Strategic Petroleum Reserve

Supplement
Final Environmental
Impact Statement
West Hackberry
Salt Dome

FEA 76/77-4

April 1977

Federal Energy Administration

Strategic Petroleum Reserve Office

FEA/S-77/114

SUMMARY

STATEMENT TYPE: ( ) Draft ( ) Final Environmental Statement

(X) Supplement to a Final Environmental Statement

PREPARED BY: The Strategic Petroleum Reserve Office, Federal Energy Administration, Washington, D. C. 20461

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

2. Brief Description of the Proposed Action:

On January 14, 1977, the Federal Energy Administration issued a Final Environmental Impact Statement (EIS) for the development of the West Hackberry salt dome as a storage site for the Strategic Petroleum Reserve (FES 76/77-4). The salt dome is located in Cameron Parish, Louisiana. The original oil distribution system proposed in the EIS consisted of two parts. The first would provide for interim fill via a new barge dock on the southwest branch of the Alkali Ditch. The second would be a permanent system consisting of a new tanker terminal on the Calcasieu Ship Channel and a connecting pipeline to the site. Since the EIS was published, the availability of the Sun Terminal in Nederland, Texas, and the Amoco Barge Dock on the southeast branch of the Alkali Ditch has prompted a re-evaluation of the oil distribution system. The system assessed in this supplement to FES 76/77-4 involves construction of a temporary surface pipeline from the site to the Amoco dock and use of the dock for interim fill, and construction of a permanent buried pipeline from the site to the Sun Terminal. In addition, the construction and use of a temporary surface brine disposal pipeline is addressed. This pipeline would be used only for interim fill until the permanent buried brine disposal pipeline proposed in FES 76/77-4 is constructed.

3. Summary of Environmental Impacts and Adverse Environmental Effects

This supplement assesses the environmental impacts caused by the construction and operation of the new components of the system. The differences between the new and the original proposals can be analyzed in terms of five (5) system components: (1) the barge dock; (2) the pipeline to the barge dock; (3) the tanker terminal; (4) the pipeline to the tanker terminal; and (5) pipeline to the brine disposal wells. The dredging associated with construction of the originally proposed new barge dock would have adverse impacts on geology and soils, land use, water quality and ecology. The new proposal is to use an existing dock thus eliminating the need for dredging. In the original proposal the new barge dock was to be located on the site, and an oil pipeline consequently was not required. In the new proposal, a 1.25 mile pipeline is to constructed. This would cause temporary disruption to land use, water quality, air quality and the terrestrial ecology. For the operation phase eight (8) acres would be maintained as a pipeline. In the new proposal, a 1.25 mile pipeline is to be constructed. This would cause temporary disruption to land use, water quality air quality and the terrestrial ecology. For the operation phase eight (8) acres would be maintained as a pipeline. The dredging associated with the originally proposed new tanker terminal on the Calcasieu Ship Channel would have an impact on geology and soils, land use, water quality and ecology. The new proposal would use the existing Sun Terminal and thus no such impacts would result. The original pipeline to the tanker terminal was to be four (4) miles long. Construction would cause short-term and minor disruption to geology and soils, land use, water quality, air quality and ecology. The new proposal calls for a 41.5 mile pipeline which would also cause similar temporary disruption over a larger, more ecologically sensitive area. Construction of a temporary surface brine disposal pipeline for interim fill will cause temporary disruption to land use, water quality, air quality and the terrestrial ecology.

4. Alternatives Considered:

Interim fill - New Barge Dock

Permanent system

Terminals

- Lone Star (conversion)
- Calcasieu Ship Channel (new)

Alternative pipeline route

5. Comments on the Supplement have been requested from the following:

Federal Agencies

Dept. of Agriculture
Dept. of the Army
Dept. of Commerce
Dept. of Defense
Dept. of Helath, Education & Welfare
Dept. of Housing and Urban Development
Dept. of the Interior
Dept. of Labor
Dept. of State
Dept. of Transportation
Dept. of the Treasury
Advisory Council on Historic Preservation
Appalachian Regional Commission
Council on Environmental Quality
Energy Research and Development Administration

Federal Energy Administration
(10 Regional Offices)
Federal Power Commission
Interstate Commerce Commission
National Science Foundation
Nuclear Regulatory Commission
Tennessee Valley Authority
Water Resources Council
U. S. Fish & Wildlife Service
National Marine Fisheries Service

State Agencies

Louisiana State Clearinghouse
Texas State Clearinghouse

Individuals and Organizations

American Petroleum Institute
Center for Law & Social Policy
Electric Power Research Institute
Environmental Defense Fund
Environmental Policy Center
Friends of the Earth
Fund for Animals
Institute for Gas Technology
Interstate Natural Gas Association of America
Izaak Walton League of America
Energy Conservation Committee
National Association of Counties
National Audubon Society
National Parks & Conservation Association
National Resource Defense Council
National Wildlife Federation
Office of Energy Analysis-New York State
U. S. Conference of Mayors

Edison Electric Institute
Louisiana Offshore Terminal Authority
New Orleans Audubon Society
South Central Planning and Development Commission
Kaiser Engineers
Florida Audubon Society
Louisiana Wildlife Federation
Acadiana Planning & Development District
Cameron Parish Police Jury
Environmental Resources & Energy Group
Olin Chemicals

Sierra Club - Gulf Coast Regional
  Conservation Committee
LOOP, inc.
Seadock, Inc.
Ecology Center of Louisiana, Inc.
Gulf States Marine Fisheries Commission
American Fisheries Society
American Littoral Society
Baton Rouge Audubon Society
Council on the Environment
The States - Item
Calcasieu Rod & Gun Club
Sierra Club - Delta Chapter
Sierra Club - New Orleans Group
League of Women Voters
Louisiana Power and Light
The Times - Picayune
The Courier
Louisiana Dept. of Justice
Canoe & Trail Shop, Inc.
RESTORE, Inc.

6. Date made available to CEQ and the Public:

The Final Environmental Impact Statement was made available to the Council on Environmental Quality and to the public on January 14, 1977. This supplement was made available on April 22, 1977.

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1. DESCRIPTION OF PROJECT

1.1 BACKGROUND

This document is a supplement to the final environmental impact statement (EIS) for an underground crude oil storage facility at the West Hackberry salt dome (FES 76/77-4) located in Cameron Parish, Louisiana. The storage facility at the West Hackberry salt dome is part of the Strategic Petroleum Reserve (SPR) program currently being planned by the Federal Energy Administration (FEA). 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). The Act further requires the creation within three years of an Early Storage Reserve (ESR) of 150 million barrels as the initial phase of the SPR to provide early protection from near-term disruptions in the supply of petroleum products.

A final programmatic environmental impact statement (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 16, 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 draft 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 West Hackberry final EIS (FES 76/77-4) was made available to the Council on Environmental Quality and the Public on January 7, 1977. That document reflects the design of the facility at the time of publication. That design included construction of a new tanker terminal on the Calcasieu Ship Channel and a new barge dock on the southwest leg of the Alkali Ditch. Since that time, the availability of the Sun Terminal in Nederland, Texas and the Amoco barge dock on the southeast leg of the Alkali Ditch have prompted a redesign of the oil distribution system. This change in design eliminates the need to construct the two new vessel docking facilities but requires the construction of longer pipelines in both cases to connect the existing facilities to the storage site.

Another pipeline design change incorporated in this supplement involves above ground exposure of the temporary pipelines whereas previous plans were to bury all on-site pipelines. Because of the necessity of beginning initial fill operations as soon as possible, temporary pipelines supported on pilings would connect the storage facility to the temporary barge dock and to the first of the brine disposal wells. These exposed pipelines would be dismantled after the permanent facility is in operation.

This supplement addresses the environmental impacts associated with the proposed design changes.

1.2 PROPOSED FACILITIES

1.2.1 Location

The West Hackberry salt dome is located in north-central Cameron Parish of southwestern Louisiana (see Figure 1.1). Portions of the dome are presently used by Olin Corporation for brine production and by Cities Services for hydrocarbon product storage. The dome area is extensively developed with hundreds of oil and gas wells located on its perimeter. It is among the largest salt domes in the Gulf Coast region with 11.5 cubic miles of salt above the depth of 10,560 feet. The depths to the caprock and salt are 1,234 and 1,960 feet, respectively. Little or no mining has taken place in the caprock.

Road access to the dome from Lake Charles is via State Highway No. 27. Hackberry, the local unincorporated town of 1,300 population, is approximately 4 miles east of the proposed site. The Sabine National Wildlife Refuge lies approximately 2 miles to the south.

The salt dome exhibits two topographic expressions. The western portion of the dome is overlaid by a definite mounded area from 2 to 21 feet in elevation. It is the highest point in Cameron Parish with an area of about 890 acres elevated above 5 feet, (48.6% of the area inside the 2,000 feet depth of salt contour). The eastern half of the dome area is covered by lakes and marsh.

A network of gravel roads serves the brining and storage facilities on the western portion of the dome. The eastern portion of the dome is served by canals allowing barge access to most of the area. Developing road access to the eastern portion of the dome would require substantial cost.

Barge access to Black Lake from the Intracoastal Waterway is via an 80 to 150 foot wide canal some 3.8 miles long. This canal is presently navigable by 6 to 7 foot draft barges. The site is favorably located with respect to ship terminals at Lake Charles

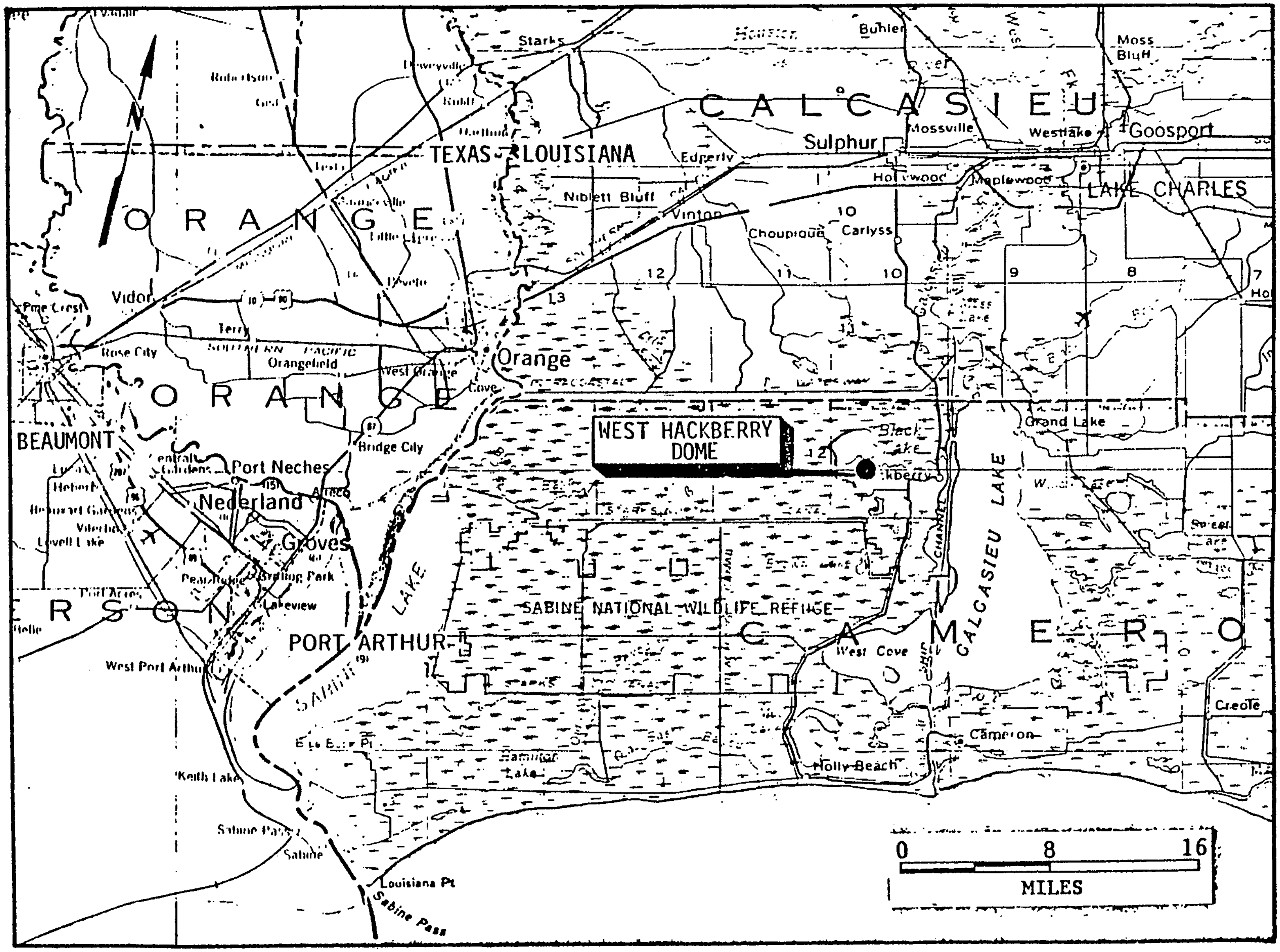

Figure 1.1 Location Map - West Hackberry Dome

about 30 miles away (see Figure 1.1). For the proposed facility, a new 41.5 mile oil distribution pipeline is needed to connect the storage site with Sun Terminal in Nederland, Texas. Tankers serving the area would be limited to the 40-foot draft capability of the Neches River (see Figure 1.2). Also proposed is a new temporary 1.25 mile pipeline connection between the site and the existing Amoco barge dock on the Alkali Ditch (see Figure 1.3). The Alkali Ditch and the Amoco Dock currently accommodate 40,000 barrel barges.

1.2.2 System Description

The presently planned SPR facility involves only the conversion of existing brine cavities to bulk crude storage. Hence no leaching of new cavities is anticipated. Crude oil supplies for filling the salt cavities are planned from two sources. Initially, crude would be supplied from barges at the existing Amoco Dock which is located on the Alkali Ditch approximately 1.25 miles east of the site (see Figure 1.2).

Upon completion of the proposed oil distribution pipeline, crude would be supplied from the Sun Terminal in Nederland, Texas. The pipeline would be manifolded into the present distribution system at Sun Terminal allowing oil to be distributed by tanker, barge or inland pipeline. The Sun Terminal is situated on the southern bank of the Neches River and can accommodate tankers up to 70,000 DWT (490,000 bbl). After completion of the new pipeline, all the crude oil would be supplied to the storage site from the Sun Terminal.

As currently planned, the Amoco Dock would be used for initial fill operations only, and not for distribution. For withdrawal of the stored oil, displacement water taken from Black Lake Bayou (Figure 1.2) would be injected into the storage cavity through the well tubing, pushing the crude oil out and through the pipeline to the Sun distribution terminal.

1.3 SITE DEVELOPMENT AND CONSTRUCTION

1.3.1 Temporary Facilities

Initial crude oil fill operations are planned via the Amoco Dock located on the nearby Alkali Ditch. A temporary 1.25 mile surface pipeline (10-3/4 inch) would be constructed between the site and the dock. The dock can handle barges up to 40,000 bbl. However, it is more likely that barges of 20,000 to 25,000 barrel capacity would be used, based on availability. The current plan anticipates an average fill rate of 2 barge loads or 50,000 bbl/day. The barge pumps would be sufficient to transfer the oil from the dock to the storage site. During this initial or interim fill only one cavern and one disposal well would be required. A temporary 2.5 mile brine disposal pipeline would be constructed above ground on piles to connect the site with this disposal well. No other facilities are needed for this temporary operation.

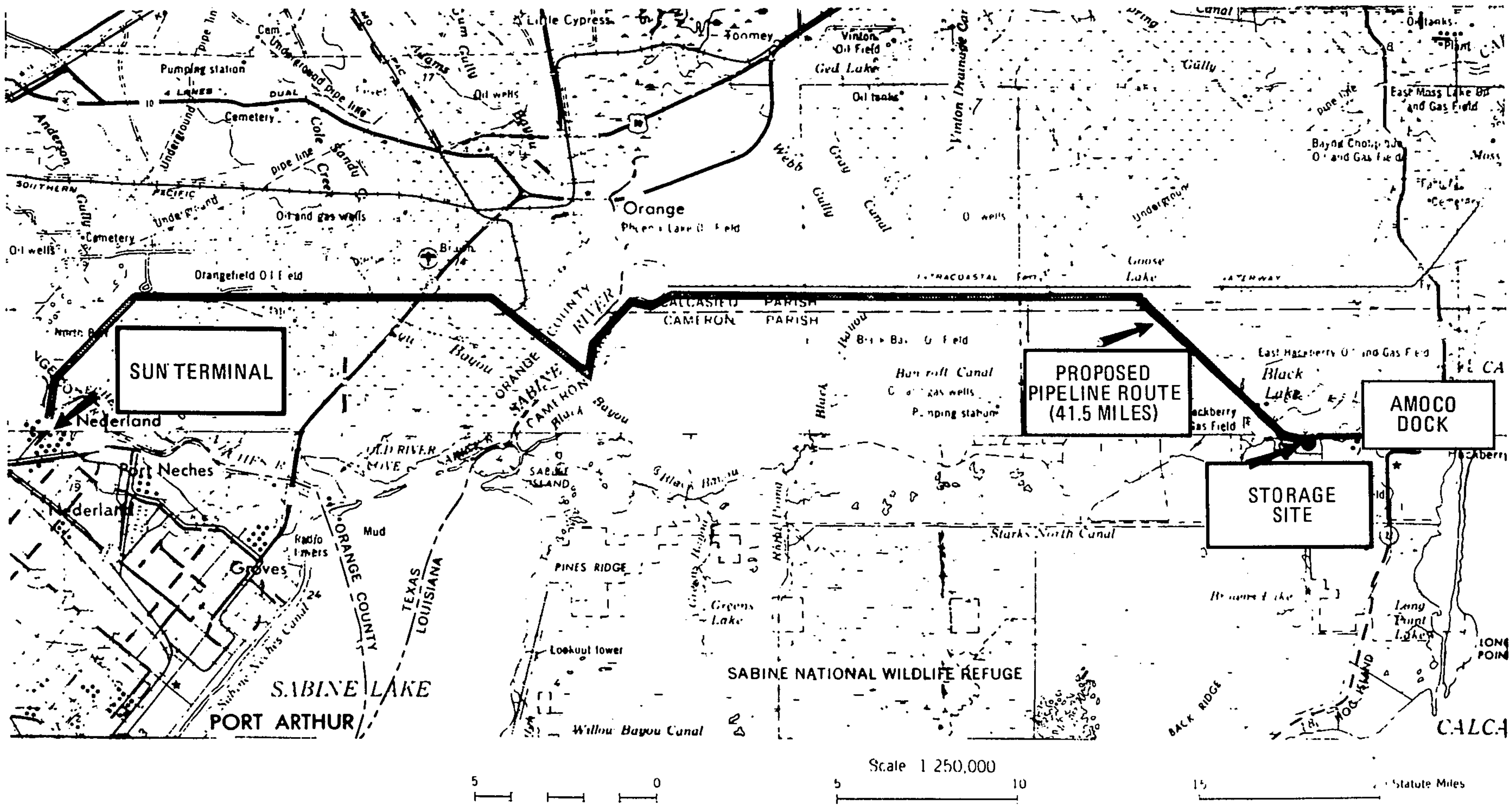

Figure 1.2 Proposed Oil Distribution Pipeline Route

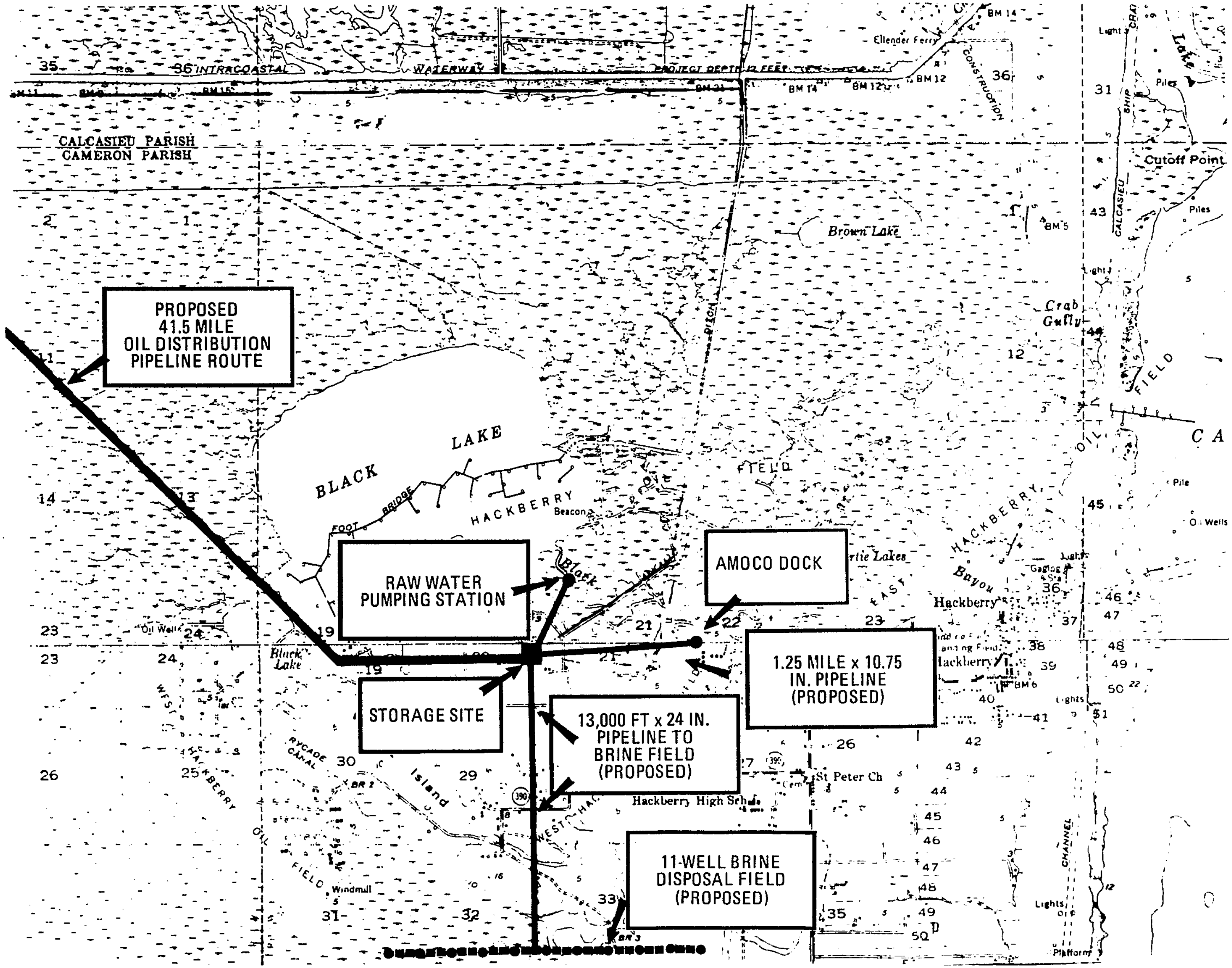

Figure 1.3 Proposed Facilities for West Hackberry Site

1.3.2 Permanent Facilities

At this particular site, it is planned to bury the permanent on-site pipeline connectors. This is standard procedure for facilities located on high and dry land, especially when utilized for grazing. A new permanent 2.5 mile brine disposal pipeline to the injection field would also be buried. The temporary surface pipeline would then be dismantled. A tentative pipeline flow diagram for the permanent facility is shown in Figure 1.4

Distribution System

Current designs for permanent systems components specify electric pumps and equipment, with the power being supplied by local utilities. No onsite backup generation is currently planned. Crude oil supplies and distribution would be handled by Sun Terminal in Nederland, Texas, following the construction of a new pipeline (Figure 1.3). The pipeline would be manifolded into the existing system at Sun Terminal including oil surge tanks and ballast treatment facilities. An additional pumping station and metering facility would be constructed at the terminal to transfer oil from the surge tanks to the storage site. The tentative location for the brine disposal deep well injection system is about 2 miles directly south of the salt dome as indicated in Figure 1.2. The planned location of the raw water intake station for displacement operations is in a portion of Black Lake Bayou, some 2,000 feet north of the proposed central pump station (Figure 1.2). The central pumping and control buildings are to be located near the site of the existing wash plant for the Olin brining plant at the end of the southwest leg of the Alkali Ditch.

According to preliminary designs, all oil injection pumps, brine injection pumps, and raw water injection pumps would be housed in a central pump building. Oil pumps are used for injection and withdrawal operations. Pipeline transfer pumps are located at Sun Terminal for pumping oil to the site. Fill operations require oil, transfer and brine disposal pumps. Withdrawal operations require oil, displacement and water supply pumps. All pump specifications can be seen on Table 1.1. Another building would be required to house the main office, all electrical control equipment, a repair shop, and a chemical lab. At this lab, brine samples would be analyzed to calculate the rate of new leaching (in the case of existing cavities, additional leaching is caused by the introduction of displacement water). Also, tests would be conducted on crude oil samples to determine their compatibility with other stored oils.

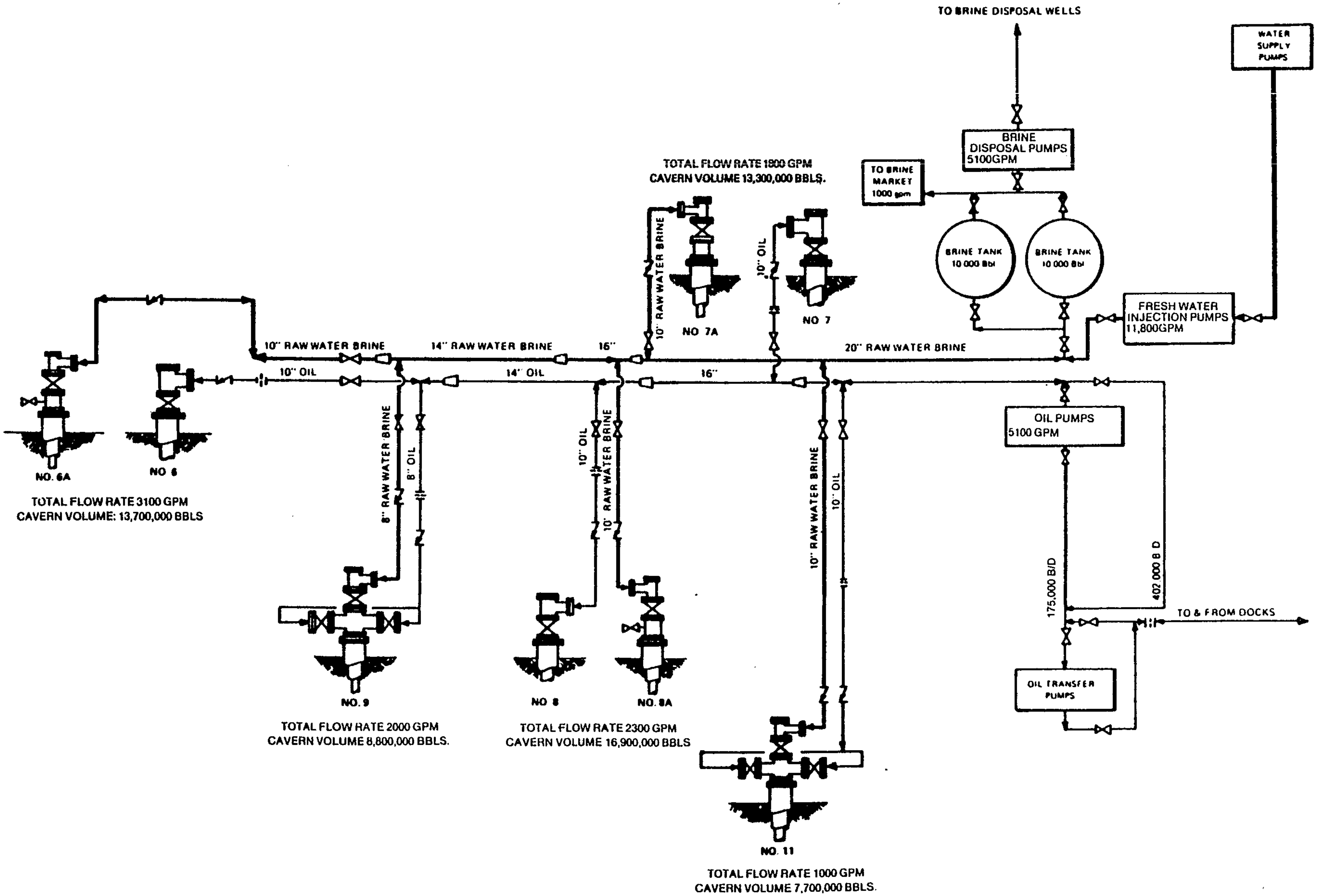

Figure 1.4 Flow Diagram - Permanent Facility

TABLE 1.1 PROPOSED PUMP REQUIREMENTS

PUMP TASK	QUANTITY	HORSE-POWER	DISCHARGE PRESSURE (psi)	SUCTION PRESSURE (psi)	TOTAL DESIGN FLOW RATE(B/D)
Oil Injection and Withdrawal	1	1000	40	0	
	1	1000	408	40	
	1	1000	775	408	402,000
	1	1000	890	775	
	2(standby)	1000			
Oil Displacement	1	500	100	0	
	1	500	300	100	423,000
	1	500	500	300	
Brine Disposal	4	1500	1260	0	175,000
	2(standby)	1500			
Raw Water Supply	3	800	115	0	423,000
	1(standby)	800			
Pipeline Transfer: Dock to Site	2	900	135	0	175,000
	1	500	135	0	
	1(standby)	500			

At West Hackberry, brine disposal by a closed system, i.e., not exposed to air, is planned. The proposed method of disposal for the saturated brine (about 265 ppt) displaced during crude oil fill operations is deep well injection into subsurface saline reservoirs off the southern flanks of the salt dome. At the required oil injection rates, an average of 5100 gallons per minute (7300 barrels per hour) would be produced. Olin Corporation plans to increase its brine requirements from the dome and may be able to take up to 1000 gallons per minute of the brine for feedstock. The facility disposal system, however, would be sized to handle the worst case condition, or the full 5100 gallons per minute. Two 10,000 barrel brine surge tanks located onsite would be of standard steel construction and enclosed by dikes.

The West Hackberry dome has multiple options for the supply and distribution of crude oil. For initial filling a temporary pipeline from the Amoco barge dock would be employed. The Amoco dock situated on the Alkali Ditch is capable of handling 40,000 bbl barges. Present plans call for 2-25,000 barrel barges per day for a total delivery of 50,000 barrels per day.

For the second phase of the fill operations and for later emergency distribution, a pipeline would connect the storage site with the existing Sun Terminal in Nederland, Texas. The pipeline is expected to be completed about 10 months after the initial phase of the filling operation begins (see Table 1.2). At this time, the remaining fill at the site would be from tankers via Sun Terminal and the new pipeline. The docks at the terminal would provide mooring for up to 70,000 DWT (490,000 barrel) oil tankers or transport barges.

The dock facility at Sun Terminal is equipped to handle unloading and loading of both tankers and barges, treatment of wastes and control of spills. The current dock facility includes one barge dock and 2 tanker docks, as seen in Figure 1.5, with capabilities of handling a 100,000 DWT and 130,000 DWT tanker. Two additional tanker docks designed for 130,000 DWT (910,000 bbls) tankers are planned to be completed by the end of 1977. However, a fully loaded 130,000 DWT tanker requires a channel depth of 50 feet and the Neches River channel has a navigational depth of only 40 feet at present. Therefore, tankers of this size would be light loaded. The Corps of Engineers is now studying a proposal to increase the Neches River navigation channel depth to 50 feet within about 5 years.

At the Sun Terminal distribution site, crude oil surge facilities and ballast treatment facilities would be available to expedite the onloading and offloading of tankers. It is anticipated that three 200,000 barrel surge tanks would be employed during fill operations. The required tanks would be floating roof structures, commonly used in the oil industry.

Table 1.2 Timetable for Conversion and Fill (Revised)

Month Period	Fill Rate (MB/D)	No. of Months	Cum. Storage (MMB)	Phase of Development
0-3.5	0	3.5	0	Site preparation
3.5-13.5	50	10.0	16	Interim fill from Amoco Dock
13.5-21.5	175	8.0	60	Pipeline to Sun Terminal complete. Final fill.

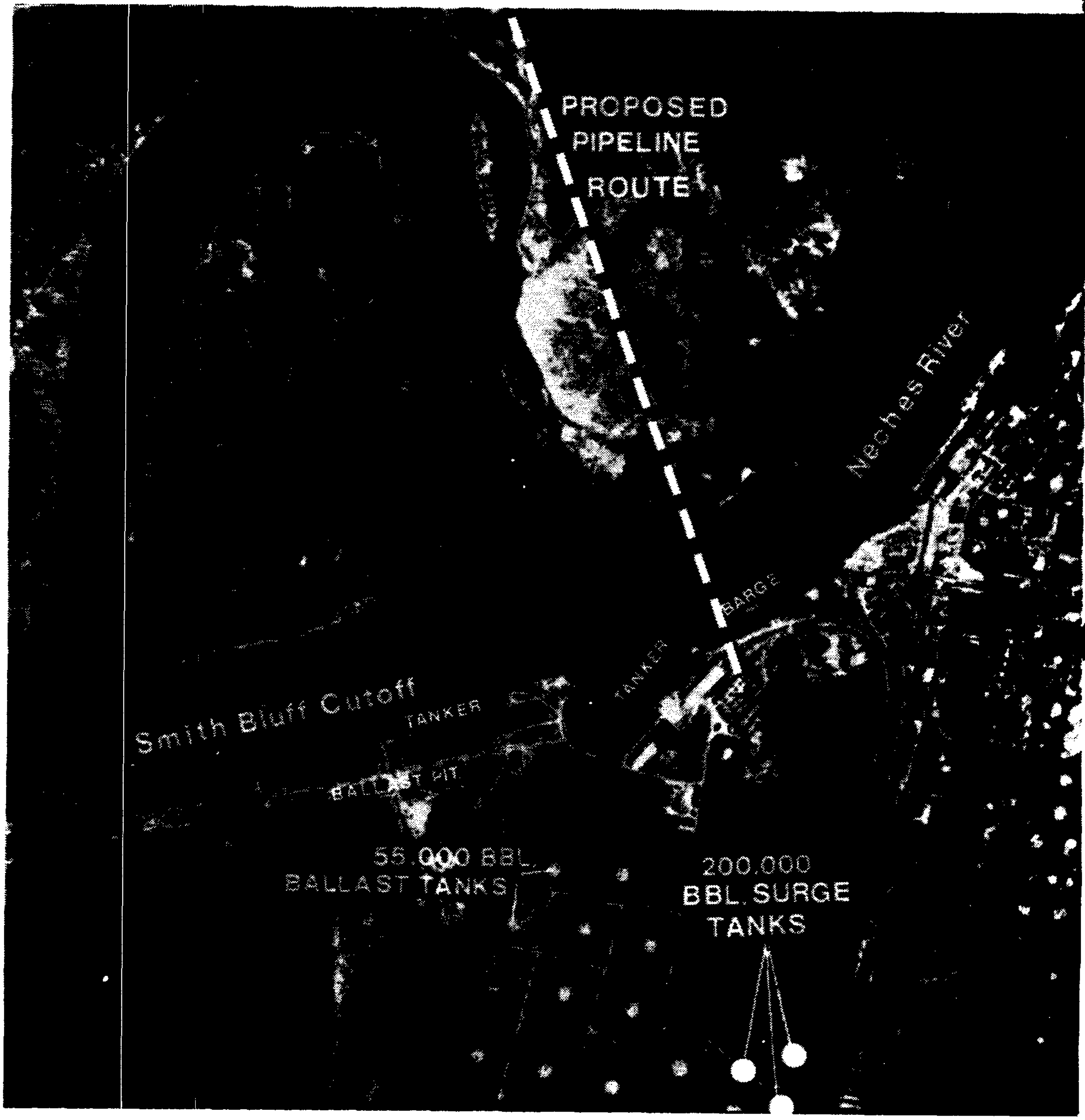

Figure 1.5 Aerial Photograph of Sun Distribution Terminal

These tanks are approximately 160 feet in diameter and 56 feet in height. All surge tanks at Sun Terminal are enclosed by retention dikes as required by federal regulations (40 CFR 112.7).

During the oil withdrawal and distribution phase, the existing ballast treatment facility would be available when needed. The facility consists of two 55,000 barrel ballast water tanks and the associated water cleanup systems capable of treating and discharging water at an average rate of 20,000 gal/hr with a maximum oil concentration of 7.5 ppm. The treated water is discharged to the surface of a ditch that flows directly into the Neches River. There are existing facilities for the treatment of rain run-off from the dock areas and oily surface waters taken from minor routine spills around loading and unloading tankers. The potentials for these and major spills are discussed in Section 3.7.2.

The present plan is to distribute 50 percent of the oil over docks and 50 percent through inland pipelines. Tankers up to about 65,000 DWT (450,000 barrels) may be employed; thus for a distribution rate of 400,000 barrels/day the average tanker traffic would be one tanker per 27 hours. The Neches River channel and the tanker turn around area in the vicinity of Sun Terminal was designed for tankers up to 70,000 DWT (490,000 barrels).

Transfer of oil to and from the storage site would be via either two 36-inch diameter steel pipes or one 42-inch diameter steel pipe. Since the impacts associated with construction and operation of two 36-inch diameter pipes would represent a worst case, the environmental assessment was performed for two 36-inch pipes. Main crude oil transfer pumps located at Sun Terminal would consist of one 500 hp pump and two 900 hp pumps which would deliver the required 175,000 barrels per day (5100 gallons per minute) to the manifold side of the injection pumps at the storage site. There would be a second 500 hp pump on standby at all times.

During oil withdrawal operations, the oil displaced from each cavern would be transferred to the Sun Terminal distribution system via the new proposed pipeline. Oil pumps would be required at the site for oil transfer due to the length of the pipeline. Four 1000 hp pumps are presently planned for oil transfer during this operation. These pumps are sufficient to transfer 60 million barrels of crude in 150 days.

Pipeline Description

The proposed oil distribution pipeline route between the West Hackberry site and the Sun Terminal is 41.5 miles long (see Figure 1.3). An alternate 46 mile route is discussed in Section 7.2.3.

The proposed route begins at the central plant area and proceeds approximately 1.4 miles due west across the dome itself (prarie land) to the southwest end of Black Lake, then northwest approximately 0.5 miles across Black Lake itself. After leaving Black Lake, the proposed route continues in the same direction (NW) through marshland for approximately 5.2 miles to the southern spoil bank of the ICW, near Goose Lake. The pipeline route then follows the southern spoil bank of the ICW due west to the entrance of the ICW into the Sabine River (13.8 miles). At this junction the pipeline proceeds for 2.1 miles downriver along the eastern bank of the Sabine River, crossing into Cameron Parish in the process. The route then crosses the Sabine River 1.1 river miles north of the entrance of Cow Bayou into the Sabine River, and enters Orange County, Texas.

After crossing the Sabine River (perpendicular to the river), the route traverses a marsh in a northwest direction for approximately 1 mile and then cleared dry land for 1 mile in the same direction. The pipe then swings westward crossing high marsh, marsh, dry prairie land, gum-oak-cypress groves and a pine forest for approximately 11.25 miles. At this point the route turns southwest crossing wooded land and marsh for 2.75 miles and then south for 1.5 miles thus reaching the Neches River bank. The distribution pipeline to Sun Terminal would require a 50-foot permanent right-of-way, thus requiring a total of 242 acres. During construction, however, a 75 foot right-of-way is required on dry land and a 150 foot right-of-way for marsh land. Table 1.3 shows the land requirements for each land type to be impacted.

The proposed pipeline route from the site to the Amoco Dock would be 1.25 miles in length extending due east from the central plant facility. The route would be aligned to bypass the branches of the Alkali Ditch in the area and therefore traverse only dry land. This pipeline would require 8 acres of permanent right-of-way (11 acres during construction).

The entire project including pipelines, site facilities and brine disposal area would require a total of 518 acres.

Table 1.3 Land Requirements (Acres)

		Dry Land	Marsh	River Bank	Woodland	Gum Oak Cypress	Roads
Proposed Route (41.5 miles)	A	43	68	98	23	9	1
	B	64		147	35		1.5
	C		203			27	
Temporary Route Site to Amoco Dock (1.25 miles)	A	8					
	B	11					
	C						

Note: A - Permanent right-of-way = 50 feet
B - Dry land construction right-of-way = 75 feet
C - Wet land construction right-of-way = 150 feet

1.3.3 Pipeline Construction Techniques

Three basic methods of construction may be used during construction of the offsite pipelines: (1) flotation canal method, (2) push ditch method, and (3) conventional dry land method.

The flotation canal method of construction is required in the marshy portions of a pipeline route where the ground cannot support heavy construction equipment. Therefore, the work must be done on construction barges operating in a canal.

The push ditch method of construction would be used in the swampish portions of the pipeline route where the ground can support marsh buggy mounted excavating and backfilling equipment, but cannot support conventional dry land pipeline construction equipment.

For the pipeline routes presently planned, all three methods of pipeline construction would be required. When crossing any navigable body of water, hydraulic or bucket dredges are used to dig a channel in which to lay the pipe. For the proposed pipeline, four major navigable bodies of water are crossed, resulting in 415,000 - 460,000 cubic yards of dredged material that would be disposed of along the banks in areas specified for this purpose (Section 3.2.1).

Corrosion Protection

All buried portions of the pipelines would be externally covered with a mastic coating as a physical barrier between the pipe and environment. In areas that are more highly corrosive, magnesium sacrifical anodes or impressed electrical currents would be employed in addition to the mastic coating. Sealed casings are required at highway or railway crossings, with insulators and spacers to electrically isolate the pipelines from the casing.

1.3.4 Preliminary Development Timetable

According to present plans, during the first 3.5 months of project construction, the site would be prepared for an early fill from the Amoco Dock. After 13.5 months the distribution pipeline from Nederland would be finished and the second stage of the filling operation would begin. Using the Amoco Dock for 10 months (50,000 barrels per day) would fill the caverns to 27 percent of their total anticipated 60 million barrel capacity. From month 13.5 to month 21.5 the remaining 73 percent of site storage capacity would be supplied from Sun Terminal at an average rate of 175,000 barrels per day. By the time the 60 million barrel design capacity is reached, all facilities required for emergency drawdown operations would be complete (see Table 1.2). This timetable is preliminary only, and the total time required for fill would be reduced if the pipeline to Nederland is completed earlier than now projected.

2. DESCRIPTION OF THE ENVIRONMENT

2.1 LAND USE CHARACTERISTICS

Agriculture

There is agricultural development along the pipeline routes from the storage site to Sun Terminal, with most of the 64 acres of dry land (see Table 1.5) being used as pasture or rice land.

Residential/Commercial Development

Within one to two miles of the pipeline route from the storage site to the Sun Oil Terminal there is some residential and industrial development at Bridge City, Orangefield, and West Orange, Texas.

Recreation and Wildlife Resources

The recreational and wildlife resources of the coastal marshlands and prairie are both vast and varied. However, the area to be impacted by the development of the West Hackberry salt dome is neither large nor particularly sensitive. The primary uses of the marshlands and coastal prairie around the site are fishing, fowl hunting, trapping, and boating. Along the pipeline route there is sport fishing along Cow Bayou and commercial crab production in Sabine Lake. Black Lake is important to commercial and sport fishermen. Two miles to the south of West Hackberry salt dome is the Sabine National Wildlife Refuge.

2.2 WATER ENVIRONMENT

The proposed pipeline route in southwestern Louisiana and southeastern Texas extends from the western fringe of the Calcasieu River Basin, through the Sabine River Basin to the Neches River Basin. As shown in Figure 2.1, the pipeline crosses two rivers (Sabine and Neches), Black Lake, and two Bayous (Black and Cow) and for more than 12 miles the pipeline would be laid along the southern bank of the Intracoastal Waterway (ICW). These six bodies of water, and associated marshlands and drainage canals, comprise the surface water system which would be affected by the pipeline.

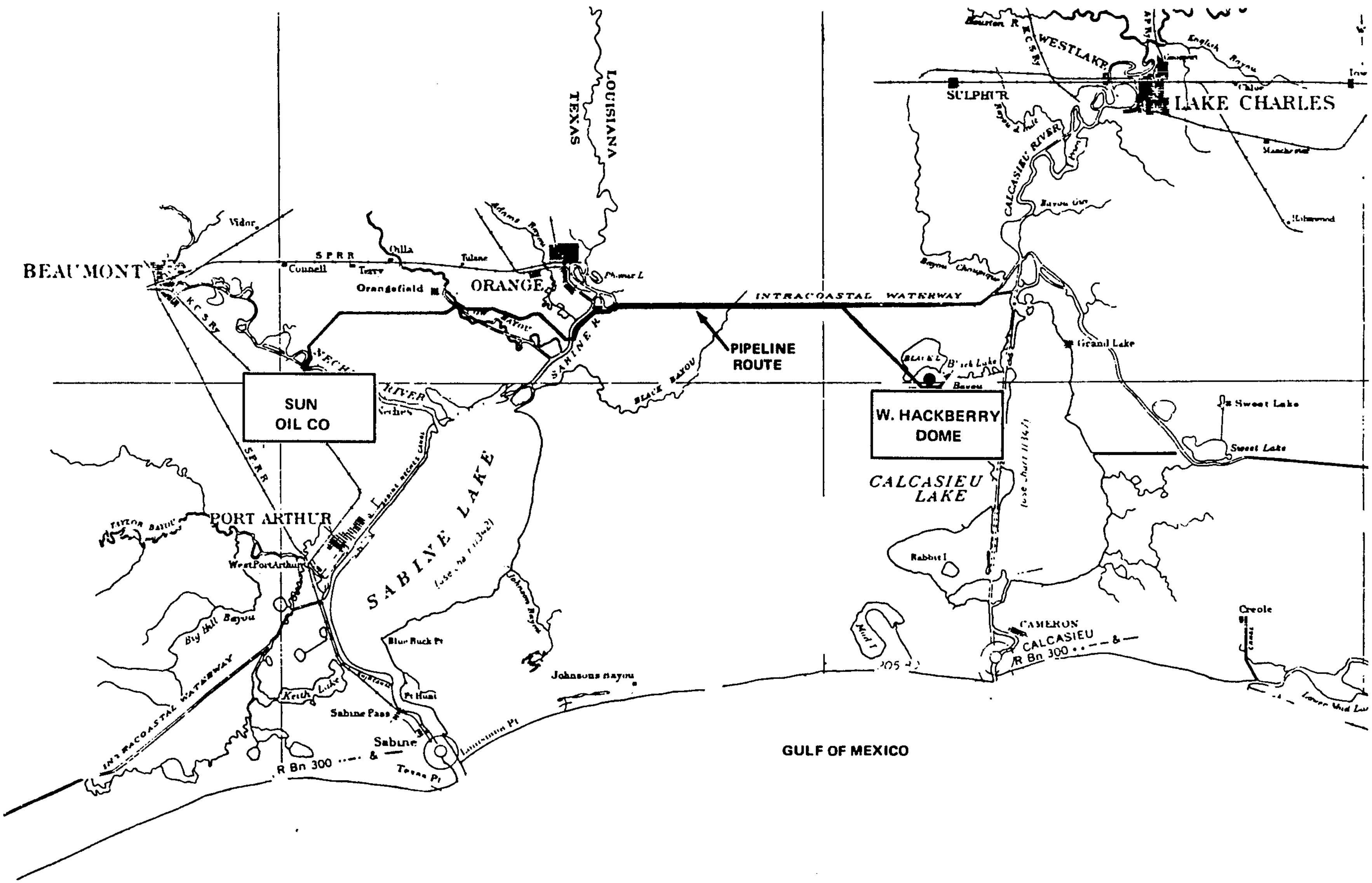

Figure 2.1 Surface Water System Associated with Pipeline from West Hackberry Dome to Sun Oil Dock

In describing the existing water quality environment it is useful to identify any water quality parameter which appears, for some reason, to be too high or low. In order to make such an identification the available measured water quality and sediment quality data must be compared with appropriate standards and criteria. Some confusion exists concerning the distinction between, and the proper usage of, the terms standards and criteria. For purposes of organization and clarity in this document the term standard will be used to refer to any enforceable water quality regulation, such as established by a state. The term criterion will be used to refer to any recommended limit placed on a water or sediment quality parameters. As discussed in Appendix C, criteria are not enforceable. If a measured water quality parameter falls outside of the prescribed standard it will be described as violating the standard. When a measured parameter lies outside of an applicable criterion it will be referred to as exceeding the criteria. In certain cases because of (1) detection threshold limitation for the measured data, or (2) the absence of applicable standards or criteria, or (3) ambiguities in existing standards or criteria, a precise judgment is not possible. In such cases, if there is good reason based on the experience of the water quality analyst to expect some particular water or sediment quality problem the appropriate parameter will be described as posing a possible problem.

Intracoastal Waterway

The portion of the Intracoastal Waterway paralleling the pipeline lies 4.1 miles north of the West Hackberry dome, extending generally in an east-west line from the Calcasieu River to the Sabine River. A description of this waterway is provided in the West Hackberry FES[1] including all available water quality data standards, and criteria. The results of a comparison of the measured data with the applicable standards and criteria are included in Table 2.1. No sediment quality or standard elutriate data are available for the portion of the ICW under consideration.

Black Bayou

Approximately 12 miles west of the West Hackberry site the pipeline would cross three channels which are connected with or are considered part of Black Bayou. From east to west the first of these channels is the Vinton Canal, the second (located 0.35 miles to the west of the canal) is an unnamed branch of the bayou, and the third is Black Bayou Cutoff. Black Bayou is approximately 18.7 miles long and flows to the southwest emptying into Sabine Lake. The bayou has a mean width of 170

Table 2.1 Summary of Water Quality Analysis

Body of Water	Sample Station†	Date	Violates State Standards	Exceeds Proposed EPA Numerical Criteria*	Poses a Possible Problem
Gulf Intracoastal Waterway	13	3-23-75	none**	Lindane, O.P'-DDT	Toxaphene, endrin and P.P'-DDT
Sabine River	SN-15	9-25-74	none**	Cadmium, zinc	
Sabine River	SN-16	9-25-74	none**	Cadmium, zinc	
Sabine River	SN-17	9-25-74	none**	Cadmium, zinc, copper	
Cow Bayou	CB-3	9-25-74	no state standard	Cadmium, zinc	
Cow Bayou	CB-4	9-25-74	no state standard	Cadmium, zinc	
Neches River	NR-2	9-25-74	none**	Cadmium, zinc, copper	
Neches River	NR-3	9-25-74	none**	Cadmium, zinc	
Neches River	NR-4	9-25-74	none**	Cadmium, zinc, copper	

†The locations of all sampling stations are shown in Figure C.1.
*Marine water constituents (aquatic life), provided in Appendix C.
**No measurements taken for any water quality parameter covered by the state standards.

feet, a depth of 3 feet, a surface area of 386 acres and a volume of 1,158 acre feet.[2] The Vinton Canal is classified as a navigation channel with a controlling depth of 9 feet and a width of 60 feet.[3] The canal is generally oriented in a north-south direction and extends 8 miles from Vinton, Louisiana to Black Bayou.

The Water Quality Standards for the State of Louisiana[4] for Black Bayou and the Vinton Canal are provided in Appendix C. As indicated by these standards both water bodies are to be used for secondary contact recreation and for the propagation of fish and wildlife. In addition to the state standards, certain proposed EPA numerical criteria[5] are relevant. Because both water bodies are classified as tidal, the proposed EPA numerical criteria for marine water constituents (aquatic life) appear most applicable and are provided in Appendix C.

Sabine River

The Sabine River forms the boundary between southwestern Louisiana and southeastern Texas. The pipeline would cross the river approximately 3 miles downstream of the junction of the ICW with the river. This portion of the river coincides with the Sabine River Ship Channel which is maintained at a dredged depth of 30 feet. The river width is approximately 1000 feet. As noted in the United States Coast Pilot,[6] "practically no periodic tides occur" in this reach of the river. The rise and fall of the water depend upon the meteorological conditions. Currents in the river are about 4.2 ft/sec during high stages.[6] Approximately 21 miles upstream near Ruliff, Texas hydrologic data are available.[7] Volumetric flow data are presented in Appendix D.1. The volumetric flow of the river during the period October 1974 through September 1975 varied from a minimum of 774 ft^3/sec (on October 14) to a maximum of 40,700 ft^3/sec (on May 14). The mean flow rate was 14,210 cfs. It should be noted that the river flow is regulated by releases from Toledo Bend Reservoir.

Both Louisiana and Texas specify the same water quality standards for the river.[4,8] These standards, which are provided in Appendix C.3 indicate that the water is to be used for primary and secondary contact recreation and for the propagation of fish and wildlife. Because the reach of the river under consideration is classified as tidal in the state standards, the most relevant of the proposed EPA numerical criteria* are judged to be the criteria for marine water

*proposed EPA criteria refers to criteria developed by an expert advisory panel for EPA.

constituents (aquatic life) which are also included in Appendix C. Although no official criteria currently exist for sediment quality, certain unofficial criteria have been recommended.[9,10] These criteria are also included in Appendix C.

In the vicinity of the pipeline crossing the river, both water quality and sediment quality data collected in September 1974, are available at three sampling stations.[11] The locations of these stations are indicated in Figure C.1 in Appendix C, and the measured data are included in the same appendix.

Examination of the water quality data reveals that no comparison with the state standards is possible because no measurements of dissolved oxygen, pH, fecal coliform, or temperature were obtained. When the measured water quality data are compared with the proposed EPA numerical criteria, however, excessive levels of certain contaminants have been identified and are shown in Table 2.1.

Comparison of the available sediment data in Appendix C with the recommended sediment limits in the same appendix also reveals excessive levels of certain contaminants, as summarized in Table 2.2.

The current standard method of evaluating sediment quality and its potential impact on the water columns involves use of standard elutriate* test as discussed in Appendix C. However, because no standard elutriate data are available for the portion of the Sabine River under consideration, water and and sediment quality data available for station SN-15** in the Sabine River were used. These data were obtained before and during dredging operations,[11] and are included in Appendix C. Examination of these data, which were collected approximately six months after the water and sediment quality data previously discussed, reveals that the water quality at station SN-15 before and during dredging conformed to the proposed EPA numerical criteria already mentioned for the parameters measured. This result is inconclusive because of the absence of measured levels for copper and zinc. The level of cadmium as measured in March 1975 was only about 25% of the level obtained earlier in September 1974. This difference may result from differences in the flow rates of the river at the time the samples were taken.

* The "standard elutriate" is the supernatant resulting from the vigorous 30-minute shaking of one part of bottom sediment with four parts water (on a volumetric basis) collected from the same sample site, followed by a one-hour settling time and appropriate 0.45μm filtration.

**The location of station SN-15 is shown in Figure C.1 in Appendix C.

Table 2.2 Summary of Sediment Quality Analysis

Body of Water	Sample Station†	Date	Exceeds Unofficial Recommended Criteria*
Sabine River	SN-15	09-25-74	TKN, COD, Oil and Grease, Zinc
"	SN-17	09-25-74	TKN, COD, Oil and Grease, Zinc
Cow Bayou	CB-3	09-25-74	TKN, COD, Oil and Grease, Zinc, Lead
"	CB-4	09-25-74	TKN, COD, Oil and Grease, Zinc, Lead
Neches River	NR-2	09-25-74	TKN, COD, Oil and Grease, Zinc, Lead
"	NR-3	09-25-74	TKN, COD, Oil and Grease, Zinc, Lead
"	NR-4	09-25-74	TKN, COD, Oil and Grease, Zinc, Lead

†The locations of all sampling stations are shown in Figure C.1.

*Included in Appendix C (Table C.4).

Cow Bayou

As indicated in Figure C.1 of Appendix C, the pipeline would cross Cow Bayou at a point approximately 6 miles northwest of the junction of the bayou with the Sabine River. The bayou at this point is approximately 280 feet wide with a dredged depth of 10 feet.[12] Volumetric flow rate data for the bayou are available near Mauriceville, Texas, approximately 11 miles upstream of the crossing point.[7] These data are included in Appendix C. During the period from October 1974 through September 1975, the flow rate varied from a maximum of 2060 ft^3/sec in June to a minimum of 0.5 ft^3/sec in October. Because of the many connections joining Cow Bayou and other bayous and canals in the region between the gauging station and the pipeline crossing, it is not clear if these flow rates are truly representative of the portion of the bayou under consideration.

No specific water quality standards for Cow Bayou have been established by the State of Texas. For this reason the water uses for which this stream is intended are unknown. The most appropriate EPA numerical criteria* are judged to be the criteria for marine water constituents (aquatic life) which are included in Appendix C.

Water and sediment quality data are available for two sampling stations on the bayou as indicated in Figure C.1 of Appendix C.[11] One of these stations (CB-4) is immediately downstream of the pipeline crossing point while the other (CB-3) is located approximately 1.5 miles downstream. The water and sediment quality are included in Appendix C. The results of an analysis of the available water quality data are included in Table 2.1. Examination of the sediment data for Cow Bayou, as presented in Appendix C, reveals that certain parameters exceed the unofficial recommended criteria as indicated in Table 2.2

Neches River

The pipeline would cross the Neches River, as indicated in Figure 2.1 approximately 8 miles upstream of the point where the river empties into Sabine Lake. The river in this area has a width of approximately 800 feet with a dredged channel

*Cow Bayou lies between the Sabine and Neches Rivers. The lower reaches of both rivers are classified as tidal and the lower reach of Cow Bayou is assumed to be tidal. For tidal streams the proposed EPA criteria for marine water constituents (aquatic life) are judged to be appropriate.

depth of 40 feet.[11] Periodic tides in the river are weak with the rise and fall of the water depending upon meteorological conditions.[6] The nearest gauging station on the river is located at Evadale, Texas, 31 miles upstream of the crossing point.[7] Volumetric flow data collected at this station during the period of October 1974 through September 1975 are included in Appendix C. During this period the flow rate ranged from a maximum of 19,800 ft^3/sec (January 26, 27) to a minimum of 1,780 ft^3/sec (September 19), with a mean flow rate of 9,905 ft^3/sec.

The specific Texas State Water Quality Standard[8] for the reach of the Neches River under consideration are included in Appendix C. According to such standards, the river water is to be used for non-contact recreation and for the propagation of fish and wildlife. Because the reach of the river under consideration is classified as tidal, the most pertinent of the proposed EPA numerical criteria are judged to be those criteria pertaining to marine water constituents (aquatic life) which are presented in Appendix C.

Water quality and sediment quality data for three stations along the river in the vicinity of the pipeline crossing[11] are included in Appendix C. The locations of the three sampling stations are indicated in Figure C.1.

Comparison with the proposed EPA numerical criteria reveals that certain contaminants exceed the recommended criteria, as summarized in Table 2.1. As shown in Table 2.1, a comparison with the state numerical criteria for the level of dissolved oxygen, pH, fecal coliform, and temperature cannot be accomplished as none of those parameters were included in the measured data.

The results of a comparison of the available sediment data provided in Appendix C with the unofficial recommended criteria for sediment contained in that Appendix are included in Table 2.2.

Marshes

Most of the pipeline route would be located in or near marshland. Along the ICW in Louisiana, the pipeline crosses fresh marshes, intermediate marshes, and brackish marshes.[13] In Texas, between the Sabine and Neches Rivers, similar marshes are encountered.[11] No hydrologic or water quality data are available for those marshes. The waters are shallow, with a depth of one to two feet and are highly turbid. Seasonal precipitation and tides have a strong effect on the depth of the water.

2.3 METEOROLOGICAL CONDITIONS

2.3.1 Climatological Conditions*

The climate of the area including the permanent storage facility at the West Hackberry, Louisiana site and the crude oil terminal at Nederland, Texas (33 miles west 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°F.[14] 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.[15,16] 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 2.2.[17,18]

The November through March period is typically the coldest with monthly normal temperatures in the 50°'s; January to April is typically the driest period with less than 4.3 inches of rain each month.[13] The monthly normal rainfall at Hackberry[19] and Port Arthur[13] is illustrated in Figure 2.3. June, July and August are usually the hottest, wettest, and most humid months

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*The nearest weather monitoring stations were within 22 miles of the proposed facilities. The stations used were:

Hackberry (Station Code 8SSW), the NOAA cooperative station, approximately 6 miles south of the permanent storage facility, for temperature and precipitation averages.

Lake Charles, La. (National Weather Service Station (nWS) 72240, or Air Force Station 13941), approximately 22 miles northeast 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.

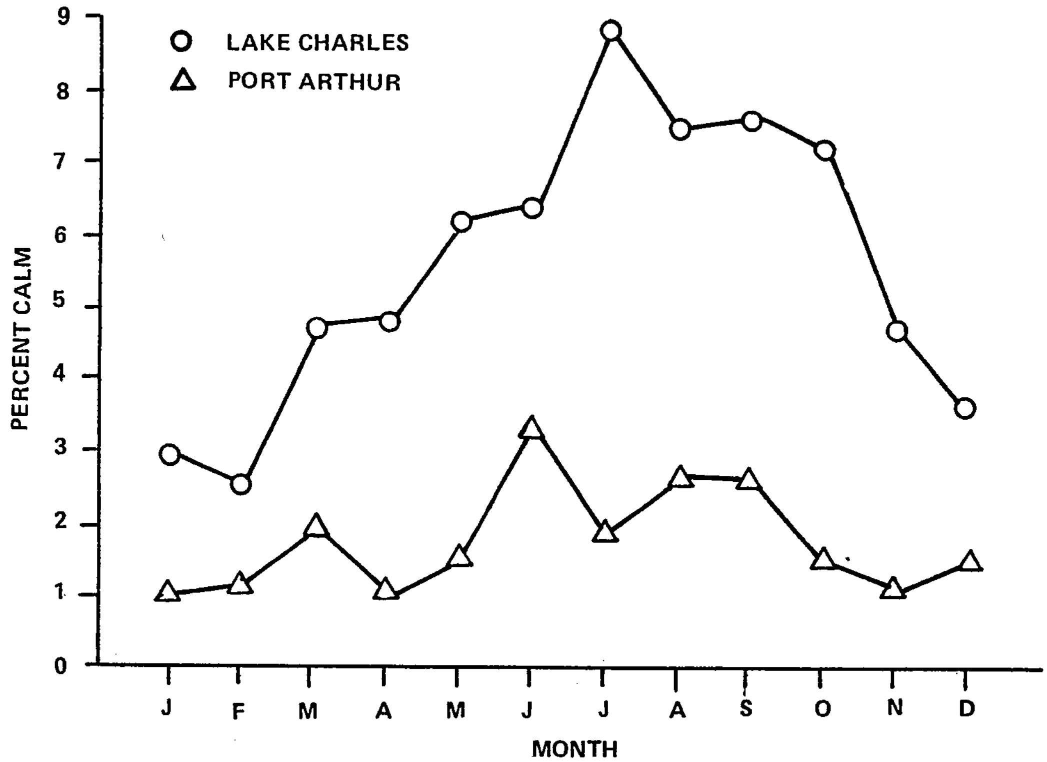

Figure 2.2. Monthly percentage calm at Lake Charles[17](5/42-10/44, 10/45-9/53) and Port Arthur[18](1/59-12/63)

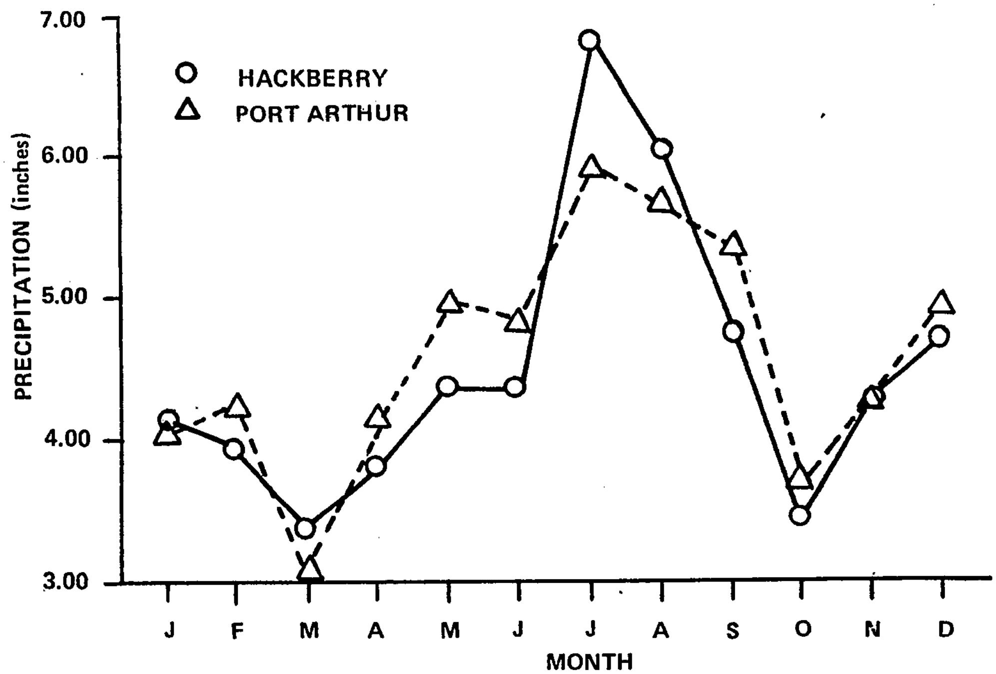

Figure 2.3. Monthly normal precipitation at Hackberry[21] and Port Arthur[16] (1941-1970)

with monthly normal temperatures in the low to mid 80^{o}'s (Figure 2.4), normal July rainfall of six inches and average relative humidity of 65 percent at noon. As illustrated in Figure 2.5, thunderstorm 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.[14]

Wind rose data for Lake Charles[19] and Port Arthur[20] are illustrated in Figure 2.6. The annual percent frequency of winds by speed groups for Lake Charles[17] and Port Arthur[18] 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 100 mph for a 100 year recurrence interval.[22]

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.[23]

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.[24]

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.[25] 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.[25]

Severe storm statistics within two 50 nautical mile strips (57.6 statute mile strips) of Louisiana coastline surrounding West Hackberry[26] are summarized in Table 2.4.

2.3.2 Existing Air Quality

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

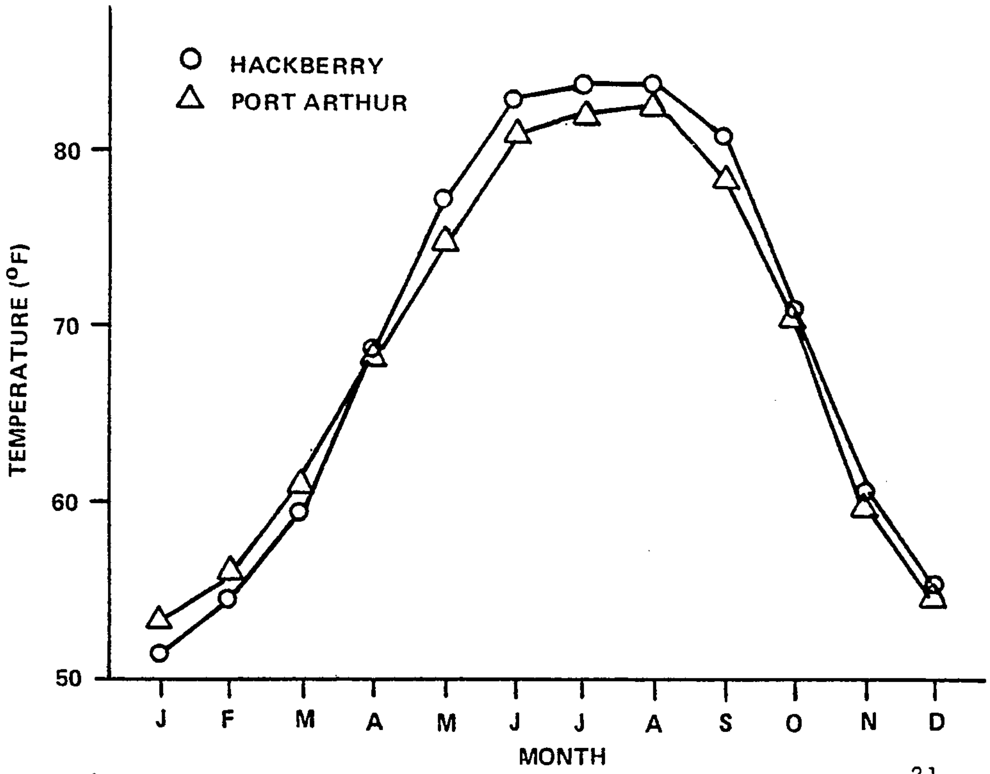

Figure 2.4. Monthly normal temperatures at Hackberry[21] and Port Arthur[16] (1941-1970)

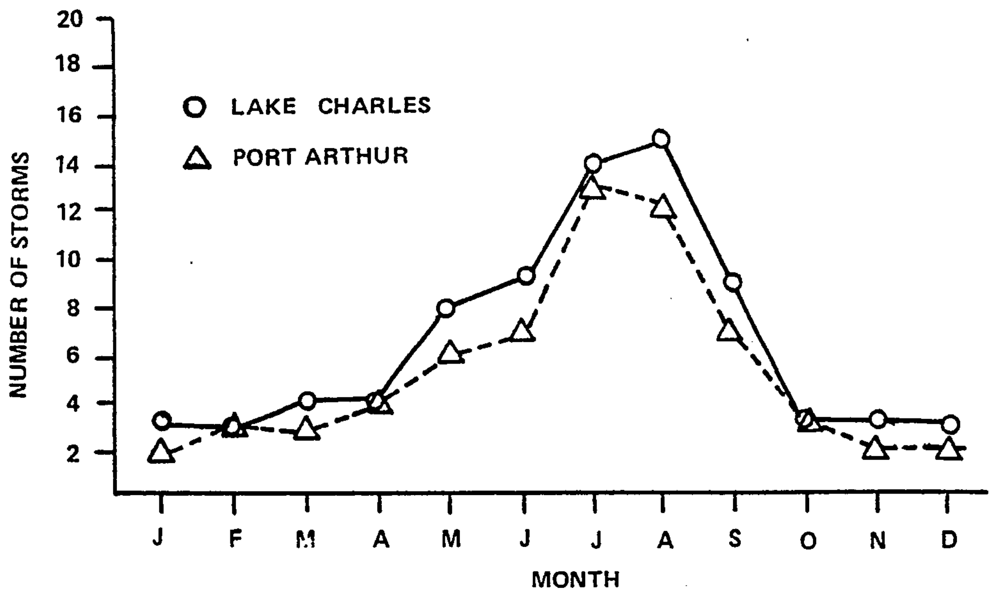

Figure 2.5. Average number of thunderstorms per month at Lake Charles[15] (1962-1975) and Port Arthur[15] (1954-1975)

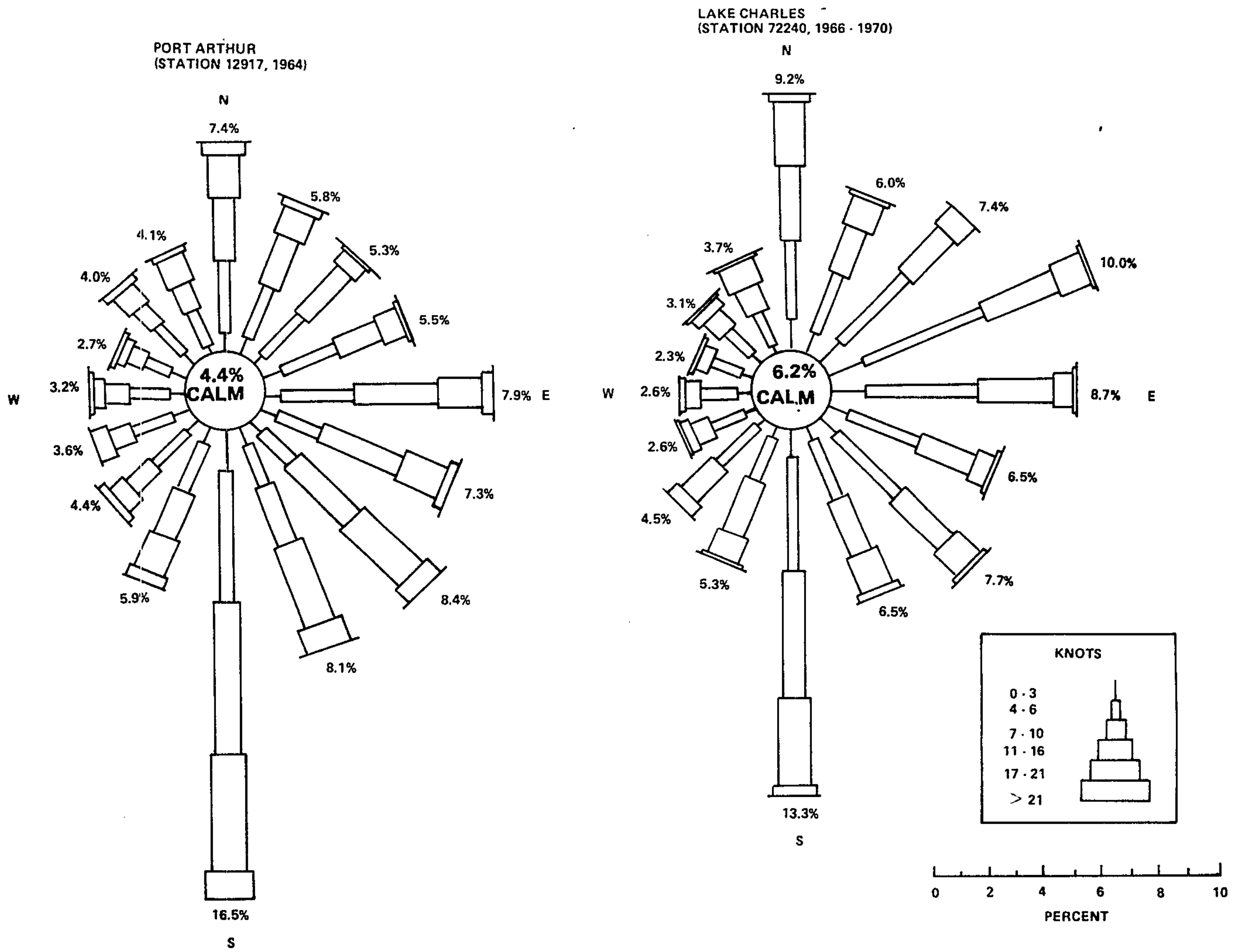

Figure 2.6 Annual wind rose data for Lake Charles[19] (1966-1970) and Port Arthur[18] (1964)

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 West Hackberry[26]

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 western 50 miles and the eastern 50 miles in sequence, which surround West Hackberry on the west and east, respectively.

Definitions:

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

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

In compliance with the Federal Clean Air Act, the states of Louisiana and Texas have initiated Implementation Plans[27,28] 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 SPR 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 Louisiana 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 West Hackberry are located in the highly industrialized area 20-22 miles to the northeast, 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 West Hackberry salt dome is in Cameron Parish, and is 3 miles south of the border of Calcasieu Parish. Cameron Parish is a marsh dominated area. Calcasieu Parish is essentially dry land, and it is more industrialized and urbanized than Cameron Parish. The measure of emissions in tons/year[27] is not convenient for comparison, so 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. Included is 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. In Calcasieu Parish, high emissions come from petroleum refineries. Petrochemical plants alone contribute greater than 95 percent of the total parish sulfur

Table 2.5 Federal Ambient Air Quality Standards

Pollutant	Primary Standard	Secondary Standard
Particulates:		
Annual Geometric Mean	$75\mu g/m^3$	$60\mu g/m^3$
24-hour Maximum	$260\mu g/m^3$	$150\mu g/m^3$
Sulfur Dioxides:		
Annual Arithmetic Mean	$80\mu g/m^3$ (0.03 ppm)	$60\mu g/m^3$ (0.02 ppm)
24-hour Maximum	$365\mu g/m^3$ (0.14 ppm)	$260\mu g/m^3$ (0.10 ppm)
3-hour Maximum		$1300\mu g/m^3$ (.5 ppm)
Sulfur Acid Mist and/or Sulfur Trioxide:		
24-hour Maximum	$12\mu g/m^3$	
1-hour Maximum	$30\mu g/m^3$	
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	$160\mu g/m^3$ (0.08 ppm)	$160\mu g/m^3$ (0.08 ppm)
4-hour Maximum	$98\mu g/m^3$ (0.05 ppm)	$98\mu g/m^3$ (0.05 ppm)
Hydrocarbons (non-methane):		
3-hour Maximum	$160\mu g/m^3$ (0.24 ppm)	$160\mu g/m^3$ (0.24 ppm)
Nitrogen Dioxide (NO_2):		
Annual Arithmetic Mean	$100\mu g/m^3$ (0.05 ppm)	$100\mu g/m^3$ (0.05 ppm)

$\mu g/m^3$ = 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 CHARLES	
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.

oxide emissions. The combination of petroleum refineries, and petrochemical and chemical plants accounts for greater than 70 percent of the total Calcasieu Parish point source emissions of hydrocarbons and particulates. Cameron Parish is shown to be a very "clean" parish with regard to air quality. This is also true of the vicinity of West Hackberry.

A large portion of the hydrocarbon emissions associated with the Hackberry SPR 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.[28]

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 standard). 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 are probably due 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

2.4 SPECIES AND ECOSYSTEMS

In addition to the major ecological areas surrounding the West Hackberry Storage Site, described in FES 76/77-4, the pipeline route would cross several other habitat types. The following is a synopsis of all habitat types the pipeline would impact:

	Louisiana	Texas
Prairie	X	X
Marsh		
Brackish	X	X
Intermediate	X	X
Fresh	X	X
High	-	X
Waterway banks & ridges	X	X
Transferred material	X	X
Inland & estaurine waters	X	X
Oak-Gum Cypress	-	-
Mixed Hardwoods	-	X
Urban and Industrial	-	X

2.4.1 Marsh Ecology

Comparative Marsh Ecology - Louisiana

The area of southwestern Louisiana that would be impacted by the pipeline construction is included in Hydrologic Unit IX, the western half of the Chenier Plain Zone.[29] Hydrologic Unit IX includes all of the southwest Louisiana marsh zone west of Calcasieu Lake. The acreages of different habitat types in Hydrologic Unit IX are shown in Table 2.11, demonstrating the predominance of marshland* and water bodies and the absence of swampland* in the area. Chabreck,[29] who based his classification on one reported by Penfound and Hathaway,[30] subdivided the Louisiana coastal marshes into four vegetation types, based mainly on the salinity of the surface waters. The four marsh types and their average salinities and ranges of salinities, according to Chabreck[31] are as follows:

*Swamps are distinguished from marshes by the presence of trees compared to the predominance of grasses and sedges which characterize marsh vegetation.

Table 2.11 Acreages Contained in Habitat Types of Hydrologic Unit 9 of the Louisiana Coastal Region.

Surface Feature	Vegetative Type					
	Saline	Brackish	Intermediate	Fresh	Non-marsh	Total
	Acres					
Marshes:						
Natural marsh	6,455	84,073	91,658	30,176	---	212,362
De-watered marsh	---	---	---	---	39,858	39,858
Water Bodies:						
Ponds and lakes	---	178,958	30,176	19,418	---	228,552
Bays and sounds	---	---	---	---	---	---
Bayous and rivers	---	1,227	1,360	675	---	3,262
Canals and ditches	---	1,675	1,880	300	---	3,855
Swamp	---	---	---	---	---	---
Dry Land[a]	---	---	---	---	51,746	51,746
TOTAL	6,455	2,65,933	125,074	50,569	91,604	539,635

[a]Includes active beaches, cheniers, spoil deposits, ridges and elevated bayou and lake banks.

Source: Chabreck, R. H., 1972. Vegetation, Water and Soil Characteristics of the Louisiana Coastal Region, Bulletin No. 664, Louisiana State University, Agricultural Experiment Station, 72 pp.

Marsh Type	Avg. Water Salinity(ppt)	Salinity Range(ppt)
Fresh Marsh	1.5	0 - 4.0
Intermediate Marsh	3.3	2.0 - 6.0
Brackish Marsh	8.1	3.0 - 18.0
Saline Marsh	15.9	6.0 - 29.0

The soil and water chemical characteristics for the four different marsh vegetation types in Hydrologic Unit IX are shown in Table 2.12. Marshes closest to the coast generally have the highest salinities, with the salinity levels decreasing as one proceeds inland. However, exceptions to this rule are fairly numerous, especially along drainage systems. In the Chenier Plain zone, 165 miles or 75% of the ICW, is marsh bordered. The distribution of the different vegetation types along the ICW in the Chenier Plans Zone is given in Table 2.13. Most of the route of the ICW lies within the freshwater zone with salinities of less than 0.5 ppt.[1]

Chabreck[29] gives the percent coverage* for the vegetation of the four marsh types found in Hydrologic Unit IX of the Louisiana coastal marshes. These values for the saline, brackish, intermediate and fresh marshes are 82.34, 65.12, 68.19, and 71.03 percent, respectively. Table 2.14 shows the species composition for these same marsh types and area.

Two prominent features which emerge from these tables are the higher standing crop and lower species diversity of the saline marshes in comparison with the other types. Chabreck[31] lists 93 species for the freshwater marsh, making it the most diverse.

In Hydrologic Unit IX, as is seen from the tables, saline marshes are dominated by Batis maritima, maritime saltwort, (20%), Distichlis spicata, salt grass, (55%), and Spartina alterniflora, smooth cordgrass, (24%). Brackish marshes are dominated by Spartina patens, salt marsh cordgrass, (60%), with a number of other species (Bacopa monnieri, Monnier's hedge hyssop, Distichlis spicata, Paspalum vaginatum, and Scirpus olney, Olney bulrush), each comprising between 5 and 10 percent of the cover. Intermediate marshes are also dominated by Spartina patens (47%) with Paspalum vaginatum (13%) next in importance, and a number of other species, Phragmites communis (common reed), Sagittaria falcata (bull tongue), Scirpus californicus (giant bulrush), and Scirpus olneyi, all contributing between 4 and 7% cover. Intermediate marshes usually occur as narrow bands between brackish and fresh marshes. Due to salinity changes in the southwestern Louisiana area (salt intrusion) related to man's activities (channel modifications and ground water consumption) the intermediate marshes are shifting inland.

*Percent coverage refers to the degree to which a marsh is covered with vegetation. 100% minus % cover = % unvegetated marsh area.

Table 2.12 Soil and Water Chemical Characteristics of the Marsh Vegetative Types in Hydrologic Unit 9.

FRESH MARSH

Variable	No. of Samples	Mean	Standard Deviation	Range
Water salinity (ppt)	6	1.27	.89	.33 - 2.89
Total soil salts (ppt)	3	1.60	1.32	.27 - 2.92
Organic matter (%)	3	11.92	8.07	6.14 - 21.14
Nitrogen (%)	3	.54	.38	.27 - .98
C/N ratio	3	12.58	.34	12.51 - 13.18
Phosphorus (ppt)	3	.03	.02	.009 - .06
Potassium (ppt)	3	.14	.12	.06 - .29
Calcium (ppt)	3	.71	.60	.04 - 1.22
Magnesium (ppt)	3	1.04	.29	.75 - 1.35
Sodium (ppt)	3	1.00	.16	.81 - 1.10
pH	3	5.60	.60	5.00 - 6.20

INTERMEDIATE MARSH

Variable	No. of Samples	Mean	Standard Deviation	Range
Water salinity (ppt)	10	2.43	1.45	.90 - 6.04
Total soil salts (ppt)	11	5.12	4.52	.55 - 16.53
Organic matter (%)	11	28.35	22.51	2.60 - 69.19
Nitrogen (%)	11	1.05	.53	.39 - 2.20
C/N ratio	11	15.62	4.49	8.19 - 24.14
Phosphorus (ppt)	11	.01	.01	.002 - .05
Potassium (ppt)	11	.16	.09	.05 - .31
Calcium (ppt)	11	.63	.42	.13 - 1.45
Magnesium (ppt)	11	1.30	.72	.40 - 3.06
Sodium (ppt)	11	2.20	1.50	.42 - 5.88
pH	11	5.78	.38	5.30 - 6.30

BRACKISH MARSH

Variable	No. of Samples	Mean	Standard Deviation	Range
Water salintiy (ppt)	21	6.41	4.38	.49 - 15.79
Total soil salts (ppt)	21	6.60	3.11	1.48 - 12.56
Organic matter (%)	21	18.93	10.48	7.65 - 52.05
Nitrogen (%)	21	.72	.30	.27 - 1.49
C/N ratio	21	14.74	2.49	10.50 - 20.26
Phosphorus (ppt)	21	.03	.03	.004 - 1.29
Potassium (ppt)	21	.32	.14	.11 - .59
Calcium (ppt)	21	.51	.33	.12 - 1.28
Magnesium (ppt)	21	1.37	.35	.78 - 2.10
Sodium (ppt)	21	3.34	1.23	1.27 - 5.68
pH	21	6.16	.36	5.20 - 6.80

Table 2.12 (Continued)

SALINE MARSH

Variable	No. of Samples	Mean	Standard Deviation	Range
Water salinity (ppt)	--	--	--	---
Total soil salts (ppt)	1	3.07	--	3.07 - 3.07
Organic matter (%)	1	2.14	--	2.14 - 2.14
Nitrogen (%)	1	.06	--	.06 - .06
C/N ratio	1	20.66	--	20.66 - 20.66
Phosphorus (ppt)	1	.13	--	.13 - .13
Potassium (ppt)	1	.29	--	.29 - .29
Calcium (ppt)	1	7.28	--	7.28 - 7.28
Magnesium (ppt)	1	3.22	--	3.22 - 3.22
Sodium (ppt)	1	2.55	--	2.55 - 2.55
pH	1	7.70	--	7.70 - 7.70

Source: Chabreck, R. H., 1972. Vegetation, Water and Soil Characteristics of the Louisiana Coastal Region, Bulletin No. 664, Louisiana State University, Agricultural Experiment Station, 72. pp.

Table 2.13 Distribution of Plant Communities along the Gulf Intracoastal Waterway and Associated Waterways, Chenier Plain Zone, Louisiana.

Zone	Marsh			Bottomland Forest/ Swamp	Cleared/ Cultivated Lands	Urban Industrial Areas
	Fresh	Intermediate	Brackish			
Miles of Canal Bordered	100.2	28.3	36.7	4.3	49.1	0.4
% of Canal Bordered	45.7%	12.9%	16.8%	2.0%	22.4%	0.2%

Source: U.S. Army Corps of Engineers, Gulf Intracoastal Waterway, Petit Anse, Tigre and Carlin Bayous; and Bayou Grosse Tete, Louisiana, New Orleans District, New Orleans, Louisiana, Draft Environmental Statement 1975.

Table 2.14 Species Composition of Marsh Types[a] Within Hydrologic Unit 9 of the Louisiana Coastal Marshes.

Species	Vegetative Type: Saline	Brackish	Intermediate	Fresh
	---------- Percent	----------	----------	----------
Acnida alabamensis	--	--	1.21	--
Alternanthera philoxeroides	--	--	2.24	25.87
Bacopa monnieri	--	5.33	2.49	2.99
Batis maritima	20.24	--	--	--
Cynodon dactylon	--	--	--	2.99
Daubentonia texana	--	--	--	1.29
Distichlis spicata	54.66	8.96	--	1.99
Echinochloa walteri	--	--	--	2.19
Eleocharis sp.	--	--	--	8.46
Juncus effusus	--	--	3.00	--
Leptochloa fascicularis	--	--	--	1.99
Numphaea odorata	--	--	--	1.99
Paspalum vaginatum	--	7.22	13.29	5.77
Ruppia maritima	--	1.18	--	--
Phragmites communis	--	--	3.97	--
Sagittaria falcata	--	--	4.59	22.88
Scirpus californicus	--	--	6.73	4.98
Scirpus olneyi	--	6.99	6.21	--
Scirpus robustus	--	2.49	1.21	--
Sesbania exaltata	--	--	2.07	--
Setaria glauca	--	1.38	--	--
Spartina alterniflora	24.29	--	--	--
Spartina patens	--	59.81	46.83	7.96
Spartina spartineae	--	1.58	1.73	--
Stricularia cornuta	--	--	--	3.98
Other species[b]	.81	5.06	4.43	2.68

[a]Includes only natural marshes.

[b]Includes only plants making up less than 1.00 percent of the species composition.

Source: Chabreck, R. H., 1972. Vegetation, Water and Soil Characteristics of the Louisiana Coastal Region, Bulletin No. 664, Louisiana State University, Agricultural Experiment Station, 72 pp.

The fresh marshes have Alternanthera philoxeroides, alligator-weed, (26%) and Sagittaria falcata (23%) as co-dominants with secondary species (5-10%) including Eleocharis sp., spikerush, Paspalum vaginatum, Scirpus californicus, and Spartina patens.

2.4.2 Rare and Endangered Species of the Study Area - Louisiana

The following information on the Bald Eagle and Red Wolf supplements material already mentioned in the West Hackberry Final Environmental Statement for these and other officially designated "endangered" species.

An official of the U. S. Fish and Wildlife Service states that the Bald Eagle has been sighted on numerous occasions along the Sabine River, south of Orange, Texas.[33] These birds were mostly immature individuals and no official sightings of nesting birds have been recorded for the area. The last confirmed nests of this species along the Sabine River was in the early 1950's.

There are currently fewer than 100 Red Wolves (Canis rufus) left in Jefferson, Chambers, and Southern Liberty Counties in Texas and Cameron and Calcasieu Parishes in Louisiana. The U. S. Fish and Wildlife Service is currently trapping wolves in these counties in order to breed and later introduce individuals to areas outside Texas and Louisiana.[34] They are not being reintroduced back into these states because cross-breeding with coyotes in the area is eradicating the wolf as a pure species. In addition, human disturbance in coastal areas is reducing the amount of suitable habitat currently available to the animals.

Some bird species are considered "rare" for the marsh area near West Hackberry Dome.[32] These species appear on no state or federal lists as protected species, but their occurrence in the area is important because they give indications of the uniqueness of the local environment. There have been several sightings of uncommon species in the Gum Cove area south of the Intracoastal Waterway. Among these are the Greater Kiskadee and White-winged Dove whose presence in the area represents the northermost extent of their range. Also sighted frequently in this area is a pheasant-like bird, the Black Francolon, which is not native to the U. S., but has established a breeding population in the higher ground of the Cove. Another bird, Audubon's Caracara, has been sighted 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 a permanent resident. For some unknown reasons two birds, the Fish Crow and Olivaceous Cormorant, are very abundant around the Sabine River and Sabine Lake all winter and are absent for many miles to the east and west.

2.4.3 Gulf Intracoastal Waterway Banks and Transferred Material - Louisiana

History and Physical Conditions

At most locations along the ICW, the banks and adjoining land have been and/or are presently being used as disposal areas for material dredged from the waterway. In the 24 mile section from Calcasieu River to Sabine River, the disposal areas are more extensive than most locations along the ICW due to the fact that this portion of the waterway was originally deep dredged to a depth of 50 feet. Disposal areas occurring along this reach average approximately 120 acres per mile, while the average for the ICW as a whole is 40-60 acres per mile.

However, because this 50 foot channel depth is no longer required, there has been no material dredged from or deposited on the banks of the ICW in this area for at least the last 30 years.[13] In addition, no need for dredging is anticipated for the next 20 or so years.[35] The disposal areas along the ICW in this section are shown in Figure 2.7 along with the habitat types of the adjoining landscape. The total spoil acreage represented for this section of the ICW is 2892 acres; Table 2.15 shows the proportion of this total acreage bordered by the various habitat types in the region.

While not presently in use, the U. S. Army Corps of Engineers is holding these and other areas as potential disposal sites for the future. In fact current dredge material disposal easements along the ICW from Calcalsieu River to the Sabine River total 6612 acres.

Disposal areas along the ICW (Figure 2.7) which would be included in the proposed pipeline route extend from the junction of Alkali Ditch with ICW approximately 8.8 miles along the ICW to the Gum Cove Ferry Road intersection with the waterway on Gum Cove Ridge. The disposal areas begin again from approximately 1/4 mile west of Black Bayou Cutoff to the Calcasieu-Cameron Parish line.

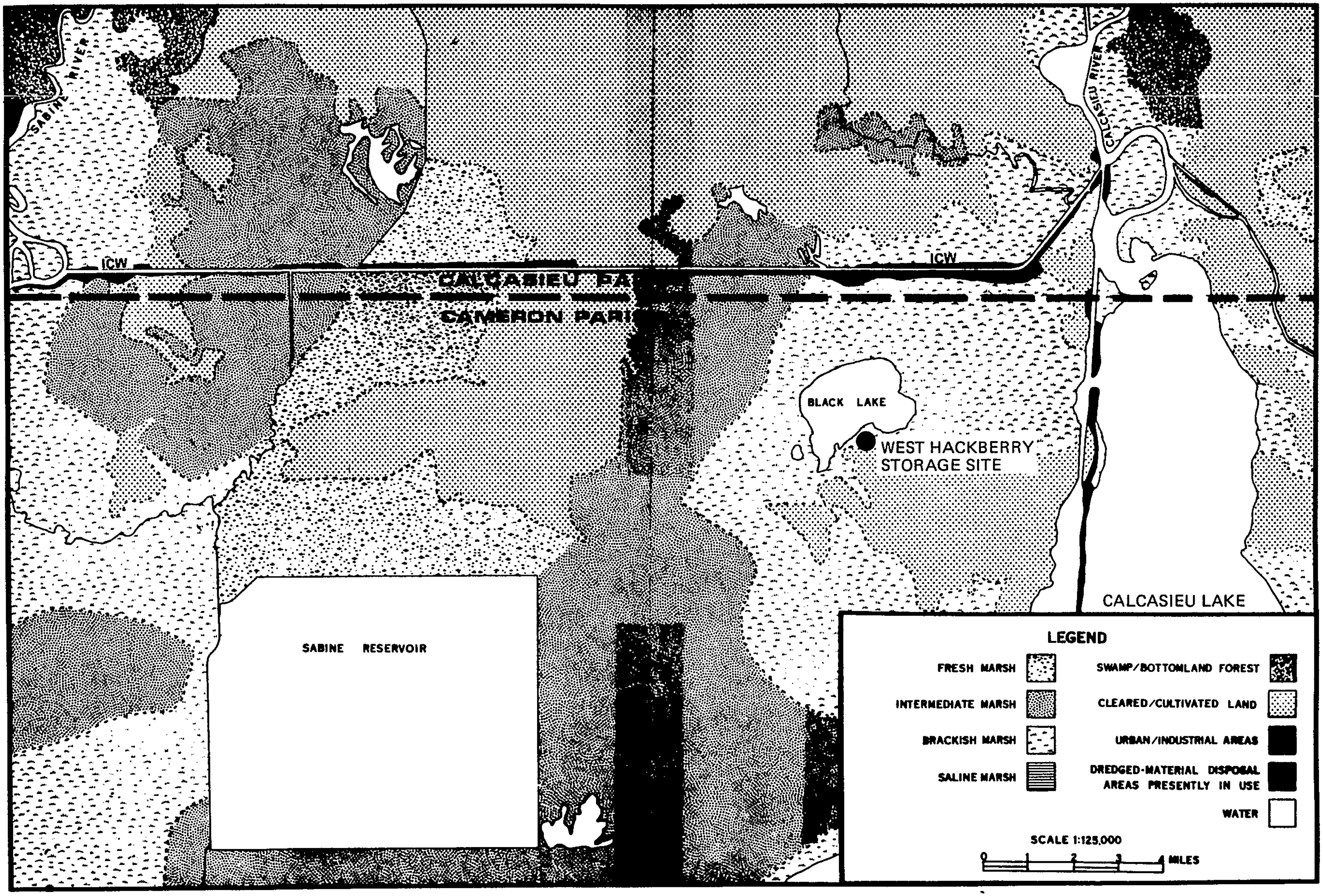

Figure 2.7 Area surrounding the West Hackberry Storage Site with associated habitat types, including dredged-material disposal sites presently in use by the U.S. Corp of Engineers. These disposal areas are ones that were used in the past and for which, the Corp retains easement rights, but are not necessarily presently in active use.

Table 2.15 Disposal Areas in Use Along the ICW by Plant Community for the Calcasieu River to Sabine River Section (24 miles)

GULF INTRACOASTAL WATERWAY	Length of Reach (miles)	Fresh Marsh	Inter-mediate Marsh	Brackish Marsh	Swamp Bottomland Forest
Calcasieu River to Sabine River	24.0	285	1388	903	------

Cleared/ Cultivated Land	All Communities	Average Per Mile of GIWW
316	2892	120.5

Source: U.S. Army Corp of Engineers, 4 Nov. 1975, "Maintenance Dredging, Sabine-Neches Waterway, Texas," Galveston District, Galveston, Texas. Final Environmental Statement.

The route passes from the Calcasieu-Cameron Parish line along the east bank of the Sabine River/ICW until it crosses the Sabine River into Texas, 1.1 river miles above the confluence of Cow Bayou and Sabine River. This bank also includes transferred material that has a history similar to that in Calcasieu Parish, with apparently little disturbance since the waterway was first constructed. The area is not one of the disposal areas proposed by the Army Corp of Engineers[11] for their Sabine-Neches Waterway Maintenance dredging, therefore, little disturbance of this nature is anticipated for the immediate future. This area is shown in Figure 2.8.

The width of the spoil bank along this section of the ICW varies from approximately 100 feet to 1/4 mile, with little or no spoil being deposited along the section passing through the western portion of Gum Cove Ridge. Relief of the spoil banks varies from a few feet above sea level to approximately 18 feet above sea level.

Vegetation

The vegetation on the banks of the ICW 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 mowed.

Dredged material areas support a wide range of species, particularly pioneer species which invade disturbed sites. Taller vegetation in these areas include 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 ICW disposal areas are eastern baccharis, marsh elder, and elderberry (Sambucus canadensis). Common ground cover species along the ICW are blackberry (Rubus duplaris), roseau, ironweed (Sida rhombifolia), broomsedge (Andropogon virginicus), giant ragweed (Ambrosia trifida), common ragweed (Ambrosia artemisiifolia), and camphorweed (Pluchea camphorata). Low-lying disposal areas bordering marshlands often support thick carpets of alligatorweed (Alternanthera philoxeroides) with typical marsh species interspersed.

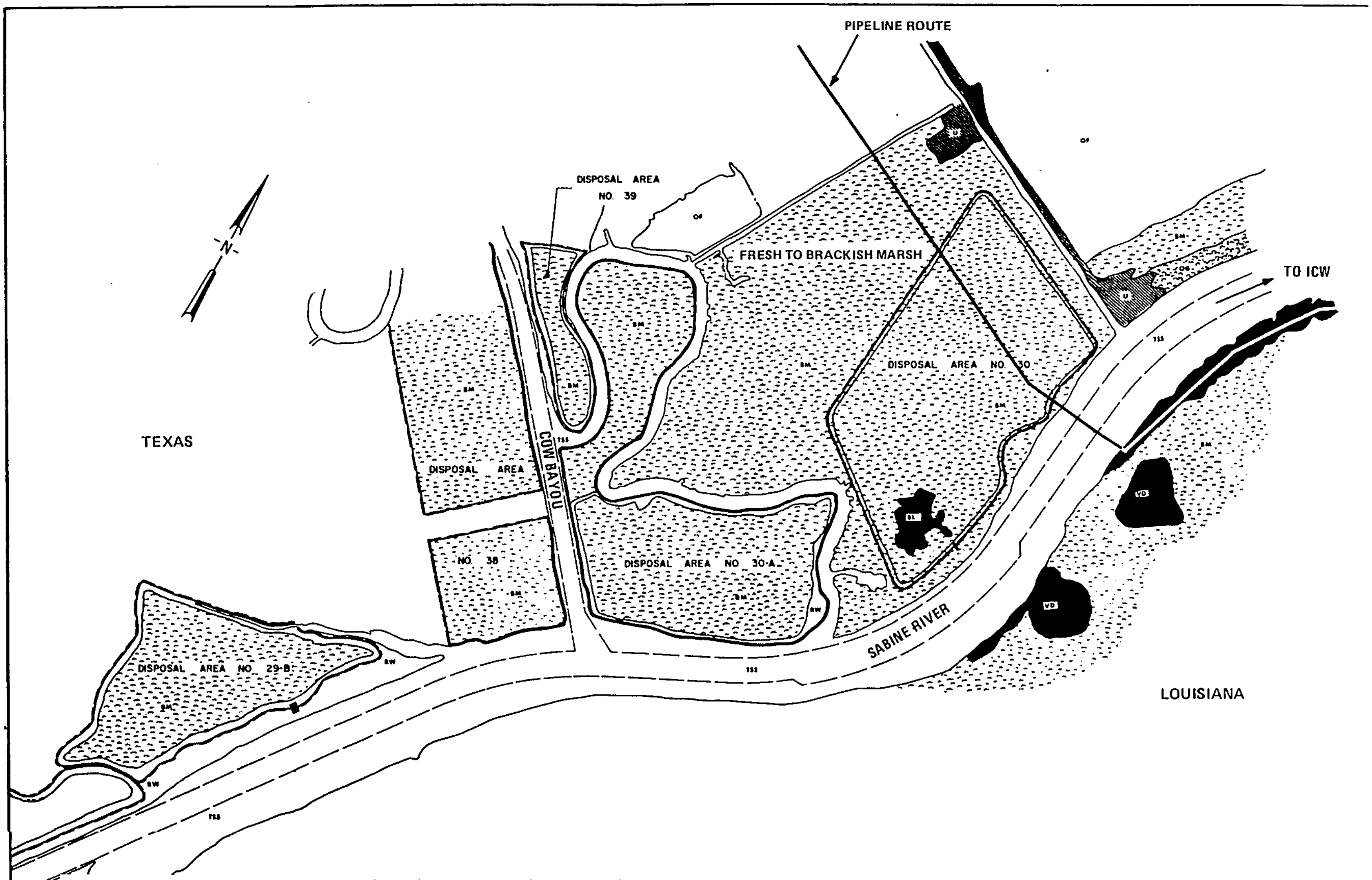

Figure 2.8 Area map for pipeline route in the vicinity of crossing of the Sabine River, showing U. S. Army Corp dredge disposal areas and waterway spoil banks (in black).

Source: U.S. Army Corp, Galveston District. Final Environmental Statement, Maintenance Dredging Sabine-Neches Waterway, Texas

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Old dredge material embankments bordering brackish to intermediate marsh supports vegetation different from the marsh itself, 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 patens), Bermuda grass (Cynodon dactylon), blackberry and roseau, while similar sites in the intermediate marsh are dominated by eastern baccharis and to a lesser extent hog cane (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 ICW, with willow invasion common in some areas where water levels are decreasing. Although black willow dominates most ICW disposal areas in fresh marsh situations, tallow tree (Sapium sebiferum) often dominates some of the better-drained disposal areas in the Chenier Plain Zone. In areas of the ICW bordering on bottomland forest, the willows often dominate a narrow band between the canal and the forest.

Some dredged material disposal areas along the ICW 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.

Appendix F contains a list of plant species found in the Sabine-Neches Waterway area. Representatives of almost all of the terrestrial habitat types (including marshes) are found along the ICW.

As mentioned previously, from 1000 feet west of Black Bayou Cutoff to Nederland, Texas, the route parallels a right-of-way maintained by the Colonial Pipeline Company. In these areas, vegetation is kept in an early state of succession by periodic mowing to maintain accessability to the pipeline. However, the pipeline would not lie within the confines of the maintained right-of-way and, therefore, disturbances in this reach would not differ from those in the area where no present right-of-way exists.

2.4.4 Species and Ecosystems - Texas

Introduction and Vegetation Types

The majority of the pipeline route in Texas would pass through or very near to the Sabine-Neches Waterway in Orange County. This area through which the pipeline would pass is a mosaic of marshland (fresh, fresh to brackish or intermediate and high marsh) with accompanying bayous and channels, grassy plains, which have, for the most part, been converted to cropland(rice and soybeans) or pastureland, and several woody associations, including pine-hardwood, oak-gum-cypress and mixed hardwoods. The right-of-way would also pass through several waterway banks and ridges as well as urban and industrial areas. Three major running water systems are also traversed in the route. These are the Sabine River 1.1 river miles north of the confluence of Cow Bayou and Sabine River, the Neches River at Nederland, Texas, and Cow Bayou at the northwest end of Bridge City, Texas. All three are classified, as tidal in the areas of pipeline crossing, but are fresh further north. Table 2.16 provides data on the areal coverage and species diversity of the aforementioned habitat types in the Sabine-Neches Waterway, and those species listed as rare or endangered in the Texas Rare and Endangered Plant List are shown in Table 2.17. An extensive list of plant species for each habitat is provided in Appendix K.

Orange County, Texas is located in a transition area between the coastal marsh vegetation to the south and the upland pines and hardwoods to the north. The county is bounded on the south and west by the Neches River and on the east by the Sabine River.. The entire land area of the county is included in the drainage network of these two rivers which become nontidal (freshwater) in the northern part of the county. In the tidal reaches of these rivers and their major tributaries (Cow Bayou) the vegetation consists of brackish to fresh marshes, with a scattering of cypress-tupelo swamps and pine (loblolly)-hardwood vegetation along

TABLE 2.16 Data on Plant Composition and Coverage of the Plant Communities and Habitat of the Sabine-Neches Waterway

Habitat Type	Areas: Size (acres) Disposal	Areas: Size (acres) Adjacent	Areas: Percent Disposal	Areas: Percent Adjacent	Plants: Species (numbers)	Plants: Families (numbers)
Open freshwater	0	178	0.0	0.3	17	13
Tidal streams and rivers	14	11,140	0.1	14.6	8	3
Bays	4,379	1,462	21.7	1.9	6	3
Freshwater streams	0	88	0.0	0.1	14	13
Submerged vegetation	22	45	0.1	0.1	12	12
Floating vegetation	0	0	0.0	0.0	11	8
Salt marsh	1,568	1,986	7.8	2.6	29	10
Fresh-to-brackish marsh	3,312	46,221	16.4	60.4	27	9
Freshwater marsh	2,133	8,266	10.5	10.8	58	27
High marsh	358	313	1.8	0.4	41	16
Bare or lightly vegetated transferred material	5,116	296	25.3	0.4	50	24
Heavily vegetated transferred material	724	1,153	3.6	1.5	50	24
Ridges, waterway banks, and walkways	1,488	785	7.3	1.0	83	36
Pine and hardwood	203	333	1.0	0.4	62	28
Oak-gum-cypress	708	3,450	3.5	4.5	43	25
Mixed hardwoods on ridges and strandplains	95	253	0.5	0.3	19	13
Coastal prairie	0	0	0.0	0.0	24	6
Irrigated crops	0	0	0.0	0.0	6	4
Beach, sand, and shell	42	448	0.2	0.6	...	...
Urban and industrial	33	0	0.2	0.0	47	24

Source: U.S. Army Corp of Engineers, Galveston District. Final Environmental Statement, Maintenance Dredging Sabine-Neches Waterway, Texas.

TABLE 2.17

PLANTS ON TEXAS RARE AND ENDANGERED PLANT LIST
WHICH ARE FOUND IN THE SABINE NECHES AREA

Common Name	Scientific Name	State Range
Quillwort	Isoetes melanopoda	Eastern half of Texas
Broad beech fern	Thelypteris hexagonoptera	Timber belt of east Texas
Fingergrass	Chloris texensis	Coastal prairies, Rio Grande plains
Beak-rush	Rhynchospora macra	Eastern Texas
Beak-rush	Rhynchospora filifolia	Eastern Texas
Sedge	Carex gigantea	Eastern and southeastern Texas
Sedge	Carex stricta	Eastern Texas
Sedge	Carex physorhyncha	Eastern, southeastern, and north-central Texas
Sedge	Carex atlantica	Eastern and southeastern Texas
White sheath sedge	Carex hyalina	Eastern Texas
Wingseed	Carex alata	Eastern Texas
Sedge	Carex albolutescens	Eastern and southeastern Texas
Bush palmetto	Sabal minor	Eastern Texas, west to Edwards Plateau and south to Aransas County
Yellow sunny-bell	Schoendirion texanum	Western edge of southeastern Texas
Yellow sunny-bell	Schoendirion croceum	Southeastern Texas
Dog's tooth-violet	Erythronium rostratum	Eastern Texas
Great Solomon's seal	Polygonatum biflora	Eastern and north-central Texas
Yellow ladys-slipper	Cypripedium calceolus	Eastern Texas
Whorled pogonia	Isotria verticillata	Eastern Texas
Bearded grass-pink	Calopogon barbatus	Eastern Texas
Oval ladies' tresses	Spiranthes ovalis	North-central and east Texas
Corkwood	Leitneria floridana	Southeastern and south-central Texas
Nutmeg hickory	Carya myristicaeformis	Eastern Texas
Virginia dutchman's pipe	Aristolochia serpentaria	Edwards Plateau and eastern Texas
Bloodroot	Sanguinaria canadensis	Eastern Texas
Grass-of-Parnassus	Parnassia asarifolia	Eastern Texas

TABLE 2.17 (Continued)

Common Name	Scientific Name	State Range
Red chokeberry	*Pyrus arbutifolia*	Eastern Texas
Silky camellia	*Stewartia Malacodendron*	Eastern Texas
Water-purslane	*Peplis diandra*	Eastern Texas
Indian-pipe	*Montorpa uniflora*	Eastern Texas
Shooting-star	*Dodecatheon Medadio*	Eastern third of Texas
Gromwell	*Lithospermum tuberosum*	Eastern Texas
False foxglove	*Aureolavia dispersa*	Southeastern Texas
Butterweed	*Senecio glabellus*	Eastern Texas

Source: University of Texas Rare Plant Study Center, *Rare and Endangered Plants Native to Texas*, Austin, Texas, 1974.

U. S. Department of Army, Corps of Engineers, *Trinity River and Tributaries, Texas*. Progress Report, Fort Worth, Texas, 1975.

the less saline reaches. As the rivers become fresh in the north and topography becomes steeper, the predominantly marsh vegetation gives way to bottomland forest mixed with cypress-tupelo swamps in the more permanently inundated areas, while the adjoining uplands contain a wide array of pine and hardwood vegetation. Transition areas from the bottoms to the uplands have been extensively cleared and used for pasture and crops (rice and soybeans). Figure 2.9 is a generalized vegetation map of Orange County, Texas. More detailed delineation of the vegetation along the pipeline route in Texas is shown in Figure 2.10 (Sabine River to Cow Bayou) and Figure 2.11 (Cow Bayou to Nederland, Texas).

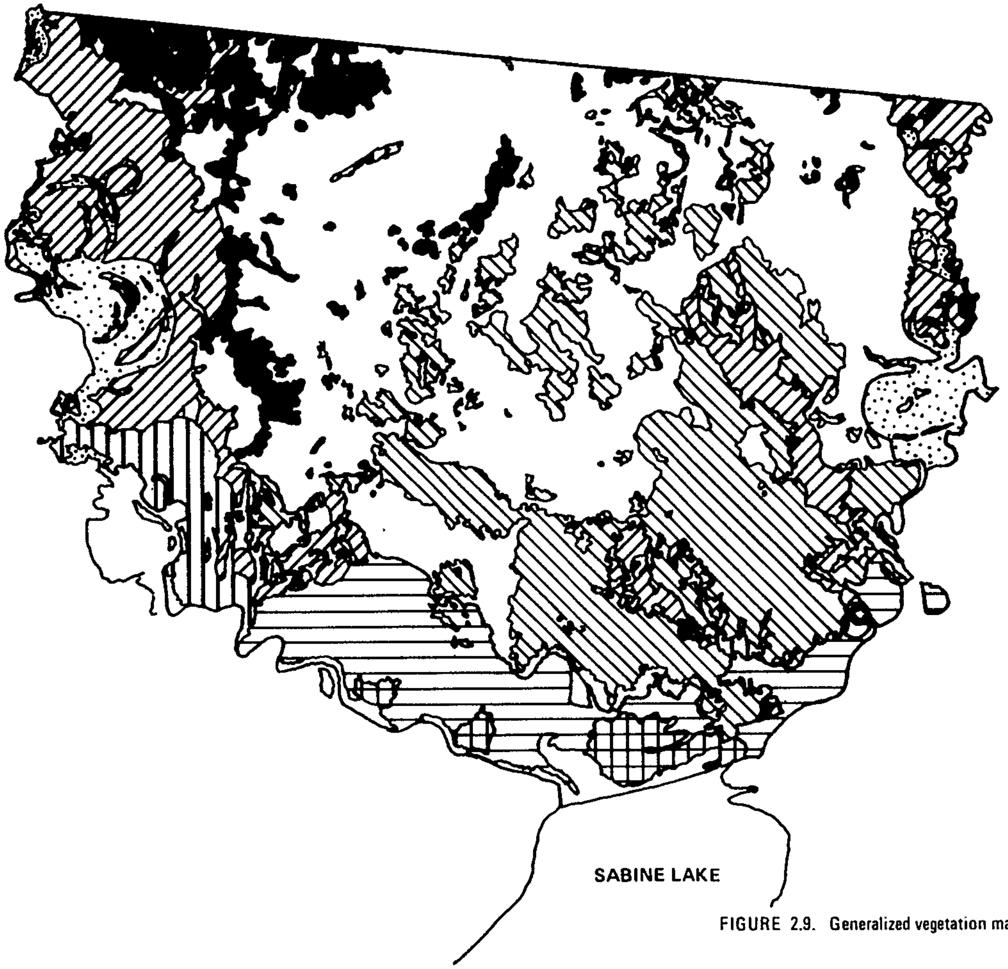
Marsh vegetation and ecology have been discussed in the West Hackberry FES (Section 2.4.2) and in this supplement (Comparative Marsh Ecology) for the southwest Louisiana area. The marshes of Southwest Louisiana and Southeast Texas are very similar. Figure 2.12 is a schematic profile of marsh-swamp vegetation as it grades from open salt water to the interior uplands of the Sabine-Neches Waterway area, and lists some of the more common species associated with each habitat type.

Figure 2.13 shows the landscape type drained by the Neches River above Nederland, Texas, and includes a generalized cross section showing vegetation types associated with the different landscape units as one proceeds from uplands to rice bottom and back to uplands.

The oak-gum-cypress vegetation includes those vegetation associations that inhabit areas that range from deep swamps, backwaters and sloughs along marshes, estuaries and poorly drained bottomlands and flood plains to well-drained first bottoms and other moist, but infrequently inundated alluvial sites. The major factor determining the species composition in the complex of habitat types is the frequency and duration of inundation.

On the wettest sites, the deep swamps and backwaters, the major components are bald cypress (Taxodium distichum) and water tupelo (Nyssa aquatica), with numerous water weeds (including Paspalum spp, Cladium jamaicense or saw grass, and Rhynchospora corniculata or break-rush) as secondary components of the community.

In areas where the soils are better drained and the frequency and duration of the inundation more moderate, cypress and water tupelo become less important, giving way to species more characteristic of shallow swamps, first bottoms,



Small prairies in forested uplands, coarse grass with scattered pines and hardwoods, mud, mammals and fowl

Mixed pine and hardwood forest, sand and clay, well drained, loblolly pine, longleaf pine, shortleaf pine, gum, cypress, oak, hickory, mammals, fowl, snakes

Prairie grasslands, flat to gently rolling upland, prairie grasses, mud and sand substrate, much of area cultivated, blue stem, indiangrass, sparse mesquite, hackberry, huisach, chaparral, cactus, fowl and small mammals

Fluvial woodland, water-tolerant hardwoods,pecan, hickory, live-oak, water oak, blackjack oak, elm, hackberry,MAGNOLIA, sweetgum, red haw, ash, shortleaf pine, carpetgrass, bermudagrass, greenbriar, yaupon, grape, mammals, fowl, snakes

Swamp, poorly drained, sediment and water supplied by overbanking fluvial systems, sand and mud, dwarf palmetto, cypress, elm, bay,mulberry, water oak, bum, grapevine, and yaupon, raccoon, opossum, some mink and squirrels, fowl, snakes

Inland fresh-water marsh, sand and mud, rushes, bullrush, cattail, slough grass, mammals, fowl

Brackish to fresh-water marsh, sand, muddy sand, and mud, grades into salt marsh, coastal sacahuista, marshy cordgrass, big cordgrass, bullrush, cattail, rushes, mammals, snakes, fowl

Salt-water marsh, frequently inundated by tides, sand, muddy sand to mud, cordgrass, glasswort, seepweed, sea-oxeye, mammals, fowl.

FIGURE 2.9. Generalized vegetation map of Orange Co, Texas.

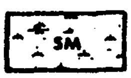
LEGEND FOR FIGURE 2.10

Cover maps for plant communities and habitats for dredged material banks and adjacent areas: Sabine-Neches Waterway

OF -Open freshwater
TSS -Tidal streams and rivers
SB -Bays
SF -Freshwater streams
RW -Ridges, waterway banks, and walkways

SV -Submerged vegetation
FV -Floating vegetation

BM -Fresh-to-brackish marsh
FM -Freshwater marsh

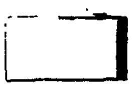


SM -Salt marsh
HM -High marsh

BL -Bare or lightly vegetated transferred material

VD -Heavily vegetated transferred material

PH -Pine and hardwood
OG -Oak-gum-cypress
MH -Mixed hardwoods on ridges and strandplains



CP -Coastal prairie

IC -Irrigated crops
BSS -Beach, sand, and shell
U -Urban and industrial

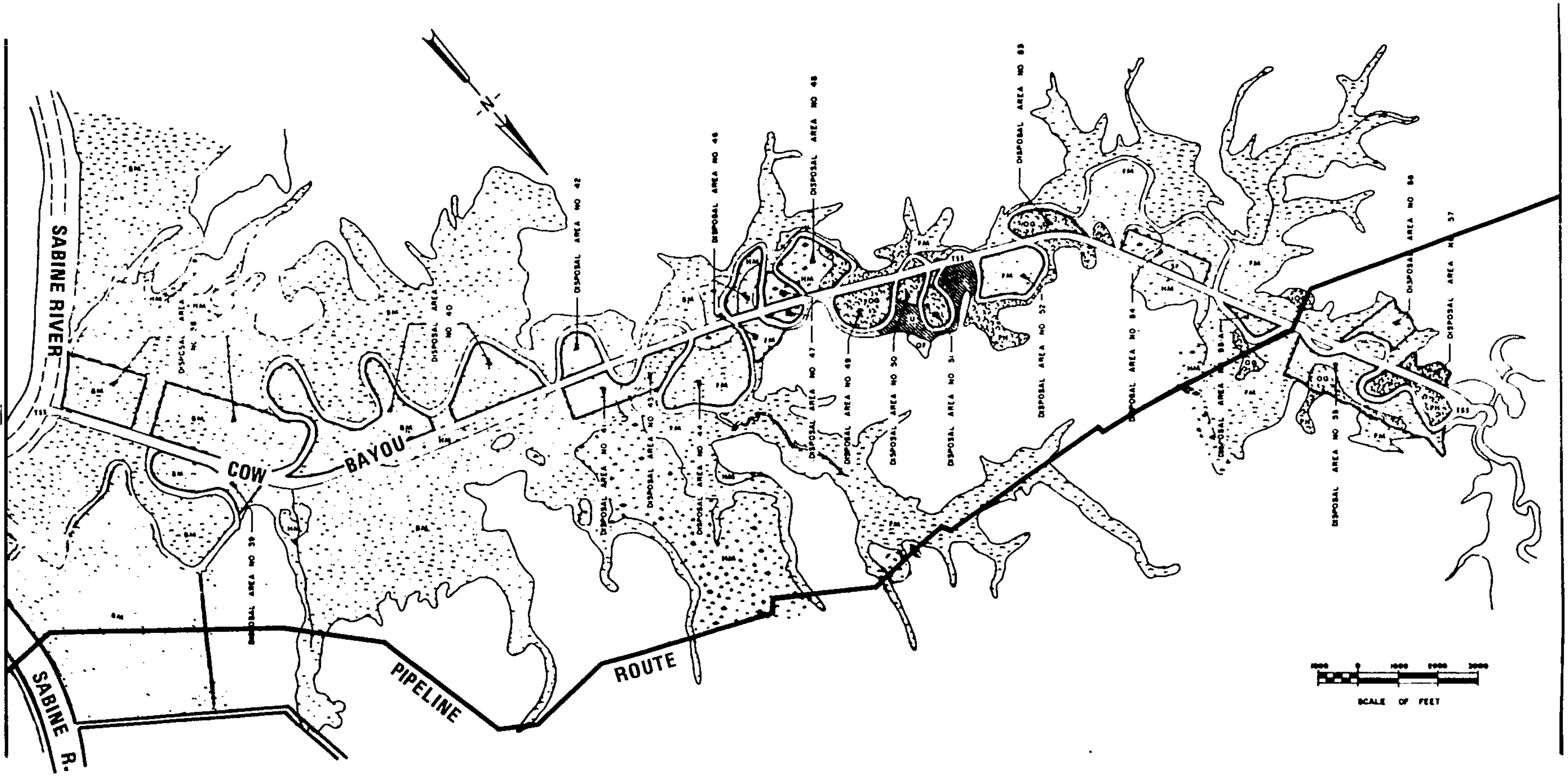


FIGURE 2.10. Pipeline route from Sabine River to Cow Bayou, Orange Co., Texas, including U.S. Army Corp. of Engineers dredged material disposal sites and vegetation types in the area. Clear areas denote coastal prairie (agricultural land).

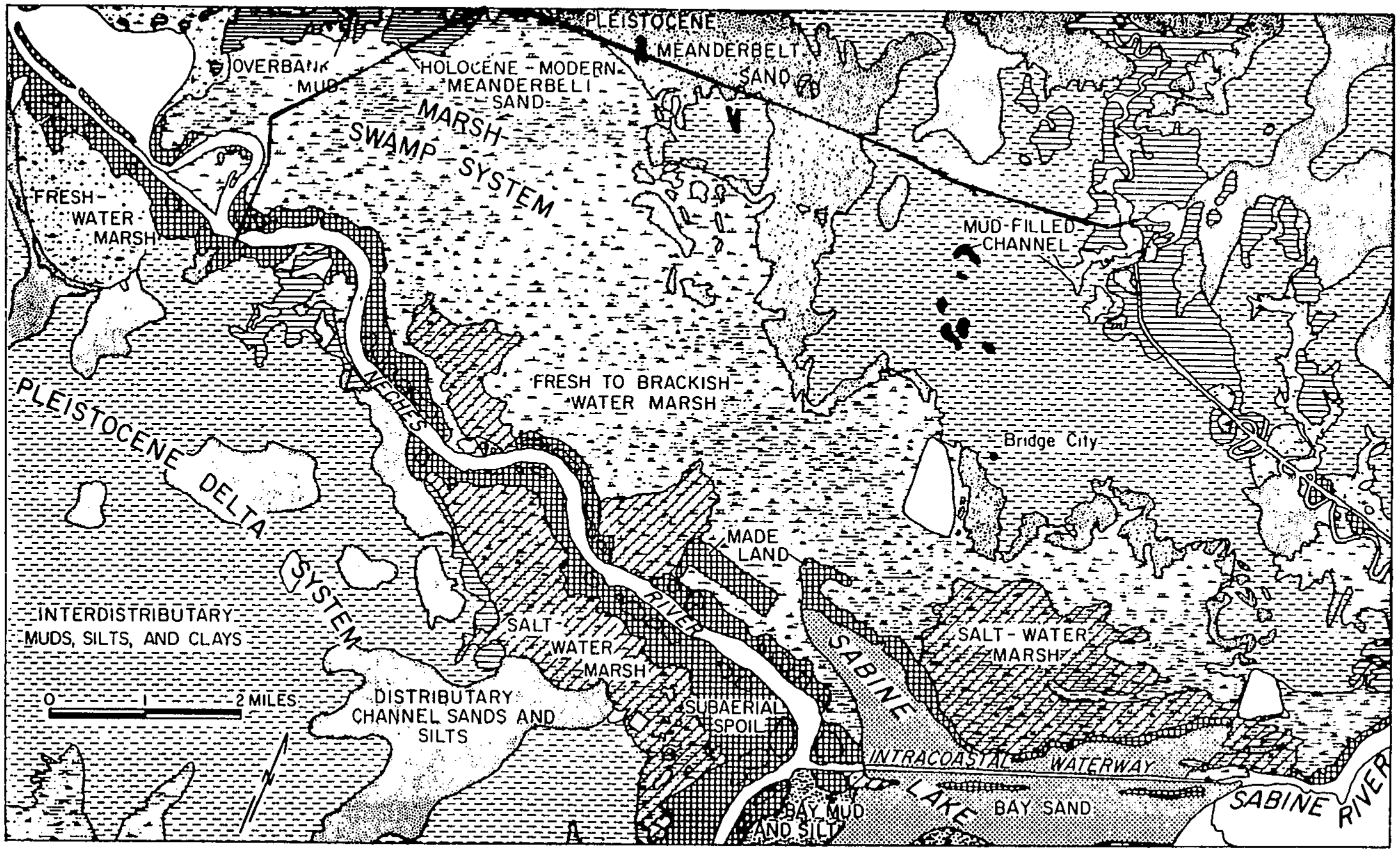


FIGURE 2.11. Habital types in the area of the Neches River-Cow Bayou portion of the proposed pipeline route. Pleistocene meanderbelt sand is characterized by extensive heavy growths of pine-hardwood vegetation. Interdistributary muds, silts and clays contained native prairie vegetation, which has since been converted to agricultural land. Modern-Holocene meanderbelt sands support dense stands of water-tolerant hardwoods.

SOURCE: Bureau of Economic Geology
University of Texas

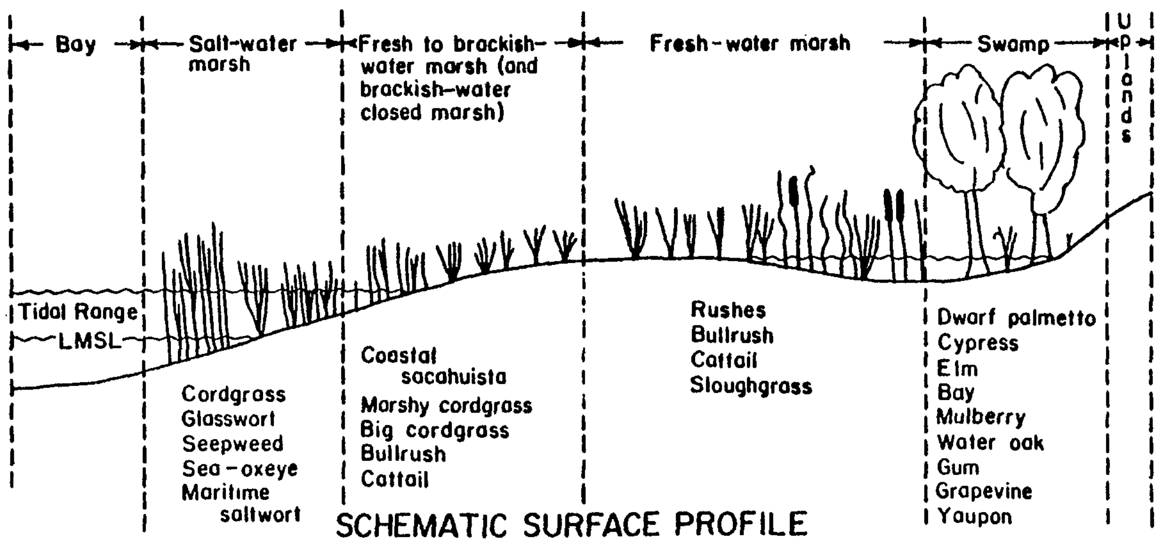


Figure 2.12 Schematic profile of the Modern marsh-swamp system that occupies extensive areas landward of the Gulf of Mexico shoreline and within the lower valleys of the Sabine and Neches rivers and headwater eroding streams of the study area.

Source: Bureau of Economic Geology, The University of Texas, 1973. Environmental Geologic Atlas of the Texas Coastal Zone - Beaumont-Port Arthur area.

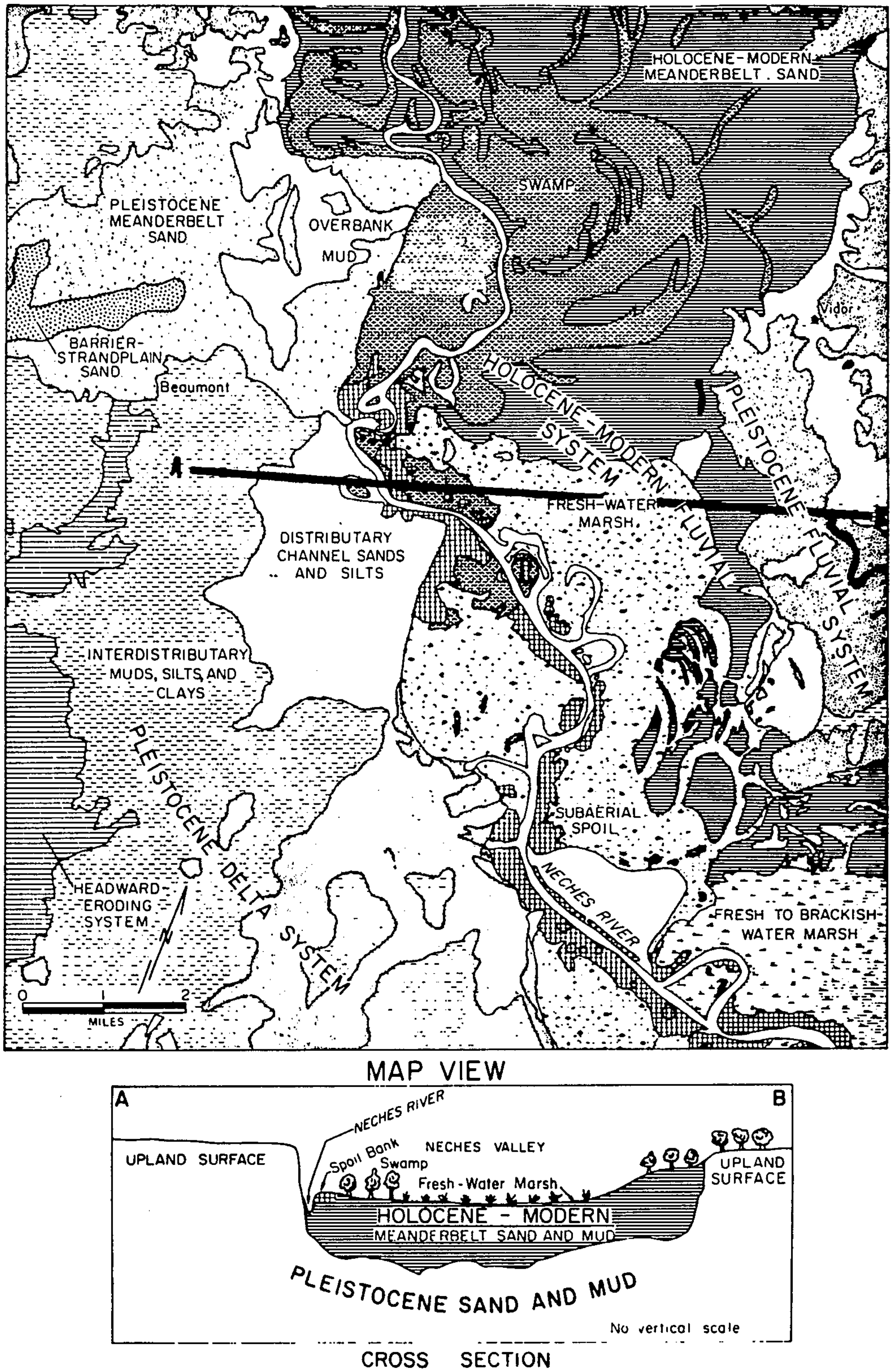


Fig. 2.13 Holocene and Modern fluvial and marsh deposits within incised Neches valley, above Port Arthur, Texas. Valley was eroded into older Pleistocene fluvial-deltaic facies when sea level dropped during the last glaciation. Marsh deposits cover Modern-Holocene estuarine deposits. Generalized cross-section shows gradient of vegetation types from river bottom to uplands.

Source: Bureau of Economic Geology, University of Texas.

swamp banks and bayheads. This community, a transition type from the permanent swamps to the well-drained bottomlands, includes swamp tupelo (Nyssa sylvatica var. bifloray) overcup oak (Quercus lyrata), water hickory (Carya aquatica), swamp hickory (Carya leiodermis), black willow, red maple (Acer rubrum var. drummondi), water oak (Fraxinus carolinia), pumpkin ash (Fraxinus tomentosa), water locust (Gleditsia aquatica), and pecan (Carya illinoensis), as major species. Major shrubs include Swamp privet (Forestiera acuminata), common buttonbush (Cephalanthus occidentalis), and water elm or planertree (Planera aquatica).

On the better-drained bottomland sites, including transition areas from flats to ridges, other, more mesic* species take over. These include sweetgum (Liquidambar styriciflua), willow oak (Quercus phellos), water oak (Quercus nigra), sugarberry (Celtis laevigata), blackgum (Nyssa sylvatica), green ash (Fraxinus subintegerrima), white ash (Fraxinus americanus), overcup oak, and cherrybark oak (Quercus falcata var. pagodaefolia) as major species, along with laurel oak (Quercus laurifolia), pecan, American basswood (Tilia americana), swamp chestnut oak (Quercus michauxii), cottonwood (Populus deltoides) and American elm (Ulmus americana) as secondary species.

Common understory species include swamp privet, swamp dogwood (Cornus foemina), hawthorne: (Crataegus spp.), American hornbeam (Carpinus caroliniana) and rough-leaf dogwood (Cornus drummondic).

Mixed hardwoods on ridges and strand plains include those species requiring well-drained conditions typical of the cheniers,** sand spoil banks and uplands of the area. Major components of this forest assemblage include live oak (Quercus virginiana), hackberry (Celtis occidentalis), blackjack oak (Quercus marilandica) post oak (Quercus stellata), southern red oak, white oak (Quercus alba), white ash, with blackberry (Rubus sp.) and rough-leaf

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*mesic - refers to habitats with well-drained soils where soil water is available in abundant supply during the growing season.

**cheniers - stranded beaches generally paralleling the Gulf Coast and formed by alternating processes of fluvial sediment deposition, erosion and subsequent redeposition, controlled primarily by changes in the course of the Mississippi River.

dogwood and tallowtree (Sapium subiferum) as secondary species. Live oak, which occurs on a wide variety of well-drained soils forms a climax type vegetation on ridges bordering coastal marshes. The species is resistant to salt spray and can tolerate salt concentrations in soil water of greater than 2 percent.

Major pine species in the area are loblolly pine (Pinus taeda) and longleaf pine (Pinus palustris), with shortleaf pine (Pinus echinata) and southern red cedar (Juniperus silicicola) as secondary species. Loblolly pine inhabits a wide variety of soil conditions, growing best in soils with poor surface drainage, such as is common in the flat ground water podzolic soils* of the lower coastal plain and the flood plain of major rivers. Pure loblolly stands are wide-spread in certain areas where moisture is plentiful. Since it can occupy a wide variety of sites, loblolly pine has many hardwood associates. On poorly drained sites, swamp and black tupelo, water oak, willow oak, laurel oak, sweetbay (Magnolia virginiana) and redbay (Persea borbonia) are commonly present with the loblolly pines, while on better-drained bottoms, loblolly pine occurs with sweetgum, black tupelo, and southern red oak. The well-drained sites find it accompanied by post oak, blackjack oak, and white oak.

Associated shrubs include wax myrtle (Myrica cerifera), pepperbush (Clethea alnifolia) gallberry (Ilex glabra), Viburnum spp., and a number of ericaceous** shrubs.

In the East Texas-Southwest Louisiana area mixtures of loblolly and shortleaf pine grow, with shortleaf pine predominantly on the drier ridges and loblolly pine being dominant on the wetter sites. Occurring with these two species of pine are several hardwoods, including sweetgum, black tupelo, hickories, and southern red oak.

Longleaf pine prefers sites with sandy, infertile soils having good drainage and low organic matter content. Common associates are turkey oak (Quercus laevis), blackjack oak, and occasionally shortleaf pine, although it occurs on more moist sites with loblolly pine, dogwood, sweetgum, southern red oak, water oak, laurel oak and yellow poplar. Common associate shrubs are gallberry, southern wax myrtle, and yaupon.

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*Flat ground water podzolic soils are located in areas of little or no slope and are acidic and highly weathered, with a leached surface layer and poor drainage due to the presence of ground water in the profile during much of the year.

**Heath-like

The entire pipeline route from the Sabine River to Nederland, Texas would parallel the Colonial Pipeline Company pipeline right-of-way. Since the Colonial route is mowed biannually, the vegetation would be in an earlier stage of succession, with species composition varying with the type of habitat, but composed mainly of pioneer or invading species capable of inhabitating disturbed sites. The proposed pipeline route would traverse less disturbed areas adjacent to the existing right-of-way.

Mammals

A number of species of mammals inhabit the study area. Muskrats are abundant in the rice fields and marshes, with brackish marsh the preferred type. Nutria are most abundant in the fresh and intermediate coastal marshes where it feeds on the marsh vegetation. Both muskrats and nutria are also common along lakes, streams and canals, making use of the dredged material banks as refuges when water levels are high. Their burrowing often causes damage to the levee/bank system. Mink are most common in the cypress-tupelo swamps but also occur in marshes where some high ground is available for refuge. The raccoon occurs in brackish and fresh marshes, swamps, and bottomland forests, also utilizing disposal areas seasonally for feeding and refuge from high waters. Otters, which are not common in the area, seek permanent open water areas with intermittent high ground. They occur in a variety of aquatic habitats but prefer fresh to brackish marsh. White-tailed deer prefer the bottomland forest, especially where an ecotone* with cleared land is available, but they are also found in the marshes where they also seek high ground during periods of high water.

Two species of rabbits are common in the area. The cottontail is found mainly on well-drained woodlots, along fence rows, and in old fields. The swamp rabbit is generally found in wet woodlands, marsh ridges and disposal areas. Two common species of squirrels, the eastern gray squirrel and eastern flying squirrel are typical of woodlands, with the gray squirrel preferring the dense bottomland hardwood and swamp forests and the flying squirrel found in drier, less dense woodland. Skunks, opossum, the 9 Banded armadillo, cotton mouse, and hispid cotton rat are also found in the bottomland forests. Major predators in these bottomland and swamp forests include the bobcat, with the red and gray foxes present but not common. The coyote is the main mammalian predator in the prairie type vegetation, feeding on rodents such as the cotton rat and plains pocket gopher.

*Area where two habitat types merge.

Mammals typical of the developed areas of Orange County include mainly rodents such as the house mouse, roof rat and Norway rat.

Table 2.18 is a more complete list of the mammals characteristic of the Sabine-Neches Waterway area.

Birds

The vast marshlands of the Gulf Coast provide an array of habitats suitable for use by a wide variety of resident and transient species of birds, being especially important as a wintering area for many species of waterfowl. Common dabbler ducks include the mallard, gadwall, baldpate, green winged teal, blue-winged teal, shoveler, pintail and mottled ducks. The preferred habitat of these ducks is fresh marsh and rice fields but they are generally found in all marsh types within the proposed pipeline area. Diver ducks common to the water bodies of the area include the canvasback, lesser scaup, and red-breasted merganser. Ducks seldom make use of the dredged material sites in these marsh areas. The wood duck is the only common species of duck that has established permanent populations in the region, but this duck is rarely seen in the marshes, preferring swamps and bottomland forests. All common migratory ducks are winter residents. Several species of geese also utilize the area wintering grounds. The Canadian goose is found mainly in rice fields and marshes, and the snow goose prefers brackish marsh, rice fields and pastures. The other common species, the white fronted goose favors rice fields. The American coot is also common in fresh water lakes and marshes.

Other common winter residents of the marsh and lake shores include the common snipe, marsh hawk, gull-billed tern, tree swallow, short-billed marsh wren, and the greater and lesser yellowlegs.

Common residents of the area include several rail birds (King and Clapper) and gallinules (purple and common) with the rail birds found along the marshes and the gallinules in shallow-fresh water ponds. All are shorebirds. Other permanent residents of the marshes include numerous wading birds, including the willet, great blue heron, Louisiana heron, black-crowned night heron, yellow-crowned night heron, the great egret, snowy egret, the least bittern and American bittern. Other permanent residents of the marshes include the red-winged blackbird, short-billed marsh wren and seaside sparrow.

TABLE 2.18

MAMMALS IN THE SABINE NECHES WATERWAY AREA

Common Name	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Opossum	A			
Short-tailed shrew	U			
Little short-tailed shrew	C			
Eastern mole	U			
Georgia bat	O			
Big brown bat	O			
Red bat	C			
Seminole bat	C			
Yellow bat	O			
Evening bat	O			
Mexican freetail bat	O			
Raccoon	A			
Ringtail	O			
Black bear	U			E
Long-tailed weasel	U			
Mink	C			
River otter	U			T
Spotted skunk	U			
Striped skunk	A			
Red fox	U			
Gray fox	U			
Coyote	C			
Red wolf	U	E	T	E
Gray wolf	H	E		

*A - Abundant
C - Common
U - Uncommon
O - Within potential range of the species
H - Historical records but not now occurring in the region

**E - Endangered
T - Threatened
P - Peripheral
UD - Status undetermined

1/ USF&WS - United States Fish and Wildlife Service
2/ TPW - Texas Parks and Wildlife Department
3/ TOES - Texas Organization for Endangered Species

TABLE 2.18 (CONT)

Common Name	Abundance* Locally	Endangered or Threatened Status** USF&WS[1/]	TPW[2/]	TOES[3/]
Ocelot	H		T	P
Cougar	O	E		E
Bobcat	C			
Eastern gray squirrel	C			
Eastern flying squirrel	C			
Plains pocket gopher	A			
Beaver	U			
Dwarf harvest mouse	O			
Long-tailed harvest mouse	A			
Pygmy mouse	U			
White-footed mouse	O			
Cotton mouse	O			
Northern rice rat	A			
Hispid cotton rat	A			
Florida wood rat	C			
Muskrat	C			
House mouse	A			
Roof rat	A			
Norway rat	A			
Nutria	A			
Eastern Cottontail	A			
Swamp rabbit	A			
White-tailed deer	U			
Nine-banded armadillo	A			
Caribbean manatee	U		T	E
Atlantic bottlenose dolphin	C			
West Indian seal	U			E
Gulf stream beaked whale	U			T
Goose-beaked whale	U			T
Sperm whale	H	E		T
Pygmy sperm whale	U			T
Dwarf sperm whale	U			T
Pygmy killer whale	U			T
Finback whale	U	E		E
Blue whale	U	E		E
Black right whale	U	E		E

Source: U.S. Army Corp of Engineers, Galveston District. Final Environmental Statement, Maintenance Dredging Sabine-Neches Waterway, Texas.

Common inhabitants of the farmlands, old fields and other early succession habitats include the bobwhite, several species of doves, the kildeer, crow, several thrushes, starling, and Savannah and field sparrows.

Many forest songbirds cross the study area in the spring of the year as they migrate from Mexico to their breeding grounds. During periods of bad weather, these species will temporarily reside in the scattered woodlands located on the cheniers in the area.

Forest residents in the area include the mourning dove, bobwhite (open woods), Wilson's snipe, and several species of owls, woodpeckers and warblers.

Top predators include the red-tailed hawk, marsh hawk and the American kestrel. The red-tailed hawk nests in woodlands and feeds in open fields. Marsh hawk inhabits grasslands and marshes, while the American kestrel prefers open and semiopen terrestrial sites. The major scavenger, the turkey vulture, utilizes fields to a major extent. Table 2.19 is an annotated list of the birds in the Sabine-Neches Waterway area, including their local abundance and status on various endangered and threatened species lists. The list includes marine species occurring along the Texas Coast as well as more inland species.

Amphibians and Reptiles

Among the common amphibians and reptiles in the study area, one of the most widespread in the flooded river bottoms, swamps and brackish to fresh marshes is the American alligator. Turtles common to the study area include two snapping turtles, the common and alligator, two softshell turtles, the midland smooth and pallid spiny, and the diamondback terrapin. The latter species inhabits brackish and salt marshes, while the snapping turtles prefer freshwater rivers, swamps, lakes and ponds. Softshell turtles are found mainly in open waters. Mud and musk turtles (including the stinkpot) are mainly aquatic, inhabiting a wide variety of habitats including marshes, rivers, swamps, and lakes in the study area.

Most of the toads in the area (including Woodhouse's toad, Fowler's toad and Gulf Coast toad) inhabit fields bordering on water. One exception is Hurter's spadefoot toad which is found mainly in woodlands. The tree frogs (squirrel and southern gray) are located in moist forested areas, along

TABLE 2.19

BIRDS IN THE SABINE NECHES
WATERWAY AREA

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Common loon	U			
Red throated loon	U			
Eared grebe	U			
Horned grebe	U			
Least grebe	U			
Pied-billed grebe	A			
Audubon's shearwater	U			
White-tailed tropicbird	U			
White pelican	C			
Eastern brown pelican	U	E	E	E
Blue-faced booby	U			
Gannet	U			
Double-crested cormorant	A			
Olivaceous cormorant	C			P
Anhinga	C			
Great blue heron	A			
Little blue heron	U			
Louisiana heron	A			
Yellow-crowned night heron	A			
Black-crowned night heron	A			
Cattle egret	A			
Reddish egret	U			E
Great egret	A			
Snowy egret	A			
Least bittern	C			
American bittern	C			
Wood ibis	U			
White faced ibis	A			T
White ibis	A			

*A - abundant
C - common
U - uncommon

**E - endangered
T - threatened
P - peripheral
UD - status-undetermined

1/ USF&WS - United States Fish and Wildlife Service
2/ TPW - Texas Parks and Wildlife Department
3/ TOES - Texas Organization for Endangered Species

Source: U.S. Army Corp of Engineers, Galveston District. Final Environmental Statement, Maintenance Dredging Sabine-Neches Waterway, Texas

TABLE 2.19 (CONT)

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Roseate spoonbill	C			P
Canada goose	U			
Brant	U			
White-fronted goose	A			
Snow goose	A			
Blue goose	A			
Ross' goose	U			T
Fulvous tree duck	U			E
Black-bellied tree duck	U			
Mallard	C			
Black duck	U			
Mottled duck	A			
Gadwall	A			
Pintail	A			
Green-winged teal	A			
Blue-winged teal	A			
Cinnamon teal	U			
American widgeon	A			
Shoveler	A			
Wood duck	C			
Redhead	A			
Ring-necked duck	U			
Canvasback	A			
Greater scaup	U			
Lesser scaup	A			
Common goldeneye	U			
Bufflehead	U			
Oldsquaw	U			
White-winged scoter	U			
Surf scoter	U			
Ruddy duck	U			
Masked duck	U	E		
Hooded merganser	U			
Common merganser	U			
Red-breasted merganser	A			
Turkey vulture	A			
Black vulture	U			
White-tailed kite	U			P
Mississippi kite	U			
Sharp-shinned hawk	U			
Cooper's hawk	U			
Red-tailed hawk	A			
Harlan's hawk	U			

TABLE 2.19 (CONT)

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS[1/]	TPW 2/	TOES[3/]
Red-shouldered hawk	U			
Broad-winged hawk	U			
Swainson's hawk	U			
Rough-legged hawk	U			
Ferruginous hawk	U			
Golden eagle	U			T
Bald eagle	U	E	E	E
Marsh hawk	A			
Osprey	U			E
Caracara	U			
American Peregrine falcon	U	E	E	E
Arctic Peregrine falcon	U	E	E	E
American kestrel	A			
Pigeon hawk	U			T
Bobwhite quail	A			
Atwater's greater prairie chicken	U	E	E	E
Sandhill crane	C			
Whooping crane	U	E	E	E
King rail	A			
Clapper rail	A			
Virginia rail	U			
Sora	U			
Black rail	U			
Purple gallinule	A			
Common gallinule	A			
American coot	A			
Semipalmated plover	U			
Piping plover	U			
Snowy plover	U			
Wilson's plover	A			
Killdeer	A			
American golden plover	A			
Black-bellied plover	A			
Ruddy turnstone	U			
American woodcock	U			
Common snipe	A			
Long-billed curlew	A			
Whimbrel	U			
Upland plover	U			
Spotted sandpiper	A			
Solitary sandpiper	A			
Willet	A			

TABLE 2.19 (CONT)

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Greater yellowlegs	A			
Lesser yellowlegs	A			
Knot	U			
Pectoral sandpiper	A			
White-rumped sandpiper	U			
Baird's sandpiper	A			
Least sandpiper	A			
Dunlin	A			
Short-billed dowitcher	U			
Long-billed dowitcher	A			
Stilt sandpiper	A			
Semipalmated sandpiper	A			
Western sandpiper	A			
Buff-breasted sandpiper	U			
Marbled godwit	U			
Hudsonian godwit	U			
Sanderling	U			
American avocet	A			
Black-necked stilt	A			
Wilson's Phalarope	A			
Parasitic jaeger	U			
Long-tailed jaeger	U			
Herring gull	U			
Ring-billed gull	A			
Laughing gull	A			
Franklin's gull	U			
Bonaparte's gull	C			
Gull-billed tern	A			
Forster's tern	A			
Common tern	U			
Least tern	A			
Royal tern	C			
Sandwich tern	U			
Caspian tern	U			
Black tern	A			
Black skimmer	U			
Ground dove	U			
Rock dove	C			
White-winged dove	U			
Mourning dove	A			
Inca dove	U			
Yellow-billed cuckoo	A			
Black-billed cuckoo	U			

TABLE 2.19 (CONT)

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Roadrunner	U			
Smooth-billed ani	U			
Groove-billed ani	U			
Barn owl	U			
Great horned owl	U			
Screech owl	C			
Burrowing owl	U			
Barred owl	C			
Long-eared owl	U			
Short-eared owl	U			
Saw-whet owl	U			
Chuck-will's widow	A			
Whip-poor-will	U			
Common nighthawk	A			
Chimney swift	U			
Ruby-throated hummingbird	U			
Belted kingfisher	A			
Yellow-shafted flicker	C			
Red-shafted flicker	U			
Ivory-billed woodpecker	U	E	E	E
Red-bellied woodpecker	C			
Red-headed woodpecker	U			
Yellow-bellied sapsucker	U			
Hairy woodpecker	C			
Downy woodpecker	C			
Red-cockaded woodpecker	U	E	E	E
Eastern kingbird	A			
Western kingbird	U			
Scissor-tailed flycatcher	U			
Great-crested flycatcher	U			
Eastern phoebe	A			
Yellow-bellied flycatcher	U			
Acadion flycatcher	C			
Eastern wood pewee	U			
Olive-sided flycatcher	U			
Vermilion flycatcher	U			
Horned lark	U			
Violet-green swallow	U			
Tree swallow	A			
Bank swallow	U			
Rough-winged swallow	U			
Barn swallow	A			
Cliff swallow	U			
Purple martin	A			
Blue jay	C			

TABLE 2.19 (CONT)

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Common crow	C			
Fish crow	U			
Carolina chickadee	C			
Tufted titmouse	C			
White-breasted nuthatch	U			
Red-breasted nuthatch	C			
Brown-headed nuthatch	C			
Brown creeper	U			
House wren	U			
Winter wren	U			
Bewick's wren	U			
Carolina wren	C			
Long billed marsh wren	U			
Short-billed marsh wren	A			
Mockingbird	A			
Catbird	A			
Brown thrasher	A			
Sage thrasher	U			
Robin	A			
Wood thrush	U			
Hermit thrush	U			
Swainson's thrush	A			
Gray-cheeked thrush	U			
Veery	U			
Blue-gray gnatcatcher	A			
Golden-crowned kinglet	U			
Ruby-crowned kinglet	U			
Water pipit	A			
Sprague's pipit	U			
Cedar Waxwing	A			
Loggerhead Shrike	C			
Starling	A			
White-eyed vireo	C			
Yellow-throated vireo	C			
Solitary vireo	U			
Red-eyed vireo	U			
Philadelphia vireo	U			
Black-and-white warbler	U			
Prothonotary warbler	U			

TABLE 2.19 (CONT)

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Golden winged warbler	U			
Blue-winged warbler	U			
Tennessee warbler	A			
Orange-crowned warbler	U			
Nashville warbler	U			
Worm-eating warbler	U			
Parula warbler	U			
Yellow warbler	A			
Magnolia warbler	A			
Black-throated blue warbler	U			
Myrtle warbler	A			
Audubon's warbler	U			
Townsend's warbler	C			
Yellow-throated warbler	U			
Black-throated green warbler	A			
Cerulean warbler	U			
Blackburnian warbler	U			
Chestnut-sided warbler	U			
Blackpoll warbler	U			
Bay breasted warbler	U			
Pine warbler	U			
Prairie warbler	U			
Palm warbler	U			
Ovenbird	C			
Northern waterthrush	A			
Louisiana waterthrush	U			
Kentucky warbler	U			
Yellowthroat	A			
Yellow-breasted chat	U			
Hooded warbler	U			
Canada warbler	U			
American redstart	A			
House sparrow	A			
Bobolink	U			
Eastern meadowlark	A			
Western meadowlark	U			
Yellow-headed blackbird	U			
Redwinged blackbird	A			

TABLE 2.19 (CONT)

Bird	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Orchard oriole	A			
Baltimore oriole	C			
Rusty blackbird	C			
Brewers blackbird	C			
Great-tailed grackle	U			
Boat-tailed grackle	C			
Common grackle	A			
Brown-headed cowbird	A			
Scarlet tanager	U			
Summer tanager	U			
Cardinal	C			
Rose-breasted grosbeak	A			
Blue grosbeak	C			
Indigo bunting	A			
Painted bunting	U			
Dickcissel	A			
Purple finch	C			
Pine siskin	U			
American goldfinch	U			
Rufous-sided towhee	U			
Savannah sparrow	A			
Grasshopper sparrow	C			
LeConte's sparrow	U			
Sharp-tailed sparrow	U			
Seaside sparrow	A			
Vesper sparrow	U			
Lark sparrow	U			
Bachman's sparrow	U			
Slate-colored junco	U			
Chipping sparrow	U			
Field sparrow	U			
Harris' sparrow	U			
White-crowned sparrow	U			
White-throated sparrow	U			
Lincoln's sparrow	U			
Swamp sparrow	A			
Song sparrow	U			

with the northern spring peeper and upland chorus frog. The green tree frog is an exception, preferring areas with permanent bodies of standing water. Other species preferring a similar habitat include several species of salamanders (southern dusky and dwarf), the central newt, bullfrog and southern leopard frog. The mole salamanders (small-mouthed and marbled) breed in open water but live underground in woodlands much of their lives.

Of the common lizards, the western slender glass lizard, the six-lined racerunner, and the Texas horned lizard frequent dry fields, grasslands and dry open woods. The northern fence lizard similarly prefers dry sites, being especially partial to open pine woods with rotting logs and stumps. In contrast, several common species prefer wetter sites. These include the ground skink an inhabitant of woodland floors, the five-lined skink, which prefers damp cutover woodlands with rock piles and rotting stumps, and the broad-headed skink, the most arboreal of the skinks, whose choice habitat is swamp forests where it utilizes hollow trees and holes in trees for cover. However, several of the abovementioned species also adapt to urban and residential habitats frequenting the walls and foundations of buildings as well as vacant urban lots. These include the ground skink and especially the green anole.

Various water snakes are found in the low-lying swamps and bottomlands with permanent bodies of water nearby. All the poisonous species (the western cottonmouth, western pygmy rattlesnake, canebrake rattlesnake, southern copperhead and Texas coral snake) are creatures of these wetter habitats, although the latter species is often in well-drained upland areas. Moist woodlands are also preferred by the Gulf Coast ribbon snake and western mud snake.

Drier woodlands areas usually are inhabitated by the eastern hognose snake and Mississippi ringneck snake. Earth snakes are usually found in fields. The marsh brown snake, garter snake, racer, eastern coachwhip, rough green snake, rat snakes and kingsnakes are found in a wide variety of habitats in the area.

Table 2.20 is an annotated list of the reptiles and amphibians known to frequent the area of the Sabine-Neches Waterway and includes an index of local abundance as well as the status of the different species on various rare and endangered species lists.

TABLE 2.20

REPTILES AND AMPHIBIANS IN THE SABINE NECHES WATERWAY AREA

Common Name	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Reptiles				
American alligator	C	E	E	E
Snapping turtle	A			
Alligator snapping turtle	C			
Stinkpot	A			
Razor-backed musk turtle	C			
Mississippi mud turtle	C			
Three-toed box turtle	C			
Ornate box turtle	U			
Texas diamondback terrapin	C			T
Mississippi map turtle	C			
Sabine map turtle	C			
Red-eared turtle	A			
Mobile cooter	U			
Missouri slider	C			
Western chicken turtle	C			
Atlantic green turtle	U			E
Hawksbill turtle	U	E		E
Atlantic loggerhead turtle	U			E
Atlantic ridley turtle	U	E	E	E
Leatherback turtle	U	E		E
Midland smooth softshell	C			
Pallid spiny softshell	C			

*A - Abundant
C - Common
U - Uncommon

**E - Endangered
T - Threatened
P - Peripheral
UD - Status undetermined

1/ USF&WS - United States Fish and Wildlife Service
2/ TPW - Texas Parks and Wildlife Department
3/ TOES - Texas Organization for Endangered Species

TABLE 2.20 (CONT)

Common Name	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Mediterranean gecko	U			
Green anole	A			
Northern fence lizard	A			
Texas horned lizard	C			
Six-lined racerunner	A			
Ground skink	C			
Five-lined skink	C			
Broad-headed skink	C			
Western slender glass lizard	C			
Green water snake	C			
Diamondback water snake	C			
Yellow-bellied water snake	C			
Broad-banded water snake	C			
Gulf salt marsh snake	C			
Graham's water snake	C			
Gulf glossy water snake	C			
Marsh brown snake	C			
Eastern garter snake	C			
Gulf coast ribbon snake	C			
Rough earth snake	U			
Eastern hognose snake	C			
Mississippi ringneck snake	C			
Western mud snake	C			
Eastern yellow-bellied racer	C			
Eastern coachwhip	C			
Rough green snake	C			
Texas rat snake	C			
Corn snake	U			
Great Plains rat snake	U			
Speckled kingsnake	C			
Louisiana milk snake	U			
Prairie kingsnake	U			
Northern scarlet snake	U			
Texas coral snake	U			
Southern copperhead	C			
Western cottonmouth	A			
Western Pygmy rattlesnake	C			
Canebrake rattlesnake	C			

TABLE 2.20 (CONT)

Common Name	Abundance* Locally	Endangered or Threatened Status** USF&WS 1/	TPW 2/	TOES 3/
Amphibians				
Western lesser siren	C			
Three-toed amphiuma	C			
Marbled salamander	C			
Small-mouthed salamander	C			
Central newt	C			
Southern dusky salamander	A			
Dwarf salamander	C			
Hurter's spadefoot	C			
Woodhouse's toad	A			
Fowler's toad	A			
Gulf coast toad	A			
Northern cricket frog	C			
Northern spring peeper	A			
Green treefrog	A			
Squirrel treefrog	A			
Southern gray treefrog	C			
Upland chorus frog	C			
Eastern narrow-mouthed toad	C			
Bullfrog	A			
Pig frog	U			
Bronze frog	C			
Southern leopard frog	A			
Southern crawfish frog	C			
Pickerel frog	U			

Source: U.S. Army Corp of Engineers, Galveston District. Final Environmental Statement, Maintenance Dredging Sabine-Neches Waterway, Texas.

Aquatic Ecology

The Sabine River forms a natural boundary between Texas and Louisiana from a point near Logansport, Louisiana, southward to its confluence with the Gulf of Mexico at Sabine Pass. The river basin is approximately 300 miles long and 30 miles wide (average) with a maximum width of 45 miles.[36] Stream bed gradients of the tributaries are very low and most of the length of the Sabine River has a slope of less than 0.8 feet per river mile. The river meanders through heavily forested areas of loblolly pine, shortleaf pine and longleaf pine in the upper reaches, with fresh marsh predominating in the lower reaches.

A major change in the river system occurred in October of 1966, with the partial closing of the Toledo Bend Reservoir (186,000 surface acres), a joint venture of Texas and Louisiana to supply water and hydroelectric power for both states. Filling of the lake to normal pool elevation (172.0 MSL) was completed in May 1968.[38]

The drainage area of the Sabine River (9700 square miles) receives approximately 48 inches of rainfall per year, of which 13 inches flow to the Gulf of Mexico. There is a gradient in precipitation along the system, with the greatest amounts falling in the lower one-third of the basin. The upper part of the drainage system generally has higher values for water hardness due to areas of Cretaceous limestone, chalk and marl deposits.

Highest levels of streamflow occur from December through June, paralleling the precipitation/evapotranspiration regime, but amelioration of extremes in river discharges began with the closing of Toledo Bend Reservoir.

Average values for turbidity below Toledo Bend Reservoir range from 40-60 turbidity units, with readings as high as 200 units accompanying increased stream discharges. Mean bicarbonate alkalinity and total alkalinity values below the reservoir are approximately 45 ppm and 30-50 ppm, respectively, increasing with discharge. Mean bicarbonate alkalinity values increase to between 70-100 ppm during periods of high flow and decrease to 12-35 ppm for low flow. These values show the general soft nature of the waters of the Sabine River system (average hardness less than 60 ppm), with the exception of the upper section where Calcareous rock outcrops (60-120 ppm - moderately hard). The lowest one-third of the basin is very soft with less than 30 ppm river water hardness.

The direct relationship between streamflow and hardness demonstrates the fact that dissolved solid concentration of the river waters is dependent, to a large extent, on the dissolved solid content of the incident precipitation, with this value decreasing the longer the period of time the water is in contact with the geologic substrate of the basin.

Total chloride and specific conductivity values, upstream and downstream of Toledo Bend Reservoir, averaged 121 and 110 ppm and 756 and 498 microhms, respectively. These values, to a large extent, reflect the brine pollution from oil fields in the upper basin- East Texas oil fields and the Pendleton Oil field in Sabine Parish, Louisiana. Bayou Negreet, which drains the Pendleton oil field, shows salinity increases from a pre-impact level of 2-12 ppm[38] to 976 ppm after development of the oil field (McDaniel, 1968).[39] Additional surface water pollution occurs from a salt dome area in Van Zandt County, Texas. The data at hand suggests that in the non-tidal portion of the river system, total conductivity and salinity decrease downstream.

Due to the soft nature of the river waters very little free carbon dioxide is present, 1.0-1.4 ppm. The hydrogen ion levels tend toward winter pH values of 6.8-7.0 and summer pH values of 7.2-7.4 . Dissolved oxygen ranges between 8 and 10 ppm in winter to low values of 4-7 ppm in summer. Water temperatures show normal seasonal warming to the mid-80°F range in July and August and cooling to the mid-40°F range in January and February.

Lantz[37] states that the Sabine River Basin has an abundant supply of excellent quality waters, only locally contaminated by oil field brine discharges.

The Neches River is generally similar to the Sabine, draining similar landscapes and having a past history of human disturbance that parallels that of the Sabine River. Major dams on the Neches include Steinhagen Lake southeast of Jasper, Texas and Lake Palestine at Frankston, Texas. In addition, a major tributary to the Neches, Angelina River, has been impounded north of Jasper, forming Sam Rayburn Reservoir.

Sabine Lake is a predominantly brackish water estuary with salinity content ranging from 16-20 ppt at Sabine Pass to 0 ppt at times at the northern end of the lake, near the mouths of Sabine and Neches Rivers. Variation in salinity content are due to tidal and aeolian (borne or deposited by the wind) factors, as well as the fluvial* hydrologic regime of the drainage basins of the Sabine and Neches Rivers.

*fluvial - flowing

The major lotic* habitats which would be directly impacted include the ICW between Calcasieu and Sabine River, several bayous, including Black Bayou and Cow Bayou, and portions of the Sabine and Neches Rivers in the vicinity of Orange, Louiiana and Nederland, Texas, respectively. The major rivers, Sabine and Neches Rivers, and Cow Bayou are classified as tidal within the area to be impacted, although they are undoubtedly freshwater rivers at least during some of the year. Because they experience a range of salinities, they contain some biotic components characteristic of both fresh and estuarine waters.

Lantz[37] reports on a biological survey of the Sabine River, above and below Toledo Bend Reservoir, with the lowest monitoring station located approximately 18 air miles above the entrance of the ICW into Sabine River (at crossing of state Highway 12 east of Starks, La.). Net plankton counts and net and nannoplankton** concentrations (gm/m^3) are given in Table 2.21 and Figure 2.14 respectively for the lowest station. Net plankton counts and weights were lowest during late fall and winter of each year with productivity increasing by February of each year. However, during the warm months productivity is variable, with counts and weights showing sporadic pulses with no predictable trend toward summer maximum productivity. Similar trends were seen for nanno plankton weights. Mean study gravimetric results showed .124 gms/m^3 for net plankton as opposed to 3.496 gms/m^3 for nanno plankton. Rotifers, especially *Keratella* spp. dominated the zooplankton during peak occurrence of zooplankton. Chrysophyta was the dominant algal group, with high counts of *Pennales* sp. and lesser numbers of *Synura* sp. during phytoplankton pulses. Other algal groups represented were Chlorophyta and Cyanophyta, with the former present during three to four months of the year and represented by species of *Spirulina* and *Chroococcus*.

Table 2.22 represents pigment analysis for the lowest station of Lantz's study[37] and indicates pulses of plankton productivity in the Sabine River varying from month to month, with the lack of an extended period of plankton productivity during the spring and summer of each year, probably associated with stream discharges of turbid waters during periods of high flow.

Data are also presented on the bottom fauna of the Sabine River,[37] and Table 2.23 is the results of the study for the lower-most station. The major groups represented were the Tubificidae and Chironomidae. Data were not adequate to determine productivity.

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*Lotic - running water.
**Nannoplankton - plankton which pass through a #25 bolting cloth Wisconsin style plankton net. Net plankton are retained by a #25 bolting cloth Wisconsin style plankton net.

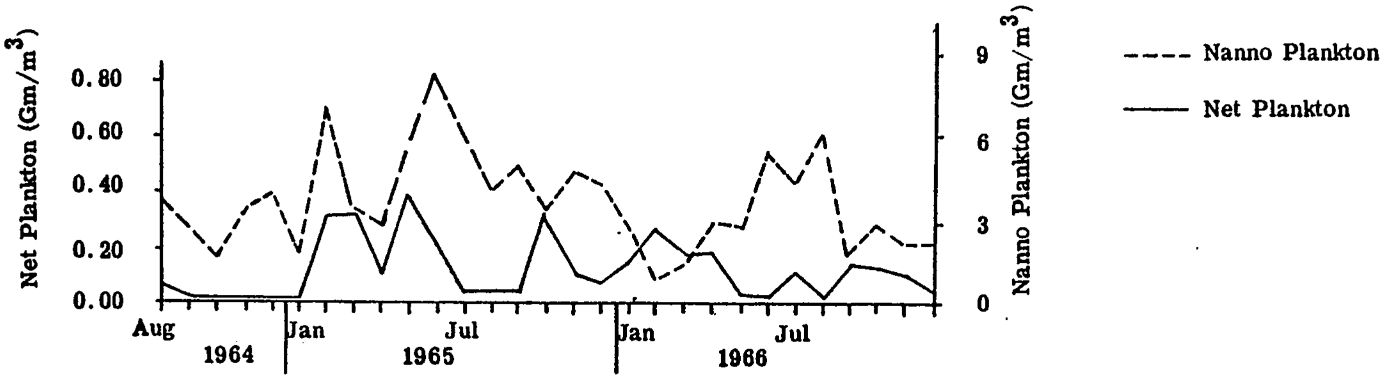
TABLE 2.21

MONTHLY NET PLANKTON COUNTS PER LITER FROM SABINE RIVER

Organism	1964 Sept.	Oct.	Nov.	Dec.	1965 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Zooplankton																
Cladocera	..	..	..	..	..	..	...	..	..	..	..	..	..	..		1
Copepoda	..	..	..	..	..	..	...	2	..	1	..	..	..		..	..
Nauplius	..	..	..	..	..	2	..	2	..	1	..	..	..	..	..	..
Rotifera	..	..	..	..	..	..	100	100	..	..	..	..	..	..	..	..
TOTAL	0	0	0	0	0	2	100	104	0	2	0	0	0	0	0	1
Phytoplankton																
Chlorophyta	...	100	...	...	...	...	...	2800	300	...	100	...	...	...	...	...
Chrysophyta	...	...	...	...	...	200	...	....	...	500	100	...	...	900	100	300
Cyanophyta	...	300	200	...	...	...	...	....	400	100	...	...	...	...	...	...
Euglenophyta	100	...	...	...	...	...	...	....	...	...	...	...	...	...	...	...
TOTAL	100	400	200	0	0	200	0	2800	700	600	200	0	0	900	100	300

Organism	1966 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1967 Jan.	Mar.
Zooplankton														
Cladocera	..	..	..	1	..	2	..	..	..	..	..	5	..	..
Copepoda	..	..	1	..	..	..	..	..	..	..	..	..	..	..
Nauplius	..	..	..	1	5	..	..	..	..	..	..	..	5	..
Rotifera		..	..	300	..	..	..	..	..	..	..	..	100	..
TOTAL	0	0	1	302	5	2	0	0	0	0	0	5	105	0
Phytoplankton														
Chlorophyta	200	...	100	...	...	200	100	100	...	...	...	...	100	200
Chrysophyta	100	...	1100	...	...	...	100	...	100	200	200	100	...	1500
Cyanophyta	...	...	....	...	...	...	300	...	...	100	...	100	...	..
Euglenophyta	...	...	....	...	...	...	...	...	...	...	...	...	..	....
TOTAL	300	0	1200	300	0	202	500	100	100	300	200	200	100	1700

Source: Lantz(1970).



Monthly Variations of Weight (Gm/m3) of Net and Nanno Plankton at Station IV of Sabine River

Figure 2.14

Source: Lantz (1970).

TABLE 2.22

PHYTOPLANKTON PIGMENTS FROM STATION IV OF SABINE RIVER*

Month	*Chlorophyll a*	*Chlorophyll b*	*Chlorophyll c*	*Carotenoid ac*	*Carotenoid nac*
August, 1964	3.94	1.16	3.62	0.32	0.64
September	...	...	...	...	...
October	1.86	0.54	0.84	0.20	0.44
November	0.92	0.55	1.58	3.01	0.35
December	2.15	0.83	4.15	0.48	0.03
January, 1965	2.44	0.92	1.82	0.44	0.12
February	1.53	0.83	2.01	0.39	0.02
March	4.80	3.35	16.50	2.68	1.49
April	3.16	1.00	4.62	0.72	0.01
May	2.45	1.81	3.87	0.76	0.15
June	0.68	0.57	1.78	0.05	0.13
July	0.77	0.71	1.60	0.22	0.14
August	1.59	1.62	2.22	0.42	0.11
September	2.60	1.59	3.48	0.47	0.03
October	...	...	...	...	...
November	0.95	1.08	1.61	0.29	0.19
December	1.08	1.22	1.29	0.30	0.06
January, 1966	0.85	0.53	0.29	0.19	0.05
February	0.65	0.70	1.17	0.09	0.07
March	2.03	1.97	1.48	0.21	0.22
April	0.23	0.23	0.00	0.00	0.00
May	...	...	...	...	...
June	5.21	4.66	3 06	0.37	0.72
July	2.22	2.20	1.18	0.16	0.37
August	3.20	2.93	2.12	0.35	0.40
September	2.70	2.31	0.49	0.24	0.28
October	2.70	2.31	0.49	0.24	0.28
November	1.25	1.07	2.13	0.20	0.05
December	0.96	0.83	0.57	0.11	0.02
January, 1967	1.22	1.12	1.05	0.17	0.04
Mean	2.01	1.43	2.41	0.48	0.24

*Milligram per liter (mg/ l)—chlorophyll a and chlorophyll b values
Milligram specific pigment units (MSPU)—chlorophyll c, carotenoid ac and carotenoid nac values.

Source: Lantz (1970).

TABLE 2.23

SEASONAL COUNTS, WEIGHTS, AND VOLUMES OF BOTTOM FAUNA
FROM SABINE RIVER

Organism	*Fall 1964*	*Winter 1964-65*	*Spring 1965*	*Summer 1965*	*Fall 1965*	*Winter 1965-66*	*Spring 1966*	*Summer 1966*	*Fall 1966*	*Winter 1966-67*
Tubificidae	63	2	14	..	6	1	..	4	..	..
Odonata	2	..	..	..	..	1	2	..	..	..
Ephemeroptera	20	..	..	3	..	4	..	..	..	..
Trichoptera	..	..	..	..	..	3	..	2	..	..
Coleoptera	..	..	..	..	..	3	..	..	..	..
Chironomidae	1	..	1	..	38	1	..	18	..	..
Viviparidae	1	..	1	..	1	..	1	..	..	..
Unionidae	..	..	..	..	..	..	..	..	..	..
Gammaridae	3	..	2	..	..	44	..	2	..	
TOTAL (no/ft²)	90	2	21	3	45	57	3	26	*	*
Weight (gm/ft²)	0.691	0.002	3.742	0.008	0.015	0.071	0.248	0.019		
Volume (cc/ft²)	0.02	0.21	2.10	0.10	0.20	0.20	0.40	0.20		

Source: Lantz (1970).

Lantz[37] also reported on the fishes of the Sabine River. However, his most downriver stations were all located just below Toledo Bend Reservoir, far upriver from the present study area. Even so, the data in Tables 2.24, 2.25 and 2.26 are probably representative of the freshwater fish fauna of the river. The only marine or estuarine species listed in these tables is the striped mullet. The fauna is comprised mainly of representatives of the Cyprinidae and Centrarchidae, with the total fauna consisting of 41 species. The author also reports no major change in the fauna as compared to earlier work. Probably some of the other species listed in Table 2.24 especially the darters (Percidae), gars, needlefish, Texas shiner and freshwater drum are also present below the reservoir. Since the parts of the Sabine and Neches Rivers and Cow Bayou in the study area are tidal, most of the bay and marsh species of fish that inhabit Sabine Lake are probably also present in these tidal reaches and will be discussed below.

The coastal marshes, Sabine Lake and associated marshes, the tidal reaches of the Sabine and Neches Rivers, Cow and Black Bayou and several smaller bayous provide brackish water habitat suitable for several species of crustaceans and fishes, including the white and brown shrimps, blue crabs, the red drum, black drum, sheepshead, flounder, croaker, bay anchovy, menhaden and striped mullet, several types of killifish, the mosquitofish, the sailfin molly, and several species of silversides. Due to varying salinity levels, components of the freshwater fish fauna of the area often invade these tidal reaches. Table 2.27 is an annotated list of the commercially important members of the fish fauna of the Texas coast and includes habitat remarks and seasonality of occurrence. In addition to the freshwater and brackish members, the list also includes those species which do not or only rarely invade inland waters.

There has been an appreciable decrease in the quality of the aquatic habitat in the Sabine-Neches waterway causing a decline in the commercial and sport fishery in Sabine Lake. Among the causes for this decline are the maintenance of the Sabine-Neches Waterway with its accompanying spoil disposal and containment problems, removal of marsh habitat due to draining and spoil deposition, industrial pollution from oil fields, industrial and municipal pollution from effluents deposited in the rivers and bayous, and the creation of artifical reservoirs on the major fluvial waters emptying into the lake.

TABLE 2.24

FISH COLLECTED IN COMMON SENSE SEINE
SABINE RIVER MARCH-SEPTEMBER, 1966

Number Collected at Each Station

Species	S-1B	S-2B	S-3B
Atlantic needlefish	...	...	...
Spotted gar	...	...	...
Longnose gar	...	...	...
Freshwater drum	...	...	...
Striped mullet	...	...	...
Gizzard shad	...	...	...
Threadfin shad	...	...	2
Brook silverside	...	...	...
Hybognathus sp.	939	211	636
Speckled chub	5	...	...
Golden shiner	2	...	...
Pallid shiner	...	...	...
Emerald shiner	66	14	376
Ghost shiner	...	...	152
Ribbon shiner	...	...	...
Red shiner	162	164	1724
Sabine shiner	69	50	84
Weed shiner	...	...	1
Redfin shiner	37	...	...
Blacktail shiner	23	17	7
Mimic shiner	...	2	...
Pugnose minnow	2	...	1
Suckermouth minnow	...	...	43
Bullhead minnow	10	1	125
River carpsucker	...	...	...
Blue sucker	...	...	2
Smallmouth buffalo	...	...	1
Spotted sucker	...	...	...
Blacktail redhorse	...	...	...
Yellow bullhead	1	...	...
Channel catfish	...	...	...
Freckled madtom	4	...	1
Flathead catfish	...	...	...
Mosquitofish	19	30	95
Golden topminnow	...	...	...
Blackstripe topminnow	10	7	3
Blackspotted topminnow	7	8	11
Yellow bass	...	...	...
Bluegill	6	1	1
Longear sunfish	5	2	4
Redear sunfish	...	...	...
Spotted sunfish	2	...	2
Spotted bass	9	1	12
Largemouth bass	22	...	...
White crappie	...	...	...
Black crappie	...	...	...
Western sand darter	20	...	30
Scaly sand darter	20	27	16
Eastern redfin darter	...	...	...
Bluntnose darter	...	...	...
Slough darter	...	...	...
Harlequin darter	...	...	...
Logperch	...	...	...
Dusky darter	...	...	...
River darter	...	...	3

Source: Lantz (1970).

TABLE 2.25

NUMBER OF FISH CAUGHT PER NET DAY IN HOOP NETS
Sabine River, March-September, 1966

Species	*S-1B 25 Net Days*	*S-2B 22 Net Days*	*S-3B 16 Net Days*
PREDATORY GAME FISH			
Largemouth bass	...	0.05	0.13
White crappie	...	0.23	0.06
Black crappie	0.12	0.14	0.13
Total	0.12	0.42	0.32
NON-PREDATORY GAME FISH			
Bluegill sunfish	...	...	0.06
Longear sunfish	...	0.09	...
Redear sunfish	...	...	...
Warmouth	...	...	...
Total	...	0.09	0.06
NON-PREDATORY FOOD FISH			
Smallmouth buffalo	0.32	0.05	0.13
Carp	0.12	0.64	0.13
River carpsucker	0.20	0.05	...
Spotted sucker	0.04	...	...
Blue sucker	...	...	...
Striped mullet	...	0.05	...
Total	0.68	0.79	0.26
PREDATORY FOOD FISH			
Channel catfish	0.32	0.18	...
Flathead catfish	...	0.14	0.06
Total	0.32	0.32	0.06
FORAGE FISH			
Gizzard Shad	...	0.05	...
Chestnut lamprey*	...	0.05	...
Total	...	0.10	...
GRAND TOTAL	1.12	1.72	0.70

*Chestnut lampreys attached to smallmouth buffalo

Source: Lantz (1970).

TABLE 2.26

NUMBER OF FISH CAUGHT IN WIRE TRAPS PER TRAP DAY
SABINE RIVER, MARCH-SEPTEMBER, 1966

Species	*S-1B 8 Trap Days*	*S-2B 8 Trap Days*	*S-3B 8 Trap Days*
PREDATORY GAME FISH			
Spotted bass	...	...	...
White crappie	...	...	...
Black crappie	...	...	0.13
Total	...	...	0.13
NON-PREDATORY GAME FISH			
Bluegill	...	...	0.25
Longear sunfish	2.59	0.50	2.25
Orangespotted sunfish	0.38	0.50	0.88
Redear sunfish	...	...	...
Spotted sunfish	...	...	0.13
Warmouth	...	...	...
Total	2.97	1.00	3.51
NON-PREDATORY FOOD FISH			
Carp	...	...	...
Freshwater drum	...	...	...
Smallmouth buffalo	...	...	...
River carpsucker	0.13	0.25	...
Total	0.13	0.25	...
PREDATORY FOOD FISH			
Channel catfish	0.13	1.75	0.63
Flathead catfish	...	0.13	...
Blue catfish	...	0.25	...
Yellow bullhead	...	...	...
Spotted gar	0.13	...	...
Total	0.26	2.13	0.63
FORAGE FISH			
Chestnut lamprey	...	...	...
Spottail shiner	...	...	0.50
Bullhead minnow	...	0.13	...
Total	...	0.13	0.50
GRAND TOTAL	3.36	3.51	4.77

Source: Lantz (1970).

TABLE 2.27

DISTRIBUTION OF COMMON COMMERCIAL FISH SPECIES ALONG THE TEXAS COAST WITH SEASONAL OCCURRENCES AND ABUNDANCES

Species Common Name	Habitat-Remarks	Winter	Spring	Summer	Fall
Pomatomus saltatrix Bluefish	offshore; in schools	O	X	X	O
Sarda sarda Atlantic bonito	offshore; blue water	O	O	O	O
Ictiobus bubalus Smallmouth buffalo	freshwater bays	O	X	X	X
Ictalurus punctatus Channel catfish	streams, turbid to clear rivers and lakes, low salinity bays	O	X	X	X
Bagre marinus Gafftopsail catfish	bays, passes and along beaches, active in currents, all Texas Gulf coast	X	X	X	X
Rachycentron canadum Cobia	around floating objects, harbors and docks	O	O	X	O
Coryphaena hippurus Dolphin	open water near floating seaweed and driftwood, warm seas	O	O	O	O
Pogonias cromis Black durm	shallow bays, all Texas coast	X	O	X	O
Aplodinotus grunniens Freshwater drum	freshwater lakes, streams, rivers, brackish waters, all of Texas	O	X	X	X
Sciaenops ocellata Red drum	bays, passes, channels	X	X	X	X
Paralichthys lethostigma Southern flounder	sandy, silty bottoms along shores of bays	X	X	X	X

O = Present

X = Abundant

TABLE 2.27 (Continued)

Species Common Name	Habitat-Remarks	Winter	Spring	Summer	Fall
Epinephelus nigritus Warsaw grouper	large specimens on snapper banks, small ones in bays near channels	O	O	O	O
Caranx hippos Crevalle jack	offshore, young in bays, around bridges, pilings	O	O	X	O
Epinephelus itajara Spotted jewfish	jetties, pilings, old wrecks, inshore coral reefs, entrances to creeks and sloughs	O	O	X	X
Menticirrhus littoralis Gulf kingfish	feed in sandy bottom bays, gulf	X	X	X	X
M. americanus Southern kingfish	feed in sandy bottom bays, gulf	X	X	X	X
Scomberomorus cavalla King mackerel	reefs, deep clear water	O	O	X	O
S. maculatus Spanish mackerel	mouths of harbors and passes, young in surf	O	O	X	O
Makaira nigricans Blue marlin	deep blue water, solitary, Port Isabel	O	O	X	O
Brevoortia patronus Gulf menhaden	gulf, bays, open water	O	O	X	X
B. gunteri Finescale menhaden	gulf, bays, open water	O	O	X	X
Mugil cephalus Striped mullet	habors, beaches, mouths of rivers and bays, school	X	X	X	X
Trachinotus carolinus Florida pompano	passes, in surf	O	O	X	X

TABLE 2.27 (Continued)

Species Common Name Habitat-Remarks	Winter	Spring	Summer	Fall
Istiophorus platypterus Sailfish far offshore, deep water	O	O	X	O
Cynoscion nebulosus Spotted seatrout bays, gulf beaches, grassy-areas	X	X	X	X
Archosargus probatocephalus Sheepshead pilings, jetties, oyster reefs	X	X	X	X
Lutjanus campechanus Red snapper generally on offshore reefs	X	X	X	X
Centropomus undecimalis Snook mouths of rivers and streams, frequent passes, inlets, cuts spawn during summer	O	O	X	O
Thunnus atlanticus Blackfin tuna offshore waters, feed on menhaden, school in offshore waters	O	O	O	O
T. thynnus Bluefin tuna offshore waters, feed on menhaden, school in offshore waters	O	O	O	O
T. albacares Yellowfin tuna offshore waters, feed on menhaden, school in offshore waters	O	O	O	O
Acanthocybuim solanderi Wahoo open ocean and Gulf Stream, deep reefs Freeport - Port Isabel	O	O	O	O
Anchoa mitchilli Bay anchovy bays, passes, channels	X	X	X	X
Anchoa hepsetus Striped anchovy bays, passes, channels	O	O	O	O
Notropis amabilis Texas shiner rivers, bayous	O	O	O	O
Notropis texanus Weed shiner rivers, bayous	O	O	O	O

TABLE 2.27 (Continued)

Species Common Name	Habitat-Remarks	Winter	Spring	Summer	Fall
Notropis venustus Blacktail shiner	rivers, bayous	O	O	O	O
Notropis lutrensis Red shiner	rivers, bayous	O	O	O	O
Ictalurus natalis Yellow bullhead	rivers, bayous	X	X	X	X
Ictalurus furcatus Blue catfish	rivers, bayous	O	O	O	O
Pylodictis olivaris Flathead catfish	bayous	O	O	O	O
Fundulus grandis Gulf killifish	bayous, marshes	X	X	X	X
Fundulus similis Longnose killifish	lakes, bayous	X	X	X	X
Cyprinodon variegatus Sheepshead minnow	bayous, marshes	O	X	X	O
Gambusia affinis Mosquitofish	ponds, freshwater bayous	X	X	X	X
Poecilia latipinna Sailfin molly	ponds, marshes, rivers	O	O	O	O
Mendia beryllina Tidewater silverside	bayous, marshes	O	O	O	O
Membras martinica Rough silverside	salt bayous, lake shores	X	X	X	X
Micropterus salmoides Largemouth bass	bayous, rivers	O	O	O	O
Lepomis gulosus Warmouth	bayous, rivers	O	O	O	O
Lepomis microlophus Redear sunfish	bayous, rivers	O	O	O	O

TABLE 2.27 (Continued)

Species Common Name	Habitat-Remarks	Winter	Spring	Summer	Fall
Lepomis macrochirus Bluegill	bayous, rivers	X	X	X	X
Pomoxis annularis White crappie	bayous, rivers	X	X	X	X
Pomoxis nigromaculatus Black crappie	bayous, rivers	O	X	X	O
Leiostomus xanthurus Spot	bays, nearshore	O	O	O	O
Micropogon undulatus Atlantic croaker	bayous, channels, offshore	O	X	X	O
Cynoscion arenarius Sand seatrout	bays, channels, offshore	X	X	X	X
Cynoscion nothus Silver seatrout	bays, channels, offshore	O	O	O	O
Chaetodipterus faber Atlantic spadefish	bays, channels, offshore	O	O	O	O
Ancylopsetta quadrocellata Ocellated flounder	bays, nearshore shelf	O	O	O	O

O = Present

X = Abundant

Source: Pew (1958), Bailey (1970), and Parker, Callaway, and Moore (1972) as reported by the U.S. Corp of Engineers.

2.5 SOCIOECONOMIC CHARACTERISTICS

2.5.1 Population Density and Growth

The project site is located in Cameron Parish, the largest parish in the state and the least populous. The pipeline to the tanker terminal at Nederland, Texas, would cross through Calcasieu Parish which, because of its higher population, would supply a large part of the required labor force. Table 2.16 in the West Hackberry DES shows the population density of these two parishes and of the State of Louisiana, and the extent of their urban and rural development. Cameron Parish is shown as being entirely rural because it has no communities with populations of 2,500 or more. The project site is in a rural area where much of the land is wetland or pasture.

Towns and Urban Areas

There are three small communities within a 10 mile radius of the site: Hackberry, Grand Lake, and Moss Lake. Hackberry is 3 miles east of the storage site and will be affected by the construction and operation of the project. Commercial businesses servicing the area are located in Lake Charles, about 26 miles northeast of the site via Louisiana Highway 27 and Interstate 10. Figure 2.15 shows these centers of populations in relation to the site.

2.5.2 Characteristics of the Nederland Oil Terminal Area

Population and Social Profile

Nederland, Texas is one of a cluster of cities that form an industrial triangle at the northern edge of Sabine Lake. Beaumont, Orange, and Port Arthur form the three points of the triangle, and Nederland lies about midway between Beaumont and Port Arthur as shown in Figure 2.15. Each of the cities is within 30 miles of the others, and their populations are as follows:*

Nederland	16,800
Beaumont	115,900
Orange	24,500
Port Arthur	57,400

*Population statistics supplied by the Texas State Department of Highways and Public Transportation in conjunction with the Texas Tourist Bureau. Nederland Chamber of Commerce estimates present population to be approximately 19,500.

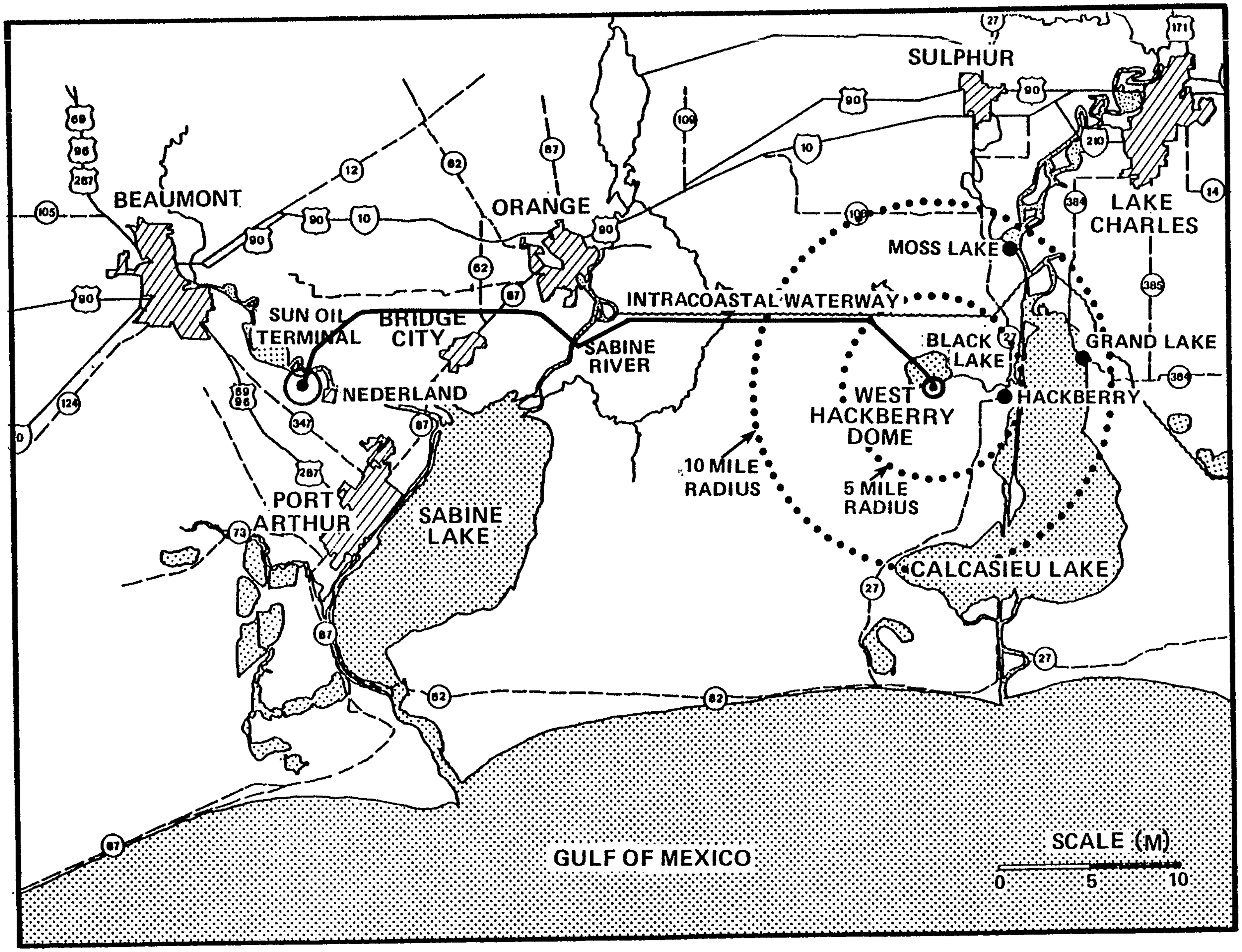


Figure 2.15 Population Centers

Nederland, Beaumont, and Port Arthur are the principal cities of Jefferson County. They are separated from Orange (which lies in Orange County) by the Neches River.

The combined populations of the three cities in Jefferson County comprise about two-thirds of the population of the entire county.

Nederland itself has an area of about 6 square miles. Most of its recent growth has been in the residential sector. The Sun Oil Terminal actually lies adjacent to the city boundary. A large proportion of the residents of this community commute to jobs in Beaumont and Port Arthur.

Community services include one hospital with a 100 bed capacity, one fire station with a staff of 10 professional firemen in addition to a trained group of volunteers, and a police dispatch station which works in close collaboration with the neighboring police stations of Beaumont and Port Arthur. The school district encompasses an area of 25 square miles, and operates 4 elementary schools, 2 junior high schools and one senior high.

Economic Profile

The tanker facilities at Nederland lie within the Sabine Customs District, which includes the ports of Beaumont, Orange, Port Arthur, and Lake Charles. Cargo shipped to and from the area averages about 23,000,000 tons annually, a large portion of which is petroleum and petrochemical products. Nearly a million barrels per day of crude oil are refined in the industrial areas of these cities. There are more than 15 major petrochemical plants within a twelve-mile radius of the city of Nederland.

Nederland does not have a municipal port. Shipping to and from the local industries is confined to private terminals along the Neches River.

2.6 UNIQUE FEATURES

2.6.1 Archaeological and Historical Sites

The marsh area through which the pipeline would pass was formerly occupied by Atakapa Indians. They were a settled agricultural group having a fairly large community in the Black Bayou area. There are approximately 75 known archaeological sites in the general area southeast of Beaumont, Texas extending into Louisiana.[40] The sites are primarily shell middens, which contain refuse discarded by the Indians near their dwellings. They are valuable archaeologically in that they contain bits of pottery, arrowheads, and implements indicating the lifestyle of the inhabitants of the region. Most of the early sites can be dated at between 300 and 400 A.D. The oldest site known in the area was from the Preceramic Period around 1500 A.D.[40] The files of the Texas Historical Commission, located at the Texas Archaeological Research Laboratory in Austin, were consulted for all known sites along the proposed pipeline route.[41] Although 19 sites were found within one mile of the route, none of the locations would be altered by construction.

In Louisiana, eight archaeological sites have been previously recorded for an area one mile on either side of the proposed pipeline route. These sites are recorded in the files of the Louisiana Archaeological Survey and Antiquities Commission at Baton Rouge. There is a high probability that three of these sites would be affected by pipeline construction due to their proximity to the proposed pipeline route. The remaining five sites would be unaffected, because their distance from the construction area.

Areas officially designated by the government as having historic value are listed in the National Register of Historic Places. A search of the National Register for the counties of Jefferson and Orange and the parishes of Cameron and Calcasieu lists the following areas of historical importance:[43]

a. The Lucas Gusher, Spindletop Oil Field three miles south of Beaumont.
b. French Home Trading Post at 2995 French Road, Beaumont.
c. McFadden House Complex at 1906 McFadden, Beaumont.
d. Pompeiian Villa at 1953 Lakeshore Drive, Port Arthur.

In Orange County, Texas there is only one location listed in the National Register, which is at the current time under a status of "pending nomination."[44] This is the W.H. Stark House at 611 W. Green Avenue, Orange. In Cameron and Calcasieu

Parishes, Louisiana, there are no locations listed in the National Register.

State historical offices in Texas and Louisiana were asked to locate areas of historical significance as listed in the State Registers. Louisiana has three historic marker locations in Calcasieu Parish and none in Cameron Parish.[45] In Texas, 33 historic markers are located in Jefferson County, and 4 in Orange County.[46] No areas of state or national importance would be disturbed by construction of the pipeline.

2.6.2 Wildlife Refuges

Although no unique wildlife areas or parks are within the area of potential impact, several important areas are near the proposed pipeline route (Figure 2.16).

Sabine National Wildlife Refuge south of the pipeline route is the largest waterfowl refuge on the Gulf Coast covering 142,846 acres. The original intent in establishing the refuge was to provide protection to marsh habitat important to wintering snow geese and ducks. Coastal marshes in southwest Louisiana were formally one of the most famous fur-producing areas of the country. Access canals dug through this area have since changed the ecological situation considerably by blocking the drainage of fresh water and allowing the intrusion of salt water. One of the management goals of Sabine Refuge is the re-establishment of a high quality marsh habitat over a large area through proper manipulation of water levels.[47]

Sydney Island is a private wildlife refuge managed by the National Audubon Society at the northern end of the Sabine Lake. The island has been in existence since 1915, when it was created as a spoil island from sand and silt dredged from the adjacent waterway. Although only 126 acres in size it has an extremely large concentration of nesting birds, mainly egrets, herons, night-herons, and ibis. In addition, it has one of the largest colonies of Roseate Spoonbills in the United States, with 600 nests counted in 1975.[48] Similar islands on Sabine Lake lack sizable bird population due to the disturbing effects of human habitation and the presence of cattle and hogs.

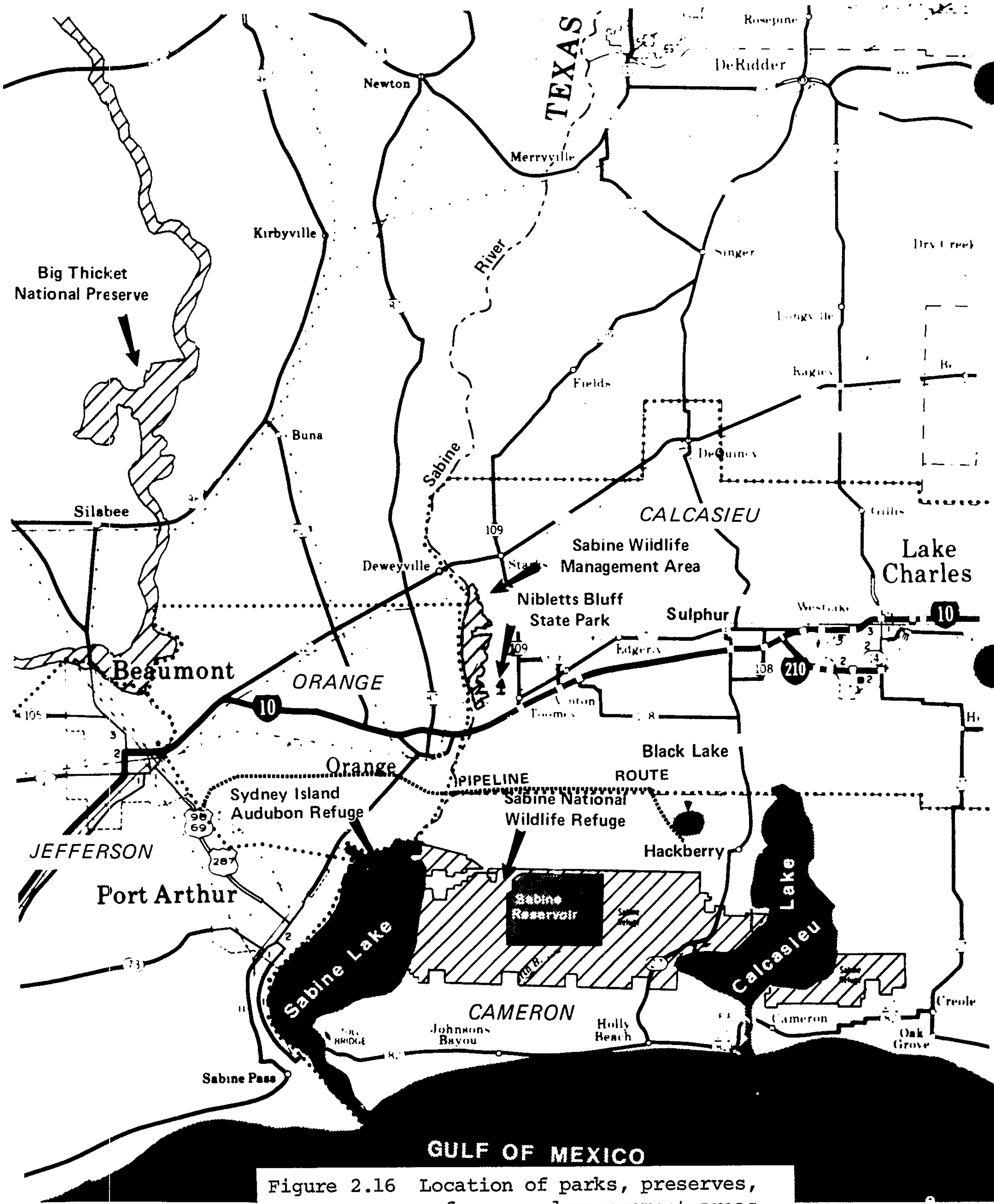


Figure 2.16 Location of parks, preserves, refuges, and management areas in the vicinity of the proposed pipeline.

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2.6.3 State and National Recreation Parks

Northwest of Beaumont, Texas lies the newly created 84,500 acre Big Thicket National Preserve covering seven counties. The preserve was created to save excellent examples of southern swamp and upland forest habitat, known locally as "the Big Thicket." The pipeline route would come no closer than eight miles to the closest unit near Beaumont, Texas.[49]

The only officially designated park area in the vicinity of the pipeline is Nibletts Bluff State Park. The park is located near the Sabine River approximately 10 miles north-east of Orange, Texas and 10 miles north of the pipeline route. Activities such as picnicing, boating, fishing, and camping can be pursued there. In addition, two miles west of Nibletts Bluff and six miles from the pipeline route is the Sabine Wildlife Management area. Covering approximately 9,000 acres, the area is managed primarily for waterfowl hunts.

2.6.4 Biologically Sensitive Areas

The pipeline route to Sun Terminal would border sensitive intermediate and brackish marsh habitat as well as crossing miles of marsh. The plant and animal communities in these areas are highly sensitive to fluctuating salt concentrations. Dramatic shifts in salinity are currently due to the building of canals and structures which restrict the drainage of fresh water to the coast and allow brackish water to flow inland. Obstacles which restrict this normal water flow have been instrumental in excluding species such as the alligator and many fresh water fish from coastal areas.

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3. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

The proposed action that would cause environmental or social impacts is the construction of two proposed pipelines; an oil supply line between the West Hackberry site and the Amoco dock and an oil distribution line between the site and the Sun Terminal. As discussed in Chapter 1, the pipeline route to Sun Terminal would be a 41.5 mile route from West Hackberry to Nederland, Texas. During construction, impacts would be attributable to emissions from construction equipment, disruption of the ecosystems along the pipeline routes, noise to adjacent communities, water quality effects due to dredging, and loss of affected land to other uses as well as effects on the local economies. Use of these pipelines during operation can also lead to some environmental impacts such as oil spills and corrosive products being expelled into the environment. Expected and potential impacts (both positive and negative) are described in Section 3.

3.1 LAND FEATURES AND USES

3.1.1 Geologic Impacts

Because of the heavy rainfall in Cameron Parish, Louisiana, and Orange County, Texas, minor soil erosion would result from excavation during pipeline construction activities. Soil erosion rates are not expected to increase significantly; however, there would be some erosion of bare ground before revegetation could occur (Section 3.4.2).

Material excavated from the pipeline trench would be retained along the trench for backfilling. As a result of this process, soil profiles would be inverted, but no significant adverse geologic effects are expected.

Dredging operations associated with waterway crossings would result in some turbidity. Since the proposed dredging would be done hydraulically and the spoil would not be backfilled. the amount of material put into suspension would not constitute a significant geologic impact. Hydraulic dredging, because of suction at the cutterheads, tends to remove much material that would otherwise be transported down river in suspension. Water quality impacts that would be produced by the proposed pipeline are discussed in Section 3.2.

3.1.2 Land Use Impacts

During construction of the oil distribution pipeline up to 477 acres of various land types would be temporarily affected (Table 1.3). After completion of the backfill operations, the permanent right-of-way would be reduced to 50 feet resulting in 242 acres permanently committed. Dry land rights-of-way would be maintained throughout the life of the project, marshes would be restored by careful backfilling and subsequent re-growth of vegetation. Total dry land affected by the proposed route would be 157 acres. Dry land constitutes roads, woodlands, river banks, and other dry land categories from Table 1.3.

The temporary oil supply pipeline from the Amoco dock would require 11 acres of dry land during construction and 8 acres of right-of-way during the ten (10) months of barge fill. This right-of-way would not be required after the pipeline is dismantled.

3.2 WATER QUALITY

The proposed pipeline route has been described in Section 1.0. The bodies of water which the pipeline would cross have been described in Section 2.2. The construction of the pipeline would necessitate that dredging be carried out in several rivers and bayous. The impact on the water quality due to the operation is discussed in Section 3.2.1.1. The impact on the water quality due to disposal of the dredged material is discussed in Section 3.2.1.2. Section 3.2.2 deals with the discharge of treated ballast water.

3.2.1 Impacts of Dredging

3.2.1.1 Impact of Dredging Operation

The pipeline when crossing a navigable river would be buried 15 ft below the river bottom. This would require dredging a ditch which would be 30-40 ft. wide at the bottom and 300 ft. wide at the top with a hydraulic cutterhead. In the smaller bayous the pipe would be buried 4 ft. below the stream bed and bucket dredging would be used.

Dredging in the Sabine River

The dredging in the Sabine River, which is approximately 1000 ft. wide at the point where the pipeline would cross, would require removal of approximately 175,000 to 200,000 cubic yards of dredged material. 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. If the bottom sediments are polluted, the release of a fraction of these pollutants during dreding 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 turbidity 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. Of primary concern is the possibility of (1) an increase in turbidity,* (2) the release of toxic sulfides, (3) the release of toxic metals, (4) the release of pesticides or non-pesticide toxic hydrocarbons or (5) a reduction in dissolved oxygen due to the increase of chemical oxygen demand for the oxidation of dredged materials.

*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.

Turbidity. The physical composition of the bottom sediments in the vicinity of the dredging site is probably sandy, with clay, silt, and organic debris also present. At times the river does transport fine silts and clays which are eventually deposited in the middle of Sabine Lake,[6] but the lack of an appreciable delta in the lake indicates that the river does not transport large quantities of clays and silts. Core samples indicate that at depths below 40 ft. a stiff clay soil is present; consequently a major portion of the dredged material would probably consist of clays. Dredging for the proposed pipeline would expose portions of the virgin river channel. This would remove a large quantity of relatively unpolluted dredged material. This clay tends to be finer grained than the shallower sediments sand and silt.

The variation of settling velocity* with type of sediment is shown in Figure 3.1. As indicated in the figure, a clay particle 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 20mm, and 20mm/sec for a fine sand particle with a diameter of 200mm. The period of time an individual particle remains suspended in a turbidity plume and the distance the particle is transported downstream 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.

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 size and duration of the turbidity plume would depend on the number and size of the dredges operating in the area, the skill of the dredging operators, the length of time during which dredging occurs, bottom sediment characteristics, and river flow conditions. A measurable increase in turbidity would be expected 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 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. As noted previously, clay is likely to be a major component of the dredged spoil since the dredging will extend to depths as great as 47 feet. The clay particles would

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

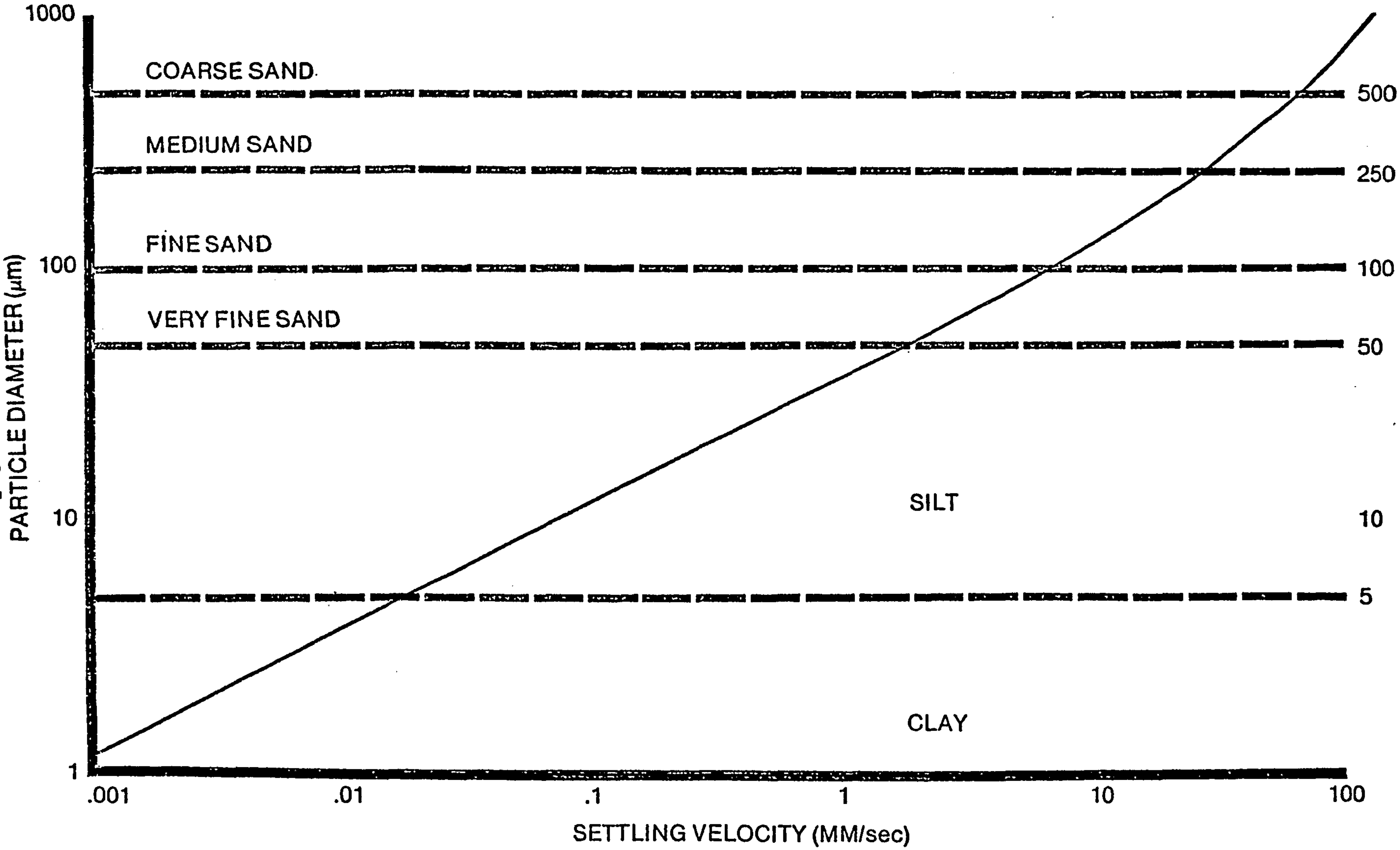

FIGURE 3.1 **Variation of Settling Velocity with Particle Diameter**

be transported as far as the middle of Sabine Lake. Eventually, through ebb tides a portion of the sediment would be transported into the Gulf. The time required for movement of material into the Gulf is unknown. Such increases in turbidity should have little if any adverse long-term impact on water quality of the surface water system. Sabine Lake has been and is presently the recipient of much dredge spoils along its western edge.[6]

Toxic Metals. As noted in Section 2.2, the water quality data in Table C.8 indicate that the levels of cadmium, zinc, and copper were in excess of the suggested EPA criteria. The sediment tests taken at the same time indicated that the zinc level in the sediment was in excess of the unofficial recommended criteria. Six months later (Table C.9), when the river flow rate was increased significantly, the cadmium concentration in the water was well within the EPA criteria both before and during the dredging operations. The zinc and copper levels were not measured during the same time period. During maintenance dredging operations in the Sabine River the level of nickel and chromium increased while the concentration of lead, cadmium and mercury actually decreased in the water, in comparison to the levels measured before dredging operations started. This decrease is characteristic of heavier metals (lead and mercury), which are generally less soluble, precipitating out on 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 or to form insoluble salts. Thus dredging could increase the concentrations of lighter metals, potentially exceeding the suggested values, while the concentration of heavy metals would generally be reduced.

Pesticides and/or Toxic Hydrocarbons. The heavy industrialized Port Arthur-Beaumont region is primarily petrochemically based and is probably responsible for the high grease and oil values in the sediment samples of Table C.4. The presence of high grease and oil values suggests that other crude oil constituents and waste water pollutants such as phenols could be present. The dredging operations could potentially release some of these into the water column.

Chemical Oxygen Demand (COD). The results of sediment tests shown in Table C.8 indicate that two of three samplings had values for chemical oxygen demand (COD) exceeding the unofficial recommended criteria. Additional samples before and during dredging* also indicate that dissolved oxygen decreases when dredging takes place. This decrease occurs because many materials in the sediment are readily oxidized, thus consuming the dissolved oxygen in the water. These results indicate that the dredging operation associated with the ESR program would probably increase the COD in the water column.

Summary. Some of the dredge material from the greatest depths beneath the channel would be unpolluted; consequently the potential for release of toxic materials is somewhat diminished. An increase in turbidity and increased chemical oxygen demand would still be expected. A significant portion of the pipeline would be dredged through the spoil and shoal areas off the main channel. This portion of the dredging operation would generally have a greater probability for releasing toxic materials. A slight increase in certain lighter metals in the water would be expected, but the more toxic heavier metals concentration would be reduced. There would be a definite increase in the COD due to the nature of the dredged material. 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 Neches River

The dredging in the Neches River, which is approximately 800 feet wide would require dredging approximately 140,000-160,000 cubic yards of dredged material. It is anticipated that the same hydraulic dredging technique would be used as discussed for the Sabine River. The water quality and sediment data indicate that in general the same impacts anticipated for the Sabine River are likely to be encountered in the Neches River.

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*The dredging referred to was carried out by the Corps of Engineers in July 1975.

**Both Texas and Louisiana have established site-specific guidelines, governing water quality during dredging, as part of the dredging permit issued by the state. Because such guidelines have not yet been established for the sites discussed in this document, it is not possible to state whether or not the guidelines would be met.

Dredging in Cow Bayou

The dredge operation in Cow Bayou would be carried out with a bucket dredge. Approximately 50,000 cubic yards would be dredged. Since the water quality and sediment data for Cow Bayou are similar to the Sabine and Neches Rivers, similar impacts would be expected. The use of a bucket dredge in lieu of a hydraulic dredge would produce slightly more turbidity.

Dredging at Black Bayou

The proposed pipeline route would require that dredging operations be carried out across three bodies* of water joining with Black Bayou as described in Section 2.2. The volume of dredged material from the three would be on the order of 50,000 cubic yards. The impact of the dredging operation should be similar to that noted for the Sabine River.

Dredging in Black Lake

The proposed pipeline route would require dredging across the southwestern tip of Black Lake as shown in Figure 2.1. The distance across the lake at this point is approximately 3000 feet. The dredging depth would be approximately 5 ft. beneath the lake bottom. A bucket dredge would be used with the volume of dredged material being on the order of 56,000 cubic yards. The general impact of the dredging process would differ somewhat from that noted for the Sabine or Neches River. First, because currents in the lake are much weaker than in the river, it is anticipated that all effects would be more localized. Second, in Black Lake standard practice for dredging pipeline channels involves using the dredged spoil to back-fill the trench after the pipe is laid, while in the rivers the dredge spoil would not be used for back-filling. Thus, the dredged spoil in Black Lake would remain in contact with the water column for a longer period of time and may introduce a greater fraction of contaminants into the water.

3.2.1.2 Impact from Disposal of Dredged Material

In the disposal of the dredged material basic concerns pertaining to the disposal area are: (1) an increase in turbidity of the water, (2) a significant release of aquatic nutrients, (3) the depression of dissolved oxygen levels, (4) the release of toxic sulfides, (5) the release of toxic metals, (6) the release of

*The three bodies of water are the Vinton Canal, an unnamed branch of Black Bayou, and Black Bayou Cutoff.

pesticides or non-pesticide toxic or (7) 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 system is in part determined by the method of disposal and distance the slurry might be piped. 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 a weir* to be emplaced adjacent to the disposal area for retaining much of the excess water from the spoil so suspended material can settle out. A drainage ditch would channel overflow water from the disposal area back into the bayous or rivers. Thus in addition to having an impact on the confined disposal area, the disposal would also have an impact on the original body of water. Impacts on ecological processes are discussed in Section 3.4. Site-specific impacts of the disposal operations are provided in the discussion which follows.

Turbidity Increase. The dredging operation would involve a hydraulic dredge with cutterhead. The dredged material would be transported via pipeline to the disposal site. The use of a hydraulic dredge would tend to mix more water with the dredged material. Piping the mixture more than 1000 feet would also tend to break up the clay lumps into smaller particles. Thus within the confined disposal area a large increase 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 total suspended solids would be reduced below 8 grams per liter prior to the water returning to the Sabine River.

Release of Aquatic Nutrients. In confined areas the release of phosphorus, nitrogen, and ammonia, is of concern because these materials tend to encourage the excessive growth of aquatic vegetation, typical of eutrophic** conditions. There are no data on the phosphorus in the sediment. The Total Kjeldahl Nitrogen (TKN) in the bottom sediment exceeds the unofficial recommended criteria (see Table C.8).

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

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

**Eutrophic signifies a water body rich in dissolved nutrients but often shallow and with seasonal oxygen deficiency.

Depression of Dissolved Oxygen Levels. The COD of the sediment exceeds the unofficial recommended criteria. Based on experience of the Corps of Engineers in the Gulf Intracoastal Waterway it would appear 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. 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. Algae consume oxygen during periods of darkness.

Windom[7] observed a significant increase in DO in confined disposal areas. If the confinement area were designed so that the sediment transport water were returned to the waterway after sufficient time for suspended solids to be deposited and nutrients to be removed by algae, but before the algae population becomes senescent and dies, 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.

Release of Toxic Sulfides. The levels of oil and grease in the sediment exceed the unofficial recommended criteria and thus some hydrogen sulfide may be present. Thus in the disposal operation some release of sulfides would tend to combine with the metals to form insoluble salts. This process would tend to offset the release of sulfides from the oil and grease.

Toxic Metals Release. As discussed earlier the concentrations of heavy metals in water usually decrease when suspended matter is present. Thus, while the concentration of zinc exceeds the unofficial recommended criteria in some sediment samples from the Sabine River, an increase in the level of zinc in the water is expected. However, based on data (Table C.9) taken before and after dredging in the Sabine River the concentration of chromium and nickel may increase in the disposal area waters.

Pesticides and Toxic Hydrocarbons Release. Due to the absence of large agricultural areas that require spraying, high levels of pesticides are not anticipated to be present in the sediment. Thus the release of pesticides at the disposal site should not be significant.

The high levels of oil and grease found in sediments as noted earlier indicates the potential for release of toxic hydrocarbons. Toxic phenols which can come from crude oil and the waste water from petrochemical plants are of particular concern. The quantities of oil and grease suggest that phenols and other toxic hydrocarbons are present and would be released.

Summary. The impact of the dredged material on the Sabine River disposal site should consist of increases in turbidity, possibly TKN, 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 marsh may also be affected, depending on the location and design of the disposal area. The impact of the dredging disposal operation can be localized and minimized by employing the most recent disposal technology.[8,9,10,11]

Impact on Sabine River due to Effluent from Disposal Area

During the dredging a contained disposal area would be used to retain solids in the slurry. Excess water must be discharged from the disposal area back into the river since in most cases it represents 80 to 95 percent of the total volume of materials pumped into the containment structure. The impact of this excess water on the Sabine River would vary according to the quality and volume of the receiving water and the quality and quantity of the effluent. If the disposal area is properly designed with sufficient capacity to allow adequate retention time for the water, the effluent should be relatively free of suspended solids. Current practice is to design the disposal area so the level of total suspended solids will be less than 8 grams per liter at the exit spillway.

Impact on the Neches River Disposal Area

The same dredging procedures and disposal techniques used in the Sabine River would be used on the Neches River pipeline crossing. The sediment analysis for the two river beds indicate similar pollutants and characteristics. The impact of the disposal of the dredged material on the Neches disposal area should be similar to that already described for the Sabine River.

Impact on Neches River due to Effluent from Disposal Area

Eighty to 95 percent of the total volume of materials pumped into the disposal area would consist of water which ultimately would be returned to the Neches River. The impact on the river would be essentially the same as that already described for the Sabine.

Impact on Cow Bayou Disposal Area

The dredging would utilize a bucket dredge operation with disposal in nearby confined areas. The water quality in Cow Bayou and bottom sediments are similar to those in the Sabine and Neches Rivers, and thus the potential for leaching of pollutants is similar to that described for the Sabine and the Neches Rivers. Because the dredged material will be less broken up by the bucket dredge than by a hydraulic dredge less turbidity in the disposal area around Cow Bayou would be expected.

Impact on Cow Bayou due to Effluent from Disposal Area

The impact of effluent from the disposal area near Cow Bayou would resemble that previously described for the Sabine and Neches Rivers. Because of the use of bucket dredging in the bayou, as opposed to hydraulic, a smaller fraction of the total volume of material transplanted to the disposal area would be water, and thus the volume of the effluent returning to the bayou would also be proportionately smaller.

Impact on Black Bayou Disposal Area

The impact on the disposal site is related to the dredging and disposal techniques, and to the pollutants in the dredged material. A bucket dredging technique would be utilized and the disposal area is to be confined. As noted in Section 3.2.1.1, data are available from the Gulf Intracoastal Waterway (ICW) which shows a high degree of pesticide pollution. Since the ICW is near rice growing areas, it is assumed that the sediments do have significant quantities of pesticides in them which would be released from the dredged material in the disposal area. Other impacts should be similar to those impacts for the Cow Bayou disposal area already described.

Impact on Black Bayou due to Effluent from Disposal Area

The impact on Black Bayou produced by the effluent from the disposal area would be similar to that already described for Cow Bayou.

Impact on Black Lake Disposal Area

As noted previously, the dredged spoil for the dredging in Black Lake would be used to back-fill the trench after the pipeline is laid. Thus no separate disposal area would be required and no additional impact due to the disposal operation is anticipated.

3.2.2 Discharge of Water from Ballast Treatment System

As noted in Section 1.0 each tanker prior to receiving oil at the tanker dock 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.[12] 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[13] indicates that such a film becomes visible when the oil concentration is approximately 7.5 ppm. 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 2.6 ft^3/sec or 40,000 bpd.*

As described in Section 1.0, 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. In order to obtain some estimate of the impact, the ditch was assumed to contain only the treated ballast water from the tankers associated with the transport of oil from the West Hackberry facility. Thus the discharge rate was taken as 2.6 ft^3/sec with a salinity of 30 ppt and an oil concentration of 7.5 ppm. The river flow velocity was taken

*This rate of discharge is based on the assumption that 50 percent of the oil removed from the storage facility would be transported by tanker from the Sun Oil Dock.

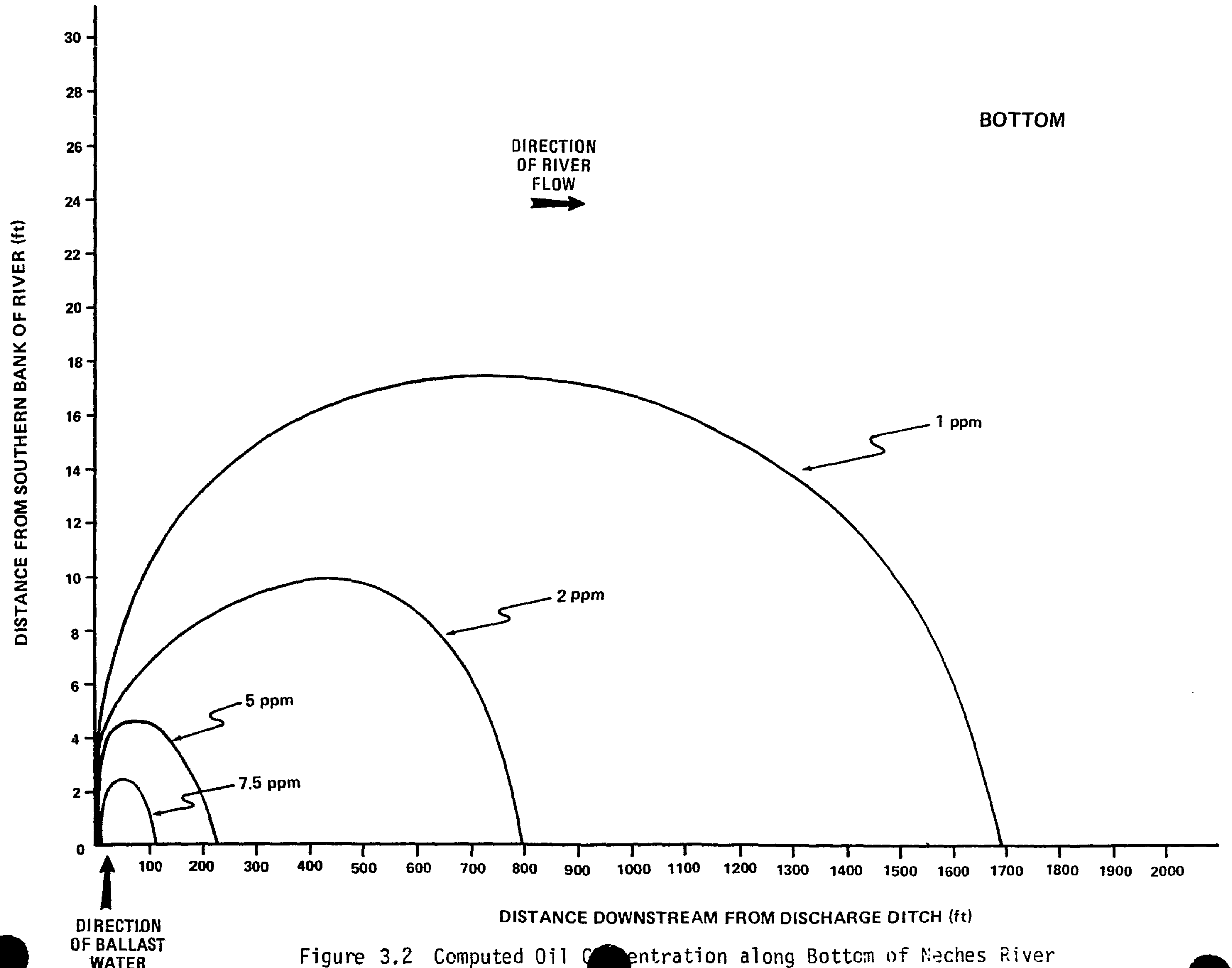

Figure 3.2 Computed Oil Concentration along Bottom of Neches River

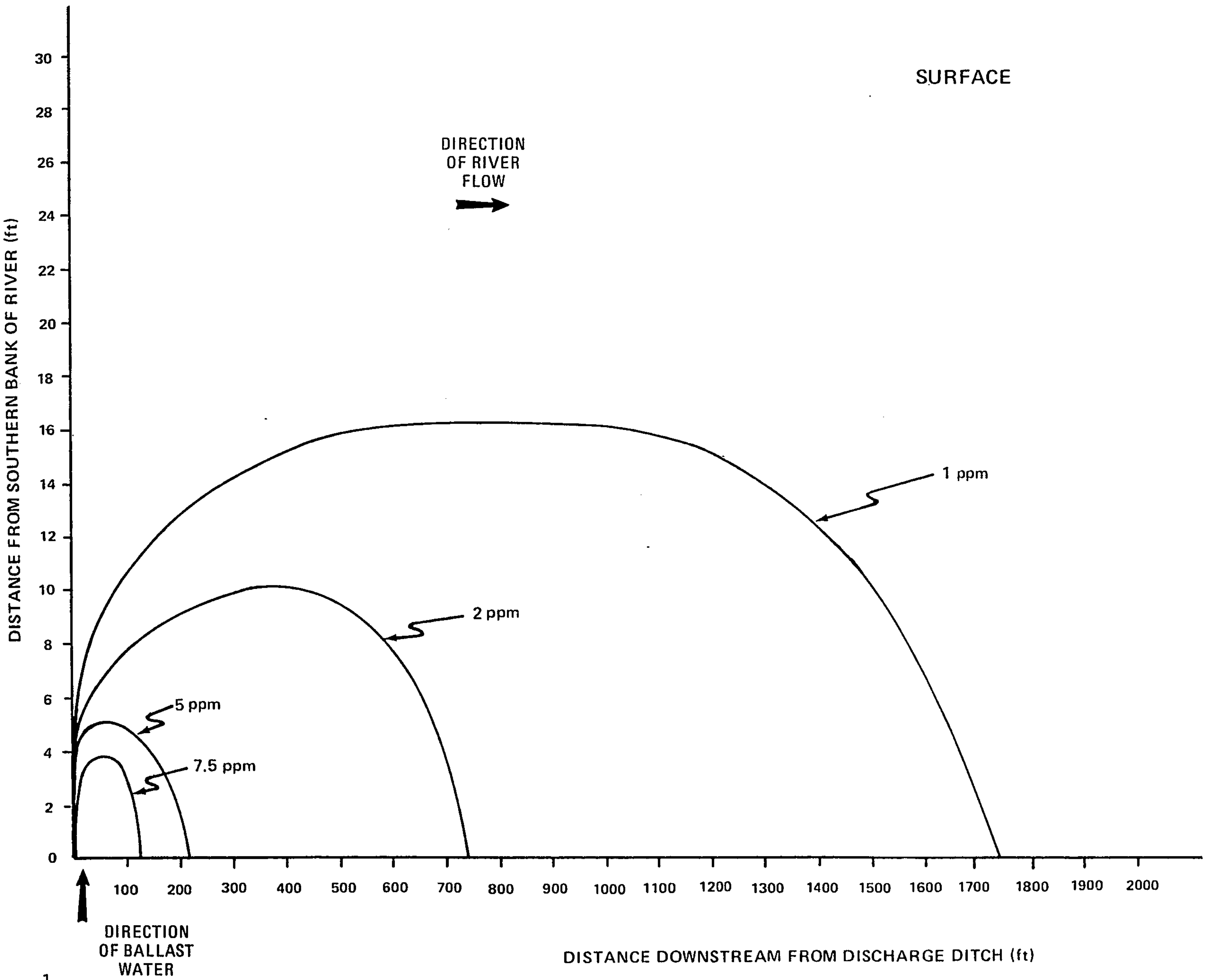

Figure 3.3 Computed Oil Concentration on Surface of Neches River

1

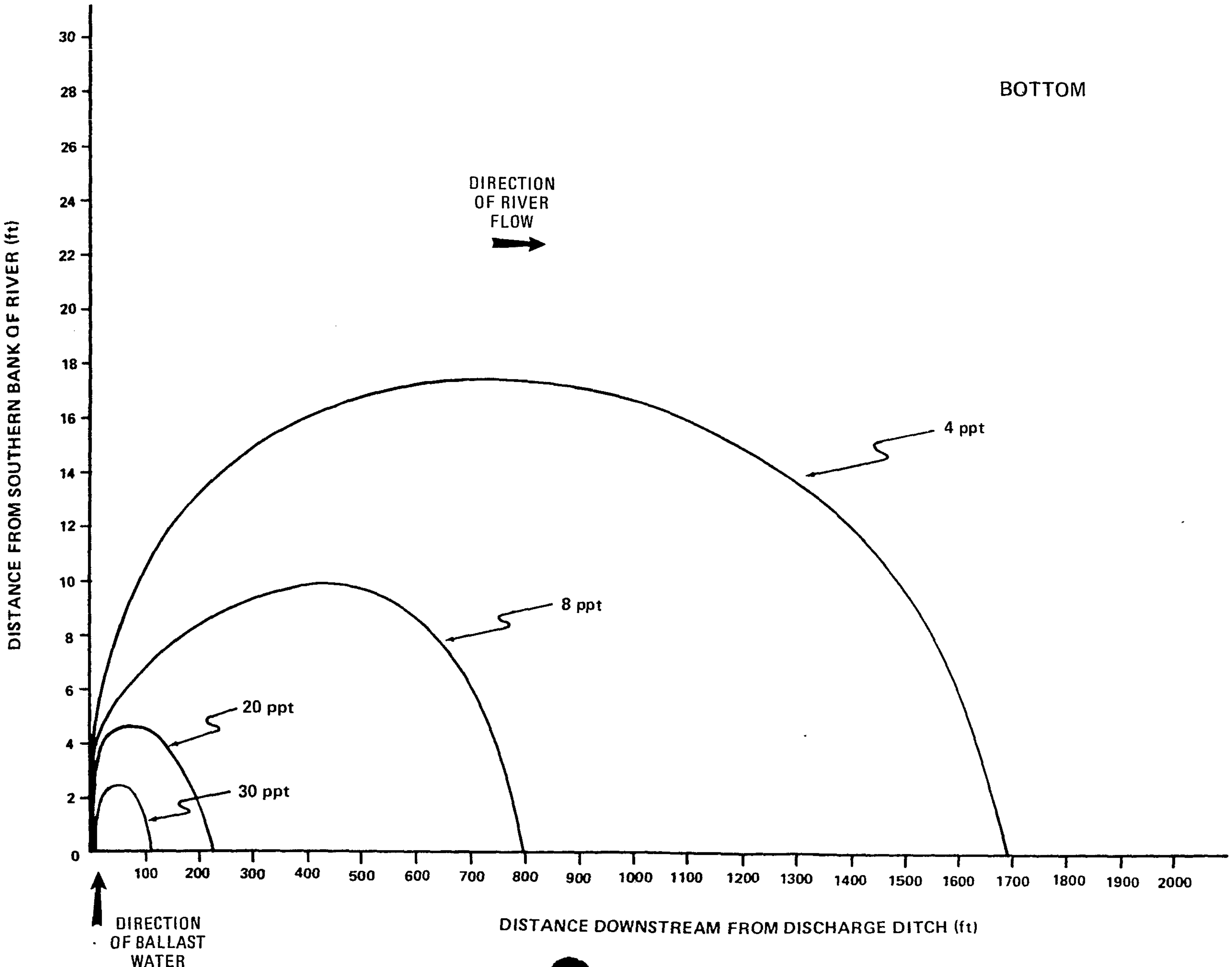

Figure 3.4 Co[illegible]ed Salinity along Bottom of Neches River

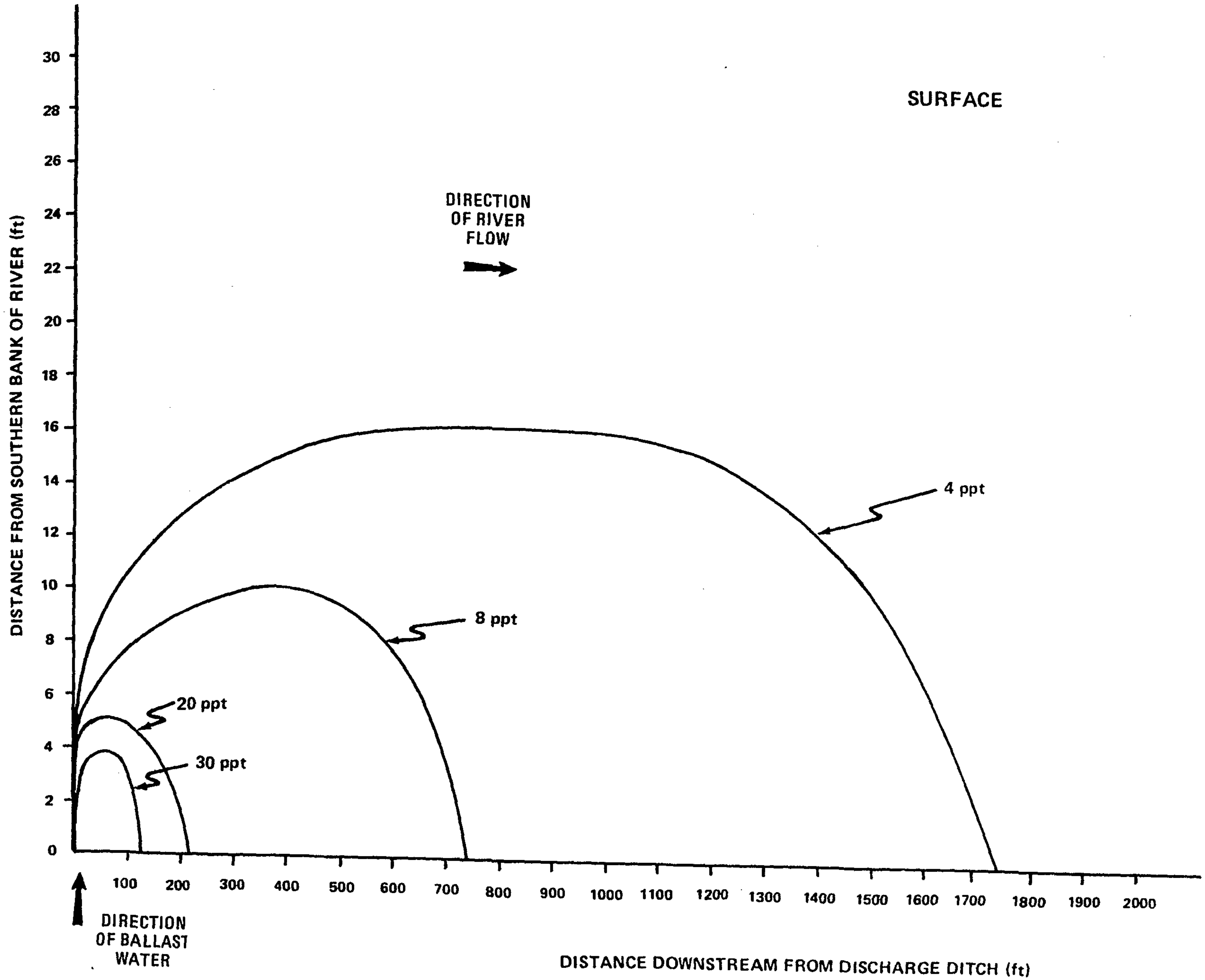

Figure 3.5 Computed Salinity on Surface of Neches River

at 0.765 ft/sec based on the minimum flow rate reported during the water year 1975.[14] The river depth was assumed to vary from 5 feet near the shore to 40 feet in the navigation channel. The behavior of the resulting plume was modeled by means of a computer program utilizing the general solution of the diffusion equation for a finite moving medium.[15] By means of images, the top and bottom of the river and the river banks were accounted for. The program was used to compute the distribution of oil and salinity downstream of the ditch. Figures 3.2 and 3.3 present the computed contours for oil concentration on the river bottom and river surface respectively. In similar fashion, Figures 3.4 and 3.5 present the corresponding plots of isohalines (lines of constant salinity). Figures 3.2 through 3.5 can be interpreted as planar views of the Neches River. The ballast water discharge ditch is located on the southern bank of the river and river flow is Gulfward.

Figure 3.2 indicates river bottom oil concentration values of 7.5 ppm occurred as far as 110 feet downstream of the ditch. The oil concentration would exceed 1 ppm for a distance of approximately 1690 feet downstream.

On the river, surface oil concentrations of 7.5 ppm are encountered as far as 120 feet downstream as shown in Figure 3.3. Concentrations in excess of 1 ppm occur as far as 1750 feet downstream. On both the river bottom and surface no concentration greater than 1 ppm occurs beyond roughly 18 feet from the southern bank of the river.

The isohalines shown in Figure 3.4 for the river bottom indicate that salinities of 30 ppt persist as far as 110 feet downstream. Salinities greater than 4 ppt are encountered for a distance of 1690 feet downstream.

On the river surface, as shown in Figure 3.5, the 20 ppt isohaline extends downstream 120 feet. Salinities in excess of 4 ppt occur as far as 1750 feet downstream.

The total area* exposed to a given (or greater) concentration of oil is presented as a function of oil concentration in Figures 3.6 and 3.7 for the river bottom and surface, respectively. Figures 3.8 and 3.9 provide similar data for the total area* exposed to a given (or greater) level of salinity. In each case, an area of approximately 400 square feet or less is exposed to the maximum levels of oil and salinity.

*In the horizontal plane.

The cross sectional area* of the portion of the river affected by the discharge of treated ballast water would be less than 0.4 percent of the total cross sectional area of the river. A mixing region of this size would be well within Texas State Water Standards. Thus, the discharge of treated ballast water into the Neches River would have a minor impact on the river.

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*In the vertical plane.

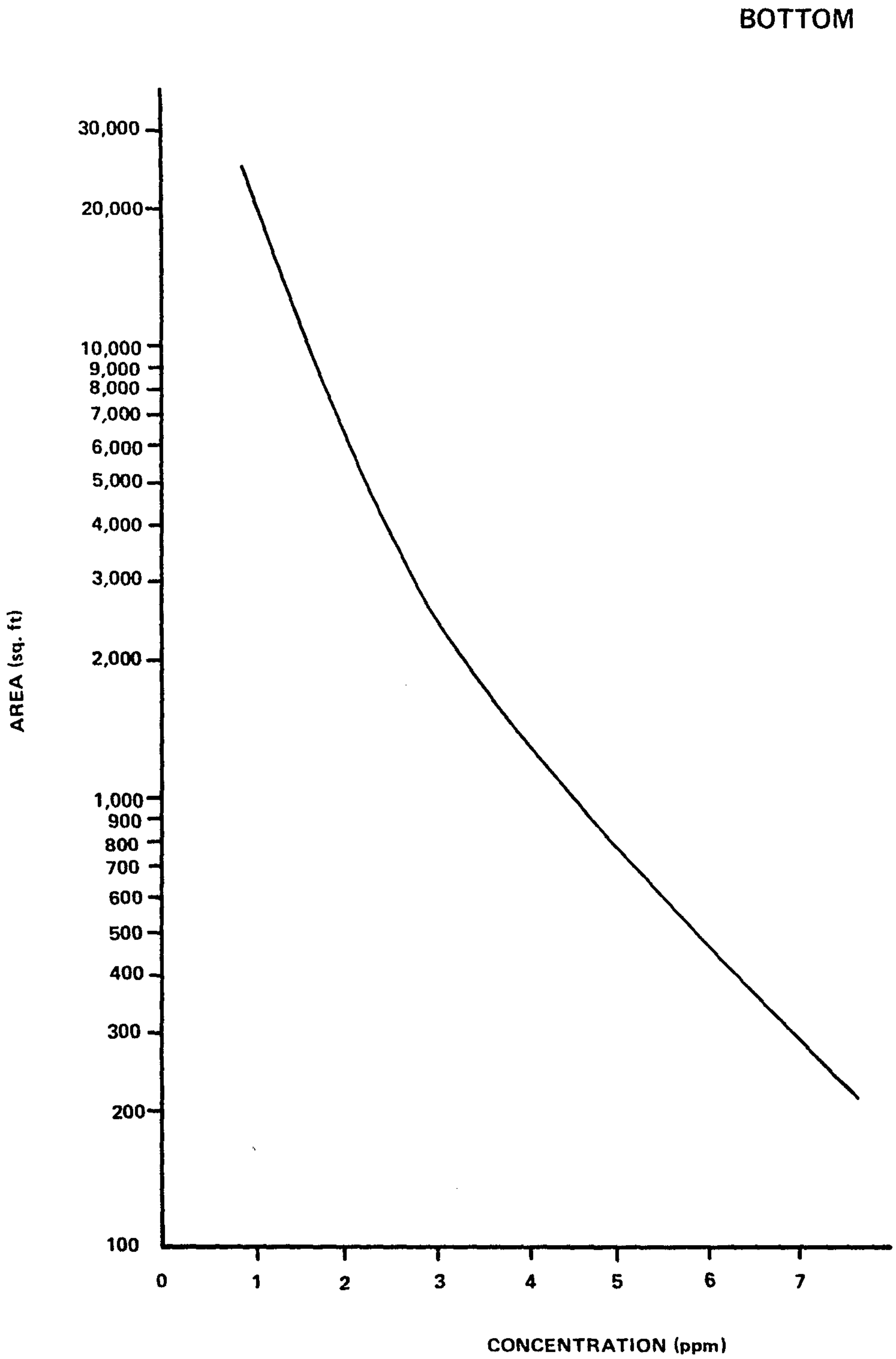

Figure 3.6 Variation of Affected Area with Oil Concentration along Bottom of Neches River

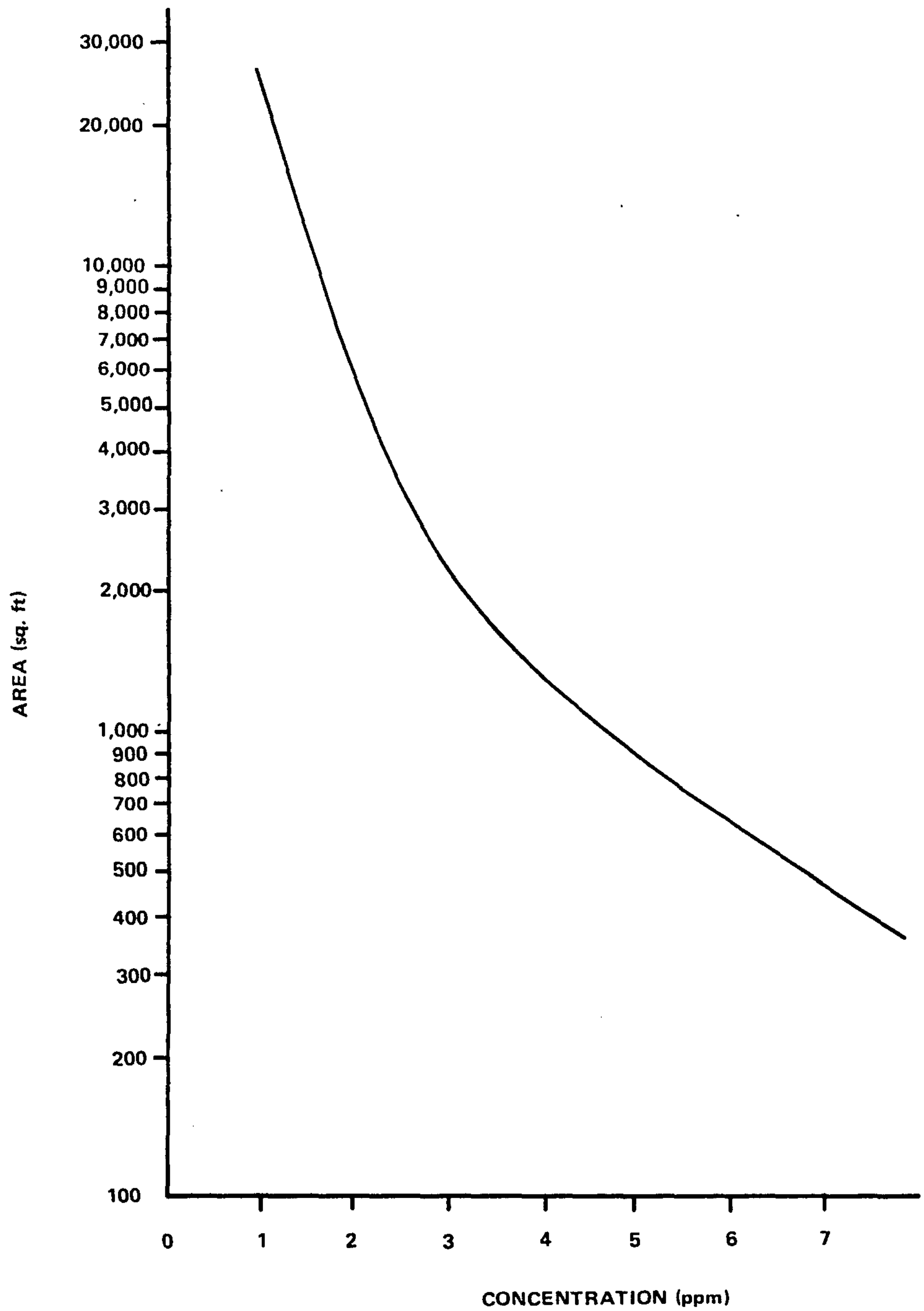

Figure 3.7 Variation of Affected Area with Oil Concentration on Surface of Neches River

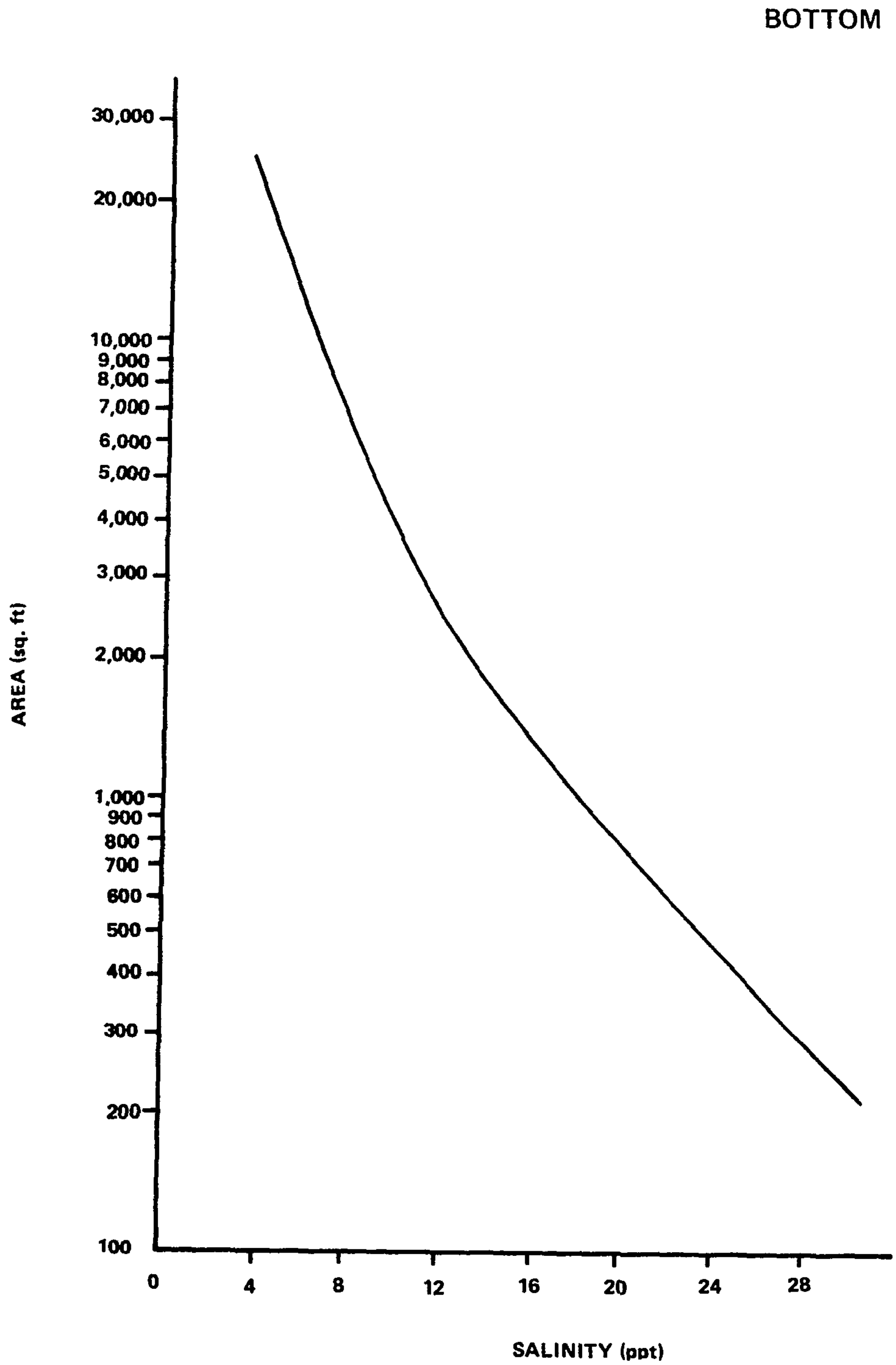

Figure 3.8 Variation of Affected Area with Salinity Concentration Along Bottom of Neches River.

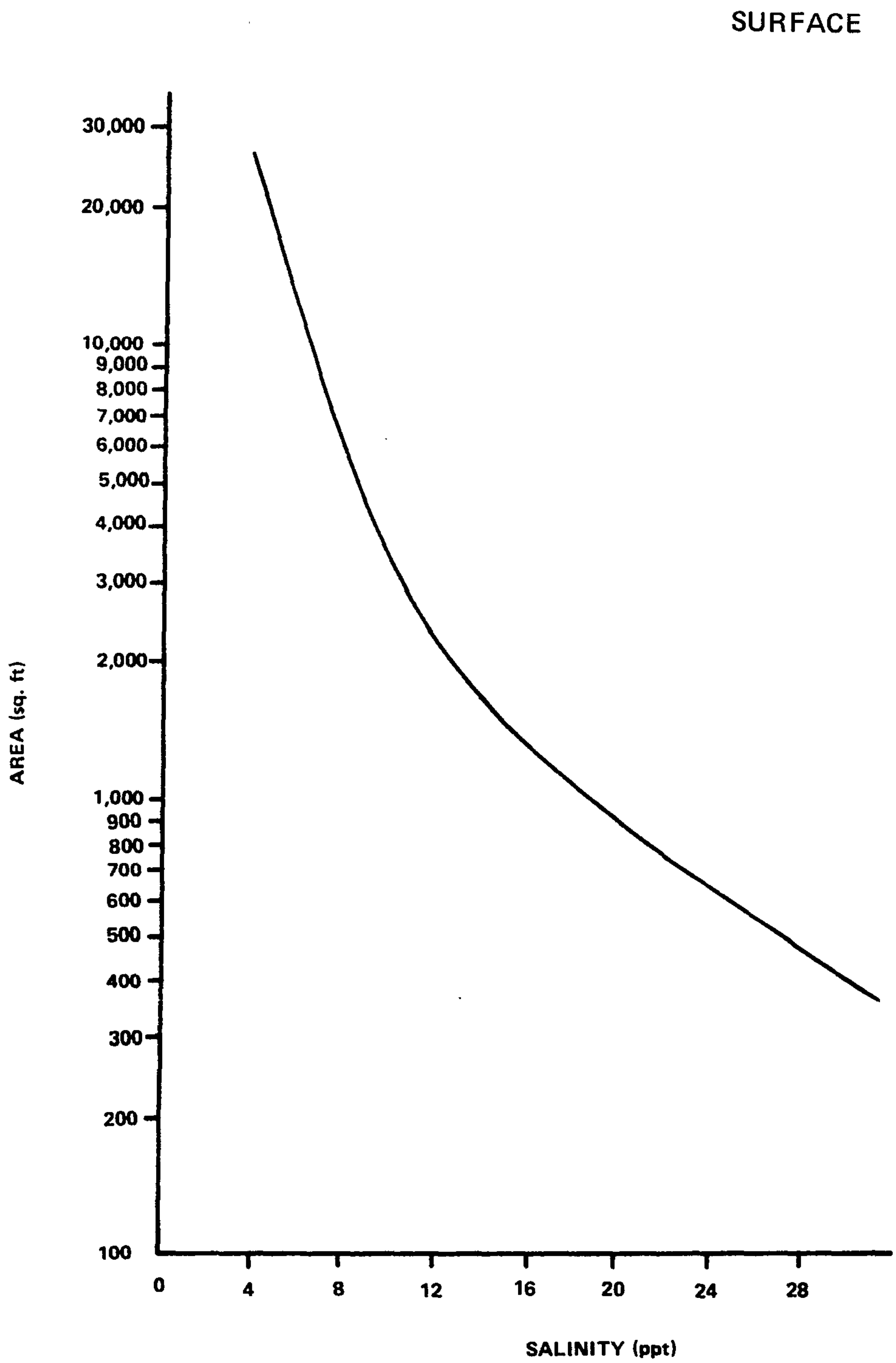

Figure 3.9 Variation of Affected Area with Salinity Concentration on Surface of Neches River

3.3 AIR QUALITY

Air quality at the West Hackberry dome and along the pipeline route would be slightly affected during the pipeline construction. The storage facility is located in Cameron Parish which has a relatively low level of petrochemical and refinery activity in comparison to Calcasieu Parish to the north and Jefferson and Orange Counties, Texas to the west. Although there are no site-specific air quality measurements available, the existing pollutant levels for the SPR site area can be extropolated from the nearby monitoring stations at Lake Charles, Louisiana and West Orange, Texas. The data from these stations revealed that the standards for non-methane hydrocarbons (NMHC) and photochemical oxidants (O_3) were violated based on 1975 monitoring data.[16] This indicates that levels of these pollutants presently exceed standards for the region and that violation of the standards for these parameters can be anticipated at the West Hackberry site area. Sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and hydrogen sulfide (H_2S) concentrations are presently in compliance with all applicable air quality standards indicating a lack of heavy regional concentration of combustion concentrations.

It is planned that 90 percent of the West Hackberry storage capacity would be received by pipeline from the Sun Terminal at Nederland, Texas. The crude oil would be supplied to the Sun Terminal by tankers. The remaining 10 percent would be received onsite by barge. In the event that drawdown of the facility is required the total capacity would be returned to Sun Terminal where 50 percent would be transported by pipeline to refineries and the remaining 50 percent would be shipped by tankers.

If mitigating measures are not taken it is anticipated that the largest air quality impact associated with the oil distribution system would occur as a result of marine vessel loading and unloading of crude oil. This impact would occur in the vicinity of the Sun Terminal in Nederland, Texas.

3.3.1 Sources of Emissions

Prior to site preparation and construction, plans and specifications for the proposed facility must be submitted to the Louisiana Air Control Commission,[17] and all sources of potential emissions and estimates of quantity must be provided. Identifiable emission sources during the construction phase include (1) fugitive dust, and (2) general construction vehicles. Key sources during the operational phases include the following:

- Marine terminal crude oil transferring
- Crude oil storage tank
- Pipeline pump seals and valves
- Onboard vessel power plants

The following paragraph will discuss the major emission and emission factors for the various emission sources.

Fugitive Dust

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 operation of 1.2 tons of fugitive dust per acre of construction per month of activity.[18] 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 Texas and Louisiana where the climate is humid and the soil is wet and marshy, i.e., it would tend to overstate the impacts of the contemplated construction.

General Construction Vehicles

Typical heavy duty vehicles used during the construction phase include track laying tractors and shovel loaders, motor graders, scrapers, off-highway trucks, wheeled loaders and tractors, rollers, wheeled dozers, and other miscellaneous pieces of equipment. USEPA has published emission factors for various heavy and light construction vehicles based on typical equipment usage factors.[18] These emission factors combined with the vehicle usage factor can be used to determine the specific emission rates resulting from construction vehicles. In the present analysis, the onsite vehicles are assumed to consist of 10 heavy-duty diesel vehicles and 10 heavy-duty gasoline vehicles. The average vehicle speed is assumed to be 10 miles per hour and the vehicle usage rate is 2,000 hours per year. The total vehicle emissions during construction for the West Hackberry site are presented in Table 3.1 below:

Table 3.1 Vehicle Emissions during Construction

	Construction Vehicles gm/sec
CO	0.1380
HC	0.0117
NO_2	0.0211
SO_2	0.0020
Particulate	0.0019

Crude Oil Storage Tank

There would be three 200,000 barrel floating-roof storage tanks at the Sun Terminal in Nederland, Texas. These tanks would not suffer breathing loss or working loss, but would have a standing storage loss due to the space between the seal and shoe of the tank. This hydrocarbon loss is estimated to be 244 pounds per day (1.28 gm/sec) for each tank.[18]

Marine Vessel Transferring of Crude Oil

Emissions of hydrocarbons vapors occur during ballasting operations after delivery and during vessel loading. The total mass and the rate of emissions are dependent on the following:

- ship or barge
- loading or ballasting rate
- extent of tank cleaning prior to loading
- previous cargo
- volume of cargo or ballast loaded
- the volatility of the cargo
- tanks used for ballasting.

Testing programs have been conducted recently to evaluate the interrelationship of these and other important factors in developing up-to-date emission factors for ship and barge loading and ballasting emissions. Most of those studies completed have developed emission factors for gasoline. Crude oil transferring operations are under study in California, sponsored by the Western Oil and Gas Association.[19]

A detailed discussion of emission mechanisms and assumptions required to estimate emission factors resulting from vessel crude oil transferring operations is presented in Appendix E. This appendix derives emission factors for crude oil transferring operations which represent a reduction in emission factors presented in earlier FEA Environmental Impact Statements.

The hydrocarbon emission from tanker loading operations is estimated to be 10 gm/sec based on an emission factor of 0.55 pounds per 1,000 gallons. The hydrocarbon emission rate from tankers unloading, as the result of ballasting procedures, is calculated to be 6.2 gm/sec based on an emission factor of 0.42 pound per 1,000 gallons and 40 percent ballasting capacity.

The barges responsible for the initial 10 percent filling of the site would not be ballasted following unloading; therefore no significant emissions are anticipated from barge operations at the site.

3.3.2 Impacts on Ambient Air Quality

The quality of the air near the site would be affected by the activities of site preparation and construction. During the start-up period, construction will take place at the site for about a year and at the tanker terminal for about 30 months. Emissions due to construction machines, paint, and oil transfer would degrade the air with dust, CO, SO_2, NO_2, HC, H_2S, and particulates.

The impact of these emissions depends on ambient air quality and the dispersal characteristics of the atmosphere. Ambient air quality has been discussed in Chapter 2. Atmospheric dispersion calculations are based on methods recommended by the Environmental Protection Agency[20] and averaged over appropriate time intervals as outlined in Appendix A.

Emissions from vehicles, valves, pump seals, and gauges would be small. Hydrocarbon loss to the air would be less than 10 pounds (4.5 kg) per day; other pollutants from vehicles would be smaller. These emissions would not impact the environment significantly.

Fugitive dust emissions are expected to be 0.3 tons per acre of construction per month of activity. This amount of dust would cause no serious air quality degradation. Present ambient dust levels are unknown, but are estimated to be low due to high ground moisture levels.

Air quality would not be significantly degraded during the operational phase of facility operation. During fill and drawdown phases, the transfer of large quantities of oil would cause significant hydrocarbon emissions at the Sun Terminal site. The downwind concentrations associated with these emissions has been calculated using the diffusion model described in Appendix A.

The typical and worst case downwind hydrocarbon concentrations listed in Table 3.2 are representative of the effects of transfer and storage operations in the vicinity of large marine crude oil terminals. Under typical meteorological conditions, the calculated concentrations for tanker loading, tanker ballasting, and barge loading will not exceed the National Primary Standard for non-methane hydrocarbons (NMHC) except within 1 km downwind distance. The calculated concentrations for storage tanks, ship engines, and tug engines are all in compliance with the applicable standards.
Even under the worst meteorological conditions, the National Primary Standard (3 hour average) will not be exceeded for downwind distances beyond 2 km.

Table 3.2 Typical and Worst-Case Downwind Concentrations (μgm/m^3) at Sun Terminal

Source	Annual Emissions (g/s)	Annual Emissions (Tons/yr)	3-Hour Ground-Level Concentration (μg/m^3)[b] Distance (km)	Typical	Worst-Case
Storage Tanks[a]	2.3	80			
			0.5	250	402
			1.0	76	122
			2.0	26	42
			5.0	6	10
			10.0	2	3
Tanker Unloading (Ballasting)	5.6	195			
			0.5	466	980
			1.0	170	358
			2.0	61	128
			5.0	15	32
			10.0	6	13
Tanker Loading	10.0	347			
			0.5	832	1750
			1.0	303	637
			2.0	109	229
			5.0	27	57
			10.0	10	21
Barge Loading	3.7	128			
			0.5	308	648
			1.0	112	236
			2.0	40	84
			5.0	10	21
			10.0	3	6
Ship Engines	0.1	3			
			0.5	5×10^{-11}	0.17
			1.0	2×10^{-6}	0.14
			2.0	3.2×10^{-3}	0.07
			5.0	4.2×10^{-2}	0.03
			10.0	4.4×10^{-2}	0.02
Tug Engines	0.3	10			
			0.5	2.3	6
			1.0	4.2	4.5
			2.0	2.4	2.5
			5.0	0.8	0.9
			10.0	0.2	0.5

(a) Distance downwind from the center of a triangle formed by connecting the midpoints of the three storage tanks.

(b) 3 Hour Federal and state standard for non-methane hydrocarbons; levels calculated are for total hydrocarbons.

Although the ground level concentrations resulting from terminal transfer operations are clearly not in violation of the existing standards, it does, however, represent a potential addition of hydrocarbon emission in the existing non-attainment areas.

The existing annual hydrocarbon levels as shown in Table 3.2 do not constitute a problem in terms of standards as none have been promulgated for the annual period. However, the short-term and long-term concentrations predicted for hydrocarbon pollutant downwind of the SPR sources may contribute to the increase of photochemical oxidant levels. In view of this, it is possible that an emission tradeoff strategy may be necessary in order to further reduce the hydrocarbon levels in this area.

3.3.3 Current Regulations

The Louisiana State Implementation Plan (SIP), revised in 1972, had exempted from regulation the hydrocarbon emission from crude oil storage and handling. At that time, the SIP had not been developed to detail projected levels of air quality by region but predicted that all primary standards would be met by 1976. However, because of the high 1 hour photochemical oxidant levels which have been tabulated from 1975 data, the EPA has disapproved the control strategy for attainment and maintenance of the national primary and secondary air quality standards for photochemical oxidants in the Southern Louisiana - Southeast Texas AQCR.*

The State has been ordered to prepare and submit by July 1, 1977, a revision containing:

a. All achievable emission limitations that are needed to provide for the attainment of the national standard for photochemical oxidants, and

b. A demonstration of the effect on air quality concentrations of such measures.

If additional control measures such as land use and transportation measures are needed for attainment of the national standard, the State will submit by July 1, 1978:

*41 Federal Register, No. 138, July 16, 1976.

a. Such measures for attainment of the standard for photochemical oxidants, and

b. A demonstration that the control strategy will attain the standard for photochemical oxidants.

The foregoing revision requirements are currently under review by the Louisiana Air Control Commission; a hearing will be held in March of 1977 to provide its response to the new requirements.

As a result of the current status of the Louisiana SIP, neither vapor emissions from crude oil storage nor those from crude oil transfer operations are regulated at this time. Although it is impossible to predict with certainty if any control measures will be required when the final EPA-approved SIP is promulgated, it is possible to gain an insight into the probable approach which may be taken toward crude oil storage and transfer operations by examining the recently proposed EPA revision to the Texas SIP for the Houston-Galveston AQCR.*

Like Louisiana, the Texas SIP has not been approved by EPA because of the inability to meet the primary standard for photochemical oxidant. Furthermore, parts of the Houston-Galveston AQCR have experienced much more severe violations of the one hour standard (both with regard to level and duration) than have been experienced generally in the Southern Louisiana-Southeast Texas AQCR. The new proposal would require controls for previously exempt emissions from crude oil storage tanks. Floating roof tanks are considered by EPA to be the best available control technology. However, regulation of emissions resulting from vessel loading and unloading of crude oil was not specified in the proposed SIP revision.

Another requirement for SIPs to meet the National Ambient Air Quality Standards (NAAQS) is new source review. The most recent ruling from EPA regarding new source review has established the tradeoff system.** Under this proposed provision, new sources would be required to show that emissions proposed from the new source plus SIP-required reduction from existing sources equal a net decrease in emissions. That is, the new

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*"Proposed EPA Revision to the Texas State Implementation Plan", Environmental Reporter, Current Developments, Volume 7, No. 29, November 19, 1976, pp. 1065-1083.

**"EPA Draft Preamble to Interpretative Ruling on New Source Review Requirements", Environmental Reporter, Current Developments, Vol. 7, No. 29, November 19, 1976, pp. 1091-1094.

source should not delay progress toward achieving the NAAQS in non-attainment AQCRs. The effects, if any, of this ruling on the SPR program remain uncertain at this time.

Summary of Air Quality

The only expected detrimental effect upon ambient air quality associated with the West Hackberry facility would be the temporary elevation of total hydrocarbon concentrations at the marine terminal (Nederland, Texas) during loading and unloading operations. These emissions are presently exempt from Texas air quality regulations. However, the USEPA has proposed to change control strategies regarding hydrocarbon reactivity.[21] The ship and barge proposal which includes a requirement for vapor control of at least 85 percent efficiency, however, is intended only for gasoline transferring as previously described in the Louisiana SIP. Another key proposal is elimination of crude oil exemptions.[16] In addition, the policy of eliminating fractional hydrocarbon reactivity factors will result in higher projected hydrocarbon emissions. It is anticipated that all new sources will be required to apply best available control technology.

3.3.3 Noise

Pipeline construction activities may cause some noise impacts for residential, recreational, farming and other land use areas in the described portions of Cameron Parish and Orange County. The construction would occur at locations shown in Figures 3.10 and 3.11.

During operations at the storage facility, the primary noise generation would be from pumps associated with fill and discharge operations. Early fill operations (80,000 barrels per day) would commence at 3.5 months into construction and continue for 2.5 months. The barges would be in operation at the Amoco Dock on the Alkali Ditch and diesel pumps associated with this operation would be a contributing source to the overall construction noise at the site.

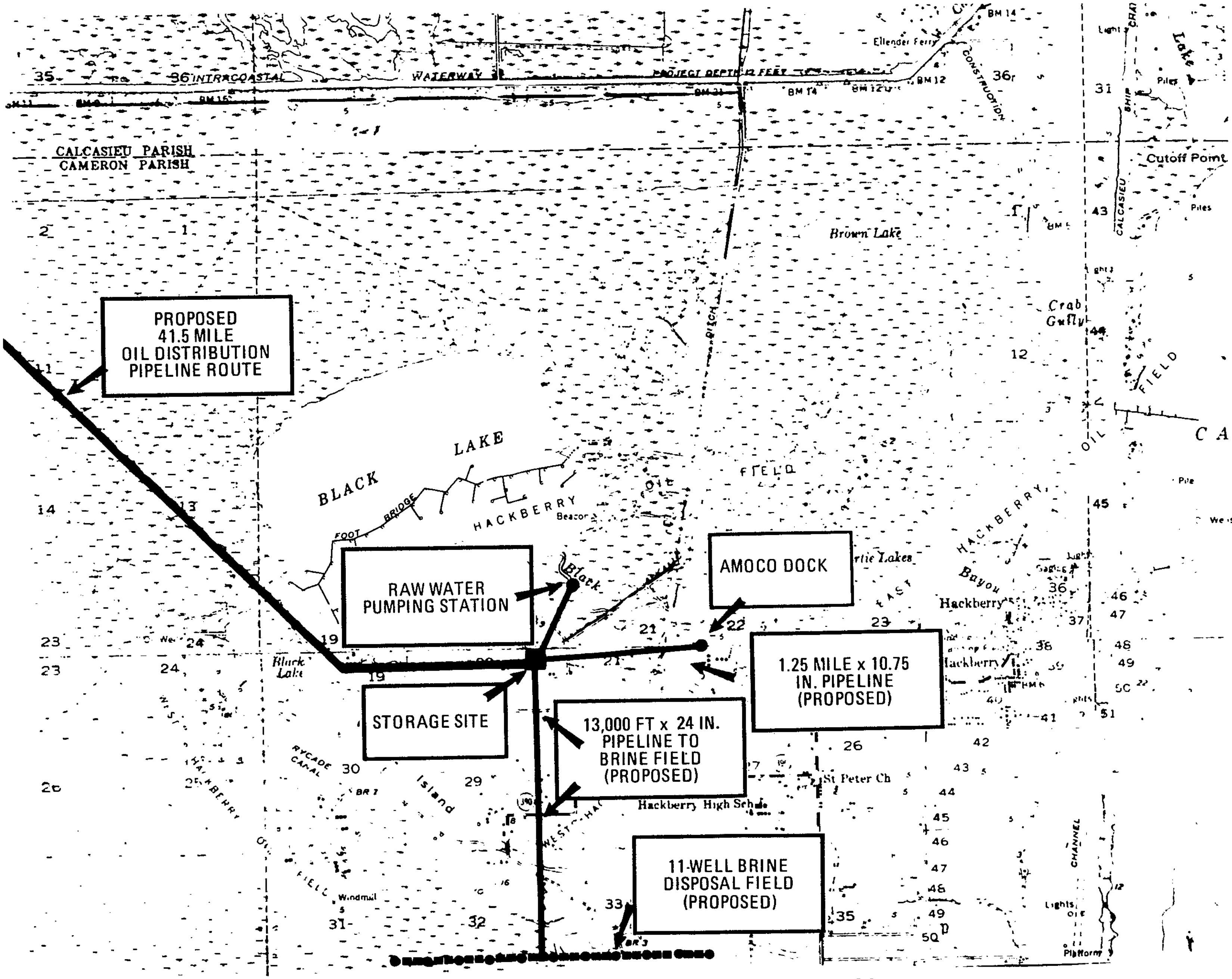

Figure 3.10 Proposed Facilities for West Hackberry

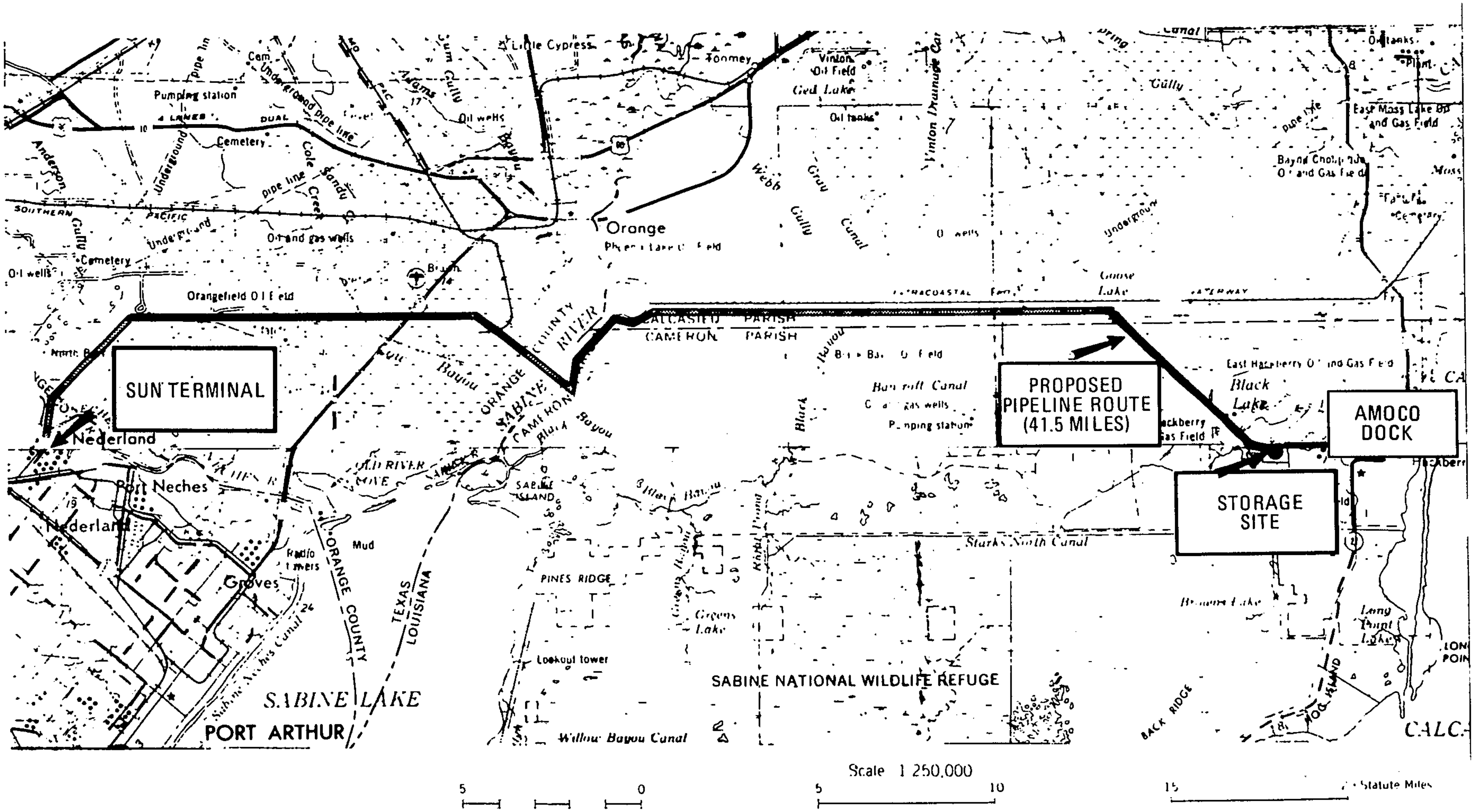

Figure 3.11 Proposed Oil Distribution Pipeline Route

After completion of the pipeline to Sun Terminal at Nederland, Texas, fill operation would require the operation of 4 oil injection pumps with 1,000 hp motors and 4 brine disposal pumps with 1,500 hp motors. These pumps along with the water displacement pumps (3-500 hp) would be sheltered in a pump house at the storage facility. Although noise levels within the pump house could be expected to exceed 90 dBA, typical pump house construction should reduce exterior noise from this source to less than 70 dBA at 50 feet from the structure. Oil transfer pumps located at Sun Terminal (1-500 hp and 2-900 hp) would have a similar housing arrangement and should have lower noise levels than onsite pumps since they have less overall power.

Pipeline Corridors

Two pipeline systems would be built for this project; one in the West Hackberry area connecting the site to the Amoco Dock and a second connecting the site with Sun Terminal in Nederland, Texas (Figures 3.10 and 3.11). At West Hackberry the pipeline to Amoco Dock would consist of a 1.25 mile temporary oil pipeline. The other pipeline would extend 41.5 miles to Sun Terminal in Nederland, Texas. The pipeline construction consists of: (1) excavation and/or dredging, (2) laying of pipe, (3) welding, and (4) finishing operations. The only location along the proposed route to Sun Terminal that is potentially noise sensitive would be the Bridge City, Texas area. The nearest residential section of Bridge City is located about 1300 feet south of the route which is also outside of the noise impact boundary. A summary of sound level contribution during construction is given in Table 3.3.

The pumps for both tanker loading and pipeline transfer to the storage area would be electrically powered and would be housed in a pump house at Sun Terminal. Noise from the diesel engines powering the tankers and tanker discharge pumps would contribute negligibly to daytime and nighttime ambient levels. Tanker operations are presently conducted around the clock.

Table 3.3 Summary of Sound Level Contribution (dB) from Construction Activities

Construction Site	L_{eg}	L_{dn}	Distance from Center of Site
Storage Site Area	<55	<55	2,000' (nearest residence)
Pipeline Corridors			500'
Brine Disposal Area			1,800'

*No nighttime activity planned.

3.4 SPECIES AND ECOSYSTEMS

3.4.1 Impacts of the Pipeline Route

Marshes

Construction of the crude oil distribution system would impact 203 acres of marshland temporarily (150' right-of-way). Typical marshlands along the Gulf Coast have a net primary productivity of 2.424×10^3 gms dry wt./m^2/yr., (1.518×10^3 gm dry wt/m^2/yr macrophyte production and $.906 \times 10^3$ gm dry wt/m^2/yr production by planktonic and benthic algae). Thus construction activities would remove as much as 1.99×10^6 Kg. of primary production (1.25×10^6 Kg. macrophyte production plus 0.74×10^6 Kg. algae production). Since the marshes themselves serve as nurseries for fish and shellfish, with a minimum direct value of these marsh by-products, (fish, shellfish, recreation, etc.) estimated at $100/acre[22], losses would amount to $20,300 during the year in which construction activities occur. In addition to these losses, a very minor effect is expected in the open water estuary of Sabine Lake and the adjacent ocean systems due to the fact that approximately one-half of the annual macrophyte production is normally exported as detritus by the tides to these systems. This detrital organic material provides nutrients for the organisms of these estuary systems and such exported nutrients from the Gulf Coast marshes are known to provide the basis for Louisiana's and Texas' extensive bay and offshore commercial fisheries.

Since the pipeline right-of-way is not maintained in any way after the construction phase, impacts would be expected to be confined to the year of construction, with recovery of the marsh system anticipated one to two years after the end of construction.

Many animals are dependent on marshes for feeding and nesting areas. Waterfowl, wading birds, alligators and small fur-bearers such as nutria, muskrat, mink, and otter are heavily dependent on marshlands for habitat requirements. Occasional inspections of the pipeline right-of-way would disturb wild-life (waterfowl and small mammals) on an infrequent basis. These disturbances would be relatively minor subsequent to construction clearing and would not prevent the return of wild-life to the right-of-way. The portion of the pipeline route which cuts across the marshlands west of the dome would pass within approximately 1 mile of a wading bird rookery and 1-2/3 miles of another. The construction activity would not be close enough or expected to be loud enough to affect bird breeding success.

Dry Land

Cleared land along the crude oil pipeline route to Sun Terminal is primarily used for cattle grazing and to a lesser extent rice farming. Assuming all 64 acres of dryland in the construction right-of-way were in pasture, a one year's loss of grass production would mean that between 64 and 96 cow-calf units of potential beef production (1 to 1-1/2 cow-calf units per acre) would be lost.[24,25] Using a 6 year (1970-1975) Louisiana average for calf value per acre of $272,[24] the value of this beef production would be $17,408*. Grazing would return to normal within a year except for the narrow band of pasture within the right-of-way that would be dug up and pipeline laid through it. This band could take more than one year to completely recover, depending on extent of subsoil disruption, and would be somewhat less productive for a time. Human activity associated with pipeline construction in this habitat would produce minimal disturbances to wildlife.

The temporary pipeline from the site to the Amoco dock would impact 11 acres of dry land. Because the pipeline would be on the surface rather than buried, only minor disturbances would be anticipated to the dry land vegetation.

Spoil Bank

Approximately 147 acres of spoil area adjacent to the ICW would be temporarily disturbed by pipeline construction. Initially, construction of the pipeline would require removal of the vegetation, especially shrubby forms like eastern baccharis, marsh elder, black willow and tallow bush. Ground cover, sedges, rushes and grasses (see Section 2.4) would also be destroyed. Secondary regrowth of these forms would occur rapidly with cover forming generally within a year to eighteen months, depending upon the season of construction.

Noise and human activities during pipeline construction would disrupt the spoil area as a feeding and nesting area for wildlife, but when construction is terminated wildlife would return. Several mammals utilize dredged

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*This value is a slight overestimate since calf crop for the same period (1970-1975) was 86% and not 100% as assumed in the calculations.

disposal sites only during high water; these include muskrats (Ondatva zibethicus) and white-tailed deer (Odocoileus virginianus).[1] Nutria (Myocaster coypus), on the other hand, are concentrated on disposal areas and the northern raccoon (Procyon lotor) feeds there as well as using them as a refuge during high water. Neartic river otter (Lutra canadensis) locate den sites in these areas and rabbits (Sylvilagus spp.) are abundant.[1] Pipeline construction and maintenance would displace some mammals as well as some birds and reptiles. Because of the pioneer characteristics of many of these species (i.e., disturbance tolerant and adapted to a successional vegetative environment), animals populations would readily reestablish and little, if any, wildlife habitat would be permanently lost.

Woodlands

Sixty-two acres of woodlands would require clearing for the pipeline right-of-way and 32 acres would be cleared of woody vegetation for the life of the pipeline. All of these woodlands are in Orange County, Texas, and 9 of the 32 acres are oak-gum-cypress with the remaining acreage a mixture of pine and decidous hardwoods (see Section 2.4). Loss of 32 acres represents a small (0.024%) reduction in the timber acreage in Orange County.[26] In addition, wildlife habitat would be altered and noise and human activities during construction and maintenance would cause temporary emigration of wildlife and birds.

As a result of clearing and maintenance activities, early successional plant and animal species would be more prevalent than forest types. Rabbit, quail, and possibly deer densities would be increased over the long term due to increased cover, browse, and other habitat changes associated with the creation of the strip of secondary regrowth vegetation. Forest dependent fauna such as squirrels would suffer a permanent habitat loss of 32 acres. Revegetation, while dependent upon the season in which the pipeline is laid, would be rapid.

Water

The proposed pipeline route would cross 22 water bodies ranging in size from major rivers (Neches and Sabine Rivers) to small piroque ditches in the marsh west of the site. A 1/2 mile section of Black Lake would also be crossed. The major water bodies that would be crossed, and the water quality impacts resulting from these crossings are discussed in Section 3.2 of this document. Approximately 6.9 acres of the Sabine River bottom would be dredged (300 feet strip at top of sediment in navigable waters) and the material deposited in designated disposal areas. The benthic fauna in this 6.9 acres would be destroyed. In the area of the Sabine River below Toledo Bend Reservoir tubificid worms, mayfly (Ephemeroptera) nymphs and chironomid fly larvae (see Table 2.21 in Section 2.4 of this report) are the most abundant benthic forms with an average density of 30.9 organisms per square foot.[27] These organisms serve as food for fish and aid in the decomposition of organic debris in the river bottom substrate. It should be mentioned that the Sabine Channel is a 40 feet deep by 500 feet wide navigation channel which is dredged every 10 years.[27]

A number of fish species have been collected upstream of the proposed Sabine pipeline crossing (see Tables 2.22, 2.23 and 2.24 in this report). Based on seine data (Table 2.22) Hybognathus sp. and shiners were most numerous; mosquito fish, darters, bass and catfish were less numerous than the Hybognathus sp. and shiners. Dredging the river bottom would increase the amount of solids suspended in the water column at and downstream from the crossing site. Some turbid water would also be expected to drain from the disposal areas. Visually oriented fish would temporarily vacate the area of dredging activity and the more turbid portions of the turbidity plume. Feeding would necessarily decrease in these areas and the denuded bottom would contain few organisms suitable as fish food for several months. Since material which is hydraulically dredged from the river bottom cannot be used to refill the trench, new fill material is required. This material would probably not contain as much suitable fish food as the original material. Benthic organisms would gradually colonize this altered section of river bottom with the species composition strongly affected by the composition of the fill material (mud, sand, etc.). Bottom foraging fish (catfish, carp and suckers) would be less affected by turbidity, but because of their bottom foraging habits, affected more by a direct loss of several acres of potential food. Fish that remain in the turbid areas and clams immediately downstream would suffer some gill clogging and depressed oxygen levels as a result of the increase in suspended solids in the water. Because of the temporary nature of the dredging activities, these effects should be short term and relatively minor.

Zooplankton in the Sabine River (Table 2.19) are dominated by rotifers,* with substantially fewer cladocera, copepods and nauplii present.[28] Green, red, and blue-green algaes constitute the phytoplankton.[27] Dredging activities would tend to stimulate planktonic growth, but such effects would be short-lived.

Comparable data are not available for the Neches River, but similarities in drainage characteristics, distance from Sabine Lake and other factors suggest that biological impacts would be similar. Approximately 5-1/2 acres of the Neches River bottom would be impacted.

Cow Bayou is a popular sport fishing area[28] and is not as wide or as deep as either the Sabine or Neches Rivers. Less than 2 acres of bottom sediment would be disturbed and sport fishing would not be detrimentally affected. Black Bayou would also have less than 2 acres impacted.

Crossing Black Lake would require a minimum of 3 acres for the pipeline; however, pipeline construction in Black Lake would be different in several ways from crossing rivers and bayous. Black Lake is large and quite shallow (4 feet average depth), and along the southwestern edge has numerous pipelines in the sediment already. It is likely that many of these existing pipelines would have to be cut, the proposed pipeline laid and sections welded back into the existing lines. Cutting the existing lines would release some of the heretofore contained residues (oil, gasoline, etc.) into Black Lake waters even though the lines would, of course, be "empty" when cut. The amount of such releases would be minor and the area of contamination would be relatively small. The effects of suspended solids would last longer than in a lotic (running) water body because the current is much less.

Because of the small areas in Black Lake to be dredged, the methods (primarily hydraulic), and the confinement of dredge spoil, pesticide and heavy metal mobilization

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*Rotifers - a phylum of aquatic microscopic, multicellular animals characterized by a ciliary organ on the anterior part of the body.

is not expected to be biologically significant at any proposed crossing. This conclusion is based on water and sediment quality data which are not site specific, but are assumed to be representative of the crossing sites. Associated with the water crossings would be approximately 37 to 74 acres of disposal area (assuming 600,000 cubic yards of spoil deposited 5 to 10 feet deep). Impacts on vegetation would be similar to those discussed earlier for dry land, spoil banks, and marshes depending upon the location of spoil deposition. The entire acreage would be temporarily void of vegetation and unsuitable for wildlife habitat.[29] The spoil area would revegetate within one to two years and it would be colonized and/or used by wildlife as the spoil hardens and becomes covered with vegetation.

Roads

Because of the biologically barren nature of roadways, construction of the proposed pipeline under as much as 1.5 acres of roads would have almost no direct biological impact. Some turbid water may runoff the disrupted road acreage into nearby marshes or drainage canals, but impacts would be very slight compared to normal road construction.

3.4.2 Impacts of Terminal Operations

Oil transfer operations at the Amoco dock and the permanent Sun Terminal dock would primarily involve barge and oil tanker movements. Sediments would be resuspended as barges traverse the 7-1/2 foot deep Alkali Ditch, thereby disrupting benthic organisms, fish, shellfish, and retarding plankton growth. Sediment resuspension due to barge movement in the Alkali Ditch would occur during the initial fill cycle and would strongly inhibit aquatic production in the immediate vicinity and in waters receiving turbid inflows. Spillage of oil during operations is projected to be slight (see Section 3.7).

Tankers moving up Sabine Lake and the Neches River would utilize the ICW, which is maintained by the U.S. Army Corp of Engineers. The Corp periodically dredges this channel, and the channel is already heavily travelled. Some minimal addition to sediment resuspension would occur as a result of the additional tanker traffic.

Discharge of treated ballast water into the Neches River would temporarily increase oil and saline concentrations in the receiving waters (Section 3.2.6). Crude oil concentrations of 5 to 10 ppm, which are virtually identical to release concentrations, have been shown in laboratory studies to inhibit the growth of three Gulf Coast species of phytoplankton, Isochrysis galbana, Cyclotella nana, and Glenodinium halli, after 72 hours exposure.[30] These concentrations of crude oil are not known to produce mortality or detectable stress in zooplankton and benthic fauna populations although the eggs of some fish species are killed by chronic exposure to low oil concentrations. The eggs of one fish species, the Sand Sole, experienced between 80 percent and 100 percent mortality in the laboratory at crude oil concentrations of 10 ppm which is slightly higher than the proposed discharge concentration. Assuming the eggs of Gulf Coast fish species are equally sensitive, then the immediate area around the ballast water outfall would be unsuitable as fish breeding ground. Adult fish are not harmed by these concentrations.

The effects of the increased salinity of the ballast water would be limited to organisms in the immediate vicinity of the outfall. Mobile organisms such as fish which prefer freshwater would temporarily emigrate from the discharge area. Saline sensitive benthic organisms should be few in number near the discharge point because of present operation of the ballast treatment facility. At most, less than 1 acre of river bottom and water column overlying it would be subject to water in excess of 4 ppt (see Figures 3.8 and 3.9). As a result of prior operation of the ballast treatment facility, the environment near the discharge point is probably biologically degraded. Operation associated with the SPR program would not contribute appreciably to the already altered condition of this part of the Neches River.

3.4.3 Impacts of Surface Brine Disposal Pipeline

The placement of a temporary above ground brine disposal pipeline along the same corridor as the permanent buried pipeline would produce relatively little addition to the impacts of laying the permanent line. Some trampling effects caused by the additional vehicular and foot traffic would occur. Additional noise would disrupt wildlife to a minor extent. Removal of the temporary line would result in trampling of vegetation. Very small amounts of brine or salt caked to the inside of the pipeline may be accidentally spilled during pipeline removal. Impacts from such accidents would be very localized and minor.

Operationally a surface pipeline would be easier to effectively patrol for possible leaks or breaks in the line. Because a leak would be easier to detect and cleanup, biological impacts to biota would tend to be less significant than with the buried brine pipeline.

3.5 WASTE DISPOSAL

Waste associated with the construction of the proposed oil pipelines would be disposed of by techniques corresponding to acceptable industry practice. During pipeline construction, generated wastes include surplus lumber and metal goods, paper, waste concrete, earth excavations, personnel sewage and various types of containers.

All construction wastes are handled by the construction contractor, who is required to leave the route clear as the work is completed. 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 local landfill sites. Probably no more than a few thousand cubic feet of each type of material would be generated during the pipeline construction. Several landfill sites are located in Orange and Jefferson Counties, Texas. One is just south of the city of Orange, two east of Orangefield and one is near the Neches River and Sabine Lake junction. Landfill sites in Cameron Parish, Louisiana has previously been discussed in the West Hackberry environmental impact statement (FES 76/77-4). It is anticipated that these sites would more than satisfy the need for solid waste disposal during pipeline construction.

The earth material excavated while burying pipe on dry land would be used to refill the ditch. The excess earth generated due to the pipeline size is generally plowed smooth over the original area. Dredge material generated during water crossings would be disposed at sites specified by the Corp of Engineers. Some spoil deposition sites exist along all the major waterways in Cameron Parish, Louisiana and Orange County, Texas. A further discussion of dredge spoil can be found in sections 3.2 and 3.4.

Personnel sewage treatment and disposal would be through common portable septic tank systems. These portable systems use chemical treatment procedures while in the field with ultimate disposal of sewage in commercial sewage systems.

3.6 SOCIOECONOMIC EFFECTS

3.6.1 Manpower Requirements

Construction of Pipeline to Nederland

The pipeline from the storage site to the tanker terminal at Nederland would require about 6 months to complete. More than one work crew would be employed. One group of workers would lay pipe across the land, and a special crew working around the clock in shifts would be used to lay the pipeline across the Sabine River and the Neches River. These river crossings would each take about 45 to 60 days of construction time. During this time, the number of workers required for the various pipeline construction activities would rise to about 320 persons. At least two-thirds of these workers would be welders, pipefitters, equipment operators, and other workers in the skilled trades.

Summary of Construction Labor Force

Construction of facilities at West Hackberry and laying of pipelines to Nederland would require a total of about 380 workers of which 320 would be involved in the pipeline construction. This level of manpower would be reached in the third month of construction and would be maintained for two to three months. It is anticipated that workers for portions of the pipeline construction would be contracted from the Beaumont-Port Arthur area which includes Nederland. After the pipelines have been constructed, oil would be pumped to the site from Nederland. Additional drilling of brine disposal wells would continue concurrently with the oil filling activity, for another ten to twelve months. By the end of about the eighteenth month, the storage site would be on a standby status.* These activity levels are summarized in Figure 3.12.

3.6.2 Impacts on Community Services

Security guards would be stationed at the storage facility site and at the dock to prevent theft of equipment and materials. They would cooperate in their activities with the sheriff's departments of Cameron Parish and of Jefferson County, which have jurisdiction over these areas. Fire fighting equipment would be on hand at the site and the dock, and auxiliary aid would be available from Hackberry.

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*At this point, the cavities could be filled.

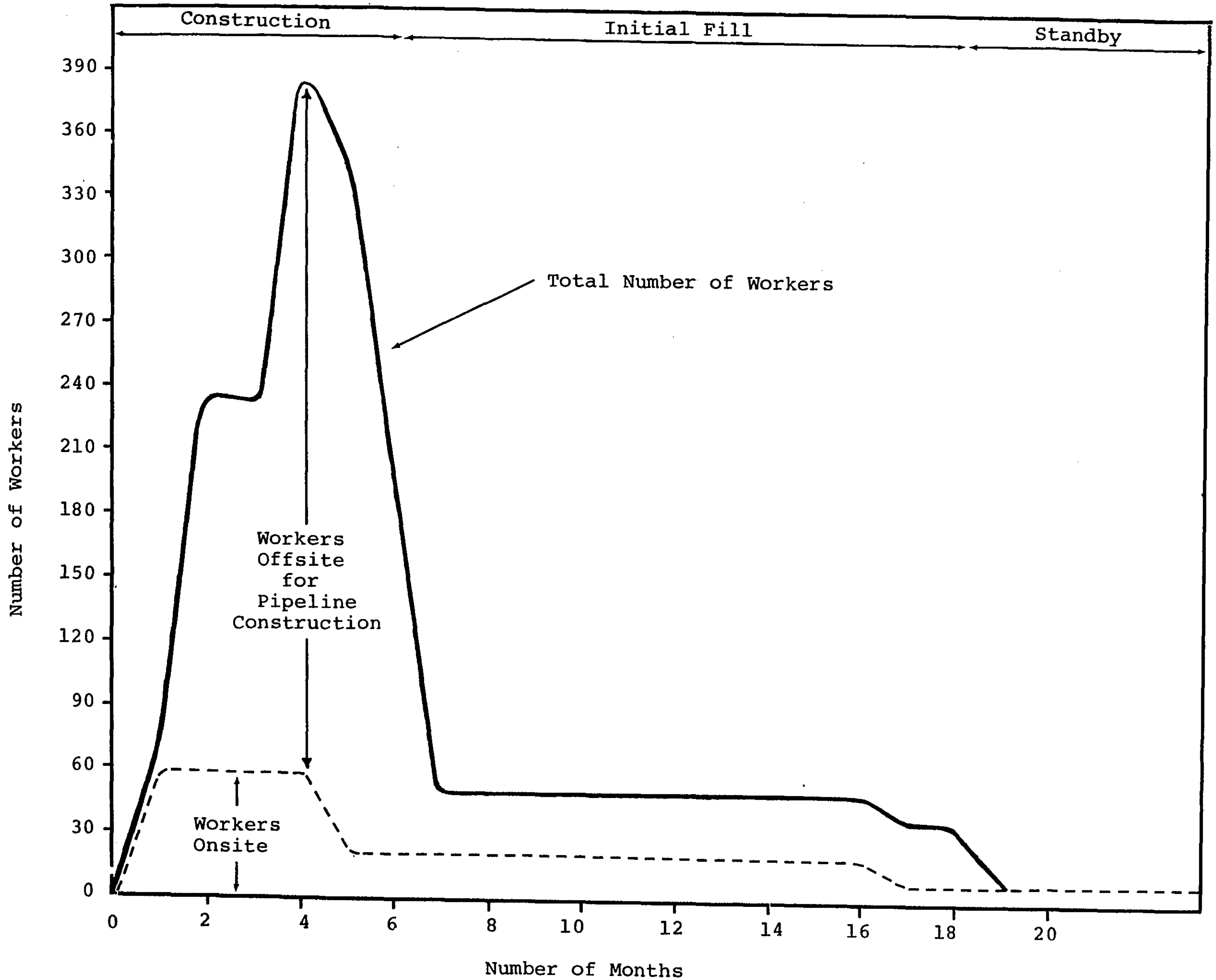

Figure 3.12 Manpower Requirements for West Hackberry

Medical facilities in Sulphur and Lake Charles would be used to provide emergency care to workers injured at the site, and the combined medical facilities of the Beaumont-Port Arthur area would be available for those injured 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.

3.6.3 Economic Impacts

Employment and Payroll

The major local benefits of the proposed construction 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 site preparation and construction would be approximately as follows:*

1st - 3rd month:	$370,000 per month
4th - 6th month:	590,000 per month
7th - 16th month:	100,000 per month
17th - 18th month:	80,000 per month

The payroll for the 18 months of construction and initial fill would total about $4,040,000.

Tax Benefits (Texas)

State sales and use tax is the largest single source of state revenue in Texas, where the sales tax on general goods and services is 4 percent. Municipal sales tax is also levied in many cities, but is second to property taxes as the source of municipal income. State and local income from the proposed pipeline would be derived from the taxes incurred by workers employed on the project and living in Texas.

*Based on the average wage rate of $2,000 per month. These payroll figures are for work at the site in addition to work on the pipeline to Nederland, and represent total payroll that would be paid if the pipeline to Nederland is built instead of the dock facilities on the Calcasieu Ship Channel.

3.7 ACCIDENTS AND NATURAL DISASTERS

The potential for accidents and natural disasters is discussed in this section with particular emphasis on the possible occurrence of crude oil spills.

The probabilities of occurrence were generated from historical accident or natural disaster data. Care has been taken to use probabilities generated for circumstances and environments similar to those existing in this project.

The major risk of oil spills arises primarily during the transport of oil to and from the salt dome storage areas. Table 3.4 compares these risks in summary form for the actions proposed in the FES and this supplement. One of the significant differences, from the facilities described in the FES (FES 76/77-4) would be the use of two 36-inch diameter crude oil pipelines between the Sun Terminal on the Neches River and the site. For the system in the FES, a pipeline only 4 miles long would connect the proposed marine terminal at Hackberry and the salt dome at West Hackberry. Hence, the risk of spills of crude oil from pipelines being analyzed by this supplement is about 23 times that of the FES system. Risk of spills of crude oil during tankship transport is about the same for the two options. The frequency of spills from the tankships is slightly higher for the revised system because of a small probability of ship collisions. Because of one-way traffic, the probability of ship collisions in the Calcasieu ship channel is assumed to be zero. Assuming both options would use transport by tank barges to the same extent, namely to provide ten percent of the initial fill, the risk and impact of oil spills from this mode of transportation for the two options are the same. For loading and offloading at a marine terminal, the risk of oil spills is the same for both options since the same operations are involved.

Risks arising from other accidents and natural disasters are very small and are nearly the same for the two options.

3.7.1 Pipeline Accidents

The available pipeline accident or failure data gathered by the Department of Transportation covering the years 1968 through 1973 show fairly consistent statistics.[31] Analyses of these data performed in conjunction with the submission of the Louisiana Offshore Oil Port (LOOP) Project environmental impact assessment indicated that an accident rate of 0.00136 incidents occurred per mile/year. However, taking into account the improvements in pipeline materials, manufacturing processes,

Table 3.4 Comparison of Impacts of Accidental Oil Spills

Transport Mode	Number of spills expected for fill or withdrawal of 60×10^{6} bbls		Median Spill Size, bbls		Affected Areas	
	FES	Amend.	FES	Amend.	FES	Amend.
Pipeline	0.8×10^{-3}[d]	34×10^{-3}[e]	1000	1000	Prairie and marshland between Hackberry and West Hackberry.	Woodlands, prairie, marshlands, rivers and the ICW between Sun Terminal and West Hackberry.
Marine Operations						
Tankships[f]	4.9×10^{-3}	7.6×10^{-3}	8300	8300	Calcasieu Lake and ship channel and bordering marshlands.	Sabine Pass, Sabine Lake, Neches River and the Port Arthur segment of the ICW.
Tankbarges[b]	15.4×10^{-3}	15.4×10^{-3}	1100	1100	Calcasieu Lake and ship channel, ICW and Alkali Ditch and bordering marshlands	Calcasieu Lake and ship channel, ICW and Alkali Ditch and bordering marshlands.
Loading-Offloading at Dock[c]	1.2	1.4	18[a]	0.5	Calcasieu ship channel at Hackberry.	Neches River and river banks at Sun Terminal.

a The median spill size of 18 bbls was based on a limited analysis of the U. S. Coast Guard PIRS data. A subsequent and more thorough analysis of these data revealed that the median spill size was 0.5 bbls.

b Assumed to be used for ten percent of the initial fill only, 286 tankbarge trips.

c For the permanent tankship system only.

d Estimated for 4 miles of pipeline for a 5 month period.

e Estimated for 83 miles of pipeline for a 10 month period.

f Estimated assuming each fill or withdrawal requires 150 tankship trips.

construction, and testing procedures, reasonable accident/failure frequency was projected to be $5x10^{-4}$ per mile/year. These probabilities include spills caused by external forces including natural disasters, corrosion, operational reliability, and better than a 10 percent contingency category.[32]

Using this accident/failure frequency, the probability of an incident per year for the various types of pipelines in this SPR project is given in Table 3.5. Also present in this table are the lengths of each of the pipeline systems and the number of operational years associated with a program of five fill/withdrawal cycles. In this context, the number of operational years is computed by adding the time of each period of active operations for each pipeline system. The number of operational years for the barge dock pipeline is one year (during the first part of the initial fill). For the permanent crude oil pipeline between Sun Terminal and West Hackberry, the operational period is 25 years; the lines would remain full of oil even if no fill or distribution of oil is being performed. Brine and raw water spills are computed on the basis that there would be an 18-month initial fill period and four refills requiring 10 months each. There are to be five distributions requiring five months each. Although the system is presently scheduled for an 18-month initial fill period and is designed for a ten month refill period, for purposes of these calculations, longer periods were assumed based on possible lower crude availability. These longer periods give conservative results (higher spill likelihood).

Employing data from Table 3.5, the probability of a given number of spills from each of the types of pipelines during the life of the project have been computed and are presented in Table 3.6. For the barge pipeline system the most probable number of pipeline spills is zero. For the permanent pipeline system, however, the probability of a spill is more substantial. These results must be tempered by the fact that the probability data are based upon higher pressure oil lines whereas the operating pressures for most of the crude pipelines at this SPR site are relatively low (less than 500 psi).

The same data base that was used to compute an accident frequency rate projects the mean spill size to be about 1,000 barrels. Using this mean spill size, the annual crude spill volume expectation is 28 barrels and the total crude spill volume expected over the life of the project is about 700 barrels. Assuming that the spilled oil affects only the area associated with approximately one mile of pipeline right-of-way, the probability that any specific area along the proposed route would be affected by a crude oil pipeline is

Table 3.5 Accident/Failure Frequency

Type of Pipeline	Approximate Length (mi)[1]	Accident/Failure Frequency (Events/Year)	Approximate Number of Operational Years[2]
Crude Oil			
Barge Fill Only	1.2	.0006	1.0
Normal Operation[4]	83.0	.0420	25.0
Brine			
Barge Fill Only[3]	3.6	.0018	1.0
Normal Operation	6.0	.0030	4.5
Raw Water	2.0	.0010	2.1

1. Includes approximately 1.1 miles of line on the dome site for each type.
2. Assumes approximately 1 year of barge dock operation and 14 months of permanent dock (Sun Terminal) operation to complete initial fill, 5 five-month withdrawals, and 4 ten-month refill periods. The pipeline to the dock will remain full during the entire project lifetime.
3. One or two brine injection wells will be adequate during the barge fill phase.
4. Two 36-inch lines laid over the route of 41.5 miles.

Table 3.6 Probability of Pipeline Failure During Project*

Number of Crude Spills	Probability (%)
Barge Fill Period:	
None	99.94
1	.06
More than 1	nil
Normal Operation	
None	34.20
1	37.50
2	19.70
3	6.60
4	1.60
More than 4	0.40

*Assumes that pipeline integrity is tested prior to initiation of each withdrawal/refill cycle.

$$\frac{0.66 \text{ (the probability of at least one spill)}}{41.5 \text{ mi (approximate length of right-of-way)}} = 0.016$$

The crude oil pipeline would be buried along its entire route. It would cross two rivers (the Neches and Sabine) and Cow Bayou, for which the burial depth would be 15 feet. It would cross a number of non-navigable waters for which the burial depth is to be 15 feet. Finally, the pipeline would cross woodlands, prairie lands and marshlands, under which it would be buried at least 3 feet.

Since the water table along the entire route is near or at the surface, leaking oil from a break in the pipeline is expected to migrate to the surface along a path of least resistance. Thus, in the prairie and woodlands, the leaking oil may migrate along the trench a considerable distance before surfacing. After surfacing, it would behave as runoff material. In these areas, the oil spill may be contained to some degree by constructing dikes and trenches.

In marshlands, oil would rise and spread out on the surface of the water. Water, soil and vegetation would be contaminated. Cleanup and removal is difficult in these areas since such efforts may in themselves cause substantial environmental damage.

Leaks near or at the river crossings would create an oil slick which would spread and float downstream toward Sabine Lake. Contamination of the marshes along the boundaries of these rivers would be expected and contamination of the Intracoastal Waterway and bordering marsh would be expected from leaks from the pipelines buried in the adjacent spoil banks.

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 initial fill only, the voyage of the barge tow along the Calcasieu Ship Channel and associated waterways from the Gulf to the terminal (Amoco Dock) at West Hackberry, and loading and offloading operations at that terminal, and (2) for the permanent dock at Sun Terminal, the voyage of the tankship through the Sabine Pass, the Sabine-Neches Canal and the Neches River to the terminal, and loadings and offloadings at the terminal. Accidents include vessel casualties such as collisions and groundings, and mishaps at the marine terminal such as failure of a hose connector, overfilling a tank, opening the wrong valve, etc.

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

The estimates are based primarily on statistical analyses. The number of vessel casualties, which would result in the spill of oil, were derived from the Coast Guard's listing of Commercial Vessel Casualties for fiscal years 1969 through 1974. The count of ship transits was obtained from Waterborne Commerce of the United States, U. S. Army Corps of Engineers. Combined, these data yielded the expected frequency of spills per transit of a tankship or tankbarge from the Gulf to the terminal. This procedure was followed for all vessel casualties except tank ship collisions 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 ship speed and dimensions. 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. The distribution of the quantity of oil spilled, with the number of spills, was developed from the 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 the marine terminal 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 is summarized in Table 3.7. The estimates assume the transport of crude oil in a nominal 55,000 DWT tankship containing 400,000 bbls to or from the Sun Terminal. The tank barges used in the

*Primarily the Mississippi River System

Table 3.7 Risk of Spills of Crude Oil from Marine Transport Accidents at the West Hackberry Site

	Temporary Fill System-Barges	Permanent System Tankships
Frequency of oil spills from vessel casualties[1] spills/trip	$5.4x10^{-5}$	$5.1x10^{-5}$
Median quantity of oil spilled from vessel casualties[1], bbls/spill	1100.000	8300.000
Expectation quantity of oil spilled from vessel casualties[1], bbls/trip	0.150	1.420
Frequency of oil spills from accidents at the marine terminal, spills/trip	$9.2x10^{-3}$	$9.2x10^{-3}$
Median quantity of oil spilled from accidents at the marine terminal, bbls/spill	0.500	0.500
Expectation quantity of oil spilled from accidents at the marine terminal, bbls/trip	0.086	0.086
Total expectation quantity of oil spilled for transport of $60x10^6$ bbls, bbls	67[2]	225[3]

[1]Groundings, rammings, structual failure of vessel, etc.

[2]286 barge trips for 10 percent of the initial fill, $6x10^6$ bbls.

[3]150 tankship trips.

Calcasieu Channel during the initial fill are assumed to be nominal 3,000 DWT containing 21,000 bbls. Larger tankships, up to 100,000 DWT, might be used but these would be light loaded so that their draft would not exceed 40 feet. In this case it is assumed that they would contain approximately 400,000 bbls, also.

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 0.15 barrels per trip for the barges (21,000 barrels capacity), and 1.42 barrels per trip for the tankships (400,000 barrels capacity). Accidents at the marine terminal, such as overfilling a tank, opening the wrong valve, etc., have an expectation quantity spilled of 0.086 barrels per trip for either barges or tankships. The total expected quantity of oil spilled during the transport of 60×10^6 barrels is 225 barrels for transport by tankship. Figures 3.13 and 3.14 show the frequency distribution (per trip) of spill sizes for tankship and barge transportation accidents.

Oil spilled onto water produces a very extensive slick. The following relationship between spill quantity, ultimate slick area, and radius, assumes unhindered (no wind, currents, or surface obstacles) spreading and a circular-shaped slick:[31]

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

Where A is square meters, r is the radius of the slick in meters, and V the volume spilled in barrels.

These dimensions are achieved 24 to 48 hours after the spill. For median spill quantities listed in Table 3.7, the ultimate slick dimensions were computed:

	Quantity Spilled (barrels)		
	0.5	1,100	8,300
Slick area (m^2)	0.015×10^6	4.81×10^6	21.9×10^6
Slick radius (m)	123	1,237	2,640

*The delineation of this relationship is described in Reference 38.

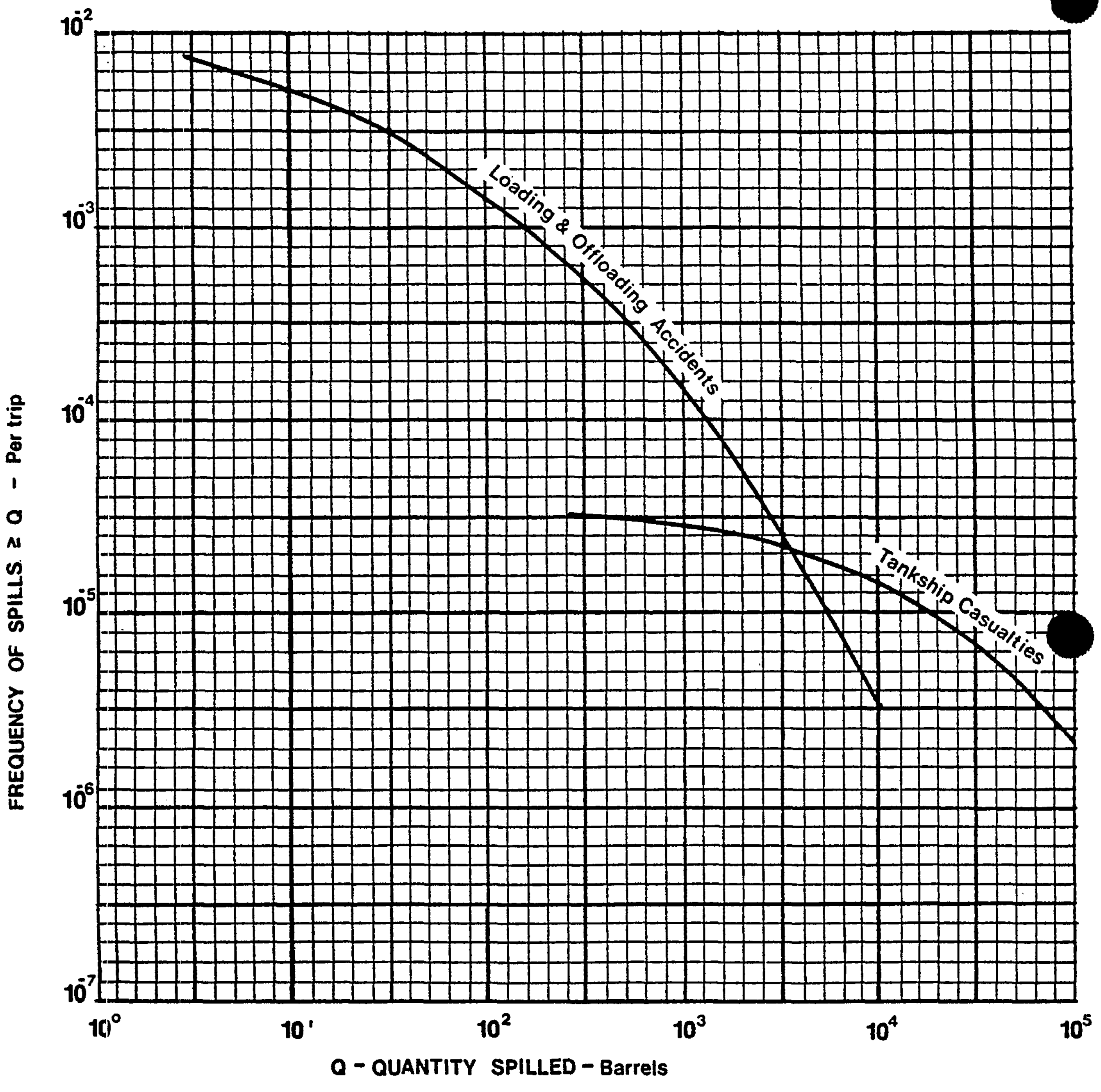

Figure 3.13 Estimated Frequency Per Trip of Crude Oil Spilled from Accidents During Transport by Tankship

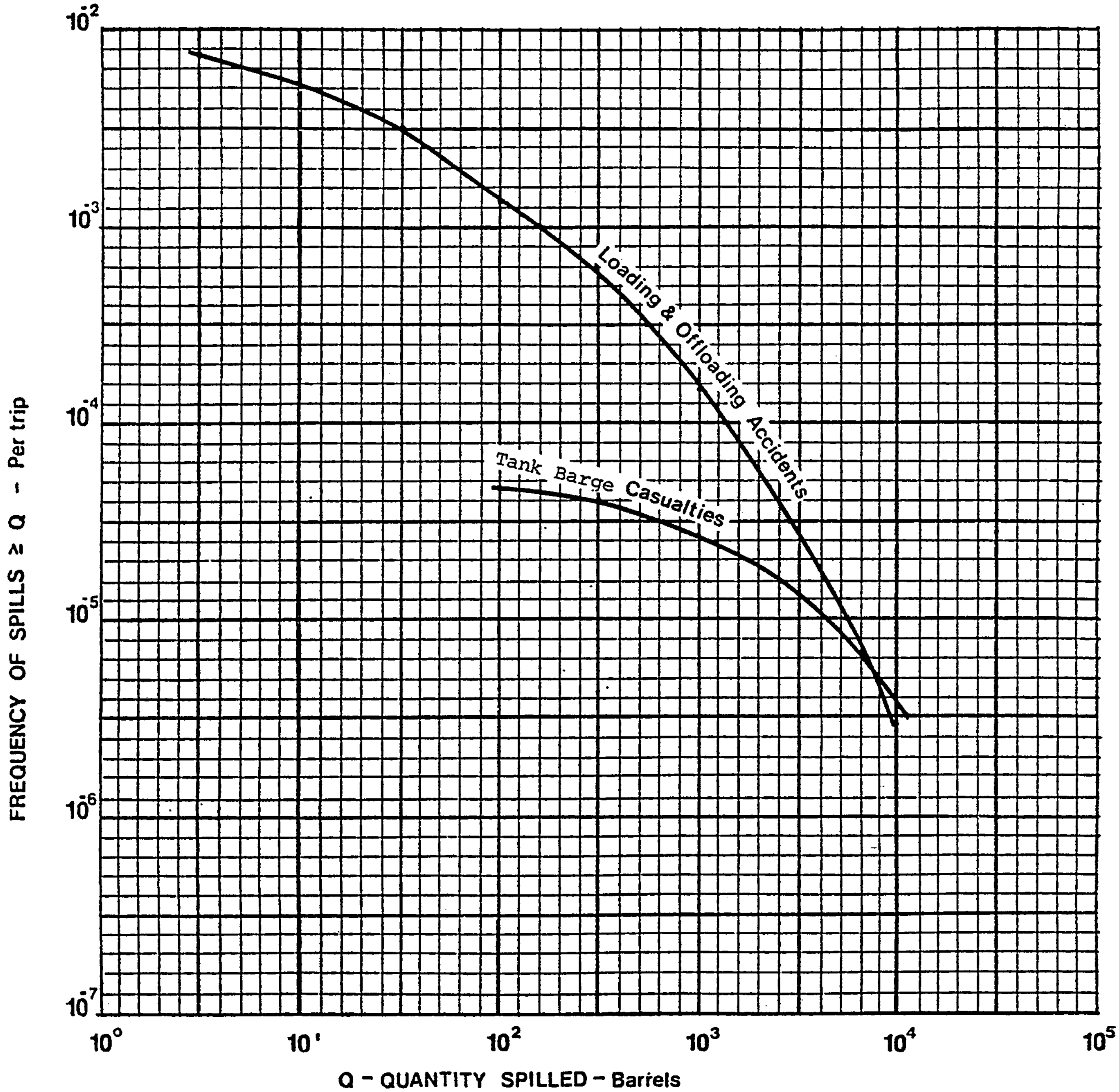

Figure 3.14 Estimated Frequency Per Trip of Crude Oil Spilled from Accidents During Transport by Tankbarge

The ultimate slick areas calculated above correspond to an average coverage of oil ranging from 0.1 barrels per acre for the 0.5 barrel spill to approximately 1 barrel per acre for the largest spill. These coverages are somewhat lower than those estimated to cause significant environmental damage as discussed in Section 3.7.2.4.

With respect to the temporary barge-fill system, spills at the Amoco terminal are expected to remain at the site, and in the absence of booms or other containment measures, they would spread into the surrounding marsh areas rather evenly. There are no known major water currents in the area and the vegetation above the water surface in the marshes would greatly limit the effect of wind on the movement of the slicks. Spills in the Alkali Ditch and the Intracoastal Waterway would be expected to behave similarly during periods of light winds (occurring 19 percent of the time). However, during periods of higher winds, the slick would be blown along these waterways at about 2 to 3 percent of the wind velocity.[33] Slicks in the Intracoastal Waterway would move in a westerly direction about 25 percent of the time. However, the edges of the slick which have penetrated into the bordering marshes would tend to remain in place, unaffected by the wind.

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 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.

3.7.2.2 Risks of Spills from Vessel Casualties

The estimation of the frequency of shipping accidents and spills of oil was based on the number of reported accidents to tankships and tankbarges 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 Tables 3.17 and 3.18 in the West Hackberry FES for tankships and tankbarges, respectively. These tables are repeated in this document as Tables 3.8 and 3.9.

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 tankship casualties for which there was a loss of cargo leaves something to be desired. Therefore, the frequency of collision caused casualties were estimated using a previously developed model.[34]

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 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." With this model, the computed estimate of a collision and spill from the SPR tankship is 0.687×10^{-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 U.S. Gulf Coast area, Table 3.8. 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 1.03×10^{-5} per trip of the SPR tankship. The details of the model and the calculations performed to make these estimates are described in Appendix I.

The model was not used for collision caused spills from SPR tankbarges because the traffic is restricted to one way in the Calcasieu Channel.[32] Also, the model has not been extended to estimation of spills from groundings, rammings, etc. For the estimation of these frequencies, the number of spill accidents in Tables 3.8 and 3.9 in the West Hackberry FES were divided by the appropriate total inbound tank vessel traffic for the

Table 3.8 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, undertermined)	11	0
Total	208	3
Total (less collisions)	127	2

*This table is equivalent to Table 3.17 in the West Hackberry FES.

Table 3.9 Tank Barge 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)	712	25
Rammings (collisions with fixed, floating and submerged objects)	383	9
Groundings	122	8
Fires and Explosions	19	0
Structural Failures	25	4
Other (flounderings, capsizing, flooding, undetermined)	35	4
Total	1,296	50
Total (less collisions)	584	25

*This table appears as Table 3.18 in the West Hackberry FES.

Gulf Coast region. During calendar year 1974, there were 9,830 inbound tank ship trips and 76,856 inbound tank barge trips. For a 6-year period corresponding to FY1969 through FY1974, it was estimated that there were 50,000 tank ship trips into Gulf Coast ports during which liquid cargo was carried.

These estimates are believed to be correct to within at least a factor of 2. The reason for this is that the count of outbound ships and barges very nearly equals the inbound count and it is likely that many, it not most, carry a liquid cargo.

This count of tankship traffic was combined with the count of non-collision casualties having a cargo loss, Table 3.8, to obtain an estimate of spill frequency from rammings and groundings:

$$\frac{2 \text{ (losses in 6 years)}}{59{,}000 \text{ (transits in 6 years)}} = 3.39 \times 10^{-5} \text{ spills/transit}$$

In using this estimate, it must be kept in mind that it represents an average of the entire Gulf Coast area. Since vessel traffic conditions and channel configuration of the Sabine Pass, Canal and Neches River differ from the other Gulf Coast port areas, the actual loss frequency to be expected could be somewhat different.

Similarly for spills from SPR tank barge casualties, it was estimated that there were a total of 460,000 tank barge trips in Gulf Coast ports, during FY 1969 and FY 1974, in which a liquid cargo was carried. This value was combined with the count of ramming and grounding casualties with cargo loss from Table 3.9 in the DES to yield,

$$\frac{25 \text{ (losses in 6 years)}}{460{,}000 \text{ (trips in 6 years)}} = 5.4 \times 10^{-5} \text{ spills/transit,}$$

for tank barges in the Calcasieu Channel and Alkali Ditch.

The Coast Guard Vessel Casualty data reports the dollar value of the cargo loss. These data for tank barge casualties in both the Gulf Coast region and on Western Rivers (mainly the Mississippi Ohio River system) have been plotted in Figure 3.16 in the FES (repeated here as Figure 3.15). The cost of the material spills in each incident is distributed log normally with the number of spills. The cumulative distribution curve in

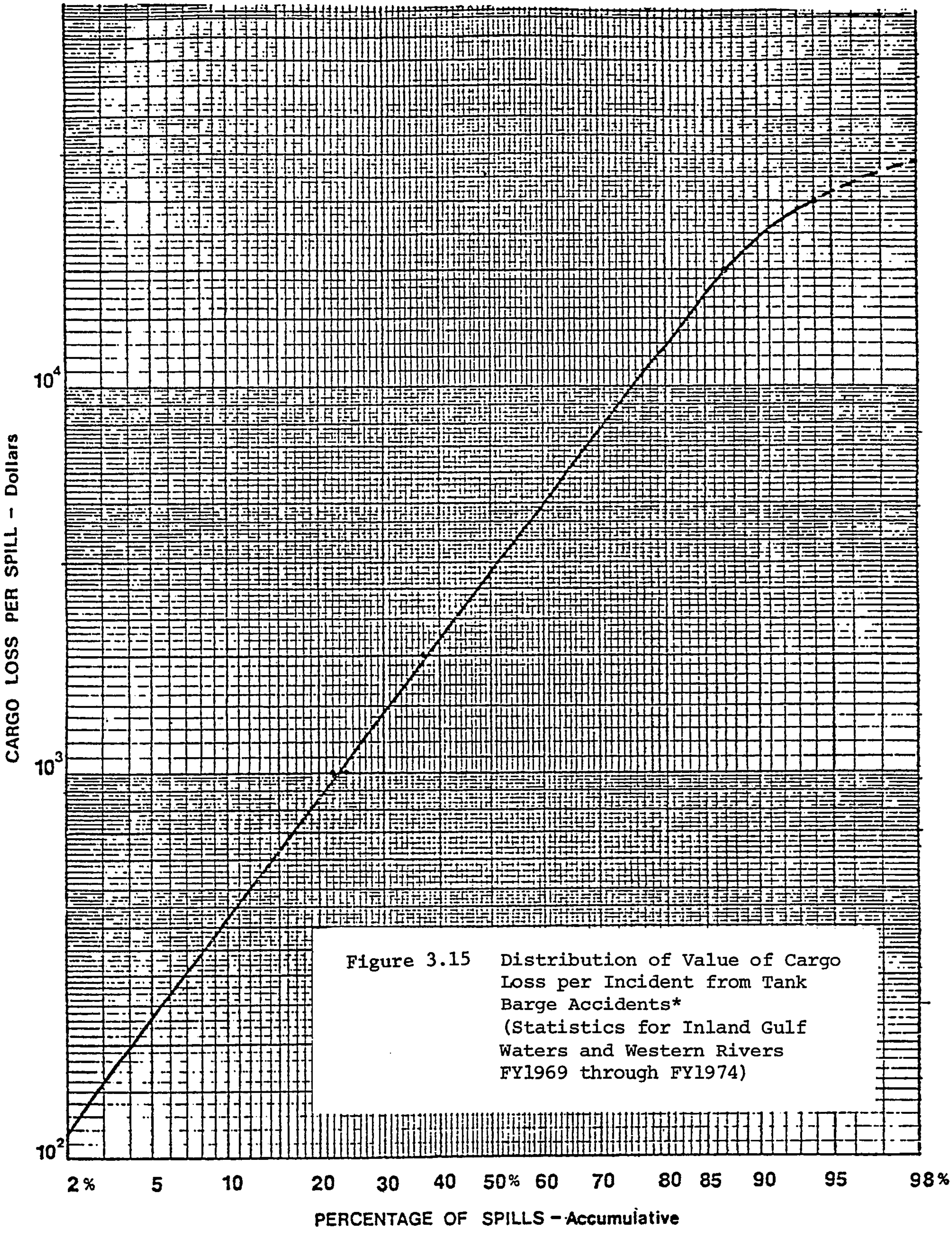

Figure 3.15 Distribution of Value of Cargo Loss per Incident from Tank Barge Accidents* (Statistics for Inland Gulf Waters and Western Rivers FY1969 through FY1974)

*This figure appears as Figure 3.17 in the West Hackberry FES.

Figure 3.15 should be interpreted as a given percent of all spills having cargo value equal to or less than the indicated value. Most of the spilled cargos consisted of crude oil and petroleum fuels, and at the time most of the spills occurred, it is assumed that the average value of these materials was $3.00 per barrel. Using this value, the data in Figure 3.15 were converted to a frequency distribution of quantity spilled as shown in Figure 3.16, (equivalent to Figure 3.18 in the FES). The curve in Figure 3.16 begins to bend over at spill quantities of 8,000 to 10,000 barrels and this reflects the fact that the capacity of many barges is between 10,000 t0 20,000 barrels.

The median quantity spilled is approximately 1,100 barrels. From Table 3.19 in the FES, the most common tank barge sizes are 1,500, 2,750 and 3,000 tons. The two larger sizes are those planned for use in the temporary phase to fill the West Hackberry salt dome cavities. These barges will hold 15,000 to 21,000 barrels of oil in 6 tanks of 2,500 to 3,500 barrel capacity each. Hence the median spill represents approximately 1/3 the capacity of a typical barge 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.

The barge spill distribution curve was modified to estimate the spill size distribution for tank ship casualties. For this, it was assumed that the loss of 1/3 the volume of a single tank would be equivalent the median spill from a tank ship casualty.

Table 3.10 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 100,000 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 25,000 barrels in each wing tank. Accordingly, loss of one third the contents of one of these tanks is 8,300 barrels which is assumed to be the median spill. Also, assuming the same as for the tank barge spill distribution, the estimated spill size distribution for tank ships, shown in Figure 3.19 in the FES is obtained (Figure 3.17 this document).

Figure 3.17 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 55,000 DWT tank ship as expected since the casualties include a large number of smaller tank ships.

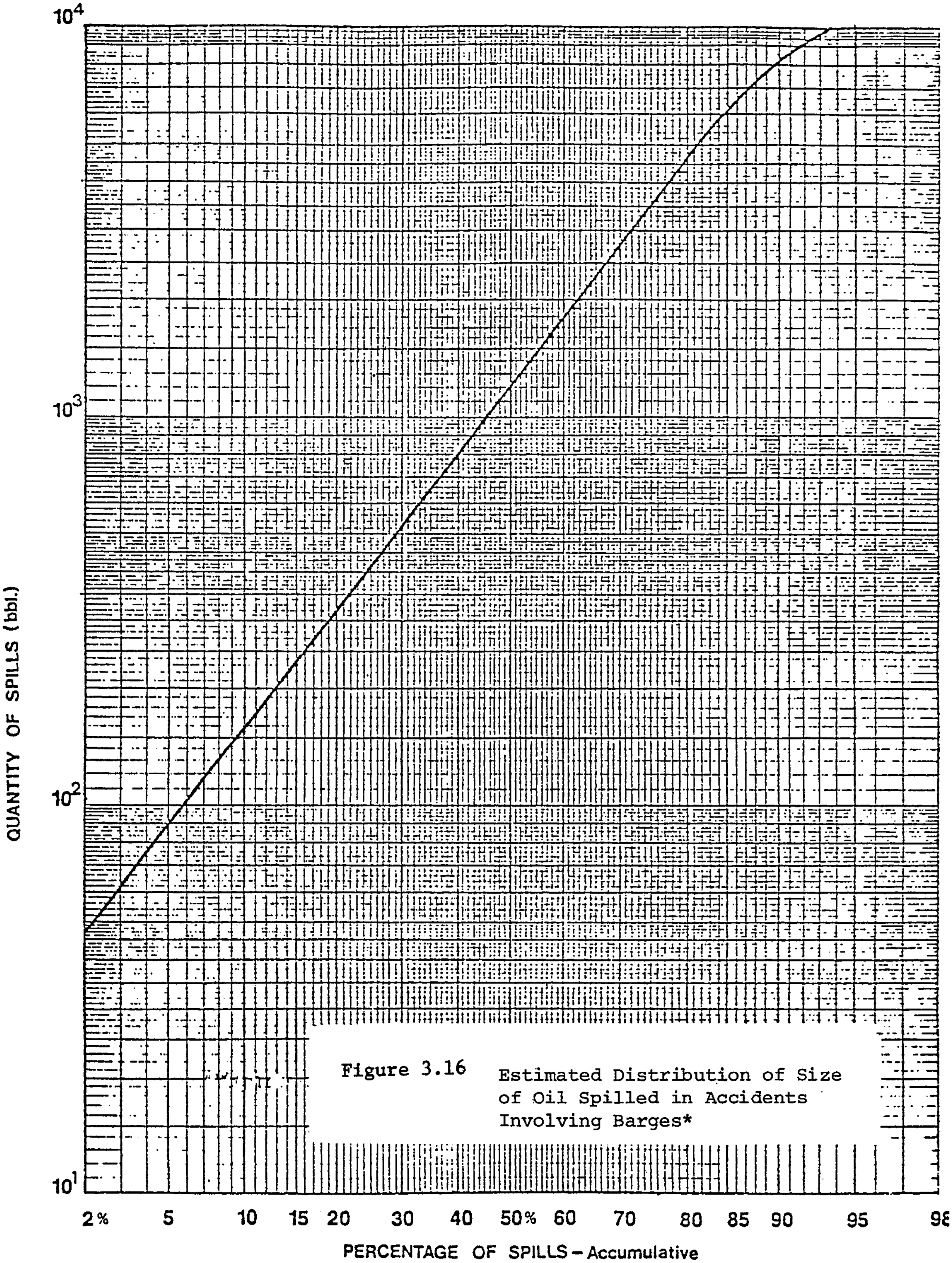

Figure 3.16 Estimated Distribution of Size of Oil Spilled in Accidents Involving Barges*

*This figure appears as Figure 3.18 in the West Hackberry FES.

Table 3.10 Characteristics of a 60,000 DWT Tankship

Length Overall	731 feet
Beam	105 feet
Draft	43 feet
Gross Tonage	32,000
Net Tonage	23,000
Number of Wing Tanks	8
Approximate Capacity of the Wing Tanks	27,500 bbls
Number of Center Tanks	5
Approximate Capacity of the Center Tanks	46,000 bbls

Source: "Offshore Petroleum Transfer Systems for Washington State," Oceanographic Institute of Washington, December 16, 1974, p. III-54.

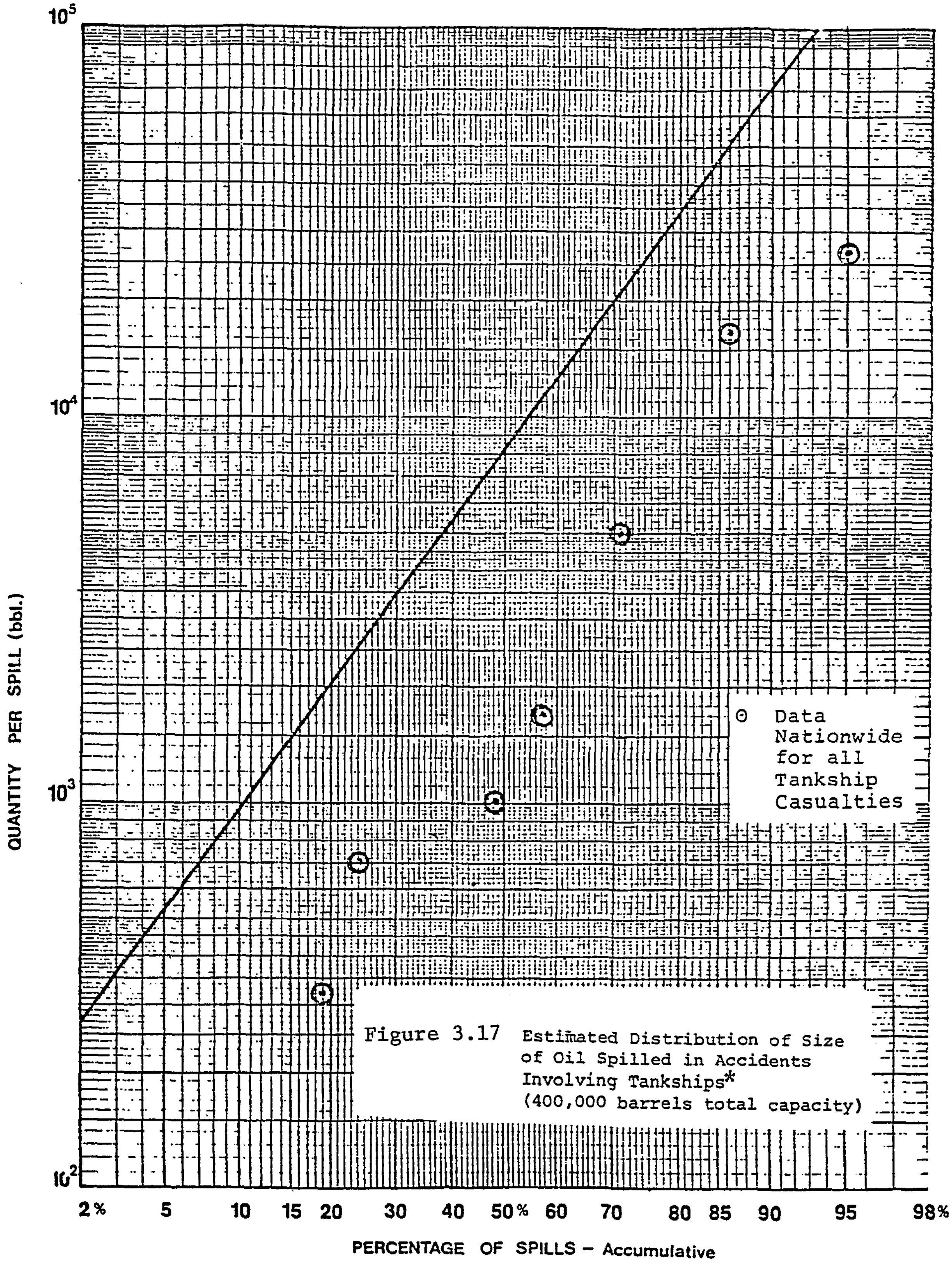

Figure 3.17 Estimated Distribution of Size of Oil Spilled in Accidents Involving Tankships*
(400,000 barrels total capacity)

*This figure appears as Figure 3.19 in the West Hackberry FES.

Estimates of the expected spill size frequency from tank ship and barge casualties are presented in Tables 3.11 and 3.12, respectively. The per trip frequencies are simply the product of the spill frequency and the fraction of spills in the given size range from Figures 3.16 and 3.17. From the discussion above the frequency of spills per barge trip is 5.4×10^{-5} caused by rammings and groundings. The frequency for tank ships is 5.1×10^{-5} spills per trip which includes collisions as well as rammings and groundings. These data were used to help derive the estimates presented in Table 3.7 and Figures 3.13 and 3.14 discussed above. The expectation quantity of crude oil spilled is the sum of the products of frequency and quantity spilled (average of the ranges in Tables 3.13 and 3.14) for all spill sizes.

3.7.2.3 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).[31] 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 3.13. 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 3.11

Estimated Spill Size Frequency
From Tankship Accidents
(Permanent Fill and Distribution System)

Spill Size (bbls)	Frequency (Per Tankship Trip	Frequency per Transport of 60 x 10^6 bbls[a]
<300	1.12×10^{-6}	1.68×10^{-4}
300-1000	4.08×10^{-6}	6.12×10^{-4}
1000-3000	8.67×10^{-6}	1.30×10^{-3}
3000-10,000	1.40×10^{-5}	2.10×10^{-3}
10,000-30,000	1.18×10^{-5}	1.77×10^{-3}
30,000-100,000	7.85×10^{-6}	1.18×10^{-3}
>100,000[b]	3.46×10^{-6}	5.19×10^{-4}

[a] 150 Trips

[b] Maximum quantity spilled is 400,000 bbls, the capacity of the tankship.

Table 3.12

Estimated Spill Size Frequency
From Barge Accidents
(Intermediate Fill System)

Spill Size (bbls)	Frequency (Per Barge Trip)	Frequency per Transport of 6×10^6 bbls[a]
<100	3.83×10^{-6}	0.0011
100-300	7.61×10^{-6}	0.0022
300-1000	1.41×10^{-5}	0.0040
1000-3000	1.34×10^{-5}	0.0038
3000-10,000	1.16×10^{-5}	0.0033
>10,000	3.62×10^{-6}	0.0010

[a] 286 barge trips for 10 percent of the initial fill, 6×10^6 bbls.

[b] The maximum quantity spilled is 21,000 bbls, the capacity of the barge.

Table 3.13

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

Table 3.14 Estimated Spill Size Frequency from Accidents During Loading or Offloading at the Dock

Spill Size (bbls)	Frequency (Per Operation)	Frequency for Transport of 60 x 10^6 bbls By Tank Ships[a]	Frequency for Transport of 6 x 10^6 bbls By Tank Barge[b]
<3	7.56×10^{-3}	1.13	72.0
3-10	1.03×10^{-3}	0.155	9.80
10-30	3.18×10^{-4}	0.16	3.03
30-100	1.84×10^{-4}	0.09	1.75
100-300	6.60×10^{-5}	0.03	0.63
300-1000	2.75×10^{-5}	0.014	0.26
>1000	1.19×10^{-5}	0.006	0.11

[a] 150 Tank Ship Trips

[b] 286 Tank Barge Trips

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.[36] A major fraction of tank barge traffic into U. S. ports occurs in Gulf Coast ports, approximately 76,000 trips inbound annually.[37] 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 3.13, 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 3.18, and represents the best data available for this information since it is specific to the type of operation 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. These have been listed in Table 3.14, and were further utilized to construct Figures 3.13 and 3.14 as have been discussed above. The data listed in Table 3.14 also were used to calculate the medium spill size and expected spill quantities listed in Table 3.6 above.

3.7.2.4 Ecological Impacts of Oil Spills

In addition to the potential impacts of oil related accidents on the West Hackberry site as discussed in the FES, risks associated with the use of proposed distribution facilities involve accidental releases from barges, tanker spills, pipeline ruptures, terminal facility storage accidents, and ballast water discharges. Such releases pose potentially adverse impacts to the Neches and Sabine Rivers, the Intracoastal Waterway, Sabine Lake, and Black Lake.

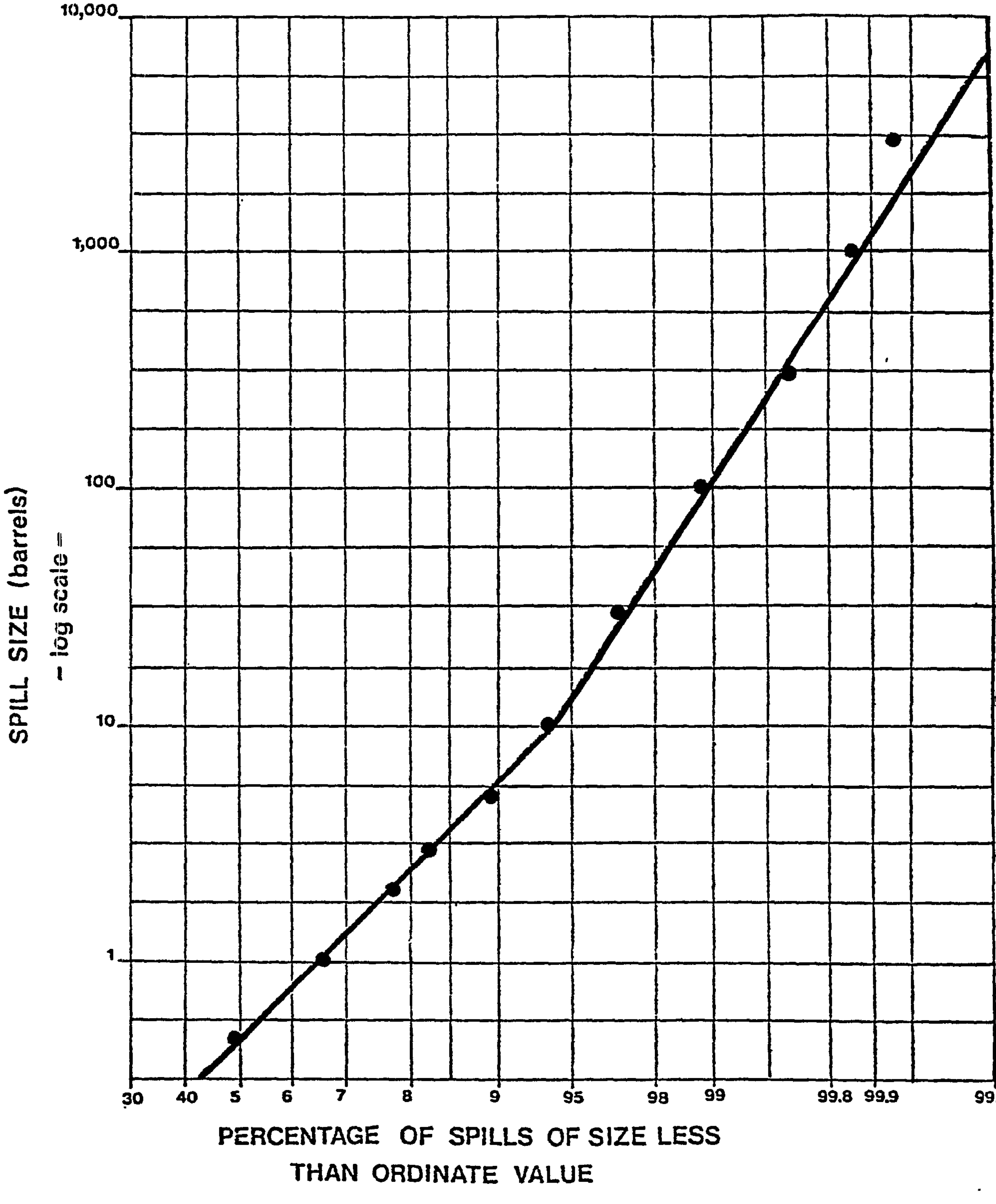

Figure 3.18 Distribution of Quantity of Oil Spilled in Accidents During Loading and Off-loading Tankships and Tankbarges.

Background Pollution

Oil and grease levels in the sediment and the water column in the Sabine and Neches Rivers and Sabine Lake exceed the minimum values normally associated with polluted water and sediment. 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. Plankton and mobile organisms such as fish, shrimp and birds are the groups most likely to first contact an oil spill on a water body. Benthic and sediment dwelling forms would be affected if oil sinks to the bottom. A detailed discussion of the effects of crude oil on aquatic organisms is provided in the West Hackberry FES and that discussion is not repeated here. Planktonic organisms because of their small size, relative immobility and sensitivity to oil (see Section 3.4.6) are impacted by oil spilled in an aquatic habitat. Recovery of planktonic populations is generally rapid.

The effects of various types of oil on fish and benthic organisms are summarized in Tables 3.15 and 3.16. Crude oils are less toxic than refined fuels and oil concentrations are not expected to exceed tolerance levels (amount and time of exposure) unless the oil and the organisms are trapped in shallow coves in which case local fish mortality could occur. Benthic organisms suffocate when oil settles to the bottom and covers the inhabitants. 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.

Oil on the water's surface spreads under the influence of forces of gravity, surface tension, viscosity, surface currents and surface winds. Oil spilled in the Neches River would be transported downstream by water currents and depending on the size of the spill and local conditions could be transported several miles. Small spills in standing water (up to 300 bbls) tend to spread to a density of 6 to 12 bbls per acre of water surface by surface tension alone. Thus, a spill of 200 bbls would produce a slick of from 33 to about 17 acres if there were no water movement.

Weathering changes the oil's physical characteristics and influences the rate of movement. The oil is affected after release and/or during transport by separating processes of evaporation, dissolution, emulsification, sedimentation, and chemical oxidation, as well as biological degradation. The

Table 3.15 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.

[3] D. Ahearn, et al, 1971 as reported by J.H. Stone and J.M. Robbins. Louisiana Superport Studies, Report 3 of the Center for Wetlands Resources, LSU, Baton Rouge. 1973.

*TLm = median tolerance limit; number indicates hours of exposure

**estimate of oil concentration at low tide

Table 3.16 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

lighter, more toxic oil components are lost by evaporation. This creates a heavier surface residue which may become heavy enough to sink. Particles in suspension (silt, clay, organic material) may combine with the oil so that sedimentation is increased. Conditions of increased turbidity, such as during periods of high surface water runoff or water turbulance would increase this effect. Bacterial masses in the slicks can increase sedimentation also. Emulsification results in suspended globules which eventually settle out after contact with suspended particles.

Marshes

The Neches River and Sabine Lake are bordered by extensive areas of intermediate and brackish marshes including substantial areas of Sabine National Wildlife Refuge which borders the eastern margin of Sabine Lake. The effects of oil on marshes bordering Calcasieu Lake is discussed in the West Hackberry FES (76/77-4). Marshes and beaches are the inland communities likely to be impacted by tanker or terminal facility oil spill. Using the calculated frequency of tanker spillages (Section 3.7.2.1) the probability of extensive sections of marsh bordering Sabine Lake or the Neches River receiving in excess of 4 exposures to oil as a result of the SPR program in any 2 or 3 year period is small. This is important because 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. Adverse but short-term effects are death of shoots exposed to oil, reduced germination of contaminated seeds, and reduced populations of annual species.[38] Recovery by marsh vegetation would be rapid (less than 2 years) under these conditions because of new growth from plant bases. Successive spillages within a few months of one another, however, produce longer lasting effects.

The degree of weathering of crude oil directly affects its toxic content and several studies[39,40] have indicated that several days of weathering, i.e., period at sea before beaching, reduces the deleterious effects of oil on plants. The more toxic aromatic compounds have time to evaporate and disperse during this period. The large size and enclosed nature of Sabine Lake means that oil that is not cleaned up or which quickly sinks to the bottom would be desposited along the shoreline before a great deal of weathering can take place. This, of course, depends on the location of any such spill, its size, the prevailing wind and water circulation patterns and the efficiency of cleanup operations.

The area around Sabine Lake is an important overwintering ground for a tremendous variety of migratory bird species (Chapter 2). Sabine National Wildlife Refuge which contains extensive breeding grounds borders the eastern margins of the lake. This refuge, which is at the southern end of the Mississippi Flyway, is an important national resource and harbors large populations of mallard, mottled duck and green-winged teal. The southern bald eagle, an endangered species, may occur near Sabine Lake and peregrine falcon migrate through the area. For these reasons, oil spills in Sabine Lake or the Neches River, which may be deposited in the Refuge's marshes, are of potential significance. Oil spills in the lake to date have had no noticeable impact on bird populations.

Ecological Impacts of Oil Pipeline Spills

The pipeline route from the West Hackberry site to the Sun Terminal at Nederland, Texas is bordered by extensive areas of intermediate and brackish marshes, spoil deposition areas, and some cleared, agricultural lands. The pipeline would parallel the Intracoastal Waterway for 15-1/2 miles and would cross the southern portion of Black Lake, the Sabine and Neches Rivers, Cow Bayou, and several smaller water bodies. Oil pipeline ruptures can be expected to vary in impact depending on the amount of oil leakage, where it occurred, and the habitat type in which it occurred.

An 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 leached away eventually over a period of years. The exact coverage depends on soil types, viscosity of oil, pipeline pressure, soil moisture, and other factors. If oil reaches the water table which along the pipeline route is 2 to 3 feet deep, slow discharge of oil into a body of water (the Intracoastal Waterway, Black Lake, Sabine River, Neches River, or the bordering marshes) via water table transport may occur. Thus, a spill of approximately 1,000 bbl can 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 is to dig a trench near the point of entry into such a water body, and when oil collects (generally after rains) it can be pumped off.

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 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. Absorbent materials are generally used at a dock or on open water after most of the oil has been removed by pumping and skimming. Biological effects of cleanup operations at docks and in open water are generally minimal.

Cleanup operations in marshes, on beaches, and along river banks would involve removal of damaged vegetation and dead animals as well as oil removal. Such operations would result in trampling and other detrimental effects on vegetation within and adjacent to the oil coated areas; however, properly supervised cleanup operations would generally produce only minor impacts in and near an oil spill area. The use of heavy equipment would result in more extensive impacts, and in certain areas could result in soil erosion. Since toxic chemical cleansing agents would not be used, vegetative regrowth would be rapid.

The cost of cleaning up an oil spill in a marsh is approximately $90 to $120 per barrel. The cost for cleaning up a river or lake is generally less.

The amount of absorbent materials used in any given oil spill situation is highly variable. One absorbent material that is used for relatively viscous oils will recover as much as 1 barrel of oil per 10 lbs of absorbent. After the oil is removed, such materials are generally transported to designated landfill sites for disposal.

3.7.3 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 indicate that the flash point is below 20°F. About one percent by weight of the oil consists of volatile pentane and lower weight hydrocarbons. Thus the vapor from spills of unweathered crude oil may be easily ignited provided an ignition source is nearby.

Of prime importance in evaluating offsite fire risks is the maximum downwind travel of a flammable vapor air mixture. 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 3.17 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 4,500 g/m^3, which is typical of aliphatic hydrocarbons. The table indicates that spills of 1000 bbls or less (e.g., from pipeline leaks and accidents at the Sun Terminal) probably would not be ignited since the flammable plume would rarely extend off-site. On site, 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 (8300 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 and could be ignited. However, this generally would present little danger to persons living on shore since less than 10 percent of the vapor would be mixed with air in a flammable composition.

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 cause of ignition is not known precisely, but apparently short circuited electrical wires and hot metal fragments play a major role. For the storage and terminal facilities, accident experience at bulk petroleum marine terminals during 1971 through 1974 indicated a total of 29 fires originated from accidents on the terminal property, and of these only one spread to property offsite.[41] 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

$$\frac{1}{4 \times 700} = 4 \times 10^{-4} \text{ per year.}$$

Table 3.17 Maximum Downwind Drift of Flammable Crude Oil Vapor-Air Mixtures

Pasquill Atmospheric Stability	Relative Frequency of Occurrence	Downwind Distance (meters)		
		0.5 bbl Spill	1100 bbls Spill	8300 bbls Spill
A,B,C,D	.64	<100	250	550
E	0.13	<100	350	750
F	0.23	150	600	1250

Actually this probably is a high estimate since many of the liquids (such as gasoline) handled at the 700 terminals are much more flammable than crude oil.

The environmental impact of a crude oil fire generally would be a localized destruction of vegetation and the release of 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 feed back from the flame is insufficient to vaporize the high molecular weight components. For a 27^{o} API 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.

3.7.4 Accidental Injury

Because accidental fires would be localized to the spill area, it may be expected that injuries also would be localized. Hence, it is mainly employees and the crews of the 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 3.18 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 two 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 3.14 for refined petroleum fuels, gasoline, fuel oil, aviation fuel and napthalene, which are <u>much more</u> 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 26,000 bulk storage establishments for petroleum fuels in the United States.[42] Assuming an average of 20,000 over the 26 year period covered by the data, the frequency of non-employee deaths per establishment is

$\frac{31}{26} \times \frac{1}{26,000} = 6 \times 10^{-5}$ per year, where the unknown

Table 3.18 Civilian and Employee Fatalities from Fires and Explosions Involving Flammable Liquid Bulk Storage During the Years 1950-1975

Product	Employee Deaths	Non-Employee	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.

category in Table 3.18 has been included with non-employee death. The corresponding estimate for the frequency of employee deaths is

$$\frac{43}{26} \times \frac{1}{20,000} = 8 \times 10^{-5} \text{ per year.}$$

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 6×10^{-4} civilians injured per year and 8×10^{-4} employees injured 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 very small.

3.7.5 Natural Disasters

The region of Sabine Lake and the Sun Terminal are described as a Zone 0 seismic risk area, meaning an area of negligible risk of damage from an earthquake.

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4. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED AFTER APPLICATION OF MITIGATION MEASURES

4.1 INTRODUCTION

Within this section, probable adverse environmental effects associated with the proposed amendments to the originally proposed facility for oil storage at the West Hackberry salt dome are presented. The originally proposed facility was discussed and analyzed in FES 76/77-4, published January 1977 by the FEA. That document reflects the design of the facility at the time of publication. Since that time, the availability of Sun Terminal in Nederland, Texas has prompted a redesign of the oil distribution system. This change in design eliminates the need to construct a new terminal facility on Calcasieu River, as described in FES 76/77-4.

4.2 SUMMARY

Environmental impacts associated with constructing pipelines from Sun Terminal and from Amoco Dock to the storage site at the West Hackberry salt dome are summarized below. Table 4.1, presented at the end of this section, contains a summary of those impacts along with an identification of mitigative measures.

Construction Impacts

Construction operations would be disruptive, inducing soil erosion and increasing turbidity levels in all water bodies along the pipeline route. Impacts to the aquatic community would include destruction of small amounts of benthic organisms and a reduction in plankton production. The construction of pipelines and site development would involve the temporary disturbance of 64 acres of existing grazing and agricultural land. Resident wildlife would emigrate to more tranquil settings until disruption ceases. These impacts would occur only during the six-month construction period. The period of disturbance should not exceed two to three months at any one location. Benthic and plankton communities should be reestablished within three months after construction activities have ceased. Vegetation would reestablish in one to two years. Restoration of wildlife habitat would follow revegetation.

Many of the water systems to be dredged for pipeline construction are subjected to periodic maintenance dredging to maintain a desired depth of channel. The impacts associated with new pipeline construction would not exceed these periodic impacts. Dredging in all areas would result in turbidity plumes (increased localized concentrations of suspended solids), and in depressed oxygen levels. These impacts would be short-term and localized. Oxygen levels would not be depressed below levels prescribed by applicable regulations. Dredging operations through spoil and shoal areas of waterways would not result in significant releases of toxic substances contained in the spoil. The disposal of dredged material into adjacent marshland would temporarily destroy vegetation and render the area unsuitable for wildlife habitat. This spoil area would revegetate within two years, and would be colonized by wildlife as the spoil hardens and vegetation appears.

Operational Air Quality Impacts

The handling of crude oil in general results in temporary, localized increases in hydrocarbon concentrations at the dock facilities. As discussed in Section 3.3, these concentrations would be very high during loading and unloading operations. However, these worst-case concentrations would be reduced if vapor recovery systems for tanker loading and unloading were installed. Emission control technology for marine terminals require three systems: (1) a ship-side vapor collection system, (2) a shore-side collection system, and (3) a vapor control unit. The vapor control unit represents the key consideration in emission control technologies, and there are several units which are currently used in the petroleum industry, although they are not generally used for marine terminal and oil transfer operations.

The shipboard vapor collection system would convey the hydrocarbon vapors to the shore-side system, with both systems having collection efficiencies between 90 and 95 percent. These vapors would be incinerated via an elevated, smokeless flare. Smokeless flares convert the hydrocarbons to carbon dioxide and water with better than 99 percent efficiency. Flaring these gases can create sulfur dioxide and nitrogen oxides if sufficient sulfur and nitrogen are present in the vapors. These combustion by-products can be removed with at least 90 percent recovery by scrubbing the gas with water. The overall efficiency of a collection-incineration emissions control system is greater than 95 percent.

Refrigeration of the collected hydrocarbon vapors results in the liquification of the vapors which can then be reinjected into the crude oil at the marine terminal. This recovery method has been shown to be greater than 90 percent efficient. Should reinjection not be feasible, the recovered vapors can be used for fuel or sold to petrochemical industries. The overall efficiency of such a vapor recovery system is about 86 percent.

These vapor control systems and the indicated efficiencies are representative of the technologies available in the petroleum industry. Gasoline vapor control technology has been applied in some cases for vessel transferring operations where the liquid and vapor spaces are closed. These systems have not been applied to marine terminal operations for large tankers carrying either crude oil or gasoline. The principles involved in marine vapor collection and control are well understood. Applicable vapor control technology and explosive vapor processing technology have been developed in other fields; however, these technologies need to be refined with respect to marine loading of gasoline. Hydrogen sulfide levels are expected to be minimal since most crude expected to be delivered would have weathered sufficiently during transit to substantially reduce these emissions.

Emissions from construction work force traffic would not significantly impact the local communities. Localized, temporary increases in traffic congestion would occur. A majority of the work force would commute from surrounding communities.

Pipeline Accidents

An estimated total of 700 barrels of oil is projected to be spilled during the lifetime of the project as a result of crude-oil pipeline accidents. The impacts from a pipeline rupture varies with the quantity of oil spilled, the location of the spill, and the habitat type subjected to the spilled oil. Pipeline ruptures on dry land would impact invertebrates and plants. Effects on soil organisms would be severe, but localized. Spilled oil would degrade or be leached away over a period of several years.

The water table along the pipeline route is two to three feet below ground level. Initial oil penetration due to a single spill of 700 barrels would be less than ten centimeters. The potential for aquifer contamination via a pipeline accident is small. In the event of a spill, seepage prevention methods would be employed.

Above ground pipelines would be constructed at the storage site, the Amoco Dock, and the Sun Terminal. All spills in these areas would be readily detectable by inspection. The magnitude of a spill is not expected to exceed tens of barrels. These spills are easily contained and cleaned up, minimizing environmental damage.

Tankships and Barge Oil Spills

The expected frequency of crude oil spills from transport vessel casualties is 0.000054 per trip for barges and 0.000051 per trip for tankships. For an entire storage-site fill of 60 million barrels, involving approximately 150 trips each day by barge and by tankship, the total expected spillage would be 292 barrels. For five fill and withdrawal cycles, the expected spillage would be 2,320 barrels.

A spill onto open water, in the absence of currents, wind, and/or obstacles, would result in an uncontained oil spill ranging from 1,200 acres median barge spill (1,100 barrels spilled) to 5,400 acres median 100,000 DWT tank spill (8,300 barrels spilled) in a one to two day period. These quantities exceed expected spill volumes, and containment would be provided within the one to two day period.

Spills in the Intracoastal Waterway would be blown in a predominately westerly direction. The edges of such a slick would penetrate surrounding marshland and would dissipate slowly. Spills in the Port Arthur Canal and the Sabine-Neches Canal would be confined by adjacent land and spoil banks. These barriers would become contaminated. Such spills would be contained by booms prior to contaminating surrounding land forms. Spills entering Sabine Lake would tend toward the western shore and not penetrate into the marsh of the Sabine National Wildlife Refuge bordering the eastern shore because of the predominance of winds in the westerly direction. Spills in the Neches River and at the Sun Terminal would contaminate the marshy banks of the Neches River.

The resulting oil concentrations from expected spills would not exceed tolerance levels of contacted fish and organisms, unless both oil and organisms are trapped in shallow coves. Benthic organisms would not be impacted unless the oil settled to the bottom of a water body. This settling would suffocate benthic inhabitants. Planktonic organisms would be impacted due to their small size, their relative immobility, and their sensitivity to oil. Recovery of planktonic populations would be rapid. Containment and clean-up of spilled oil would significantly reduce exposure to benthic and planktonic populations.

Marshes and beaches would be impacted by an oil spill resulting from tanker or terminal facility traffic. The probability of extensive sections of marsh bordering the Sabine Lake or the Neches River receiving a lethal exposure of oil is small. The probability of more than four spills occurring in any two to three year period is small. Marsh plants can survive oil spills of a single exposure. Recovery of marsh vegetation is within two years. Successive exposures, which would be lethal, would not be expected to occur.

Release of Ballast Treatment Water

All ballast water would be treated by existing systems located at Sun Terminal. This treatment system reduces oil concentrations to 7.5 ppm. Effluent from the treatment system would be assimilated into the receiving water system within 400 square feet of the point of discharge.

4.3 CONSIDERATION OFFSETTING ADVERSE ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTION

The utilization of the Sun Terminal and the Amoco Dock for petroleum distribution will result in an increase in the area disrupted by pipeline construction, but will eliminate the dredging required in the construction of new facilities. The utilization of an existing terminal facility (Sun Terminal) has potential for reducing the amount of oil that would have to be delivered by barge and in so doing would reduce the danger of oil spills from barge traffic. The connection of the West Hackberry storage facility to the Sun Terminal would also allow easy distribution of a portion of the oil by the Texoma pipeline without the need to transport oil by ship from the Calcasieu facility to the Nederland, Texas area.

TABLE 4.1 SUMMARY OF PRIMARY ENVIRONMENTAL IMPACTS, MITIGATION PROCEDURES AND UNAVOIDABLE ENVIRONMENTAL EFFECTS

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Dredging			
Sabine River	-moderate increase in turbidity, temporary increase in lighter metals in water column, increased COD	None	-same as primary impact
	-6.9 acres of river bottom habitat disturbed with benthos lost	-backfill pipeline trench	-benthos disturbed
Neches River	-moderate increase in turbidity, increase in light metals in water column, increased COD	none	-same as primary impact
	-5.5 acres of river bottom habitat disturbed; loss of benthos	-backfill	-benthos disturbed
Spoil Disposal from Sabine and Neches Rivers	-37 to 74 acres of disposal areas covered; loss of vegetation and fauna temporarily	-reduce area covered by spoil	-smothering of soil organisms and vegetation
	-turbid runoff into rivers, contaminants released	-sufficient settling time in a diked enclosure area	-reduced temporary increase in turbidity and contaminants

TABLE 4.1 (CONTINUED)

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Oil Distribution Pipeline	∿477 acres disturbed during construction	-return to productive uses where possible	-242 acres permanently disturbed for pipeline right-of-way
	∿35 acres of pasture disturbed. Removes pasture land with net productivity of 1.24×10^9 Kcal/yr.	-bury pipelines and return to pasture usage	-temporary disturbance until pasture regrowth is complete
	∿61 acres of marsh land disturbed	bury and backfill	natural drainage of 61 acres minimally disturbed
	-loss of marsh community productivity of 1.99×10^6 Kg for 203 acres	none	-same as primary impact
	∿23 acres of wood land cleared	-bury pipeline	-change in species composition
	∿140 acres of spoil bank disturbed	-bury pipeline	-temporary loss of vegetation
	Potential disruption of bird breeding activities west of Black Lake	Construction of pipelines between August and February	Minimal disturbance of bird populations
Temporary Oil Pipeline to Amoco Dock	∿11 acres of dry land disturbed (mostly pasture)	none	-same as primary impact

TABLE 4.1 (CONTINUED)

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Additional Barge and Tankship Traffic at Sun Terminal	-erosion from increased wave action on the banks of the Alkali Ditch	-seed and plant banks with native brush and underbrush to waterline	-reduced erosion from wave action
	-bottom scour from increased turbulence	none	-same as primary impact
	-increased chance of oil spill at docks or in transit	-construction of spill retention device at docks	-increased chance of oil spill
<u>Additional Barge Traffic</u>			
Alkali Ditch	-emissions of hydrocarbons, sulfur oxides, carbon monoxide, nitrogen oxides and particulates	none	-same as primary 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	-possible hazard to wildlife using the Sabine National Wildlife Refuge for breeding grounds	-rapid cleanup	-reduced severity of primary impact
	-temporary contamination of sediment	-rapid cleanup	-reduced severity of primary impact

TABLE 4.1 (CONTINUED)

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
	-moderate oil contamination of marsh vegetation will cause death of some roots, reduced germination of contaminated seeds and a reduction in annual species (recovery relatively rapid in <2 yrs.)	-rapid clean-up	-reduced severity of primary impact
Above Ground Oil Pipeline Spill	-contamination of soil and vegetation in small area near spill	-clean-up promptly	-temporary contamination of organisms and vegetation
Underground Oil Pipeline Spill	-contamination of soil to 10 cm depth from spill ($\sim$1000 bbl) covering $\sim$0.4 acres	-dig trenches near spill site and collect and dispose of oil	-temporary contamination of soil surrounding pipeline until degredation 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	-temporary contamination of water bodies from oil not collected
Operation of Sun Terminal	-floating roof surge tanks standing storage loss of 1.28 g/sec of hydrocarbons	-use of a vapor recovery system	-reduction in hydrocarbon concentrations
	-at 2 Km, the maximum hydrocarbon concentration resulting from tanker loading operations would be 229 $\mu gm/m^3$ (57 $\mu gm/m^3$ at 5 km)	-use of a vapor recovery system	-reduction in hydrocarbon emissions

5. RELATIONSHIP BETWEEN SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

There would be short-term adverse effects to the vegetation, the aquatic and terrestrial organisms, and the wildlife indigenous to the storage site and along the oil distribution pipeline right-of-way. Vegetation, organisms, and wildlife would reestablish in these areas with some alteration in species balance resulting from periodic clearing of vegetation at the site or along the pipeline rights-of-way. Hunting and fishing, in some areas, would be temporarily impaired during construction.

Permanent alteration by the pipeline of less than 10 acres at the Nederland Terminal and on the site is expected to result in only a minor and localized reduction in long-term productivity. This estimate of permanently altered acreage represents less than 3 percent of the total permanent right-of-way for the proposed pipeline. This permanently altered acreage would be surrounded by land that was temporarily altered by construction activities but returned to original uses following these activities. Because of the small quantity of land permanently altered, the long-term productivity would not be significantly affected.

The pipeline could enhance the long-term productivity of the region along its route by serving as a linkage to major oil distribution terminals. Such a conduit could induce development of other storage sites within the region. The existing expansive oil and gas distribution system including crude oil terminals, pipelines, and refineries would be augmented. Long-term productivity would be additionally enhanced by insuring an adequate supply of future energy from crude oil stored in, and available to, Louisiana and the Gulf Coast. A major portion of the oil stored at the West Hackberry domes would be for regional consumption.

6. IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES

The originally proposed facility for storing crude oil at the West Hackberry Salt dome site was discussed and analyzed in FES 76/77-4, published in January 1977 by the FEA. That document reflects the design of the facility at the time of publication. Since that time, the availability of Sun Terminal in Nederland, Texas has prompted a redesign of the oil distribution system. The environmental analysis of the new distribution system design is being prepared as an amendment to FES 76/77-4. Irreversible or irretrievable commitments associated with the new proposed distribution system are identified below. Similar information for the other portions of the facility, not amended, are presented in FES 76/77-4, and are not repeated below.

Land Area, Vegetation, and Wildlife

Approximately 300 acres of land would be periodically cleared of obstructive vegetation to maintain pipeline rights-of-way. The natural vegetation and wildlife indigenous to this acreage would be displaced. Wildlife habitat would be altered for the duration of the project.

Construction Materials

Approximately 27,000 tons of steel would be required (pipe, valves, etc.) to build the proposed pipelines. No valid estimates of salvage are available. This quantity of steel is considered an irretrievable commitment.

Labor

Approximately 200 man-years of labor would be required to construct the proposed pipeline. This assumes a construction work force of approximately 100 workers for a six-month duration. This estimate does not include labor requirements for site construction nor for operational effort.

Investment

The costs of constructing the proposed pipeline connecting the Sun Terminal to the West Hackberry salt dome is estimated to be 25 million dollars. This estimate was computed based on the difference in total system costs (pipelines plus all components) of the originally proposed facility reported in FES 76/77-4 of 52 million dollars, and the same costs including the proposed oil distribution system of 77 million dollars. Operating costs for the proposed pipeline are not included in the above estimates. Operating cost for the proposed pipeline are not yet known.

7. ALTERNATIVES TO THE PROPOSED ACTION

7.1 INTRODUCTION

The originally proposed facility for storing crude oil at the West Hackberry salt dome site was discussed and analyzed in FES 76/77-4, published in January 1977 by the FEA. That document reflects the design of the facility at the time of publication. Since that time, the availability of Sun Terminal in Nederland, Texas has prompted a redesign of the oil distribution system. The environmental analysis of the new distribution system design is being prepared as a supplement to FES 76/77-4.

In the original design (FES 76/77-4), the proposed oil distribution system comprised the establishment of a termporary barge dock at the end of the southwest leg of the Alkali Ditch for temporary fill operations, and the development of a permanent dock on the Calcasieu Ship Channel. Pipeline construction for this original distribution system consists of a 12-mile pipeline connecting the temporary docks on Alkali Ditch to the site, and a 4-mile pipeline connecting the permanent docks on the Calcasieu ship Canal to the site.

Present plans specify that initial storage site oil fill will be from the existing Amoco Dock located on Alkali Ditch. Permanent oil transport for the storage site would be via the existing facilities of Sun Terminal at Nederland, Texas. The major alternative to the present plans are the originally proposed West Hackberry Terminal as shown in Figure 7.1. Other alternatives based on utilization and expansion of existing pipelines and/or terminal facilities as well as alternatives to other facility components and storage sites are presented in FES 76/77-4 and are not repeated in this amendment. These other alternatives include development of the Lone Star Terminal (Figure 7.2), and pipeline connections and expansions to utilize existing oil refineries and transport facilities in the area. Impacts associated with these alternatives are summarized in Table 7.1. Impacts associated with the West Hackberry alternative facility components are discussed in section 7.2.

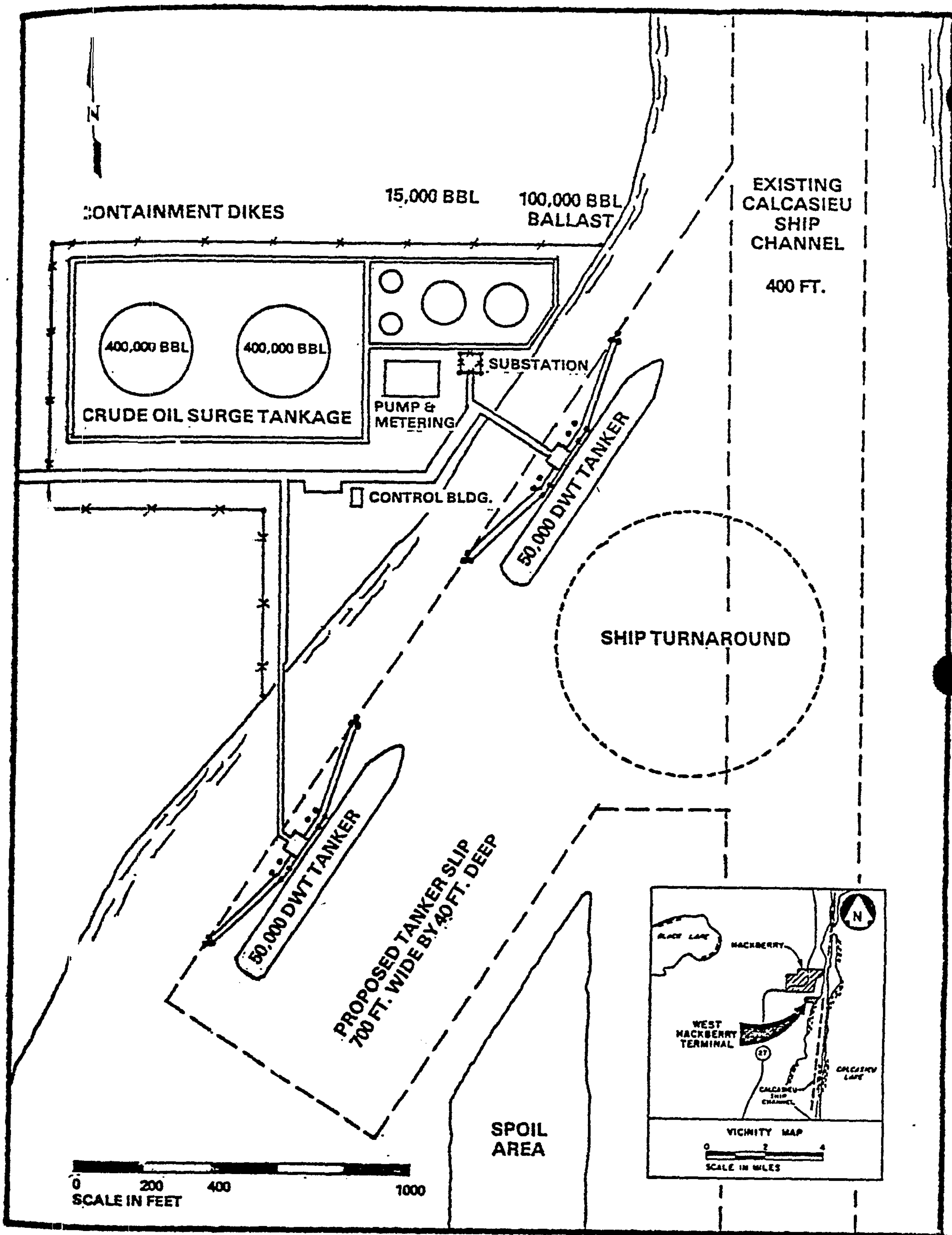

Figure 7.1 Alternate West Hackberry Distribution Terminal

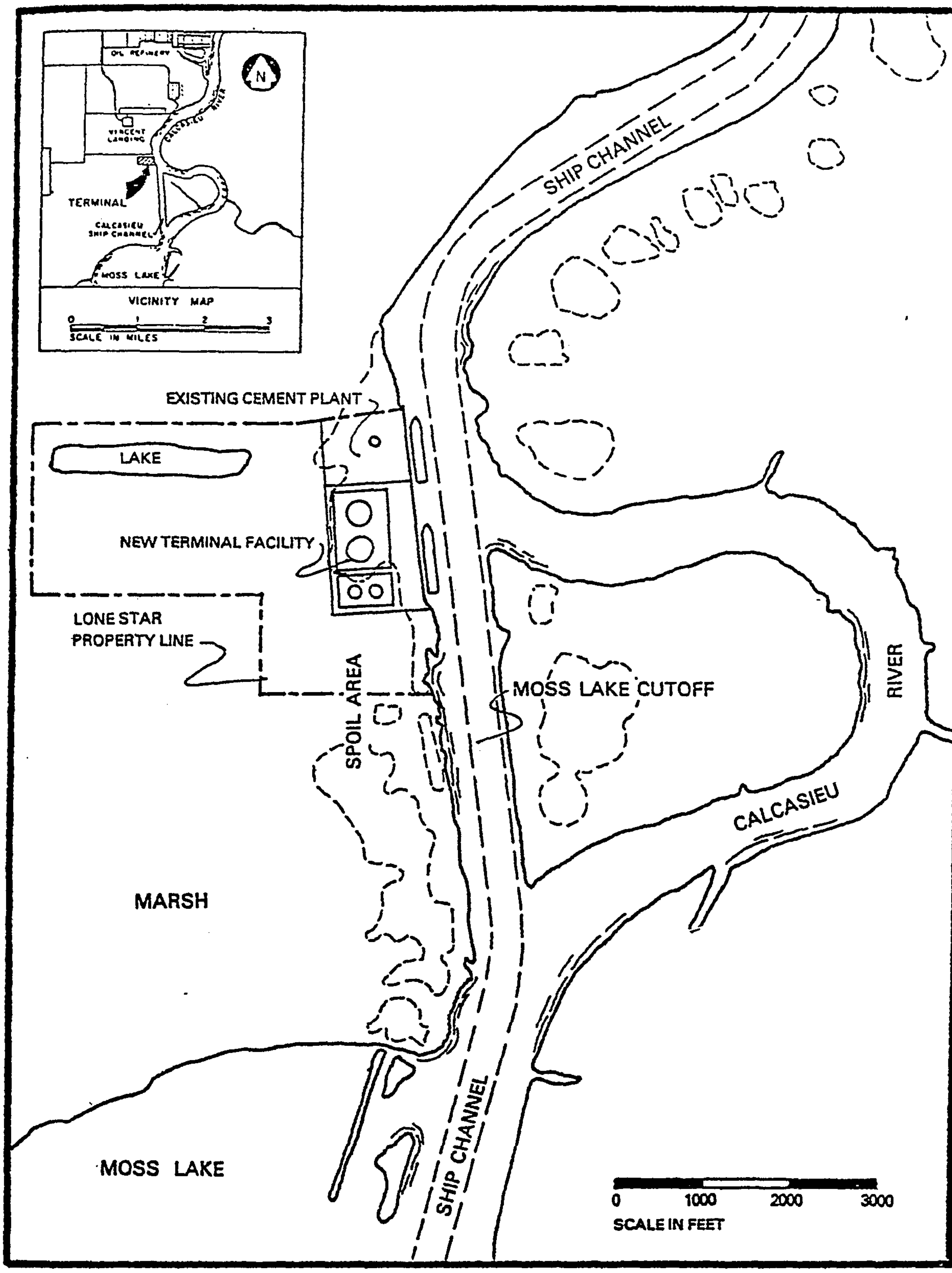

Figure 7.2 Alternative Lone Star Distribution Terminal

Table 7.1 Summary of Alternative Facility and Major Environmental Impacts*

Disruption	Construction	Operational
1. Proposed temporary use of Amoco barge dock	None	Increased barge traffic, 2 barges per day for 2 1/2 months. Small risk of oil spill.
2. Alternate temporary dock on Alkali Ditch	Dredging Alkali Ditch of 35,000 cubic yards; destroy benthos temporarily (2 mo.) interrupt local populations.	Increased traffic (2 barges/day; 2 1/2 mo. duration). Small risk of damaging oil spill.
3. Proposed use of existing Sun Terminal	None	Increased traffic through the Sabine Pass, the Sabine-Neches Canal and the lower part of the Neches River, approximately 1 tankship trip per day. Increased risk of spill.
4. Alternate permanent dock at Lone Star Terminal	Dredging tanker berth 660,000 10^6 cu. yds.; channel area already a much disturbed habitat. On-site grading and tank construction on industrial property. Pipeline route to site crosses 6 mi. of brackish marsh, but use of existing Alkali Canal could minimize disruption of the habitat. Temporary interruption of ICW traffic.	Increased traffic (max. two tankers per day, 560,000 barrels/day; 5 mo. duration). Increased transshipment time. Share facility with another SPR site. Small risk of damaging oil spill. Major spill could disastrously affect fishing and waterfowl feeding in Moss Lake.
5. Alternate permanent dock on the Calcasieu Ship Channel	Dredging tanker berth of 2.5 million cu. yds; channel area already a much disturbed habitat. On-site grading and tank construction on 28 acres of shore property, precludes use for hunting or fishing. Pipeline crosses dry agricultural land, former use restored after construction.	Increased traffic (max. 2 tankers per day, 400,000 barrels/day; 5 mo duration). Small risk of damaging oil spill. Major spill could disastrously affect fishing and waterfowl feeding on Calcasieu Lake as well as shrimp and oyster production.

*Alternatives presented in FES 76/77-4 are not repeated here.

7.2 ALTERNATIVE FACILITY COMPONENTS

7.2.1 Alternative Initial Distribution Facilities

Construction

A temporary dock could be established on Alkali Ditch and used in lieu of the Amoco Dock. This new facility would be connected to the Intracoastal Waterway by a 4.2 mile canal, as shown in Figure 7.3. This new facility would be constructed as an existing canal adjacent to the storage site. Dredging of the canal would be required.

Environmental impacts associated with this action are confined to the water system and the spoil disposal area. Ditching would be required to restore the canal to a 7.5 feet depth, requiring the removal of 35,000 cubic yards of sediment. Dredged material would be deposited on the northwest bank of the canal. These dredging operations would result in increased levels of turbidity and depressed oxygen levels in Alkali Ditch. The potential for release of toxic materials (if present in the sediment) is small and would be minimized by using modern dredging methods. Effects to water quality would be confined to Alkali Ditch.

Impacts associated with the disposal of dredged material on adjacent canal banks include temporary destruction of benthic organisms, and some vegetation, as well as possible alterations in wildlife habitat. These impacts are short-term only and vegetation would reestablish quickly. Returning wildlife would follow revegetation.

Operation

The operation of this new facility would increase barge traffic in the Ditch over present levels, thereby increasing the probability of accidents as well as contributing to bottom scour and bank erosion. Due to the temporary use of this dock, minimal temporary impacts would be expected. The operational effects would not exceed those previously identified with the use of the Amoco Dock as discussed in Section 3.

7.2.2 Alternative Permanent Distribution Facility

The construction of a new permanent facility on the Calcasieu Ship Channel, located approximately 4 miles east of the storage site as shown in Figure 7.4. Construction of this alternative would be phased so that intermediate storage site fill by barge could begin as soon as the 4-mile connection pipeline and docks were installed.

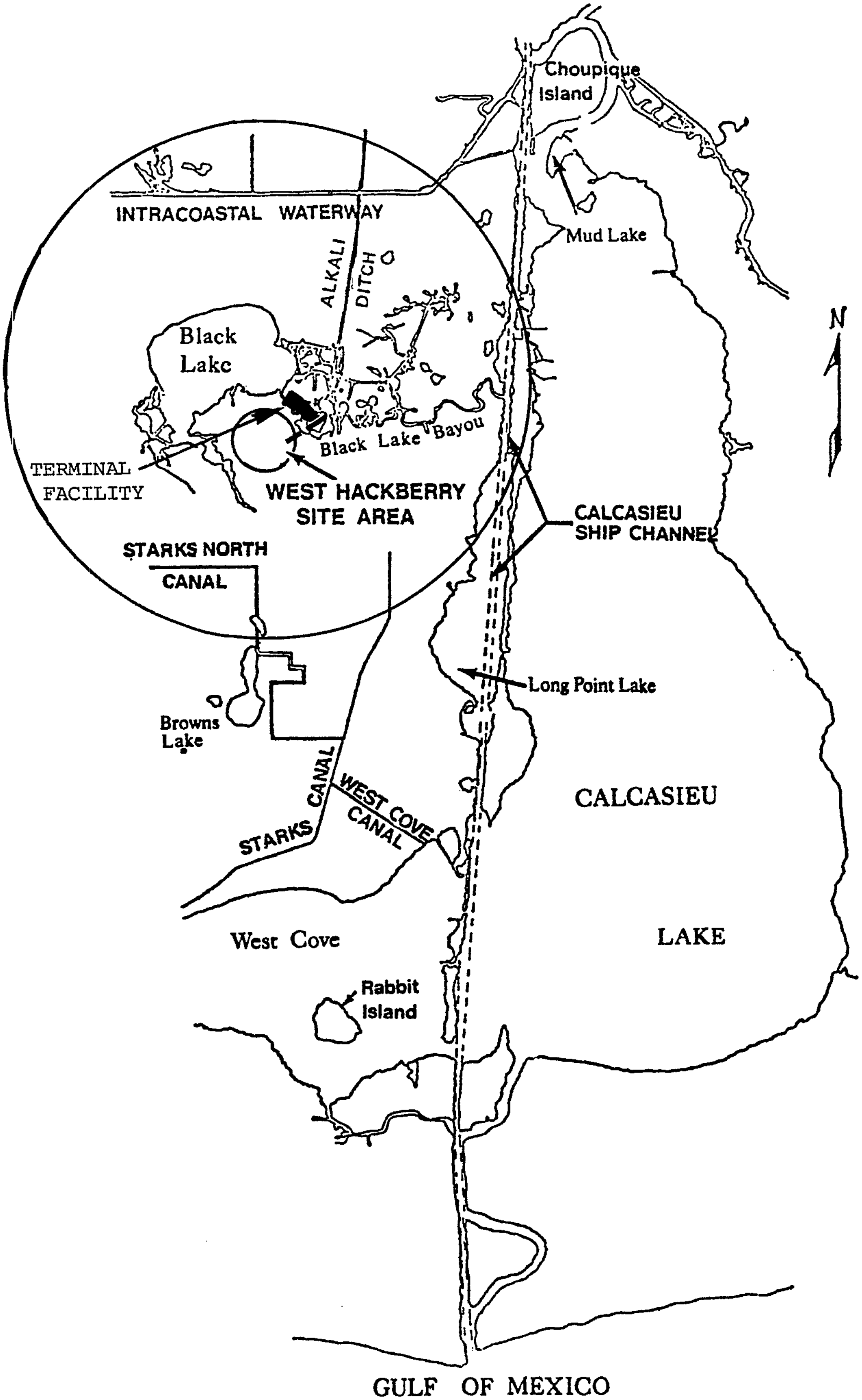

Figure 7.3 Alternate Temporary Oil Distribution System

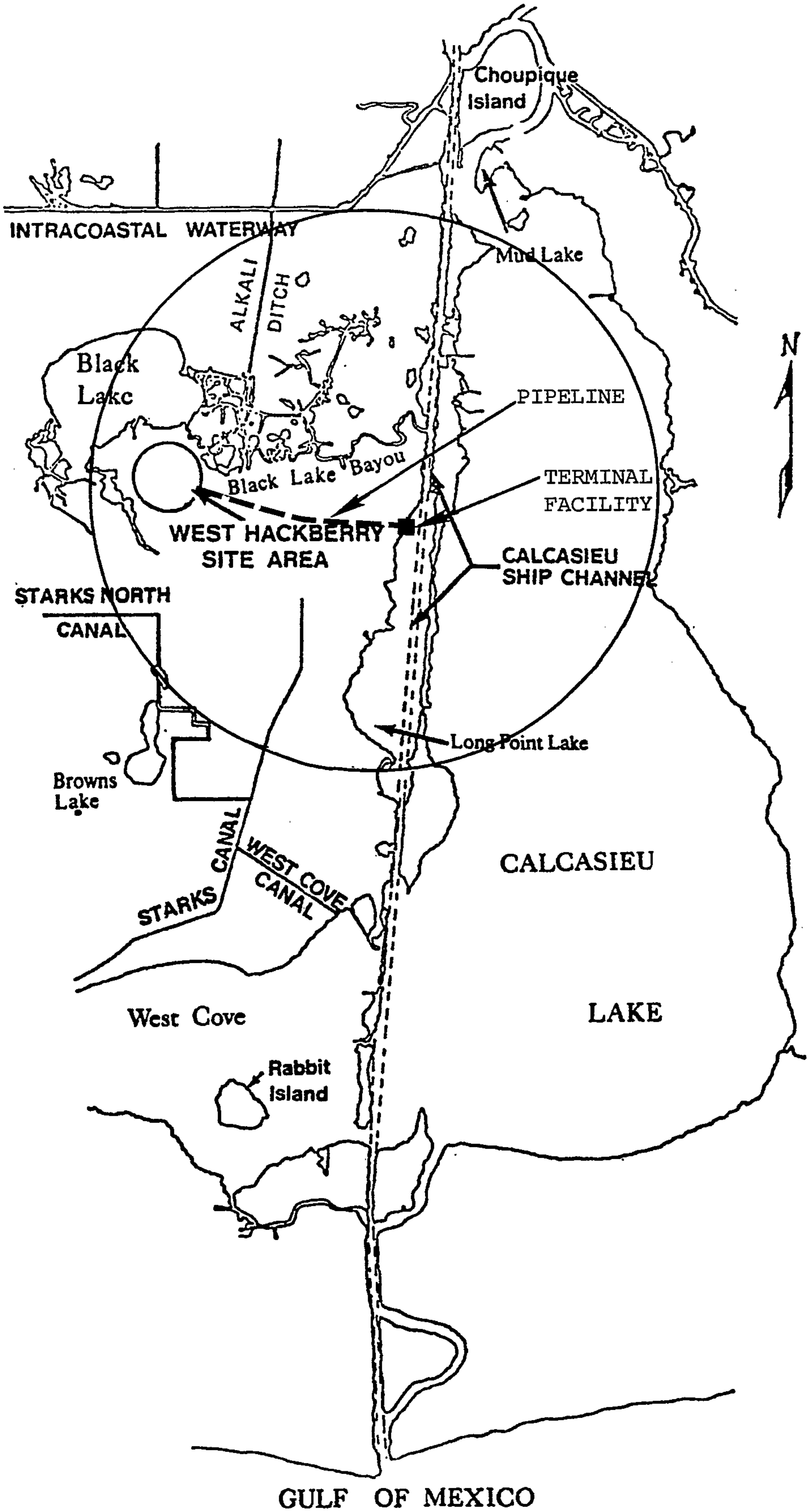

Figure 7.4 Alternate Permanent Oil Distribution System

Terminal Site Considerations

Facilities similar to those available at Sun Terminal would have to be built, including the construction of new docks. These include crude oil surge tanks, ballast tanks, ballast treatment systems, a control building, an electrical power substation, and other support facilities. Dock designs would specify two moorings, each approximately 1,000 feet long. Channel frontage requirements would not exceed 3,000 feet. Sufficient capacity would be provided to accommodate two 500,000 dwt (350,000 barrels) tankers or oil transport barges.

Extensive dredging would be required. The estimated volume of sediment to be removed is 2,500,000 cubic yards. Dredging would be confined to a 3,000 foot reach extending southwest from approximately one mile downstream of the mouth of Black Lake Bayou. Dredged spoil would be deposited into designated areas on either side of the channel. Impacts would primarily be confined to the water system and to the spoil disposal area, but could extend into Calcasieu Lake. Extensive turbidity plumes would be present, due to the large volume of material removed, and the two to three years required for its removal. Additionally, northern migration of salt water from the Gulf of Mexico could occur.

The west bank of the channel in the region of dredging activity is wet marshland. The east bank is partially dry. Disposal of the large volume of spoil on the west bank would result in pockets of intermittent dry land. This would result in destruction of benthic and planktonic communities and vegetation. Both communities and vegetation could reestablish itself within a several year time period. Increased levels of turbidity would be present in a region extending approximately one mile from the disposal site. Impacts associated with spoil deposition on the east bank of the channel would not be as extensive due to the presence of patches of dry land.

Terminal Pipeline Connection

The four mile pipeline connecting the storage site to this new facility would transverse 55 acres of dry agricultural land of five or more feet in elevation. The pipeline route to the presently proposed terminal at Nederland, Texas is 41.5 miles long crossing some 242 acres (see Table 7.2). This pipeline would not cross any major waterways. It would cross Highway 27. Conventional dry land construction methods would be used. No severe environmental impacts would be attributable to the construction of this pipeline.

Table 7.2 Pipeline Alternatives and Affected Areas

		Dry Land	Marsh	River Bank	Woodland	Gum Oak Cypress	Roads
Proposed Route (41.5 miles)	A	43	68	98	23	9	1
	B	64		147	35		1.5
	C		203			27	
Alternate Route (46 miles)	A	35	61	140	23	9	1
	B	53		210	35		
	C		183			27	1.5
Temporary Route Site to Amoco Dock (1.25 miles)	A	8					
	B	11					
	C						
Alternate Temporary Barge Dock (0.25 miles)	A	1.5					
	B	2.3					
	C						
Alternate Permanent Tanker Dock (4 miles)	A	23					1
	B	35					1.5
	C						

Note: A - Permanent right-of-way = 50 feet
B - Dry land construction right-of-way = 75 feet
C - Wet land construction right-of-way = 150 feet

7.2.3 Alternative Texoma Pipeline Route

An alternate oil distribution pipeline route between the West Hackberry site and Sun Terminal was considered. As shown in Figure 7.5, it would pass east of Black Lake along the Alkali Ditch to the Intracoastal Waterway (ICW) for a total pipeline length of 46 miles. This is 4.5 miles longer than the proposed route.

The alternate route would begin at the central plant area and proceed in a northeast direction traveling approximately 0.25 miles across the dome and then in a northeast direction along the west side of Alkali Ditch for 1 mile. At this point the ditch changes directions and runs north to the ICW. The pipeline would continue to follow this leg of Alkali Ditch for 3.6 miles to its intersection with the ICW. The pipeline would then proceed due west along the southern spoil bank of the ICW for approximately 7 miles to a point near the intersection of Goose Lake and the ICW. This initial leg of the alternate route is a total of 11.85 miles in length. The remaining 34 miles from this point is identical to the proposed route to Sun Terminal.

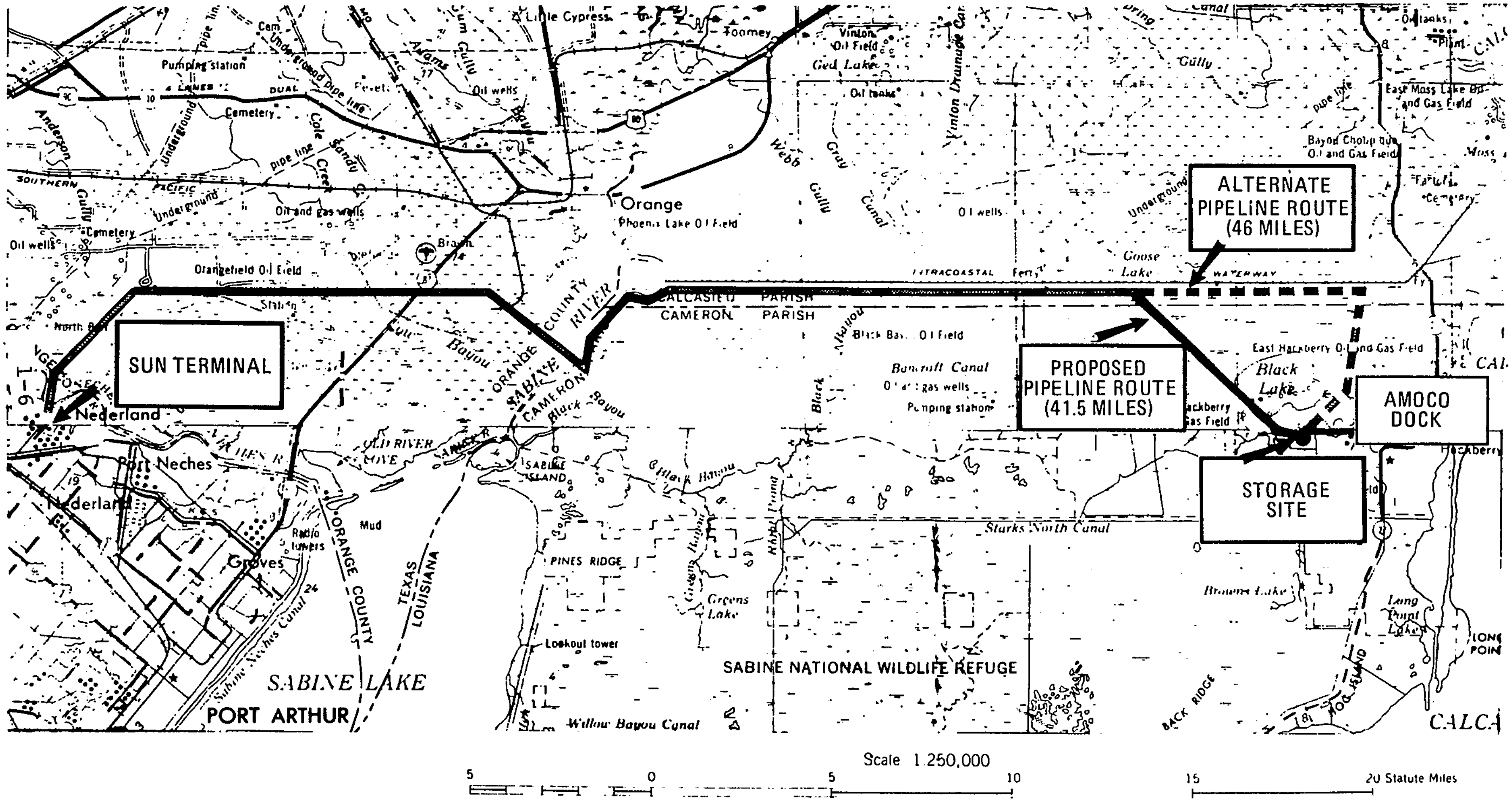

Figure 7.5 Alternate Pipeline Route

8. RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS

Present and Future Land Use

The proposed pipeline would cross the wetlands of Cameron Parish north of the West Hackberry salt dome, then follow the Intracoastal Waterway westward through Calcasieu Parish toward Texas. (See Figure 8.1). Large portions of land adjacent to the salt dome have been designated as oil and gas extraction areas[1] and are presently crossed by numerous pipelines. The establishment of a pipeline right-of-way through this part of Cameron Parish would not constitute an alteration of current land use patterns. The portion of the proposed pipeline to be laid along the Intracoastal Waterway would be buried in the spoil bank along the side of the waterway, and would not interfere with its use as a shipping channel.

The pipeline route would cross through Gum Cove Ridge which extends north and south across the marshes about midway between the Calcasieu River and the Sabine River. There are pimple mounds and undisturbed prairie marshes along Gum Cove Ridge, and for this reason, it is one of eight candidate sites for a state park in Southwestern Louisiana.[2]

The proposed pipeline right-of-way through Cameron and Calcasieu Parishes is in a rural area which, because of extensive wetlands, will remain rural for the foreseeable future.

At the point where the Intracoastal Waterway meets the Sabine River, the proposed pipeline would cross the river and would be buried at a depth of about 15 feet below the bottom substrate. This would prevent the pipeline from interfering with navigational use of the Sabine River.

The proposed pipeline route would then cross the southern third of Orange County, Texas and the Neches River, to the Sun Terminal. This portion of Texas is within the Southeast Texas Planning Region, which is an area of rapid urban growth. The pipeline would be routed about midway between the city of Orange and Bridge City, and would continue through agricultural lands, woodland, and marshes to its river-crossing at Nederland.

The populations of the Orange and West Orange county subdivisions declined by 9.1 percent and 13.6 percent, respectively, from 1960 to 1970, while the Bridge City -

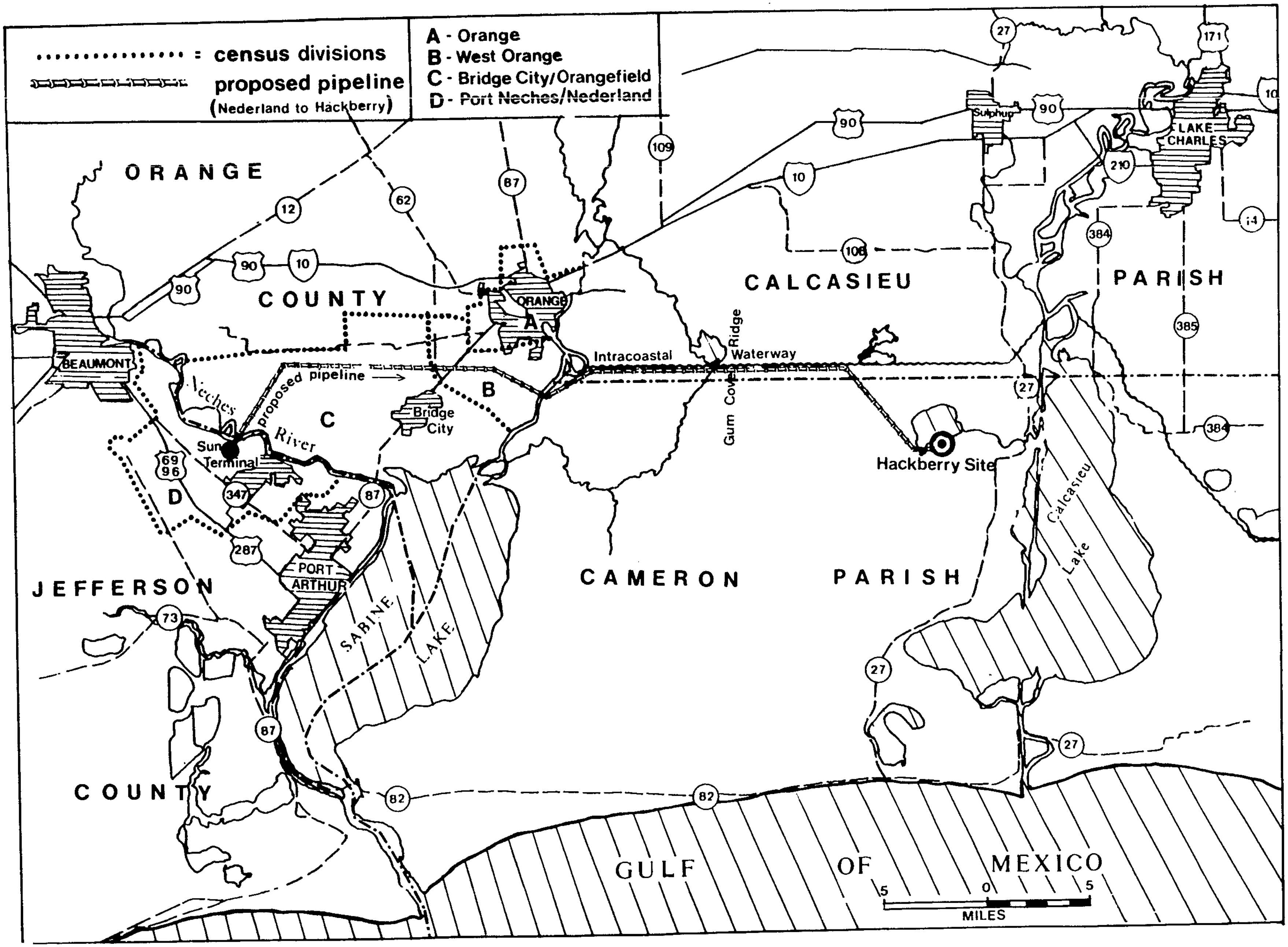

Figure 8.1 Pathway of the Proposed Pipeline

Orangefield subdivision grew by 59.9 percent. Population projections for these areas and for the Port Neches-Nederland subdivision at Jefferson County are shown in Table 8.1. The population of the southern third of Orange County is expected to increase at a slower rate than areas in the northern and western sections of the county, and to reach a nearly static population level at around the year 2000.

Urban expansion in the southern part of Orange County is limited by extensive wetland areas along the Neches River and Sabine Lake. A comparison of present land use in the proposed pipeline corridor with projected land use in 1990 indicates that the west bank of the Sabine River will be changed from open space and pasture to industrial use. The cropland belt between Orange and Bridge City on both sides of Highway 87 will be converted to residential and commercial use, and industrial development will occur on present marshlands along the southwestern bank of the Neches River on both sides of Nederland, and in an area immediately across the river from the Sun Terminal.[3]

Plans have been proposed to construct a new bridge across the Neches River in the Beaumont-Port Arthur area, but have not been sufficiently developed to permit construction in the near future.[4] It is likely that existing major highways would be extended across the river, in which case the bridge would probably be built between Beaumont and Nederland, northwest of the proposed pipeline corridor and dock facilities, or at Port Neches, in which case, the highway northeast of the river would cross the proposed pipeline.

<u>Land Use Plans</u>

The proposed pipeline rights-of-way in Cameron Parish do not lie within areas governed by zoning jurisdictions. Calcasieu Parish has authority to direct the pattern of development throughout the parish, in accordance with the Comprehensive Zoning Law of Calcasieu Parish enacted in 1962. Work is currently underway to complete the classification of properties in the parish, and efforts are directed primarily toward the regulation of development in areas adjacent to the major cities. The land which would be affected by the proposed pipeline is not classified, and is not a priority area for zoning classification.

In Orange and Jefferson Counties, the county governments do not have the authority to restrict development through zoning regulations. City zoning laws apply to areas within corporate city limits. The proposed pipeline

Table 8.1 POPULATION PROJECTIONS OF SELECTED COUNTY SUBDIVISIONS

	1960	1970	1980	1990	2000
Orange County					
Orange Division	26,891	24,457	32,000	35,500	37,500
Orange City	25,605	24,457	31,400	34,500	36,100
West Orange Division	7,656	6,614	7,100	7,950	8,500
Cove City*	1,749	1,611	1,800	2,200	2,500
West Orange City	4,848	4,820	5,050	5,500	5,600
Bridge City-Orangefield Division	6,292	10,060	12,100	16,000	19,500
Bridge City**	4,677	8,164	9,000	11,000	12,000
Jefferson County					
Port Neches-Nederland Division	24,582	33,086	34,600	37,150	40,600
Nederland City	12,036	16,810	17,500	18,500	19,100
Port Neches City	8,696	10,894	11,400	12,100	12,500

* Incorporated into City of Orange as of 1971.
** Unincorporated.

Source: U. S. Census of Population, 1970, and Southeast Texas Regional Planning Commission, Population Projections, November 1972.

right-of-way through eastern Texas would lie within the Orange city limits, but in the extraterritorial land outside of the area bounded by the corporate limits. Industries located in the extraterritorial area receive municipal services on a limited basis in return for payments which amount to a set percentage of the taxes that would be paid if they were within the corporate city limits.

The proposed right-of-way lies outside of the zoned areas of both Orange and Bridge City and is, therefore, not in conflict with existing land use regulations. The continued residential development in Bridge City will result in the extension of present city limits so that the pipeline would be inside its corporate boundaries within 15 years. At present there are pipeline rights-of-way through the city, and such corridors are subject to regulations governing their maintenance. These regulations require that the rights-of-way be properly drained and the vegetation moved, so that the right-of-way will not be a nuisance to the adjacent residential areas.

REFERENCES

[1]Imperial Calcasieu Regional Planning Commission, Future Land Use Plan for 1990, June, 1975.

[2]Louisiana State Parks and Recreation Commission, Outdoor Recreation Plan, June 1974.

[3]Southeast Texas Regional Planning Commission, maps, Land Use 1972, and Land Use 1990.

[4]Fred Hellen, personal communication, Southeast Texas Regional Planning Commission, December 1976.

9. CONSULTATION AND COORDINATION WITH OTHERS

In preparation of the amendment to the West Hackberry FES, numerous agencies, governmental units and groups were consulted for information and technical expertise pertaining to the proposed pipeline route. These are listed below:

Federal Agencies

Army Corps of Engineers, New Orleans
Army Corps of Engineers, Galveston
U.S. Fish and Wildlife Office
U.S. Department of the Interior, Rare and Endangered Species
U.S.D.A. Agricultural Experiment Station, Beaumont, Texas

State Agencies

Texas Forest Service, College Station
Southeast Texas Regional Planning Commission
Texas Historical Commission
Louisiana Archaeological Survey and Antiquities Commission
Louisiana Forestry Commission
Texas Parks and Wildlife Commission

Other

Sun Oil Company; Nederland Distribution Terminal
Colonial Pipeline Company; Beaumont, Texas
Sabine Audubon Society; Orange, Texas
Coastal Ecosystems Management, Inc.; Forth Worth, Texas
Pyburn and Odum; Baton Rouge, Louisiana
National Audubon Society; Washington, D.C.
Texas A & M; College Station, Bryan, Texas
University of Texas, Rare Plant Study Center

APPENDIX A

WEST HACKBERRY

Atmospheric Dispersion Model

The pollutants associated with the proposed project which impact ambient air quality are treated as continuous emissions over periods of hours to a year. A two dimensional Gaussian 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]

The basic averaging time considered in the model is 10 minutes. The averaging time is extended to one hour with confidence and to 24 hours with degraded accuracy. Annual averages are computed using sector averaging and annual wind distributions by Pasquill stability class.[4,5] "Worst case" results apply to concentration averages over periods up to 24 hours. The variation in annual averages is sufficiently small that worst case results would not be appreciably different.

The 10-minute average downwind concentration is calculated according to:

$$\chi\ (x,y,z=o,H) = \frac{10^6 Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{Y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \quad (1)$$

where:

- χ = concentration ($\mu gm/m^3$) at downwind distance, x(m), and crosswind distance, Y(m), at ground level (z=0)
- Q = source emission rate (gm/sec)
- σ_y = horizontal dispersion coefficient (m)
- σ_z = vertical dispersion coefficient (m)
- u = average wind velocity (m/sec)
- H = effective stack height (m)

The values of σ_y and σ_z are taken from reference 1. An effective release height of 20 meters is used for the emissions from the surge tanks at the Sun Terminal. The worst case atmospheric stabilities for such a release are a function of distance from the source[1]. The calculated worst case concentrations given in the upper part of Table A1 are for E stability for a downwind distance of .5 km and F stability for the other distances. All other emissions are treated as ground level releases. Stability class F is appropriate for worst case calculations for ground level releases. A wind speed of 1 m/sec is used for all worst case calculations. In addition the base of a stable layer is assumed to exist at 100 meters altitude to hold the emissions close to the ground. This factor increases calculated concentrations for downwind distances greater that 5 km for D stability; there is no appreicable increase for F stability[1]. Estimates of downwind concentration for sampling times greater than 10 minutes but not more than 24 hours can be made according to the equation

$$\chi_t = \chi_{10}\left(\frac{10}{t}\right)^{.17} \qquad (2)$$

where t is the sampling time in minutes and χ_{10} is calculated according to equation (1). Equation (2) may be applied only when the average wind direction is constant.

The worst case downwind concentrations at various distances for a unit source are given in Table A1. Similar data for a more typical set of meteorological conditions are given in Table A2. Stability class D (neutral stability) and a mean wind speed for that class were chosen for the calculation of typical downwind concentrations; these conditions were observed to occur 26 percent of the time at Port Arthur[5] and 41 percent of the time at Lake Charles .

A measure of the lateral extent of the plume is obtained by setting the exponential term involving the crosswind distance, y, in Equation (1) equal to 1/10 and solving for y;

$$y_{10} = 2.146\ \sigma_y \tag{3}$$

where y_{10} is the lateral distance in meters from the centerline to the location where the concentration is reduced to 1/10 the centerline concentration.

Table A3 contains values of y_{10} applicable to calculated worst case concentrations (Table A1) and typical concentrations (Table A2).

Annual average concentration independent of direction from the source was calculated for D stability according to:

$$\chi_a = \frac{2.03 \times 10^6 Q}{\sigma_z x} \sum_i f_i/u_i \tag{3}$$

where χ_a = annual average concentration ($\mu gm/m^3$)

u_i = wind speed (m/sec) for the i^{th} group chosen as the mid-value of the wind speed interval

f_i = percent occurrence of the i^{th} wind speed group for D stability.

Values for u_i and f_i for D stability obtained from the "Star" summaries for Lake Charles[4] and Port Arthur[5] are given in Table A4. Annual average concentrations ($\mu gm/m^3$) for a 1 gm/sec emission rate are listed in Table A5 for several distances. The differences indicated between West Hackberry and Sun Terminal reflect differences in the distribution of wind speed for stability class D at Lake Charles and Port Arthur.

Table A1: Worst Case Downwind Concentrations From a Continuous 1 gm/sec Source

Elevated Release, H = 20m, u = 1 m/sec
E Stability at .5 km
F Stability at other distances

χ ($\mu gm/m^3$)

SAMPLING TIME

x(km)	10 min.	30 min.	1 hr.	3 hr.	8 hr.	24 hr.
0.5	270	224	199	165	140	116
1	245	203	181	150	127	105
2	150	125	111	92	78	64
5	53	45	39	32	27	23
10	24	20	18	15	12	10

Ground Level Release, H = 0
F Stability, u = 1 m/sec

χ ($\mu gm/m^3$)

SAMPLING TIME

x(km)	10 min.	30 min.	1 hr.	3. hr.	8 hr.	24 hr.
0.5	2130	1768	1570	1303	1103	915
1	690	570	509	422	357	296
2	240	199	177	147	124	103
5	62	51	46	38	32	27
10	25	21	18	15	13	11

Table A2: Typical Downwind Concentrations From a Continuous 1 gm/sec Source

WEST HACKBERRY

D stability, u = 5.096 m/sec*, H - 20 m

χ ($\mu gm/m^3$)

SAMPLING TIME

x(km)	10 min.	30 min.	1 hr.	3 hr.	8 hr.	24 hr.
0.5	51	42	37	31	26	23
1	24	20	18	15	12	11
2	9.0	7.5	6.7	5.5	4.7	3.9
5	2.7	2.3	2.1	1.7	1.5	1.2
10	1.5	1.2	1.1	.90	.77	.65

*Mean Wind Speed for D Stability Based on Lake Charles "Star" Data[4]

SUN TERMINAL

D stability, u = 6.177 m/sec**, H = 20 m

χ ($\mu gm/m^3$)

SAMPLING TIME

x(km)	10 min.	30 min.	1 hr.	3 hr.	8 hr.	24 hr.
0.5	42	35	31	26	22	19
1	19	16	15	12	9.7	8.9
2	7.4	6.1	5.5	4.5	3.9	3.2
5	2.3	1.9	1.7	1.4	1.2	.97
10	1.2	1.0	.89	.74	.63	.53

**Mean Wind Speed for D Stability Based on Port Arthur "Star" Data[5]

Table A3: Crosswind Distance, y_{10}, to Reduce Concentrations of Tables A1 and A2 by a Factor of 10

x (km)	y_{10} (km)	
	Table A1 $H^{*} = 20m$	Table A2
0.5	.056	.076
1.0	.072	.146
2.0	.137	.279
5.0	.318	.643
10.	.586	1.18

* y_{10} = .038 for H = 0; all other values of y_{10} for H = 0 are the same as those listed for H = 20m

Table A4 Mean wind speed and relative frequency of occurrence (f_i) of wind speed groups for D stability at Lake Charles and Port Arthur

Wind Speed Group (knots)	u_i (m/sec)	f_i (dimensionless) Lake Charles	Port Arthur
0-3	.77	.011508	.00251
4-6	2.57	.063634	.024315
7-10	4.38	.162203	.065525
11-16	6.95	.153572	.124315
17-21	9.78	.016439	.033333
>21	11.33*	.001438	.004566
Total D Stability		.408	.255
Mean Wind Speed (knots) for D Stability		9.9	12.2

*u_i for this group selected to be 22 knots (11.33 m/sec) otherwise u_i is the mid-point of the group interval

Table A5: Annual Sector-Averaged Concentrations for a 1 gm/sec Source, D Stability

Downwind Distance x(km)	Concentration χ_a ($\mu gm/m^3$)	
	West Hackberry*	Sun Terminal**
0.5	22.7	11.1
1.	6.59	3.23
2.	2.04	1.00
5.	.459	.225
10.	.151	.0743

*Based on Lake Charles "Star" Data[4]

**Based on Port Arthur (Jefferson Co. Airport) "Star" Data[5]

REFERENCES

1. Workbook of Atmospheric Dispersion Estimates, U. S. Environmental Protection Agency, 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, 2 4, 1961.

4. Wind Distribution of Pasquill Stability Classes. Star Program, Lake Charles, Louisiana (Station 13941), 1966 1970, Environmental Data Service, National Climatic Center, Asheville, North Carolina.

5. Wind Distribution by Pasquill Stability Classes, Star Program, Port Arthur Texas (Station 12917), 1964, Environmental Data Service, National Climatic Center, Asheville, North Carolina.

APPENDIX B

AIR POLLUTION MONITORING DATA

The following data were provided by the Louisiana Air Control Commission (LACC) and the Texas Air Control Board (TACB). The data represent the most thorough and consistent monitoring results these organizations have compiled to date. Statistical summaries of the air pollution monitoring data are presented in Tables B-1 through B-11; an index to the tables is given below.

Source	Data	Location	Table
LACC	Suspended Particulates (1975)	Lake Charles, LA	B-1
"	Suspended Particulates (1975)	Lake Charles, LA	B-2
"	Suspended Particulates (1975)	Lake Charles, LA	B-3
"	Continuous Oxidant (1975)	Lake Charles, LA	B-4
"	Continuous Sulfur Dioxide (1975)	Lake Charles, LA	B-5
TACB	Suspended Particulates (1974-75)	Nederland, TX	B-6
"	Continuous Sulfur Dioxide (1974-75)	Nederland, TX	B-7
"	Continuous Carbon Monoxide (1974-75)	Nederland, TX	B-8
"	Continuous Ozone (1974-75)	Nederland, TX	B-9
"	Non-Methane Hydro-Carbons (1974-75)	Nederland, TX	B-10
"	Nitrogen Dioxide (1974-75)	Nederland, TX	B-11

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/m³ SAMPLING TYPE:

2° Standard 24-hr. max = 150 μg/m³, Annual Geometric mean = 60 μg/m³

NUMBER OF SAMPLES: 56

ANNUAL GEOMETRIC MEAN: 43

MONTH	DAY	24 HR. MEASURE μg/m³	MONTH	DAY	24 HR. MEASURE μg/m³
Jan	6	33	July	5	47
	12	22		11	51
	30	24		17	44
Feb.	5	31		23	32
	23	31		29	44
Mar.	1	38	Aug.	4	35
	7	79		10	27
	13	54		16	33
	19	60		22	37
	25	121		28	43
	31	40	Sep.	3	85
Apr.	6	50		9	40
	12	38		15	70
	18	68		21	49
	24	45		27	68
	30	28	Oct.	3	88
May	6	45		9	48
	12	42		15	29
	18	67		21	52
	24	41		27	38
	30	18	Nov.	2	41
June	5	49		8	30
	11	37		14	83
	17	33		20	27
	23	77		26	42
	29	40	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° Standard 24-hr. max. = 260 μg/m^3 — SAMPLING TYPE: Population Oriented

2° Standard 24-hr. max = 150 μg/m^3, Annual Geometric mean = 60 μg/m^3

NUMBER OF SAMPLES: 57

ANNUAL GEOMETRIC MEAN: 68

MONTH	DAY	24 HR. MEASURE μg/m^3	MONTH	DAY	24 HR. MEASURE μg/m^3
Jan.	6	99	July	5	46
	12	40		11	68
	24	98		17	64
	30	74		23	45
				29	54
Feb.	5	57			
	17	70	Aug.	4	48
	23	39		10	37
				16	51
Mar.	1	101		22	55
	7	86		28	99
	13	52			
	19	79	Sept.	3	85
	25	165		9	60
	31	81		15	83
				21	60
Apr.	6	68		27	79
	12	100			
	18	154	Oct.	3	64
	24	215		9	51
	30	73		15	29
				21	96
May	6	113		27	59
	12	74			
	18	93	Nov.	2	59
	24	126		8	50
	30	76		14	79
				20	39
June	11	81		26	39
	17	129			
	23	53	Dec.	2	96
	29	40		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/m^3

SAMPLING TYPE: Population Oriented

2° Standard 24-hr. max = 150 μg/m^3, Annual Geometric mean = 60 μg/m^3

NUMBER OF SAMPLES: 55

ANNUAL GEOMETRIC MEAN: 57

MONTH	DAY	24 HR. MEASURE μg/m^3	MONTH	DAY	24 HR. MEASURE μg/m^3
Jan.	6	56	July	5	115
	12	27		11	93
	24	51		17	96
	30	48		23	57
				29	64
Feb.	5	17	Aug.	4	57
	17	42		10	56
	23	35		16	88
Mar.	1	103		22	47
	7	89	Sep.	15	66
	13	44		21	39
	19	55		27	76
	25	146	Oct.	3	63
	31	51		9	50
Apr.	6	63		15	29
	12	50		21	99
	18	102		27	52
	24	75	Nov.	2	47
	30	41		8	36
May	6	97		14	76
	12	55		20	25
	18	96		26	34
	24	43	Dec.	2	53
	30	45		8	31
June	5	122		14	43
	11	71		20	63
	17	125		26	38
	23	52			
	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^o and 2^o 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^{o} Standard: 24-hr. max. = 0.14 ppm, Annual Geometric Mean = 0.03 ppm

2^{o} 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

Table B-6 Texas Air Control Board Particulate Data

Location: Nederland, Texas Location Code: 453830003

Federal Standards ($\mu g/m^3$) for Total Suspended Particulates (TSP)

	Primary	Secondary
Annual Geometric Mean	75	60
24-hour Maximum	260	150

24-hour Samples	1974* 23 Jan-31 Dec	1975 6 Jan-26 Dec
Number of Samples	34	40
Maximum	117	133
Second Maximum	117	129
Geometric Mean	53	56

*Due to the nature of the sample distribution, these data may be seasonally biased.

Table B-7. Texas Air Control Board
Continuous Monitoring Data - Sulfur Dioxide (SO_2)

City: Nederland, Texas   Location Code: 3830003

Federal Standards: 1° standard: 24-hour max = 0.14 ppm
2° standard: 24-hour max = 0.10 ppm
3-hour max = 0.5 ppm

Concentrations reported in ppm

24-hour Averages	1974 1 Jan-31 Dec	1975 1 Jan-31 Dec
Arithmetic Mean	.00	.01
σ	.00	.00
% hours >0.10 ppm	.00	.00
% hours >0.14 ppm	.00	.00
Highest Average	.01	.01
2nd Highest	.01	.01
Total # of Averages	149	238
3-hour Running Averages		
Arithmetic Mean	.00	.00
σ	.00	.00
Highest Average	.04	.11
Date	28 Feb	7 Jan
2nd Highest	.04	.09
Date	28 Feb	7 Jan
Total # of Averages	4008	5734
1-hour Average		
Highest Average	.05	.18
Date	28 Feb	7 Jan
2nd Highest	.05	.15
Date	30 Dec	5 Dec
Total # of Hours	4248	5995

Table B-8. Texas Air Control Board
Continuous Monitoring Data - Carbon Monoxide (CO)

City: Nederland, Texas   Location Code: 3830003

Federal Standards: 1^{o} & 2^{o}: 8-hr. max. = 9 ppm, 1-hr. max. = 35 ppm

Concentrations reported in ppm.

8-hour Running Averages	1974 1 Jan-31 Dec	1975 1 Jan-31 Dec
Arithmetic Mean	.4	.2
σ (standard dev.)	.3	.2
Highest Average	3.8	1.4
Date	28 Jan	4 Jan
2nd Highest Average	3.5	1.4
Date	28 Jan	4 Jan
50% hours. ≤	.4	.1
70% hrs. ≤	.4	.2
90% hrs. ≤	.6	.4
Total # of Averages	4989	6416

1-hour Averages		
Arithmetic Mean	.4	
σ	.3	
Highest Average	5.2	3.7
Date	28 Jan	20 Oct
2nd Highest Average	4.5	3.1
Date	28 Jan	10 Dec
% hours ≥ 35 ppm	0	0
50% hrs. ≤	.4	.1
70% hrs. ≤	.5	.2
90% hrs ≤	.7	.5
Total # of Averages	4966	6382

Table B-9. Texas Air Control Board
Continuous Monitoring Data - Ozone

City: Nederland, Texas   Location Code: 3830003

Federal Standards: 1^{o} & 2^{o}: 1-hr. maximum = 0.08 ppm

Concentrations reported in ppm

1-hour Averages	1974 1 Jan-10 Dec	1975 8 Jan-31 Dec
Arithmetic Mean	.028	.028
σ	.022	.023
Highest 1-hr. Average	.174	.194
Date	27 Mar	21 Jul
2nd Highest Average	.159	.177
Date	27 Mar	8 Aug
% hrs. >0.08 ppm	2.7	3.4
50 % time < than	.025	.024
70 % time < than	.035	.028
90 % time < than	.058	.056
Total # of Hours	4300	7377

Table B-10. Texas Air Control Board
Continuous Monitoring Data - Non-Methane Hydrocarbons

City: Nederland, Texas Location Code: 3830003

Federal Standards: 1^o & 2^o: 3-hr. max. = 0.24 ppm
Concentrations reported in ppm

6-9 a.m. Measurements	1974 1 Jan-31 Dec	1975 1 Jan-31 Dec
Arithmetic Mean	.7	.6
σ	.9	.5
Highest Average	5.5	3.5
Date	6 Aug	8 Aug
2nd Highest Average	4.4	3.1
Date	29 July	21 Oct
% hrs. >0.24 ppm	71.3	68.0
50% time < than	.4	.4
70% time < than	.6	.7
90% time < than	2.0	1.3
Total # of Averages	150	284

1-hour Averages		
Arithmetic Mean	.7	.4
σ	.9	.5
Highest Average	9.6	6.8
Date	15 Aug	9 Jan
2nd Highest Average	7.4	5.4
Date	1 Aug	9 Jan
50% time < than	.4	.4
70% time < than	.7	.7
90% time < than	1.7	1.3
Total # of Hours	3614	6686

Table B-11. Texas Air Control Board
Continuous Monitoring Data - Nitrogen Dioxide

City: Nederland, Texas Location Code: 3830003

Federal Standards: 1° & 2°: Annual Arithmetic Mean = 0.05 ppm

Concentrations reported in ppm

24 Hour Running Averages	1974 4 Jan-31 Dec	1975 10 May-31 Dec
Arithmetic Mean	.01	.01
σ (standard dev.)	.01	.01
Highest Average	.06	.04
Date	5 Jan	16 Jan
2nd Highest Average	.05	.03
Date	13 Dec	24 Jan
50% hours ≤	.01	.00
70% hours ≤	.01	.01
90% hours ≤	.03	.02
Total # of Averages	255	219

1-Hour Averages		
Arithmetic Mean	.01	.01
σ	.02	.01
Highest Average	.16	.11
Date	30 Jan	6 Jan
2nd Highest Average	.15	.10
Date	5 Jan	20 Oct
% Hours ≥ 35 ppm	.00	.00
70% hours ≤	.01	.01
90% hours ≤	.03	.03
Total # of Averages	6406	5644

APPENDIX C

HYDROLOGIC DATA

This appendix consists of three parts. The first, C.1, contains applicable water and sediment quality standards and criteria. The second, C.2, contains volumetric flow data and the third, C.3, contains water and sediment quality data.

C.1 WATER AND SEDIMENT QUALITY STANDARDS AND CRITERIA

The site specific data for water quality standards* for the states of Louisiana and Texas for the pertinent bodies of water are in Tables C.1 and C.2, respectively. These standards specify how the water of a bayou, canal, or river may be used, and also upper and/or lower limits for certain water quality parameters. It is important to note that these state standards represent enforceable regulations.

In addition to specific water criteria set forth by the state, there exists certain numerical criteria proposed by EPA in 1973 for water quality in general. Table C.3 provides the criteria for marine constituents (aquatic life). Table C.4 provides recommended concentration criteria of selected sediment parameters. It is important to note that these federal water quality criteria and recommended sediment quality criteria contained in Tables C.3 and C.4 do not represent enforceable regulations.

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*For purposes of organization and clarity in this document, any enforceable state water quality regulation will be referred to as a "standard." In Louisiana such "standards" are called both "criteria" and "standards." In the document, however, the term "criteria" will be reserved for water quality limits or guidelines which are recommended, but not enforceable in the legal sense.

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 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 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 than 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)

$$\frac{(0.1\ C_e + 0.9\ C_w)}{C_w} \leq 1.5$$ (Based on 40 CFR 230, 40 FR 19794)

where C_e = Concentration from the standard elutriate test (dissolved) and 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 C.1, C.2, and C.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 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 is available but not elutriate data, the need arises for comparing the sediment quality data with some limit. Table C.4 provides certain recommended criteria for various sediment quality parameters and can be used for such a comparison. The data in Table C.4 are, however, not official and thus serve only as guidelines.

Table C.1 Water Quality Standards for Louisiana

SEGMENT: AGENCY I.D. NUMBER	SEGMENT: DESCRIPTION	WATER USES: PRIMARY CONTACT RECREATION	WATER USES: SECONDARY CONTACT RECREATION	WATER USES: PROPAGATION OF FISH AND WILDLIFE	WATER USES: DOMESTIC RAW WATER SUPPLY	CRITERIA: CHLORIDE (mg/l) Not to exceed	CRITERIA: SULPHATE (mg/l) Not to exceed	CRITERIA: DISSOLVED OXYGEN (mg/l) Not less than	CRITERIA: pH RANGE	CRITERIA: Bacteria Standard	CRITERIA: TEMPERATURE °C	CRITERIA: TOTAL DISSOLVED SOLIDS (mg/l) Not to exceed
100070	Sabine River - Morgan's Bluff to Sabine Lake (Tidal)	X	X	X		--	--	4.0	6.0 to 8.5	1	35*	--
100090	Black Bayou - Intracoastal Waterway to Sabine Lake (Tidal)		X	X		--	--	4.0	6.0 to 8.5	2	35*	--
100100	Vinton Waterway - Vinton to Intracoastal Watarway (Tidal)		X	X		--	--	4.0	6.0 to 8.5	2	35*	--
030160	Intracoastal Waterway (East - West) - Sabine River to Calcasieu Lock (Tidal)		X	X		--	--	4.0	6.0 to 8.5	2	35*	--

*Louisiana Stream Control Commission (1973)

Table C.2 Texas Water Quality Standard Fresh and Tidal Waters

SEGMENT NUMBER	SEGMENT DESCRIPTION	WATER USES DEEMED DESIRABLE: CONTACT RECREATION	WATER USES DEEMED DESIRABLE: NONCONTACT RECREATION	WATER USES DEEMED DESIRABLE: PROPAGATION OF FISH & WILDLIFE	WATER USES DEEMED DESIRABLE: DOMESTIC RAW WATER SUPPLY	CRITERIA: CHLORIDE (mg/l) avg. not to exceed	CRITERIA: SULFATE (mg/l) avg. not to exceed	CRITERIA: TOTAL DISSOLVED SOLIDS (mg/l) avg. not to exceed	CRITERIA: DISSOLVED OXYGEN (mg/l) not less than	CRITERIA: pH RANGE	CRITERIA: COLIFORM: FECAL/(100ml) - log. avg. not more than (see Gen. Statement)	CRITERIA: TEMPERATURE °F (°C)
0501	Sabine River Tidal	X	X	X					4.0	6.0-8.5	200	95(35)
0601	Neches River Tidal		X	X					2.5*	6.0-8.5	2,000	95(35)

*Texas Water Quality Board (1976)

Table C.3 Proposed EPA Numerical Criteria for Water Quality Marine Water Constituents (Aquatic Life)*

Parameter	µg/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 and 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

*U.S. Environmental Protection Agency (1973). Proposed Criteria for Water Quality, Vol. I.

Table C.4 Classification of Polluted and Unpolluted Sediments*

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]				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.

* The classification of polluted and unpolluted sediments presented is based on the combination of quality parameter values for a given sample.

C.2 VOLUMETRIC FLOW DATA

This appendix contains three tables containing data for volumetric flow of the Sabine River, Cow Bayou, and Neches River. Table C.5 presents data for the average discharge rate for the Sabine River near Ruliff, Texas from October 1974 to September 1975 on a daily basis. The monthly, mean maximum and minimum, are also given. Table C.6 contains discharge rates for Cow Bayou near Mauriceville, Texas from October 1974 through September 1975. Monthly means, maximum and minimum, are given for that time period. Table C.7 has discharge rates for the Neches River near Evadale, Texas from October 1974 through September 1975 on a daily basis. The monthly mean, maximum and minimum, are also given.

Table C.5 Discharge Rates for the Sabine River at Ru liff, Texas - October 1974 through September 1975*

SABINE RIVER BASIN

0803050O Sabine River near Ruliff, Tex.
(Radiochemical and national stream-quality accounting network)

LOCATION.--Lat 30°18'13", long 93°44'37", Calcasieu Parish, La.-Newton County, Tex. State line, at downstream side of bridge on Texas State Highway 12, 2.4 miles (3.9 km) north of Ruliff, 4.2 miles (6.8 km) upstream from the Kansas City Southern Railway Co. bridge, 4.5 miles (7.2 km) downstream from Cypress Creek, and at mile 40.2 (64.7 km).

DRAINAGE AREA.--9,329 mi² (24,162 km²).

PERIOD OF RECORD.--Discharge: October 1924 to current year.
Water quality: Chemical analyses: October 1945 to September 1946, October 1947 to current year. Chemical and biochemical analyses: October 1967 to current year. Pesticide analyses: January 1968 to current year. Water temperatures: October 1947 to current year.

GAGE.--Water-stage recorder. Datum of gage is 4.08 ft (1.244 m) above mean sea level. Prior to Mar. 1, 1941, nonrecording gage at Kansas City Southern Railway Co. bridge, 4.2 miles (6.8 km) downstream and at datum 2.02 ft (0.616 m) lower. Mar. 1, 1941, to Dec. 8, 1948, nonrecording gage at present site and datum.

AVERAGE DISCHARGE.--42 years (1924-66) prior to completion of Toledo Bend Reservoir, 8,422 ft³/s (238.5 m³/s), 6,102,000 acre-ft/yr (7.52 km³/yr); 9 years (1966-75) regulated, 7,969 ft³/s (225.7 m³/s), 5,774,000 acre-ft/yr (7.12 km³/yr).

EXTREMES.--Discharge: Current year: Maximum discharge, 40,700 ft³/s (1,150 m³/s) May 14 (gage height, 15.33 ft or 4.673 m); minimum daily, 774 ft³/s (21.9 m³/s) Oct. 14.
Period of record: Maximum discharge, 121,000 ft³/s (3,430 m³/s) May 22, 1953 (gage height, 19.38 ft or 6.090 m); minimum, 270 ft³/s (7.65 m³/s) Sept. 27-30, Oct. 1-3, 17-20, 1956.
Historic: Maximum stage since at least 1835, 22.2 ft (6.77 m) in May or June 1884 (adjusted to present site and datum on basis of slope of flood of June 8, 9, 1950); flood of Apr. 26-29, 1913, reached a stage of 19.5 ft (5.94 m), present site and datum, from information by local resident.
Water quality: Current year: Maximum daily specific conductance, 165 micromhos Jan. 31, Feb. 17; minimum daily, 63 micromhos Aug. 9. Maximum water temperatures, 31.0°C July 24; minimum, 9.0°C Jan. 13-16.
Period of record: Maximum daily specific conductance, 779 micromhos Aug. 31, 1966; minimum daily, 29 micromhos Sept. 19, 1963. Maximum water temperatures, 36.0°C Aug. 14, 1962; minimum, 1.0°C Jan. 28, 1948.

REMARKS.--Discharge records fair. Flow is partly regulated by Toledo Bend Reservoir (station 08025350) 116.3 miles (187.1 km) upstream.

REVISIONS (WATER YEARS).--WSP 1282: 1941(M), 1942. WSP 1442: 1925-29, 1937-39, 1943. WSP 1732: Drainage area.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	3,450	1,600	14,600	32,100	17,500	25,200	17,100	9,520	24,200	12,400	7,260	7,060
2	2,550	3,210	13,600	30,800	17,200	24,100	17,100	11,500	25,700	12,800	9,910	5,380
3	2,740	2,910	12,700	29,800	17,000	23,500	17,100	14,400	24,100	13,000	10,600	4,130
4	1,940	3,020	12,700	27,400	16,900	22,600	17,100	16,000	21,400	13,400	11,000	5,160
5	1,310	3,070	13,300	26,200	16,900	21,600	17,100	16,300	18,300	13,800	11,100	6,430
6	1,190	2,610	14,300	26,200	17,800	20,200	16,900	16,200	16,700	14,400	9,670	7,130
7	1,000	2,290	15,100	29,100	14,500	19,200	16,600	18,000	15,500	14,400	8,580	7,350
8	926	2,120	15,400	31,400	21,500	18,500	17,600	24,700	14,400	14,000	9,070	7,180
9	883	2,160	17,200	29,100	22,200	18,400	18,200	33,000	14,600	[illegible]300	9,640	5,370
10	850	2,260	19,200	28,000	21,500	18,200	17,900	34,400	13,400	12,400	9,380	4,000
11	822	2,400	20,500	27,200	20,500	17,300	17,400	36,100	10,300	11,000	8,700	5,030
12	807	2,700	19,600	25,800	19,500	17,600	17,900	38,000	11,400	9,740	7,930	5,440
13	792	3,440	18,300	25,000	18,900	17,400	18,400	39,300	14,400	9,300	6,690	6,370
14	774	1,740	17,500	26,700	18,600	17,500	18,400	40,600	18,600	9,300	6,710	6,550
15	786	3,150	17,800	25,700	18,700	18,530	18,200	39,500	20,700	8,400	7,260	6,280
16	816	2,590	17,700	23,400	19,000	19,600	16,900	35,300	19,700	6,800	7,470	4,320
17	1,230	2,120	17,700	22,200	19,000	22,100	15,900	28,600	18,500	6,480	7,650	3,440
18	1,620	2,010	17,900	20,800	19,100	22,600	14,800	22,900	17,400	6,730	7,830	5,380
19	1,400	2,220	20,400	20,100	21,500	22,600	13,800	19,400	16,200	6,860	7,750	6,950
20	1,130	4,410	24,400	19,700	26,800	22,900	12,500	18,400	14,500	6,860	6,850	7,950
21	1,050	7,360	26,500	20,200	33,400	24,700	11,600	17,400	12,900	6,380	6,740	8,160
22	909	9,760	25,400	20,300	37,300	25,500	11,200	16,100	11,400	4,600	7,190	7,620
23	864	11,900	24,900	20,300	38,400	24,400	11,200	13,900	11,000	3,910	7,750	5,190
24	822	14,100	24,900	19,700	36,000	22,100	12,100	11,200	10,600	5,570	7,860	2,860
25	798	15,500	24,700	19,000	35,900	20,300	13,300	9,940	10,400	7,200	7,320	2,780
26	813	15,400	24,400	18,500	32,800	19,200	13,700	9,760	10,600	8,490	6,840	4,460
27	920	14,200	24,200	17,800	29,400	18,600	13,200	10,200	11,200	9,210	5,610	5,420
28	895	14,200	26,200	17,800	25,700	18,000	11,900	11,700	11,600	9,080	5,810	5,870
29	920	15,000	29,600	17,800	------	17,800	9,000	14,800	11,700	7,310	5,710	5,680
30	1,160	15,600	32,500	17,600	------	17,500	7,820	18,000	12,200	5,590	7,280	3,810
31	2,920	------	33,400	17,400	------	17,200	------	21,000	------	6,240	7,270	------
TOTAL	38,942	188,890	637,400	734,100	661,700	635,400	452,320	666,920	463,600	288,970	247,450	169,170
MEAN	1,256	6,296	20,560	23,680	23,630	20,500	15,080	21,510	15,450	9,322	7,982	5,639
MAX	3,450	15,600	33,400	32,100	38,400	25,500	18,400	40,600	25,700	14,400	11,100	8,160
MIN	774	2,010	12,700	17,400	16,900	17,200	7,820	9,520	10,300	3,910	5,610	2,780
AC-FT	77,240	374,700	1,264M	1,456M	1,312M	1,260M	897,200	1,323M	919,600	573,200	490,800	335,500

CAL YR 1974 TOTAL 4,268,862 MEAN 11,700 MAX 84,000 MIN 774 AC-FT 8,467,000
WTR YR 1975 TOTAL 5,184,862 MEAN 14,210 MAX 40,600 MIN 774 AC-FT 10,280,000

*Water Resource Data for Texas Water Year 1975, Volume 1, Arkansas River Basin, Red River Basin, Sabine River Basin, Neches River Basin, Trinity River Basin and Intervening Coastal Basins, U.S. Geological Survey Water-Data, Report TX-75-1.

Table C.6 Discharge Rates for Cow Bayou Near Mauriceville, Texas - October 1974 through September 1975*

SABINE RIVER BASIN

08031000 Cow Bayou near Mauriceville, Tex.

LOCATION.--Lat 30°11'10", long 93°54'30", Orange County, near center of span at downstream side of bridge on State Highway 12, 0.4 mile (0.6 km) upstream from Kansas City Southern Railway Co. bridge, and 2.7 miles (4.3 km) southwest of Mauriceville.

DRAINAGE AREA.--83.3 mi² (215.7 km²).

PERIOD OF RECORD.--March 1952 to current year (October 1956 to September 1957, monthly discharge only).

GAGE.--Water-stage recorder. Datum of gage is 4.73 ft (1.442 m) above mean sea level. Prior to Oct. 23, 1957, nonrecording gage at same site and datum.

AVERAGE DISCHARGE.--23 years, 96.6 ft³/s (2.736 m³/s), 15.75 in/yr (400 mm/yr), 69,990 acre-ft/yr (86.3 hm³/yr).

EXTREMES.--Current year: Maximum discharge, 2,060 ft³/s (58.3 m³/s) June 10 (gage height, 15.77 ft or 4.807 m); minimum, 0.05 ft³/s (0.001 m³/s) Oct. 18-22.
Period of record: Maximum discharge, 4,600 ft³/s (130 m³/s) Sept. 19, 1963 (gage height, 18.15 ft or 5.532 m); no flow at times. Maximum stage since at least 1940, 18.16 ft (5.535 m) Oct. 28, 1970.

REMARKS.--Records fair. No large diversion above station. Base flow is partly sustained by springs.

REVISIONS.--WSP 1732: Drainage area.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.08	2.3	38	406	17	11	7.7	481	999	200	100	31
2	.08	2.1	28	319	22	9.2	6.6	391	1,040	250	153	20
3	.08	1.4	21	281	34	7.9	5.6	434	980	300	245	13
4	.10	48	15	227	263	30	4.8	446	822	320	451	37
5	.11	63	12	170	249	43	3.8	394	525	300	643	228
6	.11	25	16	128	212	35	3.1	303	282	250	649	375
7	.11	11	23	468	188	38	2.5	214	152	150	469	392
8	.11	22	20	883	161	40	99	275	62	70	461	408
9	.11	15	21	830	131	37	243	226	719	40	445	404
10	.09	12	26	870	102	35	297	184	2,020	25	316	348
11	.06	25	43	937	77	32	422	205	1,780	15	269	263
12	.06	17	49	942	60	27	353	242	1,420	10	227	173
13	.07	16	47	894	45	34	260	226	1,120	8.0	165	92
14	.06	15	53	772	35	53	550	194	869	12	83	54
15	.17	10	221	586	26	73	659	156	551	25	45	30
16	.09	6.7	147	413	47	93	625	127	283	35	32	20
17	.06	74	122	297	106	95	610	99	141	31	29	26
18	.05	53	129	353	87	116	545	86	43	17	17	23
19	.05	47	145	269	74	124	415	103	15	10	10	17
20	.05	111	134	143	51	136	291	112	13	8.6	7.0	13
21	.05	102	111	96	36	144	205	97	28	7.5	5.7	9.9
22	.05	98	85	71	27	143	152	63	25	7.2	5.3	8.0
23	.06	119	65	53	25	126	108	36	28	39	5.9	6.7
24	.06	137	53	57	21	93	83	19	79	125	18	5.1
25	.06	143	82	76	17	63	61	13	73	178	30	3.6
26	.06	115	310	56	14	42	39	8.9	145	184	60	2.7
27	.06	91	484	43	12	28	23	5.9	154	152	104	1.8
28	.33	79	504	33	12	20	15	148	137	147	102	1.3
29	2.2	65	531	27	------	15	12	750	120	143	75	.86
30	1.5	51	523	22	------	12	249	848	150	110	58	.59
31	1.1	------	484	18	------	9.6	------	933	------	92	46	------
TOTAL	7.23	1,576.5	4,547	10,740	2,150	1,764.7	6,350.1	7,809.8	14,775	3,261.3	5,325.9	3,007.55
MEAN	.23	52.6	147	346	76.8	56.9	212	252	493	105	172	100
MAX	2.2	143	531	942	260	144	659	933	2,020	320	649	408
MIN	.05	1.4	12	18	12	7.9	2.5	5.9	13	7.2	5.3	.59
CFSM	.003	.63	1.76	4.15	.92	.68	2.55	3.03	5.92	1.26	2.06	1.20
IN.	.003	.70	2.03	4.80	.96	.79	2.84	3.49	6.60	1.46	2.38	1.34
AC-FT	14	3,130	9,020	21,300	4,260	3,500	12,600	15,490	29,310	6,470	10,560	5,970

CAL YR 1974 TOTAL 29,774.55 MEAN 81.6 MAX 1,240 MIN .05 CFSM .98 IN 13.30 AC-FT 59,060
WTR YR 1975 TOTAL 61,315.08 MEAN 168 MAX 2,020 MIN .05 CFSM 2.02 IN 27.38 AC-FT 121,600

PEAK DISCHARGE (BASE, 300 FT³/S)

DATE	TIME	G.HT.	DISCHARGE
1-12	1300	12.13	946
6- 2	0900	12.56	1,040
6-10	0530	15.77	2,060

*Water Resource Data for Texas Water Year 1975 Volume 1, Arkansas River Basin, Red River Basin, Sabine River Basin, Neches River Basin, Trinity River Basin and Intervening Coastal Basins, U.S. Geological Survey Water-Data, Report TX-75-1.

Table C.7 Discharge Rates for Neches River near Evadale, Texas - October 1974 through September 1975*

NECHES RIVER BASIN

08041000 Neches River at Evadale, Tex.
(National stream-quality accounting network)

LOCATION.--Lat 30°21'22", long 94°05'36", Jasper-Hardin County line, near center of channel on downstream side of pier of bridge on U.S. Highway 96 at Evadale, 0.8 mile (1.3 km) upstream from Mill Creek, 16 miles (26 km) upstream from Village Creek, and at mile 55.6 (89.5 km).

DRAINAGE AREA.--7,951 mi^2 (20,593 km^2).

PERIOD OF RECORD.--Discharge: July 1904 to December 1906, April 1921 to current year. Monthly discharge only for some periods, published in WSP 1312.
Water quality: Chemical and biochemical analyses: October 1947 to current year. Pesticide analyses: January 1968 to current year. Water temperatures: October 1947 to current year. Sediment records: October 1974 to September 1975.

GAGE.--Water-stage recorder. Datum of gage is 8.25 ft (2.515 m) above mean sea level. July 1, 1904, to Dec. 31, 1906, nonrecording gage on Gulf, Colorado, and Santa Fe Railway Co. bridge at site 1.2 miles (1.9 km) downstream at datum 5.50 ft (1.676 m) lower; Apr. 1, 1921, to Dec. 7, 1948, nonrecording gages at site 1.2 miles (1.9 km) downstream at present datum; Dec. 8, 1948, to Nov. 8, 1963, water-stage recorder at site 1.2 miles (1.9 km) downstream at present datum.

AVERAGE DISCHARGE.--45 years (1904-6, 1921-64) prior to regulation by Sam Rayburn Reservoir, 6,308 ft^3/s (178.6 m^3/s), 4,570,000 acre-ft/yr (5.63 km^3/yr); 11 years (1964-75) regulated, 5,184 ft^3/s (146.8 m^3/s), 3,756,000 acre-ft/yr (4.63 km^3/yr).

EXTREMES.--Discharge: Current year: Maximum discharge, 19,800 ft^3/s (561 m^3/s) Jan. 26, 27 (gage height, 16.74 ft or 5.102 m); minimum daily, 1,780 ft^3/s (50.4 m^3/s) Sept. 19.
Period of record: Maximum discharge, 92,100 ft^3/s (2,610 m^3/s) May 11, 1944 (gage height, 23.58 ft or 7.187 m, from floodmark), at site then in use; minimum daily, 63 ft^3/s (1.78 m^3/s) Nov. 26-28, 1956.
Historic: Flood in May 1884 (stage 26.2 ft or 7.99 m at former site, discharge about 125,000 ft^3/s or 3,540 m^3/s) and flood in August 1915 (stage 24.5 ft or 7.47 m at former site, discharge about 102,000 ft^3/s or 2,890 m^3/s) are the highest since at least 1884. Stages by Gulf, Colorado, and Santa Fe Railway Co.
Water quality: Current year: Maximum daily specific conductance, 177 micromhos Sept. 30; minimum daily, 38 micromhos June 1. Maximum water temperatures, 30.0°C on several days during August; minimum, 8.0°C Dec. 4, Jan. 13, 15.
Period of record: Maximum daily specific conductance, 422 micromhos Jan. 25, 1957; minimum daily, 23 micromhos Sept. 19, 1963. Maximum water temperatures, 34.0°C June 29, 1953; minimum, 3.0°C Jan. 30, 31, 1948, Jan. 31, 1949, and Jan. 24, 1963.

REMARKS.--Discharge records fair. Flow regulated by B. A. Steinhagen Lake (station 08040000) 58.1 miles (93.5 km) upstream (capacity, 124,700 acre-ft or 154 hm^3) and Sam Rayburn Reservoir (station 08039300) 95.7 miles (154.0 km) upstream (capacity, 4,442,000 acre-ft or 5.48 km^3). Some diversions upstream for municipal use.

REVISIONS (WATER YEARS).--WSP 718: 1929. WSP 1342: 1905-7, 1924. WSP 1732: Drainage area at former site.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	4,710	3,050	7,650	9,540	13,600	18,900	9,630	8,420	16,600	8,290	8,020	8,470
2	4,190	3,250	7,610	8,410	11,300	18,800	9,210	9,050	16,200	8,770	7,990	8,900
3	3,150	4,520	7,570	7,640	10,500	18,700	8,710	9,860	15,900	9,450	7,960	8,190
4	2,610	6,310	7,470	7,080	12,700	18,800	9,520	10,500	15,000	9,470	8,040	6,790
5	2,470	7,410	7,030	6,850	15,700	19,200	8,690	10,700	12,200	8,930	8,220	6,000
6	2,350	7,840	6,750	7,380	16,500	19,200	8,930	10,800	7,790	8,560	8,090	5,650
7	2,310	7,670	7,250	9,220	16,400	19,500	8,970	11,700	7,400	8,370	8,100	5,490
8	2,240	7,380	8,540	11,700	16,000	19,500	9,020	14,600	7,360	8,260	8,510	5,420
9	2,270	7,150	9,470	13,900	15,600	18,400	8,770	16,600	7,360	8,210	8,910	5,390
10	2,120	6,840	9,630	16,400	15,300	16,700	8,120	17,300	8,190	8,160	9,050	5,370
11	2,080	6,630	9,580	17,600	15,400	15,100	6,520	17,800	9,340	8,200	9,040	5,370
12	2,240	6,100	10,000	18,200	15,600	14,100	5,490	16,600	11,200	8,240	8,530	5,390
13	2,330	5,520	11,300	17,200	15,900	14,100	6,160	18,800	13,400	8,240	7,900	5,540
14	2,310	5,610	13,200	17,500	16,900	14,200	7,350	18,800	12,400	8,290	7,550	5,570
15	2,390	5,650	15,400	16,100	18,000	14,200	7,750	19,000	8,120	8,250	7,380	5,050
16	2,420	5,650	16,400	15,000	18,800	14,800	8,470	19,200	6,920	8,010	6,930	3,270
17	2,410	5,850	16,400	14,400	19,300	15,700	9,260	19,100	6,160	7,100	6,440	2,130
18	2,370	6,230	16,600	14,200	19,400	16,300	9,750	19,000	6,080	6,310	6,200	1,850
19	2,330	7,130	15,600	14,500	19,400	14,800	10,300	18,800	6,430	6,190	6,150	1,780
20	2,310	7,770	14,400	14,900	19,400	13,200	10,500	18,600	7,230	6,330	6,520	1,920
21	2,240	9,420	13,500	15,500	19,400	12,000	10,300	18,300	8,490	6,330	6,670	3,280
22	2,240	8,970	12,200	15,900	19,500	11,000	10,300	17,500	9,520	6,090	6,330	3,920
23	2,280	9,200	10,500	16,000	19,600	10,300	10,000	16,900	10,100	5,810	5,420	4,090
24	2,270	8,970	8,670	17,000	19,500	10,000	10,100	16,600	10,300	5,720	4,920	4,040
25	2,270	8,500	7,420	18,400	19,600	9,830	10,100	16,700	9,750	5,830	4,690	3,810
26	2,270	8,190	7,170	19,500	19,400	9,720	9,300	16,300	8,860	6,550	4,600	3,580
27	2,260	8,100	7,460	19,800	19,200	9,690	8,210	15,400	8,370	7,540	4,570	3,170
28	2,330	7,960	8,370	19,300	18,900	9,690	7,740	15,000	8,210	8,290	4,550	2,810
29	2,660	7,840	9,280	18,200	------	9,690	7,330	16,000	8,180	8,370	4,730	2,730
30	3,090	7,700	9,820	17,000	------	9,690	7,620	17,000	8,190	8,060	5,920	2,680
31	3,250	------	10,100	15,700	------	9,690	------	17,000	------	7,990	7,410	------
TOTAL	78,880	207,440	322,740	450,020	477,000	445,500	261,120	499,930	291,240	238,210	215,540	137,650
MEAN	2,545	6,915	10,410	14,520	17,040	14,370	8,704	15,800	9,708	7,684	6,953	4,588
MAX	4,710	9,200	16,400	19,800	19,600	19,500	10,500	19,200	16,600	9,470	9,050	8,900
MIN	2,080	3,050	6,750	6,850	10,500	9,690	5,490	8,420	6,080	5,720	4,550	1,780
AC-FT	156,500	411,500	640,200	892,600	946,100	883,600	517,900	971,800	577,700	472,500	427,500	273,000

CAL YR 1974 TOTAL 3,327,030 MEAN 9,115 MAX 26,900 MIN 2,080 AC-FT 6,599,000
WTR YR 1975 TOTAL 3,615,270 MEAN 9,905 MAX 19,800 MIN 1,780 AC-FT 7,171,000

*Water Resource Data for Texas Water Year 1975 Volume 1, Arkansas River Basin, Red River Basin, Sabine River Basin, Neches River Basin, Trinity River Basin and Intervening Coastal Basins, U.S. Geological Survey Water-Data, Report TX-75-1.

C.3 WATER AND SEDIMENT QUALITY DATA

This appendix contains salinity data from the Sabine National Wildlife Refuge and water quality and bottom sediment data for the Sabine and Neches Rivers, Cow Bayou, and Gulf Intracoastal Waterway. Table C.8 contains data for three stations (SN-15, SN-16, and SN-17) on the Sabine River. Table C.9 contains additional water quality data before and after dredging on the Sabine River at station SN-15. Table C.10 presents data for stations CB-3 and CB-4 on Cow Bayou and Table C.11 contains data at stations NR-2, NR-3, and NR-4 on the Neches River. Figure C.1 indicates the locations of the various sampling stations.

Table C.8 Sabine River Water and Sediment Quality Data

Results of Tests of Water

SWD Sample No.	Field Sample No.	Total Residue	Total Volatile Residue	Chlorides Cl	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Carbon	Total Inorganic Carbon	Total Organic Carbon	Chemical Oxygen Demand	Oil & Grease	(a) Arsenic As µg/l	(a) Cadmium Cd	Chromium (Total) Cr	(a) Copper Cu	(a) Lead Pb	(a) Mercury Hg µg/l	(a) Nickel Ni	(a) Zinc Zn
EPA Criteria of October 1973 (Proposed)																				
C-[illegible]	SN-74A-15W	11,400	2,500	5,400	0.43	0.25	0.18	31	15	16	52	13	2	0.012	0.03	0.30	0.01	0.9	0.07	0.[illegible]
C-9042	SN-74A-16W	8,500	1,700	4,000	0.45	0.20	0.25	31	13	18	31	12	1	0.011	0.04	0.24	0.01	0.7	0.06	0.19
C-[illegible]	SN-74A-17W	7,900	1,500	3,600	0.62	0.38	0.24	32	14	18	47	12	0	0.012	0.05	0.41	0.01	0.2	0.08	0.16

(a) Retested.
(b) Insufficient sample available for retest.

Notes: All results are in mg/l except as noted.

RESULTS OF TESTS OF BOTTOM SEDIMENT

SABINE-NECHES WATERWAY

SWD Sample No.	Field Sample No.	Moisture Content % Dry Wt.	Total Solids % by Wt.	Total Volatile Solids % Dry Wt.	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Organic Carbon	Oil & Grease	Chemical Oxygen Demand	(a) Arsenic As	(a) Cadmium Cd	Chromium (Total) Cr	Copper Cu	(a) Lead Pb	(a) Mercury Hg	(a) Nickel Ni	(a) Zinc Zn
C-9094	SN-74A-15S	222	31	7.3	2180(b)	200	1980	11,000	3100	73,000(b)	4.1	1.7	45	40	39	0.25	29	102(b)
C-[illegible]	SN-74A-16S	72	58	3.2	580	85	795	9,400	1100	32,000	4.3	0.9	10	6	14	<0.1	10	29
C-9096	SN-74A-17S	237	28	8.5(b)	2360(b)	200	2160	10,000	2400	74,000(b)	4.5	1.4	27	23	39	0.22	71	77(b)

Table C.9 Water Quality Data in Area of Dredging in the Sabine River

PART (A)

	Sample No.	Date Sampled	Station	Dist-Ft From C	Water Depth MLT-Ft	Water Temp °C	Dissolved Oxygen mg/l	pH	Salinity ppt	Conductivity umhos/cm	Air Temp °C	Wind Direction	Moisture Content % Dry Wt	Total Solids mg/l	Total Solids % By Wt	Total Volatile Solids mg/l	Total Volatile Solids % Dry Wt	Total Kjeldahl Nitrogen mg/l	Total Kjeldahl Nitrogen mg/kg
							AREA NO. 12												
							Before Dredging-Channel Area												
Sediment	SNW-SN-75A-15S	3/27/75	570+00	0	19.3								56		64		3.4		1000
Water	SNW-SN-75A-15W	3/27/75	570+00	0	19.3	21.0	9	8.5	5.0	8,700	24.5	SE		4130		640		0.2	
							During Dredging-Channel Area												
Water	SNW-75B-SN-15W	7/24/75	570+00	0	41.5	31.0	5	8.5	14.0	23,000	29.0	NW		14,200		2520		2.1	

PART (B)

	Sample No.	Oil & Grease mg/l	Oil & Grease mg/kg	Chemical Oxygen Demand mg/l	Chemical Oxygen Demand mg/kg	Chlorides mg/l	Arsenic µg/l	Arsenic mg/kg	Cadmium mg/l	Cadmium mg/kg	Chromium (Total) mg/l	Chromium (Total) mg/kg	Copper mg/kg	Lead mg/l	Lead mg/kg	Mercury µg/l	Mercury mg/kg	Nickel mg/l	Nickel mg/kg	Zinc mg/kg
								AREA NO. 12												
								Before Dredging-Channel Area												
Sediment	SNW-SN-75A-15S		590		32,000			3.3		0.4		14	9		24		<0.1		9	34
Water	SNW-SN-75A-15W	0.		81		1,330	5		0.003		0.01			0.02		0.49		0.05		
								During Dredging-Channel Area												
Water	SNW-75B-SN-15W	0.0		69		7,600	5		<0.002		0.03			0.01		0.3		0.11		

Table C.10 Cow Bayou Water and Sediment Quality Data

Results of Tests of Water

SWD Sample No.	Field Sample No.	Total Residue	Total Volatile Residue	Chlorides Cl	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Carbon	Total Inorganic Carbon	Total Organic Carbon	Chemical Oxygen Demand	Oil & Grease	(a) Arsenic As µg/l	(b) Cadmium Cd	Chromium (Total) Cr	(a) Copper Cu	(a) Lead Pb	(a) Mercury Hg µg/l	(a) Nickel Ni	(a) Zinc Zn
G-9050	CB-74A- 3W	2,300	460	1,100	0.35	0.28	0.07	48	8	40	17	13	1	0.010	0.05	0.39	0.01	0.6	0.03	0.20
G-9051	CB-74A- 4W	3,400	830	1,700	0.70	0.45	0.25	51	7	44	39	12	2	0.013	0.03	[illegible]	0.01	0.3	0.04	0.18

(a) Retested.
(b) Insufficient sample available for retest.

Notes: All results are in mg/l except as noted.

RESULTS OF TESTS OF BOTTOM SEDIMENT

SWD Sample No.	Field Sample No.	Moisture Content % Dry Wt.	Total Solids % by Wt.	Total Volatile Solids % Dry Wt.	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Organic Carbon	Oil & Grease	Chemical Oxygen Demand	(a) Arsenic As	(a) Cadmium Cd	Chromium (Total) Cr	Copper Cu	(a) Lead Pb	(a) Mercury Hg	(a) Nickel Ni	(a) Zinc Zn
[illegible]	CB-74A- 3S	244	29	10.4(b)	3700(b)	200	3500	13,000	2600	110,000(b)	7.1(b)	0.8	46	14	78(b)	0.28	18	72
[illegible]	CB-74A- 4S	316	24	13.2(b)	4310(b)	370	3940	16,000	4800	130,000(b)	5.8(b)	0.8	34	13	52(b)	0.16	35	62

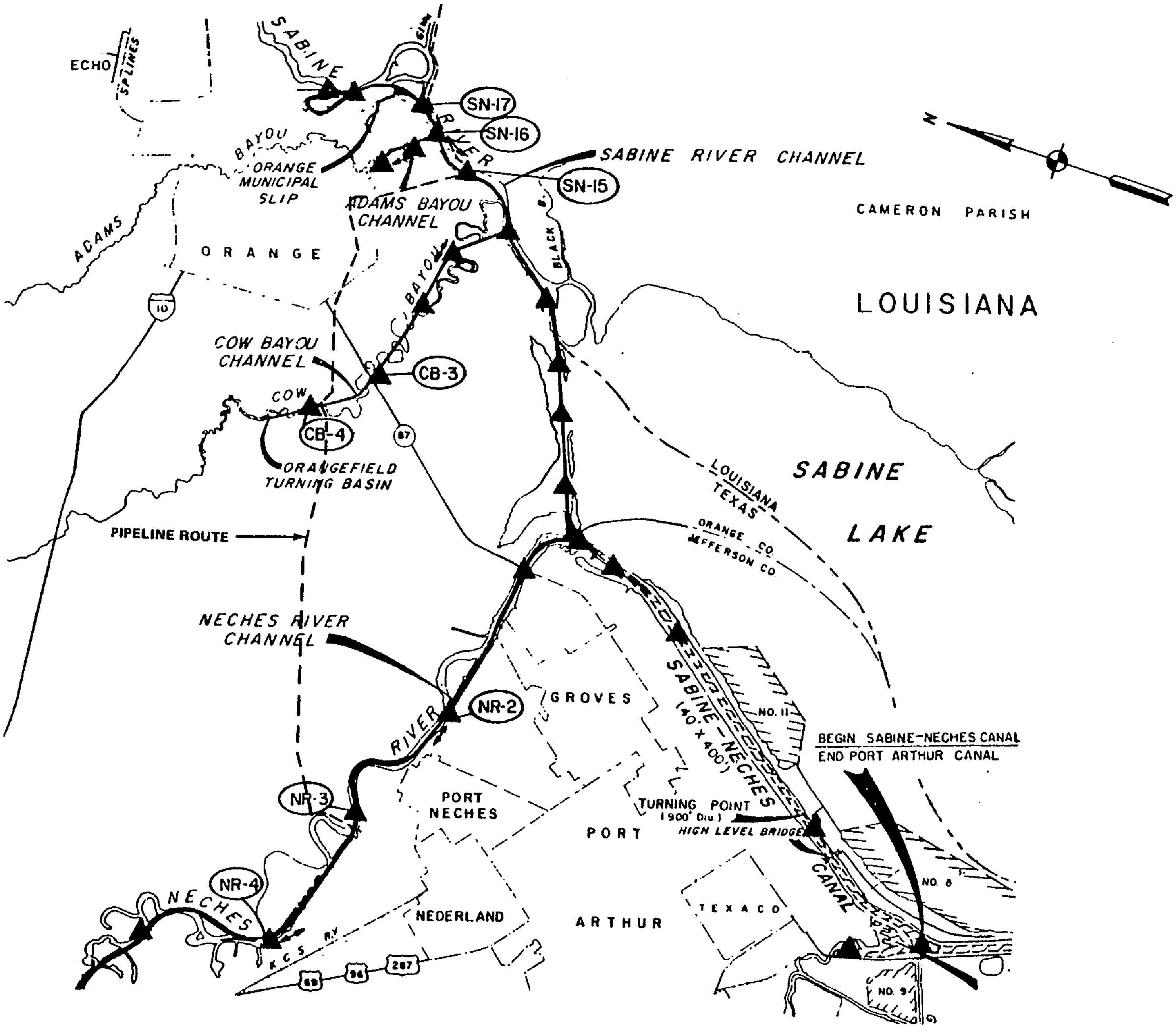

Figure C.1 Location of Sampling Stations on Sabine River, Cow Bayou and Neches River

Table C.11 Neches River Water and Sediment Quality Data

Results of Tests of Water

SWD Sample No.	Field Sample No.	Total Residue	Total Volatile Residue	Chlorides Cl	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Carbon	Total Inorganic Carbon	Total Organic Carbon	Chemical Oxygen Demand	Oil & Grease	(a) Arsenic As µg/l	(b) Cadmium Cd	Chromium (Total) Cr	(a) Copper Cu	(a) Lead Pb	(a) Mercury Hg µg/l	(a) Nickel Ni	(a) Zinc Zn
G-9053	NR-74A- 2W	12,400	2,400	6,600	0.58	0.38	0.20	56	15	41	56	10	1	0.014	0.04	0.50	0.02	0.2	0.06	0.23
G-9054	NR-74A- 3W	11,200	2,100	5,600	0.85	0.22	0.63	62	13	49	37	11	0	0.013	0.03	0.40	0.01	0.4	0.07	0.23
G-9055	NR-74A- 4W	10,800	2,000	5,300	1.0	0.30	0.70	51	14	37	29	16	(b)	(b)	0.03	0.35	0.02	0.2	0.07	0.18

(a) Retested.
(b) Insufficient sample available for retest.

Notes: 1. All results are in mg/l except as noted;

RESULTS OF TESTS OF BOTTOM SEDIMENT

SWD Sample No.	Field Sample No.	Moisture Content % Dry Wt.	Total Solids % by Wt.	Total Volatile Solids % Dry Wt.	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Organic Carbon	Oil & Grease	Chemical Oxygen Demand	(a) Arsenic As	(a) Cadmium Cd	Chromium (Total) Cr	Copper Cu	(a) Lead Pb	(a) Mercury Hg	(a) Nickel Ni	(a) Zinc Zn
G-9106	NR-74A- 2S	170	37	6.4	1750(b)	150	1600	11,000	2400	62,000(b)	0.0	0.6	38	37	53(b)	0.17	22	67
G-9107	NR-74A- 3S	222	31	8.2(b)	2180(b)	170	2010	13,000	2600	82,000(b)	4.9	0.2	37	23	70(b)	0.16	17	67
G-9109	NR-74A- 4S	244	29	9.3(b)	2130(b)	180	1950	16,000	3400	96,000(b)	5.9(b)	0.3	59	19	116(b)	0.20	20	85(b)

APPENDIX D

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 in either 55,000 or 100,000 dwt tankers, and the results are presented as the probability of spill per transit of either of these vessels. 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 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 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 The Record published by the American Burean of Shipping;[2] relationships derived from these sampled characteristics were used to provide the required data.

Table D.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 D.1 Sample Channel Traffic for Neches River

Ship Type		Number of Transits	Draft (feet)	Speed (knots)	Length (feet)	Beam (feet)	Displacement (1,000 DWT)
Tanker	(T1)	34	40	6	713	121	60.7
	(T2)	61	39	7	692	118	56.0
	(T3)	79	25	6	408	56	11.1
	(T4)	158	20	8	310	46	5.3
	(T5)	26	15	7	225	36	2.0
	(T6)	6	13	6	195	31	1.0
Passenger/Cargo	(P/C1)	14	40	8	795	106	39.4
	(P/C2)	1	38	6	746	100	35.0
	(P/C3)	39	26	6	441	63	10.7
	(P/C4)	31	25	7	417	60	9.2
	(P/C5)	516	14	7	190	34	1.4
	(P/C6)	1,047	11	6	150	28	1.0
Tank Barges							
w/tug	(TB1)	6	26	7	907	180	38.7
	(TB2)	6	19	6	853	180	35.8
	(TB3)	3	18	7	825	170	33.4
	(TB4)	14	18	7	587	88	13.7
	(TB5)	8	18	8	508	70	9.2
Barges							
w/tug	(B1)	47	14	7	780	74	22.6
	(B2)	36	8	6	582	41	3.1
SPR Vessel		1	42	9	800	95	55.0

angle of impact, and it is believed that narrow channels will in general cause this angle θ, as shown in Figure D.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 D.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 D.2 for the same vessel types listed in Table D.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 D.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

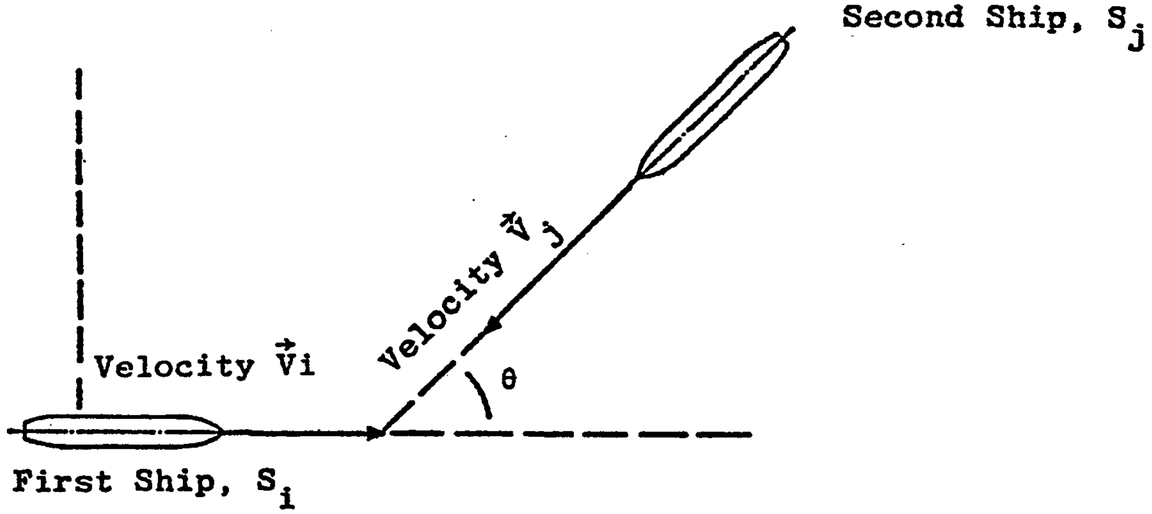

Figure D.1 Two Colliding Ships

Table D.2 Probabilities of Collision, Penetration, and Spill for Sample Cases in Nechez River (Per Transit of 55,000 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	(T1)	0.(a)	-(b)	0.(a)	-(b)	0.(a)
	(T2)	0.(a)	-(b)	0.(a)	-(b)	0.(a)
	(T3)	$.176 \times 10^{-6}$	.409	$.367 \times 10^{-7}$	.471	$.405 \times 10^{-7}$
	(T4)	$.281 \times 10^{-6}$	.174	$.306 \times 10^{-7}$	.280	$.293 \times 10^{-7}$
	(T5)	$.446 \times 10^{-7}$	0.(c)	0.(c)	0.(d)	0.
	(T6)	$.105 \times 10^{-7}$	0.(c)	0.(c)	0.(d)	0.
Passenger/Cargo	(P/C1)	$.364 \times 10^{-7}$	.490	$.848 \times 10^{-8}$	-(e)	0.(e)
	(P/C2)	$.297 \times 10^{-8}$	.469	$.574 \times 10^{-9}$	-(e)	0.(e)
	(P/C3)	$.898 \times 10^{-7}$	.151	$.676 \times 10^{-8}$	-(e)	0.(e)
	(P/C4)	$.645 \times 10^{-7}$	.358	$.127 \times 10^{-7}$	-(e)	0.(e)
	(P/C5)	$.853 \times 10^{-6}$	0.(c)	0.(c)	-(e)	0.(e)
	(P/C6)	$.174 \times 10^{-5}$	0.(c)	0.(c)	-(e)	0.(e)
Tanker Barge w/Tug	(TB1)	$.189 \times 10^{-7}$	.456	$.379 \times 10^{-8}$	.648	$.686 \times 10^{-8}$
	(TB2)	$.202 \times 10^{-7}$	.442	$.367 \times 10^{-8}$	.641	$.763 \times 10^{-8}$
	(TB3)	$.898 \times 10^{-8}$	.428	$.175 \times 10^{-8}$	.634	$.310 \times 10^{-8}$
	(TB4)	$.339 \times 10^{-7}$	.191	$.320 \times 10^{-8}$	.512	$.877 \times 10^{-8}$
	(TB5)	$.169 \times 10^{-7}$	.037	$.345 \times 10^{-9}$	.430	$.326 \times 10^{-8}$
Barges w/Tug	(B1)	$.127 \times 10^{-6}$	.340	$.187 \times 10^{-7}$	-(e)	0.(e)
	(B2)	$.907 \times 10^{-7}$	0.(c)	0.(c)	-(e)	0.(e)

(a) These collision probabilities are taken to be zero since the Sabine Pilots Vessel Traffic Control Movement Limitations do not allow the meeting of vessels 48,000 dwt or greater in these channels. The opportunities and likelihood of collisions in crossing or overtaking situations for such vessels are also negligibly small, compared to other collision probabilities enumerated in this table. The spill probabilities for these cases are therefore also taken to be zero.

(b) Since the collision probabilities for these cases are zero, no calculation of penetration probabilities was made.

(c) 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.

(d) 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.

(e) 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. So as to illustrate the effectiveness of such rules in reducing the risks of collision and oil spillage, one calculation has been carried out for the supposed nonexistence of such rules; this result will be compared to results with traffic rules in effect.

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 D.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 1.717×10^{-5} per transit for the case of a 55,000 dwt tank vessel, and as 1.240×10^{-5} for the 100,000 dwt vessel. The smaller probability for the case of the larger vessel is primarily due to the effect of the pilots' vessel traffic constraints discussed above.

Comparison of calculated collision and spill probabilities for this case of SPR Vessel transit in the hypothetical absence of the pilots' traffic control rules with the results just presented has been made. The beneficial effect of these rules may be directly observed in Table D.4 where resulting estimates of the percentage reductions in spill probabilities are presented in the same format as for Table D.3. It is clear that the intent of the rules is to reduce the risks of maneuvering the particularly larger vessels, and the results in both Table D.3 and Table D.4 show this effect dramatically in very quantitative terms. The spill probability for operating the larger alternative SPR vessel (100,000 dwt) is reduced by 44 percent compared to 10 percent for the smaller. This bias in reduction of risk is sufficient to cause the estimate of oil spill probability per transit to be significantly less for the larger 100,000 dwt vessel than for the smaller alternative.

It should be noted also that the spill probability per transit of the 55,000 dwt alternative vessel, $\sim 1.7 \times 10^{-5}$, is approximately equal to the overall average spill probability per transit calculated for the entire Gulf coast region, whereas that for the larger 100,000 dwt vessel is approximately 27.8 percent less than this overall average.

Table D.3 Overall Spill Probabilities Resulting From Possible Collisions with Other Vessel Traffic in Transit from Gulf of Mexico to Sunoco Wharf in Neches River

Case A: SPR Vessel 55,000 dwt

Channel Segment	Spill Probability per Transit (SPR Vessel Struck)	Spill Probability per Transit (SPR Vessel Striking)
Gulf of Mexico to Nechez River (24.3 mi)	0.591×10^{-5}	0.825×10^{-5}
Nechez River to Sunoco Wharf (7.2 mi)	0.958×10^{-6}	0.207×10^{-5}
Entire Transit	0.687×10^{-5}	0.103×10^{-4}
Total Spill Probability per SPR Vessel Transit = 1.717×10^{-5}		

Case B: SPR Vessel 100,000 dwt

Channel Segment	Spill Probability per Transit (SPR Vessel Struck)	Spill Probability per Transit (SPR Vessel Striking)
Gulf of Mexico to Nechez River (24.3 mi)	0.355×10^{-5}	0.621×10^{-5}
Nechez River to Sunoco Wharf (7.2 mi)	0.693×10^{-6}	0.195×10^{-5}
Entire Transit	0.424×10^{-5}	0.816×10^{-5}
Total Spill Probability per SPR Vessel Transit = 1.240×10^{-5}		

Table D.4 Beneficial Effect of Pilots' Traffic Control Agreement on Spill Probabilities for SPR Vessel Transits

Case A: SPR Vessel 55,000 dwt

Channel Segment	Percentage Reduction in Spill Probability	
	SPR Vessel Struck	SPR Vessel Striking
GM	11.7%	11.2%
NR	7.9%	4.6%
ET	11.1%	10.4%
Overall Reduction in Spill Probability = 10.5%		

Case B: SPR Vessel 100,000 dwt

Channel Segment	Percentage Reduction in Spill Probability	
	SPR Vessel Struck	SPR Vessel Striking
GM	53.7%	43.0%
NR	42.7%	22.3%
ET	52.2%	39.1%
Overall Reduction in Spill Probability = 44.3%		

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 D.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 D.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

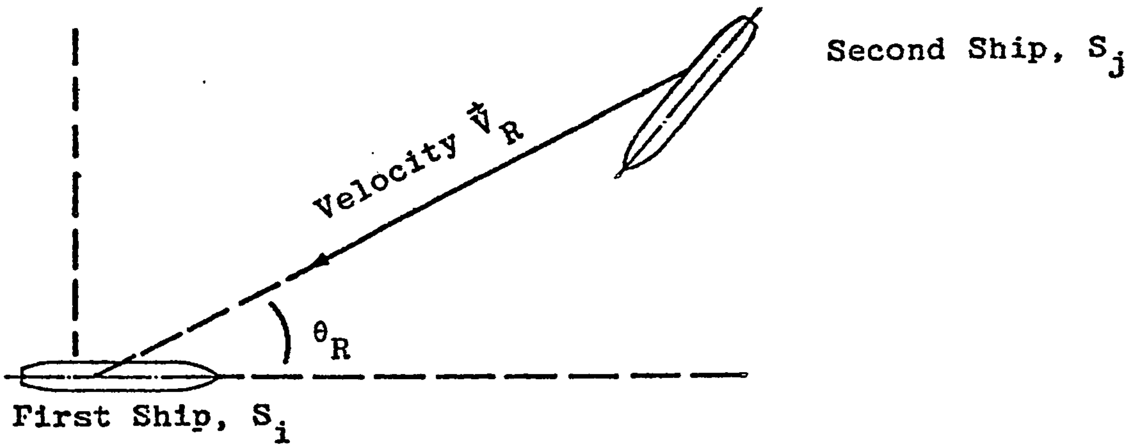

Figure D.2 Coordinate System for Analysis

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

$$C_i = t_i \sum_{j=1}^{N-1} P_j P_{ij} \tag{1}$$

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

$$t_i = \frac{d}{V_i} \tag{2}$$

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:

$$P_j = \frac{t_j}{Y} = \frac{d}{V_j Y} \tag{3}$$

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

$$\phi \propto \vec{\sigma} \cdot \vec{V}_R \tag{4}$$

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 D.2, are illustrated in Figure D.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:

$$P_{ij} = \int_{\substack{\text{all collision}\\ \text{angles}}} \lambda \cdot \Phi \, d\theta_R \qquad (5)$$

where λ is the weight function corresponding to the transformation to the moving coordinate system

$$\lambda = \frac{V_R^{\;2}}{V_j^{\;2} - V_i^{\;2} + V_i V_R \cos\theta_R}$$

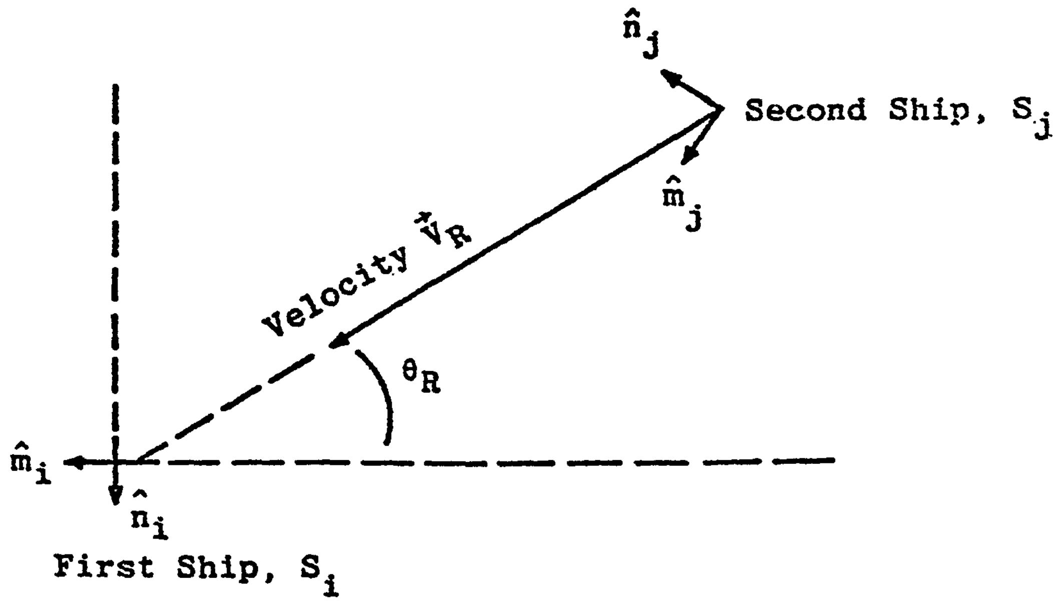

Figure D.3 Unit Normal Vectors

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 $V_j \geq V_i$,

$$C_i = \frac{1}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_i}{V_j} \left(2 \cos^{-1} \left(- \frac{V_i}{V_j} \right) - \pi \right) + 2 \frac{w_i}{V_i} \sin \cos^{-1} \left(- \frac{V_i}{V_j} \right) + \frac{w_j}{V_i} \pi + 2 \frac{\ell_i}{V_i} + 2 \frac{\ell_j}{V_j} \right] \tag{6a}$$

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

$$C_i = \frac{1}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_j}{V_i} \left(2 \cos^{-1} \left(- \frac{V_j}{V_i} \right) - \pi \right) + 2 \frac{w_j}{V_j} \sin \cos^{-1} \left(- \frac{V_j}{V_i} \right) + \frac{w_i}{V_j} \pi + 2 \frac{\ell_i}{V_i} + 2 \frac{\ell_j}{V_j} \right]. \tag{6b}$$

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 $V_j \geq V_i$,

$$C^{(\alpha)}_{i,\text{struck}} = \frac{2\alpha}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_j \pi}{V_i} + \frac{2\ell_i}{V_i} \right]$$

and, for $V_i \geq V_j$,

$$C^{(\alpha)}_{i,\text{struck}} = \frac{2\alpha}{\pi Y} \sum_{j=1}^{N-1} \left[\frac{w_j}{V_i} \left(2 \cos^{-1} \left(\frac{-V_j}{V_i} \right) - \pi \right) + \frac{2 w_j}{V_j} \sin \cos^{-1} \frac{-V_j}{V_i} + \frac{2\ell_i}{V_i} \right]$$

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 for the Federal Power Commission[1] 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 Ship 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 E

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 ship 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

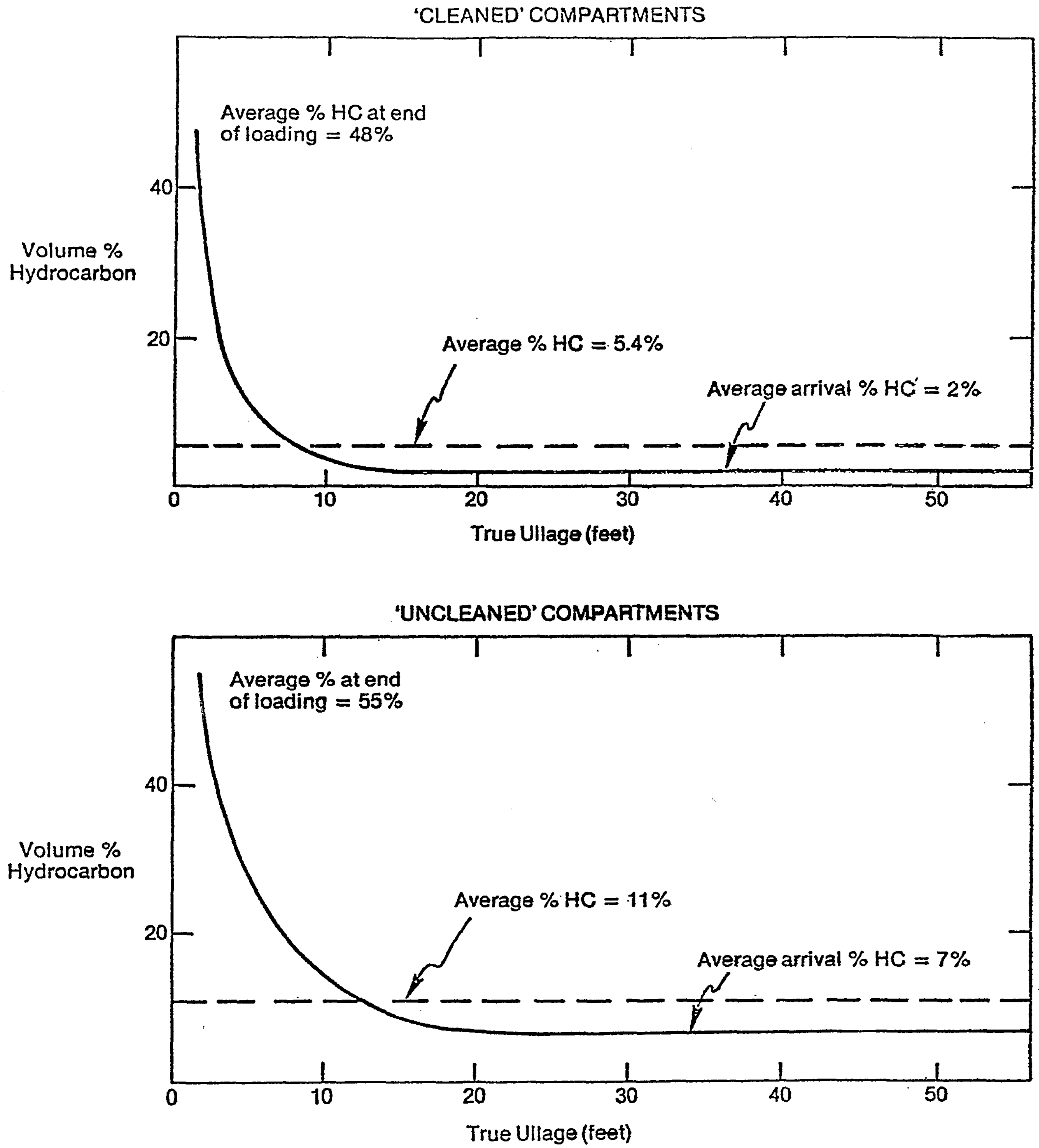

Figure 1. Typical Ship Emission Profiles

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 volatile 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 Emissions

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^{o} 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,

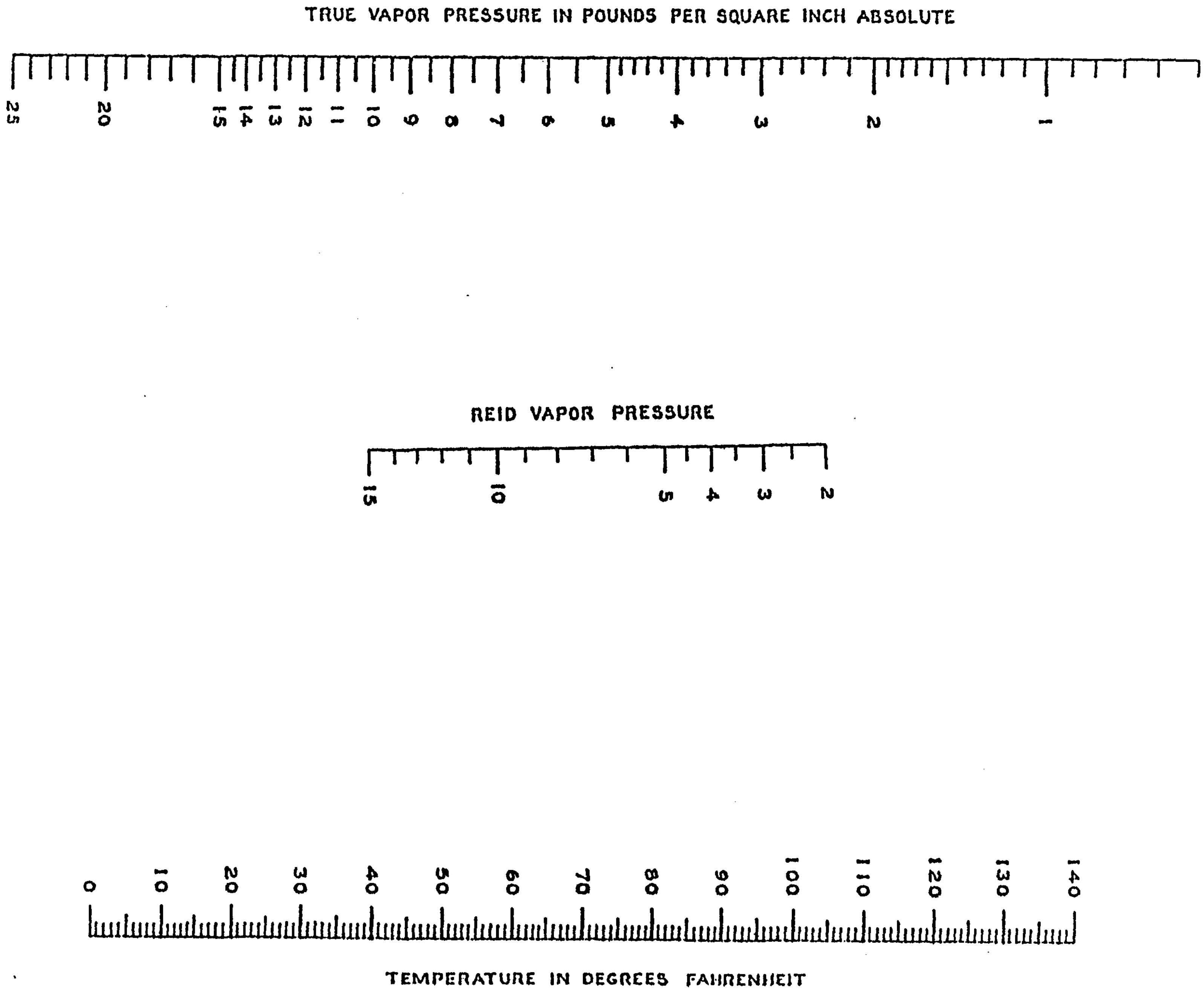

Figure 2. Vapor Pressures of Crude Oil

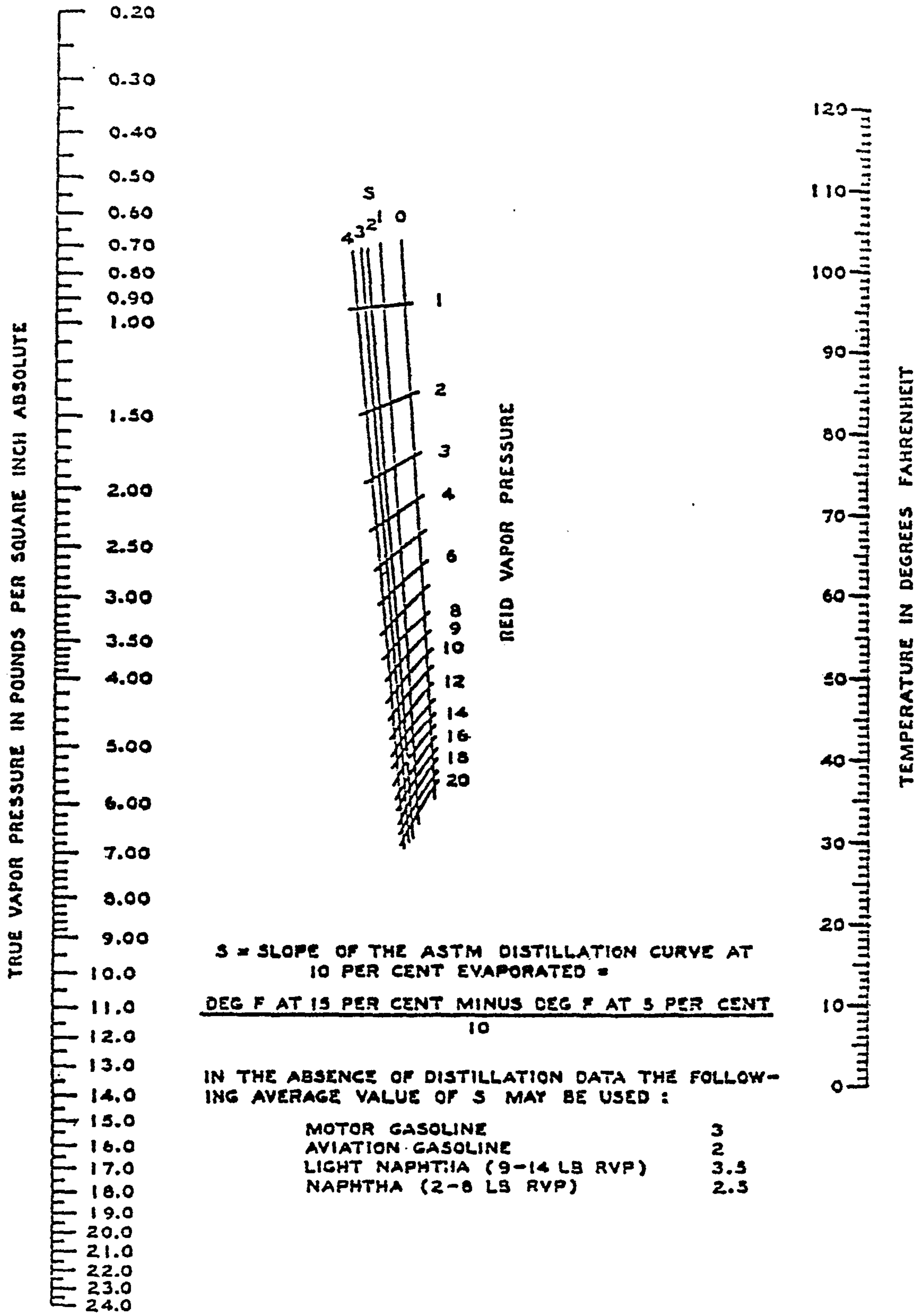

Figure 3. Vapor Pressures of Gasolines and Finished Petroleum Products

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 (Ref 3).

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).

Table 1. Summary of Petroleum Industry Testing Programs on Marine Loading Emissions

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	<u>Gasoline Loading</u> 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) <u>Aviation Gasoline Loading</u> 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) <u>Weighted Average Dock</u> 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	<u>Gasoline Loading on Tanker</u> 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, Ill	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:

$$H_f = \left(\frac{Xv}{100}\right) \left(\frac{K.W_m}{V_k}\right) \left(\frac{100+F}{100}\right) \tag{1}$$

and

$$F = \left[\frac{(1-X_T)\left(\frac{U_i}{U_i-U_f}\right) - (1-X_r)\left(\frac{U_f}{U_i-U_f}\right)}{(1-X_v)}\right]^{-1} \tag{2}$$

where:

H_f = hydrocarbon emission factors, lb/1,000 gal

X_v = volumetric average of HC concentration of vented vapor, percent

K = constant, 133.7 ft^3/1,000 gal

W_m = molecular weight of HC vapor, lb/lb-mole

V_k = molar volume of perfect gas, 379.44 ft^3/lb mole at STP conditions

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 $ft^3/ft^2 \cdot$ psia)
U = final true ullage correction in $ft^3/(ft^2 \cdot$ psia) from Figure 4

Assuming $V = A\ (U_i - U_f)$, Equation (5) becomes

$$X_v = \left[\frac{C}{100}\right] + \left[\frac{P \cdot (G - U)}{(U_i - U_f)}\right] \qquad (6)$$

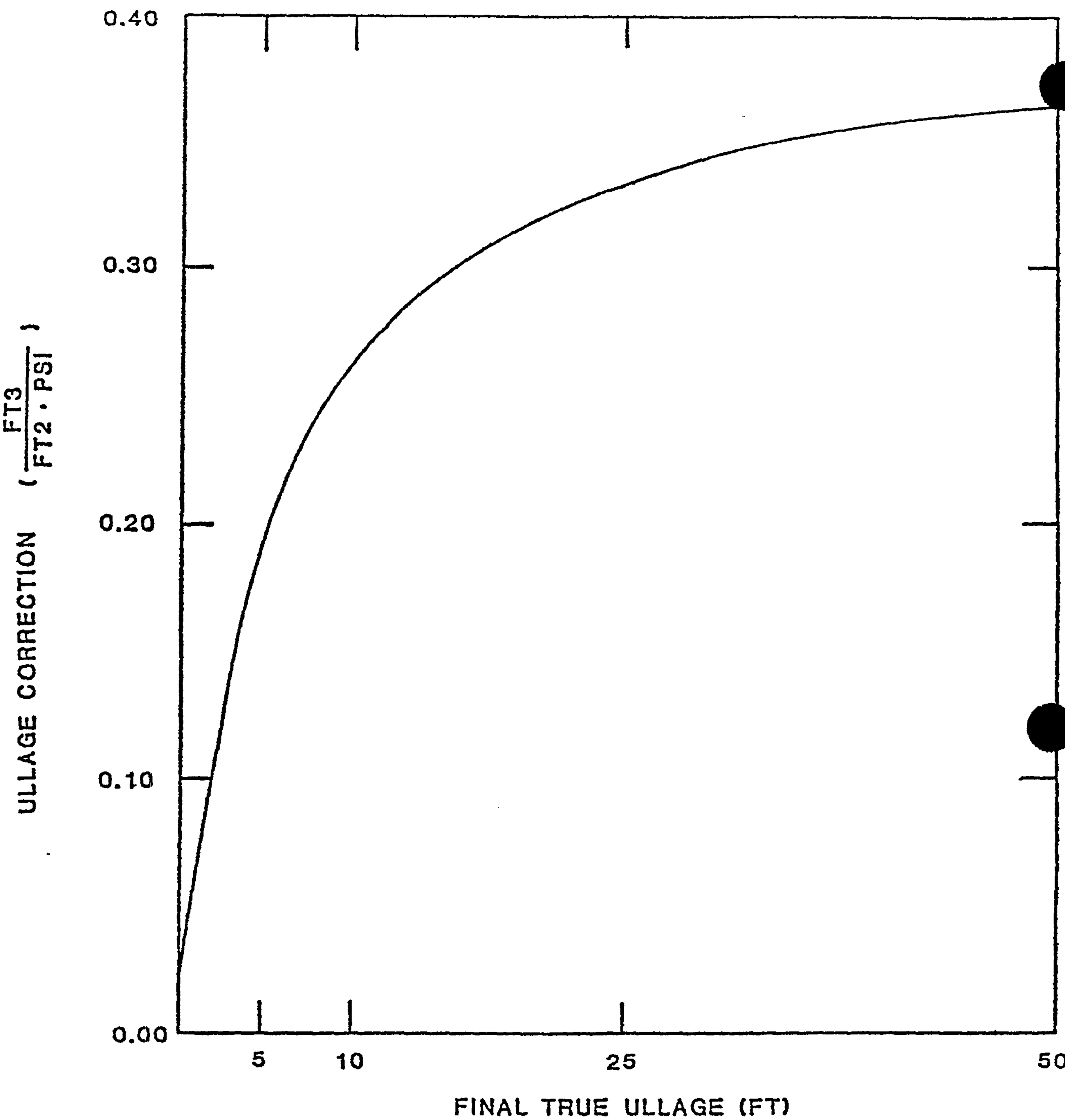

Figure 4. Hydrocarbon Generation Coefficient, Final Ullage Correction to the EXXON Corporation

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 α_1 and α_2, respectively. Thus, for crude oil loading operation:

$$X_v = \alpha_1 \left[\frac{C}{100}\right] + \left[\alpha_2 \frac{P \cdot (G - U)}{(U_i - U_f)}\right] \qquad (7)$$

In the above correlation, α_1 is principally affected by the characteristics of the previous cargo, whereas the value of α_2 is independent to the conditions of previous cargo.

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 such as gasoline. Thus,

- o $\alpha_1 = 1$, when previous cargo is gasoline
- o $\alpha_1 = \alpha_2$, when previous cargo is crude oil.

The correction factor α_2 can be interpretated 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 α_2 thus can be determined by

$$\alpha_2 = \frac{K_c}{K_g} = \frac{\left(S_c^{-0.67}\right)_{\text{crude oil}}}{\left(S_c^{-0.67}\right)_{\text{gasoline}}}$$

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:

$$\alpha_2 = \frac{(\mu/\rho D_{AB})^{-0.67} \text{ crude oil}}{(\mu/\rho D_{AB})^{-0.67} \text{ gasoline}} \tag{8}$$

and

$$D_{AB} = 0.0018583 \frac{\sqrt{T^3\left(\frac{1}{M_A} + \frac{1}{M_B}\right)}}{p\sigma_{AB}^2 \, \Omega_{D,AB}} \tag{9}$$

$$\mu = 2.6693\text{x}10^{-5} \frac{\sqrt{MT}}{\sigma^2 \Omega_{\mu_{AB}}} \tag{10}$$

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 gasoline 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 α_2 can be determined as 0.381.

The appropriate arrival HC hydrocarbon concentration, (C), can be calculated based on API gasoline emission 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	$\frac{7.5\ (0.36-0.010)}{(55-1.5)}$ 3.64	1.71 (2.50)
	Uncleaned	2.5	3.64	6.65 (8.00)
Barges	Cleaned	1.2	$\frac{7.5\ (0.36-0.27)}{(55-12)}$ 1.57	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, α_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 lb/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/1000 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)

Simarily, 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

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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^o F.

c Based on RVP = 4.0 and temperature of 70^o F.

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1. Chevron Research Company, "Hydrocarbon Emissions During Marine Tanker Loading, WOGA Test Program, Interim Report No. 1," November 1976.

2. American Petroleum Institute, "Hydrocarbon Emissions from Marine Vessel Loading of Gasoline," API Bulletin 2514-A, December 1976.

3. Environmental Protection Agency, "Background Information on Hydrocarbon Emissions from Marine Terminal Operations," Volume I and II, EPA-450/3-76-038a,b, November 1976.

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.

OPEN FRESHWATER AND FRESHWATER STREAMS

Algae

Ankistrodesmus sp.
Chlamydomonas sp.
Chlorella sp.
Coelastrum sp.
Crucigena sp.
Micractinium sp.
Scenedesmus acuminatus
Scenedesmus quadricauda
Cyclotella menghiniana
Gomphonema anugstafum
Gomphonema parvulum
Navicula biconica
Navicula cryptocephala
Nitzschia acicularis
Nitzschia palea
Nitzschia rhynchocephala
Oscillatoria sp.
Eugelena sp.
Euglena oxyaris
Stigeoclonium tenue
Phacus sp.
Synedra acus
Synedra ulma
Stauroneis anceps

Floating Vegetation

Azolla caroliniana Willd.
Floating chain fern

Limnobium Spongia (Bosc.) Steud.
Common frog's-bit

Lemna spp.
Duckweed

Eichhornia crassipes (Mart.) Solms.
Water-hyacinth

Juncus repens Michx.
Floating rush

Nelumbo lutea (Willd.) Pers.
Yellow lotus

Nuphar luteum (Small) E.O. Beal
Yellow cow-lily

Nymphaea odorata Ait.
White water-lily

Brasenia Schreberi J.F. Gmel.
Water-shield

Nymphoides aquatica (Gmel.) O. Ktze.
Floating-heart

Utricularia inflata Walt.
Floating bladderwort

Submerged Vegetation

Potamogeton nodosus Poir.
Longleaf pondweed

Najas guadalupensis (Spreng.) Magnne
Southern naiad

Mayaca Aubletii Michx.
Bogmoss

Heteranthera dubia (Jacq.) MacM.
Water-stargrass

Ceratophyllum demersum L.
Common hornwort

Juncus repens Michx.
Floating rush

TIDAL STREAMS, RIVERS, AND BAYS

Algae

Agmenellum thermale (Kütz.) Drouet and Daily

Anacystis aeruginosa (Zanardini) Drouet and Daily

Anacystis dimidiata Drouet and Daily

Coccochloris elabens Drouet and Daily

Entophysalis conferta Drouet and Daily

Entophysalis deusta Drouet and Daily

Spirulina subsalsa Oersted

Oscillatoria corallinae (Kütz.) Gomont

Oscillatoria laetevirens Crouan

Oscillatoria nigro-viridis (Thwaites) Gomont

Oscillatoria salinarum Collins

Phormidium subuliforme Gomont

Lyngbya confervoides Gomont

Lyngbya gracilis (Meneghini) Rabenhorst

Lyngbya lutea (C. Agardh) Gomont

Lyngbya majuscula Gomont

Symploca atlantica Gomont

Symploca hydnoides Gomont

Microcoleus chthonoplastes Thuret

Skujaella erythraea (Ehrenberg) J. de Toni

Plectonema terebrans Bornet and Flahault

Calothrix crustacea Thuret

Entocladia viridis Reinke

Entocladia wittrockii Wille

Ulvella lens Crouan

Phaeophila dendroides (Crouan) Batters

Enteromorpha clathrata (Roth) Greville

Enteromorpha flexuosa (Wulfen) J. Agardh

Enteromorpha lingulata J. Agardh

Ulva lactuca L.

Ulva fasciata Delile

Chaetomorpha brachygona Harvey

Chaetomorpha gracilis Kütz.

Rhizaclonium riparium (Roth) Harvey

Cladophora delicatula Montagne

Cladophora fascicularis (Mertens) Kütz.

Cladophora glaucescens (Griffiths) Harvey

Cladophora gracilis (Griffiths) Kütz.

Cladophora repens (J. Agardh) Harvey

Bryopsis pennata Lamouroux

Bryopsis hypnoides Lamouroux

Penicillus capitatus Lam.

Caulerpa mexicana (Sonder) J. Agardh

Caulerpa sertularioides (Gmelin) Howe

Ostreobium quekettii Bornet and Flahault

Acetabularia crenulata Lamouroux

Acetabularia schenckii (Möbius) Solms-Laubach

Batophora oerstedi J. Agardh

Vaucheria sp.

Pylaiella antillarum (Grunow) de Toni

Ectocarpus siliculosus (Dillwyn) Lyngbye

Giffordia mitchellae (Harvey) Hamel

Giffordia duchassaigniana (Grunow) Taylor

Giffordia rallsiae (Vickers) Taylor

Sphacelaria furcigera Kütz.

Dictyopteris delicatula Lamouroux

Dictyota dichotoma (Hudson) Lamouroux

Dictyota indica Sonder

Padina vickersiae Hoyt

Myriotrichia subcorymbosa (Farlow) Blomquist

Petalonia fascia (Muller) Küntze

Sargassum fluitans Børgesen

Sargassum natans (L.) Meyen

Asterocystis ornata (C. Agardh) Hamel

Goniotrichum alsidii (Zanardini) Howe

Erythrocladia subintegra Prosenvinge

Bangia fuscopurpurea (Dillwyn) Lyngbye

Achrochaetium hoytii Collins

Achrochaetium seriatum Børgesen

Gelidium corneum (Hudson) Lanouroux

Gelidium crinale (Turner) J. Agardh

Lithophyllum pustulatum (Lamouroux) Foslie

Fosliella farinosa (Lamouroux) Howe

Heteroderma lejolisii (Rosanoff) Roslie

Amphiroa fragilissimi (L.) Lamouroux

Jania decussato-dichotoma (Yendo) Yendo

Jania rubens (L.) Lamouroux

Corallina subulata Ellis and Solander

Halymenia floridana J. Agardh

Grateloupia filicina (Wulfen) C. Agardh

Gracilaria armata (C. Agardh) J. Agardh

Gracilaria blodgettii Harvey

Gracilaria caudata J. Agardh

Gracilaria ferox J. Agardh

Gracilaria foliifera (Forsskal) Børgesen

Pagardhiella tenera (J. Agardh) Schmitz

Hynea musciformis (Wulfen) Lamouroux

Rhodymenia pseudopalmata (Lamouroux) Silva

Lomentaria unicinata Meneghini

Champia parvula (C. Agardh) Harvey

Ceramium gracillium (Griffiths) Harvey

Ceramium fastigiatum (Roth) Harvey

Centroceras clavulatum (C. Agardh) Montagne

Spyridia aculeata (Scrimper) Kütz.

Spyridia clavata Kütz.

Spyridia filamentosa (Wulfen) Harvey

Callithamnion byssoides Arnott

Callithamnion corymbosum (Smith) Lyngbye

Dasya rigidula (Kütz.) Ardissone

Polysiphonia denudata (Dillwyn) Kütz.

Polysiphonia ferulacea Suhr

Polysiphonia hapalacantha Harvey

Polysiphonia havanensis Montagne

Polysiphonia howei Hollenberg

Polysiphonia macrocarpa Harvey

Polysiphonia ramentacea Harvey

Polysiphonia subtilissima Montagne

Bryocladia cuspidata (J. Agardh) de Toni

Digenia simplex (Wulfen) C. Agardh

Herposiphonia secunda (C. Agardh) Ambronn

Herposiphonia tenella (C. Agardh) Ambronn

Chondria curvilineata Collins and Hervey

Chondria tenuissima (Goodenough & Woodward) C. Agardh

Acanthophora spicifera (Vahl.) Børgesen

Laurencia intricata Lamouroux

Laurencia obtusa (Hudson) Lamouroux

Laurencia poitei (Lamouroux) Howe

Vascular plants

Ruppia maritima L.
Widgeon-grass

Saggittaria lancifolia L.
Coastal wapato

Thalassia testudinium Kõnig.
Turtle-grass

Zizaniopsis miliacea Michx. Doel and Asch.
Giant cutgrass

Eichhornia crassipes (Mart.) Solms.
Water-hyacinth

Crinum americanum L.
Southern swamp lily

Alternanthera philoxeroides (Mart.) Griseb.
Alligator-weed

Numphar luteum (Small) E.O. Beal
Yellow cow-lily

SUBMERGED VEGETATION

Potamogeton nodosus Poir.
Longleaf pondweed

Ruppia maritima L.
Widgeon-grass

Halodule Beaudettei den Hartog
Shoal grass

Cymodocea filiformis (Kũtz.)
Manatee-grass

Najas guadalupensis (Spreng.) Magnus.
Southern naiad

Thalassia testudinium Kõnig.
Turtle-grass

Eleocharis parvula (R.&S.) Link
Dwarf spikerush

Mayaca Aubletii Michx.
Bogmoss

Heteranthera dubia (Jacq.) MacM.
Water stargrass

Juncus repens Michx.
Floating rush

Ceratophyllum demersum L.
Common hornwort

Myriophyllum pinnatum (Walt.) B.S.P.
Water-milfoil

FLOATING VEGETATION

Azolla caroliniana Willd.
Floating chain fern

Limnobium Spongia (Bosc.) Steud.
Common frog's-bit

Lemna spp.
Duckweed

Eichhornia crassipes (Mart.) Solms.
Water-hyacinth

Juncus repens Michx.
Floating rush

Nelumbo lutea (Willd.) Pers.
Yellow lotus

Nuphar luteum (Small) E.O. Beal
Yellow cow-lily

Nymphaea odorata Ait.
White water-lily

Brasenia Schreberi J.F. Gmel.
Water-shield

Nymphoides aquatica (Gmel.) O. Ktze.
Floating-heart

Utricularia inflata Walt.
Floating bladderwort

SALT AND FRESH-TO-BRACKISH MARSH VEGETATION

Paspalum lividum Trin.
Longtom

Panicum virgatum L.
Switchgrass

Setaria geniculata (Lam.) Beauv.
Knotroot

Schizachyrium scoparium (Michx.) Nash
Little bluestem

Sporobulus virginicus (L.) Kunth.
Coastal dropseed

Spartina alterniflora Lois.
Smooth cordgrass

Spartina cynosuroides (L.) R.&G.
Big cordgrass

Spartina sparyinae (Trin.) Hitchc.
Gulf cordgrass

Spartina patens (Ait.) Muhl.
Saltmarsh cordgrass

Distichlis spicata (L.) Greene
Salt grass

Monanthochloë littoralis Engelm.
Saltflat grass

Scirpus californica (C.A. Mey.) Steud.
Giant bulrush

Fimbristylis castanea (Michx.) Vahl.
Marsh fimbristylis

Juncus Roemeriane Scheele.
Blackrush

Acnida cuspidata Spreng.
Southern water-hemp

Salicornia Bigelovii Torr.
Bigelow's glasswort

Salicornia virginica L.
Glasswort

Suaeda linearis (Ell.) Moq.
Sea-blite

Philoxerus vermicularis (L.) R. Br.
Silverhead

Batis maritima L.
Maritime saltwort

Portulaca oleracea L.
Purslane

Limonium Nashii Small.
Sea-rosemary

Agalinis maritima (Raf.) Raf.
Salt marsh gerardia

Baccharis halimifolia L.
Sea-myrtle

Aster subulatus Michx.
Annual saltmarsh aster

Aster tenuifolius L.
Perennial salt-marsh aster

Iva frutescens L.
Marsh elder

Heliopsis gracilis Nutt.
Bushy sea ox-eye

Borrichia frutescens (L.) D.C.
Sea ox-eye daisy

FRESHWATER MARSH VEGETATION

Osmunda cinnamonea L.
Cinnamon fern

Osmunda regalis L.
Royal fern

Taxodium distichum (L.) Rich.
Bald cypress

Typha latifolia L.
Common cat-tail

Typha augustifolia L.
Narrow-leaved cat-tail

Sagittaria lancifolia L.
Coastal wapato

Sagittaria graminea Michx.
Arrowhead

Sagittaria latifolia Willd.
Duck-potato

Arundinaria gigantea (Walt.) Muhl.
Giant cane

Zizaniopsis miliacea (Michx.) Doel and Asch.
Giant cutgrass

Phragmites communis Trin.
Common reed

Paspalum distichum L.
Knotgrass

Paspalum lividum Trin.
Longtom

Panicum hemitomon Schult.
Maidencane

Echinochloa colonum (L.) Link
Jungle-rice

Echinochloa crusgalli (L.) Beauv.
Wild millet

Echinochloa Walteri (Pursh.) Heller
Saltmarsh cockspur grass

Spartina cynosuroides (L.) Roth.
Big cordgrass

Scirpus maritimus L.
Salt-marsh bulrush

Scirpus Olneyi E. & G.
Olney bulrush

Scirpus americanus Pers.
Sword-grass

Scirpus validus Vahl.
Soft-stem bulrush

Scirpus californicus (C.A. Mey.) Steud.
Giant bulrush

Eleocharis cellulosa Torr.
Spikerush

Eleocharis parvula (R.&S.) Link
Dward spikerush

Cyperus erythrorhizos Muhl.
Flatsedge

Cladium jamaicense Crantz.
Saw-grass

Rhynchospora corniculata (Lam.) Gray
Beak-rush

Carex hyalinolepis Steud.
Sedge

Sabal minor (Jacq.) Pers.
Bush palmetto

Arisaema triphyllum (L.) Schott
Jack-in-the-pulpit

Peltandra virginica (L.) Kunth
Arrow-arum

Orontium aquaticum L.
Never wet

Pontederia cordata L.
Pickerel-weed

Juncus tenuis Willd.
Slender-rush

Juncus coriaceus L.
Rush

Juncus repens Michx.
Floating rush

Hymenocallis Eulae Shinners
Spider-lily

Crinum americanum L.
Southern swamp lily

Iris virginica L.
Southern blue-flag

Saururus cernuus L.
Lizard's-tail

Carya aquatica (Michx. f.) Nutt.
Water hickory

Planera aquatica (Walt.) J.F. Gmel.
Water-elm

Persicaria punctata (Ell.) Small.
Dotted smartweed

Alternanthera philoxeroides (Mart.) Griseb.
Alligator-weed

Magnolia virginiana L.
White bay

Persea Borbonia (L.) Spreng.
Red bay

Acer rubrum L.
Red maple

Ammannia teres Raf.
Ammannia

Ludwigia alternifolia L.
Rattle-box

Hydrocotyle verticillata A. Rich.
Pennywort

Nyssa aquatica L.
Tupelo, cotton-gum

Nyssa sylvatica Marsh.
Black-gum

Bacopa Monnieri (L.) Wettst.
Monnier's hedge hyssop

Cephalanthus occidentalis L.
Common buttonbush

Solidago sempervirens L.
Seaside goldenrod

Aster subulatus Michx.
Annual saltmarsh aster

Bidens laevis (L.) B.S.P.
Bur-marigold

HIGH MARSH VEGETATION

Osmunda cinnamonea L.
Cinnamon fern

Osmunda regalis L.
Royal fern

Sphenopholis obtusata (Michx.) Scribn.
Prairie wedgescale

Panicum virgatum L.
Switchgrass

Echinochloa Walteri (Pursh.) Heller
Saltmarsh cockspur grass

Setaria magna Griseb.
Giant bristlegrass

Setaria geniculata (Lam.) Beauv.
Knotroot bristlegrass

Setaria glauca (L.) Beauv.
Yellow foxtail

Schizachyrium scoparium (Michx.) Nash
Little bluestem

Cynodon Dactylon (L.) Pers.
Bermuda grass

Spartina spartinae (Trin.) Hitchc.
Gulf cordgrass

Spartina patens (Ait.) Muhl.
Saltmeadow cordgrass

Distichlis spicata (L.) Greene
Saltgrass

Juncus Roemerianus Scheele.
Black rush

Smilax laurifolia L.
Bamboo-vine

Salix nigra Marsh
Black willow

Myrica cerifera L.
Wax-myrtle

Batis maritima L.
Maritime saltwort

Liquidambar styraciflua L.
Sweet-gum

Platanus occidentalis L.
Sycamore

Rubus duplaris Shinners
Blackberry

Vigna luteola (Jacq.) Benth.
Wild cowpea

Amorpha fruticosa L.
Indigo bush

Sesbania vesicaria (Jacq.) Ell.
Bladder pod

Sesbania macrocarpa Muhl.
Hemp sesbania

Tilia americana L.
American basswood

Hibiscus militaris Cav.
Scarlet rose-mallow

Hibiscus cubensis A.
Mallow

Hydrocotyle umbellata L.
Marsh pennywort

Ipomoea sagittata Poir.
Arrow-leaf morning glory

Mikania scandens (L.) Willd.
Climbing hemp-weed

Baccharis Halimifolia L.
Sea-myrtle

Solidago sempervirens L.
Seaside goldenrod

Boltonia asteroides (L.) L'Her.
Doll's daisy

Pluchea camphorata (L.) D.C.
Camphor-weed

Pluchea purpurascens (SW) D.C.
Marsh-fleabane

Iva frutescens L.
Marsh-elder

Heliopsis gracilis Nutt.
Bushy sea ox-eye

Borrichia frutescens (L.) D.C.
Sea ox-eye daisy

Helenium tenuifolium Nutt.
Bitterweed

Pyrrhopappus carolinianus (Walt.) D.C.
False dandelion

BARE OR LIGHTLY AND HEAVILY VEGETATED TRANSFERRED MATERIAL

Osmunda cinnamonea L.
Cinnamon fern

Osmunda regalis L.
Royal fern

Typha latifolia L.
Narrow-leaved cat-tail

Arundinaria gigantea (Walt.) Muhl.
Giant cane

Uniola paniculata L.
Sea oats

Eriochloa sericea (Scheele) Munro
Texas cupgrass

Axonopus affinis Chase
Common carpetgrass

Paspalum plicatulum Michx.
Brownseed paspalum

Paspalum Urvillei Steud.
Vasey grass

Panicum Scribnerianum Nash
Scribner panicum

Panicum virgatum L.
Switchgrass

Panicum dichotomiflorum Michx.
Fall panic

Setaria geniculata (Lam.) Beauv.
Knotroot bristlegrass

Cenchrus incertus M.A. Curtis
Grassbur

Andropogon Gerardi Vitman
Big bluestem

Andropogon virginicus L.
Broomsedge

Sporobolus Tharpii Hitchc.
Coastal sacaton

Cynodon Dactylon (L.) Pers.
Bermuda grass

Spartina alterniflora Lois.
Smooth cordgrass

Spartina patens (Ait.) Muhl.
Saltmeadow cordgrass

Monanthochloë littoralis Engelm.
Salt flat grass

Distichlis spicata (L.) Greene
Saltgrass

Salix nigra Marsh.
Black willow

Myrica cerifera L.
Wax-myrtle

Carya myristicaeformis (Michx. f.) Nutt.
Nutmeg hickory

Celtis occidentalis L.
Southern hackberry

Rumex crispus L.
Yellow dock

Salicornia virginica L.
Glasswort

Batis maritima L.
Maritime saltwort

Phytolacca americana L.
Pokeweed

Sesuvium maritimum (Walt.) B.S.P.
Sea purslane

Persea Borbonia (L.) Spreng.
Red bay

Liquidambar Styraciflua L.
Sweet-gum

Rubus louisianus Berger
Blackberry

Rubus duplaris Shinners
Blackberry

Vigna luteola (Jacq.) Benth.
Wild cowpea

Wisteria macrostachya T.&G.
Wisteria

Sesbania macrocarpa Muhl.
Hemp sesbania

Rhus toxicodendron L.
Poison ivy

Tilia americana L.
American basswood

Hibiscus cubensis A. Rich.
Mallow

Ipomoea sagittata Poir.
Arrow-leaf morning glory

Phyla nodiflora (L.) Greene.
Common frog-fruit

Callicarpa americana L.
American beautyberry

Solanum americanum Mill.
American nightshade

Lonicera japonica Thunb.
Japanese honeysuckle

Pluchea camphorata (L.) D.C.
Camphor-weed

Pluchea purpurascens (Sw.) D.C.
Marsh-fleabane

Helenium tenuifolium Nutt.
Bitterweed

Sonchus asper (L.) Hill
Sow thistle

RIDGES, WATERWAY BANKS, AND WALKWAYS

<u>Osmunda cinnamonea</u> L.
Cinnamon fern

<u>Osmunda regalis</u> L.
Royal fern

<u>Pinus taeda</u> L.
Loblolly pine

<u>Juniperus virginiana</u> L.
Eastern red cedar

<u>Juniperus silicicola</u> (Small) Bailey
Southern red cedar

<u>Typha latifolia</u> L.
Common cat-tail

<u>Phragmites communis</u> Trin.
Common reed

<u>Uniola paniculata</u> L.
Sea oats

<u>Elymus virginicus</u> L.
Virginia wildrye

<u>Eriochloa sericea</u> (Scheele) Munro
Texas cupgrass

<u>Axonopus affinis</u> Chase
Common carpet grass

<u>Paspalum floridanum</u> Michx.
Florida paspalum

<u>Paspalum plicatulum</u> Michx.
Brownseed paspalum

<u>Paspalum Urvillei</u> Steud.
Vasey grass

<u>Paspalum lividum</u> Trin.
Longtom

<u>Panicum Scribnerianum</u> Nash
Scribner panicum

<u>Panicum virgatum</u> L.
Switchgrass

<u>Panicum dichotomiflorum</u> Michx.
Fall panic

<u>Echinochloa crusgalli</u> (L.) Beauv.
Wild millet

<u>Setaria magna</u> Griseb.
Giant bristlegrass

<u>Setaria geniculata</u> (Lam.) Beauv.
Knotroot bristlegrass

<u>Cenchrus incertus</u> M.A. Curtis
Grassbur

<u>Schizachyrium scoparium</u> (Michx.) Nash
Little bluestem

<u>Andropogon Gerardi</u> Vitman
Big bluestem

<u>Andropogon virginicus</u> L.
Broomsedge

<u>Sorghum halepense</u> (L.) Pers.
Johnson grass

<u>Tripsacum dactyloides</u> (L.) L.
Eastern gamagrass

<u>Tridens flavus</u> (L.) Hitchc.
Purpletop

<u>Sporobolus Tharpii</u> Hitchc.
Coastal sacaton

<u>Sporobolus indicus</u> (L.) R. Br.
Smutgrass

<u>Sporobolus vaginaeflorus</u> (Torr.) Wood
Poverty grass

<u>Cynodon Dactylon</u> (L.) Pers.
Bermuda grass

<u>Distichlis spicata</u> (L.) Greene
Saltgrass

<u>Aristida longespica</u> Poir.
Three-awn grass

Cladium jamaicense Crantz
Saw-grass

Salix nigra Marsh
Black willow

Populus deltoides Marsh
Eastern cottonwood

Myrica cerifera L.
Wax-myrtle

Carya myristicaeformis Michx. f.
Nutmeg hickory

Quercus virginiana Mill.
Live oak

Celtis laevigata Willd.
Texas sugarberry

Celtis occidentalis L.
Southern hackberry

Rumex crispus L.
Yellow dock

Batis maritima L.
Maritime saltwort

Phytolacca americana L.
Pokeweed

Sesuvium maritimum (Walt.) B.S.P.
Sea purslane

Portulaca oleracea L.
Purslane

Persea Borbonia (L.) Spreng.
Red bay

Liquidambar styraciflua L.
Sweet-gum

Platanus occidentalis L.
Sycamore

Rubus louisianus Berger
Blackberry

Rubus duplaris Shinners
Blackberry

Wisteria macrostachya T.&G.
Wisteria

Sesbania macrocarpa Muhl.
Hemp sesbania

Vigna luteola (Jacq.) Benth.
Wild cowpea

Melia Azedarach L.
Chinaberry-tree

Rhus Toxicodendron L.
Poison ivy

Ilex verticillata (L.) Gray
Black alder

Ilex decidua Walt.
Possum-haw

Acer Negundo L.
Boxelder

Acer rubrum L.
Red maple

Tilia americana L.
American basswood

Hibiscus militaris Cav.
Scarlet rose-mallow

Hibiscus cubensis A. Rich.
Mallow

Opuntia lindheimeri Engelm.
Texas prickly pear

Hydrocotyle verticillata A. Rich.
Pennywort

Ipomoea Pes-caprae (L.) Sweet.
Soilbind morning glory

Ipomoea sagittata Poir.
Arrow-leaf morning glory

Heliotropium curassavicum L.
Seaside heliotrope

Phyla nodiflora (L.) Greene
Common frog-fruit

Solanum americanum Mill.
American nightshade

Cephalanthus occidentalis L.
Common buttonbush

Lonicera japonica Thunb.
Japanese honeysuckle

Melothria pendula L.
Creeping cucumber

Liatris spp.
Button-snakeroot

Mikania scandens (L.) Willd.
Climbing hemp-weed

Eupatorium capillifolium (Lam.) Small
Dog fennel

Baccharis halimifolia L.
Sea-myrtle

Pluchea camphorata (L.) D.C.
Camphor-weed

Pluchea purpurascens (Sw.) D.C.
Marsh-fleabane

Borrichia frutescens (L.) D.C.
Sea ox-eye daisy

Helenium tenuifolium Nutt.
Bitterweed

Erechtites hieracifolia (L.) Raf.
Fireweed

PINE AND HARDWOOD

Pinus pacustris Mill.
Longleaf pine

Pinus Elliottii Engelm.
Slash pine

Pinus echinata Mill.
Shortleaf pine

Pinus taeda L.
Loblolly pine

Juniperus silicicola (Small) Bailey
Southern red cedar

Juniperus virginiana L.
Eastern red cedar

Chasmanthium sessiliflorum (Poir.) Yates
Longleaf uniola

Elymus virginicus L.
Virginia wildrye

Paspalum floridanum Michx.
Florida paspalum

Paspalum plicatulum Michx.
Brownseed paspalum

Panicum Scribnerianum Nash
Scribner panicum

Sorghastrum Elliottii (Mohr.) Nash
Indian grass

Sporobolus indicus (L.) R. Br.
Smutgrass

Sporobolus junceus (Michx.) Kunth
Pineywoods dropseed

Aristida purpurascens Poir.
Arrowfeather three-awn grass

Sabal minor (Jacq.) Pers.
Bush palmetto

Arisaema Dracontium (L.) Schott
Green dragon

Arisaema triphyllum (L.) Schott
Jack-in-the-pulpit

Tillandsia usneoides (L.) L.
Spanish moss

Salix nigra Marsh
Black willow

Populus deltoides Marsh
Eastern cottonwood

Myrica cerifera L.
Wax-myrtle

Carya leiodermis Sarg.
Swamp hickory

Quercus macrocarpa Michx.
Bur oak

Quercus lyrata Walt.
Overcup oak

Quercus alba L.
White oak

Quercus stellata Wang.
Post oak

Quercus virginiana Mill.
Live oak

Quercus Phellos L.
Willow oak

Quercus nigra L.
Water oak

Quercus marilandica Muenchh.
Blackjack oak

Celtis occidentalis L.
Southern hackberry

Celtis laevigata Willd.
Texas sugarberry

Ulmus americana L.
American elm

Ulmus alata Michx.
Winged elm

Magnolia grandiflora L.
Southern magnolia

Magnolia virginiana L.
White bay

Liquidambar styraciflua L.
Sweet-gum

Platanus occidentalis L.
Sycamore

Rubus louisianus Berger
Blackberry

Rubus duplaris Shinners
Blackberry

Prunus serotina Ehrh.
Black cherry

Gleditsia aquatica Marsh
Water locust

Wisteria macrostachya T.&G.
Wisteria

Melia Azedarach L.
Chinaberry-tree

Sapium sebiferum (L.) Roxb.
Chinese tallow tree

Rhus Toxicodendron L.
Poison ivy

Ilex verticillata (L.) Gray
Black alder

Ilex decidua Walt.
Possum-haw

Acer Negundo L.
Boxelder

Acer rubrum L.
Red maple

Tilia americana L.
American basswood

Eryngium yuccifolium Michx.
Button snake-root

Nyssa aquatica L.
Tupelo, cotton-gum

Nyssa sylvatica Marsh
Black-gum

Cornus Drummondii C.A. Mey.
Rough-leaf dogwood

Cornus foemina Mill.
English dogwood

Fraxinus caroliniana Mill.
Water ash

Fraxinus americana L.
White ash

Callicarpa americana L.
American beautyberry

Lonicera japonica Thunb.
Japanese honeysuckle

Melothria pendula L.
Creeping cucumber

OAK-GUM-CYPRESS

Taxodium distichum (L.) Rich.
Bald cypress

Juniperus silicicola (Small) Bailey
Southern red cedar

Juniperus virginiana L.
Eastern red cedar

Paspalum plicatulum Michx.
Brownseed paspalum

Panicum Scribnerianum Nash
Scribner panicum

Cladium jamaicense Crantz
Saw grass

Rhynchospora corniculata (Lam.) Gray
Beak-rush

Sabal minor (Jacq.) Pers.
Bush palmetto

Arisaema triphyllum (L.) Schott
Jack-in-the-pulpit

Tillandsia usneoides (L.) L.
Spanish moss

Smilax laurifolia L.
Bamboo-vine

Crinum americanum L.
Souther swamp lily

Salix nigra Marsh
Black willow

Populus deltoides Marsh
Eastern cottonwood

Myrica cerifera L.
Wax-myrtle

Carya aquatica (Michx. f.) Nutt.
Water hickory

Carya leiodermis Sarg.
Swamp hickory

Quercus macrocarpa Michx.
Bur oak

Quercus lyrata Walt.
Overcup oak

Quercus alba L.
White oak

Quercus virginiana Mill.
Live oak

Quercus Phellos L.
Willow oak

Quercus nigra L.
Water oak

Celtis occidentalis L.
Southern hackberry

Ulmus americana L.
American elm

Ulmus alata Michx.
Winged-elm

Planera aquatica (Walt.) J.F. Gmel.
Water-elm

Persicaria punctata (Ell.)
Dotted smartweed

Magnolia grandiflora L.
Southern magnolia

Magnolia virginiana L.
White bay

Liquidambar styraciflua L.
Sweet-gum

Platanus occidentalis L.
Sycamore

Gleditsia aquatica Marsh.
Water locust

Ilex verticillata (L.) Gray
Black alder

Ilex myrtifolia Walt.
Myrtle holly

Acer Negundo L.
Boxelder

Acer rubrum L.
Red maple

Tilia americana L.
American basswood

Nyssa aquatica L.
Tupelo, cotton-gum

Nyssa sylvatica Marsh.
Black-gum

Cornus Drummondii C.A. Mey.
Rough-leaf dogwood

Fraxinus caroliniana Mill.
Water ash

Lonicera japonica Thunb.
Japanese honeysuckle

MIXED HARDWOODS ON RIDGES AND STRANDPLAINS

Populus deltoides Marsh.
Eastern cottonwood

Carya leiodermis Sarg.
Swamp hickory

Quercus alba L.
White oak

Quercus stellata Wang.
Post oak

Quercus virginiana Mill.
Live oak

Quercus marilandica Muenchh.
Blackjack oak

Celtis laevigata Willd.
Texas sugarberry

Celtis occidentalis L.
Southern hackberry

Ulmus americana L.
American elm

Ulmus alata Michx.
Winged-elm

Platanus occidentalis L.
Sycamore

Rubus duplaris Shinners
Blackberry

Gleditsia aquatica Marsh.
Water locust

Acer rubrum L.
Red maple

Tilia americana L.
American basswood

Cornus Drummondii C.A. Mey.
Rough-leaf dogwood

Fraxinus americanus L.
White ash

Callicarpa americana L.
American beautyberry

Lonicera japonica Thunb.
Japanese honeysuckle

COASTAL PRAIRIE

Elymus virginicus L.
Virginia wildrye

Sphenopholis obtusata (Michx.) Scribn.
Prairie wedgescale

Eriochloa sericea (Scheele) Munro
Texas cupgrass

Paspalum floridanum Michx.
Florida paspalum

Paspalum plictulum Michx.
Brownseed paspalum

Panicum Scribnerianum Nash
Scribner panicum

Panicum dichotomiflorum Michx.
Fall panic

Cenchrus incertus M.A. Curtis
Grassbur

Schizachyrium scoparium (Michx.) Nash
Little bluestem

Andropogon Gerardi Vitman
Big bluestem

Andropogon virginicus L.
Broomsedge

Sorghum halepense (L.) Pers.
Johnson grass

Tripsacum dactyloides (L.) L.
Eastern gamagrass

Tridens flavus (L.) Hitchc.
Purpletop

Sporobolus indicus (L.) R. Br.
Smutgrass

Sporobolus vaginaeflorus (Torr.) Wood
Poverty grass

Cynodon Dactylon (L.) Pers.
Bermuda grass

Aristida longespica Poir.
Three-awn grass

Rubus duplaris Shinners
Blackberry

Opuntia Lindheimeri Engelm.
Texas prickly pear

Eryneium yuccifolium Michx.
Button snake-root

Callicarpa americana L.
American beautyberry

Liatris spp.
Gay feather

Erechtites hieracifolia (L.) Raf.
Fireweed

IRRIGATED CROPS

Oryza sativa L.
Rice

Sorghum bicolor (L.) Moench
Sorghum

Saccharum officinarum L.
Sugar cane

Carya illinoinensis (Wang.) K. Koch.
Pecan

Glycine Max (L.) Merr.
Soybean

Gossypium hirsutum L.
Cotton

Pinus palustris Mill.
Longleaf pine

Pinus Elliottii Engelm.
Slash pine

Pinus echinata Mill.
Shortleaf pine

Juniperus silicicola (Small) Bailey
Southern red cedar

Juniperus virginiana L.
Eastern red cedar

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Tripsacum dactyloides (L.) L.
Eastern gamagrass

Cynodon Dactylon (L.) Pers.
Bermuda grass

Aristida longespica Poir.
Three-awn grass

Salix nigra Marsh.
Black willow

Populus deltoides Marsh.
Eastern cottonwood

Myrica cerifera L.
Wax-myrtle

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Quercus lyrata Walt.
Overcup oak

Quercus alba L.
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Quercus stellata Wang.
Post oak

Quercus virginiana Mill.
Live oak

Quercus Phellos L.
Willow oak

Quercus nigra L.
Water oak

Quercus marilandica Muenchh.
Blackjack oak

Celtis laevigata Willd.
Texas sugarberry

Celtis occidentalis L.
Southern hackberry

Ulmus americana L.
American elm

Ulmus alata Michx.
Winged-elm

Phytolacca americana L.
Pokeweed

Magnolia virginiana L.
White bay

Liquidambar Styracifula L.
Sweet-gum

Platanus occidentalis L.
Sycamore

Rubus louisianus Berger
Blackberry

Rubus duplaris Shinners
Blackberry

Prunis serotina Ehrh.
Black cherry

Sesbania macrocarpa Muhl.
Hemp sesbania

Sapium sebiferum (L.) Roxb.
Chinese tallow-tree

Ilex decidua Walt.
Possum-haw

Acer Negundo L.
Boxelder

Acer rubrum L.
Red maple

Opuntia Lindheimeri Engelm.
Texas prickly pear

Cornus Drummondii C.A. Mey.
Rough-leaf dogwood

Fraxinus americana L.
White ash

Solanum americanum Mill.
American nightshade

Lonicera japonica Thunb.
Japanese honeysuckle

Pluchea camphorata (L.) D.C.
Camphor-weed

Source: U.S. Army Corp of Engineers, Galveston District. Final Environmental Statement, Maintenance Dredging Sabine-Neches Waterway, Texas.