SABINE PASS
ENVIRONMENTAL ANALYSIS

STATE OF TEXAS

JAN 1980

Coastal Zone Management Program

Sabine Pass Environmental Analysis

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STATE OF TEXAS

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1. Introduction

The area around Sabine Pass, in common with many other coastal environments on the Gulf of Mexico, is a highly productive marshland and estuarine system that supports a variety of recreational activities and a flourishing shrimping industry. Recently, increased levels of offshore exploration and development have brought a number of industries into the area, and Sabine Pass now serves as a major center for many offshore-related activities (Rice Center, 1979). The advent of industrial development, particularly in the context of a natural system with high intrinsic value, introduces the need for conscientious environmental management.

The broad objective of the study was to develop appropriate guidelines for managing land-development activities in the Sabine Pass area that would allow the integrity of the natural environment to be preserved, while still maintaining the possibility for further industrial and urban development. Specifically, the possibility of using environmental performance standards as a means for managing development was investigated.

In addressing issues of land management in this region several lines of investigation were pursued. They included: (1) development of detailed descriptions of the natural resources in the area, (2) identification of likely land use/environmental interactions, and elements of the natural system that appeared most sensitive to developmental processes, and (3) valuation of the marshland system based on quantitative estimates of some of its commercial, recreational, and functional value to the region.

The question of likely environmental response to land-use development is a fundamental ingredient in the concept of environmental impact assessment, which in turn is crucial to the formulation of appropriate management guidelines or performance standards. Valuation of the marshland system is also important in assisting decision-makers faced with the task of evaluating alternative plans or strategies for natural resource management, as it establishes a basic component of the potential "social costs and benefits" that can be associated with various forms of marshland use. This exercise also serves the function of alerting decision-makers and others to the intrinsic value of natural systems, and the free goods and services provided by them, which have been long taken for granted.

The development of land-use guidelines on the basis of the natural system's capacity to absorb impacts is not a new idea, and the methodological aspects of this research closely follow those of prior studies. Godschalk (1978) presents a detailed description and analysis of a number of environmental studies which incorporate the concept of "environmental carrying capacity" as a central idea. McHarg (1969) used map overlay techniques for defining geographical areas that were particularly suitable, environmentally speaking, for certain types of development. Clark (1974) in his treatment of ecological considerations for the management of coastal environments also introduces this concept. Many of the technical issues involved in arriving at an operational definition of the "carrying capacity" concept have been addressed by the Urban Studies Center (1972) and Rice Center (1974 and 1976). Several practical guides for performing environmental impact assessments also deal with the definition of sensitive or critical geographic areas (Burchell and Listolin, <u>et. al.</u>, 1975; Coates <u>et. al.</u>, 1972; and Ditton and Goodale (1972). Others, such as Hopkins (1973), Warner and Preston (1974) and Belknap (1967), present comparative assessments of a number of techniques for developing environmentally responsive guidelines for land-use development.

In this report, the use and implementation of environmental performance standards is investigated for the Sabine Pass area. As originally conceived, performance standards are flexible regulations which govern the functioning of the natural system as altered or modified by man. The approach taken in this report is to identify the most sensitive areas first, and then to develop environmental performance standards for any development occuring within those areas.

The report is organized into four sections following this introduction. The first documents the natural resource inventory. Here, various characteristics of the natural setting, such as its climate, geology and wildlife, are described in detail. The second section deals with valuation of the marsh based on the goods and services it provides, and includes a detailed review of valuation techniques. Identification and description of sensitive areas is the subject of the third section and the report concludes with a section dealing with the management of development in the Sabine Pass area. This final section includes a discussion of guidelines for managing development, and some suggested performance standards which illustrate the type of standards which can be set using available data., It also addresses the question of how much growth can be expected in Sabine Pass over the next ten years, and how much land will be required. Also included in this section are suggested additional research that would usefully extend and assist the management effort.

USE OF THIS STUDY

The results of this study are intended to provide public and private decision makers with the necessary background information and broad guidelines from which a specific management program for the Sabine Pass area can be developed. These guidelines are expressed in the general form of performance standards. However available resources precluded establishment of precise performance thresholds for some items. Further refinement of the performance standards approach to environmental management in the area would require that additional studies be performed in order to establish these thresholds. Finally, this report will be of use to the City or others concerned with environmental planning for Sabine Pass, because it can serve as the basis of any management effort.

2. Natural Resource Inventory

It is the purpose of this chapter to present a natural resource inventory for Sabine Pass. The study area is, specifically, that area annexed by the City of Port Arthur, formerly Jefferson County Fresh Water District No. 1. Because natural ecosystem boundaries do not coincide with human jurisdictional boundaries, an inventory for a much larger region is presented. The study area for this natural resource inventory included an area of roughly 200 square miles, as shown in Figure 1. Encompassed within this region are two national wildlife refuges, currently owned in fee simple by the federal government. They are: the Sea Rim Marsh, due south of the community of Sabine Pass, and the McFaddin Marsh, several miles to the west of Sabine Pass. In addition, there is one state park, Sea Rim State Park, and the J.D. Murphree Wildlife Management Area. These areas are all indicated by thick solid lines on Figure 1. Port Arthur city limits are also shown in Figure 1 as an alternating dotted-dashed line. This area is the focal point of this study. Sabine Lake is partially visible on this map, as are the Sabine-Neches Ship Channel and the Gulf Intracoastal Waterway.

The following sections contain a detailed description and inventory for: climate, geology, hydrology, vegetation, soils, wildlife, and aquatics. This inventory will provide the basis for understanding the natural systems, and taking steps to preserve their functioning.

CLIMATE

The climate of Sabine Pass is humid-subtropical, with warm summers and moderate winters. January is the coldest month, with a mean daily low temperature of 42.4 ° F. August is the warmest month, with a mean daily maximum temperature of 92.6° F. Sea breezes prevent extremely high temperatures in the summer, except on rare occasions, and the area lies far enough south so that cold air masses of winter are moderated by the time they reach Sabine Pass (N.O.A.A., 1978). Mean monthly temperatures, and daily maxima and minima are shown in Figure 2.

Rainfall is fairly evenly distributed throughout the year (Figure 3) averaging 52.49 inches annually. Heaviest rainfall

Figure 1
Sabine Pass Area
Key to Symbols

—·—·	Port Arthur City Limits
▬	Jurisdictional Boundaries

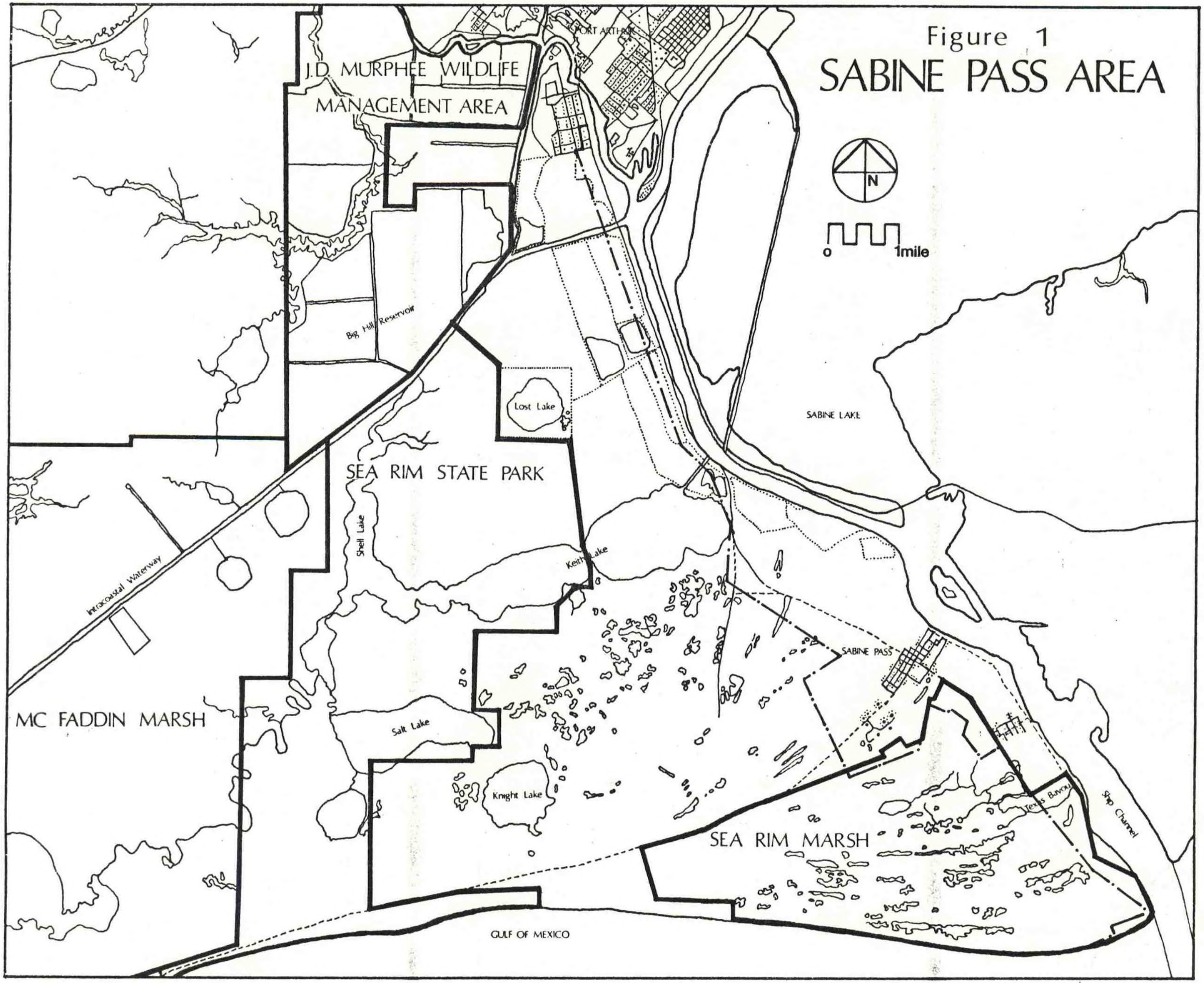


Figure 1
SABINE PASS AREA
N
0
1mile
J.D. MURPHEE WILDLIFE MANAGEMENT AREA
PORT ARTHUR
Big Hill Reservoir
Lost Lake
SABINE LAKE
SEA RIM STATE PARK
Shell Lake
Keith Lake
Intracoastal Waterway
MC FADDIN MARSH
Salt Lake
Knight Lake
SABINE PASS
Texas Bayou
Ship Channel
SEA RIM MARSH
GULF OF MEXICO

occurs in the summer months, from May through September, with a secondary peak in December and January. Lightest rainfall occurs in March, April and October. High monthly rainfall distributed evenly through the year, coupled with prevailing southerly winds bearing moist air from the Gulf explain the generally high humidity of the region (N.O.A.A., 1978). The extensive wetlands in the region act as reservoirs because of their water storage capacity, exerting a moderating effect on temperature and contributing to the high humidity of the area.

Prevailing wind direction is northerly from September through January and southerly from February through August. Mean annual windspeed is 10.1 mph, with higher values occuring from November through March (N.O.A.A., 1978).

The Sabine Pass area is subject to hurricanes and tropical storms. A tropical storm is a large, cyclonically swirling (counterclockwise) storm covering thousands of square miles. Peak winds may be in excess of 200 mph near the center, and the storm may have associated rain bands or squalls which can extend up to 200 miles from the center (Henry and McCormack, 1975). The Sabine Pass area has a recurrence interval for tropical storms of 2.3 years. A hurricane (sustained winds of

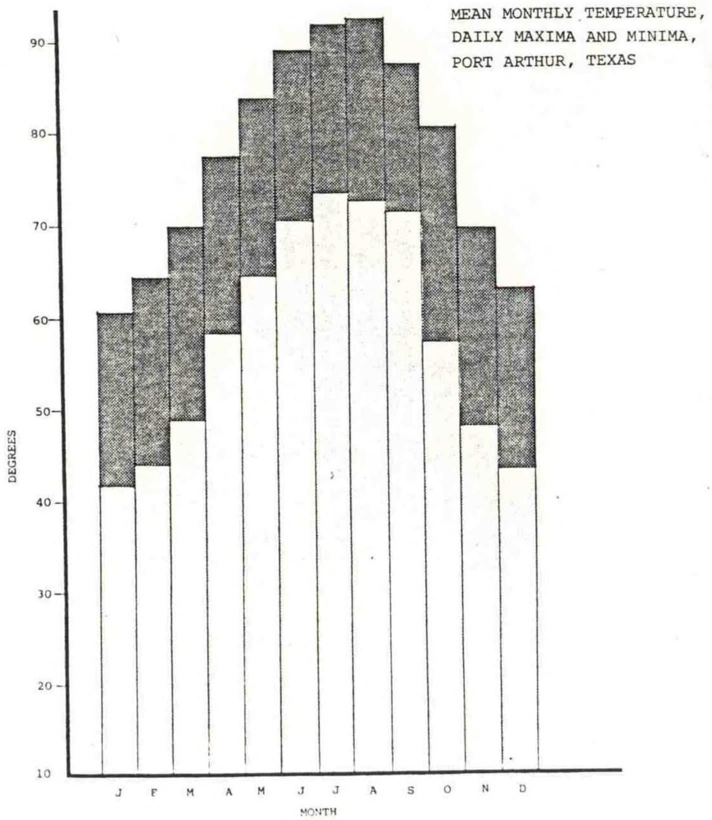


Figure 2

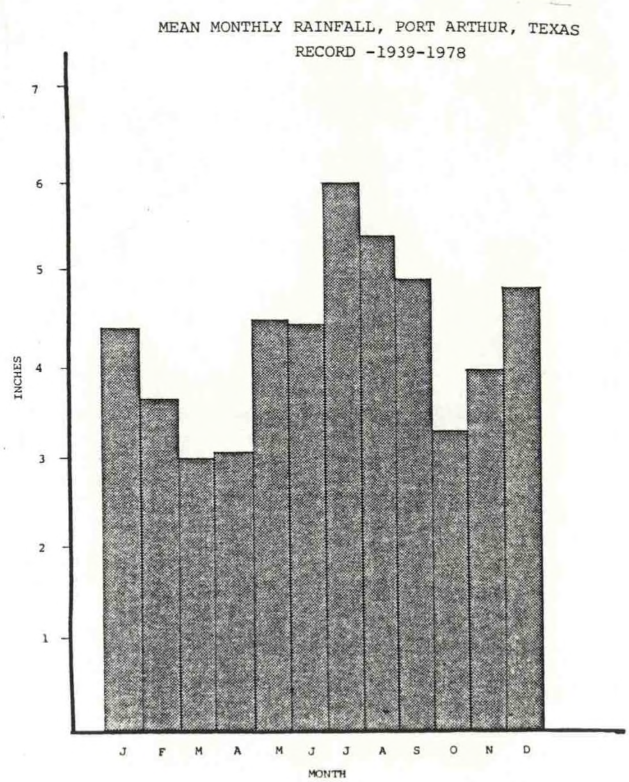


Figure 3

74 mph or greater) can be expected about once every 5 years (U.S. Army C.O.E., 1973), while an extreme hurricane (maximum winds of 136 mph or greater and minimum central pressure of 28.00 inches or less) occurs once every 20 years (Henry and McCormack, 1975).

A hurricane striking the coast in the vicinity of Sabine Pass would result in salt and brackish water flooding of hundreds of square miles of low-lying coastal marshes and prairies. Water would be pushed upstream in both the Sabine and Neches Rivers, and Taylor Bayou and its tributaries would be flooded to Hamshire-Fannett (Fisher et al., 1973). The storm surge would deposit sand and shell berms on the beaches, push sand from the continental shelf up onto the shoreface, and might breach the strandplain-chenier ridge forming storm or washover channels. The Active Processes map, Figure 4 , shows areas flooded by the storm surges of hurricanes Carla and Beulah.

GEOLOGY AND PHYSIOGRAPHY

Pleistocene and Holocene (Recent) geologic processes have set the stage for the processes now active in the Sabine Pass area. The Holocene epoch began some 18,000 years ago with the retreat of the massive ice sheets, or glaciers, which covered the continents during the Pleistocene epoch. Concurrent with the retreat of the glaciers was a rise in sea level, which resulted in deposition of sediments (accretion) along the coast and on floodplains of major streams. Sea level reached its present position approximately 4,500 years ago, marking the beginning of Modern geologic processes which are responsible for the formation of the coastline as we know it, and which continue to modify it (Fisher et al., 1973).

When sea level reached its modern position, the Sabine-Neches estuary was 8-10 miles wide, and extended inland from the open Gulf through the present Sabine Pass and Sabine Lake (Fisher et al., 1973). This estuary has been progressively filled by sediments supplied by the Sabine and Neches Rivers, and by longshore or littoral drift from the east. The Sabine and Neches Rivers were responsible for filling the upper reaches of the estuary, while the coastline reflects changes in sediment supplied by the Mississippi River.

Over the past 6,000 years, the Mississippi River has shifted between its eastern and western delta lobes numerous times. During shifts to its western delta lobes, in the vicinity of Vermilion Bay and the Atchafalaya River, there have been significant increases in the amount of sediment supplied to the Sabine Pass Area by littoral drift. When the Mississippi River

Figure 4
Active Processes Map[1]
Key to Symbols

	DEP	Shoreline, Depositional
	EQ	Shoreline in Equilibrium
	ER	Shoreline, Erosional
	BK	Bulkhead
	BT	Storm tide, Hurricane Beulah
	CT	Storm tide, Hurricane Carla
	MSc	Area of Moderate Erosion or scour
	Sp	Spoil Deposition, Sabine Lake
	TD	Tidal Delta, Sabine Lake

[1] This map was adapted from Fisher et al., (1973).

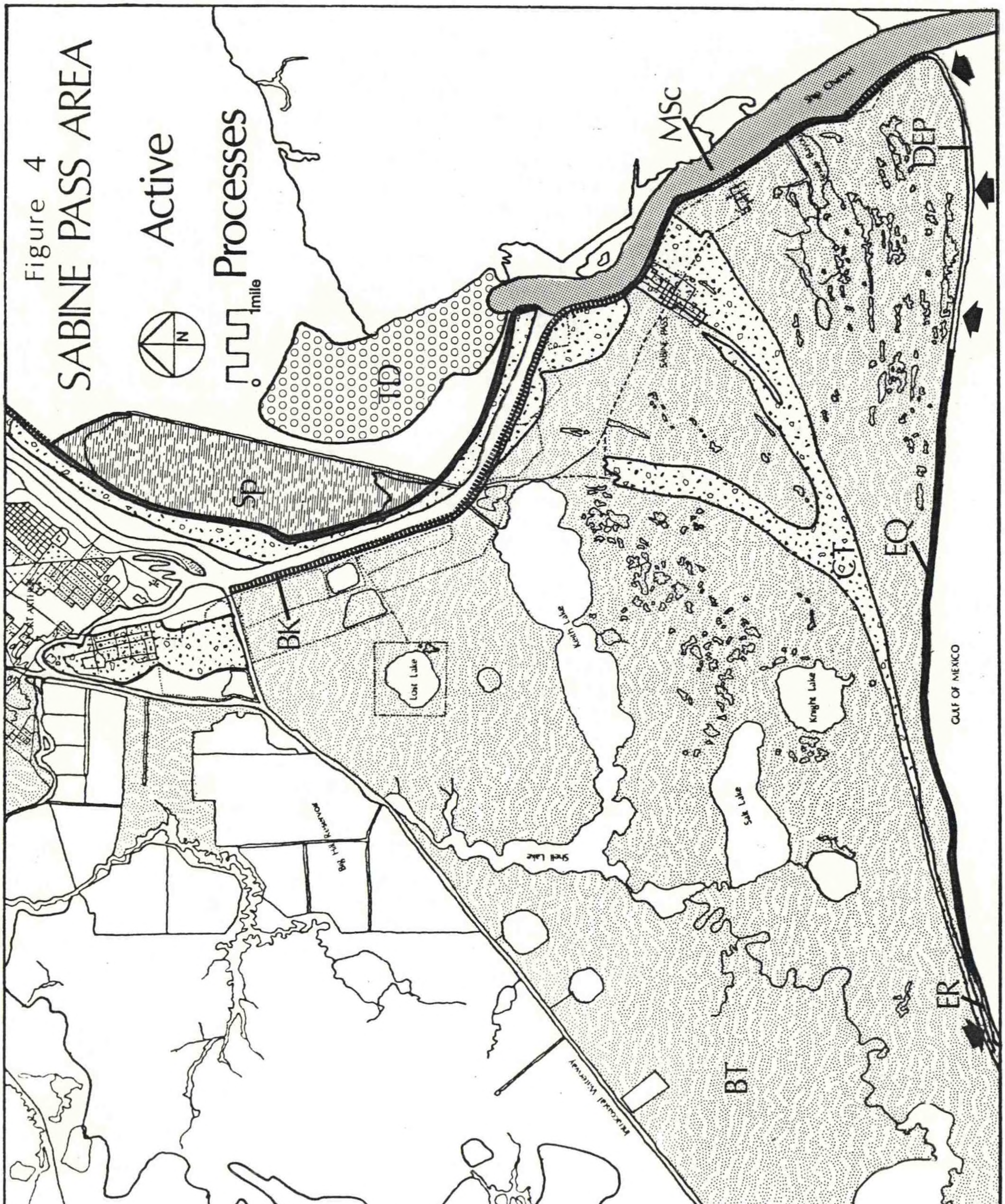


Figure 4
SABINE PASS AREA
Active
Processes
N
0
1mile
SP
TD
BK
MSc
DEP
CT
EQ
ER
BT
Sabine Pass
Lost Lake
Keith Lake
Knight Lake
Salt Lake
Shell Lake
Big Hill Reservoir
GULF OF MEXICO

shifted back to its eastern delta lobes (where it is now maintained by the U.S. Army Corps of Engineers), sediment supplied to Texas diminished, and shelly, sandy beaches called cheniers were developed. When the river shifted westward again, the increased sediment supply resulted in rapid deposition of muddy sediments, stranding the cheniers (or relict beach ridges). Thus, cheniers record former positions of the shoreline, when sediment supply was low. In this manner the original, broad Sabine-Neches estuary has gradually been closed off by several periods of rapid shoreline accretion, and gradual sedimentation in the river valleys upstream.

The late Quaternary geologic history of the Mississippi River and its delta lobes is presented by Van Lopik (1955), while Gould and McFarlan (1959) document the development of the Chenier Plain. Coleman (1966) presents a short summary and synthesis which demonstrates the importance of westward littoral drift in controlling the dynamic coastal processes of the Chenier Plain. Fisher et al., (1973) relate the geologic history of the Beaumont-Port Arthur area, while Bernard and LeBlanc (1965) provide a generalized account for the Gulf Coast.

In addition to showing those areas flooded by the storm surges of hurricanes Carla and Beulah, the Active Processes Map (Figure 4) also shows coastlines experiencing erosion or deposition, those in equilibrium, and those which are artifically stabilized. Because of the prevailing southeasterly wind, waves approach the shore at a slight angle. This generates a net longshore or littoral drift to the west. Sediment particles are repeatedly moved onshore and then washed offshore, with net movement to the west along the coast. Sediments being transported by littoral drift either move into Sabine Pass on flood tide, or move southward down the coast toward Bolivar Peninsula. If they move into Sabine Pass, they are either deposited in the channel or in the flood delta in Sabine Lake, or they may be returned to the Gulf on ebb tides.

For the last several thousand years, these processes have resulted in net shoreline accretion just south of Sabine Pass. Farther west is an area of equilibrium, where deposition and erosion are roughly balanced, and even farther west, the coastline is erosional (Figure 4). Erosional beaches are usually sand-starved, and are composed primarily of broken shell and rock fragments. They are generally shifting landward because they are not supplied with sufficient sand or other fine sediments. Along the ship channel, and along certain portions of Sabine Lake, much of the shoreline is bulkheaded or artificially stabilized to prevent erosion and scouring.

Summarizing, the dominant geological features of the Sabine Pass Area are its cheniers, (stranded beach ridges) (Figure 5) composed of coarse, sandy material and broken shell. These represent ancient, sediment-starved coastlines, which were stranded during later periods of high deposition (accretion). During the periods of accretion, rather muddy sediments were deposited, and these now underlie the marshes which are interfingered with the cheniers. The deposition of this whole area is comparatively recent, having occurred within the last 4,500 years.

HYDROLOGY

The hydrologic regime of the Sabine Basin is quite complex, mainly because of numerous modifications by man over time. The processes which control circulation in a shallow estuarine system like the Sabine Basin are river discharge, tides, winds, evaporation, and precipitation. These processes are superimposed on the basic physiography of the region to determine salinity, tidal extent, erosion, deposition and the frequency and duration of wetland inundation. All of these processes are subject to radical alteration because of the activities of man. In the Sabine Basin, as we shall see, human alteration has been significant.

The combined discharge of the Sabine and Neches Rivers is greater than discharge into any other Texas bay system or any other Chenier Plain system. Individual and combined monthly flows for the two rivers for 1974-75 are shown in Table 1 (Wiersema, et al., 1976). Prior to the development of the area, the entire flow of these two rivers was directed into Sabine Lake, and records indicate that it was originally a fresh water lake (Wiersema and Mitchell, 1973).

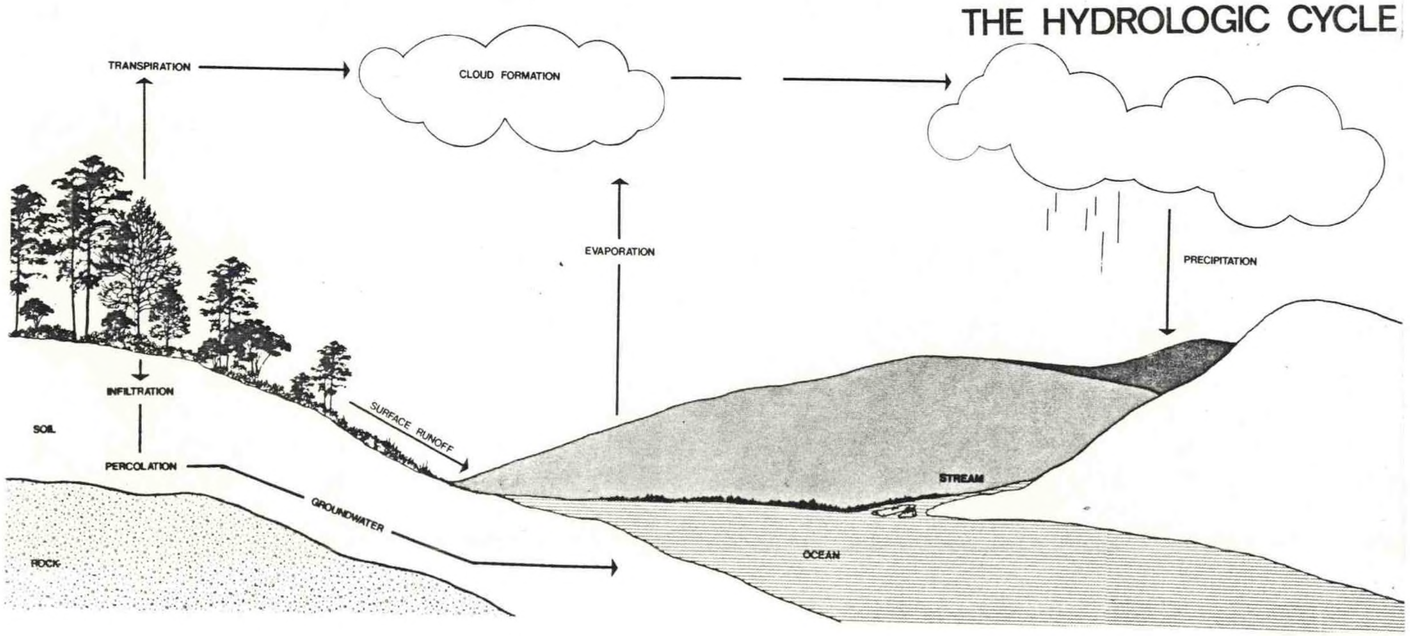


Figure 5
Environmental Geology[1]
Key to Symbols

	SM	Salt marsh, mud and local sand substrate
	CR	Chenier ridge and flat, coarse sand and shell vegetated with grass and local trees.
	BM	Fresh to brackish marsh,mud and sand
	CM	Closed brackish marsh, mud and sand
	TC	Tidal channel, active, mud and some sand
	Str	Strandplain and beach ridge, sand and shell
	CL	Coastal lake, mud-filled
	Sp	Spoil, made-land

1. This map was adapted from Fisher et al., (1973).

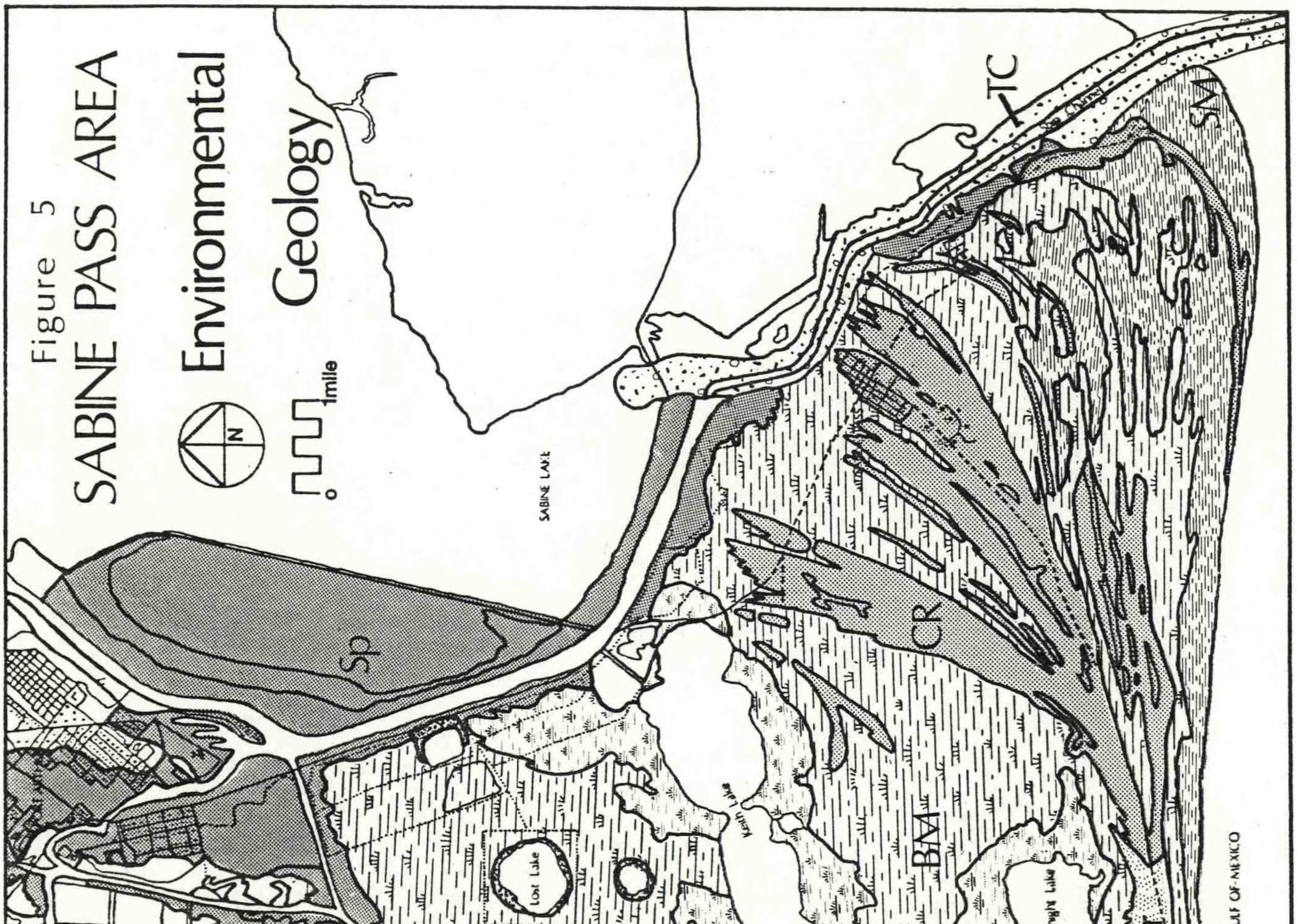


Figure 5
SABINE PASS AREA
Environmental
Geology
N
0
1mile
SABINE LAKE
Sp
CR
BM
CM
CL
SH
TC
SM
Lost Lake
Keith Lake
Knight Lake
Salt Lake
Shell Lake
Big Hill Reservoir
Intracoastal Waterway
GULF OF MEXICO

TABLE 1: COMBINED MONTHLY RIVER FLOWS, cfs.
1974-75
Neches and Sabine Rivers

	Sabine	Neches	Total
September	5,727	4,565	10,292
October	1,256	2,545	3,801
November	6,296	6,915	13,211
January	23,680	14,500	30,970
February	23,630	17,040	40,670
March	26,500	14,370	34,870
April	15,080	8,709	23,784
May	21,510	15,800	37,310
June	15,450	9,708	25,158
July	9,322	7,684	17,006
August	7,982	6,953	14,935

Tides are mixed diurnal-semidiurnal, with a mean tidal range at Sabine Pass of 1.3 feet (U.S. Fish and Wildlife Service, 1979). Sabine Pass is a very narrow, elongate channel, and maximum tidal energy is focused within the channel itself. Tidal range is thus attenuated inland, and averages less than one foot at the Salt Bayou Wier on the Intracoastal Canal (Stelly, unpublished, 1979), and a little more than 0.6 feet at Sidney Island (U.S. Fish and Wildlife Service, 1979). Because of the constricting pass, Sabine Lake's tidal range is not as affected by prevailing southerly winds as are those of other Texas estuaries with more open access, but ebb-tidal flow is increased when ebb tide coincides with strong northerly winds.

Although the Sabine Pass marshes are quite level and quite close to sea level, the small tidal range indicates that only the flattest areas near the Gulf will be regularly flooded. "Regular flooding" as used in this section refers to at least daily inundation by marine tidal water. Although most of the marshes will contain standing water for much of the time, they are considered to be irregularly flooded, because they are not often flushed with tidal water. These areas are more dependent on rainfall for water supply.

The cheniers also act as barriers to flow, and the areas north of the chenier may experience less extensive tidal inundation because inland waters experience an attenuated tidal range. The areas shown as salt marshes on the vegetation map (Figure 7) are areas which experience regular flooding with marine water. In general, brackish marsh areas are irregularly flooded. However, the areas close to Keith Lake or other water exchange points are regularly flooded with less saline water. Exchange points are shown in Figure 6.

Historically, man has been a significant agent of change in the Sabine Basin ecosystem. Activities such as dredging, filling, channelization, and impoundment almost certainly have altered the water flow significantly throughout the system, but the effects of such alterations are poorly documented and difficult to assess in the field. Important modifications which have occurred in this basin are shown in Table 2.

Channel construction and deepening has led to intrusion of salt water as far as 45 miles inland, and has necessitated the placing of salt water barriers on the Sabine and Neches Rivers and Taylor Bayou. Impoundment of the Sabine and Neches Rivers in reservoirs has altered seasonal patterns of freshwater discharge, altered seasonal water level fluctuations, reduced sediment inputs, and contributed to salt water intrusion (Wiersema and Mitchell, 1973).

Leveeing of spoil disposal sites and shell dredging in Sabine Lake have reduced habitat areas within the lake, and the closing of Little Keith Lake resulted in the removal of approximately 54,343 acres of marsh from active contribution to the productivity of Sabine Lake. Wiersema and Mitchell (1973) have linked a decline in the Sabine Lake fishery to the effects of these modifications. The Keith Lake Water Exchange Pass was reopened in 1976, and there has been a significant increase in utilization by desirable fish and shellfish species (Bob Fish, Texas Parks and Widlife Dept. Biologist, personal communication).

Other effects of channelization include diversion of water by the Sabine-Neches Canal around Sabine Lake. This effect was first noted by Captain Arthur P. Von Deesten, Corps of Engineers, in his comprehensive salinity report of 1924. Ward (1973) estimated that 80 per cent of the combined discharge is now diverted down the Sabine-Neches canal and is separated from the main lake. This water is generally fresh at the surface, and even though most of the river discharge is shunted around the lake, Sabine Lake itself is still the freshest bay in Texas. Its salinity is correlated with river discharge. When discharge is high, surface salinities are lowered, ranging from 2 to 18 ppt (parts per thousand). When discharge is low, surface salinities are elevated, ranging from 10 to 28 ppt. (Fisher et al., 1973).

Salt water enters through Sabine Pass from the Gulf. Because seawater is denser than freshwater, the seawater forms a separate layer or wedge at the bottom of the deep channel. A water body with a dense saline layer below a lighter fresh water layer is said to be "stratified". Sabine Lake is shallow enough that wind- and tide-caused mixing keeps it from being

Figure 6
Hydrology Map
Key to Symbols

- Major Exchange Points
- Minor Exchange Points
- Direction of Flow
- Impoundment

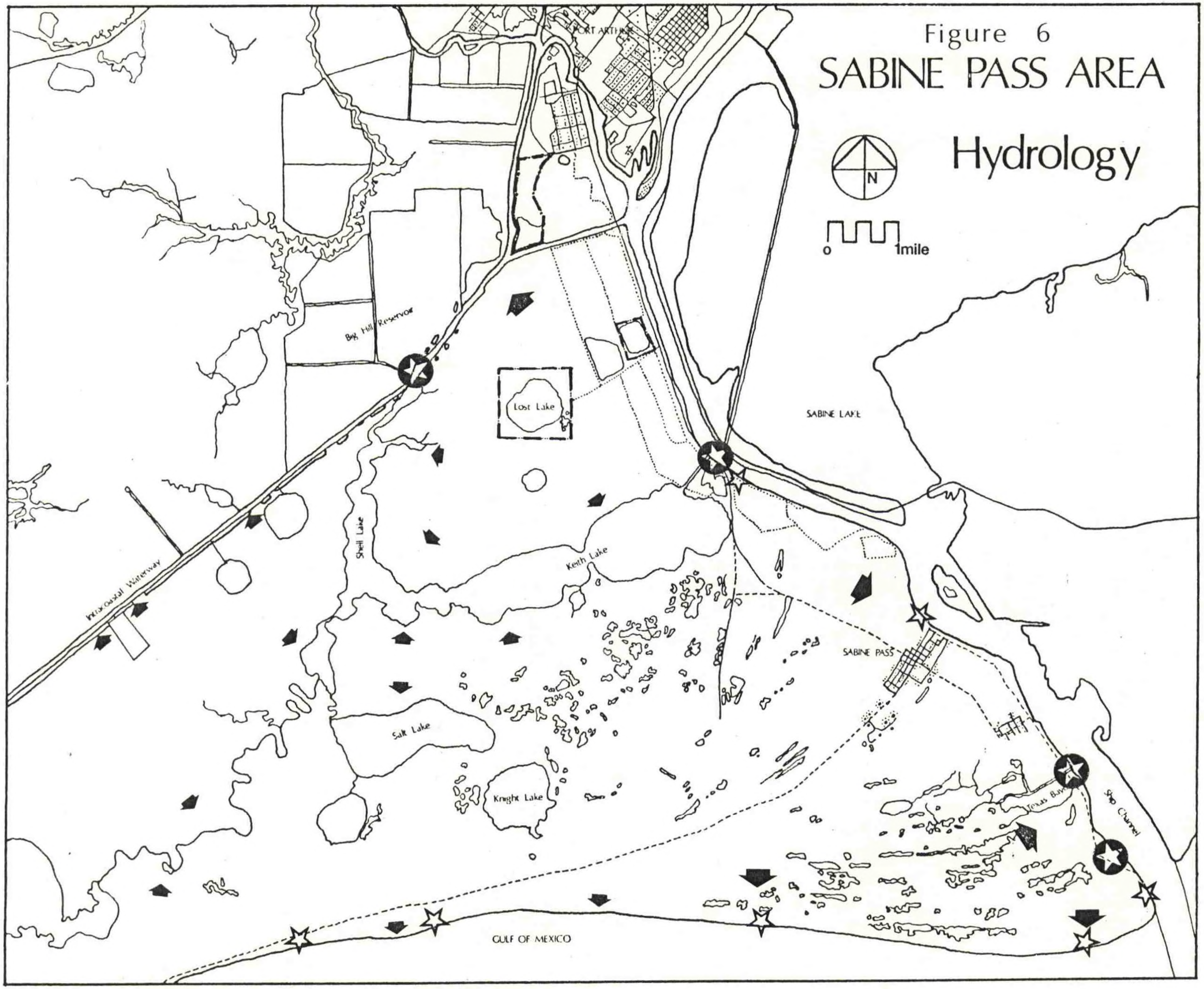


Figure 6
SABINE PASS AREA
Hydrology

stratified. However, the deep channels in the canal and the Sabine and Neches Rivers are typically stratified, with a bottom layer of saline water. If this layer is mixed with the surface water by winds or other means, it can be introduced into Sabine Lake from the northern end as well as the southern end, trapping a pool of fresher water in the middle of the lake (Wiersema et al., 1976).

TABLE 2
MAJOR MODIFICATIONS TO SABINE BASIN
(after Wiersema and Mitchell, 1973)

CHANNEL CONSTRUCTION	
Channelization of Sabine Pass to 12 feet	1878
Deepen Sabine Pass to 15 feet.	1880
Deepen Sabine Pass to 25 feet, construct jetties	1900
Dredge Sabine-Neches canal to 25 feet	1911
Dredge Channel to Beaumont, 30 feet	1919
Construct Gulf Intracoastal Waterway,12 feet	1927-1930
Deepen Ship Channel to 34 feet	1943
Deepen Ship Channel to 36 feet	1950
Deepen Ship channel to 40 feet	1967
SALT WATER INTRUSION FIRST NOTED, TAYLOR'S BAYOU	1901
SALT WATER INTRUSION PROBLEM DESCRIBED BY CORPS OF ENG.	1911
SALT WATER INTRUSION UP NECHES PAST BEAUMONT	1914-NOW
IMPOUNDMENT OF NECHES RIVER IN SAM RAYBURN RESERVOIR	1965
IMPOUNDMENT OF SABINE RIVER IN TOLEDO BEND RESERVOIR	1966
LEVEEING OF SPOIL DISPOSAL AREAS IN SABINE LAKE	1967, 1968
LEVEEING OF LITTLE KEITH LAKE	1967
REOPENING OF KEITH LAKE WATER EXCHANGE PASS	1976

It also appears that a significant portion of the fresh water discharge which bypasses Sabine Lake flows toward East Bay through the Gulf Intracoastal Waterway (GIWW). Since the GIWW is shallower than the Sabine-Neches Ship Channel, the fresher surface layer flows into the GIWW, while the dense, saline water remains in the deeper channel (Wiersema et al., 1976).

The major hydrologic features of the study area are shown on the Hydrology map (Figure 6). The general direction of drainage is shown by solid arrows, and major water exchange points are indicated by encircled stars. Minor water exchange points are indicated by stars. Major exchange points were located from the literature or by field reconnaissance. Minor exchange points were identified from false-color infra-red photography furnished by NASA (Johnson Space Center, 1975).

The cheniers are a natural impediment to north-south drainage, and the marshes north of the cheniers originally drained primarily to the east and north-east. The construction of the GIWW undoubtedly changed local drainage patterns, allowing many of the wetlands to drain northward. In addition, much draining and filling has occurred along the Sabine-Neches ship channel, and the west bank has been built up, cutting off direct drainage into the channel and Sabine Lake from the west, except through the exchange points shown. Many of these are man-made, and their drainage areas are generally unknown.

Tidal waters flow into the marshes through exchange points, rendering the marshes accessible to estuarine organisms which otherwise would not gain access to them. Exchange points also serve as the routes by which fixed carbon and nutrients exported from marshes reach the channel and finally, the Gulf.

South of the cheniers, drainage is either eastward through the Texas Bayou exchange point, or southward. Some areas experience no overland drainage and hold water until it either evaporates or percolates into the soil. These undrained swales range in size from a few hundred square feet to several acres.

VEGETATION

The vegetation analysis was accomplished primarily through reconnaissance by helicopter and was supplemented by limited site visits. Preliminary vegetation maps prepared by the Remote Sensing Center of Texas A and M University were also consulted, but the plant associations or groupings did not satisfy the needs of this research.

Classification was based in part on studies done in Chambers County (Harcombe and Neaville, 1977; Henderson and Harcombe, 1976. Resultant vegetation types were compared to those

Figure 7
Vegetation Map
Key to Symbols

SM	Salt marsh
BM–SF	Mixed salt flat and brackish marsh
B–1	Brackish marsh, type 1
B–2	Brackish marsh, type 2
B–3	Brackish marsh, type 3
CH	Coastal hardwoods
Pr	Coastal prairie
Im	Impoundment
SPr	Salty prairie
Fr	Fresh marsh
Br	Brushland
S	Spoil

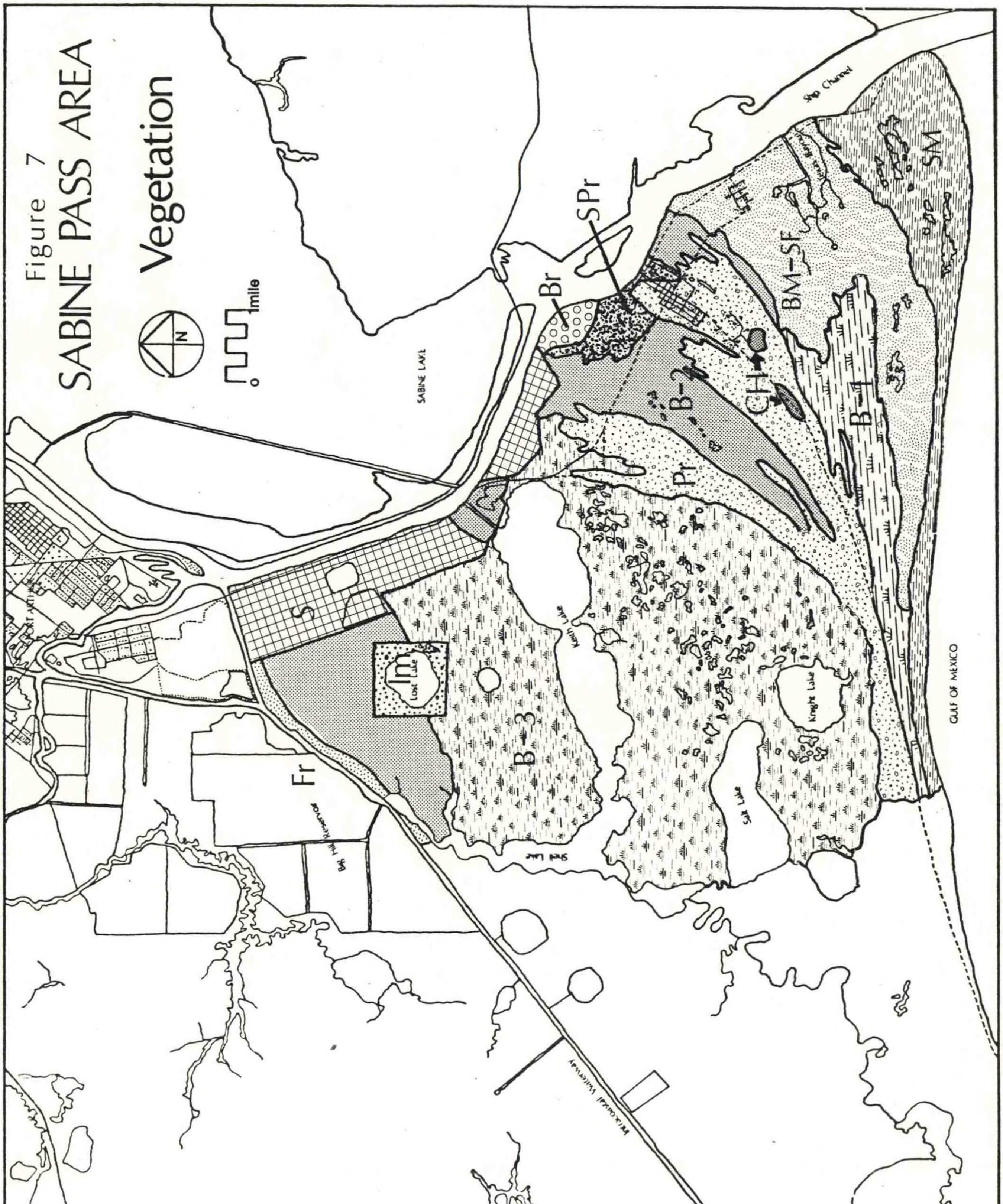
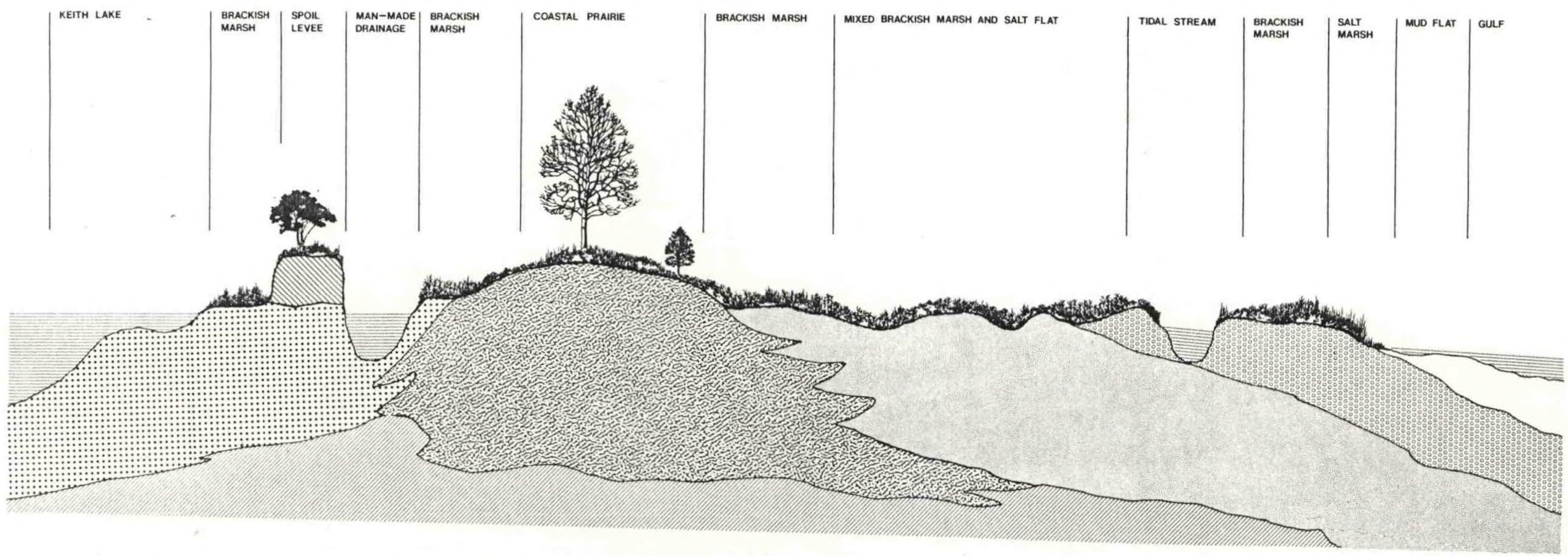


Figure 7
SABINE PASS AREA
Vegetation



CROSS SECTION: Texas Point To Keith Lake

NOTE: VERTICAL SCALE EXAGGERATED FOR ILLUSTRATIVE PURPOSES of the Soil Conservation Service (U.S.D.A., 1966). Scientific names of plant species referred to in the text are after Correll and Johnston (1970).

The vegetation of the Sabine Pass area is the product of a complex interaction among a number of environmental factors including climatic variables, salinity, tides, soils, topography, and disturbance. We have identified twelve different vegetation types in the Sabine Pass area which are shown on the Vegetation Map, Figure 7. A gradient of salinity and topography is evident in the vegetation pattern, as shown in the cross-section diagram on the previous page. The twelve types are: Salt Marsh, three types of Brackish Marsh, Mixed Salt Flat-Brackish Marsh, Prairie, Salt Prairie, Coastal Hardwoods, Fresh Marsh, Impoundments, Brushland, and Spoil Banks. Three of these, the Spoil bank, Brushland type, and Impoundment result from human disturbance or modification, while the rest represent relatively natural vegetation. Differences among them result mainly from differences in topography, soils, and local hydrologic regime, although human influence over the long term may have significantly altered their floristic make-up.

Along the coast, there is a narrow fringe of Salt Marsh, which widens to encompass Texas Point. This area, dominated by smooth cordgrass (Spartina alterniflora), is frequently flooded with sea water, and represents the most saline conditions. Behind this type is a marshy area characterized by a mound-and-swale topography which supports alternating Brackish Marsh and Salt Flat vegetation. The Brackish Marsh is dominated by marsh-hay cordgrass (Spartina patens) and seashore salt grass (Distichlis spicata) with some smooth cordgrass, while the most saline Salt Flat areas are characterized by succulent halophytes like Batis and Salicornia.
To the east, the Mixed Marsh-Salt Flat grades into an area of pure Brackish Marsh or saltmeadow dominated by marsh-hay cordgrass and seashore saltgrass. Usually, clumps of rush or sedge species such as saltmarsh bulrush and olney bulrush (Scirpus maritimus and Scirpus olneyi) are scattered throughout.

Prairie vegetation occupies the cheniers, and it is characterized by salt-tolerant grasses, with a few live oaks (Quercus virginiana), and sugarberry (Celtis laevigata) locally in the Coastal Hardwoods type. Important grasses include little bluestem (Scizachyrium scoparium), indiangrass (Sorghastrum avenaceum), gulfdune paspalum (Paspalum monostachyum) with switchgrass (Panicum virgatum), longtom (Pasapalum lividum), and gulf cordgrass (Spartina spartinae) (Harcombe and Neaville, 1977). Along the channel on the eastern edge of the study location is an area of Salt Prairie, dominated by a nearly pure stand of gulf cordgrass. This area is also somewhat higher than the surrounding Brackish Marsh.


Spartina patens
a
b
c
Distichlis spicata

In the "y" formed by the fan-shaped chenier is an area of Brackish Marsh with a large component of saltmarsh bulrush (Scirpus maritimus) in addition to the dominant marsh-hay cordgrass. It has been suggested (U.S.D.A., 1965) that this is indicative of burning or other disturbance.

North of the strand plain-chenier (or river-mouth accretion) ridges lies an extensive area of Brackish Marsh characterized by large stands of pure marsh-hay cordgrass, but also containing a few areas of mixed big cordgrass (Spartina cynosuroides) and rush or sedge species. This marsh is characterized by extensive shallow coastal lakes or ponds (Keith Lake, Shell Lake, Salt Lake, Fence Lake) connected by sluggish, meandering streams or bayous.

Lost Lake is an Impounded Area, and is characterized by fresh marsh species, including common reed (Phragmites communis), spikerush (Juncus sp.) and bulrush (Scirpus sp.), with big cordgrass and some spikerush. Bordering the Gulf Intracoastal Waterway is an open Fresh Marsh area, dominated by common reed.

The Spoil Areas have variable assemblages, but contained such weedy species as rattlebox (Sesbania drummondii), sea myrtle (Baccaharis halmifolia), bigleaf seepweed (Iva frutescens), sea ox-eye (Borrichia frutescens) and annual sumpweed (Suaeda linearis). The area of Brushland is also quite disturbed, and contains mostly sea myrtle, rattlebox, and other weedy shrubs and annuals.

Summarizing, the vegetation of the Sabine Pass area reflects patterns of topography and salinity, along with the effects of human disturbance. The salinity gradient runs generally north-south, becoming fresher as one moves northward, while complex patterns of ridge and swale topography are clearly indicated in the interfingering patterns of vegetation.

SOIL

The soils of the study area are of two general types: soils of the marshes, and soils of the prairie or beach ridge. General soil types are shown in Figure 8. As a rule, marsh soils are unsuitable for development, since they are unstable, perennially wet, and of high compressibility. Soils of this type include Harris clay (Ha), salt marsh, and tidal marsh soils (Figure 8). Salt marsh and tidal marsh soils are included in the (Ot) designation. Prairie soils include Sabine Loamy fine sand (Sa), Harris clay (shallow) over sand (Hs), and coastal soils (Cs). The Hs soils are generally higher in elevation than the Ha soils, and are slightly better drained. Also, because of the underlying sand layer, they are lower in compressibility and in shrink-swell potential. However, they are the poorest of the prairie soils.

Figure 8
Soils Map
Key to Symbols

	Sa	Sabine loamy fine sand
	Cs	Coastal soils, coarse sandy soils
	Ha	Harris clay
	Hs	Harris clay shallow over sand
	Ot	All other soils

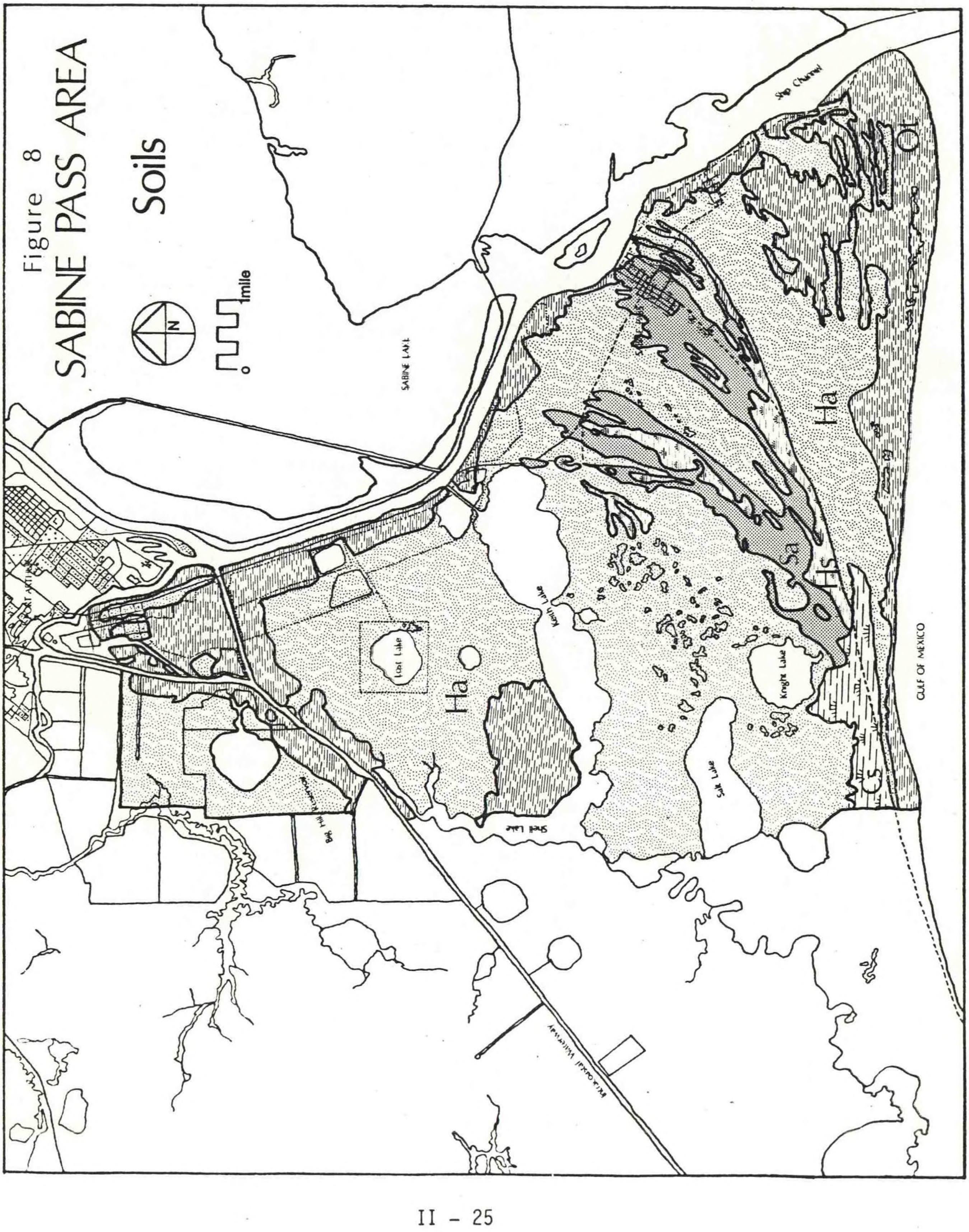


Figure 8
SABINE PASS AREA
Soils
N
0
1mile
SABINE LAKE
Ship Channel
Keith Lake
Lost Lake
Knights Lake
Salt Lake
Shell Lake
GULF OF MEXICO
Ha
Ha
Sa
Hs
Ol
Intracoastal Waterway

The Sabine soils (Sa) are the least compressible and best drained, being both higher in elevation and higher in sand content, but they are subject to inundation during tropical storms. All other soils in the study area (Ot) (mainly dredge spoil and levees) are variable in nature depending on parent soils and subsequent treatment. Special studies should be conducted on these soils before any sort of development is contemplated. Data on the soils of the study are are readily available from the Soil Conservation Service and are published in the Jefferson County Soil Survey (U.S.D.A., 1965).

WILDLIFE

The extensive brackish marshes in the Sabine Pass area, interlaced with numerous shallow streams, potholes and coastal lakes provide excellent habitat for waterfowl, wading birds, marsh birds, and fur-bearers. The study area is of great importance to coastal wintering populations of migratory waterfowl in the central flyway (U.S.F.W.S., 1977).

Aerial censuses conducted by the Texas Parks and Wildlife Department estimated peak waterfowl population in excess of 150,000 on the watershed during 1974-75. Table 3 presents a summary of waterfowl data for the Keith Lake Area, adjacent to Sea Rim State Park, and north of Sea Rim Marsh (U.S.F.W.S., 1977). The data illustrate that extremely high waterfowl populations may inhabit this area. Common waterfowl include gadwall, baldpate, green- and blue-winged teal, American wigeon, northern shoveler, pintail, and mottled duck. On the larger water bodies, diving ducks such as scaup, ruddy duck, redhead, and canvasback may be found in varying numbers (U.S.F.W.S., 1977).

Geese (primarily snow geese) use the marshes to some extent, but are more common in rice fields to the north. The inland lakes, pools, streams, and marshes provide optimum habitat for a great variety of marsh and wading birds. Common species include: roseate spoonbill, great, snowy, and cattle egret, great blue, little blue, Louisiana, and green herons, yellow-crowned and black-crowned night heron, least and American bittern, eared and pied-billed grebe, common and purple gallinule, long-billed curlew, whimbrel, golden and black-bellied plover, and common snipe. Other common species include black-necked stilt, American oyster-catcher, and willet. During the winter, all six species of North American rails are present. Two, possibly three of the rail species are known to breed in the area: the king, clapper, and perhaps black rail (U.S.F.W.S., 1977). Less common species include white-faced and white ibis, olivaceous and double-crested cormorant, anhinga, and white pelican. Table 4 gives the scientific names for each bird species mentioned in the text.

TABLE 3: Summary of Waterfowl Data for the 15,000-acre Area East of and Adjacent to Sea Rim State Park

Census Period	Number of Censuses	Average Number of Waterfowl Observed on a Census	Number of Waterfowl
October 11, 1974, to February 21, 1975	22	7,251	0-27,142
October 28, 1975 to January 20, 1976	12	12,019	3,074-43,341
October 28, 1976 to February 3, 1977	9	3,411	1,414- 8,036

1. Data provided by Texas Parks and Wildlife Department. The data provided is for an area north and west of the proposed Sea Rim Marsh. It is estimated by Texas Parks and Wildlife Department that the above counts are approximatly one-third higher than actual numbers on the project area.

TABLE 4: Selected Waterfowl and Marsh Birds of the Study Area, with Scientific Names

Gadwall	Anas strepera
American wigeon	Anas americana
Green-winged teal	Anas crecca
Blue-winged teal	Anas discors
American wigeon	Mareca americana
Northern shoveler	Spatula clypeata
Pintail	Anas acuta
Mottled duck	Anas fulvigula
Lesser scaup.	Aythea affinis
Bufflehead	Bucephala albeola
Redhead	Aythya americana
Canvasback	Aythya valisineria
Roseate spoonbill	Ajaia ajaja
Great egret	Casmerodius albus
Snowy egret	Egretta ibis
Great blue heron	Ardea herodias
Little blue heron	Egretta caerulea
Louisiana heron	Egretta tricolor
Green heron	Butorides virescens
Yellow-crowned night heron	Nycticorax violacea
Black-crowned night heron	Nycticorax nycticorax
Least bittern	Ixobrychus exilis
American bittern	Botaurus lemtogomopsis
Eared grebe	Podiceps nigricollis
Pied-billed grebe	Podilymbus podiceps
Common gallinule	Gallinula chloropus
Purple gallinule	Porphyrula martinica
Long-billed curlew	Numenius americanus
Golden plover	Pluvialis dominica
Black bellied plover	Pluvialis squatarola
Common snipe	Capella gallinago
Black-necked stilt	Himantopus mexicanus
American oystercatcher	Haematopus palliatus
Willet	Catoptrophorus semipalmatus
King rail	Rallus elegans
Clapper rail	Rallus longirostris
Virginia rail	Rallus limicola
Black rail	Latterallus jamaicensis
Yellow rail	Coturnicops noveboracensis
Sora rail	Porzana carolina
White-faced ibis	Plegadis chihi
White ibis	Endocimus albus
Olivaceous cormorant	Phalacrocorax olivaceus
Double-crested cormorant	Phalacrocorax auritus
Anhinga	Anhinga anhinga
White pelican	Pelecanus erythrorhynchus
Greater yellowlegs	Tringa melanoleuca
Snow goose	Chen caerulescens
Coot	Fulica americana
Marsh Hawk	Circus cyaneus
Swamp sparrow	Melospiza georgiana
Forsters tern	Sterna forsteri

Larger mammals characteristic of these marshes include nutria (Myocastor coypus), raccoon (Procyon lotor), muskrat (Ondatra zibethicus), swamp rabbit (Sylvilagus aquaticus), mink (Mustela vison), river otter (Lutra canadensis), and red wolf (Canis rufus). Numerous smaller rodents are also present. The red wolf is an endangered species, and it is now thought to be largely absent from the study area. However, it is found in the sandier, upland parts of the McFaddin Marsh to the west. (U.S.F.W.S., 1977). Other mammals which may occur in the study area include oppossum (Didelphis virginiana), skunk (Mephitis mephitis), bobcat (Lynx rufus). grey fox (Urocyon cinereoargenteus) and possibly, red fox (Vulpes fulva). White-tailed deer (Odocoileus virginianus) occur on the wooded portions of the chenier (U.S.F.W.S., 1977).

Common reptiles of the study area are the American alligator (Alligator mississippiensis), red-eared turtle (Pseudemys scripta elegans) the snapping turtle (Chelydra serpentina), stinkpot (Sternotherus odoratus), speckled king snake (Lampropeltis getulus), and the cottonmouth (Agkistrodon piscivorous). The American alligator is a threatened species in this part of Texas. Texas Parks and Wildlife personnel estimate that the J.D. Murphree Wildlife Management Area has the densest populations in the state, followed by the Willow Slough Marsh on the McFaddin Marsh property to the west. One very large alligator, and several smaller individuals were noted during the helicopter reconnaissance.

Common invertebrates of the study area include snails (Melampus sp. and Littorina irrorata), clams (Rangia cuneata), blue crabs (Callinectes sapidus) fiddler crabs (Uca sp.), shrimp (Penaeus sp.) the crawfish (Procamberus clarkii), and a host of polychaetes, insects, spiders, and other crustaceans.

AQUATIC SPECIES

Phytoplankton, such as diatoms, dinoflagellates, and green and blue-green algae are the major aquatic plant species. These organisms capture solar energy and serve as the base of the aquatic food chain. Aquatic systems in the study area also receive an energy "subsidy" from the surrounding wetlands in the form of dissolved or particulate organic materials, called "detritus". Figure 9 shows a generalized aquatic food web, and Table 5 gives examples of consumer species represented by each hexagonal symbol. As can be seen from this diagram, an organism may utilize one or more food sources, depending on its age, the season, or availability of food (Gosselink, et al., 1979).

Figure 9. Generalized aquatic food web. Major sources of food originating within the water are phytoplankton (1) and benthic plants (2). This is supplemented by organic detritus input from the marshes and adjacent habitats (3). Much of this production enters the aquatic detrital system (4). The letters within the hexagonal symbols represent different consumers which utilize certain food sources, as indicated by the arrows.Representative species for each are listed in Table 5. (Figure and list modified after U.S.F.W.S., 1979).

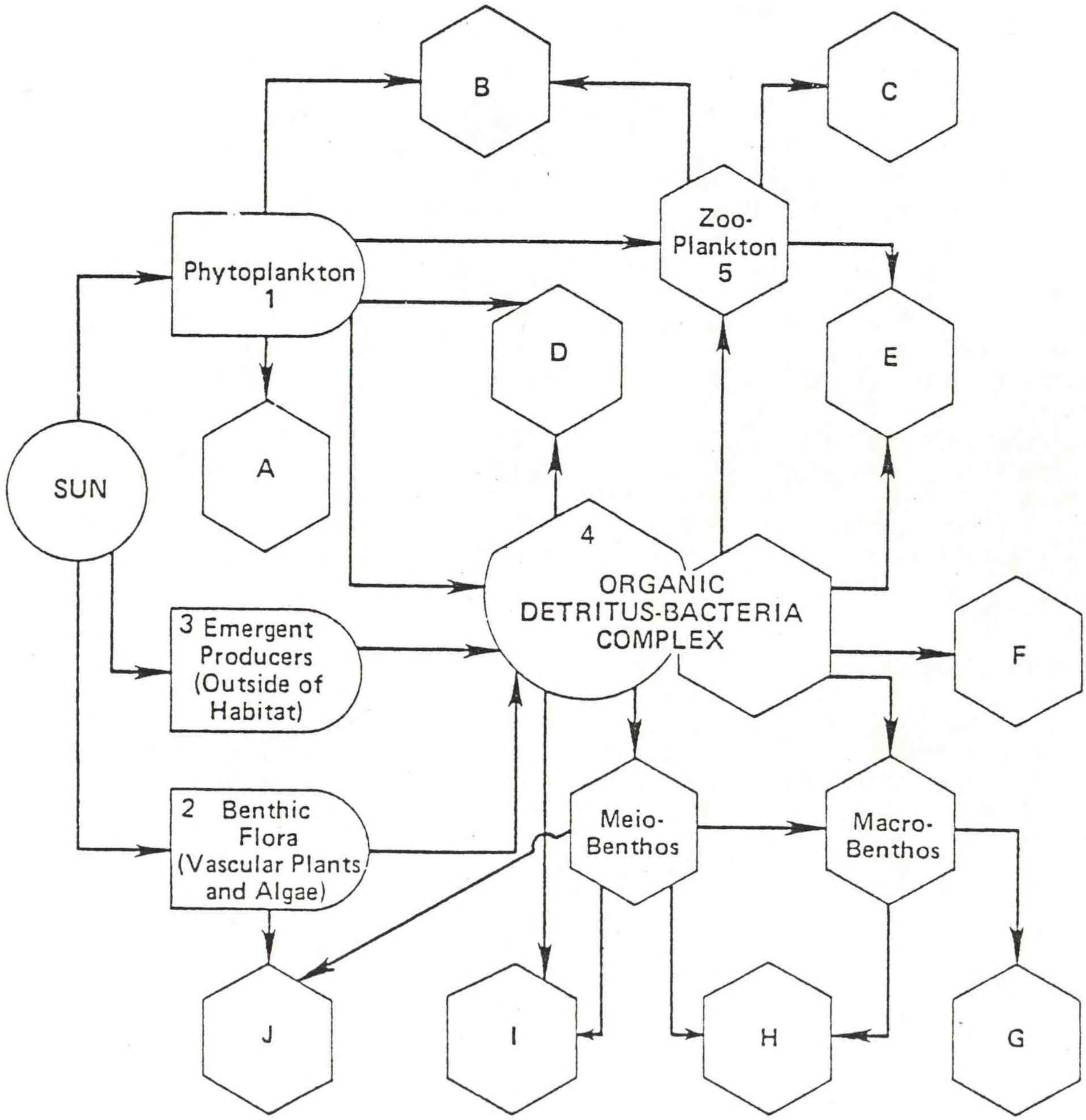


TABLE 5: Consumers Species Represented by Lettered Hexagonal Symbols (Figure 9)

A.

Gulf menhaden (juvenile)

B

Threadfin shad (juvenile)

C

Sand seatrout (juvenile)

D

Marsh clam or Rangia (adult)
Gulf Menhaden (adult)

E

Bay anchovy (juvenile and adult)
Atlantic croaker (young-of-the-year)

F

Gulf Menhaden (juvenile)
Striped mullet (juvenile and adult)

G

Largemouth bass (adult)
Tidewater silversides (adult)
Red drum (adult)
Black drum (juvenile)
Sand trout (adult)
Spotted gar (adult)
Alligator gar (adult)
Speckled trout (adult)
Southern flounder (adult)
American alligator (adult)
Snapping turtle (adult)
Red-eared turtle (juvenile and adult)
Eared grebe (adult)
Great blue heron (adult)
Little blue heron (adult)
Green heron (adult
Pinfish (adult)
White-faced ibis (adult)
White ibis (adult)
King rail (adult)
Clapper rail (adult)
Other ducks, gulls, terns and wading birds

G (continued)

Common muskrat (adult)
Northern raccoon (adult)
Nearctic river otter (adult)
North American mink (adult)

H

Blue crab (juvenile and adult)
Sea catfish or hardhead (juvenile and adult)
Blue catfish (adult)
Brown snake (adult)
Garter snake (adult)
Pied-billed grebe (adult)
Least bittern (adult)
Northern shoveler (adult)
Hooded Merganser (adult)
Virginia rail (adult)
Sora
Kildeer (adult)
Other shorebirds

I

White shrimp (juvenile)
Freshwater prawn (adult)
Gizzard shad (adult)
Tidewater silversides(adult)
Pinfish (juvenile)
Spot (juvenile and adult)

Atlantic Croaker (juvenile and adult)
Channel catfish (juvenile)
Blue catfish (juvenile)

J

Sheepshead (adult)
Pinfish (adult)
American coot (adult)
Canada goose (adult)
Nutria (adult)

Phytoplankton have been studied in the long-term for Sabine Lake (Wiersema et al., 1976), while some sampling has been done in Sea Rim State Park, specifically Keith Lake (Texas Parks and Wildlife Dept., unpublished, 1977). Comparison of the data is shown in Table 6.

TABLE 6
Phytoplankton Abundance, Sabine Lake and Keith Lake
Per Cent and Total Density

Type	Sabine Lake[a]	Keith Lake[b]
Green Algae	36.4	Trace
Diatoms	45.0	16.2
Blue-green algae	4.6	63.8
Euglenoids	7.1	-
Dinoflagellates	5.5	Trace
Other	1.4	19.6
Total Density June, in cells/cu.ft.	5,573,500	29,569,500

a. 1975 b. 1977

From this table, it is apparent that phytoplankton densities are much higher within the Keith Lake Compex than in Sabine Lake. Furthermore, the populations are very different in composition . The densities found in Sabine Lake are low in comparison to most Texas freshwater reservoirs, marine coastal areas, and other estuaries in Texas, while the Keith Lake complex has comparatively high densities (Wiersema et al., 1976). The blue-green component is large in the Keith Lake sample, as is characteristic of Texas reservoirs. Diatoms and dinoflagellates in both samples were a mixture of fresh and brackish water species which are frequently found in coastal areas of the Gulf of Mexico (Wiersema et al., 1976).

Wiersema et al.,(1976) link low densities and low levels of primary productivity in Sabine Lake to the fact that much of the phytoplankton present in the lake is derived from populations recently introduced from freshwater or the open sea. These populations are unable to propagate or have a limited survival potential in the lake itself. Complex north-south salinity gradients resulting from intrusion of saline water at both ends of the lake may contribute to sudden shifts in salinity, or the creation of conditions unfavorable for phytoplankton propagation.The Keith Lake complex is probably more stable, supporting a native population, well adapted to the prevailing conditions. Data also exist which suggest that Sabine Lake is nitrogen deficient, and if more nitrogen were available, the standing crop of phytoplankton might increase (Wiersema et al., 1976). Since the densities in Keith Lake were so high, it is improbable that nutrients such as nitrogen are limiting phytoplankton growth. Zooplankton in Sabine Lake and in Keith Lake were dominated by the copepod Acartia tonsa. Sabine Lake summer densities averaged 4,333 organisms/cu.yd. during 1975, while the Keith Lake complex averaged 9,691 organisms/cu.yd. during June of 1977. However, Sabine Lake often experienced densities quite comparable to those in Keith Lake under good conditions. In Sabine Lake, peak Acartia populations occurred during periods of relatively low flow, high salinity and high temperature.

Unlike the phytoplankton, the zooplankton of Sabine Lake appear to develop substantial native populations which successfully grow and reproduce within the estuary. High densities of protozoans (Tintinnids) were found in Keith Lake also, but these organisms were not sampled in the Sabine Lake study (Wiersema et al, 1976). The copepod Acartia is probably an important food source for other organisms in Sabine Lake, and in the Keith Lake system as well.

The most abundant species found by Stelly (1979, unpublished) in the Keith Lake system was bay anchovy (Anchoa mitchilli), followed by Atlantic croaker (Micropogon undulatus), Gulf menhaden (Brevoortia patronus), sand seatrout (Cynoscion arenarius), and white shrimp (Penaeus setiferus). Also noted were redfish (Sciaenops ocellata), speckled trout (Cynoscion nebulosus), and southern flounder (Paralichthys lethostigma). The five most common organisms caught in Sabine Lake are shown in Table 7. Table 8 is a list of species captured in a Spartina patens marsh close to Sabine Pass. This list is quite representative of area marshes (Wiersema et al, 1976).

TABLE 7

Scientific Name	Common Name	per cent occurence in total samples
Anchoa mitchilli	Bay anchovy	86
Micropogon undulatus	Atlantic croaker	84
Sciaenidae	(Trout, redfish, drum, croaker, whiting)	55
Brevoortia sp.	Menhaden	19
Penaeus setiferus	White shrimp	49

TABLE 8
LIST OF TAXA CAPTURED IN MARSH ENTRAPMENT STUDY

Species	Common Name
Alligator gar	Lepisosteus spatula
Spotted gar	Lepisosteus oculatus
Ladyfish	Elops saurus
Speckled worm eel	Myrophis punctatus
Bay anchovy	Anchoa mitchilli
Atlantic needlefish	Strongylura marina
Sheepshead minnow	Cyprinodon variegatus
Rainwater killifish	Lucania parva
Bayou killifish	Fundulus pulverus
Gulf killifish	Fundulus pulverus
Saltmarsh topminnow	Fundulus jenkinsi
Sailfin molly	Poecilia latipinna
Mosquitofish	Gambusia affinis
Tidewater silversides	Menidia beryllina
Redear sunfish	Lepomis microlophus
Sand seatrout	Cynoscion arenarius
Spot	Leiostomus xanthurus
Atlantic croaker	Micropogon undulatus
Stripped mullet	Mugil cephalus
Fat sleeper	Dormitator maculatus
Goby	Gobiidae sp.
Violet goby	Gobioides broussoneti
Naked goby	Gobiosoma bosci
Goby	Microgobius sp.
Clown goby	Microgobius gulosus
Lyre goby	Evorthodus lyricus
Darter goby	Gobionellus boleosoma
Freshwater goby	Gobionellus shufeldti
Southern flounder	Paralichthys lethostigma
Brown shrimp	Penaeus aztecus
White shrimp	Penaeus setiferus
Freshwater prawn	Macrobrachium ohione
Grass shrimp	Palaemonetes pugio
Grass shrimp	Palaemonetes intermedia
Blue crab	Callinectes sapidus
	Xanthidae(family)
Stone crab	Menippe mercenaria
Mud crab	Panopeus herbstii*

*Not collected in trawl samples stations (1-25).

The opening of the Keith Lake water exchange pass is thought to have improved access and salinity conditions within the Keith Lake estuarine system, thereby increasing utilization of this area by desirable estuarine-dependent species, including important finfish and shellfish. The prior closing of this exchange point in 1966 was linked with both a decline in the Sabine Lake fishery for finfish and shrimp (Wiersema and Mitchell, 1973), and in a reduction of desirable species within the system (U.S.D.A., 1976).

REVIEW OF GENERAL SYSTEM FUNCTION

The entire Sabine Pass area is linked as a single system by water. As an estuarine system, it is characterized by the interaction and mixing of seawater originating in the Gulf and freshwater entering from the Sabine and Neches Rivers and Taylor's Bayou. The coastal lakes, potholes, and ponds are linked to the Gulf of Mexico and Sabine Lake by numerous streams, bayous, man-made channels and canals. Productive brackish and saline marshes rim these water bodies. They provide food, in the form of fixed organic carbon, for a host of estuarine-dependent fish and shellfish. They provide habitat for numerous and diverse organisms important to man either directly (as in furbearers, waterfowl, fish and shellfish which are all harvested) or indirectly (as in the small benthic organisms which serve as food to common game species, or the microscopic algal cell which adds oxygen to the water during the course of photosynthesis).

Geologic processes which have been molding and shaping the face of the region for several thousand years are also important to understand. The activities of man can affect these processes in subtle or dramatic ways, many of which are only now being fully understood. For example, it was understanding the accretionary processes responsible for Sabine Pass and the Chenier Plain in their current configurations which led to our understanding of the importance of Mississippi River sediments in nourishing the coastlines of Texas and western Louisiana even now. As long as the Mississippi River is maintained in its current position, the coastlines in Texas and Western Louisiana will continue to undergo net erosion over time.

It is only by understanding ecosystem function in the Sabine Pass area that it becomes possible to identify sensitive areas, or evaluate the benefits inherent in the preservation of certain functions. The following sections will begin the process of sound environmental planning for Sabine Pass.

3. The Value Of An Acre Of Marsh

Decision-makers are often faced with the task of evaluating alternative plans or strategies for natural resource development. A major problem encountered in such a task is settling on a system of accounting which allows comparison of essentially unlike benefits and costs. Increasingly, decision-makers have sought to attach a dollar value to items formerly thought to be priceless (or at least free): clean air and water, wildlife, ecosystem functioning (Westman, 1977). The expectation is that by reducing all costs and benefits associated with a set of alternatives to dollar values, an objective basis for decision-making can be achieved.

There are a number of limitations to this approach. The major limitation is that there are no market values attached to many of the benefits provided by functioning ecosystems because there is no market for them. Nature has, until now, provided them free and in sufficient quantity. Thus, people have had to develop various methods of estimating or attributing values to functions or processes for which no market exists. This is done by assuming that the functions or processes contribute to certain markets, and then attempting to estimate the monetary value of that contribution by various means.

This chapter will address the value of the Sabine Pass marsh. In the following section, the functional and structural benefits provided by marsh-estuarine ecosystems will be set forth. Next, the various valuation techniques will be reviewed, and their limitations discussed. One technique, the Gross Benefits Technique, was selected, and applied to the Sabine Pass area. The results of the application of this valuation technique will then be compared with actual real estate values.

PUBLIC BENEFITS PROVIDED BY THE MARSH-ESTUARINE ECOSYSTEM

Ecologists often speak of ecosystems in terms of their structure and function. Ecosystem structure refers to the species present, the total amount of living material (biomass) and its spatial and temporal arrangement. Ecosystem functions are those transfers of material and energy carried out by the system as a part of existence and survival. The stuctural components of ecosystems are the "free goods" of nature, while the functions can be thought of as "nature's free services" (Westman, 1977).

Following Westman's logic, society reaps two major types of benefits from the ecosystem structure: (1) the direct harvest of biomass for marketable goods and products, and (2) the use and enjoyment of the ecosystem for recreation, education, or for some intrinsic value attributed it by a human ethic (Ehrenfeld, 1976). Ecosystem functions also provide society with a number of services, including cycling and storage of chemical elements, flood control, fixation of solar energy, stabilization of soil, and decomposition of organic matter. The potential structural and functional benefits of the marsh-estuarine complex are listed in Table 9.

The most familiar structural benefits are harvestable goods - items for which a ready market exists. These include fish and shellfish, nutria, muskrat, mink and edible game species. The ecosystem structure also affords certain recreational oppportunities, including sport hunting, fishing, and non-consumptive uses. People are less accustomed to thinking about the functions of the ecosystems as beneficial. Yet study has shown that the complex interactions between the living and non-living elements of ecosystems can be of great benefit to human health and welfare. Functional benefits of this sort include flood control, filtering of sediments, pollutant removal, climate regulation, gas exchange, and shoreline stabilization. A short but fairly complete discussion of these functions is found in Thurow, et. al., (1975). John Clark, in his book Coastal Ecosystems: Ecological Considerations for Management of the Coastal Zone, has presented detailed descriptions of marsh-estuarine ecosystem functioning and has enumerated some of the complex mechanisms by which the functions benefit man.

Flood control is a good example of a functional benefit of coastal wetlands which has been long overlooked. Coastal wetlands may serve as barriers to storms and floods. They are capable of absorbing and retaining significant amounts of water from runoff. They can absorb storm water from the sea and buffer inland areas from some of the effects of storm surges and erosion.

In addition, there are other beneficial services provided by both the structure and functioning of ecosystems. Educational opportunities exist, both for teaching and for scientific study of the structural and functional aspects of ecosystems. This could take the form of school field trips or the learning that children experience from visiting and observing natural ecosystems on their own. Finally, the natural area may have some intrinsic value. A person could see it as aesthetically

TABLE 9
PRIMARY BENEFITS PROVIDED BY MARSH-ESTUARINE ECOSYSTEM

<u>FUNCTIONAL</u>

(1) BENEFITS OF WATER DETENTION & STORAGE

- Flood Control
  - Fur-bearers
  - Filtering of sediments
  - Pollutant Removal
- Aquifer Recharge & Soil Moisture Storage
- Water Availability in Times of Drought

(2) BENEFITS OF ENERGY FIXATION, STORAGE, RELEASE, AND TRANSPORT

- Renewal of Harvestable Goods
- Climate Regulation
- Gaseous Balance in Atmosphere and Water

(3) BENEFITS OF PLANT SOIL-WATER INTERACTIONS

- Shoreline Stabilization
- Soil Stabilization

(4) REMOVAL AND TRAPPING OF WIND-BORNE PARTICULATES

(5) EDUCATIONAL BENEFITS

- Scientific Study
- Teaching

(6) INTRINSIC VALUE

- Ethical
- Aesthetic

(7) UNDISCOVERED VALUE

<u>STRUCTURAL</u>

(1) HARVESTABLE GOODS

- Fish
- Fur-bearers
- Forage for Cattle
- Edible Game Species

(2) RECREATION

- Sport Hunting, Sport Fishing
- Bird-watching, Hiking, Camping, Tourism, Other

(3) EDUCATIONAL BENEFITS

- Scientific Study
- Teaching

(4) INTRINSIC VALUE

- Ethical
- Aesthetic

(5) UNDISCOVERED VALUE

valuable, meaning that they perceive beauty in it, or because of a personal system of morals and values, one could impart some ethical value to the ecosystem. Traditionally, monetary values are not assigned to such values, but it is important to keep in mind that they do exist. It is also important to recall that there may be some as yet undiscovered structural or functional value in any ecosystem.

Many of the benefits listed in Table 9 accrue directly to the landowners (sale of cattle, lease of land for hunting). Others accrue to the public at large - if they are provided for one member of society, they are provided for all (Thurow, et al., 1975) (gas exchange, water purification). This is particularly true of the functional benefits, but it is also true of many structural ones as well. In addition to the primary benefits listed in Table 9, numerous secondary benefits accrue to others beside the landowner. Examples of secondary benefits include those resulting from tourism or the processing and marketing of commercial items harvested such as cattle or fur-bearers.

MARKET IMPERFECTIONS

Clean water and air have traditionally been thought of as free goods and have been treated as if they had no value (i.e. as disposal sites for residuals of "productive" activities). When these discharges impose a cost on others and are not borne by the entity discharging the waste, an "externality" (Anderson, 1978) is said to exist. This results in a misallocation of resources (a market imperfection) because the producer will be paying production costs lower than if he were required to pay for prevention, compensation, or repair of the externality, and people who do not benefit from the production bear some of the cost of that activity.

This sort of market imperfection also applies to the non-valuation of public benefits by the real estate market. Real estate values are generally determined by the "highest and best use", usually defined as that use which generates maximum income for the owner. Thus, real estate values do not take into account those benefits which do not directly accrue to the owner. An individual wetland owner cannot sell his climate regulation function or flood control function on the open market, and he cannot prevent people who do not pay for the functions from benefitting from them. He can, however, fill and develop the land and increase his income and the value of the real estate. The land will no longer provide the public benefits that it did, and society will bear the cost of the externality. The cost borne by society might be an increase in flood or hurricane damage to homes or businesses because of the lost water retention function. Eventually, the community might be forced to construct a seawall or other flood control structure to replace the function. Losses of other functions, like the carbon fixation function, might cause a slight degradation of water quality or a reduced fish catch, but these effects would be difficult to trace or quantify, and the effects would be cumulative.

Summarizing, there are a number of public benefits provided by marsh-estuarine ecosystems. These include both "goods" and "services", most of which are not valued in the private real estate market, but which may be essential to the public health, safety and well-being. In the following section, a number of methods of evaluating the monetary value of these public benefits will be examined.

VALUATION TECHNIQUES: A REVIEW

A number of authors have dealt with the question of estimating the "true" value to society (as opposed to the real estate value) of tidal marshes (Odum and Odum, 1972; Gosselink et al., 1974; Hill, 1976; Mumphrey et al., 1978; Westman, 1977; and Ehrenfeld, 1976). All of these authors use one or more variations of the "component-function" approach, wherein the products, uses, and functions which are judged to have a value to man are identified, some value is attached to them, and the values for non-competing products, uses and functions are summed. There is general agreement among all authors as to the products, uses, and functions which should be included in the evaluation. But there is little agreement about how a monetary value should be arrived at for each component.

Gross Benefits Technique

One way to arrive at a value is to sum the monetary values of all primary and secondary goods and services associated with or dependent upon the marsh. The use of this approach assumes that the total value of all of these goods and services represents the gross benefit to the economy attributable to the marsh. Use of this approach (known as the Gross Benefits, or Input-Output approach) limits the consideration to those goods and services which are bought and sold, and ignores non-market values. In addition, it requires some ingenuity to obtain reasonable estimates of secondary benefits attributable to the marsh. Finally, it takes all the values of the associated economic transactions and attributes them to the marsh. This approach indicates the dependency of the jobs and industries on the existence of the natural resource (Gosselink et al., 1974). Usually, such a calculation is meaningful only if applied on a regional scale or over some large area. Application of this approach to the Sabine Pass Area is found in the next section.

Consumers' Surplus Technique

Another way to estimate a value utilzes the concept of consumers' surplus (Gosselink et al., 1974; and Mumphrey et al., 1978), namely the difference between the purchase price and the highest price that the consumer would be willing to pay. The highest price minus the actual cost (labor, capital outlay, operation, management and profit) represents the consumers' surplus. The producers' surplus (profit) plus the consumers' surplus represents the net value of the resource to society (Mumphrey et al., 1978).

Large amounts of data are required for the implementation of this approach and most of it is not readily available. It would be theoretically possible to determine a consumers' surplus value for non-market goods and services which are now provided free by nature, based on survey response. However, it would be extremely difficult to interpret the results and apply them in any meaningful way. Because of the need for voluminous and detailed economic and survey data, this approach was not selected for implementation in this study.

Least Cost Alternative Technique

A third method, which is particularly applicable to the evaluation of functions for which there is no existing market, is the "least cost alternative" approach. In this method, the value of each function is assumed to be equal to the cost of using the next-best method to accomplish the same result (Odum and Odum, 1972; Gosselink et al, 1974).

Of course, there is the possibility that no alternative method exists to perform some of the functions which the natural ecosystem performs, but the estimation of the costs associated with the loss of some of nature's free services may serve to illustrate the magnitude of the loss. This technique has been applied to such functions as secondary and tertiary waste treatment (Gosselink et al., 1974), flood control and aesthetic value (Larson, 1975). This approach will be applied to selected functions not valued by the "Gross Benefits" technique.

Life Support Technique

The final method is suggested by the work of H.T. Odum and E. P. Odum (Odum (1971), and Odum and Odum (1972), and is enumerated in Gosselink et al., (1974). The approach is based on estimating the "life support" function as total energy fixed by a system. This method has the advantage of estimating an overall value for a region without specifying how the work is divided among all the components. Based on estimates of gross primary productivity, this method ignores work done by other means, such as water flow, imported organic matter, and temperature. However, it can serve as an indicator of the amount of work a system can do, and it has the added advantage of accounting for biological work we have not discovered (undiscovered benefits based on marsh production), and being applicable to a particular acre of marsh. Application of this technique will also be shown in the following sections.

MARSH VALUATION: GROSS BENEFITS

The first technique will focus on the gross economic benefits which accrue to the region as a result of activities dependent on the marsh. The major components which can be evaluated in this way are commercial fish catch, trapping, sport fishing, hunting, and recreation.

Table 10 shows the average annual value (1975 dollars) of the major commercial species landed in the Sabine Basin.

TABLE 10: COMMERCIAL FISHING: SABINE PASS

Commercial Fish	Avg. Annual Value (1975 Dollars)
Shrimp[1]	$ 2,447,431
Blue Crab[2]	108,400
Menhaden[2]	1,153,600
Finfish[2]	13,300
REPORTED TOTAL	$ 3,722,731
Average value-added multiplier[3]	3.0755
Gross Retail Value	$ 11,449,259
Acres of Marsh (1975)[2]	105,071 acres
Value/Acre (avg. annual)	$108.97

[1]Value calculated from N.M.F.S. Data, Orman Farley, personal communication.

[2]Value from Gosselink, et al. (1979), for 1975.

[3]Value from Mumphrey et al., (1978), for 1975.

Admittedly, there is some question as to whether it is valid to attribute this catch to Sabine Basin marshes. First, one cannot prove that all of the fishery would be destroyed if the marshes were destroyed. Second, one cannot prove that all of the fish caught originated in the Sabine Basin, or were dependent upon it. Third, this value is based upon reported catch, which may represent only one-third to one-half of the actual catch (Orman Farley, N.M.F.S , pers. comm.). Even so, these figures do represent the known landings in the basin, and as such, are the best estimates available. The Sabine Basin is sufficiently large that it can be assumed that the number of fish "exported" to other Basins is approximately equal to the number of fish entering the Basin before being caught.

Therefore, assuming these figures to be correct, the dockside value of the landing is $3,722,731. Using a value-added multiplier of 3.0755 to include all value added in processing and packaging (Mumphrey et al., 1978), the average annual gross retail value of all landings is $11,449,259 (1975 dollars). Dividing by 105,071 acres of marsh in the Basin, the average annual return per acre is $108.97 for commercial fisheries (Table 10).

For trapping, the average annual value of muskrat and nutria pelts is $937,500 (Table 11). Using a value-added factor of 3.0755 to represent the value added in processing probably underestimates the true amount, but since no data were available, it seemed best to use conservative values (Mumphrey, et al., 1978). Gross retail value was calculated as $2,883,281, and the average annual return per acre for trapping was $27.44. This was averaged over all marsh types, although brackish marshes are actually the most valuable for fur-bearers.

TABLE 11: TRAPPING, SABINE BASIN

	Average Annual Value
Muskrat and Nutria, Pelts only[1]	$ 937,500
Average value-added Factor[2]	30,755
Gross Retail Value	2,883,281
No. of Acres..........105,071	
Trapping Value/Acre	$27.44

[1]Value from Gosselink, et al. (1979), for 1975

[2]Value taken from Mumphrey et al., 1978. This value is assumed to underestimate the actual value-added multiplier, for which no data were available.

Table 12 gives two alternative values for sport fishing within the basin, based on a calculated expenditure per day or the Water Resources Council suggested value (1976) for a day of fishing. The calculated expenditure per fisherman annually is $281.97 for food, lodging, fees, equipment, and transportaton (Mumphrey et al., 1978). This figure was divided by 4.18 man-days/man/year of sport fishing demand (Gosselink, et al., 1979). to obtain an average daily expenditure of $67 per man-day of sport fishing. This figure is consistent with others used in this technique because it represents a gross benefit to the economy of a certain amount of retail sales.

TABLE 12: DEMAND FOR AND VALUE OF SPORT FISHING IN THE SABINE BASIN

	Activity Days /Yr X 1000[1]	Value/ Day (WRC)	Value/ Day[2] (RC)*	Total (WRC)	Total (RC)*
Saltwater	337.8	$2	$67	$ 675,600	$22,632,600
Freshwater	641.7	$2	$67	$1,283,400	$42,993,900
Shrimping	77.1	$2	$67	$ 154,200	$ 5,165,700
Crabbing	266.8	$2	$67	$ 533,600	$17,875,600
Crayfishing	87.8	$2	$67	$ 175,600	$ 5,882,600
No. of Acres of Marsh	105,071				
Value/Acre				$26.86	$ 899.87

[1] Source, Gosselink, et al. (1979)

[2] Source, Mumphrey et al., (1978), as shown in text.

*This study.

The Water Resources Council (1973) has set the value of a day of recreation at $2/day. This figure seems unrealistically low, but it is included for the sake of completeness. Because it is such a conservative figure, it is used so that a range of values can be obtained. It is not updated to current dollars because it does not necessarily represent a market value, although it is often used in place of one. Using the gross expenditures figure, the average annual/acre is $899.87, while using the Water Resources Council figure, the annual return is $26.86 per acre (see Table 12 above).

TABLE 13: USE AND VALUE OF HUNTING AND WILDLIFE ORIENTED RECREATION IN THE SABINE BASIN

	Activity Days[1]	Value/ Day (WRC)	Value/Day[2] (RC)*	Total (WRC)	Total (RC)*
Wildlife Oriented Recreation	141.80	$2	$122	$ 283,600	$ 17,299,600
Hunting	787.00		$122	$ 4,630,800	$ 96,014,000
Small Game	(408.70)	$3		$(1,226,100)	
Big Game	(47.30)	$9		$ (425,700)	
Waterfowl	(331.00)	$9		$(2,979,000)	
TOTAL				$ 4,914,400	$109,750,000
No. of Acres of Marsh	105,071				
Value/Acre (assuming 60 per cent attrib. to wetlands)				$ 28.06	$ 745.34

[1]Source, Gosselink et al. (1979).
[2]Source, Mumphrey, et al., (1978).

*This study.

Values for hunting and wildlife-oriented recreation (Table 13) were obtained in the same way, with the additional assumption that only 60 per cent of such expenditures are wetlands - related (Mumphrey et al., 1978). Those values were $28.06 and $592.46 per acre respectively.

Summing the values obtained above , the average annual return per acre of marsh was calculated as either $191.33 or $1782.13, depending on whether gross expenditures or the Water Resources Council's figures for a day of recreation were used to calculate benefits (Table 14). These values represent an estimated range for the potential annual benefit to the region's economy because of the presence and functioning of the marshes, which accrues to the region at large (i.e. the Sabine Basin), and not necessarily to the landowner.

TABLE 14: VALUE/ACRE ON GROSS ECONOMIC BENEFITS

Element	Value/Acre (WRC)	Value/Acre (This Study)
Commercial Fishing	$ 108.97	$ 108.97
Trapping	27.44	27.44
Sport Fishing	26.86	899.87
Hunting and Wildlife Oriented Recreation	28.06	745.85
TOTAL ANNUAL RETURN	$ 191.33	$ 1,782.13
Net Present Value (8 1/2 per cent, 1975 dollars)	is $2,251	$ 20,966.00
Net Present Value (1979 dollars)	is $2,887.	$ 26,891.00

Assuming an infinite income stream from the natural resources (Gosselink et al., 1974; Mumphrey et al., 1978) the equation to calculate net present value is:

$$V = \frac{a}{r}$$

where V = net present value
a = average annual return
r = interest rate.

Assuming a rate of 8 1/2 per cent, which is midway between the Corps of Engineers rate (6 7/8 per cent) and the current rate for long-term treasury bills (10 3/8 per cent), the net present value for an acre of marsh is either $2,887 per acre or, using the gross benefits technique, $26,891 per acre

LEAST COST ALTERNATIVE TECHNIQUE

In addition to the values calculated above, it is theoretically possible to evaluate some of the other functions performed by the marsh, including BOD (biological oxygen demand) removal, phosphorous removal and recycling (Gosselink et al., 1974), and soil stabilization.

Gosselink et al. (1974) point out that a major contribution of the estuaries is to treat wastes discharged into them. They estimate that the mid-Atlantic estuaries assimilate an average of 19.4 pounds of BOD per acre per day, providing both primary and secondary treatment (see Table 15). This yields a value of $405 per acre annually, or a net present value of $5,647 per acre. A value for tertiary treatment (e.g. phosphorous removal) can be arrived at in the same way based on removal and recycling of mineral nutrients by the natural system. Tertiary treatment is much more expensive, and values for phosphorous removal are given in Table 15 on an annual basis, and converted to net present value. Given data on phosphorous loading rates for the Sabine Pass (Gosselink et al.,1979), the value of this function was reduced to $150 from a potential $480 per acre. It should be recalled that this value is for phosphorous only, and does not account for other elements such as nitrogen and sulfur.

TABLE 15: SOME LEAST-COST ALTERNATIVE VALUES[1]

Function	Annual Return/Acre	Net Present Value
BOD Removal	$ 405	$ 4,765
Phosphorus Removal		
Mid-Atlantic Estuaries	$ 480	$ 5,647
Sabine Basin	$ 150	$ 1,765

[1]Values from Gosselink, et al., 1974.

One problem with this method is the difficulty of selecting an appropriate alternative, one which is truly equivalent. Such a choice is not only subjective, but may, in fact, be arbitrary, and subject to differing interpretations. Furthermore, it lacks the flexibility of allowing trade-offs, because there is no base for comparison. Perhaps its only utility is in demonstrating that humans would have a difficult time of it if they were required to take over the performance of nature's work.

LIFE SUPPORT TECHNIQUE

The final approach, estimating the "life support" function of ecosystems relies on the concept of energy flow. It makes the assumption that a unit of energy fixed by a natural system is equivalent to a unit of energy used by a factory or home in the production of goods. It assumes that since money and energy flow in opposite directions, that the ratio of Gross National Product to National Energy Consumption can be used to equate energy with money. It is possible to question both assumptions for numerous reasons, and this value should be accepted only as a gross approximation. In round figures, 10^{16} kilocalories are consumed to produce 10^{12} dollars of goods, making 10^{4} Kilocalories equivalent to one dollar (approximately). At this rate, using net primary productivity data from Chambers County marshes (about 13,400 lbs.acre/year of dry matter), the annual return is $2,479 per acre, and the net present value is $29,165. This figure is comparable to the results of the Gross Benefits technique, $21,440 per acre.

REAL ESTATE VALUES

Part of the purpose of estimating or arriving at a monetary value or values for the marsh is to compare it to real-estate values. Reported values and comparable sales data used in this report are drawn from a study done for the City of Port Arthur by Donnie M. Jones and Associates (1979). This section describes the results of the analysis of real-estate values. All values have been adjusted for inflation by updating to 1979 dollars. Based on the results of the natural resource inventory, the study area was divided into three land types, based roughly on capability. The major criteria for classification were soil and vegetation types. The three categories were chenier, spoil, and marsh. Within each major category, the specific piece of land was evaluated for three characteristics: highway access, water access, and whether the land was bulkheaded or not. Presumably, these characteristics determine the relative desirability of land for development. Results of this exercise are shown in Table 16.

It is apparent that spoil with good water and highway access is the most valuable. Average price per acre was $34,338, with a high of $50,002, and a low of $8,089. This land is likely to be used for light industry. All spoil seemed to have a high value, averaging $26,916 per acre.

Lands on the chenier were much less expensive. Uses are mainly as residential and commercial property with little industry. Mean price per acre is $2,021. Marsh lands are the least expensive in terms of real estate value, and their value was not clearly dependent on either water or highway access. Average price per acre was $301.

As these values clearly show, there is a dichotomy between the real estate value and the value to society. Lands which have little public benefit value may have high real estate values, based on annual income which accrues to the owner. These high values may create a pressure on marsh owners to convert their land to a more profitable use. In the ideal situation, this would be accomplished without interruption or diminishment of the public benefit natural functions. However, this is seldom the case. Usually, development of marshes involves draining, filling, and total conversion to other uses, terminating their contribution to the functioning of the marsh-estuarine system. In chapter five, the concept of performance standards wil be investigated, as a way of allowing development while still maintaining critical functions.

TABLE 16: ESTIMATED MARKET VALUE OF SELECTED LAND TYPES

Highway Access	Water Access	Bulkhead	Average Price per acre (Adjusted for inflation)
		Spoil	
Good	Good	Yes	$ 34,338 (near other offshore industry)
		No	$ 19,187 (near bridge a port)
	Average	Yes	-
		No	-
	Poor	N.A.	-
Average	Good	Yes	$ 9,209
		No	$ 3,197
	Average	Yes	-
		No	$ 4,103
	Poor	N.A.	-
Poor	Good	N.A.	$ 3,124
	Average	N.A.	-
	Poor	N.A.	-
		CHENIER	
Good	Good		-
	Average		$ 2,255
	Poor		$ 2,100
Poor	Good		-
	Average		$ 2,213
	Poor		$ 1,121
		MARSH	
Average	Average		$ 260
Poor	Good		$ 325
	Average		$ 289
	Poor		$ 321

4. Sensitive Areas

In this chapter, specific sites within the study area sensitive to development will be identified. For the purposes of this study, sensitive areas are defined as those whose intrinsic functions may be incompatible with development or significant alteration. Strategies for protection of these sensitive areas will depend on the functions of interest, and the availability of data.

WATER EXCHANGE POINTS

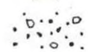
Water exchange points and associated tidal channels are critical to the maintenance of tidal exchange and circulation between Sabine Pass aquatic systems and associated marshes. The exchange points are shown in Figure 10. The marsh-water interface is characterized by extremely high productivity (Gosselink et al., 1979), and maximization of this interface is accomplished naturally in these systems through a system of sinuous, interlacing tidal streams, bayous, shallow coastal lakes, and potholes (see Hydrology section).

Two features of this interface are particularly important to the organisms which depend on the marshes. Detritus (decayed organic material) carried out of the marsh and nutrients and silt carried onto it by high waters are concentrated at the interface (Gosselink et al., 1979). Thus, food and nutrients are in the highest supply here. In addition, the low, irregular edge, thick plant growth, and the mat of roots and culms all provide habitat and protection from predators for a host of smaller organisms.

The normal branching pattern of sinuous streams, branching blind bayous and numerous small coastal ponds and potholes maximizes the contact, contributing to the high productivity of the marsh-estuarine system. In contrast, a straight dredged canal with spoil banks on both sides has a low marsh-to-surface water ratio. Furthermore, the edges with spoil banks do not fuction as normal marsh edges because the elevated banks prevent the normal flooding and exchange of water and organisms.

Water exchange points also provide access for various organisms into the marshes. For example, before the opening of the Keith Lake water exchange pass, organisms could gain access to the marshes only by traveling up the intracoastal waterway 56 km. from East Bay or 30 km. from the Gulf of Mexico to the

Figure 10
Sensitive Areas Map
Key to Symbols

★		Exchange Points
	(OM)	Type 1 Open Marsh
	(OM)	Type 2 Open Marsh
	C	Chenier
	L	Satellite Estuary

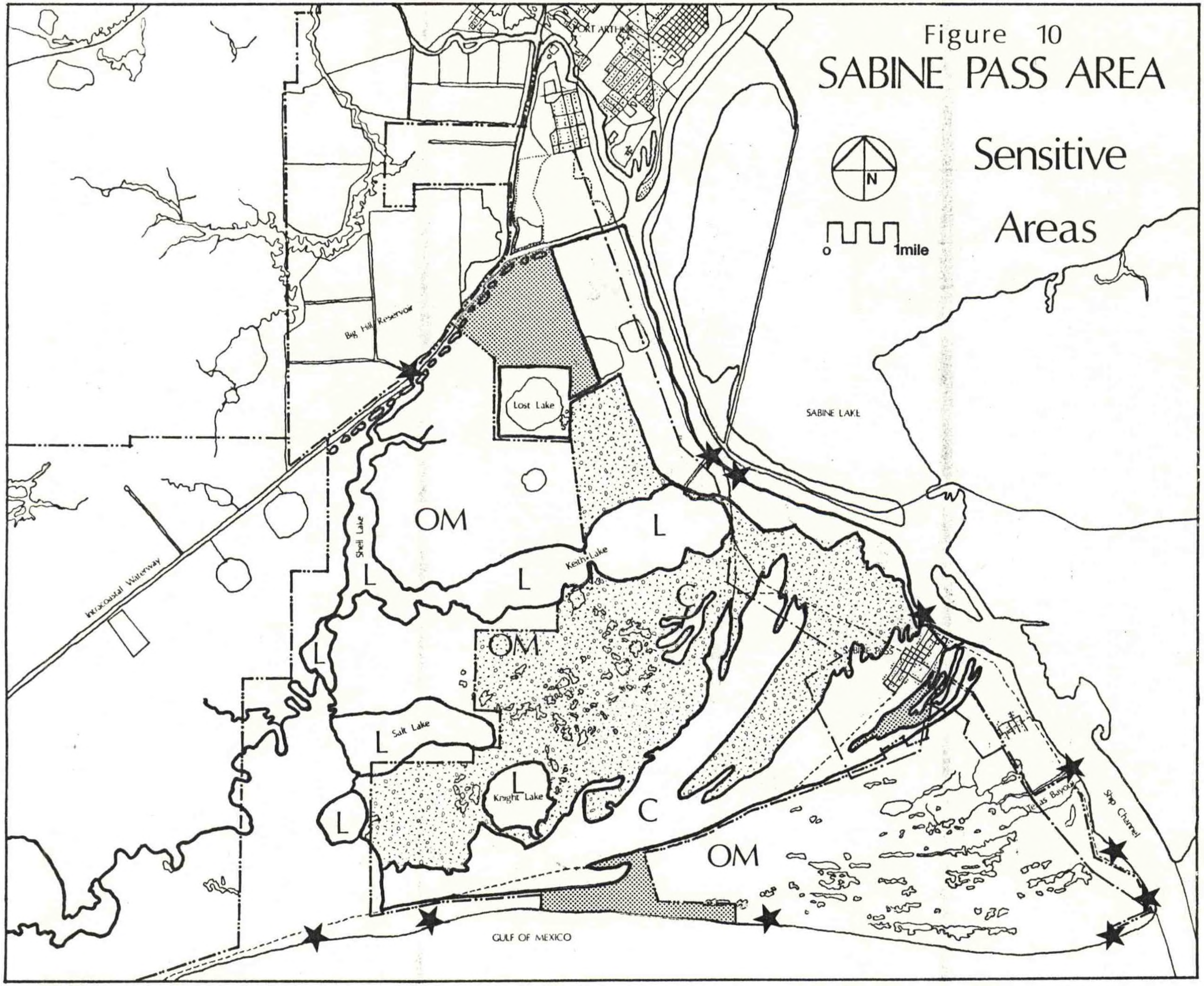


Figure 10
SABINE PASS AREA
Sensitive
Areas
N
0
1mile
PORT ARTHUR
Big Hill Reservoir
Lost Lake
SABINE LAKE
Intracoastal Waterway
Shell Lake
Keith Lake
OM
L
L
L
L
OM
L
Salt Lake
L
Knight Lake
L
C
OM
SABINE PASS
Texas Bayou
Ship Channel
GULF OF MEXICO

Sabine-Neches ship channel, into the intracoastal waterway, and west to the Salt Bayou Wier. During extended trips through these heavily-used channels, the organisms were presumably at greater risk because of increased exposure to toxic materials in these highly turbid and disturbed waters, although it would be extremely difficult to detect increased mortality. It is known that the marshes in the Sabine Pass area were used by estuarine-dependent organisms, but at a rate far below their estimated capacity.

With the opening of the pass, travel distance to the satellite estuary was decreased to only 16 km., none of it through the intracoastal waterway. As stated previously in this report, it is estimated that utilization of the Keith Lake complex by commercially and ecologically important species has increased significantly since the opening of the pass (Bob Fish, Texas Parks and Wildlife Dept. Biologist, 1979).

KEITH LAKE AREA (SATELLITE ESTUARY)

Keith Lake and its surrounding marshes are an important part of a larger estuarine system. All of the coastal lakes and ponds in the Sabine Pass area are thought to function as shallow estuarine areas, and are designated as satellite or inland estuaries. The majority of the organisms which utilize these estuaries enter and leave through the Keith Lake Water Exchange Pass and through Keith Lake itself. The system of satellite or inland estuaries and lakes is shown in Figure 10 by (L).

The surrounding marshes serve as part of the system, providing habitat and functioning as sources of fixed carbon and as sites of nutrient and gas exchange. Keith Lake is intimately connected to both the Sea Rim State Park, and the McFaddin Marsh by water, and the quality of habitat in these publically-owned natural areas is largely dependent on the quality of Keith Lake and its surrounding marshes. Maintenance of the public benefit natural functions of Keith Lake is imperative if the functions of those areas to the west are to be maintined and preserved.

CHENIER

Since significant natural relief in the Chenier Plain is rare, even a relatively low surface feature can be very important. The importance of cheniers is related to their elevation. They are generally above the influence of the tide, and support a wide variety of trees, shrubs and plants. They provide protection against storm surges, avenues for entrance to the wetlands for terrestrial animals, and refuge for a host of organisms during floods or storm surges (Gosselink et al., 1979).

Cheniers are included in this section only because they are under pressure from man for residential, agricultural and other forms of development which may affect their uses as listed above. Although natural washover channels have breached the strand plain chenier in several places, any development should be carefully planned so that the integrity of the chenier as as barrier is maintained.

Spoil banks may serve at least some of the same functions as cheniers, including serving as avenues for entrance and exit for terrestrial species, increasing species richness and diversity, and serving as nesting, roosting, and basking sites for numerous birds and reptiles. However, they are much smaller, although their total area is increasing over the chenier plain.

OPEN MARSH

Open marsh is defined as marsh which has unimpeded connection with a tidally-influenced water body (Figure 10). Closed marsh, on the other hand, is marsh which is isolated hydrologically. Because of the connections, open marsh is capable of being flooded, and free exchange is possible when water levels are sufficiently high.

Open marsh areas are extremely important in providing the functions discussed in Chapter 2. Development of these areas generally involves draining, bulkheading, diking, and filling, which are incompatible with many of the natural functions. In Figure 10, two types of open marsh are identified which are sensitive to development:those which are associated with a satellite estuary such as Keith Lake or Fence Lake, and those which are not. Only those marshes which are not publicly owned are included in the delineation, because it is assumed that those which are publicly owned are being managed for the public good. Because of their proximity to the satellite estuaries, the Type 1 marshes are thought to be more sensitive to development.

OIL SPILLS

It is likely that the area around Sabine Pass routinely experiences exposure to low levels of oil and related hydrocarbons, resulting from small spills and releases from the nearby refinery complexes and the numerous ships and tankers which use the ship channel. Very little is known about the effects of chronic exposure to oil on estuarine organisms. However, if oil resulting from a massive offshore spill were to be deposited on the mudflats and beaches, there would probably be a substantial kill of the infauna associated with these habitats, including clams, polychaetes, hermit crabs, and ghost crabs. In addition, sea birds and shore birds would be oiled and many would die as a result. The estuary itself, however, could probably be protected by the placing of booms or other barriers to oil at the entrance points

Were such a spill to occur within the ship channel itself, both Sabine Lake and the marshes and wetlands would be threatened. It is possible that the oil could be quickly contained, and access to the marshes and estuarine lakes could be controlled until the oil could be cleaned up, thus minimizing the adverse effects.

The effects of an oil spill in an estuary are more severe than at sea, because estuaries are generally small and semi-enclosed. This causes the oil to remain concentrated for a longer period of time. Furthermore, the larval and juvenile stages of many commercially and ecologically important fish and shellfish species are spent in the estuaries, and it is known that the larval stages are 10 to 100 times more sensitive to oil contamination than are adults of the same species. Thus, these sensitive organisms are exposed to more concentrated toxicants for longer periods.

If the oil were transported into the marshes, the marsh grasses could be killed back to the roots. Aquatic and amphibian animals would also experience mortality, especially those unable to escape or avoid the worst contamination. The effects of oil on alligators, turtles, nutria, and muskrats is not known, but may be a function of body weight and the general physical condition of the organism. One of the most conspicuous effects would be the oiling and subsequent death of numerous wading birds and waterfowl. At certain times of the year, when large migratory populations are present, this effect could be extremely serious.

In general, the effects of a spill on the area would depend on a number of factors, including the type and amount of oil spilled, its location, the duration of exposure, weather conditions, sea state, and the amount of effort required to contain the oil. Damage could thus range from minor to moderate or quite severe.

5. Managing Development In Sabine Pass

The City of Port Arthur is currently faced with the potentially conflicting goals of: 1) providing for economic growth and development in the newly annexed Sabine Pass area and 2) maintaining the natural resource values of the Sabine Pass marshes. The fact is that these goals need not be mutually exclusive or in total conflict. Growth can be accomodated in the Sabine Pass area without damaging the valuable marsh-estuarine system. This growth, however, must be carefully managed by the City.

This chapter will discuss performance controls and other mechanisms for the management of residential, commercial, and industrial development in the Sabine Pass area. First, the concept of performance standards will be reviewed and discussed. Second, certain beneficial processes will be identified which are important components of the public benefit derived from the natural system. Third, these functions will be examined to ascertain whether performance standards are appropriate or feasible.

SABINE PASS: GROWTH OVER THE NEXT TEN YEARS

One of the first questions which should be asked is how much land will be needed to accommodate Sabine Pass' anticipated growth. As part of another study (Rice Center, 1979), growth projections were made for Sabine Pass. Based on current densities, the number of acres necessary for each type of development was also estimated. Results are shown in Table 17.

Table 17
Sabine Pass 1980-1990

	1979	1990
Basic Employment	719	1,382
Acres Required	869	1,670
Non-Basic Employment	144	277
Acres Required	58	111
Population	937	1,803
Acres Required	873	1,681
TOTAL ACRES REQUIRED	1,800	3,462

It is apparent from this table that even at current densities, Sabine Pass will only require a total of approximately 3460 acres to accommodate development. And, in comparison to other Texas cities, densities in Sabine Pass are quite low. This means that the requirements for land could be much less than those projected here, because new growth could "fill in" existing developed areas rather than expanding to new areas. Table 18 gives the estimated acreages for various land types in and around Sabine Pass.

Table 18
Acreages of Various Land-Types

Salt Marsh	7,440
Mixed Salt Flat/Brackish Marsh	5,160
Brackish Marsh Type 1	2,472
Brackish Marsh Type 2	5,333
Brackish Marsh Type 3	15,648
Brushland	250
Salt Prairie	542
Coastal Prairie (Chenier)	5,597
Coastal Hardwoods	91
Fresh Pond	422
Spoil	2,458
Fresh Marsh	389
TOTAL	45,802

By comparing Tables 17 and 18, it can be seen that projected development could easily be confined to higher ground, namely spoil areas and the chenier. However, marsh land is so much less expensive than spoil or even chenier, that there may be pressure on some owners to fill their land and increase its real estate values.

PLANNING STANDARDS AND CONTROLS

There are three general forms which planning standards can assume: prescriptive, proscriptive, and performance. Prescriptive standards are those which specifically set the allowed use or building site specifications. Zoning is a land use control which is generally accomplished through prescriptive standards which set allowable uses within each zoning district. For example, an R-I residential district might allow only single-family or duplex housing units. Subdivision regulations are controls which are generally based on prescriptive standards. For example, most set residential streets at a certain minimum width, set minimum structure set-back from the street, and set minimum side-yard distances. Proscriptive planning standards are those which forbid certain designs, structures, facilities, or uses. Implied in both prescriptive and proscriptive standards is that the public good-- health, safety, and welfare-- is being provided for or protected.

In comparison to these two types of standards, performance standards address the expected public good directly--setting standards for the way in which an action or development must perform in order that the public good is served. For example a zoning ordinance written with performance standards would allow any land use within a specific district as long as it performs in the desired manner. Performance zoning may set the maximum number of vehicle trips allowed to and from the site in a day, it may set limits on noise generation from the site, it may set height limitations or floor area ratios, and it may also set allowable air or waterborne discharge and excess storm water runoff from the site. In performance standards, the community good or value which is to be preserved or provided is explicit--no traffic, no noise, no pollution, no flooding. Therefore a person could operate a commercial mail order processing office in a residential area without adversely affecting the neighborhood. A meat processing plant would, however, be restricted from the residential neighborhood because of its expected performance.

There are other examples of controls which are based on performance standards. In Savannah, Georgia, new development was allowed in the historical district as long as the new facility matched the adjacent building in at least six out of thirteen building characteristics such as materials, color, window placement, height, width, door treatment, window treatment, etc. This is an example of using a flexible performance standard to provide neighborhood continuity while encouraging new investment.

In Dekalb County Geogia, an urban runoff control ordinance was passed which allowed development in a basin prone to flooding only if the developer would make provisions to retain on-site the excess water* generated by the development. Also included in the same ordinance were proscriptive standards for vegetation protection, erosion control, sedimentation control, grading, and proving, and performance standards for drainage bypass and storm drainage systems.

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*A calculated quantity that would run off of the developed property minus the runoff which occurs in the natural state.

Performance standards are the ideal basis for environmental controls. But in many cases, performance is difficult, if not impossible, to define quantitatively, evaluate, and monitor. For other more subjective community values such as the promotion of a higher quality of life, performance standards may not be appropriate.

Because performance standards are more difficult to set, implement, and enforce than either prescriptive or proscriptive standards, they require careful research in order that the measures and allowable performance can be set in a defensible manner. The implementation of these standards puts some additional burden on the private developer who must demonstrate that the performance of a proposed development meets or exceeds the specified standards, and also on government officials who must be capable of reviewing such plans to determine likely performance. Finally, additional government burden is evident in performance standards because monitoring of the performance of the in-place facility, structure, or development is necessary, and may become difficult and time-consuming.

However, where enactment of performance standards is possible, the benefits to be derived from clear, specific, and flexible standards often override the implementation problems. The benefits are most clearly demonstrated when looking at performance standards for environmental protection. The wastewater discharge permitting programs, which are mandated by Congress (PL 92-500) and enforced by EPA and the individual states, use performance standards. In these permits, municipal and industrial facilities are allowed to discharge pollutants into area streams and lakes only to the extent which the receiving water-body can assimilate the wastes. Therefore, if a stream can only assimilate 200 pounds per day of organic matter, industrial or municipal development can take place as long as that performance standard is not violated. If raw domestic sewage rates are .2 pounds/capita/day then the stream could accommodate the sewage from 1000 persons if untreated; 2000 persons if 50 per cent treatment efficiency is accomplished; 10,000 persons if 90 per cent treatment efficiency is accomplished; or 100,000 persons if 99 per cent of the organics could be removed. On the other hand, a proscriptive standard, based on a historical treatment technology might have limited population in the basin to 2000 persons. With performance standards, technological innovation can be invoked to allow growth and development without adversely affecting the environment.

To develop environmental performance standards for an area like Sabine Pass, those natural processes closely associated with the public health, safety, and welfare and which provide the community with important benefits must first be identified. Table 19 identifies some of the beneficial functions of the Sabine Pass marsh-estuarine ecosystem, along with the mechanism of action and the associated physical features. It is important to track through this type of scheme so that the functions can be clearly associated with the actual physical features which contribute to them. In order to maintain a function, it is necessary to understand and preserve the actual physical feature or features which enable the natural environment to perform that function. One approach to setting performance standards would be to identify and maintain those physical features necessary for the continuation of critical functions. This approach is of great utility where it is difficult or impossible to set a numerical level for the ecosystem function of interest.

The major advantage to this approach is that the area or extent of the feature can be used as a surrogate measure of the level of the function itself. By assuming that the function is maintained if the associated physical features are maintained, the need for establishing a level for the function itself is eliminated. In fact, it may be impossible to establish a meaningful numerical level for some of the functions, because the natural systems themselves may be quite variable. It is somewhat easier to ensure the continuity of the function by preserving the feature itself.

There are both advantages and disadvantages to the use of this approach. First, it may not be possible to identify all of the features necessary for the continuation of the process. This is one area which could be profitably addressed by additional basic research on each function of interest. Second, the function may not occur in direct proportion to the amount or extent of the physical feature or features identified. On the other hand, the use of this scheme may not require the vast and extensive amounts of sampling required to ascertain numerical levels for the functions of interest. Most importantly, linking important functions with specific physical features avoids the trap of setting legal standards for natural processes. In dynamic systems like marshes and estuaries, which may experience natural cycles and fluctuations which are not yet fully understood, it may be impossible to determine specific numerical standards which are enforceable.

It is also helpful to identify activities which could adversely affect the public benefit natural functions in Table 19. A

TABLE 19

Beneficial Functions or Structure	Mechanism	Physical Feature
Flood Control Water Availability Soil Moisture Storage	Water Detention (slows down run-off, absorbs storm surge)	Chenier Marshes 1. Grasses 2. Streams 3. Lakes
Enhancement of Water Quality	1. Use of dissolved and particulate organics by organisms as food sources. 2. N, P, other nutrients are taken up. 3. Toxics are settled out in sediments, absorbed 4. Sediments are allowed to settle.	Open Marsh Tidal Streams Coastal Lakes Ship Channel and spoil areas
Aquifer Recharge	Interconnection of chenier sandy substrate to aquifer	Chenier
Climate Regulation Maintenance of gaseous balance	Evapotranspiration Evapotranspiration cooling Temperature and humidity regulation by water Uptake of CO_2, Release of O_2	Surface area of vegetated marsh Volume of stored water in the marsh, streams and lakes
Shoreline stabilization Soil stabilization	Plant succession	Existing vegetation (source for seed or propagules)
Scientific Study Teaching	High quality natural system Continuation of function and structure	Established vegetation Appropriate land-sea interactions Access Publicly owned Minimal disturbance Large area

Fish and shellfish	Salinity, D.O., T^{O}, pH, Food Source Detritus Phytoplankton Zooplankton Benthos	Tidal inflow Freshwater inflow Channels Water Exchange Points Inlets to Marsh Coastal Lakes Blind bayous Producers (green plants)
Fur-bearers	Food Source Cover Water	Proper mix of plant and animal species for the diet, especially leafy threesquare grass Access to water bodies
Cattle	Forage High ground Water (fresh)	Levees or chenier Healthy grasses Wells or other fresh water source
Game Birds	Food Cover Water bodies	Marshes Lakes, streams (nearby rice fields for geese)
Red wolf	Food Cover	Marshes Prairie Rabbits Nutria Muskrats
Alligator	Fresher water bodies Some high ground for nesting Food source	Brackish or brackish-to-fresh marshes Low swales Smaller vertebrates Nutria Muskrats Turtles Frogs Cheniers, levees

list of potentially harmful activities is shown in Table 20. The conduct of many of these activities within the marsh-estuarine ecosystem will be regulated to some degree by the performance standards. However, where other specific guidelines or means of regulation would be desirable, this has been indicated in Table 20. Thus, in order to protect the natural resource values of the Sabine Pass marsh-estuarine ecosystem while providing for continued economic growth, a mix of performance and other controls may be required.

It can be said with some certainty that, barring climatic changes, if none of the activities in Table 20 were introduced into the Sabine Pass area, the natural values of the marsh would be preserved. However, the pressures for industrial and offshore services development in Sabine Pass area will likely continue for the next 10 years, bringing with it residential and commercial growth. The issue is: how can this anticipated growth be accommodated without adversely affecting the natural value of the Sabine Pass marshes, and estuaries, and the wildlife, fish, and shellfish that are dependent upon them.

Table 20

	Potentially Harmful Activities	Preferred Type of Standard
1.	Modifications of water exchange channels	PS
2.	Containment and placement of spoil	PS,PRES
3.	Waste discharges	PS,PROS
4.	Groundwater withdrawal	PRES
5.	Road-building	PS
6.	Channelization	PS
7.	Impoundment	PRES
8.	Filling and Dredging	PS
9.	Devegetation	PS,PROS
10.	Modifications leading to erosion	PRES
11.	Construction of groins and jetties	PROS
12.	Oil spills	PROS

PS Performance Standards
PRES Prescriptive Standards
PROS Proscriptive Standards

ENVIRONMENTAL PERFORMANCE STANDARDS FOR SENSITIVE AREAS

In this section, environmental performance standards will be discussed for each of four sensitive areas, as identified in Chapter 4. For each area, certain specific functions will be identified, which should be preserved. The applicability of performance standards will be assessed, and alternate means of protection may be suggested if performance standards do not appear to be feasible. Areas requiring further research will be identified where necessary.

Water Exchange Passes

Principal water exchange passes are identified in Figure 10. These should be identified by ordinance, and their function protected. Performance standards are an appropriate means of regulation of water exchange passes. Ideally, the performance standards should specify the minimum and maximum flows necessary for the continuation of marsh-estuarine interaction. It was beyond the scope of this research to determine these levels.

However, it is not unreasonable to place the burden of this determination on the individual or corporation requesting the modification. Suggested wording could be as follows:

> Any fill, diversion, channelization, or other modification to one of the designated water exchange passes shall not impede flow in or out of the pass. If any modifications are requested, engineering plans and specifications must be submitted to the city engineers' office which demonstrate that the potential flow rates in and out of the modified pass are the same as before modification.

The intent of this regulation is to insure that development along the ship channel and waterway does not cut off the marshes and coastal lakes from crucial water linkages to the Gulf of Mexico. Values being protected include fish and shellfish production, wildlife habitat, nutrient cycling, and enhancement of water quality.

One area which could be beneficially addressed by further research would be the characterization of each individual water exchange pass. This could be accomplished through a long-term monitoring program of water and flows, with additional sampling of water quality and biota.

Satellite Estuary, Not in Public Ownership

Satellite estuaries or coastal lakes are also identified as sensitive areas in Figure 10. These areas are critical in maintaining fish and shellfish productivity because they function as habitat for commercially and ecologically important species. Performance standards for these areas could be worded as follows:

> Developments involving designated Satellite estuaries shall be conducted in such a manner that they:
>
> 1. Maintain existing flows of water in or out of said water bodies.
> 2. Maintain the depth and the character of the bottom sediments.
> 3. Do not cause water pollution through direct discharge of pollutants, location of domestic waste disposal systems in unsuitable soils, dredging, improper spoil disposal, or solid waste disposal.
> 4. Maintain the marsh-water interface and its characteristic vegetation.

Some sampling has been done in the satellite estuaries around Sabine Pass, especially in Keith Lake (Stelly, unpublished). However, a program of sampling could be undertaken concurrently with that of the water exchange passes which could better our knowledge about natural flow patterns, and the extent of tidal flooding. This, in turn, would aid in understanding the direct interactions between the wetlands and the coastal lakes. One other type of research which might be useful would be to examine allowable levels of temperature, dissolved oxygen, turbidity, pH, salinity, and other parameters so that the term "water pollution" can be specifically defined.

Enforcement of this standard may be more difficult because performance of several functions is being regulated. Also, functioning of the Type 1 marshes is important to the functioning of satellite estuaries, and both areas should be protected (see next section) for best results.

Open Marsh, Type 1 and 2

Type 1 open marshes are defined as those marshes which contribute to satellite estuaries. Type 2 open marshes do not border satellite estuaries. Those defined as "sensitive" are those not in public ownership. It is assumed that publicly-owned marshes will be managed for the continuation of their public benefit natural functions. The sensitive marshes are shown in Figure 10.

Ideally, only that development which can demonstrate a need for being in the wetlands should be allowed there. As we have seen, there is adequate high ground in the area to accommodate growth. However, it is possible to develop some performance standards for development in the marshes.

Type 1 marshes interact in many ways with the satellite estuaries, and are strongly influenced by their hydrologic linkages. Ideally, performance standards would call for maintaining a certain level of productivity for the marshes and a certain amount of interaction. Realistically, it would be extremely difficult to ascertain or regulate marsh productivity, or to set required levels for functions and interactions which may not even occur at consistent levels in nature. One approach to solving this problem is to assume that productivity is proportional to the area. This implies that if the marshes are to function at 50 per cent of their current levels, one acre should be set aside in perpetuity for each acre developed (assuming development to be incompatible with natural functions). This approach ignores any innate differences in productivity.

A better approach would be to assume that productivity is inversely proportional to distance from the water body. Odum (1972) and others have found that marshes which are next to streams are more productive than those farther away. Under this assumption, severe limitations would be set on development closest to the lake, and more lenient measures would be imposed on marshes farther back from it. Using this approach, standards for the closest marshes might read as follows:

> Any development or activity in Type 1 open marshes shall be conducted in such a manner that they:
>
> 1. Maintain the marsh-water interface and its characteristic vegetation.
> 2. Allow natural flooding and drainage of the marsh.
> 3. Maintain 90 per cent of the natural wetland vegetation on the site.
> 4. Maintain the water table at its normal level
> 5. Do not cause water pollution through the direct discharge of pollutants, toxics, location of domestic waste disposal systems in marsh soils, improper spoil disposal, or solid waste disposal.

Far away from the lake, or in closed marsh, which is isolated from others, more development could be allowed. Sample standards could be written as follows:

Any development or activity in Type 2 open marshes or closed marshes shall be conducted in such a manner that they:

1. Maintain the marsh-water interface and its characteristic vegetation.
2. Allow natural flooding and drainage of neighboring marshes and at least 50 per cent of the site.
3. Maintain at least 50 per cent (or some other percentage) of natural vegetation on the site.
4. Maintain the natural water table level over at least 50 per cent of the site, and
5. Do not cause water pollution through the direct discharge of pollutants, toxics, location of domestic waste disposal systems in improper soils, or solid waste disposal.

The intent of these two sets of standards is to preserve and protect the beneficial functions provided by the marshes of Sabine Pass, particularly the fish and shellfish production and the wildlife habitat function. In fact, the bulk of all the public benefit natural functions could probably be preserved in this way while still allowing landowners considerable leeway in determining the uses to which their land can be put. The 50 per cent figure used in the sample standards above was used as an example. In fact, it is probably a safe figure.

Further research is necessary to help refine the definition of type 1 and type 2 marshes as outlined in this report, and to assess their relative productivity and contribution to the basin as a whole. One other strand of research which would be extremely useful in setting meaningful performance standards and in documenting the contributions of the marsh-estuarine ecosystem would be to set up a project to assess the extent to which these marshes act as water storage sites. It would be useful to know just how much water these marshes can store, and under what conditions this is likely to be significant. Much has been made of the water storage capacity of marshes and wetlands, but little specific work has been done in this regard for Gulf coastal marshes. Given the vulnerability to hurricanes, it would seem that people would be quite interested in elucidating the extent of this function in existing marsh areas.

Chenier

As discussed in Chapter 4, cheniers are also important to the continued functioning of the Sabine Pass system. Performance standards for development on the chenier could read as follows:

Any development or activity taking place on a chenier or beach ridge should be conducted in such a manner that:

1. It maintains the integrity of the chenier as a natural barrier to a storm surge.
2. Significant and harmful erosion will not occur.
3. Natural drainage is maintained.
4. Does not cause water pollution through the direct discharge of pollutants, toxics, the location of domestic waste disposal systems in imporper soils, or solid waste disposal.

This regulation protects the chenier itself from being breached so that a focus for storm water washover would not be created. It also mentions erosion as a potential problem. Monitoring for erosion increase might be difficult. However, it should be possible to make sure that the developer is cognizant of the problem, and knows ways to minimize and prevent damaging erosion.

Limitations of These Performance Standards

One limitation is that adoption of these standards may create the need for trained personnel in order to enforce them The city planning department may have to work with another department to adequately monitor and enforce these regulations. Also, some procedures for application, permitting, and appeal will have to be worked out.

An alternate means of controlling development in the wetlands would be to examine the Corps of Engineeers Section 404 and 208 permits under the authority of the Clean Water Act of 1977, and Section 10 of the Rivers and Harbors Act of 1899. Letters of no objection are required from the local governing body, and the city should receive a public notice describing each permit application. If any state or local agency denies the permit, then the Corps, as a matter of policy, denies the permit (Coastal Environments, 1977). By monitoring these permit applications carefully and denying permits or suggesting appropraite mitigation measures for unacceptable projects, the City can make sure that development conforms to their long-term plans. One final method of maintaining the essential character of the area while still allowing growth would be to commission a "Handbook for Developers", which would apprise people who wanted to develop or modify the marsh areas of the hazards of improper land use, and of techniques which could mitigate any adverse environmental effects.

One area for which it is inappropriate to set environmental performance standards is major oil spills. They are extremely damaging to estuarine ecosystems, and should not happen at all. One means of minimizing their effects is to develop a plan for cleaning up spills or blocking the entrance of spilled oil to sensitive areas. The City might share clean-up and prevention responsibility with the Coast Guard, N.O.A.A., Texas Parks and Wildlife, or U.S. Fish and Wildlife Service, all of whom have an interest in minimizing damages to natural systems resulting from oil spills. It would be best to contact these agencies and formulate a contingency plan before such a spill occurs.

One person who has done some research for N.O.A.A. on the effects of oil spill clean-up on a salt marsh is Dr. Richard C. Harrel of Lamar University (Harrel and McCauley, 1979, unpublished). He might serve as a contact person or advisor to the City of Port Arthur in this endeavor.

Summary of Research Topics

1. Long-term monitoring of water-exchange passes to determine the inflows, outflows, dissolved organic carbon, particulate organic carbon, salinity, dissolved oxygen,and any other physical parameters of interest.

2. Long-term monitoring of satellite estuaries for similar parameters.

3. Sampling to determine biological utilization of the passes, estuaries, and marshes.

4. Hydrological sampling to estimate the water storage capacity of the marshes, and to understand the significance of this capacity in the prevention or mitigation of damaging flooding in Sabine Pass, Port Arthur, and even Beaumont.

5. Sampling of the marshes and sediments to try to ascertain the extent to which the marshes and estuaries serve as sinks for pollutants released upstream.

Summary and Conclusions

1. The marsh-estuarine ecosystem in the Sabine Pass area, although less productive than more pristine areas in Louisiana, is probably the most important system in the Sabine Basin. It provides a number of important natural benefits which accrue to the region as a whole.

2. Although Sabine Pass will continue to grow over the next ten years, this development can easily be confined to the higher ground and spoil areas.

3. Because marsh land is so much less expensive than high ground, marsh owners may experience pressure to convert their marshes to more intensive uses.

4. Environmental performance standards are appropriate tools for managing most types of development in Sabine Pass. However, it is almost certainly impossible to set strict numerical environmental standards for marsh and estuarine functioning. An alternative approach is developed in this report which relies on the preservation of key physical environmental features associated with identified sensitive areas and functions.

BIBLIOGRAPHY

Anderson, Robert C., 1978. Evaluation of Economic Benefits of Resource Conservation. Municipal Environmental Research Laboratory, U.S.E.P.A. Grant No. R803880-01-1. Doc. EPA-500/5-78-015.

Aronow, Saul, 1965. "Geology of Jefferson County", in Jefferson County Soil Survey, U.S.D.A. Soil Conservation Service.

Belknap, Raymond K., et al., 1967. Three Approaches to Environmental Resource Analysis. Washington, D.C.: The Conservation Foundation.

Benton, Bob, 1979. Preliminary Vegetation Maps, Sabine Pass Area. Texas A & M University Remote Sensing Center.

Bernard, H. and LeBlanc, R., 1965. Resume of the Quaternary Geology of the Northwestern Gulf of Mexico Provinces, in The Quaternary of the United States, H. Wright and D. Frey, eds., Princeton, New Jersey.

Borey, Roland B., 1979. Hydrology and Organic Carbon Export of An Irregularly Flooded Brackish Marsh on The Upper Texas Coast. Unpublished Ph.D. thesis, Rice University, Houston, Texas.

Burchell, R.W. and D. Listolin, et al., 1975. The Environmental Impact Handbook. New Brunswick, N.J.: Center for Urban Policy Research, Rutgers, the State University.

Clark, John, 1974. Coastal Ecosystems: Ecological Considerations for Management of the Coastal Zone. The Conservation Foundation, Washington, D.C., 178 pp.

Coates, Donald R., ed. 1972. Environmental Geomorphology and Landscape Conservation. Stroudsburg, Pa.: Dowden, Hutchinson, and Ross.

Coleman, J.M., 1966. Recent Coastal Sedimentation: Central Louisiana Coast. L.S.U. Press, Baton Rouge, La. 73 pp.

Correll, D.S. and M.C. Johnston, 1970. Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas.

Ditton, R.B., and T.J. Goodales, eds. 1972. Environmental Impact Analysis: Philosophy and Methods. Madison, University of Wisconsin Sea Grant Program.

Ecology and Environment, Inc., 1977. Environmental Assessment Report, Sabine Pass Terminal Project. Prepared for Sabine Pass Terminal.

Ehrenfeld, David W., 1976. The Conservation of Non-Resources. American Scientist 64:648-657.

Fisher, W.L., L.F. Brown, Jr., J.H. McGowen, and C.C. Groat, 1973. Environmental Geologic Atlas of the Texas Coastal Zone: Beaumont-Port Arthur Area. Bureau of Economic Geology, University of Texas, Austin.

Fruh, E. Gus, et al., 1972. The Management of Bay and Estuarine Systems - Phase I. Prepared for the Coastal Resources Management Program, Division of Planning and Coordination, Office of the Governor, by the Division of Natural Resources and the Environment, University of Texas,Austin.

Gosselink, J.G., C.L. Cordes and J.W. Parsons, 1979. An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas. 3 vols. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/DBS-78/9 through 78/11.

Gosselink, J.G., E.P. Odum, and R.M. Pope, 1974. The Value of the Tidal Marsh. Center for Wetland Resources, Louisiana State University. Doc. No. LSU-SG-74-03.

Gould, H.R. and E. McFarlan, Jr., 1959. Geologic History of The Chenier Plain, Southwestern Louisiana. Trans. Gulf Coast Assoc., Geol. Soc. Vol. 9: 261-270.

Harcombe, P. A., and J.E. Neaville, 1977. Vegetation Types of Chambers County, Texas. Texas Jour. Sci. 29:209-234.

Harrel, R.C., and C.A. McCauley, 1979. Effects of Oil Spill Cleanup Techniques on a Salt Marsh. Research Project Report, Project No. RD0000 87121480 2517 for National Oceanic and Atmospheric Administration.

Henderson, G.A., and P.A. Harcombe, 1976. "Net Primary Productivity of Chambers County Marshes", in Environmental Analysis Case Study Applications and Selected Technical Papers, Vol. 7 of Environmental Analysis for Development Planning, Chambers County, Texas. Rice Center for Community Design and Research, Houston, Texas.

Henry, W. K. and J. P. McCormack, 1975. Hurricanes on the Texas Coast: Description and Climatology. Center for Applied Geosciences, Texas A a M University. TAMU-SG-75-510.

Hill, Douglas, 1976. A Modeling Approach To Evaluate Tidal Wetlands. Trans. North Am. Wildl. Nat. Res. Conf. 41: 105-118.

Hopkins, Lewis P. 1973. Environmental Impact Statements: A Handbook for Writers and Reviewers. Urbana-Champaign: Department of Landscape Architecture, University of Illinois, August.

Jones, Donnie M., and Associates, 1979. General Information Sabine Pass Area Land Sales, Identification and Data. Prepared for the City of Port Arthur, November 1979.

Krutilla, J. and Fisher, A. 1975. The Economics of Natural Environments. Baltimore: John Hopkins.

Krutilla, J.V., 1975. The Use of Economics in Project Evaluation. Trans. North Am. Wild. Nat. Res. Conf. 40:374-381.

Larson, J.S., 1975. Evaluation Models for Public Management of Freshwater Wetlands. Trans. North Am. Wildl. Nat. Res. Conf. 40:220-228.

McHarg, Ian, 1969. Design With Nature. New York: Natural History Press.

Mumphrey, A.J. Jr., J.S. Brooks,T.D. Fox, C.B. Fromberg, R.J. Marak and J.D. Wilkinson, 1978. The Value of Wetlands in the Barataria Basin. Urban Studies Institute, University of New Orleans, Mimeo.

Murray, G.E., 1961. Geology of the Atlantic and Atlantic and Gulf Coastal Province of North America: Harper and Brothers, New York.

Odum, E.P. and Odum, H.T., 1972. Natural Areas as Necessary Components of Man's Total Environment. Thirty-Seventh North American Wildlife Conference, pp. 178-198.

Rice Center for Community Design and Research, 1974. An Approach to Natural Environmental Analysis, Vol. 1 of Environmental Analysis for Development Planning, Chambers County, Texas. Houston, Texas.

Rice Center for Community Design and Research, 1976. Texas Gulf Coast Project Research Report 1. Houston, Texas.

Rice Center, 1979. Sabine Pass Economic Base Analysis. Prepared for the City of Port Arthur.

Stelly, Terry D. 1979. "A Preliminary Report on Currents and Biota at the Salt Bayou Wier and Keith Lake Water Exchange Pass, Sea Rim State Park", prepared for the Texas Parks and Wildlife Department, Austin, Texas.

Thurow, Charles, William Toner, and Duncan Erley, 1975. Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators. EPA 600/5-75-005.

U.S. Army Corps of Engineers, 1970. Report on Gulf Coast Deep Water Port Facilities, Texas, Louisiana, Mississippi, Alabama, and Florida. Volume I-V, with appendices.

U.S.Department of Agriculture, 1965. Jefferson County Soil Survey, Soil Conservation Service, Series 1960, No. 21.

U.S.Department of Agriculture, 1976. "Keith Lake Water Exchange Pass Fish and Wildlife Development, Environmental Assessment". Prepared by U.S.D.A. Soil Conservation Service for Texas Parks and Wildlife Department and the Coastal Soil and Water Conservation District, Soil Conservation Service, Temple, Texas.

U.S. Department of Commerce, N.O.A.A., 1978. "Climatological Data, Annual Summary, Port Arthur, Texas". Environmental Data Services, National Climatic Center, Asheville, N.C.

U.S. Fish and Wildlife Service, 1977. Environmental Assessment, Proposed Land Acquisition, McFaddin Marsh area, Jefferson County, Texas. U.S. Dept. of Interior, Albequerque, New.Mexico.

U.S. Fish and Wildlife Service, 1977. Principles and Standards for Planning Water and Related Land Resources, Proposed Land Acquisition, McFaddin Marsh ARea, Jefferson County, Texas. U.S. Dept. of Interior, Albequerque, New Mexico.

U.S. Fish and Wildlife Service, 1977. Environmental Assessment, Proposed Land Acquisition, Sea Rim Marsh Area, Jefferson County, Texas. U.S. Dept. of Interior, Albequerque, New Mexico.

U.S. Fish and Wildlife Service, 1977. Principles and Standards for Planning Water and Related Land Resources, Proposed Land Acquisition. U.S. Dept. of Interior, Albequerque, New Mexico.

Urban Studies Center, 1972. "Airport Natural Environment Analysis", Louisville Region, Indiana Area-Wide Analysis for the Louisville and Jefferson County Air Board. October 1972. Mimeo, unpaged.

Van Lopik, J.R., 1955. Recent geology and geomorphic History of central coastal Louisiana. Louisiana State University. Coastal Studies Inst. Tech. Dept. 7, 89 pp.

Ward, G., Jr., 1973. Hydrodynamics and temperature structure of the Neches Estuary. Vol. 1 and 2. Tracor Document Nos. T73-AU-9309U and T73-AU-9510U. Austin, Texas.

Warner, M.L., and E.H. Preston, 1974. A Review of Environmental Impact Assessment Methodologies. Washington, D.C.: Office of Research and Development, U.S. Environmental Protection Agency, April.

Westman, Walter, 1977. How Much Are Nature's Services Worth. Science 197:960-964.

Wiersema, J.M. and R.P. Mitchell, 1973. Sabine Power Station Ecological Program. 2 vols. Tracor Document Nos. T73-AU-9507-UC(r) and T73-AM-9506U. Austin, Texas.

Wiersema, J.M., P.T. Price, J. Davenport, and R.P Mitchell, 1976. Ecological Studies of Sabine Lake 1974-1975. Espey-Huston Document No. 7644.