Strategic Petroleum Reserve

Final Environmental Impact Statement

Volume I

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Federal Energy Administration

Strategic Petroleum Reserve Office

SUMMARY

STATEMENT TYPE: ( ) Draft (X) Final Environmental Statement

PREPARED BY The Strategic Petroleum Reserve Office, Federal Energy Administration, Washington, D. C.

1. Type of Action: ( ) Legislative (X) Administrative

2. Brief Description of the Proposed Action:

The Federal Energy Administration proposes to implement the Strategic Petroleum Reserve, Title I, Part B of the Energy Policy and Conservation Act of 1975 (P.L. 94-163). The purpose of the Reserve is to mitigate the economic impacts of any future interruptions of petroleum imports. One hundred fifty MMB of oil will be stored by 1978 in the Early Storage Reserve, and five hundred MMB will be stored by 1982 under the full program. It is proposed that crude oil be stored underground in solution-mined salt cavities, and conventional mines. However, modification to the proposal may require that petroleum products be stored aboveground in tanks.

3. Summary of Environmental Impacts and Adverse Environmental Effects:

This programmatic EIS identified particularly sensitive environmental parameters that are being investigated in more detail in specific EIS's for each candidate site. The most sensitive parameters appear to be water quality and geology. The adverse impacts that could result from the program include the degradation of surface water quality from construction runoff, increased dredging, and more frequent oil spills. In addition, brine disposal associated with solution mining salt cavities will increase the salinity of the receiving waters, whether underground saline aquifers or small portions of the Gulf of Mexico. Changes in water quality will have a short-term impact on aquatic organisms in local areas. Use of large quantities of ground water for developing salt cavities (although not now anticipated) could cause some surface subsidence over water storage areas, slow salt water encroachment, and movement of near-surface geologic faults. Hydrocarbon emissions from fill and withdrawal operations may cause temporary localized violations of the Federal standard, but no long-term adverse impact on air quality would result.

4. Alternatives Considered:

Non-Structural Alternatives to the Strategic Petroleum Reserve
- Increase Domestic Energy Supplies
- Reduce Energy Demand by Conservation
- No Action

Alternative Methods of Acquiring the Oil
- Naval Petroleum Reserve Oil
- Royalty Oil
- Old Oil
- Open Market Purchase of Oil
- Imported Oil

Implementing the Industrial Petroleum Reserve

Structural Alternatives
- Solution-Mined Cavities in Salt
- Conversion of Salt and Other Mines
- Aboveground Tanks
- Laid-Up Tankers

5. Agencies and Others from Whom Comments were Received:

Department of Agriculture
Department of Commerce
Department of the Interior
Department of Labor
Department of the Treasury
Environmental Protection Agency
Nuclear Regulatory Commission
Tennessee Valley Authority
Arizona
California
Colorado
Delaware
Florida
Georgia
Hawaii
Idaho
Illinois
Indiana
Iowa
Kentucky
Maryland
Massachusetts
Mississippi
Missouri
New Jersey
Nebraska
New Mexico
North Carolina
North Dakota
Ohio
Oklahoma
Oregon

Pennsylvania
South Dakota
Texas
Vermont
Wisconsin
Wyoming
American Petroleum Institute
Amoco Oil Co.
Bonaire
Intertanko
National Science Foundation
Standard Oil Company of California
Texaco, Inc.

6. Date made available to CEQ and the Public

Final statement was made available to the Council on Environmental Quality and the public on December 16, 1976.

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I. INTRODUCTION AND SUMMARY

All agencies of the Federal Government are required by the National Environmental Policy Act of 1969 (NEPA), 16 U.S.C. 4321 *et seq*., as implemented by Executive Order 11514 of March 5, 1970, the Council on Environmental Quality (CEQ) Guidelines of August 1, 1973, to prepare a detailed environmental impact statement (EIS) on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objectives of NEPA are to (1) build into the agency decision-making process an appropriate and careful consideration of all environmental aspects of proposed actions, (2) explain potential environmental effects of proposed actions and their alternatives for public understanding, (3) avoid or minimize adverse effects of proposed actions, and (4) restore or enhance environmental quality as much as possible.

The designated agency responsible for the preparation and filing of this EIS is the U. S. Federal Energy Administration (FEA). The FEA was established by the Federal Energy Administration Act of 1974 (88 Stat. 96), which became effective June 28, 1974. The FEA is vested with broad authorities relating to the production, conservation and allocation of energy to ensure that the supply of energy available to the United States will continue to be sufficient to meet our total energy demand. The FEA also is to ensure that in the event of energy shortages, priority needs for energy are met, and that the burden of the shortages is borne with equity. The FEA has adopted policies and procedures for the preparation of EIS's on its own actions which were published in the Federal Register, Vol. 41, No. 21, January 30, 1976.

The subject of this EIS is the Strategic Petroleum Reserve program which was mandated by the Energy Policy and Conservation Act of 1975, Title I, Part B. A programmatic EIS serves the purpose of satisfying NEPA requirements for any major Federal action significantly affecting the human environment when the action involves no immediate discrete and site-specific undertaking. As expressed by the Council on Environmental Quality, the purpose of a programmatic impact statement is to "...provide an occasion for a more exhaustive consideration of efforts and alternatives than would be practicable in a statement on an individual action. It ensures consideration of cumulative impact that might be slighted in a case-by-case analysis and it avoids duplicative reconsideration of basic policy questions", (CO-382).

Consistent with this approach FEA has identified three alternative storage systems for satisfying the objectives of the program. These alternatives, which consist of solution-mined cavities in salt, conventional mines and aboveground tankage are all treated evenhandedly in this EIS. Prototype "worst case" facilities were developed to characterize these systems and to provide a basis for determining potential program impacts and resource requirements.

Because this is a programmatic EIS analytic efforts were focused on the impacts expected at national and regional levels, specifically the Gulf Coast and the East Coast. The names and locations of specific sites under consideration are not given here to avoid hindering FEA's ability to acquire such sites at a reasonable cost. Subsequent site-specific EIS's for each candidate storage location will evaluate the sensitivities of each of the proposed sited to the characteristics of a particular storage system.

A. Overview of Program Objectives

The Energy Policy and Conservation Act of 1975, Title 1, Part B, Strategic Petroleum Reserve, provides for the creation of four distinct but overlapping reserves:

- Strategic Petroleum Reserve (SPR) - Sections 151 and 154. To reduce the impact of disruptions in supplies of petroleum products*, and to carry out U. S. obligations under the International Energy Program (IEP) agreement, the EPCA provides for the storage of at least 150 million barrels of petroleum products, including crude oil, by December 22, 1978, and authorizes the storage of up to 1 billion barrels. The Act requires FEA to develop a national plan for crude oil storage which must provide for, to the maximum extent practicable, the storage of crude oil equal to the volume of crude oil imports into the United States during the three consecutive highest import months in the 24 months preceding December 22, 1975 (subsequently determined to be approximately 500 million barrels, which were imported during October-December 1975), by December 22, 1982. The Act requires at least 10 percent of this goal be satisfied within 18 months of enactment, 25 percent within 36 months, and 65 percent within 60 months.

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* Petroleum products, as defined in the legislation, means crude oil, residual fuel oil, or any refined petroleum product, including natural (gas) liquid and any natural gas liquid product.

- Early Storage Reserve (ESR) - Sections 151 and 155. The Act further requires creation of an ESR as part of the SPR to provide limited protection from near-term disruptions in the supply of petroleum products and to fulfill U. S. obligations to the IEP. To this end, if the SPR Plan has not become effective, the ESR must contain at least 150 million barrels of petroleum products to be stored, to the maximum extent practicable, in existing capacity by December 22, 1978. The ESR must also provide for meeting needs for residual fuel oil and refined petroleum products in FEA regions that depend on petroleum imports to fill a substantial portion of their total energy requirements.

- Industrial Petroleum Reserve (IPR) - Section 156. The Act grants the FEA discretionary authority to establish an IPR as part of the SPR. Specifically, the Act authorizes the FEA to require importers and refiners to acquire, store, and maintain in readily available inventories amounts of petroleum equal to 3 percent of the amount imported or refined by them in the previous calendar year.

- Regional Petroleum Reserve (RPR) - Section 157. The SPR plan must provide for the establishment of an RPR in or readily accessible to any FEA region in which imports were used to meet more than 20 percent of residual fuel oil or refined product demand during the preceding 24 months. The quantity of petroleum product in the RPR is part of, rather than in addition to, the quantities of crude required in the SPR. Although the RPR is designed to provide substantial protection against regional supply interruption, it is not to exceed the aggregate of imports of the highest three consecutive months of the preceding 24-month period, computed annually. The FEA may substitute crude or product for amounts of residual or other refined petroleum products stored in the RPR, if substitution is necessary or desirable for purposes of economy or efficiency and if there will be no delay or other adverse effect on satisfying the purpose of the RPR.

B. Major Types of Storage Facilities

The FEA has investigated many types of storage facilities, of which three are still under consideration: solution-mined cavities in salt, conventional underground mines and aboveground tankage. These alternative storage systems are summarized briefly here.

1. Solution Mined Cavities in Salt

A highly promising method for satisfying the requirements of large quantities of petroleum product storage near distribution and processing facilities is the development of new caverns or the modification of existing caverns in salt domes or salt beds. There are more than 350 known salt domes within a 50,000 square mile area along the Gulf Coast, many near major refinery centers. FEA's background investigations have revealed that several of the domes offer high integrity as a storage medium and maximum protection against fire, storm, and sabotage. The techniques for storing hydrocarbons in salt caverns have been proven in the United States and elsewhere. Also, appreciable cavern space exists, a factor that is particularly appealing for satisfying the ESR objectives.

To develop a new cavern or modify an existing cavern in a salt dome requires essentially the same processes and equipment. A well is drilled into the dome, appropriate tubing strings are installed and the cavern is prepared by injecting water into the well and circulating it to cause the dissolution of salt. This process is sometimes called "leaching". As the water approaches saturation with dissolved salt, it is displaced from the cavern by incoming water. The cavern configuration is controlled by proven dissolution mining techniques. One salt dome can readily accommodate multiple caverns; for example, a storage facility at a salt dome may consist of twenty caverns each of 10 MMB capacity for a total of 200 MMB storage. Approximately 196 MMB of light hydrocarbons are currently stored in salt dome cavities in this region. An additional 88 MMB are stored in salt beds in this region and in other parts of the country.

Equipment required for development of the facility is found in standard petroleum industry inventories. Conventional construction equipment is sufficient for preparing sites and for laying of pipelines. Drill rigs and work-over rigs are planned for preparing the well and tubing translation during solution mining. Other items are pumps, motors, valves, and pipelines.

2. Mines

It is technologically feasible to store substantial volumes of oil in either existing mines or new mines that are excavated solely for petroleum storage. Existing mines not requiring extensive modification are prime candidates for participation in the ESR. New mines, because of the time required for development, are limited to achieving the ultimate goals of the SPR.

Conversion of existing mines to petroleum storage facilities requires principally excavation of sump pumps, equipment shafts and vents, and the construction of curbs and bulkheads, surface pumping stations, wellheads, surge tankage, and pipelines. Similar activities are required for construction of new mines.

3. Tankage

In the East Coast region, where suitable salt structures or formations are not available for subsurface storage, conventional tankage is a flexible but extremely costly alternative. This type of storage can be designed to integrate into existing distribution facilities. Petroleum products can be stored in tanks near distribution terminals for timely delivery to consumers. There are four basic types of tank storage suitable for the SPR: (1) fixed roof, (2) floating roof and internal floating covers, (3) variable vapor space, and (4) pressure.

An aboveground storage facility will consist of a tank farm comprised of tanks, pipelines, valves, pumps, motors, and ancillary equipment for safety and environmental protection. The size of the tank farm will be dictated by a particular region's petroleum demands and available sites. Development of storage reserves using conventional tankage can be accomplished with standard construction equipment and techniques.

4. Prototype Storage Facilities

For the purposes of the environmental impact analysis, prototype facilities were devised in an attempt to identify any particularly sensitive environmental parameters. These prototypes represent a "worst case" since they are the largest facilities contemplated at this time. These prototypes consist of:

- an existing 90 MMB solution-mined cavity in salt,
- a new 200 MMB solution-mined cavity in salt,
- an existing 90 MMB conventional salt mine,
- an existing 15 MMB rock mine,
- a new 30 MMB rock mine, and
- a new 10 MMB tankage facility.

C. Description of the Environment

Two major areas of the nation were characterized at the regional level: the Gulf Coast and the Atlantic or East Coast. The Gulf Coast was chosen because of its extensive natural salt dome formations which provide existing and potential storage capacity and because of the significant petroleum refinery and distribution facilities located there. The East Coast region is included because it may require storage of refined products under the SPR.

The environmental parameters of geology, hydrology, water quality, meteorology, climatology, air quality, noise, history, archaeology, land use, demography and economics are broadly described. These descriptions provide the basis against which to measure the impacts associated with each parameter.

D. Environmental Impacts on the Gulf and East Coasts

1. Geology

Halokinesis - The stability of salt domes is not expected to be appreciably affected by storage of even large volumes of petroleum (e.g., 200 MMB). Replacement of salt with liquid media will change the thermodynamic behavior of a dome and consequently could change the "rise rate" of the dome.

Subsidence - Very slight subsidence occurring locally over a dome cavity field could occur. Appreciable local subsidence will likely occur in subsidence-sensitive areas of the Gulf Coast if large amounts of ground water are used for solution mining.

Seismic Stability - The overall risk of seismic damage to facilities in the Gulf Coast region is very low and the risk of damage to a salt dome cavity is even lower. The likelihood of damage from seismic events generally is low for the East Coast region also.

2. Hydrology

Brine Disposal - Because local industry will not be able to consume all of the brine produced by developing salt dome caverns in all cases, two additional methods of brine disposal were evaluated: deep well injection and disposal into the Gulf. Deep well injection of industrial wastes, including brine, into saline aquifers is a standard practice in the Gulf Coast region. However, the volumes and rates required in developing a 200 MMB cavern exceed those that have been experienced to date. Therefore, there is a possibility that barriers between fresh and salt water aquifers could become contaminated. However, if proven downhole injection techniques are employed, environmental risks are minimized.

Disposal of saturated brine into the Gulf under worst case conditions of simultaneously developing caverns for a 200 MMB storage facility was simulated by mathematical modeling. Results showed that the change in salinity that can generally be detected by aquatic life occurs between 5,000 feet and 12,000 feet downcurrent of the brine diffuser, depending on the ocean currents. Depending again on the currents, the area experiencing a salinity increase of 0.5 parts per thousand would be no greater than 3,000 acres. From investigation of marine life tolerance and response to changes in salinity, it was concluded that brine disposal into the Gulf will not create a hazard to marine life if brine is disposed of far enough from the shoreline such that detectable salinity changes do not encroach upon known reefs, banks, or important fishing areas, or impede marine ingress or egress at tidal inlets.

Water for leaching salt caverns will come from groundwater sources, major river systems or the Gulf of Mexico. Removal of large quantities of ground water could increase subsidence, depending on specific site conditions. If surface water is used, intake structures will be designed and located to minimize the impingement of aquatic organisms in intake screens. The use of either ground or surface-water sources requires new pipelines which disturb soils, remove vegetation, and change wildlife feeding patterns. The extent of these impacts will depend upon specific site conditions.

3. Meteorology

The Gulf Coast region is occasionally affected by catastrophic meteorological phenomena, the most destructive of which are hurricanes and tropical storms. Tornadoes are fairly common but are usually rather weak. Tropical cyclones occur about every five years. Even in the event of damaging meteorological events, salt cavern facilities will not be completely destroyed. Surface structures could conceivably be totally destroyed while the underground storage remains intact. Some oil spillage from the surface facilities only is expected. The extent of the spill will depend on the volumes of oil in the pipelines, pumping equipment, and other surface facilities.

In the East Coast region, tropical cyclones are most common in the sector extending from Rhode Island to Nantucket, with tropical cyclones occurring about every fours years, hurricanes every fourteen years, and great hurricanes every eighty-five years. If subjected to storm surge from a great hurricane, storage facilities could be heavily damaged, depending on their nearness to shore and the size of landfall. However, the probability of a great hurricane achieving landfall at a specific storage site is very low.

4. Air Quality

The direct impact on air quality of Gulf Coast storage facilities will be minimal. Some localized dust emissions will occur during the construction phases. Evaporative hydrocarbon emissions during filling and operation of the facilities will be negligible, but tanker unloading and loading is predicted to cause local and temporary violations of Federal standards under worst-case meteorological conditions.

If aboveground tanks are used on the East Coast, filling activities may cause the Federal hydrocarbon standards to be exceeded for storage of distillate fuel oil only; they will not be exceeded for storage of residual oil.

5. Noise

For the Gulf Coast storage systems, noise fields resulting from drilling operations could cause residents within a radius of 1,500 feet of the drilling site to voice opposition to the construction activity. Noise from operating the facility could conceivably be of concern within a distance of 3,500 feet of the site. Noise from pipeline construction will be short-term but is a likely source of human annoyance in the proximity of activity.

Noise from construction of a tank farm could annoy residents within 3,000 feet of the center of activity. Filling and operation are not expected to generate noise levels high enough to be of local concern.

6. Biology

The Gulf Coast region is comprised of many diverse biotic assemblages. Impacts were assessed on the basis of eighteen different biotopes and their vulnerability to disturbance by construction, filling, and operations activities. Construction will affect, on a short-term basis, the habitat of both terrestrial and aquatic life. The degree of impact will depend greatly on the relationship of the facility site to wetland-estuarine nursery areas and locations of known endangered species.

Impacts from filling and operations will be less pronounced than from construction, but will be of a longer duration. The primary effect will be the loss of land area for use by animals and the productivity of plants once occupying the site and temporary disturbances along pipeline routes during construction. The transport and handling of large quantities of petroleum, will increase the probability that oil spills will occur. Biotopes will respond differently to spills and recover at different rates. Small chronic spills in the past have caused the most permanent adverse ecological effects. However, the worst case would be an acute spill near the shore in a major estuarine system surrounded by very productive wetlands.

Except for the effects of brine disposal, the same general types of impacts can be expected to occur to East Coast biotopes as those described for the Gulf Coast.

7. Historical and Archaeological

Construction and excavation for surface buildings, pipelines, roads, etc., could result in physical damage or alteration of any historical or archaeological resources within the area. Site-specific studies will determine the means for minimizing or eliminating the impacts.

8. Land Use

Because the Gulf Coast region comprises the major petrochemical production area of the United States, it is not expected that planned storage facilities will cause an appreciable impact on regional land uses. However, site-specific impact studies will determine any likely changes that would occur locally.

Land use impact of storage facilities on the East Coast is also highly site specific. Development in areas supporting similar facilities will have the least effect on land use whereas an appreciable effect would occur in undeveloped areas. In general, land use conflicts will be larger in the New England sector of the region.

9. Socioeconomics

The demographic and economic analysis demonstrated that construction and operation of Gulf and East Coast storage facilities will have an insignificant socioeconomic impact. The short-term impacts caused by construction will be more pronounced than long-term impacts to be experienced during operation and maintenance.

10. Economics

Input-Output economic models were exercised for assessing the effects of construction of representative storage facilities. The direct government expenditures associated with each type of storage facility and the total employment and economic impact that would result is summarized below.

TABLE I-1

Facility Type	Storage Capacity (MMB)	Direct Expenditure (Million Dollars)	Total Economic Impact (Million Dollars)	Construction Period (Yrs.)	Employment
Existing Cavity in a Salt Dome	90	$ 90.00-135.00	$252.00-378.00	1-2	714
New Cavity in a Salt Dome	200	252.00-312.00	705.60-873.00	3-5	1427
Existing Conventional Salt Mine	90	81.00-135.00	226.80-378.00	2-5	902
Existing Non-Salt Mine	15	9.75-22.95	27.30-64.24	2-7	390
New Non-Salt Mine	30	120.00-180.00	56.00-504.00	4-8	700
Conventional Storage Tanks	10	60.00-120.00	168.00-336.00	2-5	200

11. Oil Spills

Because of the large volume of petroleum that will be handled in a compressed time frame, the potential for oil spills is increased. Risk analysis suggests that transhipment and lightering are feasible alternatives that produce about the same frequency and amount of spilled oil. Such spills can cause adverse impacts upon ecosystems, which range from very small to extensive, depending on spill location, spill quantity, control measures, weather, and other factors.

E. Measures to Mitigate Adverse Impacts

For each area of environmental concern summarized above, certain policies and measures exist that at least partially attenuate environmental impacts. The EIS describes two categories of mitigating measures:

- mitigating measures mandated by legislation or regulation, and

- mitigating measures that are available to developers of the storage system through engineering design and construction practices.

The first category includes requirements of a number of Federal agencies that are superimposed on this program and function as mitigating measures, as well as the requirements of a number of state and local agencies which may also apply. The second category includes those policy decisions and physical actions that may be adopted by participants to minimize environmental impact.

F. Irreversible and Irretrievable Commitments of Resources

Some irreversible and irretrievable commitments of resources will result from implementation of the program.

1. Land Resources

If large quantities of ground water are used, subsidence in the vicinity of the withdrawal well field will probably occur and alter the topography of the land. In construction of new mines, some rock material will be rendered useless and discarded. Some land for all facility types will be permanently altered from its original state.

2. Water Resources

Deep-well injection of brine will commit the injection zone to use as a future brine source only or as a liquid waste disposal site. Should large quantities of fresh ground water be used, permanent changes in head relationships and flow patterns in aquifers could occur. For developing 200 MMB of new solution mined cavities, 180,000 to 200,000 acre-feet of fresh or sea water will be converted to brine.

3. Ecological Resources

The potential exists for disturbance and possible loss of endangered species, but none are certain to be affected.

4. Archaeological and Historical Resources

Any disturbance of archaeological and historical resources could be irretrievable. It is uncertain whether any sites will be affected.

5. Human Resources

For the ESR, an estimated 500 man-years of direct labor will be expended, for the SPR, the level of direct labor expended could range from 1,000 to 3,800 man-years. Statistically, some loss of life can be expected in construction phases and other losses will occur from increased population, increased traffic accidents, and other causes.

6. Materials

Some materials such as paint, asphalt, lumber and glass will be irretrievably lost. A significant amount of steel used for tank construction will be unavailable for other uses.

7. Energy

The amount of energy required to construct the Reserve is estimated to be no more than 0.9 million megawatt-hours. The system will store up to 1.7 billion megawatt-hours of energy.

G. Program Alternatives

This section addresses the non-structural alternatives to the Strategic Petroleum Reserve and their environmental impacts. Three types of non-structural alternatives are discussed. The first consists of the other Federal supply and conservation programs that contribute to the national goals of energy self-sufficiency and independence from reliance on oil imports. The "no-action" alternative is part of this discussion. The second type consists of the various methods available to acquire the oil for the Reserve. The third discusses the Industrial Petroleum Reserve.

1. Alternatives to the Proposed Action

a. Increase Domestic Energy Supplies

Measures being considered to increase domestic energy supplies include the following:

- reopening and expanding the Pacific Outer Continental Shelf (OCS), developing the Atlantic and Alaskan OCS, and developing the Alaskan onshore oil fields, including Naval Petroleum Reserve No. 4.;

- encouraging further exploration of new onshore deposits of oil, and increased use of secondary and tertiary production techniques;

- accelerating nuclear power plant construction;

- producing synthetic fuels from oil shale and coal; and

- developing advanced technologies such as solar and geothermal energy.

Although all of these measures could contribute to energy independence and a reduction in oil imports in the long-term, only the first four have the potential for appreciable implementation within the seven-year time frame of the SPR. The extent to which each of these alternatives would provide near-term protection against import interruptions and impact on the environment is described in Section III.A.1.a.

b. Reduce Energy Demand by Conservation

There are also many options available to the Government to accelerate energy conservation. A comprehensive Federal program to encourage and require businesses and individuals to conserve energy was proposed in early 1975, as part of the Energy Independence Act of 1975. The ultimate goal of the program is to hold imports to 3-5 MMBPD and to make the U. S. a net energy exporter again by 1985. The program includes conservation measures in the transportation, residential and commercial, industrial, and utilities sectors, some of which have already been authorized in EPCA. The savings resulting from conservation measures in each of these sectors are defined in Section III.A.1.b., along with their economic and environmental impacts.

c. No Action

In the event of a severe interruption of the Nation's foreign oil supply, several other Federal authorities could be called upon to mitigate some of the adverse economic effects, even if the Strategic Petroleum Reserve Program were not implemented. These include the Energy Conservation Contingency Plans and the Rationing Contingency Plan authorized on a standby basis by EPCA, and the Emergency Petroleum Allocation Act of 1973, as amended. Of these three, only the Energy Contingency Plans actually reduce the country's energy requirements; the Rationing Contingency Plan and the Emergency Petroleum Allocation Act simply allocate the available supply among classes of users in accordance with established priorities.

A preliminary environmental assessment by FEA of the conservation plans and the Rationing Contingency Plan indicates that any environmental effects of their implementation would be beneficial. More detailed information on the economic and environmental effects of these programs will be available in the plans themselves, due for submission to Congress in January, 1977. The petroleum allocation program, like the rationing plan, simply allocates available fuel supplies. Therefore, no significant environmental impacts are anticipated.

2. Alternative Methods for Acquiring the Oil

Section 160(a) of the EPCA authorized several methods for use by FEA in acquiring the oil for the Strategic Petroleum

Reserve. At the time the draft programmatic EIS was prepared, FEA was actively examining and evaluating the various methods and combination of methods of acquisition, and no firm decision had been reached. The alternatives authorized by EPCA, all of which have been carefully considered by FEA, are:

- using (or exchanging) Naval Petroleum Reserve Oil;
- using (or exchanging) royalty oil;
- purchasing "old" oil;
- purchasing oil on the open market;
- importing oil.

All of these alternatives would have the effect, directly or indirectly, of increasing oil imports. Additional imports would increase tanker traffic and associated oil handling operations, and hence the risk of oil spills. The environmental impacts of oil discharge are discussed in Section V.D. of this EIS.

Based on its examination of these alternatives, FEA expects to acquire the oil for the SPR on the open market from either foreign or domestic sources, pursuant to the Federal procurement regulations, probably using negotiated procurement. However, in addition FEA would utilize the statutory authority in the Emergency Petroleum Allocation Act (EPAA) to allow crude oil suppliers to participate in an "entitlements" program whereby the amount paid them by FEA would be reduced by the value of entitlements received by the suppliers, which they then could sell to recover the full amount of their sale prices. This should result in a price to the government roughly equal to the national average composite price to refiners (including imports) plus an incremental cost (in the form of a handling fee) in servicing the SPR.

3. Industrial Petroleum Reserve (IPR)

The FEA has considered the threshold question of whether the IPR authorities should be exercised, and is proposing in the SPR Plan that no IPR be implemented.

In dealing with this unresolved question, the following three alternatives for implementing an IPR were considered:

- industry supplies the oil for storage in government-owned bulk facilities;
- each company supplies the oil for storage in its own facilities;
- industry supplies the oil and acts together to provide bulk facilities for comingled oil storage.

When viewed from the national perspective it is FEA's conclusion that a Federal Government Reserve could be more efficient than an Industry Reserve and that the cost to the Nation would be less if the government rather than industry were to build the Reserve. The added costs and inefficiencies of an IPR stem from the added administrative cost to government and industry associated with an IPR stored in centralized underground storage facilities. The U. S. Government's administrative costs and industry's costs would increase significantly if industry met an IPR obligation by building local dispersed storage. Similarly, the utility of the Reserve would decrease while environmental impacts and inequities among companies might increase with an IPR that utilizes dispersed, company-owned and constructed storage.

The economic impacts of the IPR would depend on whether importers and refiners were allowed and were able to pass on IPR program costs to the oil users, thereby causing a part of the cost of the storage program to be borne by consumers. If costs could not be passed on, the industry might not be able to recover the capital needed for implementation.

There would be no additional environmental impacts associated with the oil acquisition aspects of the IPR, inasmuch as the oil stored under the IPR would be part of, rather than in addition to, the ESR or SPR. If industry were to construct either centralized or decentralized storage facilities, their impacts would be the same as those already discussed.

H. Environmental Impact Statement Content

This EIS is structured to comply with the requirements of NEPA and to enable the reviewer to examine the various influences and the resulting effects associated with the program. It is organized in eight major chapters; each have a relationship to the impact of the proposed program. These chapters are listed as follows:

I. Introduction and Summary

II. Program Description

III. Alternatives

IV. Description of the Environment

V. Environmental Impact of the Proposed Program

VI. Unavoidable Environmental Impacts and Mitigating Measures

VII. Irreversible and Irretrievable Commitments of Resources

VIII. The Relationship Between Local Short-Term Uses of Man's Environment and the Maintenance and Enhancement of Long-Term Productivity

While not treated in separately identified sections, the relation of the proposed project activities to land use plans and policies is discussed in Section V.A.8. and V.B.8. of this EIS, while discussion of the need for the program and the public interest in its accomplishment is set forth in part II.A.

Two additional sections, Bibliography (IX) and Consultation and Coordination (X), are included to document sources of information and multiparty participation. A central reference document (RA-223)* contains a compilation of pertinent supportive information developed during this EIS investigation.

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* Alphanumeric characters in parentheses designate source materials; references are listed in the Bibliography, Chapter IX.

II. PROGRAM DESCRIPTION

This chapter describes the major elements of the Strategic Petroleum Reserve Program.[1] The need for a stand-by energy supply is documented, followed by a discussion of the legislative history and requirements for the Strategic Petroleum Reserve. Major types of storage facilities and distribution systems are summarized, followed by a description of the process by which candidate storage sites have been designated. The chapter concludes with a discussion of the issues associated with acquiring the sites and implementing the program.

A. Need for Strategic Petroleum Reserve

The United States possesses abundant natural resources and yet is dependent upon the importation of large quantities of fuels. It has become increasingly dependent upon petroleum imports, which now constitute approximately 35-45% of the Nation's oil consumption and account for 20% of the total domestic energy usage. In 1974, the annual cost of these imports was over 25 billion dollars (NA-261).

In the past twenty-five years, the United States has experienced four sudden denials of oil imports for various reasons by oil-exporting countries. Not until the oil embargo of 1973-74 did the Nation find itself without the capacity and resources to offset the interruption of oil imports. This embargo reduced the quantities of petroleum exported to the United States by approximately 2 million barrels per day for 19 weeks and caused world prices for crude oil to escalate.

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[1] "Strategic" in this document in no way implies a relationship to military action or planning.

Although the economic impacts of these events on the U.S. economy are still under study and debate, most of the macroeconomic study estimates of the repercussions of supply denial and simultaneous price increases tend to indicate a Gross National Product (GNP) loss of approximately $35-45 billion. Although not all of this GNP loss can be ascribed to the embargo, there is no doubt the interruption contributed significantly to increases in the consumer and wholesale price indices. In addition, the GNP loss was reflected in higher unemployment and stagnation in several sectors, including automobile sales and housing starts, which exacerbated the economic downturn believed to have started in late 1973. During this period, the embargo prevented real growth that probably would have stabilized unemployment and provided a stronger base for eventual economic recovery.

The United States is now more vulnerable to a petroleum supply interruption than it was in the fall of 1973. Higher energy prices, natural gas shortfalls, and continued uncertainty about the availability and prices of alternative forms of energy have induced many energy users to restrict their energy consumption and emphasize more effective energy management practices. As a result, many relatively easy steps to conserve energy have already been taken, and significant improvements in energy efficiency have been achieved; further improvements will require substantial investment, longer lead times, and even more intensive energy management. Further, the program to convert oil- and gas-fired utilities and industrial plants to coal[1] will have converted many plants to coal, which will largely preclude conversion to coal during a future supply interruption. Some estimates have

[1]Provided under the Energy Supply and Environmental Conservation Act of 1974 and its Amendments.

shown that a future supply interruption of the magnitude of the one in 1973-74 could cause a reduction in GNP that, in terms of employment impact, would be equivalent to the loss of jobs for two million workers. Economic effects would not be limited to some geographical areas or industries, but would impact the entire Nation (NA-261).

Standby supplies of petroleum have been proposed repeatedly as a way to buffer the impact of future supply interruptions. The National Petroleum Countil (NPC), Ford Foundation, the Energy Laboratory at the Massachusetts Institute of Technology (MIT), and the Research and Policy Committee of the Committee for Economic Development have all recommended this action. In addition, the International Energy Program (IEP) agreement, which has been entered into by the U.S. and 17 other energy-importing countries, provides for the establishment of this type of reserve. Although the western European countries and Japan have developed stockpiles, the only appreciable stocks in the United States are working inventories.

B. Authorization for the Strategic Petroleum Reserve

The concern voiced by the above-mentioned organizations and by the public, in addition to the Nation's formal commitments to the IEP, provided strong impetus for an emergency storage program. President Ford recommended a storage program in his State of the Union message in January 1975, and Titles I and II of the Administration's Energy Independence Act provided for the creation of such a reserve (RA-151). Thereafter, the Senate and the House of Representatives passed separate bills (S. 622 and H.R. 7014, respectively) requiring creation of a strategic storage reserve, and the legislative differences were resolved at conference into Title I, Part B, Sections 151 through 166, of the Energy Policy and Conservation Act of 1974 (PL 94-163).

Briefly, the Act provides for the creation of four distinct but overlapping reserves:

- Strategic Petroleum Reserve (SPR) - Sections 151 and 154. To reduce the impact of disruptions in supplies of petroleum products,[1] or to carry out U.S. obligations under the IEP, the Act provides for the (creation of) storage of at least 150 million barrels of petroleum products, including crude oil, by December 22, 1978, and authorizes the storage of up to 1 billion barrels. The Act requires FEA to develop a national plan for crude oil storage that must provide, to the maximum extent practicable, for the storage of crude oil equal to the volume of crude oil imports into the United States during the 3 consecutive highest import months in the 24 months preceding December 22, 1975. The Act requires at least 10% of this goal be satisfied within 18 months of enactment; 25% within 36 months, and 65% within 60 months.

- Early Storage Reserve (ESR) - Sections 151 and 155. The Act further requires creation of an ESR as part of the SPR to provide limited protection from near-term disruptions in the supply of petroleum products and to fulfill U.S. obligations to the IEP. To this end, if the SPR Plan has not become effective, the ESR must contain at least 150 million barrels

[1] Petroleum products, as defined in the legislation, means crude oil, residual fuel oil, or any refined petroleum product, including natural (gas) liquid and any natural gas liquid product.

of petroleum products, to be stored (to the maximum extent practicable) in existing capacity by December 22, 1978. The ESR must also provide for meeting needs for residual fuel oil and refined petroleum products in FEA regions that depend on petroleum imports to fill a substantial portion of their total energy requirements.

- Industrial Petroleum Reserve (IPR) - Section 156. The Act grants the FEA discretionary authority to establish an IPR as part of the SPR. Specifically, the Act authorizes the FEA to require importers and refiners to acquire, store, and maintain in readily available inventories amounts of petroleum equal to 3% of the amount imported or refined by them in the previous calendar year.

- Regional Petroleum Reserve (RPR) - Section 157. The SPR Plan must provide for the establishment of an RPR in or readily accessible to any FEA region in which imports were used to meet more than 20% of residual fuel oil or refined product demand during the preceding 24 months. The quantity of petroleum product in the RPR is part of, rather than in addition to, the quantities of crude required in the SPR. Although the RPR is designed to provide substantial protection against regional supply interruption, it is not to exceed the aggregate of imports of the highest 3 consecutive months of the preceding 24-month period, computed annually. The FEA may substitute crude or product for amounts of residual or other refined petroleum products stored in the RPR, if substitution were necessary or desirable for purposes of economy or efficiency, and if there were no delay or other adverse effect on satisfying the purposes of the RPR.

Section 153 of the Act also established within FEA a Strategic Petroleum Reserve Office (SPRO) to implement the storage program. Since its inception, this office has developed alternative approaches to satisfying the legislated requirements, including types of storage facilities, optimal locations for storage, and preliminary engineering descriptions of storage elements, as described in Chapter III. A detailed plan for the Early Storage Reserve (ESR) was prepared and submitted to Congress on April 22, 1976, pursuant to Section 155 of the Act. That plan described the manner in which the first 150 million barrels of oil will be stored. FEA is currently preparing the Strategic Petroleum Reserve Plan to be submitted to Congress, pursuant to Section 154 of the Act. That Plan will present in detail the manner in which FEA proposes to implement the entire SPR Program. It will describe the quantities and types of oil to be stored, method of acquisition, types and locations of storage facilities, management of the Reserve, and distribution of oil in the event of a future supply shortage. The proposals presented in the SPR Plan will become effective after forty-five calendar days of continuous session of Congress from the time the Plan is submitted to Congress, unless it is disapproved under Section 159 of the Act.

FEA has examined the environmental and socioeconomic impacts of implementing the Strategic Petroleum Reserve, in accordance with the requirements of the National Environmental Policy Act of 1969 (NEPA). That programmatic environmental analysis was incorporated into a draft environmental impact statement (EIS), published June 26, 1976, and into this final EIS. Because the draft was prepared at an early stage of program development, many of the proposals contained in the SPR Plan had not yet been formulated, and thus much of the information presented in the draft was couched in terms of alternative actions and their impacts. In order to present a more complete assessment, the proposals contained in the SPR Plan which are germane to an environmental assessment are presented in this final EIS. In addition, FEA has analyzed the environmental impacts of developing the initial five alternative candidate storage sites for the ESR. The results of these analyses have been incorporated into five draft EIS's (DES 76-4 through 76-8), and other site-specific draft EIS's are in preparation.

C. Requirements for Storage Capacity

The Strategic Petroleum Reserve program provides for petroleum storage reserves based on 1974 and 1975 U.S. petroleum imports. Depending upon future U.S. imports, flexibility is given to the FEA to increase or decrease the quantity of stored petroleum in order to fulfill the purpose of the storage program.

1. Strategic Petroleum Reserve

In order to calculate the storage requirements of the program as it now exists, FEA examined 1974 and 1975 crude oil import data. Included in these data were imports to the Virgin Islands, Puerto Rico, and Guam, as summarized in Table II-1. The three consecutive months in which crude oil imports were highest were October through December of 1975. Based on imports in these months, the Strategic Petroleum Reserve is required to contain approximately 500 MMB of crude oil by December 1982.

2. Early Storage Program

In addition, the Early Storage Reserve requires that at least 150 million barrels of petroleum be stored by December 1978 to provide limited protection from near-term interruptions.

TABLE II-1

CRUDE IMPORTS 1974-1975

	MB/CD					
	USA	PR[1]	VI[2]	GUAM	Total	MMB
January 1974	2,382	190	610	28	3,210	99.5
February	2,248	190	398	28	2,864	80.2
March	2,462	190	458	28	3,138	97.3
April	3,267	190	381	28	3,866	116.0
May	3,748	183	277	28	4,236	131.3
June	3,957	239	561	28	4,785	143.6
July	4,167	227	619	28	5,041	156.3
August	3,852	211	354	28	4,445	137.8
September	3,758	193	593	28	4,572	137.2
October	3,936	190	344	28	4,498	139.4
November	3,997	140	402	28	4,567	137.0
December	3,979	159	854	28	5,020	155.6
January 1975	3,964	212	740	28	4,944	153.3
February	4,061	228	429	28	4,746	132.9
March	3,853	195	446	28	4,522	140.2
April	3,416	221	467	28	4,132	124.0
May	3,493	171	346	28	4,038	125.2
June	3,907	185	311	28	4,431	132.9
July	4,337	204	690	28	5,259	163.0
August	4,661	178	689	28	5,556	172.2
September	4,664	206	270	28	5,168	155.0
October	4,416	170	807	28	5,421	168.1*
November	4,630	171	489	28	5,318	159.5* } 497.9
December	4,657	220	590	28	5,495	170.3*

[1]Puerto Rico
[2]Virgin Islands
*Three highest consecutive months of crude imports. Total is 497.9 MMB.

Source: RE-182

TABLE II-2

FEA ADMINISTRATIVE REGIONS

REGION I	REGION II	REGION III	REGION IV	REGION V
Maine New Hampshire Vermont Massachusetts Connecticut Rhode Island	New York New Jersey Puerto Rico Virgin Islands	Pennsylvania Maryland West Virginia Virginia District of Columbia Delaware	Kentucky Tennessee North Carolina South Carolina Mississippi Alabama Georgia Florida Canal Zone	Minnesota Wisconsin Michigan Illinois Indiana Ohio
REGION VI	**REGION VII**	**REGION VIII**	**REGION IX**	**REGION X**
Texas New Mexico Oklahoma Arkansas Louisiana	Kansas Missouri Iowa Nebraska	Montana North Dakota South Dakota Wyoming Utah Colorado	California Nevada Arizona Hawaii Pacific Trust Territories American Samoa Guam	Washington Oregon Idaho Alaska

Source: RE-182

3. Regional Petroleum Reserve

At the time the draft programmatic EIS was prepared, FEA was actively evaluating the need for and method of implementing a Regional Petroleum Reserve (RPR) as provided for in Section 157 of EPCA. That section requires that the SPR Plan provide for establishment of an RPR in, or readily accessible to, any FEA region that imported 20 percent or more of its refined petroleum products during the previous 24 months. The states included in each FEA region are shown in Table II-2. Based on further analysis performed since the publication of the draft EIS, only FEA Regions I-IV qualify for regional storage, and these qualify only for residual oil (Table II-3). Section 157 also permits FEA to store crude oil in substitution for products required to be stored in a RPR, if it is necessary or desirable and can be made without delaying or adversely affecting the fulfillment of the purpose of the RPR.

The FEA's analysis has concluded that crude oil stored in large centralized facilities in the Gulf Coast area would be readily accessible to Regions I-IV; would offer greater distributional flexibility than dispersed storage in the regions in terms of the ability to respond to a variety of interruptions; would reduce environmental hazards; and would represent significant cost advantages over storage in qualifying regions. Therefore, the Administrator of FEA has found that substitution is necessary and desirable for purposes of economy, efficiency, and for other reasons, and would not delay or otherwise affect fulfillment of the purpose of the RPR. FEA proposes that RPR requirements be achieved through substitution of crude oil stored in centralized underground facilities.

Sufficient transportation capacity and refinery capacity is forecast to be available to distribute and refine the

TABLE II-3

REFINED PRODUCT DEMAND AND IMPORTS BY FEA REGION

	JANUARY 1974 - DECEMBER 1975								
	MOTOR GASOLINE			DISTILLATE FUEL OIL			RESIDUAL FUEL OIL		
FEA REGION	DEMAND[1] MB/CD	DEMAND[2] MB/CD	%	DEMAND[3] MB/CD	IMPORTS[2] MB/CD	%	DEMAND[3] MB/CD	IMPORTS[2] MB/CD	%
1	294	29	10	309	55	18	380	221	58
2	534	34	6	484	59	12	592	376	64
3	634	10	2	348	13	4	424	233	55
4	1106	1	0	342	4	1	339	230	68
5	1337	0	0	800	1	0	192	12	6
6	763	9	1	286	11	4	172	10	6
7	405	0	0	139	0	0	18	0	0
8	222	1	1	101	0	0	30	0	0
9	714	1	0	164	1	1	304	24	
10	228	1	1	127	0	0	78	0	0

[1] PAD level data from BOM Mineral Industry Surveys 1974-1975, distributed to FEA regions proportionally from Ethyl Corp. data.

[2] PAD level data from BOM Mineral Industry Surveys 1974-1975, distributed to FEA regions proportionally from FEA Office of Oil and Gas Report of Oil Imports 1974-1975. Shipments of products from Puerto Rico and Virgin Islands have been removed from BOM data.

[3] Source BOM Sales of Fuel Oil and Kerosine in 1974.

centrally-stored crude oil with no adverse effects on the Regions. Therefore, storage of refined products or crude oil within FEA Regions I-IV would not be necessary or appropriate.

The analysis of the regional impact of petroleum supply interruption has considered the needs of regions other than Regions I through IV. In particular, consideration has been given to the ability of the SPR and the associated distribution plan to assure the protection of areas such as the West Coast and the Northern Tier region of the country. It is concluded that the planned system will permit the equitable protection of all areas of the Nation.

4. Industrial Petroleum Reserve (IPR)

The Act gives FEA discretionary authority to require oil importers and refiners to store up to 3% of the previous year's imports or throughput as part of the ESR or SPR. The U.S. consumption of petroleum products (which approximates refiners' throughput) was 16.6 MMBPD or 6059 MMB in 1974 (FE-153) and is projected to grow at a rate of 2% per year compounded annually. At this rate, refiners could be required to store as much as 200 MMB in the SPR, of which 30% or 60 MMB could be required for the ESR.

FEA has carefully studied this option and concluded that the establishment of an IPR is not justified. FEA is therefore proposing in its SPR Plan being submitted to Congress, that the discretionary authority to create an IPR not be exercised. There would likely be serious legal and administrative problems with implementing an IPR, which could delay the SPR program and increase its costs. If the Industrial Reserve were dispersed throughout the country, it would reduce the response flexibility of the SPR, as well as increase the possibility of environmental damage. It would increase the cost to the economy for the storage because of more costly facilities, and most of these higher costs would be passed along to petroleum consumers. It also would create inequities among refiners and importers because of different costs of compliance and varying abilities among firms to pass the costs along to consumers.

The planned oil acquisition process for the SPR will pass a share of the Reserve costs along to the industry and users, without the inequities and the complex regulatory process that would be required for an Industrial Reserve.

The levels of petroleum inventories maintained by industry will be monitored, to assure that industry does not begin to rely on the SPR stocks to substitute for their own inventories to meet peak demands or other contingencies. If there is a clear downward trend in industry inventories in the future, consideration will be given to requiring that industry maintain minimum levels of inventories as part of the SPR or pursuant to EPCA S-458.

5. Noncontiguous Areas

The Act requires FEA to assure that to the maximum extent practicable, each noncontiguous area lacking overland access to crude oil production has its own component of the SPR within its respective territory. Among the noncontiguous areas to be considered are the Virgin Islands, Puerto Rico, Guam, Hawaii, American Samoa, and the Trust Territory of the Pacific Islands.

FEA currently expects to propose not to have storage of either product or crude oil in any of the noncontiguous areas. The legislative history makes clear that FEA is vested with considerable discretion in determining the practicability of noncontiguous storage, and FEA has concluded that in this instance practicability properly is to be determined in light of the cost-benefit relationship of such storage. Important in any cost-benefit analysis is the fact that in the event of a severe interruption, the Virgin Islands and Puerto Rico would have ready access to reserve crude stored centrally in the Gulf, and would not require regional storage reserves. In the Pacific areas, Hawaii which imports Indonesian crude and Guam, which imports Middle Eastern crude, are expected to have ample inventories of products from the SPR and the associated allocation program, although problems of timely delivery could occur and spot shortages could develop. Likewise, spot shortages of gasoline and distillate could occur in the Pacific Trust territories. These would be very small, however, and it is expected that conservation measures could be taken to minimize the impact of shortages.

The noncontiguous areas should have equitable access to storage petroleum reserves. The Pacific areas could take precautions against untimely delivery of reserve products and development of spot shortages by modifying their refinery plants and equipment to enable the refiners to shift to use of Prudhoe Bay crude oil by 1980.

D. Summary of Major Storage and Distribution Facilities

The FEA's background studies have explored various approaches for storage and distribution of crude petroleum and petroleum products that appear promising for satisfying program objectives. These investigations have included both underground and aboveground facilities, as well as several other storage concepts. The analysis of transportation and distribution systems has included pipelines and port facilities.

1. Major Types of Storage Facilities

In its preliminary feasibility studies, the FEA has emphasized underground storage because of its large capacity, low cost, and small environmental impact relative to other storage concepts. There are two proven methods for storing crude petroleum and petroleum products beneath the ground: (1) existing or new cavities in salt domes or salt beds; (2) existing or new underground mines in hard, impermeable rock formations. The more promising of these methods for satisfying the requirements of large quantities of storage near distribution and processing facilities is the development of new cavities or the modification of existing cavities in salt domes or salt beds. There are about 500 known salt domes within a 50,000 square mile area along the Gulf Coast, many of which are near major refinery centers. Investigations have shown that several of the domes offer high integrity as a storage medium and maximum protection against hazards such as fire, storm, and sabotage. Approximately 196 MMB of light hydrocarbons are currently stored in salt dome cavities in the Gulf region. An additional 88 MMB are stored in salt beds in this region and in other parts of the country (WE-215).

Storage in specially adapted abandoned or working mines in salt or other minerals is a technique that has been proven in countries other than the United States. A large storage system of this type has been in operation in South Africa since 1969. FEA's background studies investigated about 300 existing mines, both salt and non-salt, for their applicability as storage facilities. The development of new caverns in impermeable rock formations has proved to be a satisfactory method for storage of light hydrocarbons in some 60 projects in the United States (NA-261).

The storage of crude petroleum and petroleum products aboveground in steel tanks offers the advantage of locational flexibility, since this type of storage can be integrated into existing distribution networks. Crude may be stored in tanks at selected refineries and products may be stored near distribution terminals for timely delivery to consumers. The disadvantages of tank storage are that it is relatively expensive and in many instances not readily available. Because of the initial high cost of construction, steel tanks that are currently being used for petroleum storage are normally kept in service to the maximum extent possible. An FEA study of tank storage in the Northeastern United States has shown that there is relatively little excess tankage available for the storage of product. Although there have been some preliminary indications of unused tankage scattered about the rest of the country, in general these tanks are inappropriately located. Consequently, any storage in existing tankage would be limited and the construction of new tankage would also be required to implement this option.

Several other storage concepts were identified early in the program, including storage in depleted oil reservoirs, surplus tankers, abandoned missile silos, and a fully developed, shut-in Naval Petroleum Reserve at Elk Hills, California (NPR-1). Storage in depleted oil reservoirs is not a viable option because the oil cannot be injected or withdrawn quickly enough to satisfy the legislated storage program objectives. Additionally, the potential locations do not meet distribution requirements and there is considerable uncertainty as to how much oil could actually be recovered.

Preliminary investigations were also conducted on the use of surplus tankers (both U.S. and foreign) as a storage option. This alternative is not being prepared because of its relatively high cost and potential environmental hazards.

The storage of petroleum in abandoned missile silos was also evaluated. When compared to other alternatives, this option was eliminated primarily because of the low capacity and high cost required to couple the storage facilities to oil distribution networks.

Investigation of the possibility of fully developing and shutting-in the NPR-1 showed that this was not a viable alternative because of inherent limitations on withdrawal rates. At the optimistic production rate of 400,000 barrels per day, over 3 1/2 years of pumping would be required to replace a 90-day supply of imports (500 MMB).

As a result of this preliminary review of major storage concepts, the FEA decided to focus its subsequent effort on the feasibility, cost, and environmental impact of the following storage approaches, listed in priority order:

- conversion of existing solution-mined cavities in salt,
- conversion of existing conventional mines (abandoned and operating),
- construction of new solution cavities in salt,
- utilization of surplus government tankage,
- utilization of excess privately-owned tanks,
- expansion of existing tank facilities,
- construction of new mines, and
- construction of new tank farms.

For the purposes of the environmental impact analysis, facility descriptions representative of those that will actually be implemented were devised as prototypes in an attempt to identify any particularly sensitive environmental parameters. These prototypes represent a "worst case" since they are the largest facilities contemplated at this time. These prototype facilities include:

- an existing solution-mined cavity in salt with a storage capacity of 90 MMB,
- an existing conventional salt mine with a storage capacity of 90 MMB,
- a new solution-mined cavity in salt with a storage capacity of 200 MMB,
- an existing conventional rock mine with a storage capacity of 15 MMB,
- a new conventional mine with a capacity of 30 MMB, and
- a 10 MMB tank facility.

Although the interaction of a facility with a site-specific environment is required for an accurate environmental analysis, the assessment of prototypical facilities and environments provides guidance in evaluating available program options and developing individual EIS's.

2. Distribution and Transportation Facilities

Each storage facility will require a distribution system to move the petroleum to the site (filling) and from the site (withdrawal). The distribution system will include connections to a major existing pipeline (i.e., Seaway-Freeport, Texoma-Port Neches, and Capline-St. James) and/or connections to existing or newly constructed port facilities (see Section IV.C).

The program anticipates construction of pipelines ranging in length from less than one mile to approximately 60 miles and running between the storage site and a port facility and/or an existing major distribution pipeline. In some instances, the newly constructed pipelines could parallel existing pipelines to minimize right-of-way problems.

Decisions regarding fill and withdrawal from the storage sites will reflect present and projected capacity of the existing pipelines for domestic and foreign petroleum. Those transporting domestic petroleum would continue, in most cases, to carry roughly the same amount of petroleum, whereas those pipelines transporting foreign petroleum would be carrying significantly less petroleum during a supply interruption. Therefore, depending upon the area and number of refineries to be served, the withdrawal system would be designed to use available capacity in the pipelines of the existing petroleum distribution network.

Port facilities (i.e., piers, docks, barge slips, and associated elements such as surge tanks and ballast treatment facilities) will either have to be expanded or constructed. In instances where docks are currently under construction, the present design might be expanded to accommodate the storage program, or the construction schedule could be accelerated. Use of port facilities that already exist or are under construction will minimize the need for new facilities designed primarily for the storage program.

E. Selection of Candidate Storage Sites

Given the probable petroleum storage levels and viable storage facility options, the FEA identified and screened underground and aboveground storage sites for further technical, distributional, environmental, and economic analysis. Approximately 300 salt domes were identified, of which 154 have existing caverns that could be used for the ESR. In addition, approximately 300 existing mines were identified. Finally, 16 sites suitable for new tank farm facilities were located.

1. Underground Storage Sites

The FEA applied six major criteria to the underground sites which reduced the large number under consideration to 18 salt domes and 14 mine sites. The criteria are:

- Existing and potential capacity. To respond to the needs of both the ESR and the SPR, storage facilities were selected[1] on the basis of their available capacity in the short term (i.e., 3 years) and their total capacity over the longer term (i.e., 7 years). To provide the near-term storage capacity required for the ESR, efforts were concentrated on existing salt caverns and mines with potentially usable capacity by December 1978.

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[1] Selection refers to the choice of sites for further technical, cost, and environmental study, and in no way implies a final decision has been made that any candidate site will definitely be utilized as part of the storage program.

- Accessibility to the distribution network. To respond to regional requirements in the shortest time possible during a supply interruption, storage sites must have access - preferably direct access - to appropriate existing distribution facilities (e.g., docks, ports, waterways, and pipelines). Access to ports and pipelines is particularly important because all oil subject to disruption enters the United States by water.[1] In addition, ports will provide accessibility to the major U.S. areas of need - i.e., the East Coast, the Louisiana and Texas Gulf region, Puerto Rico, the Virgin Islands, and, if necessary, the West Coast - as well as to secure refined product sources such as Trinidad and the Netherlands Antilles. Of the average 3.6 million barrels of crude oil that entered U.S. ports each day in 1975, between 450,000 and 600,000 barrels per day were transported significant distances by pipeline. The remaining 3 million barrels per day were usually refined fairly close to the ports in which they were offloaded - roughly 1.1 million barrels at East Coast ports, 700,000 barrels in Puerto Rico and the Virgin Islands, 600,000 barrels at Gulf of Mexico ports, and 600,000 barrels at West Coast ports.

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[1] Petroleum imported from Canada is an exception. These imports amounted to 600,000 barrels per day in early 1975 but will be terminated by early 1980.

- Technical desirability. Candidate sites with technical (e.g., structural) restrictions that would significantly delay construction or increase conversion costs were eliminated.

- Extent of environmental impacts. Each potential storage site was evaluated on a preliminary basis in terms of the potential environmental damage that might occur if the site were used for the storage programs.

  For salt caverns, each potential site was evaluated based on the availability of water for leaching and for the withdrawal of oil, and on the ease of disposing of the brine. Brine can be disposed of in nearby nonpotable waters (which may or may not be environmentally detrimental), injected deep into natural underground salt water aquifers near the dome, or disposed of in the Gulf of Mexico. In addition, many salt dome sites are located near chemical plants which use saturated brine as feedstock, thus minimizing or eliminating the brine disposal problem. In addition to water-related issues, salt caverns have the usual environmental problems associated with construction of access roads, pipelines, and on-site structures and with seismic hazard.

  In evaluating the potential environmental impacts associated with existing conventional mines, FEA considered the impacts of constructing pipelines, access roads, and utility corridors, as well as flood and seismic hazard, the disposal of spoil, other water pollution problems, and the venting of hydrocarbon gases.

- <u>Feasibility of acquiring the sites</u>. In determining how readily the sites could be acquired, consideration was given to whether the sites had existing caverns or were undeveloped. In the case of operating salt or mine sites, the interests of the owner or lessor were considered to determine whether the site could be a candidate for the program.

- <u>Costs</u>. For each potential location, preliminary estimates were made of the cost of site acquisition, architectural and engineering design, construction and operation of the site and related facilities, and environmental control.

In the next phase of the site selection process, FEA reevaluated the 32 candidate salt dome and mine sites in terms of their potential for meeting the requirements of the Early Storage Reserve. Sites requiring substantial new construction at the site or for connection to distribution facilities were dropped from further consideration for the ESR. This second screening left 8 sites - 3 domes and 5 mines - for detailed feasibility and environmental studies for ESR use. Together the eight sites have an existing storage capacity of 385 million barrels - well above the ESR requirement of 150 million barrels.

Not all of the sites are comparable in terms of their capacity or distributional flexibility. Five of the sites (including both salt domes and mines) account for 75% of the storage capacity and allow for maximum distributional flexibility. More specifically, these 5 sites are accessible to all of the major oil distribution networks and could supply all of the major refinery areas for U.S. products. These sites can therefore be considered as alternatives to one another and are so considered in the site-specific environmental impact statements (DES 76-4 through 8).

The remaining three underground sites are also important to the ESR is that they augment the capacity of the five larger sites. Thus, each of these sites can be viewed as an alternative to full utilization or expansion of one or more of the larger sites. Site specific draft EIS's are being prepared by FEA for each of these candidate storage sites.

2. Aboveground Tank Sites

The FEA applied similar criteria to the selection of candidate tankage sites and reduced the initial list of 16 sites to five. Two existing government-owned tankage facilities were also identified. The criteria used to select candidate sites were:

- Access to the fuel oil distribution system. Sites were evaluated in relation to the fuel oil distribution system, including pipelines, ports, and railroad lines.

- Suitability of the land for tank construction. Candidate sites were selected which are of suitable size, shape and slope, require little ground clearing, and have appropriate geotechnical characteristics (rocks, soils, and drainage patterns) for construction.

- Adjacent land uses. The proximity of residential and other sensitive areas was considered so as to avoid public or private opposition.

- Climate. Climate was considered because ambient temperatures affect the need for heaters, which are a major cost item.

- Infrastructure. The availability of utilities and services needed for construction and operation of a tankage facility was evaluated.

- Environmental considerations. The potential sites were evaluated in terms of the difficulty of meeting federal, state, and local environmental requirements.

Because of the high cost of conventional steel tank storage relative to underground storage, no leased or purchased tank storage is currently planned as part of the ESR or SPR. However, if either the FEA proposal to store only crude oil for the RPR or its proposal not to implement an IPR is changed, then tank facilities could be considered. For this reason, the environmental impacts of tank storage are assessed in this programmatic EIS.

F. Implementation of the Reserve

Once the storage sites have been selected and facility design studies are underway, FEA must acquire the storage sites and related facilities, purchase the petroleum products to be stored, and manage the reserve in such a way that it can be withdrawn and distributed efficiently when it is needed.

1. Facility Acquisition

The storage system in any one locale consists of one or more storage facilities and the ancillary pipelines, environmental controls system, pumping stations, tanks, terminals, and port facilities necessary to receive oil from and deliver it to the existing distribution infrastructure. The government must acquire the property or right-of-way to all the elements of the storage system through purchase, lease, or condemnation, or contract for storage or other services. It is possible that some portions of the storage system will be government-owned and government-developed, while other elements will be privately developed and leased to the government.

In determining the feasibility of acquiring different kinds of sites, the FEA will take a number of factors into consideration. The acquisition of salt caverns involves existing surface rights, mineral rights, storage rights where new leached caverns are required, and such other rights as may be required for storage security. The legal question about the rights to use existing caverns in salt domes for storage can be quite complex. In some situations, surface, mineral (either fee or leasehold), and storage rights are held by different parties, making negotiation of a purchase difficult or lengthy. Mines under consideration are either abandoned or currently operating. If a mine is operating, suitable compensation for relocation will have to be negotiated. As with salt caverns, surface rights, storage rights in existing cavities, and mineral rights involving other necessary interests may have to be acquired. Legal problems associated with ownership of surface rights and storage rights exist here as well. Tankage sites involve no significant acquisition problems because federally-owned lands are available and usable.

2. Petroleum Acquisition

The Act authorizes FEA to acquire petroleum products in a manner consistent with the following objectives:

- Minimization of the cost of the reserve,
- Orderly development of the NPRs to the extent authorized by law,
- Minimization of the Nation's vulnerability to a severe energy supply interruption,
- Minimization of the impact of such acquisition on supply levels and market forces,
- Encouragement of competition in the domestic petroleum industry.

In order to acquire the oil for the SPR, the Act authorizes the Administrator to: (1) use or exchange government royalty oil; (2) use or exchange NPR oil (to the extent authorized by the recently enacted P.L. 94-258; or (3) obtain oil by purchase, exchange, or otherwise.

Also, the Act grants the FEA Administrator discretionary authority to require domestic refiners and importers to provide an Industrial Petroleum Reserve (IPR) of up to 3% of the amount of refined or imported oil in the previous year. However, FEA proposes not to exercise this authority for the reasons discussed in Section III.A.3.

Based on its analysis, FEA expects to acquire all of the oil for the SPR on the open market through competitive Federal procurement procedures, while using a crude oil "entitlements" program pursuant to the regulatory authority of the Emergency Petroleum Allocation Act of 1973 (EPAA). The entitlements program is designed to facilitate acquisition at or near the national average price (including imports), and this program will extend at least until the expiration of the mandatory allocation authority on May 31, 1979. Accordingly, at least until this date, funding initially will be requested to support purchases at about the national average price.

Other possible options which were considered for government acquisition of the oil for the SPR are discussed in Section III.A.2. Alternative Methods for Acquiring the Oil.

3. Management of the SPR

The SPR will be managed through an interconnected system of controls, regulations, and withdrawal and allocation procedures.

To ensure the integrity of the purchase, transport, storage, and distribution of crude oil and refined products, FEA will establish and maintain financial audit controls, purchasing and receiving controls, site security and storage monitoring, an independent inspection and auditing system, and withdrawal controls. In addition, FEA will issue and enforce regulations regarding the method of drawdown and the way in which the petroleum would be allocated in the event of a supply disruption.

The rate at which crude oil will be withdrawn and distributed will vary with the nature of the supply interruption and the size of the reserve. It will be based on the amount of petroleum in the reserve and the estimated length of time it must last (i.e., the projected length of the supply interruption), the estimated size of the supply shortfall in relation to U.S. consumption, and the implementation of other contingency plans.

The storage facilities and all related facilities, which include pipelines, surge tanks, terminal facilities, and associated port facilities, will be integrated with existing crude oil distribution systems and will be adequate to meet fill and disbursal rates. During a severe shortage, petroleum will be transported to those areas requiring supplies, using the existing transportation facilities. Tankers and barges could be used to transport crude oil to the East Coast, Caribbean, and Gulf of Mexico refineries. In the event of a severe interruption, idle foreign flagships might be used, although this would require a waiver of the Jones Act provision which generally precludes the use of foreign flagships for transportation from one U.S. port to another.

III. ALTERNATIVES

This chapter addresses the non-structural and structural alternatives for the Strategic Petroleum Reserve and the environmental impacts of the non-structural alternatives. Two types of non-structural alternatives are discussed. The first consists of the other Federal policies and programs that contribute to the national goals of energy self-sufficiency and independence from reliance on oil imports. The "no-action" alternative is part of this discussion. The second type consists of the various alternative methods available to acquire the oil for the Reserve. A discussion of the Industrial Petroleum Reserve is also included in the non-structural alternatives section. The structural alternatives consist of the different methods for storing crude oil and refined products. These include existing and new solution-mined cavities in salt, existing and new conventional mines, existing and new aboveground steel tankage and laid-up tanker ships.

Although the SPR Plan is proposing that only centralized underground storage facilities be used for the program, it is possible that changes may be required to the Plan. Therefore, due to the uncertainties about which types of storage facilities will ultimately be selected, the Structural Alternatives section is presented as alternatives <u>of</u> the program rather than alternatives <u>to</u> the program. Since each alternative is at this time a potential program element, the Structural Alternatives section is essentially an extension of the Chapter II Program Description. Therefore, the environmental impacts of the structural alternatives (except tankers) are presented in Chapter V, following the Chapter IV Description of the Environment so that the impacts can be discussed in relation to the existing conditions. The impacts associated with tanker storage are presented in Chapter III as part of the discussion of that alternative, since the potential tanker locations have not been selected and thus the impacts cannot be regionally categorized within the structure of Chapter V.

A. Non-Structural Alternatives and Their Impacts

This section describes the non-structural alternatives of the storage program and their environmental impacts on three levels. Addressed initially are those Federal policies and programs which, in conjunction with the Strategic Petroleum Reserve, move the Nation closer to energy self-sufficiency and independence from reliance on oil imports through accelerated domestic energy production, fuel conversion, or energy conservation. Included in the discussion are the standby energy authorities provided in the Energy Policy and Conservation Act of 1975 (EPCA) and the Emergency Petroleum Allocation Act of 1973, both of which would mitigate the economic disruption of a major shortage or interruption of its foreign oil supply, even if the storage program were not implemented. These programs and authorities and their environmental effects are treated as the "no-action" alternative.

The second discussion addresses the alternative methods available for acquiring the petroleum required for the program and their environmental impacts. These acquisition alternatives consider both the sources and costs of the petroleum.

The third discussion addresses the options available to FEA in implementing the Industrial Petroleum Reserve and their impacts.

1. Alternatives to the Strategic Petroleum Reserve

Reducing the Nation's sensitivity to import interruptions is only part of a comprehensive policy of energy self-sufficiency. FEA is presently considering a broad spectrum of options and strategies, one of which is the Strategic Petroleum Reserve, for achieving the broader goal of energy independence. The different policies and programs are not true alternatives which can be measured in terms of relative effectiveness in reaching that goal; rather, a combination of these strategies is being employed to achieve energy independence. A strategic reserve will afford a quantum of near-term independence by protecting against an import interruption, while the other measures will gradually create permanent independence as they become implemented. Even if the United States attains a position of non-dependency on foreign oil imports in the period after 1985, it is quite probable that for years or even decades thereafter the most economically advantageous course will be to continue to import significant quantities of foreign oil -- assuming that the risk of an import interruption is reduced to acceptable levels. The primary reason for reducing oil imports to the lowest possible level is to reduce the vulnerability of the United States to an interruption of foreign oil supplies. If such vulnerability is reduced to a sufficiently low level, it will probably be economically advantageous for some years to come to continue to import several million barrels of foreign oil a day.

Therefore, even given the scenario of U.S. non-dependency on foreign oil, the SPR should continue to serve a valuable purpose. By its existence it will reduce U.S. vulnerability to an import interruption, thereby giving the nation a greater degree of flexibility in its oil import policies. In particular, the nation will have the flexibility to rely intentionally on a significant--but reduced--level of imports with the knowledge that in the event of a supply interruption, the SPR will provide some margin for making adjustments to compensate for the reduction in foreign oil imports.

The longer-term measures for attaining national independence from foreign oil can be classified generally into two broad categories:

- Increase domestic energy supplies by developing presently unavailable resources, and

- Reduce energy demand by conservation.

While these measures complement the SPR program and one another when viewed as components of a strategy for achieving the broader goal of energy independence, for the purpose of this document, they are examined as potential partial alternatives to a strategic reserve in its role of providing near-term protection against import interruptions. Their value as potential partial alternatives can be assessed by comparing the time frame within which each program could be implemented with the legislated three-year time frame for creation of the Early Storage Reserve and seven-year time frame for creation of the Strategic Petroleum Reserve. In order to be a potential partial alternative to the Early Storage Reserve, a program must be capable of significantly reducing oil imports by the end of 1978; in order to be a potential partial alternative to the Strategic Petroleum Reserve, a program must be capable of significantly reducing oil imports by the end of 1982. To the degree that any program can reduce the Nation's foreign oil dependency within the 1978-1982 time frame, it is a potential partial alternative in that it provides a basis for reassessing the size of the reserve required to protect against a supply interruption.

In evaluating such potential partial alternatives, primary reliance has been placed on 1980 projections since:

- 1980 is likely to approximate the earliest date at which the various alternative programs could begin to have a significant impact on the quantity of oil imports.

- 1980 provides an assessment point in the fifth year after initiation of the SPR program, but at a time when a significant portion of the strategic reserve will not yet be in place.

- 1980 is the year closest to 1982 for which FEA has made detailed projections of energy supply and demand. Corresponding 1985 projections are set forth as providing a longer term frame of reference.

The programs which qualify under these criteria are shown in Table III-1, along with the projected increase in energy production or reduction in consumption available if those programs were to proceed on an "accelerated development" schedule. Their environmental impacts are addressed on the following pages under the categories of programs designed to increase energy supply and to reduce demand. The "no-action" alternative is also addressed as a separate category.

TABLE III-1
PROGRAM ALTERNATIVES TO THE ESR AND SPR

Source	1980 Business As Usual	1980 Accelerated Development	1980 Difference	1985 Business As Usual	1985 Accelerated Development	1985 Difference
Increased Supply:						
Domestic petroleum	12.80*	14.3**	1.50	13.9*	17.6*	3.7
Nuclear power	2.40***	2.8***	0.40	4.3*	4.9*	0.6
Synthetic fuels	0.05+	0.1+	0.05	0.3+	1.7+	1.4
Subtotal	15.25	17.2	1.95	18.5	24.2	5.7
Decreased Demand:						
Conservation (Total petroleum and natural gas consumption)	29.0++	27.4++	1.6	32.8+++	30.5+++	2.3

All figures are given in million barrels of petroleum per day (MMB/D) equivalents, taking the quadrillion BTUs (quads) per year as equivalent to one million barrels of oil per day.

* 1976 National Energy Outlook (FEA, February 1976). Accelerated 1985 includes 0.9 MMB/D from NPR-4.

** Unpublished FEA PIES projection.

*** Project Independence Report (FEA, November 1974). This is the most recent FEA projection showing 1980 accelerated nuclear development. Both BAU and accelerated would now be less. Only a portion of the increased production of nuclear power would substitute for oil.

\+ Synthetic Fuels Commercialization Report, Vol. IV (Synfuels Interagency Task Force, December 1975). Figures are for maximum possible development of synthetic fuels from both oil shale and coal. Project Independence Blueprint Final Task Force Report - Synthetic Fuels from Coal (Interagency Task Force on Synthetic Fuels from Coal, November 1974) and Project Independence Blueprint Final Task Force Report - Oil Shale (Interagency Task Force on Oil Shale, November 1974) give the same figures for total production of liquid fuels from oil shale and coal. However, the Synthetic Fuels from Coal Task Force Report estimated that an all out national crash program could not only produce 100,000 barrels a day of liquid fuels from coal in 1980 and 700,000 barrels a day in 1985, but also 0.5 trillion cubic feet of high-BTU synthetic gas (equivalent to 250,000 barrels a day of petroleum) in 1980 and 3 trillion cubic feet (equivalent to 1.5 MMB/D of petroleum) in 1985. For accelerated development short of an all out crash program FEA projects total synthetic fuel production at no more than 880,000 barrels a day by 1985. 1976 National Energy Outlook, pg. 39

\++ Project Independence Report, supra.

\+++ 1976 National Energy Outlook, supra. Almost all of the projected savings result from the automobile efficiency measures already contained in EPCA.

a. Increase Domestic Energy Supplies[1]

In 1974, total domestic consumption of petroleum in the United States was 6.07 billion barrels of 33.4 quadrillion BTU's[2] (quads), while total domestic consumption of fossil fuels (coal, petroleum, and natural gas) was 68.7 quads. In addition, energy consumption included 1.2 quads of nuclear power. Assuming an invariant import price of $13 a barrel in constant July 1975 U.S. dollars and a "business as usual" (BAU) approach, FEA projects that by 1980 domestic petroleum consumption will reach 6.5 billion barrels (35.6 quads), with total consumption of fossil fuels at 74 quads and nuclear power at 3.9 quads. Under this same projection, total domestic crude production in 1980 (including natural gas liquids) is estimated at 12.8 million barrels a day (MMB/D), while crude imports would be 4.4 MMB/D.

By 1985, a BAU projected consumption for $13 constant price imported oil is 716 billion barrels (41.5 quads) of petroleum, 86.3 quads of fossil fuels and 817 quads of nuclear power. Under this projection, total domestic crude oil production (including production of natural gas liquids) is estimated at 13.9 MMB/D, while crude imports are estimated at 5.9 MMB/D.

This subsection discusses possible programs of accelerated development of domestic energy sources and their impact on

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[1]Statistics throughout this section are from FE-153 and FE-076.

[2]BTU is an abbreviation for British thermal unit, a standard measure of energy production and consumption. A BTU is the quantity of heat needed to raise the temperature of one pound of water one degree Fahrenheit. Two quads are the energy equivalent of using one million barrels of petroleum a day for an entire year.

reducing the demand for imported petroleum. The FEA projections assume the same imported oil price of $13 a barrel and estimate that with accelerated development, domestic petroleum production in 1980 might be increased by 1.1 MMB/D over the BAU projection (from 12.8 to 14.3), while domestic production in 1985 might be increased by 2.1 MMB/D over the BAU amount (from 13.9 to 17.6). Additionally, increased production and use of coal and nuclear power would substitute for some petroleum demands. However, increases in domestic energy supplies alone will not eliminate the need for substantial imports of foreign petroleum in the near term. This is particularly true of the period between now and 1982. Indeed, this is the primary reason that Congress mandated creation of the ESR and SPR--to provide a short-term measure of protection while long-term measures of increased domestic energy supply and energy conservation are being implemented. Moreover, one aspect of accelerated development of domestic petroleum resources is an expected decline from peak production levels in the period after 1985.

Measures being considered to increase domestic energy supplies include the following:

- Reopening and expanding the Pacific Outer Continental Shelf (OCS), developing the Atlantic and Alaskan OCS, and developing the Alaskan onshore oil fields, including Naval Petroleum Reserve No. 4,

- Encouraging further exploration of new onshore deposits of oil, and increased use of secondary and tertiary production techniques,

- Accelerating nuclear power plant construction,

- Producing synthetic fuels from oil shale and coal, and

- Developing advanced technologies such as solar and geothermal energy.

Although all of these measures could contribute to energy independence and a reduction in oil imports in the long-term, only the first four have the potential for appreciable implementation within the seven-year time frame of the SPR.[1]

Outer Continental Shelf and Alaska

In 1975 domestic production from the oil fields located on the Outer Continental Shelf of the "Lower-48" area of the United States was 1.2 million barrels a day (MMB/D). while production from oil fields in Alaska (all from offshore fields) was 0.2 MMB/D. The FEA's Project Independence Evaluation System (PIES) projections, based on an assumed oil import price of $13 a barrel in constant dollars and a moderately

[1]FEA estimates that even with accelerated development, by 1985 geothermal capacity would only increase from a BAU of 1650 megawatts to a total of 6100 megawatts, an increase less than one-fifth the increased nuclear capacity projected to result from an accelerated nuclear program. An accelerated solar energy program is projected to result in 2600 megawatts of solar electric capacity, including wind power, by 1985, less than one-half the projected accelerated geothermal capacity. While additional solar energy will provide heating and cooling for a number of buildings, it will primarily displace electricity generated from coal-fired and nuclear plants rather than petroleum.

optimistic "business as usual" (BAU) approach to development and recovery of oil, were that production from the Lower-48 OCS would increase to 2.1 MMB/D by 1980 and 2.3 MMB/D by 1985, while total Alaskan production would increase to 1.7 MMB/D by 1980 and 2.4 MMB/D by 1985. With accelerated development, the unpublished FEA PIES projection is that Lower-48 OCS production would not increase significantly (less than .1 MMB/D) over the base 1980 projection while Alaskan production would increase only by .1 MMB/D. By 1985, through accelerated development, the unpublished projections show that Lower-48 OCS production might be increased by 1.2 MMB/D over the base 1985 projection, while Alaskan production might be increased by 1.1 MMB/D. Even greater increases might be experienced by 1985 if optimistic estimates of reserves and development of recovery enhancement techniques prove correct.

Normal exploration, development and production of Lower-48 OCS leases are expected to disturb the ocean floor, beach, and wetlands biota during pipeline burial; inconvenience local navigation; and aesthetically degrade the environment from pumping stations and similar facilities. The secondary development of support facilities, refineries or petrochemical plants related to an offshore oil field could also affect the onshore socioeconomic and natural environment. In addition, the risk and adverse effects of oil spills are higher for offshore development than for onshore, although they are lower than those associated with the use of tankers in oil import operations. (See Section V.D. for the impacts associated with oil spills.) Detailed discussions of the socioeconomic and environmental effects of OCS development can be found in the following documents: Oil and Gas - An Environmental Assessment, Council on Environmental Quality; Identification and Analysis of Mid-Atlantic Onshore OCS Impacts, Mid-Atlantic Governor's Coastal Resources Council; Mid-Atlantic Regional Study - An Assessment of the Onshore Effects of Offshore Oil and Gas Development, American Petroleum Institute; and the EIS's prepared for offshore oil leases by the Department of the Interior.

The environmental impacts of Alaskan oil exploration, development and production (both on and offshore) have also been well documented. The danger of oil spills is aggravated by frequent winter storms, earthquakes and accompanying tidal waves. Also, the potential for impact from a spill is greater because spills in the Gulf of Alaska would generally be more likely to reach land than those occurring off the coasts of the lower-48. Beyond the risks of damage from spilled oil, the impacts of both on and offshore Alaskan oil development (including secondary economic growth) on the delicate arctic terrestrial ecosystem and on the existing economic, social and cultural patterns of Alaskan inhabitants are substantial and irreversible. Detailed discussions of the effects of Alaskan oil development can be found in the following documents: Onshore Impact of Oil and Gas Development in Alaska, Gulf of Alaska Operator's Committee; Northern Gulf of Alaska Lease Sale EIS, Department of the Interior; and Alaska Natural Gas Transportation System Draft EIS; Department of the Interior.

Development of the Lower-48 OCS and of Alaska, whether or not on an accelerated basis, will probably be carried out independently of whether the SPR program is implemented. Thus, many of the adverse impacts discussed above will occur in any event.

Accelerated Development of and Enhanced Recovery from Lower-48 Onshore Fields

In 1974, domestic onshore production of petroleum in the Lower-48 United States was 8.9 MMB/D. FEA's unpublished projections show that under a BAU approach and assuming $13 per barrel for foreign oil, such production will increase slightly to 9.0 MMG/D by 1980 and 9.2 MMB/D by 1985. With accelerated exploration and development of new onshore oil fields and accelerated use of secondary and tertiary recovery techniques, FEA projects that by 1980 Lower-48 onshore production could be increased to 10.4 MMB/D, an increase of 1.4 MMB/D over the BAU projection. In 1985, assuming accelerated development and using optimistic assumptions as to the size of available reserves, FEA projects that Lower-48 onshore will increase to 10.6 MMB/D. This is 1.4 MMB/D over the 1985 BAU projection.

The exploration and production of petroleum in the lower onshore United States will result in varying degrees of environmental impacts dependent upon the character of the area in which the operations are conducted. Generally speaking, the environmental risks and potential impacts of Lower-48 onshore development are less than those for development in Alaska and in the OCS. However, excepting special problems such as those created by tundra and permafrost, the operations and expected impacts of development in the Lower-48 onshore are of the same general nature as those for development in Alaska.

Expected impacts on air quality are minimal and localized, but emissions of particulates and gases would result from removal of ground cover, the operation of vehicles and equipment, occasional blowouts of wells, vapor venting from storage tanks, and combustion of waste products. Some localized disturbance would also result from noise and vibration, which may alter the feeding and nesting patterns and disturb habitats of birds and other wildlife. Construction of roads and removal of ground cover may disturb drainage patterns and accelerate erosion, thereby adversely affecting water quality.

The major environmental risk involves spillage or discharge of oil or brine. U.S. Coast Guard data for oil spills in U.S. and coastal water shows that in 1972 1,730 spills were reported from onshore facilities, totaling 245,000 barrels of oil. This represented about half of all of the reported oil spillage. However, only three percent of the spillage by volume was from operations involving onshore production, refining and storage facilities. The impacts of oil spills are discussed in Section V.D. and also in the reports and environmental impact statements cited in the discussion of OCS and Alaskan development. Disposal of brine generated during oil production is regulated by state conservation authorities and by the U.S. Geological Survey in the case of Federal and Indian lands.

Onshore oil development may affect land use, both by the impact of discharges of harmful substances onto nearby lands, thereby killing vegetation and decreasing soil fertility, and by secondary impacts, such as demand for improved road networks. However, producing wells are not uncommon in areas that remain devoted to other primary uses, such as parks.

For the most part, the environmental impacts of enhanced recovery techniques are no greater than those accompanying primary recovery. However, use of water flooding techniques will involve a large increase in water use. For example, in 1962 the petroleum industry used 0.9 million barrels of water a day in primary recovery operations, but used 11.8 million barrels a day for secondary recovery (US-540). While most injection water used is brine produced with the oil, additional water is usually also needed. In 1962, new water for water-injection enhanced recovery averaged 4.5 barrels per barrel of oil produced by such techniques. However, more recent data indicate that typical make-up water requirements may be substantially lower, approaching one barrel of make-up water for each increased barrel of production (LO-181). The use of fresh water for make-up varies greatly, from less than 3% of the total water injected in California, to 100% in Pennsylvania (US-540). For production in coastal and offshore areas, sea water is used.

Chemical additives used in water injection may contaminate aquifers or soil, but such risks are minimal when operations are properly conducted.

Potential methods of tertiary recovery, such as high-pressure gas injection, appear to involve no special environmental risks not already associated with primary and secondary oil production.

Nuclear Power

In 1974 domestic nuclear power production totaled 112.8 billion kilowatt-hours or 1.2 quads, the energy equivalent of about 0.6 MMB/D of petroleum. FEA projects that under BAU conditions and with $13 per barrel for foreign oil, nuclear power will increase to 3.9 quads (energy equivalent of nearly 2 MMB/D of petroleum) by 1980 and to 8.7 quads (equivalent to about 4.3 MMB/D of petroleum) by 1985.

FEA projects that with accelerated development, nuclear power could reach 9.9 quads by 1985, an increase over BAU of 1.2 quads or an equivalent 0.6 MMB/D of petroleum. In its update of the Project Independence Report, FEA did not project the impact of accelerated development on 1980 production of nuclear power. The FEA's 1974 Project Independence Report projected that with accelerated development, production of nuclear power would reach 5.7 quads by 1980, but this was based on a BAU projection of 3.9 quads. As it seems unlikely that the difference between 1980 BAU and 1980 accelerated has increased since 1974, the difference projected in the Project Independence Report, namely, 0.9 quads, or less than one-half million barrels of oil a day equivalent, provides an upper limit on the probable increase of nuclear power that could be generated in 1980 through an accelerated program.

To achieve the additional nuclear power projected for accelerated development, 26 additional 1000 megawatt (MW) plants would have to be in operation by the start of 1985. The environmental impacts associated with nuclear plant construction and operation have been well documented (e.g., the Nuclear Energy Center Site Survey), (NRC, January 1976), and the various final EIS's for individual nuclear power plants). They include impacts on water quality and land use as well as the risks associated with the use of radioactive materials. There are three basic types of reactors currently in use or being developed in the United States: the light water reactor (LWR), the high temperature gas reactor (HTGR), and the liquid metal fast breeder reactor (LMFBR).

Nearly all nuclear power currently produced in the United States is generated by LWR's and this will be the predominant type of new installation over the next decade. In the LWR, heat created by nuclear fission is removed by the circulation of water through the fuel core. This circulating water can either be converted to steam and used directly to drive turbine generators or can be circulated as high temperature water with a heat exchanger to transfer heat to a separate steam loop. Fuel consists of slightly enriched uranium dioxide pellets encased in tubing of zirconium alloy.

In the HTGR, heat created by nuclear fission of thorium dioxide and enriched uranium dioxide is transferred to helium which is circulated through the core and then retransferred to water in a steam generator. HTGR's may become an important source of nuclear power in the period after 1985.

LMFBR's, the most controversial type of reactor, are not expected to be on line until the last decade of this century. LMFBR's use liquid metal (sodium) to transfer heat from the reactor to water, which is converted to steam. The LMFBR contains a central core which is fueled with a mixture of plutonium and uranium and an outer core loaded with uranium only. As the plutonium in the central core fissions, uranium in both the central and outer cores is converted to plutonium, so that for every four pounds of plutonium consumed by the LMFBR, about five pounds will be created. As the LMFBR will not be a source of energy within the next decade, the particular risks and hazards it creates will not be discussed herein. These are documented in the Liquid Metal Fast Breeder Reactor Final EIS (ERDA, December 1975). As any accelerated development program between now and 1985 will rely almost entirely on use of LWR's, the discussion below is addressed to the impacts of accelerated LWR construction and operation. However, the impacts of HTGR construction and operation appear to be no more adverse than those for LWR's.

A reactor releases approximately 50 percent more waste heat into its cooling water than a fossil-fueled plant of similar capacity. The effects of waste heat depend upon many factors, including the cooling method used and the location of the plant. For a 1000 MW plant utilizing a "once through" direct discharge system, 250 to 360 billion gallons of water per year are required. For the 26 additional plants contemplated by an accelerated program, 6 to 9 trillion gallons a year will be needed. The effects of thermal discharge depend largely upon the size and flow rate of the receiving waters. Use of large amounts of water from some streams can disrupt their flow regimes. Closed-loop cooling systems can be used to minimize the water demand and the thermal discharge to the water source.

Impacts on land use arise from uranium mining and plant and transmission line construction. A surface (open pit) mine reduces the suitability of a few hundred acres for other uses. An underground mine requires a smaller amount of land for dumping waste rock. Careful planning for environmentally sound land use, once the mine has been abandoned, can minimize adverse impacts. The construction of a 3000 MW plant (three 1000 MW units) requires the exclusive use of 1000-1500 acres. A cooling lake, if needed, requires an additional 3000-6000 acres. Thus, twenty-six 1000 MW units could require as much as 170,000 acres for plant construction and cooling ponds. Single tower transmission line rights-of-way require the use of 10 to 15 acres per mile of line.

Potential impacts also arise from the use, transportation and processing of radioactive fuel and the storage of radioactive waste. Nuclear plants are designed to minimize the risk of accidents by utilizing a "defense-in-depth" principle. According to the Nuclear Regulatory Commission's Reactor Safety Study (October 1975), the average number of fatalities per year from the operation of 100 reactors is two. The probability of an accident resulting in 100 or more fatalities is about 1 in 10,000,000 per plant per year; while the probability of an accident resulting in 1000 or more fatalities is 1 in 100,000,000 per plant per year. The highest number of predicted fatalities under any circumstances is 3300, with a probability of 1 in 1,000,000,000 per plant per year that this will occur. Given that the estimated fatalities resulting from an accident have an uncertainty factor of 4 (i.e., the worst case could be as low as 800 or as high as 13,000) and that the estimated probabilities have an uncertainty factor of 5, under a worst case scenario and assuming no improvements in nuclear safety, operation of 26 additional nuclear reactors might be expected to cause 10 deaths per year. Over a 30-year operating life, there would be a probability of about 1 in 3,000 of an accident resulting in more than 100 fatalities and a probability of 1 in 300,000 of an accident resulting in 13,000 fatalities.

The nuclear fuel cycle requires the transportation of radioactive materials by truck or rail at several stages. Transportation regulations and cask designs have been developed to ensure that accidents will result in only minimal releases of radioactivity. Radioactive emissions during fuel reprocessing are greater than those occurring during normal power plant operation, but the estimated maximum dosage is near natural levels. Spent fuel can be reprocessed to a degree, but the waste which remains will have to be concentrated and stored in solutions for five years, then solidified, sealed in containers, and put into long-term underground storage (hundreds to thousands of years). Reprocessing the spent fuel from a 1000 MW nuclear plant would yield 65 cubic feet per year of high-level solid waste. The operation of 26 plants over a 30 year period would thus generate approximately 51,000 cubic feet of radioactive waste. There are currently no reprocessing plants in operation in the

United States, and thus no end-product waste is being generated. However, there is currently about 2000 metric tons of uranium in the form of highly radioactive spent fuel in temporary storage awaiting reprocessing. In addition, there exists approximately 600,000 gallons of high-level waste from previous reprocessing activities in interim storage. There are at present no operational facilities for the ultimate storage of high-level waste. The government is currently investigating possible methods of providing long-term underground storage for the waste and/or the spent fuel in the event that no reprocessing plants are opened.

Synthetic Fuels

The Synthetic Interagency Task Force Report--Recommendations for a Synthetic Fuels Commercialization Program (December 1975) (herinafter cited as "Synfuels Report") projected the maximum credible production of synthetic fuels from coal and oil shale to be about 100,000 barrels a day by 1980; 400,000 barrels a day by 1982; and 1.7 million barrels a day by 1985. (Synfuels Report, at pp. I-13, I-16.) The Project Independence Report estimated that with a BAU approach and $7 oil, production of fuel from shale oil would be 50,000 barrels a day by 1980 and 250,000 barrels a day by 1985. (At p. 132, Table II-25.) The same report estimated that without government action there would be virtually no production of synthetic fuel from coal prior to 1985. (Id. at pp. 137-188.) Thus, accelerated development of both shale and coal could increase synthetic fuel production by 50,000 barrels a day in 1980 and by almost 1.5 million barrels a day in 1985.

The adverse environmental impacts of such a program are set forth in detail in the Synfuels Report and in the Project

Independence Blueprint Final Task Force Report--Oil Shale (Interagency Task Force on Oil Shale, November 1974). To briefly summarize these impacts, synthetic fuel plants will emit sulfur oxides, nitrogen oxides, particulates, hydrocarbons, carbon monoxide and aldehydes. In addition, potentially toxic materials will be produced and it is not yet known if and what amounts such materials may be emitted into the air. While acute effects on human health would probably not occur, chronic health effects and even cancer might result from long-term exposure to aromatic hydrocarbons and trace elements emitted from synthetic fuel plants. In addition, some damage to flora and fauna would probably occur. Emissions from some plants under certain conditions might cause a violation of the Federal 24-hour secondary standard for particulate and might even cause a violation of the Federal annual secondary standard for nitrogen dioxide. Moreover, the construction of any plant in any location would probably violate nondegradation requirements unless the area were classified as Class III (which allows air quality to deteriorate to the level of the Federal standards).

Large volumes of water would be required for the synthetic fuel plants and for the reclamation of mined areas in the western United States. Mining the coal and oil shale would interrupt underground aquifers, thereby lowering water levels, drying up springs and shallow wells, and reducing stream flow around the mines. The extent of such impacts would depend upon the specific nature of the operation involved and of the site. Even with reclamation, groundwater flow patterns may be altered and aquifer storage capacity reduced. If groundwater is used for water supply, water levels may be lowered and there may be some surface subsidence.

Extensive synthetic fuel production would create a potential for degradation of local and even regional water quality. Construction and mining would cause increased erosion and sedimentation. Acid mine drainage could be a problem, particularly in the eastern United States. Production of synthetic fuels would produce potential water pollutants, including dissolved and suspended solids, ammonia, non-degradable organic compounds, cyanides, phosphates and trace elements. Even with pollution controls, some pollutants would be discharged. Plant consumption could reduce stream flow, thereby increasing pollutant concentrations and salinity. The permanent population increases in the areas around plants would also result in increased discharges of pollutants and could overtax existing sewage treatment facilities. Again, the nature of such impacts would be site specific.

The construction of mines, synthetic fuel plants, transportation facilities and facilities for community expansion would disrupt soil horizons and characteristics. Soil moisture relationships, infiltration rates, density and fertility would be affected, producing a surface which for many years would be a less viable habitat for plant and animal life. The topography of some areas would also be changed due to mining, construction and disposal of solid waste--prominent points might be leveled or steep slopes might be created; the surface might subside in some places; canyons might be filled in and spoil banks created. Construction of impoundments would cause large areas to be inundated. Such changes would directly destroy some flora and fauna and would have secondary impacts on a much larger number. Reclamation would not be completely successful in all areas, particularly in semiarid or arid regions.

In many areas major social impacts would occur because large numbers of people would move into small communities, in some instances, possibly quadrupling existing populations. Local governments could be hard pressed to provide necessary services for such increased populations. Permanent population increases might range up to 95,000 each in the Appalachian Region and in the area where Colorado, Utah and Wyoming meet. Other areas would also have significant permanent population increases. This effect would be most severe in the Colorado-Utah-Wyoming three-corner region where the impact could be to almost double the permanent population. Temporary population increases during the plant construction phase would be even greater.

Such sudden population increases could cause housing shortages. School facilities might well be inadequate. Health services in particular would suffer since it would take years to build necessary medical facilities and medical personnel would be easily attracted to the involved areas. Crime rates, alcoholism and suicide rates would likely increase.

Extensive economic impacts would result from increased employment, increased population, increased demand for goods and services and increased tax revenues. Not all such impacts would be beneficial as the local and regional cost of living is likely to increase and tax revenues of local government would probably increase more slowly than the demand for public services.

b. Reduce Energy Demand by Conservation

There are also many options available to the Government to accelerate energy conservation. A comprehensive Federal program to encourage and require businesses and individuals to conserve energy was proposed in early 1975, as part of the Energy Independence Act of 1975. The ultimate goal of the program is to hold imports to 3-5 MMBPD and to make the U.S. a net energy exporter again by 1985. The program includes conservation measures in the transportation, residential and commercial, industrial, and utilities sectors, some of which have already been authorized in EPCA.

Conservation measures, per se, have no direct adverse environmental impacts, with the possible exception of automobile fuel efficiency improvement. Beneficial impacts can vary, depending upon changes in the energy mix. The Coal Conversion Final EIS (FEA, April 1975) described the conservation measures, their potential energy savings and the environmental impacts that could result from each. That information is summarized below. These impacts are also described in the Energy Independence Act of 1975 DES (FEA, March 1975) and the Final Assessment of the State Energy Conservation Program (FEA, April 1976). The conservation measure having the most significant impact on petroleum consumption--namely, automobile efficiency standards--was enacted in EPCA. However, as there is provision in the Act for reduction in automobile efficiency standards in order to meet other Federal standards, this has been considered as an alternative.

Transportation

The program includes measures to (1) establish a mandatory efficiency standard for automobiles, and (2) increase the use of public transit as an alternative to the automobile.

EPCA requires that every automobile manufacturer meet an average fuel economy standard of 20 miles per gallon by 1980 and 27.5 miles per gallon by 1985, although provision is made for a manufacturer to meet a lower standard if it can be shown that other federal requirements prohibit the attainment of the fuel economy standard. Therefore, to fully realize the potential savings, some relaxation in emission and safety standards may be required. A 20 mile-per-gallon standard is expected to increase the cost of manufacturing an automobile by approximately $250-$325 and require a capital investment of approximately $200-$400 million per year. FEA's Project Independence Report estimated the savings from such a standard to be 0.7 quads (energy equivalent of about 0.4 MMB/D of petroleum) in 1980 and 1.9 quads (equivalent to almost 1 MMB/D) in 1985. The 1976 National Energy Outlook also projects savings of 1 MMB/D from automobile efficiency standards by 1985. Use of car pool incentives could save an additional 100,000 barrels a day in 1980 and 125,000 barrels a day in 1985, while a change in CAB regulations to increase airline load factors from 55 to 65% could save 50,000 barrels a day in 1980 and 100,000 barrels a day in 1985.

Public transit is two to four times more energy efficient than travel by auto and offers the benefits of improved air quality, reduced traffic congestion, and gasoline savings. The Project Independence Report estimated that, though aggressive development of public transit, an energy savings of 0.9 quads could be achieved in 1980 (about 0.5 MMB/D) and 1.2 quads in 1985 (about 0.6 MMB/D), assuming $11 oil. However, these estimates assume that Government action will be taken to encourage increased use of public transit.

There are several measures that could be taken to encourage the use of urban public transit and discourage the inefficient use of automobiles. Consumer costs for operating cars could be increased by raising tolls on bridges and highways entering cities, by increasing urban parking fees and by higher gasoline taxes. Urban auto operation could be made less convenient by increasing the use of auto-free zones, reducing parking capacity, and designating existing travel lanes for the use of buses. Urban Mass Transportation Administration (UMTA) capital grant programs could be expanded, and legislation could be enacted establishing a Federal operating subsidy for urban public transit systems. Under this option, bus production could be increased to over 100,000 vehicles by 1980. The capital costs for these buses would be $950 million per year, and the federal share would be $760 million a year. Since operating deficits could be expected to grow substantially, increased federal operating subsidies would be necessary.

Residential and Commercial

Thirty-two percent of all energy used in the United States is consumed in the household and commercial sector. Of this, 70 percent is consumed by the household portion and 30 percent by the commercial portion. Approximately 57 percent of the energy is used for space heating, 33 percent for operating equipment, and 10 percent for lighting. Legislative conservation measures would improve the energy efficiencies of appliances and operating procedures for buildings.

For appliances, EPCA requires efficiency labeling and the establishment of voluntary energy efficiency improvement targets of at least 20 percent. It also provides that mandatory energy efficiency standards to set if it appears that the voluntary improvement targets will not be met. Such standards could save an estimated 0.2 quads by 1980 and 0.5 quads by 1985

Other residential and commercial conservation measures include insulation of existing homes (potential savings of 0.5 quads by 1980 and 0.8 quads by 1985) and commercial buildings (approximately 0.2 quads in both 1980 and 1985), national thermal efficiency standards for new residential and commercial buildings (0.5 quads in 1980 and 1.0 quads in 1985), and mandatory lighting standards for commercial buildings (approximately 0.2 quads in 1980 and 0.3 quads in 1985).

Industrial

Since such a large portion of the total U.S. end-use energy demand (33 percent in 1972) is accounted for by industry, it is essential that adequate plans for industrial energy conservation be prepared for each of the major energy consuming establishments in the United States. EPCA requires that FEA establish an industrial energy efficiency improvement target for each of the ten most energy-consuming industries. Reports of progress toward improving energy efficiency are required, and FEA is responsible for annually reporting this progress to Congress.

The 1974 Project Independence Report estimated that through aggressive industry conservation programs, assisted by Government research and development directed toward increased industrial efficiency, a savings of 0.9 quads could be achieved in 1980 and 1.5 quads in 1985. Research and development would have to be performed in the areas of boiler efficiency, heat management, improved insulation, reduced electricity usage, increased process efficiency and new materials. Research, development and educational programs directed at increasing industry awareness of the various techniques that could be employed to increase energy efficiency would also be required. The cost for such a research and development program is estimated to be $250 million in 1977. Costs would decrease to about $100 million in 1980 and $50 million in 1985 when most of the front-end research and development investment will have been made.

A more recent FEA projection estimates that with an affirmative Government action program in the industrial sector (namely, an expanded energy accounting and SEC reporting system, technical assistance programs, and efficiency guidelines for selected industrial equipment) savings of 485,000 barrels a day could be achieved by 1980 and 590,000 barrels a day by 1985. (FE-153)

Utilities

The conservation opportunities in the utilities sector include (1) reducing overall energy usage through end-use conservation, (2) leveling peak loads through various management programs, and (3) increasing energy conversion and transmission efficiencies. To realize potential savings of 0.5 quads by 1980, a program could be established to demonstrate the energy conservation potentional of various activities which could be undertaken by individual electric companies under the auspices of the state Public Utility Commissions (PUC). By 1985, such a program could save 0.9 quads a year. This program would be coupled with the development of advisory PUC guidelines which would identify the specific energy conservation measures available to the utility industry. The cost in direct Federal outlays would be approximately $100 million per year with no substantial social costs, environmental costs or resource constraints. If the advisory guidelines which detail these activities were not followed by the State PUC's, consideration would be given to amending the Federal Power Act to make such guidelines mandatory.

c. No Action

In the event of a severe interruption of the Nation's foreign oil supply, several other Federal authorities could be called upon to mitigate some of the adverse economic effects, even if the Strategic Petroleum Reserve Program were not implemented. These include the Energy Conservation Contingency Plans and the Rationing Contingency Plan authorized on a standby basis by EPCA, and the Emergency Petroleum Allocation Act of 1973, as amended. Of these three, only the Energy Contingency Plans actually reduce the country's energy requirements; the Rationing Contingency Plan and the Emergency Petroleum Allocation Act simply allocate the available supply among classes of users in accordance with establishment priorities. The two contingency plans authorized under EPCA would be implemented only after approval by the Congress and upon determination by the President that the petroleum shortage was severe.

Four energy conservation contingency plans are now being prepared in accordance with the requirements of Sec. 201 and 202 of EPCA. In general, they mandate:

- restricted parking for commuters;
- closing gas stations half a day on Saturday and all day Sunday;
- lowered temperature levels in all non-residential buildings; and
- regular boiler inspection.

A preliminary assessment by FEA of the conservation contingency plans indicates that most of the environmental effects of their implementation would be beneficial. More detailed information on the economic and environmental effects of this program will be available in the plan itself, due for submission to Congress in January, 1977.

A Rationing Contingency Plan is now being developed for the rationing of gasoline and diesel fuel used in motor vehicles and the ordering of priorities among classes of end-users. This plan will rely on local boards to make adjustments in the entitlements of end-users. The Rationing Contingency Plan would be implemented by the President after the Conservation Contingency Plan became effective, and then only if the economic effects of the supply interruption or shortage continued to be severe. The economic and environmental effects of the Rationing Contingency Plan are now under study, and a report on them is due for submission to Congress in January 1977. However, it is unlikely that the Rationing Contingency Plan would itself have any significant environemntal effects, since it simply allocates the supply of motor fuel available without increasing or decreasing it.

The Emergency Petroleum Allocation Act, enacted in late November 1973, established the Federal Energy Office and granted the President authority to mandate a program for allocating crude oil, residual fuel oil and certain refined petroleum products. The intention of the allocation program, like the Rationing Contingency Plan, is to ensure that all regions and economic sectors receive equitable shares of available fuels and petroleum products. Thus, neither the Emergency Allocation Act of 1973 nor the regulations issued pursuant to that Act specify allocation levels to end-users, i.e., retail purchasers. Instead, they require all suppliers of allocable substances to distribute available products equitably to end-users in accordance with the objectives of the Act, which are:

- protection of public health, safety, and welfare;
- maintenance of public services, agricultural operations and national defense;
- preservation of an economically sound and competitive petroleum industry;

- minimization of economic impact; and

- the allocation of crude oil to permit domestic refineries to operate at optimum capacity.

While allocations of crude oil are handled by direct, published assignments, the program to allocate refined products is designed around five major concepts:

- Supplier-purchaser relationships are "frozen" as of December 1, 1973. Suppliers must supply their purchasers as of that time and new purchasers are assigned a supplier by the FEA.

- Various classes of purchasers are established and assigned an allocation level, which may be either:
  a. Their current requirement; or
  b. Some percentage of their purchases in the "base period" (calendar year 1972).

- A basic priority system is established to ensure that:
  a. Defense uses and agricultural production uses are fully provided for;
  b. All other uses bear a proportionate share of any shortage.

- An allocation fraction is used to quantify the degree to which allocable supplies are capable of meeting supplier's obligations to purchasers in category 3(b) above and to guide deliveries to all purchasers.

- A state set-aside is established to meet emergency needs and hardships.

The allocation program does not insure that the total quantity of fuel available to any wholesale purchaser, state or region is sufficient in view of all current conditions or requirements. It does, however, insure that each will receive an equitable share of available fuel as it was distributed during the base period, calendar year 1972.

No environmental analysis of the petroleum allocation program was done when it was enacted because of the emergency nature of the act. However, like the rationing plan, it simply allocates available fuel supplies. If the program were to stimulate some consumers to switch to coal, then there could be significant environmental impacts, particularly in the area of air quality.

2. Alternative Methods of Acquiring the Oil

Section 160(a) of the EPCA authorizes three methods for use by FEA in acquiring the oil for the Strategic Petroleum Reserve: (1) crude oil produced from Federal lands (including the Naval Petroleum Reserves), (2) crude oil which the United States is entitled to receive in kind as royalties from production on federal lands, and (3) petroleum products (including crude oil) acquired by purchase, exchange or otherwise. FEA has examined the alternatives within this legislative directive and has proposed to implement a method of acquisition based on the authority provided in Method three (3) above. At the time the draft programmatic EIS was prepared, FEA was considering these alternatives:

- Using (or exchanging) Naval Petroleum Reserve oil
- Using (or exchanging) royalty oil
- Purchasing "old" oil
- Buying oil on the open market
- Importing oil

Subsequent to the publication of the draft EIS, FEA determined that it was possible to utilize the technique of open market purchases, yet achieve a result comparable to acquiring a proportionate share of price-controlled domestic crude oil, though a crude oil "entitlements" program under the authority of the Emergency Petroleum Allocation Act of 1973 (EPAA).

a. Acquisition Methods and Economic Impacts

This section describes the petroleum acquisition method proposed by FEA, and the various other methods which were considered, and also discusses the economic implications associated with each. Since the environmental effects of these alternatives are similar, they are treated in a single section following this one.

FEA proposes to use the authority granted by the EPAA to allow the Government to obtain the benefit of price controlled domestic crude oils for fill in the SPR, at least until the mandatory allocation authority of the EPAA expires. The Government will engage in competitive procurement but expects to receive the benefits of cost equalization through an "entitlements" program pursuant to the EPAA.

Under this proposal the Government would acquire crude oil to fill the SPR pursuant to the Federal procurement laws and regulations, probably using negotiated procurement. Suppliers, however, would be able to earn entitlements for volumes sold to the Government by inclusion of those volumes in their crude runs under the entitlements program. Depending upon the source of the crude oil, a supplier would either be required to purchase or permitted to sell entitlements for the crude sold to the Government.

The value of entitlements would flow through to the Government since suppliers' offers would be subject to subsequent adjustment by an amount equal to the value of any entitlement earned. The price to the Government would be roughly equal to the national average composite price to refiners (including imports) plus any incremental cost (in the form of a handling fee) in servicing the SPR.

If acceptable offers are obtained from U.S. refiners and importers, or other offerors, this approach would reduce the need for direct Government involvement in the world oil market.

This procurement approach is also calculated to have the least adverse impact on the competitive environment in the industry. The "burden" of providing the SPR oil at near the national average price would be spread among U.S. refiners/importers and petroleum consumers through the entitlements program, in the form of slightly higher costs for crude and higher product prices (estimated to be less than 3/10 of a cent per gallon on the average over the acquisition period).

FEA's proposed approach would be consistent with Federal procurement laws. This approach is also considered to be consistent with the authorities and objectives of the EPAA, including the objectives of economic efficiency and minimization of economic distortion and interference with the market. The SPR would be filled without the need for any compulsory sales to the Government. Finally, this approach is expected to allow FEA to meet another of the EPCA objectives, that is, minimization of the cost of the SPR.

All potential sellers, both foreign and U.S., would be given an opportunity to present offers under this option. The Government would be free to consider all valid offers, including those of foreign bidders which might reflect a discounted price for foreign oil, thus preserving the opportunity to reduce the total cost to the economy. In addition, it should permit relatively low net costs to the budget of the SPR oil (near the national average price plus any extra handling costs associated with the procurement, such as Cargo Preference Act costs which could add about a dollar a barrel to imported crude due to using high cost U.S. flag ships). Therefore, budget costs should be reduced by about $2.25 a barrel compared with Government procurement at world market prices. This reflects the estimated average differential between import prices and national average prices until price controls end.

FEA's approach would require industry and petroleum users, in effect, to pay some of the costs of the SPR oil, by paying the higher costs of imports to compensate for oil sold to the SPR. Industry and consumers would, in effect, pay about $470 million of the SPR oil costs between now and May 31, 1979, assuming an average differential of $2.25 a barrel, and purchases of 210 MMB by the time the mandatory oil allocation authority is due to expire on May 31, 1979.

This approach appears to be most desirable in view of the opportunity it provides to hold down the budget costs of the

SPR and to pass along some of the SPR costs to the oil industry and consumers in a way that avoids serious inequities among firms or users of oil. This approach can also be tailored to permit FEA to test the feasibility of obtaining significant discounts on foreign oil. Thus, the requests for proposals will make it clear that the award decision will consider the cost to the economy as well as the cost to the budget. If significant discounts are offered directly from foreign sources, FEA will then be able to consider the desirability of accepting such offers for at least a part of the SPR needs, even though costs to the budget--but not to the economy--may be higher than for other offers.

Naval Petroleum Reserve Oil

Acquiring NPR oil appears to have few advantages. It would have only small budgetary benefits compared to open market purchases and it would have higher budget costs than the national average price during price controls. Its use would also be an administrative inconvenience because of transportation problems or the need to exchange it for other oil. Since it is sold competitively without price controls and is located at a great distance from the SPR reserves, it is more cost-effective for the Government to continue to sell the NPR oil on the market. This provides revenues to the Federal budget that reduces the total Federal outlays.

Under P.L. 94-258, which authorized the sale of NPR oil, it must be sold for not less than the upper tier price ($10.54 at the time the contracts were signed). Present regulations treat NPR oil as imported oil for entitlements purpose, so that it can be expected to sell in new contracts at only slightly less than the import price. NPR oil is free of price regulation under P.L. 94-258, and is sold competitively. While price controls continue it is expected that the price will remain substantially above the effective average acquisition price for large refiners.

Production of NPR oil began July 4, 1976, at 34 MBD, constrained by processing problems. It is expected that production will reach 80 MBD from the Steven's Zone and 30 MBD from the Shallow Zone by the end of 1976. Production is projected to peak at 200 MBD in 1979.

Only Steven's Zone oil from Elk Hills meets the crude oil specifications required by the SPR. Transportation costs to Gulf Coast storage sites via coast-wise shipping, however, would make storage of NPR oil more costly than exchanging it in West Coast markets.

Royalty Oil

This approach would impact small refiners that now rely upon and benefit from access to this oil that is produced from U.S. Government lands. Royalty oil is now sold to refiners at an average price of about $8.00 per barrel. The supply of royalty oil is not sufficient for the SPR, and, even if this approach were adopted, other oil would be required.

Moreover, at best, transportation costs for moving this widely dispersed oil to any market would be substantially greater than the cost of unloading ocean tankers into reserve facilities.

This approach would have unfavorable impacts that would extend beyond the small refiners immediately concerned. Because Government royalty oil has been sold for many years, strong patterns of use and reliance on it have developed. Thus, the taking of royalty oil would upset the established patterns in state revenues, including monies that have long been allocated to support reclamation funds for state projects (especially in Alaska).

"Old" Oil

FEA's analysis has concluded that there is not sufficient statutory authority for use of FEA regulatory programs to allocate only lower tier-priced domestic oil (formerly referred to as "old" oil) to the Government for the SPR. If authority could be obtained to implement this approach, it would minimize Federal spending for SPR oil, and hence reduce the cost to the taxpayers. However, this approach would likely encounter considerable opposition from the industry and consumers, because lost access to lower-tier oil would have to be replaced with higher cost imports, with a resulting significant impact on prices. This opposition would make it difficult to obtain authority to implement this approach, and even should such authority be obtained, ensuing legal and administrative challenges could delay purchases for at least a time period past that legislated for the ESR stage of the SPR.

Imported Oil

A variation of one other approach mentioned in the draft EIS, "Imported Oil", is essentially incorporated in the acquisition method proposed by FEA. The purchases would be open market purchases, including imports, but the Government would receive the benefit of crude cost equalization through an entitlements program so that a total price below the import price would be paid. It is anticipated that oil offered to the SPR will be primarily imported oil.

b. Environmental Impacts of Acquiring the Oil

It is certain that imports will increase under the proposed acquisition method, as they would also have increased under any of the other alternatives considered. Under the proposed method, the increase will either occur directly, in the case of specific quantities of imported oil offered for the SPR, or indirectly, in the case of any use of domestic oil, since that is oil presently consumed by the nation and would have to be replaced. It is possible that there could be increased demand for domestic oil as a result of SPR fill under an acquisition plan other than that now proposed by FEA. This could stimulate domestic production of oil, especially in the OCS and Alaskan oil fields. The impacts of OCS and Alaskan development are discussed in Section III.A.1.a.

The impacts of increased imports would result from the additional tanker traffic and associated oil handling operations. Oil discharges from tankers are either intentional or accidental. The two primary sources of intentionally discharged oil are shoreside ballast treatment facilities and tanker cleaning operations during transit. Since ballast treatment normally takes place at the loading end of the system, virtually all intentional discharge in U.S. coastal zones comes from in-transit cleaning operations. The average cleaning discharge rate in 1969-1970 was 0.074 percent of the cargo. Assuming that filling the reserve results in the importation of 500 MMB of oil over a five-year period, an average intentional discharge of approximately 200 barrels per day attributable to cleaning operations could be expected.

With respect to accidental discharge, the 1970 Pollution Incident Reporting System data indicates that approximately 0.0015 percent of the oil handled in the United States was spilled during the handling operations (US-159). Therefore, an average accidental discharge rate of less than 5 barrels per day could be expected. While such a spill rate produces minimal environmental effects, the consequence of any one single event could be quite substantial, depending on the size and location of the spill. Section V. D. describes the environmental impacts generally associated with oil spills.

Increased petroleum imports will require an increase in the number and/or size of tankers. Filling a 500 MMB reserve in five years would require delivery by the equivalent of one additional 300,000-barrel tanker daily.

If the use of conventional ports continues, tanker capacity will generally be restricted to 300,000 barrels. This restriction to small and medium-sized tankers would result in a marginal increase in ship traffic. This added congestion would increase the risk of collision and subsequent oil pollution.

The problems of port congestion could be alleviated through the use of very large tankers making deliveries directly to U.S. terminals. The increased imports for the Reserve could serve as part of the justification for the construction of such terminals. The environmental impacts of a terminal to handle large tankers will be determined by the location. Enlarging the channels and harbors of existing ports could require dredging, which could endanger sensitive estuarine areas. These areas are important as nursery grounds for many species. Expansion of existing port facilities in populated areas could also conflict with existing or planned land uses.

Offshore terminals could greatly reduce the risks of dredging and port congestion depending upon the facilities' distance from shore. Terminals which are sited close to shore would generally require dredging. Oil spills from such terminals might reach the shore before they are dispersed or cleaned up. Such facilities could therefore damage estuarine areas. A terminal farther offshore could obviate the need for dredging and might allow spills to disperse or be cleaned up before reaching sensitive areas. However, offshore sites are more expensive and could constitute a navigational hazard.

The construction of a breakwater or island to serve as an offshore terminal would permanently eliminate from productivity the area of seafloor and volume of water it occupies. However, some of this loss would be offset by fish havens formed by the rubble mounds and structures. A deeper offshore setting would affect fewer species. A breakwater could reduce wave action at the shoreline and thereby reduce erosion of the beach. This could lead to the deposition of suspended sediments and accretion of the beach. Continued accretion could cause the development of a sand spit which might ultimately extend to the offshore structure. If this accretion were located at the upper end of the beach system, the normal supply of sand would be cut off and erosion of the beach would occur.

Two applications for construction of offshore terminals in the Gulf of Mexico have been filed with the Secretary of Transportation pursuant to the Deepwater Port Act of 1974. However, neither is expected to be in operation prior to 1980, and therefore could be used only for part of the filling operations. Environmental impact statements to provide detailed information for these terminals currently are being prepared.

A detailed analysis of the risks associated with various methods of importing oil is provided in Section V.D.

3. Alternatives Under the Industrial Petroleum Reserve

The FEA has carefully analyzed and assessed the advantages and disadvantages of exercising the discretionary authority to implement an IPR. As a result of this analysis, FEA is proposing in the SPR Plan that an IPR not be created. The primary reasons for this are that:

- An IPR is likely to result in slightly higher costs to the national economy as a whole;
- An IPR would not enhance the speed of the SPR buildup and may, because of legal challenge, delay the SPR program;
- An IPR would not provide regional protection beyond that achievable with government-owned reserves;
- An IPR could create substantial programmatic, legal and environmental problems, and
- The shifting costs from the U.S. Government to the petroleum industry (and to consumers of petroleum products) is the only apparent advantage of an IPR, but this does not in itself offer significant economic or conservation benefits.

In essence, the decision is based on the belief that the modest benefits derived from an IPR are outweighed by the resulting higher national cost, and by the programmatic, legal and environmental problems that would result from creating such a Reserve.

The planned Federal Government oil acquisition for the SPR will pass a share of the Reserve costs along to industry and users through the "entitlements" program. These benefits will be gained without the possible inequities and the complex regulatory process that would be required for an Industrial Petroleum Reserve.

FEA anticipates establishing a reporting system to monitor the levels of petroleum inventories maintained by industry. This would assure that industry did not begin to rely on the SPR stocks in lieu of maintaining its own protective inventory. If there is a clear downward trend in industry inventories in the future, consideration will be given to proposing a requirement that industry maintain minimum levels of inventories.

In dealing with the question of whether to implement an IPR, the following three implementation methods were investigated:

- Industry supplies the oil for storage in Government-owned bulk facilities,
- Each company supplies the oil for storage in its own facilities; and
- Industry supplies the oil and acts together to provide bulk facilities for commingled oil storage.

Regardless of the manner of implementation, however, the analysis led to similar conclusions.

a. Potential Industry Impacts and Other Economic Disadvantages

While an IPR does offer a modest conservation benefit and an opportunity to lower Federal spending, the IPR could adversely impact industry.

Refiners and importers could be required to pay the cost of acquiring, storing, and maintaining as much as 195 million barrels of oil. The capital investment in crude oil at the end of 1982 for a 185 MMB IPR would be $2.3 billion in 1976 dollars. This would be an average capital outlay of about $0.07 per year per barrel used in the U.S. over the five years when most of the investment would be made. The new capital outlays in all refineries in the Nation in 1974 was $1,775 billion, or $0.37 per barrel refined according to figures published by the Chase Manhattan Bank. FEA evaluated the new capital outlays and net book value of refineries for representative companies. The required IPR capital outlay of $0.07 per barrel per year would be from 14 to 65 percent of the 1975 new annual outlays for refinery properties for the companies studied. The total capital required for the purchase of oil ($0.37 in 1967 dollars) is 1 to 3 percent of the total capital employed for the companies studied.

FEA anticipates that other inequities and adverse effects on the competitive nature of the industry may develop if an IPR is implemented because:

- Large firms, with greater access to sources of crude and capital, wider product mixes, and wider geographical marketing areas, have more flexibility in passing through costs than small firms.

- Differences do exist in the abilities of even the largest integrated firms effectively to pass-through costs, due in large part to the degree of their dependence on imported crude and products. This accounts for the large disparity in size of banks among the majors.

- Small firms have by nature a more limited ability to effect a cost pass-through.

- Small firms, because of their vulnerability, have historically been granted special treatment under many programs, e.g., the Entitlements, Oil Import and Crude Oil Buy-Sell Programs. This special treatment has at times resulted in unfair competitive advantages for some small refiners, to such a degree that modifications in this treatment were at times required. Implementation of an IPR would have to take these problems into account.

- The existence of banked costs in the industry is evidence of market forces controlling selling prices. Such banks are also a valid indication of inability to fully pass-through allowable cost increases. Insofar as they indicate market control of price, banks are a primary reason for proposing selective decontrol of products.

- The disparity in magnitudes of cost banks among firms of the same relative size, and the special treatment afforded smaller firms by FEA, both serve to underline the effect of cost competition on cost pass-through. In addition, special treatment as a result of the entitlements, bias, exemptions, exceptions or other special circumstances, have resulted, in some instances, in certain firms receiving a competitive advantage.

The likely result of an IPR is that unequal abilities of individual firms to absorb and/or pass-through the costs associated with an IPR could lead to some further competitive distortion in the marketplace, and to competitive disadvantage for some firms.

The existence of an IPR would also have an impact on industry structure due to the lower profit margins of some operations. FEA studied the ratio of the cost of an IPR to exemplary companys' published earnings in 1975. The implications are that some less profitable or more specialized companies might be required to invest new capital in excess of earnings in order to meet their obligations under an IPR.

- There will be moderate economic impacts to industry as a whole if industry has to finance the $2.4 billion capital cost over the six years, as well as pay the annualized cost of $0.042 per barrel for the life of the program.
- Funds could be diverted from other investments, including energy producing ventures.
  - Marginal or specialized firms may fail to obtain financing and may close or be absorbed.
  - If only some firms are unable to pass costs through, they may be at a competitive disadvantage with those who can pass-through costs on different products in other areas or at different times.

b. <u>Environmental Impacts</u>

There would be no incremental oil acquisition impacts associated with IPR implementation, inasmuch as the oil stored under the IPR would be credited as part of, rather than in addition to, the ESR or SPR. However, depending upon the method chosen for implementation, the environmental effects could range from inconsequential to substantial. The impacts of method 1, using Government-owned bulk storage, are addressed in Chapter V. Furthermore, it is assumed that the impacts of method 3 will be substantially the same, because it is unlikely that industry would choose to utilize bulk storage methods different from those considered herein (i.e., underground caverns). Any significant impacts of implementation would be the result of using method 2, and would most likely be those associated with the construction of any new tankage which individual companies will need to build to store their share of the IPR. (It is not anticipated that any single company's share would be large enough to justify construction of an underground bulk storage facility.) Should underground storage be utilized by an individual company, the impacts would be those of method 3. The particular impacts of each construction would depend to a great extent upon where the company required the facility. The site-specific analysis of such hypothetical activities is not appropriate for this document. However, Section V.B. may be consulted for an analysis of the impacts of tank construction in the East Coast region.

B. Structural Alternatives

FEA is proposing in the SPR Plan to implement the program through the exclusive use of centralized underground storage facilities. However, since that proposal is contingent upon the absence of Congressional disapproval of the Plan, all of the technically feasible methods remain possible alternatives for the program.

This section describes the alternate means of crude-product storage, including the physical requirements and a detailed description of each type of storage facility. Wherever appropriate, differences in requirements of the ESR and SPR are identified in order to differentiate between possible courses of action in the early and late phases of the storage program.

1. Solution-Mined Cavities in Salt

a. Geologic Characterization

Salt is widely distributed and occurs at many places in the United States in deposits of sufficient size to constitute true rock masses. The major salt basins of the conterminous United States are shown in Figure III-1. Owing to their large number, relatively low cost, and strategic location (near refineries, pipeline networks, port facilities, and large supplies of water) as discussed below, only the salt domes in the Gulf Coast region are being proposed as candidate sites for the storage program. About 500 salt domes have been identified in Alabama, Mississippi, Arkansas, Louisiana, Texas, and beneath the continental shelf off Louisiana and Texas (Figure III-2) (HA-271).

The Gulf Coast salt, designated stratigraphically as the Louann Salt of Triassic-Jurassic age (approximately 170 to 140 million years ago) underlies virtually the entire Gulf Coast basin. The average salt thickness is poorly known and ranges from one thousand to five thousand feet. The Louann salt probably was deposited contemporaneously throughout the depositional basin, which at that time was a restricted basin on the continental margin that permitted at least partial evaporation of marine water and accumulation of evaporite deposits. However, the development of the interior salt domes probably preceded the development and growth of similar features in the more coastal areas, including the offshore domes (Figure III-3).

The origin of the salt dome structure derives from the difference in specific gravity between the bedded salt and overlying sediments and the resulting buoyance of the salt.

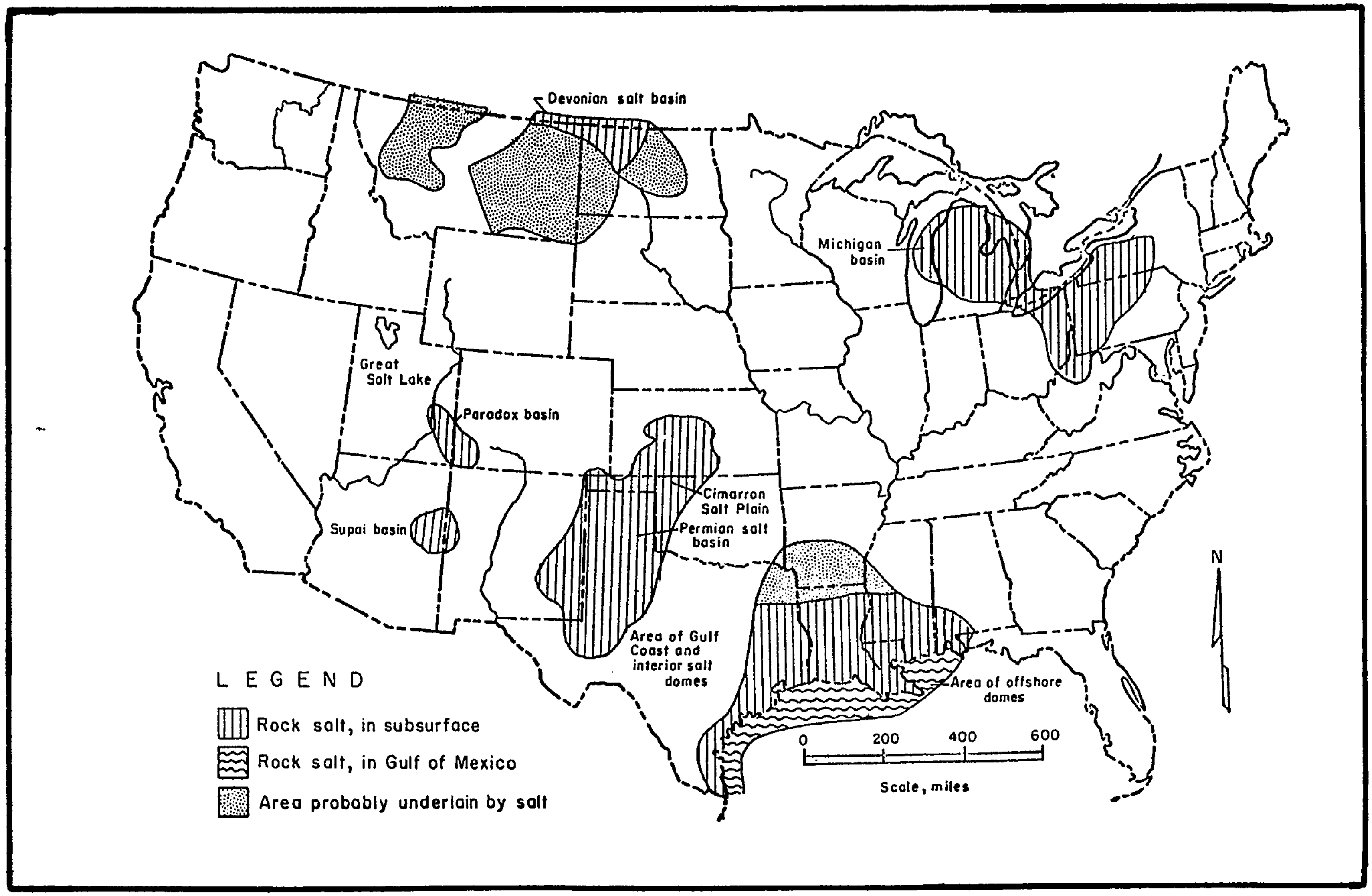


FIGURE III-1

ROCK SALT DEPOSITS OF THE UNITED STATES

Source: HA-271

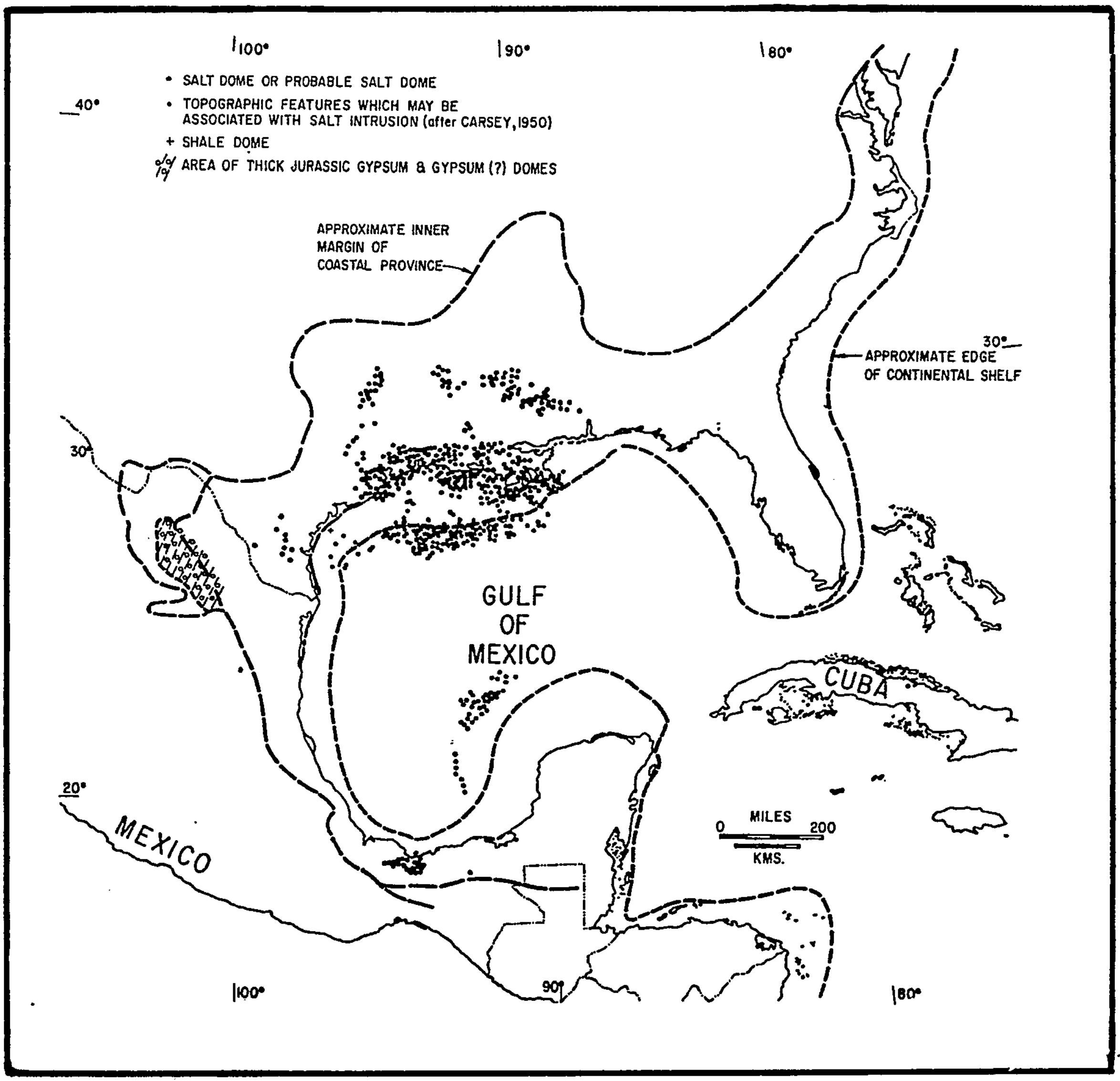


FIGURE III-2

KNOWN DISTRIBUTION OF SALT DOMES IN THE GULF COAST STORAGE REGION

Source: MU-075

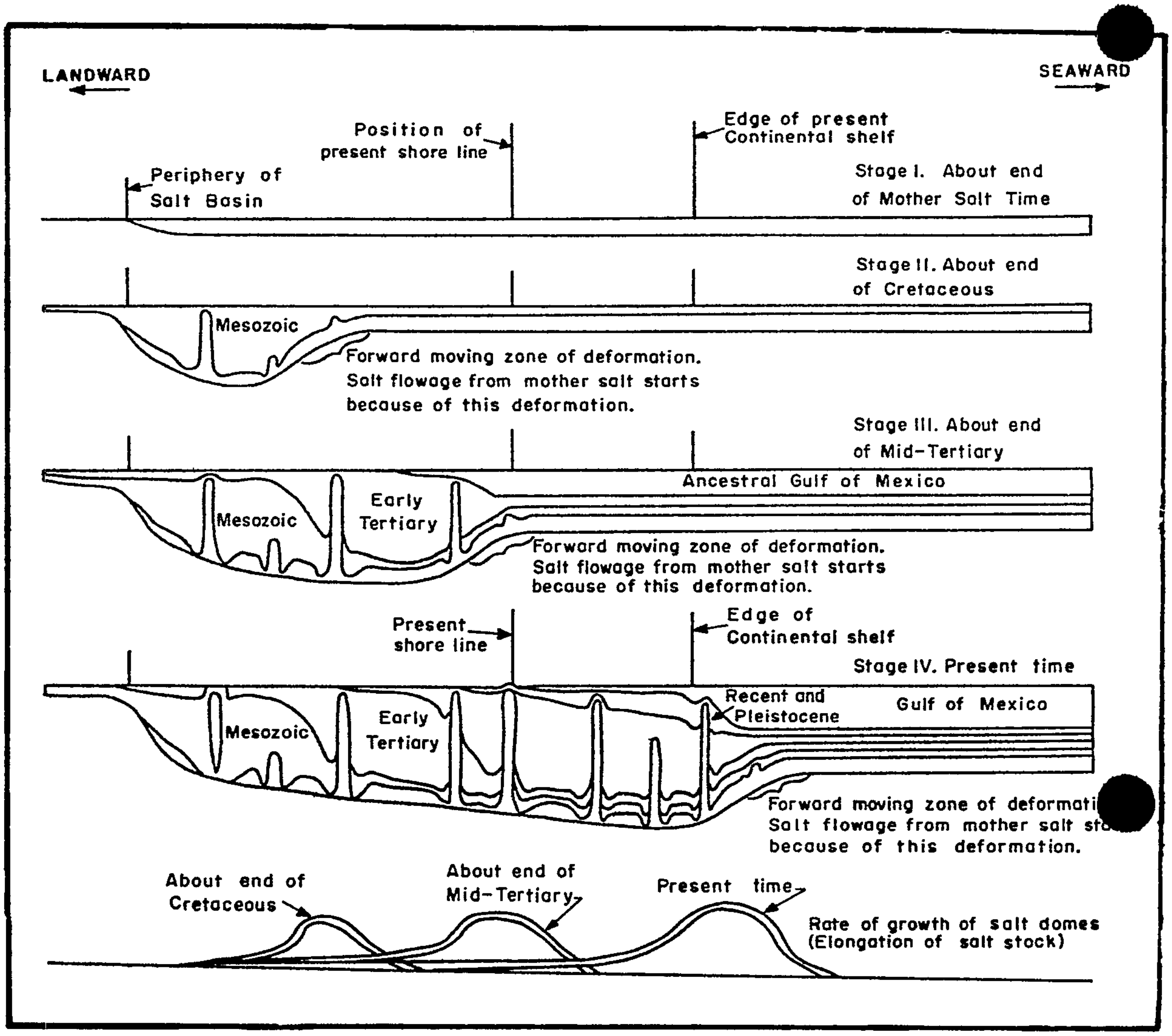


FIGURE III-3

IDEALIZED SECTION SHOWING DEVELOPMENT AND GROWTH OF THE SALT DOMES ON THE GULF COAST

Source: HA-271

Upward movement of the salt is not initiated until sufficient sediments have been deposited over the salt bed. Sediment deposition causes viscoplastic flow owing to the weight (pressure) of the overburden and the higher temperatures due to the geothermal gradient (KU-097). While no drill has yet penetrated the bottom of a salt dome, the flanks of the dome usually are thinly sheathed in a fine-grained material called "gouge", which is crushed rock resulting from the movement of the salt. Upturned, radially and obliquely faulted strata generally encircle the comes and thus provide excellent structural and stratigraphic traps for hydrocarbons that usually are associated with salt domes (HA-272). Essentially, the domes resemble gigantic plugs, tens of thousands of feet deep and commonly several square miles in area, that have risen forcibly upward into overlying strata.

It should be recognized that at least some salt domes, particularly offshore or coastal domes, are generally considered dynamic features, viscoplastically rising more or less continuously at a small but finite rate on the order of 1 millimeter per year. The domes are concomitantly consumed at the upper surface through dissolution by ground water (BO-179). A keyed map of salt domes in the Gulf Coast Basin and the salient characteristics of each are tabulated in a central reference document (RA-223).

It has been recognized for a long time that salt domes are very attractive storage or disposal sites for gases, liquids, or solids, and a number of these are presently used to store petroleum products; recently, some crude condensate has been stored in cavities in a Louisiana salt dome (WE-215). Moreover, storage of crude in salt domes is an integral part of the proposed LOOP (Louisiana Offshore Oil Port) deep-water port facilities. Existing cavities have also been formed to supply brine feedstocks to petrochemical plants.

b. Physical Requirements for Storage

Cavities are formed by dissolving the salt with circulating unsaturated water (incorrectly, but commonly, termed "leaching" the cavities). The description of the dissolution process and the requisite facilities is given in more detail in Section III.B.1.c. In this section, a number of general considerations and the physical requirements of the solution cavity system are briefly reviewed.

Location

Although the location of salt domes and existing cavities contained therein is fixed, selection of the small number of domes necessary for the program from the hundreds of domes of potential utility requires evaluation of a number of important factors. Each of these factors is discussed here with respect to the resources required by the program. These factors include strategic considerations, required water source, and brine disposal sites.

The candidate salt domes must be distributed in a geographic pattern that would insure both adequate cost-effective integration into the crude-oil distribution network and responsiveness to market needs in the event of a severe supply interruption. Current plans are to store only crude oil in solution cavities in salt domes. Consequently, the single market-place for crude stored is domes in refineries that, at least partially, depend on imported crude as feedstock. The major crude-oil pipelines and crude-handling ports are the intervening link, and are thus the critical factor in selection of a salt dome as part of the program. The analysis of distribution requirements is the subject of Section IV.C.

Beyond the distribution requirements, a reliable source of water is required for both creation of new cavities and the withdrawal of stored crude from existing and new cavities. Theoretically, for each barrel of new storage volume created, 6.2 barrels of fresh water or 6.8 barrels of normal sea water are required. The precise storage capacities required at a given salt dome will not be known until acquisition negotiations are complete. To insure distribution flexibility and to minimize environmental impacts, it is anticipated that no more than 200 million barrels (200 MMB) will be stored at any new storage site. Based on the availability of existing cavities which appear feasible for program use, it is anticipated that no more than 90 million barrels (90 MMB) will be stored at any site in existing cavities. Table III-2 presents maximum rates of fluids (raw water and brine) for constructing and operating both types of storage facilities. To meet applicable storage program timing requirements, cycling requires somewhat higher fluid rates than constructing the cavities.

To obtain the requisite amounts at the necessary rates, clearly a large water source is required. Consequently, the salt dome must be located near a large surface-water body or over an aquifer with sufficient (saturated) thickness and permeability. Since the water need not be fresh water, those domes near the Gulf of Mexico or offshore and those sites over the voluminous Gulf Coast aquifers containing slightly saline to saline waters at moderate depths are especially advantageous.

TABLE III-2

AVERAGE WATER RATES[1] REQUIRED FOR A NEW 200 MMB STORAGE FACILITY AND AN EXISTING 90 MMB STORAGE FACILITY IN A SALT DOME

ACTIVITY	200 MMB NEW FACILITY (DURATION IN MONTHS)			90 MMB EXISTING (DURATION IN MONTHS)		
SOLUTION MINING PHASE	36	42	48			
Water for Dissolution						
Sea water	36	31	27		None	
Fresh water	33	28	24			
Brine to Disposal						
From sea water	41	35	31		None	
From fresh water	37	32	28			
CYCLING PHASE	4	5	6	4	5	6
Water for oil displacement						
With sea water	49	39	32	22	18	14
With fresh water	50	40	33	22	18	15
Brine displaced by filling (or refilling) with oil	Variable, but less than or equal to above rates for oil displacement					

[1] In thousands of gallons per minute, assuming (a) constant rate, (b) 100 percent salt saturation, and (c) refilling only to original capacity of each cavity.

All cavities, whether existing or new, will require brine disposal (or storage-recirculation) facilities because nearly saturated brine (230,000 ppm NaCl) results from cycling (emptying-refilling) of the storage system as well as from cavity development. For example, the construction of a single 10 MMB cavity within a 42 month period will require constant disposal of about 1,730 gpm of brine, and cycling this cavity will displace up to 1,940 gpm of brine. When this amount is multiplied by the number of cavities required at a dome (less than or equal to 20), brine disposal becomes a significant concern. The Gulf of Mexico, deep aquifers containing saline water or brine, and use by petrochemical plants are disposal options. Salt domes selected for use in the storage program must be accessible to at least one of these disposal alternatives.

Dimensional Considerations

Dimensional considerations such as area, depth, and configuration place constraints on the use of solution cavities for storage.

Land usage will depend on amount of oil stored and land required for pipeline rights-of-way. At a macroscopic level, the surface area required for implementing the storage programs is less sensitive to the total amount of oil stored than to the distances from both the water supply/brine disposal area and the trunk crude-oil pipeline. It is not possible now to define precisely the land usage required for pipeline rights-of-way, because neither the individual domes nor their water supply or brine disposal locations are known with certainty. However, on the basis of preliminary studies it is known that those sites with the shortest pipeline distances (and hence the smallest associated land usage) are the most likely to be incorporated into the program (other factors being equal) due to their lower cost.

The land surface usage at the individual domes is variable but rather small. On the order of one-two percent of the surface area over the dome is required, primarily for pumps, access roads, and pipes/manifolds connecting individual cavities. This could amount to as much as 135 acres for a 90 MMB facility with existing cavities and 260 acres for a 200 MMB facility with new cavities. During construction, perhaps twice this area of land would be disturbed.

As presented in RA-223, the volumes of individual salt domes are very large; for example, 200 MMB of storage space would be less than one percent of a small dome of 1.0 cubic mile volume. The storage volume will not be distributed uniformly throughout the dome; rather only the upper few thousand feet of the dome will contain the cavities (RA-157). In addition, it is probable that the cavities will not be distributed uniformly in the area underlain by the dome. The cavities will be "clustered" primarily in the central part. Twenty cavities of 10 MMB capacity could be readily constructed at the same level within the central 20 percent of the cross-sectional area of a dome two square miles in cross-sectional area. This figure includes a factor for cavity "growth" by dissolution during cycling with unsaturated water. The cavities are designed to undergo at least five cycling events, which will approximately double the storage volume initially present. Most of the cavity growth will be lateral, since the build-up of insoluble matter of the bottom of the cavity retards downward growth. Cycling with saturated brine would increase the land use appreciably, since brine storage tanks or ponds of volume equivalent to the oil in storage would be required.

The depth of suitable cavities is limited primarily by cavity stability and to a lesser extent by operating costs. Salt has a larger thermal conductivity than its surrounding sediments (GU-079). The geothermal heat flow through a dome is believed to be greatest in the central part. Heat flow contributes to the plasticity of the salt, which permits continued growth of the dome and rapidly seals induced fractures. This self-sealing capability restricts the placement of stable cavities within the domes to areas where overburden pressure is less than 3000 psi and temperature is less than 400°F (BR-178). If these limits are exceeded, cavities in the salt will tend to close due to "creep" (i.e., viscoplastic flow). Consequently, a probable maximum depth for open cavities is about 4000 feet (CO-227); cavities that operate with higher internal pressures, such as provided by a full head of brine, may be constructed to depths of about 7000 feet. New cavities in domes must be located deep enough to prevent catastrophic collapse of the cavity. Rock mechanics studies and experience suggest that 500 feet is an acceptable minimum depth below the top of the salt.

Finally, an economic constraint on cavity depth is the cost of emplacing oil for storage: the deeper the oil, the higher the cost of operating the system.

The internal configuration of the cavity must permit recovery of virtually all of the oil stored there with a small number of wells. Modification of some existing cavities may be necessary to achieve complete recovery, particularly if the cavities were previously used for storing gaseous products or for only producing brine for chemical feedstocks.

The intradome configuration of the cavities is likewise an important consideration. After allowance is made for dome growth, cavities will be spaced at least 300 feet apart laterally. If multi-level storage is used, 500 feet vertical separation will be employed. This spacing is essentially a buffer to prevent instability problems and to allow for some non-ideal cavity configurations that occasionally result from non-optimal practice or local inhomogeneities in the salt. Similarly, a larger buffer, 800 feet or more, is established between the trunk of the dome and the nearest cavity to allow for incorrect estimation of the position of the dome flank.

Physical Character

The single property of salt that makes it most attractive for crude oil storage is its virtual in-situ impermeability. No other common rock type could contain crude as safely, solely by the impermeability of the in-place host. Impermeability is aided by the "self-sealing" property as described in the previous section. The best demonstration of this impermeability is that salt mines within domes are virtually dry, despite very high hydrostatic pressures in the geologic strata flanking the domes. The small water inflows that exist in some mines are generally attributable to these high hydraulic gradients and to large shale streaks or other inhomogeneities that were encountered in the mining.

In overall aspect, however, salt domes are remarkably homogeneous. An average sodium chloride (halite) content for rock of Gulf Coast domes is greater than 95 percent; nearly all of the remainder is calcium sulfate (anhydrite) (KU-097). Table III-3 contains an analysis of major constituents of Gulf Coast domal salt.

TABLE III-3

TYPICAL CHEMICAL COMPOSITION OF DOMAL SALT

Constituent	Percent Abundance
NaCl	99.03
$CaSO_4$	0.22
$MgCl_2$	0.01
$CaCl_2$	0.01
H_2O	0.02
H_2O Insoluble	0.71
Total	100.00

Source: GI-093

Timing Requirements

The chief attraction of using existing cavities is that they can be modified for crude oil storage efficiently and cost-effectively, a feature that is required by the ESR. As described in Section I.C., at least 150 MMB of petroleum must be stored by the end of 1978 to meet the legislative timetable of the ESR. More than 200 MMB or currently existing space in solution-mined cavities is potentially convertible to oil storage. In conjunction with existing salt mines, such space is the only means of storing the required amount of crude in the required time frame. Even so, careful consideration is required in order to select ESR storage sites which do not require time-consuming modifications. Existing facilities that would require more conversion time remain prime candidates as sites for the SPR.

Even if use of existing space is maximized in the ESR and SPR, the use of newly developed cavities in salt domes will be necessary to achieve the SPR goal of storage of 500 MMB of crude oil within seven years. Constructing this new space must be carried out on a rather exacting schedule, and some domes may not be amenable to timely construction owing to poor surface working conditions, relatively large distances from brine disposal areas or a water supply, or similar physical constraints. Even for those locations that will be selected as favorable with respect to those aspects, there may be local logistical constraints; the availability of materials and equipment such as pumps, pipe, and drilling rigs is critical to achieving program objectives. The major equipment necessary for the program is summarized below.

It is anticipated that three or four drilling rigs and two workover rigs will be needed at each salt dome of 200 MMB storage capacity. Drilling rigs will operate simultaneously and continuously, if materials are available. The drilling rigs would be released from contract when the appropriate number of holes (twenty maximum) is drilled. It is estimated that it would take six months to drill twenty holes to a total depth of 2500 feet, including 1500 feet through salt, with average caprock conditions. Loss of circulating fluid during drilling of the caprock is of considerable concern in terms of cost and time. One of the palliative measures taken for particularly adverse zones, viz., reduction in borehole size by setting casing, conceivably could force construction of additional cavities to meet storage requirements owing to the smaller pumping rates possible through the smaller diameter annulus and tubing. To the extent compatible with other criteria, those domes will be selected where operating experience within the caprock zone has been favorable in this regard.

Unlike the drilling rigs, workover rigs will be required on-site at all times during new cavity construction, rotating among the various cavities. It seems likely that the lease or purchase rather than contractual use of workover rigs will be cost-effective. Distribution strategies will require that the domes selected for use in the program are likely to be geographically separated by a considerable distance. As a result, there will be little opportunity for sharing of equipment among the individual domes.

Perhaps 150,000 feet each of injection (10 inch) and intermediate (13-3/8 inch) tubing and about 75,000 feet of rather large diameter (15-20 inch) casing will be required to complete the program. In view of the current rather sparse availability of oilfield tubing and the requirement for a large amount of this pipe near the outset of the program, its availability is probably on the critical path. If there is a local pipe shortfall, the drilling of the holes for some cavities that could otherwise be initiated would be postponed until pipe could be obtained.

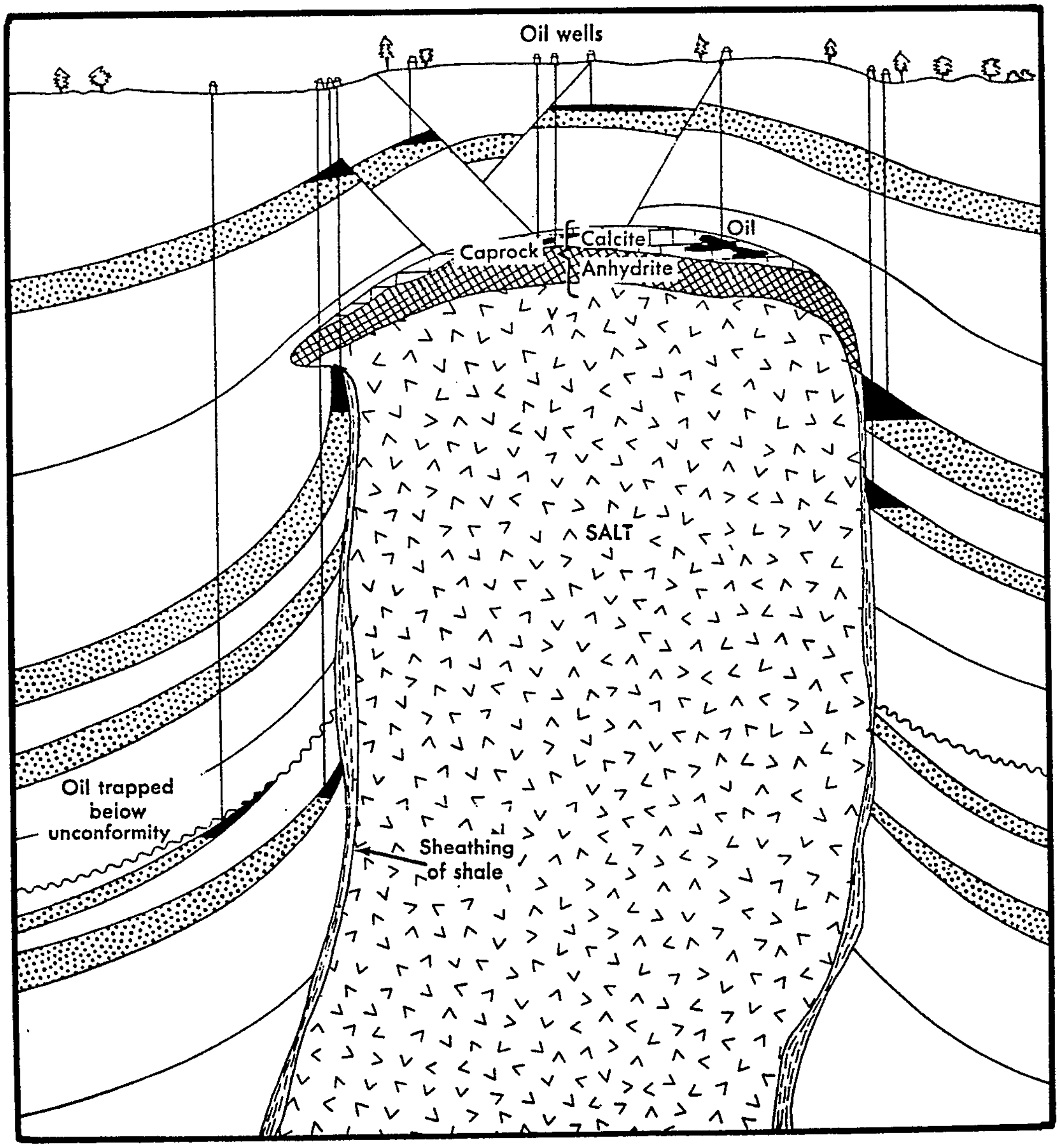
c. Development of Salt Dome Storage Facilities

A number of salt dome cavities are presently being used in the United States for the storage of petroleum. Although the engineering problems associated with cavity developments are, for the most part, theoretically understood, a great deal of field expertise seems to be required to consistently develop the desired cavity size and shape (RA-151). In this section, the more significant engineering and cost constraints, cavity design theory, energy requirements, and other sources of environmental impacts will be discussed.

Development and Conversion of Onshore Salt Dome Cavities

This subsection describes typical, general procedures used in the construction or development of new cavities and in the conversion of existing cavities. Minimum physical requirements for the construction or the development of a salt dome for storage of petroleum include a geologic salt formation, an adequate supply of water for solution mining and/or cycling, and an acceptable means of brine disposal. A descriptive illustration of a typical salt dome is shown in Figure III-4. To develop a cavern in such a dome, water is injected into a well and circulated, causing dissolution of the salt. As the brine approaches saturation, it is displaced from the cavity by incoming water. The dissolution of the salt and removal of brine results in the eventual formation of a cavern.

Before actual "leaching" or solution mining activities can begin, a well must be drilled. The selection of the proper well diameter is critical and will influence the leaching process. Larger well diameters not only allow larger leaching rates, but after the cavity is formed and put into operation, they allow larger oil acquisition and delivery rates. However, it may be difficult to obtain a large number of drilling rigs that can handle large diameter drilling equipment and it may



SOURCE: CL-072

FIGURE III-4

TYPICAL SALT DOME STRUCTURE AND RELATED STRATA be more feasible to drill several smaller diameter wells. Typical well diameter sizes range from ten inches to approximately twenty-two inches, depending primarily on the oil retrieval rates required for the strategic storage program and the desired rate of cavity development. A rig capable of handling sixteen inch pipe or casing is roughly equivalent to a rig that is capable of drilling a ten to twelve thousand foot well. In addition to the rig, various tanks are required to store drilling mud and water. In a typical operation, the water used in the first drilling operation is normally supplied from nearby fresh or saline groundwater sources. The groundwater well is then the water source for preparing mud for drilling into the salt domes (RA-151).

During the drilling process, casing is placed and grouted in the hole to provide a sealed passage between the salt dome and the surface. After the drilled hole penetrates the caprock, a minimum additional five hundred feet is drilled into the salt before the final casing is placed and grouted. This last joint of casing locates the top of the cavity to be developed.

A grouted pad is placed around the bottom of the casing to insure that the salt does not dissolve away from the casing. Drilling continues without additional casing until the desired depth, near the bottom of the cavity, is reached.

The drilling equipment is then removed and the strings of pipe used for leaching are inserted. Pipe strings for leaching usually consist of two pipes of different diameters which are placed in the well concentrically. The large diameter pipe extends downward just below the top of the proposed cavern ceiling. The smaller inner pipe extends to the bottom of the drilled well.

The two basic methods used for the development of a salt dome are bottom or direct circulation and reverse circulation. Bottom circulation is the most commonly used method and is accomplished by injecting water near the bottom of the cavern through the smaller string and withdrawing brine through the larger diameter string near the top of the cavern. An illustrative description of this process is shown in Figure III-5. For reverse circulation, water is injected through the casing annulus or larger diameter string at the top of the cavern and brine is removed by displacement through the smaller tubing near the bottom of the cavern. Similar equipment and procedures are required for both methods.

A noncorrosive blanket material of either natural gas, propane, butane, diesel oil, or crude oil is injected in the topmost interval of the cavern to control the cavity shape by prohibiting leaching of salt from around the cemented casing, and to protect the casing from internal corrosion. The presence of the inert blanket insures a pressure-tight cavern and prohibits the development of voids in the cavern roof from which stored petroleum could not be recovered. Once the cavity has reached size of approximately one million barrels, it becomes advantageous to use crude for the inert floating blanket, thereby storing crude simultaneously with cavity development. However, this process will be dependent upon the crude availability and acquisition rate. An illustrative schematic of an onshore salt dome storage facility is shown in Figure III-6.

Existing leached space generally contains brine prior to its conversion for storage. Existing space is the prime candidate and offers the most practical solution for large-volume storage facilities in the ESR. In many aspects, the conversion of existing cavities is similar to the construction of

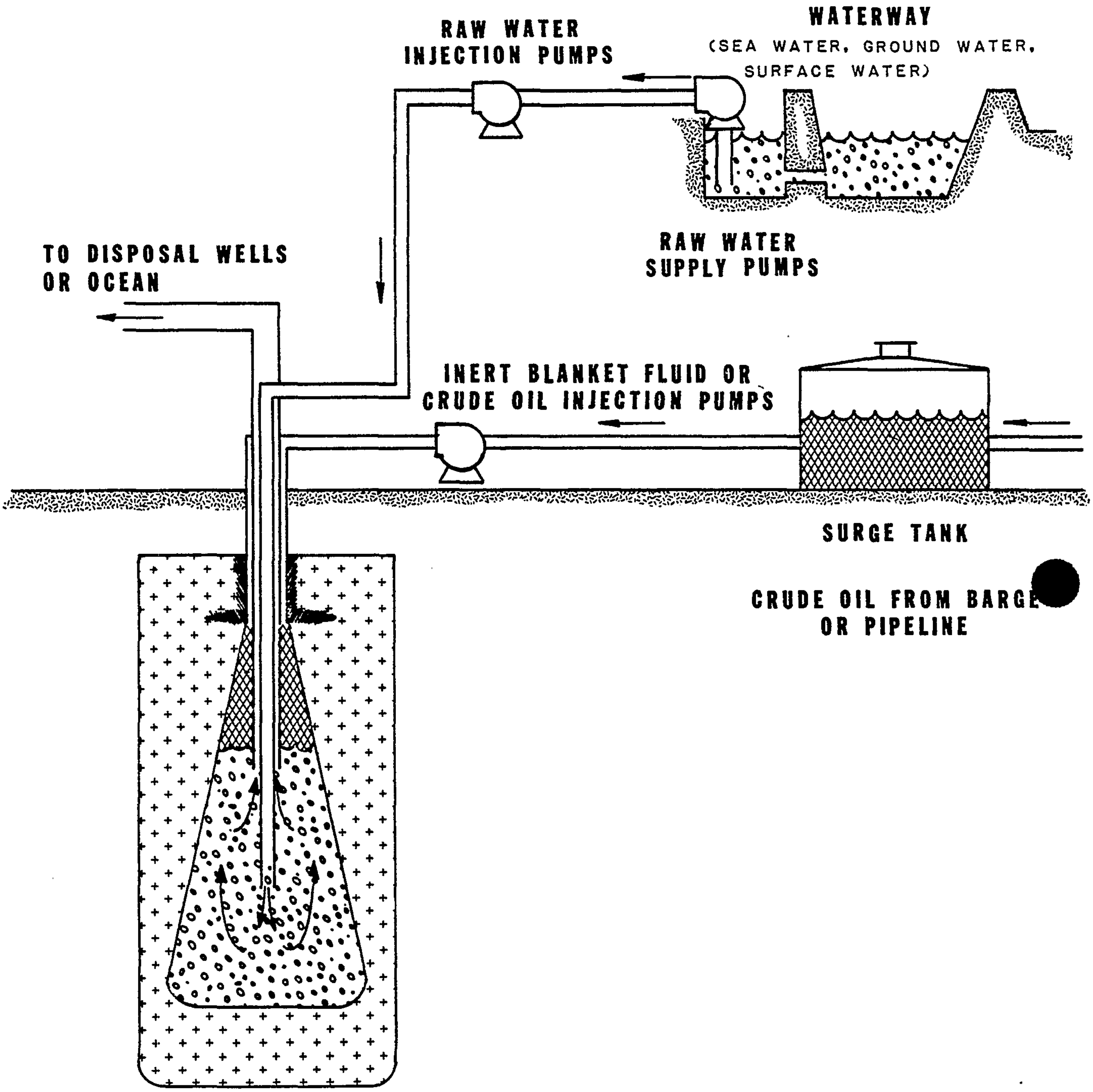


FIGURE III-5

TYPICAL DIRECT CIRCULATION TECHNIQUE USED IN SOLUTION MINING

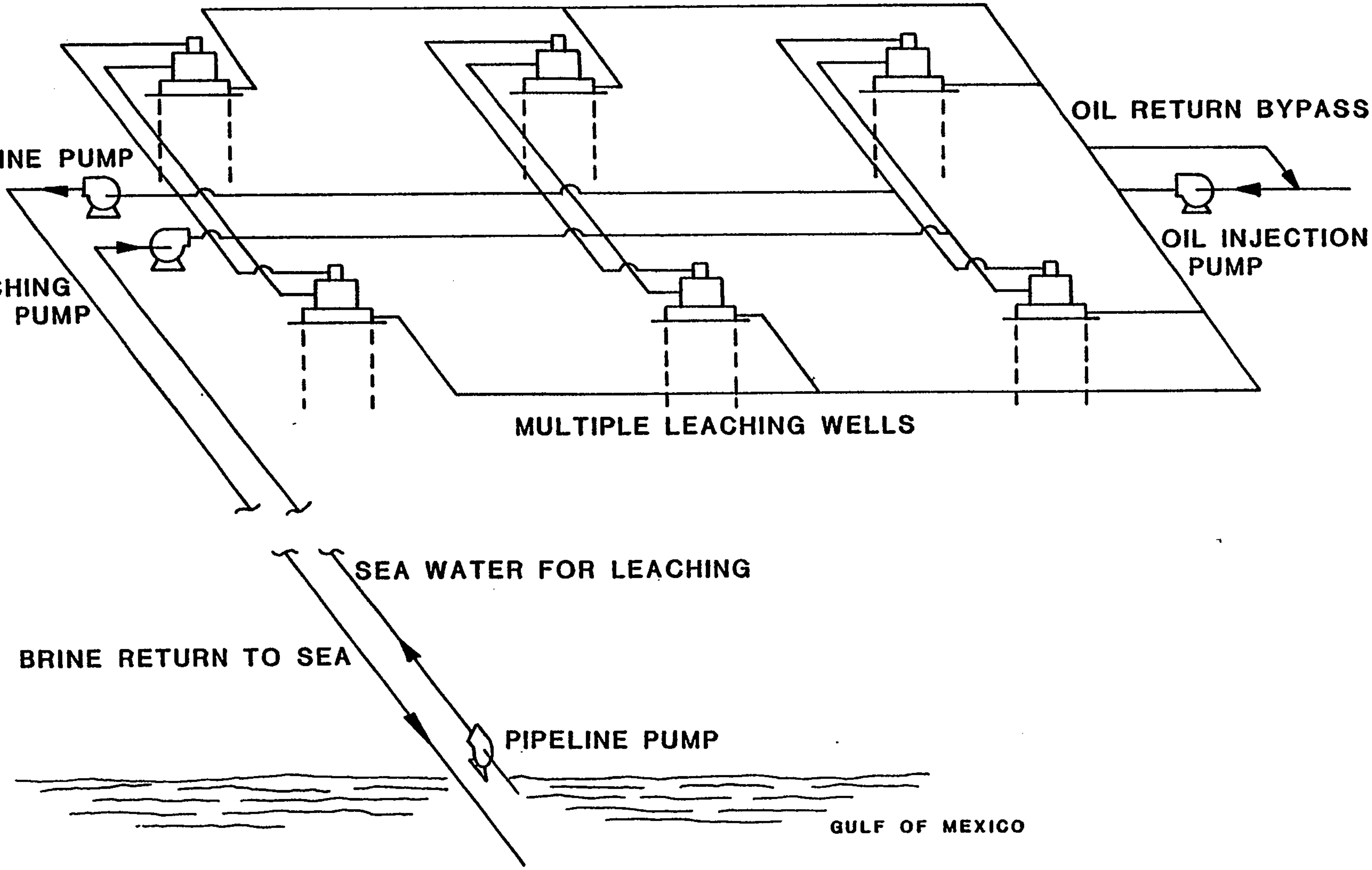


FIGURE III-6

SCHEMATIC OF OPERATING ONSHORE SALT DOME STORAGE FACILITY new ones; the primary difference lies in the fact that generally very little, if any, fluid circulation through the cavity is required, and therefore much smaller amounts of raw water must be supplied and much smaller amounts of brine must be disposed. The operational mode is the same for new or existing cavities. Typical activities that may comprise conversion of existing cavities in a salt dome include:

- Drilling and completion of water-supply wells for modifying the cavities (if required) and for oil displacement.

- Drilling and completing new injection wells for the brine resulting from cavity modification and cycling.

- Construction of various pipelines and pumping stations to water source, to brine disposal area(s), and to oil acquisition/delivery points.

- Construction of about 2 days' surge tankage at delivery point on crude oil trunk pipeline; possibly smaller surge tankage for brine.

- Drilling of vent holes in the cavity.

- Rehabilitation or redrilling for enlargement of existing cavity wells, including additional grouting and cementing of new casing and installing new wellheads.

- Fluid circulation in selected zones of the cavity to insure efficient oil recovery.

- Displacement and disposal of brine in the cavity concomitant with initial filling of cavity with oil. (Where feasible, this "initial" brine will be furnished to local petrochemical industries as feedstock, although future cycling may not be able to dispose of all of its brine in this manner owing to the high rates.)

To a large degree, the extent of these activities associated with conversion (or continued development) of a storage facility with existing cavities is dependent upon the inventory of existing equipment such as pumps and pipelines and the existing or past usage of that equipment. The sizes (i.e., capacities) of existing pumps and pipes are critical in determining what additional equipment is necessary.

Development of Offshore Salt Domes

A significant number of salt domes are located offshore beneath the Gulf of Mexico and a few of which can potentially be used for petroleum storage. No offshore salt cavern facilities currently exist, and FEA is not proposing to create and use any new caverns in offshore domes. However, engineering technology is sufficiently advanced that no inordinate obstacles are anticipated in this development. Drilling rig platforms can be constructed onshore and barged to the specific offshore construction sites. After the platforms and drilling rigs are in place, drilling can proceed as for onshore wells.

The leaching equipment can also be constructed onshore and assembled on a platform which can be barged to a central location for the leaching wells. Submerged pipelines can be laid between the pumping platforms and each of the wells, and leaching can begin. This centrally located leaching or or pumping station can later be used for single point mooring operations for each of the offshore salt cavities.

The obvious candidate for water supply is the surrounding Gulf waters. Leaching and storage can be accomplished concurrently in much the same manner as for onshore facilities. Similarly, brine disposal generally will be to the Gulf; there is no technical reason preventing deep-well injection offshore, but the cost may be prohibitive and it appears unnecessary since direct discharge into the Gulf should have no significant adverse impacts.

Two possibilities exist for developing a petroleum distribution system for offshore facilities. Pipelines can be placed between the shore and the offshore pumping station for fill and withdrawal operations. However, single point mooring systems for both fill and withdrawal operations using tankers offers more flexibility in petroleum distribution and eliminates additional distribution pipe. The size of the tankers used will be dictated by the depth of water at the centrally located pumping station or mooring station. A schematic of an offshore salt dome storage facility in operation is shown in Figure III-7.

Recovery from Storage

Recovery of stored product by displacement with saturated brine is the most commonly used retrieval practice in solution mined storage caverns. Pumping oil directly out of the cavern is less desirable because it may lead to structural problems in the partially empty or empty cavern. Ponds with volumes equal to the cavern are sometimes used to store the brine at the surface. However, the brine ponds required for

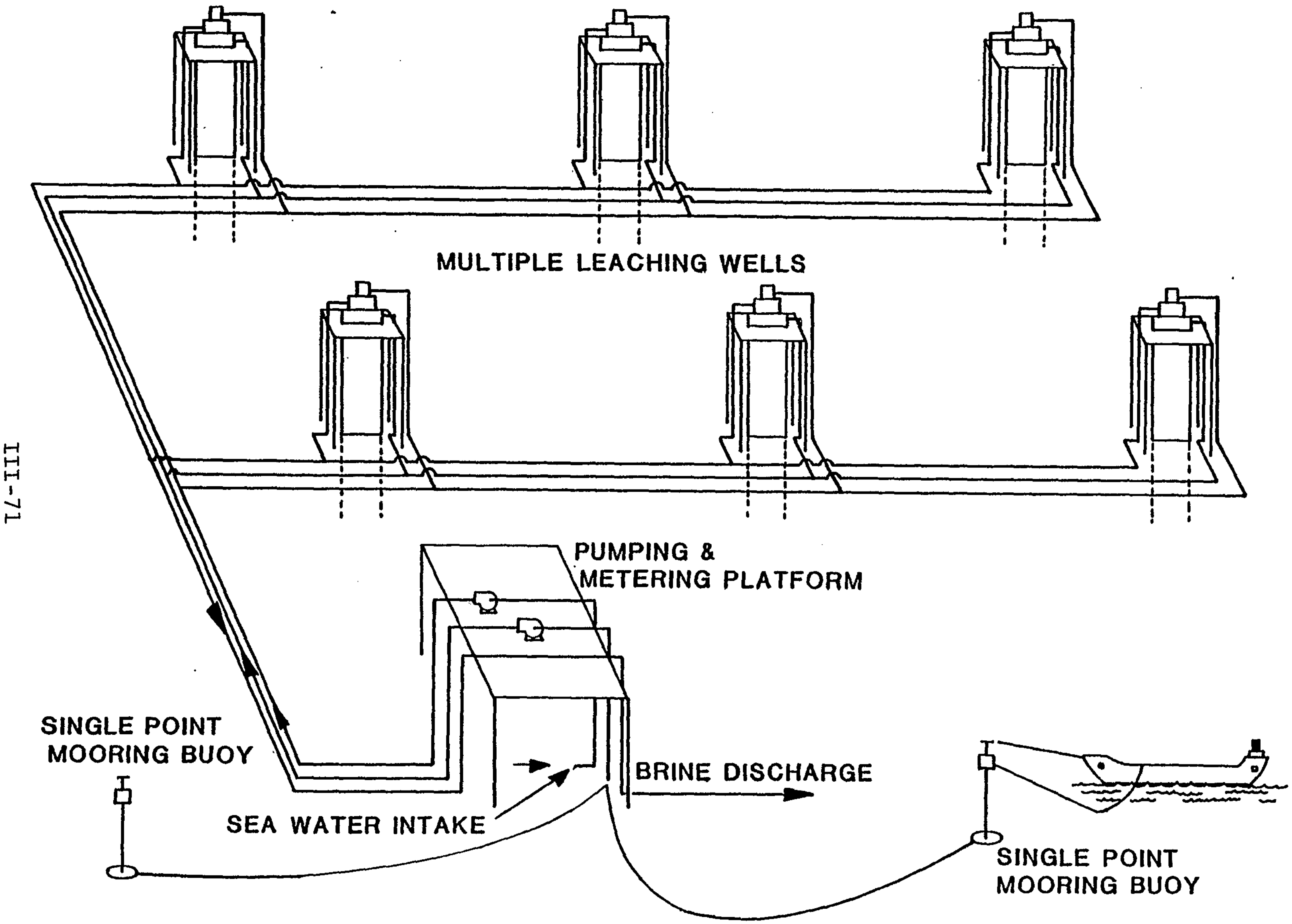


FIGURE III-7

SCHEMATIC OF AN OPERATING OFFSHORE SALT DOME STORAGE FACILITY this program would be extremely large and could be more expensive to construct than the caverns.

For shallow domes, a pumpout operation may also be considered. Pumps can be suspended in the caverns to remove the brine at the completion of the leaching operation. The same pumps could also be used to pump oil from the caverns. However, such pumps are expensive to operate and maintain, and their size is limited to the borehole size. Additionally, vibrations from the operation of the suspended pumps could cause cavity roof instability.

Water supply requirements for oil displacement during withdrawal from a 10 MMB capacity cavity are approximately 2020 gpm if fresh water is used and approximately 1960 gpm if sea water is used. Use of fresh water or sea water as a displacement fluid will result in continued leaching and enlargement of the cavity, because the walls of the cavity will continue to leach until the displacement liquid is saturated. For the Strategic Petroleum Reserve, new leached caverns are to be designed to allow five fill-recovery cycles with each cycle only refilling to the original capacity and not the new enlarged capacity. It has been estimated that under these conditions, cavern enlargement will range from approximately 73 percent if sea water is used to approximately 86 percent if fresh water is used.

d. Fire Hazards

Fires around salt domes could occur within the partially filled storage cavities or at the surface. Either fire should be of short duration and the effects should be of little consequence. If the fire were to occur within the cavity, the oxidation reactions would soon consume all the oxygen and the fire would be quickly smothered. For a fire to occur at the surface, oil must be present at the surface. In the event that sabotage or catastrophe caused a well head to be sheared, only a small quantity of oil would escape to the surface and any fire hazard would be minimal.

e. Energy Requirements

New Onshore Facility

The major energy requirements for the development of a new onshore salt dome storage facility include requirements for drilling wells, supplying leaching water, and disposing of brine. Drilling activities include drilling the salt cavity, water supply and/or brine disposal wells. Water supply systems for cavity development require energy for water injection pumps and delivery of water from either on-site wells or the ocean. Brine disposal systems require energy to transport the brine to either wells or the ocean. If wells are used for brine disposal, more energy will be required for injection than ocean disposal.

Operation of an onshore salt dome storage facility requires energy for water supply systems, brine disposal systems, oil distribution systems, and crude oil injection systems. Energy requirements for the oil distribution system include energy for both the transport of crude to the storage site and delivery from the storage site to the refinery center.

The estimated energy requirements for development and operation of a new 200 MMB onshore salt dome storage facility are itemized and summarized in Table III-4. Development energy requirements reflect the total energy required for each item listed to completely develop a typical salt dome site.

Operation energy requirements indicate the estimated total energy requirements for one fill/recovery cycle. Energy requirements for construction and placement of equipment required for development and operation and energy requirements for the placement of pipelines are not included in this study.

TABLE III-4

ESTIMATED ENERGY REQUIREMENT FOR DEVELOPMENT AND OPERATION OF AN ONSHORE SALT DOME FACILITY

DEVELOPMENT	
	10^6 kWhr
Drilling	
Cavity wells	6
Water supply wells	6
Brine disposal wells	3
Water Supply	
Injection	47
Delivery from wells	31
Delivery from Gulf	55
Brine Disposal	
Injection in wells	95
Delivery to wells	21
Delivery to Gulf	55
OPERATION	
Water Supply	
Injection in cavity	5/cycle*
Delivery from wells	4/cycle
Delivery from Gulf	6/cycle
Brine Disposal	
Injection in wells	12/cycle
Delivery to wells	2/cycle
Delivery to Gulf	6/cycle
Crude Oil Injection	2/cycle
Oil Distribution	
Delivery for fill	3/cycle
Delivery to refining center	3/cycle

*Cycle is defined as one complete fill/recovery operation

Existing Onshore Facility

The only significant energy requirement for the development or conversion of an existing salt cavity for strategic storage is for drilling of water supply wells or brine disposal wells if such facilities are used. Energy requirements for the operation of the existing facility are identical to the requirements for the operation of a similar new facility.

The estimated energy requirements for the development and operation of an existing 90 MMB onshore salt dome storage facility are itemized and summarized in Table III-5. Development energy requirements reflect the total energy required for each item listed to completely develop or convert the existing salt dome facility. Operation energy requirements indicate the estimated total energy requirements for one fill/recovery cycle.

TABLE III-5
ESTIMATED ENERGY REQUIREMENTS FOR DEVELOPMENT
AND OPERATION OF AN EXISTING 90 MMB SALT DOME FACILITY

DEVELOPMENT	10^6 kWhr
Drilling	
Water supply wells	6
Brine disposal wells	3
OPERATION	
Water Supply	
Injection in Cavity	5/cycle
Delivery from wells	4/cycle
Delivery from Gulf	6/cycle
Brine Disposal	
Injection in wells	12/cycle
Delivery to wells	2/cycle
Delivery to Gulf	6/cycle
Crude Oil Injection	2/cycle
Oil Distribution	
Delivery for Fill	3/cycle
Delivery to Refining Center	3/cycle

Energy requirements will largely be supplied from local electrical facilities. Energy requirements for construction and placement of equipment required for development and operation and energy requirements for the placement of pipeline are not included in this study.

Offshore Facility

The significant energy requirements for the development of an offshore salt dome storage facility are for drilling proposed cavity wells, drilling of brine disposal wells if such facilities are used, water supply from the Gulf for solution mining, water injection pumps, and brine disposal pumps. Brine will either be disposed of by discharge in the Gulf near the ocean floor or by injection into deep salaquifers.

Significant energy requirements for the operation of an offshore facility include requirements for water supply facilities, water injection pumps, brine disposal pumps, crude injection pumps and oil distribution systems. Oil distribution systems include the transport of crude to the offshore facility by tanker and from the storage site by tankers to the refinery centers.

The estimated energy requirements for the development and operation of a new 200 MMB offshore salt dome storage facility are itemized in Table III-6. Development energy requirements reflect the total energy required for each item listed to completely develop the offshore facility. Operation energy requirements indicate the estimated total energy requirements for one fill/recovery cycle. All energy requirements will be supplied by a generator located on the offshore platform. Energy requirements for construction, dredging, and placement of facilities required for the development and operation of an offshore salt dome storage facility are not included in this study.

TABLE III-6

ENERGY REQUIREMENTS FOR THE DEVELOPMENT AND OPERATION OF A NEW 200 MMB OFFSHORE FACILITY

DEVELOPMENT	10^6 kWhr
Drilling cavity wells	6
Drilling Injection wells for brine disposal	3
Water supply	24
Water injection	173
Brine Disposal	Negligible
OPERATION	
Water Supply	3/cycle
Water injection	6/cycle
Brine disposal	
Ocean discharge	Negligible
Deep well disposal	
Injection to wells	12/cycle
Delivery to wells	2/cycle
Crude Injection	3/cycle
Oil Distribution	
Delivery for fill	Not determined
Delivery to refining center	Not determined

f. Manpower Requirements

Manpower requirements for the development of onshore salt dome storage facilities will include qualified drilling crews for drilling the cavity wells, water supply wells and brine disposal wells and experienced construction workers for the installing of equipment and for performing the solution mining activities. A small crew will also be required to operate and maintain the facilities after development.

The development of existing facilities will require substantially fewer personnel. Wellheads will have to be installed and borehole casing will have to be replaced. Additionally, experienced drilling crews may have to drill water supply wells and/or brine disposal wells. Operational manpower requirements are identical to the operational manpower for similar new facilities.

Manpower requirements for the development of an offshore salt dome facility will include a qualified offshore drilling crew to drill the proposal cavity well. Also experienced steel workers and welders will be required to fabricate platforms to be placed in the Gulf at the development site. Operational manpower requirements are minimal.

In all three cases, relatively few workers, skilled and nonskilled, will be required. Only in the development phase might a significant manpower force be required. However, this force will be required for only a short period of time and the total manhour requirements will be relatively small.

g. Feasibility of Onshore and Offshore Salt Dome Storage Facilities

It is technologically feasible to construct and operate a storage facility in either onshore or offshore salt domes. Each system has relative advantages and disadvantages with respect to both operational and environmental concerns.

An offshore site has a number of relatively attractive features: (1) it is possible that the use of offshore land beyond the U.S. territorial limits would eliminate the need for the payment of a purchase price; (2) the immediate proximity and availability of Gulf water reduces the transportation cost of water supply and brine disposal, and eliminates any questions as to sufficiency of the supply; (3) the farther offshore the brine outfall diffuser is located, the less the likelihood that significant ecological impacts would take place; (4) an offshore storage facility could be serviced (i.e., unload oil from or load oil on) by VLCCs directly and thereby achieve lower transport costs and perhaps incur smaller risks and impacts of oil spills; (5) areas that already have critically high concentrations of photochemical oxidants at crude oil transfer locations could be avoided; and (6) any land use conflicts that could arise with onshore facilities, including aesthetic degradation, potential interference with recreational or fishery resource usage, and archaeological resource disruption would be eliminated. An offshore site is, however, much more costly to implement, and is a pioneering effort in that no precedence exists and therefore costs for these first attempts (i.e., all offshore storage) are likely to cost even more than any subsequent offshore storage facilities. Because there is no precedence, there is also no reasonable guarantee that offsite storage sites could be developed within the time frame mandated by the legislation. While the risk of spilling oil is perhaps lower than in other scenarios, if oil were spilled during, say, the unloading or loading step at an offshore facility the control and cleanup of the oil would likely be more difficult and/or less effective in the open seas environment. The system would also be more vulnerable to sabotage, and it is very likely a lengthy pipeline to shore will be required in order to provide required distribution flexibility.

An onshore storage site also has advantages: (1) perhaps the most important criterion for a salt dome's suitability as a storage site is the ready access to the far-ranging crude distribution system that connects the petrochemical province of the Gulf Coast with much of the nation; onshore salt domes may be selected that are crossed by or are very near this crude pipeline network and provide multiple options for distribution; (2) a considerable base of experience exists for solution-mining on land and standard engineering practice may be used to implement the program; (3) salt dome development and operation could be achieved with smaller costs and are much more likely to be completed within the time constraints of the program particularly with respect to domes with existing storage space; (4) the geometric configurations of onshore domes is much better known than offshore ones, most of which have been explored only through geophysical mapping; and (5) the need for response to unforseen situations or difficulties may be more easily and immediately recognized, and the response itself is likely not to be as constrained as with offshore domes. Perhaps the largest disadvantage to the use of onshore domes is related to their chiefly coastal location, where the existence of sensitive ecosystems and the proximity of population and industrial centers require careful assessment of primary and secondary impacts associated with developing and operating the system.

After weighing the programmatic goals and many operational and environmental considerations, such as those described above, FEA has decided that onshore domes are superior to offshore domes for the purpose of providing the underground storage facilities for the SPR program. Therefore, FEA is proposing to use only onshore domes.

2. Mines

It is technologically feasible to store substantial volumes of crude oil and/or refined products in either existing mines or new mines that are excavated solely for petroleum storage. Existing mines, particularly those that are abandoned and do not require extensive modification, are prime candidates for participation in the Early Storage Reserve; conversely, the time required for constructing new mines necessitates their consideration as an option only for achieving the ultimate goals of the Strategic Petroleum Reserve program. Several of the candidate sites under consideration for the storage of crude oil are existing mines. They include those in several salt domes in the Gulf Coast region as well as others that are strategically located in other parts of the U.S. FEA is not proposing to construct any new mines during implementation of the SPR. However, if the proposal to satisfy the RPR requirements through centralized storage or crude is modified, FEA would reconsider the storage of liquid petroleum products such as residual fuel oil in new mines in the northeastern U.S.

a. Physical Requirements

As with storage in solution-mined cavities and conventional tankage, a number of requirements and constraints are imposed upon petroleum storage in mined caverns. These are discussed below in the general categories of location, physical characteristics, and safety.

Location

The absolute restriction as to location of suitable rock types is more amply discussed below under Physical Characteristics. An existing or new mine for petroleum storage must be reasonably near appropriate distribution pipelines and port facilities. Such facilities serve as both a supply source under normal conditions and a means of deploying stored oil if the normal supply is severely disrupted. For crude oil storage, the refineries to which the storage facility is linked must have sufficient capacity available to refine the stored crude, either by use of unused excess capacity or by means of in-plant adjustments or by involuntary reduction of their normal supply during a severe supply interruption. The location of any product storage ideally should be in the area of greatest demand for imported refined products or refined products produced from imported oil in order to reduce distribution costs.

An underground location is less susceptible to seismic damage than an aboveground structure in an earthquake. The possibility of facility failure can be essentially eliminated by locating mined storage caverns in zones of seismic quiescense (see Figure IV-7). As with all structures, areas should be avoided which contain active or potentially active faults across which major displacement could occur.

At a more local scale, the individual facilities must be sited so that flooding of access portals by surface-water inflow can be eliminated. The topographic setting must permit reasonable access and have sufficient area for surface facilities (pipelines, pump houses, holding ponds, water treatment facilities, and equipment staging) and for the temporary stockpiling of excavated rock at new mines. Depending on the designed configuration, surface facilities may occupy from ten to several tens of acres of land surface; surface land use is reduced considerably by multi-modular operation and by locating piping and monitoring equipment underground. Conversion of existing mines requires significantly less land use than construction of new mines. Stockpiling may require from 300 to 400 acres of land for a 30 MMB storage facility in a new mine. Conversion of existing mines would require only a few acres, if any, for disposal of the small amounts of waste rock likely to be encountered at a selected site.

Physical Characteristics

A discussion of all considerations involved with the design, construction, and operation of mined storage caverns is not warranted here. However, some basic principles and limiting considerations are very important for assessing environmental impact. These are summarized in this subsection and are based on FEA feasibility studies.

A prime requisite for utilizing any storage cavern is the long-term stability of the excavated void within the rock. Ideally, the rock should have high shear and compressive strength and low geochemical reactivity, and it must be massive (i.e., relatively nonstratified) and unfractured. Departures from the ideal must be expected and can be offset by increase use of artificial roof support, grouting, or reduced gallery size. Existing mines have been identified on the basis of these criteria. For new rock caverns, unweathered crystalline igneous rocks such as granite or diorite-gabbro types, high-grade metamorphic rocks such as granite gneiss or paragneiss, and massive limestone and evaporites appear particularly suitable. Such rock types occur over large areas in many regions of the United States.

Sufficient cover (overburden) is required to insure that the mechanical stability of the roof may be maintained at reasonable cost. Stability is a function of the in-situ state of stress in the rock, which is very site-specific, as well as the dimensions of the underground chambers and the mechanical properties of the rock. A conservative, general guideline is 180 feet of cover for a cavern span of 60 feet within a rock mass. An existing mine has an added advantage of permitting observation of its structural performance prior to commitment for storage purposes. Existing mines selcted for the storage reserve therefore will have been carefully screened for geo-mechanical stability.

The geometry of storage caverns newly constructed for storage purposes will reflect the mechanical properties of the rock type, the storage volume required, and existing technology for economical construction. Generally, vertically-sided caverns are envisaged, with dimensions of 90 to 100 feet high, 600 to 1000 feet long, and a span of 50 to 75 feet; each of these caverns would permit storage of between 1 and 1.5 MMB of petroleum. A storage facility would likely be a series of such caverns, and its configuration, operation, and associated equipment are discussed below in Facility Descriptions.

The most desirable and least expensive geometry will generally by simple geometrical configurations, such as room-and-pillar developments draining towards a common pump shaft. Other configurations, such as adit mining, sublevel stoping, and shrinkage stoping, may require extensive modification, additional mining, or bulkheading if maximum use of the excavated space for oil storage is to be made. Consequently, these have been avoided. For both new and existing mines, the basic consideration with respect to mine geometry is the recoverability of essentially all oil in storage with the minimum number of pump locations.

Two chief methods of containing the oil in storage in mined caverns are available to the storage program. One of these is emplacement within a virtually impermeable host rock. Rock salt is probably the only abundant geologic material that approximates impermeability in large masses (Section III.B.1), so mines in salt have excellent potential for strategic storage. The other means by which containment is achieved accepts and utilizes the fact that in rock material other than salt, some secondary permeability exists; by maintaining hydrostatic pressures in the host rock greater than the internal pressure of petroleum in storage, outflow of hydrocarbons is prevented. This containment scheme may use either natural or artificial hydraulic gradients to provide containment, but must provide for seepage of ground water into the storage cavity and subsequent removal. For a 30 MMB storage facility, tolerated water inflows may be on the order of 100 gallons per minute. The removal and treatment of this water during conversion/construction and operation is expensive, and consequently rocks of low primary (interconnected pores) and secondary (interconnected fractures) permeability are desirable if not required. Some grouting of larger fractures will probably be required in conversion or construction of storage caverns in any rock type, not necessarily to prevent product outflow but to reduce the in-seepage of water that accompanies containment. All mines will be selected or designed to achieve sufficient natural hydraulic pressure for containment at the storage depth. The maximum depth is determined largely by economic considerations, viz., the increased cost of constructing shafts and other accesses to the caverns and any adjacent or superjacent galleries, and also the higher pumping (operational) costs due to larger lifts. Generally, anticipated depths of mines for petroleum storage in the proposed program are less than 500 feet for new mines and between 300 and 1400 feet for those existing mines under consideration.

Manpower Requirements

A relatively large work force would be required to construct a new 30 MMB mine storage facility. The actual number is quite sensitive to site characteristics and the time frame in which construction must take place. An initial estimate of 400 personnel, primarily semi-skilled or skilled workers and support personnel, appears reasonable as a first-order approximatation. It is assumed that most of this work force would be available from the populous East Coast region, but not necessarily locally.

The personnel requirements for converting an existing mine to a petroleum storage facility are even more site-specific but generally much smaller. A probable order of magnitude is 100 personnel, generally not as highly skilled as the new cavern construction and consequently more local in overall aspect.

b. Facility Descriptions

The following descriptions relate to two hypothetical storage facilities of 30 MMB each, one an existing mine converted for crude storage, and the other a new mined rock cavern facility for storing residual fuel oil. The purpose of this section is to demonstrate typical features of such facilities; actual storage facilities may be expected to differ to some degree depending primarily on site-specific factors.

Conversion of Existing Mines

The conversion of existing mines to petroleum storage facilities generally will include the excavation of pump sumps, equipment shaft(s), and vents and the construction of curbs and bulkheads, surface pumping stations, wellheads, off-site (only) surge tankage, and pipelines. Some modifications will probably be required or desired for some mines. These include breaching of proximal galleries, floor channeling, additional roof bolting at critical points, grouting of water-bearing fractures or solution channels, and removal of rock falls. The selection of a mine site for such conversion considers and minimizes the need for such modifications.

Other features and components of such a facility will be more or less similar to a new mined cavern, as described below. However, underground storage of crude oil requires that the storage space be able to accommodate the sludge that precipitates from stored crude without interference with oil removal devices (SK-034). Generally the sludge is allowed to accumulate on the floor between widely separated inlet and outlet pipes, or provision is made for raising the oil pumps as sludge levels rise. Although the conversion design generally will permit installation and operation of sludge sumps, the removal of sludge from the mines is not envisioned, and therefore no related solid-waste disposal problems will ensue.

The relative volatility of crude oil requires that special precautions be taken if a vapor space exists within the mine. Light oil fractions will evolve at atmospheric pressure and may exert pressures of one to three atmospheres that must be accounted for by appropriate design (SK-034). During filling the air in the mine is allowed to escape to the atmosphere until the vapor phase begins to build, at which point the vent is closed and the vapor pressure is allowed to increase until a pressure of one-three atmospheres is reached and the vapor space is supersaturated. At this point the pressure is maintained by controlled venting. The vented vapors may be disposed of in one of two ways. As one alternative, a temporary flare system can be used to eliminate vapor emissions. In the second alternative, the vented vapors may be directed through a condensation unit on the surface and the condensed liquid is returned to the storage cavern. The supersaturation of the vapor phase is maintained during storage. During withdrawal the vapor pressure is monitored until it approaches one atmosphere, at which point an inert gas (e.g., nitrogen) is injected, precluding any oxygen buildup. Vapor pressures are closely monitored at all times, and the system is designed so that shutdown will occur in the case of component failure, thus preventing the buildup of an explosive condition.

As in the new rock caverns discussed below, pump-out techniques will be utilized for cycling, rather than the fluid displacement method required for solution cavity storage. The pump-out techniques are relatively simple in design, have small surface area requirements, and are economic at the moderate depths of those existing mines under consideration. Except for mines in salt, all existing mines must provide a seepage water collection and removal system. This system will be analogous to fixed-bed systems described in the following section.

In some existing mines, continuation of mining operations with relocation of existing mining activities to nearby (but physically unconnected) areas may be required. Special compensations for these situations, such as construction of extra access shafts and of transport facilities may be a prerequisite. Safety considerations generally will dictate more extensive monitoring of the potential for explosive atmosphere as well as increased ventilation. FEA has established formal contact with the Mine Enforcement and Safety Administration (MESA) regarding proximal oil storage and mining production. FEA will be guided by applicable existing MESA legislation and by recommendations received from MESA pursuant to its ongoing investigation.

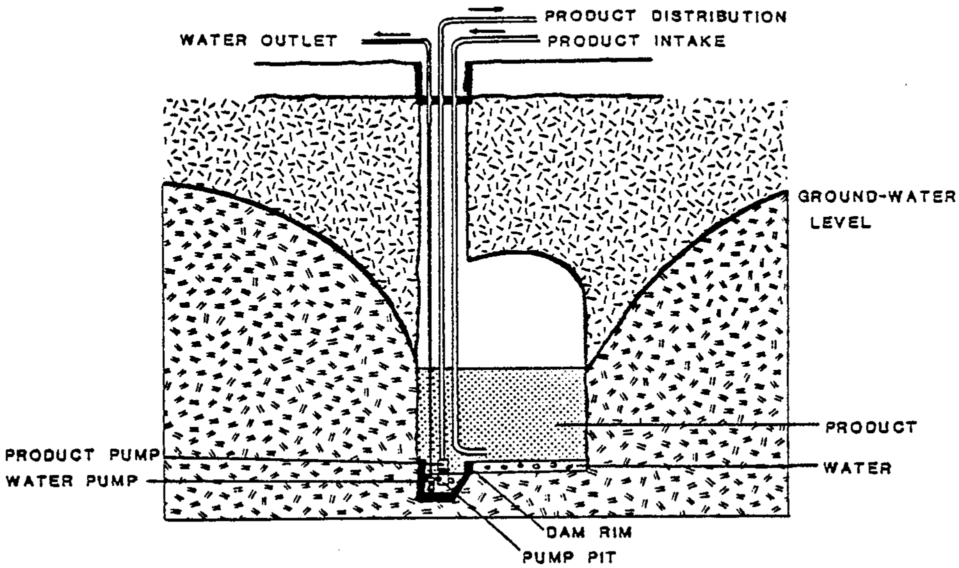
Construction of New Rock Caverns

The utilization of mined rock caverns for petroleum product storage includes on-site storage and support (including heat transfer) facilities, off-site transport facilities, and waste rock disposal. Each of these component subsystems is characterized in the paragraphs that follow.

Within an individual storage cavern, either a fixed or mobile water-bed system may be used (SK-034), as illustrated diagrammatically in Figure III-8. The mobile water-bed which maintains the cavern full of liquid at all times, requires that large volumes of water be available and able to be treated and is more costly and complicated to operate. Current practice is to use the fixed water-bed system, in which a cushion of water (perhaps two to three feet deep) is maintained, with the product floating on this cushion. In this method, seepage inflow is continuously pumped out, and a vapor space exists that is variable inversely with the amount of product in storage (Figures III-8 and III-9).

To achieve the required volumes of storage, a number of similar individual caverns are required. As noted in a previous section, the volume of a single cavern is on the order of 1 to 1.5 MMB. It is, of course, possible for each of these to be operated separately, but whenever possible, they are usually operated conjunctively, either by cavern interconnections or by manifolding beyond the caverns. It may be desirable however, to provide for individual operation to permit storage of different petroleum products.

A typical module for a fixed water-bed system that permits such flexibility is shown schematically in plan and elevation views in Figure III-10. Storage of 30 MMB, for example, could be achieved by six replicates of such an installation, with the cavern dimensions given previously. The length of the cavern is chosen to give the required volume for each cavern,



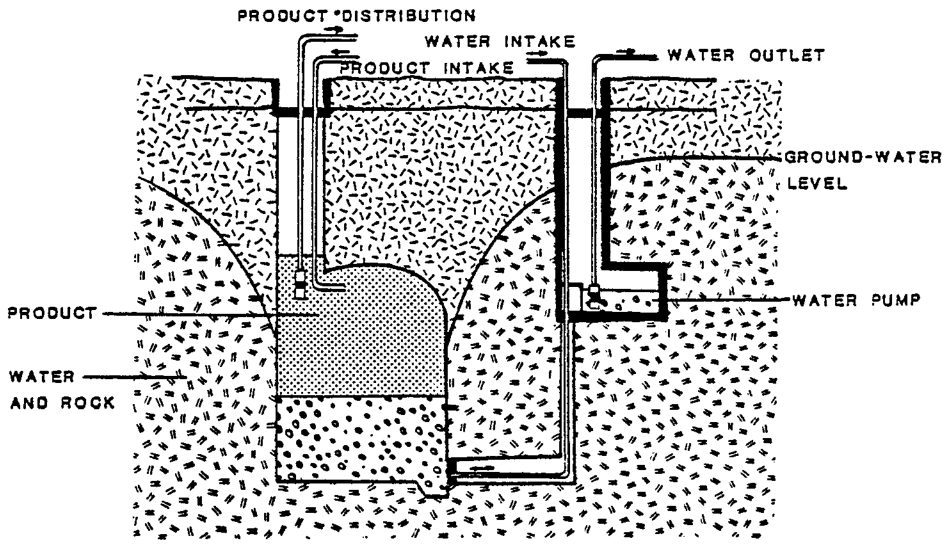


FIGURE III-8

OPERATIONAL ALTERNATIVES FOR ROCK CAVERNS

(Above) Fixed Water-bed System,
(Below) Mobile Water-bed System

(After SK-034)

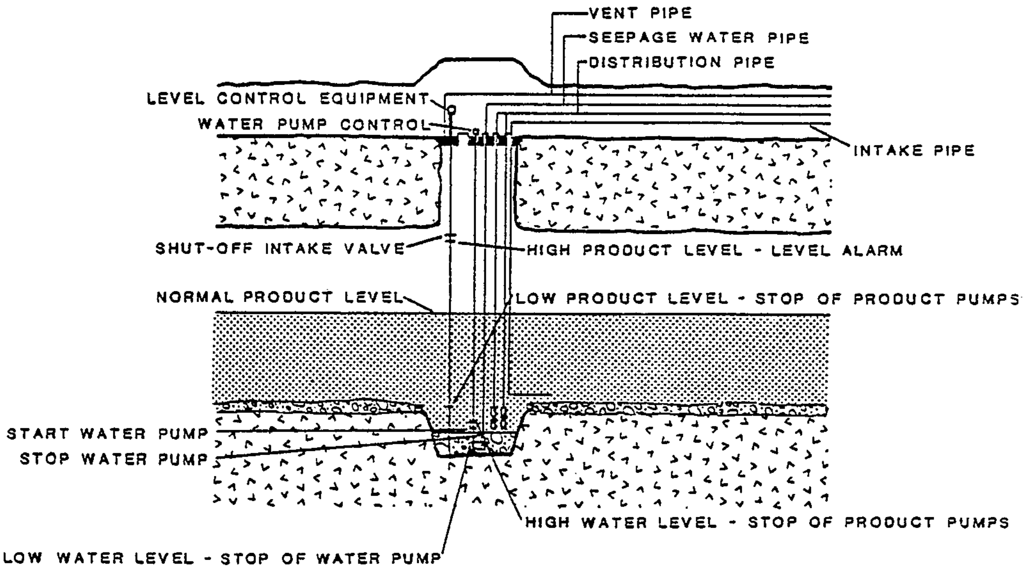


FIGURE III-9
DETAIL ALONG LONGITUDINAL SECTION OF A ROCK CAVERN

(After SK-034)

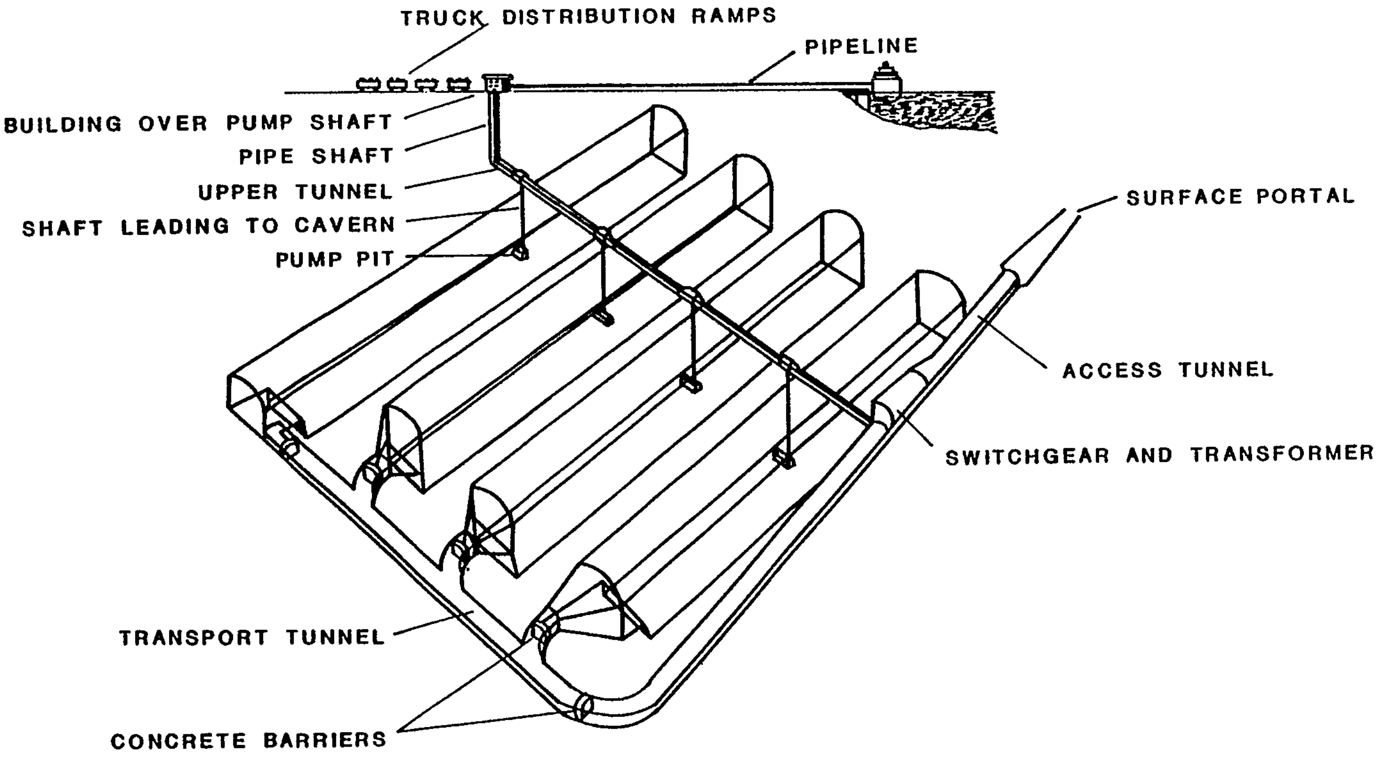


FIGURE III-10

SCHEMATIC VIEW OF A FOUR-GALLERY STORAGE MODULE while the _in situ_ state of stress, overburden thickness, and rock quality dictate maximum spans and gallery heights.

It should be noted that the upper tunnel shown in Figure III-10 is a convenient but optional feature connected the surface by a shaft and/or the transport tunnel. If the upper tunnel is omitted, then each cavern (or set of interconnected caverns draining to a common pit or sump) is in direct contact with the surface via lengthened cavern pump shafts. This would also be the usual configuration in converting an existing mine. Increased land use (about 2 acres per cavern) and surface disruption by pipelines and manifolds are necessary consequences of this option, while double-tier land use (i.e., surface use unencumbered by the storage facility) is encouraged through usage of the intermediate-level equipment tunnel.

When the blasting required for excavation is completed and the pump pit (Figure III-10) is constructed, the access tunnel, through which all blasted rock is removed, is sealed off. The upper ends of the pump shafts are covered by a concrete deck in which are cast apertures for filling pipe, vent pipe, product pump(s), seepage water pump, manhole, and the necessary fluid-level control and other sensors. The shaft(s) to the surface are usually covered with a simple building that houses switchgear, control panels, oil-water separators and other water treatment facilities, and heating equipment. Compressors may be located either above or below ground (SK-034).

For very viscous products such as residual oil it is generally necessary to heat the oil in order for it to be pumped economically. This heating is usually accomplished indirectly, by passing water from the pump pit through a heat exchanger, probably a gas- or oil-fired boiler, and circulating that water through the oil by density difference, such that it returns to the pump pit while distributing its heat throughout the cavern. Geologic media provide very effective insulators, and once thermal equilibrium with the surrounding rock is achieved the maintenance of elevated temperatures requires only small amounts of energy; however, large amounts of seepage can offset this benefit by the discharge of heat along with the seepage water.

Another option for heating the residual oil is circulating the oil directly through a heat exchanger (SK-034). Subsequently the heated oil must be distributed so that satisfactory circulation is achieved. Owing to these more complicated distribution requirements, direct oil heating is not likely, unless the product must be circulated for other reasons related to its quality.

Each cavern and each integrally operated module will have its own monitoring system for both inventory and operational control. Typical parameters that are likely to be monitored are storage vapor pressure, petroleum level in the cavern, water levels in the water cushion and/or in the pump sump, inflow rates (via pump discharge), bulkhead internal pressures, and periodically, seepage quality. These monitors may be easily integrated into an automatic operator with remote, real-time control involving a minimal number of operations personnel. In addition, the local hydrogeologic environment around the storage caverns will be monitored by piezometers before and during cavern operation. This ambient monitoring provides a positive indication of containment effectiveness, i.e., against possible contamination of ground waters. In addition, potentially dangerous trends in ground-water levels can be delineated and appropriate preventive action initiated, e.g., such levels can be increased by artificial recharge through wells or water-filled galleries.

As with any other method of storage, mines will require integration into a distribution network. For residual oil, both truck transport from a terminal on-site and tanker transport from nearby port facilities, connected to the storage location by pipeline, are considered feasible. Insulation of the pipe may be required if residual oil is to be pumped over distances greater than a few miles. Construction of the pipeline is probably the most severe off-site surface disruption likely to be engendered by the mined cavern storage facility. For a new mined cavern storing a product other than heavy fuel oils, about two days' volume at the design discharge rate can be stored in surge tankage at the connection with a distribution pipeline. No on-site surge tankage is anticipated.

A consideration that is unique to new mined caverns for petroleum storage is the disposal of the waste rock excavated from the storage space. About 5500 acre-feet of surface storage would be required for an aggregate 30 million barrel facility in crystalline rock.

For mined caverns in crystalline rock, the excavated material will likely be of high quality and marketable. Its value will depend upon local factors and on-going construction activities, and the excavated rock may be placed in competition with other sources of aggregate or other construction material. The possibility of significantly reducing the volume requiring ultimate disposal by land fill and simultaneously offsetting the cost of excavation must be addressed at a site-specific level, as must the potential consequences of such action, e.g., depressing the local market. Nonetheless, it seems likely that a substantial volume of rock must be stockpiled at least temporarily on or near the storage site. Landfilling, especially "head-of-hollow fills" in hilly terrain, is a probable means of disposal of the waste rock. Transport is likely to be by diesel or electric-powered trucks and/or by belt conveyors. Transport is a significant economic consideration particularly in hilly or mountainous terrain.

Treatment/Disposal of Seepage

Characteristics of seepage water removed from existing and new mines after storage has commenced will be similar to those of wastewater emanating from oil refineries. Significant concentrations of suspended solids, dissolved solids, oil, biodegradable organics, and other oxygen demanding materials can be anticipated. Moreover, by commingling with stored petroleum, the seepage water may also contain phenols, cresols, and similar organic compounds that are persistent in the environment. Up to 5 percent water in the oil that is discharged from storage may also undergo treatment.

The various pollutants which contaminate this water must be removed if the effluent is to be environmentally acceptable. Several options are available for treatment which include the use of existing refinery wastewater treatment facilities, municipal wastewater treatment facilities in cases where such facilities are designed to accommodate this type of effluent, and on-site package treatment facilities. Another possibility which does not include treatment is to dispose of this water by deep well injection.

Existing refinery wastewater treatment facilities may offer the best alternative of the three treatment options considered. These treatment facilities are located at the refinery site and may be easily accessed from the storage facilities. Additionally, these treatment facilities are designed specifically to treat wastewaters with similar characteristics.

The relatively low flows expected from the mine dewatering operations will not significantly increase the loading on the existing refinery wastewater treatment facilities and no problems are anticipated.

The use of municipal wastewater treatment facilities may also provide an acceptable alternative for treatment of effluents from mine dewatering operations provided such facilities are located in the near vicinity of the storage mine and are easily accessible. The specific unit processes available at the municipal facility will determine the level of treatment that can be achieved. Municipal wastewater treatment plants are not generally designed to treat wastewaters of this nature, and treatment may result more from dilution of the wastewater stream rather than through removal of pollutants. However, most municipal facilities can treat small concentrations of oily wastewater which appear in street and parking lot runoff, and the relatively low volumes of water expected from the mine dewatering operations should not pose any significant problems.

If neither an existing refinery wastewater treatment facility nor a suitable municipal wastewater treatment facility is available, a small package treatment facility might be considered. Such a facility must be capable of oil and water separation and BOD, suspended solids, and organic material removal.

It should be emphasized that a sufficient quantity of water must be treated to economically justify the employment of an on-site package treatment facility. The first two options discussed, i.e., the use of existing refinery wastewater treatment facilities or existing municipal wastewater treatment facilities, should be given primary consideration. However, if such facilities are unavailable or are too difficult to access, on-site facilities can be provided to produce an acceptable effluent.

If an on-site package treatment facility is used, the storage facility will generate another solid waste stream from the solids associated with the physical separation and aeration processes. The solid rates are likely to be very low, and their ultimate disposal will probably be by nearby existing landfill on a contractual basis.

Another option that may be employed at suitable locations is deep-well disposal of seepage water and water produced with the oil. This option is the subject of a more detailed discussion in Section V.B.2 with respect to disposal of brine from solution mining of salt. If existing mines in salt domes of the Gulf Coast region are converted to petroleum storage, the small inflows of briny character that currently exist at some locations may be best accommodated by deep-well injection rather than treatment. It should be recognized that deep-well injection in areas of crystalline rock has severe physical limitations and is probably not a viable option in such geologic terrain.

Beyond the well-disposal considerations in Section V.B.2, injection of seepage inflows or water separated from oil has two potential problem areas that may restrict its usefulness. Both of these relate to the long-term performance of the injection zone: any oil that is injected will tend to clog the void space around the injection well, and any dissolved air or suspended solids from the oil-water separation step may similarly plug the injection zone. Pretreatment may be necessary to overcome these and similar problems at specific sites (SA-218).

3. Tankage

Aboveground tankage is another alternative method for storing petroleum products for the Strategic Petroleum Storage Program. In parts of the East Coast area where suitable formations are not available for subsurface storage, aboveground tankage is the most convenient method of product storage. In the event that the FEA proposal to have only centralized underground storage of crude oil is modified, it is likely that storage tank facilities may be required.

a. Physical Requirements

Tanks

Tanks used by the petroleum industry range in size from several thousand barrels to over one million barrels. Tank heights normally range from fifteen feet to fifty-six feet although most large capacity tank heights fall in the range of forty to forty-eight feet. Standard tank diameters range from fifteen feet up to three hundred feet (BL-078).

Although storage tanks may be constructed in a wide variety of sizes, most storage tanks adhere to American Petroleum Institute (API) and ASME construction codes. These codes include specifications on materials, construction methods, and soil conditions. For average soils, the maximum bearing load is 3000 pounds per square foot, which corresponds to a tank height of forty-eight feet for distillate oil storage and forty-six feet for residual oil storage.

The effective working height of a tank is several feet less than the tank wall height. The top three to five feet of a floating roof tank is taken up by the height of the floating roof and sealing ring. Space is also reserved in the top of storage tanks for foam delivery equipment. In addition, storage tanks have a minimum liquid level termed "minimum working level" below which liquid cannot be withdrawn without causing vortex problems. The minimum working level is normally two feet above the tank nozzle.

There are four basic types of storage tanks used by the petroleum industry for crude and petroleum product storage: fixed roof, floating roof and internal floating covers, variable vapor space, and pressure.

The fixed roof tank is a cylindrical steel tank with a conical steel roof (Figure III-11). Today, fixed roof tanks are normally equipped with pressure/vacuum valves set at several inches of water to contain minor vapor volume changes.

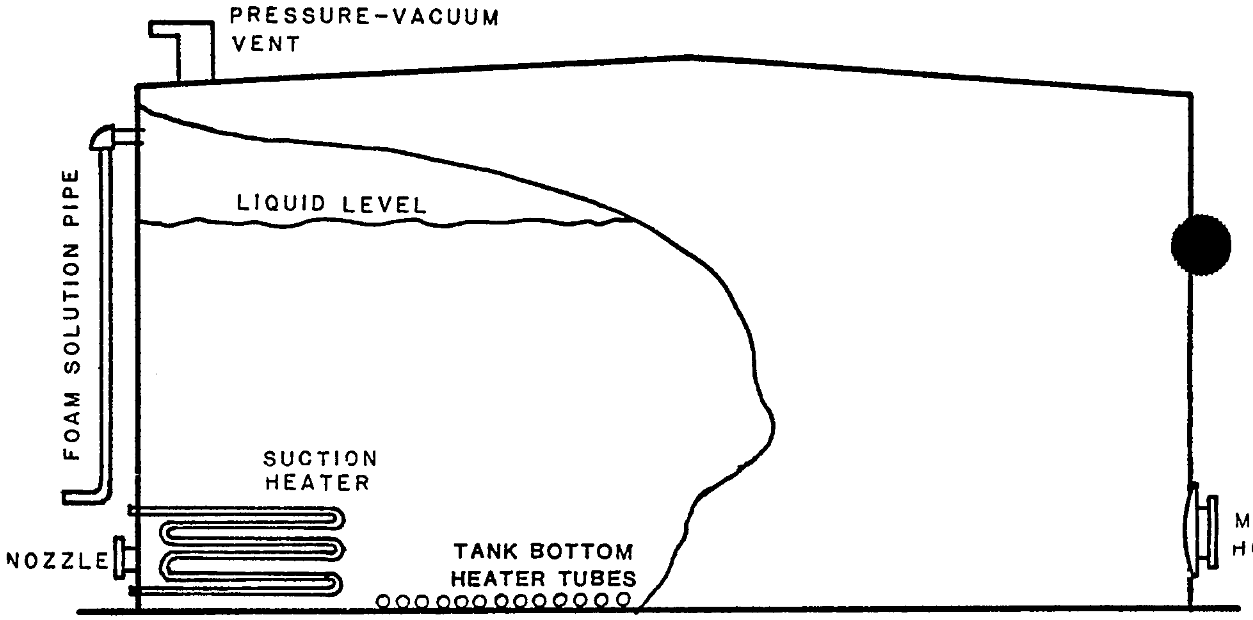


FIGURE III-11
STANDARD FIXED ROOF TANK

Floating roof tanks are cylindrical steel tanks similar to fixed roof tanks. However, instead of a fixed roof, they are equipped with a sliding roof, designed to float on the surface of the product. A sliding seal attached to the roof seals the annular space between the roof and vessel wall and prevents product evaporation. Floating roof tanks eliminate the vapor space of fixed roof tanks.

Internal floating covers are a modification of floatign roofs designed to circumvent the buoyancy problems caused by snow and rain accumulation on the floating roofs. They are essentially fixed roof tanks equipped with an internal floating cover similar to a floating roof. Internal floating covers utilize sliding seals to seal the annular space between the cover and the vessel wall.

There are two basic types of variable vapor space tanks. The lifter roof tank has a telescopic roof, free to travel up and down as the vapor space expands and contracts. A second type of variable vapor space tank is the diaphragm tank equipped with an internal flexible diaphragm to accommodate vapor volume changes.

Floating roof tanks, internal floating covers, and variable vapor space tanks are used for the storage of petroleum products where contact with the atmosphere is not desirable because of the product degradation, product loss, or excessive emissions.

Pressure tanks are completely sealed tanks which store products at pressures ranging from slightly above atmospheric pressure to 200 psig. These tanks are constructed in a wide variety of shapes, cylindrical, spheroid, and hemispheroid. Normally, pressure tanks are used to store highly volatile products. The true vapor pressure of petroleum products stored in pressure tanks is normally greater than 11 psia.

For proper operation and safety, each storage tank is equipped with product nozzles situated around the periphery, attached foam nozzles, manholes, vortex brakers, valves, water condensate drains, pressure/vacuum valves on roof, meters and gages, ladders, flame arrestors, rectangular clean-outs, suction heaters, and tank bottom heaters (AM-041, BL-078).

Siting Requirements

A considerable quantity of land is required for an aboveground tankage facility. Items requiring land area include tanks, maintenance and control facilities, roads, piping, dikes, fire-fighting equipment, pumping stations and steam generating units.

The largest portion of the land required for a tankage facility is occupied by the tanks and their diked area. As a safety precaution against leaks, each tank in a large petroleum storage facility is enclosed in a diked area of sufficient volume to retain the contents of the tank. Access roads for fire-fighting equipment are normally supplied on two sides of each tank.

As an added safety precaution, petroleum tankage facility components are widely spaced. Petroleum tankage is estimated to occupy fourteen to twenty acres per million barrels of storage capacity (VA-117).

Ideally the petroleum storage facility should be located near existing residual oil distribution systems and designed so that the stored petroleum can be fed in the current distribution systems with minimal disruption of normal activities. The bulk of the residual oil used on the East Coast is brought in by tanker to a marine terminal located within six miles of the point of consumption. Residual oil is pumped in heated lines from the terminal to the customer. There are numerous marine terminals along the East Coast. Residual oil consumers located significant distances from the coast receive their fuel oil from marine terminals by rail tank cars and by tank trucks. Design of petroleum storage facilities to interface with existing transportation facilities, expedite the distribution of petroleum products, and minimize the cost of handling is an essential consideration.

Resource Requirements

The estimated steel plate requirements for construction of large petroleum storage tanks alone is 4300 tons of steel plate per million barrels of storage capacity. The total steel requirement for construction of a complete petroleum storage facility is 8.5 to 9 pounds of steel per barrel of storage capacity (NA-261).

The availability of large amounts of steel plate in the United States is very dependent on the economy. Currently, there is an excess in steel plate manufacturing capacity. However, no new steel mills have been brought onstream recently and an economic boom would deplete this excess capacity (VA-117).

b. Facility Description

Tanks

Fixed roof storage tanks were selected for application in the tankage module. Fixed roof storage tanks are the least expensive form of aboveground petroleum storage, and they represent the worst case environmentally because they emit hydrocarbon vapors at a higher rate than any of the other three types described. In addition to cost, another advantage of fixed roof tanks over other forms of tankage is their ability to withstand adverse weather conditions. Heavy snow and rain loads can create buoyancy problems with floating roof tanks. During cold weather withdrawals viscous residual oil adheres to tank walls, impeding the movement of floating roofs. Extensive roof and seal damage generally results when this phenomenon occurs. Fixed roof tanks also present the advantages of easy accessibility and cleaning. Residual fuel oil is very dirty and the tankage in the module may require cleaning during tank outages.

The net tankage module capacity of ten million barrels is achieved by twenty 500,000 barrel storage tanks. New and better heat-treated steels make tanks of this size very economical. The tank dimensions are 290 feet in diameter by 48 feet in height. Of the 48 feet height, only 43 feet compose the working space of the tank. For fire and safety considerations the storage capacity of the fixed roof tank is reduced by the volume in the upper three feet (VA-117) and the lower two feet.

Site Requirements

Figure III-12 presents a plot plan of the tankage module. Each tank is located within an individual diked area sized to retain the entire tank volume in the event of a product spill. These earthen dikes are six feet tall and constructed with a 50 percent slope. Each diked area is 690 feet by 690 feet square. Service roads and pipeline lanes are provided between the tank rows. Operating buildings, maintenance shops, pumping stations, foam generating facilities, steam generators, and wastewater storage are located well away from the tankage

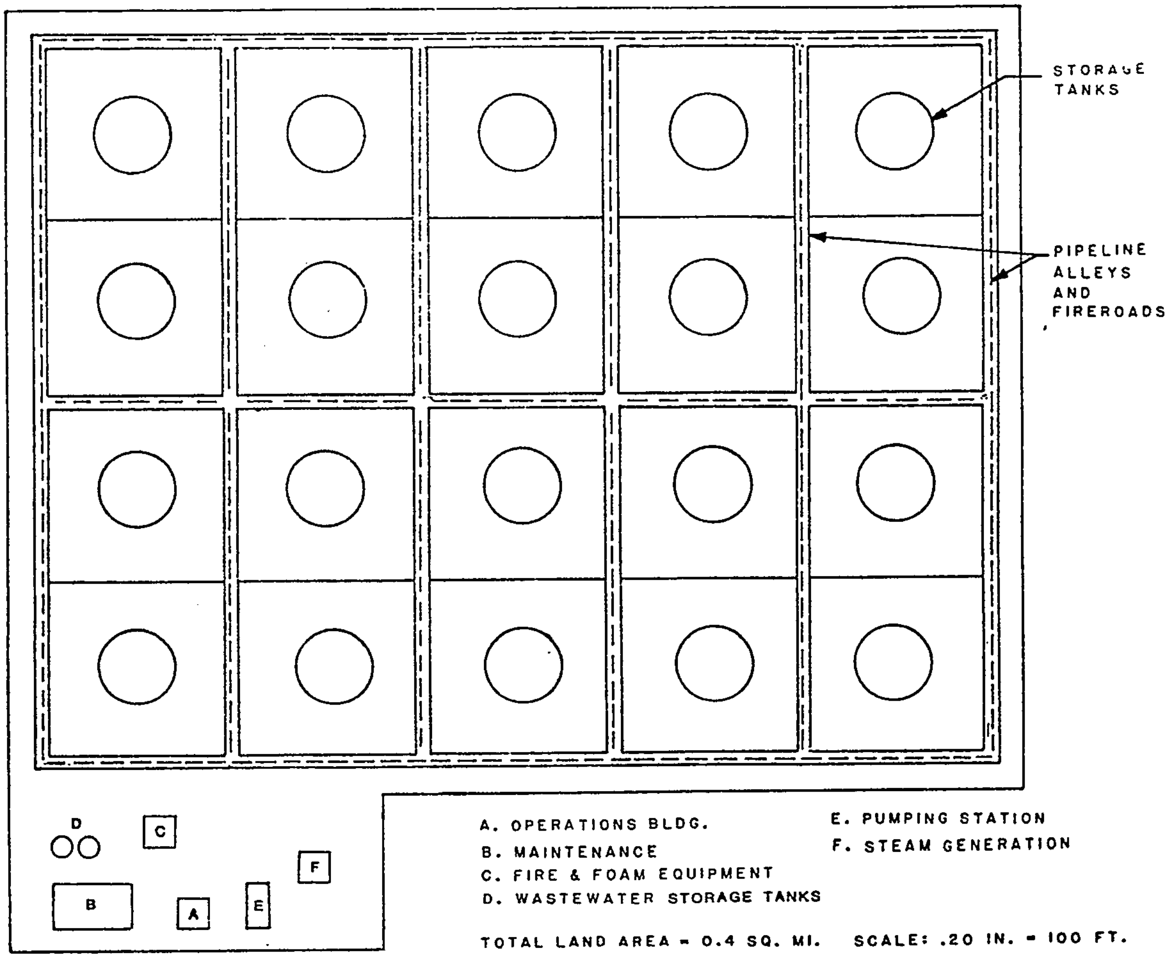


FIGURE III-12
TANKAGE MODULE PLOT PLAN

as a safety precaution. The total land area required for the tankage module is 0.4 square miles.

Each tank in the tankage module is manifolded into a piping netowrk leading to the pumping station. The valving used in the piping network is arranged such that any two tanks can be drained or filled simultaneously. To cope with stratification, the tanks are also valved such that product from the bottom of the tank can be recycled to the top of the tank for mixing purposes. Network piping is steam traced, sized for flow rates of 5000 barrels per hour, and on the order of eighteen inches in diameter. The pumping station is equipped with two 600 horsepower pumps, each capable of pumping 5000 barrels per hour of fuel oil. A twenty-six inch steam traced pipeline connects the tankage module to a marine terminal facility less than five miles away.

Generally, a tankage module will require some form of water disposal system. Contaminated water is generated by two sources in a residual oil storage facility; tankage condensate and rain water runoff. Tankage condensate is water which collects in the bottom of storage tanks. This condensate is primarily attributable to moisture in the tank vapor space condensing on tank walls and collecting in the tank bottom. Rain water may enter the storage tanks from roof leaks. Small amounts of water are also present in residual oils as they arrive from the refinery. In unstable fuel oils, water may form as a by-product of polymerization reactions. Water drained from storage tanks gnerally contains hydrocarbons, organics, suspended solids, trace elements, and small quantities of fuel oil additives.

A second source of wastewater from a fuel oil storage facility is rain water which collects within the diked areas. This water may be contaminated with leaked and spilled oil in addition to silt and sediments. The rainwater is retained within the diked area either to be absorbed into the ground or evaporated.

The water which collects in the bottom of storage tanks is drained regularly into a closed gathering system connected to a wastewater storage facility. The volume of tankage condensate is expected to be small and easily managed by periodic delivery to a waste disposal company.

Auxiliary Equipment

In addition to the tankage, a petroleum storage facility will require auxiliary equipment to provide necessary support functions. Operations buildings must be provided to house control rooms, guard stations, small test laboratories, maintenance shop, and spare equipment storage. A pumping station must be provided with accompanying piping networks for individually filling and draining each tank in the storage facility. Boilers are also needed to supply heating steam to the residual oil storage tank heaters and to the steam traced pipelines.

The flammability of fuel oils requires that safety systems be installed on fuel oil storage facilities. The two most common types of safety systems are foam systems and fire water.

Manpower Requirements

During the construction phase of the tankage module, a labor force of eighty to one hundred persons will be required. Site work, foundations, and piping will require thirty to forty persons from a broad range of trades. There will also be three tank construction crews of fifteen to twenty persons each on-site.

Subsequent to construction and filling operations, there are several ongoing operations required to maintain the fuel oil storage facility in a proper state of preparedness. These are residual turnover, wastewater treatment and routine maintenance. The tankage module is designed to operate with a small number of employees. A permanent staff of twelve to fifteen people will be required to perform continuous security and inspection duties. Because of the nature of these duties, a storage site consisting of two or three tankage modules will only require a few additional personnel. Tankage emptying, tankage condensate draining, and major maintenance projects can be conducted by mobile maintenance crews employing on the order of ten people. These mobile crews will service several tankage modules on a regular rotating basis.

Schedule

Estimates of the time ranges required to construct a tankage module are presented in Table III-7. The construction schedule is presented in Figure III-13 and was generated based on data of Table III-7. An estimated six months are required to complete preliminary designs and initiate environmental impact studies. An additional eighteen months are required for completing the module design, completing environmental impact studies, and for obtaining all necessary permits. At the end of two years, site work and foundation preparation are initiated. After an estimated six months, tank construction crews can begin tank assembly. Employing three construction crews will allow the completion of three 500,000 barrel storage tanks every six months. The ten million barrel storage module will be completed six and on-half years after program initiation.

It is conceivable that preliminary design work, detailed engineering design work, environmental studies, and permit approvals can be obtained under an accelerated program in twelve to eighteen months. Site preparation and tankage construction can possibly be accelerated to require twelve months collectively. Therefore, with a concerted effort,

TABLE III-7

TIME REQUIREMENTS FOR STORAGE FACILITY CONSTRUCTION

PHASE	TIME PERIOD (years)
Preliminary engineering design and Preliminary EIS	0.25 to 0.5
Detailed EIS and permit acquisition	0.5 to 1.5
Initial site work and foundation preparation	0.5
Completion of first tank	1.0 to 1.5
TOTAL	2.25 to 4.0

Sources: NA-261, VA-117

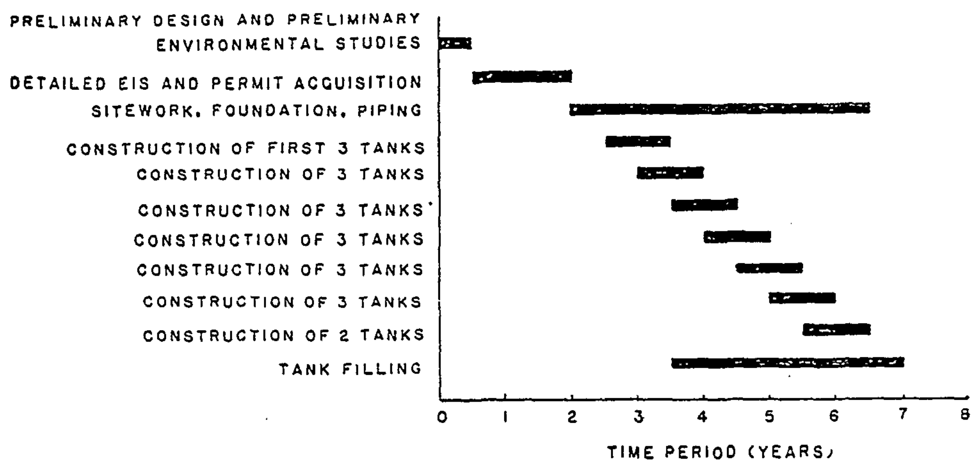


FIGURE III-13

CONSTRUCTION SCHEDULE

initial tankage may be completed for storage within two to two and one-half years after project initiation.

Filling operations can begin three and one-half years after program initiation. The total tankage capacity of ten million barrels can be filled within seven years after program initiation.

In the event that the stored residual fuel oil is needed, the storage tanks are emptied in the reverse manner that they are filled. Steam from a generator is supplied to the bottom heaters and suction heaters of the storage tanks to be emptied. The time required to melt the nearly solid residual oil is dependent on the physical properties of the particular residual oil and its bulk storage temperature, however, it is estimated that flow can be initiated in less than one week. The heated fuel oil is pumped from two tanks simultaneously by the two six-hundred horsepower pumps and transported through the twenty-six inch pipeline to the distribution system. The time required to empty two of the 500,000 barrel storage tanks is slightly over four days.

4. Tankers

Another storage method considered, but not proposed, for use by the SPR is laid-up tankers. At an early point in the development of the program, tankers were identified as a potential temporary means of achieving the goals of the ESR. Because of the recent world decline in petroleum consumption, a significant number of tankers have been laid-up due to lack of a charter. Included in this laid-up tanker fleet are ships of the supertanker class as well as a variety of smaller ships. The feasibility of using this laid-up tanker fleet for petroleum storage will depend upon several factors, including (1) the willingness of tanker owners to sell or lease their laid-up tankers for a period of up to three years, (2) the cost of procuring the needed storage capacity, and (3) the environmental impact of storing petroleum in tankers. The following sections discuss the above considerations.

a. Tanker Availability

The first question which must be answered before laid-up tankers can be considered as a means of storage is how much laid-up tanker capacity is available. Moreover, the sizes and condition of these laid-up tankers must also be ascertained. As of November 1, 1976, there were 403 laid-up tankers with a total tonnage of 37,340,000 dead weight tons (DWT); most of these are foreign flag vessels (AS-050). Since one DWT provides about seven barrels of petroleum capacity, these vessels could concievably store about 261 MMB of petroleum. This large amount of excess tanker capacity is expected to continue until at least 1985. Therefore, it appears that the use of laid-up tankers for short-term petroleum storage is feasible from an availability viewpoint.

In addition to the laid-up tankers of the world fleet, the United States Navy has a moth-balled reserve fleet. These ships are under control of the Maritime Administration (MARAD) and have been reported to have a storage capacity of 2.5 MMB. However, most of these ships have been stripped of much of their internal equipment and because of their age (World War II and earlier vintage) may require substantial refurbishing prior to their use for storage purposes.

b. Implementation of Storage

In order to implement tanker storage, several factors must be considered. Tanker owners willing to sell their vessels or allow their vessels to be used for up to three years must be found and lease contracts negotiated. Anchorage sites capable of handling the size and number of tankers anticipated must be selected. The amount of preparation work required to ready the laid-up vessels for storage must be evaluated.

The above considerations are for the most part different for each tanker. Since this study is on a programmatic level, definitive statements are not made concerning exactly what must be done to implement tanker storage. Therefore, the following sections are discussions of the major considerations which are anticipated to be pertinent to tanker storage in general. Any or all of the factors discussed could apply to each vessel considered for storage use.

Selection of Anchorage Sites

The selection of harbors in which to anchor the tankers requires consideration of more than the harbor depth or maximum ship size that can be accommodated. Water space that does not block or endanger navigable waters must be available. Since the anchoring of loaded tankers for a long period of time is a new concept, studies which are specific to each harbor will have to be performed to determine the best arrangement for multiple vessel anchorages. Considerations such as tides, winds, proximity to navigable water and harbor bottom characteristics would need to be examined in these studies.

Auxiliary Requirements

The condition of laid-up tankers is specific to each tanker. Some of these vessels are old and will require repair prior to use while others have had a portion of their equipment removed to provide replacement parts of other vessels. Most vessels also are winterized prior to lay-up. This operation includes coating internal equipment with a protective substance designed to retard rusting and corrosion. Therefore, in order to use laid-up tankers for strategic storage purposes, some equipment additions, modifications and/or cleaning may have to be performed. This preparation work will depend upon the method employed to moor or anchor the tankers during the storage program as well as the present condition of the tankers.

Conversations with the United States Coast Guard and MARAD indicate the cost of maintaining an anchored tanker in sailing readiness is substantial. Therefore, for the purpose of this study, it is assumed that the tankers used for storage will not be kept ready for sailing. Small transfer or ferry vessels will be employed to load and unload petroleum from the storage vessels.

While the amount of preparation work required to ready a laid-up tanker for storage purposes is dependent upon the specific vessel, the following list details some of the major steps that could be required to prepare a tanker for storage.

1. The vessel's tanks would have to be cleaned to prevent contamination of the stored crude oil by any residual cargo or water. The bilges should be cleaned to permit any bilge water accumulated during storage to be discharged directly to the sea, since the presence of oil in the bilges would pose an environmental problem and necessitate treatment of the bilge water before discharge.

2. The integrity of the vessel's tank walls and hull must be assured to prevent leakage of the stored petroleum from the vessel or into the bilges. Repair of leaks, barnacle scraping, and painting are standard practices employed to restore and maintain tank integrity.

3. Pumps, piping, flow meters and level indicators are required to provide for loading and unloading of the petroleum as well as removal of water from the bilges.

4. Lighting and foghorns are required for safety purposes at night and in bad weather. A ship-to-shore communication system is necessary to permit the watchmen to maintain contact with shore facilities.

5. Where more than one tanker is anchored in a harbor, living accommodations for the watchmen will probably only be required on one ship. These accommodations should include sleeping quarters, lighting, heating and cooking facilities and a waste disposal system. The power for these facilities can be supplied by an electrical generator located on the vessel. In addition, this generator could be utilized to run the ship's lighting, foghorns and pumps. The electrical requirement of the other anchored vessels may also be supplied by this central generator, or small generators may be installed on each ship.

6. The condition, length, and number of anchors required for safe anchorage depends on the type of anchorage selected for a given site. The repair, replacement or addition of anchors and chains will be ship and site specific.

7. The use of marker buoys during anchorage will depend upon the specific site of anchorage and the regulations governing that particular harbor. In addition, oil spill containment and clean-up equipment may be required on each vessel. Alternatively, this task may be accomplished by contracting for spill control with local clean-up organizations.

Manpower Requirements

Once a tanker is at anchor in a harbor, the only anticipated manpower requirements to maintain the storage reserves are watchmen. The position of the vessel must be checked regularly to detect if the vessel is dragging its anchors and possibly drifting into dangerous waters. The frequency of the position checks is dependent upon the harbor characteristics including the magnitude of currents, tidal effects, weather patterns, and type of harbor bottom. Estimates by the Maritime Administration of the number of watchmen required range from one for anchoring only a few tankers in an ideally suited harbor to one watchman per tanker for harbors with less desirable characteristics.

c. Cost

The cost of utilizing laid-up tankers for temporary storage of petroleum is dependent on several factors. The first and probably most important factor is the expense incurred in obtaining the use of the tanker. The United States government might elect to purchase or lease the tanker capacity required.

A recent study indicates that $23 per DWT ($3.24 per barrel) would be a representative purchase price of tankers for the SPR. Additional costs for refurbishing, movement to the U.S., and vapor recovery systems and other operational items required for storage would increase the initial cost to $4.33 per barrel (AS-050). This is an average value involving the purchase of tankers in both the scrap market and the operational market. Twenty-three dollars per DWT is representative of tankers in the 30,000 to 50,000 DWT range that are being sold as scrap; smaller tankers cost more per DWT, larger ones cost less. However, very few of the larger tankers are being scrapped because they have not reached retirement age. The Government would probably have to compete in the market for operational tankers to purchase larger tankers (above 90,000 DWT). Further, large-scale government purchases would probably increase the prices in both markets. Operational tankers prices could range upward from scrap value to over $100 per DWT, depending mainly on the age of the vessel.

The purchase of laid-up tankers leads ultimately to the problem of their disposal at the completion of the early storage program. The ability to sell tankers in a market already overloaded with excess capacity is a serious consideration. It is possible that all or part of the purchase price could be recovered if the vessels are sold for scrap. However, the future nature of the scrap market is unforeseeable, and the current "soft" world tanker market does not inspire confidence as to the scrap sale potential.

The actual cost of leasing a tanker is specific to each tanker under consideration. However, a simple economic analysis may give some insight to the cost of leasing laid-up tankers. While a tanker is in lay-up, the owner is losing money through (1) the cost of the lay-up, (2) the depreciation of his property, and (3) lost revenue. A major oil company presently has a 50,000 DWT tanker for which annual lay-up costs are $500,000. To the extent they are available, the per barrel cost of leasing larger tankers would be less. It may be possible to negotiate an agreement for the use of such tankers in return for the defrayment of all or a portion of this cost. Similar agreements might be worked out with other ship owners.

Essentially, the government would be offering to pay for the cost of laying-up a tanker. Whether this agreement will cover depreciation and lost revenues incurred by the owner must be negotiated with the individual owners and is beyond the scope of this study.

A second cost of using laid-up tankers for storage involves the amount of equipment repair, replacement and/or addition which may be needed to ready a tanker for storage pruposes. The use of fairly new vessels, less than fifteen years old, may minimize the amount of preparation needed since these vessels probably have not been stripped of their equipment to provide replacement parts for other vessels. The hulls and bulkheads of newer vessels will also probably be in good condition and need a minimal amount of repair work. The newer vessels that are in lay-up tend to be larger capacity vessels, which minimizes leasing costs.

The use of the United States Naval Reserve Fleet may pose several problems with respect to the amount, and hence cost, of preparation work. Most of the ships are of World War II vintage and have had much of their equipment removed. The engine cooling water inlet and outlet ports have been blanked and as a result, the engines are inoperable. In addition, the condition of the tanker's hull and bulkheads is questionable. The amount of work required to prepare these tankers for storage purposes may be extensive. The preparation costs must be examined for each tanker.

d. Environmental Impacts

The storage of petroleum in laid-up tankers will produce pollutant emissions during the preparation, filling/emptying and static phases of the storage. These emissions would include air emissions from the storage tanks, liquid discharges from leaks and the bilges and solid wastes generated from maintaining living quarters for watchmen.

Before laid-up tankers can be used for storage purposes, equipment additions, modifications and/or repairs may have to be performed. The extent of these preparation activities will depend upon the condition of each tanker to be utilized. Emissions arising from this phase of tanker storage are anticipated to be minimal. Because of the ship-specificity of the preparation work, quantification of the construction emissions cannot be made. Potential sources of emissions may include, but may not be limited to (1) welding operations, (2) small generators, (3) painting operations, and (4) tank cleaning procedures. Section V.D addresses oil spill risk associated with tanker loading and unloading.

The loading of tankers with petroleum inherently results in the expulsion of saturated hydrocarbon vapors. Based on storing crude oil with 3.4 psia vapor pressure and a density of 300 lb/BBL, the uncontrolled filling loss for tankers is 0.034 pounds of hydrocarbon per barrel of crude oil fill (RA-223). For an 80,000 DWT tanker which has a capacity of 560,000 barrels, the uncontrolled filling loss would be 19,000 pounds of hydrocarbons. The installation of vapor control equipment such as thermal oxidizers or any of the compression/refrigeration vapor recovery processes would reduce the filling losses. Thermal oxidizers can provide essentially 100% hydrocarbon emission control while the vapor recovery system can reduce hydrocarbon losses by 90%, resulting in 1,900 pounds of hydrocarbons being emitted during the filling of an 80,000 DWT tanker.

The unloading of the tankers would also contribute hydrocarbon emissions. These result from ballasting operations following unloading. Water pumped into the tanker's storage compartments expels vapor rich air. These emissions would amount to about .022 lb per barrel unloaded (RA-223). For an 80,000 DWT tanker, the total emissions would be 12,320 lbs. Vapor control equipment could also reduce these emissions by over 90%. See VI.A.5 for further discussion of emission prevention methods. Section V discusses the ambient air impact of hydrocarbon emissions from tanker unloading and loading.

During the static phase, tankers require electricity for maintaining living quarters, ship lights, foghorns, pumps, etc. This electricity will most probably be supplied by small generators which will emit combustion gases. Since the quantity and composition of the emissions will be dependent on the electricity requirements of each ship and the fuel used to run the generators, quantitative data for combustion emissions cannot be calculated. However, the use of natural gas, gasoline, or other clean fuel will minimize these emissions.

The storage tanks will emit hydrocarbon vapors as breathing losses much the same as conventional tankage. The quantity of breathing losses is dependent upon several factors including (1) the amount of vapor space in the tanks, (2) the shape of the tanks, (3) the color and condition of the vessel's paint, and (4) the diurnal temperature change of stored petroleum. Because the storage tanks aboard a loaded tanker are essentially below water level, the insulation effect of the water will assure that the diurnal temperature changes experienced by the stored petroleum should be minimal. Therefore, it is anticipated that breathing losses for tanker storage will be less than for conventional tank storage under similar conditions. To illustrate what the maximum breathing losses would be, the emissions from crude oil storage in cone roof tanks can be examined. The hydrocarbon emission factor for crude storage is 0.043 lb/day-10^3 gal for new tanks. Using these factors and assuming an 80,000 DWT tanker holds 560,000 barrels of crude oil, the emissions are 1,140 lbs/day. If a 90% efficient vapor recovery system were employed, the emissions would be reduced to 110 lbs/day (RA-223).

Liquid effluents arising from static storage will consist mainly of bilge water and oil leaks. The bilges collect miscellaneous liquids from all parts of a vessel. If the ship's storage tanks are in good repair, negligible oil leakage should accumulate in the bilges. In addition, during the storage period little of the ship's equipment will be used. Therefore, coolant and lubricant leaks should be negligible and only a minimal amount of bilge water should accumulate. Any bilge water that does accumulate could be disposed of by local contractors or pumped overboard if it is not contaminated with oil.

IV. DESCRIPTION OF THE ENVIRONMENT

A. Purpose

This section describes the major environmental, economic, social and physical elements which characterize the regions most likely to be affected by implementation of the program. It provides a broad generalized description of the baseline conditions, i.e., the environment as it now exists. Part B describes each of the impact areas in detail and Part C describes existing distribution and refinery facilities.

For a programmatic level analysis, the primary impetus is to provide sufficient detail in the baseline description to enable assessments of the impacts associated with execution of the program and viable alternatives to the program. Consequently, attempts were made to present the level of detail associated with each environmental parameter in a manner commensurate with the degree of expected impact. In some cases, little or no impact is directly accorded an environmental parameter but the parameter is characterized for the purpose of completeness and instruction.

B. Impact Areas

As discussed in Chapters I, II and III, two major regions of the Nation have been determined to be the most feasible for satisfying the requirements of the Strategic Petroleum Reserve Program. These two areas are the Gulf Coast and Atlantic or East Coast regions. In summary, the Gulf Coast was chosen because of the widespread presence of usable existing and potential storage capacity in salt dome formations; coupled with this resource is the presence of significant petroleum refining and distribution facilities. Supply-demand analyses and forecasts indicate that the East Coast region may require service from storage of primarily refined petroleum products under the SPR. Within the time frame for development of the Reserve, it is anticipated that the Alaskan pipeline and oil fields will be sufficiently developed to satisfy the import requirements of the West Coast regions. Petroleum energy requirements for other regions of the Nation can be satisfied from these three areas and by current supply practices. The two storage regions characterized in this study are depicted generally in Figure IV-1.

Because the primary goal of this programmatic EIS is to examine at a high level those potentially sensitive areas and bring them to the attention of policy makers and the public, no attempts were made to perform detailed site-specific investigations. This EIS provides an initial framework from which exhaustive and detailed statements will be prepared for each candidate storage facility.

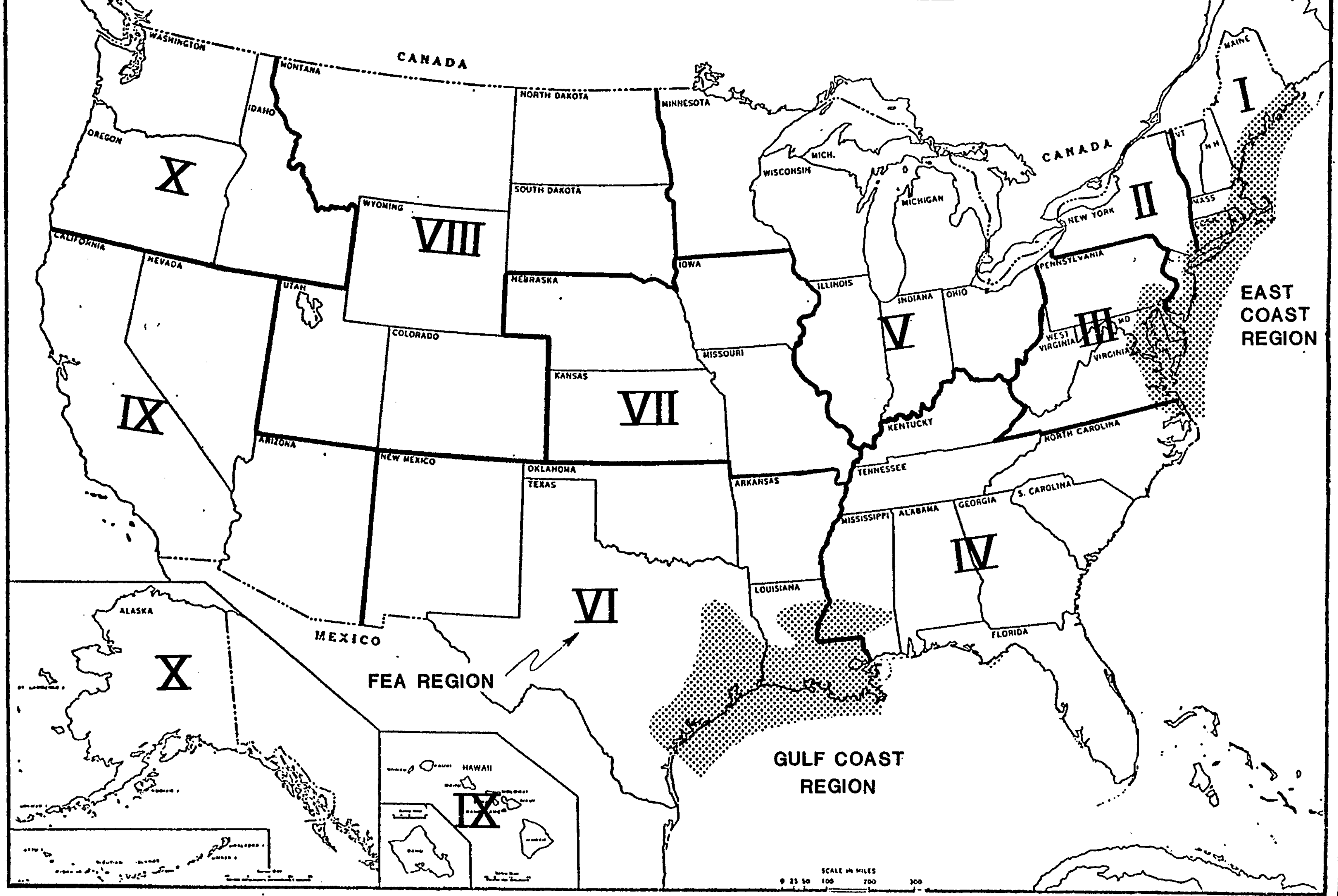
1. Gulf Coast Storage Region

a. Geology

For the purposes of the following discussion, the Gulf Coast region generally encompasses the area of the Louann Salt Basin, as depicted in Figure IV-2. The region includes the locations of all potential storage facilities that represent existing salt dome cavities, new salt dome cavities, and existing salt mines.

FIGURE IV-1

GENERAL LOCATION OF STORAGE REGIONS



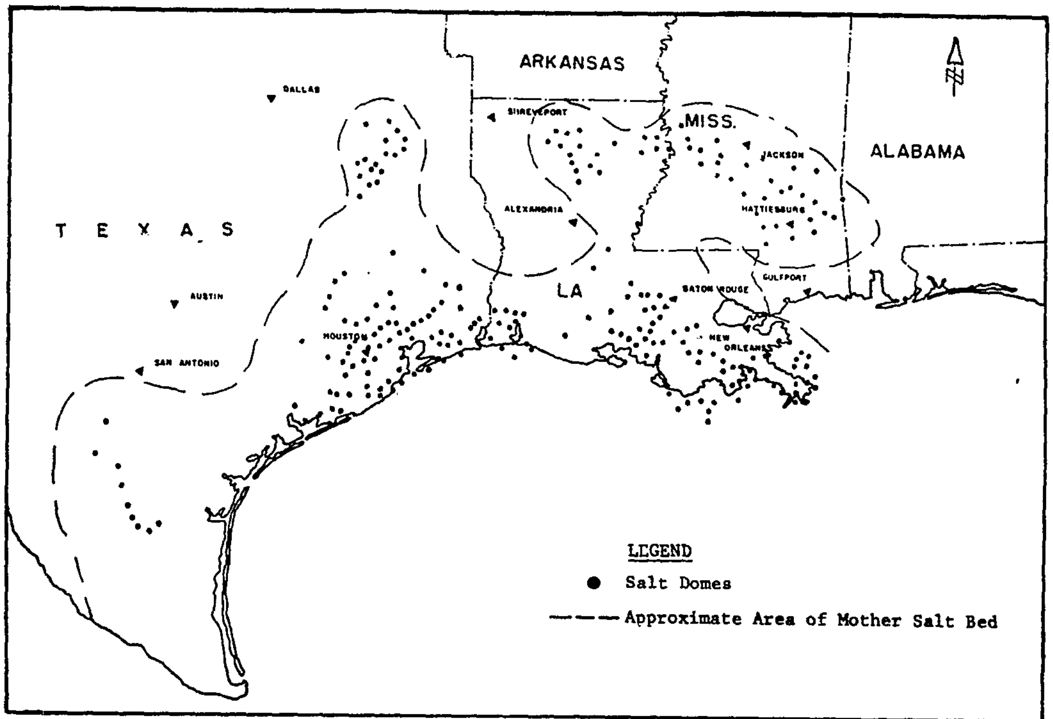


FIGURE IV-2

GULF COAST STORAGE REGION SALT DOMES

Source: HO-247

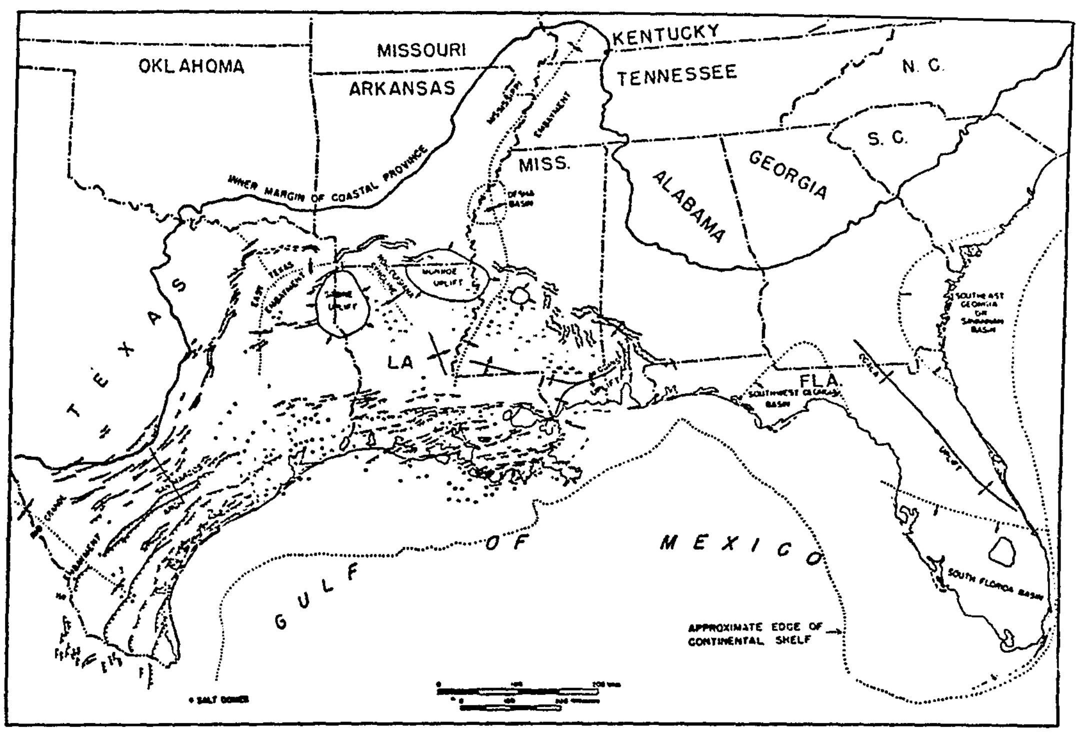


FIGURE IV-3

MAJOR STRUCTURAL ELEMENTS OF THE GULF COAST STORAGE REGION

Source: MU-101

Physiography

The region is located entirely within the Western Gulf Coastal Plain Province. The structural elements which indirectly affect physiography are shown in Figure IV-3. The inner Coastal Plain, including most of the embayments, is characterized by distinctly belted topography, owing to the outcrop of alternating older strata of different erosional resistances (MU-101); gently rolling hills are typical of this portion of the region. The subaerial part of the outer Coastal Plain is characterized chiefly by a broad, nearly flat prairie, sloping imperceptibly toward the Gulf at a rate of about five feet per mile (CA-297). Laterally extensive coastal marshes, which may extend inland from the Gulf as much as twenty miles, and bay estuaries and offshore bars near major streams are the primary coastal features. Onshore salt domes, of which there are over three hundred, commonly provide local relief of several tens of feet. The subaerial Coastal Plain surface continues under the Gulf as the Continental Shelf for more than one hundred miles with even more subdued topography owing to blanketing by marine sediments (MU-101).

The Mississippi River Delta complex roughly coincides with the northeast boundary of the region. Other major streams that drain the region are the Pearl, Sabine, Neches, Trinity, Brazos, Colorado, Guadalupe, and Nueces Rivers. These rivers are typically incised by several to several tens of feet, with headward-eroding tributaries providing most of the local relief of the area. These streams have moderately-sized flood plains, perhaps as much as ten miles wide locally, and are transverse to the regional sedimentary trends.

Areal and Subsurface Geology

For a programmatic EIS, it is not only appropriate, but also necessary, to approach geological characterization as a regional overview. At any other scale the geology is of a complexity that any attempt to describe and discuss lithologic and stratigraphic relations of individual formations is far beyond the scope and purpose of this statement. Detailed and comprehensive descriptions of the geology will be developed for each site-specific EIS.

From a macroscopic viewpoint, the geology of the region is quite simple. Deposition within the continually subsiding Gulf of Mexico Sedimentary Basin and its embayments, from at least the end of the Mesozoic Era (seventy million years ago) to the present day, has created an extremely thick accumulation of gently dipping, semi-consolidated to unconsolidated sandstone, (clay) shale, and minor limestone (HO-247). These deposits generally thicken and have larger dips in the Gulfward direction in the subsurface. Dips of formations at or near the surface, however, are only a few feet per mile toward the Gulf. Regionally, except for the alluvial deposits on the primary streams, the individual, heterogenous formations crop out at the surface in sedimentary-structural trends subparallel to the present coast, with the older formations exposed progressively away from the coast.

More than 50,000 feet of Cenozoic sediments (Figure IV-4) of fluvial-deltaic and marine origin have accumulated upon older strata (including salt) in the Gulf Coast Basin. Sedimentation rates varied and loci of deposition (depocenters) generally shifted seaward with time (HO-247). The time-stratigraphic correlations of these units are shown in Table IV-1.

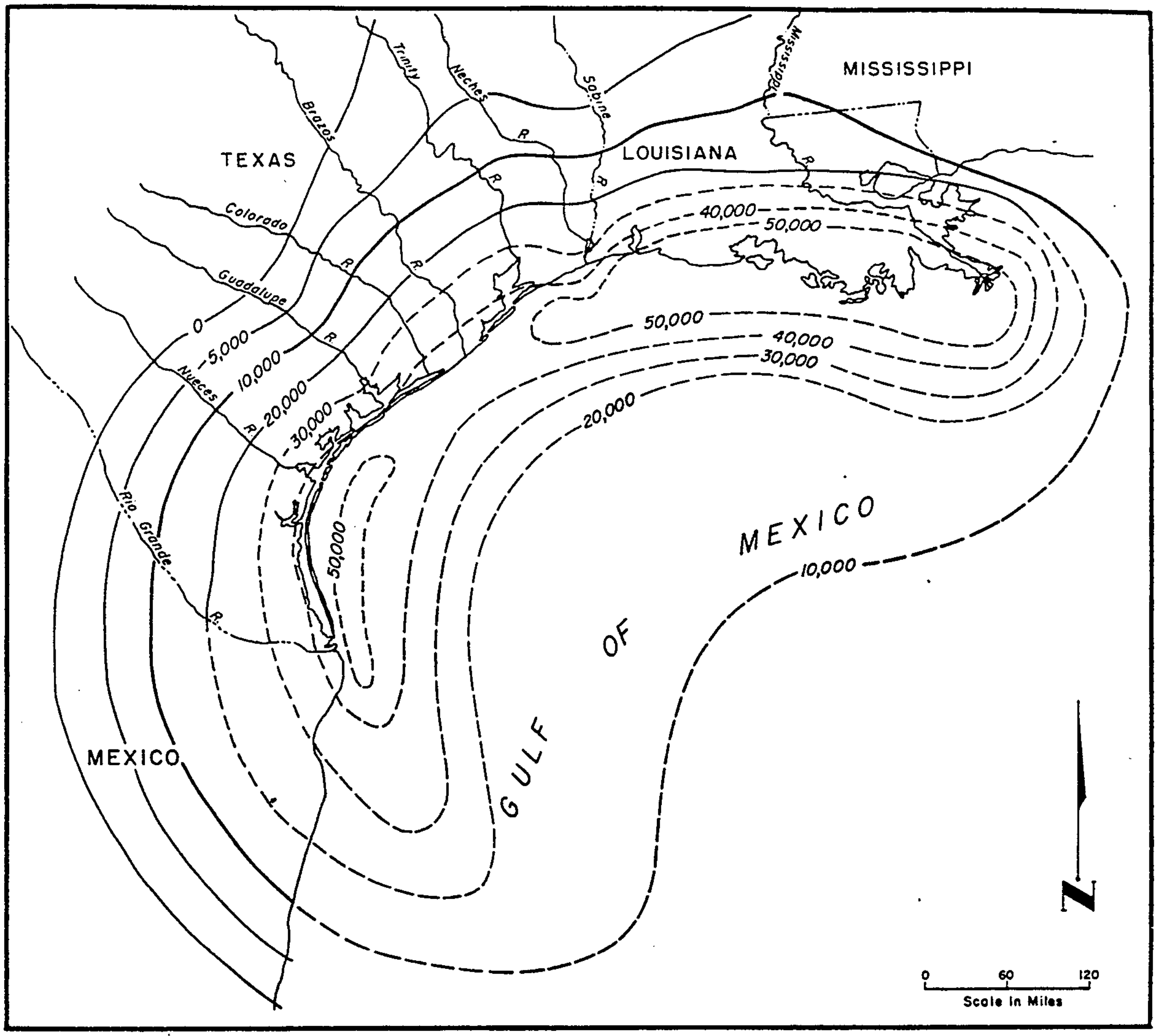


FIGURE IV-4

CENOZOIC SEDIMENT THICKNESS (FEET) IN THE GULF COAST STORAGE REGION

Source: HO-247

TABLE IV-1 CENOZOIC CORRELATION CHART

Generalized Standard Section: System	Series	Group or Stage	Texas Gulf Coast: Formation	Member	Foraminifera	Louisiana: Formation	Member	Section Foraminifera	Mississippi (thins Eastward →): Formation	Member	Foraminifera
QUATERNARY	RECENT										
QUATERNARY	PLEISTOCENE	HOUSTON	BEAUMONT LISSIE WILLIS	Terrace Deposits	(Becomes marine only in downdip)	PRAIRIE MONTGOMERY BENTLEY WILLIANA	Terrace Deposits	(Becomes marine only in downdip land and offshore section)	Loess and Terrace Deposits		(Mainly fluvial and non marine)
TERTIARY	PLIOCENE	CITRONELLE	GOLIAD	Marine zones in post-Anahuac present only in downdip land and offshore	Buliminella sp.			Buliminella sp.	Alluvial and Deltaic Deposits		
TERTIARY	MIOCENE	FLEMING	LAGARTO		Robulus (E) Bigenerina (A) Cristellaria (K) Discorbis (5) Textularia (L) Bigenerina nod. directa Textularia (W) Bigenerina humblei Cristellaria (I) Cibicides opimus	MIOCENE	Upper	Robulus (E) Bigenerina (A) Cristellaria (K) Buccella mansfieldi Discorbis (5) Textularia (L)	PASCAGOULA		Micrangia microjohnsoni (Pelecypoda) Potamides matsoni (Gastropoda)
							Middle (Heterostegina facies)	Bigenerina nod. directa Textularia (W) Bigenerina humblei Cristellaria (I) Cibicides opimus Amphistegina (B) Robulus (43) Operculinoides assemblage			
			OAKVILLE		Amphistegina (B) Robulus (43) Discorbis bolivarensis Marginulina ascensionensis Siphonina davisi		Lower (Planulina-Abbeville facies)	Discorbis bolivarensis Marginulina ascensionensis Siphonina davisi Planulina palmerana Lenticulina jeffersonensis Nodosaria vertebralis Siphogen. fredsmithi	HATTIESBURG		
	OLIGOCENE	CATAHOULA	ANAHUAC		Discorbis nomada Discorbis gravelli Heterostegina sp. Bolivina perca Marginulina idiomorpha Marginulina vaginata Marginulina howei	ANAHUAC		Discorbis nomada Discorbis gravelli Heterostegina sp. Bolivina perca Marginulina idiomorpha Marginulina vaginata Marginulina howei Camerina (A)	CATAHOULA SD.		Heterostegina sp. Lepidocyclina (Eulepidina) sp.
			FRIO	Hackberry Facies	Cibicides hazzardi Marginulina texana Gyroidina scalata Bolivina alazanensis and others Nonion struma Nodosaria blanpiedi Textularia seligi Anomalina bilateralis	FRIO	Hackberry Facies	Cibicides hazzardi Marginulina texana Gyroidina scalata Bolivina alazanensis and others Nonion struma Nodosaria blanpiedi Textularia seligi Anomalina bilateralis	PAYNES HAMMOCK CHICKASAWHAY		Cibicides hazzardi Nonion struma Nodosaria blanpiedi
		VICKSBURG			Textularia warreni Textularia tumidula and association			Cibicides mississippiensis Textularia warreni Textularia tumidula and association	BUCATUNNA		
									BYRAM		Lepidocyclina supera Textularia tumidula
									MARIANNA		Lepidocyclina mantelli
			RED BLUFF	(Only in downdip subsurface)		RED BLUFF	(Only in downdip subsurface)		FOREST HILL	RED BLUFF	
	EOCENE	JACKSON	WHITSETT	Fashing Clay Calliham Sd. Dubose Sd.-Sh. Stones Switch Sd.	Discorbis texana Massilina pratti	YAZOO	Danville Landing Beds	Massilina pratti	YAZOO	Shubuta Clay	Bulimina jacksonensis Marginulina cocoaensis Globorotalia cocoaensis Hantkenina alabamensis
			Mc ELROY	Manning Clay Wellborn Sd. Wesleys Bluff Clay	Textularia hockleyensis		Verda	Textularia hockleyensis		Pachuta Marl	Textularia hockleyensis
			CADDELL		Textularia dibollensis		Union Church Tullos	Textularia dibollensis		Cocoa Sd. North Creek	Textularia dibollensis
				[illegible]	[illegible]	MOODY'S BRANCH		[illegible]	MOODY'S BRANCH		[illegible]
		CLAIBORNE	YEGUA		Discorbis yeguaensis Eponides yeguaensis	COCKFIELD		Discorbis yeguaensis Eponides yeguaensis	COCKFIELD		Discorbis yeguaensis Eponides yeguaensis
			CROCKETT		Ceratobulimina eximia Operculinoides sabinensis	COOK MOUNTAIN		Ceratobulimina eximia Operculinoides sabinensis	COOK MOUNTAIN		Ceratobulimina eximia Operculinoides sabinensis
			SPARTA			SPARTA			SPARTA		
			WECHES		Textularia smithvillensis	CANE RIVER		Cyclammina caneriverensis Discocyclina advena	ZILPHA		Cyclammina caneriverensis
									WINONA		Discocyclina advena
			QUEEN CITY						TALLAHATTA		
			REKLAW								
		WILCOX	CARRIZO			CARRIZO			HATCHETIGBEE	Bashi Marl	Globorotalia wilcoxensis Spiroplectammina wilcoxensis
			SABINETOWN		Cytheridea sabinensis (Ostracoda)	SABINETOWN		Cytheridea sabinensis (Ostracoda)	TUSCAHOMA		Mollusks
			ROCKDALE			PENDLETON		(Rare mollusks)			
			SEGUIN		Ostrea multilirata (Pelecypoda)	MARTHAVILLE		Ostrea thirsae (Pelecypoda) Discorbis washburni	NANAFALIA	Fearn Springs Sd	Ostrea thirsae [illegible]
	PALEOCENE	MIDWAY	WILLS POINT	Solomon Creek Kerens Mexia	Robulus midwayensis Vaginulina longiforma Vaginulina midwayana Marginulina tuberculata Polymorphina cushmani	HALLS SUMMIT LOGANSPORT NABORTON		Robulus midwayensis Vaginulina longiforma	BETHEDEN		(Non-Marine)
						PORTERS CREEK		Vaginulina midwayana	PORTERS CREEK	Matthews Landing Marl	Vaginulina midwayana
			KINCAID	Tehuacana Pisgah Littig Glauc.	Discorbis newmanae Robulus pseudocostatus	KINCAID		Robulus pseudocostatus	CLAYTON		Vaginulina gracilis Robulus pseudocostatus

Source: HO-247

While the interplay among sediment sources, delivery and dispersal determined the gross sedimentologic aspects, the lithic character and thickness of the formations in the table are spatially variable, owing to the influence of numerous, contemporaneous local structures during deposition. Generally, the earlier tertiary formations comprise variable, unequal amounts of sand and clay, and the more recent quaternary formations, representing only the uppermost few thousand feet of sediments, generally are more sandy, yet also have substantial amounts of clay (MU-101). The exemplary, generalized cross-sections of Figure IV-5 illustrate typical subsurface relations commonly encountered between marine and non-marine sediments. Generally speaking, the near-surface strata at locations of interest to this program will be alternating sand and clay in beds of variable thickness and lithology.

Tensional or gravity faulting, associated with the subsiding depocenters, and the density difference between the thick beds of salt and superjacent strata account for much of the local structural variations in the province (MU-101). Numerous fault zones of regional extent but variable displacement, usually having only subsurface expression, generally accord with the modern trend of adjacent strata (Figure IV-6). In addition, the emplacement of the salt dome is generally accompanied by numerous radial, tangential, and circumferential faults of various displacements but generally only local (i.e., not regional) structural extent. The overall structural aspect of the region is one of vertical movement, both at regional and local scales. These structural features not only offset strata but also commonly affect stratigraphic characteristics by thinning, thickening, and erosional truncation of proximal contemporaneous or pre-existing sediments (HA-272).

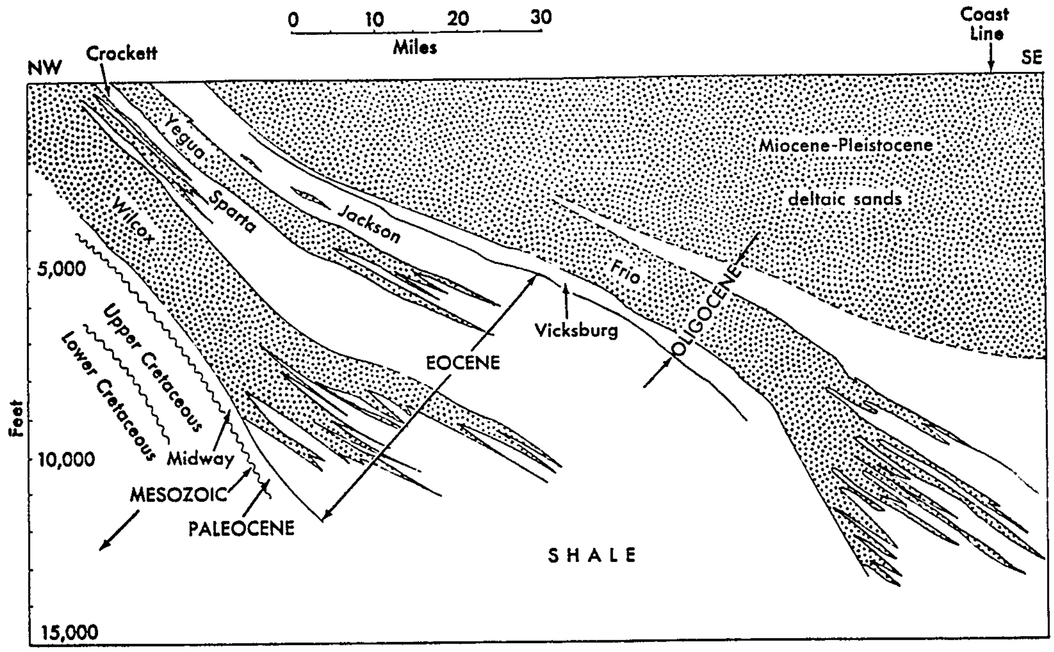
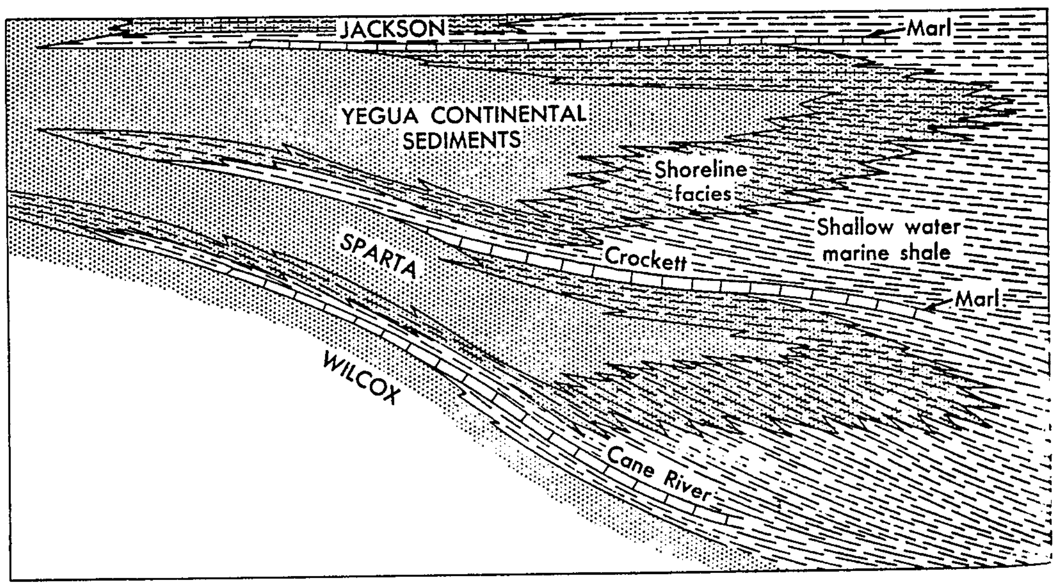


FIGURE IV-5

DIAGRAMMATIC REPRESENTATIONS OF TYPICAL STRATIGRAPHIC VARIATIONS IN THE GULF COAST REGION (ABOVE) DIP SECTION SHOWING REGIONAL RELATIONS OF SANDY (STIPPLED) AND CLAYEY (WHITE) UNITS (BELOW). DETAIL OF THE FACIES IN ONE PART OF THE ILLUSTRATION ABOVE.



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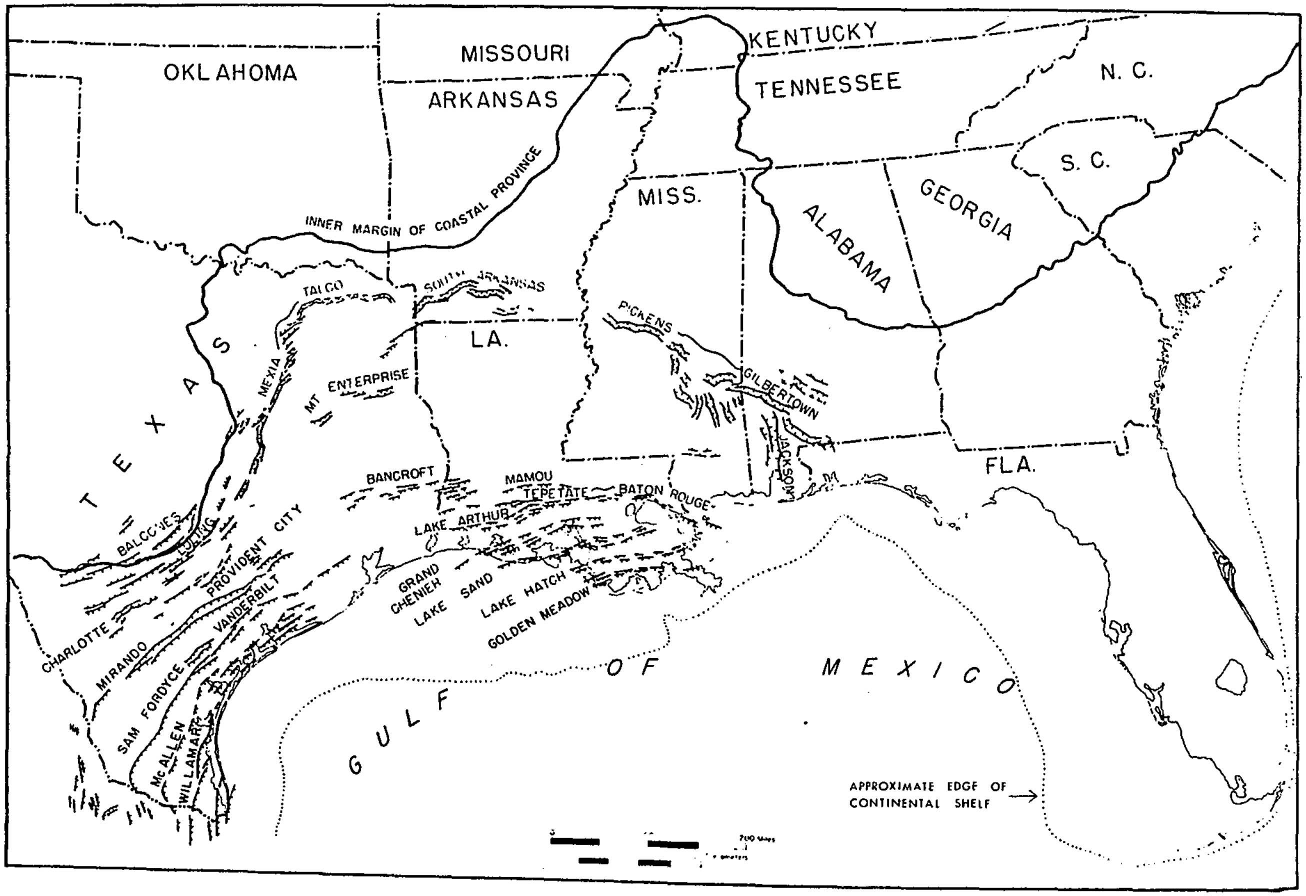


FIGURE IV-6

MAJOR FAULT ZONES IN THE GULF COAST STORAGE REGION

Source: MU-101

Seismicity

Although the Gulf Coast Basin is actively subsiding, particularly near depocenters like the Mississippi Delta, it is seismically "quiet", at least for the geological present. Current risk data indicate that the seismic risk for surface structures in the Texas Coastal Plain is zero, and very low in Louisiana and in the area of Mississippi where the domes are located (Figure IV-7). These estimates of earthquake damage are based on information regarding epicenter location and intensity for over 28,000 earthquakes in the conterminous United States (US-328). The Modified Mercalli Scale, on which the figure is based, is presented in Table IV-2.

Owing to the thick, unconsolidated, and relatively saturated surficial deposits that typically underlie the region, the fundamental ground period (induced by earth-shaking motion) of these deposits tends to be long (NI-031). Damage from a possible, though low-probability, seismic event in the region could tend to be greater for the taller multistory buildings than for single-story buildings. The reason for this expectation is that the fundamental periods of single-story buildings are much shorter than taller buildings; consequently, the likelihood of resonance between the building and the ground, which can be particularly damaging, is small (NI-031).

It is important to recognize that while there are numerous "active faults" (not those previously shown in Figure IV-7) documented in the Gulf Coast region, this faulting is not tectonic in origin and is not genetically or causally related to earthquakes (BR-184). Movement along these faults is inherently gradual and areas away from such faults or zones are not subject to damage. The active faults in the Gulf Coast region are of

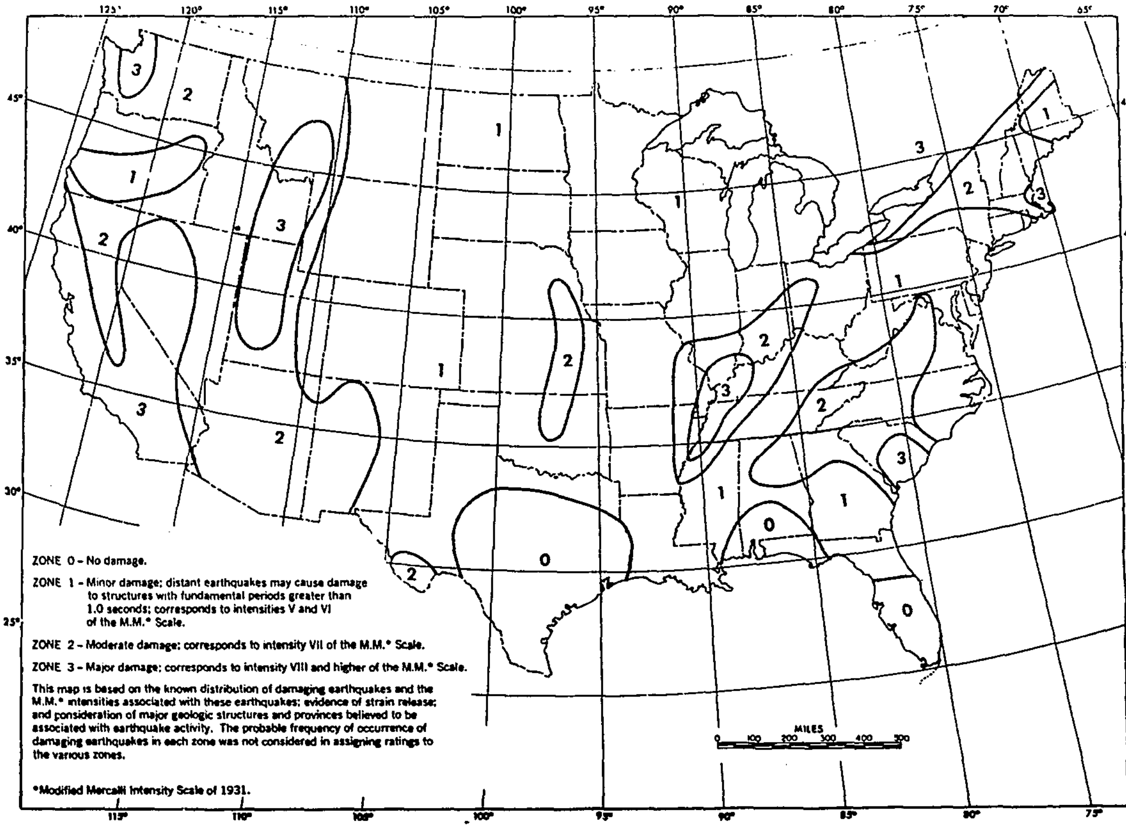


FIGURE IV-7

SEISMIC RISK MAP OF THE UNITED STATES

Source: US-328

TABLE IV-2

MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITY

I.	Not felt except by very few under especially favorable circumstances.
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III.	Felt quite noticeably indoors, especially on upper floors, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated.
IV.	During the day felt indoors by many; outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V.	Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
VI.	Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures: considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well-water levels. Disturbs persons driving motor cars.
IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations, ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed over banks.
XI.	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upwards into the air.

some general concern, however. The potential for substantial damage to man-made structures that straddle faults (or are within a fault zone) due to differential compaction has been demonstrated, and the concern is compounded by the fact that local subsidence resulting from existing resource extraction by man (particularly ground-water production) evidently can activate and/or increase fault movements (BR-184).

Mineral Resources

The most important mineral resources in the Gulf Coast region are oil and gas, which are extensively produced throughout the region. Oil and gas production is often associated with salt domes, and most known domes in the province have been extensively explored on their margins for petroleum. Salt domes are also the source of commercial salt and brine, which are used both as chemical feedstocks and as a source of salt for commercial purposes. The caprock of many salt domes is an important source of sulfur, which is produced by the Frasch process in which superheated water is pumped into wells open to sulfur-bearing caprock material to melt the sulfur; the molten sulfur is forced up the intermediate annulus by compressed air in injection tubing.

A resource of the coastal plains that is just now being appreciated as an important energy source is lignite, which exists under variable cover over a large area of the inner Coastal Plain (KA-152). Lignite is found principally in the Wilcox Yegua-Jackson trends of Eocene age, chiefly associated with fluvial and deltaic sediments. Its primary use is as fuel for steam-electric generation, generally at surface mine-mouth generating stations.

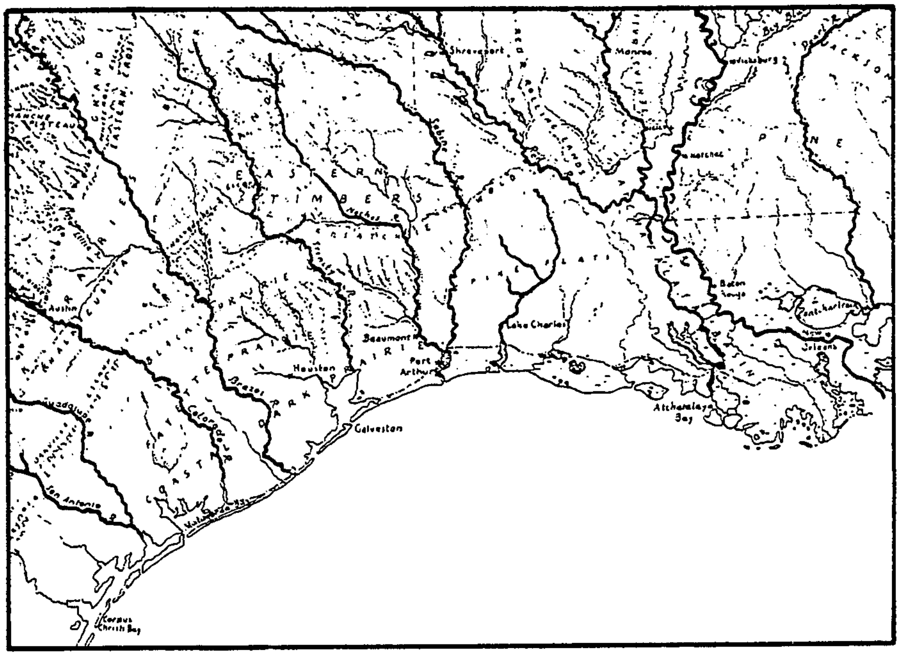
Sand and gravel, used as aggregate in making concrete, are mined by surface mining techniques throughout the Coastal Plain. Most of the material is mined from the extensive and moderately thick flood-plain deposits in the upper reaches of most major streams, although some sand and gravel production, especially in Louisiana and Mississippi, occurs from broad alluvial terraces of relict or ancient streams rather than the modern floodplains (LO-141). Other mineral resources exploited at several locations in the Coastal Plain include uranium, bentonite, and limestone.

b. Hydrology

Surface-Water Hydrology

The surface drainage of the area of interest in the Gulf Coastal Plain is shown in Figure IV-8, and pertinent hydrologic data on these streams are summarized in Table IV-3. The largest discharge, of course, is by the Mississippi River, and the smallest is by the Nueces River, near the southwestern boundary of the region.

While average discharge is a strong function of drainage areas, the regular decrease in runoff rates and low flow from northeastern area streams to southwestern streams (i.e., down the table) is striking. (The Guadalupe River system's flow character is somewhat anomalous due to the combined influence of several very large springs near the inner margin of the Coastal Plain.) This regular decrease is primarily caused by the much larger evapotranspiration in the southwestern portion of the Coastal Plain and toward its streams' headwaters beyond (CH-156). Isohyetal maps indicate that rainfall is fairly equal in distribution over that part of the Gulf Coast region



Source: MU-101

FIGURE IV-8

LANDFORMS AND SURFACE DRAINAGE OF THE GULF COAST REGION

TABLE IV-3

SUMMARY OF STREAMFLOW IN GULF COAST STORAGE REGION

Most downstream fresh water gaging station on	Drainage Area (Σ) (mi^2)	Average Flow (Σ) (cfs)	Unregulated: Average Runoff (cfs/mi^2)	Unregulated: Average Annual Runoff (in)	Unregulated: Extremes (cfs) Low	Unregulated: Extremes (cfs) High	Water Available
Mississippi-Atachafalaya River	1,244,000	611,000	0.49	6.64	--	--	Yes
Mississippi River	1,144,500	554,000	0.48	6.50	99,400	2,080,000	Yes
Calcasieu River	1,700	2,613	1.54	20.9	r	182,000	Yes
Sabine River	9,329	8,443	0.91	12.3	270	121,000	Yes
Neches/Village Creek	(8,811)	(7,082/4,843)	0.80	10.8	--	--	No
Trinity River	17,186	7,155/6,489	0.42	5.69	102	111,000	No
Brazos River	44,340	7,508	0.17	2.30	40	797,000	No
Colorado River	41,650	2,285r	0.55r	0.74r	0	84,100	No
Guadalupe/San Antonio	(9,119)	(2,219)	0.24	3.24	small	--	Yes
Nueces River	15,600	858	0.55	0.74	0	141,000	No

Notes:
1. Figures in parentheses indicate summation of data on individual streams; "r" indicates significant regulation of flow; slask mark between figures indicates unregulated/regulated flow averages.
2. Mississippi River data through 1965, others through 1973.
3. Several very large springs discharge to Guadalupe River system.

Source: US-394 through 398 and US-146 through 150.

under study, although the headwaters of more eastern streams have substantially more precipitation and therefore also contribute to the trends indicated by Table IV-3.

The average annual runoff in streams of the region, exclusive of the Mississippi-Atchafalaya River system, has been estimated at 39.1 billion gallons per day (bgd) or 60,500 cfs; 50% of the time runoff will not exceed 37.5 bgd, and 5% of the time it will be less than 11.4 bgd (TO-028). Flood flows can occur at any time of the year on a given stream, but for the study region as a whole, flows generally are highest in March and May, and low flows generally occur during August and September.

The natural flow of all these streams is materially affected by upstream reservoir regulation, agricultural and municipal diversions, and return flows. The surface-water resource in the Texas Coastal Plain is essentially fully (if not optimally) developed, and considerable water reuse is now taking place. Of particular note is the requirement for definite fresh water inflows of certain, variable quality for maintenance of existing estuarine conditions. Nearly every one of the major streams in the Gulf region has a significant estuary and associated salt marshes, which support an economically significant fishing industry. Currently, release of stored water downstream to maintain the estuaries is a significant and critical water use. Water use upstream of the estuaries is critically examined by regulatory agencies.

The suspended sediment content of the coastal streams is relatively high. The estimated average annual sediment yield of drainage areas in the Mississippi River is 5200 tons/square mile, and for the rest of the region, watersheds yield an average

1800 tons/square mile/year (TO-028). As a consequence, the waters of coastal streams along the Gulf Coast are normally turbid.

The water quality of most streams is generally good during most of the year. Typical water chemistry/quality for a major coastal stream is shown in Table IV-4. Dissolved solids contents typically vary inversely with stream flows, and suspended solids vary directly with flow. There is a moderate organic load shown, which is not unusual, but toxic organics are very low; persistent pesticides presumably from agricultural runoff do accumulate to a small degree in bottom sediments. Most streams that cross the Coastal Plain are deemed suitable for all uses including public drinking water supplies.

A number of water quality problems are currently experienced, however, in the area streams from both natural and anthropogenic sources. Natural salt deposits in the upper Brazos River (out of the study area) are a source of brine influent to the stream which contribute to a relatively high dissolved solids load for that stream, particularly during low-flow conditions (BR-175). In addition, intrusion of marine water to nearly all streams takes place during especially high meteorological tides and/or low fresh-water flows; this natural phenomenon can grossly affect the short-term water quality particularly of bottom waters for distances of over one hundred miles inland. Generally, however, the normal fresh-water flows of most coastal streams are large enough to displace the salt-water/fresh-water interface nearly to the coast, although tidal effects on stream stage may extend several tens of miles inland (JO-119).

To some extent, the water quality of all streams draining the region is affected by man. Mere consumptive use

TABLE IV-4 WATER QUALITY OF TYPICAL GULF COASTAL STREAM (TRINITY RIVER, CROCKETT, TEXAS)

WATER QUALITY DATA, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973

DATE	TIME	INSTAN-TANEOUS DIS-CHARGE (CFS)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM PLUS POTAS-SIUM (MG/L)	BICAR-BONATE (HCO3) (MG/L)	CAR-BONATE (CO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	ORGANIC NITRO-GEN (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	AMMONIA NITRO-GEN (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	TOTAL NON-FILT-RABLE RESIDUE (MG/L)	VOL. NON-FILT-RABLE RESIDUE (MG/L)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	SODIUM AD-SORP-TION RATIO	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)
OCT.																								
06...	1300	502	8.6	40	7.8	110	144	0	91	94	1.1	--	--	--	5.8	--	448	--	--	130	14	4.1	772	7.7
16...	1130	401	13	44	11	99	158	0	85	88	.4	.26	.06	.19	7.7	5.1	453	42	12	160	30	3.5	796	6.9
NOV.																								
14...	0700	2100	10	46	4.7	37	113	0	44	51	.4	--	--	--	.7	--	252	--	--	130	41	1.4	467	7.7
29...	1145	1380	11	41	4.8	50	98	0	71	50	.2	.24	.16	.05	2.0	1.4	287	79	27	120	42	2.0	492	7.0
DEC.																								
11...	1245	911	13	47	9.8	71	142	0	82	76	.0	.21	.12	1.9	2.6	2.0	384	41	16	160	42	2.5	663	7.4
28...	0700	1120	12	49	8.1	62	130	0	80	62	.5	--	--	--	3.7	--	353	--	--	160	51	2.2	596	7.7
JAN.																								
04...	0700	1720	14	47	7.9	70	110	0	69	88	.6	--	--	--	4.1	--	360	--	--	150	60	2.5	688	7.4
24...	1100	1700	12	50	9.5	56	126	0	82	60	.6	.29	.08	1.9	4.0	2.2	355	79	20	160	60	1.9	608	6.6
FEB.																								
06...	1245	5850	7.8	38	6.1	25	110	0	43	26	.3	.27	.04	.35	1.1	.78	206	364	60	120	30	1.0	363	7.3
14...	0700	13200	5.5	47	7.0	27	122	0	61	23	.3	--	--	--	2.2	--	240	--	--	150	46	1.0	420	7.5
MAR.																								
01...	1030	2300	9.1	60	5.7	51	155	0	76	54	.5	.24	.12	1.8	1.6	1.9	342	77	9	170	46	1.7	614	7.5
26...	0700	23300	5.5	31	3.6	19	95	0	27	18	.2	--	--	--	.3	--	153	--	--	92	14	.9	283	6.9
APR.																								
02...	0945	10200	7.4	48	4.4	28	131	0	43	28	.2	.30	.09	.27	1.8	.65	232	288	32	140	31	1.0	412	7.2
30...	0700	32000	7.4	36	2.5	13	113	0	21	8.0	.2	--	--	--	.8	--	148	--	--	100	7	.6	270	7.0
MAY																								
16...	0700	14500	3.4	48	5.4	15	140	0	27	19	.3	--	--	--	.9	--	191	--	--	140	27	.5	373	7.4
21...	1000	11300	4.9	50	4.2	26	146	0	38	24	.3	.39	.00	.09	1.0	.61	225	288	58	140	21	.9	409	7.3
JUNE																								
09...	0700	22000	2.9	22	3.4	10	72	0	17	10	.2	--	--	--	.01	--	100	--	--	69	10	.5	219	8.2
25...	1100	13300	6.1	44	4.9	19	123	0	41	16	.3	.35	.00	.08	1.6	.65	199	548	112	130	29	.7	351	7.2
JULY																								
09...	0700	6800	6.0	58	4.2	26	166	0	38	28	.3	--	--	--	.5	--	245	--	--	160	26	.9	458	7.5
26...	1015	1670	8.4	54	3.5	31	158	0	43	26	.4	.22	.01	.00	1.2	.39	250	21	8	150	20	1.1	464	7.4
AUG.																								
21...	1015	1060	5.8	58	6.0	40	170	0	52	42	.4	.16	.00	.02	.8	.23	292	23	18	170	31	1.3	522	7.0
28...	0700	700	9.0	60	7.7	73	199	0	72	66	.9	--	--	--	2.0	--	396	--	--	180	18	2.4	782	7.7
SEP.																								
14...	0700	2270	10	40	4.2	61	130	0	57	50	.5	--	--	--	3.2	--	301	--	--	120	10	2.5	514	7.5
26...	0945	1050	9.9	46	6.6	58	144	0	64	50	.5	.46	.00	.05	3.2	1.9	320	--	--	140	24	2.1	549	7.6

DATE	TEMPER-ATURE (DEG C)	COLOR (PLAT-INUM-COBALT UNITS)	TUR-BID-ITY (JTU)	DIS-SOLVED OXYGEN (MG/L)	PER-CENT SATUR-ATION	BIO-CHEM-ICAL OXYGEN DEMAND (MG/L)	PHENOLS (UG/L)	METHY-LENE BLUE ACTIVE SUB-STANCE (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED CHRO-MIUM (CR) (UG/L)	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED LITHIUM (LI) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED STRON-TIUM (SR) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)
OCT.																						
06...	25.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16...	27.0	--	--	7.6	94	3.0	0	.10	19	10	10	0	0	0	4	0	0	10	10	16	440	20
NOV.																						
14...	22.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29...	12.0	30	45	8.7	81	14	1	.15	16	--	--	--	--	--	--	--	--	--	--	--	--	--
DEC.																						
11...	7.0	40	25	8.1	66	7.6	0	.15	13	--	--	--	--	--	--	--	--	--	--	--	--	--
28...	20.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
JAN.																						
04...	10.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24...	14.0	50	50	7.6	73	12	2	--	16	--	--	--	--	--	--	--	--	--	--	--	--	--
FEB.																						
06...	14.0	110	170	10.0	96	2.7	2	--	20	50	0	0	0	0	0	80	0	0	0	14	320	40
14...	10.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MAR.																						
01...	12.5	30	40	7.4	69	6.6	1	.10	12	--	--	--	--	--	--	--	--	--	--	--	--	--
26...	10.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
APR.																						
02...	17.0	55	120	8.4	87	2.6	1	--	40	20	0	0	0	1	4	100	0	0	0	0	480	40
30...	18.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MAY																						
16...	22.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
21...	23.5	20	110	7.2	84	4.0	0	.00	12	--	--	--	--	--	--	--	--	--	--	--	--	--
JUNE																						
09...	23.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25...	28.0	30	240	7.4	94	1.5	0	--	18	--	--	--	--	--	--	--	--	--	--	--	--	--
JULY																						
09...	28.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26...	31.0	10	35	7.0	93	1.1	0	.00	11	--	--	--	--	--	--	--	--	--	--	--	--	--
AUG.																						
21...	29.0	20	10	8.2	105	.6	0	--	15	10	0	0	0	0	3	0	2	0	0	0	500	20
28...	28.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SEP.																						
14...	28.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26...	25.0	--	--	8.5	101	2.2	0	.12	18	--	--	--	--	--	--	--	--	--	--	--	--	--

Source: US-150

TABLE IV-4 (Continued)

WATER QUALITY OF TYPICAL GULF COASTAL STREAM (TRINITY RIVER, CROCKETT, TEXAS)

MONTHLY AND ANNUAL MEANS AND LOADS FOR WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973

MONTH	DISCHARGE (FT³/S)	SPECIFIC CONDUCT-ANCE (MICRO-MHOS)	DIS-SOLVED SOLIDS (MG/L)	DIS-SOLVED SOLIDS (TONS)	DIS-SOLVED CHLORIDE (MG/L)	DIS-SOLVED CHLORIDE (TONS)	DIS-SOLVED SULFATE (MG/L)	DIS-SOLVED SULFATE (TONS)	HARDNESS (CA, MG) (MG/L)
OCT. 1972....	52929	464	260	37200	40	5720	46	6570	140
NOV.	90110	448	250	60800	37	9000	45	10900	140
DEC.	59915	493	280	45300	45	7280	50	8090	140
JAN. 1973....	144000	457	250	97200	39	15200	46	17900	140
FEB.	186690	432	240	121000	34	17100	43	21700	140
MAR.	417040	329	180	203000	15	16900	30	33800	120
APR.	382540	322	170	176000	14	14500	30	31000	120
MAY	623810	359	190	320000	21	35400	34	57300	140
JUNE	680790	309	160	294000	12	22100	28	51500	110
JULY	176100	443	250	119000	36	17100	44	20900	140
AUG.	93929	495	280	71000	45	11400	50	12700	140
SEP.	64045	523	290	50100	51	8820	54	9340	150
TOTAL	2971898	--	--	1590000	--	181000	--	282000	--
WTD. AVG. ...	8142	368	200	--	22	--	35	--	130

WATER QUALITY DATA, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973

DATE	TIME	DIS-CHARGE (CFS)	TEMPER-ATURE (DEG C)	SUS-PENDED SEDI-MENT (MG/L)	SUS-PENDED SEDI-MENT DIS-CHARGE (T/DAY)	TOTAL SEDI-MENT DIS-CHARGE (T/DAY)	STREAM WIDTH (FT)	STREAM VELOC-ITY (FPS)	MEAN DEPTH (FT)	NUMBER OF SAM-PLING POINTS
NOV.										
08...	1140	3000	16.5	374	3030	3133	182	2.1	7.6	7
20...	1130	--	--	339	--	--	--	--	--	--
JAN.										
16...	1405	2130	7.0	175	1010	1070	170	2.0	6.2	3
31...	1115	--	--	742	--	--	--	--	--	--
MAR.										
27...	1500	22100	18.0	300	17900	18800	395	2.9	18	7
APR.										
19...	1510	16900	17.5	399	18200	18900	290	2.8	20	8
MAY										
15...	1340	13900	22.0	263	9870	10800	270	3.2	16	7
JUNE										
25...	1415	12900	27.5	520	18100	18800	265	2.9	16	7
JULY										
26...	1305	1460	32.0	124	489	497	162	1.5	5.9	6
31...	1135	--	--	946	--	--	--	--	--	--
SEP.										
25...	1245	--	--	23	--	--	--	--	--	--

SPECIFIC CONDUCTANCE (MICROMHOS/CM AT 25 DEG. C), WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973
RANDOM (INSTANTANEOUS)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	829	388	595	646	377	647	315	267	422	394	633	759
2	854	389	616	645	393	609	417	279	445	416	620	732
3	811	369	595	647	429	583	463	296	443	425	544	729
4	757	391	599	688	430	600	466	320	438	422	452	729
5	813	361	603	695	480	534	449	343	339	424	466	593
6	808	351	636	611	393	460	445	353	298	415	498	588
7	704	413	629	550	442	335	466	359	243	416	440	650
8	796	466	661	456	483	286	541	367	211	417	470	628
9	792	462	666	467	482	294	521	375	219	458	450	624
10	766	455	677	426	442	395	580	382	223	450	433	675
11	821	477	683	426	353	500	557	406	238	465	445	745
12	845	506	686	438	355	400	538	403	252	453	439	747
13	838	472	690	468	403	342	576	403	262	458	444	486
14	767	467	675	497	420	314	512	393	281	457	437	514
15	809	484	566	512	419	298	574	403	290	488	465	454
16	810	479	420	544	402	323	576	373	306	448	467	458
17	839	469	410	520	423	345	516	373	310	521	482	423
18	835	486	314	521	430	345	314	380	312	492	501	432
19	870	601	40[illegible]	533	500	340	281	392	320	458	516	507
20	873	620	404	575	524	332	260	408	338	500	520	547
21	810	598	443	592	478	356	265	420	352	412	523	588
22	754	585	468	590	471	375	293	435	368	421	562	556
23	693	513	485	592	473	376	316	404	415	428	613	514
24	750	537	512	614	533	320	334	394	405	438	629	527
25	641	599	515	582	537	277	303	405	395	418	649	496
26	472	610	518	418	596	283	286	379	361	462	676	543
27	470	607	539	421	670	265	266	382	383	495	690	544
28	480	503	596	400	623	254	246	408	398	524	702	493
29	490	501	59[illegible]	307	---	267	271	410	386	567	715	420
30	221	562	624	427	---	287	270	409	348	596	728	360
31	281	---	636	349	---	307	---	409	---	629	760	---
MONTH	719	491	563	521	463	376	407	378	333	463	547	568

DATE	TIME	ALDRIN (UG/L)	ALDRIN IN BOTTOM DE-POSITS (UG/KG)	DDD (UG/L)	DDD IN BOTTOM DE-POSITS (UG/KG)	DDE (UG/L)	DDE IN BOTTOM DE-POSITS (UG/KG)	DDT (UG/L)	DDT IN BOTTOM DE-POSITS (UG/KG)	DI-ELDRIN (UG/L)
NOV.										
20...	1130	.00	.0	.00	.0	.00	.0	.01	.0	.01
JAN.										
31...	1115	.00	--	.00	--	.01	--	.02	--	.02
JULY										
31...	1135	.00	.0	.00	.0	.01	.0	.00	.0	.06
SEP.										
25...	1245	.00	--	.00	--	.00	--	.00	--	.02

DATE	DI-ELDRIN IN BOTTOM DE-POSITS (UG/KG)	ENDRIN (UG/L)	ENDRIN IN BOTTOM DE-POSITS (UG/KG)	HEPTA-CHLOR (UG/L)	HEPTA-CHLOR IN BOTTOM DE-POSITS (UG/KG)	HEPTA-CHLOR EPOXIDE (UG/L)	HEPTA-CHLOR EPOXIDE IN BOT-TOM DE-POSITS (UG/KG)	LINDANE (UG/L)	LINDANE IN BOTTOM DE-POSITS (UG/KG)	CHLOR-DANE (UG/L)
NOV.										
20...	.6	.00	.0	.00	.0	.00	.0	.00	.0	.0
JAN.										
31...	--	.00	--	.00	--	.00	--	.00	--	.1
JULY										
31...	.7	.00	.0	.00	.0	.00	.0	.02	.0	.0
SEP.										
25...	--	.00	--	.00	--	.00	--	.00	--	.0

DATE	CHLOR-DANE IN BOTTOM DE-POSITS (UG/KG)	PCB (UG/L)	PCB IN BOTTOM DE-POSITS (UG/KG)	DI-AZINON (UG/L)	MALA-THION (UG/L)	METHYL PARA-THION (UG/L)	PARA-THION (UG/L)	2,4-D (UG/L)	SILVEX (UG/L)	2,4,5-T (UG/L)
NOV.										
20...	1	.0	0	.07	.00	.00	.00	.00	.00	.00
JAN.										
31...	--	.0	--	.08	.02	.00	.00	.04	.00	.02
JULY										
31...	0	.0	0	.13	.00	.00	.00	.05	.00	.03
SEP.										
25...	--	.0	--	.09	.00	.00	.00	.03	.00	.20

TABLE IV-4 (Continued)

WATER QUALITY OF TYPICAL GULF COASTAL STREAM (TRINITY RIVER, CROCKETT, TEXAS)

DATE	TEMPER-ATURE (DFG C)	COLOR (PLAT-INUM-COBALT UNITS)	TUR-BID-ITY (JTU)	DIS-SOLVED OXYGEN (MG/L)	PER-CENT SATUR-ATION	BIO-CHEM-ICAL OXYGEN DEMAND (MG/L)	PHENOLS (UG/L)	METHY-LENE BLUE ACTIVE SUB-STANCE (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)
OCT.											
06...	25.0	--	--	--	--	--	--	--	--	--	--
16...	27.0	--	--	7.6	94	3.8	0	.18	19	10	10
NOV.											
14...	22.0	--	--	--	--	--	--	--	--	--	--
29...	12.0	30	45	8.7	81	14	1	.15	16	--	--
DEC.											
11...	7.0	40	25	8.1	66	7.6	0	.15	13	--	--
28...	20.0	--	--	--	--	--	--	--	--	--	--
JAN.											
04...	18.0	--	--	--	--	--	--	--	--	--	--
24...	14.0	50	50	7.6	73	12	2	--	16	--	--
FEB.											
06...	14.0	110	170	10.0	96	2.7	2	--	20	50	0
14...	18.0	--	--	--	--	--	--	--	--	--	--
MAR.											
01...	12.5	30	40	7.4	69	6.6	1	.10	12	--	--
26...	18.0	--	--	--	--	--	--	--	--	--	--
APR.											
02...	17.0	55	120	8.4	87	2.6	1	--	40	20	0
30...	18.0	--	--	--	--	--	--	--	--	--	--
MAY											
16...	22.0	--	--	--	--	--	--	--	--	--	--
21...	23.5	20	110	7.2	84	4.8	0	.00	12	--	--
JUNE											
09...	23.0	--	--	--	--	--	--	--	--	--	--
25...	28.0	30	240	7.4	94	1.5	0	--	18	--	--
JULY											
09...	28.0	--	--	--	--	--	--	--	--	--	--
26...	31.0	10	35	7.0	93	1.1	0	.00	11	--	--
AUG.											
21...	29.0	20	10	8.2	105	.6	0	--	15	10	0
28...	28.0	--	--	--	--	--	--	--	--	--	--
SEP.											
14...	28.0	--	--	--	--	--	--	--	--	--	--
26...	25.0	--	--	8.5	101	2.2	0	.12	18	--	--

of the water has increased the in-stream salinity owing to loss of dilution, and return flows, particularly from irrigated agriculture, have materially added to the dissolved solids content. More important than these, however, is the widespread salt pollution from oil-field brines. Abandoned pits and poorly plugged or cased deep wells under artesian pressure have been of great local and even regional concern, although palliative and preventive measures have essentially reduced the current problem to local areas.

Most emphasis by regulatory authorities is being placed now on two other factors that may adversely affect water quality. Industrial and municipal (point source) discharges, abetted by hot weather and nearly stagnant flows, have created locally severe reductions in the dissolved oxygen content of some coastal streams, particularly the San Antonio River as tributary to the Guadalupe River, the Houston Ship Channel which is a natural tributary to Galveston-Trinity Bay, and the Trinity River. Some improvement in water quality has been affected in recent years by upgrading of treatment facilities. However, the problems are likely to be difficult to solve completely, since the low flows of these natural streams are generally effluent-dominated. The other area of current concern relates to the water quality of the major estuarine bays - Vermilion-Atchafalaya Bay, Sabine Lake, Galveston-Trinity Bay, Matagorda Bay, Lavaca Bay, and Corpus Christi Bay. The extensive industrial facilities co-located with these bays are often perceived as a long-term threat to water quality owing to chronic low-level pollution and the oil spill hazard; in addition, the hydrographic changes caused by sediment starvation due to upstream reservoir operation and the changes in nutrient supply by upstream developments may have detrimental effects on estuarine ecology.

Ground-Water Hydrology

The more continuous sandy strata that underlie the region are able to transmit water to varying degrees; these sands hydrologically coalesce into aquifers. There are two primary aquifers of regional extent, each of which is a very important source of ground water of potable quality over at least part of the region (WO-044).

The Wilcox-Carrizo aquifer of early Eocene age is an important fresh-water supply on and near its outcrop, along the inner Gulf Coastal Plain and in the East Texas embayment. The aquifer comprises hydrologically-connected sands in a consolidated or semi-consolidated sand-shale sequence. The permeabilities are spatially variable, but hydraulic conductivities average perhaps 30 gpd per square foot, or greater than one darcy equivalent, in those areas where this aquifer is used. The maximum thickness of the aquifer is about 3,000 feet down dip, but near the outcrop ranges from several to 1,500 feet.

Most of the region and virtually all of the outer Coastal Plain is underlain by a very thick aquiferous sequence of alternating unconsolidated to semi-consolidated sands, silts, and clays, which is designated the Gulf Coast aquifer. In large areas of Louisiana and Texas, the aquifer is separated by aquitards (extensive low-permeability zones with more clay than sand that retard the flow of water) of variable efficiencies, and the Gulf Coast aquifer is subdivided into two or more aquifers of large areal extent and thousands of feet thick. The subdivisions are usually based on differences in lithology, water levels in wells, and permeabilities. In some areas, particularly Southwestern Louisiana and Southeastern Texas, the sands are in excellent geohydrologic connection and the aquifer has very large transmissivities (LO-141). Permeability values of aquifers are commonly larger than 1,000 gpd per square foot, but an average value is much lower, perhaps 200 gpd per square foot.

At the outcrop of the individual sandy zones that comprise the Wilcox and Gulf Coast aquifers, the ground water is unconfined, and water-table conditions exist. The outcrops are the surface recharge areas of the aquifers where direct precipitation or infiltration from streams replenishes the aquifer. Under the influence of gravity and subsequently under hydrostatic pressure, water moves very slowly downdip in the sandy zones, generally toward the Gulf. Some water is discharged to surface streams. As the water moves Gulfward, it is confined by superjacent strata under increasingly greater hydraulic pressure, or head; the aquifer then is artesian or leaky artesian. Artesian pressure generally increases with depth if the ground water is not influenced by pumping. Water tends to move not only downward but also outward from these aquifers through aquitards in the direction of lower pressures, i.e., upward. Thus the confined aquifer receives recharge from leaky artesian aquifers below and, if not subjacent to an aquiclude, its water discharges upward into overlying strata. Faults may facilitate this movement by transposing strata of greater permeability or by providing an actual avenue for upward movement. In areas of extensive ground-water development such as the Houston-Galveston area, pumping may lower the head so that the natural hydraulic gradient is reversed and water moves downward into underlying aquifers. The water that is not discharged "naturally" by interformational leakage or artifically by pumping eventually (perhaps hundreds of thousands of years later) is discharged to the Gulf of Mexico, presumably through sediment on the continental slope.

Water quality ranges from fresh to very briny, depending on a number of factors. Water near the outcrop is fresh and of the sodium-calcium bicarbonate type, but becomes more saline with sodium chloride as it moves Gulfward. Consequently, at a given location water is progressively more saline generally with depth even within the same aquifer, although zones of especially high permeability may contain fresh water at considerable depths. In general, fresh water (containing less than 1000 mg/l dissolved solids) may be found in the Wilcox-Carrizo aquifer at depths as great as 5,000 feet and in the Gulf Coast aquifer typically to about 2,000 feet (less in the southern part of the region) (TE-231). Normal interformational leakage tends to degrade water quality, and salt domes may have a profound yet erratic adverse effect on the quality of proximal ground water, owing to fragmentation of the area into smaller reservoirs by faulting, dissolution of salt, and upward discharge of brine from much deeper strata via faults. Away from salt domes, the "background" water quality in the deeper aquifers ranges typically between 50,000 and 100,000 mg/l of dissolved solids, primarily sodium chloride, with locally substantial amounts of dissolved hydrogen sulfide and methane (CO-373).

Coastal Hydrodynamics and Water Quality

Few generalizations concerning Gulf characteristics are possible at the programmatic level; they are most appropriately addressed at the site-specific level owing to the large temporal and spatial variations in the near-shore Gulf. For comprehensiveness in the environmental description, however, the upper Gulf of Mexico is briefly and generally described in the following paragraphs.

Water circulation patterns in the Gulf are a complex interaction of wind, tides, bottom topography, fresh-water inflow, density and gravity. In the region of interest, i.e., the northeastern shelf, there is a general westward and southward sweep of surface currents at an average speed of from 0.7 to 1.0 knots west of the Mississippi Delta. Other surface currents in the western Gulf region converge with this current in a large region off the Coastal Bend area of Texas. Bottom currents, while also persistent, are generally substantially retarded with respect to surface current, perhaps by as much as an order of magnitude. Tides, which locally may influence currents appreciably by producing a shoreward component, are generally of the diurnal type, sometimes with an extended stillstand, and with an astronomical range of about 2.5 feet. Semi-diurnal tides with restricted ranges occur for a few days in some cycles. Meteorological tides commonly augment the astronomical tides by a few feet. Wind waves may average four or five feet, but are usually less during summer months when average wind speeds are less.

Water temperatures are variable with the season. During summer, average surface temperatures are fairly uniform at about 84°F, but during winter, a strong thermal gradient toward shore is established, with near-shore surface temperatures of approximately 65°F. Water salinity is quite variable, both spatially and temporally at several different scales. Salinity of waters on the Continental Shelf in the region of interest tends to be less than the open Gulf norm of 36 ppt. While summer salinities may be near the norm, offshore winds and fresh-water runoff tend to lower coastal salinities during winter to about 30 ppt. Density currents, chiefly reflecting the influence of fresh-water inflows, can cause much wider variations (tens of ppt) locally and over short time periods (hours). The extensive marshes and relatively high river runoff from the Louisiana coastal region create generally lower and quite variable salinities in that near-shore area. Broad areas as much as tens of miles offshore may have salinities as low as 10 ppt during parts of the year, even though not necessarily in an estuarine circulation system. Generally, a salinity differential of several ppt may be found between surface and bottom waters on the shelf.

c. Meteorology and Climatology

The Gulf Coast storage region considered in this study is composed of the Gulf of Mexico coastline extending from Corpus Christi, Texas eastward and northeastward to New Orleans, Louisiana.

The region may be characterized as humid, subtropical, and strongly moderated by the Gulf of Mexico. Due to its heat capacity, this large water body warms the air during the winter and cools it during the summer. Annual average temperatures are thus moderated and remain fairly constant throughout the region. Rainfall is abundant throughout the region but shows wide variation with average annual totals ranging from 28.5 inches per year at Corpus Christi to 56.8 inches at New Orleans. Due to proximity to water, fog formation is enhanced. Also enhanced is mean annual relative humidity, ranging from 75% inland to 80% along the immediate coastline (See Table IV-5 for local climatological data for selected stations).

On an annual basis, the entire Gulf Coast region is affected by prevailing southerly winds. Because of the orientation of large-scale pressure systems, prevailing winds along the Texas coastline are south-southeasterly and southeasterly. Along the Louisiana coast, the prevailing winds are southerly, turning

TABLE IV-5

CLIMATOLOGICAL DATA ALONG THE GULF COAST

Normals, Means, And Extremes

Station: CORPUS CHRISTI, TEXAS INTERNATIONAL AIRPORT Standard time used: CENTRAL Latitude 27° 46' N Longitude 97° 30' W Elevation (ground) 41 feet

Month	Temperatures °F Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year
(a)				10		10					36		36		32	
J	66.5	46.1	56.3	91	1971	25	1973	304	34	1.58	10.78	1958	0.03	1971	6.38	1958
F	69.8	49.3	59.6	88	1974	27	1974	199	48	1.95	9.24	1958	T	1974	2.99	1958
M	75.5	56.2	64.9	97	1971	29	1965	120	117	1.10	4.80	1974	T	1971	2.67	1945
A	82.1	63.4	72.8	97	1964	39	1971	0	238	2.15	8.04	1956	T	1960	7.19	1956
M	86.6	69.1	77.9	99	1973	47	1970	0	400	3.17	9.38	1968	T	1961	4.65	1968
J	91.2	73.6	82.4	97	1972	59	1970	0	522	2.67	13.35	1973	0.13	1969	4.72	1970
J	94.4	75.2	84.8	101	1964	64	1967	0	614	1.88	10.99	1942	0.00	1957	3.73	1961
A	94.8	75.4	85.1	100	1969	64	1967	0	673	3.20	12.44	1953	0.10	1952	6.38	1970
S	90.0	72.0	81.0	100	1965	54	1967	0	480	4.90	20.33	1967	0.78	1953	8.76	1967
O	84.1	63.7	73.9	93	1964	40	1964	7	243	2.77	10.66	1960	0.00	1952	7.25	1960
N	75.2	54.6	64.9	92	1965	29	1969	81	78	1.63	8.53	1947	T	1949	3.44	1947
D	69.3	48.9	59.1	90	1972	18	1973	219	37	1.53	7.80	1960	0.01	1950	3.86	1960
YR	81.6	62.1	71.9	101	JUL 1964	18	DEC 1973	930	3474	28.53	20.33	SEP 1967	0.00	JUL 1957	8.76	SEP 1967

Month	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct. Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F Max. (b) 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average station pressure mb. Elev. 44 feet m.s.l.
(a)	36		36		10	10	10	10	32	15	32	32		32	32	32	32	32	35	35	35	32	10	10	10	10	2
J	1.2	1940	1.1	1940	86	90	71	73	12.0	SSE	59	NE	1943	47	6.8	7	7	17	8	*	1	6	*	0	3	0	1017.2
F	1.1	1973	1.1	1973	84	88	65	66	12.9	SSE	52	N	1967	52	6.4	8	5	19	7	*	1	5	0	0	2	0	1018.0
M	T	1962	T	1962	85	88	63	66	14.0	SSE	56	S	1950	56	6.6	7	8	16	6	0	2	4	1	0	*	0	1010.5
A	0.0		0.0		87	90	65	70	14.4	SE	49	SE	1944	57	6.7	5	10	15	5	0	2	3	2	0	0	0	1012.2
M	0.0		0.0		89	91	66	71	13.0	SE	65	NW	1967	62	6.3	6	12	13	6	0	5	1	5	0	0	0	1010.0
J	0.0		0.0		89	93	65	69	12.1	SE	56	SE	1962	74	5.2	9	14	7	6	0	3	*	16	0	0	0	1011.4
J	0.0		0.0		87	93	57	63	11.7	SSE	40	S	1952	83	4.8	11	14	6	5	0	3	*	27	0	0	0	1013.8
A	0.0		0.0		87	93	61	66	10.9	SSE	120	SW	1970	78	4.8	12	12	7	6	0	4	*	25	0	0	0	1013.4
S	0.0		0.0		86	91	65	70	10.2	SE	72	E	1967	67	5.2	10	11	9	9	0	5	*	15	0	0	0	1011.9
O	0.0		0.0		86	90	61	69	10.0	SE	46	N	1959	69	4.6	13	10	8	7	0	3	1	4	0	0	0	1016.3
N	T	1959	T	1959	85	88	62	71	11.4	SSE	46	N	1951	57	5.7	9	9	12	6	0	1	3	*	0	*	0	1016.1
D	0.0		0.0		84	87	66	72	11.2	SSE	47	NW	1947	48	6.4	8	7	16	7	0	1	5	*	0	1	0	1016.8
YR	1.2	JAN 1940	1.1	FEB 1973	86	90	64	69	12.0	SSE	120	SW	AUG 1970	64	5.8	103	119	141	76	*	31	29	96	0	7	0	1014.8

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 105 in July 1934; lowest temperature 11 in February 1899; maximum monthly snowfall 6.0 in January 1897; maximum snowfall in 24 hours 5.0 in January 1897.

Normals, Means, And Extremes

Station: GALVESTON, TEXAS POST OFFICE BUILDING Standard time used: CENTRAL Latitude 29° 18' N Longitude 94° 48' W Elevation (ground) 7 feet

Month	Temperatures °F Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)				104		104					104		104		104	
J	59.4	48.3	53.9	77	1969	11	1886	365	20	3.02	10.39	1899	0.02	1909	5.38	1923
F	61.5	50.9	56.2	83	1932	8	1899	273	27	2.67	8.29	1881	0.09	1954	6.55	1952
M	66.0	55.9	61.0	85	1879	27	1943	187	83	2.60	9.49	1973	0.06	1953	8.10	1973
A	73.3	65.0	69.2	92	1953	38	1938	20	146	2.63	11.04	1904	0.01	1887	9.23	1904
M	80.0	71.8	75.9	93	1911	52	1954	0	338	3.16	10.50	1929	T	1889	6.23	1916
J	85.2	77.4	81.3	99	1918	57	1903	0	489	4.05	15.49	1919	T	1907	12.56	1961
J	87.4	79.0	83.2	101	1932	66	1910	0	564	4.41	18.74	1900	T	1962	14.35	1900
A	87.6	78.9	83.3	100	1924	67	1966	0	567	4.40	19.08	1915	0.00	1902	9.05	1915
S	84.6	75.3	80.0	96	1927	52	1942	0	450	5.60	26.01	1885	0.04	1924	11.65	1961
O	78.0	68.1	73.1	94	1952	41	1925	12	263	2.83	17.78	1871	T	1952	14.10	1901
N	68.8	58.2	63.5	85	1886	26	1911	105	60	3.16	16.18	1940	0.03	1903	9.01	1940
D	62.7	51.5	57.1	80	1918	18	1880	262	17	3.67	10.28	1887	0.23	1889	9.43	1964
YR	74.5	65.0	69.8	101	JUL 1932	8	FEB 1899	1224	3004	42.20	26.01	SEP 1885	0.00	AUG 1902	14.35	JUL 1900
											10.79	1975			7.71	1975

Month	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct. Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind: ‡ Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F Max. (b) 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average station pressure mb. Elev. 54 feet m.s.l.
(a)	104		104		35	87	57	87	93		103	103		84					103	103			88	104	104	104	*
J	2.5	1973	2.5	1973	84	85	77	80	11.6		53	S	1919	48					10	*			0	*	2	0	
F	15.4	1895	15.4	1895	82	84	74	77	11.8		60	N	1927	51					9	*			0	*	1	0	
M	T	1932	T	1932	84	85	74	79	11.9		50	SE	1952	56					8	0			0	0	*	0	
A	0.0		0.0		85	86	75	80	12.1		57	NW	1961	61					6	0			*	0	0	0	
M	0.0		0.0		82	84	73	77	11.5		66	W	1959	68					6	0			*	0	0	0	
J	0.0		0.0		80	81	70	73	10.7		62	SE	1921	76					6	0			1	0	0	0	
J	0.0		0.0		80	81	70	73	9.8		68	NW	1943	72					9	0			3	0	0	0	
A	0.0		0.0		78	81	69	73	9.4		91	E	1915	71					9	0			5	0	0	0	
S	0.0		0.0		78	81	68	75	10.1		100	NE	1900	68					9	0			1	0	0	0	
O	0.0		0.0		76	80	65	71	10.3		66	SE	1949	72					6	0			*	0	0	0	
N	0.0		0.0		81	84	72	77	11.2		54	N	1950	61					8	0			0	0	*	0	
D	0.2	1924	0.2	1924	82	86	77	80	11.3		50	NW	1954	49					10	0			0	*	1	0	
YR	15.4	FEB 1895	15.4	FEB 1895	81	83	72	76	11.0		# 100	NE	SEP 1900	64					96	*			11	*	4	0	

100 m.p.h. recorded at 6:15 p.m. Sept. 8 just before anemometer blew away. Maximum velocity estimated 120 from NE between 7:30 and 8:30 p.m.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

‡ Through 1964.

Source: NA-273

TABLE IV-5 (Continued)

CLIMATOLOGICAL DATA ALONG THE GULF COAST

Normals, Means, And Extremes

Station: LAKE CHARLES, LOUISIANA — MUNICIPAL AIRPORT. Standard time used: CENTRAL. Latitude 30° 07' N. Longitude 93° 13' W. Elevation (ground) 9 feet.

Month	Temp. °F Normal Daily maximum	Normal Daily minimum	Normal Monthly	Extremes Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F Heating	Cooling	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)				10		10					13		13		13	
J	61.6	42.9	52.3	79	1972	20	1970	415	21	4.04	12.69	1974	0.78	1971	3.60	1972
F	64.6	45.5	55.1	83	1972	26	1970	306	29	4.47	6.75	1969	0.80	1962	3.28	1963
M	70.0	50.5	60.3	86	1974	29	1968	200	54	3.84	7.40	1973	0.27	1971	4.91	1973
A	78.2	59.5	68.9	92	1965	36	1971	26	143	4.33	10.95	1973	0.64	1963	5.50	1973
M	84.3	66.0	75.2	93	1972	50	1971	0	316	5.06	11.01	1974	0.57	1963	4.20	1971
J	89.6	71.8	80.7	98	1969	56	1974	0	471	5.04	8.90	1968	0.84	1969	4.98	1964
J	91.2	73.6	82.4	99	1970	61	1967	0	539	6.55	10.06	1969	0.48	1962	3.63	1969
A	91.2	73.2	82.2	97	1970	61	1967	0	533	4.75	17.36	1962	1.07	1963	14.10	1962
S	87.9	68.8	78.4	96	1966	47	1967	0	402	4.13	19.96	1973	1.01	1962	7.88	1973
O	81.6	58.4	70.0	91	1971	36	1964	36	191	3.48	17.28	1970	T	1963	7.24	1970
N	71.1	49.2	60.2	88	1971	25	1969	177	93	4.08	7.30	1974	0.11	1967	3.51	1966
D	64.2	44.3	54.3	82	1966	24	1973	338	7	3.70	13.27	1967	3.36	1963	6.88	1971
YR	78.0	58.6	68.3	99	JUL 1970	20	JAN 1970	1498	2739	55.47	19.96	SEP 1973	T	OCT 1963	14.10	AUG 1962

Month	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct Hour 00	Hour 06	Hour 12	Hour 18 (Local time)	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility 1/4 mile or less	Temperatures °F Max. 90° and above (b)	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average station pressure mb. Elev. 12 feet m.s.l.
(a)	13		13		10	10	10	10	13	2	13	13			13	13	13	13	13	13	13	13	10	10	10	10	8
J	4.0	1973	0.6	1973	88	89	71	79	10.4	N	58	32	1962		7.2	6	5	20	9	*	3	9	0	0	5	0	1018.5
F	0.3	1968	0.3	1968	85	86	61	68	10.6	S	40	25	1971		6.0	9	5	14	7	0	3	3	0	*	3	0	1019.3
M	T	1968	T	1968	87	89	62	69	10.7	S	40	18	1973		6.4	7	9	15	7	0	4	6	0	0	1	0	1013.1
A	0.0		0.0		88	90	62	68	10.4	S	44	06	1973		6.6	6	9	15	6	0	4	3	*	0	0	0	1015.1
M	0.0		0.0		89	91	62	68	9.0	S	43	32	1973		5.9	8	12	11	8	0	8	2	1	0	0	0	1012.2
J	0.0		0.0		89	91	59	65	7.5	SSW	38	16	1974		5.4	9	13	8	7	0	9	1	16	0	0	0	1013.6
J	0.0		0.0		91	93	63	70	6.5	SSW	35	12	1974		6.4	6	14	11	10	0	14	*	23	0	0	0	1015.3
A	0.0		0.0		91	93	64	71	6.2	SSW	46	11	1964		5.9	6	15	10	11	0	14	1	20	0	0	0	1015.4
S	0.0		0.0		90	93	64	75	7.4	ENE	40	36	1971		5.6	9	11	10	9	0	9	3	10	0	0	0	1013.8
O	0.0		0.0		89	91	56	73	7.6	ENE	33	27	1973		4.5	14	9	8	5	0	3	5	1	0	0	0	1018.3
N	0.0		0.0		87	89	59	76	9.3	ENE	31	34	1962		5.3	10	9	11	7	0	3	6	0	0	1	0	1018.2
D	T	1963	T	1963	89	90	69	81	9.4	NE	32	31	1973		6.6	7	8	16	9	0	3	8	0	0	3	0	1018.8
YR	4.0	JAN 1973	0.4	JAN 1973	89	90	63	72	8.8	S	58	32	JAN 1962		6.0	95	121	149	95	*	76	48	71	*	13	0	1015.8

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 104 in August 1951; lowest temperature 12 in January 1948; maximum monthly precipitation 21.45 in May 1907. Maximum precipitation in 24 hours 16.01 in June 1947; maximum monthly snowfall 5.0 in February 1960; maximum snowfall in 24 hours 5.0 in February 1960.

Normals, Means, And Extremes

Station: NEW ORLEANS, LOUISIANA — NEW ORLEANS INT'L AIRPORT. Standard time used: CENTRAL. Latitude 29° 59' N. Longitude 90° 15' W. Elevation (ground) 4 feet.

Month	Temp. °F Normal Daily maximum	Normal Daily minimum	Normal Monthly	Extremes Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F Heating	Cooling	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)				28		28					28		28		28	
J	62.3	43.5	52.9	83	1957	14	1963	403	28	4.53	12.62	1966	0.54	1968	4.77	1955
F	65.1	46.0	55.6	85	1972	19	1970	299	35	4.82	10.56	1959	1.02	1962	5.60	1961
M	70.4	50.9	60.7	87	1963	26	1968	188	55	5.49	19.09	1948	0.24	1955	7.87	1948
A	78.4	58.8	68.6	91	1948	32	1971	29	137	4.15	10.47	1973	0.33	1965	4.35	1953
M	84.9	65.3	75.1	96	1953	41	1960	0	313	4.20	14.33	1959	0.99	1949	9.86	1959
J	89.8	71.2	80.4	100	1954	55	1972	0	462	4.74	8.87	1962	1.12	1952	4.19	1953
J	90.4	73.3	81.9	99	1951	60	1967	0	524	6.72	11.46	1954	3.45	1951	4.30	1966
A	90.8	73.1	81.9	100	1951	60	1968	0	524	5.27	11.77	1955	2.00	1952	3.06	1969
S	86.6	69.7	78.2	97	1954	42	1967	0	396	5.58	16.74	1971	0.24	1953	6.50	1971
O	79.9	59.8	69.8	92	1962	35	1968	40	189	2.28	6.45	1959	0.00	1952	3.23	1972
N	70.3	49.8	60.1	86	1973	24	1970	179	32	3.88	14.58	1947	0.21	1949	6.38	1953
D	64.2	43.3	54.8	84	1971	17	1962	327	11	5.13	10.77	1967	1.46	1950	4.85	1973
YR	77.7	58.9	68.3	100	JUN 1954	14	JAN 1963	1465	2706	56.77	19.09	MAR 1948	0.00	OCT 1952	9.86	MAY 1959

Month	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct Hour 00	Hour 06	Hour 12	Hour 18 (Local time)	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility 1/4 mile or less	Temperatures °F Max. 90° and above (b)	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average station pressure mb. Elev. 10 feet m.s.l.
(a)	28		28		26	26	26	26	26		15	15		1	26	26	26	26	26	26	26	26	28	28	29	28	2
J	0.1	1973	0.1	1973	84	86	67	73	9.5		33	28	1966	23	6.8	7	7	17	10	0	2	7	0	*	5	0	1018.8
F	2.0	1958	2.0	1958	82	84	62	68	10.2		43	26	1970	66	6.1	8	6	14	10	*	3	4	0	0	3	0	1019.4
M	T	1959	T	1959	82	84	60	65	10.2		37	18	1969	62	6.2	8	9	14	9	0	4	4	0	0	1	0	1014.2
A	0.0		0.0		85	88	60	66	9.8		35	07	1960	70	5.6	8	11	11	7	0	4	2	*	0	*	0	1016.0
M	0.0		0.0		86	89	60	65	8.3		55	36	1973	53	5.1	11	11	9	7	0	6	1	3	0	0	0	1013.2
J	0.0		0.0		88	89	62	67	7.0		48	05	1971	60	5.1	10	13	7	10	0	9	*	17	0	0	0	1014.1
J	0.0		0.0		89	90	66	73	6.3		36	24	1973	56	6.1	5	15	11	15	0	16	*	20	0	0	0	1015.6
A	0.0		0.0		89	91	66	73	6.1		42	33	1969	57	5.5	9	13	9	13	0	13	*	19	0	0	0	1015.8
S	0.0		0.0		87	89	66	74	7.5		69	09	1965	57	5.3	10	11	9	10	0	7	*	8	0	0	0	1013.7
O	0.0		0.0		85	88	59	73	7.7		40	17	1964	82	4.1	16	7	8	6	0	2	2	1	0	0	0	1016.7
N	T	1950	T	1950	84	86	60	74	8.9		30	31	1969	64	5.0	11	9	10	7	0	1	4	0	0	1	0	1018.8
D	2.7	1963	2.7	1963	84	86	67	75	9.3		46	28	1973	53	6.2	8	8	15	10	*	1	6	0	*	4	0	1018.3
YR	2.7	DEC 1963	2.7	DEC 1963	85	88	63	70	8.4		69	09	SEP 1965	59	5.6	111	120	134	113	*	68	31	68	*	15	0	1016.4

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 102 in June 1954 and earlier (City Office), lowest temperature 7 in February 1899; maximum monthly precipitation 25.11 in October 1937; maximum precipitation in 24 hours 14.01 in April 1927, maximum monthly snowfall 8.2 in February 1895; maximum snowfall in 24 hours 8.2 in February 1895.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degr

Source: NA-273

again to southeasterly in the eastern edge of the study region. Throughout the study region, the strongest monthly average winds occur during April with weakest monthly average winds in August and October. Figure IV-9 provides annual wind rose data with velocity distributions for the Gulf Coast region. "Extreme mile" winds, the fastest winds measurable at 30 feet above the ground, are caused by hurricanes or tropical storms. The area most often affected by these "extreme mile" winds extends from the upper Texas coast to the southeastern tip of Louisiana (See Figure IV-10). However, since these winds will be caused by hurricanes, the "extreme mile" winds will decrease slightly in inland areas.

Statistically, the probability of tropical cyclones achieving landfall along the Gulf Coast storage region is greatest in the 50-mile stretch of coastal land from Galveston County to mid-Jefferson County in Texas. A secondary maximum extends from fifty miles west of New Orleans to the city itself. The probability of landfall of a tropical cyclone for these two areas is 20% and 18%, respectively, well above the regional average of 13%. Figure IV-11 shows the probabilities of tropical cyclones along the Gulf Coast.

Severe local storms, including tornadoes, have a fairly high frequency of occurrence in the Gulf Coast region. In most cases, tornadoes moving through the region are small and short lived. Storms producing large hailstones (larger than two inches in diameter) are also quite rare in the area. Severe local storms, including those which produce tornadoes, are most common in March, April and May.

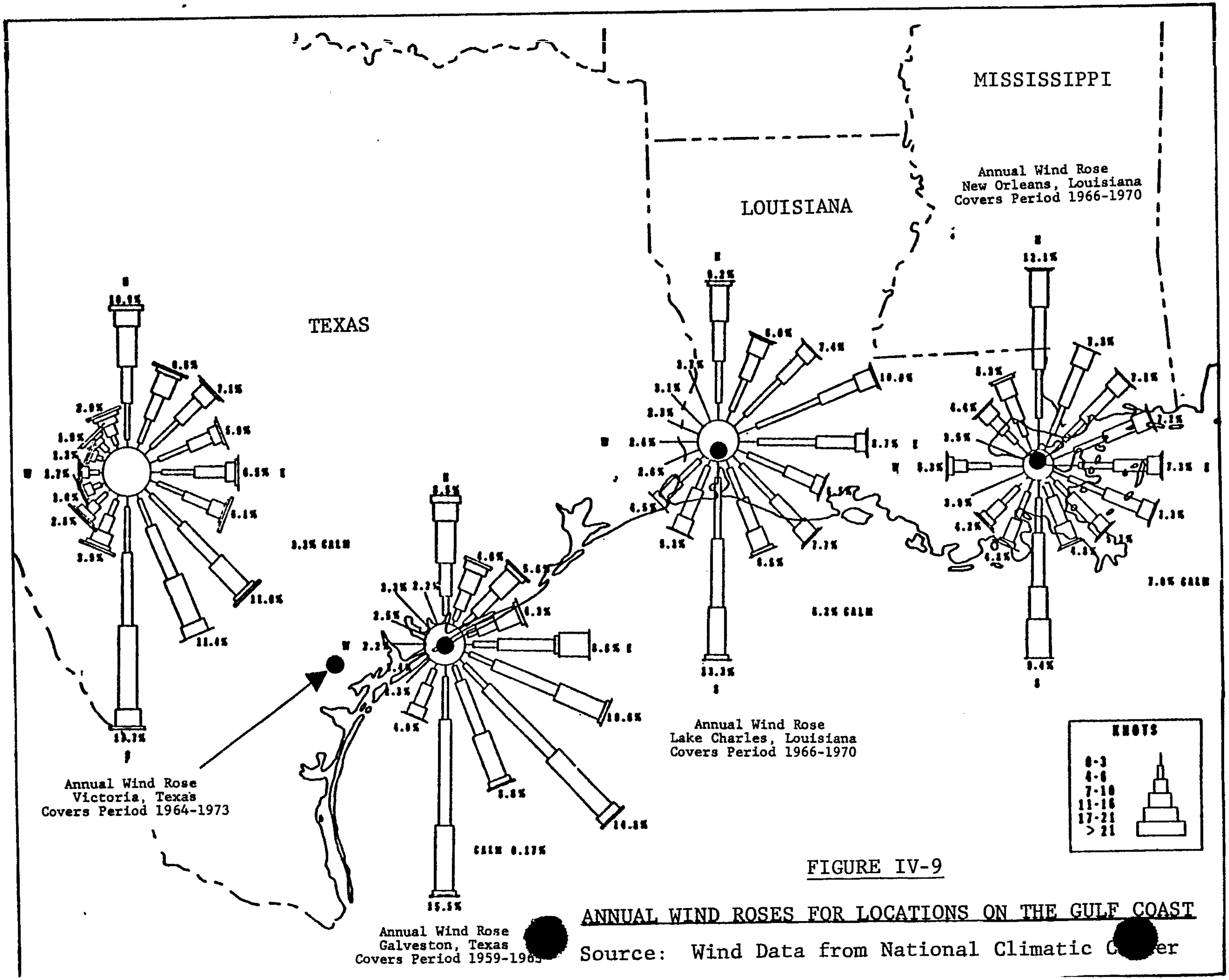
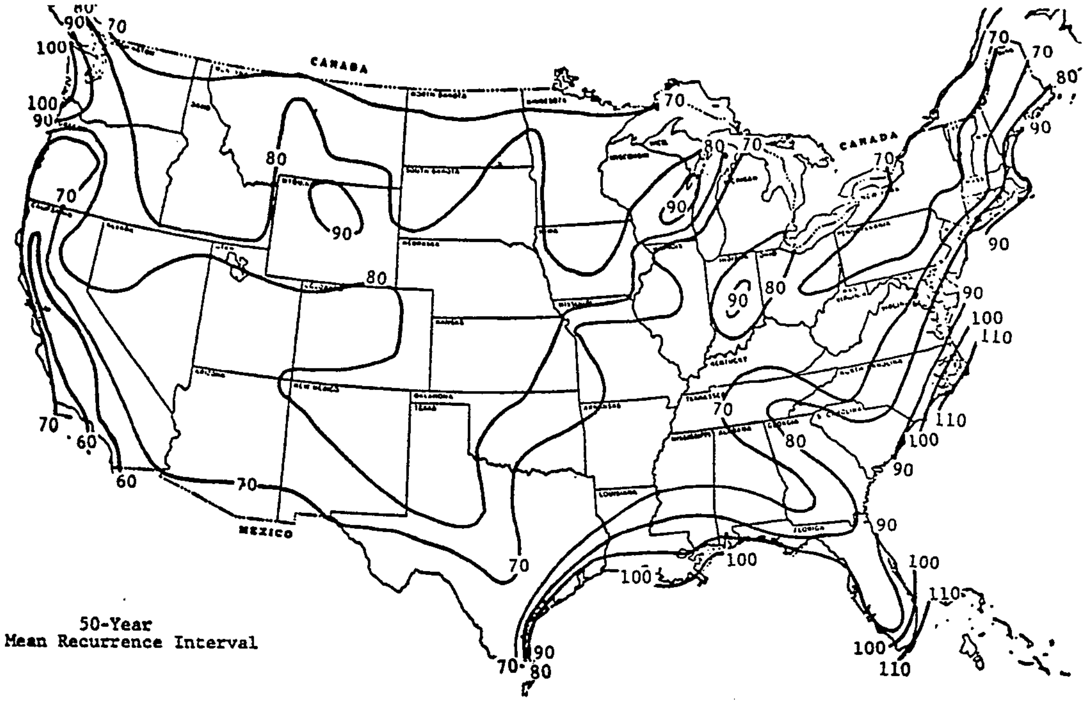


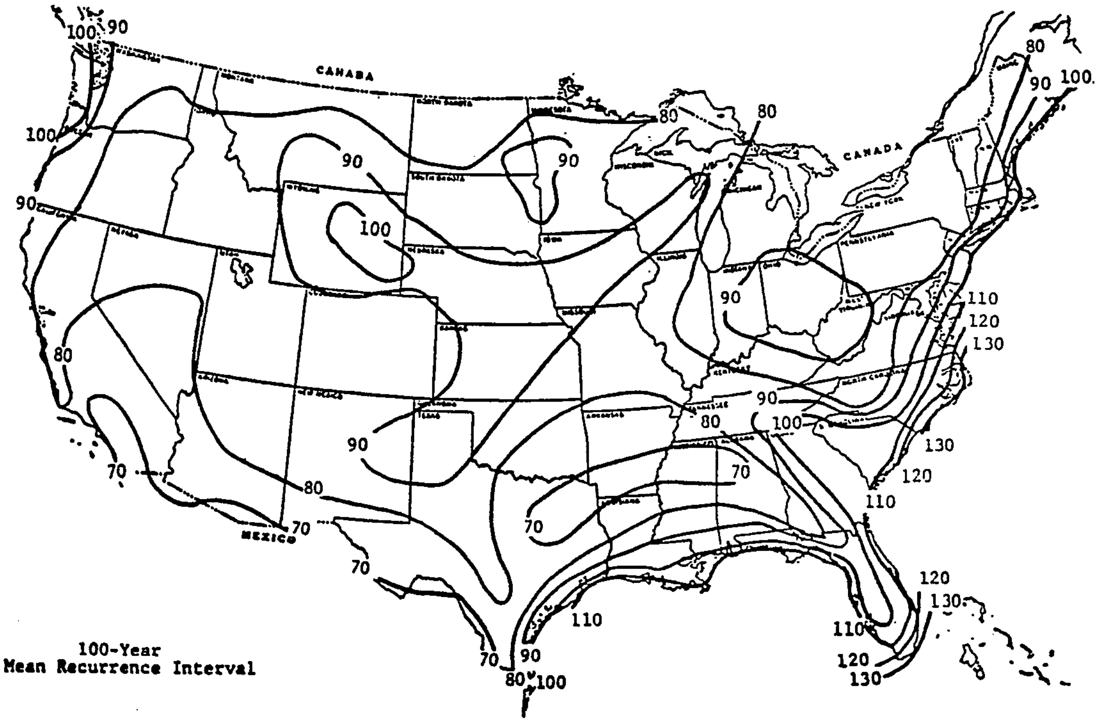
FIGURE IV-9

ANNUAL WIND ROSES FOR LOCATIONS ON THE GULF COAST

Source: Wind Data from National Climatic Center



This map shows the fastest winds or "extreme mile" winds measurable at 30 feet above the ground from any kind of storm or synoptic-scale pressure gradient. These isotachs depict the maximum sustained winds in the units of miles per hour.



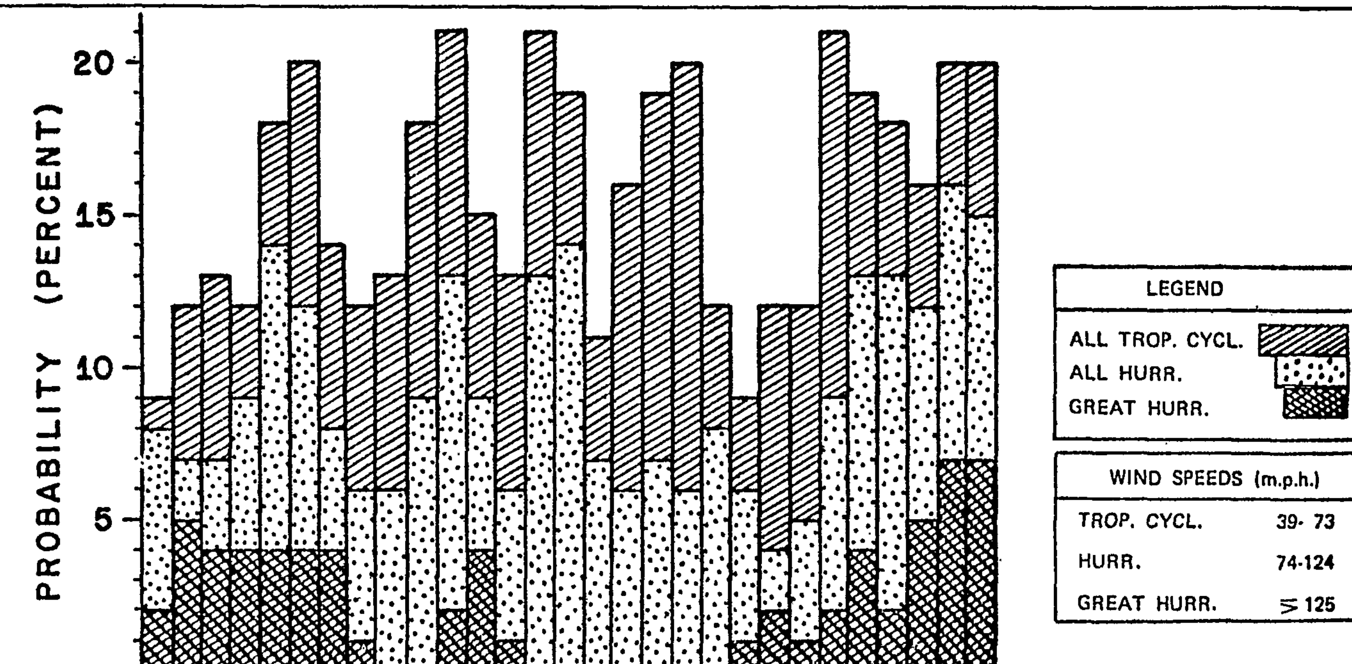
This map shows the fastest winds or "extreme mile" winds measurable at 30 feet above the ground from any kind of storm or synoptic-scale pressure gradient. These isotachs depict the maximum sustained winds in the units of miles per hour.

FIGURE IV-10

ISOTACHS OF "EXTREME MILE" WINDS AT 30 FEET ABOVEGROUND FOR 50- AND 100-YEAR MEAN RECURRENCE INTERVALS

Source: TH-079

This histogram and table show the probability (percent) that a tropical storm, hurricane, or great hurricane will occur in any one year in a 50 mile segment of the U.S. Gulf of Mexico coastline.



COASTAL SECTOR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
ALL TROPICAL CYCLONES	9	12	13	12	18	20	14	12	13	18	21	15	13	21	19	11	16	19	20	12	9	12	12	21	19	18	16	20	20
ALL HURRICANES	8	7	7	9	14	12	8	6	6	9	13	9	6	13	14	7	6	7	6	8	6	4	5	9	13	13	12	16	15
GREAT HURRICANES	2	5	4	4	4	4	4	1	–	–	2	4	1	–	–	–	–	–	–	–	1	2	1	2	4	2	5	7	7

TX | LA | MI-AL | FL

Source: NA-116, SI-110

FIGURE IV-11

RISK OF TROPICAL CYCLONES

FOR U.S. GULF OF MEXICO COASTLINE

Tidal wave height is also important in this region and has, therefore, been used as a criterion for screening storage sites. The candidate sites which have been identified would not be subjected to a five-foot tidal wave more than once in 50 years.

d. Air Quality

Air quality of the Gulf Coast storage region will be characterized on the basis of three geographical air quality control regions (AQCR's) defined by the United States Environmental Protection Agency for the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS) (see Section VI.B.5.a). The boundaries of two intrastate AQCR's, Corpus Christi-Victoria and Metropolitan Houston-Galveston, and one interstate AQCR, Southern Louisiana-Southwest Texas, approximately encompass the Gulf Coast region under study as shown in Figure IV-12.

Status of 1973 ambient air quality levels for the criteria air pollutants (suspended particulates, sulfur dioxide, carbon monoxide, and photochemical oxidants) is shown in Figures IV-13 through IV-16. These figures indicate which AQCR's had violations of the primary standards. All three AQCR's in the Gulf Coast region had at least one monitoring site reporting violation of the primary standards for suspended particulates and ozone.

Table IV-6 presents a summation of the average morning and afternoon mixing heights in the Gulf Coast region during each of the four seasons and on an annual basis. The table is for five representative points of the region: Corpus Christi,

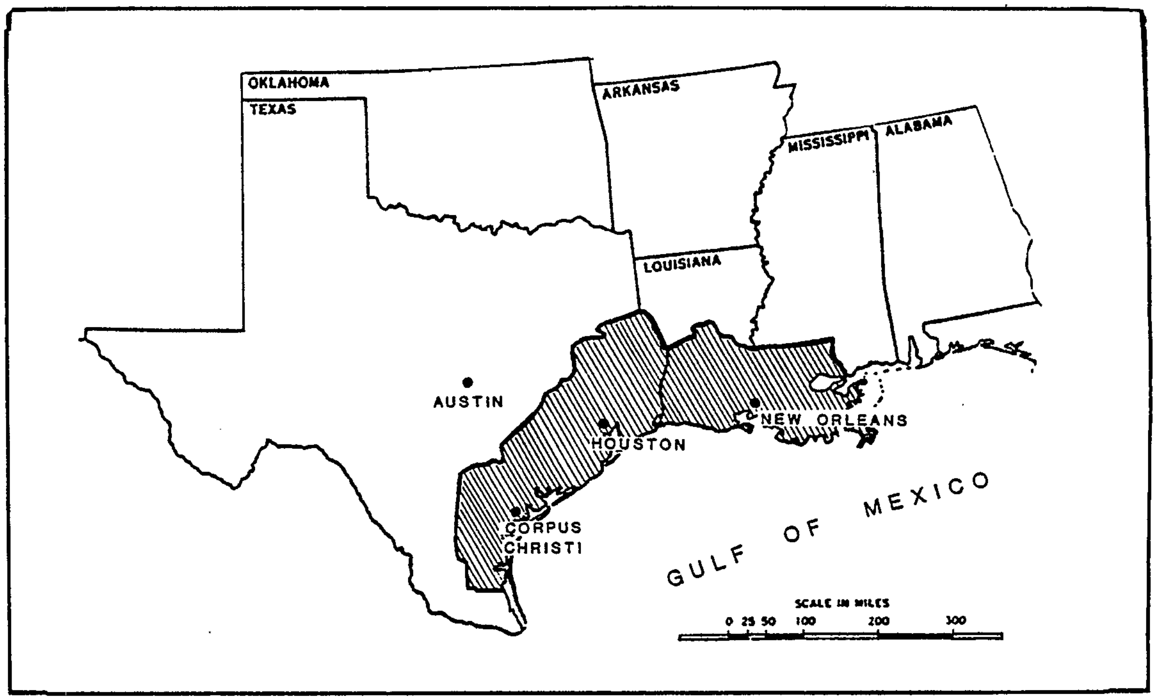


FIGURE IV-12

BORDER OF AQCR'S ENCOMPASSING GULF COAST STORAGE REGION

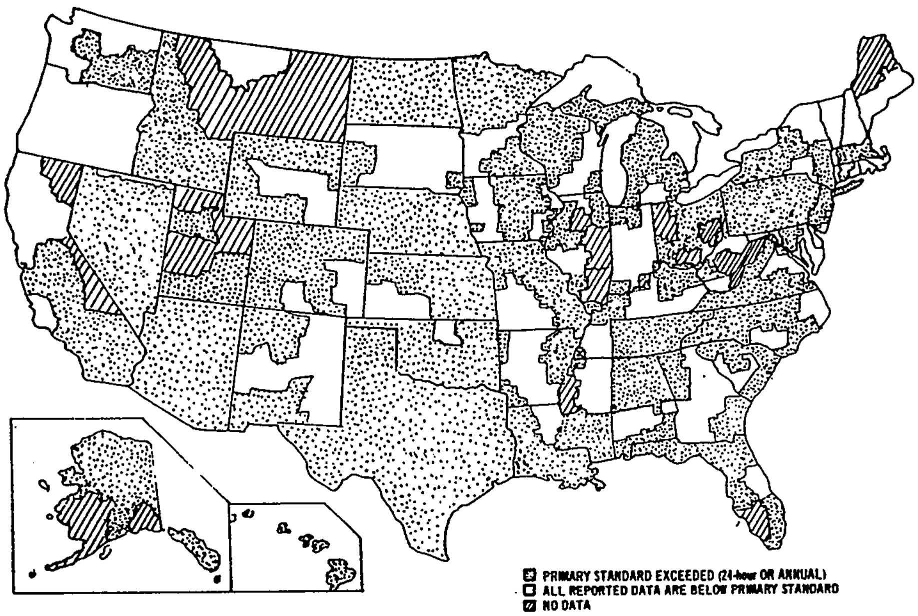


FIGURE IV-13

STATUS OF SUSPENDED PARTICULATE LEVELS, 1973

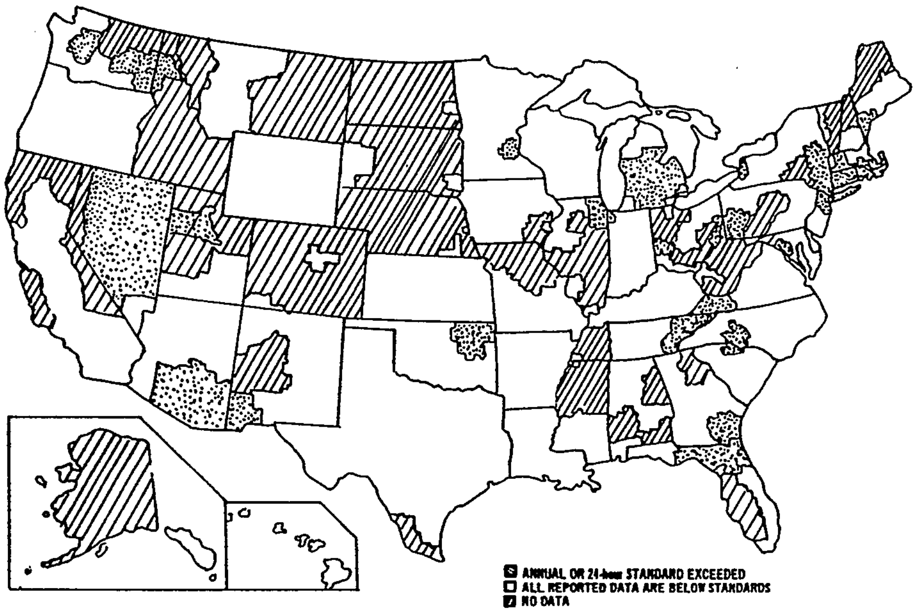


FIGURE IV-14

STATUS OF SULFUR DIOXIDE LEVELS, 1973

Source: EN-216.

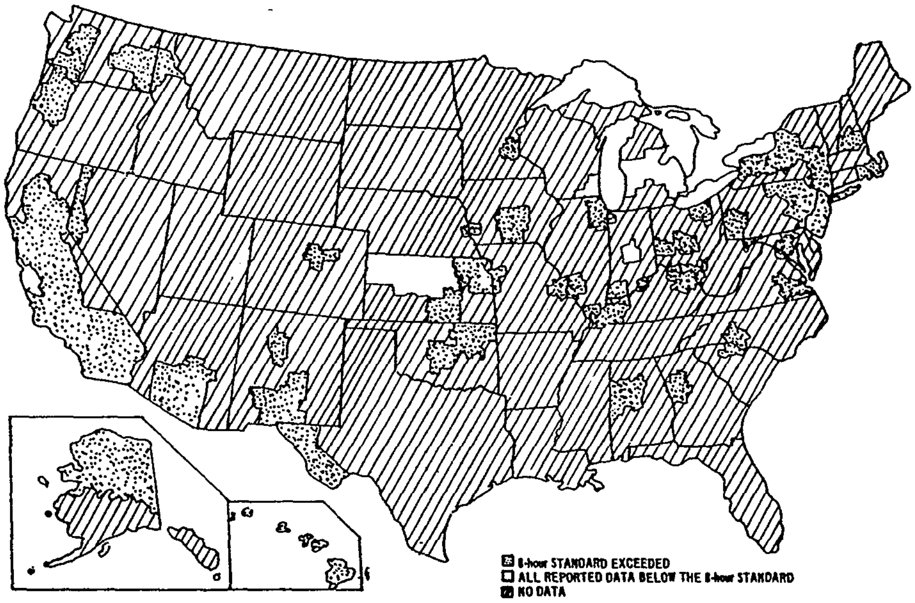


FIGURE IV-15

STATUS OF CARBON MONOXIDE LEVELS, 1973

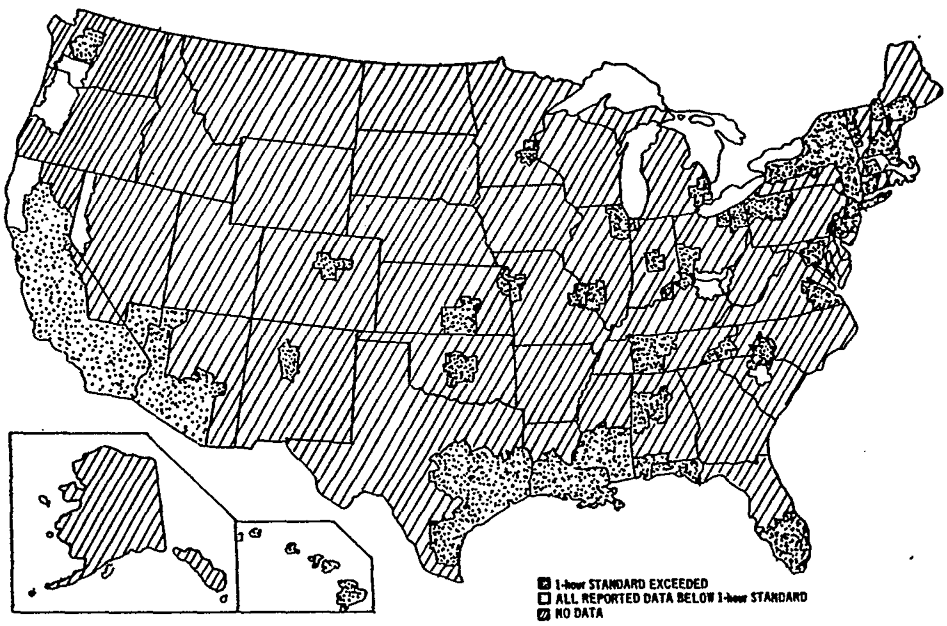


FIGURE IV-16

STATUS OF OXIDANT/OZONE LEVELS, 1973

Source: EN-216

TABLE IV-6

MIXING CONDITIONS IN THE GULF COAST REGION

Location	Period of Record	Mixing Height (in meters)		Wind Speed (in meters/second)	
		Morning	Afternoon	Morning	Afternoon
Corpus Christi, Texas	Winter	450	950	7.0	7.5
	Spring	650	1150	7.0	8.0
	Summer	750	1700	5.5	6.5
	Fall	525	1350	5.5	7.0
	Annual	600	1300	6.0	7.5
Galveston, Texas	Winter	425	900	7.0	7.5
	Spring	550	1100	6.0	7.0
	Summer	700	1450	5.0	5.5
	Fall	450	1300	5.0	6.5
	Annual	525	1150	5.5	7.0
South of Lake Charles, Louisiana	Winter	400	850	7.0	7.0
	Spring	500	1100	5.5	7.0
	Summer	600	1350	4.5	5.5
	Fall	400	1300	5.0	6.0
	Annual	475	1100	5.5	6.5
Southeastern Tip of Louisiana	Winter	600	750	7.5	7.0
	Spring	700	900	6.5	6.5
	Summer	1200	1200	4.0	5.0
	Fall	1100	1150	6.0	6.0
	Annual	900	950	6.0	6.0
New Orleans, Louisiana Vicinity	Winter	550	800	6.5	7.0
	Spring	600	1000	6.0	6.5
	Summer	900	1350	4.0	5.0
	Fall	800	1150	5.5	5.5
	Annual	750	1100	5.5	6.0

Source: HO-049

Galveston, south of Lake Charles, southeastern tip of Louisiana, and New Orleans vicinity. Average wind speeds through the mixing layer during each of the periods are also listed. The table indicates that the Gulf of Mexico increases morning mixing heights (when compared to inland stations) but decreases afternoon mixing heights.

Considering the Pasquill stability classes on an annual basis, the stability distributions are very similar throughout the Gulf Coast region. Those points closer to the coastline will have greater frequencies of occurrence of neutral stability ("D" stability) and smaller frequencies of occurrence of unstable ("A", "B", and "C" stabilities) and stable ("E & F" stability) classes because of the stronger winds and additional cloudiness which normally prevail at these locations. Using a few representative stations, the normal annual ranges for the Pasquill stability as determined by the STAR Program (a program which generates a table of the bivariate frequencies of wind speed and wind direction as a function of stability) in the region are as follows (NA-274):

A Stability:	1.1%
B Stability:	7.3 - 8.4%
C Stability:	10.9 - 12.9%
D Stability:	38.1 - 40.8%
E & F Stability:	39.6 - 40.0% (Source: NA-274)

e. Noise

Like many environmental parameters addressed in this EIS, detailed noise characterization requires knowledge of influences of a particular site for a storage system. For this programmatic level assessment, description of environmental noise is presented in a general manner but with characterizations that may be used in the impact section for assumed existing conditions.

Many measures have been devised to describe environmental noise and each is generally adapted to satisfy the specific objectives of a noise evaluation program. Of these measures, L_{dn} has been widely accepted in practice as the most useful for relating environmental noise levels to human response (EN-108). L_{dn} is the long-term equivalent A-weighted sound level with an adjustment to account for differences in response during daytime and nighttime periods.

Examples of typical noise levels measured as L_{dn} are illustrated in Figure IV-17. In general, noise will tend to increase with increasing population from rural conditions to downtown urban areas. Noise at specific storage locations will, of course, vary with proximity to transportation facilities such as airports, highways, and railroads.

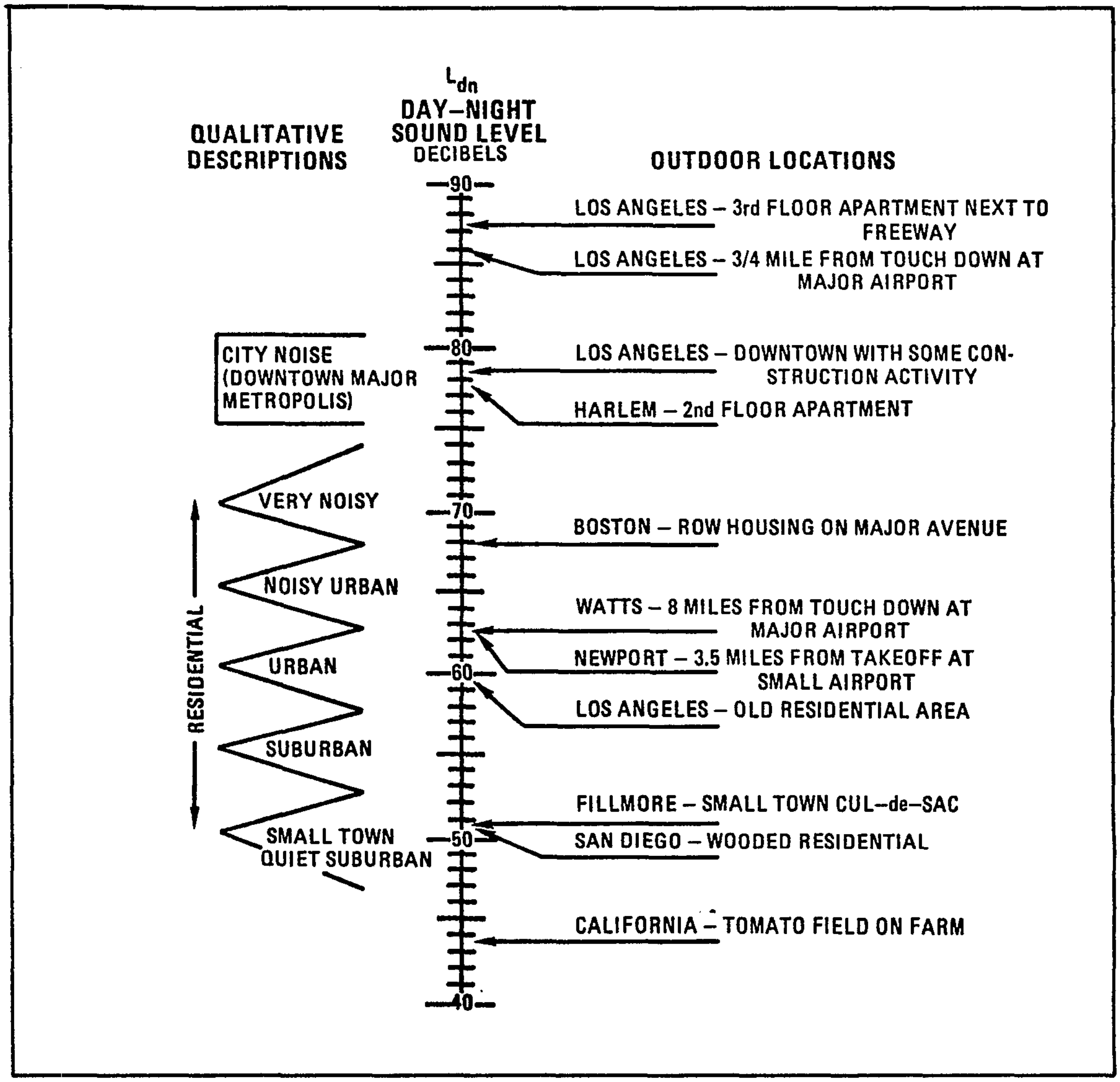
A means of estimating noise levels as a function of population density has been devised (GA-171). The expression

$$L_{dn} = 10 \log_{10} N + 22 \text{ dB},$$

where N = thousands of people per square mile,

provides a good estimate of noise within general urban residential areas removed from airports or freeways and with average traffic speeds. A graph of this expression is shown in Figure IV-18.

The two charts illustrate that if development and construction activities for the storage facilities cause the



Source: EN-108

FIGURE IV-17

OUTDOOR DAY-NIGHT SOUND LEVELS IN dB AT VARIOUS LOCATIONS IN THE UNITED STATES

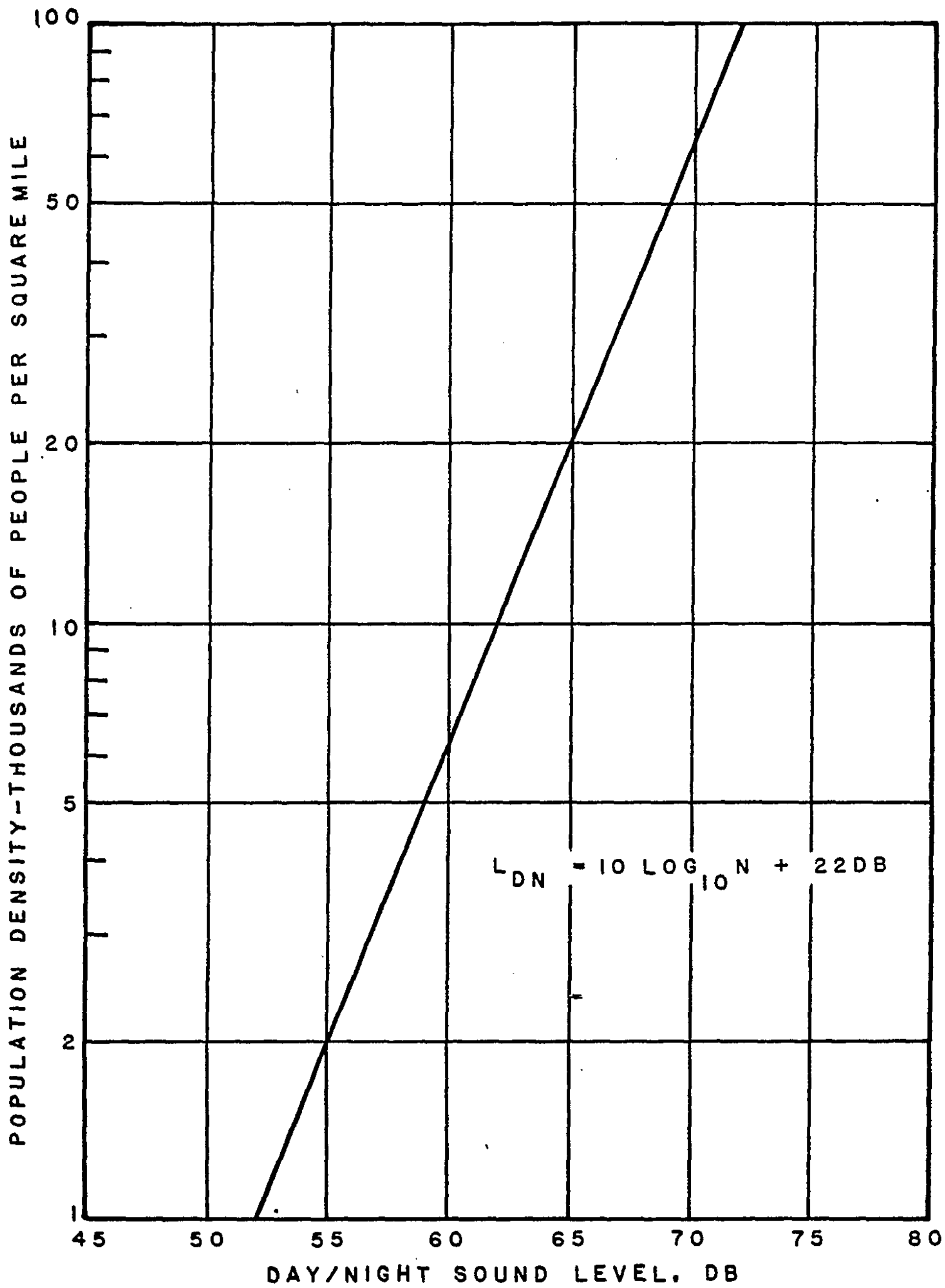


FIGURE IV-18

DAY/NIGHT SOUND LEVEL AS A FUNCTION OF POPULATION DENSITY

Source: GA-171

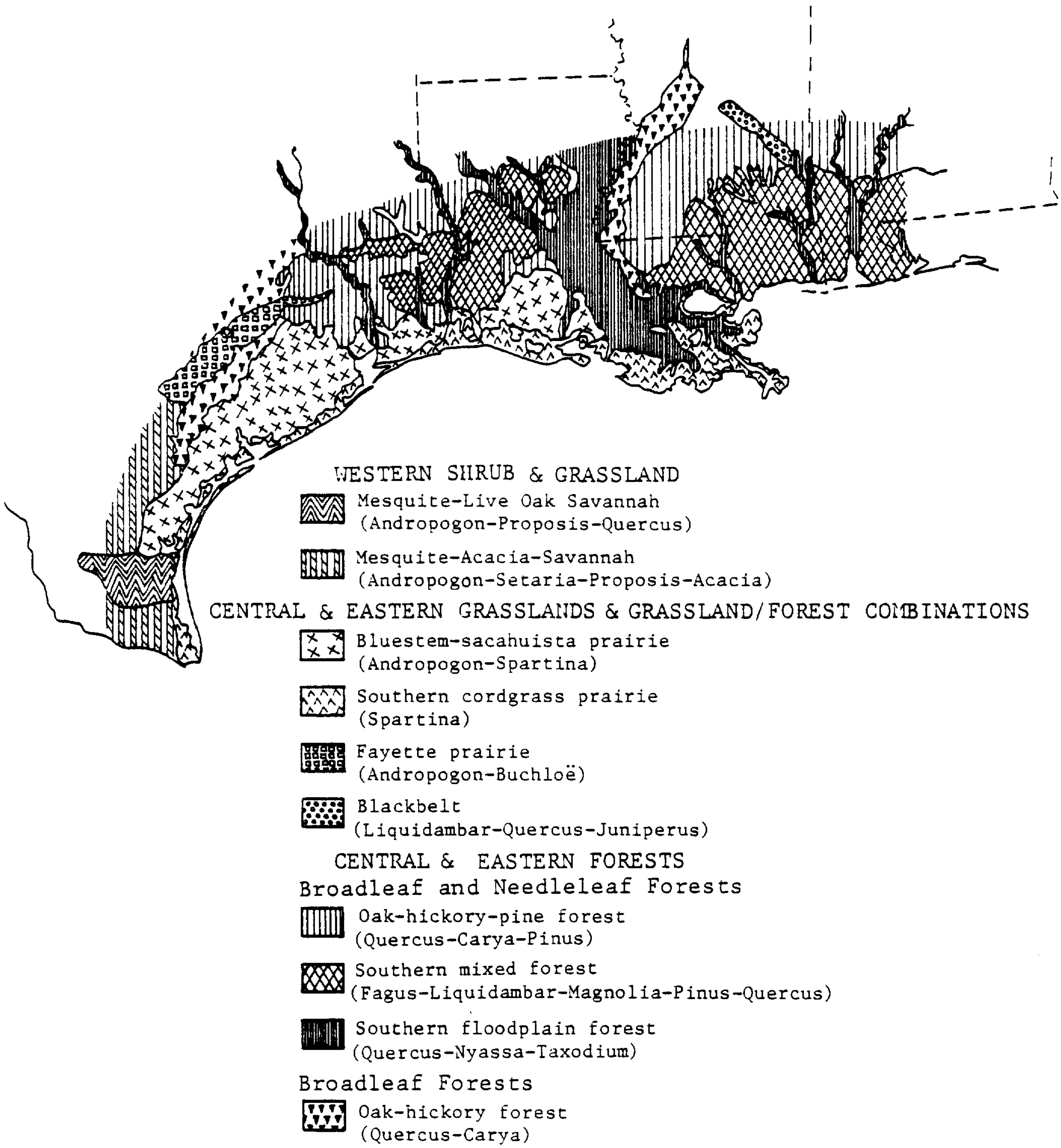
L_{dn} to be 45-50 dB, 50-55 dB, or 55-60 dB, this is equivalent to the normal background L_{dn} of areas classified as rural, small town/suburban and urban, respectively.

f. Biology

Characterization of the Region

For biological purposes, the Gulf Coast region will encompass the area from the Texas-Mexico border to the Louisiana-Mississippi border and from approximately 50 miles (or one county or parish) inland to the edge of the Continental Shelf in the Gulf. The terrestrial and wetlands ecology varies a great deal due to the climatic, geologic, and pedologic differences throughout the region. The marine fisheries vary somewhat less due to the mitigating influences of the Gulf of Mexico's more constant physical and chemical composition. Due to the large area of the Gulf Coast region, the biological descriptions will be somewhat broad in coverage. Only the major features and components will be emphasized at the programmatic level since site-specific EIS's will provide the detail where it is necessary. More detailed background information is presented for selected sections in RA-223.

The vegetation of the Gulf Coast region consists mainly of ten major associations. These are shown in Figure IV-19 as types of potential vegetation. Within these areas, considerable variation exists; however, the vegetation type listed is the major component or would be if nature was free from man's activities. The primary vegetation that stretches along the coast in a narrow band throughout the region is Southern cordgrass prairie. This includes all of the coastal wetlands and related transition vegetation. Various units of



Source: US-155

FIGURE IV-19

POTENTIAL NATURAL VEGETATION

these major areas are discussed in the following sections. The animal species vary considerably with specific changes in vegetation and other basic habitat factors. The region is temperate to semi-tropical; it contains few true tropical species and no high altitude or northern species except migrating birds in the spring and fall.

A large portion of the Gulf Coast region consists of wetlands. These are loosely defined as areas of aquatic inundation (tidal or fresh water) which contain vegetation and animals dependent on an aquatic or semiaquatic environment. These include swamps; fresh to salt marshes; and sand, mud, and algal flats. The wetlands are usually extremely variable. Many subunits are intermixed areas of both terrestrial habitat and open water.

This zone exports a large portion of its primary productivity to the aquatic system. A general diagram of this nutrient cycle is given in Figure IV-20. Not only the marsh areas, but also other areas within the transition zone exchange nutrients with the aquatic habitats. The exact type, quality and quantity of a particular wetland sub-unit depends on the microhabitat parameters such as elevation, rainfall, and amount of tidal inundation. The primary vegetation types are _Spartina alterniflora_, _Spartina patens_, various rushes, sedges, spike rushes, salt tolerant grasses, and algae.

The wetlands zone contains many types of animals. Many invertebrates (clams, worms, snails, etc.) burrow in the mud or survive on the surface of the plants. Small fish and the fry and larvae of many aquatic animals live or at least spend a part of their life cycle in the shallow waters of the wetlands. Many birds (ducks, geese, shore birds, etc.) spend

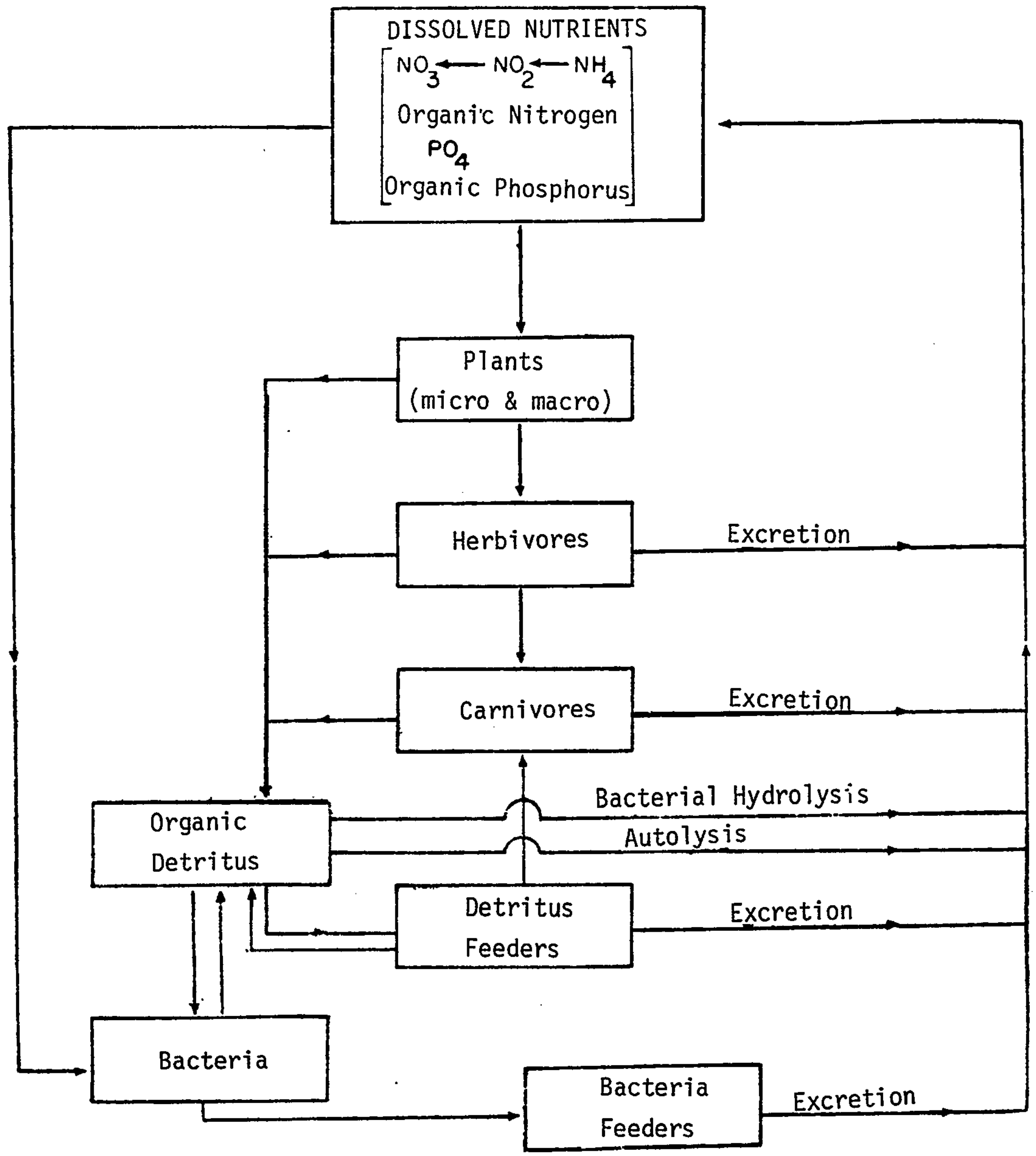


FIGURE IV-20

DIAGRAMMATIC DESCRIPTION OF NUTRIENT FLOWS THROUGH AQUATIC SYSTEMS

Source: DA-166

a portion of their life cycle in these highly-productive areas for the purposes of breeding, feeding, nesting, hiding, etc. Some mammals are found in the wetlands either as permanent residents (nutria, muskrat, raccoon, etc.) or just feeding (coyotes, foxes, bobcats, etc.). Many reptiles and amphibians also live in the wetlands. Most are permanent residents (alligators, snakes, frogs, toads, and turtles).

The aquatic areas are closely related to the wetlands on the one side and extend out to the open Gulf of Mexico on the other (Continental Shelf for this study). The vegetation consists of submerged grasses of several types, many types of algae and innumerable types of phytoplankton. The rooted grasses occur only in relatively shallow areas (less than two meters usually) where light can penetrate to the bottom. The deeper areas of the bays, inlets, and open Gulf contain phytoplankton as the primary "vegetation".

Several researchers have estimated that over one-half of the total organic production of the Gulf Coast estuary originates in the marshes. It is also well documented that the majority of marine species harvested in the nearshore Gulf and bays are dependent on the estuaries during at least part of their life cycle. The offshore areas of "banks", "reefs", and "holes" (i.e., any deviation from the normal, rather uniform bottom topography of the nearshore Continental Shelf) also harbor species of fish that are important to man (red snapper, grouper, etc.).

The majority of the bays and estuaries of the Gulf Coast region average less than three meters deep. Much of the area is actually less than one meter deep. These areas with their dense grass beds or oyster reefs provide the habitat for many of the estuarine fish or shellfish. The areas of open water also provide feeding grounds for many fish-eating birds and migratory ducks and geese.

Characterization of Environmental Types (Biotopes)

There have been several studies using various methods of characterizing the coastal environment of the Gulf of Mexico. Odum, Copeland, and McMahan (OD-012) have based their classification on "potential energy flow". Oppenheimer and Gordon (OP-018) have classified the biologic systems of the Texas coast into recognizable biotic assemblages called "biotopes" which have more or less uniform environmental conditions. Table IV-7 compares the units of these two systems.

These two classifications, when combined and applied to the Gulf Coast region, clearly characterize the coastal environment. Although they are derived from seemingly very different bases, they correlate well in their description of the actual environment that can be seen in the field. Even though the "biotopes" of Oppenheimer and Gordon were characterized in Texas, they fit very well in Louisiana due to similar conditions in East Texas and Louisiana.

Figures IV-21 and -22 show the major classifications of the Gulf Coast region as described by Odum and Copeland with the "biotope" classification of Oppenheimer and Gordon stated beside their counterpart type. The use of "biotopes" has been added for this study since large amounts of data are available concerning the components of each biotope. Also the biotope concept has already been used to measure impacts of development in various areas of the Texas Coast (OP-019, JO-180).

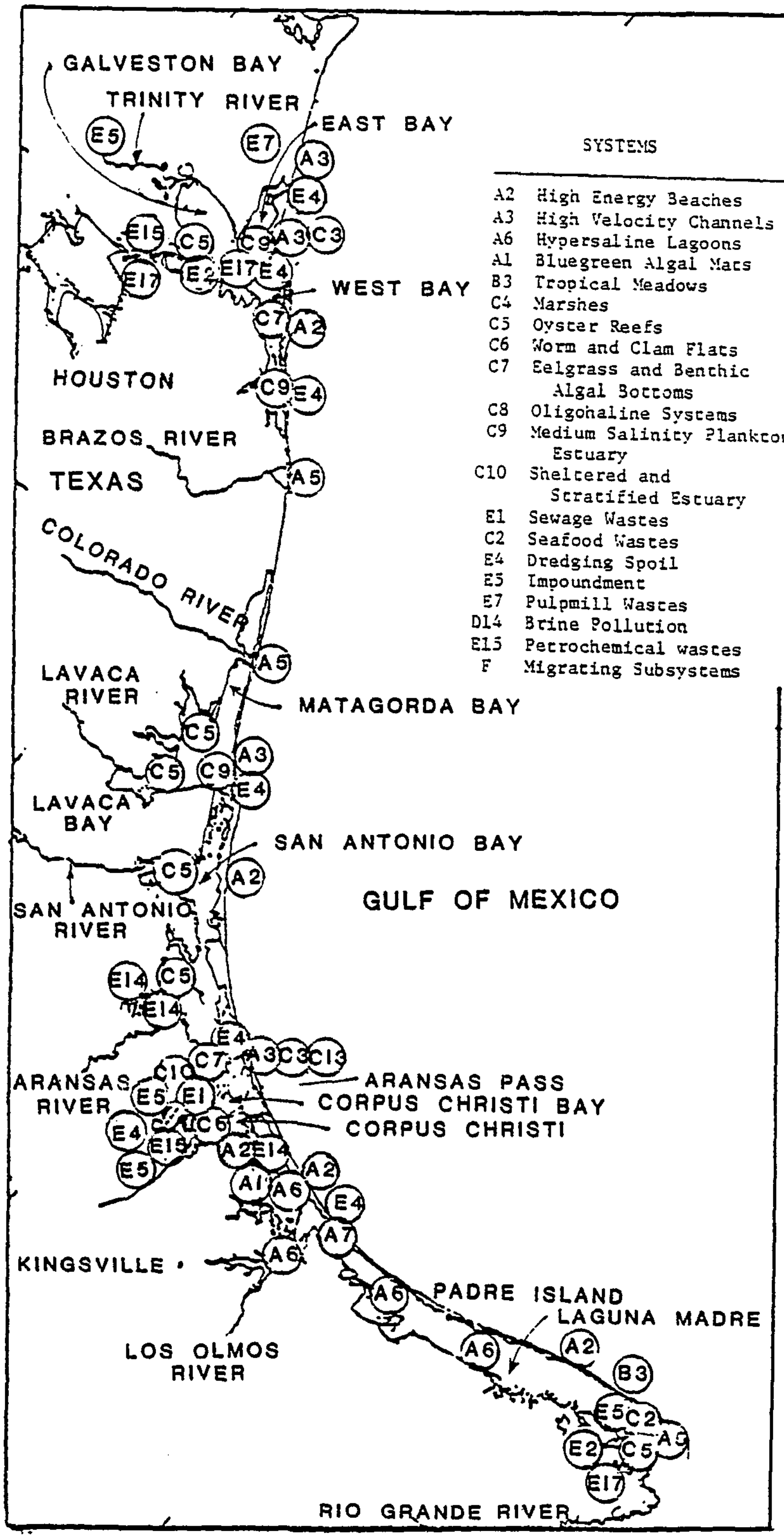
TABLE IV-7

CORRESPONDING BIOLOGIC UNITS

*BIOTOPES OF THE TEXAS COASTAL ZONE	†BIOTOPES OF THE COASTAL ECOLOGICAL SYSTEMS
Open Beach and Shelf	High Energy Beaches
Dune and Barrier Flat	None
Spoil Bank	Bird Islands and Dredge Spoil
Jetty and Bulkhead	Piling
Oyster Reef	Oyster Reef
Grass Flat	Tropical Meadows and Temperate Grass Flats
Salt Water Marsh	Marsh
Fresh Water Marsh	Marsh
Mud Flat	Worm and Clam Flats
Sand Flat	Worm and Clam Flats
Bluegreen Algal Flat	Bluegreen Algal Mat
Hypersaline	Hypersaline Lagoon
River Mouth	Oligohaline Systems
Bay Planktonic	Medium Salinity Plankton Estuary
Channel	High Velocity Channel
Prairie Grassland	None
Upland Deciduous Forest	None
River Floodplain Forest	None

* (OP-018).

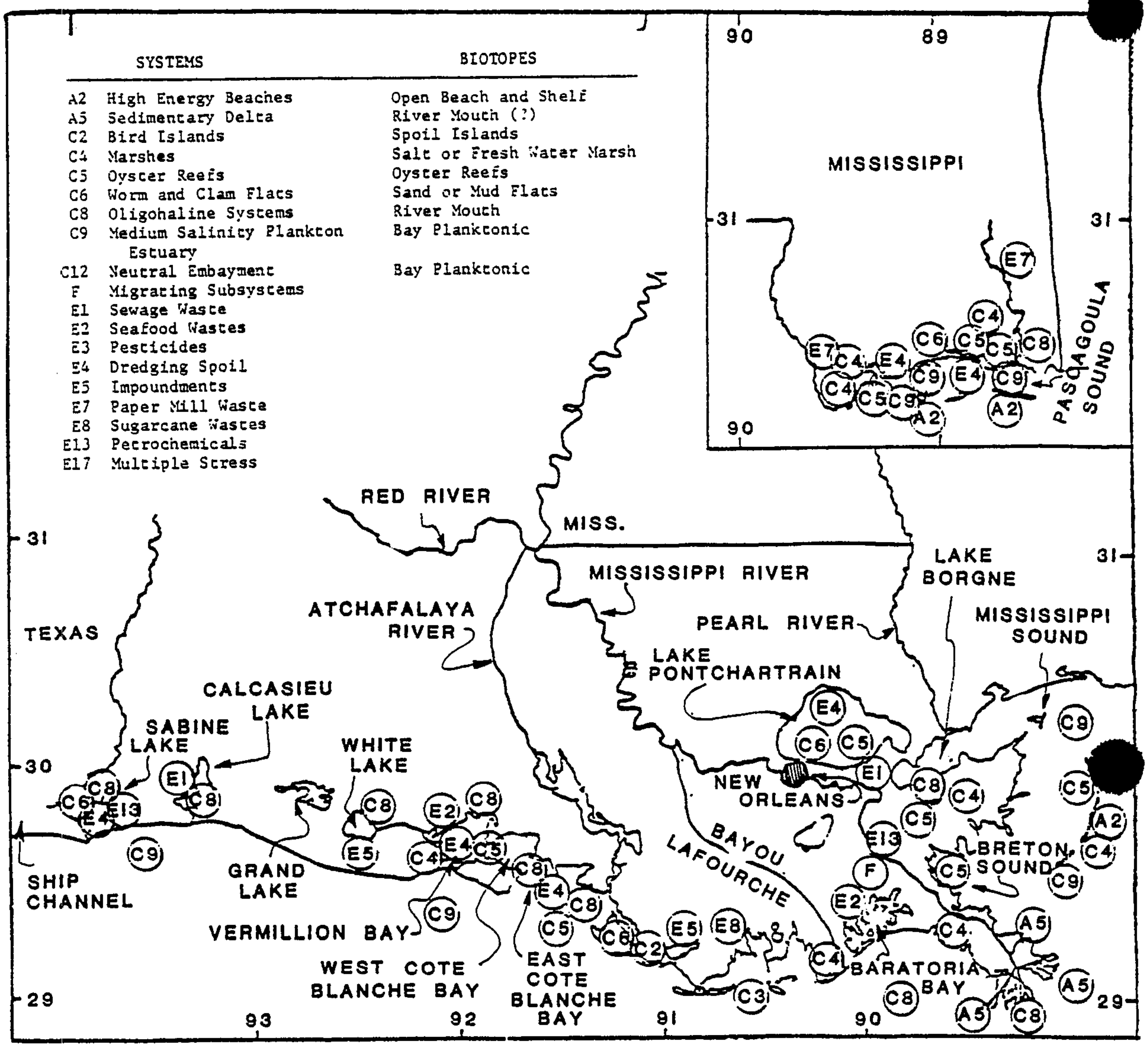
+ (OD-012).



SYSTEMS		BIOTOPES
A2	High Energy Beaches	Open Beach and Shelf
A3	High Velocity Channels	Channel
A6	Hypersaline Lagoons	Hypersaline
A1	Bluegreen Algal Mats	Bluegreen Algal Flats
B3	Tropical Meadows	Grass Flats
C4	Marshes	Salt and Fresh Water Marsh
C5	Oyster Reefs	Oyster Reefs
C6	Worm and Clam Flats	Sand or Mud Flats
C7	Eelgrass and Benthic Algal Bottoms	
C8	Oligohaline Systems	River Mouth
C9	Medium Salinity Plankton Estuary	Open Bay or Bay Plantonic
C10	Sheltered and Stratified Estuary	
E1	Sewage Wastes	
C2	Seafood Wastes	
E4	Dredging Spoil	Spoil Bank
E5	Impoundment	
E7	Pulpmill Wastes	
D14	Brine Pollution	
E15	Petrochemical wastes	
F	Migrating Subsystems	

FIGURE IV - 21
COASTAL ECOLOGICAL SYSTEMS OF TEXAS

Source: OD-012



SOURCE: OD-012

FIGURE IV-22

COASTAL ECOLOGICAL SYSTEMS OF LOUISIANA AND MISSISSIPPI

The biology of the Texas coast is currently being mapped by various state and Federal agencies; however, only some of the maps are finished. The Bureau of Land Management (U.S. Department of the Interior) has currently published several maps of the Gulf of Mexico containing some biological information. These can be found in RA-223. These maps provide an excellent picture of the biological resources of the Gulf Coast as a whole and specific information on the Gulf Coast region.

Commercially Important Species

Table IV-8 lists the commercially important aquatic organisms of the Texas coast and the amount caught in 1973. Tables IV-9 and -10 give comparable data by area for both the Louisiana and Texas coasts for 1971 and 1972, respectively, including the Gulf of Mexico. Figure IV-23 illustrates the area of the Gulf where various catches were made and the amounts of fish and shellfish. With the exceptions of red snapper and menhaden, over 90% of the species caught are estuarine-dependent during at least a portion of their life cycle.

The most valuable in terms of dollars are shrimp, oysters, red drum, sport and sea trout, red snapper, menhaden, and freshwater catfish, bullheads, and crayfish. The shrimp are by far the most important group of organisms to man in the coastal area of the Gulf Coast region. There are three major species of shrimp: white (*Penaeus setiferus*), brown (*Penaeus aztecus*), and pink (*Penaeus duorarum*). They provide a direct commercial harvest, and they are also one of the main food items for many estuarine and marine fish.

Water fowl are not commercially harvested; however, there are many commercial establishments that arrange hunting

TABLE IV-8

COMMERCIALLY IMPORTANT ORGANISMS

COMMON NAME	SCIENTIFIC NAME	TEXAS CATCH 1973 (pounds/kilogram)
Croaker	*Micropogon undulatus*	115,670/52,577
Drum, Black	*Pogonias cromis*	1,207,407/548,821
Redfish	*Sciaenops ocellatus*	1,680,147/763,703
Flounder	*Peralichthys*	354,600/161,182
Menhaden	*Brevoortia patronus*	43,059,600/19,572,545*
Mullet	*Mugil cephalus*	168,055/76,389**
Sea Trout, Spotted	*Cynoscion nebulosus*	1,991,769/905,350
Oyster	*Crassostrea virginica*	2,353,785/1,069,902
Blue Crab	*Callinectes sapidus*	6,737,549/3,062,522
Shrimp (Brown, White, Pink)	*Penaeus* sp.	80,969,481/36,804,310

*1970 Values
**Very productive but not a common table fish

(NA-295)

TABLE IV-9

LOUISIANA COMMERCIAL FISH LANDINGS BY DISTRICTS, 1971

Species	DISTRICT					
	Eastern		Central		Western	
Fish	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Bluefish	35	2	-	-	-	-
Bowfin	10	-	4,083	118		
Buffalofish	40,813	5,344	517,420	70,743	37,131	4,517
Cabio	101	5	3,326	275	150	6
Carp	10,169	840	4,194	176	3,238	125
Catfish and Bullheads	654,933	198,966	2,455,022	691,619	240,613	62,008
Croaker	106,146	12,548	187,936	27,234	260	8
Drum, black	231,856	19,547	272,620	16,129	1,194	103
Drum, red (Redfish)	417,407	86,365	293,117	47,580	12,267	2,636
Flounders, unclassified	143,249	28,208	289,120	43,641	30,771	5,588
Garfish	223,085	21,808	149,210	11,448	63,974	5,245
Groupers	194	17	2,414	186	316	53
Herring, Thread	3,221,360	51,542	-	-	502,500	7,602
Jewfish	65	3	2,338	210	-	-
King Whiting or "Kingfish"	171,534	17,954	252,195	14,112	7,322	424
Menhaden	*	*	603,212,400**	9,773,734**	633,880,300	10,241,189
Mullet	3,416	151	4,777	241	-	-
Paddlefish or Spoonbill	-	-	-	-	1,297	97
Pompano	1,480	1,472	17,764	15,280	-	-
Sawfish	165	8	35	2	-	-
Sea Catfish	26,890	3,852	38,303	2,219	-	-
Sea Trout, spotted	611,275	170,107	510,145	126,395	622	154
Sea Trout, white	58,708	7,139	72,853	8,341	-	-
Sharks	230	11	675	35	-	-
Sheepshead, fresh-water	8,356	1,026	184,839	16,006	7,272	870
Sheepshead, salt-water	103,022	6,222	135,845	7,395	247	17
Snapper, red	17,246	5,916	138,682	45,983	5,755	1,789
Spanish Mackerel	18,970	1,389	20,675	1,730	-	-
Spot	5,964	412	12,411	708	-	-
Tripletail	3,908	419	3,667	239	-	-
TOTAL FISH	5,080,587	641,273	608,786,066	10,921,779	634,795,229	10,332,431
Shellfish	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Crabs, blue, hard	6,954,947	733,722	4,494,311	440,072	736,460	82,079
Crabs, blue, soft and peeler	120,541	122,313	6,168	3,457	-	-
Crawfish, fresh-water	574	126	1,541,474	328,885	-	-
Shrimp, fresh-water	-	-	4,881	1,220	-	-
Shrimp, salt-water (heads-on)	26,730,202	10,845,106	49,449,800	22,597,473	16,295,419	9,841,329
Oysters (meats)	5,716,938	2,703,673	4,810,444	1,933,622	-	-
Squid	1,010	80	2,088	126	-	-
Terrapin	372	141	250	88	-	-
Turtles, sea	7,723	1,843	130	13	-	-
Turtles, snapper	5,503	1,273	2,402	680	-	-
Frogs	-	-	5,905	3,082	-	-
TOTAL SHELLFISH	39,537,810	14,408,277	60,317,043	25,308,718	17,031,879	9,923,408
GRAND TOTAL	45,618,397	15,049,550	669,103,109	36,230,497	651,827,108	20,255,839

* Included with landings of another district
** Includes landings of another district

Source: EN-333

TABLE IV-10

TEXAS COMMERCIAL FISH LANDINGS BY AREA, 1972

Species	Gulf of Mexico		Sabine Lake		Galveston and Trinity Bays	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Fish						
Cabio (Ling)	22,600	2,645	-	-	-	-
Croaker	22,500	1,241	-	-	8,900	817
Drum, black	45,000	5,467	-	-	72,700	7,970
Drum, red (Redfish)	97,900	25,812	-	-	33,600	8,433
Flounders	331,900	83,296	-	-	21,100	6,186
Grouper	97,500	10,729	-	-	-	-
King Whiting	92,800	8,365	-	-	15,700	1,469
Mullet	18,300	922	-	-	59,400	2,849
Pompano	1,200	461	-	-	-	-
Sea Catfish	6,000	436	-	-	3,200	216
Sea Trout, spotted	261,800	68,739	-	-	128,400	32,764
Sea Trout, white	500	60	-	-	18,700	2,677
Sheepshead	81,500	8,162	-	-	27,900	3,000
Snapper, red	1,238,000	571,984	-	-	-	-
Unclassified for food	78,200	4,980	-	-	44,900	3,130
Unclassified for bait, reduction, and animal food	4,900	247	-	-	59,200	2,013
TOTAL FISH	2,400,600	793,546	-	-	493,700	71,524
Shellfish						
Crabs, blue	14,400	1,141	1,288,700	127,369	1,870,100	191,649
Oyster (meats)	-	-	-	-	3,259,700	2,114,613
Shrimp, brown and pink (heads-on)	78,095,200	64,355,036	-	-	1,398,500	430,982
Shrimp, white (heads-on)	10,849,800	10,287,414	9,300	4,698	2,956,700	2,132,363
Shrimp, other	24,500	6,161	-	-	-	-
Squid	2,700	375	-	-	2,400	334
TOTAL SHELLFISH	88,986,600	74,650,127	1,298,000	132,067	9,487,400	4,869,941
GRAND TOTAL	91,387,200	75,443,673	1,298,000	132,067	9,981,100	4,941,465

Species	AREA					
	Matagorda, East Matagorda and Lavaca Bays		San Antonio, Mesquite, Espiritu Santo Bays, and Green Lake		Aransas and Copano Bays	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Fish						
Croaker	-	-	1,300	56	6,000	292
Drum, black	50,600	6,505	28,000	3,066	91,700	10,704
Drum, red (Redfish)	76,900	21,175	55,500	16,730	264,100	86,489
Flounders	23,900	7,414	6,700	2,035	36,800	11,942
King Whiting	-	-	-	-	-	-
Mullet	3,000	185	1,800	72	8,100	356
Pompano	-	-	-	-	300	122
Sea Catfish	6,300	470	2,600	198	9,200	1,176
Sea Trout, spotted	23,000	34,740	49,000	14,664	228,100	76,597
Sea Trout, white	800	122	-	-	-	-
Sheepshead	18,100	1,761	13,400	1,443	18,400	1,015
Unclassified for food	3,100	276	-	-	900	46
Unclassified for bait, reduction, and animal food	-	-	47,200	2,314	20,300	897
TOTAL FISH	305,700	72,648	205,500	40,578	683,900	189,636
Shellfish						
Crabs, blue	882,000	89,931	995,500	99,539	1,338,900	135,518
Oyster (meats)	214,900	132,703	398,000	219,031	60,600	40,145
Shrimp, brown and pink (heads-on)	238,100	44,345	91,800	16,812	137,500	18,667
Shrimp, white (heads-on)	1,294,300	965,150	959,100	592,144	1,072,600	897,170
Squid	200	35	100	19	-	-
TOTAL SHELLFISH	2,629,500	1,232,164	2,444,500	927,545	2,609,600	1,091,500
GRAND TOTAL	2,935,200	1,304,812	2,650,000	968,123	3,293,500	1,281,136

Species	AREA					
	Corpus Christi and Neuces Bays		Baffin Bay and Upper Laguna Madre		Central and Lower Laguna Madre	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Fish						
Croaker	1,200	67	1,700	84	16,700	857
Drum, black	102,900	11,897	493,500	62,999	280,500	26,776
Drum, red (Redfish)	101,500	31,497	244,300	72,761	594,000	145,902
Flounders	8,500	2,505	10,300	2,867	14,600	3,490
Mullet	400	51	700	60	-	-
Pompano	300	132	1,000	420	2,200	1,038
Sea Catfish	1,000	158	200	11	-	-
Sea Trout, spotted	88,900	27,317	272,900	80,906	347,300	84,341
Sheepshead	8,400	421	50,700	2,804	19,000	1,028
Unclassified for bait, reduction and animal food	3,700	158	-	-	-	-
TOTAL FISH	316,800	74,203	1,075,300	222,912	1,274,300	263,432
Shellfish						
Crabs, blue	70,700	7,065	4,100	427	-	-
Oyster meats	-	-	-	-	1,200	710
Shrimp, brown and pink (heads-on)	53,500	7,710	-	-	-	-
Shrimp, white (heads-on)	397,000	340,079	-	-	-	-
TOTAL SHELLFISH	521,200	354,854	4,100	427	1,200	710
GRAND TOTAL	838,000	429,057	1,079,400	223,339	1,275,500	264,142

Source: EN-333

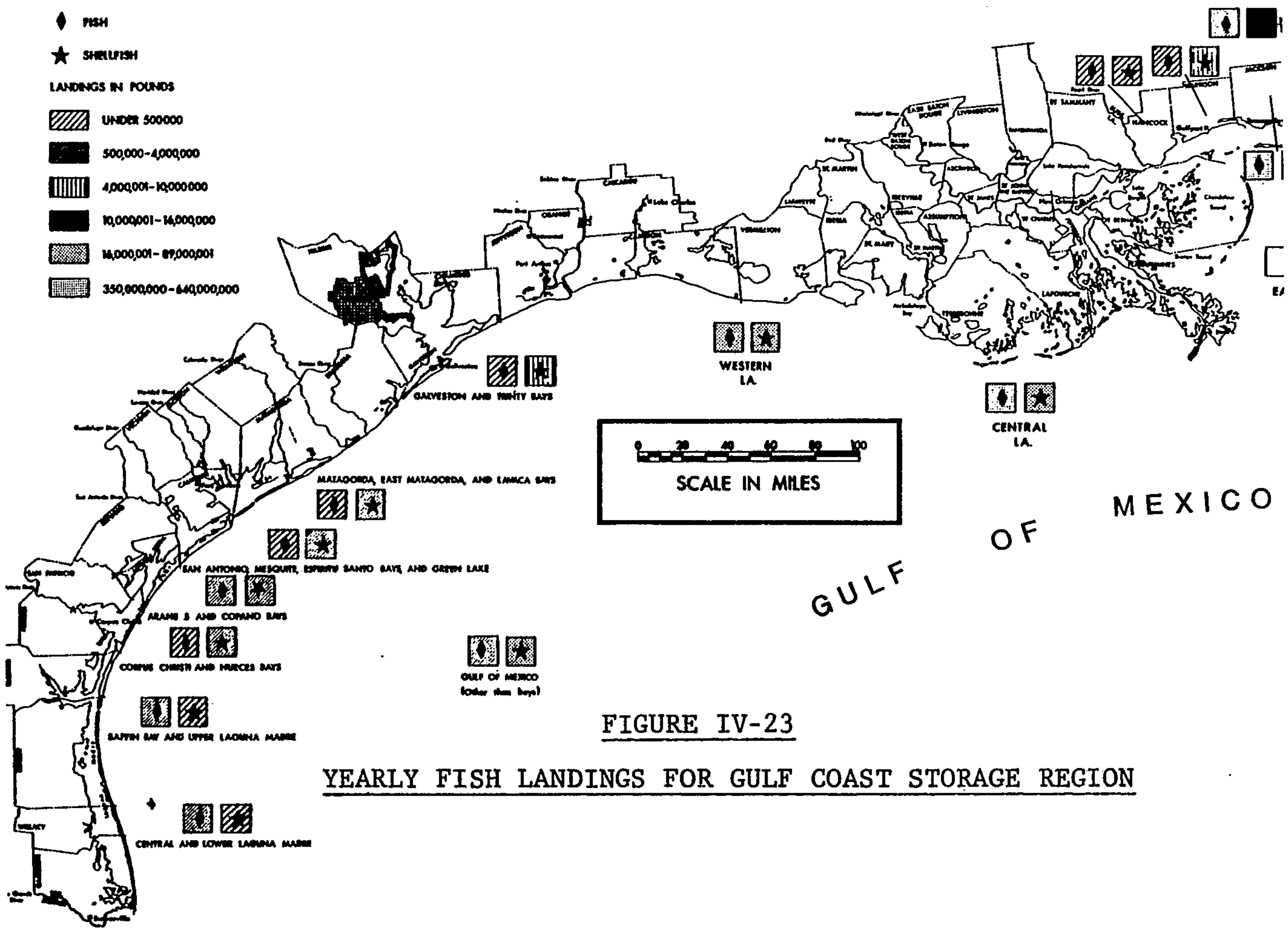


FIGURE IV-23

YEARLY FISH LANDINGS FOR GULF COAST STORAGE REGION

Source: EN-333

trips during the fall and winter seasons. The same is true of most mammals, especially deer. Trapping of fur-bearing animals (muskrats, nutria, mink, and raccoons) is practiced commercially in East Texas and Louisiana. Table IV-11 shows the types of animals trapped and their dollar value for Louisiana in the period 1971-1973.

Important Sports Species

Hunters and fishermen spend millions of dollars each year in the Gulf Coast region while enjoying their particular sport. The major saltwater species that interest fishermen are listed in Table IV-12. Table IV-13 shows a comparison of sport and commercial catches for four major bays of Texas: Galveston, San Antonio, Aransas and lower Laguna Madre from September 1974-1975. Some freshwater species are of sports importance in the region, especially in the Mississippi River Delta area. These generally are bass, sunfish, catfish, and crayfish. During the fall and winter, hunters by the thousands seek migratory water fowl (ducks and geese), deer, turkey, quail and a few miscellaneous species of animals in the Gulf Coast region. As can be seen in Figures IV-24 and IV-25, the two largest migratory routes, the Central and Mississippi Flyways, end in Texas and Louisiana. With the exception of the ducks on the endangered species list (in a later section) all ducks and geese are considered fair game in the quantities described by the state's hunting regulations. All of the birds and mammals that are legal to hunt are carefully managed by state and Federal agencies.

TABLE IV-11

COMPARATIVE TAKES OF FUR ANIMALS IN LOUISIANA FOR 1971-73 SEASONS

1971-72 Season	No. Pelts		Approximate Price to Trapper	Value
*Muskrat (Eastern)	98,000	@	$ 2.00	$ 196,000.00
*Muskrat (Western)	228,513	@	3.50	799,795.50
Mink	24,299	@	4.00	97,196.00
*Nutria (Eastern)	500,000	@	2.00	1,000,000.00
*Nutria (Western)	786,622	@	4.00	3,146,488.00
Raccoon (Coastal)	30,000	@	2.00	60,000.00
Raccoon (Upland)	50,632	@	3.50	177,212.00
Opossum	8,310	@	.50	4,155.00
Otter	5,440	@	38.00	206,720.00
Skunk	114	@	.50	57.00
Fox	476	@	4.50	2,142.00
Bobcat	136	@	6.00	816.00
Beaver	126	@	6.00	756.00
Coyote	11	@	5.00	55.00
Civet Cat (spotted skunk)	3	@	2.00	6.00
Total Pelts	1,732,682			$5,691,398.50
Nutria Meat	8,250,000 lbs	@	.08	660,000.00
Muskrat Meat	200,000 lbs	@	.08	16,000.00
Raccoon Meat	440,000 lbs	@	.20	88,000.00
Opossum Meat	80,000 lbs	@	.20	16,000.00
Total Meat	8,970,000			$ 780,000.00
Total Pelts and Meat				$6,471,398.50
1972-73 Season				
*Muskrat (Eastern)	173,393	@	$3.50	$ 606,875.50
Muskrat (Western)	173,394	@	4.75	823,621.50
Mink	44,062	@	6.00	264,372.00
*Nutria (Eastern)	611,623	@	3.25	1,987,774.75
*Nutria (Western)	1,000,000	@	4.75	4,750,000.00
Raccoon (Coastal)	49,274	@	4.50	221,733.00
Raccoon (Upland)	100,000	@	6.00	600,000.00
Opossum	17,065	@	1.25	21,331.25
Otter	7,668	@	42.00	322,056.00
Skunk	405	@	1.00	405.00
Fox	1,899	@	10.00	18,990.00
Bobcat	481	@	12.00	5,772.00
Beaver	956	@	5.00	4,780.00
Coyote	112	@	10.00	1,120.00
Total Pelts	2,180,332			$ 9,628,831.00
Nutria Meat	10,000,000 lbs	@	.08	800,000.00
Muskrat Meat	300,000 lbs	@	.08	24,000.00
Raccoon Meat	840,000 lbs	@	.22	184,800.00
Opossum Meat	160,000 lbs	@	.20	32,000.00
Total Meat	11,300,000			$ 1,040,800.00
Total Pelts and Meat				$10,669,631.00

*primarily coastal.

Source: DA-166

TABLE IV-12

IMPORTANT SPORTS ORGANISMS OF THE GULF COAST REGION

Bay and Surface	Offshore
Spotted seatrout	Spanish mackerel
Sand seatrout	King mackerel
Atlantic croaker	Red snapper
Black drum	Sail fish
Gafftopsail catfish	Cobia
Southern kingfish	Dolphin
Gulf kingfish	Wahoo
Pinfish	
Red drum	
Sea catfish	
Sheepshead	
Southern flounder	
Blue crab	
Shrimp	
Oyster	

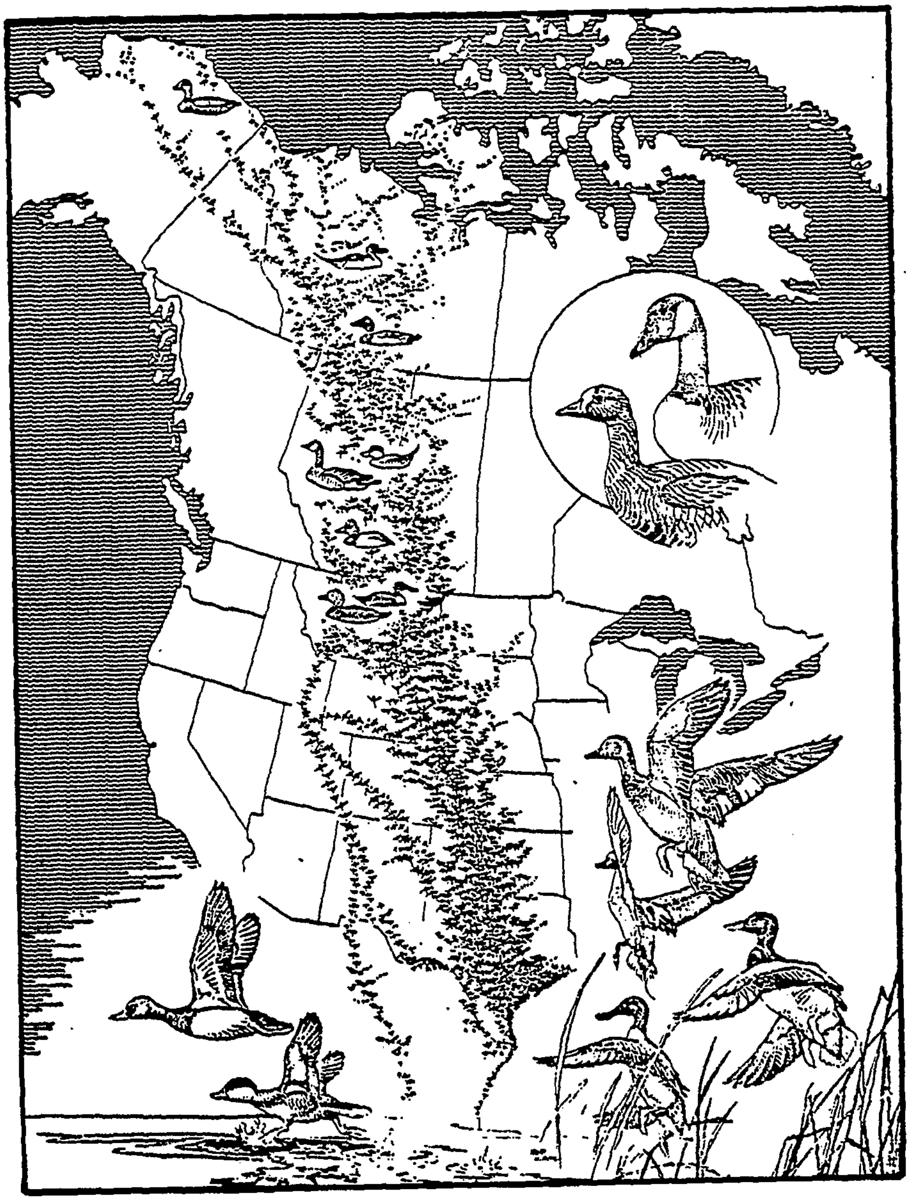
Source: OP-019

TABLE IV-13

COMPARISON OF SPORT CATCH AND COMMERCIAL FISH CATCH BY WEIGHT (SEPTEMBER 1974-AUGUST 1975)

	Sport ($x10^3$)	Commercial ($x10^3$)
Spotted seatrout	2,243	925
Redfish	412	878
Black drum	313	498
Southern flounder	247	112
Sheepshead	212	125
Atlantic croaker	464	
Sand seatrout	551	
Gafftopsail catfish	144	68
Other	242	
TOTAL	4,827	2,606

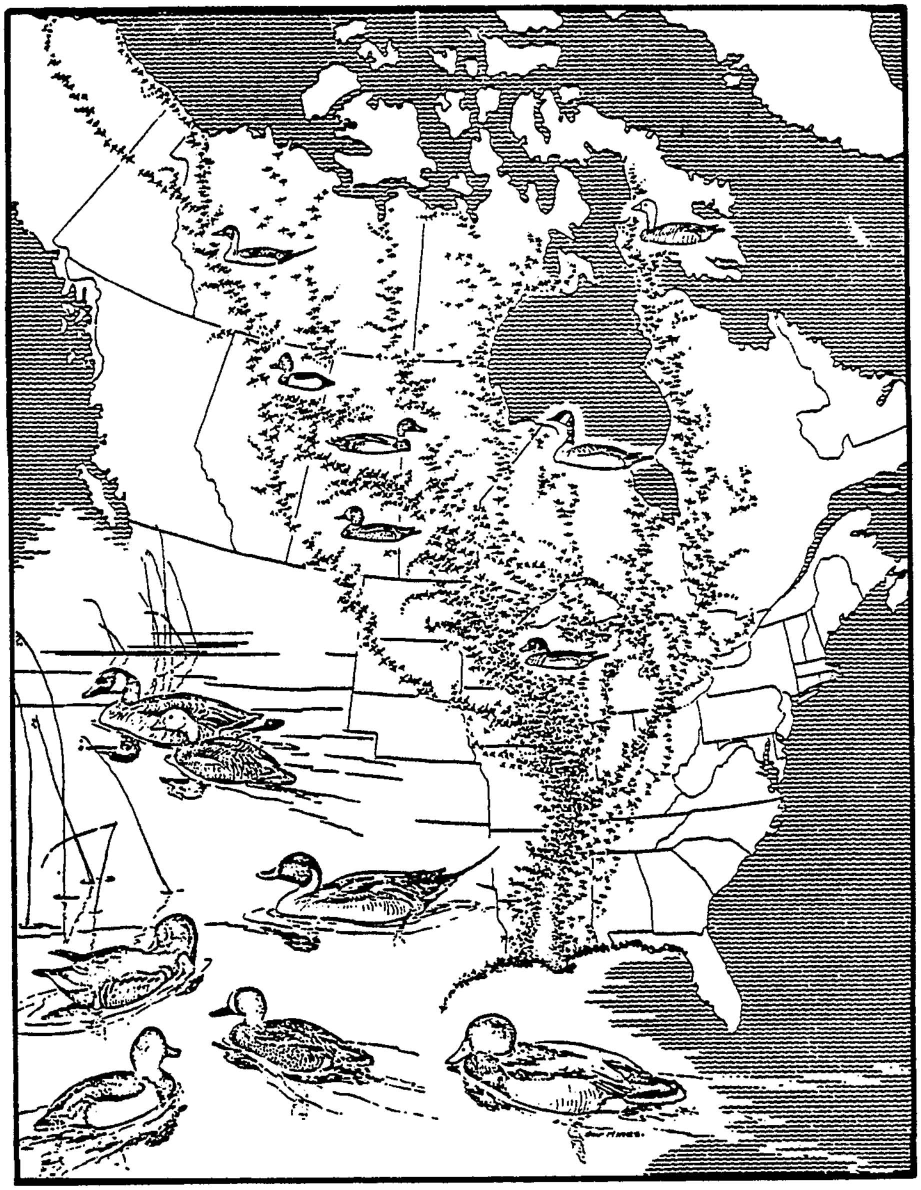
Source: HE-217



Source: US-344

FIGURE IV-24

CENTRAL FLYWAY MIGRATORY WATERFOWL MIGRATION ROUTE



Source: US-344

FIGURE IV-25

MISSISSIPPI FLYWAY MIGRATORY WATERFOWL MIGRATION ROUTE

Species Important to the Ecosystem

Except for certain biotopes which depend heavily upon one or a very few species for their continued stability, most are made up of many species of more or less equal importance. They may not be in equal proportions; however, the food chain and trophic levels are usually in some type of dynamic equilibrium. The biotopes which depend upon one species or a few are listed below with their major species.

Salt Marsh
- *Spartina alterniflora* (smooth cordgrass)
- *Spartina patens* (marsh hay cordgrass)

Fresh Marsh
- *Juncus* spp. (reeds)
- *Phragmites* spp. (cane)

Grass Flat
- *Halodule wrightii* (shoal grass)
- *Thalassia testudinum* (turtle grass)
- *Ruppia maritima* (widgeon grass)

Oyster Reef
- *Crassostrea virginica* (American eastern oyster)

Regionally Endangered or Rare Species

The following table, Table IV-14, lists those species which may occur in the study area and are thought to be rare, endangered, or of questionable status. The biotopes preferred by each species and other pertinent information are also given.

TABLE IV-14

SPECIES THOUGHT TO BE RARE, ENDANGERED, OR QUESTIONABLE

Birds	Status	Habitat and Miscellaneous
American ivory-billed woodpecker *Campehilus p. principalis*	Endangered	Upland deciduous and river floodplain forests of East Texas or Western Louisiana
Eastern Brown Pelican *Pelecanus occidentalis carolinensis*	Endangered	Marshes, bay planktonic
Whooping crane *Grus americana*	Endangered	Winters in marshes, prairie grass-lands and shallow bay planktonic near San Antonio Bay, Texas
Southern Bald Eagle *Haliaectus l. leucocephalis*	Endangered	Nests in scattered places along coastal region
Attwater Prairie Chicken *Tympanuchus cupide attwaterii*	Endangered	Coastal prairies of Central and East Texas
Eskimo curlew *Numenius borealis*	Rare	Migrant to coastal areas
American Peregrine Falcon *Falco peregrinus anatum*	Rare	Migrant to lower Texas barrier islands in winter
Artic Peregrine Falcon *Falco Peregrinus tundrius*	Rare	Migrant to lower Texas barrier islands in winter
Red Cockaded Woodpecker *Dendrocopus borealis*	Rare	Pine trees of forests in East Texas and Louisiana
Northeastern Least Grebe *Podiceps dominicus brachyptecus*	Peripheral	Marshes
Eastern Reddish Egret *Dichromanasso r. rutescens*	Peripheral	Marshes and shallow bay planktonic
Roseate spoonbill *Ajaia ajaja*	Peripheral	Marshes and shallow bay planktonic on lower and Central Texas coast
Wood Ibis *Mycteria americana*	Questionable	
Mexican Duck *Anas diazi*	Peripheral	Migrant to lower Texas coast
Mammals		
Red Wolf *Canis rufus*	Endangered	Prairie grasslands, marshes, forests of East Texas and Western Louisiana Coasts
Amphibians and Reptiles		
Alligator *Alligator mississippiensis*	Rare-Endangered	Marshes of coastal region
Atlantic Ridley Turtle *Lepidochelys kempii*	Rare-Endangered	Marine
Hawksbill Turtle *Eretmochelys imbricata*	Rare-Endangered	Marine
Leatherback Turtle *Dermochelys coriacea*	Rare-Endangered	Marine
Green Turtle *Chelonia mydas*	Endangered	Occasional visitation on beaches
Houston Toad *Bufo houstonensis*	Rare	Prairie grasslands near streams in Houston area
Fish		
Tarpon *Megalops atlanticus*	Questionable	Offshore Gulf and bays, decreasing in late 1950's, now increasing
Paddlefish *Polyodon spathula*	Peripheral	Fresh water in Red River and Mississippi River
Shovelnose Sturgeon *Scaphichynchus platorynchus*	Peripheral	Fresh water in Red River and Mississippi River

Sources: OP-018, TE-267

Species-Specific Information

Various tables presented in RA-223 contain data concerning the tolerances, preferences, occurrences, etc. for many of the aquatic species mentioned in the previous two subsections.

Much of this information has been summarized from various data sources and compiled for easy reference. Tables show the time of year, biotope, life stage and bay system that several migratory species inhabit along the Gulf Coast. This gives a very good idea of areas of greatest importance and at what time of the year they are most important to each species. Tables illustrate growth rates for selected aquatic organisms, list salinity and temperature ranges and optima for selected "important" species, illustrate various data pertaining to salinity tolerances of various Gulf species, and give the various food items of "important" aquatic species. Many other types of pertinent background information have been included from which the interested reader can draw his or her own conclusions concerning the existing environment of the Gulf Coast region.

g. Historical and Archaeological Resources

The Gulf Coast region has numerous sites of historical and archaeological significance. Coordinated efforts to systematically identify the historical and archaeological resources of each state are relatively new. Current efforts result largely from the National Historic Preservation Act of 1966 and Executive Order 11593. To date, there is no comprehensive inventory of historical and archaeological sites for the Gulf Coast region. The National Register of Historic Places and the statewide inventories completed to date are the most complete records available.

Available records of historical resources are far more complete than records of archaeological resources in this region. Historical resources are usually visible and have been the subject of frequent inventories. As new areas are inventoried and as the definition of historical and cultural significance is broadened, existing records are continually being updated. Thus, lists of sites are obsolete almost as soon as they are compiled.

Available records are very incomplete with regard to archaeological resources in the Gulf Coast region. Most archaeological surveys which have been conducted have concentrated on areas threatened by destruction through inundation or development (EN-333). Other study areas have been those where a heavy concentration of sites is expected.

The National Register of Historic Places (February 1976 and subsequent monthly supplements) lists 548 sites of national, state, and local significance within the Gulf Coast region. Of these, ninety-two properties are located in coastal counties, with fifty-six in Louisiana coastal counties, thirty-five in Texas coastal counties, and eleven in Mississippi coastal counties.

Because site listings from statewide inventories are rapidly outdated, no totals from these sources are given here. The State Historical Preservation Officer (SHPO) in each state is the best source for the most current listing at any given time. The SHPO in each state is also the best source of information concerning how the state inventory is being compiled, when it will be completed, and how it will be used in project planning.

A baseline assessment of the Gulf of Mexico coastal zone identified historical sites and major archaeological sites within the coastal zone (EN-333). Both registered (National Register) and non-registered sites are included in this survey. Figure IV-26 shows the location of these sites.

h. Land Use Patterns

The Gulf Coast study region considered is the area encompassed by the coastal counties or parishes of Texas and Louisiana.

The Coastal Zone is one of the most rapidly growing areas of both states, experiencing approximately a 21% increase in population between 1960 and 1970 as compared to 13.3% for the Nation. Most of this growth has been concentrated in the existing urban areas (see Figure IV-27).

One out of every three people living in the states of Texas and Louisiana lived in the Coastal Zone area in 1970 (RE-172). As shown in Table IV-15, the coastal strip had a population of 5.2 million in 1970. Within this area, population is centered in a series of five standard metropolitan statistical areas (SMSA's): Corpus Christi, Galveston-Texas City, Houston, Beaumont-Port Arthur-Orange, and New Orleans.

In Louisiana, 69.2% of the total population of the coastal zone was centered in towns or cities of greater than 2,500 inhabitants, while in Texas the percent of urban population was somewhat higher, 81.8%. This represents a mean urban population density of 3,135 individuals per square mile in Louisiana and 2,050 individuals per square mile in Texas. The difference in population densities indicates that while a greater

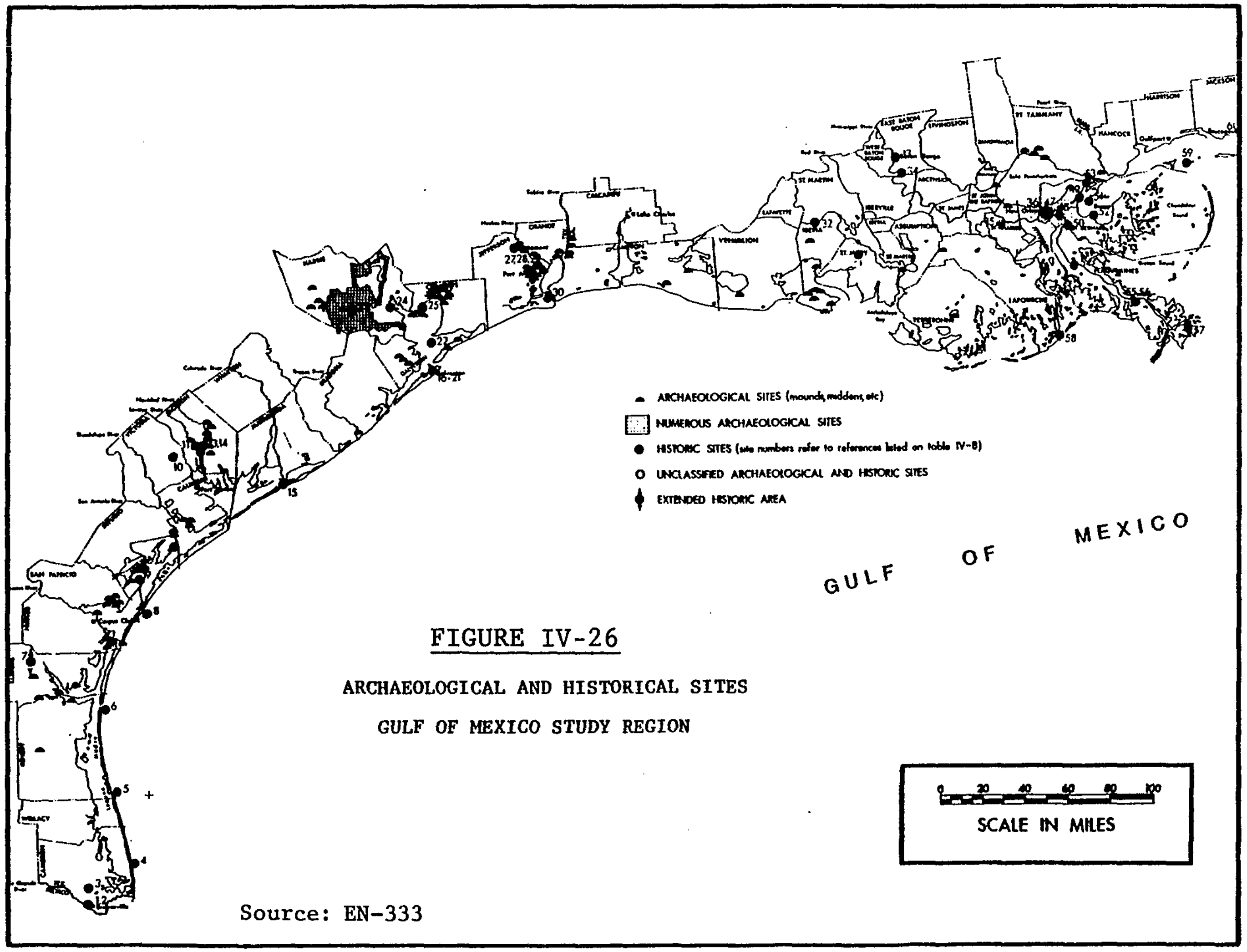


FIGURE IV-26

ARCHAEOLOGICAL AND HISTORICAL SITES

GULF OF MEXICO STUDY REGION

Source: EN-333

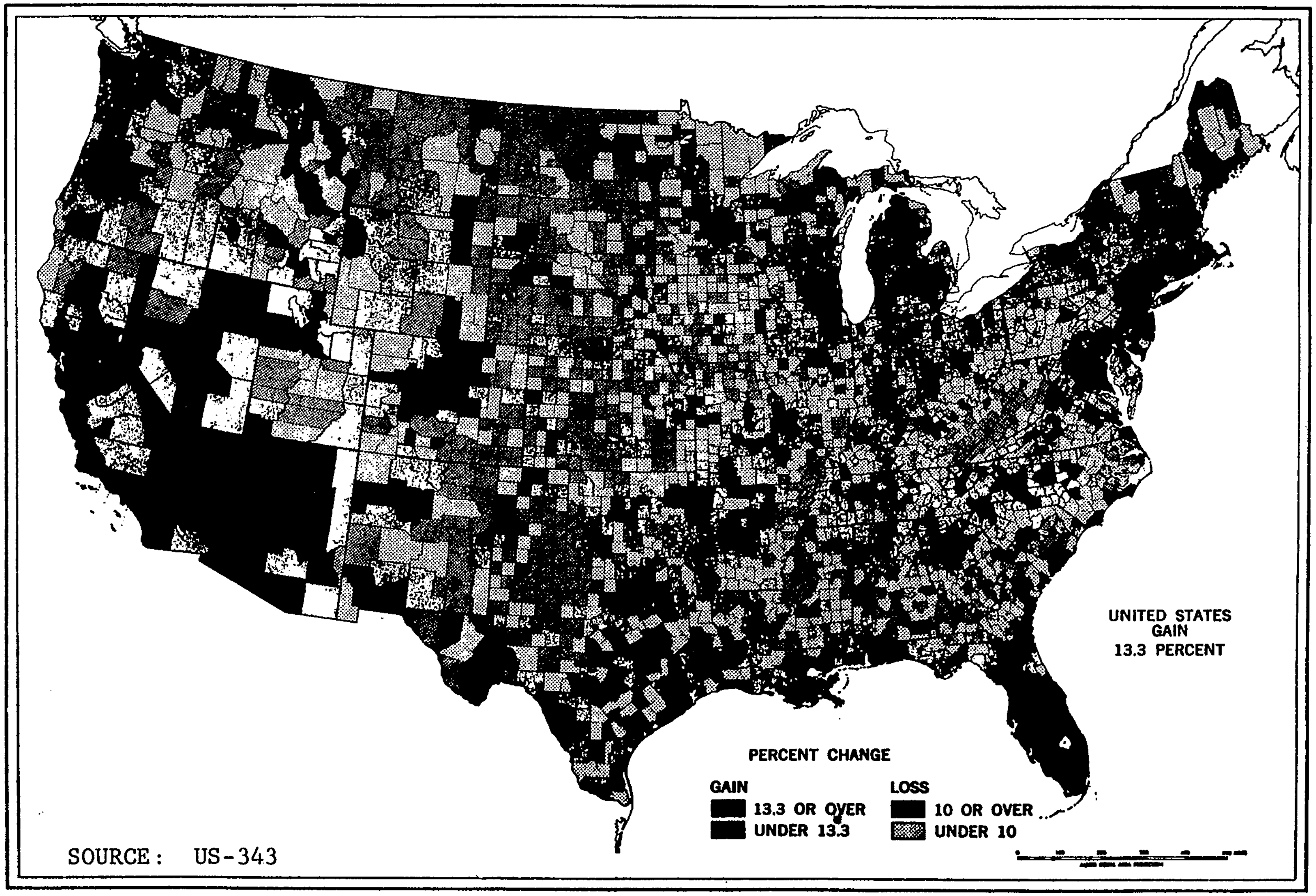


FIGURE IV-27

PERCENT OF CHANGE IN TOTAL POPULATION BY COUNTIES: 1960-1970

TABLE IV-15

LAND USE BY URBAN VERSUS RURAL PERCENT FOR GULF COAST

	Total Area (sq.mi.)	Urban Area (sq.mi.)	Urban (%)*	Total Population	Urban Population	% Urban Population	Rural Population	Rural (%)
Louisiana	15,695.0	494.2	3.1	2,239,033	1,549,823	69.2	688,210	30.8
Texas	22,770.6	1,192.4	5.2	2,990.639	2,445,589	81.8	545,050	18.2
TOTAL	38,465.6	1.686.6	4.3	5,228,672	3,995,412	76.4	1,233,260	23.6

* Urban is defined as within the city limits of a city of population size of 2,500 or greater, according to the 1970 census.

Source: RE-172

percentage of individuals are urbanized in Texas, a greater percentage of land per person is given over to urban development in Texas. Viewed differently, one might say that urban areas are more extensively populated, more crowded, in Louisiana.

The majority of the land is privately owned (see Figure IV-28). However, the remaining land covering a majority of the coastline is government owned. Tourism has already developed in many areas along the Coastal Zone with several state and national parks and wildlife refuges existing within the region (see Figure IV-29).

Recreational activities along the Texas and Louisiana Coast contribute significantly to the economy of each state. In many ways, recreational activities in both states are synonymous. However, in Texas there are activities unique to the area because of locational factors.

In Texas recent studies have shown that over 10 million visitors annually visit coastal counties to participate in water sports and other recreational activities. These activities include: camping, boating, fishing, picnicking, swimming, hunting, and sight-seeing. A statewide survey showed that expenditures for recreation were concentrated in three counties: Galveston, Harris, and Nueces*.

The many miles of white sand beaches along the Texas Coast are a prime attraction to recreation-seeking visitors. The most popular, Padre Island, attracts thousands of visitors each year. Also, the Lower Rio Grande Valley has a large tourism industry.

* Texas Parks and Wildlife Department, <u>1968 Texas Outdoor Recreation Household Demand Survey</u> and <u>1970 Texas Outdoor Recreation On-Site Demand Survey</u>, Austin, Texas, 1972.

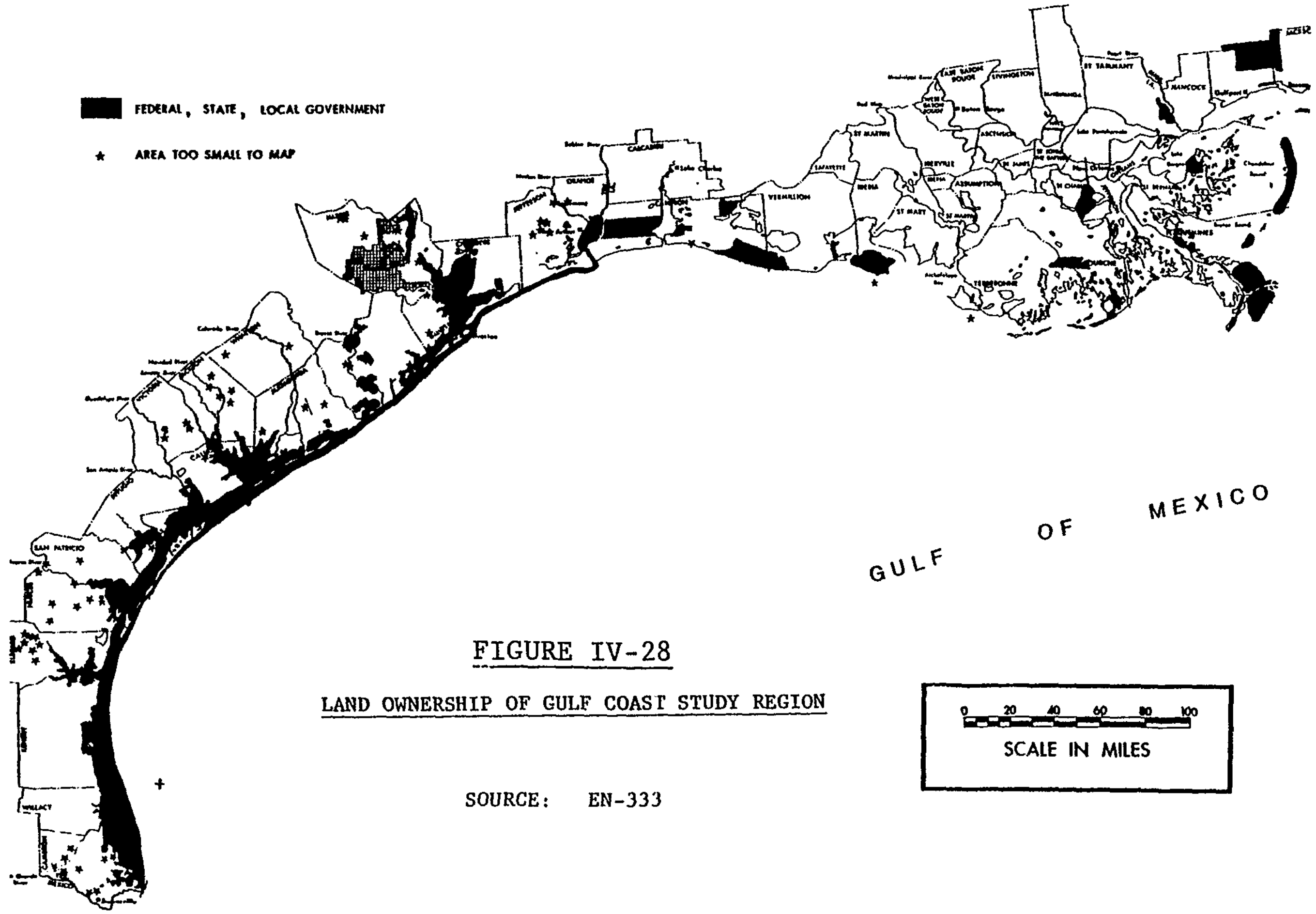


FIGURE IV-28

LAND OWNERSHIP OF GULF COAST STUDY REGION

SOURCE: EN-333

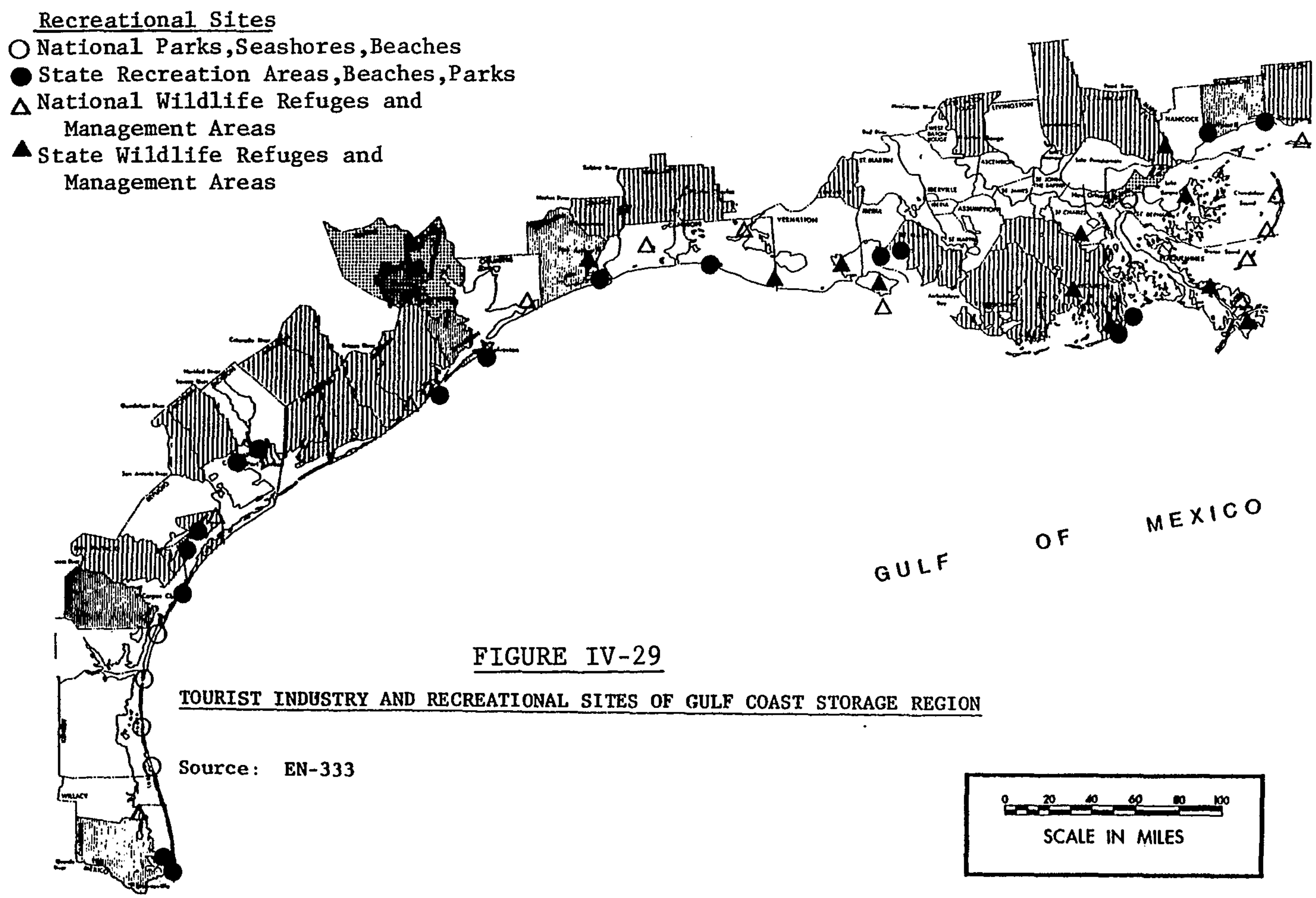


FIGURE IV-29

TOURIST INDUSTRY AND RECREATIONAL SITES OF GULF COAST STORAGE REGION

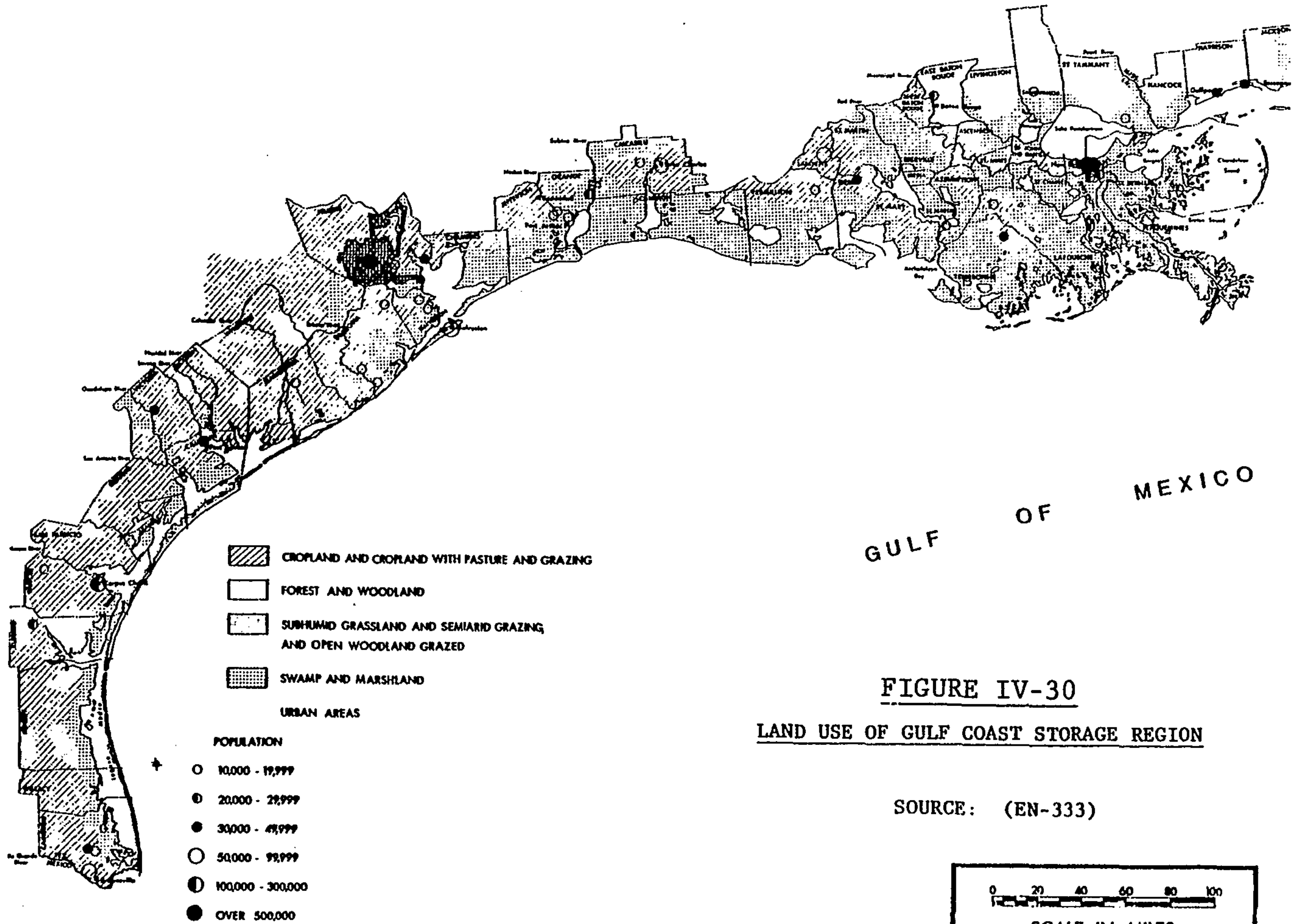
Source: EN-333

Tourism in the Valley consists of three types of visitors: (1) those who stay overnight on their way to the Mexican interior, (2) those who stay three days to a week on a short vacation, and (3) those who live there in mobile homes during the winter season. Other attractions along the Texas Coast include various cultural and athletic activities in the Houston and upper coastal area.

Tourism and recreational activities in Louisiana are much like those in Texas with the exception of those activities related to beaches and Mexico. Louisiana does not enjoy the vast quantity of accessible beaches that Texas does. However, Louisiana does have coastal areas that are quite conducive to fishing, boating, and other coastal activities. Also, tourism is significant because of the attraction of historical sites and the various activities in New Orleans.

Land use is similar in both states. While agricultural land, including land use for range/ranch activities, predominates, forestry activity claims an impressive amount of land in both states. Another major land user is the commercial-residential-industrial sector (EN-333) (see Figure IV-30).

When considering land use for industrial development, a land use which provides a high percentage of jobs per square mile of land, it is important to note the significance of the petrochemical industry in the study region. A broad perspective of the various commercial/industrial activities sited within the study region is given in Figure IV-31.



<u>FIGURE IV-30</u>

<u>LAND USE OF GULF COAST STORAGE REGION</u>

SOURCE: (EN-333)

0 20 40 60 80 100

SCALE IN MILES

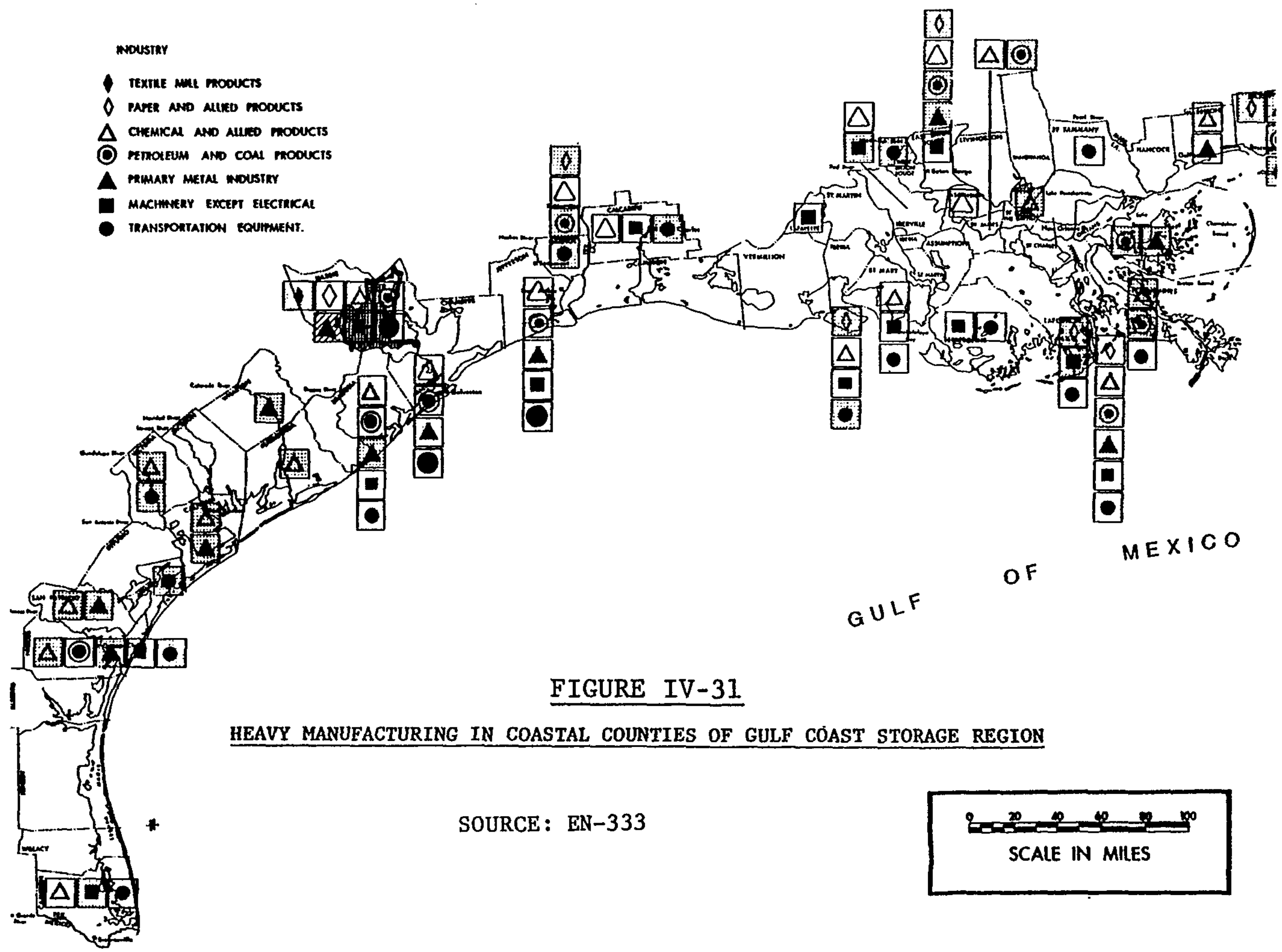


FIGURE IV-31

HEAVY MANUFACTURING IN COASTAL COUNTIES OF GULF COAST STORAGE REGION

SOURCE: EN-333

i. Land Use Planning

Louisiana - State Land Use Planning

The responsibilities for management of the coastal region primarily lie with three agencies: Louisiana Wildlife and Fisheries Commission, Louisiana Department of Conservation, and the Department of Public Works. The Wildlife and Fisheries Commission has authority over most resource development and use in the coastal region excluding mineral development and major water resources development. The Commission regulates shellfish harvesting, canal and water-way dredging, sport hunting and fishing, refuges and preserve management, water pollution abatement, and oil and gas exploration.

The Department of Conservation regulates oil and gas production and the extraction of other minerals. The Department of Public Works manages navigation, flood protection, and water resource programs in the state. Its activities include construction of dams and reservoirs as well as water diversion projects for navigation and water supply, digging canals and harbors, providing flood control assistance to local levee boards, and technical assistance to local governments.

In the middle and western parishes (but not the eastern parishes) the Louisiana Coastal Commission carries on activities related to: (1) the construction and operation of the Intracoastal Seaway and other canals, levees, locks, etc., to improve navigation; (2) increasing the freshwater supply; (3) preventing saltwater intrusion; (4) promoting flood control; and (5) abatement of water pollution.

The State Planning Office is in the process of preparing a Coastal Zone Management Plan. Until the completion of this management plan and designation by the legislature of an agency responsible for such jurisdiction, land use regulation in Louisiana is accomplished essentially through zoning. The ten Coastal Zone parishes vested with authority to enforce parish-wide zoning ordinances are Ascension, Calcasieu, East Baton Rouge, Jefferson, St. Bernard, St. Charles, St. John, St. Tammany, Tangipahoa, and West Baton Rouge.

The Louisiana Legislature by Senate Concurrent Resolution No. 84 in 1970, created the Joint Legislative Committee on Environmental Quality. Based on recommendations of the Joint Legislative Committee, HB 118 (Act 35-1971) was passed establishing the Coastal and Marine Resources Commission.

The Commission was established to propose guidelines for a Coastal Zone Management Plan and recommended an existing permanent state agency as most appropriate to implement the plan. As set forth in the original legislation, the Commission ceased to exist effective September 15, 1974. Although not a comprehensive plan, the Commission report did cover many broad issues related to a Coastal Zone Management Plan for Louisiana. The Governor's Office has directed the State Planning Office to utilize a variation of the proposed guidelines in the development by a Coastal Zone Management Plan.

Texas - State Land Use Planning

The State of Texas has taken initial steps toward developing a comprehensive coastal resources management program. Principal responsibility for planning is being shared by the Texas Council on Marine-Related Affairs and the Interagency

Natural Resources Council, Division of Planning Coordination, in the Governor's Office.

The Governor's Office has prepared a conceptual report, "The Management of Bay and Estuarine Systems, Phase I & II", identifying guidelines for a model to be developed later. This report will list activities affecting Texas bays and estuaries. The Governor's staff has also completed technical reports in the areas of waste management, air pollution, transportation, and economic considerations. At present, several state agencies carry out traditional line functions which include water pollution control programs, fish and game management, and permit issuance for oil and gas explorations. The last Legislature gave the General Land Office responsibility for state-owned land and designated the Land Office as lead agency to coordinate with NOAA and the Office of Coastal Environment.

j. Population and Economic Factors

Generalized Socioeconomic Situation

The Gulf Coast storage region encompasses most of the Gulf Coast areas of Texas and Louisiana. In Texas, this covers the counties from Corpus Christi around the coast to Houston and to the Beaumont-Port Arthur area. In Louisiana, the coastal parishes as well as those of Lake Charles, Baton Rouge, and New Orleans are included. These regions in both Texas and Louisiana contain large population centers and a large percentage of the total population of each state. The Gulf Coast region is rich in minerals as well as being a highly productive agricultural area.

Because of the large geographical expanses and population, the impacts of the oil storage in salt domes on social and economic systems of the Gulf Coast region would be minimal. Localized impacts can be rather large depending on the proximity of the salt domes to urbanized areas. This proximity factor is the strongest factor influencing population, employment, and land use on a regional as well as a subregional basis. Due to the population density of most areas of the Gulf Coast region, many of the acceptable salt dome sites are located within twenty to thirty miles of fairly large urban areas, thus mitigating many of the effects on population and employment that might be felt by an isolated rural socioeconomic structure. The offshore dome sites are considered to be, in a socioeconomic sense, near urban areas since they will be served by the nearest coastal area with a port. They are unique in the sense that some of the sociological factors associated with land-based salt domes are looked at in a different way. The safety factor, for instance, is viewed with respect to the safety of the construction and operation crews since there are few neighbors living in the area. However, the concern of an oil spill is much more prominent in an offshore dome.

Population

The 1974 population of the Gulf Coast region is estimated to be almost five and one-half million people. Almost three million live in the Texas portion of the region with the remainder in Louisiana. These totals represent approximately 24% of the Texas population and 64% of Louisiana's population. The estimates for this region show slightly faster growth rates since 1970 than do the other areas of the states. Population centers in the region include Corpus Christi, Houston, Beaumont, Lake Charles, Baton Rouge, and New Orleans. These centers and the immediate areas surrounding them are heavily populated, while the other areas of the region are rather sparsely populated.

Population projections for the United States and various regions have been made using several assumptions regarding the number of children born to each woman in the childbearing ages. These projections, titled Series C, Series D, Series E, and Series F, assume averages of 2.8, 2.5, 2.1, and 1.8 births per woman in the childbearing age. Assumptions regarding mortality and immigration are the same for all four series. All series project a continued increase in population to the year 2000. Table IV-16 shows projected increases for 1970 to 1980 ranging from 8.3% to 12.7%, resulting in a difference of over nine million people. Estimates to 1985 differ by over eighteen million people. These projections produce a percentage increase per year of 0.8% for Series F to 1.4% for Series C.

TABLE IV-16

PROJECTED PERCENT INCREASE IN TOTAL POPULATION OF UNITED STATES

	Series C	Series D	Series E	Series F
1970-1980	12.7	11.6	9.4	8.3
1970-1985	21.4	19.1	15.0	12.7
1975(est)-1980	7.0	6.2	4.8	4.0
1975(est)-1985	15.2	13.0	9.2	7.0

Source: US-178

On a regional basis, the states in the Gulf Coast storage region are projected to increase in population almost 1.35% per year for the Series C projections and 0.99% per year for Series E through 1980. These values are slightly lower than the U. S. values for corresponding years and series, 1.14% and 1.08%, respectively (US-178).

The 1972 Office of Business and Economic Research Service (OBERS) projections for the U. S. Water Resources Council show an increase in United States population for 1970 to 1980 of 9.6% or 0.93% per year. The projection for 1970 to 1985 is 15.0% or 0.94% per year. This series shows an increasing rate of growth in the 1980 to 1985 projection of 9.96% per year increase.

The OBERS projections for the Gulf Coast storage region population show a percentage increase of 9.2% for 1970 to 1980, which is slightly less than the national average. However, this area is projected to grow at a faster rate than the U. S. in the years from 1980 to 1985. Table IV-17 summarizes the percentages and projected rates of growth of the United States and the Gulf Coast storage region.

TABLE IV-17

PROJECTED POPULATION PERCENTAGE INCREASE

(PERCENT INCREASE PER YEAR)

	United States	Salt Dome Storage Region States
1970-1980	9.6 (0.93)	9.2 (0.88)
1970-1985	15.0 (0.94)	15.2 (0.95)
1980-1985	4.9 (0.96)	4.4 (1.07)

Source: US-122

A regional study conducted by the Houston-Galveston Area Council has produced projections for population and employment in the Texas portion of the salt dome storage region. These figures show very large increases in population in the area as contrasted with the Census Bureau projections as well as the Water Resources Council projections. The Houston-Galveston Area Council has predicted population increases of 3.54% per year from 1970 to 1980 for a total increase of 47%.

An increase of 72% from 1970 to 1985 has been projected with the growth rate per year for 1980 to 1985 escalating to 3.96% (HO-248).

The Midwest Research Institute recently published its Quality of Life Indicators in the U. S. Metropolitan Areas, 1970 (MI-203). This study was an effort to assess the quality of life in SMSA areas according to the following components: (1) economic concerns, (2) political concerns, (3) environmental concerns, (4) health and education concerns, and (5) social concerns. One hundred and twenty variables were selected and described in connection with the five major components or goals. All SMSA's were ranked on bases of data collected.

While no clear-cut conclusions about migration to the highly ranked cities may be made, the wide publication of the results of this study may indeed prompt people to reconsider where they want to locate. Thus, it may be useful to note the relative rankings of the cities included in the Gulf Coast and East Coast storage regions.

It is obvious that none of the cities involved received a particularly high rating in the quality of life items. In the Gulf Coast region, only Houston (ranked twenty-seventh out of sixty-five cities) was in the top half of the rankings. Both New Orleans and Lake Charles were very low in their respective categories. It would appear that Houston may continue its population boom, for quality of life is considerably higher there than among the other salt dome region cities. Table IV-18 lists "quality of life" rankings for SMSA's in the salt dome region.

TABLE IV-18

QUALITY-OF-LIFE RANKINGS FOR SMSA'S IN SALT DOME REGION

Large SMSA's (total number=65)	Medium SMSA's (total number=83)	Small SMSA's (total number=95)
Houston 27	Baton Rouge 44	Galveston-Texas City 52
New Orleans 63	Corpus Christi 55	Lake Charles 83
	Beaumont 57	

Source: MI-203

Note: For example, Baton Rouge has the 44th highest quality-of-life index of all 83 medium-sized SMSA's in the Nation.

Employment

The highly industrialized and labor-intensive manufacturing industries in the Gulf Coast region generate many jobs in the area. In 1970, the civilian labor force in these areas totaled almost two million workers of which over 95% were employed. In both Texas and Louisiana, the percentage of people employed as a percentage of the state employment is greater than the percentage of population the area contains. In Texas, the area has almost 24% of the state population and over 25% of the employment. In Louisiana, the figures are 64% of the population and over 66% of the employment.

In the economy of the region, the manufacturing sector produces more than 21% of the total earnings. Wholesale and retail trade produce over 18% of the earnings, followed by governmental employment with 15% and services with 14%. Mining and agriculture are small contributors to total earnings in the Gulf Coast storage region with 5.5% and 2.6%, respectively. Other sectors for the economy are given in Table IV-19 (US-122).

TABLE IV-19

PERCENT OF TOTAL EARNINGS BY INDUSTRY 1971

	United States	Gulf Storage Region
Manufacturing	26.8	21.1
Wholesale and retail trade	16.7	18.4
Government	18.0	15.1
Services	15.3	14.8
Transportation, communication and public utilites	7.2	8.9
Contract construction	6.3	8.7
Mining	1.0	5.5
Finance, insurance and real estate	5.4	5.0
Agriculture	3.4	2.6

Source: US-122

There are more than five thousand manufacturing establishments in the region with almost three hundred thousand employees. These account for approximately 27% of the establishments and almost 33% of the manufacturing employees in the region. There are large numbers of mineral industry establishments in the region. Almost 40% of the total number of mineral industry employees and establishments are located in the salt dome storage region. The region contains valuable farmlands on which rich crops of rice, cotton, and grain sorghum thrive. However, the farm population of the area accounts for only 12% of the total farm populations of Texas and Louisiana. The value of the farm products sold is approximately 11% of the states' totals (US-343).

According to the Bureau of the Census, the labor force in the United States is projected to increase from 85.9 million in 1970 to 101.8 million in 1980. This change of 18.5% represents an annual growth rate of 1.71%. The growth of the labor force is expected to slow down from 1980 to 1985 as seen in the projections that the annual growth rate for these years is 1.13%, producing a total increase of 5.8%. The growth thus projected for 1970 to 1985 in total labor force is 25.4% (US-178).

The OBERS projections for the United States show an increase in total number of employees of 18.7% for the decade 1970 to 1980. A 5.2% increase from 1980 to 1985 shows the same tendency for decreased rate of growth as was projected for the labor force by the Bureau of the Census.

As seen in Table IV-20, the economy of the United States, viewed in terms of total earnings by industry, is projected to have rather large percentage changes in the manufacturing and the services sectors. Manufacturing, which accounted for 27.8% of total earnings in 1970, is expected to drop to 26.2% by 1980 and 25.5% by 1985. The total earnings in manufacturing,

TABLE IV-20

PROJECTED PERCENT OF TOTAL EARNINGS BY INDUSTRY FOR THE UNITED STATES

	1970	1980	1985
Manufacturing	27.8	26.2	25.5
Government	17.7	17.6	18.0
Wholesale and retail trade	16.6	16.0	15.6
Services	15.1	17.9	18.9
Transportation, communication and public utilities	7.1	7.0	7.0
Contract construction	6.1	6.2	6.1
Finance, insurance and real estate	5.1	5.8	6.0
Agriculture	3.5	2.5	2.2
Mining	1.0	0.8	0.7

Source: US-122

however, will increase by 42.2% from 1970 to 1980 and by 15.3% from 1980 to 1985. The services sector is projected to increase considerably, from 15.1% of total earnings in 1970, to 17.9% in 1980, and 18.9% in 1985. The total earnings in services are estimated to increase 70.3% from 1970 to 1980 and 24.9% from 1980 to 1985.

In the economy of the Gulf Coast storage region, just as in the United States totals, the manufacturing sector produces the largest percentage of total earnings. However, in the salt dome storage region manufacturing accounts for only 21.1% of the total earnings. Projections show that most of the sectors in the economy remain relatively the same. The largest increase is in the services sector, expanding from 14.9% of total earnings to 18.4% in 1985. Modest decreases are projected for several sectors. Mining is projected to decrease from 5.5% of total earnings to 3.8%, and the projected contract construction decrease is from 9.1% to 7.6%. The total earnings in these sectors, however, increase by 26.0% and 51.1%, respectively, from 1970 to 1985. Table IV-21 lists the projected percentage of total earnings by industry for the salt dome storage region (US-122).

TABLE IV-21

PROJECTED PERCENT OF TOTAL EARNINGS BY INDUSTRY FOR THE SALT DOME STORAGE REGION

	1970	1980	1985
Manufacturing	21.1	21.7	21.6
Wholesale and retail trade	18.1	18.0	17.6
Government	14.9	14.8	15.1
Services	14.9	17.4	18.4
Contract construction	9.1	7.7	7.6
Transportation, communication and public utilites	8.9	8.5	8.3
Mining	5.5	4.3	3.8
Finance, insurance and real estate	4.7	5.6	5.8
Agriculture	2.7	2.0	1.8

Source: US-122

The Houston-Galveston Area Council Demographic Projections show that for the Texas portion of the salt dome storage regions jobs should increase by over 50% from 1970 to 1980. From 1980 to 1985 there should be a 22.5% increase. Due to the similarity between the Texas and the Louisiana portions of the salt dome region, corresponding increases in jobs can be projected for the entire region. However, due to the tremendous growth of the Houston metropolitan area, the growth of the Texas portion of the region should be larger than the Louisiana portion (HO-248).

2. East Coast Storage Region

a. Physiography

For the purposes of this and related discussions, the East Coast region stretches from the Norfolk, Virginia vicinity in the south to the Maine-Canada border on the northeast; the inland boundary is an arbitrary ten-mile distance from the coast or its embayments, and the region extends seaward to the continental slope. As such, the region encompasses those areas where strategic storage in conventional, aboveground tankage and in new mined rock caverns is under consideration.

The area may be divided into two major physiographic provinces: the Atlantic Coastal Plain province on the south, incorporating at its northern boundary extreme southern New England to Cape Cod, Massachusetts, and the New England province to the north (FE-141). Within the New England province, the Seaboard Lowland comprises most of the land area (Figure IV-32), although the Triassic Lowland and Central Upland subprovinces also exist in the region.

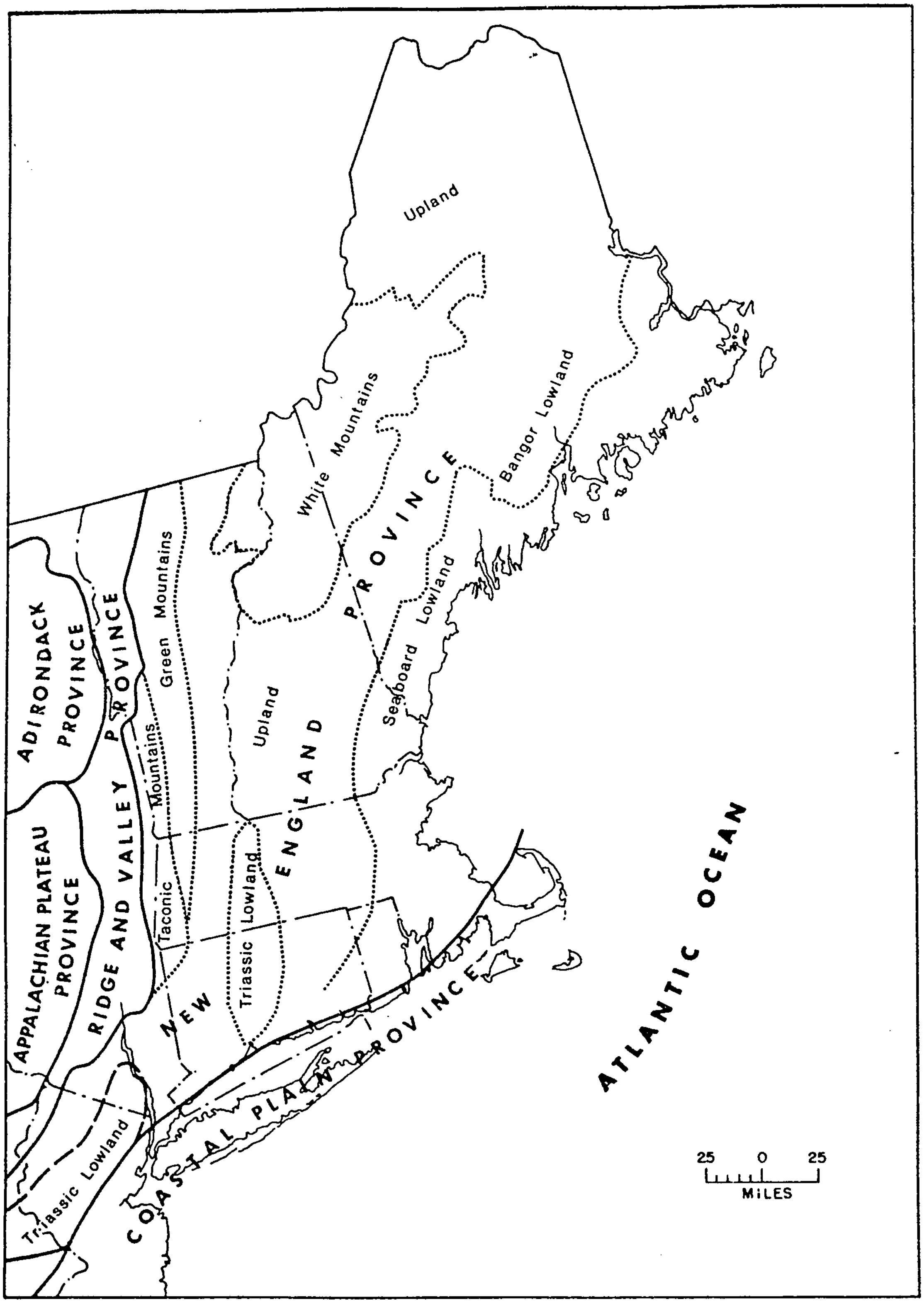


FIGURE IV-32

PHYSIOGRAPHIC PROVINCES AND DIVISIONS OF THE NEW ENGLAND AREA

Source: RE-172

The Atlantic Coastal Plain consists of gently sloping lowlands primarily upon unconsolidated Tertiary and Quaternary sediments. This plain is dissected by numerous large rivers ending in drowned tidal valleys along the coast (SP-066). The width of the emergent portion increases from a few miles to 100 miles in a southerly direction. The province generally has only slight relief characterized by several broad depositional terraces subparallel to the coast (SP-066). From approximately New Jersey northeastward, the coastal plain surface consists of low ridges and glacial material (MU-101). Immediately adjacent to the strand, broad coastal marshes, deep, irregular estuaries, and broken offshore bars dominate the landscape throughout; low bluffs are situated close by, particularly in the New England portion of the Coastal Plain. The Coastal Plain continues onto the continental shelf with little change in character, a broad plain sloping gently seaward, although it is decidedly undulatory near shore (RU-064). In the New England area, the Coastal Plain is almost completely submerged. It extends over much of the northeastern shelf, although it is buried by recent sediments.

In contrast, the region within the New England province has an extremely irregular and rocky shoreline, typically submergent in character. The complex association of erosion-resistant igneous and metamorphic rocks that comprise most of the province has moderate to high topographic relief. Nearer the coast in the Seaboard Lowlands the topography is lower, owing partly to local structural basins that are filled with younger, less-resistant sedimentary rocks, e.g., Narragansett Basin (RE-172). The sand beaches that characterize the marine-terrestrial interface are evidence of the active erosion currently taking place in this portion of the province. All of the New England province (and parts of Long Island and other islands of the Atlantic Coastal Plain province) has undergone continental glaciation within geologically recent times, and widespread deposits of glacial till and outwash thinly cover much of the area (MU-101).

b. Geologic Setting

The following is, of necessity, only a very general description of the complex geology of the East Coast region. The cursory treatment presented here is not intended to denigrate the importance of this topic and others related to it, such as ground-water hydrology; rather, these factors must be examined on a more local site-specific level, owing to the complexity and areal variability of the geology, before meaningful generalizations and conclusions can be reached as to the efficacy and effects of the specific actions contemplated. This programmatic overview, then, only serves as a further introduction to the East Coast region, in lieu of a detailed description of the local geologic environment.

Coastal Plain Geology

The Atlantic Coastal Plain is a distinct wedge-shaped (in the land-sea dimension) zone of sedimentary deposits, ranging in age from Cretaceous, generally to the west of the East Coast region, to Pleistocene. These chiefly unconsolidated deposits accumulated under alternating terrestrial and marine conditions, and they consist of both fine and coarse-grained heterogenous sediments. Along the present coast, these deposits range from several thousand to about ten thousand feet in thickness (MA-503), and they rest on Precambrian and Paleozoic crystalline "basement" rocks tilted generally seaward (Figure IV-33). Table IV-22 is a correlation chart presenting, in stratigraphic order, the individual formations or groups within this thickness

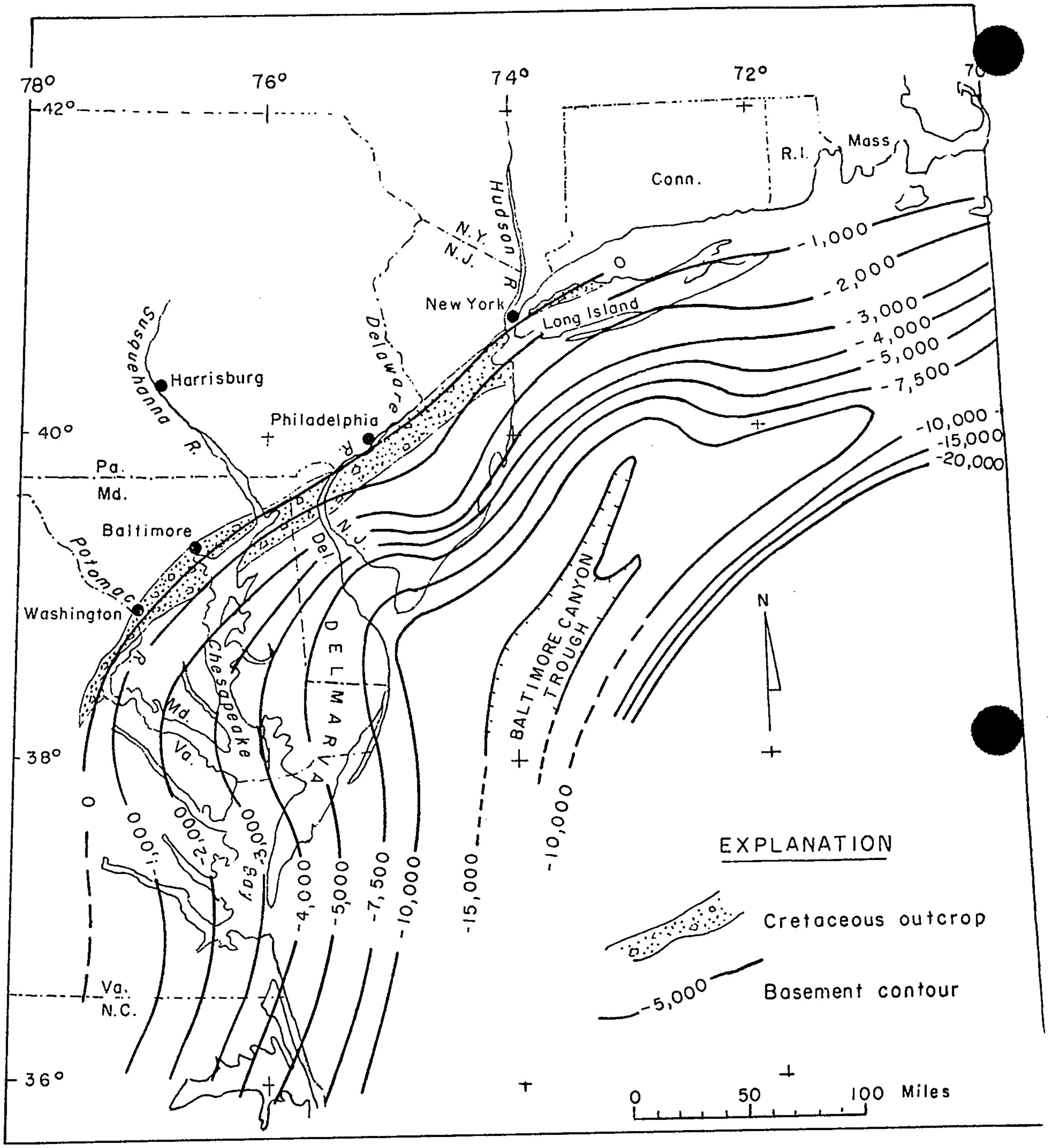


FIGURE IV-33

STRUCTURAL CONFIGURATION OF BASEMENT ROCKS BELOW THE ATLANTIC COASTAL PLAIN SEDIMENTS

Source: HA-411

TABLE IV-22

CORRELATION CHART FOR COASTAL PLAIN STRATIGRAPHIC UNITS

AGE	NEW JERSEY	DELAWARE	MARYLAND	VIRGINIA	GULF
Pliocene	Beacon Hill	Bryn Mawr (?)	Brandywine Bryn Mawr	Upland gravels and sands (in part)	Goliad
Miocene	Cohansey Kirkwood	Chesapeake group (undifferentiated)	Chesapeake gr.: St. Marys Choptank Calvert	Chesapeake gr.: Yorktown St. Marys Choptank Calvert	Pascagoula Hattiesburg Catahoula
Eocene	"Jackson" (subsurface)	Piney Point (?) (subsurface)	Piney Point	Chickahominy (subsurface)	Jackson
	Shark River Manasquan	unnamed sediments	Pamunkey gr.: Nanjemoy	Pamunkey gr.: Nanjemoy	Claiborne
	Vincentown Hornerstown		Aquia	Aquia	Wilcox
Paleocene	Hornerstown	mainly subsurface	Brightseat	Mattaponi subsurface	Midway
Upper Cretaceous	Monmouth group: Tinton Red Bank Navesink Mount Laurel	Red Bank Navesink-Mt. Laurel	Monmouth	not recognized in outcrop	Navarro
	Matawan group: Wenonah Marshalltown Englishtown Woodbury Merchantville	Wenonah Merchantville	Matawan		Taylor
	Magothy	Magothy	Magothy		Austin
	Raritan	Raritan	Raritan		Woodbine
Lower Cretaceous	Absent in outcrop	Undifferentiated: Patapsco Patuxent	Potomac group: Patapsco Arundel Patuxent	Potomac group: Patapsco Patuxent	Comanche

SOURCE: RU-064

of sediments along with a comparison with the stratigraphic equivalents in the Gulf Coast region.

Like their counterparts in the Gulf Coast, the Atlantic Coastal Plain sediments increase in thickness and in dip in a seaward direction. At the surface, dips are usually much less than one degree, and the formations crop out subparallel to the coast (MA-503). No significant faulting within these sediments is known in the Atlantic Coastal Plain sediments (e.g., the structural control on sedimentation is rather passive, influenced principally by the structurally negative Cheasapeake-Delaware embayment, in which most of the sediments in the study region accumulated) (MU-101). Older sediments crop out progressively toward the margins of this large-scale structural feature.

New England Geology

A very simplified geologic map of the New England province is shown in Figure IV-34. The region of interest consists chiefly of a complex association of igneous and metamorphic rocks whose regional trend lies north-northeast to northeast, an extension of the Appalachian mountain belt (RE-172). These rocks are geosynclinal accumulations of Paleozoic age that are intensely folded and faulted and regionally metamorphosed during the Appalachian orogeny (time of mountain-building) and its precursors. These are included in the stippled areas on the map. Concurrently, a broad variety of light-colored intrusive igneous and volcanic rocks were emplaced on a more local scale. In combination with lithologically similar but older intrusive rocks, a substantial part of the southern part of the New England coastal area is underlain by these intrusive (plutonic) rocks, as indicated by the diagonally-ruled pattern on the map.

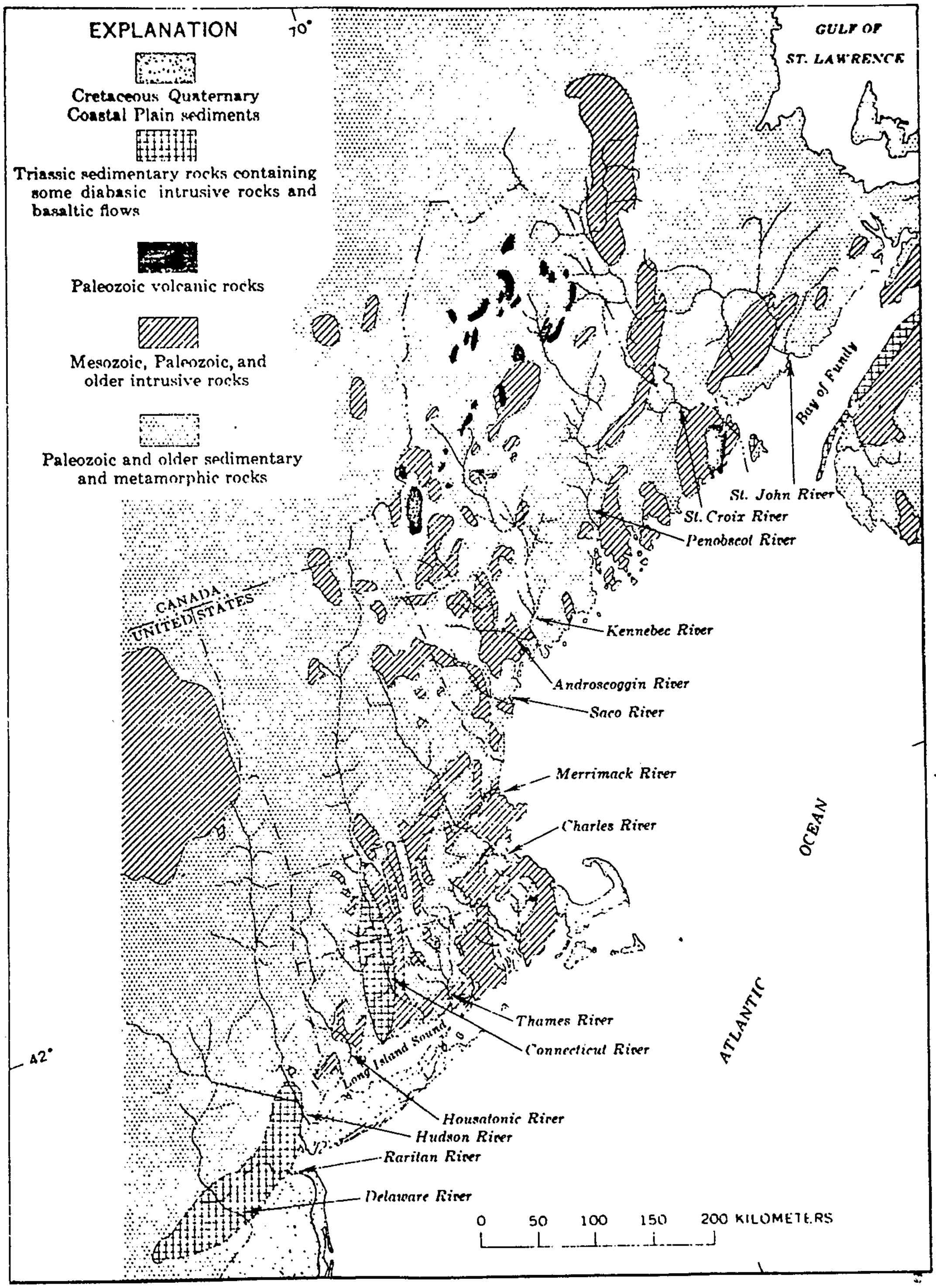


FIGURE IV-34

GENERALIZED GEOLOGIC MAP OF THE NEW ENGLAND STUDY AREA

Source: RE-172

contain unmetamorphosed or poorly metamorphosed rocks of sedimentary origin: volcanic detritus, conglomerates, shales and sandstone, i.e., eugeosynclincal facies. Another major area of unmetamorphosed or poorly metamorphosed sedimentary rock is in the fault basins that are present in the study region in both the New Jersey-New York area and central Connecticut ("Triassic Lowlands"). These rocks are of both Triassic and Devonian age and are generally similar to the other basin accumulations, except that intrusive and extrusive igneous rocks are more commonly associated with the more western deposits (CL-072).

More recent sediments, of Cretaceous and Tertiary age, are of marine origin and are found in isolated coastal areas in the Gulf of Maine (RE-172). Also, unconsolidated Pleistocene glacial debris crops out along portions of this shoreline.

Generalized Seismicity

As shown by the seismic risk map (Figure IV-7), the East Coast region has moderate to high seismicity, increasing generally toward the Boston area from both the south and the north. Most perceived earthquakes have caused little or no damage. Seismic risk is much less a concern in the mid-Atlantic states than in the New England area; the following discussion consequently focuses on the New England area and relies heavily on information in RE-172.

A zone of seismic activity, as indicated by epicenter locations, extends along the southern and southeastern coastal zone of New England between Long Island and Maine. Another zone of seismic activity, the "Boston-Ottawa trend", is aligned at right angles to the southern New England trend and is defined by epicenters crossing New Hampshire and northern Vermont into Quebec. The seaward extension of this trend into the Gulf of

Maine has been the location of several moderate to intense earthquakes, suggesting that its activity may be associated with an "unhealed" fault zone related to late Paleozoic crustal fracturing. This suggestion is supported by other data and interpretations, and it implies that the Southern Gulf of Maine area is subject to recurring earthquakes of damaging intensity. Quakes of about magnitude VIII (Modified Mercalli Scale) have occurred several times in this area. The greatest shock of record in the region occurred near Cape Ann, Massachusetts, in November, 1755.

South and west of this trend, a series of earthquake epicenters appear to be localized around the margins of the Boston and Newbury structural/stratigraphic basins. The implication that the fault boundaries to these basins are still somewhat active may or may not apply to the Narragansett Basin, the largest of these Paleozoic basins. Several other areas of current seismic activity appear to be related to periodically active fault zones including northeastern Maine (Fundian Fault Zone) and the Central New Jersey area (the Ramapo Fault). The epicenters of a number of minor, recent earthquakes extend across Central New Jersey onto the Continental Shelf and represent perhaps the most tectonically active system in the East Coast region.

Soils Development

The East Coast region may be divided into northern and southern subregions on the basis of both climatography and physiography. Each of these subregions has its own characteristic soil type (TR-075), as soils are generally the product of climate acting on the geologic substrate.

North of the approximate latitude of Philadelphia, the soils typically are gray-brown podzolic soils characterized by good fertility, good (well-developed) structure, and good adaptability. Much of this soil has been developed since continental-glaciated times, or is the result of re-deposition by glaciation. The rest of the region is actually a transition zone to red-yellow podzolic soils. These soils are thick, forest-type soils resulting from the high degree of chemical weathering and leaching due to relatively higher temperatures and abundant, year-round rainfall. Their fertility is relatively low, with generally low plant-food mineral or organic content. Commonly these soils are light-textured and sandy.

Further description of soil types generally is best done on a site-by-site basis. Of special concern are soil characteristics that may be adverse and/or require special engineering for anticipated land use: erodibility (a complex function of grain size, organic matter, permeability, and structure of the soil), shrink-swell potential, corrosivity, and the shear and bearing strengths (FL-062). These characteristics are quite site-specific, as particularly suitable and particularly adverse soils may occur together within the boundaries of a large facility.

c. Surface-Water Character

The East Coast region is drained by streams whose aggregate watersheds comprise the North Atlantic Water Resource Region (U. S. Water Resources Council). The mean natural runoff on an annual basis from this region is 163 billion gallons per day (BGD) or 252,000 cfs. Ninety-five percent of the time, the annual flow will exceed 112 BGD or 173,000 cfs (TO-028). Flows tend to be highest during March and April and lowest during August and September. The mean runoff is about 13.5% of the runoff for the conterminous United States; this high runoff rate (on an area basis) reflects primarily the abundant precipitation and the topographic relief in this part of the country.

This large stream flow is not distributed evenly throughout the region. As shown in Table IV-23, a relatively few streams have mean flows in excess of 10,000 cfs.

TABLE IV-23

STREAMS EXCEEDING AVERAGE RUNOFF RATE

Stream	Drainage Area (square miles)	Average Flow (cfs)
Penobscot R., ME	8,570	11,560
Connecticut R., CN	11,265	16,060
Hudson R., NY	12,650	12,710
Delaware R., NJ	6,780	11,850
Sesquehanna R., MD	25,990	36,460
Potomac R., D.C.	11,560	11,260

Source: TO-028

In contrast, some areas have a relative scarcity of surface water; these areas include Northern Coastal Maine, Southern Coastal Maine, Coastal Massachusetts and Rhode Island, Long Island, and Northern New Jersey (RE-173). Due to the very high population density of the near-coastal region, a disproportionate demand is being made on freshwater supplies that, in some geographic areas, are not completely adequate to serve all intended uses. In particular, the Northern New Jersey - New York City - Western Connecticut metropolitan complex and the Rhode Island - Eastern Massachusetts metropolitan area are demonstrably susceptible to water deficiencies during prolonged low-flow periods.

The high density of people and industries in the Northeastern United States has also resulted in significant water quality degradation in virtually every watershed of the region (RE-173).

The assimilative capacities of the streams are now being exceeded during a substantial portion of their flow range, which results in critically low dissolved oxygen levels and locally insufficient dilution of toxic substances (especially heavy metals) in the receiving streams. Water quality problems are of special concern for the Northern Maine coast (pulp and paper industry); the Southern New England area, from Southeastern Maine to New York City (textiles, paper, food products, primary metals, and non-industrial sources); the lower Hudson River and Long Island area (textile, foods, chemicals, petroleum, and primary metal industries, and non-industrial sources); and the Delaware and Chesapeake Bays (various industrial and non-industrial sources) (RE-172). As a general statement, industrial sources of pollutants have contributed about twice the oxygen-demanding material as non-industrial wastewater sources (including municipal sewage and urban runoff) to the streams of the East Coast region. However, it is anticipated that the proportion of industrial versus municipal oxygen-demanding effluent will decrease in the future.

Ultimately, the pollution loads from the surface streams are discharged to bays and estuaries downstream. The pollutant loads (including heat); their potentially synergistic effects; the detention time afforded by the poorly flushed back bays of these estuaries; the stratification, recycling, and subsequent overturning that is experienced in the deeper estuaries; and the high natural primary productivity of such areas lead to severe ecological stresses in many of these embayments. As they now exist, nearly all estuaries in the study region are in an especially fragile stressed state due in part to water quality. Some progress is being made in ameliorating adverse conditions.

d. Ground-Water Hydrology

The ground-water resources of the East Coast region are determined chiefly by the hydrogeologic character of the geologic formations. It is convenient to address the hydrogeologic environment by categories according to the geologic provinces of the region.

Atlantic Coastal Plain

Both water-table and artesian aquifers may be found in extensive areas of the Coastal Plain province. Sediments in nearly all the formations previously listed in Table IV-22 are able to transmit water to varying degrees; the more permeable strata of these units are used regionally as ground-water supplies. The principal freshwater-bearing units in the Coastal Plain sediments that are artesian in the coastal area include, from oldest (deepest) to youngest, the Potomoc Group (Patuxent-Patapsco aquifers), the Magothy formation, and the Cohansey and Yorktown of the Chesapeake group; minor aquifers used at some locations include the Monmouth-Matawan formation, the Aquia formation, the Nanjemo formation, the Piney Point formation, and the Cheasapeake group (excluding the Cohanset and Yorktown aquifers) (HA-411). Recharge to these aquifers is furnished by precipitation and infiltration on their outcrops and by interformational leakage from higher-pressured, generally deeper aquifers.

At the surface in many parts of the Atlantic Coastal Plain are fluvial sands and gravels of Plio-Pleistocene age. These coarse-textured sediments are referred to as the Columbia group (HA-411) and are locally very important sources of ground water. This ground water is unconfined, i.e., it is a water-table aquifer. It is generally tributary to surface streams and wetlands, but it is subject to degradation from surface sources, such as septic tanks, landfills, and marine saltwater encroachment with development. The Columbia group also serves as a source bed for recharge of underlying permeable material; because it is in unconformable contact with these underlying units, such recharge may be made to different aquifers in different areas (e.g., either the Piney Point, Yorktown, or Cohansey formations). In other areas where the Columbia group is missing, older aquifers such as the Cohansey in New Jersey may be unconfined and may serve in an analogous role. They are also subject to the same problems with respect to recharge with poor-quality water (e.g., septic tanks on Long Island).

New England Province

Ground water in the New England province is generally much less abundant and available than in the Coastal Plain province. Both glacial deposits and consolidated rocks may serve as aquifers in this area.

Glacial deposits can range from extremely poor to prolific aquifers but are areally variable (LA-213); generally, however, highly permeable sands and gravels are present in nearly all valleys at intermediate and low altitudes. Depending on streamflow recharge, they may have sustained yields as high as two million gallons per day per linear mile of major rivers (RE-173). Ground water in glacial deposits is often perched water, and it can be both confined and unconfined; typically confinements are not extensive owing to the patchy distribution of the confining beds and/or their semi-permeable character.

The ground water in consolidated rocks of this province is contained chiefly in secondary fractures of competent rocks. Most fractures decrease in density and in size with depth, so most ground-water movement takes place within the upper, more weathered part of the bedrock (DA-173). Ground water in fractures in consolidated rocks may recharge adjacent valley-fill alluvial or glacial aquifers or may receive recharge from these materials depending on the hydrologic setting. Enlargement of fractures in limestone by dissolution provides for more extensive, prolific aquifers than in fractured metamorphic rocks.

e. Meteorology and Climatology

Due to large latitudinal differences, the characteristics of this region are extremely varied. This region can best be characterized as humid, modified continental, with definite maritime influences. Although the Atlantic Ocean exerts a moderating influence, large variations in annual average temperature occur due to the latitudinal differences. Precipitation remains fairly consistent throughout the region. Mean annual relative humidity is affected by proximity to the Atlantic Ocean and ranges from 67% inland to 75% along the immediate coastline. Table IV-24 shows local climatological data for selected stations.

The region is located near the mean position of the polar front jet stream during most of the year. Therefore, it is routinely affected by extratropical low pressure systems which

TABLE IV-24

CLIMATOLOGICAL DATA ALONG THE EAST COAST

Normals, Means, And Extremes

Station: PORTLAND, MAINE — PORTLAND INTERNATIONAL JETPORT — Standard time used: EASTERN — Latitude: 43° 39' N — Longitude: 70° 19' W — Elevation (ground): 43 feet

Month	Temp. °F Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				34		34					34		34		34		34		34	
J	31.2	11.7	21.5	64	1950	-26	1971	1349	0	3.38	9.41	1958	0.76	1970	2.04	1966	38.2	1966	14.2	1944
F	33.3	12.5	22.9	64	1957	-39	1943	1179	0	3.52	6.76	1971	1.26	1968	3.21	1965	61.2	1969	21.5	1969
M	40.8	22.8	31.8	86	1946	-21	1950	1029	0	3.60	9.97	1953	0.81	1965	3.47	1951	46.6	1956	11.7	1972
A	52.8	32.5	42.7	85	1957	8	1954	669	0	3.34	9.90	1973	0.71	1941	5.26	1973	15.7	1967	8.7	1971
M	63.6	41.7	52.7	92	1944	23	1956	381	0	3.33	7.74	1948	0.49	1965	2.33	1952	7.0	1945	7.0	1945
J	73.2	51.1	62.2	97	1941	33	1944	106	22	3.10	6.23	1967	0.70	1941	5.58	1967	0.0		0.0	
J	79.1	58.9	69.0	98	1949	40	1965	27	120	2.61	5.87	[illegible]	0.61	1965	2.23	1947	0.0		0.0	
A	77.6	55.2	66.4	100	1948	33	1965	55	99	2.60	8.30	1946	0.27	1947	4.18	1946	0.0		0.0	
S	69.9	47.6	58.7	95	1945	23	1941	200	11	3.09	9.81	1954	0.30	1948	7.49	1954	T	1959	T	1959
O	60.2	38.0	49.1	88	1963	18	1974	493	0	3.31	12.27	1962	0.26	1947	7.71	1962	3.8	1969	3.6	1969
N	47.5	29.7	38.6	74	1974	5	1940	792	0	4.86	9.81	1963	2.10	1946	3.39	1951	15.6	1972	11.1	1972
D	34.9	16.4	25.7	62	1962	-21	1963	1218	0	4.06	9.69	1969	0.98	1955	3.82	1969	54.8	1970	22.8	1970
YR	55.3	34.7	45.0	100	AUG 1948	-39	FEB 1943	7498	252	40.80	12.27	OCT 1962	0.26	OCT 1947	7.71	OCT 1962	61.2	FEB 1969	22.8	DEC 1970

Month	Relative humidity pct. Hour 01	Hour 07	Hour 13	Hour 19 (Local time)	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility 1/4 mile or less	Temperatures °F Max.: (b) 90° and above	32° and below	Min.: 32° and below	0° and below	Average station pressure mb, Elev. 63 feet m.s.l.
(a)	34	34	34	34	34	15	34	34		34	31	34	34	34	34	34	34	34	34	34	34	34	2
J	76	77	62	71	9.2	N	50	SE	1951	55	6.1	10	7	14	11	4	0	2	0	17	30	6	1014.1
F	75	77	60	69	9.6	N	58	N	1952	59	6.0	9	7	12	10	4	*	2	0	12	27	5	1013.6
M	76	75	59	70	10.0	N	76	NE	1947	56	6.3	9	7	15	11	3	*	3	0	4	26	1	1013.1
A	80	74	55	70	10.0	S	57	S	1946	56	6.4	8	7	15	12	1	1	3	0	*	15	0	1010.2
M	85	75	58	72	9.2	S	49	NW	1950	56	6.6	7	9	15	13	*	2	6	*	0	3	0	1011.5
J	89	78	60	74	8.2	S	45	SW	1969	59	6.3	7	10	13	11	0	4	6	1	0	0	0	1013.2
J	90	80	59	75	7.7	S	44	W	1941	64	6.2	8	11	12	9	0	4	7	2	0	0	0	1011.5
A	90	84	59	78	7.5	S	69	E	1954	65	5.7	10	11	10	9	0	3	6	2	0	0	0	1014.8
S	90	86	61	81	7.8	S	62	SE	1960	61	5.6	11	7	12	8	0	2	6	*	0	1	0	1016.8
O	88	85	59	78	8.5	N	45	N	1963	58	5.6	11	8	12	9	*	1	5	0	0	9	0	1017.0
N	83	84	64	77	8.8	W	76	NE	1945	46	6.7	8	6	16	12	1	*	4	0	1	20	0	1011.5
D	79	80	63	74	9.0	N	62	SE	1957	53	6.2	10	7	14	11	4	*	2	0	12	29	3	1013.9
YR	83	80	60	74	8.8	S	76	NE	MAR 1947	58	6.1	108	97	160	127	18	18	53	5	48	168	15	1013.3

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 103 in July 1911; maximum monthly precipitation 12.29 in January 1935; minimum monthly precipitation 0.09 in October 1924; maximum snowfall in 24 hours 23.3 in January 1935.

Normals, Means, And Extremes

Station: BOSTON, MASSACHUSETTS — GEN LOGAN INTERNATIONAL AP — Standard time used: EASTERN — Latitude: 42° 22' N — Longitude: 71° 02' W — Elevation (ground): 15 feet

Month	Temp. °F Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				10		10					23		23		23		39		39	
J	35.9	22.5	29.2	63	1974	-4	1968	1110	0	3.69	9.54	1958	0.89	1970	2.07	1958	32.5	1948	12.8	1943
F	37.5	23.3	30.4	58	1970	-3	1967	969	0	3.54	7.08	1969	1.15	1968	2.68	1969	41.3	1969	19.4	1958
M	44.6	31.5	38.1	70	1974	6	1967	834	0	4.01	11.00	1953	1.48	1962	4.13	1968	31.2	1956	17.7	1960
A	56.3	40.8	48.6	85	1974	22	1965	492	0	3.49	7.82	1958	1.24	1966	2.31	1973	3.3	1967	3.1	1956
M	67.1	50.1	58.6	93	1964	37	1974	218	20	3.47	13.38	1954	0.53	1964	5.74	1954	T	1967	T	1967
J	76.6	59.3	68.0	97	1973	46	1965	27	117	3.19	8.63	1959	0.48	1953	2.46	1960	0.0		0.0	
J	81.4	65.1	73.3	98	1968	54	1963	0	260	2.74	8.12	1959	0.52	1952	2.42	1959	0.0		0.0	
A	79.3	63.3	71.3	99	1973	47	1965	8	203	3.46	17.09	1955	0.83	1972	8.40	1955	0.0		0.0	
S	72.2	56.7	64.5	95	1969	38	1965	76	61	3.16	8.31	1954	0.35	1957	5.64	1954	0.0		0.0	
O	63.2	47.5	55.4	88	1971	30	1974	301	0	3.02	8.68	1962	0.96	1967	4.26	1962	T	1972	T	1972
N	51.7	38.7	45.2	77	1974	17	1972	594	0	4.31	8.18	1969	1.72	1952	3.33	1955	10.0	1938	8.0	1940
D	39.3	26.6	33.0	70	1966	-3	1968	992	0	4.24	9.74	1969	1.03	1955	4.17	1969	27.9	1970	13.0	1960
YR	58.7	43.8	51.3	99	AUG 1973	-4	JAN 1968	5621	661	42.52	17.09	AUG 1955	0.35	SEP 1957	8.40	AUG 1955	41.3	FEB 1969	19.4	FEB 1958

Month	Relative humidity pct. Hour 01	Hour 07	Hour 13	Hour 19 (Local time)	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility 1/4 mile or less	Temperatures °F Max.: (b) 90° and above	32° and below	Min.: 32° and below	0° and below	Average station pressure mb, Elev. 19 feet m.s.l.
(a)	10	10	10	10	17	15	16	16		39	39	39	39	39	23	39	39	39	10	10	10	10	2
J	66	67	57	61	14.3	NW	61	NW	1974	54	6.2	9	7	15	12	3	*	2	0	11	25	1	1016.6
F	65	68	58	61	14.4	WNW	57	S	1970	56	6.2	8	7	13	11	3	*	2	0	9	25	*	1015.5
M	67	68	58	62	14.2	NW	55	SW	1971	57	6.4	8	8	15	11	2	*	2	0	2	18	0	1014.8
A	68	68	54	61	13.5	WNW	52	NW	1963	56	6.5	7	9	14	12	*	1	2	0	0	3	0	1011.9
M	73	71	58	65	12.3	SW	50	NE	1967	58	6.5	6	11	14	12	0	2	3	*	0	0	0	1012.6
J	78	74	60	68	11.4	SW	40	NW	1959	63	6.2	7	10	13	11	0	4	2	2	0	0	0	1014.6
J	76	73	56	66	10.9	SW	45	N	1964	65	6.2	7	12	12	9	0	5	2	5	0	0	0	1013.5
A	77	75	56	67	10.9	SW	45	SW	1971	66	5.6	9	11	11	10	0	4	2	3	0	0	0	1016.3
S	80	79	61	72	11.4	SW	57	S	1960	64	5.5	10	9	11	9	0	2	2	1	0	0	0	1016.6
O	75	76	56	67	12.2	SW	45	NW	1963	61	5.5	11	8	12	9	0	1	2	0	0	1	0	1018.6
N	73	75	62	69	13.2	SW	54	NE	1968	51	6.4	8	7	15	12	*	*	2	0	*	7	0	1013.7
D	70	72	62	66	13.9	WNW	49	NW	1962	52	6.2	9	7	15	12	2	*	1	*	5	21	*	1015.6
YR	72	72	58	65	12.7		61	NW	JAN 1974	59	6.1	99	106	160	128	11	28	23	11	27	108	1	1015.0

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 104 in July 1911; lowest temperature -18 in February 1934; minimum monthly precipitation T in March 1915; fastest mile wind 87 S in September 1938.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Source: NA-273

TABLE IV-24 (Continued)

CLIMATOLOGICAL DATA ALONG THE EAST COAST

LATITUDE 41° 44' N
LONGITUDE 71° 26' W
ELEVATION (ground) 55 feet

NORMALS, MEANS, AND EXTREMES

PROVIDENCE, RHODE ISLAND
T. F. GREEN AIRPORT

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	33		33		(b)	(b)	33		33		33		33	33		33	
J	36.8	20.4	28.7	68	1932	-8	1957+	1125	3.75	7.12	1953	0.76	1955	2.55	1935	8.6	31.9	1948	15.0	1943
F	36.8	20.4	28.6	68	1930	-17	1934	1019	3.84	5.80	1909	1.18	1908	2.39	1924	9.7	28.2	1907	14.5	1945
M	45.0	28.6	36.8	80	1945	2	1950	874	3.88	8.31	1953	0.07	1915	2.56	1947	6.9	31.6	1956	14.7	1956
A	54.8	37.3	46.0	91	1938	11	1923	570	3.37	6.70	1953	0.72	1942	2.41	1954+	1.0	9.6	1907	8.8	1917
M	68.3	47.3	56.8	95	1944	29	1956	258	3.02	9.25	1948	0.57	1939	3.10	1954	T	T	1917+	T	1917+
J	78.9	56.3	65.6	101	1952	39	1945	58	3.17	7.21	1938	0.04	1949	3.04	1931	0.0	0.0		0.0	
J	80.8	61.8	71.0	101	1949	49	1954	0	3.06	6.92	1938	0.24	1952	3.83	1922	0.0	0.0		0.0	
A	78.6	60.3	69.4	102	1948	44	1940	26	3.63	12.24	1946	0.78	1916	5.47	1955	0.0	0.0		0.0	
S	72.0	53.3	62.7	99	1953	33	1914	107	3.19	9.74	1944	0.48	1914	6.17	1932	0.0	0.0		0.0	
O	62.1	43.3	52.7	90	1949	25	1936	381	2.83	7.00	1908	0.15	1924	3.31	1939	T	T	1957+	T	1957+
N	50.9	34.3	42.6	82	1950	6	1932	673	3.74	8.50	1945	0.31	1917	3.71	1933	1.2	10.2	1948	6.9	1948
D	39.4	23.7	31.6	68	1912	-12	1917	1038	3.48	8.44	1936	0.88	1955	2.78	1936	8.6	28.7	1945	11.8	1948
Year	58.1	40.6	49.4	102	Aug. 1948	-17	Feb. 1934	6128	39.63	12.24	Aug. 1946	0.04	June 1949	6.17	Sept. 1932	33.0	31.9	Jan. 1948	18.0	Jan. 1943

Month	Relative humidity: 1:00 a.m., EST	7:00 a.m., EST	1:00 p.m., EST	7:00 p.m., EST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 90° and above	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below
(a)	18	18	18	18	44	9	49	49		53	53	53	53	53	53	53	53	8	53	53	53	53
J	71	73	60	67	11.8	NW	70	NW	1919	49	5.9	10	7	14	12	3	*	3	0	10	26	1
F	72	73	56	65	12.0	NW	63	SW	1953	56	5.5	10	7	11	10	3	*	2	0	7	24	1
M	72	72	53	66	12.5	NW	69	NW	1920	58	5.4	11	8	12	12	2	1	2	0	3	18	0
A	75	71	51	65	12.1	SW	65	NW	1929	57	5.7	9	9	12	12	*	1	3	*	*	5	0
M	81	74	55	68	10.8	SSW	58	N	1920	60	5.6	9	11	11	11	0	3	3	*	0	*	0
J	84	76	56	70	10.0	SW	60	NW	1932	63	5.4	10	11	9	10	0	4	3	3	0	0	0
J	87	78	56	73	9.1	SW	58	NW	1924	63	5.4	10	12	9	10	0	5	2	4	0	0	0
A	87	82	56	75	8.8	SW	49	NW	1920	62	5.2	11	11	9	9	0	4	2	2	0	0	0
S	87	84	58	77	9.4	SW	95	SW	1938	60	5.0	12	9	9	8	0	3	3	1	0	0	0
O	83	83	54	74	10.3	SW	60	W	1925	60	4.7	13	9	10	8	0	1	4	*	0	1	0
N	78	80	58	71	11.0	SW	60	NW	1924	51	5.5	10	9	11	10	*	*	3	0	1	11	0
D	73	74	57	68	11.4	WNW	65	W	1916	50	5.7	10	8	13	11	2	*	2	0	6	23	*
Year	78	77	56	70	10.8	SW	95	SW	Sept. 1938	58	5.4	125	110	130	123	10	21	32	9	30	108	2

Normals, Means, And Extremes

Station: NEW YORK, NEW YORK JOHN F. KENNEDY INTL AIRPORT Standard time used EASTERN Latitude 40 39 N Longitude 73 47 W Elevation (ground) 13 feet

Month	Temperatures °F: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs. #	Year
(a)				14		14					27		27		27	
J	38.0	24.8	31.4	69	1974	0	1968	1042	0	2.69	5.77	1949	0.21	1956	1.80	1958
F	39.1	25.2	32.2	65	1972	-2	1963	918	0	3.09	5.48	1960	1.41	1974	2.87	1958
M	46.5	32.1	39.3	72	1963	7	1967	797	0	3.77	7.93	1953	1.35	1966	2.27	1962
A	58.1	41.7	49.9	87	1973	26	1969	433	0	3.39	6.98	1973	1.12	1963	2.12	1971
M	68.4	51.1	59.8	99	1969	34	1966	188	27	3.54	6.14	1951	0.38	1955	2.88	1968
J	78.0	60.9	69.5	99	1964	45	1967	9	144	2.98	6.70	1972	T	1949	2.23	1973
J	83.2	66.9	75.1	104	1966	55	1963	0	313	4.04	8.48	1969	0.46	1954	3.21	1969
A	81.7	65.4	73.6	98	1973	46	1965	0	267	4.30	17.41	1955	0.42	1972	6.59	1955
S	75.4	58.6	67.0	94	1961	40	1963	42	102	3.31	9.60	1960	0.70	1951	5.83	1960
O	65.8	48.7	57.3	86	1967	25	1961	247	8	2.76	6.41	1958	0.09	1963	3.42	1972
N	53.7	39.3	46.5	78	1974	20	1967	555	0	3.90	9.51	1972	1.10	1974	4.09	1972
D	41.3	28.4	34.9	68	1962	5	1962	933	0	3.60	6.16	1969	1.46	1971	2.46	1974
YR	60.8	45.3	53.1	104	JUL 1966	-2	FEB 1963	5184	861	41.53	17.41	AUG 1955	T	JUN 1949	6.59	AUG 1955

Month	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs $	Year	Relative humidity pct.: Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility 1/4 mile or less	Temperatures °F: Max.: (b) 90° and above	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below	Average station pressure mb. Elev. 22 feet m.s.l.
(a)	16		16		13	13	13	13	16		11	11			16	16	16	16	16	16	16	16	13	13	13	13	2
J	17.4	1965	13.0	1964	69	71	59	64	13.4		52	26	1966		6.1	8	9	14	10	2	*	3	0	9	23	*	1018.7
F	25.3	1961	19.9	1969	67	70	58	62	14.2		46	25	1967		6.3	7	8	13	10	2	*	3	0	6	22	*	1016.8
M	21.1	1960	8.1	1967	68	70	57	63	14.0		44	28	1971		6.2	7	10	14	11	1	1	4	0	1	13	0	1015.4
A	3.2	1971	3.2	1971	70	69	55	65	13.2		44	26	1970		6.2	7	10	13	11	*	2	3	0	0	2	0	1013.6
M	T	1967	T	1967	76	70	57	68	12.0		44	16	1973		6.1	7	12	12	11	0	3	3	*	0	0	0	1013.1
J	0.0		0.0		80	74	61	72	10.9		32	24	1972		6.2	7	11	12	10	0	4	4	2	0	0	0	1013.1
J	0.0		0.0		77	73	57	70	10.7		37	34	1969		6.1	7	12	12	9	0	5	2	5	0	0	0	1014.8
A	0.0		0.0		78	76	57	71	10.4		46	30	1965		5.7	7	14	10	9	0	4	2	2	0	0	0	1017.2
S	0.0		0.0		79	78	57	70	10.8		40	30	1970		5.4	10	10	10	8	0	2	1	1	0	0	0	1017.3
O	0.5	1962	0.5	1962	75	77	54	68	11.2		39	26	1967		5.2	12	9	10	7	0	1	3	0	0	*	0	1019.8
N	2.1	1967	2.1	1967	72	74	57	67	12.5		44	03	1968		6.3	7	9	14	11	*	*	2	0	0	5	0	1015.8
D	16.4	1960	8.2	1960	71	73	61	66	12.9		46	06	1974		6.4	8	8	15	11	1	*	3	0	4	19	0	1016.6
YR	25.3	FEB 1961	19.9	FEB 1969	73	73	57	67	12.2		52	26	JAN 1966		6.0	96	122	149	117	7	22	32	10	19	83	*	1016.2

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

$ Greatest calendar day through March 1969.
# Greatest calendar day August 1966 through March 1969.

Sources: NA-166, NA-273

TABLE IV-24 (Continued)

CLIMATOLOGICAL DATA ALONG THE EAST COAST

Normals, Means, And Extremes

Station: BALTIMORE, MARYLAND — BALTIMORE-WASHINGTON INTL AP — Standard time used: EASTERN — Latitude 39° 11' N — Longitude 76° 40' W — Elevation (ground) 148 feet

Month	Temp. Normal Daily maximum	Temp. Normal Daily minimum	Temp. Normal Monthly	Extremes Record highest	Year	Extremes Record lowest	Year	Normal Degree days Base 65 °F Heating	Cooling	Precip. Water equivalent Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity pct Hour 01	Hour 07	Hour 13	Hour 19 (Local time)	Wind Mean speed m.p.h.	Prevailing direction	Fastest mile Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F Max (b) 90° and above	Max 32° and below	Min 32° and below	Min 0° and below	Average station pressure mb (Elev. 155 feet m.s.l.)
(a)				24		24				*	24		24		24		24		24		21	21	21	21	24	13	24	24		24	24	24	24	24	24	24	24	24	24	24	24	24	2
J	41.9	24.9	33.4	75	1967	-7	1963	980	0	2.91	5.27	1966	0.29	1955	2.54	1968	21.4	1966	12.1	1966	69	72	57	62	9.9	WNW	63	NE	1958	51	6.2	8	8	15	10	2	*	4	0	6	25	*	1014.9
F	43.9	25.7	34.8	76	1954	-1	1967	846	0	2.81	6.21	1971	0.72	1968	2.10	1971	20.1	1967	15.5	1958	68	72	56	60	10.8	NW	68	W	1954	55	6.2	8	7	13	9	2	*	4	0	4	22	*	1012.9
M	53.0	32.5	42.8	85	1963	6	1960	688	0	3.69	6.80	1953	0.93	1966	3.18	1958	21.6	1960	13.0	1962	66	71	51	55	11.2	WNW	80	SE	1952	55	6.3	8	9	14	11	2	1	3	0	1	15	0	1011.2
A	65.2	42.4	53.8	94	1960	20	1965	340	0	3.07	8.15	1952	1.61	1968	2.80	1952	0.4	1964	0.4	1964	69	73	50	55	11.0	WNW	70	W	1954	55	6.2	7	9	14	11	*	2	2	*	0	3	0	1009.8
M	74.8	52.5	63.7	98	1962	32	1966	110	70	3.61	7.10	1960	0.43	1964	3.64	1960	T	1963	T	1963	76	77	52	59	9.7	W	65	SW	1961	57	6.1	8	10	13	11	0	4	2	2	0	*	0	1008.7
J	83.2	61.6	72.4	100	1959	40	1972	0	225	3.77	9.95	1972	0.15	1954	5.23	1972	0.0		0.0		82	80	53	63	8.8	WNW	80	SW	1952	62	5.7	8	12	10	9	0	6	1	7	0	0	0	1010.2
J	86.7	66.5	76.6	102	1966	52	1967	0	380	4.07	8.18	1960	0.30	1955	5.86	1952	0.0		0.0		81	81	53	63	8.2	W	57	NW	1962	65	5.6	9	12	10	8	0	6	1	11	0	0	0	1011.0
A	85.1	64.7	74.9	102	1953	48	1952	0	307	4.21	18.35	1955	0.77	1951	7.82	1955	0.0		0.0		83	84	55	67	8.3	W	54	NE	1955	62	5.6	10	10	11	10	0	5	1	8	0	0	0	1012.7
S	79.0	57.9	68.5	99	1967	35	1963	27	132	3.12	8.50	1966	0.21	1967	4.33	1960	0.0		0.0		83	85	55	69	8.4	S	56	W	1952	61	5.2	11	9	10	7	0	2	2	4	0	0	0	1013.2
O	68.3	46.4	57.4	92	1954	25	1969	250	14	2.81	6.88	1971	T	1963	3.49	1955	T	1972	T	1972	79	82	53	67	9.0	NW	73	SE	1954	60	5.0	13	7	11	6	0	1	3	*	0	2	0	1015.8
N	56.1	36.0	46.1	83	1974	13	1955	567	0	3.13	7.68	1952	0.68	1965	3.43	1952	8.4	1967	8.4	1967	74	77	54	64	9.6	WNW	58	E	1952	51	5.9	9	8	13	9	*	*	3	0	*	12	0	1012.9
D	43.9	26.6	35.3	74	1951	0	1960	921	0	3.26	7.44	1969	0.20	1955	2.02	1974	20.4	1966	14.1	1960	72	75	59	66	9.5	WNW	57	W	1953	48	6.4	9	6	15	9	1	*	4	0	4	21	*	1012.4
YR	65.1	44.8	55.0	102	JUL 1966	-7	JAN 1963	4729	1108	40.46	18.35	AUG 1955	T	OCT 1963	7.82	AUG 1955	21.6	MAR 1960	15.5	FEB 1958	75	77	54	63	9.5	W	80	SW	JUN 1952	57	5.9	108	107	150	112	8	28	30	31	14	100	*	1012.1

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 107 in July 1936; maximum monthly snowfall 33.9 in February 1899; maximum snowfall in 24 hours 24.5 in January 1922.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

NORMALS, MEANS, AND EXTREMES

Station: NORFOLK, VIRGINIA — NORFOLK REGIONAL AIRPORT — Standard time used: EASTERN — Latitude: 36° 54' N — Longitude: 76° 12' W — Elevation (ground): 22 feet

Month	Temperature Normal Daily maximum	Normal Daily minimum	Normal Monthly	Extremes Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity Hour 01	Hour 07	Hour 13	Hour 19 (Local time)	Wind & Mean speed	Prevailing direction	Fastest mile Speed	Direction &	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max (b) 90° and above	Max 32° and below	Min 32° and below	Min 0° and below	Average daily solar radiation - langleys
(a)	(b)	(b)	(b)	22		22		(b)	(b)	22		22		22		22	22		22		22	22	22	22	22	15	17	17		17	22	22	22	22	22	22	22	22	22	22	22	22	
J	50.2	32.2	41.2	78	1970	10	1966	738	3.33	6.60	1954	1.60	1969	3.30	1967	3.4	14.2	1966	7.3	1966	74	76	60	69	11.7	SW	56	SW	1959	58	6.1	10	6	15	10	1	*	2	0	3	17	0	
F	51.0	32.2	41.6	78	1965+	8	1965	655	3.21	5.72	1958	0.86	1950	1.87	1970	1.8	7.5	1963	6.3	1963	73	75	58	67	12.0	NNE	66	SW	1965	58	6.2	8	6	14	10	1	*	3	0	1	14	0	
M	57.2	38.7	48.0	85	1968+	20	1950	533	3.45	6.41	1958	1.34	1967	3.16	1958	0.6	7.9	1960	3.9	1960	72	73	53	62	12.4	SW	57	N	1963	63	6.0	9	8	14	11	*	2	2	0	*	7	0	
A	68.0	47.9	58.0	97	1960	28	1964	216	3.10	5.50	1953	1.29	1963	2.40	1953	0.1	1.2	1964	1.2	1964	74	74	52	63	11.8	SW	62	N	1956	65	6.0	8	10	12	11	*	3	2	1	0	0	0	
M	77.3	57.7	67.5	97	1956	36	1966+	37	3.36	7.77	1961	1.48	1965	2.94	1961	0.0	0.0		0.0		81	77	56	68	10.1	SW	53	SW	1965	67	6.0	6	11	12	10	0	5	2	2	0	0	0	
J	84.9	66.3	75.6	101	1964	45	1967	0	3.61	9.72	1963	0.37	1954	6.45	1963	0.0	0.0		0.0		83	78	57	68	9.4	SW	52	W	1970	68	5.7	8	12	10	9	0	*	2	7	0	0	0	
J	87.9	69.6	78.8	103	1952	57	1962	0	5.92	12.83	1950	1.69	1961	5.44	1969	0.0	0.0		0.0		85	82	60	72	8.6	SW	63	SW	1956	65	6.0	8	11	12	11	0	8	1	11	0	0	0	
A	86.2	68.8	77.5	99	1968	52	1965	0	5.97	11.19	1967	2.06	1970+	11.40	1964	0.0	0.0		0.0		87	85	62	76	8.7	SW	57	NE	1957	65	5.8	8	12	11	11	0	7	2	8	0	0	0	
S	80.9	64.3	72.6	98	1954	45	1967	0	4.22	12.26	1964	0.36	1958	6.79	1959	0.0	0.0		0.0		85	84	61	76	9.6	NE	73	W	1960	64	5.7	9	9	12	7	0	3	2	3	0	0	0	
O	70.9	53.1	62.0	95	1954	29	1965	136	2.92	8.78	1959	0.93	1967	4.19	1959	0.0	0.0		0.0		83	84	61	76	10.4	NE	78	S	1954	62	5.2	13	6	12	7	0	2	3	0	0	0	0	
N	61.0	41.8	51.4	85	1950	20	1953	408	3.05	7.01	1951	0.49	1965	3.35	1952	T	0.6	1950	0.6	1950	77	80	56	70	10.7	SW	52	SE	1962	61	5.4	11	8	11	8	0	*	2	0	0	4	0	
D	51.8	33.1	42.5	77	1956+	14	1962	698	2.74	4.84	1967	1.08	1965	2.12	1958	1.5	14.7	1958	11.4	1958	73	76	56	68	10.9	SW	48	NW	1960	58	5.9	10	7	14	8	*	*	2	0	1	13	0	
YR	68.8	50.5	59.7	103	JUL. 1952	8	FEB. 1965	3421	44.94	12.83	JUL. 1950	0.36	SEP. 1958	11.40	AUG. 1964	7.4	14.7	DEC. 1958	11.4	DEC. 1958	79	79	58	69	10.5	SW	78	S	OCT. 1954	53	5.8	110	106	149	114	2	37	24	31	5	57	0	

& To 8 compass points only.

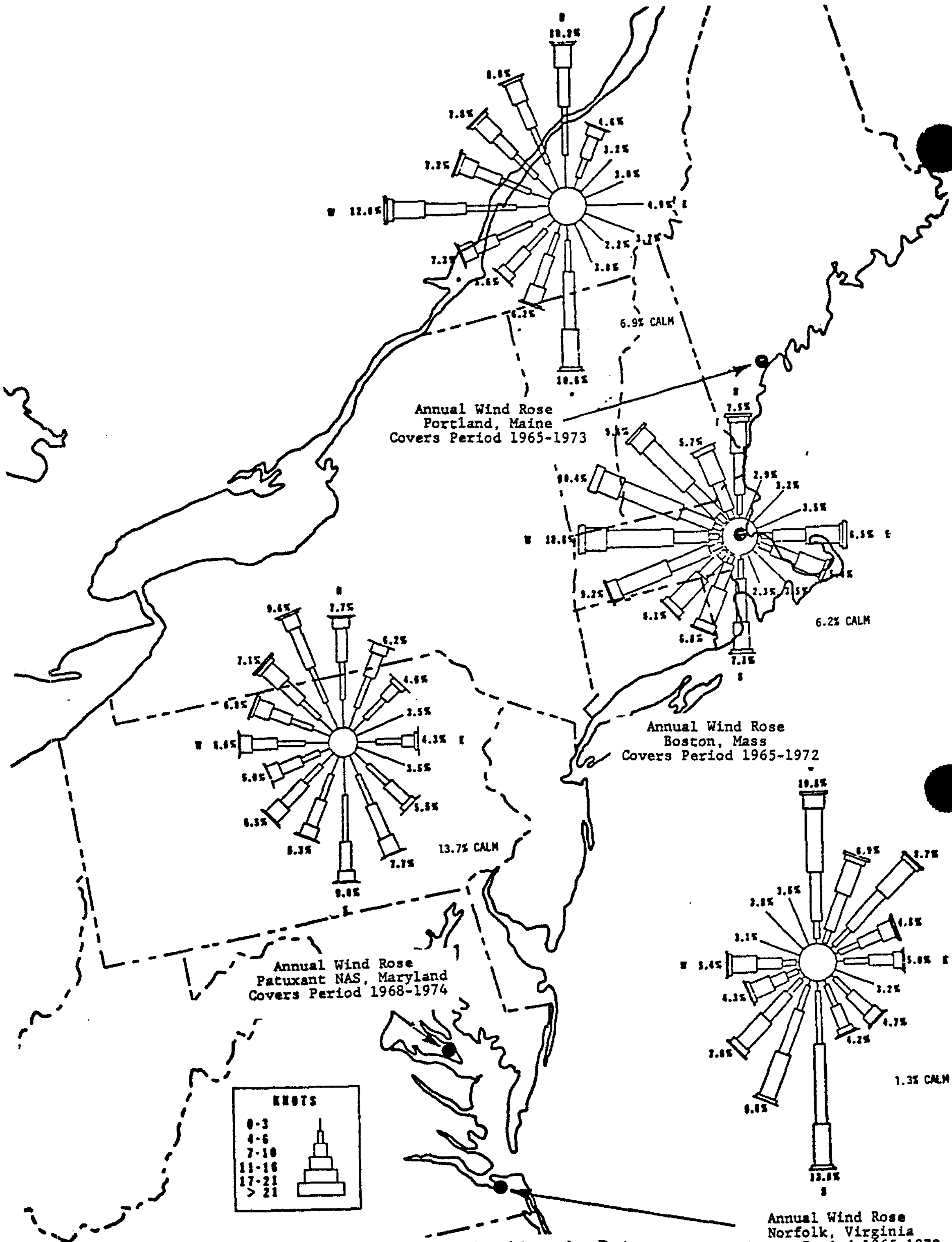
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 105 in August 1918, lowest temperature 2 in February 1895, [illegible] monthly precipitation 15.61 in August 1942, minimum monthly precipitation 0.04 in October 1874, maximum monthly snowfall 18.6 in December [illegible] maximum snowfall in 24 hours 17.7 in December 1892, fastest mile wind 80 W in June 1925.

Sources: NA-273, NA-166

track eastward or northeastward. Southerly and northerly winds are equally frequent, reflecting the progression of weather systems over the area. On a seasonal basis, the winds are predominantly from a northerly or northwesterly direction during the winter and from a southerly or southwesterly direction during the summer (See Figure IV-35). The regions of strongest winds within the East Coast region are the southern Virginia coastline and the Cape Cod area of Massachusetts (TH-079) (See Figure IV-10). The study area is occasionally affected by strong offshore extratropical cyclones, "northeasters," during the fall, winter, and spring and infrequently by tropical storms or hurricanes during the summer.

Statistically, the probability of tropical cyclones achieving landfall along the East Coast storage region is somewhat lower than the probability of such an occurrence in the Gulf Coast storage region. The probabilities are 7% and 13%, respectively. However, within the East Coast study region two 50-mile stretches of land significantly deviate from the average 7% probability, the area from Rhode Island to Nantucket, Massachusetts (21%), and the northernmost 50-mile stretch of Maine coastline (13%) (see Figure IV-36).

Severe local storms including tornadoes are not extremely frequent in the East Coast region. The number of days on which thunderstorms occur varies significantly throughout the East Coast region. The mean annual number of days with thunderstorms along the coastal section of Maine was 20, while the mean number for the southern coastline of Virginia was 40. The distribution of tornadoes, however, is generally uniform.



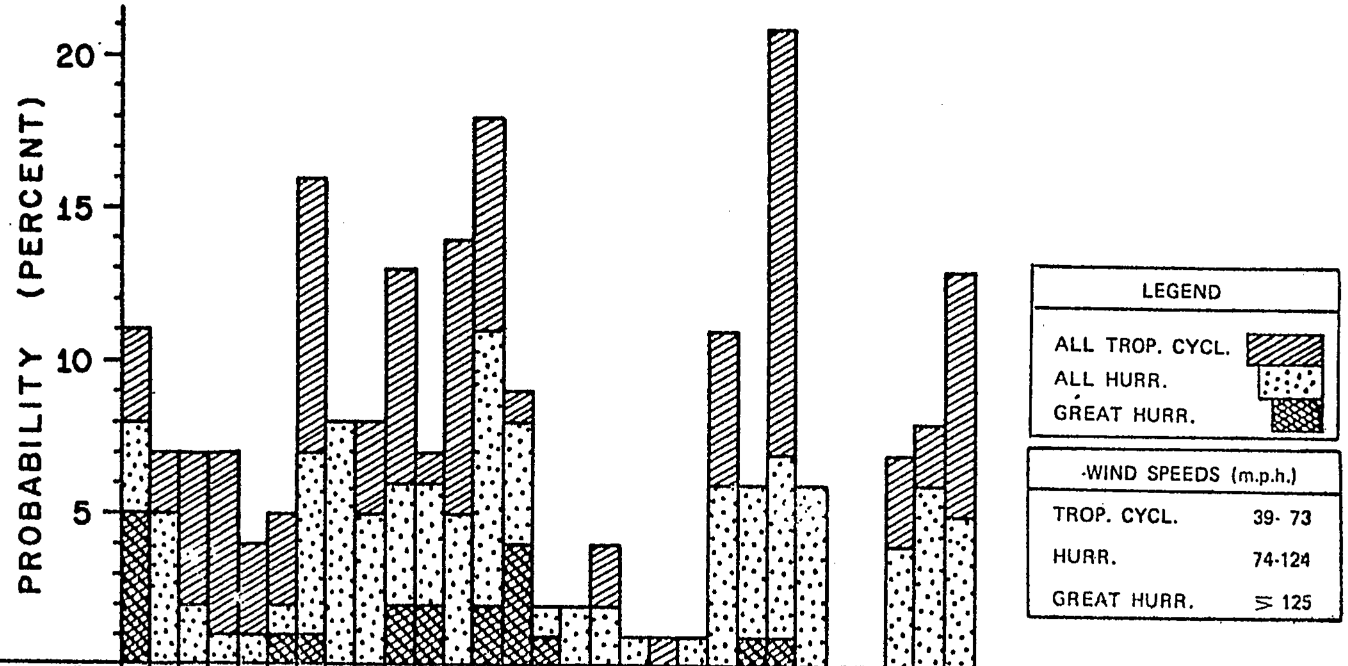
Source: Wind data from National Climatic Data

FIGURE IV-35

ANNUAL WIND ROSES FOR

LOCATIONS ON THE EAST COAST

This histogram and table show the probability (percentage) that a tropical storm, hurricane, or great hurricane will occur in any one year in a 50 mile segment of the U.S. Atlantic Coastline.



COASTAL SECTOR	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
ALL TROPICAL CYCLONES	11	7	7	7	4	5	16	8	8	13	7	14	18	9	2	2	4	1	1	1	11	6	21	6	–	–	7	8	13
ALL HURRICANES	8	5	2	1	1	2	7	8	5	6	6	5	11	8	2	2	2	1	–	1	6	6	7	6	–	–	4	6	5
GREAT HURRICANES	5	–	–	–	–	1	1	–	–	2	2	–	2	4	1	–	–	–	–	–	–	1	1	–	–	–	–	–	–

FL | GA-SC | NC | VA MD DE | NJ | NY | RI-MA NH | ME

Sources: NA-116, SI-110

FIGURE IV-36

RISK OF TROPICAL CYCLONES
U.S. ATLANTIC COASTLINE

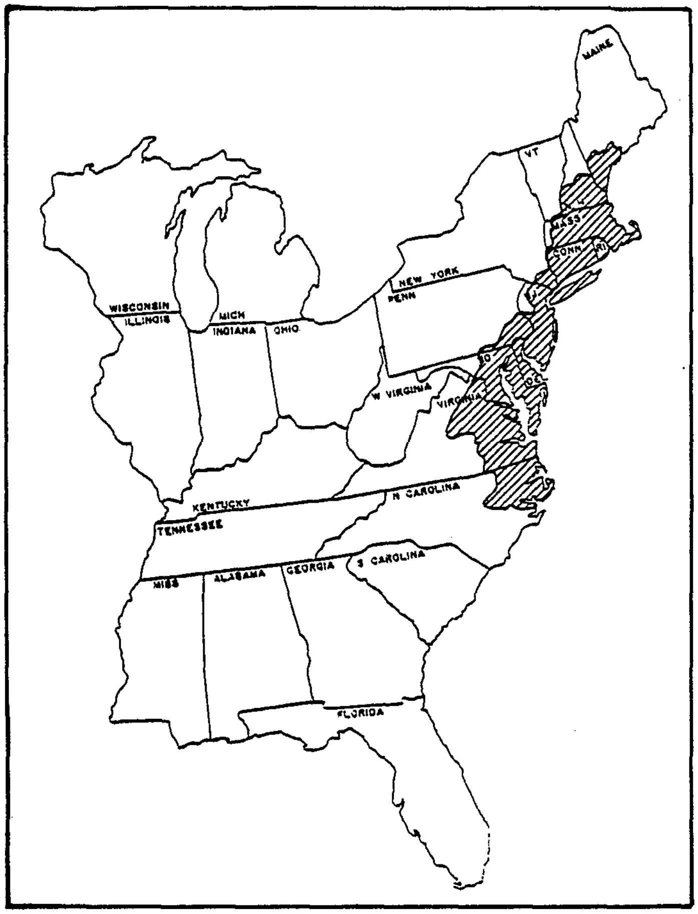


FIGURE IV-37

BORDER OF AQCR'S ENCOMPASSING EAST COAST STORAGE REGION

f. Air Quality

Air quality of this region will be described on the basis of twenty geographical air quality control regions (AQCR's), defined by the United States Environmental Protection Agency for the attainment and maintenance of the national ambient air quality standards (NAAQS) (see Section VI.B.5.a). The regions are Eastern Connecticut, Hartford-New Haven-Springfield, New York-New Jersey-Connecticut Interstate (New York City), Northwestern Connecticut, Metropolitan Philadelphia, Southern Delaware, National Capital, Metropolitan Portland (ME), Eastern Shore (MD), Metropolitan Baltimore, Southern Maryland, Central Massachusetts, Metropolitan Boston, Metropolitan Providence, Merrimack Valley-Southern New Hampshire, New Jersey (Remainder), Northern Coastal Plain (NC), Hampton Roads (VA), Northeastern Virginia, and State Capital (VA). The border of these AQCR's is shown in Figure IV-37.

The status of 1973 ambient air quality levels for the criteria air pollutants (suspended particulates, sulfur dioxide, carbon monoxide, and photochemical oxidants) is shown in Figures IV-13 through IV-16. These figures indicate which AQCR's had violations of the primary standards. Nine of the twenty AQCR's in the East Coast region reported at least one violation of a primary standard for suspended particulates; four had a violation of a primary sulfur dioxide standard; nine had a violation of a primary carbon monoxide standard; eight had a violation of a primary photochemical oxidant standard, and one had a violation of the nitrogen dioxide standards (EN-216).

Synoptic-Scale Effects

The East Coast region has a moderate problem with large-scale poor dispersion conditions. The problem arises from the tendency of upper-level ridging to take place over the Eastern United States. The upper-level flow pattern of ridging is characterized by the anticyclonic curvature of wind streamlines. This ridging aloft is generally accompanied by high pressure systems in the lowest levels of the atmosphere. These stagnating anticyclones (high pressure systems) are the cause of the poor dispersion conditions. The surface anticyclone generally has a weak pressure gradient and subsiding air (sinking air). The subsiding air warms up as it is compressed; consequently, temperature inversions are formed by the subsiding air. The weather regime associated with an anticyclone is, therefore, characterized by weak winds, clear skies, and temperature inversions which inhibit or damp vertical motions. The resulting mixing depths associated with anticyclones are small due to the massive subsidence of the air within the air mass. The total number of stagnation cases (stagnating anticyclones that last four or more days) during the 30-year period ending in 1965 ranges from sixty in Southern Virginia to five in Maine. Although the tendency for anticyclones is high in the Southeastern U. S., the influence of the relatively warmer air over the ocean tends to raise the mixing heights within an anticyclone. The effect of this marine air is to decrease the number of forecast-days of high meteorological potential for air pollution along the coastline region. In conclusion, although the number of cases of anticyclones is much higher in Southern Virginia than in Maine, the meteorological potential for air pollution is uniformly equal along the East Coast region due to the effect of the warm maritime air on the stagnating anticyclones.

Mixing Conditions in the Region

Table IV-25 presents a summation of the average morning and afternoon mixing heights in the East Coast region during each of the four seasons and on an annual basis. The table is for five representative points in the region: Norfolk; Washington, D.C.; Atlantic City; Boston; and Portland. Average wind speeds throughout the mixing layer during each of the periods are also listed. The table and figures indicate (when compared to inland stations) that the Atlantic Ocean increases morning mixing heights but decreases afternoon mixing heights.

Stability

Considering the Pasquill stability classes on an annual basis, the stability distributions are very similar throughout the East Coast region. Those points closer to the coastline will have greater frequencies of occurrence of neutral stability ("D" stability) and smaller frequencies of occurrence of the unstable ("A", "B", and "C" stabilities) and stable ("E&F" stability classes) because of the stronger winds and additional cloudiness which normally prevail at these locations. Using a few representative stations, the normal annual ranges of the Pasquill stability, as determined by the STAR program (program which generates a table of the bivariate frequencies of wind speed and wind direction as a function of stability) in the region are as follows:

A Stability: 0.1 - 1.1%
B Stability: 2.9 - 7.1%
C Stability: 9.8 - 12.5%
D (Day) Stability: 21.3 - 28.8%
D (Night) Stability: 23.5 - 30.6%
E&F Stability: 27.3 - 34.6%

TABLE IV-25

MIXING CONDITIONS IN THE EAST COAST REGION

LOCATION	PERIOD OF RECORD	MIXING HEIGHT (in meters)		WIND SPEED (in meters/second)	
		MORNING	AFTERNOON	MORNING	AFTERNOON
Norfolk, Virginia	Winter	700	900	7.5	7.5
	Spring	650	1400	7.0	8.5
	Summer	650	1500	5.0	6.5
	Fall	600	1100	6.0	6.5
	Annual	650	1200	6.5	7.0
Washington, D.C.	Winter	672	1054	6.3	7.3
	Spring	585	1890	5.4	7.9
	Summer	421	1924	3.4	5.6
	Fall	436	1412	4.4	6.4
	Annual	528	1570	4.9	6.8
Atlantic City, New Jersey	Winter	900	900	9.0	9.0
	Spring	800	1400	7.5	9.0
	Summer	700	1400	5.5	7.0
	Fall	800	1100	7.0	7.5
	Annual	800	1200	7.0	8.0
Boston, Massachusetts	Winter	800	900	8.0	8.5
	Spring	750	1200	7.5	8.5
	Summer	450	1200	5.5	7.5
	Fall	650	1000	7.0	8.0
	Annual	650	1100	7.0	8.0
Portland, Maine	Winter	618	945	6.6	7.8
	Spring	689	1479	6.4	8.7
	Summer	501	1476	4.8	7.6
	Fall	506	1141	5.6	7.4
	Annual	578	1260	5.9	7.8

Source: HO-049

g. Noise

The discussion on noise in Section IV.B.1.e applies equally well to the East Coast region.

h. Biology

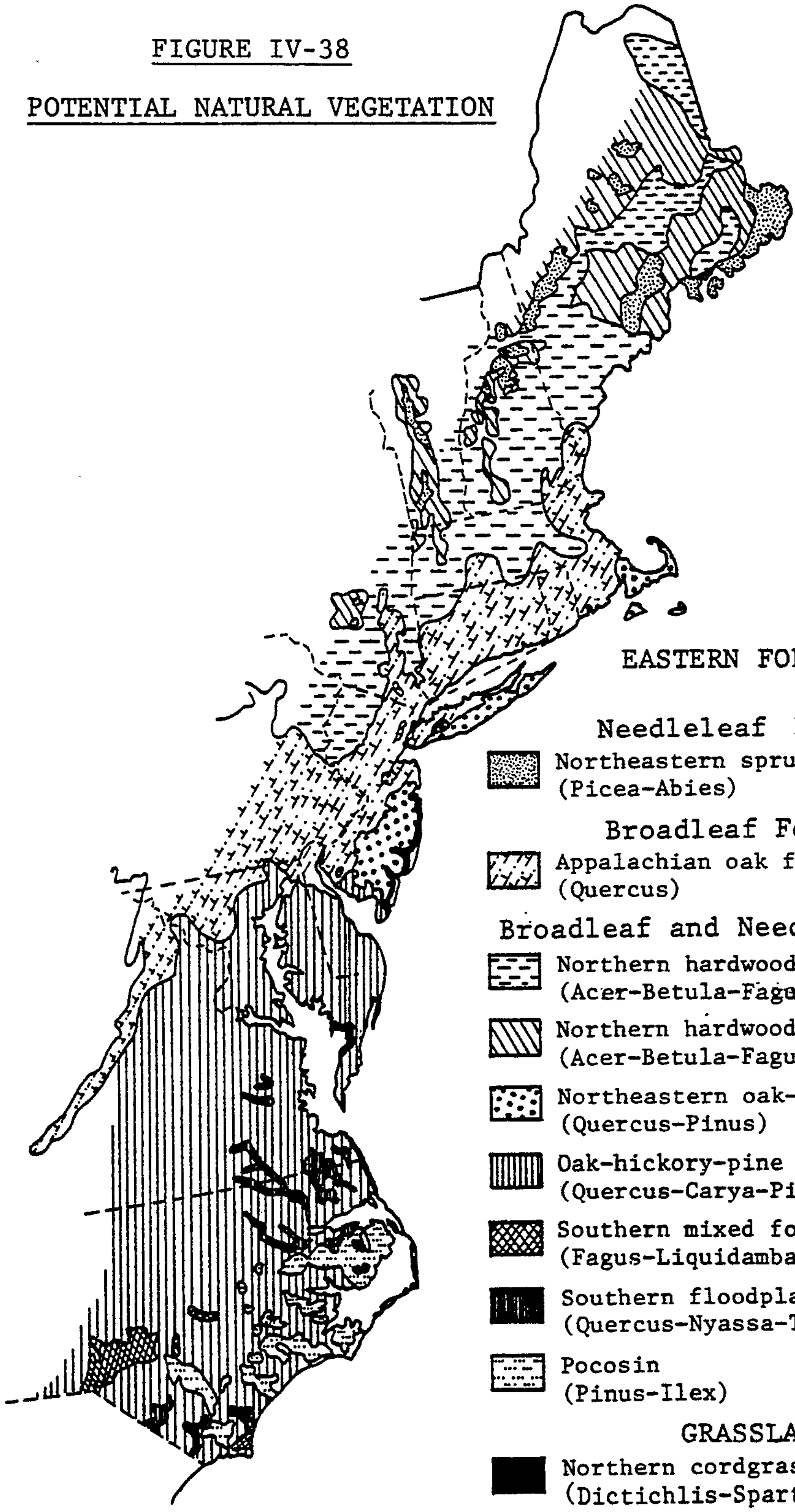
General Characterization of the Region

For biological purposes, the East Coast region will encompass the area from North Carolina through Maine inclusive. It will extend approximately fifty miles or one county inland and offshore to the edge of the Continental Shelf. The terrestrial and wetlands ecology varies widely due to the climatic, geologic, and pedologic differences throughout the region. The marine fisheries vary less due to the mitigating influence of the Gulf Stream current along the Atlantic Coast. This provides a more constant environment except for very near shore where river flows exert an influence. Due to the large area, the biologic description will be of broad coverage. Only the major features and components will be emphasized at the programmatic level since site-specific EIS's will provide detail where it is necessary.

The vegetation of the East Coast region is extremely variable due to the many different geologic and soil types and the latitudinal differences causing greatly different weather conditions. Figure IV-38 illustrates the potential vegetation types generally expected for the region if man had not disturbed the area. The majority of the region is forested except where man has devegetated for developments. Along the coastal edge of the middle of the region extends a line of *Spartina-Distichlis* prairie. These are more or less wetlands depending on the exact terrain. The animals are generally temperate and north temperate species including migratory water fowl.

FIGURE IV-38

POTENTIAL NATURAL VEGETATION



Source: US-155

EASTERN FORESTS

Needleleaf Forests

- Northeastern spruce-fir forest (Picea-Abies)

Broadleaf Forests

- Appalachian oak forest (Quercus)

Broadleaf and Needleleaf Forests

- Northern hardwoods (Acer-Betula-Fagus-Tsuga)
- Northern hardwoods-spruce forest (Acer-Betula-Fagus-Picea-Tsuga)
- Northeastern oak-pine forest (Quercus-Pinus)
- Oak-hickory-pine forest (Quercus-Carya-Pinus)
- Southern mixed forest (Fagus-Liquidambar-Magnolia-Pinus-Quercus)
- Southern floodplain forest (Quercus-Nyassa-Taxodium)
- Pocosin (Pinus-Ilex)

GRASSLAND

- Northern cordgrass prairie (Dictichlis-Spartina)
- Bluestem prairie (Andropogon-Panicum-Sorghastrum)

Wetlands of various character extend along the North Carolina coast and throughout much of the northeastern coast, except for the rocky shores of Maine. The North Carolina and Virginia coasts have extensive marshes with vast expanses of Spartina alterniflora salt marsh. These estuaries and marshes are extremely productive areas. The areas of marsh are smaller progressively northward, and along the Maine Coast they have given way to rocky shorelines as the major system. As in the Gulf Coast region, all species of aquatic estuarine organisms and many species of marine organisms are dependent upon the wetlands during a portion of their cycles. Migratory waterfowl and shore birds abound in the wetlands. The wetlands of the East Coast region are much more productive than those of the Gulf Coast. This is primarily due to the higher tidal range (up to three meters) introducing more nutrients into the marshes on a regular basis and the high rainfall rate on the freshwater marshes. The upper reaches of the region contain many embayments of various sizes and configurations and range in wetland types from pockets of marsh to rocky shore and high energy beaches. These are extremely variable in species composition and productivity, and must be addressed on a site-specific basis in the site-specific EIS's.

The aquatic areas of the East Coast range from the bay planktonic biotope similar to the bays of the Gulf Coast in the southern portion, through barrier beaches with sloping shelf regimes, to steeply sloping rock-bottomed areas that contain primarily attached vegetation and colder water species. Many species of aquatic organisms depend upon the estuaries and coves for a portion of their life cycles. There are areas of submerged grass beds in the region that serve the same function as those in the Gulf Coast region although they are composed of different species of grasses and attached algae.

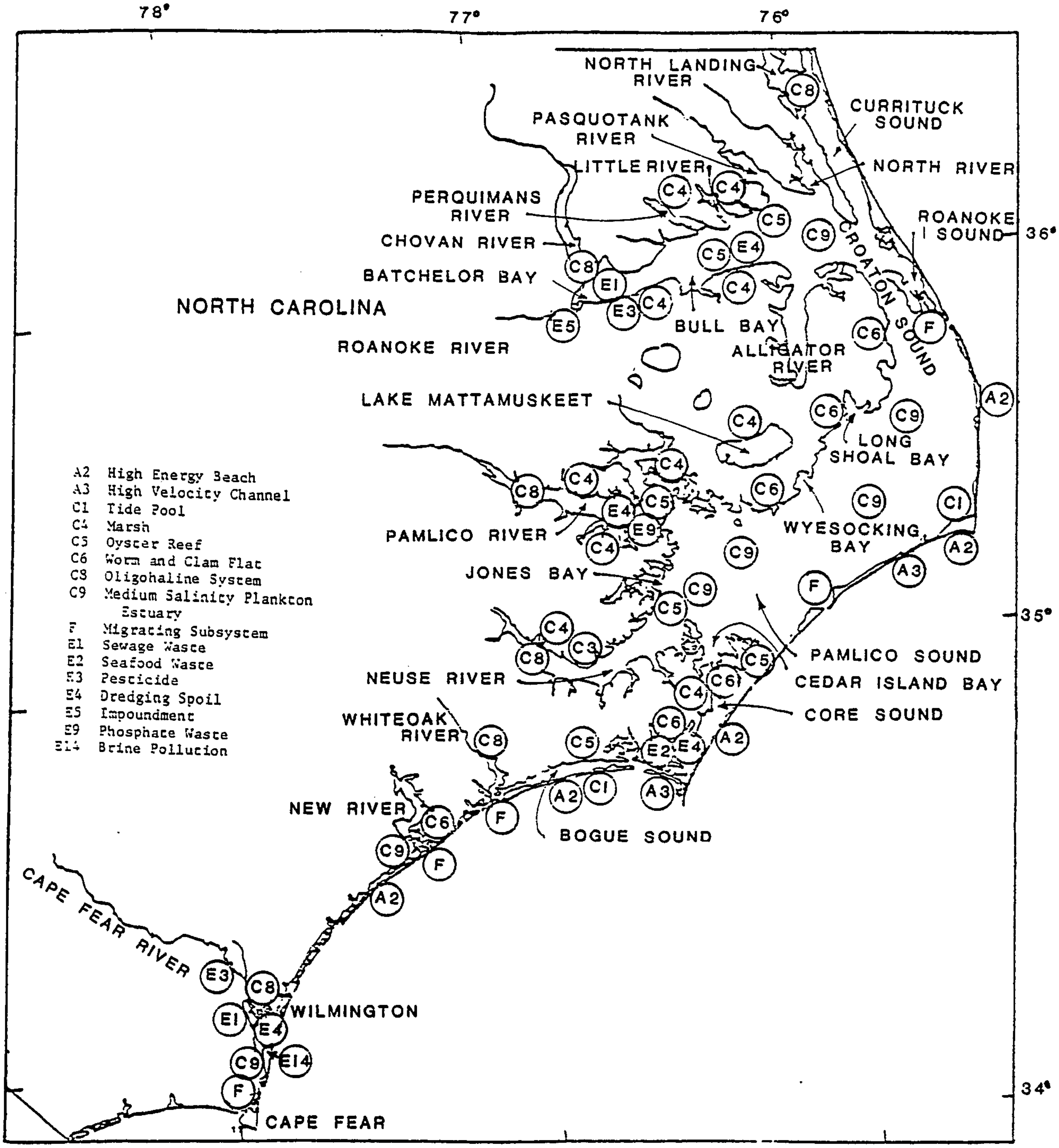
Characterization of the Environment (Biotopes, Habitat Areas)

The maps of Odum, Copeland and McMahan (OD-012) are presented as a general description of certain biologic areas within the region. Although the "biotopes" of Oppenheimer and Gordon (OP-018) were developed on the Texas Coast, they are generally applicable to most biological assemblages of the East Coast regions. They aid in identification of working units of the environment and their relative inputs to the total coastal ecosystem. Figures IV-39 through IV-44 depict the various biological areas according to Odum, Copeland and McMahan.

Important Sport and Commercial Species

Many types of fish and shellfish are harvested both commercially and by sportsmen in the East Coast region. Some of the same species that inhabit the Gulf Coast region are also found in the southern portion of the region, such as red drum, flounders, seatrout and shrimp. Much of the northern portion is used for commercial harvesting of many oceanic species and for sport fishing for striped bass and other species. The striped bass is the major sport fish in the northern portion of the East Coast region (see Table IV-26).

Some mammals are hunted in the East Coast region. These consist primarily of deer, rabbits, foxes, and woodchucks. Trapping of fur-bearing animals also occurs. Bird hunting is a large industry from the sports aspect, with turkey and migratory water fowl the major game. Figure IV-45 shows the Atlantic flyway down which the migratory species fly each fall. Tables in the supporting document (RA-223) list the major species known to migrate through and to live in the East Coast region.



Source: OD-012

FIGURE IV - 39

COASTAL ECOLOGICAL SYSTEMS OF NORTH CAROLINA

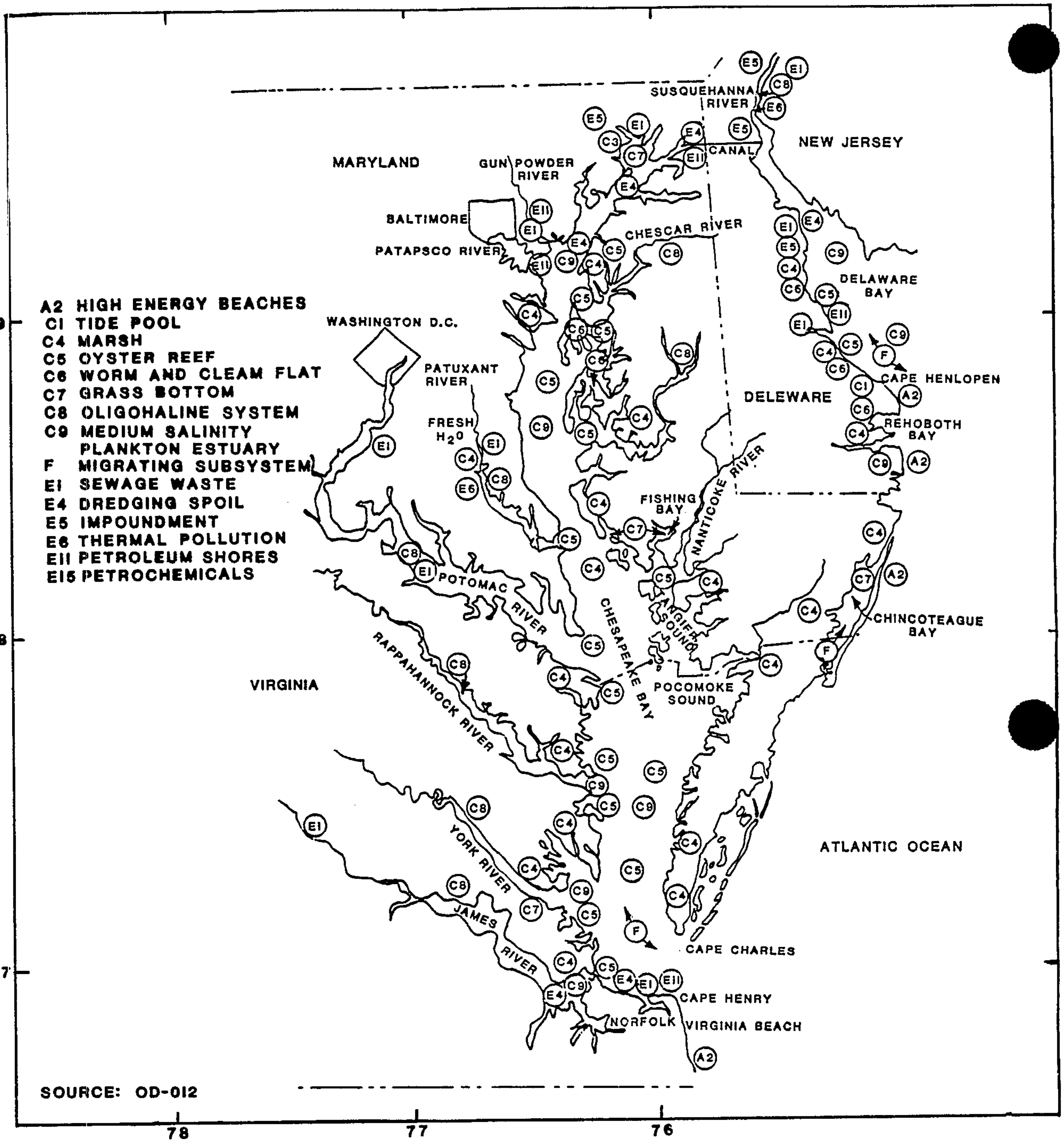


FIGURE IV - 40
COASTAL ECOLOGICAL SYSTEMS OF MARYLAND

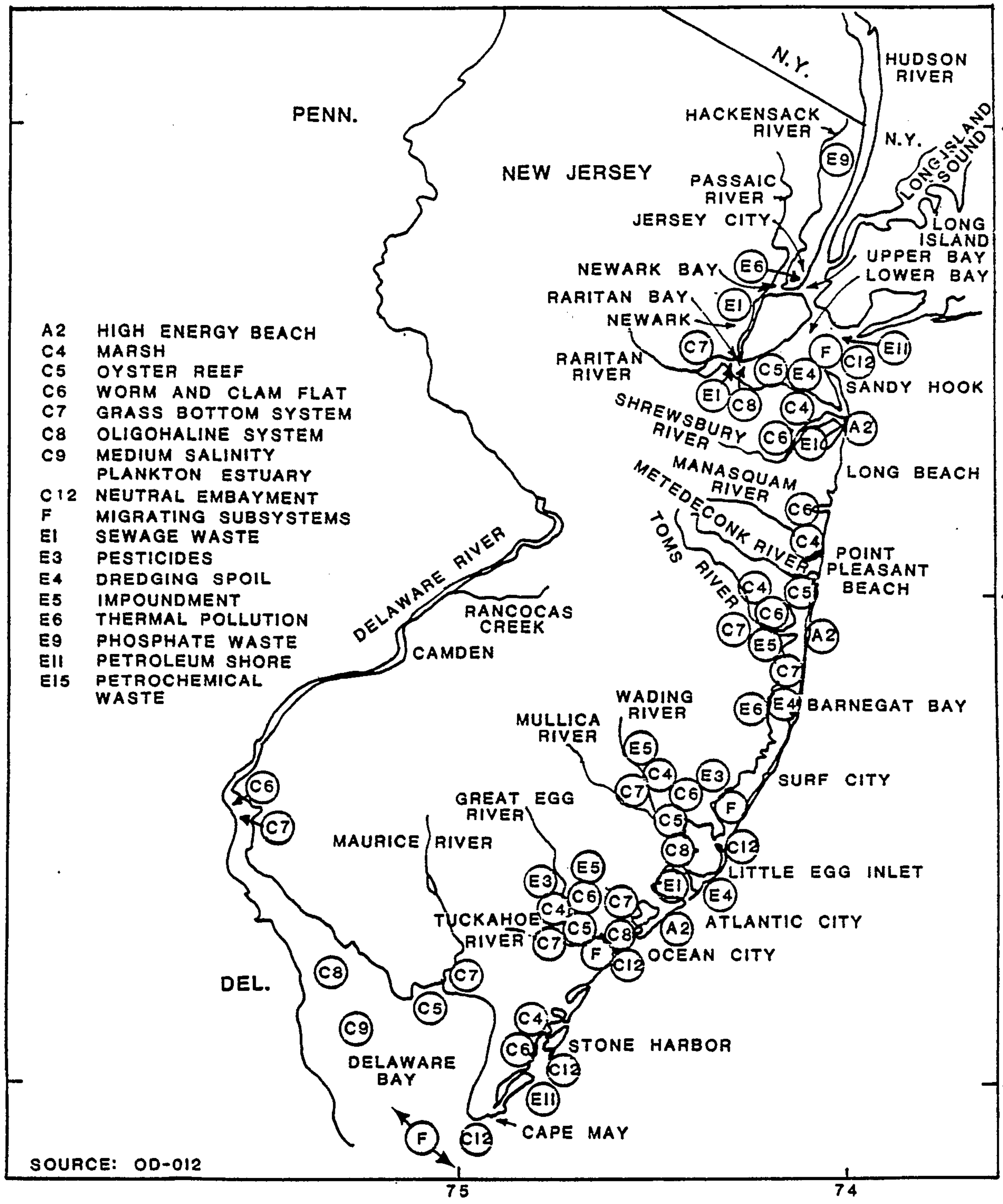
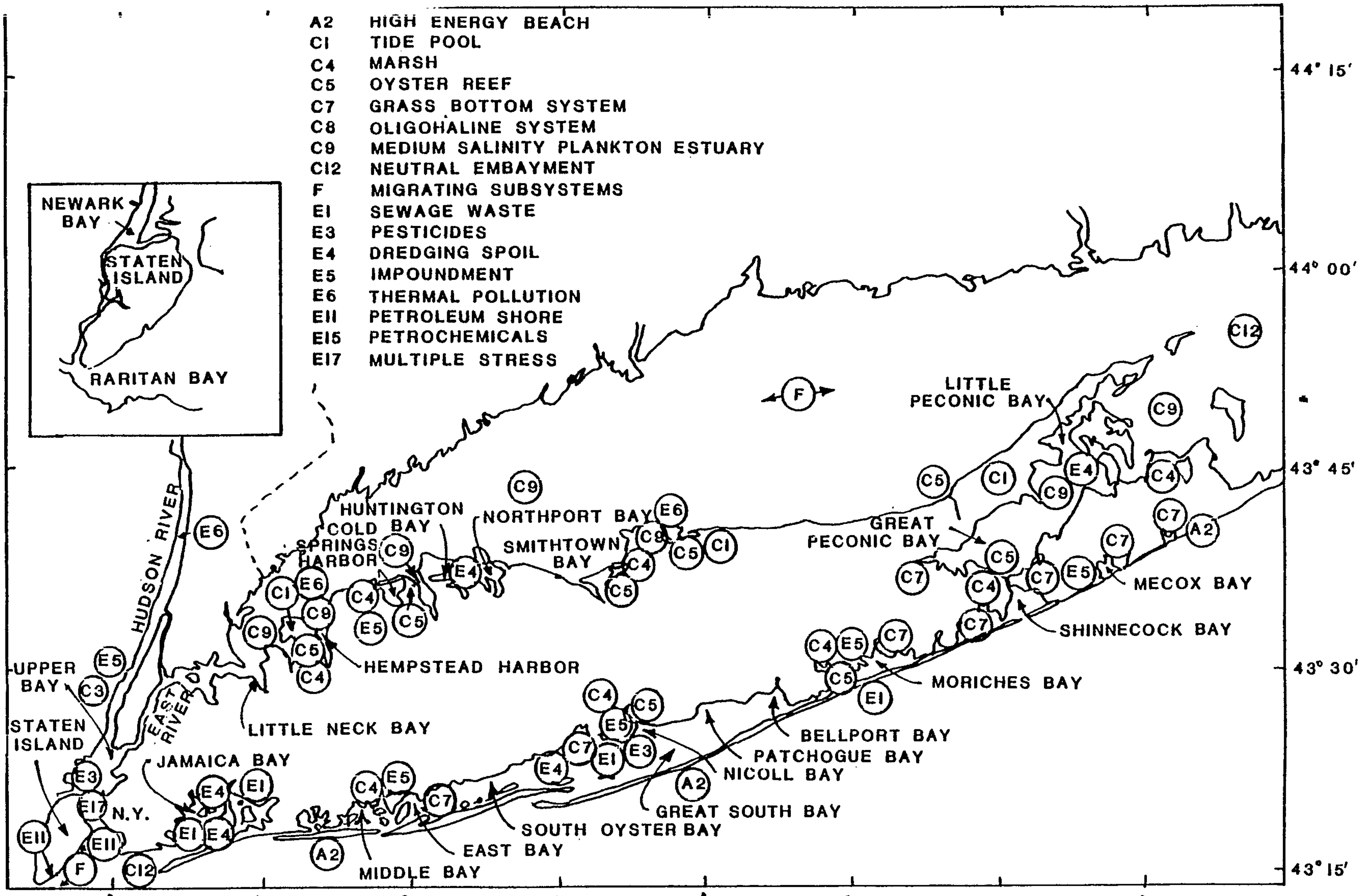


FIGURE IV - 41

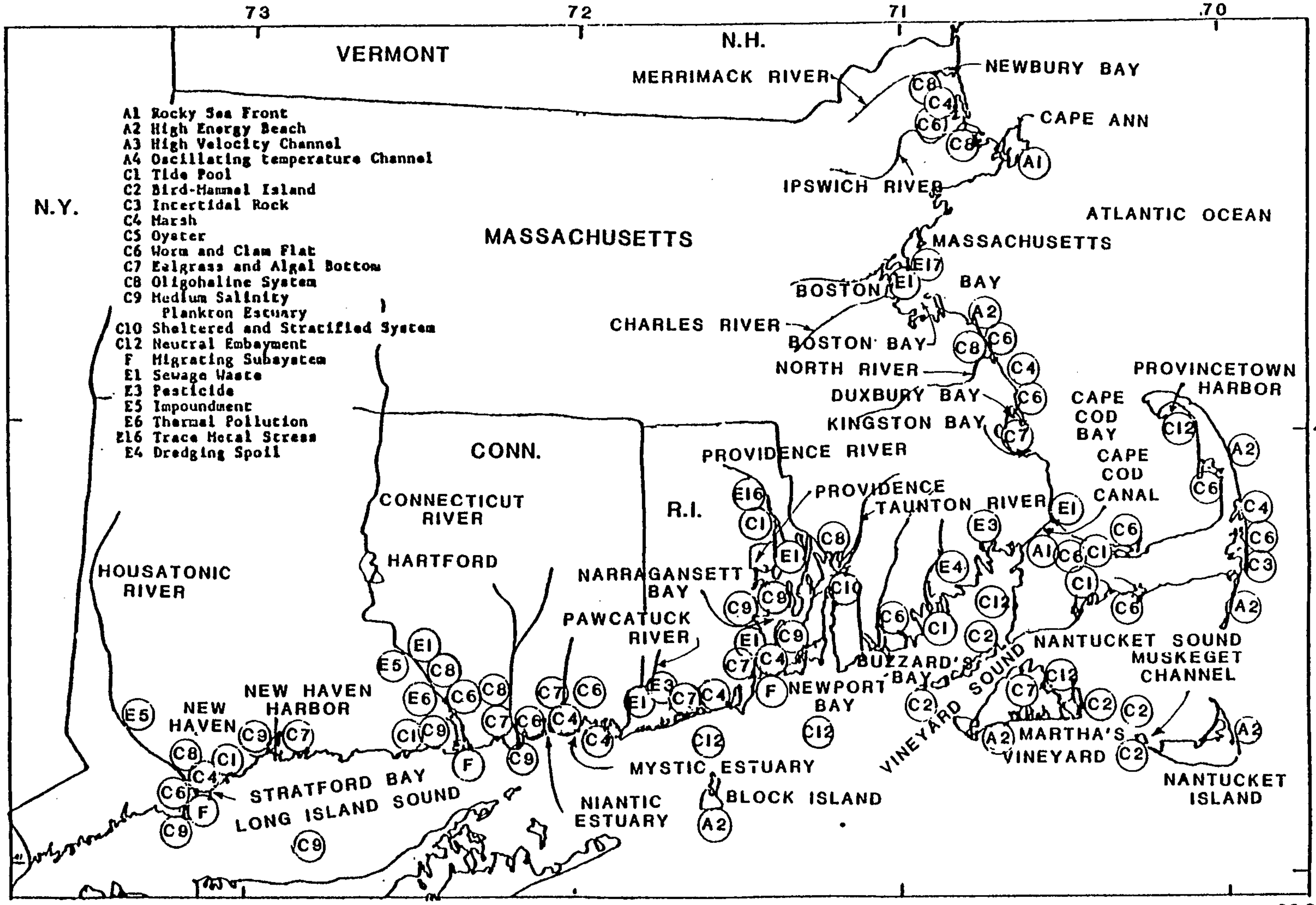
COASTAL ECOLOGICAL SYSTEMS OF NEW JERSEY



SOURCE: OD-012

FIGURE IV - 42

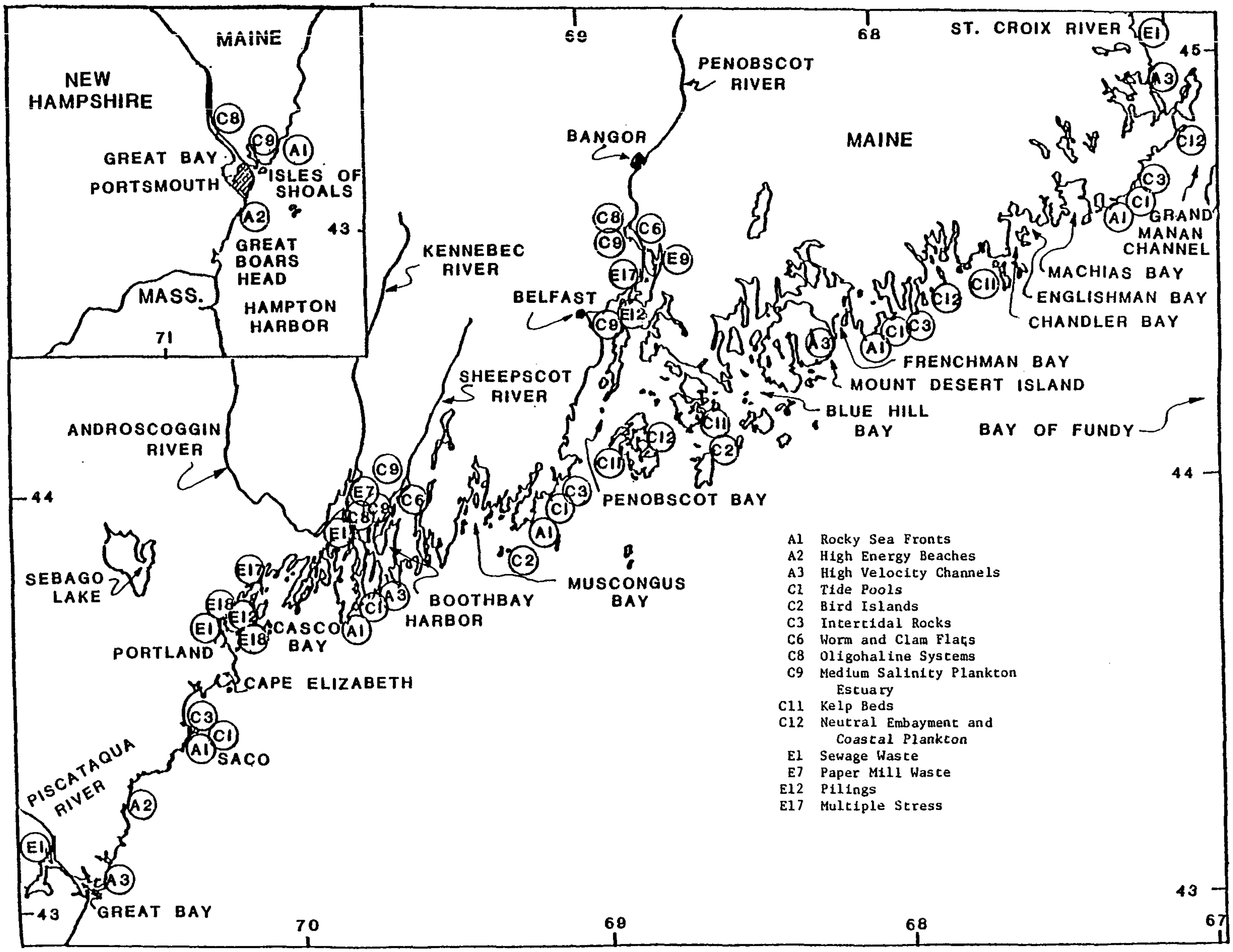
COASTAL ECOLOGICAL SYSTEMS OF NEW YORK



Source: OD-012

FIGURE IV - 43

COASTAL ECOLOGICAL SYSTEMS OF RHODE ISLAND, CONNECTICUT AND MASSACHUSETTS



SOURCE: OD-012

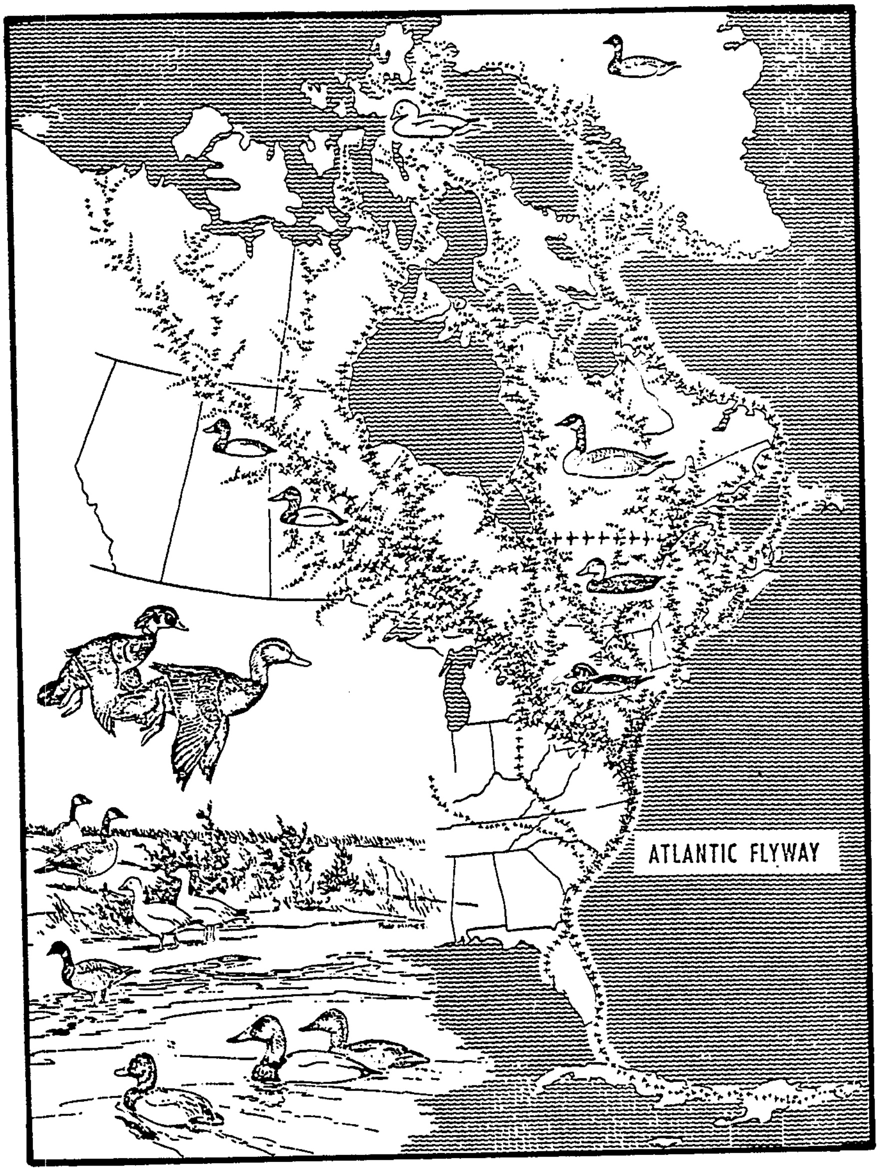
FIGURE IV-44

COASTAL ECOLOGICAL SYSTEMS OF MAINE AND NEW HAMPSHIRE

TABLE IV-26

SPORTS AND COMMERCIALLY IMPORTANT SPECIES

Fish	
Winter flounder	*Pseudopleuronectes americanus*
Atlantic croaker	*Micropogon undulatus*
Striped bass	*Morone saxatilis*
Summer flounder	*Paralichthys dentatus*
Scup	*Stenotomus chrysops*
Weakfish	*Cynoscion regalis*
Red drum	*Sciaenops ocellata*
Striped mullet	*Mugil cephalus*
Tautog	*Tantoga onitus*
Bluefish	*Pomatomas saltatrix*
Alewife	*Alosa pseudoharengus*
Shad	*Alosa sapidissima*
Atlantic mackerel	*Scomber scomber*
Atlantic menhaden	*Brevoortia tyrannus*
Black seabass	*Centropristis striata*
Atlantic herring	*Clupea harengus*
American plaice	*Hippoglossoides platessoides*
Grey sole	*Glyptocephalus cynoglossus*
Yellowtail flounder	*Limanda ferriginea*
Bluefin tuna	*Thunnus thynnus*
Swordfish	*Xiphias gladius*
Redfish	*Sebastes marinus*
Atlantic salmon	*Salmo salar*
Spiney dogfish	*Squalus acanthus*
Silverhake	*Merluccius bilinearis*
Pollock	*Pollachius virens*
Atlantic cod	*Gadus morhua*
Cunner	*Tautogolabrus adspetsus*
Shellfish	
Oyster	*Crassotrea virginica*
Hardclam	*Mercenaria mercenaria*
Sea scallop	*Plactopecten magellanicus*
Blue crab	*Callinectes sapidus*
Lobster	*Homarus americanus*
Surf clam	*Spisula solidissima*
Bay scallop	*Aquipecten irradicans*
Shrimp	*Penaeus* sp.



Source: US-344

FIGURE IV-45

ATLANTIC FLYWAY MIGRATORY WATERFOWL MIGRATION ROUTE

Species Important to the Ecosystem

The marsh biotopes are generally heavily dependent upon one or two species of plants. Salt marsh is composed primarily of smooth cordgrass (Spartina alterniflora) in the tidal areas and marsh hay cordgrass (Spartina patens) in the areas just above the high tide range. Freshwater marshes are primarily composed of either Phragmites (cane) or one or more species of Juncus (reed). Most other biotopes are not heavily dependent on only a few species.

Regionally Endangered Species

There are many species of both plants and animals considered rare, endangered, threatened, peripheral or questionable by various organizations in the East Coast region. Table IV-27 lists the major ones recognized by the U. S. Department of the Interior. Tables IV-28 and IV-29 list species considered rare, endangered, or questionable by several other agencies. Site-specific impact statements will describe those likely to be found in the immediate vicinity of each proposed site.

Species-Specific Information

Detailed information pertaining to the various plant and animal species found in the East Coast region is presented in tabular and graphic form in the central reference document (RA-223). There has been no single comprehensive survey of the entire region; however, there have been several surveys of subregions. Some of the information contained in these subregional surveys is included in order to give broad coverage and identify the species that may be expected and some of their environmentally associated parameters. Due to the variability of the region

TABLE IV-27

ENDANGERED ANIMALS

NEW YORK
Shortnose sturgeon

NEW JERSEY
Southern bald eagle
Eskimo curlew

DELAWARE
Southern bald eagle

MARYLAND
Maryland darter
Southern bald eagle
Delmarva Peninsula fox squirrel

VIRGINIA
Southern bald eagle

NORTH CAROLINA
American alligator
Eastern brown alligator
Southern bald eagle

Source: US-155

TABLE IV-28

CURRENT CLASSIFIED LIST OF RARE, ENDANGERED, AND THREATENED VERTEBRATE SPECIES ON THE ATLANTIC COASTAL PLAIN AND THE MAINE COAST

SPECIES NAME	STATUS U.S.D.I.	STATUS I.U.C.N.	OTHER STATUS REFERENCES
Fish			
American Brook Lamprey	-	-	MI-202
Shortnose Sturgeon	E	2(a),4(a)	MI-202
Atlantic Sturgeon	-	2(a)	MI-202
American Shad	-	-	MI-202
Atlantic Salmon	-	-	MI-202
Sunapee Trout	R	1(6)	MI-202
Atlantic Tomcod	-	-	MI-202
Waccamaw Killifish	UD	-	MI-202
Waccamaw Silverside	UD	4(a)	MI-202
Suwannee Bass	R	4(a)	MI-202
Waccamaw Darter	UD	4(a)	MI-202
Maryland Darter	E	2(a)S	MI-202
Amphibians			
Pine Barrens Tree Frog	R	1(a)R	-
Reptiles			
American Alligator	E	1(a)***PT	-
Bog Turtle	R	2(a)	-
Green Turtle	P	3(a)PT	CA-295
Loggerhead Turtle	-	3(a)PT	CA-295
Hawksbill Turtle	-	1(a)PT	CA-295
Atlantic Ridley Turtle	-	1(a)T	CA-295
Pacific Ridley Turtle	-	-	CA-295
Leatherback Turtle	-	-	CA-295
Birds			
Brown Pelican	E	-	-
Florida Great White Heron	R	-	-
Southern Bald Eagle	E	2(b)P*	-
Osprey	UD	-	AM-167
American Peregrine Falcon	E	2(b)P**	-
Arctic Peregrine Falcon	E	-	-
Florida Sandhill Crane	R	2(b)P*	-
Eskimo Curlew	R	1(a)P***	-
Common Tern	-	-	AM-167
Arctic Tern	-	-	AM-167
Roseate Tern	-	-	AM-167
Least Tern	-	-	AM-167
Ivory-billed Woodpecker	E	1(a)P***	-
Red-cockaded Woodpecker	E	-	-
Bachman's Warbler	E	3(a)PM***	-
Kirtland's Warbler	E	3(a)PM*	-
Ipswich Sparrow	R	2(a)P*	-
Mammals			
Dismal Swamp Shorttail Shrew	-	-	HA-410
Delmarva Peninsula Fox Squirrel	E	1(b)R	-
Eastern Fox Squirrel	UD	4(b)	-
Cumberland Island Pocket Gopher	-	-	-
Gray Seal	-	-	HI-144
Harbor Seal	-	-	RA-218
Block Island Meadow Vole	R	4(b)	RA-218
Beach Meadow Vole	R	4(a)	-
Eastern Panther	E?	3(b)	-
Florida Panther	E	1(b)P	-
Florida Manatee	E	4(b)PR	-

Source: RE-172

TABLE IV-28 (Continued)
CURRENT CLASSIFIED LIST OF RARE, ENDANGERED, AND THREATENED VERTEBRATE SPECIES ON THE ATLANTIC COASTAL PLAIN AND THE MAINE COAST

Categories and Definitions

Categories and definitions used in this report are drawn from those used by the USDI Redbook, 1970 edition, and IUCN Red Data Books and are similar to, or identical with, them.

ENDANGERED: An endangered species or subspecies is one whose survival and reproduction are in immediate jeopardy, hence in immediate danger of extinction. Continued survival of the species is unlikely without the aid of special protective measures. (Corresponds with IUCN pink sheets, category 1)

RARE: A rare species or subspecies is one which occurs in such small numbers throughout its range, and/or occurs in such a restricted or specialized habitat that it may become endangered and disappear if conditions worsen. (Corresponds with IUCN white sheets, category 2)

THREATENED OR DEPLETED: A species or subspecies which still occurs in numbers adequate for survival, however the species has been heavily depleted and continues to decline at a rate which seems threatening and gives cause for serious concern. (Corresponds with IUCN amber sheets, category 3)

PERIPHERAL: A species or subspecies whose occurrence in the U. S. is at the edge of its natural range and which is rare and endangered within the U. S. but not in its range as a whole. Special attention is necessary to assure retention in U. S. fauna.

STATUS UNDETERMINED: A species or subspecies which is possibly or apparently endangered, but insufficient data is currently available with which to determine its status. (Corresponds with IUCN blue sheets, category 4; and with Blue List for birds, National Audubon Society)

****

Key to IUCN Classifications on List

(a) = Full species (b) = Subspecies
M = Under active management in a national park or other reserve
P = Legally protected, at least in some parts of its range
R = Included because of its restricted range
T = Subject to substantial export trade
S = Secrecy still desirable

1 = Endangered 3 = Depleted
2 = Rare 4 = Indeterminate

***Species or subspecies critically endangered

TABLE IV-29

LIST OF ENDANGERED SPECIES (FROM USFWS 1973) WITH PROBABLE CAUSE(S) AND SPECIES ON THE AUDUBON SOCIETY BLUE LIST (ARBIB 1973)

SPECIES	CAUSE
Endangered Species	
Southern Bald Eagle X	Proximity of residents; illegal shooting; loss of nest trees; pesticide effects on reproduction.
Peregrine Falcon X American Arctic	Cumulative effects of pesticides on reproductive success.
Florida Everglades Kite	Hunting, habitat loss by drainage of swamps; proximity of residents; decline of sole food, the small Pomacea, snail.
Brown Pelican X+	Thinning of egg shells resulting in breeding failure.
Dusky Seaside Sparrow X	Habitat alteration; mosquito and flood control practices.
Bachman's Warbler	Obscure; possible cutting of virgin swamp and bottomland timber.
Kirtland's Warbler	Limited nesting habitat; parasitism by cowbirds
Ivory-Billed Woodpecker	Habitat scarcity.
Red-Cockaded Woodpecker	Limited number of specialized nesting sites (old living pines with red-heart disease) and current forestry practices.
Blue List Species	
Red-throated Loon X+	Black-crowned Night Herron X+
Western Grebe *+	Wood Stork X+
White Pelican X	White Ibis X
Double-crested Cormorant X+	Fulvous Tree Duck *+
Sharp-shinned Hawk	Gull-billed Tern X
Cooper's Hawk	Least Tern X
Red-shouldered Hawk*	Barn Owl
Marsh Hawk X+	Burrowing Owl
Osprey X+	Florida Scrub Jay
Caracara	Bewick's Wren*
Merlin	Loggerhead Shrike
American Kestrel	Yellow Warbler +
Limpkin X	Common Yellowthroat +
American Oystercatcher X	Bachman's Sparrow
Snowy Plover *X	Grasshopper Sparrow
Henslow's Sparrow +	

*Accidental or casual in coastal southeastern United States.

+Populations in study area not declining. Of concern elsewhere in range.

XLife history summary included.

from north to south and within each state, the lists of species must be interpreted as being representative only within the limits of habitat preferences of each species.

i. Historical and Archaeological Resources

The East Coast region has numerous sites of historical and archaeological significance. As described in the previous discussion on the Gulf Coast (IV.B.1.8), coordinated efforts to systematically identify the historical and archaeological resources of each state are relatively new. Current efforts result largely from the historic preservation legislation of 1966 and 1971. To date, there is no comprehensive inventory of the historical and archaeological resources of the East Coast. The National Register of Historic Places and the statewide inventories compiled to date are the most complete records available.

As is true on the Gulf Coast, records of historical resources are more complete than records of archaeological resources in this region. New sites of both state and national significance are continually being added to the list of historical and archaeological resources, as new inventories are conducted and the interpretation of historical and cultural significance is broadened. Thus, current listings are continually outdated.

Records of archaeological resources are very incomplete for the East Coast. No comprehensive surveys of archaeological resources have been completed. In New England, archaeologists agree that only a fraction of the potential sites have been identified since very little research in the field of archaeology has been performed (RE-172). Limited research funds and staff have restricted comprehensive archaeological surveys to areas threatened by destruction and areas where a high concentration of sites is predicted.

The February 1975 edition of the National Register of Historic Places lists 2,758 sites of national, state, and local significance within the East Coast region. Of these, 1,745 properties are located in coastal counties. Table IV-30 lists the total number of sites in these counties for each state.

TABLE IV-30

COASTAL SITES OF NATIONAL SIGNIFICANCE

STATE	NUMBER OF SITES IN COASTAL COUNTIES
Maine	229
New Hampshire	44
Massachusetts	179
Rhode Island	182
Connecticut	139
New York	187
New Jersey	200
Delaware	145
Maryland	240
Virginia	200
	TOTAL 1,745

Site listings for statewide inventories are being updated continually as these inventories are still underway in most states. The State Historical Preservation Officer in each state is the best source for the most current list at any time.

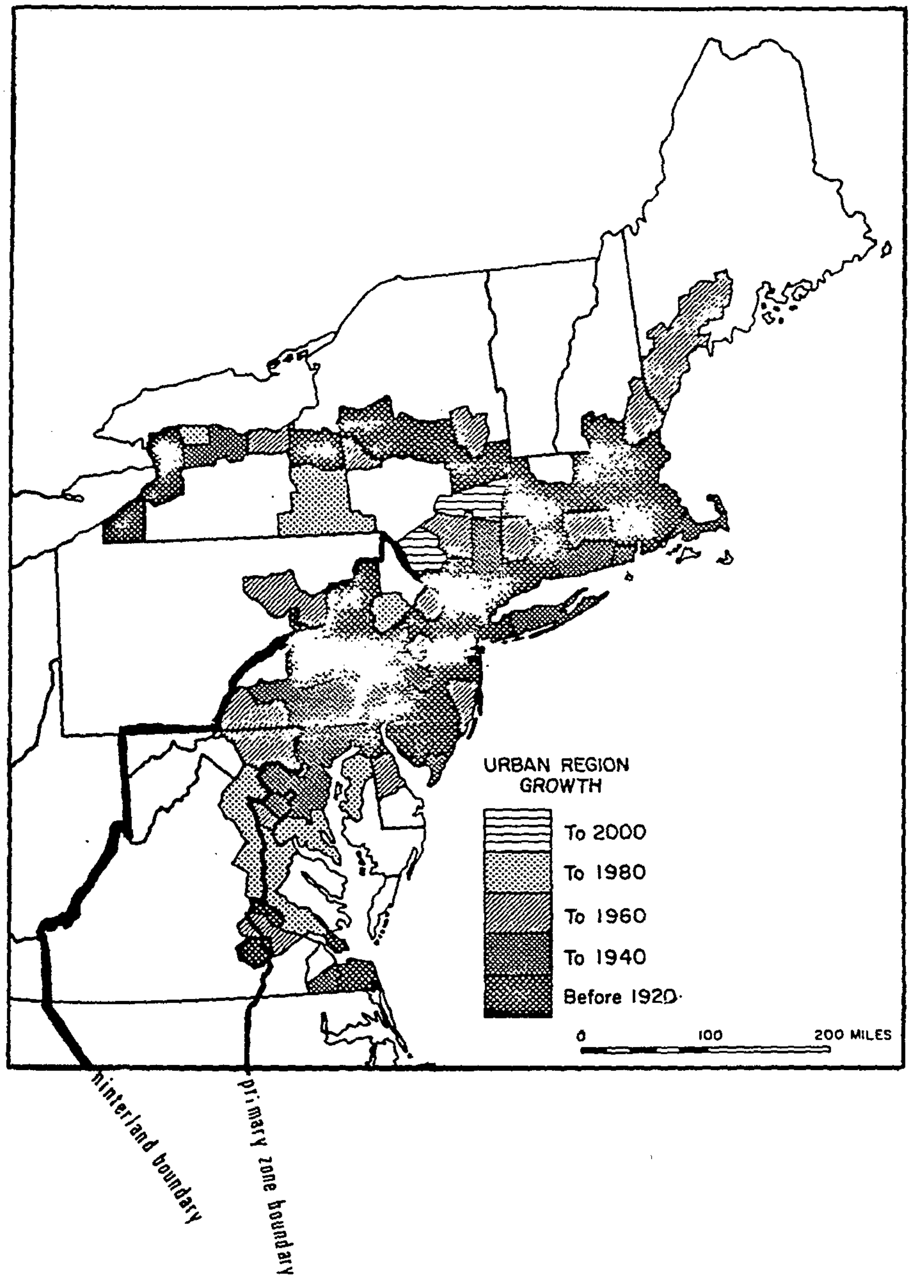
j. Land Use Patterns

The overwhelming influence on land use patterns in this area is the high population density. The area is heavily urbanized, especially along the Atlantic seacoast from slightly south of Washington, D.C. to Massachusetts. Significant urbanization occurred in this area prior to 1940 (Figures IV-46 to IV-48). It is especially important to this programmatic study that note be taken that population density projections through the year 2000 reflect the increasing preponderance of urbanization in the area (Table IV-31).

An essential ramification of the heavy urbanization experienced in the East Coast region is expeditious use of land. Support of a highly urbanized population is achieved by providing maximum employment on a minimum of land; hence, the area is heavily industrialized. Figure IV-49 presents major industrial centers in the East Coast study region. As might be expected, these mirror population centers. Another important aspect of this heavy urbanization is the demand for transportation facilities. A significant amount of land is given over to transportation facilities.

Recreational Activities and Facilities

Recreational facilities along the Atlantic Coast are an important resource to the region and the country, both in monitary terms and in enjoyment provided the users. In general, the recreation centers are swimming, sun-bathing, walking on the beach, boating, hunting, fishing, touring of scenic and historic sites, camping, picnicking, and bird-watching.



SOURCE: RE-172

FIGURE IV-46
URBAN GROWTH - PAST, PRESENT AND FUTURE
ATLANTIC SEABOARD URBAN REGION

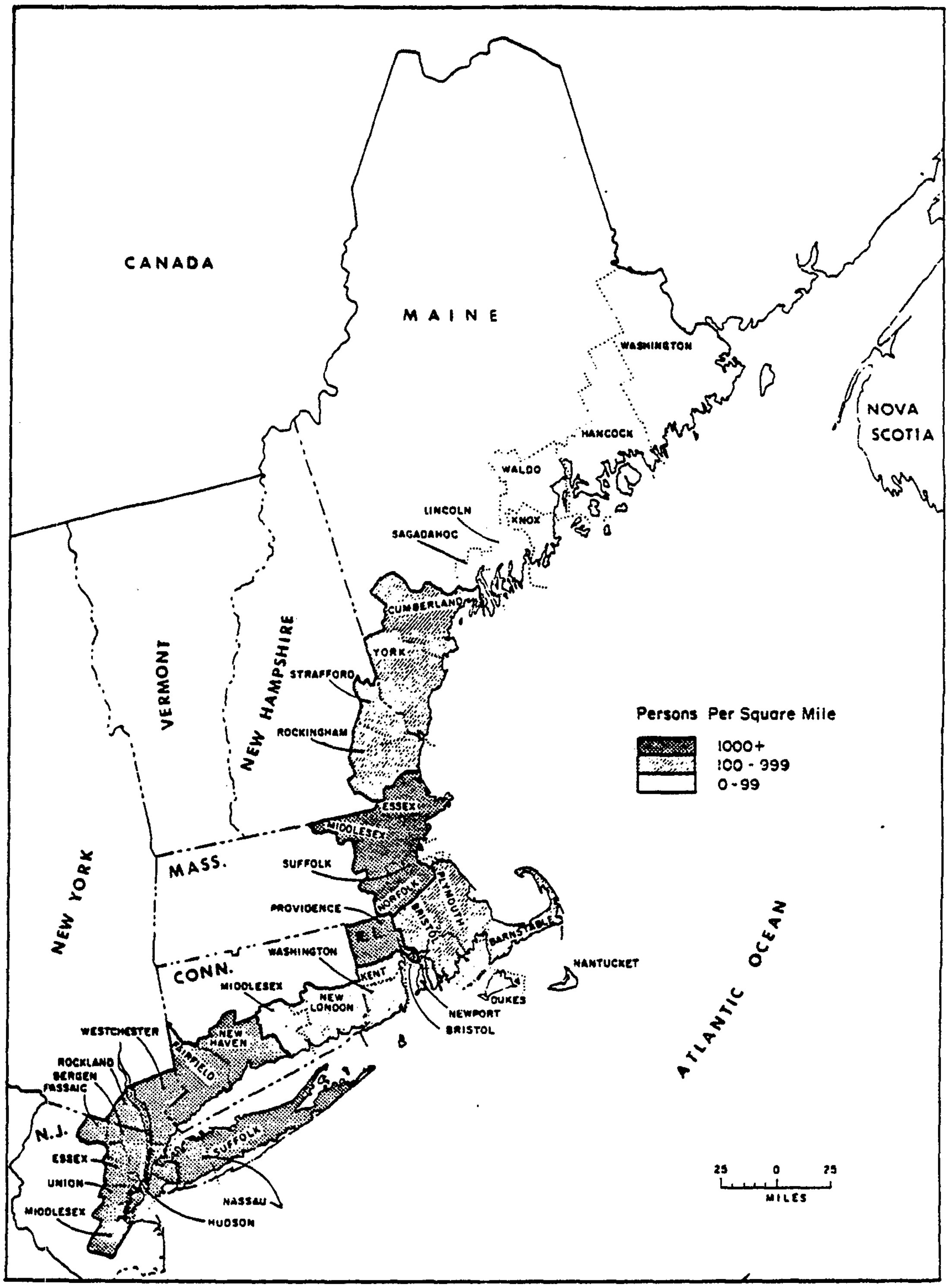


FIGURE IV-47

POPULATION DENSITY, 1970

Source: RE-172

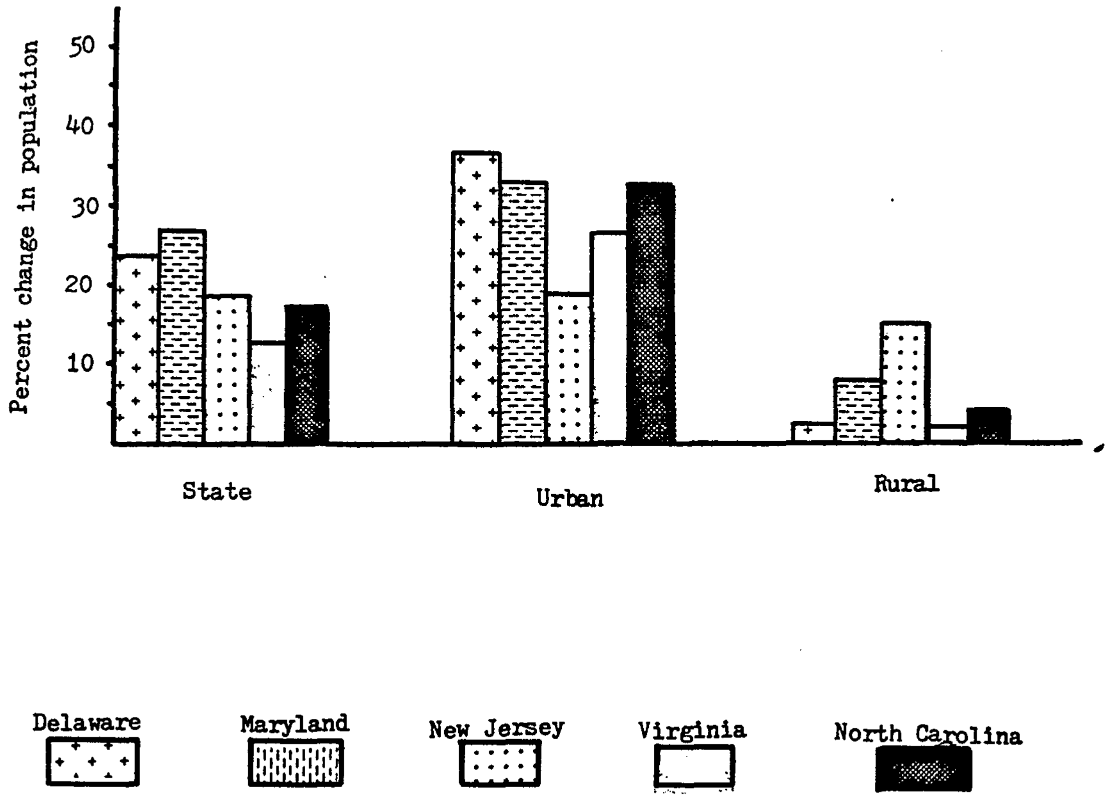


FIGURE IV-48

MID-ATLANTIC POPULATION GROWTH, 1960-1970

SOURCE: RE-172

TABLE IV-31

SUMMARY OF POPULATION DENSITY PROJECTIONS - 1980, 1990, 2000

AREA	1980	1990	2000
TOTAL NORTH ATLANTIC	369.6	402.2	436.1
COASTAL	1340.8	1455.7	1549.3
INLAND	167.6	183.1	204.6
MAINE	32.3	32.7	33.1
COASTAL	60.7	63.0	64.1
INLAND	22.8	22.6	22.8
NEW HAMPSHIRE	87.8	92.4	96.0
COASTAL	213.6	240.9	255.4
INLAND	70.8	72.3	74.4
MASSACHUSETTS	804.6	879.3	944.8
COASTAL	1358.2	1556.7	1633.1
INLAND	359.1	333.3	390.4
RHODE ISLAND	1002.4	1066.5	1132.5
COASTAL	1002.4	1066.5	1132.5
INLAND			
CONNECTICUT	714.2	815.0	917.2
COASTAL	887.3	925.4	965.1
INLAND	570.8	727.7	885.7
NEW YORK	408.0	435.1	468.1
COASTAL	5613.7	5912.3	6259.9
INLAND	163.8	178.1	196.3
NEW JERSEY	1085.4	1225.6	1358.4
COASTAL	4554.6	5167.0	5719.9
INLAND	540.8	606.9	673.7

Source: RE-172

The coastal waters of the Northeast and Mid-Atlantic states attract fishermen seeking primarily the flounder, mackerel and blue fish, as well as the shellfish of the bays and estuaries. Associated with the backwater areas of the bays and estuaries are a great variety of birds for observing, photographing and hunting. Figure IV-45 shows that the entire region is on the Atlantic flyway for migrating birds which makes for both excellent hunting and bird-watching.

Undoubtedly, the most widely enjoyed recreational activities are those occurring at the water's edge: swimming, surfing, beach-walking, sun-bathing, picnicking and boating. Every state has extensive areas of public and private beaches available to millions of people. Pleasure boating is popular where adequate harbor facilities are available.

Figure IV-49 shows some major recreational areas of the region. Obviously, the wildlife refuges of the area are a great asset. Figure IV-49 is only suggestive of the recreational areas of the region.

k. Population and Economic Factors

This region includes the areas near the coast in the states of Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Maine and the District of Columbia. Several very large population centers are in this densely inhabited region. This area, although small in land mass, contains over 20% of the total population of the United States. It is a manufacturing and trade center for the country.

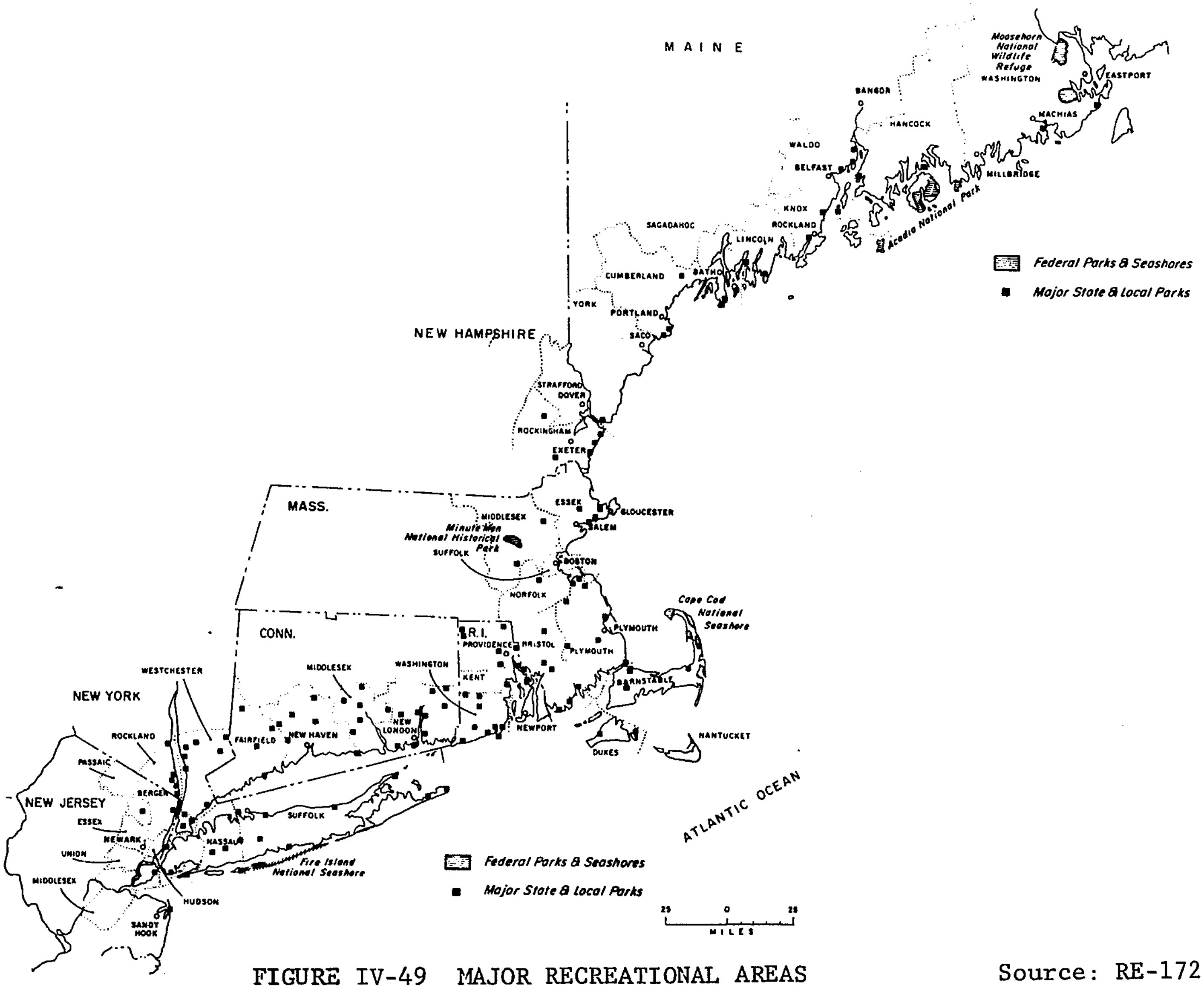


FIGURE IV-49 MAJOR RECREATIONAL AREAS

Source: RE-172

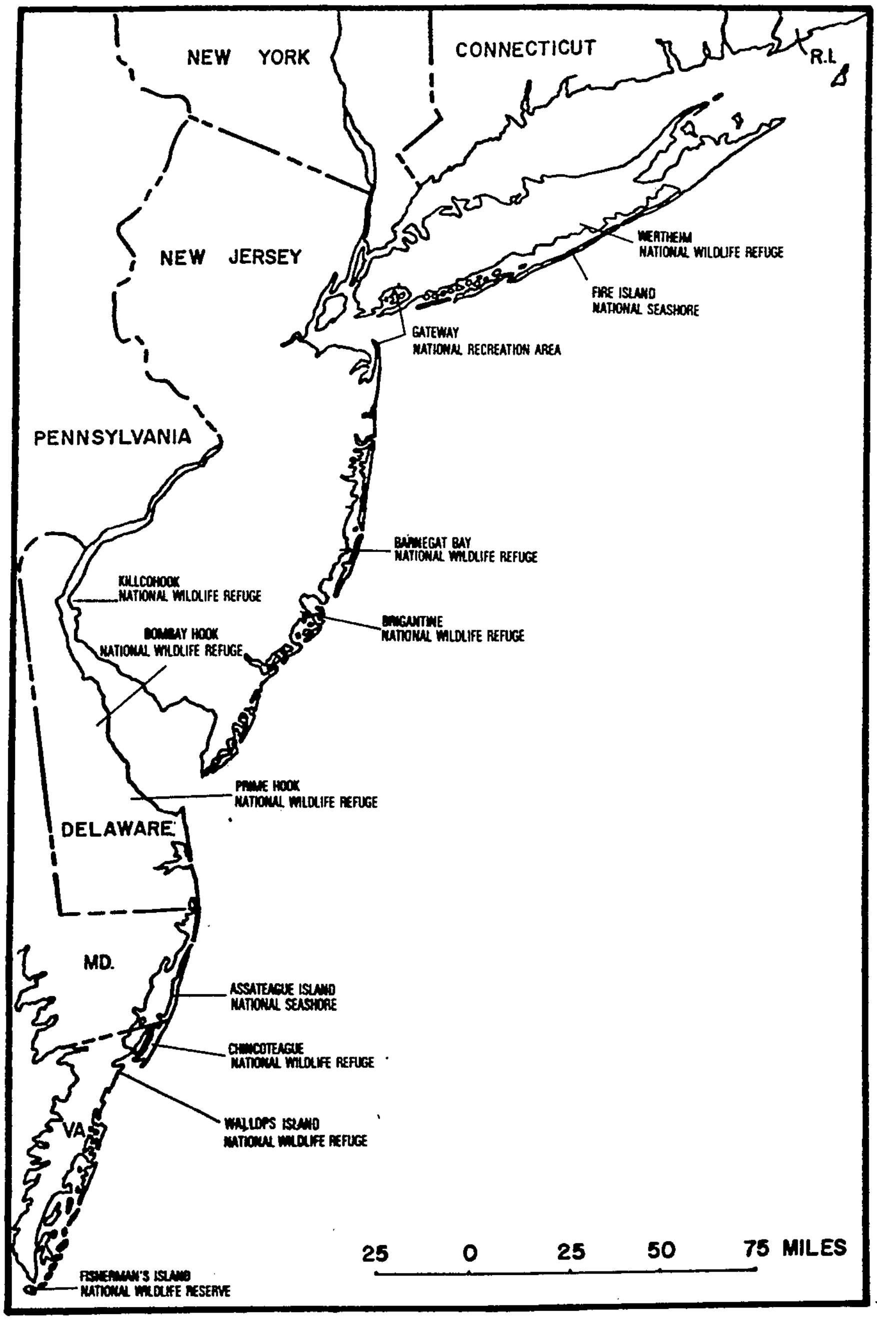


FIGURE IV-49 (continued)

MAJOR RECREATIONAL AREAS Source: US-454

Due to the density of the population in this region, the storage sites will be fairly close to urbanized areas, thus alleviating much of the direct socioeconomic impact. As in the Gulf Coast region, the proximity of facilities to urban areas is the largest factor to study in assessing localized socioeconomic impacts.

Population

The population of the East Coast region is estimated to be over forty-five million people. This total represents over 20% of the population in the United States. The region includes some sparsely populated areas between population centers as well as the most densely populated areas in the United States. Population centers in the region include Baltimore, Washington, Philadelphia, New York City, Newark, and Boston.

As can be seen from Table IV-16, the population of the United States is projected to grow from 8.3% to 12.7% between 1970 and 1980 depending on the childbearing assumption used. The states comprising the East Coast Region are predicted to have a slightly larger growth rate than the United States. Series E projections for the states in the region show a 10.0% increase versus 9.4% for the U. S. from 1970 to 1980. Similarly, Series C projections are 12.8% and 12.7% for the region and the U. S., respectively. The New England states and the South Atlantic states of the region have Series E projections of 11% or greater. The Middle Atlantic states of New York, New Jersey, and Pennsylvania show a somewhat slower growth rate of 8.7%. The growth rates per year for Series E and Series C projections are 0.96% and 1.21% (US-178).

The OBERS projections for the East Coast region show a population of over forty-eight million in 1980 and over fifty million in 1985. The projected increases are slightly less than the corresponding percentages for the United States for 1970 to 1980. A slightly higher rate of growth is projected for the East Coast region for the years 1980 to 1985 than is projected for the United States. Table IV-32 summarizes the projected growth rates for the United States and the East Coast region (US-122).

TABLE IV-32

PROJECTED POPULATION PERCENTAGE INCREASE

(PERCENT INCREASE PER YEAR)

	United States	East Coast Region
1970-1980	9.6 (0.93)	9.2 (0.88)
1970-1985	15.0 (0.94)	14.7 (0.92)
1980-1985	4.9 (0.96)	5.1 (1.00)

Source: US-122

In the Midwest Research Institute studies on the quality of life discussed in Section IV.B.1.j, several East Coast region cities were included in the top half of the rankings. Out of sixty-five large standard metropolitan statistical areas (SMSA's), Hartford ranked seventh, Washington twentieth, Boston twenty-third, and New York thirty-third. These areas have increased their metropolitan populations steadily over the past decade, and their quality-of-life rankings could indicate that trend will continue. The small projected population influx due to the location of storage facilities in these areas will have virtually no effects of a socioeconomic nature. Plans to accommodate thousands of people have long been in the developing process for these urban areas.

In the densely populated states of Connecticut and Massachusetts, the quality of life in many medium and small SMSA's appears extremely good. Table IV-33 lists all of the large SMSA's in the East Coast region and their respective rankings. The medium and small SMSA's that could be classified as either outstanding, excellent, or good are also listed along with their rankings (MI-203).

TABLE IV-33

QUALITY OF LIFE RANKINGS FOR SMSA'S IN EAST COAST REGION

Large SMSA's (total number=65)	Medium SMSA's (total number=83)	Small SMSA's (total number=95)
Hartford 7	Stamford, Conn. 5	Norwalk, Conn. 7
Washington 20	New Haven, Conn. 15	Bristol, Conn. 10
Boston 23	Bridgeport, Conn. 16	Danbury, Conn. 11
New York 33	Lawrence-Haverhill, Mass. 18	Pittsfield, Mass. 14
Newark 38	Waterbury, Conn. 21	Manchester, N.H. 24
Baltimore 55	Worcester, Mass. 26	Fitchburg-Leomister, Mass. 27
Philadelphia 57	Lowell, Mass. 30	Meriden, Conn. 33
	Wilmington, Del. 41	Nashua, N.H. 48
	Trenton, N.J. 50	Portland, Me. 49
	New London, Groton, Norwich, Conn. 52	New Britain, Conn. 58

Source: MI-203

Note: For example, Hartford has the 7th highest quality-of-life index of all 65 large SMSA's in the Nation.

Employment

The East Coast region encompasses most of the East Coast and the highly industrialized northeastern section of the United States. The manufacturing industries in this region generate a large portion of the employment. These industries are typically clustered around the metropolitan and population centers of the region. The areas surrounding these centers are less densely populated but do not lend themselves to extensive agricultural activities or mineral industries. There are approximately eighteen million people employed in this region, accounting for almost 23% of the employment in the United States (US-122).

In the economy of the region the manufacturing sector is predominant, producing almost 25% of the total earnings. Because of the inclusion of the Washington, D.C. area in the region, the governmental sector of the economy is the second largest in total earnings, accounting for almost 19%. The next two largest sectors are services and wholesale and retail trade. The mining and agricultural sectors produce a very small portion of the total earnings of the region, with 0.7% and 0.1%, respectively. Other sectors of the economy are listed in Table IV-34.

Manufacturing is a major segment of the economy of the East Coast region. This can be seen in the fact that there are over ninety-three thousand manufacturing establishments in the region. These firms employ over five million people or almost 30% of the total number of people employed. Governmental employees in the region total approximately 17% of the labor force. Mineral industries and agriculture occupy very small parts of the region's economy. Approximately forty thousand are employed

TABLE IV-34

PERCENT OF TOTAL EARNINGS BY INDUSTRY, 1971

	United States	East Coast Region
Manufacturing	26.8%	24.8%
Government	18.0%	18.9%
Services	15.3%	18.1%
Wholesale and retail trade	16.7%	16.5%
Transportation, communication and public utilities	7.2%	7.4%
Finance, insurance and real estate	5.4%	7.2%
Contract construction	6.3%	6.1%
Mining	1.0%	0.7%
Agriculture	3.4%	0.1%

Source: US-122

in mining establishments, and just over two million people live on farms. Almost 80% of the farm population lives in Maryland and Massachusetts (US-343).

As seen in Table IV-19, the manufacturing sector of the economy produces more total earnings than any other sector of the United States economy. It is projected to decrease from 27.8% of the total earnings in 1970 to 25.5% in 1985, but it is still over 65% ahead of any other sector of the economy. The economy of the East Coast region also has manufacturing as the leading earnings-producing segment, but the projections through 1985 are considerably different. Manufacturing, while experiencing a 46.6% increase in total earnings from 1970 to 1985, is projected to decrease in percentage of total earnings from 26.2% to 22.1%. During this same period, the services sector is expected to increase 120.1% in earnings and to assume 22.4% of the total earnings of the East Coast region. As can be seen in Table IV-35, the percentages produced by other sectors of the economy are projected to remain fairly static.

From 1970 to 1985, the total earnings produced in the East Coast region is estimated to increase by 74.2% with a 47.3% increase from 1970 to 1980. At the same time, total employment is projected to grow from almost eighteen million to nearly twenty-three million workers, an increase of 27.3% for the fifteen-year period. These growth rates are somewhat higher than those of the United States for the same period (US-122).

TABLE IV-35

PROJECTED PERCENT OF TOTAL EARNINGS BY INDUSTRY FOR THE EAST COAST REGION

	1970	1980	1985
Manufacturing	26.2	23.2	22.1
Government	18.4	18.5	18.9
Services	17.8	21.2	22.4
Wholesale and retail trade	16.5	15.7	15.3
Transportation, communications and public utilities	7.4	7.2	7.1
Finance, insurance and real estate	6.9	7.4	7.5
Contracy construction	5.8	6.0	6.3
Agriculture	0.8	0.6	0.5
Mining	0.1	0.1	0.1

Source: US-122

C. Existing Petroleum Distribution and Refinery Resources

The United States' petroleum-handling network consists of processing centers (refineries) and transportation systems (pipelines, ports, tankers, etc.). The locations and capacities of these various facilities are important considerations in the siting of emergency petroleum reserves. The identification of the segments of the handling network that would be affected by a petroleum import curtailment is one of the major tasks to be performed before the location of emergency petroleum reserves can be determined.

As of January 1, 1976, U. S. refining capacity was 15.1 MMB per calendar day. Table IV-36 lists the refining capacity located in each state. The crude oil feedstocks for the nation's refineries are supplied in two ways, either via pipelines or ships.

The U. S. has a vast network of oil pipelines which interconnect the oil fields, processing facilities, and major markets as shown in Figures IV-50 and IV-51. This network consisted of 222,355 miles of oil pipelines in 1974 (AM-166). Sixty-five percent are gathering and trunk lines, and the remaining 35 percent are product lines.

A survey of oil pipeline construction indicates that at the close of the calendar years 1973 and 1974, the mileage of pipeline constructed totaled 7,541 miles (LA-137, LA-138). Forecasts for 1975 are that 4,032 miles of oil pipelines will be constructed (LA-139). Table IV-37 lists the distribution of these pipelines according to the type of pipeline, i.e., as gathering and trunk lines, product lines, and offshore lines. Table IV-38 classifies them according to pipe diameter.

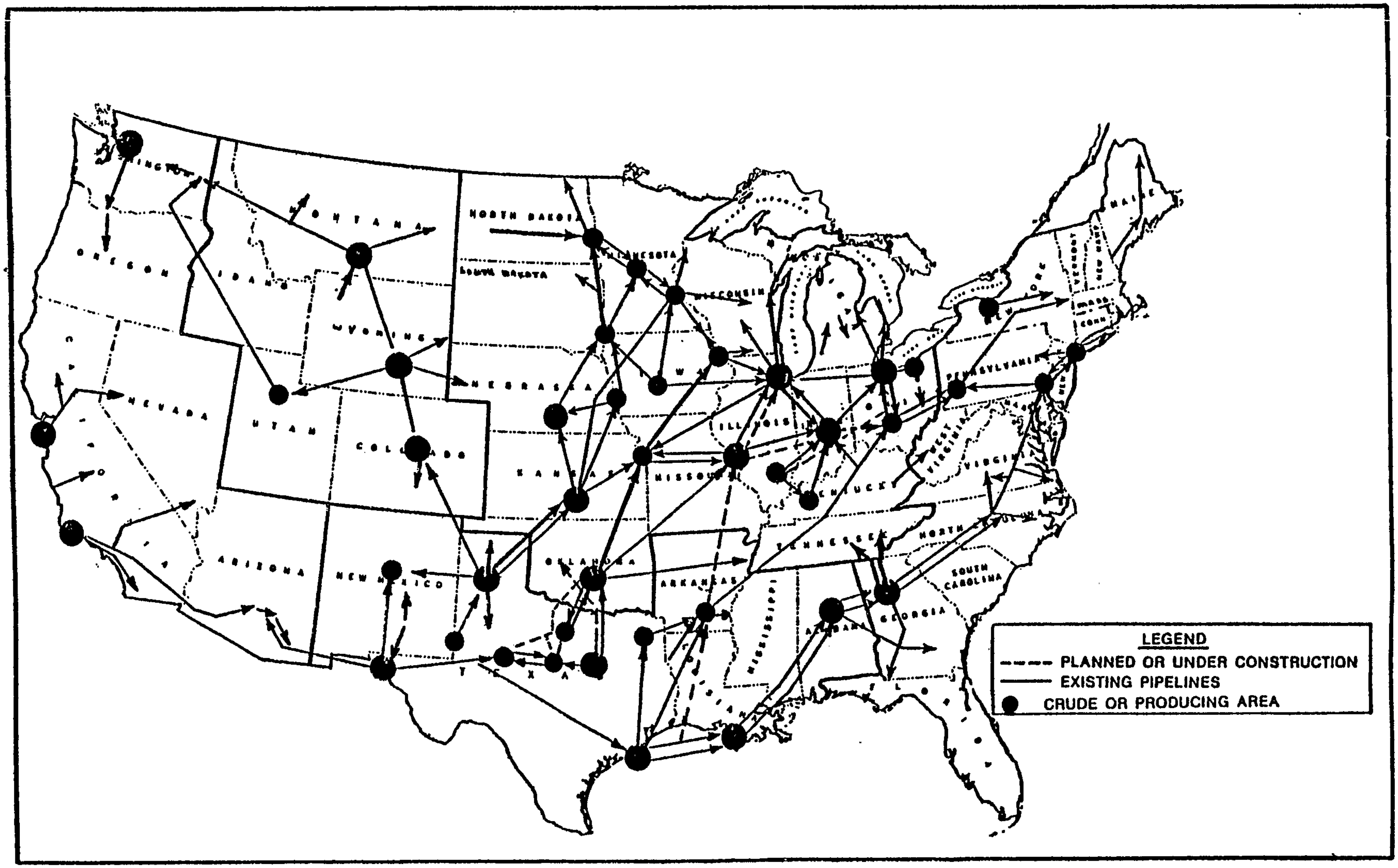
The status of U.S. crude and product pipeline projects in 1974 is given in Table IV-39. The table shows that the 789-mile long Alaskan pipeline is estimated to be completed by 1977 (PI-045). More recent information indicates that the

TABLE IV-36

Survey of operating refineries in the U.S. (state capacities as of January 1, 1976)

State	No. plants	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking: Fresh feed	Cat cracking: Recycle	Cat reforming	Cat hydrocracking	Cat hydrorefining	Cat hydrotreating	Production capacity—b/sd: Alkylation	Aromatics/Isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Alabama	3	49,875	53,000	17,500				5,500		9,000	11,400				10,500		
Alaska	4	74,250	78,158					6,000			6,000				300		
Arizona	1	4,000	4,211	2,500													
Arkansas	4	60,786	62,425	23,100		15,000	3,000	5,750			13,100	4,500		4,250	7,700	2.9	
California	35	1,903,935	1,993,503	944,650	473,083	485,611	135,600	495,339	319,822	149,244	681,622	90,028	22,490	22,300	109,760	734.1	15,233
Colorado	3	62,125	65,000	10,500	22,000	22,500	1,400	13,100			18,500				3,300	1.0	30
Delaware	1	140,000	150,000	90,700	44,000	62,000	15,000	42,000	17,000		110,000	8,000				72.0	1,500
Florida	1	5,700	6,000	3,400											2,400		
Georgia	2	18,000	19,400											200	11,600		
Hawaii	2	101,750	107,105	15,000		14,100	8,900	11,000			12,400	4,130	1,350		1,300	2.5	
Illinois	11	1,176,050	1,232,958	420,499	145,300	429,277	94,000	315,377	66,500	108,000	494,243	105,822	10,100	5,600	42,500	82.0	3,933
Indiana	7	561,160	527,300	267,000	24,000	193,000	10,800	127,100		30,160	210,500	30,200	3,200	11,300	56,600		885
Kansas	11	451,180	468,940	138,650	36,400	163,700	42,750	104,200	3,100	3,000	145,700	39,100	3,400	4,000	18,800	4.2	1,500
Kentucky	3	164,000	169,500	68,000	4,000	54,000	1,000	30,500			43,000	6,400	18,500		23,500		
Louisiana	19	1,753,095	1,827,031	502,342	141,333	617,778	59,950	377,033	80,500	114,500	415,311	131,089	26,800	24,750	39,850	73.0	5,850
Maryland	2	28,500	31,211	13,800											21,700		
Michigan	6	147,200	151,395	42,000		39,500	7,400	29,500		12,500	33,200	4,900			11,450		
Minnesota	3	216,800	223,905	137,000	23,000	71,500	3,000	30,100		20,000	72,100	11,500			57,000		1,300
Mississippi	5	329,500	346,842	156,000	6,700	70,500	6,350	70,700	71,000	53,000	53,450	9,200	6,000			109.0	320
Missouri	1	107,000	108,000	40,000	10,000	41,000	12,000	14,000			53,000	4,500			6,500		550
Montana	7	156,181	164,016	49,250	14,950	46,300	26,200	42,550	5,020	14,000	89,900	10,200	4,600		24,425	16.7	250
Nebraska	1	5,000	5,500	2,400		2,400	500	1,100									
New Jersey	4	539,000	562,764	286,653	38,144	229,444	40,000	118,944		110,000	314,945	17,133		6,400	73,000		975
New Mexico	7	104,230	106,305	12,400	2,250	12,400	5,160	10,920			11,550	2,925			700		
New York	2	111,385	114,500	43,000		41,000	6,000	24,000		20,000	41,500	2,800	3,000		18,000		
North Dakota	3	58,658	60,163		1,100	23,000	11,000	10,200			11,600	2,600					
Ohio	7	589,770	614,500	207,500	28,600	202,460	46,040	162,500	83,000	45,000	157,500	35,300		2,100	30,400	24.0	1,280
Oklahoma	12	545,775	559,719	173,863	51,866	191,200	40,475	131,147	4,500		160,803	44,133	15,606	11,100	33,000	59.5	1,655
Oregon	1	14,000	14,737	15,000											8,600		
Pennsylvania	11	757,020	796,415	328,378	2,750	206,000	18,300	221,708	53,700	161,000	278,250	38,100	11,300	29,575	36,500	45.0	
Tennessee	1	43,900	44,800	15,000		13,500		10,000			11,000	4,000			8,000		
Texas	46	3,966,330	4,144,778	1,348,241	317,188	1,257,166	270,405	1,009,542	153,167	374,500	1,478,143	222,751	201,516	93,922	64,900	159.0	6,257
Utah	7	152,000	158,878	44,050	18,500	53,600	16,560	23,800	1,000	5,500	29,500	10,450	2,550		4,700		350
Virginia	1	53,000	55,000	28,000	14,000	27,000	5,000	9,000			24,000						710
Washington	7	366,900	383,105	135,616	36,000	91,500	27,100	93,222	35,000	20,500	155,667	25,333	2,900	1,900	6,600	60.0	1,500
West Virginia	3	19,450	20,200	8,675				6,160		4,440	7,510			6,700		1.2	
Wisconsin	1	45,400	46,800	15,500		9,700	1,000	10,000		5,800	10,000	1,200			12,000		
Wyoming	11	187,340	194,557	66,726	4,444	58,778	15,300	30,794		16,644	59,194	7,840	1,500	1,470	14,817		139
Total	256	15,074,845	15,687,321	5,672,893	1,459,608	4,744,914	930,190	3,592,788	883,309	1,276,788	5,211,888	874,134	334,812	225,567	760,402	1,446.1	44,217

Source: CA-236



Source: FE-076

FIGURE IV-50

PRODUCT PIPELINE DISTRIBUTION

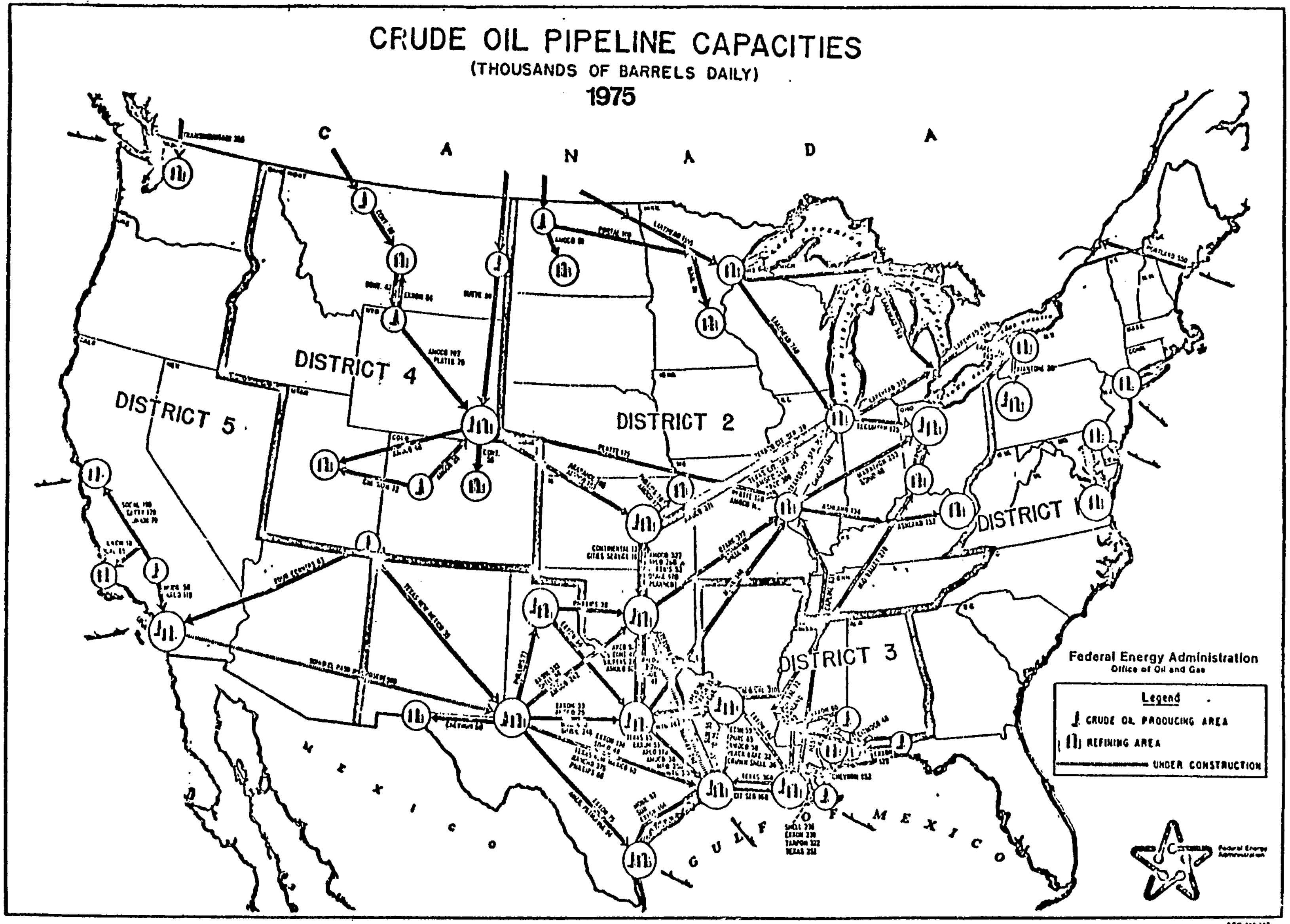


FIGURE IV-51
CRUDE OIL PIPELINE CAPACITIES

TABLE IV-37

SURVEY OF U.S. OIL PIPELINE CONSTRUCTION

PIPELINE NETWORK	YEAR 1973 (ACTUAL)	1974 (ACTUAL)	1975 (FORECAST)
CRUDE OIL			
Trunk Lines (Miles)	486	695	948
Gatherline Lines (Miles)	523	946	1122
PRODUCT LINES (Miles)	2995	1548	1774
OFFSHORE (Miles)	186	162	188
TOTAL (Miles)	4190	3351	4032

TABLE IV-38

MILEAGE OF PIPELINE BY PIPE SIZE
(Gas Distribution Not Included)

PIPE NOMINAL DIAMETER (Inches)	YEAR 1973 (ACTUAL)	1974 (ACTUAL)	1975 (FORECAST)
2 - 4	1063	640	680
6	768	428	426
8	975	472	538
10	914	565	422
12	826	489	453
14	6	6	20
16	874	624	579
18	124	82	44
20	487	328	366
22	15	15	20
24	443	389	436
26	386	318	327
28	92	48	68
30	795	570	602
32	16	16	25
34	78	112	154
36	442	785	678
38 - 40	0	0	0
42	26	64	56
48 - 50	61	61	318

Total of diameters does not equal industry total as some companies did not indicate diameters

Sources: LA-138, LA-139

TABLE IV-39

1974 STATUS OF U.S. CRUDE AND PRODUCT PIPELINE PROJECTS

Company (Including) joint ownership participatants)	Est. Cost US or Equiv. ($mm)	Location of Project	Length (Miles)	Pipe Diam. (Inches)	Type of Service and material to be carried (Loop, trunkline Oil Product)	Compressor or pump station hp and Location	Project Status	Estimated Completion Date
Alyeska P.L. Service	5.98 bil.	Alaska	789	48	Trunkline,Oil		Working	1977
Anderson-Pritchard Pipeline Co	1.5	Cyril, Okla.	41	6,8	Trunkline,Oil		Under Study	1976
Atlantic Richfield Co.	26	Lisbon, Utah	192	16	Shale Oil		Planned	1975
Buckeye Pipeline Co.	7 1.2 4.4	Lima,Ohio to Cygnet, Ohio,Lower Michigan Ohio	61 9 36	12 12 10	Trunk,products Trunk,products Trunk,products & Crude		Planned Planned Planned	Dec. 75 Sept. 75 Dec. 75
CRA,Inc.	1.8	Kansas	42	10	Trunkline,Oil	100	Await Start	Summer 75
El Paso Natural Gas Co.	7.1	N.Mex & Texas	Various	24	Trunkline,Oil	2,470	Before FPC	1975
Explorer Pipeline Co.	1.7 2.7 0.4 0.3	Texas Missouri Missouri Okla.	14.5 4.9 1.2 2.2	8,12 14 12 16	Distr. Oil Distr.,Products Distr.,Products Distr.,Oil		Under Study Under Study Planned Under Study	1976 1976 Feb.76 1976
Exxon Pipeline Co.	5.8	Offshore Calif.	8	12	Gath.,Gas,oil		Before FPC	
Interstate Energy Co.	60	Pennsylvania	94	8,18	Trunk,Products	20,000 @ 2 Sta.	Await Start	1975
Lakehead Pipeline Co.,Inc.	7.9 10.6	Mich.Ind. Ind.Mich.	 27	 30	Trunkline,oil Looping,oil	46,250	Working Planned	Mid 75 Mid 76
New England Petroleum Co.		Albany to Oswego New York	165	20	Trunkline,oil		Planned	
Seadrift Pipeline Corp.		Texas	130	6	Trunk,Products	500@ 2 Sta.	Planned	April 76
Seaway Pipeline(Phillips, Apco,Cities Service,Continental,CRA, Diamond Shamrock,Nat'l.Corp Ref.Assn.)	130	Freeport, Texas Cushing, Okla.	530	30,36	Trunkline,oil		Planned	Late 75
Shell Pipeline Corp.		Calif. Michigan Texas	5 94 3	42 4,6,8 10 6	Trunkline,oil Trunk,Gath,Oil Trunk,Products		Planned Planned Planned	1975 Dec. 75 1975
Sohio Petroleum Co.	3.6	Texas			Storage,Oil		Working	Feb. 75
Sohio Pipeline Co. (Amdel Pipeline,Inc.)	3.7 0.8	East Tx. East Tex.			Trunkline,Oil Trunkline,Oil	6,000 Total @ 6 sta. 1,000 Port Arthur	Working Working	Dec. 75 July 75
Standard Oil Co.(Ohio)	1 Billion	U.S. West Coast to Midwest	2000		Trunkline,Oil		Under Study	1977
Texoma P.L. Sun Oil Co. Mobile Oil Corp. Skelly Oil Co. Kerr-McGee Texaco Tex.East Transmission Rock Is.Refinery Vickers United Refinery Corp. ~~Western Crude Oil Co.~~	130	Beaumont/ Port Arthur to Cushing,Okla.	490	30	Common Carrier Crude		Working	June 76
Williams Pipeline	8.8 0.6 3.2	Minnesota Oklahoma Oklahoma	116 35 45	12 10 8	Trunkline,Oil Trunk,Products Trunk,Products Loop	8,000	Under Study Planned Under Study	Nov. 75 Oct. 75 Jan. 76
Wolverine Pipeline Co.	30	Illinois Michigan	181	16,18	Trunkline,Oil		Planned	1975

*Legend

UNDER STUDY: Includes all pipeline projects which are being considered or for which a feasibility Study is being made or has been made but no decision has been reached regarding its being built.

PLANNED: Includes all pipelines planned or proposed for construction. The proposal can have been made to the operating company, government authorities, etc.; but excludes U.S. gas pipelines presented to F.P.C. for approval.

BEFORE FPC: Gas pipeline projects within U.S. where planned construction has been submitted to FPC for approval, but not yet granted.

FPC APPROVED: Projects authorized for construction.

APPROVED: Projects outside the U.S. approved for construction by a government or other agency.

AWAITING START: Projects out for bid or awaiting start of construction.

WORKING: Projects underway

SOURCE: FI-045

530-mile Seaway crude oil line from Freeport, Texas to Cushing, Oklahoma, started initial filling of its 30" line on October 4, 1976, while the 490-mile Texoma crude oil line from Port Neches, Texas to Cushing began full operations in the late Spring of 1976. The 634-mile Capline crude oil pipeline from St. James, Louisiana to Patoka, Illinois is undergoing an expansion from 793,000 BPD to 988,000 BPD by adding pumping capacity (CA-292); this project was scheduled to be complete in mid-1976, but is about one-half year behind schedule.

Movement of oil by sea can be accomplished by either barge or tanker. Table IV-40 lists the major port areas of the U. S. and their volume of petroleum traffic in 1973, while Table IV-41 is a selected list of U. S. ports showing maximum channel depth and estimated maximum permissible vessel size. In connection with oil shipment by tankers, there are thirty-one petroleum refineries having a daily (calendar) crude oil capacity of 100,000 barrels or greater which are located in or adjacent to major seaports (CA-339). These refineries had a total capacity of about 6,500,000 barrels per calendar day as of January 1, 1975 (CA-339). The names and geographical locations of these refineries are listed in Table IV-42.

TABLE IV-40

PETROLEUM TRAFFIC AT SELECTED U.S. PORTS IN 1973

PORT	FOREIGN IMPORTS			TOTAL FOREIGN PETROLEUM IMPORTS*	TOTAL TRAFFIC OF ALL GOODS (IMPORTS AND EXPORTS)
	Crude Oil	Residual Fuel Oil	Distillate Fuel Oil		
Portland, ME	22,563,374	1,292,064	97,713	23,964,396	28,844,110
Portsmouth, N.H.	-	792,412	223,209	1,087,609	2,314,900
Port of Boston, MA	242,964	6,732,905	474,417	8,485,278	27,056,868
Providence River and Harbor, R.I. and Fall River Harbor, MA	249,048	4,397,408	190,790	4,999,878	14,861,424
New Haven, CT	110,470	3,014,775	872,572	3,997,817	13,709,265
Port of New York	20,459,551	12,665,490	21,808,534	59,319,698	216,896,434
Delaware River Ports	43,091,054	6,588,576	646,205	50,754,105	110,077,961
Baltimore, MD	835,705	4,141,769	113,309	5,303,045	53,786,715
Hampton Roads, VA	298,149	6,100,866	157,823	6,556,838	63,963,750
Tampa, FL	91,385	3,043,985	230,610	3,365,980	41,923,222
Mobile, AL	279,350	79,601	-	358,951	30,518,422
New Orleans, LA	1,064,429	1,204,967	763,256	3,229,619	136,104,315
Sabine-Neches Waterway, TX	8,113,844	98,329	169,153	8,584,546	84,707,017
Houston Ship Channel, TX	4,583,307	640,731	277,819	6,074,792	88,517,992
Long Beach, CA	6,823,131	1,448,140	327,928	8,657,187	27,133,022
Los Angeles, CA	5,624,753	356,382	142,574	6,123,709	25,977,491
San Francisco Bay Ports**	11,447,532	124,541	23,170	11,984,952	71,304,983
Seattle, WA	53,022	10,696	7,584	347,630	17,000,178

*Includes crude oil, distillate fuel oil, residual fuel oil, gasoline, jet fuel, and kerosene

**Includes San Francisco Harbor, Oakland Harbor, Richmond Harbor, San Pablo Bay, Mare Island Strait, and Carquinez Strait

Units are short tons

Source: US-320

TABLE IV-41

SELECTED U.S. PORTS HANDLING SIGNIFICANT AMOUNTS OF BULK CARGO

	Controlling Depth (feet)	Estimated Maximum Permissible Vessel Size When Fully Loaded (DWT)
EAST COAST		
Delaware River Ports	40	53,000
Hampton Roads, VA	45	80,000
New York, NY	35	40,000
Portland, ME	45	80,000
Baltimore, MD	42	53,000
Boston, MA	40	40,000
GULF COAST		
New Orleans, LA	40	50,000
Tampa, FL	34	35,000
Baton Rouge, LA	40	50,000
Mobile, AL	40	45,000
Corpus Christi, TX	45	50,000
Houston, TX	40	50,000
Brownsville, TX	36	30,000
Pascagoula, MI	38	35,000
PACIFIC COAST		
Long Beach, CA	52	150,000
Los Angeles, CA	51	150,000
San Francisco Bay Ports	35	40,000
Seattle, WA	73	250,000

Source: US-124

TABLE IV-42

SUMMARY OF PETROLEUM REFINERIES OF THE UNITED STATES HAVING A DAILY CRUDE OIL CAPACITY* OF 100,000 BARRELS PER DAY** OR GREATER WHICH ARE SITUATED IN OR ADJACENT TO MAJOR SEAPORT AREAS***

COMPANY	LOCATION	CAPACITY (Barrels Per Calendar Day)
Atlantic Richfield Co.	Carson, CA	181,500
Mobil Oil Corp.	Torrance, CA	123,500
Phillips Petroleum Co.	Avon, CA	110,000
Shell Oil Co.	Martinez, CA	100,000
Standard Oil Co. of CA	El Segundo, CA	230,000
Standard Oil Co. of CA	Richmond, CA	190,000
Union Oil Co. of CA	Los Angeles, CA	108,000
Union Oil Co. of CA	San Francisco, CA	108,000
Getty Oil Co.	Delaware City, DE	140,000
Cities Service Oil Co.	Lake Charles, LA	268,000
Exxon Co.	Baton Rouge, LA	455,000
Gulf Oil Co.	Belle Chasse, LA	180,400
Shell Oil Co .	Norco, LA	240,000
Texaco, Inc.	Convent, LA	140,000
Standard Oil Co. of KY	Pascagoula, MI	240,000
Exxon, Co.	Linden, NJ	265,000
Atlantic Richfield Co.	Philadelphia, PA	185,000
B.P. Oil Corp.	Marcus Hook, PA	143,000
Gulf Oil Co .	Philadelphia, PA	174,300
Sun Oil Co.	Marcus Hook, PA	165,000
AMOCO Oil Co.	Texas City, TX	333,000
Atlantic Richfield Co.	Houston, TX	213,000
Coastal States Petroleum Co.	Corpus Christi, TX	185,000
Crown Central Petroleum Corp.	Houston, TX	100,000
Gulf Oil Co.	Port Arthur, TX	312,000
Exxon Co.	Baytown, TX	390,000
Mobil Oil Corp.	Beaumont, TX	325,000
Shell Oil Co.	Deer Park, TX	294,000
Southwestern Refining Co. Inc.	Corpus Christi, TX	124,000
Texaco, Inc.	Port Arthur, TX	406,000
Union Oil Co. of CA	Nederland, TX	120,000
	TOTAL	6,578,700

*Crude oil capacity of refineries is the maximum daily average crude oil distillation capacity of a plant in complete operation.

**All capacity figures are expressed in barrels per calendar day.

***Refineries located in Illinois, Indiana, Kentucky, Ohio, and Oklahoma not tabulated due to remoteness from major seaport areas.

†Barrels per stream day.

Source: CA-339

V. ENVIRONMENTAL IMPACTS

This section presents a description of the environmental, social and economic impacts as they relate to the ESR and SPR. As discussed in Chapter II, worst-case prototype facilities were chosen for each potential storage option to provide a firmer basis for assessing impacts than otherwise would be possible. In addition, a summary of cumulative impacts has been projected for both an "expected" and a "worst-case" mix of types of storage facilities.

For the Gulf Coast region, the impacts of a prototypical 90 MMB existing salt cavern facility, a 90 MMB existing salt mine and a 200 MMB new salt cavern facility were assessed to provide an example of the type and magnitude of impacts expected to occur. For the East Coast region, impacts of an existing rock mine of 15 MMB, a new rock mine of 30 MMB and conventional tankage of 10 MMB were investigated.

A. Gulf Coast Storage Region

1. Geology

Impacts related directly to the geological regime are not quantifiable and generally are speculative or subject to supposition. These impacts may be discussed in terms of their relation to halokinesis, subsidence, seismic stability, or engineering suitability.

a. Halokinesis

The impacts of program implementation on phenomena related to halokinesis are somewhat uncertain. Despite twenty years of experience in storage in domal salt in the United States, little is known of regional impacts. One reason for this is that no apparent program exists for constant monitoring and measurements which would be required, since regional effects are not obvious. Further, there is no record of adverse regional effects for the past twenty years.

Existing cavities are located in many widely separated domes in the Gulf Coast region. Likewise, the planned development of new cavities will be spread over several domes rather than concentrated in a single area. The volume of domal salt anticipated to be replaced under this program is approximately twice the total volume that has been replaced to date. Moreover, there is even greater uncertainty of the phenomena related to halokinesis in the case of a single 200 MMB facility (twenty 10 MMB cavities) in one dome, due to the unprecedented size of such a development. Replacement of domal salt in the order of 70 MMB has taken place in a single dome without apparent adverse effects. In the case of existing conventional mines in salt domes, salt mining has continued over several years, resulting in the creation of large volumes of void space, e.g., as much as 90 MMB in one mine alone. Some of these mines have been operating since the late 1800's and early 1900's.

Because the geomechanics of salt domes are only poorly understood, only tentative qualitative estimates of impacts are possible. One of the prime considerations of the storage scheme is the stability of the individual cavity and of the dome itself. Some cavity shrinkage, or "creep," due to halokinesis is inevitable (CO-027). The actual stability of an individual cavity is dependent to a large degree upon its size and upon the configuration of the dome. Sufficient technology and operating experience in construction of brine cavities are available to control these factors and to insure reasonable cavity stability with the projected configurations.

If considerable cavity development takes place within one dome, both the heat flow and the isostatic balance (i.e., the dynamic balance due to density differences) between the salt and surrounding sediments of the dome itself could be affected. It is currently unknown if development of the largest capacity planned for a single dome, viz. 200 MMB, is "considerable" in the above context; however, as mentioned in Chapter III, this maximum storage volume (comprised of twenty 10 MMB cavities) is less than one percent of even a small dome's volume of salt. Nevertheless, the smaller salt volume may establish a larger thermal gradient to transmit an equivalent quantity of geothermal heat, which in turn could result in an incremental change in the viscoplastic flow of the salt. Similarly, the replacement of salt volume with oil or brine decreases the bulk density of the salt dome to varying degrees, which could increase the buoyant "driving force" of the dome. It is conceivable that those two factors may increase the salt dome rise rate, but the net impact of this event is unknown. An increase in ground-water salinity or slight land-surface disturbance (e.g., local alteration of drainage) is possible. These effects probably would be masked by other unrelated, existing factors subject to natural variation.

b. Subsidence

Subsidence of the land surface is a phenomenon of special concern in the low-lying lands of the outer coastal plain. The proposed program has the potential for various degrees of some subsidence. In a dome with many solution cavities, the summation of salt "creep" toward an equilibrium state of stress may be manifested by very slight subsidence; the effects of this subsidence, though small, will be of more than local extent, although greatest directly over the dome cavities (MA-331). Catastrophic collapse of the cavity by mechanical failure of the roof can cause significant subsidence and subsequent flooding of the affected area.

Such collapse may disrupt aquifers overlying or adjacent to the dome (MA-329).

Limited use of ground water for cavity development or oil displacement is anticipated at selected sites. Unless properly controlled, excessive use of ground water for these purposes could result in substantial subsidence in the areas of groundwater withdrawal. The amount of subsidence depends principally on the decline in hydrostatic pressure and the amount of clay present in the lithic sequence (sedimentary layer) affected by the decline (GA-122). Furthermore, the time frame for this subsidence evidently depends on the thickness and hydraulic character of the clay beds which undergo compaction. At the maximum sustained rates of water usage projected for a salt dome, ultimately several feet of subsidence over a large area may accrue during cavity development and for several years afterward. This estimate is based on observation of several locations in the Gulf Coast region where large amounts of ground water have been withdrawn (BR-184).

The existing conventional salt mines within salt domes in the Gulf Coast region have been in operation for several years. Many of these mines have experienced little or no subsidence problems, although in a few cases measurable subsidence has occurred. There is nothing to indicate that storing oil in these mines would create subsidence problems where they did not formerly exist. These mines are generally stable and little heaving or cracking is apparent that would indicate active closure, although in at least two instances closure has been measurable over a few years. Closure will ultimately result in surface subsidence after a number of years, but the phenomenon will not occur so long as the mines are filled with a fluid. Therefore, storing oil in salt mines could result in the forestalling of subsidence that might otherwise have occurred with a vacated cavity.

The primary environmental impacts of subsidence are on ground and surface water. Subsidence on the Gulf Coast has caused a significant increase in salt-water flooding. If subsidence were to occur near a surface water source, it could cause the surface configuration of that water body to change. If subsidence were to occur over a ground-water supply, it could increase or decrease the capacity of local wells.

In addition to these water supply impacts, subsidence has also been known to cause structural damage due to differential settlement. Also, subsidence is now believed to activate fault "movement," actually a manifestation of the different amount of clay and sand frequently encountered on either side of coastal faults, which is a more long-term consideration.

If any of these primary impacts were to occur, minor secondary impacts on wildlife and vegetation could also be expected. Aquatic vegetation would be altered, as would terrestrial vegetation that become flooded. In addition, wildlife might be required to change their feeding and watering patterns if the vegetation and surface water sources which they used were changed. Both of these impacts would be localized and could not be expected to have any long-term effects on species populations, unless subsidence was located in wetlands where salt-water flooding could be particularly adverse.

c. Seismic Stability

As discussed in Chapter IV, the risk of seismic damage to surface structure in the Gulf Coast region is quite low. The risk of damage to an underground cavern (either a solution-mined cavity or a conventional mine) is even lower, because resonance generally does not take place between the cavity and the vibrating medium that contains it, and any differential movements within the rock mass are not amplified. Furthermore, the impacts associated with a given seismic event are probably less for salt dome storage than for any other geologic (or man-made) structure, because salt's viscoplastic properties minimize the likelihood of fracture development and also "heal" any fractures that might result from earthquake activity and seismic loading.

d. Engineering Suitability

Some surficial deposits and environments within certain areas of the coastal region are inherently less suited for several of the proposed activities than other areas (FL-062). These areas are widespread but of only local extent and are not subject to delineation in this document. Generally speaking, areas of dominantly clay and mud soils and substrates and swampy or marshy areas will require special attention owing to their high plasticity, very high shrink-swell potential, very high corrosion potential, high compressibility, and low shear and load-bearing strength (WE-102). All of the individual operations which would be required to implement the program have been or are now being conducted in the region. The geologic environment now affects the ease with which such operations are performed, and thus the costs and gross impacts as well.

2. Hydrology

Only a very general characterization of the hydrologic environment was possible in this programmatic assessment, and consequently, the hydrological impacts considered in this chapter are not site-specific. Nevertheless, several analytical tools were used in delineating water-related impacts of the proposed program at a regional or nongeographic level.

Of principal interest in the analysis of solution-mining and oil displacement within salt domes are the effects of brine disposal on surface-water quality. For the case of disposal into the Gulf of Mexico, a mathematical model was used to simulate the discharge of brine from a diffuser and to find the approximate area and volume affected by the increased salinity. The model considers, and implicitly or parametrically examines, the combined effects of flow rate, brine concentration, prevailing current velocity, brine density, temperature, turbulent dispersion and its flux, and the depth of water and of the source within the water body. A more detailed description of this model is included in a central reference document (RA-223).

The flow of water through porous media is subject to many constraints and boundary conditions. Analysis of the effects of ground-water withdrawal and emplacement of fluids within the subsurface environment requires a somewhat sophisticated approach, particularly at the site-specific level. For the programmatic analysis, the primary means of evaluating the geohydrologic environment was to develop an analytical solution to the Theis nonequilibrium equation under conditions of unsteady radial flow of an incompressible fluid in leaky artesian aquifers (WA-243). An error is introduced into the analysis for fluid emplacement (as opposed to withdrawal) due to the assumption of water as incompressible, as it is in fact slightly compressible. Within the constraints imposed by operational considerations or physical limitations, this error is not very large and makes the interpretations somewhat conservative with respect to the environment. To facilitate computations, a finite-difference approximation to the flow equations that had been pre-checked with the analytical solution was employed; this quasi-three-dimensional simulation model is similar to one that is in common use for ground-water resource evaluation (PR-055). Typical (regional average) values were used for formation constants and other parameters, but the simulation was not calibrated to the conditions at a specific site, which would be required for an accurate simulation. The model only provides a basis on which to judge potential problems associated with ground-water movement due to the possible program requirements.

a. Brine Disposal

A large amount of brine will require disposal in order to construct and operate solution-mined cavities in salt domes. In a solution-mined cavity, brine will be pumped in to displace the oil when it is needed. This withdrawal method keeps the cavern filled at all times which is structurally more stable than when emptied. No brine disposal is required in the case of conventional salt mines because the oil will be withdrawn by pumps rather than displaced with water.

It is estimated that up to 41,000 gpm of virtually saturated brine will be produced continuously over a 36-month period in solution mining a new 200 MMB storage facility (see Table III-2). Refilling cavities upon cycling will produce 40,000 gpm of brine for disposal, assuming refill is accomplished in 150 days. Clearly, the construction rate requirements are the most critical, although the same facilities can be used for both construction and operation. Where existing cavities are used, a 90 MMB facility for the ESR will produce about 18,000 gpm for disposal during both initial fill and subsequent cycling, again assuming a 150-day fill schedule.

Because these volumes and rates of brine disposal are larger than those experienced anywhere previously, the impacts of brine disposal are of special concern and are treated explicitly. The program anticipates the possible use of three disposal methods: usage by local industry, deep-well injection, and dispersal to the Gulf of Mexico. Although usage by industry is the most environmentally desirable of the three options, its potential application is limited to the brine already in existing cavities which would be displaced with oil during the initial fill and the brine which would be created by the displacement of the oil with water during any subsequent cycling of the Reserve. Under these circumstances, it might be feasible in some cases to regulate the fill rates (and thus the brine disposal rates) to match industry consumption. In preliminary discussions, local petrochemical companies have indicated a willingness to take all or most of the brine produced in such a manner. However, where very large volumes of brine are produced by the solution mining of new cavities or where no local industry is available to take the brine displaced during fill, deep-well injection or dispersal to the Gulf of Mexico will be used for disposal. A decision as to which one will be used for a particular site will depend on the location of the dome relative to the Gulf, the proximity of saline aquifers for disposal, relative cost of the two disposal methods at any individual site, and site-specific environmental impacts.

Deep-Well Injection

Deep-well injection refers to emplacement of the brine, generally under pressure, in permeable strata within the subsurface and beneath a confining layer(s) that serves to isolate the injected fluid from potable water supplies and other elements of the biosphere. The injected brine is accommodated by displacing existing fluids or by compressing or deforming the reservoir strata Usually, the formation fluid is highly saline water and the injection zone is termed a salaquifer (YO-039).

About 300 waste injection wells currently exist, and a substantial number of these are in the Tertiary sands of the Gulf Coast region. In addition, thousands of wells on the Gulf Coast have been used for injection of brine in conjunction with secondary recovery (water-flooding) in producing oil reservoirs and for the return of brine co-produced with oil and gas. While this operating experience is invaluable to the proposed program, neither brine injection nor water injection is currently accomplished at the scale envisioned for this program (EN-371).

The technology of injection-well construction and operation for wastes other than brine is probably more applicable to the proposed program than oil-field brine injection. A typical injection system for municipal and industrial wastes is illustrated diagrammatically in Figure V-1. Ninety percent of such wells extend at least 1,000 feet below land surface, and seventy-eight percent of the existing injection wells operate with well-head injection pressures of less than 600 psi and at injection rates of less than 400 gpm. Only a few specially designed, expensive (larger-diameter, under-reamed, gravel-packed, and extensively screened) disposal wells are capable of injecting fluids at sustained rates of as much as 1,000 gpm within permissible pressure limits. The feasibility of injecting fluids at rates of up to 1,000 gpm varies with the permeability and thickness of the sedimentary rock layer which governs the pressure build-up. (It is appropriate to note here that the storage program does not propose to use the cavernous caprock as a disposal zone; past practice in disposing of brine resulting from salt solution mining and oil fields in such a manner has resulted in contamination of fresh-water or otherwise potable ground-water supplies.)

The absolute storage volume of the aquiferous sands underlying an area of a few square miles is immense. The pressure regime is probably of more concern than storage volume because the increase in formation fluid pressure upon injection extends over a much larger area than the area that will be required to accommodate the brine (FE-140). Pressures are greatest at the well bore and decrease exponentially with radial distance (Figure V-2), with the larger aquifer transmissivity causing lower initial pressures and more rapid pressure decay. The possibility of fracturing geological strata that are aquicludes and losing containment

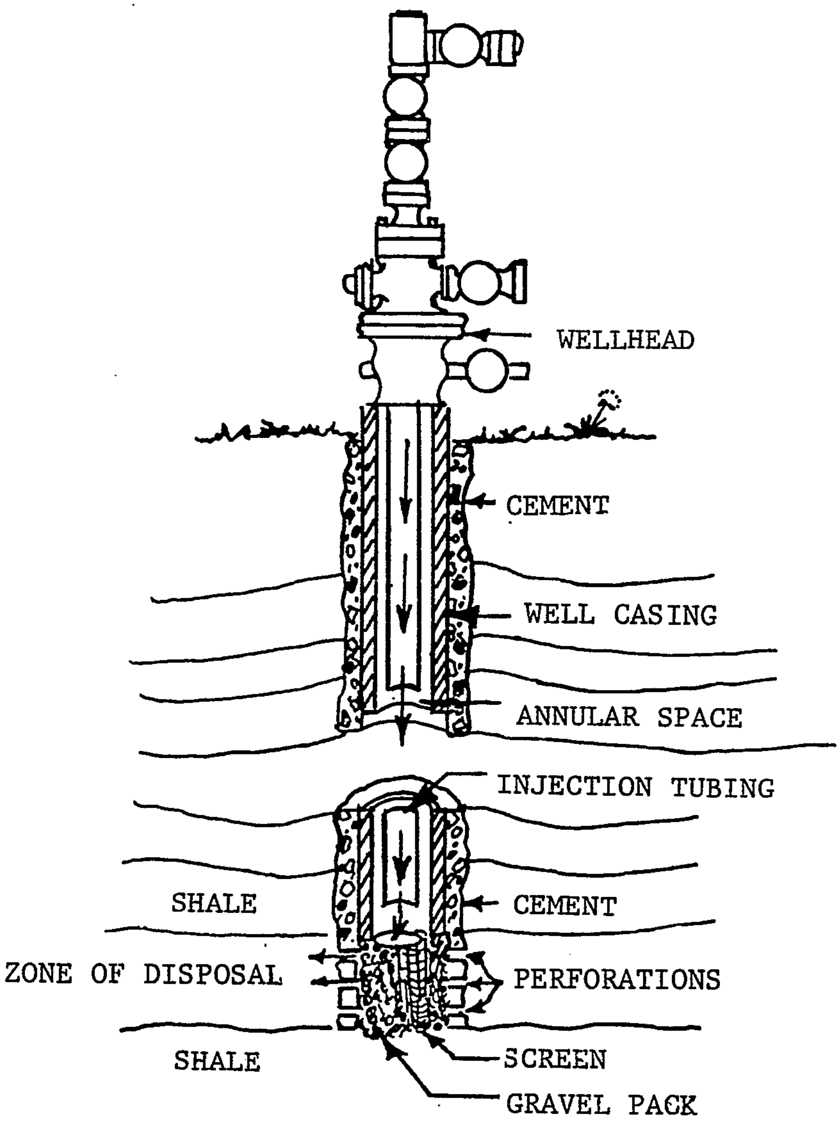
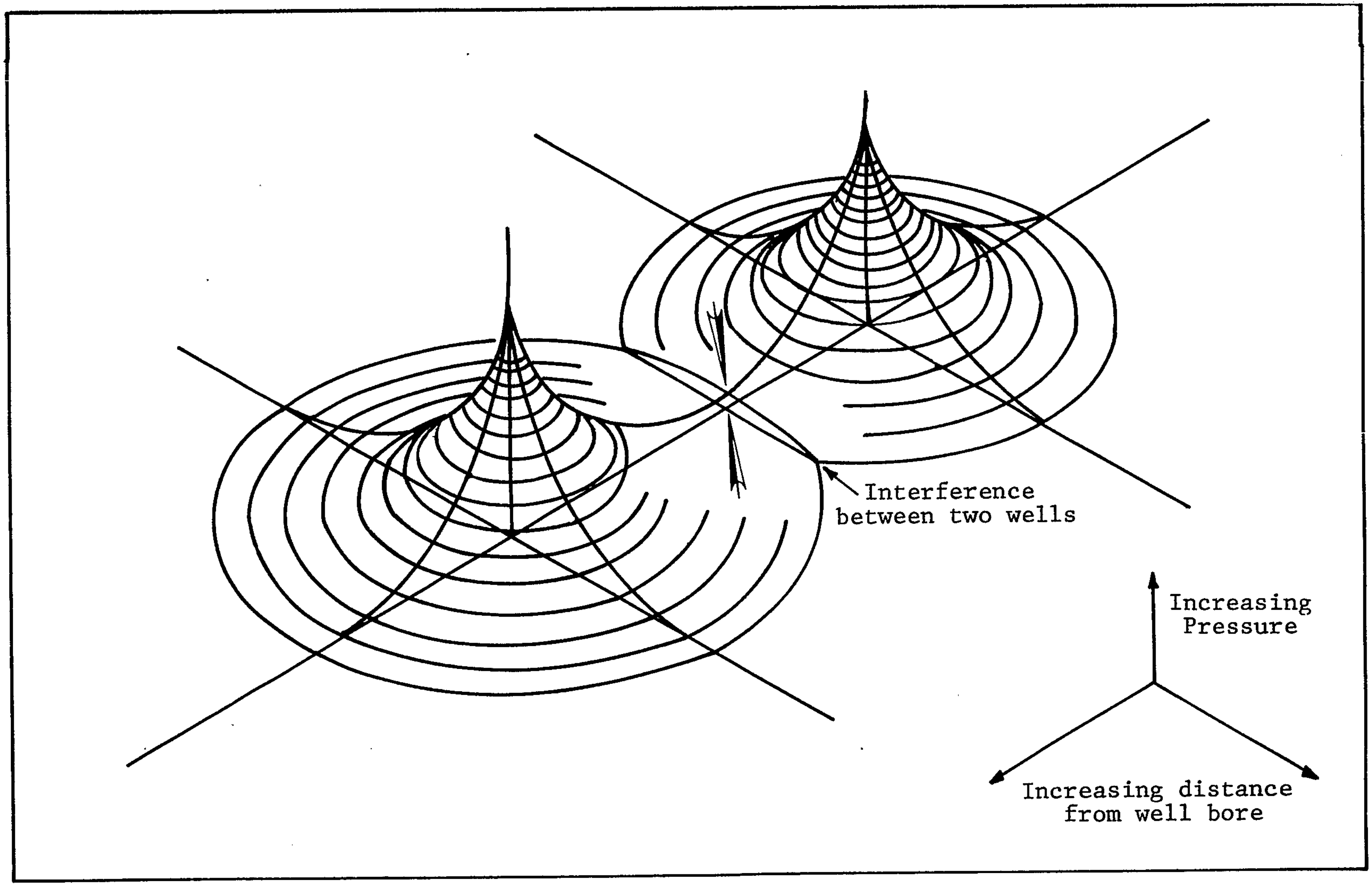


FIGURE V-1

TYPICAL WASTE INJECTION WELL SYSTEM
Source: BA-142



SOURCE: FE-134

FIGURE V-2

SYMBOLIC DEPICTION OF PRESSURE PROFILE WITHIN A BRINE DISPOSAL RESERVOIR of the brine (or of deforming strata thereby interfering with oil and gas recovery) is of primary concern (US-329). Consequently, the maximum pressure that is ultimately allowable, with respect to physical properties, is equal to the hydrofracturing pressure. The unconsolidated to poorly consolidated sediments of the Gulf Coast are widely believed to have hydrofracture pressures no less than about 0.5 psi per foot of overburden (for example, 500 psi at 1,000-foot depths). This value is significantly less than the normal lithostatic pressure of the overburden (about 1.0 psi/foot depth), which may represent an effective upper limit on pressures that would not usually cause hydrofracturing. However, even if the more conservative, lower limit is considered, the fairly large depths at which brine and other wastes are now injected would provide an upper injection pressure limit that considerably exceeds the pressures usually encountered (or required) in current injection practice. However, the usual lack of knowledge on the character of the geohydrologic environment and the lack of a sufficient data base on which to judge performance of high-pressure, high volume injection wells has produced a cautious approach toward deep-well disposal by regulatory agencies in the past. Consequently, in the Gulf Coast, deeper injection wells have been restricted to maximum pressures that are generally less than 2,000 psi (EN-371). In addition to the need to prevent extensive hydrofracturing, pressure is restricted also to avoid significant mutual interference in the pressure regime of two or more adjacent injection wells, which results in cumulative increases, and to offset the incremental effects of any geohydrologic boundaries in the vicinity of the injection site. Geohydrologic boundaries, such as faults, fairly abrupt thinning, or facies changes in the salaquifer, are of particular concern to the proposed program because such boundaries often occur in the vicinity of salt domes. The geologic strata near salt domes may consequently cause inordinate pressure rises upon injection, especially with time, and with a poorly-sited well, the fragmentation by faulting may physically limit the volume of brine that can be injected.

Injection of the nearly-saturated brine increases the salinity and dissolved solid content of the injection salaquifer only. The water quality problems for deep-well injection that can affect the biosphere are therefore remote and can ensue only upon nonstandard or unforeseen operating conditions (Figure V-3a, b, c, and d). Possible consequences of the brine injection include: (1) the displacement of saline water to fresh-water zones at some distance from the well; (2) the fracturing of aquicludes separating fresh and saline ground waters; (3) the migration of the brine or saline formation fluids along or through existing or created fractures or faults; (4) the upward transfer of brine along deteriorated well casings; (5) the interconnection of low-pressure fresh, or nearly fresh, ground waters by unplugged or poorly plugged abandoned wells that penetrate both zones of permeability; and (6) more unlikely, gross readjustment of surrounding strata (e.g., activitation of faults in underpressured zones where frictional resistance is overcome by hydrostatic pressures) (EN-099). Of all of these possibilities, the danger of encountering old, perhaps unknown, wells that are not sufficiently plugged is probably the greatest and is one reason that injection zones are usually placed at relatively great depths (very old wells are usually relatively shallow). While pressure increase alone is of some concern in this respect, contamination by injected brine <u>per se</u> is not likely due to (1) the relatively local, slow advance of the brine front (DO-101); (2) the density difference between brine and formation fluid, which results in a steady-state frontal position at the <u>top</u> of the injection zone even during injection (KA-209); and (3) the gravity effects of the denser brine which, in conjunction with the regional dip, restrict the frontal movement in the updip direction.

FIGURE V-3a

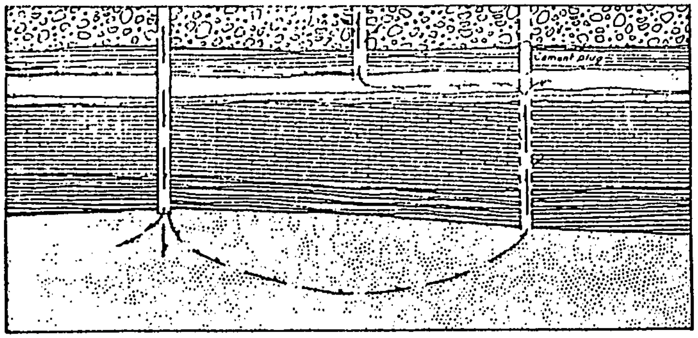


FIGURE V-3b

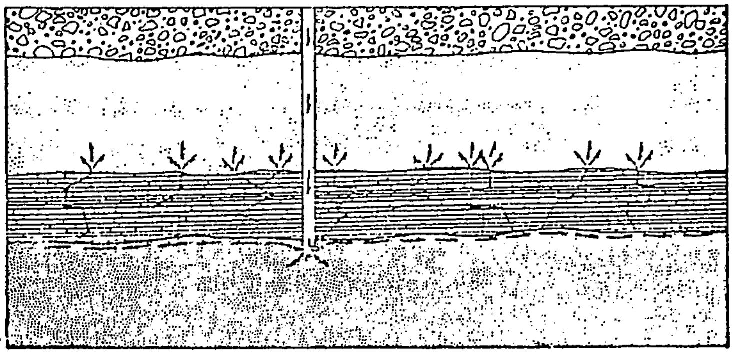


FIGURE V-3c

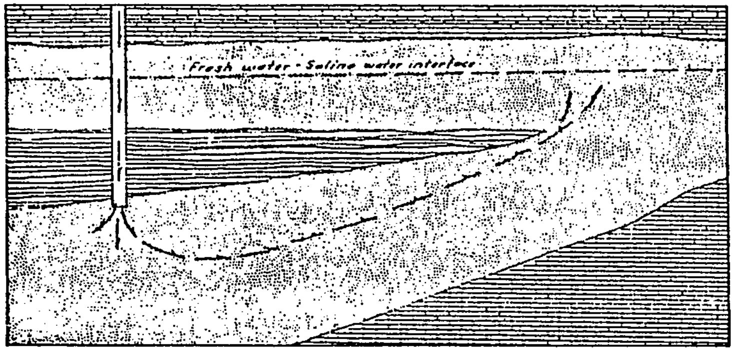
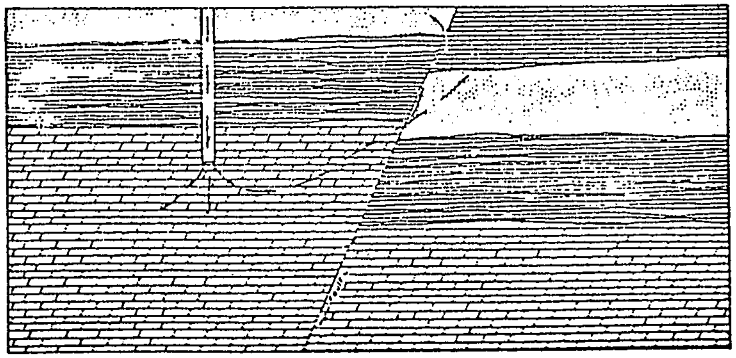


FIGURE V-3d



Source: US-239

FIGURE V-3

MECHANISMS FOR INJECTED BRINE TO AFFECT WATER QUALITY IN OTHER AQUIFERS
a) through unplugged or inadequately plugged abandoned wells;
b) by fracturing the overlying aquiclude
c) by displacing water updip or by natural strategic facies changes;
d) by transposing of other aquifers by faulting or migration of fluids along faults

Disposal to the Gulf of Mexico

This method of brine disposal will result in an increase in salinity of marine waters near the point of discharge; the areal extent of an increase in salinity of a given magnitude is the principal determinant of adverse impacts on the aquatic (especially benthic) community. To evaluate the area that may be affected to various degrees by such disposal operations, a dispersion model was developed to describe the steady-state, two-dimensional distribution of the excess dissolved solids at various depths. The basic equation describing this dispersion is:

$$K_y \frac{\partial^2 C}{\partial x^2} + K_y \frac{\partial^2 C}{\partial y^2} + K_z \frac{\partial^2 C}{\partial z^2} + u \frac{\partial C}{\partial x} = S$$

K_y - lateral dispersion coefficient, ft^2/sec

K_z - vertical dispersion coefficient, ft^2/sec

y - lateral distance, measured perpendicular to current flow

x - distance from diffuser, in direction of current

z - vertical distance above seabed

u - prevailing net current in x - direction, in ft/sec

C - excess dissolved solids concentration, relative to ambient water, in ppt s - source term (ppt/sec), including each diffuser port

This equation governs the advection and eddy current diffusion processes which cause the salt plume to spread as it is transported downstream. Virtual mirror source images are used to represent the effect of seabed and surface boundaries on the concentration. Gravitational effects due to density differentials are incorporated explicitly using empirical relations describing plume behavior for fluids of differing densities.

The diffuser typically would be designed to permit substantial initial dilution of the wastewater (brine) with Gulf of Mexico water via vertical mixing. Nevertheless, the mixed water just beyond the diffuser will have a somewhat greater density than the surrounding water, and the excess salinity plume from the diffuser will tend to sink. This negative buoyancy results in an accumulation of excess solids on and near the sea-floor bottom relatively near the diffuser, which dissipates in concentration via dispersion and advection with increasing distance from the diffuser. The model incorporates the various effects of initial flow/mass rates, negative buoyancy, lateral dispersion, vertical dispersion, and advective velocity; it is intended to analyze parametrically the water quality effects of brine disposal to the Gulf. In this section, the results of the modeling under typical, conservative assumed parameters are described; a detailed description of the model is included in a central reference document (RA-223). Ecological impacts are discussed in Section V.B.6.

The assumptions and conditions under which the model was exercised are:

Diffuser Design

- Diffuser length: 700 (effective) feet
- Port diameter: 0.75 feet
- Exit velocity: 3 feet per second, vertically upward
- Port spacing: 10 feet
- Brine discharge: 42,000 gallons per minute (93.6 cfs)
- Location in water column: 5 feet from bottom
- Location from shore: 5 miles
- Water depth: 50 feet
- Orientation: perpendicular to current direction

Model Parameters

- Initial vertical dispersion coefficient: .001 ft^2/sec
- Initial lateral dispersion coefficient: 1 ft^2/sec
- Final vertical dispersion coefficient: .001 ft^2/sec
- Final lateral dispersion coefficient: 322 ft^2/sec

- Current velocities:
  - (a) 0.1 feet per second longshore
  - (b) Vector sum of 2 feet per second longshore and 0.5 feet per second onshore.

Model Output

- Isohaline contours at depths from 0 to 50 feet, in 5-foot increments (to examine the effects of density differences)

  Excess salinity concentrations laterally from the diffuser ranging from 0.25 ppt to 10 ppt (to determine affected areas)

The diffuser design is arbitrary, but it follows standard engineering practice for design of sewerage diffuser outfalls. The flow rate of 42,000 gpm is the maximum flow likely to be generated in either construction or operation of a 200 MMB salt dome storage facility, the prototype for this assessment. The Federal Energy Administration currently expects any such outfall diffuser to be no closer than five miles to shore and in water depths not less than about 50 feet.

Only sparse information is available on dispersion coefficients. Measurement of dispersion coefficients is very difficult and has taken place to a credible degree only in estuarine settings; consequently, typical estuarine values have been used in the model analysis. According to cognizant personnel from the National Oceanic and Atmospheric Administration's laboratory at Key Biscayne, Florida, reasonable values of the (final) lateral dispersion coefficient in the Gulf may lie in the range of 0.2×10^6 to 50×10^6 cm^2/sec, and corresponding vertical dispersion coefficients range from 1 to 30 cm^2/sec, depending on whether a low energy or a high-energy environment is under consideration

(HA-557). In the model, the (final) vertical and lateral dispersion coefficients are correspondingly presumed to be on the order of 1 cm^2/sec (.001 ft^2/sec) and 0.3 x 10^6 cm^2/sec (322 ft^2/sec), respectively, which are conservatively small. The initial dispersion coefficients are required in the mathematical treatment, but have negligible influence on the final result; they are assumed to be very small.

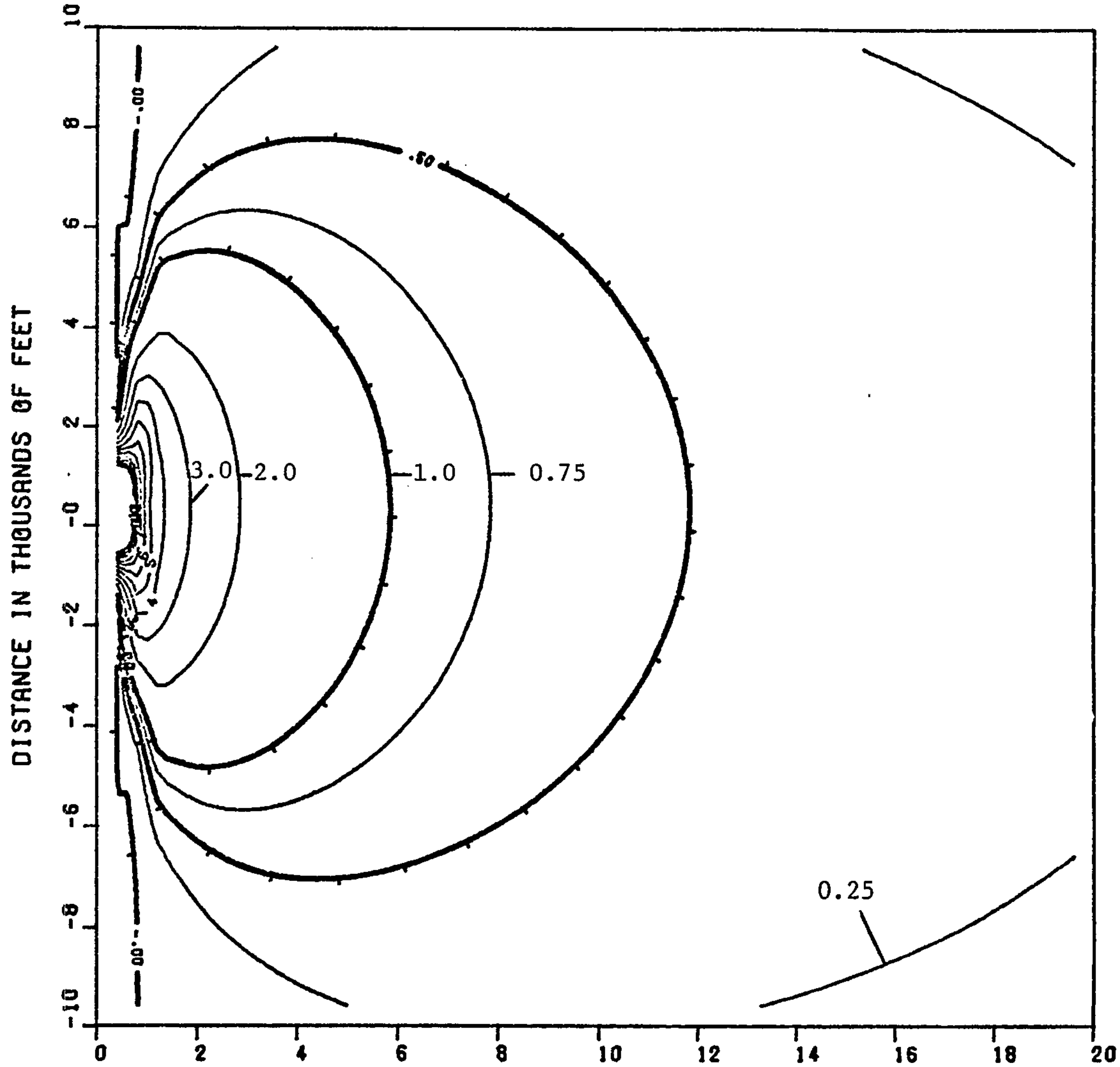
A sensitivity analysis indicates that the current velocity is a strong determinant of excess salinity concentrations in the model. The character of the flow regime in the Gulf of Mexico is, of course, very site-specific and time-specific, but generally two current velocities can be identified that correspond to two different time scales: (1) short-term time scale, on the order of 1 to 10 hours, with a net current typically having a 2 fps longshore component and 0.5 fps onshore component, and (2) a long-term time scale, on the order of 1 day to 100 days, typically with a net current velocity of 0.1 fps (or more) longshore (HA-557). Both of these advective conditions are modeled independently to examine (1) the likelihood and effect of plume migration and impingement at some point on or near the shore, and (2) the maximum likely area of excess salinity effects, respectively. These two conditions are believed to represent typical extremes of a spectrum of current conditions, and therefore should be meaningful to the analysis.

The model was exercised under two radically different hydraulic conditions, one representing a hypothetical, unrealistic worst-case condition, and one that corresponds more closely to physical reality in the proximity of the diffuser. The worst-case condition assumes no vertical mixing near the diffuser exit, which is contrary to the diffuser design. Under these conditions the gravitational effects are magnified and result in much larger areas to be affected than can reasonably be expected. Modeling such worst-case conditions with the smaller solute advection term results in "pooling" of brine in the near-field, within a few hundred feet of the diffuser, with decreasing gravitational effects and diminishing salt concentrations at increasing distances. Figures V-4 and V-5 show the modeled distribution of excess salinity for very poor mixing and net advection at the sea bottom and at an elevation of 10 feet from the bottom, respectively. The magnified effects of gravity on the denser plume are easily recognized by comparing these figures, but even under these unrealistic worst-case conditions, the areal extent of the significant part of the plume is not great, relative to the distance from shore. Figure V-4 and V-5 provide ample evidence for restricting further impact analysis to the environs of the sea bottom, where the excess salinity concentrations are largest due to negative plume buoyancy, and where sedentary or less mobile benthos are subject to the imposed stress of increased salinity.

A more realistic hydraulic condition in diffuser operation is the immediate vertical mixing of discharged brine and ambient sea water over some vertical mixing depth, as influenced by diffuser design. While this mixed plume is also subject to gravitational effects, the density differences with ambient water are significantly less than in the worst-case condition described above, and the gravitational forces decrease and become negligible at smaller distances from the diffuser. A more diffuse salinity gradient is established within the water column, but with maximum values still occurring at the sea floor elevation within one hundred feet of the diffuser. The vertical mixing depth greatly affects the excess salinity distribution; while the diffuser undoubtedly could, and probably would, be designed to induce larger mixing depths and therefore smaller water quality impacts, a minimum feasible mixing depth of from five to ten feet appears reasonable and has been used conservatively in the calculations here as a parameter.

FIGURE V-4

EXCESS SALINITY CONCENTRATION



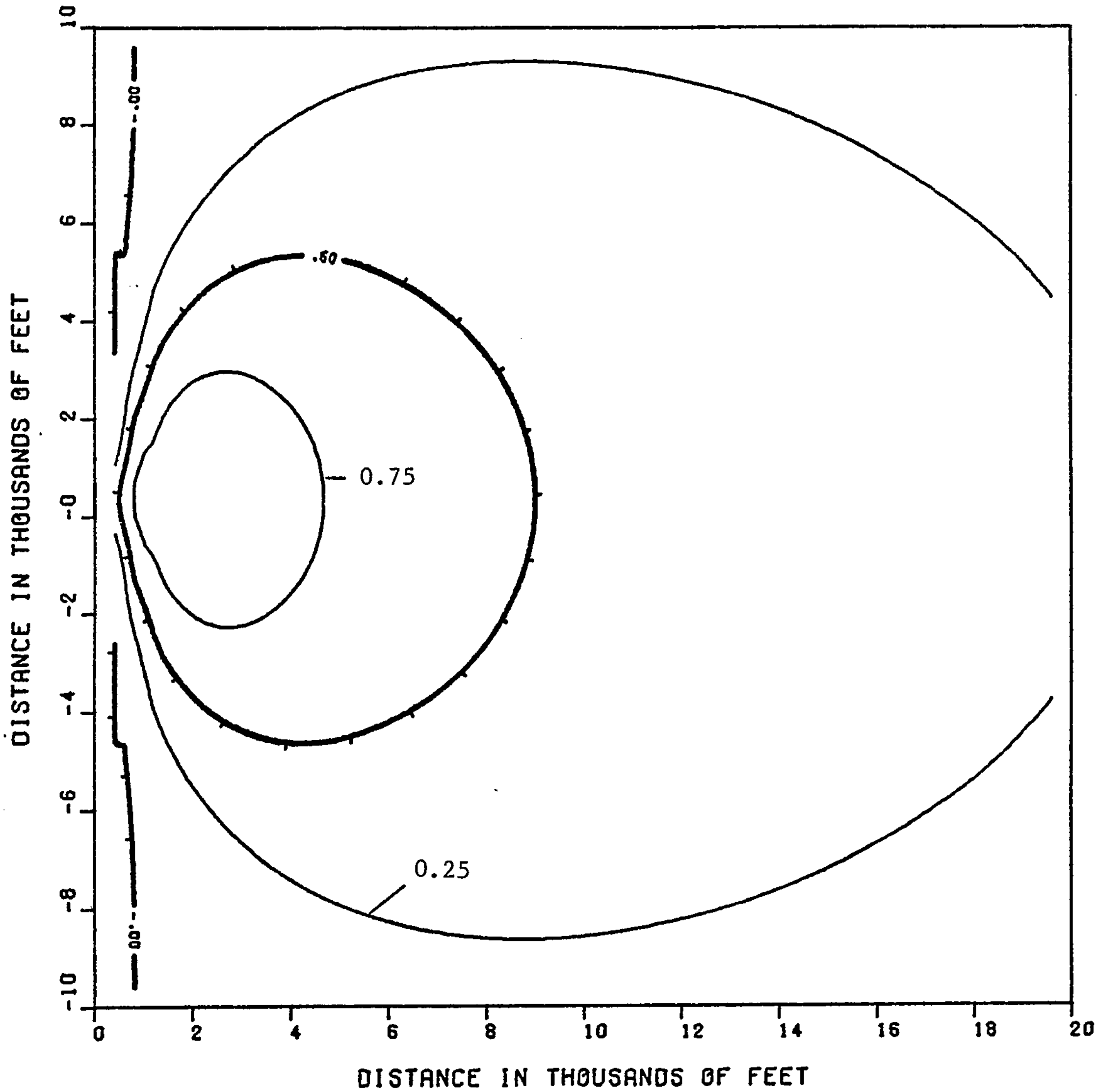
NO VERTICAL MIXING AT DIFFUSER PREVAILING CURRENT = .1 FT/SEC

EFFLUENT CONCENTRATION = 230 PPT FLOW RATE = 42000 GPM

EXCESS SALINITY CALCULATED AT THE BOTTOM

FIGURE V-5

EXCESS SALINITY CONCENTRATION



NO VERTICAL MIXING AT DIFFUSER PREVAILING CURRENT = .1 FT/SEC

EFFLUENT CONCENTRATION = 230 PPT FLOW RATE = 42000 GPM

EXCESS SALINITY CALCULATED 10 FEET ABOVE BOTTOM

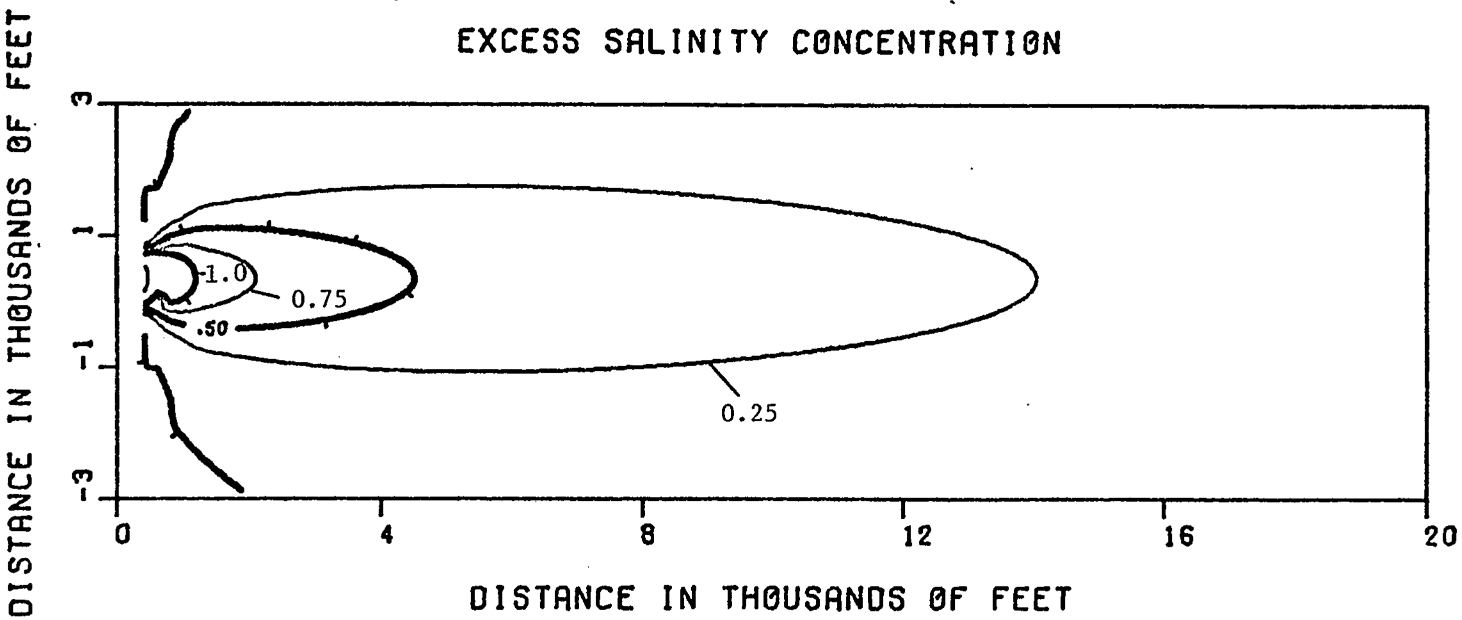
Typical excess salinity distributions that may be expected at the sea floor for the two current regimes under consideration are shown in Figures V-6 and V-7. It is obvious from these figures that the faster prevailing current, with a shoreward component, will not cause plume impingement on shore or significant migration toward shore, and that the slower prevailing current, while affecting a larger area and therefore representative of more critical conditions, still causes only a limited adverse impact, relatively close to the diffuser. Furthermore, higher energy environments, such as might be generated during tropical storms, would create substantially less impact than either current regime, if solution mining were continued during such inclement conditions. It is concluded that the five-mile off-shore limitation is an effective buffer that mitigates impacts of brine disposal on water quality, even with inordinate variance from the model's assumptions, as long as the diffuser is not placed within an estuarine circulation system.

Table V-1 presents the approximate bottom area affected by excess salinities of various concentration under different scenarios of extent of vertical mixing as modeled above. In evaluating these results, it should be recognized that the natural salinity of coastal waters vary considerably during the year and averages may range from 10 to 36 ppt; however, most fluctuations represent a salinity decrease (by dilution with fresher water) rather than a salinity increase. Clearly, the ecological effects of salinity variations, particularly salinity increases, will be species-specific; the salinity tolerances of typical, representative benthic biota is the subject of a discussion in Section V.B.6.

An evaluation of potential effects of recirculation of discharged brine was also made in the course of the brine dispersion modeling. If recirculation occurred to a significant extent, the salinity of "dilution water" could conceivably increase to a point where the isohalines resulting from brine

FIGURE V-6

EXCESS SALINITY CONCENTRATION



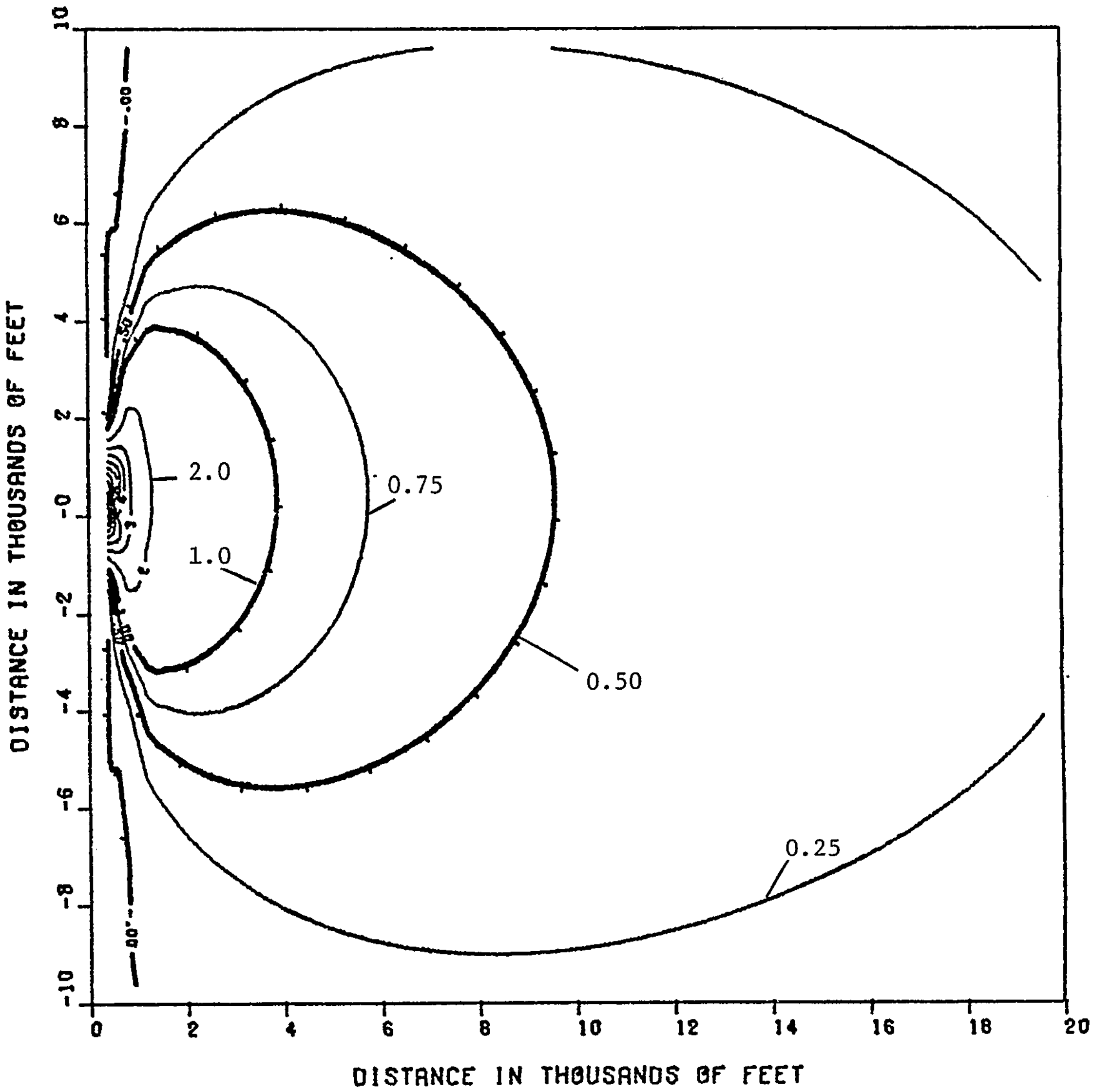
VERTICAL MIXING EXTENT -- 5 FEET   PREVAILING CURRENT = 2.1 FT/SEC

EFFLUENT CONCENTRATION = 230 PPT   FLOW RATE = 42000 GPM

EXCESS SALINITY CALCULATED AT THE BOTTOM

FIGURE V-7

EXCESS SALINITY CONCENTRATION



VERTICAL MIXING EXTENT -- 10 FEET   PREVAILING CURRENT = .1 FT/SEC

EFFLUENT CONCENTRATION = 230 PPT   FLOW RATE = 42000 GPM

EXCESS SALINITY CALCULATED AT THE BOTTOM

TABLE V-1

SEA-BOTTOM AREAS THAT EXPERIENCE EXCESS SALINITY
OF A GIVEN CONCENTRATION FOR
VARIOUS DIFFUSER DESIGN CONFIGURATIONS
AND TWO DIFFERENT CURRENT REGIMES

		Acres Affected By At Least:				
Current Velocity	Extent of Vertical Mixing	0.5 ppt	0.75 ppt	1.0 ppt	2.0 ppt	5 ppt
0.1 fps parallel to shore	No vertical mixing	3,156	1,665	1,030	306	43.0
	5 feet vertical mixing	2,787	1,387	812	190	22.8
	10 feet vertical mixing	2,037	868	448	65.8	7.6
2.1 fps at 14° with shore	No vertical mixing	711	380	240	75.9	15.2
	5 feet vertical mixing	119	32.9	7.6	--	--
	10 feet vertical mixing	12.6	--	--	--	--

discharge encompassed larger areas than shown in Table V-1. Calculations of the effect of continuous recirculation of discharged brine to the diffuser indicate that two different sizes of recirculation cells must be considered. Recirculation cells with mean flow paths of about 100 miles or more (effective radii greater than 16 miles) would increase the excess salinity shown in Figures V-6 and V-7 by no more than 0.5 ppt, if such recirculation took place continuously over a 42-month period at an average speed of 1.0 foot per second (conservatively high assumptions). On the other hand, recirculation cells with smaller mean flow paths and effective radii could produce a more marked effect on the excess salinity distribution, if they operated continuously over a 42-month period; for example, a recirculation cell with a flow path of 10 miles (effective radius of 1.6 miles) which is about equivalent in scale to the unaffected excess salinity plume, could increase the excess salinity in the area of the cell by about 6 ppt. However, it is highly doubtful that such a small recirculation cell would be maintained over a period of a few weeks, much less the entire 42-month period. For time periods appropriate to the scale of these smaller cells, increases in excess salinity due to recirculation are probably in the range of 0.5 to 1.0 ppt. Proper siting of the diffuser will generally permit avoiding areas where small recirculation cells may operate, or where normally long flow paths may be "short-circuited" by unusual site-specific factors. This evaluation of recirculation indicates that in shelf waters, recirculation is not considered to be a necessary or even a likely hazard to brine disposal operations, but the potential for recirculation and possible impacts on excess salinity should be addressed at a site-specific level. For each proposed diffuser outfall, these site-specific factors will be evaluated in the individual EIS's.

It should be noted that the ratio of the salinities of discharged brine (230 ppt) to the excess salinity at any point represents the amount of dilution that has occurred at that point. This dilution factor is valid for not only the overall salinity, but specific components of the discharged brine as well. For example, the Ca/Mg ratio of the plume, which can also be important to some benthic species, reflects only about 1% of the somewhat higher Ca/Mg ratio in the brine, at the 2 ppt excess salinity isohaline. There is no indication that the large dilution afforded by a diffuser operation would not effectively prevent any inordinate water quality problems with respect to specific components or combinations of components; the relative composition of brine from the dissolution of salt, a marine evaporite, should not be expected to be orders of magnitude different from the relative composition of sea water. Because there appears to be a lack of available information concerning trace elements in domal salt, FEA has requested the U.S. Geological Survey to corroborate this expectation for those domes that are selected to participate in the storage program.

b. Other Water Quality Impacts

Surface Water

A small, short-term increase in stream or estuarine siltation will accompany construction activities. Runoff from areas disturbed by road building, pipeline construction, grading, and equipment staging will show increases in suspended and dissolved solids content that cannot be avoided even with control procedures (EN-101). In addition, the flushing of pits and other surface storage at drilling sites by large storms is another source of pollutants. The sizes of these affected areas are rather small and are not expected to materially affect erosional or depositional patterns after construction is completed.

The most significant surface water quality impacts that may occur during the program relate to the possible need for fairly extensive dredging at one or more Gulf port facilities in order to provide for the additional traffic which will occur during filling operations. The program may require dredging to create new channels or to alter existing channels and also may increase the amount of maintenance dredging required. Because anything that affects the bottom will necessarily have an impact on the ecological balance, and perhaps man's use of the coastal area, dredging is of some general concern and is now being more closely scrutinized by regulatory agencies as to potential impacts at a specific location.

A dredge is an earth-moving machine designed to remove bottom material from under water to either increase the water depth or to gain the bottom material for fill or commercial use. A dredge may be either of a mechanical type or a hydraulic type. A mechanical dredge picks up and lifts material with various type buckets and shovels. A hydraulic dredge utilizes a centrifugal pump which moves a slurry of water and material from the bottom and transports it through a piping system to a point of discharge. Hydraulic dredges handle more material today than do mechanical dredges.

Dredging is conducted now on a continuous basis in order to maintain navigable intracoastal waterways along the Gulf Coast of the United States. Intracoastal waterways traverse estuarine areas characterized by the existence of extensive salt marshes. Material dredged from these environments is, in most cases, deposited in spoil banks on the salt marshes. Alternative disposal sites would require costly transport of the dredged material to more remote areas.

Dredging has the potential of being the major force for modifying or altering the water quality and the environment in coastal bays, marshes, and estuaries. Since salt marsh estuarine environments are extremely productive and provide suitable nursery grounds for sports and/or commercial fisheries, it is important to minimize environmental disturbances resulting from dredging activities in these areas.

Pollution problems associated with dredging can be classified as either primary or secondary. Primary pollution problems are of local significance but are relatively small in magnitude when compared with secondary pollution problems.

Primary or self-generated pollution includes the domestic waste and other discharges from dredges and associated facilities and the water quality problems associated with dredging of "natural materials." Mechanical disturbances of the bottom material results in removal of substrate upon which fauna depend. Motile and benthic organisms may be either removed or disturbed during dredging operations. The resuspension of sediments can cause a significant reduction in light penetration and will result in a corresponding decrease in photosynthesis and production. The redeposition of the suspended sediments could bury highly productive grass flats or oyster reefs if care is not taken in the planning and operation of dredging.

A large portion of the physical, chemical, and biological pollutants which are discharged into our waterways end up as bottom deposits in navigable waterways and estuaries. Dredging causes secondary pollution by resuspension and redeposition of these materials. This secondary pollution can be particularly dangerous if these bottom deposits contain unusually high pesticides or other organics, radionuclides, heavy metals, or virus levels as a result of adsorption of the materials onto the sediment particles. Further problems exist where the bottom materials are made up of large quantities of unoxidized or partially oxidized organic material, where the deposits have high percentages of petroleum or petrochemical derivatives, and where high nutrient levels exist in the bottom deposits.

If the bottom materials being removed have no commercial value they may be used for fill and redeposited on salt-marsh lands. The productivity of the marsh lands selected for the ultimate disposal of spoil can be destroyed, so disposal sites require careful evaluation. Also, during deposition of dredged material on undiked salt marshes, it is possible that some chemical constituents of the dredged sediment may be released in the runoff water of the spoil bank. Thus, surrounding water quality could be impaired.

Another potential surface water quality impact is oil spilled from crude handling facilities and transportation vessels. Owing to its very large potential impact and its importance to the Gulf Coast region, this impact is addressed in another section of this chapter.

Ground Water

Degradation of ground-water quality in the normal course of program implementation, except as discussed in the preceding section, is not anticipated. However, there is a potential for serious deterioration of ground-water quality via several mechanisms:

1) Salt-Water Encroachment - Use of very large amounts of nearly-fresh ground water will tend to slowly shift the fresh-water/salt-water

interface present in the coastal region toward a more inland and/or shallower location, with a resulting increase in salinity of the ground water in wells.

2) Ruptured Brine-Well Casings - Ruptured casing passing through fresh-water aquifers may permit either brine or crude oil from salt dome cavity, or more saline water from other deeper strata, to invade these aquifers. The standard practice of using multiple, cemented, concentric casing strings, of pressure testing the casing and annular space, and of logging boreholes will minimize this possibility.

3) Catastrophic Collapse of Cavities - The collapse of the roof of a cavity would locally disrupt near-surface fresh water aquifers and the quality probably would be degraded by the more saline water from deeper strata. Roof collapse is not likely if an adequate salt roof is maintained and the cavity is kept filled with brine or oil.

c. Impacts Related to Water Quantity

The acquisition and use of water for the program is an important consideration, owing principally to the large volumes and rates of water required at a single salt dome. For constructing a 200 MMB storage facility (twenty 10 MMB cavities), about 33,000 gpm of fresh water or 36,000 gpm of sea water will be required over the 42-month period and will result in up to 41,000 gpm of saturated brine. To displace 200 MMB of crude oil from such a facility in 150 days, about 40,500 gpm of fresh water or 39,300 gpm of sea water will be required. Smaller capacities require proportionately lower rates for both construction and oil displacement. Similarly, for an existing 90 MMB cavity, only displacement water will be required, which will amount to about 18,200 gpm of fresh water and 17,700 gpm of sea water over 150 days. In contrast, storage in existing salt mines will not require a large volume of water because the oil will be pumped from the mine.

The direct environmental impacts of the program are determined primarily by the rates of water used at the individual sites, and secondarily by the total amount used. However, maximum utility will be made of nonpotable supplies. Construction of new salt cavities may require up to 210 billion gallons of water. This is equivalent to the total water withdrawal for domestic, public, commercial, and industrial uses from the public water supply systems of a city of about one million inhabitants (on a 1980 per capita basis) during the same time frame (TO-028). Similarly, oil displacement from new and existing salt cavities will require up to the equivalent of the total water withdrawals by a city with a population of over 1.5 million for more than two years (up to 178 billion gallons). It should be pointed out that the severe degradation in quality of this water dictates that this water use be considered essentially consumptive. Moreover, water for oil displacement must be available on demand at any time.

Surface Water

It is currently expected that surface water would be the primary source utilized in the program. At this time, there are few undedicated, fresh surface water supplies in the region, other than the Mississippi River, that are large enough to accommodate this water use. However, not all dedicated water rights are currently being used. The Brazos and especially the Sabine River each could supply enough water now to construct one, or possibly two, new 200 MMB facilities in salt domes without physical detriment to other allocated uses. Water from these streams (particularly the Brazos) for cycling the storage system on demand likely would not be available after about five years without rationing prior water rights, an unrealistic event. The possibility of overdrafts essentially restricts consideration of fresh surface-water usage to the Mississippi River only. Usage of water from the lower Mississippi River is not allocated at the present time, a fact that is indicative of the river's very large flow.

The water intake structures must conform to environmental restrictions on intake design velocities of less than 0.5 feet per second to minimize impingement and entrainment of aquatic biota. Such intake structures, whether in the Gulf of Mexico or on a large coastal region stream, may be considered a navigation hazard that would not otherwise exist. Navigation hazards are of importance environmentally due to the increased risk of oil spills and the possible release of transported toxic materials to surface waters.

On any stream in the region except the Mississippi River, the continuous withdrawal of fresh water, even if physically available at the required rates, may have several more adverse impacts of general consequence. The fresh-water/salt-water interface in the tidal portion of the stream will shift upstream during at least the lower flows of the river, resulting in more extensive brackish conditions. The change in the flow regime and salinity milieu conceivably could seriously impair or prevent the growth of important commercial fish and shellfish, which spend at least part of their life cycle in this environment. Furthermore, a long-term reduction in low flows can alter erosional and depositional patterns of the stream, which may necessitate increased dredging or result in the premature silting of productive estuarine marshes.

If the intake(s) were located in an estuary, impingement and entrainment of estuarine biota would be severe, since larval and some juvenile forms cannot be prevented from entering the intake. In this setting, induced changes in local water currents or salinity (areally or vertically) are of special concern in that either can cause some degree of community reorganization.

For an intake located several miles offshore, the same considerations mentioned above also apply, but there is a significant difference in degree. For example, fewer larval and juvenile forms may be expected offshore than in an estuary. Slight changes in water currents or salinity variations due to large water withdrawals would probably not be noticed, given the large natural variations having no ecological consequence. Withdrawal of water from the middle of the water column should minimize ecological impacts but will require the intakes to be positioned at a considerable distance from the shore.

Ground Water

Ground water could also be used at least as a supplementary water supply for some storage locations. Because the hydrogeology of nearly all the Gulf Coast is fairly well known, ground-water development on a fairly large scale can take place with minimal impacts if proper resource evaluation procedures are carefully employed. In fact, it is technically feasible to meet the total water requirements for constructing and operating a 200 MMB salt-cavity storage facility using moderately saline (5,000-20,000 mg/1 TDS ground water.

Using reasonable regional values for pertinent parameters, it can be shown that such ground-water usage, with adequate spacing between wells in an optimally-sited well field, will cause the ground-water table to drop over 150 feet in the immediate vicinity of the wells, gradually recovering with distance.

This decline in ground-water pressure will be extensive and will have several other consequences. Land surface subsidence, ultimately up to several feet at the well field, will take place (Section V.A.1.b.); this may lead to a reduction in storage capacity of the aquifers due to compaction (GA-122) and in certain coastal areas greatly increased salt-water flooding of wetlands which could cause at least local if not regional ecological impacts. Local hydraulic gradients may be altered such that recharge-discharge relations among adjacent aquifers (interformational leakage) or among aquifers and surface streams are reversed or changed in magnitude substantially. Adverse changes in water quality may develop from such changes. Perhaps the greatest impact of ground-water declines would be the preclusion or increased cost of ground-water usage by other proximal wells in the same zone owing to the need for either deeper drilling or larger pumping lifts at these other wells.

3. Meteorological and Climatological Impacts

While the proposed storage system will produce no adverse meteorological or climatological impacts in the Gulf Coast region, the impact of meteorological and climatological phenomena on the proposed storage system could be signficant. To avoid the adverse impacts of high tides and winds associated with hurricanes, candidate storage sites which would be subjected to a tidal wave of greater than five feet more than once in fifty years have been excluded from further consideration. Further, there are no storage facilities planned within 2 miles of the Gulf Coast. However, there remains a very small probability that a very large storm within the area could cause some damage to aboveground storage equipment such as surge tanks, pump sheds, and administrative buildings.

The damage caused by Hurricane Camille along the Mississippi-Louisiana Gulf Coast can be used as an example to estimate the effects of a great hurricane (DI-098). Using meteorological instrumentation on offshore oil rigs, various parameters were measured during this storm. At one rig, a maximum wind speed of 172 mph was recorded at the 100-foot level. When extrapolated to the 30-foot level (standard level used by the National Weather Service), the peak gust was calculated to be 144 mph, with a sustained wind of 115 mph. Yet, this oil rig did not experience the strongest winds of the hurricane; sustained winds of 125 mph occurred near the center of the storm. Wave conditions were considered severe. At an offshore fixed platform, a maximum wave height of 77.4 feet was recorded.

Most of the damage from Camille was due to the storm surge which produced a record-breaking tide of 24.6 feet near Pass Christian, Mississippi causing heavy damage up to 400 yards (one quarter mile) inland. The erosion by the severe wave action completely destroyed some islands off Mobile Bay which have not reappeared. The storm surge was powerful enough to carry an oil storage tank inland from its original position (DI-098). A report on the nature and extent of structural damage presented to the United States Department of Commerce in 1972 stated that "at least 60 percent and possibly as much as 75 percent of the total structural damage in the Mississippi coastal area was caused by wind action, or was initiated by wind acting on an individual structure or building" (SA-219).

The National Weather Service has recently assembled past statistics of wind and storm-surge damage and has devised a hurricane disaster potential scale. This disaster-potential scale assesses the destructive scale of a hurricane from actual data taken during the hurricane. The classification of hurricanes by scale numbers represents an estimate of the storm damage to a coastal area, assuming that the hurricane undergoes no change in its destructive power. Table V-2 presents the "Hurricane Disaster Potential Scale" from the National Weather Service (HU-139). Hurricane Camille was assessed as a Scale Number 5. In the last one hundred years, only one other hurricane, 1935, was accorded this level of destructiveness.

If a hurricane of this destructiveness were to hit the Gulf Coast in the vicinity of an underground storage facility, it is likely that some wind and water damage would occur. The extent of the damage would depend on the facility's elevation above sea level and distance from the shore. No facilities currently under consideration are less than 15 feet above sea level and within 500 yards of the shore (See Table V-2) and hence hurricane damage is likely to be minor.

Severe Storms

Although severe local storms, including tornadoes, occur fairly frequently in the Gulf Coast region, the effects are minor compared with the effects of the hurricanes and tropical storms which have achieved landfall in the region. In most cases, the tornadoes which move through the region are small and short-lived. Storms producing large hailstones (larger than about two inches in diameter) are also quite rare in the area. Severe local storms, including those which produce tornadoes, are most likely to occur in March, April, and May, although they can occur during any month of the year. For the 20-year period extending from 1951 to 1971, the highest annual tornado density (mean number of tornadoes per 1,000 square mile unit area per year) was 3.0 (mostly waterspouts)

TABLE V-2

HURRICANE DISASTER POTENTIAL SCALE

SCALE NUMBER 1

Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real damage to other structures. Some damage to poorly constructed signs. OR Storm surge 4 to 5 feet above normal. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorages torn from moorings.

SCALE NUMBER 2

Winds of 96 to 110 miles per hour. Considerable damage to shrubbery and tree foliage, some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major damage to buildings. OR Storm surge 6 to 8 feet above normal. Coastal roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from morrings. Evacuation of some shoreline residences and low-lying island areas required.

SCALE NUMBER 3

Winds of 111 to 130 miles per hour. Foliage torn from trees, large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some wind and door damage. Some structural damage to small buildings. Mobile homes destroyed. OR Storm surge 9 to 12 feet above normal. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Flat terrain 5 feet or less above sea level flooded inland 8 miles or more. Evacuation of low-lying residences within several blocks of shoreline possibly required.

SCALE NUMBER 4

Winds of 131 to 155 miles per hour. Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes. OR Storm surge 13 to 18 feet above normal. Flat terrain 10 feet or less above sea level flooded inland as far as 6 miles. Major damage to lower floors of structures near shore due to flooding and battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Major erosion of beaches. Massive evacuation of all residences within 500 years of shore possibly required and of single-story residences on low ground within 2 miles of shore.

SCALE NUMBER 5

Winds greater than 155 miles per hour. Shrubs and trees blown down, considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Some buildings overturned to blown away. Complete destruction of mobile homes. OR Storm surge greater than 18 feet above normal. Major damage to lower floors of all structures less than 15 feet above sea level within 500 yards of shore. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Massive evacuation of residential areas on low ground within 5 to 10 miles of shore possibly required.

STATISTICAL DEFINITION OF THE SCALE

Category	Central Pressure (millibars)	Winds (mph)	Surge (ft)	EXAMPLE
1	>980	74- 95	4- 5	Agnes, 1972 (Florida coast)
2	965-979	96-110	6- 8	Cleo, 1964
3	945-964	111-130	9-12	Betsy, 1965
4	920-944	131-155	13-18	Donna, 1960 (Florida) Carla, 1961 (Texas)
5	<920	>155	>18	1935 Storm on Florida Keys

Source: HU-139

along the middle Texas Coast. The rest of the Gulf Coast region had tornado densities between 1.5 and 3.0 during that period, again mostly due to waterspouts, as opposed to actual tornadoes (OR-021).

In terms of flooding potential from cloudbursts caused by severe local storms, the region has a 100-year mean recurrence interval for 30-minute rainfalls of 3.5 inches; 1-hour rainfalls of 4.5 inches; and 2-hour rainfalls of 5.5 and 6 inches, except for slightly higher totals at the southeastern tip of Louisiana (HE-163).

4. Air Quality

Although some violations of primary ambient air quality standards do occur, in general, the Gulf Coast region has few problems with large-scale poor dispersion conditions. When problems are experienced, they are usually caused by a combination of a stagnating anticyclone with a weak pressure gradient at the surface and a strong ridge aloft. This flow pattern forces the air to sink, warming by compression in the process. Under such a regime, winds are light, skies are clear, and mixing depths are rather low. The eastern half of the Gulf Coast region experiences the most dispersion problems (relatively few in comparison with the eastern United States), with the potential for air stagnation decreasing from east to west across the region. The general dispersion conditions throughout the region are fairly good, partly because of the sea breeze influence. An average of only about five periods of extended poor dispersion conditions (conditions requiring the issuance of an Air Stagnation Advisory by the United States Weather Service) occur in any part of the region per year. These stagnation conditions most commonly occur during August, September, and October, although they can occur during any month of the year.

The air impact of the salt dome storage in the region can be divided into the drilling, filling, operational, and withdrawal phases of the program. During the construction and drilling phase for onshore salt domes, fugitive dust emissions will occur from the activity around the site. The quantity of emissions generated is extremely site-specific, dependent on soil characteristics, climate, amount of construction activity, and dust suppression measures (EN-071). Impacts will be localized and short-term. The impact of diesel-fueled equipment during drillings is also estimated to be slight, since little aboveground site preparation will be required. At the salt dome sites evaporative hydrocarbon emissions from the filling and withdrawal phases will be negligible since the storage facilities will be closed.

Fugitive hydrocarbon emissions from tanker unloading and loading operations in port must also be considered. Emissions occur during ballasting and purging. To estimate maximum annual emissions from the two example salt dome facilities, the following case was evaluated: unloading of the crude into salt dome storage, and reloading the entire amount into tankers for transport to distant refineries. Estimated emissions have been computed for this extreme case and are presented in Table V-3. For comparative purposes this table also presents published estimates of 1973 hydrocarbon emissions from all sources in each of the three AQCR's as defined in Chapter II. Considering the Gulf Coast region as a whole, estimated worst-case emissions for the new salt dome facility would be less than 0.3 percent of total emissions estimated for 1972. For multiple facilities in a single AQCR, the likely maximum emissions should not exceed 0.75 percent of total hydrocarbon emissions. On the other hand, the emissions resulting from the implementation of storage (unloading only) in the existing dome facility would amount to only 0.1 percent of 1973 emissions in AQCR 106. Furthermore, during loading (withdrawal) triggered by an interruption of imported oil, any emissions that would occur would be in lieu of and traded-off by those emissions which would normally occur as a result of crude oil handling in the area.

The impact on ambient air quality of these HC emissions must be determined at the site-specific level. EPA has acknowledged that no accurate mathematical model exists for predicting the impact of reactive pollutant emissions from a single source, viz hydrocarbon evaporation from tanker unloading (39 FR 42510). However, if the emissions are assumed nonreactive, mathematical dispersion modeling will yield an estimate of ambient hydrocarbon concentrations. As described in the technical support document (RA-223), a short-term model is employed to estimate 3-hour, worst-case, ambient HC concentrations. The worst-case hourly emissions would result from loading two marine tankers, each at the rate of 10,000 BBLS/hr. Hydrocarbon emissions would be approximately 440 lbs/hr. The maximum downwind ambient concentration under worst-case dispersion conditions would be over 10,000 $\mu g/m^3$ (3-hour average). This would be a substantial temporary violation of the 160 $\mu g/m^3$ standard (see V.B.4.) The estimated concentrations (and therefore impact) could be reduced by (1) reducing the loading rate of petroleum, (2) performing operations during periods least favorable for ozone formation, and (3) use of vapor recovery control equipment. Refer to Section VI.A.5. for a more detailed discussion of these mitigating measures and of current perceptions as to the relationship between hydrocarbon emissions and pertinent regulations requirements.

Normal operations during storage will contribute very minor amounts of hydrocarbon air emissions as a result of pump seal leaks. It is estimated that annual fugitive hydrocarbon emissions would total less than .1 ton per year from pumps, valves, and fittings at the site of either the example 200 MMB new salt dome facility or the 90 MMB existing facility (see Table V-3 and RA-223). The impact of these hydrocarbon emissions will be negligible. For offshore salt domes, the on-site production of power will contribute combustion product emissions from the diesel generator used. The impact of these emissions on air quality will also be negligible.

TABLE V-3

COMPARISON OF FUGITIVE HYDROCARBON EMISSIONS FROM

TWO EXAMPLE SALT DOME FACILITIES TO AQCR EMISSIONS FROM ALL SOURCES

EXAMPLE SALT DOME FACILITIES	SALT DOME SITE EMISSIONS	TANKER EMISSIONS UNLOADING	TANKER EMISSIONS LOADING	TOTAL*
New 200 MMB	<1 ton per year	2,200 tons/year	3,400	5,600
Existing 90 MMB	<1	990	1,530	2,520

AQCR NO.	NAME	1973 ANNUAL HYDROCARBON EMISSIONS**
106	S. Louisiana, SE Texas	941,473 tons
214	Corpus Christi	225,389
216	Houston-Galveston	608,376
	GULF COAST REGION TOTAL	1,775,238

*Based on a hypothetical conservative annual cycle, consisting of tanker unloading and filling of the facilities over a 6-month period and loading the stored oil in tankers over a 5-month period.

**Based on an incomplete inventory of hydrocarbon sources.

The possibility of a catastrophic accident, such as an accidental break in an aboveground pipeline must also be considered. If during static operation an entire wellhead were sheared off, it is estimated that no more than 100 barrels of oil would escape the cavity because the downhole pressure exerted by the water column would equalize the oil column pressure. Some amount of hydrocarbons from the spill would evaporate to the air. The air quality impact of this occurrence would be short-term and minor.

As with salt domes, salt mine construction activities will generate some fugitive dust. Hydrocarbon emissions from the mines will either be flared and the vent subsequently sealed, or run through a condensing system and returned to the mine. Thus, no appreciable air quality impact is anticipated. Evaporative hydrocarbon emissions from tanker unloading and loading would be similar to those presented in Table V-3.

5. Noise

The methodology for predicting human and animal response to noise emissions from construction, fill, and operation of storage facilities is summarized in the paragraphs that follow.

Based upon many laboratory and field studies, quantitative values of noise level can be related to effects, in general, upon people. Some twenty different measures of noise have been developed and are used in practice. A particular measure is generally adopted to satisfy the specific objectives of a noise evaluation program.

For evaluation of the impact of environmental noise, criteria documented by the Environmental Protection Agency in "Information on Levels of Noise Requisite to Protect Public

Health and Welfare with an Adequate Margin of Safety" were used as a basis for estimating the effect of noise from construction, fill, and operation of storage facilities (EN-108). In development of the criteria, EPA did not make a distinction between health and welfare but defined health as the World Health Organization does: "a total physical, physiological, and psychological well-being of the individual." Therefore, spoken communication, sleep disturbance, hearing hazards, etc., all fall into the area of health and welfare.

To quantitatively measure the impact of noise, EPA recommends the use of a measure, L_{dn}, the long-term equivalent A-weighted sound level (a single value measure that approximates sound as processed by the human ear) with an adjustment to account for differences in response during daytime and nighttime periods. Mathematically, L_{dn} is expressed as

$$L_{dn} = 10 \log \frac{1}{24} \left[15 \left(10^{(L_d/10)} \right) + 9 \left(10^{(L_n + 10/10)} \right) \right] \text{ dB}$$

where

$L_d = L_{eq}$ for daytime (0700 hours to 2200 hours)

$L_n = L_{eq}$ for nighttime (2200 hours to 0700 hours)

which essentially states that a 10 dB penalty is applied for nighttime operations. For the purposes of this program, it may be assumed that L_{eq} is measured or predicted sound level approximated by a normal distribution having a standard deviation equal to zero and that these sound levels are those that are exceeded 50% of the time. As such, measured or predicted levels can be considered to be equal to L_{eq} (EN-108).

Table V-4 summarizes noise level limits in terms of L_{dn} and L_{eq} considered essential to protect public welfare and safety. Note that L_{dn} = 55 dB and L_{eq} = 55 dB are values that are representative of outdoor areas that will likely be impacted by development of storage facilities. This table serves as the basis for general assessment of environmental noise as required by this program. Further refinement of these guidelines can be achieved by considering the factors discussed below.

TABLE V-4

SOUND LEVELS REQUIRED TO PROTECT PUBLIC HEALTH AND WELFARE

EFFECT	LEVEL	AREA
Hearing Loss	$L_{eq(24)} \leq 70$ dB	*All Areas*
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	Outdoor and residential areas, farms and other outdoor areas where people spend widely varying amounts of time, and other places in which quiet is a basis for use
	$L_{eq(24)} \leq 55$ dB	Outdoor areas where people spend limited amounts of time such as school playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas.
	$L_{eq(24)} \leq 45$ dB	Other indoor areas with human activities such as schools, etc.

Source: EN-108

The ability to communicate effectively depends upon the presence and level of ambient or "masking" noise. The values of Table V-5 illustrate the person-to-person separation that will permit 95% speech intelligibility in the presence of different A-weight sound levels (dBA) and vocal efforts. The data are representative of male voices with individuals face-to-face outdoors.

TABLE V-5

MAXIMUM A-WEIGHTED SOUND LEVELS THAT WILL PERMIT ACCEPTABLE SPOKEN COMMUNICATION FOR VOICE LEVELS AND LISTENER DISTANCES SHOWN

DISTANCE (feet)	AMBIENT SOUND LEVEL IN dBA Vocal Effort: Low	Normal	Raised	Very Loud
1	60	66	72	78
2	54	60	66	72
3	50	56	62	68
4	48	54	60	66
5	46	52	58	64
6	44	50	56	62
12	38	44	50	56

Additional evaluation may be made by considering the effect of noise upon communication by telephone. The quality of telephone usage in the presence of a steady-state masking noise may be obtained from Table V-6.

TABLE V-6

QUALITY OF TELEPHONE USAGE IN THE PRESENCE OF STEADY-STATE MASKING NOISES

NOISE LEVEL (dBA)	TELEPHONE USAGE
30-50	Satisfactory
50-65	Slightly Difficult
65-75	Difficult
Above 75	Unsatisfactory

The change in ambient sound level is an important factor in assessing the impact from added noise sources. It is possible to just detect a 2-3 dBA change while a 5 dBA is readily apparent. A 10-decibel increase is judged by most people as a doubling of the loudness of sound and each 10-decibel increase impresses a listener as doubling the loudness.

The effects of noise upon wildlife and domestic animals are not well understood. Studies of animals subjected to varying noise exposures in laboratories have demonstrated physiological and behavioral changes, and it may be assumed that these reactions are applicable to wildlife. However, no scientific evidence currently correlates the two. It is known that large animals adapt quite readily to high sound levels. Conversely, it has been demonstrated that loud noise disrupts brooding in poultry and consequently can affect egg production.

The major effect of noise on wildlife is related to the use of auditory signals. Acoustic signals are important for survival in some wildlife species. Probably the most important effect is related to the prey-predator situation. An animal that relies on its ears to locate prey and an animal that relies on its ears to detect predators are both impaired by intruding noise.

In addition, the reception of auditory mating signals could be limited and therefore affect reproduction. Distress or warning signals from mother animals to infants (or vice versa) or within groups of social animals could be masked and possibly lead to increased mortality. There are clues that short-term high noise levels may startle wild game birds and stop the brooding cycle for an entire season (ME-050).

These effects are only qualitative and as such, comprise criteria that will be used as guidance only.

In this study, noise levels were predicted using a simple model that incorporates information on ambient air and topographic conditions and the properties of energy dispersion in air media under these conditions. The results of this model predict energy levels at selected distances from single or multiple sources.

Results will be presented in simple terms, based on the measure L_{dn}. Figure V-8 illustrates the basis for general assessment for expected community response to various levels of noise.

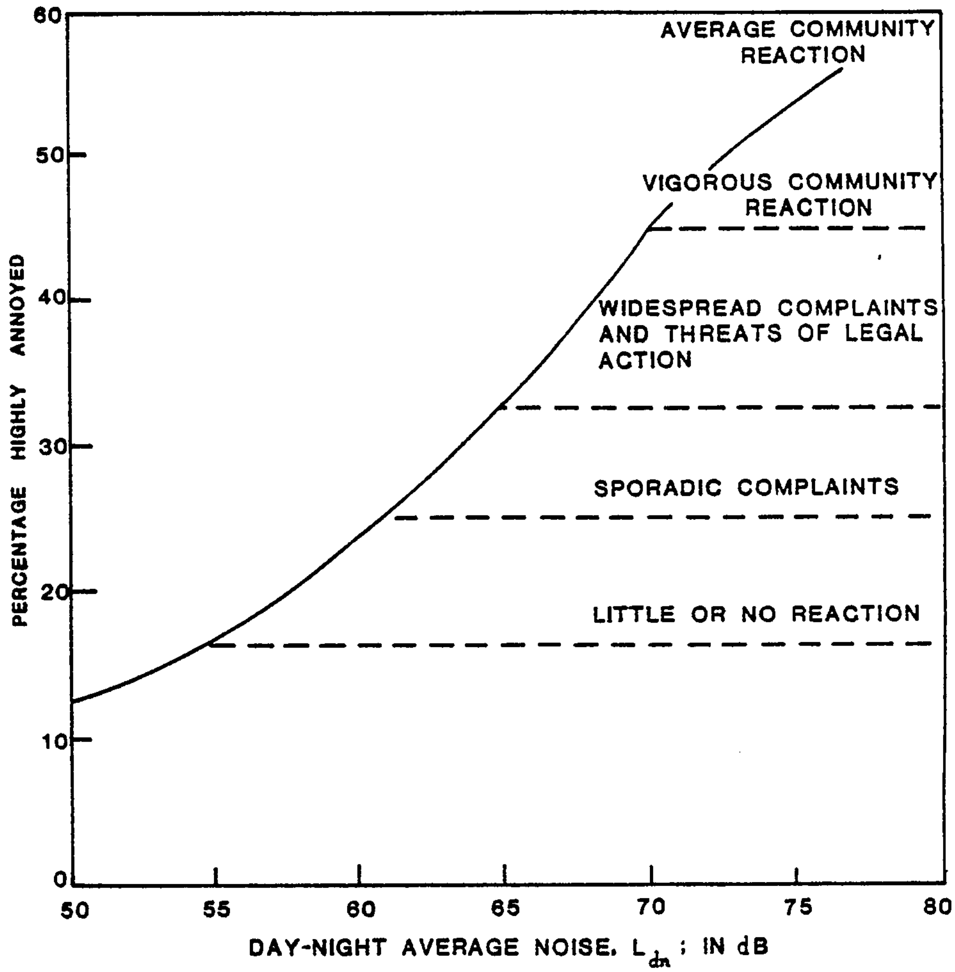


FIGURE V-8

EXPECTED COMMUNITY RESPONSE
TO VARIOUS LEVELS OF NOISE

Source: EN-108

Equipment required for evacuation of salt domes consists primarily of drilling rigs, vehicles, pumps, and ancillary support machinery. Operation of these equipment generate noise of sufficient levels to be a source of concern some distance from the rig site.

a. Drilling

A gross estimation of noise emitted from a single drilling activity was obtained using standard acoustical field equations. Uniform noise radiation, absence of physical barriers, and a standard day were assumed in the prediction. Additionally, the following sound spectrum level at fifty feet from the drilling operation was used:

TABLE V-7

SOUND PRESSURE LEVEL (dB) AT 50 FEET FROM DRILLING

Frequency - Hz								
63	125	250	500	1000	2000	4000	8000	Hz
77	77	83	80	77	73	77	72	dB

Computations revealed the following:

Distance from Rig (Feet)	Predicted L_{dn} (dB)
500	63
1000	58
1500	54
2000	51
2500	48

When compared to Figure V-8, it may be concluded that at distances up to 1,000 feet, sporadic complaints about noise may be expected and 25% of the population experiencing the noise will be highly annoyed. The computations, as with aboveground tankage, provide only grossly approximate answers but do indicate that noise could be a source of environmental concern during the drilling operations. These estimates did not take into account impulsive noises associated with rig operation. Such noises aggravate the problem when considering human response.

b. Evacuation

Evacuation of salt domes requires motors, pumps, and pipelines. To estimate levels of radiated noise from a pumping field, it was assumed that sixteen pumps for salt caverns and six pumps for mines were driven by 500-horsepower electric motors and all were operated continuously. Of the two, electric motors will dominate the noise field and will radiate levels approximately as follows:

TABLE V-8

SOUND PRESSURE LEVEL (dB) AT 50 FEET FROM MOTORS

	Frequency - Hz							
	63	125	250	500	1000	2000	4000	8000
Single motor	86	86	86	86	84	81	77	63
Six motors	93	93	93	93	91	88	84	70
Sixteen motors	99	99	99	99	97	94	90	76

Source: TR-063

From the center of the pumping field, noise levels were computed as follows:

DISTANCE FROM CENTER OF PUMPING FIELD (FT)	PREDICTED L_{dn} (dB) CAVERNS	MINES
1000	76	72
2000	68	64
3000	62	58
4000	57	53
5000	53	49

The predicted values indicate that acoustically untreated pumping equipment, for both caverns and mines, could create significant adverse reactions from residents living within 3,500 feet of the pumping field. As before, these estimates simply indicate that problems with noise could be expected.

c. Pipeline Construction

Pipeline construction machinery exhibits high noise levels and is a source of concern in the proximity of activity. However, because it will be operational only for a short period of time within a local area, adverse reaction is not expected to be a serious problem.

d. Operations

Assuming that motors and pumps used in evacuation of salt domes will be employed during the operations stage, noise levels can be expected to be on the order of those predicted in the evacuation section. Based upon the previous assumptions, noise from operations could be a problem if inhabited areas are located within about 3500 feet of the storage field for caverns and 2500 feet for mines.

6. Biology

The methodology used to assess the impacts of the proposed program is quite basic. The recognizable biologic assemblages, "biotopes" (OP-018), of the study areas are ascertained. These biotopes can be discussed as units of the environment with the inherent characteristics of a certain composition of species of organisms, a certain range of primary productivity, certain physical and chemical conditions, and general vulnerability to various types of disturbances. The species of organisms associated with each biotope have inherent tolerances and preferences for all of their ecological variables (i.e., food type, salinity, bottom type, shelter, etc.). Once the biotopes, their general coverage of the region, and the major species of each have been ascertained, the impacts may be assessed in terms of changes within or between biotopes. Since each biotope is a part of the surrounding ecosystem which is in a state of dynamic equilibrium, changes in one part of the biotope may affect other biotopes and finally the entire system. It is up to the biologist making the assessment to discern the amount of change to each biotope and its effects upon the system as a whole. This may be stated in terms of changes in productivity, fish catch, amount of a certain biotope, species abundance or species composition. These changes are the biological impacts of the program which must be evaluated against the other factors involved to arrive at the total impact of the program.

The Strategic Petroleum Reserve program will have various effects on the biota of the Gulf Coast region. Table IV-6 presented the environmental assemblages of the region. Their "vulnerability to disturbance" is presented in the matrix of Table V-9 for ease in discussing the relative effects of various types of disturbances resulting from the use of salt domes in the Gulf Coast region for storage of petroleum. The scale from zero to five represents the vulnerability of the biotope to the type of activity, with zero being the least vulnerable.

At the programmatic level, the biological impacts must be discussed on a rather hypothetical level. The biota of the area around the salt domes may vary considerably, especially since some domes are inland, some are in wetlands, and some are offshore. No matter which domes or which kinds of

TABLE V-9

THE IMPACT OF MAN'S ACTIVITIES ON THE COASTAL BIOTOPES

COASTAL ZONE ACTIVITIES / BIOTOPES	1. Open Beach and Shelf	2. Dune and Barrier Flat	3. Spoil Bank	4. Jetty and Bulkhead	5. Oyster Reef	6. Thalassia (grass flat)	7. Spartina (salt water marsh)	8. Juncus (fresh water marsh)	9. Mud Flat	10. Sand Flat	11. Blue-green Algal Flat	12. Hypersaline	13. River Mouth	14. Bay Planktonic	15. Channel	16. Prairie Grassland	17. Upland Deciduous Forest	18. River Floodplain Forest
1. Liquid waste disposal	4	3	3	4	5	5	5	5	4	4	4	5	5	5	5	0	1	3
2. Gaseous waste disposal	1	0	0	3	1	3	0	5	0	0	0	4	5	4	4	0	0	0
3. Solid waste disposal	0	4	3	0	4	2	5	5	2	2	1	4	5	2	0	4	5	5
4. Offshore construction	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Coastal Construction	2	5	0	0	1	1	4	4	3	3	2	1	0	2	0	0	0	2
6. Inland construction	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	4	4
7. Land canals	1	0	0	0	4	0	4	0	3	3	0	0	0	0	0	4	0	5
8. Offshore channels	1	0	0	3	5	5	4	4	3	4	2	2	3	4	4	0	0	0
9. Dredging and spoil disposal	4	0	5	5	5	5	5	5	5	4	3	5	4	5	1	0	0	1
10. Excavation	0	5	0	0	5	3	4	3	5	2	2	1	1	0	0	2	1	2
11. Drainage	0	0	0	0	0	0	4	5	2	1	2	2	3	0	0	3	0	1
12. Filling	0	0	0	0	4	4	5	5	3	3	3	4	3	0	0	1	1	1
13. Draining	0	0	0	0	4	0	5	5	4	1	2	2	3	0	0	0	0	0
14. Well development	2	3	4	1	4	1	1	1	1	1	1	3	1	1	1	3	1	1
15. Devegetation	0	5	4	0	0	2	5	5	1	1	1	0	0	0	0	5	5	5
16. Traversing with vehicles	0	5	4	0	0	0	1	2	0	0	0	0	0	0	0	4	1	0
17. Use of Fertilizers & Pesticides	0	5	4	2	5	5	5	5	0	1	3	4	4	5	5	4	4	4

Source: OP-018

facility (solution cavities or mines) are used, there will be biological impacts from both construction and operation.

During construction, all onshore facilities will potentially be subject to the impacts of pipeline laying, road building and dredging. In addition, the construction of both new and existing solution cavity facilities may involve well drilling. New cavity construction will also involve brine disposal and may involve barge and ship traffic. Accidental oil spills may occur if construction and filling are simultaneous.

Due to the time required to create new cavities in salt domes and fill them with crude oil (approximately four years), the effects of construction will be of considerable duration. This will mean a continued disturbance to the biota of the area for the entire construction period. The conversion of existing solution cavities will require substantially less time (one to two years), principally because that portion of the construction phase associated only with the leaching of new cavities will not be needed. This would result in substantially lower brine-related impacts. The conversion of existing salt mines will impact the biological environment at an even lower level than conversion of existing solution cavities. Although the construction times are comparable, must less land will be required (a few tens of acres) resulting in a smaller area of biological impact. Also, there will be no drilling or brine-related impacts.

The operational stage for both types of salt dome storage, after all construction is completed, will be relatively free of biological disturbances with the exception of ship or barge traffic, accidental spills of crude oil and in the case of solution cavities, water intake and brine discharge.

a. Construction Effects

Since the construction impacts associated with new solution cavities are potentially much greater than those of existing solution cavities or mines, the effects of new cavity construction are addressed as a "worst case" analysis for the available Gulf Coast region storage options.

The impact of constructing new solution-mined salt dome storage facilities will occur for slightly more than four years. Each inland site will necessitate fencing and surface construction of roads, pipelines, and well drilling over most of the entire 260-acre site. This may include dredging and filling operations in wetland areas. All construction will have noise (drilling rigs, road construction machinery, etc.) and general human disturbance. This will generally cause all larger animals to avoid the construction area by various distances. Some animals such as raccoons, skunks, and oppossum seem relatively undisturbed by such activities. Deer, foxes, red wolves, bobcats, turkey, and bald eagles, however, are sensitive to disturbances within their range. Eagles will very often abandon their nests, which they generally use every year, if human activity encroaches within a mile or so of the nesting site. Most of the others will avoid the construction zone and seek new ranges if there are any suitable habitats available nearby. If suitable habitat is not present, or if resident populations have saturated the area's carrying capacity, populations will decline accordingly or individuals will be smaller and less healthy. This impact will not severely damage the Gulf Coast region as a whole unless developments are in the best wetland-estuarine nursery area in a particular coastal area or in the vicinity of endangered species. This may destroy enough of a biotope to cause a noticeable decline in a certain species or in the fin and shell fisheries of the immediate area.

Siltation of streams or estuarine waters caused by runoff from the site and dredging may cause decreases in oyster and clam populations and grass beds if not properly controlled. This could lead to locally-diminished fisheries if undertaken at the time of year when migrations may be taking place.

Brine disposal from the construction of the salt dome cavities will create a minor disturbance in the Gulf of Mexico immediately surrounding the diffuser. Figures V-4 through V-7 illustrate the areal extent of salinity changes out to .25 ppt above ambient under varying conditions. The hypothetical "worst cases" would be Figures V-4 and V-5. More plausable cases are represented by Figures V-6 and V-7. Table V-1 shows the areal extent of the various salinity isopleths in acres for each case. As can be seen, the maximum area affected (to the .5 ppt isopleth) is 3,157 acres. The maximum area covered by water with a 1 ppt increase is 1030 acres. The increases in salinity over ambient conditions, which may range from 10 to 35 ppt in the coastal area, may be compared to: Table V-10, for salinity information concerning the major Gulf of Mexico sport and commercially important organisms; Table V-11 for the upper tolerance or recorded occurrence (the salinity at which they have been collected) of those organisms in the computer data bank whose recorded upper limits of tolerance or occurrence is less than 35 ppt; and Tables III-1 through III-5, in Part I of the Ancillary Supporting Document of the EIS, which list the actual recorded salinity tolerances and recorded occurrences of many of the marine and estuarine organisms of the shelf area of the Gulf of Mexico. It is readily concluded that the vast majority of animals that might occur near the diffuser have salinity ranges well above 35 ppt. Most have an upper limit above 40 ppt and some can tolerate as high as 70 ppt salinity. The few organisms listed whose upper salinity tolerance limit or recorded occurrence is below 35 ppt are either brackish water species that exist in

TABLE V-10

SALINITY-TEMPERATURE LIMITS FOR SELECTED MARINE SPECIES IN THE GULF COAST

Species Adult	Salinity: Range Observed (o/oo)		Salinity: "Optimum" or Preferred Range (o/oo)		Temperature: Range Observed (°C)		Temperature: "Optimum" or Preferred Range (°C)		Temperature: Lethal Under Certain Conditions (°C)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Pink shrimp	00.6	60.0	20.0		10.8	35.5	18.0	26.0		
White shrimp	00.1	57.0			9.0	36.0			4.0	
Stripped mullet	00.0	75.0			10.7	34.5				
Southern flounder	02.0	60.0	25.0		9.9	30.5				
Black drum	02.6	75.0	15.0	20.0	3.0	35.0	16.0	25.0		
Atlantic croaker	02.0	70.0			3.0	35.0			3.3	
Sand seatrout	04.8	45.0	15.0	25.0	13.7	36.7				
Spotted seatrout	02.3	75.0	30.0		4.0	34.9				45
Red drum	02.1	50.0	10.0	35.0	8.0	44.0	11.0	40.0		
Blue crab	02.8	60.0			10.0	34.0				
Gulf menhaden	00.5	60.0			9.1	31.6				

Source: Derived from OP-023

TABLE V-11

ORGANISMS WITH UPPER SALINITY

LIMITS OF OCCURRENCE OR TOLERANCE LESS THAN 35 ppt

(Adult Unless Noted)

Scientific Name	Common Name	Salinity ppt
Adenia xenica	Diamond Killifish	30.5
Callinectes sapidus	Blue Crab (eggs) (tol.)	32.0
Evorthodus lyricus	Lyre Goby	31.7
Gobiesox strumosus	Skilletfish	20.7
Gobionellus belosoma	Darter Goby	30.0
Gobionellus hastatus	Sharptail Goby	24.6
Hemicaranz amblyrhynchus	Bluntnosed Jack (juvenile)	24.3
Leptophrys trigonus	Trunkfish	18.6
Lutjanus griseus	Gray Snapper	16.1
Sygnathus elucens	Shortfin Pipefish	29.4

Source: OP-023

stuarine areas or truely marine organisms
ded only a few times and those few collections
less than 35 ppt salinity. Since the various
ar shore Gulf of Mexico vary as much as 2 ppt,
t even sessile benthic organisms would be in-
ity changes in the 0.5 to 2.0 ppt range. The
ect minor salinity changes and minor changes in
ity parameters such as temperature, calcium and
ntration, etc. however, it is doubtful if changes
n the brine disposal will be of significant magni-
large scale changes in the disposal area.

e existence of natural brine pools or discharges has
en discovered, by Drs. Bright and Presely of Texas A&M
, in two areas of the Gulf of Mexico off the Texas and
coasts. These are located off the Mississipppi River
near the East Flower Garden Bank off Galveston, Texas.
as are in several hundred to several thousand feet of
d appear to have sources of brine which keep the salinity
her than the surrounding Gulf waters. These areas are
ly under study and are mentioned here to demonstrate that
scharge of brine into the waters of the Gulf Coast continen-
helf is not a totally new phenomenon. However, in low-energy
ronments such as those where the brine pools in depressions,
flora and fauna are drastically different. The only organism
n in the Flower Garden Bank pool so far has been an alga (BR-353).
ese observations emphasize the importance of mixing brine with
mbient water in the design of diffusers in order to avoid drastic
changes in the flora and fauna, and of siting diffusers away from
the many fishing "holes" known on the near-shore shelf area of the
Gulf.

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The area offshore from the mouth of the Mississippi River and its extensive tidal marshes may have salinities much lower than 35 ppt in areas where outfalls could be located. This area of decreased salinity probably varies in size with fresh-water inflow to adjacent parts of the Gulf, especially from the Mississippi River and its distributary streams. A salinity gradient therefore exists in many offshore areas. The modeled results, in terms of excess salinity, are virtually identical whether 35 ppt, 10 ppt, or an intermediate ambient water salinity is used as initial conditions in the model. Thus, the possible differential effects on biota from discharging brine to lower salinity waters rests in the species that may be affected.

Lower salinity waters will allow some estuarine species to venture out into the Gulf, away from their normal marsh or bay habitats. However, due to the fluctuations in salinity caused by changes in fresh-water inflow, these species in all probability venture into this area only sporadically, to feed or escape predators. Their natural habitats are the inshore bays and marshes which have much higher primary productivity and therefore a more available food supply. The propagation of largely estuarine biota and of biota that spend a critical part of their life cycle in such areas depends heavily upon the proper salinities in the marshes and bays (BA-482). Conversely, changes in the salinity of offshore waters may also ultimately affect the high productivity of the coastal wetlands if such changes occur in offshore areas where partially estuarine species migrate or venture. The fact that extensive offshore areas, particularly along the Louisiana coast, have lower salinity suggests that any brine disposal outfalls in such areas must be sited with extreme care and only after careful site-specific assessments of potential impacts on estuarine ecosystems. These site-specific factors will be evaluated in detail in the EIS's for any of the individual sites proposing to use ocean outfalls.

Since the continental shelf area of the Gulf of Mexico supports a very large shrimp population with a multimillion dollar a year industry based primarily upon the Brown and White shrimp, any change in the bottom fauna and flora upon which the shrimp feed will affect the entire shrimp fishery. Assuming that large scale pooling of the brine does not occur, as the modeling data indicate. it will not, and assuming that the outfall diffusers avoid biologically sensitive areas, the short-term impact of a maximum of about 3,000 acres of bottom surface affected by a rise of 1.0 ppt salinity on the benthic populations and upper food chain organisms should not significantly alter the Gulf of Mexico shrimp and fish populations.

The placement of the diffuser 5 feet above the bottom in about 50 feet of water, 5 miles off shore will obviate any possibility that the saline plume will reach shore with a detectable rise in concentration. This will also place the affected area out of most migration routes for organisms moving parallel to and near the shoreline.

Current water intake structure design practices enable construction of an intake that will preclude impingement of most aquatic animals on the intake screens. Small planktonic organisms will be entrained and can pass through the pumps. They will die when the water becomes nearly saturated with salt from the solution cavity. This will not cause undue biological damage if the intake is placed in an area of low biological productivity where few larvae and eggs and low concentrations of zooplankton and phytoplankton may be found.

There is an increased possibility of spills of various types. These are discussed in the next section (Operational Effects) and Section V.D. (Oil Spills).

Pipeline construction may have a considerable impact if pipelines pass through wetlands, breeding grounds or areas which contain endangered species. The effect will be minimal and of short duration if the pipelines are routed around these areas and good pipeline construction practices are used such as the "push" method (MC-251). These effects will be evaluated in more detail in individual site EIS's after exact pipeline alignments and methods have been selected.

b. Operational Effects

The impacts on the biology of the area in and surrounding the salt dome storage site from long-term operation of the facility are less than those of the construction period in general. These impacts are usually of longer duration than construction impacts. The loss of the use of the area by animals and the primary productivity of the plants in the case of a marsh area or grass flat is a long-term effect. The area will not totally recover unless the site is restored as it was prior to construction. Some animals will use the site after the initial disburbance of construction is over. These may not be the same species as those prior to construction. The site will probably be suited only for those species of small animals and birds that do well in close association with man. Many migratory birds and game animals dependent upon the specific cover type removed from the site will probably not use the site, even if they did previously. The long-term effects on offshore sites will be minimal and may be beneficial if typical oil rig communities populate the underwater structures. These increase the diversity of the area by permitting more habitats and increasing the types of food available.

Barge and ship traffic will increase during filling and emptying cycles. These will cause some turbidity of the water and erosion of shorelines in small canals and channels. Unless the site is in a remote area where there are no disturbances of this type, there will be little change in the biota.

Brine disposal from cycling will cause no more impact than will the disposal of brine from the solution-mining because the layer of brine in proximity with the crude oil will not be discharged, thus preventing the discharge of any suspended oil or water-soluble toxic fractions from oil. Oil sensors will be designed into the disposal line which will automatically shut down the system in the event oil appears in the brine.

Petroleum spills are a distinct probability when dealing with such large quantities of crude oil and petroleum products in so many vessels and pipelines. There have been many case studies of spills of various types of oil and products in various coastal biotopes. These have all been reviewed and will only be mentioned where directly applicable to this section on biological impacts. A detailed explanation of the various aspects of oil spills is included in Section V.D.

Basically, the effects on the biota of a single spill of large magnitude include coating of the water surface, plants, birds, and soils, thereby interfering with oxygen transport and availability; the toxicity of some products and "dirty crude;" and deposition of oil in the sediments where it may penetrate to 70 cm and release toxins for quite some time. Much of the information on the effects of oil spills emphasizes the variability of each biotope's response to a spill. The worst place for an acute spill is very close to shore or in a major estuarine area surrounded by very productive wetlands. While most wetlands studied have been observed to recover rapidly from a single, acute oiling, chronic exposure of animals and plants to petroleum in small to medium quantities is usually very damaging. Wetlands cannot function with a chronic coating of oil. Animals can live but are unfit for human consumption due to the "oily" taste.

7. Historical and Archaeological Resources

Guidelines for evaluating the environmental impact of the proposed program on the archaeological and historical resources of the Gulf Coast are the "Criteria of Effect" which have been established for National Register properties or properties eligible for inclusion therein by the Advisory Council on Historic Preservation. An undertaking will be considered to have an effect on a property when a change, beneficial or adverse, in the quality of the historical, architectural, archaeological, or cultural character that qualifies the property for inclusion in the National Register is caused by the undertaking (AD-029).

Once an effect has been established, the "Criteria of Adverse Effect," also established by the Advisory Council on Historic Preservation, must be applied. These criteria are as follows:

> Generally, adverse effects occur under conditions which include but are not limited to:
>
> a) destruction or alteration of all or part of a property;
>
> b) isolation from or alteration of its surrounding environment;
>
> c) introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting;

d) transfer or sale of a federally-owned property without adequate conditions or restrictions regarding preservation, maintenance, or use; and

e) neglect of a property resulting in its deterioration or destruction (AD-029).

In applying the "Criteria of Effect" the limits of the historical or archaeological properties as well as their surrounding environment should be considered. The limits of a property can be established from the boundaries given in the National Register. The surrounding environment should be determined on a case-by-case basis in consultation with the appropriate state historic preservation officer.

The potential adverse impact of salt dome and mine storage on historical and archaeological resources is summarized below in terms of both the construction and operation of these storage facilities.

Construction or excavation for surface buildings or equipment, roads, pipelines or pipeline tie-ins could result in physical alteration or damage of any historical or archaeological resources within the construction area. The presence of roads, surface buildings, and/or equipment could also result in the alteration of the esthetic atmosphere by introducing elements which are out of character with the site.

It is anticipated that no subsidiary industrial development will occur as a result of the operation of the proposed storage facilities. Such changes in land use often have an adverse effect by causing isolation from or alteration of the surrounding environment of an archaeological or historic property.

For the ESR, less construction activity will be required than for the total program and consequently less risk of damage to archaeological and historical resources is expected.

8. Land Use

a. Effects of Sites on Surrounding Land Use

The proposed solution-mined salt dome storage cavities and the necessary surface facilities for one 200 MMB site would utilize a land surface area of 260 acres maximum. Existing salt mine storage will require a much smaller area, on the order of fifty acres per site. Impacts associated with construction and operation of these facilities are considered to be minor. The most significant of these impacts during the construction phase will be the use of existing roads for construction of new roads for movement of equipment to and from the site and construction of any new pipelines necessary to "tie in" the storage facility with existing transportation systems.

The study region as defined by this report contains the major petrochemical production area within the United States; therefore, it is anticipated that the addition of drilling equipment, personnel, wellheads and additional pipelines will not cause a major impact on land uses surrounding the sites.

Construction and operation of the facilities will preclude other uses of the enclosed lands. The majority of domes are located in rural settings. Therefore, it is anticipated that in the vast majority of cases the surface character of the dome surface enclosure will remain very similar to its preconversion uses. Essentially, there will be a wellhead per nine acres with connecting roads, pipeline row, and a small pump station, all enclosed by a fence.

Solid Waste

Solid waste production from a solution mining process is similar to the waste generated from conventional well drilling activities. The only significant solid waste generated will be chemical mud, laden with hole cuttings which result from the drilling operations. This waste, as with those in oil field development, generally is disposed of by landfilling. Acceptable waste disposal methods will be dictated by the agency authorizing the particular solution-mining activity.

Solid waste may also be generated by the construction crews that install the wellheads and place the various pipeline facilities. This waste will include such articles as discarded machine parts, steel cables, metal containers, engine parts, etc. Construction contractors are generally required to remove such debris before completion of their work.

b. Site Uses

The surface uses of the selected salt dome sites are anticipated to be limited to the construction and operation activities related to a particular dome. It is anticipated that future compatible engineering activities might be generated on site but that other land use activities, such as housing, etc., would be limited to outside the boundary lines.

c. Land Use Planning

It is anticipated that most, if not all, selected sites will be in rural locations. The construction and operation of the salt dome storage facilities will have a very slight effect on land use planning. Within this region there is essentially no planning outside built-up areas; therefore, there will be little, if any, effect on existing land use planning. There will be some effect on future land use planning in terms of land use and zoning adjacent to the sites and the connector pipelines. Historically, within this region, planning officials have recommended that a safety corridor be left on either side of pipelines; in most cases the existing right-of-way will suffice. Once the corridor is established, the normal planning process occurs. Future land uses adjacent to the site will possibly have a tendency to be zoned commercial or industrial due in part to possible future developments that may occur near the sites themselves.

d. Recreation

The potential negative impact on recreational opportunities because of activity from the SPR program would appear to be minimal. There will be construction activity related to the salt domes and pipeline construction that will have some effect on natural habitat reserves in the coastal area. Also, proper disposal of brine can be accomplished so as not to affect adversely vegetation that supports wildlife and marine life. However, unless a catastrophic disaster occurred that caused the release of a large quantity of crude petroleum to force a direct and significant impact on natural habitat, normal events associated with the SPR program will not affect recreational opportunities in the Gulf Coastal area. Also, there should not be a significant increase in the utilization of recreational areas and facilities since the number of people involved will be very low.

9. Economic and Social Impacts

The potential economic and social impacts associated with the modes of storage considered for the Gulf Coast will all be relatively minor. Some variation is expected, however, depending on the size and type of the individual facilities. It must be emphasized that the construction and operational costs, which form the basis for the economic impact analyses given below, are the result of preliminary feasibility studies and therefore are at best only rough approximations of the actual costs which will be incurred. The actual costs for a particular facility will be very sensitive to site-specific factors.

a. <u>Salt Domes</u>

The construction and operation of oil storage facilities in solution-mined salt domes in the Gulf Coast region will have minimal socioeconomic impacts on the region. The short-term impacts associated with the construction period of one to two years for conversion of existing cavities and three to four years for solution of new cavities will be somewhat larger than similar types of impacts experienced later during operation. The work force associated with construction, as well as the expenses of construction, will be substantially greater than those of the operation and maintenance phase. Direct economic and demographic consequences of both, however, are small.

<u>Economic Impacts</u>

For purposes of this analysis, the region in which salt domes may be used for storage was defined as the Gulf Coastal portions of Texas and Louisiana. To model the impacts of placing storage facilities there, multipliers appropriate to this region were derived, based on the Texas State Input-Output Model, its Houston regional submodel, and the Louisiana State Model. A weighted average of multipliers from the three models was adjusted to reflect differences between salt dome activities and their nearest analogs among the sectors used in the models. The sector used to simulate construction effects was facilities construction, while operation and maintenance were represented by a combination of the mining, refining (storage), and warehousing sectors of the economy. This process tends to sharpen the focus of the analysis in terms of sector interrelationships, but obscures local differences in economic response. The end result is a moderately precise representation of the impact of the particular activity, expressed as a sort of regional average.

In the Early Storage Reserve (ESR) phase of the Strategic Petroleum Reserve (SPR) program, only existing cavities in salt domes which can be converted without substantial effort will be used. In calculating the impact of constructing and operating one such facility, the following assumptions were used.

Storage Capacity	90 million barrels
Construction and Acquisition Cost	$1.00-1.50 per barrel
Construction Employment	75
Construction Time	1-2 years
Operation and Maintenance Employment	25
Operation and Maintenance Cost	$0.0104 per barrel per year

Operation and maintenance employment reflects the maximum number that could conceivably be employed. Depending on operating conditions, actual employment might be lower.

The effects of both construction and operation phases calculated in this manner are presented in Tables V-12 and V-13.

TABLE V-12

IMPACTS OF CONSTRUCTING A STORAGE FACILITY IN AN EXISTING 90 MMB SALT DOME CAVITY

Direct Expenditure	$45.0-135.0 million/yr*
Total Economic Impact ("Gross Regional Product")	$126-378 million/yr
Employment (Number of People)	
Direct	75
Indirect	154
Induced	485
Total	714
Total Increase in Personal Income	$34.2-103.0 million/yr

*Minimum=1.00 x 90/2 years   Maximum-1.50 x 90/1 year

TABLE V-13

IMPACTS OF OPERATING AND MAINTAINING A STORAGE FACILITY IN AN EXISTING 90 MMB SALT DOME CAVITY

Direct Expenditure	$0.937 million/yr
Total Economic Impact ("Gross Regional Product")	$2.34 million/yr
Employment (Number of People)	
Direct	25
Indirect	6
Induced	16
Total	47
Total Increase in Personal Income	$0.633 million/yr

The longer-term SPR program may require the construction of wholly new salt dome storage facilities. The assumptions used in calculating the impact of constructing and operating a totally new facility were:

Storage Capacity	200 million barrels
Construction and Acquisition Cost	$1.26-1.56 per barrel
Construction Employment	150
Construction Time	3-5 years
Operation and Maintenance Employment	25
Operation and Mainte- Cost	$0.00375 per barrel per year

Results of the construction impact calculations are presented in Table V-14. Operating and maintaining such a facility require a certain minimal level of effort which is largely unrelated to the size of the facility because of its generally custodial character. Therefore, operation impacts are assumed to be the same for the two facility sizes.

TABLE V-14

IMPACTS OF CONSTRUCTING A NEW 200 MMB SALT DOME STORAGE FACILITY

Direct Expenditure	$50.4-104 million per year*
Total Economic Impact ("Gross Regional Product")	$142-291 million per year
Employment	
Direct	150
Indirect	307
Induced	970
Total	1427
Total Increase in Personal Income	$38.3-79.0 million per year

*Minimum = 1.26 x 200/5 years

Maximum = 1.56 x 200/3 years

The construction-phase impact may be considered as a short-term pulse to the regional economy, being replaced by long-term operational effects. Some of the construction impacts will spread beyond the regional boundaries, mainly depending on where certain supplies are obtained. In the case of salt dome storage facilities, most needed supplies are available within the region; and the bulk of the economic impact may be expected to be retained.

Probably a small percentage (less than one-fourth) of the total employment generated will be in the immediate vicinity of the site (in the same county, for example). The rest will be dispersed, as will be the other impacts of construction, over the region as a whole, extending several hundred miles from the site. To gain a perspective of the magnitude of local impact on employment, we can examine the case of Brazoria County, Texas. Brazoria County has a small population of roughly 120,000 and represents a possible "worst case" as regards the magnitude of impact. The county's 1975 labor force was about 54,000; the total local employment generated by building a storage facility in an existing or new salt cavern in Brazoria County would, therefore, be equal to 0.4 percent and 0.8 percent of the labor force, respectively. Operational employment corresponds to 0.06 percent of the labor force. For purposes of comparison, unemployment has been running about 4 percent to 5 percent. In a more populous, economically-active area, such as Harris County, Texas, which includes Houston, the effect would be even more diluted.

Impacts on Population

The construction of salt dome oil storage capacity in the Texas or Louisiana Gulf Coast area will have a very small impact on the region's population. During the construction phase an average of approximately 150 workers will be required for each 200 MMB facility. Of these workers, only 25-30 must have special skills; they may not be available locally and would have to be brought in from adjacent counties within the region. The other 100-200 workers can probably be hired within the county, thus temporarily reducing some local unemployment. The 90 MMB facilities are expected to employ an average of about 75 workers each, varying with the locality, of which perhaps 12-15 might be specially skilled.

Depending on the location of the dome, some in-migration into the immediate vicinity can be expected to fill some of the unskilled jobs. While a certain amount of localized readjustment may take place within the overall Gulf Coastal region due to minor population shifts, it is unlikely that any measurable in-migration into the region, or significant increase in total population, will occur as a result of construction efforts. The total direct, indirect, and induced employment associated with the project, assuming that there are four existing cavities and one new cavity is constructed, is about 4300, spread throughout the entire Gulf Coast region. It is very likely that all of this theoretical employment increase will be accounted for by the existing labor force.

Local readjustments of population will have little or no impact on local demands for public services and facilities. In view of modern ease of mobility and the relatively close spacing of towns throughout the Gulf Coast region, it is very unlikely that movement would be great enough to exert a measurable influence on any particular community.

Taxes

Tax revenues generated by the construction and operation of salt dome storage facilities will reflect both taxes paid directly as part of the project (e.g., sales and excise taxes) and indirectly because of household income generated (e.g., property and income taxes). The magnitudes of these taxes, as calculated using the regional multipliers, are given in Table V-15.

TABLE V-15

TAXES GENERATED BY A GOVERNMENT-OWNED SALT DOME STORAGE FACILITY

STORAGE FACILITY IN AN EXISTING SALT DOME CAVITY (90 MMB)	
Construction	
Federal	$9.0-10.5 million/year
State	$1.0-1.17 million/year
Local	$.45- .53 million/year
Operation and Maintenance	
Federal	$0.195 million/year
State	$0.020 million/year
Local	$0.012 million/year
STORAGE FACILITY IN A NEW SALT-DOME CAVITY (200 MMB)	
Construction	
Federal	$12.6-26.1 million/year
State	$1.41-2.91 million/year
Local	$ .65-1.35 million/year
Operation and Maintenance	
Same as for storage in an existing cavity	

The taxes shown in the table do not reflect the value of the facility itself and the land associated with it. The manner in which direct property taxes enter the picture depends on whether ownership of the land and facilities rests with the Government or remains in private hands. To examine the impacts on local revenues from both modes of operation, Brazoria County was once again considered, this time because of its low tax rate. Based on a combination of the tax rates themselves and the fraction of assessed or fair market valuation to which they are applied, property owners in Brazoria County pay a total of $1.14 per hundred dollars of actual worth.

For a 90 MMB storage facility with existing cavities, total land requirements are roughly 135 acres, while a new 200 MMB facility could require up to 260 acres. Applying an average county tax rate to a typical land value yields a probable revenue of $1,000 to $3,000 on the site with existing cavities and double that amount for new sites, assuming property is unimproved. If the Federal Government elects to lease the land for a facility, development of that facility could occur in either of two ways. First, the present owners could lease the surface rights to the land, and the rights to the cavity itself, to the government leaving the additional equipment and buildings installed by the government in public ownership. The second option is for the present owners to develop the storage facility at their own expense and lease the entire installation outright to the government. If the first option is chosen, the land owned by the lessor will continue to be taxed at the original rate, subject to future rate changes or increases in assessed valuation. The value of the additional improvements to the site required to turn it into a storage facility will not be taxed, however, as they will not be privately held. There will be no net impact on tax revenues from the property. If the improvements themselves become subject to property tax, however, there can be a very substantial increase in revenues at the local level, depending on how the improvements are assessed. While this determination would be made by a County Assessor on a case-by-case basis, an estimate of the magnitude of the tax revenues which could potentially be generated may be made by assuming a fair market valuation equal to the cost of construction.

Calculated on such a basis, a 90 MMB facility might be taxed at a half-million dollars, and a 200 MMB facility at double that.

If the Federal Government purchases the land outright, it becomes exempt from taxation, lowering total county revenues by that amount, all other factors being equal. In 1972, total tax revenues in Brazoria County, for example, were $27.9 million; thus, the impact of the removal of up to 260 acres in a single parcel would not be significant, even from the relatively low tax base of this county. Furthermore, additional local taxes generated indirectly by the project are expected to exceed these losses by an order of magnitude. Since local taxes are largely property-based, these two opposing tendencies should result in a net overall increase in revenue. Similar lease arrangements to those described for the smaller storage depot could either permit continued taxation of the land on the original basis or result in increased revenues in the neighborhood of one to three million dollars, if the improvements to the site are taxed.

In summary, regardless of ownership of the storage facilities, local tax revenues stand to increase. This increase will be least in the case of complete government ownership, when it will result from that portion of indirect taxes, on income generated by the project, remaining after the loss of the site from the local tax base has been compensated. If the Federal Government retains title to all of the improvements made to the site, while the land and/or the original cavern remain in private ownership, no net increase in tax revenues from the property results, but it remains part of the tax base and the full impact of indirect tax revenue is felt. Finally, if the entire facility is leased and taxed according to its full value, very large increases in local revenues may result, amounting in effect to an indirect federal subsidy. Since the lessor's tax burden is normally passed on to the lessee, these revenues will ultimately come from the Treasury.

Sociological Factors

Safety

The concept of storage of hydrocarbon liquids in salt domes is not new; oil products have been safely stored in United States' salt domes since World War II. In Europe, oil storage capacity in underground caverns already exists and further facilities are currently being constructed in France and Germany. In Stockholm, Sweden, an apartment building is located directly above an operating oil storage cavern which is 320 feet below the surface. Excavation and blasting have been carried out within fifty feet of another underground oil storage facility in Europe. The probability of fire or explosion in a salt dome is minimal because of the lack of oxygen in the cavity. The threat of damage to the facility by natural phenomena is intrinsically low, if placed in a zone of low seismic risk; in a salt dome storage facility, only a few pumps, wellheads, and pipelines are aboveground. For the same reason, the threat of sabotage is very slight.

Many safety features are designed into the storage facility. Devices are installed on the wellhead to prevent cavern overfill. Fail-safe gate valves are located on wellhead openings. Safety switches are also installed to operate valves which secure wellheads and protect against overfill or line breaks. Pressure gauges, valve limit switches, and other warning devices are used to activate alarms to signal operational personnel of safety problems (FE-135).

Esthetics

There will be very little visual impact on the landscape due to the storage of oil in salt domes. During construction there will be several drilling rigs at the site, along with the equipment generally associated with well drilling. Since the salt dome storage region is located in an area with many oil and gas wells, several more drilling rigs on the horizon will not make a noticeable impression. Once the dome is completed, the rigs will be replaced by a few pump houses, wellheads, pipelines, surge tanks for water and product, transformers, and access roads.

Land Use Impacts

The total land requirements of a salt dome storage site are quite small, but depending on its location, acquisition of such a parcel may require relocating the present occupants. In addition to the site itself, it may be necessary to acquire rights-of-way for short pipeline interties with existing distribution systems. The presence of a storage facility will probably not, in and of itself, preclude most residential, commercial, or industrial uses of surrounding lands. In practice, the proximity of the storage depot may render certain kinds of residential development less attractive, but large losses in value of adjacent property are not expected to occur.

Political/Administrative Impact

Because little population movement is expected to result from the employment generated by the program, additional social services will probably not be needed. In the event that all or part of the installation at a particular site becomes taxable, the additional revenues so generated may make it possible to expand the pattern of services and administration already in use.

The impact of placing the facilities, as a local political issue, will probably vary widely between sites chosen, depending on the priorities of the area residents. Providing early and continuing opportunities for public input into the site selection, planning, and environmental evaluation processes will help to decrease the likelihood of strong public opposition.

b. Existing Conventional Salt Mines

Both the amount of storage space available in a converted salt mine and the cost of preparing it can vary widely depending on the nature of the site. Generally, estimated per-barrel construction and operation costs are greatest for small mines and decrease with the volume stored. However, costs of storage in mines also reflect the need to compensate any present owners for the loss of a working mine. This is done by providing for the cost of acquisition, construction, taxes and insurance either on an addition to the existing workings or on a new mine at a different location. These relocation costs would not exist if abandoned mines were used.

Economic Impacts

Conversion of prototype mines for storage involves activities similar to those required to convert salt dome solution cavities. This similarity permitted the use of the same economic impact model and the same multipliers for both the salt dome and mine analysis. The 90 MMB prototype mine facility can be characterized as follows:

Storage Capacity	90 million barrels
Construction and Acquisition Cost	\$.90-1.50 per barrel
Construction Employment	120
Operation and Maintenance Employment	1

Operation and Maintenance Cost	$0.02 per barrel per year

It will be noted that operation and maintenance employment is much smaller in this case than for solution-mined cavities, owing to their relative lack of complexity. This figure does not include security personnel who would increase the total to five or six, still an insignificant number. Based on these assumptions, the impacts on several representative economic parameters were calculated, as shown in Tables V-16 and V-17.

As is the case with salt domes, converting a salt mine for use as a storage facility creates a temporary impact during the construction phase, subsiding to a negligible level during operation. Most of the construction impact stems from the need to purchase materials and services. This leads to an increase in overall "gross regional product," regional employment, and personal income that will probably be concentrated outside the immediate vicinity of the activity itself. The degree of impact locally (within the county) will depend on the amount of purchasing that can be done locally in a predominantly rural county. Perhaps only a fourth of the total employment generated would consist of local jobs.

A more urbanized county, with many more goods and services available, would retain a greater share of the project's economic benefits. The total effect, however, compared with an already high level of economic activity, would be smaller than what would be felt in a rural area. In the discussion of salt domes, Brazoria County, Texas, was used as an example of such a rural county as a means of demonstrating the effects of a storage construction project in a situation which would maximize its impact. Using the same county as an example, employment generated locally by the conversion of a salt mine for storage would

TABLE V-16

IMPACT OF CONSTRUCTING A STORAGE FACILITY IN AN EXISTING SALT MINE

Capacity	90 MMB
Direct Expenditure	$32.4-54.0 million/yr.
Total Economic Impact ("Gross Regional Product")	$90.8-151.6 million/yr.
Employment	
Direct	120
Indirect	246
Induced	536
Total	902
Total Increase in Personal Income	$24.1-40.1 million/yr.

TABLE V-17

IMPACT OF OPERATING AND MAINTAINING A STORAGE FACILITY IN AN EXISTING SALT MINE

Capacity	90 MMB
Direct Expenditure	$0.19 million/yr.
Total Economic Impact ("Gross Regional Product")	$0.47 million/yr.
Employment	
Direct	1
Indirect	0
Induced	0
Total	1
Total Increase in Personal Income	$0.13 million/yr.

correspond to about 0.06 percent of the 1975 labor force, a proportion too small to be distinguishable.

Impacts on Population

It is not expected, given the relatively low levels of employment generated even by mine conversion, that any significant changes in population will result at the regional level. At the local level, there may be a small, temporary in-migration of workers needed to fill jobs requiring special skills not available in the immediate vicinity. Depending on location, however, many of these skilled workers may find it feasible to commute from adjacent counties as, for example, from the Houston-Galveston area, to Brazoria County. Thus, the maximum impact of the employment generated by the project at the local level would be the temporary in-migration of probably no more than twenty or twenty-five new families. Brazoria County's population, by way of comparison, is roughly 120,000.

Taxes

It is expected that the Federal Government will own many storage facilities in existing salt mines, which will make them exempt from property taxes. The revenues generated by the project will derive principally from taxes paid in the course of doing business, e.g., excise and sales taxes, and as a result of increased household income (income taxes and sales or property taxes resulting from increased household spending). Table V-18 shows the range of tax revenues expected, based on the prototype 90 MMB facility and Brazoria County's tax rate. These figures include taxes incurred in relocating the original owner of the mine.

TABLE V-18

TAXES GENERATED BY A 90 MMB GOVERNMENT-OWNED SALT MINE STORAGE FACILITY

Construction	$1.90 million per year
Federal	$1.90 million per year
State	$0.21 million per year
Local	$0.09 million per year
Operation and Maintenance	
Federal	$0.04 million per year
State	$0.004 million per year
Local	$0.002 million per year

When the government assumes ownership of a converted mine, its value will be lost to the local tax base. The amount of revenue lost will vary considerably, according to the worth of the mine and its assessed valuation. In the case of new salt dome cavities, the impact of this loss (determined for Brazoria County on the basis of existing land values) was found to be an order of magnitude lower than the anticipated overall increase in local revenues. A working conventional salt mine, however, will have a considerably higher value as property than the land overlying an undeveloped salt dome. In addition, the low operational cost of a converted mine storage facility is reflected in a very minor local tax increase. In the prototype discussed here, therefore, it appears that a loss in revenue would be felt by local taxing entities as a result of a transfer to government ownership of the mine site. However, if the owner is relocated, the new mine will contribute to the tax base in its own right, offsetting the loss of the old mine. These two opposing tendencies should be roughly equivalent, and should cancel out one another.

B. East Coast Storage Region

The program alternatives under consideration for this region include the storage of refined petroleum products in surface tanks and new rock caverns, and the storage of crude oil in existing mines. The prototype facilities assessed here include a 10 MMB tankage facility, a 30 MMB new rock mine and a 15 MMB existing rock mine. The impacts of these alternatives are addressed in the following sections.

1. Geology

From a geotechnical viewpoint, the geologic setting of New England is highly amenable to construction of rock caverns. However, the seismic risks in the North Atlantic region are significant, and construction within fault zones is imprudent. Surface structures are more likely to be damaged than underground facilities at a given location for a given seismic event so conventional storage tanks would be better suited in the southern part of the region, while a properly-sited underground facility may prove feasible generally throughout the region.

If inadequate geologic substrate strength or other unusually adverse properties are unexpectedly encountered, catastrophic loss of the storage structure or long-term recurrent problems could occur. Possible consequence of collapse of underground rock caverns are especially severe land-use disruptions and surface and subsurface drainage alterations, as well as the obvious safety hazards. However, this impact may be completely avoided by appropriate reconnaissance, design engineering, and construction practices, such as are currently available to geotechnical specialists.

2. Hydrology

Hydrologic impacts associated with installation or operation of the storage facilities on the East Coast are of some concern only if poor design and construction practices are employed. Perhaps the largest potential hydrologic impact may result from construction activities adjacent to wetlands or streams. Erosion of borrow materials, excavated areas, and berms and dikes that are not vegetatively stabilized, and runoff from rock spoil areas may cause locally severe surface-water siltation. In the East Coast region many coastal ecosystems are already acutely stressed; further siltation and chronic subjection to other construction site pollutants may, therefore, cause disproportionate effects. In particular, highly erodible soils exist in some areas that will cause problems if erosion by storm water runoff from construction sites is not diligently controlled and if vegetative and/or structural sediment control is not practiced (EN-101). The stability of artificial slopes and their potential for mass movement also must be critically examined with respect to their ability to cause siltation.

New dredging or an increase in maintenance dredging for tanker access to port facilities servicing some sites may be required where the pipeline connects to water-borne transportation. Locally severe short-term water quality degradation will occur, with increased turbidity and higher concentrations of heavy metals and oxygen-demanding material released from bottom sediments. The ecological effects of these water quality changes and habitat disruptions are addressed in Section V.B.6.

If conventional tankage and underground rock caverns are constructed under the SPR, they also may alter local drainage patterns. The resulting disequilibrium will itself lead to increased soil loss, but also can modify local ecological relations in areas removed from the site (e.g., by lowering the water table of an area, by increased temperatures due to shale removal or decreased ground-water seepage, and by increased turbidity). These effects are likely to be minimal in the low-relief areas of the coastal plain region, and probably will be overshadowed at all locations by the effects of habitat attrition. Conversely, drainage alteration may be beneficial in areas subject to recurring floods, if properly designed.

Ground-water contamination may result from both conventional tankage and underground rock caverns if either is poorly sited hydrogeologically. Leakage from tanks may be more prevalent than is generally recognized (EN-098), and even small quantities of oil can render ground water objectionable. A strict pressure-testing and monitoring program is required on all tanks, and special interest in the results of such programs is in order for those tank-farm sites on permeable fresh water-bearing strata. Similarly, leakage from "temporary" holding ponds for wastewaters or detention basins for storm-water runoff, which carry a variety of pollutants, may also contaminate near-surface, unconfined aquifers during the long time span envisaged for constructing the storage facilities. It must be recognized that shallow ground water will discharge to coastal wetlands whose biological productivity may be damaged if this seepage inflow is contaminated.

In addition, the storage of residual fuel oil would generate effluent in the form of tankage condensate. Tankage condensate is water which collects in the bottom of storage tanks and must be drained regularly. The primary source of tankage condensate is moisture which condenses from the air in the tank vapor space and collects on the tank bottom. Some water enters residual oil storage tanks as water entrained in the residual oil. Water can also be formed during residual oil storage as the by-product of gum-forming and polymerization reactions.

Potential contaminants in the tankage condensate include:

additives from the oil,

free-floating oil,

oil-water emulsions,

trace elements from the residual oil,

dissolved organic species, and

suspended solids.

There is also the possibility that potentially carcinogenic polynuclear organic compounds would be present in the tankage condensates.

The volume of the tankage condensates generated by a ten-man tank farm would be small and easily handled by storage in on-site tanks and periodic delivery to a waste disposal company.

A second source of aqueous effluent would be rain runoff water. Rain runoff from the tankage area might be contaminated with spilled oil and suspended solids. Rain runoff would be contained within the dike areas until absorbed into the ground or evaporated. These effluents would not be released into adjacent water systems.

Waste rock storage piles at newly mined rock caverns offer another avenue for ground-water contamination if they are located over near-surface aquifers. The fresh rock that has been mined will rapidly undergo weathering in a humid climate, which may introduce a variety of dissolved solids into infiltrating water via leaching. The spoil pile itself, due to its high bulk permeability, may act as a recharge mound of appreciable size. This relatively poorer quality water is then introduced into any underlying aquifers that are in hydrologic communication with the surface. If the recharge mound is perched on relatively impermeable material, such as glacial till, the resulting subsurface runoff from the stockpiled spoil may require treatment before discharging to surface streams. However, the excavated rock pile, acting as a recharge mound, can have the beneficial effect of storing valuable water supplies. Furthermore, the resulting water could possibly be of a better quality than the receiving streams, lakes and ponds.

Creation of the rock caverns will also alter the geohydrologic regime, since the caverns will serve essentially as horizontal well galleries from which incoming water must be pumped. In general, these changes are probably not significant in terms of regional geohydrology but any local users of ground water in the immediate vicinity of the rock caverns may be adversely affected by lowered water levels. This area of influence should stabilize over a period of time, depending on the permeability of the host rock. Furthermore, water loss will not be a problem once the mine is filled with petroleum.

The hydrological impacts discussed above are significantly less in the case of an existing mine, whether abandoned or operating. Regional and local ground-water regimes are generally stabilized, there is little or no rock spoil, and surface construction activities related to conversion of the mine are considerably less than those associated with surface tankage or new mine construction.

3. Meteorological and Climatological Impacts

The discussion of Section V.A.3. for the Gulf Coast region is equally applicable to the East Coast region.

4. Air Quality

The impact of aboveground tank storage of petroleum on air quality is divided in the construction, filling, operational, and emptying phases. At the time the Draft EIS was published, the available data indicated that it was possible for both distillate and residual fuel oil to be stored in above-ground tanks in the East Coast Region as part of the RPR. The most recent data show that only residual oil would be required (see Table II-3). However, the air quality impacts of tank storage are analyzed using the emission rates for both distillate and residual oil. This is considered more appropriate as a worst-case analysis in view of the fact that, because of the less desirable handling and storage characteristics of residual oil, it is likely that a lighter oil with similar burning characteristics (and a greater volaticity) would be stored. In addition, evaporative hydrocarbon emissions are estimated for marine tanker unloading and filling operations in port. If new tanks are constructed, fugitive dust emissions would occur at the site because of the construction activity. These emissions would be site-specific depending on the degree of ground cover, existing development at the site, local meteorological conditions, etc. Although these emissions cannot be quantified at the programmatic level, their impact on air quality is expected to be short-term and minor. Additionally, precautions such as wetting down gravel roads can be taken to reduce emissions substantially.

The impact of dust emissions from sandblasting the tanks and evaporative hydrocarbon emissions from tank painting is also expected to be short-term. Prior to painting, each tank must be sandblasted. No data are available on the level of particulate emissions generated by sandblasting operations. During tank painting operations, there is an estimated 1,100 pounds of hydrocarbon emissions per ton of paint applied (EN-071). The accumulative emissions from applying primer and paint to a 500,000-barrel storage tank are approximately 1.5 tons of hydrocarbons.

The primary air impact during the filling, operating, and emptying phases results from evaporative hydrocarbon emissions. What may be termed fugitive hydrocarbon emissions occur from pump seals and connecting points in the supply oil pipeline during filling. These emissions are generally minor if equipment is well maintained. Air impact of these fugitive emissions is estimated to be negligible. More substantial hydrocarbon emissions occur during tank storage filling and standard and marine tanker fillings. A detailed discussion of the sources of these fugitive hydrocarbon emissions is presented in RA-223. On an annual basis, maximum total emissions would occur from the following worst-case: tanker unloading, transfer to tank facility, filling tanks, unloading tanks, transfer back to marine tanker for shipment to end users. The expected emissions from this scenario are presented in Table V-19. Also, this table lists published 1973 hydrocarbon emission totals from all sources in the AQCR's defined for the East Coast region (See IV.B.2.f.). The estimated emissions from storage of distillate oil in one 10 MMB prototype facility would amount to only .002 percent of emissions from all sources in these AQCR's.

The ambient air impact of the emissions presented in Table V-19 is estimated using a Gaussian atmospheric dispersion model which employs dispersion coefficients from Turner's workbook (TU-001). The model was applied using meteorological conditions representative of worst-case atmospheric dispersion during the 6:00 a.m. - 9:00 a.m. period in the East Coast region so as to produce estimated concentrations which can be compared to the

TABLE V-19

COMPARISON OF FUGITIVE HYDROCARBON EMISSIONS FROM EXAMPLE TANK STORAGE FACILITY TO TOTAL ANNUAL EMISSIONS IN AQCR'S ON EAST COAST

10 MMB TANK FACILITY OPTIONS	ON-SITE EMISSIONS		MARINE TANKER EMISSIONS		WORST-CASE* TOTAL
	FILLING	STANDING	UNLOADING	LOADING	
Distillate, Fixed Roof Tanks	85	6	1	1	93
Residual, Fixed Roof Tanks	<1	4	<1	<1	4

AQCR NO.	TOTAL HYDRO-CARBON EMISSION	AQCR NO.	TOTAL HYDROCARBON EMISSIONS**
041	24,700 tons/year	116	11,500 tons/yr
042	197,700	118	51,000
043	1,040,103	119	272,000
044	8,200	120	163,000
045	522,400	121	118,900
046	22,700	150	39,100
047	204,500	168	42,200
110	50,500	223	117,300
114	25,100	224	39,700
115	249,900	225	84,300
		EAST COAST TOTAL	3,600,000 tons/year

*All emissions given in tons on an annual basis

**Based on a hypothetical annual cycle that consists of tanker unloading and filling of storage facilities over a six-month period and loading all stored oil to tankers over a five-month period

***Total is based on an incomplete inventory of hydrocarbon sources national ambient air quality standard for hydrocarbons. (Refer to RA-223 for a more detailed description of the dispersion model and the meteorological conditions used). Hourly emissions were estimated for tank filling and standing and for marine tanker unloading and loading. These are presented in Table V-20 along with predicted maximum 3-hour ambient hydrocarbon concentrations. Predicted concentrations shown in Table V-20 do not account for any chemical reactions occurring during transport of the hydrocarbons. Since the evaporative hydrocarbon emissions being modeled are non-methane, the predicted concentration can be conservatively compared with the non-methane hydrocarbon standard of 160 $\mu g/m^3$, maximum 3-hour concentration, not to be exceeded more than once per year. In actuality, the existing background concentration of hydrocarbons and the contributions of any other neighboring sources must be considered to determine compliance with the standard. This can be accomplished only at the site-specific level.

The national hydrocarbon standard is a guide for achieving the national photochemical oxidant standard. The two standards are coupled because historical ambient air monitoring data for various urban centers across the United States showed that the level of oxidant (ozone) for a 24-hour day was always associated with morning (6:00 a.m. - 9:00 a.m.) non-methane hydrocarbon levels. For example, the data showed that the early morning non-methane hydrocarbon concentrations must be below 200 $\mu g/m^3$ if the maximum 1-hour oxidant concentration for the day is to be kept below 200 $\mu g/m^3$. Thus, the 160 $\mu g/m^3$ hydrocarbon 3-hour standard was set as a guide to assure that the 160 $\mu g/m^3$ oxidant 1-hour standard would not be violated (NA-009). The U.S. EPA has acknowledged the lack of an accurate model for predicting oxidant concentrations from a single source such as considered in this EIS (39 FR 42510). Thus, the hydrocarbon concentrations shown in Table V-20 cannot be used to determine whether the oxidant standard will be violated.

TABLE V-20

HOURLY HYDROCARBON EMISSIONS FROM EXAMPLE TANK STORAGE FACILITY AND ESTIMATED AMBIENT IMPACTS

10 MMB TANK FARM OPTIONS	HYDROCARBON EMISSIONS		PREDICTED AMBIENT HC CONCENTRATIONS	
	FILLING	STANDING	FILLING	STANDING
Distillate, Fixed Roof	11.2 lbs/hr	1.9	350 $\mu g/m^3$	122
Residual, Fixed Roof	0.11	0.93	3	6

Air emissions are also released by the tankage module during emptying operations in conjunction with generating steam for tankage heating. For winter withdrawals, an estimated 650 gallons of fuel oil per hour are required to generate heating steam. Combustion emissions from the small on-site boiler are presented in Table V-21. During a total withdrawal of stored fuel oil, these emission rates would continue for approximately fifty days. The impact of these emissions on the ambient air qual[illegible] would be minor.

TABLE V-21

COMBUSTION EMISSIONS FROM STEAM BOILER FOR HEATING STORED PRODUCT

EMISSION	EMISSION FACTORS ($lb/10^3$ gal)	EMISSION RATES (lbs/hr)
Particulates	23	15
Sulfur dioxide	110	72
Sulfur trioxide	2	1
Carbon monoxide	4	3
Hydrocarbons	3	2
Nitrogen oxides	80	52
Aldehydes	1	1
Heating oil rate is 650 gallons per hour for a tankage withdrawal rate of 10,000 barrels per hour		

Source: EN-071

Accidental occurrences during the phases of the tank storage program also must be considered. Oil spills resultant from oil pipeline breakage would contribute some amount of evaporative hydrocarbon emissions to the air. The impact of these emissions is difficult to estimate but should be short-term. Any catastrophic fire occurring from the upset of one or more tanks, of course, would contribute major combustion product emissions to the air. The impact of these may be severe but would be short-term.

In summary, the normal operations of the 10 MMB tank farm module storing residual oil would not have a significant impact on air quality. The impact of storing distillate oil would be greater, especially during the filling phase. The maximum impact would occur from distillate hydrocarbon emissions during filling operations. The absolute impact of the example tank farm module can only be considered at the site-specific level so as to take into account other sources and the actual probability of the estimated worst-case meteorological conditions used in this analysis. The possible storage of more than 10 MMB at one site would also have a proportionally greater impact on air quality. The regional effect of multiple storage locations for the tank storage program can only be evaluated after the actual sites are selected.

The impacts of East Coast mine operations are essentially the same as those for the Gulf Coast region. Fugitive dust will be more significant because of the larger areas required for mine development but is of only minor importance.

5. Noise

The methodology for predicting human and animal response to noise emissions presented in Section V.A.5. is equally applicable to the following discussion.

The construction phase is the only activity associated with tank storage which will generate noise at any appreciable level. The acoustic noise sources considered as primary contributors to construction noise are listed in Table V-22. The radiated sound pressure level spectrum may be considered as representative of noise from an acoustically untreated piece of equipment at a distance of fifty feet. The equipment complement may differ from location to location depending upon soil conditions, access, etc. The predominant sources of noise, in order, are air compressors, dump trucks, cranes, and welding generators. The other sources are not important singly in comparison to these, but their combined acoustic radiation is noticeable.

As an example case, the complement of equipment listed in Table V-22, and representative sound levels, was assumed to be operational twenty-four hours a day in construction of a 10 MMB tank farm storage system. Predictions of sound level as a function of distance from the center of activity were performed to obtain a gross estimate of the degree of intruding noise into surrounding areas. Several simplifying assumptions were made for performing the computation; the results, however, provide clues to whether an environmental noise problem may be expected. Results of the exercise are as follows:

TABLE V-22

CONSTRUCTION NOISE SOURCES AND REPRESENTATIVE RADIATED SOUND SPECTRA

Equipment	Number Active	Sound Pressure Level (in Octave Bands) in dB re 20 $\mu N/m^2$ at 50 Feet — Frequency - Hz: 63	125	250	500	1K	2K	4K	8K	Sound Level for One Unit in dBA	Sound Level for All Units in dBA
Bulldozer (Soil, 270 hp)	3	72	72	75	73	70	65	69	65	76	81
Brick Unloader (3 hp)	2	65	69	67	65	64	63	61	59	70	73
Air Compressor (Portable)	12	74	83	87	86	83	76	74	69	87	98
Welding Generator (25 KW, 5 hp)	12	70	71	75	74	71	73	69	58	78	89
Pump (7 hp)	10	65	70	65	60	60	57	52	50	65	75
Compactor	2	72	68	65	65	69	62	51	45	71	74
Front Loader	4	73	73	73	73	73	68	62	58	76	82
Backhoe	4	73	73	73	73	73	68	62	58	76	82
Crane	4	80	86	85	83	78	73	67	61	84	90
Concrete Mixer	6	70	70	70	70	70	63	57	51	73	81
Grader	2	80	80	80	80	76	70	64	58	81	84
Paver	2	80	80	80	80	76	70	64	58	81	84
Truck (Dump)	10	78	83	85	80	72	70	63	55	81	91

Distance from Center of Activity in Feet	Predicted L_{dn} (dB)
1000	75
2000	68
3000	60
4000	55
5000	50

An examination of this tabulation and the criteria of Figure V-8 shows that within about three thousand feet from the center of activity, individual and organized community reaction should be anticipated. Likewise, wildlife having living patterns sensitive to noise may be expected to be disturbed during construction. This case, of course, is highly assumptive and simply illustrates that noise could become a problem area during construction of tank farms.

Noise resulting from conversion of an existing mine or creation of a new mine would be significantly less than that of a tank farm. The construction of servicing facilities on the surface above a mine are analogous to construction of a medium-sized building. Construction noise associated with creation of a new mine would be relatively greater than an existing mine due to the increased traffic resulting from hauling rock from the site and from the initial drilling and blasting.

Filling and emptying of tank and mine storage facilities are not expected to create appreciable noise. Petroleum pumps driven by electric motors do generate and radiate noise, but emission levels are low enough that they are not a source of concern more than several hundreds of feet from their locations. Assuming two 600-horsepower pumps driven by electric motors, sound pressure levels representative of acoustically-untreated motor-pump equipment operating at 3600 rpm, at a distance of 50 feet are given as follows.

SOUND PRESSURE LEVEL IN dB BY FREQUENCY

Frequency in Hz	63	125	250	500	1000	2000	4000	8000
dBA	79	84	92	93	90	88	85	80

6. Biology

Assessment methodology for the Gulf Coast region was also used for the East Coast region. As with the storage of crude oil in salt domes, most impacts of tank or mine storage are very site-specific. However, the general impacts of storing crude oil or petroleum products in tank modules and mines along the East Coast region are similar to the general impacts of the salt dome crude oil storage along the Gulf Coast region, except that there will be no discharge of brine or other water. Each tank module will cover about 256 acres, with up to three modules in close proximity. This would result in a total disturbed area of about 768 acres, plus pipelines in and out of the site. A possible additional impact would be the installation of a small waste treatment lagoon of a maximum one acre in size. This would receive the separated condensate from the tanks. No oil should be in the lagoon after the condensate goes through an API separator. The actual amount of discharge may be so small as to be easily disposed of by trucking to a waste disposal facility, in which case no lagoon would be necessary.

A new mine complex, if used, would create about the same general degree of disturbance as a two-module tank facility. It would occupy about 50 acres if several shafts were used and all equipment were aboveground. In addition, about 300 acres would be needed to store the mine refuse (mined rock and dirt), unless it were disposed of in some other manner. Much less area would be necessary if most of the rock were sold and only the unsaleable refuse stored. For an existing mine, there would be virtually no need for disposal or storage of waste rock and consequently, no associated impacts would occur.

The general effects of various types of activities are shown in Section V.A.6. for the various biotopes that may be encountered in the region.

a. <u>Construction Effects</u>

If aboveground storage tank modules are constructed at various sites in the East Coast region, it will substantially disrupt whatever biotopes are on the sites to be developed for tankage. Everything inside the fenced area, with the possible exception of a buffer zone of one hundred feet or so from the dike to the fence, will be cleared. It is unlikely that the sites will be in wetland areas since land acquisition and construction costs would be prohibitive; however, dock facilities, roads, channels, and pipelines will probably cross these areas.

The majority of animals found in the region will attempt to avoid the disturbance by moving to similar adjacent habitats, if they are available. Generally, the populations will not change significantly on a regional level because the required area is not a large percentage of the total region. Locally, the animals around the sites will be disturbed by the noise and general presence of man during construction. Only the large predatory birds (eagles, etc.) and mammals (bobcats, deer, foxes, turkey, etc.) may move a considerable distance to avoid the site. Most of these animals, except possibly the eagle, usually become habituated to the activity and move back to the near vicinity prior to the end of construction, wherever adequate cover is available.

The earth-moving required to construct dikes and/or levees for tanks will create some siltation and excess turbidity from runoff in the nearby streams if not properly controlled. This is a source of concern if the site is on a major spawning river for anadromous fish such as salmon or trout. If adequate precautionary measures are taken, oil spills and silt during construction should be contained on the site and disposed of properly. The construction activities should not affect the migratory waterfowl or the fin fish and shell fisheries of the region unless the site is in a resting, feeding, nursery, or wetland area. Sites chosen in forest or upland prairie biotopes will minimize biological impacts. The site should be away from any areas containing endangered species of plants or animals if possible. An area of predominantly industrial land use would be the least environmentally damaging of all site possibilities.

The construction and related activities involved in creating a new mine storage complex will be similar to those of building a tank facility, yet not as much of the biota will be changed on the mine site proper since the entire area will not be cleared. However, if the mine wastes (rock or dirt) are stored nearby, all the storage area will be unsuitable for other uses. This maximum area of about 300-400 acres would roughly equal the area of a two-module tank facility. An area of about 50 acres is the minimum expected if most of the rock is sold. The impacts should be the same, with the addition of airborne particulates from mined materials and possibly more siltation from runoff from the stored refuse unless adequate control measures are employed. For the case of an existing mine, the impacts would be substantially less for the reasons stated previously.

Pipeline construction for both tanks and mines could create large adverse impacts if they pass through wetlands or breeding grounds or areas which contain endangered species. If these are avoided the impacts of pipeline construction will be minimal.

b. Operational Effects

The operational effects on the biota of both tank and mine facilities should be generally the same as the salt dome facilities without the discharge of liquid wastes such as brine. These should be minimal except for increases in barge or ship traffic during loading and unloading, and accidental spills. Since no new ports are anticipated, no additional coastline construction will be needed.

Spills will affect the biota in the East Coast region generally the same way as in the Gulf Coast region. Because of the higher daily tidal amplitude and frequency of tides (generally two a day on the East Coast), the crude oil or product spilled will tend to be carried more quickly into the wetland areas and shores thereby causing more extensive damage in a shorter period of time. For a complete analysis, refer to Section V.D.

The odor of oil that will be present near the facility from the "breathing" of the tanks should not interfere with the olfactory responses of various amphibians and mammals to any significant extent on a regional level. This could be a factor on a localized level if species are present which use smell in their breeding ritual.

7. Historical and Archaeological Resources

As described when discussing the impact of the proposed program on the Gulf Coast, the "Criteria of Effect" established by the Advisory Council on Historic Preservation should be applied to all National Register properties or properties eligible for inclusion therein when evaluating the impact of the proposed program. An undertaking will be considered to have an effect on a property when a change, beneficial or adverse, in the quality of the historical, architectural, archaeological, or cultural character that qualifies the property for inclusion in the National Register is caused by the undertaking.

Once an effect has been established, the "Criteria of Adverse Effect," also established by the Advisory Council on Historic Preservation, must be applied. These criteria are as follows:

> Generally, adverse effects occur under conditions which include but are not limited to:
>
> a) destruction or alteration of all or part of a property;
>
> b) isolation from or alteration of its surrounding environment;
>
> c) introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting;
>
> d) transfer or sale of a Federally-owned property without adequate conditions or restrictions regarding preservation, maintenance, or use; and

e) neglect of a property resulting in its deterioration or destruction (AD-029).

The Criteria of Effect should be applied to the physical limits of a property and to its surrounding environment. The limits of a property can be established from the boundaries given in the National Register. The surrounding environment should be determined on a case-by-case basis in consultation with the state historic preservation officer.

The potential adverse impact of the construction and operation of storage tanks on the East Coast is discussed below.

Tankage construction poses a potential threat to archaeological and historical sites within the construction area. In addition to the direct alteration or damage which may be caused by machinery or the covering of a large area by tankage, the visual intrusion of large tanks is a factor which may detract from the esthetic value of a site in the vicinity.

Any land use changes from subsidiary industrial development could have an effect on any existing archaeological or historical resources by causing isolation from or alteration of their surrounding environment. With the exception of the visual impact discussed above, no other impacts are anticipated from the operation of the proposed storage facilities.

8. Land Uses

If new tank farms are constructed, a module of 10 MMB will occupy a surface space of about 0.4 square miles. The actual impact will depend heavily on the specific sites chosen. The potential sites can be discussed in two general categories. The first category would be the addition of a tank model to an existing facility of a similar type. This case will effect the least impact on land use since the surrounding environment will have already reacted to the existing tank farm as well as the subsidiary facilities necessary to operate and maintain such a facility.

The second category is the construction and operation of a tank module in a virgin area. Regardless if the area is totally rural or partially populated and built up, the construction of such a facility will create a ripple effect on surrounding land uses. Such effects can be minimized through definitive land use controls at the local or state level, which will mandate some type of visual barrier to isolate the storage model from other types of active land use. Construction of new sites will also include the development of such support facilities as roads, rails, docks, new pipelines, and power lines, which in themselves, will cause varying levels of impacts to surrounding land uses. It is not foreseeable that the site could have any other use after construction of the tank module.

Construction of new mines will have essentially the same considerations on land use as those for tanks. Alteration of an existing mine, being a developed capacity, will have minimal impact on land use.

The major negative impact on recreational areas and facilities is associated with the possibility of oil spill, either at sea or along the route to the eventual storage site. There may be some short-term inconvenience to certain recreational facilities during a construction phase. There will not be a substantial increase in the use of recreational facilities due to population growth induced by the project since the number of people involved is very small.

9. Social and Economic Impacts

The impacts of constructing and operating any of the storage facilities considered for the East Coast are anticipated to be very minor on the whole. However, local impacts vary somewhat in character depending on the storage mode employed. As with the Gulf Coast facilities, the construction and operational costs assumed for the analysis given below are approximations only, and the actual costs for a particular facility will be highly dependent upon site-specific factors.

a. Existing Mines

An alternative to the use of salt mines for storage is the conversion of mines in other kinds of rock. An analysis of the economic impact of such a project has been made, based on statistics appropriate to a single mine investigated by FEA. Multipliers were used that reflect the facilities construction and warehousing sectors of the New England economy. Assumptions used in the analysis were as follows:

Storage Capacity	15 million barrels
Construction and Acquisition Cost	$.65-1.53 per barrel
Construction Employment	150
Construction Time	2.7 years
Operation and Maintenance Employment	1
Operation and Maintenance Cost	$0.006 per barrel

Low operation and maintenance employment figures reflect, as they do in the case of salt mines, the relative simplicity of this type facility, which can be automated to a large degree. The addition of security guards might bring the total employees to five or six.

Impacts estimated on the basis of these assumptions are presented in Table V-23 and V-24 for the construction and operation phases.

TABLE V-23

IMPACTS OF CONSTRUCTING A 15 MMB STORAGE FACILITY IN AN EXISTING ROCK MINE

Direct Expenditure	$3.37-7.92 million per year
Total Economic Impact ("Gross Regional Product")	$8.32-19.6 million per year
Employment	
Direct	150
Indirect and Induced	240
Total	390
Total Increase in Personnel Income	$2.33-5.49 million per year

TABLE V-24

IMPACTS OF OPERATING AND MAINTAINING A 15 MMB STORAGE FACILITY IN AN EXISTING ROCK MINE

Direct Expenditure	$0.084 million per year
Total Economic Impact ("Gross Regional Product")	$0.184 million per year
Employment	
Direct	1
Indirect and Induced	0
Total	1
Total Increase in Personnel Income	$0.05 million per year

The impacts of converting and using an existing rock mine are much the same as those of using existing salt mines. These impacts are generally too small to be felt at a regional scale. At the local scale, the institution of such a project could help relieve unemployment but would not be expected to induce any migration of workers which might, in turn, affect local services and facilities.

As is the case with salt mines, it is probable that the government would purchase rock mines for conversion and relocate the original owner. This tends to counteract the loss of the original mine from the local tax base by the addition of the value of a new facility roughly equivalent to the old. If the new mine falls into the same tax district as the original mine, the net impact should be very small. If the two facilities fall in separate districts, however, the relocation of the mine will in effect divert tax revenues from the district containing the converted mine to that containing the new mine. In many East Coast areas, as opposed to the Gulf Coast, property taxing entities are often local rather than county governments, which increases the likelihood of such a situation.

Taxes generated in the process of doing business and through the payment of wages and salaries are summarized in Table V-25.

TABLE V-25

TAXES GENERATED BY A GOVERNMENT-OWNED FACILITY IN AN EXISTING ROCK MINE

Construction	
Federal	$0.348-0.819 million/yr.
State	$0.074-0.174 million/yr.
Local	$0.044-0.103 million/yr.
Operation and Maintenance	
Federal	$14,000 per year
State	$ 4,200 per year
Local	$ 2,400 per year

b. New Rock Mines

Because of the successful operation of such facilities elsewhere in the world, it has been proposed that new rock mines be considered for use in the SPR. In particular, some 30 MMB of residual fuel oil needed for the Regional Petroleum Reserve could be stored underground in a rock cavern mined out for this purpose somewhere in the New England region.

Economic and Demographic Impacts

Quarrying multipliers derived for New England from the National Input-Output Model were checked against similar multipliers from existing Input-Output Models of South Texas and Kentucky, both active mining and quarrying regions. A weighted average of the quarrying multipliers, and multipliers for facilities construction in New England, South Texas and Kentucky, were used to approximate the actual activity of preparing a rock cavern for use in the storage program.

Calculations of the impact of developing a new rock-mine storage facility were based on the following assumptions:

Storage Capacity	30 million barrels
Construction and Acquisition Cost	$4.00-6.00 per barrel
Construction Employment	270
Construction Time	4.8 years
Operation and Maintenance Employment	2
Operation and Maintenance Cost	$0.017 per barrel

The effects of constructing and operating such a facility are given in Tables V-26 and V-27.

TABLE V-26

IMPACTS OF CONSTRUCTING A 30 MMB STORAGE FACILITY IN A NEW ROCK MINE

Direct Expenditure	$25.0-37.5 million per year
Total Economic Impact ("Gross Regional Product")	$61.8-92.6 million per year
Employment	
Direct	270
Indirect and Induced	430
Total	700
Total Increase in Personnel Income	$17.3-25.9 million per year

TABLE V-27

IMPACTS OF OPERATING AND MAINTAINING A 30 MMB STORAGE FACILITY IN A NEW ROCK MINE

Direct Expenditure	$0.51 million per year
Total Economic Impact ("Gross Regional Product")	$1.17 million per year
Employment	
Direct	2
Indirect and Induced	0
Total	2
Total Increase in Personnel Income	$0.32 million per year

These impacts will not be felt evenly throughout the region. Activity centered around the project will be most intensive within a local subregion covering several counties which includes the labor source for the project and suppliers of readily available materials and services. Multipliers for such a subregion were estimated, and the "local" component of the total project impact was calculated as follows:

Construction Impact	
Gross Regional Product	$32.5-48.8 million per year
Employment	400
Operation and Maintenance	
Gross Regional Product	$0.58 million per year

Within the already populous and economically-active New England area, impacts at this scale would not make a noticeable change in population distribution or overall economic level. For example, in the urbanized area of Providence, Pawtucket, and Warwick, Massachusetts and Rhode Island, the total civilian labor force in 1972, according to the Department of Commerce County and City Data Book, was more than 340,000. Generation of 400 construction-related jobs would provide employment for a maximum of only 0.01 percent of this force. Since the New England area in general is experiencing a period of depressed activity in construction, most, if not all, of the labor force should be available locally.

Taxes

Taxes will be generated in both the construction and operation phases by the purchase of materials and services and the payment of wages and salaries. The estimated direct and indirect impacts of these activities on tax revenues are given in Table V-28.

TABLE V-28

TAXES GENERATED BY A GOVERNMENT-OWNED STORAGE FACILITY IN A NEW ROCK MINE

Construction Phase	
Federal	$2.58-3.86 million per year
State	$0.55-0.83 million per year
Local	$0.33-0.49 million per year
Operation Phase	
Federal	$0.086 million per year
State	$0.024 million per year
Local	$0.015 million per year

The Federal Government will either lease or own outright any new rock cavern built for the storage program; a government-owned facility would be automatically exempt from local property taxes. The total land area required for buildings, facilities, and waste rock stockpiling will be between 300 and 400 acres; taxes on an undeveloped parcel of this size would vary considerably with its location, but an average is likely in the neighborhood of $5,000 to $7,000. Transfer to government-ownership would involve a net loss to the local taxing entities of this amount, while indirect increases in local taxes brought about by the project, after the initial construction phase, would be an order of magnitude less. In the New England area the net impact would not be large since cumulative local tax revenues summed at the county level typically run in the hundreds of millions.

Rock Disposal

Another impact of developing a new rock cavern involves the disposal of rock removed from the cavity. It is anticipated that some of the rock produced could be sold on the open market as a means of offsetting the high cost of construction where the rest would be landfilled. The total amount of rock produced will be roughly 14 MMT; spaced over the total construction period, this comes to about three MMT a year. Recent statistics from the Bureau of Mines Minerals Yearbook (US-144) indicate that the amount of stone used in each of the New England states averaged only 9,300 tons per year in 1972 and 1973. Even the highest users, New York and New Jersey, consumed an average of only 38,000 tons and 16,000 tons, respectively. Releasing even a portion of the rock removed from the mine into the market would have a detrimental effect on local suppliers. Since crushed rock typically is not worth transporting long distances (i.e., more than a few tens of miles), this effect would not be felt regionally, or even at the state level.

c. Aboveground Steel Tanks

Some use of tankage in the East Coast is possible as an alternative storage mode for the SPR. Extensive use of tankage may not be feasible because of cost, but the convenience of tank storage makes it worth investigating at a small scale.

Economic and Demographic Impacts

The region within which the impact of constructing and operating tankage was evaluated consists of the portion of the Atlantic seaboard running from New Jersey to Maine. A fully developed input-output model for the New England states is not presently available; therefore, a partial model was applied based on the model of the nation as a whole, for purposes of checking the estimated construction and operational impacts.

The process of "scaling down" the national model first identified the outputs of the various sectors of interest in the region being studied. The sum of these outputs was then held constant in the regional model. The next step was to determine the ratio, for each sector to be modeled, of the intensity of that activity within the region to its intensity nationwide; these "location quotients" were then used to transform the national model into a regional model, reflecting the region's unique internal structure. Where an activity was under-represented in the region, versus the nation as a whole, the regional model was allowed to behave as though the difference were being imported; where an activity was over-represented, the model exports the difference.

The actual impacts were modeled using the Houston-Beaumont regional submodel of the Texas Input-Output Model. Since this area, like the New England region, contains a large amount of petroleum and petroleum-based activity, including tank storage, it was thought to be representative of conditions in New England. The complete model of this region was then checked against the partial New England model and found to show a satisfactory degree of similarity with respect to the activity to be modeled. Consequently, it was decided to use the Houston-Beaumont model, rather than to complete the New England regional model.

Assumptions used in the calculations are as follows:

Storage Capacity	10 million barrels in twenty 500,000-barrel tanks
Construction and Acquisition Cost	\$6.00-12.00 per barrel
Construction Time	2.5 years
Construction Employment	150-200
Operation and Maintenance Employment	40
Operation and Maintenance Cost	\$0.125 per barrel per year

The results of the analysis are given in Tables V-29 and V-30.

TABLE V-29

IMPACTS OF CONSTRUCTING A TANK FARM STORAGE FACILITY

Direct Expenditure	\$24.0-48.0 million per year
Total Economic Impact ("Gross Regional Product")	\$78.2-156.5 million per year
Employment	
Direct	150-200
Indirect	5,750-7,700
Induced	13,000-17,430
Total	18,900-25,325
Total Increase in Personal Income	\$22.0-44.0 million per year

TABLE V-30

IMPACTS OF OPERATING AND MAINTAINING A TANK FARM STORAGE FACILITY

Direct Expenditure	$1.25 million per year
Total Economic Impact ("Gross Regional Product")	$3.54 million per year
Employment	
Direct	40
Indirect	134
Induced	169
Total	343
Total Increase in Personal Income	$0.65 million per year

As can easily be seen, the impact of building tank-farm storage capacity is far greater than that of developing salt domes for the same purpose. The construction of tankage, unlike solution of salt domes, involves the use of much more material (such as steel plate) which must be fabricated from other materials. This results in increased activity in many sectors and accounts not only for the much greater effect on employment but also for the substantially greater impact on "gross regional product."

Another point of difference between the two storage modes is the greater tendency of the economic impact of constructing tankage to "leak" away from the region to centers producing needed materials. Production of steel plate is probably the single largest factor behind this draw-off. This impact of producing the needed plate is not, however, likely to be localized because of the placement of large orders with a small number of suppliers. What will happen is that the firms obtaining contracts to supply the plate needed for the tank farms will allow a certain amount of the demand, which they would otherwise have satisfied, to be displaced onto other suppliers. In this way, for example, a firm in New England selected to supply plate for the storage program would be unable to supply all the additional local demand, forcing other users to order from the next closest suppliers along the eastern Great Lakes, who in turn give up some potential business to firms in Detroit or Chicago. Thus, the impact is dispersed throughout the nation; the storage program acts simply as one more entry in a pre-existing national queue.

Sociological Factors

Safety

Of major importance in the storage of oil in aboveground tanks is the safety of area residents. Although many safety features are built into the tanks, the threat of fire or explosion is always present. The aggregation of tanks into a tank farm magnifies this threat. Typically, tank farms are not located in residential areas so the probability of injury to bystanders should be low. The threat of sabotage to a tank farm is much greater than the threat to other oil storage facilities such as salt domes.

Esthetics

The 20-30 half-million-barrel tanks and the associated pumps and pipelines comprising the typical tank farm installation would not generally be considered esthetically pleasing. However, most of the potential sites for new tankage are in close proximity to existing tank farms and oil distribution systems. This factor will help to alleviate some of the visual impact of new tank farms. In addition, proper landscaping of the area surrounding the farm would greatly aid in reducing the visibility of the new tank farms.

Land Values

With approximately 17 acres of land being used for each million barrels of oil tankage, a tank farm would require a fairly large site. If any of the new tankage is near residential areas, there is a strong possibility that the land values around the tank farm will be reduced. This could lead to local alterations in land usage patterns contributing to an even larger reduction in nearby land values.

Taxes

Tank farms could be either leased by the Government or owned outright. In the former case, there would be no net change in the tax base as long as the tanks themselves were not subject to taxation. If, however, the entire facility were owned privately, not only the site but its improvements would be taxed and substantial revenues, many times the magnitude of those from unimproved property, would be generated. As discussed earlier in the case of solution-mined cavities in Gulf Coast salt domes, such a situation would amount to an indirect Federal subsidy of local government through the fees paid to the lessor for the use of the space. In the case of Government ownership, the reverse of this impact takes place: land presently part of the tax base is removed and its revenues lost. The extent of this loss would vary considerably with location but would probably run in the thousands of dollars for an unimproved site of 170 acres or so. Given the very large annual revenues typically taken in by taxing entities in densely populated and highly developed industrial areas in New England, where such a facility would probably be placed, a loss of this magnitude would probably not constitute a significant proportion of the total.

Table V-31 shows the magnitude of taxes generated in the course of doing business and by wages and salaries in both construction and fill periods.

TABLE V-31

TAXES GENERATED BY A GOVERNMENT-OWNED TANK FARM

Construction	
Federal	\$2.60-5.20 million per year
State	\$0.55-1.10 million per year
Local	\$0.32-0.64 million per year
Operation and Maintenance	
Federal	\$179,000 per year
State	\$ 36,000 per year
Local	\$ 31,000 per year

C. Summary of Cumulative Impacts

The concept of cumulative impacts of the SPR program can be defined in two ways. First, it can be defined in terms of those impacts which become additive due to the location of the storage facilities. That is, it is possible that because of the proximity of two or more sites to one another, the total impact from them as a group could cause a standard to be violated that would not ordinarily be exceeded by the operation of any one facility (e.g., the evaporative hydrocarbon emissions from two or more tank farms constructed close together). This type of cumulative analysis is dependent to a large extent on the location of the storage sites and the baseline environmental conditions in those areas. It is, therefore, impossible to address the cumulative impacts in this manner until the sites have been selected. The degree to which any particular candidate site would be affected by any other site will be addressed in the site-specific EIS for that site.

A second approach to cumulative impacts consists of estimating on a per-site basis those impacts for which quantification is possible, and then projecting the impacts to show the estimated totals for the entire program, taking into account possible "worst-case" and "expected" combinations of storage facility types. This approach was adopted for application in this programmatic EIS. The estimated cumulative impacts were obtained by projecting the results of the analysis described in Section V.A. and V.B. involving hypothetical storage sites.

The type and amount of impacts associated with the SPR program will vary greatly depending on the mix of storage facilities selected for the program. A principal consideration affecting that decision is the relative proportions of the SPR which will be stored in each of the two storage regions. As calculated from Table II-3, a maximum of 95.4 MMB of petroleum products could be stored locally in the East Coast region in satisfying the requirements of the Regional Petroleum Reserve (RPR). As mentioned in Chapter II, FEA is proposing in the SPR Plan that the RPR requirement be satisfied through substitution of crude oil stored in centralized underground facilities. However, since it is possible that the proposal may be modified, the possibility of regional storage was assessed. For purposes of analysis, the two extremes of maximum local storage of product and maximum crude oil substitution have both been analyzed in order to place limits on the possible cumulative impacts. The air quality impacts of tank storage in the East Coast region were calculated using the emission rates for distillates, rather than residual oil. This was deemed more appropriate as a worst-case analysis in view of the fact that, because of the less desirable handling and storage characteristics of residual oil, it is likely that a lighter oil with similar burning characteristics would be stored.

In addition, within each scenario two possible mixes of types of storage sites (in terms of number of barrels stored in each type) were assumed for analysis. The first represents a "worst-case" mix from an environmental standpoint. The second represents what can be termed a probable or expected mix, given what is known at this time about the requirements, resources, and limitations of the SPR program. The assumptions made with respect to the worst-case and expected mix of facility types for both the maximum regional storage and maximum substitution scenarios are given in Table V-32.

In arriving at projected cumulative impacts, only those types of impacts were addressed for which it is appropriate to project the total impacts of the program on the basis of modeled impacts of prototype sites. In some cases, the impacts do not accumulate unless two or more sites interact to produce an additive effect (e.g., noise) as described above. In other cases, the type and severity of impacts are almost entirely dependent on site location (e.g., biological) and therefore the quantitative analysis will be left to each site-specific EIS. The four categories of impacts for which cumulative quantification is appropriate include air, water, land use, and socioeconomic. The cumulative impacts of these categories are shown in Tables V-33 through V-36 for both the worst-case and expected mix of sites for the maximum local storage scenario and the maximum substitution scenario. The totals were projected by reducing the impacts estimated in Chapter V for each prototype facility to a "per-barrel" multiplier, and then applying it to the number of barrels shown in Table V-32. The only cases in which this approach was not used were the socioeconomic impacts of facility operation for all underground storage sites and the land use impact for existing-mine storage sites. Since the size of the operational work force needed for all underground sites and the surface area required for an existing-mine facility would both remain essentially constant on a per-site basis, regardless of the storage capacity, the totals shown are based on an estimated number of sites for each case. That number is shown in parentheses with each cumulative total.

TABLE V-32

AMOUNT OF OIL STORED BY FACILITY TYPE

Facility Type	Maximum Local Storage of Product* Worst Case (MMB)	Expected (MMB)
Product		
Conventional tanks	95	15
New Rock Mines		80
Crude Oil		
New solution salt dome cavities	405	150
Existing solution salt dome cavities		165
Existing salt mines		70
Existing rock mines**	___	20
Total	500	500
	Maximum Substitution of Crude Oil	
Crude Oil		
New solution salt dome cavities	500	200
Existing solution salt dome cavities		160
Existing salt mines		120
Existing rock mines**	___	20
Total	500	500

*A 90-day supply of residual oil imports for Regions I-IV is 95.4 MMB. This figure was rounded to 95 MMB to facilitate computation.

**Although located in or near the East Coast region, these mines would contain crude oil rather than product.

TABLE V-33

CUMULATIVE IMPACTS - MAXIMUM LOCAL
STORAGE OF PRODUCT (WORST-CASE)

	East Coast: 95 MMB of Product in New Tanks	Gulf Coast: 405 MMB of Crude in New Solution Caverns
Air*	Marine Tanker Unloading: 7 tons of HC Tank Painting: 285 tons of HC Filling (one cycle): 808 tons of HC Diurnal Breathing: 57 tons of HC Marine Tanker Loading: 11 tons of HC	Marine Tanker Unloading: 4,460 tons of HC Marine Tanker Loading: 6,890 tons of HC
Water	Minor Impacts	Brine Disposal: Produced during solution mining - 12.9 x 10^{10} gal. Produced during displacement - 1.7 x 10^{10} gal. with oil (one refill) Area affected if brine disposed of in the Gulf during solution mining and subsequent cycling - Maximum area of 1 ppt increase in salinity (assumes no vertical mixing) - 2,090 acres Water requirements: Required for solution mining - 10.6 x 10^{10} gal. fresh water, or 11.6 x 10^{10} gal. sea water, Required for displacement (one emptying) - 1.8 x 10^{10} gal. fresh water 1.7 x 10^{10} gal. sea water
Land Use	2,450 acres	522 acres
Socio-Economic	Effects of construction: Direct Expenditures** - \$570-\$1,140 Total Economic Impact - \$1,860-\$3,720 Total Employment*** - .5 x 10^6 - .6 x 10^6 man-years Total Increase in Personal Income - \$520-\$1,040 Effects of Operation: Direct Expenditure - \$12 per year Total Economic Impact - \$34 per year Total Employment*** - 3,250 persons Total Increase in Personal Income - \$6 per year	Effects of construction: Direct Expenditure - \$510-\$632 Total Economic Impact - \$1,437-\$1,764 Total Employment*** - 8,660-14,632 Total Increase in Personal Income - \$388-\$497 Effects of Operation: Direct Expenditure - \$1.9 per year (2) Total Economic Impact - \$4.7 per year (2) Total Employment*** - 94 persons (2) Total Increase in Personal Income = \$1.3 per year (2)

*All emissions on an annual basis
**All dollar amounts in millions of dollars
***Includes direct, indirect, and induced employment

TABLE V-34

CUMULATIVE IMPACTS - MAXIMUM
LOCAL STORAGE OF PRODUCT (EXPECTED)

	East Coast: 15 MMB of Product in New Tanks	East Coast: 80 MMB of Product in New Rock Mines
Air*	Marine Tanker Unloading: 1 ton HC Tank Painting: 45 tons of HC Filling (one cycle): 128 tons of HC Diurnal Breathing: 9 tons of HC Marine Tanker Loading: 2 tons of HC	Marine Tanker Unloading: 6 tons HC Marine Tanker Loading: 9 tons HC
Water	Minor Impacts	Minor Impacts
Land Use	549 acres	933 acres
Socio-Economic	Effects of Construction: Direct Expenditure** - $90-$180 Total Economic Impact - $294-$587 Total Employment*** - $.7 \times 10^5$ - $.9 \times 10^5$ man-years Total Increase in Personal Income - $83-$165 Effects of Operation: Direct Expenditure - $1.9 per year Total Economic Impact - $5.4 per year Total Employment*** - 514 persons Total Increase in Personal Income - $.96 per year	Effects of Construction: Direct Expenditure - $320-$480 Total Economic Impact - $793-$1,190 Total Employment - $.9 \times 10^4$ man-years Effects of Operation: Direct Expenditure - $2.0 per year (4) Total Economic Impact - $4.7 per year (4) Total Employment*** - 8 persons (4) Total Increase in Personal Income - $1.3 per year (4)

*All emissions on an annual basis
**All dollar amounts in millions of dollars
***Includes direct, indirect, and induced employment

TABLE V-34 (Cont.d)

CUMULATIVE IMPACTS - MAXIMUM LOCAL STORAGE OF PRODUCT (EXPECTED)

	Gulf Coast: 150 MMB of Crude in New Solution Caverns	Gulf Coast: 165 MMB of Crude in Existing Solution Caverns
Air*	Marine Tanker Unloading: 1,650 tons of HC Marine Tanker Loading: 2,550 tons of HC	Marine Tanker Unloading: 1,820 tons of HC Marine Tanker Loading: 2,810 tons of HC
Water	Brine Disposal: Produced during solution mining - 4.8×10^{10} gal. Produced during displacement - 6.5×10^{9} gal. with oil (one refill) Area affected if brine disposed of in the Gulf during solution mining and subsequent cycling: Maximum area of 1 ppt increase in salinity (assumes no vertical mixing) - 773 acres Water requirements: Required for solution mining - 3.9×10^{10} gal. fresh water, or 4.2×10^{10} gal. sea water Required for displacement - 6.6×10^{9} gal. fresh water, or (one emptying) 6.3×10^{9} gal. sea water	Brine Disposal: Produced during solution mining - none Produced during displacement - 7.2×10^{9} gal. with oil (initial fill) Area affected if brine disposed of in the Gulf during initial fill and subsequent cycling: Maximum area of 1 ppt increase in salinity (assumes no vertical mixing) - 850 acres Water requirements: Required for solution mining - none Required for displacement - 7.2×10^{9} gal. fresh water, or 7.0×10^{9} gal. sea water
Land Use	195 acres	248 acres
	Effects of Construction: Direct Expenditure** - $189-$234 Total Economic Impact - $533-$656 Total Employment*** - 336-536 man-years Total Increase in Personal Income - $144-$177 Effects of Operation: Direct Expenditure - $.94 per year (1) Total Economic Impact - $2.3 per year (1) Total Employment*** - 47 persons (1) Total Increase in Personal Income - $.63 per year (1)	Effects of Construction: Direct Expenditure - $165-$248 Total Economic Impact - $462-$711 Total Employment*** - 1,306-2,612 Total Increase in Personal Income - $126-$188 Effects of Operation: Direct Expenditure - $1.9 per year (2) Total Economic Impact - $4.7 per year (2) Total Employment*** - 94 persons (2) Total Increase in Personal Income - $1.3 per year (2)

*All emissions on an annual basis
**All dollar amounts in millions of dollars
***Includes direct, indirect, and induced employment

TABLE V-34 (Cont.d)

CUMULATIVE IMPACTS - MAXIMUM
LOCAL STORAGE OF PRODUCT (EXPECTED)

	Gulf Coast: 70 MMB of Crude in Existing Salt Mines	East Coast: 20 MMB of Crude in Existing Rock Mines
Air*	Marine Tanker Unloading: 771 tons of HC Marine Tanker Loading: 1,191 tons of HC	Marine Tanker Unloading: 220 tons of HC Marine Tanker Loading: 230 tons of HC
Water	Minor Impacts	Minor Impacts
Land Use	50 acres (1)	100 acres (2)
Socio-Economic	Effects of Construction: Direct Expenditure** - $63-$105 Total Economic Impact - $177-$295 Total Employment*** - 1,750 man-years Total Increase in Personal Income - $47-$78 Effects of Operation: Direct Expenditure - $.19 per year (1) Total Economic Impact - $.47 per year (1) Total Employment *** - 1 person (1) Total Increase in Personal Income - $.13 per year (1)	Effects of Construction: Direct Expenditure - $9.8-$23 Total Economic Impact - $30-$71 Total Employment*** - 1,400 man-years Effects of Operation: Direct Expenditure - $.17 per year. (2) Total Economic Impact - $.17 per year (2) Total Employment*** - 2 persons (2) Total Increase in Personal Income - $0.10 per year (2)

*All emissions on an annual basis
**All dollar amounts in millions of dollars
***Includes direct, indirect, and induced employment

TABLE V-35

CUMULATIVE IMPACTS - MAXIMUM
SUBSTITUTION OF CRUDE OIL (WORST-CASE)

	Gulf Coast: 500 MMB of Crude in New Solution Caverns	No East Coast Storage
Air*	Marine Tanker Unloading: 5,506 tons of HC Marine Tanker Loading: 8,506 tons of HC	
Water	Brine Disposal: Produced during solution mining - 1.6 x 10^{11} gal. Produced during displacement - 2.2 x 10^{10} gal. with oil (one refill) Area affected if brine disposed of in the Gulf during solution mining and subsequent cycling: Maximum area of 1 ppt increase in salinity (assumes no vertical mixing) - 2,580 acres Water requirements: Required for solution mining - 1.3 x 10^{11} gal. fresh water - 1.4 x 10^{11} gal. sea water Required for displacement - 2.2 x 10^{10} gal. of fresh water (one emptying) - 2.1 x 10^{10} gal. of sea water	
Land Use	650 acres	
Socio-Economic	Effects of Construction: Direct Expenditure** - $630-780 Total Economic Impact - $1,780-$2,180 Total Employment*** - 1,070-1,780 man-years Total Increase in Personal Income - $480-$590 Effects of Operation: Direct Expenditure - $2.8 per year (3) Total Economic Impact - $7.0 per year (3) Total Employment*** - 141 persons (3) Total Increase in Personal Income - $1.9 per year (3)	

*All emissions on an annual basis
**All dollar amounts in millions of dollars
***Includes direct, indirect, and induced employment

TABLE V-36
CUMULATIVE IMPACTS - MAXIMUM
SUBSTITUTION OF CRUDE OIL (EXPECTED)

	Gulf Coast: 200 MMB of Crude in New Solution Caverns	Gulf Coast: 160 MMB of Crude in Existing Solution Caverns
Air*	Marine Tanker Unloading: 2,202 tons of HC Marine Tanker Loading: 3,402 tons of HC	Marine Tanker Unloading: 1,762 tons of HC Marine Tanker Loading: 2,722 tons of HC
Water	Brine Disposal: Produced during solution mining - 6.5×10^{10} gal. Produced during displacement - 8.6×10^{9} gal. with oil (one refill) Area affected if brine disposed of in the Gulf during solution mining and subsequent cycling: Maximum area of 1 ppt increase in salinity (assumes no vertical mixing) - 1,030 acres Water requirements: Required for solution mining - 5.2×10^{10} gal. fresh water - 5.7×10^{10} gal. sea water Required for displacement - 8.8×10^{9} gal. fresh water - 8.5×10^{9} gal. sea water	Brine Disposal: Produced during solution mining - none Produced during displacement - 6.9×10^{9} gal. with oil (initial fill) Area affected if brine disposed of in the Gulf during initial fill and subsequent cycling: Maximum area of 1 ppt increase in salinity (assumes no vertical mixing) - 820 acres Water requirements: Required for solution mining - none Required for displacement - 7.0×10^{9} gal. fresh water (one emptying) - 6.8×10^{9} gal. sea water
Land Use	260 acres	240 acres
Socio-Economic	Effects of Construction: Direct Expenditure** - $256-$312 Total Economic Impact - $710-$874 Total Employment*** - 4,480-7,140 man-years Total Increase in Personal Income - $192-$236 Effects of Operation: Direct Expenditure - $.94 per year (1) Total Economic Impact - $2.3 per year (1) Total Employment*** - 47 persons (1) Total Increase in Personal Income - $.63 per year (1)	Effects of Construction: Direct Expenditure - $160-$240 Total Economic Impact - $448-$672 Total Employment*** - 1,270-2,540 man-years Total Increase in Personal Income - $122-$183 Effects of Operation: Direct Expenditure - $2.8 per year (3) Total Economic Impact - $7.0 per year (3) Total Employment*** - 141 persons (3) Total Increase in Personal Income - $1.9 per year (3)

*All emissions on an annual basis
**All dollar amounts in millions of dollars
***Includes direct, indirect, and induced employment

TABLE V-36 (Cont.d)
CUMULATIVE IMPACTS - MAXIMUM
SUBSTITUTION OF CRUDE OIL (EXPECTED)

	Gulf Coast: 120 MMB of Crude in Existing Salt Mines	East Coast: 20 MMB of Crude in Existing Rock Mines
Air*	Marine Tanker Unloading: 1,321 tons of HC Marine Tanker Loading: 2,041 tons of HC	See Table V-34 (page V-127)
Water	Minor Impacts	
Land Use	100 acres (2)	
Socio-Economic	Effects of Construction: Direct Expenditure** - $108-$180 Total Economic Impact - $303-$506 Total Employment*** - 3,000 man-years Total Increase in Personal Income - $80-$134 Effects of Operation: Direct Expenditure - $.38 per year (2) Total Economic Impact - $.94 per year (2) Total Employment*** - 1 person (2) Total Increase in Personal Income - $.26 per year (2)	

*All emissions on an annual basis
**All dollar amounts in millions of dollars
***Includes direct, indirect, and induced employment

D. Oil Spills

Because of the potential for adverse temporary effects upon ecosystems due to oil spills, and the public sensitivity to this issue, the risk of such spills has been given a more comprehensive treatment and impact evaluation than some other aspects of the program. Because SPR oil spills are a possibility on both the Gulf and East Coasts, they are treated in this separate section to avoid redundancy, although different subsections focus on the individual regions. Significantly increased transportation of crude oil and petroleum products to and from port facilities is the aspect of the proposed SPR program that creates the most substantial risk of spillage.

A facility which handles, processes, transports, or stores petroleum has the potential to discharge the material accidentally into adjacent waters. This section discusses the likelihood and potential impacts of oil spills; resources for controling and cleaning up spilled oil are addressed in Chapter VI, Section A.10. as mitigating measures. The following major subsections comprise this discussion.

- Oil Spill Statistical Analysis
- Behavior of Petroleum in the Marine Environment
- Ecological Impacts
- Ecological Effects of Onshore Spills
- Ecological Effects of Spills of Refined Products
- Regional Overviews

1. Oil Spill Statistical Analysis

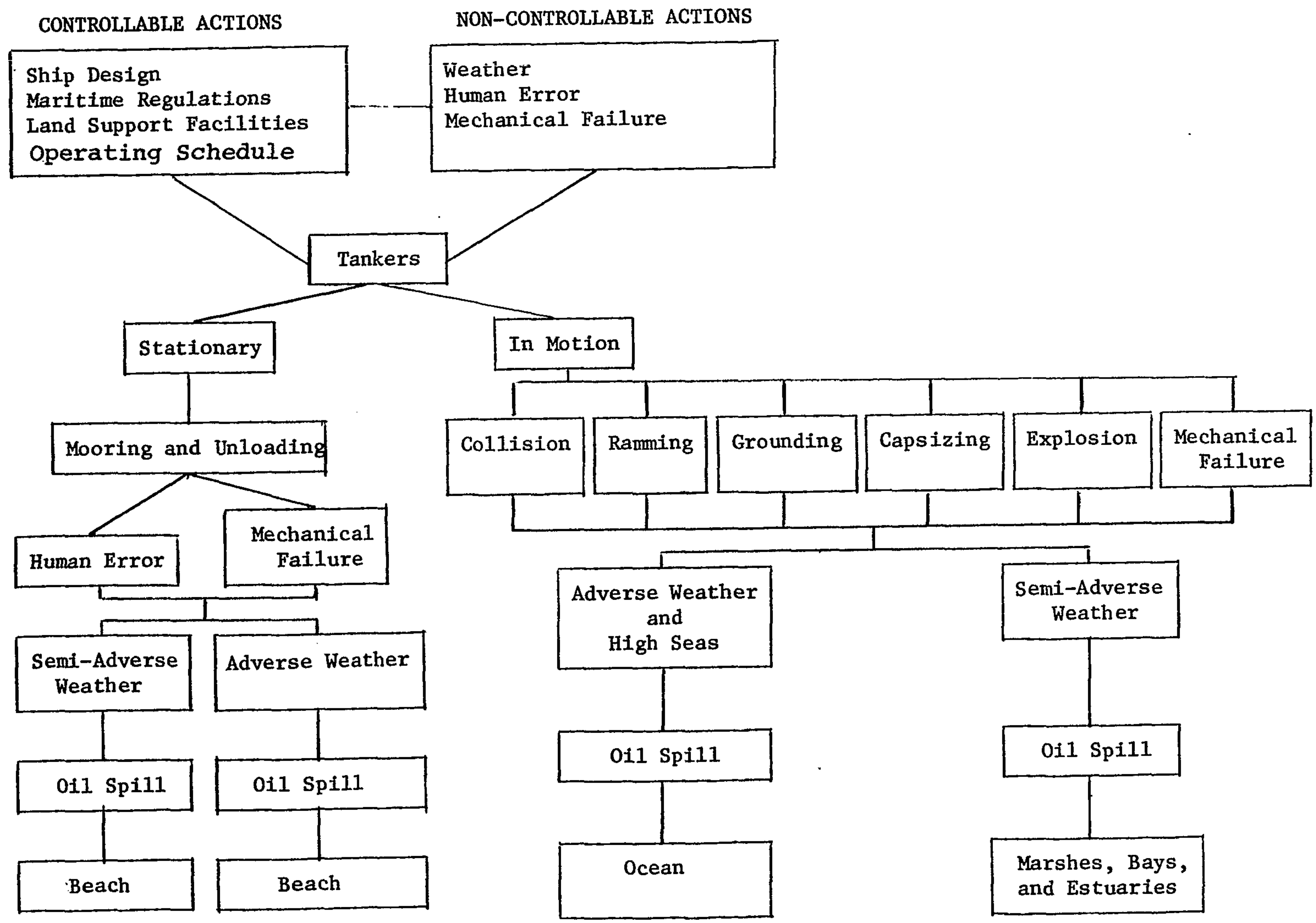
The transporting and processing of crude petroleum involves potential economic and environmental impacts as a result of oil spills. Oil spills, or the unwanted discharge of crude petroleum into the environment, can occur because of a multiplicity of unlikely events. These have been magnified by the high publicity of several incidents such as the grounding of the tanker Torrey Canyon on the English coast in 1967 and the blowout of an oil well in the Santa Barbara, California, channel in 1969. The Torrey Canyon discharged 714,000 barrels of crude oil and the Santa Barbara incident released 16,700 barrels of oil. Because of these and other damaging mishaps, oil spill prevention has become a major concern to those involved in drilling, transporting, and processing crude oil. It would be advantageous, both logistically and economically, to have crude oil reserves and processing complexes close together; however, in many cases, the feedstock for petroleum refineries must be transported long distances. It is through the transportation process that many oil spills occur. Technology related to the prevention and reclamation of natural systems affected by oil spills has increased in recent years. However, the danger of spills, their potential impacts on ecosystems, and the costs involved are still of major concern.

The following discussion deals exclusively with oil spills from tankers. Oil stored in all of the potential types of facilities considered for the Strategic Petroleum Reserve will be delivered at least partially by tanker during the filling stages. In the event of an emergency, oil will be transported out of the storage facility to refineries either by pipelines or by tankers through an on-shore terminal connected to the storage facility by short pipelines. The risks and impacts of catastrophic pipeline spills, which are minimized by effective fail-safe design features, will be discussed in site-specific EIS's.

It is the purpose of this section to analyze the likelihood of an oil spill from tankers of various sizes based on four different transport scenarios. The quantity of oil that may be discharged into the environment is also an important factor to consider. Predicting potential oil spills from tanker accidents is tantamount to attempting to predict earthquakes, floods, and other natural disasters. There has been little analysis and predictive methodology developed in this area of concern. The analysis used in this section will be based on published data from the United States Coast Guard and other knowledgeable entities. The scenarios set forth are those developed by the Federal Energy Administration for purposes of comparison of a representative set of conditions. At the outset, it may be helpful to refer to Figure V-9, which is a diagram of the relationship of the factors involved in a tanker mishap and which determine the severity of resulting oil spills. The analysis will be directed toward both parts of the diagram, i.e., those tankers in motion and those which are stationary and in the process of unloading.

a. Background

Tables V-37 and V-38 list some general characteristics of various sizes of tankers which will be a part of the analysis. Various natural and man-made facilities govern the capability of domestic and international ports to serve different size tankers. For example, in Texas, which contains 25 percent of the nation's petroleum refinery capacity, there are no deepwater port facilities. (A deepwater port is one with a channel depth of 65-70 feet or more.) In the United States, there are presently no deepwater ports capable of serving supertankers or VLCC's (very large crude carriers). Although there are some ports such as Long Beach, California which could provide access for VLCC's if some moderate changes were made, and deepwater ports have been proposed for construction at several locations along the Gulf,



Sources: DA-166, DU-096.

FIGURE V-9

TANKERS-OIL SPILL FLOW DIAGRAM

FIGURE V-9 (Cont.)

TERMINOLOGY

1. Stationary - a tanker either moving in the bay/port or unloading at dockside terminal or at offshore terminal.

2. In-motion - a tanker in the act of moving from one point to another; not unloading or mooring.

3. Collision - an impact of tanker and a fixed object; dock or terminal.

4. Ramming - an impact of two oceangoing vessels.

5. Grounding - landing of a tanker on the ocean floor caused by operating in shallow waters.

6. Capsizing - overturning of tanker due to high seas and inclement weather.

7. Explosion - an explosion or fire on a tanker.

8. Adverse weather/high seas - weather extremely hazardous to safe maritime operations; wave lengths over 30 feet.

9. Semi-adverse weather - weather hazardous to safe maritime operation.

10. Ocean - those waters outside bays, estuaries, and land; saline water; high seas.

11. Bays - area separated from open seas and marshland with restricted circulation of fresh and saline water.

12. Marsh - always has emergent grasses; can be fresh, brackish, or saltwater; edge of bay/estuary, river mouth, ocean - near fresh-saline water interface.

13. Beach - interface of land and water subject to ebb and flow of tide; subject to wave impact intervals; usually sand

TABLE V-37

STATISTICAL DATA - TANKER SIZE

Item	Small Tanker	Medium Tanker	Very Large Crude Carrier	Ultra Large Crude Carrier
1. Size	35,000 DWT	55,000 DWT	250,000 DWT	400,000 DWT
2. Draft (feet) loaded	35-40	40-50	65-70	80-90
3. Terminal Areas	Inner Areas of Major Harbors	Outer Areas of Major Harbors	Deepwater Ports Offshore Terminals	Offshore Terminals
4. Risk of Oil Reaching Shore from:				
a. Routine Operation				
1. terminals	highest	high	intermediate	lowest
2. tankers	highest	high	lowest	lowest
b. Accidents				
1. terminals	highest	high	intermediate	intermediate
2. tankers	highest	high	lowest	high

Source: US-124

TABLE V-38

CRUDE OIL CAPACITY OF TANKERS

Size of Tankers 1000 dwt	Capacity Range 1000 bbls	Mean Range 1000 bbls
0 - 30	0 - 218	109
30 - 70	218 - 508	363
70 - 150	508 - 1,088	798
150 - 250	1,088 - 1,813	1,450
300 +	2,175 +	

Source: Capacity was determined using a factor of 7.25 bbl per dead weight ton. This coefficient was derived from unpublished data provided by former staff members of the Texas Offshore Terminal Commission and from Environmental Analysis: Louisiana Offshore Oil Port, Dames and Moore, October, 1975.

Coast, the scenarios will be analyzed without regard to the availability of a deepwater port facility in the United States.

Table V-39 lists data provided by the United States Coast Guard relative to the number of spills in recent years in United States waters. The data show that the most likely occurrence of a spill is in Gulf Coast waters, probably because of the heavy tanker traffic in that region to and from the vast refining complex in Texas and Louisiana. The quantity of oil spilled is not a direct function of the number of occurrences. For example, the Gulf Coast area accounted for one third of the number of spills in 1973-74 but only 16-23 percent of the total volume of oil spilled.

Table V-40 lists data relative to the location of spills in United States waters. The data show that most spills occurred in coastal waters as opposed to inland waters and high seas.

Data relative to the causes associated with spills are presented in Table V-41. The two most frequent kinds of spills are those involving hull/tank ruptures and tank overflows.

The quantity of spillage from a tanker is a function of the type of accident, type of fluid discharged, and recovery procedures. Accidents in United States waters have been few relative to those accidents worldwide. There has never been a complete loss of a loaded tanker in United States coastal waters. Thus, spill factors relative to tankers operating in United States waters are somewhat lower than those tankers operating worldwide. The amounts of oil spilled per event in United States waters are also significantly lower than those in international waters. There are various reasons for these differences. First weather and geographic conditions in the United States are more conducive to safe tanker operations than conditions worldwide. Also,

TABLE V-39

GEOGRAPHIC AREAS OF OIL SPILLS*

GENERAL AREA	NUMBER OF SPILLS		PERCENT OF TOTAL		VOLUME IN BARRELS		PERCENT OF TOTAL	
	1973	1974	1973	1974	1973	1974	1973	1974
Atlantic Coast	3,505	3,517	26.3	25.2	100,734	72,110	17.4	17.9
Gulf Coast	4,422	4,470	33.2	32.0	90,217	92,005	15.6	22.9
Pacific Coast	3,173	2,715	23.8	19.4	203,363	11,749	35.1	2.9
Other Areas	2,228	3,264	16.7	23.4	184,611	226,736	31.9	56.3
TOTAL	13,328	13,966	100.00	100.00	578,925	402,600	100.0	100.0

TABLE V-40

TYPE OF LOCATION FOR OIL SPILLS*

LOCATION	NUMBER OF SPILLS		PERCENT OF TOTAL		VOLUME IN BARRELS		PERCENT OF TOTAL	
	1973	1974	1973	1974	1973	1974	1973	1974
COASTAL WATERS								
Bays, Estuaries and Sounds	1,511	2,519	11.3	18.0	13,668	7,665	2.4	1.9
Ports	4,590	4,783	34.4	34.3	58,045	129,337	10.0	32.1
River Areas	3,279	1,681	24.6	12.0	227,904	37,420	39.4	9.3
Other	1,062	771	8.0	5.5	79,190	13,924	13.7	3.5
Subtotal	10,442	9,754	78.3	68.8	378,807	188,346	65.5	46.8
INLAND WATERS								
Ports	463	617	3.5	4.4	5,372	9,631	0.9	2.4
River Areas	777	826	5.8	5.9	120,920	35,059	20.9	8.7
Other	482	1,372	3.6	9.8	43,167	167,899	7.4	41.7
Subtotal	1,722	2,815	12.9	20.2	169,459	212,589	29.2	52.8
CONTIGUOUS ZONE AND HIGH SEAS	1,164	1,397	8.7	10.0	30.662	1,834	5.3	0.4
TOTAL	13,328	13,966	99.9	100.0	578,928	402,769	100.0	100.0

*Sources: US-250, US-263

TABLE V-41

CAUSES OF TANK BARGE AND TANK SHIP OIL SPILLS*

CAUSE	NUMBER OF SPILLS 1973	NUMBER OF SPILLS 1974	PERCENT OF TOTAL 1973	PERCENT OF TOTAL 1974	VOLUME IN BARRELS 1973	VOLUME IN BARRELS 1974	PERCENT OF TOTAL 1973	PERCENT OF TOTAL 1974
Hull/tank rupture/ leak	396	486	25.7	27.0	87,167	77,307	61.7	83.2
Transportation pipeline rupture/ leak	8	6	0.5	0.3	717	18	0.5	0.0
Other structural	27	34	1.8	1.9	61	90	0.0	0.1
Pipe rupture/leak	28	54	1.8	3.0	163	44	0.1	0.0
Hose rupture/leak	63	57	4.1	3.2	925	234	0.6	0.3
Valve failure	126	120	8.2	6.7	537	722	0.4	0.3
Pump failure	15	18	1.0	1.0	25	19	0.0	0.0
Other rupture/leak	19	19	1.2	0.8	329	154	0.2	0.2
Other equipment failure	129	134	8.4	7.4	809	712	0.6	0.8
Tank overflow	298	366	19.3	20.3	1,619	2,916	1.1	3.1
Improper valve operation	54	58	3.5	3.2	341	552	0.2	0.6
Improper hose handling	41	33	2.7	1.8	39	62	0.0	0.1
Other improper equipment handling	63	81	4.1	4.5	292	97	0.2	0.1
Other personnel error	81	106	5.2	5.9	189	1,282	0.1	1.[illegible]
Bilge pumping	48	75	3.1	4.2	5,135	950	3.6	1.0
Ballast pumping	10	15	0.6	0.8	35,868	41	24.8	0.0
Other intentional discharge	21	22	1.4	1.2	67	25	0.1	0.0
Natural or chronic phenomenon	7	4	0.4	0.2	2	0	0.0	0.0
Unknown	109	116	7.1	6.4	8,150	7,647	5.6	8.2
TOTAL	1,543	1,799	100.1	99.8	144,435	92,872	99.8	99.9

*Sources: US-250, US-263.

maritime activity in the United States is more strictly governed with respect to safety regulations and the prevention of accidents. As shown in Figure V-10, explosions are the most significant cause of oil spills in the United States.

b. Scenario Analysis

In order to analyze the probability of oil spills as they relate to the shipment of crude oil in the Strategic Petroleum Reserve Program, it was necessary to postulate scenarios. The four scenarios selected represent a cross-section of normal tanker activity.

For each scenario it was desirable to estimate the number of tanker mishaps which could occur as well as the expected amount of oil spilled during the 18-month process of amassing the Strategic Petroleum Reserve at a given site. Since accident rates are related to tanker size, the total number of accidents (N_T) in a given scenario may be represented as:

$$N_T = \sum_{i=1}^{n} N_i$$

where N_i = total accidents involving tankers of size class i,

and $$N_i = \sum_{j=1}^{n} r_j \, Y_i$$

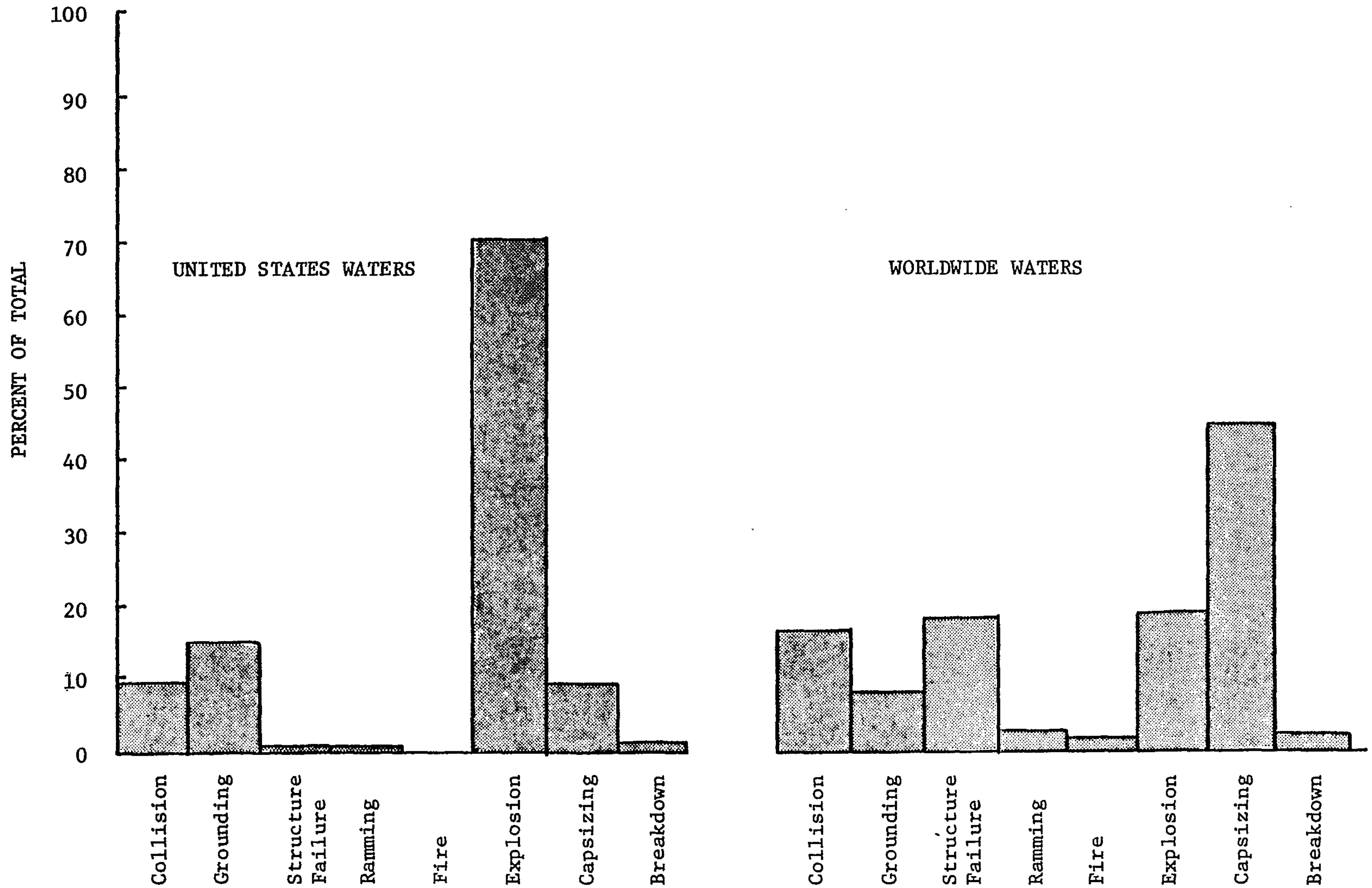
where r_j = observed rate of accidents of the j^{th} type per vessel-year

Y_i = total vessel-years for i^{th} size-class tankers.

Each scenario must specify the size of tanker used and the distance travelled by each. Then, knowing the capacity of

FIGURE V-10

1971-1972
SPILLAGE FACTORS - MEAN LOSS IN BBLS*



*In order to obtain % distribution, data in Table 7 were summarized for United States and Worldwide sectors; then a % distribution was obtained by dividing each entry into the sum total.

each size of tanker and its rate of speed, the total number of vessel-years required may be calculated. Accident rates are taken from Table V-42 and used to calculate total numbers of accidents. Worldwide figures are considered appropriate since tankers are assumed to carry Middle East crude. Table V-43 displays mean oil losses and are used to estimate the differential oil losses among the various scenarios.

In addition to the specific assumptions made for each scenario, several general assumptions were made for all scenarios. There are:

- All scenarios begin in the Middle East and end at the Gulf Coast. This is a worst-case assumption, recognizing that the Gulf Coast historically has the highest tanker accident rate in the United States, and that the distance travelled by the tankers is the longest that could reasonably be expected.

- Only crude oil is carried on the tankers

- There is no limit to the availability of tankers. This is a simplifying assumption which tends to maximize the number of vessel-years used in each scenario calculation.

- Normal maintenance down-time is an insignificant fraction of the total operating life of any vessel. This is also a simplifying assumption, which tends to minimize the total number of vessel-years required for each scenario.

- Adequate docking facilities exist for tankers of all sizes.

TABLE V-42

WORLDWIDE ANNUAL AVERAGES OF CATASTROPHIC POLLUTING INCIDENTS IN 1971 AND 1972 BY CERTAIN VESSEL SIZE CATEGORIES AND TYPES OF ACCIDENTS

Size of Vessel / Type of Accident	ANNUAL ACCIDENT RATE (Per Vessel-Year Exposure)			Number of Accidents
	20,000-30,000 DWT	30,000-70,000 DWT	Over 200,000 DWT	Category Totals
Collision	.00258	.00917	.00568	21
Grounding	.00164	.01427	.01136	23
Structural Failure	.00164	.01325	.01136	22
Ramming	.00117	.00306	.01136	10
Fire	.00047	.00306	.01705	8
Explosion	.00117	.00510	.00568	11
Capsizing	.00047	.00102	NONE	3
Annual Frequency of Accidents	.00914	.04893	.06249	
Total Accidents in 1971 and 1972	39	48	11	98
Percent of All Accidents Considered	40%	49%	11%	
Percent of World Fleet Considered	79%	18%	3%	

Source: Derived from data base presented in HE-205

TABLE V-43

NUMBER OF ACCIDENTS AND OIL LOSSES
IN THREE VESSEL SIZE CATEGORIES AND BY ACCIDENT TYPE

Vessel Size and Type of Accident	Total No. Polluting Casualties*	Mean Spill Size (bbls) (7.25bbl=1T)	Range of Spill Sizes (bbls)
20,000-30,000 DWT			
Collision	11	4,685	138-22,113
Grounding	7	21,960	109-145,000
Structural Failure	7	80	36-87
Ramming	5	1,798	979-3,625
Fire	2	1,990	355-3,625
Explosion	5	6,547	471-20,481
Capsizing	2	2,864	877-4,850
30,000-70,000 DWT			
Collision	9	1,432	435-7,975
Grounding	14	2,551	341-10,150
Structural Failure	13	24,029	87-290,000
Ramming	3	677	73-379
Fire	3	249	36-355
Explosion	5	63,197	471-22,994
Capsizing	1	246,500	- -
Over 200,000 DWT			
Collision	1	1,450	- -
Grounding	2	4,531	1,813-7,250
Structural Failure	2	406	87-725
Ramming	2	1,450	1,450
Fire	3	261	73-355
Explosion	1	471	- -

*Exclusive of those incidents where oil was deliberately discharged after a casualty

Source: HE-205

There are two basic routes that may be used in transporting Mideast crude oil to the United States. The shorter distance is from the Mediterranean, then through the Straits of Gibraltar past Florida and to the Gulf Coast. The longer distance is from the Persian Gulf around the Cape of Good Hope through the Straits of Florida to the Gulf Coast area. Only tankers of no more than 50-60,000 DWT capacity can use the shorter route. In some cases, the port of origin could be in the Persian Gulf and the route would be through the Suez Canal, thus eliminating VLCC traffic. The greatest danger of an oil spill reaching land along the routes could occur at the Straits of Gibraltar, the Straits of Florida, in the Cape of Good Hope area, or at a transshipment unloading facility in the Caribbean Sea. This does not include any mishap which may occur at the port of origin or destination. At any other point along the route, the tankers would be at high sea where a spill would have little chance of reaching land.

The preceding Tables V-42 and V-43 summarize oil spill experience in 1971 and 1972 (considered not atypical years) by accident type and by tanker size categories that are of interest in the scenario analyses. The data concern oil losses from ship casualties and do not consider oil losses that result from mismanagement of normal operations, since the losses typically are very small in comparison to catastrophic casualties and would inordinately skew the frequency analysis. The data base from which these numbers have been extracted is small for tankers greater than 200,000 DWT in size, and therefore the data should be used with particular caution in analyzing VLCC risks. The mean spill sizes derived from these experiences are small in comparison to the total cargoes carried by these vessels, and no more than three incidents of any one type were recorded. Within accident categories, many factors can influence the amount of damage sustained and amount of oil spilled, and without a much larger number of incidents of each type for VLCC's, it is not possible to place a large degree of confidence either in observed accident frequencies or amounts of oil spilled. In the absence of a more comprehensive, representative data base, however, a graph that compares expected accident rates with mean spill sizes has been prepared for each scenario. Since accident frequencies are calculated on a vessel-year basis, multiplying the ordinate and abcissa of these graphs does not produce a quantitative true estimate of total oil expected to be spilled.

1. Scenario A

The first situation to be considered involves small and medium-sized tankers only. Assume that the specifications of the tankers are 25,000 DWT and 50,000 DWT, with carrying capacities of approximately 180,000 and 360,000 barrels of crude petroleum, respectively. The route used by the tankers is from the Middle East through the Mediterranean Sea and Atlantic Ocean to the Gulf of Mexico. Approximate average speed of the tanker is 15 knots. The destination of the tanker is a Texas port capable of handling tankers of this size - assume the docking facilities at Port Arthur, Texas.

The target of the Strategic Petroleum Reserve Program is transferring 500 million barrels of oil to underground salt dome deposits. Each scenario will be analyzed based on that method of shipment as being the only method in service. Shipping distances used as the basis for sailing time were obtained through personal communication with the Texas Offshore Terminal Commission and verified by Lykes Shipping Co.

It would take approximately 2762 trips to transport 500 million barrels of crude oil from the Mideast to storage facilities at Port Arthur in 25,000 DWT tankers. In 50,000 DWT tankers it would take 1389 trips. For purposes set forth in the scenario, assume that in this case the transportation of 500 million barrels of crude oil will be accomplished in 1111 trips by the 25,000 DWT tanker and 833 trips by the 50,000 DWT tanker. This assumes that 200 million barrels will be shipped in the smaller vessel and 300 million barrels in the larger vessel. The time period for these transactions is 18 months.

The statistical analysis for Scenario A is shown in Table V-44. The probability of accidents occurring in any of the four scenarios is highest for tankers in Scenario A. These estimates are higher largely because of the number of trips associated with transporting 500 million barrels of crude oil from the Middle East to the Gulf Coast storage region in smaller vessels. Based on recent experience, a total of about six accidents might be expected in the course of the 18-month fill period, most occurring near the two terminal points.

Figure V-11 graphically shows the relationship between accident type, mean spill size, and anticipated accident rate. Clearly the most likely mishaps associated with this scenario are grounding, structural failure, collision, and explosion, and these carry with them a reasonable expectation of the largest oil losses. No statistically significant differences are ascribed to the two vessel sizes. This scenario consequently has by far the highest likelihood of a large polluting incident.

2. Scenario B.

The second scenario to be considered involves transport in very large crude carriers (VLCC's), with lightering to small tankers for ultimate destination purposes. In this analysis, 200,000 DWT VLCC's will have a carrying capacity of 1,450,000 barrels of crude petroleum. Vessels for lightering are assumed to be entirely 50,000 DWT tankers, with capacities of about 360,000 barrels of crude.

TABLE V-44

ANALYSIS - SCENARIO A

Given: 45 days per trip

1111 trips by 25,000 DWT tanker, equivalent to 137 vessel-years

833 trips by 50,000 DWT tanker, equivalent to 103 vessel-years

Number of Onshore Port Exits /Entries: 1944 Exits in Mideast

1944 Entries in Gulf Coast

3888 Total

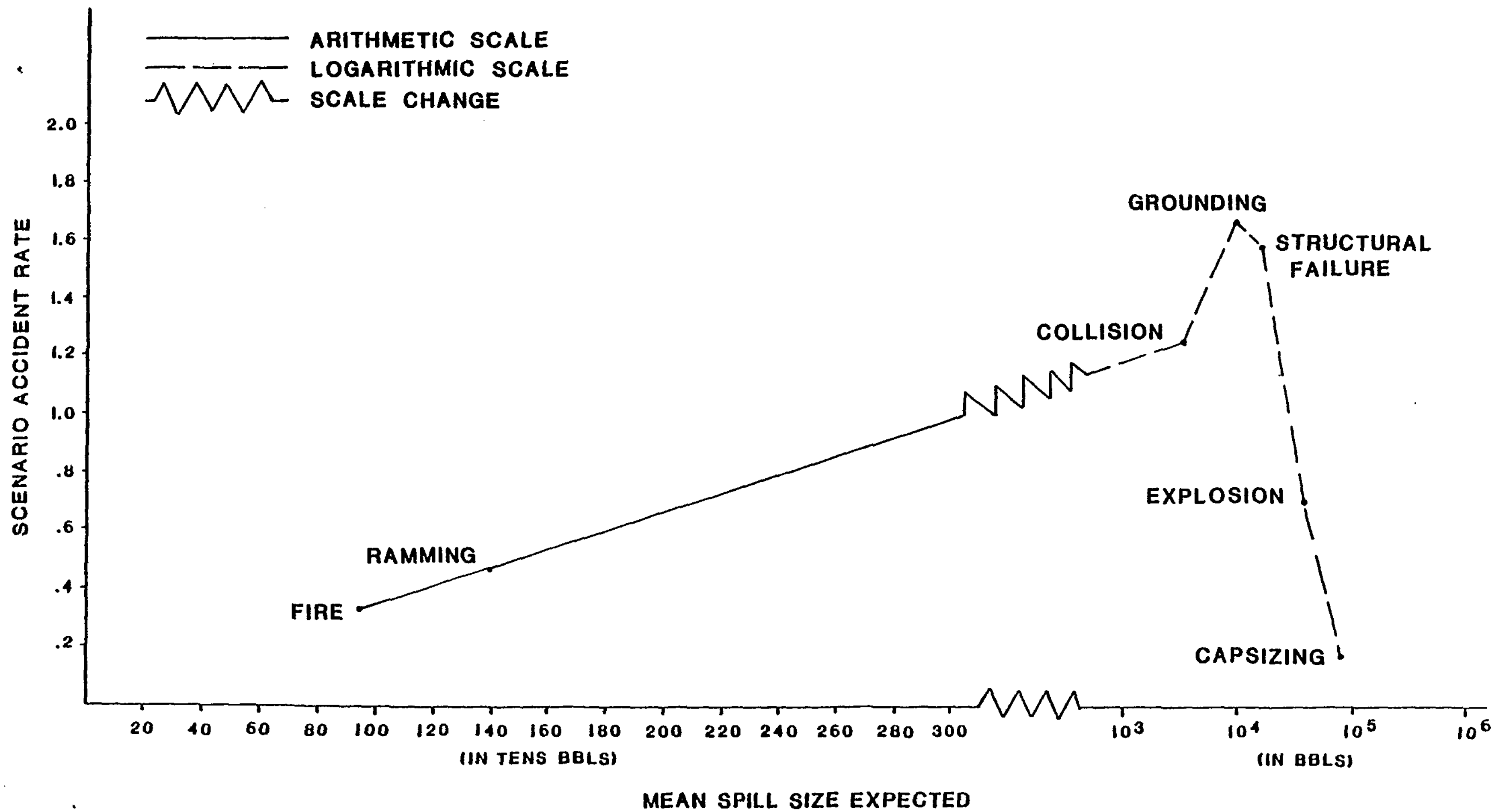
Number of At-Sea Transfers: None

FREQUENCY OF ACCIDENTS BY TYPE AND TANKER SIZE

	25,000 DWT		50,000	
Accident Type	Observed Accident Rate	Accidents/137 v-yrs	Observed Accident Rate	Accidents/103 v-yrs
Collision	.00258	.35	.00917	.94
Grounding	.00164	.22	.01427	1.47
Structural Failure	.00164	.22	.01325	1.36
Ramming	.00117	.16	.00306	.31
Fire	.00047	.06	.00306	.31
Explosion	.00117	.16	.00510	.53
Capsizing	.00047	.06	.00102	.11
Total Rate		1.23		5.03

Aggregated Total Accident Rate (Annual Basis) = 6.26 accidents in Scenario A

FIGURE V-11
MEAN SPILL SIZE FREQUENCY DISTRIBUTION FOR SCENARIO A



The statistical analysis of risk for Scenario B is shown in Table V-45. Figure V-12 portrays the calculated relationship between accident rate and mean spill size for this scenario. The probability of an accident in this scenario is next to lowest among the four scenarios, with about 4.0 accidents likely to occur. The most likely mishap is fire, which carries with it the smallest mean spill size; grounding and structural failure, followed closely by ramming, are equivalent in expected number of accidents, but have a very large range in amounts of oil spilled. Based on the 1971 and 1972 data, risk in terms of frequency per vessel-year appears to be not much different for the VLCC component than for the smaller tankers. However, the mean spill size for VLCC's is much lower. The cautions previously addressed with respect to the VLCC data should be recognized; specifically no major spills from VLCC's were recorded during the period of record under consideration, and therefore no basis exists for predicting the loss of the entire contents of one or more compartments on such a tanker. Such loss to coastal waters could have very great environmental consequences. Because of the VLCC's much longer journey, the VLCC leg contains the highest accident rate, even though its port entrances and exits are small in comparison to the lightering tankers. This dichotomy is discussed further in the following subsection.

3. <u>Scenario C</u>

The next scenario to be analyzed also involves VLCC's with transshipment to small tankers for transportation to ultimate destination. The VLCC's enroute from the Mideast would transfer crude oil to a terminal in the Caribbean. The crude oil would then be loaded on small tankers for shipment to the Gulf Coast storage region. The VLCC's to be used in this analysis would have specifications of 200,000 DWT with a carrying capacity of 1,450,000 barrels of crude petroleum. Approximate speed would be 15 knots and

TABLE V-45

ANALYSIS - SCENARIO B

Given:

60 days per VLCC trip[1]
345 trips by 200,000 DWT tanker, equivalent to 57 vessel-years
2 days per lightering trip (loaded)
1,389 trips by 50,000 DWT tanker, equivalent to 8 vessel-years

Number of Onshore Port Entries/Exits: 345 Exits in Mideast
1,389 Entries in Gulf Coast
1,734 Total

Number of At-Sea Transfers: 1,389 near Gulf Coast

FREQUENCY OF ACCIDENTS BY TYPE AND TANKER SIZE

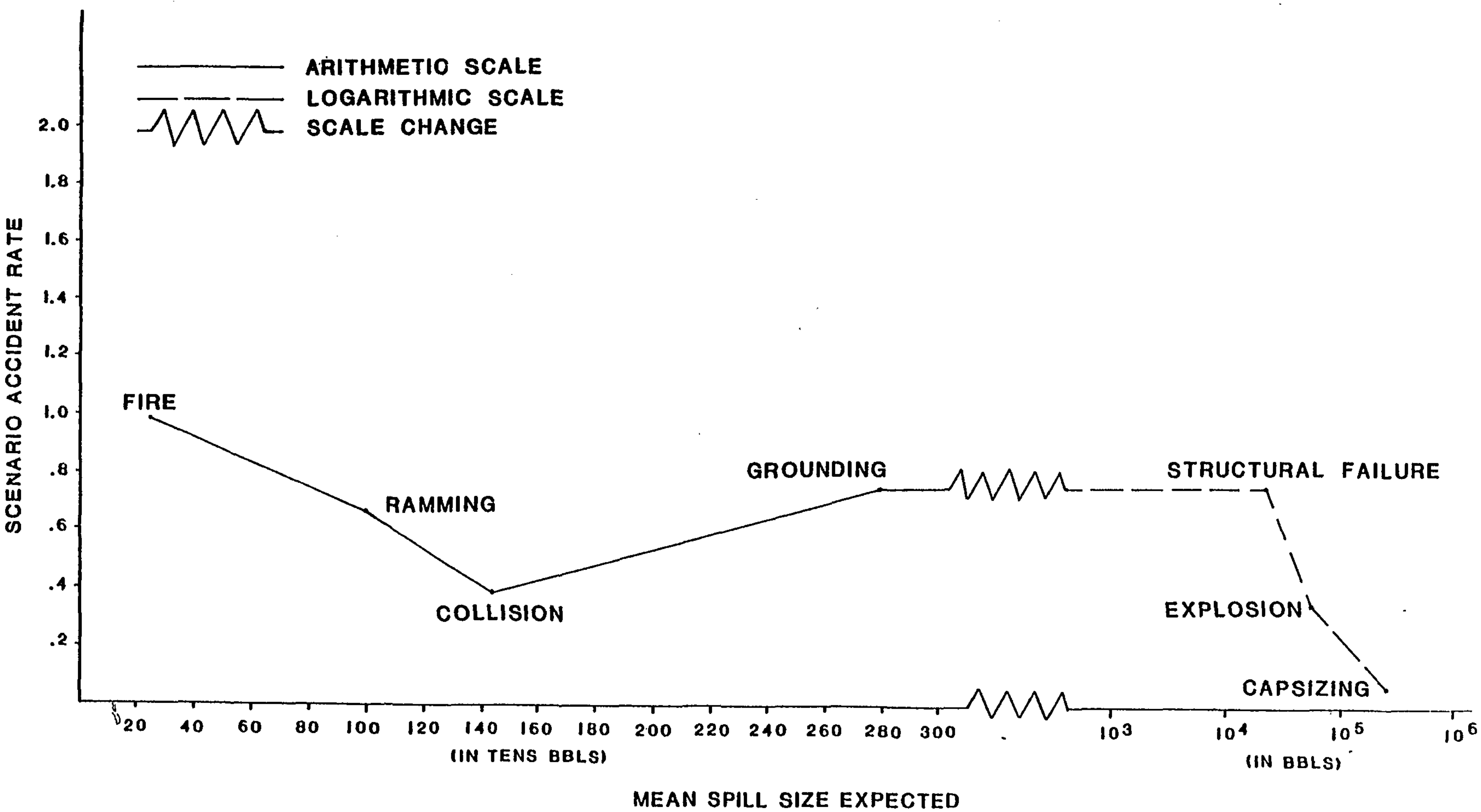
	200,000 DWT		50,000 DWT	
Accident Type	Observed Accident Rate	Accidents/57 Vessel Years	Observed Accident Rate	Accidents/8 Vessel Years
Collision	.00568	.32	.00917	.07
Grounding	.01136	.65	.01427	.11
Structural Failure	.01136	.65	.01325	.11
Ramming	.01136	.65	.00306	.02
Fire	.01705	.97	.00306	.02
Explosion	.00568	.32	.00510	.04
Capsizing	--	--	.00102	.08
		3.56 accidents		0.45 accidents

Aggregated Total Accident Rate (annual basis) = 4.01 accidents in Scenario B

[1]VLCC's are too deep to pass through the Suez Canal and must go around Cape of Good Hope

FIGURE V-12

MEAN SPILL SIZE FREQUENCY DISTRIBUTION FOR SCENARIO B



the transatlantic shipment would be accomplished over an 18-month period. This process would take approximately 345 trips. The small tankers that would be a part of the final transfer of the crude oil are assumed to be about 50,000 DWT. The final destination would be Port Arthur, Texas, dock facilities.

The statistical analysis for Scenario C is shown in Table V-46. The principal difference between the frequency analyses of Scenarios B and C is the longer time spent in the Caribbean-to-Gulf Coast leg. A total of 4.5 accidents is indicated for this scenario during the fill period, and the transshipment facility may be the critical site with respect to oil spill location. As shown in Figure V-13, grounding and structural failure are the most likely mishaps, and are associated with fairly large mean spill sizes; other mishaps that reasonably might be expected have much smaller spill sizes. Again, the VLCC component appears to be substantially about the same as the smaller tankers in overall accident rates, but the smaller mean spill size mitigates the risk with VLCC's. The VLCC component ultimately has the larger number of expected accidents due to the somewhat larger number of vessel-years required in the transatlantic crossing.

4. Scenario D

This analysis will be concerned with VLCC's with direct offloading to an offshore deepwater port in the Gulf of Mexico. For this analysis, the VLCC's are assumed to have specifications of 200,000 DWT and carrying capacities of 1,450,000 barrels of crude petroleum. Approximate average speed of the VLCC's is 15 knots.

The statistical analyses for Scenario D are summarized in Table V-47 and Figure V-14. Of the four scenarios, the least

TABLE V-46

ANALYSIS - SCENARIO C

Part A (Mideast to Caribbean via VLCC)

Given:

45 days per trip
345 trips by 200,000 DWT tanker, equivalent to 43 vessel-years

Number of onshore port exits/entries:

345	Exits in Mideast
345	Entries in Caribbean
1,389	Exits in Caribbean
1,389	Entries in Gulf Coast
3,368	Total

Number of At-Sea Transfers: None

FREQUENCY OF ACCIDENTS BY TYPE

Accident Type	Observed Accident Rate	Accidents per 43 Vessel-Years
Collision	.00568	.24
Grounding	.01136	.49
Structural Failure	.01136	.49
Ramming	.01136	.49
Fire	.01705	.73
Explosion	.00568	.24
Total Accident Rate		2.68

TABLE V-46 (Continued)

Part B (Caribbean to Gulf Coast)

Given:

10 days per trip
1389 trips by 50,000 DWT tanker, equivalent to 38 vessel-years

FREQUENCY OF ACCIDENTS BY TYPE

Accident Type	Observed Accident Rate	Accidents per 38 Vessel-Years
Collision	.00917	.35
Grounding	.01427	.54
Structural Failure	.01325	.50
Ramming	.00306	.12
Fire	.00306	.12
Explosion	.00510	.19
Capsizing	.00102	.04
Total Accident Rate		1.86

Aggregated Total Accident Rate (Annual Basis) = 4.54 Accidents in Scenario

FIGURE V-13
MEAN SPILL SIZE FREQUENCY DISTRIBUTION FOR SCENARIO C

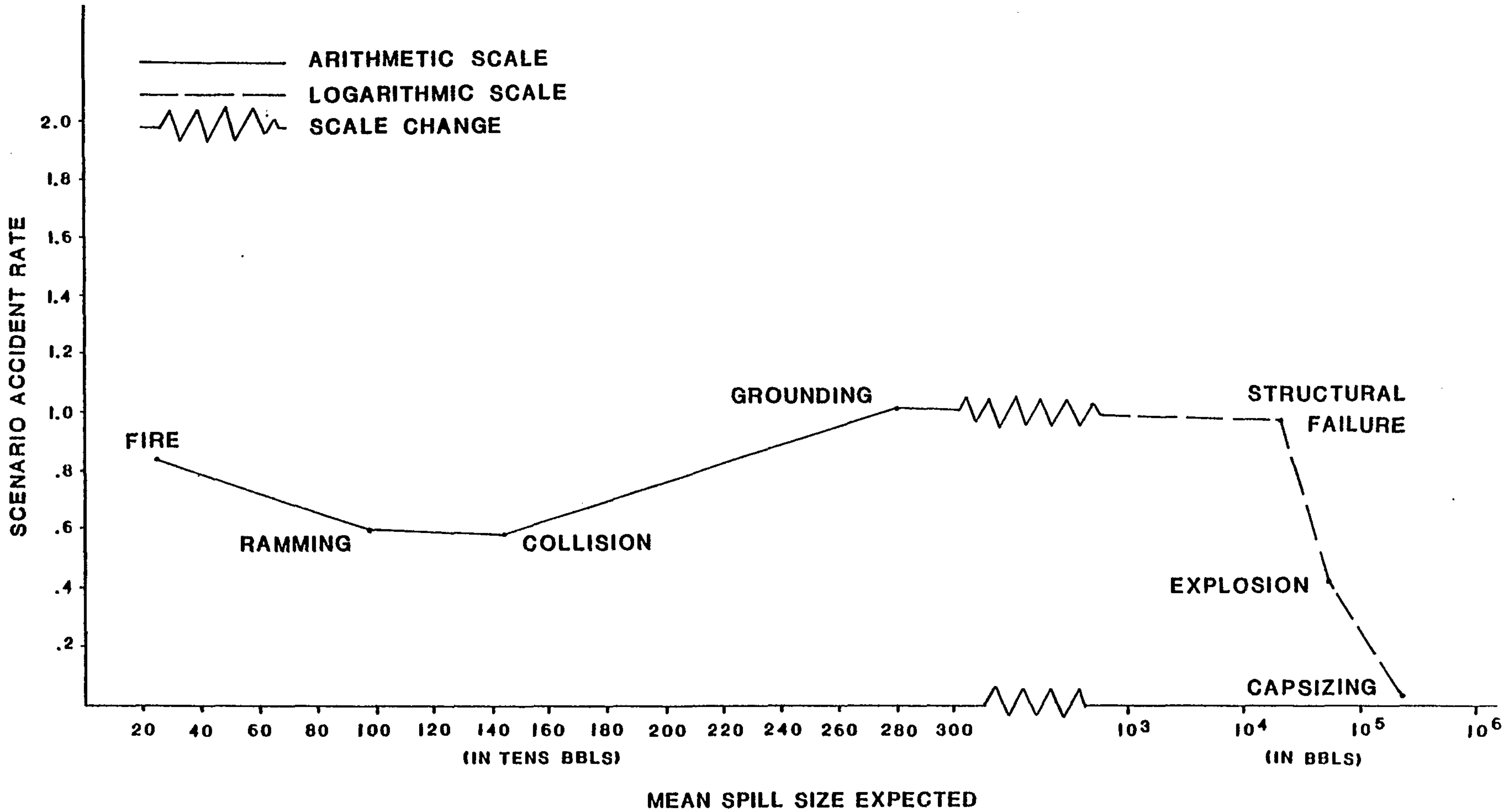


TABLE V-47

ANALYSIS - SCENARIO D

Given:

60 days per trip
345 trips by 200,000 DWT tanker, equivalent to 57 vessel-years

Number of Onshore Port Exits/Entries = 345 in Mid East

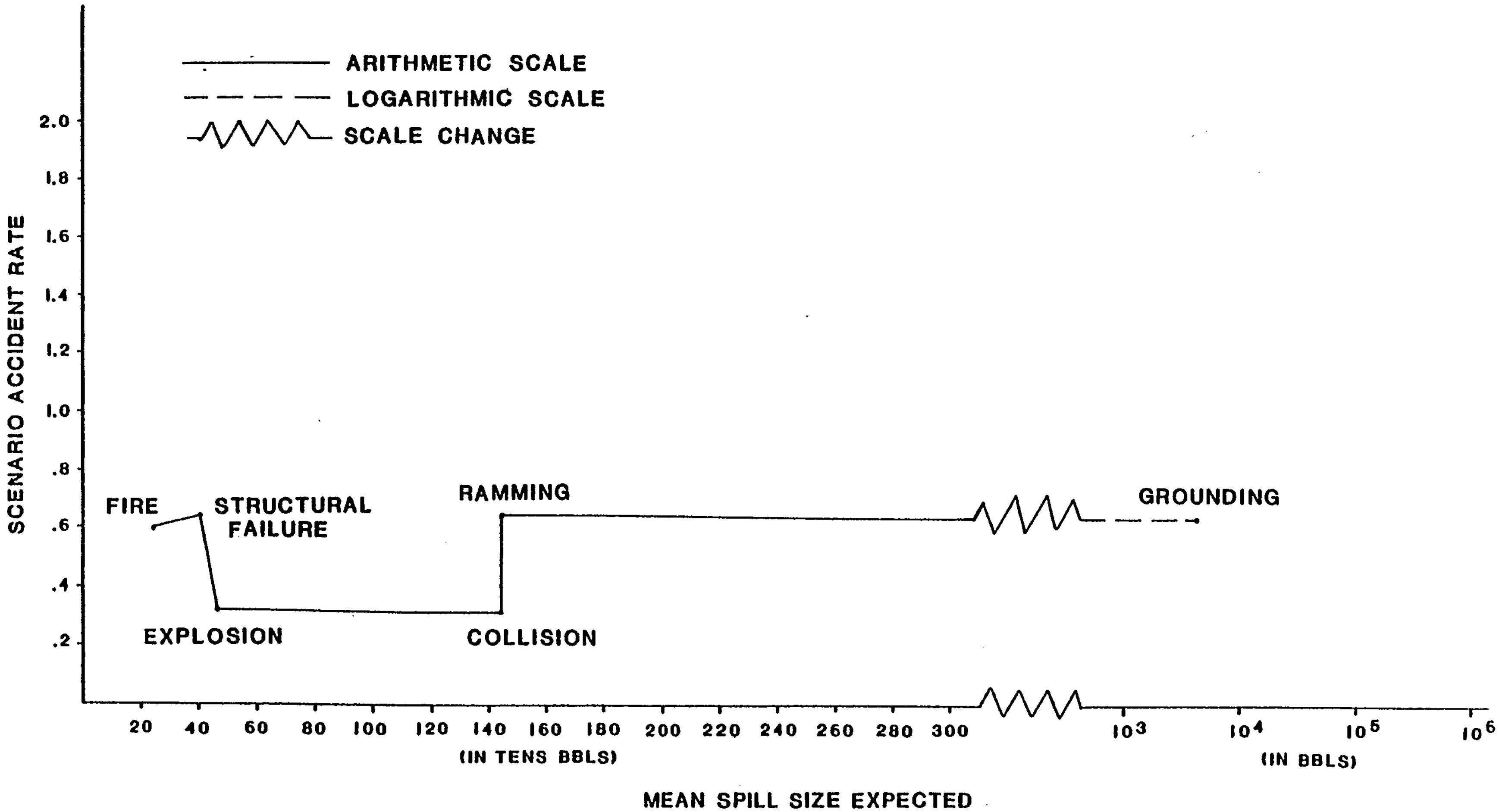
Number of At-Sea Transfers: 345 near Gulf Coast

FREQUENCY OF ACCIDENTS BY TYPE

Accident Type	Observed Accident Rate	Accidents of 41 Vessel-Years
Collision	.00568	.32
Grounding	.01136	.65
Structural Failure	.01136	.65
Ramming	.01136	.65
Fire	.01705	.97
Explosion	.00568	.32
Total Accident Rate (Annual Basis)		3.56

FIGURE V-14

MEAN SPILL SIZE FREQUENCY DISTRIBUTION FOR SCENARIO D



number of accidents and the smallest amount of spilled oil is expected in Scenario D. The highest accident rates in this scenario are indicated to be structural failure, ramming, and grounding, in order of increasing spill size, but they are substantially less than the highest rates in other scenarios. Except for grounding, the mean spill sizes for all casualties considered are less than 1500 barrels. Even though of small probability in an absolute sense, the potential effects of a grounding with a VLCC is of considerable environmental consequence, particularly as the release of a relatively large amount of oil from such an accident is indicated as probable, and this indication is based on a data base that may not reflect upper limits of all spill types.

c. Discussion of Oil Spill Risks

The data and analyses in the preceding subsection require considerable interpretation and comprehension of analytical limitations. It appears clear, however, that the number of accidents and amount of spilled oil will be greatest under Scenario A and will be least under Scenario D. The current unavailability of offshore or deepwater ports in the U.S. and the proposal to not use offshore domes, under which Scenario D is operative, focuses attention to Scenarios B and C as potential environmentally cost effective methods of transporting crude for the SPR.

The comparison of all transport alternatives, and particularly of Scenarios B and C, is hampered by the "per vessel-year" basis on which the probabilities are required to be calculated. The small differences between Scenarios B and C lie chiefly in the different vessel-years required to implement the program, and within the limitations of the data base, the two scenarios are considered equivalent in the number and amounts of oil spills likely to occur. To account for differences that are not included in the categorization in the statistical data base, consideration must also be given to the likelihood of (1) where spills occur, as the most environmentally costly spills are those in-shore or very near shore, and (2) how they are generated, i.e., catastrophically or as an unfortunate adjunct of normal operations. Perhaps one measure of the relative likelihood of near-shore spills among the scenarios is the number of harbor entrances and exits required (Tables V-44 through V-47). However, it should be recognized that the likelihood of catastrophic accidents in and around harbors is strongly dependent on the amount of other traffic in the vicinity; this dependence suggests that transshipment points, generally sited in remote areas away from other ship traffic, may have a somewhat smaller probability of casualties than other onshore port facilities. On the other hand, transfers in the open sea (such as with "lightering" from a larger to a smaller vessel) while generally regarded as likely to produce some spilled oil in a more difficult setting to contain and clean up, are part of normal operations. These transfers usually involve relatively small amounts of spilled oil, compared to spills from catastrophic casualties, and at distances far enough from shore to permit weathering so as to mitigate its ecologic effects even if it should reach shore.

The results of the spill risk analysis indicate that:

(1) Any transport scenario that uses tankers smaller than VLCC's in any step apparently incurs a significantly larger oil spill risk (especially potential impact) than through exclusive use of VLCC's,

(2) The most environmentally unacceptable transport method is through the exclusive use of smaller tankers of 70,000 DWT or less,

(3) Neither the spill probabilities, potential amount of oil spilled or the likely ecologic impacts between transshipment or lightering are significantly different so as to select one method over the other on the basis of oil spill risk,

(4) No method of shipment evidently will avoid the statistical likelihood of a spill on the order of 10,000 barrels of oil.

The conclusions of this analysis consequently must be that both Scenarios B and C are equally acceptable from an environmental viewpoint in transporting crude for the SPR. It should be recognized that both methods may be required to meet programmatic deadlines, and that the probability of casualties at transshipment points may thereby be reduced. Furthermore, "lightering" is an option whose spill probabilities and impacts are, at least to some degree, operationally controllable or minimized by programmatic stipulations. The appropriate necessary stipulations and a detailed oil spill risk analysis are an integral part of the site-specific development plans and EIS's.

2. <u>Behavior of Petroleum in the Marine Environment</u>

a. <u>Physical and Chemical Changes</u>

Crude oil is a complex mixture of many hydrocarbon compounds. The various types of hydrocarbons exhibit different effects in marine organisms.

The chemical composition of spilled oil is altered significantly by evaporation, dissolution, and microbial and chemical oxidation. Because the varying constituents of oil are affected at different rates by these "weathering" processes, the relative composition (and, therefore, biological effects) of spilled oil also varies.

Evaporation depletes the more volatile components (fractions 1, 3, and 5, Table V-48) but causes little separation (fractionation) between hydrocarbons that have the same boiling points but substantially different structures and effects on organisms. Hydrocarbons lost through evaporation go into the atmosphere.

Dissolution also removes preferentially the lower molecular weight components from an oil slick. Some potentially toxic fractions, such as the aromatic hydrocarbons, have a higher solubility than other less toxic compounds (paraffins) of the same boiling point. Once dissolved in seawater, these soluble constituents may follow quite different pathways than the more conspicuous slick.

Biochemical (microbial) attack affects compounds within a much wider boiling range than evaporation and dissolution. Hydrocarbons with the same general structures are attacked roughly at the same rates. Normally, paraffins are most readily degraded. Continued biochemical degradation causes gradual removal of the branched alkanes. Cycloalkanes and some aromatic hydrocarbons (fractions 3-8) are most resistant and disappear at a much slower rate. Biochemical degradation rates evidently are higher in areas of chronic oil pollution than in areas that have not previously experienced oil pollution.

Chemical degradation processes of oil during weathering are not well understood and little information is accepted as incontrovertible. Oxidation most readily affects aromatic hydrocarbons of intermediate and higher molecular weight. The effect

TABLE V-48

BASIC DATA - OIL SPILL WEATHERING

FRACTION	DESCRIPTION[a]	% BY WEIGHT[a] IN CRUDE OIL	DENSITY[b] (gm/ml)	BOILING POINT[b] (°C)	MOLECULAR WEIGHT[b]	VAPOR PRESSURE 20°C(mm)	SOLUBILITY[c] (gm/10^6 gm of H_2O)
1	Paraffin C_5-C_{12}	0.1-20	0.66-0.77	69-230	86-170	110-0.1	9.5-0.01
2	Paraffin C_{13}-C_{25}	+0-10	0.77-0.78	230-405	184-352	0.1	0.1-0.00[illegible]
3	Cycloparaffin C_5-C_{12}	5-30	0.75-0.9	70-230	84-164	100-1	55-1
4	Cycloparaffin C_{12}-C_{23}	5-30	0.90-1	230-405	156-318	1-0	1-0
5	Aromatic (Mono- and Di-cyclic) C_6-C_{11}	0-5	0.88-1.1	80-240	78-143	72-0.1	1780-0
6	Aromatic (Polycyclic) C_{12}-C_{18}	+0-5	1.10-1.2	240-400	128-234	0.1-0	12.5-0
7	Naptheno-aromatic C_9-C_{25}	5-30	0.97-1.2	180-400	116-300	1-0	1-0
	Residuals (including heterocycles)	10-70	1-1.1	400	300-900	0	0

NOTES:

a - For further detail see:

1. Bestougeff, M.A. in Nagy, Bartholomew and Colombo, Fundamental Aspects of Petroleum Geochemistry, Elsevier Publishing Company, New York, New York, 1967.
2. Rossini, Frederick, D., Hydrocarbons in Petroleum, Journal of Chemical Education, Vol. 37, No. 11, November, 1960.
3. Smith, H. M., Qualitative and Quantitative Aspects of Crude Oil Composition, U.S. Bureau of Mines, Bulletin 642, 1968.

b - Taken or estimated from:

1. Handbook of Physics and Chemistry
2. Physical/Chemical Constants for Organic Compounds

c - Taken or estimated from:

1. Klevens, H.B., Solubization of Polycyclic Hydrocarbons, Journal of Petroleum Chemistry, 54:283-298 (1950).
2. Peake, Eric, and G. W. Hodgson, Alkanes in Aqueous Systems. II. The Accomodation of C_{12}-C_{13} n-Alkanes in Distilled Water, J. Am. Oil Chemists' Society, Vol. 44, pp 696-702, December, 1967.
3. McAuliffe, Clayton, Determination of Dissolved Hydrocarbons in Subsurface Brines, Chem. Geol., 4(1969), 225-233.
4. Gerarde, H.W., Toxicology and Biochemistry of Aromatic Hydrocarbons, Elsevier Publishing, London, 1960.

(Compiled by Moore and Dwyer, 1972)
Source: US-124

of these weathering processes is believed to be the rapid (within 48-96 hours) depletion of lower boiling fractions (boiling point 250°C) from a spilled slick by evaporation, and dissolution and slower degradation (possibly in terms of years for some fractions) of higher boiling fractions by microbial and chemical oxidation.

Oil incorporated into marine sediments apparently does not undergo the same changes as those observed in oils exposed to the atmosphere. In particular, decomposition is retarded by sediment; the absence of abundant dissolved oxygen in most marine sediments and the shielding from sunlight presumably cause the oil to retain its original composition for much longer periods. Thus, oil originally incorporated in sediment may be later released to the environment, little altered from its original composition, if the deposit is disturbed by the actions of waves, tidal currents, or dredging. After release, the oil can be moved into other areas where it can cause deleterious effects. Furthermore, the oil released from sediments may contain pesticides, or their decomposition products, which were originally associated with mineral grains incorporated in the deposits. (Biological effects are described later.)

b. Emulsion Formation

Oil, when mixed with seawater, tends to form emulsions. Depending on the chemical composition of the oil and presence or absence of other surface-active constituents (surfactants), the emulsions may be either oil-in-water (as is milk) or water-in-oil (as is butter). Emulsion formation changes the physical characteristics of the oil and its physical and chemical behavior in the ocean and, therefore, alters its effects on marine organisms.

Many oils, when vigorously mixed with seawater, form oil-in-water emulsions. The fine oil droplets are then dispersed through a large volume of water, often disappearing from the ocean surface. In a stable, dispersed form the oil does not "wet" surfaces and also provides maximum surface area for microbial and chemical degradation of the oil. The large surface area also permits soluble constituents in the oil to dissolve more readily in seawater.

c. Movement of Oil Slicks

A volume of oil suddenly dropped on the sea surface is free to spread horizontally. The oil spreads at three different rates, depending on when one looks at the spill. Each rate is determined by a balance of various properties of oil and water. The first two spreading rates involve balances between the buoyancy-induced spreading force, and initially the oil's inertia, then later the water's viscuous drag. It is convenient, therefore, to distinguish three different phases in the spreading of a spill, an inertia phase, a viscous phase, and finally, a surface-tension phase. The duration of each phase depends on the amount of oil initially released. It is commonly observed that oil slicks cease to spread after some time. Various theories have been developed to explain this phenomenon. One of the more successful theories assumes that the hydrocarbons responsible for the observed surface tension are lost through either evaporation into the air or dissolution into the water.

In addition to the well-documented spreading phenomena, an oil spill exhibits two other important properties. At some time during the spreading process, variations in the wind, waves, and current usually separate a large spill into several large patches surrounded by many smaller patches. The large patches tend to move apart through time. This increases the width of the path swept by the spill and also increases the rate of dissolution of hydrocarbons into the water. Furthermore, waves on the open ocean, or surf near shore, mix a portion of the oil into the seawater. The tiny oil droplets suspended in the water substantially increase the surface area available for dissolving hydrocarbons into the water. (Water-in-oil emulsions may also be formed as described earlier.)

The suspension of oil droplets in seawater is related to the turbulence in surface waters. Energy imparted by winds to surface waves is much greater than that imparted to turbulence in near surface waters. Turbulence is increased when waves break, so that winds strong enough to cause whitecaps substantially increase the turbulence of surface waters. The depth to which this wave-induced turbulence penetrates varies, but 20 to 35 feet might be a representative range for the depth of penetration of the strong wave generated surface turbulence. Thus, the fine oil droplets dispersed by wind mixing would be most abundant in near-surface waters (less than 35 feet). Mixing of waters caused by strong tidal currents in estuaries can mix oil droplets to much greater depths.

Oil droplets respond to turbulence depending on their size; the rise velocity of a small oil droplet will be much less than the rise velocity of a large droplet. Thus, one can expect to find small oil droplets fairly deep, while large droplets should remain near the surface. Increased mixing also increases the depth of droplet penetration into the water.

Wind blowing over the water surface imparts momentum to the water and sets the water in motion. At the very surface this water layer will move in the direction of the surface wind.

It will continue to move in that direction so long as the wind continues to blow. The motion while the wind blows is of importance because the surface layer of water and associated oil slicks can move substantial distances.

d. <u>Movement of Oils and Oil Slicks in Estuaries</u>

In an estuary, movement of oil slicks are a result of complex interactions of wind, local currents strongly affected by oscillatory tidal motion, and coriolis force. Therefore, a slick in an estuary will behave somewhat differently than it would in the open ocean when tidal currents have relatively little effect.

In the surface layers, the spilled oil will be extended into an elongated horizontal plume by tidal currents. Through the action of mixing processes previously described, these will develop a widespread slick of relatively low concentration on which is superimposed, with each tide, a relatively narrow plume of higher concentration.

Tidal currents moving past irregularities in the shoreline further disperse the oil. Intense mixing of oil and surface waters can occur where strong tidal currents move slicks across an irregular bottom such as the sills (submerged ridges) in fiord-like estuaries.

Frequently, eddies associated with embayments or with points of land that project into the estuary will temporarily trap water containing high concentrations of oil as the plume is carried past by tidal currents. Most of the oil is carried out past the shore feature by the tidal current while the trapped oil slowly spreads out into the main stream, causing dispersal behind the main body of the slick. When the tide reverses, the process is repeated with a resulting dispersion on the opposite side of the slick.

The prediction of likely movement of oil spills obviously is a site-specific concern and cannot be addressed at a programmatic level. However, consideration of such movement will be an integral part of the assessment in the site-specific EIS's.

e. Transfer of Oil Films to Atmosphere

To this point, the discussion has centered around oil slicks formed by discharges of large volumes of oil from tanker accidents or other mishaps. As indicated in other sections of this statement, oil is also released to the ocean during loading operations, from leaks, and from discharges of engine cooling waters. Observations of the elimination of these oil films from large lakes suggest that other important processes may be actively removing oil from the sea surface and injecting it into the atmosphere to be carried away by the winds.

Recreation-generated oil films are eliminated from the water surface in 70 to 90 hours after boating activity has stopped. There is no evidence that these oils are removed by evaporation or either dissolution or emulsification in the water, the major processes previously discussed. Instead, it appears that most of the removal occurs by formation of tiny droplets (aerosols) which are injected into the atmosphere. Furthermore, the droplets carried in the atmosphere preferentially absorbed salts and certain polar organic materials from the water. In other words, the chemical composition of the bulk water does not provide a reliable indicator of the chemical composition of these airborne droplets. The combined action of bubbles and ultraviolet irradiation was found in laboratory experiments to be most effective in removing oily films from the water surface. While conclusive data are still lacking, these pro ;sses may be the cause of reported rapid disappearance of oil slicks in many marine areas. Exposure to the atmosphere and ultraviolet radiation apparently oxidized the hydrocarbons in these films. The film materials will also preferentially pick up other oil-soluble constituents in the water. Surfaces of droplets are also likely to be colonized by bacteria and other micro-organisms.

f. Behavior of Spilled Oil on Shore

When an oil slick reaches the shore, its behavior depends on the nature of the oil, its emulsions, and the shore. Usually, much of the oil will be carried to the beach and deposited at the high-water mark by successive tides; well-weathered or heavy oils have mixed with sand or plant debris during this process, forming "oil cakes." These cakes, formed from freshly spilt oil or by the action of hot sun, may cause greater trouble by sinking into sand and gravel or clinging to seaweeds.

Pebble beaches are more troublesome to clean because the oil may sink among the pebbles to a depth of 0.5-1m. Oil does not sink so readily into wet sand. Breakers may, however, throw fresh sand over the oil-containing sand, burying it. In this way a beach may appear clean shortly after an oil slick has come ashore. Later removal of surface layers during storms or in seasonal sand movements exposes the oil.

Oil may also persist on dry rock surfaces or among weeds, barnacles and mussels, where, in addition to the biological processes (described below), it is slowly removed by drying, hardening and the incorporation of sand particles, finally eroding or flaking off. Although they fail to wet the mucous body surfaces of animals or the mucilaginous surface of certain algae, some oils cling to the byssus-threads of mussels and the outer layer of shells and certain upper-shore weeds which have a naturally oily surface. Oil also has an affinity for some marine grasses and flowering plants.

3. Ecological Impacts

The damage to aquatic biota caused by large oil spills usually results from its physical properties as a coating or fouling agent, the toxicity of some of its components which dissolve readily in water, or its tendency to form aggregates with suspended sediment and sink to the bottom, where it may be carried away from the original site of the spill. Direct damage occurs primarily through smothering attached and floating organisms, including the eggs and larvae of fish and shellfish, and by fouling the feathers of water birds.

These effects are probably enhanced by the toxicity of the oil itself in some cases. This is most notably observed in oiled birds, which ingest a good deal of oil in attempting to clean themselves (HA-269). The soluble toxins in spilled oil probably take effect within minutes to hours, as was observed in the case of the Santa Barbara oil spill (HO-163). Planktonic forms are ordinarily exposed to high concentrations of these substances close to the floating film of oil. Oil also temporarily reduces photosynthesis by reducing light penetration, sometimes as much as 90 percent (NE-079).

In fresh or brackish waters, oil interferes with the respiration of aquatic insects and larvae, including those of mosquitoes and various flies which typically occur at the surface.

The primary effect of spilled oil on benthic organisms, other than intertidal species which may be directly coated, arises from the deposition of clay coated with organic matter and adsorbed petroleum. There it can continue to release soluble toxins over a long period of time. Brackish docking areas and turbid, sluggish estuaries are particularly liable to develop this type of bottom sludge (NE-080). The increased biological and chemical oxygen demand associated with this sludge can deplete bottom waters of dissolved oxygen, as has been observed in Los Angeles harbor (BO-110) and in certain ecosystems along the Texas coast (CO-222). These effects are generally localized, however, and are most significant in areas of chronic pollution rather than waters affected by a single major oil spill.

When spilled oil enters a saltmarsh, it is very difficult to remove. The oil adheres to plants and does not wash off easily, usually killing the parts exposed to the oil (BA-264). A film of oil lying over the soil can also slow or prevent gas exchange (ST-210) and probably decrease the productivity of minute mud algae. These algae are important to the ecosystem; Pomeroy in 1959 (PO-110) found that they contributed as much as one-third of the annual production of a Georgia saltmarsh. Sluggish or non-mobile animals living in the marsh may also become fouled; shore crabs such as the mud crabs (Xanthidae), fiddler crabs (*Uca* spp.) and blue crabs (*Callinectes* sp.), which live in shallow burrows, are particularly sensitive, not only to direct contamination but to poisoning through ingesting harmful quantities of oil from oil-fouled food (NE-080).

An oil spill in a saltmarsh can be particularly damaging if it occurs at a time when the shallow "nursery areas" contain large numbers of juvenile fish and shellfish which are likely to be fouled directly or succumb to dissolved toxins.

a. Relative Vulnerability of Organisms

Perhaps those organisms most severely affected by a major oil spill are the water birds, particularly the grebes, pelicans, herons and egrets, shorebirds, kingfishers, cranes and their allies, and ducks and geese. It has been suggested that birds are attracted to the dead and dying marine life found floating in oil slicks, or that they are unable to distinguish oiled waters from normal calm areas and land on them preferentially. The problem seems greatest, however, with extensive slicks on the open sea; in coastal areas, birds can easily escape the oil by moving a short distance inland (JA-086).

Plankton also appear to be quite sensitive to oil pollution, although there is a great deal of disparity in the figures published by different authors. In general, it appears that zooplankton are somewhat more liable to direct mortality than are phytoplankton and that those forms such as copepods which pass their entire existence in a floating state (holoplankton) are more sensitive than the floating eggs, larvae, and juveniles of fish and shellfish which as adults are not planktonic (meroplankton). These larvae themselves appear in general to be more sensitive than the adult forms (KU-077, HU-089). In spite of their sensitivity (in some cases to as little as 1 to 100 ppm crude oil in water) no long-term effects of oil spillage on holoplankton have yet been documented, probably because of their rapid reproductive rate. There is a greater threat, however, to the meroplanktonic forms which will not be as readily replenished.

Bottom organisms are affected primarily by the deposition of oily bottom sludges, although this will not occur to any great extent following a spill which is rapidly cleaned up. Most of the species studied are typical of rocky shores. Very little work has been done with estuarine forms. Such information as does exist, however, indicates that organisms such as the tube-worms and certain annelid worms which can survive low concentrations of dissolved oxygen are the most tolerant of bottom sludge (NE-080) while amphipods, which typically live in the sediment itself, are notably intolerant (BO-110). Barnacles also recover quickly (ST-212, NE-079). However, very small quantities of hydrocarbons (between 1 and 40 ppb) have been shown to interfere with the feeding behavior of such species as lobster (Homarus americanus) and the snail (Nassarius obsoletus) (AT-050, JA-085). The young shrimp using the nursery areas are bottom dwellers and feeders, and some species typically burrow into the bottom by day. They would, therefore, be particularly vulnerable if oily sludges were deposited on the bottom.

Fish appear to be able to avoid serious damage from oil spills simply by moving away. Smaller catches following spills may often be due more to the closure of harbors or the fouling of boats than to an actual decrease in the fish available (ST-212). Fish may avoid the oil, or in some cases, be protected by the natural mucus covering their bodies. Massive contamination of fish probably occurs only when oil is spilled into confined waters from which the fish cannot escape. Fish are, however, thought to be vulnerable to sensory disturbance by very small quantities of dissolved petroleum compounds. This could possibly interfere with normal migration in and out of the estuarine zone, a process in which fish orient themselves partly through olfaction (JA-086, MI-136, BL-059).

One group of organisms, at least, appears to benefit consistently from oil in the marine environment. A number of yeasts and bacteria are able to oxidize oil and are generally found in areas of chronic oil spills (ZO-009). These organisms also may be responsible for the disappearance of a good deal of oil spilled in the Louisiana area (EN-203). Through bacterial attack, some of the energy available from the oil moves into the marine food web, from the bacteria and yeasts to protozoans, plankton, and other organisms.

Loss of a significant number of the year's production of larval and juvenile fish and shellfish could exert a significant effect upon population stability. As is pointed out in a study of the possible environmental effects of a supertanker port off the Texas Coast (JA-086), many of the important groups of commercial and sport fish and shellfish of the Gulf Coast, including sea trouts and Atlantic croaker, may live only 18 to 24 months. Thus, each year's catch is highly dependent upon the reproductive success of the preceding year. A major spill could, therefore, have immediate consequences on the fishery, which might take years to recover. A relatively small spill, however, such as might occur from a single Handy tanker, would be unlikely to cause damage this extensive.

It is considered likely that oil spills will occur at the sites; however, with effective control and cleanup measures, the biological impacts can be maintained at a minimal level. Major ecological impacts would result from a poorly contained, massive spill in spring, during peak use of nursery areas or chronic, uncontrolled spills at sites in estuarine wetland areas.

b. Relative Toxicity of Oils and Petroleum Products

The major toxic principles in crude and refined oil products are generally thought to be the low-boiling saturated hydrocarbons and the low-boiling aromatics, such as benzene, xylene, naphthalene, and phenanthrene. Though these materials evaporate easily, some of them are slightly soluble in seawater, especially the aromatic compounds (BO-110). In general, paraffins are less toxic than naphthenes, which are in turn less toxic than olefins and aromatics, with the smaller molecules in each series causing the greatest damage (BA-266).

Among refinery products, gasoline and kerosene are generally the most harmful, with light fuel oils also capable of highly toxic effects (OT-022, BO-110). Fresh crudes of various kinds show a wide range of toxic effects, especially on plants. Ottaway (1971) (OT-022) found that the toxicity of several crudes to salt marsh vegetation was related to their aromatic content. Weathered crudes and heavy residuals appear to be less toxic generally than fresh crudes (CO-223, OT-022, BO-110). In some of Ottaway's experiments, F35 and F80 residue blends from Kuwait oil actually appeared to enhance productivity in some types of salt marsh grasses.

c. Biological Recovery

Recovery of a marine area after experiencing an isolated major spill may be quite rapid (ST-212, EN-203, JA-086), although the persistence of long-term ecosystem effects has not been adequately dealt with to permit broad conclusions (NE-080).

Some British salt marshes have exhibited the ability to recover from severe oilings in two years (CO-224, ST-211), although less time might be required in the warmer Gulf area (JA-086, BA-264). British marsh vegetation has recovered after as many as four experimental oilings per year.

In general, as is the case with many other ecological stresses, it appears that the resiliency of a marine community to a single, isolated spill is much higher than it is to chronic oil pollution, or many successive spills. The single spill represents a sudden, localized perturbation of one portion of an ecosystem, after which it can proceed to recover without further disturbance and with ample stocks available nearby for recolonization. Chronic pollution alters the basic conditions under which the ecosystem must function, often forcing it to reach a new equilibrium state which may be less diverse than the old.

d. Effects of Chronic Oil Pollution

Depending on the exact configuration of barge loading and unloading facilities, localized chronic oil pollution problems of varying degree may develop. Inshore barge slips with restricted circulation would show the greatest potential for chronic pollution, and offshore docking facilities the least. The impact of these facilities will be dealt with in detail in the site-specific EIS's developed for each individual storage site.

Chronic oil pollution of this type can have severe impacts on biota in the areas affected. In Texas and Louisiana shallow-water ecosystems receiving oily wastes on a regular basis show lowered species diversity, and large diurnal fluctuations in dissolved oxygen and often develop anaerobic, near-reducing bottom conditions. Soluble toxins tend to repress the metabolic rate of some organisms, while nutrients released through bacterial decomposition of the wastes themselves stimulate others;

accordingly, community metabolism as a whole may fluctuate widely (CO-222). Localized reductions of fish and shrimp production in oil-polluted inshore Gulf waters have also been reported (SP-043). In contrast to these reports, recent studies by the Gulf Universities Research Consortium (GURC) have found no significant changes in the ecosystem of Louisiana's Timbalier Bay, despite a forty-year history of offshore drilling and a present inventory of over 400 oil and gas wells. These two examples illustrate the importance of specific site factors in determining whether chronic oil pollution will become a problem.

The bacteria which decompose petroleum products in water ordinarily attack alkanes with greatest preference, degrading successively smaller quantities of branched alkanes, cycloalkanes, and aromatics. Aromatics may, therefore, be left behind in the sediment, there to concentrate with time as new oil settles to the bottom and is in its turn decayed. The most directly toxic aromatics are only slightly soluble. Therefore, they could persist in the sediment. Some of the high-boiling aromatics, including benzopyrenes, dibenzantracenes, chrysenes, 10-methylanthracene, and nitrogenous derivatives such as dimethylbenzidene are known or suspected carcinogens (BO-110). Circumstantial evidence links petroleum hydrocarbons to tumors in bottom-feeding fish and clams (NE-079, BA-268, BA-269).

Productivity in planktonic algae may be both stimulated and depressed by the presence of petroleum, depending on the species and the concentration of hydrocarbon (GO-079). There is some evidence to suggest that bluegreen algae may have a tendency to develop large populations in oil-contaminated waters, while other fresh-water algae decline (BA-267, KA-145).

The effect of chronic low-level oil pollution on the movement of organisms, chiefly fish, crabs, and shrimp, is impossible to specify without a more complete knowledge of the timing and mode of their migrations. Interference with sensory orientation through the olfactory system, as well as severe local oxygen depletion, would probably be the major means by which normal up and down river movements could be disrupted.

e. Summary of Effects on Marine Organisms

Data now available permit qualitative evaluations of effects of spills of petroleum products on marine life within a given region. Quantitative assessments and predictions of the effects of petroleum spills at sea are not yet possible, although certain physical and chemical processes can be predicted with some confidence.

Various fractions of petroleum have different effects on marine organisms.

Aromatic fractions (some of them water-soluble) are toxic to many marine organisms. Acute effects are most often observed in the range of 1 to 100 ppm, although concentrations of water-soluble aromatic derivatives as low as 0.1 ppm may be toxic to larvae (MI-136); some adult organisms are sensitive to concentrations of 2 ppm (AN-142). Crustaceans and burrowing animals other than bivalves are most sensitive; fish and bivalves are moderately sensitive; gastropods and plants are least sensitive. Most laboratory tests have involved exposures of more than 24 hours; in an actual oil spill incident, potentially toxic levels of petroleum-derived substances would be rapidly diluted to ppb levels.

Concentrations of soluble aromatic derivatives in the range of 10-100 ppm may cause changes in behavioral patterns of many marine organisms.

Incorporation of hydrocarbons in tissues of marine organisms has raised the question of public health implications for humans, although marine organisms may not be obviously affected. However, although carcinogens may be accummulated by marine organisms, there are no known cases of human cancer caused by such exposure. Objectionable tastes (tainting) in commercial seafood can result from various concentrations of hydrocarbons in seawater. Petroleum hydrocarbons are soluble in lipids and may, therefore, persist in organisms for periods of months. Unpleasant tastes would probably prevent humans from consuming seafood containing carcinogens concentrated from oil-contaminated waters.

Weathered crude oil which has lost its more volatile components, including many of the aromatic fractions, is less damaging to marine organisms than freshly spilled crude or many refined products. Physical effects due to coating by the heavy oil residues include smothering or changes in substrate for the organisms.

Oil spilled at sea can move as a slick or gelatinous emulsion at the surface, dissolve into the underlying water, be dispersed as fine droplets in an oil-in-water emulsion, evaporate into the atmosphere, be adsorbed on particulate matter and sink to the bottom, or be carried by droplets into the atmosphere by action of wind and waves.

Data now available do not permit detailed predictions of the movement or fate of the different petroleum constituents, their movement through the food web for marine organisms, or possible introduction into the human food supply.

4. Ecological Effects of Onshore Spills

There is a remote possibility of a wellhead shearing off, a pipeline rupturing, or a valve failing, etc., thereby allowing crude oil or petroleum products to spill onshore. In the case of tankage in the East Coast region, all spills inside the tankage module would be contained by safety dikes. Only spills outside the module, probably a pipeline rupture, would have an adverse ecological effect. In the Gulf Coast region, a wellhead could be sheared off by a storm or other accidental cause, allowing crude oil to flow from the pipe until stopped or until equilibrium was reached between the weight of water in the injection pipe(s) and the weight of the oil in the annular space(s). The amount would vary depending upon the volume of the pipes. This has been estimated to be no more than 100 barrels if allowed to reach equilibrium. With warning devices and automatic shut off valves in the pipelines, a spill other than at the wellhead should be less than 100 barrels.

Small pipeline leaks can be totally contained in the soil before they move a great distance horizontally or downward if the quantity is small enough. Chronic leaks, if undetected, may travel large distances both horizontally and downward. If porous backfill is used in a trench made in impermeable material, the oil will migrate along the pipeline within the trench. This usually can be cleaned up rather easily with little environmental consequences.

In both the East and Gulf Coast regions, spills of small magnitude on land could be easily and quickly cleaned up; however, the vegetation and soil organisms would probably be destroyed by either the oil or product or the cleanup operations which usually consist of removing contaminated soil. The possible exception would be large trees that could survive if cleanup was rapid.

The destruction of the vegetation would temporarily displace whatever animals lived in the area prior to the spill. It is estimated that most animals would be able to avoid the spill area and not be harmed. The cleaned area would revegetate, depending upon the type of original vegetation, in several months to several years. This could be assisted by reseeding or replanting the proper vegetation after all cleanup is completed.

Allowed to go uncontrolled for several days, the effects would be much more extensive and cleanup much more difficult. The effects would be felt by the aquatic organisms in the streams and throughout the drainage system affected if the spill is washed downstream. The effects will be lessened downstream as the spill is diluted, however, cleanup might destroy more habitat than the spill if not carefully controlled. The toxic effects of crude oil and refined products on fresh water aquatic organisms are similar to marine organisms, however, little experimental work is available in this area for detailed comparison.

5. Ecological Effects of Spills of Refined Products (US-124)

Previous discussions of oil spills have dealt primarily with crude oil; but as indicated in the discussion of ecological impact of petroleum, refined products are usually more damaging to marine organisms and communities of these organisms. It is therefore necessary to consider the effect of the wreck and complete loss of cargo of a tanker carrying refined petroleum products. The range of refined products is enormous and neither space nor available data permit a detailed discussion of the impact of each product. Instead, two products, No. 2 fuel oil and Bunker C, will be described as examples of the probable impacts from spills of refined products. Spills of these products have been studied in the sub-Artic waters of Nova

Scotia (the Arrow spill), in San Francisco Bay, and in the area around West Falmouth, Massachusetts.

The Handy tankers (35,000 DWT) are generally used for carrying these refined products and are capable of operating in most U. S. ports. It is in these port areas that a wreck and complete loss of cargo would have the greatest environmental effect. Carried by tidal currents, the products would be widely distributed throughout the harbor unless containment and cleanup procedures were able to protect certain areas. The spilled products would be washed ashore and enter small bays and wetlands adjoining the harbor.

Tidal currents and the estuarine circulation in the harbor will distribute the petroleum products in surface and subsurface waters. Being less dense than seawater, most products spilled in an estuary will move with the net flow of surface waters in a seaward direction. But extensive mixing will also distribute the oil throughout the water column through the formation of oil-in-water emulsions and dispersion. Tiny oil droplets or soluble constituents will eventually be carried into subsurface waters and the net landward flow will carry these materials back into the harbor and disperse the products widely throughout the system. The dispersed oil may enter marine food webs through plankton or through benthic organisms.

The lighter petroleum products contain higher concentrations of the more toxic constituents of petroleum, as previously described. When washed ashore quickly after a spill, before loss by evaporation or dissolution or burial in sediments, these refined products can cause massive destruction of marine organisms in wetlands. In addition, if this material is rapidly buried under a layer of sediment and subjected to anaerobic conditions, it could represent a danger to the environment for many years.

However, the impact in a harbor area is highly dependent on the history of the region and its exposure to previous spills. Even a major port such as New York Harbor still has major wetland areas (Jamaica Bay) which would be affected by a massive spill of petroleum products. Few areas around ports are still used for commercial fish or shellfish production so that major losses would come from damage to marine life and the resulting possible effects on recreational fisheries. The recovery of the area would depend on the extent of other stresses on the region, such as discharges of municipal sewers which are themselves sources of petroleum products such as waste lubricating oils.

Bunker C is a heavy residual fuel oil widely used for fueling ships and various industrial operations. It has low volatility and does not readily evaporate. Its propensity to form water-in-oil emulsions, combined with its high viscosity, causes it to tend to remain at the surface and facilitates its recovery or removal by mechanical processes. Chemical composition is extremely variable and poorly known.

Since it remains at the surface, a spill of Bunker C could cause major losses among marine birds in the harbor and adjacent wetlands, if rapid cleanup measures were not immediately implemented. The major impact of a spill of Bunker C would come primarily from physical effects of oil coatings, including those on shorelines. Some loss of marine mammals could be expected. Studies of a spill of about 10,000 tons of Bunker C in Chedabucto Bay, Nova Scotia (February 4, 1970), showed no major effects on commercial fisheries for groundfish, lobster, mackerel, herring, smelts, salmon and many other species. Oil on fishing nets and gear was removed in a plant set up for the purpose.

6. Regional Overviews

It is expected that oil-spill impacts will be assessed independently for each storage site as the specific program elements are developed. A generalized impact analysis at the regional level for comparison purposes is believed to have some merit, however, and is incorporated in this section. This part of the report briefly summarizes pertinent portions of the final EIS for the Maritime Administration Tanker Construction Program (US-124), which drew from CEQ studies on supertanker port sites; the conclusions drawn should be of general applicability to potential impacts of oil spills of moderate size that may occur as a result of the SPR program.

Texas Gulf Coast

Two offshore sites were investigated as potential superport facilities to serve the Texas Gulf Coast. The two sites were generally southeast of Freeport, Texas, in waters 60 to 90 feet deep, 10 to 30 miles offshore. Effects of port construction and operation were considered. The data can be used, however, to indicate probable effects of supertanker operations in the area.

Operation of supertankers and a port facility off the Texas coast will undoubtedly increase the potential for oil spills to occur in the area. Port operations should, however, substantially decrease the probability of oil spills in the estuaries. Many of these beaches are little used for recreation.

Barrier islands along approximately 300 miles of the Texas coast protect bays and estuaries from most effects of offshore oil spills. The small tidal range on the coast has resulted in few and small tidal openings through the islands. The small size of these inlets will inhibit the movement of large volumes of oil into the estuaries.

An offshore oil spill will most likely create short-term problems on beaches because of deposition of stranded oil. Such effects on the barrier beaches appear to be preferable to long-term effects that might occur if the oil spill occurs in the bays or estuaries.

The biological productivity of the marine environment of the Gulf of Mexico is lowest in open waters, increases toward the coast and is greatest in the estuaries. The toxicity of an offshore oil spill decreases as it approaches the coast. If an oil spill does occur, it will have less impact if it happens offshore and approaches the coast, rather than occurring in highly productive marine areas or near vulnerable wetlands.

An oil spill inside a Texas bay would result in higher concentrations of the more toxic fractions of oil in the water column than a similar spill offshore. In the shallow bays there will be less water available for dilution. In addition, the slow flushing characteristics of the estuarine systems will result in a longer contact time of the marine organisms with the spilled oil.

Winds and currents can be expected to drive spilled oil toward the Texas coast approximately 60 percent of the time. However, present control and containment technology can be effective in containing much of the spill volume at sea about 80 percent of the time in the relatively calm Gulf waters. Oil that reaches the shore approximately 2 to 3 days later will be relatively non-toxic owing to "weathering" at sea. Concentrations of the more toxic soluble fractions in the water column are expected to be below the level that has been shown to have an adverse effect on marine organisms. The oil that is not contained at sea and reaches the coast is expected to be absorbed by the sandy coastal beach and has little chance of entering the estuaries. The impact on the waterfowl is expected to be minimal since they will be protected by the barrier islands most of the time.

Present technology can be utilized to reduce the impact of a 300,000-ton spill. Damage will still occur, but it is not considered irreversible or permanent. The effects of the soluble fraction of the oil on the water column organisms will be small. The concentration levels of the toxic compounds are expected to go below the levels that affect adult organisms, but might affect the larval stages.

If the oil does reach the beach, it is expected to travel along the coast with the longshore current until it is absorbed by the sandy beach and estuaries. Oil spill control procedures can be established along the beach whereby sorbent material is added to the slick and both the sorbent material and oil are removed along the beach. Plans for disposal of this material should be developed prior to operation of the offshore port.

Fortunately, most of the waterfowl concentrations are not near major estuary inlets and are naturally fairly well protected from the impact of a major offshore oil spill; however, plans for barriers across the tidal inlets should be developed in order to minimize potential impacts.

Low-level continuous spills, if they materialize, will only affect areas near the port site; they are not likely to reach the shore. Soluble fractions from thin oil films will be diluted enough to prevent damage to swimming organisms. Spillage at levels expected from supertankers was common in association with past offshore drilling operations on the Gulf Coast and no noticeable effect has yet been reported or is expected. It is probable that biological decomposition should be able to handle this level of oil contamination.

Southeastern Coastal Area of Louisiana

Two sites for a proposed superport, off the Southeastern Louisiana shore (south of Bayou LaFourche) were evaluated for the potential environmental impact on the coastal region. The most vulnerable areas along the Louisiana coast are the estuaries. Oil drift projections (based on regional winds and local currents) indicate that the (supertanker) site most distant from the shore will have the least effect because a potential spill there will probably not reach the estuarine areas.

Estuarine areas of Louisiana are flanked by levees and, on the Gulf side, usually by barrier islands. This configuration, coupled with a gentle slope, has produced a nutrient-rich environment that now supports over four million acres of estuarine marshlands -- one of the world's most extensive coastal wetland areas. The climatic regime provides high solar radiation, abundant rainfall and a wind system that interacts with the physical setting in such a way that primary production supports the largest fishery in the United States. The principal commercial species are menhaden and shrimp. These species depend on the estuaries for a habitat and/or nursery area and for detrital food -- the product of marsh grass disintegration.

Oil drift projections are based on a hydrodynamical numerical model. By using four wind conditions, local tides and bathymetry, the hypothetical oil spills at the closest site moved either northwest toward Timbalier Bay, Louisiana, or northeast toward Barataria Bay, Louisiana. Oil spills at the farthest site did not impinge on the shorelines or estuaries. Oil spills at both sites usually assumed an east-west orientation and moved somewhat faster than drift projections based solely on winds.

Effects resulting from an oil spill would be potentially most severe in the estuaries. If repeated oilings occurred, valuable oyster grounds located in this area could be destroyed. Oil could temporarily damage extensive areas of marsh grass, thereby eliminating or reducing important spawning and nursery grounds. Most of the marsh fauna is located near the boundary between the grass zone and deeper estuarine waters. If oil enters the estuaries, it is believed that it will concentrate in this boundary area and thereby possibly cause high mortalities to these forms and damage the fishery species since they use this area for protection, spawning and nursery grounds, and as a food source. The larval and juvenile stages of the fishery species use the tidal passes into and out of the estuaries as migratory routes. If oil reached these areas during such a movement, juvenile mortalities could have severe effects on later fish harvests. Damage to the Gulf shoreline from spilled oil will probably be minimal unless the oil concentrates in the littoral currents which are used as a migratory aid. The most severe effect offshore would probably be damage to the spawning waters or feeding grounds used by the fishery species.

Delaware Bay (Cape May) and Two Offshore Sites

Three potential superport sites in or near the entrance of Delaware Bay were analyzed to determine the probable environmental vulnerability to oil spills from superport operations. The results of that study will be briefly noted here.

One site on the eastern side of Delaware Bay (near Cape May, N. J.) was found to be more vulnerable to oil spills than either of the two offshore sites. One site was located approximately 8 miles east of Cape Henlopen, Delaware, and the other about 20 miles offshore. These offshore sites were considered to be less vulnerable.

Winds, waves and currents in the coastal ocean offshore from Delaware Bay closely resemble those observed in the New York Bight region and indeed are part of the same coastal circulation cell. Delaware Bay waters generally circulate in a large rotary current. The flow is generally southward along the Delaware shore and northward along the New Jersey shore. Tidal currents generally dominate the Bay circulation although river discharge and local winds can modify current patterns and strengths.

Oil spilled in the region will generally be blown offshore during winter and spring months and move southward with coastal currents. During summer months when the circulation is more sluggish, spilled oil will tend to remain near the Bay entrance. In fall, the oil will likely be moved into the Bay. An oil spill in the Bay would have serious effects on bottom-dwelling organisms, especially on the commercially important oysters. Effects on phytoplankton and zooplankton cannot be estimated owing to the lack of data. Effects on finfishes would likely be greatest on bottom-feeding species. Effects on wetland and marine birds could be quite serious depending on the season of the spill.

Lower New York Bay and in New York Bight

Three locations were examined: (1) the Sandy Hook Bay site -- in the area defined as greater Raritan Bay (commonly subdivided into Raritan Bay, Lower New York Bay, and Sandy Hook Bay); (2) the Castle Hill site -- offshore from Sandy Hook near the head of Hudson Channel; and (3) the Tobay Beach site -- farther offshore about 35 nautical miles (65 km) east of the New Jersey shore and 18 miles (33 km) south of Tobay Beach on long Island, New York.

Environmental effects of operation of a supertanker terminal at one of the three sites would appear to be related primarily to either chronic leakage or accidental spills. By any criteria based on spillage, the site in Sandy Hook Bay (Lower New York Bay) would clearly be the least desirable. Traffic in and out of the port of New York is the heaviest of any port in the nation; the water inside the entrance to greater Raritan Bay is shallow, fogs are frequent, especially in summer, and there is as yet no adequate system of traffic control. Congress has recently decided to approve the Gateway National Recreation Area, and this will make it mandatory to intensify efforts to rehabilitate the environment in the Raritan Bay area. The relatively high risk of collisions or groundings and the necessity not only to avoid further contamination of greater Raritan Bay, but also to improve the marine environment in that area, would appear to be adequate justification to remove this site from consideration.

If chronic leakage or accidental spills can be contained or cleaned up quickly, then the environmental consequences of operating a deepwater terminal at either of the offshore sites probably would be acceptable. It appears to be the general view that the risk to the coastal zone environment decreases with increasing distance from shore. Therefore, it is recommended that if it is decided to construct a supertanker terminal in New York Bight it should be placed as far offshore as practical. Although the Tobay Beach site is farther offshore and in deeper water than the Castle Hill site, it may be a less desirable location because it might interfere with nearby commercial clamming and fishing operations. The extent of such interference, if any, must be determined by surveillance of fishing operations in the area.

Machias Bay, Maine

Machias Bay, Maine, the site of a proposed terminal for supertanker operations, is located on a rocky, typical northern New England embayment. The proposed superport site is near the mouth of Machias Bay and provides waters deeper than 100 feet close to the terminal site. The circulation of coastal water along the Maine coast is generally southward during the cooler months of the year. This circulation is driven primarily by density effects associated with local river discharges and modified by regional winds and is most vigorous in early spring. In autumn when winds are relatively weak and river discharge is low the circulation is sluggish. Tidal currents dominate the circulation of near-coastal waters but the details of the circulation near the proposed supertanker site are not well known. The complicated geometry of the coastline near the Machias Bay site make it difficult to develop simple mathematical simulation models that adequately describe the nearshore circulation that would play a dominant role in moving oil slicks resulting from accidents to ships or at the terminal.

Analysis of probable slick trajectories indicate that virtually the entire shoreline of Machias Bay would be coated by oil within 24 to 48 hours following a spill of 30,000 tons. A spill of 500 tons would probably deposit oil over lesser areas of the Bay shoreline. Exact trajectories would be highly dependent on local winds before and after the spill, the location of the spill, and tidal currents.

Oil would have severe effects on the intertidal organisms living on the rocky shoreline. Oil would also likely enter the small wetland areas and cover the small beaches at the head of small coves in the area. Data on marine communities of intertidal rocky shorelines are adequate to permit qualitative assessments of damage from the stranded oil. Less data is available for wetland areas and information needed for assessment of damages to aquatic organisms in the coastal waters or on the continental shelf is inadequate for reliable assessments. The study concluded that such oil spills could possibly cause localized permanent changes in communities of marine organisms.

The study concluded that the spills from supertankers would have the greatest effect on Machias Bay itself and adjoining marine areas. The impacts on adjacent Maine coastline were considered to be less, due to the longer period for the "weathering" of the oil at sea.

VI. MITIGATING MEASURES AND UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

A. Mitigating Measures

For each area of environmental concern discussed in Chapter V, certain policies and measures exist that at least partially attenuate potential environmental impacts. This section of Chapter VI addresses these mitigating aspects by environmental discipline, paralleling the discussions of Chapter V. Two categories of mitigating influences are presented:

(1) mitigating measures implemented by regulatory agencies or legislative mandate, and

(2) mitigating measures that are available to developers of the storage system by means of engineering design and construction practices.

The first category derives from the requirements of a number of federal agencies that are superimposed on this program, as well as the requirements of a number of state and local agencies which may also apply. By design these function as an environmentally mitigating influence on program implementation. Experience has shown that acknowledgment and incorporation of these requirements into the planning and design process is timely and cost-effective and that environmental impacts are thereby substantially decreased. Recognition of the likely requirements of environmental permits constitutes a mitigating measure owing to the subsequent reduction in impacts that could otherwise occur. This program proposes to meet or exceed all applicable permit requirements and other legislative and regulatory mandates of environmental protection.

The second category refers to those policy decisions and physical actions that may be adopted by participants to prevent or minimize environmental impact. They can be implemented in all facility design features, construction methods, personnel training, operating procedures, inspection and maintenance, and in general good engineering practices. Only the most significant of these mitigating measures are denoted.

1. General Programmatic and Multi-disciplinary Aspects

National Environmental Policy Act (PL 91-190)

PL 91-190 (NEPA) is the primary reason that this document, a comprehensive programmatic environmental analysis, is being prepared. Pursuant to NEPA, the Federal Energy Administration (FEA) is required to prepare this Environmental Impact Statement (EIS) for the proposed Strategic Petroleum Reserve since the project is undertaken directly by a federal agency and is likely to have impacts "significantly affecting the quality of the human environment." The statement will be submitted to the Council on Environmental Quality (CEQ), other Federal agencies, states, other private parties and the general public for review. Final approval, disapproval, or modification of the program with respect to the environment will be made by the FEA Administrator after receiving comments from these parties. The program must be designed to demonstrate, to the satisfaction of the Administrator that:

> the federal agency, to the fullest extent possible, is directing the policies, plans, and programs so as to meet national environmental goals, to encourage productive and enjoyable harmony between man and his environment, to promote efforts pertaining to eliminating damage to the environment and biosphere and stimulating the health and welfare of man, and to enrich the understanding of the ecological systems and natural resources important to the nation.

CEQ guidelines (40 CFR § 1500.6(d)(1)) state that "(in) many cases, broad program statements will be required ... Subsequent statements on major individual actions will be necessary where such actions have significant environmental impacts not adequately evaluated in the program." This document now under consideration is a "broad program statement" of environmental impact of the Strategic Petroleum Reserve program.

Use of Existing Storage Space

The kinds and magnitudes of environmental impact are generally more significant with the construction of new facilities vis a vis conversion of existing ones. It is the intent of the storage program to maximize the amount of existing storage space used in both the ESR and the SPR. Approximately 370 million barrels of existing space are potentially convertible in the storage program. This represents a substantial share of the storage volume required by the Act and, therefore, is a substantial mitigating measure as well.

Oil Procurement Criteria

As explained in Chapters II and III, FEA is proposing that oil for the SPR be acquired through open market purchase, using the normal Government procurement procedures. The criteria for evaluating the proposals to supply oil will include consideration of the manner in which suppliers will transport the oil to minimize the associated environmental impacts.

Design and Construction

Design and construction of storage facilities will employ the best available technology. This will provide the principal basis for an efficient, dependable, and environmentally compatible storage system. The chosen design concepts will combine modern, industrially proven technology with practical considerations to prevent or minimize environmental impact. Project construction will employ well-trained personnel, high-quality materials and equipment, comprehensive plans and specifications, detailed procedural guidelines to be followed for critical construction practices, and thorough, systematic inspections. Facility design and construction will conform to applicable codes and standards. Pre-operational, operational, and early-warning monitoring systems will be extensively deployed.

Location

Perhaps the most valuable recourse in mitigating adverse impacts, other than sound construction engineering of the facilities, is the flexibility with respect to their location at both regional and local levels. For example, at the regional level, storage facilities (especially surface structures) may be located only in those areas that do not have appreciable seismic risk. At the local level, ecological impacts may be mitigated by selecting sites and pipeline rights-of-way away from highly productive wetlands, breeding areas, nesting areas, tidal inlets and offshore banks and reefs. (If it is necessary to disrupt such areas during pipeline construction, it may be possible to select those areas where construction may take place during non-breeding, non-nesting, or non-migration seasons for the biota likely to be otherwise affected.)

Pipelines

Pipelines required for the storage facility will have a number of features intended to avoid rupture or corrosion damage. The pipelines will be designed for the 100-year storm conditions with appropriate safety factors. The pipes will be coated externally with an asphalt-sand mixture or coal tar enamel for corrosion protection. Pipelines also will have sacrificial zinc anodes (40-year lifetime) spaced appropriately to prevent pipeline corrosion.

Segments of pipe will be joined by welding. The integrity of each weld will be confirmed by X-ray; welded joints will also be coated. For offshore installations, the pipeline will be lowered onto the sea floor and hydraulically jetted beneath the sea bed. Safe clearance will be provided at pipeline crossings. Offshore, pipes will be lowered to provide at least three feet of clearance. Onshore, in accordance with industry practice, pipelines will be placed beneath existing lines, except where it is more practical and permissible to lower existing lines. Special design measures will control pipeline leaks.

Careful attention will be given to backfilling of pipeline trenches particularly at beach and surf zones to avoid erosion or affecting littoral currents. The pipeline route should avoid barrier islands and tidal passes which are of special importance to birds and migratory aquatic life.

Pipelaying canals will be backfilled and spoil banks lowered to approximately the original contour to preserve the natural water sheet-flow patterns. This will minimize post-construction effects on tidal exchange, vegetative growth, and migratory fish passage.

Accident Prevention

All facility buildings and equipment are designed, constructed, and inspected to adhere to all applicable federal, state and industry standards. A monitoring system will be included to provide checks of all facilities, including pressure in the pipelines. Mechanical equipment will be protected where necessary from temperature, pressure, and vibration damage by sensors which activate warning and/or shutdown devices. All pipelines will be internally and externally coated for corrosion protection. Peaking generators will provide power in the event of a utility system power failure.

Rock Disposal

The rock excavated during construction or modification of caverns and mines is a potentially valuable mineral resource. The rock is usually of high quality for purposes of road-building, aggregate, or general construction. The marketing of this material will reduce the volume that must be stockpiled in large landfills, thereby reducing potential impacts on water quality, aesthetic quality, and future land use. Generally, the marketability of this rock will result in only a small decrease in the amount of rock requiring disposal.

2. Geology

While the geologic effects of salt-dome storage of crude oil are indeterminate, the fact that only a very small part of the total volume of a salt dome will be excavated is certainly a mitigating factor. Moreover, no adverse effects have been noticed at domes whose existing cavities' volume approaches 100 million barrels.

Another mitigating influence related to geology is the ability of underground storage facilities in general, and cavities in salt in particular, to better withstand seismic events than aboveground steel tankage.

3. <u>Hydrology</u>

a. <u>Federal Water Pollution Control Act Amendments (PL 92-500)</u>

The major piece of legislation that affects water quality-related aspects of this program is PL 92-500 (FWPCAA), whose objective is "to restore and maintain the chemical, physical, and biological integrity of the nation's waters." Goals set by FWPCAA are:

- elimination nationally of the discharge of pollutants into navigable waters by 1985;
- water quality that provides for protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water by July 1, 1983; and
- prohibition of discharge of toxic pollutants.

Achievement of these major goals is to be obtained through a multi-faceted approach; those features that may directly affect the strategic storage program are discussed briefly below.

Effluent Standards

Every "new point source discharger" of pollutants is required to achieve a standard of performance that represents the best available demonstrated technology (BADT) for pollution control, as established by the EPA for that point source category. The specific, applicable effluent standards for this program, particularly brine discharge, have not yet been promulgated. (The effluent standards for the production, i.e., manufacture, of sodium chloride by the solution brine-mining process, a subcategory of the inorganic chemicals industry, have been promulgated; these standards of performance, however, are probably not applicable to this program, which proposes to discharge, rather than utilize, the "product" of the promulgated regulation.) In lieu of an applicable regulation, all discharges associated with the Strategic Petroleum Reserve Program will be judged, on an *ad hoc* basis and at the discretion of the regional EPA office, as to achievement of BADT performance. It is of interest that generally no limitation is made on the discharge of total dissolved solids in any point-source category in order to promote water recycle/reuse.

Guidance also exists for toxic effluents, but actual toxic effluent standards have not yet been promulgated. Proposed limitations and standards of performance are presented in Table VI-1. Moreover, EPA is empowered to prohibit any discharge of a toxic pollutant in any amount, as it deems necessary.

TABLE VI-1

PROPOSED TOXIC EFFLUENT LIMITATIONS
(38 FR 35388 et seq.)

Constituent	Acute Limitation (μg/l) to:*			
	FWS	FWL	EST	COAST
Aldrin-Dieldrin	0.5	0.5	5.5	5.5
Benzidine	1.8	1.8	1.8	1.8
Cadmium	40	40	320	320
Cyanide	100	100	100	100
DDT-Endrin	0.2	0.2	0.6	0.6
Mercury	20	20	100	100
PCB's	280	280	10	10
Toxaphene	1	1	1	1

*Daily average values for discharges that will undergo immediate 10:1 dilution/diffusion in:

FWS = Fresh Water Stream;
FWL = Fresh Water Lake;
EST = Estuary

	Maximum Permissible Mass Rate (lb/day)**			
	FWS	FWL	EST	COAST
Aldrin-Dieldrin	0.162	0.135	1.512	1.782
Benzidine	0.97	0.97	0.97	0.97
Cadmium	12.96	10.8	86.4	102.6
Cyanide	N/A	N/A	N/A	N/A
DDT-Endrin	0.0648	0.054	0.162	0.194
Mercury	1.62	1.35	2.70	3.24
PCB's	0.0648	0.0540	0.459	0.551
Toxaphene	0.324	0.270	0.270	0.324

**FWS = Fresh Water Stream:
FWL = Fresh Water Lake
EST = Estuary

Oil and Hazardous Substance Liability

The discharge of oil and hazardous materials in quantities deemed harmful (e.g., oil productng a visible film or sheen) to a body of water is prohibited; unlawful discharge is subject to substantial fines and/or imprisonment. The FWPCAA differs from most states' requirements in that it emphasizes measures to prevent oil spills. Such measures at new sources include fail-safe design concepts and innovative spill prevention methods and procedures. A readily deployed Spill Prevention Control and Countermeasure Plan at each facility is required, as is the reporting of all oil spills. Moreover, a national contingency plan for oil and hazardous substance pollution provides for an integrated, coordinated response by various federal and other entities.

Oil spills will fall under the jurisdiction of EPA from non-transportation-related facilities, including oil storage facilities and appurtenances, and under the jurisdiction of the Department of Transportation for transportation-related equipment and facilities and for operation of vessels.

NPDES Program

The primary vehicle to achieve the goals of the FWPCAA is the Section 402 permit program establishing the National Pollutant Discharge Elimination System (NPDES). Because the installations associated with the Strategic Petroleum Reserve are federal facilities, the NPDES permit program will be administered by the appropriate EPA region, even if it is in a state authorized to otherwise self-administer the permit program. State certification that the discharge will comply with applicable effluent standards and will meet the appropriate in-stream water quality standards is required, however, if the discharge is made within the territorial limits of a state; more stringent controls may be imposed by the state if BADT is not sufficient to comply with current in-stream standards.

A proper and complete permit application is reviewed by both the interested public and various federal offices. In particular, the Corps of Engineers must evaluate the impact of the proposed discharge on anchorage and navigation; the Corps may unilaterally veto the application, or require changes and/or conditions to safeguard navigation. The Corps is the permit authority for disposal of dredged or fill material, as discussed in a subsection below. Also, a permit will not be issued if discharge is planned to coastal or ocean waters and the discharge does not meet EPA's guidelines for those waters, or if at EPA's discretion insufficient information is available to make such a determination. Ocean discharge is also specifically addressed below.

The permit itself is essentially a contract between the Federal Government and the discharger. It specifies which pollutants may be discharged and sets average and maximum daily limits, with respect to mass rates, on those discharges as needed to meet effluent standards, water quality standards, or any other Federal or state requirements. The permit is for a fixed period of time, but for no more than five years. If compliance is not possible upon issuance (or for nine months thereafter), a schedule of compliance is established which requires progressive action or achievement of interim effluent limitations by specific date(s) no more than nine months apart. In lieu of such action or achievement, written progress reports are required. The permittee is generally required to monitor regularly and periodically all major discharges and any discharge containing a toxic pollutant, as promulgated by EPA, and to report at least annually the results of all monitoring activities. Monitoring and reporting may be required of any discharge at the discretion of either EPA or the state whose territorial waters are affected by the discharge.

Ocean Discharge

The criteria for evaluation of ocean discharges are currently under revision. At the present time, in absence of more directly applicable guidelines, ocean discharge by offshore outfalls is administered as a part of ocean dumping. A "special permit" would likely be required under these promulgated regulations, but no difficulties in obtaining or renewing (required for the program) such a permit are immediately apparent; most of the emphasis in current ocean dumping regulations concerns toxic or potentially toxic contaminants and these are strictly regulated.

About mid-1976, i.e., before construction of the storage facilities begins, the evaluation and permitting of discharges of effluent through all ocean outfalls is scheduled to be transferred from the Ocean Dumping Section to the Municipal Construction Division. The new guidelines have not yet been made publicly available, but the superseding regulations and criteria are not anticipated to be significantly different in application than those under ocean dumping. The permittee must demonstrate, however, generally through properly conceived and applied mathematical models, that all important aspects and ramifications for aquatic ecosystems have been considered. Such a demonstration is included, of course, in this statement with respect to brine discharges, the only potential ocean discharge anticipated from the storage program.

It is appropriate to note here that the permit for ocean discharges satisfies requirements not only of Sections 401 and 403 (Ocean Discharge Criteria) of PL 92-500, but also those under Title I, PL 92-532, the Marine Protection, Research, and Sanctuaries Act of 1972. Both laws require the permits to be based upon criteria that take account of the effects on human health, marine life, and amenities; the permanence and persistence of those effects; and the possible alternative disposal methods. PL 92-532 is the authority for actual promulgation of final regulations, and PL 92-500 requires the establishment of specific guidelines for determining ocean water quality degradation as well as the applicant's submission of sufficient information without which no permit can be issued.

b. Safe Drinking Water Act (PL 93-523)

The Safe Drinking Water Act, PL 93-523, was recently passed into law. This is the first legislation that explicitly deals with ground-water quality degradation and protection, and, as such, it will have a far-reaching effect. Most features of the Act are intended to be carried out immediately after promulgation by the states, with the Federal Government serving only to insure that ground-water protection is provided. However, owing to the potential problems with respect to ground water engendered by subsurface emplacement of fluids, EPA is actively pursuing one of the mandates of the Act that is important to the proposed storage program, viz, regulation of deep well injection. Regulations have been proposed, although not yet promulgated, concerning both interim guidelines to be administered by EPA and also necessary elements of state underground injection control permit programs with respect to deep-well injection. (Shallow-well injection is anticipated to be given more flexibility in regulation among the states and generally will be by rule rather than by permit.)

Typical information requirements for evaluating a brine disposal well system are anticipated to be similar to those given in Table VI-2. These are necessary and sufficient to insure that potable ground water is not endangered, within the provisions of the issued permit. Permit conditions and contents and also monitoring requirements that may be expected are given in Table VI-3.

c. National Flood Insurance Program Requirements

As a federal action, the proposed storage program is subject to the provisions of the 1968 National Flood Insurance Act as variously amended. The provisions of the Act are to:

- Constrict the development of land which is exposed to flood damage where appropriate;
- Guide the development of proposed construction away from locations which are threatened by flood hazard;
- Assist in reducing damage caused by floods; and
- Otherwise improve the long-range land management and use of flood-prone areas.

The essential requirement pertinent to this storage program is that any structures associated with crude or product storage within a stream's flood plain must either be flood-proofed (technically unfeasible) or flood-protected (isolated from the flood waters, generally by berms). Flood-protective berms can affect stream hydraulics, and, consequently, it must also be shown that any encroachment within the floodway does not increase the water-surface elevation of the 100-year flood plain by more than one foot at any point in the immediate vicinity of the facility.

TABLE VI-2

MINIMUM INFORMATION REQUIRED* FOR PROPOSED WASTE INJECTION-WELL PERMIT

UNDER PL 93-523

(a) An accurate map showing location and surface elevation of the injection facility, property boundaries, and surface and mineral ownership.

(b) An accurate map showing the location of water wells; surface bodies of water; oil, gas, exploratory or test wells (with depths of penetration); mines (surface and subsurface) and quarries; and other pertinent surface features including residences, roads, bedrock outcrops, and faults and fractures within a two-mile radius of the injection facility.

(c) Maps and cross sections indicating the vertical and lateral limits, water levels, and direction of movement of the water in every drinking water source** which may be affected by the proposed injection.

(d) Maps and cross sections detailing geologic structure for the local area and generalized maps and cross sections illustrating the regional geologic setting.

(e) Description of chemical, physical, and biological properties and characteristics of the fluid to be injected.

(f) Volume, injection rate and injection pressure of the fluid to be injected.

(g) The following geological and physical characteristics of the injection interval and the overlying confining beds:

- (1) thickness;
- (2) areal extent;
- (3) lithology;
- (4) location, extent and effects of known or suspected faulting, fracturing and natural solution channels;
- (5) formation fluid chemistry, including total dissolved solids; and
- (6) fracturing gradients.

(h) The following engineering data:

- (1) diameter of hole and total depth of the well;
- (2) type, size, weight, and strength of all casing strings;
- (3) proposed cementing procedures and type of cement;
- (4) proposed formation testing program;
- (5) proposed artificial fracturing or stimulation program;
- (6) proposed injection procedure;
- (7) plans of the surface and subsurface construction details of the system including engineering drawings;
- (8) plans for monitoring both well head and annular fluid pressure, injection zone and other aquifers;
- (9) expected changes in pressure, native fluid displacement and direction of movement of injected fluid; and
- (10) contingency plans to cope with all shut-ins or well failures to prevent endangerment of underground drinking water sources.

(i) A written evaluation of alternative disposal practices in terms of maximum environmental protection.

*to the extent known to the applicant or readily available

**defined to include all ground water having less than 10,000 mg/1 total dissolved solids

Source: EN-374

TABLE VI-3

TYPICAL INJECTION-WELL PERMIT LIMITATIONS AND MONITORING REQUIREMENTS

UNDER PL 93-523

The terms and conditions of each issued permit must comply with the following:

(a) Adherence to any applicable, more stringent limitations including those (i) necessary to meet treatment standards, or schedules of compliance, established pursuant to State law or regulation, or (ii) necessary to meet other Federal law or regulation.

(b) Allowance of no underground injection of contaminants until after:

    (1) the use of appropriate techniques for construction, operation and maintenance of the injection system; and
    (2) provisions for adequate monitoring of the underground injection operation.

(c) Allowance of no contaminant to enter an underground drinking water source if the presence of such contaminant may endanger such drinking water source.

(d) Adequate contingency plans to cope with malfunctions or failure of the underground injection system.

(e) Adequate procedures for detecting failure of the system in a timely fashion.

(f) Provisions for the posting of bonds, assigning liability for the injected contaminants, or such other measures as the Director finds necessary to assure the availability of adequate financial resources for dealing with underground injection systems which either are improperly abandoned or may otherwise cause contamination of underground drinking water sources.

(g) That all injections authorized by the UIC permit shall be consistent with the terms and conditions of the permit and that the injection of any contaminant at a greater rate or pressure than that authorized by the permit, or a volume in excess of that authorized by the permit shall constitute a violation of the terms and conditions of the permit.

(h) That the permit may be modified, suspended, or revoked in whole or in part during its term for cause including, but not limited to, the following:

    (1) The underground injection endangering underground drinking water sources;
    (2) Violation of any material terms or conditions of the permit;
    (3) Obtaining a permit by misrepresentation or failure to disclose fully all relevant facts; or
    (4) A change in any condition that may indicate failure of the underground injection system.

TABLE VI-3 (Cont'd)

(i) That the permittee shall allow the Director or his authorized representative, upon the presentation of appropriate credentials:

(1) To enter permittee's premises in which a contaminant source or injection system is located and in which any records are required to be kept under terms and conditions of the permit;
(2) To have access to and copy records required to be kept under terms and conditions of the permit;
(3) To inspect the permittee's facilities, including any monitoring equipment or analytical devices; and
(4) To sample any fluid being injected.

(j) That the permittee at all times shall maintain in good working order and operate efficiently any facilities or systems of control installed by the permittee to achieve compliance with terms and conditions of the permit.

(k) That immediately following the permanent cessation of underground injection, the applicant shall notify the Director and follow the procedures prescribed by the Director for plugging and abandonment.

The following record-keeping requirements are specified:

(a) The permittee shall retain, for a period of five years, records of all information resulting from any monitoring activities required by the UIC permit or by regulation. This requirement shall continue in effect during the five-year period following abandonment of the well. The period of retention shall be extended when requested by the Director.
(b) Records of monitoring activities and results shall include for all samples; (1) the date, place, and time of sampling; (2) the dates analyses were performed; (3) who performed the analyses; (4) the analytical techniques/methods; and (5) the results of such analyses.

Typical monitoring activities will include:

- Weekly readings of the surface injection pressure.
- Weekly readings of the tubing - long string annulus pressure.
- Weekly total volume of injected fluid.
- Periodic well tests, including but not limited to:

  (a) Water analyses;
  (b) Bottom hole pressure readings of the injection zone;
  (c) Well conditions.

- All shut-in periods and time contingency measures used for handling the fluid to be injected.

SOURCE: EN-374

In coastal areas with potentially serious flood water levels, new construction or expansion is restricted to the landward side of mean high tide, and use of fill for structural support is forbidden; in addition, designs to withstand flooding without substantial hydraulic consequences are also required.

d. <u>State Water Quality Permits</u>

Individual stream segments of a state including coastal waters are subject to in-stream water-quality standards. The standards provide for achieving water quality goals by assigning suitable uses and specific minimal criteria for certain water quality parameters (e.g., total dissolved solids, fecal coliform, dissolved oxygen, temperature) during specified flow conditions in order to protect and enhance those uses. These numerical criteria are essentially the reference points against which water quality degradation is measured and periodically reviewed for effectiveness. A stream whose in-stream quality complies with these criteria is designated "effluent-limited," i.e., any discharges into that segment must primarily meet effluent limitations as promulgated under federal law but subject to state certification. A stream whose in-stream quality can not comply with one or more of the minimal criteria is designated "water-quality limited." A discharge permit may require that all point-source discharges to that segment be governed by a waste-load allocation program. The program will specify a requisite level of treatment for the out-of-compliance parameter(s).

e. <u>State Solid Waste Permits</u>

Most states now have a permit system designed to prevent surface-water or ground-water pollution by solid waste disposal facilities which may be applicable to the SPR. Of most concern in the permitting process is the geohydrologic isolation of the disposal site, usually by means of excavation in (or lining with) material of low permeability. A secondary concern is the prevention of extraneous surface water from entering the site (e.g., by flooding) to minimize infiltration of solid waste and leaching. In the proposed program, only very small amounts of solid waste would be generated; potential sources include wastewater treatment sludges, very saline drilling mud, various construction residuals, and ash from incinerating construction combustibles. In a broader context, the unmarketable rock from mined-cavern construction is another and volumetrically substantial solid waste which may require permitting, as such, in some states.

f. State Deep Well Disposal Permits

Only a very few states have specific deep-well disposal legislation which may apply to the SPR, but, notably, one of these is Texas. Texas' regulations were used in large part as a model for EPA's proposed regulations on underground injection control for implementation by all states pursuant to the Safe Drinking Water Act. Consequently, the Texas regulations are essentially no different from the pertinent requirements of the Safe Drinking Water Act that is discussed in a preceding section. Deep-well injection for disposal of brine will be subject to these provisions and will require a state permit in Texas. For crude storage, the Texas Railroad Commission (TRC), which regulates oil and gas activities in Texas, will be the permitting agency. If any cavities are to be used as product storage, the Texas Water Quality Board (TWQB) will probably be the permitting agency. The only substantive difference between these agencies with respect to deep-well injection permits is that the maximum injection (well-head) pressure allowable by the

TRC is 0.5 psi per foot of depth to the top of the injection zone, while the TWQB allows only 0.4 psi per foot of depth.

g. Brine Disposal

Detailed geologic and hydrogeologic reconnaissance, subsequent proper siting and spacing disposal wells, and specialized injection well design matched to expected aquifer performance will minimize the number of injection wells and the environmental consequences of deep-well disposal of brine. With dynamic pressure monitoring and positive control over injection rates and wellhead pressures, dangerously high pressure gradients may be completely avoided. Maximum utility may be made of existing injection-well performance in the proposed receiving reservoir near the disposal site. It should be mentioned that sound disposal to salaquifers is essentially a safe environmental practice.

For brine disposal in the Gulf, the primary measure for mitigating impact is the placement of the outfall diffuser and the resultant orientation of the plume under all reasonable ambient conditions. By avoiding reefs and banks that are known to support abundant, diverse marine biota and by not obstructing tidal inlets with the salinity plume, adverse ecological impact will be restricted to the immediate vicinity of the diffuser. A large distance between the shore and the outfall will serve as an additional buffer against environmental damage. The brine diffuser will be sited and designed to provide minimal physical obstruction to those normal activities that take place in coastal waters. That part of the diffuser that extends above the sea bed will be clearly marked according to navigational conventions.

The amount of brine requiring disposal and therefore attendant environmental impacts will be reduced to the fullest extent possible by furnishing the brine to proximal petrochemical industries as feedstock.

h. Sediment Production

The amount of sediment produced and the consequences with respect to stream siltation may be minimized with sound, available erosion and sediment control practices. The methods suitable for accomplishing this must be evaluated on a site-by-site basis but generally will include avoidance of potentially difficult areas, diversion of runoff, vegetative buffers, and stabilization and sediment trapping by vegetative filters and detention (or retention) basins.

i. Dredging

The adverse impacts of dredging may be mitigated and localized to the removal and disposal sites by good engineering practices, especially by proper disposal site selection to minimize ecological impacts and by prior characterization of the dredged material as to its toxicity to aquatic organisms. Moreover, dredging associated with this program is likely not to include areas that have never been dredged; the substrate in previously dredged areas is not conducive to benthic recruitment, and consequently the likelihood of extensive damage to benthic organisms is generally small.

j. Water Use

The large volumes of water to be used in constructing and operating solution mined-cavities cannot be reduced. However, the impact of this water use can be largely mitigated by using water of poor quality, i.e., high salinity. The Gulf of Mexico represents an essentially unrestricted source of saline water. Large amounts of saline ground water are available in storage and it is not likely that this water would have competing uses during the course of the program. Storage of saline surface water in brine ponds may also be used to provide the required water supply.

k. Aqueous Discharge

Aqueous wastes associated with aboveground tankage consist of tankage condensates and rainwater runoff. The impact of aqueous wastes on the environment is minimized by waste water containment and proper disposal. Tankage condensates are stored in a closed vessel and delivered to a waste disposal company. Rain runoff water is retained within the diked areas until absorbed or evaporated.

4. Meteorology and Climatology

Whenever possible, tankage and other above-ground appurtenances will be constructed out of or above the hurricane surge zone.

5. Air Quality

a. Clean Air Act

Basic Features

The Clean Air Act (42 U.S.C. 185, et seq., the Act,) includes the Clean Air Act of 1963 (PL 88-206) and amendments made by the Motor Vehicle Air Pollution Control Act (PL 89-272, October 20, 1965), the Clean Air Act Amendments of 1966 (PL 89-675, October 15, 1966), the Air Quality Act of 1967 (PL 90-148, November 21, 1967), the Clean Air Amendments of 1970 (PL 91-604, December 31, 1970), the Comprehensive Health Manpower Training Act of 1971 (PL 92-157, November 18, 1971), and the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL 93-319, June 22, 1974). The basic features of the Act are described below followed by a description of particular portions applicable to the proposed program.

National Ambient Air Quality Standards

National Ambient Air Quality Standards (NAAQS) were promulgated by the Environmental Protection Agency in 1971. Two levels of protection were defined. Primary standards were set to protect the public health with a margin of safety. Secondary standards were set to protect the public welfare. Public welfare includes, but is not limited to, effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being. In 1971, standards were set for six "criteria" pollutants: suspended particulates, sulfur dioxide, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen dioxide. These standards as amended are presented in Table VI-4.

The Act required states to submit to EPA legally enforceable implementation plans which would achieve and maintain the NAAQS. The plans were to provide for attainment of the primary standards within three years from the date of plan approval. The Act also required secondary standards to be achieved within a "reasonable time." EPA has defined "reasonable time" to be three years for areas which can attain the secondary standards through application of reasonably available control technology.

TABLE VI-4

NATIONAL AMBIENT AIR QUALITY STANDARDS

	Primary µg/m³ (ppm)	Secondary µg/m³ (ppm)
Particulate Matter		
Annual geometric mean	75	60†
Maximum 24-hour††	260	150
Sulfur Dioxide		
Annual arithmetic mean	80 (0.03)	--
Maximum 24-hour††	365 (0.14)	--
Maximum 3-hour††	--	1,300 (0.5)
Carbon Monoxide		
Maximum 8-hour††	10,000 (9)	10,000 (9)
Maximum 1-hour††	40,000 (35)	40,000 (35)
Photochemical Oxidants		
Maximum 1-hour††	160 (0.08)	160 (0.08)
Hydrocarbons (non-methane)		
Maximum 3-hour (6 to 9am)††	160 (0.24)†††	160 (0.24)†††
Nitrogen Dioxide		
Annual arithmetic mean	100 (0.05)	100 (0.05)

† A guide to be used in assessing implementation plans to achieve the 24-hour standard

†† Not to be exceeded more than once per year

††† A guide in devising implementation plans to achieve oxidant standards

Source: CO-182

For other areas "reasonable time" depends upon the degree of emission reduction needed for attainment and the social, economic and technological factors involved in the required control strategy (CO-182).

Initial state implementation plan (SIP) approvals and disapprovals were published May 31, 1972, by EPA (EN-420).

Most plans required attainment by July 1975. Some portions of some plans have received time extensions until July 1977.

Subsequent to the initial plan approvals and disapprovals, court decisions determined that the plans did not contain measures necessary to ensure maintenance of the primary standards after attainment (EN-423). The EPA has since published lists of regions termed air quality maintenance areas (AQMA's) which the states must analyze for possible violation of national standards within a ten-year period subsequent to the attainment date. The states are currently formulating plans which will obviate any predicted maintenance problems.

The initially approved plans also were challenged in court on the question of degradation of areas already well below secondary standards. The courts decided that EPA must regulate such degradation. On December 5, 1974, EPA promulgated regulations to control such degradation even though acknowledging expected legislation which may strike down the non-significant deterioration mandate of the Clean Air Act (EN-419). The promulgated regulations define three classes of allowable increases in ambient air quality for particulate matter and sulfur dioxide. States are given the option of specifying the stringency of non-degradation allowed by designating the class of increment allowed for an area, so long as the increment does not cause violation of the secondary standard. Specifically, EPA has identified nineteen source categories which are subject to "new" source review prior to construction. The review must show that the proposed "new" plant will not violate the class air quality increment extant for the region of the plant's location. In summary, the regulations attempt to avoid air deterioration of entirely "clean" AQCR's and clean portions of "dirty" AQCR's.

The recent energy situation has also affected the Clean Air Act. Provisions in the Energy Supply and Environmental Coordination Act of 1974 have required some rural area power plants to switch from liquid to higher sulfur, solid fossil fuels. Section 119 of the Clean Air Act now allows certain time extensions for compliance with plan emission limitations so long as the primary standards will not be violated.

The national ambient air quality standards remain the goal of the Clean Air Act, with the state implementation plan the vehicle. The basic features of the plans include new source review and emission limitations to implement the NAAQS. In addition, the Act has required EPA to promulgate New Source Performance Standards (NSPS) for major pollution potential source categories. The above provisions are discussed below along with their applicability to the proposed program.

Emission Limitations

The most basic provision of the Clean Air Act for attaining the national ambient air quality standards requires control of pollutant emissions at the source, i.e., emission limitations. For stationary sources, this type of regulation requires a certain level of emission control through the use of "reasonably available" control technology. To meet emission limitations, industrial process emission sources may employ add-on control devices which collect generated pollutants prior to emission or process alterations which prevent the generation of the pollutant. Fuel combustion emission sources may employ alternate fuels, different quality fuels, add-on control devices, or combustion alterations to meet emission limitations for criteria pollutants such as particulates, sulfur dioxide, and nitrogen oxides.

Emission limitations for other categories of sources have in some cases been difficult to specify because of various problems such as sampling. An example of this is fugitive dust emissions from miscellaneous distributed sources such as unpaved roads, agricultural operations, major construction activities, etc. These categories of sources are estimated to be, in some areas, major contributors to violations of the 24-hour particulate matter standards. Quantification of these types of emissions is much more difficult than typical stack-vented emissions. Emission limitations for these fugitive dust type sources specify the type of control required, e.g., paving gravel roads, rather than a percentage emission reduction required.

New Source Review

Another requirement for state implementation plans to meet the NAAQS is the new source review. In addition to compliance with emission limitations, the new source must be analyzed on the basis of its location to determine if it will cause or contribute directly or indirectly to violation of any national standard (CO-182). This provision directly affects land use planning and produces secondary or indirect effects on various human activities. Interpretation of this provision has undergone some changes, but the basic goal is to assure that a new source location will not infringe on the existing air quality such that the primary air quality standards are violated.

The most recent ruling from EPA regarding new source review has established the trade-off system (EN-492). Under this provision new sources are required to show that emissions from the new source plus SIP-required reductions from existing sources equal a net decrease in emissions. That is, the new source should not delay progress toward achieving the NAAQS in non-attainment AQCRs. The effects, if any, of this ruling on the SPR program remain uncertain at this time.

New Source Performance Standards (NSPS)

The Clean Air Act also requires EPA to establish federal standards of performance for "new" sources in categories which contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare. EPA has now promulgated NSPS for over a dozen categories of sources including liquid petroleum storage vessels. NSPS generally are emission limitations which require use of the best available control equipment for an emission source. Primary responsibility for enforcement of NSPS lies with EPA, although states can request delegation of this authority as a part of their SIP's.

Applicability

In general, the proposed program will be required to conform to the Clean Air Act. The program phases of construction, operation and maintenance for each type of storage must not cause or contribute to the violation of any of the NAAQS. Specifically, the equipment and operations of each proposed storage program will be subject to emission limitations of the state implementation plan. The actual requirements are site (state or local) specific and cannot be definitely set forth on the programmatic level.

Potentially, the storage systems must restrict petroleum hydrocarbon evaporative emissions such that they do not cause or contribute to violation of the national hydrocarbon and photochemical oxidant standards. Storage of petroleum in tankage will be regulated by the new source performance standards (NSPS) if the petroleum stored is any finished or intermediate product manufactured in a petroleum refinery except Numbers 2 through 6 fuel oils as specified in A.S.T.M. D 396-69, gas turbine fuel oils Numbers 2-GT through 4-GT as specified in A.S.T.M. D 2880-71, or diesel fuel oils Numbers 2-D and 4-D as specified in A.S.T.M. D-975-68 (CO-182). Storage of residual or distillate fuel oil in on-shore tankage is exempt from NSPS. Also, underground storage of petroleum in salt domes or mines is entirely exempted from NSPS (CO-182). Presently, no specific federal air pollution regulations regulate crude oil unloading and loading from marine tankers, although some SIP's do regulate tanker operations handling gasoline. See the following section.

As described above, EPA policy regarding major new hydrocarbon sources in non-attainment AQCRs is still developing. It is recognized that although the proposed program may be within existing state implementation plans, future revisions may require additional controls to existing facilities. In addition, on-going development of new source performance standards for marine tanker unloading and loading may affect the proposed program.

b. State Air Quality Standards and Emission Limitations

As discussed in Section VI.A.5.a, Clean Air Act, states have the responsibility to implement the national ambient air quality standards in their state. This is accomplished through legally enforceable state implementation plans. In addition, states or other local governments have the option to legislate air quality standards for their state more stringent than the NAAQS and which may be applicable to the SPR. These state standards, along with the regulations required to implement them, may or may not be part of the state implementation plan (SIP) required by the Clean Air Act. State standards in some cases also regulate non-criteria pollutants such as fluorides, hydrogen sulfide, etc.

Applicability to the proposed program of more stringent state or local standards cannot be specified on the programmatic level. In the site-specific analysis, these factors can be determined for the area in question. As an example, the Texas SIP regulates marine tanker hydrocarbon vapor emissions but specifically excludes crude oil (CO-182). Moreover, facilities at certain sites may incur more stringent regulatory requirements under the emerging federal policy concerning non-attainment, even though they are in conformance with the applicable SIP.

c. Pressurized Underground Storage Space

To reduce the explosiveness of the vapor space in mined storage facilities containing volatile products or crude, the vapor would be allowed to build to a pressure greater than atmospheric at which point the vapors would be vented to the atmosphere. The elimination of hydrocarbon emissions may then be accomplished in one of two ways. As one alternate method, a temporary flare system may be used. A second alternative would provide for the vented vapors to be directed through a condensation unit on the surface, and the condensed liquid returned to the storage caverns.

d. Air Residuals of Aboveground Tankage

Mitigating measures available in the design of aboveground tankage are presented below. Mitigating measures for tankage can be divided into four categories, those applicable to the construction phase, the filling phase, the static storage phase, and the emptying phase.

Construction

Air residuals generated by the construction of aboveground tankage were identified in Section II.F.2 as dust from earth-moving operations, fine particulates from sandblasting, and hydrocarbons from spray-painting. Dust generated by earth-moving operations can be greatly reduced by dampening the ground regularly. Tank sandblasting operations are not controllable. However, alternative grinding techniques may be available which generate fewer fine particulates. Hydrocarbon emissions from spray painting operations can be reduced by using high density primers and paints which reduce the required number of coats and therefore the hydrocarbon emissions by potentially 50 percent.

Filling

The primary air emissions generated during filling operations at an aboveground tankage facility consist of hydrocarbon vapors displaced from the filled tank. Floating roof tanks or combinations of floating and fixed-roof tanks, and vapor control systems are efficient in reducing these emissions. In addition, to the extent practicable, filling operations can be carried out during periods least conducive to oxidant formation (i.e., winter and spring).

Static Storage

Residuals generated by aboveground tankage during the static storage phase have been identified in Section III.A.3 and RA-223 as hydrocarbon vapors and wastewater. Hydrocarbons emissions from static storage are attributable to diurnal tank breathing. Hydrocarbon emissions from residual oil and distillate oil storage are small compared to transfer losses. Mitigating measures for transfer losses (e.g., floating-roof tank) are also effective in minimizing static storage losses.

Emptying

Emissions occurring during emptying operations are associated with the combustion products generated by the steam boiler. Heating steam is required to liquify residual oil. Major combustion emissions are particulates, sulfur oxides, and nitrogen oxides. Under most conditions these emissions will have negligible impact. Nitrogen oxide emissions can be reduced through combustion modifications, and sulfur oxide emissions can be reduced by burning a lower sulfur fuel.

e. Marine Tanker Operations

The hydrocarbon vapor emissions occurring from unloading and loading marine tankers has been shown to have the largest air impact (Sections V.A.4 and V.A.5). Several measures for prevention of these impacts are presented here. Because of cost limitations, some of these measures may only be feasible for new tankers. Refer to RA-223 for a more detailed explanation of these emissions and the reference for the following.

Unloading Operations

Emissions are caused by ballasting subsequent to unloading. One method of reducing in-port emissions from ballasting would be to take on less water in port. Also, tankers which have segregated ballast tanks could be used. These types of tankers use separate tanks for ballast and oil cargo storage. The number of these types of ships available for use in the proposed program is thought to be small.

Another emission prevention method would be hydrocarbon vapor control equipment. Hydrocarbon vapors are collected onboard the tanker and piped to on-shore recovery or disposal equipment. Refrigeration, absorption, and incineration are the most likely control devices used on-shore. Incineration, although having an effective control efficiency of over 99 percent, is a potential hazard due to explosion.

Loading

Loading hydrocarbon emissions from tanker cargo tanks occur by the displacement of vapor-rich air by in-coming crude. Emissions can be prevented by two methods. The first is to purge empty tanks at sea so as to remove hydrocarbon vapors. Two forms of this clean-up operation are heel washing and butterworthing. Heel washing removes puddles of oil left from the previous cargo shipment after unloading. Butterworthing is the washing down of tank walls. It is estimated that these housekeeping activities could reduce in-port filling emissions by over 50 percent. The second means of emission prevention is to employ vapor control equipment as described for unloading operations. Estimates of installed costs for vapor control equipment range from $200,000 to $1,000,000 per 10,000 bbl/hr of loading capacity. These costs are for shore-side equipment only. Installation costs for ship collection system range from $300,000 to $350,000 per vessel.

6. Noise

Construction noise levels will be kept as low as practical through proper maintenance of exhaust systems and through adherence to OSHA standards. Personnel will be protected in their work environment according to established OSHA noise level standards. For sites near inhabited areas, it may be necessary to institute a noise reduction program with installation of noise abatement designs.

7. Biology

Two Federal laws are directly applicable to mitigating impacts and protection of biota: the Endangered Species Act of 1973, and the Fish and Wildlife Coordination Act.

Endangered Species Act of 1973 (PL 93-205)

This act gives the Departments of Interior and Commerce authority to determine endangered and threatened species and to protect them and their habitat. Section 7 of the Act requires that all federal departments and agencies utilize their authorities by carrying out programs for the conservation of endangered and threatened species. Section 7 of the Act also explicitly directs all federal departments and agencies to insure that any actions taken by them do not jeopardize endangered or threatened species or result in the destruction or modification of their habitat.

The Fish and Wildlife Coordination Act (16 U.S.C. 661-667e)

This act requires that the U.S. Fish and Wildlife Service be consulted whenever the waters of any stream or other body of water are proposed or authorized to be controlled or modified for any purpose whatever by any department or agency of the United States, or by any public or private agency under federal permit or license. The purpose of the consultation and ensuing recommendations is the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for their development and improvement in connection with water-resource development.

In addition to the legislation described above, the reader should also refer to the following subsections:

- Multidisciplinary Aspects, NEPA
- Multidisciplinary Aspects, Location
- Multidisciplinary Aspects, Pipelines
- Hydrology, PL 92-500
- Hydrology, Brine Disposal
- Control and Cleanup of Spilled Oil.

8. Historical and Archaeological Aspects

Due to the importance of historical and archaeological resources, legislation has been enacted to provide for their protection and preservation. Each piece of major legislation is briefly described below.

Antiquities Act of 1906 (Public Law 209)

This act provides for the protection of all historic and prehistoric ruins or monuments on federal lands. It prohibits any excavation or destruction of such antiquities without permission of the Secretary of the Department having jurisdiction. It authorizes the Secretaries of the Interior, Agriculture and War to give permission for excavation to reputable institutions for increasing knowledge and for permanent preservation in public museums. It also authorizes the President to declare areas of public lands as national monuments and to reserve lands for that purpose.

Historic Sites Act of 1935 (Public Law 74-292)

This act declared as national policy the preservation for public use of historic sites, buildings, and objects. It led to the establishment of the Historic Sites Survey, the Historic American Buildings Survey, and the Historic American Engineering Record, by giving the Secretary of the Interior the power to make historic surveys, to secure and preserve data on historic sites, and to acquire and preserve archaeological and historic sites. The National Historic Landmarks program and its Advisory Board were also established under this act to designate properties having exceptional value as commemorating or illustrating the history of the United States.

National Historic Preservation Act of 1966 (Public Law 89-665)

This act provided for an expanded National Register of Historic Places to register districts, sites, buildings, structures and objects significant in American history, architecture, archaeology, and culture. It provided for a program of matching grants-in-aid to the States for historical surveys and planning and for preservation, acquisition, restoration, and development projects. The act also established the Advisory Council on Historic Preservation, to advise the President and the Congress on matters relating to historic preservation. The Advisory Council is authorized to secure information it may need from federal agencies in order to carry out its responsibilities. Section 106 of the Act requires federal agency heads to allow the Advisory Council opportunity to comment when undertakings to be licensed, funded, or executed by their agency will affect properties listed in the National Register.

The Archaeological and Historic Preservation Act of 1974 (PL 93-291)

Enacted May 24, 1974, the Act is directed to the preservation of historic and archaeological data that would otherwise be lost as a result of federal construction or other federally licensed or aided activities. It authorizes the Secretary of the Interior, or the agency itself, to undertake recovery, protection, and preservation of such data. Where the Federal Government financially aids in activity that may cause irreparable damage, the Secretary of the Interior may survey the data and undertake recovery and preservation. Archaeological salvage or recording by the Historic American Buildings Survey or the Historic American Engineering Record are among the alternatives available to the Secretary. When the activity takes place on private land, the Secretary must compensate the owner for any resultant delays or loss of use of the land. This Act presents two innovations over previous law: (1) only dams were covered; now all federal projects are; and (2) up to one percent of project funds may be used for this purpose. This Act is not a substitute for federal agency responsibilities under other environmental and historic preservation legislation.

Executive Order 11593

This Executive Order, entitled "Protection and Enhancement of the Cultural Environment," emphasizes the leadership role of the Federal Government in the preservation of the Nation's cultural environment. It directs federal agencies to establish procedures, in consultation with the Advisory Council on Historic Preservation, regarding the preservation and enhancement of non-federally owned historic and cultural resources. The order also directs all federal agencies, in cooperation with the appropriate State Historic Preservation Officer, to locate, inventory, and nominate to the Secretary of the Interior all properties under their jurisdiction or control which appear eligible for listing in the National Register of Historic Places. In addition, the Advisory Council procedures for the implementation of Executive Order 11593 call for the identification of cultural resources in the potential environmental impact area of federal projects. Agencies, in consultation with the appropriate SHPO, are to supply the National Register criteria for evaluation to these resources. For all properties which appear to meet these criteria, or where it is questionable whether the criteria are met, the agency is responsible for requesting offical determinations of eligibility for inclusion in the National Register from the Secretary of the Interior. Proposed procedures for determinations of eligibility have been published in the "Federal Register" and, when approved, may be found at 36 CFR part 63.

a. Programs for the Protection and Preservation of Historical Resources

Subsequent to the legislation discussed above, various programs have been established to implement the measures specified.

The National Register of Historic Places

The National Register of Historic Places is defined as a register of districts, sites, buildings, structures, and objects which, on the basis of established criteria, are considered to be significant to American history, architecture, archaeology and culture. It has further been described as a "protective inventory of irreplaceable resources" (AD-029). The Register is maintained by the Secretary of the Interior.

The following guidelines have been established for evaluating properties proposed for inclusion in the National Register:

"The quality of significance in American history, architecture, archaeology, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling and association, and;

(A) that are associated with events that have made a significant contribution to the broad patterns of our history; or

(B) that are associated with the lives of persons significant in our past; or

(C) that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

(D) that have yielded, or may be likely to yield, information important to prehistory or history.

"Ordinarily cemeteries, birthplaces, or graves of historical figures, properties owned by religious institutions or used for religious purposes, structures that have been moved from their original locations, reconstructed historic buildings, properties primarily commemorative in nature, and properties that have achieved significance within the past fifty years shall not be considered eligible for the National Register. However, such properties will qualify if they are integral parts of districts that do meet the criteria or if they fall within the following categories:

(A) a religious property deriving primary significance from architectural or artistic distinction or historical importance; or

(B) a building or structure removed from its original location but which is significant primarily for architectural value, or which is the surviving structure most importantly associated with a historic person or event; or

(C) a birthplace or grave of a historical figure of outstanding importance if there is no appropriate site or building directly associated with his productive life; or

(D) a cemetery which derives its primary significance from graves of persons of transcendent importance, from age, from distinctive design features, or from association with historic events; or

(E) a reconstructed building when accurately executed in a suitable environment and presented in a dignified manner as part of a restoration master plan, and when no other building or structure with the same association has survived; or

(F) a property primarily commemorative in intent if design, age, tradition, or symbolic value has invested it with its own historical significance; or

(G) a property achieving significance within the past fifty years if it is of exceptional importance." (AD-029)

Nominations to the National Register are made by each state through the SHPO. In addition, federal agencies are responsible, under Executive Order 11593, for nominating all properties under their jurisdiction and control that might quality for the National Register. Procedures for nominating properties to the National Register are found in 36 CFR Part 60.

Advisory Council on Historic Preservation

The Advisory Council on Historic Preservation (ACHP) was established by the National Historic Preservation Act of 1966 to advise the President and Congress on historic preservation matters. The Council reviews all federally-assisted and federally-licensed activities which impact National Register properties or those eligible for inclusion in the Register. This review must precede approval of an activity. Procedures for this review are found in 36 CFR 800, "Procedures for the Protection of Historic and Cultural Properties." A summary of 36 CFR 800 is given below.

As a first step in planning a project for a specific site and before the initiation of any activity, FEA would identify properties located within the area of the undertaking's potential environmental impact that are included in or eligible for inclusion in the National Register. Procedures would be undertaken in accordance with 36 CFR 800.4(a)(2), and in consultation with the appropriate SHPO.

All environmental impact statements involving historical, archaeological, architectural, or cultural resources, whether or not included or eligible for inclusion in the National Register, should be submitted to the Department of the Interior for review (AD-029, AR-068).

As previously stated, all federal, federally-assisted, or federally-licensed activites affecting National Register properties or properties eligible for inclusion therein must be submitted to the Advisory Council on Historic Preservation for review and comment, an authority established by Section 106 of the National Historic Preservation Act of 1966. This review will precede approval of the activity. Statements of no adverse effect and/or adverse effects must be submitted for all affected National Register properties and all properties eligible for the National Register. Accompanying documentation should include all relevant information concerning the undertaking to allow for an evaluation of the undertaking, its effects, and appropriate alternatives (AD-029).

In cases of adverse effect, an attempt will be made to implement "a feasible and prudent alternative to avoid or satisfactorily mitigate any adverse effect" of the undertaking (AD-029). This decision will be made by the Executive Director of the Council in consultation with the Agency Official submitting the request for approval and the State Historic Preservation Officer. Mitigation measures could include professional salvage of a site to preserve a meaningful record of its existence or selection of an alternate location for the undertaking. Should there be no feasible or prudent alternative, the requirements of 36 CFR 800 will be met.

b. Program Policy

It is the expressed policy of the ESR and SPR Programs to utilize only those sites and rights-of-way that do not affect historical and archaeological resources listed in or eligible for inclusion in the National Register. Should there by no prudent or feasible alternative to the use of sites and rights-of-way that affect such resources, the requirements of 36 CFR 800 will be met as stated above. FEA will conduct a survey of such resources of each site, and will request review and concurrence from appropriate federal and state agencies.

9. Land Use and Related Planning

a. State Land Use Programs

Table VI-5, "State Land Use Programs," has been designed to illustrate at a glance the status of programs and/or controls within the principal states involved with the Strategic Petroleum Storage Program. These programs are unique to each state and therefore actual program impact can be evaluated only when specific sites are selected. There is no federal land use legislation at present, although there is much activity in both support of and opposition to proposed legislation.

TABLE VI-5

STATE LAND USE PROGRAMS (September 1974)

STATE	STATEWIDE LAND USE PLANNING & CONTROL (a)	COASTAL ZONE MANAGE-MENT (b)	WETLANDS MANAGE-MENT(c)	DESIGNATION OF CRITICAL AREAS (d)	LAND USE TAX INCENTIVES (e)	FLOOD PLAIN MANAGE-MENT (f)
CONNECTICUT	P	-	Yes	-	Yes	Yes
DELAWARE	P	Yes	Yes	-	Yes	-
LOUISIANA	-	-	Yes	-	Yes	-
MAINE	P & R	Yes	-	Yes	Yes	Yes
MARYLAND	P & R	-	Yes	-	Yes	Yes
MASSACHUSETTS	-	-	Yes	-	-	-
NEW HAMPSHIRE	-	-	Yes	-	Yes	-
NEW JERSEY	-	-	Yes	-	Yes	Yes
NEW YORK	P	-	Yes	Yes	Yes	-
NORTH CAROLINA	P	Yes	Yes	-	Yes	Yes
RHODE ISLAND	P	Yes	Yes	-	Yes	-
TEXAS	-	Yes	-	-	Yes	-
VIRGINIA	-	Yes	Yes	-	Yes	-

a. P Indicates the State has a land use planning program underway. R indicates the State has authority to review local plans or has direct control.
b. State has authority to plan or review local plans or the ability to control land use in the coastal zone
c. State has authority to plan or review local plans or the ability to control land use in the wetlands.
d. State has established rules, or is in the process of establishing rules, regulations, and guidelines for the identification and designation of areas of critical state concern (e.g., environmentally fragile areas, areas of historical significance).
e. State has adopted tax inducements to withhold or delay development of open space (e.g., tax on present use, rollback penalty, contract between the State and landholders to provide preferential tax for commitment to open-space usage).
f. State has authority to regulate the use of flood plains.

Source: CO-377

b. Size of Affected Area

For security reasons, the surface area above a storage facility must not entertain other land uses and will likely be fenced to deny access to unauthorized personnel. The size of this area can be reduced, however, to mitigate land use impacts. For storage in new cavities in salt domes, the surface area affected may be diminished by multiple-tier cavity development. If any neighboring land use results in conflicting goals at those locations, this mitigating measure may substantially reduce the problem area to a resolvable size. At new or converted mine sites, locating support equipment and piping underground and interconnecting the individual storage galleries minimize the surface area required for storage appurtenances. Similarly, marketing the mined rock from a new mine reduces the volume for disposal and decreases land use by the program.

10. Control and Cleanup of Spilled Oil

A principal criterion governing storage system operational procedures is the need to prevent chronic or major releases of oil to the environment. Considerable efforts will be made to educate personnel and to supervise, monitor, and improve operations to prevent any accidental releases of oil.

An oil spill contingency plan which outlines response activities and areas of responsibility in the event an oil spill accident or leak should occur will be developed. (See discussion in VI.A.3.a.) The plan objective will be to deploy the proper equipment as quickly as possible for containment of the oil, to recover the oil as efficiently and completely as possible, and to clean up impacted areas to original condition, insofar as practicable. This section summarizes control and cleanup methods and procedures. Means of mitigating not only the effects of spilled oil but also the ecological impacts of the cleanup process are described.

Current guidance (33 CFR 153.305) for removing spilled oil emphasizes the timely and effective use of mechanical/manual methods and judicious use of sorbents (agents used to absorb oil on a floating mass for subsequent collection and removal) that minimize secondary impacts. A variety of other treating agents have been used effectively in the past to control oil spills. These include:

- Burning agents are chemicals or other materials which assist ignition or enhance combustion of spilled oil.
- Dispersants are chemicals forming oil-in-water suspensions.
- Biodegradants are substances that promote oxidation of oil by bacterial action.
- Gelling agents are chemicals that form semi-solid oil agglomerates and facilitate removal.
- Herding agents are chemicals that concentrate the spilled oil in a small area.

However, the use of these chemical treating agents is now carefully regulated as their secondary effects can also be adverse, and they may be employed only on a site-by-site basis after evaluation and authorization by the federal response team as set forth in Annex X of the CEQ's National Oil and Hazardous Substances

Pollution Contingency Plan (40 CFR 2001 and following). The selected methods of control of accidental spills depend to a large extent on whether the spill is located at the terminal, at sea, or near shore.

Containment and Cleanup at Terminal

In the past, routine operations in terminal areas caused chronic, low-level oil pollution from small spills. While industry has substantially ameliorated such conditions in recent years, the potential for small oil spills at terminal areas is still relatively high, and containment and removal equipment will be required to be on-site, ready for immediate deployment should oil be spilled.

In addition to booms and pneumatic barriers, there are other methods of controlling and collecting spilled oil. Skimming devices scrape oil off the water surface or force it along rotating elements (plates, disks, belts, etc.) from which it can be recovered. Vortex generating devices to separate oil and water have been developed. Magnetic liquids can be added to the oil, and recovery by magnetic pick-up devices is then possible. One of the most promising of all these collection devices for use in offshore terminal harbors appears to be a skimmer boat using an inclined plane. As the collection boat moves through the water, oil and water-in-oil emulsions are forced along the moving plane. When the oil-water mixture reaches the collection well it is pumped to an auxiliary collection tank.

Using known containment and cleanup techniques, it appears that control of small oil spills from ships in a terminal can be effective. Control should be a relatively minor problem if terminal site selection and design incorporates environmental.

considerations for proper functioning of existing oil spill containment and removal devices. If the containment or oil removal devices are ineffective, oil can spread in the harbor or terminal area to enter various ecological systems with harmful effects as previously described.

Containment at Sea

Although it is recognized that containment and recovery of spilled oil at sea is highly desirable, no system is now available that is applicable to the possible range of oil spill sizes. Wave heights of six to eight feet and currents greater than one knot are conditions which commonly occur at sea and which have caused considerable difficulty in containment and removal of spilled oil.

From those reports currently available, it can be generally concluded that:

- presently available containment barriers (booms) are ineffective in currents greater than one knot and six- to eight-foot high waves;

- large removal devices have yet to be systematically developed and evaluated for optimum, efficient designs; and

- dispersants, although economic and effective in heavy seas, are toxic and their use has been restricted.

Experience with existing capability indicates that a spill of 30,000 tons or larger, while remote, could not be contained effectively in the open sea; depending on local conditions and proximity to shore, the spill could conceivably reach shore before it was able to be contained.

Containment at Coastal Inlets

Bays, lagoons, and many estuarine areas along much of the Atlantic and Gulf Coast are naturally protected by barrier beaches. Various inlets penetrate the barier beaches and provide passages for spilled oil to enter estuaries or lagoons.

In the event that oil from a major spill approaches the coast, it would be desirable to seal off the inlet(s) involved with containment booms. Thus, oil would be kept out of the most ecologically important areas with a minimum effort. However, should oil reach a barrier beach area far from an inlet, natural longshore sand transport processes would tend to eventually move the contaminated sand along the shore until an inlet is reached. From there, it could spread to the estuary or adjacent wetland area.

Beach Cleanup

When oil comes ashore, pronounced economic and ecological damages usually result. In many cases of offshore spills, complete removal or dispersal of the oil will be impossible; therefore, methods and procedures for beach restoration must be available. When a spill occurs and oil washes ashore, it accummulates along the shoreline and may contaminate vessels and shore installations. On beaches, the main impact is aesthetic and the immediate remedy is physical removal of the oil-contaminated sands.

Oil contamination of beaches usually causes one or both of the following situations. (1) Beach material becomes uniformly contaminated with a thin layer of oil up to the high tide mark and/or deposits of oil dispersed randomly over the beach surface. Oil penetration is usually limited to approximately one inch, unless dispersants have been used. (2) Agglomerated pellets of oil-sand mixture or oil-soaked material such as straw and beach debris are distributed randomly over the surface and/or mixed into the sand.

The choice of restoration methods depends upon the economic and recreational value of the area and the urgency of returning the area to "normal" conditions. A highly developed resort complex, where a large proportion of the area's economic activity depends upon retaining the attractiveness of the beach, will require implementation of cleaning methods chosen more for their quickness than for their cost. In other instances, where the shoreline is mainly valued for its view, the presence of contaminants on the beach will not be so critical and restorative techniques of a slower, less costly nature will be found adequate.

In conclusion, it appears that the most effective beach-cleaning methods available under the current state of the art are:

- for rocky areas - sandblasting and/or steam cleaning;
- for sandy beaches - removal of the top oily layer of sand entirely or screen-separation where the contaminant occurs in lumps or nodules; and
- disposal of debris in approved areas.

Other methods of cleaning contaminated sand that have been tried include froth flotation cleaning at an estimated cost in pilot operations of 50-70 cents per ton of sand cleaned and hot water fluidization, a method that has not been successful.

Bacterial Degradation and Other Biological Processes

Another strategy for dealing with an oil spill, often the only feasible one where a relatively small spill has reached shore in a remote area, is to leave the spilled oil to be decomposed by biological processes. Bacteria have an important role in removing oil from the sea, shore and wetland areas. Bacterial oxidation can proceed as much as ten times as fast as auto-oxidation and there is no doubt that bacteria can utilize a variety of hydrocarbons. In general, however, bacteria cannot degrade the heavier aromatics and branched hydrocarbons such as those found in residual oil. Also, bacterial decomposition is slow, permitting an oil slick to spread over a large area.

Micro-organisms capable of decomposing petroleum occur in the ocean, especially in near-shore areas subjected to frequent oil spills. Under laboratory conditions, normal marine bacteria have been observed to decompose nearly 60 percent of added fuel-oil in 8 weeks. Light oils are oxidized more rapidly than heavier ones and paraffinic (aliphatic) hydrocarbons more rapidly than aromatics. Decomposition proceeds most rapidly at higher temperatures and in the presence of abundant oxygen. On-going work at the Virginia Institute of Marine Science indicates that petroleum-degrading bacteria also become abundant in salt-marsh sediments after oiling.

Anaerobic degradation occurs at a much slower rate. This process also depends on the availability of nitrates, phosphates or sulfates which are sources of oxygen for anaerobic bacteria.

The final products of aerobic oxidation are carbon dioxide and water. Many of the intermediate products are water-soluble and almost all are readily susceptible to further attack by micro-organisms commonly present in coastal waters. Some of the intermediate decomposition products may themselves be deleterious to marine organisms.

Intermediate products of degradation, as well as the bacteria themselves, provide support for many higher micro-organisms, protozoa, fungi, and lower algae. Many ciliates occur among oil droplets, some with oil in food vacuoles, and an increase has been noted in the numbers of protozoans following that of oil-degrading bacteria in polluted waters. The small polychaete *Ophrytotrocha* burrows into weathered oil, presumably to feed on the bacteria.

Larger animals contribute directly to oil removal, although they probably do not actually digest oil. Limpets (Patella), which exist in great numbers along the coasts of the U.S., can scrape weathered oil from rocks during their normal browsing. Oil then appears in the feces, mixed with rock fragments and plant debris, while the limpets are apparently unharmed. Some three to four months after a fairly severe oil spill, parts of the Cornish shore were cleared of oil except for a band deposited above the highest level beyond which limpets could not feed. On the worst-affected shores in Cornwall, England, after the *Torrey Canyon* wreck, all limpets were killed by emulsifier spraying. Chitons, which occupy a similar ecological niche to limpets but are nearly twice as large, removed much of the fuel-oil spilled from the stranded *General Colocotronis* from limestone beaches in the Bahamas.

Costs of Oil Spill Cleanup

Historically, oil spills have contaminated the environment to varying degrees depending on the quantity of the oil spilled, location, weather conditions, and a variety of other variables. Oil can dissipate quite rapidly through evaporation, wave dispersion, or sinking. However, once the oil comes in contact with the shoreline it tends to stick or be absorbed by grasses, sand, or rock. Data of actual oil spill incidents were reviewed to obtain an approximate estimate of cleanup costs. The cost data are highly specific to the particular incident; therefore, a range of possible cleanup costs was developed rather than a specific value. This range of costs results from selected incidents which represent a wide variation in oil spill variables.

Cleanup costs include all attempts or actions to salvage, contain, remove, or cleanse oil on the surface of the water, shore, or private property. Costs also include, where appropriate, removal of oil from a damaged vessel which posed a threat to the environment.

There is a wide variation in the cleanup cost per barrel of cargo. In the World Glory mishap, where no shore contamination occurred, the cleanup cost was comparatively low, at about $1.00 per barrel. However, for the Santa Barbara offshore leak, cleanup costs were nearly $50 per barrel due to the heavy oil contamination of beach and harbor areas in Santa Barbara and Ventura, California. Thus, the estimated oil spill cleanup costs range from a minimum of $1.00 to perhaps $50 per barrel, or $7.00 to $350 per tanker DWT. Therefore, for the complete loss of cargo from a 400,000 DWT tanker the cleanup cost may range from a minimum of $2.8 million to as high as $140 million if all the oil damage was concentrated on valuable beach and property areas.

Generally, the cleanup cost per barrel is smaller as the amount of oil spilled becomes larger, so the $140 million cost figure would apply only in a particularly unfortunate set of circumstances.

The above comparison pertains to actual data from relatively large unintentional oil spills. There is some indication that smaller spills (less than 5,000 gallons) in waterways and harbors are more expensive to clean up on a per-barrel basis. A recent study indicates an average cleanup cost of about $4 per gallon or $168 per barrel on spills between 500 and 5,000 gallons (US-124). Other sources indicate small spills can cost as high as $1,000 per barrel for cleanup. These smaller spills are generally related to tanker operational discharges and cargo transfer accidents.

B. Unavoidable Adverse Impacts

1. Geology

a. Gulf Coast Region

There are no certain unavoidable impacts related to the geological characteristics of the region. Probably a very small change in the geothermal gradient within the salt domes in which new cavities are constructed will occur; also, the geomechanical stability of the portion of the salt dome covering the mined cavities will be decreased. The magnitude of the environmental impact of any kind, if any, engendered by these changes is not known with certainty, but is believed to be insignificant. The historical precedence of petroleum storage, albeit, at a smaller local scale, indicates negligible impact under conditions of sound engineering design and construction practices.

b. East Coast Region

Any storage facility or other structure, existing or new, in the New England area is subject to higher risks of significant damage due to earthquakes than in most other areas of the country. Catastrophic seismic damage, while only a remote possibility, could result in loss of oil containment, and in ensuing environmental damage from massive oil spills.

2. Hydrology

a. Gulf Coast Region

Surface-Water Impacts

Runoff from construction sites will introduce higher concentrations of suspended solids into proximal water bodies during the construction phase and for a short time thereafter. The likely impact of this will be short-term increases in the naturally higher turbidity during storm/runoff events.

The program will require a continuation or an increase in the dredging activity for channel deepening or maintenance at several Gulf Coast ports or docking locations. Short-term, direct water quality degradation by increased suspended and dissolved solids will accompany this dredging, and the dredged bottom material generally represents a long-term potential source of various pollutants that requires attentive maintenance for confinement to the disposal site. The direct effects on water quality will be limited to the project area and may include: increased turbidity and its effects, viz., reduction in photosynthetic activity, flocculation of planktonic algae, and a decrease in available food supply; sediment build-up that may smother benthos; oxygen depletion; and removal of substrate materials and associated benthos. The more long-term effects are less well-known but may include the slow release of toxic dissolved heavy metals, hazardous organic compounds, and anaerobic gases (methane and hydrogen sulfide).

Increased traffic of vessels carrying petroleum and petroleum products in the coastal region will result in higher potential for oil spills during the initial filling phase of the program and probably also during cycling. Water supply intakes and brine diffuser pipelines, if any, constitute an additional navigation hazard that would not otherwise exist. The increased probability of catastrophic degradation in water quality due to spillage of oil or other hazardous substances and ensuing water quality problems from disposal of oil spill cleanup debris cannot be avoided, although consequent impacts are site-specific and also may be mitigated.

If brine is discharged into the Gulf of Mexico as a result of either solution mining or fluid displacement, the salinity of Gulf waters near the diffuser will be increased. Owing to dispersion and advection, the plume of excess salinity will reach a steady-state condition. Under reasonable worst-case conditions of highest brine rates (from a 200 MMB facility), very little solute advection, and low dispersion, the approximate area over which the increased salinity may be detected by aquatic organisms is 3000 acres; this water quality change would primarily affect the bottom waters rather than surface layers. Behavioral changes (including avoidance) for mobile species or possibly death for sessile species may be encountered in an area of several hundred acres. In addition, about seven acres of marine bottom would be severely disrupted by construction activities for each mile along each of the diffuser pipelines' rights-of-way. Up to five widely separated areas such as those described above may be affected by implementation of the proposed program. No interactions of water quality-related effects among the various areas are predicted, however.

Ground-Water Impacts

Although usage of ground water and any consequent impacts may be avoided by using surface water, especially Gulf water, at any location, it is viable alternative water-supply at some locations. Owing to the projected fresh surface-water shortages in the western Gulf Coast over the next few decades, ground water may be particularly attractive for use at more inland locations during the long term, where operation of the storage facility during a crude shortfall may require an instantaneously available, reliable water supply. If ground water were used to displace stored crude from a 200 MMB facility during a five-month period, an equivalent water inflow crude outflow of 39,000 gallons per minute (or 56 million gallons per day) would be required. The production of this ground water from a properly designed well field will lower the potentiometric surface in the aquifer being pumped as much as 150 feet. Such large drops in hydrostatic pressure within the aquifer system may be accompanied by a few feet of surface subsidence, slow salt-water encroachment up-dip within coastal aquifers, and "activation" of near-surface faulting with differential compaction. Within the area of ground-water pressure declines, foundation damage due to differential settlement and increased flooding potential, particularly in more coastal settings, are possible results. The effects are site-specific in that they depend on the aggregate amount and thickness of the clay beds in the lithologic sequence as well as the actual pressure decline.

While most compaction takes place in the clay beds, some compaction of the aquifer material may also occur, which results in long-term loss of storage capacity and thereby may affect the local water-yielding properties of the aquifer. Recovery of water levels will occur fairly rapidly after pumping ceases, but some of these physical changes may be irreversible.

Brine disposal by deep-well injection will nearly always degrade the quality of the existing formation fluid. Effects on the biosphere are not a necessary consequence, however, if prior, adequate evaluation and design are conducted.

b. East Coast Region

A minor degree of water quality degradation within surface water bodies near construction sites is unavoidable. The principal pollutant of concern is suspended sediment from eroded areas. Dredging will also cause short-term deterioration in water quality in marine and estuarine locations; the effects of dredging are summarized in the "Gulf Coast Region" section immediately above.

3. Meteorology and Climatology

Catastrophic meteorological events could conceivably destroy surface facilities at a salt dome storage system, but impact from the facility will be minimal. Some oil spillage will occur from fractured pipelines and flow from the storage cavern. This impact will be negligible when compared to that caused by such a storm.

Tanks are expected to survive the effects of hurricanes, and oil spills from connecting pipelines will be minor. Tank damage from great hurricanes could be severe causing loss of stored oil.

4. Air Quality

No impact of significance on the quality of air in the Gulf Coast region will occur from construction, filling, or operation of salt dome storage facilities. Tanker loading and unloading, under worst-case meteorological conditions, is predicted to cause local and temporary violations of federal hydrocarbon standards.

For storage of distillate fuel oil in tanks and the required tanker operations, hydrocarbon emission levels will exceed the national standards and associated ozone levels will likely be exceeded.

5. Noise

Noise from acoustically untreated equipment used during construction of tank farm storage facilities will have an adverse impact on human and wildlife populations within approximately one-half mile of the activity. Radiated noise from filling and operation will be of sufficiently low levels to be of no environmental consequence.

Noise from drilling activities in developing salt dome storage will cause an unavoidable adverse impact up to about 1500 feet from the drilling site. Operation of the facility will impact the area within 3500 feet of the center of the pumping station.

6. Biology

Unavoidable biological impacts will be the temporary loss of habitat from development activites and long-term loss of habitat from physical existence of storage facilities, roads, pipelines, dredged channels, etc. Aquatic organisms will be damaged or killed by entrainment and impingement on intake structures if used for water withdrawal in the solution mining of salt caverns. Aquatic organisms will be temporarily disturbed in the area of brine disposal into the Gulf. Streams, rivers, and estuaries will have temporarily increased siltation caused by dredging, drilling, and construction of roads and pipelines. In the Gulf Coast Region, endangered species of animals could be disturbed. Odor from storage in tanks could disturb organisms.

7. Historical and Archaeological Resources

Impacts to historical and archaeological resources listed in or eligible for inclusion in the National Register will be avoided by the selection of sites and rights-of-way away from such resources. Should there be no prudent or feasible alternative to the use of sites and rights-of-way that affect such resources, the requirements of 36 CFR 800 will be met.

8. Recreational Resources

Some areas may be eliminated as recreational resources for sport hunting. Fishing and swimming could be temporarily affected in waters where high siltation occurs, but this condition is not certain to occur at any site.

9. Land Uses

Construction of new facilities in the proximity of the storage systems is expected to be of a small scale and consequently no appreciable impact on land use is anticipated.

10. Land Use Planning

No impact on land use planning is anticipated. The land area occupied by storage facilities will be committed for this purpose, however.

11. Economic and Social Impacts

a. Gulf Coast Region

Short-term effects for development of a new 200 MMB salt-dome storage facility in the SPR include a direct expenditure ranging from $50 million to $104 million per year for several years and a total employment of 1427 persons, with about one-fourth located in the vicinity of the facility. The conversion of existing facilities in the ESR and the SPR, using a solution-mined storage facility of 90 MMB capacity would involve a direct expenditure of $45 to $50 million per year for two years and a total employment of 714 persons. The construction/conversion phase may be considered a pulse in the regional economy, which decays with time after completion. The long-term effects caused by operating either new or existing solution-mined facilities will result in a direct expenditure of about $940,000 with a total employment of about 47 persons, about half of which will be in the vicinity of the site. Most needed supplies are available within the region and the bulk of the economic impact is expected to be retained there.

The conversion of existing salt mines to crude oil storage will also "pulse" the regional economy. Conversion will entail a direct expenditure of from \$21 million to \$32 million per year for 2.5 years, with total employment ranging from 900 to 1400 persons; operation will involve direct expenditures between \$190,000 and \$340,000 per year with a total employment of one person.

It is conceivable that small local readjustments of population caused by the storage program could have a very minor and temporary impact on local demands for public services and facilities. No measurable influence on any particular community in this region is anticipated.

b. East Coast Region

For development of a 10 MMB tank farm facility, direct expenditure will be approximately \$24 to \$48 million per year for 2.5 years and the economic level impact about \$78 to \$157 million per year. Total employment will be about 19,000 to 25,000 persons per year with 150 - 200 persons directly employed. Long-term effects from operations and maintenance reflect direct expenditures of \$1.25 million per year and an economic level impact of \$3.5 million per year. Direct employment will be 40 persons and total employment, 343 persons.

Development of a new 30-million barrel capacity mine in the New England region will cause a direct expenditure of \$25 to \$38 million per year for almost five years and a regional economic level impact of \$62 to \$93 million per year. Total employment is estimated to be 700, including 270 directly employed by the project. Long-term effects include a direct expenditure of \$510,000 per year for operation and maintenance and a total employment of two persons.

In the ESR, some existing mines in the East Coast Region may be converted to storage facilities. Such conversion of a 15 MMB capacity mine, for example, would result in direct expenditures of $3 to $8 million per year for 3 years, a direct employment of 150, and a total employment of 390 persons. Operation and maintenance would support employment of one person and would have direct expenditures of $84,000 per year.

For storage facilities other than new above-ground tankage, the demographic and socioeconomic impacts are considered insignificant at a regional level. Construction of new steel tankage, on the other hand, may cause significant economic and socioeconomic impacts. A principal economic factor is the large demand for steel plate, which may produce indirectly several tens of thousands of jobs in allied industries. Tank farms generally are perceived as potential threats to safety and a cause of reduced aesthetic value and decreased neighboring land values, especially to residential areas. It is probable that tank farms would be near more populated (though not necessarily residential) areas, but if in a more rural community setting, sociological impacts may include significant increased demands for housing, schools, and municipal services such as energy, water, and wastewater without a timely increase in the tax base.

VII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Some irreversible and irretrievable commitments of resources will occur from implementation of the Strategic Petroleum Reserve Program. The irreversible and irretrievable nature of the use of each is described for each resource, and, to the extent possible, these commitments are quantified.

A. Land Resources

If large quantities of ground water are used for initially developing salt-dome cavities or possibly if ground water is used to displace stored oil, subsidence in the vicinity of the withdrawal well field will occur. Subsidence will irreversibly and irretrievably alter the topography of the land in direct proportion to the pumping rate and time period in which ground water is pumped; ultimately, the land surface elevation may be lowered as much as two feet.

The geology of newly developed salt domes will be irretrievably changed. The volume of even a large storage facility represents only a very small fraction, generally less than one percent, of a single salt dome, and no measurable changes are anticipated. Though insignificant in amount compared to that in all salt domes, the salt removed from domes irretrievably decrements the salt resources and reserves; the total maximum amount of storage space likely to be developed in the SPR is 0.004 percent of estimated salt reserves of Texas and Louisiana.

In the construction of new mines as storage facilities, some rock material may be rendered useless and discarded, even though most is potentially marketable and therefore not irretrievably committed. The geological and hydrogeological aspects of the developed mine area will be permanently, if ineffectually, altered.

Whether land required by any storage facility or its appurtenances could be restored to its original state and/or use after the life of the facility is unknown. It seems likely that some irreversible damage could possibly occur to the present land composition. Rock disposal (or long-term storage) areas and dredged spoil disposal areas are essentially irreversibly committed to that use and realistically generally irretrievable.

B. Water Resources

Deep-well injection of brine commits the injection zone to use either as a future brine source only or as a liquid waste disposal site. The extensive pressure changes in the aquifer may produce slight regional changes in water quality of adjacent aquifers that are irretrievable and irreversible in human time terms. If fresh water aquifers are contaminated, the aquifer will be irretrievably contaminated on a local scale.

Should large quantities of nearly fresh ground water be used, permanent changes in head relationships and flow patterns in aquifers could occur. Changes in the hydraulic regime of aquifers could slightly affect the quality and quantity of discharge into springs and streams.

Large quantities of water, ranging from 108,000 to 767,000 acre-feet, will be irreversibly committed to this project for developing new solution-mined cavities. The severe salinity degradation makes this commitment irretrievable from a practical standpoint. Operation of the facilities during a period of interrupted supply may require up to 106,000 acre-feet per complete cycling event on demand at any time; this water is also an irreversible and irretrievable commitment to the storage program.

C. Ecological Resources

The loss of any endangered species constitues and irreversible and irretrievable resource commitment. In particular, the Southern bald eagle could be sufficiently disturbed by activity at several sites under consideration to seek other nesting areas more remote from developed sites. This change may be tantamount to a resource commitment.

D. Archaeological and Historical Resources

Any disturbance of archaeological and historical resources would be an irretrievable loss. While it is as yet unknown how many historic and cultural resources may be affected by this program, it is FEA policy to survey each project area to locate such resources and to avoid them whenever possible. Where avoidance is not possible, FEA will consult the appropriate SHPO and, if appropriate, the ACHP, to develop a plan to mitigate the adverse impact of the project on such resources.

E. Human Resources

The major sociological resources to be committed are people's work hours and personal time spent on the project. Personal relationships can be uprooted because of the migration of workers to a project area. Locally, relationships may be broken because homesteads will have to be sold to accommodate the oil storage facility.

An approximate amount of manpower required to implement the program is difficult to establish with certainty, owing to inadequate information on program components. In the ESR, about 500 man-years of direct labor will be required, and in the SPR, from 1000 to 3800 man-years may be expended depending on program capacity (500 MMB to 1000 MMB) and on whether new mines are constructed.

Statistical predictions are that fatal accidents will occur in construction of the storage facilities as in construction of any large facility. Other loss of life will result from increased population in traffic accidents and other increased human interactions.

F. Materials

Some materials used in the storage facilities will be committed and therefore represent an irretrievable resource. Besides materials such as paint, asphalt, lumber, and glass that will deteriorate or be discarded in lieu of reuse, a significant amount of steel may be irretrievably lost for other uses. Most of this steel loss is represented by several hundred thousand feet of down-hole casing and pipe that will eventually corrode; some pipeline materials, especially water and brine piping, may also be irretrievable. Most oil pipeline material is anticipated to be salvageable, owing to measures designed to prevent erosion, corrosion, and subsequent rupture.

G. Energy

The energy consumed in constructing and operating the Reserve is a commitment of electric power, and therefore equivalent amounts of solid and liquid fuels that will be irretrievably lost to other uses. The amount of energy to construct the

Reserve is estimated to be no more than about 0.9 million megawatt-hours, and to cycle the total system will consume less than 0.17 million megawatt-hours of energy. The system will store up to 1.7 billion megawatt-hours of energy.

In a broader context, the crude petroleum itself acquired for filling the reserve is a resource that is destined for irretrievable, although not irreversible, consumption that could not otherwise take place. In this sense, it is a resource commitment, but it is also the raison d'être of the storage program. The quantity of petroleum ultimately required will depend upon the ultimate capacity of the Reserve and the number of times that it will serve as an emergency supply. The legislation authorizes storage of up to one billion barrels; current projects indicate that a reserve of 500 MMB is probably realistic for the next decade.

VIII. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

Both short- and long-term uses of man's environment will alter the long-term productivity of development areas. Most changes will be local to the storage facilities; more wide-spread changes will depend upon the number and lengths of pipelines servicing the facilities. Long-term productivity will be wide-spread and enhanced by providing more stabilized socio-economic circumstances in the event of future interruptions of supply. These observations are discussed by technical discipline in the following paragraphs.

A. Geology and Hydrology

For the Gulf Coast region, the geological relationship between short-term and long-term results will depend greatly upon the methods chosen for developing salt caverns and the susceptibility of the geological regime to a particular method. Should ground water be used for leaching of salt dome caverns, a risk of subsidence by proportional compaction of affected strata is present. As a natural resource, surface and subsurface composition will be permanently altered should such occur. The affected aquifer may cause changes in local hydraulic gradients. The removal of large quantities of salt (about 150 MM tons ultimately for a 200 MMB facility) will change a salt dome's original structure. None of the effects caused by short-term uses will maintain nor enhance the long-term geological or hydrological productivity.

For the East Coast region, development of new tank farms will have negligible impact on the short-term/long-term relationships. Construction of new mines will alter the local geology and in some cases hydrology in the mine vicinity.

Use of existing mines, salt caverns and tankage for the Early Storage Reserve will require an insignificant change in existing hydrological and geological conditions. Long-term productivity should remain essentially the same as for pre-storage periods.

B. Water Quality

For development of new facilities, short-term water quality impacts arise primarily from dredging and ditching required to emplace pipelines. Near the dredging operations, increased siltation causing increased turbidity will occur. Resuspension of waterway bottom deposits may raise the pollutant levels of heavy metals, pesticides, and organics. Modification of existing capacity to convert it to storage systems will cause less severe degradation of water quality except where new roads or pipelines require development. Increased oil transportation will increase oil spillage about one percent during the fill period, and result in some water quality degradation.

In the long term, water quality as related to activities of the storage system will stabilize to prestorage conditions.

C. Air Quality

In the short term, air quality will be only slightly degraded by the development of either new or existing storage capacity. Some fugitive dust emissions will result near storage sites and will be present only during construction phases. Hydrocarbon levels will not be measurably increased during movement of residual oil and distillate fuel oil into and out of the storage facilities. Marine tanker unloading and loading of crude oil may cause some temporary increases in hydrocarbon and oxidant levels above the NAAQS. No long-term degradation of air quality is expected.

D. Biology

Short- and long-term biological productivity of certain limited areas will be lowered by implementing the program, primarily from construction of new storage facilities and increased oil spills. Short-term productivity will be affected by the reduction of available habitat by the occupying facility and destruction of organisms during construction activities. Increased noise levels will disturb and displace some wildlife. The effect on long-term productivity will be negative but local to the storage site. Increased population will have a very small effect on biological productivity in the long term because the percentage of increase in a local area is small.

For modification and development of existing mines, tanks, and salt caverns, a small to moderate biological disturbance of each site will occur. Development of existing facilities will have appreciably fewer short-term effects than will development of new storage facilities. Long-term productivity will be about the same.

E. Archaeological and Historical Resources

During surveys in preparation of new site development, those archaeological and historical resources that are discovered will provide important gains to scientific knowledge regarding the history and prehistory of the site. The long-term loss of productivity will accrue because reserach of the sites in their original setting will not be possible, and therefore their value is decremented.

F. Recreation

For development of new facilities, three types of recreation will be principally affected on the short-term basis: hunting, fishing, and water-contact sports. Game birds and animals will be displaced from the area occupied by the site. Game fish will avoid stream and estuarine waters in areas of excess siltation, and such water-contact sports as swimming will be limited in these areas. The potential for increased oil spills during the fill period could increase pollution on bathing beaches. In long term, wildlife may return to the affected areas both on water and land.

G. Agriculture

If the developed site were previously used for agriculture, some short-term loss of agricultural productivity will occur. Usage of existing storage capacity will have little effect upon agriculture; some right-of-way for pipelines may remove land previously under cultivation. Fencing of facilities may impede grazing of livestock and will lessen available pasturage.

Implementation of the program could result in both short-term and long-term benefits to agricultural productivity. In the event of another severe supply interruption, all industries, including agriculture, will be affected. With the storage reserve in place, the severity of the associated impact will be lessened.

H. Socioeconomic Factors

Development activities associated with the program will provide new jobs on both short-term and long-term bases. The short-term effects will be significant at a local level, particularly in rural areas. Long-term job productivity is not appreciable but is present. Local inhabitants will benefit by having increased job opportunities and additional revenue. On a regional basis, the increase in jobs and capital will be insignificant.

The overriding objective of the program is enhancement of socioeconomic conditions during and after a severe interruption of imported supplies. This can best be measured in terms of impact without the program. Some estimates indicate that an impact in terms of job losses could reach an additional two million persons unemployed if a storage buffer is not available. Such loss of jobs carries with it the attendant human suffering, anxiety, and personal hardships for those affected. With the project, the effects will be significantly lessened.

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X. COORDINATION AND CONSULTATION

A. Coordination and Contact with Others in Preparation of the Draft and Final EIS

In the course of developing this programmatic EIS, information and guidance were obtained from many agencies. The following tabulation lists those offices or companies that were contacted.

AGENCY OR COMPANY	LOCATION
National Oceanic and Atmospheric Administration	Key Biscayne, Florida
National Climatic Center	Asheville, N.C.
Environmental & Land Use Planning Division, HUD	Washington, D.C.
Interstate Commission on Potomac River Basin	Bethesda, MD
U.S. Geological Survey	Reston, VA
U.S. Army Corps of Engineers	Washington, D.C.
U.S. Department of Transportation, Coast Guard Division (Deep Water Ports)	Washington, D.C.
MARAD, Office of Ports and Intramodal Development	Washington, D.C.
Environmental Protection Agency	Washington, D.C.
Environmental Protection Agency, Region VI	Dallas, Texas
Department of the Interior Bureau of Land Management	Washington, D.C.

AGENCY OR COMPANY	LOCATION
AIP, National Trust	Washington, D.C.
Environmental Data Services Deep Water Ports, NOAA	Washington, D.C.
State Health Department Air Monitoring (Baltimore)	Baltimore, MD
Department of Recreation and Parks	Leonardtown, MD
Maryland Wildlife Admin.	Annapolis, MD
Maryland Department of Water Resources, Permits	Annapolis, MD
Maryland Department of Natural Resources, Fisheries Administration	Annapolis, MD
Maryland Geological Survey	Baltimore, MD
State Soil Conservation Service	College Park, MD
Kentucky Geological Survey	Lexington, Kentucky
University of Kentucky, Geology Department	Lexington, Kentucky
Georgia Office of Planning and Budget	Atlanta, Georgia
South Carolina Wildlife and Marine Resources Department	Columbia, S.C.
South Carolina Wildlife and Marine Resources Department Charleston	Charleston, S.C.
Virginia Division of State Planning and Community Affairs	Richmond, Virginia
Florida Division of State Planning	Tallahassee, Florida

AGENCY OR COMPANY	LOCATION
North Carolina Office of State Planning	Raleigh, N.C.
Coastal Plains Regional Commission	Washington, D.C.
Geological Section, Texas Water Quality Board	Austin, Texas
Texas Governor's Office, Division of Planning and Coordination	Austin, Texas
Boston Port Authority	Boston, MA
New York Port Authority	New York, New York
Captain of the Port of New York	New York, New York
Historic Trust	St. Mary's County, MD
Soil Conservation Society	Leonardtown, MD
Office of Land Use and Development	Leonardtown, MD
St. Mary's County Historical Society	Leonardtown, MD
Physical Planning Department	Baltimore, MD
Department of Environmental Sciences (Water Quality Management)	Baltimore, MD
Lexington/Fayette Urban County Planning Commission	Lexington, KY
Blue Grass Area Development	Lexington, KY
New England Regional Commission	Washington, D.C.

AGENCY OR COMPANY	LOCATION
Supervisor of Assessments St. Mary's County	Leonardtown, MD
Coastal Plains Regional Commission	Washington, D.C.
Steuart Oil Company	Piney Point, MD
American Petroleum Institute Division of Transportation	Washington, D.C.
Association of Oil Pipelines	Washington, D.C.
Independent Liquid Terminals Association	Washington, D.C.
Oil and Gas Journal	Tulsa, OK
Fenix & Scisson, Inc.	Tulsa, OK
Central Rock Company Mine	Lexington, KY
Texas Brine, Inc.	Houston, Tex.
Resource Planning Assoc.	Cambridge, MA
Acres American, Inc.	Buffalo, NY
Yankee Atomic Energy Company	West Borough, MA
Mobil Oil Corporation	New York, New York
Sprague Oil Company	Boston, MA
Dow Chemical	Freeport, Texas
Radian Corporation	Austin, Texas

B. <u>Agencies and Others from Whom Comments Were Requested</u>

Department of the Army, Corps of Engineers
Department of Commerce
Department of Defense
Department of Housing and Urban Development
Environmental Protection Agency
Federal Power Commission
Tennessee Valley Authority
Department of Agriculture
Department of the Treasury
Department of State
Nuclear Regulatory Commission
National Science Foundation
Energy Research and Development Administration
Department of Labor
Interstate Commerce Commission
Council on Environmental Quality
Department of Health, Education, and Welfare
Department of Interior
Department of Transportation
Appalachian Regional Commission
53 State Clearinghouses, including the Virgin Islands, Puerto Rico and District of Columbia
Environmental Defense Fund, Inc.
Friends of the Earth
Izaak Walton League of America
National Association of Counties
National League of Cities
National Resource Defense Council, Inc.

The National Wildlife Federation
Sierra Club
U.S. Conference of Mayors
New York State, Office of Environmental Analysis
Institute of Gas Technology
Interstate Natural Gas Association
Electric Power Research Institute
American Petroleum Institute
American Gas Association, Inc.
Gulf States Marine Fisheries Commission
American Fisheries Society
American Littoral Society

C. Agencies and Others from Whom Comments Were Received

Department of Agriculture
Department of Commerce
Department of the Interior
Department of Labor
Department of Transportation
Department of the Treasury
Environmental Protection Agency
Nuclear Regulatory Commission
Tennessee Valley Authority
Arizona
California
Colorado
Delaware
Florida
Georgia
Hawaii
Idaho

Illinois
Indiana
Iowa
Kentucky
Maryland
Massachusetts
Mississippi
Missouri
New Jersey
Nebraska
New Mexico
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
South Dakota
Texas
Vermont
Wisconsin
Wyoming
American Petroleum Institute
Amoco Oil Co.
Bonaire
Intertanko
National Science Foundation
Standard Oil Company of California
Texaco, Inc.

D. Summary of Substantive Comments

Department of Agriculture

1. Comment: The discussion should recognize that only a small portion of the rock excavated from new mines will be marketable. Response: FEA recognizes that even though marketing the rock is a mitigating measure, only a relatively small portion of the total amount can be marketed. The text has been modified accordingly.

2. Comment: The use of the current USDA soil classification systems is recommended.
Response: At the programmatic level, the use of this or other classification systems appears to be of limited utility. While FEA acknowledges that the 7th Approximation System is a useful tool of soil scientists, the decision was made to use a more descriptive approach that probably is more comprehensible to the general public.

3. Comment: The compressibility of the injected and formation fluids does not provide appreciable space for disposing of waste brine.
Response: FEA concurs that this compressibility is of little consequence, and reference to it has been deleted.

4. Comment: Permits for new point source discharges are not likely to be granted beyond January 1, 1985, and this should be reflected in the text.
Response: In light of the recent findings of the National Commission on Water Quality concerning progress toward the objectives of PL 92-500, FEA believes that it would be inappropriate to include the suggested statement.

Department of Commerce

1. Comment: The dispersion model is difficult to evaluate due to lack of description on estuarine and near-shore parameters. Increasing salinity due to recirculating water could affect the size of the area of influence and detectable change.
Response: The model has been reformulated and exercised under conditions that are related to typical extremes with respect to salinity distribution, including recirculation effects. A new section in Section IV.B.1.b. has been added to describe coastal hydrodynamics and water quality aspects.

2. Comment: The use of high quality biological teams and consultants for each site-specific impact analysis is recommended instead of the use of arbitrary values for judging salinity effects.
Response: FEA did not intend for the level of analysis in the programmatic statement to suffice for each and every storage facility. Each site will receive professional environmental assessment as a matter of course in project implementation. This will include an analysis of ecologic and water quality impacts.

3. Comment: The need for actual biological community descriptions and interactions over biotope classifications in assessing potential impacts to biological communities and systems should be stressed.
Response: Text has been added to clarify and expand the ecological descriptions. FEA contends that the level of detail to describe and assess these interactions can be presented only at the site-specific level. However, the general nature of these interactions was considered in assessing regional impacts.

4. Comment: East Coast commercial and sport fish data are sparse.
Response: The biologic features were described in detail commensurate with their expected impact at a regional level on fish.

5. Comment: The cumulative construction and operation impacts on water quality and resident biota need emphasis.
Response: The tables in Section V.C. provide the estimated cumulative impacts of those aspects of construction and operation for which it is possible to derive such cumulative totals. The justification for this categorization is given in the text. However, it is inappropriate to address the cumulative effects of such impacts on water quality and biota because those effects are very site-specific in nature and the cumulative totals can only be expressed as the sum of the effects at all of the sites. To the extent that two or more sites interact to cause cumulative effects, they will be addressed in the site-specific EIS's.

6. Comment: These two references describe the existing environm[ent] of the impact area (Gulf Coast, East Coast), but they were not cited.

   U.S. Department of the Interior, Proposed Increase in Oil and Gas Leasing on the Outer Continental Shelf, Final EIS, July 1975, Washington, D. C.

   U.S. Department of the Interior, Proposed Outer Continental Shelf Oil and Gas Lease Sale Offshore the Mid-Atlantic States, Final EIS, May 1976, Washington, D. C.

   Response: The two regions are believed to be adequately described using other data sources, including primary data and information, for purposes of a programmatic level assessment. It is not the intent of this EIS to compile a comprehensive bibliography.

7. Comment: The summary maps of coastal environmental systems in Section IV need improvement.
Response: These maps have been re-drafted.

8. Comment: Expenditures in Section I.D.10, Table I-1, were stated without the methods of their derivation or length over which they would be expended.
Response: These expenditures are explained in more detail in appropriate parts of Section V. The time period has been added to Table I-1, and total dollar amounts indicated.

9. Comment: More information was requested on the heavy metal content of salt and brine.
Response: FEA attempts to obtain this information for inclusion in the DEIS were not successful; evidently few studies have been made, and owners of those that FEA knows to exist have claimed that they are proprietary. Consequently, FEA has commissioned the U.S. Geological Survey to determine the trace-element composition of those domes which will be used for salt-mining. This fact has been referenced in the text.

10. Comment: A more careful evaluation and appropriate modeling of diffusion processes is required. This additional data could assure the reviewer that brine disposal at sea does not result in dense brine layers overlying extensive areas of the bottom or collecting in topographic lows with adverse ecological consequences.
Response: The brine dispersal model has been revised to incorporate the effects of disparate lateral and vertical dispersion coefficients, and to more adequately and realistically model gravitational effects due to density differences. FEA has met with appropriate NOAA representatives to review this modeling effort and to establish reasonable values for parameters in the model. The description of the model and its results have been rewritten to reflect these changes.

11. Comment: The laid-up tonnage and total tonnage potentially available to the SPR requires updating to reflect significantly different current status.
Response: Appropriate changes have been made in the text to update the statistics and the potential storage available.

12. Comment: The need for contractual "escape clauses" is questioned.
Response: The reference to escape clauses has been deleted as those contractual matters are not deemed to have environmental import, and the need therefore may vary from case to case in any event.

13. Comment: The reference to air emissions from boilers in the discussion of environmental impacts of tankers should be deleted because neither main nor auxiliary boilers are expected to be in operation.
Response: FEA does not believe that boiler emissions can be categorically excluded from consideration. Elsewhere in the discussion, it is recognized that not all impacts or requirements would pertain to every tanker in the storage program.

14. Comment: Suggestions were made to change "Maritime Commission" to "Maritime Administration" and "bilge tanks" to "bilges."
Response: These changes have been made in the text.

15. Comment: The statement regarding the problems associated with the purchase and resale of tankers for use as storage facilities is unreasonable, given the current market oversupply and the probable realignment of the supply/demand relationship in future years.
Response: FEA agrees that the present status of the market could result in the purchase of tankers at a somewhat lowered price, and also that it is possible for the market to recover

in the future. However, this latter point is speculative only, and FEA believes that the position presented in the DEIS is reasonable, given the fact that no data were presented to substantiate the claim regarding market recovery.

16. Comment: The lay-up cost information pertaining to tanker storage was questioned as being unrepresentative of the current market situation.
Response: The costs presented in the EIS reflect the most recent data and most current analysis (November, 1976) performed by FEA and others concerning the use of tankers as storage facilities.

17. Comment: The use of the Torrey Canyon incident to illustrate effects of catastrophic events on tanker storage is objectionable.
Response: The discussion of impacts has been restructured to reflect this concern. Oil spills are now addressed only in Section V.D. from a statistical standpoint.

18. Comment: The Final EIS should include tidal information and an isohaline map of Louisiana.
Response: While the suggestion is deemed inappropriate for inclusion in the programmatic statement, additional text has been added in the "hydrology" section discussing the general nature of coastal hydrodynamics and water quality in the region.

19. Comment: Inclusion of habitat characterization and location of the biota and their value is suggested.
Response: This level of treatment is more appropriately and usefully addressed in the site-specific EIS's.

20. Comment: Information and impacts pertaining to the adjustment of tidal marshes and periodic marshes to even a small degree of subsidence should receive attention.

Response: This impact would be significant in the coastal region, and the magnitude and type of the impact would be highly site-specific and time-specific. Because ground-water production is not planned for every potential site, these concerns are more appropriately addressed in the site-specific EIS's.

21. Comment: Analysis should be given to the speed and degree of mixing in both the Gulf waters of low ambient salinities and oceanic waters.

Response: The assumptions used in the new brine model explained in the FEIS are considered by FEA and NOAA sufficient to model adequately the anticipated range of conditions. Oscillatory currents result in net advection, as modeled, but the oscillations are not in themselves a worst-case condition. The results of the model, in terms of salinity excess, are valid for ambient salinities from 10-35 ppt.

22. Comment: Brine disposal as it relates to salinity tolerances of aquatic biota, including those in brackish water, should be discussed.

Response: The modeled salinity increases are valid for all Gulf waters. The text has been modified to emphasize the salinity tolerances of important representative species. The impact assessment was based on a data bank with 12,000 data from 500 references concerning life history of both marine and estuarine organisms of the Gulf of Mexico.

23. Comment: Advantages and disadvantages of two types of pipeline construction and backfilling relation to construction site impact should be considered.
Response: The backfilled push-ditch method of pipeline excavation in wetlands is considered by FEA to be an effective mitigating measure. Consideration of the most appropriate method for pipeline construction will be judged at a site- and time-specific level in individual EIS's.

24. Comment: Secondary industrial or domestic developmental impacts on the coastal wetlands due to construction and operation of a salt dome storage system should be included.
Response: The construction phase of the SPR program will be temporary and is not expected to create any secondary growth. Likewise, no additional development should result because the stored oil in place during the static storage phase is not available for other uses.

25. Comment: The source of Table V-33, DA-179, 1974 is inconsistent with respect to the data it presents and its bibiliographic listing.
Response: In the extensive revision of the oil spill impacts discussion, the need for this table was eliminated.

26. Comment: The movement of spilled oil is the result of a complex interaction of wind, currents, and coriolis force and is not as simple as stated.
Response: While the intent is not to present a treatise on oil spill movement, the section V.D.2.c. has been modified to reflect the comment's contention. Of necessity, the discussion is not detailed but no intent exists to minimize its importance. Movement of spills requires site-specific treatment.

27. Comment: Chapter X, "Coordination and Contacts with Others," should list contacts and consultations required in the development of plans for storage in a specific salt dome.
Response: The purpose of this chapter in a programmatic EIS is to show those contacts which were made during the preparation of the EIS, not those required for implementation of the program at a proposed site. Each site-specific EIS will contain a list of the contacts required during program implementation.

Department of the Interior

1. Comment: The text does not adequately discuss the Federal agencies which would be involved in offshore dome development.
Response: The program does not now anticipate the use of offshore salt domes. If this proposal is modified, the site-specific EIS for each salt dome will address in detail the role of each Federal agency involved.

2. Comment: Consideration should be given to the value of mineral resources eliminated in the storage facilities.
Response: The reduction in salt reserves caused by the program is inconsequential when the total amount of salt in-place is considered. The temporary effects of dislocating existing mines is a socioeconomic consideration addressed in individual EIS's.

3. Comment: The DEIS failed to discuss the effects of the SPR on the Bureau of Land Management's OCS leasing program for the Atlantic Coast as well as the effects of this program on the SPR.
Response: In formulating the projections presented in Table III-1 and discussed in Section III.A.1, FEA assumed that the necessary leases would be sold to allow production at the projected rates. No effect of the SPR Program on the OCS leasing program has been identified.

4. Comment: The impact of tank farms in the northeast should address recent reactions by citizens to new petrochemical developments.
Response: These considerations are site-specific in nature and will be assessed on a site-by-site basis. FEA is aware of these concerns and they are taken account of in the decision-making process.

5. Comment: More extensive use of BLM OCS Environmental Impact Statements as sources for baseline descriptions of socio-economic and environmental data for coastal areas, as well as to aid in evaluating onshore impacts of the development of the SPR, was requested.
Response: Sufficient information was available from other sources to permit regional assessment. It was not the intent of the EIS to compile a comprehensive bibliography of all related work for the region.

6. Comment: An example of the meanings of and assumptions behind the "quality of life" rankings used in the socioeconomic and environmental data was requested.
Response: A note based on the Midwest Research Institute (MRI) quality of life index has been added to the table in order to clarify the comparison. The referenced MRI study has experienced wide distribution since its publication; FEA does not believe that it is necessary to also discuss the basis for this rather comprehensive index in the FEIS.

7. Comment: The use of two major studies (citations included in comments) to supplement material presented for Gulf Coast on fish and wildlife resources was recommended.
Response: These studies were used as source material in the description of the existing environment.

8. Comment: Two laws were provided for inclusion in the subsection in mitigating measures for biology.
Response: The Endangered Species Act of 1973 and the Fish and Wildlife Coordination Act reference to these laws was added to Section VI.A.7.

9. Comment: An indication of how FEA plans to fulfill requirements of Federal historic preservation laws and regulations (specifically how FEA plans to identify potentially significant cultural resources not already listed in or eligible for inclusion in the National Register or in state inventories) was requested.
Response: The "Mitigating Measures" section of Chapter VI was modified to reflect FEA's commitment to carrying out the intent of Section 106 of the National Historic Preservation Act of 1966 and 36 CFR 800 as well as requesting review and concurrence of appropriate Federal and state agencies before implementation of the individual projects.

10. Comment: The National Historic Preservation Act of 1966, Executive Order 11593 and the current National Register should be appropriately referenced in the "Description of the Existing Environment" section.
Response: This has been done by adding the appropriate references in the text.

11. Comment: FEA should indicate (a) when a list of properties on state cultural inventories will be compiled, (b) who will compile it, and (c) how it will be used in planning.
Response: This list will be developed for all sites as they are identified and will be addressed in the individual EIS's. However, clarifying comments have been added to the text.

12. <u>Comment</u>: Resources used in a referenced historical and archaeological inventory (EN-333) should be indicated.
<u>Response</u>: The depth of treatment is judged sufficient for purposes of the EIS. More detailed information should be obtained from the study itself.

13. <u>Comment</u>: The EIS should indicate at appropriate places in the text that the "Criteria for Effect" were established by the Advisory Countil on Historic Preservation
<u>Response</u>: This has been done.

14. <u>Comment</u>: The clarification of "half-mile radius" as a definition of "surrounding environment," and rewordings in the discussion of cultural resources, were requested.
<u>Response</u>: These recommended changes were made.

15. <u>Comment</u>: Clarification and correction of the discussion of the role of the State Historic Preservation Officer was requested.
<u>Response</u>: Appropriate changes have been made in the text.

16. <u>Comment</u>: Correction of inaccuracies in the historic preservation legislation was given.
<u>Response</u>: These sections have been corrected.

17. <u>Comment</u>: Changes in the discussion of programs for the preservation of historical and archaeological resources were suggested for purposes of relevancy and emphasis.
<u>Response</u>: FEA has altered the discussion in this section to reflect its intentions with respect to protecting cultural resources.

18. Comment: Substantiation of two general comments on degradation of existing recreational resources was requested, and more detailed treatment of this area of concern was recommended.
Response: FEA concurs, and this section has been rewritten.

19. Comment: The inclusion of a general provision for mapping solution-mined cavities in salt to aid in evaluation of impacts on ground water was reqested.
Response: The requirements and techniques for such mapping will vary from site to site and must therefore be addressed on that basis. FEA recognizes the fact that such mapping is a necessary mitigative measure in developing solution-mined cavities.

20. Comment: Clarification of two discrepancies (V-9 and V-31, VI-53) concerning hydrofracturing pressures and ground water drawdown was requested.
Response: The two different inconsistencies were reconciled by text changes.

21. Comment: The proposed depth of installation of sacrificial anodes was requested.
Response: These depths are considered to be an element of detailed site design; the depths will be governed by good engineering practice. Ground-water impacts of the anodes must also be addressed site-specifically.

22. Comment: Mention should be made that the Act provides for storage of up to 1 billion barrels.
Response: This information was contained in Section I.A. of the DEIS.

23. Comment: The study of marine life tolerance should be referenced and its availability indicated.
Response: The reference was to the environmental assessment supporting this EIS. Textual changes were made to emphasize this.

24. Comment: The sentence about tropical cyclones should read, "great hurricanes every 80 years."
Response: The appropriate corrections were made to this section.

25. Comment: The differences in impacts with and without the SPR should be included in the summary of the "No Action" alternative.
Response: This refers to the need for, rather than the environmental effects of the program; such analysis was not deemed necessary for inclusion in greater detail than at present.

26. Comment: An inconsistency was noted between Chapters II and VI with respect to the amount of existing storage capacity.
Response: This inconsistency has been corrected.

27. Comment: The candidate existing government-owned tankage facilities should at least be identified as to location and capacity.
Response: Since no individual storage sites have yet been selected, none of the potential candidate sites of any type are identified in this programmatic EIS, but will be identified in site-specific EIS's to the extent that such sites are proposed as alternatives for storage.

28. Comment: An inquiry was made as to whether the government would obtain the storage sites by condemnation or through bids submitted by private companies.
Response: Acquisition of storage sites and property for ancillary facilities will be obtained through the U.S. Government's normal real property acquisition methods, which include condemnation in those situations where it is necessary.

29. Comment: The Industrial Petroleum Reserve (IPR) should not be categorized as a non-structural alternative.
Response: The structural alternatives section (III.B.) of this EIS assesses the various types of storage facilities available. In contrast, the IPR is one possible method of implementing a portion of the program by providing petroleum for storage. It could include any or all of the structural alternative storage types.

30. Comment: An inaccuracy was noted in the frequency of tanker unloading necessary to fill the SPR.
Response: The inaccuracy has been corrected.

31. Comment: A more recent map for Section IV.B.1.a. is plate 3 of the U. S. Geological Survey Open File Report 76-61, Sediments, Structural Framework, Petroleum Potential, Environmental Conditions, and Operational Considerations of the Mid-Atlantic Area.
Response: This map was not available during preparation of the DEIS. It is believed that the map used is sufficiently accurate for purposes of identifying the geologic setting on a regional basis.

32. Comment: The earthquake off Cape Ann took place in November, 1755.
Response: This typographical error was corrected.

33. Comment: It is time-consuming to extract the information from Chapter V which also contains information on background, theory, and methodology that might better be placed in an appendix.
Response: The referenced information is judged to be useful in placing the impacts in perspective. Impacts are summarized in Chapter I.

34. Comment: The basic equation for brine dispersion modeling is not dimensionally correct as written. In site-specific environmental statements, consideration should be given to determining the duration and velocity of the prevailing currents in order to guarantee that the dispersion-model conditions are met.
Response: This equation is the practical, functional form of the differential equation. The more complete equation has been substituted and its parameters more completely dimensioned. Brine-modeling will be performed for each individual site and will examine various site-specific factors. The modeling in the programmatic EIS is designed to be representative of the anticipated normal range of conditions.

35. Comment: An inquiry was made as to whether the figure of 260 acres for surface facilities apply to each site or to the total program.
Response: The figure refers to one 200 MMB storage facility which is the prototype for the assessment.

36. Comment: Although the wastes will be periodically delivered to a waste-disposal company, the impacts of off-site disposal should be analyzed.
Response: These impacts depend on the method of ultimate disposal and are more appropriately addressed in site-specific EIS's. It is sufficient for programmatic purposes to be aware that off-site impacts, though small, exist.

37. Comment: Minimum excavation is the normal and economical procedure. Any excavation has an effect, although it may be limited, and should not be considered to be mitigation.
Response: The mitigating factor referred to is that a large amount of the salt remains after excavation, and should prevent appreciable subsidence or changes in upward viscoplastic flow.

38. Comment: Water consumed is irretrievable. However, water rights and allotments (commitments) can be changed. Therefore, a water allotment cannot be considered irreversible or irretrievable until the water is actually consumed.
Response: The "commitment" referred to is the commitment of water resources solely to the project, not that commitment or allotment to water users which involves water rights.

Department of Labor

1. Comment: A discrepancy was noted between Section I.F.5. and VII.E. regarding the level of direct labor to be expended for the Strategic Petroleum Reserve.
Response: The discrepancy has been corrected.

Department of Transportation

1. Comment: The energy savings and increased energy production capabilities discussed in the "Alternatives" section of the DEIS were not compared to the SPR, and no framework for comparison is created. Pursuit of a combination of the alternatives could increase oil production and achieve conservation savings of a total one billion barrels of oil, and, thus, be more effective than the SPR in both near and long terms in mitigating the impact of an oil embargo.

Response: The EIS makes clear that energy production and conservation are not true alternatives to the SPR. The goals of energy self-sufficiency and independence from reliance on imported oil require that a combination of measures be employed. Energy production and conservation already are being pursued along with establishment of an SPR. As stated in the text, accelerated development of energy sources could not achieve a significant impact before 1980. But even after energy production has been increased and conservation goals have been met, this country may continue to require imported oil; and U.S. oil production is projected to decline from peak production after 1985. Thus, an SPR will continue for the foreseeable future to play a valuable role. The size of the SPR is, however, subject to alteration at a later date, and the degree of success realized in increasing energy production or effecting conservation will be relevant considerations in determining what size SPR is appropriate.

2. Comment: An inconsistency was noted between Table III-1 and the text describing it.
Response: The inconsistency has been corrected.

Department of the Treasury

1. Comment: The SPR should maximize the use of crude oil in underground storage.
Response: The FEA is proposing, subject to Congressional review, to store only crude oil in centralized underground storage.

2. Comment: The need for petroleum stockpiles is a national need and the costs should be borne by the taxpayers.
Response: The FEA is proposing to use the normal Federal procurement process to acquire all oil for both the ESR and the SPR and does not propose to implement an IPR. Most of the costs will be met out of general tax revenues. However, it is proposed that the cost of the Reserve be minimized through industry participation in an "entitlements" program, and the cost thereby shared by industry and oil consumers.

Environmental Protection Agency

1. Comment: Environmental effects and practicality of offshore/onshore salt caverns should be compared.
Response: Both onshore and offshore domes have been considered as storage facilities in the DEIS. A new section (III.B.1.g.) has been added to highlight this comparison.

2. Comment: The feasibility of extensive substitution of seawater for freshwater for solution-mining should be addressed.
Response: The DEIS considered both seawater and freshwater as equally viable alternatives at the programmatic level. A possibly misleading discussion of potential water supplies in Section V.A.2.c. has been clarified. The site-specific EIS's will consider the substitution of seawater for freshwater where applicable.

3. Comment: The possibility of recycling leaching water from deep aquifers to cycle salt cavities should be considered.
Response: This approach while theoretically appealing was judged technically infeasible owing to: (1) the inordinately high pumping and capital cost; (2) the questionable feasibility of using the same wells for both injection and production; and (3) the increased impacts associated with the substantially greater number of wells needed for production, due to the lower pumping rates.

4. Comment: The compatibility of site-selection with appropriate SIP's and EPA's hydrocarbon non-attainment policy should be addressed.

Response: The compatibility of sites with particular SIP's and AQCR's must be evaluated at the site-specific level. The total emissions likely to result from reasonable storage scenarios have been compared to aggregated baseline emissions for AQCR's likely to be affected by one or more storage systems in order to permit a general evaluation of attainment issues under the hypothesized scenarios. FEA agrees that the emerging EPA policy concerning non-attainment may affect the SPR sites and a more detailed discussion of non-attainment is found in Section VI.A. 5.a.

5. Comment: A more extensive examination of alternate methods of transporting foreign oil to U.S. ports is needed.

Response: A description and analysis of the relative risks of oil spills associated with various methods of transporting oil to U.S. ports for use in the SPR has been added to Section V.D. The specific sources of oil for the SPR have not been determined at this time.

6. Comment: The DEIS should differentiate between abandoned program alternatives and remaining preferred plans as set forth in the Early Storage Reserve Plan and the Strategic Petroleum Reserve Plan since these are important steps in the FEA decision-making process.

Response: This has been done throughout the FEIS based on the program proposals to be submitted to Congress by FEA in the Strategic Petroleum Reserve Plan.

7. Comment: The placement of storage cavities in the Gulf rather than onshore could enable more efficient collection of oil during the filling process, both from offshore drilling operations and from planned deepwater port projects.
Response: Because of the proposed open market oil acquisition method, FEA does not know the source or shipping route of the oil for the SPR, which could be of both domestic and foreign origin. However, regardless of the source of oil used in the storage program, U.S. oil imports must increase by approximately the amount of oil to be acquired for the Reserve. For these reasons, offshore storage lacks the advantages cited. Moreover, deepwater port projects will not be ready in time to accommodate SPR initial fill. The relative effects of using onshore and offshore domes are discussed in Section IIIB.1.g.

8. Comment: The Final EIS should resolve the apparent inconsistency in water volume requirements.
Response: As stated in Section III.B.1.b., the first set of numbers is based on theoretical, stoichiometric relations. The second set of numbers uses factors that are considered more typical of actual operating conditions in solution-mining of Gulf Coast salt. Much of the difference in numbers, however, is simply attributable to rounded-off values. FEA does not consider that a serious error has been introduced.

9. Comment: More information is needed on the feasibility of environmentally safe deep-well injection.
Response: While FEA agrees that deep-well injection requires in-depth study, such study must be undertaken at the site-specific level. General (regional) information was utilized in the formulation and assessment of brine disposal alternatives.

10. Comment: Methods of pretreating contaminated brine before disposal or cycling should be discussed.
Response: The storage system will be operated in such a way that the oil-water interfacial region will not be discharged with the rest of the brine during leaching or fill operations. The brine which is discharged during these operations is not expected to contain sufficient concentrations of oil to require pretreatment.

11. Comment: Pipelines should be treated to impede internal corrosion.
Response: Such corrosion protection is standard engineering practice in the oil industry; that practice will be a performance standard, as stated in Section VI.A.1.

12. Comment: The indiscriminate or unauthorized use of treating agents is proscribed.
Response: The EIS has been revised to reflect the intent of Annex X of the National Oil and Hazardous Substances Pollution Contingency Plan.

13. Comment: Biological degradation should not be relied upon as a mitigative measure, inasmuch as these processes do not break down the heavier hydrocarbons found in oil products.
Response: FEA agrees that biological processes should not be the primary means of correcting oil spills; much spilled oil will be cleaned up using mechanical and chemical methods. However, for some spills and locations, this mechanical removal may be impossible. It is in this context that there is no alternative to leaving spilled oil.

14. Comment: Municipal wastewater treatment facilities should not be considered an alternate method of treating effluent, unless they are designed to treat such effluent.
Response: FEA agrees, and the EIS has been revised accordingly.

15. Comment: The type of petroleum liquid stored, the location for a particular storage type, and the method of storage should be discussed.

Response: FEA is proposing to store only crude oil in centralized underground facilities. These factors will be considered in the allocation of various potential crude types to storage locations suitable for distribution to various users. The amount and characteristics of the stored crude oil are being selected with the objective of meeting the refineries' requirements, including the need to minimize any deviations from their normal feedstock and, consequently, of air emissions. However, actual selection of crude oil types will depend partly on responses to FEA's procurement; final site selection has not yet taken place, and therefore, it presently is impossible to furnish the information requested.

16. Comment: Degassing of stored crude should be fully discussed.

Response: Degassing of the crude oil is not anticipated to be of concern with respect to operational or environmental aspe[illegible], including fire hazards. Tanker-transported crude has largely degassed during the transport phase, but pipeline-transported crude usually has had the evolved gas periodically re-injected. The desirability of degassing such crude before storage is essentially an economic issue, depending on the source(s) of crude, refinery configurations, and distance over which pumping takes place. Because crude in storage would always be under pressures equal to or greater than a full head of brine, little degassing would occur. That which does occur does not represent a significant fire hazard because of the lack of oxygen in the storage space in cavities or because of the vapor contro system required in salt mines for heating the much larger volum of volatiles from crude evaporation. The only reason that a crude degassing unit (consisting of heating and flashing units) might be desirable at the Gulf Coast domes involves the economi penalty of pumping a two-phase fluid to a refinery over a considerable distance. Even in this situation, the gas produced would very likely be re-injected to aid pumping and later removed more efficiently at the refinery where a ready distribution system exists. Current gas-handling operations take place in a closed system with respect to the environment.

17. Comment: New Source Performance Standards under the Clean Air Act are applicable to underground tanks in certain specific conditions.
Response: Use of underground storage tanks is not contemplated for the SPR program.

18. Comment: The FEIS should contain an analysis of the potential abandonment alternatives for the SPR facilities.
Response: The potential abandonment alternatives are discussed in the site-specific EIS's for the candidate sites.

19. Comment: Data from existing salt dome storage should be incorporated in the FEIS as reference material.
Response: While these data may be appropriate for inclusion in site-specific EIS's where circumstances are similar, it does not appear germane to a programmatic EIS in which specific locations and facility types are dependent upon future program decisions. To the extent that this data are meaningful in the site-specific context, it has been incorporated into the five site-specific EIS's published thus far and will be included in future site-specific EIS's where appropriate.

20. Comment: The FEIS should contain a general discussion of mitigative and security measures planned for the SPR.
Response: Since the mitigative and security measures are highly dependent upon the type and location of the facility, these program elements are discussed in the site-specific EIS's for candidate storage facilities.

21. Comment: Inconsistency was noted in the DEIS with respect to the manpower requirements for constructing salt dome storage facilities; more labor was required to create a 200 MMB facility than the entire 500 MMB requirement of the SPR.
Response: The manpower requirements have been corrected to remove the inconsistency.

Nuclear Regulatory Commission

1. Comment: Concern is expressed about the effects of subsidence due to the use of ground water to leach (and to operate) a salt dome storage facility with respect to adverse impacts that may accrue for nearby nuclear generating stations.
Response: The possibility for and the various effects of subsidence are virtually entirely site-specific, and will be addressed in the individual site EIS's.

Tennessee Valley Authority

1. Comment: Pumping should be stopped within developed fields and held as ready reserve, and new fields should be located, proved, developed, and shut-in until strategic situations arise.
Response: The discussion in Chapter II has been expanded to discuss why oil in shut-in fields is not an appropriate alternative for the SPR.

Arizona

1. Comment: Arizona has been ignored as a storage site; it has potential for 500 MMB of oil storage.
   Response: Because the aim of the SPR program is to develop initial petroleum reserves as quickly as possible and with the greatest flexibility and utility to the entire nation, FEA has proposed to locate those reserves in areas with existing terminal and docking facilities and with ready access to the crude oil distribution networks.

California

1. Comment: The DEIS is deficient in its discussion of air quality impacts in areas where increased domestic petroleum production (NPR-1 and NPR-2) would occur as a result of the SPR.
   Response: The Naval Petroleum Reserves Production Act of 1976 requires that the Department of the Navy develop and produce oil from NPR-1, 2, and 3 at the maximum efficient rate, and the Environmental Policy and Conservation Act provides that the oil which is produced may be considered for the SPR. However, this oil would be produced regardless of whether it is used in the SPR. Therefore, no increase in production from the California NPR will occur due to the increased demand for petroleum during fill of the SPR.

2. Comment: Emissions associated with the transport of petroleum from the NPR to the Gulf of Mexico and the Eastern Seaboard should be quantified, and the effects of such emissions should be stated.

Response: Since the FEA is proposing that oil for the SPR be acquired through open market purchase, the ultimate source of this oil is uncertain at present. If this proposal is modified and NPR oil is required to be used for the SPR, it is likely that this oil would be exchanged for oil which meets the specifications for the SPR since only a portion of the NPR oil meets these specifications of sulfur content and viscosity.

3. Comment: An inquiry was made as to why the NPR cannot fulfill the function of an SPR by leaving it in place and producing oil from it in the event of a foreign supply interruption.
Response: As discussed in Section II.G.1., the production rates required to replace a shortfall in supply caused by an interruption in oil imports cannot be achieved by developing shut-in capacity.

4. Comment: An inquiry was made whether the SPR is related to the proposed SOHIO Oil Terminal (Port of Long Beach) or the development of NPR-1 (Elk Hills).
Response: Since no West Coast storage is planned for the SPR, the program does not interrelate with the subject terminal. As discussed above, the Congressionally-mandated development of NPR-1 will proceed independent of the SPR.

5. Comment: The possible use of liquified natural gas (LNG) or synthetic natural gas (SNG) for the SPR described in the DEIS should be discussed in more detail.
Response: No LNG or SNG storage is being proposed for the SPR. These energy sources are discussed only in the context of possible alternatives to the SPR because of their potential for accelerated development which could affect the size of the Reserve.

Delaware

1. Comment: An above-ground SPR storage facility in Delaware could result in significant hydrocarbon emissions.
   Response: FEA has proposed in its SPR plan that no above-ground storage facilities will be utilized for the SPR. If this proposal is modified, the use of any above-ground tank storage facilities would be discussed in separate site-specific assessments. The air quality effects of above-ground tank storage in the East Coast region are discussed generally in Section V.B.4.

Hawaii

1. Comment: The special needs of Hawaii for crude petroleum and petroleum product reserves have been overlooked, and are not being provided for. Hawaii states its belief that a storage program in Hawaii is essential.
   Response: The subject of storage in contiguous areas is now covered in Section II.C.5. FEA has concluded that Hawaii's needs can be met without local storage being required.

Maryland

1. Comment: The table entry for employment associated with conventional storage tanks in Section I.D.10. is in error.
   Response: The table entry has been corrected.

2. Comment: Explanation of the specific effects related to the "type" of product to be stored, including "how" and "where" it will be stored and site-specific environmental impacts is needed.

Response: FEA is proposing to store only crude oil in centralized underground facilities. These factors will be considered in the allocation of various potential crude types to storage locations suitable for distribution to various users. The amount and characteristics of the stored crude oil are being selected with the objective of meeting the refineries' requirements, including the need to minimize any deviations from their normal feedstock and, consequently, to minimize air emissions. However, actual selection of crude oil types will depend partly on responses to FEA's procurement; final site selection has not yet taken place; and therefore it presently is impossible to furnish the information requested.

Mississippi

1. Comment: The SPR should store foreign crude oil and not domestic oil.
   Response: The source of the oil to be stored in the SPR will depend on the supplier. FEA proposes to acquire oil using the normal Federal procurement process and thus the supplier(s) and source(s) are as yet undetermined. However, since there is no "surplus" domestic oil available, the result of this technique will be an incremental increase in imported oil to fill the SPR.

2. Comment: The DEIS did not give adequate consideration to the potential for storing oil for the SPR in the state of Mississippi.
   Response: Although the initial candidate sites have been selected for the ESR, no final decisions have been made concerning the location of longer-range SPR sites. Analysis is continuing for viable candidate sites, and no acceptable sites have been eliminated. The criteria for the site selections are discussed in Section II.E.

3. Comment: The proportion of refined products stored should be maximized.
Response: FEA is proposing in its SPR plan that only crude oil will be stored.

4. Comment: The coverage of impact on transportation systems is inadequate and does not take into account the Tennessee-Tombigbee Waterway or locations of proposed deep-water ports.
Response: The intent of this programmatic EIS is not to discuss alternatives which are site-specific, but to disclose the environmental impacts of the SPR program as a whole. Later site-specific EIS's will discuss the proposed deep-water ports and affected local waterways when appropriate.

5. Comment: The impact of resulting industrial growth in the SPR vicinity should be addressed.
Response: The SPR will not be available during periods of normal import supplies for other users, and should not instigate secondary industrial growth.

6. Comment: Since Mississippi is in a region which qualifies for regional storage, it should be given more consideration as a location for storage sites.
Response: The objective of the Reserve is to ensure that all regions of the country are supplied sith adequate oil supplies during a supply disruption. To achieve this objective, FEA is proposing to store all of the oil in centralized underground facilities rather than in dispersed storage in the regions. The import-dependent status of the individual states is not a criterion for site selection of the centralized reserve.

7. Comment: The section on mineral resources omits mentioning the bentonite and limestone being mined in South Mississippi.
Response: These resources were added to the list in the text.

8. Comment: Most of the geologic and seismicity discussions do not address Southern Mississippi.
Response: Appropriate references to Mississippi have been added in these discussions.

North Dakota

1. Comment: The SPR should be expanded to include salt cavern storage along the proposed Northern Tier pipeline to assure a supply of crude to northern refineries.
Response: FEA recognizes its responsibility to make SPR oil available to the Northern Tier refineries in the event Canada carries out its announced intention to stop exporting oil to the U.S. The proposed Northern Tier pipeline is only one of the methods under consideration for supplying these refineries. Others include projects to connect the pipelines originating in the Gulf Coast to the Northern Tier area. The proposed Gulf Coast storage facilities would be able to supply these refineries if this latter approach is implemented. The final size and location of the SPR facilities will be influenced by industry's future decisions in solving the Northern Tier problem.

Pennsylvania

1. Comment: Notice was made of design and other criteria necessary for storage in that state.
Response: FEA presently has no plans for storage in that state. Should these plans change, design and other siting criteria will be addressed in site-specific environmental impact statements

2. Comment: The weight, volume, and cost of the barrels required to store 10 million barrels of oil aboveground is prohibitive.
Response: FEA does not propose to store oil in individual barrels.

3. Comment: At current consumption rates, the 150 MMB for the ESR is only a 9-day supply, while the 500 MMB planned for the SPR is less than a 30-day supply. Therefore, the utility of the program appears questionable in comparison to the cost.
Response: The SPR is not intended to replace the entire oil consumption of the nation. Its purpose is to temporarily replace any shortfalls in supply resulting from an interruption in foreign oil imports.

Texas

1. Comment: The effects of allocating "old" oil and participation in entitlements as methods of acquiring oil for the SPR should be more fully described.
Response: Section III.A.2. has been restructured to reflect the FEA proposal to acquire oil through the normal government procurement procedures. However, it is proposed that the cost of the Reserve be minimized through industry participation in an "entitlements" program, and the cost thereby shared by industry and the oil consumers. The effects of this approach are discussed, as are the implications of the FEA determination that it would be inappropriate for the government to purchase "old" oil, in Section III.A.2.

2. Comment: The "No Action" alternative should be analyzed more comprehensively in light of the fact that if imports decline, there may be no need for such a program and should imports increase, the program may be too small to be of value.

Response: The "No Action" alternative is designed to place the program in perspective for decision makers inside FEA as well as for those outside the Agency, such as the Congress. Present legislation mandates that FEA store 150 million barrels within 3 years and what amounts to at least 500 million barrels in 8 years. Should continued study by FEA indicate that imports are in fact decreasing or increasing during program implementation, a recommendation to increase or decrease the size of the program can be made.

3. Comment: The specific effects of sealing inlets against oil spills should be addressed.
   Response: The sealing of inlets in the event of an oil spill is an emergency measure to prevent the oil from entering the inlet from the ocean side. Normal cleanup operations would occur and the floating seal would be removed.

4. Comment: The subsidence effects of using ground water for leaching and cycling should be given full consideration.
   Response: The possibility of resulting subsidence is recognized by FEA, and to the extent that ground water is considered as an alternative supply for leaching and for cycling at any particular site, the impacts will be discussed in the site-specific impact statements.

5. Comment: Water supply concerns with regard to quantity and quality should be given serious consideration in the selection of water sources, and associated impacts should be discussed.
   Response: The selection of water sources and discussion of the effect of this choice must be relegated to site-specific EIS's, since the need for large quantities of water depends on the type of facility chosen, and the alternative sources (where large quantities are required) depend on the site location. Full consideration will be given to these concerns in site-specific EIS's.

6. Comment: The potential damage from oil spills is serious and requires every possible protective measure.
Response: FEA recognizes the serious potential consequences of oil spills and will take all practicable and feasible protective measures to avoid the impacts of oil spills both through precautionary measures and rapid cleanup operations.

7. Comment: A map showing the boundaries of FEA regions should be included in the FEIS.
Response: The FEA regions have been shown on the map in Figure IV-1.

8. Comment: Sections I.F.7. and III.B.1.e. should be made more complete by discussing the amounts of energy required for transportation and refining the stored oil, as well as energy requirements for construction and placement of developmental and operational facilities.
Response: Crude oil to be stored in the SPR will be utilized only during emergency situations; it does not represent additional new energy to be consumed but will replace shortfalls in existing supplies. Energy utilized for transportation and refining is therefore reflected in the baseline data for current operations and practices. The site-specific EIS's will address energy needs for site development and operation in more detail than presented in the programmatic statement.

9. Comment: Pin fish and sea catfish should be omitted from the list of important sports organisms of the Gulf.
Response: This suggestion has been implemented.

10. Comment: The use of a report and enclosed data to provide more recent information on finfish harvest and endangered species was recommended.
Response: The text and appropriate tables were changed, and the information was evaluated as to differential effect.

11. Comment: Different ratings were recommended for the interaction matrix table used in assessing ecological impacts.
Response: FEA believes the ratings used in the DEIS represent the concensus of many coastal ecologists, and that changes in response to this unsupported comment are inappropriate at this time.

12. Comment: The discussion of possible impacts of brine disposal in the Gulf of Mexico should be expanded to include those impacts that may affect shrimp and shrimp migration routes.
Response: FEA is conducting detailed site-specific analyses of those areas that may be affected by brine disposal in the Gulf. These analyses will be incorporated in the site-specific EIS's and will serve as the basis for locating the brine diffuser to minimize impacts of brine disposal, especially on shrimp and other marine resources.

13. Comment: Resultant impacts of brine discharge, not only in light of salinity but with reference to toxic effects due to reversed Ca:Mg compared to normal sea salts, should be discussed.
Response: FEA agrees and has expanded its discussion in Section V.A.2.a. to address this point.

14. Comment: Resultant impacts of discharge of brine with highly soluble, low-boiling, toxic aromatics leached from the stored crude while in contact with subsurface stored oil should be discussed.
Response: Aromatic hydrocarbons are only very slightly soluble to insoluble, as reflected by changes in Section V.D. Their concentrations in brine that is discharged are considered to be of negligible ecological significance.

15. Comment: Minimizing underwater obstructions in the Gulf of Mexico is recommended to be included in the Mitigating Measures section.
Response: FEA concurs in this recommendation and has incorporated the suggestion in Section VI.A., Mitigating Measures.

16. Comment: Salt dome storage sites should be carefully selected to minimize ground-water contamination.
Response: FEA recognizes the potential for endangerment of ground water; the site-specific EIS's will address this matter in full detail.

17. Comment: The use of 60 L_{dn} as an acceptable noise criterion is questioned.
Response: As discussed, the criteria of EPA's "levels" document (EN-108) is appropriate for a programmatic-level noise evaluation. For a specific site, the existing noise setting will be a factor in determining the degree of impact.

18. Comment: Increased noise during nighttime operations should be considered in the assessment and included in the presentation of data.
Response: The use of L_{dn} in the text as a measure for evaluating impacts incorporates a perceived 10 dB increase in noise levels from 2200 hours to 0700 hours.

19. Comment: The noise for one electric motor is recorded as being higher than six motors.
Response: The data has been changed to reflect the correct values.

20. Comment: Preparation of a special plan to insure overall, uninterrupted technical, administrative, and operational custody during the phased build-up of the reserve is requested.
Response: FEA will be preparing detailed site-specific EIS's for appropriate candidate SPR sites. In addition, FEA intends to follow normal good engineering and construction management practices while sites are being developed.

21. Comment: The impact of the reserves programs on vested surface-water rights should be examined.
Response: Site-specific EIS's will address water-rights and water sources as applicable for individual sites.

22. Comment: A section which examines in detail the environmental effects of brine disposal, including impacts of "washing out" a cavity, should be included.
Response: The detailed impacts of brine disposal, including those from leaching a salt cavity will be addressed in the site-specific EIS's as applicable. Further analysis is not considered appropriate in the programmatic EIS since brine disposal systems are site-dependent.

23. Comment: The "No Action" alternative is insufficiently discussed, particularly if imports drop to 1.2 MMBPD by 1985. The size of the SPR should be analyzed more comprehensively to match impacts.
Response: FEA feels that the "No Action" alternative discussion is adequate and that import reductions to a 1.2 MMBPD level by 195 are unlikely given the present trend. The precise size of the SPR will be reviewed periodically by FEA and Congress. Present legislation authorizes up to 500 MMB storage in the SPR.

24. Comment: The environmental assessment on groundwater quality and related economic aspects of inadequately designed brine disposal wells should be expanded regarding the leaching of caverns in Gulf Coast salt domes.
Response: FEA recognizes the potential for serious environmental and economic impacts if improper design practices are followed for salt domes. FEA will conform to all good engineering practices and will analyze the detailed brine disposal impacts in the site-specific EIS's. Economic impacts of brine disposal and cavern development will also be treated in the site-specific EIS's.

25. Comment: The potential collapse of salt mines used as storage sites if the overburden is structurally incompetent should be discussed.
Response: FEA recognizes that detailed engineering and geological analysis must be performed for all selected SPR sites. Full consultation with states will occur for any selected site and FEA intends to avoid selecting any site with geologic or structural hazards. Further discussion of this matter will be included in applicable site-specific EIS's.

26. Comment: Texas Air Control Board (TACB) construction permits and vapor controls may be required, depending on subsequent assessment of individual projects (by TACB).
Response: FEA recognizes that appropriate permits and control equipment will be needed as sites are developed. These considerations are fully discussed in the site-specific EIS's.

Wisconsin

1. Comment: All emission factors for tank storage in the DEIS are questioned as they are not consistent with EPA publication AP-42, July, 1973.
   Response: Emission factors are based on a large amount of data that recently has led to revision of the estimated factors in AP-42.

2. Comment: Reconsideration, in light of possible revision of emission factors, of statements concerning ambient hydrocarbon concentrations and air quality impacts should be done.
   Response: While emission factors used in the DEIS are believed to be correct, the statements concerning air quality impacts have been amplified to differentiate various sources of these impacts.

3. Comment: Need for vapor control, such as floating roof tanks, should be considered.
   Response: Floating roof tanks are not required for fuel oil storage by new source performance standards. These standards represent best available control technology. However, FEA recognizes that such tanks do reduce hydrocarbon emissions and therefore serve as mitigative measures. They will be considered on a site-specific basis and will be installed where required by SIP's.

4. Comment: The section on tankage should be revised to clarify which petroleum liquids will be stored and how they will be stored.
   Response: The section on tankage has been revised to emphasize that no crude storage in tanks is now anticipated. The impact analysis uses distillate as a worst-case assumption.

5. Comment: Mention should be made of the seasonal variability of HC emission violations, and consideration should be given to the possibility of filling tankage in seasons or weather conditions where HC emission hazards are low or non-existent.
Response: The seasonal variability has been recognized in the DEIS (V.A.4., V.B.4.). It is stated that emission impacts may be mitigated by filling during periods least conducive to oxidant formation, i.e., winter and spring. However, program requirements may require filling during other periods when temporary adverse oxidant levels will result.

6. Comment: Consideration should be given to venting of underground storage caverns while filling.
Response: There will be no direct contact between crude and air during filling (as the salt dome cavern is full of brine). Fugitive leaks from pumps, valves, and fittings will be minimal if these are well maintained.

7. Comment: The inquiry was made as to what type of emission controls will be employed for underground facilities.
Response: No flares or condensers will be used in salt dome caverns. Underground rock caverns will have one of these two vapor controls, but the implementation and selection is a site-specific design consideration.

8. Comment: The zero HC background concentration is not realistic.
Response: The simplifying assumption of zero background has been deleted.

9. Comment: Inquiry is made as to whether siting considerations will include cumulative air quality impacts.
Response: Cumulative air impact analyses will be an integral part of all site-specific EIS's.

10. Comment: New Source Performance Standards apply to crude oil stored in aboveground tanks and to any "unexcluded finished or intermediate (petroleum) product".
Response: The program does not propose to store crude in aboveground tanks.

11. Comment: Inquiry was made as to the frequency of and pollution rate for temporary flares.
Response: These considerations must be addressed site-specifically as they depend on size, filling rate, and type of stored product.

12. Comment: The source of emission factors for residual oil should be given.
Response: The source for the emission factors was an ongoing EPA-sponsored study (Contract No. 68-02-1889-1) to update emission factors. This update should be available in early 1977.

13. Comment: The emission factors for any other aboveground-stored petroleum liquids should be given.
Response: Emission factors are presented and analyzed for two products, residual and distillate, that represent typical storage liquids.

14. Comment: Inquiry was made as to why the use of vapor recovery systems is inconvenient with residual oil storage.
Response: The text was expanded to describe further applicable vapor control systems for both residual and distillate oils.

15. Comment: It is noted that the references to residual and distillate oil are inadvertently reversed.
Response: The lower vapor pressure of residual oil causes less impact than distillate and crude oil. The references to the categories of products were reversed and have been corrected.

16. Comment: The pertinent air quality question does not concern long-term degradation, but violation of the one-hour standard.
Response: Tanker loading and unloading during worst-case meteorological conditions is predicted to exceed the one-hour standard. However, no long-term degradation is foreseen since the SPR program will be an intermittent source of air pollutants.

17. Comment: The treatment of advanced technologies, especially those related to solar energy, were not adequately discussed as alternatives to the SPR in the DEIS.
Response: The potential contribution from these sources were not quantified because they do not appear to be significant within the time frame in which the SPR is to be developed. In order to be an alternative to the SPR, a potential energy source must be able to contribute to the energy supply within the time period.

American Petroleum Institute

1. Comment: Statements made grossly underestimate the seriousness of HC emissions.
   Response: The FEIS has been modified in appropriate sections to differentiate the various sources of hydrocarbon emissions likely to occur and more fully describe the nature of the problem. The impact of emerging EPA non-attainment policies is discussed in Section II.A.5.

2. Comment: The statement concerning dissolution and degradation of higher boiling fractions is only an opinion and has not been established.
   Response: FEA concurs; the text has been modified accordingly.

3. Comment: Recent studies by GURC contradict the statement that "fish and shrimp production are reduced in oil-polluted Gulf waters."
   Response: GURC's summary does indicate a reduction in shrimp and fish production, although this reduction was in confined waters chronically polluted by oil field wastes which also were affected by two major spills in 1970. FEA believes its statement to be essentially correct, but has added reference to GURC's studies by way of qualification.

4. Comment: The statement that "circumstantial evidence links petroleum hydrocarbons to tumors in bottom-feeding fish and clams" is not based on established cause-and-effect relationships.
   Response: The term "circumstantial evidence" was used to indicate precisely that no cause-and-effect relationships had been established by rigorous, scientific technique. However, certain studies (BO-110, NE-079) do support the text as written.

5. Comment: Concentrations of 0.1 ppm of water-soluble aromatics derived from petroleum are probably an order of magnitude lower than those to which larval marine organisms are sensitive.
Response: The numbers presented in the DEIS are lower limits; most observations here are in the range of 1-100 ppm, with some fish tolerances rating several thousand ppm. The statement has been modified to call attention to these facts.

6. Comment: There is no demonstrated public health risk from bio-accumulated carcinogens, nor will shellfish be tainted.
Response: Two studies recently have been funded by API on the subject of shellfish depuration after contamination by hydrocarbons (API Publication Nos. 4191 and 4249). These studies indicate that hydrocarbons accumulate several hundredfold over background levels in shellfish placed in contaminated waters. In an experimental oiling of a shrimp pond, naphthalenes accumulated in oyster (*Crassostrea virginica*), shrimp (*Penaeus setiferus*), and clam (*Rangia cuneata*) to levels which can impart unpleasant odors or tastes to shellfish. The API studies also indicate that shellfish purge themselves of hydrocarbons, tissue concentrations returning to background levels after two to sixty days from the point when exposure ceases. Shellfish would retain some taint at least thorugh the first half of this period. Earlier field observations associated oil lost from a wild off-shore well with an oily taste in oysters which persisted two months (Institute of Marine Sciences, University of Texas, Pub-Lication 7:230-261). More recent studies following the West Falmouth oil spill also reported taints in oysters lasting for two months (Woods Hole Oceanographic Institute, Technical Report 70-1).

One of the API studies (Anderson, 1975) specifically followed the accumulation of benzo-a-pyrene (BAP) in laboratory tests with a clam, *Rangia cuneata*. These tests indicated a concentration by a factor of 200 or more in 24 hours, followed by a return to normal levels in 30-60 days. BAP is only one of many potential carcinogens in oil, making up as much as a fifth of the entire concentration of carcinogenic substances. It is highly unlikely, however, that any human being would consume enough seafood contaminated by this and other carcinogens during the natural depuration period following an oil spill to cause cancer.

In the absence of a known lower threshold of carcinogens in the human body below which no cancers would ever be chemically initiated, FEA feels a cautious tone is appropriate. However, the paragraph has been amended to read less strongly than the original.

7. Comment: Although no detailed prediction of the movement of hydrocarbons through marine food chains can be made, entry of hydrocarbons into the human diet is not likely since marine organisms purify themselves of oil.
Response: Hydrocarbons may persist for several months in contaminated shellfish. It is not possible to state with certainty that in that time no contaminated shellfish would be harvested for food. Consequently, FEA believes that the original statement is correct. However, the discussion has been modified to further qualify the statement.

8. Comment: Spilled oil is not likely to harm salt-marsh microbial populations which participate in the breakdown of detritus, according to ongoing studies conducted by the Virginia Institute of Marine Science.
Response: The comment is correct and the text has been reworded accordingly, emphasizing that chronic exposure to oil is necessary to produce the effects described.

9. Comment: References CO-223 and CO-224 are to Cowell, rather than to Colwell, as typed.
Response: The correction has been made.

Amoco Oil Company

1. Comment: Establishment of an IPR would be an inefficient diversion of capital from exploration and production projects, and the impact of industry funding of the SPR through an IPR was not adequately discussed in the DEIS.
Response: The FEIS reflects the FEA proposal that the authority to create an IPR not be exercised. It includes an economic analysis of the effects of implementing an IPR, should one eventually be proposed.

2. Comment: The assignment of "old" oil or of entitlements should not be used as a method of acquiring oil for the SPR.
Response: After careful analysis of various oil acquisition techniques, FEA is proposing that the government acquire oil for the SPR through the use of normal government procurement techniques. However, it is proposed that the cost of the Reserve be minimized through industry participation in an "entitlements" program and the cost thereby shared by industry and oil consumers.

Bonaire Petroleum Corporation

1. Comment: The DEIS did not describe and discuss the alternative methods of transporting oil which should have included transshipment and a comparison of it with other alternatives.
Response: A description and analysis of the relative oil spill risks associated with various methods of transporting oil to U.S. ports for use in the SPR, including transshipment, has been added to section V.D.

2. Comment: The treatment of "Petroleum Acquisiton" should reflect that the cost of transportation is a major ingredient of the total cost of the SPR.
   Response: The cost of crude oil transportation is only one element of the cost of the Reserve, and with the possible exception of cost impacts from compliance with cargo preference laws, is comparable to the relatively nominal costs of operating the Reserve and facility costs. With this exception, it is not to be considered major when compared to the cost of acquiring crude oil.

3. Comment: The demand for tankers caused by the SPR will tend to increase chartering costs.
   Response: Given the excess tanker capacity now available and the small incremental percentage increase in oil importats for the SPR, it is FEA's judgement that the minor increased demand should have little effect on charter rates.

4. Comment: The administrative aspects and mechanics of scheduling and coordinating tanker shipments into U.S. ports should be addressed.
   Response: These are details of the fill and withdrawal schedule for specific sites which have not yet been formulated. It is likely, in any event, that the proposed open market purchase of oil will result in accomplishment of the necessary scheduling and coordinating by FEA's suppliers in the normal course of their business.

5. Comment: The reference to transfer of oil from VLCC's to smaller tankers at foreign ports mischaracterizes the nature of transshipment facilities.
   Response: The text has been changed to clarify the fact that use of small and medium-sized tankers will increase tanker traffic at U.S. ports.

6. Comment: Superports will not be available for use in filling the Early Storage Reserve since none will be in operation before 1980.
Response: This fact has been noted and the text has been changed to reflect this situation.

International Association of Independent Tanker Owners

1. Comment: The basis for elimination of tankers as a means of storing oil for the SPR and the validity of the preliminary analysis should be further studied.
Resonse: After additional analysis, FEA has reaffirmed its initial determination that storage of oil in tankers is not advantageous.

2. Comment: The laid-up tonnage and total tonnage potentially available to the SPR requires updating to reflect significantly different current status.
Response: Appropriate changes have been made in the text to update the statistics and the potential storage available.

3. Comment: The need for contractual "escape clauses" is questioned.
Response: The reference to escape clauses has been deleted as these contractual matters are not deemed to have environmental import, and the need therefore may vary from case to case in any event.

4. Comment: The technical considerations involved in tanker operations and maintenance are exaggerated.
Response: FEA believes the statements made are correct, and that Intertanko's position is overly optimistic.

5. Comment: The reference to the Torrey Canyon catastrophe is inappropriate.
Response: FEA concurs, and the subsection on catastrophic events has been deleted here in favor of referencing the risk analysis of oil spills in Section V.D.

6. Comment: The cost information related to tanker acquisition, maintenance, and final disposition are questioned.
Response: The costs presented in the FEIS reflect the most recent data and the most current analysis (November, 1976) performed by FEA and others concerning the use of tankers as storage facilities.

Standard Oil Company of California

1. Comment: No IPR should be established because the funding responsibilities should be borne by the national economy.
Response: The FEIS reflects the FEA proposal to be submitted to Congress in the Strategic Petroleum Reserve Plan that the authority to create an IPR not be exercised.

2. Comment: Private firms should not be excluded from planning, designing, constructing, operating, and managing the SPR.
Response: FEA does not intend to exclude private firms from assisting in most of these tasks, nor was such exclusion implied in the DEIS.

3. Comment: The Regional Petroleum Reserve is unnecessary.
Response: FEA is proposing in the Strategic Petroleum Reserve Plan to meet the substantive requirements of Section 157 of the EPCA concerning the Regional Petroleum Reserve through storage of crude oil in centralized storage, rather than by storage within regions.

4. Comment: The SPR should contain crude oil and not refined products.
Response: FEA is proposing in the SPR plan that the SPR contain only crude oil.

5. Comment: Oil should not be acquired for the SPR by allocating price-controlled oil to the Government or by Government participation in the entitlements program.
Response: After careful analysis of various oil acquisition techniques, FEA is proposing that the Government acquire oil for the SPR through the use of normal Government procurement techniques. However, it is proposed that the cost of the Reserve be minimized thorugh industry participation in an "entitlements" program, and the cost thereby shared by industry and oil consumers.

6. Comment: The use of tankers as an interim storage technique is inferior to storage in existing underground caverns.
Response: FEA's proposal for implementing the SPR emphasizes underground storage and does not involve tanker storage.

7. Comment: The treatment of oil spills, impacts, and cleanup needs to be updated.
Response: FEA has modified the presentation to reflect a more current and accurate treatment.

8. Comment: The projected level of production of domestic crude and LNG is overly optimistic.
Response: The production levels reflect the latest Project Independence Evaluation System (PIES) projections, and are considered realistic, based on the constraining assumptions.

9. Comment: There was no OCS production in 1975 in Alaska. All producing fields--except Swanson River--were outside state waters in Cook Inlet.
Response: The correction was noted and the text was modified. The sentence refers to offshore production.

10. Comment: Indirect methods of increasing oil imports will not stimulate domestic production of oil.
Response: It is FEA's assessment that the SPR will result, directly or indirectly, in incremental oil imports roughly equal to the amount of oil to be stored; the discussion has been changed to reflect this assessment.

11. Comment: The figure given for tanker deliveries is incorrect.
Response: The correct figure was inserted into the text.

12. Comment: Sufficient data do not permit the assumption that the six-year period estimated to construct solution-mined cavities in salt can be reduced.
Response: The four-year period refers to construction and leaching periods only. FEA is fully aware of the time requirements for implementing all types of the storage facilities proposed, and the exact timing will be established upon selection of specific sites and subsequent site-specific studies.

13. Comment: The section on oil spills is negative in tone.
Response: The section has been modified to present what FEA considers a fair appraisal of oil spills and their effects.

14. Comment: The discussion of oil spills does not take into account up-to-date studies of "fate and effects" of oil spills and cleanup and prevention methods and should also take note of recent API studies.

Response: The text has been modified to present a fair, current account of these concerns and the API studies have been added to the data base on which these modifications are made.

15. Comment: The introductory sentence to the section on oil spills is too harsh and should be amended to reflect the temporary nature of most oil spill damage.
Response: FEA concurs and the requested change was made.

16. Comment: Treating agents should be discussed under a separate heading.
Response: FEA concurs, and the text has been modified appropriately.

17. Comment: The implication that the entire amount or a large portion of a 30,000 ton oil spill in coastal ocean waters would reach shore is in error.
Response: This implication was not intended by the statement; appropriate changes clarifying the paragraph have been made.

18. Comment: The DEIS should explain that a containment boom is available to facilitate diversion of oil from areas of extreme ecological importance.
Response: FEA believes this suggestion is redundant. Furthermore, the discussion refers to the need for protecting estuaries and lagoons from oil moving into them from the open sea; thus, a boom across the inlet is desirable, whether another diversion boom is utilized or not.

19. Comment: The DEIS omits mentioning the alternative of natural removal of oil from beaches which are inaccessible or rocky.
Response: This alternative, which is a last-resort strategy, was addressed in the DEIS under "Bacterial Degradation and Other Biological Processes" as a cleanup/control measure.

20. Comment: The cost extrapolation for a large spill is unrealistic.

Response: FEA concurs, and the text has been modified to emphasize the generally decreasing unit costs with larger spills.

21. Comment: Containment and cleanup in the ocean environment are possible under all but the most extreme conditions.

Response: While considerable progress has been made in this area, FEA believes that the marine conditions addressed have continued to be upper limits for reliable containment and cleanup.

Texaco, Inc.

1. Comment: The assessment in the DEIS of the economic impact of an IPR was misleading.

Response: The statement has been modified to reflect the current FEA assessment.

2. Comment: An increase in demand for domestic crude will not stimulate production of domestic crude.

Response: It is FEA's assessment that the SPR will result, directly or indirectly, in incremental oil imports about equal to the amount to be stored; the discussion has been changed to reflect this assessment.

3. Comment: The statement concerning relative adverse effects of onshore and offshore oil spills was incomplete.

Response: The statement has been expanded to more fully describe the situation.

4. Comment: Some East Coast and Gulf Coast refineries are not capable of processing NPR Oil.
Response: The treatment of NPR oil has been modified to reflect the fact that only a portion of the oil from NPR-1 meets the viscosity and sulfur specifications required by the SPR.

5. Comment: The statement that industry has contributed greatly to pollution in the form of oxygen-demanding materials should be updated to reflect the present situation.
Response: The statement in the DEIS is accurate when cumulative loadings through time are considered. FEA recognizes, however, that industry is more likely to achieve 1983 water quality objectives than municipalities, and this has been indicated by additional text.

6. Comment: The Input-Output Model was not modified to reflect the capital costs of purchasing the oil required for the SPR.
Response: The purpose of the Input-Output analysis was to assess the regional economic impacts associated with construction and operation of storage facilities. Uncertainty as to the source and ultimate cost of the oil for the Reserve make it impracticable to include the cost of the stored oil in input-output analysis. Moreover, a large part of the required investment would occur outside of the economic system characterized by the national input-output model (i.e., purchase of foreign oil).

7. Comment: The depth of wave-induced effects is incorrect.
Response: The text was modified to reflect that 20-35 feet is a more reasonable range of wave-induced effects.

8. Comment: The impacts described for barge facilities are overly adverse if currently prevailing modern transfer practices are employed, and both EPA and Coast Guard requirements are met.
Response: FEA concurs that the paragraph concerning chronic pollution at barge docks was overly negative in view of recent improvements, and appropriate text changes have been made. The effects of chronic oil pollution also will be addressed in more detail in site-specific EIS's.

9. Comment: Aromatics found in spilled oil are generally only slightly soluble in water (McAuliffe, C., 1976. Solubility in Water of Paraffin, Cycloparaffin, Olefin, Acetylene, Cycloolefin, and Aromatic Hydrocarbons, J. Phys. Chem. 70(4): 1274).
Response: This is correct, and the sentence in the text has been changed accordingly.

10. Comment: API studies showing that marine animals purge themselves of hydrocarbons from oil spills invalidate the suggestion that humans may be exposed to carcinogens through the marine food chain. Also, ingestion of cancerous tissues is not considered by cancer experts to cause cancer in humans.
Response: Two recent API studies (API Publication No. 4191 and API Publication No. 4249) indicate that hydrocarbons accumulate several hundredfold over background levels in shellfish placed in contaminated waters. These studies indicate that shellfish purge themselves of hydrocarbons, and tissue concentrations return to background levels after two to sixty days. The second part of this comment is apparently a misreading of the statement; the statement refers to the ingestion of carcinogenic compounds accumulated by marine organisms, and not to cancerous tissue itself.

3. <u>Comment</u>: The FEIS should be clarified to differentiate between environmental impacts of the storage and the effects of environmental factors on the storage.

<u>Response</u>: After further consideration, the FEA has concluded that these impact types are adequately differentiated because of the nature of the discussion of each impact.