
--	--	--	--	1.1	0.6	0.7	0.9
--	--	--	--	0.2	5.5	3.9	3.5
1025.5	932.7	856.5	778.1	692.5	613.0	595.1	10439.3
--	--	--	--	--	0.1	1.1	0.5
--	--	--	--	--	--	0.7	0.3
1587.0	1522.6	1450.4	1357.7	1235.0	1108.2	1045.1	
579.3	555.7	529.4	495.6	450.8	404.5	381.5	
10489.0	11044.7	11574.1	12069.7	12520.4	12925.0	13306.2	

"--" = Not Applicable (No production reported)

Other Point McIntyre includes Larch, N. Prudhoe Bay, and W. Beach

Endicott includes Ivishak

Source: Alaska Department of Natural Resources, Division of Oil and Gas *Annual Report 2000*, (August 2000) pp. 24-28.

**Table A3. Alaska North Slope Oil, Condensate and NGL Production Projections
for Producing Fields and Developing Projects**
(Thousand barrels per day for field level; other units shown)

Fields	Cumulative to 12-31-00 (MMbbl)	2001	2002	2003	2004	2005
Alpine	2.2	70.0	80.0	80.0	80.0	80.0
Endicott	408.6	31.0	26.5	22.5	19.2	16.4
Sag Delta North	7.3	--	--	--	--	--
Point McIntyre	326.5	65.5	54.7	45.7	38.2	31.9
Other Point McIntyre	5.5	0.9	0.7	0.5	0.4	0.3
Lisburne (Pt. McIntyre)	138.9	9.6	8.9	8.2	7.6	7.0
Niakuk (Pt. McIntyre)	59.9	17.7	15.4	13.4	11.6	10.1
Kuparuk River	1735.6	192.6	179.6	167.4	156.1	145.5
West Sak	4.0	5.0	10.0	15.0	20.0	25.0
Milne Point	129.1	43.2	41.1	39.1	37.2	35.4
Sag River	1.0	--	--	--	--	--
Schrader Bluff	14.4	8.0	9.0	10.0	15.0	20.0
Northstar	0.0	--	--	30.0	60.0	53.2
Prudhoe Bay Unit	10439.3	543.9	497.0	454.3	415.2	379.4
Prudhoe Bay Satellites	0.0	5.8	16.1	25.4	33.9	31.6
Additional Satellites	0.0	29.1	81.4	113.8	139.0	155.0
Polaris	0.5	1.5	1.4	1.2	1.1	1.0
Midnight Sun	3.5	3.6	3.2	2.9	2.6	2.4
Tabasco	4.3	4.8	4.4	4.0	3.7	3.3
Liberty	0.0	--	--	--	20.0	38.0
Tarn	21.7	21.8	20.0	18.2	16.7	15.2
Badami	2.8	2.3	2.1	1.9	1.7	1.5
Eider	0.9	1.3	1.1	1.0	0.9	0.8
Aurora	0.3	8.0	7.2	6.5	5.9	5.4
Daily Rate - Mbb/d	--	1065.6	1059.8	1061.3	1086.0	1058.5
Annual - MMbbl	--	389.0	386.8	387.4	396.4	386.4
Cumulative - MMbbl	13306.4	13695.4	14082.2	14469.5	14865.9	15252.3

See footnotes at the end of table.

Table A3. Alaska North Slope Oil, Condensate and NGL Production Projections for Producing Fields and Developing Projects
(Thousand barrels per day for field level; other units shown) (Continued)

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
72.4	65.5	59.3	53.6	48.5	43.9	39.7	35.9	32.5	29.4
13.9	11.9	10.1	8.6	7.4	6.3	5.3	4.6	3.9	3.3
--	--	--	--	--	--	--	--	--	--
26.6	22.3	18.6	15.5	13.0	10.8	9.0	7.6	6.3	5.3
0.2	0.2	0.1	--	--	--	--	--	--	--
6.4	6.0	5.5	5.1	4.7	4.3	4.0	3.7	3.4	3.1
8.8	7.6	6.6	5.8	5.0	4.4	3.8	3.3	2.9	2.5
135.7	126.5	118.0	110.0	102.6	95.6	89.2	83.1	77.5	72.3
30.0	30.0	30.0	30.0	30.0	28.3	26.6	25.1	23.6	22.2
33.6	32.0	30.4	28.9	27.5	26.2	24.9	23.7	22.5	21.4
--	--	--	--	--	--	--	--	--	--
20.0	18.5	17.0	15.7	14.5	13.4	12.4	11.4	10.5	9.7
47.2	41.9	37.1	32.9	29.2	25.9	23.0	20.4	18.1	16.0
346.8	316.9	289.7	264.7	241.9	221.1	202.1	184.7	168.8	154.3
28.5	25.7	23.2	21.0	18.9	17.1	15.4	13.9	12.6	11.3
158.3	155.3	149.2	138.4	125.1	113.1	102.3	92.4	83.6	75.5
0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4
2.2	2.0	1.8	1.6	1.5	1.3	1.2	1.1	1.0	0.9
3.1	2.8	2.5	2.3	2.1	1.9	1.8	1.6	1.5	1.4
34.4	31.1	28.2	25.5	23.0	20.9	18.9	17.1	15.4	14.0
13.9	12.7	11.6	10.6	9.7	8.9	8.1	7.4	6.8	6.2
1.4	1.3	1.1	1.0	0.9	0.8	0.8	0.7	0.6	0.6
0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.3
4.9	4.4	4.0	3.6	3.3	2.9	2.7	2.4	2.2	2.0
990.0	916.0	845.5	776.3	710.0	648.2	592.0	540.9	494.4	452.1
361.4	334.3	308.6	283.3	259.2	236.6	216.1	197.4	180.5	165.0
15613.7	15948.0	16256.6	16539.9	16799.1	17035.7	17251.8	17449.2	17629.7	17794.7

See footnotes at the end of table.

Table A3. Alaska North Slope Oil, Condensate and NGL Production Projections for Producing Fields and Developing Projects
(Thousand barrels per day for field level; other units shown) (Continued)

Fields	2016	2017	2018	2019	2020	2021	2022
Alpine	26.6	24.1	21.8	19.7	17.9	16.2	14.6
Endicott	2.8	2.4	2.0	1.7	1.5	1.3	1.1
Sag Delta North	--	--	--	--	--	--	--
Point McIntyre	4.4	3.7	3.1	2.6	2.1	1.8	1.5
Other Point McIntyre	--	--	--	--	--	--	--
Lisburne (Pt. McIntyre)	2.9	2.7	2.5	2.3	2.1	1.9	1.8
Niakuk (Pt. McIntyre)	2.2	1.9	1.6	1.4	1.2	1.1	0.9
Kuparuk River	67.4	62.8	58.6	54.6	50.9	47.5	44.3
West Sak	20.9	19.7	18.6	17.5	16.5	15.5	14.6
Milne Point	20.4	19.4	18.5	17.6	16.7	15.9	15.1
Sag River	--	--	--	--	--	--	--
Schrader Bluff	9.0	8.3	7.7	7.1	6.5	6.0	5.6
Northstar	14.2	12.6	11.2	9.9	8.8	7.8	6.9
Prudhoe Bay Unit	141.0	128.9	117.8	107.6	98.4	89.9	82.2
Prudhoe Bay Satellites	10.2	9.2	8.3	7.5	6.8	6.1	6.4
Additional Satellites	68.3	61.7	55.8	50.4	45.6	41.4	37.4
Polaris	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Midnight Sun	0.8	0.7	0.7	0.6	0.5	0.5	0.4
Tabasco	1.2	1.1	1.0	0.9	0.9	0.8	0.7
Liberty	12.6	11.4	10.4	9.4	8.5	7.7	6.9
Tarn	5.7	5.2	4.7	4.3	3.9	3.6	3.3
Badami	0.5	0.5	0.4	0.4	0.3	0.3	0.3
Eider	0.3	0.3	0.2	0.2	0.2	--	--
Aurora	1.8	1.6	1.5	1.3	1.2	1.1	1.0
Daily Rate - Mbbbl/d	413.6	378.5	346.5	317.3	290.7	266.5	245.2
Annual - MMbbl	151.0	138.2	126.5	115.8	106.1	97.3	89.5
Cumulative - MMbbl	17945.7	18083.8	18210.3	18326.1	18432.2	18529.5	18619.0

See footnotes at the end of table.

Table A3. Alaska North Slope Oil, Condensate and NGL Production Projections for Producing Fields and Developing Projects
(Thousand barrels per day for field level; other units shown) (Continued)

2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
13.2	12.0	10.8	9.8	8.9	8.0	7.3	6.6	5.9	5.4
0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.3	--	--
--	--	--	--	--	--	--	--	--	--
1.2	1.0	0.9	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8
0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.2
41.3	38.5	35.9	33.5	31.2	29.1	27.1	25.3	23.6	22.0
13.8	13.0	12.2	11.5	10.8	10.2	9.6	9.0	8.5	8.0
14.4	13.7	13.0	12.4	11.8	11.2	10.6	10.1	9.6	9.2
--	--	--	--	--	--	--	--	--	--
5.1	4.7	4.4	4.0	3.7	3.4	3.2	2.9	2.7	2.5
6.1	5.4	4.8	4.3	3.8	3.4	3.0	2.6	2.3	2.1
75.1	68.6	62.7	57.3	52.4	47.9	43.8	40.0	36.5	33.4
5.8	5.2	4.7	4.4	3.2	2.2	1.2	0.4	--	--
33.8	30.6	27.6	25.1	22.7	20.5	18.6	16.8	14.2	10.1
0.2	0.2	0.1	--	--	--	--	--	--	--
0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3
6.3	5.7	5.1	4.7	4.2	3.8	3.4	3.1	2.8	2.6
3.0	2.8	2.5	2.3	2.1	1.9	1.8	1.6	1.5	1.3
0.2	0.2	0.2	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
0.9	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.4
224.9	206.3	189.4	173.1	158.3	144.8	132.4	121.0	109.8	98.4
82.1	75.3	69.1	63.2	57.8	52.8	48.3	44.2	40.1	35.9
18701.1	18776.4	18845.5	18908.7	18966.5	19019.3	19067.6	19111.8	19151.9	19187.8

See footnotes at the end of table.

Table A3. Alaska North Slope Oil, Condensate and NGL Production Projections for Producing Fields and Developing Projects
(Thousand barrels per day for field level; other units shown) (Continued)

Fields	2033	2034	2035	2036	2037	2038	2039
Alpine	4.9	4.4	4.0	3.6	3.3	3.0	2.7
Endicott	--	--	--	--	--	--	--
Sag Delta North	--	--	--	--	--	--	--
Point McIntyre	--	--	--	--	--	--	--
Other Point McIntyre	--	--	--	--	--	--	--
Lisburne (Pt. McIntyre)	0.7	0.7	0.6	0.6	0.5	0.5	0.5
Niakuk (Pt. McIntyre)	0.2	0.2	0.2	--	--	--	--
Kuparuk River	20.5	19.1	17.8	16.6	15.5	14.4	13.5
West Sak	7.5	7.1	6.7	6.3	5.9	5.6	5.3
Milne Point	8.7	8.3	7.9	7.5	7.1	6.8	6.5
Sag River	--	--	--	--	--	--	--
Schrader Bluff	2.3	2.1	2.0	1.8	1.7	1.5	1.4
Northstar	1.8	1.6	1.5	1.3	1.1	1.0	0.9
Prudhoe Bay Unit	30.5	27.9	25.5	23.3	21.3	19.5	17.8
Prudhoe Bay Satellites	--	--	--	--	--	--	--
Additional Satellites	6.4	3.0	3.0	--	--	--	--
Polaris	--	--	--	--	--	--	--
Midnight Sun	0.1	0.1	0.1	--	--	--	--
Tabasco	0.3	0.2	0.2	--	--	--	--
Liberty	2.3	2.1	1.9	1.7	1.5	1.4	1.3
Tarn	1.2	1.1	1.0	0.9	0.9	0.8	0.7
Badami	--	--	--	--	--	--	--
Eider	--	--	--	--	--	--	--
Aurora	0.3	0.3	0.3	--	--	--	--
Daily Rate - Mbb/d	87.9	78.1	72.4	63.7	58.9	54.5	50.4
Annual - MMbbl	32.1	28.5	26.4	23.2	21.5	19.9	18.4
Cumulative - MMbbl	19219.9	19248.4	19274.8	19298.0	19319.5	19339.4	19357.8

See footnotes at the end of table.

Table A3. Alaska North Slope Oil, Condensate and NGL Production Projections for Producing Fields and Developing Projects

(Thousand barrels per day for field level; other units shown) (Continued)

Fields	Projected from 1/1/01 (MMbbl)	Ultimate to 12/31/39 (MMbbl)
Alpine	410.7	413.0
Endicott	76.0	484.6
Sag Delta North	0.0	7.3
Point McIntyre	143.6	470.1
Other Point McIntyre	1.2	6.7
Lisburne (Pt. McIntyre)	43.6	182.6
Niakuk (Pt. McIntyre)	49.1	109.0
Kuparuk River	971.9	2707.5
West Sak	228.1	232.2
Milne Point	277.2	406.3
Sag River	0.0	1.0
Schrader Bluff	111.3	125.7
Northstar	202.0	202.0
Prudhoe Bay Unit	2237.4	12676.8
Prudhoe Bay Satellites	139.5	139.5
Additional Satellites	841.3	841.3
Polaris	5.3	5.7
Midnight Sun	13.3	16.8
Tabasco	19.4	23.7
Liberty	148.6	148.6
Tarn	89.8	111.5
Badami	8.1	10.9
Eider	4.2	5.1
Aurora	29.8	30.0
Total Remaining - MMBbbls.	6051.6	
Ultimate Recovery - MMBbbls.		19358.0

"--" = Not Applicable (No production reported).

Other Point McIntyre includes Larch, N. Prudhoe Bay, and W. Beach.

Endicott includes Ivishak.

Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Appendix B

Production History and Projection Graphs

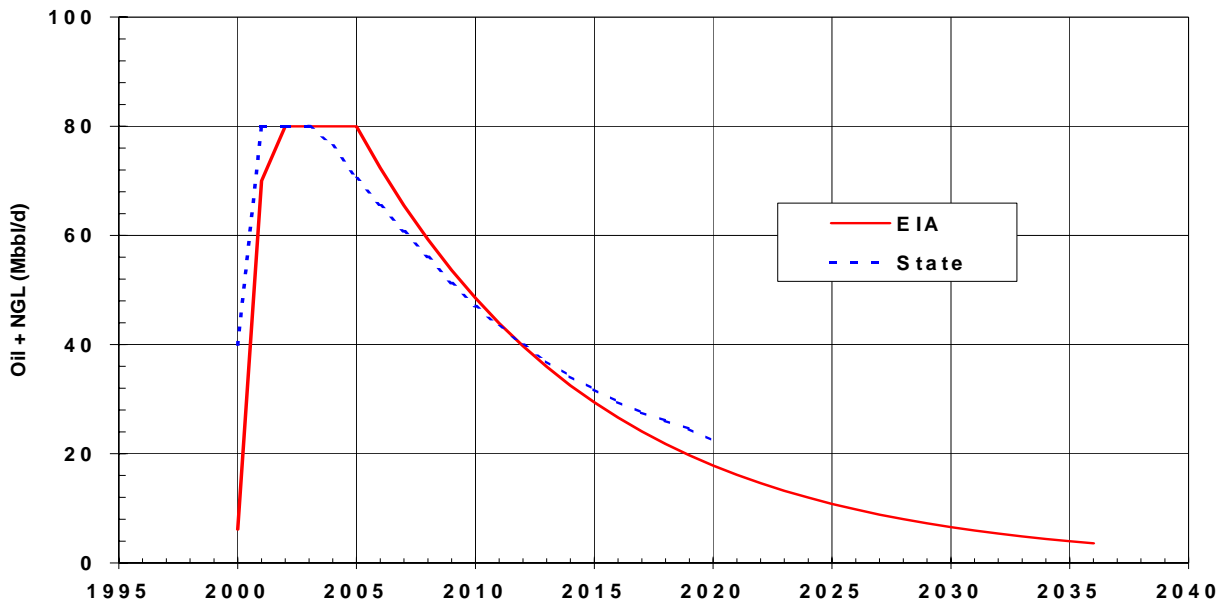
Appendix B

Production History and Projection Graphs

Graphs for each of the producing fields and for fields being developed are plotted in **Appendix B**. The graphs show the historical production and projections reported by the State of Alaska and the Energy Information Administration (EIA) based on 2000 data. The projections by the Alaska Department of Natural

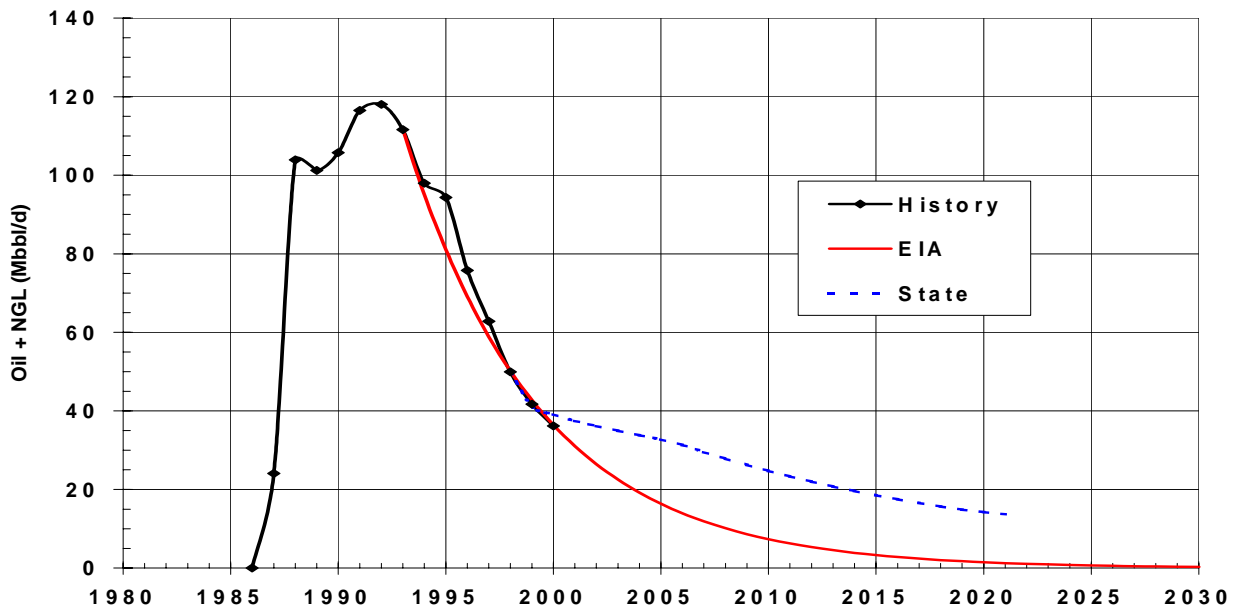
Resources, Oil and Gas Division are reported in *Annual Report 2000*. The EIA projections used in this report are calculated by exponential decline based on production history or anticipated rates reported by the North Slope operators.

Figure B1. Alpine Field, Alaska North Slope, Projected Oil and NGL Production



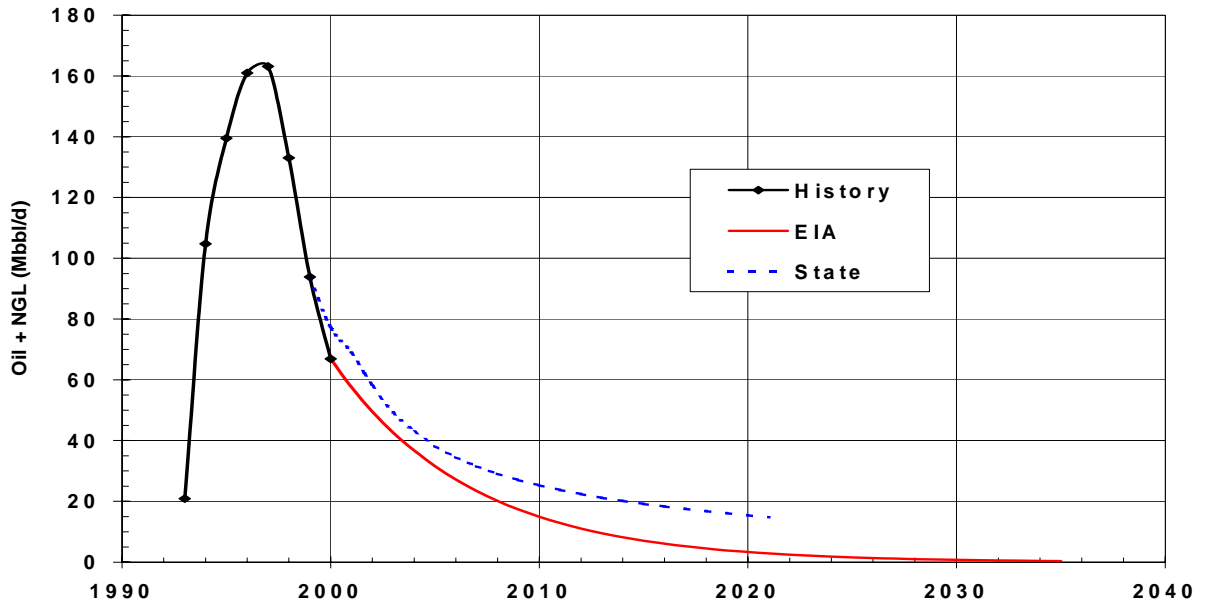
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B2. Endicott and Sag Delta North Fields, Alaska North Slope, Historical and Projected Oil and NGL Production



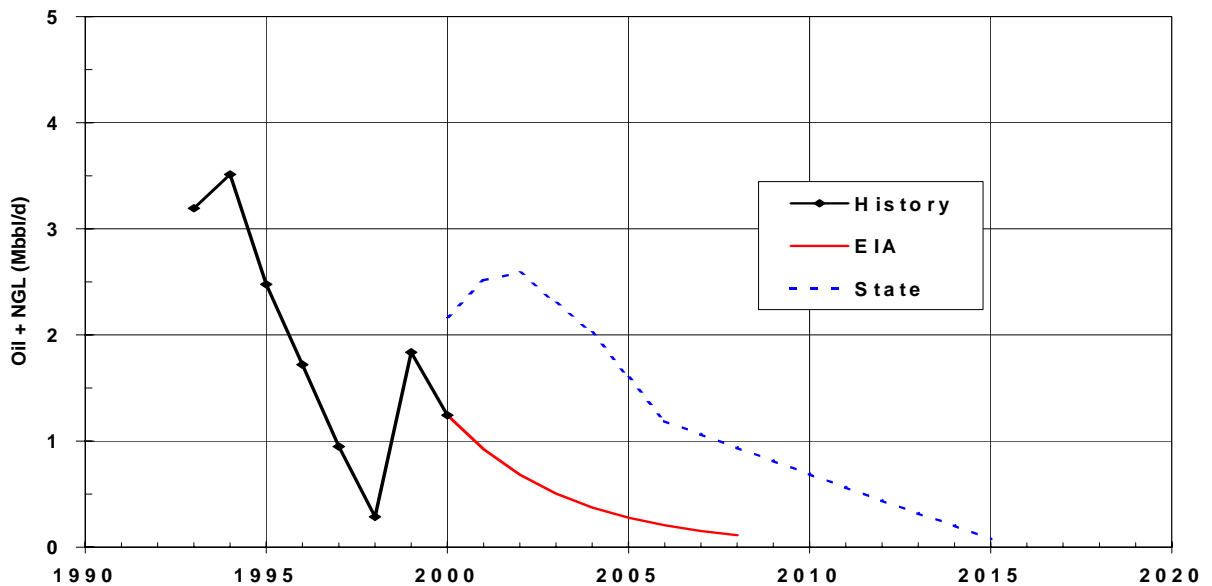
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B3. Point McIntyre Field, Alaska North Slope, Historical and Projected Oil and NGL Production



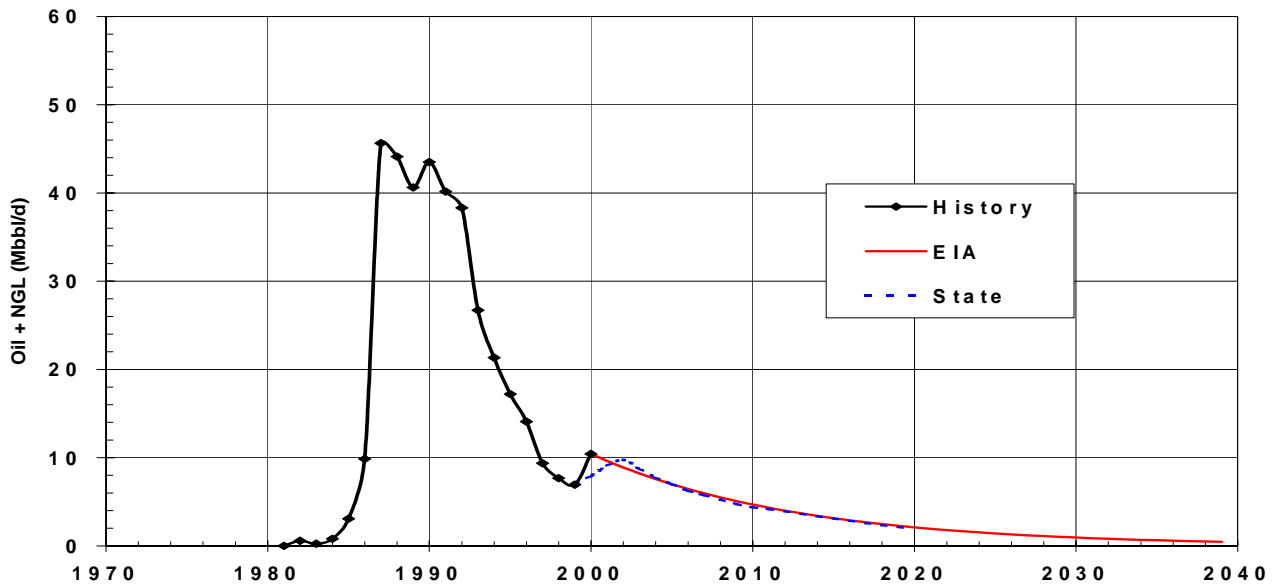
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B4. Other Point McIntyre Fields, Alaska North Slope, Historical and Projected Oil and NGL Production



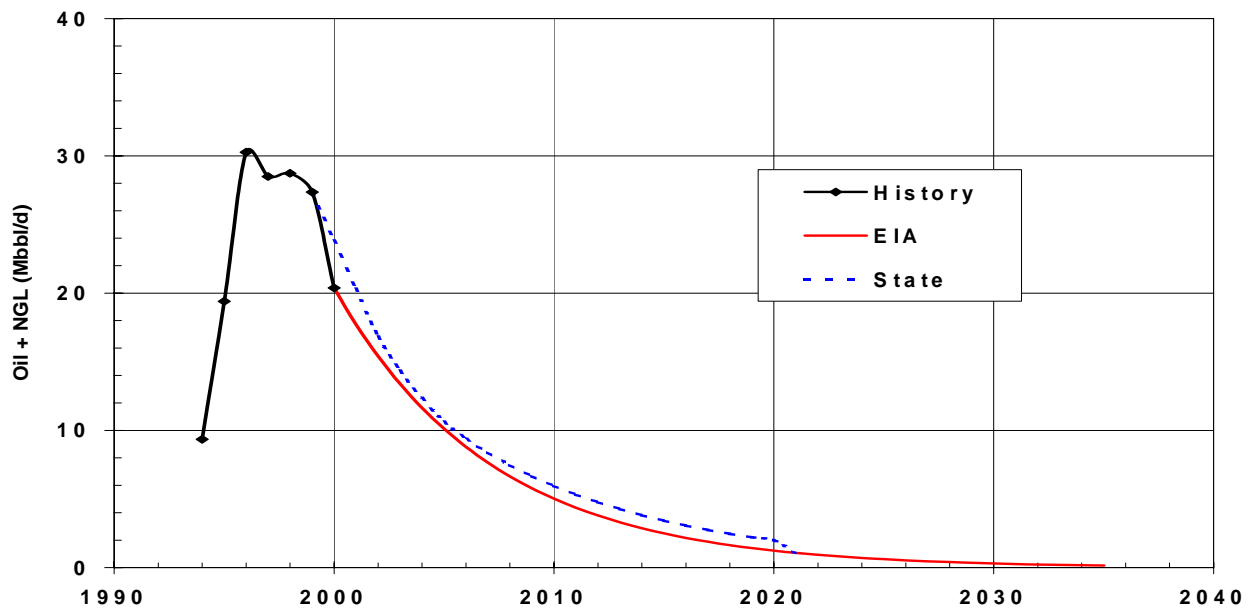
Note: Other Point McIntyre Fields include North Prudhoe Bay State and West Beach.
 Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B5. Lisburne Field, Alaska North Slope, Historical and Projected Oil and NGL Production



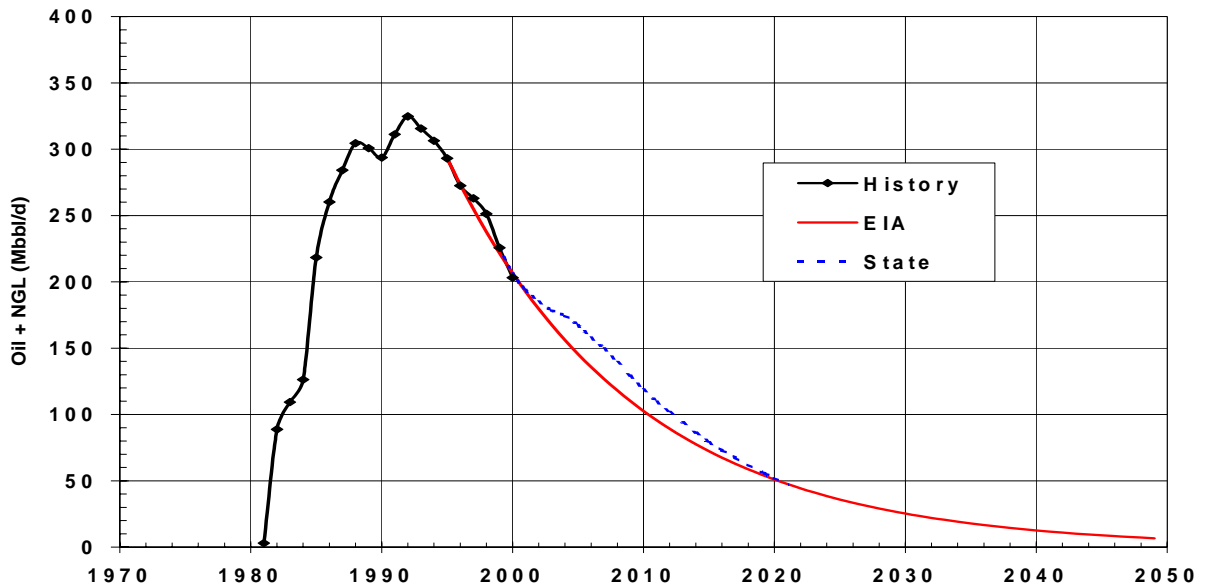
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B6. Niakuk Field, Alaska North Slope, Historical and Projected Oil and NGL Production



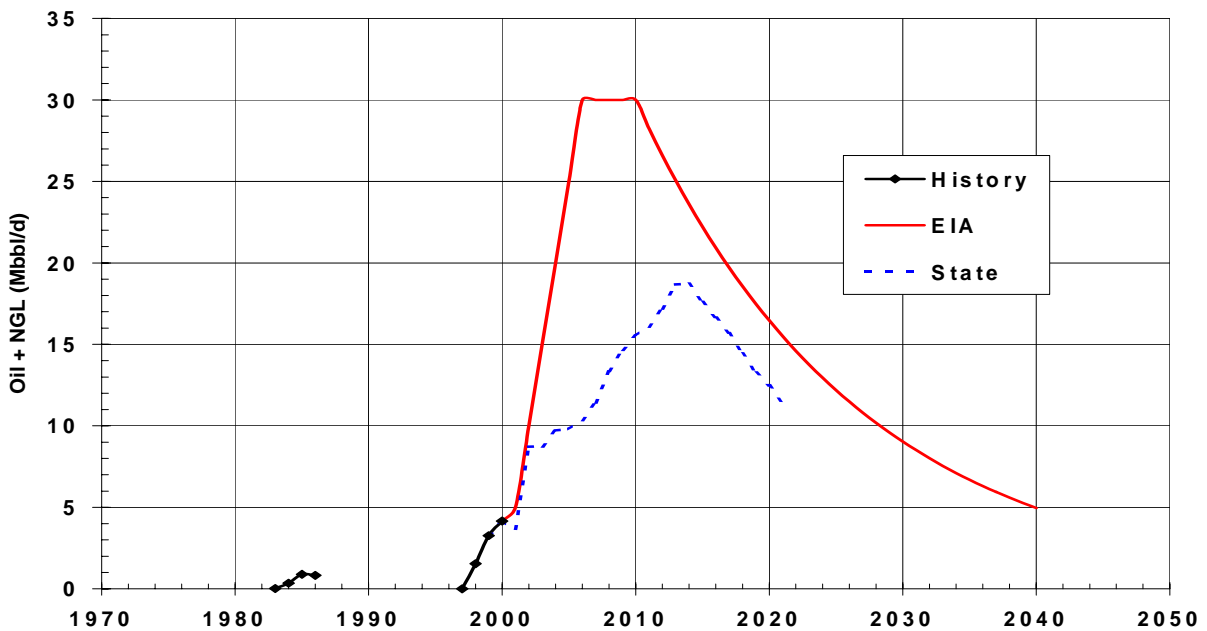
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B7. Kuparuk River Field, Alaska North Slope, Historical and Projected Oil and NGL Production



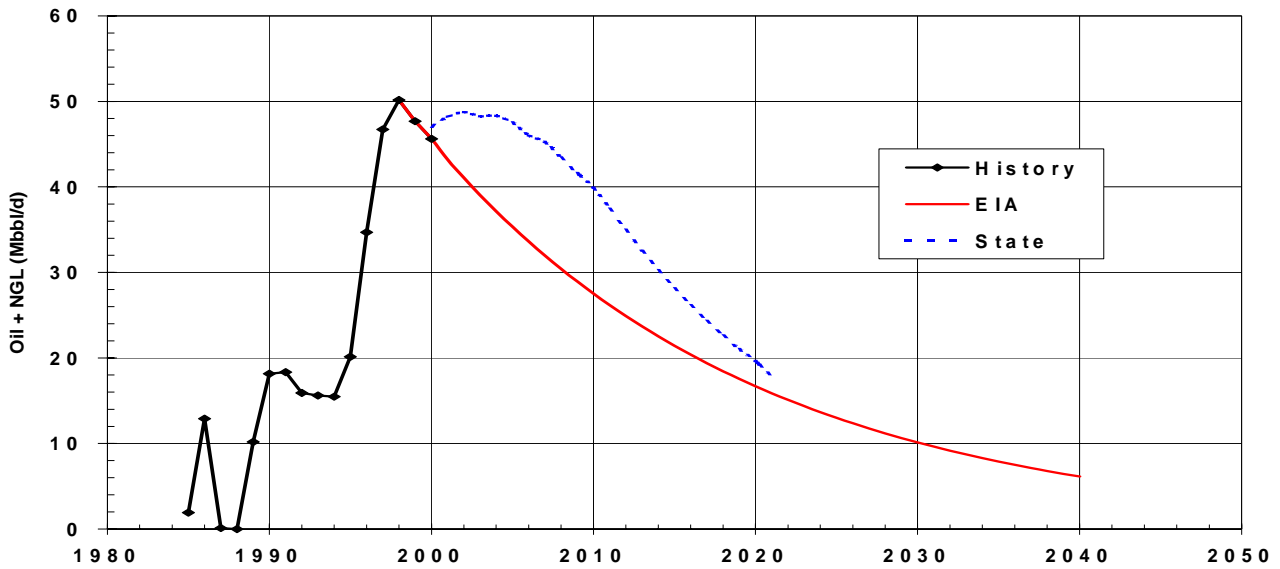
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B8. West Sak Field, Alaska North Slope, Historical and Projected Oil and NGL Production



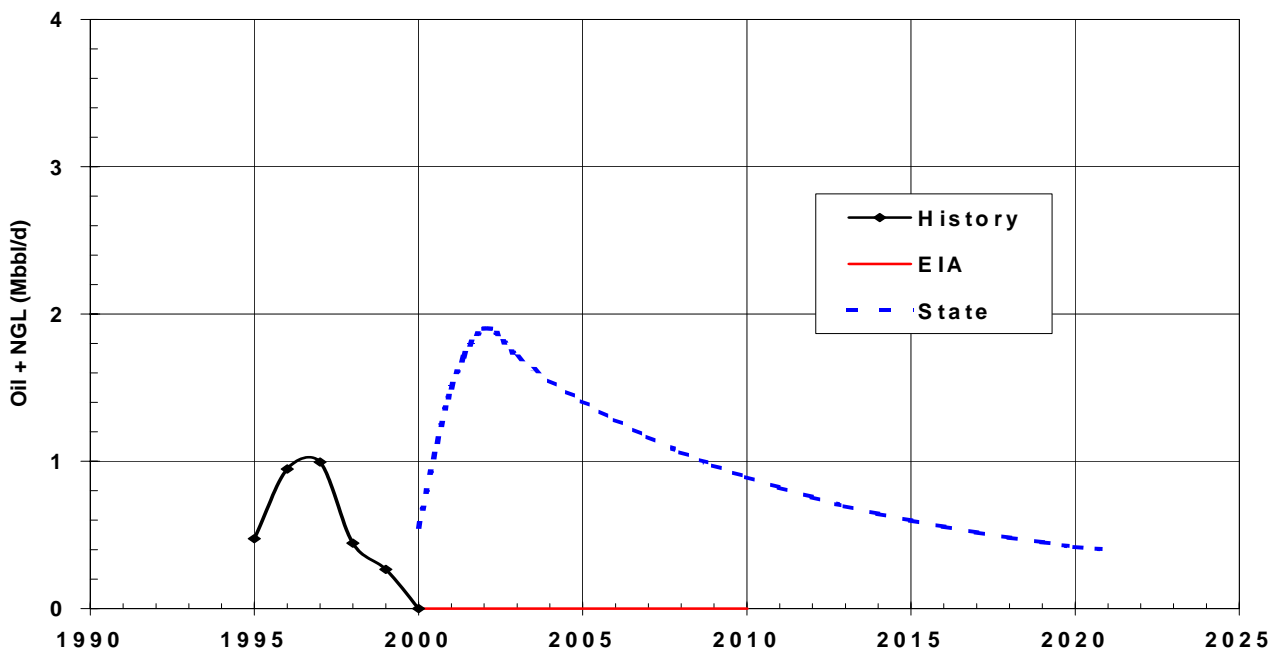
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B9. Milne Point Field, Alaska North Slope, Historical and Projected Oil and NGL Production



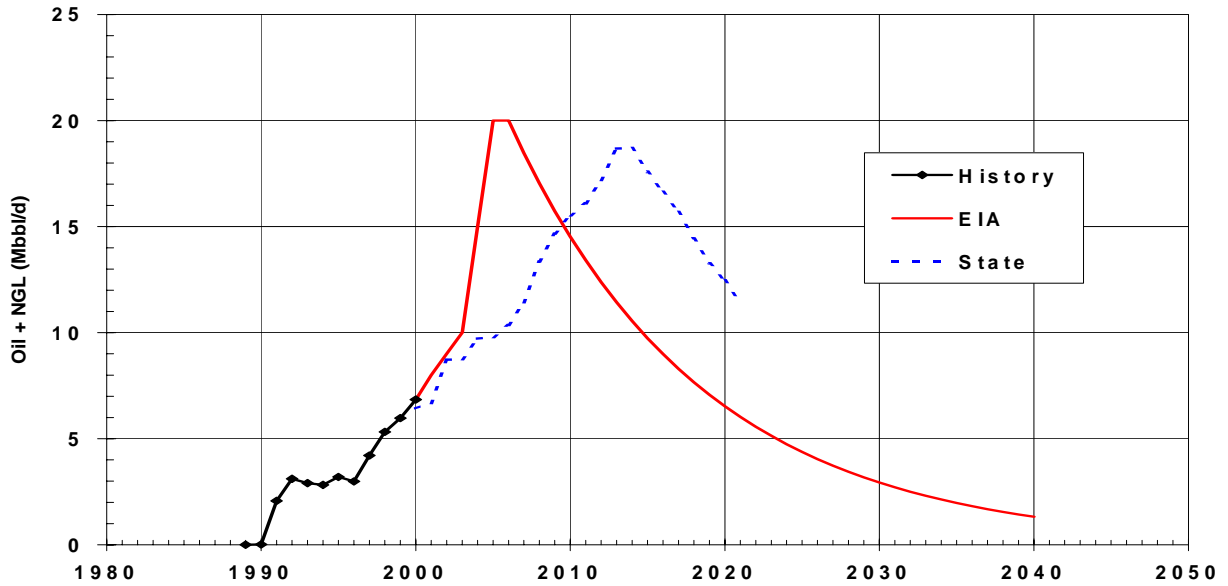
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B10. Sag River Field, Alaska North Slope, Historical and Projected Oil and NGL Production



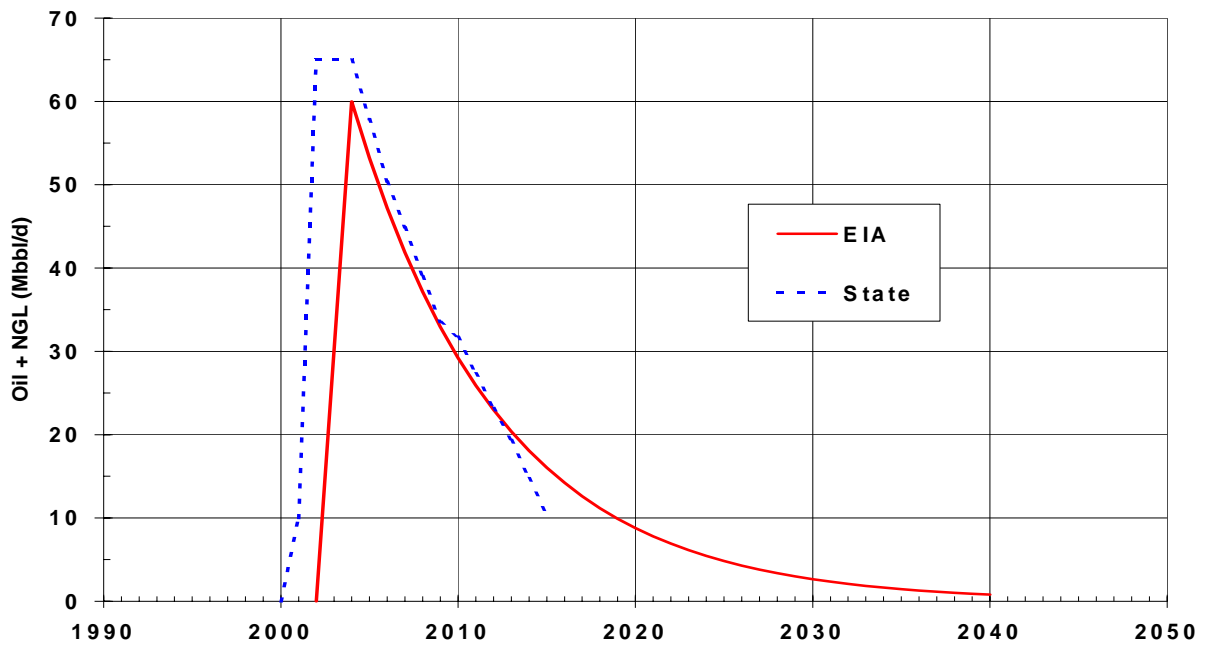
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B11. Schrader Bluff Field, Alaska North Slope, Historical and Projected Oil and NGL Production



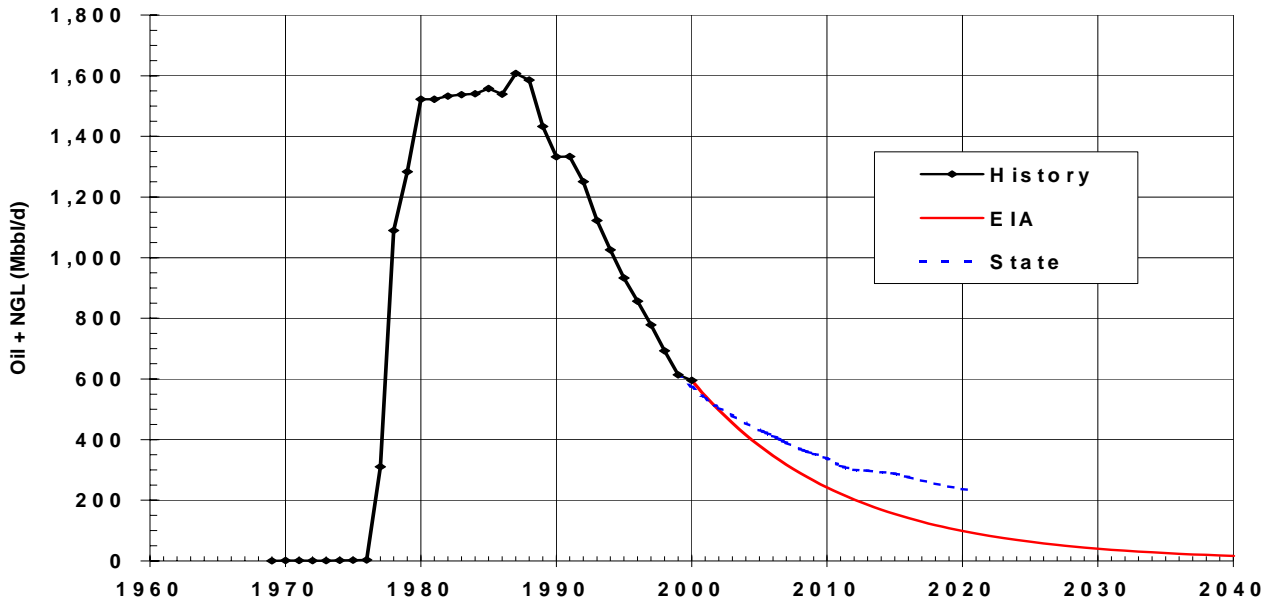
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B12. Northstar Field, Alaska North Slope, Projected Oil and NGL Production



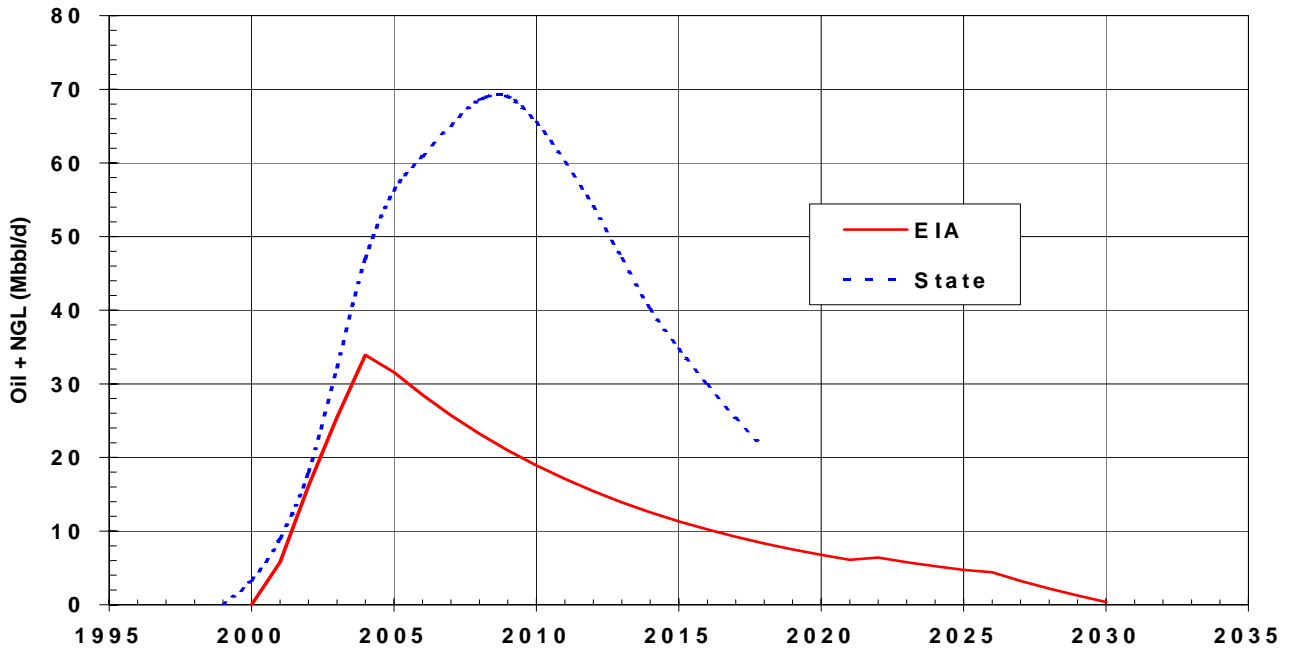
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B13. Prudhoe Bay Field, Alaska North Slope, Historical and Projected Oil and NGL Production



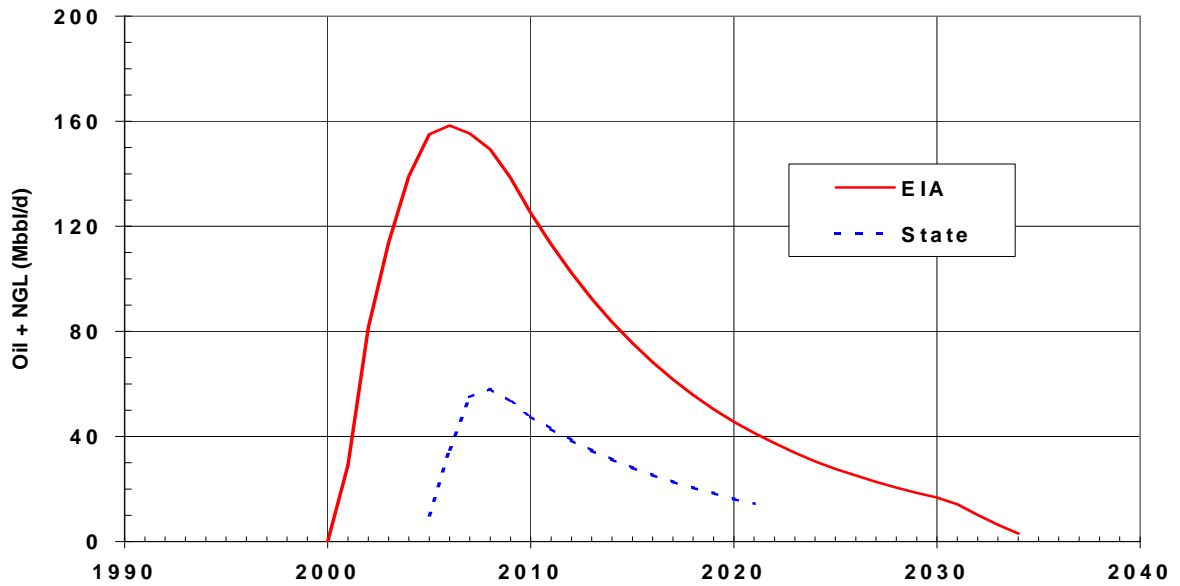
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B14. Prudhoe Bay Satellite Fields, Alaska North Slope, Projected Oil and NGL Production



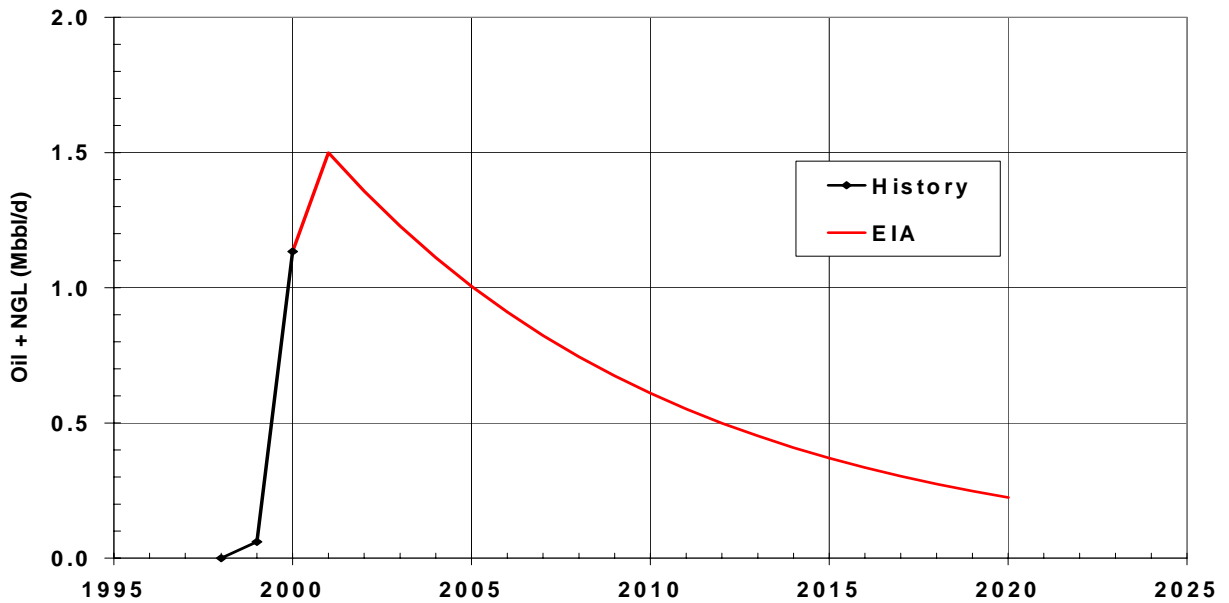
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B15. Additional Satellite Fields, Alaska North Slope, Projected Oil and NGL Production



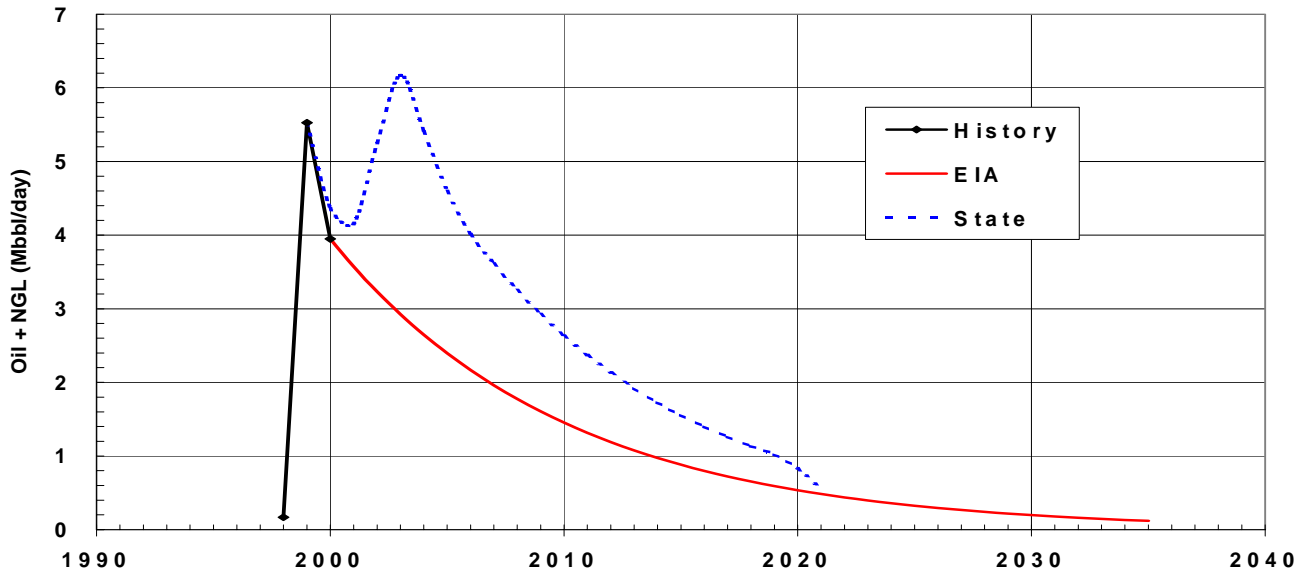
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B16. Polaris Field, Alaska North Slope, Historical and Projected Oil and NGL Production



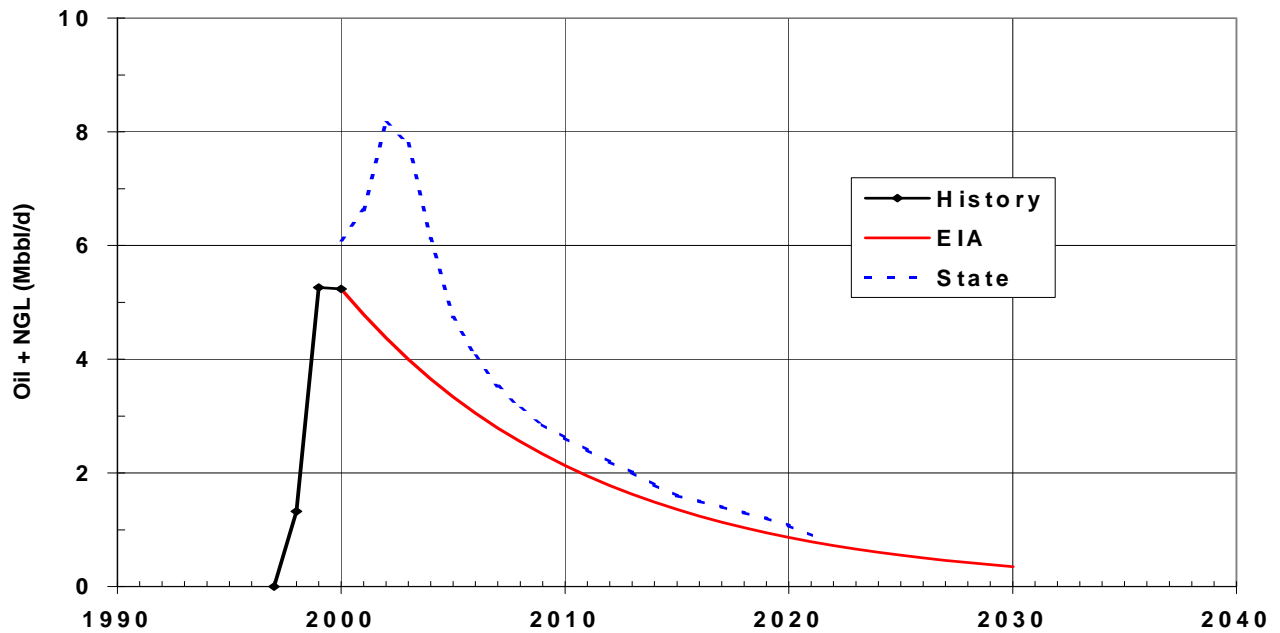
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B17. Midnight Sun Field, Alaska North Slope, Historical and Projected Oil and NGL Production



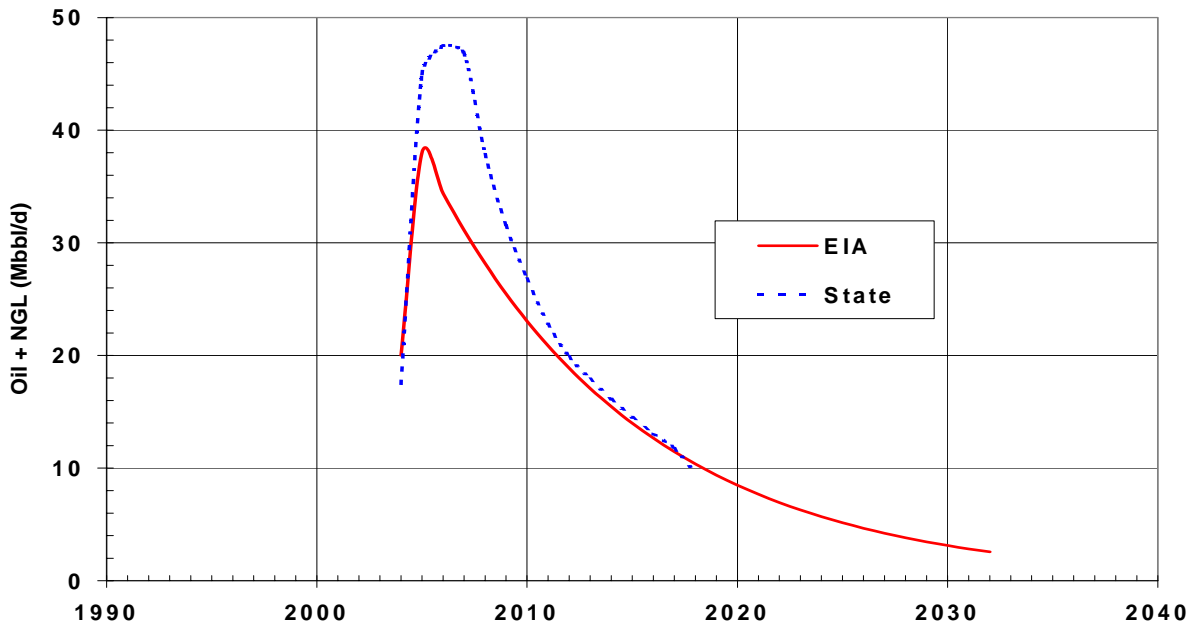
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B18. Tabasco Field, Alaska North Slope, Historical and Projected Oil and NGL Production



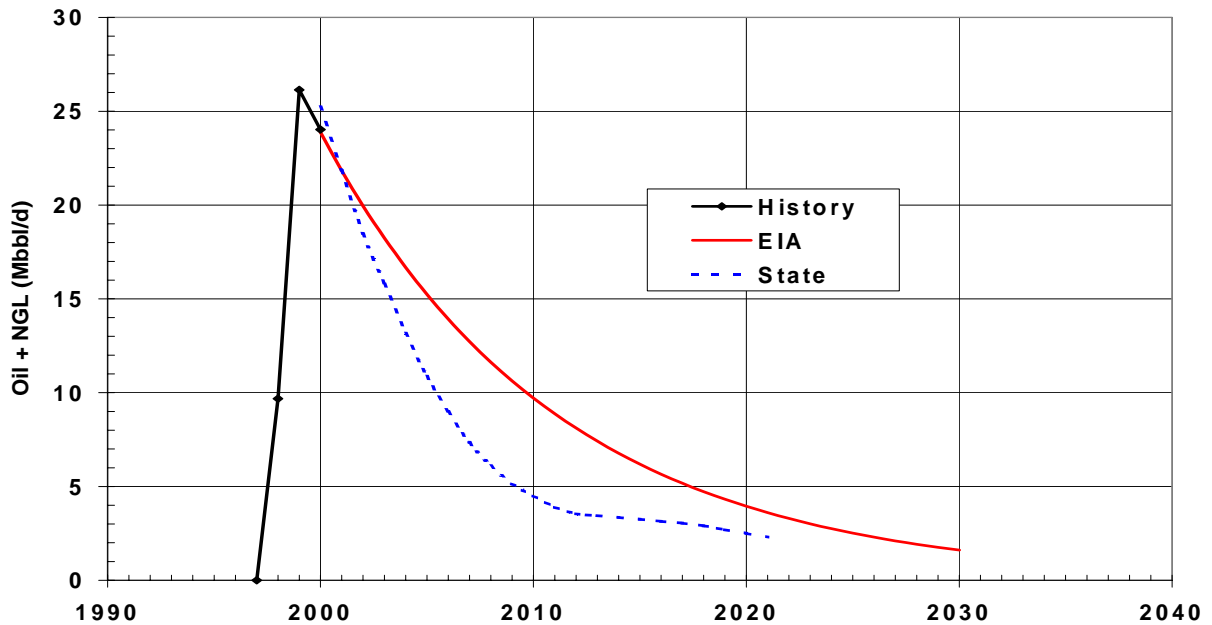
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B19. Liberty Field, Alaska North Slope, Projected Oil and NGL Production



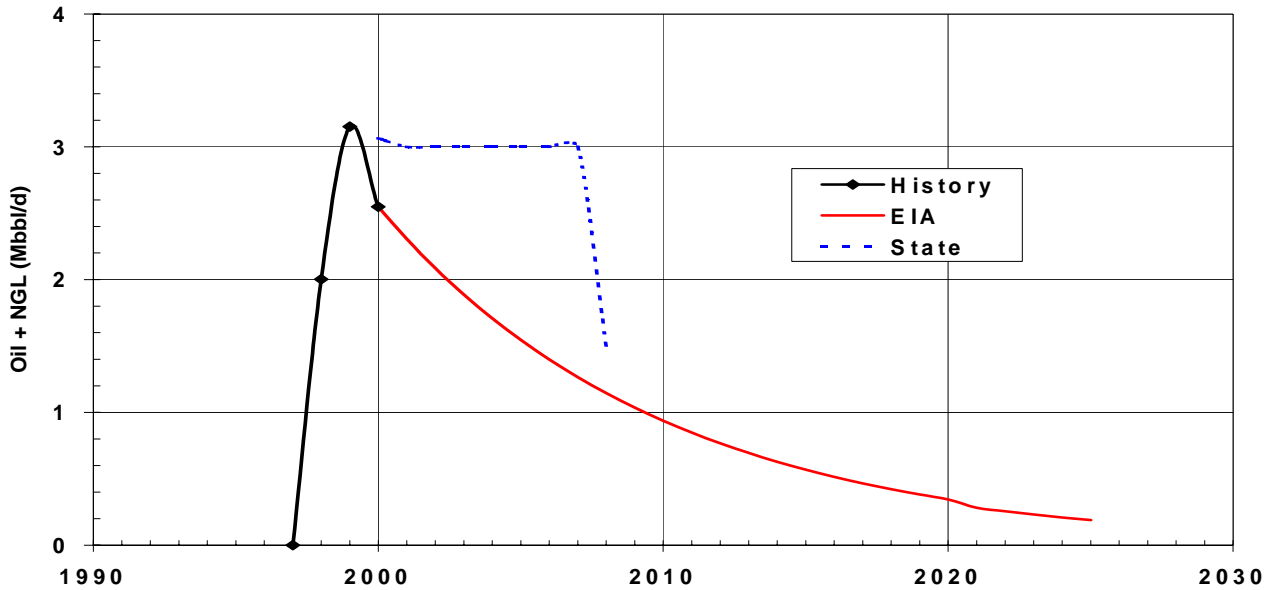
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B20. Tarn Field, Alaska North Slope, Historical and Projected Oil and NGL Production



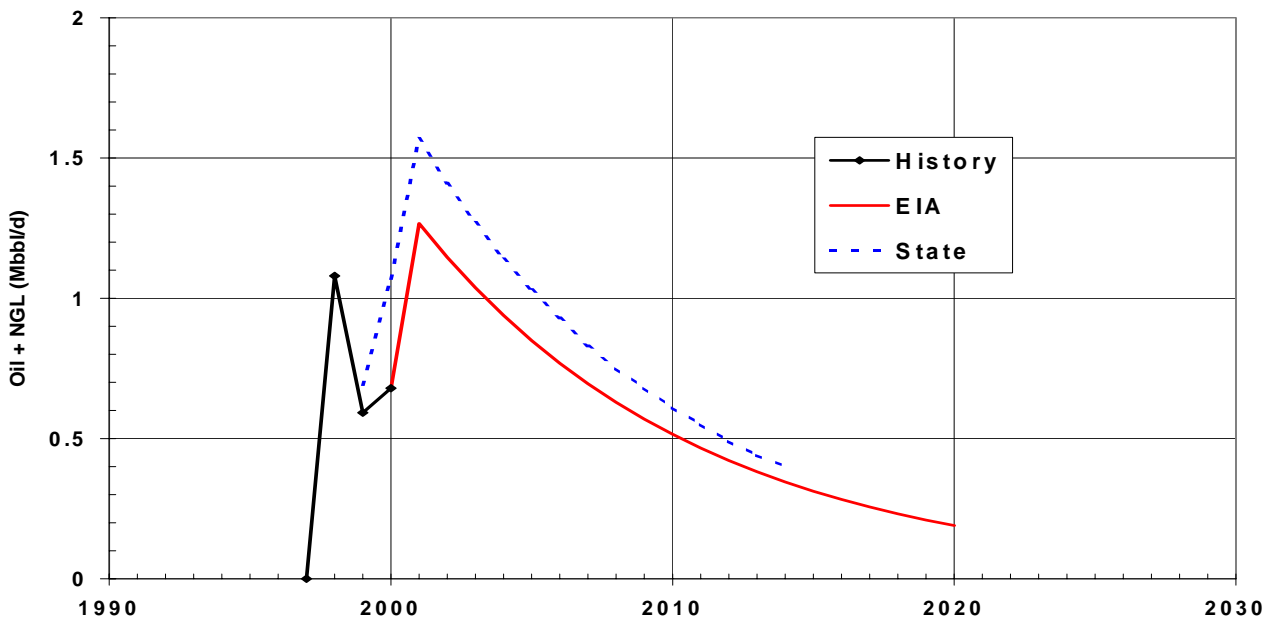
Source: State projection from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B21. Badami Field, Alaska North Slope, Historical and Projected Oil and NGL Production



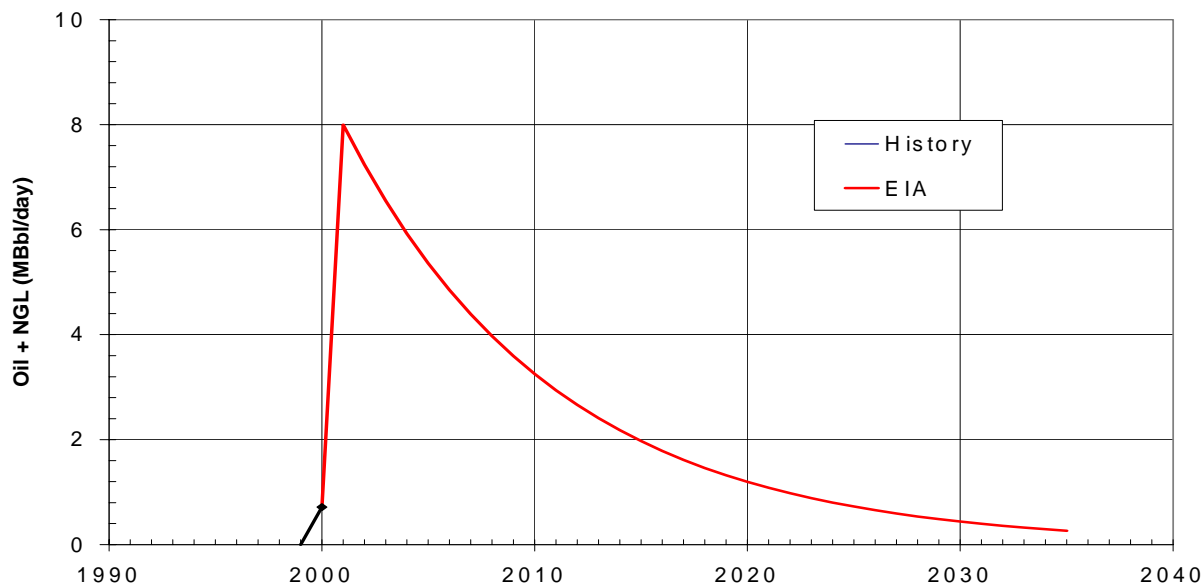
Source: Production history from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B22. Eider Field, Alaska North Slope, Historical and Projected Oil and NGL Production



Source: Production history from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Figure B23. Aurora Field, Alaska North Slope, Historical and Projected Oil and NGL Production



Source: Production history from Alaska Department of Natural Resources, Division of Oil and Gas, *Oil and Gas Annual Report-2000*, August 2000; EIA projection from Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Appendix C

Production Projections

Appendix C

Production Projections

The production projections for each of the scenarios analyzed are tabulated in **Table C1**. The projections are tabulated for each of the North Slope areas at the 95 percent (19 in 20 chance) and 5 percent (1 in 20 chance) probabilities of occurrence as well as the mean (expected) cases. Average annual rates in thousands of barrels per day are reported.

The production projections from 2001 to the annual TAPS minimum operating limit of 300,000 barrels per day are tabulated for each case. Data in the year of occurrence are shaded. Also tabulated for each case is production to 2039. Production projections to a different TAPS minimum operating limit can be calculated from the information in this table if desired.

Table C. Production Projections for Alaska North Slope Producing and Developing Fields and Undiscovered Resources at 95% Probability, Mean, and 5% Probability of Success. (Mbbls/d)

Year	2001	2002	2003	2004	2005	2006	2007
95 % Probability Cases							
Mbbls/day							
Producing and Developing Fields	1065.6	1059.8	1061.3	1086.0	1058.5	990.0	916.0
Central Area	--	--	--	--	10	20.0	30.0
NE NPR-A Area	--	--	--	--	--	--	--
West NPR-A Area	--	--	--	--	--	--	--
TOTAL	1065.6	1059.8	1061.3	1086.0	1068.5	1010.0	946.0
Mean Cases							
Mbbls/day							
Producing and Developing Fields	1065.6	1059.8	1061.3	1086.0	1058.5	990.0	916.0
Central Area	--	--	--	--	25.0	65.0	115.0
NE NPR-A Area	--	--	--	--	--	--	--
West NPR-A Area	--	--	--	--	--	--	--
TOTAL	1065.6	1059.8	1061.3	1086.0	1083.5	1055.0	1031.0
5 % Probability Cases							
Mbbls/day							
Producing and Developing Fields	1065.6	1059.8	1061.3	1086.0	1058.5	990.0	916.0
Central Area	--	--	--	--	25.0	105.0	177.4
NE NPR-A Area	--	--	--	--	--	--	--
West NPR-A Area	--	--	--	--	--	--	--
TOTAL	1065.6	1059.8	1061.3	1086.0	1083.5	1095.0	1093.3

See notes at end of Table

Table C. Production Projections for Alaska North Slope Producing and Developing Fields and Undiscovered Resources at 95% Probability, Mean, and 5% Probability of Success. (Mbbbls/d) (continued)

2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
845.5	776.3	710.0	648.2	592.0	540.9	494.4	452.1	413.6	378.5
27.1	24.6	22.2	20.1	18.2	16.5	14.9	13.5	12.2	11.0
--	--	10.0	30.0	52.0	71.9	89.9	106.2	121.0	124.3
--	--	--	--	--	--	--	5.0	12.0	10.9
872.7	800.8	742.3	698.3	662.2	629.3	599.2	576.8	558.8	524.7
845.5	776.3	710.0	648.2	592.0	540.9	494.4	452.1	413.6	378.5
160.2	201.2	238.2	271.7	302.1	304.5	289.3	261.8	236.9	214.3
--	--	12.5	37.5	72.5	104.2	132.8	158.8	182.2	190.9
--	--	--	--	--	--	--	15.0	35.0	60.0
1005.8	977.4	960.8	957.4	966.6	949.6	916.6	887.7	867.7	843.8
845.5	776.3	710.0	648.2	592.0	540.9	494.4	452.1	413.6	378.5
242.9	302.2	355.8	404.3	448.2	487.9	523.9	556.4	585.8	612.5
--	--	25.0	75.0	125.0	170.2	211.2	248.2	281.7	312.1
--	--	--	--	--	--	--	25.0	75.0	125.0
1088.4	1078.4	1090.8	1127.5	1165.2	1199.1	1229.5	1281.7	1356.2	1428.0

See notes at end of Table

**Table C. Production Projections for Alaska North Slope Producing and Developing Fields and Undiscovered Resources at 95% Probability, Mean, and 5% Probability of Success.
(Mbbbls/d) (continued)**

Year	2018	2019	2020	2021	2022	2023	2024
95 % Probability Cases							
Mbbbls/day							
Producing and Developing Fields	346.5	317.3	290.7	266.5	245.2	224.9	206.3
Central Area	10.0	9.0	8.2	7.4	6.7	6.1	5.5
NE NPR-A Area	116.4	105.3	95.3	86.2	78.0	70.6	63.9
West NPR-A Area	9.8	8.9	8.0	7.3	6.6	6.0	5.4
TOTAL	482.7	440.6	402.2	367.4	336.5	307.5	281.1
Mean Cases							
Mbbbls/day							
Producing and Developing Fields	346.5	317.3	290.7	266.5	245.2	224.9	206.3
Central Area	193.9	175.5	158.8	143.7	130.0	117.6	106.4
NE NPR-A Area	185.2	167.5	151.6	137.2	124.1	112.3	101.6
West NPR-A Area	82.6	103.1	121.6	138.4	153.5	152.3	144.7
TOTAL	808.2	763.5	722.7	685.7	652.8	607.1	559.0
5 % Probability Cases							
Mbbbls/day							
Producing and Developing Fields	346.5	317.3	290.7	266.5	245.2	224.9	206.3
Central Area	611.6	553.4	500.7	453.1	409.9	370.9	335.6
NE NPR-A Area	314.5	289.3	261.8	236.9	214.3	193.9	175.5
West NPR-A Area	170.2	211.2	248.2	281.7	312.1	339.5	364.3
TOTAL	1442.8	1371.2	1301.5	1238.1	1181.5	1129.2	1081.8

See notes at end of Table

Table C. Production Projections for Alaska North Slope Producing and Developing Fields and Undiscovered Resources at 95% Probability, Mean, and 5% Probability of Success. (Mbbbls/d) (continued)

2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
189.4	173.1	158.3	144.8	132.4	121.0	109.8	98.4	87.9	78.4
5.0	4.5	4.1	3.7	3.3	3.0	2.7	2.5	2.2	2.0
57.8	52.3	47.3	42.8	38.7	35.1	31.7	28.7	26.0	23.5
4.9	4.4	4.0	3.6	3.3	3.0	2.7	2.4	2.2	2.0
257.0	234.3	213.7	194.9	177.7	162.0	146.9	132.0	118.3	105.9
189.4	173.1	158.3	144.8	132.4	121.0	109.8	98.4	87.9	78.4
96.3	87.1	78.9	71.3	64.6	58.4	52.9	47.8	43.3	39.2
91.9	83.2	75.3	68.1	61.6	55.8	50.5	45.7	41.3	37.4
130.9	118.4	107.2	97.0	87.7	79.4	71.8	65.0	58.8	53.2
508.5	461.9	419.6	381.2	346.3	314.6	285.0	256.9	231.3	208.1
189.4	173.1	158.3	144.8	132.4	121.0	109.8	98.4	87.9	78.4
303.7	274.8	248.6	225.0	203.6	184.2	166.7	150.8	136.5	123.5
158.8	143.7	130.0	117.6	106.4	96.3	87.1	78.9	71.3	64.6
361.8	332.1	300.5	271.9	246.0	222.6	201.4	182.3	164.9	149.2
1013.6	923.7	837.5	759.3	688.4	624.2	565.1	510.3	460.7	415.6

See notes at end of Table

Table C. Production Projections for Alaska North Slope Producing and Developing Fields and Undiscovered Resources at 95% Probability, Mean, and 5% Probability of Success. (Mbbbls/d) (continued)

Year	2035	2036	2037	2038	2039	Projection from 2001	
						to PL Limit	to 2039
95 % Probability Cases							
Mbbbls/day						MMbbbls	MMbbbls
Producing and Developing Fields							
Central Area	1.8	1.7	1.5	1.3	1.2	107.0	121.7
NE NPR-A Area	21.3	19.2	17.4	15.8	14.3	445.7	612.7
West NPR-A Area	1.8	1.6	1.5	1.3	1.2	29.1	43.2
TOTAL	97.5	86.2	79.3	72.9	67.1	6051.8	6834.9
Mean Cases							
Mbbbls/day						MMbbbls	MMbbbls
Producing and Developing Fields							
Central Area	32.4	26.3	20.7	15.7	11.2	1540.6	1622.8
NE NPR-A Area	33.8	30.6	27.7	25.1	22.7	860.4	948.6
West NPR-A Area	48.2	43.6	39.4	35.7	32.3	620.0	745.5
TOTAL	187.0	164.1	146.7	130.9	116.6	8866.4	9392.7
5 % Probability Cases							
Mbbbls/day						MMbbbls	MMbbbls
Producing and Developing Fields							
Central Area	111.7	101.1	91.5	79.5	68.7	3819.2	3819.2
NE NPR-A Area	58.4	52.9	47.8	43.3	39.2	1603.0	1603.0
West NPR-A Area	135.0	122.2	110.6	100.0	90.5	1844.3	1844.3
TOTAL	377.8	339.8	308.7	277.3	248.8	13299.8	13390.6

PL Limit is the assumed minimum operating limit of the pipeline of 300,000 bbls/d.

Shaded numbers indicate the year that the producing rate falls below the assumed pipeline limit.

Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division.

Glossary

Glossary

1002 Area: Coastal plain of ANWR.

ANILCA: Alaska National Interest Lands Conservation Act.

ANS: Alaska North Slope.

ANWR: Arctic National Wildlife Refuge.

Associated-Dissolved Gas (Solution Gas): Natural gas in solution with a liquid oil phase in the reservoir.

Basin: A low area in the earth's crust, of technique origin, in which sediments have accumulated. Such basins were drainage basins at the time of sedimentation, but not necessarily so today.

Bbbl: Billion barrels, a liquid measure.

Bbl: Barrel, 42 U. S. gallons, a liquid measure.

Bcf: Billion cubic feet, a gas measure.

Condensate: Hydrocarbon liquid usually separated from produced gas at the lease, included with NGL in this analysis.

Developed: Having an installed infrastructure necessary for production.

DOE: Department of Energy.

EIA: Energy Information Administration, independent energy statistical agency within the Department of Energy.

Exponential Decline: Systematic reduction in production rate that can be defined by a mathematical exponential function.

Gas Liquification: Conversion of natural gas to a liquid phase by temperature reduction and increased pressure.

Geology: The study of the history of the earth as recorded in its rocks; the study of the earth's rocks to locate hydrocarbons.

GTL (Gas-to Liquid): conversion of natural gas to a stable liquid.

Heavy Oil: Having a low API gravity and high viscosity.

Hydrocarbon: An organic chemical compound of carbon and hydrogen produced in a gaseous or liquid phase.

Mbbl: Thousand barrels, a liquid measure.

Mcf: Thousand cubic feet, a gas measure.

MMbbl: Million barrels, a liquid measure.

MMcf: Million cubic feet, a gas measure.

MMS: Minerals Management Service, Department of Interior.

NGL: Natural gas liquids usually recovered at a gas processing plant, included with condensate in this analysis.

NPR-A: National Petroleum Reserve – Alaska.

Peak Production: Highest producing rate in the life of a measured unit (well, field, area, etc.)

Permeability: Measure of the capacity of reservoir rock for transmitting a fluid, such as hydrocarbon.

Play: A set of known or postulated petroleum accumulations sharing similar geologic, geographic, and temporal properties such as source rock, migration, pathway, timing, trapping mechanism, and hydrocarbon type.

Porosity: (Porous) Void space of reservoir rock relative to the total volume of the rock.

Production Decline: Reduction of production rate usually caused by depletion.

Production Projection: Estimate of future production.

Reserves: Known recoverable hydrocarbon within defined limits (proven, probable, or possible).

Reservoir: Subsurface geologic formation containing hydrocarbons.

Resource: Estimated volume of technically recoverable hydrocarbon including undiscovered volume.

TAPS: Trans Alaska Pipeline System.

Tcf: Trillion cubic feet, a gas measure.

Ultimate Recovery: Estimate of the total amount of hydrocarbon that will be produced from a reservoir.

Undiscovered: Hydrocarbon volume projected to be discovered in the future.

USGS: United States Geological Survey, Department of Interior.

Viscosity: A measure of the flow characteristics of liquids.

Viscous: High viscosity, resistant to flow, relating to "heavy oil."

Yearly Petroleum Development Rate: The amount of petroleum potentially made available through drilling of wells and installation of infrastructure in a region in a year (usually expressed in barrels per year).