

A. Reserves

One method for determining "How much oil is there?" is to respond with an estimate of the amount of oil reserves that can be proved from the known oil in place. Unfortunately, any estimate of oil reserves must be treated as an approximation for two main reasons. First, the volume of oil in place, even in a well-defined field, can never be precisely known. Second, even if the volume is known, estimates of production would depend on assumptions about the techniques that are used to recover the oil and the levels of success of these techniques.

For the United States, the American Petroleum Institute has adopted a conservative definition of proven (or proved) reserves. According to the American Petroleum Institute, proven reserves are "the estimated quantities of all liquids statistically defined as crude oil, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions".*

From this definition one infers that there are additions to proven reserves when new discoveries are made, recovery techniques are improved or when increases in the price of oil make additional fields economical to develop. In general, estimates of proven reserves for the U.S. include oil obtainable from primary and secondary recovery but not enhanced recovery.

* American Petroleum Institute, Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the U.S. and Canada, as of December 31, 1977, Vol. 32, Washington, D.C., June, 1978, p. 14.

It is important to recognize that while estimates of proven reserves are the most reliable estimates available in world oil statistics, most industry officials consider the estimate for the U.S. to be accurate only within 20%. A study published by the National Academy of Sciences in 1976 underscored the range of possible error in estimating the oil and natural gas reserves in an individual field. Two consulting firms were asked to check the Federal Power Commission estimates of gas reserves under lease in certain fields in the Gulf of Mexico. This was done for a random sample of 19 out of 168 fields. For 9 of the 18 fields checked the two consulting firms differed by a factor of over 100%.*

Outside the U.S., the American Petroleum Institute definition for proven reserves is not strictly followed in determining an estimate of reserves. In addition to proven reserves, an allowance is sometimes made for probable reserves. Probable reserves are those situated in a conjectural part of the field or reservoir which is as yet incompletely evaluated, undrilled, and where the characteristics of the producing zone and its fluid content are assumed favorable for commercial production.

One of the few private compilations of estimates of proven crude oil reserves is the Oil and Gas Journal.** The Oil and Gas Journal does not make its own independent appraisal; their estimates are obtained from oil

* National Academy of Sciences, Gas Reserves Estimation of Offshore Producing Shut-in-Leases in the Gulf of Mexico, Washington, D.C., March, 1976.

** Annually (in August) World Oil magazine releases its estimates for proven reserves for the beginning of the year. This estimate is comparable (typically 15% lower) with the Oil and Gas Journal. Lower estimates are normally given for Saudi Arabia, Iran, Mexico, and the North Sea resulting from a more conservative estimate of proven reserves.

companies, governments, and other petroleum organizations. Although these estimates are listed as proven reserves, many estimates include reserves that would not be classified as proven reserves according to the American Petroleum Institute definition. In particular, the Mexican proved reserves estimates, taken from the Mexican government oil company Petroleos Mexicanos, include 11 billion barrels for the Chicontepec field which would not be classified as proven reserves according to the American Petroleum Institute definition.

Non-communist proven crude oil reserves were estimated at approximately 550 billion barrels in December 1979 as shown in Table 1.

Several features of this estimate deserve mention. First the world's reserves are concentrated in a small number of countries. The eleven countries with reserves of over 10 billion barrels contain 482 billion barrels or over 87% of the non-Communist world's reserves. Saudi Arabia alone contains over 30% of the non-Communist world's reserves. These facts are illustrated graphically in Table 2.

The dominance of the Middle East region (Egypt, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Saudi Arabia, Syria, and United Arab Emirates) and of Arab OPEC (Algeria, Bahrain, Egypt, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, Syria, United Arab Emirates) is also apparent. The 362 billion barrels of reserves in the Middle East represent over two thirds of the non-Communist oil reserves while the 336 billion barrels in Arab OPEC represent approximately 60%. On the other hand the industrialized countries, which are the major consumers of oil, possess only 11%. A breakdown by geographical region of the world's oil reserves is illustrated graphically in Table 3.

TABLE 1

NON-COMMUNIST WORLD PROVED CRUDE OIL RESERVES

BILLION (10⁹) Barrels
January 1, 1980¹

OECD GROUP COUNTRIES

United States	26.5
Canada	6.8
Western Europe	23.4
Japan, Australia, N.Z.	2.1
TOTAL	58.8

NON-OPEC DEVELOPING COUNTRIES

Latin America	
Mexico	31.2
Other	7.3
Africa	7.2
Middle East	4.5
Asia	7.6
TOTAL	57.8

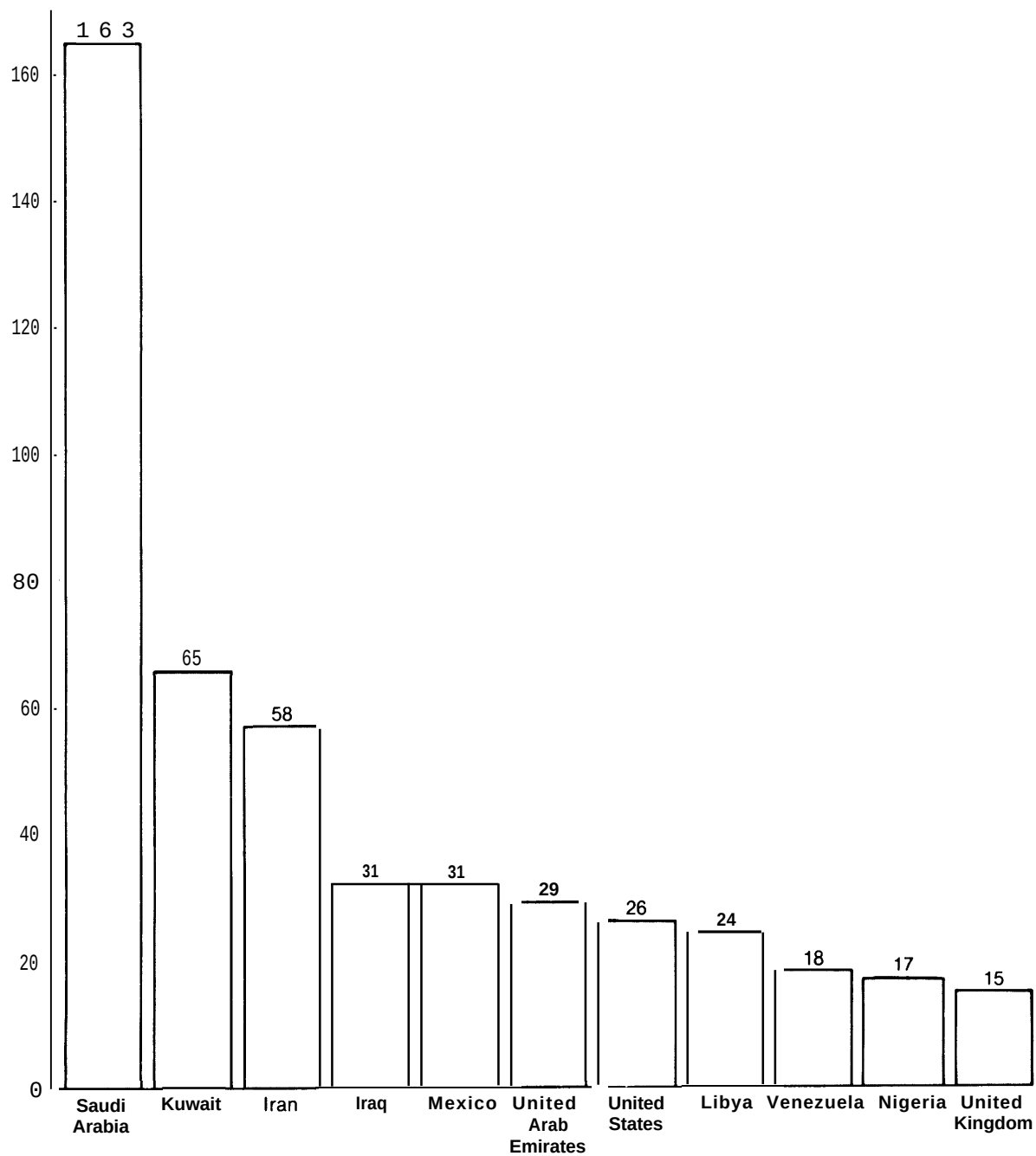
OPEC

Saudi Arabia	163.4
Iran	58.0
Iraq	310.0
Kuwait	65.4
UAE	29.4
Qatar	3.8
Neutral Zone	6.3
Nigeria	17.4
Libya	23.5
Algeria	8.4
Gabon	.5
Venezuela	17.9
Ecuador	10.1
Indonesia	9.6
TOTAL	435.7

Total Non-Communist World 551.6
(totals do not add due to rounding)

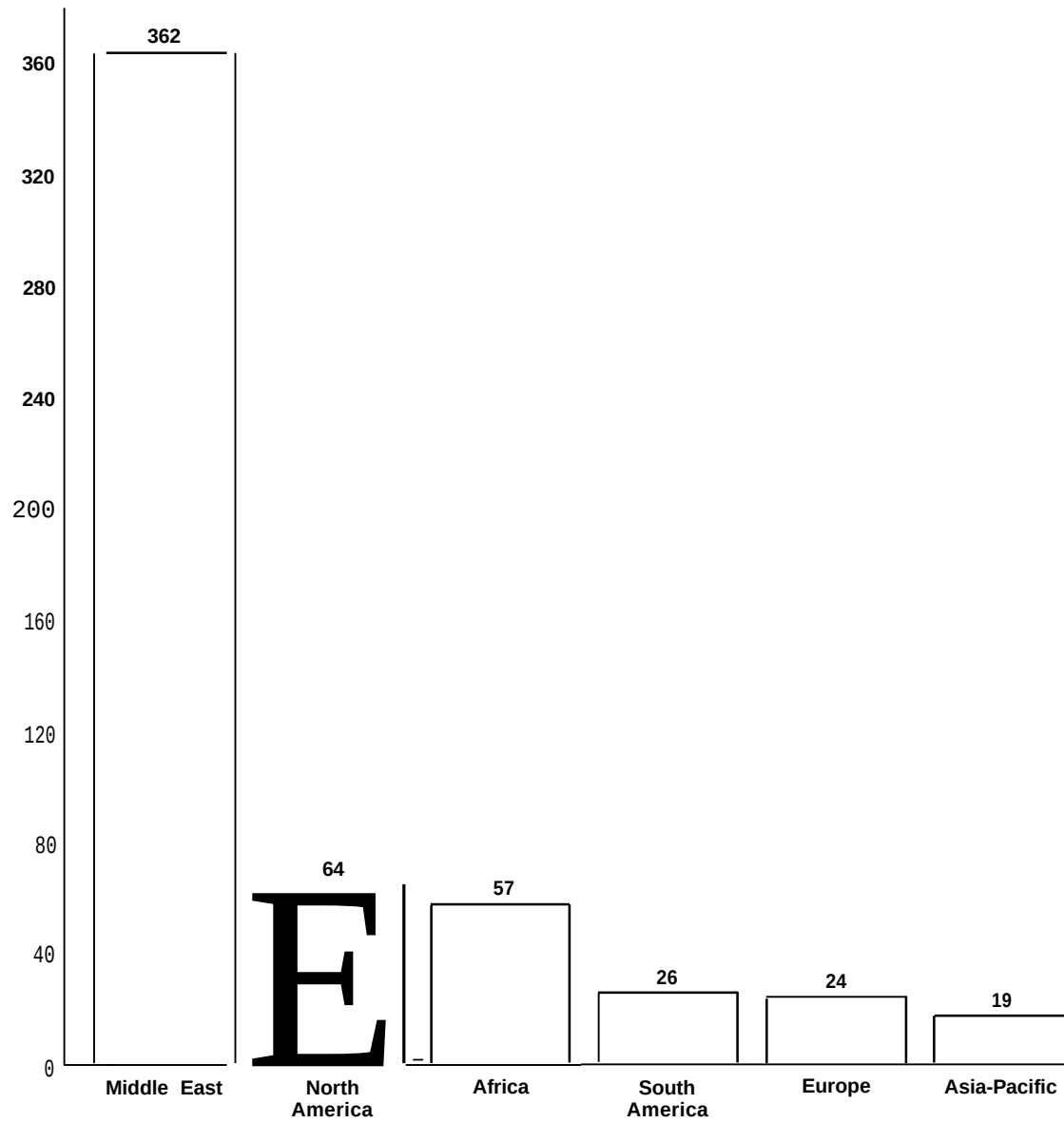
¹ Oil and Gas Journal, December 31, 1979, pp. 70-71.

Table 2.—Non-Communist Countries With Reserves in Excess of 10 Billion Barrels



SOURCE: *Oil and Gas Journal*, Dec. 31, 1979, pp. 70-71

Table 3.—Regional Distribution of Non-Communist Oil Reserves



SOURCE *Oil and Gas Journal*, Dec. 31, 1979, pp. 70-71

The importance of proven (and probable) reserves is that they are the major source of oil production in the short term (1-7 years). Additional discoveries and enhanced recovery techniques will add to the estimates in Table 1 but these contributions will have negligible effects on short-term production potential.

The size of these reserves can be illustrated by the following statements:

- a. The 552 billion barrels of reserves correspond to approximately 31 years of production at today's non-Communist crude oil production rate of approximately 48.2 million barrels per day. (17.6 billion barrels per year).
- b. The 26.5 billion barrels of U.S. reserves correspond to approximately 8.5 years of production for the United States at the current production rate of 8.5 million barrels per day (3.1 billion barrels per year).
- c. The 163.4 billion barrels of reserves correspond to approximately 48 years of production for Saudi Arabia at the current crude oil production rate of 9.5 million barrels per day (3.5 billion barrels per year).

However, these production rates cannot be maintained for the entire period without further reserve additions as explained above.

For the Communist areas the overwhelming majority of the proven oil reserves lie in the Soviet Union and China. Estimates of the Soviet Union and China must be treated as very rough approximations due to the limited availability of data. Three estimates are given in Table 4, the much lower estimate for the Soviet Union given by the Central Intelligence Agency is based upon their estimate of proven reserves. The Oil and Gas Journal estimate is the Soviet Union estimate for "explored reserves" which includes an undetermined amount in addition to proven and probable reserves.

TABLE 4
COMMUNIST AREA OIL RESERVES

	<u>LIQUID PETROLEUM</u>	<u>CRUDE OIL</u>
USSR	40	67 58
China	20	20 20
Other	5	3 2
Total	651	90 ² 80 ³

¹ Central Intelligence Agency, International Energy Statistical Review, March 2, 1979, proved reserves estimate.

² Oil and Gas Journal, December 31, 1979, pp. 70-71, "explored reserves."

³ World Oil, August 15, 1979, estimate for end of 1978, proven reserves.

B. Total Potential Resources

A different way to answer the question "How much oil is there?" is to estimate the quantity of oil which will ultimately be recovered. This quantity called the ultimate recovery estimate includes:

- 1) oil that has already been produced (cumulative production)
- 2) proven reserves
- 3) oil from additions to known fields through extensions, full development and enhanced recovery techniques
- 4) oil from new discoveries.

The last three items constitute remaining resources which will determine future production rates.

It must be stressed, however, that the rate at which additional quantities in (3), (4) are added to reserves may be the critical factor in determining the production rates for the next several decades. Additions to

reserves in the non-Communist world have been declining from over 20 billion barrels annually through the 1950's to approximately 13 billion barrels in the late 1970's (1975-78). During the period 1975-1978 production exceeded additions to reserves through new discoveries.*

Several methods for estimating ultimate recovery exist. For any method, the uncertainties are large, and methods can only be expected to yield rough approximations. A principal reason for the lack of precision is the necessity for an assumption about the size and number of new discoveries. This assumption requires a subjective estimate of the quantity of oil in unexplored (by drilling) or partially explored areas based upon a comparison with those geologically similar areas which have been sufficiently explored to determine their ultimate recovery. The limited success of recent drilling in the Baltimore Canyon and the Gulf of Alaska illustrates the range of error possible in this assumption. A second reason for the lack of precision in the ultimate recovery estimate is the necessity of an assumption about the price of oil which will influence both the extent to which enhanced recovery techniques will be employed and also the size and location of new finds that will be sought and developed if found.

The importance of large fields mentioned earlier suggested a determination of the remaining undiscovered resource by a consideration of the expected number and size of new discoveries with particular emphasis on large fields. This approach is based upon the belief that large fields will contain the majority of the remaining future discoveries. Even in the

Petroleum Intelligence Weekly (3/24/80) quoting an Exxon report. Estimates of additions in each period are averaged additions. Revisions in estimates of fields are attributed to the period of initial discovery.

extensively explored U. S., which contains a relatively large number of small fields, large fields containing at least 100 million barrels of recoverable oil account for 70% of the oil discovered.

This emphasis on large fields is sometimes criticized because of a belief that small fields will play a larger role in the future than they have in the past. The U.S., is cited, incorrectly, as an example to support this argument. Some observers have speculated that the amount of oil produced from small fields in the U.S. results from the fact that the U.S. oil resources are closer to depletion than fields elsewhere in the world. It is speculated that the importance of small fields will increase in other countries as exploration and development continues.

However, drilling experience in the United States does not in fact support the criticism of the emphasis on large fields. If the U.S. had been forced to turn to small fields because of the depletion of larger areas, it would be expected that the significance of smaller fields in the U.S. would be increasing. This is not the case. The proportion of oil found in smaller fields (less than 100 million barrels of known recovery) in the U.S. was 30.0% between 1961-1976 compared to 29.5% since 1859.*

It appears instead that the relatively high production from small fields in the U.S. results primarily from the unique geology of the Gulf Coast Syncline which consists of several adjacent major and intermediate size provinces with large numbers of small fields. Most of the larger provinces in the world have been explored sufficiently to eliminate the possibility of this type of reoccurrence elsewhere.

* R. Nehring, Giant Oil Fields and World Oil Resources; Rand Corporation, June, 1978, pp. 72-73.

(1) Nehring's Estimates of World Crude Oil Resources

In 1978, Nehring* conducted a comprehensive analysis of recoverable resources including Communist areas with emphasis on large fields for new discoveries. Ultimately recoverable crude oil resources were estimated in the range of 1700-2300 billion barrels. This estimate includes 1000 billion barrels of proven reserves and cumulative production that were known at the end of 1975. Thus, the study estimates that approximately 700-1300 billion barrels will be added to the world's known oil from additional recovery and new field discoveries.** Tables 5, 6 detail and illustrate graphically a breakdown by type and region.

Additional recovery, consisting of additions to known fields through extensions, full development and enhanced recovery is expected to add an estimated 420-730 billion barrels to the known oil total. The major contribution to this total, about 250-400 billion barrels, will come from the Middle East.

New discoveries, while expected to be less than additional recovery, are still a large source and are estimated world-wide at 263-555 billion barrels. The breakdown of the new discoveries by size and number, illustrating the expected continuing importance of large fields, is given in Table 7. Outside the Middle East, a large portion of the total of 263-555 billion barrels is expected to come from offshore areas. Many of these promising areas lie in the area of the Arctic Circle, which will be very expensive and slow to

*Ibid

** Recently, **Nehring** has updated this study based upon further work. **His** estimate has been lowered to 1600-2000 billion barrels for the ultimately recoverable liquid petroleum resource. This work was outlined at the **UNITAR** Conference on Long-Term Energy Resources in Montreal, Canada, November 26 - December 7, 1979.

TABLE 5

ULTIMATELY RECOVERABLE WORLD CRUDE OIL RESOURCES**

	Known	Additional Recovery ¹	Additional Recovery ¹ & New Discoveries	Ultima Recoverable Reserves	Cumulative Production Through 1975	Remaining Resource**
North America*	179.8	43-95	100-200	280-380	122	-60-260
South America	24.6	20-40	52-92			80
Western Europe	24.6	5-10	25-45	0		0 0
Eastern Europe/ Soviet Union	102.4	20-40	63-123	165-225	51	110-170
Africa	75.6	15-30	40-94	120-170	21	100-150
Middle East	509.9	250-400	350-600	860-1140	85	780-1060
Asia/Oceanic	50.8	15-25	54-104	105-155	13	90-140
Unspecified	X	20-30	A	X	X	X
- *	600	420-730	700-1300	1700-2300	336	1360-1960

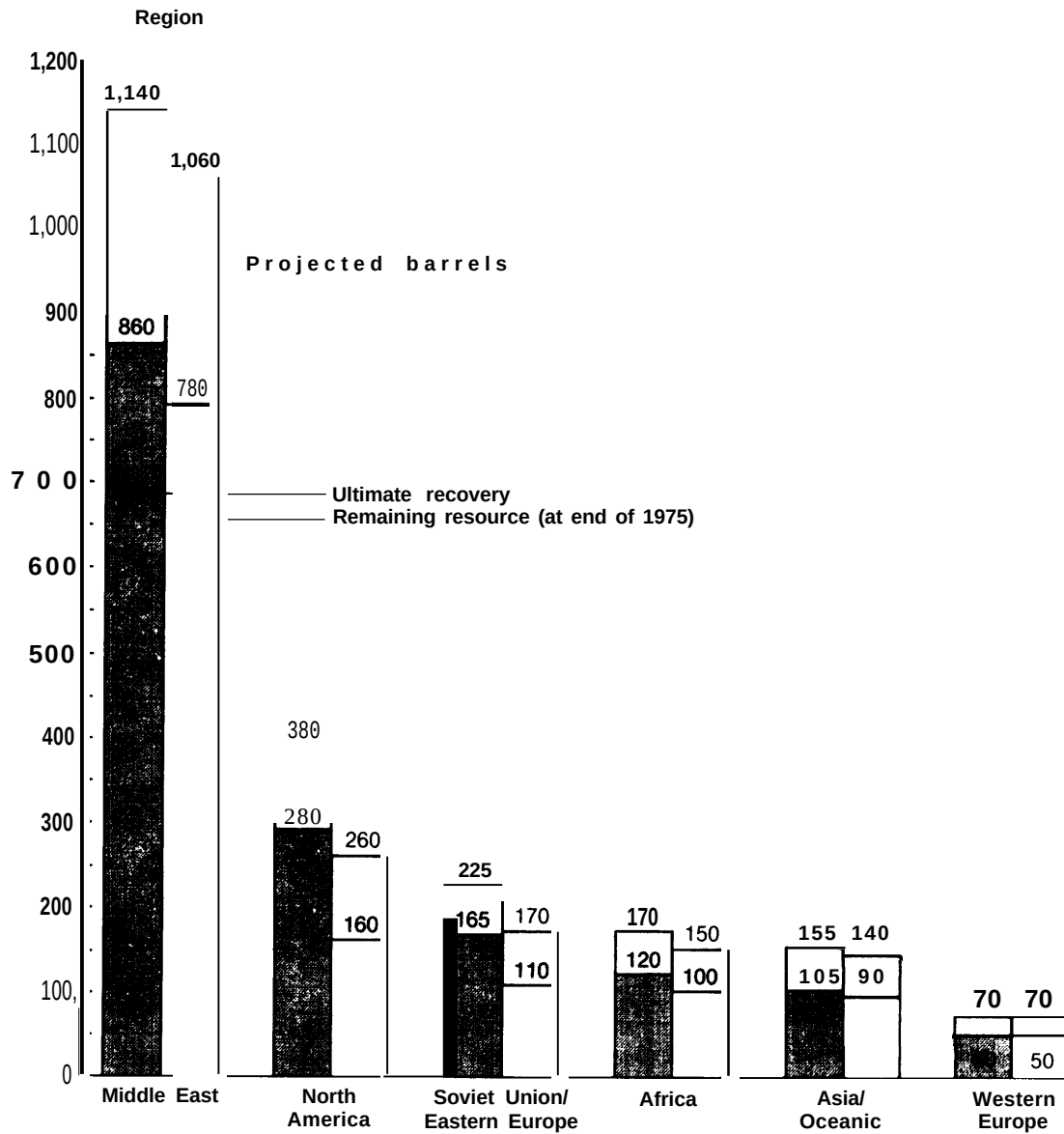
** May not add due to rounding

¹ In known fields

* includes Mexico)

Source: Nehring: Giant Oil Fields and World Oil Resources, Rand Corp., June 1978, p. 88.

Table 6.—Estimate of Regional Distribution of Oil Resource



SOURCE, Nehring, *Giant Oil Fields and World Oil Resources*, RAND Corp., June 1978, p 88

TABLE 7
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EXPECTED FUTURE DISCOVERIES

TYPE	NUMBER	TOTAL RECOVERY (in billion barrels)
Super-giants (7.5 to 10 billion barrels each)	4-10	30-100
Giants (.8 to 1 billion barrels each)	125-175	100-175
Large Non-Giants (150 to 200 million barrels each)	400-800	60-160
Smaller	x	73-120
Total		263-555

SOURCE: R. Nehring, Giant Oil Fields and World Oil Resources, Rand Corporation, June 1978, pp. 54-84.

develop because of their severe climate. As mentioned earlier some of the potentially promising major new areas involve regions of territorial dispute. These regions include the Malvinas basin off the Falkland Islands, the South China Sea, and Spitsbergen.

On the basis of the Nehring study, the overall dominance of the Middle East can be expected to continue since 775-1055 billion barrels (or over 50%) of the remaining resources are believed to occur there. The breakdown by region given in Table 5 illustrates, in addition to the continued dominance of the Middle East, that the worldwide distribution of ultimately recoverable oil resources is not expected to differ significantly from the distribution that exists today.

(2) Other Estimates of World Oil Resources

It is difficult to compare the Nehring resource estimate with other studies due to their limited documentation. Moreover, all studies do not make explicit an estimate of what ultimate price of oil will influence the areas explored and developed and the extent of enhanced recovery utilization.

The total of 1700-2300 billion barrels in the Nehring study is in general agreement with the average of most other recent estimates. Several studies and their estimates are given in Table 8. Since many of these estimates borrowed common information and each other's work, these estimates cannot be considered independent. In particular, the World Energy Conference estimate was obtained by means of a Delphi poll among 29 government, academic, and industry geologists.

Nehring differs substantially from other studies in his appraisal of the Middle East and the Soviet Union. He presents a larger estimate (775-1055 billion barrels) for the Middle East than most studies (630 in Moody-Esser).*

In addition, the Nehring estimate of 125-225 billion barrels for the Soviet Union presents a more pessimistic view than some of the other recent studies. For example, the earlier work of Moody/Esser (1974)** had estimated Communist resources, including the People's Republic of China, at 500 billion barrels. This basis for this analysis is not known; it may have simply been based upon a volumetric analysis. The more pessimistic view of Nehring is partially based upon the information learned since 1974 that most new discoveries in potential petroleum areas of the Soviet Union are turning out to be natural gas rather than oil.

* J.D. Moody, R.W. Esser, Mobil Oil Corporation, 1974.

** Ibid.

TABLE 8

ESTIMATE OF ULTIMATELY RECOVERABLE WORLD CRUDE OIL RESOURCES

AUTHOR	ORGANIZATION	DATE OF ESTIMATE	QUANTITY IN BILLION BARRELS
H.R. Warman ¹	British Petroleum Ltd.	1973	1915
J.D. Moody and R.W. Esser ¹	Mobil Oil Corporation	1974	2000
M. King Hubbert ¹	U.S. Geological Survey	1974	2000
B. Grossling ²	U.S. Geological Survey	1974	2600-6500
Delphi Approach ³	World Energy Conference	1977	2230 (average of 28 est.)
R. Nehring ⁴	Rand Corporation	1978	1700-2300
R. Nehring ⁵	Rand Corporation	1979	1600-2000

¹ Source:
From M. King Hubbert, "World Oil and Natural Gas Resources" in Project Independence, Library of Congress, Washington, D.C., 1977, Committee Print 95-33, pp. 632-644.

² B. Grossling, U.S.G.S. Survey Circular 724, 1974.

³ World Energy Conference, Oil and Gas Resources. IPC Science and Technology Press, 1978, p. 30.

⁴ R. Nehring (June 1978) previously cited.

⁵ R. Nehring (December 1979) at the UNITAR Conference in Montreal.

Although most estimates for ultimate recovery have centered around 2000 billion barrels, a recent study by Grosling* has suggested that a much higher figure is possible. That study claims that many of the prospective petroleum areas, primarily those in underdeveloped countries and offshore areas, have been insufficiently explored out causing their total potential to be underestimated significantly. This premise leads one to estimate the ultimate recovery of these prospective petroleum areas by using the ultimate recovery figure of certain areas, which have been so thoroughly developed that their estimate of ultimate recovery can be estimated accurately (referred to as benchmark areas).

The principal difficulty with this approach is that wide ranges of estimates are possible depending upon the choice of benchmark areas. Using certain areas in the Soviet Union as benchmark areas, Grossling** obtains an estimate of approximately 6000 billion barrels as the total expected ultimate recovery for the world, which is triple most recent estimates. While within the realm of possibility, given the uncertainty in the benchmark figures for the Soviet Union (recent CIA work suggests that their expected recovery may be inflated), this estimate does not appear plausible. Indeed, the benchmark figure used in that portion of Grossling's study is 200,000 barrels per square mile of prospective petroleum area. For the entire conterminous U.S. and Canada, the comparable figure is approximately 45,000 to 60,000 barrels

* Grossling, "A critical Survey of World Petroleum Opportunities", in Project Interdependence, Library of Congress, 1977, Committee Print 95-33, pp. 645-658.

**Ibid.

per square mile of prospective area. * With the "benchmark" figure of 45,000 (60,000) barrels an estimate is obtained of 2125 (2500) barrels for the total world ultimate recovery.** These numbers are in rough agreement with the previous estimate of 1700-2300 billion barrels.

Additionally, the premise of using "benchmark" estimation has been challenged by some oil companies.*** These companies argue that extrapolative analysis is not valid since most of the world's sedimentary basins have been assessed at least by geophysical methods and that exploratory activity is justified only if the initial geophysical assessment looks promising. Some areas, while sedimentary and nominally prospective, do not contain all the requisite features that are expected for petroleum deposits.

(3) The Deep Ocean and Anarctica

Estimates of the world's ultimately recoverable oil typically do not include any amount for the deep ocean or Anarctica. There is considerable speculation over the oil potential of both of these areas, but the technology for developing these areas and the necessary economic incentives do not exist now even if oil is found in large quantities.

* The conterminous U.S. and Canada have a total prospective petroleum area of 4,421,000 square miles. Using an estimate of 195-245 billion barrels adapted from Nehring as the expected ultimate recovery (15 billion barrels from Alaska have been subtracted), one obtains the above estimates.

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The total prospective petroleum area outside the Middle East is approximately 25,000 square miles (See Grossing). Using the "benchmark" figure of 45,000 (60,000) barrels per square mile, one obtains an estimate of 1125 (1500) billion barrels as the total recovery outside the Middle East. Adding 1,000 billion barrels as the recovery for the Middle East, one obtains the above numbers.

*** Exxon, Exploration in Developing Countries, May, 1978.

Currently, American oil companies are beginning to drill in one thousand feet of water in the Gulf of Mexico, which would be the deepest water in which petroleum has ever been produced. This drilling is somewhat deeper than the North Sea finds, which are in less than six hundred feet of water. However, the Gulf of Mexico drilling is considerably less than the depth of the Atlantic region in which the United States Geological Survey announced on August 31, 1979, as a potential resource on the basis of seismic work alone. That region occurs at depths of 12,000 feet of which the first six thousand feet are water.