M. Chatelain

DOE/EIS-0010

EF-83

Final Environmental Impact Statement
(Final Statement to FEA-DES-77-6)

STRATEGIC PETROLEUM RESERVE

Sulphur Mines Salt Dome
Calcasieu Parish, Louisiana

U.S. DEPARTMENT OF ENERGY

March 1978

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Sulphur Mines Salt Dome

Calcasieu Parish, Louisiana

Responsible Official

James L. Liverman
Acting Assistant Secretary for Environment

U.S. DEPARTMENT OF ENERGY
Washington D.C. 20545

March 1978

SUMMARY

STATEMENT TYPE: ( ) DRAFT (X) FINAL STATEMENT

PREPARED BY: Strategic Petroleum Reserve Office, Department of Energy, Washington, D. C. 20461

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

2. Brief Description of the Proposed Action:

This document is a site specific environmental impact statement (EIS) for the proposed storage of 24 million barrels of crude oil at the Sulphur Mines salt dome located in Calcasieu Parish, Louisiana. Sulphur Mines is a candidate site for the Strategic Petroleum Reserve (SPR) program currently being implemented by the Strategic Petroleum Reserve Office (SPRO) of the Department of Energy (DOE). Creation of the SPR was mandated by Congress in Title I, part B of the Energy Policy and Conservation Act of 1975, P.L. 94-163 (the Act) for the purpose of providing the United States with sufficient petroleum reserves to minimize the effects of any future oil supply interruption. The Act requires that within seven years, the SPR contain a reserve equal to the volume of crude oil imports during the three consecutive highest import months in the 24 months preceding December 22, 1975 (approximately 500 million barrels). To implement the provisions of the Act, the Strategic Petroleum Reserve Office transmitted to Congress on February 16, 1977, the Strategic Petroleum Reserve Plan. The SPR Plan became effective on April 18, 1977. In addition, the President has proposed that the schedule for implementing the SPR be accelerated, so that 250 million barrels is stored by 1978, and 500 million barrels by 1980. An amendment to the SPR Plan describing Program acceleration was transmitted to Congress and became effective on June 20, 1977.

3. Summary of Environmental Impacts and Adverse Environmental Effects.

This site-specific Environmental Impact Statement (EIS) has identified particularly sensitive environmental parameters that have been investigated in detail for the Sulphur Mines, Louisiana site. The most sensitive parameters to be affected by oil storage development at this site appear to be water quality and air quality. However, the use through several cycles at the Sulphur Mines site would be limited due to the close proximity of the caverns to the periphery of the dome.

The adverse impacts to the physical environment that could result from the program include: degradation of surface water quality due to sedimentation from runoff and erosion during pipeline construction activities which would increase the amount of suspended particulates, toxic sulfides, heavy metals, arsenic, pesticides and other toxic hydrocarbons; a moderate increase in hydrocarbon emissions during transfer and storage of oil; locally significant increases in hydrocarbon emissions during transport of oil from the Gulf of Mexico to Sun Terminal; and the potential for an increase in the frequency of oil spills along the transportation corridors. Changes in water quality would have a short-term impact on the aquatic organisms in local areas and could result in some minor sedimentation in downstream impoundments. Oil spill releases to land and water environments could cause localized losses to vegetation and fauna along the pipeline corridor and at the terminals.

Brine disposal into subsurface aquifers appears to have the necessary total capacity to accommodate the total volume of brine to be disposed. However, excessive pressure buildup may be anticipated from sands, and during the fifth cycle pressure buildup would be close to the fracture limit.

The transfer of crude oil at Sun Terminal would have a minor adverse impact on the amount of hydrocarbons (in the form of volatile vapors) released to the atmosphere. The amount of hydrocarbons to be released has been estimated at 38.8 tons of hydrocarbons for a single fill cycle (a period of 240 days). More significant hydrocarbon emissions would occur during each fill operation at the following locations: 291 tons in the Gulf of Mexico; 74 tons at the Nederland, Texas tanker docks. During the lifetime of the project, assuming five withdrawals and fills of oil, the equivalent of approximately 2,767 barrels of oil would be emitted to the atmosphere.

A total of 453 barrels of oil are projected to be spilled during the project lifetime in transporting the crude oil. Of this total, 45 barrels would be released in the Gulf of Mexico, 215 barrels into the inland water bodies, and the remainder from the pipelines. The maximum credible spill size is 400,000 barrels for tankers and 10,000 barrels from the pipeline system. A spill of this size could severely pollute several hundred acres, depending on location, but the probability of occurrence is extremely low.

4. Alternatives Considered:

Alternative Storage Sites
- Cote Blanche Salt Mine
- Ironton Salt Mine
- Central Rock Salt Mine
- Kleer Salt Dome Mine

Alternative Facility Components
- Alternative Distribution Facilities
  - Alternative Distribution Terminal
- Alternative Pipeline Connection to Existing Refineries
- Alternative Brine Disposal Facilities
- Alternative Displacement Water Supply

5. Date Made Available to CEQ and the Public

The draft statement was made available to the Council on Environmental Quality and the public in September 1977. This final statement was made available to the Council on Environmental Quality and the public in March 1978.

6. Comments on the Draft Statement Have Been Received from the Following:

Federal Agencies:

- Department of the Army - New Orleans District Corps of Engineers
- Environmental Protection Agency
- Department of the Interior
- Department of Health, Education and Welfare
- Advisory Council on Historic Preservation
- Nuclear Regulatory Commission

State Agencies

- Texas Department of Agriculture
- Texas General Land Office
- Texas State Department of Highways and Public Transportation
- Texas Industrial Commission
- Texas Parks and Wildlife Commission
- Texas Department of Water Resources

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1. DESCRIPTION OF PROJECT

1.1 BACKGROUND

This document is a site specific environmental impact statement (EIS) for the proposed storage of crude oil at the Sulphur Mines salt dome located in Calcasieu Parish, Louisiana. Sulphur Mines is a candidate site for the Strategic Petroleum Reserve (SPR) program currently being implemented by the Strategic Petroleum Reserve Office of the Department of Energy (DOE). Creation of the SPR was mandated by Congress in Title I, Part B of the Energy Policy and Conservation Act of 1975, P.L. 94-163 (the Act) for the purpose of providing the United States with sufficient petroleum reserves to minimize the effects of any future oil supply interruption. The Act requires that within seven years, the SPR contain a reserve equal to the volume of crude oil imports during the three consecutive highest import months in the 24 months preceding December 22, 1975 (approximately 500 million barrels). To implement the provisions of the Act, the Strategic Petroleum Reserve Office (SPRO) transmitted to Congress on February 16, 1977, the Strategic Petroleum Reserve Plan. The SPR Plan became effective on April 18, 1977. In addition, the President has proposed that the schedule for implementing the SPR be accelerated, so that 250 million barrels is stored by 1978, and 500 million barrels by 1980. An amendment to the SPR Plan describing Program acceleration was transmitted to Congress and became effective on June 20, 1977.

A final programmatic EIS (FES 76-2) addressing the effects of the SPR program as a whole was filed with the Council on Environmental Quality and made available to the public on December 15, 1976. That statement considers several different types of storage facilities, including the use of existing solution-mined cavities in salt formations and conventional mines, the construction of new solution-mined cavities and conventional mines, the use of existing and the construction of new conventional surface tankage, and the use of surplus tanker ships. The final programmatic EIS should be consulted for a description of each of these storage methods and the potential impacts which might result from its use. The programmatic EIS also assesses the cumulative impacts which could be expected from use of various combinations of the different facility types.

The Sulphur Mines salt dome is one of several candidate storage sites that have been identified by means of a screening process involving the application of a series of six criteria. These criteria are capacity, distribution accessibility, technical feasibility, potential environmental concerns, ease of acquisition, and cost. Section II.E.1 of the programmatic EIS describes in detail how the criteria were applied to approximately 300 salt domes and approximately 300 existing mines to select 32 candidate sites.

In addition to the Sulphur Mines salt dome, eight other candidate sites with existing storage space readily available, have been identified. These include the West Hackberry salt dome (Cameron Parish, Louisiana), the Bayou Choctaw salt dome (Iberville Parish, Louisiana), the Bryan Mound salt dome (Brazoria County, Texas), the Weeks Island salt mine (Iberia Parish, Louisiana), and the Cote Blanche salt mine (St. Mary Parish, Louisiana), the Ironton limestone mine (Lawrence County, Ohio), the Central Rock limestone mine (Fayette County, Kentucky) and the Kleer salt mine (Van Zandt County, Texas). Final EISs on the eight alternative candidate sites (FES 76-4 through 76-8, 76/77, 9-10 and 77-2) have been filed with the Council on Environmental Quality and made available to the public. The first four (West Hackberry, Bayou Choctaw, Bryan Mound and Weeks Island) have been selected for use in the SPR. The remaining four sites are addressed in Section 7.1 as alternatives to Sulphur Mines.

1.2 PROPOSED FACILITIES

1.2.1 Concept for Storage in Salt Domes

The use of salt domes for petroleum storage is attractive because of both the relative low cost of such bulk storage and the extreme geological stability of rock salt masses. In addition, being deep underground provides security from most natural catastrophes or sabotage. In the Gulf Coast region, over 50 salt domes, both onshore and offshore, appear feasible for development (see Figure 1.1).

Salt domes are a major source of brine feedstock for chemical and salt industries in the Gulf region. Cavities are formed by dissolving the salt with circulating water and pumping out the resulting brine (see Figure 1.2). The process requires a large volume of leach water (about 7 barrels fresh water or about 8 barrels of seawater for every barrel of space created). Some of these cavities are currently used to store a number of petroleum products. In the U. S., the products stored are primarily LPG products such as propane, ethylene, etc., as well as some fuel oil.

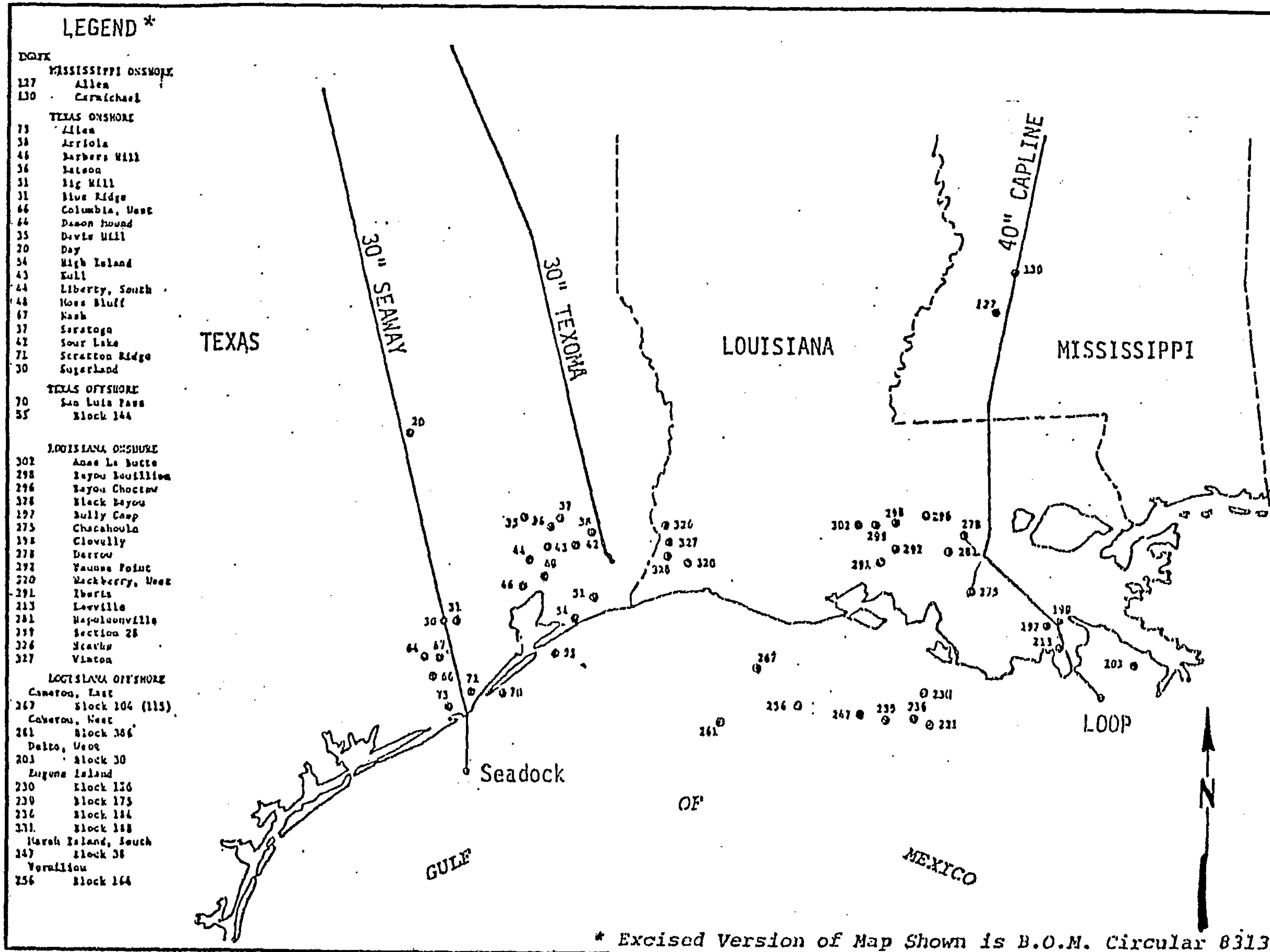


Figure 1.1 Gulf Coast Region Salt Domes.

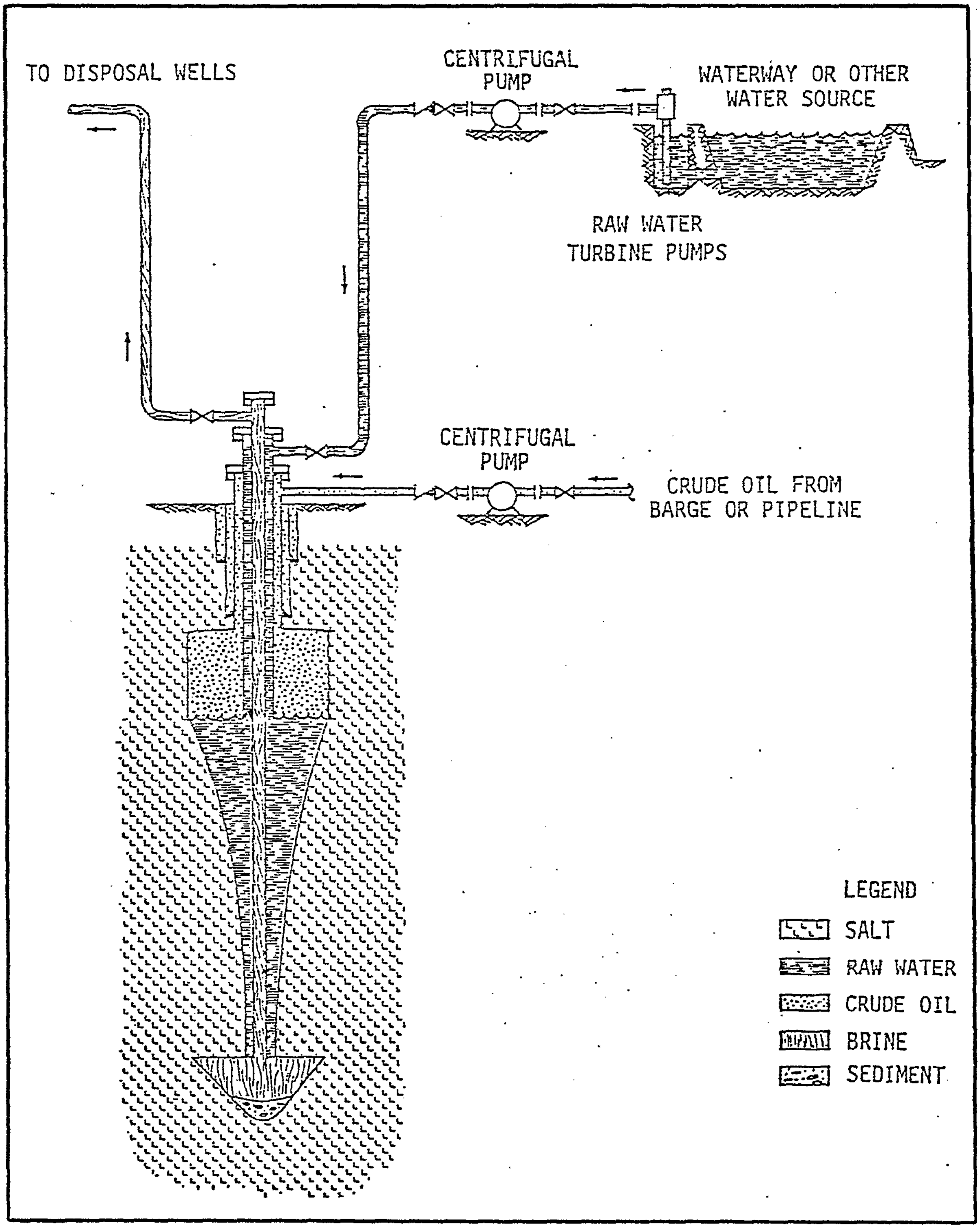


Figure 1.2 Typical Solution Cavity in Salt Formations.

Although crude oil storage in solution cavities does not present difficult technical problems, it has been done principally in other countries. The one exception in the United States is the Venice Dome in Louisiana.

Both existing salt dome cavities and new cavities to be developed are being considered for the SPR. Salt domes with existing cavities have been identified as candidates for the ESR because they require less time to prepare for oil storage. Approximately 900 cavities with a total capacity of 300 million barrels are known to exist in salt domes and bedded salt formations. In some cases, it is feasible to enlarge existing cavities or to leach additional cavities at selected sites.

1.2.2 Proposed Storage Site

The proposed Sulphur Mines facility as currently designed would provide up to 24 million barrels of the SPR requirements in the Texoma/Lake Charles/Beaumont storage region. Five existing brine caverns would be adapted to provide the required storage volume.

The Frasch Method of sulfur mining was first developed at the Sulphur Mines salt dome, and an estimated 9.4 million tons of the chemical were extracted from the dome's caprock between 1903 and 1924.

The dome is presently used by Allied Chemical Corporation, Houston, Texas, for hydrocarbon product storage and by PPG Industries, under lease from Allied, for brine feedstock production. Sulphur Mines is a comparatively small salt dome with only 1.1 cubic miles of salt above the depth of 10,560 feet. The caprock is abnormally thick, an average of 1,100 feet, with the subsurface depths of caprock and salt being 315 and 1,460 feet, respectively.

There are no salt mines at Sulphur mines. Therefore the potential for conflicting use of the dome between crude oil storage and radioactive waste isolation does not exist.

1.2.3 Location

The Sulphur Mines salt dome is located in central Calcasieu Parish, Louisiana, about 2 miles west of the city of Sulphur (population about 20,000) and 12 miles west of Lake Charles (population about 85,000). The site is one mile north of U.S. Highway 90 and the Southern Pacific Railroad. Interstate Highway I-10 passes 2.5 miles south of the dome (See Figure 1.3).

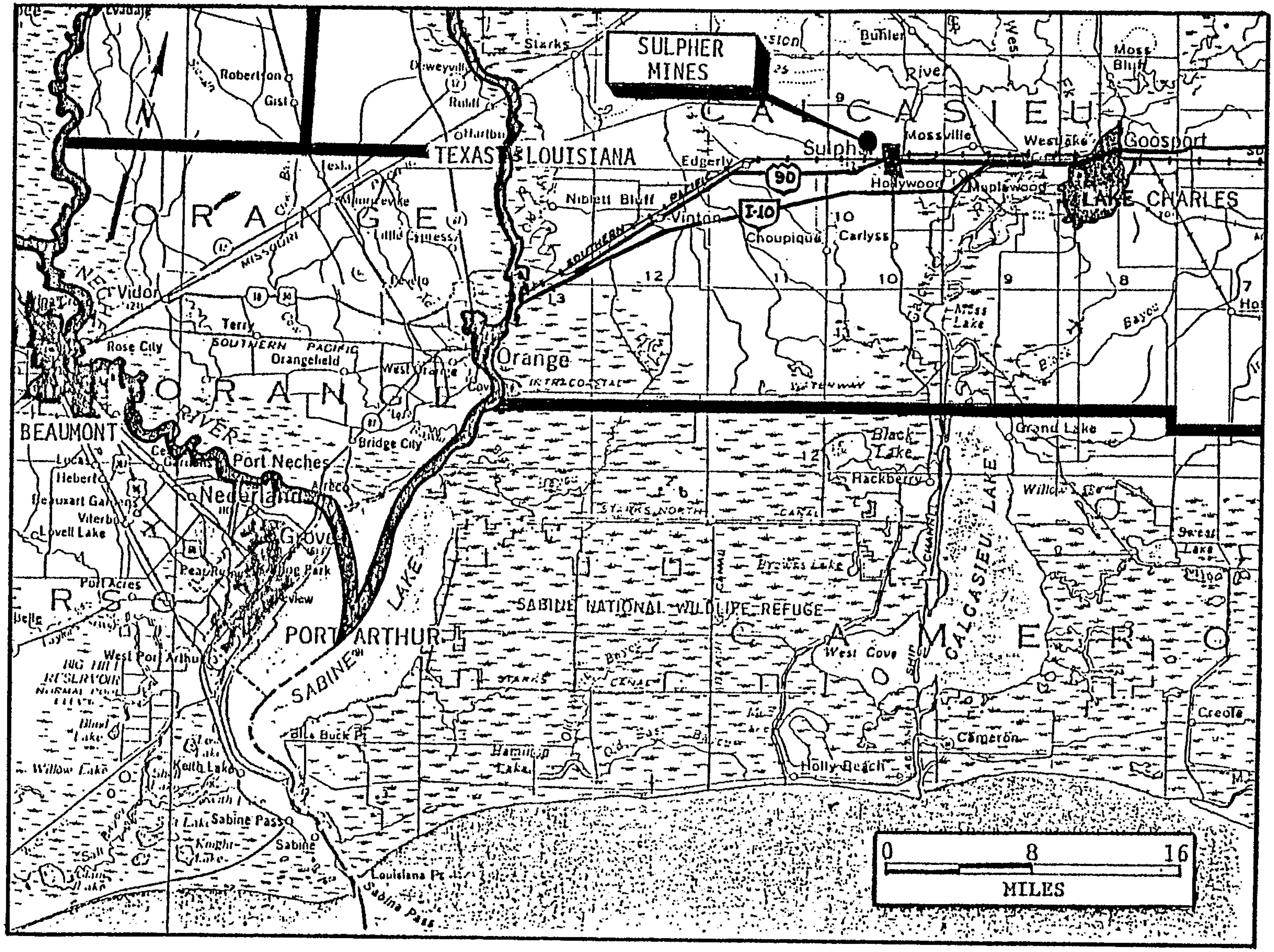


Figure 1.3 Texoma/Lake Charles/Beaumont Storage Region.

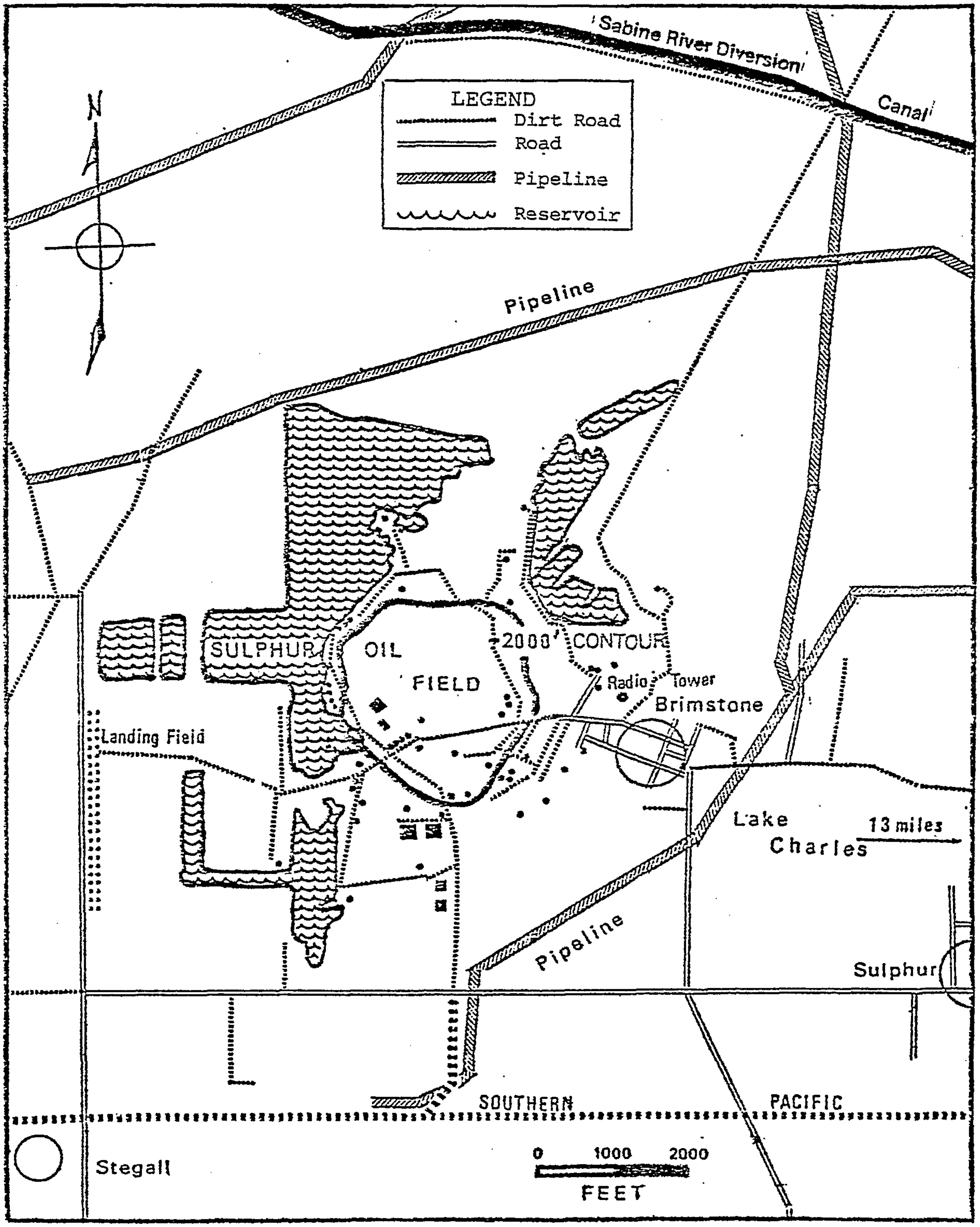
A paved parish road provides access to the site from the city of Sulphur. Access to most portions of the dome is provided by a network of gravel roads servicing the past and present operations at the site. The surface area above the salt dome is mostly cleared land, with elevations ranging from 12 to 18 feet above sea level; the lowest portion is over the center of the dome where sulfur extraction has caused subsidence. Much of the area has been altered to meet various industrial needs over the years. Large ponds with a total surface area of around 252 acres have been constructed around the dome periphery (see Figure 1.4).

A branch spur of the Southern Pacific Railroad passes within 3,000 feet south of the proposed site. The Intracoastal Waterway is about 14 miles south of the dome. Ship terminals at Lake Charles are connected via the Calcasieu River Shipping Channel to the Gulf of Mexico, some 34 miles to the south. Tankers using the shipping channel are limited to about 50,000 deadweight ton (DWT).

1.2.4 Development Capacity

The total developed storage capacity of the existing available caverns in the Sulphur Mines dome is about 24 million barrels, (see Appendix H). The caverns are currently used for brine production, and Allied has commitments to PPG to supply them with brine feedstock at the rate of approximately 2,500 gallons per minute (gpm). They are developing an additional storage capacity of two million barrels per year at their present brining rate. Allied has indicated that they could develop replacement wells or increase their brine production from Starks Dome to fulfill their obligations. Two other caverns developed by Allied have been converted to ethylene storage and are under lease to Conoco. PPG has developed a third ethylene storage cavern.

The Sulphur Mines dome has a limited capacity for leaching new caverns. Although the surface area is small with respect to other Gulf Coast domes (150 acres within the 2,000 foot contour) sufficient area remains to construct 5 ten million barrel caverns at 20 acre spacing. Much of this acreage, however, lies beneath the area where sulfur mining operations were conducted and problems could be encountered in completing wells through this mined zone. (See the discussion of drilling procedures in Appendix H.)



SULPHUR MINES DOME

Figure 1.4 Existing Site Layout.

1.2.5 General System Description*

The proposed facility presently planned for Sulphur Mines requires the conversion of 3 existing caverns from brine production to crude oil storage. Crude oil for filling the cavities would be supplied by pipeline from the Sun Terminal in Nederland, Texas. A new 17 mile spur pipeline would be required to connect the site to the West Hackberry - Sun Terminal ESR main distribution pipeline.

One grade of crude oil would be injected into the gallery consisting of caverns 2-4-5, and caverns 6 and 7 (see Figure 1.5), by pumps located at a central pump building on the storage site. The existing brine in the salt caverns would be displaced and disposed of. If an agreement can be reached, it is possible that a portion of the brine might be marketed as feedstock to PPG and other chemical industries. However, to date, no such willingness has been expressed by these companies. Therefore, for purposes of analysis it has been assumed that all of the brine will be injected. The present plan for brine disposal is to drill 4 deep subsurface injection wells southwest of the dome and to pump the waste brine into deep saline aquifers.

To withdraw the stored oil, displacement water from either the onsite 162-acre reservoir (see Figure 1.5) or the nearby Sabine River Diversion Canal** would be injected into the lower portion of the storage cavity at sufficient pressure to push the crude oil out of the cavities and then transfer pumps would deliver it through the pipeline to the distribution terminal. The oil would be distributed by tankers and inland pipelines, including the Texoma pipeline which originates at Sun Terminal, to local and regional refineries

1.3 SITE DEVELOPMENT AND CONSTRUCTION

1.3.1 Physical Facilities

The 3 caverns proposed to be converted for SPR storage are located on the western and southern edges of the large subsided area over the center of the dome (see Figure 1.5). The subsided area, caused by past sulfur extraction from the

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*Derived from preliminary engineering designs. Details may change as designs are finalized, so the maximum facility requirements are assumed.

**The Sabine River Diversion Canal was previously called the Houston River Canal and is sometimes referred to as the Industrial Water Canal.

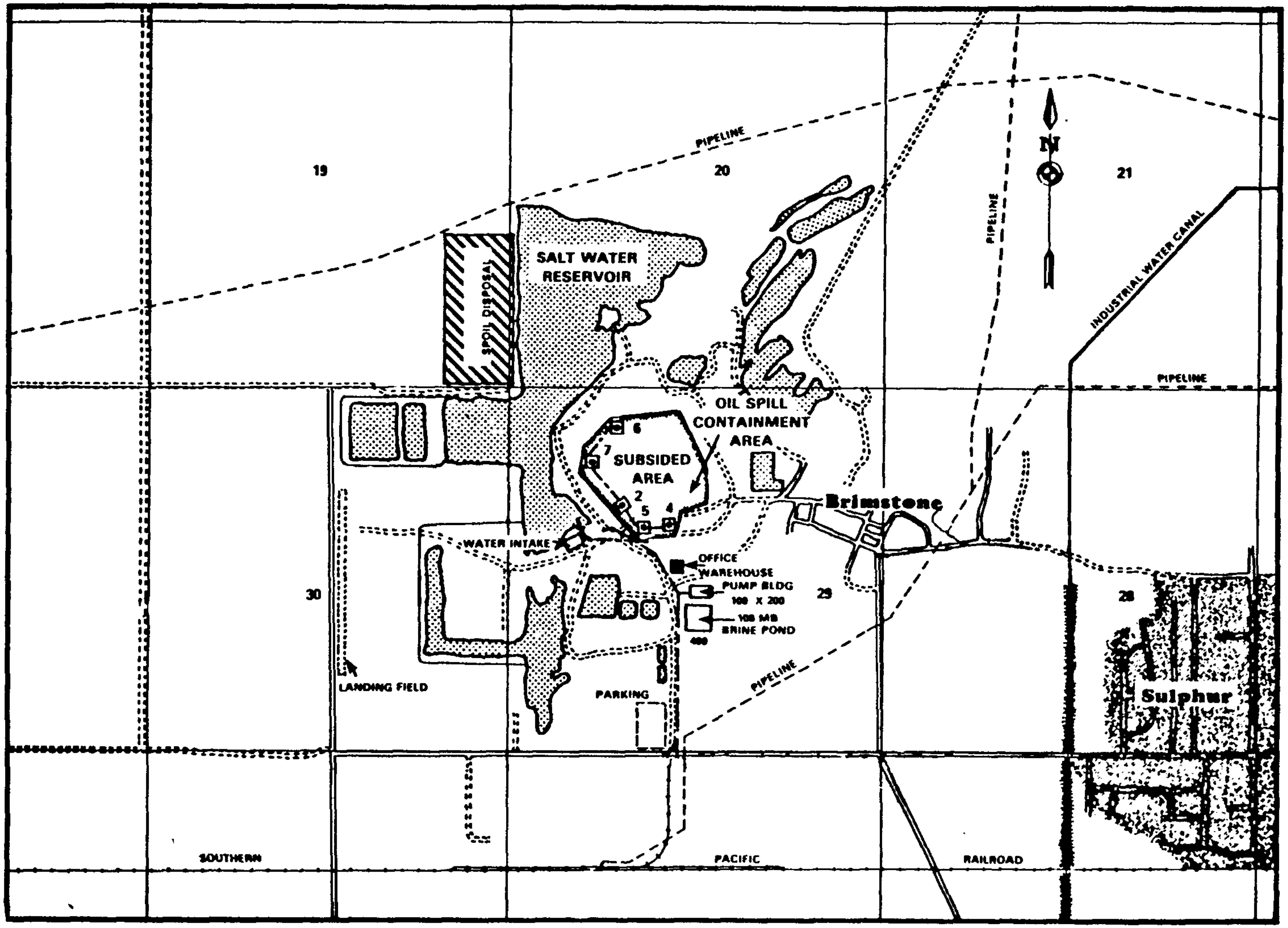


Figure 1.5 Proposed Site Development

dome's caprock, is about 40 acres in area and is currently kept drained of rain water by sump pumps. As presently planned, containment dikes would be constructed around the storage wells so that any accidental oil spill from the wellheads would be diverted into the subsided area which would act as a retention pond.

Central pumping facilities would be located south of the storage well area, near the site entrance road, just north of the brine pond location (see Figure 1.5). The injection of crude oil requires two 1000 hp centrifugal pumps, handling a total of 2,900 gpm. Another three 1,500 hp turbine pumps would be used to inject the displaced brine into subsurface disposal zones at the same 2,900 gpm rates. The injection of raw water during crude oil withdrawal operations will be accomplished by using the pumps also used for brine disposal. Oil delivery to the distribution terminal at a rate of 168,000 barrels/day (4,900 gpm) would be accomplished by the same 1000 hp crude injection pumps.

A 100,000 barrel surge pit (400 feet by 400 feet) would be located adjacent to the south side of the central pumping plant. It would be used as a brine holding pond for the displaced brine during oil fill operations, and for a raw water surge pond during oil withdrawal operations. The pond would provide temporary brine storage in event of a temporary brine injection system breakdown, and would permit any insolubles which could damage pumps or clog the disposal wells to settle out. A flow diagram showing the system interfaces is given in Figure 1.6.

Buildings and Other Structures

All oil handling pumps, brine injection pumps, and raw water injection pumps, would be housed in an open air shelter located adjacent to the brine holding pond (see Figure 1.5). The main office and warehouse building would be located in an area nearby. The office/warehouse would contain the business office, the maintenance and warehouse area, the central control room, laboratory, the supervisory control equipment, the communications equipment and the comfort and locker room facilities for the on-duty workers. In addition, a motor control center building would be constructed to contain the motor controls and switch gear for the main equipment area pumps.

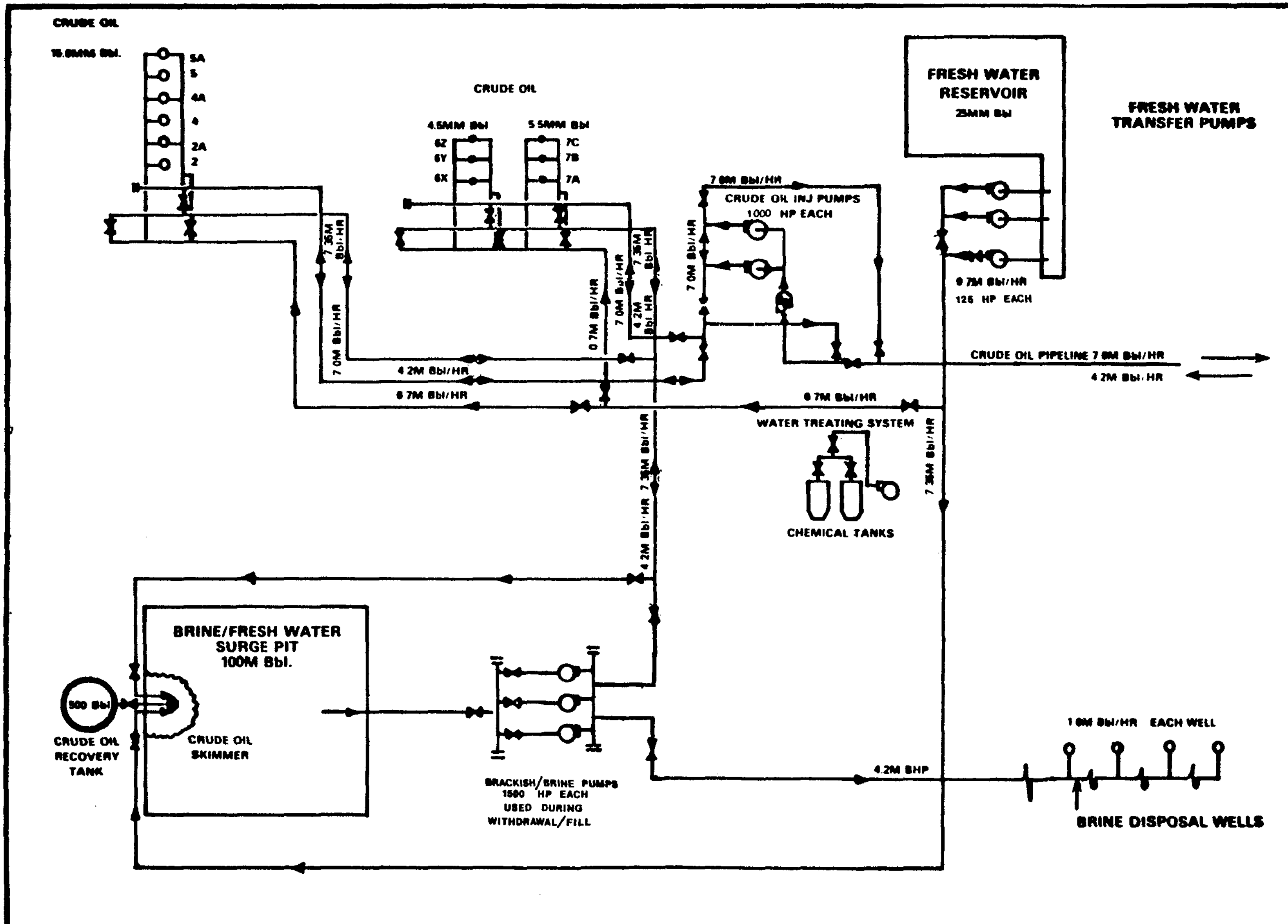


Figure 1.6 Sulphur Mines Flow Diagram

Brine Disposal

Brine which would be displaced during crude oil fill operations would have a salt concentration of approximately 265 ppt. It would be injected into subsurface saline aquifers off the southeast flanks of the salt dome. The salinity of these aquifers has been estimated to range from 35 to 44 ppt. The salt concentration at which salt would precipitate out of solution (called the saturation limit) has been estimated at 320 ppt for these aquifers. Therefore, the injection aquifers currently range from being 11 to 19 percent saturated. At the required oil injection rates, an average of 2,900 gpm of brine would be produced over the 240 day fill period. For purposes of impact assessment, it is assumed that this entire amount would be injected.

The disposal system which is presently planned would require four brine injection wells. Each well would accept an average of 730 gpm and a maximum disposal volume of 1000 gpm. The four disposal wells, which would be spaced at 1000 foot intervals, will be located south-west of the site along U.S. Highway 90.

The 12-inch brine disposal pipeline would run in a south-west direction from the storage site to the disposal wells. Its route would parallel the route of the oil distribution pipeline until reaching the eastern boundary of the disposal field with both pipelines sharing a common right-of-way. At that point the oil line would continue in a south-west direction and the brine pipeline would branch south for 700 feet to connect with the brine disposal area.

The joint brine disposal-oil distribution pipeline route would require clearing of a 75 foot wide right-of-way during construction and the maintenance of a 50 foot wide permanent right-of-way.

Most of the land which would be required for brine disposal system is wooded. Approximately 26.4 acres would be cleared for construction of the brine disposal pipeline, for injection well pads and for access roads into the brine injection area. Twenty acres would remain permanently cleared for inspection and maintenance of the brine disposal system. Land requirements for oil and brine pipeline routes are listed in Table 1.1.

Table 1.1 Land Requirements for Pipeline Routes

		BRINE DISPOSAL PROPOSED	OIL DISTRIBUTION*
EXIST. ROADS	M	0.1	0.1
	P	0.6	0.6
	C	0.9	0.9
DRY LAND	M	0.1	7.4
	P	0.6	44.4
	C	0.9	66.6
CULTIVATED	M		4.3
	P		25.8
	C		38.7
WOODED	M	2.0	2.3
	P	12.1	13.8
	C	18.2	20.7
MARSH	M		0.4
	P		2.4
	C		3.6
SPOIL BANKS	M		0.1
	P		0.6
	C		0.9
INLAND WATER	M		0.2
	P		1.2
	C		1.8
TOTAL	M	2.2 miles	14.6 miles
	P	13.2 acres	88.8 acres
	C	19.8 acres	133.2 acres

M - distance in miles
P - area required for permanent right-of-way in acres
C - area required for construction right-of-way in acres
* - the total length of the oil distribution pipeline would be 17 miles. However, the initial 2.2 miles of the oil distribution pipeline would utilize the same right-of-way which would be used for the brine disposal pipeline. Therefore, the acreage requirements for the right-of-way for this initial segment have not been included here.

Displacement Water Supply

The proposed source for raw water supplies for the Sulphur Mines facility is the onsite reservoir at the western edge of the salt dome. To replenish the reservoir during and after each displacement cycle, the site would also be connected by a 20 inch pipeline to the Sabine River Diversion Canal one mile north of the onsite reservoir. The canal will be a section of the Sabine River Diversion Project to bring fresh water to Lake Charles area industries. Water to replenish the reservoir would be available from the canal on a contract basis. Approximately 7,350 barrels per hour (5,145 gpm) of displacement water is required for crude oil withdrawal operations. Due to the increased cavern size resulting from the dissolution of salt by the fresh water pumped into the cavity and the relative compressibility of water, the raw water injection rate is about 5 percent greater than the rate of oil displacement (7,000 barrels per hour).

The present capacity of the onsite reservoir, which was created during sulfur mining operations, is 20 million barrels. In order to create a reservoir nearly sufficient to supply to 25.2 million barrels of water for one complete oil withdrawal cycle, the existing reservoir would be dredged out to a 25 million barrel capacity.

About one million cubic yards of bottom would be dredged from the southern portion of the lake. Conventional clam-bucket dredging would be the method used, and the spoil would be deposited on Allied property in the northwest corner of the onsite reservoir (see Figure 1.5). Spoil would be contained between an existing dike surrounding the reservoir and a second dike which would be constructed as a backup in such a way that runoff from the disposal area would be diverted back to the reservoir. Assuming a 10 foot depth, the spoil area would cover approximately 60 acres.

Crude Oil Distribution

The proposed facility is designed so that the oil may be withdrawn in 150 days or less. For a planned storage capacity of 24 million barrels, a delivery rate of 168,000 barrels per day (4,900 gpm) is planned. This would allow a 5 percent slack in withdrawal time to compensate for short operational delays.

The proposed method of crude oil supply and distribution for the Sulphur Mines site is to construct a new 20 inch spur pipeline between the Sulphur Mines sites and the West Hackberry-Sun Terminal pipeline. The spur pipeline would be 17 miles long and run in a south-south westerly direction from the Sulphur storage site (see Figure 1.7).

The ecologic setting of the oil distribution pipeline route is described in Section 2.4.1.2. Table 1.1 summarizes acreage requirements for the various land types which would be affected by pipeline construction. Major road and waterway crossings which the oil distribution route will make include: Southern Pacific Railway, U.S. Routes 90 and 10, Choupique Bayou, Wing Gully, Spring Gully and the Gulf Intracoastal Waterway.

The Sulphur Mines spur oil distribution pipeline would intersect the West Hackberry-Sun Terminal oil distribution pipeline near Goose Lake on the south side of the Gulf Intracoastal Waterway. The pipeline route supplement to the West Hackberry Final Environmental Impact Statement (FES 76/77-4) describes the West Hackberry oil distribution pipeline route and the Sun Terminal facilities. The distance from the intersection to the terminal is 34.4 miles and the length of the new connection would be 17 miles, for a total distance of 51.4 miles between Sulphur Mines and the Sun Distribution Terminal.

1.3.2 Land Requirements

Allied Chemical Corporation owns in fee all of the approximately 150 acres over the Sulphur Mines salt dome, plus most of the surrounding area totaling roughly 4,000 acres. DOE would acquire a simple fee tract of approximately 640 acres which would include the reservoir and the brine disposal field (see Figure 1.8). The SPR facilities would affect various portions around the dome vicinity (see Figure 1.5). The wells to be converted for storage are located on the southwest border of the 40 acre subsided area over the center of the dome. The subsided area would serve as a crude oil spill containment area for the storage wells. The area to be developed around the wells, including the subsided area, encompasses about 55 acres. The central pumping facilities and brine pond, requiring a 6 acre plot, are located several hundred feet south of the storage area. Offices and warehousing facilities would require 8 acres. The existing 162 acre water reservoir surrounding the western side of the dome would be used for a raw water

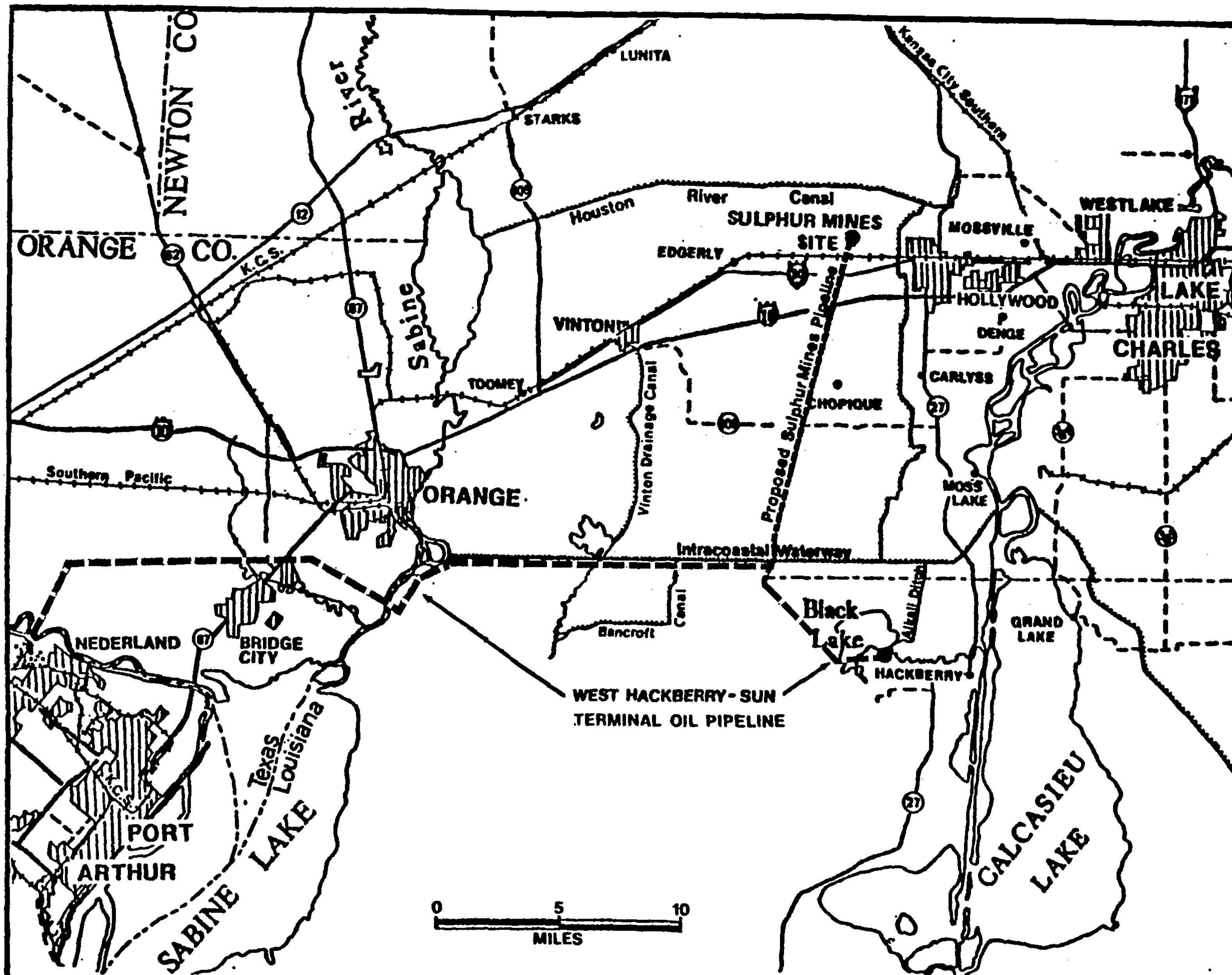


Figure 1.7 Crude Oil Distribution System, West Hackberry-Sulphur Mines Site

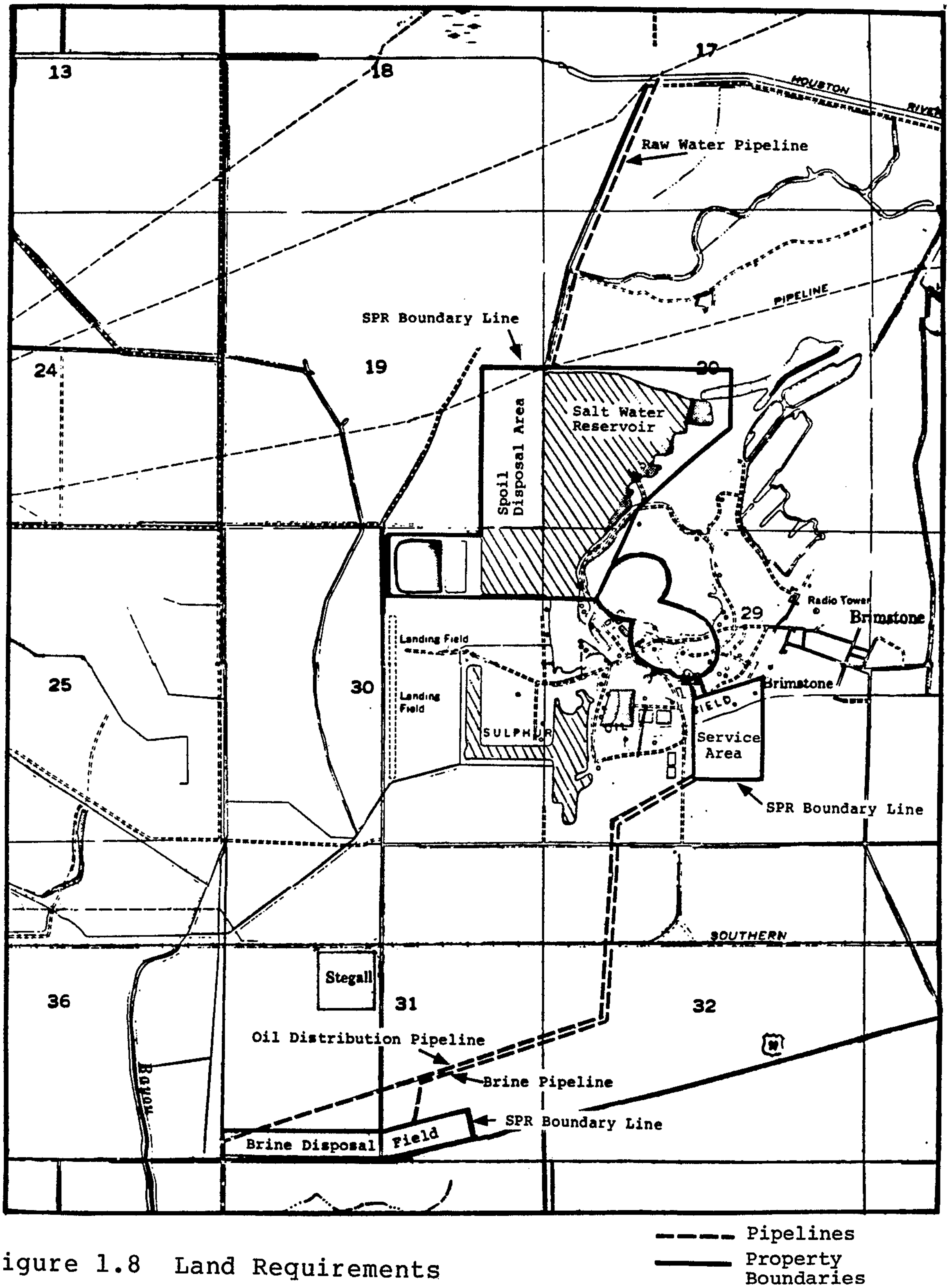


Figure 1.8 Land Requirements

supply during oil withdrawal. About 60 acres near the reservoir would be required for disposal of dredge spoil from deepening the lake. A pump station on the eastern edge of the reservoir would require 2 acres. The pipeline connecting the reservoir to the Sabine River Diversion Canal would be 0.95 miles long and would utilize a 50-foot right-of-way. Acreage requirements would be 5.8.

The maximum design for the brine disposal system requires approximately 11,700 feet of pipeline connections between the individual disposal wells. The pipeline would utilize a 50 foot permanent right-of-way, thus requiring an area of approximately 14 acres.

The distribution system would require additional properties. The 17 mile distribution pipeline to the West Hackberry distribution pipeline on the Intracoastal Waterway would utilize a 50 foot permanent right-of-way, thus requiring 103 acres.

In total, approximately 813 acres are needed for the project as planned.

1.3.3 Road Construction and Other Grading

There are existing roads to the various storage wells. About 0.25 miles of new roads would be constructed to provide access for drilling and servicing the brine disposal wells. These roadways would require a 40 to 50 foot right-of-way through primarily mixed pine forest in which the disposal system would be located. In addition, each disposal well site would require clearing an area approximately 200 feet by 200 feet for the construction and maintenance of the wells. About 2500 square feet of this area would be used as a drilling-mud pit during drilling operations, but would be restored after the wells are completed. The area is mainly firm dry land and would only require clearing, grading, and graveling for the road bed. A total of 8.8 acres would be disturbed for construction of roads and well plots.

A levee system is planned to enclose the storage well area and to divert runoff into the adjacent subsided area. This is a precaution against oil spills from a ruptured wellhead which may contaminate the local environment. The dikes would be approximately four to five feet in height. Dike enclosures are a standard engineering practice for compliance with the Spill Prevention Control and Countermeasure Plan (SPCC). Construction of the containment dikes at both locations would require moving an estimated 11,000 cubic yards of earth.

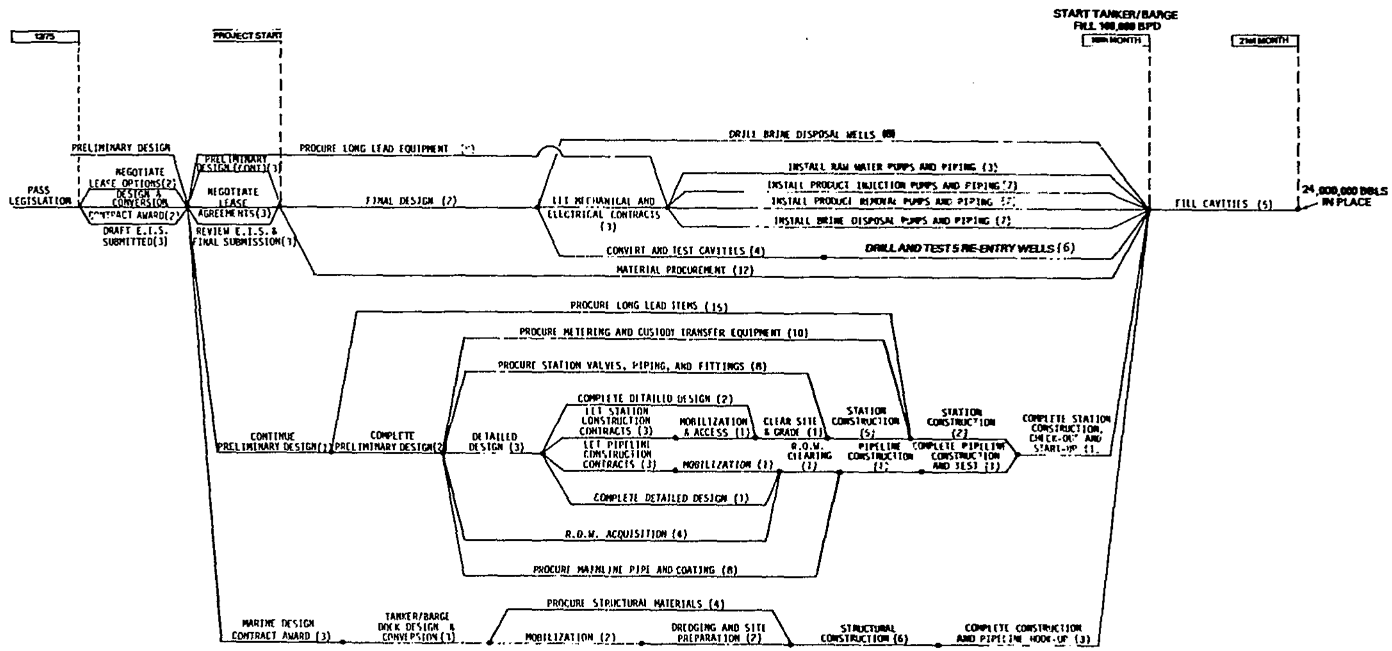
1.3.4 Pipeline Construction Techniques

The offsite pipelines would be constructed by the conventional dry land method, since the majority of the land is dry and capable of supporting heavy construction equipment. A permanent right-of-way width of approximately 50 feet would be cleared with an additional 25-foot right-of-way for the construction period. This additional construction right-of-way is necessary for maneuvering equipment, and stacking supplies and construction materials. Excavation equipment digs the pipe ditches. The pipe joints are then strung along the ditches and welded together, and the pipe is lowered into the ditch which is backfilled to the proper depth in accordance with 49 CFR Part 195.

The route lies mostly on dry ground; however, concrete weights or coating would be used in low areas or where the water table is high. Fusion bonded epoxy coating and impressed current cathodic protection would be applied over the entire length of the line.

1.3.5 Development Timetable

According to present plans, the proposed Sulphur Mines facility would begin the cavity filling operations 16 months into the development program (see Figure 1.9). The facility is designed so that the cavities could be filled in 9 months. The main physical plant construction, including cavity conversion, drilling of re-entry and brine disposal wells, and installation of pumps and piping, would occur over an eleven-month period.



Note: Numbers in ( )
designate months.

Figure 1.9 Preliminary Plan - Construction Diagram - Sulphur Mines
(Ultimate Storage 25,000,000 Barrels)

1.4 OPERATION AND MAINTENANCE

1.4.1 Operating Procedures

1.4.1.1 Storage Phase

The proposed facility at Sulphur Mines could have 24 million barrels of oil in storage by the end of the 21st month of the project (see Figure 1.9). In the event that the oil must be drawn while the facility is under construction, the system would be equipped with oil return bypass valves which allow intermittent recovery of stored oil. However, it is expected that there would be an interim period from the time of facility completion until a need arises for emergency distribution of the stored oil. During this interim period, the only activities at the site would be security and maintenance activities.

Security measures: Security measures planned for the facility are standard for petroleum storage facilities. The main storage site would be fenced and properly lighted. All electrical equipment would be housed in a security building. All pipelines would be monitored with pressure switches at each end of the line for early detection of leaks. The facility would maintain standard fire prevention systems and warning devices.

Equipment testing and maintenance: During the storage period, all equipment would be serviced and tested on a regular basis to ensure proper working order. Pumps, pressure valves, and safety equipment would be lubricated and operated at least once a month. Maintenance crews would be on duty on a 24-hour basis.

1.4.1.2 Extraction Phase

The SPR Program plans for an emergency delivery of stored oil over a 5-month period. The plan would require delivery rates for the 24 million barrel facility of 168,000 barrels per day or an average of 7000 barrels per hour.

Recovery process: Crude oil stored in each salt cavity would be recovered by pumping raw water into the bottom of the cavity, thus displacing the oil through the concentric tubing at the top of the cavity. The oil would leave each wellhead and transfer pumps would boost it to a pressure capable of transporting the oil via pipeline to the distribution facility.

Distribution: A 17 mile spur line would tie into the West Hackberry distribution line to the Sun Terminal in Nederland, Texas, a total of 51.4 miles away. From the terminal, the oil would be transported inland by the Texoma pipeline and to the East Coast and Caribbean markets by tankers.

1.4.1.3 Refill Phase

After an oil supply crisis has ended and provided that supplies are stabilized and new imports are sufficient for additional storage reserves, refill of the storage facility is planned. The rate of fill would depend on the availability of surplus imports.

Refill process: The refill process is the reverse of the recovery process. The crude oil would be injected into the top of the storage cavity, thus displacing the brine which would go to the disposal wells. The brine disposal systems and cavity injection system are sized to handle a refill rate equal to the initial fill rate, i.e., 100 thousand barrels per day (2,900 gpm) over a 240 day period.

Refill capacity: Although the cavern capacity enlarges during each cycle, only the original amount of oil designated for each cavity would be replaced in a subsequent refill. The fact that a smaller percentage of fresh displacement water would be introduced into the cavern during successive displacement cycles reduces the continued leaching process from about 101 percent enlargement to about 75 percent over five withdrawal cycles. Furthermore, due to casing limitations, total usage of the enlarged capacity would not allow as rapid total displacement during subsequent withdrawals.

1.4.2 Safety Procedures

The following is a list of normal safety and engineering practices for oil storage and oil handling facilities which will be followed at the Sulphur Mines storage site.

1.4.2.1 Protective Control Devices

All storage cavity wellheads would be equipped with (1) hydrocarbon detection devices to protect against overfill, (2) pneumatic gate valves on crude and brine wellhead openings with high-low pressure switches for remote control of safety valves, and (3) valve limit switches, signal devices, and alarms.

Pump control and protective devices would be installed on all major pumping equipment to monitor critical operating variables and to automatically shut down the affected equipment in the event that an unsafe operating condition develops.

Pump station emergency shutdown systems would be installed at all stations to allow the shutdown and isolation of the pumping station in the event of an emergency. Pipelines would have meter bases and pressure switches monitored and would be visually inspected as a precaution against leaks. Pressure relief valves would be installed on piping, equipment, and pressure vessels as needed to prevent these systems from exceeding safe limits.

1.4.2.2 Fire Protection

Pump stations and meter stations would be provided with portable fire extinguishers to be selected, installed, classified, and rated in accordance with applicable standards of the National Fire Protection Association. Two fire pumps (one diesel and one electric) would be located at the intake station on the water reservoir. Surface oil holding tanks at the distribution terminal would be equipped with standard foam fire prevention systems.

All buried portions of the pipelines would be externally coated with a fusion bonded epoxy coating and protected by impressed electrical currents. Sealed casings are required at highway or railway crossings, with insulators and spacers to electrically isolate the pipelines from the casing.

1.4.2.3 Protection from External Damage

All electrical equipment and control systems would be housed in buildings and elevated on fill where required for protection against flooding.

Protection of the pipelines from external damage would be provided by burying them and by marking their location. Additional weight and mechanical protection for those portions of the pipeline in areas of swamp or marsh, and at waterway crossings, would be provided by the external coating of wire-mesh reinforced concrete.

1.4.2.4 Protection of Local Surface Environment

Oil which normally leaks from pumps and valves in and around pumping stations, and oil that may be drained from the system during normal or emergency operations or maintenance, would be collected and piped into a central waste oil sump of 500 barrel capacity, complete with skimming boom, and oil/water separator, and drain system to return the treated water to the site lake and the oil to a slop tank. Waste oil collected in this manner would be returned periodically to the storage system or sold to local "slop oil" marketers.

The surface tanks would be enclosed in adequate retention dikes to protect the area environment from leakage of oil. An oil/water separator would also be used to clean accumulated rainwater. An SPCC Plan will be prepared and will comply with the code of Federal Regulations 40 CFR 112 (Oil Pollution Prevention; Non-Transportation Related Onshore and Offshore Facilities).

1.4.2.5 Security

The storage site access roadways would be equipped with security guards to prevent any interference with the facility by unauthorized persons. Security personnel would be on duty at all times. Pump stations would be fenced and/or housed in pump buildings. All fenced facilities would have warning signs posted conspicuously to warn the public of the nature of the facility.

2. DESCRIPTION OF THE ENVIRONMENT

2.1 LAND FEATURES AND USES

2.1.1 Evolution of Salt Domes

The Sulphur Mines salt dome is one of nearly 450 salt domes in the Gulf Coast region of the United States and Mexico. The salt in these domes was originally deposited in a broad shallow sea, probably during Jurassic time [135 to 190 million years ago, see Geologic Time Scale Appendix I (Glossary)]. Then the salt basin was buried to depths of 35,000 to 65,000 feet by Miocene shallow marine sediments (12-26 million years ago). In general the salt was deposited in horizontal beds; however, in many places the surface of the salt had topographically high areas. Since the mechanism of initiating salt dome growth is one of isostatic adjustment, these topographic highs began to first rise and eventually formed the nucleus of present day salt domes.[1] Salt begins to rise because the overlying sediment column has an average density that is greater than the density of the salt (2.164 gm/cm^3). The sediment overlying the topographic high has a lower density than the sediments overlying the salt on all sides of the high; consequently, the salt flows laterally and up toward the area of least resistance, namely the topographic high. In addition, any faults in the overlying sediment are zones of weakness through which the salt can rise. Approximately 4,000 feet of overburden is needed to exceed the density of the salt, and a sediment depth greater than that will initiate upward movement of salt[2] (see Figure 2.1). Growth of domes deforms the sediments above the salt as well as those that have been pierced. Sediments above the salt are subjected to tensional forces that produce normal faulting. As the domes rise through aquifers having water with a salinity low enough to dissolve the salt, dissolution occurs, leaving various insoluble residues, principally anhydrite, along with minor amounts of such minerals as dolomite, calcite, barite, pyrite, and quartz. Continued rise of the salt fractures the anhydrite caprock, increases water circulation and results in the chemical alteration of anhydrite to gypsum, and gypsum to sulphur and calcite.

2.1.2 Physiography

The Sulphur Mines salt dome lies within the Gulf Coastal Plain. This is an area of low topographic

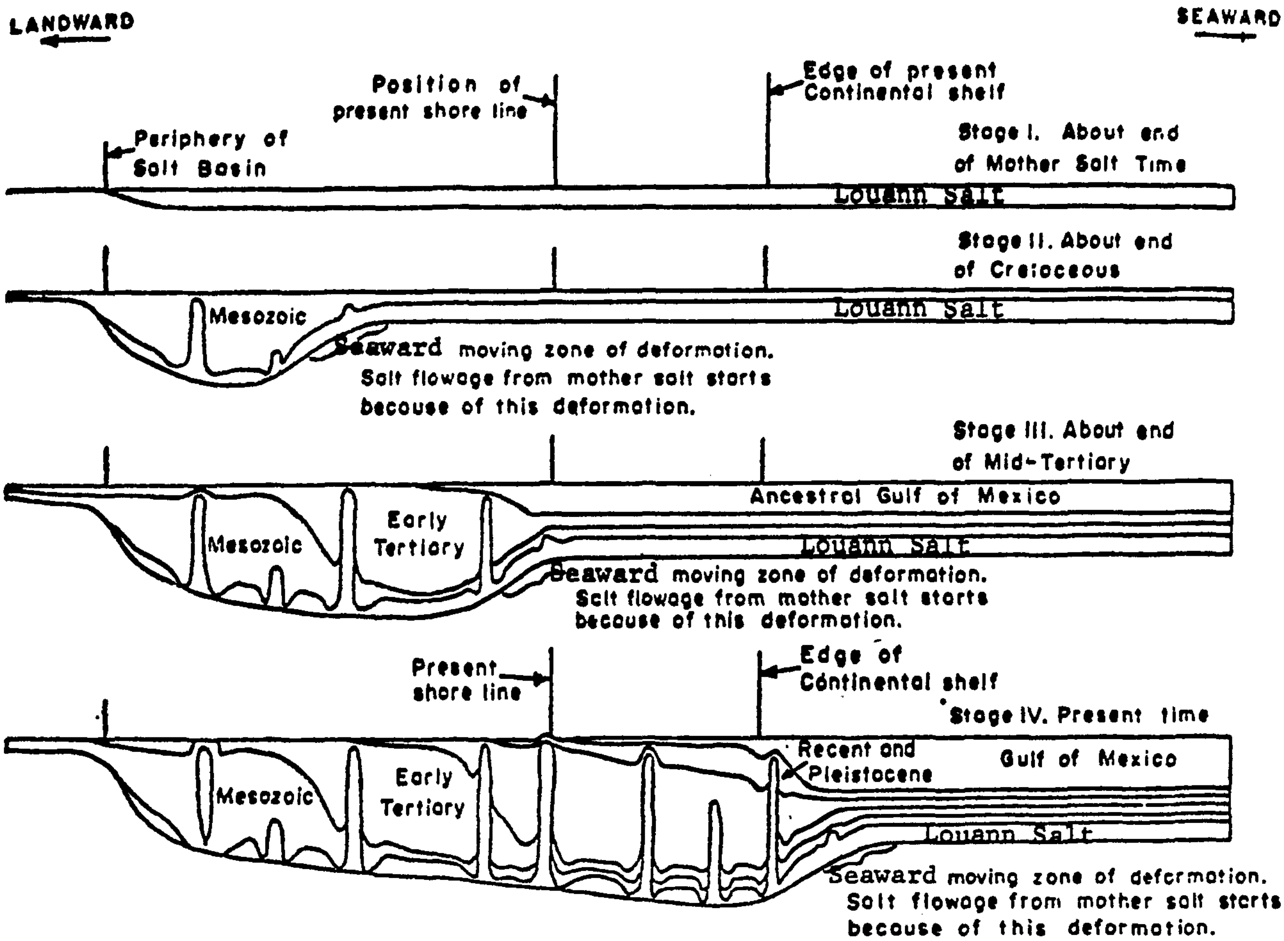


Figure 2.1 Idealized Sections Showing Development of the Gulf Coast Geosyncline and Growth of the Salt Domes.

Modified from: M.T. Halbouty, Salt Domes: Gulf Region, United States and Mexico, Gulf Publishing Company; Houston, Texas, 1967.

relief with elevations ranging from about 2 feet above sea level on the flood plains of the Sabine and Calcasieu Rivers to about 90 feet in the area northwest of the city of DeQuincy. North of the Houston River the terrain is hilly, with elevations ranging from about 20 to 90 feet. South of the Houston River the terrain is a flat plain with elevations ranging from 25 feet near the river to 2 feet in the coastal marsh.

Meander scars, representing courses of ancestral streams, and pimple mounds are present on the Pleistocene surface throughout Calcasieu Parish. The pimple mounds are low, circular or elliptical hummocks, generally 30 to 50 feet in diameter and about 1 to 5 feet high.

The flood plains are usually swampy in comparison to the surrounding uplands so that plant growth on the flood plains is quite different from that on the better drained Pleistocene surfaces. The flood plains generally support growth of oak, gum, and magnolia trees, and dense undergrowth, whereas the Pleistocene surface which is not under cultivation supports grassland and pine trees. In the vicinity of the Sulphur Mines dome, the land has been cleared as a result of petroleum, natural gas, sulfur, and salt extraction.

The elevation of the surface over the dome ranges from about 12 feet to 18 feet above sea level. Subsidence has occurred in a 40 acre area over the center of the dome at Sulphur Mines. This subsidence is attributed to the removal of sulfur from the caprock of the dome. An attempt was made to inject mud into the voids created during the sulfur mining operations. The dredging of the mud resulted in the formation of the ponds on 3 sides of the dome (north, west, and south). The total area of these ponds is about 252 acres (see Figure 2.2).

2.1.3 Regional Geology

The Sulphur Mines salt dome lies within the Gulf Coast geosyncline. Within 3,000 feet of the dome center there is about 7,000 feet of poorly consolidated Miocene and younger sands and shales. The dome is located north of the east-west tending axis of the Gulf Coast geosyncline which is approximately parallel to the Louisiana coastline. During subsidence of the geosyncline throughout Cenozoic time, thick wedge-shaped deposits of clay, silt, sand, and gravel were laid down. These deposits reached their greatest thickness (about

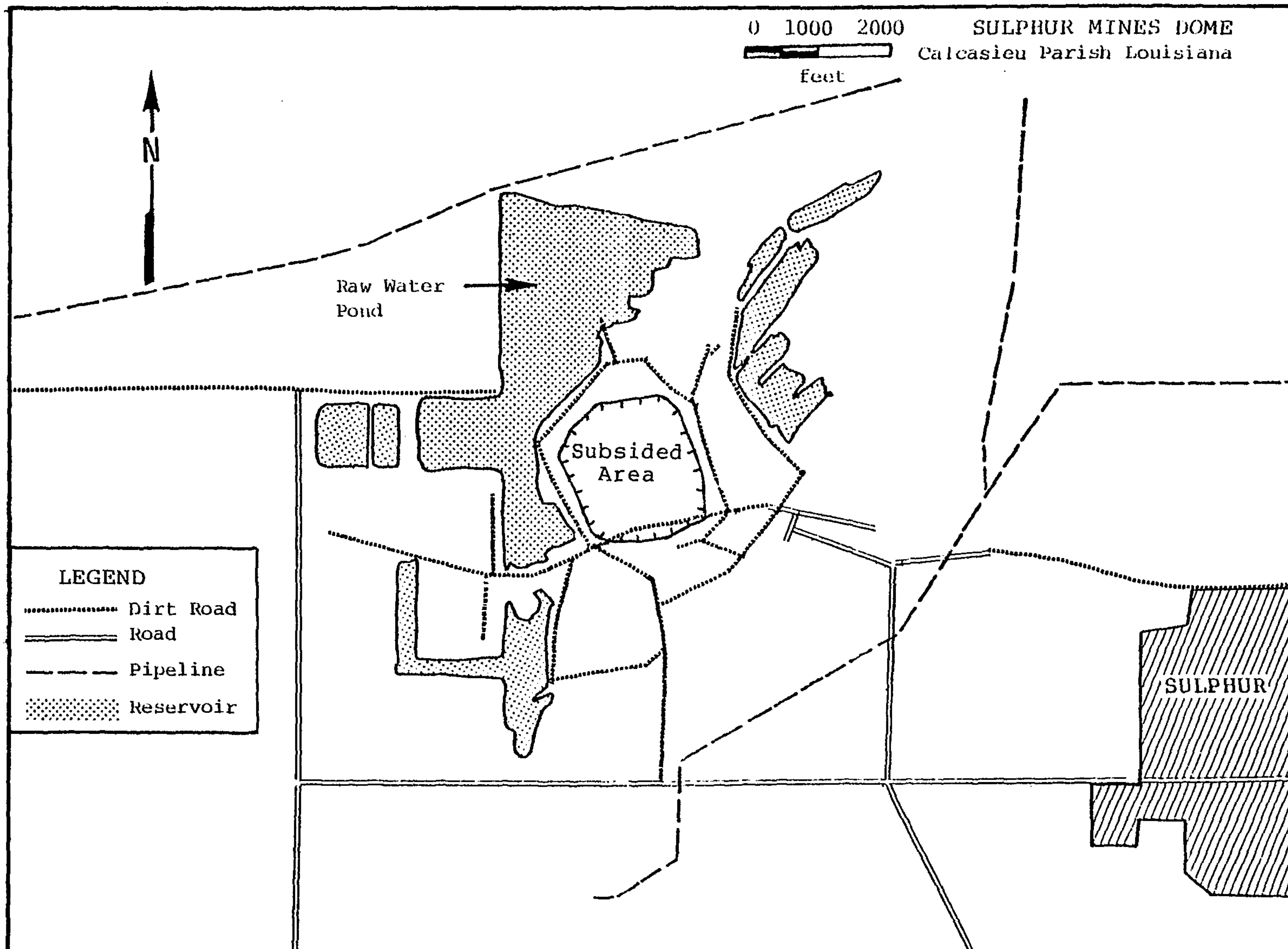


Figure 2.2 Surface Features - Sulphur Mines Dome

65,000 feet) along the geosyncline axis. The monoclinal strata of the geosyncline, through which the salt is rising, dip in a southeasterly direction. The Miocene sediments are faulted by normal faults that strike northeast and are downthrown to the south. Regional faulting of sedimentary rocks as young as Pleistocene has occurred in the vicinity of the Houston River; and local deep-seated faults are commonly found during exploration for oil. The dominant direction (strike) of these normal faults is east to northeast. The faulting mechanism is largely related to sediment compaction and basin subsidence that is occurring toward the south, and to local penetration of salt plugs into overlying strata.

Recently, seismic activity in the Gulf Coast region has been very low. The National Oceanic and Atmospheric Administration (NOAA) has classified the United States into 4 zones with differing degrees of expected seismic risk. These subdivisions are based upon the recorded history of past seismic activity. Zone 0 covers areas having no reasonable expectancy of surface earthquake damage; Zone 1, expected minor damage; Zone 2, expected moderate damage; and Zone 3, possible major destructive earthquakes.

The Sulphur Mines dome project area lies within the boundary of seismic risk Zone 1. However, in order to acquire more specific information, an earthquake data search was requested from the NOAA seismic information service. This NOAA office has catalogued the records of all known tremors occurring since the mid 1800s. The data search was requested to cover the rectangle from 28°55' north to 30°19' north, and from 90°10' west to 95°45' west. The results of the search indicated that only one earthquake was reported in this area. It occurred on October 19, 1930 at an epicenter approximately 4 miles southeast of Donaldsonville, which is 140 miles east of Sulphur Mines. A Richter magnitude was not recorded but the intensity was recorded as VI on the modified Mercalli scale at Donaldsonville. The modified Mercalli scale appears in Appendix F.

2.1.4 Local Geology

The Sulphur Mines salt dome is circular in plan (top) view and in profile it is flat topped and steep-sided. The dome is a piercement structure that is located within the Texas-Louisiana coastal salt dome belt. Because this dome has been extensively explored and drilled for sulfur, salt, and petroleum, the geologic structure, stratigraphy, and dome configuration are well documented.

Sulphur Mines is a comparatively small salt dome whose diameter at the 2,000 foot depth contour is approximately 1/3 to 1/2 mile. Partially consolidated silt, clay, sand, and gravel of Pliocene, Pleistocene, and Recent age with an aggregate thickness of 350 to 400 feet overlie the dome. Local stratigraphy suggests that during Pleistocene deposition the older sediments above the dome were elevated above mean terrain resulting in deposits 100 to 300 feet thicker around the periphery of the dome than over the top. Immediately adjacent and peripheral to the dome, these sediments have been dragged upward by the rising salt plug (see Figure 2.3).

<u>Caprock</u>

The Sulphur Mines salt dome has an unusually thick caprock (see Figure 2.3). It averages about 1,100 feet in thickness; the bottom 900 feet, which is in contact with the salt plug, is nearly pure anhydrite ($CaSO_4$). Above that, sulfur occurs in a zone of brecciated dolomite, calcite, gypsum, anhydrite and limestone 100 to 120 feet thick. Above the sulfur-bearing zone there is an oil saturated zone 100 to 150 feet thick which consists of brecciated to vuggy limestone with secondary filling by veins and blebs of calcite together with some arenaceous and dolomitic limestone.

The sulfur deposits scattered throughout the upper layers of caprock are the result of bacterial separation of free sulfur from sulphates. The residual is calcium carbonate ("limestone"). The sulfur is finely disseminated in the voids and fractures of the caprock.

A geological cross-section A-A' (Figure 2.3), constructed using electric logs, shows the local sedimentary sequences and their relationship to the piercement salt rock.

The caprock is intensely fractured, faulted, and brecciated as a result of the compressive forces exerted by the rising salt stock. The permeability and water circulation in the caprock is increased by the fracturing. The increased circulation, if it extends to the salt/caprock interface and

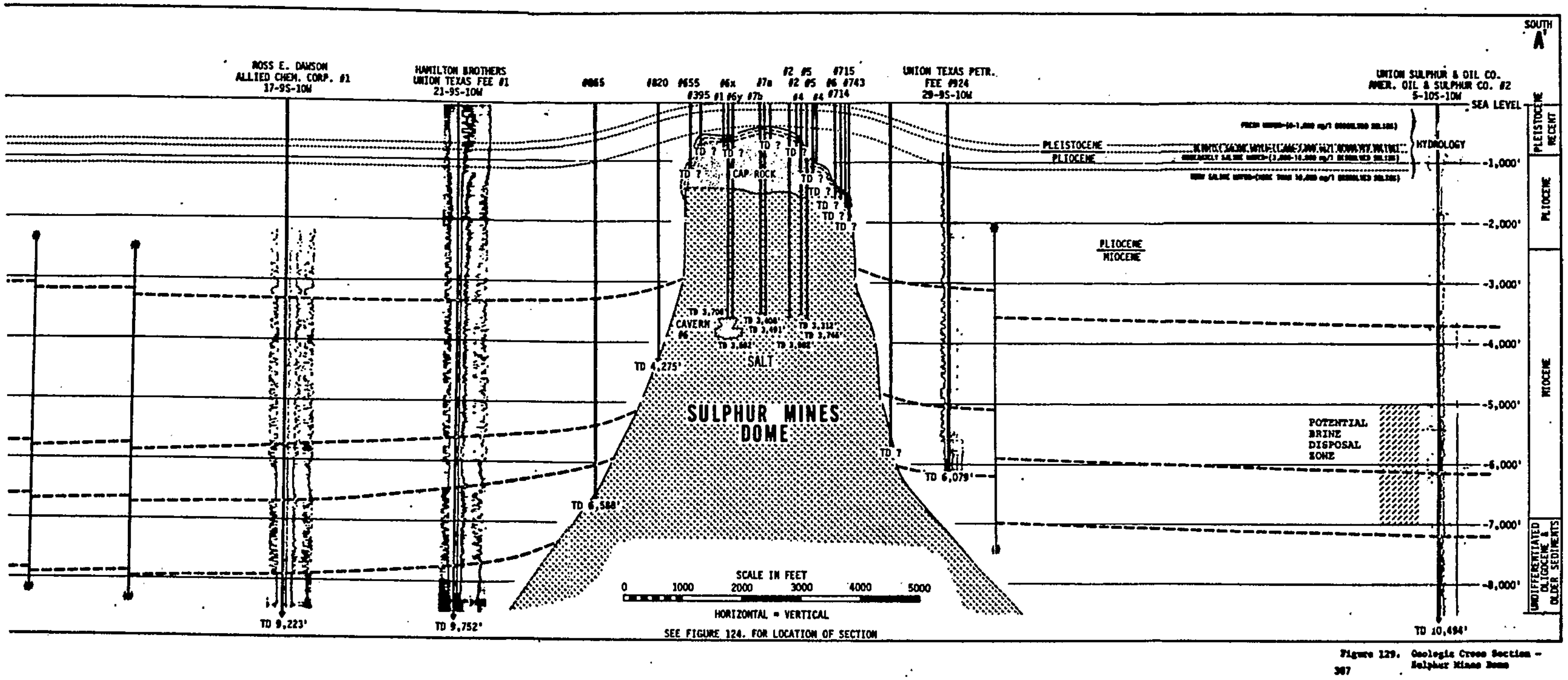


Figure 2.3 Geologic Cross-Section of Sulphur Mines Showing Four Electric Well Logs and Various Exploratory Wells Drilled into and Around the Salt Dome

if the water is not salt saturated, would result in dissolution of salt and formation of new caprock from the insoluble residues.

Removal of sulfur from the caprock leaves many small voids which can collapse. This collapse, if the total void space is large, may result in subsidence which can damage surface facilities such as roads, pipelines, pumping equipment, storage tanks, and ponds.

Salt

A subsurface map (Figure 2.4) contoured on the top surface of the salt stock, and the geologic cross-section A-A' (see Figure 2.3) show the shape of the salt mass as indicated by data from approximately 70 drill holes reported to have intersected and terminated in salt. It is a sharp, piercement structure whose symmetrical shape is nearly circular in plan. The top of the salt plug is almost flat and located at a depth of about 1,460 feet below sea level. The sides of the dome are in contact with the enclosing sediments which dip 75° to 80° away from the stock.

The composition of the salt varies throughout the dome. In general, however, finely bedded and disseminated anhydrite is present in amounts of perhaps 3 to 7 percent; other insoluble minerals comprise less than one percent of the volume of the dome. Blocks of sandstone and shale through which the piercement structure has passed may be imbedded in the outer margins of the salt.

2.1.5 Soils

There are two general soil associations at Sulphur Mines, the Wrightsville-Acadia Association and the Morey-Beaumont Association.

The USDA Soil Conservation Service describes the Wrightsville-Acadia Association as

> "...an area of level to very gently sloping soils on low ridges and broad flats mostly in the central part of the parish. This area is dissected by numerous small drainageways. These soils are used for cultivated crops, pasture and woodland. The poorly drained Wrightsville soils

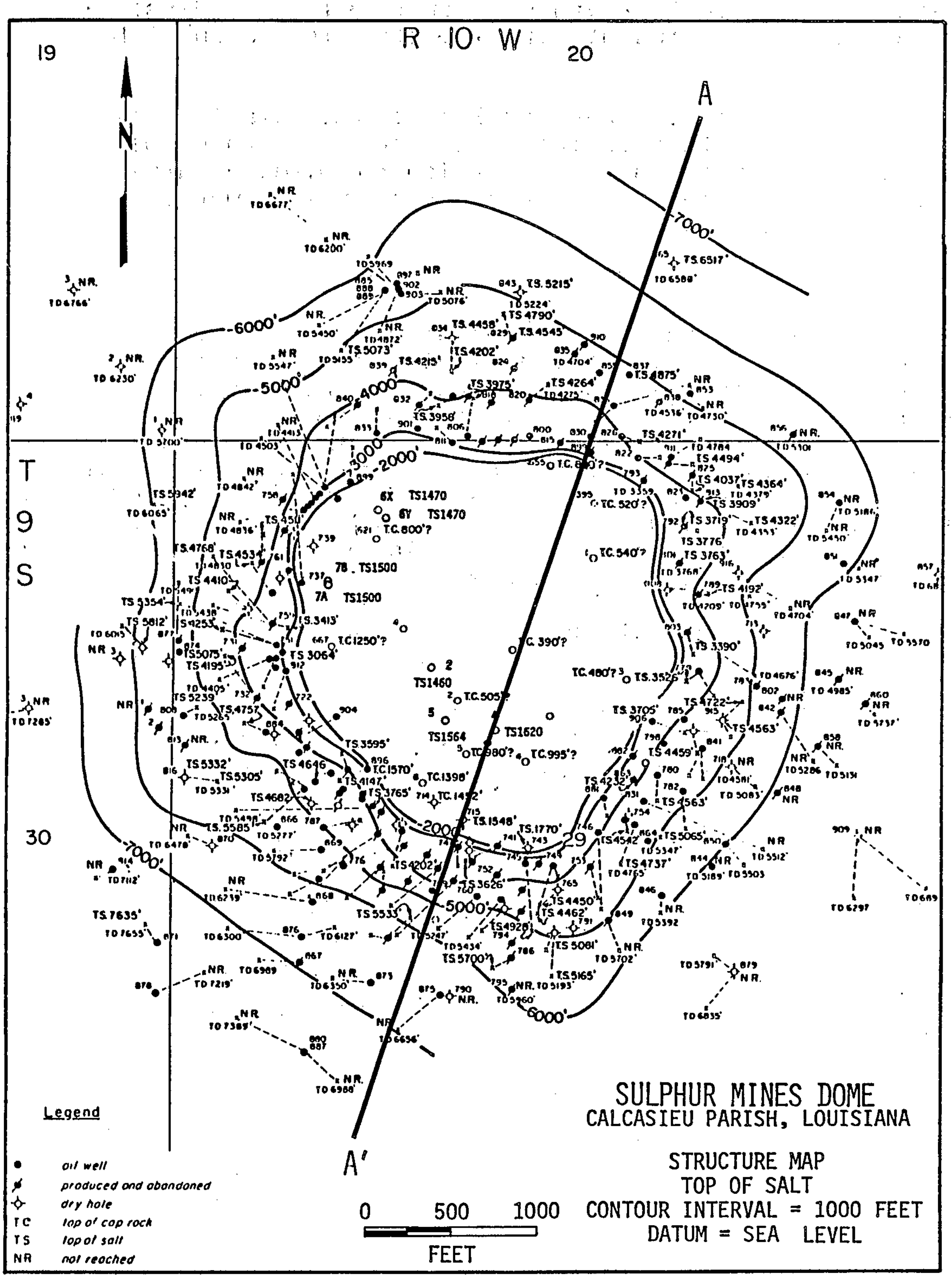


Figure 2.4 Structure Map - Top of Salt - Sulphur Mines Dome

on the broad flats and depressed areas make up about 55 percent of the association. They have a gray silt loam surface and a gray silty clay subsoil mottled with brown or red. The somewhat poorly drained Acadia soils on the low nearly level to gently sloping ridges make up about 25 percent of the association. They have a grayish-brown silt loam surface and a brownish-yellow silty clay loam upper subsoil mottled with gray and red and a gray clay lower subsoil mottled with red and brown. Gore, Caddo, and Beauregard soils and soils in small drainageways make up most of the remaining 20 percent of the association."

The Morey-Beaumont Association is described as

"...an area of level to depressed, poorly drained soils on broad flats mostly in the southwestern and southeastern part of the parish. These soils are used mostly for cultivated crops and pasture. The Morey soils on the broad flats and depressed areas make up about 70 percent of the association. They have a very dark gray or black silt loam or silty clay loam surface and a gray silty clay loam subsoil mottled with yellowish-brown. The Beaumont soils on the flats and depressed areas make up about 15 percent of the association. They have a very dark gray or black silty clay loam or clay surface and a gray silty clay or clay subsoil mottled with yellowish-brown. Mowata soils make up most of the remaining 15 percent of the association."

2.1.6 Land Use

The land use in the vicinity of the Sulphur Mines dome is devoted entirely to oil and gas production, and brining operations. Sulfur mining was a major activity here until 1924; very little sulfur has been mined since. There are no agricultural uses of the land and the nearest residences are 2 miles away in the city of Sulphur.

Oil and Gas Production

Oil was first produced from Union Sulphur Company's Fee No. 719 well. It appears that production has been uniformly distributed around the rim of the salt dome. However, the greatest density of drilling is on the western and southern flanks of the dome. Interpretation of the salt structure map and geologic cross-sections suggests that oil and gas occur on the flanks of the dome in Miocene or later sediments that are faulted or pinched out against the sides of the dome.

Although some minor oil deposits are known to occur in the limestone portion of the caprock, no wells are producing over the top of the dome in the area proposed for the storage facility.

Sulfur Production

The technology of sulfur mining using the Frasch process was developed at Sulphur Mines. The Louisiana Petroleum and Coal Oil Company was formed to drill for oil on the Sulphur Mines dome in 1867; and although this drilling failed to find commercially significant amounts of oil, a large deposit of native sulfur was discovered in the caprock at a depth of 650 feet. Many attempts were made in the next 30 years to mine the sulfur using conventional shaft-sinking techniques, but they were all doomed to failure due to uncontrollable encroachment of water, quicksand or lethal hydrogen sulfide gas.

During the 1890s, Herman Frasch, a petroleum research chemist, developed an approach to mine this type of sulfur deposit. He injected hot water into a well bore, melted the sulfur and forced the liquid sulfur up the borehole to the surface. With improvements to this process over a number of years, the United States replaced Italy as the world's leading sulfur producer by 1912.

Sulfur mining was conducted at Sulphur Mines dome until 1924 and resulted in a cumulative production of approximately 9,400,000 tons or 153,500,000 cubic feet of sulfur. There have been occasional attempts to resume sulfur production at Sulphur Mines dome, but the resulting low yields have not made the operation profitable.

After the sulfur has been melted and evacuated from the host formation, the voids can collapse. Underground collapse is sometimes manifested in surface subsidence over the dome. This subsidence can create surface problems related to pipelines, roadways, surface equipment, and drainage. Subsidence of as much as 10 feet in places has occurred in a 40 acre area within the 100 acre area of sulfur mining. The likelihood of further collapse has been greatly reduced by injecting mud into the voids left by sulfur removal. The mud was dredged from the ponds on the north, west and south sides of the dome.

Storage Caverns

There are six solution-mined cavities in the Sulphur Mines dome. Figure 2.5 shows the location of all eight wellheads associated with those cavities. Three of those caverns are currently being used for the storage of ethylene (Numbers 1, 3, and PPG). Sonar-caliper surveys for those three caverns are not available nor is the storage capacity available to DOE for those three caverns. The remaining 3 caverns at Sulphur Mines have been used for brine production. Two of those caverns, Number 6 and 7 are available for the storage of petroleum products. Wells 2,4, and 5 enter the three-cavern gallery which is located on the southern flank of the Sulphur Mines dome and covers a surface area of about 15.5 acres. The 3 wells in this gallery were completed in 1946, 1949, and 1953, respectively, and have been leached to a total estimated volume of 15 million barrels. From sonar profiles conducted at wells 2, 4, and 5 in September 1977, it is determined that the three caverns have coalesced. This 3 cavern gallery has been successfully pressure tested in September of 1977. Figure 2.6 is a profile of Caverns Numbers 6 and 7 as obtained by the sonar-caliper technique. This diagram also shows the relative position of the 2 caverns. At the nearest point, caverns 6 and 7 are separated by about 150 feet. Figures 2.7 and 2.8 illustrates the relative position of caverns 2,4,5. This is the best two dimensional representation of complex three dimensional cavern configurations and areas of coalescence in several planes. Dotted lines indicate corridors through which these caverns have coalesced. The descrepancy between reflecting surfaces recorded by the caliper from two different wells is a function of the 5^{o} increments of the vertical scan and the fact that the cross-section plane is not exactly in the plane of one of the 8 profiles recorded for each cavern. For example the location of a reflecting surface on a near horizontal roof of a coalescence corridor would be significant depending on relative depth of the caliper and the angle of the vertical scan.

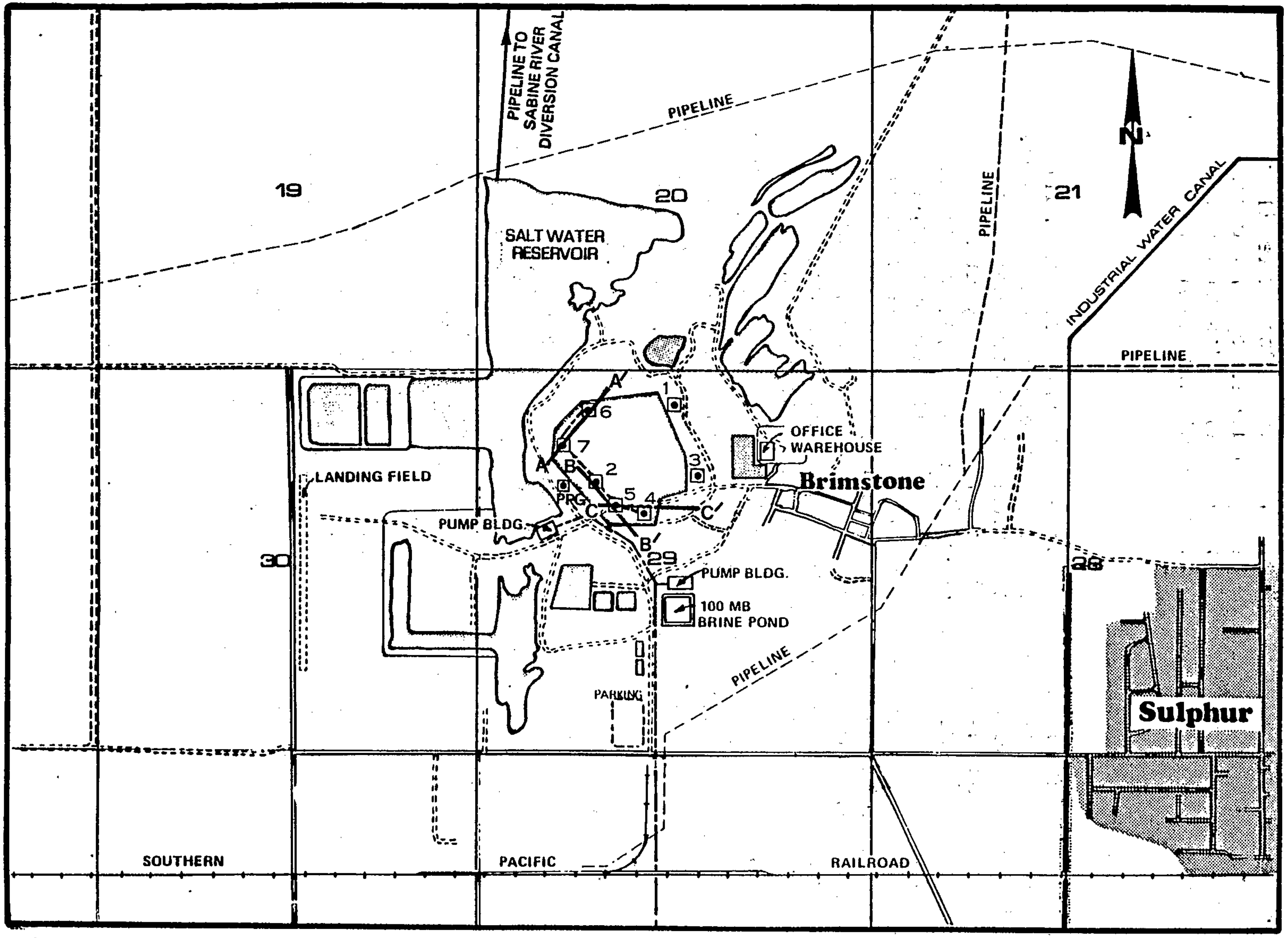


Figure 2.5 Sulphur Mines site map showing the location of well heads associated with cavities in the salt. Ethylene storage wells (1, 3, and PPG) are indicated on the eastern edge of the dome. See Figures 2.7 and 2.8 for geologic cross-sections (A to A') through caverns 6 and 7, (B to B') through caverns 2 and 5, and (C to C') through caverns 4 and 5.

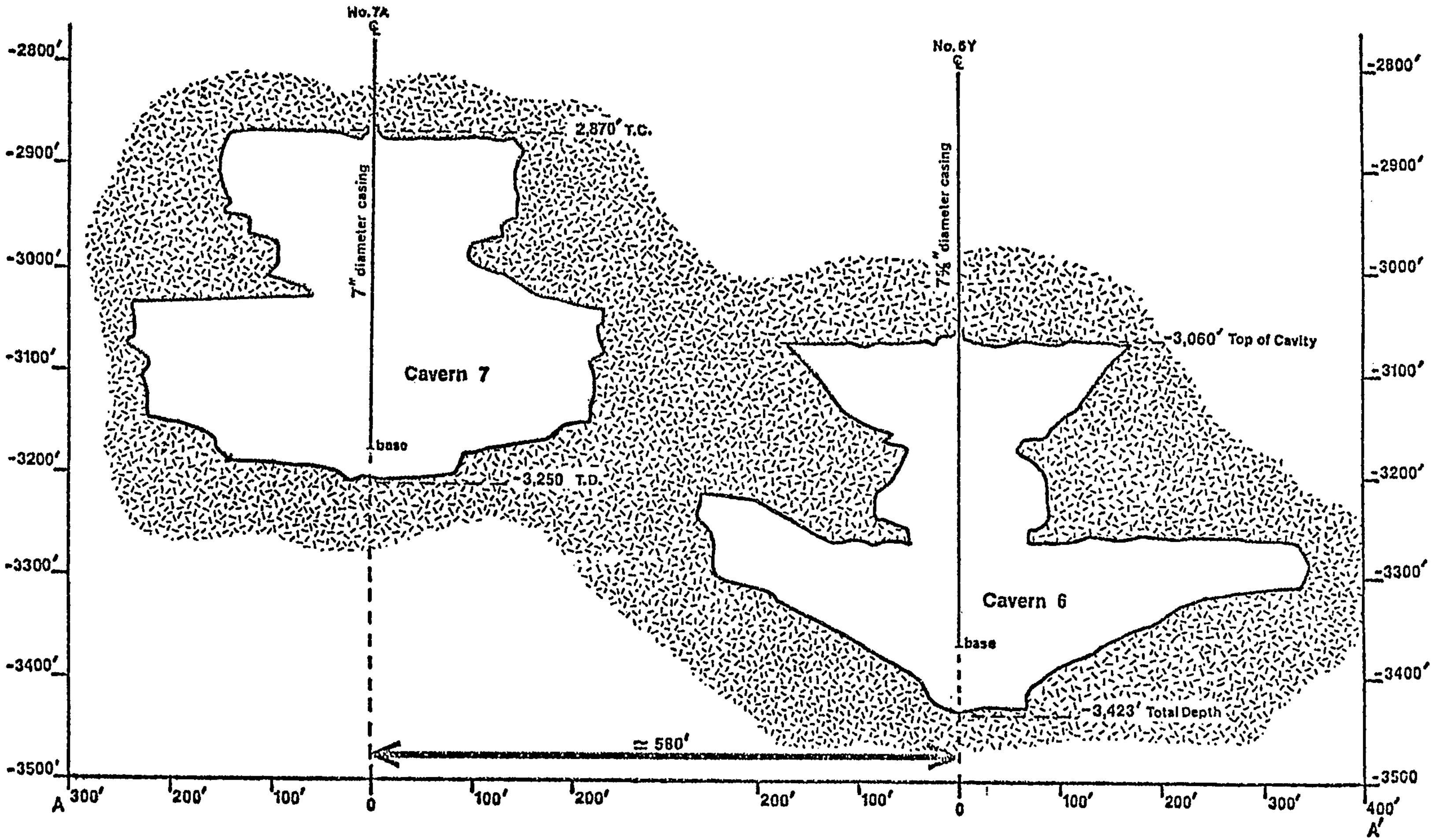


Figure 2.6 Cross-section of Cavities Number 6 and 7 Showing Their Relative Size and Proximity. Sonar caliper surveys were conducted at caverns 6 and 7 on October 15, 1975, and on October 14, 1975, respectively. (Well strings are assumed to be vertical.)

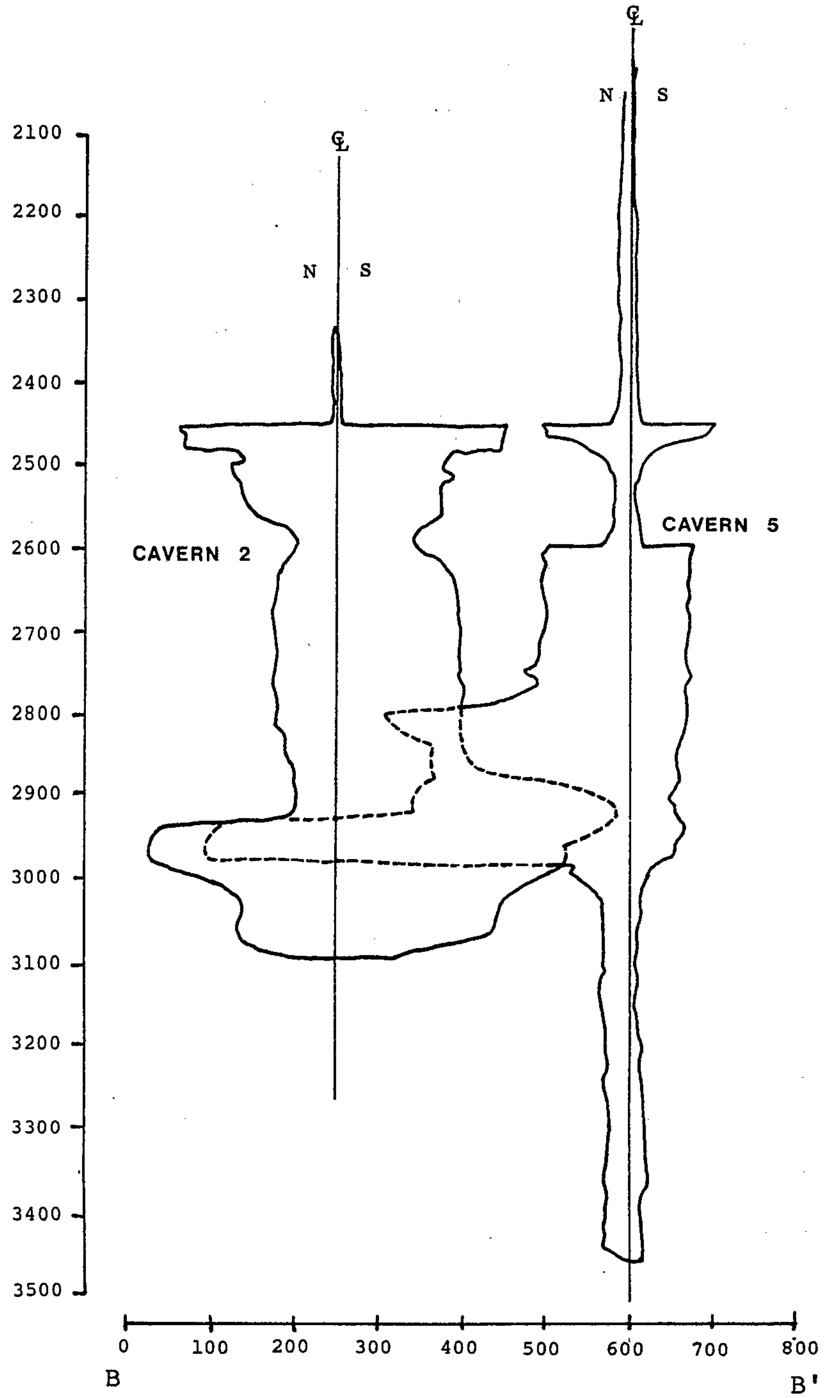


Figure 2.7 Cross-section of caverns number 2 and 5 showing their relative size and proximity. Sonar caliper surveys were conducted at caverns 2 and 5 on September 8, 1977 and on September 2, 1977, respectively. This is the best representation in two dimensions. Dotted lines indicate areas of coalescence.

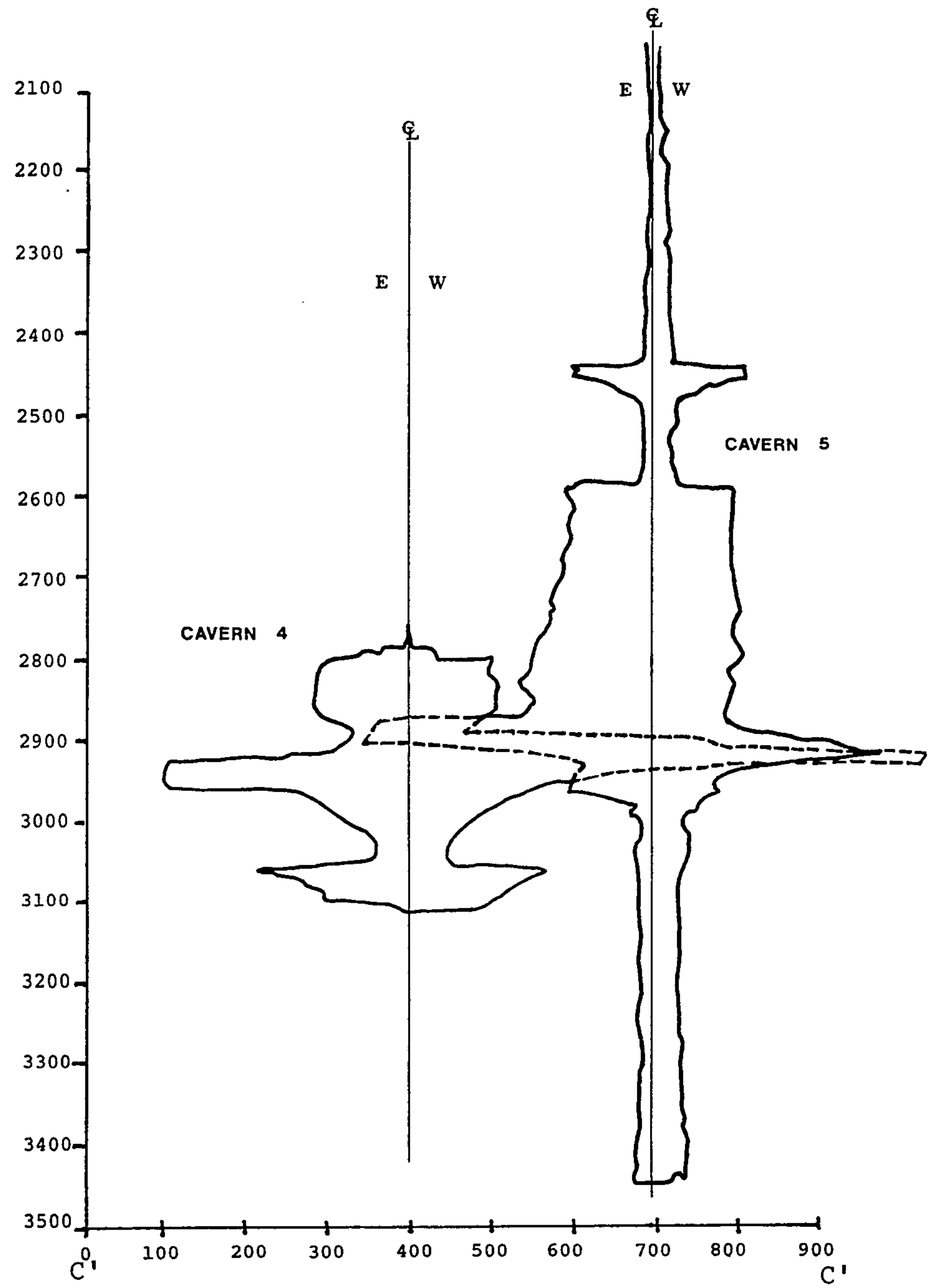


Figure 2.8 Cross-section of caverns number 4 and 5 showing their relative size and proximity. Sonar caliper surveys were conducted at caverns 4 and 5 on August 30, 1977 and September 2, 1977, respectively. This is the best representation in two dimensions. Dotted lines indicate areas of coalescence.

2.2. WATER ENVIRONMENT

The Sulphur Mines salt dome is located in approximately the center of Calcasieu Parish, southwestern Louisiana, on the periphery of the Calcasieu River basin. Surface water in the area is generally fresh although salt water intrusion has been encountered in the Calcasieu River to the east and the Sabine River to the west. Undisturbed inland streams throughout southwestern Louisiana typically are soft, have a pH of about 7, and contain less than 100 ppm of dissolved solids. They are low in calcium and magnesium bicarbonates, sodium chloride, sulfates, and, reputedly, suspended sediments. Silica is generally below 25 ppm but may be one-fourth to one-half of total dissolved solids.[3] Annual precipitation is on the order of 55 inches.[4] The region generally experiences a winter-spring precipitation surplus* of approximately 16 inches.[5] In spite of the apparent abundance of rainfall, during certain months of the growing season, which extends from February through November, there is a moisture shortage for vegetation. This precipitation deficit** amounts to approximately 6-7 inches per year.[6] Detailed precipitation charts for the region are provided in Appendix D.1.

The surface water system represents the primary source of displacement water. The shallow aquifers represent an alternate source of displacement water while the deeper aquifers represent the primary site for brine disposal.

2.2.1 Surface Water System

Surface bodies of water in the immediate vicinity include: (1) a number of reservoirs and ponds dredged at the mine site, (2) marshes in the vicinity of the dome, (3) seasonal water standing in terraced rice fields and drainage ditches, (4) Bayou Choupique and Bayou D'Inde, and (5) an extensive canal system. In addition to these surface water bodies, the Sabine River to the west of the site, the Houston River to the north, and the Intracoastal Waterway

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*Precipitation surplus represents the "extra" precipitation which is not utilized for evapotranspiration or soil moisture recharge; the surplus, therefore, represents water available for ground water recharge or surface runoff.[6]

**The deficit is defined as the difference between actual and potential evapotranspiration; it represents an index of moisture shortage for vegetation.[6]

to the south, must be considered. The general arrangement of the surface water system is shown in Figures 2.9 and 2.10.

2.2.1.1 Local Ponds and Reservoirs

In the immediate vicinity of the Sulphur Mines site there are several man-made ponds or reservoirs. The location of these bodies of water is indicated in Figure 2.11, and some of their characteristics are included in Appendix D.3. The primary source of displacement water would be the South Sector of Salt Water Reservoir, also known as Reservoir No. 3. The entire Salt Water Reservoir has a volume of 4,244,000 cubic yards. In the past it has been periodically used as a dilution reservoir for brackish water from Frasch process sulfur mining. The reservoir was used in this manner most recently during the period from approximately 1966 to 1970[7] when sulfur extraction was resumed on a small scale, after many years of no mining. As authorized by a state permit, waste water was discharged from those operations into Bayou D'Inde via a drainage ditch after reservoir spray aeration for hydrogen sulfide removal.[7] An average of 200,000 gallons of water a day was released once the salty water was sufficiently diluted.[7] The reservoir has also been used in the past as a dilution pond for waste water from oil production operations. The reservoir presently has a slight crust of long dried-up, hardened oil along its edge.[8] Contrary to its name, the reservoir currently appears to be fresh or nearly fresh water with higher life forms present.[9] No water quality data are available for the reservoir.

The other ponds and reservoirs in the area have nearly always contained fresh water. The only exception appears to be the Waste Oil Residue Pit. This pit, however, has been out of service for a number of years and currently retains rainwater to a shallow depth. No water quality data are available for any of these bodies of water. Several of the shallow ponds/reservoirs, including No. 15 (Freshwater Reservoir), No. 16 (Waste Oil Residue Pit) and No. 17 (North Tank Battery Lake), normally dry up during periods of low precipitation. Water levels in deeper ponds on the site seem to be little affected by periods of low precipitation and are presumed to be partly maintained by recharge from ground water.

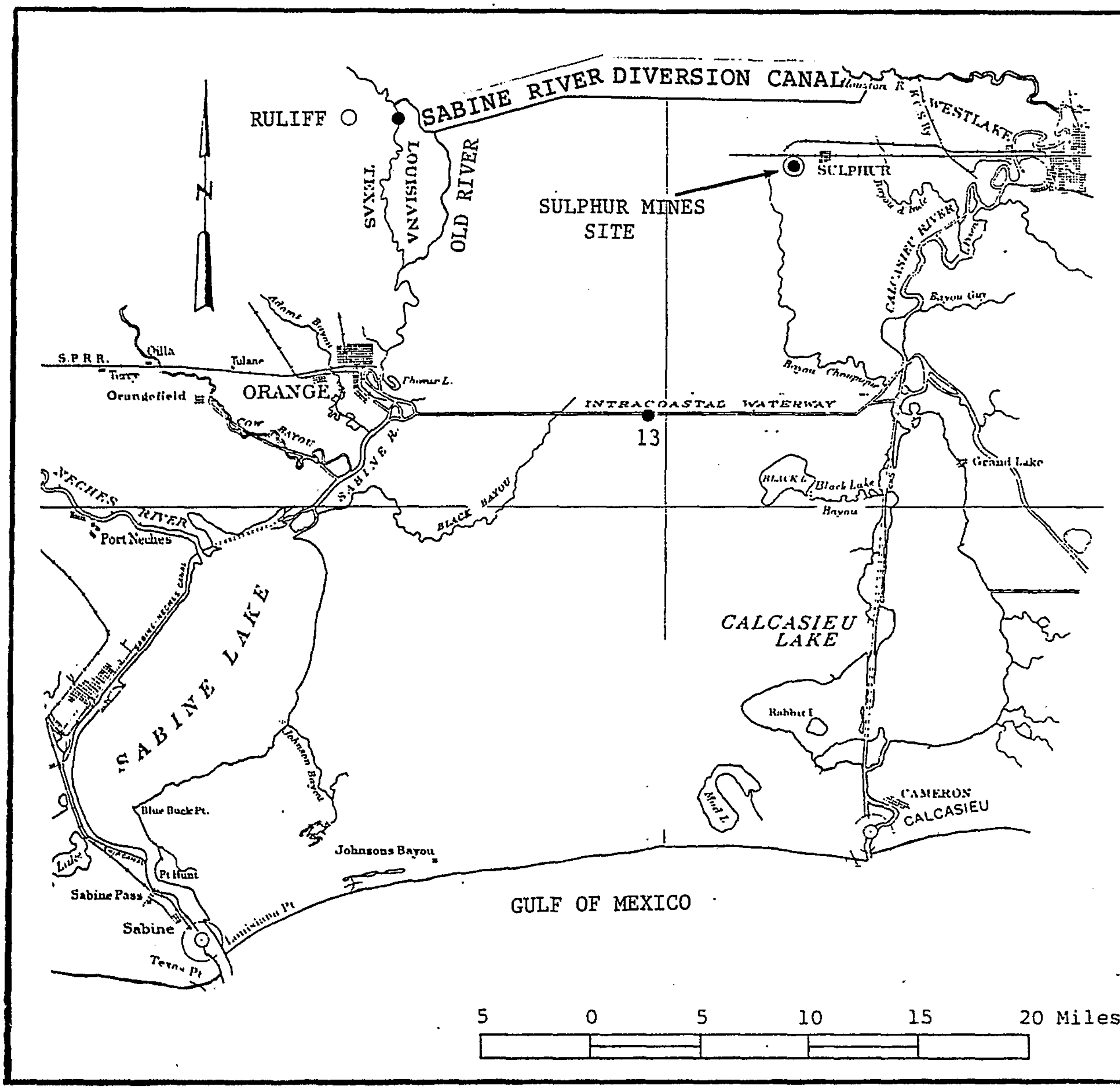

Figure 2.9 Regional Surface Water System

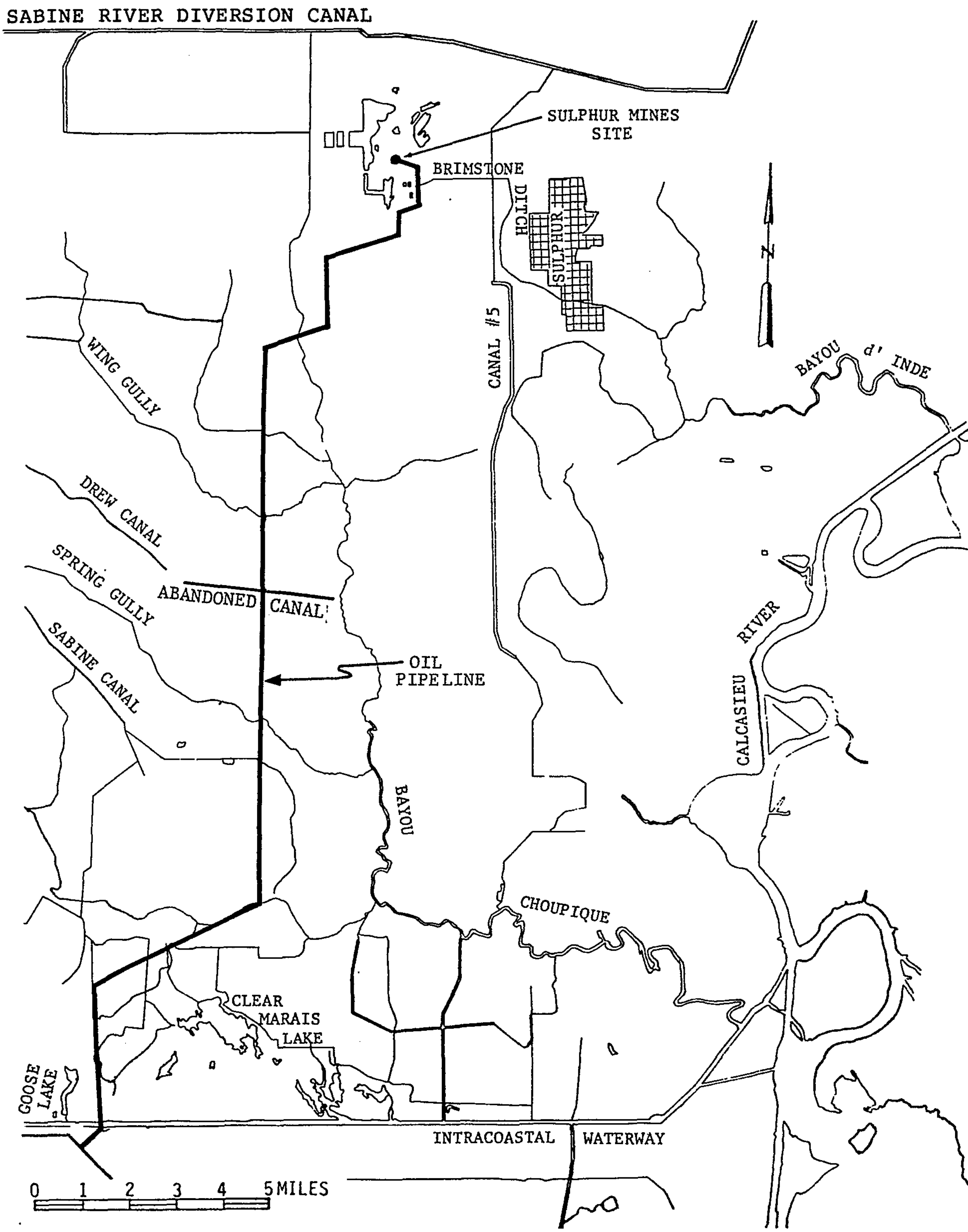

Figure 2.10 Surface Water System Near Sulphur Mines.

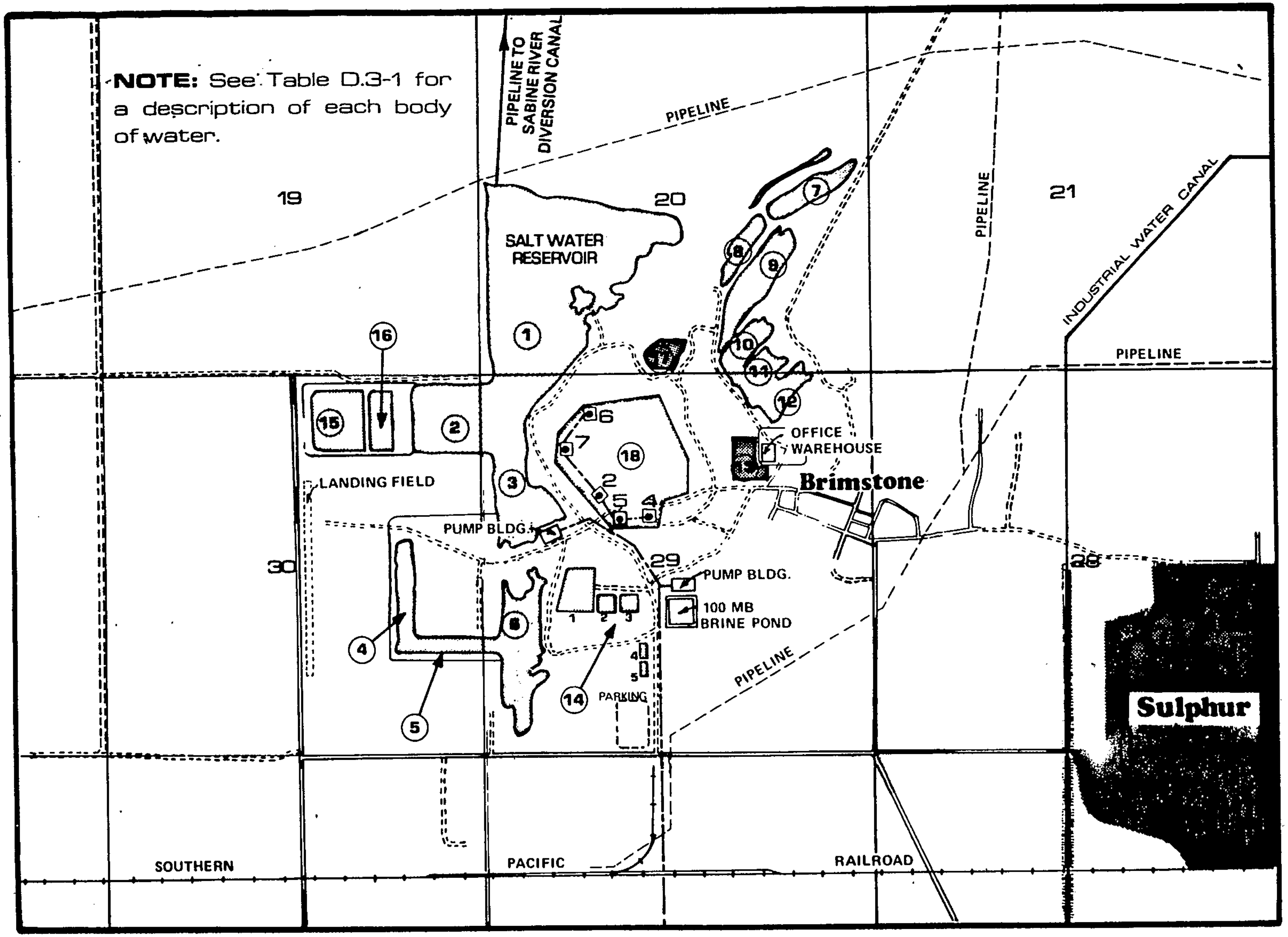

Figure 2.11 Ponds and Reservoirs in the Vicinity of the Sulphur Mines Site. Circled numbers are keyed to Description in Appendix D.3

The total surface water volume of all ponds and reservoirs in the vicinity is 5,836,000 cubic yards (28 million barrels).

2.2.1.2 Marshes

Marshes are prevalent around the north and east periphery of the dome site. In addition, to the southwest, between the South Sector of Salt Water Reservoir and the northeastern sector of Crystal Lake (No. 6), lies Onion Grass Marsh. No water quality data for any of these marsh areas are available.

2.2.1.3 Surface Water Drainage

The clay subsoil in the region around Sulphur Mines is relatively impervious to water penetration. Since area stream channels do not generally cut entirely through the clay layer, most of the water in the streams is surface runoff.[3] Portions of area canals are enclosed by levees, and water in them frequently is at a higher elevation than the surrounding land surface. The levees impede drainage. Drainage ditches are present at the Sulphur Mines location. The largest part of the system is connected to Brimstone Ditch, which carries runoff to the east. The impermeable clay layer beneath the soil contributes to the area's suitability for cultivation of rice since it permits water retention in surface storage.[3] A study is currently underway to identify surface drainage patterns in more detail. The results of this study will be used to assure that facilities will not interfere with surface drainage patterns or agricultural activities.

2.2.1.4 Bayous

The two bayous nearest the site are Bayou Choupique to the southwest and Bayou D'Inde to the east and southeast. Nearly all runoff from the dome site is channeled to the east via Brimstone Ditch to Bayou D'Inde, which flows to the southeast and empties into the Calcasieu River approximately 3 1/2 miles south of Lake Charles. Bayou Choupique flows to the south-southeast and empties into the Intracoastal Waterway near the junction of the Waterway with the Calcasieu River. Bayou Choupique is little affected by surface runoff from Sulphur Mines. No streamflow data concerning either bayou is available. No specific state water quality standards exist for Bayou Choupique. For Bayou D'Inde the specific state water quality standards are provided in Appendix D.2. The state standards specify that

Bayou D'Inde can be used for secondary contact recreation and for propagation of fish and wildlife. These standards classify the bayou as tidal and thus the most pertinent EPA numerical criteria would be those for marine life, which are included in Appendix D.2.

A limited amount of water quality data for the two bayous is available and is presented in Appendix D.4. An evaluation of the available data for Bayou D'Inde reveals levels of pH consistently below the State standards. Similar values of pH occur in Bayou Choupique.

Bayou D'Inde serves as the receiving stream for domestic wastes from the city of Sulphur as well as industrial wastes from several industrial facilities. A summary of such domestic and industrial wastes are included in Appendix D.4. Water quality data for the effluent from one of these facilities, the Cities Service Refinery, is also provided in Appendix D.4. There is no requirement for such effluent to satisfy the specific state criteria or the EPA numerical criteria. However, the level of pH in the effluent exceeds both the state standards and EPA criteria. The level of ammonia is approximately 12 times the level recomended by the EPA numerical criteria. Because of the limited amount of data available, a complete picture of the water environment in Bayou D'Inde cannot be developed. Based on the available data, however, the bayou can be characterized as polluted.[10]

2.2.1.5 Canal Systems

A number of canals have been constructed in the general area of the dome. This discussion is limited to those canals which would be affected by the construction or operation of the facility. During the main period of sulfur mining, which extended into the late 1920's, fresh water was supplied to the mining site via an unnamed canal which joined the northwestern corner of the North Sector of Salt Water Reservoir to the Houston River Canal, approximately 1.5 miles north of the dome. At that time, the Houston River Canal was connected to both the Houston River and the Sabine River. The unnamed canal has been abandoned since the late 1920's when the primary sulfur mining operations ceased. The Sabine River Diversion Canal, which was previously called the Houston River Canal is currently being enlarged and modified as part of the Sabine River Diversion Project. The purpose of the project is to supply fresh water to industries in southwestern Louisiana between the Sabine and Calcasieu Rivers. As the new name suggests, the primary source of water for the enlarged canal system is the Sabine River, with the Houston River serving as an alternate source. The enlargement process is primarily being accomplished by widening and raising the levees. As indicated in Figures 2.9 and 2.10 the new canal system is primarily composed of an east-west segment, which is the main canal, and a north-south branch*, which passes approximately 1 mile east of the Sulphur Mines site.

The east-west canal width will be 112 feet at the top and 60 feet at the bottom with a depth of 13 feet.[11] When the canal is opened (expected late 1978), it will have a maximum flow rate of 340 cfs supplied by three 50,000-gallon per minute pumps located at the junction of the canal with the Sabine River. At a later date, a fourth 50,000-gallon per minute pump will be added and the maximum flow rate will be increased to 450 cfs. In addition to the pumping station on the Sabine River, two 35,000-gallon per minute pumps are being installed at the junction of the canal with the Houston River. A third pump of similar capacity will be installed later if the need arises. The pumps at the Houston River are designed to provide an alternate or backup source of water to the Sabine River. Flow velocities in the canal will normally be approximately 1 to 1.5 fps from west to east.

The north-south canal (Canal No. 5) has a width of 76 feet at the top and 40 feet at the bottom with a depth of approximately 9 feet. It has a designed capacity of 125 cfs with a maximum flow velocity of approximately 0.4 fps. User demand for Canal No. 5, as currently projected, amounts to 40% of its capacity.

Industries which are currently using or will in the near future begin using water from the Sabine River Diversion Canal system include:

- Olin Corporation.
- PPG Industries,
- Firestone Synthetic Rubber and Latex Company,
- Cities Service Oil Company, and
- Gulf States Utilities Company.

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*This branch is referred to as Canal No. 5 of the Sabine River Diversion Canal System.

Although the individual water requirements of each of the preceding industrial facilities are not known, the total water requirements represented by all industries currently using or planning to use water from the canal are well within the initial capacity of the canal system (340 cfs).[12]

2.2.1.6 Sabine River

As noted in the preceding subsection, the Sabine River represents the primary source of water for the canal system. The river in this region actually is divided into three widely separated branches. The junction of the Sabine River Diversion Canal with the Sabine River is located approximately 3 miles north of Niblett Bluff on the most eastern branch, which is called the Old River.

Approximately 4 miles upstream near Ruliff, Texas* both volumetric flow data and water quality data** are available. Volumetric flow data are presented in Appendix D.5. The volumetric flow of the river during the period October 1974 through September 1975 varied from a minimum of 774 cfs in October to a maximum of 40,600 cfs in May. Based on earlier studies of the Sabine River, it would appear that approximately 50% of the total volumetric flow of the river passes through the Old River.[13] The river flow is regulated by releases from Toledo Bend Reservoir.

State water quality standards for the river are provided in Appendix D.2. According to such standards the water is classified as fresh and is to be used for primary and secondary contact recreation, propagation of fish and wildlife, and domestic raw water supply. The most pertinent EPA numerical criteria would be those for domestic water supply and freshwater aquatic life, which are also presented in Appendix D.2.

The available water quality data is presented in Appendix D.5. The results of a comparison of the available data with the pertinent standards and criteria are summarized

*This point is upstream of the region where the river is divided into three separated branches.

**Water quality data are pertinent because of the problem of compatibility of waters for brine injection discussed in Appendix D.8.

in Table 2.1. As indicated by the table and the data in Appendix D.5 the level of fecal coliform in the river exceeded the state water quality standards in six out of eleven samples.

A limited amount of sediment data is also provided in Appendix D.5. This data, which is limited to pesticides and other toxic hydrocarbons, indicates that the sediment is free of contamination with respect to such compounds.

No data regarding municipal or industrial discharges into this reach of the river are available. With respect to water utilization, the states of Louisiana and Texas share the water on an equal basis. Each state is currently authorized to withdraw 90,000 acre feet (698 million barrels) annually at a maximum rate of 454 cfs, free of royalty. In Louisiana all of the 90,000 acre feet of royalty-free water is to be used for the irrigation of rice land. In Texas 48,000 acre feet are to be used in a similar fashion with the remaining 42,000 acre feet to be used for municipal and industrial facilities.[16] It is noteworthy that the initial capacity of the Sabine River Diversion Canal (340 cfs) represents approximately 1.9 billion barrels annually. Unlike the royalty-free water previously noted, the water for the canal must be purchased.[12]

2.2.1.7 Houston River

As described in subsection 2.2.1.5, the Houston River represents an alternate or backup source of water for the Sabine River Diversion Canal. The junction of the canal with the river is in the vicinity of the point where State Highway 27 crosses the river, approximately 4.5 miles northeast of the Sulphur Mines site. The river flows to the southeast and joins the West Fork of Calcasieu River approximately 10 miles downstream of the canal junction. No quantitative hydrologic data for the Houston River is available. The river is, however, part of "Ungaged Area B"[9] and the monthly and weekly steam flows for this region from 1947 to 1951 suggest an extreme variation of flow in the region ranging from 2.2 to 3500 cfs. This extreme variation was one of the reasons the river was not considered suitable as the primary source of water for the Sabine River Diversion Canal.[16]

Table 2.1. Summary of Water Quality Analysis for Sabine River.

Body of Water	Sample Station	Date	Violates State Standards	Exceeds EPA* Numerical Criteria
Sabine River	Ruliff, Texas	1974	Fecal Coliform	Cadmium Iron Lead Mercury Phosphorous pH

*1976 EPA criteria for freshwater aquatic life provided in Appendix D.2.

No water quality data for the Houston River are available. The specific Louisiana State Water Quality Criteria for the river are included in Appendix D.2. These criteria apply to fresh water and indicate that the river should be suitable for the propagation of fish and wildlife.

2.2.1.8 Intracoastal Waterway (ICW)

The ICW lies approximately 14 miles south of the Sulphur Mines facility as shown in Figure 2.10. The waterway extends generally in an east-west direction, with a width of 300 feet and a controlled depth of 12 feet*. Currents in the waterway are variable, being strongly influenced by winds and tides. Flow rates in the Sabine River to the west are generally greater than the flow rates in the Calcasieu River to the east. Thus, there is a general tendency for water in the canal to flow from west to east.

A limited amount of water quality data has been collected on the waterway at Station 13, 12.5 miles west of the Calcasieu River and is included in Appendix D.4. The applicable state water quality standards are included in Appendix D.2. These standards classify the waters as tidal, and indicate that the water is to be used for secondary contact recreation, and the propagation of fish and wildlife. Because the waters in the waterway are classified as tidal the most pertinent EPA numerical criteria would be those for marine and aquatic life which are included in Appendix D.2. Results of a comparison between the available data and the applicable state standards and EPA criteria are summarized in Table 2.2.

2.2.2 Subsurface Water System

The subsurface water system may be affected by the Sulphur Mines facility in two distinct depth

*During World War II the segment of the ICW under consideration was dredged to a depth of 30-40 feet. This depth, however, has not been maintained by dredging. Currently the maximum depth of the waterway is reported to be 14 feet.

Table 2.2 Summary of Water Quality Analysis for Intracoastal Waterway

Body of Water	Sample Station+	Date	Violates State Standards	Exceeds EPA* Numerical Criteria
Intracoastal Waterway	13	03-23-75	None violated	Phosphorous, Arsenic, Mercury, Toxaphene, Lindane, Heptachlor, Aldrin, Chlordane, Dieldrin, Endrin, O,P' -DDT

+The location of sample Station 13 is shown in Figure D.4-2.
*Marine water constituents, provided in Appendix D.2-4.

intervals. First, shallow subsurface aquifers,* which represent an alternate source of displacement water, are encountered in the depth interval from approximately 30 to 2,900 feet. These aquifers are described in Subsection 2.2.2.1. At greater depths, between 5,000 and 7,000 feet, Miocene-Oligocene subsurface aquifers are encountered, as described in Subsection 2.2.2.2. These aquifers are the proposed site for brine disposal.

2.2.2.1 Shallow Aquifers

In the vicinity of the Sulphur Mines site, two aquifers are encountered within 2,900 feet of the surface. The upper is the Chicot aquifer; the lower is the Evangeline.

Chicot Aquifer

The Chicot aquifer (Pleistocene Age) represents an alternate source of displacement water. Examination of well logs shown in Appendix D.6 in the vicinity of Sulphur Mines has revealed a layer of silt and clay approximately 30 feet thick separating this aquifer from the surface water. This layer of sediment acts as an aquitard** and it would thus appear there is not, in general, a natural connection between the shallow subsurface aquifers and the surface water. The man-made reservoirs and ponds in the area may be sufficiently deep in some cases, however, to provide limited connections.

The Chicot aquifer consists of a massive sand sequence which extends down from 30 feet to approximately 800 feet. This sand sequence is broken by several thick and extensive clays (30 feet or more) between the surface and 350 feet and a single clay zone from approximately 550 to 600 feet. The aquifer is continuous for more than 100 miles east-west and north-south. Well No. 3 (in Figure D.6-1 of Appendix D.6) is located at Sulphur Mines and shows the sequence of aquifers and clays. The Chicot aquifer

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*An aquifer is a water-bearing stratum of permeable rock, sand, or gravel.
**An aquitard is a geologic formation of a rather impervious and semi-confining nature which transmits water at a very slow rate compared with an aquifer. Over a large area of contact, however, it may permit passage of large amounts of water between adjacent aquifers.

in Calcasieu Parish is commonly divided into the "200-foot", "500-foot" and "700-foot" sands, on the basis of the depth of such sands in the Lake Charles industrial area. The "200-foot" sand generally consists of one or more thin sands of variable occurrence in northern and western Calcasieu Parish and western Cameron Parish. The "500-foot" sand can be traced as a thick sequence of lenticular sands which in Calcasieu Parish is divided into upper and lower units by a lenticular bed of clay. The base of the lower unit (the "700-foot" sands) is the base of the Chicot aquifer. Clays separating the "200-," "500-" and 700-foot" sands are locally absent, allowing the sands to be hydraulically connected. In the Lake Charles industrial area these local connections permit water to move from the "700-foot" sand into the "500-foot" sand.[18]

The slope of the aquifer is gulfward, 18 feet/mile (0.3% slope), but this general slope is significantly distorted in the vicinity of the dome, where the aquifers must rise up nearer the surface. Thus, relative to the dome center, a quaquaversal condition exists (along any radial line proceeding outward from the dome center, the slope is downward). Figure D.6-1, which is based on data at least nine years old, indicates that in the vicinity of Sulphur Mines the Chicot aquifer contains no saline water, with the fresh water-salt water (horizontal) interface occurring in the aquiclude* between the Chicot and Evangeline aquifers. Because of the effects of industrial pumpage in the vicinity of Lake Charles approximately 10 miles to the east, there is the distinct possibility that, in the nine or so more years since the basic data was obtained, saline water has penetrated the basal sands of the Chicot aquifer near the site. According to the data presented in Appendix D.6 the fresh water-salt water (vertical) interface lies approximately nineteen miles to the southeast of the site. There is evidence which indicates that this interface is

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*An aquiclude is a geologic formation so impervious that for all practical purposes it completely obstructs the flow of ground water (although it may be saturated with water itself), and completely confines other strata with which it alternates in deposition.

moving northward toward the Lake Charles area at a rate of from 70 to 200 feet per year. Thus, the current distance between the vertical interface and Sulphur Mines is probably slightly less than the distance in 1967.

Recharge* of the Chicot aquifer occurs at the outcrop 30 miles north of Sulphur Mines. An effective line of recharge occurs a few miles northwest of Sulphur Mines. This is not from surface recharge, but may result from changes in the form of the aquifer (thickening) or may represent recharge from connections with deeper sands.

Water compatibility for brine injection is discussed in Section 3.2.2.2 and Appendix D.8. In general, as noted in a study conducted in 1967, ". . . water in the Chicot aquifer is primarily of a sodium calcium bicarbonate type. As this water in the west is less likely to be mixed with that from other aquifers, the water typifies that generally contained in the Chicot aquifer. In typical water of the Chicot aquifer, sodium plus potassium make up more than 35 percent, but less than 50 percent of the cations present, and bicarbonate plus carbonate make up more than 55 percent, but generally less than 90 percent of the anions."[18]

Typical concentrations of silicon, iron, and chloride ions in fresh water from the Chicot aquifer are provided in Appendix D.6. All hardness in the water is carbonate hardness as indicated in the table. Other factors influencing the chemical composition of fresh water in the Chicot aquifer are recharge from the underlying Evangeline aquifer and diffusion of salt water in the vicinity of the fresh-salt water interfaces within the Chicot aquifer.[18]

The Chicot aquifer is a source of fresh water. The city of Sulphur, approximately 2.5 miles east of the site draws its water from 5 wells in the depth interval from 540 to 560 feet. The volumetric flow rate is approximately 4×10^6 gallons per day.[19] Approximately 10 miles to the east, the city of Lake Charles also utilizes the shallow subsurface aquifers for its municipal water supply source. The water well depths range from 500 to 700 feet.

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*An aquifer is "recharged" when the water pressure is replenished by ground seepage of rainfall, or by other water sources.

The total yield is approximately 9×10^6 gallons per day.[20]

In addition to serving as a source of municipal water, the Chicot aquifer also provides water for industrial use in the Lake Charles area. Approximately 121 million gallons per day are currently withdrawn from the aquifer for industrial use with the majority coming from the "500-foot" sands.

The combined municipal and industrial rate of withdrawal of water from the Chicot aquifer is plotted versus time for the period from 1935 through 1965 in Figure 2.12.[18] As indicated in the figure, the rate of withdrawal steadily increased during that time period and by 1980 the rate of withdrawal is projected to exceed 140 million gallons per day. These large withdrawal rates have created and will continue to create a cone of depression in the water level within the three major sand beds which comprise the aquifer. For the "500-foot" sand, these cones of depression are presented in Figure 2.13 for the period from 1903 to 2000.[21] These cones of depression indicate that in the 20-year period from 1980 to 2000 in the vicinity of the Sulphur Mines site the water level in the "500-foot" sands will drop approximately 70 feet due to pumpage in the Lake Charles area.

<u>Evangeline Aquifer</u>

The Evangeline aquifer lies beneath the Chicot aquifer in the depth interval from approximately 800 to 2,800 feet. This aquifer consists of unconsolidated fine-to-medium-grained sand. Throughout central and south Calcasieu Parish in general, and specifically in the vicinity of Sulphur Mines, the aquifer consists of saline water. Because saline subsurface water is not in so great a demand as fresh subsurface water, the characteristics of the Evangeline aquifer in Calcasieu Parish are not as well defined as those in the Chicot aquifer. Apparently no map of the base of the aquifer exists. Individual sand beds within the aquifer are generally thin with average sand thicknesses from 10 to 27 feet in the upper portion of the aquifer.* Available evidence indicates that these beds are interfingered and have relatively poor continuity from one to another. In spite of the poor continuity the

*In the lower portion the sand thickness appears to be greater.

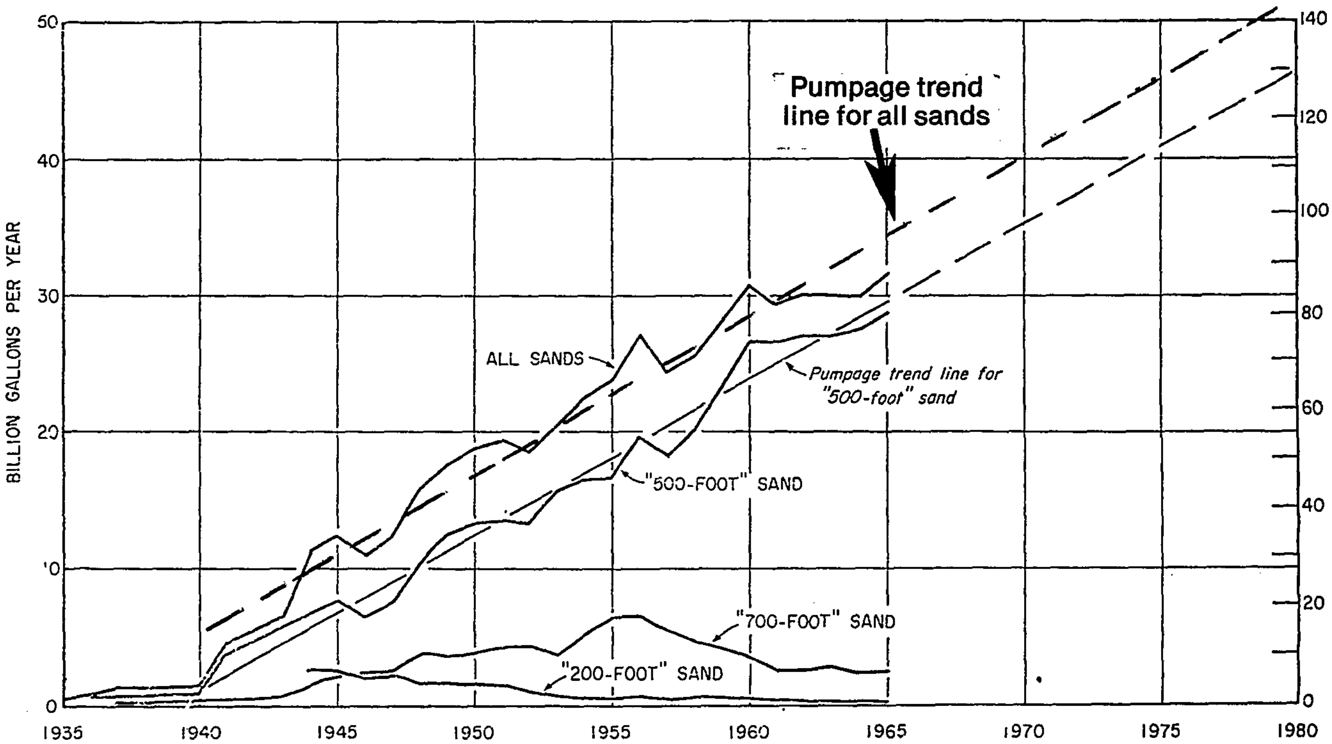

Figure 2.12 Withdrawals from the Chicot Aquifer for Industrial and Municipal Use in the Lake Charles Area.

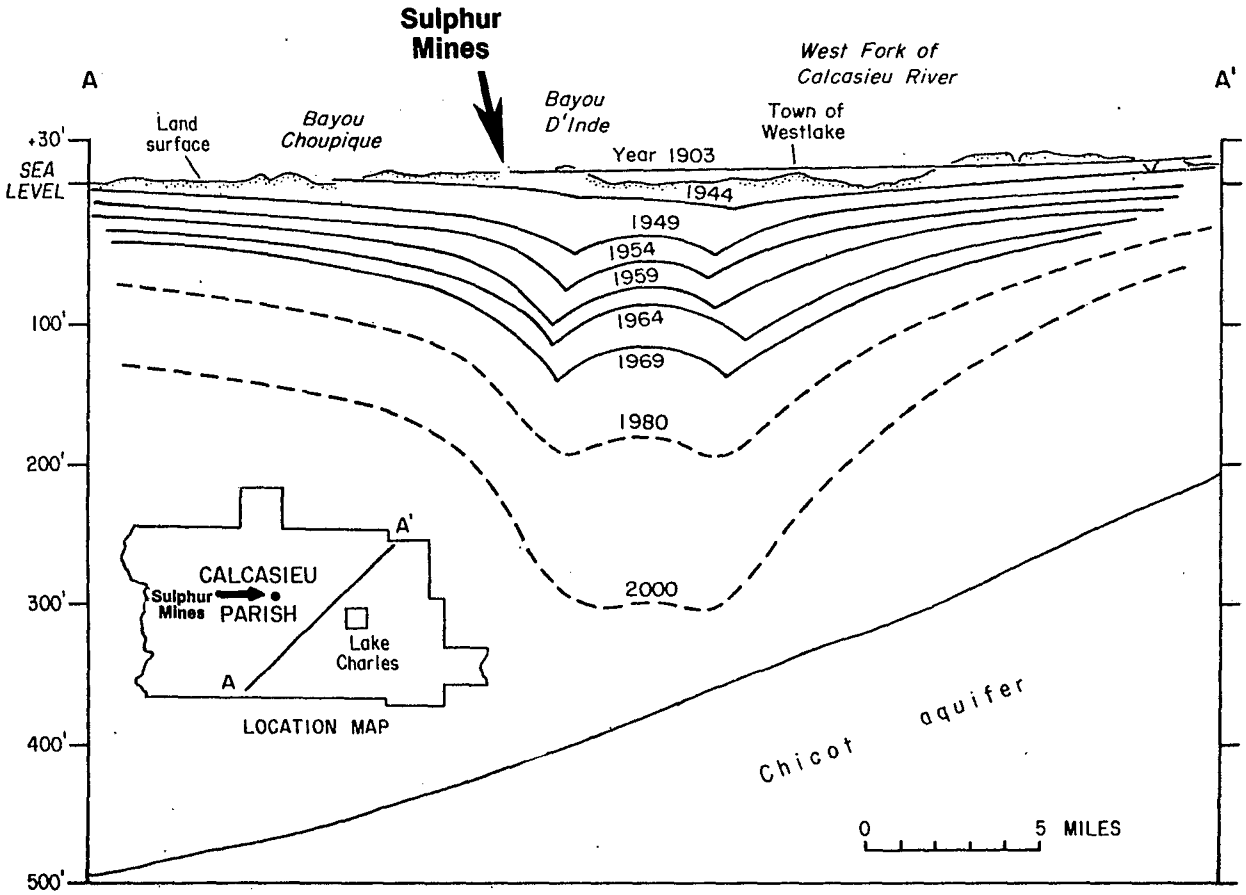

Figure 2.13 Past and Predicted Water Levels in Wells Screened in the "500-foot" Sand of the Lake Charles Industrial Area.

individual sand beds are connected and form a continuous hydraulic system.[18] Further information is included in Appendix D.6.

Specific water quality data for the Evangeline aquifer in the vicinity of Sulphur Mines are not available. Based on an analysis of saline ground water charts,[22] the upper 300 feet of the aquifer (from 800 down to 1,100 feet) contains water with a salinity of from 3 ppt to 10 ppt. Below 1,100 feet the salinity is greater than 10 ppt. In the upper 300-foot interval the yield of an individual well is estimated to be from 500 to 2,000 gallons per minute while in the lower interval the yield is estimated to range from 5,000 to 8,000 gallons per minute.*

Data concerning utilization of water from the Evangeline aquifer is quite limited. Approximately 550,000 gpd were withdrawn from the aquifer in Calcasieu Parish in 1969 for public use.[21] Such withdrawal apparently occurred in the northern part of the parish where some fresh water is found in the upper portion of the aquifer.

The aquifer has been used to a considerable extent for the disposal of salt water. In Calcasieu Parish in 1974 over 18 million barrels of salt water were injected into the depth interval from approximately 1,220 to 2,750 feet (which generally corresponds to the Evangeline aquifer). At Sulphur Mines during that year, 152,061 barrels were injected at a depth of 1,220 feet.

2.2.2.2 Deep Aquifers

For brine disposal the primary disposal site under consideration is the depth interval from 5,000 to 7,000 feet within the deep aquifers. As described in Appendix D.7, nine wildcat well logs in the vicinity of Sulphur Mines

*The potential yield of an individual well is based on a drawdown of 100 feet after one day of pumping. It is also assumed that not more than 200 feet of sand is screened in the well. If the sand thickness is less than 200 feet, then the full thickness is assumed to be screened. The diameter of the well screen is assumed to be 12 inches, and the screened section is assumed to be 100 percent efficient. The yields given are for individual wells, and the estimates do not consider the interference effects of pumping from other wells.

have been studied. Two potential disposal zones have been identified within the proposed depth interval.

The upper potential disposal zone contains alternating layers of Miocene sands and clays between 5,000 and 6,000 feet. This zone is distinguished by a 200-foot thick clay and silt layer above and a 500-foot clay layer at its base. Individual sand layers are continuous (mappable)* for a distance of only a few miles. The entire zone, however, is mappable in all the wells that were checked. This gives a proven distance of correlation of the zone of 7 miles east-west and 5 miles north-south. Potential reservoir sands typically range from as thin as 20 feet to a thickness of 70 feet within a distance of one mile. The average total thickness of sand in the Miocene zone is 600 feet. Typical existing wells penetrate 2 sands 100 feet thick and 10 sands 50 feet thick with lateral continuity of less than 2 miles.

The second potential disposal zone contains alternating layers of Oligocene clays and sands from 6,500 feet to 7,500 feet. This zone is sandwiched between 500 feet of clay above and more than 2,000 feet of clay below. This zone is present in all wells. Individual sands vary greatly in thickness from well to well and are definitely correlated for only about 3 miles. Approximately 50 percent of the zone is sand. Typically 2 sands 100 feet thick and 5 sands at least 50 feet thick are penetrated in the Oligocene zone by existing wells.

Two potential hydraulic boundary conditions, which could substantially reduce the areal extent, and therefore the volume, of the reservoirs, must be considered. First, numerous faults are characteristic of sediments surrounding and overlying salt domes. At Sulphur Mines faults may exist, as yet undiscovered, which could result in compartmentalization of sands surrounding the dome. In this instance brine reservoir volume would be reduced, and pressure increase due to injection would be limited by fault barriers.

The secondary boundary condition that could affect brine disposal operations at Sulphur Mines is the termination of

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*Interception of a specific series of sediment, sand, or rock strata at regular intervals provides data for maps like the one shown in Figure D-6.1 (Appendix D.6).

sand formations against the salt dome. At a depth of 7,000 feet below sea level the eastern flank of the dome may lie within 800 feet of the north-south line of proposed injection wells at the closest point. At 6,000 feet below sea level the distance between the salt and the proposed injection wells is approximately 1,300 feet. These potential boundary conditions must be considered in the design and evaluation of the brine disposal system at Sulphur Mines.

As shown in Appendix D.6 over 36 million barrels of salt water were injected into subsurface aquifers in 1974 in Calcasieu Parish. The deepest average disposal depth was 4,400 feet. A limited amount of data is also available for certain types of industrial waste disposal wells operating in the city of Lockport within Calcasieu Parish in 1971. These data are provided in Appendix D.6, but do not include the rate of disposal. At a depth of 3,500 feet two Cities Service Refining wells injected wastes containing suspended and dissolved solids, hydrogen sulfide, phenols, iron sulfate, and ammonia. At a depth of 4,850 feet two Pittsburg Plate Glass Industries injected wastes containing salt (sodium chloride), sodium sulfate, sodium carbonate, mercury, calcium, and magnesium. The available data for Calcasieu Parish indicates no experience with injections at depths of 5,000 to 7,000 feet, the depth of brine disposal for the proposed project.

2.3 METEOROLOGICAL CONDITIONS

2.3.1 Climatological Conditions*

The climate of the area including the permanent storage facility at the Sulphur Mines salt dome site near Sulphur, Louisiana and the crude oil terminal at Nederland, Texas (39 miles southwest of the storage facility) is classified as "humid-subtropical with strong marine influences." Seasonal fluctuations are moderate. Sea breezes usually prevent extremely high temperatures in summer and the area is sufficiently far south so that the cold air masses of winter are not severe. The average freezing season in the area is from mid-December to mid-February with typically 5 to 10 days having temperatures equal to or less than $32^{o}F$.[23] The foggiest months at Lake Charles and Port Arthur are December and January with 7 to 9 days per month of heavy fog restricting visibility to less than a quarter mile.[24,25] November through May is usually the windiest period with mean wind speeds of 9 to 10 mph at Lake Charles and 10 to 12 mph at Port Arthur. The monthly percentage occurrence of calms is largest in summer as illustrated in Figure 2.14.[26,27]

The November through March period is typically the coldest with monthly normal temperatures in the 50^{o}'s; January to April is typically the driest period with less than 4.3 inches of rain each month. The monthly normal rainfall at Lake Charles[28] and Port Arthur[29] is illustrated in Figure 2.15. June, July and August are usually the hottest, wettest, and most humid months, with monthly normal temperatures in the low to mid 80^{o}'s (Figure 2.16), normal July rainfall of six inches and average relative humidity of 65 percent at noon. As illustrated in Figure 2.17, thunderstorm

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*The nearest weather monitoring stations were within 10 miles of the proposed facilities. The stations used were:

> Lake Charles, La. (National Weather Service Station (NWS) 72240, or Air Force Station 13941, approximately 10 miles east of the permanent storage facility, for wind rose, fog and thunderstorm data.
>
> Port Arthur, Texas (NWS Station 12917 at Jefferson County Airport, 5 miles southwest of the Sun Terminal at Nederland, for temperature and precipitation normals, wind rose, fog and thunderstorm data.

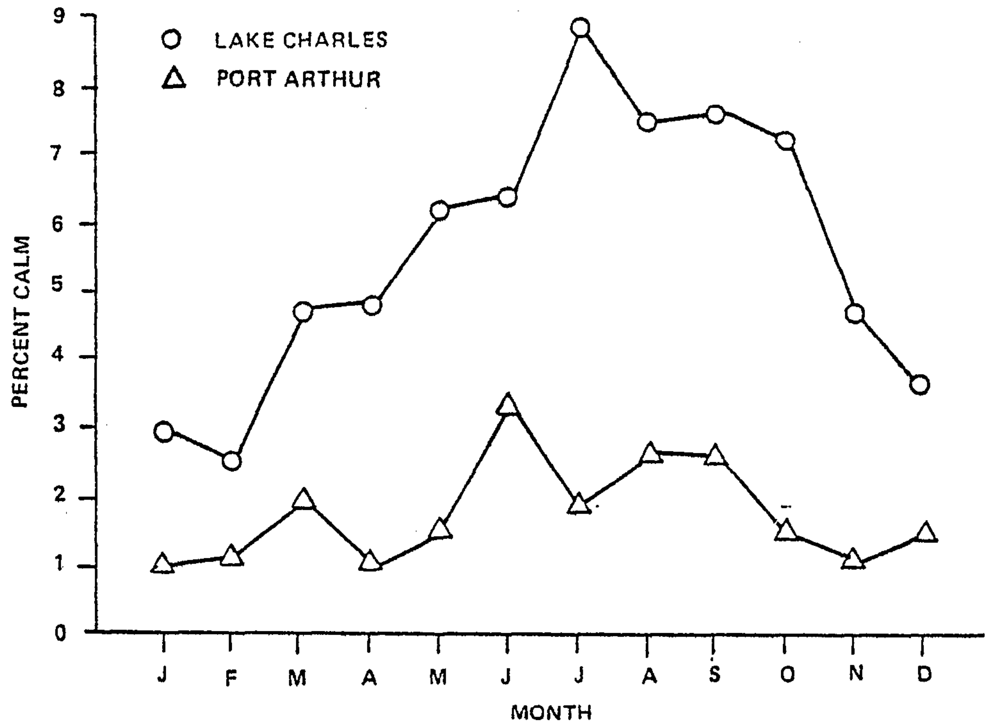

Figure 2.14 Monthly Percentage Calm at Lake Charles[26] (5/42-10/44, 10/45-9/53) and Port Arthur[27] (1/59-12/63).

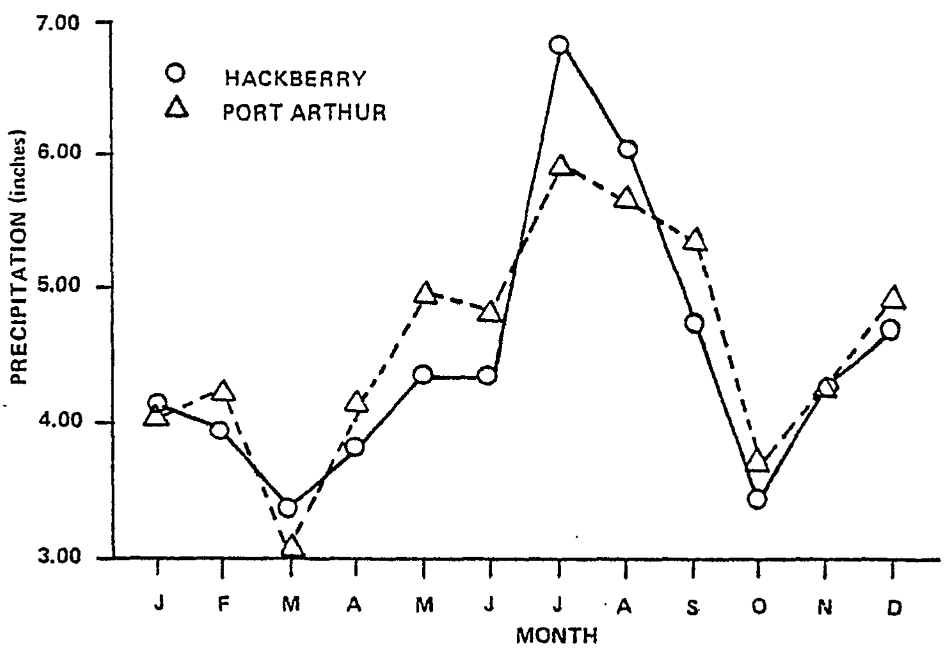

Figure 2.15 Monthly Normal Precipitation at Lake Charles[24] and Port Arthur[25], (1941-1970).

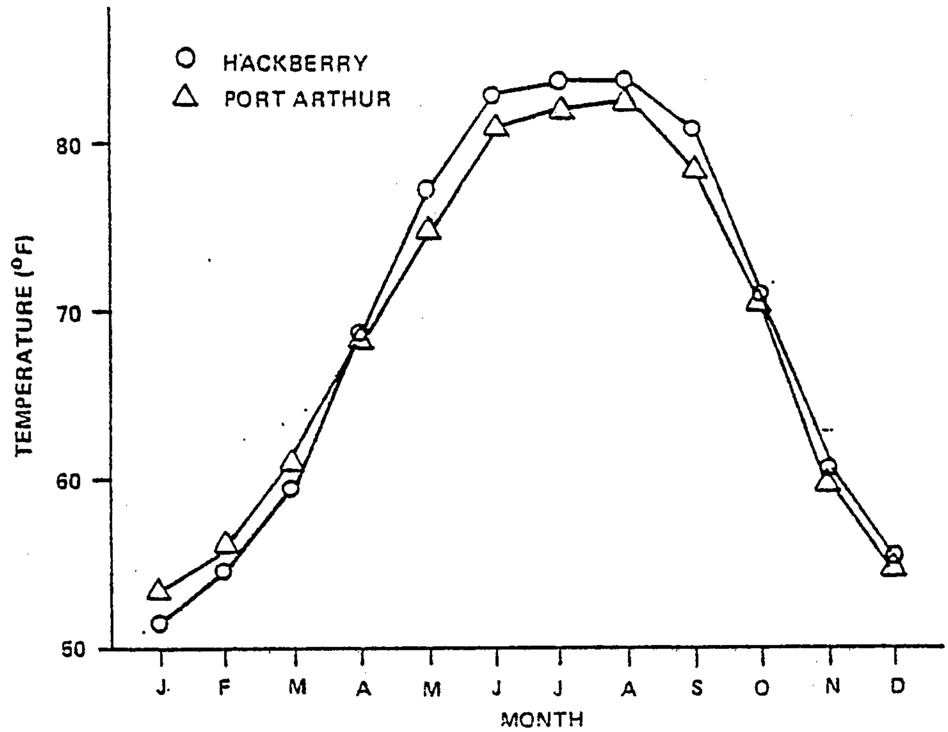

Figure 2.16 Monthly Normal Temperatures at Lake Charles[24] and Port Arthur[25], (1941-1970).

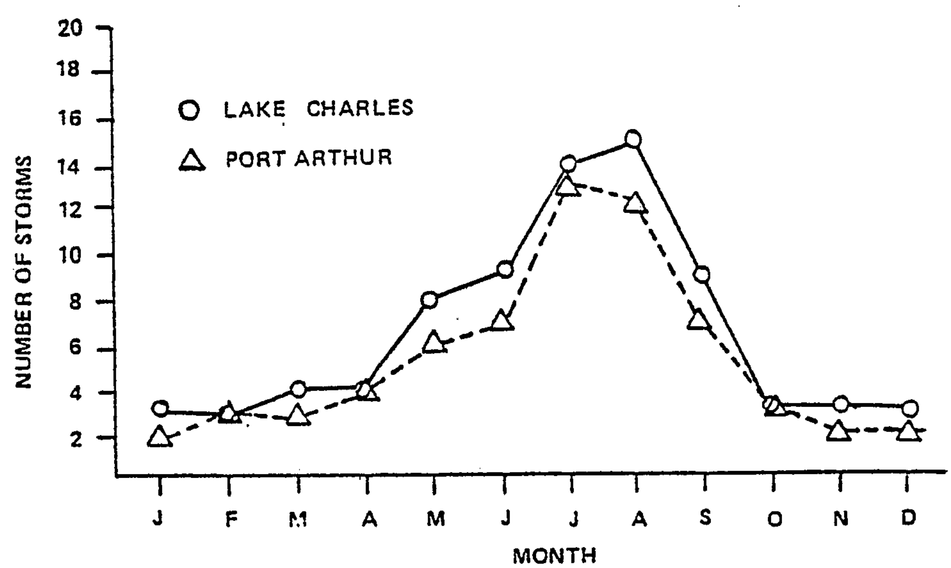

Figure 2.17 Average Number of Thunderstorms Per Month at Lake Charles[24], (1962-1975) and Port Arthur[25], (1954-1975).

activity in the area is greatest in July and August; the normal mean annual number of days with thunderstorms is 78 for Lake Charles and 65 for Port Arthur. The normal annual rainfall in the area is approximately 55 inches and the annual lake evaporation is approximately 51 inches.[23]

Wind rose data for Lake Charles [28] and Port Arthur[30] are illustrated in Figure 2.18. The annual pecent frequency of winds by speed groups for Lake Charles[26] and Port Arthur[27] is given in Table 2.3. Seventy-seven percent of the wind speeds observed at Lake Charles and 71% at Port Arthur do not exceed 12 mph. Extreme winds are projected at 95 mph for a 50 year recurrence interval and 200 mph for a 100 year recurrence interval.[31]

Atmospheric stagnation periods are minimal because of the Gulf Coast winds. The total number of forecast days of high meteorological potential for air pollution in a 5 year period ranges from approximately 5 to 10 days.[32]

The seasonal inversion frequency as percent of total hours is reported to be approximately 35 percent for winter, 25 percent for spring, 30 percent for summer, 40 percent for fall.[33]

Within the past twenty years, two storms passed through the area with winds 100 miles per hour or greater. These were Hurricane Audrey (25-29 June 1957), which passed west of Lake Charles between Calcasieu Lake and Sabine Lake, and Hurricane Edith (5-18 September 1971), which passed southeast of the area.[34] Hurricane Bertha (8-12 August 1957 was a lesser storm (recorded winds less than 100 miles per hour through its path), and passed from southeast of Hackberry to just north of Port Arthur.[34]

Severe storm statistics within two 50 nautical mile strips (57.6 statute mile strips) of Louisiana coastline surrounding West Hackberry[35] are summarized in Table 2.4.

2.3.2 Existing Air Quality

The activities associated with the establishment, filling and drawdown of the ESR facility at Sulphur Mines would occur in the federally designated "Southern Louisiana-Southeast Texas" Interstate Air Quality Control Region (Region 106).

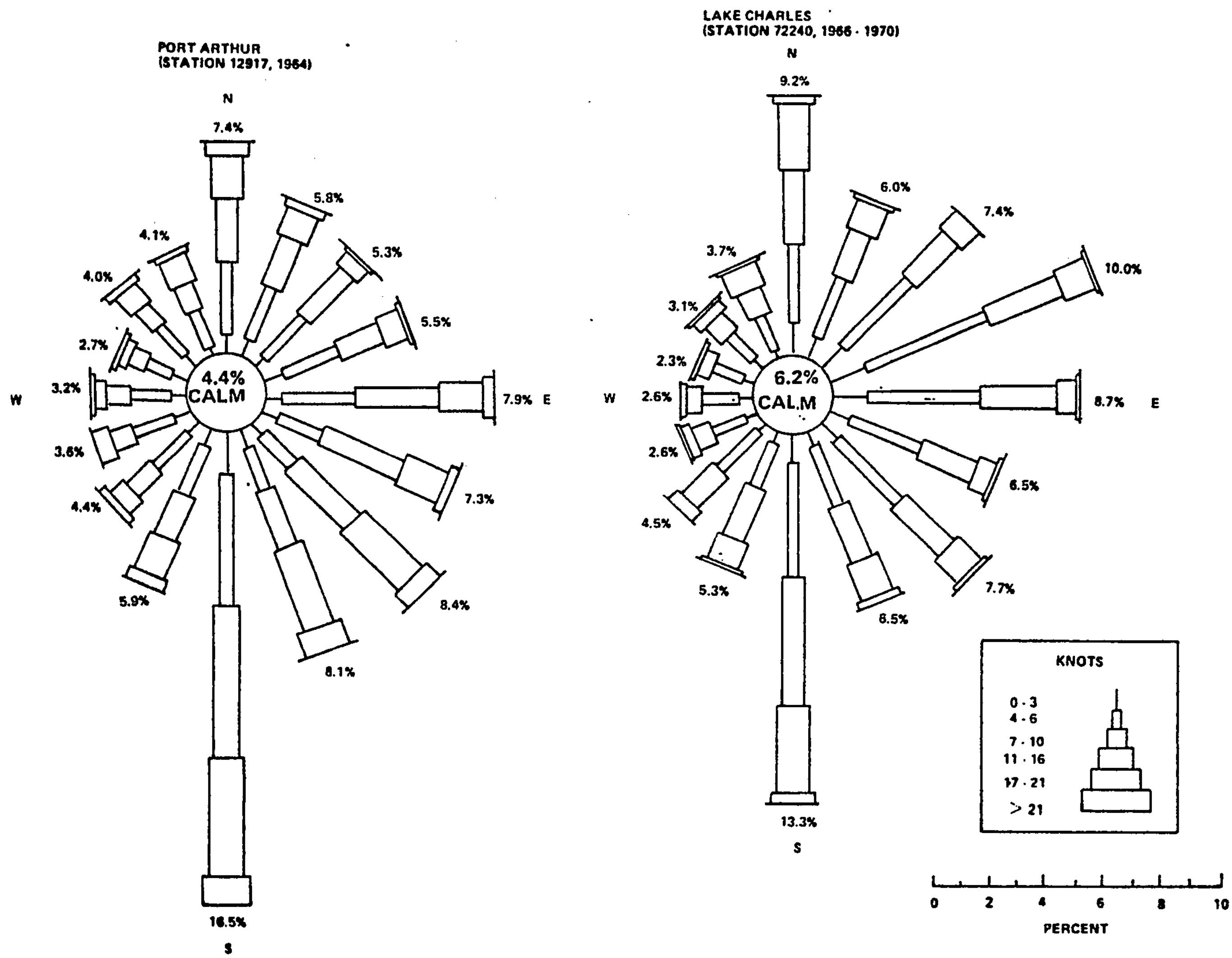

Figure 2.18 Annual Wind Rose Data for Lake Charles[19] (1966-1970), and Port Arthur[18], (1964).

Table 2.3 Annual Percent Frequency of Winds by Wind Speed Groups for Lake Charles and Port Arthur.

Wind Speed Groups (mph)	Annual Percent Frequency Lake Charles[17]	Port Arthur[18]
Calm	5.7	1.7
1-3	11.0	5.6
4-12	60.2	63.2
13-24	21.1	28.7
25-31	1.7	0.6
32-46	0.3	0.1
>47	0.0	0.0
Mean Speed (mph)	8.8	10.0

Table 2.4 Summary of Severe Storm Statistics Within Two 50 Nautical Mile Strips of Louisiana Coastline Surrounding Sulphur Mines Domes.[35]

Number of Tropical Cyclones Reaching the Mainland 1886-1970*

	West	East
All Tropical Cyclones	12	10
All Hurricanes	7	5
Great Hurricanes	3	1

Number of Years Between Tropical Cyclone Occurrences (Average for Period 1886-1970)

	West	East
All Tropical Cyclones	7	8
All Hurricanes	12	17
Great Hurricanes	28	85

Risk of Tropical Cyclones**

	West	East
All Tropical Cyclones	14%	12%
All Hurricanes	8%	6%
Great Hurricanes	4%	1%

*Dual numbers represent statistics for the 50 miles west and east of Sulphur Mines.

Definitions:

Tropical Cyclone	39-73 mph.
Hurricane	74-124 mph.
Great Hurricane	>125 mph.

**Risk requals the proability (%) that a tropical storm, hurricane or great hurricane will occur in any one year in a 50 nautical mile segment of coastline.

In compliance with the Federal Clean Air Act, the states of Louisiana and Texas have initiated Implementation Plans[36,37] which provide for the implementation, maintenance and enforcement of the Federal Air Quality Standards promulgated by the Environmental Protection Agency (EPA) on 30 April 1971 (36 FR 8186). The Texas Air Quality standards are identical to the federal standards as listed in Table 2.5, with a few additions. The additions pertinent to the ESR Program activities are listed in Table 2.6. The Louisiana standards are listed in Table 2.7.

For the purpose of evaluating existing air quality, data were obtained from the Lousiana Air Control Commission (LACC) and the Texas Air Control Board (TACB). The nearest LACC air monitoring stations in the vicinity of the permanent storage facility at Sulphur are located in the highly industrialized area 10 to 12 miles to the east, at Lake Charles and West Lake. The data from these stations is limited because of equipment problems. Tabulations of suspended particulate, oxidant and sulfur dioxide data for 1975 are presented in Tables B-1 through B-5 of Appendix A. A summary of the data for 1974 and 1975 is given in Table 2.8. It is indicated that (from Tables B-1 through B-3), for a sample of 168 suspended particulate observations during 1975 at the three locations in the Lake Charles area, the 24-hour primary standard was not exceeded and the secondary standard was exceeded on three occasions. Continuous oxidant measurements during 1975 indicated 36 violations of the 1-hour federal standard (Table B-4). There were no violations of the federal standard for sulfur dioxide (Table B-5). It is obvious that these data are somewhat limited in scope, and they are representative of an industrialized area. The Sulphur Mines salt dome is in Calcasieu Parish, and Cameron Parish is about 20 miles south. Cameron Parish is a marsh-bayou dominated area. Since Calcasieu Parish is essentially dry land, it is more industrialized and urbanized than Cameron Parish. The measure of emissions in tons/year[36] is not a fair description to compare parishes. Thus, these numbers were reduced to a roughly common form of pounds per square mile per hour. Table 2.9 shows these adjusted emissions for Cameron and Calcasieu Parishes. Data on the predominant industry of each parish, based on census statistics of the total work force and the distribution among the various industry and commerce operations in each parish, is also included in Table 2.9. In Calcasieu Parish, high emissions come from petroleum refineries, with the petrochemical industry

Table 2.5 Federal Ambient Air Quality Standards

Pollutant	Primary Standard	Secondary Standard
Particulates:		
Annual Geometric Mean	75μg/m^3	60μg/m^3
24-hour Maximum	260μg/m^3	150μg/m^3
Sulfur Dioxides:		
Annual Arithmetic Mean	80μg/m^3 (0.03 ppm)	60μg/m^3 (0.02 ppm)
24-hour Maximum	365μg/m^3 (0.14 ppm)	260μg/m^3 (0.10 ppm)
3-hour Maximum		1300μg/m^3 (.5 ppm)
Sulfur Acid Mist and/or Sulfur Trioxide:		
24-hour Maximum	12μg/m^3	
1-hour Maximum	30μg/m^3	
Carbon Monoxide:		
8-hour Maximum	10mg/m^3 (9 ppm)	10mg/m^3 (9 ppm)
1-hour Maximum	40mg/m^3 (35 ppm)	40mg/m^3 (35 ppm)
Photochemical Oxidants:		
1-hour Maximum	160μg/m^3 (0.08 ppm)	160μg/m^3 (0.08 ppm)
4-hour Maximum	98μg/m^3 (0.05 ppm)	98μg/m^3 (0.05 ppm)
Hydrocarbons (non-methane):		
3-hour Maximum	160μg/m^3 (0.24 ppm)	160μg/m^3 (0.24 ppm)
Nitrogen Dioxide (NO_2):		
Annual Arithmetic Mean	100μg/m^3 (0.05 ppm)	100μg/m^3 (0.05 ppm)

μg/m^3 = Micrograms per Cubic Meter

mg/m^3 = Milligrams per Cubic Meter

Table 2.6 Texas Ambient Air Quality Standards (As specified in conjunction with the Federal Ambient Air Quality Standards).

Suspended Particulates:	
5-hour average	100 $\mu g/m^3$
3-hour average	200 $\mu g/m^3$
1-hour average	400 $\mu g/m^3$
Visible Emissions:	
5-minute period	not to exceed 20% opacity
(for any stationary flue constructed after 31 January 1972)	
Sulfur Dioxide (SO_2):	
30-minute average	net ground level concentration*
Orange, Jefferson Counties	0.32 ppm
Harris, Galveston Counties	0.28 ppm
All other counties	0.40 ppm
Hydrogen Sulfide (H_2S):	
30-minute average	net ground level concentration*
(1) downwind concentration effecting property used for residential, business or commerce purposes	0.08 ppm
(2) downwind concentration effecting property used for other than the above specified land uses; e.g. vacant land, range land, industrial property	0.12 ppm

*net ground level concentration is the downwind concentration minus the upwind concentration.

Table 2.7 Louisiana Ambient Air Quality Standards.

POLLUTANTS	STANDARD (maximum permissible concentrations) PRIMARY	SECONDARY
Suspended Particulates:		
Annual Geometric Mean	75 $\mu g/m^3$	60 $\mu g/m^3$
Maximum 24-hour mean	260 $\mu g/m^3$	150 $\mu g/m^3$
Dust Fall	20 $tons/mi^2$/month	
Coefficient of Haze:		
Annual geometric mean	0.06 COH/1000 lin. ft.	
Annual arithmetic mean	0.75 COH/1000 lin. ft.	
Maximum 24-hr. mean	1.50 COH/1000 lin. ft.	
Sulfur Dioxide (SO_2)		
Annual Mean	80 $\mu g/m^3$	60 $\mu g/m^3$
Maximum 24-hour mean	365 $\mu g/m^3$	260 $\mu g/m^3$
Maximum 3-hour mean	---	1300 $\mu g/m^3$
Sulfur Acid Mist: (Sulfur Trioxide or any combination thereof)		
Maximum Annual Mean	4 $\mu g/m^3$	
24-hour Mean	12 $\mu g/m^3$ } not to be exceeded more than	
1-hour Mean	30 $\mu g/m^3$ } 1% of the time	
Carbon Monoxide (CO):		
8-hour Maximum	10 mg/m^3	10 mg/m^3
1-hour Maximum	40 mg/m^3	40 mg/m^3
Hydrocarbons (non-methane):		
3-hour Maximum between 6:00 and 9:00 a.m.	160 $\mu g/m^3$	160 $\mu g/m^3$
Total Oxidants:		
Annual Arithmetic Mean	58.8 $\mu g/m^3$	58.8 $\mu g/m^3$
4-hour Maximum	98.0 $\mu g/m^3$	98.0 $\mu g/m^3$
1-hour Maximum	160 $\mu g/m^3$	160 $\mu g/m^3$
Nitrogen Dioxide (NO_2):		
Annual Arithmetic Mean	100 $\mu g/m^3$	100 $\mu g/m^3$

Note: hourly means are not to be exceeded more than once per year

Source: Air Control Regulations, Louisiana Air Control Commission, New Orleans, Louisiana, August 1, 1974.

Table 2.8 Louisiana Air Quality Commission Air Quality Data.

	CONCENTRATIONS IN MICROGRAMS PER CUBIC METER				
	1974		1975 (4)		
	WEST LAKE	LAKE CHARLES	WEST LAKE	LAKE CHARLE	
Suspended Particulates			(1)	(2)	(3
Annual Geometric Mean	60	65	57	43	68
Daily Maximum	150	120	146	121	215
SO_2					
Annual Average	1.3	5.5	-	-	-
Monthly Maximum	11	27	-	-	-
NO_2					
Annual Average	48	66	-	-	-
Monthly Maximum	72	160	-	-	-
Oxidant (O_3)					
Number of Violations of the Federal 1-hr standard (.08 ppm)	-	-	-	-	36

NOTES: (1) Site at 701 Johnson Street

(2) Site at intersection of Ryan and McNeese Street

(3) Site at 721 Prien Lake Road

(4) Data are representative only of concentrations during stations operation.

Table 2.9 Emissions and Industry Profiles for Calcasieu and Cameron Parishes (1970).

Parish	Area Sq. Mi.	Pop. Density	SO_x lb/mi^2-hr	Hydrocarbons lb/mi^2-hr	Particulates lb/mi^2-hr	Predominant (% of Total Work Force) Industry: Mining	Manufacturing	Industry as % of Manufacturing Work Force: Chemical	Transportation Equipment
Cameron	1444	5.7	0.08	0.004	0.006	16%	11.8%	9%	11%
						13% = Agriculture, Forestry and Fisheries (% of Total Work Force)			
Calcasieu	1105	131.6	11.4	11.8	1.6	3.6%	19%	37%	5%
% Petroleum Refinery and Petrochemical Operations Point Source Contribution			98%	35%	63%	2.3% = Agriculture, Forestry and Fisheries (% of Total Work Force)			
						11% = Construction (% of Total Work Force)			
% Chemical Industry Point Source Contribution				43%	8%				

Source: Public Affairs Research Council of Louisiana, Inc., "Parish Profiles," Baton Rouge, Louisiana, 1973.

Emissions from LACC Implementation Plan.

point sources contributing greater than 95 percent of the total parish sulfur oxide emissions. The combination of petroleum refining, petrochemical, and chemical industry point source emissions accounts for greater than 70 percent of the total Calcasieu Parish emissions of hydrocarbons and particulates. Cameron Parish is seen to be a very "clean" parish; the only real emission sources are vehicles.

The current use of three cavities for ethylene storage, the brine production and associated activities, and the gas and oil production operations at the Sulphur Mines salt dome cause a small elevation of air pollutant concentrations locally. This is considered to be insignificant and should pose no extraordinary constraints upon further development of this area.

A large portion of the hydrocarbon emissions associated with the Sulphur Mines ESR program would occur at the Sun Terminal site (Nederland, Texas), mainly as a result of tanker loading or unloading and surge tank crude oil storage. Nederland is located in the southeast corner of Texas Air Quality Control Region X. The major economic activity in this part of the region is petroleum refining and the petrochemical industry. In this area there are seven petroleum refineries and approximately 21 chemical plants. A majority of these plants are located in the major metropolitan area of Beaumont, Port Arthur and Orange.[37]

Tabular summaries of air quality data obtained by the TACB in Nederland are presented in Appendix B (Tables B-6 through B-11); an abbreviated summary of the Nederland air quality data is given in Table 2.10. These data indicate that the federal standards for nitrogen dioxide, carbon monoxide, sulfur dioxide and suspended particulates were not violated during 1974 and 1975. Concentrations of non-methane hydrocarbons were observed to exceed standards at Nederland (approximately 70 percent of the hours for which data were available during 1974 and 1975 had concentrations exceeding the federal standards). These high concentrations do not correlate with ozone concentration statistics calculated from measurements at the same location during the same period; as indicated in Table 2.10, the concurrent ozone measurements exceeded the federal standard approximately three percent of the time. The occurrence of excessive hydrocarbon concentrations may be attributed to the presence of tank farms, petrochemical activities and the petroleum deliveries in the Nederland area.

Table 2.10 Abbreviated Summary of Air Quality Data for Nederland, Texas. Data Source: Texas Air Control Board.

	Nitrogen Dioxide (ppm)	Non-Methane Hydrocarbons (ppm)		Ozone (ppm)		Carbon Monoxide (ppm)		Sulfur Dioxide (ppm)	Suspended Particulates (ppm)	
Federal Standards (Primary)	AAM* = .05	3 hr. max. = 0.24		1 hr. max. = .08		8 hr. max. = 9	1 hr. max. = 35	24 hr. max. = .14	AGM** = 75 24 hr. max. = 260	
	AAM	% hrs > .24	Mean	% hrs > .08	Mean	% hrs > 9	% hrs > 35	% hrs > .14	AGM	% hrs > 260
Data 1974	.01	71.3	.7	2.7	.028	0	0	0	53	0
1975	.01	68.0	.6	3.4	.028	0	0	0	56	0

*AAM = Annual Aritmetic Mean

**AGM = Annual Geometric Mean

2.3.3 Noise

Noise at the site and in the near vicinity of the Sulphur Mines salt dome is typical of a secluded, essentially flat, moderately forested area. In the winter and spring, the contributing noise sources are wind in the trees, periodic bird calls and the rustling of the grasses and brush. The day-night weighted levels are around 48 dBA on reasonably calm days (winds less than 10 mph).[38] In the summer, because of the high humidity and warmth, the marshland noise is dominated by the buzz of mosquitoes and other insects, frogs, crickets, and bird calls, and the noise of the foliage on the trees and brush, as winds blow through. On a normal summer evening, the noise levels can be as much as 10 to 15 dBA higher than winter levels because of activities of native creatures and insects.

The Sulphur Mines site is characterized by remote area noise patterns. Local activity nearby on public roads barely penetrates to the site because of the sound attentuation of moderately dense forests.

In preparation of the environmental impact report for the proposed offshore superport, Seadock, Inc. performed a brief ambient noise survey in the area of Jones Creek (a small community southwest of Freeport, Texas) where the onshore facilities will be located.[38] While this study is not site specific for Sulphur Mines, the area is similar (in degree of urbanization relative to the closest residences to Sulphur Mines) and the ambient levels and spectra can be assumed to be representative of noise sensitive areas around the site. Figures 2.19 and 2.20 show the daytime, evening, and nighttime octave band spectra for two sites chosen by Seadock, Inc. on the basis of their sensitivity to interruption by noise. The first is approximately 2,000 feet from a running creek, the second is at a small commmunity roadside. These spectra were taken in early March when deciduous trees are still barren and the insect population is relatively low. Figure 2.21 is the ambient spectrum taken from a Department of Transportation noise survey of the Florida Everglades.[39] This spectrum is a little "quieter" than the Jones Creek area daytime spectrum which can be attributed to the lack of human activity (road traffic in particular) in the Everglades.

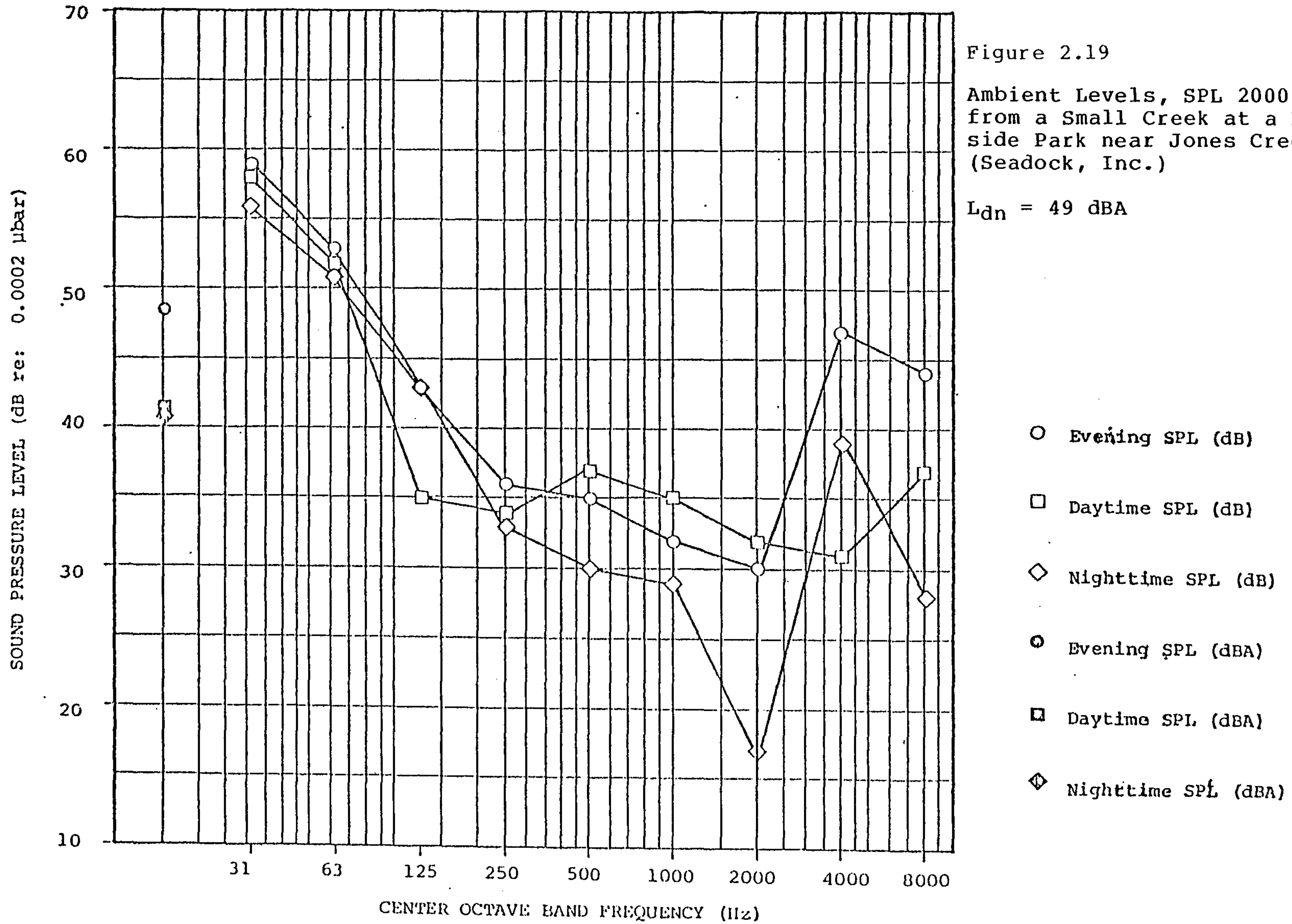

Figure 2.19

Ambient Levels, SPL 2000 Feet from a Small Creek at a Roadside Park near Jones Creek (Seadock, Inc.)

L_{dn} = 49 dBA

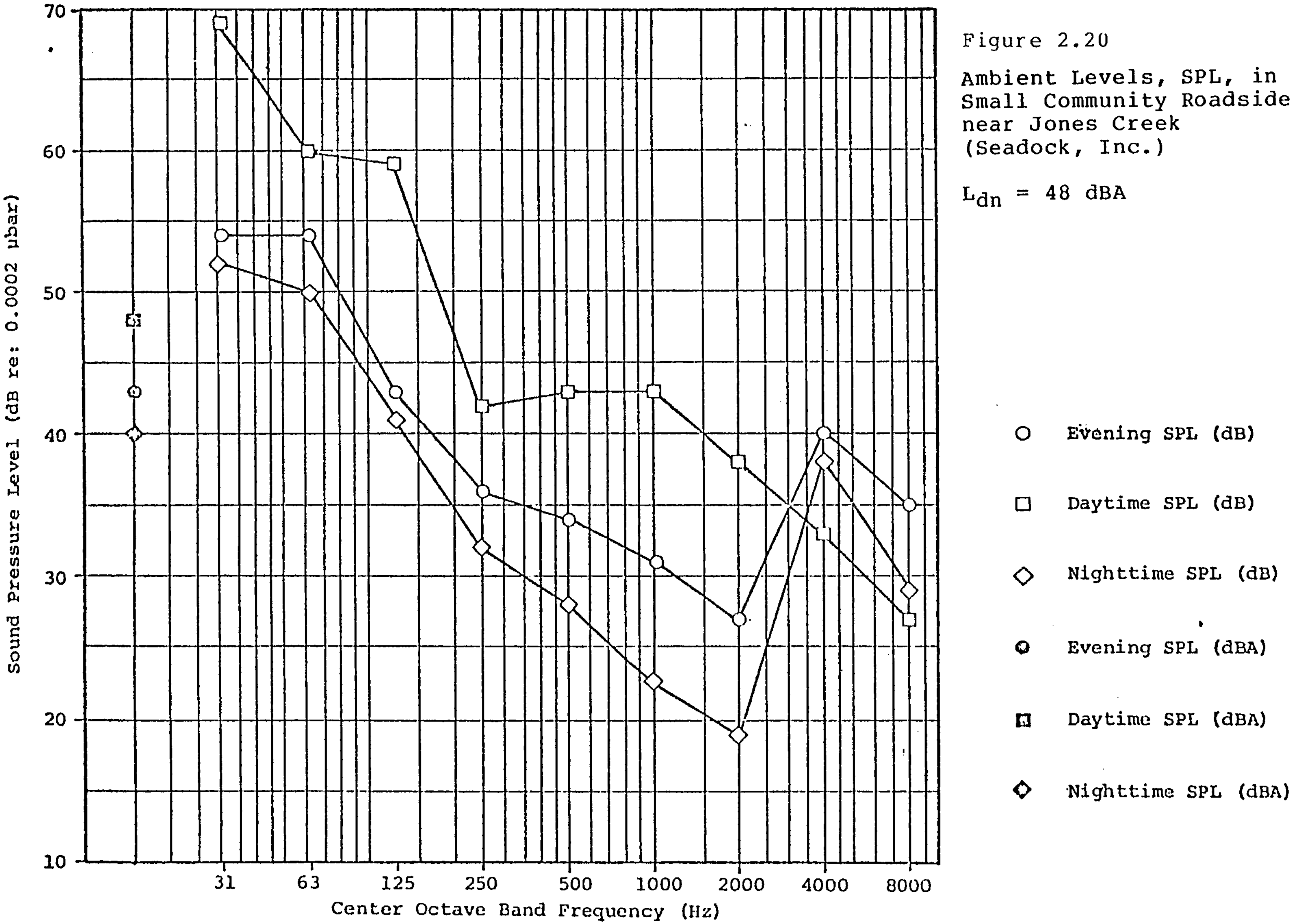

Figure 2.20

Ambient Levels, SPL, in Small Community Roadside near Jones Creek (Seadock, Inc.)

L_{dn} = 48 dBA

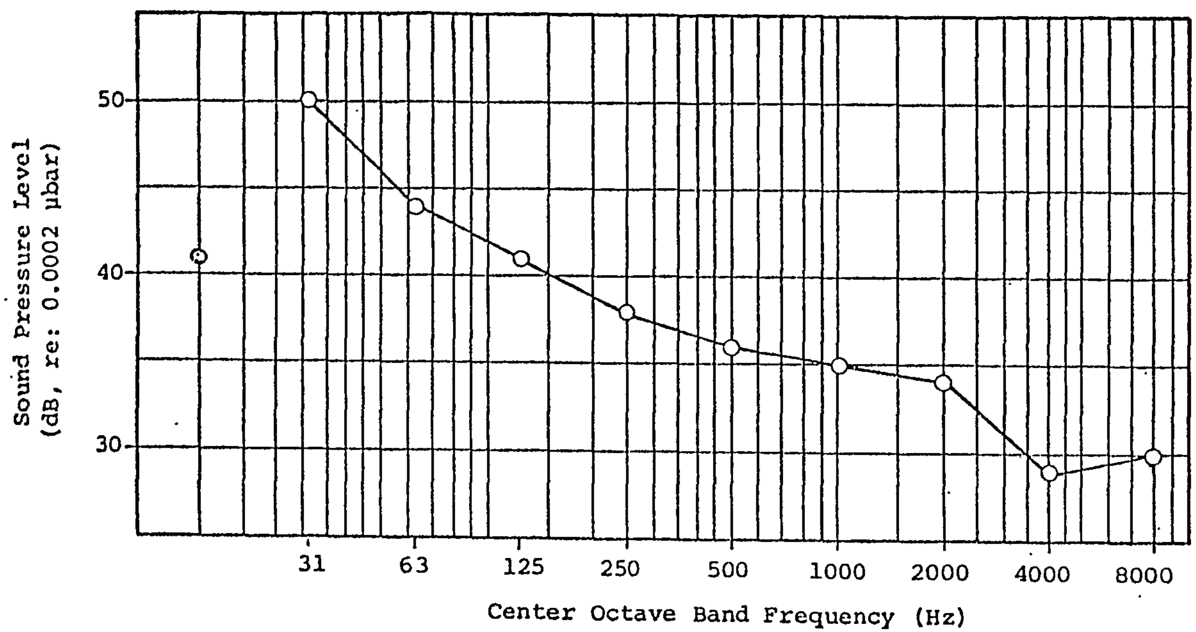

Figure 2.21

Ambient Levels, SPL,
Florida Everglades,
Early March, Daytime.

○ SPL (dB)

ʘ SPL (dBA)

The A-weighted* levels range from a low of 40 dBA (nighttime) to a high of 48 dBA (daytime). In the summer, these ambient levels may be as high as 50 dBA in the evening.

*The A-weighting is a method of adjusting the sound pressure level (dB re: 0.0002 bar) at each center octave band frequency in much the same way that the human ear does in attentuating incident sounds. Essentially, a young, normal human ear is much more sensitive to sounds between 500Hz and 8000Hz than it is to low and high frequency sounds. The apparent "attenuation" is very closely matched by the A-weighted scale used in sound measurements.

2.4 SPECIES AND ECOSYSTEMS

2.4.1 Natural Environments of the Area

The Sulphur Mines salt dome is near the center of Calcasieu Parish, Louisiana. Orange and Jefferson Counties in Texas would be impacted by the storage project along with Calcasieu Parish since the oil distribution pipelines would lie in them also. The storage location is to the west of a chain of lakes on the Calcasieu River. The higher land (generally less than 30 feet above sea level) in all but the northern part of the parish to the west of the river is mainly former prairie which has been put to agricultural uses. Naturally occurring trees are prevalent only along flood plains on the marginal slopes of streams. However, commercial timber is produced on some former prairie areas and further to the north. There are stretches of swamp forest and bottomland hardwoods along the Calcasieu River flood plain (north of the city of Lake Charles) and along the Sabine River, which forms the western boundary of the parish. Flatwoods are present in the northern part of the parish, and a different bottomland hardwood association is present along the stream courses located there. Most of this northern area has been greatly altered by lumbering, with much of the area covered by stumps and low brush. Such land frequently is used to provide pasture forage.

Intermediate, fresh, and brackish marshlands are present in some of the southern part of the parish which is of particular interest. Other portions of the area between the Calcasieu and Sabine River systems are mainly former prairie. There is an extensive network of canals in this southern section of the parish which reaches northward beyond the latitude of the storage site. At the south end of the network is the Intracoastal Waterway (ICW), a deepdraft channel important to regional water commerce. The oil distribution pipelines would pass along the southern part of the ICW enroute to the Sun Oil Terminal in Nederland, Texas.

The oil distribution pipelines would pass through the south part of Orange County and thence slightly into northeastern Jefferson County. The Sabine River, Cow Bayou, and the Neches River are along this part of the route. The southern part of Orange County contains woodlands, cultivated lands (mainly located on former prairie), marshes, swamps, and disposal areas for dredged spoil. The terminus of the oil distribution lines in northeastern Jefferson County, Texas, is an industrialized area on the Neches River.

2.4.1.1 Ecosystems in Calcasieu Parish

For the purposes of this report, five main ecosystems in Calcasieu Parish have been identified. These correspond to units utilized in the Inventory of Basic Environmental Data - South Louisiana.[40] These ecosystems are:

i) woodlands
ii) prairie
iii) marshlands
iv) cleared lands
v) estuarine and inland waters

Characteristic flora and fauna of these ecosystems as well as their environmental subcategories are summarized in Table 2.11.

Woodlands

Dominant species within the region include the loblolly (*Pinus taeda*) and the longleaf (*Pinus palustris*) pines. Hardwoods, gums and oaks are relatively common in creek and river bottoms (Table 2.11).

Vegetation within swamps is predominantly tupelo gum (*Nyssa* sp.) and cypress (*Taxodium* sp.). Water oak, (*Quercus niger*), mayhew (*Crataegus* sp.), tupelo gum, and ironwood (*Bumelia* sp.) can be found[41] in Calcasieu Parish along the Sabine, northern Calcasieu, and Houston Rivers and associated tributaries.

Wildlife within woodland areas consists mainly of smaller forms. The striped skunk (*Mephitis mephitis*), the cottontail rabbit (*Sylvilagus floridanus*) and the swamp rabbit (*S. aquaticus*) are common. Gray and fox squirrels (*Sciurus carolinensis* and *S. niger*) are abundant in the bottomland hardwood regions. Other wildlife throughout woodlands of the study area are the raccoon (*Procyon lotor*), cotton mouse (*Peromyscus gossypinus*), hispid cotton rat (*Sigmodon hispidus*), and the nine-banded armadillo (*Dasypus novemcinctus*).

Table 2.11 Representative Biota in Ecosystems in Calcasieu Parish

Ecosystems	Woodlands		Prairie Lands	Marshlands	Cleared Lands	Inland and Estuarine Waters
Environmental Subcategory	Flatwoods	River Bottoms and Swamps	Prairie	Fresh, Intermediate and Brackish	Cropland, Suburban, and Urban	Lakes, Rivers and Intra-coastal Waterway
Typical Herbs, Grasses, and Trees	slash pine, longleaf pine, oaks, magnolia, palmetto	hardwoods, sweet gum, tupelo gum, cypress, loblolly pine	bluestem, switch grass, indian grass, prairie wild-grass	maiden cane, alligatorweed, wiregrass, widgeongrass, bulltongue	rice soybeans	N/A
Typical Mollusks and Crustaceans	snails	clams, snails	snails	clams, snails, shrimp, crab	snails	shrimp, clams snails, crabs
Typical Amphibians and Reptiles	tree frogs, box turtles	tree frogs, water snakes, alligators, western cottonmouth	grass snakes, land turtles	water snakes, alligators	N/A	frogs, alligators
Typical Mammals	fox squirrel, gray squirrel, rabbit, mice, rats	fox squirrel, gray squirrel, swamp rabbit, mice, rats, mink, nutria, otter	eastern cottontail rabbit, mice, striped skunk	nutria, muskrat, raccoon, mink, striped skunk	domesticated mammals, Norway rat, housemouse	N/A
Typical Fish	N/A	mosquitofish (swamp)	N/A	gar, killifish, crappie, sunfish, catfish	N/A	mullet, catfish, shad, cyprinids
Typical Birds	owls, bobwhite, mourning dove songbirds	owls, woodpeckers, warblers	marsh hawk, eastern meadowlark	Red-winged Blackbird, egrets, ibises, shore birds, Marsh Hawk, ducks	American Robin, Starling, House Sparrow, Brown-headed Cowbird	ducks, herons, gulls

Swamp forests within Calcasieu Parish contain mink (Mustela vision), otter (Lutra canadensis) and white tailed deer (Odocoileus virginianus). Predatory mammals within woodlands include the bobcat (Lynx rufus), and the red and gray fox (Vulpes fulva and Urocyon cinereoargenteus). Bird populations of swamp forests and woodlands are largely composed of the mourning dove (Zenaidura macroura), bobwhite (Colinus virginus), Wilson's snipe (Capello galinago) and several species of owls, woodpeckers, and warblers.

Prairielands

The prairie area is largely used for agricultural purposes. Vegetation found within remnants of the natural prairie ecosystem consists predominantly of switch grass (Panicum virgatum), big bluestem (Andropogon sp.), Indian grass (Sorghastrum avenaceum), and prairie wildgrass (Sphenopholis obtusata).

Predominant species of mammals located in the prairie environment within the study area are mice and rats (i.e.: Peromyscus gossypinus and Sigmodon hispidus), and quadruped predators such as the coyote (Canis latrans), fox and occasionally the red wolf (Canis niger).

Avian wildlife within this environment primarily consists of small birds, field birds and migratory waterfowl. The bobwhite (Colinus virginianus), killdeer (Haradrius vociferus), common crow (Corvus brachyrhynchos), various thrushes, starling (Sturnus vulgaris), Savannah sparrow (Passerculus sandwichensis) and field sparrow (Spizella pusilla) are only a few common birds known to inhabit the region.

Marshlands

There are four distinct marsh types based primarily on vegetation. Vegetation types have been described by Chabreck (1972).[42] Marsh types have been determined based primarily on the salinity of water within the marshlands. The three types represented in Calcasieu Parish are:

- fresh water
- intermediate marsh, and
- brackish marsh

Predominant species of vegetation within the fresh water marshes of the region are Alternanthera philoxeroides (alligator-weed), and Sagittaria falcata (bulltongue) which comprise 48.8% of the vegetation. Other important freshwater marsh vegetation species are: Eleocharis sp. (spikerush), Paspalum vaginatum, and Spartina patens (wiregrass) which comprise 8.5 percent, 5.8 percent, and 7.9 percent of the vegetation, respectively. Others which may be present include waterhyssop (Bacopa monnieri), Bermuda grass (Cynoden dactylon), rattlebox (Daubentonia texana), salt grass (Distichlis spicata), Walter's millet (Echinochloa walteri), soft rush (Juncus effusus), Maidencane (Panicum hemitomon), Bullwhip (Scirpus californicus) (6.7 percent) and Scirpus olneyi (three-cornered grass) (6.2 percent).

Brackish marsh vegetation is dominated (59.8 percent) by Spartina patens. Other species within the environment each account for less than 9.0 percent of the total vegetation. Some of these lesser important species are Distichlis spicata, Bacopa monnieri, Paspalum vaginatum, and Scirpus olneyi.

Avian wildlife within the marshes of the study area is abundant and diverse. Numerous species of passerine birds and waterfowl reside within the area as permanent or transitory residents. Marshland furbearers within the study area are dominated by nutria (Myocastor coypus), northern raccoon (Procyon lotor), muskrat (Ondatra zibethicus) and mink. White-tailed deer (Odocoileus virginianus) are present. Small quadrupeds within the marsh are limited to two species of rabbit (Sylvilagus floridanus and S. aquaticus) and the striped skunk. The diverse wildlife within the marshes include aquatic reptiles and amphibians. The alligator (Alligator mississippenis) and various snakes such as the western cottonmouth (Agkistrodon piscivorus leucostoma) are common.

Cleared Lands

Cleared lands within the Parish include agricultural, suburban, urban, and industrial tracts. These environments do not support a characteristic fauna but they often provide habitats for immigrant species from surrounding areas. Domestic livestock, blackbirds and sparrows are typical wildlife. The most common crops are rice and soybeans. Dominant pasture species are signal grass (Brachiaria platyphylla) and goatweed (Croton capitatus). Several types of improved pasture grasses have been introduced.

Estuarine and Inland Waters

Predominant water bodies within the central part of the parish include Moss Lake, Prien Lake, Lake Charles, the Calcasieu River and the Intracoastal Waterway. Saltwater intrusion has extended as far inland as the Calcasieu River and its tributaries above Lake Charles in the rice growing district.[3] To control this however a saltwater barrier was constructed between miles 38.6 and 43.5 on the Calcasieu River in 1968 and has been in operation since that time.

Diatoms are the most abundant members of both the freshwater and estuarine phytoplankton communities. Coscinodiscus spp. are most frequently reported in freshwater samples. Green algae (Pediastrum and Scenedesmus) are also found in freshwaters. The most common larger freshwater zooplankter in this vicinity is the cyclopoid copepod (Eucyclops agilis) followed by the calanoid copepod (Eurytemora affinis).

Benthic fauna in fresh waters is dominated by chironomid and chaborinid dipterans (true and phantom midges), oligochaetes (worms) and amphipod crustaceans. Freshwater sponges are also abundant.

Major freshwater fish found in the study area include the blue and channel catfish (Ictalurus furcatus and I. puntatus), largemouth bass (Micropterus salmoides), sunfish (Lepomis spp.), gar (Lepisosteus spp.), mosquitofish (Gambusia affinis), Fundulus spp., freshwater drum (Aplodinotus grunniens) and buffalo (Ictiobus spp.). Table 2.12 lists major commercial and sport fishes and their major habitat types in coastal Louisiana.

Spoil and Canal Banks

A small area long the Intracoastal Waterway within Calcasieu Parish is covered by spoil banks (2,892 acres). These spoil banks have not been disturbed by addition of new spoil within at least the past 30 years. Dredged material was placed on both sides of the waterway and is bordered by cleared, generally cultivated land; brackish marsh, intermediate marsh, and fresh marsh. Width of the spoil areas varies from about 100 feet to 1/4 mile. The spoil is not continuous along the Waterway.

Table 2.12 Freshwater Commercial and Sport Fishes in Coastal Louisiana+[44,45,46,50,51]

Name	Status	MAJOR TYPE HABITAT Large River Channels	Small Rivers, Large Tributary Creeks	Oxbow, Swamps, Flood Plain Sloughs Borrow Pitts
Blue Catfish*	U	X	U	X
Channel Catfish*	X	X	X	X
Black Bullhead	X	U	X	X
Yellow Bullhead*	X	U	X	X
Flathead Catfish*	U	X	U	X
Freshwater Drum*	U	X	U	X
Paddlefish	U	X	U	X
Bowfin*	X	X	U	X
Spotted Gar*	X	U	X	X
Alligator Gar*	U	X	U	X
Longnose Gar*	X	X	X	X
Shortnose Gar	U	X	U	X
Carp (Introduced)	X	-	-	-
Smallmouth Buffalo*	U	X	U	X
Bigmouth Buffalo*	U	X	U	X
Gizzard Shad*	X	X	X	X
White Bass*	X	X	U	X
Yellow Bass*	U	X	U	X
Largemouth Bass*	X	U	X	X
Spotted Bass	X	U	X	U
White Crappie*	X	X	U	X
Black Crappie*	X	X	U	X
Warmouth*	X	X	X	X
Bluegill*	X	X	X	X
Redear Sunfish*	X	U	X	X
Green Sunfish	X	U	X	U
Orange Spotted Sunfish*	U	X	U	U
Spotted Sunfish*	X	U	X	X
Longear Sunfish	X	X	X	X
Flier	X	U	U	-

* Species that frequently occur in brackish or saline water.
U - Expected or known occurrences but probably uncommon.
X - Definitely known occurrence and existence of well-established populations.

The vegetation on the banks of the Intracoastal Waterway is dependent on several factors, including time since disturbance, drainage (as influenced by soil characteristics and elevation) and characteristics of the adjacent landscape, especially the salinity of the water. Since little disturbance has occurred for at least 30 years, succession has proceeded to a near climax situation, except on maintained rights-of-way which are periodically moved. From 1000 feet west of Black Bayou Cutoff to the Texas border, right-of-way is maintained by the Colonial Pipeline Company. In these areas, vegetation is kept in an early state of succession by periodic mowing to maintain accessibility to the pipeline.

Dredged material areas support a wide range of species, particularly pioneer species which invade disturbed sites. Taller vegetation in these areas includes eastern baccharis or sea myrtle (Baccharis halimifolia), marsh elder (Iva frutescens), wax myrtle (Myrica cerifera), black willow (Salix nigra), roseau (Phragmites communis), rattlebox (Daubentonia texana), sweet acacia (Acacia angustissima), and bush palmetto (Sabal minor). Shrubs most frequently observed along the Intracoastal Waterway disposal areas are eastern baccharis, marsh elder, and elderberry (Sambucus canadensis). Common ground cover species along the Intracoastal Waterway are blackberry (Rubus duplaris), roseau, ironweed (Sida rhombifolia), broomsedge (Andropogon virginicus), giant ragweed (Ambrosia trifida), common ragweed (Ambrosia artemisiifolia), and comphorweed (Pluchea camphorata). Low-lying disposal areas bordering marshlands often support thick carpets of alligatorweed (Alternanthera philoxeroides) with typical marsh species interspersed.

Embankments of old dredge material, bordering brackish to intermediate marshes support vegetation different from the marshes themselves, including sweet acacia, sedge (Cyperus articulatus), rattlebox, roseau, broomsedge, rushes (Juncus spp.), marsh elder, sea myrtle (Baccharis halimifolia), peppergrass (Lepidium virginicum, and vervain (Verbena brasiliensis). The most common species on disposal sites in brackish areas include marsh elder, eastern baccharis, wiregrass (Spartina cynosuroides) with roseau and soft rush (Juncus Effusus) sometimes assuming dominant status.

Giant cutgrass (Zizaniopsis miliacea), elephant's ear (Colocasia antiquorum), and black willow often dominate the fresh marsh/canal interface along the Intracoastal Waterway disposal areas in fresh marsh situations, tallow tree (Sapium sebiferum) often dominates some of the better-drained disposal areas.

Some dredged material disposal areas along the Intracoastal Waterway are currently being managed for improved pasture with vegetation being similar to other managed coastal pastures, including such species as Bermuda grass, St. Augustine grass (Stenotaphrum secundatum), white clover (Trifolium repens), reversed clover (Trifolium resupinatum) and various weedy annuals.

Dredging along the Calcasieu Ship Channel up to the level of the salt water barrier, which spans the Calcasieu River above Lake Charles, occurs on a variable basis. Spoil banks in various stages of revegetation are present along nearly the entire extent of this channel in western Calcasieu Parish in close proximity to the lakes (Moss Lake, Prien Lake, Lake Charles) along it. Revegetation results in generally the same plant types as those present on spoil banks along the Intracoastal Waterway. Plant populations usually develop within 12 to 18 months following deposition of new sediment.

A number of canals have been dredged in approximately the southern two-thirds of western Calcasieu Parish. The levees produced as a result support vegetation similar to that of natural levees[44] if they are not mowed. This generally could include loblolly pine, water oak, cherry, bark oak, overcup oak, red gum, persimmon, hackberry, and butter pecan and other trees.[47]

2.4.1.2 Ecosystems through which the Oil Distribution Lines in Texas would Pass.

Within Texas the project's oil distribution pipelines would pass through marsh, former prairie, gum-oak cypress groves, pine forest, other wooded land, and open water. The biota of these ecosystems is similar to that described for the same types of ecosystems in Calcasieu Parish, Louisiana. The general biotic characteristics of Orange County are presented in Figure 2.22.

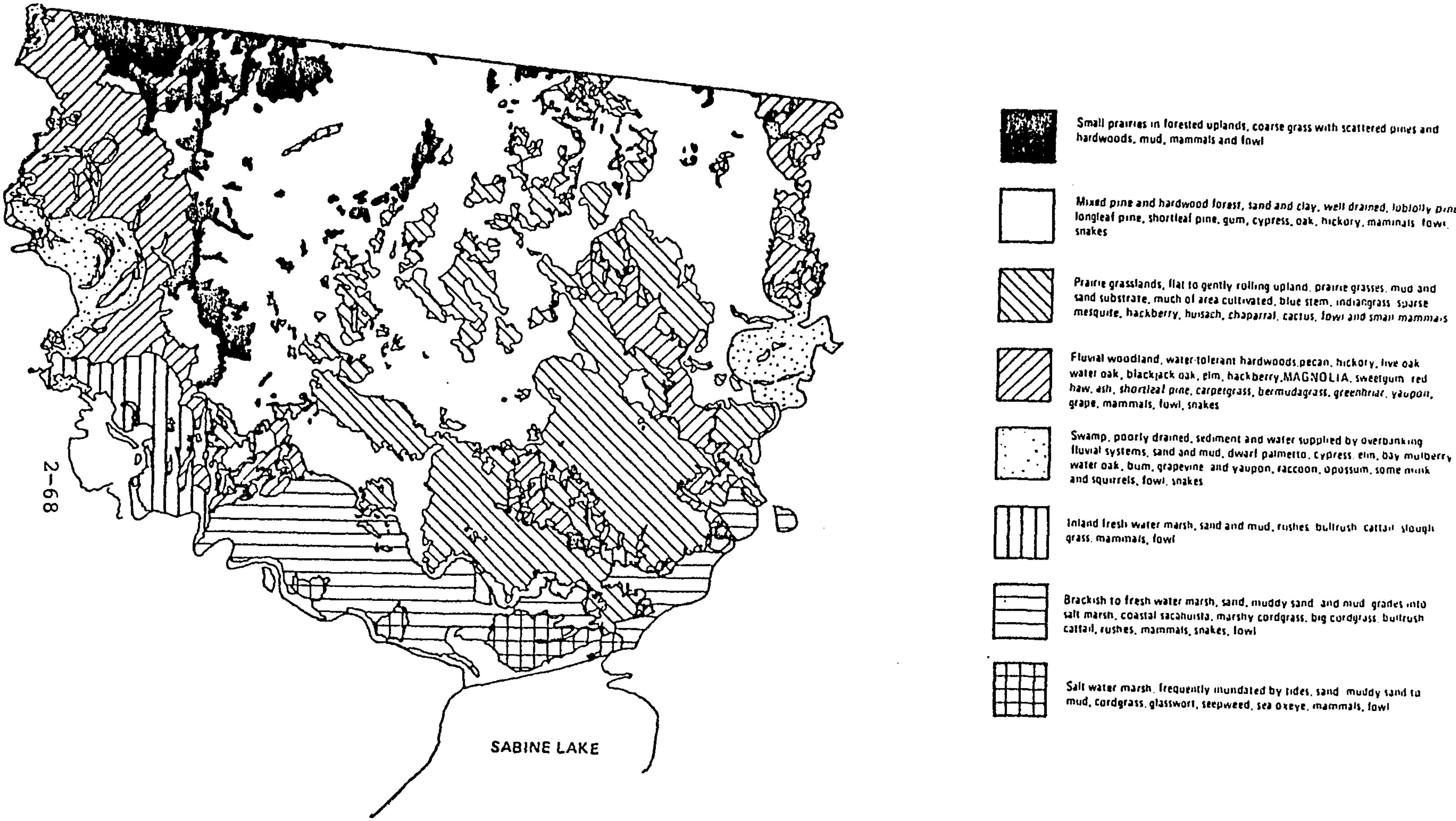

Figure 2.22 Generalized Biotic Divisions of Orange County, Texas

2.4.1.3 Endangered and Threatened Species of the Study Area

At the present time, the U.S. Fish and Wildlife service does not recognize any plant species in Calcasieu Parish, Orange County, or Jefferson County as being endangered or threatened. However, the Rare Plant Study Center at the University of Texas in Austin has described seven species found in Jefferson County and three species found in Orange County as being rare threatened or endangered for the State of Texas. They are:

Jefferson County

Aureolaria dispersa (Beaumont aureolaria)
Carex alboutescens (yellow-white sedge)
Carex gracilescens (slender sedge)
Carex physorhyncha (hidalgo sedge)
Carex tribuloides (sand sedge)
Carya myristicaeformis (nutmeg hickory)
Thelypteris palustris var. *haleana* (southern marsh fern)

Orange County

Conyza bonariensis (Buenos Aires conyza)
Ilex verticillata (black alder)
Ruellia pinetorum (pinebarren ruellia)

At the current time the Rare Plant Study Center is considering only two of these species for submission to the Office of Endangered Species, Fish and Wildlife Service. *Ruellia pinetorum*, a member of the Acanthus family, occurs in low pine barrens of the coastal plain. *Aureolaria dispersa* is found in sandy thickets and oak lands and has been known to occur along streams in the long-leaf pine belt.[48]

Endangered or threatened animal species which at one time inhabited the area, or which are currently present, include: the red wolf (*Canis rufus*), brown pelican (*Pelecanus erythrorhynchos*), masked duck (*Oxyura dominica*), bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), Atwater's greater prairie chicken (*Tympanuchus cupido*), whooping crane (*Grus americana*), red-cockaded woodpecker (*Dendrocopus borealis*), ivory-billed woodpecker (*Campephilus principalis*), and the American alligator (*Alligator mississippiensis*).

The red wolf is on the verge of extinction. The U.S. Fish and Wildlife Service is trapping the remaining individuals of the species to attempt to establish them elsewhere, where a greater amount of suitable habitat is available. The brown pelican and the bald eagle are slowly recovering from a decline caused by food-chain accumulation of chlorinated hydrocarbons. The whooping crane, ivory-billed woodpecker, and Atwater's greater prairie chicken are no longer present in the area. The masked duck, peregrine falcon, and red-cockaded woodpecker have been sighted very infrequently.

Information on sightings of uncommon birds in the coastal marsh areas was provided by an official of the National Audubon Society.[49] These sightings include records of the great kiskadee (Pitangus sulphuratus), and white-winged dove (Zenaida asiatia), species which are more common in Mexico. The black francolon (Francolinus francolinus), a pheasant-like bird, has also been sighted in the area. It is not native to the U.S., but has established a breeding population in the higher ground in Gum Cove, 5 miles northeast of Black Bayou. Another bird, Audubon's caracara (Caracara cheriwan), has been observed for a number of years in the vicinity of the Intracoastal Waterway south of Toomey, Louisiana. Indications are that there are a pair of Caracara and they would represent the northernmost occurrence of this species in the U.S. as permanent residents. The waterways in this area have also become a desirable habitat for the fish crow (Corrus ossifraqus), and olivaceous cormorant (Phalacrocorax olivaceus). They are very abundant around Sabine River and Sabine Lake all winter and are uncommon for many miles to the east and west.

The status of the American alligator is unique in Cameron, Vermilion, and Calcasieu Parishes in Louisiana. In other areas of the United States, the alligator is either classified as threatened or endangered. These status listings prohibit activities which would adversely affect this animal. But because of its abundance in Cameron, Vermilion and Calcasieu parishes, the alligator is listed as threatened there only due to the 'similarity of appearance' provision: Section 17.42 of CFR 50 allows the taking of the American Alligator in these parishes, in accordance with State law. Controlled harvesting has been permitted in Calcasieu Parish and the other parishes referred to above. The status of the alligator in Texas has recently been changed from "endangered" to the less restrictive "threatened" classification.

2.4.1.4 Commercially Important Species

The vegetation of primary commercial interest is found in the prairie region of the study area and consists of agricultural products, in particular rice. Soybeans are another crop of importance, but are secondary to rice. Of those farms registered with the U. S. Department of Commerce, Bureau of the Census in 1969, Calcasieu Parish had 75,316 acres planted in rice, 29,100 acres of soybeans, 5,029 acres of hay, 294 acres of sorghum, 283 acres of corn and 41 acres of wheat.[55] Most of the longleaf pine forests in Calcasieu Parish were cut for timber production several decades ago. Some of the land has been reforested. The area surrounding the salt dome is woodland. The important crops in Orange County are generally the same as those which are important in Calcasieu Parish.

Fur and fisheries harvests are not very important in the areas which would be impacted by the project. Cattle grazing is very prevalent in the area.

2.4.1.5 Vectors

There are several species found in the aquatic and semiaquatic ecosystems of the proposed project area which are of concern because they are vectors, (potential carriers of disease). The organisms of concern include four genera of mosquitos (Anopheles spp., Culex spp., Aedes spp., and Psorophora spp.), horse flies (Tabanus spp.), and deer flies (Chrysops spp.). These are biting insects which can transmit pathogens to humans and animals.

The Anopheles mosquitos are carriers of the protozans which cause malaria. Encephalitis, which can affect humans and horses, can be caused by mosquitos of the Culex and Aedes genera. Anthrax, which affects both man and animals is carried by certain species of horse flies. Livestock diseases such as anaplasmosis and swamp fever (infectious anemia) can be carried by deer flies.

The larvae of all of these genera are aquatic, requiring a permanent or slow moving aquatic habitat in which to develop. The actual habitat requirements and length of development vary from species to species. Concern is often raised when a construction project may permanently increase standing water, thereby creating new habitats for these organisms and increasing the risk of disease for man and animals. Standing water can be created by altering surface drainage patterns, by improper backfilling of canals and other areas of excavation or by closing off portions of a waterbody which previously were subject to regular flushing action.

2.4.2 Environmental Setting of the Sulphur Mines Site

The proposed Sulphur Mines Dome storage facility site covers approximately 1,500 acres in central Calcasieu Parish. The dome is dry to marshy with elevations ranging from 12 to 18 ft. mean sea level (MSL). Lowest elevations occur over the center of the dome where subsidence has occurred. This area is pumped to keep it dry. Much of the surrounding area is covered with mixed pine and deciduous forests (see Figure 2.23).

The surface at the site has been altered in various industrial uses. Sulfur mining was carried out in the past. Presently the site is utilized for hydrocarbon product storage and for brine feedstock production. A network of gravel roads services most of the dome. Large, shallow ponds with a total surface area of about 252 acres have been dredged on the periphery of the dome.

2.4.2.1 Terrestrial Ecology

The Sulphur Mines Dome is located in an area which historically was prairies and mixed deciduous and longleaf pine forest. At present, the prairies have been replaced with cropland and pastureland, and longleaf pine shares dominance with loblolly and slash pine. The dome and immediate vicinity is now covered by pastureland, mixed pine forest, and developed parts and bare areas. Some of the bare areas were used for sulfur stockpiling and are essentially barren.

The forests in the dome vicinity have been managed for some time. The Sulphur Mines owners, Union Texas Petroleum have timber holdings to the east. Hunter Oil Company, American Oil Company and Powell Lumber Company also have holdings nearby. Although mainly mixed pines, these forests include about 10 percent hardwoods.[57] The typical shrubs of pinelands include saw palmetto (*Screnoa repens*), wax myrtle (*Myrica* spp.), gallberry (*Ilex* sp.) and St. Johnswort (*Hypericum* spp.). Common herbs are violets (*Viola* spp.) and yellow-eyed grass (*Xyris iridifolia*).[40].

The prairie type vegetation is primarily found in pastureland adjacent to the site. Cattle are grazed near the airstrip to the west, to the north of the airstrip, and to the east of the dome where the former sulfer workers' camp was located. They are also pastured in surrounding west and north about 3 to 3 miles away and soybeans are raised about 3 miles to the south. Natural prairie vegetation found at the site is predominantly switch grass (*Panicum virgatum*), big bluestem (*Andropogon* spp.), Indian grass (*Sorghastrum avenaceium*), and prairie wildgrass (*Sphenopholis obtusata*). However, improved pastures are

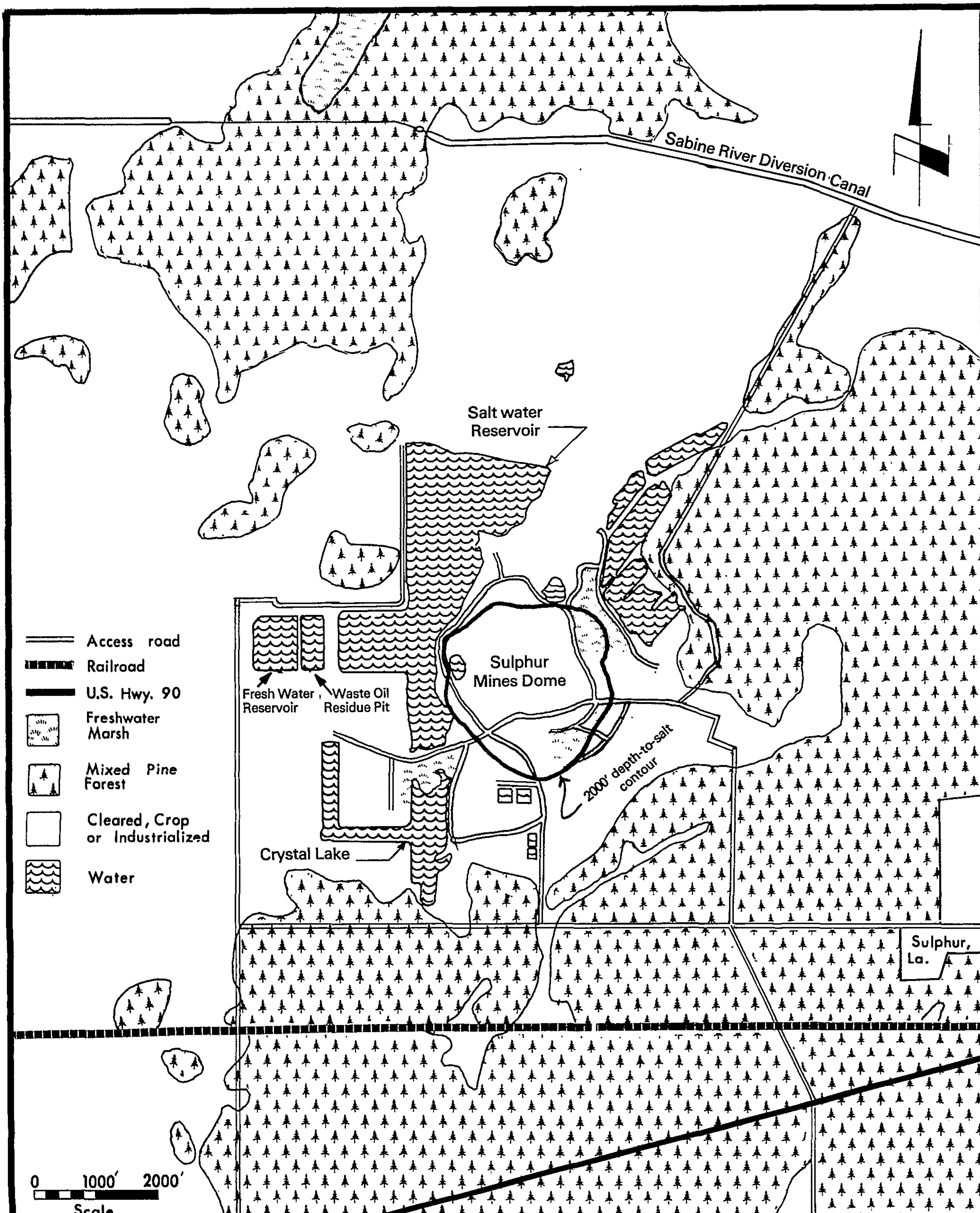

Figure 2.23. Vegetation and other features surrounding the Sulphur Mines salt dome, Calcasieu Parish, Louisiana.

likely to have ryegrass, coastal Bermuda, and/or lespedeza. The mixture of two or more vegetation types as is found at the site provides an edge effect which attracts some wildlife, such as bobwhite, which may not be found in any one vegetation type alone. In some instances these animals may be found in one vegetation type but are more abundant near the edge where both types may be utilized for feeding, cover, and/or nesting.

Common bird residents of the woodland prairie vegetation mixture are the Eastern meadowlark (Sturnella Magna) American robin (Turdus migratorius), downy woodpecker (Dendrocopus pubscews), red-bellied woodpecker (Centurus carolinus), hairy woodpecker (Dendracopos villosus), Carolina chickadee (Parus carolinensis), tufted titmouse (Parus bicolor), Carolina wren (Thryothorus ludovicianus), and red-shouldered hawk (Buteo lineatus).[40]

Mammals of the vicinity are the white-tailed deer, raccoon, fox squirrel, cottontail rabbit, opossum, striped skunk, armadillo, southern flying squirrel, white-footed mouse, and bobcat.[40]

Typical herptofauna of the site may include king snakes (Lampropeltis spp.), many species of turtles (Graptemys spp., Malaclemys spp., and Terrepene spp.), and several species of toads and frogs (Bufo spp., Hyla spp., and Rana spp.).[40]

2.4.2.2 Aquatic Ecology

Surface water on the Sulphur Mines storage facility site includes several large, shallow ponds (totalling about 252 acres) around the edges of a central subsided area and marshy areas on the north and east within the incomplete ring of these ponds. There also is marsh at the north end of an arm of a pond on the southwest edge of the area. This 40-acre pond and six others totalling about 40 acres have developed into excellent fishing habitats. The latter 6 ponds flank the east side of the dome. The 40-acre pond has an average depth in different parts ranging from about 10 to 19 feet. The mean depth of the other ponds is about 8 feet. These ponds were created during the early period of sulfur mining which ceased in the 1920's (except for a 3-year period in the late 1960's). Typical freshwater marsh plant species should be present in the marshes and in the ponds. The main species in this type of marsh are listed in the text under Marshlands in Subsection 2.4.1.1.

The main species of fish present include crappie, largemouth bass, sunfish, gar and carp (Cyprinus carpio)[57] Other fish which may inhabit the ponds include bowfin (Amia calva) and catfish (Ictalurus spp.).[44]

Alligators are present but are unobtrusive. Nutria and raccoons are sometimes found in the marshy areas. Ducks are sometimes present in the marshes also, and on the water. Water snakes such as Natrix spp. and water moccasins, turtles and amphibians (cited in Section 2.4.2.1) are no doubt present.

Benthic invertebrates known to occur in similar water bodies include the dipteran larvae Procladius spp., Cryptochironomus spp., and Bezzia spp.; the oligochaete worms (Limnodrilus spp. and Peloscolex spp); and the amphipod Corophium spp.[44]

Common zooplankton in the area include the copepod genera Eucyclops, Eurytemora, Diaptomus and Cyclops, the dipteran larvae Chaoborus spp., the cladocerans Bosmina and Daphnia; and the rotifers Brachionus, Keratella, Platyias and Kellicottia.[44]

The most common phytoplankters found in ponds of this type include the diatoms Melosira spp., Coscinodiscus spp. and Pleurosigma spp., the green algae Scenedesmus spp., Pediastrum spp. and Staurastrum spp., and the blue-green algae Anabaena spp. and Oscillatoria spp.[44] Other genera which may be present include the diatoms Asterionella, Tabelloria, and Fragiloria; Chrysophyceae such as Dinobryon and Uroglena; colonial green algae such as Volvox, Pandorina, and Eudorina; dinoflagellates such as Ceratium and Peridinium; and others.[58]

2.4.3 Environmental Setting of the Displacement Water Source

Displacement water would be pumped from the 162 acre Salt Water Reservoir on the western edge of the salt dome, when it becomes desirable to recover stored crude oil from the five Sulphur Mines storage caverns. This relatively shallow pond was formerly used as a brine holding pond but is now essentially fresh and supports fish and a few aquatic macrophytes. Most of the land immediately bordering this pond is cleared and disturbed. Replenishment water for the reservoir would ultimately be obtained from the Sabine River by a pipeline-canal complex (see Section 1.3.2). Land adjacent to the Sabine River Diversion System main canal (formerly Houston River Canal) is mostly agricultural.

Rice growing and cattle-raising predominate along a 25 mile section of this canal; 5 miles of the canal border wooded areas and 2 miles border residential areas.[59] Present construction activities on the canal have disturbed vegetation and wildlife and affected water quality.

2.4.4 Environmental Setting of the Brine Disposal Area

Displaced brine from the caverns would flow into a 100,000 barrel brine pond to be constructed on 3.7 acres of cleared land before being injected deep underground. This area is highly disturbed and virtually barren due to previous use as a sulfur stockpile area. A retention dike and pumping facility would also be placed in this barren area. Brine would be pumped via a pipeline to a disposal field southwest of the dome. This disposal field would be located primarily in mixed pine forest with the disposal wells adjacent to an Highway 90.

2.4.5 Environmental Setting of the Pipelines

A pipeline network would be required for distribution of the displacement water utilized during recovery operations. Land requirements for pipelines have not been finalized, but the displacement water pipeline is projected to connect to the Sabine River Diversion Canal north of the Salt Water Reservoir. The pipeline would cross marsh and partially cleared mixed woodland just north of the reservoir.

The crude oil line would pass to the southwest from the storage site across roads, miscellaneous dry land, cultivated areas, wooded areas, marshland, spoil banks, and inland water in its passage to the Intracoastal Waterway. An ecological description of the systems through which the oil distribution pipelines will cross is presented in Sections 2.4.1.1. and 2.4.1.2. The total length of the proposed oil distribution pipeline is 17 miles, however, the initial 2.2 miles would utilize the same right-of-way as the brine disposal pipeline.

The route would leave the southern side of the central plant area and follow the western side of the site access road 0.3 miles to a paved parish road. The route would cross the road and enter woodland for 0.4 miles to the Southern Pacific Railroad. It would cross the railroad and continue for another 1.6 miles to Interstate Highway 90. After crossing Route 90, the pipeline would traverse 0.8 miles of cleared land and on across through 0.6 miles of woodland to Bayou Choupique. After entering 0.2 miles of woodland on the other side of the Bayou, the route would cross 0.4 miles of pasture and another 0.5 mile of woodland. At this point the pipeline would cross Interstate Highway 10.

The highway has a wide median at this point and the crossing would be 0.1 miles wide. After crossing 1.7 miles of primarily cleared agricultural land, the route would cross Wing Gully, a small stream. On the other side of this water crossing the route would pass 0.8 miles through a small pasture and a rice field to a medium duty parish road. From there the route would cross 0.9 miles of pasture before crossing an abandoned canal. Then 1.5 miles of mostly high dry pasture would be crossed, also including a private road and a Gulf State Power transmission line along the way, to Spring Gully. The route would continue across this small stream and 0.3 miles of pasture to Highway #108.

Continuing across the highway and 3.3 mile of mainly pasture land, crossing one small creek and several drainage ditches, the route would come to another parish road. After extending across the road and 1.4 miles of pasture, the route would turn due south crossing 0.3 miles of marsh and another 0.8 miles of dry pasture land. Then turning in a southwesterly direction, it would pass through 0.1 mile of marsh and 0.7 mile of dry land, crossing one farm road, to the north bank of the Intracoastal Waterway. Another 0.4 miles would take the route across the waterway and southern spoil bank to the point of intersection with the other proposed pipeline. See Table 1.3 for a summary of the land types which would be affected by this pipeline connection.

From this point, the proposed mainline ESR pipeline between West Hackberry and the Sun Terminal would be used. See the supplement to FES 76/77-4 for a description of this pipeline route and the Sun Terminal facilities. The distance from the intersection to the terminal is 34.4 miles and the total length of the new connection would be 14 miles, for a total distance of 48.4 miles between Sulphur Mines and the Sun Distribution Terminal.

2.5. SOCIOECONOMIC CHARACTERISTICS

2.5.1. Population

2.5.1.1 Population Density

The storage site is located in the central area of Calcasieu Parish, which lies within the Southwest Louisiana Planning District. The pipeline which would carry oil to and from the storage site would lead southwestward from Sulphur Mines to a point near Cameron Parish where it would be connected to a planned oil pipeline that terminates at the Sun Oil Terminal in Nederland, Texas. Local impacts from the project are expected to be confined to Calcasieu and Cameron parishes. Table 2.13 shows the population density of the two parishes and the State of Louisiana, and the proportion of urban and rural components. Cameron Parish is shown as being entirely rural because it has no communities with populations over 2,500. The project site is in a rural area surrounded by woodlands.

2.5.1.2 Towns and Urban Areas

The major city in the area is Lake Charles, about 13 miles east of the site. Along the corridor between the storage site and the city lie several towns: Westlake, 8 miles distant; Hollywood, 4 miles; Sulphur, 2 miles; and residential developments: Mossville and Maplewood. Lake Charles and Sulphur are expected to bear the greatest impact from the project. Figure 2.24 shows the centers of population in relation to the site. Towns to the north and west include: DeQuincy, 16 miles; Starks, 16 miles, and Vinton, 12 miles away. Carlyss is a residential area 6 miles southeast of the proposed storage site. Calcasieu Parish lies on the border of the State, and Orange, Texas is 25 miles from the site, across the Sabine River.

Sulphur

Some of the work force for the project will come from Sulphur. This town takes its name from the sulfur that was produced at the salt dome. The Sulphur Mines started as a conventional mining operation in the 1880sand large numbers of Mexicans came to town for the work. Conventional mining methods failed, many miners were killed, and the operation was forced to close. However, the Frasch method of sulfur production was put into practice in the 1890s, and continued until 1924 when the sulfur deposits were practically exhausted. The city has grown rapidly since the 1940s due partly to the establishment of oil refineries and petrochemical industries at Lake Charles, and partly to its own annexation

Table 2.13 Population Density of Surrounding Parishes

	Calcasieu	Cameron	Louisiana
Population			
total	145,415	8,194	3,643,180
per square mile	131.6	5.7	
Rural Population			
farm	1,171	894	113,757
non-farm	35,816	7,300	1,118,627
Urban Population			
% rural	25.2	100.	23.9
% urban	74.8	0	66.1

Source: Statistical Profiles of Calcasieu and Cameron Parishes, published by the Public Affairs Research Council, Inc., Baton Rouge, Louisiana, 1973.

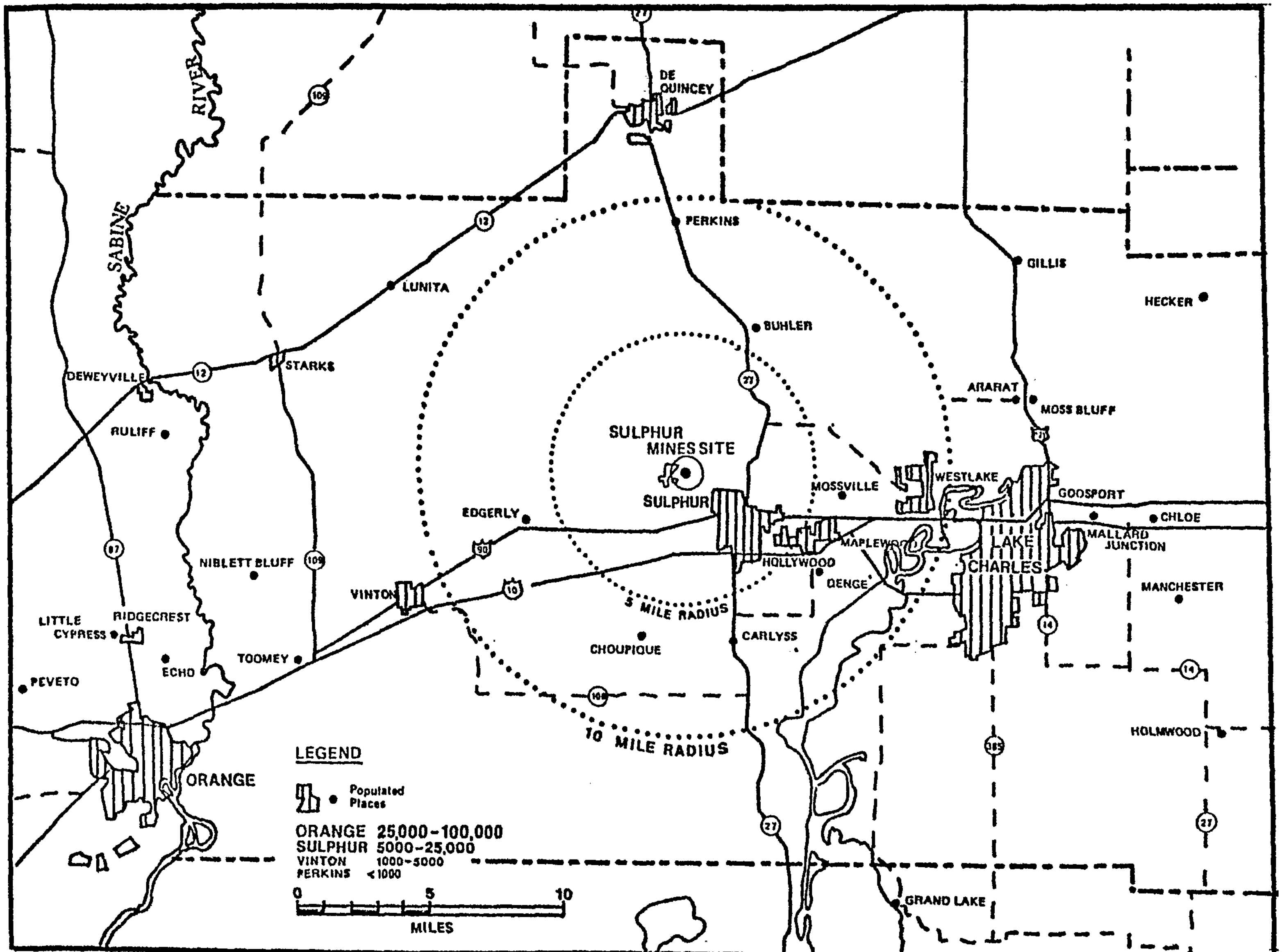

Figure 2.24 Population Centers Surrounding the Sulphur Mines Site.

of surrounding territory and expansion of municipal services. The city now occupies slightly over 8 square miles. The population was registered as 15,247 in 1970, a local census taken in 1972 recorded 18,007 persons, and it is estimated that the 1975 population was over 20,000.

Lake Charles

The population of Lake Charles was about 78,000 in 1970 and has been projected to be about 85,000 in 1975.[63] It is a major manufacturing center, particularly for the chemical industry, and an important port for the region. A deep water channel has been dredged through Calcasieu Lake and the lower portion of the Calcasieu River to connect Lake Charles with the Gulf of Mexico, 34 miles south. The lake and city are named for one of the early French colonists, Charles Sallier. Lakes Charles became the parish seat for Calcasieu Parish in 1852.

2.5.1.3 Historical Growth and Trends

Population growth and projections for the area are shown on Table 2.14. The population of Calcasieu Parish increased by 62.3 percent between 1950 and 1960, but marginally declined between 1960 and 1970. During this period of decline for the parish, however, Sulphur grew by 33 percent and Lake Charles by 23 percent. Cameron Parish increased by 10.7 percent between 1950 and 1960, and by 18.6 percent between 1960 and 1970.

Population projections for Calcasieu Parish vary greatly because of uncertainties as to whether the decline noted between 1960 and 1970 will continue. Recent estimates by the Louisiana Technology College of Administration and Business, in cooperation with the U.S. Census Bureau indicate a 3.5 percent increase for Calcasieu Parish in the 5 years since the 1970 census, and a population of about 150,520 in 1975. This compares with a 3.5 percent increase for the Southwest Louisiana Planning District as a whole, and a 4.1 percent increase for the state during the same 5 year span.[64]

2.5.2 Cultural Patterns

For a number of years, Sulphur Mines, Louisiana was the largest complex of sulfur mines in the world. A village was constructed at the site to house the mine workers, and a number of homes remained until the early 1950s when they were sold and removed, leaving only the traces of streets and the empty shells of two small concrete dormitories.

Table 2.14 Population and Population Projections, by Parish

	Calcasieu	Cameron
1950		
Population	89,635	6,244
1960		
Population	145,475	6,909
% change	62.3	10.7
1970		
Population	145,415	8,194
% change	(-0.1)	18.6
1978		
Series E*	135,000	7,600
Series C*	153,000	8,600
Statistical Abstract	163.382	9,304
1990		
Series E*	138,000	7,800
Series C*	160,000	9,000
Statistical Abstract	181,647	10,617

*Figures are based on BEA Areas 138 and 139 and provide only the first three significant figures.

Sources: Dept. of Commerce, Bureau of the Census, Characteristics of the Population, 1960 and 1970; U.S. Water Resources Council, OBERS Projections, Regional Economic Activity in the U.S. Series C, 1970; U.S. Water Resources Council, OBERS Projections, Regional Economic Activity in the U.S., Series E, 1972; Louisiana State University, Division of Business and Economic Research, 1974 Statistical Abstract of Louisiana, 5th Edition.

The culture of the area is a unique combination of Western and French influence. Sulphur hosts a number of rodeos, including those for youth clubs and for professional competitors. The number of French speaking people in Sulphur is about 14.8 percent, compared to 23.8 percent in Calcasieu Parish and 42.4 percent in Cameron Parish.

The Lake Charles area was settled by a mixture of English, French, Spanish and Dutch colonists. When the city of Lake Charles was primarily a lumber port, the citizens were predominantly Anglo-Saxon. A later influx of French people from the east and central parts of the state has resulted in the city now having almost an equal mixture of Anglo-Saxon and French cultural influence.

2.5.3 Community Services

2.5.3.1 Housing

The housing situation in Calcasieu Parish reflects its population pattern. There was a sharp increase in population and housing between 1950 and 1960 followed by a period during which the parish grew far more slowly than neighboring parishes and the state. During the decade of 1960 and 1970, the number of year-round housing units in Calcasieu Parish increased only 4.6 percent, and its median value of housing (which is just under the state median) increased by 16.22 percent, or less than half the increase experienced in the state.

The number of housing units, occupancy, and availability of housing in Calcasieu and Cameron Parishes and in Lake Charles are shown on Table 2.15. The vacancy rate indicated on these tables include a number of housing units that do not have all the standard plumbing facilities, i.e., hot and cold water faucets in the structure, flush toilet, and bathtub or shower. The vacancy rate of units with complete plumbing facilities is not available but can be assumed to be lower than the vacancy rate of all units.

The median value of owner-occupied units in Cameron Parish is substantially below that of the state: $8,800 compared to $14,600.* A comparison of the percentages of increase in housing value between 1960 and 1970 shows that values are rising slightly faster in Cameron Parish than in the State. Also, the growth in the number of year-round housing units in Cameron Parish is 35.4 percent in that same time period, and is comparable to the 36.4 percent growth rate for the state.

2.5.3.2 Education

The public school system in Calcasieu Parish is the fifth largest in the state. The number of public and private schools in the parish is as follows:

	Public	Private**
Elementary	37	7
Jr. High School	16	
Sr. High School	14	1
Pupil Enrollment	38,300	3,000

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*Based on one-family houses on less than 10 acres and excluding mobile homes.

**Includes grades 1-8 in elementary schools and 9-12 in high school.

Table 2.15 Housing Units and Occupancy, by Parish

	Calcasieu	Cameron
Year-round Housing Units	45,461	3,098
Occupancy and Tenure		
Occupied Dwelling Units	42,065	2,310
Owner-Occupied	29,922	1,774
Renter-Occupied	12,143	536
Lacking Some or All Plumbing Facilities	2,865	476
Vacant For Sale or Rent	2,007	121
% Vacant For Sale or Rent	4.4	4.0
Median Value (Owner Occupied)	$12,900	$8,800

Source: 1970 Census of Housing

	Lake Charles
Year-Round Housing Units	24,893
Owner-Occupied	14,887
Renter-Occupied	8,186
For Sale	337
Homeowner Vacancy Rate	2.2
For Rent	1,014
Rental Vacancy Rate	11.0
With All Plumbing Facilities	948
Mobile Homes or Trailers	235
Owner-Occupied	192
Renter-Occupied	43

There is also a private academy for grades 1-12 with an enrollment of about 200 students. The number of students per teacher in the public schools of Calcasieu Parish is 23.2 at the elementary grade level and 19.4 at the secondary level.[65] This compares favorably with the Louisiana State guidelines which recommend a maximum of 27 pupils per teacher at the elementary grade level and 25 per teacher at the secondary level. Sulphur public schools have an enrollment of 6,365 pupils, and the church-supported school has 230 students.

There are about 5 industrial and technical schools in Lake Charles area, including proprietary institutions and public vocational centers.

McNeese State University offers a variety of higher education programs. It is located in South Lake Charles, and has an enrollment of about 5,700 students. The university started in 1939 as a junior college affiliated with Louisiana University. Two-year degree programs are available in the Department of Technology and the School of Continuing Studies. Higher degree programs include: bachelors degrees in both arts and sciences, a variety of masters programs, and doctorates in education.

2.5.3.3 Police and Fire Protection

The police department in Sulphur is equipped with six patrol cars and two motorcyles. In Lake Charles, there is a force of 75 uniformed police officers, with additional guards for night security patrol, school crossings, and shoplifting detail.

The Calcasieu Parish Sheriff's Department will have jurisdiction in the site area and pipeline rights-of-way. In Cameron Parish, the sheriff's deputies hold full time jobs in addition to their law enforcement duties.

Fire protection equipment would be provided at the site for all buildings and installations. Auxiliary fire-fighting assistance would be available from the three fire stations at Sulphur. The municipal fire department at Lakes Charles has a staff of 111 paid firemen to serve the community.

2.5.3.4 Hospitals and Medical Personnel

The hospital facilities nearest the site are located at Sulphur where the West Calcasieu-Cameron Hospital offers operating facilities, an intensive care unit, and an emergency department. It has 111 beds, a 262 member staff, and an ambulance service affiliated with it.

Lake Charles has 3 hospitals; Lake Charles Charity Hospital with 110 beds; Lake Charles Memorial Hospital with 227 beds; and St. Patrick Hospital of Lake Charles with 246 beds.[67] An independent ambulance service operates out of Lake Charles.

This area is part of the Lake Charles Health Service Planning Region, which includes Beauregard and Jefferson Davis Parishes as well as Cameron and Calcasieu Parishes. Medical services for this region are concentrated in the Lake Charles metropolitan area, which is centrally located in the region. A study of health services relative to population shows this region to be below the national norm in availability of medical and health practitioners, but it compares well with other regions of Louisiana.[68]

2.5.3.5 Civic and Recreational Facilities

There are 7 civic organizations in Sulphur. The recently founded Brimstone Historical Society is collecting information about the history of western Calcasieu Parish and developing a museum.* Several historical markers have been placed by the society. Sulphur maintains the Frasch Park which covers 191 acres in the southwest part of the city and offers a variety of recreational facilities.

There are a number of community-sponsored cultural activities in Lake Charles, such as a civic orchestra, choir, drama groups, and associations to promote concerts, exhibits, and art educational programs in the city. McNeese State University also sponsors cultural activities and sports events.

In addition to boating and swimming, major forms of recreation include hunting and fishing. Statistics for the 1970-71 hunting and fishing season show that well over 1,600 resident hunting licenses were issued in Cameron Parish, or about 1 for every 5 persons, while in Calcasieu Parish, the ratio was slightly less than 1 license for every 8 persons.

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*Mr. Glen Bonin, President and Founder of the Brimstone Historical Society, was contacted regarding the relationship of the society to the remains of a community named "Brimstone" which lies within the storage site. That community housed 200 to 300 people who worked in the sulfur production operations. The homes were removed around 1952, leaving only traces of streets and two empty concrete dormitories. The Brimstone Historical Society chose its name only because "brimstone" was the old common term for sulfur.

Calcasieu Parish issued over 4,700 big game licenses that year, more than were issued in any other coastal parish. The two parishes together issued over 2,000 licenses for nonresident hunting trips, more than a quarter of all such licenses issued in the state.[69]

Fishing is especially important in Cameron Parish, where over 4,000 resident fishing licenses were sold (although the population of the parish is only about twice that number). While Calcasieu Parish sold over 9,000 fishing licenses, the ratio of licenses to population is only 1 to 16. A large number of licenses are also granted for nonresident fishing trips.

2.5.4 Economic Characteristics

2.5.4.1 Basic Economy of the Area

Minerals

Louisiana is a major oil producing state and has almost one-third of the total U. S. reserves of natural gas. For the state as a whole, onshore levels of oil and gas exploration and production are gradually dropping while offshore levels increase. Its natural gas reserves and number of new gas wells completed per year have remained fairly constant, while oil reserves have begun to show a decline. The importance of this industry to the state is revealed by the fact that during the 6 year period from 1964 to 1970, the State of Louisiana received about 27 percent of its total revenues from severance taxes on mineral production and from mineral leases.[70]

The extraction of petroleum and natural gas ranks as the primary income-producing industry in Cameron Parish. Over $10,000,000 in severance taxes were collected each year in the 5 year span from fiscal year 1966-67 through 1970-71, and over 90 percent of this was derived from oil and gas production. Revenue from gas extractions is about twice that derived from oil.[71] Cameron Parish far exceeds Calcasieu in the production of petroleum and gas, as shown on Table 2.16, and its economy is much less diversified. The value of all mineral production in the two parishes for the years 1969 through 1971 is shown on Table 2.17. Cameron Parish is one of the ten leading parishes in production of oil and gas in Louisiana, but the reserves of these commodities are greater in the coastal parishes farther east.

In addition to direct employment in the oil and gas fields, a substantial number of persons are employed in those industries that service the actual production.

Table 2.16 Production of Crude Oil, Condensate, Casing Head Gas and Natural Gas.

	Calcasieu		Cameron	
	1971	1972	1971	1972
Crude Oil (barrels)	6,599,966	7,117,785	15,648,933	12,766,896
Condensate (barrels)	3,102,304	2,710,327	6,642,130	4,267,184
Casing Head Gas (Mcf, 15.025#Abs.)	4,961,691	4,369,532	19,234,167	16,247,238
Natural Gas (Mcf, 15.025#Abs.)	64,370,789	54,636,536	553,602,819	393,403,690

Table 2.17 Value of Mineral Production

	Calcasieu	Cameron	State
Minerals listed in order of their importance in the economy	Petroleum Natural Gas Natural Gas Liquids Lime Salt Sand & Gravel	Natural Gas Petroleum Natural Gas Liquids Salt Shell	
1969*	$61,156,000	$270,883,000	4,685,326,000
1970**	$66,168,000	$289,105,000	5,102,321,000
1971**	$63,506,000	$312,357,000	5,553,009,000

* U.S. Dept. of Interior, Bureau of Mines. Minerals Yearbook, 1969, Vol. II, Area Reports: Domestic, "The Mineral Industry of Louisiana, Washington, D.C.

** Area Reports: Domestic, p. 337-354. U.S. Dept. of the Interior, Bureau of Mines. Minerals Yearbook, 1971, Vol. II, "The Mineral Industry at Louisiana" by David A. Carleton and Leo W. Hough, Washington, D.C. 1973.

Source: Corps of Engineers - Baton Rouge - New Orleans Inventory

Manufacturing

In 1946, Louisiana passed a law to exempt new industries from direct taxation for a period of 10 years. Gas fields led to the growth of industry in the state. The greatest single source of employment in Calcasieu Parish is manufacturing, which accounts for about 10,000 jobs in the parish, and a payroll of about $27 million. The manufacture of chemicals and allied products comprises more than a third of this employment.[72] Among the local industries that each employ 500 people are: Cities Service Oil Company, Continental Oil Company, Firestone Synthetic Rubber and Latex Co., Conaco, Olin Corporation, and PPG Industries.

Other manufacturing industries in Calcasieu Parish include: lumber and wood products, fabricated metal products and machinery, building materials, and food products, especially dairy goods. The primary manufacturing industry in Cameron Parish is the processing of fish: two firms produce packaged fish, fish oil, and fishmeal fertilizer.

Fishing

Louisiana is the leading state in the nation in terms of the volume of commercial landings of fish and shellfish, though it ranks third (after Alaska and California) in the dollar value of these products. In 1973 and 1974, the commercial catch exceeded one billion pounds* and netted over $98 million and $86 million in each year respectively. A record landing for the state occurred in 1971 when slightly over one billion four hundred million pounds of fish were harvested.

The menhaden catch accounts for the major volume of fish; over one billion pounds were landed in 1974. The Louisiana menhaden industry is the largest in the nation and in 1974, it supplied 55 percent of the total domestic menhaden catch.[73]

Cameron ranked second among the nation's ports in terms of the volume of commercial fish landings in 1974. Over 405 million pounds of fish were harvested, valued at $18,724,000.[73] The large catch of menhaden landed at Cameron accounts for the high volume and relatively low value of fish. Most of it is processed into fishmeal, menhaden oil, and menhaden solubles; the rest is used for bait.

*This indicates live weight for all items except univalue and bivalue mollusks such as clams, oysters, and scallops which are shown in weight of meats excluding the shell.

The season for menhaden is from April to October, and the heaviest harvest is during June, July, and August. The fish are caught in purse seines (large nets with floats along the top and weights on the bottom) which are strung in a large circle and enclose the fish. This manner of fishing does not employ great numbers of people relative to the volume of fish caught.

Contract Construction

Contract construction is another major source of employment in Lake Charles. A 1973 report shows that about 4,000 people were employed by this industry in mid-March, and that the payroll for that quarter totaled nearly $9 million.[72] Within this industry, employment distribution is nearly equal among heavy construction contractors, general building contractors, and special trades.

The work forces in both manufacturing and construction are heavily unionized. Union membership in Lake Charles has been estimated to be about 11,000 persons, producing a situation whereby about one-third of the city's population is in a union or union-supported.[73] About three or four years ago, the Committee of Contractors and Union Representatives was established to arbitrate jurisdictional disputes between individual trade unions.

Lake Charles Port Facilities

In tonnage of goods handled, the port at Lake Charles ranks twentieth in the nation, tenth among the Gulf ports, and third in Louisiana. Total tonnage handled for selected years is as follows:[44]

Year	Tonnage
1955	15,396,366
1960	17,433,441
1965	14,469,783
1967	16,697,672
1969	16,154,684
1970	17,600,000

In 1970, the tonnage at Lake Charles was 38,7 percent of what was handled at Baton Rouge and 14.2 percent of that at New Orleans. The overwhelming proportion of goods handled at Lake Charles was in the domestic market. Crude petroleum was the largest single item, followed by gasoline. Rice was the largest foreign export in 1970, a total of 503,000 tons were shipped out. Other exports include paper and lumber. Automobiles, fertilizer, and coke are major bulk items that are imported to the area.

Barge traffic provides low-cost transport of such commodities as petroleum and petroleum products, grain, soy beans, sand, gravel, and other bulk products. The Intracoastal Waterway near the project site is a major link between the industrial centers of Beaumont and Port Arthur, Texas, and Lake Charles.

Agriculture

Agricultural income in this region of Louisiana is derived mainly from growing rice and raising cattle. The quantities of land, labor, and income from agricultural pursuits in the two parishes are as follows:[44]

	Cameron	Calcasieu
Acres	22,700	102,600
Paid Farmers	117	731
Value of Goods Sold	$3,193,000	$13,332,000

There has been a trend in Cameron Parish to convert rice acreage to pastureland. Growing rice requires large quantities of fresh water, and since the dredging in ship channels along Calcasieu Lake and the Intracoastal Waterway, fresh water bodies have become contaminated with salt water from the Gulf of Mexico.

2.5.4.2 Employment Distribution

The unemployment rate in this area is low (see Table 2.18, Employment Status). The table also shows that few workers are available in Cameron Parish, and it can be expected that the majority of the project labor force would commute from Calcasieu Parish. The percentage of unemployed persons in 1970 was substantially lower than what was recorded in 1960, when Cameron Parish had 10 percent of its men unemployed, and Calcasieu had 8 percent.

The number of men in the civilian labor force in the Lake Charles metropolitan area in February 1976 was over 57,000. Of these, 8.6 percent, or 4,925 were listed as unemployed. Contract construction and oil and gas field explorations, which form a substantial number of employment resources, fluctuate widely in the number of jobs available for semi-skilled and unskilled workers.

Table 2.18 Employment Status, by Parish

	Calcasieu		Cameron	
	Male	Female	Male	Female
In Labor Force*	33,863	16,682	2,062	672
Employed	32,033	15,615	1,984	617
Unemployed	1,830	1,067	78	55
% Unemployed	5.4%	6.4%	3.8%	8.2%

* Excludes military personnel.

Source: Public Affairs Research Council of Louisiana, Inc., based on 1970 census data.

Primary sources of job opportunities are: manufacturing and construction in Calcasieu Parish, and oil and gas production and fisheries in Cameron Parish. The occupational distribution of men and women employed by all industries is shown on Table 2.19. Those occupational groups most heavily drawn upon by the proposed project would be: (1) craftsmen, foremen and kindred; (2) operators and kindred; and (3) laborers. Calcasieu Parish offers a substantial number of workers in these categories. A study of the commuting patterns for persons living in Lake Charles and in the surrounding standard metropolitan statistical area (SMSA) shows that a large proportion of workers in these occupational groups go to jobs outside the city.

2.5.4.3 Income Distribution Patterns

The income of workers in various occupational groups is shown in Table 2.20. It should be noted that in the groups that the project will draw from, median earnings for workers in Cameron and Calcasieu Parishes are higher than those for the state. The relatively high income levels can be attributed to: (1) the strength of unions in obtaining wage gains for these workers, and (2) a relatively constant demand for workers in these occupational groups despite the employment fluctuations natural to the primary industries, particularly in contract construction.

Comparison of income levels in these two parishes with those of the State show that this area has a relatively strong economy. Median family income in both parishes is above that of the state, and the percentage of families below the poverty level is less than that of the state.

Table 2.19 Employment in Major Occupation Groups

	Calcasieu		Cameron	
	Male	Female	Male	Female
Total	32,033	15,615	1,984	617
Prof., tech. & kindred	3,744	3,137	122	83
Farmers & farm mgrs.	331	5	108	6
Mgrs., officials & props.	3,321	725	281	47
Clerical & kindred	2,049	5,061	66	139
Sales workers	1,722	1,300	25	38
Craftsmen, foremen & kindred	8,492	162	380	0
Operatives & kindred	4,869	370	443	32
Private household	33	1,419	0	29
Service workers except private household	2,036	3,162	137	201
Farm laborers	382	13	58	5
Laborers	2,965	136	256	5
Other	2,089	125	108	32

Source: Public Affairs Research Council of Louisiana, Inc., based on 1970 census data.

Table 2.20 Median Earnings of Selected Occupation Groups

	Calcasieu	Cameron	Louisiana
Male, total with earnings	$7,551	$6,546	$6,536
Prof., mgrs., & kindred	9,792	7,840	9,511
Craftsmen, foreman & kindred	8,237	8,635	7,294
Operatives & kindred	7,396	6,400	5,786
Laborers, except farm	4,238	4,776	3,714
Female, total with earnings	$3,040	$1,748	$3,003
Clerical & kindred	3,702	2,774	3,808
Operatives, including transport	2,611	1,450	2,915

Source: Public Affairs Research Council of Louisiana, Inc., based on 1969 income figures.

2.6 UNIQUE FEATURES

2.6.1 Archaeological and Historical Sites

Indian artifacts have been found in scattered areas throughout western Calcasieu Parish, but there are no known Indian mounds or other archaeological sites in the area of potential impact.

Sulphur Mines itself is of historical significance locally because it was there that Herman Frasch developed his unique process of mining sulfur. The Brimstone Historical Society, located in the City of Sulphur, has compiled an exhibit to illustrate the early days of sulfur production at the mines. This exhibit is on display at the Frasch Museum in Sulphur. Sulphur Mines, however, is not a state or nationally recognized historical site, and no historical markers have been placed there because it is not open to the public.

2.6.2 Parks, Wildlife Refuges and Scenic Areas

Two state parks, Sam Houston State Park, 5 miles north of Lake Charles, Louisiana, and Nibletts Bluff State Park, northwest of Vinton, Louisiana and on the Texas-Louisiana border, are in Calcasieu Parish. Neither park would be impacted by the project. Frasch Park, a municipal park in the southwest corner of Sulfur, is approximately two miles east of the closest brine disposal well. It is conceivable that air quality could be impacted during construction of the facility (Section 3.1). No unique wildlife sites are in the area of potential impact with the possible exception of Sabine National Wildlife Refuge which could be impacted by tanker oil spills. This 142,000 acre sanctuary is located in southern Cameron Parish with portions on each side of Calcasieu Lake.

2.6.3 Biologically Sensitive Areas

Cleared lands comprise a relatively large proportion of the area of potential impacts and they are not considered particularly sensitive. However, cleared agricultural lands and woodlands are sensitive to changes in subsurface water levels.

Biologically sensitive areas that could be impacted by the project are the extensive marshes south of the dome site. These marshes are adjacent to oil tanker waterways.

Conceptually, two principal gradients strongly influence the ecology and zonation of the marshlands. One is the water salinity which increases from the fresh (less than 0.5 ppt salt) water table of the coastal prairies toward the coastline of the Gulf of Mexico. The other gradient is that which represents the degree of soil saturation which is a function of elevation in the marshlands. It is the response to these two gradients that causes the general zonation of the plant communities parallel to the coastline.

The tidal marsh is an estuarine environment that serves as a nursery ground for commercially important fish and shellfish. It was estimated that two-thirds of the cash value of species harvested on the gulf coasts are estuarine dependent. Even coastal species which do not breed their young in the estuaries or tidal marshes are still dependent upon the food chain which is at least partially based on the productivity of the tidal marshes as a source of mineral and organic nutrients.

CHAPTER 2
SULPHUR MINES
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3. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

3.1 LAND FEATURES AND USES

Minor geologic impacts are expected at the Sulphur Mines site, the offsite oil pipeline, and the Sun Terminal, during construction. During operation, careful monitoring of cavern growth during each cycle is needed so steps can be taken to preclude geological impacts such as cavern closure and/or collapse, and surface subsidence. Monitoring during brine injection will also be required to determine the ability of the aquifer to accept the brine. Cavern contact with the salt-sediment boundary and cavern instability due to increased size are conditions that could occur at Sulphur Mines during normal operation. Further definition of the salt boundary is therefore required to determine the acceptability using caverns 6 and 7. A comprehensive cavern testing program will be carried out to acquire this information. Testing is described in Section 3.1.3.

3.1.1 Construction

The primary geologic impact during construction of the oil pipeline would be minor soil erosion which can be controlled after construction by planting suitable ground cover. Minor erosion would also occur during the construction of roads, brine disposal well pads, and the 100,000 barrel brine pond. Appendix E presents a more detailed discussion of soil erosion during construction of the proposed facilities. After construction, the disturbed land would be protected from erosion by vegetation and/or gravel.

3.1.2 Operation

The geological and land use impacts can be divided into those that occur during normal operation and those that would occur during various unforeseen events.

Land Use

Routine operation of the facility is not expected to result in significant land use impact because the facilities at the dome for the storage program would be very similar to the type of facilities already present on the site, namely, oil, gas, and brine wells, with associated offices and other buildings. Although there is a permanent right-of-way for the oil and brine pipelines, original use of the land would not be precluded (i.e., pasture, rice fields). Land requirements at the Sun Terminal will not cause a significant land use impact because the land is already owned by Sun Oil Company, which conducts related activities on the property.

Geology

Routine operating conditions are not expected to affect soil conditions significantly. No agricultural or grazing activity would be impacted by normal construction and operation activities on the site. The small amounts of fill required for road construction, well pads, and containment dikes would bury existing soil.

Contamination of fresh water aquifers by brine held in the proposed brine pond is unlikely because the brine pond would be lined to prevent drainage and because it will be designed to prevent overflow. No danger of subsidence under the brine pond due to voids left by sulfur mining exists because the pond is to be located outside of the area of sulfur mining.

The brine pond is a place of temporary storage. The brine from this pond would eventually be injected into saline aquifers 5000 to 7000 feet deep. There are several potential environmental problems associated with subsurface brine disposal:

- earthquakes,
- aquifer fracture,
- interference with oil and gas wells,
- the contamination of fresh ground water,
- the contamination of surface water.

Earthquakes may be induced when faults are lubricated by fluid injection. There is documented evidence of earthquakes being triggered as a result of subsurface injection of fluid accompanied by an increase in injection reservoir pressure. The two known cases of this phenomenon have occurred in Colorado in an area of high natural rock stress. One occurred near Denver and was associated with a disposal well containing liquid waste from the Rocky Mountain Arsenal. The other occurred near Rangely, Colorado and was associated with water injection into wells of the Rangely oil field. The mechanisms causing the earthquake are not well understood. However, one possible explanation is that stresses on opposite sides of existing fault planes were not sufficiently large to overcome frictional forces along the plane and cause movement until the waste fluids were injected and acted as a lubricant. Stresses are relieved by plastic deformation or rupture of rocks. Stated simply, if the plasticity of a rock is relatively low the stress continues to increase until rupture (faulting) occurs. In the Gulf Coast area, the unconsolidated sediments (as opposed to the consolidated rock in Colorado) are very plastic and stress relief comes in the form of plastic deformation. Although faults do exist in the Gulf Coast, movement along those planes due to lubrication by injected brine seems unlikely. Numerous flood water and liquid waste injection sites have been in operation along the Louisiana-Texas Gulf Coast for many years without reported occurrences of earthquakes. Detailed discussion of aquifer fracture, interference with oil and gas wells and ground water and surface water contamination are given in Section 3.2.2.

The most serious geologic impacts that could occur during the operation phase of the storage program are dependent on cavern stability. Cavern stability in turn depends on certain factors including, but not limited to, cavern height and diameter, depth in salt, proximity to the salt dome boundary or other caverns (especially intermediate pillar thickness), the potential of internal and external dissolution of salt by water, and internal cavern pressure.

Cavern closure is the gradual reduction in cavern size when the salt surrounding the cavern flows inward. It occurs if internal cavern pressure is not maintained or if structural support is removed. Closure in itself will not result in adverse geologic impacts at the cavern depths of Sulphur Mines. If the caverns were much closer to the surface, closure might trigger caprock collapse and surface subsidence.

The maximum diameter of caverns 6 and 7 are 585 and 500 feet respectively, according to sonar caliper surveys conducted on October 15 and 14, 1975. If these caverns coalesce, as is expected, after 4 cycles, the maximum and minimum horizontal dimensions of the combined cavern would be approximately 1,200 feet by 650 feet. The horizontal dimensions of the cavern formed by the coalescense of caverns 2, 4 and 5 are approximately 1,150 by 700 feet and vertical dimensions are 333 to 625 feet, based on September 1977 data. This span could result in cavern roof closure but probably not failure due to the amount of salt above the cavern.

The stability of this cavern (2-4-5) is not now affected by other caverns which are over 300 feet away. After 5 cycles, cavern (2-4-5) and cavern 7 could have as little as 170 feet ($\pm$ 20 feet) of salt between them. The intervening salt mass consists of more salt than 5 cycles would dissolve. The coalesced cavern (2, 4, and 5) is 600 feet away from the salt boundary, therefore, there is no chance of boundary contact during the proposed project.

Figure 3.1 is a salt contour map and shows the location of wells 7A and 6Y at caverns 6 and 7.* The minimum pillar width between the caverns is 150 feet, which would be dissolved after 4 cycles (Figure 3.2). The relationship between the edge of the salt and caverns 6 and 7 has not been conclusively established. The salt depth contours near wells 6 and 7 were verified by data from two wells drilled in 1930. There are various descriptions however of the precise wellhead locations relative to these contours. A map obtained from Allied Chemical (the present owner of the site) and a map on file with the Louisiana Department of Conservation do not agree on the location of wells 6 and 7.

Based on the data from Allied Chemical, cavern 6 may be as close as 125 feet to the salt dome boundary and cavern 7 may be 40 feet from the boundary (see Figures 3.3 and 3.4). Based on the Department of Conservation map there is at least 300 feet of salt between the wall of cavern 6 and the salt edge; cavern 7 has a wall thickness of approximately 200 feet. These estimates of wall thickness are made with the assumption that the original wells drilled were vertical, however it is common for these wells to deviate from the vertical during drilling. A gravity survey conducted in September 1977 indicated that cavern number 7 is about 170 feet from the dome boundary.

If a cavern enlarged by dissolution of salt to a point of reaching the dome boundary, oil might migrate through the sediments (depending on the oil pressure, the sediment pore pressure, and its permeability to oil), or it might be contained in the cavern by the sediments. The amount of oil lost via a leak from the dome into surrounding sediments would be negligible. The occurrence of a leak of this kind could not be easily detected because the leak would be slow and the oil may never surface. If oil did move out of the cavern it would come in contact with very saline aquifers. Movement of the oil would most likely

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*Each cavern has two wells. One would be used to inject and withdraw water (6Y, 7A) and the other would be used to inject and withdraw oil (6X, 7B).

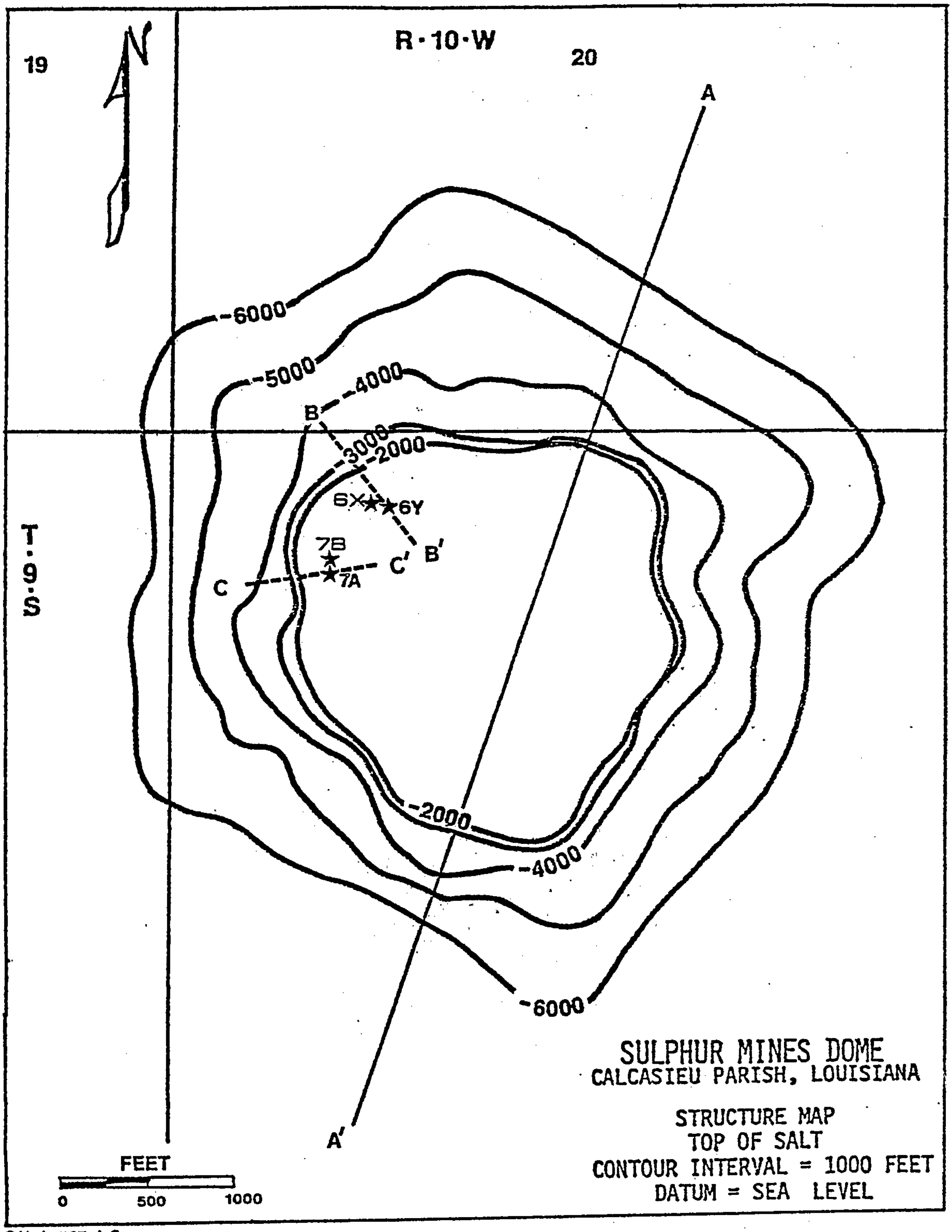

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Figure 3.1 Geologic cross-section lines B - B' and C - C' through well 6Y and 7A respectively are shown. The geologic cross-section along A - A' appears in Figure 2.3.

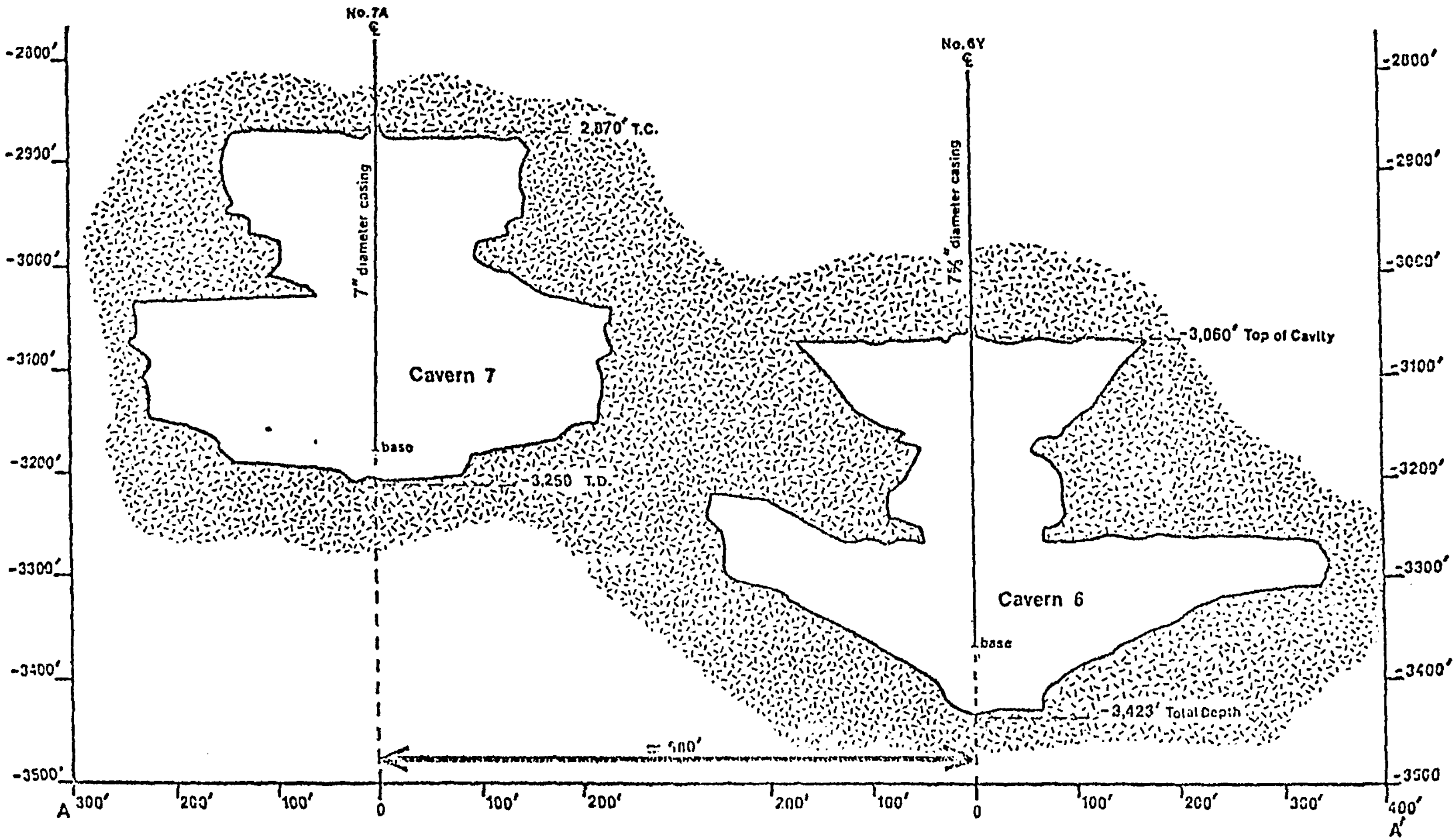

Figure 3.2 Cross-Section Relationship of Caverns 6 and 7 at Sulphur Mines.

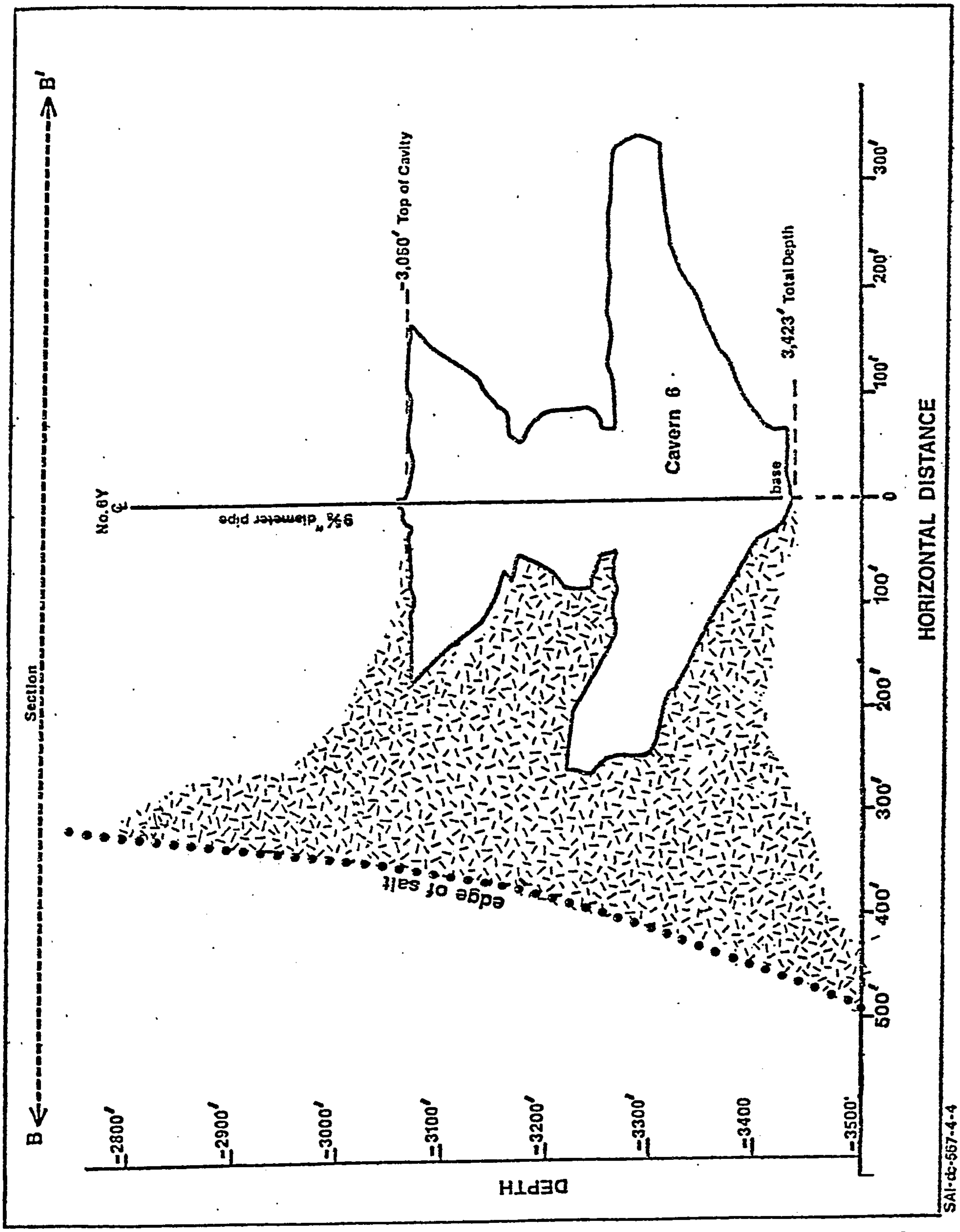

Figure 3.3 Illustration of the Proximity of Cavern 6 and the Salt Boundary. The Sonar Caliper Survey was conducted on October 15, 1975. (The well string is assumed to be vertical.)

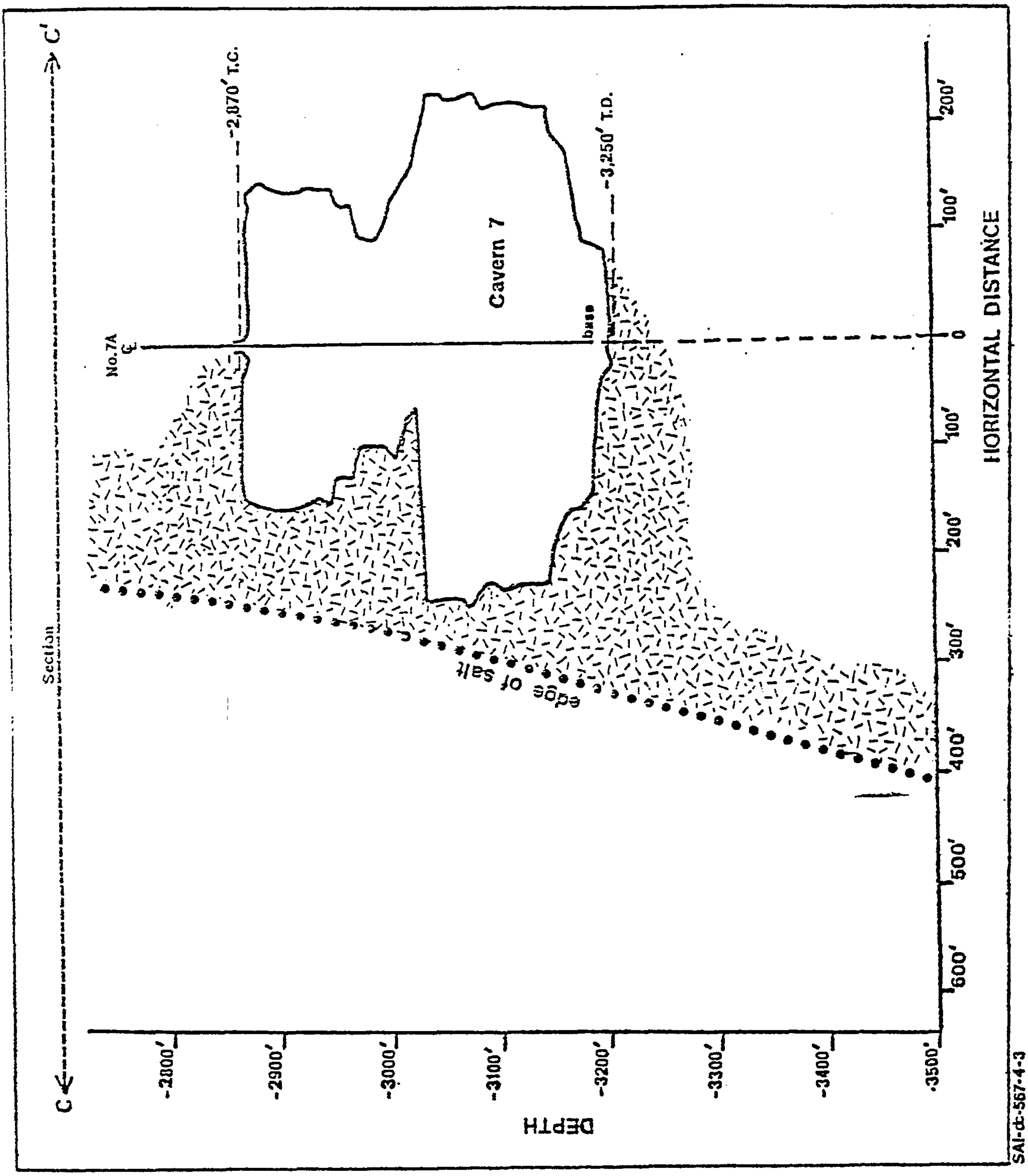

Figure 3.4 Illustration of the Proximity of Cavern 7 and the Salt Boundary. The Sonar Caliper Survey was conducted on October 14, 1975. (The well string is assumed to be vertical.)

be upward but extremely slow (this is conjectural because oil migration through sediments is a complicated process depending on many factors). The oil would eventually become trapped beneath impermeable clays which curve up and are in tight contact with the dome forming a trap in which natural accumulations of oil are commonly found throughout the Gulf Coast. A testing program to determine cavern wall thickness is discussed in Section 3.1.3.

The external dissolution of the salt dome where in contact with the aquifer would not affect cavern stability because the process of dissolution of salt along the vertical boundary is extremely slow. Therefore, this is not a concern.

Removal of the oil blanket could result in both lateral and upward dissolution of the salt by water that comes in contact with the roof. During normal operation it is not possible to remove the oil blanket because the withdrawal annulus is below the roof level. The oil blanket will be maintained at all times.

Coalescence of caverns 6 and 7 could create a situation where uncontrolled upward leaching of cavern 6 would occur. When these caverns coalesce the oil blanket of cavern 6 would be lost to cavern 7. Therefore, without a mechanism for maintaining an oil blanket in cavern 6, upward growth of the cavern would continue up to the roof or to the level of the oil brine interface of the upper cavern. Coalescence would probably not have any additional adverse effects.

3.1.3 Testing Program

Prior to placing oil in solution mined caverns, the status of certain critical factors such as cavern configuration, depth, location (proximity to other caverns, and salt dome boundary) and cavern isolation (no external communication with other caverns, caprock or sediments outside of the dome) must be known.

A comprehensive cavern testing program will be conducted at Sulphur Mines to insure that these critical factors are thoroughly analyzed, and that the caverns are acceptable for storing oil. These tests could include: azimuth and well deviation survey, sonar caliper survey, surface wellhead survey, a modified shallow seismic survey, a cavern pressure test, a gravimetric survey, and exploratory drilling.

Azimuth and well deviation surveys are conducted to determine the magnitude and direction of the well's deviation from vertical. The internal structure of the salt often deflects the drill bit from the vertical toward the center of the dome. This deflection therefore impacts the location of the cavern to be subsequently leached. In the absence of this data however, the best approximation of relative cavern proximity is to assume that the wells are vertical.

The sonar caliper survey provides oriented cavern configuration data. This data helps to identify preferred directions of salt dissolution which is important in determining the proximity of adjacent caverns. Often points of cavern coalescence can be identified. The sonar caliper is particularly useful in determining cavern growth patterns when a survey is conducted after the oil withdrawal stage.

The surface wellhead survey is required to determine the precise location of the well. From this data and the well deviation and sonar caliper an accurate three dimensional model of cavern configurations and relative proximity to one another can be constructed.

Since caverns 6 and 7 are close to the salt dome boundary in the depth range of 3,000 to 3,200 feet, a modified seismic survey must be conducted to determine the thickness of the salt between these caverns and the dome boundary. The geophones for this survey would be lowered into the caverns. An energy source such as dynamite would be placed outside of the dome boundary so that the seismic energy would be transmitted through the salt wall between the caverns and the dome boundary. The differential velocity of this energy through sediments, salt, and brine will be the basis for interpreting the distance of caverns 6 and 7 from the salt dome boundary.

To determine if caverns 6 and 7 at Sulphur Mines are sealed, that is, not in communication with other unknown caverns, or the caprock, the caverns will be pressure tested. If the pressure of the air pumped into a cavern decreases at the rate predicted for a sealed cavern, then the cavern can be assumed to be isolated from the caprock, other caverns and possibly the sediments surrounding the dome. Caverns 2, 4, and 5 have been successfully pressure tested in September 1977.

Gravimetric survey data may be used to describe the gross external structure of the dome. However, for the purpose of determining whether caverns 6 and 7 could enlarge enough to come in contact with the sediments surrounding the dome, aerial gravimetric surveys are not precise enough and downhole surveys have a limited range. Therefore, gravity surveys will not provide sufficient definition of the edge of the dome in the vicinity of caverns 6 and 7.

Perhaps the most precise method of locating a salt dome boundary is by drilling a small diameter exploratory well. The area of exploration can be increased if several side track holes are drilled from the main well. Information on the sediment types can also be obtained to determine if a potential wash out would occur in permeable or impermeable sediments.

The most effective means of determining: (1) how close caverns 6 and 7 are to the northwest salt dome boundary, (2) how close the two caverns are to each other*, and (3) are the caverns sealed and able to contain oil without leaking through breaks in the casing to the caprock or through unknown connections to other caverns, would be to conduct a sequence of surveys: surface wellhead survey, azimuth and well deviation survey, sonar caliper survey, modified seismic survey, the cavern pressure test, and possibly exploratory drilling. A comprehensive program developed from among these available tests will be performed to ensure that caverns 6 and 7 are suitable for oil storage.

3.2 WATER QUALITY

Impacts on the water environment would occur in two phases. The first phase corresponds to the site preparation and construction time period. The impacts associated with this phase are presented in subsection 3.2.1. The facility operation time period represents the second phase and the impacts associated with this phase are discussed in subsection 3.2.2.

3.2.1 Water Quality Impacts During Construction

Effects on water quality during site preparation and construction can be assigned to four major categories: (1) the impact on the water environment resulting from dredging the south sector of the Salt Water Reservoir, (2) the impact of dredging activity associated with the construction of the oil pipeline, (3) sediment transport

* From this it can be determined during which withdrawal cycle the caverns are likely to coalesce.

produced by runoff from the construction sites, and (4) introduction of chemical and biological pollutants into surface waters. The four subsections which follow provide a description of these four categories.

3.2.1.1 Dredging in the South Sector of Salt Water Reservoir

As noted in subsection 1.3.1.4, one million cubic yards of material would be dredged from the south sector of Salt Water Reservoir to increase its total capacity to approximately 25 million barrels. Current plans call for a clam shell bucket dredge to be used, with the spoil to be deposited in a confined area next to the existing reservoir. A small area of grassland and brushwood, amounting to approximately 60 acres would be utilized for disposal of dredge spoil. Confinement dikes would be constructed so that all drainage would flow back into the reservoir itself as discussed in Chapter 1. The clay soils which underlie this disposal area have been estimated to have low permeability. Approximately 30 feet of relatively impermeable silt and clay would separate this disposal area from the underlying Chicot Aquifer which provides potable water for communities. No water quality impacts to this aquifer are expected to be caused by leaking from the disposal area.

No state standards or federal criteria would be applicable because the reservoir is the property of Allied Chemical and was originally constructed for industrial use only. No natural water bodies in the vicinity would be affected. Water quality would be degraded in the reservoir during and after dredging. The decline in quality would cause adverse effects on organisms as described in Subsection 3.4. Suspension of sediment and subsoil would increase turbidity and release dissolved or adherent substances contained between sediment and subsoil particles. The sediments are probably unusual in composition since the reservoir has been used as a holding pond for brine and for sulfur-contaminated acidic water from the 40-acre subsided area on the dome and as an aeration pond for removal of hydrogen sulfide from water used in sulfur mining the the later 1960's (see Subsection 2.2). Particles of the clay subsoil typical of the region (discussed in Subsection 2.1) would be likely to remain in suspension for a relatively long period, possibly weeks or months. Likewise, during the dredging and for a similar period of time afterwards, the dissolved oxygen level in the reservoir should be significantly depleted. This is due to the high COD of the materials deposited in the reservoir during its use.

3.2.1.2 Dredging for the Oil Pipeline Construction

Construction of the oil pipeline would involve dredging across Bayou Choupique, the Intracoastal Waterway, Wing Gully and Spring Gully as indicated in Figure 3.5. For all these streams except the Intracoastal Waterway, bucket dredging would be utilized. Dredging in the Intracoastal Waterway would be hydraulic dredging. Spoil disposal for all sites would be in confined areas. Small areas of grassland or brushwood would be utilized for disposal of dredge spoil. Burial of the pipeline would result in temporary removal of vegetation and benthic populations across about 1500 feet of marshes. Use of an alternate route running north of Goose Lake and crossing the ICW approximately 2000 feet west of the crossing utilized by the route indicated in Figure 3.5 would avoid the temporary effects of a pipeline marsh crossing, but would require an extra 1000 feet of pipeline.

<u>Dredging in Bayou Choupique, Wing Gully and Spring Gully</u>

The latter two streams are unnavigable; Bayou Choupique is classified as navigable by the Corps of Engineers, although the crossing is two miles upstream from the year-round head of navigation. For all three, the pipeline would be buried from 4 to 5 feet below the bottom surface. About 10,000 cubic yards of dredged material would be removed from Bayou Choupique. Wing and Spring Gullies are each about 40 feet wide and would each require removal of 5,000 cubic yards of material.

An inevitable increase in turbidity would occur in these streams during dredging activity. If the bottom sediments are polluted a number of pollutants would be released. Most researchers have concluded that the dredging operation, using modern techniques, has little long-term effect on the water overlying the sediments.[2,3,4] This appears to be the case even when the sediments are highly polluted. These investigators report that some dredging activities increase water turbidity and other parameters to a very minor degree up to a mile from the dredge site under certain conditions. Of primary concern is the possibility of (1) an increase in

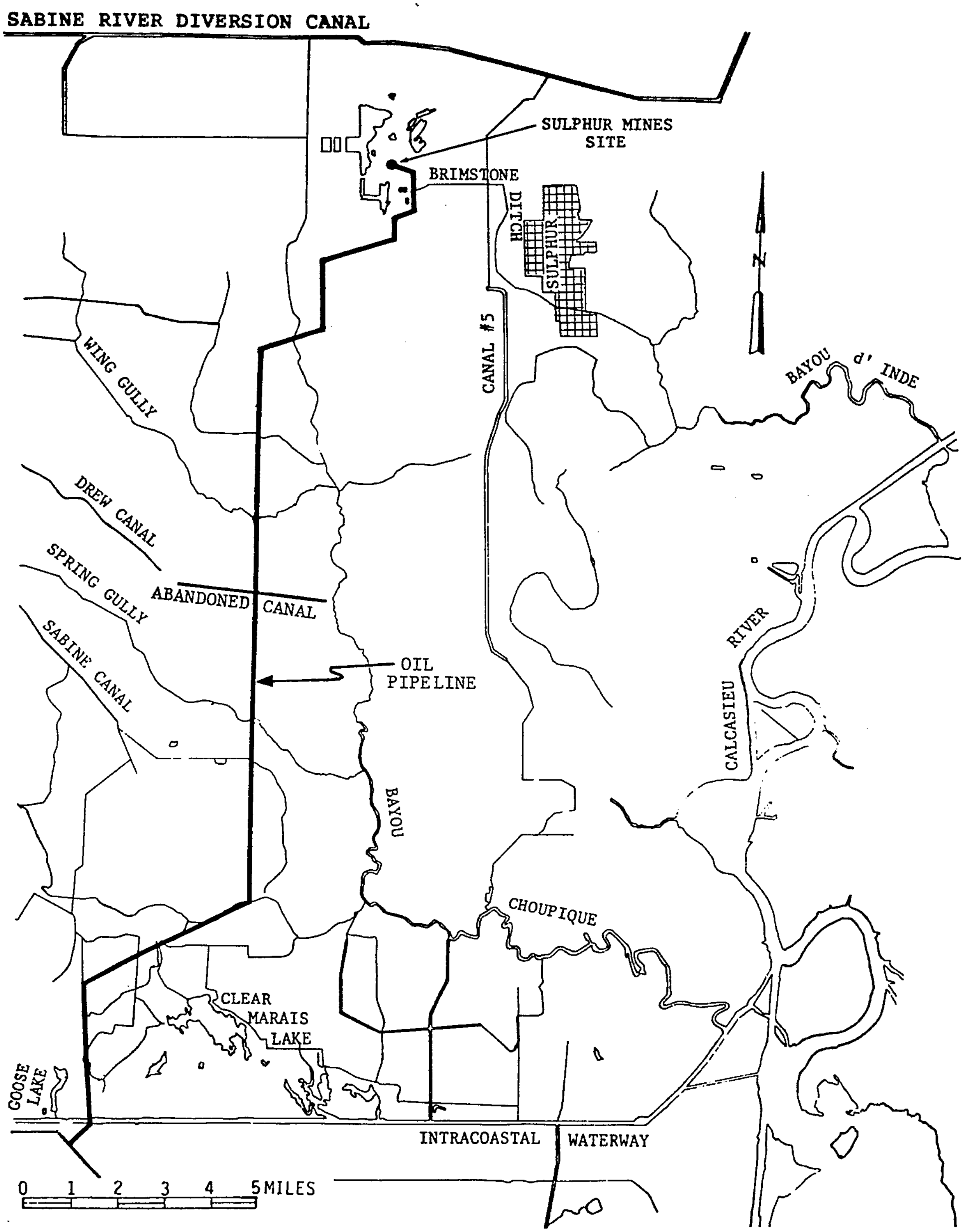

Figure 3.5 Waterbodies Which Would be Dredged During Pipeline Construction

turbidity*, (2) a reduction of dissolved oxygen due to the increase of chemical oxygen demand for the oxidation of dredged materials, (3) the release of aquatic nutrients, (4) the release of pesticides or non-pesticide toxic hydrocarbons, and (5) the release of toxic metals.

(1) Turbidity

The physical composition of the bottom sediments in the cavity of the dredging sites is probably clay materials, with sand, silt, and organic debris also present. It should be noted that dredging for the proposed pipeline would involve three previously undisturbed stream channels, (Figure 3.5). Thus a major portion of the dredged sediment would very likely be relatively unpolluted. These clays tend to be finer grained than the shallower sediments, sand and silt.

The variation of settling velocity** with type of sediment is shown in Figure 3.6. As indicated in the figure, a clay particulate with a diameter of 2mm would have a settling velocity of approximately 0.003mm/sec, compared to 0.3mm/sec for a silt particle with a diameter of 20 mm. The period of time an individual particle remains in a turbidity plume and the distance downstream the particle is transported while in the plume are both approximately inversely proportional to the settling velocity. Thus a turbidity plume composed of clay particles could in theory persist for a distance of several miles while a plume composed of sand particles might extend less than 10 feet.

Since bucket dredging is to be used, the size and duration of the turbidity plume would depend on the number and size of the dredges operating in the area, the skill and concern of the dredging operators, the length of time during which dredging occurs, bottom sediment characteristics, and flow

*Turbidity is a measure of the amount of light that will pass through a liquid and describes the degree of opaqueness produced by a suspended particulate material. In contrast to turbidity, measurement of suspended solids quantifies the actual amount of particulate material in the water.

**Settling velocity is the maximum downward speed a particle would achieve if released in a body of water and permitted to fall without restrictions.

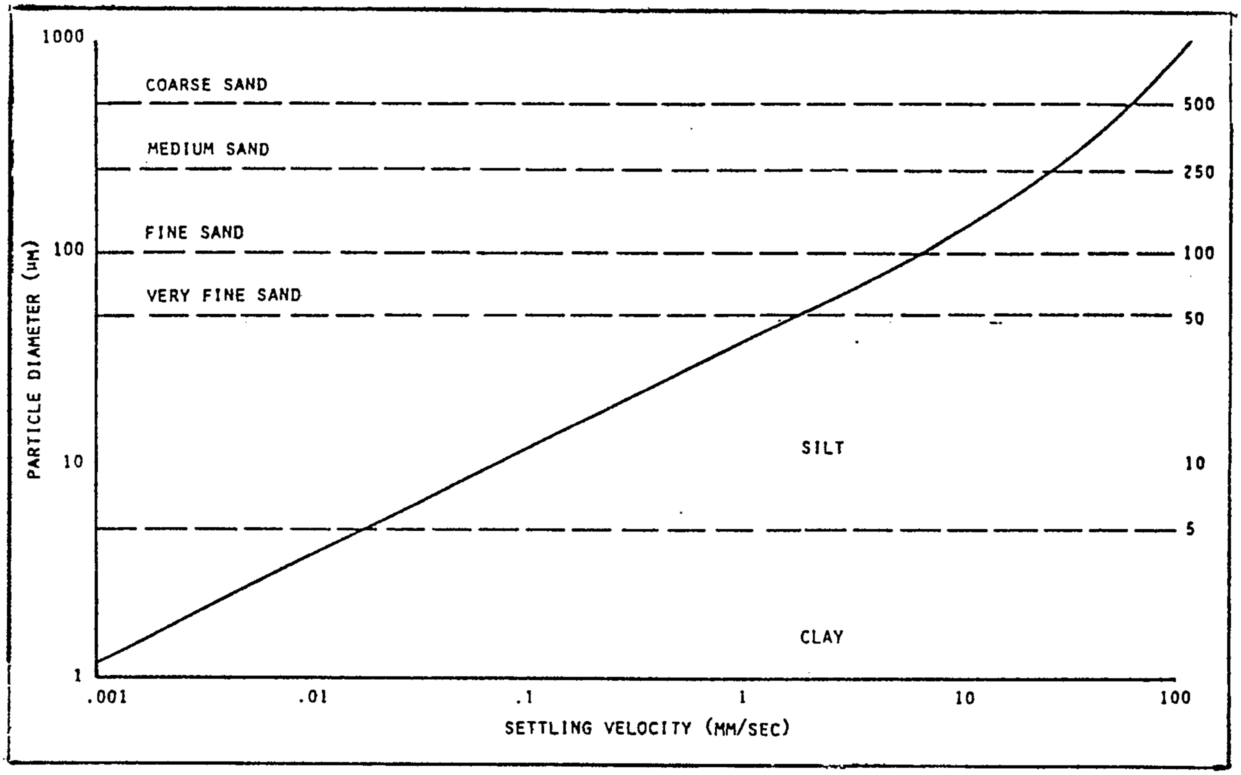

Figure 3.6 Variation of Settling Velocity with Particle Diameter.

dredging occurs, bottom sediment characteristics, and flow conditions. A measurable increase in turbidity could occur for up to one mile downstream from each dredging site. The last of the larger suspended particles would settle out soon after dredging ceases, probably within a few days. Silt and clay particles might be suspended or perhaps resuspended for longer periods.

(2) Dissolved Oxygen

In general, dredging releases readily oxidized organic materials as well as other oxygen consuming substances. The dredging would release an unknown amount of such materials, raising the COD and thus lowering the dissolved oxygen in the water column an undetermined amount. Available water quality data indicated no significant problem of low dissolved oxygen levels for Bayou Choupique.

(3) Release of Aquatic Nutrients

Dredging could release phosphorus and various forms of nitrogen (nitrates, nitrites, and ammonia). The release of these materials can induce the growth of a large aquatic biomass, typical of eutrophic* conditions.

(4) Pesticides and Toxic Hydrocarbons

Agricultural activity near the reach of the streams under consideration could introduce a degree of pollution from pesticides and hydrocarbons. During dredging, these substances could be released.

(5) Toxic Metals

In general, levels of "heavier" metals, such as lead and mercury, which might be present could actually decrease during dredging operations, as these metals are generally less soluble, precipitating out of the suspended solids or combining with sulfides to form insoluble salts. The lighter metals, like nickel, chromium and zinc, are more soluble and thus less likely to precipitate out on the suspended solids. Thus, dredging could increase the concentrations of lighter metals, while the concentration of heavy metals would generally be reduced.

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*"Eutrophic" describes water bodies rich in dissolved nutrients.

(6) Summary

An increase in turbidity and chemical oxygen demand (COD) (resulting in decreases in dissolved oxygen levels) would be expected. As these streams have not been dredged before, release of toxic materials should be minimal. A slight increase in certain lighter metals in the water would be expected, but the more toxic, heavier metals concentration could be slightly reduced. These effects would reduce the water quality somewhat during dredging and for a period of several days after the completion of the dredging operations.

Dredging in the Intracoastal Waterway

The pipeline burial would be at least 15 feet below the bottom of the canal as required for navigable waterways. About 75,000 cubic yards of material would be dredged. The dredging would be performed using hydraulic dredges, thus reducing the resulting turbidity plume to some extent. The turbidity increase would be one of the expected impacts. Some decrease in the dissolved oxygen levels and increases in aquatic nutrients would occur due to release of oxygen consuming material (including aquatic nutrients) from the sediment. The phosphorus levels in the water column are already high, which might indicate high sediment levels (Table D.4-5). Water quality data on the Intracoastal Waterway a short distance to the west of the proposed pipeline crossing indicates that levels of several metals including arsenic and mercury exceed the EPA suggested criteria[5]. Also, the level of nickel, though it exceeds no numerical criteria, appears to be outside reasonable limits. As discussed in general earlier, release of these metals, especially the nickel, could be expected during the dredging operation. Release of "heavier" metals such as the arsenic and mercury might be minimized to some degree by combination with sediment particles or with substances such as sulfides which might be present in the sediments. Levels of pesticides, as indicated in Table D.4-6, are elevated above the EPA criteria in this portion of the Intracoastal Waterway. Subsequently, the sediment is expected to contain significant amounts of the various compounds, and dredging would release some portion of these into the water column. Thus, some increase in pesticides could be expected in the aquatic food chain.

Disposal of Dredged Material

Current designs call for disposal in a confined area adjacent to the streams. The land in such areas is primarily marshes. Standard practice would call for retention of excess water by means of a weir* for sufficient time to allow most of the suspended material to settle out. A drainage ditch would channel overflow water from the disposal area back into the bayous or streams. Thus, in addition to having an impact on the confined disposal area. the disposal operation would also have an impact on the original body of water. Site specific impacts of the disposal operations are provided in the discussion which follows.

Impact on Bayou Choupique, Wing Gully, Spring Gully and Intracoastal Waterway Disposal Areas

The impact on the disposal area is generally assessed by determining how polluted the dredged material is. The level of pollution of the dredged material may be estimated from a study of available sediment and water quality data.

Basic concerns are (1) an increase in the turbidity of the water, (2) a significant release of aquatic nutrients, (3) the depression of dissolved oxygen levels, (4) the release of toxic metals, (5) the release of pesticides, or (6) the loss of wetlands habitat. The greatest impact from increased turbidity and suspended solids on the aquatic resources would be realized in the disposal of the dredged materials. The relative impacts of the suspended solids on the aquatic systems is in part determined by the methods of disposal and the distance the slurry must be piped in the case of hydraulic dredging.

(1) Turbidity

The dredging operation would involve both bucket dredges and a hydraulic dredge with cutterhead. The dredged material would be transported via pipeline or barge to the disposal sites. The use of a hydraulic dredge would tend to mix more water with the dredged material. Piping the mixture from the hydraulic dredge more than 1000 feet would also tend to break up the clay lumps into smaller particles. Thus, within the confined disposal area a larger increase

*A weir is a vertical partition or obstruction in an open channel over which water flows.

in turbidity would occur. Since the dredged material is to be retained in the confined areas for some period of time it is anticipated that the level of suspended solids would be reduced to below 8 grams per liter prior to the water returning to the original water bodies.

(2) Aquatic Nutrients

As earlier discussion indicated, the potential for release of water quality degrading nutrients, especially phosphorus and nitrogenous compounds to the water during disposal of the dredged material is a real concern. The primary concern is the development of an extensive increase in the growth of aquatic biomass which in turn tends to produce eutrophic conditions, especially for a confined area.

The release of nutrients, particularly nitrogen, in a confined disposal area could encourage the growth of excessive populations of algae and the consequent degradation of water quality.

(3) Dissolved Oxygen

Based on experience of the Corps of Engineers in the Intracoastal Waterway, it would appear likely that the sediments would release oxygen-demanding substances. The disposal of dredged materials in a confined area and retention of the associated water for sufficient time would avoid a harmful depression of dissolved oxygen (DO) levels in adjoining waters which would occur if oxygen-demanding substances were released into them. If the oxygen-demanding sediments are dispersed adequately into a shallow retention area where the overlying water may undergo atmospheric reoxygenation, then the effect would be to satisfy the oxygen demand without risking a water quality problem. The growth of algae in a confined area, stimulated by the release of nutrients from the sediments, would further aid in satisfying oxygen demand since algae produce oxygen during photosynthesis, although consuming oxygen during periods of darkness.

Windom[6] observed a significant increase in DO in confined disposal areas. If care is taken in design of the confinement area so that the sediment transport waters are returned to the waterway after sufficient time suspended solids will be deposited and nutrients will be removed by algae, but the algae population will not yet have become senescent and died. Then the returning transport water would be of good quality with high oxygen and low nutrient content. Under these circumstances, the confined disposal area would serve much like an oxidation pond similar to those used for many years to treat municipal and industrial organic wastes.

(4) Toxic Metals Release

As discussed earlier, the concentration of heavy metals in water usually decreases when suspended matter is present. No significant increase in the levels of these in the water is expected.

(5) Pesticide Release

The concentrations of pesticides in the water (Table D.4-6) of the Intracoastal Waterway indicate that a high level of pesticides is also likely in the sediment. Thus, release of some level of these within the disposal areas and into the nearby waterway by effluent from the disposal areas would be expected.

(6) Loss of Wetlands Habitat

The confined disposal areas must be capable of containing a total of approximately 95,000 cubic yards of dredged material for the four sites. Based on the assumption that the spoil can be stacked to a mean height of five feet, this volume of spoil would require a total of approximately 11.7 acres of disposal area. Table 3.1 is a summary of the land requirements for these sites (located near pipeline crossings shown in Figure 3.1).

Table 3.1 Land Requirements for Spoil Disposal

Site	Acreage Utilization
Intracoastal Waterway	9.3
Bayou Choupique	1.2
Wing Gully	0.6
Spring Gully	0.6
Total	11.7

(7) Summary

The impact on water quality of the dredged material from the disposal sites should consist of increases in turbidity, possibly increases in nitgrogen and phosphoric and chemical oxygen demand (COD), possibly leading to a decrease in DO. High COD levels can be averted by appropriate retention of water from the spoil for a relatively long period (probably months) before it is released. The flow of surface water in the area may also be affected, depending on the location and design of the disposal area. The total land utilization for spoil disposal would amount to 11.7 acres. The impact of the dredging disposal operation can be localized and minimized by employing the most recent dredging technology [4,7,8,9]

3.2.1.3 Impact of Earth Movement

Sediment represents the major nonpoint source of water pollution on most construction sites, especially on those which required extensive grading. Sediment includes solids and organic materials detached from the ground surface by erosion and carried into the drainage system principally by runoff. The introduction of sediment into various natural bodies of water and the associated turbidity and solids deposition result in numerous adverse physical, chemical, and biological effects. Excess suspended sediment ultimately reduces the storage capacity of waterways, increases flooding hazards, fouls and destroys aquatic habitats, impedes navigation, increases water treatment costs, diminishes recreational and property values, and increases the transport of other harmful pollutants such as human and animal wastes, pesticides, and petrochemicals.

The site preparation and construction activity at Sulphur Mines involves a significant amount of earth movement. Because of the approximately 55 inches of annual precipitation encountered in this region a significant amount of earth could be transported from disturbed surface areas into the surrounding surface water system. Some of this earth would pass into the ponds, reservoirs and marshes in the vicinity of the dome. Some fraction of the sediment would pass into Bayou D'Inde via Brimstone Ditch and drainage pathways to Brimstone Ditch. From the bayou some portion would ultimately reach the Calcasieu River. At the storage site approximately 20 acres of land would be disturbed; 19 acres associated with fill activities and 1 acre associated with excavation. This does not include the 60 acres to be filled with dredged spoil from the south sector of Salt Water Reservoir.

3.2.1.4 Chemical and Biological Pollutants

Numerous solid and liquid products, both organic and inorganic, used in construction are a source of water pollution. The major sources of construction-related chemical pollution can be broadly grouped under the following headings:

- Petroleum products
- Herbicides and pesticides
- Fertilizers
- Metals
- Soil additives
- Construction chemicals
- Miscellaneous wastes

Of these, petroleum products, herbicides and pesticides, and fertilizers appear to be the best known and the best documented sources of chemical pollution.

Pollution from petroleum products generally occurs from improper disposal of waste materials such as crankcase oil and various cleaning solvents, leakage of fuels and oil from storage facilities and damaged or improperly maintained vehicles, fuel spills during equipment refueling operations, and the use of oils for dust control on roadways.

Herbicides and pesticides are used on some construction sites to control undesirable vegetation, insects, and rodents. A major cause of significant water pollution is the improper use, handling, and disposal of these chemicals. Biological magnification of certain chemicals, especially long-lived chlorinated hydrocarbons, can result from such actions.

Fertilizers are extensively utilized in the revegetation of areas affected by grading operations. Like herbicides and pesticides, the primary causes of damaging pollution are improper use, i.e., applying too much fertilizer or improper preparation of the ground surface prior to application.

The biological pollutants which generally enter water bodies as a result of construction activities are bacteria, fungi, worms, viruses, and less prevalent organisms.

Biological pollution is primarily a result of poor sanitary conditions at a construction site - generally improper disposal of human wastes, garbage, and other organic material. The disturbance, exposure, and subsequent erosion of surface soils that contain bacteria and other organisms are also contributing factors. The biological pollutants of major concern are the pathogenic organisms associated with human wastes.

Prediction of the impact of such chemical and biological contaminants is quite difficult because of the human element involved. Assuming standard industrial and construction practices are followed, the impact on the water environment should be minimal.

3.2.2 Water Quality Impacts During Facility Operation

During operation of the facility, water quality in the vicinity of the dome would be affected in three ways. The first effect would involve withdrawal of water from the surface water system for displacing oil from the caverns. The second effect results from the disposal of the brine displaced by oil in the caverns during the fill phase. The third effect is concerned with the discharge of treated water from the Ballast Treatment System. These three effects are described in the subsections which follow.

3.2.2.1 Withdrawal of Displacement Water

For the Sulphur Mines Dome each displacement operation requires 5,145 gpm of water over a 150-day period, amounting to a total of 25.2 million barrels. This water would be pumped into the caverns to displace the oil stored there.

The immediate source of displacement water, as shown in Figure 1.5 in Chapter 1, would be the Salt Water Reservoir with the intake point located on the east bank of the south sector. Based on an annual precipitation rate of 55 inches and a surface area of 7,060,000 feet, the reservoir should be replenished by rainfall at a rate of approximately 2.4 million barrels during the 150-day displacement period.* Rainfall would thus be insufficient to refill the reservoir.

*This assumes a near uniform distribution of rainfall during the course of the year.

If the water level in the reservoir is to be maintained at a constant level, the primary replenishment source would be the Sabine River Diversion Canal. In the extreme case, the entire 25 million barrels would have to be replaced from the canal. The impact on Sabine River Diversion Canal due to withdrawal of 5,145 gpm (approximately 11.5 cfs) of water does not represent a water quality or supply problem. The canal was designed for industrial use, and this withdrawal rate, which is less than 4 percent of its initial capacity, would be met without restricting the water available to any other current or projected water user.[10] Water quality in the canal would be better than water quality in the Salt Water Reservoir (water quality is discussed in Subsection 2.2) and thus water additions to the Salt Water Reservoir from the canal would improve the reservoir water quality. Withdrawals from the canal would not affect water quality in the canal because the canal would continuously draw water of like quality from the Sabine River.

If the water withdrawal from the reservoir is not matched by the replacement from the Sabine River Diversion Canal, the reservoir level would drop. The reservoir level would be restored after withdrawal operations ceased. Such a procedure could consume essentially the entire volume of water in the reservoir and reduce the reservoir to a mud hole if carried to an extreme. The impact on aquatic life in the reservoir for this case would be quite significant, as discussed in Section 3.4.2. No significant impact on water quality or water availability in the Sabine River Diversion Canal System would be produced.

3.2.2.2 Brine Disposal

During each filling process at the Sulphur Mines site, 267 ppt brine would be displaced at the rate of 2,900 gpm for a period of 240 days. Current design calls for the disposal of the brine by means of 4 brine-injection wells spaced 1,000 feet apart, with each well capable of a maximum injection rate of approximately 1,000 gpm (See Figure 1.5). Injection depths would range from 5,000 to 7,000 feet. The potential environmental problems associated with subsurface brine disposal are:

- o earthquakes,
- o the danger of aquifer fracture,
- o chemical, physical, and biological complications interference,
- o the contamination of fresh ground water,
- o the contamination of surface water,
- o interference with oil and gas wells.

The impacts of earthquakes are considered in Subsection 3.1.

Aquifer Fracture Analysis

A satisfactory reservoir for subsurface waste disposal must possess adequate volume and have impermeable strata such as shale aquicludes* above and below the storage layer. Excessive pressure buildup could lead to aquiclude fracture and loss of containment. Pressure buildup depends upon:

- o the aquifer size,
- o the pumping rate,
- o the quantity of waste fluid,
- o the aquifer porosity,
- o the aquifer permeability, and
- o clogging agents in the waste such as colloids or materials which support bacterial growth.

Brine would be injected at a rate of 25,000 barrels per day at each of the four wells. (This injection rate is approximately four times the reinjection rates for the East Texas oil fields.[15]) The wells will probably terminate at different levels in 50-foot and 100-foot thick aquifers of the Miocene-Oligocene sands. The characteristics of these aquifers are provided in Table 3.2.

Assuming that three of the wells inject into 250 feet of aquifer and one injects into 300 feet of aquifer, the total brine disposal capacity has been calculated (see Appendix D.7). The basic equations governing the behavior of slightly compressible fluid in porous

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*An aquiclude is a geologic formation so impenetrable that for all practical purposes it completely obstructs the flow of ground water (although it may be saturated with water itself).

Table 3.2 Characteristics of 8 Miocene-Oligocene Aquifers in the Vicinity of Sulphur Mines Proposed for Use in Brine Disposal.

Total Thickness of Disposal Sands	1,050 feet
Composite Reservoir Characteristics	
Equivalent Diameter	15,840 - 23,760 feet
Average Depth	6,000 feet
Thickness	50 - 100 feet
Initial Pressure	3,000 psig
Normal Pressure Gradient	0.5 psi/ft
Fracture Pressure Gradient	0.75 psi/ft
Temperature	54^{o} C (130^{o} F)
Porosity	33%
Average Permeability	1.00 darcy
Well Conditions	
Diameter	5 inches
Surface Flow Rate	25,000 BPD per well
Fluid Properties	
Viscosity	0.550 centipoises
Compressibility (effective)*	10^{-5}/psi
Density	10 ppg

*Includes water and rock.

medium were used.[11] The characteristics of the field and the resulting capacity are presented in Table 3.3. The calculated capacity of 235 million barrels is nearly twice the total amount of brine to be injected in five cycles (120 million barrels). Thus, in terms of total capacity, the aquifers appear capable of holding the total volume of brine discharged during the use of the facility.

As described in Appendix D.7, the average pressure increase in the aquifers for one cycle of the displacement process would be 91.5 psi. For the full five cycles, if no leakage occurs from the aquifers, the average pressure increase would thus be 457.5 psi. It is important to note, however, that the thickness of the sands varies from well to well, ranging from 250 to 300 feet total per well. If each well injects the same total volume of brine, the average pressure buildup in each reservoir will be inversely proportional both to the sand thickness and to the square of the equivalent diameter. As long as the areal extent of the aquifer is 5 square miles or more, however, fracture pressure will not be reached. During operation, pressure will be monitored to prevent the fracture pressure from being exceeded.

Chemical and Physical Considerations

The preceding computations are based on certain additional assumptions. First, no deposit of slightly insoluble material is present to clog up the porous formations about the well bottoms. (The brine settling pond is designed to eliminate this problem.) It is also assumed that no biological growth will render the porous sands impermeable.

The various assumptions noted were necessary because of the current lack of data to permit more detailed computations. Such computations cannot be performed until (1) complete chemical, physical and biological analyses have been conducted on the brine to be injected; (2) chemical analyses are made on the water within the aquifer; and (3) corrosive effects of the brine upon metals of the disposal system are evaluated. Such analyses are necessary because of three potential problem areas.[12,13,14,15,16,17]

(1) Incompatibility of waters
(2) Water-sensitive formations
(3) Water quality considerations

Additional discussion of the potential problems resulting from chemical and biological reactions occurring during injection is provided in Appendix D.8.

Table 3.3 Brine Storage Capacity at Sulphur Mines

Length of Disposal Site	4 miles
Width of Disposal Site	4 miles
Area of Disposal Site	16 $miles^2$
Thickness of Disposal Sands	1,050 feet
Gross Volume of Disposal Sands	1.67×10^{11} ft^3
Net Volume of Disposal Sands	15.7×10^{9} bbls
Allowable Average Pressure Increase	1500 psi
Brine Disposal Capacity	2.35×10^{8} bbls

The injection process would increase the salinity of the aquifers involved to a small degree.[18] Salinity in these aquifers is estimated to range from 35 - 45 ppt. The injection of 120×10^6 bbls of brine with a salinity of 267 ppt would cause an increase of approximately 1.8 ppt over the present level based on the assumption of complete mixing. This (4 to 5%) increase appears insignificant.

Contamination of Fresh Ground Water and Surface Water

Fresh ground water may be contaminated by leakage through unknown aquifer connections or faults, aquiclude fracture, poorly plugged old wells, and well blowout. Surface water is most likely to be contaminated through poorly plugged old wells or well blowout. The danger of blowout may be minimized by using dense mud as a plugging agent if the hazard is known.

As noted in Appendix D.7, the possibility exists that brine injection could possibly cause pollution of shallow fresh ground water zones if abandoned wells at Sulphur Mines permit flow to shallow aquifers from the brine injection zone. This could occur if the old well casings are corroded and therefore open in both the fresh water aquifers and brine injection zones.

The location of proposed brine disposal wells is indicated in Figure 1.8. A study of oil and gas maps of the Louisiana Department of Conservation has revealed 40 abandoned wells drilled to depths greater than 5,000 feet within 5,000 feet of the injection wells.

The Louisiana Department of Conservation requires that at least two and sometimes three cement plugs be placed in a well at abandonment. One of the plugs must be placed at the base of the fresh water aquifer and is specifically designed to protect the fresh water from any contamination due to leakage of fluids from below. In addition, the well bore below this cement plug must be left full of a liquid that is of sufficient density to resist the pressure gradient of the formations below the plug and thus prevent flow into the old well bore. Many times, this fluid remaining in the well is a gel mud which tends to thicken and harden, and become impermeable with time. This further reduces the possibility of leakage.

A preliminary analysis of leakage from a disposal aquifer through an improperly plugged abandoned oil well has been carried out (see Appendix D.7). The rate of leakage depends entirely on the assumptions made concerning such parameters as aquifer pressure at the time of leakage, distance from injection wells, effective diameter of the leaking well, and thickness open to flow in both disposal aquifer and freshwater aquifer. In the analysis, a 0.01-inch wide leak is assumed to exist before brine disposal begins. Total leakage is found to be small, with 50 barrels of brine escaping over a 3 year period.

In general, given a leaky well and sufficient time, any leak will result in some of the water stored in the disposal aquifer being discharged into another aquifer. The leakage will stop when the two aquifer pressures equalize. If the discharge is from a limited reservoir into a shallow freshwater aquifer, the volume of leakage could be approximately equivalent to the volume of brine originally injected.

To avoid the possibility of leakage of any type, the record of the abandoned wells in the vicinity of the brine disposal field would be checked to insure that it was properly plugged. Because the brine disposal reservoirs possibly are uplifted by the dome, it is essential that abandoned wells completed at depths shallower than the disposal reservoir also be checked. If any wells are found to be improperly plugged, they would be replugged in accordance with the procedure previously outlined. If a substantial number of the wells appear to need replugging, it may be advisable to move the injection site.

As noted in the preceding paragraph, the brine disposal reservoir may be uplifted nearer the surface in the vicinity of the dome. In such a situation brine injected in the disposal zone could be forced up close to the surface or could force existing saline water into the reservoir nearer the surface. As described in Appendix D.7, at another salt dome in Louisiana brine was injected into a permeable formation near the dome, the saline water originally in the formation began to flow to the surface as a result of the increased reservoir pressure. To stop the upward flow the injection process was halted and a new and deeper disposal system was built. At Sulphur Mines the caprock is less than 400 feet below the surface. The possibility that the disposal reservoirs, from 5,000 to

7,000 feet below the surface and approximately one mile from the dome, could be raised up near the surface over the dome should be investigated. If such a situation exists, injection pressure buildup could cause surface or near surface discharge of saline water (salinity estimated at 35 to 45 ppt dissolved solids) which could pollute fresh water in the area.

Interference with Oil and Gas Wells

Louisiana rules and regulations prevent brine injection into oil and gas reservoirs except when prescribed procedures are followed. In such cases, the brine serves to offset the pressure loss in the reservoir due to the removal of oil and gas. In general, disposal wells must be designed to avoid inadvertent injection into oil and gas sands unless prior clearance is obtained (see Appendix D.7).

The proposed zone of brine injection, from 5,000 to 7,000 feet does overlap the oil and gas producing interval (3,000 - 7,600 feet) at Sulphur Mines. Brine disposal at Sulphur Mines should not, however, adversely affect existing overall oil and gas production. Those areas with the greatest density of producing wells are generally 7,000 feet or more from the proposed line of disposal wells. It is possible that pressure buildup in the disposal sands would be accompanied by slight pressure increases in oil and gas strata. This could benefit overall hydrocarbon production by reducing the effect of pressure loss due to oil and gas depletion. The effects on individual wells, however, would vary.

Summary

Based on available data, combined with the assumptions noted in the preceding paragraphs, the Miocene-Oligocene aquifers appear to have the necessary total capacity to accommodate the total volume of brine to be disposed. Because the disposal site is well removed from both producing and abandoned wells, interferences with oil and gas production should be slight and the potential for leakage from improperly plugged abandoned wells is small. The question of well plugging or clogging cannot be rigorously answered until the necessary chemical and biological analysis have been completed.

3.2.2.3 Discharge of Water from Ballast Treatment System

As noted in Chapter 1, each tanker, prior to receiving oil at the tanker dock at Sun Oil Terminal, would discharge a volume of ballast water amounting to 20 percent of its total capacity. This water would normally have been pumped into the tanker while at sea and therefore would be saline ($\sim$30 ppt). The ballast water after discharge from the tanker would pass through the existing ballast water treatment system which is designed to conform to Texas water quality standards.[19] Texas standards require that no visible film of oil be produced on the water surface. The concentration of oil necessary to produce such a film is not precisely established but available experimental data[20] indicates that oil sheen visibility begins to occur in the 5-10 ppm range of oil concentration. The salinity of the water would not be affected by the treatment process. The treated ballast water would be discharged into the Neches River at a rate of 2.2 $ft.^3$/sec or 33,000 bpd.

As described in Chapter 1, the treated ballast water would enter the Neches River via a small drainage ditch immediately downstream of the dock facility on the southern bank of the river. The dimensions of this ditch are not specified at this time nor is its total discharge rate or the flow velocity of the discharged fluid. The ditch was assumed to contain only the treated ballast water from the tankers associated with the transport of oil from the Sulphur Mines facility. Thus, the discharge rate was taken as 2.2 ft^3/sec with a salinity of 30 ppt and an oil concentration of 7.5 ppm. The river flow velocity was taken at 0.765 ft/sec based on the minimum flow rate reported during the water year 1975[21] the river depth was assumed to vary from 5 feet near the shore to 40 feet in the navigation channel.

The discharge conditions which have been described are identical to those used in a previous analysis[22] with the exception that the rate of discharge in the case under consideration is only 88% of that used in the previous study. In that earlier study, the discharge process was shown to have a minor impact on the river. Thus, in the current case with a smaller discharge rate, the impact would logically decrease, and should be of even less significance.

3.3 AIR QUALITY

3.3.1 Sources of Emissions During Construction

The construction of the proposed oil storage facility at Sulphur Mines would result in vehicle emission and fugitive dust along the pipeline right-of-way and at the dome and Sun Terminal locations. Many of these emissions would be insignificant and would exert a negligible impact on local ambient air quality. A summary of the types of sources existing during site construction activities is listed in the following:

- o Site Preparation
- o Unpaved Roads
- o Paved Roads
- o Heavy-Duty, Diesel-Powered Equipment
- o Light-Duty Vehicles
- o Storage Tank Preparation
  - a. Surface Grinding
  - b. Paint and/or Primer Application

The degree of construction activity would depend on existing site conditions. The construction of access roads or the extension of existing roads would result in fugitive dust emissions during initial grading operations. These emissions would continue during subsequent daily usage if access roads are not paved. Fugitive dust emissions would also be generated during construction due to site preparation activities such as land clearing and grading.

Vehicular emissions during site construction activities would arise due to the use of heavy-duty construction equipment such as bulldozers, caterpillars, and graders. Emissions due to the use of normal, light-duty vehicles such as pickup trucks and automobiles are also anticipated. Drill rigs would be used during construction in the preparation of (1) new well holes into existing cavities, and (2) brine injection wells. Emissions emanating from the above sources include particulates, sulfur oxides (SO_3 and SO_2), carbon monoxide (CO), non-methane hydrocarbons (NMHC), nitrogen oxides (NO_x as NO_2), and small amounts of aldehydes and organic acids. Actual emission strengths would be a function of fuel use preference, that is, gasoline, or diesel.

A final source of construction emissions involves the grinding and subsequent painting of the large storage tanks. The painting of these tanks would comprise a significant source of hydrocarbon vapors during application. This activity may be repeated during the operational phase as a part of routine site maintenance activities.

The following paragraphs describe the development of short- and long-term emission rates suitable for use (1) in the subsequent impact analysis, and (2) in a comparison of the relative importance of each of the construction sources. Appendix A contains a listing of the short- and long-term emission rates for those sources included in the mathematical modeling analysis, while Table 3.4 lists the annual tonnage emissions for all sources.

Site Preparation

The extent of fugitive dust emissions during construction operations is dependent largely upon the soil silt content and the aridity of the site climate. The USEPA has developed an approximate emission factor for construction operations of 1.2 tons of fugitive dust per acre of construction per month of activity[23]. This factor is based upon moderate activity levels, moderate silt content, and a semiarid climate. As such, this factor should be conservative for use in Coastal Louisiana where the climate is humid, and the soil is wet and marshy. At Sulphur Mines, the dome site would comprise 100 acres, while 130 acres would be utilized at the Sun Terminal. In addition, 64 acres of dry land right-of-way are required for pipeline construction.

For the purpose of calculations, it is assumed that the emissions are continuous during the construction phase and that they would be conservatively represented by point sources. Pipeline emissions were not modeled as they occur very diffusely and sporadically over long distances and their resultant impact on local ambient air quality is felt to be insignificant. The nature of these sources does not prove amenable to short-term modeling analyses, hence, the emissions are only included in the annual calculations.

Unpaved Roads

The use of unpaved roads during the construction phase would result in fugitive dust emissions. The USEPA has

Table 3.4 Annual Tonnage Emission Rates at Sulphur Mines During Construction.*

Source or Activity	Annual** Emissions (Tons)				
	HC	Particulate	SO_2	NO_2	CO
Site Preparation	-	2324	-	-	-
Unpaved Roads	-	5079	-	-	-
Paved Roads	-	-	-	-	-
Heavy Duty, Diesel Powered Equipment(1)	0.3	0.3	0.3	0.6	1.4
Light-Duty Vehicles	0.6	-	-	0.6	6.9
Surface Grinding Tanks	-	3.5	-	-	-
Painting - Tanks(2)	6.9	-	-	-	-
Total - Construction	7.8	7407	0.3	1.2	8.3

*Includes construction activities at dome and terminal sites and along pipeline right-of-way.
**If activity persists for less than a year (e.g., painting - tanks) then total emissions for this shorter period are listed.
1. The dome and terminal sites considered as independent construction sites of equal magnitude.
2. Two coats of paint.

also developed a relationship suitable for the development of an emission factor for fugitive dust losses resulting from vehicular traffic over unpaved surfaces (EPA 1976). A sample calculation based upon a typical silt content of 12 percent for a gravel road, an average vehicle speed of 30 miles per hour and typical regional rainfall trends yields an emission factor of 6.9 pounds per vehicle mile for the West Hackberry site. Forty percent of this material would comprise very large (>30 mm) particulates which can be ignored. The annual tonnage emission rate contained in Table 3.4 is based upon an average daily road usage rate in terms of vehicle-miles. At Sulphur Mines there would be 4 miles of access roads at the dome site It is assumed that half the roads are paved at each location and that 150 workers use the roadways. The annual tonnage emission rate was then calculated by assuming that each employee travels twice the access road distance daily during a 260 day work year. These sources are only expected to have a very local impact on ambient air quality and have not been included in the modeling analyses.

Paved Roads

Paved roads are also a minor source of particulate emissions. Cowherd and Mann[24] have developed fugitive dust emission rates for vehicular usage of paved surfaces. These rates are dependent upon local land use factors and vary from about 1 to 15 grams per vehicle mile of particulates less than 30 mm in diameter. The impact of this source is negligible, and has not been included in the present modeling analysis. The calculation of the annual tonnage emission rate presented in Table 3.4 is based upon the assumptions discussed in the preceding paragraph and an emission factor of 7.5 grams per vehicle mile.

Heavy-Duty, Diesel-Powered Construction Equipment

Exhaust emissions can be anticipated due to the use of heavy-duty construction equipment. Annual tonnage emission rates have been calculated based upon typical equipment usage factors which are provided in Table 3.5, and the emission factors developed by the USEPA[23] and presented in Table 3.6. The equipment usage factors presented in Table 3.5 are representative of a public works construction site for five distinct phases[25].

Table 3.5 Typical Usage Factors* of Equipment in Public Works Construction.

Equipment	Construction Phase					Average Usage Factor Per Equipment Per Construction Period
	Clearing	Excavation	Foundation	Erection	Finishing	
Off-Highway Truck	.16(2)**	.16	.4(2)	.2(2)	.16(2)	.47
Wheeled Loader	.3	.4	.2	-	.16	.18
Tracklaying Loader	.04	.4	.04	-	.04	.08
Scraper	.08	-	.2	.08	.08	.10
Roller	-	-	.01	.5	.5	.22
Motor Grader	.08	-	-	.2	.08	.08
Wheeled Dozer	.17(2)	.4(2)	.2	-	.16(2)	.26
Miscellaneous	.4	.5	.6	.5	.4	.50
Fraction of hrs. at site for each phase	.14.	.14	.29	.29	.14	

*Fraction of the hours at the site per item.

**Numbers in parenthesis represent average number of items in use if the number is greater than one. Blanks indicate zero or very rare usage.

Table 3.6 Emission Factors* for Heavy-Duty, Diesel-Powered Construction Equipment

POLLUTANT	TRACKLAYING TRACTOR	WHEELED TRACTOR	WHEELED DOZER	SCRAPER	MOTOR GRADER	WHEELED LOADER	TRACKLAYING TRUCK	OFF-HIGHWAY TRUCK	ROLLER	MISCELLANEOUS
CO	175	973	336	660	97.7	261	72.5	610	83.5	188
HC**	50.1	67.2	106	284	24.7	84.7	14.5	198	24.7	71.4
NO_2	665	451	2290	2820	478	1000	265	3460	474	1030
Aldehydes	12.4	13.5	29.5	65	5.5	18.8	4.0	51.0	7.4	13.9
SO_2	62.3	40.9	158	210	39	82.5	34.4	206	30.5	64.7
Particulate	50.7	61.5	75	184	27.7	77.9	26.4	116	22.7	63.2

* grams per hour

** exhaust hydrocarbons

The USEPA[23] has indicated that at a distance of 100 meters from a highway, annual NO_2 concentrations would not be altered and one-hour CO concentrations would be no greater than 40 g/m^3. As a result, combustion emissions from these sources, as well as from the light-duty vehicle sources discussed in the following section, are expected to have a minimal impact on the ambient air quality and are not included in the modeling analysis. Annual tonnage emission rates for these sources are included in Table 3.4 based upon 2,000 hours of annual vehicle operation.

Light-Duty Vehicles

Exhaust emissions can also be anticipated at each of the proposed sites due to the use of automobiles and light-duty, gasoline powered trucks by employees. The assumptions necessary for the development of emission factors are the same as those employed in the preceding paragraphs on the use of onsite roads with the addition of the assumption that a 50/50 split exists between automobiles and light--duty[23] trucks. The emission factors recommended by the USEPA for calendar year 1972 vehicles are presented in Table 3.7 and are used to develop the site-specific emission rates.

Drill Rigs

Diesel powered drill rigs would be required during the construction phase for the preparation of the salt dome cavities and for development of the brine disposal wells. Table 3.8 summarizes USEPA emissions data for portable well drilling equipment and is appropriate for use in estimating pollutant levels associated with construction drilling operations.

Annual tonnage emission rates at Sulphur Mines have been developed using the assumptions that (1) the rigs have a total rated horsepower of 1500, (2) the rigs operate at 75 percent of capacity and (3) for 20 hours per day during the construction phase. Short-term modeling calculations have been performed for this point source utilizing the emission rates presented in Appendix A. Source buoyancy has been assumed to be negligible in the calculations.

Table 3.7 Summary of Routine Vehicular Emissions*

VEHICLE DESCRIPTION	CO	HC**	NO_2	SO_2	Particulate
Automobile	36.9	3.0	4.6	0.1	0.5
Light-Duty Gasoline-Powered Trucks	42.8	3.4	5.3	0.2	0.5

* grams per mile

**exhaust hydrocarbons

Table 3.8 Emission Factors For Diesel-Powered Industrial Equipment

Pollutant	Emission Factors (g/hp·hr)
CO	3.0
Exhaust HC	1.1
NO_2	14.0
Aldehyde	0.2
SO_2	0.9
Particulate	1.0

Surface Grinding - Tanks

During the construction phase, it is anticipated that the storage tanks would be blasted with abrasives prior to the application of light-colored paint. The use of abrasives results in the emission of fugitive dust. Approximately 1 percent of the applied material is emitted in this manner[26]. Assumptions necessary for the determination of an annual tonnage emission rate for this source include: (1) the abrasives application rate, (2) total tank surface area, and (3) the actual work rate. Calculations of particulate ground level concentrations are made for short-term averaging periods using a point source assumption.

Painting - Tanks

The application of paint to the ESR storage tanks during the construction phase would result in the emission of hydrocarbons due to evaporative losses. The rate of emission is dependent upon the same variables as discussed for surface grinding of the tanks except for the actual emission factor for paint application. The USEPA[23] recommends an emission factor of 1,120 pounds of hydrocarbons per ton of paint applied. Short-term modeling calculations have been made using a point source approximation. This assumption has a small impact on the accuracy of the results, particularly over the short-term, resulting in slightly conservative predictions close to the source. It is assumed that two coats of paint would be applied. Annual tonnage emission rates are presented in Table 3.4.

3.3.2 Sources of Emissions During Operations

The operational phase includes a two-part scenario comprised of (1) the injection of crude oil into the salt dome cavities and (2) the subsequent extraction of the oil at a future date as required by demand. The majority of the pollutant emissions associated with these activities would entail evaporative losses of gaseous hydrocarbons from exposed liquid surfaces of crude oil.

Other operational phase emissions include vehicle exhausts and fugitive dust due to the routine operation of project vehicles. Combustion contaminants would also occur during the unloading and loading of ocean-going tankers since ship boilers must operate to supply shipboard power. The following sections would categorize project emissions in terms of: (1) tanker loading, unloading and ballasting; (2) tanker and tug engines; (3) surge-storage and (4) pipeline pumps seals and valves.

The following paragraphs describe the development of emission rates for operational phase activities at the Sulphur Mines dome and Sun Terminal. Annual tonnage emission rates are presented for all sources in Table 3.9.

Vehicle Emissions

Exhaust and fugitive dust emissions due to the generation of light duty vehicles on site roadways are assumed to have the same emission factors (Table 3.5) as discussed in Section 3.3.1.

Tanker Loading

The loading of tankers during the operational phase of the program would be a major source of hydrocarbons due to evaporative losses. 24,000,000 barrels of crude oil would be distributed during the 150 day drawdown period with 60 percent of the total being shipped from the Sun Terminal facility by 65,000 dwt (450,000 barrel) tankers.

Table 3.9 Annual Tonnage Emission Rates at Sulphur Mines During Fill and Drawdown*

Source or Activity	Annual** Emissions (Tons)				
	HC	Particulate	SO_2	NO_2	CO
Tanker Loading VLCC to Tanker	291	-	-	-	-
Tanker Loading Sun Terminal	146	-	-	-	-
Tanker Ballasting	69	-	-	-	-
Tanker Engines - Loading at Sun Terminal(1)	0.3	2.4	34.7	10.4	0.35
Tanker Engines - Unloading at Sun Terminal(2)	0.6	3.5	5.2	17.3	0.7
Tug Engines - Loading and Unloading(3)	3.5	6.2	2.8	5.2	4.5
Tankage Standing and Withdrawal Storage Losses(4)	38.8	-	-	-	-
Pump Seals and Valves(5)	4.2	-	-	-	-
Total - Fill and Drawdown	553.4	12.1	114.7	32.9	5.6

*Combustion and fugitive dust emissions due to onsite road usage by project vehicles not included. See Table 3.7.
**If activity persists for less than a year (e.g., painting - tanks) then total emissions for appropriate shorter period are listed.
1. Based upon 69 deliveries by 450,000 bbl tankers.
2. Based upon 35 deliveries by 450,000 bbl tankers.
3. Based upon 4 hours of assistance during maneuvering operations during each delivery. Values are for loading and unloading on an individual basis.
4. Includes all tanks with a crude TVP of 4 psia.
5. Includes all pump seals and values.

The average hydrocarbon emission factor used for ship loading of crude oil is 0.55 lb/1,000 gallons. This emission factor was derived based on a modified analytical procedure using API[28] and Exxon[29] gasoline data. For estimating crude oil emission factors, the procedure employs correction factors for both arrival and generation components of the hydrocarbon vapor concentration previously derived from gasoline data. These emission factors are described in detail in Appendix B.

The short-term flow rate of oil by tanker may be substantially larger than the projected daily average of 96,000 barrels per day at Sun Terminal. Bad weather may prohibit open sea operations or mechanical breakdowns could result in dead time requiring increased flow rates in order to insure that drawdown can be completed in 150 days. In the Gulf Coast region, a weathering factor of 2 is often included in estimates of such operations[27] and a factor of 1.5 does not seem unreasonable for these operations. As a result, short-term tanker emission rates are based upon a maximum projected daily flow rate which is 150 percent of the average rate. The annual emission rate has been developed by assuming that the total mass of hydrocarbon emissions calculated for a period of a year occurs continuously over that period. PTMAN* and CDM* runs have been made for this source based upon the emission rates listed in Appendix A.

Loading the VLCCs to tankers occurs sufficiently far offshore that the associated emissions have not been modeled. However, the annual tonnage emission rate is listed in Table 3.9.

Tanker Ballasting

All oil would be delivered to the Sun Terminal during the initial fill by 45,000 dwt (320,000 bbl) tankers over a 5 month period. These tankers would have received their cargo from VLCCs in a lightering operation conducted 50 miles or further offshore. During unloading at Sun Terminal, the tankers would take on ballast water prior to putting out to sea. This results in the displacement of substantial amounts of hydrocarbon vapors which accrue in the ship's tanks during the unloading process. A tanker ballasting emission rate of 0.42 pounds of hydrocarbons per 1,000 gallons of crude capacity taken onboard has been utilized based upon the data discussed in the paragraph on

* PTMAN - Dispersion model for computing hourly pollutant concentrations at selected downwind locations.
CDM - Climatological dispersion model for computing long-term pollutant concentrations.

tanker loading. It is assumed for the purpose of this analysis, that tankers normally take on 40 percent of their capacity as ballast. Calculations are based upon a daily delivery rate of 18,000 barrels of crude oil per hour during the initial fill. A weathering factor of 1.5 has been incorporated in the development of short-term emission rates as discussed in the paragraph on tanker loading.

Short- and long-term model calculations have been made for tanker ballasting using a point source approximation. The omission of the ship's structure wake effect may result in a small over-prediction of non-methane hydrocarbons ground level concentrations close to the source.

Tanker Engines

Tanker boilers are continuously fired resulting in combustion emissions during all operations. Emission factors have been developed on a fuel consumption basis, where tanker fuel is nonvolatile Bunker C fuel oil (#6 fuel oil). Table 3.10 summarizes the emission factors developed by Esso Research and Engineering Company[33].

Table 3.10
Emission Factors for Tanker Boilers

POLLUTANT	POUNDS/BARREL FUEL	POUNDS/TON FUEL**
SO_2	6.7(S)*	44.7(S)*
NO_2	4.36	29.1
Particulate	0.966	6.44
HC	0.134	0.893
CO	0.084	0.560

* S = %S; for 2%S, SO_2 = (6.7)(2) = 13.4 #/bbl.

** 8 # fuel/gallon and 2240 #/ton.

Tanker engines would be in operation at variable boiler capacities during both the loading and unloading processes. Boiler activity can be classified as either: (1) discharge cargo-full capacity; (2) hotelling or (3) maneuvering. During cavity fill operations, tankers would unload utilizing full boiler capacity. These operations would result in a total loading time of 21 hours and an unloading time of 24 hours.

Emission rates are estimated on the basis of fuel consumption rates during specific operations. Fuel consumption rates for 70,000 DWT tankers have been estimated by Pacific Environmental Services, Inc.[31] Tankers delivering SPR crude oil would be 45,000 DWT in size while 65,000 DWT tankers would be used for distribution. However, fuel consumption rates for 70,000 DWT tankers would be employed in the present analysis. Table 3.11 summarizes the fuel consumption rates for three typical operating conditions. Sea passage fuel consumption rates have not been included as boiler emissions would be dispersed over large distances and would have an insignificant impact on local ambient air quality.

Table 3.11
Tanker Boiler Fuel Consumption Rates

OPERATION	TONS/HOUR*
Discharging cargo and ballast at full capacity	2.4
Maneuvering in port	2.3
Hotelling**	0.33

* Ton = 2,240 pounds
** 10-15% of full power

Table 3.12 provides the emission rates which result for each phase of boiler operation. Annual tonnage emission rates, presented in Table 3.9, can then be calculated based upon the projected number of terminal visits during the loading and unloading phases. These emissions were not included in the modeling analysis as the impact of these buoyant sources on local ambient air quality would be insignificant.

Table 3.12
Tanker Boiler Emission Rates*

POLLUTANT	TANKER OPERATION		
	Discharging Cargo & Ballast	Maneuvering	Hoteling
SO_2	27.1	26.0	3.72
NO_2	8.80	8.44	1.21
Particulate	1.95	1.87	0.27
HC	0.27	0.26	0.04
CO	0.17	0.16	0.02

* Grams per second

Tug Engines

Tugs would be required to assist both tankers and barges during maneuvering operations. Combustion contaminants would result due to engine operation. The emission rates for tugs depend upon the number of tugs required for ship or barge assistance, the rated horsepower and the duration of assistance. The average fuel consumption underway as reported by USEPA[23] is 0.34 pounds of diesel fuel per horsepower per hour (#/hp-hr). All tugs use diesel fuel and it is assumed the sulfur content is 0.275 percent. For the purpose of computing pollutant emissions from tugs, the following relationship (Table 3.13) has been developed which gives the combined horsepower requirements (all tugs used) for tanker assistance[31].

Table 3.13
Tug Horsepower Requirements
Based Upon Projected Tanker Size

TANKER SIZE (DWT)	HORSEPOWER REQUIREMENTS (hp)
70,000 - 80,000	3,000
120,000 - 150,000	4,000
165,000 - 188,000	6,000

For 70,000 DWT tankers, the total tug horsepower requirements are calculated to be 3,000 hp, provided by two tugs of 1,500 hp each. Therefore, 1020 #fuel/tug/hour of assistance is required. Table 3.14 provides emission rates prepared by PESI[31]. for tug assistance for this size of tanker.

Table 3.14
Maximum Emission Factors for Tug Boats

POLLUTANT	LBS/HR OF ASSISTANCE*
SO_2	5.61
NO_2	9.54
Particulate	13.6
HC	6.12
CO	8.16

* Total hp = 3,000

Annual tonnage emission rates based upon the projected number of tanker visits are presented in Table 3.9. Two tugs will assist the tankers during maneuvering operations. These slightly buoyant emissions would not be included in the modeling analysis since the impact on local ambient air quality would be insignificant.

Storage and Treatment Tanks

Evaporative hydrocarbon losses can be anticipated at the Sulphur Mines dome and Sun Terminal sites due to standing storage losses from the surge storage tanks and the ballast water separation tanks. There would be two 200,000 bbl surge storage tanks and two 55,000 bbl ballast treatment tanks at the Sun Terminal facility. At the dome site, there would be two 7,500 barrel oil slop tanks. The surge storage tanks constitute the major contributor at each location. The evaporative hydrocarbon emissions from storage tanks can be attributed to standing loss and working (withdrawal) loss. The emissions calculated utilizes the relationship previously developed by the American Petroleum Institute,[32] show that the standing loss contributed the predominant portion of the overall emissions, and is a function of many variables including: (1) tank diameter; (2) color of tanks; (3) type of tanks; (4) type of fuel; (5) temperature; (6) wind speed; and (7) crude true vapor pressure (TVP).

However, with the advent of modern floating roof tanks with double seal design, the emissions resulting from standing loss can be greately reduced. Based on recent tests conducted by Chicago Bridge and Iron Company, standing loss emissions from tanks employing double sealed floating roof tanks, are only about six percent of those calculated by API. Thus, The SPR tanks would employ modern floating roofs with double seal design and would be painted light grey or aluminum to minimize temperature variability. Emissions are considered to be continuous and a TVP of 4 psia was assumed for long-term calculations and 5 psia for short-term analyses. During withdrawal of crude oil from the tanks, they would continue to be a source of evaporative losses due to adherence of oil to the tank sides. Techniques exist for the development of emission rates due to adherence losses; however, the present analysis employs the simplifying assumption that the tanks continuously emit hydrocarbons due to standing storage losses. This assumption is not felt to significantly alter the results of the air quality impact analysis. In the case of the ballast water treatment tanks, the oil will sit on top of the water and be directly exposed to evaporative losses.

Short- and long-term emission rates utilized in the subsequent modeling analysis are presented in Appendix A. For modeling analyses, the tank farms are assumed to be point sources. The omission of the building wake correction factor would yield slightly conservative results close to the point of emission. Annual tonnage emission rates are presented in Table 3.9 and are based on the assumption that the tanks emit continuously for the entire period. This could occur during initial fill which is scheduled to last for 5 months but is unlikely during the 150 day drawdown phase.

Pump Seals and Valves

Liquid crude oil losses from pump seals and valves will constitute a hydrocarbon emission source at the pump houses established near the dome and terminal sites. Pipeline flange leaks are negligible[33]. Emission factors have been developed through measurement programs at refineries in the Los Angeles Air Basin. These factors are summarized in Table 3.15.

Table 3.15
Emission Factors for Pump Seals and Pipeline Valves

Pump Seals	4.2 #/day/seal
Pipeline Valves	0.15 #/day/valve

In estimating losses from SPR pump seals and valves, all pumps are assumed to have two seals. An average of 6.25 valves per pump is assumed based on estimates for the Alaskan Crude Oil Delivery Terminals in California of 50 valves for eight pumps[31].

The necessary variable for the determination of the emission rates for these sources is simply the number of pumps. For Sulphur Mines, a pump house is located at the dome site and at the Sun Terminal. There would be 2 pumps at the former location and 4 pumps at the Sun Terminal. Once again it is conservatively assumed that these sources emit at a continuous rate over an annual period. Short- and long-term modeling calculations have been performed for these point sources.

3.3.3 Current Regulations

Current regulations restricting air pollutant emissions from all operations necessary for the development and use of the SPR facilities can be grouped into emissions regulations and ambient air quality standards.

Emission Regulations: Federal

The USEPA has set New Source Performance Standards (NSPS) limiting allowable emissions for certain industrial facilities. These include standards for petroleum refineries and storage vessels for petroleum liquids. The NSPS for storage vessels would normally impact the SPR project as it applies to vessels with a capacity greater than 40,000 gallons (950 barrels). However, a recent EPA emissions offset policy set forth on all major hydrocarbon sources may exempt the storage caverns from this standard (see discussion on State section). This regulation does not apply to pressure vessels, subsurface caverns, porous rock reservoirs, or underground tanks under some conditions.

The Federal regulations for the storage of liquid volatiles (40 CFR Part 60, Subpart K) are as follows:

- o If the true vapor pressure (TVP) of the petroleum liquid, as stored, is equal to or greater than 78 mm Hg (1.5 psia) but not greater than 570 mm Hg (11.1 psia), the storage vessel shall be equipped with a floating roof, a vapor recovery system, or their equivalents.

- If the TVP of the petroleum liquid as stored is greater than 570 mm Hg (11.1 psia), the storage vessel shall be equiped with a vapor recovery system or its equivalent.

Presently, the NSPS for the former category is a single seal floating roof. However, EPA is currently considering requiring the double seal design in areas of poor air quality. Because of the substantial benefits they provide, DOE will employ double seal floating roofs on all tanks constructed for the SPR program.

In December 1976, USEPA adopted an "emission offset" policy under which construction permits for new industrial sources in non-attainment areas could be issued if any increase in air pollution from the new source was more than offset by additional emission reductions by existing sources beyond those levels required by the applicable state implementation plan. The newly enacted Clean Air Act Amendment of 1977 (42 U.S.C. 7401 et. seq.) accepts this offset process and extends the date by which states must attain the primary standards to July 1, 1979 in these currently non-attainment areas.

The construction, filling, and withdrawal phase of the SPR project would spontaneously increase the air emissions of the surrounding area; however, there are currently no enforced Federal regulations which specifically limit emissions from construction equipment or marine terminal operations. EPA has determined that, because of the temporary and intermittant nature of emissions associated with the Bayou Choctaw SPR site, the emission offset policy does not apply to this particular activity. It would appear that this determination would apply to other similar SPR sites, including Sulphur Mines. In any event, it is not anticipated that the permanent component of the emissions (i.e., that for above ground tanks at Sun Terminal) would exceed the 100-ton threshhold for offset applicability.

Emission Regulations: State

Texas. In a review of the Texas Implementation Plan, the USEPA determined that the plan was inadequate for attainment and maintenance of the NAAQS for particulates in Houston, Galveston, and other areas, and directed the state to submit a revised plan. The USEPA also promulgated amendments to the current plan such that a permit to construct a new source in the Houston-Galveston AQCR would not be issued unless the TACB determined that the source would emit reactive hydrocarbons at a rate of less than 3 lb/hr and less than 15 lb/day. Exemptions are made for paint application processes such as would be used in painting the crude storage tanks for the SPR project (40 CFR 52, Subpart 52.2292).

Texas Regulation V, concerning the storage and handling of volatile hydrocarbon compounds, requires floating roofs and/or vapor recovery systems for storage vessels of volatile hydrocarbon compounds with capacities larger than 420,000 gallons (10,000 barrels). Until recently crude oil containers were exempt from this requirement. Under special conditions, variances may be granted to crude oil storage vessels with a storage capacity of 10,000 barrels or less. Ship and barge loading and unloading is currently exempt from emission controls and no restrictions are foreseen for crude; however, gasoline emissions would probably be regulated soon.

Although there is no hydrogen sulfide (H_2S) NAAQS, Rule 203 of Texas Regulation II states that no source may emit H_2S such that net ground level concentration is exceeded: (1) 0.08 ppm averaged over any 30-minute period if the downwind concentration of H_2S affects a property used for residential, business or commercial purposes, or (2) 0.12 ppm if it affects only property used for other than residential, recreational, business or commercial purposes, such as industrial property and vacant tracts and range lands not normally occupied by people. In practice, this rule does not potentially impact the SPR program since no significant amount of H_2S would be encountered in the sweet crude being stored at the SPR sites, due to the weathering of the oil during transit.

During the construction phase and, to a lesser extent, during the operational phase of the program, the SPR project would have to comply with Rule 104 of Texas Regulation I. This rule states that in any Standard Metropolitan Statistical Area, where the NAAQS for particulate matter are exceeded, no fine material may be handled, transported or stored without taking precautions specified in the regulation. This rule also requires measures to prevent particulates from being airborne when a road is used, constructed, altered or repaired. Typical particulate abatement techniques include application of water or oil to unpaved surfaces or the requirement of reduced vehicular speeds.

Several states, including Texas and Louisiana, have differentiated between "reactive" hydrocarbons and "low-reactive" hydrocarbons. This approach was used as a modeling tool to determine the amount of hydrocarbon emission reductions required to attain the oxidant standard. However, recently USEPA has found that almost all non-methane hydrocarbons are photochemically reactive and that low-reactivity hydrocarbons eventually form as much photochemical oxidants as the highly-reactive hydrocarbons. Therefore, the policy regarding hydrocarbon reactivity may soon be modified.

Louisiana. The Louisiana State Implementation Plan regulates new sources of volatile hydrocarbon compounds; however, crude oil has been considered virtually unreactive in the formation of oxidants and is thus exempt (LACC Regulation 22.10). The LACC has indicated, however, that a possible modification to LACC Regulation 22.10 to make this regulation consistent with the Federal NSPS would require floating roofs and vapor recovery systems for tanks of the capacity presently being considered for the SPR project. Louisiana also requires the control of fugitive dust losses in the manner described previously by regulations set by the State of Texas.

Louisiana currently has no regulations controlling ship and barge loading and unloading operations and currently does not anticipate implementing any such regulations. Should the USEPA deem such controls necessary for the AQCR to attain and maintain the NAAQS, the USEPA may promulgate regulations for these operations. Louisiana's Implementation Plan was declared inadequate by the USEPA for attainment and maintenance of the primary NAAQS for photochemical oxidants and the state has been directed to submit a revised plan. The modified Louisiana S/P was submitted to EPA in November 1977.

Ambient Air Quality Standards

The NAAQS which are listed in Table 3.16, establish primary and secondary standards. The primary standards have been set to protect the public health. The secondary standards protect the public welfare from any known or anticipated adverse effects of a pollutant, including 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. The newly enacted Clear Air Act Amendments have also authorized EPA to promulgate prior to August 1978 a National Primary Ambient Air Quality Standard for NO_2 concentrations over a period of not more than 3 hours.

The State of Texas has not enacted any air quality regulations more stringent than the existing Federal Regulations given in Table 3.16 with the exception of the additional regulation of H_2S mentioned earlier. Although Louisiana has promulgated stricter standards than the NAAQS, the stricter standards

Table 3.16 National Ambient Air Quality Standards[a]

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Particulate Matter[b]	Annual (Geometric mean)	75 μg/m³	60 μg/m³
	24-hour	260 μg/m³	150 μg/m³
Sulfur Dioxide	Annual (Arithmetic mean)	80 μg/m³ (0.03ppm)	
	24-hour	365 μg/m³ (0.14 ppm)	
	3-hour	---	1300 μg/m³ (0.5 ppm)
Carbon Monoxide	8-hour	10 μg/m³ (9 ppm)	Same as Primary
	1-hour	40 μg/m³ (35 ppm)	
Photochemical Oxidants[c]	1-hour	160 μg/m³ (0.08 ppm)	Same as Primary
Hydrocarbons[d] (nonmethane)	3-hour	160 μg/m³ (0.24 ppm)	Same as Primary
Nitrogen Dioxide	Annual (Arithmetic mean)	100 μg/m³ (0.05 ppm)	Same as Primary

(a) All standards (other than annual standards) are specified as not to be exceeded more than once per year. The measurement methods are also specified as Federal Reference Methods. The air quality standards and a description of the reference methods were published on April 30, 1971 in 42 CFR 210, recodified to 40 CFR 50 on November 25, 1972.

(b) The secondary annual standard (60 $\mu g/m^3$) is a quide to be used in assessing implementation plans to achieve the 24-hour secondary standard.

(c) Expressed as ozone by the Federal Reference Method.

(d) This NAAQS is for use as a guide in devising implementation plans to achieve oxidant standards.

are not presently actively enforced. This is a direct result of their intent of making the State Standards consistent with Federal limits in the near future. Table 3.17 shows Louisiana Ambient Air Quality Standards which are in addition to those adopted shown in Table 3.16. In 1974 the USEPA also developed standards for the prevention of significant deterioration. These standards regulate SO_2, and total suspended particulates in a manner dependent upon existing levels of ambient air quality. The area classifications are as follows:

Class I: Any change in air quality would be considered significant.

Class II: Deterioration normally accompanying moderate well-controlled growth would be considered insignificant.

Class III: Deterioration up to the National Standards would be considered insignificant.

In August 1977, the Clear Air Act Amendments made provisions in the significant deterioration standards, (Table 3.18) to consider other pollutants including hydrocarbons, carbon monoxide, photochemical oxidants and nitrogen oxides. The Amendments required EPA to conduct a study and to promulgate regulations within two years to prevent the significant deterioration of air quality which would result from the emission of these other pollutants.

The Amendments also allowed variances from the Class I sulfur dioxide increments to be granted for up to 18 days a year. Such a variance can be granted through the approval of the state governor and the federal land manager. Should these two offices disagree on the advisability of such a variance, the final decision would be left to the President, and would not be subject to judicial review. Variances of 8 and 15 percent from increments for both SO_2 and particulates in Class II areas will be allowed in low and high terrain areas, respectively.

Table 3.17 Louisiana Ambient Air Quality Standards in Addition to NAAQS[a]

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Dustfall	1 month	20 tons/sq. mile	---
Coeffient of Haze	Annual (Geometric mean)	0.6 coh/1,000 linear feet	---
	Annual (Arithmetic mean)	0.75 coh/1,000 linear feet	---
	24-hour	1.50 coh/1,000 linear feet	---
Sulfur dioxide	Annual (Arithmetic mean)	---	60 $\mu g/m^3$ (0.03 ppm)
	24-hour	---	260 $\mu g/m^3$ (0.10 ppm)
Sulfur Acid Mist, Sulfur Trioxide or any combination thereof	Annual (Arithmetic mean)	80 $\mu g/m^3$ (0.03 ppm)	---
	24-hour	365 $\mu g/m^3$ (0.14 ppm)	---
Total Oxidants	Annual (Arithmetic mean)	58.8 $\mu g/m^3$ (0.03 ppm)	58.8 $\mu g/m^3$
	4-hour	98.0 $\mu g/m^3$ (0.05 ppm)	58.8 $\mu g/m^3$ (0.05 ppm)

(a) All standards (other than annual standards) are specified as not to be exceeded more than once per year. The measurement methods are also specified as Federal Reference Methods. The air quality standards and a description of the reference methods were published on April 30, 1971 in 42 CFR 210, recodified to 40 CFR 50 on November 25, 1972.

Table 3.18 Maximum Allowable Increase in Concentrations for the Prevention of Significant Deterioration

	Maximum Allowable Increase in Concentration[1] ($\mu g/m^3$)								
	Class I			Class II			Class III		
Pollutant	3-hour	24-hour	Annual	3-hour	24-hour	Annual	3-hour	24-hour	annual
Particulates	--	10	5	--	37	19	--	75	37
SO_2	25	5	2	512	91	20	700	182	40

1. Arithmetic mean value except as noted.

3.3.4 Ambient Air Quality Impact During Construction Phase

The following paragraphs discuss the results of the modeling analysis and ambient air quality impact conducted for each significant source at Sulphur Mines during the construction phase. The modeling consists of: (1) the use of the model PTMAN to predict the frequency of occurrence of violations of applicable standards and the distribution of pollutant concentrations at downwind receptor locations and (2) the prediction of annual centerline pollutant ground level concentrations by the model CDM utilizing nearby historical meteorological data.

This approach is employed for all identifiable sources except those which have a negligible impact on air quality (e.g., the salt dome storage cavity) or those whose erratic nature makes the use of the Gaussian modeling approach irrelevant over a short-term averaging period. Many of the activities planned for the construction phase are indicative of this latter type of source. For example, fugitive dust losses due to the use of heavy-duty construction equipment during site preparation are spread over a large area and occur intermittently at variable emission rates. Such a source cannot be reliably modeled over the short-term; however, it can be reasonably included in the annual modeling analysis through the use of CDM in conjunction with simplifying point-source assumptions. Other sources have been discussed solely in terms of annual tonnage emission rates. Sources handled in this manner included: (1) the use of paved and unpaved roads and (2) the use of heavy and light-duty vehicles.

Unabated annual emissions for all sources are presented in Table 3.4. The use of paved and unpaved roads accounts for less than 5 percent of the construction phase particulate emissions and the vast majority of this total (e.g., 300 ton/year) is represented by the use of unpaved surfaces. These emissions can be further minimized by the use of control methods with efficiencies ranging from 25% to 80%[23]. Control techniques include the application of water, chemical treatment and speed control. The latter approach can be quite effective. The impact of these emissions is quite local (i.e., 40% of the total will fall off within 0.5 km radius) and is in compliance with primary (260 $\mu g/m^3$) and secondary (150 $\mu g/m^3$) EPA air quality standards for particulates.

Combustion contaminants would result during construction due to the use of heavy and light duty vehicles. As indicated in Table 3.4 this activity would account for a small portion of the combustion contaminants emitted during construction. The impact of these sources would be well dispersed over the construction areas and the overall impact in terms of ambient air quality would be insignificant.

Long-term or annual pollutant ground level concentrations would be insignificant for construction phase activities with the exception of large scale land clearing operations at the dome. Calculations have been performed for these locations using a point source approximation. The modeling results are presented in Figure 3.7 and indicate that the Federal primary standard for particulates would not be exceeded. The calculations are based upon unabated emission rates. The USEPA[23] indicates that an effective water spraying program would reduce emissions by 50 percent. Such a program is planned for the Sulphur Mines construction sites and it is anticipated that the resultant level of particulate emissions would be in compliance with the applicable standards.

3.3.5 Air Quality Impact During the Operational Phase

Annual tonnage emission rates have been developed for all operational phase sources. The modeling steps and models employed are identical to those described for construction impacts (Section 3.3.4).

The following paragraphs discuss the results of the modeling analysis conducted for each significant source at Sulphur Mines and Sun Terminal during the operational phase. The modeling consists of (1) the use of the model PTMAN to predict the frequency of occurrence of violations of applicable standards, and the distribution of pollutant concentrations at downwind receptor locations, and (2) the prediction of annual centerline pollutant ground level concentrations by the model CDM utilizing nearby historical meteorological data.

The operational phase of the program would consist of three types of activity: (1) initial fill, (2) drawdown, and (3) refill. All crude oil would be delivered to the Sun Terminal by tankers during the initial fill and refill phases. During the 150 day drawdown, 60 percent of the oil would be distributed by tanker, while the remainder would be distributed

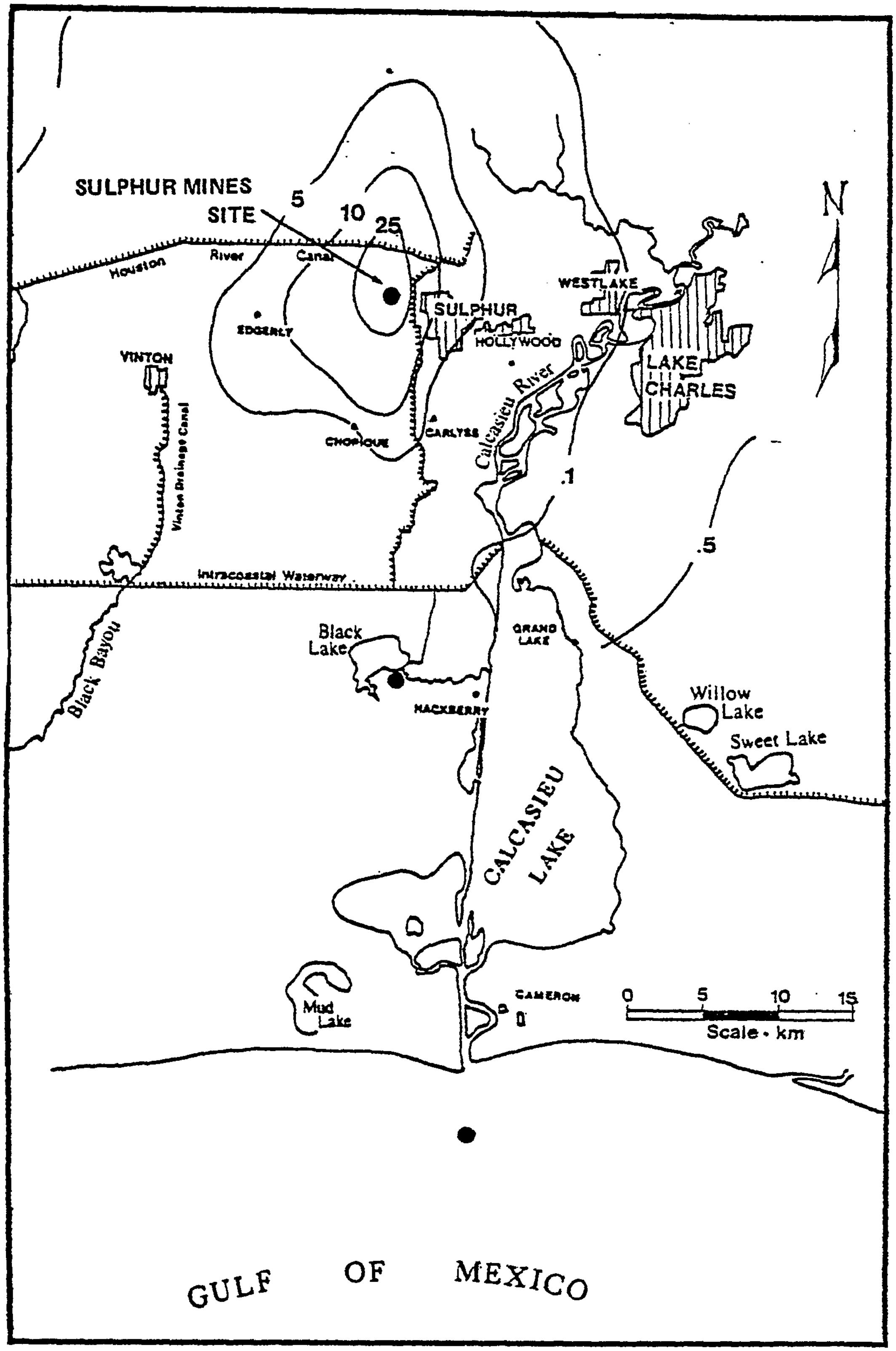


Figure 3.7 Annual Average Particulate Ground Level Concentrations ($\mu g/m^3$) for the Dome Site During the Construction Phase at Sulphur Mines.

by overland pipelines. Evaporative losses of hydrocarbons would emanate from exposed surfaces of crude oil during each project phase. The largest volume of hydrocarbon emissions would be associated with ship crude oil handling activities during loading and unloading. There would be concomitant evaporative hydrocarbon losses from the Sun Terminal tank facilities as well as the terminal pump house. At the dome site, additional evaporative hydrocarbon losses would emanate from onsite tanks and the dome pump house. Combustion contaminants could also be anticipated at the Sun Terminal due to boiler emissions from the dockside tankers and from tug engines during tanker assistance. Annual tonnage emission rates for these sources are contained in Table 3.9.

Short-term modeling calculations have been performed for project hydrocarbon emissions at both the dome and terminal sites. The calculations are based upon concomitant emissions at each location from all sources including tankers, tanks and pump houses. In addition, two separate scenarios were modeled at the Sun Terminal to handle both ship loading and unloading phases. The results of the modeling analyses indicate that at the dome site short-term NMHC ground level concentrations would be in compliance with the 3-hour standard. However, during tanker loading and unloading operations at the Sun Terminal, the standard would be exceeded. This indicates that during tanker loading during the distribution phase, the 3-hour NMHC standard would be violated 1 percent or more of the time annually out to downwind distances in excess of 5 kilometers with the maximum impact occuring to the west of the terminal. During ship ballasting operations following the completion of tanker unloading, the applicable standard would be exceeded out to a downwind distance of approximately 5 kilometers with the maximum impact occurring west of the facility where the frequency of violation is in excess of 2.5 percent annually.

Annual NMHC ground level concentrations have also been calculated for the dome and terminal sites. Figure 3.8 provides the results of this analysis for the Sun Terminal. This calculation is based upon the conservative assumption that both the fill and drawdown phases could occur, at least in part, during the same annual period. The results of the calculation indicate that annual ground level concentrations would be generally less than 1.0 $\mu g/m^3$. Similar calculations were performed for the dome site and are presented in Figure 3.9. Annual NMHC concentrations would be generally less than 0.1 $\mu g/m^3$ downwind of the dome site sources.

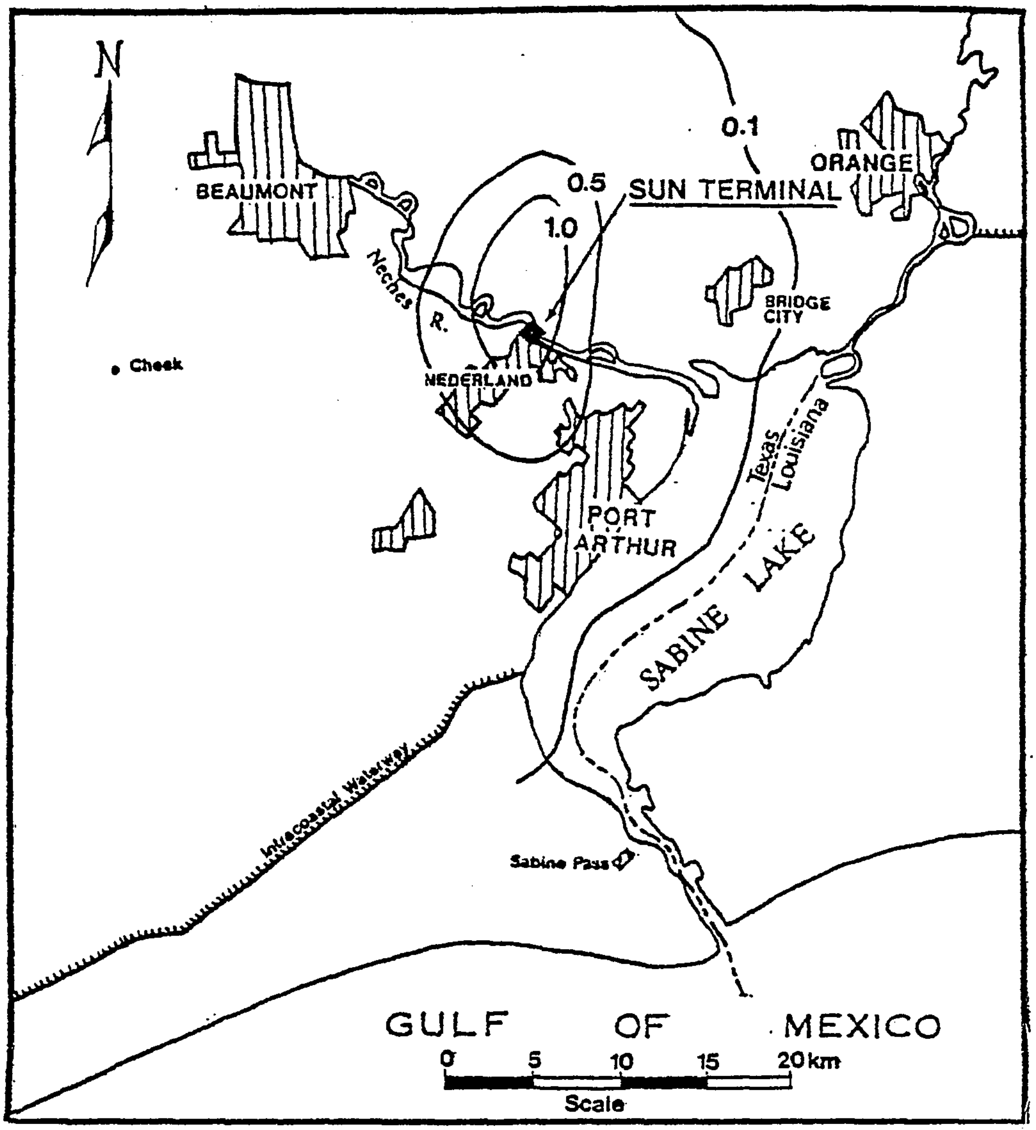


Figure 3.8 Annual Average HC Ground Level Concentrations ($\mu g/m^3$) for the Sun Terminal During the Operational Phase at Sulphur Mines.

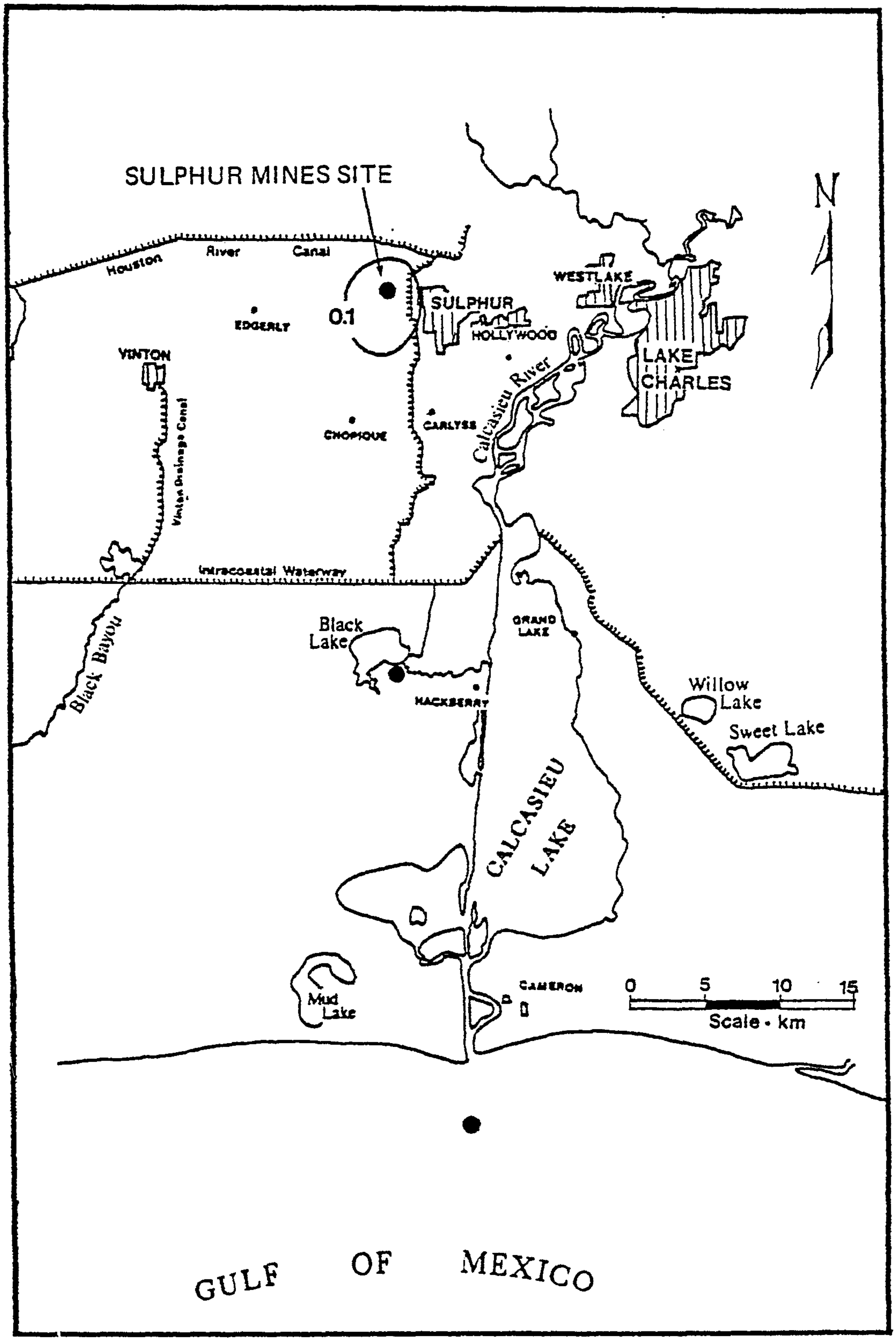


Figure 3.9 Annual Average HC Ground Level Concentrations ($\mu g/m^3$) for the Dome Site During the Operational Phase at Sulphur Mines.

In summary, the Sulphur Mines dome and Sun Terminal facilities would be sources of NMHC, and to a lesser extent, combustion contaminants. However, in present form, the level of hydrocarbon emissions at the Sun Terminal and Sulphur Mines site is insufficient to have an important impact on regional levels of photochemical oxidant. The annual tonnage emission rate for Sulphur Mines is relatively small in comparison to regional hydrocarbon emission levels, thus it is unlikely that the proposed facility would have a significant impact on observed levels of photochemical oxidant. The facility (i.e., the storage site itself) would not result in violations of standards.

3.3.6 Cumulative Air Quality Impacts Resulting From the West Hackberry and Sulphur Mines SPR Operations

Crude oil supplies and distribution for the Sulphur Mines and West Hackberry SPR sites will be handled at Sun Terminal in Nederland, Texas. For both sites, lightering from VLCCs onto 45,000 DWT and/or 55,000 DWT tankers will occur in the Gulf of Mexico. These tankers will then travel through the Sabine Pass, the Sabine-Neches Canal and the Neches River to the terminal. Crude oil for both facilities will then be distributed via the same pipeline for approximately five miles (see Figure 1.7). Concurrent operation of both sites will have a cumulative impact for certain activities.

Annual tonnage emission rates will increase due to the increased operations at Sun Terminal. Cumulative emission rates are given in column c of Table 3.19. For means of comparison columns a and b of Table 3.19 represent the emission rates for the Sulphur Mines and West Hackberry SPR sites respectively. Hydrocarbon emissions from tanker loading and unloading and lightering operations for the West Hackberry SPR site will be in excess of the Federal 3-hour standard for hydrocarbons (160 g/m^3). The dome site facility would not result in violation of short-term and annual ambient air quality standards for hydrocarbons. However, during tanker loading and unloading operations at Sun Terminal, the three-hour NMHC standard would be exceeded out to a downwind distance of approximately 5 kilometers. The annual frequency of these violations is estimated to be less than three percent with the most impact occurring west of the terminal facility. It is anticipated that during adverse meteorological conditions,

Table 3.19 Annual Tonnage Emission Rates at (a) Sulphur Mines*, (b) West Hackberry**, (c) Sulphur Mines and West Hackberry.

Source or Activity	Annual Emissions (Tons)														
	HC			Particulate			SO_2			NO_2			CO		
Site	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Storage Tanks (Sun Terminal)	(3) 38.8	(4)(5) 80	118.8	--	--	--	--	--	--	--	--	--	--	--	--
Tanker Unloading (Ballasting) (6)	69	(4)(7) 195	264	--	--	--	--	--	--	--	--	--	--	--	--
Tanker Loading	146	(4)(5) 347	493	--	--	--	--	--	--	--	--	--	--	--	--
Ship Engines	(1) .9	(5)(7) 3	3.9	(1) 5.9	(5)(7) 24.3	30.2	(1) 39.2	(5)(7)(4) 329.6	368.8	(1) 27.7	(5)(7)(4) 107.6	135.3	(1) 1.05	(5)(7)(4) 2.1	3.15
Tug Engines	(2) 3.5	(5)(7)(8) 10	13.5	(2) 6.2	(5)(7)(8) 20.8	27	(2) 2.8	(5)(7)(8) 5.9	8.7	(2) 5.2	(5)(7)(8) 10.4	15.6	(2) 4.5	(5)(7)(8) 10.4	14.9
VLCC to Tanker (Lightering)	291	694	985	--	--	--	--	--	--	--	--	--	--	--	--

* If activity persists for less than a year then total emissions for appropriate shorter period are listed.

** Emission rates are based on the assumption that all sources emit continuously at a fixed average annual rate. (Data taken from FEA 76/77-4 and Final Report Air Quality Impact Analysis for Five Potential Strategic Petroleum Reserve Salt Dome Storage Sites. Part II: Site Specific Air Quality Impact of the Proposed SPR Program, March 1977).

1. Based upon 69 deliveries by 450,000 barrel tankers for loading and 35 deliveries for unloading.
2. Based upon 4 hours of assistance during maneuvering operations during each delivery. Values are for loading and unloading on an individual basis.
3. Includes all tanks with a crude TVP of 4 psia.
4. Based upon 150 deliveries per year by 450,000 barrel tankers.
5. 50 percent of oil distributed by tanker.
6. Based upon tankers using 40 percent of their capacity for ballast water.
7. 90 percent of oil delivered by tanker to Sun Terminal.
8. Based upon 6 hours of assistance during maneuvering operations during each delivery and 150 deliveries per year.

reduction of terminal hydrocarbon emission is required. Several alternative measures can be applied to reduce hydrocarbon emission at Sun Terminal. These include (1) the installation of tall venting stacks, (2) the utilization of vapor recovery and emission control equipment, (3) reduction of the tanker loading and unloading rates, and (4) the combination of the above measures.

3.3.7 Noise

The Sulphur Mines site preparation construction activities and facility operation after construction would create only minor and temporary noise impacts for residential, recreational, farming, and other non-industrial land uses in and near the site area. Plans are for the construction activities to take place over a period of approximately 12 months. The major noise from construction and facility operation would occur at the storage site, along the pipeline corridor, and at the terminal docks.

Sulphur Mines Dome Storage Site Area

Contributing noise sources at the storage site area during site preparation would be air compressors, trucks, diesel engines, pumps, drilling rigs, impact equipment, concrete mixers, and general construction related equipment. Noise levels typical of this equipment are given in Table 3.20. An evaluation of the construction noise sources indicates that diesel engines would provide the most consistent source of noise and that impact and drilling equipment would create the peak sound levels. Land located on or adjacent to the proposed storage site is not a noise sensitive use area. The areas adjacent to the storage site are forest areas and are unpopulated.

After completion of the storage site preparation, fill operations would require the use of injection pumps and brine disposal pumps. These, together with other pumps which would be used for oil discharge operations, would be sheltered in a pumphouse at the storage facility. Although noise levels within the pumphouse can be expected to exceed 90 dBA, typical pumphouse construction (see Appendix C) should reduce exterior noise from this source to less than 70 dBA at 50 feet from the structure.

Table 3.20. Construction Equipment Noise Levels

Equipment	A-weighted sound level at 50 feet dB
Air Compressor	81
Backhoe	85
Concrete Mixer	85
Crane Mobile	83
Dozer	87
Generator	78
Grader	85
Pile Driver	101
Pump	76
Rock drill	98
Truck	88

Source: "Noise Emission Standards for Construction Equipment Background Document for Portable Air Compressors," U.S. Environmental Protection Agency, EPA 550/9-76-004.

Noise from drilling operations (for approximately 11 months) is expected at the storage site and at the brine injection wells to the southeast of the storage facility. It is anticipated that conventional oil drill-rig equipment would be used. Noise from conventional oil drilling equipment reaches levels of 95 to 100 dBA at 50 feet from the drill rig. The noise impact zone (L_{eq} = 55 dB) is estimated to extend approximately 1,800 feet from the drilling sites; however, all drilling sites are in remote areas and noise from these sites should have little effect on residences. In addition, approximately 2 miles of pipeline construction would be required for the brine disposal system. The pipeline construction for brine disposal along with the drilling activity would contribute to the noise of construction activities at the storage site.

Additional noise at and near the storage facility would be caused by the slight increased vehicle traffic from maintenance and operating personnel. It is estimated that noise from all sources associated with fill/discharge operations would increase the noise levels less than 2 dB at the site perimeter.

Based upon the existing land use and the remoteness of the site from residential and noise sensitive use areas (4 miles from Sulphur), it is not anticipated that noise from storage facility operations would interfere with outdoor or indoor activities near the storage site.

Pipeline Corridor

A spur pipeline would be required for transporting crude oil between the storage site and the West Hackberry - Sabine River distribution pipeline. The pipeline (20 inch diameter would traverse approximately 14 miles and pass through mostly undeveloped areas.

The noise impact boundary is estimated to be L_{eq} = 55 dB at 500 feet from the pipeline right-of-way. The annual L_{dn} levels along the pipeline are not expected to be affected because of the relatively short period of construction activity at specific sites.

Summary of Noise Impacts

Noise impacts from the construction associated with the Sulphur Mines site preparation are summarized in Table 3.21.

During fill and/or discharge operations, there would be noise generated from the continuous operation of pumps at both the storage and terminal facilities. The noise is expected to be continuous day and night during these operations; however, since the pumps at both the storage and terminal facility would be enclosed in pumphouses, it is anticipated that there would be negligible noise impacts (See Appendix C for Federal guidelines) on the nearest residential areas in the vicinity of these facilities.

Table 3.21 Summary of Sound Level Contribution (dB) from Construction Activities

Construction Site	L_{eq}	L_{dn}	Distance from Center of Site feet
Storage Site Area	<55	<55	2,000
Pipeline Corridor*	<55	<55	500
Terminal and Dock Area*	<64	<55	2,000

*No nighttime activity planned.

3.4 SPECIES AND ECOSYSTEMS

3.4.1 Impacts at the Sulphur Mines Site

The Sulphur Mines dome area consists of a developed tract used in mining operations, more than 20 man-made bodies of water including the 162-acre Salt Water Reservoir and the 40-acre Crystal Lake, an airstrip, and a network of access roads. Biological effects of sulfur mining operations are still evident, although some areas have partially revegetated. Areas used to stockpile sulfur are essentially barren. Virtually the entire dome site has been cleared with only a few sparse patches of pine scattered in the area. No additional clearing for construction would be required on the dome itself.

Activities on the dome would include constructing dikes around the five existing storage caverns, building a central pump house and an office-warehouse-storage complex. Because of brining operations, the existing pads for the storage caverns are highly disturbed and little additional impact to these areas is expected as a result of the project.

Construction of oil spill containment dikes would cover the 3-5 acres surrounding the well pads with earth. An estimated additional 11.5 acres would be graded in preparing the contours around the wellheads so that leaking oil would be channelled into the subsidence lake area. This would result in destruction of the ground cover (mostly grass) and soil organisms present on a total of fifteen acres. The dikes and graded area would be revegetated within two growing seasons. Precipitation runoff from the dikes and graded area would increase turbidity and siltation in the standing water in the 40-acre subsidence lake area. This water body has no natural outlet and varies in size with drainage inflow. Allied Chemical regularly pumps the acidic waters from this area into Brimstone Ditch. Since only the hardiest forms can survive the acidic conditions and fluctuations in water level, little life is present and the impact of constructing dikes upslope from the subsidence area and around the well would be negligible.

Construction of the office-warehouse-storage complex would permanently remove the vegetation and associated organisms from 8.0 acres currently used for industrial purposes.

Use of this land for a building complex would have a negligible impact in the environment.

The central pump house would occupy 2.0 acres in a biologically barren area (formerly a sulfur stockpile area). Thus, no significant detrimental biological impact would be attributable to construction of this facility.

A limited variety of wildlife would be found on or near the dome and the wildlife would probably be accustomed to human activity in the area. Construction activities would temporarily disturb some wildlife and birds, but they would adjust rapidly, provided construction activities do not interfere with breeding and nesting. Densities of various bird and wildlife species on the dome site are not known but are probably low compared to nearby woodlands.

3.4.2 Impacts on the Displacement Water Source Species

Displacement water for crude oil withdrawal would be taken from the 162-acre Salt Water Reservoir west-northwest of the dome. Since rainfall and ground water seepage would be inadequate to replenish this reservoir (Section 3.2), additional water would be taken from the Industrial Water Canal via a pipeline. Because of the reservoir's small capacity, one million cubic yards would be dredged from the southern portion of the reservoir. Dredging would impact benthic biota and fish. Benthic invertebrates would be destroyed over a 43 acre area. No quantitative biological data are available for the Salt Water Reservoir; however, studies in Anacoco Lake, an artifical impoundment north of Sulphur Mines, revealed 1.95 chironomid and chaoborid fly larvae, mayfly (Elphemeridae) nymphs, and unionid clams per sq. ft. or 20.99 per sq. meter.[34] These organisms are not of commercial importance, although mayfly nymphs are sometimes used by fishermen as bait. A total of 3.65×10^6 benthic invertebrates on the 43 acres of reservoir bottom would be destroyed by dredging. This represents a production loss (wet weight standing crop) of 575.9 kilograms or 1267 lbs. These loss figures are based on the highest densities and standing crops that can be expected for such a reservoir, especially considering the uses to which the reservoir has been put. Macrophytes are very scarce in the reservoir and impacts on them would be slight. Increased sedimentation associated with dredging operations would probably affect some additional benthic invertebrates.

Fish populations are very small and this reservoir is not actively fished. Since the reservoir is not connected to other surface water bodies and receives only very limited surface runoff, it is relatively infertile. This reservoir was created solely for industrial purposes and the larger aquatic biota occurring here are introductions. The gills of some fish would be coated because of the increased turbidities resulting from loose soils on and near the retention dike being washed into the reservoir. This impact would be most severe if heavy rainfall occurred during or shortly following dike construction. This area would be susceptible to erosion until revegetated. If the construction of dikes occurs relatively early in the growing season, it is expected the banks would begin to be colonized by plants during the same season. The reestablishment of a plant community would act to retard erosion.

Dredge material would be placed between the existing levee at the reservoir's southwestern edge and the new dike which would be constructed behind this levee. The new dike would cover approximately 60 acres of land, mostly grassland. Cattle are not grazed here and the major impact would result from transport of dissolved and suspended materials into the Salt Water Reservoir (discussed above). Except for land alteration, no significant permanent impacts of the diking and dredge deposition are expected. Revegetation, primarily by grasses and forbs, would be rapid and primary production losses would be short-term and insignificant.

The intake system would include the pumping station and an intake structure. A single one-half inch mesh screen would cover the intake structure in the Salt Water Reservoir and another screen may be employed at the pipeline intake - Industrial Water Canal junction. Engineering design is preliminary but the biological impacts that would occur with such a system are evaluated. A maximum current of 0.5 ft/sec. would be induced at the screens. Most phytoplankton and zookplankton and other immobile organisms in the displacement water would be entrained (drawn in). A serious impingement (entrapment against the intake screen) problem would not develop because most aquatic animals large enough to become trapped on the screen (such as fish and amphibians) would possess sufficient mobility to escape the 0.5 ft/sec. maximum current. Because of the extensive agricultural and/or industrial use of the water in the canal and Salt Water Reservoir, production losses from plankton would have relatively little ecological impact on the aquatic system in the canal. The amount of plankton lost from the Sabine River to the Sulphur Mines site would be relatively insignificant considering the small amount of the Sabine River's flow which would be diverted to it.

There is a minor probability that the Salt Water Reservoir would be almost completely drawn down before any replacement water from the Industrial Water Canal could be acquired. This would severely impact fish and other forms that are dependent on a continuous water supply. Burrowing forms might temporarily become dormant until water was reintroduced.

3.4.3 Impact of Brine Disposal System

A 100,000 barrel brine surge pond, an injection field and connecting pipelines comprise the brine disposal system. Construction of the brine pond would utilize 3.7 acres of biologically unproductive land. This area was used to stockpile sulfur and the persistent acidic nature of the soil has precluded most forms of life from reestablishing there. An indeterminate number of insects, spiders and other arthropods from adjacent terrestrial and aquatic habitats would be killed, but the impact would be minor. Construction and operation of the brine pond would not produce significant short or long-term biological impacts.

The brine injection field would cover a maximum of 48.0 acres of which 18.8 acres would require clearing (8.8 acres for well pads and roadways and 10 acres for brine pipeline within the brine field). All 18.8 acres are in mixed pine woodlands common to the area. The trees requiring removal are suitable for pulp wood and possibly some saw timber, and their accessibility to existing roads makes logging practical. Secondary regrowth of various grasses, herbs, and shrubs would occur within a few months along the pipeline route, but right-of-way maintenance (mowing) would prevent the reestablishment of woodlands. The 8.8 acres for well pads and roadways would be completely cleared of vegetation and would be lost as a potential future timber resource and as habitat for wildlife, song birds and other animals.

Noise and human activities during facility construction would disrupt the area as a feeding or nesting site for wildlife, but when construction is terminated wildlife would gradually return. Some openland species would probably reside and forage in and adjacent to the regrowth vegetation, even though maintenance activities would be a source of redisturbance. The four well pads parallel an existing roadway (parish road), and human activity is already a part of the environment. In addition, the abandoned mining camp at Brimstone just east of the dome, which would be near two well pads in the potential expansion area of the brine disposal field, is overgrown and used as a cattle forage area.

The brine injection pipeline would cross Brimstone Ditch, a polluted body of water that flows intermittently from the dome site east to Bayou d'Inde. Bayou d'Inde passes through the town of Sulphur where it receives waste discharges (Section 3.2). The water would receive some sediment input from the pipeline construction and an insignificant number of benthos would be destroyed. Given the small area involved (approximately one-tenth of an acre) and the generally degraded nature of the aquatic habitat in the ditch, biological impacts would be inconsequential and short term.

3.4.4 Impact from Pipelines

In addition to the pipeline of the brine injection system, pipelines needed for the proposed crude oil storage development at Sulphur Mines include: (1) the water supply pipe connection between the Reservoir and the Sabine River Diversion Canal, (2) the oil distribution connection to a planned pipeline between a storage facility at West Hackberry and Sun Terminal, (3) connections from the Salt Water Reservoir to the surge pond, and (4) crude oil and brine pipelines from the central pump facility to the storage cavities. Impacts from construction and operation of these lines are evaluated below with the exception of potential losses resulting from oil spills. The ecological impacts of oil spills are discussed in Section 3.7.2.4.

Water Supply Pipeline

The water supply line would traverse shallow marsh and partially cleared mixed woodland just north of the Reservoir. The pipeline would be about one mile long. Only a small area would be involved and the biological conditions are presently degraded along the route, with the exception of the mixed-pine forest. The trees in the pipeline right-of-way would be cut and could be used as timber or pulpwood. It would be necessary to periodically mow the right-of-way to prevent the regrowth of trees in the pipeline route. Grasses, herbs, and shrubs would become established in the right-of-way, providing food and habitat for insects, song birds, and other animals.

Oil Distribution Pipeline

The oil distribution pipeline connection to the West Hackberry - Sun Terminal ESR oil distribution pipelines has been described in Section 1.3.1. This pipeline would cross roads, 7.4 miles of uncultivated dry land, 4.3 miles of cultivated land, 2.3 miles of wooded land, 0.2 mile of open water, 0.4 mile of marsh, and 0.1 mile of spoil banks. The uncultivated dry land is mainly pasture and the cropland is used for growing rice. Water bodies which would be crossed include Bayou Choupique, Wing Gully, Spring Gully, drainage ditches, a canal, an unidentified bayou or creek, and the Intracoastal Waterway.

An estimated $14,334 loss in cattle production would occur in the 7.4 miles of oil pipeline which would be constructed through uncultivated dry land. This estimate is based partially on the assumptions that the entire permanent right-of-way through uncultivated dry land and all in cattle pasture would be altered. This probably is an overestimate since destruction of vegetation would largely be confined to where the trench was made. Two further assumptions are: beef production value of $272/acre/year[35,36] and the reestablishment of pasture grasses within the second year after pipeline burial.

Rice production would be lost on less than 2.4 acres of the permanent right-of-way for one year and reduced for an indefinite number of additional years. This reduction would occur because the subsoil layers would be redistributed during backfilling of the pipeline trench. The subsoil materials are relatively infertile compared to topsoil. These subsoil layers are also virtually impermeable and, in an undisturbed situation, are instrumental in causing the high water retention qualities of the topsoil in this area. When both layers become disturbed the water retaining qualities of the soil would be reduced. This would result in reduced suitability for rice production.

A total of 20.7 acres of woodland would be eliminated during the clearing of the right-of-way. The 13.8 acres of permanent right-of-way would be maintained by periodic mowing. Thus secondary succession would occur on 6.9 acres. The original size of trees would not be reached again for decades. Wildlife habitat would be altered in the entire 20.7 acres cleared. Forest dwelling forms may experience a depression in population densities because of this habitat loss. Noise and human activities during construction and maintenance would cause temporary emigration of wildlife and birds. Cottontail rabbit and possibly quail and deer population densities would be increased over the long term due to the increases in cover, browse and other habitat changes created by the strip of secondary regrowth vegetation. Revegetation, while dependent upon the season in which the pipeline is laid, would be rapid.

As described previously, the pipeline would cross several bodies of water. A small strip of benthos, comprised primarily of fly larvae (chironomids and Chaoborinids) and oligochaete worms, would be destroyed in the water bodies. Densities are very dependent on season with lowest densities occurring during the winter months (or 250 organisms/m^2).[37] Benthic animals in the Intracoastal Waterway are estimated at approximately 1,800/m^2 as a highest figure for March.[38] Benthic animals of the Intracoastal Waterway include mollusks, polychaetes, and amphipods in addition to fly larvae and oligochaete worms assumed for the other waterways. Using these values for the waterways crossed other than the Intracoastal Waterway, more than 3.3 x 10^6 benthic animals could be destroyed if all animals in the right-of-way were eliminated.

Animals and phytoplankton in the vicinity of the excavation would also be affected by increases in siltation and tubidity.

Such increases would also result from drainage of adjacent land areas denuded of vegetation by the pipeline construction. Section 3.2.1.2 concludes that dredging activities will result in short-term increases in pesticides, toxic hydrocarbons and light metals such as nickel, chromium and zinc. This degradation in water quality is expected to last for only a few days. Therefore ecologic impacts by incorporation of toxic substances into the food chain are not expected to be severe.

Six months would probably be required for substrate stabilization and development of large new populations of benthic animals. Other animals and phytoplankton would be negligibly impacted, because turbidity and siltation would rapidly decline, and these organisms either would move from the area or would be transported out of the area by the water flow. Although turbidity and siltation would probably be rapidly increased by runoff during and following rain, the general pattern would be one of short-term exposure.

Burial of the connector oil pipeline through 0.4 mile of marshland would destroy non- and slightly mobile biota such as marsh grasses, epiphytic organisms and benthic organisms in the excavation path and would kill and injure some of the organisms in proximity to the burial trench. Deleterious impacts to biota on the sides of the trench would result from mechanical injury from vehicles which would guide the pipeline when it was emplaced; from temporary storage of excavated sediment on top of the marsh vegetation and substrate; and from increases in suspended solids resulting from excavation, manipulation and erosion of marsh substrate. Increased suspended solids would result in reduced light penetration into the marsh water and increased siltation. Attenuation of light would reduce photosynthesis by epiphytic algae. Settling of suspended matter would cover over benthic organisms and their habitat, interfering with respiration and feeding and otherwise reducing the suitability of the habitat. Suitability of the area for fish would also be reduced. An overall estimate of impacts cannot be derived. Assuming that one-half of the vegetation and other biota within the construction right-of-way were to be destroyed, and recovery was 50% within a year complete within two years, standing crop and productivity would be lost in 3.6 acres over the equivalent of a year. Estimated gross primary production losses (marsh grasses and epiphytes) would be 156,221 kg dry wt of food which would have been used by bacteria and marsh animals. These estimates are based on values presented in Day, et al.[39] The calculations of estimated gross primary production loss are based on an average of streamside, inland, and general marsh production. The direct economic (fishery and recreation) loss of 3.6 acres of marsh for a year is estimated at less than $100.00 based upon an average value for the region presented by the U.S. Army Corps of Engineers [40].

The 0.1 mile of spoil bank through which the connecting oil pipeline would pass would be minimally disturbed. No spoil has been deposited on these disposal areas for about 30 years. The main impact would be direct destruction of spoil bank organisms in the pipeline path, increased erosion and sedimentation following exposure of bare substrate, and disturbance of wildlife. The spoil banks would be expected to revegetate within a year. Erosion and sedimentation resulting from the small and short-term exposure of bare soil involved would not be expected to have any detectable deleterious impact on area biota.

Onsite Pipelines

The brine, water, and oil pipelines running to the storage caverns onsite would pass through highly disturbed ground. Impacts to biota constructing these pipelines would be very slight; a small amount of ground cover and associated organisms would be destroyed, there would be a slight increase in erosion and sedimentation, and wildlife in the immediate vicinity would be disturbed by noise and human activity.

3.4.5 Impacts on Endangered or Threatened Species

The bald eagle is a broad ranging bird that is sighted with some regularity in Lacassine,[41] Sabine,[39] and Rockefeller National Wildlife Refuges[43]. This species or other rare or endangered species (discussed in Section 2.4.1.3) could pass over the dome site or the pipeline routes, but it is extremely unlikely that nesting areas are near enough to the site or pipeline for them to be negatively impacted by the project. The red wolf is not known to inhabit the site. No plants that are officially listed as endangered or threatened by the U.S. Fish and Wildlife Service are present.

The official Status of the American Alligator (Alligator Mississippiensis) is discussed in Section 2.4.1.3 of this Report. Because of the dramatic increase in numbers of this species in parts of its range, 44, 45, limited harvesting of the alligator is being carried out in Calcasieu, Cameron and Vermilion Parishes. The American alligator has been reported in the immediate site vicinity 46, and most likely occurs along pipeline routes, but because of provisions set forth in 50 CFR 17.42 the animal is not treated as threatened in any area which would be affected by Sulphur Mines construction or operation. No special Federal or State regulations must be observed.

3.4.6 Summary of Biological Impacts

The Sulphur Mines dome site is biologically highly disturbed as a consequence of past sulfur mining operations and present use of the area for brine production. Roads, barren areas, scattered trees and patches of trees, and grass and shrub-covered areas are present on dry land. Many water bodies are present as a result of dredging operations during the period of sulfur mining. Construction activities onsite would require removal of some trees. The general ground cover vegetation destroyed during pipeline burial, dredge spoil disposal and dike construction would quickly reestablish itself, probably reaching its former level of development within two growing seasons. The total area involved is large (more than 75 acres), but recovery would occur fairly rapidly. Fifteen acres would be cleared of present vegetation during construction of the oil retention dikes and a smaller area would be covered by pipeline burial. Coverage of sixty acres of land by dredge spoil and containment dikes would result from the enlargement of the onsite reservoir so it could serve as a raw water source.

Vegetation and associated organisms would be lost for at least the life of the storage facility from the 8 acres where the office-warehouse-storage complex would be constructed. This is a relatively small area and loss of the organisms on it would not be significant. The other building to be constructed on the site, the control pump house, would be built on barren land. Its construction would not result in destruction of any organisms. Construction activities and increased human activity on and near the site and along the brine, water, and oil pipeline routes would disturb birds and other wildlife for different time periods. A small number of nests could be destroyed and less mobile vertebrates could be killed during these construction activities. Except at the storage site, disturbance would not be continuous over a long time period. The wildlife at the site is already composed of animals which have adjusted to disturbance. Many of these animals would probably adjust to the additional disturbance from developing the site for oil storage.

Organisms in the water-supply reservoir would be entrained, destroyed by dredging, or stressed by increased suspended solids and sedimentation. The reservoir could also be completely drawn down, in which event, only burrowing animals which could exist in a dormant state would be likely to survive. The total standing crop of organisms involved is relatively small and is not significant in view of the relatively large amount of freshwater pond/lake habitat in the region. The sacrifice of plankton contained in replenishment water from the Industrial Water Canal is a loss of plankton which would have been killed in any case. The brine surge pond would cover 3.7 acres of barren land and the brine injection field, 48 acres. An area of 18.8 acres of woodland in the brine field would be permanently cleared and lost as a potential timber growing resource and as wildlife habitat. Noise and human activity during construction and right-of-way maintenance would disrupt wildlife. Biological impacts of the pipeline crossing Brimstone Ditch would be short term and inconsequential.

The water supply pipeline is relatively short (one mile long) and would require clearing a right-of-way through forest over much of its length. Burial of the pipeline would kill additional vegetation and associated organisms. The right-of-way would rapidly revegetate and would be maintained by mowing. Prematurely cutting timber in a small part of this marginal pine forest would not be a significant impact. Maintenance of the right-of-way would have little effect on the forest and would provide food and habitat for various animals capable of utilizing such a resource.

The oil distribution connection pipeline to the planned pipelines linking the West Hackberry Salt Dome to the Sun Oil Terminal would cross roads, pasture (approximately 8.7 miles of the route), cropland (0.4 mile), woodland land (4.0 miles), open water (0.2 mile), marsh (0.4 mile), and spoil banks (0.1 mile). Construction of the pipeline would result in estimated losses of (1) $14,334 of cattle production, (2) rice production of less than 2.4 acres for a year, (3) 24.2 acres of forest for at least the lifetime of the storage project, plus an additional 12.2 acres for an indefinite number of years, (4) more than 3,300,000 benthic animals in the permanent construction right-of-way in open water, (5) 156,221 kg of gross primary production and 10,985 kg of food which would have been used by bacteria and animals in marshland (economic loss less than $100.00), and (6) a limited number of spoil bank plants and other spoil bank organisms. The region through which the oil connector pipeline passes is rich in biotic resources of the kinds listed above and the losses to the region would not be important viewed from a comparative standpoint.

Section 2.4.1.5 discusses the vectors which could be encountered in the aquatic and semi-aquatic areas of construction. These vectors present a risk of disease to humans and domestic animals. They include several species of mosquitoes, horse flies, and deer flies. The larvae of these insects require an aquatic habitat in which to mature. Any construction activities which would permanently increase standing water would provide additional habitat for these insects, and would increase the probability of occurrence of certain diseases.

These construction activities include alteration of surface drainage patterns, and improper backfilling of canals or trenches in marsh or swamp areas. However, because the high natural productivity of these wetland systems could be adversely impacted by improper reclamation activities, maximum attemps are made to maintain surface drainage patterns.

The amount of construction which would be carried out in wetland areas would not be large. These areas are currently highly productive of the vectors discussed in Section 2.4 1.5. If care is taken during construction and reclamation not to alter surface drainage, there will be insignificant increase in these vectors over natural occurring levels.

It is unlikely that any endangered or threatened species would be adversely impacted during project construction and facility operations. Endangered or threatened plants are not known to inhabit the site or any proposed pipeline routes.

3.5 WASTE DISPOSAL

During the site preparation and construction phase, generated wastes would include surplus lumber and metal goods, paper, waste concrete, sewage and, possibly, formation water from the drilling process.

Construction wastes are usually handled by the construction contractor, who is required to leave the site clear of wastes. Surplus lumber and scrap metal are normally sold to local dealers who handle such materials. Disposal of waste paper, concrete, and other non-marketable goods is usually at a local landfill site. Probably no more than a few thousand cubic yards of each of these types of materials would be generated during the entire project. The nearest municipal solid waste disposal site is a 20 acre landfill about 2 miles east of Sulphur or 4 to 5 miles from Sulphur Mines. The anticipated capacity of the landfill is an average of 75 tons per day from the City of Sulphur and from the private sector. Earth bulldozed for tank site preparation and construction of the brine pit would be used for containment dikes. Dredged material from the deepening of the existing reservoir intended for raw water supply would be deposited on Allied property.

During site preparation and construction chemical toilets systems would be utilized. Sewage treatment and disposal of waste from these would be through the existing septic tank system at the Allied facilities. If these Allied facilities prove to be inadequate, disposal would be handled by transporting wastes to acceptable municipal or industrial treatment facilities.

Formation water produced during the well-drilling process would probably be reinjected into the well hole with the drilling mud, or collected by drilling support tank trucks supplied by the drilling contractor to handle such wastes.

Once the drilling is complete, the drilling contractor hauls off all the drilling mud to be processed and reused on another project. The mud pits where drilling mud is prepared and stored would be cleaned and covered with topsoil.

The major waste product during operation is ballast water received from the tankers during oil on-loading. During withdrawal of the stored oil, tankers up to

50,000 DWT are expected at the Sun Oil Terminal. Up to 38,500 barrels of ballast water would be generated by each 50,000 DWT tanker loaded, of which as much as 5 percent or 1,925 barrels per tanker may be recoverable oil. To recover this oil, the ballast water would be processed through a Ballast Water Treatment Facility, which reduces the oil content of the waste water to 5-10 ppm or less before the water is discharged into the ship channel. The recovered oil would be injected into the main oil storage cavities, or sold to slop oil marketers.

Waste oil from terminal facility sources, such as minor leaks from pumps and valves, would also be collected and injected into the storage cavities or combined with the slop oil.

In conclusion, only minor environmental impacts would result from solid waste disposal.

3.6 SOCIOECONOMIC EFFECTS

3.6.1 Manpower Requirements

The work force required by the project would be divided into two separate contingents: (1) those who work at the storage site and (2) those who work at the docks and along the oil distribution pipeline. A summary manpower curve indicating the estimated level of work force required in these two areas during the initial stages of the project, is shown in Figure 3.10.

Onsite Drilling and Construction

Preparation of the storage site would take about a year. One drill rig would be used to open 5 new wells for access to the storage cavities and another rig to drill 4 brine disposal wells. An estimated 8 months would be required to drill these wells, during which the rigs would be operated continuously. Three drilling crews would operate the rig in shifts, using a total of 23 workers per rig.

Construction of buildings and installation of equipment at the site is expected to take 7 months and employ an average of 20 to 25 skilled craftsmen and laborers per month. Up to a month may be required prior to construction activities to clear and grade the land for foundations and access roads.

Construction work would proceed concurrently with drilling operations and result in a peak level of manpower at the site during the third month of activity. At that time, the labor force at the site during the day is expected to average about 133 workers. An additional 15 or 16 men would remain at the site during each of the two night drilling shifts and during weekends.

Construction of the Pipelines

The oil distribution pipeline would be laid between the storage site and a planned oil pipeline running east and west along the south spoil bank of the Intracoastal Waterway. It would be about 14 miles long and could be built in approximately 4 to 5 weeks using a combination of teams for clearing the right-of-way, digging the trench, welding and coating the pipe, laying the pipe, back filling, restoring the right-of-way, and bringing in

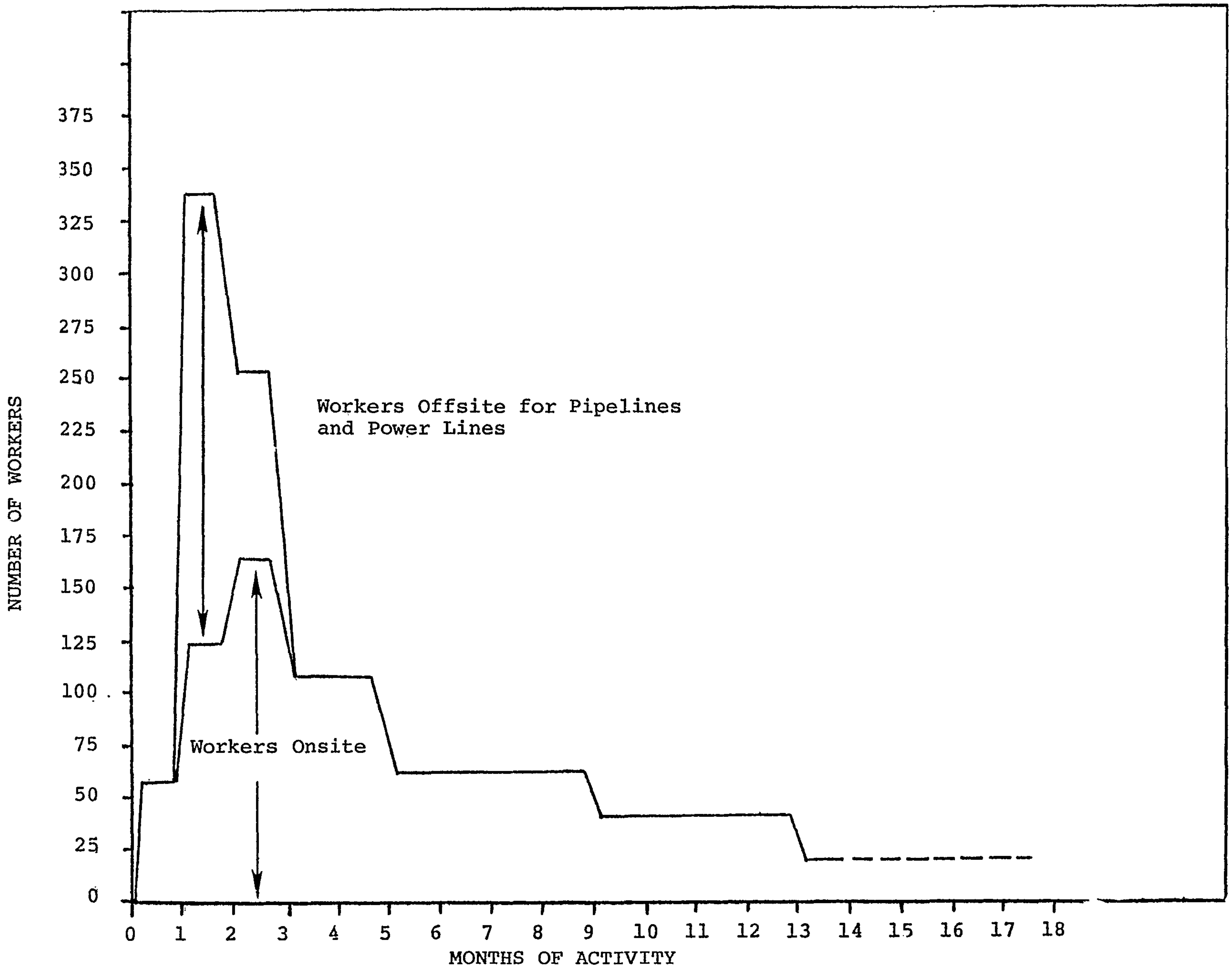


Figure 3.10 Labor Requirements at the Sulphur Mines Site.

supplies. Each team would consist of 20 to 30 workers, and the combination of teams would raise the peak labor requirements, for the pipeline alone, to about 175 workers.

The pipeline from the site to the raw water intake structure on the Industrial Canal would be only one to two miles long. It would cross through a forested area, requiring somewhat more time to lay than pipelines across fields and pastures. The line could be completed in one to two weeks.

The number of workers employed offsite also includes about 40 who would be needed for about a month to construct transmission lines for bringing additional electrical power to the site.

Construction Manpower Summary

Construction of oil storage facilities at Sulphur Mines would involve about 340 workers. This level would be reached in the second month, but would last for only 4 to 6 weeks. The average number of workers employed during the 13 months of construction would be approximately 100 per month.

The 340 workers who had been employed by the project during the construction phase would proably seek replacement work in the Lake Charles area. The number of these unemployed workers would be very small compared to total civilian labor force (projected to be in the range of 60,000 persons at the time of completion of the project).

Operation of Facilities

Approximately 10 personnel would be required to maintain the facilities and to monitor operations at the storage site, at the permanent dock, in the brine disposal field, and along the pipeline rights-of-way. It is anticipated that 8 skilled workers and technicians, one supervisor, and one person for clerical work would be needed.

During oil recovery procedures, a work force of 10 to 15 additional workers would be required for a period of up to 5 months. This estimate includes personnel to operate and monitor pumps and valves, and to keep the equipment in good working order. A similar level of manpower would be necessary when the cavities are refilled at the end of the petroleum shortage period.

3.6.2 Potential Sources of Labor and Supplies

Construction is a major industry in the Lake Charles area, and it is anticipated that contractors would be available from Sulphur, Westlake, and Lake Charles itself. Work similar to that required for the proposed project has been performed by local firms involved in the development of oil fields, and in the construction of facilities for large chemical plants.

The work requires primarily skilled workers who would be permanent employees of the contractors, and would be living in the Lake Charles area. They would commute to their jobs at the Sulphur Mines site and at the dock site on the Sabine River.

Many of the supplies can be purchased from local firms in the Lake Charles area. Specialized equipment, pipe, and wellheads may be brought in from regional suppliers in New Orleans, Baton Rouge, the Beaumont-Port Arthur area, and Houston.

3.6.3 Effects on Community Services

No significant migration of workers to the area is anticipated to result from the project. The major impact would be increased traffic on Highway 90 leading from Lake Charles to Sulphur, and on parish roads leading to the storage site and the dock. The pipeline to the dock would cross an area of recent residential development between Sulphur and Carlyss, causing temporary traffic congestion during construction. The pipeline would utilize an existing right-of-way as it crosses this residential area, and is not expected to require the removal of homes or businesses.

The housing situation in Calcasieu Parish does not allow for an influx of workers to purchase homes in small communities there. Rental units are available in the Lake Charles area to accommodate the few workers and workers' families that may be drawn to the project from other parts of the region.

School systems are not expected to be affected by the project since it would not draw significant numbers of new families with school age children to the area.

Security guards would be stationed at the storage facility site and at the dock to prevent theft of equipment and materials. They would cooperate with the sheriff's department of Calcasieu Parish, which has jurisdiction over these areas. Fire fighting equipment would be on hand at the site and the dock. Auxiliary aid is available from Sulphur.

Medical facilities in Sulphur and Lake Charles would be used to provide emergency care to workers injured at the site and at the dock. Since workers and their families would primarily be established residents of the area, no additional stress on health services is expected to result from the project.

3.6.4 Economic Impact

Employment and Payroll

The major local benefits of the project would be the direct employment and payroll. It is anticipated that a number of local contractors would be hired for various phases of construction. Including the personnel detailed to the project by these contractors, the payroll during construction and operation of the facilities would be approximately as follows*:

1st month:	$115,000 per month
2nd month:	680,000 per month
3rd month:	510,000 per month
4th through 5th month:	215,000 per month
6th through 9th month:	120,000 per month
10th through 13th month:	75,000 per month

Total for Site Preparation and Construction:	$2,515,000
Standby Operation for the Life of the Project:	$ 21,000 per month
Oil Recovery and Refill Procedures:	$ 46,000 per month

Income received by workers would tend to circulate in the Lake Charles area.

*Based on an average wage rate of $2,000 per month.

Local Business and Industry

The construction phase of the project would benefit local firms engaged in the following businesses: building contractors, construction material suppliers, pump and pipe manufacturers and distributors, metal fabricators and suppliers, and drilling companies. Also, a number of firms in the area specialize in the repair of the kinds of equipment that would be used.

The additional business generated by the project would not create a significant number of new jobs, but would be an important source of income for local firms. Because the duration of construction for the project is confined to 12 months, it is anticipated that no new businesses would be induced by it.

Tax Benefits

Sources of tax revenue for Louisiana and the parishes are: (1) severance taxes (and royalties) from the extraction of oil and gas, (2) property taxes, and (3) 5 percent sales tax (3% state tax plus 2% city and parish tax on general goods and services). Severance tax would not apply to this operation. Since the storage site and equipment installed at the site would be federally-owned and therefore, exempt from taxation, use of Sulphur Mines would not significantly affect local governmental revenues from property tax.

In the event that the oil is withdrawn from the salt cavities, the companies that purchase the oil would be exempt from state sales tax if they are registered whole-salers (most oil companies are registered). Tax benefit from the project would accrue indirectly from the increased income and purchasing power of the workers.

Costs

Costs to the community would be primarily those paid for public services, police and fire protection, and the added costs of road maintenance in the vicinity of the site and the dock.

The present and projected growth of general construction, heavy industry, and the oil and gas industry in the area indicates that opportunities for replacement jobs at the end of the project's construction period would be available.

3.7 EFFECTS OF ACCIDENTS AND NATURAL DISASTERS

The potentiality of accidents and natural disasters is discussed in this section, with particular emphasis on the possibility of crude oil or brine spills. The discussion is based on probabilities of occurrence contained in appropriate literature and applied to the specific facilities proposed for the Sulphur Mines Salt Dome.

3.7.1 Oil and Brine Spills from Pipelines

Estimates of the frequency and the amount of oil spilled because of possible pipeline accidents are based in part on statistics collected by the Office of Pipeline Safety (OPS), Department of Transportation.[47] By law, U. S. pipeline operators must report spills to the OPS if they exceed 50 barrels, or if there is an injury or death associated with the accident. The population of pipelines to which the spill statistics apply were obtained from the Bureau of Mines, Department of Interior. Every three years they issue a report giving the total mileage of crude oil and oil product trunklines and gathering pipelines in the U.S. As of January 1, 1974, there were 222,355 miles of pipeline in the U. S., which are distributed fairly evenly between the three groups.[48] Of this total, 190,331 miles were 12 inches in diameter or less. Only 32,024 miles of pipeline were larger than 12 inches, and only 2,272 miles were 36 inches in diameter or larger.

Information on spills from pipelines is reported to OPS on DOT Form 7000-1, and includes the owner of the pipeline, the spill location, the cause of the spill, the installation date of the pipeline, the diameter, the product carried, and the amount of oil spilled (usually a best estimate). Table 3.22 lists pipeline spills during the five year period, 1971 through 1975, by cause. The major cause of spills from older pipelines, those installed before 1950, is external corrosion. Since the 1940's, much improved techniques have come into usage to prevent corrosion. Thus, the major cause of spills in newer pipelines is accidental breakage by excavation or construction equipment. Most larger pipe, that greater than 12 inches in diameter has been installed since 1950, and for it, too, the major cause of spills is damage by excavation equipment.

Table 3.22 Causes of Pipeline Leaks and Spills in the U.S. During 1971 - 1975.

Cause	Pipelines 12 Inches and Less in Diameter		Pipelines Greater Than 12 Inches in Diameter
	Installed Before 1950 (Number of Incidents)	Installed After 1950 (Number of Incidents)	(Number of Incidents)
External Corrosion	297	50	9
Internal Corrosion	40	46	8
Line Ruptured by Excavation Equipment	142	128	28
Prior Damage By Excavation Equipment	6	18	3
Defective Pipe Seam	83	71	19
Defective Weld	22	11	7
Rupture of Gasket, Seal, Etc.	23	56	2
Fire or Explosion	6	14	0
Flow Control Malfunction	3	11	0
Flow Control-Operator Error	23	12	0
Incorrect Operation by Carrier Personnel	2	11	0
Natural Disasters (Landslide, Flood, Windstorm, Freezing, Etc.)	36	24	0
Unknown	55	67	8
TOTAL INCIDENTS	738	519	85

The spillage data were broken down into two categories according to size. There are insufficient data, statistically, for a breakdown for each individual size of pipeline. In general, pipe 12 inches or less in diameter is used for individual lines to a salt dome cavity. Larger pipe is used for trunklines and manifolds.

The spill rate from pipelines less than 12 inches in diameter was estimated by dividing the total number of spills by the mileage existing at the beginning of 1974, and normalizing to one year:

$$\frac{738 + 519}{190,331} \times \frac{1}{5} = 1.32 \times 10^{-3} \text{ spills/mile-year}$$

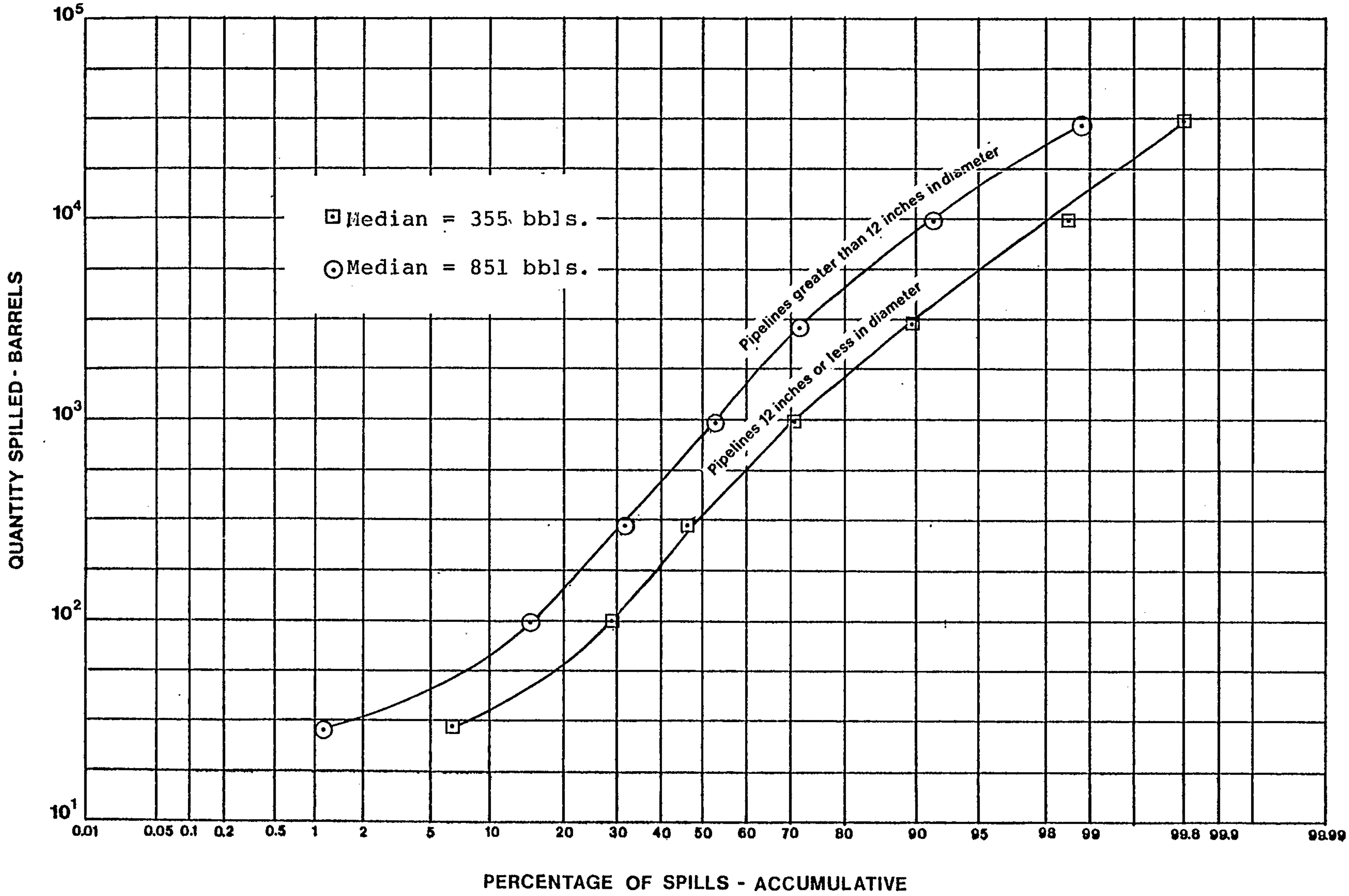
Because the data necessary to distinguish between the populations of older and newer pipe are unavailable, it was necessary to sum the spills from both groups of pipe. For this reason, it is believed that the above estimated spill rate is higher than it would actually be for the newly installed SPR pipelines. For pipelines greater than 12 inches in diameter, a similar treatment gives:

$$\frac{85}{32,024} \times \frac{1}{5} = 5.31 \times 10^{-4} \text{ spills/mile-year}$$

The data from OPS also were used to estimate the spill size frequency distribution. These data have been plotted on log normal probability coordinates in Figure 3.11. For the larger diameter pipelines, these data show the median spill size to be approximately 850 barrels. For pipelines less than 12 inches in diameter, the median spill size is 360 barrels. The data in Figure 3.11 and the estimates of spill frequency were combined to give the frequency of spills exceeding a given quantity, as shown in Figure 3.12.

These data were applied to predict the risk of oil spills from the pipelines proposed for the Sulphur Mines storage site. Table 3.23 lists the lengths of the crude oil and brine pipelines and the expected frequency of accidental spills per year from these pipelines. For this analysis, the pipeline between the Sun Terminal and West Hackberry is assumed to be in existence, and therefore, any risk of oil spills from this portion of the line is associated with oil storage at West Hackberry. Table 3.23 lists only the 14 miles of pipeline connecting the West Hackberry line with the Sulphur Mines site.

Figure 3.11 The Distribution of Size of Spills from Pipeline Accidents.



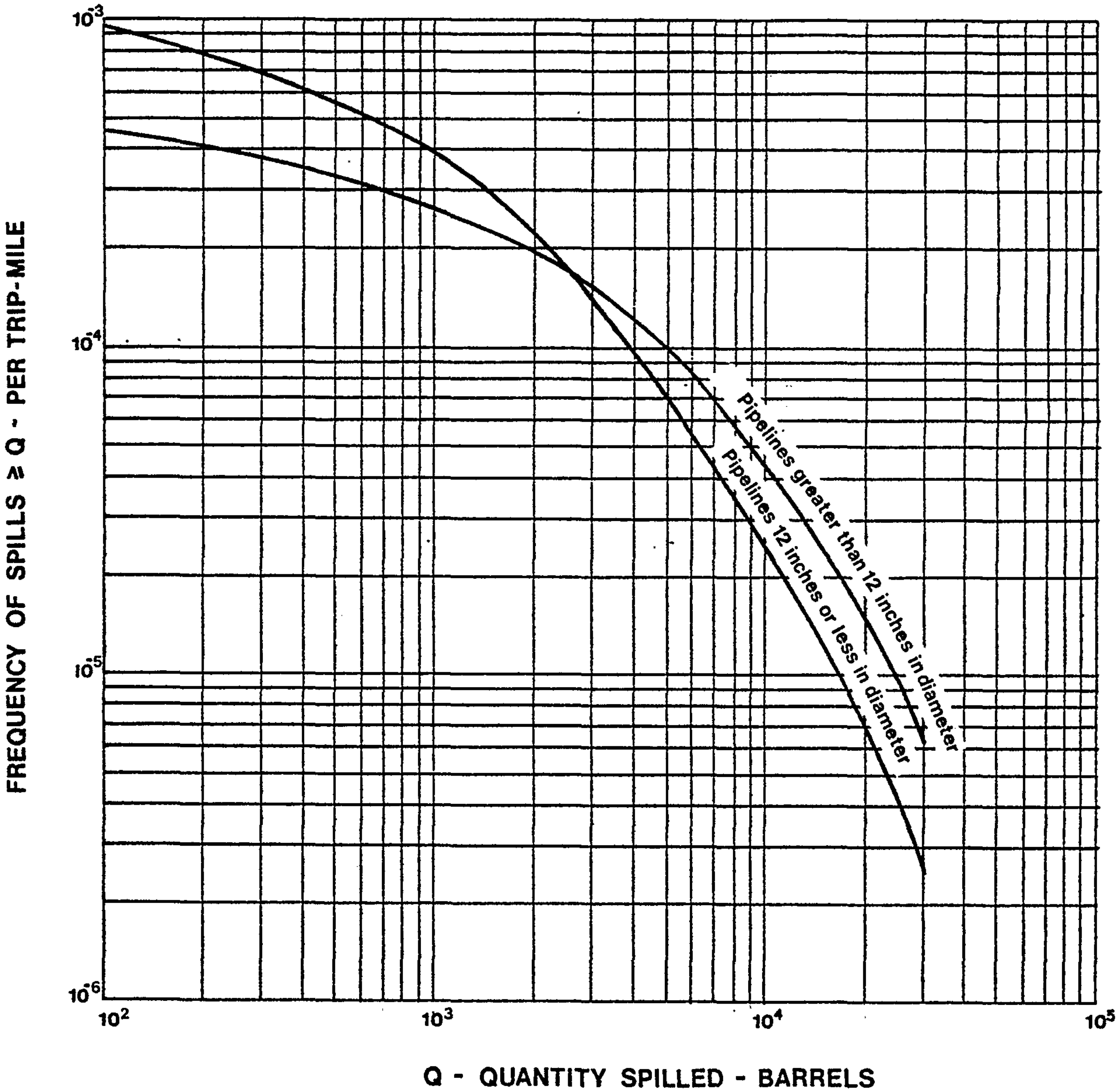


Figure 3.12 Frequency per Mile-Year of Crude Oil Spills From Pipeline Accidents.

Table 3.23 Crude Oil Pipelines and Accident Frequency: Early Storage Reserve.

Type of Pipeline	Approximate Length (miles)	Accidental Spill Frequency (per year)	Number of Operational Years[a]
Crude oil Trunk Line, 20 in.	14	7.43×10^{-3}	25
Site:			
< 12 inches	0.3	1.59×10^{-4}	25
> 12 inches	0.5	6.60×10^{-4}	25
Brine Disposal (Deepwell)	0.5	2.66×10^{-4}	2.1
On-Site	1.7	2.24×10^{-3}	2.1

[a] All crude oil pipelines are assumed to remain full of oil throughout the entire length of the project. For the brine lines, these are assumed to contain brine only during use, i.e., during filling of the salt cavities. For this, a total of five fill cycles of five months each have been assumed for the 25 year lifetime.

The annual spill frequencies were estimated as the product of pipeline length and the frequencies (per mile-year) developed above. The table also lists the number of years the pipelines are expected to be in use for the SPR project. Crude oil lines are assumed to contain brine at all times, whereas the brine lines contain oil only during each fill cycle. It has been assumed that this period is 25 years for all sites. Table 3.24 lists the probability of spills exceeding a given size for each site and the trunklines. These values were estimated using the annual spill frequencies listed in Table 3.23, and the spill size distribution shown in Figure 3.11. Also, the spill probability for a period of years was assumed to be described by the binomial distribution.

The results presented in Table 3.24 show that only for the crude oil trunkline is there a significant risk of a spill of more than 100 bbls, 15 percent. For the pipelines on the site, the risk of a spill greater than 100 barrels is less than 6 percent. This result is reflected in an alternative presentation of spill risk, the expectation quantity of oil spilled, also listed in Table 3.24.

In considering these results, it should be kept in mind that the probabilities are based on conservative assumptions which tend to make them high. In particular, a 25 year utilization period was assumed. Although the crude oil lines would be full of oil during this period, they would be in active use only during approximately one-third of this time, assuming five fill-distribution cycles. During the periods of inactivity, the pressure in the line would be reduced, and block valves would be closed. The amount of oil released in an accident during this time would be substantially less than when the pipeline is active.

The areas affected by the spilled oil vary from open water to dry land. Crude oil lines and brine lines at the site would be located in (buried), or on dry land. The modest amount of oil expected to be spilled accidentally would be confined to a localized area near the spill. Also, because of the high water table in the area, leaks of oil from the buried portions of the pipelines would not be expected to move very far in a lateral direction. During rainy periods, oil migrating to the surface would behave as runoff material. As indicated in Table 1.1, the crude oil trunkline, between the site and

Table 3.24 Risk of Spills of Crude Oil and Brine from Pipeline Accidents.

Quantity Spilled	Probability of Spill Over 25-Year Lifetime	
	Crude Oil	Brine
Oil-Trunkline		
Probability of Spill		
> 100 bbls	0.146	--
> 1,000 bbls	0.084	--
> 10,000 bbls	0.015	--
Expectation Quantity of Oil Spilled, bbls.	158	--
Oil-Site Pipelines		
Probability of Spill		
> 100 bbls	0.017	0.052
> 1,000 bbls	0.0093	0.029
> 10,000 bbls	0.0014	0.0051
Expectation Quantity of Oil Spilled, bbls.	15	23

the Sun Terminal-West Hackberry Pipeline, crosses a variety of terrain. Most of the route crosses prairie and woodlands.

Should an oil or brine spill occur within a diked area, the spill would be contained until it could be removed. Should a spill occur above ground in an undiked area, it would tend to flow to a lower level until trapped by the terrain, or until it flowed into a body of water. Some of the spill would soak into the ground. A spill from a buried pipeline would soak into the ground; part of the spill might surface where it would behave as runoff material. Spilled brine remaining in the ground would increase the salinity of ground water in the immediate vicinity.

3.7.2 Risk of Oil Spills During Marine Transportation

3.7.2.1 Introduction and Summary

This section presents estimates of both the probability and the size of oil spills arising from accidents during marine operations and transport. Marine operations considered include: (1) for the permanent dock at Sun Terminal, the voyage of a 45,000 DWT tankship through the Sabine Pass, the Sabine-Neches Canal and the Neches River to the Sunoco Terminal, and loadings and offloadings at that terminal, and (2) lightering from VLCCs onto the 45,000 DWT tankship and its voyage to the entrance to the Sabine Pass.

A detailed description of the estimated risk of oil spills from accidents is presented in the following three subsections. A summary is provided in the following paragraphs.

The estimates are based on statistical analyses. The number of vessel casualties, which would result in the spill of oil, were derived primarily from the Coast Guard's listing of Commercial Vessel Casualties for fiscal years 1969 through 1974. The count of the ship transits in the Sabine Channel was obtained from Waterborne Commerce of the United States[49] and Engineer's Annual, both publications of the U. S. Army Corps of Engineers. Combined, these data yielded the expected frequency of spills per transit of a tankship from the Gulf to the terminal. This procedure was followed for all vessel casualties except tankship collisions in the Sabine Channel for which the frequency was estimated via a model. This model allows the use of a much broader data base and accounts for the length of the channel, traffic density, and the speed and dimensions of the ships. The frequency of spills for loading and offloading oil at the terminal was obtained from incidents reported by the Coast Guard's Pollution Incident Reporting System and Corps of Engineer traffic data, both for the U.S. Gulf Coast region. Because of the high degree of similarity between lightering and offloading at terminals, the spill frequency for the former was assumed to be the same as for the latter. The distribution of the quantity of oil spilled, with the number of spills, was developed from Coast Guard Commercial Vessel Casualty data for losses from tank barges in Western Rivers* and the inland Gulf region. The quantities spilled are distributed log normally versus number fraction of spills. This relationship was modified for application to tankship casualties. The distribution of quantity of oil spilled during loading and offloading at marine terminals was developed from the Pollution Incident Reporting System data.

The above methodology is based on the assumptions that the planned crude oil transport operation is essentially the same as that for which the accident experience has accrued. This assumption seems justifiable since the facilities, tankships and barges to be used would be nearly the same as those now used in the area.

The estimates of risk of accidental oil spills are summarized in Table 3.25. The estimates assume the transport of crude oil to fill the salt dome caverns in a nominal 45,000 DWT tankship containing 400,000 bbls to or from the Sun Terminal. Only 60 percent of the stored oil would be distributed by tankship. Larger tankships, up to 100,000 DWT, might be used but these would be light loaded such that their draft would not exceed 40 feet. In this case it is also assumed that they would contain approximately 400,000 bbls.

The expectation quantity of crude oil spilled per trip from vessel accidents, such as collisions, groundings, rammings (striking fixed objects, submerged or on or above the water surface), structural failure, fires and explosions, etc., is

*Primarily the Mississippi River System

Table 3.25 Risk of Oil Spills During Marine Transport for Filling and Distributing the Crude Oil from the Sulphur Mines Site.

	Fill 25 x 10^6 bbls.	Distribute 15 x 10^6 bbls.
Number of Vessel Trips	63	38
Spills in Inland Waters:		
Expectation quantity of oil spilled, bbls.	43	26
Probability of a spill exceeding		
100 bbls.	0.0102	0.0061
1,000 bbls.	0.0032	0.0019
10,000 bbls.	0.0008	0.0005
Spills in The Gulf of Mexico:		
Expectation quantity of oil spilled, bbls.	9	N/E
Probability of a spill exceeding		
100 bbls.	0.0073	N/E
1,000 bbls.	0.0010	N/E
10,000 bbls.	0.0001	N/E

N/E - Not Evaluated.

0.60 barrels per trip for the tankships in the Sabine-Neches Canal and 0.058 barrels per trip in the Gulf between the lightering point and Sabine Pass. The median spill from tankship casualties is 3,100 bbls. Accidents at the marine terminal, such as overfilling a tank, opening the wrong valve, etc., have an expectation quantity of 0.086 barrels spilled per trip for tankships. The median spill during transfer at the dock is 0.5 bbl. The total expected quantities of oil spilled during the transport of the oil to fill or to be distributed are listed in Table 3.25. This table also lists the probability of a spill exceeding certain amounts during the movement of the stated amount of oil.

Oil spilled onto water produces a very extensive slick. The following relationship between spill quantity, and ultimate slick area or radius, assumes unhindered (no wind, currents, or surface obstacles) spreading and a circular-shaped slick:

$$A = \pi r^2 = 2.52 \times 10^4 (V)^{3/4}$$

where A is square meters, r is the radius of the slick in meters, and V the volume spilled in barrels.[50]

These dimensions are achieved 24 to 48 hours after the spill. For median spill quantities listed above, the ultimate slick dimensions were computed:

	Quantity Spilled (Barrels)	
	0.5	3,100
Slick Area (m^2)	0.015×10^6	10.5×10^6
Slick Radius (m)	69.1	1,826

The ultimate slick areas calculated above correspond to an average coverage of oil ranging from 0.1 bbl/acre for the 0.5-barrel spill to approximately 1 bbl/acre for the largest spill. These coverages are somewhat lower than those estimated to cause environmental damage, as discussed in Section 3.7.3. Hence, the ultimate slick diameter in open water may be 5 to 50 times the area in which actual environmental damage may occur.

Spills from a tankship in the Sabine Pass or jetty channel would tend to be confined by the jetties, land or spoil banks. However, the tidal currents (1 to 2 knots typical in Sabine Pass) would carry a slick out to sea or into Sabine

Lake if not confined in time by booms. Contamination of marsh and shore along Sabine Pass would be expected from any spills.

Similarly, spills from accidents in the Port Arthur Canal and the Sabine-Neches Canal also would be confined by adjacent land and spoil banks, which would become contaminated. In these canals there is a negligible current and the spread of the slick in either direction could be readily prevented by booms. However, spills in the upper part of the Sabine-Neches Canal near the mouth of the Sabine River might spread into Sabine Lake and contaminate adjacent shore and marsh lands. Because of the predominance of easterly and southerly winds in the area, oil slicks entering the lake would probably contaminate only the lake's western shore and not the marsh of the Sabine National Wildlife Refuge bordering the eastern shore.

Spills from accidents in the Neches River and at the Sun Terminal probably would contaminate the marshy banks of the river. The current in the river is weak except during periods of high water and hence oil slicks are expected to be carried downstream into Sabine Lake only during these periods.

Spills during lightering and trans-shipment across the Gulf to the entrance to Sabine Pass could affect any of the shore both east and west of Sabine Pass. Figure 3.13 shows the approximate location of the lightering area relative to Sabine Pass and the Port Arthur areas. Figures 3.14 and 3.15 show the probability distribution of directions and speeds of currents during winter and summer months in the lightering area. Similarly, Figures 3.16 and 3.17 show the probability distribution (wind rose) of wind speeds and direction. Since oil slicks drift with the water current and approximately 3 percent of the wind velocity, these data may be used to estimate the landfalls of uncontained, spilled oil.

During both summer and winter the ocean currents average about 1 knot and are towards the north, west and northwest approximately 60 percent of the time. In summer the ocean currents are supported by winds of 10-11 knots in the same direction 65 percent of the time. In winter, the frequency of winds in these directions decreases to 50 percent of the time, and strong winds of 14-15 knots blow away from shore approximately 40 percent of the time. These latter

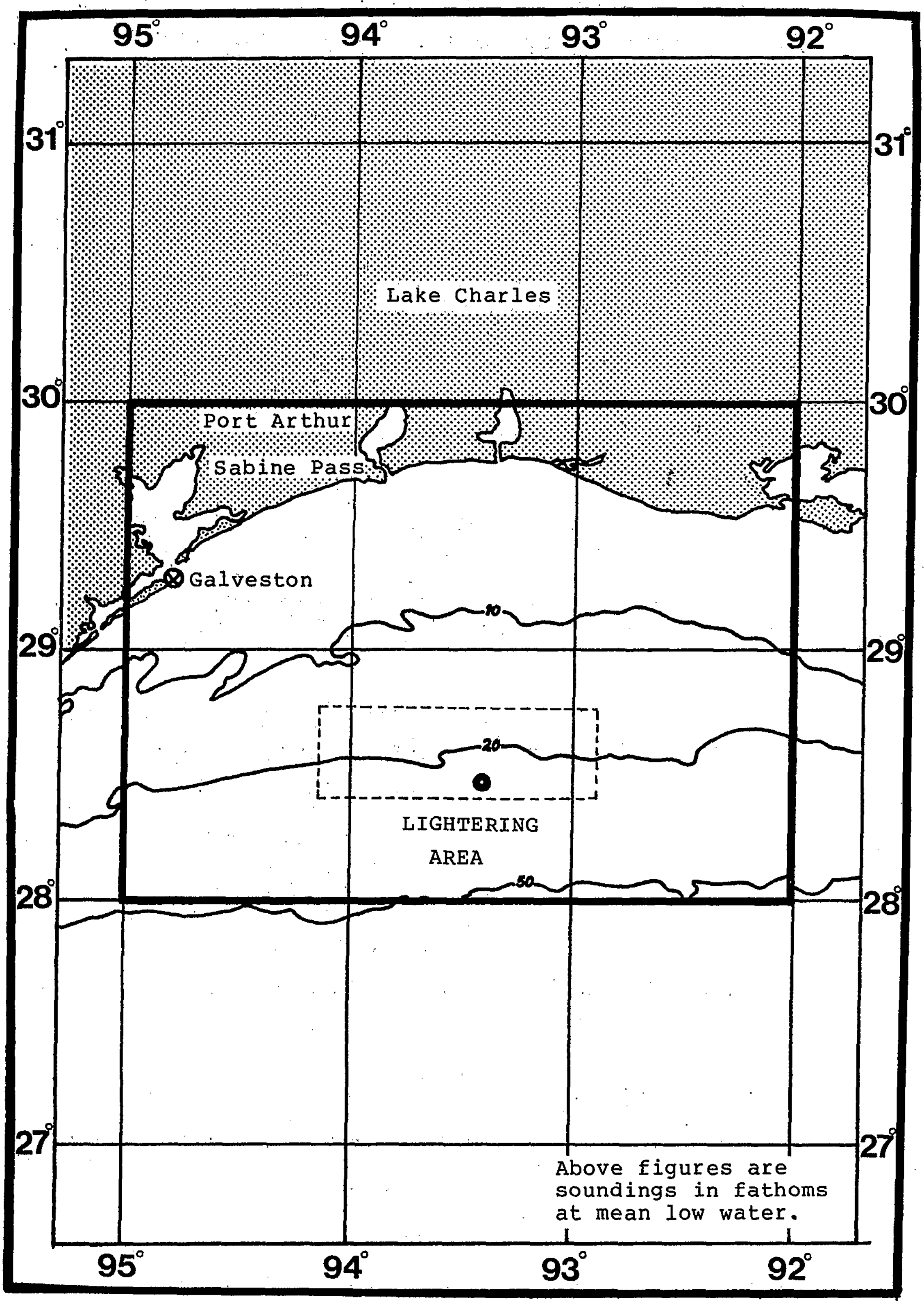


Figure 3.13 Approximate Location of Lightering Operations.

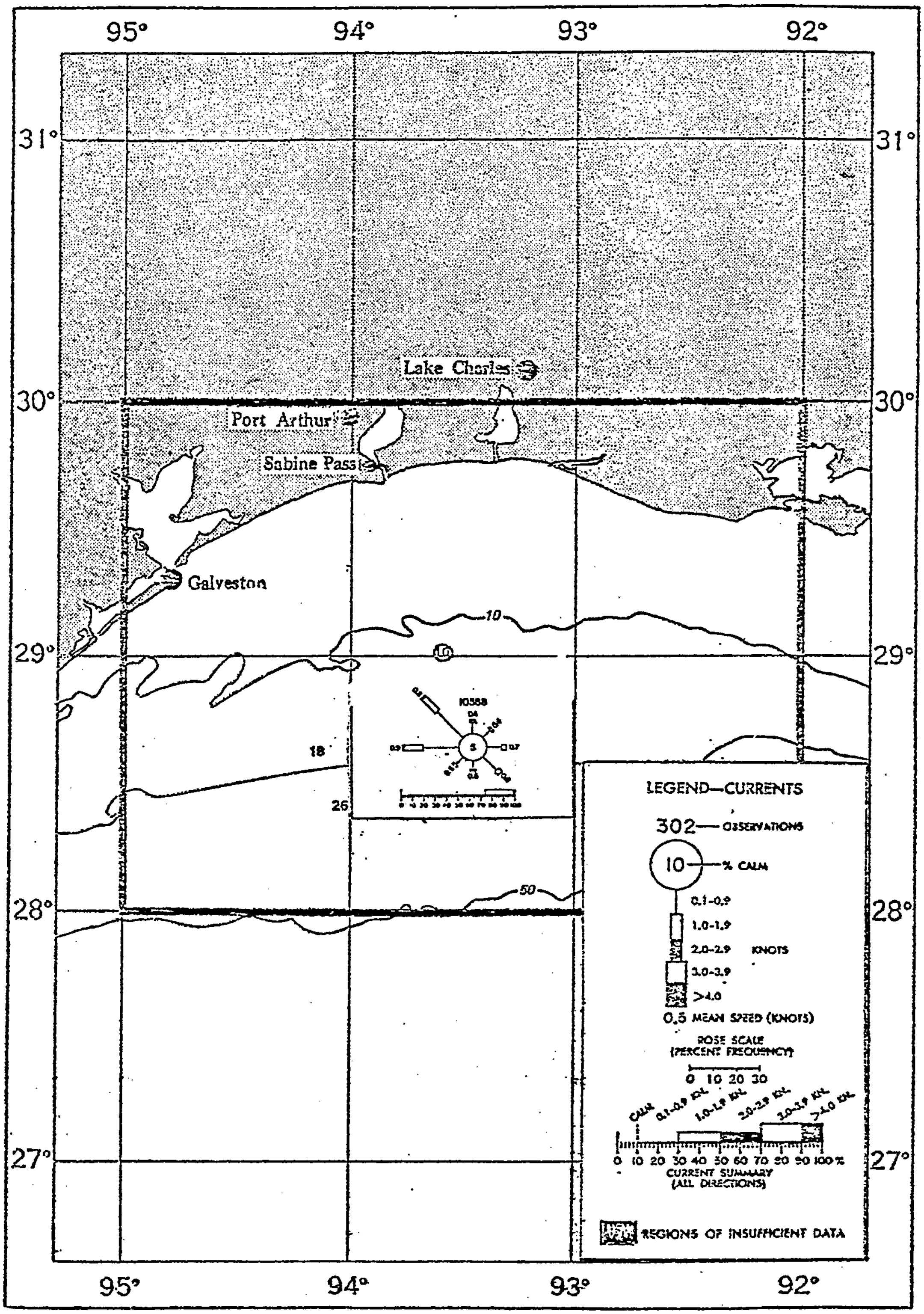


Figure 3.14 Probability Distribution of Ocean Currents During Winter in the Vicinity of the Lightering Site.

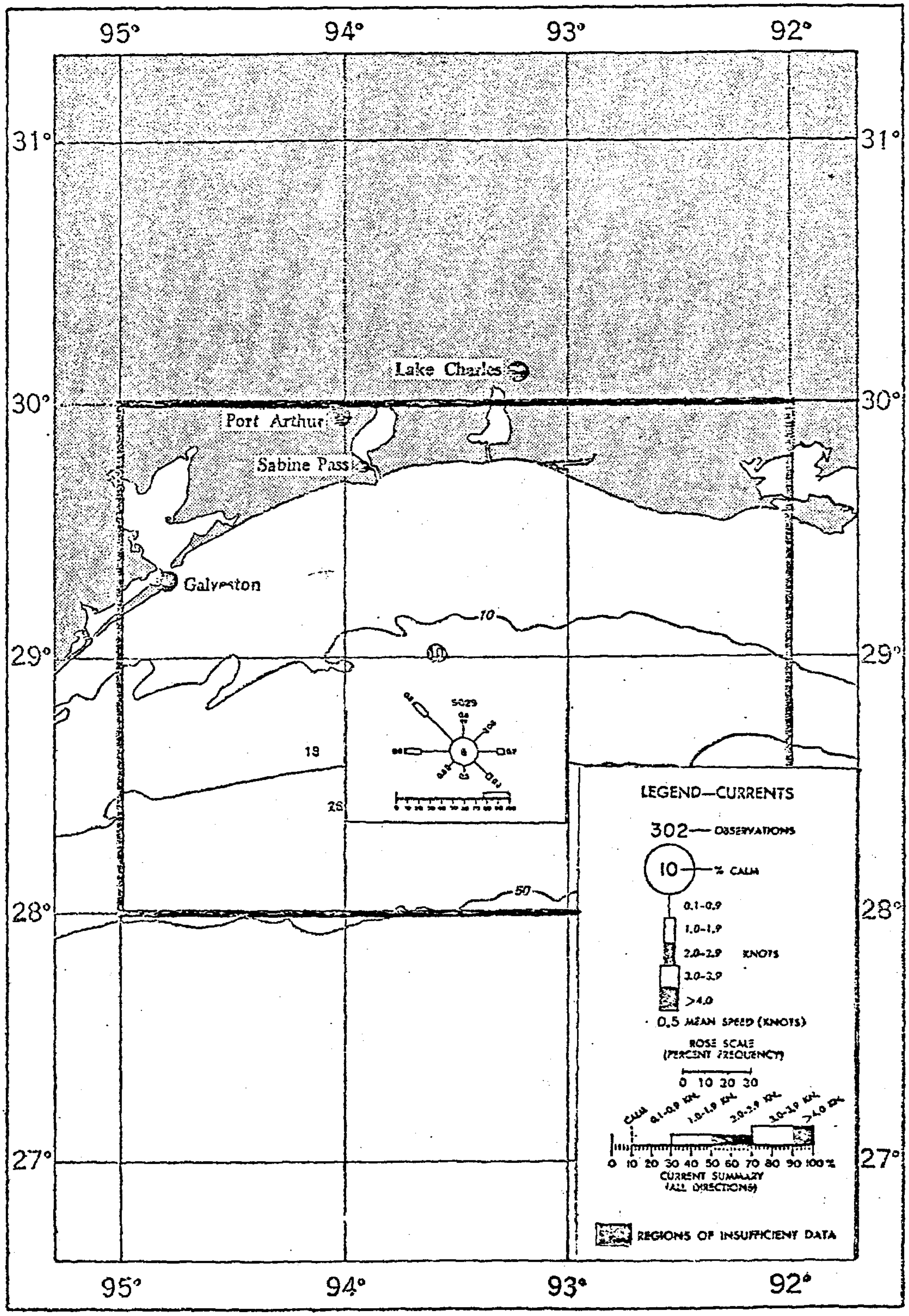


Figure 3.15 Probability Distribution of Ocean Currents During Summer in the Vicinity of the Lightering Site.

WINTER WIND ROSE
(Jan-Mar & Oct-Dec)

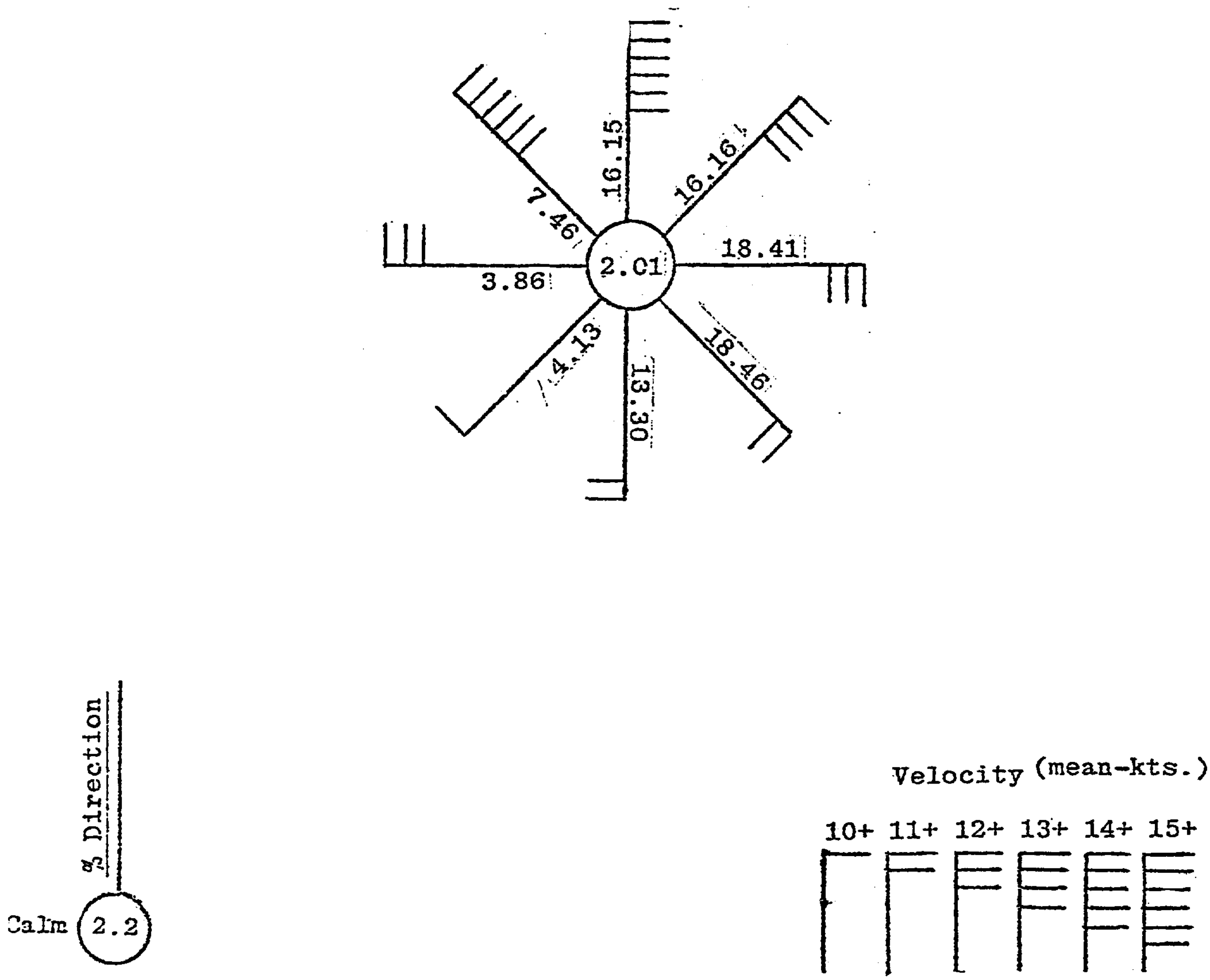
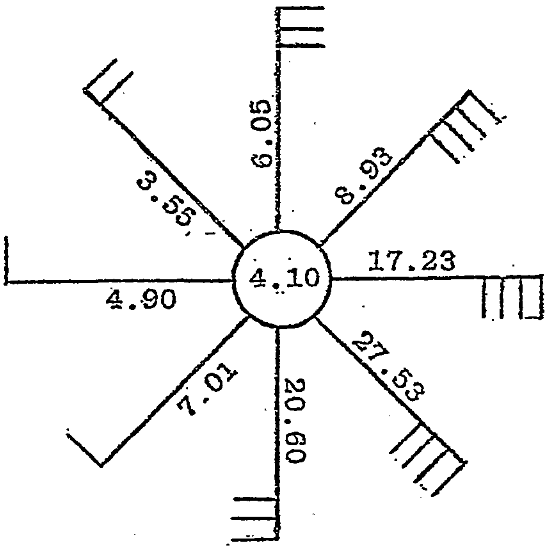
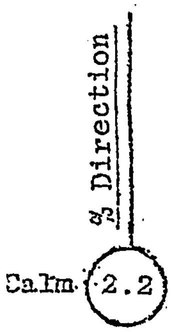


Figure 3.16 Wind Rose for the Lightering Site During Winter.

SUMMER WIND ROSE
(Apr-Jun & Jul-Sep)





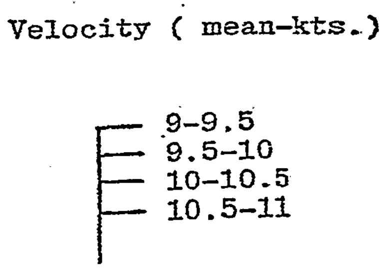


Figure 3.17 Wind Rose for the Lightering Site During Summer.

winds would tend to cause an oil slick to drift away from shore at approximately 0.4 to 0.5 knots. The data suggest that oil spilled during lightering could drift ashore somewhere between the Calcasieu Pass and the Matagorda Bay areas approximately 60 percent of the time in summer and 40 percent of the time in winter. In either season, a slick when reaching these areas would be well weathered, having been at sea for at least 3 days (a minimum distance of 75 miles from shore divided by 1 knot, the average current speed).

3.7.2.2 Oil Spills from Lightering and Transshipment

For analysis purposes, it has been assumed that crude oil would be shipped into the Gulf of Mexico aboard VLCC's and lightered off onto smaller vessels, approximately 45,000 dwt, for shipment to the Sun Terminal. The lightering operation would be performed 50 to 100 miles out to sea from Sabine Pass. The analysis of the risk of oil spills considered both the lightering operation and the transshipment from the point of lightering to the entrance of the Sabine Pass Channel.

It is known that lightering of VLCCs in U. S. coastal waters has become a routine operation. It has been estimated that approximately 20 percent of the oil imported comes in via lightering. The exact amount lightered is not reported, however, during 1975, there is indirect data suggesting that approximately 13 x 10^6 short tons (equivalent to 84 x 10^6 barrels of API 27^o crude oil) of oil were imported into Gulf Coast ports by this method.* Considering the size of tankships available for lightering service in the Gulf, an average size of 28,000 dwt, this is equivalent to approximately 467 lightering tankship trips per year into Gulf Coast ports.

Even though this rather extensive operation exists, there are no data on the spillage of oil during lightering, apparently because there is no requirement to report such spillages. Moreover, there are no reported spills from casualties associated with

* Based on data reported by the U.S. Army Corps of Engineers for the total amount of imported oil 67 x 10^6 short tons, in Waterborne Commerce, and oil imported, 54 x 109^6 short tons, in foreign trade ships, in Engineers' Annual.

lightering operations. (Casualties would become known to the Coast Guard and would appear on Lloyds Weekly Casualty List.) However, this lack of reported polluting incidents does not mean that they do not occur. For this analysis, it has been tentatively assumed that the spill frequency and sizes are the same as for loading and offloading at a dock. These data are developed and discussed in Section 3.7.2.4. Accordingly, the spillage frequency is 9.2×10^{-3} per lightering operation and the median spill size is 0.5 barrels.

The justification for this assumption is the high degree of similarity between ship-to-ship transfers and off-loading at a dock. During lightering, the two ships are tied to each other with numerous mooring lines and with large cylindrical rubber fenders in between. The resilience of the latter takes up any slack in the mooring lines and thereby minimizes fatigue stress in the lines. The oil transfer is performed as at dockside with 10 or 12 inch hoses hoisted by the ship's lifting gear. The hoses are supported in such a manner to prevent sharp bends and kinking. All connections are carefully checked before transfer begins and as a further check, the pumps are brought up to speed slowly while the connections are checked again for leaks. These precautions are observed also during dockside transfers.

Oil spill risk from transport of the oil in the lightering ships between the point of lightering and the entrance to Sabine Pass was estimated using casualty statistics for tankships operating in the Gulf of Mexico and the Caribbean Sea. During the period 1969 through 1975, there were 7 tankship casualties in which some or all of an oil cargo or oily ballast was lost. These are listed in Table 3.26, including the cause of the casualty and an estimate of the loss of oil if known.

The estimate of casualty frequency was derived by dividing the number of casualties by the "exposure" of tankships to accidents: the number of tankship operating hours in the Gulf and Caribbean. Tankship traffic consists primarily of coastwise trade (in U. S. Flag ships), and imports of foreign oil and petroleum products. Most of the coastwise trade is between Gulf Coast ports and East Coast ports. Hence, most of the tanker traffic crosses the Gulf of Mexico, going through the Florida Straights or the Caribbean and Gulf, passing through the Yucatan Channel.

Table 3.26 Oil Spills from Tankship Casualties in the Gulf of Mexico and Caribbean Sea.

Tankship	Size (1,000 dwt)	Year	Type of Casualty	Location[a]	Oil Outflow (barrels)
Texaco Nevada Full Cargo	19.9	1969	Structural Failure	Open Sea	Unknown Amount
Vassiliki	69.1	1971	Structural Failure	Open Sea	Unknown Amount
Stolt Sveve	16.3	1971	Breakdown	Open Sea	Unknown Amount
Mar Star	17.5	1971	Breakdown	Open Sea	Unknown Amount
V. A. Fogg	20.8	1972	Explosion	Coastal	11,200
Zoe Colotron	25.7	1973	Grounding	Coastal	35,000
(Liberian Flag)	Unknown	1975	Collision	Open Sea	714

[a]Coastal means within 50 nautical miles of shore whereas open sea means beyond 50 nautical miles of shore.

Based on an analysis of traffic into Gulf Coast ports for the year 1975, presented in Appendix G-2, the following ship count was derived (loaded tankships traversing the Gulf and/or the Caribbean into U. S. ports):

Shipping	Number of Trips
Foreign Flag Tankers	4,316
U. S. Flag-Foreign Trade Tankers	182
Lighter Tankers	467
Non-petroleum Tankers	407
U. S. Flag - Domestic Trade Tankers	5,533
Total	10,905

Similarly, counts of tankship traffic were estimated for the other years of the 1969 through 1975 period. The total number of trips made during this period was 66,390. Assuming that the average trip across the Gulf and Caribbean is 1,000 nautical miles, and that the average speed is 12 knots, the average duration of a trip is 3.5 days. Therefore, the total number of tankship years of exposure during this period was

$$\frac{3.5}{365} \times 66{,}390 = 637 \text{ tankship years.}$$

Since the tankship casualty data includes ships in ballast (see Appendix G-2), the traffic count should be doubled. It is assumed that for each trip made by a loaded tankship there is a return trip made across the Gulf and Caribbean in a ballasted condition. On this basis, the exposure to accidents during 1969 through 1975 is 1,274 tankship years.

Combining this value with the number of incidents yields

$$\frac{7}{1274} = 0.0055 \ \frac{\text{casualty caused oil spills}}{\text{tankship-year}} .$$

It is of interest to note that this oil spill rate in the Gulf of Mexico and the Caribbean Sea is approximately one third that of world-wide experience. Card, Ponce and Snider[51] reported that there were 452 oil polluting incidents from tankship casualties during 1969 through

1973. In 1969, the world population of operating tankships was 5,869, and in 1975, it was 6,607 tankships. During the 5-year period of 1969 through 1973, the exposure to accidents was 31,964 tankship years. Therefore, the worldwide accident and spill rate was

$$\frac{452}{31,964} = 14x10^{-3} \frac{\text{casualty-caused oil spills}}{\text{tankship-year}} .$$

Assuming an average speed of 10 knots, the time required for a lightering ship to traverse the 75 miles between the lightering location and the entrance to Sabine Pass is approximately 8 hours. Therefore, the exposure time is $\frac{8}{24x365}$ years, and the probability of a casualty and spill during that trip is

$$0.0055 \times \frac{8}{24x365} = 5.0x10^{-6} \text{ spills per trip.}$$

The size distribution of spills from tankship casualties is derived in Section 3.7.2.3 and is presented in Figure 3.21. The size distribution of spills during ship-to-shore transfer operations is derived in Section 3.7.2 and is presented in Figure 3.21. That distribution is assumed to apply to ship-to-ship transfer operations, as well as to terminal operations, because of the similarity of the operations as discussed above. All of these data were combined to give the per trip frequency of oil spills of selected size ranges, listed in Table 3.27 and the per trip frequency of oil spills exceeding a given size, shown in Figure 3.18. These data, in turn were utilized to develop the probabilities for spillage during the transport of stated amounts of oil, listed in Table 3.25.

Table 3.27 Estimated Spill Size Frequency from Lightering Operations and Transshipment.

Spill Size (barrels)	Frequency of Spill During Lightering (per trip)	Frequency of Spill from Vessel Casualty (per trip)
>1	$6.01x10^{-3}$	
1-3	$1.55x10^{-3}$	
3-10	$1.03x10^{-3}$	
10-30	$2.9 x10^{-4}$	
30-100	$1.85x10^{-4}$	
100-300	$7.2 x10^{-5}$	
300-1,000	$2.02x10^{-5}$	$8.3 x10^{-7}$
1,000-3,000	$9.12x10^{-6}$	$1.21x10^{-6}$
3,000-10,000		$1.36x10^{-6}$
10,000-30,000		$7.55x10^{-7}$
30,000-100,000		$3.45x10^{-7}$
>100,000		$9.0 x10^{-8}$

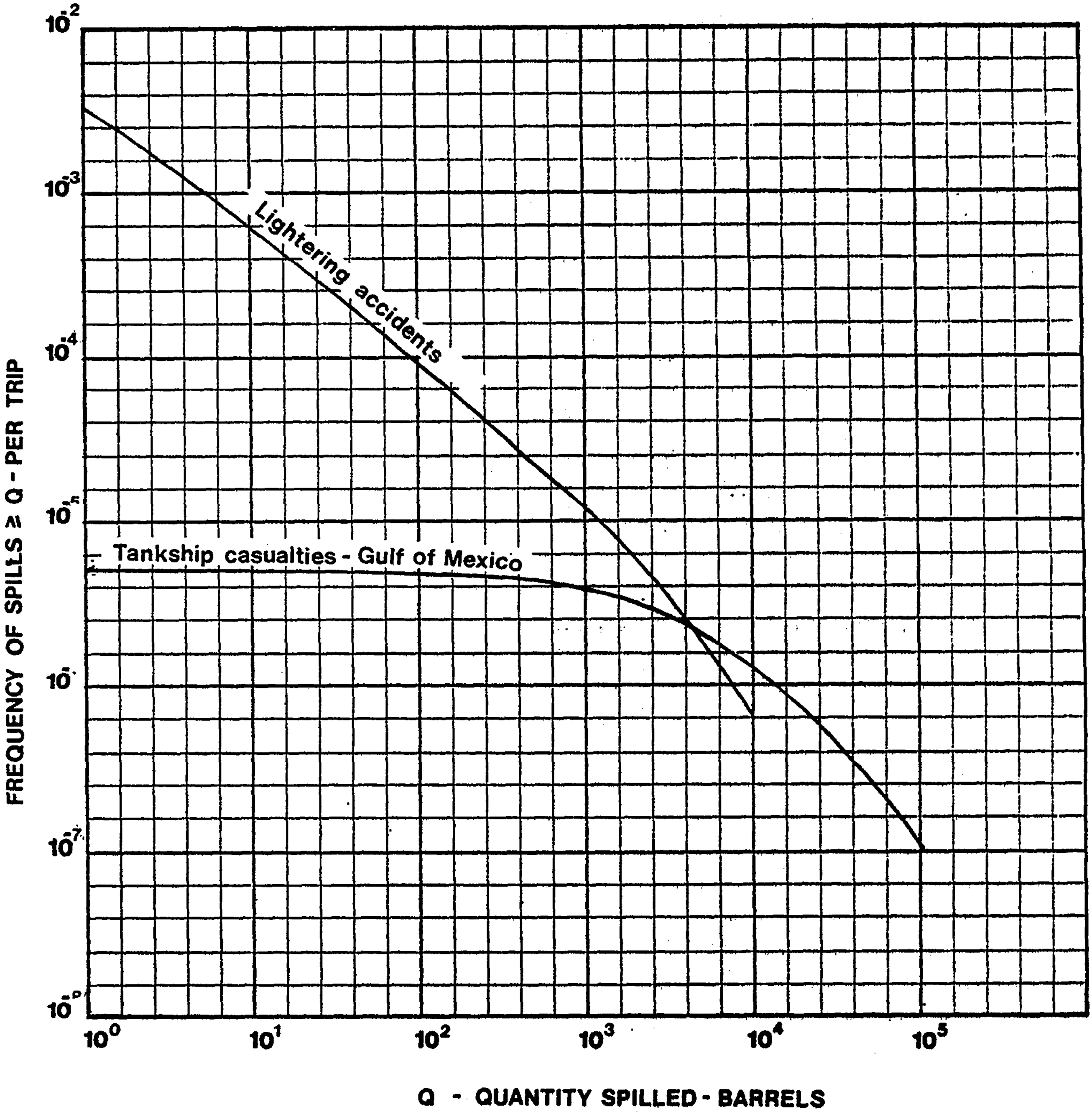


Figure 3.18 Estimated Frequency of Crude Oil Spill per Trip in the Gulf of Mexico from Tankship Accidents.

3.7.2.3 Risks of Spills from Vessel Casualties in Harbors and Channels.

The estimation of the frequency of shipping accidents and spills of oil was based on the number of reported accidents to tankships compared with the number of trips these vessels made into U.S. ports along the Gulf Coast (Brownsville, Texas to Key West, Florida). The accident data was obtained from the U.S. Coast Guard Commercial Vessel Casualty Reporting System in which pertinent items of information have been recorded on magnetic tape. The data for the Gulf Coast area are summarized in Table 3.28.

This data base is believed to be accurate and complete. The reporting system has been in effect for over 10 years, and by law all vessel casualties with more than $1,500 total damages must be reported. Casualties sufficiently severe to cause the loss of cargo invariably involve total damages much greater than $1,500. However, the statistical significance of tank ship casualties for which there was a loss of cargo leaves something to be desired. Therefore, the frequency of collision caused caualties were estimated using a previously developed model (Appendix G-1).

The ship collision model interpolates collision experience between different U.S. ports. It takes into account local ship traffic density, the dimensions and speeds of individual ships and their resistance to collision damage. The model is calibrated to actual collision experience as obtained from the Coast Guard Commercial Vessel Casualty data together with traffic data from the U.S. Army Corps of Engineers "Waterborne Commerce of the United States".[49] With this model, the computed estimate of a collision and spill from the SPR tank ship is 0.613×10^{-5} per trip along the 31.5 miles from the entrance of the Sabine Pass to the Sun Terminal. This frequency is slightly smaller than might be estimated from the accident experience for the entire U.S. Gulf Coast area, Table 3.23. The Model also permits calculation of collisions with other tank vessels in which the SPR vessel is the striking ship. The estimated frequency of a spill from the other tank vessel is 1.14×10^{-5} per trip of the SPR tank ship. The details of the model and the calculations performed to make these estimates are described in Appendix G.1.

Table 3.28 Tankship Accidents in Inland Gulf Waters During Fiscal Years 1969-1974*

Cause	Number of Vessel Casualties	Number of Vessel Casualties With Cargo Loss
Collisions (with other vessels	81	1
Rammings (collisions with fixed, floating and submerged objects	75	1
Groundings	14	1
Fires and Explosions	3	0
Structural Failures	24	0
Other (flounderings, capsizing, flooding, undetermined	11	0
Total	208	3
Total (less collisions)	127	2

The probability distribution of size of spills from tank ship accidents was estimated using the large quantity of data for spills from tank barge accidents. These data indicate that the median spill is approximately 1/3 the volume of a single cargo tank. This reflects the facts that the damage in a casualty is such that all the cargo cannot leak out and that the outflows often are sufficiently slow to permit taking measures, such as transfer of the cargo to another vessel or tank, to limit the amount lost.

Table 3.29 shows the characteristics of a tank ship with a cargo capacity slightly more than 400,000 barrels. Although large tank ships may be used (up to 125,000 DWT), these would be light loaded. Regardless of the size of the tank ship used, it is assumed that they would carry approximately 400,000 barrels of oil with approximately 9,200 barrels in each wing tank. Accordingly, loss of one third the contents of one of these tanks is 3,100 barrels which is assumed to be the median spill. Assuming the same variance as for tank barge spills, the spill size distribution for tank ships was estimated as shown in Figure 3.19.

Figure 3.19 also indicates the reasonableness of this estimated distribution. The distribution of spill sizes from all tank ship casualties in U.S. inland coastal waters during fiscal years 1969 through 1974 is shown by the points plotted. These lie below the estimated curve for a 45,000 DWT tank ship as expected since most of the casualties involved smaller tank ships.

Estimates of the expected spill size frequency from tank ships are presented in Table 3.30 and Figure 3.20, respectively. The per trip frequencies are simply the product

Table 3.29 Characteristics of a 45,000 dwt Tankship

Length Overall	743 feet
Beam	102 feet
Draft	39.5 feet
Gross Tonnage	30,000
Net Tonnage	19,800
Number of Wing Tanks	24
Approximate Capacity of the Wing Tanks	9,200 barrels
Number of Center Tanks	11
Approxmiate Capacity of The Center Tanks	18,000 barrels
Approximate Total Cargo Volume	409,500 barrels

Source: "Offshore Petroleum Transfer Systems for Washington State," Oceanographic Institute of Washington, December 16, 1974, p. III-54.

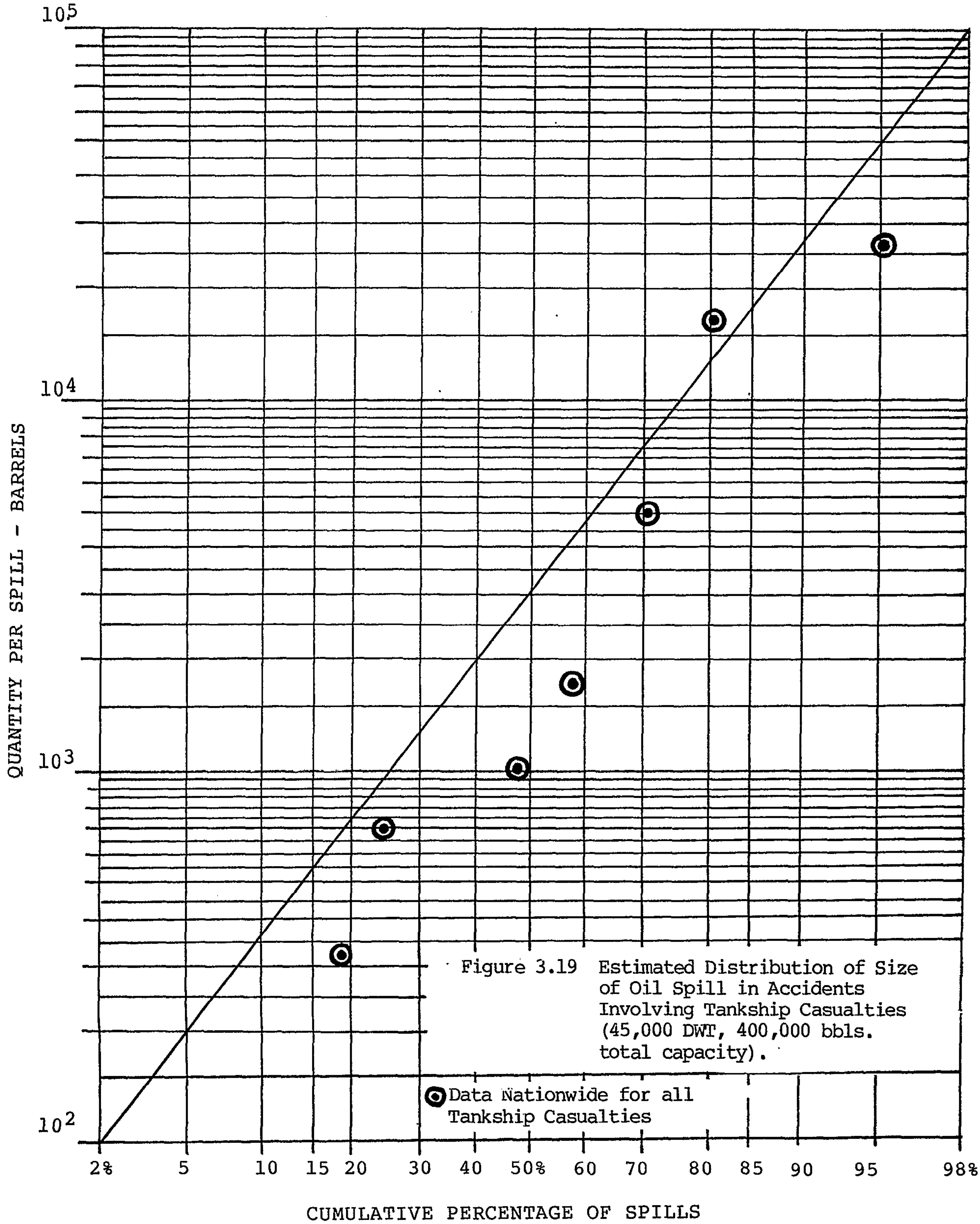


Figure 3.19 Estimated Distribution of Size of Oil Spill in Accidents Involving Tankship Casualties (45,000 DWT, 400,000 bbls. total capacity).

Table 3.30 Estimated Spill Size Frequency From Tankship Casualties.

Spill Size (barrels)	Frequency[a] (per tankship trip)
<100	1.00×10^{-6}
100-300	3.20×10^{-6}
300-1,000	8.40×10^{-6}
1,000-3,000	1.24×10^{-5}
3,000-10,000	1.39×10^{-5}
10,000-30,000	7.66×10^{-6}
30,000-100,000	3.52×10^{-6}
>100,000	9.18×10^{-7}

a The maximum quantity that can be spilled is 400,000 barrels.

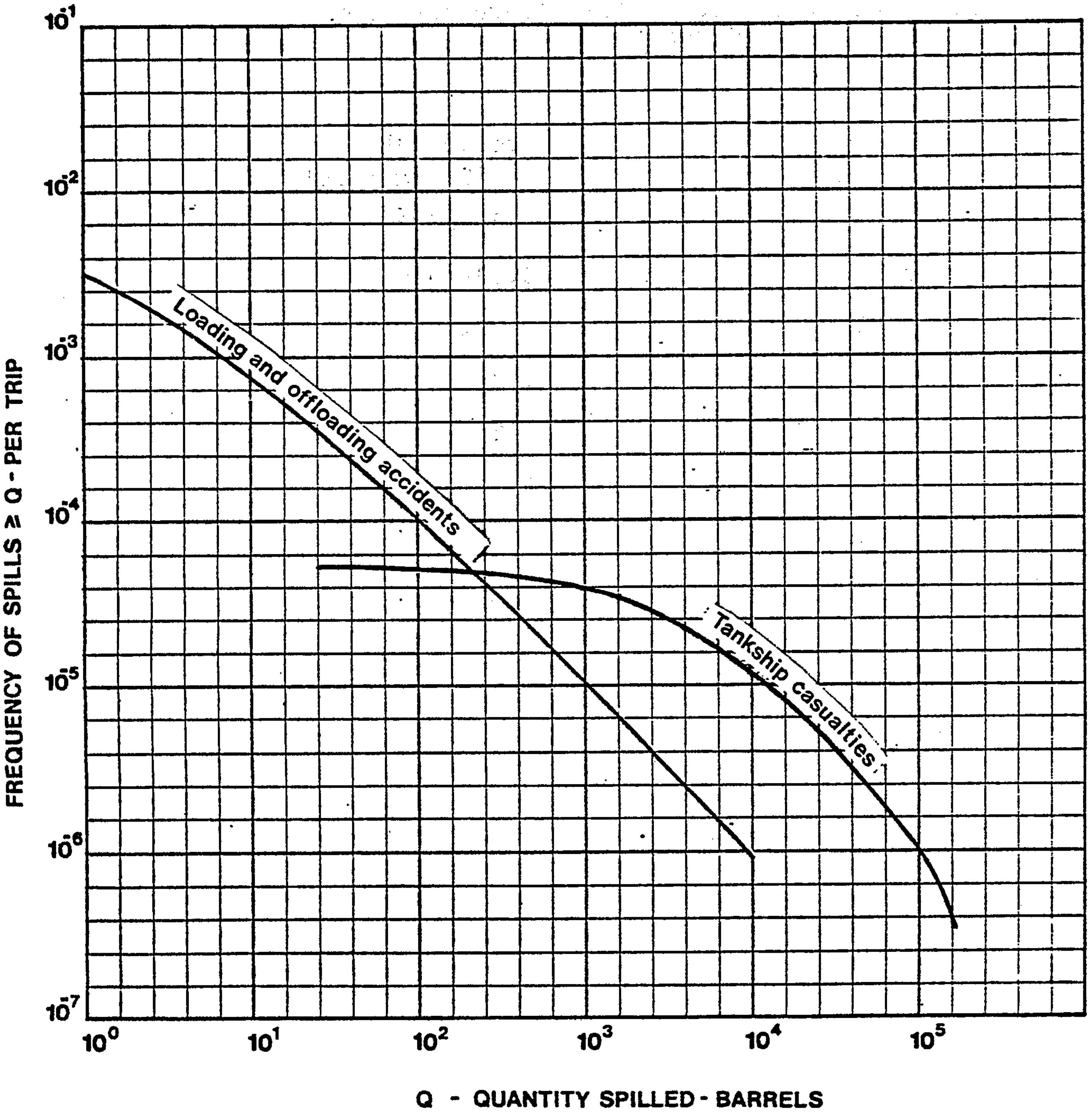


Figure 3.20 Estimated Frequency of Crude Oil Spill per Trip in Channels and Harbors From Tankship Accidents.

of the spill frequency and the fraction of spills in the given size range from Figure 3.19. From the discussion above, the frequency for tank ships is 5.1×10^{-5} spills per trip which includes collisions as well as rammings and groundings. The expectation quantity of crude oil spilled is the sum of the products of frequency and quantity spilled, the average of the size ranges in Table 3.30 for all spill sizes. For tankship casualties, the expectation quantity is 0.60 bbl.

3.7.2.4 Spills at the Marine Terminal

The frequency and size of spills during operations at the barge and tank ship terminals have been estimated in a manner similar to that used for vessel casualties. An analysis was made of the total number of spills as well as the quantity spilled at marine terminals in the Gulf Coast region during the period January 1974 through September 1975. Next, an estimate was made of the total number of barges and tank ships loaded or unloaded at these terminals. Spill frequency was obtained simply by normalizing these data to the same time period and dividing the number of incidents by the number of loading and offloading operations. A spill size distribution was derived from analysis of the spill data.

The data base for both the number and size of spill incidents was the U.S. Coast Guard's Pollution Incident Reporting System (PIRS).[52] Information concerning all pollution incidents reported to the Coast Guard and/or investigated by them are encoded and recorded on magnetic tape; the information includes locations, material spilled, quantity, cause, source and operation. Although this system has been in operation from the beginning of 1971, some Coast Guard officials feel that a high level of reliability of the data base was not achieved until 1974. On this basis, only data for the years 1974 and 1975 were used (data for 1976 have not yet been made available). All cases that did not pertain to loading and offloading at marine facilities (docks, terminals, etc.) in the Gulf Coast region were rejected from consideration, and the relevant cases were then sorted by source and size of spill. The final results of this sorting, for the time period January 1974 through September 1975, are shown in Table 3.31. The average number of spills during a twelve month period was 794; the average and median spill sizes were 11.5 and 0.5 barrels respectively.

Table 3.31 Spills Occurring at Gulf Coast Marine Facilities January 1974 - September 1975

Number of Incidents are Characterized by Size and Source

Barrels Discharged	Source						
	Marine Facility: Bulk Cargo Transfer	Marine Facility: Non-Bulk Cargo, Fueling, Other	Tankship	Tank Barge	Other Vessel	Total No. of Incidents by Size	Percentage of Total Incidents
0-.5	89	124	114	307	70	704	50.65
.5-1.0	20	28	43	96	20	207	14.89
1-2	13	23	36	84	7	163	11.73
2-3	7	8	14	38	5	72	5.18
3-5	11	8	29	41	5	94	6.76
5-10	3	12	19	26	2	62	4.46
10-30	6	8	5	21	4	44	3.17
30-100	2	6	10	9	1	28	2.01
100-300	1	3	1	5	1	11	0.79
300-1000	0	1	1	1	0	3	0.22
1000-3000	0	0	1	0	0	1	0.07
3000-10,000	0	0	0	1	0	1	0.07
Total No. of Spills	152	221	273	629	115	1390	100.00

No. of incidents per year = 794 Average Spill Size = 11.5 barrels Median Spill Size = 0.5 barrels

The manner in which the number of loading and offloading operations were counted tends to overestimate the frequency of spills. During 1974 (12 months), there were approximately 9,800 tank ship trips into all Gulf Coast ports.[49] A major fraction of tank barge traffic into U.S. ports occurs in Gulf Coast ports, approximately 76,000 trips inbound annually.[49] It is assumed that for each inbound trip into a port, a tank ship or tank barge makes at least one stop to load or offload a bulk liquid cargo. This adds to a total of 86,000 loading and offloading operations. Not included in this count is an appreciable tank barge traffic along the Intracoastal Waterway. The reason this was left out was to avoid double counting; many of the barges arriving and departing at Gulf Coast Ports also travel the waterway as part of the same trip.

Combining this value with the number of spill incidents listed in Table 3.31, the following spill frequencies are obtained:

$$\frac{1,390}{86,600} \times \frac{12}{21} = 9.17 \times 10^{-3} \text{ spills/trip}$$

for loadings and offloadings at the marine terminal.

The results from analysis of the Coast Guard's PIRS relevant spill data have been used to plot a spill size distribution. This distribution is shown on Figure 3.21, and represents the best data available for this information since it is specific to the type of operations and geographic region, as current as is possible, and statistically meaningful. Using this distribution, and the spill frequency, the frequency of spills in particular size ranges were calculated, shown in Table 3.32. These data also were presented in Figure 3.20. The data presented in Table 3.32 also were used to calculate the median spill size and expected spill quantity per off loading, 0.5 bbls and 0.086 bbl., above.

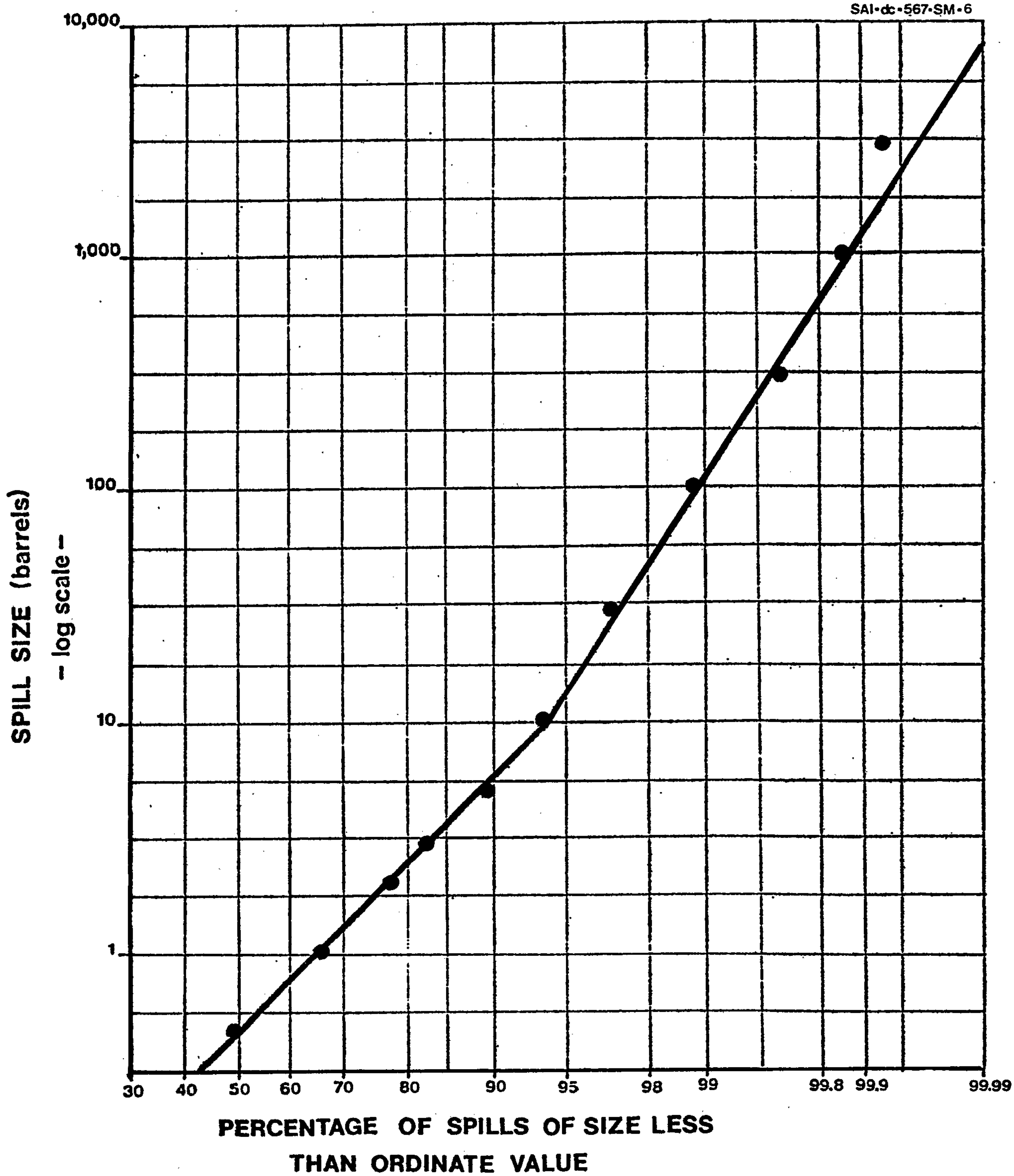


Figure 3.21 Distribution of Quantity of Oil Spilled in Accidents During Loading and Offloading Tankships and Tankbarges

Table 3.32 Estimated Spill Size Frequency From Accidents at a Marine Terminal.

Spill Size (barrels)	Frequency[a]
<1	6.01×10^{-3}
1-3	1.55×10^{-3}
3-10	1.03×10^{-3}
10-30	0.291×10^{-3}
30-100	0.184×10^{-3}
100-300	0.072×10^{-3}
300-1,000	0.020×10^{-3}
1,000-3,000	0.009×10^{-3}
>3,000	0.004×10^{-3}

3.7.2.5 Cumulative Oil Spill Probabilities Resulting From the West Hackberry and Sulphur Mines SPR Operations.

Crude oil supplies and distribution for the Sulphur Mines and West Hackberry SPR sites will be handled at Sun Terminal in Nederland, Texas. For both sites, lightering from VLCCs onto 45,000 DWT and/or 55,000 DWT tankers will occur in the Gulf of Mexico. These tankers will then travel through the Sabine Pass, the Sabine-Neches Canal and the Neches River to the terminal. Concurrent operation of both sites will have a cumulative effect on spill probability.

Cumulative spill probabilities for 45,000 DWT and 55,000 DWT tankers is given in Tables 3.33 and 3.34 respectively. The probabilities are based on one fill cycle at each site. Addition of the Sulphur Mines spill probabilities to the West Hackberry spill probabilities results in approximately 30 percent increase in probability for the three spill sizes.

Table 3.33 Oil Spill Probabilities During Marine Transport by 45,000 DWT Tankers.

	150 Tanker Trips for * Hackberry SPR Fill. The Probability of a Spill Exceeding:			63 Tanker Trips for Sulphur Mine SPR Fill. The Probability of a Spill Exceeding:			Probability of a Spill for One Fill Operation for Both West Hackberry and Sulphur Mine SPR sites Exceeding:		
	300 bbls.	1,000 bbls.	10,000 bbls.	300 bbls.	1,000 bbls.	10,000 bbls.	300 bbls.	1,000 bbls.	10,000 bbls.
Tankship Accident (Inland Waters)	.007	.0057	.0019	.003	.0024	.0008	.010	.0081	.0027
Tankship Accident (Gulf of Mexico)	.00069	.00056	.00019	.00029	.00024	.00008	.00098	.0008	.00027
Lightering Operations	.0045	.0018	.00009	.00019	.00076	.00004	.0064	.00256	.00011
Marine Terminal Offloading Spills	.0045	.0015	.00015	.0019	.00063	.000063	.0064	.00213	.000213
Totals	.017	.0096	.0023	.0071	.004	.001	.024	.014	.0033

* West Hackberry probabilities computed from data in FEA 76/77-4 Section 3.7.2.

Table 3.34 Oil Spill Probabilities During Marine Transport by 55,000 DWT Tankers.**

	150 Tanker Trips for * Hackberry SPR Fill. The Probability of a Spill Exceeding:			63 Tanker Trips for Sulphur Mine SPR Fill. The Probability of a Spill Exceeding:			Probability of a Spill for One Fill Operation for Both West Hackberry and Sulphur Mine SPR sites Exceeding:		
	300 bbls.	1,000 bbls.	10,000 bbls.	300 bbls.	1,000 bbls.	10,000 bbls.	300 bbls.	1,000 bbls.	10,000 bbls.
Tankship Accident (Inland Waters)	.0074	.0069	.0034	.0031	.0029	.0014	.0105	.0098	.0048
Tankship Accident (Gulf of Mexico)	.00073	.00068	.00034	.00031	.00028	.00014	.00104	.00098	.00048
Lightering Operations	.0045	.0018	.00009	.00019	.00076	.00004	.0064	.00256	.00011
Marine Terminal Offloading Spills	.0045	.0015	.00015	.0019	.00063	.000063	.0064	.00213	.000213
Totals	.017	.011	.004	.0072	.0046	.0016	.024	.015	.0056

* West Hackberry probabilities computed from data in FEA 76/77-4 Section 3.7.2.
** Spill percentages for 55,000 DWT tankers taken from FEA 76/77-4 page 3-67.

3.7.3 Zoological Impact of Oil Spills

Oil related risks associated with oil storage in the Sulphur Mines salt dome facility involve accidental releases from barges, tanker spills, pipeline ruptures, terminal facility storage accidents and ballast water discharges. Such releases pose potentially adverse impacts to Bayou Choupique, the Intracoastal Waterway, the Sabine River, Sabine Lake, Cow Bayou, the Neches River, and bordering environs. The extent of such impacts depends primarily on (1) the amount and type of oil released; (2) the time of year; (3) how long the oil "weathers"; (4) whether releases are chronic or acute, i.e., one or multiple spillages; and (5) type and efficiency of cleanup operations.[53] In addition, the levels of background oil pollution from industrial drilling and transportation operations, spills not associated with the Early Strategic Reserve program, and industrial effluents discharged into the lower Sabine and Neches River systems are stresses to the integrity of these ecosystems.

Background Pollution

Oil and grease levels in the sediment and the water column in the Sabine and Neches River and Sabine Lake are moderately high, compared to suggested EPA criteria. These levels reflect the industrial activities along these water bodies.

Potentially Impacted Organisms

The likelihood of oil significantly impacting particular habitats varies with location and size of spill, season and other factors. The toxicity of oil decreases rapidly after a spill. This is primarily due to the fact that the lighter fractions of crude oil, which are those most toxic to organisms, are lost rapidly by evaporation. Therefore the organisms which are likely to have immediate contact with freshly spilled crude oil are likely to experience the most severe impact. These organisms would include plankton and mobile forms such as shrimp and birds. Recovery of planktonic populations is generally rapid. Evaporation of these lighter more toxic components creates a heavier surface residue which may sink to the bottom.

Adverse effects of various types of oil on fish and benthic organisms are summarized in Tables 3.35 and 3.36.

Table 3.35 The Effects of Various Types of Oil on Fish. Oil concentration levels in water, test conditions, and specimen localities are indicated.

Taxa	Oil Type	Oil Concentration (ppm)	Effects	Conditions	Specimen Locality
Menidia beryllina	S. Louisiana crude	7,600	TLm24*	oil in water dispersions (lab)	Galveston, Texas
(tidewater silverside)[1]	Kuwait crude	20,000	"	"	"
	#2 fuel oil	260	"	"	"
Fundulus similis	S. Louisiana crude	6,610	"	"	"
(longnosed killifish)[1]	Kuwait crude	17,500	"	"	"
	#2 fuel oil	48	"	"	"
Cyprinodon variegatus	S. Louisiana crude	80,000	"	"	"
(sheepshead minnow)[1]	Kuwait crude	>80,000	"	"	"
	#2 fuel oil	250	"	"	"
Brevoortia spp. (menhaden)[2]	Empire Crude Oil Mix	250**	smaller fish lost equilibrium; eaten by larger fish	estuarine pond	coastal Mississippi
Gambusia affinis (mosquitofish)[2]	Empire Crude Oil Mix	250**	no apparent ill effects	"	"
Lebistes reticulatus[3]	Louisiana crude	40,000	TLm24	static bioassay	------
(common guppy)	Mississippi crude	40,000	no adverse effects over 30-day period	"	------

[1] J.W. Anderson, Laboratory Studies on the Effects of Oil on Marine Organisms: An overview. American Petroleum Institute Publication 4249, 1975, 82 p.

[2] J.S. Lytle, Fate and Effects of Crude Oil on an Estuarine Pond, pp. 595-600. Proceedings of the Joint Conference on Prevention and Control of Oil Spills, March 25-27, 1975.

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*TLm = level at which one-half of the population was killed in a 24-hour exposure.

**estimate of oil concentration at low tide

Table 3.36 The Effects of Various Types of Oil on Benthic Organisms. Oil concentration levels in water, test conditions, and specimen localities are indicated.

Taxa	Oil Type	Oil Concentration (ppm)	Effects	Conditions	Specimen Locality
oysters[1]	Empire Crude Oil Mix	250*	no apparent stress; no mortality	estuarine pond	coastal Mississippi
oysters (*Crassotrea gigas*)[2]	Kuwait crude	2500	uptake of 25 mg/gram wet weight	exposed 12 hours	California, British Columbia
	S. Louisiana crude	2500	" <0.5 "	"	"
Uca sp. (fiddler crab)[1]	Empire Crude Oil Mix	250*	no apparent stress; no mortality	estuarine pond	coastal Mississippi
Dungeness crab (*Cancer* sp.)[2]	#2 fuel oil	4778	TLm96	metered inflow	California, British Columbia
Crabs (Blue, stone, and Pacific shore crab)[3]	napthalene and alkayl napthalene	0.1 to 1	completely inhibited response (detection of food poor); when oil extracts mixed with food, feeding intensity reduced	24 hour exposure	California

[1]J.S. Lytle, Fate and Effects of Crude Oil on an Estuarine Pond, pp. 595-600. Proceedings of the Joint Conference on Prevention and Control of Oil Spills, March 25-27, 1975.

[2]B.E. Vaughan, Effects of Oil and Chemically Dispersed Oil on Selected Marine Biota--A Laboratory Study. Battelle Pacific Northwest Laboratories for the American Petroleum Institute (API publication 4191), 1973.

[3]J.S. Kittredge, Effects of Crude Oil on Marine Invertebrates, Office of Naval Research, Final Report.

*estimate of oil concentration at low tide

Crude oils are less toxic than refined fuels. Oil concentrations are not expected to exceed tolerance levels (amount and time of exposure) unless the oil and the organisms are trapped in shallow covers. Local fish mortality could occur in this case and benthic organisms could suffocate after oil settled to the bottom and covered them. As long as the oil remains in a slick and does not settle to the bottom benthos are generally not killed, although they may be stressed by oil in the water column.

Marshes and shores could be coated by oil transported by water or by oil released into or onto them from ruptured pipelines. Multiple releases of oil in the same place would be unlikely, with the greatest probability of releases being associated with the Sun Oil Company tanker terminal facility vicinity. Even in this vicinity the probability of receiving in excess of 4 exposures to oil as a result of the SPR program in any 2 or 3 year period would be small.

Marshes are capable of rapid recovery after a single exposure to oil. Many studies have shown that marsh plants survive light to moderate oil exposure in a single application. Short-term adverse effects are: death of shoots exposed to oil, reduced germination of contaminated seeds, and reduced populations of annual species.[54] Recovery by marsh vegetation would be rapid (requiring less than 2 years) after a single exposure to oil because of new growth from plant bases. Successive spillages within a few months of one another would, however, produce longer lasting effects. The oil which was not dissipated soon after coating a marsh or shore area would be physically and bacterially decomposed. This decomposition process would probably have a fertilizing effect if it occurred in a marsh area -- inorganic plant nutrients would be released.[53] Any oil pipeline rupture on dry land would impact primarily invertebrates and plants. Effects on soil organisms (collembola, mites, nematodes, earthworms, etc.) and plants can be expected to be severe but very localized in the immediate area of the leakage. The oil would be degraded and/or washed away eventually over a period of years. The exact coverage depends on soil types, viscosity of oil, pipeline pressure, soil moisture, and other factors.

Effects of Cleanup Operations

Containment and cleanup operations of oil spills from tankers at dock facilities and spills from oil pipeline ruptures are the responsibility of the polluter. The U.S. Coast Guard must be notified whenever a spill occurs, and an on-scene Coordinator oversees cleanup operations and takes whatever steps necessary to assure appropriate cleanup procedures are implemented. The use of emulsifiers and other chemical agents to dissipate oil in water has been virtually discontinued and would have to be approved on the scene by the U.S. Coast Guard. Mechanical removal procedures (booming, skimming, and pumping) would ameliorate the potentially harmful effects of an oil spill and would not be a significant source of negative biological impact. Sorbent* materials are generally used at a dock or on open water after most of the oil has been removed by pumping and skimming. The amount of sorbent materials used in any given oil spill situation is highly variable. After the oil is removed, such materials are generally transported to designated landfill sites for disposal. Biological effects of cleanup operations at docks and in open water are generally minimal.

The choice of a technique for cleanup of crude oil in a marsh area is dependent upon a large range of variables. No one technique is environmentally acceptable or produces satisfactory results in all cases.

Low pressure water flooding is effective in moving oil out of the marsh without damage to plants or disturbance of the substrate or rhizomes. Biologic impacts are minimized by this technique and the technique is effective for all types of marshes and on all types of oil. However the technique is sometimes ineffective in removing all spilled oil from vegetation and is impractical if the spill has spread over a large surface area of the marsh.

Mechanical removal of vegetation is effective for *Spartina* marshes and in some cases for marshes characterized by perennial shrub vegetation. The removal technique is not feasible for soft muds of interior marshes. The advantages of mechanical removal include:

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* Sorbent - A substance that takes up and holds another substance by adsorption or absorption.

- o Elimination of a source of recontamination
- o Protection of incoming migratory birds
- o Protection of aquatic or benthic organisms from repeated rainbow skims
- o Protection of the substrate from oil oozing down plant stalks
- o Protection of adjacent marsh and estuarine area by contamination from repeated wash offs.

The disadvantages include:

- o Damage to root systems from plant cutting
- o Erosion of mudflats due to loss of stabilizing vegetation
- o Contamination of soft, lower muds and damage of phozones by trampling of workers boots
- o Accidental transfer of oil from plants to substrate

Controlled burning is feasible in only a limited number of situations and the effectiveness is tenuous. Burning can be employed only in Spartina marshes and only during the period when winter die-back of leaves and stems permits combustion. Crude oil weathers rapidly. As the lighter fractions evaporate, the combustibility of the oil greatly decreases. Therefore, if burning is not initiated soon after the spill, it may be difficult to induce combustion. There are several disadvantages to this technique including air quality impacts, damage to organisms inhabiting the marsh and fire control problems.

Because of the adverse effects of mechanical and burning cleanup techniques, the no-action approach can be a valid alternative. This technique exposes the oil to natural degradation. Weathered oil will eventually lose its toxic properties and can serve as a substrate for the reestablishment of marsh organisms. Because marsh plants exhibit a high recovery rate after a single exposure to oil, the no-action approach may, in many cases, be the environmentally preferred technique.

If oil were to reach the water table (2 to 3 feet deep along the pipeline route), slow discharge of oil into a body of water (Bayou Choupique, Wing Gully, the Intracoastal Waterway, Cow Bayou, or the bordering marshes) via water table transport could occur. A spill could act as a source of low level contamination for periods exceeding several years. Steps would be taken to prevent seepage of this oil into navigable waters. One method that is frequently employed would be to dig a trench near the point of entry into such a water body. When oil collected (generally after rains) it could be pumped off.

3.7.4 Fires and Explosions

The expected specific gravity and Reid Vapor Pressure of the crude oil to be imported are 27° API and 3.0 psi, respectively. These characteristics suggest that the flash point is below 20°F and that about one percent by weight of the oil will volatilize at temperatures below 80°F.[55] Thus, spills of crude oil may be easily ignited provided an ignition source is nearby.

The maximum downwind travel of a flammable vapor air mixture is of prime importance in evaluating off-site fire risks. From the properties mentioned above, it is estimated that a maximum of one percent of the crude oil can vaporize spontaneously. This vapor can mix in the surrounding air and be ignited at some distance downwind from the spill. Table 3.37 lists estimated maximum distances for the existence of a flammable vapor mixture from spills typical of pipeline breaks and marine accidents. The estimates were calculated assuming Gaussian diffusion, "instantaneous" vaporization and a lower flammable limit of 4500 $\mu g/m^3$, which is typical of aliphatic hydrocarbons. The table indicates that spills of 1,000 barrels or less (e.g., from pipeline leaks and accidents at the Sun Oil Company Terminal) most likely would not be ignited since the flammable plume would rarely extend off-site. Onsite, ignition sources would be few, in keeping with the usual fire safety practices characteristic of oil storage and transfer facilities. Spills from vessel casualties, especially tankship casualties (8,300 barrel median spill), if not ignited during or shortly after the collision (see below), could produce a flammable vapor-air mixture which would reach shore along the Sabine River and could be ignited. However, this generally would present little danger to persons living on shore since less than 10 percent of the vapor evolved would be in the flammable range.

Table 3.37 Maximum Downwind Drift of Flammable Crude Oil Vapor-Air Mixtures.

Pasquill Atmospheric Stability	Relative Frequency of Occurrence	Downwind Distance (meters)		
		0.5 barrel Spill	1,100 barrel spill	8,300 barrel spill
A, B, C, D	.64	<100	250	550
E	0.13	<100	350	750
F	0.23	150	600	1,250

Accident experience indicates that only localized fires are to be expected from spills of crude oil. Data from the U.S. Coast Guard's reports on commercial vessel casualties indicate that spills of crude oil from ship collisions are ignited immediately in at least 90 percent of the instances. The causes of ignition are unknown, but apparently short circuited electrical wires and hot metal fragments play a major role. Experience from 1971 through 1974 at bulk petroleum marine terminals indicates a total of 29 fires originated from accidents on the terminal property, and of these only one spread to property offsite.[55] The same data indicated that there were an average of 700 such terminals in operation during the four year period. Hence, from these data the frequency of offsite fires is approximately

$$\frac{1}{4 \times 700} = 3.6 \times 10^{-4} \text{ per year.}$$

Actually, this is a high estimate for SPR facilities since many of the liquids handled at the 700 terminals (such as gasoline) are much more flammable than crude oil.

A crude oil fire would destroy local vegetation and release smoke and combustion products to the atmosphere. Not all the spilled crude oil would burn in a "pool" fire. Only the more volatile components would be consumed; heat feedback from the flame is insufficient to vaporize the high molecular weight components. For a 27° APR gravity oil, it is estimated that a maximum of 50 percent of the spilled oil would burn in a "pool" fire. The emissions would consist of soot, hydrocarbons, CO, and SO_2. Negligible nitrogen oxides are expected because of the low flame temperatures characteristic of pool fires. These emissions would cause only a temporary and very localized degradation of air quality.

3.7.5 Accidental Injury

Because accidental fires would be confined to the spill area, it may be expected that injuries also would be limited. Hence, it is mainly employees and the crews of ships that would suffer the consequences of any accidents. This is supported by data on accidents and fires compiled by the Coast Guard and the National Fire Protection Association. Table 3.38 summarizes the fatalities resulting from fires and explosions that have occurred in bulk liquid storage terminals (both marine and otherwise) nationwide during the 25-year period 1950 through 1975. Only four employee deaths and two non-employee deaths have resulted from fires involving the storage of crude oil. The non-employee deaths were two boys who were playing on top of storage tanks. A cap pistol ignited the vapor in one of the nearly empty tanks. Applying the accident experience in Table 3.38 for refined petroleum fuels, gasoline, fuel oil, aviation fuel, and napthalene, which are much more flammable than crude oil, an upper limit on the frequency of fatalities and injuries may be estimated for the storage of crude oil. In 1967 there were 25,000 bulk storage establishments for petroleum fuels in the United States.[62] Assuming an average of 20,000 over the 26 year period covered by the data, the frequency of non-employee deaths per establishment is

$$\frac{31}{26} \times \frac{1}{20,000} = 6.0 \times 10^{-5}$$ per year, where the unknown

category in Table 3.38 has been included with "non-employee" death. The corresponding estimate for the frequency of employee deaths is

$$\frac{43}{26} \times \frac{1}{20,000} = 8.3 \times 10^{-5} \text{ per year.}$$

Since as a rule of thumb, the injury rate in accidents is approximately 5 to 10 times the mortality rate, it is estimated that there will be a maximum frequency of 6×10^{-4} employee injuries per year.

Because these frequencies were derived from data for much more flammable materials, it is concluded that the risk of death and injury to employees and persons off-site is substantially smaller than the frequencies given by the above computations.

3.7.6 Natural Disasters

Natural disasters that may affect the dome include seismic events, hurricanes, tornadoes, high winds, lightning, and floods. These phenomena are not expected to pose a severe threat to the project, nor to cause the project to seriously degrade the environment. The frequency of natural disasters which result in pipeline breaks or oil spills has already been factored into the statistics of Section 3.7.1 and 3.7.4. Potential effects of other disasters are examined in this section.

Table 3.38 Non-Employee and Employee Fatalities from Fires and Explosions Involving Flammable Liquid Bulk Storage During the Years 1950-1975.

Product	Number of Employee Deaths	Number of Non-Employee Deaths	Number of Unknown
Gasoline	27	11	4
Fuel Oil	5	4-10	0
Aviation Fuel	1	0	0
Napthalene	3	0	0
Flammable Ink	2	0	0
Crude Oil	4	2	0
TOTALS	43	17-23	4

Source: National Fire Protection Association, Fire Case Histories, via personal communications from M. L. Sullivan, Environics, Inc., April 1976.

Seismic Events

The National Oceanic and Atmospheric Administration (NOAA) has classified the United States into 4 zones of expected seismic risk based on the recorded history of past seismic activity. Zone 0 covers areas having no reasonable expectancy of surface earthquake damage; Zone 1, expected minor damage; Zone 2, expected moderate damage; and Zone 3, possible major destructive earthquakes.

The area of Sulphur Mines salt dome lies on the western edge of seismic risk Zone 1 as defined above.[18] The area to the immediate west is in Zone 0. A search conducted by NOAA indicates that no earthquake has been recorded for the immediate Sulphur Mines area.

Hurricanes, High Winds, Tornadoes, and Floods

A major hurricane passes through this area about every 4 years.[61] Winds at the site exceeded 100 mph during hurricanes in 1964 and 1965. Heavy rainfall, local and regional floodings, and tornadoes often accompany hurricanes.[58] The storage integrity of the facility would not be threatened by a hurricane. Sufficient hurricane warning is available so that oil transfer would be stopped and surge tanks emptied. Except at the marine terminal, all oil and brine pipelines are buried and therefore, would not be affected.

Tornadoes not associated with hurricanes could be more hazardous because of the lack of warning. It is possible that a tornado could strike one of the large oil surge tanks at the marine terminal and cause a major oil loss. Tornado frequency in this area is about 3 tornadoes per 10,000 square miles per year.[59,60]

Thom has computed a mean ground track area of 2.8 square miles per tornado.[59] Howe[61] has recomputed ground track area by state and region, arriving at an estimate of 0.61 square miles per tornado in Louisiana. The frequency, f, of the marine terminal being struck by a tornado in one year is:

$$f = \frac{3}{10,000} \times 0.61 = 1.83 \times 10^{-4} \text{ per year.}$$

Assuming only one filling or withdrawal occurs in any one year, then the surge tanks contain oil only 5 months out of the year. Therefore, frequency of being struck by a tornado while oil is present is

$$\frac{5}{12} \times 1.83 \times 10^{-4} \text{ per year.}$$

The oil surge tanks are designed to withstand very strong winds and should remain intact for small tornadoes and large tornadoes which are "near misses." However, should the tank be damaged, the tornado might "suck up" some of the oil. This oil would be dispersed over such a wide area that adverse environmental effects would be minimal. Any oil leaking from the damaged tank would be retained inside the dike.

Lightning

Lightning may interrupt operations and cause fires if certain system components are hit. There is a low probability that fires would occur, but in the event that they occur, they would cause only slight environmental degradation in the form of air pollution (see Section 3.7.6).

3.7.7 Cavern Stability

The inherent characteristics of solution mined caverns make them one of the safest possible means for crude oil storage. The plastic nature of salt at the temperatures and pressures present permit the caverns to withstand shock forces far in excess of any earthquake known to have occurred in the Gulf Coast region. Although cavern collapses have occurred in this region, these collapses seem to have occurred as a result of factors such as uncontrolled leaching adjacent to the caprock, with subsequent subsidence of the unsupported overburden.[62]

A number of factors affect the stability of caverns in salt domes including: cavern depth, diameter, and temperature, dissolution, and proximity of the salt dome boundary to other caverns. These factors were considered in selecting the caverns proposed for development.

For existing caverns, the major factor is changes in proximity to salt dome boundaries or multiple caverns. Since caverns used for oil storage grow approximately 15 percent during each cycle of fill and withdrawal due to dissolution of salt, it may be necessary to control growth of the cavern in some cases. This may be accomplished in the upward direction by maintaining a blanket of oil near the cavern ceiling and may be controlled in all directions by using saturated brine rather than fresh water as the displacement fluid.

The proposed storage caverns use a blanket of crude oil to control growth in the upward directions (see Figure 3.22). The location of the oil-brine interface may be monitored by any one of several available instruments such as sonic interface detection, nuclear logging, and oil column pressure gauging. One or more of these devices would be utilized to monitor the oil-brine interface. Thus, the level of the oil-brine interface can be controlled to preclude upward leaching. Also, as may be noted from Figure 3.22, the physical arrangement of the well casings prohibits withdrawal of oil above the location of the annulus through which the oil is withdrawn. Thus, an oil blanket would always be present in any leached space above the location of the annulus. This provides a fail-safe design not subject to operator error. Casing cement failures at upper levels (for example the 16 inch at 2,500 feet in Figure 3.22) would be easily detected and repaired using standard techniques.

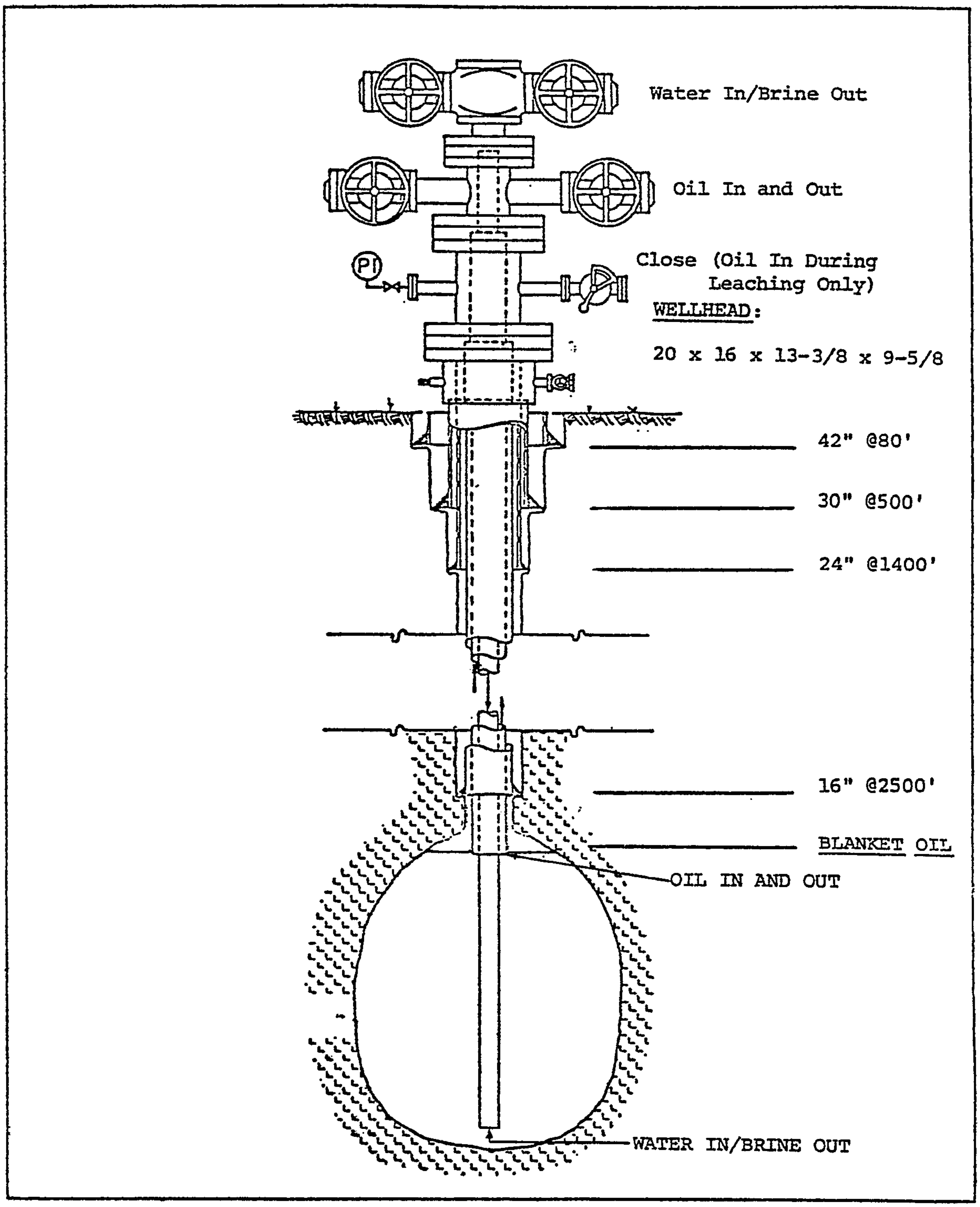

Figure 3.22 Typical Storage Well.

CHAPTER 3
SULPHUR MINES
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4. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

SUMMARY

The anticipated environmental impacts of the construction and operation of the proposed Strategic Petroleum Reserve storage program at the Sulphur Mines salt dome are abstracted in this section. Mitigating measures and unavoidable impacts are summarized in tabular form in Table 4.1 at the end of this section.

Construction operations would be the most environmentally disruptive, including unavoidable soil erosion, increased turbidity and sediment-resuspension in the onsite reservoirs. The construction of roads and pipelines, and further development of the storage site would temporarily disturb existing industrial and agricultural land and forest, and would force resident wildlife to emigrate to more tranquil settings until human disruption ceases. Most of the land to be impacted is industrial, although about 106 acres of nonindustrial land would also be disrupted.

The surrounding surface water system would experience very localized, unavoidable temporary increases in turbidity, resuspension of sediments and/or pollutants from dredging operations and erosion. The resultant impacts on the aquatic community would primarily involve the elimination of minor amounts of benthic organisms and reduce plankton production in the dredged area. During drawdown operations, the use of the Salt Water Reservoir/Sabine River Diversion Canal for the water supply would result in a minor water level fluctuation in the lake and possibly could enhance the water quality of the reservoir as it is replenished from the fresher Sabine River Diversion Canal. While some loss of organisms is expected from entrainment, the impact is not considered significant (see Section 3.4). During the construction phase of the SPR program, air pollutant levels in the vicinity of the salt dome and the docks would be raised principally due to heavy-duty diesel equipment. The major pollutant levels in the vicinity of the salt dome and the docks would be raised principally due to heavy-duty equipment. The major pollutors are expected to be the drill rigs with emission rates of 0.3 μgm/sec to 1 μgm/sec for hydrocarbons, sulfur dioxide, carbon monoxides and particulates. Nitrogen dioxide emission rates could be as high as 5 μgm/sec at the site.

SUMMARY OF PRIMARY ENVIRONMENTAL IMPACTS
MITIGATION PROCEDURES AND UNAVOIDABLE ENVIRONMENTAL EFFECTS

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Dredging			
Disposal of spoil dredged from Salt Water Reservoir	60 acres of artifically created marshland will be covered by dredge spoil from deepening reservoir	none	same as primary impact
	mobile animals (especially birds) would leave the area; they may return within 2-3 months of completion	none	same as primary impact
	slight temporary localized increase in turbidity, TKN (detrital matter and ammonia) COD	follow most recent advances in dredging technology and dredge disposal technology	turbidity localized to within 200 feet, smaller increase in turbidity, TKN and COD
	possible slight decrease in total dissolved oxygen	withhold dredge water for sufficient time to allow oxygenation	dissolved oxygen content will be less diminished
	temporarily eliminate as many as 3.65×10^6 benthic forms in areas dredged	none	same as primary impact
	temporary decrease in primary productivity due to increased turbidity	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
	dredge spoil will smother soil organisms and vegetation were disposed of on 60 acre site	reduce the area covered by spoil by maximizing spoil stacking depth	minimize loss of habitat
Dredging for Displacement Water Intake Station on Salt Water Reservoir	benthic organisms destroyed and decreased plankton production from dredging-induced turbidity	none	same as primary impact
Withdrawal of Displacement Water from Salt Water Reservoir	entrainment in intake structures of plankton organisms	clear screen to minimize higher velocities of water through screens	reduced number of planktonic organisms entrained
	impingement of some fish against intake structures (These fish are not important commercial or sport species)	design intake structure to avoid creation of intake velocity greater than fish's ability to escape and clear screens	no impact
Injection of Fresh Water into Cavities	Approximately 15 percent volume increase of the cavities during each draw-down refill cycle	use saturated brine for displacement water to limit enlargement of cavities	less than 15 percent enlargement during each cycle
	potential loss of cavity structural support	assure maintenance of structural support. use sonar device for testing the shape of cavities which may coalesce	no impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
	Potential coalescence of cavities #6 and #7	use of saturated brine for displacement water in cavities	no impact
Brine Injection	well head blowouts if wells are drilled through pressure zones and excessive pressure buildup occurs	careful evaluation of aquifer capacity, extent and pressure gradients	no impact
	possible strata fracture and contamination of freshwater aquifers	use conservative spacing of injection wells; 1000 feet; discontinue injection	no impact
	interference with existing oil production operations	secure wellhead plugs on all abandoned oil wells	no impact
	temporary increase in pressure equalized over short period at end of injection	none	same as primary impact
	subsurface pressure increase due to brine insolubles	brine cleanup treatment prior to injection	reduced increase in subsurface pressure
	increase in salinity (~1 ppt) in the aquifer	none	same as primary impact
Enclosure of the Storage Site	~346 acres of industrial land utlized	none	same as primary impact
	possible destruction of a very small number of nests and individual animals	none	same as primary impact
	some mixed vegetation would be destroyed and regrowth would not be allowed	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
	noise would cause mobile wildlife to temporarily leave the site	none	same as primary impact
<u>Pipelines</u>			
pipeline connections to 5 storage cavities, to brine settling tanks	up to 15 acres disturbed (undetermined right of way for onsite pipelines	lay pipelines during winter which is a low growth period and is the local dry season (ground does not freeze hard)	reduced impact on courting and nesting birds
oil distribution pipeline	55 acres disturbed, permanent loss of timber and temporary loss of grazing land	none	permanent loss of timber production
displacement water (brine) disposal system construction	18.8 acres of mixed pine forest permanently cleared	none	same as primary impact
<u>Additional Tankship Traffic</u>	erosion from increased wave action on the banks of the Sabine River	seed and plant banks with native brush and underbrush to waterline	minor erosion from wave action
	bottom scour from increased turbulence	none	increase in bottom scour due to turbulence
	increased chance of oil spill at dock or in transit	construction of spill retention device at dock	minimized spread of oil spill
	emissions of hydrocarbons, sulfur oxides, carbon monoxide, nitrogen oxides and particulates	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
	increased noise levels from vessel operations and from pumping of crude oil	enclose pumps in acoustically insulated pump houses	slight increase in noise levels close to dock facilities; levels below 55 dB at nearest residence
Oil Spilled from Vessel in Transit	potential oil spill of 3100 bbl will spread to cover 2600 acres of open water, possibly in Sabine Lake	rapid containment with booms, absorbents to minimize spread of slick with the tides and winds	reduce area covered by slick depending on volume contained in 48 hours
	temporary contamination of sediment	rapid cleanup	less contamination
	oil may affect taste of oysters and decrease oyster larvel development	none	same as primary impact
	moderate oil contamination of marsh vegetation will cause death of roots, reduced germination of contaminated seeds and a reduction in annual species (recovery relatively rapid in <2 years)	rapid cleanup	less contamination
	possible hazard to wildlife using the Sabine National Wildlife Refuge for breeding grounds	none	same as primary impact
Above Ground Oil Pipeline Spill	contamination of soil and vegetation in small area near spill	clean up promptly	minor surface soil and vegetation contamination

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Underground Oil Pipeline Spill	contamination of soil to 10 cm depth from spill (~1000 bbl) covering ~0.4 acres	none	minor contamination of soil surrounding pipeline until degradation and migration dilute oil concentration
	migration of oil via water table into water bodies	dig trenches at point of entrance into water body and collect and dispose of oil	minimal contamination of water bodies from oil not collected
Road Construction, Building Foundations, Wellhead Pads	115 acres disturbed	none	same as primary impact
	erosion	plant or seed with native vegetation	erosion and runoff confined prior to successful establishment of vegetation
	290 cu. yd/yr sediment washed into water from erosion due to rainfall on 115 disturbed acres	plant or seed with vegetation avoid landfill work during rainy season	less than 290 cu. yd/yr sediment runoff
Drill Rig	at .5 km, centerline concentrations of emissions CO (1 hr): 721 $\mu g/m^3$ HC (3 hr): 219 $\mu g/m^3$ NO_2 (annual mean): 25 $\mu g/m^3$ SO_2 (24 hr): 158 $\mu g/m^3$ (only HC concentration exceeds standards; due to point source assumption, see Table 3.5)	none	same as primary impact
	noise levels less than 55 dB at nearest residence	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Vessel Loading	maximum of 4610 μg/sec hydrocarbon emissions during unloading at a rate of 30,000 barrels per hour	use of vapor recovery system at dock	negligible hydrocarbon emissions
	surge tank working loss hydrocarbon emissions of 6.47 μg/sec primary standards exceeded to 2 km (for 10 mo.)	use of a vapor recovery system on tank	negligible hydrocarbon emissions
	at 2 km, centerline concentrations of emissions HC (3 hr): 430 $\mu g/m^3$ (only HC concentration exceeds primary standard due to point source assumption	use of vapor recovery system	reduced hydrocarbon emissions
	daytime ambient noise levels increased for residents (see Table 3.19) to $L_{eq} \sim 64$ at 2000 feet	none	same as primary impact
Employment of Skilled Laborers	possible delay in re-employment of these laborers at the completion of construction operations	none	same as primary impact
	increase in local traffic load	none	same as primary impact
	increased demand for local maintenance operations	none	same as primary impact
Operation of Facility	increased use of community protective services to assure security and respond to fire hazards	SPR employment of dedicated security and fire fighting capabilities	minimal demand on local police and fire fighting

The painting of the tanks at the Sun Terminal dock facilities would temporarily (less than 3 months) raise the hydrocarbon levels of the area above the ambient standards within 1 to 2 kilometers of the site. While these hydrocarbon emissions would elevate local levels, they are primarily non-photochemically reactive species (lighter, saturated hydrocarbons) and should not contribute significantly to oxidant concentrations in the area. These estimates are based on the assumption of very stable wind conditions (<5 mph) which are not characteristic of the Gulf Coast region in general. The predicted oxidant concentrations are therefore more severe than would actually be expected.

The injection of brine into deep saline aquifers off the southern flanks of the salt dome would increase the downhole pressure of the aquifer temporarily. The magnitude of these deep aquifers tends to allow rapid pressure equilization provided the injected brine does not clog the aquifer and seal the local injection area off from lateral communication with the rest of the aquifer. A brine settling pond is to be employed to assure this does not happen. Additional treatment of the brine may be required if it is determined that it is chemically incompatible with the saline water in the aquifer.

Pipeline Accidents

Unavoidable crude oil spills along the buried pipeline routes, of a median volume of 1,000 barrels, would result in an initial infiltration of 10 centimeters into the surrounding soil. This infiltration would affect 0.4 acres of land. Over a period of years the oil contamination of this area would decrease due to degradation of the crude and dissolution due to the heavy annual rainfall in the area. Because the surface water in the Sulphur Mines area is held near the surface by substrate clay, some quantity of any oil spilled from a pipeline failure would consequently seep with the natural surface water migration, resulting in a with the natural surface water migration, resulting in a low level contamination of nearby water bodies for several years. Should a spill occur, the magnitude of this contamination could be minimized by digging trenches at the point of entry into the nearby waterbody (Industrial Water Canal and Bayou D'Inde). The oil then would be collected from these trenches as it migrates towards the water body. Oil migration is aided by heavy rainfalls and thus the location of the point of entry into either the Industrial Water Canal or Bayou D'Inde would have to be determined fairly rapidly after spills of a significant size.

The effects of an underground pipeline spill on soil organisms in the immediate vicinity (a distance of one meter or less) could be severe. If such a spill occurred, organisms such as mites, collembola, nematodes, earthworms, etc., would be killed. It is not anticipated that the soil organisms in the path of the oil migration in the water table would be as severely affected, since the concentration is increasingly diluted with time, rainfall and distance from the spill site. This migration would cause an unavoidable loss of soil organisms and some vegetation.

The only above ground pipelines would be at the storage site and at the Nederland terminal. An above ground spill would be readily detectable by inspection. The magnitude of such a spill is expected to be 1,000 barrels or less. These spills are readily contained and cleaned up, causing negligible unavoidable environmental damage such as destruction of soil organisms and localized vegetation, respectively.

Tankships and Barge Oil Spills

The probability of unavoidable tankship spills, those greater than 300 barrels and those greater than 10,000 barrels (for 63 trips to transport 24 x 10^6 barrels), is estimated to be 0.01 and 0.0008, respectively. The total expected spill volume of crude spilled is 43 barrels for the fill of the cavity to 24 x 10^6 barrels, with 63 tankship trips. Over the life of the facility, assuming five fill and drawdown cycles, the total expected quantity of oil spilled from tankship casualties in inland waters is 345 barrels. The expected total spill volume over the lifetime of the project reflects the amount of crude that may be spilled from both transport accidents and terminal accidents relative to the number of trips made, the total volume of crude handled, and the low probability of such spills, but does not reflect the anticipated median quantity of such a spill should it occur (e.g, 0.5 barrels at the terminal and 3,100 barrels/spill for tankships).

Should a spill of median expected volume occur on open water, an oil slick, uncontained, could cover as much as 2,600 acres in 24-48 hours (3,100 barrels), assuming no currents, wind or obstacles. Depending on the weather conditions and the rapidity of containment and clear-up operations, oil slicks could cover a significant portion of the shipping channels of the Sabine-Neches system. Spills near the junction of the Neches River and the Intracoastal Waterway would threaten Sabine Lake.

A general increase in the background level of oil contamination in the bottom sediments would result in an unavoidable disruption of the benthic community structure.

Most types of vegetation appear to be able to withstand light to moderate oil contamination. Short-term effects are generally the death of oil-coated roots, reduced germination of contaminated seeds and consequently the reduction in annual species reproduction. Recovery is relatively rapid, taking less than two years. If more than four oil spills (1,000 barrels) occur within a two to three year period, substantial unavoidable vegetation mortality would be sustained and recovery would be retarded. The occurance of spills of this magnitude and frequency is unlikely because of the low probability of spills and the expected fill and refill frequency of the SPR program.

Mitigation of Impacts

The plan for mitigating the impacts identified in Table 4.1 is part of SPR's environmental planning process and is being incorporated into a Site Environmental Action Report (SEAR) if the site is selected for use. The SEAR would outline detailed design criteria, construction practices, and operational procedures which, when implemented at each site, would minimize or avoid environmental impacts, consistent with the environmental policy of the Strategic Petroleum Reserve Office. Planning for the prevention of, as well as the containment and cleanup of oil and brine spills will be accomplished by the preparation of a Spill Prevention Control and Countermeasure (SPCC) Plan required under 40 CFR, Part 112 and an Oil Spill Contingency Plan required under 40 CFR Part 1510. The SPRO environmental policy as stated in these documents would be implemented by engineering contractors developing each storage site, and by SPRO staff or contractors operating each site.

5. RELATIONSHIP BETWEEN SHORT-TERM USES OF THE ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY.

Presently, the Sulphur Mine salt dome site is being used extensively by the Allied Chemical Company for hydrocarbon product storage and for the production of brine which is sold to PPG, Inc. The commitment of the dome to the SPR program would preclude further production of brine in that part of the salt dome in the vicinity of the storage site. However, portions of the salt dome could still be used for brine extraction if new wells were developed. The subsurface disposal of brine would render some salt irretrievable. This quantity is small in relation to the net amount available, thus the long term consequence from this loss of salt would be insignificant. The SPR program should have no effect on the storage of hydrocarbon products due to the location of these cavities in relation to the cavities and facilities required for the crude oil storage.

During construction at the site, activities causing short-term impacts on the land include road construction, well drilling and preparation, and general construction activities associated with the various facilities located on site. There would be no impacts to the stratigraphy or geologic structure in the area. While the facility is in operation there would be no long-term impacts on drainage patterns in the area and only minor impacts on the soil caused by soil erosion. Minor alteration of the topography would occur as a result of spoil disposal.

During construction of the oil spur pipeline, minor short-term changes in the topography would result from pipeline burial. However, any impacts to various land forms, including these spoil mounds would only occur in the short term since the original land contours would be restored immediately following pipeline burial. No impact to the soil would occur other than vertical mixing along the pipeline trench caused by the original soil removal and replacement.

In summary, the impacts from facility location at the Sulphur Mines salt dome site would be minor soil erosion and minor topographic changes caused by spoil disposal and oil pipeline burial. While the facility is in operation, existing industrial use of the site will be allowed to continue. Creation of a spoil area may result in a temporary reduction in biological productivity.

The natural vegetation and wildlife that is lost for the brine disposal system is a resource committed for the life of the project and must be considered irretrievable. A maximum 45 acres of land would be continuously cleared of obstructive vegetation, altering the associated habitats for the duration of the project. Also a 9 mile stretch of land would be committed for the life of the project to maintain the pipeline right-of-way. This could limit construction within the pipeline corridor which may eventually be partially within the Sulphur city limits.

During construction, there will be a temporary loss of productivity to the on-site salt water reservoir due to dredging. This loss of productivity is considered insignificant when the total productivity of the area is evaluated (see Section 3.4).

During operation, some organisms would be entrained with the displacement water. These would be lost from the population. Because the number of organisms is small when compared to the normal population, the effects would be less than from natural mortality. No commercial or recreational species are found in the salt water reservoir.

Resource use and depletion involved with the Sulphur Mines Dome would have a minor impact on environmental productivity associated with the Industrial Water Canal.

During oil recovery, there would be a short term use of freshwater from the Industrial Water Canal. The flow of the canal ranges between 340 and 450 cfs which is equivalent to a rate of between 2.18×10^5 barrels/hour and 2.88×10^5 barrels/hour. The maximum withdrawal for the Sulphur Mine site would be 6.94×10^3 barrels/hour. This means that less than 3.6 percent of the water in the canal would go to the Sulphur Mine site, and its use should have an insignificant effect on the amount of water available to the industries dependent on the canal water.

The disposal of up to 24 million barrels of brine in the saline aquifers would increase their salinity slightly. Because the brine would be injected at depths of approximately -5,000 to -7,000 feet, the depths overlap the oil and gas producing interval. Therefore, care would be exercised to assure that brine is not inadvertently injected into oil and gas sands in a manner which would reduce oil and gas production. It is possible that the injection would offset losses in pressure in the geological formation due to oil and gas depletion, thereby possibly enhancing oil and gas recovery.

During construction, there would be a short term (220 $\mu g/m^2$) increase of local hydrocarbon levels in the air at a distance of 500 meters downwind of the site from the drilling operation. However, this would not present a health hazard within the site boundary and would diminish to levels well below the Federal Standards at offsite locations. During fill operations there would be a short term increase in hydrocarbon emissions at a rate of 14.0 g/sec (Section 3.3) at maximum fill rate of 4,200 barrels hour. These incremental increases in hydrocarbons would be present for 12 months during construction and for 5 months during fill operation. Due to the short period of hydrocarbon exposure little long term effect is expected.

6. IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES

Of the resources committed to the development and operational phase of the facilities at the Sulphur Mines salt dome, only a few of these commitments are irreversible or irretrievable. They are:

Water Resources

Assuming that 5 cycles are involved during the life of the project, approximately 5 x 10^9 gallons (18,000 acre feet) of water would be taken directly from the surface water system of the on-site salt water reservoir (indirectly from the Sabine River Diversion Canal), and ultimately injected into the deep saline aquifers. This water would be irretrievable in its original low saline form, since the salt in the dome would dissolve to saturate the brine during periods when water is in the cavity. When the amount of surface water available in the area from run-off is considered, the loss of this volume over the life of the project is insignificant.

Biologic Resources

A majority of biologic impacts would be short term. Following the construction period, most of the land cleared during facility development would be allowed to revegetate and would return to its natural state of productivity within two years. Eight acres would be utilized for the complex of office, warehouse and storage buildings for the life of the project. An additional 13.8 acres of naturally wooded acreage would be kept clear of trees for pipeline right-of-way during the life of the project.

Construction Materials

Most of the concrete, steel, and other materials used in construction must be considered as irretrievably committed, since no valid estimate of salvage can be made at this point. Approximately 3,500 tons of steel would be required for pipe, wells, and other components.

Energy

During fill cycles, when placing oil into storage, the pumps required for oil injection and for brine disposal would consume 21.5 x 10^6 kilowatt-hours over a 240 day period. For the five planned fill cycles, a total of 107.5×10^6 kilowatt-hours would be consumed.

Twenty-four million barrels of oil would be transported from Sulphur Mines to designated market regions in the event of a foreign oil supply interruption. The pumps required to displace this amount of oil and load it onto tankers over a 150-day period is 5.5×10^6 kilowatt-hours. For the 5 planned withdrawal cycles, a total of 27.5×10^6 kilowatt-hours would be consumed.

Thus, the entire facility energy expenditure, as planned for 5 fill and withdrawal cycles, is 1.35×10^8 kilowatt-hours. This total energy consumption is 0.063 percent of the equivalent energy value 2.125×10^{11} kilowatt-hours of the 120 million barrels of oil which would be stored at the facility during the life of the project.

Electrical power needed to operate machinery (such as pumps) represents an irreversible and irretrievable commitment of energy and thus, the fuels needed to produce the power. Because electrical power is generated by fossil fuel within the region, petroleum resources would be expended to produce the energy. Drilling, construction, and shipping activity associated with Sulphur Mines commits considerable petrochemical resources to the project. These resources would be irreversibly and irretrievably expended.

Salt

The deep well injection of the brine from solution mining of the salt dome irreversibly commits a solid salt resource. However, because salt domes, beds, and deposits are present throughout many parts of the United States, and since the Sulphur Mines site cavities have been created during mineral extraction, this is not a new commitment of resources.

Labor

Labor used in construction and operation of the Sulphur Mine site would constitute an irretrievable expenditure of manpower. The most construction workers that would be engaged at the site would be 340 with an average of approximately 100 man-years of effort for the one year of construction. To operate the facility approximately 20 man-years of effort are needed per year.

7. ALTERNATIVES TO THE PROPOSED ACTION

Several alternatives to the proposed action have been examined. These include alternative storage sites, alternative facility components, and no action.

7.1 ALTERNATIVE STORAGE SITES

As discussed in Section 1.1, the Sulphur Mines salt dome storage site has been included as one of a group of nine candidate sites which can provide storage capacity to meet the goal of the accelerated SPR program of 250 million barrels by 1978. Four of these sites have been selected for use. These sites are Bayou Choctaw (FEA-FES 76-5), West Hackberry (FEA-FES 76/77-4), Bryan Mound (FEA-FES 76/77-6), and Weeks Island (FEA-FES 76/77-8). The remaining four sites Cote Blanche (FEA-FES 76/77-7), Central Rock (FES 76-9), Ironton (FEA-FES 76-10), and Kleer Mines (FEA-FES 77-2) are alternatives to Sulphur Mines for the purpose of providing the necessary capacity to reach the 250 million barrel goal. Site specific EISs have been prepared for each of these four sites.

The impacts which would result from development of each of the candidate sites are described briefly in Sections 7.1.1-7.1.4. The individual statements should be consulted for a detailed assessment of these impacts.

7.1.1 Cote Blanche

Converting the Cote Blanche salt mine into a 27-million barrel oil storage facility would require relocation of existing mining operations, construction of a new pump shaft at the existing mine, enlargement of a barge slip, and construction of four barge loading platforms and associated pipelines to the site. Although they are not likely to cause long term adverse impacts, construction and operation of this facility would alter the local environment in several significant ways. These effects are shown in Table 7.1 and discussed below for storage site acquisition and construction, dock facilities and pipelines, marine operations, and facility operations.

Storage Site Acquisition and Construction

The major construction activity at the storage site itself, sinking a new 12-foot pump shaft and pump station, would require minimum surface grading over 1 acre and

Table 7.1 Environmental Impact Summary - Cote Blanche
St. Mary Parish, LA

Activity	Impacts Due to Activity: Geology and Soils	Land Use	Water Quality and Supply
STORAGE SITE CONSTRUCTION			
12 ft Pump Shaft and Associated Aboveground Equipment	Surface grading of 1 acre; no impact on mine structure; excavation of 15,000 cu. yds. of material for landfill disposal; loss of salt resource due to absorption; fracture unlikely due to absence of faulting.	No impact.	Impermeability of salt offsets potential impacts on groundwater system; no impacts.
NEW MINE DEVELOPMENT	Expanded access to salt deposits; increased gradings and soil erosion.	20 acres of pasture and forest for development of new mine.	Slight decrease from soil erosion and runoff.
Permanent Shutdown of Domtar Mine	50% reduction in site excavation and grading.	Surface acreage required for mine site would be unaltered.	Reduction erosion and siltation associated with grading.
DOCK FACILITIES			
Barge Slip and 4 Barge Loading Platforms	250,000 cu. yds. soil dredged; slightly increased runoff (barge slip now dredged biannually).	Alteration of 9 acres from marsh to open water; 20 acres required for aboveground storage, of which 15 acres are marshland and upland forest.	Small decrease at site of excavation and dredge disposal; increase in BOD, decrease in DO, reduction in pH, increase in nutrients, possible increase in heavy metals, suspended solids in access canals.
PIPELINES			
Four 0.5-mi Pipelines Between Doc and Site	Disturbance of sand, silt, and clay soils; increased runoff.	About 3 acres affected by representative 500-bbl spill; seepage and movement to barge slip where it would be contained.	No significant impact on ground or surface water.
Pipeline to St. James via Bayou Teche (80 mi)	Temporary disruption of soils along right-of-way, resulting in runoff.	Alteration of 1201 acres, of which 60% are undisturbed swamp.	Possible lowering of pH and DO and increase in nutrient concentrations and BOD from deposit of excavated soils; no impact on ground water; oil spill impacts less than with barge system.
Pipeline to St. James via Atchafalaya (60 mi)	Temporary disruption of soils along right-of-way, resulting in runoff.	Disturbance of 923 acres, of which 42% are undisturbed swamp.	Same as first alternative.
MARINE OPERATIONS			
Barges	Increased erosion on banks of ICW and access canal.	No impact.	Slightly increased turbidity in ICW and access canal from barge operations; minimal impact from spilled oil (2724 barrels expected; 60,000 maximum) due to limited potential for lateral spreading.
Seagoing Barges	Greater disruption of soils due to need for larger barge facilities and pipeline across island.	More land required for dock facilities.	Fewer water impacts due to expected spillage of 42% less oil.
FACILITY OPERATIONS	No impact.	No impact.	No impact.

Table 7.1 Environmental Impact Summary - Cote Blanche (Cont.)

AIR QUALITY	NOISE	ECOLOGY	SOCIOECONOMIC
Small quantities of dust and NO_x, SO_2 from construction vehicle exhaust; no violation of standards.	Less than 6 dB increase in night-time ambient sound levels in nearby undeveloped areas during construction; no increase in nearby towns.	No impact.	Loss of $26,000 property tax per year; no adverse impact to archaeological sites.
Slightly increased dust and construction vehicle exhaust.	37 to 70 dB at 500 feet for ground refrigeration on equipment and service shaft construction, explosives; no impact on nearby towns, however.	No impacts; site of new mine already highly disturbed.	20,000 man-weeks of construction over 83 weeks with earnings of $2,300,000 per year for 2 years; if mining interrupted, unemployment or underemployment of 60 mine workers for 74 weeks and earnings loss of $1.7 million; if mining not interrupted, continuation of 25,000 man-weeks of labor over 103 weeks and earnings of $4,000,000 per year for 2 years.
Slight reduction in air emissions during construction from those of mine relocation option.	Noise levels reduced over mine relocation option.	No impact.	Elimination of $1.2 million annually in gross wages; local loss of 120 jobs; induced loss of 200 service jobs in region.
Increased dust, NO_x, SO_2 from construction vehicle exhaust.	71 dB 10 hours each day at 500 feet from pile drivers for barge dock construction; no impact to nearby towns due to distance.	Removal of 50×10^{6} grams dry weight of oyster grass; adverse impact to 6×10^{1} grams of organisms, mostly blue crab.	Included above.
Slight hydrocarbon emissions.	68 dB at 500 feet.	Spills reaching marsh beyond barge slip probably would affect less than 5 acres and would be allowed to weather and degrade naturally.	Included above; protection of potential for archaeological finds by presence of state archaeologist.
Slight hydrocarbon emissions.	As above.	More adverse impacts on ecology of of unmodified swamp forest than on Atchafalaya route and of dock construction.	Less operation expense than for barge transport; construction employment of 150 persons for one year.
Slight hydrocarbon emissions.	As above.	Less impact than Bayou Teche route.	Less operation expense than for barge transport; construction employment of 120 persons for one year.
Hydrorarbon emissions during transit at an annual rate of 244 tons/yr, and during vessel-to-vessel transfers at an annual rate of 1200-1300 tons/yr. Tanker-barge transfers would cause hydrocarbon concentrations in excess of $160 \mu gm/m^3$ as far as 6.8 mi. downwind.	55 dB at 500 feet for one barge passby; frequency of occurence to increase by less than one additional passby per hour over present rate for 28-month fill, 5-month withdrawal period; noise levels occurring over 12 months if Weeks also developed and barges used for transfer.	Small risk to all fauna and wildlife inhabiting coastal marshes from spilled oil; temporary disruption of vegetation where oil spilled.	Significant increased demand for barges, tug boats, crews with resultant expanded employment and income in region; need for priorities in equipment use during emergency; possible impact to recreational use of water nearby from oil spill; significant cleanup costs.
Hydrocarbon emissions 37% lower than from smaller barges.	Slightly less impact than smaller barges.	Less impact due to lower expected volume of spilled oil.	Slightly greater than dock operation.
Hydrocarbon emissions during barge loading at an annual rate of 731 tons/yr, causing concentrations in excess of $160 \mu gm/m^3$ as far as 4 mi. downwind.. Minor hydrocarbon and hydrogen sulfide emissions from system leakage during pumping and minor sulfur dioxide emissions from flaring of vapors during fill.	Loading and unloading barges result in 55 dB at 500 feet (at least 12 dB lower than existing background).	No additional impact.	2-3 permanent employees to monitor equipment and provide security; 15 people for 5 months during withdrawal; 15 people for 10 months during refill.

therefore create only small, localized increases in dust, and of vehicle exhaust from construction equipment. Ecological effects would be limited to minor accumulations of dust on foliage in the immediate vicinity of the construction. Proposed freezing of the area surrounding the pump shaft would prevent any construction disturbance to the groundwater.

Development of a replacement mine would require considerably more construction activity. Approximately 20 acres of land now in pasture and forest would be needed for new mine development. Grading at the new mine site would increase soil erosion and runoff and lower surface water quality in the local area. The use of drilling mud around the walls of the hole to prevent water inflow would protect groundwater.

Although government acquisition of the mine site would eliminate the annual property tax of $26,000, construction of the storage facilities, including docks and pipelines, would provide 20,000 man-weeks of labor for 83 weeks and total annual earnings of $6.3 million for two years. Economic gain resulting from an interruption in mining to accelerate the storage schedule would be offset by unemployment or underemployment of 120 mine workers and a loss of $1.7 million in earnings. If Domtar decided <u>not</u> to construct a new mine, the 120 jobs permanently lost would eliminate annual earnings of $1.2 million. The multiplier effect of this decision would entail the loss of another 200 service jobs and associated incomes within the region.

<u>Dock Facilities and Pipelines</u>

Enlargement of the barge slip and construction of four barge loading platforms would require excavation and disposal of 250,000 cubic yards of soil materials to create 9 acres of open water from marshland and involve another 20 acres of marsh and forest. Construction of four half-mile pipelines between the docks and the storage site would also disturb soils on the island.

Surface water quality would decrease in the access canal near the excavation and disposal sites with increases in biological oxygen demand (BOD) and nutrients and decreases in dissolved oxygen (DO) and pH. Since the existing barge slip is now dredged bi-annually, the additional excavation associated with enlargement of the dock facility would be less significant than in an otherwise undisturbed area.

The dock construction would not affect any rare species but would remove a small quantity of vegetation (e.g., oyster grass), and bottom organisms (e.g., blue crab).

As an alternative to enlarging the dock, the construction of a pipeline from Cote Blanche to St. James, following a route along either Bayou Teche (80 miles) or the Atchafalaya River (60 miles), is more likely if both Cote Blanche and Weeks Island are developed for storage. The Bayou Teche route would affect a larger number of acres (1,201 as opposed to 923), of which a greater percentage is now undisturbed. Both routes would degrade the quality of surface water by lowering pH and DO and increasing nutrient concentrations and BOD from deposits of excavated soils. However, by supplanting the barges, the pipeline would cause less impact from oil spills. The pipeline would be more expensive to construct but less expensive to operate than the barge facilities.

Marine Operations

The use of barges for transporting oil to and from the storage facility would increase erosion along the banks of the Intracoastal Waterway and would in turn increase turbidity. Over the lifetime of the project, it is expected that about 2,700 barrels of oil would be spilled and that the maximum credible spill (Gulf Shore) would be 60,000 barrels from a 45,000 DWT tanker. Although slow water currents and minimal wave action would inhibit the oil from spreading, the oil reaching shore would destroy many sensitive marsh species, which would regenerate after two years.

Transporting the oil to and from the dock at the storage site would result in significant hydrocarbon emissions, both during transit and at the transfer points in the Mississippi River and in the Gulf of Mexico. System leakage ("breathing") losses from tankers and barges would occur at a maximum annual atmospheric loading rate of 244 tons/year during fill and withdrawal. These emissions would be dispersed along the Mississippi River - Intracoastal Waterway route from the Gulf to the storage site. VLCC-tanker transfers in the Gulf and tanker-barge transfers in the Mississippi River would cause emissions at maximum annual rates of 1,220 tons/year and 1,300 tons/year respectively. Under worst case atmospheric conditions, transfers at the Mississippi River transfer point would cause hydrocarbon concentration in excess of the three-hour Federal standard of 160 $\mu gm/m^3$ as far as 6.8 miles downwind. The State of Louisiana currently exempts from regulation emissions from crude oil transfers.

As an alternative to small barges, large, seagoing barges might be used to transport part of the oil directly between the tankers in the Gulf and the site. This system would require larger dock facilities and a pipeline across the island creating a greater impact on the ecology of the island. However, their use could result in a 42 percent reduction in spilled oil and a 37 percent reduction in hydrocarbon emissions.

Facility Operations

Transferring the oil from the storage cavern to the barges at the dock would result in significant hydrocarbon emissions as the barge tanks are filled with oil and the vapors contained therein are vented to the atmosphere. These venting losses would occur at a maximum annual atmospheric loading rate of 731 tons/year. Under worst case atmospheric conditions, this operation would cause hydrocarbon concentrations in excess of the three-hour Federal standard of 160 $\mu gm/m^3$ as far as 4 miles downwind. Because of unavailable system leaks, minor amounts of hydrocarbons and hydrogen sulfide would be emitted during filling of the storage cavern as a result of flaring of the vapors that would be vented during that operation.

Fifteen employees would be needed during the 150-day withdrawal and the 300-day refill periods. Only two to three permanent employees would be needed to maintain security on the site during the storage phase of the program.

7.1.2 Ironton

Conversion of the Ironton limestone mine into a 21-million barrel oil storage facility would require construction of two new vent shafts; pumping out and chemically treating seepage water currently in mine; sealing two existing shafts with double concrete bulkheads upon completion of the installation of the pumping equipment; installing oil pipelines, pump manifolds and metering equipment between the new pump station and pump shaft; installing an electrical power substation; constructing a 13-mile pipeline connection between the site and Ashland Refinery system and constructing pipeline terminal facilities at or near Ashland's Catlettsburg Terminal. Construction of this facility is not expected to have long term adverse environmental impact. Except for the remote possibility of a large oil spill, any negative impact is expected to be short term and minor in nature, (see Table 7.2).

Storage Site Conversion and Construction

Conversion of the Ironton limestone mine to an oil storage facility requires removal and treatment of seepage water, removal of existing shaft equipment, sinking of two new vent shafts, conversion of one of the existing shafts to accommodate pumping equipment, sealing of the second shaft after underground construction is complete, construction of underground drainage channels and a provision for a sump below the pump shaft. During construction activity there would be increases in fugitive dust levels, emissions from construction vehicles and ambient noise levels. These effects would be localized and temporary.

Development of the storage facility would provide 3,600 man-weeks of labor for a 55-week period and a total earnings of about $1.5 million. Mine conversion would cost an estimated $1.0 million and oil handling equipment and distribution facilities an estimated $6.7 million. The total project development cost would be more than $7.7 million or $0.37 per barrel of oil stored.

Pipeline Construction

An 18-inch diameter, 13.1-mile long pipeline would be required to connect Ironton storage facility with the Catlettsburg Terminal located at Ashland Refinery. The 40-foot wide right-of-way corridor of the pipeline would affect 64 acres of industrial, low-income residential and forestlands. Construction activity, including blasting and

Table 7.2 Environmental Impact Summary - Ironton
Lawrence County, Ohio

Activity	Impacts Due to Activity: GEOLOGY AND SOILS	LAND USE	WATER QUALITY AND SUPPLY
Storage Site and Terminal Facilities Construction	Slight erosion of bare ground; minimal re-grading of site.	2 acres for pump station on site; 2 acres for pipeline terminal facilities.	Little adverse impact to Ice Creek or Ohio River from 40 million gallons of treated mine seepage; no significant ground water contamination.
Pipeline Construction (13-mile pipe-line between Catlettsburg Terminal and site)	40 acre/feet of dis-turbed soil over route; 8 acre/feet of soil subject to runoff erosion.	63.52 acres for pipeline right-of-way corridors.	Slight increase in turbidity, suspended solids, and sediment loadings in Ice Creek; lowering of pH, increased heavy metal concentration, increased nutrients and BOD in Ohio River, signi-ficant adverse impact localized and temporary only.
Pipeline Accidents (Between St. James Terminal and site)	Soil fouled in vicinity of pipeline.	Slight possibility of an oil spill reaching developed water recre-ation areas.	(Between Catlettsburg Terminal and site) Average expected spill size in surface waters is 1,000 barrels; maximum credible spill -size-3000 barrels; slight chance of oil spill reaching Ohio River and affecting downstream water supplies. Expected total volume of oil spilled-205 barrels (between St. James and Catlettsburg Terminal); maximum credible spill 10,000 barrels.
Facility Operation	No impact.	No impact.	Minimal impact expected; no discharge of wastes to sur-face water or ground water; very remote possibility of contamination resulting from accidents involving explosion from oil pressur-ization, seepage of oil from mine, or displacement of oil resulting from water inflow into mines.
Marine Operation	Small amount of erosion on harbor bottom.	No impact.	Maximum credible spill in Gulf 60,000 barrels; total expected spillage of 585 barrels-105 at St. James, 480 in Mississippi River or in the Gulf.

Table 7.2 Environmental Impact Summary - Ironton (continued)

AIR QUALITY	NOISE	ECOLOGY	SOCIOECONOMIC
Small quantities of dust, NO_x, SO_2, CO and hydrocarbons due to construction vehicle activity; no violation of primary standards.	1 dB and 5 dB increase in daytime and nighttime ambient sound levels in the city of Ironton.	Site already highly disturbed; negligible loss of habitat.	No impact on any known archaeological or historic resource; no significant transportation impact; total gross payroll of $1.5 million; loss of $5500 in property taxes if federally owned.
Increased dust, NO_x, SO_2, CO and hydrocarbons due to construction activity; no violation of primary standards.	6 dB increase in ambient sound levels 1 mile from pipeline construction; 91 dB noise level at 1000 feet from blasting through surface limestone.	Loss of 2700 square feet of aquatic habitat from rights-of-way through 9 small streams; 20 acres of woodland habitat lost due to pipeline right-of-way.	Included in above impacts.
Hydrocarbon vapor emissions from spilled oil.	Noise from clean up operations.	Significant impacts include: oiling of birds, mammals and aquatic organisms, loss of about 5-7 acres of vegetation and grasslands, (between Catlettsburg Terminal and site), loss of wildlife habitat and food supply, and contamination of soils.	No impact.
42 lb/day hydrocarbons and .04 lb/day hydrogen sulfide expected from leakage of vapors from pipelines; 141 lb/day H_2S emitted if cavern unflared; 281 lb/day SO_2 emitted if vapors are flared, no violation of primary standards.	No anticipated increase in ambient sound level in city of Ironton; equivalent sound level contribution from pipeline facilities in the Catlettsburg Terminal would be about 55 dB at 500 feet.	No impact.	2-3 permanent employees needed to monitor equipment and provide security; 8-10 persons required for 107 weeks during fill and 21 weeks during withdrawal.
"Breathing" losses from tankers and barges-maximum annual rate atmospheric loading rate of 30 tons/yr.; maximum annual hydrocarbon emission rates for tanker transfers in Gulf-600 tons/yr.; transfers at St. James would cause emissions in excess of 3-hour Federal standard of 160 $\mu gm/m^3$ as far as 7.5 miles downwind.	Slight impact.	Maximum credible oil spill for the Gulf could render 840 to 1,680 acres of marsh non-productive for 2 years.	Reduced marketability of fish fouled by oil; possible increase in demand for tankers may have positive effect on economy.

using trucks and heavy equipment, would cause increased noise levels, fugitive dust levels, and vehicles emissions. During excavation and back filling of the pipeline trench, the soil profile would be inverted and disturbed, leaving the soil vulnerable to runoff - erosion process. Because of the blasting of limestone located close to the land surface, restoration would be required.

Pipeline Terminal Facilities Construction

The construction of the piping, instrumentation and electrical systems located at or near the Catlettsburg terminal will disturb about 2 acres of land. Construction activity would cause increased noise levels, fugitive dust levels and vehicle emissions. These effects would be localized and temporary.

Facility Operations

The storage facility would be filled by a pipeline through the Catlettsburg terminal at a rate of about 28,000 BPD over approximately 750 days. Oil would be withdrawn at a rate of 140,000 BPD over a 150 day withdrawal period. Approximately 42 pounds of hydrocarbons per day would be emitted from the storage cavern during fill periods; a temporary flare system would be used as a safety precaution to reduce concentrations of combustible gases and SO_2 in the mine area.

Eight to ten skilled employees would be required during the 150 day withdrawal and the 750 day refill period. Two or three employees would be sufficient to carry out routine maintenance, equipment monitoring, and security procedures at the storage site during standby storage periods.

Oil Spills

The potential for oil spillage at both the Ironton facility and the Catlettsburg terminal has been projected to be 0.0105 spill incidents per single fill cycle, and 0.105 spill incidents over the project lifetime. The average spill volume per incident is calculated to be 300 barrels, with a maximum credible spill being 3000 barrels. The projected volume of oil released during the project lifetime is 30 barrels.

The expected number of spill incidents of the pipeline from the Ironton storage site to the Catlettsburg terminal is .013 incidents per single filling cycle and .14 over the project lifetime. The average spill volume is estimated at 1083 barrels, with a maximum credible spill of 3000 barrels. The projected volume of oil released during the project lifetime is 156.

Transportation of Crude Oil from the Gulf of Mexico and the Catlettsburg Terminal

All facilities required for the transfer of crude oil from the Gulf of Mexico and Catlettsburg Terminal are presently in operation. There would be no construction related impacts, because no new construction would be required.

Significant hydrocarbon emissions would occur during each fill operation at the facility locations: 600 tons in the Gulf of Mexico south of the Mississippi River; 30 tons in transport up the river to St. James, Louisiana; 420 tons at St James Terminal; 13.5 tons at the tank farms in Patoka, Illinois and Owensboro, Kentucky. During the life of the project an equivalent of approximately 35,930 barrels of oil would be emitted to the atmosphere. Maximum credible spill size for pipeline accidents is 10,000 barrels.

In transporting crude oil from the Gulf of Mexico to Catlettsburg, the expected total volume of oil spilled during the project lifetime would be 570 barrels. Of this total, 150 barrels would be released in the Gulf of Mexico or Mississippi River below St. James, Louisiana and the remainder would be released accidently from the Capline or Ashland pipelines. THE VLCC to tanker transfers of crude oil in the Gulf and tanker to storage tank transfers at St. James would cause emissions at maximum annula rates of 600 tons/year and 420 tons/year, respectively. Transfers at St. James, under worse case conditions would cause hydrocarbon concentrations in excess of the 3-hour Federal Standard of 160 $\mu g/m^3$ as far as 7.5 miles downwind.

7.1.3 Central Rock

Conversion of the Central Rock limestone mine into a 14-million barrel oil storage facility would require relocation of the existing mining operations; construction of a new pump shaft and appurtenant facilities at the storage site; construction of an oil pipeline from Central Rock Mine to Tate Creek Terminal; and construction of terminal facilities (including two 120,000 barrel storage tanks) at Tates Creek

Terminal. Construction of this facility is not expected to have long term adverse environmental impact. Any negative impact is expected to be short term and minor in nature, (see Table 7.3).

Storage Site Conversion and Construction

Conversion of the Central Rock limestone mine to an oil storage facility requires removal of the existing shaft equipment, sinking of a new pump shaft, installation of oil pumps and casings, and sealing the existing production decline and service shaft. A minimal amount of surface grading would be required over an area of about 2 acres including surface area required by new mine development. During the construction activity there would be an increase in fugitive dust levels, pollutants from construction vehicle emissions, and ambient noise levels. However, these effects would be localized and temporary and would cease upon completion of construction.

Development of New Mine Site

Relocation of the mining operation would require the excavation of a production and access decline, and the drilling of a service shaft. The surface equipment and construction technique employed would be similar to those used at the storage site; however, the excavation process would require use of explosives. Both ambient and impact sound level would increase in the vicinity of the project during construction and excavation. As construction activity proceeded further underground, audible sound levels would decrease.

Construction of the storage facility and relocation of the mining operation would provide about 9,000 man-weeks of labor for a 79-week period (59 weeks with the temporary mine shut down option) and total earnings of about $2.9 million. Economic gain resulting from an interruption in mining to accelerate the storage schedule would be offset by unemployment and underemployment of up to 120 mine workers and a loss of $.7 million.

Pipeline Construction

A 13.5 mile long pipeline 16 inches in diameter would be required to connect the Central Rock storage facility with the Ashland oil booster Terminal at Tates Creek. The 40-foot wide right-of-way corridor of the pipeline would affect 65 acres of land. Construction activity, with the

Table 7.3 Environmental Impact Summary - Central Rock
Fayette County, Kentucky

Activity	Impacts Due to Activity: GEOLOGY AND SOILS	LAND USE	WATER QUALITY
Storage Site and Terminal Facilities Construction and New Mine Development	Surface Grading of 11 acres; no impact in mine structure; slight erosion of bare ground; minor destruction of weathered bedrock surface; excavation of 10,000 cubic yards of material; expanded access to limestone deposits.	11 acres total for site and terminal facilities.	Decrease in quality of water shed streams due to runoff erosion process; siltation and increased turbidity in stream; increased sedimentation within small impoundments downstream of project construction.
Pipeline Construction (13.5 mile pipeline between Tates Creek Terminal and site)	Temporary disruption of about 41 acre/feet of soil along right-of-way, about 8.2 acre/feet of soil subject to runoff erosion.	Temporary disturbance of 65 acres of agricultural and grazing land.	Increase in the runoff erosion process; temporarily higher infiltration rate along pipeline trench.
Pipeline Accidents (Between St. James Terminal and site)	Soil fouled in vicinity of pipeline.	Minimal impact to land use.	Possible contamination of surface water or shallow aquifer; total expected oil spillage is 203 barrels (between Tates Creek Terminal and site); maximum credible spill is 2500 barrels. Total expected volume of oil spilled is 165 barrels (between St. James and Tates Creek Terminal) and the maximum credible spill is 10,000 barrels.
Facility Operation	No impact.	No impact.	Minimal impact expected; no discharge of wastes to surface water or ground water; very remote possibility of contamination resulting from incidents involving explosion from oil pressurization, seepage of oil from mine, or displacement of oil resulting from water inflow into mines.
Marine Operation	Small amount of erosion on harbor bottom.	No impact.	Maximum credible spill for Gulf-60,000 barrels; expected total oil spilled-390 barrels, 70 barrels at St. James and 320 barrels on Mississippi River or in the Gulf.

Table 7.3 Environmental Impact Summary - Central Rock (continue

AIR QUALITY	NOISE	ECOLOGY	SOCIOECONOMIC
Increased dust, NO_x, SO_2, CO, and hydrocarbons due to construction vehicle activity.	Small increase of about 2 dB ambient L_d and 5 dB ambient L_n in city of Lexington during construction; impulse noise levels from blasting as high as 91 dB at 1000 feet.	Storage site already highly disturbed; negligible loss of habitat; about 9 acres of pasture-crop land habitat lost at the Tates Creek Terminal.	No impact to any known historical or archaeological resource; loss of about $.7 million in salaries if 120 workers are laid off for 20 weeks and are unable to find replacement employment.
Increased dust, NO_x, SO_2, CO, and hydrocarbons during construction activities.	Increase of about 6 dB in ambient L_d at pasture lands 1 mile from construction activity.	Temporary removal of pasture habitat along pipeline; physical disruption of about 300 square feet of existing stream bed aquatic habitat.	Included in above impacts.
Hydrocarbon vapor emission from spilled oil.	Noise from clean-up operations	Significant impacts likely to occur to terrestrial vegetation, mammals and birds, and to aquatic organisms.	No impact.
Minor hydrocarbon and hydrogen sulfide emission from system leakage during pumping and minor SO_2 emissions from flaming of vapors during fill. Daily loss of approximately 85 pounds of hydrocarbons to atmosphere from storage tank during periods of fill; worst-case emissions would exceed 160 $\mu gm/m^3$ for less than ¼ mile downwind.	Ambient sound level anticipated to be 55 dB at 500 feet, or 11 dB lower than existing background ambient sound level.	No impact.	2-3 permanent employees needed to monitor equipment and provide site security; 8-10 employees required for 5 months during withdrawal and 16 months during fill.
"Breathing" losses from tankers and barges-maximum annual atmospheric loading rate of 20 tons/yr.; maximum annual hydrocarbon emission rate for tanker transfers at St. James-280 tons/tr.; transfers at St. James would cause emissions in excess of 3-hour Federal standards of 160 $\mu gm/m^3$ as far as 7.5 miles downwind.	Slight impact.	Maximum credible oil spill for the Gulf could render 840 to 1680 acres of marsh non-productive for 2 years.	Reduced marketability of fish fouled by oil; possible increase in demand for tankers may have positive effect on the economy.

use of trucks, heavy equipment and blasting, would cause increased noise levels, fugitive dust levels, and vehicle emissions. During excavation and back filling of the pipeline trench, the soil profile would be inverted and disturbed, leaving the soil vulnerable to the runoff-erosion process. Because the pipeline right-of-way corridor is in an area developed in valuable racehorse pasture lands, restoration of this land would be a necessity.

Terminal Construction

Expansion of the Tates Creek Terminal to accommodate the oil from Central Rock storage facility will require construction of two 120,000 barrel storage tanks, plus pumps, meters, and a control system. About 9 acres of land presently zoned for residential use will be required for the expansion. Environmental impacts from construction would be similar to those resulting from mine relocation and pipeline construction, and would be short term and minor in nature. Construction of the pipeline and terminal facilities would require approximately 20 weeks.

Facility Operations

Periods of fill and withdrawal would last 500 days and 150 days respectively. The storage facility would be filled by pipeline through the Tates Creek Terminal at a minimum rate of 28,000 BPD. Withdrawal of oil would be made at a rate of 93,000 BPD through the Tates Creek Terminal.

Approximately 42 pounds of hydrocarbons per day would be emitted from the storage cavern during fill periods; a temporary flare system would be used as a safety precaution to reduce concentrations of combustible gases and SO_2 in the mine area. During each fill-withdrawal cycle, oil would be stored at Tates Creek Terminal, and approximately 85 pounds of hydrocarbons per day would be lost to the atmosphere from the two 120,000 barrel, floating roof storage tanks. Such hydrocarbon emissions might result in ambient concentrations exceeding 160 $\mu g/m^3$ in the immediate vicinity of the site.

Eight to ten trained employees would be required during the 150 day withdrawal and the 500 day refill period. Two or three employees would be sufficient to carry out routine maintenance, equipment monitoring, and security procedures at the storage site during standby storage periods.

Oil Spills

The potential for oil spillage at both the Central Rock Storage facility and the Tates Creek Terminal has been estimated at 0.007 spill incidents per single filling cycle, and 0.07 spill incidents over the project lifetime. The average spill volume is calculated to be 300 barrels, with a maximum credible spill being 2500. However, the expected volume of spillage over the project lifetime is 21 barrels.

The pipeline from the Central Rock cavern storage site to the Tates Creek Terminal would be laid through Karst topography (a limestone plateau marked by dissolution features such as sinks, or karst holes, and underground caverns and tunnels) and would be subject to breakage in case of sinkhole collapse and foundation failure. Because of the karst topography, the risk of oil spill would be greater than normal for pipelines. The spill frequency expectation per single filling cycle would be 0.009, and 0.15 over the project lifetime. The average spill volume is estimated at 1083 barrels, with a maximum credible spill of 3500 barrels. The expected volume of spillage over the project lifetime is 161 barrels.

Transportation of Crude Oil from the Gulf of Mexico to Tates Creek Terminal

All facilities required for the transfer of crude oil from the Gulf of Mexico to Tates Creek Terminal presently exist and are in operation. No new construction would be required, therefore, there would be no construction related impacts.

There would be locally significant increases in hydrocarbon emissions during each fill operation. It is estimated that 400 tons of hydrocarbon emissions would be released to the atmosphere at the Gulf of Mexico south of the Mississippi River; 20 tons in transport up the Mississippi River to St. James, Louisiana; 280 tons at St. James Terminal; 6 tons at the Patoka, Illinois, tank farm; and 4.5 tons at the Owensboro, Kentucky tank farm. This amounts to 810.5 tons per fill cycle, and 4052.5 tons of hydrocarbon or approximately 24,630 barrels of oil for 5 cycles.

A total of 550 barrels of oil are expected to be spilled during project lifetime, with 390 barrels expected to be released into the Gulf of Mexico or the Mississippi River below St. James, Louisiana. The remaining 160 barrels are expected to be released accidently from Capline or Ashland pipelines. The maximum credible spill is estimated to be 60,000 barrels for tankers in the Gulf and 10,000 barrels from the pipeline system.

7.1.4 Kleer Mine

Conversion of an existing salt mine to a 30-million barrel oil storage facility at Kleer Mine would involve the construction of a new replacement salt mine, modification of existing mine facilities to receive oil, construction of a 42-mile pipeline (22-inch pipe), and modification of the Texoma-Winnsboro Terminal. Although they are not likely to cause long term adverse impacts, construction and operation of this facility would alter the local environment in several significant ways. These effects are shown in Table 7.4 and discussed below for storage site acquisition and construction, dock facilities and pipelines, marine operations, and facility operations.

Storage Site Acquisition and Construction

The major construction activity at the storage site would require minimum surface grading over 10 acres and therefore create only small, localized increases in dust and of vehicle exhaust from construction equipment.

Construction of a new salt mine to replace that converted for oil storage would involve 10 acres of industrial land. The oil storage program would be scheduled so as not to interrupt salt mining. This program would require approximately 21,000 man-weeks of labor and provide an estimated $7.3 million in salaries.

Development of an additional 14-million barrels of storage is an option that would have a resulting loss in salt production. With a 40-week cessation in salt production at Kleer Mine, designed to expedite the completion of the storage facility, 22,500 man-weeks over 64 weeks could be required.

The net economic effect of this option is the difference between the construction earnings ($7.3 million) and the lost mine employee and opportunity earnings ($1.04 million), or a net increase of $6.3 million in wages.

Dock Facilities and Pipelines

Oil would be delivered to the Winnsboro Terminal (Winnsboro, Texas) by pipeline from the Texoma Terminal (Nederland, Texas). All facilities required to transport the oil from the Texoma Terminal currently exist and are in operation; thus no new construction is required at this site. At the

Table 7.4 Environmental Impact Summary - Kleer

Van Zandt County, Texas

Activity	Impacts Due to Activity: GEOLOGY AND SOILS	LAND USE	WATER QUALITY
STORAGE SITE CONSTRUCTION			
Conversion of existing salt mine to 30 million barrel oil storage facility (P)	Minimal regrading necessary for 10 acres.	13 acres industrial land required.	Consumptive use of water required for cement, sanitary, and other uses.
Construction of replacement salt mine with: (P)			
(Option 1) No interruption of salt mining;	1 acre regrading.	10 acres industrial land required.	With minimal water requirements, no impacts on water supply; site sufficiently elevated to avoid inundation from floods.
(Option 2) Interruption of salt mining	As above.	As above.	As above.
PIPELINES CONSTRUCTION (42 mile, 22-inch pipeline.)	42 miles along 125 foot right-of-way involved; pipeline 2-3 feet below surface, 140 acre-feet of soil disturbed; 28 acre-feet lost due to erosion.	Negligible impact on land use.	Possible significant increase in turbidity, suspended solids and sediment loading.
PIPELINE ACCIDENTS (Between Nederland Terminal and site)	Percolation of spills no deeper than water table or higher impervious level because of low soil permeability. Soil fouled in vicinity of spill.	Minimal impact.	(Between Winnsboro Terminal and site) average expected spill size 1,083 barrels; expected total volume spilled is 498 barrels; maximum credible spill is 5,000 barrels; between Nederland and Winnsboro Terminal the total expected oil spilled is 125 barrels; the maximum credible spill is 10,000 barrels; temporary adverse impact on water supply if an oil spill reaches Quitman Lake or Lake Cypress Springs.
TERMINALS			
Expansion of Winnsboro with 2 90,000-barrel storage tanks (P)	Minimal impact.	2 additional acres of oak-savannah at Texoma's Winnsboro Terminal	Minimal impact.
FACILITY OPERATIONS			
Filling (20 months/storage (unknown period)/withdrawal (5 months)	Low seismic region, no effect from maximum seismicity on underground storage and only minor damage to surface facilities.	Restriction on industrial and residential development along pipeline right-of-way.	Sanitary waste disposal via septic tanks or portable chemical treatment facility; average oil spill at each terminal per incident is 10 barrels; expected total volume spilled is 45 barrels at each terminal.
MARINE OPERATION	Small amount of erosion on harbor bottom.	No impact.	Maximum credible spill for Gulf is 60,000 barrels; expected total oil spilled is 685 barrels; 80 barrels at Nederland Terminal and 605 barrels in transit between Nederland and the Gulf.

(P) Proposed system design

(A) Alternative to the proposed system design

Table 7.4 Environmental Impact Summary - Kleer (continued)

AIR QUALITY	NOISE	ECOLOGY	SOCIOECONOMIC
Small increases in particulate, dust, and hydrocarbons (from vehicle exhaust levels during construction).	L_d increase of 2 dB; L_n increase of 4 dB at Grand Saline.	Minimal surface operations involved; no significant impact.	Daytime population increase by 300 construction workers; slight increase in transient housing; slight loss of recoverable salt due to minor oil absorbtion.
As above. As above.	Increase of 68 dB at 500 feet from construction of shafts; 37 dB at 500 feet for refrigeration plant.	As above.	Completion of new mine necessary before filling of existing mine for oil storage can begin; some employees continuing at Morton Salt; 21,000 man-weeks of labor with \$7.3 million payroll or about \$5.0 million disposable income; small positive effect on Van Zandt County; some archaeological sites may be affected by construction.
	As above.	As above.	Salt mining interrupted for 64 weeks; 192,000 tons salt production lost; 13 million barrels more oil stored than Option 1; 200-220 workers affected by temporary mine shutdown--90 unemployed or underemployed; some archaeological sites may be affected by construction.
As above.	Sound from 66 dB to 70 dB at 500 feet along route; impulse noise levels from blasting as high as 91 dB at 1000 feet.	257 acres oak-savannah vegetation destroyed and soil mixed; 61 acres of bottomland habitat with similar effects; 318 acres of tame pasture habitat subject to temporary effect; disruption of benthic organisms at stream crossings in Sabine River, Lake Fork Creek and Big Cypress Creek from disturbed substrate and sediment; possibly significant losses of eggs and larval fish; losses of fish probably minimal.	Possible \$52,000 annually in taxes to Wood County for pipeline route, only minor benefit compared with tax base; some archaeological sites possibly affected by construction of pipeline.
Hydrocarbon vapor emissions from spilled oil.	Noise from cleanup operations.	Impacts include vegetation damaged or destroyed; oiling of birds, mammals, and aquatic organisms with possible subsequent deaths, loss of wildlife habitat.	Cost of cleanup of oil spill, cost to municipalities for eliminating residual oil from water supplies; and restoring recreation areas.
During fill and withdrawal hydrocarbon emissions from storage tanks (85 lbs. per day) exceed 160 μgm/m³ standard to ½ mile downwind.	Less than 55 dB at 500 feet from pumping facility at terminal.	2 additional acres of oak savannah habitat lost.	No impact.
During fill 75 lbs. per day hydrocarbons and .075 lbs. per day H_2S lost from leakage. Hydrocarbon concentration less than 194 μgm/m³ at 300 meters downwind --exceeds 160 μgm/m³ standard.	No increase over ambient sound levels at site or pipeline pumping station.	No significant impact other than oil spills.	Minor increase in property tax revenues during operation; 2 or 3 permanent employees monitoring site; 8-10 employees during 20 months needed for fill and 5 months for withdrawal.
VLCC-tanker transfers in the Gulf would cause emissions at a maximum annual rate of 860 tons/yr.; and 600 tons/yr. for tanker-tank farm transfers. Transfers at the Nederland Terminal would cuase hydrocarbon concentrations in excess of the 160 μgm/m³ Federal 3-hour standard as far as 7.75 miles downwind.	Slight impact.	Maximum credible oil spill for the Gulf would render 840 to 1680 acres of marsh non-productive for 2 years.	Reduced marketability of fish fouled by oil; possible increase in demand for tankers may have positive effect on the economy.

Winnsboro Terminal, it is estimated that 2 additional 90,000-barrel storage tanks would be required during fill and withdrawal operations.

A 42-mile pipeline (22-inch) would be required to connect the Winnsboro Terminal and the storage facility. The construction activity would disturb 140 acre-feet of soil and temporarily increase turbidity and sediment load downstream from the site activity.

Marine Operations

Tanker operations would involve a total distance of 95 miles. Oil would be offloaded from very large crude carriers (VLCC) to 30,000 DWT tankers in the Gulf of Mexico, transported up the Neches River to Nederland, Texas. The maximum credible spill size and the expected average spill associated with tanker transport up the Neches River would be 60,000 barrels and 770 barrels respectively. The largest expected total spill volume would be associated with the transfer of oil between vessels in the Gulf (450 barrels). The total oil spillage expected during five complete fill operations would be 975 barrels.

VLCC - tanker transfers in the Gulf would cause hydrocarbon emissions at a maximum annual rate of 860 tons/year. Tanker transfer operation at Nederland would cause emissions at a maximum annual rate of 600 tons/year. Under worst case atmospheric conditions, transfers at Nederland would cause hydrocarbon concentrations in excess of the three hour Federal standard of 160 $\mu g/m^3$ as far as 7.75 miles downwind.

Facility Operations

The major impacts associated with facility operation would occur during fill and withdrawal. During fill operations oil storage tanks at Nederland and Winnsboro would release hydrocarbons at rates of 22.5 tons/year and 25.5 tons/year respectively. This would cause the Federal standard of 160 $\mu g/m^3$ to be exceeded as far as .45 miles downwind at Nederland and .25 miles downwind at Winnsboro. During withdrawal the effect would be the same at Winnsboro (the allocation of oil to markets has not been made and therefore the analysis of impacts during withdrawal extends only to Winnsboro). At the storage facility a temporary flare system would be used during fill periods for combustion of hydrocarbon and hydrogen sulfide vapors vented from the cavern. Approximately

75 pounds per day of hydrocarbons (at a 50,000 BPD fill rate) would be emitted during this period. The storage phase of the program would cause no additional significant impacts. Only 3 - 4 employees would be needed to operate the facility during the storage phase. During oil recovery operations, 8 - 10 employees would be required.

7.2 ALTERNATIVE FACILITY COMPONENTS

The Sulphur Mines facility has been designed for utilizing the most feasible options for distribution, brine disposal, and raw water supply system components.

Possible alternatives and the environmental impacts for each of these components are summarized in Table 7.5 and are discussed in detail in the following subsections.

7.2.1 Alternative Distribution Facilities

Proposed Pipeline Distribution

The present plan for oil distribution to and from the Sulphur Mines dome is to construct a 14 mile pipeline connection to the West Hackberry - Sun Terminal SPR pipeline near Goose Lake on the Intracoastal Waterway as described in Section 1.3.1.5. Thus, the Sun Terminal and the Texoma Pipeline at Nederland, Texas would serve as the supply and distribution point for both the proposed West Hackberry and Sulphur Mines SPR sites. For a description of terminal operations, see the supplement to FES 76/77-4.

Since the terminal and mainline distribution pipeline would be constructed under the West Hackberry SPR development, the major impact of the proposed Sulphur Mines distribution system would be the construction of the 14 mile spur pipeline. The proposed route would eliminate approximately 24 acres of woodland and temporarily disrupt approximately 82 acres of dry cleared land, primarily pasture. The total pipeline distance between Sulphur Mines and the Sun Terminal would be 48.4 miles.

Alternate Terminal Location

The alternate distribution system proposed for the Sulphur Mines ESR facility is to develop a tanker dock on the Calcasieu River Shipping Channel, about 9 miles to the southeast. It would be adapted from the Lone Star Cement Company barge dock, located just below Vincent Landing on a 357 acre plot with 3,380 feet of river frontage. The site provides a railroad access, 2 fresh water wells which had previously been equipped with 1,000 gpm pumps, and 28,000 square feet in four abandoned buildings. The present dock, which was built for barge traffic, is 1,230 feet long with a 14 foot draft capability.

Table 7.5 Summary of Alternative Facilities and Major Environmental Impacts.

ACTION	CONSTRUCTION IMPACTS	OPERATIONAL IMPACTS
DISTRIBUTION SYSTEM		
1. Proposed: Pipeline connection to Texoma Terminal	Pipeline connection must cross appr. 14 mi. of mixed forests, agricultural, and pasture lands. Major temporary disruption of habitat along Bayou Choupique. Recovery begins within 1 year. May take 3 years after abandonment to restore to natural state.	Would service other SPR sites in this storage region. Small chance of a spill (3.0% probability of median spill, 1000 bbls). Except for waterway crossing, the effect of a leak would be localized. Spill into waterway would require emergency treatment.
2. Alternate: Adaptation of Lone Star Dock	Dredging tanker berth - 0.33 x 10^6 cu yds, disposal on 20 acres of disturbed spoil area, scattered marsh environment. Onsite grading and tank construction on industrial property (17) of 356 acres). Nine mi. pipeline temporarily disturbs 18 acres mixed pine forest and 37 acres of cleared land. Partially parallels existing right-of-way. Dry land construction technique required.	Increased tanker traffic (max. one tanker per day,handles 167 MBPD, duration 5 mo.) Small risk of damaging oil spill (7.26 x 10^{-7} per tank trip). Major spill could disastrously affect fishing and waterfowl feeding in Moss Lake and Calcasieu Lake. Possible interference with shrimp and oyster production.
3. Alternative: Connection to Existing Refineries	Cities Service Refinery: Dredging, spoil disposal, terminal construction much the same as for Lone Star. Seven mi. pipeline follows same route as for connection to Lone Star.	Same as impact at Lone Star location for fill process. Little or no terminal activity during withdrawal.

Table 7.5 Summary of Alternative Facilities and Major Environmental Impacts. (Continued)

ACTION	CONSTRUCTION IMPACTS	OPERATIONAL IMPACTS
DISTRIBUTION SYSTEM		
3. Alternative: (Continued)	Conoco Refinery: Dredging, spoil disposal, terminal construction much the same as for Lone Star. Thirteen mi. pipeline follows existing right-of-way, temporarily disturbs 78 acres of mixed pine forest and cleared land. Dry land construction technique required.	Major spill could disasterously affect fishing and recreation in Prien Lake in addition to possible impacts on Moss Lake and Çalcasieu Lake.
BRINE DISPOSAL SYSTEM		
1. Proposed: Subsurface Injection	Construction of pipeline and service roads and pads necessitates clearing of 18.8 acres of mixed pine forest, maintained life of project. Drilling noise (12 mo. duration). Drilling mud to be reprocessed; pits reclaimed; little local impact. Minute probability of blowout during drilling.	Small probability (1.0%) of brine spill due to pipeline or wellhead failure. May destroy local grasses and undergrowth. Overpressurization could fracture aquiclude resulting in possible fresh aquifer contamination. Well clogging may require flushing, resulting in oil fill delays. Total duration -- 5 mo.
2. Alternate: Market Brine Feedstock	Construction of surge pit on site. Uses existing brine pipeline to PPG industrial plant.	May limit oil fill rates, depending on demand for brine feedstock. Would slightly reduce rate of treated ballast water release into Calcasieu River but increases duration.

Table 7.5 Summary of Alternative Facilities and Major Environmental Impacts. (Continued)

ACTION	CONSTRUCTION IMPACTS	OPERATIONAL IMPACTS
WATER SUPPLY SYSTEM		
1. Proposed: Onsite	Dredging to deepen reservoir, appr. 1 x 10^6 yd^3 spoil deposited on 60 acres Allied property runoff directed back into reservoir. Replenishment from Industrial Water Canal requires 1.7 mile pipeline across Allied property.	Replenishment rate from Industrial Water Canal would vary with demand from industrial use. Drawdown time, 5 mo.
2. Alternate: Shallow Aquifers	No new road construction. Minimum pipeline construction (.25 mi). Drilling duration, 3 mo.	Saline water withdrawn from Evangeline aquifer. Saline/freshwater interface not adversely affected. Duration-5 mo. Extremely small probability of surface subsidence.

The dock would be adapted for loading and offloading two tank barges and one tankship (see Figure 7.1). To adapt the dock for tanker traffic, 330 thousand cubic yards of bottom sediment would be dredged, thus deepening the mooring area to the 40 ft. depth of the shipping channel. Dredge spoil would be deposited in local designated spoil areas on the west bank of the ship channel at Moss Lake Cutoff just south of the terminal site (see Figure 7.2), covering an area of approximately 20 acres. The spoil area is a former intermediate marsh which has already been disturbed by deposition of spoil from the construction and maintenance dredging of Moss Lake Cutoff. Much of the area has already been raised to dry land elevations, leaving patches of isolated or subdivided marsh.

Onshore improvements for conversion of the existing industrial site to a crude oil ship terminal would require the construction of two 200,000 barrel crude oil surge tanks, two 55,000 barrel tanks for receiving oily ballast water from onloading tankers, and two 7,500 barrel ballast treatment tanks. Also required are mechanical oil/water separators to reduce oil concentrations to 30 ppm before discharge into the river channel. The tanks, of standard plate steel floating roof construction, would be enclosed in spill containment dikes as required.* The control building, power substation, and other support facilities may be adapted from part of the existing industrial facilities or they may be built new. The area affected by the onshore terminal facilities and dredge disposal for Sulphur Mines would comprise approximately 37 acres of the total 357 acre Lone Star property.

A 9-mile bi-directional 20-inch pipeline, connecting the terminal site to the storage site, would be required. A preliminary pipeline route map is shown in Figure 7.3. The route would parallel an existing Cities Service right-of-way a distance of about 4.5 miles from south of the storage site to a point just west of their refinery which is a few miles north of the Lone Star facility. The pipeline would be constructed using conventional dry land techniques for the most part (see Section 1.). The route crosses mostly stable ground, comprised of approximately 18 acres of mixed pine forest and 37 acres of cleared land.

* As a measure of compliance with the Spill Prevention Control and Countermeasure Plan (SPCC) with requirement of 40 CFR 112-7.

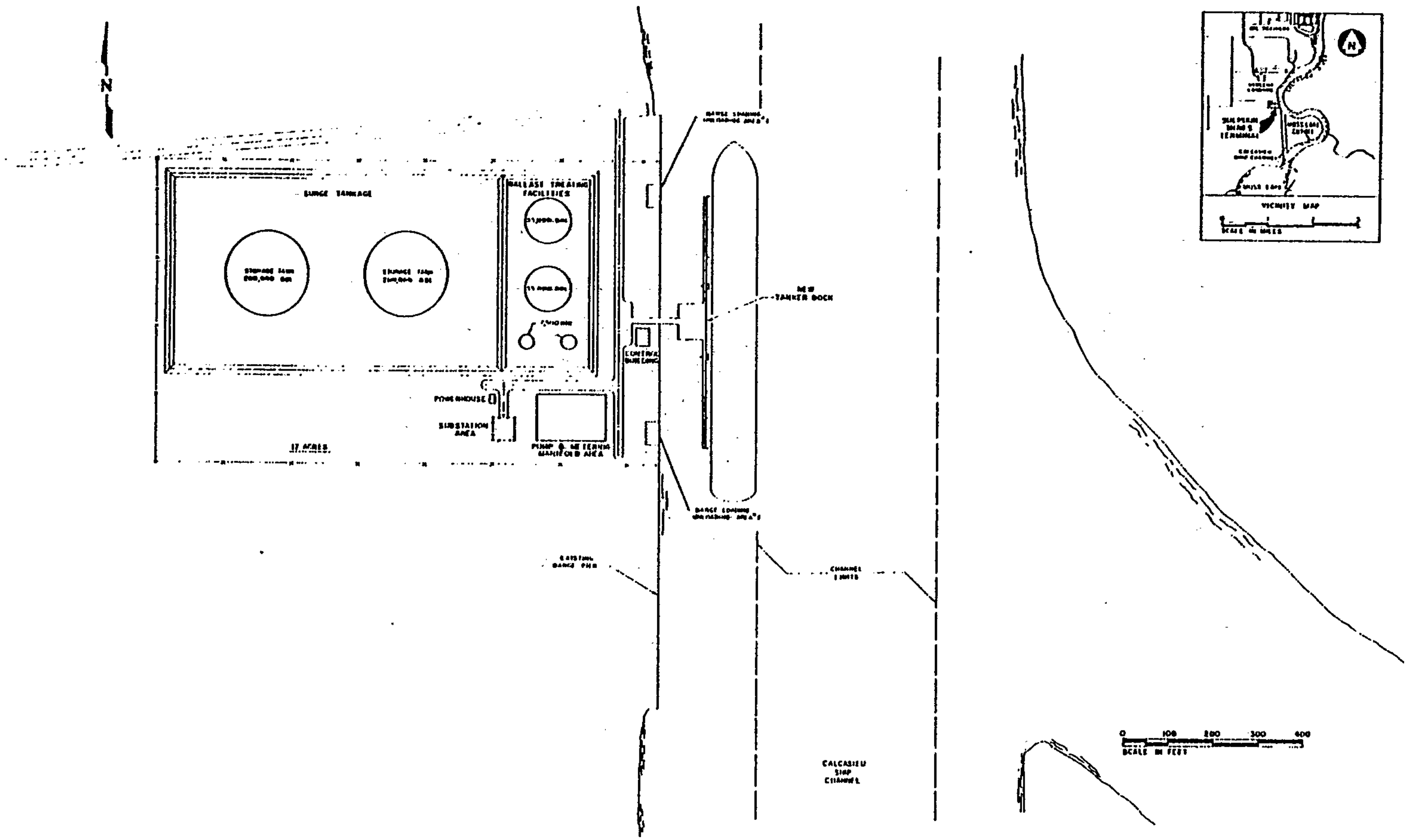

Figure 7.1 Alternative Terminal Layout - Sulphur Mines System

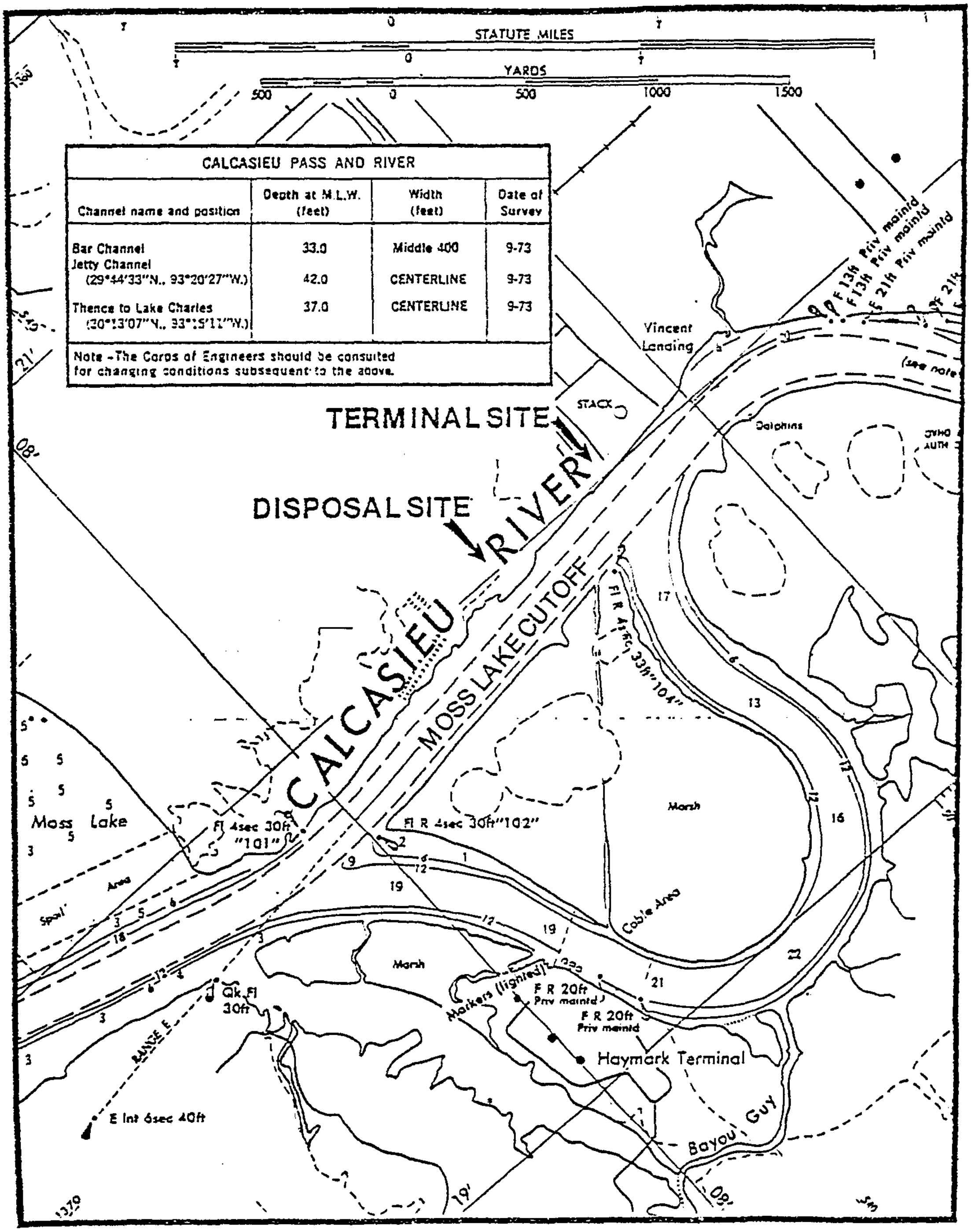

Figure 7.2 Alternative Terminal Site Location

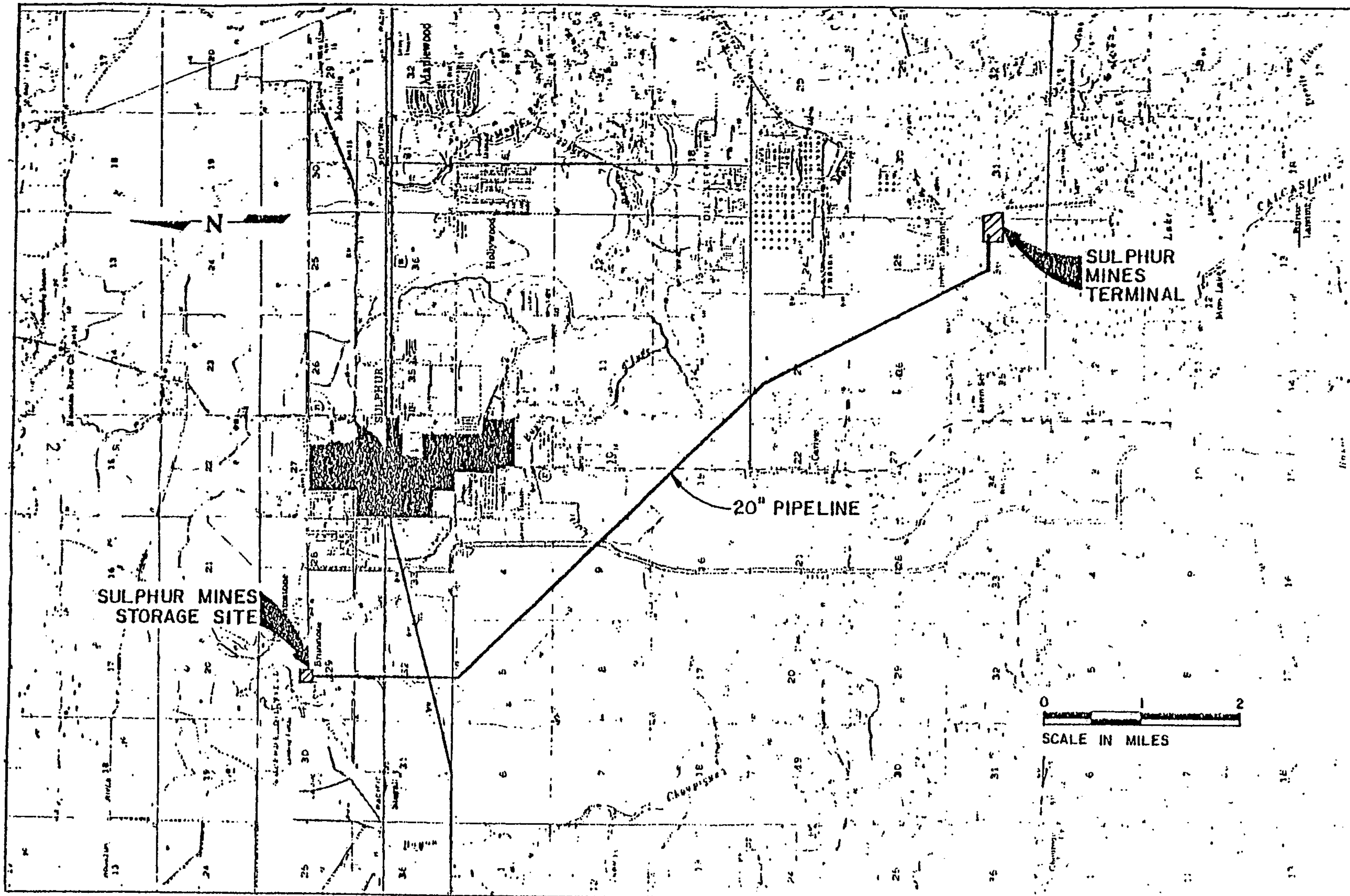

Figure 7. 3 Alternative Pipeline Route Map - Sulphur Mines.

At the site of the dredging activity, there would be an inevitable increase in turbidity* as a result of the turbulence created by the dredge. Since the bottom sediments are polluted, the release of a fraction of these pollutants during dredging cannot be avoided. Most researchers have concluded that the dredging operation, using modern techniques, has little long-term effect on the water overlying the sediments.[1,2,3,4,5] This appears to be the case even when the sediments are highly polluted. These investigators report that some dredging activities increase water tubidity and other parameters to a very minor degree up to a mile from the dredge site under certain conditions. A significant increase in any parameter has been reported only within 200 feet of the dredge.

Increases in suspended solids are generally localized near the dredging and exert little stress on surrounding aquatic organisms. Hydraulic dredges (which would be used in the proposed dredging operation) use revolving cutterheads and cause some localized turbidity. However, a large percentage of the sediment-laden water near the operating cutterhead is sucked into the dredge and discharged with the dredge material into the disposal area. The turbidity plume produced by the dredging operations would extend downstream several thousand feet. The size and duration of this plume would depend on the number and size of the dredges operating in the area, the length of time during which dredging occurs, bottom sediment characteristics, and river flow conditions. It is reasonable to expect a measurable increase in tubidity at a distance as great as one mile downstream from the dredging site. Dredging is projected to occur over a period of up to two months. The last of the suspended heavier particles would settle out soon after dredging ceases, probably within a few days. Silt and clay particles might be suspended or perhaps resuspended for longer periods. Clay is likely to be the main component of the dredge spoil since the dredging would be done along the ship channel, and the main regional shallow subsurface material is clay. Some smaller particles might pass into and be distributed in Moss Lake and farther to the south, perhaps even as far as Calcasieu Lake. The time required for movement of materials into these water

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* Turbidity is a measure of the amount of light that will pass through a liquid and describes the degree of opaqueness produced by suspended particulate material. In contrast to turbidity, measurement of suspended solids quantifies the actual amount of particulate material in the water.

bodies is unknown. Moss and Calcasieu Lakes are already recipients of fine suspended materials as indicated by the sediments in Calcasieu Lake (high in silt and, to a lesser degree, clay) and the typical conditions in coastal Louisiana streams and estuaries.[6] In shallow lakes such as these, fine sediments undergo an almost constant redistribution. Bottom materials are typically so fine that where current and wave action are weak or lacking there is a floc* or watery sediment on the bottom.[6]

The greatest impact from increased turbidity and suspended solids on the aquatic resources would be realized in the disposal of the dredged material. Standard practice would call for a weir** to be emplaced adjacent to the disposal area for retaining much of the excess water from the spoil. A drainage ditch would channel overflow water from the disposal area back into the river. The land in the disposal area is primarily marsh,[7] which has been previously disturbed by spoil deposition.

The release of nutrients, particularly nitrogen, in confined water in the disposal area may encourage excessive growth of algae and consequent degradation of water quality. In view of the high nutrient levels already present in the estuary, the increase from releases resulting from dredging or spoil disposal would not be significant. The Louisiana Advisory Commission on Coastal and Marine Resources believes the enrichment of coastal and marsh waters is beneficial.[8]

The disposal of dredged materials in a confined area and retention of the associated water for sufficient time would avoid a harmful depression of dissolved oxygen (DO) levels in adjoining waters which would occur if oxygen-demanding substances are released into them. When oxygen-demanding sediments are dispersed adequately into a shallow rentention area where the overlying water may undergo atmospheric reoxygenation, the net effect is to satisfy the oxygen demand without risking a water quality problem. The growth of algae in the confined area, stimulated by the release of nutrients from the sediments would further aid in satisfying oxygen demand since algae produce oxygen during photosynthesis, although algae do consume oxygen during periods of darkness. Windom[3] observed a significant increase in DO in confined disposal areas. The confinement area would be designed so that the dredge spoil water returns to the waterway after sufficient time for suspended solids to be deposited

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* Floc is a mixture of water and sediment forming a cloudy, fluffy mass and is deposited on the bottom.
** A weir is a vertical partition or obstruction in an open channel over which water flows.

and nutrients to be removed by algae, but before the algae population becomes senescent and dies. The returning water would be of good quality with high oxygen and low nutrient content. Under these circumstances, the confined disposal area would serve much like an oxidation pond similar to those used for many years to treat municipal and industrial organic wastes.

In addition to the increase of turbidity and the release of organic nutrients during dredging and disposal operations, pollutants from the sediments would be released into the river channel as well as the disposal site. Lead and nickel concentrations, as shown in the elutriate and water samples (Appendix D.7), exceed the proposed EPA numerical criteria for marine water aquatic life. The release of arsenic from the dredge site or disposal site, however, would not be excessive because the levels of arsenic in the elutriate samples were not higher than those in corresponding water samples and no levels exceed any known standard. Pesticides have been used heavily in the Louisiana wetlands,[9] and the release of pesticides and other toxic chemicals during dredging can result in water quality degradation and a negative impact on aquatic life. In addition to immediate effects, these chemicals can be transferred and concentrated via the food chain, to other organisms. However, because of the absence of data for pesticide levels in the elutriate samples, no specific statement can be made regarding the release of such pesticides during dredging.

During operation of the alternate tanker facility, the overall ambient hydrocarbon levels in the near vicinity of the tanker and barge docks would be noticeably increased for the duration of tanker loading or unloading. Standing storage losses from tanks would also contribute. These estimated hydrocarbon concentrations are substantially different in character from other air pollutants. Some elements of the vapor may elicit an unpleasant olfactory response, depending on the sulfur content of the oil, but the vapor would not be toxic to humans or local biota. The impacts on air quality of elevated concentrations of inert hydrocarbons such as are released from crude oil transfer operations have not been reported in the literature.* A search of the literature revealed no assessments

*At this time there are no federal or state standards which establish guidelines for acceptable levels of photochemically inert hydrocarbons.

of the impacts of these hydrocarbons in concentrations typical of the levels expected from this project.

The following concentrations of hydrocarbons are estimated for the worst case, and are controllable by the installation of vapor recovery systems for tanker loading and unloading. Loading and unloading operations would result in an estimated total hydrocarbon emission of about 46.4 tons from initial and subsequent fill operations and about 53 tons from each 150 day drawdown operation. The net hydrocarbon tonnage released to the local air environment from the Early Strategic Reserve operations at Sulphur Mines would be roughly 0.1 percent of the total emissions for the entire parish in 1970.

Alternative Pipeline Connection to Existing Refineries

An alternative to building the proposed tanker terminal at the Lone Star dock would be to construct pipeline connections to either the Lake Charles Cities Service refinery, located about 2 miles north of Lone Star, or the Conoco refinery, located about 13 miles east of the Sulphur Mines dome (see Figure 7.4). These two refineries handle more foreign crude oil than the design withdrawal rate of the stored oil. Additional dock space would have to be created for ESR fill operations.

The 7 mile alternative pipeline to the Cities Services refinery would follow the same route as described for the connection to Lone Star and would parallel an existing Cities Service right-of-way for about 5 miles. The route crosses stable ground, comprised of approximately 18 acres of mixed pine forest and 24 acres of cleared land.

On the other hand, the 13 mile alternative pipeline to the Conoco refinery would parallel an existing Conoco gas pipeline between the dome site and the refinery. Much the same type of terrain would be affected as described for the route to Lone Star or Cities Service. A total of 78 acres, roughly half of which is mixed pine forest and half of which is cleared land, would be affected by the pipeline construction. The pipeline would also cross the Industrial Water Canal and pass north of the city of Sulphur.

The construction of a tanker terminal for ESR crude oil supplies near either the Cities Service or the Conoco refinery would be required. The terminal would connect to

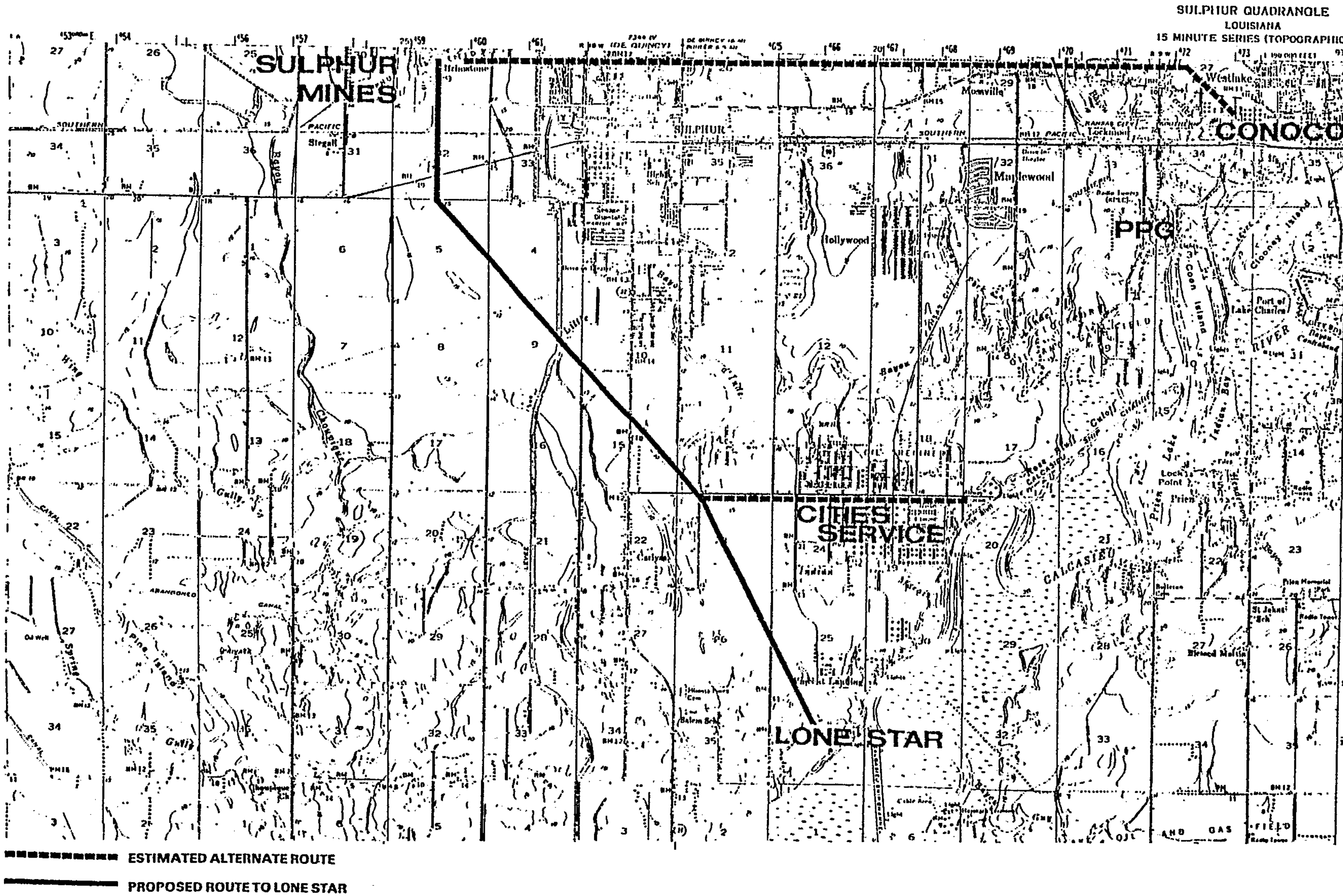

Figure 7.4 Alternative Distribution Terminal Locations

the distribution pipelines for crude oil transfer back to the dome storage site. Essentially, the same type of terminal as described for the facility at Lone Star would be built at the alternate location. It would provide mooring for one 50,000 DWT tanker or several tank barges. The dock would be about 800 to 1,000 ft. long and, as in the proposed dock design, would require about 330,000 cubic yards of bottom material to be dredged for a tanker mooring area adjacent to the ship channel. The spoil disposal area for either dock location would require approximately 20 acres of dry land and scattered patches of marsh in areas already disturbed by channel dredge spoil deposits.

Because either facility would be on the Calcasieu River, turbidity resulting from dredging would extend considerable distances downstream. Although sedimentology data are not available for the site, it can be assumed that the river contains much the same sediment composition throughout. For this reason, the extent and impacts of turbidity resulting from the alternative action would be similar to that of the terminal and dock facility at Lone Star. For further discussion, see Section 3.2.

Onshore improvements associated with the alternative distribution terminal would be equivalent to those required for the Lone Star dock. The sizes and arrangement of tanker loading pumps and pipeline transfer pumps may be different than ones projected for the Lone Star facility due to coordination with the refinery demands and possible shared facilities. Both sites, however, would be located on approximately 17 acres of heavily industrialized land and the environmental impacts of the construction and operation of either facility would be essentially equivalent.

The potential for routine small oil spills during terminal transfer operations would be essentially the same at both locations. Generally small spills occurring during normal operations do not have long range damaging effects on the environment. Successive accidental spills of greater magnitude (from 30 to 100 barrels) can have pronounced effects, however, especially in relatively confined areas such as the Calcasieu Ship Channel where spilled oil would not have time for weathering before reaching shorelines. The probability of spills of this magnitude is calculated at 4.57×10^{-5} per tanker trip. Section 3.7 deals with marine accidents in more detail.

7.2.2 Alternate Brine Disposal Facilities

Subsurface Injection Proposal

The proposed method of brine disposal is to drill a set of 4 disposal wells from 5,000 to 7,000 feet deep to the south and west of the salt dome. As described in Section 1.3, the injection system is designed to handle the entire 100,000 barrels per day (2,900 gpm) produced during fill operations.

The proposed design calls for a 100,000 barrel surge pit (approximately 400 x 400 feet) to be constructed just south of the storage site (see Figure 7.5). All the wells would be constructed on property acquired from Allied, requiring a total of approximately 48 acres of primarily mixed pine forests. An estimated 18.8 acres of the total would be cleared for roadway and pipeline construction. The individual disposal wells would be spaced on 1,000 feet intervals, and injection pumps would be located at the central pump building at the storage site.

Alternative Market Brine Feedstock

As an alternative to the proposed deep well injection of brine, an attempt could be made to market the brine for chemical industries. Since the wells proposed for ESR storage are currently used for brine feedstock production, the brine displaced by crude oil injection would be compatible with necessary quality standards. PPG Industries presently utilize brine from the Sulphur Mines dome at a rate of 2,500 gpm. Since the design rate of crude oil fill operations is 2,900 gpm, a balance of 400 gpm during the 8 month fill period would have to be marketed to other demand sources in the region. If the initial fill period were extended to 10 months, consequently cutting the oil injection rates, then PPG could utilize all of the brine produced during this extended fill process.

This alternate system of handling brine would utilize the same brine settling pond as proposed for the injection system. Existing brine pipelines, however, would connect the site with the PPG plants. Thus no additional impacts due to new construction or operation would be involved.

The problem with this alternative is that a potential brine user would not be willing to accept an unknown

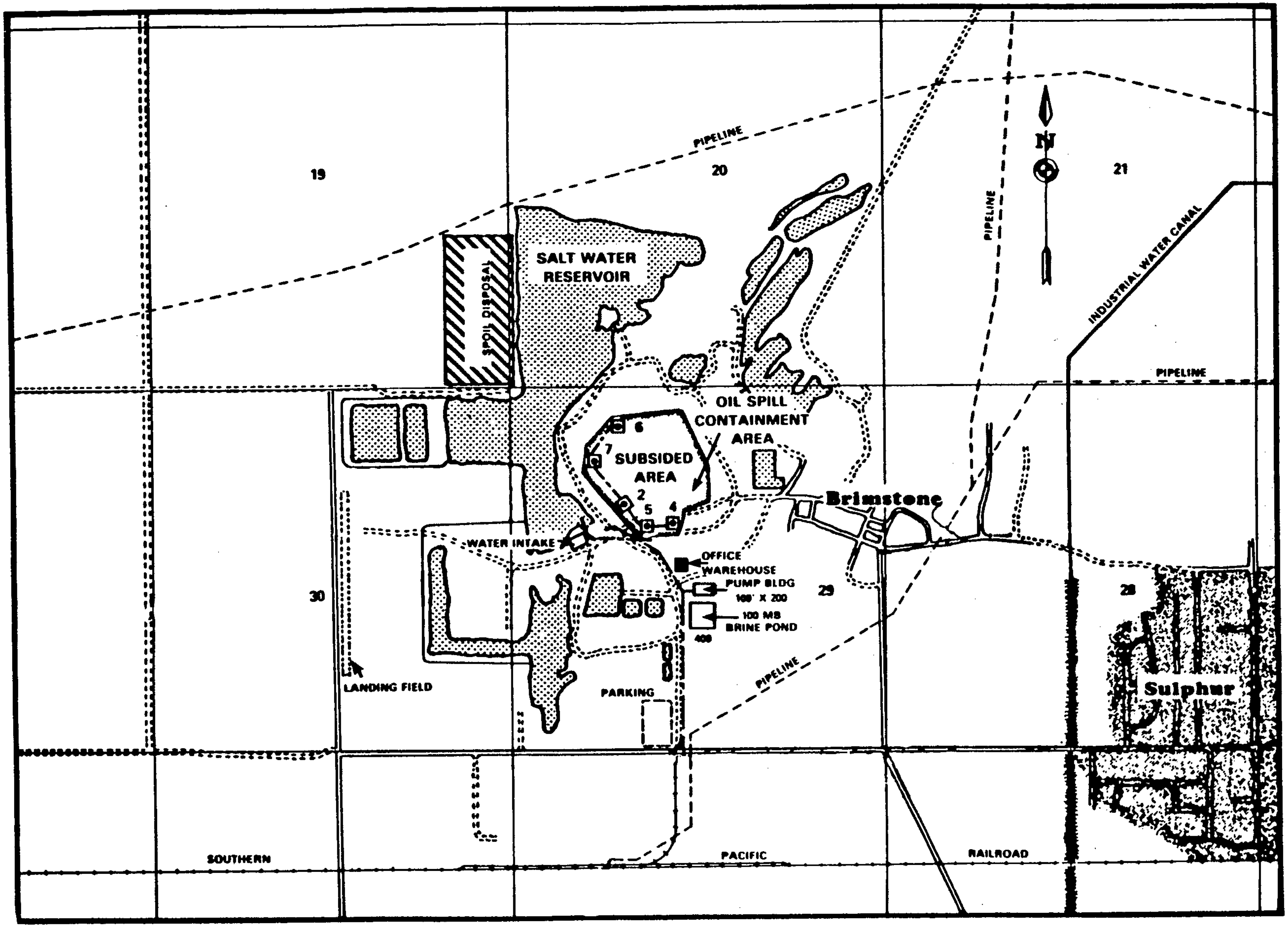

Figure 7.5 Proposed Site Development

quantity of brine on such an unpredictable schedule that is inherent in the cycling of the SPR facility at Sulphur Mines. Furthermore once these industries develop an alternate source of brine they will be unwilling and/or unable to cut off that source, and change the brine treatment process to accept brine for a relatively short period of time from Sulphur Mines.

7.2.3 Alternative Displacement Water Source

Surface Water Proposal

The preferred option for displacement water supplies at Sulphur Mines is to extract the water from the onsite reservoir (Salt Water Reservoir shown in Figure 7.5) at the western edge of the salt dome.

Approximately 7,350 barrels per hour (5,145 gpm) is required for crude oil withdrawal operations. A total of 25.2 million barrels of water would be required to displace all of the stored oil. As described in Section 1.3, the existing capacity of the reservoir is 20 million barrels, but it is currently planned to deepen its southern portion to create a total capacity of 25 million barrels. The dredging would require approximately one million cubic yards of material to be deposited on about 60 acres adjacent to the reservoir.

In addition, replenishment of the reservoir is planned from the Sabine River Diversion Canal, a leg of the Sabine River Diversion system, about one mile north of the reservoir. Water from the system would be available. The required ESR demand rate is only 3.3 percent of the canal system initial capacity. The pipeline connection would be constructed on grade on Allied property with a small pump station located on the canal.

Alternative Subsurface Aquifers

An alternate source of displacement water would be fresh or slightly saline water from shallow subsurface wells drilled to depths of from 500 to 900 feet. The location of these alternate raw water wells would be just off the southwest flanks of the dome (see Figure 7.5). A total of five wells is assumed. Although the exact yield rates obtainable from each well are unknown, experience from other wells in the vicinity suggests this as a reasonable estimate (see Section 2.2). Two shallow aquifers exist in the area. The Chicot aquifer is found in the subsurface interval from about 30 ft. to around 800 ft. and contains fresh to slightly saline water. The Evangeline aquifer extends from about 800 ft. to approximately 2,800 ft. and contains saline water. These aquifers are discussed in detail in Section 2.2.

The primary impact of the construction of the well system would be increased noise and air pollutant emission levels during the several months of drilling. Since the area is heavily industrialized and several miles from populated areas, the operation of an additional drill rig would affect only the immediate surroundings on the site. Because the exact spacing, configuration, and depths of the wells have not been determined, several possibilities were assumed for assessing the impact of extracting subsurface waters from the vicinity at the expected withdrawal rates.

As described in Appendix D.7, one possibility would involve five wells, each drawing 1,000 gpm of fresh water from the Chicot aquifer. This pumping rate is approximately 1.8 times the pumping rate for the city of Sulphur. For purposes of analysis, the wells are assumed to be placed at the four corners and at the center of a square approximately 500 feet on a side. The resulting drawdown is presented in Figure 7.6. As indicated in the figure, the drawdown would be 7.6 feet at a distance of 8,000 feet from the well field center after 150 days of pumping. This distance is roughly equal to the distance separating the dome site from the city of Sulphur. The resulting drawdown is thus representative of the effect of the withdrawal as experienced at Sulphur.

Although the drawdown described in the preceding paragraph appears small in comparison with the drawdown resulting from the pumpage of water for industrial use in the Lake Charles area, it should be noted that there is currently an inadequate supply of fresh ground water in the area.[10] This shortage is the result of salt water contamination of the Chicot Aquifer. Metropolitan areas and industry usually tap the top portions of the aquifer to obtain fresh water with low drilling costs. Reduction of the fresh water head permits pressure to drive lower quality water up into the fresh water aquifers. The brackish water must penetrate aquitards and aquicludes to contaminate the fresh water layers. Although vertical hydraulic conductivity coefficients may vary over 4 or 5

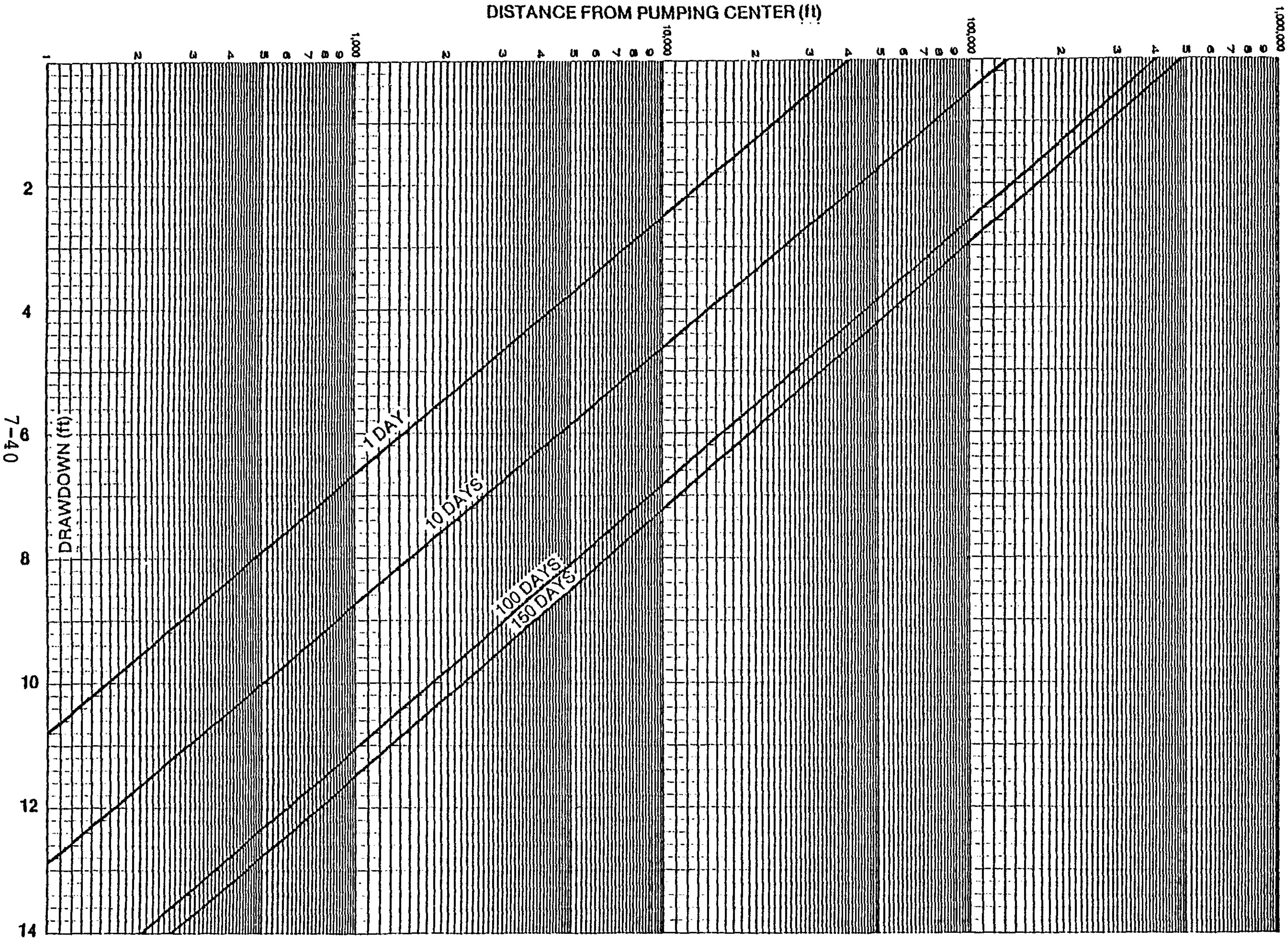

Figure 7. 6 Variation of Drawdown with Distance from the Pumping Center in the Chicot Aquifier

orders of magnitude, the resistance is usually large enough to preclude significant intermixing.[11]

Nevertheless, contamination has been observed. It is usually attributed to geologic faults, natural aquifer connections where water density variations minimize mixing prior to pumping, or to poorly plugged wells or mines. A geologic fault exists three miles south of the dome.[12] It is not known whether this fault could serve as a connection for saline intrusion into fresh ground water supplies. Such an event is unlikely due to distance and estimated head reduction.

Some of the 75 abandoned oil and gas wells drilled in this region may offer paths for intermixing of the water layers.[13] Such leakage might not be observed until large scale pumping begins in the area.

The potential for contaminating fresh water aquifers would be minimized by drilling below 800 feet and using saline water from the Evangeline aquifer for the project. Any existing short circuit water paths would draw relatively small amounts of fresh water down into the brackish layers, leaving the fresh water aquifers uncontaminated.

When ground water is removed from an aquifer, surface subsidence is possible. Lowering the artesian head of an aquifer reduces the fluid pressure within the aquifer but does not change the external pressure acting on the aquifer. The result is an increased pressure differential. The compaction in these aquifers is immediate but may be partially recovered when internal fluid pressure is restored.

Aquitards and aquicludes,* however, have low vertical permeability and high specific storage under virgin stress conditions. The vertical escape of water and the adjustment of pore pressures are relatively slow. Compaction may take place over months or years. Recovery is likely to be small.[14]

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*An aquiclude is a geologic formation so impervious that for all practical purposes it completely obstructs the flow of ground water (although it may be saturated with water itself), and completely confines other strata with which it alternates in deposition.

Subsidence has been measured in several areas of the Gulf Coast. In the Houston/Galveston area, the compacting beds lie between 200 and perhaps 2,000 feet. The artesian head decline from 1890 to 1961 reached 250 to 300 feet in several areas. The maximum subsidence ranged from three to five feet from 1943 to 1964. Over 2,600 square miles subsided by 0.5 feet or more during that 21-year period.[14]

Near Baton Rouge over 250 square miles have subsided from 1934 to 1965. The maximum subsidence is one foot. The depth of the compacting beds is 150 to perhaps 2,000 feet. The artesian head decline is over 100 feet.[14]

In New Orleans, the artesian head decline was as much as 130 feet in the 700-foot sand between 1938 and 1964. The subsidence over this 26-year period was 1.7 feet.[12]

A clear relationship between subsidence, drawdown, and time for Sulphur Mines has not been established. As noted in Appendix D.7, it appears likely that the withdrawal of water from the shallow aquifers at Sulphur Mines would result in negligible surface adjustment.

Should surface subsidence occur, the quantity of standing water in the area would increase. It is probable that detailed measurements from deep wells will be necessary to detect gradual subsidence because the character of the immediate area should not change appreciably due to a slight reduction in elevation.

In summary, the effect of a properly engineered groundwater supply for the displacement process at Sulphur Mines would be lowering of the potentiometric surface at the dome. Negligible subsidence would be encountered. The potential contamination of fresh water aquifers with brackish or saline water can be avoided by using saline water from the Evangeline aquifer as opposed to fresh water from the Chicot aquifer.

7.3 NO-ACTION ALTERNATIVE

A description of the no-action alternative and its impacts, as it applies to the entire program, is provided in the Programmatic EIS (FES-76-2). Within the SPR, a decision not to develop the Sulphur Mines facilities would result in the development of one of the other candidate sites to take its place. In that case, the impacts described in Section 3.0 would not occur and the existing environment of Sulphur Mines (as described in Section 2.0) would be maintained. However, a decision not to develop Sulphur Mines would result in other impacts: those associated with the alternate facility. Since many of the candidate sites are also located in the Gulf Coast Region, it is likely that many of the impacts resulting from the development of the replacement site would be substantially the same as those for Sulphur Mines. However, the detailed impacts of any particular facility are very site-specific and would be discussed in the EIS for that site.

CHAPTER 7
SULPHUR MINES
REFERENCES

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2. H.L. Windom, "Environmental Aspects of Dredging in Estuaries." Journal of the Waterways, Harbors, and Coastal Engineering Division, American Society of Divil Engineers, 98 (WW4), Proceedings Paper, 9342: 475-487.

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7. Larry Rocca, Private Communication, Louisiana Wildlife and Fisheries Commission, Lake Charles, Louisiana, July 29, 1976.

8. M.J. Hershman, "Louisiana Wetlands Prospectus: Conclusions, Recommendations, and Proposals of the Louisiana Advisory Commission on Coastal and Marine Resources, Baton Rouge, La., 1973.

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11. A.G. Winslow, D.E. Hillier, and A..N. Turcan, Jr.; "Saline Ground Water in Louisiana, Hydrologic Investigations Atlas HA-310," USGS, Department of the Interior, 1968.

12. W.E. Wallace; "Fault and Salt Map of South Louisiana," Gulf Coast Association of Geological Societies Transactions - Vol. 16, 1966, p. 373.

13. R.D. Bates; "Summary of Field Statistics and Drilling Operations - Louisiana - 1974," Department of Conservation, Louisiana, 1974.

14. J.F. Poland; Subsidence and Its Control, in Underground Waste Management and Environmental Implications (Symposium), The American Association of Petroleum Geologists, Tulsa, Oklahoma, 1972.

8. RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS.

Land use plans for the area which includes the Sulphur Mines site, have been developed by the Imperial Calcasieu Regional Planning and Development Commission in conjunction with the Louisiana State Planning Office. These plans are based on current land use designations and projected growth patterns. Use of these sites for the oil storage program would not change the land use designations currently applied to these areas. The proposed project would not conflict with plans that have been forwarded by the parish and regional planning commissions. The current distribution of total area of Calcasieu Parish, in which the site is located, is as follows:[1]

Agricultural Lands	336,904 acres	49.16%
Forest	183,349 acres	26.75%
Public/semi-public Lands*	8,700 acres	1.27%
Urban Areas	57,732 acres	8.43%
Undevelopable Wetlands	92,946 acres	13.56%
Water Bodies	5,696 acres	0.83%
Total	685,327 acres	100.00%

The primary concern of projected land usage plans relative to this project is the expansion of Sulphur, which is growing at a rapid rate and which is only 2 miles from the storage site. The population of Sulphur is expected to increase at a rate of 14 percent to 15 percent every 5 years, reaching a figure of about 23,500 by 1990. The formula used to estimate land requirements to accommodate this urban expansion has been based on the proportion of present population to land usage, and assumes the balance in the various urban sectors to remain constant. The resulting delineation of additional urban land required by 1990 is shown on Table 8.1.

The areas where land will be annexed to Sulphur to supply additional requirements for urban acreage are shown in Figure 8.1. Planners anticipate that the city will continue its present pattern of expanding east and south. A large proportion of the residents of Sulphur work in Lake Charles and Westlake, and the open space that now separates these communities will probably eventually merge into a continuous urbanized area. The figure shows a substantial proportion of land designated for industrial growth. This land lies east and south of Sulphur in an area where industry could take advantage of the Calcasieu River as a shipping route for supplies and products. Completion of Interstate Highway 210 which will bypass the downtown area of Lake Charles and provide road access to the area southeast of Sulphur will also prompt development there. Northern expansion of the city would be bounded by the Houston River, and southern expansion would develop on both sides of Highway 27, incorporating the existing residential community of Carlyss. A study conducted by a planning consultant for the Calcasieu Regional Planning Commission in July, 1973 recommended that municipalities such as Sulphur annex contiguous areas in order to control their development through licensing and zoning measures.[2].

This study also predicted that the rural population surrounding Sulphur would decrease significantly by 1990. Sulphur and the proposed storage site are in Ward 4 of Calcasieu Parish; the boundaries of this ward are shown on Figure 8.1. The rural population in this ward was about 11,500 in 1970 and is expected to diminish to about 2,000 in 1990 due to annexation of unincorporated residential areas by Sulphur and Westlake.

Land use plans available at this time indicate that the western boundary of the city limits of Sulphur is unlikely to be moved farther west. This means that the existing forest belt which is about a mile wide and which separates the proposed oil storage site from Sulphur, will remain. The proposed oil distribution pipeline would cross through a forest area south of the site, and would lie west of Carlyss. It would cross Route 90 and Interstate 10, Louisiana Highway 108, and three parish roads. There is some residential development along these parish roads, but the homes are scattered and can be avoided by the pipeline route.

The Comprehensive Zoning Law of Calcasieu Parish was enacted in 1962 to direct the pattern of development throughout the parish. Work is currently underway to complete the classification of properties. Land which would be affected by the proposed facilities at Sulphur Mines and in the pipeline corridor have not yet been classified for zoning regulations.

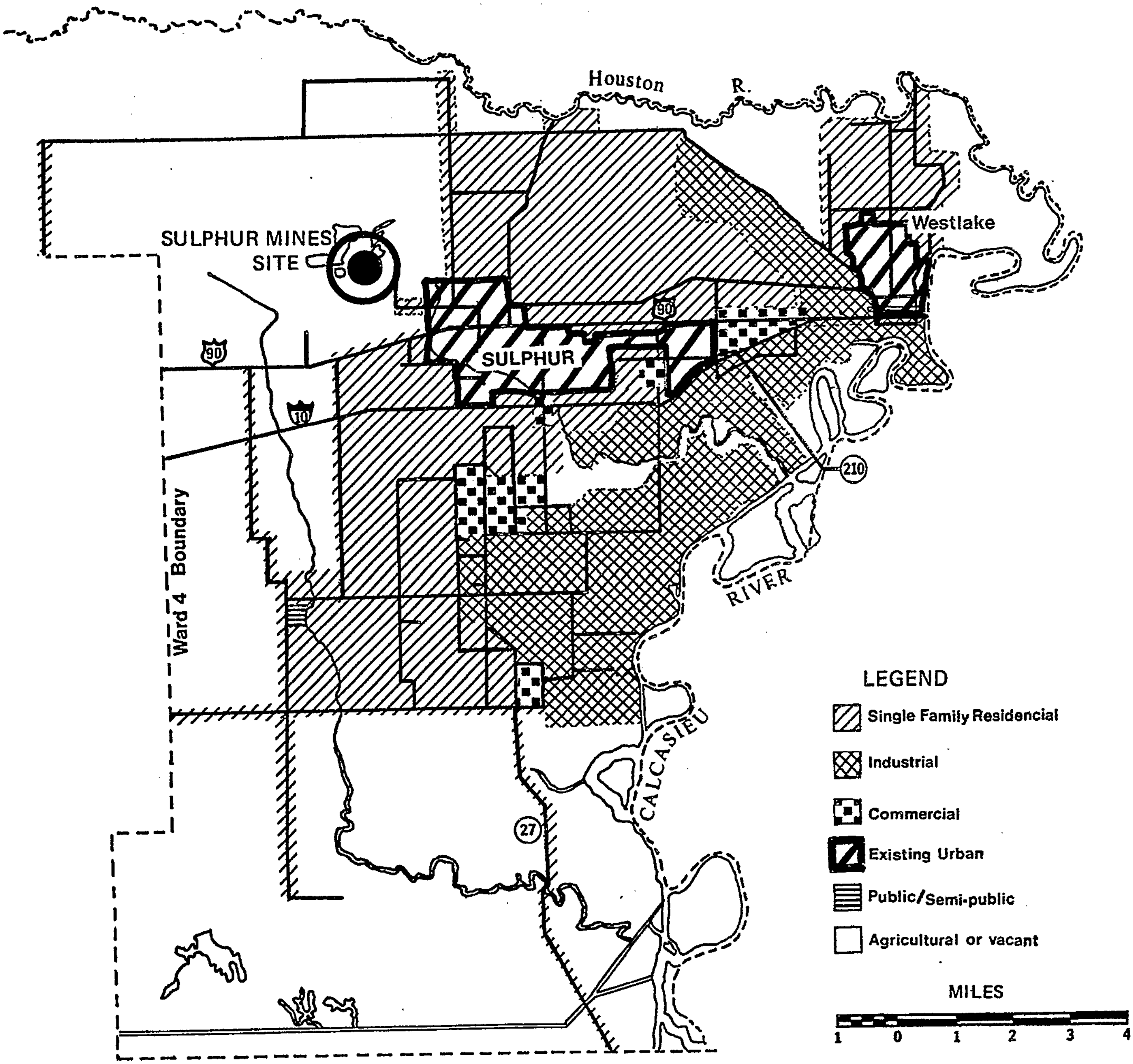


Figure 8.1 Urban Acreage Surrounding Sulphur - Proposed Land Use Plans

CHAPTER 8
SULPHUR MINES
REFERENCES

1. Imperial Calcasieu Regional Planning and Development Commission, Existing Land Use Study, June, 1974.

2. Diversified Economic and Planning Associates, Inc., Land Use Plan, prepared for the Calcasieu Regional Planning Commission, Lake Charles, Louisiana, July, 1973.

9. CONSULTATION, RELATED PERMITS, AND DISCUSSION

Various agencies, governmental units, and local groups contributed information and assistance for the preparation of this Environmental Impact Statement. A list of these agencies is given in Section 9.1. Further advice and coordination will be sought from agencies having regulatory jurisdiction over those segments of the environment which will or could potentially be affected by the proposed project. Procedures are currently underway to prepare applications for those permits and licenses which would be required to proceed with the implementation of the project. Those Federal and state agencies whose concerns interface with the proposed actions are listed in Section 9.2.

The Draft Environmental Impact Statement was released for public review and comment in September 1977. A list of those agencies and organizations from which comments were requested is given in Section 9.3. Those comments which were received within the time allotted, are included in Section 9.4. Minor changes to the text of the statement have been made in response to these comments. The comments from various agencies are included in their entirety in Appendix J.

9.1 AGENCIES AND GROUPS CONSULTED

In preparation for the Environmental Impact Report, numerous agencies, governmental units and groups were consulted for information and technical expertise pertaining to the proposed project. These groups are listed alphabetically below.

<u>Federal Agencies</u>

- Army Corps of Engineers (New Orleans Office and Vicksburg, Mississippi Experiment Station)
- Coast Guard, Port Arthur, Texas
- Environmental Protection Agency, Dallas, Texas
- Geological Survey, Reston, Virginia
- Housing and Urban Development Administration New Orleans, Louisiana
- Department of the Interior, Washington, D.C.
- Bureau of Indian Affairs, Washington, D.C.
- Bureau of Land Management, Washington, D.C.
- National Oceanic and Atmospheric Administration, New Orleans, Louisiana

Occupational Safety and Health Administration
New Orleans, Louisiana

State Agencies

Louisiana Agricultural Stabilization and Conservation Service
Louisiana Air Control Commission
Louisiana Department of Conservation
Louisiana Economic Development Administration
Louisiana State Department of Employment Security
Louisiana State Planning Office
Louisiana Commission on Stream Control
Louisiana Wildlife and Fisheries Commission

Local Government Agencies

Calcasieu Parish Police Jury
Imperial Calcasieu Regional Planning and Development Commission

Other Groups

Allied Chemical Corporation, Houston, Texas
Brimstone Historical Society, Sulphur, Louisiana
Gulf Oil Corporation, Houston, Texas
Lake Charles Harbor and Terminal District

9.1 ENVIRONMENTALLY ORIENTED PERMITS AND LICENSES

A number of Federal regulations which must be complied with during project development are listed in Table 9.2. Also included in the list are state regulations which are relevant to the program. FEA will consult with the state agencies in charge of implementing these regulations pursuant to the Intergovernmental Coordination Act of 1968.

Table 9.2 Regulatory Bodies and Their Jurisdictional Concerns

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
FEDERAL			
1. U.S. Army Corps of Engineers, New Orleans and Galveston, District Engineer Permits for Dredging or for Construction of any structure	"Regulations on Navigable Waters"	33 CFR 209	
	A. Permits for Activities in Navigable Waters of Ocean Waters	33 CFR 209.120	
	1. Prohibits the unauthorized obstruction or alteration of any navigable waters.	33 CFR 209.120(b)(2)	
	2. Discharge of dredged materials into navigable waters.	33 CFR 209.120(b)(3), (b)(7), (g)(5)(ii)	
	3. Structures or activities affecting the navigability of navigable waters; includes structures under a navigable waterway.	33 CFR 209.120(b)(3), (e)(i), (g)(5)(ii)	
	4. Discharge of refuse into navigable waters.	33 CFR 209.120(b)(4)	
	5. Temporary occupation with use of any seawall, bulkhead, etc.	33 CFR 209.120(b)(5)	
	6. Declares a national policy to encourage a productive and enjoyable harmony between man and his environment.	33 CFR 209.120(c)(4)	
	7. Preservation of the quality of the aquatic environment as it affects the conservation, improvement and enjoyment of fish and resources.	33 CFR 209.120(c)(5)	
	8. License needed which will reflect upon properties listed in the National Register of Historic Places.	33 CFR 209.120(c)(7)	
	B. Piers, Dredging, etc, in Waterways	33 CFR 209.130	
	1. Structures or activities affecting the navigability of navigable waters; includes structures under a navigable waterway.	33 CFR 209.130(b)(14)	
	2. Work connecting canals to navigable waters.	33 CFR 209.130(b)(16)	
	3. Fixed structures on the outer continental shelf.	33 CFR 209.130(q)	
	4. Piers or bulkheads at the coastline.	33 CFR 209.130(b)(13), (b)(12)	

Table 9.2 Regulatory Bodies and Their Jurisdictional Concerns (continued)

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
	C. Permits for Discharges or Deposits into Navigable Waters	33 CFR 209.131	
2. U.S. Coast Guard, District Commander of 8th Coast Guard District (New Orleans) (No Permit Requiried)	<u>Coast Guard Regulations on Oil Spills</u>	33 CFR 154	
	A. Letter of intent to operate oil transfer facility	33 CFR 154.110	Letters of intent must be submitted and approved 60 days prior to date the operation is intended to begin.
	B. Notice of Discharge of Oil	33 CFR 153	Notice for oil spilled and delegation of responsibility for cleanup.
	C. Facilities and Vessels for Transporting and Handling Petroleum	33 CFR 151.154	
	D. Large Oil Transfer Facilities	33 CFR 154	Provides equipment requirements and criteria for operations monies.
	E. Oil Transfer Operation	33 CFR 156	Regulates oil transfer.
3. U.S. Environmental Protection Agency, Region VI	<u>Regulations on Policies and Procedures for the National Pollutant Discharge Elimination System (NPDES)</u>	40 CFR 125	
	1. These Regulations proscribe the policy and procedures to be followed by the Administrator of the U.S.E.P.A. pursuant to Sections 402 and 403 of the Federal Water Pollution Control Act.	33 USC 1251 nt	
	2. Requires permits. . .for any industrial discharges into navigable waters including the "contiguous zone" territorial sea. Such a permit would probably be necessary for discharge of effluents from the off-shore and on-shore terminal waste treatment facilities. In addition, should the NPDES permit system requirements not apply to a particular operation, certification is still required from the EPA administrator (or from appropriate designated State or Interstate agencies) whenever a Federal license or permit is being sought for activities which may result in discharge into the navigable waters.		The State of Louisiana does not yet have an approved program for issuing NPDES permits. However, the State has to certify that it has seen and approved the permit application before EPA will act on it.

Table 9.2 Regulatory Bodies and Their Jurisdictional Concerns (continued)

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
	Regulations on Oil Pollution Prevention	40 CFR 112	
	A Spill Prevention, Control, and Countermeasures Plan (SPCC) must be prepared for each oil handling facility, within six months of the commencement of facility operations.	40 CFR 112.3	
	Regulations on Transportation for Dumping, and Dumping of Materials into Ocean Waters	40 CFR 220	
	Permit for ocean dumping required for brine disposal.	40 CFR 220-229	
	Air Pollution Control	40 CFR 60	New Source performance testing must be provided.
4. Department of Interior Fish and Wildlife Service	Protection of Wildlife	16 USC 661-666 16 USC 1531-1540	Fish and Wildlife Coordination Act Endangered Species Act
5. Department of Commerce National Marine Fishing Service	Wildlife Preservation	16 USC 661-666 16 USC 1531-1540	
6. Department of Transportation, Office of Pipeline Safety	Sets Standards for Pipeline Carrying Petroleum or Hazardous Materials	49 CFR 195	
State			
7. Louisiana Stream Control Commission (enforcement agency is the Louisiana Division of Water Pollution Control) (Baton Rouge)	(a) Certificate of Approval required for permission to discharge wastes into the public water. (b) State must approve applications for NPDES permits before submission to U.S. Environmental Protection Agency (c) Permit for waste disposal.	Louisiana Regulation Requiring Submission of Reports for the Discharge of Industrial Waste. . . 40 CFR 123 Subpart A, Section 123.3.	Certificate of Approval required 3 to 12 weeks before beginning discharges.

Table 9.2 Regulatory Bodies and Their Jurisdictional Concerns

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
8. Louisiana Air Control Commission (enforcement agency is the Louisiana Division of Health)	(a) Certificate of Approval for construction of sources of air pollution emissions. Applies to onshore turbines, barge loading and unloading facilities, surge tanks, pumps, and related facilities.	Louisiana Air Control Commission Regulations Section 6.1.	Prior to facility construction, plans and specifications of the facility should Louisiana Air Control Commission.
	(b) Approval for open burning of land clearing debris is not specifically required at present so long as the guidelines stipulated in the air control regulations are met. However, it is advisable to notify the Division prior to such burning to determine that predicted ambient air quality and atmospheric conditions at the time of burning will be suitable and to alert the Division that burning is planned and will be properly conducted.	Louisiana Air Control Commission Regulations, Section 11.0.	
9. Louisiana Archaeological Survey and Antiquities Commission	<u>Preservation of Archaeological and Historical Resources</u>	Louisiana Rev. Stat; Sect. 41.1601-1613	Requires a Survey in the impacted area before construction commences.
10. Louisiana State Art, Historical and Cultural Preservation Agency	<u>State Historic Preservation Officer</u>	16 USC 469 -	
11. Louisiana State Division of Health Bureau of Environ-Mental Services	(a) Permit for installation of sewage treatment facilities and for disposal of solid and oily water wastes.	Chapter 10. Sanitary Codes, Sections 10.50 and 10.56.4, State of Louisiana	
	(b) Plans and specifications must be approved before construction of a water supply system is commenced.		
12. Louisiana State Department of Conservation	(a) Well drilling for brine production.	La. Rev. Stat. Sects. 30-1, et. seq.	
	(b) Injection wells for salt water or waste disposal.		
	(c) Permit required for storage of hydrocarbons.		
13. Louisiana State Department of Highways	Right-of-way for pipelines and power lines passing under or over highways.		
14. Louisiana State Land Office	(a) Right-of-way for pipeline crossing state-owned lands and navigable waterways.	La. Rev. Stat. Sects. 41:1173-1174	
	(b) Surface lease for storage and transportation of oil and gas.		

Table 9.2 Regulatory Bodies and Their Jurisdictional Concerns (continued)

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
15. State of Louisiana Department of Public Works	(a) Levee Leakage - for pipeline crossing, construction of ramps for access to the pipeline; construction of a dock.	La. Rev. Stat. Sect. 38.1 et seq.	
	(b) Permit to lay pipelines under or across navigable waterways or across stream.		
	(c) Letters of objection or no objection concerning construction of barge facilities and tanker facilities.		
16. Louisiana State Fire Marshal	(a) Approval of plans and specifications for all barge facilities, tanker facilities, and pipeline construction.	La Rev. Stat. Sects. 40:1561-1563 41:1262-1269	
17. Not Established	Compliance with Coastal Zone Management Plan, when adopted.		
18. Louisiana Wildlife and Fisheries Commission	Commission will submit letter of objection or no objection to Corps; consultation and coordination with Commission required.	La. Rev. Code Title 56	
<u>Local</u>			
19. Calcasieu Parish Policy Jury	(a) Permits required for construction of docks, pipelines, and buildings to existing dock and new tanker facilities.		
	(b) Approval required for crossing roads, ditches, canals, and waterways during pipeline construction.		

9.3 PARTIES FROM WHICH COMMENTS WERE REQUESTED

As a part of the review process for the Environmental Impact Statement, comments have been requested from the departments, agencies, and organizations listed below:

Federal Agencies

- Appalachian Regional Commission
- Department of Agriculture
- Department of the Army
- Department of Commerce
- Department of Defense
- Department of Energy
  - (10 Regional Offices)
- Council on Environmental Quality
- Federal Power Commission
- U.S. Fish & Wildlife Service
- Department of Health, Education & Welfare
- Advisory Council on Historic Preservation
- Department of Housing and Urban Development
- Department of the Interior
- Interstate Commerce Commission
- Department of Labor
- National Marine Fisheries Service
- National Science Foundation
- Nuclear Regulatory Commission
- Department of State
- Tennessee Valley Authority
- Department of Transportation
- Department of the Treasury
- Water Resources Council

State Agencies

- Louisiana State Clearinghouse
- Louisiana Department of Justice
- Texas State Clearinghouse
- New York State Office of Energy Analysis

Local Government Agencies

- Calcasieu Parish Policy Jury, Louisiana
- Cameron Parish Policy Jury, Louisiana
- Jefferson County, Texas
- Orange County, Texas

Individuals and Organizations

Acadiana Planning & Development District
Allied Chemical Company
American Fisheries Society
American Littoral Society
American Petroleum Institute
Baton Rouge Audubon Society
Calcasieu Rod & Gun Club
Cameron Parish Policy Jury
Canoe & Trail Shop, Inc.
Center for Law & Social Policy
Council on the Environment
The Courier
Ecology Center of Louisiana, Inc.
Edison Electric Institute
Electric Power Research Institute
Energy Conservation Committee
Environmental Defense Fund
Environmental Policy Center
Environmental Resources & Energy Group
Florida Audubon Society
Friends of the Earth
Fund for Animals
Gulf States Marine Fisheries Commission
Institute for Gas Technology
Interstate Natural Gas Association of America
Izaak Walton League of America
Kaiser Engineers
League of Women Voters
LOOP
Louisiana Offshore Terminal Authority
Louisiana Power & Light
Louisiana Wildlife Federation
National Association of Counties
National Audubon Society
National League of Cities
National Parks & Conservation Association
National Resource Defense Council
National Wildlife Federation
New Orleans Audubon Society
RESTORE, Inc.
Seadock, Inc.
Sierra Club - Delta Chapter
Sierra Club - Gulf Coast Regional Conservation Committee
Sierra Club - New Orleans Group
South Central Planning and Development Commission
The Times - Picayune
U.S. Conference of Mayors

9.4 PARTIES FROM WHOM COMMENTS WERE RECEIVED

The comments on the Draft Environmental Impact Statement addressed herein are those received by the Department of Energy within the allotted comment period. Copies of those letters of comment are contained in Appendix J.

Comments received by DOE after the expiration of the time period also have been considered in the preparation of this Final Environmental Impact Statement to the degree practicable within such time limits, but are not addressed individually within Chapter 9.

9.4.1 Federal Agencies

9.4.1.1 Department of the Army New Orleans District Corps of Engineers

Comment a -

"One of the primary adverse impacts resulting from project implementation is that which would affect the project area's water quality and, consequently, the dependent aquatic organisms. As noted on page 2-15 of the text, there are numerous aquatic systems which would be affected by the proposed project. It is apparent that neither water quality nor planktonic and benthic samples were taken and analyzed from these systems prior to preparation of the draft EIS. Review and inclusion of available literature containing references to the general project area's water quality and aquatic organisms are appropriate to establish a historical setting. However, to adequately assess water quality impacts, current and more site specific information are required."

Response

The construction of oil storage facilities at Sulphur Mines would be a short-term activity and the associated water quality impacts would be temporary. Increased levels of sediment and other pollutants in the water column would impact only a limited area and would settle out shortly after the termination of construction activities. Planktonic species and a majority of benthic species reproduce rapidly and, therefore, the populations of these organisms would quickly return to normal levels. Because of the temporary nature of these impacts and the rapid recovery which populations would undergo, it is not felt that additional collection of field data is appropriate.

Comment b -

The statement on page 2-62, paragraph one, is incorrect. The reference cited is dated 1956. A saltwater barrier, located at Calcasieu River between miles 38.6 and 43.5, was constructed in 1968 and has been in operation since that time.

Response

The appropriate change has been made in the text.

Comment c -

"The references to rare and endangered species should be changed to threatened or endangered species."

Response -

The appropriate changes have been made in the text.

Comment d -

"The environmental setting section should include a discussion of the vector problems and potentials that exist in the area of the project influence. The impact section should provide a discussion as to how the proposed project would affect these vector problems. Construction activities would produce habitat for vectors, especially mosquitoes. Project completion would possibly impede normal surface drainage and also would create temporary and permanent impoundments suitable for vector production."

Response -

The report has been supplemented with appropriate information. See Section 2.4.1.5 and 3.4.6.

Comment e -

"Section 6 should address the biological resources which would be lost due to filling of marshlands and clearing and/or filling of woodlands required for construction of the storage facility, support buildings, saltwater reservoirs, pipelines, roads, pumps, and other permanent appurtenances."

Response -

The development of the Sulphur Mines storage facility would not require the filling of marshlands. The oil distribution pipeline would cross 0.4 mile of marsh. This marsh acreage would be regraded and natural revegetation would occur following construction. Section 6 has been supplemented with information concerning clearing of woodland acreage.

Comment f -

"The New Orleans District should be listed with the Galveston District in table 9.2 on page 9-5."

Response -

The suggested addition to table 9.2 has been made.

9.4.1.2 Environmental Protection Agency

Comment a -

"The statement indicates that past removal of sulphur from the caprock of the salt dome may have formed cavernous voids which could collapse and cause subsidence, resulting in severe damage to surface structures such as pipelines, storage tanks, and holding ponds. We would suggest that coring be obtained from areas of sulfur removal to obtain comprehensive load test data in order to provide information for the design of any proposed surface structure. Applicant's intentions on this matter should be addressed in the Final EIS."

Response -

Sulfur has not been mined at Sulphur Mines for almost 50 years (except for short trial periods in the early 1960's) and nearly all subsidence occurred at the time of mining. The wellheads for all storage caverns are on the perimeter of the subsidence area and there are no plans to build any SPR facilities in the subsided area.

Comment b -

"The proposed project of emplacing crude oil for storage as a strategic reserve into the Sulphur Mines dome would result in large quantities (24 million barrels per cycle; five cycles) of brine displaced. The method of brine disposal presented in the EIS is emplacement of brines into the subsurface by deep well injection. The data presented in the EIS to support this method of disposal is insufficient to allow for an effective evaluation of the environmental impact of such an operation."

EPA Administrator's Decision Statement #5 (Federal Register, Volume 39, No. 69, April 9, 1974) specifies the amount and type of data that a potential injector should provide in order to establish the acceptability of any proposed well injection. The amount and type of data required by EPA are essentially similar to that required under Title 30, Revised Louisiana Statutes, or under the proposed Underground Injection Control Regulations (as per Draft Regulations, August 31, 1976).

Because the State of Louisiana has assumed primary enforcement authority of the Water Supply Program of the Safe Drinking Water Act, and is expected to assume primacy for the Underground Injection Control (UIC) program, we recommend that the above mentioned data be organized in a format similar to that required for permit application for an underground injection operation, as specified in Statewide Order 29-B of the Louisiana Department of Conservation, Oil and Gas Division. We are requesting that the selected technical data should be provided to the public in the form of a "By request" appendix to the Final EIS. In addition, close coordination should be afforded EPA and the Louisiana Department of Conservation in all phases of data requirements, collection and presentation. DOE's intention to comply with the above recommendation should be adequately addressed in the Final EIS."

Response -

If Sulphur Mines is selected as a storage site, SPR will supply all data required in applying for a permit for underground injection of brine. This information will be presented to the Louisiana Department of Conservation at a public hearing, as was done for both the West Hackberry and Bayou Choctaw sites, subsequent to their selection for SPR use. Furthermore, DOE will continue to maintain communications with the Department of Conservation during the development of all SPR facilities.

Comment c -

"The alternate method of brine disposal is strongly recommended. This method of disposal, as proposed in the subject document, involves marketing the displaced brine as a chemical feed stock. An industrial consumer has already indicated the acceptability of the brine for its use, and its willingness to purchase the displaced brine through an existing pipeline network. It is strongly urged that the alternate method of brine disposal be adopted for the Sulphur Mines project. The applicant's intentions on this matter should be addressed in the Final Statement."

Response -

To date PPG has not indicated a willingness to purchase brine displaced from the storage caverns at Sulphur Mines for the lifetime of the project. This alternative would be pursued if the site is selected. However, for a worst-case analysis, it is assumed that all brine would be injected. The text has been clarified to reflect this.

Comment d -

"The draft statement did not adequately address the Spill Prevention Control and Countermeasure (SPCC) Plan as required under code of Federal Regulations at 40 CFR 112 (Oil Pollution Prevention; Non-transportation Related Onshore and Offshore Facilities). The Final EIS should state that an SPCC Plan will be prepared within six months after the facility begins operation and shall be fully implemented no later than one year after operation begins and will meet the requirement of 40 CFR 112."

Response -

It has been stated in the text that an SPCC plan that complies with 40 CFR 112 will be prepared.

Comment e -

"The statement indicates sewage treatment and disposal would be through an existing septic tank system operated by Allied Chemical Corporation. The statement should indicate if the Allied facilities will be adequate for the additional domestic waste loads created by the SPR program at Sulphur Mines."

Response -

Sewage disposal during site preparation and construction would utilize portable chemical toilet systems. Wastes from these would be disposed of in an existing septic tank system at the Allied Facility.

In the event that these wastes are enough to overload these existing systems, the waste sewage would be transported to an acceptable municipal or industrial treatment system for disposal.

The text has been revised to reflect these considerations.

Comment f -

"The applicant should provide substantive evaluation of all proposed and alternate actions in regard to their potential to adversely impact the wetlands. In conclusion, the selected project action should be shown to be the most practicable of all alternative actions and will provide possible mitigative measure to minimize harm to the wetlands. In the selection of any right-of-way, efforts should be made to avoid wetlands utilization. Adequate response on this matter should be provided in the Final EIS."

Response -

For the disposal of dredge spoil from the Salt Water Reservoir, the 6-acre disposal area has been relocated to a site northwest of the Salt Water Reservoir which is made up of grassland with some brushwood. Therefore no marshland would be impacted due to spoil disposal from the Salt Water Reservoir enlargement.

Further study has indicated that much of the impact on wetlands acreage, due to the disposal of dredge spoil resulting from crossings of waterways by the oil pipeline, may be avoided if disposal sites are properly sited using available non-wetlands acreage.

The only alternative would be to transport spoil from these sites to a Corps of Engineer designated spoil disposal area. The nearest such area in which the easement rights are active is on the Calcasieu River near Lake Charles approximately 9 miles to the northeast. Except for the ICW the waterways involved are not navigable at the pipeline crossing points. Movement of spoil from such areas would require tracked vehicles which in turn would cause some damage to the surface environment.

Besides spoil disposal, the other primary concern is the actual crossing of marshes. The route would cross only approximately 1500 feet of marshland. The construction activity would temporarily impact vegetation and benthic organisms along the pipeline route. However, there would not be permanent alteration or loss of wetlands. Therefore, DOE does not believe that the impact of construction along the proposed route is significant.

Comment g -

With the passage of the Clean Air Act Amendments of 1977, several changes were made in emission regulations which may be applicable to the Sulphur Mines Salt Dome project. The section of the EIS addressing Federal Emission Regulations should be revised to reflect these changes with particular regard to prevention of significant deterioration (PSD) and review of emission offset policy applicability to storage tanks. In addition, Table 3.18 no longer represents the new standards for the PSD in a Class II area. New PSD standards include all criteria pollutants (i.e., Sulphur Dioxide (SO_2), Total Suspended Particulates (TSP), Non-methane hydrocarbons, (NMHC), Nitrogen Oxide (NO_x), Carbon Monoxide (CO), and Photochemical Oxidants (O_3). These standards should be addressed in the Final EIS.

Response -

The Test has been revised to include the changes in air emission regulations. Regarding Table 3.18, PSD standards have not yet been established for criteria pollutants other than those listed in that Table.

Comment h -

"On page 3-66, it is noted that violations of the National Air Quality Standards (NAAQS) would not occur as a result of the proposed facility. However, on the preceding page, modeling calculations show that indeed the 3-hour standard for non-methane hydrocarbons (NMHC) will be exceeded due to ship loading, unloading, and ballasting operations. This discrepancy should be clarified and possible control measures to prevent these violations should be discussed in the final statement."

Response -

The dome site facility alone would not result in violation of short term and annual ambient air quality standards for hydrocarbons. However, during tanker loading and unloading operations at Sun Terminal, the 3-hour NMHC standard would be exceeded out to a downwind distance of approximately five kilometers. The annual frequency of these violations is estimated to be less than three percent with the most impact occurring west of the terminal facility. It is anticipated that during adverse meteorological conditions, reduction of terminal hydrocarbon emission is required. Several alternative measures can be applied to reduce hydrocarbon emission at Sun Terminal. These include (1) the installation of tall venting stacks, (2) the utilization of vapor recovery and emission control equipment, (3) reduce the tanker loading and unloading rates, and (4) the combination of the above measures. These measures are currently being studied in detail. DOE will determine at a later date which are practicable and should be implemented to reduce impacts.

Comment i -

In the discussion of the interpretative ruling of December 21, 1976, on page 3-53, the name "Emission Trade-Offs" is incorrectly used since it is more commonly referred to as "Emission Offsets." This discrepancy in terminology should be corrected in the final statement.

Response

The appropriate text change has been made.

Comment j -

The levels of environmental noise tabulated on page C-3 of the Draft EIS have been labelled as "established guidelines," from EPA. This phrase, "established guidelines," is incorrect. Rather, this table reflects "identified levels" which are requisites to protect public health and welfare with an adequate margin of safety for both activity interference and hearing loss. Furthermore, the noise levels cited in this table do not constitute a regulation, specification, or standard. This discrepancy should be corrected in the Final Statement.

Response

The appropriate text change has been made.

9.4.1.3 Department of Health, Education and Welfare

Comment a -

"We are concerned about impacts on the quality of the local water supply... Care must be taken to minimize the suspension of toxic compounds which may occur from erosion of dredged materials during dredging operations."

Response

Section 2.2.2.1 of the Draft EIS states that municipal water for the city of Sulphur, located 2.5 miles east of the site, and the city of Lake Charles, ten miles east of the site, is drawn from the Chicot Aquifer. None of the surface water bodies in the vicinity of the site are classified for use as public water supply.

Construction of the oil pipeline would involve dredging across Bayou Choupique, the Intracoastal Waterway, Wing Gully and Spring Gully. None of these water bodies are classified for use as public water supply (see Section 2.2.1 and Appendix D-2). Section 3.2.1.3 states that earth movement during site preparation would result in the introduction of sediment into Bayou d'Inde and the Calcasieu River, however, neither of these water bodies are classified for use as public water supply (see Appendix D-2). Therefore it is not felt that dredging activities would adversely impact the quality of public water supply systems.

Comment b -

"There is also a potential of aquifer contamination during the deep well injection of brine. A program should be established to monitor these pollutants in affected waters." (In reference to potable ground water supply.)

Response

Discussions of the potential for water quality impacts on potable groundwater appear in Section 2.2.2, 3.2.2.2, and Appendix D, Section D-7 and D-8. The likelihood of freshwater aquifer contamination as a result of deep well brine injection appears from these discussions to be remote especially since a design change has moved the brine disposal field farther from the dome and any improperly plugged wells that may exist near the dome.

Monitoring of water is routinely performed by the Water Department of the City of Sulphur, Louisiana and the Greater Lake Charles Water Company. Tests are made for iron, magnesium and pH. Although salinity is not monitored during treatment, it would be detected by consumers if there was an increase. Millions of barrels of saltwater have been injected into subsurface aquifers throughout Calcasieu Parish, and industrial wastes have been injected near Lake Charles. The water company indicated that contamination of potable water supply has not occurred as a result.

9.4.1.4 Advisory Council on Historic Preservation

Comment

Pursuant to Section 102(2)(C) of the National Environmental Policy Act of 1969 and the Council's "Procedures for the Protection of Historic and Cultural Properties" (36 C.F.R. Part 800), we have determined that your DES does not contain sufficient information concerning historic and cultural resources for review purposes. Please furnish the following data indicating:

Compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470f, as amended, 90 Stat. 1320).

The environmental statement must demonstrate that either of the following conditions exists:

1. No properties included in or that may be eligible for inclusion in the National Register of Historic Places are located within the area of environmental impact, and the undertaking will not affect any such property. In making this determination, the Council requires:

--evidence that you have consulted the latest edition of the National Register (Federal Register, February 1, 1977, and its monthly supplements);

--evidence of an effort to ensure the identification of properties eligible for inclusion in the National Register, including evidence of contact with the State Historic Preservation Officer, whose comments should be included in the final environmental statement. The State Historic Preservation Officer for Louisiana is Ms. Sandra Thompson, Old State Capitol, North Boulevard, Baton Rouge, Louisiana 70801.

2. Properties included in or that may be eligible for inclusion in the National Register are located within the area of environmental impact, and the undertaking will or will not affect any such property. In cases where there will be an effect, the final environmental impact statement should contain evidence of compliance with Section 106 of the National Historic Preservation Act through the Council's "Procedures for the Protection of Historic and Cultural Properties" (36 C.F.R., Part 800).

Response

The February 1, 1977 Federal Register and its monthly supplements have been consulted and it was determined that no archaeological or historic sites at the Sulphur Mines site or along the pipeline route are included in the National Register. A letter from the Division of Archaeology and Historic Preservation confirms that no "known archaeological or historic sites [exist] along the proposed pipeline route."

If Sulphur Mines is selected as an SPR site, a professional archaeologist will inspect the site and pipeline route to determine the presence or absence of archaeological resources. It will also be determined if properties eligible for inclusion in the National Register exist on the site or along the pipeline route.

9.4.1.5 United States Department of the Interior

Comment a -

Pages 1-5 and 1-7: In paragraphs 1.2.1 and 1.2.4, respectively, there is mention of both current brine production and the potential for development of perhaps five additional solution cavities in the future. The draft does not mention existence of an evaporation and salt processing plant in the vicinity, or plans for operation of such facilities for processing brine into commercial products.

Response

The brine produced at Sulphur Mines is transported approximately 7 miles to a chemical plant in the city of Lake Charles. There are no brine processing facilities at Sulphur Mines and there is no need to build facilities on site even if brine production continues.

Comment b -

Page 2-11: Under Sulphur Production it is mentioned that there have been "occasional attempts to resume sulphur production at Sulphur Mines dome." No sulphur production is currently underway, but there is implication in the draft that mineable amounts of sulphur remain in the cap rock. We point out that should it be possible that additional sulphur mining might be permitted in the cap rock, further subsidence would be likely which could impact on any future processing facility yielding salt products.

Response

The sulphur mining operations in the early 1960's met with many technical difficulties and were unprofitable. Those involved in those operations indicate that it is economically impracticable to mine sulphur now or within the design life of the SPR facilities at Sulphur Mines.

Comment c -

"This section (Section 2.2.1) would be improved by the deletion of the discussion of habitats and associated organisms that will not be affected by the proposed project or the various alternatives. A more detailed discussion of the fauna of the project site and alternative sites should be included in this section."

Response

Section 2.2.1 contains discussion of the water quality of the surface water systems which would be impacted by proposed activities. Section 2.4 contains discusion of the habitats and the potentially impacted organisms which are characteristic of these water bodies. It is not felt that it is necessary to repeat the discussion of species and ecosystem in Section 2.2.1.

Comment d -

Page 2-16: Local ponds and reservoirs are recognized as being in the immediate vicinity of the Sulphur Mines site. The recreation potential of these bodies should be addressed. According to the Statewide Comprehensive Outdoor Recreation Plan (SCORP), the region has a need for freshwater fishing and other water-oriented recreation.

Response

In Section 3.2 it is stated that the large reservoir near the site is on private property and the use is not subject to Federal or state regulations. The same holds true for the other water bodies on site. All were constructed for industrial purposes and have no public recreational value.

Comment e -

Page 2-95, section 2.6.1: The draft statement is inadequate in its consideration of archaeological resources. Undisturbed land in the project area should be inspected by a professional archaeologist to determine the presence or absence of archaeological resources. This would include the proposed 17-mile pipeline and 1.0 mile water-supply line. The final statement should indicate that such a survey was made, and should cite the name and institution of the investigator. If no archaeological sites were evident, it should be so stated. If sites were recorded, there should be information regarding the nature and significance of the sites and the effect of the project on such sites. If the project will adversely affect significant archaeological resources, there should be a plan of action cited to mitigate this effect. If any archaeological resources are encountered during construction, operations should cease at the discovery site and a professional archaeologist should be consulted as to the significance of the material.

Response

If Sulphur Mines is selected as an SPR site, a professional archaeologist will inspect the site and the pipeline route to determine the presence or absence of archaeological resources. It will also be determined if properties are eligible for inclusion in the National Register exist at the site or along the pipeline route. If such resources exist, the Site Environmental Action Report (SEAR) for Sulphur Mines, which is now in preparation, will outline the approved procedures for mitigating the impact of facility construction and operation on historical and archaeological resources.

Comment f -

Page 2-95, section 2.6.2: It is stated that Ward Eight Park, Interstate 210 Park, and Prien Lake Park could conceivably be impacted by tanker oil spills.

Response

This comment is incorrect and has been deleted from the text. Tankers will not be used in the Calcasieu River for the SPR program.

Comment g -

Executive Order 11990, issued by President Carter on May 24, 1977, directs Federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands. In view of this Executive Order, we recommend that FEA utilize the alternate spoil site discussed on page 1-15 for dredge material from Salt Water Lake, and attempt to locate suitable alternate sites for dredge spoil from the oil pipeline which would avoid the destruction of wetlands.

Response

The alternate dredge spoil disposal site will be used as the prime disposal site as suggested. This has been indicated in the text. DOE does not have the responsibility of selecting spoil disposal sites. The dredge spoil generated during pipeline construction will be disposed of in areas designated by the U.S. Army Corps of Engineers and will be in compliance with the Executive Order and other pertinent state and Federal regulations.

Comment h -

The text should more adequately outline the potential impacts on ground water resulting from the removal of the materials between the cavern and the salt-dome margin and should suggest any possible mitigation of effects.

Response

A discussion of the impacts has been added to the text in Section 3.1.2.

Comment i -

Pages 3-24 and 3-25, Section 3.2.2.1: This section should contain an assessment of the effects, if any that water withdrawal from the Sabine River Diversion Canal will have on salinities in downstream estuarine waters.

Response

As noted in Subsection 3.2.2.1 the displacement water withdrawn from the Sabine River Diversion Canal System represents less than 4 percent of the system's capacity (340 cfs). Current (as well as planned) industrial demands for water from the canal system are well within this capacity and thus the displacement water withdrawal process would not cause the canal system to exceed its design capacity. The environmental effects of the Sabine River Diversion Canal System have been covered in an earlier study (see reference 16, Chapter 2). It is not generally practical to develop a separate analysis of the effects of less than 4 percent of the total water used by that system.

Comment j -

Pages 3-25 through 3-30, section 3.2.2.2: The brine displacement rate (4,900 gallons per minute) will apparently exceed the combined injection-well capacity (4,000 gallons per minute). The fate of the excess brine, if any, should be discussed along with anticipated environmental impacts.

The section on surface-water contamination should include a discussion of the potential effects on plants and animals of surface leakage of brine through poorly plugged old wells or well blowouts.

Response

The brine displacement rate should be 2,900 gallons per minute instead of 4,900 gallons per minute. The text has been corrected in this respect.

Due to the relocation of the brine disposal field, only one abandoned well (drilled to a depth equal to or greater than the injection depth interval) is located within 5000 feet of the injection wells. Thus, the likelihood of surface leakage from improperly plugged abandoned wells is greatly reduced. Subsurface leaking would go undetected.

If leakage does occur, the rate of flow will depend upon a number of parameters as noted in the text (Subsection 3.2.2.2). Based on the calculations provided in Appendix D.7, the flow rates from an improperly plugged well would very likely be less than 1 barrel per day.

The chemical characteristics of the leaking water should be the same as those of the native waters of the disposal aquifer and not those of the injected brine. Such characteristics are not well defined for the deep aquifers in the Sulphur Mines region but salinities on the order of 35 to 45 ppt. appear reasonable.

A short term surface leak of 35 to 45 ppt salt water from an abandoned well would not have long term adverse impacts on the terrestrial ecosystems in the vicinity of the spill. Salt does affect plant growth by causing the accumulation of certain ions in toxic concentrations in plant tissue or by altering the plants mineral nutrition. The two latter effects would not be evidenced for a small spill unless extremely dry weather conditions prevented normal leaching of the salt out of the soil.

Grasses and herbaceous vegetation would be impacted by a spill but recovery would take place following rain induced leaching of salt from the soil. A small spill would probably not impact higher terrestrial plants because their root systems are generally deeper and cover a greater area than roots of grass and herbaceous plants.

Soil faunal communities would experience debilitating effects from a small spill. But populations would recover rapidly following rain induced leaching.

Comment k -

Page 3-30: We believe that the point should be raised concerning the need of adequate control during brine injection because high pressure in the aquifer could be detrimental to existing oil production and future exploration in this zone. Oil is currently being produced from horizons having the same depth as the intended brine-injection aquifer, and care should be taken to prevent brine from entering the oil-producing zones.

Response

As discussed in Section 3.2.2.2, the sub-surface disposal of brine will increase the pressure of the disposal formation which, in turn, will increase the pressure of any oil or gas accumulation that exists in the same formation. An increase in pressure in an oil or gas accumulation could have the following effects:

1) Increased Potential for Blow-out During Drilling Operations

High formation pressures are routinely drilled into by the petroleum industry. A well sometimes blows out when a formation containing unanticipated high pressures is penetrated. Therefore, the pressuring up of formations could increase the likelihood of a blow-out of future oil or gas wells. This is a rather remote possibility because:

a) Five cycles of brine injection are anticipated to increase disposal formation pressures by only 500 psi or so. This is a rather modest pressure increase that can certainly be contained by modern drilling methods.

b) The general area around the disposal wells is 'mature' with respect to oil and gas exploration and development. It is likely that no oil or gas wells will be drilled in the vicinity in the future.

c) A prudent oil or gas operator would certainly make himself aware of the massive disposal project and would take the proper precautions when drilling in the area.

2) Interference with Existing Oil and Gas Operations

An increase in formation pressure caused by brine injection would probably have a beneficial over-all effect on oil and gas reservoirs existing in the disposal formation. However, interference by unauthorized injection is expressly prohibited by the rules of the Louisiana Department of Conservation primarily because while the overall effect may be beneficial, the effects on individual land owners and operators is difficult to assess. In other words, some might benefit, but at the expense of others.

It is not currently known if the disposal zone is in communication with oil and gas zones. Communication is difficult to assess because of the lack of a detailed geologic study showing the structural location of the disposal zones with respect to the zones currently producing oil and gas. Furthermore, it is not certain that such a meaningful study could be made because of the relative lack of geologic control in the area of the disposal wells.

The disposal area, as of December, 1977, is about one mile further from the Sulfur Mines Field than was the disposal area described in the Draft Environmental Impact Statement of September, 1977. The potential for interference is reduced because of the increased likelihood of faults isolating the disposal area from the producing field. It is not known whether there are any faults, but the likelihood is greater merely because of the increased separation between the disposal area and the dome.

Without evidence to verify that the disposal zones are not in communication with oil or gas, it will be necessary to monitor adjacent oil and gas operations to insure that no effect occurs. This can be accomplished by a routine monitoring of the pressures of these wells. Any abnormal increase in pressure would be strong evidence of interference.

Comment 1 -

Page 3-31 and 3-32: It is stated that the proposed subsurface brine-disposal reservoirs may have been raised to near the surface during the emplacement of the salt dome. Thus, escape of saturated brine could result at the surface or into freshwater aquifers. The statement should utilize existing well logs or geophysical data to demonstrate the distribution of the saline aquifers or should propose specific methods of demonstrating their attitude before the disposal facilities are constructed.

Response

Based on the review of several additional well logs, the relationship of the deeper aquifers to the salt dome appears to be satisfactorily represented by the cross section in Figure 2.3 of the text. As in other domes of the Gulf Coast deep sediments are uplifted and faulted by the salt stock. Paine* (1966) shows the Heterostegina zone, an important biostratigraphic unit in southwestern Louisiana, is uplifted from a depth of 6,800 feet one mile from the dome to 5,500 feet at the dome. This is slightly more deformation than shown in Figure 2.3, however, it suggests that sediments proposed for brine disposal at depths from 5,000 to 7,000 feet are not uplifted more than about 1,300 feet by the dome. Furthermore, the steep sides of the dome in the interval between -5000 feet and the surface suggests the dome penetrates the sediments with minor uplift.

Thus, the concern that deep disposal aquifers are in contact with shallow fresh-wateraquifers or possibly even the surface seems unwarranted. It is still possible that deep aquifers are interconnected with shallower sands due to the structural complexities of the dome. It is possible that brine injection will result in some vertical fluid displacement because of the domal structure. This cannot be predicted with certainty. However, the chances of such an occurence are reduced by the movement of the disposal well location from the original site to the new location more than a mile southwest of the dome.

Comment m -

Pages 3-72 through 3-75, section 3.4.2: "Quantitative data on fishes and plankton should be collected in the Sabine River Diversion Canal to support, if possible, the claim that withdrawals from the canal will have relatively little impact on aquatic life."

* Paine, W.R., "Stratigraphy and Sedimentation of the Hackberry Shale and Associated Beds of Southwestern Louisiana," Transactions of the Gulf Coast Association of Geological Societies, pp. 261-274, Lafayette, Louisiana 1966.

Response

As noted in the response to Comment i, the water drawn from the Sabine Diversion Canal System represents less than four percent of the system capacity. Due to the rapid natural reproduction rate of phytoplankton and the small percentage of the population which would be entrained, there would be no long term adverse impact. It is not felt that collection of quantitative data is necessary to supplement this analysis.

The water intake velocity will be 0.5 feet per second or less. At this velocity, fish and other mobile aquatic organisms can resist the induced current and avoid entrainment or impingement. For these reasons, it is felt that the data provided in the draft statement is sufficient.

Comment n -

Page 3-80, Section 3.4.5: "The red-cockaded woodpecker has been documented as occuring in Calcasieu Parish. The statement should be supplemented to indicate whether surveys of the work area have been conducted to determine its presence or absence. If surveys have not been conducted, they should be initiated soon and the results included in the final statement. In addition, formal consultation with the Fish and Wildlife Service should be initiated if these surveys determine the presence of the red-cockaded woodpecker in or immediately adjacent to the project area, in accordance with Section 7 of the Endangered Species Act of 1973."

Response

The Strategic Petroleum Reserve Office has been working in close coordination with appropriate field offices of the U.S. Fish and Wildlife Service. If the Sulphur Mines storage facility plans are approved for construction and operation, this cooperation will continue throughout each stage of project development. Careful watch will be maintained for any biologically sensitive species. If it is determined that alteration of project plans would be necesary for the protection of any sensitive species, appropriate actions would be taken.

Comment o -

Page 3-93, Section 3.7.1: A discussion of oil and brine spills experienced at the existing West Hackberry Salt Dome Strategic Petroleum Reserve facility should be added to this section.

Response

An SPCC plan will be prepared for each oil storage site in the SPR program. The documentation of the spills that have occurred at West Hackberry will be in an appendix to the plan for West Hackberry as required. When completed, the SPCC plan and its appendices will be available to the public.

Comment p -

"Cleanup operations in marshes might involve controlled burning instead of mechanical removal of vegetation. The former method will alow revegetation in a short time, while the latter method will have much more long-term adverse effects."

Response

Controlled burning can be used under only limited circumstances and its effectiveness remains questionable. Environmental impact associated with this technique include destruction of all organisms inhabiting the burned area, uncontrolled fire, and temporary severe air quality impacts. Burning is usually not considered an environmentally preferred technique. The advantages and disadvantages of this and other cleanup measures are discussed in Section 3.7.3 of the report.

Comment q -

Page 4-1, Section 4: A statement should be included indicating the degree of commitment to implementation of each of the mitigating measures listed in Table 4.1.

Response

It is DOE's intention to develop crude oil storage facilities that are environmentally acceptable and in full compliance with pertinent state and Federal regulations which are included in section 4 of this Final EIS. It is the purpose of the EIS to assess the potential for impacts and discuss mitigative measures, above those required by law, which are available to lessen those impacts in order that an informed decision concerning the desirability of using the site can be made. If a decision to select the site is made, incorporation of appropriate mitigative measures will occur through DOE's environmental planning process.

Comment r -

Pages 7-38 through 7-42: The draft statement considers in detail the areally important Chicot freshwater aquifer as a potential source of displacement water but does not adequately evaluate the use of slightly salty or brackish ground water from the Evangeline aquifer--although it does mention that the use of the water from the Evangeline aquifer would minimize the potential for contaminating the Chicot aquifer. Inasmuch as the water of the upper part of the Evangeline has a salinity of only 3 to 10 ppt. (p. 2-31 through 2-34), the statement should more adequately evaluate the salinity and aquifer characteristics of the Evangeline--using geophysical logs if other data are not available.

<u>Response</u>

The use of the slightly saline water from the upper 300 feet of the Evangeline Aquifer, as stated in subsection 7.2.3, would minimize the potential for contaminating the overlying fresh water sands of the Chicot Aquifer. As noted in subsection 2.2.2.1, the yield of an individual well from the sands of the Evangeline Aquifer is estimated to be from 500 to 2,000 gallons per minute. Thus, 3 to 11 wells would be required to supply displacement water at a rate of 5,145 gallons per minute. Becuase the Evangeline Aquifer in the Sulphur Mines area is not suitable as a source of fresh water, very little use is currently made of its water. The withdrawal of 5,145 gallons per minute would not represent any appreciable impact on the subsurface water environment over the time intervals involved in the program.

9.4.1.6 <u>Nuclear Regulatory Commission</u>

<u>Comment</u>

"However, there may be a conflict between the use of salt mines for storing petroleum and their use for storing radioactive waste. A consideration of this possible conflict in the final statement would be useful."

<u>Response</u>

A statement indicating that there are no plans to store radioactive waste at Sulphur Mines has been added to the text.

9.4.2 State Agencies

9.4.2.1 <u>The Texas Department of Agriculture</u>

<u>Comment</u>

"We do not identify any problems with this DEIS as far as our Agency is concerned."

<u>No Response</u>

9.4.2.2 Texas General Land Office

Comment

"The Environmental Impact Statement... has no great impact on the General Land Office since the dome is located in Calcasieu Parish, Louisiana."

No Response

9.4.2.3 Texas State Department of Highways & Public Transportation

Comment

"The Department does not have any comments to offer."

No Response

9.4.2.4 Texas Industrial Commission

Comment

"We have no negative comment on the above cited draft statement. We feel that the Strategic Petroleum Reserve is of national importance, and by all means should be implemented as soon as possible.

No Response

9.4.2.5 Texas Parks and Wildlife Department

Comment

"Our review... indicates that the project impacts will occur in the State of Louisiana. Therefore, we have no comment to offer on this document."

No Response

9.4.2.6 Texas Department of Water Resources

Comment a

"The oil storage project site and related leach water and brine disposal facilities... would not have any adverse environmental impacts on the ground or surface water resources of the State of Texas."

No Response

Comment b

"The technical assessment of potential local impacts relative to land subsidence, ground contamination, oil spillage, and brine disposal is objective. Particularly, we support the technical assessment of the potential hazards... presented on pages D-40 through D-41 of the referenced DEIS."

No Response

APPENDIX A

AIR QUALITY ANALYSIS ASSUMPTIONS AND MODELS - SULPHUR MINES

APPENDIX A.1

SHORT-TERM AND LONG-TERM EMISSION RATES FOR SULPHUR MINES AND SUN TERMINALS.

TABLE A.1-1
Site-Specific Short-Term Emission Rates
and Source Locations for Sulphur Mines.

SOURCE DESCRIPTION	LOCATION	POLLUTION EMISSION RATE (g/s)+					
		HC	PARTICULATE	SO_2	NO_2	H_2S (1)	CO
Construction							
1. Drill Rigs	Dome Site	0.3	0.3	0.2	3.8	--	0.8
2. Tankage	Sun Terminal						
a. Surface Preparation		--	0.8 (2)	--	--	--	--
b. Paint Application ration		2.1	--	--	--	--	--
1. Crude Oil Transfer							
a. Loading -	VLCC to Tanker	30.3 (3)	--	--	--	--	--
Ships	Sun Terminal	15.2 (3, 4)	--	--	--	--	--
b. Ship - Ballasting	Sun Terminal	11.6 (3,5,6)	--	--	--	--	--
c. Ship Engines (7)							
i. Loading	Sun Termminal	0.1	0.9	12.5	4.0	--	0.09
ii. Unloading	Sun Terminal	0.2	1.3	19.2	6.2	--	0.1
d. Tug Engines - Ship Assistance(8) (Loading and Unloading)		1.6	3.4	1.4	2.4	--	2.0

1. It is assumed that the crude will be sufficiently weathered to contain insignificant amounts of H_2S
2. It is assumed that 40% of the total emissions fall out very close to the source
3. Based upon a maximum daily flow rate of 250,000 bbls/day
4. 50% of the oil is distributed by pipeline and 50% by tanker during drawdown
5. Ballast 40% of capacityort
6. 100% of daily flow ill be delivered by tanker to Sun Terminal
7. See Table C-3
8. Two tugs assist per tanker

\+ See Section 3 for short-term assumptions

TABLE A.1-1 (Cont.)
Site-Specific Short-Term Emission Rates
and Source Locations for Sulphur Mines.

SOURCE DESCRIPTION	LOCATION	POLLUTION EMISSION RATE (g/s)+					
		HC	PARTICULATE	SO_2	NO_2	H_2S (1)	CO
Operation (Cont'd.)							
2. Tankage (2)							
a. Surge Tanks (2)	Sun Terminal						
i. Standing Storage		0.35	--	--	--	--	--
ii. Withdrawal		3.6	--	--	--	--	--
b. Ballast Water Separation Tanks (3)							
i. Standing Storage		0.16	--	--	--	--	--
ii. Withdrawal		neg.*	--	--	--	--	--
c. Oil Slop Tanks (4)							
i. Standing Storage		0.04	--	--	--	--	--
ii. Withdrawal		neg.	--	--	--	--	--
3. Pipeline							
a. Pump Seals	Dome Site	0.1	--	--	--	--	--
	Dome Site	0.2	--	--	--	--	--
b. Valves	Dome Site	0.02	--	--	--	--	--
	Dome Site	0.024	--	--	--	--	--

1. It is assumed that the crude wil be sufficiently weathered to contain insignificant amounts of H_2S.
2. 2 - 200,000 bbl tanks
3. 2 - 55,000 bbl tanks
4. 2 - 7,500 bbl tanks

* See Section 3 for short-term assumptions

\+ neg. = negligible

TABLE A.1-2
Site-Specific Annual Emission Rates
and Source Locations for Sulphur Mines.

SOURCE DESCRIPTION	LOCATION	POLLUTION EMISSION RATE (g/s)*					
		HC	PARTICULATE	SO_2	NO_2	H_2S (1)	CO
Surge Storage Tank	Sun Terminal						
1. Standing Storage		0.29	--	--	--	--	--
2. Withdrawal		0.2	--	--	--	--	--
Ballast Water Separation Tanks	Sun Terminal						
1. Standing Storage		0.12	--	--	--	--	--
2. Withdrawal		neg.**	--	--	--	--	--
Oil Slop Tanks	Sun Terminal						
1. Standing Storage		0.35	--	--	--	--	--
2.. Withdrawal		neg.	--	--	--	--	--
Pipeline (2)							
1. Pump Seals	Dome Site	0.1	--	--	--	--	--
	Dome Site	0.2	--	--	--	--	--
2. Valves	Dome Site	0.02	--	--	--	--	--
	Dome Site	0.04	--	--	--	--	--

* Emission rates are based on the assumption that all sources emit continuously at a fixed average annual rate
** Neg. = negligible
1. It is assumed that the crude will be sufficiently weathered to contain insignificant amounts of H_2S
2. See Table D-3

TABLE A.1-2 (Cont.)

Site-Specific Annual Emission Rates and Source Locations for Sulphur Mines.

SOURCE DESCRIPTION	LOCATION	POLLUTANT EMISSION RATE (g/s)*					
		HC	PARTICULATE	SO_2	NO_2	H_2S (1)	CO
Operation							
• Tanker Loading (2)	VLCC to Tanker	8.4 (3)	--	--	--	--	--
	Sun Terminal	4.2	--	--	--	--	--
• Tanker Ballasting (5)	Sun Terminal	2.0 (6)	--	--	--	--	--
• Ship Engines - Loading (3,7)	Sun Terminal	0.01	0.07	1.0	0.3	--	0.01
• Ship Engines - Unloading (7)	Sun Terminal (6)	0.02	0.1	1.5	0.5	--	0.02
• Tug Engines (8)							
i Tanker Loading	Sun Terminal (3)	0.04	0.08	0.03	0.06	--	0.05
ii Unloading	Sun Terminal (6)	0.06	0.1	0.05	0.09	--	0.08

* Emission rates are based on the assumption that all sources emit continuously at a fixed average

1. It is assumed that the crude will be sufficiently weathered to contain insignificant amounts of H_2S
2. $\frac{(69 \text{ deliv/yr})(4.2 \text{ T/del})(2000\#/\text{T})(454\text{g}/\#)}{3.15 \times 10^7 \text{ sec/yr}}$
3. 50% of oil distributed by tanker
4. $\frac{(890\ \#/\text{del})(286 \text{ del/yr})(454 \text{ g}/\#)}{3.15 \times 10^7 \text{ sec/yr}}$
5. $\frac{(69 \text{ del/yr})(1.3 \text{ T/del})(2000\ X/\text{T})(454 \text{ g}/\#)}{3.15 \times 10^7 \text{ sec/yr}}$
6. 100% of oil delivered by tanker to Sun Terminal
7. $\frac{(69 \text{ del/yr})(\text{short-term emission rate/del})(3600 \text{ sec/hr})}{3.15 \times 10^7 \text{ sec/yr}}$; See Table 3-8 for example
8. $\frac{(6 \text{ hr assistance/del})(2 \text{ tugs})(69 \text{ del/yr})(3600 \text{ sec/hr})(\text{emission factor})}{3.15 \times 10^7 \text{ sec/yr}}$

TABLE A.1-2 (Cont.)

Site-Specific Annual Emission Rates
and Source Locations for Sulphur Mines.

SOURCE DESCRIPTION	LOCATION	POLLUTANT EMISSION RATE (g/s)*					
		HC	PARTICULATE	SO_2	NO_2	H_2S (1)	CO
Construction							
1. Site Preparation	Dome Site(3)	--	22.8(2)	--	--	--	--
	Dock Site(4)	--	29.6(2)	--	--	--	--
	Pipelines(5)	--	25.6(2)	--	--	--	--
2. Unpaved Roads(6)	Dome Sites	--	73.2(2)	--	--	--	--
	Dock Sites	--	73.2(2)	--	--	--	--
3. Paved Roads(7)							
4. Heavy Construction Equipment(8)	Dome Site(9)	0.01	0.01	0.01	0.2	--	0.04
	Dock Site	0.01	0.01	0.01	0.2	--	0.04
5. Light Duty Vehicles(10)	Dome Site(9)	0.01	neg.**	neg.	0.02	--	0.2
	Dock Site	0.01	neg.	neg.	0.02	--	0.2

* Emission rates are based on the assumption that all sources emit continuously at a fixed average annual rate.
** neg. = negligible
1. It is assumed that the crude will be sufficiently weathered to contain insignificant amounts of H_2S
2. It is assumed that 40% of the total emissions fall out very close to the source
3. 100 acres; $g/s = \frac{(1.2T/ac \cdot mp)(11\ mo.)(.6)(100\ acres)(2000\#/T(453.6g/\#)}{3.15 \times 10^7\ sec/yr}$
4. 130 acres; g/s same as #3 above
5. 112 acres; g/s same as #3 above
6. Based on the use of 1120 miles of unpaved roads by employees at the dome and dock during the main 8-hr shift
7. No paved roads.
8. See Table 3-7
9. Values prorated for 11-month construction period.
10. See Table B-3

TABLE A.1-2 (Cont.)

Site-Specific Annual Emission Rates
and Source Locations for Sulphur Mines.

SOURCE DESCRIPTION	LOCATION	POLLUTANT EMISSION RATE (g/s)*					
		HC	PARTICULATE	SO_2	NO_2	H_2S (1)	CO
6. Drill Rigs (3)	Dome Site	0.3	0.2	0.2	3.4	--	0.7
7. Tankage	Sun Terminal						
a. Surface Preparation		--	0.1 (2,4)	--	--	--	--
b. Paint Application		0.2 (5)	--	--	--	--	--

* Emission rates are based on the assumption that all sources emit continuously at a fixed average annual rate.
1. It is assumed that the crude will be sufficiently weathered to contain insignificant amounts of H_2S
2. It is assumed that 40% of the total emissions fall out very close to the source.
3. 335 days x 20 hrs/day x (0.75 capacity) x Emission Factor (g/hp·hr) x (1 yr/3.15x10^7 sec) x 1500 hp
4. 750 nozzle-hrs x 1000 #/hr x 0.01 x 0.6 x 454 g/# x 1 yr/3.15x10^7 sec)
5. 5.7 tons/coat x 2 coast x 1120 #/ton-paint x 454 g/# x (1 yr/3.15x10^7 sec)

APPENDIX A.2

Air Quality Analysis Assumptions and Models - Sulphur Mines

The pollutants associated with the proposed project which impact ambient air quality may be treated as continuous emissions over periods of hours to a year. A binormal (two dimensional Gaussian) continuous plume dispersion model is used to compute the pollutant concentration downwind from the source. Estimates of dispersion are those of Pasquill as restated by Gifford. [1,2,3]

Atmospheric Dispersion Model

The equation developed to calculate downwind pollutant concentrations has been simplified for this analysis to estimate only ground-level concentrations. Equation 1 is the generalized form of this Gaussian dispersion model for 10-minute sampling averages.

$$\chi(x,y,z=o;H) = \frac{Q}{\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \quad \text{Eq.}$$

where:

$\chi(x,y,z;H)$ is the pollutant concentration in micrograms per cubic meter ($\mu g/m^3$) at a distance x meters downwind, a cross wind distance of y meters, a height above the ground of z=0 meters for an emission source effective stack height of H meters;

Q is the rate of emissions in grams per second (g/sec) from the source;

u is the average wind speed in meters per second (m/sec)

σ_y is the standard deviation in meters of the distribution of material in the plume in the horizontal or crosswind (y) direction, at a distance of x meters downwind; and

σ_z is the standard deviation in meters of the distribution of material in the plume in the vertical (z) direction, at a distance of x meters downwind.

Values for σ_y and σ_z, at a given distance downwind and for a given atmospheric stability class were read off the graphs published in the workbook of Atmospheric Dispersion Estimates[1] for rapid evaluation of these parameters. The stability class assumed for all calculations is the neutral stability class D, which generally characterizes the atmospheric stability of night time hours. Night hours are marked by restrictions to turbulent diffusive spreading in both the lateral and vertical directions. Materials released under nighttime or D stability conditions will rise until its initial buoyancy and vertical momentum are dissipated. It then will drift downwind for sometimes as far as tens of kilometers.[5] These conditions are believed to represent a conservative case estimate of downwind pollutant concentrations and the use of the D stability class also assures the application of Equation 1 is within its intended confidence limits. The wind speed is taken to be the mean of the low wind speed group at Lake Charles with D stability. In addition, a stable layer is assumed to exist at 100 meters altitude to hold the pollutant close to the ground. This raises concentrations at 10 kilometers by about 60 percent, but does not affect concentrations at shorter distances downwind.

Sampling Time Corrections

Corrections for wind meander encountered during sampling averages for periods up to 24 hours can be applied to the 10-minute sample average concentrations calculated by Equation 1. The relationship between concentration and sampling time is shown in equation 2.

$$\frac{\chi(t)}{\chi(10\ \text{minutes})} = \left(\frac{10\ \text{minutes}}{t}\right)^{p}, \qquad \text{Eq. 2}$$

where p has been found to be between 0.17 and 0.2.[1] Equation 2 is most appropriately applied when the average wind direction is constant over the averaging time. The correction factor to estimate 1-hour, 3-hour and 24-hour sample averages from 10-minute averages are 0.74, 0.61 and 0.43, respectively. These are evaluated assuming the exponent p equals 0.17 for the conservative case.

These sampling average correction factors cannot be extended to one year to obtain estimates of annual average concentrations. Instead, the annual average downwind concentrations are given by the following equation:

$$\chi_{an} = \left(\frac{Q}{\sigma_z X}\right)\left(2.03 \times 10^{6} \sum_i \frac{f_i}{u_i}\right) \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad \text{Eq. 3}$$

where:

χ_{an} is the annual average concentration at x meters downwind; in $\mu g/m^3$;

Q, σ_z, x and H are the same variables as in Equation 1;

u_i is the average wind speed of the i^{th} wind speed group in m/sec;

f_i is the fraction of the time that the wind is blowing in the chosen direction of the i^{th} speed group.

For concentrations in Table A-1, three stack heights have been assumed; H = 13.4m for storage tanks, H = 10 m for transport vessels, and H = 3m for construction equipment. The values of f_i and u_i are taken from wind rose data compiled for the STAR program[4] at Lake Charles. The most frequent atmospheric stability, D, and the most frequent wind direction within this D stability class were used.

Crosswind Distances and Concentrations

The calculation of either the concentration at a distance x meters downwind and y meters crosswind or the calculation of the crosswind distance y for a particular concentration can be done using the following relationships:

$$y_p = \sigma_y \sqrt{2 \ln \frac{100}{p}} \quad \text{and} \quad \chi(x, y_p, z=o; H) = \frac{p}{100} \; \chi(x, y=o, z=o; H)$$

where:

σ_y is the horizontal standard deviation at a distance x meters downwind;

y_p is the crosswind distance at x meters downwind at which the pollutant concentration is equal to "p" percent of the centerline concentration $\chi(x,o,o;H)$.

Inversely, to solve for what percent of the centerline concentration is the concentration at a specified x and y, then:

$$p\% = (100) \exp\left[-\frac{1}{2}\left(\frac{y_p}{\sigma_y}\right)^2\right]$$

Treatment of Area Sources as Point Sources

Equation 1 was developed for point sources. Emission rates from large crude oil storage tanks are not correctly described as a point source with an equal emission rate. Therefore some correction must be made to maintain some realism in the estimated downwind concentrations from storage tank emissions. The method used has been to estimate the distance downwind at which the tank would "appear" as a point source. This is done by assuming the horizontal standard deviation at such a virtual point source is given by $\sigma_{y_o} = D/4.3$, where D is the diameter of the tank and σ_{y_o} is the horizontal standard deviation at the virtual point source distance from the tank, x_o meters. The virtual point source distance x_o is then read from the graphs of the horizontal standard deviation of the material in the plume vs. distance from the source in the Workbook of Atmospheric Dispersion Estimates.[1] Once the value of x_o is determined for the size of the tank and the appropriate atmospheric stability class, then the computations of the downwind concentrations use the same model as expressed in Equation 1, with different variables. For simplicity, Equation 1 is reproduced here with the different variables identified as follows:

$$\chi(x_r, y, z{=}o; H) = \frac{Q}{\pi \sigma_{y_i} \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_{y_i}}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

where:

x_r = actual or real distance downwind from the tank

σ_{y_i} = the horizontal standard deviation of the matter in the plume evaluated at a distance, $x_i = x_r + x_o$ (meters) downwind from the tank; and

Q, u, H and y are the variables as defined for equation 1.

Table A.2-1 **Annual Sector Averaged Concentrations for Three Stack Heights**

Winds at Lake Charles[4] - D Stability

$\bar{u}_i$(m/sec)	f_i (%) S Winds
0.771	0.1328
2.57	0.8288
4.37	2.8290
6.49	2.9249
9.77	0.3288
>10.80	0.0342
	7.0785

Centerline, Groundlevel X an/Q (sec/m^3) at x Kilometers Downwind

S Winds (for Q in g/sec)

x (km)	Xan/Q;H=13.4m	Xan/Q;H=10m	Xan/Q;H=3m
.5	2.71	3.05	3.48
1	.91	0.94	0.98
2	.315	0.320	0.326
5	.073	0.073	0.073
10	.024	0.024	0.024

REFERENCES

1. U. S. Environmental Protection Agency, "Workbook of Atmospheric Dispersion Estimates," Office of Air Programs, Publication No. AP-26, Revised 1970.

2. Pasquill, F., "The Estimation of the Dispersion of Windborne Material," Meteorological Magazine, 90, 1063, 1961.

3. Gifford, F. A., "Uses of Routine Meteorological Observations for Estimating Atmospheric Dispersion," Nuclear Safety, 24, 1961.

4. "Annual wind, Distribution by Pasquill Stability Classes; STAR program," Station #13970, Baton Rouge, Louisiana, January 1955 - December 1964. National Climate Center, Asheville, North Carolina.

5. U. S. Atomic Energy Commission, "Meteorology and Atomic Energy, 1968," Division of Technical Information, TID-24190.

APPENDIX B

AIR POLLUTION MONITORING DATA

APPENDIX B

AIR POLLUTION MONITORING DATA

The following data was provided by the Louisiana Air Control Commission. This data represents the most thorough and consistent monitoring results the Commission has compiled to date. The suspended particulate data monitoring capabilities are the most refined in the State, and a few key locations are operable for oxidant and sulfur dioxide monitoring. This data is included in the last two tables representing Lake Charles. This is representative only of the maximum concentrations measured during the stations on-time, as well as the number of violations of the standards recorded.

<u>Monthly Suspended Particulate Sampling Data (1975)</u>

Table B-1	Lake Charles	Suspended Particulate Sampling Data
Table B-2	Lake Charles	Suspended Particulate Sampling Data
Table B-3	West Lake	Suspended Particulate Sampling Data

<u>Continuous Oxidant (O_3) Monthly Sampling Report (1975)</u>

Table B-4	Lake Charles	Monthly Oxidant (O_3) Concentrations

<u>Continuous Sulfur Dioxide (SO_2) Monthly Sampling Report (1975)</u>

Table B-5	Lake Charles	Monthly Sulfur Dioxide (SO_2) Concentrations

Table B-1 Monthly Suspended Particulate Sampling Data

CITY: Lake Charles

SITE: Corner-Ryan and McNeese

YEAR: 1975

SAROAD CODE: 191600002

1° Standard 24-hr. max. = 260 μg/m^3

SAMPLING TYPE:

2° Standard 24-hr. max = 150 μg/m^3, Annual Geometric mean = 60 μg/m^3

NUMBER OF SAMPLES: 56

ANNUAL GEOMETRIC MEAN: 43

MONTH	DAY	24 HR. MEASURE μg/m^3
Jan	6	33
	12	22
	30	24
Feb.	5	31
	23	31
Mar.	1	38
	7	79
	13	54
	19	60
	25	121
	31	40
Apr.	6	50
	12	38
	18	68
	24	45
	30	28
May	6	45
	12	42
	18	67
	24	41
	30	18
June	5	49
	11	37
	17	33
	23	77
	29	40

MONTH	DAY	24 HR. MEASURE μg/m^3
July	5	47
	11	51
	17	44
	23	32
	29	44
Aug.	4	35
	10	27
	16	33
	22	37
	28	43
Sep.	3	85
	9	40
	15	70
	21	49
	27	68
Oct.	3	88
	9	48
	15	29
	21	52
	27	38
Nov.	2	41
	8	30
	14	83
	20	27
	26	42
Dec.	2	53
	8	37
	14	41
	20	51
	26	37

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-2 Monthly Suspended Particulate Sampling Data

CITY: Lake Charles SITE: 721 Prien Lake Road

YEAR: 1975 SAROAD CODE: 191600001

1^o Standard 24-hr. max. = 260 $\mu g/m^3$ SAMPLING TYPE: Population Oriented

2^o Standard 24-hr. max = 150 $\mu g/m^3$, Annual Geometric mean = 60 $\mu g/m^3$

NUMBER OF SAMPLES: 57

ANNUAL GEOMETRIC MEAN: 68

MONTH	DAY	24 HR. MEASURE $\mu g/m^3$
Jan.	6	99
	12	40
	24	98
	30	74
Feb.	5	57
	17	70
	23	39
Mar.	1	101
	7	86
	13	52
	19	79
	25	165
	31	81
Apr.	6	68
	12	100
	18	154
	24	215
	30	73
May	6	113
	12	74
	18	93
	24	126
	30	76
June	11	81
	17	129
	23	53
	29	40

MONTH	DAY	24 HR. MEASURE $\mu g/m^3$
July	5	46
	11	68
	17	64
	23	45
	29	54
Aug.	4	48
	10	37
	16	51
	22	55
	28	99
Sept.	3	85
	9	60
	15	83
	21	60
	27	79
Oct.	3	64
	9	51
	15	29
	21	96
	27	59
Nov.	2	59
	8	50
	14	79
	20	39
	26	39
Dec.	2	96
	8	41
	14	47
	20	52
	26	54

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-3 Monthly Suspended Particulate Sampling Data

CITY: West Lake SITE: 701 Johnson Street

YEAR: 1975 SAROAD CODE: 193180002

1° Standard 24-hr. max. = 260 μg/m³ SAMPLING TYPE: Population Oriented

2° Standard 24-hr. max = 150 μg/m³, Annual Geometric mean = 60 μg/m³

NUMBER OF SAMPLES: 55

ANNUAL GEOMETRIC MEAN: 57

MONTH	DAY	24 HR. MEASURE μg/m³	MONTH	DAY	24 HR. MEASURE μg/m³
Jan.	6	56	July	5	115
	12	27		11	93
	24	51		17	96
	30	48		23	57
				29	64
Feb.	5	17			
	17	42	Aug.	4	57
	23	35		10	56
				16	88
Mar.	1	103		22	47
	7	89			
	13	44	Sep.	15	66
	19	55		21	39
	25	146		27	76
	31	51			
			Oct.	3	63
Apr.	6	63		9	50
	12	50		15	29
	18	102		21	99
	24	75		27	52
	30	41			
			Nov.	2	47
May	6	97		8	36
	12	55		14	76
	18	96		20	25
	24	43		26	34
	30	45			
			Dec.	2	53
June	5	122		8	31
	11	71		14	43
	17	125		20	63
	23	52		26	38
	29	54			

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-4 Continuous Oxidant (O_3) Sampling Monthly Report

CITY: Lake Charles SAROAD CODE 191600001

YEAR: 1975

1° and 2° Standard: 1-hr. max. = 0.08 ppm

MONTH	HIGHEST	2ND HIGHEST	# VIOLATION	%TIME OBSERVED
January	0.0790 1/25/75	0.0290 1/19/75	0	74
February	0.0530 2/19/75	0.0470 2/27/75	0	97
March	0.0390 3/19/75	0.0370 3/16/75	0	97
April	0.0390 4/6/75	0.0290 4/8/75	0	34
May	0.0790 5/18/75	0.0680 5/12/75	0	98
June	0.0500 6/2/75	0.0450 6/6/75	0	88
July	0.1160 7/10/75	0.0990 7/8/75	14	87
August	0.1220 8/20/75	0.0990 8/31/75	8	97
September	0.0890 9/1/75	0.0850 9/12/75	3	96
October	0.1780 10/10/75	0.0730 10/12/75	7	53
November	0.1250 11/4/75	0.0750 11/5/75	4	98
December	0.0520 12/20/75	0.0450 12/3/75	0	98

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-5 Continuous Sulfur Dioxide (SO_2) Sampling Monthly Report

CITY: Lake Charles SAROAD CODE: 919600001

YEAR: 1975

1° Standard: 24-hr. max. = 0.14 ppm, Annual Geometric Mean = 0.03 ppm

2° Standard: 24-hr. max. = 0.10 ppm, Annual Geometric Mean = 0.02 ppm

MONTH	HIGHEST	2ND HIGHEST	# VIOLATION	%TIME OBSERVED
June	0.0300 6/28/75	0.0180 6/1/75	0	82
July	0.0250 7/8/75	0.0230 7/9/75	0	85
August	0.0450 8/20/75	0.0180 8/11/75	0	91
September	0.0200 9/28/75	0.0180 9/2/75	0	52
October	0.0440 10/10/75	0.0210 10/19/75	0	97
November	0.0150 11/24/75	0.0130 11/25/75	0	82
December	0.0440 12/20/75	0.0180 12/10/75	0	98

Source: Louisiana Air Control Commission, New Orleans, Louisiana

APPENDIX C

NOISE IMPACT CRITERIA AND ANALYSIS

APPENDIX C

NOISE IMPACT CRITERIA AND ANALYSIS

Definitions and Terminology

A-Weight - A frequency weighting network which is used in sound analysis to simulate the response of the human ear. (A-weighted sound levels are expressed in units of dBA).

Environmental Noise - By section 3 (11) of the Noise Control Act of 1972, the term "environmental noise" means the intensity, duration, and character of sounds from all sources.

Equivalent Sound Level - The level of a constant sound which, in a given situation and time period, has the same sound energy as does a time varying sound. Technically, equivalent sound level is the level of the time weighted, mean square, A-weighted sound pressure. The time interval over which the measurement is taken should always be specified.

Sound Level - The quantity of decibels measured by a sound level meter satisfying the requirements of American National Standards Specification for Sound Level Meters S1.4-1971. Sound level is the frequency-weighted sound pressure level obtained with the standardized dynamic characteristic "fast" or "slow" and weighting A, B, or C; unless indicated otherwise, the A-weighting is understood. The unit of any sound level is the decibel, having the unit symbol dB.

Sound Pressure Level - In decibels, 20 times the logarithm to the base ten of the ratio of a sound pressure to the reference sound pressure of 20 micropascals (20 micronewtons per square meter). In the absence of any modifier, the level is understood to be that of a mean-square pressure.

Symbols

L_{eq}	Equivalent A-weighted sound level over a given time interval.
L_d	Daytime equivalent A-weighted sound level between the hours of 0700 and 2200.
L_n	Nighttime equivalent A-weighted sound level between the hours of 2200 and 0700.
L_{dn}	Day-night average sound level - the 24-hour A-weighted equivalent sound level, with a 10 decibel penalty applied to nighttime levels.

i.e.,

$$L_{dn} = 10 \log \left[\frac{15}{24} \times 10^{\frac{L_d}{10}} + \frac{9}{24} \times 10^{\frac{L_n+10}{10}}\right].$$

FEDERAL GUIDELINES

The Federal Environmental Protection Agency has identified levels for limits of L_{dn} requisite for the protection of public health and welfare.*

Table C.1 Summary of Noise Levels Identified As Requisite to Protect Public Health And Welfare With An Adequate Margin of Safety

Effect	Level	Areas
Hearing Loss	$L_{eq}(24) \leq 70dB$	All Areas
Outdoor Activity	$L_{dn} \leq 55dB$	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq}(24) \leq 55dB$	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor Activity interference and annoyance	$L_{dn} \leq 45dB$	Indoor residential areas
	$L_{eq}(24) \leq 45dB$	Other indoor areas with human activities such as school, hospitals, etc.

$L_{eq(24)}$ represents the sound energy averaged over a 24-hour period.

L_{dn} represents the L_{eq} with a 10dB nighttime weighting.

*"Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, "USEPA, 550/9-74-004, March 1974.

Noise Measures

The descriptors L_{eq} and L_{dn} quantify those aspects of sound which have been found to correlate with cumulative community exposure to noise and community annoyance. Accordingly, the Environmental Protection Agency has selected Equivalent Sound Level (L_{eq}) for the purpose of identifying levels of environmental noise.

Equivalent Sound Level is formulated in terms of the equivalent steady noise level which in a stated period of time would contain the same noise energy as the time-varying noise during the same time period.

The mathematical definition of L_{eq} for an interval defined as occupying the period between two points in time t_1 and t_2 is:

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2(t)}{p_o^2} \, dt \right]$$

where p(t) is the time varying sound pressure and p_o is a reference pressure taken as 20 micropascals.

Analysis of Noise Impact from Construction Activity and Facility Operations

The exact determination of L_{eq} and L_{dn} requires a precise knowledge of the types of equipment used, the machine work cycles, scheduling, machine operating environment, and other factors which interact in a complex manner. In estimating noise impacts several simplifying assumptions have been made. It is assumed that the use of construction equipment on the site results in isotropic acoustic sources which have duty cycles and emission levels characteristic of a construction site type.

The construction site is viewed as a noise source consisting of equipment which is used for various intervals of time throughout the period of construction. The equipment is considered to be used in work cycles similar to those of similar past projects. The models for construction site configuration, sound propagation loss and equipment usage have been developed in detail by the Environmental Protection Agency.[1,2] For this project, the most appropriate model is that of construction for public works. The construction phases are:

- clearing
- excavation
- foundation
- erection
- finishing

The usage factors for the equipment used during each phase of general construction activity are given in Table C.1. Tables C.2 and C.3 show the equipment associated with pipeline and dock construction.

The model for construction site types locates all equipment in a circle 50 feet from a calculation point of reference. A simple propagation model in which noise is attenuated at a rate of 6 dB per doubling of distance has been assumed. Thus, around each construction site there exists a series of annuli which represent areas of greater attenuation. Because of the extraordinary low population density in the construction site areas, fractional impact calculations are not appropriate. Instead, impact zones about the sites have been constructed, using the noise measures of L_{eq} and L_{dn}

Pipeline construction is assumed to consist of discrete sites containing 1/8 mile lengths of pipeline construction. The equipment assumed for pipeline sites is shown in Table C.2.

Conventional pipeline equipment is shown for reference purposes. Pipeline construction is over varied land conditions, however, primarily swamp lands. A 10 dB reduction* has been used referenced to conventional equipment for pipeline construction noise because of the inherently quieter swamp land pipeline construction techniques.

The L_{eq} obtained using the model was converted to an L_{dn} for a 24-hour day and then converted to an annual L_{dn} by adding 10 log ($^N/365$) where N is the duration of construction in days. The sites are therefore viewed as complex noise sources with a determined annual value of L_{dn}.

Impact zones have been constructed and the land area has been examined for type of land use, i.e., residential, limited outdoor use, schools, playgrounds, etc. Where people are exposed to levels in excess of EPA guidelines

i.e. L_{dn} > 55 dB

L_{eq} (24) > 55 dB

a noise impact is indicated.

*SAI estimated reduction.

The analysis of site operations indicates that noise from equipment used during the operation of facilities is dominated by pump noise (Figure C.1).

Pumps at the site are to be located in a pump house which is assumed to have a concrete slab foundation and metal wall construction. A transmission loss of 33 dB is reasonable for metal wall construction. However, ventilation requirements will necessitate air ports which will reduce the transmission loss to approximately 23 dB.

TABLE C.1

USAGE FACTORS OF EQUIPMENT IN PUBLIC WORKS CONSTRUCTION *

Equipment **		Construction Phase: Clearing	Excavation	Foundation	Erection	Finishing	$L_{eq}(50')$ during work periods for each item, over one project
Air Compressor	[81]	1.0	1.0	.4	.4	.4(2)	79.0
Backhoe	[85]	.04	.4	–	–	.16	74.4
Concrete Mixer	[85]	–	–	.16(2)	.4(2)	.16(2)	80.7
Concrete Pump	[82]	–	–	–	–	–	–
Concrete Vibrator	[76]	–	–	–	–	–	–
Crane, Derrick	[88]	–	.1	.04	.04	–	73.8
Crane, Mobile	[83]	–	–	–	.16	–	69.7
Dozer	[87]	.3	.4	.2	–	.16	79.6
Generator	[78]	1.0	.4	.4	.4	.4	74.9
Grader	[85]	.08	–	–	.2	.08	74.1
Jack Hammer	[88]	.5	.5	–	.04	.1(2)	80.7
Loader	[79]	.3	.4	.2	–	.16	71.6
Paver	[89]	–	–	0.1	.5	–	81.4
Pile Driver	[101]	–	–	–	–	–	–
Pneumatic Tool	[85]	–	–	.04(2)	.1	.04	72.6
Pump	[76]	–	.4(2)	1.0(2)	.4(2)	–	75.7
Rock Drill	[98]	–	.02	–	–	–	82.6
Roller	[74]	–	–	.01	.5	.5	67.4
Saw	[78]	–	–	.04(2)	.04	–	63.4
Scraper	[88]	.08	–	.2	.08	.08	78.2
Shovel	[82]	.04	.4	.04	–	.04	71.1
Truck	[88]	.16(2)	.16	.4(2)	.2(2)	.16(2)	84.6
Fraction Hrs. at site		.14	.14	.29	.29	.14	

* Numbers in parentheses represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

** Numbers in brackets [ ] represent average noise levels [dBA] at 50 ft.

TABLE C.2

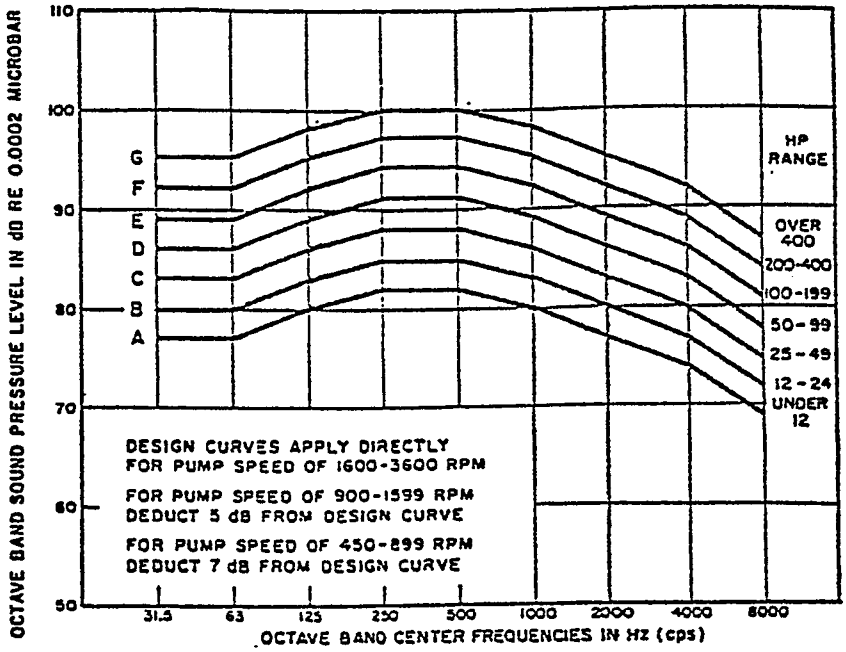
Equipment Used in Pipeline Construction

	Equipment	Number
Conventional:	Truck	(1)
	Backhoe	(1)
	Concrete Mixer	(1)
	Crane	(1)
Swamp:	Swamp Buggy	(2)
	Lay Barge	(1)

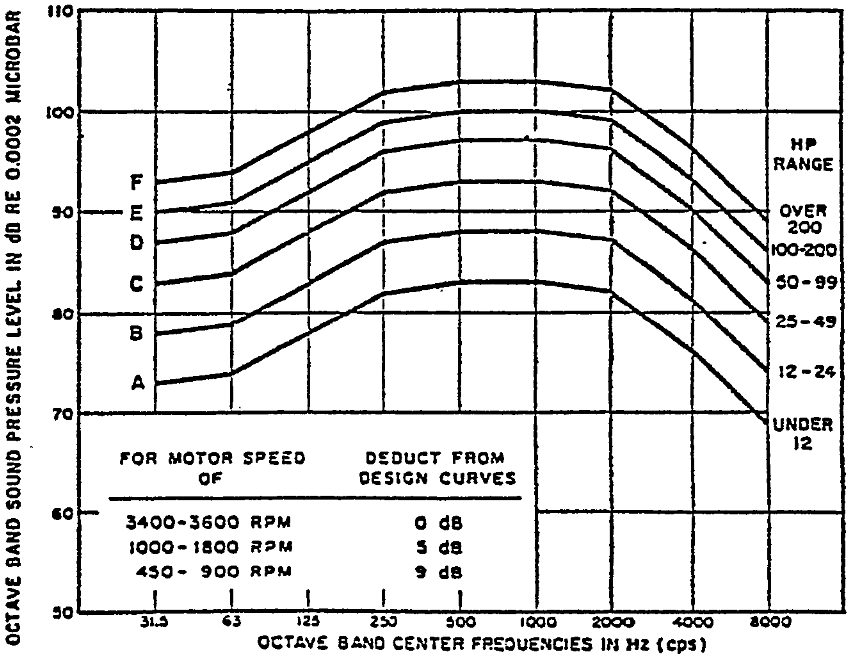
TABLE C.3

Equipment Used in Loading Dock Construction

Equipment	Number
Pile Driver	(2)
Truck	(2)



PUMP NOISE LEVELS AT 3-ft DISTANCE
(Suggested design curves for various powers and speeds)



NOISE LEVELS OF ELECTRIC MOTORS AT 3-ft DISTANCE (SUGGESTED DESIGN CURVES FOR VARIOUS POWER AND SPEED RANGES)

Figure C.1 Noise Levels of Pumps and Motors for Various Horsepower

Source: Dept. of Army Technical Manual TM-5-805-4

REFERENCES

1) Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances, U.S. Environmental Protection Agency, 12/31/1971.

2) Background Document for Proposed Portable Air Compressor Noise Emission Regulations, U.S. Environmental Protection Agency, October 1974.

APPENDIX D - WATER QUALITY

DATA AND ANALYSIS

APPENDIX D.1

PRECIPITATION DATA IN THE VICINITY

OF THE

SULPHUR MINES DOME

This appendix contains three figures concerning precipitation in the vicinity of the Sulphur Mines Dome. Figure D.1-1 presents the distribution of average winter-spring precipitation surplus in southern Louisiana based on monthly water balances for the 24-year period from 1945 to 1968. The corresponding summer-autumn precipitation surplus is given in Figure D.1-2. The average seasonal precipitation deficits for the same area are provided in Figure D.1-3.

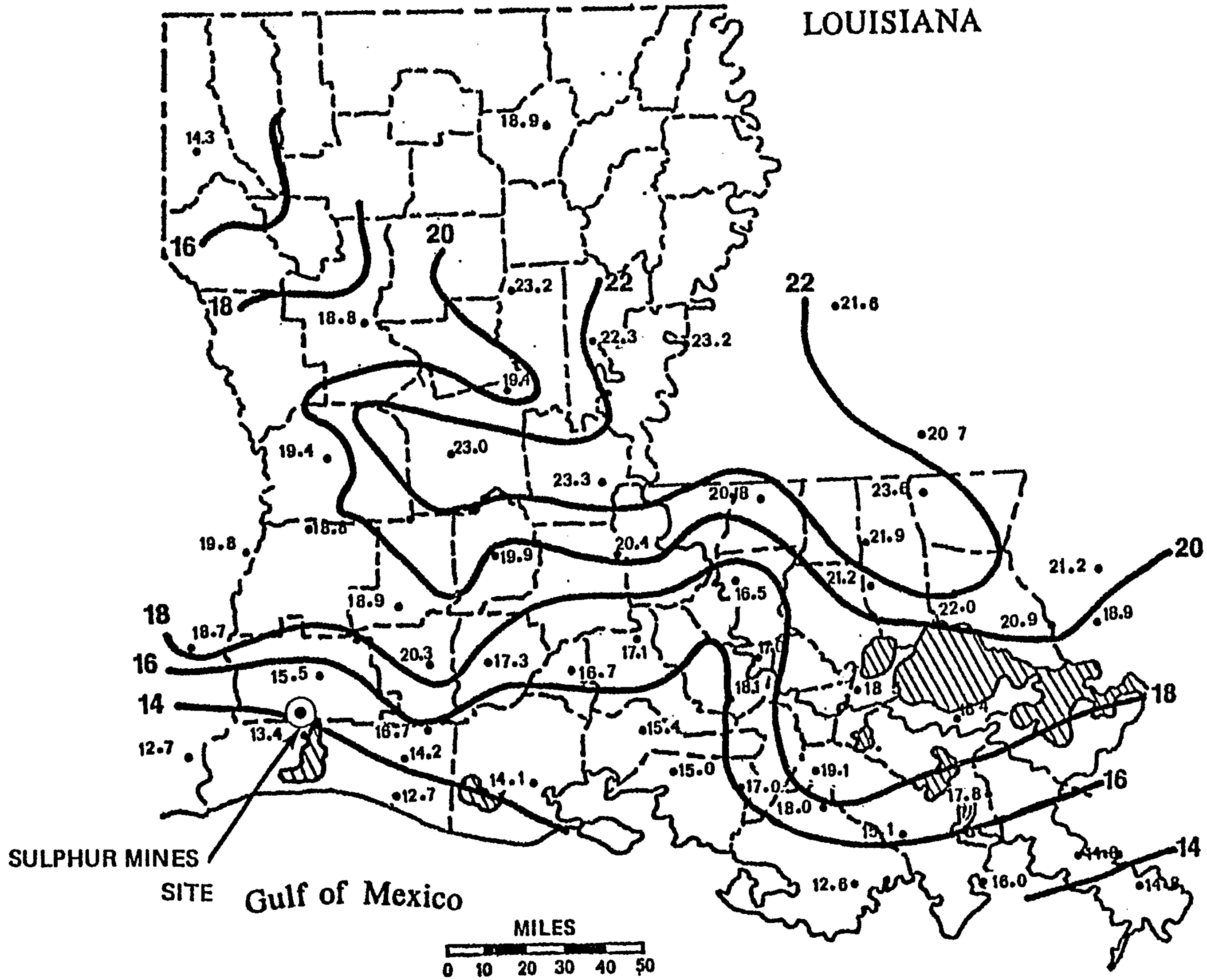


Figure D.1-1 Distribution of average winter-wpring precipitation surplus in southern Louisiana. Station averages were determined from monthly water balances for the 24-year period between 1945 and 1968. Surplus values are given in inches.

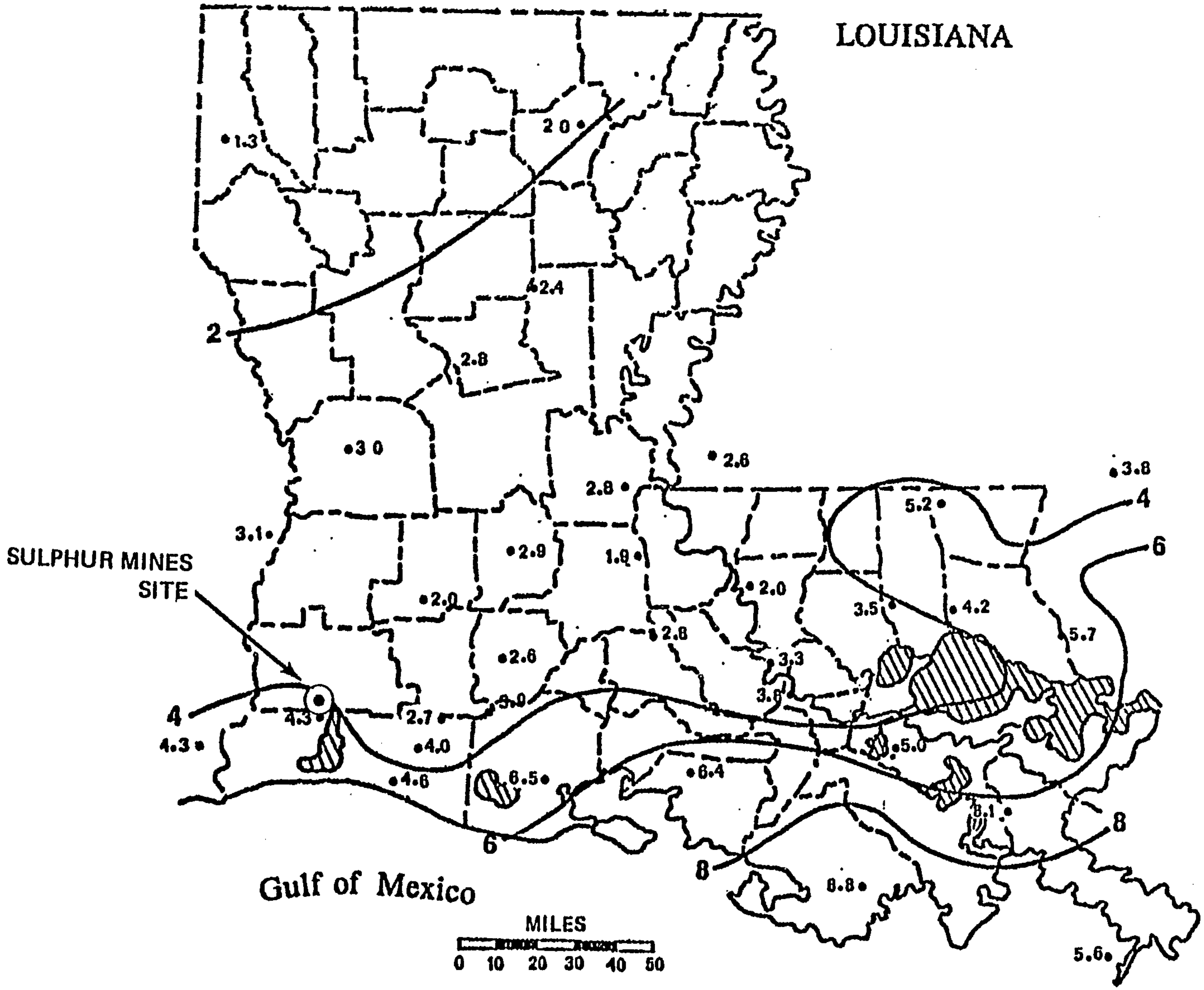


Figure D.1-2 Distribution of average summer-autumn precipitation surplus in south and central Louisiana. Station averages were determined from monthly water balances for the 24-years period between 1945 and 1968. Surplus values are given in inches.

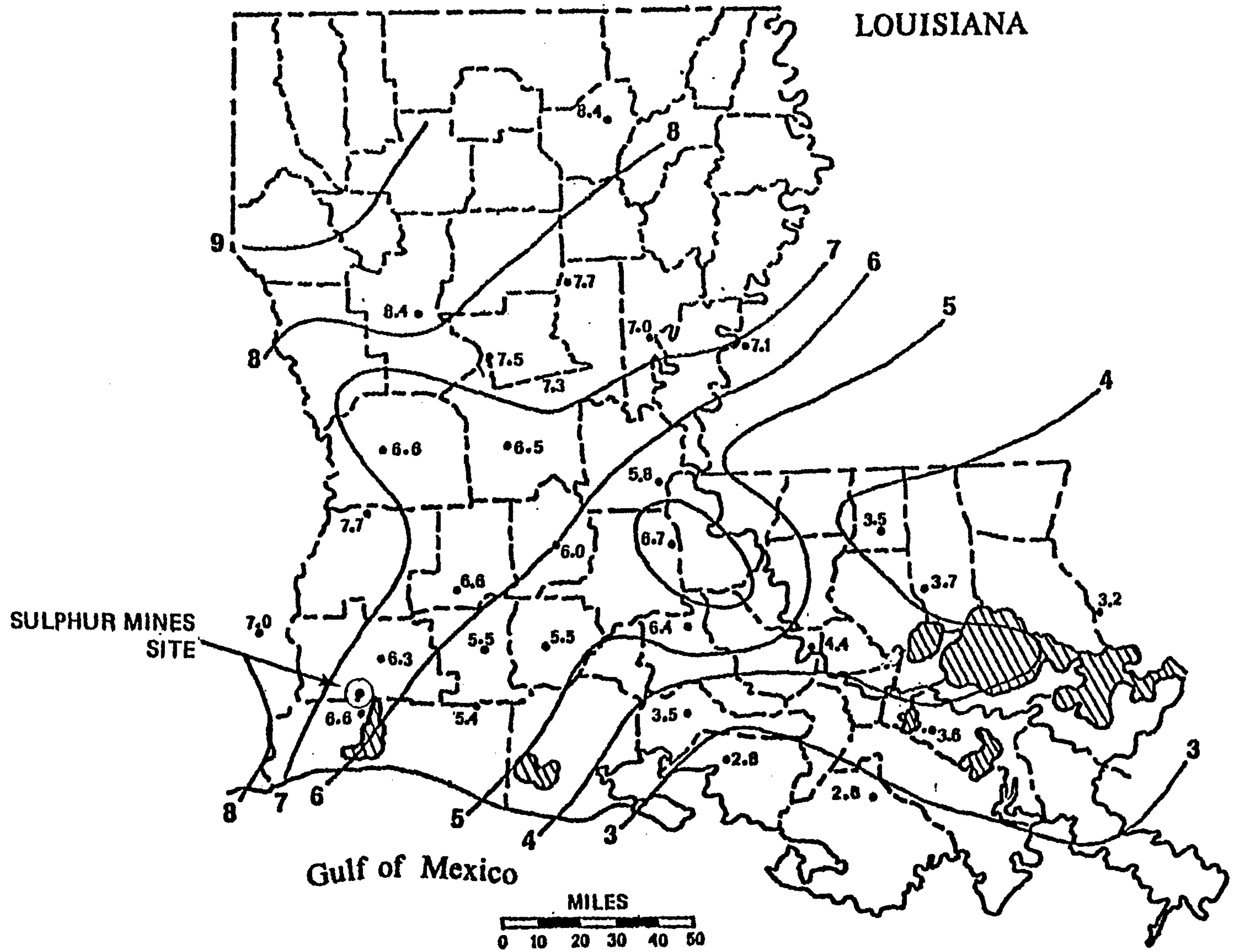


Figure D.1-3 Average seasonal precipitation deficits in south and central Louisiana. Station averages were determined from monthly water balances for the 24-year period between 1945 and 1968. Deficit values are given in inches.

APPENDIX D.2

WATER QUALITY STANDARDS

Five tables and a discussion of water quality standards comprise this appendix. Table D.2-1 presents State of Louisiana water quality criteria for the Calcasieu River, Sabine River, Houston River, and Bayou D'Inde. Table D.2-2 provides the proposed EPA numerical criteria for public water intake. The proposed EPA numerical criteria for water quality appropriate for freshwater aquatic life are included in Table D.2-3. The proposed EPA numerical criteria for water quality appropriate for marine water aquatic life is presented in Table D.2-4. Table D.2-5 provides certain recommended limits for concentrations of selected sediment parameters.

Discussion of Water Quality Standards

All specific State of Louisiana water quality criteria pertinent to the bodies of water in the vicinity of the Sulphur Mines site are provided in Table D.2-1. These criteria specify how the water of a bayou, canal, or river may be used, and also specify upper and/or lower limits for certain water quality parameters.

In addition to the specific water criteria set forth by the state, there exist certain numerical criteria proposed by EPA in 1973 for water quality in general. Table D.2-2 provides such criteria for domestic raw water supply while Table D.2-3 provides the criteria for freshwater aquatic life. The proposed EPA numerical criteria for water quality appropriate for marine water aquatic life is presented in Table D.2-4. The uses specified in the state criteria for a given water body determine which EPA criteria are applicable.

The situation regarding sediment quality criteria has undergone considerable revision in recent years. On 26 June 1973 the Environmental Protection Agency (EPA), Region VI, issued proposed regional bottom sediment criteria to be used in evaluating the suitability of the disposal of dredged or fill materials. On 15 October 1973 the EPA published in the Federal Register "Environmental Protection Agency Criteria for Evaluation of Permit Applications for Ocean Dumping" (40 CFR 227, 38 FR 28618). This criteria was to be used in evaluating the suitability of the discharge of dredged or fill material in the ocean, and, until guidelines were promulgated, in inland waters also. Dredged or fill material was considered to be unacceptable if the ratio of the constituent concentration in the standard elutriate to the constituent concentration in the receiving water was greater than 1.5. The standard elutriate results from a mixture of 4 parts unfiltered receiving water to 1 part dredged material.

On 6 May 1975 the EPA in conjunction with the Corps of Engineers published the inland water criteria for dredged or fill material entitled: "Navigable Waters Procedure and Guidelines for Disposal of Dredged or Fill Material" (40 CFR 230, 40 FR 19794). As previously stated, the Ocean Dumping Criteria's elutriate test required that after the material to be dredged had been vigorously mixed for 30 minutes with four parts of the water to which it is to be discharged and the supernatent from the mixture has been filtered through a 0.45 micron filter, the concentration of the constituents should be equal to or less that

1.5 times the concentration of those same constituents in the water before mixing. The new proposed (6 May 1975) Navigable Water Criteria allowed for application of a 10:1 dilution of the standard elutriate. Mathematical expressions of the above relationships are as follows:

$$\frac{C_e}{C_w} \leq 1.5$$ (based on 40 CFR 227, 38 FR 28618)

$$\frac{(0.1\ C_e + 0.9\ C_w)}{C_w} < 1.5$$ (based on 40 CFR 230, 40 FR 19794)

where C_e = Concentration from the standard elutriate test (dissolved)

C_w = Concentration in the receiving water (dissolved)

The newer proposed guidelines (40 CFR 230, 6 May 1975) were revised on 5 September 1975 (40 CFR 230, 40 FR 41292). These new interim final guidelines, entitled "Environmental Protection Agency - Navigable Waters - Discharge of Dredged or Fill Material," have eliminated both The 1.5 elutriate criteria as well as the 10:1 elutriate dilution of the May 6 guidelines. As a substitute, the new guidelines recommend (1) comparing the elutriate to applicable narrative and numerical guidance contained in such water quality standards as are applicable by law, (Tables D.4-1, D.4-2, and D.4-3) and, (2) possibly performing a total sediment chemical analysis. In addition, the guidelines note that EPA and the Corps of Engineers in the coming months will prepare and publish a procedures manual that will cover the summary and description of tests, definitions, sample collection and preservation, procedures, calculations, and references.

Based on the proposed procedures described in the three preceding paragraphs, no official sediment quality criteria currently are in effect. At the same time, in situations where sediment quality data are available but not elutriate data, the need arises for comparing the sediment quality data with some standard. Table D.2-5 provides certain recommended limits for various sediment quality parameters and can be used for such a comparison. The data in Table D.2-5 are not official and thus serve only as guidelines.

TABLE D.2-1 STATE OF LOUISIANA WATER QUALITY CRITERIA
FOR SELECTED WATERS NEAR SULPHUR MINES
(Louisiana Stream Control Commission, 1973)

BASIN: SABINE — SEGMENT — DESCRIPTION	WATER USES: PRIMARY CONTACT RECREATION	SECONDARY CONTACT RECREATION	PROPAGATION OF FISH AND WILDLIFE	DOMESTIC RAW WATER SUPPLY	CRITERIA: CHLORIDE (mg/l) Not to exceed	SULPHATE (mg/l) Not to exceed	DISSOLVED OXYGEN (mg/l) Not less than	pH RANGE	Bacteria Standard *	TEMPERATURE °C	TOTAL DISSOLVED SOLIDS
Calcasieu River - Salt Water Barrier to Moss Lake (Tidal)	X	X	X		—	—	4.0	6.0 to 8.5	1	35	—
Houston River - Headwaters to West Fork Calcasieu River	X	X	X		250	150	5.0	6.0 to 8.5	1	32	50
Bayou D'Inde - Headwaters to Calcasieu River (Tidal)		X	X		—	—	2.0	6.5 to 9.0	2	35	—
Sabine River - Sabine River Authority of Texas Pump Station (Approx. Mile 30.5 to Morgan's Bluff Mile 22.4)	X	X	X	X	120	60	5.0	6.0 to 8.5	1	32	50
Sabine River - Morgan's Bluff to Sabine Lake (Tidal)	X	X	X		—	—	4.0	6.0 to 8.5	1	35	—
Intracoastal Waterway (East-West - Sabine River to Calcasieu Lock Tidal		X	X		--	--	4.0	6.0 to 8.5	2	35+	--

*Standard #1 PRIMARY CONTACT RECREATION - Based on a minimum of not less than 5 samples taken over not more than 30-day period, the fecal coliform content shall not exceed a log mean of 200/100 ml. nor shall more than 10 percent of the total samples during any 30-day period exceed 40/100 ml.

Standard #2 SECONDARY CONTACT RECREATION - Based on a minimum of not less than 5 samples taken over not more than a 30-day period, the fecal coliform content shall not exceed a log mean of 1,000/100 ml. nor shall more than 10 percent of the total samples during any 30-day period equal or exceed 2,000/100 ml.

Standard #3 PUBLIC WATER SUPPLY - The monthly arithmetic average of total coliform MPN (most probable number) shall not exceed 10,000/100 ml. nor shall the monthly arithmetic average of fecal coliforms exceed 2,000/100 ml.

Standard #4 SHELLFISH PROPAGATION - The monthly total coliform median MPN (most probable number) shall not exceed 70 per 100 ml. and not more than 10 percent of the samples ordinarily exceed an MPN of 230/100 ml.

ıble D.2-2 Proposed EPA Numerical Criteria for Water Quality, Public Water Supply Intake.

ırameter	ug/l
:senic	50
ıdmium	10
ıromium	50
›pper	1000
ead	50
rcury	2
.nc	5000
ıenols	1.0
,anides	200
ldrin	1
ılordane	3
)T	50
ieldrin	1
ıdrin	0.2
ptachlor Epoxide	0.1
ptachlor	0.1
ındane	.4
ɔxaphene	5

ɔurces: U.S. Environmental Protection Agency, 1973. Proposed Criteria for Water Quality, Vol. I, Washington, D.C.

U.S. Environmental Protection Agency, 1973. Proposed Water Quality Information, Vol. II, Washington, D.C.

Table D.2-3 Proposed EPA Numerical Criteria for Water Quality (freshwater aquatic life).

Parameter	ug/l
Cadmium	30 (hardness > 100 mg/l) 4 (" < 100 mg/l)
Chromium	50
Copper	1/10 LC50
Lead	30
Mercury	0.2
Nickel	1/50 LC50
Zinc	5/1000 LC50
pH	6-9
Ammonia	1/20 LC50 (20 ug/l)
Sulfides	2
Suspended & Settleable Solids	80 mg/l
Turbidity and Light Penetration	10% change in compensation pt.
Color	10% change in compensation pt.
Oils	1. None visible on surface 2. 1000 mg/kg Hexane extractable substances in sediments 3. 1/20 LC50
Phenols	1/20 LC50 (0.1 mg/l)
Cyanides	1/20 LC50 (.005 mg/l)
PCB	0.002
Aldrin	0.01
DDT	0.002
Dieldrin	0.005
Chlordane	0.04
Endrin	0.002
Heptachlor	0.01
Lindane	0.02
Toxaphene	0.01
Diazinon	0.009
Malathion	0.008
Parathion	0.001
Methoxychlor	0.005
DDD	0.006
DO	4.0 mg/l (> 31°C)

Sources: U.S. Environmental Protection Agency, 1973. Proposed Criteri for Water Quality, Vol. I, Washington, D.C.

U.S. Environmental Protection Agency, 1973. Proposed Water Quality Information, Vol. II, Washington, D.C.

Table D.2-4 Proposed EPA Numerical Criteria for Water Quality, Marine Water Constituents (aquatic life).

Parameter	ug/l
Arsenic	50
Cadmium	10
Chromium	100
Copper	50
Lead	50
Mercury	1.0
Nickel	100
Zinc	100
Cyanides	10
Oil and Grease	a. not detectable as a visible film, sheen, discoloration of the surface, or by odor. b. does not cause tainting of fish or invertebrates or damage to biota. c. does not form an oil deposit on the shores or bottom of the receiving body of water.
Aldrin	5.5
DDT	0.6
Dieldrin	5.5
Endrin	0.6
Heptachlor	8
Lindane	5
Toxaphene	0.010
pH	6.5 - 8.5
Ammonia	400
Hydrogen Sulfide	10
Dissolved Oxygen	6.0 mg/l
Phosphorus	0.1

Sources: U.S. Environmental Protection Agency, 1973. Proposed Criteria for Water Quality, Vol. I, Washington, D.C.

U.S. Environmental Protection Agency, 1973. Proposed Water Quality Information, Vol. II, Washington, D.C.

Table D.2-5 Recommended Concentration Limits of Selected Sediment Parameters

Parameter	Units (dry weight basis)	Non-polluted mean	Non-polluted range	Polluted mean	Polluted range
COD[a]	mg/kg	21,000	2,000-48,000	177,000	39,000-395,000
TKN[a]	mg/kg	550	10-1,310	2,640	580-6,800
grease - oil[a]	mg/kg	560	110-1,310	7,150	1,380-32,100
sulfide[a]	mg/kg	140	30-150	1,700	100-3,700
COD[b]	mg/kg			50,000	
TKN[b]	mg/kg			1,000	
grease - oil[b]	mg/kg			1,500	
mercury[b]	mg/kg			1	
lead[b]	mg/kg			50	
zinc[b]	mg/kg			50	

a) O'Neal, G. & J. Scerva. "The Effects of Dredging on Water Quality", World Dredging & Marine Construction, 7 (14) pp. 24-31. 1971.

b) Slotta, L.S. & K.J. Williamson. "Estuarine Impacts Related to Dredge Spoiling", Proceedings of the 6th Dredging Seminar, Texas A & M University.

APPENDIX D.3

CHARACTERISTICS OF PONDS AND RESERVOIRS

IN THE VICINTIY OF SULPHUR

MINE SITE

This appendix contains one table which lists the characteristics of the ponds and reservoirs in the vicinity of Sulphur Mine Site. The location of each body of water is shown in Fig. 2.2-3 (Section 2.2).

Table D.3-1

Reservoirs in the Vicinity of

Sulphur Mine Site

Water Body #	Name	Area (ft^2)	Depth (ft)	Volume (yd^3)
1	Salt Water Reservoir (North)	4,420,000	18.3	2,990,000
2	Salt Water Reservoir (West)	775,000	23.6	676,000
3	Salt Water Reservoir (South)	1,865,000	8.4	378,000
4	Crystal Reservoir (West Branch)	356,000	18.6	246,000
5	Crystal Reservoir (West-East Branch)	354,000	15.6	205,000
6	Crystal Reservoir (East Branch)	1,020,000	9.7	366,000
7	Patsy Franks Dredge Hole No. 1	408,000	8.7	132,000
8	Patsy Franks Dredge Hole No. 2	215,000	4.9	38,900
9	Northern Reservoir	740,000	7.4	201,500
10	Fresh Water Pond No. 1	554,000	9.9	130,000
11	Fresh Water Pond No. 2	288,000	9.5	100,800
12	Fresh Water Pond No. 3	256,000	8.5	81,400
13	Dredge Pond 1969	191,000	6.9	48,800
14	Triple Lake Area			
	Reservoir No. 1	270,000	1.5	14,300
	Reservoir No. 2	73,000	3.3	8,900
	Reservoir No. 3	73,000	2.3	6,500
	Reservoir No. 4	27,000	3.1	3,100
	Reservoir No. 5	27,000	2.8	2,800
15	Fresh Water Reservoir	670,000	0 (dry)	0
16	Waste Oil Residue Pit	230,000	0 (dry)	0
17	North Tank Battery Lake	160,000	1	6,000
18	Center Lake	17,000	(essentially dry)	0

APPENDIX D.4

WATER QUALITY AND DISCHARGE DATA

FOR BAYOU CHOUPIQUE, BAYOU D'INDE, AND THE ICW

Four tables comprise this appendix. Table D.4-1 consists of water quality data for Bayou Choupique and Bayou D'Inde. Additional water quality data for Bayou D'Inde and Bayou Choupique is contained in Tables D.4-2 and 4-3. Discharge data for industrial and municipal wastes emptying into Bayou D'inde is included in Table D.4-4. Table D.4-5 presents the water quality for the effluent discharge into Bayou D'Inde. Table D.4-6 gives _in situ_ and laboratory water analysis for the ICW near Black Lake. Pesticide analysis for the ICW appears in Table D-7.

Figures D.4-1 and D.4-2 give sample station locations for the water quality data.

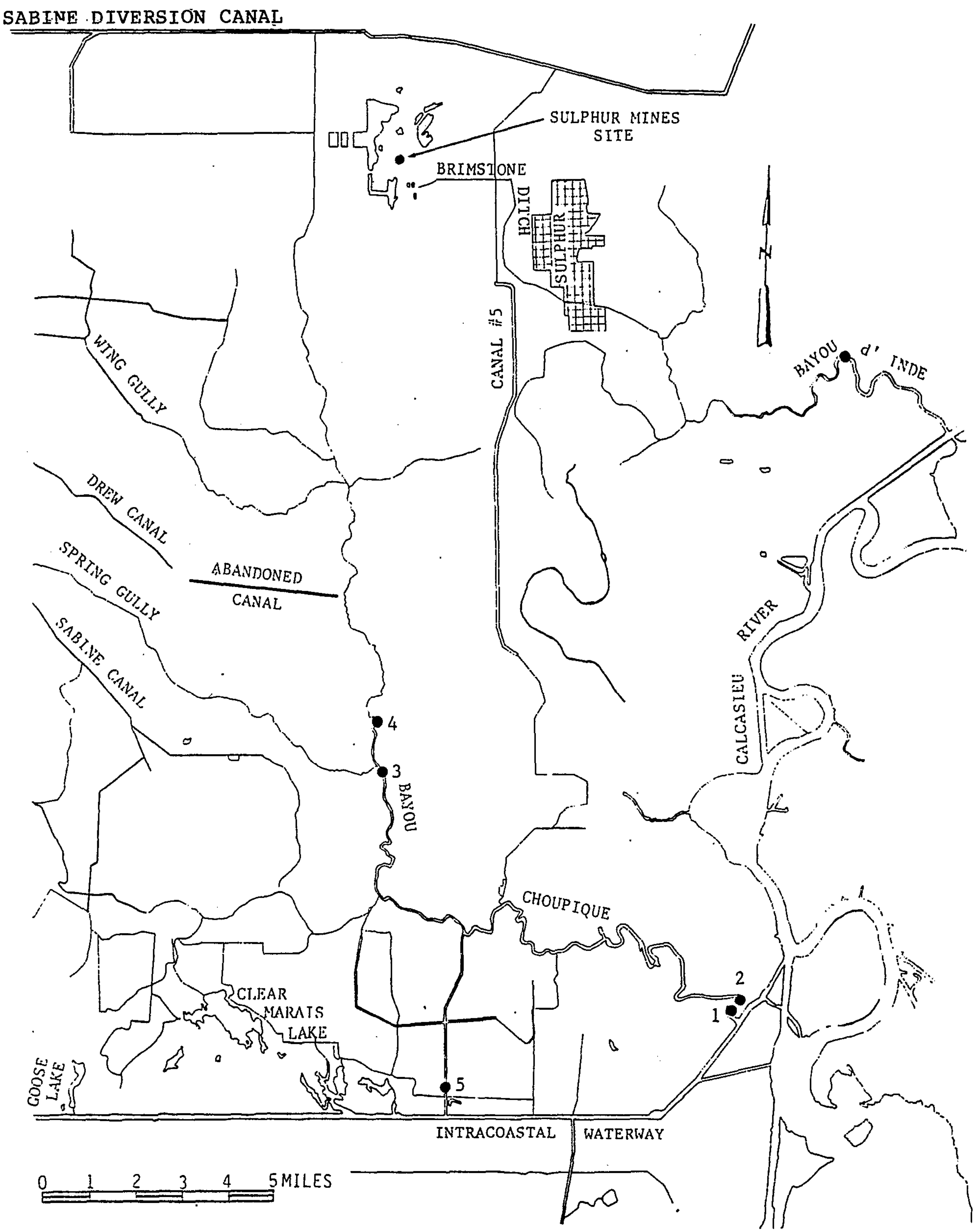


Figure D.4-1 Location of Sample Stations on Bayou d'Inde and Bayou Choupique

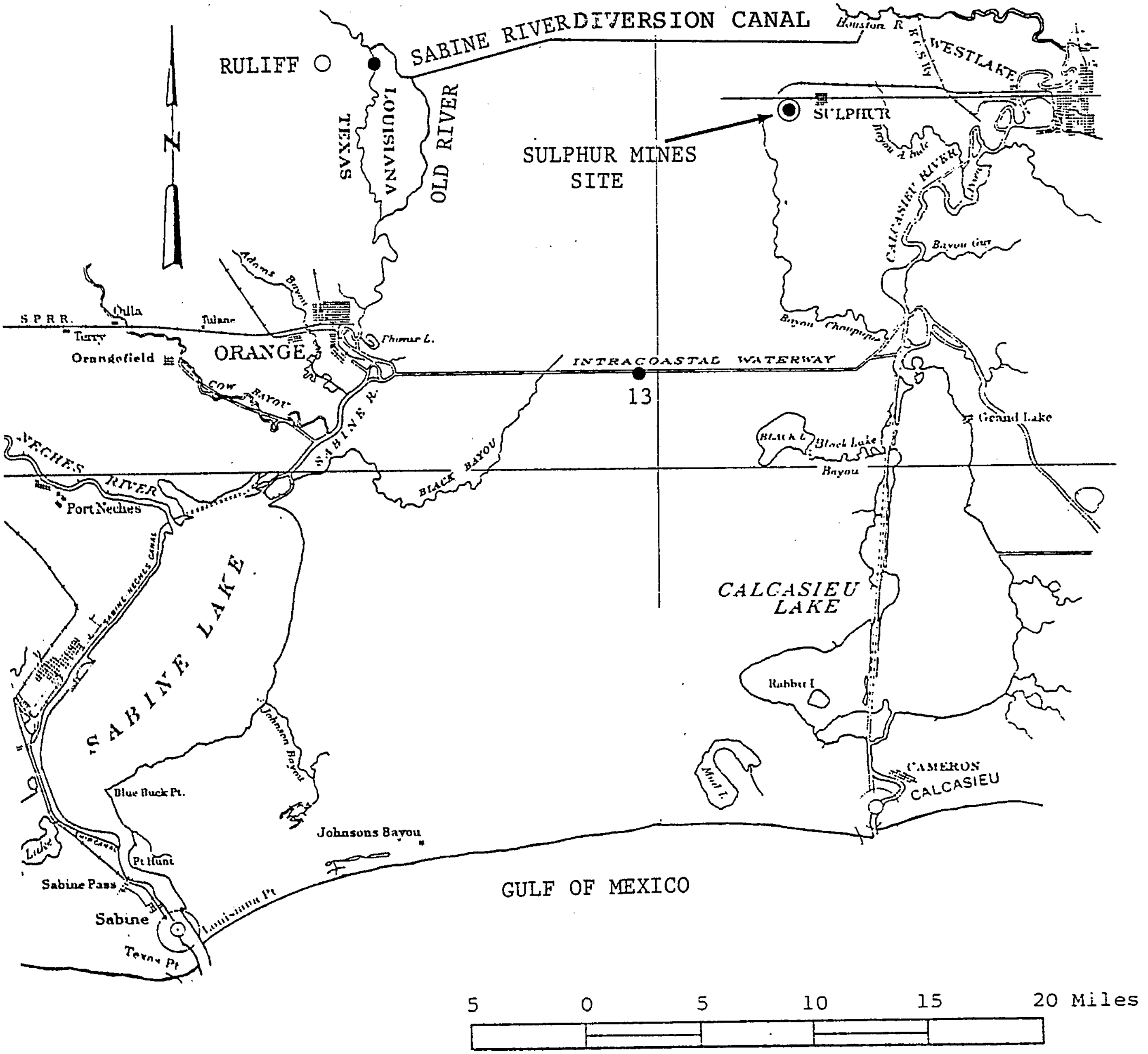


Figure D.4-2 Location of Sample Stations on Sabine River and Intracoastal Waterway

Table D.4-1 Salinity, pH, and Temperature Data for Choupique Bayou and Bayou D'Inde

Date	Locality	Salinity (ppt)	pH	Temperature (°C)	U.S. Geol. Survey Quadrangle Map Location (Sulphur Quadrangle)
4-15-66	Choupique near intersection with La. Hwy. 27	4.0	6.0	21.5	T11S, R10W, Sect. 23; in Sect. 7/16 mi. east 15/16 mi. north
4-20-66 7:55 am	Same as above	7.6	5.5	18.8	Same as above
4-20-66 2:00 pm	Same as above	7.0	6.0-6.4	25.0	Same as above
7-20-66	Same as above	7.4	5.5-6.0	35.0	T11S, R10W, Sect. 23; Sect. 7/16 mi. east, 15/16 mi. north
12-3-66	Same as above	7.7	6.0	15.0	T11S, R10W, Sect. 23; Sect. 7/16 mi. east, 5/8 mi. north
1-24-67	Same as above	9.0	6.0	15.0	T11S, R10W, Sect. 23; i Sect. 7/16 mi. east, 15/16 mi. north
7-20-66	D'Inde and I-10	4.1	6.0	35.0	T10S, R10W, Sect. 36; i Sect. 3/32 mi. east, 5/8 mi. north
7-20-66	D'Inde (Maple Fork) and I-10	5.6	5.5-6-0	32.0	T10S, R9W, Sect. 31; in Sect. 5/16 mi.east, 5/8 mi. north
9-24-66	D'Inde and I-10	1.2	6.4	26.0	T10S, R10W, Sect. 36; i Sect. 3/32 mi. east, 5/8 mi. north
1-24-67	D'Inde (Maple Fork) and I-10	4.5	6.0	19.0	T10S, R9W, Sect. 36; in Sect. 5/16 mi. east 5/8 mi. north
1-24-67	D'Inde and I-10	1.6	6.0	17.0	T10S, R10W, Sect 36; in Sect. 3/32 mi. east, 5/8 mi. north
1-24-67	D'Inde and La. Hwy. 27	0.5	6.0	19.0	T10S, R10W, Sect. 35; i Sect. no map distance east, 1/2 mi. north

From J. E. Vancil. Studies on Rotifers of the Calcasieu Estuary. Unpublished Master's Thesis, McNeese State Univ., August, 1967

Table D.4-2 Analysis of Water Quality Samples Collected from Bayou D'Inde

30 12 08.0 093 17 38.0 2
BAYOU D'INDE NR MAPLEWOOD, LA

PARAMETER				NUMBER	MEAN	MAXIMUM	MINIMUM	BEG DATE	END DATE
00095	CNDUCTVY	AT 25C	MICROMHO	2	.000000	.000000	.000000	71/04/25	71/04/25
00680	T ORG C	C	MG/L	2	9.95000	10.0000	9.90000	71/04/25	71/04/25
70299	RES-SUSP	AT 180 C	MG/L	2	7.00000	14.0000	.000000	71/04/25	71/04/25
70300	RESIDUE	DISS-180	C MG/L	2	3215.00	6430.00	.000000	71/04/25	71/04/25
71890	MERCURY	HG,DISS	UG/L	1	1.00000	1.00000	1.00000	71/04/27	71/04/27

Source: U.S. Environmental Protection Agency, STORET, Region VI, 1600 Patterson, Dallas, Texas 75201.

Table D.4-3. Water Quality Data for Bayou Choupique

30 04 47.0 093 20 20.0 2
BY CHOUPIQUE 0.1 MI WEST OF GIWW
STATION 1

PARAMETER				NUMBER	MEAN	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	28	19.4607	23.2000	12.2000	74/02/05	74/04/23
00094	CNDUCTVY	FIELD	MICROMHO	28	3217.86[f]	9100.00[f]	200.000[f]	74/02/05	74/04/23
00299	DO	PROBE	MG/L	28	8.31071	10.1000	6.90000	74/02/05	74/04/23
00400	PH		SU	28	7.13214	7.90000	6.30000[d]	74/02/05	74/04/23

Note: Locations of sample stations are given in Figure D.4-1
Explanation of superscripts is given in Table D.2-4

Sources: U.S. Environmental Protection Agency, STORET, Region VI, 1201 Elm Street, Dallas, Texas.

Table D.4-3. Water Quality Data for Bayou Choupique (Continued)

30 04 58.0 093 21 03.0 2
BY CHOUPIQUE 1.4 MI WEST OF GIWW
STATION 2

PARAMETER				NUMBER	MEAN	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	3	16.0000	16.0000	16.0000	74/02/05	74/02/05
00094	CNDUCTVY	FIELD	MICROMHO	3	200.000[f]	200.000[f]	200.000[f]	74/02/05	74/02/05
00299	DO	PROBE	MG/L	3	7.53333	7.70000	7.40000	74/02/05	74/02/05
00400	PH		SU	3	6.50000	6.50000	6.50000	74/02/05	74/02/05

Note: Locations of sample stations are given in Figure D.4-1
Explanation of superscripts is given in Table D.2-4

Sources: U.S. Environmental Protection Agency, STORET, Region VI, 1201 Elm Street, Dallas, Texas.

Table D.4-3. Water Quality Data for Bayou Choupique (Continued)

30 05 54.0 093 24 05.0 2
BY CHOUPIQUE 7.6 MI WEST OF GIWW
STATION 3

PARAMETER				NUMBER	MEAN	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	3	15.0333	15.1000	15.0000	74/02/05	74/02/05
00094	CNDUCTVY	FIELD	MICROMHO	3	200.000[f]	200.000[f]	200.000[f]	74/02/05	74/02/05
00299	DO	PROBE	MG/L	3	6.13333	8.40000	7.80000	74/02/05	74/02/05
00400	PH		SU	3	6.30000[d]	6.40000[d]	6.20000[d]	74/02/05	74/02/05

Note: Locations of sample stations are given in Figure D.4-1
Explanation of superscripts is given in Table D.2-4

Sources: U.S. Environmental Protection Agency, STORET, Region VI, 1201 Elm Street, Dallas, Texas.

Table D.4-3. Water Quality Data for Bayou Choupique (Continued)

30 06 12.0 093 25 02.0 2
BY CHOUPIQUE 8.8 MI WEST OF GIWW
STATION 4

PARAMETER				NUMBER	MEAN	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	24	18.1500	22.9000	152.6000	74/02/05	74/04/15
00094	CNDUCTVY	FIELD	MICROMHO	24	462.500[f]	2300.00[f]	200.000[f]	74/02/05	74/04/15
00299	DO	PROBE	MG/L	24	6.29166	10.0000	4.60000[d]	74/02/05	74/04/15
00400	PH		SU	24	6.65416	7.40000	5.80000[d]	74/02/05	74/04/15

Note: Locations of sample stations are given in Figure D.4-1
Explanation of superscripts is given in Table D.2-4

Sources: U.S. Environmental Protection Agency, STORET, Region VI, 1201 Elm Street, Dallas, Texas.

Table D.4-3. Water Quality Data for Bayou Choupique (Concluded)

30 04 54.0 093 24 15.0 2
BY CHOUPIQUE 8.8 MI WEST OF GIWW
STATION 5

PARAMETER				NUMBER	MEAN	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	3	15.3667	15.4000	15.3000	74/02/05	74/02/05
00094	CNDUCTVY	FIELD	MICROMHO	3	200.000[f]	200.000[f]	200.000[f]	74/02/05	74/02/05
00299	DO	PROBE	MG/L	3	10.1333	10.3000	9.90000	74/02/05	74/02/05
00400	PH		SU	24	6.53333	6.60000	6.50000	74/02/05	74/02/05

Note: Locations of sample stations are given in Figure D.4-1
Explanation of superscripts is given in Table D.2-4

Sources: U.S. Environmental Protection Agency, STORET, Region VI, 1201 Elm Street, Dallas, Texas.

Table D.4-4 Industrial and Domestic Waste Emptying into Bayou D'Inde - 1969[1]

Source of Waste	Average Daily Discharge (mgd)	Degree[2] of Treatment	Estimated Average ppm B.O.D. in Discharge
Petroleum Chemicals, Inc.	0.720	C.S.R.	Unknown
Union Texas Petroleum	Unknown	R.S.A.	Unknown
Cities Service Refinery	Unknown	C.S.R.	Unknown
Sulphur[3]	1.20	B.F.	30

[1]Information on sources, amounts, and degree of treatment of waste was obtained from the Louisiana Department of Health, 1969

[2]Symbols for degree of treatment: B.F.--Biological Filtration; C.S.R.--through Cities Service Refinery; R.S.A.--Reservoir, Spray Aeration--removal of H_2S.

[3]Sulphur has 12,800 actual domestic sewage installations.

From Louisiana Wildlife and Fisheries Commission, 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I, Area Description, and Phase IV, Biology.

Table D.4-5 Analysis of Water Quality for the Effluent Discharge into Bayou D'Inde from Cities Service Refinery

30 12 04.0 093 19 45.0
EFFL- CITIES SVC LAKE CHARLES

PARAMETER				NUMBER	MEAN	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	6	27.1667	28.0000	26.0000	71/04/21	71/04/21
00095	CNDUCTVY	AT 25C	MICROMHO	7	1171.43	1600.00	1000.00	71/04/21	71/04/22
00335	COD	LOWLEVEL	MG/L	1	612.000	612.000	612.000	71/04/22	71/04/22
00400	PH		SU	6	9.39999	9.70000	9.20000	71/04/21	71/04/21
00550	OIL-GRSE	TOT-SXLT	MG/L	1	5.00000	5.00000	5.00000	71/04/17	71/04/17
00605	ORG N	N	MG/L	1	.000000	.000000	.000000	71/04/22	71/04/22
00610	NH3-N	TOTAL	MG/L	1	5.35000	5.35000	5.35000	71/04/22	71/04/22
00680	T ORG C	C	MG/L	1	180.000	180.000	180.000	71/04/22	71/04/22
00940	CHLORIDE	CL	MG/L	1	130.000	130.000	130.000	71/04/22	71/04/22
01025	CADMIUM	CD,DISS	UG/L	1	.050000	.050000	.050000	71/04/21	71/04/21
01030	CHROMIUM	CR,DISS	UG/L	1	1.80000	1.80000	1.80000	71/04/21	71/04/21
01040	COPPER	CU,DISS	UG/L	1	.090000	.090000	.090000	71/04/21	71/04/21
01049	LEAD	PB,DISS	UG/L	1	.100000	.100000	.100000	71/04/21	71/04/21
50050	CONDUIT	FLOW	MGD	6	3.95000	3.95000	3.95000	71/04/21	71/04/21
70299	RES-SUSP	AT 180 C	MG/L	1	78.0000	78.0000	78.0000	71/04/22	71/04/22
70300	PESIDUE	DISS-180 C	MG/L	1	868.000	868.000	868.000	71/04/22	71/04/22
71890	MERCURY	HG,DISS	UG/L	1	.800000	.800000	.800000	71/04/21	71/04/21

Note: State Water Quality Standards do not apply in effluent mixing zones.

Source: U.S. Environmental Protection Agency, STORET, Region VI, Dallas Texas.

Table D.4-6 Analysis of Water Samples Taken From the Intracoastal Waterway During the Period 23 - 28 March 1975

(US Army CE, New Orleans, 1975)

Sample Station	Total COD (mg/l)	Dissolved COD (mg/l)	Total TKN (mg/l)	Dissolved TKN (mg/l)	NO_3 (mgN/l)	NO_3 (mgN/l)	Sollulble Ortho P (mgP/l)	Tot. P (mgP/l)	Total P (mg/l)	Dissolved Organic Carbon (mg/l)	Grease & Oil (mg/l)	Tot. Susp. Solids (mg/l)	Volatile Susp. Solids (mg/l)
13	33.0[f]	33.0[f]	1.84[f]	0.89[f]	<0.10[f]	0.12[f]	<0.01[f]	0.24[f]	29.0[d]	29.0[f]	<5.0[e]	43[f]	30[f]

Sample Station	Tot. Zn (μg/l)	Sol. Zn (μg/l)	Tot. Cd (μg/l)	Sol. Cd (μg/l)	Tot. Cu (μg/l)	Sol. Cu (μg/l)	Tot. Cr (μg/l)	Sol. Cr (μg/l)	Tot. Ni (μg/l)	Sol. Ni (μg/l)	Tot. Pb (μg/l)	Sol. Pb (μg/l)	Tot. As (μg/l)	Sol. As (μg/l)	Tot. Hg (μg/l)	Sol. Hg (μg/l)
13	235[f]	13[f]	0.6	<0.2[f]	10	9[f]	6	<0.5[f]	91[e]	18[f]	2.0	1.0[f]	60[d]	60[f]	9.9[d]	9.9[f]

Sample Station	Time/Date	Depth (m)	Temp (°C)	DO (mg/l)	pH	Cond. (μmho/cm)	ORP** (mv)	Sed. pH	Direction of Flow
* 13	0830/25 MAR	5.6	19.5	8.05	6.75	270	+820	7.30	E

* _In Situ_ parameters measured in the Gulf Intracoastal Waterway during the period 23-28 March 1975.

** Oxidation-reduction potential.

Location of Sample Stations are given in Figure D.4-2

Explanation of the superscripts is given in Table D.2-4

Table D.4-7 Pesticide Analysis of Water Samples Taken from the Intracoastal Waterway During the Period 23 - 29 March 1975
(All concentrations expressed as g/l)

(US Army CE, New Orleans, 1975)

	Station 13 Near Black Lake
Toxaphene	<50 [d]
Lindane	51 [d]
Heptachlor	<1.0 [d]
Heptachlor Epoxide	<1.0 [e]
Aldrin	<1.0 [d]
Chlordane	10 [d]
Dieldrin	<2.0 [d]
Ethion	ND
Methoxychlor	<1.0 [e]
Endrin	<3.0 [d]
O,P'-DDT	3.2 [d]
P,P'-DDT	<3.0 [e]
O,P'-DDE	<1.0 [e]
P,P'-DDE	<2.0 [e]
O,P'-DDD	<2.0 [e]
P,P'-DDD	<3.0 [e]

Sample Station location shown in Figure D.4-2

Explanation of the superscripts is given in Table D.2-4

APPENDIX D.5

HYDROLOGIC, WATER QUALITY, AND SEDIMENT QUALITY DATA FOR THE SABINE RIVER NEAR RULIFF, TEXAS

This appendix contains two tables. Table D.5-1 includes the discharge data for the Sabine River near Ruliff, Texas for the years 1953 through 1967. Hydrologic, water quality, and sediment data from October 1973 through 1974 are provided for the same location on the river in Table D.5-2.

Table D.5-1 **Discharge data for Sabine River (U.S.G.S. Station 8-0305 at Ruliff, Texas) (1953 - 1967)**

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	The Year
	Monthly and yearly mean discharge in cubic feet per second (cfs)												
1953	378	653	3,903	5,563	11,090	21,590	7,666	66,020	20,610	4,264	3,608	1,966	12,340
1954	994	1,162	4,965	6,083	5,756	3,131	6,079	15,660	3,672	790	514	348	4,097
1955	392	2,822	1,672	3,434	12,070	5,708	15,970	6,327	3,660	2,260	10,190	3,124	5.574
1956	1,308	958	1,966	3,039	12,630	5,652	5,746	7,298	1,509	687	364	326	3.421
1957	285	722	3,696	1,637	4,936	11,020	15,020	40,290	23,310	10,680	1,518	2,222	9,345
1958	4,898	23,290	18,350	15,120	13,770	10,420	9,608	24,150	8,773	4,472	2,624	12,330	12,290
1959	11,080	3,064	3,013	2,847	16,790	9,382	11,390	10,700	4,550	3,900	3,360	1,367	6,723
1960	2,890	2,066	7,433	15,440	16,580	17,110	4,891	3,395	2,259	3,177	1,536	1,322	6,545
1961	2,098	4,871	16,820	35,570	21,990	20,520	17,520	3,385	4,253	8,772	3,823	10,320	12,410
1962	2,207	5,258	20,810	14,200	11,310	9,395	5,801	10,790	4,908	2,100	1,346	1,854	7,500
1963	1,321	1,359	3,385	5,307	4,643	4,245	2,722	4,404	1,383	1,481	742	3,062	2,831
1964	400	1,324	2,805	3,936	3,218	9,715	7,245	6,305	1,878	868	642	536	3,250
1965	504	570	2,700	2,391	6,514	8,052	9,247	5,407	10,710	1,848	603	820	4,081
1966	728	695	4,132	5,485	24,850	5,152	3,738	32,980	10,320	1,304	1,204	1,265	7,553
1967	1,017	1,213	1,841	2,959	2,998	2,628	5,598	2,044	1,833	805	382	333	1,959
Mean	2,037	3,375	6,499	8,200	11,476	9,581	8,549	15,943	6,908	3,160	2,132	2,746	6,681

Drainage area: 9,329 sq. miles
Records maintained from Oct., 1924 to Sept., 1967; Average discharge: 8,271 cfs for 43 yrs.
Maximum discharge: 121,000 cfs, May 22, 1953; Minimum discharge: 270 cfs, Sept. 27, 30, Oct. 1, 3, 1956

Source: Louisiana Wildlife and Fisheries Commission, 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I, Area Description, and Phase IV, Biology.

Table D.5-2 Volumetric Flow Rate Data and Analysis of Samples Collected at the Sabine River near Ruliff, Texas

SABINE RIVER BASIN

08030500 SABINE RIVER NEAR RULIFF, TEX.
(Radiochemical network)

LOCATION.--Lat 30°18'13", long 93°44'37", Newton County, at gaging station at bridge on State Highway 12, 2.4 miles (3.9 km) north of Ruliff, and 4.5 miles (7.2 km) downstream from Cypress Creek.

DRAINAGE AREA.--9,329 mi² (24,162 km²).

PERIOD OF RECORD.--Chemical analyses: October 1945 to September 1946, October 1947 to September 1974.
Chemical and biochemical analyses: October 1967 to September 1974.
Pesticide analyses: Janaury 1968 to September 1974.
Water temperatures: October 1947 to September 1974.

EXTREMES.--October 1973 to September 1974:
Specific conductance: Maximum daily, 163 micromhos Dec. 17-19; minimum daily, 56 micromhos Oct. 20.
Water temperatures: Maximum, 32.0°C Aug 3; minimum, 9.0°C Dec. 22, Jan. 5.

Period of record:
Specific conductance (1945-46, 1947-70, 1971-74): Maximum daily, 779 micromhos Aug. 31, 1966; minimum daily, 28 micromhos Sept. 19, 1963.
Water temperatures (1947-70, 1971-74): Maximum, 36.0°C Aug. 14, 1962; minimum, 1.0°C Jan. 28, 1948.

REMARKS.--For information on diversions and return flows, see REMARKS paragraph in Part I of this report.

WATER QUALITY DATA, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED SODIUM PLUS POTASSIUM (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)
OCT.												
08...	0545	10900	5.0	7.5	3.0	--	10	--	23	0	10	17
14...	0545	11400	--	--	--	--	--	--	--	--	5.2	6.5
21...	0640	9200	--	--	--	--	--	--	--	--	5.2	6.5
26...	0615	2100	14	7.5	2.3	--	11	--	28	0	11	12
29...	0600	1700	--	--	--	--	--	--	--	--	14	13
NOV.												
07...	0542	5800	9.0	3.5	1.5	--	6.1	--	12	0	6.0	8.5
08...	0540	7800	--	--	--	--	--	--	--	--	10	15
17...	0600	9900	--	--	--	--	--	--	--	--	12	20
28...	0548	10500	--	--	--	--	--	--	--	--	11	18
DEC.												
06...	0600	13700	5.4	6.5	3.6	--	7.1	--	22	0	8.4	14
15...	0640	17300	--	--	--	--	--	--	--	--	12	20
19...	0730	18300	5.0	10	3.2	--	15	--	34	0	10	22
24...	0637	19200	--	--	--	--	--	--	--	--	10	20
31...	0607	23200	--	--	--	--	--	--	--	--	9.0	18
JAN.												
07...	0655	19200	5.7	8.0	2.9	--	10	--	28	0	6.8	17
14...	0640	23100	--	--	--	--	--	--	--	--	8.4	14
21...	0647	32000	--	--	--	--	--	--	--	--	5.2	10
24...	0635	58000	--	--	--	--	--	--	--	--	7.6	12
FEB.												
01...	0638	88000	6.6	7.0	2.6	--	9.1	--	22	0	8.4	15
11...	0624	18700	--	--	--	--	--	--	--	--	12	15
21...	0800	17300	6.5	8.0	3.9	--	9.3	--	25	0	12	16
24...	0700	17800	--	--	--	--	--	--	--	--	13	17
25...	0700	17100	--	--	--	--	--	--	--	--	12	16
MAR.												
08...	0645	14900	5.6	8.3	2.5	14	--	2.9	28	0	12	17
15...	0640	14800	--	--	--	--	--	--	--	--	12	15
21...	1430	2950	14	7.5	2.7	--	21	--	36	0	12	23
24...	0615	3800	--	--	--	--	--	--	--	--	8.0	12
31...	1750	10800	--	--	--	--	--	--	--	--	15	14
APR.												
08...	0640	5100	11	7.9	2.3	14	--	2.5	28	0	14	16
15...	0640	9000	--	--	--	--	--	--	--	--	6.6	7.5
23...	0644	10500	--	--	--	--	--	--	--	--	10	16
25...	1845	10700	8.2	8.1	2.1	12	--	2.7	20	0	14	17
30...	0630	4300	--	--	--	--	--	--	--	--	15	16
MAY												
07...	0640	8720	9.2	7.2	2.4	12	--	2.8	22	0	14	16
14...	0640	10300	--	--	--	--	--	--	--	--	10	15
22...	0635	8770	--	--	--	--	--	--	--	--	11	18
24...	0830	8780	7.5	7.2	2.4	12	--	3.1	20	0	15	17
30...	0645	8800	--	--	--	--	--	--	--	--	17	18
JUNE												
08...	0700	5600	10	7.8	2.5	16	--	2.7	26	0	18	18
13...	1645	6050	9.6	6.9	2.4	12	--	2.8	22	0	17	16
14...	0700	6050	--	--	--	--	--	--	--	--	14	17
21...	0652	5800	--	--	--	--	--	--	--	--	12	16
28...	0700	5200	--	--	--	--	--	--	--	--	12	18
JULY												
07...	0804	4300	8.3	7.9	1.9	12	--	2.7	22	0	15	21
10...	2000	5100	8.4	7.3	2.0	12	--	2.6	22	0	16	16
18...	0700	5100	--	--	--	--	--	--	--	--	16	18
25...	0655	6100	--	--	--	--	--	--	--	--	11	18
31...	0700	4200	--	--	--	--	--	--	--	--	16	18
AUG.												
06...	1715	6200	7.6	6.8	3.0	13	--	3.0	22	0	16	17
08...	0700	4600	8.8	7.9	2.2	15	--	2.7	24	0	18	17
14...	1235	3700	--	--	--	--	--	--	--	--	--	--
15...	0700	4600	--	--	--	--	--	--	--	--	13	16
22...	0700	5000	--	--	--	--	--	--	--	--	11	16
31...	0605	6500	--	--	--	--	--	--	--	--	14	17
SEP.												
07...	0615	5400	7.0	7.0	2.5	11	--	2.7	18	0	12	16
14...	0610	8500	--	--	--	--	--	--	--	--	12	18
21...	0607	6200	--	--	--	--	--	--	--	--	12	18
22...	0700	6250	--	--	--	--	--	--	--	--	--	--
25...	1530	4040	8.3	7.4	3.0	12	--	2.4	22	0	12	16
29...	0607	4020	--	--	--	--	--	--	--	--	10	19

Table D.5-2 (Continued)

SABINE RIVER BASIN

08030500 SABINE RIVER NEAR RULIFF, TEX.--Continued

WATER QUALITY DATA, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DATE	DIS-SOLVED FLUO-RIDE (F) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	AMMONIA NITRO-GEN (N). (MG/L)	ORGANIC NITRO-GEN (N) (MG/L)	TOTAL KJEL-DAHL NITRO-GEN (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)
OCT.											
09...	.8	.00	--	--	--	--	--	64	--	--	31
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
28...	.0	.10	.01	.12	.19	--	.04	--	40	9	28
29...	--	--	--	--	--	--	--	--	--	--	--
NOV.											
07...	.0	--	--	--	--	--	--	41	--	--	15
08...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--
DEC.											
08...	.8	--	--	--	--	--	--	56	--	--	31
15...	--	--	--	--	--	--	--	--	--	--	--
19...	.8	.20	.02	.10	.17	--	.02	83	38	6	38
28...	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--
JAN.											
07...	.1	--	--	--	--	--	--	64	--	--	32
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--
FEB.											
01...	.8	--	--	--	--	--	--	58	--	--	26
11...	--	--	--	--	--	--	--	--	--	--	--
21...	.8	.20	.02	.03	.29	--	.03	69	81	20	36
26...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--
MAR.											
08...	--	--	--	--	--	--	--	76	--	--	31
15...	--	--	--	--	--	--	--	--	--	--	--
21...	.4	.08	.00	.08	.30	--	.06	99	40	3	30
24...	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--
APR.											
09...	--	--	--	--	--	--	--	82	--	--	29
15...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
25...	--	.13	.01	.03	.32	.35	.01	75	--	--	29
30...	--	--	--	--	--	--	--	--	--	--	--
MAY											
07...	--	--	--	--	--	--	--	74	--	--	26
14...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
29...	--	.08	.00	.04	.91	.95	.02	74	--	--	28
30...	--	--	--	--	--	--	--	--	--	--	--
JUNE											
08...	--	--	--	--	--	--	--	80	--	--	30
13...	--	.07	.00	.05	.70	.75	.03	78	41	14	27
18...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--
JULY											
07...	--	--	--	--	--	--	--	80	--	--	28
10...	--	.00	.00	.01	.44	.45	.03	75	45	25	26
19...	--	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--
AUG.											
08...	--	.00	.08	.07	.74	.81	.04	77	30	1	29
09...	--	--	--	--	--	--	--	83	--	--	29
14...	--	--	--	--	--	--	--	--	40	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--
SEP.											
07...	--	--	--	--	--	--	--	67	--	--	28
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
25...	--	.07	.08	.04	.70	.74	.02	72	16	9	31
28...	--	--	--	--	--	--	--	--	--	--	--

Table D.5-2 (Continued)

SABINE RIVER BASIN

08030500 SABINE RIVER NEAR RULIFF, TEX.--Continued

WATER QUALITY DATA, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DATE	NON-CARBONATE HARDNESS (MG/L)	SODIUM AD-SORPTION RATIO	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	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 5 DAY (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)
OCT.											
08...	12	.8	133	6.3	26.0	70	--	--	--	--	--
19...	--	--	57	--	20.0	120	--	--	--	--	--
21...	--	--	66	--	19.0	140	--	--	--	--	--
28...	5	--	117	6.1	17.5	100	25	7.6	79	1.1	18
29...	--	--	131	--	21.0	120	--	--	--	--	--
NOV.											
07...	5	.7	77	6.0	19.0	140	--	--	--	--	--
08...	--	--	113	--	20.0	120	--	--	--	--	--
17...	--	--	158	--	18.0	60	--	--	--	--	--
28...	--	--	136	--	19.0	130	--	--	--	--	--
DEC.											
08...	13	.6	119	6.3	15.0	100	--	--	--	--	--
14...	--	--	160	--	15.0	60	--	--	--	--	--
19...	10	1.1	163	7.0	13.5	50	15	9.0	86	.6	11
24...	--	--	153	--	12.0	90	--	--	--	--	--
31...	--	--	167	--	14.0	120	--	--	--	--	--
JAN.											
07...	4	.8	139	6.4	11.0	100	--	--	--	--	--
14...	--	--	122	--	12.0	120	--	--	--	--	--
21...	--	--	88	--	15.0	80	--	--	--	--	--
28...	--	--	104	--	14.0	80	--	--	--	--	--
FEB.											
01...	18	--	118	6.3	14.0	100	--	--	--	--	--
11...	--	--	135	--	11.6	80	--	--	--	--	--
21...	18	.7	140	7.0	15.0	40	120	10.2	100	1.4	4.0
26...	--	--	142	--	12.0	60	--	--	--	--	--
28...	--	--	138	--	14.0	60	--	--	--	--	--
MAR.											
08...	6	1.1	148	--	18.0	--	--	--	--	--	--
19...	--	--	129	--	19.0	70	--	--	--	--	--
21...	1	--	133	7.0	18.5	60	30	8.2	87	.9	8.5
28...	--	--	102	--	18.0	70	--	--	--	--	--
31...	--	--	120	--	18.0	70	--	--	--	--	--
APR.											
08...	8	1.1	143	6.9	19.0	70	--	--	--	--	--
19...	--	--	72	--	19.5	200	--	--	--	--	--
23...	--	--	128	--	21.0	40	--	--	--	--	--
25...	13	1.0	132	5.7	20.5	--	--	--	--	--	--
30...	--	--	134	--	22.0	70	--	--	--	--	--
MAY											
07...	10	1.0	137	8.2	--	--	--	--	--	--	--
14...	--	--	116	--	23.0	40	--	--	--	--	--
22...	--	--	145	--	24.0	60	--	--	--	--	--
28...	11	1.0	141	6.5	24.0	--	--	--	--	--	14
30...	--	--	135	--	26.0	60	--	--	--	--	--
JUNE											
06...	8	1.3	157	6.7	27.0	50	--	--	--	--	--
13...	9	1.0	134	6.3	26.0	30	25	8.0	98	1.1	9.8
18...	--	--	131	--	27.0	50	--	--	--	--	--
21...	--	--	134	--	28.0	50	--	--	--	--	--
28...	--	--	139	--	28.0	40	--	--	--	--	--
JULY											
07...	10	1.0	140	6.4	28.0	40	--	--	--	--	--
10...	8	1.0	135	6.5	28.0	40	30	--	--	1.7	7.3
18...	--	--	151	--	27.0	40	--	--	--	--	--
25...	--	--	139	--	29.0	40	--	--	--	--	--
31...	--	--	142	--	28.0	50	--	--	--	--	--
AUG.											
08...	11	1.0	140	6.3	28.0	30	15	7.2	91	1.2	8.2
09...	9	1.2	154	6.5	27.0	40	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--	--
15...	--	--	130	--	28.0	40	--	--	--	--	--
22...	--	--	136	--	--	--	--	--	--	--	--
31...	--	--	136	--	27.0	40	--	--	--	--	--
SEP.											
07...	13	.9	131	6.6	23.0	40	--	--	--	--	--
14...	--	--	123	--	27.0	40	--	--	--	--	--
21...	--	--	134	--	28.0	30	--	--	--	--	--
22...	--	--	--	--	24.0	40	--	--	--	--	--
25...	13	.9	133	6.6	24.5	30	18	6.9	82	1.0	6.0
29...	--	--	144	--	25.0	30	--	--	--	--	--

Table D.5-2 (Continued)

SABINE RIVER BASIN

08030500 SABINE RIVER NEAR RUI:FF, TEX.--Continued

WATER QUALITY DATA, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DATE	TIME	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	DIS-SOLVED BORON (B) (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)
OCT. 26...	0815	100	1	--	0	0	0	2
FEB. 21...	0800	130	0	--	0	0	0	--
APR. 25...	1845	60	0	50	0	10	0	6
AUG. 06...	1715	0	0	40	0	0	0	2

DATE	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 MERCURY (HG) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED STRON-TIUM (SR) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)
OCT. 26...	830	0	0	400	4.2	0	70	20
FEB. 21...	340	--	0	70	.0	5	90	--
APR. 25...	250	6	0	0	.1	1	150	60
AUG. 06...	70	2	0	0	.1	0	100	0

DATE	TIME	INSTAN-TANEOUS DIS-CHARGE (CFS)	TEMPER-ATURE (DEG C)	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)
OCT. 26...	0815	2100	17.5	.00	.0	.00	.0	.00	.0	.00	.0
FEB. 21...	0800	16000	15.0	.00	.0	.00	.0	.00	.0	.00	.0
APR. 25...	1845	10700	20.5	.00	1.4	.00	.0	.00	.0	.00	.0
MAY 24...	0830	8780	24.0	--	--	--	--	--	--	--	--
AUG. 06...	1715	7000	28.0	.00	.0	.00	.0	.00	.0	.00	.0

DATE	DI-ELDRIN (UG/L)	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)
OCT. 26...	.00	.0	.00	.0	.00	.0	.00	.0	.00	.0	.0
FEB. 21...	.00	8.6	.00	.0	.00	.0	.00	.0	.00	.0	.0
APR. 25...	.00	45	.00	.0	.00	.0	.00	.0	.00	.0	.0
MAY 24...	--	--	--	--	--	--	--	--	--	--	--
AUG. 06...	.00	4.2	.00	.0	.00	.0	.00	.0	.00	.0	.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)
OCT. 26...	0	.0	0	.10	.00	.00	.00	.00	.00	.00
FEB. 21...	0	.0	0	.10	.00	.00	.00	.00	.00	.00
APR. 25...	0	.0	0	.10	.00	.00	.00	--	--	--
MAY 24...	--	--	--	--	--	--	--	.00	.00	.00
AUG. 06...	0	.0	0	.00	.00	.00	.00	.00	.00	.00

Table D.5-2 (Continued)

SABINE RIVER BASIN

08030500 SABINE RIVER NEAR RULIFF, TEX.--Continued

WATER QUALITY DATA, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DATE	TIME	INSTAN-TANEOUS DIS-CHARGE (CFS)	DIS-SOLVED GROSS ALPHA AS U-NAT. (UG/L)	SUS-PENDED GROSS ALPHA AS U-NAT. (UG/L)	DIS-SOLVED GROSS BETA AS CS-137 (PC/L)	SUS-PENDED GROSS BETA AS CS-137 (PC/L)	DIS-SOLVED GROSS BETA AS SR90 /Y90 (PC/L)	SUS-PENDED GROSS BETA AS SR90 /Y90 (PC/L)	DIS-SOLVED RA-226 (RADON METHOD) (PC/L)	DIS-SOLVED URANIUM (U) (UG/L)
AUG. 14...	1235	3700	2.3	1.0	5.1	1.8	4.0	1.5	.05	.02

MONTHLY AND ANNUAL MEANS AND LOADS FOR WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

MONTH	DISCHARGE (CFS-DAYS)	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. 1973.....	207020	106	56	31300	12	6710	8.6	4610	21
NOV. 1973.....	261740	140	74	52300	17	12000	12	8480	29
DEC. 1973.....	543600	149	79	116000	18	26400	13	19100	32
JAN. 1974......	1016700	114	60	165000	13	35700	9.4	25800	23
FEB. 1974......	783800	132	70	148000	16	33900	11	23300	28
MAR. 1974......	323600	135	72	62900	16	14000	11	9610	28
APR. 1974......	285560	113	60	46300	13	10000	9.3	7170	23
MAY 1974......	285020	133	70	53900	16	12300	11	8470	28
JUNE 1974......	179910	139	74	35900	16	7770	12	5830	29
JULY 1974......	176410	140	74	35200	17	8100	12	5720	29
AUG. 1974......	180810	138	73	35600	16	7810	12	5840	29
SEPT 1974......	171820	129	68	31500	15	6960	11	5100	27
TOTAL	4415990	**	**	814000	**	182000	**	129000	**
WTD.AVG.	12098	129	68	**	15	**	11	**	27

SPECIFIC CONDUCTANCE (MICROMHOS/CM AT 25 DEG. C), WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974
(ONCE-DAILY)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	141	124	141	150	118	143	123	136	136	139	156	131
2	143	115	145	152	121	142	127	136	138	139	137	134
3	141	110	149	153	124	137	131	138	139	142	130	124
4	143	106	151	151	128	142	128	138	137	152	132	122
5	146	111	145	150	131	146	130	136	135	139	136	134
6	146	96	119	142	134	146	132	135	157	136	137	118
7	138	77	117	139	134	143	122	137	141	140	141	131
8	133	113	120	138	134	141	143	128	140	144	154	136
9	125	123	129	137	137	144	138	126	142	135	136	134
10	117	127	138	137	136	145	134	130	139	135	137	130
11	128	131	146	132	135	146	130	130	139	135	137	100
12	144	142	150	125	138	145	141	129	139	135	138	116
13	129	144	155	119	140	142	146	129	136	136	142	121
14	94	146	159	122	143	136	100	116	131	137	132	123
15	69	150	166	128	143	129	72	119	136	138	130	121
16	65	153	166	131	143	124	68	122	138	137	156	127
17	64	158	163	133	141	121	69	122	137	139	134	130
18	58	157	163	136	141	116	81	133	138	151	147	125
19	57	156	163	139	139	152	90	138	137	139	130	131
20	56	154	166	109	146	113	92	142	148	144	135	134
21	66	154	161	86	140	136	112	144	139	144	131	134
22	68	153	157	79	139	135	121	145	136	142	136	139
23	61	145	152	75	138	133	128	142	137	141	142	137
24	97	145	153	88	142	102	128	140	137	141	137	137
25	109	153	154	100	136	125	129	139	137	139	138	134
26	116	155	156	102	139	137	128	135	139	141	136	137
27	122	149	151	109	139	129	128	138	155	140	134	136
28	127	136	149	104	138	116	129	138	139	139	130	140
29	131	143	148	98	---	104	131	137	138	138	140	144
30	135	136	146	102	---	107	134	135	137	139	134	135
31	135	---	147	109	---	120	---	136	---	142	134	---
MONTH	110	135	148	122	136	132	119	134	139	140	138	130

Table D.5-2 (Continued)

SABINE RIVER BASIN

08030500 SABINE RIVER NEAR RULIFF, TEX.--Continued

TEMPERATURE (DEG. C) OF WATER, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974
(ONCE-DAILY)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	19.0	16.0	12.0	14.0	12.0	20.0	22.0	27.0	---	27.0	27.0
2	26.0	18.0	16.0	11.0	15.0	12.0	20.0	21.0	26.0	28.0	28.0	27.0
3	26.0	19.0	17.0	12.0	15.0	---	19.0	21.0	25.0	27.0	32.0	27.0
4	28.0	20.0	17.0	12.0	14.0	17.0	20.0	23.0	25.0	29.0	28.0	25.0
5	26.0	21.0	16.0	9.0	14.0	18.0	18.0	21.0	26.0	29.0	27.0	23.0
6	26.0	20.0	15.0	10.0	14.0	18.0	18.0	21.0	27.0	28.0	27.0	23.0
7	28.0	19.0	15.0	11.0	14.0	18.0	19.0	20.0	28.0	28.0	27.0	23.0
8	26.0	20.0	12.0	11.0	13.0	19.0	19.0	20.0	27.0	27.0	27.0	26.0
9	---	21.0	12.0	13.0	11.0	19.0	18.0	22.0	27.0	28.0	27.0	26.0
10	28.0	19.0	12.0	15.0	11.0	19.0	18.0	23.0	27.0	27.0	28.0	26.0
11	26.0	18.0	12.0	12.0	11.0	19.0	19.0	23.0	25.0	28.0	28.0	28.0
12	25.0	18.0	12.0	12.0	12.0	19.0	20.0	25.0	24.0	28.0	29.0	26.0
13	24.0	18.0	14.0	15.0	13.0	18.0	20.0	23.0	27.0	28.0	28.0	26.0
14	24.0	17.0	14.0	12.0	13.0	18.0	21.0	23.0	27.0	28.0	28.0	27.0
15	24.0	18.0	13.0	13.0	16.0	19.0	19.0	24.0	27.0	28.0	28.0	27.0
16	23.0	19.0	14.0	14.0	14.0	18.0	19.0	23.0	27.0	28.0	28.0	26.0
17	22.0	18.0	12.0	17.0	14.0	18.0	18.0	24.0	28.0	27.0	29.0	26.0
18	21.0	19.0	12.0	16.0	14.0	19.0	19.0	24.0	28.0	27.0	29.0	27.0
19	20.0	19.0	13.0	17.0	13.0	20.0	19.0	24.0	29.0	28.0	29.0	27.0
20	19.0	20.0	11.0	15.0	13.0	21.0	20.0	24.0	29.0	28.0	29.0	27.0
21	19.0	19.0	10.0	15.0	16.0	19.0	21.0	24.0	28.0	29.0	29.0	28.0
22	19.0	19.0	9.0	15.0	14.0	19.0	21.0	24.0	29.0	29.0	29.0	28.0
23	20.0	20.0	11.0	15.0	13.0	19.0	21.0	24.0	28.0	29.0	29.0	26.0
24	21.0	20.0	12.0	13.0	12.0	18.0	20.0	24.0	28.0	30.0	29.0	25.0
25	21.0	20.0	12.0	13.0	12.0	18.0	19.0	25.0	27.0	29.0	29.0	26.0
26	21.0	21.0	12.0	16.0	11.0	14.0	19.0	24.0	---	29.0	28.0	26.0
27	21.0	22.0	12.0	16.0	11.0	14.0	21.0	26.0	25.0	29.0	28.0	23.0
28	21.0	19.0	11.0	14.0	12.0	15.0	21.0	25.0	26.0	29.0	29.0	25.0
29	21.0	14.0	13.0	13.0	---	16.0	22.0	26.0	27.0	29.0	28.0	25.0
30	20.0	17.0	13.0	13.0	---	17.0	22.0	26.0	27.0	29.0	---	24.0
31	19.0	---	14.0	13.0	---	15.0	---	26.0	---	28.0	27.0	---
MONTH	22.5	19.0	13.0	13.5	13.7	17.5	19.5	23.5	27.0	28.0	28.0	26.0

COLOR (PLATINUM-COBALT UNITS), WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974
(ONCE-DAILY)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	85	120	120	80	100	60	60	70	70	50	50	30
2	70	130	70	100	100	60	50	70	40	50	100	40
3	80	120	70	120	70	50	50	70	40	50	60	50
4	70	140	70	100	70	50	60	70	40	40	40	60
5	70	140	70	100	60	50	60	60	40	50	40	50
6	70	140	100	120	60	50	60	60	50	40	40	60
7	70	140	120	100	60	40	70	60	40	40	40	40
8	70	120	120	100	60	50	70	70	40	40	40	40
9	70	120	90	110	60	50	60	70	40	40	40	40
10	80	110	70	120	60	50	60	60	50	40	40	40
11	120	100	90	120	60	60	65	70	45	40	30	70
12	140	70	80	120	60	60	70	70	40	40	40	60
13	140	70	80	120	60	60	70	60	40	40	40	50
14	140	80	80	120	60	70	120	60	40	30	50	40
15	140	70	80	120	60	70	200	60	50	30	40	60
16	140	80	80	120	60	70	140	70	60	40	40	50
17	240	80	80	110	60	60	120	60	40	40	30	40
18	160	70	80	120	60	60	120	60	50	40	40	50
19	120	80	70	90	60	60	80	60	60	40	35	50
20	240	80	70	90	70	70	100	60	60	50	40	40
21	140	80	70	80	60	70	80	60	50	40	40	30
22	200	80	70	120	70	60	80	60	50	40	40	30
23	160	70	90	120	70	60	140	70	30	40	40	30
24	140	70	90	120	60	70	70	70	50	50	30	30
25	140	120	100	100	60	80	60	60	40	40	30	40
26	120	120	80	100	60	70	100	60	50	50	40	40
27	120	120	100	100	60	70	70	60	50	40	30	40
28	140	130	110	80	60	70	60	60	40	30	30	---
29	120	130	110	80	---	120	60	60	40	30	40	30
30	120	110	120	100	---	100	70	60	50	40	30	30
31	120	---	120	100	---	70	---	60	---	50	40	---
MONTH	120	100	90	110	65	65	85	65	46	41	40	43

Source: U.S. Geological Survey, "Water Resources Data for Texas," Part 2, 1974.

APPENDIX D.6

SUBSURFACE WATER DATA

Appendix D.6 contains two figures and three tables pertaining to subsurface water data. Figure D.6-1 shows the geohydrologic section from southeastern Texas to eastern St. Martin Parish, Louisiana, while Figure D.6-2 includes the geohydrologic section from northern Beauregard Parish to southern Cameron Parish, Louisiana. Typical concentrations of selected chemical constituents in fresh water of Chicot Aquifer are presented in Table D.6-1. Table D.6-2 contains the Salt Water Disposal Report for 1974 of the Lake Charles district. The subsurface industrial waste disposal wells in Louisiana near Sulphur Mines for the year 1971 are included in Table D.6-3.

Table D.6-1 Typical Concentrations of Selected Chemical Constituents in Fresh Water of Chicot Aquifer

Silica (SiO_2)	Iron (Fe)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Chloride (Cl)	Dissolved Solids (Residue on evaporation at 180° C)	Hardness as $CaCO_3$: Ca plus Mg	Hardness as $CaCO_3$: Non-carbonate	pH[1]
40	.1-2.0	175-225	0	45	230-280	100-150	0	7.4

[1]Laboratory measurements.

Source: Harder, A. H., Kilburn, Chabot, Whitman, H. M., and Rogers, S. M., "Effects of Ground-Water Withdrawals on Water Levels and Salt-Water Encroachment in Southwestern Louisiana", State of Louisiana, Department of Conservation, Water Resources Bulletin No. 10, October 1967.

Table D.6-2

SALT WATER DISPOSAL REPORT

LAKE CHARLES DISTRICT-1974

Field	Number of Wells	Average Depth	Pressure Range	Injection for Year (bbls)	Cumulative Injection M (bbls)
CALCASIEU					
Bayou Choupique	1	1,839	600-Vac	154,700	380.6
Beckwith Creek		3,578	1500-200	371,546	3,984.5
Bell City	0	0	0	0	1,815.1
Bon Air	0	0	0	0	138.9
Choupique	1	2,000	260-260	727,047	2,953.0
Coulee Hipolite	o	0	0	0	606.8
DeQuincy	2	3,275	1000-350	1,701,639	16,179.6
E. Bell City	1	2,455	200-0	110,000	6,198.0
E. Moss Lake	1	1,960	180-75	1,244,346	10,402.6
Edgerly	4	2,700	250-0	629,329	5,592.6
Gillis-English Bayou	3	2,500	300-0	533,561	7.075.8
Hayes	1	1,550	600-0	40,166	2,588.2
Holmwood	0	0	0	0	11,293.2
Iowa	7	3,600	450-120	12,034,339	84,091.4
Lake Charles	1	1,807	Vac	10,950	11.0
Manchester	1	4,000	1300-1100	698,160	7,090.4
N. Chalkley	1	1,710	900-200	767,015	7,159.1
N. Starks	0	0	0	0	104.0
NW Chalkey	0	0	0	0	303.6
Perkins	1	4,400	400-0	2,274,667	18,357.6
Section 32	1	1,991	380-350	21,288	21.3
So. Bell City	1	2,600	400-0	666,296	2,629.8
So. Lake Charles	1	1,385	400-150	183,092	4,718.6
So. Manchester	3	3,200	950-525	651,380	2,003.3
Starks	3	2,250	800-225	403,411	3,417.9
Sulphur Mines	1	1,220	0-0	153,061	674.9
Vinton	14	2,750	600-0	13,340,478	42,544.1
West Buhler	0	0	0	0	28.7
PARISH TOTAL	50			36,716,479	242,364.6

Source: Bates, Robert D., "Summary of Field Statistics and Drilling Operations Louisiana", 1974.

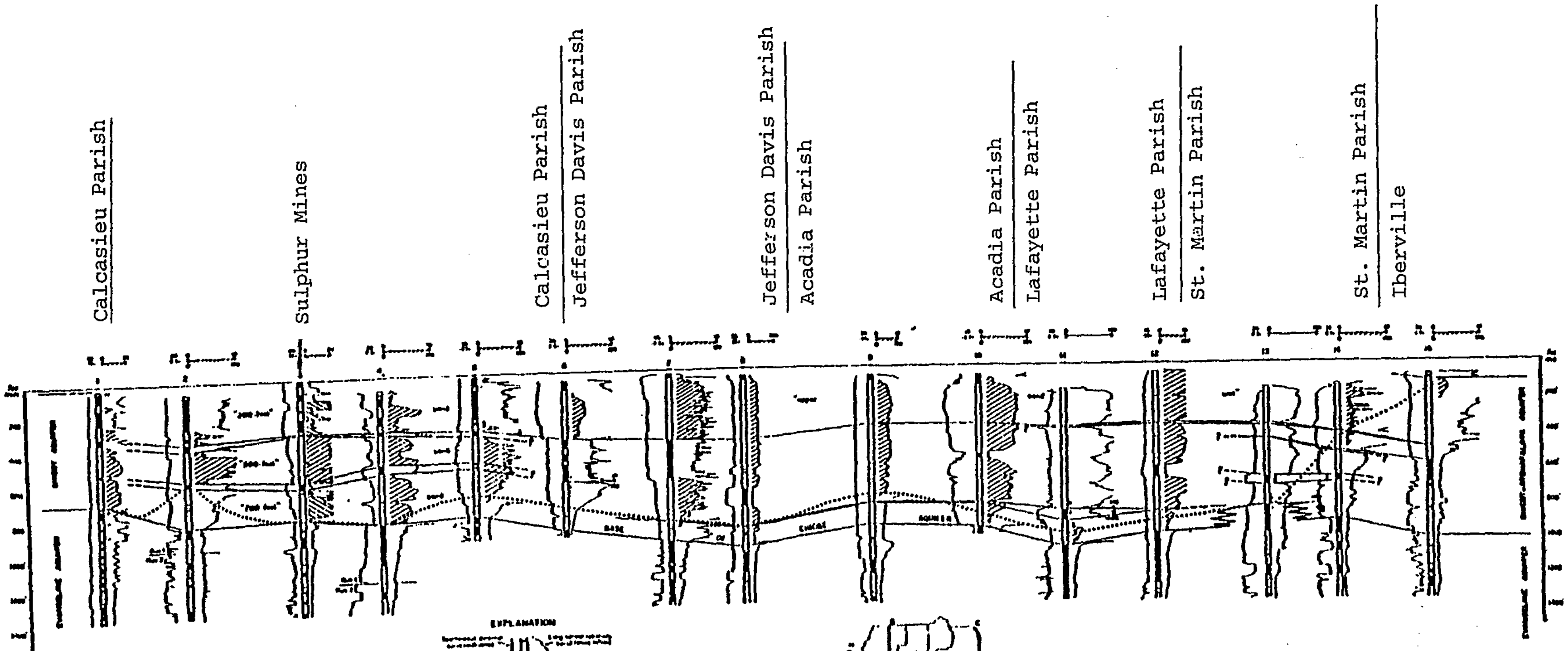
Table D.6-3

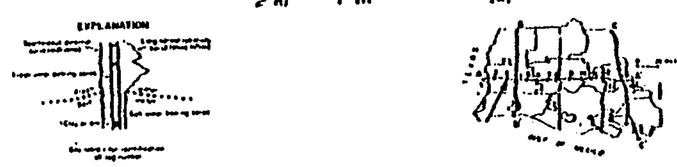
STATE OF LOUISIANA

SUBSURFACE INDUSTRIAL WASTE DISPOSAL WELLS
(1971)

Company	Well Name and Number	Parish & City	Location	Zone	Remarks
Cities Serv. Ref. Lake Charles Ref.	Waste Disposal #1	Calcasieu Lockport	19-10S-9W	3500	Suspended and Dissolved Solids H_2S, Phenol, Iron Sulfates, Ammonia
Cities Serv. Ref. Lake Charles Ref.	Waste Disposal #2	Calcasieu Lockport	19-10S-9W	3500	Suspended and Dissolved Solids, H_2S, Phenol, Iron Sulfates, Ammonia
Pittsburg Plate PPG Industries	Waste Disposal #1	Calcasieu Lockport	33-9S-9W	4850	NaCl, Na_2So_4, Na_2CO , Hg, Ca, Mg
Pittsburg Plate PPG Industries	Waste Disposal #2	Calcasieu Lockport	33-9S-9W	4850	NaCl, Na_2So_4, Na_2Co_3, Hg, Ca, Mg

Source: "Underground Industrial Waste Disposal in Louisiana", Louisiana Department of Conservation, Louisiana Geological Survey, April 1971.





Sources: Morder, A, Milburn, Chabot, Whitman, W.W., and Rogers, S.M., "Effects of Ground-Water Withdrawals on Water Levels and Salt-Water Encroachment in Southwestern Louisiana," State of Louisiana, Department of Conservation, Water Resource Bulletin No. 10, Plate 1, October 1967.

SULPHUR MINES

Figure D.6-1 Geohydrologic Section from Southeastern Texas to Eastern St. Martin Parish, La.

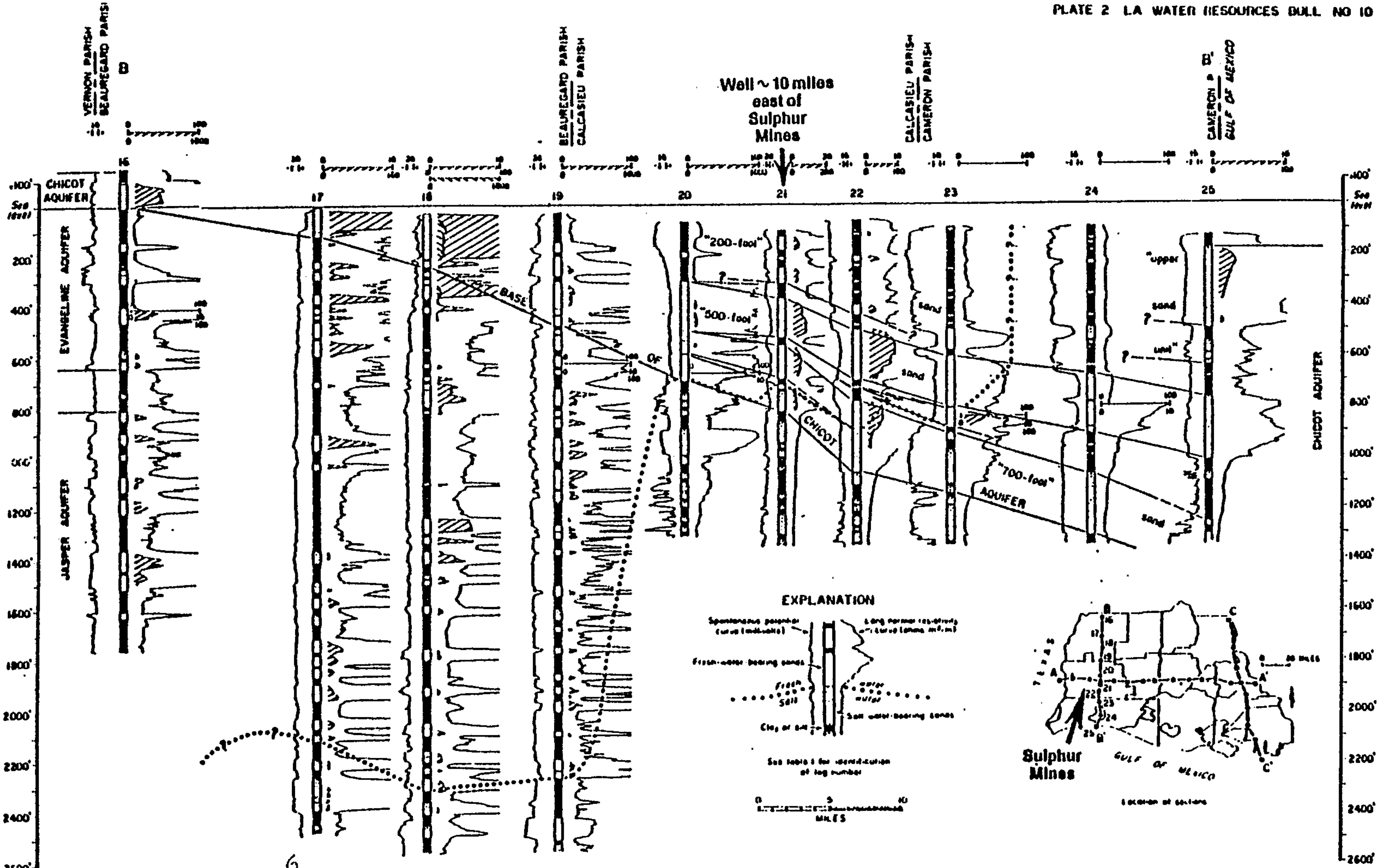


Figure D.6-2 GEOHYDROLOGIC SECTION FROM NORTHERN BEAUREGARD PARISH TO SOUTHERN CAMERON PARISH, LA.

Source: Harder, A.H., Kilburn, Chabot, Whitman, H.M., and Rogers, S.H., "Effects of Ground-Water Withdrawals on Water Levels and Salt-Water Encroachment in Southwestern Louisiana," State of Louisiana, Department of Conservation, Water Resources Bulletin No. 10, Plate 2, October 1967.

Figure D.6-2 Geohydrologic Section From Northern Beauregard Parish to Southern Cameron Parish, LA.

APPENDIX D.7

CORRESPONDENCE PERTINENT TO THE SULPHUR MINES SITE FROM THE INSTITUTE FOR ENVIRONMENTAL STUDIES (LSU)

The following appendix contains letters, papers, and tables received from C. G. Smith and William J. Bernard. These communications are principally concerned with water quality, water supply, and brine disposal questions. Correspondence from these persons received prior to 30 July 1975 and pertaining to the Sulphur Mines site is included. In some of this correspondence pertaining to Sluphur Mines references are made to correspondence originally written with respect to other salt dome sites. For completeness such correspondence is also included. All correspondence is arranged in chronological order.

LOUISIANA STATE UNIVERSITY
AND AGRICULTURAL AND MECHANICAL COLLEGE
BATON ROUGE • LOUISIANA • 70803

INSTITUTE FOR ENVIRONMENTAL STUDIES
P O DRAWER J.D.

AREA CODE 504
TELEPHONE 388-6Q03

April 2, 1976

Memorandum to: James Vancil

Subject: Ground-water at Sulphur Mines

Geohydrology of Potential Ground-water Supplies

Fresh-water is available from the Chicot aquifer (Pleistocene age) at Sulphur Mines. This massive sand sequence extends to approximately -800' and is broken by several thick and extensive clays (30 feet or more) between the surface and -350 feet and a single clay zone from approximately -550 to -600 feet. The Chicot aquifer is continuous for more than 100 miles east-west and north-south (Jones, et.al.,1954). Well no. 3 of Plate 1, Harder et al (1967), is located at Sulphur Mines and shows the sequence of aquifers and clays. The fresh-water/salt-water interface in the Chicot aquifer occurs a few miles south and a few miles west of Sulphur Mines (plate 2, Harder et.al., 1967). Salt water is available from the Evangeline Aquifer from depths greater than 800 feet.

The most important local development of ground-water use from the Chicot aquifer is at Lake Charles, 20 miles east-southeast of Sulphur Mines. It is estimated that 47 billion gallons (130 mgd) of water will be pumped from the Chicot aquifer in the Lake Charles industrial area in 1980 (Harder, et.al., 1967). The same report shows the Sulphur Mines area is on the northwestern flank of a large cone of depression centered in Lake Charles. The 1965 water levels in the Chicot aquifer were approximately 40 feet below sea level at Sulphur Mines and more than 100 feet below sea level at the center of pumpage (Harder et.al., plate 4, 1967).

Recharge to the Chicot aquifer occurs at the out crop 30 miles north of Sulphur Mines. Jones et.al.,(1954) indicate an effective line of recharge a few miles northwest of sulphur mines. This is not from surface recharge but may result from changes in the form of the aquifer (thickening) or may represent recharge from connections with deeper sands.

Mr. Vancil
Page Two

Impact of Ground-water Development

Jones et.al.,(1954) present the following graph showing the effect of pumping 1000 gpm from a well screened in the Chicot aquifer. The values

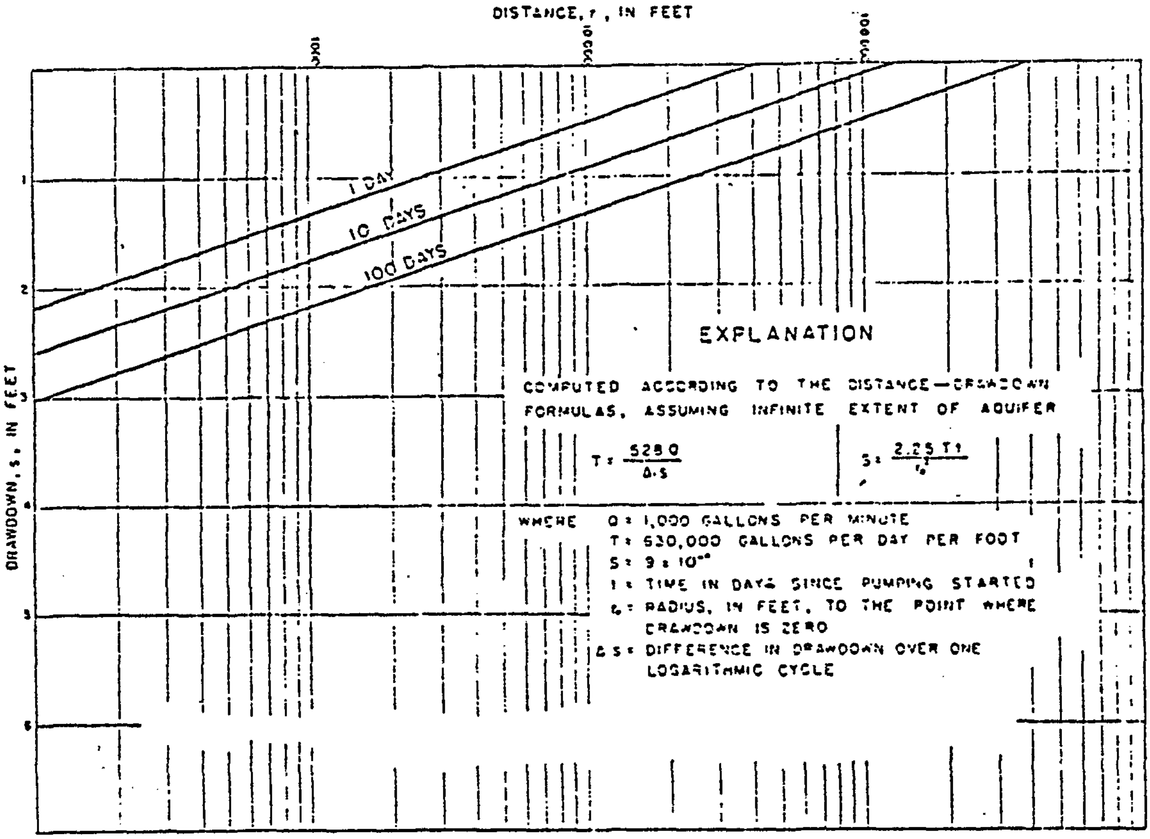


Figure 25. Graph showing the drawdown of water level at any distance from a pumped well after pumping has begun.

used to compute drawdown are assumed to be representative of the Chicot aquifer at Sulphur Mines. From this graph it is seen that drawdown at a pumping well would be about 3 feet below static level after pumping 1000 gpm for 150 days. Five wells, each pumping 1000 gpm (average rate of delivery of displacement water required is 4,900 gpm) placed at the 4 corners and the center of a square approximately 500 feet on a side, would produce a drawdown at the center of approximately 15 feet after 150 days of operation. Measurable land subsidence probably would not occur. In Lake Charles water levels have been lowered more than 140 feet since the early measurements of 1903 (Jones et.al., 1954) but a recent report of ground-water conditions in the area (Harder et.al., 1967) makes no mention of land subsidence. Obviously this is not positive evidence that subsidence has not occurred but if it has it has apparently been insignificant.

Sincerely,

Charles G. Smith, Jr.
Research Associate

CGS:mgm

cc: J. D. Martinez
Frank Tatom

Harder, A. H., Chabot Kilburn, H. M. Whitman, and S. M. Rogers, 1967. Effects of ground-water withdrawals on water levels and salt-water encroachment in southwestern Louisiana: Louisiana Department of Conservation and Department of Public Works, U. S. Geological Survey Water Resources Bulletin No. 10, 56p.

Jones, P. H., A. N. Turcan, Jr., and H. E. Skibitzke, 1954. Geology and ground-water resources of southwestern Louisiana: Louisiana Department of Conservation, Geological Survey Bulletin 30, 285 p.

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INSTITUTE FOR ENVIRONMENTAL STUDIES
P O DRAWER J D.

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TELEPHONE 388-6003

April 2, 1976

Memorandum to: Frank Tatom

Subject: Geologic Description of Potential Reservoir Zones at Sulphur Mines Dome.

It is proposed that saline sands between 5000 and 7000' below the surface be used for brine disposal at Sulphur Mines dome. Nine wildcat well logs were studied. Their locations are given in the enclosed map.

The upper potential disposal zone contains Miocene sands and clays between 4900 and 6000 feet below sea level in the Hamilton Brothers, Union Texas Fee, No. 1 well in Section 21, T9S, R10W. This zone is distinguished by a 200 foot thick clay and silt layer above and a 500 foot clay layer at its base. Individual sand layers are continuous (mappable) for a distance of only a few miles. The entire zone, however, is mappable in all the wells that were checked. This gives a proven distance of correlation of the zone of 7 miles east-west and 5 miles north-south. Potential reservoir sands typically range from as thin as 20 feet to a thickness of 70 feet within a distance of one mile. The average total thickness of sand in the Miocene zone is 600 feet. Typical wells penetrate 2 sands 100 feet thick and 10 sands 50 feet thick with lateral continuity of less than 2 miles.

The second potential disposal zone contains Oligocene clays and sands from 6500 feet to 7500 feet in the Hamilton, Union Texas Fee, No. 1 well. This zone is sandwiched between 500 feet of clay above and more than 2000 feet of clay below. This zone is present in all wells. Individual sands vary greatly in thickness from well to well and are definitely correlated for only about 3 miles. Approximately 50% of the zone is sand. Typically 2 sands 100 feet thick and 5 sands at least 50 feet thick are penetrated in the Oligocene zone.

Sincerely,

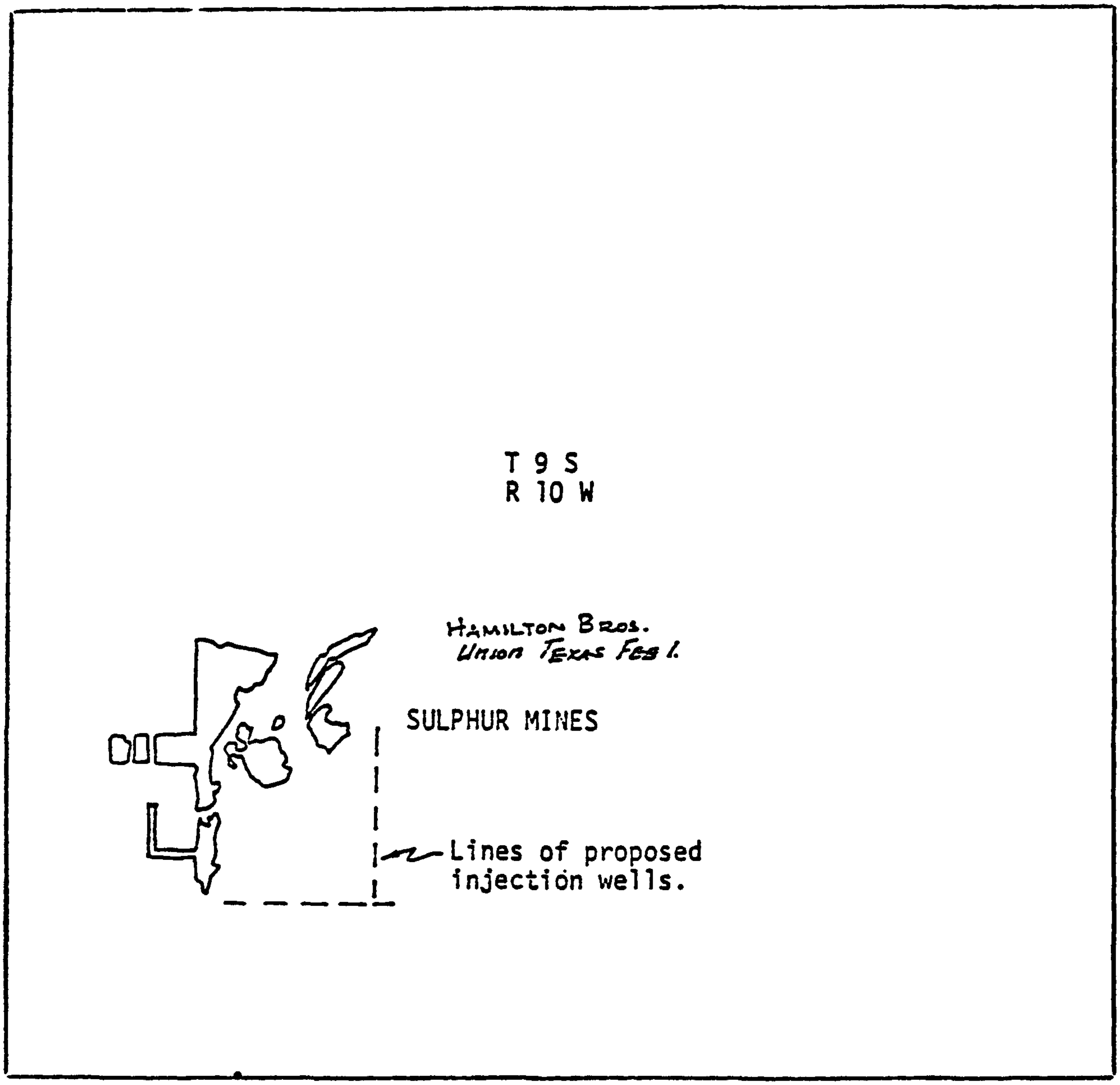
Charles G. Smith, Jr.

Charles G. Smith, Jr.
Research Associate

CGS:mgm

Enclosure

CC: J. D. Martinez
James Vancil



Map showing locations of electric logs of wildcat wells reviewed.

Note: The proposed design now calls for 4 brine disposal wells to be drilled south, southwest of the site (see Figure 1.5).

CHARLES G. SMITH
CONSULTING GROUND WATER GEOLOGIST
5743 SOUTH POLLARD PKWY.
BATON ROUGE, LOUISIANA 70808
PHONE 504-766-8055

April 24, 1977

Memorandum to: Frank Tatom

Subject; Brine Injection Reservoirs at Sulphur Mines Dome.

My memo of April 2, 1976 reported my analysis of brine disposal reservoirs at Sulphur Mines based on 9 wildcat well logs. As noted in that memo two zones of massive sands (5000 to 6000 and 6500 to 7500 feet deep) were correlatable for distances of several miles and were present in all the wells evaluated. However, individual sand strata could not be mapped for distances greater than two or three miles.

Two potential hydraulic boundary conditions, which could substantially reduce the areal extent, and therefore the volume, of the reservoirs, must be considered. First, numerous faults are characteristic of sediments surrounding and overlying salt domes. At Sulphur Mines faults may exist, as yet undiscovered, which could result in compartmentalization of sands surrounding the dome. In this instance brine reservoir voulme would be reduced, and pressure increase due to injection would be limited by fault barriers.

The second boundary condition that could effect brine disposal operations at Sulphur Mines is the termination of sand formations against the salt dome. At a depth of 7000 feet below sea level the eastern flank of the dome may lie within 800 feet of the north-south line of proposed injection wells at the closest point. At 6000 feet below sea level the distance between the salt and the proposed injection wells is approximately 1300 feet. These potential boundary conditions must be considered in the design and evaluation of the brine disposal system at Sulphur Mines.

Abandoned wells near brine disposal wells and potential brine leaks via these wells is the subject of a memo dated July 13, 1976. In addition to abandoned wells producing oil wells are also located near the proposed brine injection line. A review of the New Orleans Geological Society map included with the July 13 memo shows 15 producing wells occur within 2000 feet of the injection well line.Three of these wells are within 1000 feet of the injection line. From 2000 to 3000 feet from the injection well lines an additional 30 producing wells occur.

Oil production near the injection lines occurs generally between 5000 and 7000 feet-the same depth proposed for brine injection. It is possible that brine would be injected into formations now producing oil and gas if the present plans for brine injection are carried out. Title 30, Chapter I, Section 4, Paragraph C of the Louisiana Revised Statutes of 1950 give the Commissioner of Conservation authority to make rules and regulations to "prevent the intrusion of water into oil or gas strata". It appears proposed brine injection plans for Sulphur Mines and state regulations regarding oil and gas reserviors are in potential conflict. Because the injection wells will be located in areas as yet unexplored it may be impossible to determine whether or not brine is being injected into oil and gas sands before the injection wells are drilled and logged. To avoid such a possibility it may be prudent to relocate the line of disposal wells perhaps further to the south, further from oil production and further from the structure of the dome.

Sincerely,

Charles G. Smith

Telephone Conversation with Dr. Bill Hise

Subject: Earthquakes

Date: May 28, 1976

There is documented evidence of earthquakes being triggered as a result of subsurface injection of fluids accompanied by an increase in injection reservoir pressure. The two known cases of this phenomena have occurred in Colorado in an area of high natural rock stress. One is near Denver in association with a disposal well that injected liquid waste from the Rocky Mountain Arsenal, and the other is near Rangly, Colorado in association with a water flood in the Rangly oil field. The mechanism causing the earthquake is not well understood. However, all those who have studied the problem agree that the existence of high natural earth stress (e.g., Colorado, Wyoming, California) is a prerequisite.

In the Texas-Louisiana Gulf Coast the natural earth stress is low - here we deal with a tectonically relaxed area which is characterized almost exclusively by normal faulting. (No reverse or overthrust faults.) Numerous water flood and liquid waste injection sites have been in operation along the Louisiana-Texas Gulf Coast for many years without reported occurances of earthquakes. Therefore, it would appear that earthquake occurance along the Louisiana-Texas Coast as a result of the injection of brine from the strategic oil storage project would not be a problem that can be forseen at this time.

CHARLES G. SMITH
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MEMORANDUM TO; Frank B. Tatom

FROM: Charles G. Smith and Bill R. Hise

DATE: July 2, 1976

SUBJECT: Brine Injection

An undesirable consequence of pressuring an aquifer (not to fracture pressure levels) is the hazard it creates for future oil and gas wells that must be drilled through it. The oil and gas industry is accustomed to controlling high pressures but they are usually encountered at much greater depths. Even then these abnormally high pressures are difficult and expensive to handle, and may result in a blow out or "wild well." When unexpectedly encountered at a shallow depth, these pressures are much more likely to cause extreme hazards.

If the aquifer pressure during brine injection exceeds the fracture pressure at that depth, the injected fluid may escape the disposal aquifer. This will almost certainly be the case if injection continues for a significant period after fracture pressure is reached. The fluid may escape by one or more of the following means:

1. Through a fracture created in the overlying sediments.
2. Through a fracture created in the underlying sediments.
3. Through a failure created in the cement, or at the cement/pipe or cement/formation interface around the well bore.

In any event, control of the injected fluid is lost.

The particular consequences of exceeding the reservoir fracture pressure are uncertain. However, possible results are:

1. Hydraulic communication could develop with shallow, fresh-water aquifers thereby contaminating the potential ground-water supply.
2. Hydraulic communication developed to the surface could contaminate surface waters.

Clearly the magnitude of the undesirable consequences depends on the amount and rate of brine escape. The longer pumping continues after fracture pressure is reached, the worse the problem becomes. Thus, underground waste injection systems are designed to operate well below fracture limits. Therefore examples of reservoir fracture during brine disposal and the resulting problems are lacking.

Charles G. Smith

Bill R. Hise

CHARLES G. SMITH
CONSULTING GEOLOGIST
5743 SOUTH POLLARD PKWY.
BATON ROUGE, LOUISIANA 70808
PHONE 504-766-8055

MEMORANDUM TO: Frank B. Tatom

FROM: Charles G. Smith and Bill R. Hise

DATE: July 13, 1976

SUBJECT: Brine Injection at Sulphur Mines

State well location maps were reviewed to determine the number of abandoned wells in the vicinity of the proposed brine disposal wells at Sulphur Mines. The two lines of injection wells will border Sulphur Mines field approximately along the east and south lines of section 29, T9S;R10W (see map in Memo of April 2, 1976). In this section within 2500 feet of the injection lines there are approximately 40 abandoned wells drilled to depths between 3000 and 7000 feet along the flanks of the dome (Figure 1). The records of these wells should be checked to insure that they were properly plugged. If they were not they should be replugged to prevent the possibility of vertical flow of brine developing via these well casings. Because the brine disposal reservoirs probably are uplifted by the dome it is essential that wells completed to depths shallower than the disposal reservoir also be checked.

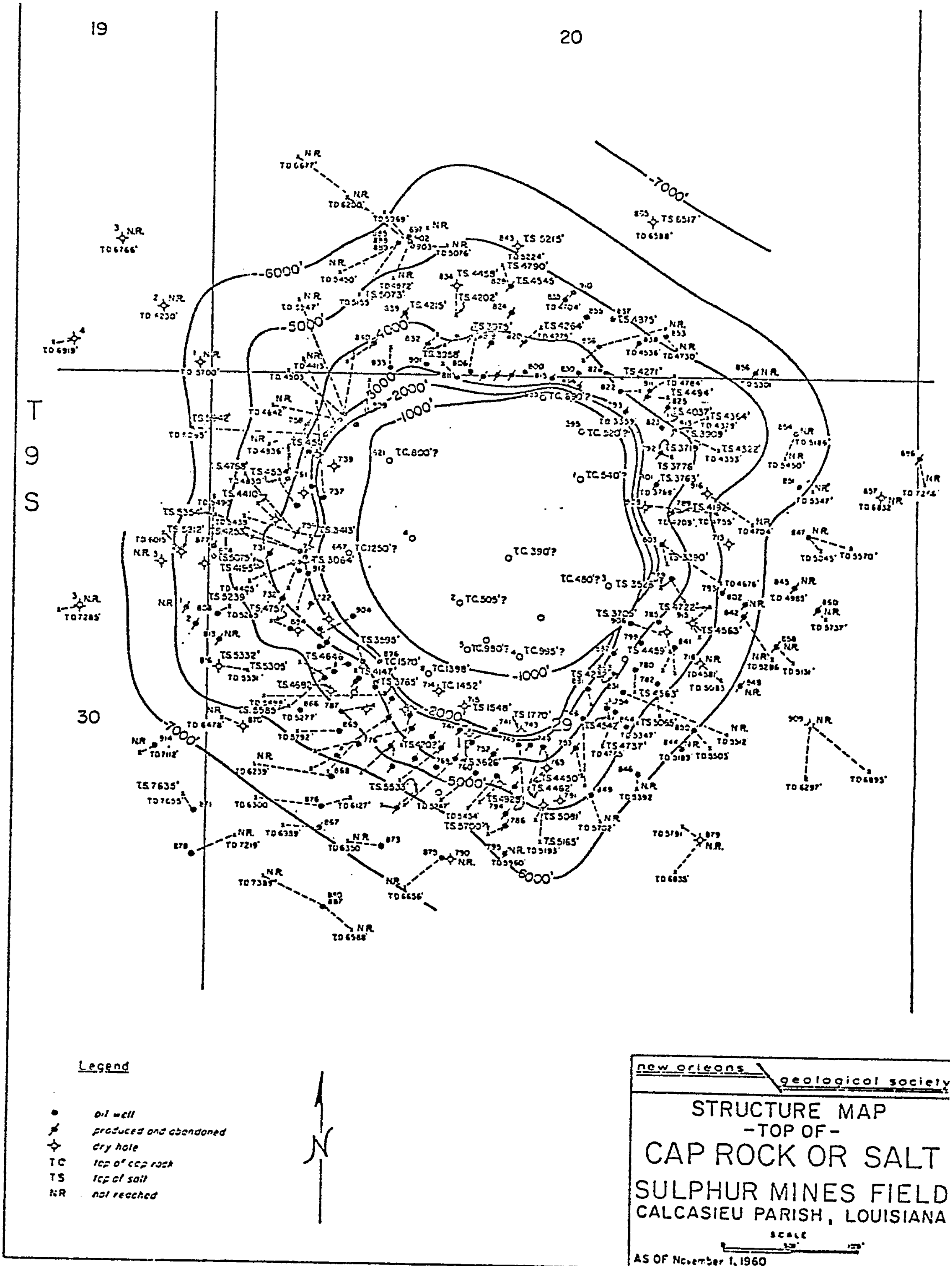
As noted in an earlier memorandum (June 21, 1976), the calculated rates and volumes of brine flow that might be anticipated in an inadequately plugged well are dependent on assumptions that must be made regarding the time of occurrence of the leak relative to reservoir pressure buildup, and whether the leaky well is considered to be open throughout the reservoir or is only partially open.

Our memorandum of July 2, 1976, outlines the consequences of pressuring and over-pressuring an aquifer during brine disposal. Although no examples are known of reservoir fracture during brine disposal a related problem was reported at a brine disposal operation near another Louisiana salt dome. Brine was injected into a permeable formation near the dome. Pressure was kept below fracture pressure. But because the formation was raised to the surface over the dome the connate saline water contained in the formation began to flow on the surface as a result of the increased reservoir pressure. Injection was halted and a new and deeper disposal system was built. Apparently the problem has been solved.

At Sulphur Mines the cap rock is less than 400 feet below the surface. The possibility that a disposal reservoir 6000 feet below the surface and a mile from the dome is raised near the surface over the dome must be investigated. In such a case injection pressure buildup could cause surface or near-surface discharge of saline water which could pollute fresh waters.

Charles G Smith
Charles G. Smith

B.R. Hise (by CGS)
Bill R. Hise



© Figure 1 From Salt Domes of South Louisiana. Vol.2, 1963, New Orleans Geological Society, New Orleans, La.

SULFUR MINES BRINE SUBSURFACE DISPOSAL

by

William J. Bernard

SUB-SURFACE PRESSURES

The analysis of subsurface brine disposal operations generally focuses on the prediction of subsurface pressures in the aquifer during the injection operation. These pressures are of prime interest because if the subsurface pressure in any part of the aquifer exceeds the fracture pressure, the brine may escape the disposal aquifer and perhaps contaminate nearby fresh water aquifers. The subsurface pressure will be a function of the overall rise in aquifer pressure because of the additional volume of the injected material (material balance type consideration) and the rise in pressure in the immediate vicinity of the well bore while actually injecting (frictional loss in the rock pore channels).

The variables influencing the subsurface pressure are the amount of fluid already existing in the aquifer (defined by areal extent, thickness, porosity, compressibility) and the ease with which the brine will flow through the rock (defined by permeability, thickness, viscosity, etc). The equation that predicts the effects of these variables on subsurface pressure is:

$$p_w = p_i + \frac{q\mu}{7.08\ k\ h} \ln \left[\frac{14.22\ k\ t}{\mu\ c\ \phi\ r_w^2}\right]$$

Where:

p_w = well bore pressure, psig

p_i = initial aquifer pressure, psig

q = injection rate, barrels per day

μ = brine viscosity, cp

k = permeability of rock, darcy

h = sand thickness, feet

t = time, days

c = aquifer-brine system compressibility, vol/vol/psi

ϕ = porosity, fraction

r_w = well bore radius, feet

This equation is valid only for a single injection well injecting at a constant rate in an aquifer of infinite extent. By the proper use of "image wells" and the mathematical theory of superposition, the equation can be utilized for multi-well injection at varying rates in aquifers of varying sizes.

In the proposed Sulfur Mines project, the following brine disposal plan has been proposed for each of five oil-fill cycles: Brine will be disposed at a rate of 100,000 barrels/day (2917 gpm) for 240 days into four injectors (25,000 barrels/day/injector). These rates are determined by the rate at which the cavities will be filled with oil. The aquifer will have been "dormant" prior to the start of each of these cycles.

Geologic information on potential disposal aquifers indicates that there exists four 100 foot thick sands and thirteen 50 foot thick sands, for a total of 1050 feet, lying between 5000 and 7500 feet subsea. Four disposal wells, each completed in separate sand bodies, will result in three wells completed in 250 feet of sand each and one well completed in 300 feet of sand. Areal extent of the aquifers is unknown but could reasonably be expected to be 16 square miles. Figure 1 and Table 2 present the results of the pressure calculations. The data used in the calculations is shown in Table 1. The maximum pressure reached is 3531 psi, which occurs on the last day of the fifth cycle of disposal. This is considerably below the expected 4500 psi fracture pressure. Therefore, a 16 square mile aquifer is quite adequate for the brine disposal.

Two potential problems exist with regard to these calculations: (1) the actual aquifer extent could be smaller than 16 square miles and (2) the disposal wells are close to the salt dome (perhaps as close as 800 feet). With regard to the first potential problem, additional calculations have shown that as long as the areal extent of the aquifer is 5 square miles or greater, fracture pressure will not be reached. With respect to the second potential problem, analysis has shown that, in the 16 square mile aquifer, if an injector is within 800 feet of the dome, the injection pressures will increase a small amount (less than 70 psi) but not enough to be of concern.

LEAKAGE THROUGH ABANDONED WELLS

If communication exists between the disposal aquifer and shallower fresh-water-bearing aquifers through an abandoned well, then brine can be expected to escape. Normally, such communication would not be expected because the State of Louisiana has certain prescribed and proven procedures for abandoning wells.

This discussion centers on the hypothesis that a fracture of some type develops along the length of the abandoned well from the disposal zone to the fresh-water zone. Furthermore, it is hypothesized that the fracture is 0.01 inch wide and extends along one-fourth of the perimeter of the abandoned well.

Before the start of brine disposal, there is virtually no potential for water to flow through the fracture because the disposal aquifer and the fresh-water aquifer are essentially in hydrostatic equilibrium. As brine injection begins, the pressure in the disposal aquifer increases and water begins to flow along the fracture. The escaping water will most likely be the native aquifer water rather than the injected brine. The rate of escape will steadily increase as the disposal aquifer pressure increases with continued disposal. At the end of the disposal cycle, water will continue to escape as long as the pressure in the disposal aquifer remains above its original level.

There are three resistances in series that impede the escape of the water and were considered in the calculations.

1. The frictional loss in the disposal aquifer
2. The frictional loss in the fracture
3. The frictional loss in the fresh-water aquifer

The results of the analysis are shown in Table 3. The rate of escape is quite small, with a total of only 50 barrels escaping over an almost three year period.

If the disposal aquifer is smaller than the sixteen square miles used in this analysis, the rate of escape will increase because of the higher pressures that will develop in the disposal aquifer. The escape rate will still represent only a small fraction of the total volume of brine injected, however.

TABLE D.7-1

DATA USED FOR SULFUR MINES BRINE DISPOSAL

Number of disposal wells = 4
Brine injected/well/cycle = 6000000 barrels
Sand thickness = 250 feet
Porosity = 33%
Depth = 6000 feet
Initial aquifer pressure = 3000 psig
Fracture pressure = 4500 psig
Brine viscosity = 0.55 cp
Brine density = 10 pounds/gallon
Permeability = 1 darcy
System compressibility = 10^{-5} vol/vol/psi
Well bore diameter = 5 inches
Areal extent of aquifer = 16 square miles
Injection rate = 25000 barrels/day/well

TABLE D.7-2

SUB-SURFACE INJECTION PRESSURES

SULFUR MINES (4 INJECTORS)

DAYS	----------- BOTTOM HOLE PRESSURE ----------- FIRST CYCLE	SECOND CYCLE	THIRD CYCLE	FOURTH CYCLE	FIFTH CYCLE
0.	3000.0	3091.5	3183.0	3274.5	3366.0
1.	3068.5	3160.0	3251.5	3343.0	3434.5
2.	3071.1	3162.6	3254.1	3345.6	3437.1
3.	3072.7	3164.2	3255.7	3347.2	3438.7
5.	3074.7	3166.2	3257.7	3349.2	3440.7
10.	3077.6	3169.1	3260.6	3352.1	3443.6
50.	3093.0	3184.5	3276.0	3367.5	3459.0
100.	3112.1	3203.6	3295.1	3386.6	3478.1
150.	3131.2	3222.7	3314.2	3405.7	3497.2
200.	3150.2	3241.7	3333.2	3424.7	3516.2
240.	3165.5	3257.0	3348.5	3440.0	3531.5
241.	3097.4	3188.9	3280.4	3371.9	3463.4
242.	3095.1	3186.6	3278.1	3369.6	3461.1
243.	3093.9	3185.4	3276.9	3368.4	3459.9
250.	3091.8	3183.3	3274.8	3366.3	3457.8
300.	3091.5	3183.0	3274.5	3366.0	3457.5

TABLE D.7-3

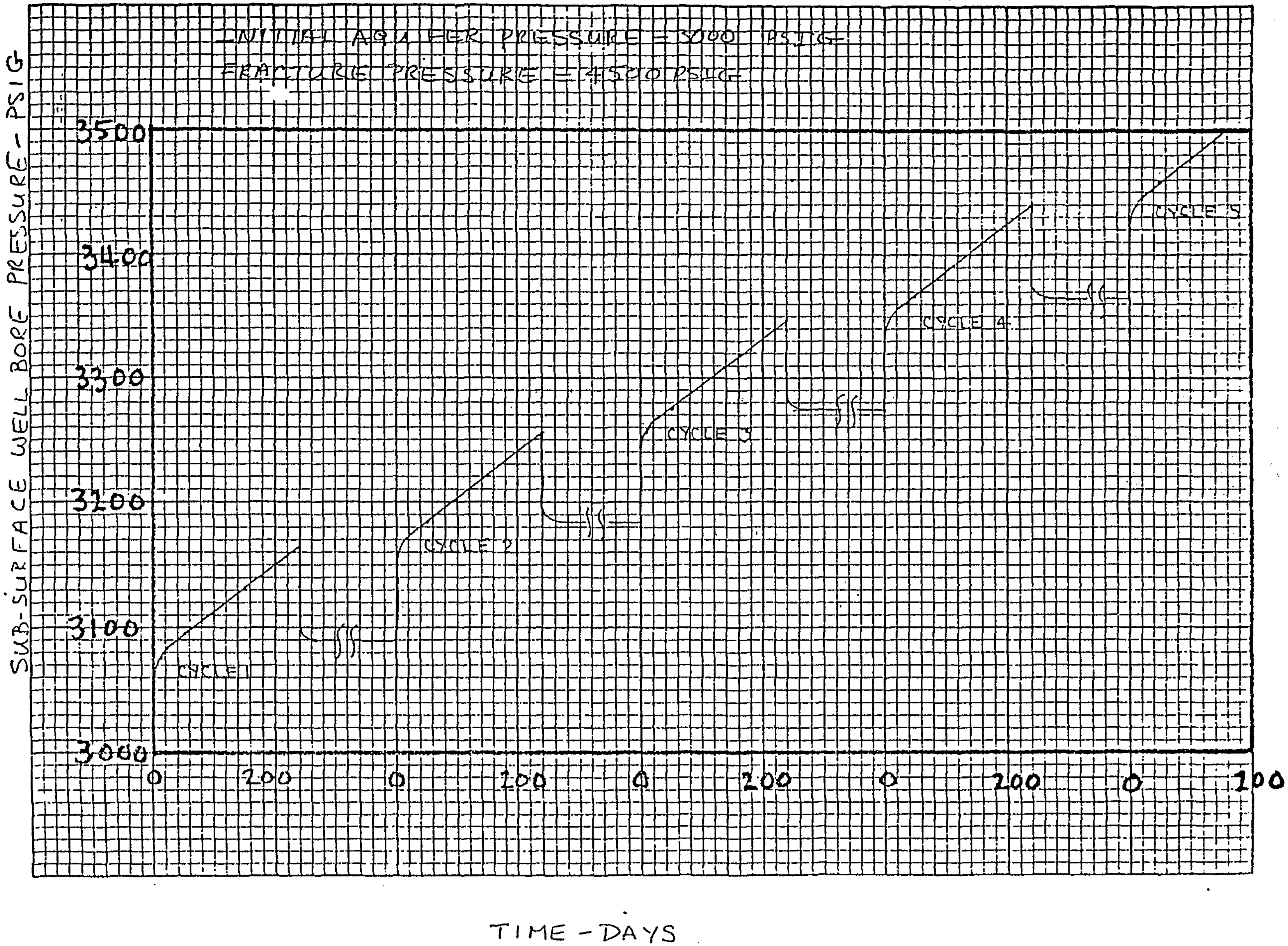
WATER LOSS THROUGH AN ABANDONED WELL

SULFUR MINES

DAYS	ESCAPE RATE BBL/DAY	ESCAPED VOLUME BBL
30.0	0.01	0.
60.0	0.02	0.
90.0	0.02	1.
120.0	0.03	2.
150.0	0.03	3.
180.0	0.05	4.
210.0	0.05	5.
240.0	0.06	7.
270.0	0.05	9.
300.0	0.06	10.
330.0	0.05	12.
360.0	0.06	14.
390.0	0.05	16.
420.0	0.06	17.
450.0	0.05	19.
480.0	0.06	21.
510.0	0.05	23.
540.0	0.06	24.
570.0	0.05	26.
600.0	0.06	28.
630.0	0.05	30.
660.0	0.06	31.
690.0	0.05	33.
720.0	0.06	35.
750.0	0.05	37.
780.0	0.06	38.
810.0	0.05	40.
840.0	0.06	42.
870.0	0.05	43.
900.0	0.06	45.
930.0	0.05	47.
960.0	0.06	49.
990.0	0.05	50.

FIGURE D.7-1

SUB-SURFACE INJECTION PRESSURES
AQUIFER EXTENT = 16 SQ. MILES
SULFUR MINES PROJECT



Potential Brine Injection Problems Resulting from Chemical and Biological Characteristics

As noted in subsection 3.2.2.2, associated with brine injection, there are three potential problem areas resulting from the chemical and biological characteristics of the waters involved. These problem areas are:

(1) Incompatibility of waters

(2) Water-sensitive formations

(3) Water quality considerations

With respect to incompatibility of waters, Ostroff[1] notes "Waters that are compatible can be mixed without producing any undesirable chemical reactions between components dissolved in the individual waters. Undesirable reactions are those that produce insoluble products such as calcium and carbonate ions, forming barium sulfate. Insoluble products produced from these reactions can decrease flow in lines, plug injection wells, or reduce permeability."

Potential problems with water compatibility exist at several different points in the brine disposal problem.[2,3] Of primary concern in the current case is the compatibility of the brine to be injected with the waters of the aquifer where injection is to occur. When brine is injected into a reservoir containing waters incompatible with the brine, deposits will form only where the brine and reservoir water make contact and mix. Deposits will form only in a small volume of water if there is a small degree of mixing, but deposits will form in a large volume of water if a large degree of mixing occurs.

The problem of water-sensitive formations has been considered by a number of investigators.[1,2,4] Certain types of rocks are susceptible to permeability damage when infiltrated by fresh or slightly saline water. Damage of this type is related to rock properties and is caused by swelling of indigenous clays and the dispersion of indigenous nonswelling particles during fluid flow.

The swelling (hydration) of clays is a function of the salinity of the water being injected. Clays which are prone to swell are more sensitive to fresh water than saline water with a minimum salinity of 2- to 50 ppt. Because the brine salinity will be considerably above this level, clay swelling appears unlikely.

The third problem concerning water quality in general is clearly related to the two already discussed. As noted by Ostroff[1], "Water quality includes the amount of suspended solids in the water, number of bacteria present, and the corrosivity of the water. All of these solids could plug the pore spaces in the formation or build up an impermeable filter cake on the face of the reservoir rock that would impede water injection. Bacteria may contribute to corrosion and corrosion products, resulting in plugging of the injection well. Bacterial growths themselves can sometimes result in plugging. Corrosive water not only damages the system but may produce corrosion products which can plug the well. A common example of this is iron sulfide formed from corrosion by hydrogen sulfide."

"The character of the reservoir rock largely influences the quality of water than can be injected. A reservoir rock with small pore sizes and low porosity requires water of very low suspended solids or high-quality water. Conversely, a high-porosity reservoir having large pores and voids would take water containing a considerable amount of suspended solids."

For evaluating water quality for injection purposes a rating system has been devised[5] as shown in Table D.11-1. At the present time, no results from these types of tests are available for water samples from the Sulphur Mines site.

A major water quality problem is concerned with suspended solids. "Suspended solids carried by water may be sand grains from the water-sand, corrosion products such as iron sulfide or iron oxide, free sulfur, or bacterial growths. If allowed to enter the injection wells, these materials will either plug the wells completely or cause increases in injection pressures. These materials are often present in water in a finely divided state and in amounts small enough so that their presence is not easily detected by looking at the water. Yet, when large volumes of water are injected, even small amounts of suspended solids can form an appreciable filter cake or deposit in an injection well pore."[1]

A second water quality problem arises from the corrosive qualities of the water. The brine to be injected should not be corrosive to the metals used in the disposal system. Such corrosion would not only be destructive to the disposal equipment but might also produce corrosion products that would plug the injection well.

A third major water quality problem results from the presence of bacteria.[1,6] "The number and type of bacteria present in injection water affect the quality of the water. Bacteria can contribute to corrosion or produce plugging. Desulfovibrio or sulfate-reducing bacteria utilize oxygen in sulfate ion to oxidize organic compounds. Corrosive hydrogen sulfide is produced in the process. Increases in sulfide content of water within the water-handling system are caused by sulfate reducers. Desulfovibrio are nearly always present, but, when conditions are not right for their growth, they are not a serious problem."

"The total bacterial count is indicative of the number of all varieties of bacteria in the water. Large growths of bacteria can result in colonies of the microorganisms plugging the injection well or otherwise fouling equipment."[1]

	Rating					
	1	2	3	5	10	20
Membrane filter test (0.45 u filter) slope	0-0.09 excellent	0.10-0.29 very good	0.30-0.49 good	0.50-0.99 acceptable	1.00-1.79 fair	1.80+ excessive
Filtered solids mg liter	0. -0.04 negligible	0.5-0.9 very low	1.0-2.4 low	2.5-4.9 moderate	5.0-9.9 large	10.0+ excessive
Tot. sulfide increases lb day/1,000 sq ft	0 none	0.001 very low	0.002-4 low	0.005-9 moderate	0.01-0.019 large	0.02+ excessive
Iron count increases lb day/1,000 sq ft	0 none	0.001-0.011 very low	0.012-0.11 low	0.12-0.59 moderate	0.60-1.1 large	1.2+ excessive
Sulfate-reducing bacteria colonies/ml	0 none	1-5 very low	6-9 low	10-20 moderate	30-90 large	100+ excessive
Total Bacteria count colonies/ml	0 none	1-99 very low	100-999 low	1,000-9,999 moderate	10,000-99,999 large	100,000+ excessive
orrosion rate (30 days (insulated coupon) mils/year	0 none	0.01-0.09 very low	0.10-0.99 low	1.00-4.9 moderate	5.0-9.9 high	10.0+ excessive
Pit depth (30 days) (insulated coupon) mils	0 none	1 shallow	2-3 minor	4-5 moderate	6-10 deep	10+ excessive
Pit frequency (30 days) (insulated coupon) pits/sq in	0 none	1 very low	2 low	3 [illegible]	4 [illegible]	5+

Appendix D.8

REFERENCES

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2. W.F. Hower, et al., "Compatibility of Injection Fluids with Reservoir Components", in T.D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 287-293.

3. Ivan Barnes, "Water-Mineral Reactions Related to Potential Fluid-Injection Problems", in T.D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 294-297.

4. Earle C. Donaldson, "Injection Wells and Operations Today", in T.D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 24-26, 1972.

5. C.C. Wright, "Rating Water Quality and Corrosion Control in Water Floods", Oil and Gas Journal, Vol. 61, No. 20, 1963, p. 154.

6. Gary G. Ehrlich, "Role of Biota in Underground Waste Injection and Storage," in T.D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 298-307.

APPENDIX E

CALCULATION OF SEDIMENT TRANSPORT

The annual volumetric transport rate for sediment can be expressed by the universal soil-loss equation developed by Wischmeier and Smith (1965). The universal soil-loss equation is a widely used calculation for estimating soil erosion on both farm land and construction sites. However, the equation has several limitations in the FEA SPR salt dome locations:

1. The slope factor will tend to overestimate the net result in land with gentle slopes;

2. The equation does not predict soil-loss that is due solely to thaw, snowmelt, or wind;

3. No known value has been developed for saline soils.

4. This equation is still being perfected for the southeastern area of the United States.

The soil-loss equation is

$$A = R\ K\ L\ S\ C\ P$$

where A is the computed soil loss per unit area - (tons per acre per year).

R, the rainfall factor, is the number of erosion-index units in a normal year's rain. The erosion index is a measure of the erosive force of specific rainfall.

K, the soil-erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow, on a 9-percent slope 72.6 feet long. The reasons for selection of these conditions as unit values is explained in the detailed discussion of this factor.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-foot length on the same soil type and gradient.

S, the slope-gradient factor, is the ratio of soil loss from the field gradient to that from a 9-percent slope.

C, the cropping-management factor, is the ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which the factor K is evaluated. If there is no cropping management factor, then C = 1.

P, the erosion-control practice factor, is the ratio of soil loss with contouring, stripcropping, or terracing to that with straight-row farming, up-and-down slope. If there is no erosion control practice, then P = 1.

For Sulphur Mines, the factors for the universal soil-loss equation are:

R = 500	P = 1
L = .3	C = 1
S = .07-.18	K = 0.25

Thus for an assumed 6 month exposure due to construction,

$$A = 500 \times 0.3 \times 0.07 \times 1 \times 1 \times 0.25 \times 0.5 \text{ years}$$

$$= 1.30 \text{ tons/acre (minimum)}$$

$$A = 500 \times (0.25) \times (0.3) \times (0.18) \times 1 \times 1 \times 0.5 \text{ years}$$

$$= 3.4 \text{ tons/acre (maximum)}$$

As noted in subsection 3.1.2, the disturbed area is 115.3 acres. To compute the amount of soil loss due to construction of the Sulphur Mines SPR facility, you multiply the soil loss per unit area (A) times the number of acres disturbed.

$$T = A \cdot \text{number of acres}$$

1.3 tons/acre x 115.3 acres = 150 tons (minimum)

3.4 tons/acre c 115.3 acres = 392 tons (maximum)

Assuming the density of the soil, which is a clay-loam, is 2,700 lb/yd^3 = ρ

To calculate the volume of soil loss (V_{sl}) due to construction at the Sulphur Mines site, one must divide the number of tons of soil loss by the density of the soil,

$$V_{sl} = T/\rho$$

$$150 \text{ tons} \times 2{,}000 \text{ lb/ton} \times \frac{1}{2{,}200} \text{ lb/yd}^3$$

$$V_{sl} = 111.1 \text{ yd}^3\text{/year (minimum)}$$

$$392 \text{ tons/year} \times \frac{2{,}000 \text{ lb}}{\text{ton}} \times \frac{1}{2{,}700} \text{ lb/yd}^3$$

$$V_{sl} = 290 \text{ yd}^3\text{/yr (maximum)}$$

The increase in the turbidity of the surface water system will depend on the total volume of water present in the surface water system in the vicinity of the Sulphur Mines site. This volume is difficult to calculate precisely. Based on the dimensions of the major bodies of water in the area

$$V_{sw} \sim 5.8 \times 10^6 \text{ yd}^3$$
$$= 1.6 \times 10^8 \text{ ft}^3$$

The most conservative assumption would be that none of the transported sediment settled out. Then the annual increase in suspended sediment in the water would be

	Minimum case	Maximum case
$\frac{T}{V_{sw}}$ =	$\frac{150 \text{ tons}}{1.6 \times 10^8 \text{ ft}^3}$	$\frac{392 \text{ tons}}{1.6 \times 10^8 \text{ ft}^3}$
	$= 9.4 \times 10^{-7}$ tons/ft^3	$= 2.5 \times 10^{-6}$ tons/ft^3
	$= 3.3 \times 10^{-8}$ tons/l	$= 8.9 \times 10^{-8}$ tons/l
	$= 3.0 \times 10^{-2}$ g/l	$= 8.1 \times 10^{-2}$ g/l
	= 30.0 mg/l (minimum)	= 81.0 mg/l (maximum)

Now the average level of suspended solids for the area is ∿20 mg/l. Thus, the increase in the suspended soil would be:

	Minimum Case	Maximum Case
ΔC =	$= \frac{30.6-20.0}{20.0}$ =	$= \frac{81.0 - 20.0}{20.0}$
=	= 50% =	= 305%

Therefore, due to construction at the Sulphur Mine site, the net increase in turbidity to the surrounding surface waters will be in the range of 50-305 percent higher than ambient for a period of 6 months.

REFERENCE

W. H. Wischmeier and D. D. Smith, Predicting Rainfall Erosion Losses from Crop Land East of the Rocky Mountains, Agricultural Handbook, No. 282, U. S. Government Printing Office, Washington, D. C.

APPENDIX F

MODIFIED MERCALLI INTENSITY SCALE

OF 1931 (ABRIDGED, RICHTER)

I. Not felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.

V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle--CFR).

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments--CFR). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks. monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations--CFR.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.

X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals. rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Masonary A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

APPENDIX G.1

RISK OF OIL SPILL RESULTING FROM SHIP COLLISION

1. Introduction

The risk estimates that are derived and presented in this appendix are for the incremental risk of oil or chemical spills associated with the marine transport of oil for the Strategic Petroleum Reserve program. It is assumed that the oil is transported a 45,000 dwt tanker, and the results are presented as the probability of spill per transit. The specific transit under consideration in this case is that from the Gulf of Mexico standing in Sabine Pass, through the Sabine-Neches Canal past Port Arthur, Texas, and up the Neches River 7.2 miles to a berth at the Sunoco Ship Loading Wharf, where the oil is to be transferred ashore for further transport by land pipeline. Section 2 provides a general description of the computer code used to calculate the spill risk for the case of interest, as well as a discussion of the results obtained. In succeeding sections are presented the detailed analytic methodology and techniques utilized in calculating these results.

The analysis used for ship collision probabilities in channels is described in Section 3. Section 4 documents the use of historical data for quantification of ship collision risks. A spill can only result from a ship collision if either ship's structure is sufficiently penetrated. The analysis used for penetration probabilities is described in Section 5.

2. Oil Spill Probabilities Due to Collision Involving SPR Tank Vessel

The analytic model for ship collision hazards described in Section 3, and the methodology described in Section 4 for estimating the probability of spill due to cargo tank rupture, were integrated to form a single computer code. One of the most important inputs to this computer code is a normalization factor α that represents the fraction of time during which ships may be assumed to operate randomly. Proper utilization of this factor in the calculations provides a correct normalization to historical ship collision data, as is explained in greater detail in Section 4.

Additional inputs required to make a complete analysis are the projected marine traffic density for specific segments of the ship channels being considered, the lengths of these segments, and the average speeds for each type of vessel comprising this traffic. Data for the marine traffic for the two channel segments from seaward up the Sabine Pass and Sabine-Neches Canal (24.3 miles) and Neches River (7.2 miles) to the Sunoco Wharf were taken from Waterborne Commerce of the U.S. for 1973.[1] Although ship traffic density has been increasing in recent years, the generally increasing size of merchant vessels is expected to lead to cessation of such traffic increases and perhaps even a decrease in total ship traffic in most ports. Data for the year 1973 may therefore be as good an estimate of marine traffic density for the years 1978 through 1980 as any projections based on this data.

It is further convenient to refine the ship traffic data base by establishing a ship size threshold including only those vessels capable of penetrating the hull of the considered Strategic Petroleum Reserve vessel. This traffic data base must also be consistent with the data base used in Section 4 for normalization to historical accidents. A ship displacement threshold of 1,000 tons was chosen for this purpose. The lengths and beams of individual ships are data required for calculation of the ship collision hazard in the computer code as well. Since the marine traffic data presented in Reference[1] give only vessel type, draft, and a count of the number of transits, it was necessary to derive values of displacement, length, and beam for each ship type and draft listed. To accomplish this, the characteristics of ships were sampled from <u>The Record</u> published by the American Bureau of Shipping;[2] relationships derived from these sampled characteristics were used to provide the required data.

Table G.1-1 is a small sample of the type of ship and barge traffic in the Neches River during 1973, and shows the derived characteristics as well as average vessel speeds. The average vessel speeds were arrived at by consultation with the U.S. Coast Guard's Captain of the Port in Port Arthur, Texas.

Another item of information required to assess the probability of penetration is the average angle of incidence of the striking vessel in the case of a collision. There is very little data from which to develop the distribution of this

Table G.1-1 Sample Channel Traffic for Neches River

Ship Type	Number of Transits	Draft (feet)	Speed (knots)	Length (feet)	Beam (feet)	Displacement (1,000 tons)
Tankers	34	40	6	713	121	60.7
"	61	39	7	692	118	56.0
"	79	25	6	408	56	11.1
"	158	20	8	310	46	5.3
"	26	15	7	225	36	2.0
"	6	13	6	195	31	1.0
Passenger/Cargo	14	40	8	795	106	39.4
"	1	38	6	746	100	35.0
"	39	26	6	441	63	10.7
"	31	25	7	417	60	9.2
"	516	14	7	190	34	1.4
"	1,047	11	6	150	26	1.0
Tank Barges w/tug	6	26	7	907	180	38.7
"	6	19	6	853	180	35.8
"	3	18	7	825	170	33.4
"	14	18	7	587	88	13.7
"	8	18	8	508	70	9.2
Barges w/tug	47	14	7	780	74	22.6
"	36	8	6	582	41	3.1
SPR Vessel	1	36.6	9	642	111	45.0

angle of impact, and it is believed that narrow channels will in general cause this angle θ, as shown in Figure G.1-1, to be smaller. Since the channels being considered are reasonably narrow, but have junctions with Intracoastal Waterway where larger collision angles could easily occur, a relatively small angle, θ of 30^{o} was specified for large ($\geq$30,000 dwt) vessel collisions with other large vessels and a larger angle θ of 45^{o} was chosen for all other cases.

Transits of the Strategic Petroleum Reserve vessel from seaward comprises a 24.3 mile run through the Sabine Pass and Sabine-Neches Canal to the Neches River, and a 7.2 mile stretch to the Sunoco Wharf on the Neches River. These two channel segments have been separately analyzed, since distinctly characteristic traffic data for each are available in Reference 1. The traffic data shown in Table G.1-1 are just a small sample of the total traffic in one of these segments, the Neches River. The vessel traffic was actually characterized in terms of 111 vessel types for Sabine Pass and Sabine-Neches Canal, and 101 types for the Neches River.

The incremental risk of oil spills being considered is that increment which can be attributed to the addition to existing traffic of the planned Strategic Petroleum Reserve vessel transits. In general, any collision between the Strategic Petroleum Reserve vessel and another vessel may result in a spill, and that spill might come from either the Strategic Petroleum Reserve vessel if it is struck, or another tank vessel or barge if it is struck. The probability for each of these possibilities has been analyzed separately within the computer code. For the case of a passenger ship, dry cargo ship, or barge being struck, the spill probability was taken to be zero since no bulk liquid cargo is involved. Sample resultant probabilities for collision, penetration, and spills are shown in Table G.1-2 for the same vessel types listed in Table G.1-1; the probabilities for penetration are conditional that the collision has occurred, and all other probabilities are expressed as per transit of a Strategic Petroleum Reserve vessel of the type and size listed at the bottom of Table G.1-1.

In the interest of increased safety, the Pilots Association in this port area have worked out a formal agreement placing specific constraints on the vessel traffic. For example, one rule followed is that, if a vessel of greater than 85,000 dwt is transiting the Sabine-Neches Canal above buoys 12 and 13, no other sea-going vessel will be piloted in the opposite direction in this channel. Another similar

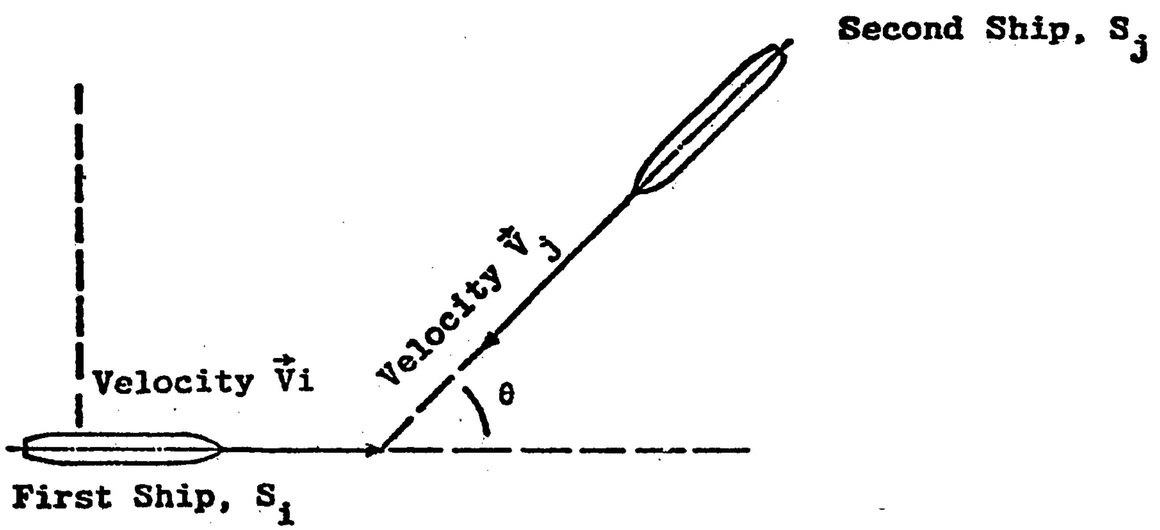

Figure G.1-1 Two Colliding Ships

Table G.1-2 Probabilities of Collision, Penetration, and Spill for Sample Cases in Neches River (Per Transit of 45,000 dwt SPR Vessel)

Other Vessel Type	Probability of Collision of SPR Vessel with Other Vessel Type	Probability of Penetration if SPR Vessel Struck	Overall Probability of Spill (SPR Vessel Struck	Probability of Penetration if SPR Vessel Strikes Other Vessel	Overall Probability of Spill (SPR Vessel Strikes)
Tankers	$.955 \times 10^{-7}$	.532	$.192 \times 10^{-7}$	.520	$.309 \times 10^{-7}$
"	$.152 \times 10^{-6}$	.522	$.337 \times 10^{-7}$	.513	$.452 \times 10^{-7}$
"	$.163 \times 10^{-6}$	.401	$.295 \times 10^{-7}$	.458	$.411 \times 10^{-7}$
"	$.255 \times 10^{-6}$	.168	$.242 \times 10^{-7}$	.271	$.299 \times 10^{-7}$
"	$.404 \times 10^{-7}$	0(a)	0(a)	0(b)	0
"	$.961 \times 10^{-8}$	0(a)	0(a)	0(b)	0
Passenger/Cargo	$.341 \times 10^{-7}$	.471	$.682 \times 10^{-8}$	-(c)	0(c)
"	$.282 \times 10^{-8}$	.451	$.461 \times 10^{-9}$	-(c)	0(c)
"	$.838 \times 10^{-7}$	.139	$.515 \times 10^{-8}$	-(c)	0(c)
"	$.596 \times 10^{-7}$	.350	$.102 \times 10^{-7}$	-(c)	0(c)
"	$.770 \times 10^{-6}$	0(a)	0(a)	-(c)	0(c)
"	$.157 \times 10^{-5}$	0(a)	0(a)	-(c)	0(c)
Tanker Barge w/Tug	$.179 \times 10^{-7}$	.436	$.309 \times 10^{-8}$	.629	$.681 \times 10^{-8}$
"	$.193 \times 10^{-7}$	.422	$.299 \times 10^{-8}$	.622	$.759 \times 10^{-8}$
"	$.849 \times 10^{-8}$	.409	$.143 \times 10^{-8}$	.616	$.308 \times 10^{-8}$
"	$.317 \times 10^{-7}$	.177	$.247 \times 10^{-8}$	.498	$.882 \times 10^{-8}$
"	$.156 \times 10^{-7}$	.026	$.198 \times 10^{-9}$	.418	$.329 \times 10^{-8}$
Barges w/Tug	$.120 \times 10^{-6}$	.323	$.147 \times 10^{-7}$	-(c)	0(c)
"	$.852 \times 10^{-7}$	0(a)	0(a)	-(c)	0(c)

(a) The probabilities of penetration are zero for these cases because vessels of these smaller tonnages cannot penetrate the SPR Vessel hull at the specified representative collision angle of 45°. Hence the spill probabilities are also zero.

(b) As the mass (or tonnage) of a struck vessel is considered to decrease, a smaller and smaller fraction of the total kinetic energy of the striking vessel contributes to collision damage, the remainder contributing to acceleration of the struck vessel. Hence the penetration probability for such cases is zero, according to the Minorsky theory.

(c) The penetration probabilities were not calculated for this case. Since passenger/cargo vessels generally do not carry oil or other liquids as bulk cargo, it is very unlikely that any substantial oil spill can result. Fuel tanks aboard such vessels are also much smaller than cargo tanks of tank vessels, which also minimizes both the likelihood and the size of spills.

rule is that no two vessels of 48,000 dwt minimum, loaded to greater than a 30 foot draft, are maneuvered so as to meet in the channel. These rules have the effect of nullifying specific intership collision probabilities, and this beneficial effect has been incorporated into the computer calculation.

The overall probability of a spill, per transit of a Strategic Petroleum Reserve vessel, is simply the sum of all the individual spill probabilities, only a sample of which have been listed. The relevant sums are shown in Table G.1-3, broken down into the two separate channel segments, as well as the distinct cases of being struck or being the striking vessel. In addition, subtotals of these probabilities are shown for a complete transit of the channel for the struck and striking cases. Finally, the total probability for a spill resulting from collision of a Strategic Petroleum Reserve vessel is given as 1.75×10^{-5} per transit for the case of a 45,000 dwt tank vessel.

It should be noted also that the spill probability per transit of the 45,000 dwt alternative vessel, ~1,75 x 10^{-5}, is approximately equal to the overall average spill probability per transit calculated for the entire Gulf Coast region.

Table G.1-3 Overall Spill Probabilities Resulting from Possible Collisions of 45,000 dwt SPR Vessel with Other Vessel Traffic in Transit from Gulf of Mexico to Sunoco Wharf in Neches River

Channel Segment	Spill Probability Per Transit (SPR Vessel Struck)	Spill Probability Per Transit (SPR Vessel Striking)
Gulf of Mexico to Neches River (24.3 mi)	0.531×10^{-5}	0.921×10^{-5}
Neches River to Sunoco Wharf (7.2 mi)	0.821×10^{-6}	0.216×10^{-5}
Entire Transit	0.613×10^{-5}	0.114×10^{-4}

Total Spill Probability per SPR Vessel Transit = 1.75×10^{-5}

3. SHIP COLLISION HAZARD MODEL

The probability of shipping accidents in the future can best be predicted by statistics of the past by use of a model to account for changes in the volume and characteristics of ships. An analytical model has been developed[3] to predict the probability of ships colliding in similar zones. This model characterizes the ship collision probability in terms of the various elements which are factors in ship collisions such as speed, length and width of ship, number of ship transits and the dimensions of the zone in question. The basic assumption of the model is that for ships to collide, they must, for some short period of time, be moving at random, rather than in accordance with rules and plans. Using this assumption, it becomes possible to ignore the interaction of the ships before a collision occurs and to solve the problem of interacting bodies as involving only the two colliding ships illustrated in Figure 1. This model analyzes the problem of two colliding ships in a coordinate system fixed on one of the ships so that in effect, a single ship is moving about another ship, which is stationary, at a velocity equal to the two ships' relative velocity. This coordinate transformation is accomplished by performing a simple transformation from the original frame to that of the moving frame.

As illustrated in Figure G.1-2, the angle which the path of the second ship makes with the first ship is defined as θ_R which is in general different from the heading of the second ship. For a collision course, this angle θ_R is the constant angle at which the first ship continually observes the second ship to be.

An analytical expression for the number of collisions of a given ship during a single transit of a zone is now formulated. If the speed of each ship is constant in a roughly square zone of characteristic dimension, d, the number of collisions expected for a single ship, S_i, in each transit is equal to the product of the time it requires to transit the zone and the probabilities of finding another ship in the same zone and colliding with that ship.

If t_i is the time ship S_i requires to transit the zone of dimension d,

P_j is the probability of finding another ship, S_j, in the zone area d^2,

P_{ij} is the probability per unit time of a collision

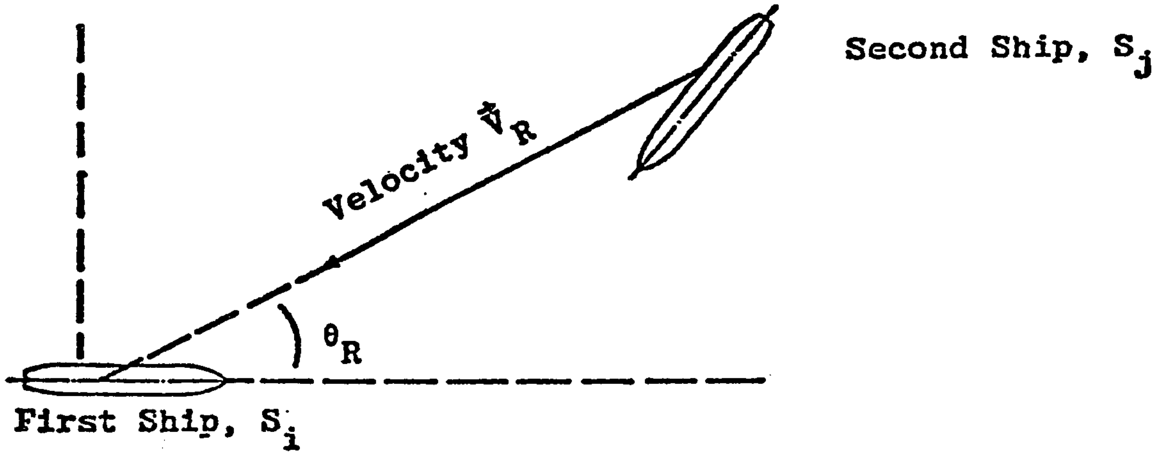

Figure G.1-2 Coordinate System for Analysis

P_{ij} is the probability per unit time of a collision between S_i and S_j given that S_j is in d^2, and

N-1 is the annual number of transits by other ships through zone

then, the number of collisions C_i, which involves S_i, is approximately

$$C_i = t_i \sum_{j=1}^{N-1} p_j P_{ij} \quad (1)$$

Each of the functions, t_i, P_j, and P_{ij} is now to be derived. The transit time of the ship S_i is equal to the zone dimension divided by its speed

$$t_i = \frac{d}{V_i} \quad (2)$$

The probability that another ship, S_j, is in the zone is equal to the fraction of a year that one transit of the zone requires:

$$P_j = \frac{t_j}{Y} = \frac{d}{V_j Y} \qquad (3)$$

where, if velocity is specified in feet per second, Y is the number of seconds in a year.

To obtain the probability per unit time of a collision between the two ships, given that both ships are in the zone, it is necessary to determine the rate that ships on any collision course will be encountered. Since this rate, and hence the probability, is directly proportional to both the size of the two ships, and the relative motion of the ships, it is convenient to formulate a function expressing these relationships. This is accomplished by constructing an expression for the flux of colliding ships at a specific angle, and later integrating this flux over all collision angles.

If the cross section of a ship is defined in this two-dimensional problem as the apparent linear dimension of a ship when viewed from a specific angle, the flux of colliding ships at any specific angle is proportional to the relative velocity times the cross section of both ships at that angle. Thus, the magnitude of the flux will increase or decrease with the apparent cross section and the velocity of the ships. That is if ϕ is the flux of colliding ships, $\vec{\sigma}$ is the cross section of both ships and $\vec{V}_R$ is the relative velocity,

then

$$\phi \propto \vec{\sigma} \cdot \vec{V}_R \qquad (4)$$

The cross section of the ships is defined as

$$\vec{\sigma} = w_i \hat{m}_i + \ell_i \hat{n}_i + w_j \hat{m}_j + \ell_j \hat{n}_j$$

w_i is the width of ship S_i

$\hat{m}_i$ is the unit vector normal to the width of ship S_i

ℓ_i is the length of ship S_i

$\hat{n}_i$ is the unit vector normal to the length of ship S_i

w_j is the width of ship S_j

$\hat{m}_j$ is the unit vector normal to the width of ship S_j

ℓ_j is the length of ship S_j

$\hat{n}_j$ is the unit vector normal to the length of ship S_j

It is important that the direction of each normal unit vector be chosen to maximize the flux. For example, the unit vectors associated with the width and length of both ships depicted in Figure G.1-2, are illustrated in Figure G.1-3.

To completely determine the flux, the proportionality factor for Equation (4) must be obtained. This factor is equal to the probability density function of the second ship being at any position and angle. The appropriate normalization is given by the factor $1/2\pi d^2$. Therefore, ϕ is given by the expression

$$\Phi = \frac{\vec{\sigma} \cdot \vec{V}_R}{2\pi d^2}$$

Finally, the probability, P_{ij}, for a collision between S_i S_j, given that both ships are in d^2 , can be obtained by integrating over all collision angles:

$$P_{ij} = \int_{\substack{\text{all collision} \\ \text{angles}}} \lambda \; \Phi \; d\theta_R \tag{5}$$

where λ is the weight function corresponding to the transformation to the moving coordinate system

$$\lambda = \frac{V_R^{\;2}}{V_j^{\;2} - V_i^{\;2} + V_i V_R \cos\theta_R}$$

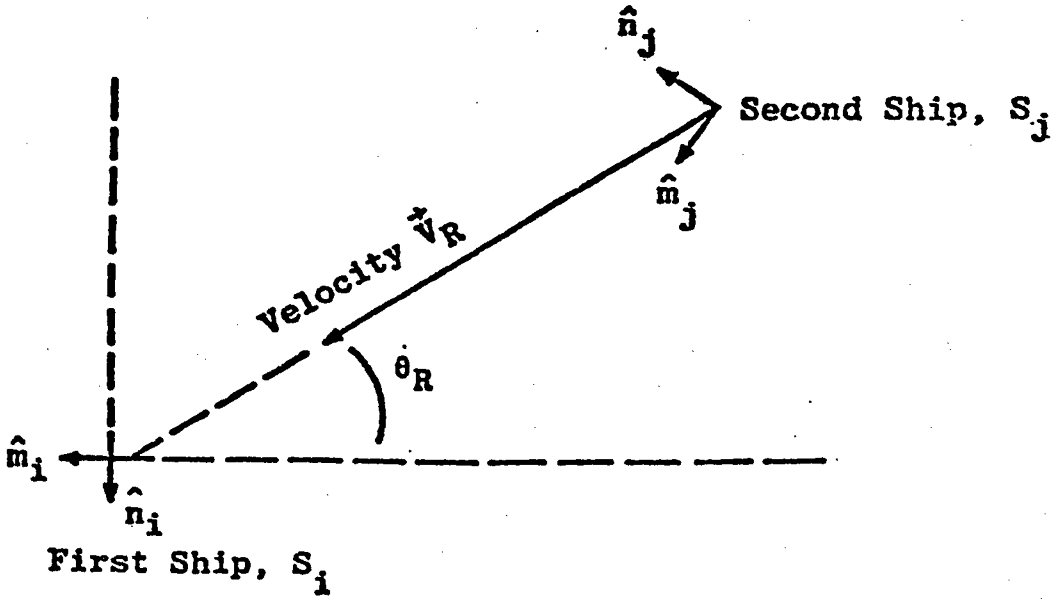

Figure G.1-3 Unit Normal Vectors

Substituting the expressions in Equations 2, 3, and 5 for the function in Equation 1, the number of collisions experienced per transit of zone d^2 by S_i is

$$C_i = \frac{1}{2\pi Y V_i} \sum_{j=1}^{N-1} \int \frac{\lambda \vec{\sigma} \cdot \vec{V}_R}{V_j} \, d\theta_R$$

To evaluate this integral, it is convenient to transform to the variable θ where

$$\theta_R = \text{ctn}^{-1} \left(\text{ctn}\, \theta + \frac{V_i}{V_j} \csc \theta \right)$$

The number of collisions per transit of the zone d^2 by ship S_i is determined to be, for $V_j \geq V_i$,

$$C_i = \frac{1}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_i}{V_j} \left(2 \cos^{-1} \left(- \frac{V_i}{V_j} \right) - \pi \right) + 2 \frac{w_i}{V_i} \sin \cos^{-1} \left(- \frac{V_i}{V_j} \right) + \frac{w_j}{V_i} \pi + 2 \frac{\ell_i}{V_i} + 2 \frac{\ell_j}{V_j} \right] \quad (6a)$$

where w_i, ℓ_i and w_j, ℓ_j are the width and length of ships S_i and S_j, respectively.

By symmetry, the number of collisions for $V_i \geq V_j$ is

$$C_i = \frac{1}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_j}{V_i} \left(2 \cos^{-1} \left(- \frac{V_j}{V_i} \right) - \pi \right) + 2 \frac{w_j}{V_j} \sin \cos^{-1} \left(- \frac{V_j}{V_i} \right) + \frac{w_i}{V_j} \pi + 2 \frac{\ell_i}{V_i} + 2 \frac{\ell_j}{V_j} \right] \quad (6b)$$

The model discussed above applies to a roughly square zone. A non-square region such as an inland channel can be approximated by assembling an appropriate number of square zones whose dimensions equal the width of the channel. This process increases the number of random collisions by a factor of L/d where L is the length of the channel and d is the width. (Alternatively, the same analytical result is obtained by considering a single rectangular zone using transit times proportional to L, and the density of ship S_j proportional to $(Ld)^{-1}$).

Having determined the collision rate for completely random ship movements, the last step of this analysis is to consider the rate of expected collisions for more orderly ship movements. Since either ship, S_i or S_j, behaves randomly during only a very small portion of the transit time in the zone of interest, the probability of a collision involving S_i is greatly reduced from the completely random probability by a factor equal to the probability that at least one of the two ships is operating in a random manner. That is, if α is the fraction of time that a ship behaves randomly in the zone of interest, the probability of a collision involving S_i is then approximately

$$C_i(\alpha) = 2\alpha C_i$$

since 2α is approximately equal to the fraction of time that at least one of the two ships obeys the random collision probability equations (Equations 6a, 6b). The parameter, α, reflects absence of the factors that normally avoid collisions.

The total number of expected collisions, $C^{(\alpha)}$ can be written as

$$C^{(\alpha)} = \frac{1}{2} \sum_{i=1}^{N} C_i^{(\alpha)}$$

where the factor 1/2 has been included to avoid double counting. α is determined from the analysis of specific accidents as will be described in Section 3.

The probability of being the struck ship in a collision can be obtained from equations 6a and 6b by counting only those collisions involving the side (or length) of ship S_i and the end (or width) of all ships S_j. This is accomplished by setting $w_i = \ell_j = 0$. Thus, the final probabilities for ship S_i of length ℓ_i, width w_i, and speed V_i, being struck by ships S_j of length ℓ_j, width w_j, and speeds V_j are, for $V_j \geq V_i$,

$$C_{i,\,struck}^{(\alpha)} = \frac{2\alpha}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_j \pi}{V_i} + \frac{2\ell_i}{V_i} \right]$$

and, for $V_i \geq V_j$,

$$C_{i,\,struck}^{(\alpha)} = \frac{2\alpha}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_j}{V_i} \left(2 \cos^{-1} \left(\frac{-V_j}{V_i} \right) - \pi \right) + \frac{2 w_j}{V_j} \sin \cos^{-1} \frac{-V_j}{V_i} + \frac{2\ell_i}{V_i} \right]$$

4. NORMALIZATION OF MODEL TO HISTORICAL ACCIDENT DATA

The analytic model developed in the previous section must be normalized to actual ship collision statistics, i.e., historical data, in order to be of use in estimating future probabilities. More specifically, a value for the parameter α, the fraction of time during which ships are assumed to behave randomly, is sought for by analyzing relevant data. The most statistically significant and relevant data base was previously analyzed by SAI for the Federal Power Commission[3] in order to assess the risks of LNG marine operations. A detailed analysis was made of the historical traffic and accidents in the Delaware River and New York Harbor. The historical accidents that occurred in each of the 9 channel regions were normalized to the ship traffic, ship mix, and channel length. The Chip Collision Hazard Model was then used to allocate the accidents over the population of ships transiting the channel. The procedure used below for estimating channel collision probabilities is derivable from the basic model by shrinking the square zone to a narrow channel of length D.

New York Harbor and the Delaware River were subdivided to account for changes in traffic density. Three zones were defined for the Delaware River and 6 zones were defined for New York Harbor. The traffic data was compiled from Waterborne Commerce of the United States.[1] Further details of the marine traffic analysis are described in Reference 3.

The basic source of accident statistics is the U.S. Coast Guard (USCG) incident data base. Each ship involved in an accident in U.S. waters with damage of $1,500 or greater is required by law to complete and submit an accident form to the USCG. Some relatively small cases close to the lower limit may not be reported. It is considered highly unlikely that there is failure to report any significant collision involving major penetration of the hull or loss of life; i.e., the type that could produce tank penetration of a vessel. A file is maintained for each case at USCG Headquarters, Washington, D.C. In addition, a coded record is generated for each ship involved in each incident for purposes of automated computer processing. The USCG prepares a summary statistical report based on these records annually. Complete computer printouts are available for the period FY 69 through FY 74.

These printouts were initially screened to identify moving collisions involving two ships of gross tonnage 100 tons or greater. The Coast Guard files on each accident thus identified were examined to determine the precise location and the displacement of the ships involved and to verify the nature of the accident. Finally, only those accidents involving two ships with a displacement greater than 1,000 tons were included in the final count. There were a total of 30 accidents identified in the 9 channel regions during the 6 year period 1969-1974 which passed all of these criteria.

The ship collision model was exercised for the 9 channel regions being analyzed, and the results expressed as the number of collisions expected for entirely random operations, A_r. The actual number of historical accidents is to be represented by A for this 6 year period. From the data an α for each channel area was calculated according to the formula

$$\alpha = \frac{A}{A_r \cdot L}$$

where A_r is proportional to the square of the traffic transiting the region, N. The method chosen to combine the α's was to weight each one according to the square of the traffic transiting that length of channel. This is appropriate since the basic scaling of accidents according to the number of transits is proportional to N^2 (actually to $N(N-1)/2$ -- since each ship interacts with each of the N-1 other ships and division by two avoids double counting).

The weighted average of α, 1.54×10^{-4}, is based on a data base which contains 30 collisions for more than a million transits in the 9 channels of ships greater than 1,000 tons over the 6 year period (1969-1974). This data base is obtained from 6 years of the average annual traffic, which was developed from Reference 1.

Having determined a value for α from historical traffic and accident experience, it is possible to estimate the frequency of collisions in a similar harbor in the future. The channel length, vessel speeds, and projected traffic density and distribution by draft and ship type are the only additional inputs required. The total number of collisions expected and the probability per transit that a given ship will have a collision can then be calculated.

5. CARGO TANK RUPTURE PROBABILITY

Considerable attention has been devoted to the analysis of the complex phenomenon of ship collisions. Many major studies have been undertaken internationally to investigate the statistical, analytical, and experimental approaches to this problem. In the United States, statistical and analytical studies were performed in the course of designing the nuclear merchant ship Savannah.[4] The principal product of these efforts was a semi-empirical method formulated by Minorsky[5] to correlate the absorbed collision energy to the amount of deformed structural material in the ships. Other studies were conducted in Japan, Italy, and West Germany to determine the collision behavior of other nuclear ships and tankers. While the Minorsky method has been modified, and many experimental tests have been conducted for the purposes of verification or augmentation of actual collision data, the basic Minorsky method provides the most efficient technique for estimating the penetration of the striking ship into the struck ship. Hence, this recognized procedure is utilized for the analysis of the probability of a cargo tank rupture for vessel collisions involving the planned Strategic Reserve Program tank ships.

The Minorsky method relates the structural resistance to deformation of the colliding ships to the total effective kinetic energy of the collision. If the resistive pressure of a ship's structure is denoted by $\vec{R}(\vec{x})$, the entire Minorsky result can be expressed as

$$\int\left(\int \vec{R}(\vec{x})\, dA\right) \cdot d\vec{x} = \int \vec{F}(\vec{x}) \cdot d\vec{x} = \int \frac{\vec{p}}{\mu} \cdot d\vec{p} = \frac{p^2}{2\mu}$$

where dA is a differential area normal to $\vec{R}$,

$\vec{F}(\vec{x})$ is the force along $\frac{\vec{R}}{|R|}$,

$\vec{p}$ is the momentum, and

μ is the effective reduced mass of the ships.

In effect, the problem simply is one of obtaining the "resistance factors" and the effective or hydrodynamic mass of the struck ship from an inspection of ship design specifications and collision statistics. Experience has shown that $\vec{R}(\vec{x})$ can be attributed to the volume of structural material parrallel to $\vec{p}$ since this material absorbs most of the energy by bending and crushing during the collision.

To calculate the penetration depth into the struck ship only the velocity component, $v_\perp$, of the striking ship normal to the side of the struck ship enters into the calculation. Thus, the struck ship is considered as having no forward motion since data obtained by Minorsky indicate that forward motion only contributes to the length of the opening and not the depth. The effective collision energy of the completely inelastic collision is

$$1/2\mu\ (v_\perp)^2 = 1/2\ \frac{m_1 m'_2}{m_1 + m'_2}\ (v_1 \sin\theta)^2$$

where m_1 is the mass of the striking ship,

m'_2 is the hydrodynamic mass of the struck ship

v_1 is the velocity of the striking ship, and

θ is the orientation of the striking ship relative to the struck ship.

According to Koch,[6] Dieudonné,[7] and Johnson,[8] the effective hydrodynamic mass of the struck ship is 1.4 m_2, so that the effective collision energy becomes, where m_2 is mass of the struck ship,

$$\frac{1.4\ m_1\ m_2\ (v_1\ \sin\theta)^2}{2\ m_1 + 2.8\ m_2} = \frac{m_1\ m_2\ (v_1\ \sin\theta)^2}{1.43\ m_1 + 2\ m_2}$$

For the purpose of analysis, it is assumed that the ships maintain their orientation during the collision process. Therefore, the only relevant components of the "resistance factor," $\vec{R}(\vec{x})$, are also normal to the side of the struck ship. The penetration analysis conservatively assumes that the point of impact on the struck vessel is at its weakest point, midway between webs, on soft plating, and that the strong transverse bulkheads do not assist in resisting the penetration. The final spill probability is thus considered to be a conservative overestimate, since the slightest penetration of the outer hull of the struck vessel is assumed to result in a spill. The threshhold speed for the striking vessel to cause cargo tank rupture is then easily calculated.

The distribution of impact speeds in collisions is not well documented. The available data seem to support the assumption that impact speeds are uniformly distributed between zero and the maximum speed at which ships transit a given region. The penetration calculations were based on uniform impact speed distributions of 0-12 knots for ships and 0-8 knots for barges in order to be conservative.

If P^c_s is the probability of being struck by a ship in category c,

P_t is the probability of a collision in an area where cargo tanks are located (note: this probability is independent of striking ship category),

P^c_v is the probability of the normal component of the striking ship's velocity being greater than the threshold velocity,

N_c is the population of ships in category c,

N is the number of ship categories being considered,

the normalized probability of a Strategic Petroleum Reserve vessel tank rupture can be expressed to first order, as

$$P_{rupture} = \frac{\sum_{c=1}^{N} N_c \, P^c_s \, P_t \, P^c_v}{\sum_{c=1}^{N} N_c} .$$

The determination of these probabilities is discussed below.

The probability, P^c_s, that the Strategic Petroleum Reserve ship is struck by another ship is equal to the probability that the Strategic Petroleum ship is involved in collision multiplied by the probability that the Strategic Petroleum Reserve ship is the struck ship. Both probabilities are obtained by category from the procedures described in Section 3.

The value used for the probability P_t that a collision would occur in a region where the cargo tanks are located is generally 0.8 or above for tank vessels. In this case, it has been taken equal to unity, again assuring a conservatively high final estimate of the spill probability.

The probability P_V^C of the striking ship being capable of producing a spill is equal to the fraction of ships whose velocity component perpendicular to the side of the struck ship exceeds the threshold velocity. The probability that the striking ship will exceed the speed is then calculated using the appropriate impact speed distribution discussed above.

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APPENDIX G.2

PETROLEUM TANKER TRAFFIC AND OIL POLLUTION INCIDENTS IN THE GULF OF MEXICO AND CARIBBEAN SEA

This appendix tabulates historical data concerning the relationship between tanker traffic density and polluting incidents, i.e., polluting spills/incidents per tanker trip.

Data has been gathered for the years 1969 through 1975. Data for 1975 is, however, the most complete, therefore that year has been selected as the baseline year.

During the subject year there were 4,316 trips into 20 U.S. Gulf Coast ports (Table G.2-1) by Foreign Flag tankers.[1] A breakdown of trips by area of origin[2] appears in Table G.2-2.

Additionally, during 1975, 182 trips were made into U. S. Gulf Coast ports (Table G.2-1) by U. S. Flag tankers engaged in foreign trade. As there is no data at hand as to the origin of these voyages* and no evidence to the contrary, it is assumed they traveled from one of the aforementioned areas (Table G.2-2), and/or from one of transhipment facilities at Bonaire, Aruba, Curacoa, or the Bahamas. In any case, they constituted a portion of the total 4,498 Gulf-Caribbean tanker trips to U. S. Gulf Coast ports for delivery of foreign petroleum and products.

The 4,498 trips by foreign flag and U. S. Flag-Foreign trade tankers resulted in the landing of some 54,075,914 short tons of oil imports. The U. S. Army Corps of

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1 Engineers' Annual (Report AE 495, 1975), prepared by the Bureau of Census for the U. S. Army Corps of Engineers.

2 Mineral Industry Surveys, Bureau of Mines, Table 5, 1975.

*Data is available on customs manifests located in the archives of the ports of entry, but time limitations precluded search of these records.

Table G.2-1 Selected* U.S. Gulf Coast Ports

Orange	Beaumont
Houston	Texas City
Freeport	Matagorda Ship Channel
Corpus Christi	Port Arthur
Galveston	Harbor Island
Brownsville	Tampa
Port St. Joe	Panama City
Pensacola	Mobile
Pascagoula	Gulfport
Lake Charles	New Orleans

*These ports were selected simply because they were the ones for which trip counts of foreign flag and U. S. Flag-Foreign trade tankers were listed in the Engineer's Annual (Report AE 495). A port listed does not necessarily indicate final destination of cargo. For example: a ship counted as a New Orleans trip could be destined for offload at Baton Rouge.

Table G.2-2

Area of Origin	No. of Trips Into Gulf Ports
Central America	112
South America	561
Europe	60
Middle East	1,338
Asia	173
Africa	2,072

Engineers[3] however, states a total of 67,142,256 short tons of petroleum were imported into Gulf Coast ports during 1975. This indicates that about 20 percent of the total imports was transported by other than foreign flag and U. S. Flag-Foreign trade tankers. This portion of the total imports was most likely brought in to ports by lightering operations. Lightering will be addressed in more detail later in this report.

Above, the U. S. Army Corps of Engineers[3] was quoted regarding total oil import tonnage. Information as to total import tonnage was also provided by other government agencies, but certain disparities were noted which could have a bearing on the numbers of tanker trips. In order to try to determine which information source was most accurate and/or to understand the reasons for the differences noted, an investigation of primary/raw data sources was initiated. The investigation indicated various sources and combinations thereof were used. In cases where the same data source was used, different elements were used and different interpretations made, counting methods and things counted differed, and there were differences in categorization of products, etc. Upon considering the comparatively small differences in totals, the relatively short, nearly direct path Corps of Engineers data traveled from raw source to published report, consistency of categorization and standardized counting procedures, it was decided to use Corps of Engineers reports as a principal data source for establishing trip totals.

The Corps of Engineers reported, in 1975, in addition to the 4,498 trips by foreign flag and U. S. flag-foreign trade tankers, 6,407 trips by U. S. flag tankers into and out of Gulf Coast ports. This latter number of trips comprised the coast-wise traffic, i.e., trips between Gulf Coast ports (Brownsville around to Tampa), and between the various Gulf Coast ports and ports along the East Coast of the U. S. Coast-wise domestic (U.S. port to U. S. port) traffic volume is shown in Table G.2-3. It will be noted that some of the tankers are obviously not petroleum carriers although they are included in the total coast-wise trip count.

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3 Waterborne Commerce in the United States, Part 2, 1975, U.S. Army Corps of Engineers

The average size of specialized U. S. Flag tankers (non-petroleum) operating in the Gulf of Mexico and along the East Coast of the U. S. is 12,700 dwt.[4] Assuming that this is the size tanker used in coastwise trade for the transport of non-petroleum liquid products (4,241,274 tons of liquid sulphur and 919,102 tons of alcohols, Table G.2-3) which total 5,160,376 tons, it is presumed that some 407 trips were made by these ships. The total coastwise/domestic trips made by petroleum carrying tankers then becomes 6,000.

It has been previously noted that about 20 percent of the total petroleum imports arrive at Gulf Coast ports by lighters. Only U. S. flag tankers are used for lightering and of the 24 U. S. tankers currently operating in the Gulf of Mexico, only four are in excess of 40,000 dwt. The draughts of these vessels exceed the published channel depths of the Gulf Coast ports[5] and therefore, unless only partially loaded, they could not be used for lightering operations. The assumption will be made that those vessels are not used for lightering. The remaining 20 U. S. tankers operating in the Gulf range in size from 16,700 dwt to 37,900 dwt; the average size being about 28,000 dwt. Presuming the 28,000 dwt tanker as the size generally used for lightering, indications are that about 467 trips per year would be required to land the 13,066,342 tons of petroleum that is not landed by foreign or U. S. flag-foreign trade tankers. This estimate of the volume of lightering agrees satisfactorily with previously developed data.[6]

Tanker trips, or some portion thereof, that transit Gulf of Mexico and Caribbean Sea waters are summarized in Table G.2-4.*

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4 U. S. Department of Commerce, MARAD Report E2-11, January 1977.

5 Waterborne Commerce of the United States, Part 2, 1975, U. S. Army Corps of Engineers.

6 DOT, USCG, Report No. CG-M-06-77, October 1976 (by ORI).

*Not included in the above are coast-wise tanker trips along the shores of other nations which bound the Gulf and Caribbean, nor are tanker trips which originated in other parts of the world and transit Gulf and Caribbean enroute to and from other Gulf and Caribbean nations. Therefore, the total of trips shown in Table G.2-4 does not represent the true total of tanker traffic in the Gulf of Mexico and Caribbean Sea.

Table G.2-3

Commodity	Receipts (tons)	Shipments (tons)
Crude	8,279,198	9,195,393
Gasoline	5,442,370	23,336,751
Jet Fuel	427,421	2,469,775
Kerosene	95,917	1,155,022
Distillate Fuel	1,605,720	20,687,674
Residual Fuel	2,507,247	11,841,169
Lubricants and Grease	389,604	1,358,725
Liquified Gases	89,335	137,905
Liquid Sulphur	2,370,308	1,870,966
Alcohols (Wines)	160,801	758,301
Naptha and Petroleum Solvents	157,070	1,013,248
Benzene and Toluene	228,759	262,189
	21,753,749	74,087,118

Total Coast-wise Tonnage 95,840,867.
Total Coast-wise Petroleum Shipments (liquid sulphur and alcohols deleted) 90,680,491 tons.

Table G.2-4

Ship	No. Trips
Foreign Flag Tankers	4,316
U. S. Flag-Foreign Trade Tankers	182
Lighter Tankers	467
Non-Petroleum Tankers	407
U. S. Flag-Domestic Trade Tankers	5,533
(Total Trips, 1975)	10,905

Information regarding spill/pollution incidents has been taken from two sources: (1) "USCG (G-MMt) Working Papers: Table 1, Tankship Accident Involvements, Oil Outflows, Total Losses, 1969-1973, Tankships over 3,000 DWT," and (2) "FY 70-75 Vessel Casualties Gulf of Mexico Sort FY/NA/VTYP, USCG, Office of Merchant Marine Safety." Fortunately, the data sources have a certain amount of time overlap which has provided the opportunity for a "double check" during that period.

The focus of this investigation is on incidents that occurred in coastal and open sea waters as opposed to incidents which occurred in waters governed by "Inland Rules of the Road." Therefore, incidents which took place in areas governed by the Inland Rules will not be considered.

In 1975, one polluting incident occurred in the open sea waters of the Gulf of Mexico. A Liberian Flag, steel tanker, (data regarding GWT and length are missing) of between 20 to 30 years of age was involved in a collision with another ship in a crossing situation. The primary cause was attributed to fault on the part of the other ship. The accident occurred at night. There is no report regarding sky conditions, precipitation, or fog. The visibility was over two miles and the surface wind was between 11 and 16 knots. There is no data regarding monetary damage to the cargo of the tanker, but medium pollution was reported. In the absence of any additional data (neither the name nor official number of the ship was obtained so further investigation cannot be pursued), the assumption is made that the amount of pollution amounted to about 30,000 gallons.

As previously noted in connection with Table G.2-4, total tanker traffic in the Gulf-Caribbean area waters is not comprised of only those tankers entering and leaving U. S. Gulf Coast ports, but because of lack of adequate data regarding the movement of tankers in and out of foreign ports in the Southern Caribbean, the assumption has been made that the traffic volume is small enough that it can safely be disregarded for the purposes of this investigation. The assumption has also been made that the tankers moving in and out of U. S. Gulf Coast ports constitutes the total traffic (i.e., freight and passenger shipping trips are not included).

There were 10,498 petroleum tanker trips in 1975 (Table G.2-4).1.

In 1974, total tanker trips numbered 10,758.[7] In that year there were no incidents in the Gulf-Caribbean coastal or open sea areas.

In 1973 there were a total of 10,471 tanker trips into U. S. Gulf Coast ports.[8]

In March of that year a German tanker, the Zoe Colotron, 25,716 dwt, traveling in coastal waters grounded. The pollution amounted to some 1,461,700 gallons.

The 1972 count of tanker traffic into U. S. Gulf Coast ports was 8,471.[9]

In February of 1972 an American chemical tanker, V. A. Fogg, in ballast, was traveling in coastal water when it exploded and subsequently sank; a total loss. The ship was 20,765 dwt, between 500 and 600 feet in length, steel hulled, and was between 20 and 30 years old. The accident occurred during the day under partly cloudy skies, visibility was over two miles, and the wind velocity somewhere between four and ten knots. Improper safety precautions (in the presence of vapors) was listed as the cause of the accident which, besides loss of the vessel, resulted in 11 fatalities, 8 injuries, and pollution in the amount of some 470,000 gallons, principally bunker fuel. This was the only incident in 1972 in the waters (coastal) of the Gulf-Caribbean area.

The total tanker trip count for 1971 was 8,797.[10]

In March of the subject year, a Liberian flag tanker, Vassiliki, 69,119 dwt, built in 1965, was traveling, fully loaded in the open sea waters of the Gulf-Carribean area when she suffered structural failure. The report indicates pollution resulted, but it was undetermined whether a spill greater than 500 long tons ocurred.

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7 Waterborne Commerce of the United States, Part 2, 1974, U. S. Army Corps of Engineers

8 Waterborne Commerce of the United States, Part 2, 1973, U. S. Army Corps of Engineers.

9 Waterborne Commerce of the United States, Part 2, 1972, U. S. Army Corps of Engineers.

10 Waterborne Commerce of the United States, Part 2, 1971, U. S. Army Corps of Engineers.

In June the Norwegian tanker, Stolt Sveve, 16,350 dwt, built in 1951 suffered a breakdown while traveling in the open sea waters of the Gulf-Caribbean area. The report indicates pollution resulted, but it was undetermined whether a spill of greater than 500 long tons occurred.

In August, the Liberian flag tanker, Mar Star, 17,505 dwt, built in 1953 was traveling in ballast in the open sea waters of the Gulf-Caribbean area when she suffered a breakdown which caused heavy damage. The report indicates pollution resulted, but it was undetermined whether a spill greater than 500 long tons occurred.

The 1970 tanker trip count report shows 8,932 trips were made into U. S. Gulf Coast ports.[11]

In the course of the year, 1970, there were no incidents reported as having occurred in the coastal or open waters of the Gulf of Mexico and Caribbean Sea areas.

Tanker trips into U. S. Gulf Coast ports during 1969 totaled 8,463.[12]

In July of that year, the U. S. flag tanker, Texaco Nevada, 19,924 dwt, built in 1944, was traveling, fully loaded, in the open sea waters of the Gulf-Caribbean area when she suffered structural failure. The report indicates pollution resulted, but it was undetermined whether a spill of greater than 500 long tons occurred.

In summary, the relationship between the total tanker trips to Gulf Coast ports during the years 1969 through 1975 and the total number of incidents/spills in the coastal and open sea waters of the Gulf of Mexico and Caribbean Sea was:

$$\frac{\text{7 incidents}}{\text{(7 years) x (66,390 trips)}} = 1.05\text{x}10^{-4} \text{ incidents per trip,}$$

and the average loss of 40.06 gallons per trip

In order to compare the results of this investigation to the findings of others, the total of polluting incidents per trip during the years 1969 through 1975 have been converted to polluting incidents per tanker year.

The assumption was made that each tanker trip involved 3.5 days underway within the confines of the Gulf-Caribbean area waters. This provided a figure of 663 tanker years for the period 1969 through 1975. During this period, there were seven polluting incidents in the coastal and open sea waters of the area of interest. Therefore:

$$\frac{7}{637} = .011 \text{ polluting incidents per tanker year}$$
(including trips in ballast)

The report, CG-D-81-74, "An Analysis of Oil Outflows Due to Tanker Accidents 1971-1972," prepared by J. J. Henry Company, Inc. indicates, on a worldwide basis, 0.028 polluting incidents per tanker year during the time period analyzed.

The report, "Tankship Accidents and Resulting Outflows, 1969-1973," LCDR James C. Card, LCDR Warren D. Snider, USCG Office of Merchant Marine Safety analyses 452 polluting incidents which occurred (worldwide) during the years 1969 through 1973. During this period, the world tankership year exposure averaged 31,964. It therefore can be estimated that the relationship was:

$$\frac{452}{31,964} = .014 \text{ polluting incidents per tanker year.}$$

APPENDIX H

SUMMARY OF INFORMATION ON EXISTING CAVITIES, CAVITY CONVERSION PROCEDURES AND DRILLING PROCEDURES

1. Existing Caverns & Conversion

Eight caverns have been created at the Sulphur Mines dome. There are 5 caverns which Allied leases to PPG Industry for brine production (all of which would be made available for the SPR program). Two other caverns developed by Allied have been converted to ethylene storage and are under lease to Conoco. PPG has developed a third ethylene storage cavern.

Three of the existing brine caverns (Nos 2, 4, and 5) available for the SPR have coalesced and are used as a backup source of brine. Caverns Nos 6 and 7 are newer ones equipped with twin displacement wells. Caverns Nos 6 and 7, however, are separated by about 125 feet of salt and would probably coalesce after one or two cycles of oil displacement. The following is a summary of the current cavern conditions along with probable modifications and redesign. A tabulation of the cavern data is shown in Table H.1.

Gallery 2-4-5

The gallery of caverns 2, 4, and 5 located on the southern flank of Sulphur dome covers an area estimated to be 15.5 acres. The three wells in this gallery were completed in 1946, 1949, and 1953, respectively, and have been leached to a total volume of 12.3 million barrels.

A Sonar survey run on September 8, 1977 showed the roof of cavern No. 2 to be -2,450 feet and the floor at -3,090 feet. The volume also shows interconnection between all caverns at approximately 2,930 feet where a reflection of a sound wave shows an expansion of 760 feet at a direction of 135° (southeast). This distance reflects the back wall of No. 5. Well No. 2 is presently standing idle with 8-5/8 inch casing suspended at -2,558 feet, perforated at -2,450 feet.

Table II.1 Cavern Data - Sulphur Mines

Cavern No.	Depth Origin ft	Depth Present ft	Depth to Top Of Cap Rock ft	Depth to Top Of Salt ft	Depth to Top Of Cavern ft	Maximum Diameter ft	Cavern Height ft	Product Casing Size in	Product Casing Depth ft
2	3,502	3,114	500	1,460	2,450	625	664	10-3/4	1,570
4	3,312	3,118	819	1,620	2,782	600	336	10-3/4	1,650
5	3,745	*	829	1,564	*	*	*	13-3/8	1,574
6X	3,708	3,423	620	1,470	3,090	585	333	10-3/4	1,836
6Y	3,692	3,423	630	1,470	3,090	585	333	9-5/8	1,911
7A	3,491	3,205	962	1,500	2,872	500	333	9-5/8	1,827
7B	3,408	3,205	980	1,500	2,872	500	333	9-5/8	1,884

* No Sonar Caliper of Cavern No. 5

A Sonar survey on August 30, 1977 showed the top of cavern No. 4 to be at -2,782 feet and the floor at -3,118 feet. This survey also shows the interconnecting horizon between the three caverns to be at ± 2,950 feet. This well is also standing idle with 8-5/8 inch casing suspended to -2,863 feet. An in-line packer at -1,502 feet was installed to cover a hole which developed in the 10-3/4 inch casing above that point.

In well No. 5, a leak developed in either the casing or around the casing shoe, causing loss of all blanket material and allowing the cavern roof to be leached from about 2,920 feet to -1,900 feet. From -1,900 feet back up to the casing shoe at 1,574 feet, the hole was conical and tapered from 42 to 20 inches. In an attempt to seal off the 13-3/8 inch shoe, a 4-1/3 inch liner was run from -1,057 to -1,709 feet and cemented the full length of the liner. This operation was successful as a natural gas blanket was introduced into the gallery through well No. 5 until gas returns were recovered from Nos 2 and 4. The fact that pressure still remains on well No. 5 and in the annulus of well No. 2 is evidence that the liner job was successful and the gallery is pressure tight.

To convert this gallery to oil storage would involve the following procedures:

1. Remove gas blanket from gallery.

2. Pressure test gallery to 400 psi surface pressure with saturated salt water.

3. Remove suspended casing strings from well Nos 2 and 4 and run Sonar surveys in all three wells.

4. Plug and abandon well Nos 2, 4, and 5 by setting bridge plugs in the liners and cementing to the surface.

5. Drill and complete 20 x 13-3/8 inch casing replacement holes at locations determined from Sonar surveys. Pressure test each casing shoe before drilling into the cavern.

6. Run 10-3/4 inch displacement string in well No. 5A only and install wellheads on all three wells.

7. Connect wells to distribution system.

Cavern No. 6

Cavern No. 6 is located on the northwest flank of Sulphur dome approximately 520 feet north and east of cavern No. 7. Development of the cavern was through a dual well system (6X and 6Y) spaced approximately 40 feet apart. A Sonar survey, run October 15, 1975 in well No. 6Y, showed the roof of the cavern to be at -3,090 feet and the floor at -3,423 feet. The calculated gross volume was 4,374,037 barrels. The east-west profile of cavern No. 6 is illustrated by Figure H.1. The roof diameters at their respective depths are illustrated by Figure H.2.

Oil storage in this cavern would best be achieved by utilizing the existing wells to inject and withdraw oil and a new well for water injection and brine withdrawal. Only the well used for water would require a displacement string. With the displacement string hung at 3,355 feet, approximately 4,124,000 barrels of oil can be stored. The following work is recommended to prepare this cavern for storage.

1. Remove suspended strings from both 6X and 6Y.

2. Pressure test casing strings in both wells.

3. Pressure test cavern.

4. Sonar survey cavern and run cement bond and casing corrosion logs in both wells.

5. Drill and complete 20 x 13-3/8 inch cased replacement well. Pressure test casing and casing shoe before drilling into the cavern.

6. Run 10-3/4 inch displacement string in new well and install wellheads on all three wells.

7. Connect wells to distribution system.

Cavern No. 7

Cavern No. 7 is located on the west flank of Sulphur dome. Development was through the use of the two-well system (7A and 7B) spaced 40 feet apart. Well No. 7B is located due north of No. 7A. A Sonar caliper run on October 14, 1975 in well No. 7A showed the cavern roof

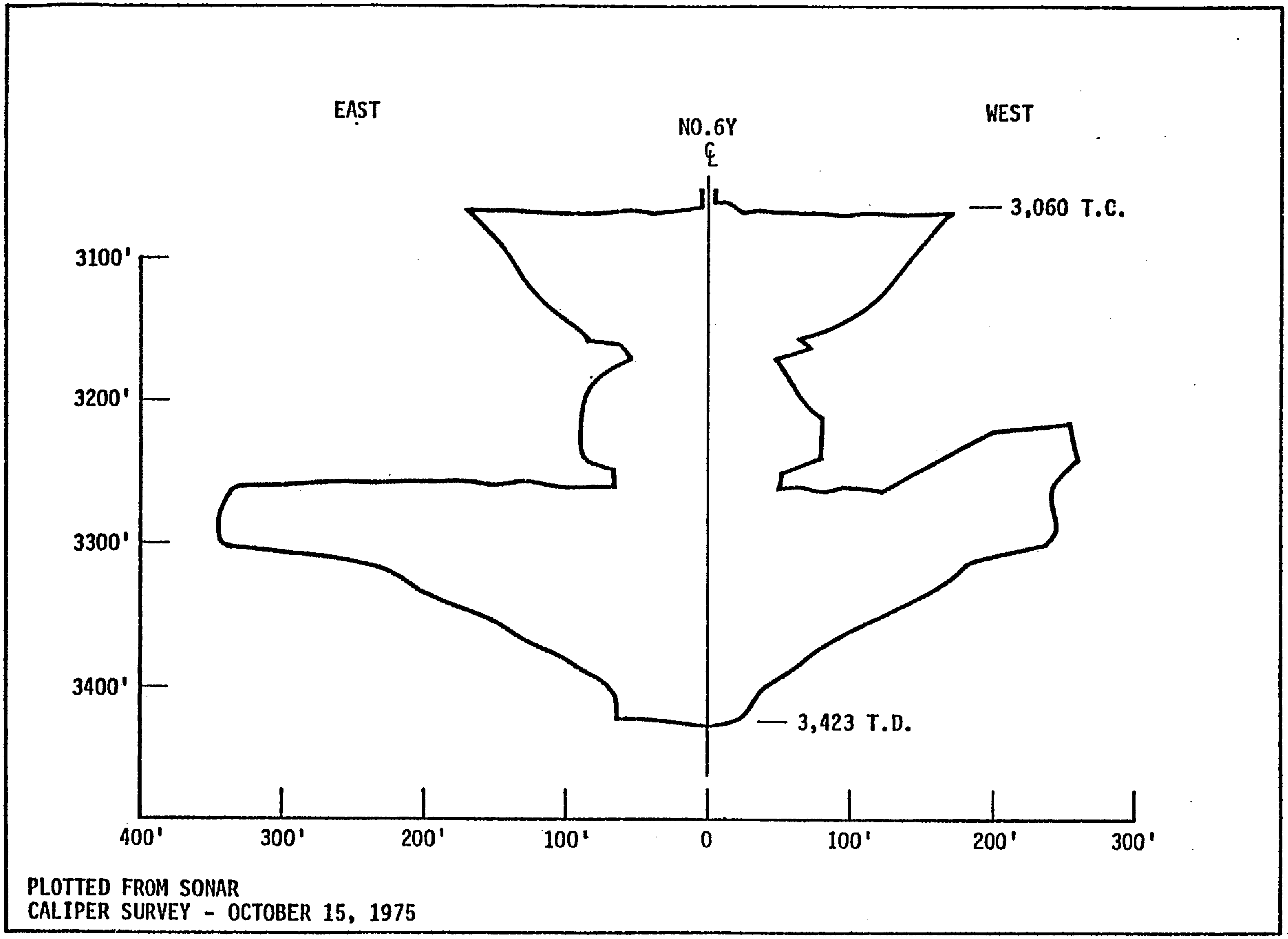

Figure II.1 Cavern No. 6 - Sulphur Mines Dome

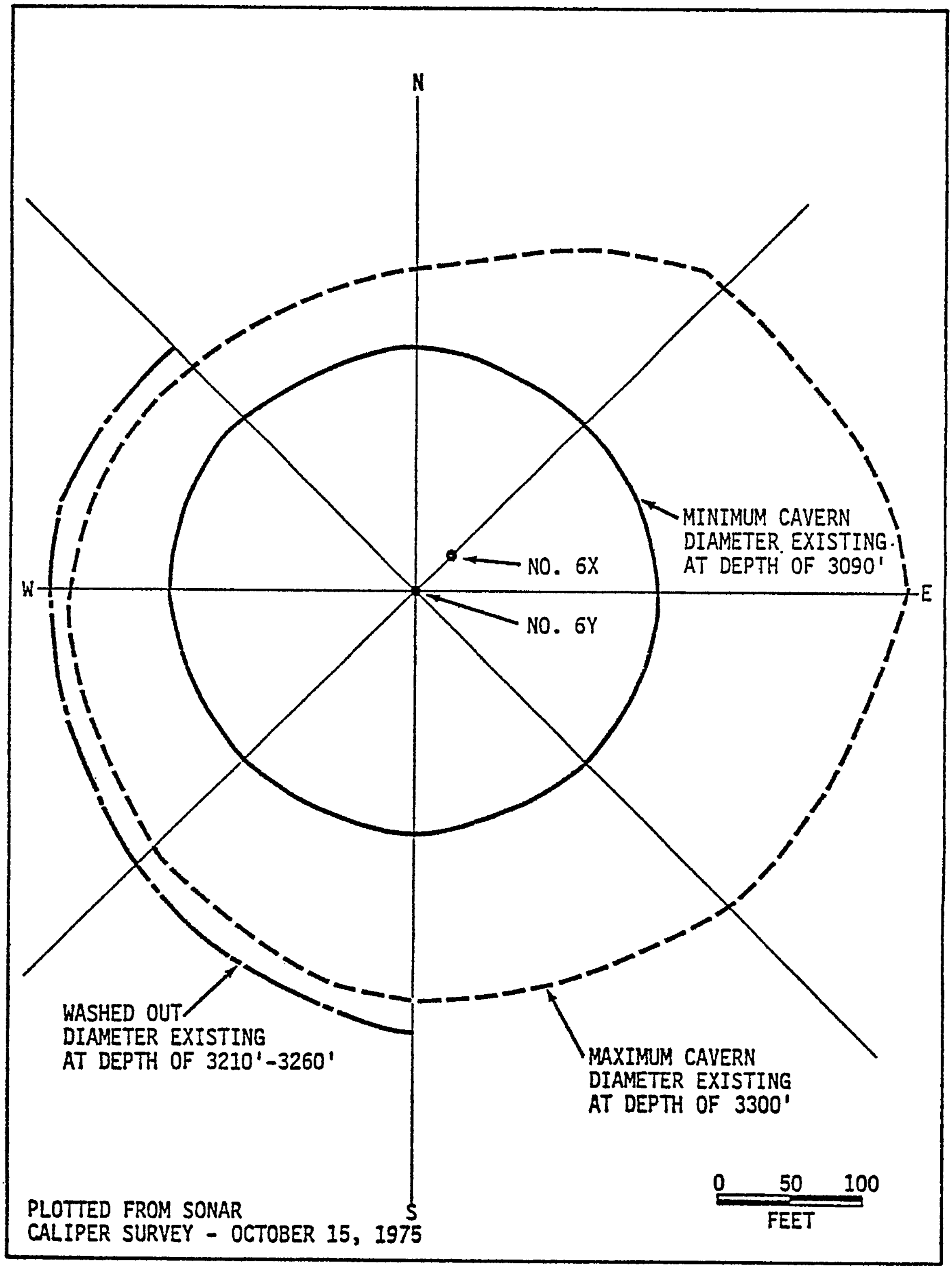

Figure H.2 Cavern No. 6 - Sulphur Mines Dome

at 2,872 feet and the floor at 3,025 feet. The calculated gross volume was 5,578,896 barels. The east-west profile of cavern No. 7 is illustrated by Figure H.3. The roof diameters at their respective depths are illustrated by Figure H.4.

Oil storage in this cavern could best be achieved in the same manner as is recommended for cavern No. 6, injecting oil into the existing wells and water into a new one. With the brine displacement casing hung at 3,170 feet, approximately 5,299,000 barrels of oil can be stored. The following work is recommended to prepare this cavern for storage.

1. Remove suspended casing strings from both 7A and 7B.

2. Pressure test cemented casing strings in both wells.

3. Pressure test cavern.

4. Sonar the cavern and run cement bond and casing corrosion logs in both wells.

5. Drill and complete 20 x 13-3/8 inch cased replacement well. Pressure test casing and casing shoe before drilling into the cavern.

6. Run 10-3/4 inch displacement string in new well and install wellheads on all three wells.

7. Connect wells to distribution system.

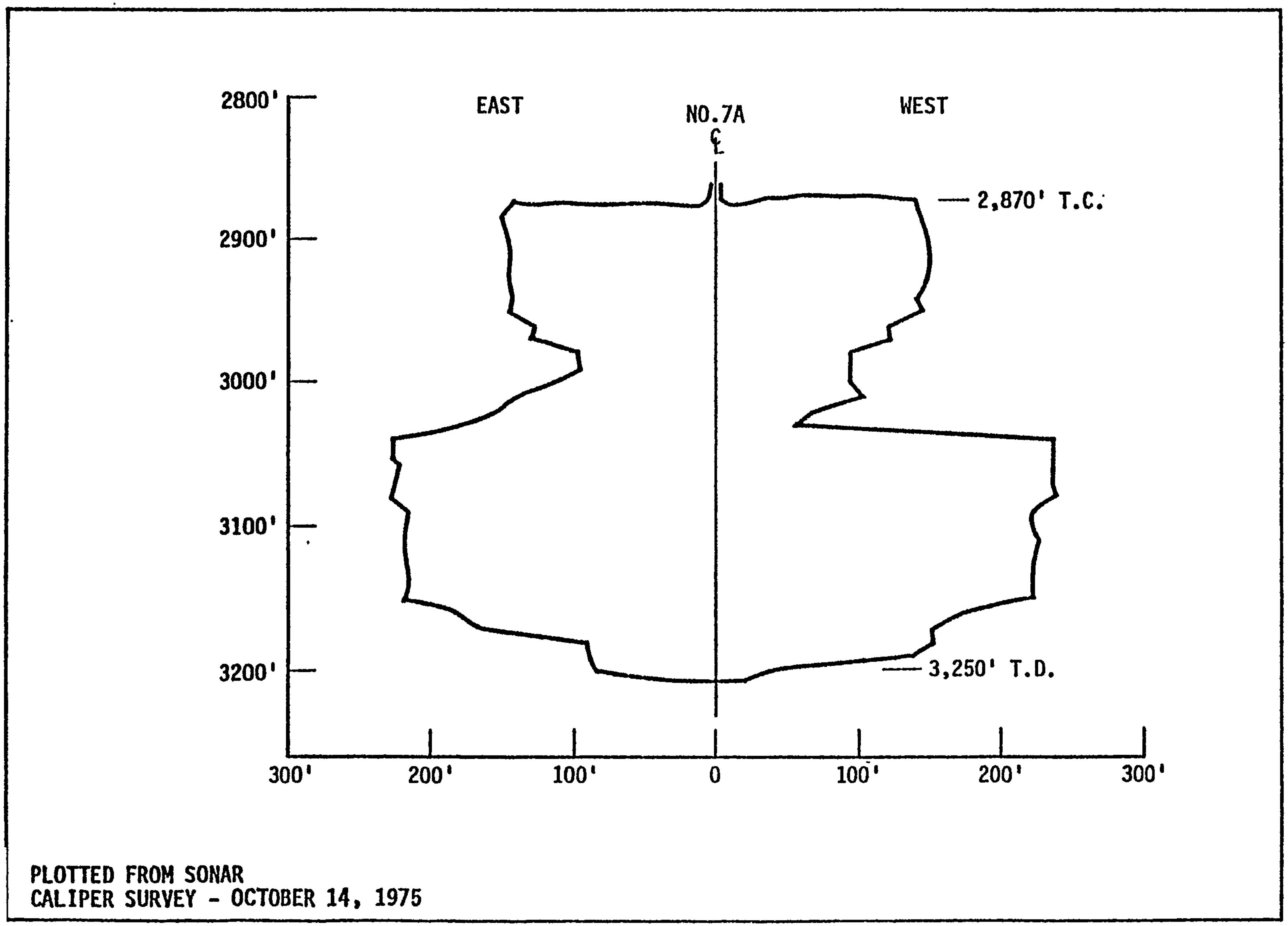

Figure H.3 Cavern No. 7 - Sulphur Mines Dome

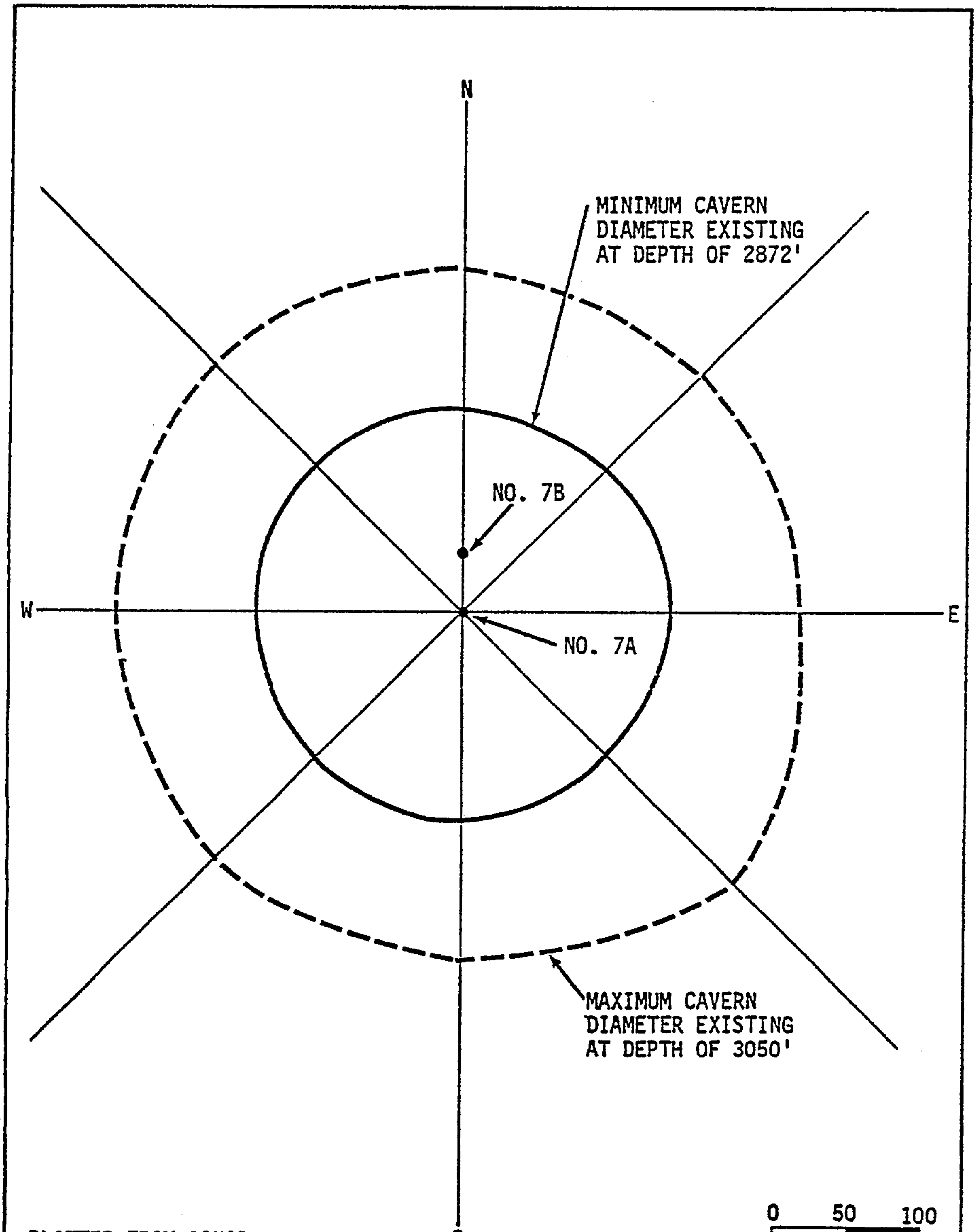

Figure H.4 Cavern No. 7 - Sulphur Mines Dome

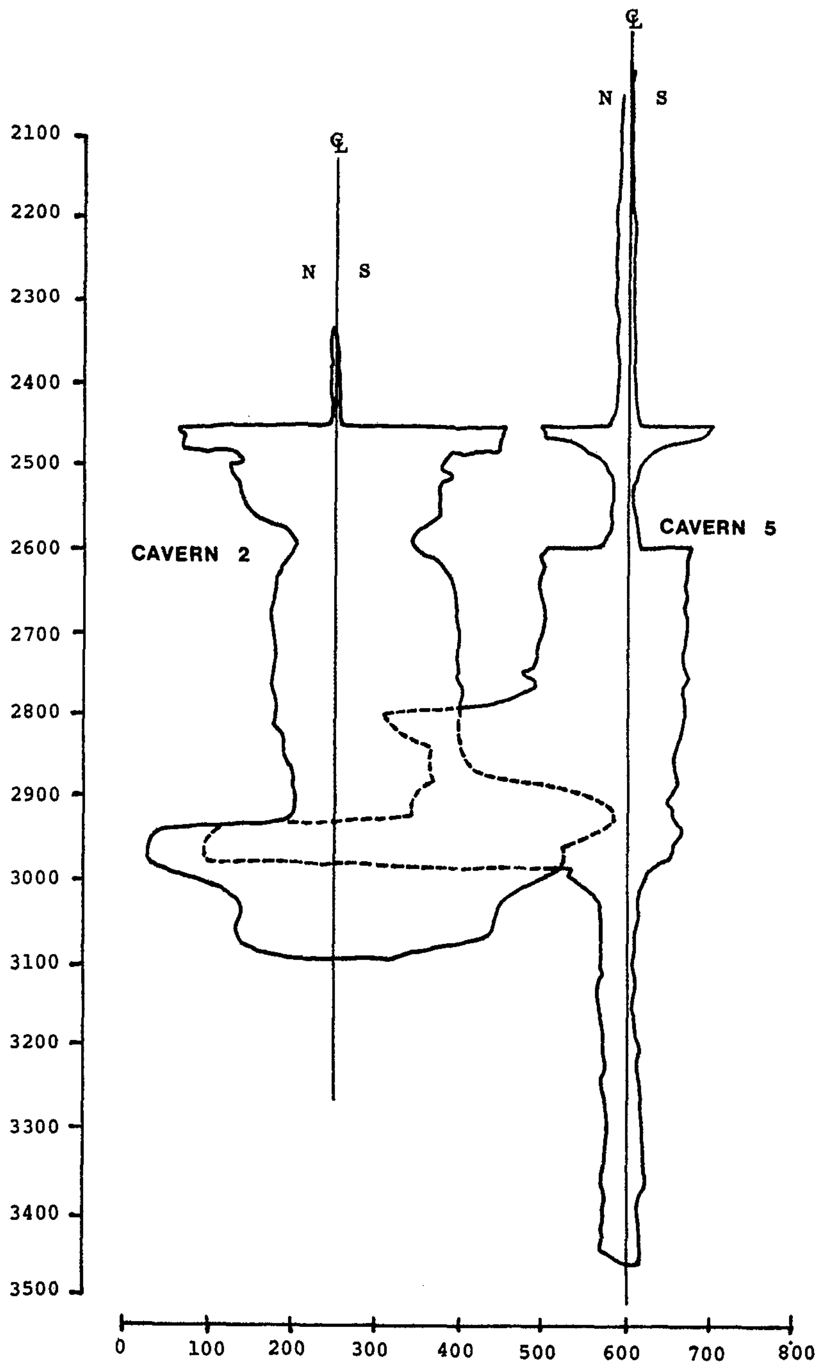

Figure H.5 Cross-section of caverns number 2 and 5 showing their relative size and proximity. Sonar caliper surveys were conducted at caverns 2 and 5 on September 8, 1977 and on September 2, 1977, respectively. This is the best representation in two dimensions. Dotted lines indicate areas of coalescence.

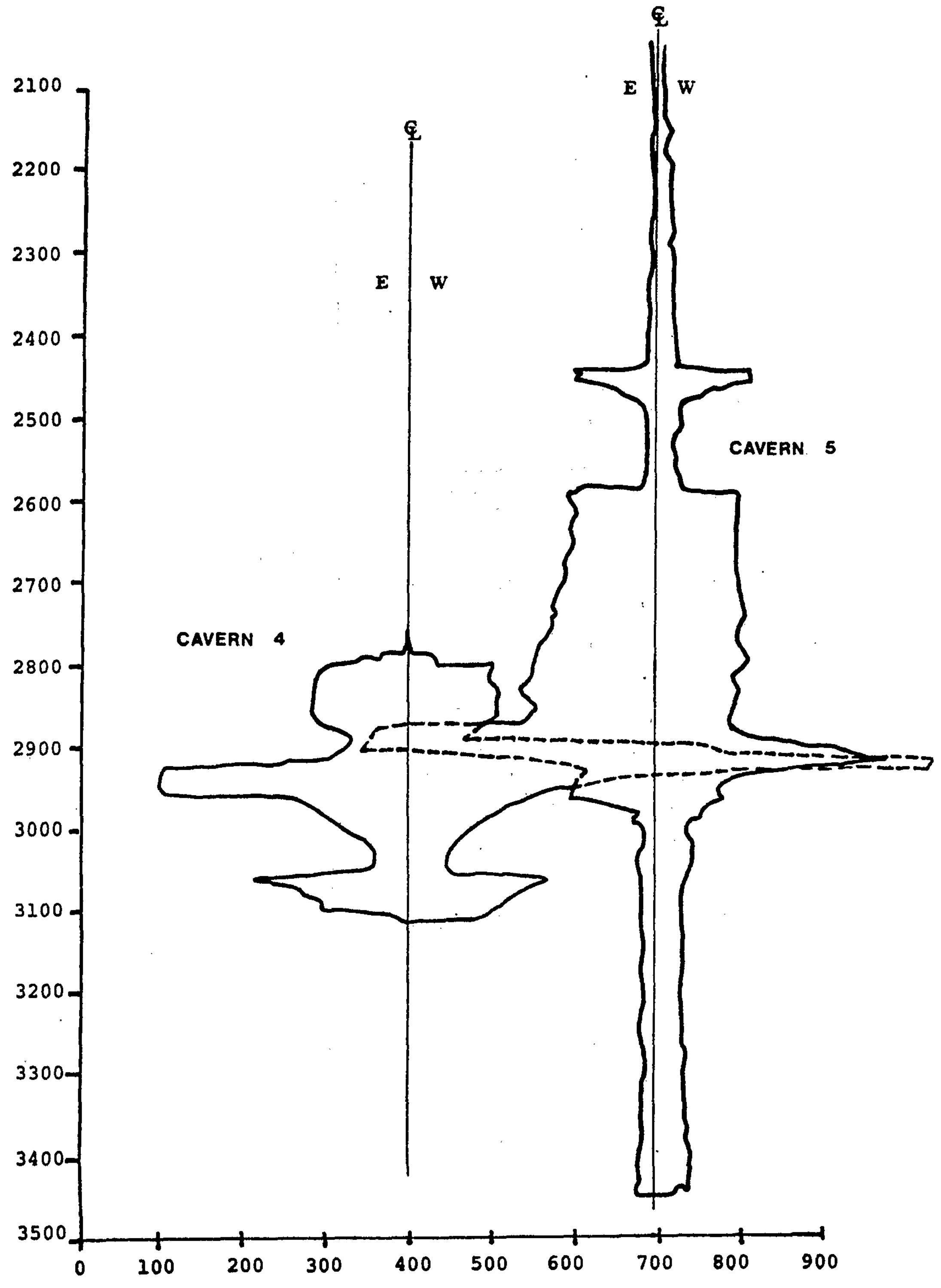

Figure H.6 Cross-section of caverns number 4 and 5 showing their relative size and proximity. Sonar caliper surveys were conducted at caverns 4 and 5 on August 30, 1977 and September 2, 1977, respectively. This is the best representation in two dimensions. Dotted lines indicate areas of coalescence.

2. Drilling Procedures

The Sulphur Mines salt dome is reached at an average depth of 1,460 ft. Caprock with an average thickness of 1,100 ft covers most of the dome's crest. The ceilings of the storage cavities range from 2,450 to 3,090 ft below the surface. The new auxiliary wells would require 13-3/8 inch casing cemented from the surface to the ceiling, and 10-3/4 inch displacement tubing suspended to the top of the sump space.

Conventional oil field rigs would be used. The majority of oil rigs are of the diesel powered rotary type. Some are direct coupled and some are diesel-electric. Casing sizes to be used for the project would be somewhat larger than required for "oil field" wells of comparable depth. Consequently, drill rigs may have "oil field" depth ratings up to 10,000 ft. The required finished casing size for the auxiliary wells would be 13-3/8 inches, but because of the larger casings needed to cement the borehole at various intervals from the cavity to the surface, the various bore capabilities of the rig is critical.

A certain amount of difficulty in drilling through the caprock would be expected. This happens most often when cavernous zones resulting from natural leaching of the anhydrite and gypsum formations cause a loss of the drilling fluid necessary for lubricating the bit and transporting spoil to the surface. In most cases, circulation could be re-established, but if caprock conditions at one of the re-entry wells fails in circulation, the well could be completed at a greater expense without full circulation. It is estimated that in 20% of boreholing through caprock some diffculty with lost circulation may be experienced. This problem would be magnified when attempting boreholes through previously mined caprock, because of additional voids induced by mining.

Drilling fluid, commonly called "mud," could be of a variety of constitutions, depending on drilling conditions. "Highly inhibited muds" may be required in difficult shales, but non-exotic clays would be used when possible. The cheapest and preferably least toxic mud that would do the job would be used, but the actual formulation would be determined by experience on the site. It may be possible, in some instances, to get by with non-toxic "native muds" until the "top hole" is cased off, and then to convert to saturated brine. The salt must be drilled with salt saturated mud or brine to prevent hole enlargement by leaching.

Disposal of used muds is also an important consideration. Normal procedure would be to transfer the mud with the rig, continually recycling a volume equal to twice the borehole size. There would be pits of saline mud which would have to be cleaned up and buried. In the Gulf Coast region, the humidity is too high to economically dry the waste. Therefore, mud would have to be hauled away when drilling operations are completed.

APPENDIX I

EMISSIONS FROM MARINE VESSEL TRANSFERRING OF CRUDE OIL

1. Introduction

Ships and barges will be used to deliver crude oil to and from the marine terminals for the Strategic Petroleum Reserve (SPR) facility. Hydrocarbon emissions are generated at marine terminals when volatile hydrocarbon liquids are either loaded onto or unloaded from ships and barges.

The magnitude of crude oil transfer emissions are dependent on many factors. Industry testing programs have been conducted recently to evaluate the interrelationship of these and other important factors in developing up-to-date emission factors for ships and barge loading and ballasting emissions. Most of those studies completed have developed emission factors for gasoline. Crude oil transferring operations are under study by the Western Oil and Gas Association (WOGA) (ref. 1).

This appendix evaluates the existing emission data and proposes an analytical procedure for estimating the probable crude oil emission factors for the SPR facility.*

Section 2 presents the general nature and characteristics of marine transfer emissions. Sources testing data compiled by many industry sources concerning marine transfer emissions are presented in Section 3. Description of a proposed procedure and assumption required to estimate emission factors for crude oil are presented in Section 4. The final section concludes the emission factor analysis and presents a summary of emission factors proposed to be used for the SPR facility.

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*This appendix derives emission factors for crude handling operations which represent a reduction in emission factors presented in earlier FEA environmental reports. The results reported here represent the best approximations possible with currently existing data.

2. Emission Sources and Characteristics

2.1 Loading Emissions

Loading emissions are attributable to the displacement to the atmosphere of hydrocarbon vapors residing in empty vessel tanks by volatile hydrocarbon liquids being loaded into the vessel tanks. Loading emissions can be separated into (1) the arrival component and (2) the generated component. The arrival component of loading emissions consists of hydrocarbon vapors left in the empty vessel tanks from previous cargos. The generated component of loading emissions consists of hydrocarbon vapors evaporated in the vessel tanks as hydrocarbon liquids are being loaded.

The arrival component of loading emissions is directly dependent on the true vapor pressure of the previous cargo, the unloading rate of the previous cargo, and the cruise history of the cargo tank on the return voyage. The cruise history of a cargo tank may include heel washing, ballasting butterworthing, vapor freeing, or no action at all.

The generated component of loading emissions is produced by the evaporation of hydrocarbon liquid being loaded into the vessel tank. The quantity of hydrocarbons evaporated is dependent on both the true vapor pressure of the hydrocarbons and the loading and unloading practices. The loading practice which has the greatest impact on the generated component is the loading and unloading rate.

A typical profile of gasoline concentration in a ship tank during loading is presented in Figure 1 (Ref 2). As indicated in the figure, the hydrocarbons present throughout most of the vessel tank vapor space are contributed to by

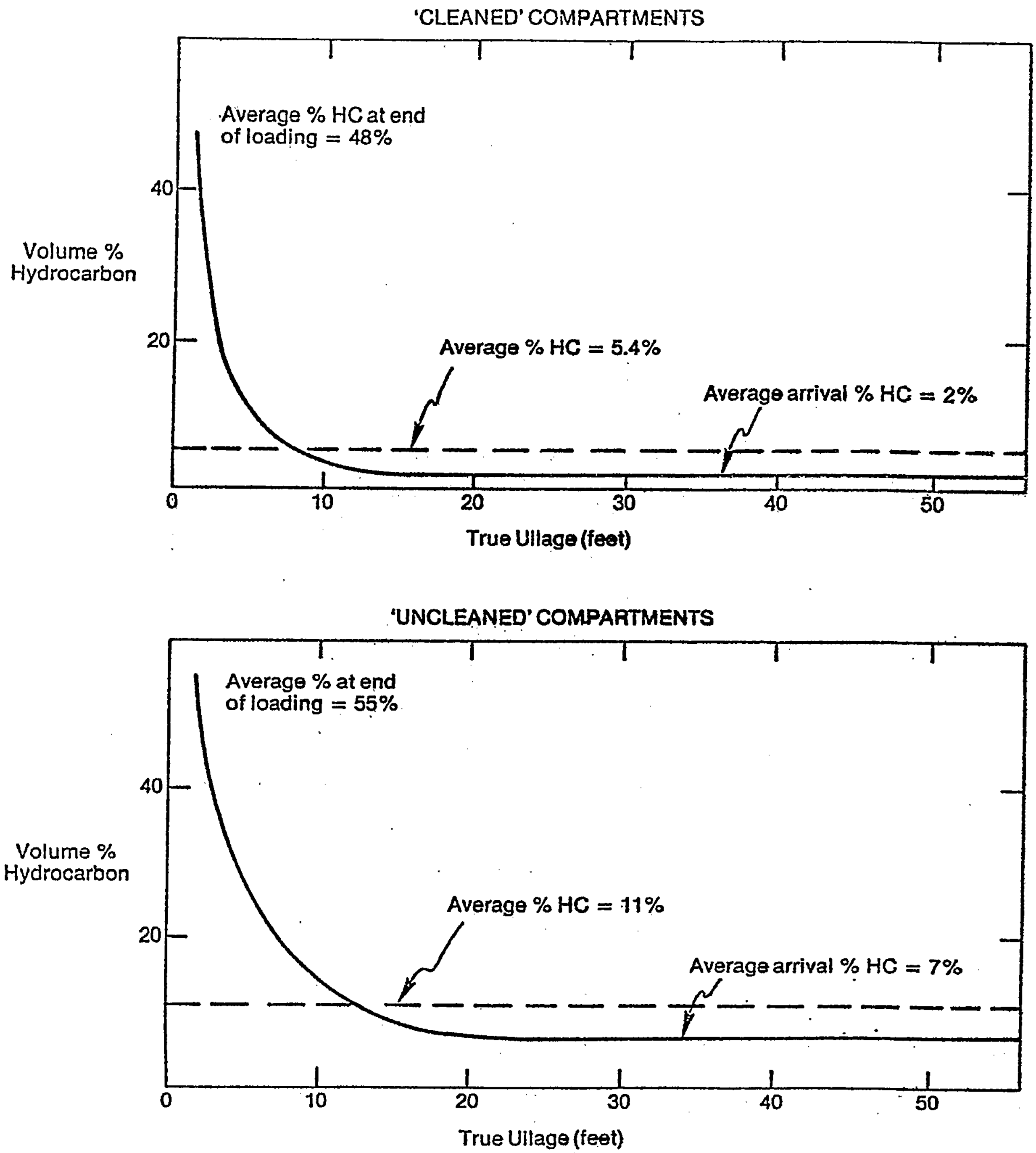

Figure 1. Typical Ship Emission Profiles

the arrival vapor component and the concentration is almost uniform. There is a sharp rise in hydrocarbon vapor concentration just above the liquid surface. This is the generated component. The generated component, also called a "vapor blanket," is attributable to evaporation of the hydrocarbon liquid.

From Figure 1 it is apparent that for large vessels with 55 foot ullages,* the average hydrocarbon concentration of vapors vented during loading operations is primarily dependent on the arrival component. For smaller vessels such as barges with 12 foot ullages, the average hydrocarbon concentration in the vented loading vapors is dependent on both the generated component and the arrival component.

2.2 Unloading Emissions

Unloading emissions are hydrocarbon emissions displaced during ballasting operations at the unloading dock subsequent to unloading a volatile hydrocarbon liquid such as gasoline or crude oil. During the unloading of a volatily hydrocarbon liquid, air drawn into the emptying tank absorbs hydrocarbons evaporating from the liquid surface. The greater part of the hydrocarbon vapors normally lies along the liquid surface in a vapor blanket. However, throughout the unloading operation, hydrocarbon liquid clinging to the vessel walls will continue to evaporate and to contribute to the hydrocarbon concentration in the upper levels of the emptying vessel tank.

Before sailing, an empty marine vessel must take on ballast water to maintain trim and stability. Normally, on vessels that are not fitted with segregated ballast tanks this

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*The term "ullage" refers to the distance between the cargo liquid level and the rim of the ullage cap.

water is pumped into the empty vessel tanks. As ballast water enters tanks, it displaces the residual hydrocarbon vapors to the atmosphere generating the so termed "unloading emissions."

2.3 Parameters Affecting Emission

Emission testing results indicate that many factors affect the magnitude of crude oil loading and unloading emissions. Due to the interrelated nature of these parameters, it is difficult to quantify the emission impacts. This section qualitatively presents the effects of the following parameters on marine loading and unloading emissions:

- loading and unloading rate
- true vapor pressure
- cruise history
- previous cargo
- chemical and physical properties

2.3.1 Loading and Unloading Rate

During the loading operation, the initial loading and unloading rate has a significant effect on hydrocarbon emissions due to the splashing and turbulence caused by higher initial loading or withdrawing rates. This splashing and turbulence results in rapid hydrocarbon evaporation and the formation of a vapor blanket. By reducing the initial velocity of entering or withdrawing rates, it is possible to reduce the turbulence and consequently, to reduce the size and concentration of the vapor blanket. Slow final loading rate can also lower the quantity of emissions. This is because when the hydrocarbon level in a marine vessel tank approaches the tank roof, the action of vapors flowing towards the ullage cap vent begins to disrupt the quiescent vapor blanket. Disruption of the vapor blanket results in noticeably higher hydrocarbon concentrations in the vented vapor (Ref 3).

2.3.2 True Vapor Pressure

The true vapor pressure (TVP) of a hydrocarbon liquid has a marked impact on the hydrocarbon content of its loading and unloading emissions. TVP is an indicator of a liquid's volatility and is a function of the liquid's Reid Vapor Pressure (RVP) and temperature. Compounds with high TVP exhibit high evaporation rates and consequently, contain high hydrocarbon concentrations in their loading and ballasting vapors. The monographs presented in Figures 2, and 3 correlate the TVP for crude oil and gasoline. The RVP of gasoline loaded in the Houston-Galveston area range from 9.5 to 13.6 psia in the winter season, while the RVP of crude oils unloaded normally range from 2 to 7 psia. For the purpose of assessing a SPR facility, the crude oil is assumed to have a maximum RVP of 5 psia and an average RVP of 4 psia at a temperature of 70° F.

2.3.3 Cruise History

The cruise history of a marine vessel includes all of the activities which a cargo tank experiences during the voyage prior to a loading or unloading operation. Examples of significant cruise history activities are ballasting, heel washing, butterworthing, and gas freeing. Cruise history impacts marine transfer emissions by directly affecting the arrival vapor component. Barges normally do not have significant cruise histories because they rarely take on ballast and do not usually have the manpower to clean cargo tanks.

Ballasting is the act of partially filling empty cargo tanks with water to maintain a ship's stability and trim. Recent testing results indicate that prior to ballasting,

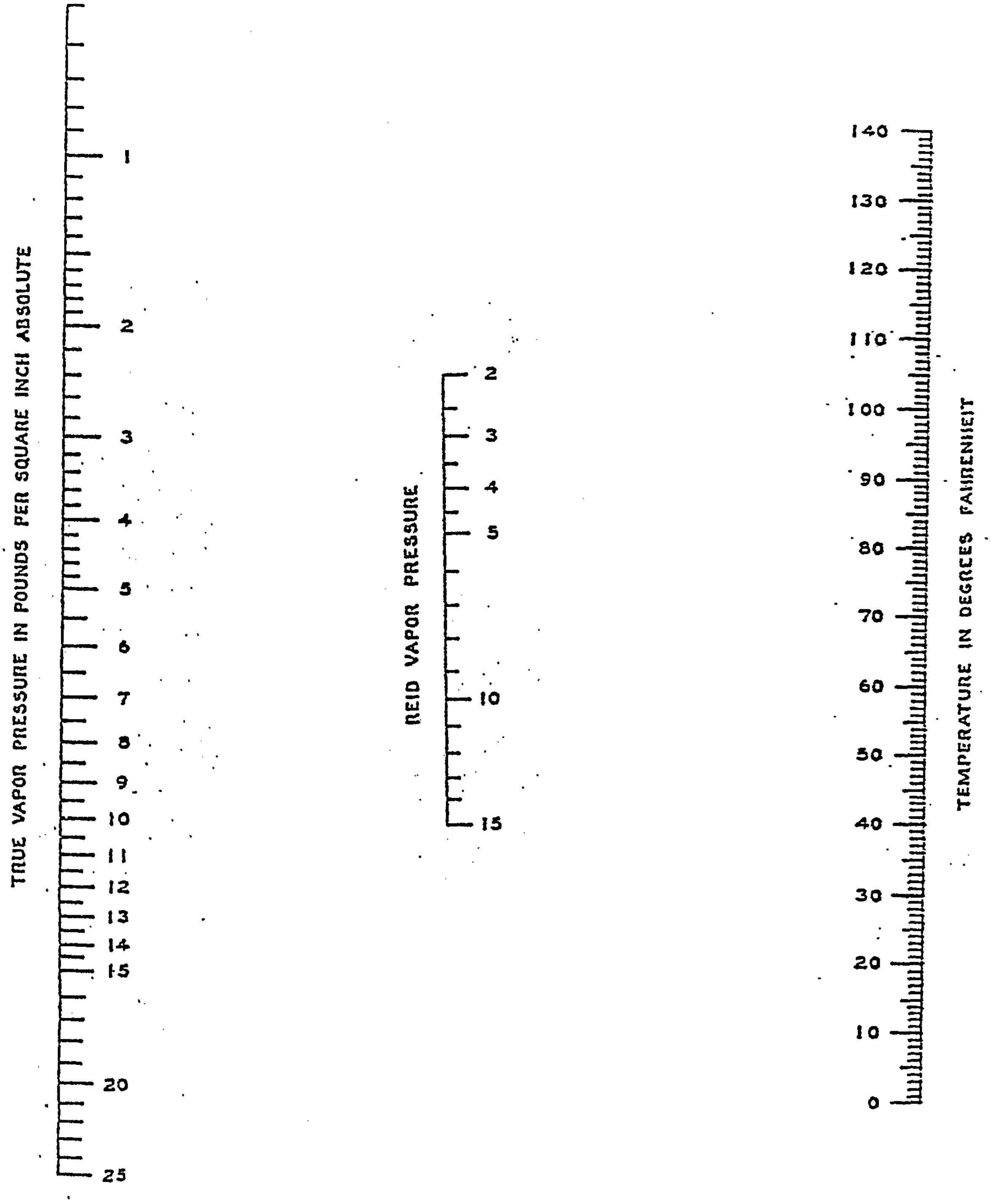

Figure 2. Vapor Pressures of Crude Oil

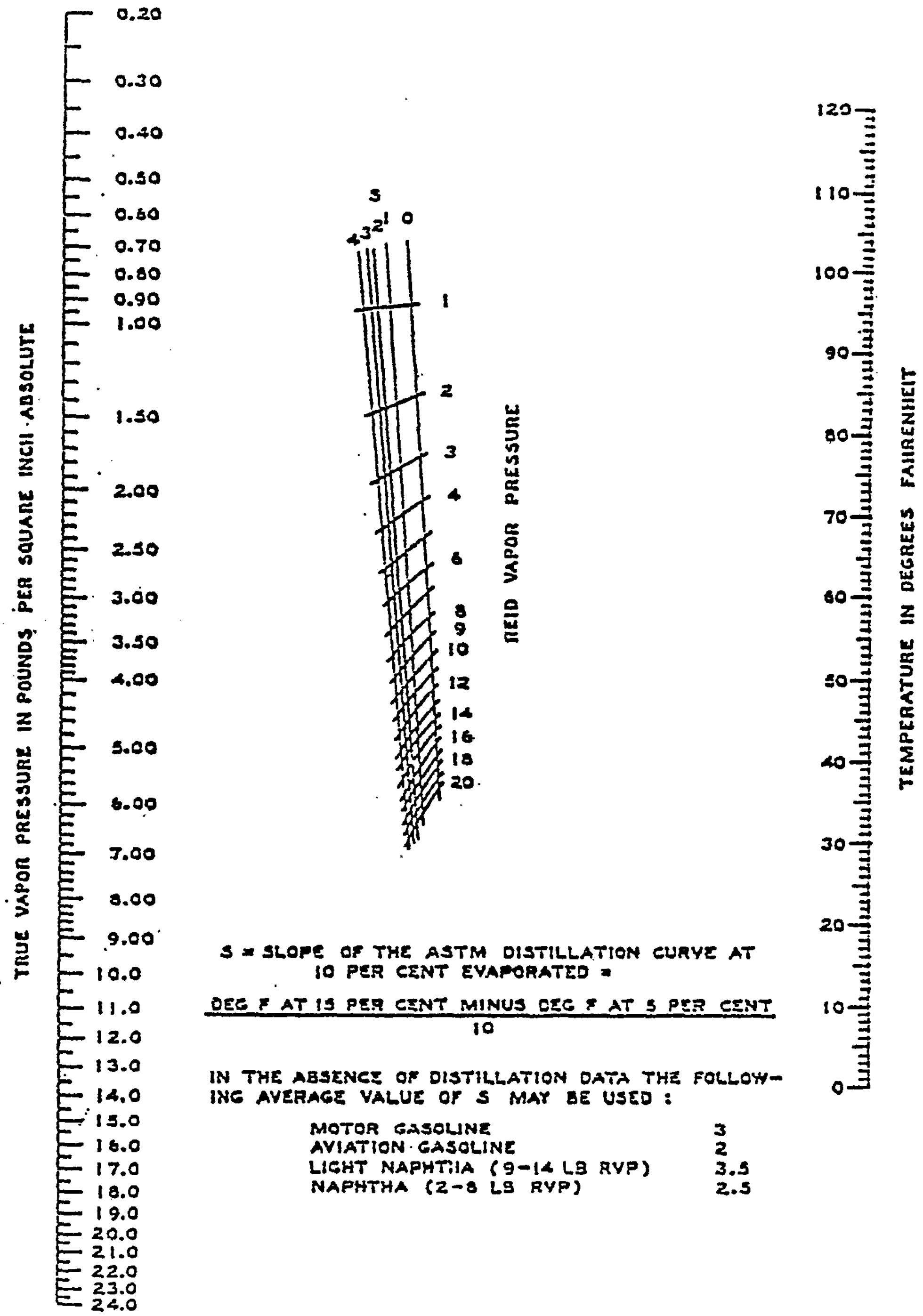

Figure 3. Vapor Pressures of Gasolines and Finished Petroleum Products

empty cargo tanks normally contain an almost homogeneous concentration of residual hydrocarbon vapors. When ballast water is taken into the empty tank, hydrocarbon vapors are vented, but the remaining vapors not displaced retain their original hydrocarbon concentration. Upon arrival at a loading dock, a ship discharges its ballast water and draws fresh air into the tank. The fresh air dilutes the arrival vapor concentration and lowers the effective arrival vapor concentration by an amount proportional to the volume of ballast used. Although ballasting practices vary from vessel to vessel, the average vessel is ballasted approximately 40%.

The heel of a tank is the residual puddles of hydrocarbon liquids remaining in tanks after emptying. These residual liquids will eventually evaporate and contribute to the arrival component of subsequent vessel-filling vapors. By washing out this heel with water, AMOCO Oil Company found that they were able to reduce the hydrocarbon emissions from subsequent filling operations from 5.7 volume percent to 2.7 volume percent hydrocarbons (Ref 3). Butterworthing is the washing down of tank walls in addition to washing out tank heels. Butterworthing also reduces loading emissions by reducing the arrival component concentration. The hydrocarbon liquids washed from the tanks are stored in a slops tank for disposal onshore (ref 3).

In addition to heel washing and butterworthing, marine vessels can purge the hydrocarbon vapors from empty and ballasted tanks during the voyage by several gas freeing techniques which include air blowing and removal of ullage dome covers. A combination of tank washing and gas freeing will effectively remove the arrival component of loading emissions (Ref3).

2.3.4 Previous Cargo

The previous cargo conveyed by a tanker also has a direct impact on the arrival component of loading emissions. Cargo ships which carried nonvolatile liquids on the previous voyage normally return with low arrival vapor concentration. EXXON Oil Company tests conducted in Baytown, Texas indicated that the arrival component of empty uncleaned cargo tanks which had previously conveyed fuel oil ranged from 0 volume percent to 1 volume percent hydrocarbons. Cargo tanks with the same cruise history which had previously conveyed gasoline, exhibited hydrocarbon concentrations in the arrival vapors which ranged from 4 percent (by volume basis) to 30 percent and averaged 7 percent (Ref 3).

2.3.5 Chemical and Physical Properties

The chemical compositions and molecular weight of crude oil vapors will vary over a wide range. The typical vapor consists predominantly of C_4 and C_5 compounds. The molecular weight ranges from 45 to 100 pound per pound mole with an average of approximately 70.

3. Industry Emission Testing Results

The petroleum industry has been involved in test programs to quantify the hydrocarbon emissions from gasoline and crude oil transfer operations at marine terminals. Table 1 summarizes the test programs which have been conducted by the petroleum industry. The industry programs have included motor gasoline, aviation gasoline, and crude oil loading onto tankers, barges, and ocean barges. Well over 200 vessel tanks were sampled in these programs. The petroleum industry tests were primarily conducted between 1974 and 1975 in the Houston-Galveston area. Tests have also been conducted on the California Coast and in the Great Lakes area (Ref 3).

Company	Types of Marine Testing	Location	Date	Extent of Testing	Emission Factors
WOGA	tanker loading and ballasting emissions for crude oil and natural gasoline	Ventura County Union Oil Terminal Getty Oil Terminal California	May 1976 (tests are ongoing)	6 tests to date	preliminary data indicates that emissions from loading a nonvolatile crude into ballasted tanks which previously carried more volatile crude and not gasoline are 0.9 to 1.0 lb/1000 gallons .
EXXON	primarily gasoline loading, but also averages and crude loading	Exxon Terminal Baytown Texas Karg Island, Iran	winter 1974-1975 summer 1975	100 ship tests 30 barge tests	**Gasoline Loading** tanker - gas free 3.24 vol % tanker - ballasted 6.96 vol % tanker - uncleaned 10.26 vol % average Exxon tanker 6.41 vol % (1.47 lb/mgal) ocean barge -gas free 5.69 vol % ocean barge -ballasted 9.08 vol % ocean barge -uncleaned 14.40 vol % avg. EXXON ocean barge 11.71 vol % (2.66 lb/mgal) barge 18.35 vol % (4.14 lb/mgal) **Aviation Gasoline Loading** tanker - gas free 1.63 vol % tanker - unclean (av. gas prev.) 6. 65 vol % tanker - unclean (no gas prev.) 10.64 vol % average EXXON tanker 5.35 vol % (1.47 lb/mgal) average military tanker 4.13 vol % (1.13 lb/mgal) barge 18.35 vol % (4.25 lb/mgal) **Weighted Average Dock** 1.8 lb/mgal Also have a TVP dependent correlation (see text)
American Petroleum Institute	motor gasoline loading	predominantly in Houston-Galveston area	1974-1976		clean tankers 1.3 lb/mgal clean barges 1.2 lb/mgal uncleaned tankers 2.5 lb/mgal uncleaned barges 3.8 lb/mgal
Arco	motor gasoline loading of tankers	Houston Refinery	Nov. 1974, Feb. and April 1975	11 tests	**Gasoline Loading on Tanker** fast load, low TVP, clean 2.1 vol % (0.4 lb/mgal) fast load, med TVP, clean 2.6 vol % (0.5 lb/mgal) slow load, high TVP, clean 4.2 vol % (0.9 lb/mgal) slow load, high TVP, part clean part lcean 6.9 vol % (1.5 lb/mgal) avg. ARCO tanker 3.9 vol % (0.84 lb/mgal)
AMOCO	primarily motor gasoline loading	Whiting, III	2/26/74-7/22/75	40-50 tests	none developed
	crude barge unloading	Texas City, Texas	5/29/74-8/5/75	9 tests	none developed AMOCO did state that average emissions for AMOCO ship less than 10.2 vol %
Shell	gasoline loading on tanker	Deer Park, Texas	Oct. 1974	5-10 tests	none developed
British Petroleum	crude oil loading on tanker	Middle East	1973	Unknown	none developed

4. Proposed Emission Factor Calculating Procedures

The emission factor calculation procedure, suggested in API publication 2514A for loading operations are used. In this method, the total mass emission factor (lb/1000 gal) is derived from the average HC volume concentration. The hydrocarbon volume concentration is then converted into a total hydrocarbon mass by multiplying an average vapor molecular weight and a correction factor accounting for vapor generation factor. These are:

$$H_f = \left(\frac{Xv}{100}\right) \left(\frac{K.W_m}{V_k}\right) \left(\frac{100+F}{100}\right) \qquad (1)$$

and

$$F = \left[\frac{(1-X_T)\left(\frac{U_i}{U_i-U_f}\right) - (1-X_r)\left(\frac{U_f}{U_i-U_f}\right)}{(1-X_v)}\right] -1 \qquad (2)$$

where:

H_f = hydrocarbon emission factors, lb/1000 gal

X_v = volumetric average of HC concentration of vented vapor, percent

K = constant, 113.7 ft^3/1,000 gal

W_m = molecular weight of HC vapor, lb/lb-mole

V_k = molecular volume of perfect gas, 379.44 ft^3/lb

F = vapor generation factor, See Equation (3)

X_T = volumetric average HC concentration of arrival vapor, percent

X_r = volumetric average HC concentration of remaining vapor, percent

U_i = total tank depth, ft

U_f = final ullage, ft

According to API calculation, a maximum volume increase (vapor generation factor F) of 6 percent for both ships and barge was determined. Thus, if we combine the constants K and V_K with a conservative value of F equivalent to 6 percent, equation (1) can be simplified to:

$$H_f = 0.3735 \cdot (X_v) \cdot (W_m) \qquad (3)$$

The total volume of HC concentration vented at loading conditions (X_v) is equal to the sum of arrival HC concentration (X_a) and the generation HC vapor concentration (X_g). Thus

$$X_v = X_a + X_g \qquad (4)$$

Based on the above relation, EXXON has further derived the following loading emission correlation:

$$X_v = \left(\frac{E}{V}\right) = \left[\frac{C}{100}\right] + \left[\frac{P \cdot (G - U) \cdot A}{V}\right] \qquad (5)$$

where:

E = total volume of HC emitted at the loading condition, CF
C = arrival HC concentration, percent
V = HC liquid loaded, ft^3
P = true vapor pressure of the HC liquid, psia
A = surface area of the HC liquid, ft^2
G = HC generation coefficient value of 0.36 ft^3/ft^2 - psia)
U = final true ullage correction in $ft^3/(ft^2$ - psia) from Figure 4

Assuming $V = A\ (U_i - U_f)$, Equation (5) becomes

$$X_v = \left[\frac{C}{100}\right] + \left[\frac{P \cdot (G - U)}{(U_i - U_f)}\right] \qquad (6)$$

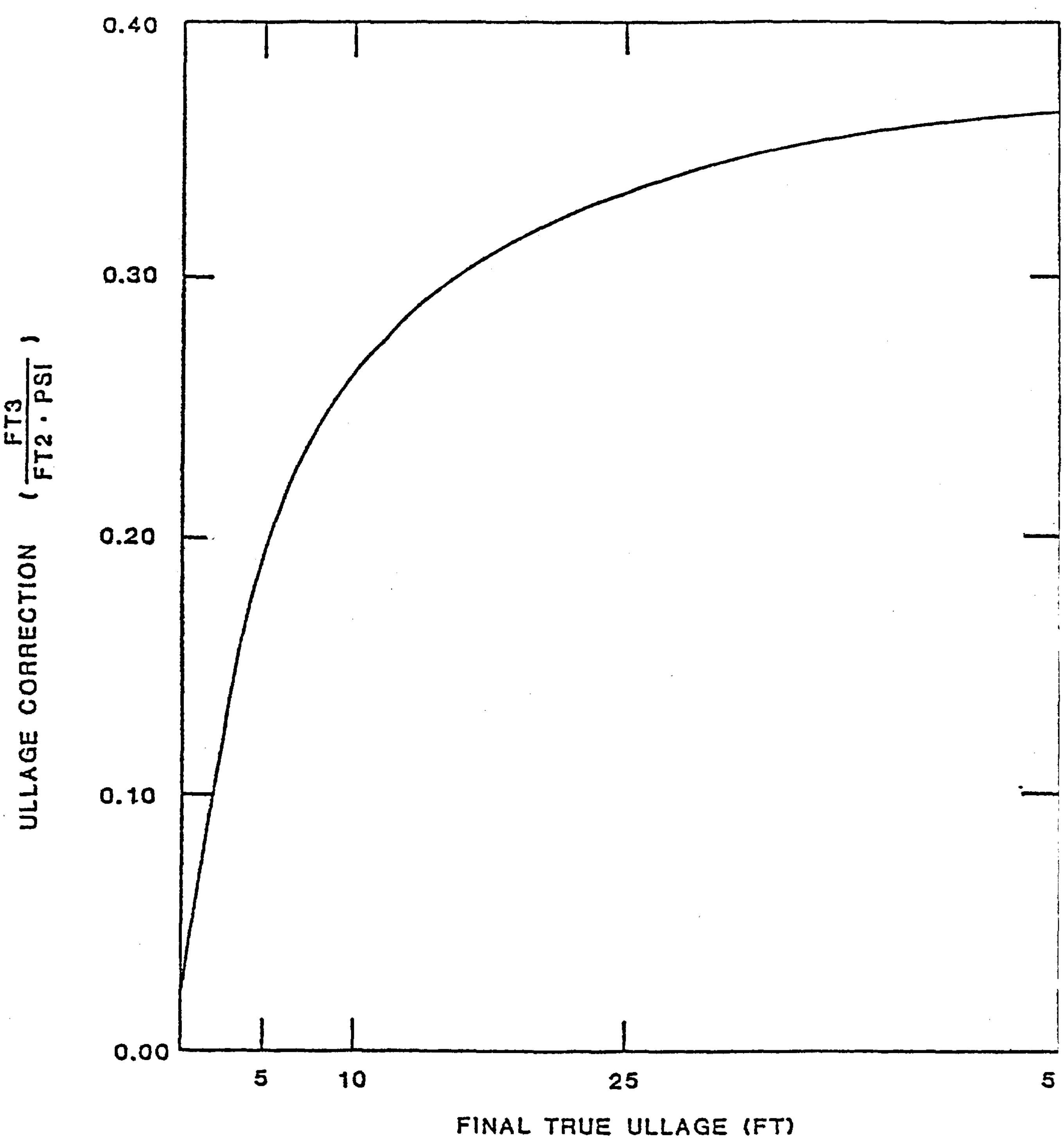

Figure 4. Hydrocarbon Generation Coefficient, Final Ullage Correction to the EXXON Corporation

The EXXON correlation of equation (6) is based principally upon gasoline loading data (Ref 3). For the loading of crude oil, SAI has proposed to adjust the first and second terms by multiplying correction factors ${}_1$ and ${}_2$, respectively. Thus, for crude oil ship loading operation:

$$X_V = {}_1\frac{C}{100} + {}_2\frac{P \cdot (G - U)}{(U_i - U_f} \qquad (7)$$

In the above correlation, ${}_1$ is principally affected by the characteristics of the previous cargo, whereas the value of ${}_2$ is independent to the conditions of previous cargo. For barge loading operation, it is further assumed that no correction factor ${}_2$ for vapor generation terms is necessary. This is because barge loadings are usually operated in short duration and the majority of hydrocarbon vapor generated during this period would be those volatile hydrocarbons with very light molecular weights.

Thus, the basic difference between vapor characteristics for gasoline and crude oil would be slight for a short barge loading duration.

For the purpose of SPR facility analysis, it is further assumed that no correction factor on C is necessary when previous cargo is a volatile hydrocarbon sch as gasoline. Thus,

- o ${}_1 = 1$, when previous cargo is gasoline
- o ${}_1 = {}_2$, when previous cargo is crude oil.

The correction factor ${}_2$ can be interpreted as the ratios of evaporation mass transfer coefficients between crude oil and gasoline. Mackay and Matsuger (Ref 6) have correlated the mass transfer coefficient (K) based on wind tunnel studies of evaporative hydrocarbon liquids. They found that the mass transfer coefficient is inversely proportional to the vapor phase Schmidt number (S_c) as follows:

$$K = f(U.A) \cdot (S_c)^{-0.67}$$

where U is wind speed, and A is the oil surface area.

The a_2 thus can be determined by

$$2 = \frac{K_c}{K_g} = \frac{S_c^{-0.67}\ \text{crude oil}}{S_c^{-0.67}\ \text{gasoline}}$$

Since the Schmidt number (S_c) is defined by the mass transport properties $\mu/\rho D_{AB}$ (Ref 7)

α_2 can then be calculated by the following equations:

$$\alpha_2 = \frac{(\mu/\rho D_{AB})^{-0.67} \text{ crude oil}}{(\mu/\rho D_{AB})^{-0.67} \text{ gasoline}} \qquad (8)$$

and

$$D_{AB} = 0.0018583 \frac{\sqrt{T^3\left(\frac{1}{M_A} + \frac{1}{M_B}\right)}}{P\sigma_{AB}^2\ \Omega_{D,AB}} \qquad (9)$$

$$\mu = 2.6693 \times 10^{-5} \frac{\sqrt{MT}}{\sigma^2 \Omega_{\mu_{AB}}} \qquad (10)$$

μ = viscosity of vapor

ρ = density of vapor

D_{AB} = binary diffusivity for system A (air) and B (hydrocarbon)

M_A, M_B = molecular weight of A, B, respectively

P = fluid pressure, atmosphere

σ_{AB} = collision diameter, A

$\Omega_{D,AB}$ = collision integral for mass diffusivity

$\Omega_{\mu,AB}$ = collision integral for viscosity

The pertinent intermolecular properties and functions for prediction of transport properties of hydrocarbon gases at low densities are presented in Table 2 and Table 3, respectively.

Table 2. Intermolecular Parameters of Hydrocarbons

Substance	Molecular Weight M	Lennard-Jones Parameters[a]	
		σ (Å)	ϵ/κ (° K)
CH_4	16.04	3.822	137.
C_2H_2	26.04	4.221	185.
C_2H_4	28.05	4.232	205.
C_2H_6	30.07	4.418	230.
C_3H_6	42.08	—	—
C_3H_8	44.09	5.061	254.
n-C_4H_{10}	58.12	—	—
i-C_4H_{10}	58.12	5.341	313.
n-C_5H_{12}	72.15	5.769	345.
n-C_6H_{14}	86.17	5.909	413.
n-C_7H_{16}	100.20	—	—
n-C_8H_{18}	114.22	7.451	320.
n-C_9H_{20}	128.25	—	—
Cyclohexane	84.16	6.093	324.
C_6H_6	78.11	5.270	440.
Other organic compounds:			
CH_4	16.04	3.822	137.
CH_3Cl	50.49	3.375	855.
CH_2Cl_2	84.94	4.759	406.
$CHCl_3$	119.39	5.430	327.
CCl_4	153.84	5.881	327.
C_2N_2	52.04	4.38	339.
COS	60.08	4.13	335.
CS_2	76.14	4.438	488.

Source: (Ref 7)

Table 3. Functions for Prediction of Transport Properties of Gasses at Low Densities[a]

$\kappa T/\epsilon$ or $\kappa T/\epsilon_{AB}$	$\Omega_\mu = \Omega_k$ (For viscosity and thermal conductivity)	$\Omega_{\mathcal{D},AB}$ (For mass diffusivity)	$\kappa T/\epsilon$ or $\kappa T/\epsilon_{AB}$	$\Omega_\mu = \Omega_k$ (For viscosity and thermal conductivity)	$\Omega_{\mathcal{D},AB}$ (For mass diffusivity)
			2.50	1.093	0.9996
0.30	2.785	2.662	2.60	1.081	0.9878
0.35	2.628	2.476	2.70	1.069	0.9770
0.40	2.492	2.318	2.80	1.058	0.9672
0.45	2.368	2.184	2.90	1.048	0.9576
0.50	2.257	2.066	3.00	1.039	0.9490
0.55	2.156	1.966	3.10	1.030	0.9406
0.60	2.065	1.877	3.20	1.022	0.9328
0.65	1.982	1.798	3.30	1.014	0.9256
0.70	1.908	1.729	3.40	1.007	0.9186
0.75	1.841	1.667	3.50	0.9999	0.9120
0.80	1.780	1.612	3.60	0.9932	0.9058
0.85	1.725	1.562	3.70	0.9870	0.8998
0.90	1.675	1.517	3.80	0.9811	0.8942
0.95	1.629	1.476	3.90	0.9755	0.8888
1.00	1.587	1.439	4.00	0.9700	0.8836
1.05	1.549	1.406	4.10	0.9649	0.8788
1.10	1.514	1.375	4.20	0.9600	0.8740
1.15	1.482	1.346	4.30	0.9553	0.8694
1.20	1.452	1.320	4.40	0.9507	0.8652
1.25	1.424	1.296	4.50	0.9464	0.8610
1.30	1.399	1.273	4.60	0.9422	0.8568
1.35	1.375	1.253	4.70	0.9382	0.8530
1.40	1.353	1.233	4.80	0.9343	0.8492
1.45	1.333	1.215	4.90	0.9305	0.8456
1.50	1.314	1.198	5.0	0.9269	0.8422
1.55	1.296	1.182	6.0	0.8963	0.8124
1.60	1.279	1.167	7.0	0.8727	0.7896
1.65	1.264	1.153	8.0	0.8538	0.7712
1.70	1.248	1.140	9.0	0.8379	0.7556
1.75	1.234	1.128	10.0	0.8242	0.7424
1.80	1.221	1.116	20.0	0.7432	0.6640
1.85	1.209	1.105	30.0	0.7005	0.6232
1.90	1.197	1.094	40.0	0.6718	0.5960
1.95	1.186	1.084	50.0	0.6504	0.5756
2.00	1.175	1.075	60.0	0.6335	0.5596
2.10	1.156	1.057	70.0	0.6194	0.5464
2.20	1.138	1.041	80.0	0.6076	0.5352
2.30	1.122	1.026	90.0	0.5973	0.5256
2.40	1.107	1.012	100.0	0.5882	0.5170

[a] Taken from J. O. Hirschfelder, R. B. Bird, and E. L. Spotz, *Chem. Revs.*, 44, 205 (1949).

Table 4 presents the comparative analysis of hydrocarbon vapor emitted by loading gasoline and crude oil. As can be seen, due to the difference in chemical compositions between and crude oil, the gasoline generally exhibits higher transport properties and thus results in a higher evaporation mass diffusivity coefficient (i.e., 1.345 for gasoline versus 0.513 for crude oil). Based on this analysis, the value of $_2$ can be determined as 0.381.

The appropriate arrival HC hydrocarbon concentration, (C), can be calculated based on API gasoline emissions factors as follows:

Vessels	Arrival Conditions	Emission Factors (lb/1000 gal)	Generation Vapor $\frac{P \cdot (G - U)}{(U_i\ U_f)}$,%	Calculated Arrival Vapor (C),%
Ships	Cleaned	1.3	(55-1.5)	1.71 (2.50)
	Uncleaned	2.5	3.64	6.65 (8.00)
			7.5 (0.36-0.27=1.57	
Barges	Cleaned	1.2	(55-12)	3.37
	Uncleaned	3.8	1.57	14.1

The calculated arrival HC vapor concentration for ships using API emission factor seems to be in close agreement with the EXXON reported value (value in parenthesis).

By substituting the appropriate values of C, $_2$, and P, Equation (7) also compares well with the latest available WOGA test data. The WOGA test on September 5, 1976 estimated the overall crude oil emission factor to be 0.62 llb/1000 gallons which falls in the middle of the calculated emission factors. The calculated emission factors using Equation (7) are 0.35 lb/1000 gallons and 0.85 lb/gallons for cleaned and uncleaned ships, respectively.

Table 4. Comparison of Chemical Compositions and Mass Transport Properties Between Gasoline and Crude Oil

Chemical Composition, Volume % of Loading Vapors	Gasoline[a]	Crude Oil[b]
$C_1 + C_2$	0.02	0.12
C_3	0.02	0.15
C_4	2.36	1.33
C_5	1.07	2.05
C_6	0.19	0.63
C_7	0.19	0.32
C_8	0.15	0.03
C_9	---	0.02
C_{10}	---	0.01
C_{11}	---	0.01
Air	96.0	95.35
$\Sigma\, \epsilon/K$	302.1	331.6
$\Sigma\, KT/\epsilon$	1.039	1.055
$\Omega_{D,AB}$	1.42	1.40
$\Omega\mu_{AB}$	1.56	1.54
σA (Air)	3.681	3.681
σB	5.28	5.21
σAB	4.48	4.45
M_B	67	77
μ	6.919×10^{-4}	7.516×10^{-4}
D_{AB}	0.36	0.081
ρ	2.99×10^{-3}	3.43×10^{-3}
$(\mu/\rho D_{AB})^{-0.67}$	1.345	0.513

[a] Shell Oil Company, Ship Valley Forge, test date 10/19/74
[b] Avila Terminal, Lion of California, test data 5/8/76

Source: (Ref 3)

Similarly, the emission from ship ballasting operation can be correlated based on arrival vapor concentrations during loading operations. Since the ballasting potentially dilutes tank arrival concentration by approximately the same percentage as that of ballasting volume, for a ship with 40 percent ballasting volume the emission factor can be calculated by dividing the arrival HC concentration (C) by 0.4.

5. Conclusion

A modified analytical procedure based on API and EXXON gasoline data enables quantitative estimation of hydrocarbon emission factors from crude oil transferring operations under various arrival conditions. The procedure employs correction factors to both arrival and generation components of the hydrocarbon vapors concentration previously derived from gasoline data. An emission reduction factor of 0.38 is derived for crude oil when comparing the evaporation mass diffusivity of crude oil with gasoline. The final hydrocarbon emission factors for crude oil loading operations are summarized in Table 5. As can be seen, the average emission factors from ship loading operations range from 0.55 to 0.58 lb/1000 gallons. Similar hydrocarbon emission factors range from 1.01 to 1.06 lb/1000 gallons for barge crude oil loading operations. The ballasting emission factors are calculated to range from 0.17 to 0.66 lb/1000 gallons.

Table 5. Summary of Maximum and Average Hydrocarbon Emission Factors (lb/1000 gallon) for Crude Oil Transport Operation

Vessels	Arrival Conditions[a]	Maximum Emission Factor[b]		Average Emission Factor[c]	
		Previous Cargo		Previous Cargo	
		Gasoline	Crude Oil	Gasoline	Crude Oil
Ship Loading					
	Cleaned	--	0.33	--	0.30
	Uncleaned	1.90	0.83	1.86	0.79
	Average	--	0.58	--	0.55
Barge Loading					
	Cleaned	--	0.52	--	0.48
	Uncleaned	3.87	1.59	3.83	1.54
	Average	--	1.06	--	1.01
Ship Ballasting					
	Cleaned	--	0.17	--	0.17
	Uncleaned	--	0.66	--	0.66
	Average	--	0.42	--	0.42

---

a Average condition lies between cleaned and uncleaned conditions. The cleaned is defined as the arrival conditions where vessels had been subjected to any cleaning process prior to loading, as well as compartments which had previously contained a nonvolatile hydrocarbon.

b Based on RVP = 5.0 and temperature of 70° F.

c Based on RVP = 4.0 and temperature of 70° F.

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4. American Petroleum Institute, "Evaporation Loss from Tank Cars, Tank Trucks, and Marine Vessels," API Bulletin 2514, November 1959.

5. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors," 2nd edition with supplements, AP-42, Research Triangle Park, N.C., 1973.

6. Mackay, D. and Matsuger, R. S., Canadian Journal of Chemical Engineering 51, 434, 1973.

7. Bird, R. B., et al, Transport Phenomena, John Wiley & Sons, Inc., 1960.

APPENDIX J

LETTERS OF COMMENT

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P. O. BOX 60267
NEW ORLEANS, LOUISIANA 70160

IN REPLY REFER TO
LMNPD-RE

16 November 1977

Mr. Michael E. Carosella
Executive Communications
Room 3309
Federal Energy Administration
Washington, DC 20461

Dear Mr. Carosella:

Your draft environmental impact statement (EIS), with cover letter dated 9 September 1977, concerning the Sulphur Mines salt dome crude oil storage site was referred to this office from our Washington office for review and comments.

We have reviewed the draft EIS in accordance with our areas of responsibility and expertise as outlined in the Council on Environmental Quality guidelines, Title 40, CFR, Part 1500, published in the "Federal Register" dated 1 August 1973; and US Army Corps of Engineers administrative procedures for permit activities in navigable waters or ocean waters, Title 33, CFR, Parts 320-329, published in the "Federal Register" dated 19 July 1977.

We offer the following comments regarding the draft EIS:

a. One of the primary adverse impacts resulting from project implementation is that which would affect the project area's water quality and, consequently, the dependent aquatic organisms. As noted on page 2-15 of the text, there are numerous aquatic systems which would be affected by the proposed project. It is apparent that neither water quality nor planktonic and benthic samples were taken and analyzed from these systems prior to preparation of the draft EIS. Review and inclusion of available literature containing references to the general project area's water quality and aquatic organisms are appropriate to establish a historical setting. However, to adequately assess water quality impacts, current and more site specific information are required.

LMNPD-RE
Mr. Michael E. Carosella 16 November 1977

b. The statement on page 262, paragraph one, is incorrect. The reference cited is dated 1956. A saltwater barrier, located at Calcasieu River between miles 38.6 and 43.5, was constructed in 1968 and has been in operation since that time.

c. The references to rare and endangered species should be changed to threatened or endangered species.

d. The environmental setting section should include a discussion of the vector problems and potentials that exist in the area of project influence. The impact section should provide a discussion as to how the proposed project would affect these vector problems. Construction activities would produce habitat for vectors, especially mosquitoes. Project completion would possibly impede normal surface drainage and also would create temporary and permanent impoundments suitable for vector production.

e. Section 6 should also address the biological resources which would be lost due to filling of marshlands and clearing and/or filling of woodlands required for construction of the storage facility, support buildings, saltwater reservoirs, pipelines, roads, pumps, and other permanent appurtenances.

f. The New Orleans District should be listed with the Galveston District in table 9.2 on page 9-5.

Personnel of the Federal Energy Administration and the Corps of Engineers have been maintaining close liaison concerning the required Corps regulatory permits. Thank you for the opportunity to review and comment on the draft EIS.

Sincerely yours,

for LTC, CE
EARLY J. RUSH III
Colonel, CE
District Engineer

Copy furnished:

Mr. Charles Warren, Chairman
Council on Environmental Quality
Washington, DC 20506

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIRST INTERNATIONAL BUILDING
1201 ELM STREET
DALLAS, TEXAS 75270

November 17, 1977

Mr. Thomas A. Noel
Acting Assistant Secretary
Resource Application
Department of Energy
1725 M Street NW
Washington, D. C. 20461

Dear Mr. Noel:

We have reviewed the Draft Environmental Impact Statement for the proposed storage of crude oil at the Sulphur Mines Salt Dome located in Calcasieu Parish, Louisiana. Sulphur Mines is a candidate site for the Strategic Petroleum Reserve (SPR) program currently being implemented by the Department of Energy (DOE). The proposed Sulphur Mines facility is presently used by Allied Chemical Corporation and would provide oil storage capacity of up to 24 million barrels (MMB) of the SPR requirements in the Texoma/Lake Charles/Beaumont storage region.

The following comments are offered for your consideration in preparing the Final EIS:

1. The statement indicates that past removal of sulfur from the caprock of the salt dome may have formed cavernous voids which could collapse and cause subsidence, resulting in severe damage to surface structures such as pipelines, storage tanks, and holding ponds. We would suggest that coring be obtained from areas of sulfur removal to obtain comprehensive load test data in order to provide information for the design of any proposed surface structure. Applicant's intentions on this matter should be addressed in the Final EIS.

2. The proposed project of emplacing crude oil for storage as a strategic reserve into the Sulphur Mines salt dome would result in large quantities (24 million barrels per cycle; five cycles) of brine displaced. The method of brine disposal presented in the EIS is emplacement of brines into the subsurface by deep well injection. The data presented in the EIS to support this method of disposal is insufficient to allow for an effective evaluation of the environmental impact of such an operation.

EPA Administrator's Decision Statement #5 (Federal Register, Volume 39, No. 69, April 9, 1974) specifies the amount and type of data that a potential injector should provide in order to establish the acceptability of any proposed well injection. The amount and type of data required by EPA are essentially similar to that required under Title 30, Revised Louisiana Statutes, or under the proposed Underground Injection Control Regulations (as per Draft Regulations, August 31, 1976).

Because the State of Louisiana has assumed primary enforcement authority of the Water Supply Program of the Safe Drinking Water Act, and is expected to assume primacy for the Undergound Injection Control (UIC) program, we recommend that the above mentioned data be organized in a format similar to that required for permit application for an underground injection operation, as specified in Statewide Order 29-B of the Louisiana Department of Conservation, Oil and Gas Division. We are requesting that the selected technical data should be provided to the public in the form of a "by request" appendix to the Final EIS. In addition, close coordination should be afforded EPA and the Louisiana Department of Conservation in all phases of data requirements, collection and presentation. DOE's intention to comply with the above recommendation should be adequately addressed in the Final EIS.

3. The alternate method of brine disposal is strongly recommended. This method of disposal, as proposed in the subject document, involves marketing the displaced brine as a chemical feed stock. An industrial consumer has already indicated the acceptability of the brine for its use, and its willingness to purchase the displaced brine through an existing pipeline network. It is strongly urged that the alternate method of brine disposal be adopted for the Sulphur Mines project. The applicant's intentions on this matter should be addressed in the final statement.

4. The draft statement did not adequately address the Spill Prevention Control and Countermeasure (SPCC) Plan as required under Coded Federal Regulations at 40 CFR 112 (Oil Pollution Prevention; Non-Transportation Related Onshore and Offshore Facilities). The Final EIS should state that an SPCC Plan will be prepared within six months after the facility begins operation and shall be fully implemented no later than one year after operation begins and will meet the requirement of 40 CFR 112.

5. The statement indicates sewage treatment and disposal would be through an existing septic tank system operated by Allied Chemical Corporation. The statement should indicate if the Allied facilities will be adequate for the additional domestic waste loads created by the SPR program at Sulphur Mines.

6. The statement indicates that the SPR at Sulphur Mine will necessitate permanent loss of 11.7 acres of existing wetland for pipeline right-of-way and approximately 60 acres of artificially created marshland through dredging and dredged material placements. We would like to point out that the policy of the Environmental Protection Agency, as published in the Federal Register 40 CFR 230 (September 5, 1975) requires that particular cognizance and consideration be given any proposal that has potential to damage or destroy wetlands by dredging activity. The applicant should provide substantive evaluation of all proposed and alternate actions in regard to their potential to adversely impact the wetlands. In conclusion, the selected project action should be shown to be the most practicable of all alternative actions and will provide possible mitigative measures to minimize harm to the wetlands. In the selection of any right-of-way, efforts should be made to avoid wetlands utilization. Adequate response on this matter should be provided in the Final EIS.

7. With the passage of the Clean Air Act Amendments of 1977, several changes were made in emission regulations which may be applicable to the Sulphur Mines Salt Dome project. The section of the EIS addressing Federal Emission Regulations should be revised to reflect these changes with particular regard to prevention of significant deterioration (PSD) and review of emission offset policy applicability to storage tanks. In addition, Table 3.18 no longer represents the new standards for the PSD in a Class II area. New PSD standards include all criteria pollutants (i.e., Sulphur Dioxide (SO_2), Total Suspended Particulates (TSP), Non-Methane Hydrocarbons, (NMHC), Nitrogen Oxide (NO_x), Carbon Monoxide (CO), and Photochemical Oxidants (O_3). These standards should be addressed in the Final EIS.

8. On page 3-66, it is noted that violations of the National Ambient Air Quality Standards (NAAQS) would not occur as a result of the proposed facility. However, on the preceding page, modeling calculations show that indeed the 3-hour standard for non-methane hydrocarbons (NMHC) will be exceeded due to ship loading, unloading, and ballasting operations. This discrepancy should be clarified and possible control measures to prevent these violations should be discussed in the final statement.

9. In the discussion of the interpretative ruling of December 21, 1976, on page 3-53, the name "Emission Trade-Offs" is incorrectly used since it is more commonly referred to as "Emission Offsets." This discrepancy in terminology should be corrected in the final statement.

10. The levels of environmental noise tabulated on page C-3 of the Draft EIS have been labelled as "established guidelines," from EPA. This phrase, "established guidelines," is incorrect. Rather, this table reflects "identified levels" which are requisites to protect public health and welfare with an adequate margin safety for both activity interference and hearing loss. Furthermore, the noise levels cited in this table do not constitute a regulation, specification, or standard. This discrepancy should be corrected in the final statement.

These comments classify your Draft Environmental Impact Statement as ER-2. Specifically, based upon the information contained in the statement, we have environmental reservations concerning the destruction of valuable wetlands and also the cumulative long-term environmental impacts that brine disposal could induce on underground aquifers. In addition, we are requesting more information on air, noise, underground injection, wastewater treatment, and other areas as specifically addressed in the above comments. Our classification and a summary of our comments will be published in the Federal Register in accordance with our responsibility to inform the public of our views on proposed Federal actions, under Section 309 of the Clean Air Act.

Definitions of the categories are provided on the enclosure. Our procedure is to categorize the EIS on both the Environmental consequences of the proposed action and on the adequacy of the impact statement at the draft stage, whenever possible.

We appreciate the oportunity to review the Draft Environmental Impact Statement. Please send us two copies of the Final Environmental Impact Statement at the same time it is sent to the Council on Environmental Quality.

Sincerely,

Adlene Harrison

Adlene Harrison
Regional Administrator

Enclosures

ENVIRONMENTAL IMPACT OF THE ACTION

LO - Lack of Objections

EPA has no objections to the proposed action as described in the draft impact statement; or suggests only minor changes in the proposed action.

ER - Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating Federal agency to re-assess these aspects.

EU - Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

ADEQUACY OF THE IMPACT STATEMENT

Category 1 - Adequate

The draft impact statement adequately sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2 - Insufficient Information

EPA believes the draft impact statement does not contain sufficient information to assess fully the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft statement.

Category 3 - Inadequate

EPA believes that the draft impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement. If a draft statement is assigned a Category 3, no rating will be made of the project or action, since a basis does not generally exist on which to make such a determination.

ant Administrator for Pesticide Programs (36 FR 9038).

Dated: April 3, 1974.

HENRY J. KORP,
Deputy Assistant Administrator for Pesticide Programs.

[FR Doc.74-8016 Filed 4-8-74;8:45 am]

SHELL CHEMICAL CO.

Notice of Filing of Petition for Food Additive

Pursuant to provisions of the Federal Food, Drug, and Cosmetic Act (sec. 409 (b)(5), 72 Stat. 1786; 21 U.S.C. 348(b)(5)), notice is given that a petition (FAP 4H5046) has been filed by the Shell Chemical Co., Suite 300, 1700 K Street, NW., Washington, D.C. 20006, proposing establishment of a food additive regulation (21 CFR Part 121) permitting the safe use of the insecticide 2,2-dichlorovinyl dimethyl phosphate in space, spot and/or crack and crevice treatments of food service, manufacturing, and processing establishments including, but not limited to, restaurants, flour mills, supermarkets, and plants handling dairy products, vegetables, oils, candy, macaroni/spaghetti, soft drinks, cake mixes, and cookies.

Dated: March 29, 1974.

JOHN B. RITCH, Jr.,
Director, Registration Division.

[FR Doc.74-8017 Filed 4-8-74;8:45 am]

SUBSURFACE EMPLACEMENT OF FLUIDS

Administrator's Decision Statement #5

The Environmental Protection Agency, in concert with the objectives of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq.; 86 Stat. 816 et seq.; Pub. L. 92-500) "... to restore and maintain the chemical, physical, and biological integrity of the Nation's water" has established an EPA policy on Subsurface Emplacement of Fluids by Well Injection" which was issued internally as Administrator's Decision Statement No. 5. The purpose of the policy is to establish the Agency's concern with this technique for use in fluid storage and disposal and its position of considering such fluid emplacement only where it is demonstrated to be the most environmentally acceptable available method of handling fluid storage or disposal. Publication of the Policy as information establishes the Agency's position and provides guidance to other Federal Agencies, the States, and other interested parties.

Accompanying the policy statement are "Recommended Data Requirements for Environmental Evaluation of Subsurface Emplacement of Fluids by Well Injection well system; and to insure ments is to provide guidance for potential injectors and regulatory agencies concerning the kinds of information required to evaluate the prospective injections well system; and to insure protection of the environment. The Recommended Data Requirements require sufficient information to evaluate complex injection operations for hazardous materials, but may be modified in scope by a regulatory agency for other types of injection operations.

The EPA recognizes that for certain industries and in certain locations the disposal of wastes and the storage of fluids in the subsurface by use of well injection may be the most environmentally acceptable practice available. However, adherence to the policy requires the potential injector to clearly demonstrate acceptability by the provision of technical analyses and data justifying the proposal. Such demonstration requires conventional engineering and other analyses which indicate beyond a reasonable doubt the efficacy of the proposed injection well operation.

Several issues within the policy should be highlighted and explained to avoid confusion. One of the goals of the policy is to protect the integrity of the subsurface environment. In the context of the policy statement, integrity means the prevention of unplanned fracturing or other physical impairment of the geologic formations and the avoidance of undesirable changes in aquifers, mineral deposits or other resources. It is recognized that fluid emplacement by well injection may cause some change in the environment and, to some extent, may preempt other uses.

Emplacement is intended to include both disposal and storage. The difference between the two terms is that storage implies the existence of a plan for recovery of the material within a reasonable time whereas disposal implies that no recovery of the material is planned at a given site. Either operation would require essentially the same type of information prior to injection. However, the attitude of the appropriate regulatory agency toward evaluation of the proposals would be different for each type operation. The EPA policy recognizes the need for injection wells in certain oil and mineral extraction and fluid storage operations but requires sufficient environmental safeguards to protect other uses of the subsurface, both during the actual injection operation and after the injection has ceased.

The policy considers waste disposal by well injection to be a temporary means of disposal in the sense that it is approved only for the life of an issued permit. Should more environmentally acceptable disposal technology become available, a change to such technology would be required. The term "temporary" is not intended to imply subsequent recovery of injected waste for processing by another technology.

Paragraph 5 of the policy and program guidance provides that EPA will apply the policy to the extent of its authorities in conducting all EPA program activities. The applicability of the policy to participation by the several States in the NPDES permit program under section 402 of the Federal Water Pollution Control Act as amended has been established previously by § 124.80(d) of Part 124 entitled "State Program Elements Necessary for Participation in the National Pollutant Discharge Elimination System," 37 FR 28390 (December 22, 1972). These guidelines provide that each EPA Regional Administrator must distribute the policy to the Director of a State water discharge permit issuing agency, and must utilize the policy in his own review of any permits for disposal of pollutants into wells that are proposed to be issued by States participating in the NPDES.

Dated: April 2, 1974.

JOHN QUARLES,
Acting Administrator.

ADMINISTRATOR'S DECISION STATEMENT NO. 5

EPA POLICY ON SUBSURFACE EMPLACEMENT OF FLUIDS BY WELL INJECTION

This ADS records the EPA's position on injection wells and subsurface emplacement of fluids by well injection, and supersedes the Federal Water Quality Administration's order COM 5010.10 of October 15, 1970.

Goals. The EPA Policy on Subsurface Emplacement of Fluids by Well Injection is designed to:

(1) Protect the subsurface from pollution or other environmental hazards attributable to improper injection or ill-sited injection wells.

(2) Ensure that engineering and geological safeguards adequate to protect the integrity of the subsurface environment are adhered to in the preliminary investigation, design, construction, operation, monitoring and abandonment phases of injection well projects.

(3) Encourage development of alternative means of disposal which afford greater environmental protection.

Principal findings and policy rationale. The available evidence concerning injection wells and subsurface emplacement of fluids indicates that:

(1) The emplacement of fluids by subsurface injection often is considered by government and private agencies as an attractive mechanism for final disposal or storage owing to: (a) the diminishing capabilities of surface waters to receive effluents without violation of quality standards, and (b) the apparent lower costs of this method of disposal or storage over conventional and advanced waste management techniques. Subsurface storage capacity is a natural resource of considerable value and like any other natural resource its use must be conserved for maximal benefits to all people.

(2) Improper injection of municipal or industrial wastes or injection of other fluids for storage or disposal to the subsurface environment could result in serious pollution of water supplies or other environmental hazards.

(3) The effects of subsurface injection and the fate of injected materials are uncertain with today's knowledge and could result in serious pollution or environmental damage requiring complex and costly solutions on a long-term basis.

Policy and program guidance. To ensure accomplishment of the subsurface protection goals established above it is the policy of the Environmental Protection Agency that:

(1) The EPA will oppose emplacement of materials by subsurface injection without strict controls and a clear demonstration that such emplacement will not interfere with present or potential use of the subsurface environment, contaminate ground water resources or otherwise damage the environment.

(2) All proposals for subsurface injection should be critically evaluated to determine that:

(a) All reasonable alternative measures have been explored and found less satisfactory in terms of environmental protection;

(b) Adequate preinjection tests have been made for predicting the fate of materials injected;

(c) There is conclusive technical evidence to demonstrate that such injection will not interfere with present or potential use of water resources nor result in other environmental hazards;

(d) The subsurface injection system has been designed and constructed to provide maximal environmental protection;

(e) Provisions have been made for monitoring both the injection operation and the resulting effects on the environment;

(f) Contingency plans that will obviate any environmental degradation have been prepared to cope with all well shut-ins or any well failures;

(g) Provision will be made for supervised plugging of injection wells when abandoned and for monitoring to ensure continuing environmental protection.

(3) Where subsurface injection is practiced for waste disposal, it will be recognized as a temporary means of disposal until new technology becomes available enabling more assured environmental protection.

(4) Where subsurface injection is practiced for underground storage or for recycling of natural fluids, it will be recognized that such practice will cease or be modified when a hazard to natural resources or the environment appears imminent.

(5) The EPA will apply this policy to the extent of its authorities in conducting all program activities, including regulatory activities, research and development, technical assistance to the States, and the administration of the construction grants, state program grants, and basin planning grants programs and control of pollution at Federal facilities in accordance with Executive Order 11752.

WILLIAM D. RUCKELSHAUS,
Administrator.

FEBRUARY 6, 1973.

RECOMMENDED DATA REQUIREMENTS FOR ENVIRONMENTAL EVALUATION OF SUBSURFACE EMPLACEMENT OF FLUIDS BY WELL INJECTION

The Administrator's Decision Statement No. 5 on subsurface employment of fluids by well injection has been prepared to establish the Agency's position on the use of this disposal and storage technique. To aid in implementation of the policy a recommended data base for environmental evaluation has been developed.

The following parameters describe the information which should be provided by the injector and are designed to provide regulatory agencies sufficient information to evaluate the environmental acceptability of any proposed well injection. A potential injector should initially contact the regulatory authority to determine the preliminary investigative and data requirements for a particular injection well as these may vary for different kinds of injection operations. The appropriate regulatory authority will specify the exact data requirements on a case by case basis.

(a) An accurate plat showing location and surface elevation of proposed injection well site, surface features, property boundaries, and surface and mineral ownership at an approved scale.

(b) Maps indicating location of water wells and all other wells, mines or artificial penetrations, including but not limited to oil and gas wells and exploratory or test wells, showing depths, elevations and the deepest formation penetrated within twice the calculated zone of influence of the proposed project. Plugging and abandonment records for all oil and gas tests, and water wells should accompany the map.

(c) Maps indicating vertical and lateral limits of potable water supplies which would include both short- and long-term variations in surface water supplies and subsurface aquifers containing water with less than 10,000 mg/l total dissolved solids. Available amounts and present and potential uses of these waters, as well as projections of public water supply requirements must be considered.

(d) Descriptions of mineral resources present or believed to be present in area of project and the effect of this project on present or potential mineral resources in the area.

(e) Maps and cross sections at approved scales illustrating detailed geologic structure and a stratigraphic section (including formations, lithology, and physical characteristics) for the local area, and generalized maps and cross sections illustrating the regional geologic setting of the project.

(f) Description of chemical, physical, and biological properties and characteristics of the fluids to be injected.

(g) Potentiometric maps at approved scales and isopleth intervals of the proposed injection horizon and of those aquifers immediately above and below the injection horizon, with copies of all drill-stem test charts, extrapolations, and data used in compiling such maps.

(h) Description of the location and nature of present or potentially useable minerals from the zone of influence.

(i) Volume, rate, and injection pressure of the fluid.

(j) The following geological and physical characteristics of the injection interval and the overlying and underlying confining beds should be determined and submitted:

(1) Thickness;
(2) areal extent;
(3) lithology;
(4) grain mineralogy;
(5) type and mineralogy of matrix;
(6) clay content;
(7) clay mineralogy;
(8) effective porosity (including an explanation of how determined);
(9) permeability (including an explanation of how determined);
(10) coefficient of aquifer storage;
(11) amount and extent of natural fracturing;
(12) location, extent, and effects of known or suspected faulting indicating whether faults are sealed, or fractured avenues for fluid movement;
(13) extent and effects of natural solution channels;
(14) degree of fluid saturation;
(15) formation fluid chemistry (including local and regional variations);
(16) temperature of formation (including an explanation of how determined);
(17) formation and fluid pressure (including original and modifications resulting from fluid withdrawal or injection);
(18) fracturing gradients;
(19) diffusion and dispersion characteristics of the waste and the formation fluid including effect of gravity segregation;
(20) compatibility of injected waste with the physical, chemical and biological characteristics of the reservoir; and
(21) injectivity profiles.

(k) The following engineering data should be supplied:

(1) Diameter of hole and total depth of well;
(2) type, size, weight, and strength, of all surface, intermediate, and injection casing strings;
(3) specifications and proposed installation of tubing and packers;
(4) proposed cementing procedures and type of cement;
(5) proposed coring program;
(6) proposed formation testing program;
(7) proposed logging program;
(8) proposed artificial fracturing or stimulation program;
(9) proposed injection procedure;
(10) plans of the surface and subsurface construction details of the system including engineering drawings and specifications of the system (including but not limited to pumps, well head construction, and casing depth);
(11) plans for monitoring including a multipoint fluid pressure monitoring system constructed to monitor pressures above as well as within the injection zones; description of annular fluid; and plans for maintaining a complete operational history of the well;
(12) expected changes in pressure, rate of native fluid displacement by injected fluid, directions of dispersion and zone affected by the project;
(13) contingency plans to cope with all shut-ins or well failures in a manner that will obviate any environmental degradation.

(l) Preparation of a report thoroughly investigating the effects of the proposed subsurface injection well should be a prerequisite for evaluation of a project. Such a statement should include a thorough assessment of: (1) the alternative disposal schemes in terms of maximum environmental protection; (2) projection of fluid pressure response with time both in the injection zones and overlying formations, with particular attention to aquifers which may be used for fresh water supplies in the future; and (3) problems associated with possible chemical interactions between injected wastes, formation fluids, and mineralogical constituents.

[FR Doc.74-8021 Filed 4-8-74;8:45 am]

FEDERAL MARITIME COMMISSION

AMERICAN WEST AFRICAN FREIGHT CONFERENCE

Notice of Petition Filed

Notice is hereby given that the following petition has been filed with the Commission for approval pursuant to section 14b of the Shipping Act, 1916, as amended (75 Stat. 762, 46 U.S.C. 813a).

Interested parties may inspect a copy of the current contract form and of the petition, reflecting the changes proposed to be made in the language of said contract, at the Washington office of the Federal Maritime Commission, 1100 L Street NW., Room 1012d or at the Field Offices located at New York, N.Y., New Orleans, Louisiana, San Francisco, California, and Old San Juan, Puerto Rico. Comments with reference to the proposed changes and the petition, including a request for hearing, if desired, may be submitted to the Secretary, Federal Maritime Commission, 1100 L Street NW., Washington, D.C. 20573, on or before April 19, 1974. Any person desiring a hearing on the proposed modification of the contract form and/or the approved contract system shall provide a clear and concise statement of the matters upon which they desire to adduce evidence.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER-77/875

NOV 11 1977

Mr. Michael E. Carosella
Associate Assistant Administrator
Federal Energy Administration
Washington, D.C. 20401

Dear Mr. Carosella:

This is in response to your letter of September 9, 1977, requesting review of the draft environmental statement for Sulphur Mines Salt Dome as a candidate site in the Strategic Petroleum Reserve.

GENERAL COMMENT

In regard to biological information, the draft statement relies too heavily on published literature and communications with knowledgeable personnel instead of providing site-specific data on the flora and fauna of the project area collected through field investigations.

SPECIFIC COMMENTS

Pages 1-5 and 1-7: In paragraphs 1.2.1 and 1.2.4, respectively, there is mention of both current brine production and the potential for development of perhaps five additional solution cavities in the future. The draft does not mention existence of an evaporation and salt processing plant in the vicinity, or plans for operation of such facilities for processing brine into commercial products. Such brine processing facilities come under the jurisdiction of the Mine Enforcement and Safety Administration, so that any occupational risks because of subsidence, air quality, or hydrocarbon spillage need to be addressed, if these facilities exist or are brought into existence in the future.

Page 2-11: Under Sulphur Production it is mentioned that there have been "occasional attempts to resume sulphur production at Sulphur Mines dome." No sulphur production is currently underway, but there is implication in the draft that mineable amounts of sulphur remain in the cap rock. We point out that should it be possible that additional sulphur mining might be permitted in the cap rock, further subsidence would be likely which could impact on any future processing facility yielding salt products. Additionally, we point out that sulphur processing installations, and in particular ones that yield graded products, may come under Mine Enforcement and Safety Administration jurisdiction for occupational health and safety.

Pages 2-15 through 2-26, section 2.2.1: The acknowledged lack of site-specific water-quality data should be remedied through collection of additional information. This section would be improved by the deletion of the discussion of habitats and associated organisms that will not be affected by the proposed project or the various alternatives. A more detailed discussion of the fauna of the project site and alternative sites should be included in this section.

Page 2-16: Local ponds and reservoirs are recognized as being in the immediate vicinity of the Sulphur Mines site. The recreation potential of these bodies should be addressed. According to the Statewide Comprehensive Outdoor Recreation Plan (SCORP), the region has a need for freshwater fishing and other water-oriented recreation.

Page 2-95, section 2.6.1: The draft statement is inadequate in its consideration of archeological resources. Undisturbed land in the project area should be inspected by a professional archeologist to determine the presence or absence of archeological resources. This would include the proposed 14-mile pipeline and 1.7-mile water-supply line. The final statement should indicate that such a survey was made, and should cite the name and institution of the investigator. If no archeological sites were evident, it should be so stated. If sites were recorded, there should be information regarding the nature and significance of the sites and the effect of the project on such sites. If the project will adversely affect significant archeological resources, there should be a plan of action cited to mitigate this effect. If any archeological resources are encountered during construction, operations should cease at the discovery site and a professional archeologist should be consulted as to the significance of the material.

The final statement should also include evidence of contact with the State Historic Preservation Officer, Mrs. Sandra S. Thompson, Secretary, Department of Culture, Recreation and Tourism, P.O. Box 44361, Baton Rouge, Louisiana 70804, and include her comments relative to the impact of the project, if any, upon properties on or eligible for inclusion in the National Register of Historic Places.

Page 2-95, section 2.6.2: It is stated that Ward Eight Park, Interstate 210 Park, and Prien Lake Park could conceivably be impacted by tanker oil spills. Table 4.1 (p. 4-2 through 4-8) should include mitigation measures and unavoidable impacts of tanker oil spills in the Intracoastal Waterway, Calcasieu River, and Prien Lake. Because of the smaller size of these water bodies and the proximity of these parks to them, the mitigation procedures listed in table 4.1 may not always be sufficient for the spill of 3,100 barrels anticipated in the table. Mitigation measures to counter oil spills should be addressed so as to avoid damage to park sites.

Page 2-96: Mention is made of the impact of possible oil spills on tidal marshes. The SCORP considers the area worthy of a possible wilderness designation as a coastal marsh. We are also concerned about the impacts to marshlands resulting from disposal of dredge material. Page 3-11 indicates that 60 acres of grass and marshland will be lost because of disposal of dredge spoil from Salt Water Lake, and page 3-12 mentions similar effects on areas totaling 11.7 acres due to dredging for the oil pipeline. Executive Order 11990, issued by President Carter on May 24, 1977, directs Federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands. In view of this Executive Order, we recommend that FEA utilize the alternate spoil site discussed on page 1-15 for dredge material from Salt Water Lake, and attempt to locate suitable alternate sites for dredge spoil from the oil pipeline which would avoid the destruction of wetlands.

Pages 3-9 and 3-10: The pre-operational testing program mentions the importance of determining the proximity of caverns to one another and to the salt-dome boundary. A footnote (p. 3-10) indicates that the test information will be used to determine during which withdrawal cycle the caverns are likely to collapse. The text should more adequately outline the potential impacts on ground water resulting from the removal of the materials between the cavern and the salt-dome margin and should suggest any possible mitigation of effects.

Pages 3-24 and 3-25, section 3.2.2.1: This section should contain an assessment of the effects, if any, that water withdrawal from the Sabine River Diversion Canal will have on salinities in downstream estuarine waters.

Pages 3-25 through 3-30, section 3.2.2.2: The brine displacement rate (4,900 gallons per minute) will apparently exceed the combined injection-well capacity (4,000 gallons per minute). The fate of the excess brine, if any, should be discussed along with anticipated environmental impacts.

The section on surface-water contamination should include a discussion of the potential effects on plants and animals of surface leakage of brine through poorly plugged old wells or well blowouts.

Page 3-30: We believe that the point should be raised concerning the need of adequate control during brine injection because high pressure in the aquifer could be detrimental to existing oil production and future exploration in this zone. Oil is currently being produced from horizons having the same depth as the intended brine-injection aquifer, and care should be taken to prevent brine from entering the oil-producing zones.

Page 3-31 and 3-32: It is stated that the proposed subsurface brine-disposal reservoirs may have been raised to near the surface during the emplacement of the salt dome. Thus, escape of saturated brine could result at the surface or into freshwater aquifers. The statement should utilize existing well logs or geophysical data to demonstrate the distribution of the saline aquifers or should propose specific methods of demonstrating their attitude before the disposal facilities are constructed.

Pages 3-72 through 3-75, section 3.4.2: Quantitative data on fishes and plankton should be collected in the Sabine River Diversion Canal to support, if possible, the claim that withdrawals from the canal will have relatively little impact on aquatic life.

Page 3-80, section 3.4.5: The red-cockaded woodpecker has been documented as occurring in Calcasieu Parish. The statement should be supplemented to indicate whether surveys of the work area have been conducted to determine its presence or absence. If surveys have not been conducted, they should be initiated soon and the results included in the final statement. In addition, formal consultation with the Fish and Wildlife Service should be initiated if these surveys determine the presence of the red-cockaded woodpecker in or immediately adjacent to the project area, in accordance with Section 7 of the Endangered Species Act of 1973.

Page 3-93, section 3.7.1: A discussion of oil and brine spills experienced at the existing West Hackberry Salt Dome Strategic Petroleum Reserve facility should be added to this section.

Page 3-137, section 3.7.3: Cleanup operations in marshes might involve controlled burning instead of mechanical removal of vegetation. The former method will allow revegetation in a short time, while the latter method will have much more long-term adverse effects.

Page 4-1, section 4: A statement should be included indicating the degree of commitment to implementation of each of the mitigating measures listed in table 4.1.

Pages 7-38 through 7-42: The draft statement considers in detail the areally important Chicot freshwater aquifer as a potential source of displacement water but does not adequately evaluate the use of slightly salty or brackish ground water from the Evangeline aquifer--although it does mention that the use of the water from the evangeline aquifer would minimize the potential for contaminating the Chicot aquifer. Inasmuch as the water of the upper part of the Evangeline has a salinity of only 3 to 10 ppt. (p. 2-31 through 2-34), the statement should more adequately evaluate the salinity and aquifer characteristics of the Evangeline--using geophysical logs if other data are not available.

We hope these comments will be of assistance to you.

Sincerely,

Larry E. Meierotto

Deputy Assistant SECRETARY

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20201

00002

OCT 27 1977

Executive Communications
Room 3300
Federal Energy Administration
Washington, D.C. 20461

Dear Sirs:

Thank you for the opportunity to review the draft Environmental Impact Statement on the Sulphur Mines Salt Dome.

We are concerned about impacts on the quality of the local water supply which may occur either during construction or operation of the proposed oil reserves and the associated pipelines.

Care must be taken to minimize the suspension of toxic compounds which may occur from erosion of dredged materials during dredging operations. There is also a potential of aquifer contamination during the deep well injection of brine. A program should be established to monitor these pollutants in affected waters.

Sincerely,

Charles Custard
Director
Office of Environmental Affairs

Advisory Council on
Historic Preservation
1522 K Street N.W.
Washington, D.C. 20005

September 30, 1977

Mr. Michael E. Carosella
Associate Assistant Administrator
Special Programs
Federal Energy Administration
Washington, D.C. 20461

Dear Mr. Carosella:

Thank you for your request of September 9, 1977, for comments on the draft environmental statement (DES) for the Sulphur Mine Salt Dome, Calcasieu Parish, Louisiana. Pursuant to Section 102(2)(C) of the National Environmental Policy Act of 1969 and the Council's "Procedures for the Protection of Historic and Cultural Properties" (36 C.F.R. Part 800), we have determined that your DES does not contain sufficient information concerning historic and cultural resources for review purposes. Please furnish the following data indicating:

Compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470f, as amended, 90 Stat. 1320).

The environmental statement must demonstrate that either of the following conditions exists:

1. No properties included in or that may be eligible for inclusion in the National Register of Historic Places are located within the area of environmental impact, and the undertaking will not affect any such property. In making this determination, the Council requires:

--evidence that you have consulted the latest edition of the National Register (Federal Register, February 1, 1977, and its monthly supplements);

--evidence of an effort to ensure the identification of properties eligible for inclusion in the National Register, including evidence of contact with the State Historic Preservation Officer, whose comments should be included in the final environmental statement. The State Historic Preservation Officer for Louisiana is Ms. Sandra Thompson, Old State Capitol, North Boulevard, Baton Rouge, Louisiana 70801.

2. Properties included in or that may be eligible for inclusion in the National Register are located within the area of environmental impact, and the undertaking will or will not affect any such property. In cases where there will be an effect, the final environmental impact statement should contain evidence of compliance with Section 106 of the National Historic Preservation Act through the Council's "Procedures for the Protection of Historic and Cultural Properties" (36 C.F.R. Part 800).

Should you have any questions, please call Michael H. Bureman at (303 234-4946.

Sincerely yours,

Louis S. Wall
Assistant Director, Office of
Review and Compliance

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

NOV 11 1977

Mr. Michael E. Carosella
Associate Assistant Administrator
Special Programs
Federal Energy Administration
Washington, D. C. 20461

Dear Mr. Carosella:

This is in response to your letter of September 12, 1977 inviting our comments on the Draft Environmental Impact Statement concerning the proposed use of the Texoma Group of salt domes for storing petroleum as part of the implementation of the Strategic Petroleum Reserve Program.

We have reviewed the statement and determined that the proposed action has no radiological health and safety impacts. However, there may be a conflict between the use of salt mines for storing petroleum and their use for storing radioactive waste. A consideration of this possible conflict in the final statement would be useful.

No other activities subject to regulation by the Nuclear Regulatory Commission have been found to be adversely affected by the proposed action. Accordingly we have no further comments or suggestions to offer.

Thank you for providing us with the opportunity to review this Draft Environmental Impact Statement.

Sincerely,

Voss A. Moore

Voss A. Moore, Assistant Director
for Environmental Projects
Division of Site Safety and
Environmental Analysis

cc: CEQ (5 copies)

ı EXAS DEPARTMENT OF AGRICULTURE
REAGAN V. BROWN, COMMISSIONER / P. O. BOX 12847 / AUSTIN, TEXAS 78711
AN EQUAL OPPORTUNITY EMPLOYER

MEMORANDUM

RECEIVED

OCT 24 1977

Budget/Planning

DATE: October 21, 1977

TO: Ward C. Goessling, Jr.

FROM: Ray Prewett RP

RE: Draft Environmental Impact Statement: Strategic Petroleum Reserve: Sulphur Mines Salt Dome

We have reviewed the Draft Environmental Impact Statement: Strategic Petroleum Reserve: Sulphur Mines Salt Dome.

We do not identify any problems with this DEIS as far as our agency is concerned.

General Land Office
AUSTIN, TEXAS 78701
BOB ARMSTRONG, COMMISSIONER

PLANNING PROGRAM
1700 North Congress Ave.
Austin, Texas 78701
(512) 475-1539

RECEIVED

OCT 20 1977

October 19, 1977 Budget/Planning

Office of the Governor
Budget and Planning Office
411 West 13th Street
Austin, Texas 78701

RE: DRAFT ENVIRONMENTAL IMPACT STATEMENT: STRATEGIC PETROLEUM RESERVE: SULPHUR MINES SALT DOME

The Environmental Impact Statement: STRATEGIC PETROLEUM RESERVE: SULPHUR MINES SLAT DOME has no great impact on the General Land Office since the dome is located in Calcasieu Parish, Louisiana.

We appreciate the opportunity to submit our comments.

Ruth Kent
Coordinator

RK/mlr

COMMISSION
[illegible]N HOUSTON CHAIRMAN
T C GREER
[illegible]ES E SIMONS

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
AUSTIN, TEXAS 78701

ENGINEER-DIRECTOR
B L DEBERRY

RECEIVED
OCT 20 1977
Budget/Planning

October 19, 1977

IN REPLY REFER TO
FILE NO

D8-E 454

Draft Environmental Statement
Federal Energy Administration
Strategic Petroleum Reserve

Sulphur Mines Salt Dome

Mr. Ward C. Goessling, Jr., Coordinator
Natural Resources Section
Governor's Budget and Planning Office
411 West 13th Street
Austin, Texas 78701

Dear Sir:

Reference is made to your memorandum dated September 22, 1977 transmitting the above captioned draft environmental statement for review and comments.

The Department does not have any comments to offer.

Sincerely yours,

B. L. DeBerry
Engineer-Director

By: Earle McCullough
FOR R. L. Lewis, Chief Engineer
of Highway Design

~~STRIAL COMMISSION

714 Sam Houston State Office Building 512-475-4331 Box 12728, Capitol Station, Austin, Texas 78711 Telex No. 776-488

RECEIVED
SEP 29 1977
Budget/Planning

MEMORANDUM

TO: Ward C. Goessling, Jr., Coordinator
Natural Resources Section
Budget and Planning Office

FROM: Phyllis Procter, Manager
Research & Program Development Department

SUBJECT: Draft Environmental Impact Statement: Strategic Petroleum Reserve: Sulphur Mines Salt Dome

DATE: September 23, 1977

We have no negative comment on the above cited draft statement.

We feel that the Strategic Petroleum Reserve is of national importance, and by all means should be implemented as soon as possible.

abb5/6

TEXAS
ARKS AND WILDLIFE DEPARTMENT

HENRY B. BURKETT
EXECUTIVE DIRECTOR

4200 Smith School Road
Austin, Texas 78744

RECEIVED
OCT 3 1977
Budget/Planning

September 28, 1977

Mr. Ward C. Goessling, Jr., Coordinator
Governor's Budget and Planning Office
Executive Office Building
411 West 13th Street
Austin, Texas 78701

Re: Draft Environmental Impact Statement; Strategic Petroleum Reserve - Sulphur Mines Salt Dome

Dear Mr. Goessling:

Our review of the draft cited above indicates that the project impacts will occur in the State of Louisiana. Therefore, we have no comment to offer on this document.

The opportunity to review and comment upon the proposed activity is appreciated.

Sincerely,

HENRY B. BURKETT
Executive Director

HBB:BDK:jg3/24

TEXAS DEPARTMENT OF WATER RESOURCES
1700 N. Congress Avenue
Austin, Texas

October 18, 1977

Mr. Charles D. Travis, Director
Governor's Budget & Planning Office
411 West 13th Street
Austin, Texas 78701

Re: Federal Energy Administration -- Draft Environmental Statement (DEIS) -- Strategic Petroleum Reserve (Sulphur Mines Salt Dome, Calcasieu Parish, Louisiana), DES-77-6, September 1977.

Dear Mr. Travis :

In response to your September 22 memorandum, the Texas Department of Water Resources staff has reviewed the referenced DEIS on the proposed storage of 24 million barrels of crude oil at the Sulphur Mines salt dome located in Calcasieu Parish, Louisiana -- a candidate site for the Strategic Petroleum Reserve program now being implemented by the Federal Energy Administration pursuant to Title I, Part B of the Energy Policy and Conservation Act of 1975 (P. L. 94-163).

The following technical staff review comments are offered:

1. The oil storage project site and related leach water and brine disposal facilities are located in the State of Louisiana and would not have any adverse environmental impacts on the ground or surface water resources of the State of Texas.

2. The technical assessment of potential local impacts relative to land subsidence, ground contamination, oil spillage, and brine disposal is objective. Particularly, we support the technical assessment of the potential hazards discussed in the three memo-

randa from Mr. Charles G. Smith, Consulting Geologist, Baton Rouge, Louisiana, presented on pages D-40, through D-41 of the referenced DEIS.

We appreciated the opportunity to review the referenced document. Please notify me if you believe that we can be of further help.

Sincerely,

Charles E. Nemir
Acting Executive Director

Available from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed Copy: $ 15.00
Microfiche: $ 15.00