- Because the better economic prospects for oil production will be exhausted by the year 2000, investment costs for new oil reserves will go to between $1.80 and $3.20 (1973 $). These costs are comparable to or greater than investments for syncrude.

- The price of crude oil in constant dollars will increase under almost any realistic scenario, particularly if national independence from foreign crude oil supplies is sought.

- Oil production from offshore and Alaskan oil resources will continue to be the center of environmental controversy. Indeed, the major impacts of future oil production result from producing resources from these areas.

B. Projected Domestic Oil Supply and Imported Oil Requirements

To project detailed domestic oil supplies for HG3, the Project Independence Oil Task Force supply projections[4] are used to define the relative percentages of oil supplied from each National Petroleum Council (NPC) region.* Figure 3-2 defines regional boundaries used in this chapter. Table 3-2 shows HG3 supplies aggregated into onshore production, offshore production, and Alaska production.† The apparent heavy reliance on oil supplies from Alaska, offshore, and tertiary recovery for future production reflects general expectations of future production.[6]

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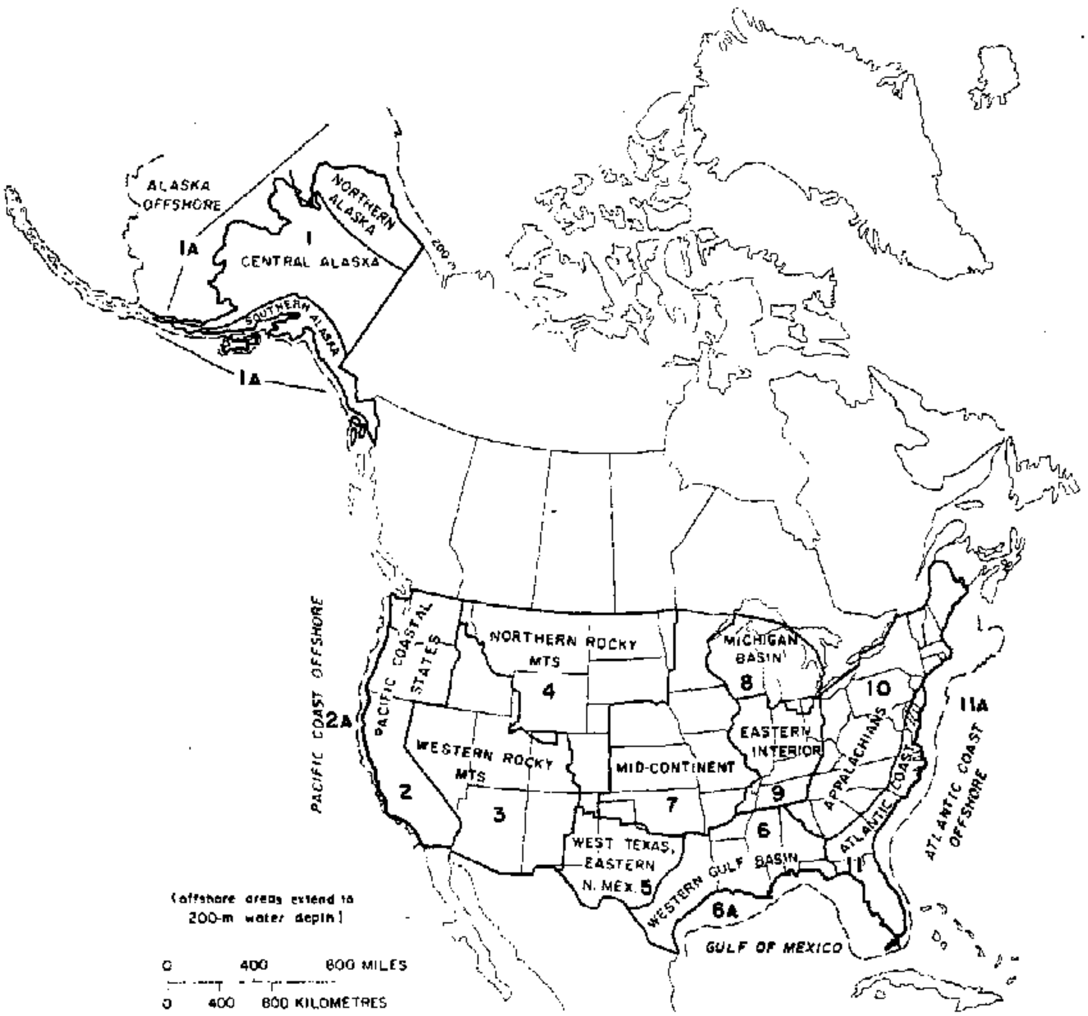
*The NPC regions (modified from the usual National Petroleum Council regions) as defined by the Oil Task Force.[4]

†Aggregated from Table B-1 of Appendix B.



Source: U.S. Geological Survey, Circular 725

FIGURE 3-2. INDEX MAP OF NORTH AMERICA SHOWING THE BOUNDARIES OF THE 15 OIL PRODUCTION REGIONS, ONSHORE AND OFFSHORE

Table 3-2

DOMESTIC OIL SUPPLY, IMPORTS, AND TOTAL DEMAND UNDER HG3

10^6 Barrels per day (% of Domestic Supply)

SUPPLY/DEMAND	YEAR			CUMULATIVE 1974-2000 (10^9 Barrels)	
	1974	1985	2000	Total	From Advanced Recovery
Domestic Supply					
Onshore Lower 48 states	8.9 (85)	6.8 (52)	5.0 (38)	63	34
Offshore Lower 48 states	1.4 (13)	3.0 (21)	4.0 (30)	28	15
Alaska Onshore and offshore	0.2 (2)	3.6 (27)	4.4 (32)	30	16
Total	10.5	13.4	13.4	121	
Imports	6.0	11.5	18.4		
Total U. S. demand	16.5	24.9	31.8		

Source: Appendix B, Table B-1.

Table 3-3 shows the onshore production for HG3 by NPC region. Table 3-4 shows the offshore production for HG3 by offshore NPC region, including production from military oil reserves in the Pacific and Gulf of Mexico offshore areas. Table 3-5 shows the Alaska production for HG3 by onshore and offshore areas.

Cumulative production under HG3 between 1973 and 2000 is approximately 130 x 10^9 barrels of oil--about 25 percent greater than the cumulative total U.S. production up to 1973. Cumulative tertiary recovery under HG3 is assumed to be about 70 billion barrels, an assumption that reflects the availability of oil through primary recovery given the 1975 USGS resource estimates.[2]

We assume that cumulative recovery between 1973 and 2000 from each region by tertiary methods is proportional to total cumulative recovery by tertiary methods divided by total cumulative recovery over the same period.

Table 3-3

ONSHORE OIL PRODUCTION FROM THE LOWER 48 STATES UNDER HG3

(10^6 Barrels per day)

Region or Source*	1974	1985	2000
Pacific Coast NPC Region 2	0.792	0.59	0.38
Naval Petroleum Reserve No. 1	0	0	0.08
Western Rocky Mountains NPC Region 3	0.215	0.16	0.12
Eastern Rocky Mountains NPC Region 4	0.614	0.34	0.23
West Texas/Eastern New Mexico NPC Region 5	2.553	1.6	1.1
Western Gulf Basin NPC Region 6	3.526	3.2	2.4
Mid-Continent NPC Region 7	0.994	0.68	0.56
Northeast NPC Regions 8, 9, 10	0.213	0.28	0.19
Atlantic Coast NPC Region 11	0.007	0	0.01
Total†	8.914	6.8	5.0

* See Figure 3-2 for geographical locations.

† Items may not sum to totals due to rounding.

Table 3-4

OFFSHORE OIL PRODUCTION FROM THE LOWER 48 STATES UNDER HG3

(10^6 Barrels per day)

Region or Source*	1974	1985	2000
Offshore military reservations	0	0	0.16
Atlantic offshore NPC Region 11A	0	0.04	0.60
Gulf of Mexico NPC Region 6A	1.311	2.3	2.0
Pacific offshore NPC Region 2A	0.058	0.6	1.2
Total†	1.369	3.0	4.0

* See Figure 3-2 for geographical locations.
† Items may not sum to totals due to rounding.

Source: Tables B-1, Appendix B

Table 3-5

ONSHORE AND OFFSHORE OIL PRODUCTION FROM ALASKA UNDER HG3

(10^6 Barrels per day)

Region or Source*	1974	1985	2000
Prudhoe Bay	0	1.8	1.2
North Slope Other than Prudhoe Bay	0	1.3	0.68
Naval Petroleum Reserve No. 4	0	0	1.6
Gulf of Alaska and other offshore areas NPC Region 1	0.201	0.54	0.96
Total†	0.201	3.6	4.4

* See Figure 3-2 for geographical locations.

† Items may not sum to totals due to rounding.

Source: Table B-1, Appendix B

The economic incentives provided by high prices for imported crude oil and refined products will tend to increase the supply from the three domestic sectors--onshore (lower 48 states), offshore (Atlantic, Pacific, Gulf of Mexico areas), and Alaska (onshore and offshore). Of course, the distribution of the supply available from each of the sectors cannot be forecast to the year 2000 with precision.

C. Projected Resource Requirements for Production of Domestic Oil

Oil can only be produced with sufficient inputs of the resources of equipment, manpower, steel, and capital. Projections of these inputs under scenario HG3 are developed in this section.

1. Drill Rigs, Labor, and Steel

Table 3-6 shows the approximate annual requirements for drill rigs, labor, and steel for the reference case. Labor and steel requirements are shown later for synthetic fuel development in the maximum credible implementation (MCI) scenario, Chapter 6. The number of rigs determines many of the oil production impacts.

Several considerations were used in generating the annual resource requirements in Table 3-6:[*] (1) Since annual production under HG3 in 2000 corresponds closely to the Project Independence 1988 $11/B Business-as-usual[4] scenario, no increase in the annual resource requirements beyond the Project Independence 1985 $11/B Business-as-usual requirements is assumed except for investment and (2) this is based on the assumption that future production is closely correlated

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*Annual oil production depends on resource inputs and exploration activity. For example, it will take several years before a new offshore field reaches peak production. More than one production platform is likely for a large field.

Table 3-6

LABOR, DRILL RIG AND STEEL REQUIREMENTS
FOR OIL PRODUCTION UNDER HG3

	1977*	1980*	1985*	1990†	1995†	2000†
Exploration Drill Rigs in Use Annually						
Onshore	930	1,100	1,250	1,250	1,250	1,250
Offshore	240	370	500	500	500	500
Alaska						
Onshore	125	125	150	150	150	150
Offshore	26	52	110	110	110	110
Offshore Production Platforms in Use Annually						
Offshore	90	150	200	200	200	200
Alaska-offshore	6	12	25	25	25	25
Labor--Rig and Platform Crewmen Employed Annually						
Onshore	22,000	25,000	29,000	29,000	29,000	29,000
Offshore	24,000	37,000	52,000	52,000	52,000	52,000
Alaska	3,000	5,000	8,000	8,000	8,000	8,000
(Offshore)	(1,600)	(3,100)	(6,500)	(6,500)	(6,500)	(6,500)
Total	49,000	67,000	89,000	89,000	89,000	89,000
Steel--Thousands of Tons Required Annually						
Onshore	1,400	1,600	1,700	1,700	1,700	1,700
Offshore	1,400	1,700	1,400	1,400	1,400	1,400
Alaska	200	200	400	400	400	400
Total	3,000	3,500	3,500	3,500	3,500	3,500

*Data up to 1985 adapted from Reference 4, Tables VI-8, VI-9 and VI-10, by excluding the heavy crude oil and tar sands data.

†All requirements after 1985 held constant.
This reflects the correspondence between production by 2000 under HG3 and the FEA $11/B BAU scenario production by 1988 used in Appendix B to generate the regional production for HG3.

to exploration activity. The same drilling activity used to achieve the FEA production by 1988 is assumed to achieve the HG3 production by 2000. The correlation is generally valid--more drilling activity results in more future production, although according to those knowledgeable in the field, it is becoming increasingly difficult to find oil with the amount of oil discovered per foot of exploratory well drilled on the decline.[6] Since that trend can be expected to continue, the resource requirements in Table 3-6 are probably underestimated.

The factors that will mean less production per unit of investment toward the end of the century are:

- Exploration of deeper oil prospects, which entails more feet of drilling per well, fewer well completions per foot of drilling, slower drilling rates per foot of well, and greater expense per completed well.
- Exploration of more remote locations, which has characteristics of exploration of deeper prospects. Moreover, the drilling season is limited in such places as arctic offshore regions.
- Exploration of the "better" prospects will be completed.

a. Drill Rig Requirements

Oil production on land requires drill rigs for exploration--thereby the adage "the only true test for oil is the drill"--and for drilling development wells and the extra wells required by secondary and tertiary recovery or for workover. Onshore drill rigs are relatively mobile and are often truck-mounted.

Offshore oil production requires drill rigs both for exploratory drilling--jack-ups, semisubmersibles and ship-mounted rigs are the most common[7]--and for production at locations where permanent platforms complete the production wells and support the production equipment. In the future, more subsurface platforms (unmanned) are likely to be used because they are cheaper and lighter than surface platforms. The subsurface, unmanned platform is fixed to the ocean floor, and the wells are drilled by a mobile drillship, which moves on after placing the production tubing. The rig requirements shown for offshore production in Table 3-6 fall into these categories.

The rig requirement shown for Alaska in Table 3-6 includes both onshore rigs (rarely truck-mounted because of the severe environment of the North Slope tundra) and offshore rigs--similar to rigs used offshore in other areas with the exception of those designed for use in pack ice regions.[8,9] Many of the impacts on Alaskan offshore waters depend on the number of offshore rig requirements.

The HG3 scenario requires substantial drilling activity. Alaska, particularly, will see large increases in drilling activity. Because of much increased drilling for tertiary recovery under HG3, onshore continues to receive the most drilling activity.

b. <u>Labor Requirements</u>

The total number of rig crewmen required depends on the number of rigs in operation and whether they are operated on or offshore. Onshore rigs each require about 25 men, while offshore rigs each require about 50 men. Project Independence[4] estimates Alaskan rigs require somewhat fewer men than other onshore rigs--less than 20 men each; however, a backup crew is also required and a large number of support personnel are required, while in onshore production elsewhere support personnel are part of the general infrastructure.

Labor requirements for drilling and production grow substantially under HG3. The HG3 requirements in 2000 are double those in 1977. The rigmen required for offshore may be overestimated if subsurface production platforms become widely used toward the end of the century, as may be likely.

c. Steel Requirements

Steel is required for the construction of drill rigs and production platforms, for the production of the tubing used to support the drill during drilling, for the well casing, and for surface equipment such as storage tanks, equipment sheds, and pumps. The steel requirements shown in Table 3-6 reflect these needs and are probably underestimated since much of the steel required for tertiary production (the extra wells) is not included. Neither are steel requirements for oil transportation and distribution or refining included. These needs can be substantial, particularly for oil pipelines from remote regions. For example, the Trans-Alaska Pipeline (TAPS) will contain about 1.2 million tons of steel. Under HG3, the annual steel requirements are about 3,000,000 tons by 2000, with onshore production requiring the most steel (refer to Table 3-6).

An impact occurs during retirement of some production facilities--the irretrievable investment of steel. Offshore rigs may be left in place after their economic life is exceeded. During periods of falling prices, rigs may remain idle which represent a large energy investment in terms of the steel in the well pipe and rig. Some offshore rigs contain as much as 25,000 tons of steel. Whether this steel will be left in place forever remains an open question. To give some feeling for what this 25,000 tons of steel represents, we give the following illustrative calculation. An offshore production platform must produce about 30,000 B/D to be economically viable. This fuel rate will supply about 900,000 cars with each car using about 0.033 B/D (20 miles/gal and 10,000 miles/yr). At 1 ton each, these cars contain about 900,000 tons, or about 36 times as much steel as the offshore platform supplying their fuel.

2. Capital Investment

To our knowledge, Project Independence contains the most recent detailed estimates of investment in crude oil production,[4] and they have been adapted to form the basis of our projections. Unfortunately, these investments were based on the 1972 USGS resource estimates discussed in Appendix A. In order to create more realistic investment estimates for HG3, we have assumed that the investment projections in Project Independence cover only the annual investment necessary for primary and secondary recovery under HG3, and we have gone on to assume that additional investment is necessary for the substantial tertiary recovery required for oil production under HG3 (discussed in Appendix B).

Table 3-2 showed cumulative production by advanced recovery techniques necessary to support the HG3 production level from each region. For this production to take place, the resources in each region must first become economically producible reserves (Appendix A). The capital investment necessary to convert resources into economically producible reserves in each region is shown in Table 3-7. The Project Independence Oil Task Force Report shows the investment required per barrel of reserve added for 1974 and 1988. To estimate the minimum capital investment necessary to convert 70 billion barrels of resource into oil recovered by advanced techniques we have assumed that these

Table 3-7

CAPITAL INVESTMENT REQUIRED
FOR SECONDARY AND TERTIARY RECOVERY

	Dollars (1973) per Barrel of Reserve Added	
	1974-1988	1988-2000
Secondary Recovery		
Region 1	$ 0.96	$ 1.92
Regions 2A, 6A, and 11A	0.64	1.28
Regions 2, 3-6, and 7-11	0.32	0.96
Tertiary Recovery		
Region 1	1.68	3.12
Region 2	1.50	3.00
Regions 2A, 6A, and 11A	1.12	2.14
Regions 3-6, 7-11	0.80	1.76

Source: Project Independence Blueprint,
Oil Task Force Report

investments pertain to the entire period to the year 2000 as shown in the table. The investments shown in the second column probably underestimate the necessary investment for HG3 since many of the better tertiary recovery prospects in each region will already be in production by the last decade of the century.

The approximate capital investment for recovery by advanced techniques is shown for onshore, offshore, and Alaska in Table 3-8. The investment estimates represent a probable lower limit to the necessary investment for reserves recoverable by tertiary methods since these estimates reflect only the tertiary recovery that is actually accomplished by 2000. In practice, there must be reserves of crude oil left after any given year; in the past, reserves have been about ten times annual production (Appendix C) so that additional investment, not shown in the Table 3-8, is required for the reserves left in the year 2000. We have assumed that the total investment for the two periods, 1974-1988 and 1988-2000, is divided uniformly on an annual basis. This probably will not be true in practice.

The approximate capital investment for all conventional oil recovery to the year 2000 is displayed in Table 3-9. Capital investment in constant dollars increases over two and half times between 1977 and 2000. Project Independence forecasts considerably less production from advanced recovery than is necessary for HG3 in the light of the 1975 USGS resource estimates.[2] Thus, we have assumed that the annual investment levels projected by Project Independence approximately cover the 60 billion barrels of production under HG3 that must come from primary and secondary recovery methods. The investment allocated for tertiary recovery in the Project Independence scenarios is probably comparable to the additional investment for the tertiary recovery reserves in 2000 left out of our analysis, so that any investment that

Table 3-8

APPROXIMATE CAPITAL INVESTMENT REQUIRED FOR ONSHORE, OFFSHORE, AND ALASKA OIL PRODUCTION BY ADVANCED RECOVERY TECHNIQUES

Region	Cumulative Production (10^9 barrels)	Investment per Barrel (1973 dollars)	Total Investment (10^9 1973 dollars)	Annual Investment (10^9 1973 dollars)
		1974-1988		
Onshore	17	\$ 0.8	\$ 14	\$ 1.0
Offshore	7.5	1.1	8.3	0.6
Alaska	8.0	1.7	14	1.0
Total				2.6
		1988-2000		
Onshore	17	1.8	31	2.6
Offshore	7.5	2.1	16	1.3
Alaska	8.0	3.1	25	2.1
Total				6.0

Table 3-9

CAPITAL INVESTMENT IN CONVENTIONAL OIL PRODUCTION FOR HG3
(In 1973 dollars annually)

	1974	1977	1980	1985	1990	1995	2000
Onshore Recovery							
Primary and Secondary	1.3	1.4	3.3	3.9	3.9	3.9	3.9
Advanced*	1.0	1.0	1.0	1.0	2.6	2.6	2.6
Subtotal	2.3	2.4	4.3	4.9	6.5	6.5	6.5
Offshore Recovery							
Primary and Secondary	0.3	0.3	0.5	0.9	0.9	0.9	0.9
Advanced	0.6	0.6	0.6	0.6	1.3	1.3	1.3
Subtotal	0.9	0.9	1.1	1.5	2.2	2.2	2.2
Alaska							
Primary and Secondary	0.7	1.2	1.2	1.3	1.3	1.3	1.3
Advanced	1.0	1.0	1.0	1.0	2.1	2.1	2.1
Subtotal	1.7	2.2	1.2	1.3	3.4	3.4	3.4
Total	4.9	5.5	6.6	7.7	12.1	12.1	12.1

*Primary and secondary recovery investment data up to 1985 adapted from Reference 4, Table IV-16, by excluding the heavy crude oil and tar sands data.

has been underestimated in Table 3-8 is probably made up by the overinvestment in primary and secondary recovery implicit in Table 3-9.

The analysis in Appendix B leads to the conclusion that over 50 percent of the recovery should be coming from advanced recovery methods toward the end of the century. Because of the higher investment levels necessary for advanced recovery relative to primary or secondary recovery (refer to Table 3-7), the investment split between primary and secondary recovery and advanced recovery should be heavily weighted toward advanced recovery projects. Table 3-9 shows such an emphasis on advanced recovery. The estimates shown in Table 3-9 are designed largely for purposes of illustrating the necessary investment for HG3. We do expect, however, that the investment projections for advanced recovery and for overall recovery are approximately correct and reflect current expectation of investment for future recovery. Recent estimates[5] of future production and investment made by Texaco and published in the Oil and Gas Journal support the rough estimates and trends for investment and production shown here for HG3.

D. Projected Environmental Impacts

The scope of the research did not permit detailed assessment of the effect of oil extraction, distribution, and refining in the reference case on the environment; however, the material presented is sufficiently detailed to indicate the probable environmental consequences of an intensive and accelerated industry effort to extract the maximum amount of oil from onshore, offshore, and Alaskan sites. Only major impacts are treated here. They are broadly grouped into land use requirements, water requirements, employment and induced population, oil spill probabilities and quantities, and major air and water pollutant emissions. No attempt is made to rank the impacts in severity.

The environmental impacts of the reference case are determined by means of scaling factors for quantifiable characteristics of the oil extraction, transport, and refining processes. For example, operation of each barrel per day (B/D) of petroleum refining capacity is responsible for a volume of water effluent averaging 770 gallons per day. With a refining capacity of 20 million B/D, the water effluent would approximate $20 \times 10^6 \times 770$ gallons per day. This 15-billion gallon per day effluent volume is a quantitative indicator of the environmental impact of petroleum refining.

Scaling factors appropriate to the various activities involved in crude oil production, distribution, and importation are derived in Section 1, below. In Section 2, environmental impacts for onshore, offshore, and Alaskan production, and oil transport (domestic and imported) are developed by applying the scaling factors to the production estimates given in Section B and the equipment and labor requirements given in Section C, above.

1. Impact Scaling Factors

a. Crude Oil Production

The scaling factors necessary for evaluating the major environmental impacts of oil exploration and production on land use, air quality, and water quality are presented in four groups:

- Impacts of normal exploration activity
- Impacts of exploration accidents
- Impacts of normal production activity
- Impacts of production accidents.

(1) Normal Exploration Activities

Impact scaling factors for the major environmental impacts of normal exploration are shown in Table 3-10. The three major consequences of normal drilling activity* are qualitatively:

- "Boom towns," increased urban growth, increased automobile use, and increased demand for housing and recreation created by the presence of drilling crews, their families, and personnel in service industries. These impacts occur off the drilling site.
- Disturbed lands or ocean bottom, displaced species, water pollution, or road construction at or adjacent the drilling site.
- Solid waste produced by drilling, which may produce water pollution or undesirable land fill.

Many important impacts of exploration result from the normal human activities and demands of the exploration drillers, their families, and associated personnel in service industries. These impacts, of course, vary in severity depending on the degree of urbanization already existent in the region: the less the urbanization, the greater the impact.

Since individual environmental impacts that occur on the drilling site are too site-specific to quantify, Table 3-10 gives only the estimated land areas impacted by a typical drilling project onshore and offshore. Onshore exploration rigs, including storage ponds for drilling mud, occupy about one acre. Offshore rigs are considerably larger than onshore rigs, containing crew quarters, storage facilities

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*Other geophysical and exploration activity results in minimal environmental impact.

Table 3-10

IMPACT SCALING FACTORS FOR NORMAL EXPLORATION OPERATIONS

Impact	Scaling Factor: Quantity	Scaling Factor: Units†
Urban development, population growth consequences of human activity		People employed per exploration rig:*
	24	Onshore
	100	Offshore
	12	Alaska (onshore)
	60	Alaska (offshore)
Surface lands affected by drilling		Approximate land area disturbed by one drilling rig:
	1 acre	plus land for service road (onshore)
	1 acre	plus land for housing (Alaska onshore)
Submerged lands affected by exploratory drilling	3000 acres	Approximate offshore land area disturbed by an offshore drilling rig[11]
Solid waste produced by drilling rig--drill cuttings consisting of rock particles, sand, and drilling mud	63 tons	Weight of cuttings (tons) produced per 1000 ft of exploratory drilling[4]

† Approximate conversion factors: 1 acre = 4000 m^2, 1 ton = 907 kg, 1000 ft = 300 m.

*Inferred from Table 3-6

for equipment, and a processing area for drilling mud; their decks occupy 1 to 2 acres of surface area. Large semisubmersible exploration rigs have as many as 2 acres of surface area.[12]

Wells can be drilled as far as 6000 ft (slant range) from an offshore platform and may therefore tap an area of 4 square miles, or 2500 acres. About a 1 mile clear zone is maintained around offshore rigs, which is intended to prevent ships and tankers from colliding with the platform. Thus, an offshore platform impacts commercial fishing and navigation by the removal of about 3000 acres* of ocean surface from many alternative uses and by presenting a hazard to navigation.[7]

In Alaska, drilling sites entail greater acreage than do sites in the lower 48 states because large rigs, needed for the relatively deep wells, must also provide shelter from the weather for the workers. Moreover, onsite housing, airfields, and other facilities occupy considerable area. The Prudhoe Bay site consists of about 400 square miles, with only a small fraction occupied by exploration rigs.

Drilling produces considerable solid waste in the form of drill tailings--sand, rock particles, and some drilling mud. The average well is about 5000 ft (1.5 km) deep and would therefore produce some 300 tons (270,000 kg) of drill tailings. In exploratory drilling offshore, the USGS orders for OCS drilling allow onsite disposal of this material; other solid waste must be fully processed or returned to shore.[11] Little is known about the environmental effects of the disposal of drilling mud, although the unconsolidated sediment makes for a

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*Assuming 1 mile (1.6 km) distance between tankers and platform is maintained.

poor home for bottom-dwelling organisms.[13]

(2) Exploration Accidents

Table 3-11 shows the major scaling factor for the impacts of accidental or abnormal drilling operations. The environmental impacts of oil in the marine environment, mainly the death of large numbers of sea birds, the loss of aquatic life, have been widely discussed.[14-18]

Blowouts, a major source of oil entry into the environment, result from excessive uncontrolled pressure buildup in the well. During drilling, the drill mud composition and density are varied to assure that the weight of drilling mud equals or exceeds the pressure in the rock formation. An oil or gas pressure exceeding this weight can force the drilling mud back up the drill hole. The resulting excess pressure, if not controlled, forces mud and oil back up the well, which causes a blowout. Blowouts can cause loss of life, equipment failure, broken pipes, and other damage, and may result in fires as well as the uncontrolled release of oil into the environment.

Onshore, the probability of an oil blowout is much less than 1 in 2500, owing to the large number of high-pressure gas blowouts included in this estimate. In part, the reduced risks of onshore drilling come from the less sophisticated demands of onshore drilling and from the more frequent drilling in oil formations with known pressures.

Table 3-11

IMPACT SCALING FACTORS FOR EXPLORATION ACCIDENTS (BLOWOUTS)

Impact	Scaling Factor: Quantity	Scaling Factor: Units
Potential for human casualties, disruption and destruction of marine biota, and scenic losses from accidental discharge of oil into the environment (blowout)		Onshore probability of a blowout:
	1	well in 2500[19] (includes high pressure gas blowouts)
		Probability of a blowout offshore:
	1	well in 500[7] (includes high pressure gas blowouts)
	1	well in 3300 (not including gas blowouts)

(3) Normal Production Activities

Table 3-12 summarizes the impact scaling factors for the major environmental impacts from normal crude oil production activities. These impacts are:

- Disturbed lands or ocean bottom, displaced species, water pollution, or road construction at the drilling site.
- Increased urban growth, increased automobile use, and increased demand for housing and recreation caused by presence of production personnel, their families, and personnel in service industries. These impacts occur away from the production site.
- Water-related effects.
- Potential for air pollution.

The first two impacts are much the same as for exploration activities.

Much of the byproduct water from oil production is reinjected into the formation so that not all of the wastewater (which contains low concentrations of oil and perhaps chemicals used in advanced recovery) enters the environment. Water demands for secondary and tertiary recovery, although large, produce severe impacts only in regions with a scarcity of water. Water injection has a number of side effects. It can trigger seismic activity and the hydraulic pressure of water injection can cause surface deformation and faulting. The injection of chemicals into wells can result in contamination of the deep aquifers which are in contact with nearly all oil reservoirs.

Table 3-12

IMPACT SCALING FACTORS FOR NORMAL PRODUCTION OPERATIONS

Impact	Scaling Factor: Quantity	Units*
Urban growth, induced population and effects on the environment from human activity	13,000	Employees per million barrels per day of production[20]
Wastewater production from normal oil production operations	2×10^8	Gallons per million barrels per day of production[20]
Makeup water requirements--water injection for secondary and tertiary recovery	360×10^6	Gallons per million barrels per day of production[19]
Land use:		
Onshore	1/4	Acres per development well[10]
Offshore	3000	Acres per production platform[11]
Alaska--onshore	65,000	Acres per million barrels per day of production[21]
Alaska--offshore	3000	Acres per production platform[11]
Chemical requirements for tertiary recovery:		
Biopolymers and polyacrylamides	$1\text{-}6 \times 10^6$	Pounds per 10^6 barrels of oil produced[22]
Surfactants (sulfonates)	$7\text{-}15 \times 10^6$	"
Cosurfactants (isopropanol)	$4\text{-}10 \times 10^6$	"
Air pollutant emissions from tertiary recovery by thermal methods:		
Particulates	120	Tons per million barrels† of oil recovered
SO_2	1,000	"
NO_x	200-420	"
CO	21	"
Hydrocarbons	16	"
Solid waste production (drill cuttings and spent mud components)	63	Tons per 10^3 feet of well‡
Oil release into offshore environments from normal OCS operations	9	Barrels per million barrels per day of production[7]
Pollution from oil produced with onshore wastewater (untreated)	50	Barrels per million barrels per day of production[7]

*Approximate conversion factors: 1 gal = 3.8×10^{-3} m^3, 1 ton = 907 kg, 1 barrel = 0.16 m^3, 1 pound = 0.45 kg, 1 acre = 4000 m^2.

†Thermal recovery of oil (steam injection) requires about 1 barrel of oil burned for steam for every four barrels produced.[23] Emissions are assumed to be the same as for burning residual fuel oil.[24]

‡Three times as many development wells are drilled as exploratory wells.[25]

Oil production can contribute to air pollution. In some regions in which it is uneconomical to transport oil's co-product, natural gas, by pipeline, the gas is flared. However, most gas is reinjected into the well if no gas transmission system is available. Tertiary recovery by thermal methods, particularly fire flooding or burning part of the oil underground to build heat and pressure in the well, can result in gaseous emissions from the formation. Recovery of high-sulfur crude may result in the release of highly toxic sulfurous gases.[26]

(4) Production Accidents

The impact scaling factors for abnormal production activities are listed in Table 3-13. The most important impact results from accidents to equipment, which release oil to the environment.

Most oil reservoirs contact groundwater aquifers. Many tertiary recovery projects will require the injection of large quantities of chemicals into oil formations and potentially can result in the exchange of water soluble chemicals with groundwater. In locations in which the hydrology is not well known, tracing the path of such chemicals into underground aquifers proves difficult.

About 98 percent of the oil entering the world's ocean environment results from man's activities.[7] Much of this oil results from accidents. To estimate a probability distribution from spills[27], we extrapolated historical data for the 25-year period between 1975 and 2000. These spill probabilities most likely represent upper limits for the number of large spills.

b. Crude Oil Distribution and Oil Imports

The crude oil distribution system has two main components-tankers and pipelines. At present, Alaskan oil flows from offshore

Table 3-13

IMPACT SCALING FACTOR FOR PRODUCTION ACCIDENTS

Impact	Scaling Quantity	Scaling Units*
Major and minor offshore oil spills:		Mean number of spills per 10^6 barrels per day of production over 25 years[27]
More than 100,000 barrels	4.3	
Between 10,000 and 100,000 barrels	13	
Between 2,000 and 10,000 barrels	39	
Average amount of oil spilled in:		Barrels per 10^6 barrels of production[7]
Major accidents	140-530	
Minor accidents	25	

*Approximate conversion factors: 10^6 B = 160,000 m^3

collector lines to onshore storage before being shipped by tanker to the lower 48 states. In the future, the Trans-Alaska Pipeline System (TAPS) will bring oil from Northern Alaska to Valdez for storage and tanker shipment to the lower 48 states. Pipelines transport most onshore oil, while tankers transport about 90 percent of the imported oil. Currently, most Canadian crude oil arrives by pipeline, but recent trends in Canadian policy make any significant crude oil shipments to the United States after 1982 unlikely.[28, 29]

The major impacts of the crude oil distribution system result from construction of pipelines, tanker ports, and storage facilities (tank farms), from the normal operations of tankers, and from the abnormal operations of tankers, pipelines, and onshore storage facilities.

(1) <u>Pipelines</u>

Table 3-14 presents the scaling factors for the major impacts of future pipeline construction. Since the present TAPS is limited in capacity to about 2.5-million B/D, a second pipeline would be required to increase production up to the 3.4-million B/D from the entire North Slope unde HG3.

The normal operation of pipelines results in minimal impact. Most onshore pipelines are buried and unobtrusive. Offshore pipelines at depths shallower than 200 ft are also buried and present minimal impact. Even the labor force necessary to operate a pipeline is small by comparison with employment for refining crude oil. For example, TAPS will employ only 300 people during its operation.[32] For the entire oil industry, only about 5 percent of the total employment is for pipeline operation--about 20,000 in 1973.[25]

Table 3-14

IMPACT SCALING FACTORS FOR THE PIPELINE DISTRIBUTION SYSTEM

Impact	Scaling Factor: Quantity	Scaling Factor: Units†
Pipeline construction: soil disturbance, vegetation removal[1]	8000	Miles per 10^6 B/D increase in crude oil supply
Air pollution from new pipelines onshore and offshore[3]		
Particulates	1.25	Tons/day per 1000 miles pipeline
SO_2	16	"
Hydrocarbons	0.38	"
NO_x	5-8.8	"
CO	0.50	"
Air pollution from a TAPS[4]		
Particulates	2	Tons/day per 1000 miles pipeline
SO_2	25	"
Hydrocarbons	2	"
NO_x	36	"
CO	11	"
Offsite impacts induced by employment, urbanization, and recreation demands		
Onshore[5]	> 0	Employees per 1000 miles of pipeline
Alaska[6]	300	Employees per Trans-Alaska Pipeline System

[1]Assuming a second TAPS from Naval Petroleum Reserve Number 4 to Valdez.

[2]Assuming 50 percent of the total pipeline mileage of 220,000 miles[19] (AF 298, Table 20) is used for crude oil transportation and assuming 13 million barrels per day of crude oil transported by pipeline. Both numbers are for 1971.

[3]A 24-inch diameter crude oil pipeline requires 150 horsepower per mile of pipe.[30] Using distillate fueled pumps which use 0.064 gallons of fuel per horsepower hour, we calculate 0.3×10^3 gallons of distillate fuel per 1 mile of pipe per day. Emission factors for distillate fuel burning pumps are:

SO_2--142 lbs/10^3 gal, particulates--15 lbs/10^3 gal, NO_x--40-80 lbs/10^3 gal, CO--4 lbs/10^3 gal.

Source: Compilation of Air Pollutant Emission Factors, Third Edition, U.S. Environmental Protection Agency, 1973.[24]

[4]Summary Report Air Quality: "Stations and Related Facilities for the Trans-Alaska Pipeline," Alyeska Pipeline Service Company, April 1974, p. 6-3[31] We assume a second TAPS would have these same emission factors.

[5]Based on the average number of employees per mile of pipe (16,000 for 220,000 miles of pipeline).

[6]Permanent employment for TAPS is anticipated to be 300 people.

†Approximate conversion factors: 10^6B = 160,000 m^3
1 ton = 907 kg
1 mile = 1.6 km

(2) Tankers

Normal tanker operations have the potential to create more environmental impact than do pipeline operations. Table 3-15 highlights the major impacts and scaling factors for normal tanker operations. The two major impacts are oil releases to the marine environment and sewage disposal. Tankers, generally in port only a few days, produce little sewage in U.S. waters. The control of tanker ballast cleaning operations, which can be a major source of water pollution, cannot be controlled beyond the U.S. 12-mile limit.

Table 3-16 shows the major impacts from storage facilities. TAPS storage is the only storage facility included since most other oil storage is located at refinery sites.

(3) Tanker and Pipeline Accidents

Tanker groundings and collisions have resulted in major oil spills, for example, the Torrey Canyon. Dragged anchors have resulted in several pipeline breaks, which released large quantities of oil.[33] Table 3-17 indicates scaling factors for the tanker and pipeline accidents that are the most likely to occur.

c. Refineries

Many of the impacts of refineries come from the manpower, materials, capital, and water requirements for its construction and operation. To provide information on refineries, analagous to that presented in the MCI scenario (Chapter 6) for the synthetic fuels technologies, Table 3-18 shows the impact scaling factors for refinery

Table 3-15

IMPACT SCALING FACTORS FOR NORMAL TANKER OPERATIONS

Impact	Scaling Factor: Quantity	Units*
Oil releases to the marine environment from ballast cleaning		
Alaska to Pacific Coast[7]	13-270	Barrels/1,000,000 barrels transported
Sewage from tanker operation in coastal waters†		
Imports[11]	1.5	10^3 gal/tanker-day
Alaska[11]	1	10^3 gal/tanker-day

*Approximate conversion factors: 10^6 B = 160,000 m^3
10^3 gal = 3.8 m^3

†Tankers are in port about 36 hours.

Table 3-16

IMPACT SCALING FACTORS FOR TRANS-ALASKA PIPELINE STORAGE TERMINAL AND DEEPWATER TERMINAL

Impact	Scaling Factor	
	Quantity	Units*
Land disturbance and land withdrawn from alternative uses[34]	800	Acres per TAPS pipeline
Tankers[34]	3	100,000 Dwt† tankers/day
Potential oil spills from ruptured storage tanks during an earthquake[36]	44	510,000 barrels per tank
Permanent employment[34]	100	People

*Approximate conversion factors: 1 acre = 4000 m^2
1 ton = 907 kg
1 barrel = 0.16 m^3

†Dwt = Dead weight tons

Table 3-17

IMPACT SCALING FACTORS FOR CRUDE OIL PIPELINES AND TANKER ACCIDENTS

Impact		Scaling Factor: Quantity	Scaling Factor: Units*
Maximum oil spill from break in an offshore pipeline		3,000	Barrels/mile of 24-inch pipeline
Maximum oil spill from break in TAPS[35]		50,000	Barrels/break
Maximum oil spill from breakup of a 200,000-Dwt† tanker		1,400,000	Barrels/tanker
Maximum oil spill from rupture of storage tanks for TAPS		20,000,000	Barrels/TAPS storage facility
Major accidents:[7]	Imports	34	Barrels/million barrels transported
	Alaska	34-182	"
Minor accidents:[7]	Imports	1.5	"
	Alaska	3	"

*Approximate conversion factors: 1 barrel = 0.16 m^3
1 inch = 0.025 m

†Dwt = Dead weight tons

Table 3-18

SCALING FACTORS FOR RESOURCE REQUIREMENTS FOR 10^6-B/D REFINERY CAPACITY

Item or Resource Required	Scaling Factors: Quantity	Units*
Construction		
Capital[37]	2,000	10^6 1973 \$ (cumulative)
Labor[38]	37,500	Man-years (cumulative)
Land[10]	22,000	Acres
Steel[38]	850	10^3 tons
Operation		
Capital[37]	500	10^6 1973 \$/year
Labor[39]	9,500	Number permanent employees
Water[37]	60	10^3 acre-ft/year
Electric power[10]	250	MW

*Appropriate conversion factors: 1 acre = $4000 m^2$, 1 ton = 907 kg, 1 acre-ft = 1,200 m^3, 10^6B = 160,000 m^3