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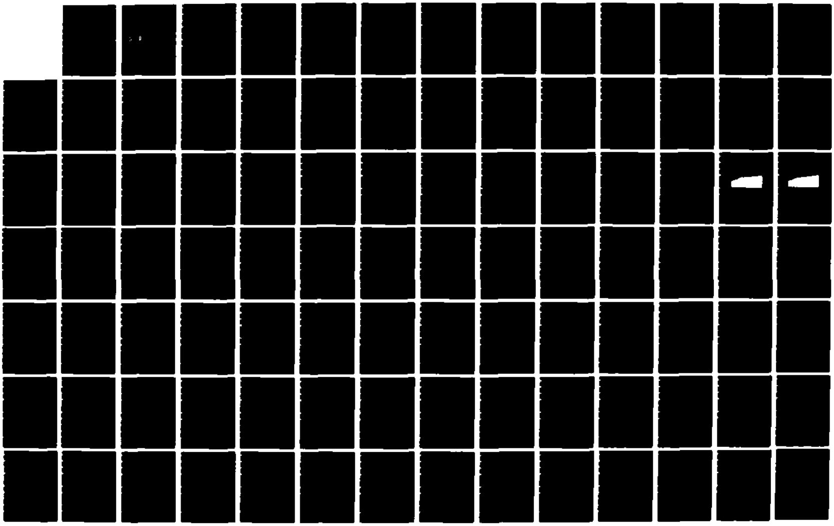

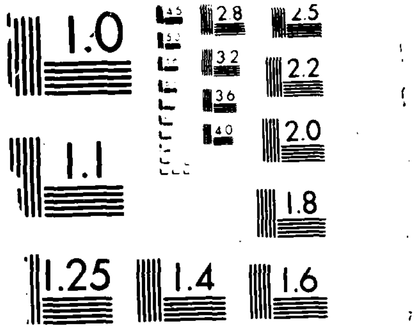

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THE STRATEGIC IMPLICATIONS FOR U.S. - PERSIAN GULF RELATIONS ON DOMESTIC AND WORLDWIDE OIL PRODUCTION FOR FUTURE U.S. OIL DEMAND

by

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March 1987

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THE U.S. DEPENDENCE ON OIL IMPORTS IS EXAMINED IN LIGHT OF CURRENT U.S. OIL PRODUCTION, ITS POTENTIAL FOR FUTURE DISCOVERIES, AND THE AVAILABILITY OF OIL PRODUCTS FORM VENEZUELA, MEXICO, AND OTHER SOUTH AMERICAN COUNTRIES. THERE IS NO GEOLOGIC REASON WHY THE U.S. CANNOT CONTINUE TO REPLACE ITS RESERVES CONSUMED ANNUALLY, CONTINUE CONSERVATION EFFORTS REDUCING ITS IMPORT DEPENDENCE, AND SHIFT ITS FOREIGN OIL SUPPLY CLOSER TO HOME, I.E. MEXICO AND SOUTH AMERICA. INCREASING THE PRICE OF OIL DOMESTICALLY ENSURES CONTINUED EXPLORATION AND SHIFTING THE SOURCE OF IMPORTS REDUCES THE LENGTH OF SLOC'S CARRYING CRITICAL OIL PRODUCTS.

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EXECUTIVE SUMMARY

The U.S. dependence on Persian Gulf oil reserves is not mandated by geologic reality. Instead, current political and economic conditions dictate the amount of U.S. import demand required to offset the shortfall between U.S. domestic oil production and consumption. Since the present oil prices of approximately $15 to $18 per barrel are low relative to the $26 to $30 per barrel price range of 1 year ago, an increasing trend of import dependence has emerged at the end of 1986 due to lowered U.S. production. U.S. oil production is highly price dependent since the U.S. reserves are expensive to produce relative to "cheaper" reserves like those found in the Persian Gulf and in Mexico. In the last 3 months of 1986 alone, U.S. imports from Saudi Arabia increased fourfold. This paper examines the geologic necessity for allowing this dependency to continue.

In the introduction, several assumptions and definitions are presented. Next, the origin and trapping of petroleum is discussed briefly to outline the basis for the distribution of oil worldwide. It is estimated that there are 9.963 trillion barrels of oil resource in place of which only 500 billion barrels (5 percent) have so far been produced. Historical development and current reserve levels in the U.S. and the Persian Gulf are provided in Appendices I and II to support the reserve figures provided at the end of Chapter I.

Chapter II considers the background of U.S. domestic petroleum demand and how U.S. consumption and production have dictated U.S. import dependence in the past. This chapter also considers future projections for U.S. consumption, production, and imports. The role of conservation in reducing U.S. demand is discussed. Under low import projections, the U.S. will not require imports to reach a level of 50 percent of consumption. U.S. production of oil will remain stable at approximately 8 million barrels of oil per day (MMBO) to the end of the century. The floor price required to achieve this goal of relative security is about $26 per barrel as estimated by various geologists and engineers. Under a high import scenario, U.S. imports of oil will go over 50% as early as the early 1990's due to lowered U.S. domestic production and the concomitant absence of exploration to replace the domestic reserves consumed. This is happening now when oil is priced below $18 per barrel. Conventionally recoverable oil reserves remaining to be discovered in the U.S. may be as much as 120 billion barrels of oil. Under the right economic stimulus, there is no reason why the U.S. cannot begin once again to replace its annual consumption of domestic reserves as it did in the early 1980's.

Chapter III examines the strategic implications of U.S. dependence on foreign sources of supply. Alternative sources of oil to the Persian Gulf are examined and, on the basis of the current availability and the potential for future discoveries, it is concluded that the oil reserves of Mexico, Venezuela, and other South American nations could meet the shortfall in U.S. production for the U.S., Japan, and Canada if these nations are encouraged to explore for and develop their oil resources. In light of the current low market price of oil, increasing the price of oil in the U.S. might provide the necessary economic stimulus.

Chapter IV explores the future U.S. oil reserve situation in both a limited war and a global war scenario. Emphasis is placed on using the historical analogues of the Korean and Vietnam Wars to extrapolate projected U.S. military demand in future conflicts. U.S. military demand was approximately 8 percent of total U.S. consumption during the Korean War and about 7 percent of the total during Vietnam. The impact of increasing U.S. military demand to 10 percent of total U.S. consumption in a future limited war in 1995 and 2000 is discussed. The impact of the Strategic Petroleum Reserve (SPR) is also examined: if military demand rises to 10 percent of total U.S. demand, the SPR would provide a 435 day supply of oil for the military only if full (750 MMBO) and a 296 day supply at its current level of 510 MMBO. If military demand rises to 20 percent, the SPR could provide a 217 day supply when full and a 148 day supply at the current fill level if it is used only for military purposes.

The final Chapter (V) makes recommendations for the Department of Defense concerning the future energy security of the U.S. These recommendations include establishing a floor price for oil in the U.S. of $26 per barrel and encouraging the conservation of oil in the U.S. Additional recommendations are made concerning the need to consider the security of sea-lines-of-communication to the chief sources of oil import supply in all operational plans and the need to establish a strategic consensus with South American producing nations to maximize the exploitation of their oil resources.

PREFACE

This paper could not have been completed without the gracious assistance of many other individuals. While the errors remaining in this report and the conclusions and recommendations I have reached are strictly my own, I would like to acknowledge and thank those people who have helped me see it through to completion. First of all, my advisors, Dr. Alvin H. Bernstein and CAPT. Timothy E. Somes, USN, gave me considerable guidance and encouragement in researching and writing this work. Ms. Lenore Alexander, of the American Petroleum Institute, and LCDR Art Jones, USN, of USCENTCOM, assisted me in gathering important information. MAJ John Prout, USA, and LCDR Charles Hopkins, USN, willingly gave me their help in using the computers. MAJ Robert Leavitt, USMC, gave me considerable amounts of his own time at the end of this project to help get it prepared for printing and he did so in the generous fashion typical of a Marine. I would also like to thank the members of the Advanced Research Program staff including Mr. Frank Uhlig, CDR Bill Gwinn, USN, and Mrs. Nancy Williams for their help. Most importantly, I want to express my appreciation to my family, Micah, Elicia, Shira, and Mrs. Thompson for their encouragement, inspiration and patience in seeing me through this effort. Without them, I could not have completed this task. Thank you all.

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CHAPTER I

INTRODUCTION

A. Background and Organization.

This paper will address the issues of oil and natural gas liquid reserves and resources in the United States, the Persian Gulf, and parenthetically in several other Western Hemisphere nations only. It will not discuss alternative energy sources and their interplay with the economics of oil. It will not address geostrategic or political reasons for committing the U.S. to a specific foreign policy regarding the Persian Gulf in order to ensure secure sources of liquid hydrocarbons for the Western Alliance. This paper will seek to answer, however, the very important question of whether or not Persian Gulf oil is crucial to the economic requirements of the U.S. for the next 2 decades.

In order to accomplish this goal, the paper is organized as follows. Chapter I will include the introduction, several definitions and assumptions, and a discussion of the geologic basis for the formations of oil resources and how this affects their distribution in time and space. An additional section will discuss the present oil reserves of the U.S. and Persian

Gulf. More extensive discussion of the oil reserves and resources of these two areas is provided in Appendices I and II respectively. Chapter II will examine the historic consumption pattern of the U.S. and how this oil demand may be met by indigenous and imported oil reserves in the future under current economic conditions operating in a non-war scenario. Chapter III will explore the oil demand of Canada and Japan as well as potential sources of oil supply in the Western Hemisphere. Chapter IV will discuss two alternative scenarios for the future supply and demand of oil for the U.S., Canada, and Japan under limited and global war conditions. Finally, Chapter V will include recommendations resulting from this analysis.

Many questions remain unanswered by this paper which is far from being even an exhaustive summary of the energy issues facing the U.S. today. However, to focus on a single question required "writing off" large areas of interest which might have been discussed. In order to accommodate this purpose, several assumptions about the future have been established which will now be presented.

B. Assumptions.

For the purposes of this paper, the following four assumptions will be made:

(1) Other than primary, secondary and existing methods of

enhanced oil recovery, no new technological breakthroughs will occur over the next two decades which will allow for more than the 30% to 70% oil recovery available today. The recovery rates will be discussed in a later section on the geology of oil production.

(2) The geological parameters/theories concerning oil resources and their origin and exploitation will be considered consistent over the study period. An alternative theory for the origin of hydrocarbons will be discussed later, but will be assumed to be unproven for the next two decades.

(3) The availability (supply), cost and research of alternative energy sources (coal, oil shale, nuclear fission and fusion, biomass, solar and geothermal) will continue to develop in response to the price of oil as they have in the past.

(4) The economic factors affecting oil will not change over the study period, in other words, oil supply and price will continue to respond to demand as it has historically.

C. Some Definitions.

At various places in this paper, reference will be made to hydrocarbons, crude oil, oil, or natural gas liquids. "Hydrocarbons" is the most general term, including all oil, natural gas liquids, tars and asphalts, heavy oils, condensate and natural gas fluids formed from biogenic sources and found in natural rock reservoirs. These materials all contain a preponderance of organic carbon and hydrogen molecules ranging from methane (CH_4), to heavier, more complex molecules, like octane (C_8H_{18}). These hydrocarbon molecules can become larger and heavier and are the basis for the science of organic chemistry. Coal is not one of the hydrocarbons, but it is closely related to them in that it too is derived from organic materials rich in carbon and hydrogen. Coal, however, contains other elements as well, notably oxygen, due to its derivation from land plants. Coal and hydrocarbons may be thought of as end members of a continuous spectrum, coal being formed from continental plants and hydrocarbons being formed from marine plants and animals. In this paper, careful use will be made of the terms hydrocarbons, crude oil, oil, and natural gas liquids. When figures are provided, they will be identified as crude oil, natural gas liquids, or recoverable reserves (of crude oil, etc.). The term "oil" will include, unless otherwise noted, both crude oil and natural gas liquids. Hydrocarbons will be used only in a general sense.

Methods for reserve calculations are not uniformly established.

> Oil and gas are retained in sand, porous rocks, etc., much like water in a sponge. Measuring methods are sophisticated, but still inexact. The only sure method is the measure all the oil and gas produced until a field runs dry. Source: Frustrated geologists and oil men.1

The trouble with "the only sure method" is that all the oil and gas from a given reservoir will probably never be produced. Calculations as to reserves in the ground, or oil in place, or total resources, are all difficult and depend, to a large extent, on the parameters selected by the person doing the estimates. As the American Association of Petroleum Geologists (AAPG) Explorer puts it, "Figures don't lie, but determining the figures can become a jumbled, confusing process, and the nagging questions usually remains. Who really knows how much is down there, and how do they know?"[2]

The first thing to define are the various kinds of reserves. The United States Geological Survey (USGS) has clarified relationships between reserves and resources based on earlier standards established by the U.S. Bureau of Mines. The terms are defined, by illustration, in Figure 1. Tables and illustrations in this report carefully describe the kind of reserve being considered. This is important, especially in Chapter IV where projections for future production and demand are provided. In general, proved reserves, those defined by producing and non-producing wells used to delineate a field, are the reserve figures used in this report. These are the most accurate reserve figures available.

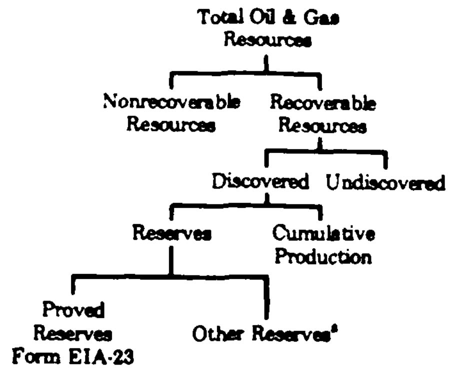
Reserves can be figured by essentially three techniques:

(1) extrapolation
(2) theoretical calculations
(3) comparisons (analogues)

Geologists and Petroleum Engineers generally use a combination of these techniques to calculate reserves. Extrapolation involves plotting production for a short period of time and extending the trends established into the future. Theoretical calculations require a knowledge of certain reservoir characteristics obtained from rock cores or electrical logs and combine it with estimates about the size and extent of a geologic structure based on map interpretation. Comparisons may be made by observing a field's performance and measuring it against the performances of other known, similar fields. The amount of data available significantly affects the quality of the calculation. Occasionally, reserve estimates must be based on the results of a single drill stem test (DST) on a drilling exploratory well. The reserve estimates used in this study are based on various reliable sources including the Energy Information Agency (EIA) of the U.S. Department of Energy, the American Petroleum Institute, or the Oil and Gas Journal. Reserve estimates attributed to other organizations or individuals are so noted in the text.

FIGURE 1

RELATIONSHIPS OF PETROLEUM RESOURCE AND RESERVE TERMS



[a] Includes "Indicated Additional Reserves of Crude Oil"

Source: U.S. Department of Energy, Energy Information Agency, U.S. Crude Oil, Natural Gas, and National Gas Reserves (Washington: U.S. Govt. Print. Off., 1986), p. 1.

D. Geologic Factors Affecting the Origin and Distribution of Hydrocarbon Resources.

The purposes of this section is are, first, to delineate how the distribution of oil is limited by geological factors, and then to estimate how much oil remains to be found worldwide. Before we examine in detail the reserve and resource status of individual states or areas it is necessary to understand how geologic parameters control the expected amount of oil remaining to be discovered.

Most geologists believe that oil is derived from organic materials deposited millions of years ago. These deposits of biogenic material accumulated with mud and clay and through the process of diagenesis, the soft, organic-rich sediments were converted into a rock, usually shale due to the relatively quiescent environment required to allow the growth of the microscopic animals and plants. This rock, called a source rock, was thermally altered under the weight and burial of additional sediments. As the temperature within the source rock increased, the organic materials in the rock began to degrade and change into kerogen, which, with additional thermal input, was altered into hydrocarbons. In essence, the process of conversion, called maturation by geologists, requires the source rock to act like a still, producing oil from kerogen. "Maturation" is not completely understood today and is the subject of lively debate. The process of organic sediments giving rise to hydrocarbon deposits is called the "biogenic theory" of oil formation.

The lead article of the January, 1987 Explorer discusses the Siljan Ring deep drilling project in central Sweden, ". . . which could possibly change the future of geology."[3] This well is being drilled to test an alternative theory, the "abiogenic theory," which stipulates that natural gas is formed from abiogenic sources probably located in the upper mantle of the earth. This idea, first discussed over 100 years ago, has most recently been championed by Thomas Gold, an astrophysicist at Cornell University. While most geologists disagree with Gold, the future course of hydrocarbon exploration could be altered forever if the Siljan Ring well is successful. For the purposes of this paper, however, the conventional theory for the origin of oil will be used.

Once oil is generated in a source rock, the pressure of overlying rock combined with the folding of rock at depth due to tectonic forces will force the oil to higher levels. It will begin to migrate, and travelling through a "carrier bed" will seek the highest level possible. A reservoir is a rock capable of storing and transmitting hydrocarbons due to the porous nature of the rock. Common reservoir rocks include sandstone and limestone which are generally much more porous and more permeable than shales. Other reservoir rocks exist as well, but sandstones and limestones are the predominant reservoir rocks producing today. A reservoir is called a trap when it is folded or blocked in such a way that migrating oil can go no further. Traps require an overlying non-porous and non-permeable rock, called a seal, to ensure that the oil cannot migrate further. Traps may be quite complex but are generally of two types: structural traps, requiring folding or faulting or both, and stratigraphic traps, in which a lithologic (rock) change in an updipping reservoir prevents the further migration of oil. Occasionally, structural and stratigraphic traps are combined. The final ingredient required for the formation of an oil reservoir is timing. The maturation, migration, trapping and sealing must take place in a definite sequence and within a certain period of time or the hydrocarbons produced by a source rock will be lost through degradation, escape, or entrapment in a rock like shale from which the extraction of oil becomes difficult. In summary, the discovery of additional oil reserves and resources is limited to those areas which contain sedimentary rocks, namely, sedimentary basins.

There exists, however, a large potential for additional discoveries of hydrocarbon resources based on the geologic evaluation of total source rock and potential traps. There is considerable discussion today among geologists concerning the importance of structural versus stratigraphic traps. Most traps found to date, including several super-giant traps*, are of the structural variety. However, a significant percentage of current oil reserves today are located in stratigraphic traps. Stratigraphic traps are called the "subtle trap" because they are not easily detected by current techniques. Most stratigraphic traps producing today were discovered accidentally and how many more remain to be discovered is an important component in estimating how much oil remains to be found. The words of Michael T. Halbouty, a respected geoscientist and very successful wildcatter known

---

*Super-giant fields have or will produce in excess of 5 billion barrels of oil each. Giant fields have or will produce in excess of 500 million barrels of oil each. Most of the world's oil reserves are contained in these two kinds of fields.

for his belief in the existence of the "subtle trap" can best conclude this discussion.

> I just wanted to say briefly that as far as the giants are concerned, I agree that there are many, many more to be found throughout the world. As far as I am concerned, I think that we might be able to find as many giants in the future as we have found in the past.
>
> In the past 120 years -- which is the historical life of the petroleum industry -- the geological and geophysical techniques have been concentrated on structures. Most all of the fields producing in the world today are on or from some type of structure. There are many so-called subtle traps; there are thousands and thousands of more subtle traps than there are structures.
>
> With that point, I will reemphasize that there are many more giants to be found. I think a lot of them are going to be found in subtle traps.4

Exactly how much oil worldwide remains to be discovered is open to speculation. A good summary of the problem is presented in an article by R.E. Roadifer in the Oil and Gas journal. He estimates that of the 2 trillion barrels of ultimately recoverable oil using currently available technology, 1,300 trillion barrels (65%) have already been found and that 700 trillion barrels (35%) remain to be discovered. More importantly, he discusses figures for oil in place. This is the total oil that was or is still in the ground and remains discovered or undiscovered.[5] It is important to realize that current conventional means of oil production produce between 30% and 70% of the oil in place in a given reservoir (the average is 35%, see Table I below).

Current conventional means of oil production include primary (solution gas drive, gas cap expansion, and water drive) and secondary (water injection or gas injection). Also included are the so-called enhanced oil recovery methods which are at present prohibitively expensive but do exist. Roadifer estimates that there are 9.963 trillion barrels of oil resource in place of which only 500 billion barrels (5%) have so far been produced worldwide.[6] The almost 10 trillion barrel figure for total oil resources includes hydrocarbons already identified in tar and heavy oil fields like Canada's Athabasca Tar Sands or Venezuela's Orinoco heavy oil belt. Clearly, further improvement in hydrocarbon extraction techniques will provide the opportunity for better exploitation of our oil requirements and may allow for the production and utilization of oil through the next century. Senator Edward Kennedy, introducing a meeting of the Americans for Energy Independence in 1979, stated that "Whatever crisis we face in the world's supply of oil, its origins lie in political and economic institutions."[7] The geologic supply of hydrocarbon resources lends credence to this statement. The challenge, therefore, is not only how to find oil, but how to produce it. The remainder of this paper will, however, deal only in terms of conventionally extractable reserves and resources using currently available and economic technology.

TABLE I

RELATIVE EFFICIENCY OF PRIMARY AND SECONDARY RECOVERY METHODS

Dominant Recovery Method	Typical Recovery Range (Percent of Original Oil in Place)
<u>Primary</u>	
Solution Gas Drive	5-20
Gas Cap Expansion Drive	20-45
Water Drive	25-55
<u>Secondary</u>	
Waterflood	30-60
Gas Injection	20-45

While these ranges are considered typical for each method, there are cases where recovery has been, or is expected to be, higher or lower. The average recovery for all known reservoirs in the world by these methods is around 35 percent.

Source: Exxon Corporation, Improved Oil Recovery (New York: 1982). p.3.

E. U.S. Reserves of Oil

The historical development of the current oil reserves of the U.S. is discussed in more detail in Appendix I. This appendix is interesting in that it discusses the connection between reserves, reserve life, and reserve replacement and their relationship with the price of oil. Furthermore, this section provides estimates as to remaining resources of oil possibly available for extraction in the U.S. A summary of the data presented in Appendix I is provided below.

Based upon current economic, geologic, and other technical constraints, the current proved reserves of U.S. crude oil are estimated to be 28.4 billion barrels of oil (BBO). Table II provides figures for various types of U.S. reserves with and without the addition of Alaskan reserves. Cumulatively, the U.S. has produced 127 BBO, more than any other country in the world. A key point to be made about these figures is that despite gloomy predictions concerning the steady decline of U.S. production and the U.S. ability to replace its reserves, this has not been the case since 1977. Under the stimulus of steadily rising prices (see Appendix I) and in anticipation of continued price increases, U.S. oil producers were encouraged to replace a larger and larger percentage of annual production. Interestingly enough, additional resources of oil remain to be discovered in the U.S. The President of the American Association of Petroleum Geologists, William L. Fisher, recently said that additional oil reserve potential in the Lower 48 states may be 100 billion barrels of "unrecovered but conventionally moveable" oil.[8] There may also be 200 billion barrels of heavy oil and other kinds of oil incapable of recovery by primary means.[9] More information concerning remaining U.S. oil resources is provided in Appendix I, but for the purposes of this paper, in addition to the current proved reserves of 28.4 BBO, the U.S. probably has 120 billion barrels of recoverable crude oil remaining to be found. Given the U.S. oil resources discussed above, the trend towards replacing reserves may continue into the future and is not at present overly-constrained geologically. The rate at which the potential reserves of the U.S. may be discovered and exploited is an economic and political question which will be examined in more detail in Chapter II.

TABLE II

U.S. RESERVES OF CRUDE OIL AND NATURAL GAS LIQUIDS

	Alaska Included	
Crude Oil		Natural Gas Liquids
28.4 BBO	proved	7.9 BBNGL
3.6 BBO	indicated	1.5 BBNGL
23.4 BBO	inferred	6.5 BBNGL
	Without Alaska	
18.9 BBO	proved	7.6 BBNGL
3.6 BBO	indicated	-
18.2 BBO	inferred	-

Current production is .016 BBO/day. Reserve Life at current production levels with no additions to the reserve base is 4.93 years.

Source: U.S. Department of Energy, Energy Information Agency, <u>U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1985 Annual Report</u> (Washington: U.S. Govt. Print. Off., 1986), p. 13.

F. Persian Gulf Oil Reserves.

The development of the oil reserves of the Persian Gulf began with the search for oil reservoirs by European companies trying to reduce European dependence on oil imports from the U.S. Details concerning this history are provided in Appendix II. Major reservoirs have been delineated and consist primarily of reef-type limestones and other biogenic rocks. Only one major clastic (consisting of terrigenous materials) play is developed in the Persian Gulf area: the Burghan sandstone play. The super-giant Burgan field contains this reservoir. Nevertheless, the absence of a wide variety of plays in the Persian Gulf region places stronger geologic constraints on additional oil resources awaiting discovery. The estimate used in this report for remaining U.S. undiscovered oil reserves (120 BBO) compares favorably with median United States Geological Survey (USGS) estimates for Persian Gulf undiscovered reserves of 174 BBO. Table III provides this figures.

TABLE III

CURRENT RESERVES AND DISTRIBUTION BY COUNTRY OF UNDISCOVERED CONVENTIONALLY MOVEABLE PETROLEUM RESOURCES IN THE ARABIAN-IRANIAN BASIN

Country	Current Reserves (BBO)	Undiscovered Petroleum Resources (BBO)		
		low	median	high
Saudi Arabia	167	24	57	111
Iran	62	11	26	50
Iraq	34	32	78	150
UAE	43	2	7	13
Oman	3	1	2	4
Kuwait	89	-	-	-
Qatar	7	-	-	-
Bahrain	0.31	-	-	-
DNZ	13	-	-	-
Totals	418.31	72	174	337

Source: U.S. Dept. of Energy, Energy Information Agency, The Petroleum Resources of the Middle East, (Washington: U.S. Govt. Print. Off., 1983), p. 63.

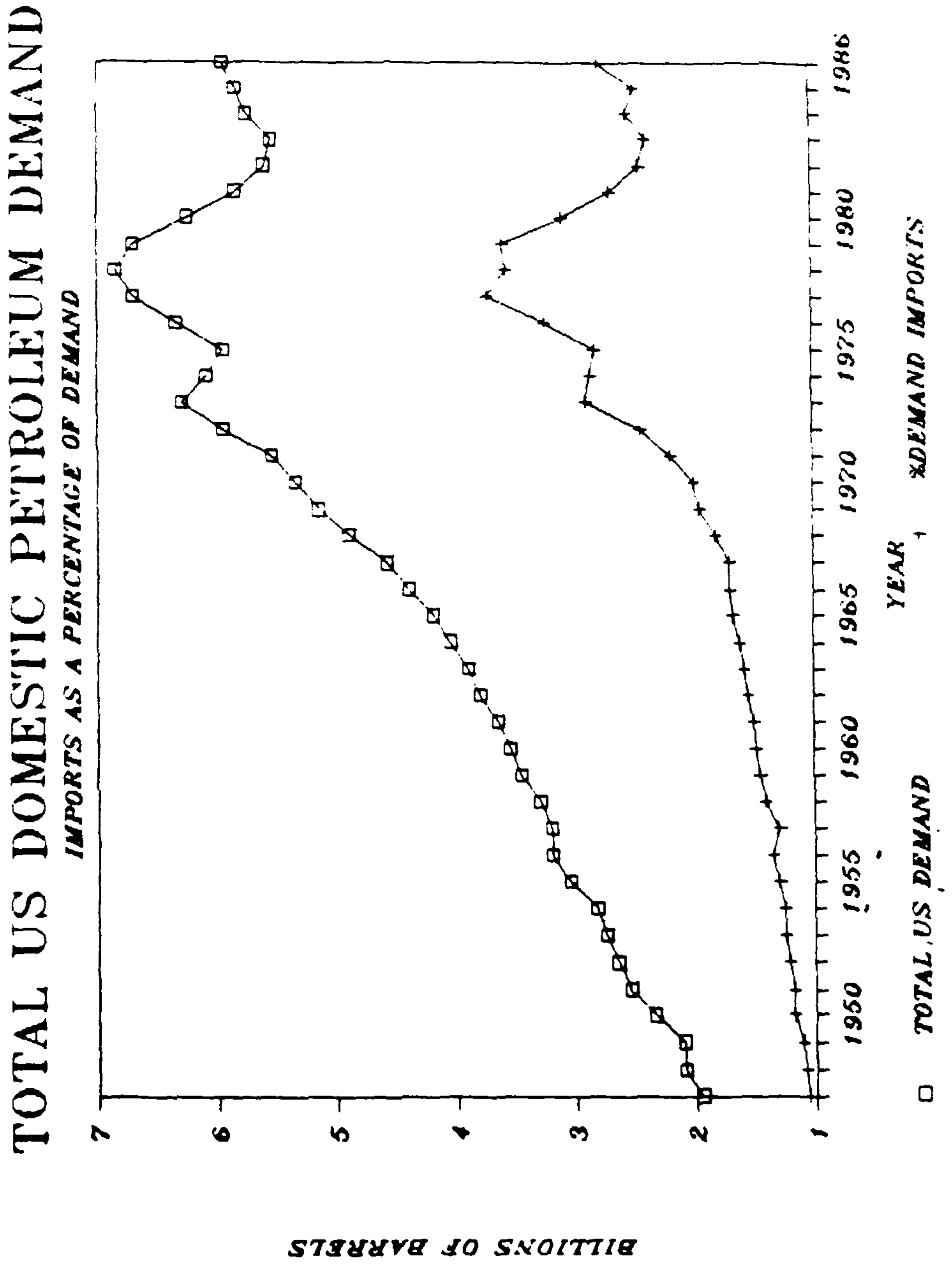
CHAPTER II

OIL CONSUMPTION AND SUPPLY FOR THE U.S. AND SEVERAL ALLIES

A. Historical U.S. Demand.

The purpose of this section is to examine U.S. demand for oil since 1947 and some of its ramifications for the future. Figure 2 depicts total U.S. domestic petroleum demand based on figures from the American Petroleum Institute (API). This figure also shows the imports for a given year as a percent of total consumption for that year only. Examination of Figure 2 shows four periods of above average growth in the rate of consumption: 1949-51, 1954-56, 1965-73, and 1975-77. Two of these periods, 1949-51 and 1965-73 occurred simultaneously with the Korean and Vietnam Wars, respectively. The above average rise in consumption during these periods may reflect the influence of military demand only. Further research would be needed to validate this hypothesis, but the limited war scenario discussed in Chapter IV will briefly touch on this issue again. The other 2 periods, 1954-56 and 1975-77 do not coincide with a war situation and may be attributable to other causes. Numerous books and studies have been prepared that examine the nature of U.S. demand. The Energy Information Agency, for example, provides statistics in its Annual Energy Outlook which examines energy consumption in various sectors, including residential, commercial, industrial, and

FIGURE 2



Source: American Petroleum Institute, <u>Basic Petroleum Data Book</u>, (Washington: 1986), sec. III, Table 3.

transportation. The API publishes a quarterly data book which extensively details not only oil and gas consumption by sector use but several alternative fuels as well. Popular books (see, for example, The Seven Sisters by Anthony Sampson) or summary reports, like the Exxon series on oil exploration, production, distribution and utilization), mention the widespread increase in fuel consumption in the energy-rich U.S. during the 1950's and 1960's. The supply of energy seemed limitless, and the consumer was secure in using more and more energy per capita. Despite warnings, however, the realization that cheap fuel was running out for the U.S. did not hit home until the 1973 Arab boycott of oil. Doran is only one of many authors who have examined in detail the relationships between economics, politics, and the geology of oil and their effect on the world economy.[1] The two sharp declines in the historically upward trend in domestic demand (Figure 2) occurred after the 1973 Arab-Israeli War, and the Iranian Revolution (1978-79). It is frequently overlooked, but conservation played an important role in lowering demand and putting downward pressure on oil prices.

B. Conservation

The price hikes and unstable supply of oil during the 1970's encouraged the "conservation" of oil resources. Techniques for reducing demand ran the gamut from hints for the consumer about ways to use less oil and gas at home to encouraging use of mass transit facilities and constructing industrial cogeneration facilities (the utilization of previously unused waste heat). Many conservation projects, such as building better insulated homes or re-insulating older structures, take place over time and their direct effects on oil consumption are hard to gauge. Others, like reducing per capita passenger miles, or buying more fuel efficient cars, are easier to see in the marketplace. Table IV provides figures about U.S. energy efficiency since 1970. There has been a steady increase in energy efficiency since 1973. As the Iranian Revolution threatened supplies during the 1978-79 period, a significant decrease in the oil energy consumption per GNP dollar was simultaneously taking place in the U.S. almost unnoticed, going from 12.2 in 1978 to 10.7 in 1980. This downward trend continued to 1985 and although the estimate for 1986 is very slightly higher than the actual 1985 figures, the 1987 projected value will return to the 1985 levels. This dramatic drop was not expected as recently as 1977, when, for example, Doran noted the "virtual absence of a U.S. consumption effort (the U.S. ranks fourteenth out of fourteen in a recent International Energy Agency Survey of member conservation programs)."[2]

TABLE IV

U.S. ENERGY EFFICIENCY

Year	GNP (Billion 1982 dollars)	Energy consumption (Trillion BTU)	Energy consumption per GNP dollar (Thousand BTU)	Oil energy consumption (Trillion BTU)	Oil energy consumption per GNP dollar (Thousand BTU)
1970	2,416	67,143	27.8	29,537	12.2
1971	2,485	68,348	27.5	30,570	12.3
1972	2,609	71,643	27.5	32,966	12.6
1973	2,744	74,282	27.1	34,840	12.7
1974	2,729	72,543	26.6	33,455	12.3
1975	2,695	70,546	26.2	32,731	12.1
1976	2,827	74,362	26.3	35,175	12.4
1977	2,959	76,289	25.8	37,122	12.5
1978	3,115	78,088	25.1	37,965	12.2
1979	3,192	78,898	24.7	37,123	11.6
1980	3,187	75,952	23.8	34,202	10.7
1981	3,249	73,989	22.8	31,931	9.8
1982	3,166	70,840	22.4	30,232	9.5
1983	3,279	70,495	21.5	30,054	9.2
1984	3,490	74,071	21.2	31,051	8.9
1985	3,585	73,939	20.6	30,922	8.6
1986*	3,679	74,150	20.1	31,835	8.7
1987†	3,783	75,410	19.9	32,460	8.6

*Estimated. †Forecast.
Source: 1970-1985 DOE, 1986 and 1987 OGJ estimates

Source: "Forecast 1987," Oil and Gas Journal, February 1987, p. 44.

Under the influence of rising prices, conservation became qualitatively more important though its effects are not easily quantified. Only the total amount of consumption tells the tale; between 1978 and 1983, total U.S. domestic refined-petroleum demand fell from 6.8 billion barrels to 5.6 billion barrels. "Since 1972, consumers have become 20% more efficient in their use of energy. The improvements in oil conservation are even larger amounting to 33% in the U.S., the largest single energy market in the world."[3]

As indicated by Anthony J. Finizza in 1979, a poor understanding of the dependence of economic growth upon increased oil consumption and conservation were the 2 areas most commonly miscalculated in predicting the future of oil consumption.[4] His sentiments are shared by others. In 1985, the Oil and Gas Journal said that "Conservation, once badly underestimated, will remain a major force. The enormous gains made in response to higher prices will not be reversed."[5] Finizza believed that those predicting an "energy demise" were too quick to downplay conservation and equally quick to assume that future growth necessitated more consumption. The likelihood of future economic growth moving upwards in lockstep with increasing consumption has been lessened. It is interesting to note that Finizza also predicted - in 1979 - that "the conditions are ripe for weakness in oil prices or limiting OPEC cartel power, because . . . the demand for OPEC oil is not increasing . . . ."[6] Obviously, the impact of U.S. conservation has been significant. However, under the current low oil price influence, consumption is increasing once again. The issue of consumption vis-a-vis imports will be discussed in a later section. However, it should be noted that Daniel Yergin stated in 1979 that:

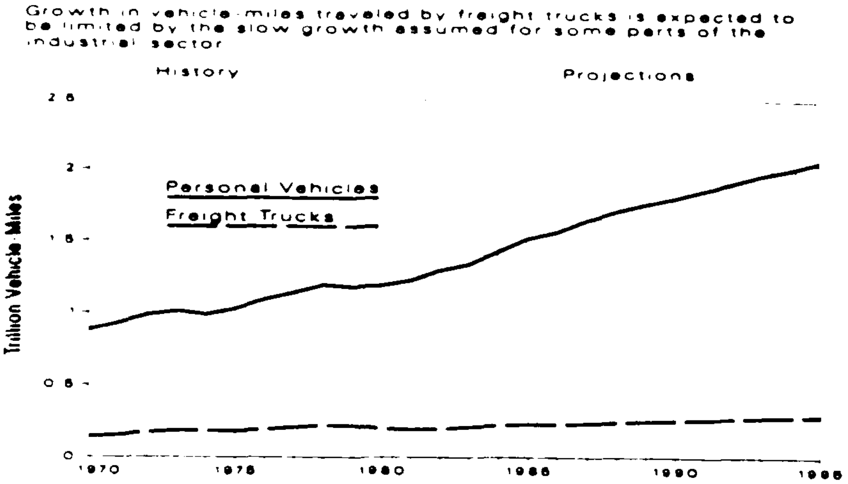
> There is, after all, the very strong role the U.S. plays as a consumer of one-third of all the oil used in the world everyday. One-ninth of all the oil is used by American motorists. We are far and away the largest importer of oil.[7]

Even with the increase in the fuel efficiency of the U.S. automobile fleet, the amount of oil we use to move people and goods is very significant. Figure 3 depicts Energy Information Agency (EIA) estimates for vehicle miles travelled to 1995. Note, however, that the EIA also indicates that vehicle use is the most sensitive consumption sector to changes in oil price.

> The transportation sector is more responsive than other end-use sectors to changes in the rate of economic growth and world oil prices. This sensitivity reflects the fact that most of the fuel used in this sector is petroleum, so oil price changes have a greater effect on total demand. In the high oil imports case, the transportation sector is projected to use nearly 10 percent more energy than in the low oil imports case in 1995. The concomitant assumption of higher economic activity also tends to increase the demand for all modes of travel in the high imports case, but this result is dampened somewhat by the introduction of a higher percentage of new vehicles into the national fleet, thus raising average efficiencies.[8]

FIGURE 3

VEHICLE MILES TRAVELED, 1970-1995



Source: U.S. Department of Energy, Energy Information Agency, Annual Energy Outlook 1985, (Washington: U.S. Govt. Print. Off., 1986), p. 31.

The main point concerning energy conservation is that the U.S. has made significant strides in reducing oil consumption through institutional changes. Current increases in consumption are largely due to increases in the demand from the transportation sector which is also the most sensitive to oil price changes. If the price of oil increased significantly again, a likely result might be a decrease or levelling of domestic oil demand for vehicular use.

C. Projected U.S. Demand Under Stable Political Conditions.

Projections concerning future U.S. consumption of oil are presented in Table V. These projections were obtained from a variety of sources indicated in the table. Like all projections, these are based on a large number of variables. Trends in consumption are difficult to establish, particularly due to variances in sectors like transportation which are so sensitive to oil price. The 1980 study by Exxon was the only one which projected demand to 2000. The Exxon figure for 2005 consumption is based on extrapolation of the downward trend developing between 1995 and 2000. Figures 4 and 5 depict the Exxon oil demand projections. It is important to note that according to Exxon, the use of oil will be declining after 1985. The Exxon projections were written in 1980 when the specter of steadily rising oil prices was firmly established. Those assumptions were not proven wrong as Figure 2 demonstrates that consumption began to go down even earlier than Exxon projected it would. Under the influence of lower prices, however, consumption is once again increasing, as indicated by Figure 2. Figures are also provided in Table V for projected oil demand for 2 important U.S. allies, Canada and Japan. While Canada produces more oil than it needs for domestic consumption (most of the small remainder is exported to the U.S.), Japan's demand is almost completely met with imports. For comparative purposes, the projections to be used in the remainder of this report are also included in Table V.

TABLE V

PROJECTED CONSUMPTION FOR THE U.S., JAPAN AND CANADA

	1985	1990	1995	2000	2005	2010
U.S.						
API	16.1	16.9	17.7	-	-	-
Krupp	15.7	16.9	18.2	-	-	-
EIA						
Base Case	15.74	16.1	16.5	-	-	-
Low Import	15.74	15.39	15.64	-	-	-
High Import	15.74	16.61	17.76	-	-	-
Exxon	16.5	16.8	16.2	15.9	15.7	-
This Report	15.74	16.5	17.0	16.5	16.1	15.0
Japan						
API	4.5	5.0	5.1	5.1	5.1	5.1
Canada						
API	1.6	1.6	1.6	1.7	1.7	1.7

Sources:

American Petroleum Institute, Petroleum Databook, 1986, (Washington: 1986), Volume III.

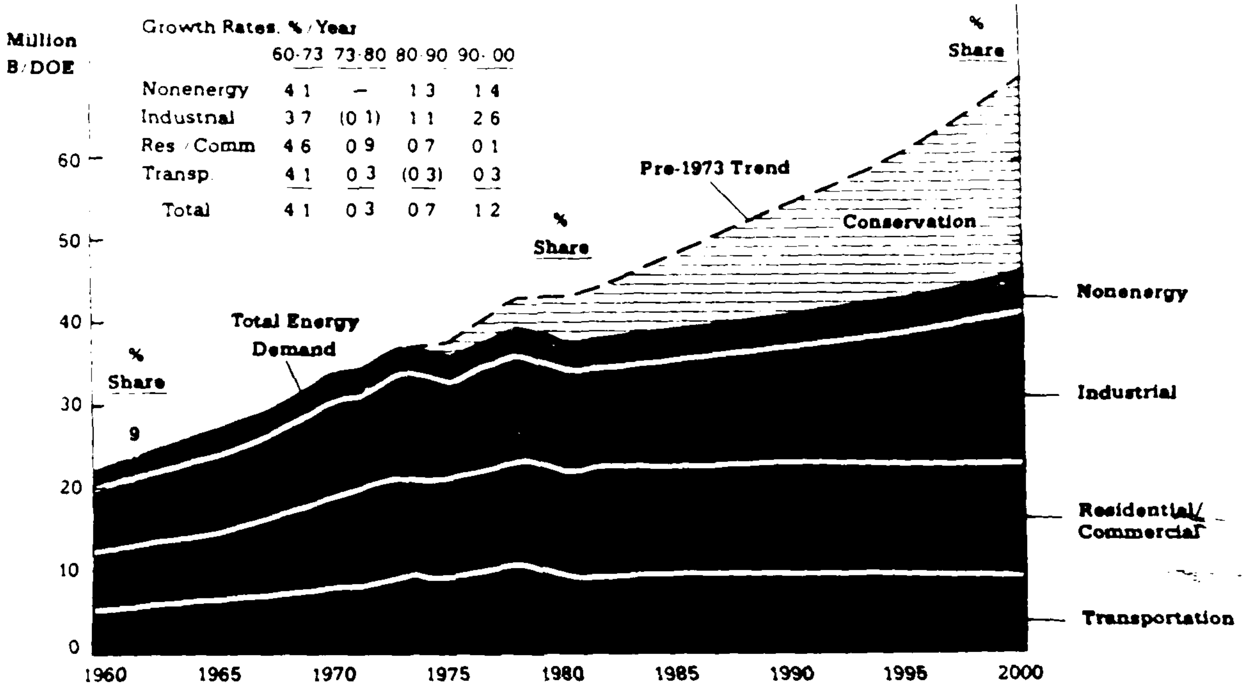
Herbert Krupp, "U.S. Imports to Soar", Petroleum Management, February 1987, p. 53.

U.S. Department of Energy, Energy Information Agency, Annual Energy Outlook, With Projections to 1995, (Washington: Govt. Print. Off., 1986), p. 8.

Exxon, Energy Outlook to 2000, (New York: 1980), p. 7.

FIGURE 4

U.S. ENERGY DEMAND BY CONSUMING SECTOR



Growth Rates, % / Year

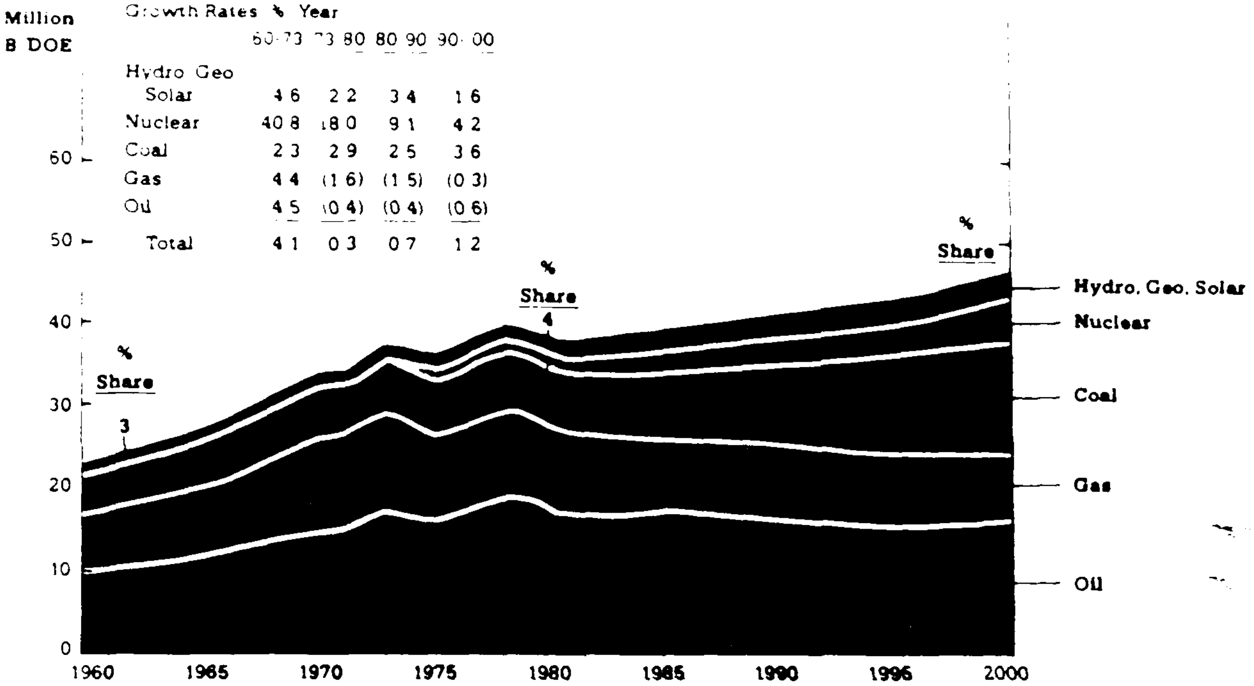
	60-73	73-80	80-90	90-00
Nonenergy	4 1	–	1 3	1 4
Industnal	3 7	(0 1)	1 1	2 6
Res / Comm	4 6	0 9	0 7	0 1
Transp.	4 1	0 3	(0 3)	0 3
Total	4 1	0 3	0 7	1 2

Note Electrical losses are allocated to each sector

Source: Exxon, Energy Outlook 1980-2000, (New York: 1980), p. 4.

FIGURE 5

U.S. ENERGY DEMAND BY FUEL CONSUMED



Growth Rates % Year	60-73	73-80	80-90	90-00
Hydro Geo Solar	4.6	2.2	3.4	1.6
Nuclear	40.8	18.0	9.1	4.2
Coal	2.3	2.9	2.5	3.6
Gas	4.4	(1.6)	(1.5)	(0.3)
Oil	4.5	(0.4)	(0.4)	(0.6)
Total	4.1	0.3	0.7	1.2

Source: Exxon, Energy Outlook 1980-2000, (New York: 1980), p. 5.

D. Projected U.S. Supply.

Figure 6 is an attempt to treat the U.S. as a single oil producing field. Petroleum engineers and geologists frequently plot the decline rate for a given field on semi-log paper using a concave upward curve to approximate decline and project it into the future. Using historic data and projections provided by various geologists and engineers[9], 3 peacetime scenarios are illustrated. In the intensive (high) exploration case, oil production is not going to fall dramatically before 2000. Chevron staff analyst W. H. Dorsett believes that cost efficiencies in producing U.S. oil will help keep "U.S. oil output . . . level to the end of the decade."[10] This statement, however, assumes that oil will remain in the $25 dollar per barrel and higher range through the end of the century. The moderate exploration model assumes that the price of oil will fluctuate between $19 and $24 dollars per barrel over the outlook period.' In this scenario, drilling will not be as intensive, but will be higher than the exploration effort of 1985 and 1986 when the rapid decline of oil prices cancelled most exploration activity. The final case, that of low exploration activity, assumes that oil will range in price below $18 dollars per barrel. At this level, current levels of production will be unsustainable.

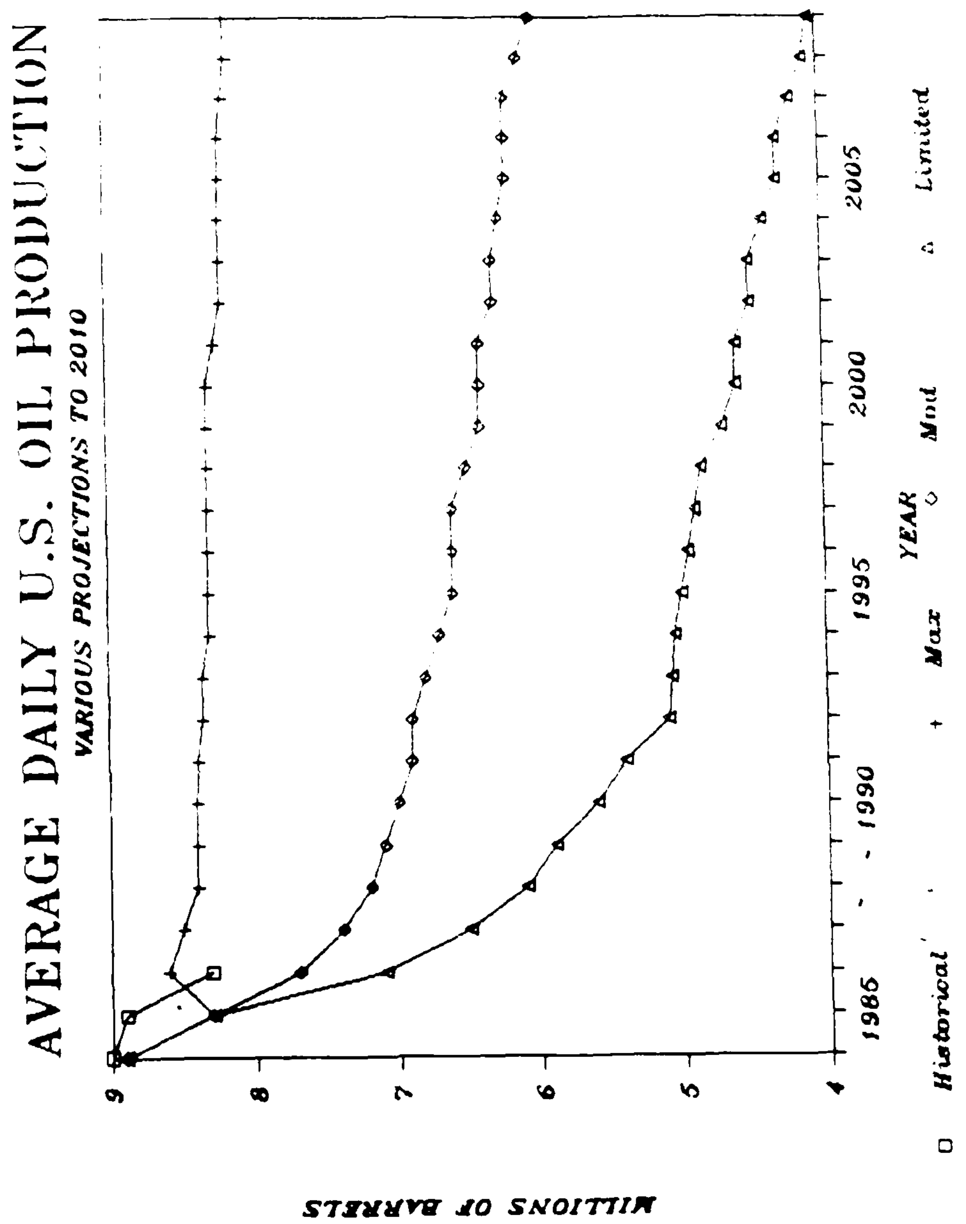
> U.S. oil output will plummet to 5.11 million barrels per day (b/d) in 1995 from 8.97 b/d in 1985,

estimates Chevron's Dorsett. If oil prices rebound to $20 - $25/barrel, the drop could be stemmed to 6.87 million b/d.11

The key point is that U.S. production is highly price dependent due to the expensive nature of most U.S. production. Geology is not a limiting factor in maintaining U.S. production, but politics and economics are. "Ultimately, the future level of oil prices holds the key to how well the U.S. replaces its oil production."[12]

As pointed out in Chapter I, the U.S. still holds significant amounts of oil awaiting discovery. However, economics will determine how quickly these reserves will be discovered. Most industry analysts see an increase in the price of oil. Recent OPEC actions to boost the oil price to $18 dollars per barrel[13] are a step in the right direction, but are not yet in the moderate U.S. oil exploration range of $19 - $25 dollars per barrel. This may or may not be an intentional goal of OPEC pricing action. Table VI provides U.S. production estimates. Both EIA and Chevron figures are provided for 3 scenarios: EIA low import = Chevron intensive exploration, EIA high import = Chevron low exploration, and the EIA base case approximates the Chevron moderate exploration case. The figures which will be used in the remainder of this study are provided for comparison under two scenarios: low import and high import. Future Canadian

FIGURE 6



Source: Bob Williams, "Slumping Prices, Natural Declines Seen Braking U.S. Oil Flow in the 1990's", Oil and Gas Journal, 15 December 1986, pp. 15-18.

production levels are also provided in Table VI. The final quotation for this section also comes from the Oil and Gas Journal:

> Fisher (AAPG President William L. Fisher) says U.S. production can stabilize if operators drill 80,000 wells/year, as they did during the drilling boom. "You just must put a price to it that's competitive, probably $26/bbl." What's critical, says Fisher, is that the added resource is marginal, in very small increments of 50,000 bbl/well.
>
> "We were stabilizing production at $26/bbl, but we can't do it at $15/bbl. But if we used the tax code to support drilling 75% of those wells, we'll have 40-50 years of transition to alternate energy sources."14

TABLE VI

PROJECTED PRODUCTION FOR THE U.S. AND CANADA
(Million Barrels of Oil/day)

	1985	1990	1995	2000	2005	2010
U.S.						
API	10.9	10.9	10.5	-	-	-
Krupp	11.4	9.5	8.2	-	-	-
EIA[a]						
Base Case	11.11	10.37	8.82	-	-	-
Low Import	11.11	10.73	9.57	-	-	-
High Import	11.11	9.94	7.77	-	-	-
Chevron[b]						
Low Explor	10.43	7.54	6.79	-	-	-
Max Explor	10.43	10.04	9.94	-	-	-
Base Case	10.43	8.84	8.39	-	-	-
Exxon						
Oils, Total		7.1	7.66	7.8	-	-
Synthetic Oils		.9	2.2	3.4	-	-
Total		8.0	9.86	11.2	-	-
congressional Research Service	10.1	9.6	8.9	8.5	-	-
This Report						
Low Import	11.1	10.6	9.9	9.2	9.0	8.6
High Import	11.1	9.0	7.5	6.5	6.0	5.5
Canada						
API	1.7	1.7	1.7	1.7	1.7	1.7

[a] EIA figures include all crude oils, condensates, natural gas liquids, and other refinery gains.

[b] Chevron projections are corrected for NGL production.

Sources:

American Petroleum Institute, Petroleum Databook, 1986, (Washington: 1986), Volume III, no. 3, Sec. 1, Tab. 1.

Herbert Krupp, "U.S. Imports to Soar," Petroleum Management, February 1987, p. 55.

U.S. Department of Energy, Energy Information Agency, Annual Energy Outlook, With Projections to 1995, (Washington: Govt. Print. Off., 1986), p. 33.

Exxon, Energy Outlook to 2000, (New York: 1980), p. 7.

E. Projected U.S. Imports.

Figure 2 at the start of this chapter, detailed the historic role of imports in total U.S. consumption between 1947 and 1986. Since 1947, the shortfall between U.S. demand and U.S. production has been made up by imported crude oil and, lately, crude oil and refined products. It is not in the scope of this paper to discuss refining trends in the U.S., but the import of refined product has cut into the U.S. capacity to refine petroleum. At the current time, the U.S. has a refinery capacity for 15.1 MMBOPD. It is projected that this will increase to 15.6 MMBOPD in 1987, but it should be noted that the U.S. currently lacks refinery capacity to refine all the crude oil it consumes in one day, approximately 16,190,000 barrels.[15]

U.S. imports of crude oil reached a peak in 1977 (see Figure 2) and fell thereafter to a low in 1983 with an increasing trend since then. The current low price of oil encourages the trend to larger imports, since under a low price scenario, U.S. production is now and will continue to fall rapidly. Stripper wells account for 14% of U.S. production based on API figures.[16] These wells are expensive to operate and maintain as they all require pump maintenance and storage facilities to hold the small amounts of oil they produce. These small amounts of oil are either gathered by pipeline or tank truck for transport to a refinery net. These wells are being abandoned in the U.S. at this time.

Exploration projects for moderate-sized domestic reservoirs are being shelved as they become economically non-viable. The lack of exploration, the dismemberment of exploration staffs going on in most domestic U.S. oil companies today, and the subsequent failure to replace oil reserves consumed combined with abandoned stripper well production results in lower U.S. production and more dependence on imports. One of the issues facing U.S. policy-makers today is how much stripper well production needs to be abandoned: strategic-military needs dictate keeping all marginal production available, economics dictate abandonment of most stripper well production.

Most importantly, total U.S. drilling footage has been declining appreciably since the downturn in oil prices starting in 1985 and accelerating in 1986. Herbert Krupp, writing in Petroleum Management highlights the oil economics problem.

> The dramatic drop in oil and gas prices this year has slashed wellhead revenues and therefore drilling expenditures in recent months. For 1986 on' the whole, revenues have fallen by $45 to $50 billion -- from $120 billion in 1985 to an estimated $70 to $75 billion in 1986. Since roughly one-fifth of revenues are typically plowed back (reinvested) in drilling activities, it is estimated that these expenditures have declined by some $9 billion to about $11 or $12 billion in 1986. This compares with spending of almost $40 billion in 1982. These tentative expenditure estimates for 1986 are supported by API data showing that U.S. well completions in the third quarter of 1986 were down by almost 50 percent from the year earlier level. The squeeze on wellhead revenues -- and E&D expenditures -- will continue to depress domestic drilling activity through the entire forecast period, although an upward drilling trend is expected to begin in 1988.17

On the basis of the analysis by Krupp, the U.S. right now is at a critical crossroads in our import future. The low levels of drilling (see Figure 7 evident since 1985 are not replacing domestic reserves lost through consumption. This rapid shift from extensive exploration to little or no exploration is threatening to undo the progress made in the early 1980's in response to increasing oil prices and oil shutoffs. Unless the price of oil increases, enabling U.S. producers to resume an active (over 300 million feet of drilling per year) development and exploratory drilling program, imports will follow the highest import scenario.

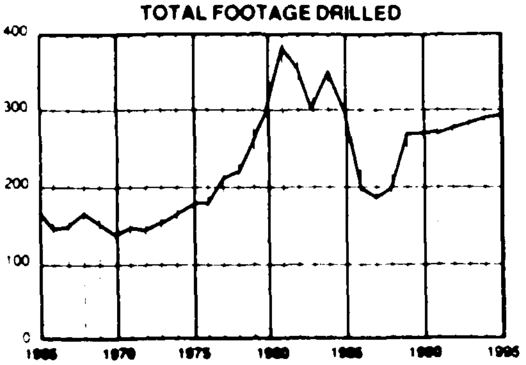
Table VII uses figures for projected U.S. demand and supply for oil (Tables V and VI) to calculate projected imports under a high import and a low import scenario. Under the high import scenario, which appears to be the most likely scenario today due to the recent resurgence of oil imports, the U.S. will be importing over 50% of its oil before 1995. In the low import scenario, the U.S. will not be importing more than 50% of its oil before 2005.

Table VIII identifies foreign sources of supply for 1985. Approximately 51% of U.S. oil imports came from the Western Hemisphere, 18% from Africa, 10% from the North Sea, and 9% each from the Persian Gulf and the southeast Asia region (Australia and Indonesia). These figures have changed drastically since then.

As prices plunged last year to the lowest levels in a decade, imports soared to the highest levels since they peaked in 1977 at 46% of U.S. consumption. As of December, 1986, imports were hovering around 40% of U.S. demand, up from 29% in 1985. Leading government and private experts project that imports will account for 50% or more of all U.S. oil consumption by the early 1990's if current trends continue.

Moreover, as U.S. production falls due to the glut of less expensive foreign oil, the Middle East is rapidly regaining the ground it lost early in the 1980's as a source of U.S. supplies. Imports from Persian Gulf OPEC producers are at the highest level in five years, having more than doubled in the first seven months of 1986 alone, from 400,000 barrels a day in 1985 to 900,000 barrels a day in the same period a year later Saudi Arabia by November 1986 jumped from being the eighth largest exporter of crude oil to the U.S. to the fourth largest.18

FIGURE 7



Source: Herbert Krupp, "U.S. Oil Imports: New Highs Expected," Petroleum Management, February 1987, pp. 53-55.

TABLE VII

PROJECTED U.S. OIL IMPORTS
(Millions of Barrels per day)

	1985	1990	1995	2000	2005
Krupp	4.3	7.4	10.0	-	-
EIA	4.89	6.43	8.44	-	-
Exxon[a]	-	8.8	6.7	4.7	-
<u>This Report</u>					
High Import	4.64	7.5	9.5	10.0	10.1
Low Import	4.64	5.9	7.1	7.3	7.1

[a] Exxon Low Import figure in 2000 is due to the addition of synthetic oils starting with the 1990 estimate.

Sources:

Herbert Krupp, "U.S. Imports to Soar", <u>Petroleum Management</u>, February 1987, pp. 53-55.

U.S. Department of Energy, Energy Information Agency, <u>Annual Energy Outlook, With Projections to 1995</u>, (Washington: Govt. Print. Off., 1986), p. 33.

Exxon, <u>Energy Outlook to 2000</u>, (New York: 1980), p. 9.

TABLE VIII

U.S. IMPORTS FROM VARIOUS NATIONS

Country	Percentage	Regional Totals
Mexico	22.3	
Canada	14.6	
Venezuela	9.9	50.8
Trinidad & Tobago	3.0	
Ecuador	1.0	
United Kingdom	8.7	
Norway	1.0	9.7
Nigeria	8.7	
Angola	3.2	
Algeria	2.5	
Gabon	1.6	17.8
Zaire	1.0	
Congo	0.5	
Tunisia	0.3	
Saudi Arabia	4.0	
Iraq	1.5	
Oman	1.1	
UAE	1.0	8.8
Iran	1.0	
Kuwait	0.1	
Qatar	0.1	
Indonesia	9.1	
Australia	0.6	9.7

Source: American Petroleum Institute, Basic Petroleum Databook, (Washington: 1986), Sec. IX, Tab. 4C.

CHAPTER III

STRATEGIC IMPLICATIONS OF U.S. OIL IMPORT DEPENDENCE

A. The Import dilemma: Threat or Boon?

> The increased dependence on foreign sources of supply represents a clear threat to the Nation's military and economic security.1

No matter how the pie is sliced, the U.S. is going to be dependent on oil imports for the next 2 decades. The questions becomes what the level of dependency will be and where the imports will come from. As discussed in the previous sections, the price of oil will largely determine whether imports will follow the high or low import scenario.

> The recent collapse of oil prices almost certainly will lead oil imports to rise to unprecedented levels within the next decade -- unless U.S. energy policies change shortly or oil prices recover rapidly.2

> The experience of the 1970's and 1980's demonstrates that oil users and producers respond forcefully to substantial changes in oil prices. In the U.S., the oil price increases of the 1970's caused the downtrend in oil production and uptrend in consumption to be reversed . . . . The fall in oil prices this year has begun to stimulate free world oil consumption and reduce non-OPEC oil production. The adverse impact on U.S. oil production has intensified in recent months.3

This intensifying of a crisis atmosphere in the U.S. oil industry has even reached the front page of the New York Times, where a lead article on 17 February 1987 discussed the issue of the unavoidability of a U.S. oil shortage.[4]

At this point, some analysts are not concerned about the prospective rise in U.S. imports due to the lowering of oil prices with the concomitant depressing results on U.S. oil production. The Department of Defense Director of Energy Policy, Jeff Jones, recently stated that reliance on the Middle East for imports is not necessarily ominous. Due to the fact that OPEC is unlikely to rein in production for an extended period of time, he said that "Until OPEC is firmly in the driver's seat and world demand is close to world productive capacity, oil as a weapon is not as likely to haunt us as in the 1970's."[5] If there were an interruption in Persian Gulf imports, the U.S. could "readily swing to more stable suppliers, such as Canada and Mexico."[6] The assumption that oil will be readily available reflects that OPEC nations and other exporters need to produce oil in order to ensure income. H. Landsberg argued in 1978 that "skyrocketing commitments to growth and social betterment leave little slack in the national budgets (of OPEC nations) and thus preclude output reductions for any extended period, or at least act as a substantial deterrent, unless such reductions come in support of an effort to raise real oil prices substantially."[7]

Other analysts, however, view any import dependence of the U.S. as a threat to security. "These officials say that increased reliance on foreign sources, coupled with inadequate refinery capacity, a shortage of tankers, and other problems, would make the U.S. military dangerously vulnerable to supply interruptions in wartime."[8] This can, of course, be extended to supply interruptions occurring in peacetime which would threaten U.S. economic well being.

In the New York Times article mentioned earlier, former Secretary of Energy Donald Hodel warned that "People will be sitting in gas lines anytime within the next two to five years."[9] Furthermore, had the oil market been tighter last year, he added that a Middle East source indicated that the Arab OPEC members (OAPEC) would have instituted a cutoff of oil flow to the U.S. in response to the Libyan bombing raid. Rapid drops in U.S. oil production capacity due to the abandonment of stripper well production and marginal exploratory efforts replacing smaller percentages of U.S. annual production all lead to increasing dependence on foreign supplies, especially from the Persian Gulf which presently is the world's largest and least expensive producer.

It is far beyond the scope of this paper to look at all the ramifications of the severe energy issues facing the U.S. today. Many better written summaries exist. The key question to be answered by this paper, however, is whether or not the U.S. must be dependent on oil from the Persian Gulf.

B. Projected Shortfall in U.S./Canadian Production.

Table IX provides a summary of figures reported earlier in this study. Consumption figures for oil plus natural gas liquids are provided for the U.S., Canada, and Japan. Production figures are provided for the U.S. (under both a high and low import scenario), and Canada. The shortfall -- the amount of oil which needs to be imported such that supply equals demand -- is shown for both the low and the high U.S. import scenarios. It is important to note here that both the low and high oil import schedules are estimates. If the price of oil returns to a high level, fostering conservation, low imports, and high exploration activity, the possibility that major new finds in the U.S. or other Western Hemisphere nations improves. If the price of oil remains low, under $18 dollars per barrel, the realities that more and more U.S. production might be shut in reducing even further U.S. production capacity become more significant. Philip Abelson, writing in Science about the U.S. energy future, outlined the events of late 1986 and put them in perspective.

> Events of 1986 have been traumatic for many people associated with the U.S. petroleum and natural gas industries. Prices at the wellhead have plunged, employment has been sharply curtailed, drilling has dropped to near longtime lows. Thus far, effects on production, consumption, and imports have not been great, but a continuation of present trends would lead to nationwide trauma at a later date. Because of longtime constants involved in developing energy sources, this country cannot afford complacency.

TABLE IX

PROJECTED SHORTFALL IN U.S. AND CANADIAN PRODUCTION

	1985	1990	1995	2000	2005	2010
Consumption (Oil plus Natural Gas Liquids)						
U.S.	15.7	16.5	17.0	16.5	16.1	15.0
Japan	4.5	5.0	5.1	5.1	5.1	5.1
Canada	1.6	1.6	1.6	1.7	1.7	1.7
Total	21.8	23.1	23.7	23.3	22.9	21.8
Production						
U.S.						
Low Import	11.1	10.6	9.9	9.2	9.0	8.6
High Import	11.1	9.0	7.5	6.5	6.0	5.5
Canada	1.7	1.7	1.7	1.7	1.7	1.7
Shortfall						
Low Import	9.0	10.8	12.1	12.4	12.2	11.5
High Import	9.0	12.4	14.5	15.1	15.2	14.6

> At one time, the United States was the world's lowest cost producer of petroleum and a substantial exporter. But the easy-to-find and inexpensive-to-produce oil has been found and exploited. There remains a large amount of oil inplace (more than 300 billion barrels), but most of it is costly to produce: $10 to $15 a barrel and more. When oil was selling above $30 a barrel in 1981 and there was a widespread expectation of even higher prices, 4561 rigs were drilling. In July, 1986, with oil at about $10 a barrel, the number of active rigs dropped to less than 700. In November, when the price rose to $14, about 850 were drilling.[10]

In February, 1983, then Secretary of Energy Hodel told the Senate Energy and Natural Resources Committee that the Persian Gulf was of less strategic value to the U.S. than it had been previously.[11] As U.S. reserve replacement was growing under the influence of increased drilling over the 1979 to 1982 period and conservation gains were reducing domestic demand, U.S. imports from the Persian Gulf were dropping below historical trends. As has been noted, this decline is now reversing itself. There are. however, other sources of oil besides the nations of the Persian Gulf.

Estimates regarding the size of oil reserves in Mexico vary. In 1979, they were estimated at a conservative 40 BBO proved reserves based upon recent discoveries in the Reforma-Campeche trend. These figures were increased in 71 BBO in the 1986 Annual Summary of Foreign Oil Developments published by the American Association of Petroleum Geologists.[12] Discoveries in the Reforma-Campeche trend have continued, and they may make it possible to increase Mexico's reserve base.

One interesting facet of Mexico's reserves are that at present, they are relatively easily and cheaply produced. Many reservoirs are located in reef-type reservoirs similar to those of the Persian Gulf.

Another nation with very significant oil reserves is Venezuela. Venezuela is one of the oldest oil producing regions in the Western Hemisphere. As was mentioned earlier, Venezuela oil began to enter the U.S. marketplace as early as the 1930's. Venezuela possess the world's largest oil field, the Orinoco Heavy Oil Belt. Oil from this field is conventionally extractable but at a higher cost than other reservoirs, such as carbonate reefs, due to the gravity and viscosity of the oil in place. While it is more expensive to extract this oil, it is possible to do so without a breakthrough in technology.

Reserve estimates for Venezuela currently range between 29 and 37 BBO,[13] however, a recent revision to that figure has been made by the official Venezuelan national oil company (Petroleos de Venezuela SA) by including some of the more easily extractable crude oil from the Orinoco Belt. The addition of these reserves brings the total Venezuela reserve base figure up to 55.5 BBO PDVSA President Juan Chacin said the Government earlier had calculated reserves "in an extremely conservative manner." He added that the new calculation is in keeping with international norms[14]

Other documented oil producing nations in South America include Ecuador (along with Venezuela a member of OPEC), Columbia, Trinidad and Tobago, and Brazil. As pointed out by Bernardo Grossling, the potential for further discoveries in South America is possibly one of the greatest in the world.[15] For a variety of political reasons, less exploration activity has occurred in South America than the potential of its sedimentary basins warrants. He described a belt approximately 7,000 km. long in the geosynclinal trough just east of the Andes Mountains which contains "innumerable opportunities" for the occurrence of stratigraphic traps. The Bolivar coastal field, a giant field, is such a stratigraphic trap along that trend. The Orinoco delta, at the eastern end of the Orinoco Heavy Oil Belt, has only marginally been explored.

> . . . the statement that the most attractive areas have already been examined does not really appear to be correct.
>
> People say "There is no room for other giant fields, we have looked at the area, and we don't see where they could be." Maybe that is the very problem -- that they cannot see them. As I mentioned, there is a belt about 7,000 km long in which to search for stratigraphic traps, and on it there is much room for giant fields.

The main idea is that in terms of known, proved reserves, Venezuela and Mexico hold over 100 BBO. In terms of probable reserves, that number increases significantly.

C. Adequate Oil to Supply the U.S.-Canadian-Japanese Import Needs Can be Found in South America.

There is no geologic reason why the U.S. must import oil from the Persian Gulf. The capability to produce enough oil for our domestic needs can be found in the Western Hemisphere. Given the size of known reserves plus the potential for further discoveries given the right economic conditions, the shortfall in U.S. - Japanese - Canadian consumption projected for the next two decades (Table IX) could be met by exports from South America if they were encouraged to do so, both politically, and technically. The current availability of oil from other non-OPEC and non-Persian Gulf members of OPEC also supports this ability for the U.S., Japan, and Canada, however, all the remaining oil importing world is competing for these resources.

For this elimination of dependency on Persian Gulf imports to take place, several things must happen now. The following is a brief discussion of several of these factors, specific recommendations will be made in Chapter VI.

(1) U.S. production must be maintained at the highest level possible for the next 2 decades. This, in turn, requires an oil price capable of:

(a) encouraging exploration, and

(b) maintaining stripper well production.

(2) U.S. demand must revert to levels characteristic of 1982 - 84, when imports were supplying less than 30% of U.S. consumption. This can be accomplished by reemphasizing conservation and energy use reduction.

(3) Maximize oil production from Mexico, Venezuela, and other South American Countries through drilling development wells and participating in active exploration programs.

CHAPTER IV

THE U.S. ENERGY FUTURE UNDER TWO WARTIME SCENARIOS

A. Historical Analogues.

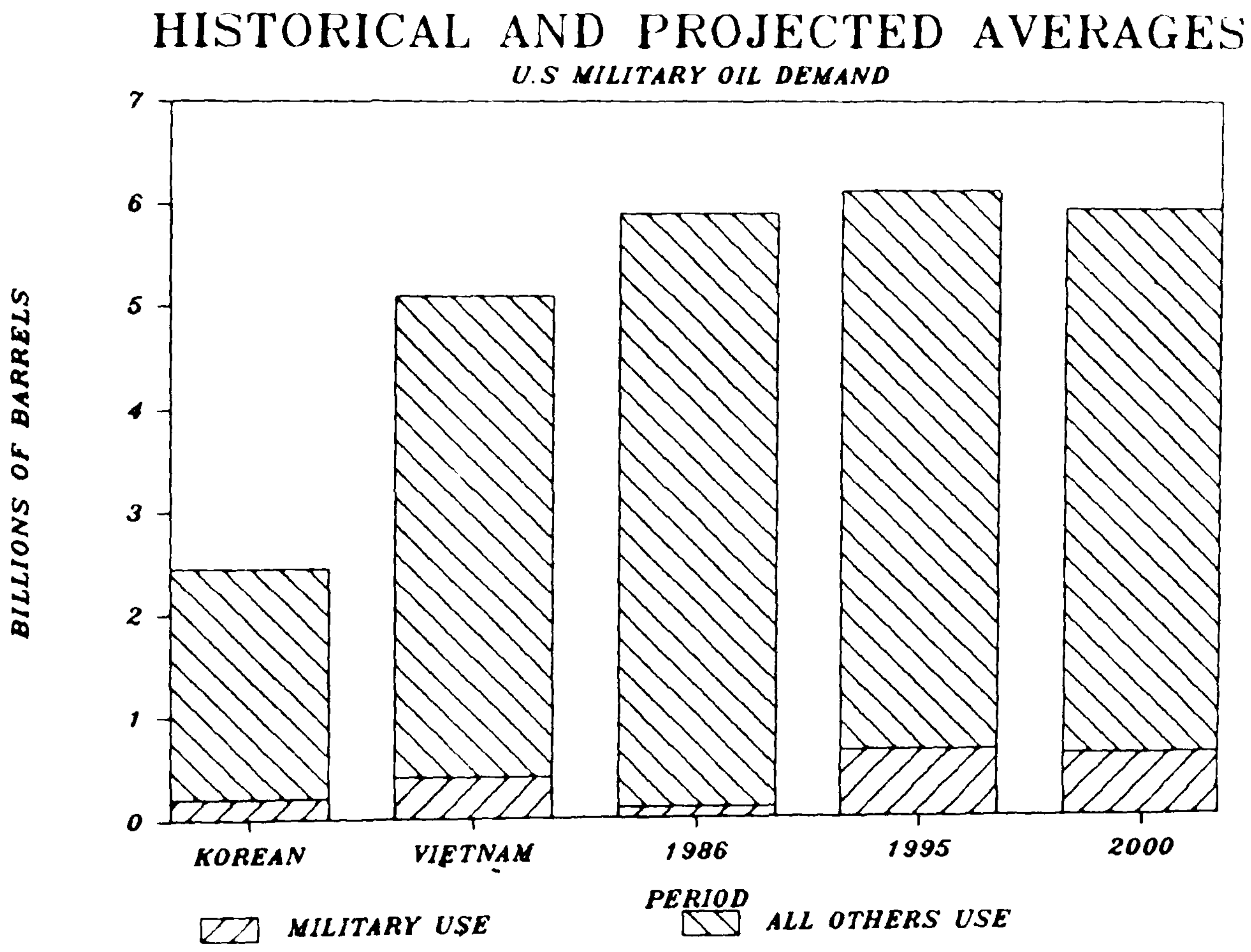
Figure 2 at the beginning of Chapter II depicted the changes in U.S. demand for petroleum over the 1947 through 1986 periods. It was noted there that two periods of rapid increase in the rate of energy consumption may have been related to the Korean War (the increase occurring over the 1949-52 period) and the Vietnam War (the oil consumption increase occurring over the 1965 to 1973 period). Figures for the Vietnam Was indicate that at the height of the war, the U.S. military was consuming 1.1 million barrels of oil per day.[1] This represents 7% of total average U.S. consumption over the period 1969 to 1973. The military consumption patterns during Vietnam may be analogous to future limited war scenarios.

In terms of energy consumption, the Vietnam analogue includes several similarities and differences with other potential limited wars involving U.S. forces. The similarities include the conduct of a war using large quantities of forces and material in a geographically distant setting, high use of mechanized equipment with its concomitant demands on petroleum products, and its lack of impact on sea-lines-of-communication. Differences include the fact that first, maximum U.S. military demand for oil during Vietnam was occurring during a period of still plentiful U.S. production of domestic oil reserves. Second, any future war scenario will likely impose heavily on U.S. overall consumption of oil products. Other differences include that future limited wars may involve threats to the maintenance of secure sea-lines-of-communication. Since most oil imports to the U.S. arrive by sea, any disruption of tanker traffic to and from U.S. ports would immediately affect domestic oil supply and demand.

Figure 8 is an attempt to quantify the impacts of two recent U.S. limited wars. Data on oil consumption for the Korean War was obtained by calculating the differences between a base level increase in oil consumption between 1948 and 1954 and the actual increase in oil use over that period provided by Figure 2. The figures for the Vietnam War were likewise obtained from Figure 2 by inspection and by comparison with data provided by Barbara Saunders.[2]

In any future limited war scenario, U.S. military consumption has been projected to increase to 10% of total U.S. demand. This figure compares favorably with the 8% level of domestic consumption obtained during Korea and the 7% level achieved during the Vietnam War. For comparative purposes, the peacetime level of U.S. military demand in 1986 is provided in Figure 8 using .56 MMBO per day as a base level for military consumption.

FIGURE 8


HISTORICAL AND PROJECTED AVERAGES
U.S MILITARY OIL DEMAND
BILLIONS OF BARRELS
7
6
5
4
3
2
1
0
KOREAN
VIETNAM
1986
1995
2000
PERIOD
MILITARY USE
ALL OTHERS USE

The two scenarios to be discussed in this study deal with the conduct of a limited war and a global war by U.S. military forces. The limited war case will be examined first, followed by the global war scenario.

B. Limited War.

Current U.S. military consumption of oil equals approximately 3% of total U.S. demand. This figure is based on an average daily U.S. military consumption rate of .56 MMBOPD. Air Force Maj. General John E. Griffith, Commander of the Defense Fuel Supply Center, estimates that military fuel consumption is only about 2% of the nation's total.[3] During peacetime, the DFSC receives most of its fuel procurements from domestic and Canadian suppliers. However, the selection of suppliers is based not on strategic considerations but more on the current price of oil. Peacetime consumption figures for the military are already included in estimates for total U.S. consumption. In a limited war scenario, however, total military requirements for oil may climb to the average 7% of total U.S. consumption recorded during the Vietnam War or to a higher level.

Any limited war scenario inherently involves more variables than a global war situation. In any limited war scenario, the U.S. faces a choice to either increase its supply (imports) to meet anticipated and actual rises in military consumption or to absorb a corresponding decrease in the amount of oil available to the U.S. public. The former case involves importing more oil with its associated risks, the latter requires facing the unpalatable decisions of allocating reduced supply.

Let us first examine the choice to import more oil to meet the U.S. military demands in a limited war. In 1995, when total U.S. demand will reach a projected 6.12 BBO per year, the peacetime (3%) amount of consumption destined for military use becomes 184 MMBO per year. A limited war increasing U.S. military demand to 10% of total U.S. consumption in 1995 would require a total of 620 MMBO per year. Additional imports would therefore need to be 436 MMBO per year since it is assumed in this scenario, and as attested by U.S. oil field performance over the last 30 years, that domestic production will not be capable of supplying the additional demand. This quantity of oil will not be unavailable in world markets in 1995 but will require additional tanker shipments to the U.S. In 2000, a limited war might require the additional import of 416 MMBO per year using the same reasoning. As mentioned earlier, security of sea-lines-of-communication (SLOC) might not be guaranteed as was essentially the case during Vietnam. Increased tanker traffic would provide more targets of opportunity for enemy forces, and long SLOC's would provide more chances for successful interdiction. Given this situation, the most desirable case would be to import additional oil using the shortest SLOC's available, namely those to the Caribbean Basin and the rest of South America. Additional risks for utilizing the increased import route during a limited war include the reliability of foreign flag tankers and crews to deliver oil to the U.S. and the possibility that governments not in support of our war aims might act to reduce or cutoff their flow of oil to the U.S. One fact begins to emerge from this brief discussion of using an increase in imports to supply additional U.S. military consumption during a limited war is that security of SLOC's is increasingly significant. By virtue of the fact that the U.S. absolutely needs imports of oil to maintain current levels of total consumption, we need to allocate military resources to ensure the security of their route of supply. The need to import oil does indeed affect our military options.

In terms of the latter case, the U.S. public would have to be firmly in support of any war resulting in a diminution of the availability of oil. If supplies are cutoff or reduced as a result of the limited war through the intervention of foreign governments, transport dislocations, or the choice of the U.S. government, the civilian economy will be affected in varying ways. As mentioned earlier in this paper, one of the most sensitive consumption sectors is transportation. One ninth of all the oil used in the world is used by American motorists (see Chapter II). Rationing of the amounts of oil available to the transportation sector would be open way to rapidly increase the amount of oil product available to the U.S. military without increasing imports.

An additional point in analyzing a limited war concerns the Strategic Petroleum Reserve. "While primarily a civilian stockpile, 10% of the Strategic Petroleum Reserve (SPR) can be tapped for military use by Presidential order."[4] This rule on drawdown was established on a projected peacetime scenario. In a limited war, full use of the SPR (designed to hold 750 MMBO, it now contains 510 MMBO) for military consumption would supply sufficient oil for 435 days if full and 296 days at the present level of filling. These figures were obtained using a total yearly military consumption of 620 MMBO per year in 1995. The use of the SPR in this manner might thus provide a temporary reserve supply until additional sources of supply can be located elsewhere or effective plans for reducing domestic consumption might be implemented. In any case, the SPR certainly could help buffer the consequences of rapid increase in U.S. military consumption.

It is not the intent of this study to comment on the tremendous fuel supply problems facing the U.S. in a limited war. Issues such as refinery capacity and transport availability for getting fuel supplies to various theaters are beyond the scope of this paper. Nevertheless, in summary, from a strict oil supply perspective, several facts present themselves. First, the increases in total consumption can be met using oil available in the Western Hemisphere and other non-Persian Gulf suppliers. Second, it would be desirable to maintain the shortest SLOC's possible for importing oil to the U.S. Third, if domestic conservation is effective, the drop in demand through civilian conservation would be close to the increase in consumption due to military demand. A 50% drop in oil demand within the transportation sector would free up nearly 15% of total domestic demand for other purposes. Finally, the delivery of oil production from Alaska also assumes great significance and sufficient military action would be necessary to ensure the safe maintenance and distribution of Alaskan oil supplies.

C. Unlimited War.

If the U.S. were to become involved in a global war, the ramifications for the U.S. supply of oil are somewhat easier to estimate. In the first case, it is assumed that a global war would be fought with the complete backing of the U.S. population. If this is the case, the need for conservation and restrictions on domestic, civilian use of oil reserves would be easier to institute. Again, a 50 percent decrease in the amount of oil consumption by the transportation sector would free up approximately 15 percent of total U.S. demand for military use. Under the scenario of a global war, it will also be assumed that the Trans-Alaska pipeline will be subject to interdiction as will any oil shipments over the various SLOC's. Under these conditions, it would be extremely difficult but not impossible to meet U.S. demand using internal production from the Lower 48 states combined with oil obtained from the Caribbean Basin. A portion of U.S. Navy assets would be required to ensure the survivability of oil shipments, both crude and refined, from the southern portions of the Basin to the U.S. or other destinations. The advisability of maintaining the shortest SLOC's possible becomes highly advantageous.

The existence of the Strategic Petroleum Reserve becomes critical especially in the case of a global war. If a short war is assumed, the SPR would provide a short term cushioning effect to help sustain U.S. domestic production efforts. Assuming military demand raises to 20 percent of U.S. total demand, when filled to capacity the SPR would provide a 218 day supply of oil if used for the military only. In the case of a longer term global war, demand on U.S. domestic sources of oil would be severe especially if they fall very much under an output of +/- 8 MMBOPD, which is the expected result of current trends in U.S. oil supply. The projected needs of both a limited and unlimited war scenario both require the maintenance of a strong U.S. domestic oil production base, lending support to the idea of protecting the U.S. industry at this time.

CHAPTER V

RECOMMENDATIONS

The U.S. is today at an important crossroads regarding the state of the domestic energy situation. The progress the U.S. has made since 1978 in reducing demand, conserving oil use, and increasing production is in danger of being eliminated in the face of lower worldwide prices for oil. Numerous agencies and associations including the AAPG, the American Petroleum Institute, and many organizations representing independent oil producers in the U.S. have called for governmental help in establishing a coherent, sensible energy policy. Many of the recommendations for assistance for the domestic industry involve the imposition of an import fee on oil supplied by foreign nations.

In light of the evidence presented in this report, a higher price for oil in the U.S. would have several important consequences. First, a higher price would encourage the maintenance of all stripper well production in the U.S. This important segment of American production is being diminished right now as inexpensive foreign supplies undercut profitability. Second, a higher price for oil encourages continued conservation and minimizes wasteful use of an important resource. Third, a higher price would encourage the exploration for oil in the Lower 48 states of the U.S., Alaska, South America, and in other areas friendly to the long term objectives of U.S. policy. Fourth, looking at oil supply from a global standpoint, a high price of oil encourages the development of alternative sources of energy. These sources are not limited to coal and other carbon based energy supplies, but also geothermal, solar, hydroelectric, and other nuclear forms of energy. The amount of oil resource in the earth is finite, though larger than generally thought, and the transition to non-carbon forms of energy are in the long term an absolute necessity. By encouraging this transition earlier, we are lessening the impact of fossil based fuels on the environment. In line with arguments presented earlier, a minimum price of $26.00 per barrel should be established to ensure the viability of the U.S. oil industry, and its ability to maintain production.

Any imposition of an oil import fee would have to take into account the need to encourage supply from South America. The opportunity to forge a strategic consensus with South American nations such as Mexico, Venezuela, Columbia and Peru could work to the long term advantage of improved U.S. - South American political and economic ties. A selective imposition of the import fee would allow oil from these suppliers to rise to the level of oil in the U.S. encouraging their production and stimulating the search for additional reserves. In line with these concerns, attention must be given in all operational planning to guarantee the security of SLOC's to the Caribbean Basin and other South American ports.

It is easy to use oil as a weapon once a nation is dependent on it for its economic well being. It is certainly not in the best interests of the U.S. to be dependent on unstable and potentially unfriendly sources of supply. With a lag time of approximately three to four years between the stimulus to explore and the actual production of oil, the U.S. should not allow the emasculation of the oil industry for short term gain.

It is therefore recommended that the Department of Defense support efforts to impose an oil import fee with adjustments for oil imported from South America. As a matter of vital national interest, DOD should also encourage conservation programs and the active exploration for additional domestic oil reserves. In the long term, DOD should support initiatives to forge a strategic consensus with the nations of South America regarding the development of oil resources and the economic well being of the entire hemisphere. DOD should develop operational plans to ensure the security of key SLOC's by which imported oil reaches the U.S.

APPENDIX I

CURRENT U.S. RESERVES AND RESOURCES

A. Historical Development of the Present U.S. Reserve Position.

Historians of the world oil industry credit the initial inception of the world oil industry with the 1859 discovery of oil at Titusville, Pennsylvania, by "Colonel" Edwin Drake. His well, drilled to a depth of 69.5 feet, recovered oil in an area known for natural oil seeps and assured the existence of the Pennsylvania Rock Oil Company. The investment initially provided by the Company promoters totalled $1000 dollars.[1] This initial discovery led to the world's first oil boom as it then appeared economically feasible for kerosene refined from crude oil to replace whale oil for lamps. In 1860 the price of oil was 20 dollars per barrel, in 1861 it plummeted to 10 cents per barrel; the first oil "boom-bust" cycle.

Exploration rapidly shifted to other areas of the country.Early drilling in the Los Angeles area in 1892 resulted in the discovery of a reservoir in the Beverly Hills area. A rash of other discoveries in the Elk Hills, Long Beach, and Bakersfield areas enable California to produce 25% of the world's oil in the early 1920's. Other areas, notably Oklahoma and Texas, also enjoyed early drilling success and the 1901 discovery of Spindletop, near Beaumont, Texas, set the stage for Texas' eventual emergence as the leading oil state by 1928. The gusher which marked the discovery of Spindletop was so intense it stampeded grazing cattle over 4 miles away.[2] It is interesting to note that Patillo Higgins, the gentleman who was responsible for discovering Spindletop, was considered a "madman" by his more skeptical neighbors. Standard Oil, already the nation's largest oil company, considered the entire southeastern Texas prairie to be non-prospective and was cut out of the development of Spindletop, "one of the great discoveries of all time."[3] Companies like Gulf Oil, Sun Oil and Texaco were founded on the success of Spindletop. The lack of field conservation, poor safety practices and outright greed caused the Spindletop reservoir to be depleted too rapidly, and by 1905 was abandoned as non-productive.

During the first decade of this century, John D. Rockefeller's Standard Oil Company controlled 90% of domestic refining capacity and its distribution. Hostility towards the monopolistic practices, secrecy and greed of Standard Oil was great: muckraking journalists, populist politicians, the legislators of Ohio and Texas all combined to influence the Supreme Court in 1911 to dissolve Standard Oil into several smaller companies.[4] The descendants of these companies include Exxon (Standard Oil of New Jersey), Mobil (Standard Oil of New York), Chevron (Standard Oil of Southern

California), Amoco (Standard Oil of Indiana), and Sohio (Standard Oil of Ohio).

Another important occurrence for the oil industry in the 1910 to 1915 period was the development of the electric light bulb. Electric lighting, based on electricity generated in coal fired steam generator plants, replaced oil based lighting. Another bust period was imminent, but the rapid development of the internal combustion engine during World War I provided new demand for refined oil products. Continued rapid production of U.S. oil resources during the 1920's resulted in a realization that some forms of regulation or conservation were required. In 1929, amid glowing reports of huge American oil reserves publicly touted by the industry, the Federal Oil Conservation Board warned that

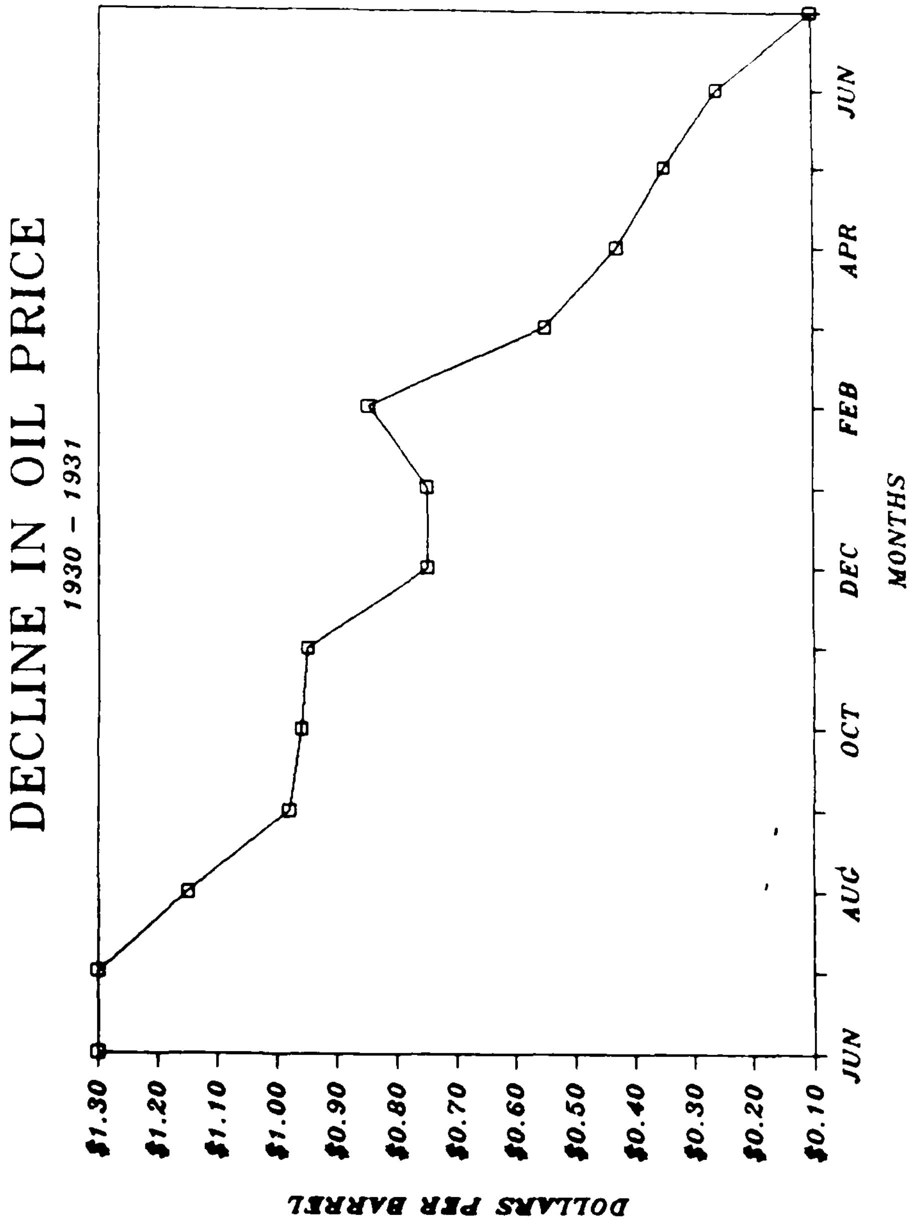
> According to the present opinion of our best petroleum geologists, our total resources, instead of being 68 percent of those of the world, are not more than 18 percent. If our petroleum reserves are not to be drawn upon at a faster rate than those of other countries, our resources should be several times larger. The obvious inference is that the United States is exhausting its petroleum reserves at a dangerous rate. If the international comparison is made, this country is depleting its supply several times faster than the rest of the world. How real is the danger expressed in this fact, and what remedy can be devised are questions confronting the American people as they play for the future. . . . The depletion rate of our own resources can be brought into accord with that of foreign resource in only one way -- importing a greater quantity of crude petroleum.5

Early regulations were aimed at achieving two goals: (1) protecting the rights of those who owned the oil in the ground (in America, those who own the land surface own the "mineral rights" of the ground beneath the surface as well: this ownership must first be purchased or leased by a company in order to produce oil), and (2) avoiding the waste due to a too rapid drawdown, or depletion of the reserves in place. This may be accomplished by establishing minimal spacing rules for wells and to try to assure sustainable depletion of a pool or reservoir through the cooperation of its producers.

East Texas Field, drilled by "Dad" Joiner in 1930, discovered what was then the world's largest series of oil reservoirs to date. Unfortunately, the reserve glut produced by East Texas combined with other discoveries in nearby Oklahoma and South America forced the price of oil down once again. Figure 9 depicts the decline in prices between 1930 and 1931.

During the 1930's and the 1940's, exploration in the U.S. continued to find new reserves of oil. It seemed as if the U.S. indeed possessed an inexhaustible supply, but in 1948 something unusual occurred: the U.S. imported more crude than it exported, the majority of the imports coming from fields in Venezuela. Another shock occurred in 1956 when USGS geologist M. King Hubbert predicted, to a widely skeptical audience of oil industry executives, that U.S. production would peak in

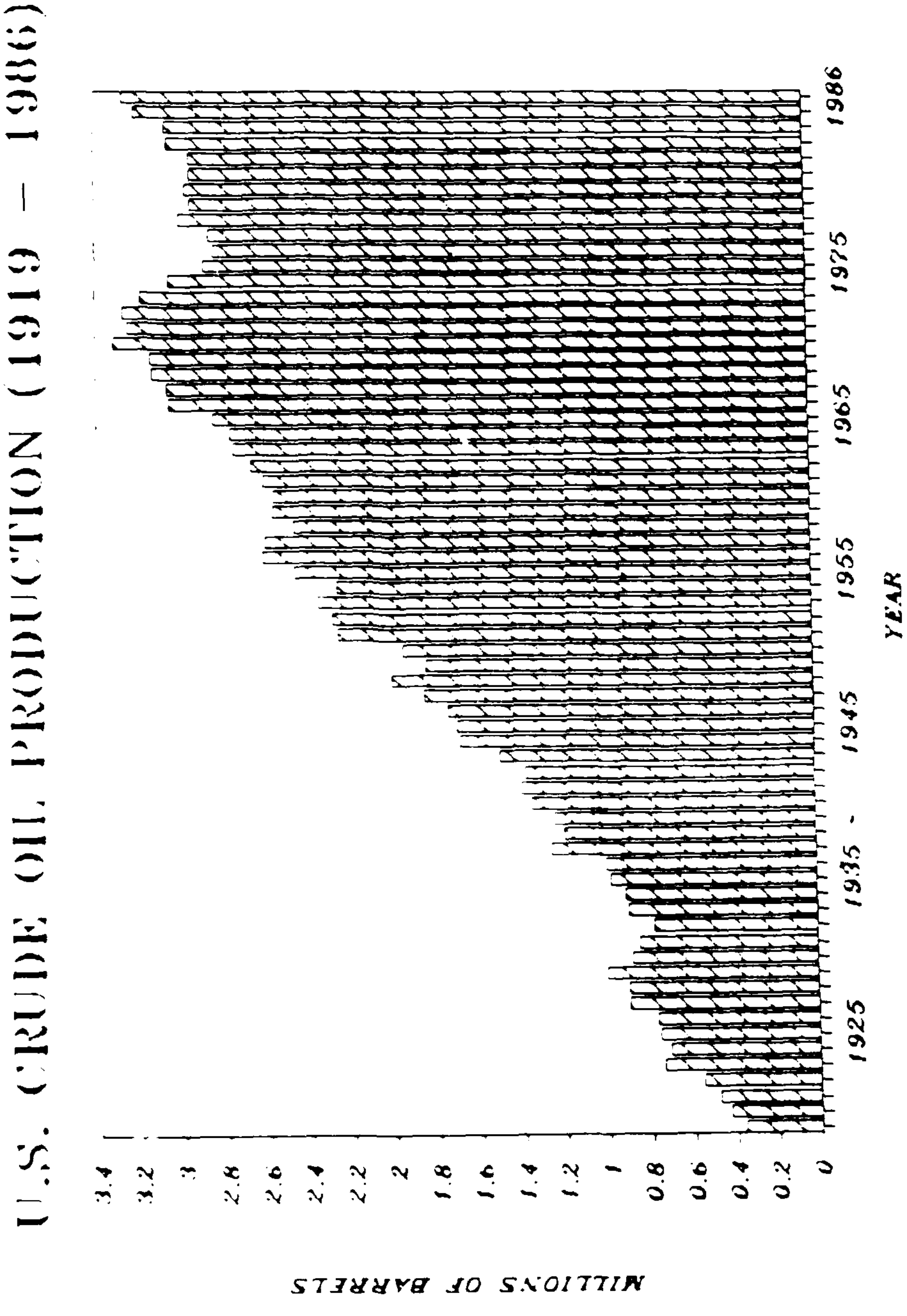
FIGURE 9



Source: James McGovern, The Oil Game, (New York: McGraw Hill, 1983), p.29.

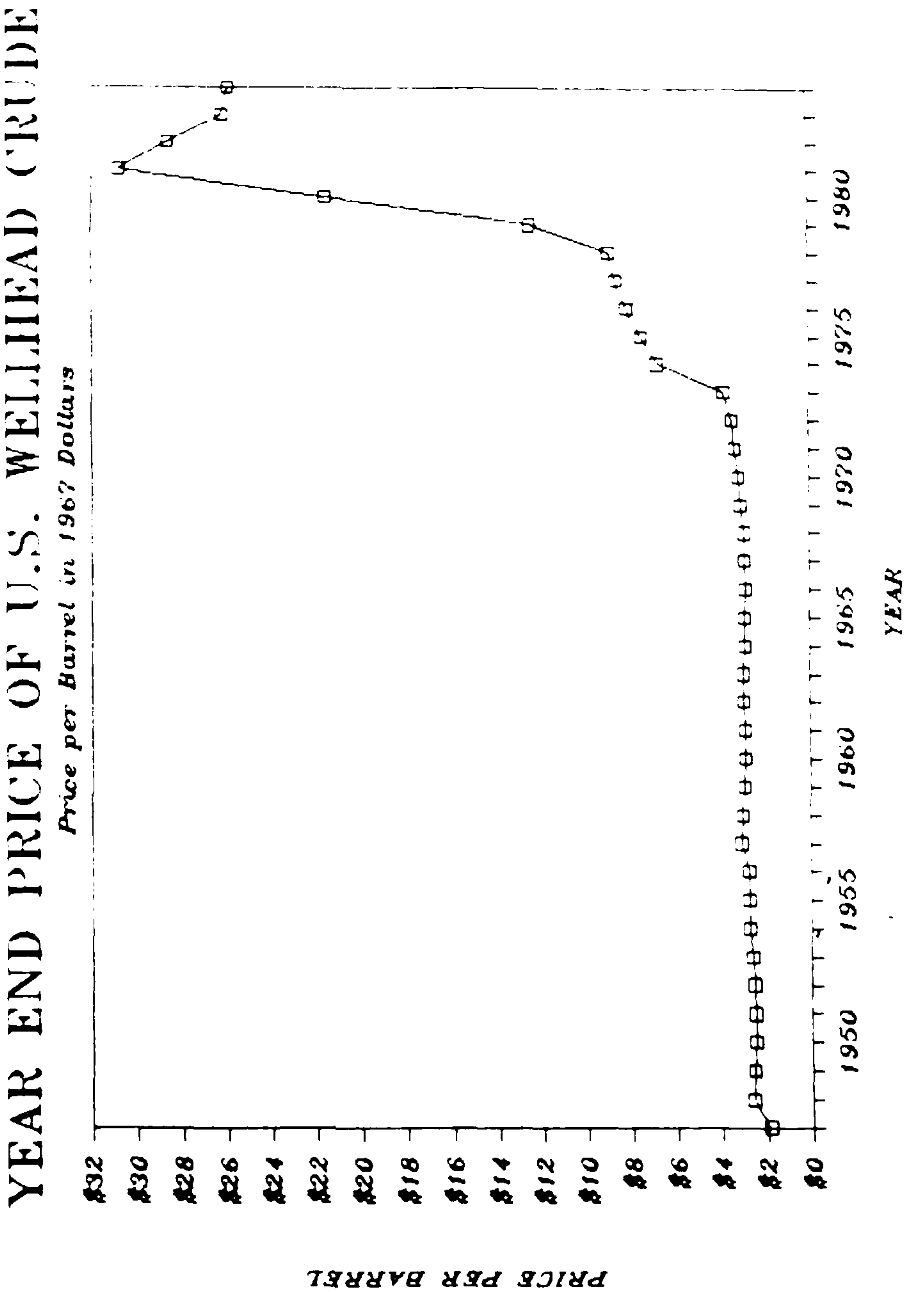
1970 and decline steadily thereafter.[6] Even with the discovery of Prudhoe Bay, a 10 billion barrel field (recoverable) on the North Slope of Alaska, the U.S. production of oil steadily declined after 1971. Figure 10 shows a downward trend from 1970 through 1977. Very significantly, 1977 reversed the downward trend in U.S. oil production. While there is no direct connection between replacing reserves with new oil discoveries and producing reserves, there is an indirect connection. Oil reserves in the ground are "assets" which are liquidated once they are produced and consumed? The ability to replace these assets is thus important to their owners. The successful ability to replace oil in the ground with new discoveries of oil can encourage producers to more fully produce their present reserves since it is anticipated that they will be replaceable.. Figures 11 and 12 depict an interesting reversal of trend. Figure 11 depicts the year end,price per barrel of oil in 1967 constant dollars for the period 1947 through 1984. Over the period 1947 to 1973, the price of oil was relatively stable. The first "oil shock" resulting from the 1973 Yom Kippur War and other economic factors is readily visible on the chart as is the second major oil price hike due to the curtailment of Iranian oil production during that nation's Islamic revolution. Figure 12 illustrates the percentage of annual production replaced by new reserve additions each year.

FIGURE 10



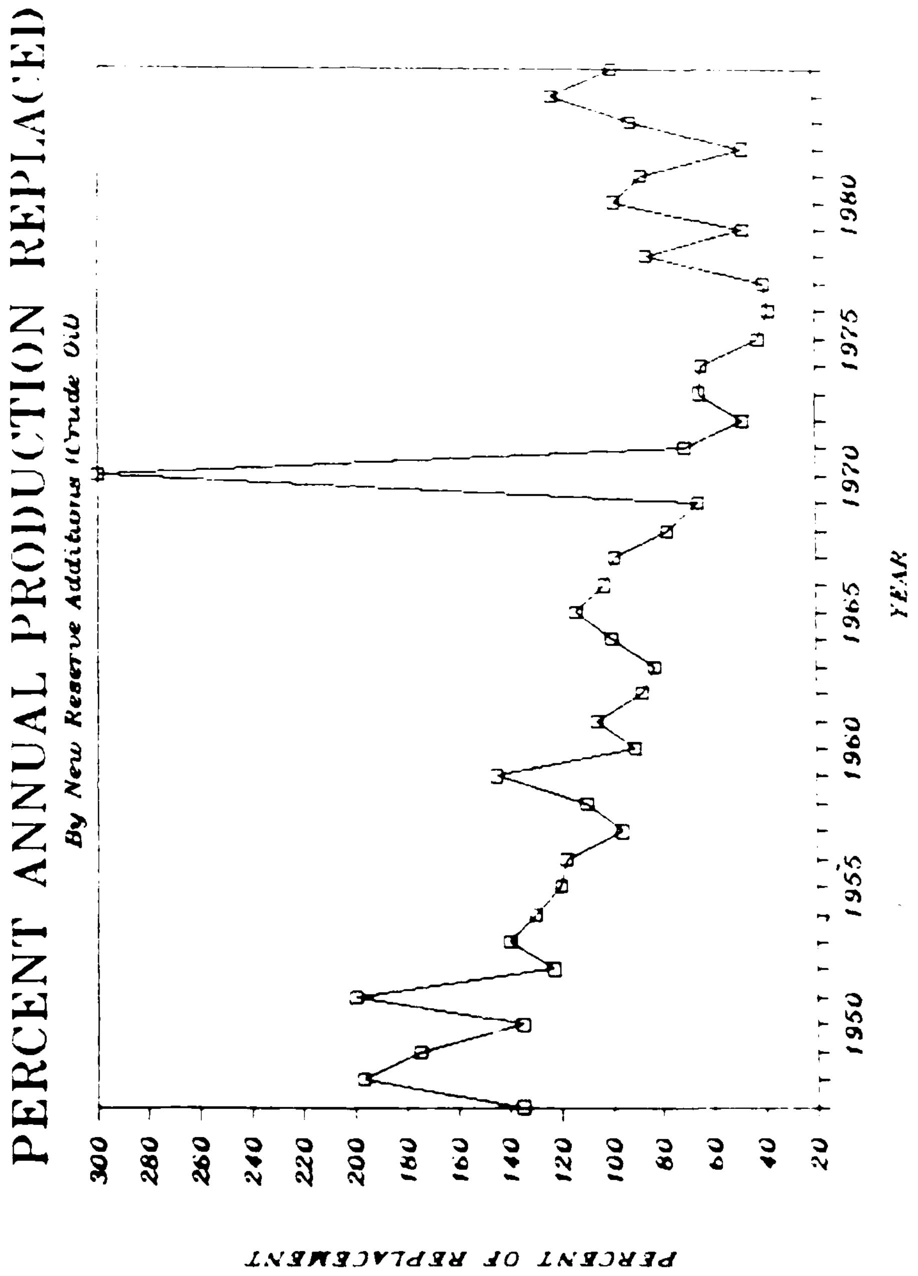
Source: American Petroleum Institute, Basic Petroleum Databook, (Washington: 1986), Sec. 1.

FIGURE 11



Source: American Petroleum Institute, Basic Petroleum Databook, (Washington: 1986), Sec. 1.

FIGURE 12



Source: American Petroleum Institute, Basic Petroleum Databook, (Washington: 1986), p. x.

This is an important illustration, because it shows how successful we are in extending our "reserve life". If a producer can discover the same amount of new oil in a given year as he has produced that year, there is no effect on year end reserve figures; the producer has replaced his reserves. This is equally true of the U.S. as a whole; every year the nation replaces 100% of its annual production, it is extending the life of its reserves. During the period 1977 through 1984, a new trend began to emerge. In response to the steadily rising prices depicted on Figure 11 and in anticipation of continued rising prices, U.S. oil producers were encouraged to replace a larger and larger percentage of annual production. In 1980, a study by the Congressional Budget Office predicted "the lowest likely price for a barrel of oil by 1990 will be $84 dollars."[8] Figure 13 summarizes this change in trend in response to higher oil prices illustrated in Figures 11 and 12. The key point to be made by this analysis is that despite gloomy predictions* about the steady decline of U.S. production and its ability to replace its reserves, this has not been the case since 1977.

The final question to be asked in this section on historical development of the current U.S. reserve picture is

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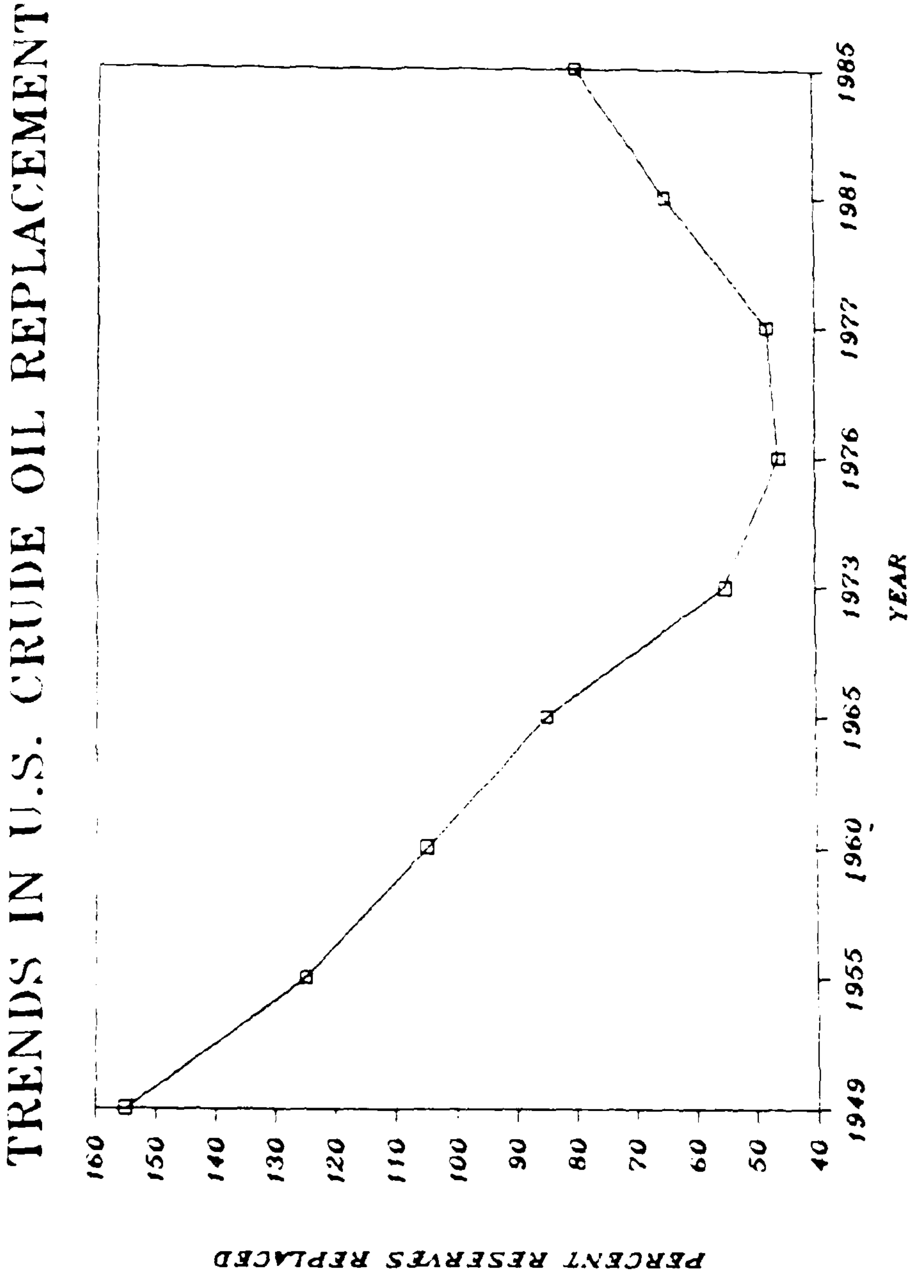
*For example, James McGovern wrote in 1981 that "The U.S. will not run out of oil next year, or the year after, but the production decline that began in 1970 will never be reversed."

FIGURE 13



Source: American Petroleum Institute, Basic Petroleum Databook, (Washington: 1986), p. x.

current U.S. reserves. Figure 14 depicts U.S. proved reserves of crude oil yearly as of 1 January for the period 1948 to 1986. Based upon current economic, geologic, and other technical constraints, the current proved reserves of U.S. crude oil are estimated to be 28 billion barrels of oil (BBO). This figure includes proved oil reserves in Alaska. Table X provides figures for various types of U.S. reserves with and without the addition of Alaskan reserves. Cumulatively, the U.S. has produced 127 BBO and is in first place in this category. Table XI lists the cumulative crude oil production for 16 nations. The key question remaining, then, is taking into account the indicated and inferred reserves illustrated in Table X how much oil resource does the U.S. still have to explore for?

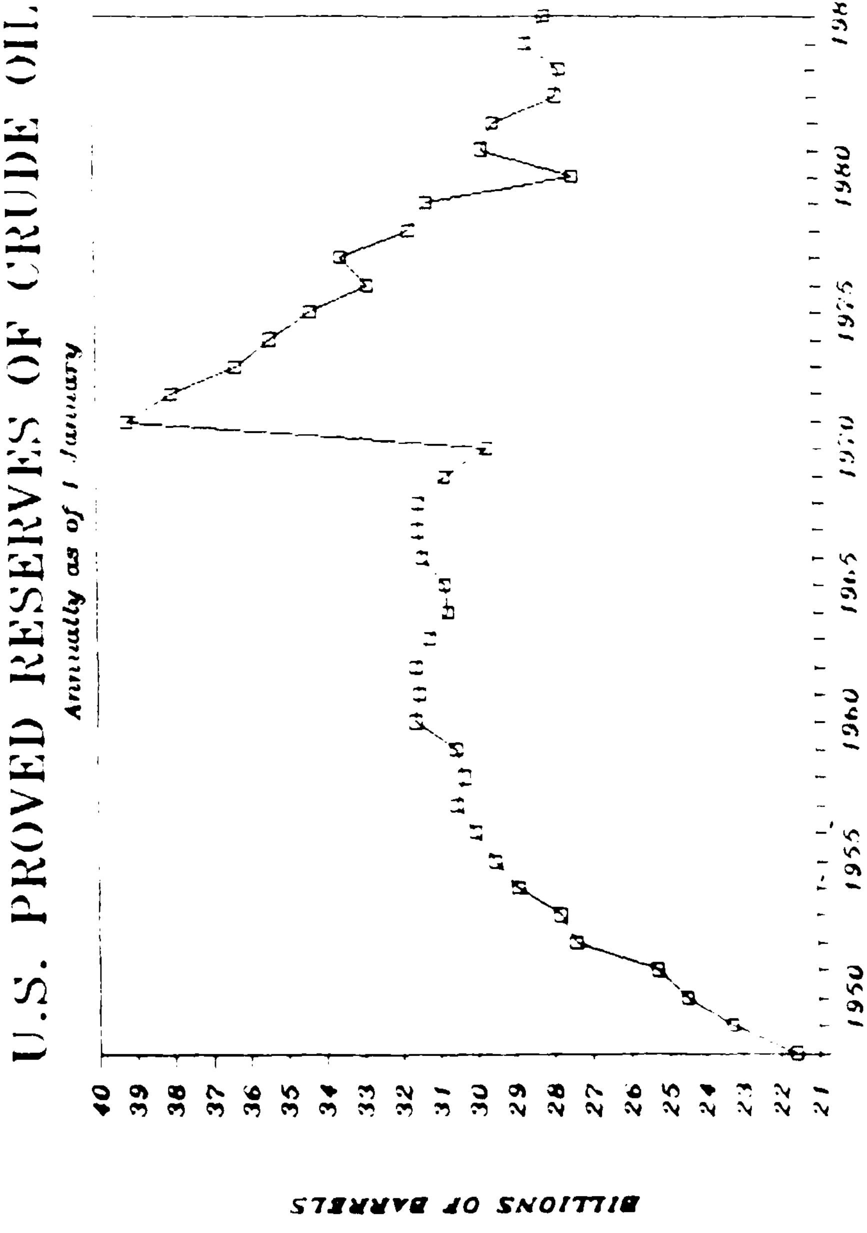
TABLE X

U.S. RESERVES OF CRUDE OIL AND NATURAL GAS LIQUIDS

	Alaska Included	
Crude Oil		Natural Gas Liquids
28.4 BBO	proved	7.9 BBNGL
3.6 BBO	indicated	1.5 BBNGL
23.4 BBO	inferred	6.5 BBNGL
	Without Alaska	
18.9 BBO	proved	7.6 BBNGL
3.6 BBO	indicated	-
18.2 BBO	inferred	-

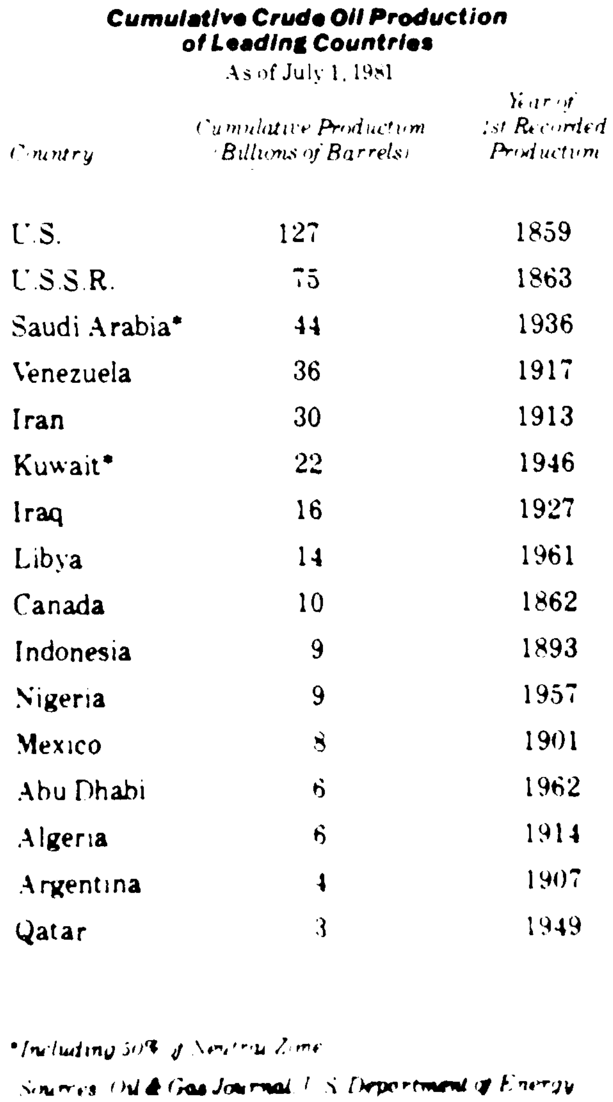
Current production is .016 BBO/day. Reserve Life at current production levels with no additions to the reserve base is 4.93 years.

FIGURE 14



Source: American Petroleum Institute, <u>Basic Petroleum Databook</u>, (Washington: 1986), Sec. 3.

TABLE XI



Cumulative Crude Oil Production of Leading Countries

As of July 1, 1981

Country	*Cumulative Production (Billions of Barrels)*	*Year of 1st Recorded Production*
U.S.	127	1859
U.S.S.R.	75	1863
Saudi Arabia*	44	1936
Venezuela	36	1917
Iran	30	1913
Kuwait*	22	1946
Iraq	16	1927
Libya	14	1961
Canada	10	1862
Indonesia	9	1893
Nigeria	9	1957
Mexico	8	1901
Abu Dhabi	6	1962
Algeria	6	1914
Argentina	4	1907
Qatar	3	1949

*Including 50% of Neutral Zone

Sources: Oil & Gas Journal, U.S. Department of Energy

Source: Exxon Company, USA, How Much Oil and Gas?, (New York: 1980), p. 15.

B. Geological Constraints on U.S. Oil Production and the Reserve and Resource Base.

One might automatically assume that since the U.S. is certainly a mature oil exploration province that little oil remains to be found. B. Grossling, addressing the issue of remaining world oil resources, in 1979 stated that over 2.4 million wells had been drilled in the U.S. -- and only .8 million in the rest of the world. Correcting these figures for wells drilled between 1980 and 1986 yields 2.9 million wells for the U.S. and about 1 million for the remaining world. In terms of prospective areas, that means that 6% of the world's oil potential area (the U.S.) has absorbed two-thirds of the drilling. Consider that in Latin America, a region containing 60% more sedimentary basin area than the U.S., only about 200,000 wells have been drilled. There are many factors contributing to this phenomena including political, economic, and even strategic prerequisites. The question that is important geologically is "why the industry continues to drill in the U.S. at all?" As mentioned earlier, there are two basic varieties of traps: structural and stratigraphic. The U.S. is well endowed with both kinds and combinations of each. Despite the intensity of drilling in the U.S., several new "frontier," or "near-frontier" areas have been opened since 1975. For example, 1975 marked the discovery of Pineview Field in northeastern Utah, near the Wyoming border. This field opened the entire western

Overthrust Belt to exploration. The complex structural geology of the region has, until then, baffled geologists and over 100 wells had been drilled in the immediate area with no apparent success. The Pineview discovery thus led to the discovery of the Whitney Canyon - Carter Creek field and East Anschutz Ranch field, both world class fields. Exploration off the coast of California resulted in prolific oil reserves in the Monterey Formation. One field, Point Arguello, has clearly found its place on the Oil and Gas Journal List of Giant Oil Fields (1986). Prudhoe Bay, on the North Slope of Alaska, was discovered in 1970. Comparison of its geologic features with those of surrounding areas suggests that there are other very prospective areas on the North Slope which have not yet been drilled. The January, 1987 issue of the AAPG Explorer discusses the significant oil potential of Nevada which, until recently, has been considered a marginally productive area. Earlier issues of the Explorer in 1986 discussed the new interest in the Mid-Continent Rift Zone, a belt of highly faulted and metamorphosed Precambrian (greater than .6 billion years old) and Cambrian (.6 to .5 billion years old) rocks stretching from Minnesota to Oklahoma. Many of these new prospective areas may remain unproved, others may result in significant oil fields. The main point is that the highly varied geology of the U.S., containing both limestone reefs and sandstone bodies in sedimentary basins, both onshore and offshore, and other prospective exploration targets allows for a large variety of drillable prospects. The U.S. is not limited to searching for only one type of reservoir. While this is true of many other sedimentary basins worldwide, it does not detract from the U.S.'s ability to produce significant amounts of crude oil well into the next century.

C. Projected U.S. Reserves.

As has been discussed earlier, the backdrop against which the life expectancy of U.S. reserves must be measured is how much undiscovered oil resources remain in the U.S. As is usually the case, given the uncertainties of estimating reserves and resources, various opinions exist as to how much oil remains to be tapped in the U.S.

M. T. Halbouty, perhaps typifying the optimism of geologists, suggests that:

> The U.S. alone may have as much as 200 billion barrels of undiscovered -- potential -- recoverable oil and natural gas liquids, and some 1,000 trillion cubic feet of natural gas. While small compared with the potential of the Middle East and the Communist block, that is still a tremendous amount of oil and gas.
>
> To put these figures in perspective, the U.S. petroleum potential is five times our current proved reserves of crude oil and natural gas liquids. And it is more oil and gas than our country has produced in the entire 120 year history of the U.S. petroleum industry.9

The USGS last estimated domestic undiscovered recoverable resources in 1980. They calculated that these resources range between ". . . 64 and 105 billion barrels of crude oil and 475 to 739 trillion cubic feet of natural gas. These estimates are stated at the 95 and 5 percent probability levels of occurrence, respectively."[10] The median (50%) resource estimate is, by calculation, 84.5 billion barrels of recoverable crude oil.

The President of the AAPG, William L. Fisher, recently stated that additional oil reserves potential in the lower 48 states may be 100 billion barrels of "unrecovered but conventionally moveable" oil. He also suggested that there may be more than 200 billion barrels of heavy oil and other kinds of oil incapable of recovery by primary means.[11] These figures are all in addition to current estimates of U.S. proved reserves of 28.4 BBO, the figure cited in Table X. Much of the remaining oil to be discovered does not rely upon novel, unconventional, or uninvented technology. As pointed out by Fisher, much of his estimate is based upon exploitation of infill drilling and extension drilling within known oil producing areas. There is an old adage in the oil business that the best place to look for new oil is where it has already been discovered. In the case of future U.S. reserves. this may well be the case. Key prospective areas within the U.S. include the North Slope of Alaska, offshore California, the Overthrust Belt of Wyoming-Idaho-Utah, and the Eastern Overthrust Belt from Vermont and New York southwards to Tennessee. Additional reserves, according to the Fisher model, will also be found in mature areas such as Texas, Oklahoma, and the Illinois, Michigan, Williston, and the Denver-Julesberg basins.

The key point to be recognized here is that in addition to our current proved reserves of 28.4 BBO, the U.S. alone, combining geologic optimism with a dose of reality using the USGS figures, probably has 120 billion barrels of recoverable crude oil remaining to be found.

APPENDIX II

CURRENT PERSIAN GULF RESERVES AND RESOURCES

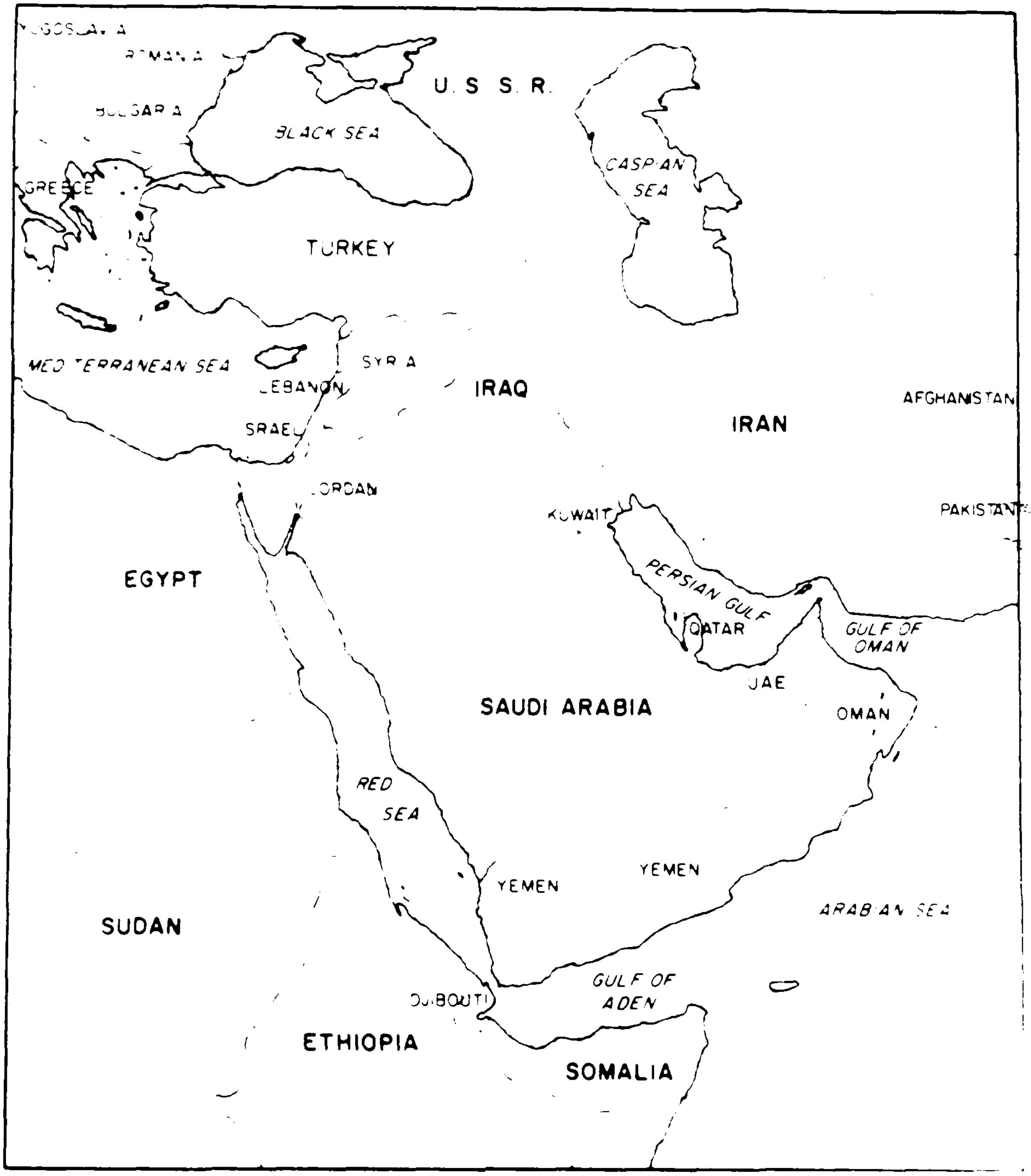
A. Historical Development of Present Persian Gulf Oil Reserves.

The proximity of the Middle East to oil-starved Europe prompted early exploration around the turn of the century. Europe was producing little or no oil at a time when the U.S. was producing 50% to 65% of the world's oil and filling 25% of non-U.S. demand worldwide. European Russia had only limited productive capabilities, and the growing need for oil reserves led Europeans to the Middle East where extant oil seeps and natural gas-flares provided indications of hydrocarbons.

The beginnings of the oil industry in the Middle East were in Iran (see Figure 15) where William D'Arcy, a British businessman, began drilling a series of exploratory wells in 1901. A string of dry holes, drilled under adverse conditions, almost ended the project, but in 1909 D'Arcy struck oil at Masjid-i-Suleiman, near Abadan. This discovery led to the formation of the Anglo-Persian Oil Company Limited (1909) and Iran first exported its crude oil from Abadan in 1912. At the start of World War I, First Lord of the Admiralty Winston Churchill recommended that Britain acquire a majority interest in Anglo-Persian which it did in 1914. Over the course of World War I, output tripled. Development of Iran's oil fields continued throughout the 1920's. Additional

FIGURE 15

THE MIDDLE EAST REGION



AD-A180 277 THE STRATEGIC IMPLICATIONS FOR US - PERSIAN GULF 2/2
RELATION ON DOMESTIC AN.. (U) NAVAL WAR COLL NEWPORT RI
ADVANCED RESEARCH PROGRAM S S KAPLAN MAR 87
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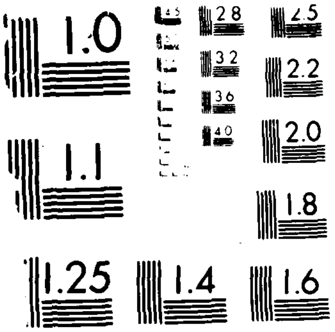

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

[illegible]

European companies desiring concessions in the Persian Gulf began exploring for oil in northern Iraq, led by the Turkish Petroleum Company (TPC) owned by British, French and Dutch concerns. U.S. interest in the region also began at this time; the warnings issued by the Federal Oil Conservation Board in 1929 and quoted in the preceding chapter came from the fear of imminent oil shortage in the U.S. It was also this concern which prompted the U.S. State Department to request "equality of commercial opportunity" in Iraq. The earliest exploratory ventures in Saudi Arabia were undertaken in 1923-24 by a British company, but their efforts were unsuccessful. In late 1927, oil was discovered at present day Kirkuk field in Iraq. This field, which has attained super-giant status, stimulated tremendous interest in the oil resources of the Persian Gulf. The next area to receive attention was the tiny island of Bahrain about 25 miles from the coast of Saudi Arabia. The first well drilled there, in 1932, discovered oil. This was the first participation for an American Company in the region. The operator for the discovery well was the Bahrain Petroleum Company, a wholly owned subsidiary of Chevron (SOCAL). This discovery encouraged Chevron to look further: in 1933 it was granted exploration rights by King Abdul Aziz ibn Saud for large areas of central and eastern Saudi Arabia. Texaco joined with Chevron by buying into the Bahrain Petroleum Company, and in 1938 the consortium that would later become the Arabian American Oil

Company (ARAMCO) discovered oil at Damman, in Saudi Arabia. Also in 1938, Kuwait Oil Company, owned by Gulf Oil and Anglo-Iranian (which later became British Petroleum), discovered the super-giant Burgan field. With original oil-in-place estimates of 190 BBO and 66.5 billion barrels of ultimately recoverable crude oil, Burgan is the third largest oil field in the world, exceeded only by Ghawar Field in Saudi Arabia (See Figure 16) (83 BBO recoverable reserve) discovered in 1948, and the Venezuelan Orinoco Heavy Oil Belt, with an estimated recoverable reserve base of 200 billion barrels of oil. In 1940, oil was discovered at Dukhan, in Qatar, but was not developed until after the war. Although geologic factors encouraged significant future exploration in the Gulf area, the onset of World War II set back exploration and development efforts in the region despite the initiation of construction for an oil refinery in 1943. The U.S., fearing rapid depletion of its own oil reserves by the war effort, wanted to establish additional source of refined product and built the original Ras Tanura refinery, completing it in 1945. The 50,000 barrels of oil per day (BOPD) refinery gave rise to the huge refinery complexes found in the Persian Gulf today, including those at Kuwait, Bahrain, and Ruwais. Figure 17 outlines the phenomenal rise in oil reserve discoveries in the

FIGURE 16

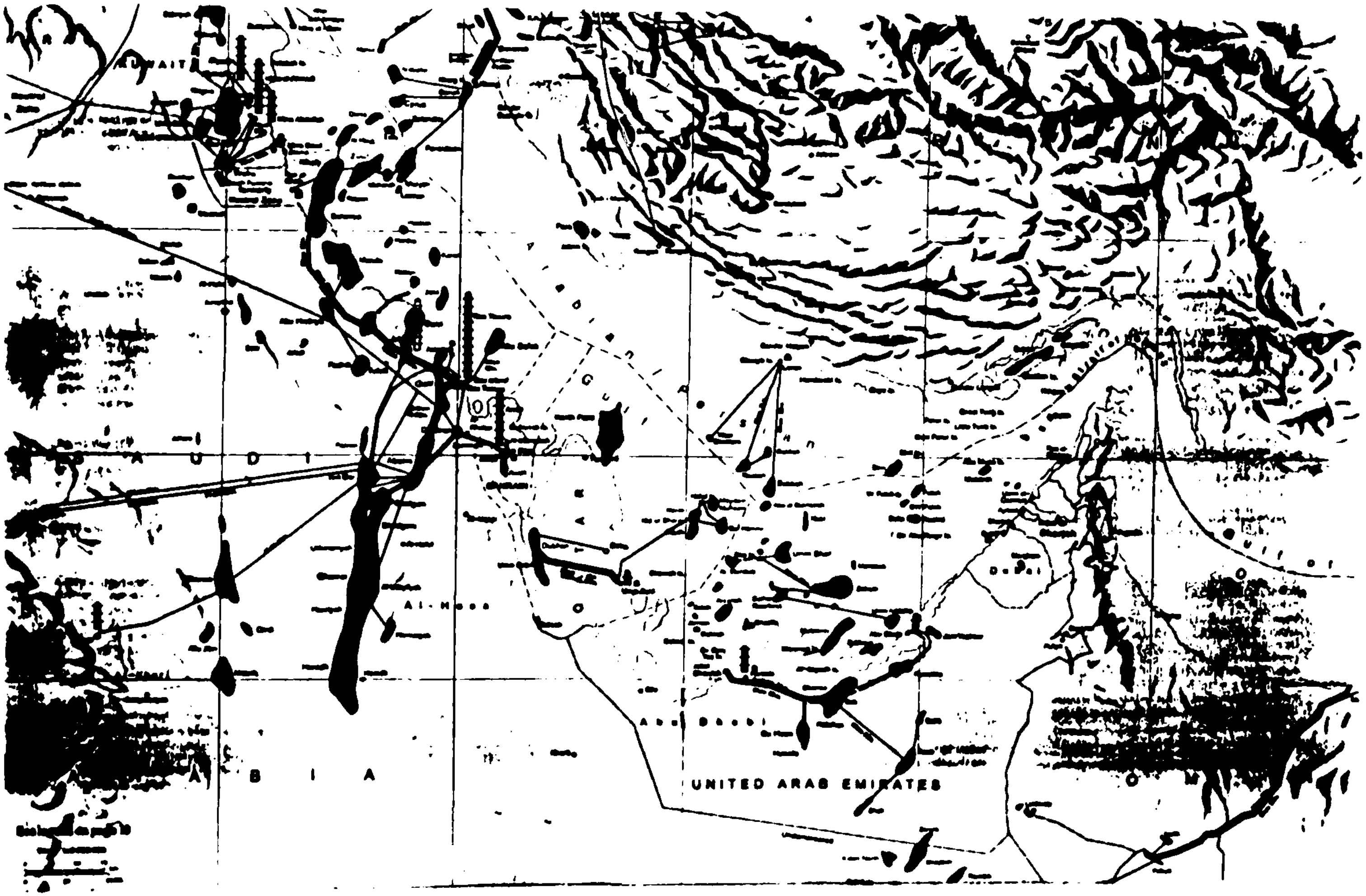
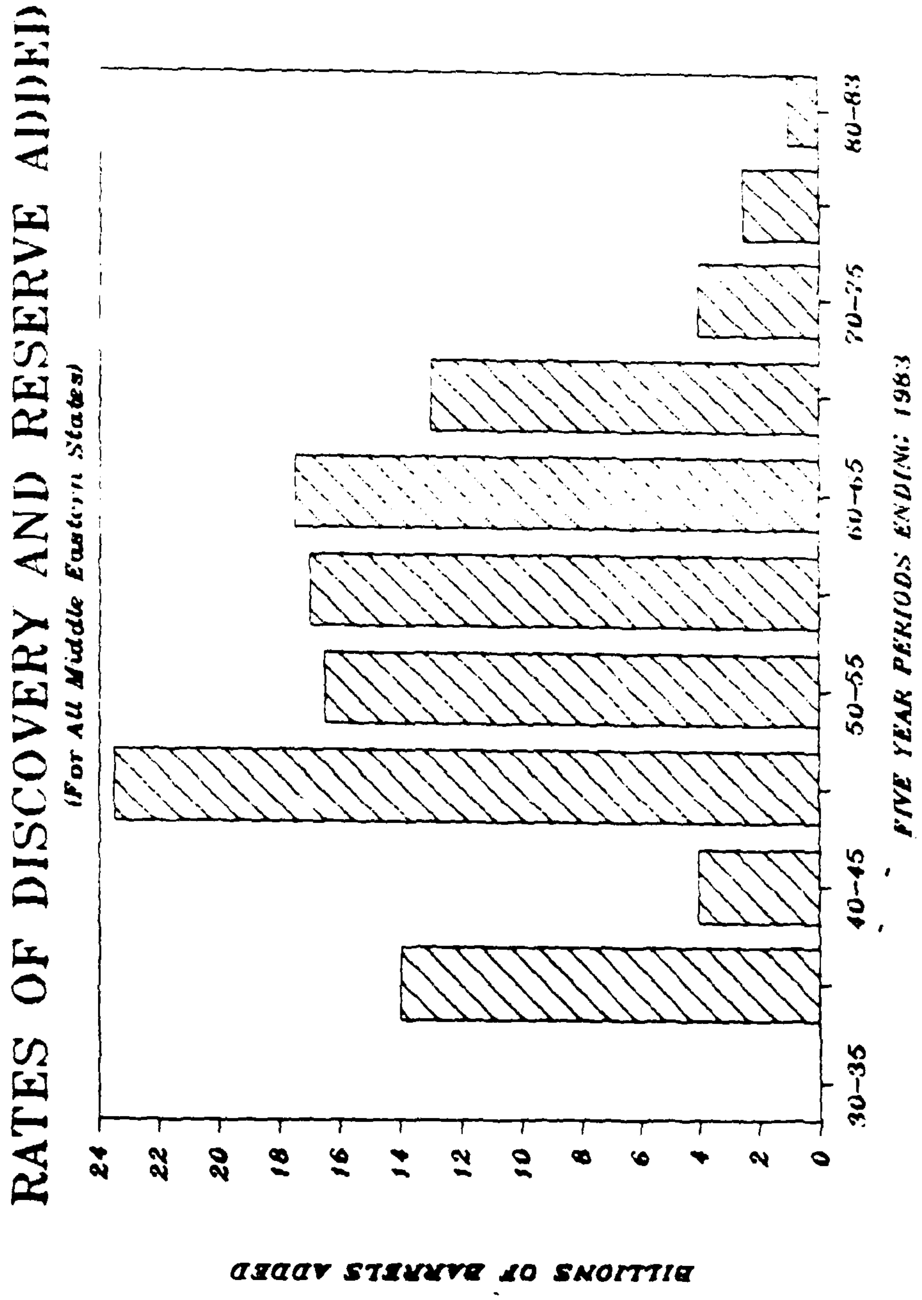


FIGURE 17



Source: U.S. Department of the Interior, U.S. Geological Survey, Circular 881, (Washington: Govt. Print. Off., 1982), pp. 1-9.

Middle East Region (the Persian Gulf plus Egypt) region for the period 1930-1983.

Estimates for amounts of crude oil reserves in the Persian Gulf region vary considerably, but the Energy Information Agency (EIA) estimates of known proven reserves are based upon considerations of field data, geology, and production history. Table XII summarizes these figures.

TABLE XII

PERSIAN GULF OIL RESERVES

Country	Estimated Proved Reserves As of Jan. 1 (BBO) 1980	Estimated Proved Reserves As of Jan. 1 (BBO) 1984
Bahrain	0.2	0.2
Iran	58.0	51.0
Iraq	31.0	43.0
Kuwait	68.5	66.8
Oman	2.4	2.8
Qatar	3.8	3.3
Saudi Arabia	166.5	168.9
United Arab Emirates	29.4	32.3
Total	359.8	368.3

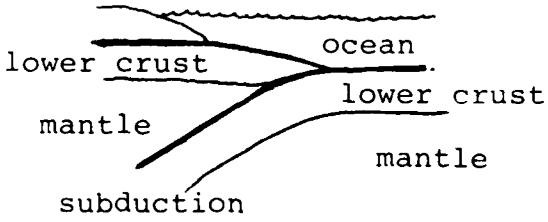
Source: U.S. Department of the Interior, United States Geological Survey, Circular 881, (Washington: U.S. Govt. Print. Off., 1980), pp. 8-9.

B. Geology of the Persian Gulf Region and its Impact on Oil Reserves.

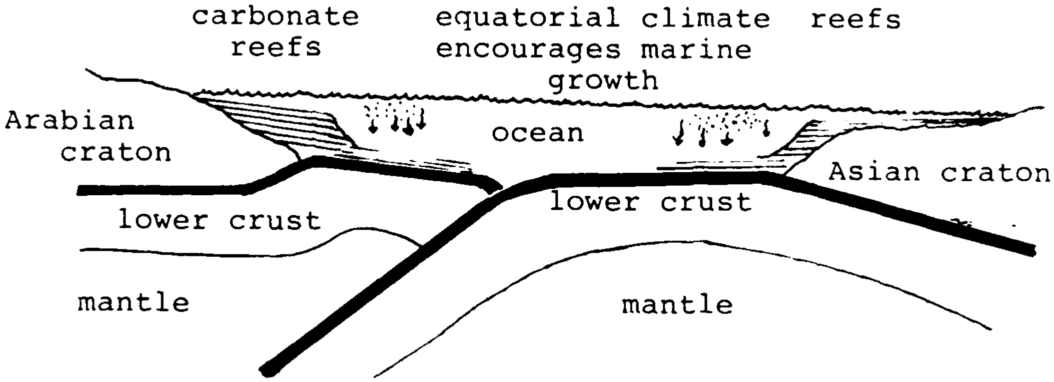
The geologic theory of Plate Tectonics provides a framework within which the unique circumstances surrounding the accumulation of hydrocarbons in the Persian Gulf took place. For the purposes of this paper, only a very simplified discussion will be provided. The Arabian craton (a craton is an ancient continental core, like the Canadian Shield, consisting of Precambrian igneous and metamorphic rocks of greater than .6 billion years of age) was attached to the northeast side of the African craton over most of geologic history. From a position near the South Pole, both cratons slowly drifted northwards. This slow northward movement enable the basin adjacent to the northeast side of the Arabian craton to be located near the equator over most of Phanerozoic (advanced life) time. It was the optimal conditions of equatorial climate which allowed for the prolific growth of organisms in the seas to the northeast of the advancing Afro-Arabian Shield. Over time, deposits of these organisms collected in the vicinity of the modern day Persian Gulf. The basin in which these organic-rich sediments were accumulating was relatively quiescent (see Figure 18) both structurally and in terms of environment. As the Arabian Shield began to approach the Asian landmass, however, a "collision" occurred with its characteristically complex geological ramifications. The resulting collision formed the Zagros Mountains foldbelt

FIGURE 18

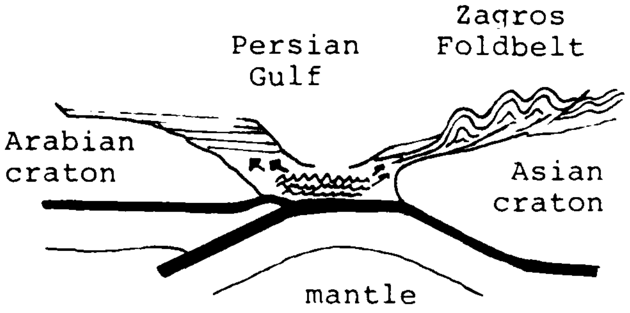
SIMPLIFIED SCHEMATIC DIAGRAM DEPICTING THE EVOLUTION OF THE ARABIAN - IRANIAN BASIN



Stage I - the Arabian Craton drifts slowly northwards



Stage II - carbonate reefs develop on the seaward edges of the cratons while organic rich sediments accumulate offshore



Stage III - the collision with the Asian craton causes the organic-rich source rocks to generate petroleum under conditions of increased temperature and pressure. The oil migrates upward into the carbonate reservoirs.

of southern Iran and produced the thermal conditions favorable for the generation of petroleum from the organic-rich sediments northeast of the Arabian craton. The petroleum generated flowed upwards from the source beds in front of the Arabian Shield into cavernous limestone reefs formed immediately adjacent to the Arabian landmass under sub-littoral conditions. That source material closest to the Iranian side of the Gulf was subjected to higher temperatures and pressures and was "distilled" beyond the oil stage, forming natural gas. If one looks at a map of oil and gas field distribution around the Persian Gulf today, it is possible to see a trend of increasing gas production proceeding north from the Arabian craton onto the central platform of Iran. The key point to realize is that the conditions for oil generation in the Persian Gulf were ideal over geologic history, resulting in what is probably the world's single richest petroleum province today.

Major "plays," or reservoir targets, in the Persian Gulf include: (1) the Upper Cretaceous and Tertiary Play (Asmari Limestone) concentrated in the Zagros Mountain Foldbelt, (2) the Lower and Middle Cretaceous Sandstone play (Burghan Sandstone) centrally located in the Arabian-Iranian basin, (3) the Lower and Middle Cretaceous Limestone play located in southeastern Saudi Arabia and the United Arab Emirates, (4) the Jurassic Play (mixed calcite cemented bioclastic, oolitic and sandy deposits) located in northeast Saudi Arabia, and (5) the Permian play, with the Khuff platform carbonate serving as reservoir and located in the south-central Arabian Gulf. Of these 5 plays, only the Lower and middle Cretaceous sandstone play is a non-carbonate play. Burgan field is located in this play area where the Burghan Sandstone contains porosities of 10% to 30% and possesses excellent permeability. The thickness of the sandstone wedge ranges between 200 and 1,200 feet. These plays, however, also provide a limit as to the amount of oil remaining to be discovered. Other than the phenomenal limestone reservoirs of the Gulf and the one sandstone play, the reservoir situation is little different from that of other areas and may, in fact, be poorer. There were few good clastic (sand) deposits in the Gulf area due to the slow drift of Arabia northwards. Examination of the schematic stratigraphic diagram presented by Masters, Klemme, and Coury[1] reveals that less than 10% of the reservoirs are clastic rocks. These deposits, which can form the "subtle traps" discussed earlier, are not widely present until the collision with Asia. These events occurred rapidly, geologically speaking, and good traps were not formed in these regions. The next section of this chapter will discuss the remaining petroleum reserves of the Persian Gulf region.

C. Predicted Persian Gulf Oil Reserves Based Upon Geological Constraints.

Numerous estimates exist regarding the amount of conventionally recoverable oil remaining to be discovered in the Persian Gulf region. The assessment provided by C. Masters, H. D. klemme, and A. B. Coury of the USGS takes into account many of the estimates provided elsewhere and represents a good point of reference. Table XIII summarizes the estimates for various nations in the Persian Gulf. Again, these figures are subject to wide interpretation. Nevertheless, consider that the median estimate of the USGS for remaining undiscovered U.S. oil reserves (84.5 BBO) compares unfavorably with the median USGS estimate for total Persian Gulf undiscovered reserves. Also bear in mind that the geologic constraints on Persian Gulf oil resources are a stronger upper limit on reserve estimates than they are in the U.S. where a greater variety of plays exists.

> Aramco has not made any significant findings of new reserves in Saudi Arabia since 1970 nor is it likely to do so.2

TABLE XIII

DISTRIBUTION BY COUNTRY OF UNDISCOVERED CONVENTIONALLY RECOVERABLE PETROLEUM RESOURCES IN THE ARABIAN-IRANIAN BASIN

Country	Crude Oil (BBO)		
	Low	Median	High
Saudi Arabia	24	57	111
Iran	11	26	50
Iraq	32	78	150
UAE	2	7	13
Oman	1	2	4
Qatar	-	-	-
Bahrain	-	-	-
Totals	72	174	337

Source: U.S. Department of the Interior, United States Geological Survey, Circular 881, (Washington: U.S. Govt. Print. Off., 1980)

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