OCS Report
MMS 96-0033

Endowments of Undiscovered Conventionally Recoverable and Economically Recoverable Oil and Gas in the Alaska Federal Offshore

As of January 1995

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U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region

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As of January 1995

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CONTENTS

TABLES

FIGURES

Endowments of Undiscovered Conventionally Recoverable and Economically Recoverable Oil and Gas in the Alaska Federal Offshore, as of January 1995

SUMMARY OF ASSESSMENT RESULTS

This report summarizes the Minerals Management Service assessment of the quantities of undiscovered oil and gas that lie beneath submerged Federal lands offshore of Alaska. Resource estimates include both the geologic endowment, consisting of conventionally recoverable resources unconstrained by economics, as well as the more modest quantities of oil and gas that can be recovered profitably, considering the costs associated with producing the resource.

This assessment of the Alaska Federal offshore was conducted as part of a national appraisal of all Federal offshore lands in the United States performed by the Minerals Management Service (MMS) concurrently with a U.S. Geological Survey (USGS) assessment of all onshore lands and submerged lands in State waters (USGS, 1995). The MMS assessments are conducted periodically (Cooke, 1985, 1991; Cooke and Dellagiarino, 1989), and the results are used to guide management of leasing and exploration policies and programs in the Federal offshore.

In Alaska, Federal waters generally extend seaward of 3 miles from shore. For the purposes of this assessment, the Alaska offshore was divided into 17 provinces. Eleven of these provinces, all on the continental shelves, offer potential for conventional supplies of oil and gas. Within these 11 assessment provinces, oil and gas endowments were calculated for 74 exploration plays.

The quantities of oil and gas were calculated using two computer models (GRASP and PRESTO) that statistically analyze input data provided as ranges of values reflecting different probabilities for occurrence. These data are drawn from a vast offshore database of geophysically mapped prospects, data from offshore wells, and development cost data gathered over years of offshore work in Alaska.

The Alaska offshore is estimated to offer a mean potential for undiscovered, conventionally recoverable oil of 24 billion barrels, with a 5-percent chance of oil resources exceeding 34 billion barrels. Gas potential (mean value) is estimated at 126 trillion cubic feet, with a 5-percent chance of gas resources exceeding 230 trillion cubic feet.

Approximately 90 percent of the conventionally recoverable oil endowment in offshore Alaska occurs within the Chukchi shelf (13 billion barrels) and Beaufort shelf (9 billion barrels) provinces, which lie adjacent to the onshore Arctic Alaska oil and gas province, the latter with original oil reserves of 16.4 billion barrels and presently producing about 1.5 million barrels per day.

Most of the oil and gas resources of the Alaska offshore occur in accumulations too small to warrant commercial exploitation within the forseeable future. Only about 15 percent of the geologic oil endowment of offshore Alaska could be profitably recovered at prices approaching those that exist today. Most of the economically recoverable oil resources occur beneath the Beaufort shelf (2.27 billion barrels of oil) and Chukchi shelf (1.14 billion barrels of oil).[1] Along the Pacific margin of Alaska, Cook Inlet is estimated to hold modest undiscovered, economically recoverable oil resources of 0.27 billion barrels of oil. Most of the conventionally recoverable gas resources occur beneath the Beaufort and Chukchi shelves, but these resources are considered uneconomic because of the lack of an infrastructure for gas transport.

This report summarizes the results of a 4-year study involving a large MMS staff of geoscientists, with technical input from industry, academia, and other government agencies. The fuller body of this work will be documented in a detailed, comprehensive report scheduled for later publication. The comprehensive report will provide a full economic analysis of all assessment provinces including price-supply curves that show how recoverable quantities vary with commodity prices. The comprehensive report will tabulate all data used in geologic modeling and the quantitative results of the modeling, and it will fully document geologic rationales used in the preparation of play data.

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[1]*Resource quantities are taken from price-supply curves at commodity prices of $18 per barrel of oil and $2.11 per thousand cubic feet of gas.*

LOCATION OF ASSESSMENT AREA

U.S. (Federal) submerged lands partly surround Alaska, starting at the U.S.-Canadian maritime boundary in southeastern Alaska, then extending west and clockwise to the U.S.-Russia maritime boundary in the Bering Sea, and then northeast to the U.S.-Canada maritime boundary in the Beaufort Sea (fig. 1). The area of Federal jurisdiction in these waters extends from the limit of State of Alaska waters, generally 3 miles offshore, to the farther of two limits as defined by either Federal Outer Continental Shelf (OCS) planning areas or the 200-mile Exclusive Economic Zone. Because submerged Federal lands extend 200 miles or farther offshore, they include all of the continental shelves as well as large areas of the continental slopes and deep abyssal plains of the north Pacific Ocean, and the Bering, Chukchi, and Beaufort Seas.

IDENTIFICATION OF ASSESSMENT PROVINCES

For purposes of the 1995 assessment, the Federal waters offshore Alaska were divided on geological grounds into 17 assessment provinces, as shown in figure 1. Six provinces embrace areas of deep water or unpromising geology that offer only negligible geologic potential for conventionally recoverable oil or gas. The deep-water assessment provinces are the Canada basin-Beaufort slope, the Chukchi Borderland, the Bering shelf-margin basins, the Bering Sea deep-water basins, and the Aleutian trench and north Pacific abyssal plain. A sixth assessment province, the Aleutian arc, consists of an intra-oceanic volcanic arc of Tertiary age and is considered to have negligible potential for oil and gas.

Assessment provinces that offer potential for undiscovered oil and gas resources are confined to the continental shelves surrounding Alaska. The Arctic subregion is divided into the Beaufort shelf, Chukchi shelf, and Hope basin assessment provinces. The Bering shelf subregion is divided into five assessment provinces: Norton basin, St. Matthew-Hall basin, Navarin basin, St. George basin, and North Aleutian basin. The Pacific margin subregion is divided into three assessment provinces: Shumagin-Kodiak shelf, Cook Inlet, and Gulf of Alaska shelf.

GEOLOGIC SETTING

The assessment provinces located offshore southern Alaska overlie the modern Pacific convergent margin, where oceanic crust of the Pacific plate moves northward and is subducted beneath the Aleutian volcanic arc and the Shumagin, Kodiak, and Gulf of Alaska continental shelves. The compression and uplift resulting from the convergence of plates along this zone has controlled the geological development of the Pacific margin of Alaska. The Aleutian volcanic arc, of Tertiary age and constructed entirely upon oceanic crust, extends eastward 1,300 km from Russian waters into a continental setting where it meets the Bering Sea continental margin (at approximately the southeast limit of the "Bering shelf-margin basins" assessment province, fig. 1). From the Bering margin northeast to the interior of southern Alaska, the modern volcanic arc is superposed upon older volcanic-arc systems ranging up to Jurassic (145 to 200 million years ago (Ma)) in age (Reed and Lanphere, 1973). East of Cook Inlet, the volcanic arc and convergent-margin tectonics gradually give way to the strike-slip fault tectonics that dominate the eastern Gulf of Alaska, where the Pacific plate moves northwest and laterally past the North American continental plate. Most of the undiscovered oil and gas resources in the assessment provinces of the Pacific margin subregion are associated with forearc basins and shelf-margin wedges of Tertiary age (66 Ma and younger). Except in Cook Inlet, these Tertiary rocks are superposed on a deformed "basement" consisting of older volcanic-arc complexes and accretionary terranes that generally offer negligible hydrocarbon resource potential.

Western offshore Alaska is dominated by the 600-km-wide Bering Sea continental shelf. From Jurassic to earliest Tertiary time, the Bering shelf hosted one segment of a larger system of volcanic arcs extending from southeast Alaska to the Russian Sea of Okhotsk. This volcanic-arc system marked the northward descent of a southern oceanic (proto-Pacific) plate encroaching from the south. Continental fragments and volcanic arcs borne along with the southern oceanic plate collided with both Russian and Alaskan elements of the volcanic-arc system in earliest Tertiary time (Worrall, 1991). The collision(s) strongly deformed the rocks of most parts of the Bering shelf segment and other parts of the volcanic-arc system. Rocks deformed by these collisions, typically Cretaceous age or older, offer only negligible potential for undiscovered oil and gas resources. The Aleutian arc was also established as a new plate boundary at this time,

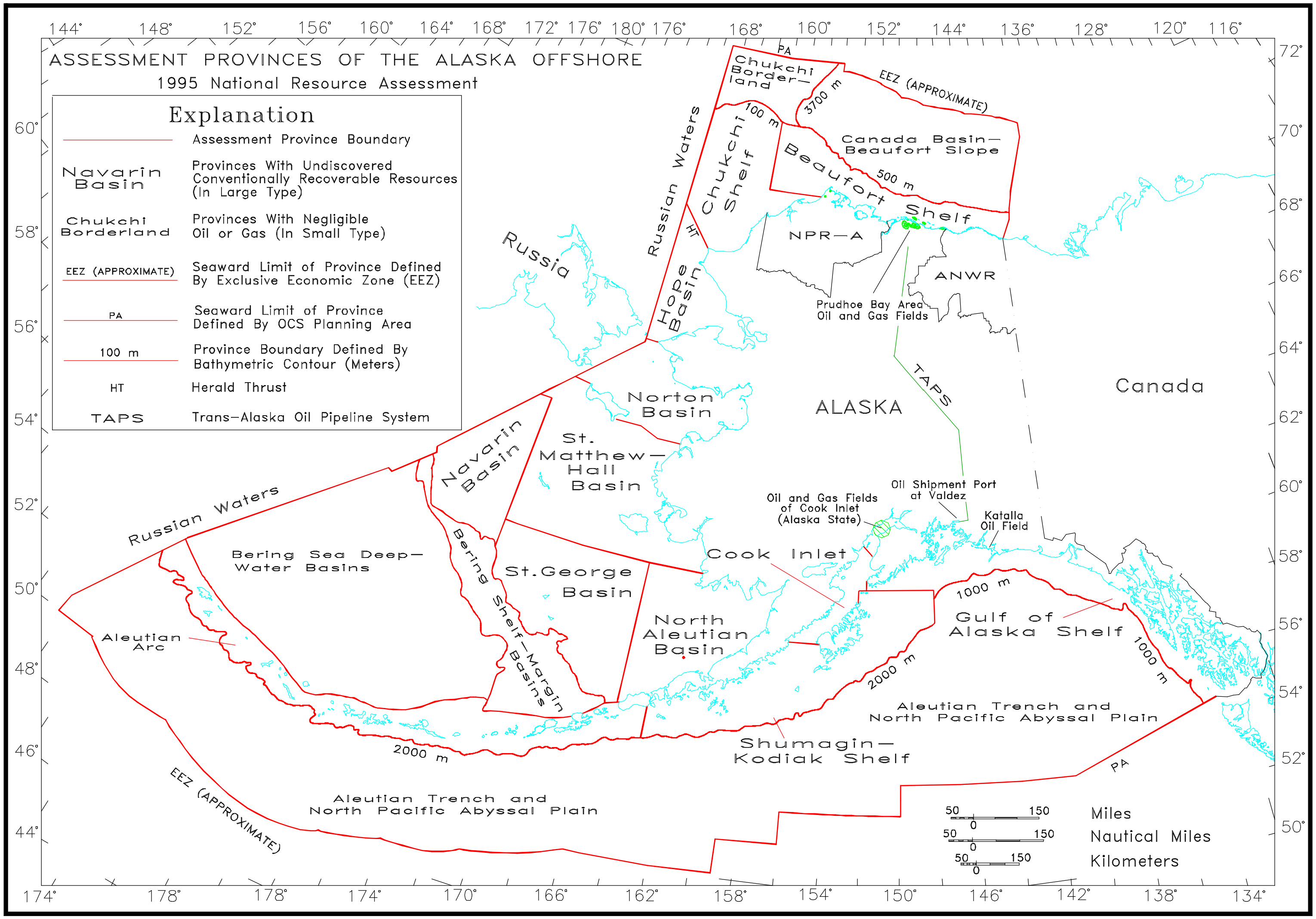

Figure 1: Alaska offshore assessment provinces, 1995 National Resource Assessment.

trapping fragments of an old volcanic arc and oceanic crust that formerly were part of the southern oceanic plate of (Marlow and others, 1982). Subduction of a spreading ridge that lay within the southern oceanic plate reorganized plate interactions in the north Pacific and caused strike-slip faulting throughout southern Alaska in early Tertiary and later time (Atwater, 1970). Most of the Bering shelf basins (Norton, St. Matthew-Hall, Navarin, St. George, and North Aleutian basins) began to subside at this time as pull-aparts or related features along strike-slip fault systems passing through the Bering shelf. Most of the undiscovered oil and gas resources offshore western Alaska are associated with Tertiary rocks deposited in the Bering shelf basins formed during this period of strike-slip faulting.

Offshore areas north and northwest of Alaska are dominated by the broad (400-km) continental shelf of Chukchi Sea and the narrow (70-km) continental shelf of Beaufort Sea. In Paleozoic and Mesozoic time (ca. 360 to 115 Ma), these shelf areas and onshore Arctic Alaska shared petroleum-rich geologic basins that were broken up or restructured in Early Cretaceous time (ca. 115 Ma) by rifting along the Beaufort shelf margin and the rise of the Brooks Range (Craig and others, 1985; Moore and others, 1992; Warren and others, 1995). These uplifts and fragmentation of the crust in northern Alaska gave rise to several new basins that received many thousands of meters of sediments during Cretaceous and Tertiary time (115 Ma to present). These events also created the geologic structures that later trapped the vast oil reserves (70+ billion barrels, in place) found in the Prudhoe Bay area of Arctic Alaska.

PETROLEUM EXPLORATION AND DEVELOPMENT IN ALASKA AND THE ALASKA OFFSHORE

Petroleum exploration in Alaska began in the late nineteenth century, and the first field (Katalla) was discovered in 1902 by drilling at the site of oil seeps along the coast of the eastern Gulf of Alaska (fig. 1; AOGCC, 1994, p. 56). In the late 1950's and the 1960's, several commercial oil and gas fields were discovered in the Cook Inlet area. Many of the commercial-sized fields discovered during this time remain in production today (presently 7 oil fields, 7 gas fields). Altogether, 8 oil fields and 22 gas fields have been discovered in Cook Inlet, with total discovered oil resources of about 1.34 billion barrels of oil (BBO) and 9.33 trillion cubic feet of gas (TCFG) (AOGCC, 1994; OGJ, 1993b; AKDO&G, 1995). Oil production from Cook Inlet fields peaked at 236,000 barrels of oil per day (BOPD) in 1970, but declined to 43,500 BOPD by 1994 (AOGCC, 1994). Total cumulative production from Cook Inlet by the end of 1994 was 1.19 BBO and 7.44 TCFG (AOGCC, 1994). Of the 7.44 TCFG produced in Cook Inlet, 2.73 TCFG were re-injected to aid oil recovery (and remain a future resource), with 4.70 TCFG, or 50-percent of discovered resources, actually delivered to market and consumed. Cook Inlet also hosts a liquefied natural gas (LNG) facility, which ships about 144 million cubic feet of gas per day to power utilities in Tokyo, Japan (AOGCC, 1994, p. 9 (N. Cook Inlet field); OGJ, 1993b, p. 24). No commercial production has occurred on Federal submerged lands in the Cook Inlet area.

Exploration of the Alaska Federal offshore began in the early 1970's with the scheduling of lease offerings in the Gulf of Alaska and Federal submerged lands of Cook Inlet. A stratigraphic-test well was drilled in the Gulf of Alaska in 1975, and a second stratigraphic test was drilled in Federal waters of Cook Inlet in 1977.

The first Federal offshore lease sale in Alaska waters was held in 1976 in the Gulf of Alaska. Three sales in the Gulf of Alaska from 1976 to 1981 leased 0.6 million acres for total high bonus bids of $670 million. Twelve exploratory wells on Gulf of Alaska leases in the period from 1977 to 1983 failed to locate commercial quantities of oil or gas. Two lease offerings in Federal waters of Cook Inlet in 1977 and 1981 leased 0.57 million acres for total high bonus bids of $403 million. Thirteen exploratory wells drilled on Cook Inlet leases in the period from 1977 to 1985 failed to find commercial quantities of oil or gas.

Petroleum exploration offshore western Alaska began in the early 1970's with the scheduling of lease sales on the Bering Sea shelf. Seismic data were gathered across large parts of the Bering shelf, and six stratigraphic-test wells were drilled from 1976 to 1983 in St. George, Norton, Navarin, and North Aleutian basins. Four lease sales were held in these same basins in the period from 1983 to 1988, and 1.9 million acres were leased for total high bonus bids of $1.36 billion. Twenty-four exploratory wells were drilled in Navarin, Norton, and St. George basins. None encountered significant shows of oil or gas. Except for a stratigraphic-test well drilled in 1983, no exploratory drilling has occurred in North Aleutian basin.

Petroleum exploration in Arctic Alaska began with the reporting of oil seeps in the Cape Simpson area near the northernmost tip of Alaska by Leffingwell of the U.S. Geological Survey in 1917. In 1923, based on the presence of these seeps and prompted by fuel shortages in World War I, President Warren Harding established

Naval Petroleum Reserve No. 4, later renamed the National Petroleum Reserve-Alaska (NPR-A, fig. 1). Fuel shortages during World War II prompted the first intensive, publicly funded exploration program in NPR-A from 1944 to 1953, resulting in the discovery of several subcommercial oil and gas fields.

With passage of Alaska statehood in 1959, exploration shifted to the lands selected by the State of Alaska in the corridor between NPR-A on the west and the Arctic National Wildlife Refuge (ANWR, fig. 1) on the east. State of Alaska lease sales in 1964 and 1965 were followed by the 1968 discovery of the 12.4 BBO Prudhoe Bay field, the largest oil field ever found in North America (fig. 1). The ultimate reserves recoverable from known commercial fields in the Prudhoe Bay area are approximately 16.4 BBO, and Prudhoe-area gas reserves are estimated at 28.2 TCFG (AOGCC, 1994; AKDO&G, 1995).

Construction of the Trans-Alaska Pipeline System (TAPS) began in 1974, and the first oil pumped through the pipeline arrived at the ice-free port of Valdez, Alaska, in 1977 for tanker shipment to the U.S. mainland (fig. 1). Pipeline throughput peaked at 2.0 million barrels of oil per day (MMBOPD) in 1988. By May 1996, production was 1.5 MMBOPD and a total of 11.2 BBO had passed through the pipeline (R. Oliver, Alyeska Pipeline Co., pers. comm., 1996).

In response to concerns about oil shortages related to the 1973 embargo of the United States by the Organization of Petroleum-Exporting Countries, government-sponsored exploration of NPR-A resumed in 1975 after a 22-year hiatus. This second program resulted in 28 exploration wells and 14,800 miles of seismic data, but no significant discoveries. The first offerings of leases for private exploration occurred in 1981, followed by a single well drilled and abandoned in 1985. This well concluded the most recent cycle of petroleum exploration in NPR-A.

The first lease sale in the Arctic Alaska offshore, offering mostly submerged lands of the Beaufort Sea near known fields in the Prudhoe Bay area, was conducted jointly by the State of Alaska and the Federal Government in 1979. Since 1979, most continental-shelf areas of the Arctic Alaska offshore were offered in four additional lease sales in the Beaufort Sea and two lease sales in the Chukchi Sea. In all seven sales, a total of 5.5 million acres of Federal lands were leased for total high bonus bids of $4.03 billion. A total of 32 exploratory wells were drilled in Arctic Federal waters between 1980 and 1993, resulting in the discovery of several subcommercial pools of oil. Northstar (Seal Island) field, estimated by BP-Alaska to contain 130 million barrels of recoverable oil, straddles State of Alaska and Federal offshore lands about 5 miles north of Prudhoe Bay field (fig. 1). The Northstar field is being considered for development, pending the results of current feasibility studies. If Northstar field is developed, the first commercial production from the Alaska Federal offshore could enter the TAPS as early as late 1998 (BP, 1995, p. 1-3).

RESOURCE ASSESSMENT MODELS

The assessment of the undiscovered oil and gas potential of the Alaska offshore involved two major tasks. The first task was to develop estimates of the undiscovered resources irrespective of any economic constraints. The focus was on frequency and sizes of hydrocarbon accumulations as a basis for calculating the total oil and gas endowments producible by conventional recovery practices. The second task was to determine how much of the total oil and gas endowments would be economic to produce under varying conditions.

To accomplish the first task, MMS used a computer program called GRASP (Geologic Resource ASsessment Program). This program was adapted by MMS from a program called PETRIMES (PETroleum Resource Information Management and Evaluation System), originally developed by the Geological Survey of Canada. The primary assessment unit is the geologic ***play***, which is composed of pools[2] or prospects[3] having a common history of hydrocarbon generation, migration, reservoir development, and trap configuration. In the Alaska offshore, a total of 74 plays were identified and individually assessed for undiscovered, conventionally recoverable quantities of oil and gas.

The MMS Alaska Region assessors followed a subjective approach in which ranges of values with varying probabilities of occurrence are estimated for geologic variables, such as pool area, pay thickness, porosity, hydrocarbon saturation, recovery efficiency, and others. Ranged values are used rather than fixed values to reflect ***uncertainty*** about the true quantity of a geologic variable at any particular site. GRASP uses

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[2]*A pool is a discovered (or undiscovered) accumulation of hydrocarbons, typically within a single stratigraphic interval, that is hydraulically separated from any other hydrocarbon accumulation*.

[3]*A prospect is an untested geologic feature having the potential for trapping and accumulating hydrocarbons.*

these variables to calculate probability distributions for sizes of recoverable pool volumes, both oil and gas, within each play. Separately, a probability distribution for the numbers of pools is calculated by combining geologic risk factors with a probability distribution for the numbers of prospects within the play.[4] A Monte Carlo process statistically combines the distribution of the ***possible sizes of pools*** with the distribution of the ***possible numbers of pools*** to compute distributions for the oil and gas volumes of individual pools. The pools are then ranked from largest to smallest and are summed to calculate the overall play resource endowment. Outputs from the program include pool size rank plots, complementary cumulative curves (e.g., fig. 2), and tabular distributions of results. Assessed commodities include crude oil, solution gas, nonassociated and associated gas, and condensate. Again, all of this work was done using GRASP.

MMS statistically aggregates the probability distributions for individual plays to the geologic-province level using a computer program named FASPAG, developed by Robert Crovelli, U.S. Geological Survey. MMS also uses FASPAG to aggregate province results to the subregional and regional levels.

To accomplish the second major task—determining the quantities of undiscovered ***economic*** resources—the MMS uses a computer program named PRESTO (Probabilistic Resource ESTimates—Offshore, generation 5). PRESTO simulates the exploration, development, production, and transportation of the pool resources for all plays within a geologic province. The geologic data used by GRASP for pool and play modeling is translated into a format usable by PRESTO. A Monte Carlo process samples the ranges of values input for engineering and economic variables. For ***each pool***, the program models exploratory efforts (numbers and costs of wells), schedules installation of development equipment (platforms and wells), estimates annual production, schedules production costs and revenues, develops a risk-weighted discounted cash flow, and calculates a present economic value. Results for all pools are summed to the play level to determine whether economic resources are sufficient to justify development of the play. Similarly, results from all of the plays are summed to determine whether sufficient resources are available to justify a transportation infrastructure for the entire geologic basin or province. This process is repeated for a large number of trials, resulting in a distribution of possible economic resources under the given conditions. Economic conditions are then modified and the entire process is repeated many times (typically 1,000 trials), finally yielding a series of possible results under many different economic scenarios.

Although numerous tables of various play and province results are available from PRESTO, the primary output is the ***price-supply curve***. Inspection of price-supply curves allows interpretation of economically recoverable volumes of oil or gas at any commodity price. Increases in price drive a corresponding direct increase in economically recoverable resources. At a very high price, the curve approaches a limit which equals the resource endowment estimated by GRASP.

CONVENTIONALLY RECOVERABLE OIL AND GAS

Federal submerged lands offshore Alaska offer a high potential for undiscovered, conventionally recoverable oil and gas resources, ranging up to 33.57 BBO and 229.53 TCFG (5-percent probability). Mean (or average) estimates for the undiscovered potential of the Alaska offshore are 24.31 BBO and 125.93 TCFG. Assessment results for subregions and assessment provinces are summarized in table 1. Cumulative probability distributions for the Alaska offshore and the three subregions (Arctic, Bering shelf, and Pacific margin) are shown in figure 2.

The Arctic subregion contains 90 percent of the undiscovered oil resources and 79 percent of the undiscovered gas resources (compared at mean values) of the entire Alaska offshore. The high proportion of offshore oil and gas resources estimated to be present in the Arctic subregion is consistent with the fact that 92 percent of Alaska's commercial oil reserves have been in the Arctic.[5] The dominance of the Arctic in the distributions of both offshore undiscovered resources and

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[4] *Estimates for prospect numbers were generally developed from the prospect count obtained by geophysical mapping and some estimates of additional prospects missed or not mapped in areas of no data.*

[5] *No gas reserves in Arctic Alaska are presently commercial because there is no transportation infrastructure. However, the untapped reserves in the Prudhoe Bay area amount to about 28.2 TCFG (AKDO&G, 1995), or about three times the commercial gas reserves in all of the Bering shelf or the Pacific margin (essentially Cook Inlet).*

TABLE 1

RISKED, UNDISCOVERED, CONVENTIONALLY RECOVERABLE OIL AND GAS

AREA	OIL (BBO)			GAS (TCFG)			BOE (BBO)			MPhc
	F95	MEAN	F05	F95	MEAN	F05	F95	MEAN	F05	
ALASKA OFFSHORE	16.85	24.31	33.57	58.01	125.93	229.53	28.68	46.72	70.61	1.00
ARCTIC SUBREGION	14.68	21.96	31.18	38.02	99.41	201.13	22.52	39.65	63.25	1.00
BERING SHELF SUBREGION	0.36	0.91	1.81	6.98	18.80	38.64	1.65	4.26	8.57	1.00
PACIFIC MARGIN SUBREGION	0.72	1.44	2.49	2.12	7.72	18.34	1.15	2.81	5.50	1.00
ARCTIC SUBREGION										
CHUKCHI SHELF	6.80	13.02	21.94	9.81	51.84	141.75	8.59	22.24	44.75	1.00
BEAUFORT SHELF	6.28	8.84	11.96	20.10	43.50	79.15	10.29	16.58	24.84	1.00
HOPE BASIN	0.00	0.11	0.34	0.00	4.06	12.67	0.00	0.83	2.59	0.61
BERING SHELF SUBREGION										
NAVARIN BASIN	0.00	0.50	1.21	0.00	6.15	18.18	0.00	1.59	4.41	0.88
N. ALEUTIAN BASIN	0.00	0.23	0.57	0.00	6.79	17.33	0.00	1.44	3.62	0.72
ST. GEORGE BASIN	0.00	0.13	0.41	0.00	3.00	9.72	0.00	0.67	2.14	0.94
NORTON BASIN	0.00	0.05	0.15	0.00	2.71	8.74	0.00	0.53	1.70	0.72
ST. MATTHEW-HALL	0.00	<0.01	<0.01	0.00	0.16	0.69	0.00	0.03	0.13	0.44
PACIFIC MARGIN SUBREGION										
COOK INLET	0.32	0.74	1.39	0.40	0.89	1.65	0.39	0.90	1.68	1.00
GULF OF ALASKA	0.18	0.63	1.43	0.94	4.18	10.59	0.36	1.37	3.27	0.99
SHUMAGIN-KODIAK	0.00	0.07	0.29	0.00	2.65	11.35	0.00	0.54	2.30	0.40

***BBO**, billions of barrels; **TCFG**, trillions of cubic feet; **BOE,** total oil and gas in billions of energy-equivalent barrels (5,620 cubic feet of gas=1 energy-equivalent barrel of oil); reported **MEAN,** resource quantities at the mean in cumulative probability distributions; **F95**, the resource quantity having a 95-percent probability of being met or exceeded; **F05**, the resource quantity having a 5-percent probability of being met or exceeded; **MPhc**, marginal probability for hydrocarbons for basin, i.e., chance for the existence of at least one pool of undiscovered, conventionally recoverable hydrocarbons somewhere in the basin. Resource quantities shown are risked, that is, they are the product of multiplication of conditional resources and Mphc. Mean values for provinces may not sum to values shown for subregions or region because of rounding.*

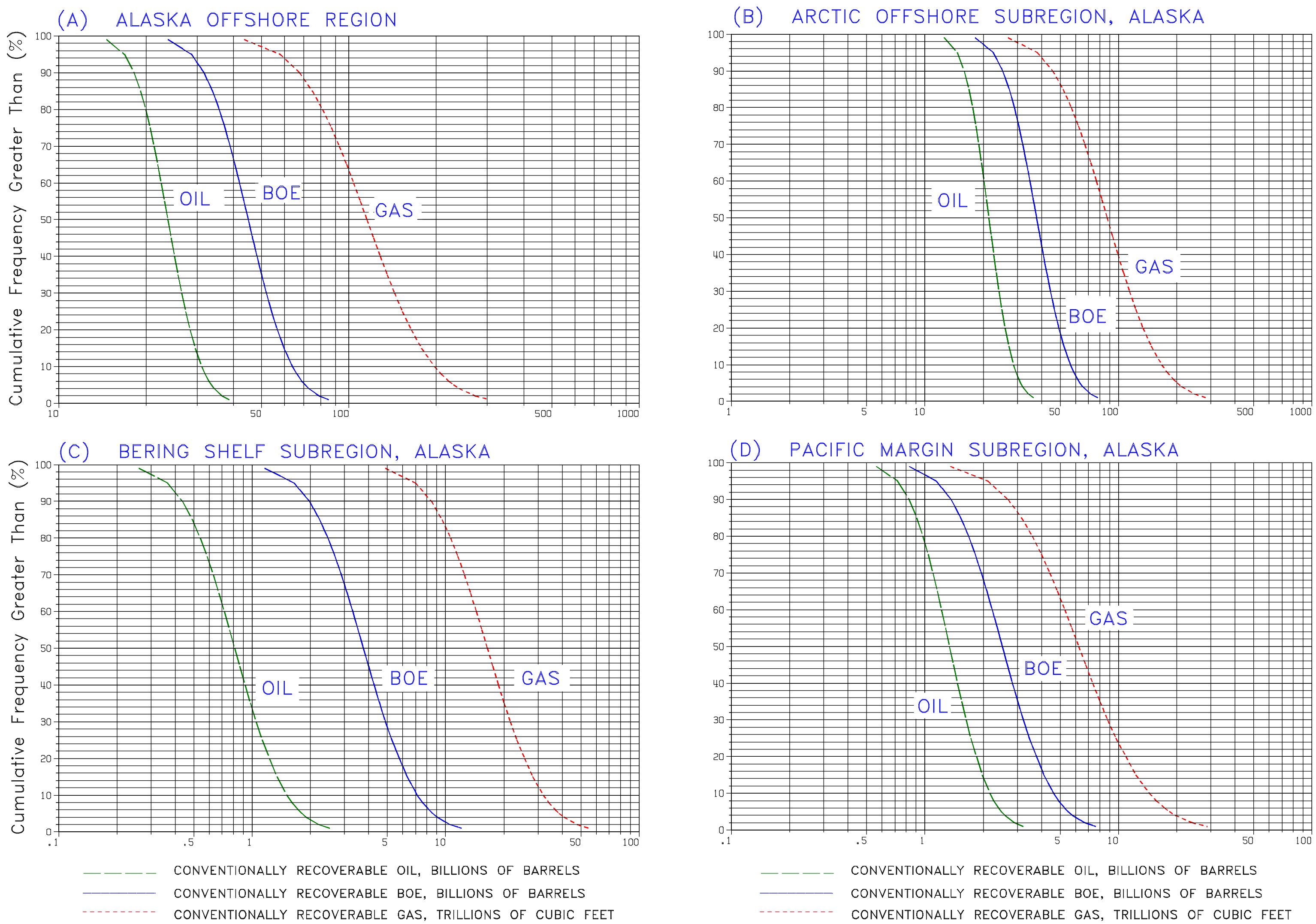


Figure 2: Cumulative probability distributions for risked, undiscovered conventionally recoverable oil, gas, and total hydrocarbon energy in BOE (barrels of oil-equivalent, 1 barrel of oil = 5,620 cubic feet of gas), for (A) Alaska (Federal) offshore region, (B) Arctic offshore subregion, (C) Bering shelf subregion, and (D) Pacific margin (Alaska) subregion.

proven onshore reserves simply reflects the rich endowment of Arctic Alaska and adjoining continental shelves with the key ingredients for oil and gas accumulations—prolific source rocks, excellent reservoir rocks, and numerous potential traps of large areal dimensions.

Among the provinces of the Arctic subregion, the sparsely explored Chukchi shelf offers the highest potential for undiscovered resources, with a 5-percent chance for recoverable oil resources as high as 21.94 BBO (table 1). Navarin basin, owing to its large size and an abundance of large potential traps, offers the greatest potential of the gas-prone provinces of the Bering shelf subregion. Among provinces of the Pacific margin subregion, Cook Inlet offers the greatest potential for remaining undiscovered oil reserves in Federal waters.

Very small quantities of liquid hydrocarbons are reported in the assessments of Norton basin, St. Matthew-Hall basin, and Shumagin-Kodiak shelf provinces. These three provinces were modeled as offering potential for gas only. The volumes reported as oil are therefore actually natural-gas liquids or condensate derived as a by-product of gas production.

ECONOMICALLY RECOVERABLE OIL AND GAS

The purpose of the economic phase of the 1995 assessment is to estimate the undiscovered resource volume in each province which, if discovered, could be produced profitably given realistic estimates for costs of exploration, development, production, and transportation. The quantities of economically recoverable resources, calculated with the PRESTO program, temper the much larger estimates for conventionally recoverable (geologic) resources calculated with GRASP. Only 8.5 percent of the conventionally recoverable resources on a barrels of oil-equivalent (BOE) basis, or 15 percent of total oil resources, are estimated to be economically recoverable under current conditions.

To provide a meaningful basis for reporting the economic results, commodity prices of $18 per barrel (oil) and $2.11 per thousand cubic feet (gas), or approximately current market prices, were selected. The economically recoverable resources in the Alaska Federal offshore are shown in table 2. This tabulation indicates that 91 percent of the risked mean undiscovered oil in the Alaska offshore that is economically recoverable under current conditions occurs in the Arctic subregion (Beaufort and Chukchi provinces). The remaining nine provinces account for the balance (9 percent) of undiscovered economically recoverable oil resources in the Alaska offshore. A similar disproportionate amount of undiscovered, conventionally recoverable gas is also expected to occur in the Arctic subregion (table 1). However, because of the lack of a gas transportation system from Arctic Alaska and the presence of huge, but marginally profitable, proven gas reserves onshore it is very unlikely that development of new offshore gas fields will occur in the foreseeable future. Therefore, no economic gas resources are reported for the Beaufort and Chukchi shelf provinces.

Other than the Beaufort and Chukchi shelf provinces, only the Cook Inlet province is likely to contain economically viable oil resources at current prices. Although the geologic resources are modest compared to the Arctic, the proximity to existing infrastructure and potential markets contributes to reduced development costs in the Cook Inlet province. As in the Beaufort and Chukchi provinces, the economic assessment for the Cook Inlet considered only oil production, largely because the reservoirs were modeled as oil pools with gas caps. To optimize oil recovery, produced gas will be reinjected for reservoir pressure maintenance. Some decades later, offshore oil production platforms could be converted to gas production to recover this resource.

The remainder of the Alaska offshore provinces are generally gas-prone and lack production and transportation infrastructure. Because potential markets are in the western Pacific Rim, the gas must be shipped to market as liquefied natural gas (LNG). The substantial costs of constructing an LNG infrastructure typically cannot be supported by the relatively small gas fields in these remote, high cost locations. Of the gas-prone provinces in the Bering shelf subregion, the North Aleutian basin province is estimated to contain the majority—79 percent of the entire Alaska offshore—of the economically recoverable gas. The small volumes of oil listed for the North Aleutian province, as in the other gas-prone provinces, are largely condensate liquids recovered as a by-product of gas production.

An indicator of the relative chances for economic success among the Alaska offshore provinces is the ratio of economically recoverable resources to conventionally recoverable resources (E/C column, table 2). The E/C ratios vary from 0.30 in the relatively low cost Cook Inlet to negligible (less than 0.01) in the relatively high cost Navarin basin. This suggests that the undiscovered hydrocarbon pools in Navarin basin are typically small, have high gas proportions, and will be very costly to develop. Although Navarin Basin has the highest total geologic endowment outside the Arctic

TABLE 2

RISKED, UNDISCOVERED, ECONOMICALLY RECOVERABLE OIL AND GAS

AREA	OIL (BBO)			GAS (TCFG)			BOE (BBO)			E/C
	F95	MEAN	F05	F95	MEAN	F05	F95	MEAN	F05	
ALASKA OFFSHORE	1.41	3.75	7.65	0.02	1.11	4.33	1.43	3.95	8.20	0.08
ARCTIC SUBREGION	1.15	3.41	7.25	0.00	0.12	0.00	1.15	3.44	7.31	0.09
BERING SHELF SUBREGION	0.00	0.02	0.22	0.00	0.99	10.82	0.00	0.19	2.11	0.04
PACIFIC MARGIN SUBREGION	0.00	0.32	0.79	0.00	negl	0.01	0.00	0.32	0.80	0.11
ARCTIC SUBREGION										
CHUKCHI SHELF	0.00	1.14	4.48	N/A	N/A	N/A	0.00	1.14	4.48	0.05
BEAUFORT SHELF	0.00	2.27	4.44	N/A	N/A	N/A	0.00	2.27	4.44	0.14
HOPE BASIN	0.00	negl	0.00	0.00	0.12	0.00	0.00	0.03	0.00	0.04
BERING SHELF SUBREGION										
NAVARIN BASIN	0.00	negl	0.00	0.00	0.04	0.00	0.00	negl	0.00	negl
N. ALEUTIAN BASIN	0.00	0.02	0.20	0.00	0.88	7.71	0.00	0.18	1.77	0.13
ST. GEORGE BASIN	0.00	negl	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.02
NORTON BASIN	0.00	negl	0.00	0.00	0.02	0.00	0.00	negl	0.00	negl
ST. MATTHEW-HALL	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E
PACIFIC MARGIN SUBREGION										
COOK INLET	0.00	0.27	0.71	N/A	N/A	N/A	0.00	0.27	0.71	0.30
GULF OF ALASKA	0.00	0.05	0.30	0.00	negl	negl	0.00	0.05	0.30	0.04
SHUMAGIN-KODIAK	0.00	negl	0.00	0.00	negl	0.00	0.00	negl	0.00	negl

ECONOMIC ASSUMPTIONS: *1995 base year, $18 per barrel oil price, $2.11 per thousand cubic feet (MCF) gas price, 0.66 gas value discount, flat real prices and costs, 3% inflation, 12% discount rate, 35% Federal tax rate; units of* ***BBO****, billions of barrels;* ***TCFG****, trillions of cubic feet;* ***BOE,*** *total oil and gas in billions of energy-equivalent barrels (5,620 cubic feet of gas=1 energy-equivalent barrel of oil). Oil resources include crude oil and natural gas liquids (NGL). Gas resources include nonassociated dry gas and associated solution gas. All provinces analyzed on a stand-alone basis. N/A refers to Not Available (lacking transportation infrastructure and/or market). N/E refers to Not Evaluated because of very low resource potential. Negl refers to negligible (less than significant figures listed).* ***E/C*** *is ratio of risked, mean economically recoverable BOE to risked, mean conventionally recoverable BOE (from table 1). Mean values for provinces may not sum to values shown for subregions and region because of rounding.*

(1.59 BBOE, table 1), it offers a much less favorable opportunity for commercial fields than most other provinces in the Alaska offshore. The comparative E/C ratios (table 2) suggest that the highest reward/risk opportunities are in the Cook Inlet, Beaufort shelf, and North Aleutian basin provinces.

All provinces were assessed on a stand-alone basis, with no sharing of development infrastructure with adjacent provinces. For some provinces (Arctic and Cook Inlet) existing infrastructure was utilized for the simulated development of undiscovered fields. Otherwise, new infrastructure was constructed and entirely supported by production from each province in the economic models. Sensitivity tests where several provinces shared infrastructure costs (for example, LNG facilities) generally resulted in improved economic viability. Despite shared infrastructure strategies, most of the gas-prone provinces nevertheless remain subeconomic at mean resource levels and current commodity prices. For these subeconomic provinces, viable resources could be recovered at lower probability levels or at commodity prices above current levels.

A form of sensitivity analysis is provided by price-supply graphs produced by the PRESTO computer program. These graphs contain curves which illustrate the increasing volumes of resources that could be profitably recovered (if discovered) at increasing commodity prices. Price-supply graphs for the provinces with economically recoverable oil under current conditions are given in figures 3, 4, and 5. The three curves shown on each price-supply graph illustrate the range of risked economic potential, with exceedance probabilities ranging from 95 percent (low-side potential) to 5 percent (high-side potential). These estimates include both the geologic probability that resources are present and recoverable as well as the economic probability that the simulated development model leads to profitable production at the prices shown.

Viewing the Beaufort shelf results (fig. 3), at an assumed oil price of $18 per barrel there is a 95-percent probability that at least 0.70 billion barrels of oil (BBO) is pooled and economically recoverable. The high-side (5 percent) potential is at least 4.60 BBO, or six times larger than the low-side potential. The mean curve represents the expected risked volume (2.27 BBO) within this broad range of available resources. The ratio of economic to conventionally recoverable resources (E/C=0.14) is second only to Cook Inlet (E/C=0.30), suggesting that the Beaufort shelf province represents a good opportunity for future commercial development.

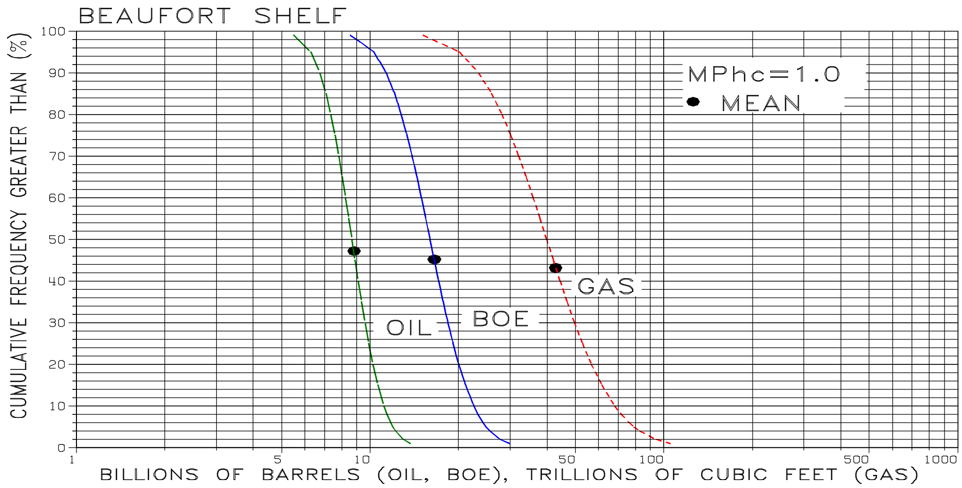
The Chukchi shelf price-supply curves (fig. 4) are steeper than the Beaufort shelf curves, meaning that higher prices are required to overcome higher development costs and still yield a profit. For the low resource case (F95), the existence of economic resources will require oil prices above $25 per barrel. A broad envelope surrounds mean recoverable volumes, with nearly a 4-fold increase from the mean (1.14 BBO) to the high-side (4.48 BBO) volume at an $18 oil price. Although the high-side resource potential of Chukchi shelf is nearly the same as Beaufort shelf (table 2), the fraction of economic to conventionally recoverable resources for the Chukchi shelf (E/C=0.05) is only one-third that of the Beaufort shelf (E/C=0.14), suggesting that commercial discoveries are much less likely. This comparatively low chance for economic success could dampen exploration interest, despite the large, conventionally recoverable resource potential.

The Cook Inlet price-supply curves (fig. 5) indicate a more modest economic potential in expected oil volume, with risked mean oil resources at an $18 per barrel price of 0.27 BBO. The high-side potential at prices approaching $50 per barrel ranges upwards of 1.0 BBO. The ratio of economic to conventionally recoverable resources (E/C=0.30) suggests that a significant fraction of the oil resources are present in commercial-sized fields.

Eventual development and production of these modeled economic resources will require extensive exploration drilling programs. Given the low chance of commercial success and the high cost of exploration wells, many of these provinces are not likely to be thoroughly tested for some decades. The few wells that may be drilled may fail to locate the commercial-sized pools in these immense provinces. Estimates of economically recoverable resources should be viewed, therefore, as province-wide opportunities, rather than as readily available reserves.

This summary of the economic assessment for the Alaska offshore has focused on provinces likely to have recoverable oil at current commodity prices. However, many Alaska Federal offshore provinces contain no economically recoverable resources ***at the mean level and current commodity prices***. Future offshore leasing and exploration in these subeconomic provinces will be driven by perceptions of high-side potential, which assumes greater reward potential at higher risk, significantly higher prices, and perhaps innovative technology to reduce development costs.

A.



B.

BEAUFORT SHELF PROVINCE		
RESOURCE TYPE	**MEAN OIL (BBO)**	**MEAN GAS (TCFG)**
CONVENTIONALLY RECOVERABLE	**8.84**	**43.50**
ECONOMICALLY RECOVERABLE ($18)	**2.27**	**N/A**
RATIO ECONOMIC/CONVENTIONAL	**0.14**	**N/A**

C.

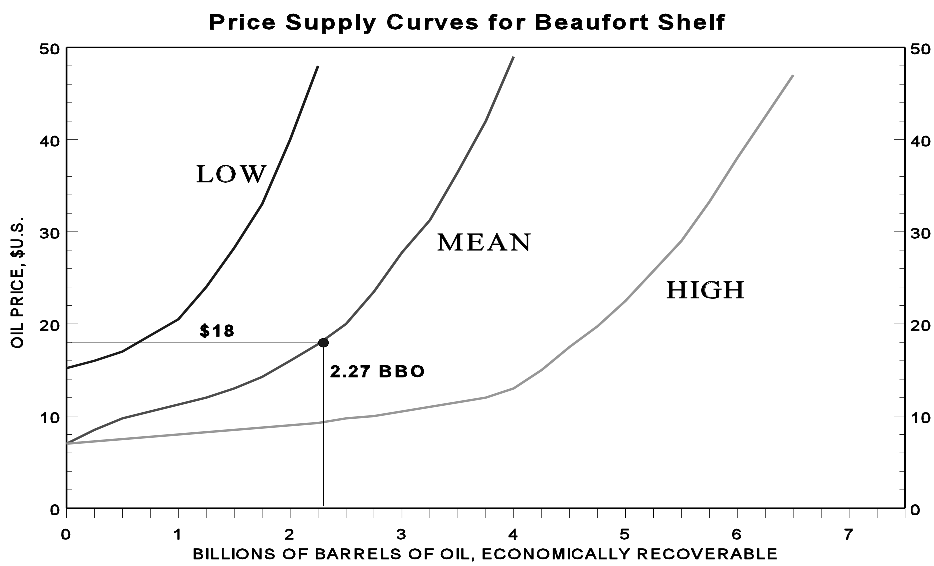
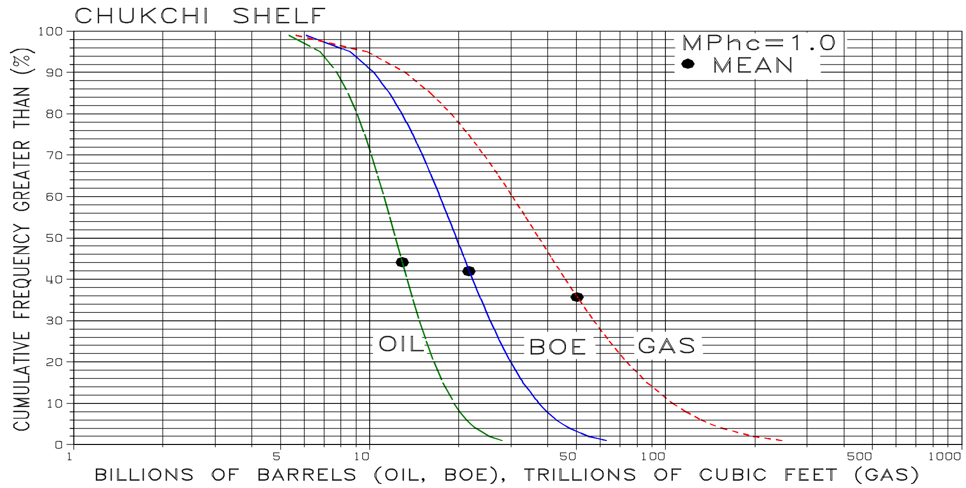


Figure 3: Beaufort shelf assessment province. (A) Cumulative frequency distributions for risked, undiscovered conventionally recoverable resources; (B) Table comparing results for conventionally and economically recoverable oil and gas; (C) Price-supply curves for **oil** at low (F95), mean, and high (F05) resource cases. BOE, total oil and gas in billions of energy-equivalent barrels; MPhc, marginal probability for hydrocarbons for basin; BBO, billions of barrels; TCFG, trillions of cubic feet.

A.



B.

CHUKCHI SHELF PROVINCE		
RESOURCE TYPE	**MEAN OIL (BBO)**	**MEAN GAS (TCFG)**
CONVENTIONALLY RECOVERABLE	**13.02**	**51.84**
ECONOMICALLY RECOVERABLE ($18)	**1.14**	**N/A**
RATIO ECONOMIC/CONVENTIONAL	**0.05**	**N/A**

C.

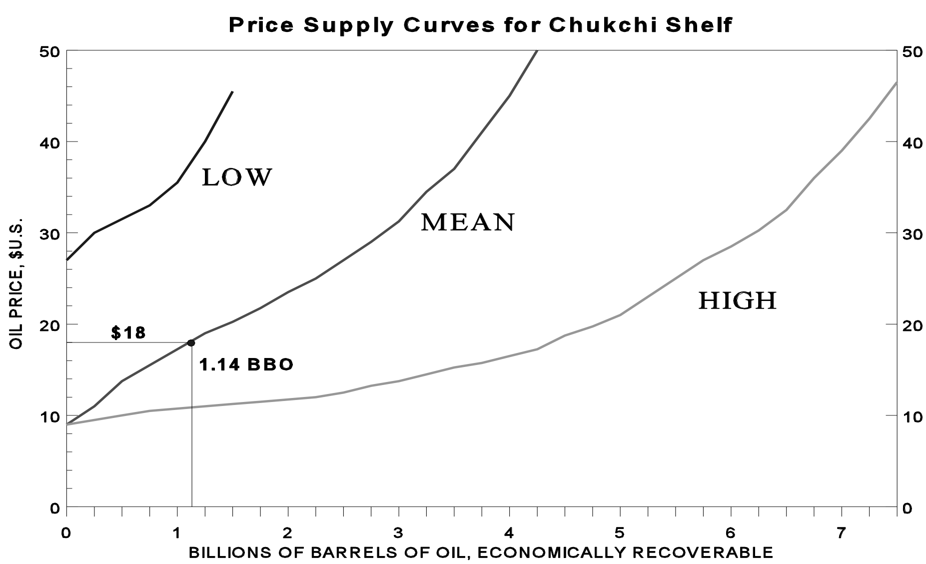
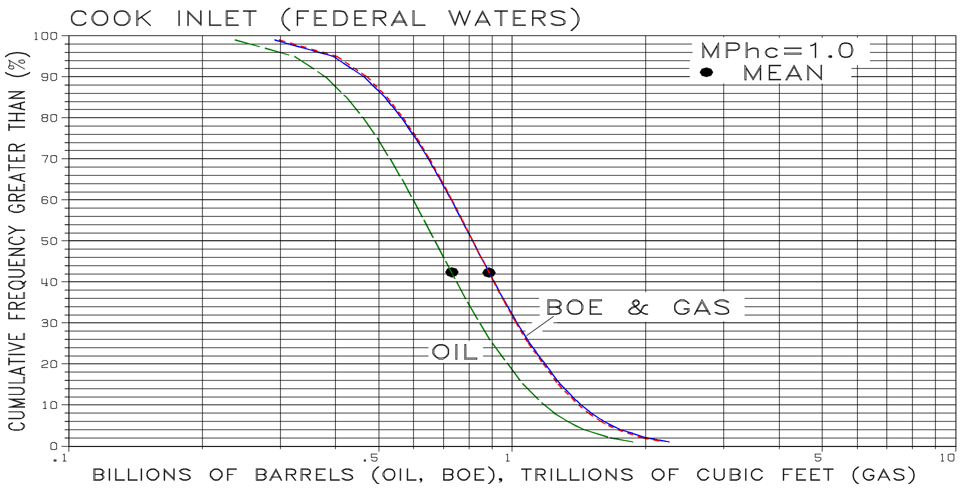


Figure 4: Chukchi shelf assessment province. (A) Cumulative frequency distributions for risked, undiscovered conventionally recoverable resources; (B) Table comparing results for conventionally and economically recoverable oil and gas; (C) Price-supply curves for **oil** at low (F95), mean, and high (F05) resource cases. BOE, total oil and gas in billions of energy-equivalent barrels; MPhc, marginal probability of hydrocarbons for basin; BBO, billions of barrels; TCFG, trillions of cubic feet.

A.



B.

COOK INLET PROVINCE		
RESOURCE TYPE	**MEAN OIL (BBO)**	**MEAN GAS (TCFG)**
CONVENTIONALLY RECOVERABLE	**0.74**	**0.89**
ECONOMICALLY RECOVERABLE ($18)	**0.27**	**N/A**
RATIO ECONOMIC/CONVENTIONAL	**0.30**	**N/A**

C.

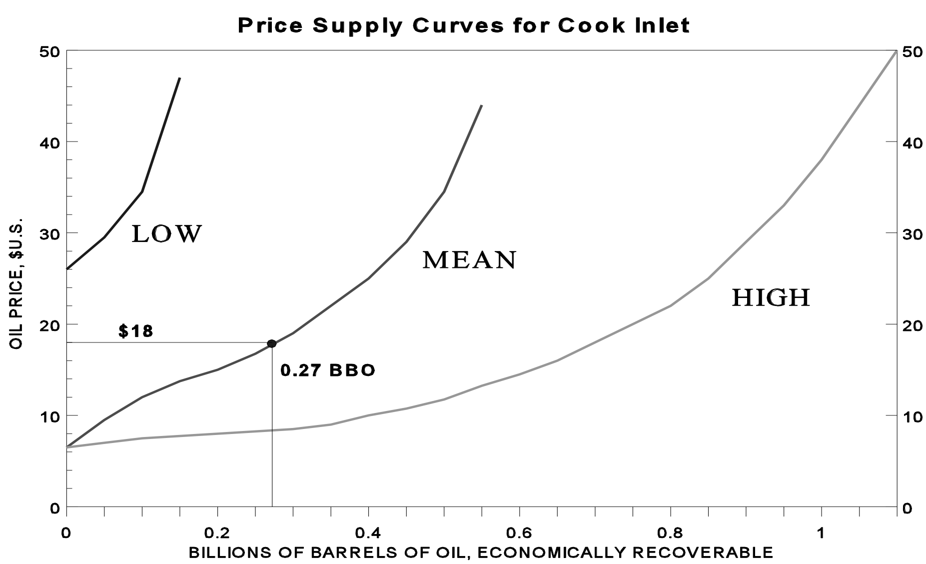


Figure 5: Cook Inlet assessment province. (A) Cumulative frequency distributions for risked, undiscovered conventionally recoverable resources; (B) Table comparing results for conventionally and economically recoverable oil and gas; (C) Price-supply curves for **oil** at low (F95), mean, and high (F05) resource cases. BOE, total oil and gas in billions of energy-equivalent barrels; MPhc, marginal probability for hydrocarbons for basin; BBO, billions of barrels; TCFG, trillions of cubic feet.

TABLE 3

COMPARISON TO PREVIOUS MMS ASSESSMENT, TOTAL ALASKA FEDERAL OFFSHORE, RISKED MEAN RESOURCES

ASSESSMENT	YEAR	OIL (BBO)	GAS (TCFG)
CONVENTIONALLY RECOVERABLE	**1995**	**24.31**	**125.93**
CONVENTIONALLY RECOVERABLE	**1987**	**3.84**	**16.75**
ECONOMICALLY RECOVERABLE	**1995**	**3.75**	**1.11**
ECONOMICALLY RECOVERABLE	**1987**	**0.92**	**0.00**

1987 data from Cooke and Dellagiarino, 1989, MMS 89-0090, p.43 (conv. rec.) and p.34 (econ. rec.). BBO, billions of barrels of oil; TCFG, trillions of cubic feet of gas.

COMPARISON OF 1995 RESULTS TO 1987 MMS ASSESSMENT

The MMS assessment of the Alaska offshore oil and gas resources conducted in 1995 cannot be properly compared with the 1987 MMS assessment, owing to numerous changes in methodology, definitions, and assumptions. However, because it is only natural for readers to want to gain additional perspective through a comparative analysis, this section will identify some of the key differences in the databases driving most of the changes between the assessments. The 1995 and 1987 estimates that are most appropriate for comparison are shown in table 3.

The ***conventionally recoverable*** oil and gas resource estimates for the Alaska Federal offshore have increased dramatically, from 3.84 BBO and 16.75 TCFG in 1987 to 24.31 BBO and 125.93 TCFG in 1995. The Chukchi shelf and Beaufort shelf provinces show the largest increase. The overall increase can be attributed primarily to an increase in the number of assessed prospects and a greater chance of success owing to a major shift in the risking philosophy.

The increase in the numbers of prospects in all provinces is related to three factors: (1) more seismic mapping; (2) the addition of subeconomic prospects; and (3) supplementing the inventory of mapped prospects with an estimate of speculative prospects which have not yet been identified.

In 1995, the assessment focused on the entire hydrocarbon endowment, where a “success” was defined as any pool of hydrocarbons recoverable into a wellbore. This definition generally resulted in much higher overall chances of success at the prospect, play, and province levels, when compared with a more conservative risking approach applied in the 1987 assessment. Another effect of the change in risking philosophy was to broaden the assessed distributions for uncertain geologic variables.

The risked mean ***economically recoverable*** resources estimated in 1995 increased to 3.75 BBO and 1.11 TCFG, compared with 0.92 BBO and no economic gas from the 1987 assessment. The most significant increases occur in the Chukchi shelf and Beaufort shelf provinces.

Direct comparisons of 1995 and 1987 economic results are not technically valid, because the economic assumptions used are so different. Given this caution, table 3 nevertheless compares the economically recoverable resources obtained using those assumptions which were considered the most representative of financial conditions at the time of the two assessments.

The key factors affecting the overall increase in economically recoverable resources are the increase in prospect numbers and the higher chances of success. Other significant changes incorporated into the 1995 economic assessment include: flat real prices (rather than ramped); revised costs; full-cycle analysis (includes exploration costs); revised discount and inflation rates; and revised gas discount factors.

Although risked means are shown for comparison in table 3, the assessment results for 1995 are better summarized by price-supply curves (figs. 3, 4, and 5). In the 1987 assessment, a primary (base) case and an alternative (higher) case resulted from two sets of economic assumptions. In the 1995 assessment, instead of just two cases, the price-supply curves portray a continuous change in recoverable resource volumes corresponding to changes in price, allowing readers to predict their own commodity prices and find the potential economic resources of an offshore province. The price-supply curves provide a much more complete summary of the ranges of economic potential.

CONCLUSIONS

The Alaska Federal offshore is estimated to contain mean undiscovered, conventionally recoverable resources of 24 billion barrels of oil and 126 trillion cubic feet of gas. Approximately 90 percent of these resources occur in areas offshore of Arctic Alaska, specifically the Chukchi shelf (13 billion barrels of oil, 52 trillion cubic feet of gas) and the Beaufort shelf (9 billion barrels of oil, 44 trillion cubic feet of gas).

Most of the undiscovered oil and gas occurs in pools that are too small to justify economic development. Only about 15 percent of the conventionally recoverable oil resources could be profitably extracted at current oil prices. Three assessment provinces offer significant quantities of undiscovered, economically recoverable oil: the Beaufort shelf (2.27 billion barrels), Chukchi shelf (1.14 billion barrels), and Cook Inlet (0.27 billion barrels). These provinces might also offer economically recoverable gas under certain future conditions. However, the lack of transportation infrastructures designed for the export of liquefied natural gas may deter significant gas production from these areas, and, from the greater Alaska offshore, for many years.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places;
and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.