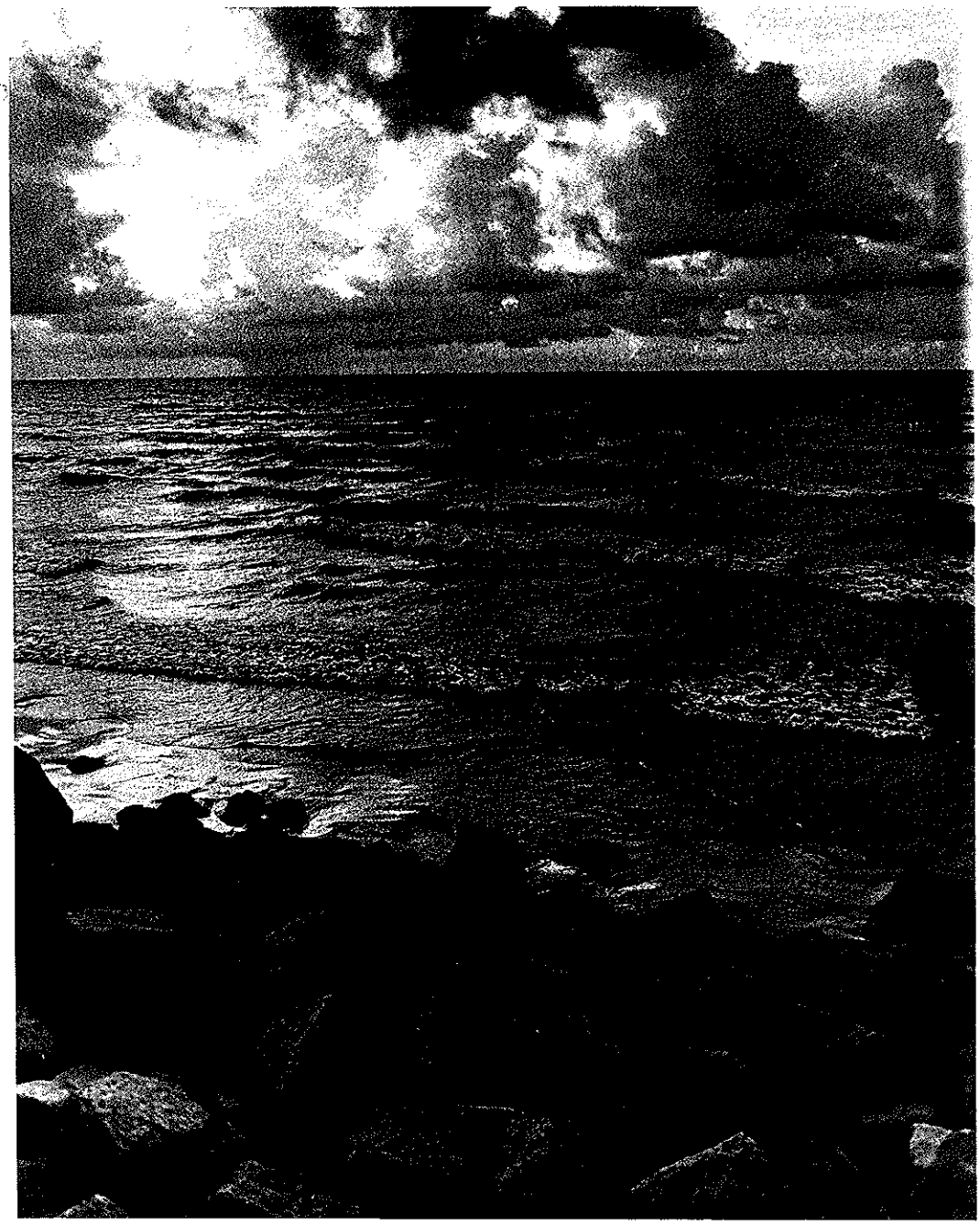
galveston bay



National Oceanic and Atmospheric Administration Estuary of the Month

Galveston Bay Seminar

Executive Summary

National Oceanic and Atmospheric Administration
Estuary of the Month
March 14, 1988
Washington, D.C.

Reprinting of this publication partially supported
by the Galveston Bay Foundation.

Additional copies available from:
Marine Information Service
Sea Grant College Program
Texas A&M University
College Station, Texas 77843-4115

TAMU-SG-88-114(r)
500 July 1988
NA85AA-D-SG128
A/I-1

Contents

The Physical Setting of the Galveston—Trinity Bay System

E.G. Wermund, R.A. Morton, Gary Powell

The geology of the Galveston Bay area reflects its location in one of the world's largest active depositional basins, Northwest Gulf of Mexico, as well as changes in the former rates and balances among sea level, basin subsidence and sediment influx. Sedimentary deposits of two ages dominate the surficial geology surrounding the bays. Deposits of the most recent interglacial period of the Pleistocene Epoch include (1) river sands and floodbasin muds of a deltaic plain, and (2) sands of a barrier island system. Modern (Holocene) sediments, which entrench and overlay the older strata, are (1) fine sands and muds of rivers and bayhead deltas, (2) muds infilling the bays, and (3) sands composing the barrier islands.

Galveston Bay is extremely shallow (10 to 12 feet deep) compared with its large areal extent of 600 square miles. Sediment samples, collected and spaced one mile apart, contain muds in the central deeper bay and coarsen shoreward where sand and reworked shell (gravel) dominate. Geochemical analyses of sediment samples indicate that barium, boron, copper, chromium, lead, nickel and zinc are locally derived pollutants.

The principal geological processes currently altering the bay include (1) rising sea level (about 2 feet in this century), (2) subsidence (nearly 10 feet at Johnson Space Center) in response to the subsurface withdrawal of water, oil and gas, (3) active faulting, and (4) coastal erosion and redeposition. Between 1850 and 1982 Galveston Bay shorelines eroded at an average rate of 2.2 feet per year; before 1930 the erosion rate was 1.8 feet per year, whereas post-1930 the rate was 2.4 feet per year. Local subsidence, which commenced in the 1930s, adds to erosional effects by increasing the inundation of the bay shoreline.

The Galveston Bay area has a subhumid, subtropical climate; mean summer high temperatures are in the 80s, and mean winter low temperatures are in the low 40s. Mean annual rainfall and surface-water evaporation are each approximately 50 inches, thus providing a balanced climate. Summer winds are dominantly southerly and southeasterly; winter winds are strongly aperiodic north winds. An average of one hurricane or tropical storm per decade interrupts the normal summer climate. Bay tides are diurnal in a 14-day cycle, and maximum tidal range is only about 2 feet. Hurricane landings may raise the bay level up to 15 feet, while strong storms from the north may lower bay level as much as 2 feet.

Recurring six-month droughts commonly affect river systems draining into Galveston Bay. From 1930 to 1980, 18 effective droughts restricted freshwater influx. Beginning about 1950, the damming of rivers altered the normal periodicity of large discharges into the bays, the magnitude of flood stage for single events has increased, but the total annual freshwater discharge has remained relatively constant. At the same time, sediment loads transported into the bays have decreased.

Systematic measurements of temperatures and conductivity (salinity) are presently used to model salinity gradients in the bay. Also, nutrient loads of relatively minor abundance and low gradient are being integrated into bay models to assist biologists who predict the health of the bay.

E.G. Wermund and R.A. Morton represent the Bureau of Economic Geology, The University of Texas at Austin; Gary Powell, the Texas Water Development Board.

Biological Components of Galveston Bay

Peter F. Sheridan, Douglas Slack, Sammy M. Ray, Larry D. McKinney, Edward F. Klima

Estuarine organisms of commercial, recreational and ecological importance typically have inshore and offshore components to their life histories. Many species spawn offshore or near estuary passes, and their larvae or postlarvae migrate into estuarine nursery areas to grow and develop prior to offshore migration and maturation. One notable exception is the American oyster which is completely estuarine. Other taxa such as birds, reptiles and fur-bearing mammals use estuarine habitats for food, refuge and reproduction. Estuarine habitats themselves are formed by plants found only in low-lying coastal areas. Although many estuary-dependent species are harvested from Galveston Bay and nearshore waters, five species of fish (flounder, Atlantic croaker, spotted and sand seatrouts, redfish) and five species of invertebrates (oysters, blue crabs, three penaeid shrimps) dominate annual commercial and recreational landings and dockside value of at least 11,000 tons and $26 million (in 1986).

These organisms do not exist independently of their surroundings but utilize estuarine habitats such as marshes, seagrass beds, oyster reefs and mud flats for food and protection during their juvenile stages. Many species are more abundant in vegetated habitats (emergent marshes, submerged aquatic vegetation) than in adjacent non-vegetated habitats. Fishery production is directly related to wetlands acreage, yet these habitats are being lost from the system through both natural phenomena and human activities. Between wetlands surveys of 1956 and 1979, the estuary lost approximately 16 percent of its marshes and swamps and an estimated 95 percent of its submerged vegetation.

Although critical estuarine habitats are being lost, abundances of most important species do not yet seem to be affected. Landings of fishery organisms and abundance of waterfowl and colonial nesting birds fluctuate annually but appear reasonably stable. On a seasonal basis, most fishery species are harvested in summer or fall months prior to their migration offshore. Oysters are harvested in winter and spring. Waterfowl and shore birds reach peak abundance in fall and winter, while colonial nesting birds are most numerous in spring and summer. Within the water column, phytoplankton blooms (primarily diatoms) are seen in late winter and early summer while the zooplankton community, dominated by copepods, peaks in spring and late summer. Benthic organisms (primarily polychaetes and molluscs) exhibit spring and fall increases in abundances.

The problem of wetlands loss will be exacerbated in the future due to continuing subsidence of coastal areas and to sea level rise from planetary warming. In 1985, the Galveston Bay system was surrounded by approximately 290 square miles of land (mostly marsh) from 0 to 5 feet above mean sea level. With an apparent sea level rise of 5 feet by the year 2100 as projected for this area, that 290 square miles would be converted to open bay with a maximum replacement potential of 140 square miles (the 1985 5- to 10-foot elevation lands). This corresponds to a 50 percent loss in potential marsh land, much of which is already modified by housing and industry. This critical loss of habitat will lead to declines in fisheries productivity and abundances of other estuary-dependent species.

Another major problem facing Galveston Bay is the disruption of timing and amounts of freshwater inflow. At least two fisheries will be impacted by regulation of river flow. The distribution and productivity of existing oyster reefs reflect the equilibrium between low salinity oyster kills and high salinity predation and disease losses. Curtailment or seasonal shifts of freshwater inflow and increasing salinity intrusion caused by man will lead to increased oyster mortality. Evidence also exists that alteration of river flow and wetlands accessibility in the nearby Sabine Lake estuary was followed by the collapse of its white shrimp fishery.

Peter F. Sheridan and Edward F. Klima represent the National Marine Fisheries Service; R. Douglas Slack, Texas A&M University; Sammy M. Ray, Texas A&M University at Galveston; Larry D. McKinney, Texas Parks and Wildlife Department.

Galveston Bay and the Surrounding Area: Human Uses, Production and Economic Values

R.B. Ditton, D.K. Loomis, D.R. Fesenmaier, M.O. Osborn, D. Hollin, J.W. Kolb

The Galveston Bay complex is adjacent to one of the most populated areas in Texas. In 1980 nearly 2.8 million people lived in the four counties surrounding the bay (Chambers, Brazoria, Galveston and Harris), with 2.4 million in Harris county alone. These four counties account for 75 percent of the population residing in the one-county strata adjacent to the Texas coast, and 20 percent of the total state population.

The purpose of this paper is to provide information on the extent to which Galveston Bay and its adjacent land area are used for various purposes and the respective values of these uses, if known. (Accompanying tables are included in Appendix I.) Data are presented for seven major use categories for the Galveston Bay complex: agriculture; fisheries; recreation and tourism; petroleum, chemicals and other manufacturing; wastewater discharge; transportation and navigation; and other uses. Where data were available, changes in Galveston Bay use levels and values over time are presented to understand trends.

The Galveston Bay complex and four surrounding counties account for a disproportionate amount of activity and value on the Texas coast. Oysters, for example, from Galveston Bay have a commercial ex-vessel value of nearly $7 million, approximately 67 percent of the state bay total. Of the 3.2 million pounds of finfish landed by recreational boat fishermen during 1986, more than 1.1 million pounds (35 percent) were landed in Galveston Bay. Sport fishing expenditures associated with the Galveston Bay estuary reportedly account for one-half of all sport fishing expenditures in bay systems along the Texas Gulf coast. Galveston Bay accounts for 30 percent of the total number of marinas on the Texas coast and 63 percent of the total wet slips in commercial marinas. Direct expenditures for "other recreation activities" in the Galveston Bay were 55 percent of total expenditures for this category for all bay systems on the Texas coast. The four counties surrounding Galveston Bay contained 85 percent of the manufacturing establishments in the 16 Texas coastal counties. Of the 31 oil refineries on the Texas coast, 12 (39 percent) are located in the four-county area and account for 44 percent of the coastwide oil refinery design capacity. Thirty-two percent of the gas processing plant design capacity is located there as well. More than one-half of the 3,756 wastewater permittees (or 1,932) in the state of Texas are located in the Galveston Bay watershed. The Ports of Houston and Galveston together account for approximately 43 percent of the total tonnage along the Texas coast. The pattern is the same for housing; 77 percent of the housing units in the 16 coastal counties are located in the four counties surrounding Galveston Bay.

The pattern of the Galveston Bay complex accounting for a disproportionate amount of activity is repeated from a national perspective. For example, nearly one-half of the total chemical production in the U.S. takes place in the four-county area, including the world's single largest chemical complex. More than 500 chemicals are produced there, including 55 percent and 34 percent of the total polypropylene and polyethylene production, respectively. Furthermore, 46 percent of the total U.S. production of ethylene and propylene takes place in the counties surrounding the Bay. Thirty percent of the U.S. petroleum industry is located adjacent to the Galveston Bay complex. Nationally, the Port of Houston is the third largest in the contiguous 48 states in terms of total shipping tonnage.

When Galveston Bay is compared with the thirteen major estuarine areas studied by Nixon, it ranked eighth in watershed area, fourth in surface and sixth in terms of 1980 population level in the adjacent land area.

R.B. Ditton and D.K. Loomis represent Texas A&M University; D.R. Fesenmaier, Texas Agricultural Experiment Station, M.O. Osborn, Texas Parks and Wildlife Department; D. Hollin, Texas Sea Grant Program; J.W. Kolb, Texas Water Commission.

Issues and Information Needs

R.W. McFarlane, T.J. Bright, B.W. Cain, M. Hightower, J. Kendall, J.W. Kolb, A. Mueller, P. Sheridan, C.B. Smith, E.G. Wermund, T.E. Whitledge

Galveston Bay today is a sea of controversy as proponents of development and protectors of natural resources challenge opposing claims of no adverse effects of development versus pending environmental calamity. A large number of projects are in progress or have been proposed. Navigation projects include enlargement of the Houston, Galveston and Texas City channels and the Gulf Intracoastal Waterway, a new channel to Liberty, and the Galveston Home Port. New reservoirs are likely to be built at Wallisville, Lake Creek, Bedias Creek and Tennessee Colony. Interbasin transfer projects will transport water from the Sabine and Trinity Rivers to Houston. Flood control projects are planned for the San Jacinto River, Buffalo Bayou and Clear Creek. A new bridge is to be built to Galveston Island, and bay shorelines will be developed for industry, waterfront housing, and bay and onshore resource extraction. Population and industrial growth have increased the demand for natural resources and disposal of waste materials.

The critical issues associated with these projects are (1) water quality changes in the bay and its tributaries, which transport nutrients and both treated and untreated wastewater discharge to the bay; (2) reductions in freshwater inflow to the bay system and its associated wetlands, and potential changes in bay salinity; (3) enlargement and maintenance of navigational channels as regards dredged material disposal, increased turbidity, resuspension of toxic or hazardous chemicals, and changes in bay circulation and salinity profiles; (4) loss of contiguous wetlands due to subsidence, erosion, decreased sediment transport or shoreline development; (5) energy production in the bay environment; (6) the need for a comprehensive assessment of the cumulative impacts of all development projects; and (7) ecosystem interconnection between the riverine systems, the bay system and the Gulf of Mexico.

Important questions persist. How much has past development influenced the bay? How will current and proposed projects affect the bay? What will be the cumulative impact on the bay of existing projects functioning at their design capacity plus the proposed future projects? All ecosystems have limits on their ability to assimilate impacts. These limits are typically unknown and unheeded. Other estuaries have suffered major, perhaps irreversible, declines in their productivity, particularly as a result of anthropogenic impacts. With Galveston Bay we have the opportunity to act — to identify and reduce or eliminate these impacts — before it is too late. The initial symptoms of stress are apparent — some species have nearly disappeared while important functional components, such as freshwater inflow, sediment transport and wetlands, continue to decline.

It is apparent that voluminous data on chemical, physical and biological parameters have been gathered on Galveston Bay by several state agencies but little of the material has been compiled in a cohesive manner or analyzed. It is essential that funds and manpower be made available to interpret the material already in hand. The uncertainties will remain until further research resolves the critical issues. In the meantime, since none of the proposed developments are time-dependent or constrained, it will be prudent to err on the side of conservation. We must avoid ecological brinkmanship, taking care not to step over the precipice. We must act to restore and enhance estuarine productivity, lest we be relegated by indifference to merely recording its decline.

R.W. McFarlane represents McFarlane & Associates; T.J. Bright and M. Hightower, Texas Sea Grant Program; B.W. Cain and A. Mueller, U.S. Fish and Wildlife Service; J. Kendall and J.W. Kolb, Texas Water Commission; P. Sheridan, National Marine Fisheries Service; C.B. Smith, Texas General Land Office; E.G. Wermund, Bureau of Economic Geology, The University of Texas at Austin; T.E. Whitledge, The University of Texas at Austin Marine Science Institute.

Management of Galveston Bay

Larry McKinney, Mike Hightower, Al Green, C. Bruce Smith

Galveston Bay, seventh largest estuary in the United States and largest in Texas, is a complex system that both provides for and confounds multiple-use philosophies. While it shares common problems with many other "urban" estuaries it is unique in that it has remained resilient and productive under intensive development pressure. This is despite the fact that the bulk of its natural resources, about 600 square miles, are trapped between its major port and the open sea.

The Port of Houston ranks third in U.S. tonnage shipped; 139 million tons of commerce annually traverses the estuary's 251 miles of channels. In 1987, the Port of Galveston shipped 5.949 million tons, while the Port of Texas City shipped 33.4 million tons in 1986. Petroleum-related industries dominate the commercial activities of this sprawling metropolitan area, eighth largest in the United States. More than 30 percent of the United States petroleum industry and 50 percent of its chemical production is concentrated on the margins of the estuary.

Economic predominance has come at some cost to this shallow, wind-dominated estuary. About 6 percent, or 39.5 square miles, of the bay's bottom is covered in dredge spoil. The upper reaches of the Houston Ship Channel, until recently, have shown little signs of life and the possibility of catastrophic oil spills within the bay remains a real threat.

Regardless, fisheries productivity in the bay and nearshore waters dominates Texas statistics — 40 percent of all shrimp landings, 67 percent of oyster production, and 50 percent of all recreational fishing expenditures. The Galveston Bay system annually accounts for almost $76 million in commercial ex-vessel fishery value. Additionally, direct recreational fishing expenditures equal $171 million and, combined with expenditures for other recreational activities, totals $239 million, all attributed to the Galveston estuary alone.

That Galveston Bay may be a system approaching the limits of assimilation and resilience is a possibility of increasing concern to resource managers. Development has continued along the bay. Twenty-five percent of development on the Texas coast that requires a dredge and fill permit occurs within this estuary. Proposed development and planning documents indicate that the pressure will not slacken in the foreseeable future. Expansion of the main shipping channel, new reservoirs and industrial developments are in various stages of planning. The indirect and cumulative impact of these actions is unknown, but experience has taught us that the possibility of adverse effects are very real.

Because of the inextricable link between economic development and population growth, direct demand upon existing resources is also increasing. Within Galveston Bay these direct impacts are readily evident as fisheries resources are more and more finely partitioned among commercial as well as recreational interests. Additionally, wetland conversion to support commercial and residential development continues to reduce valuable fisheries habitat. Subsidence from overuse of groundwater has also contributed to increased marsh loss.

The signs that this is an increasingly stressed system are becoming more evident. Large areas of the bay, for example, are closed to oystering because of pollution. In the remainder of the bay the oyster fishery has been closed because of overfishing and only recently opened in response to court order. Commercial netting of red drum (redfish) and spotted seatrout has been eliminated in favor of the recreational fishery. There simply were not enough fish to support both. Offshore, shrimping grounds have periodically been closed to protect stock populations.

Larry McKinney and Al Green represent the Texas Parks and Wildlife Department; Mike Hightower,Texas Sea Grant Program; and C. Bruce Smith, Texas General Land Office..

The single most important management concern for Galveston Bay thus becomes the question of how much more can the system absorb? What straw is it that will break the camel's back? Some managers see this straw looming over the not-so-distant future horizon. Others do not. This disagreement is reflected in the increasingly vocal and confrontational positions of opposing viewpoints. Proposed projects like Wallisville Reservoir and the expansion of the Houston Ship Channel, as well as the already permitted Texas City project and the status of commercial finfish and the oyster fishery, are indicative of these conflicting opinions. Not only are there differing interpretations of the impacts from these projects and activities, but in many cases a basic disagreement over information. Many questions regarding hydrology, the fate of contaminants trapped in dredge sediment, the carrying capacity of fisheries populations and freshwater inflows cannot be addressed because data and analyses are either lacking or conflicting. The basis of practically all of the major issues raised in the previous section can be reduced to this basic issue.

In growing recognition of a need to address this deficiency — that decisions are being forced upon us regardless of our basic understanding — managing agencies are taking corrective action. This is made more difficult because of a lack of a coordinated management entity. However, management and resource agencies have cooperated with some notable success to achieve positive benefits for Galveston Bay. Improvements in water quality within the Houston Ship Channel, protection of rookery islands, and efforts to minimize shallow bay disposal of dredge spoil are just some areas where agencies have cooperated to benefit the estuary. The state legislature has also mandated studies of Texas estuaries to assess freshwater inflow needs. Galveston Bay weighs heavily in that effort and will be a focus of attention in the near future.

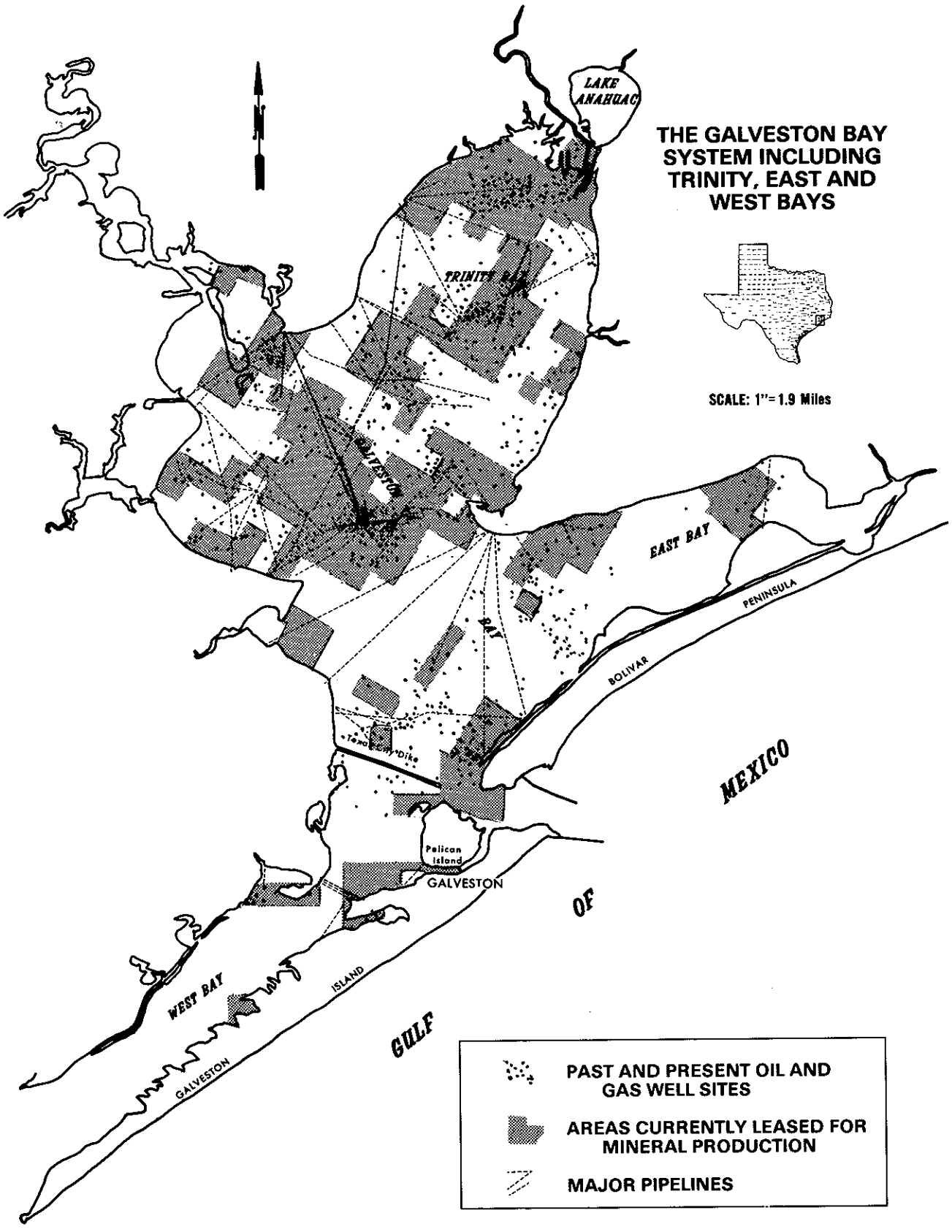
Three other important actions are also indicative of Texas' determination to both protect and manage Galveston Bay. After Galveston Bay was named a priority estuary in the Clean Water Act, the Governor of Texas initiated the process to establish a management conference. This would be a first step in establishing management goals for the system as a whole. In another, and unprecedented, action, the State's chief natural resources agencies — Texas Parks and Wildlife Department, Texas Water Commission and Texas General Land Office — jointly requested a comprehensive study of Galveston Bay. The request has been strongly endorsed by other state, as well as federal, agencies and conservation organizations. Finally, a group of prominent citizens have recently organized the Galveston Bay Foundation. Foundation membership extends across a broad spectrum of concerned individuals, and state and local officials. Their goal is to see that Galveston Bay and its vital resources are protected both now and for the future.

As resource managers we have a unique opportunity to maintain a productive estuary of national importance, Galveston Bay, while meeting multiple-use demands. Others have missed that opportunity and the cost is only now being realized. By its actions Texas has demonstrated its resolve to accomplish this goal and has committed resources toward it. The mechanism to unify this commitment with broader national goals has also become available and may well provide the vehicle to accomplish these objectives. What is still lacking are answers to some basic questions — answers vital to decision-makers if they are to act in an informed manner. Regardless of whether we have those answers, decisions will have to be made or events will make them for us. It would be far better for us if those decisions were informed ones, because therein lies the future of this most valuable resource

Appendix I
Figures and Tables

The following illustrations depict only Trinity, Galveston, East and West Bays of the Galveston Bay complex. Christmas, Drum and Bastrop Bays are not including in this summary, but as a part of the Galveston Bay complex they will be included in the final report.

OIL AND GAS DEVELOPMENT



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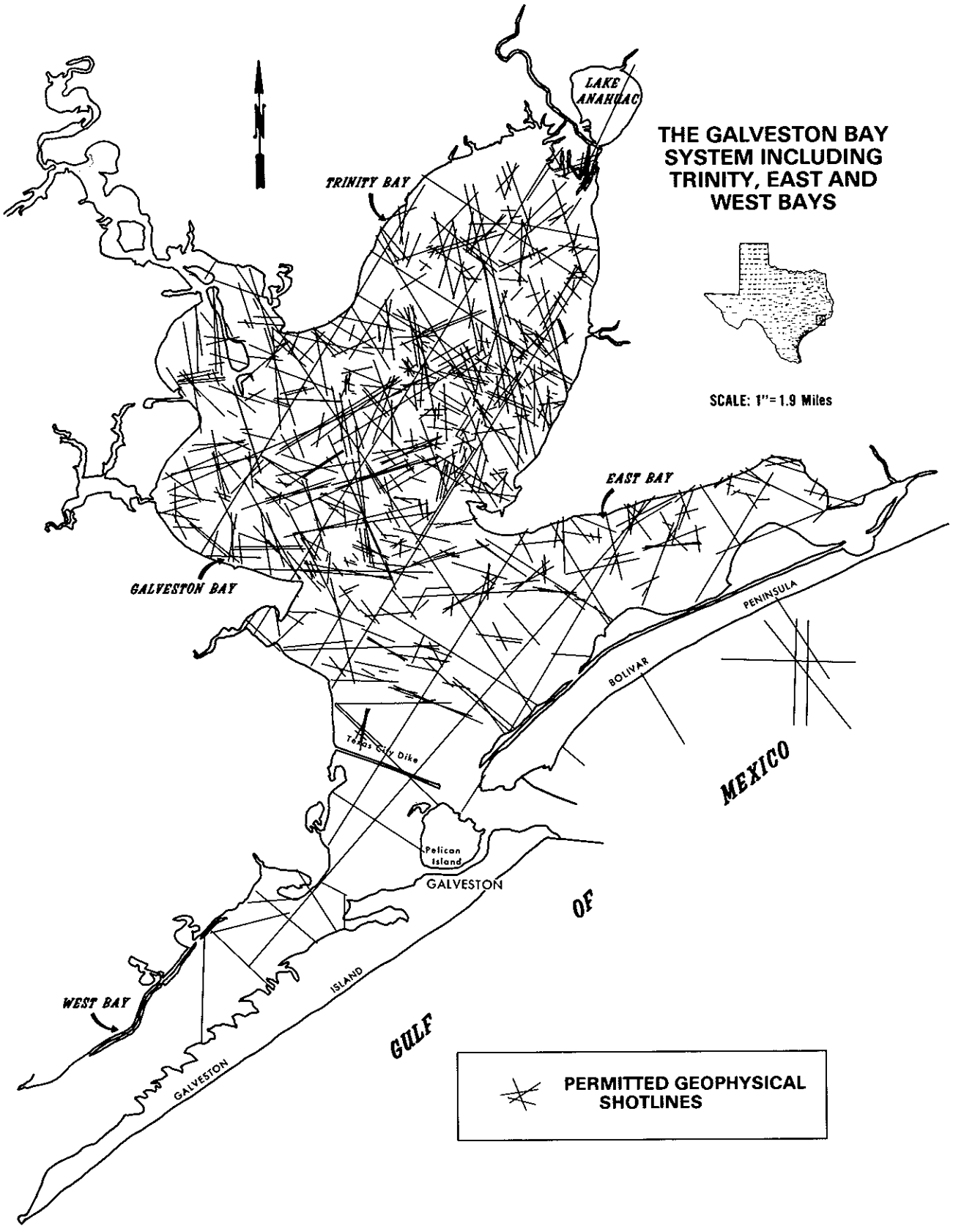
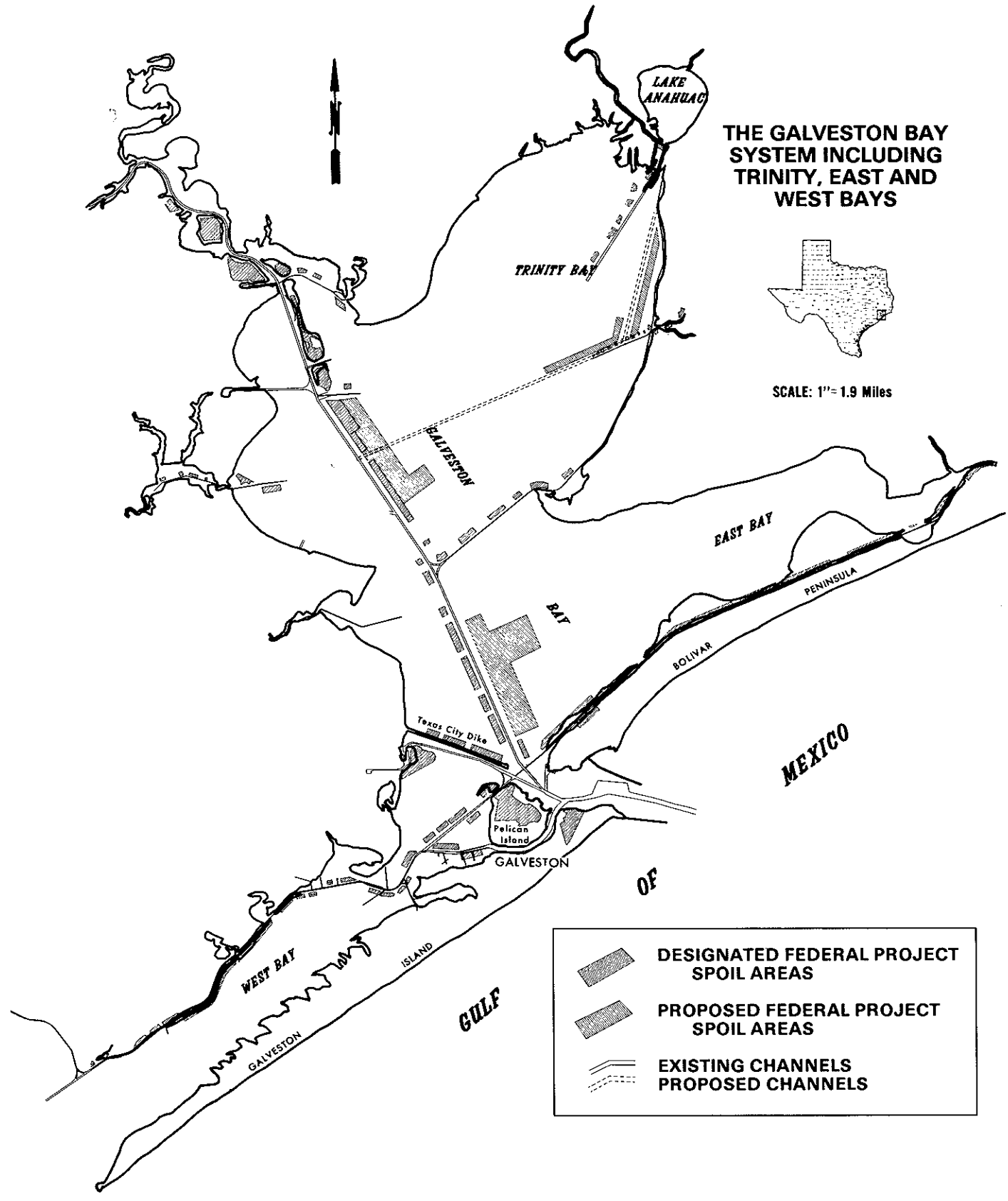
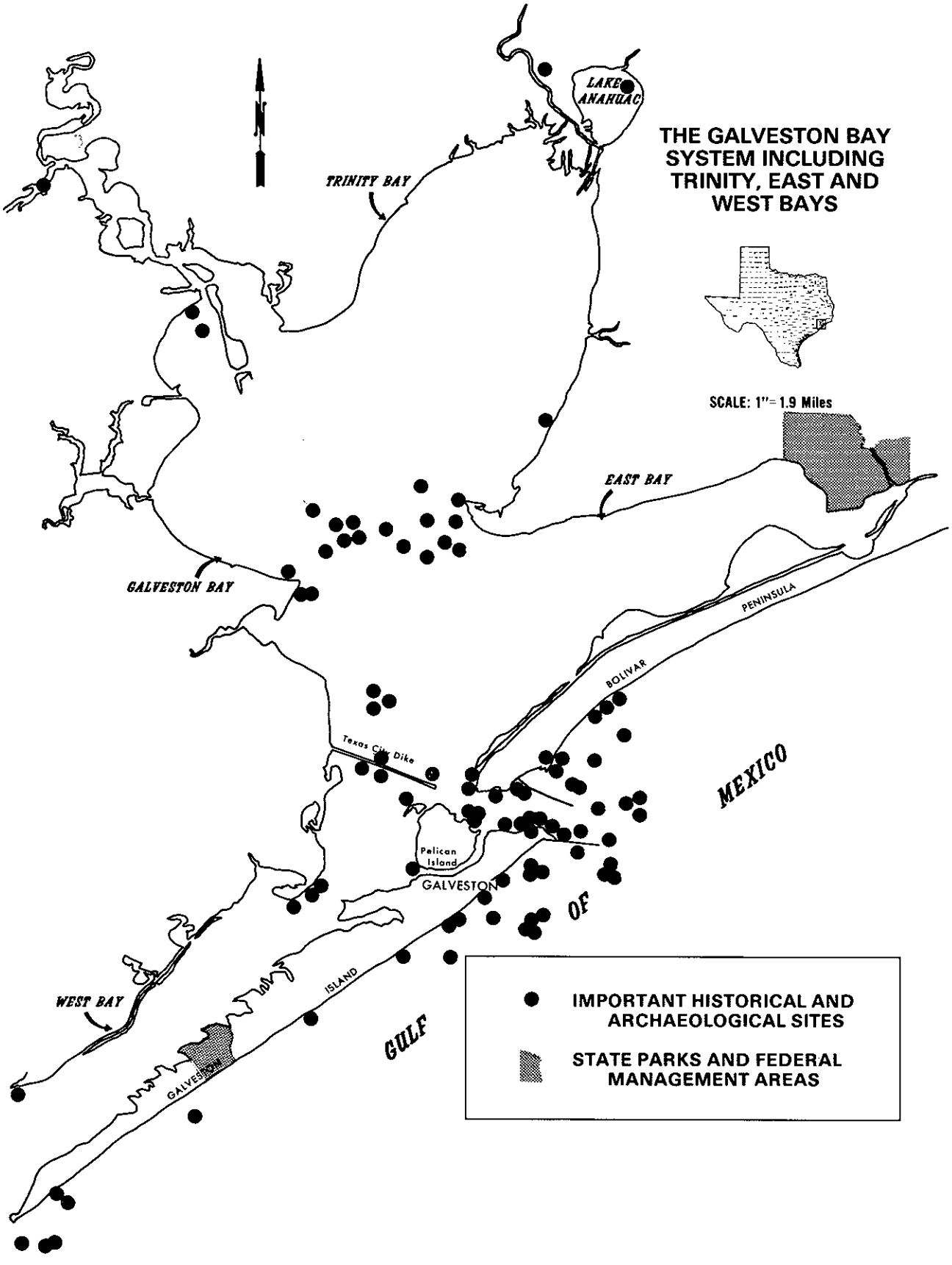


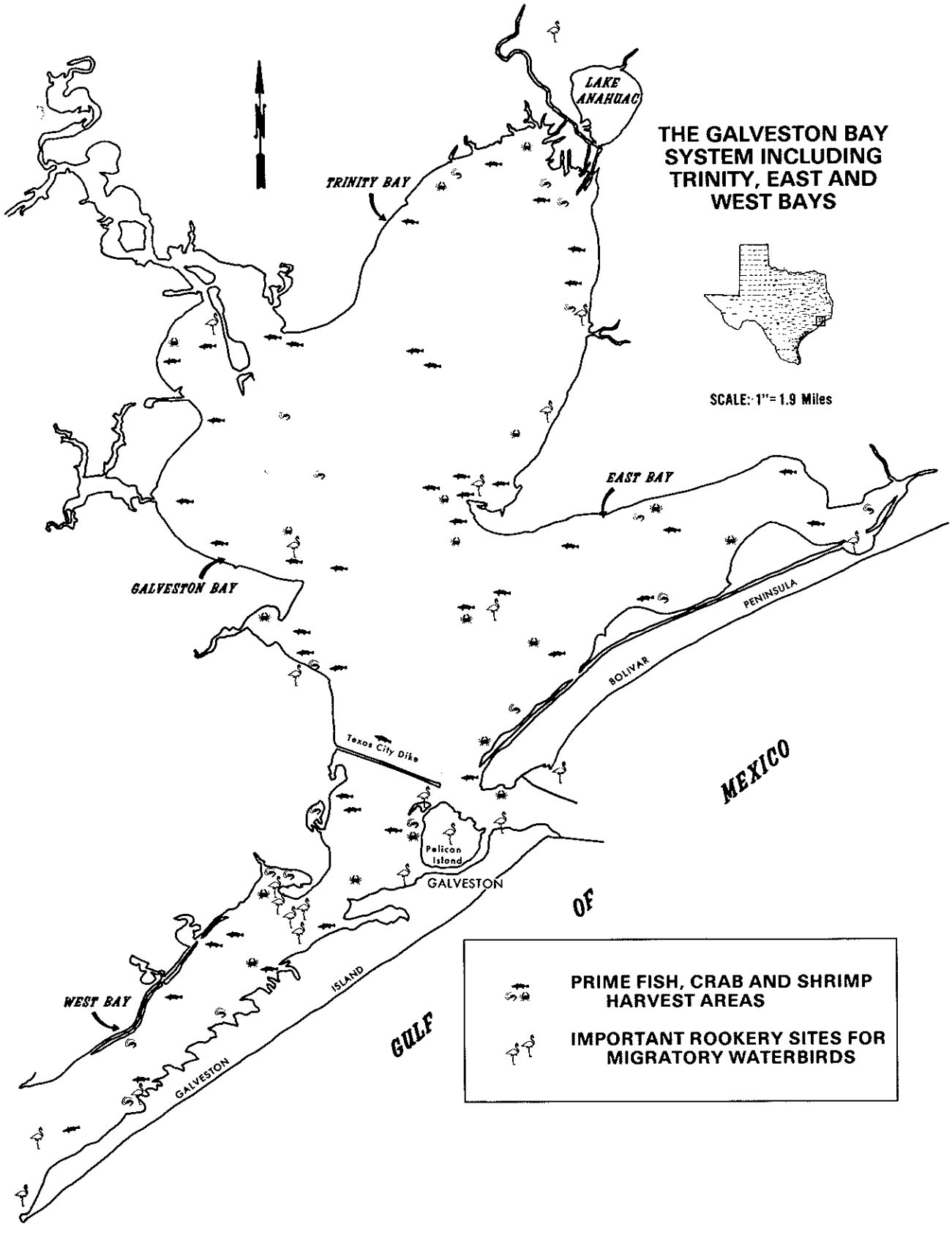
FEDERAL NAVIGATION CHANNELS AND DISPOSAL AREAS



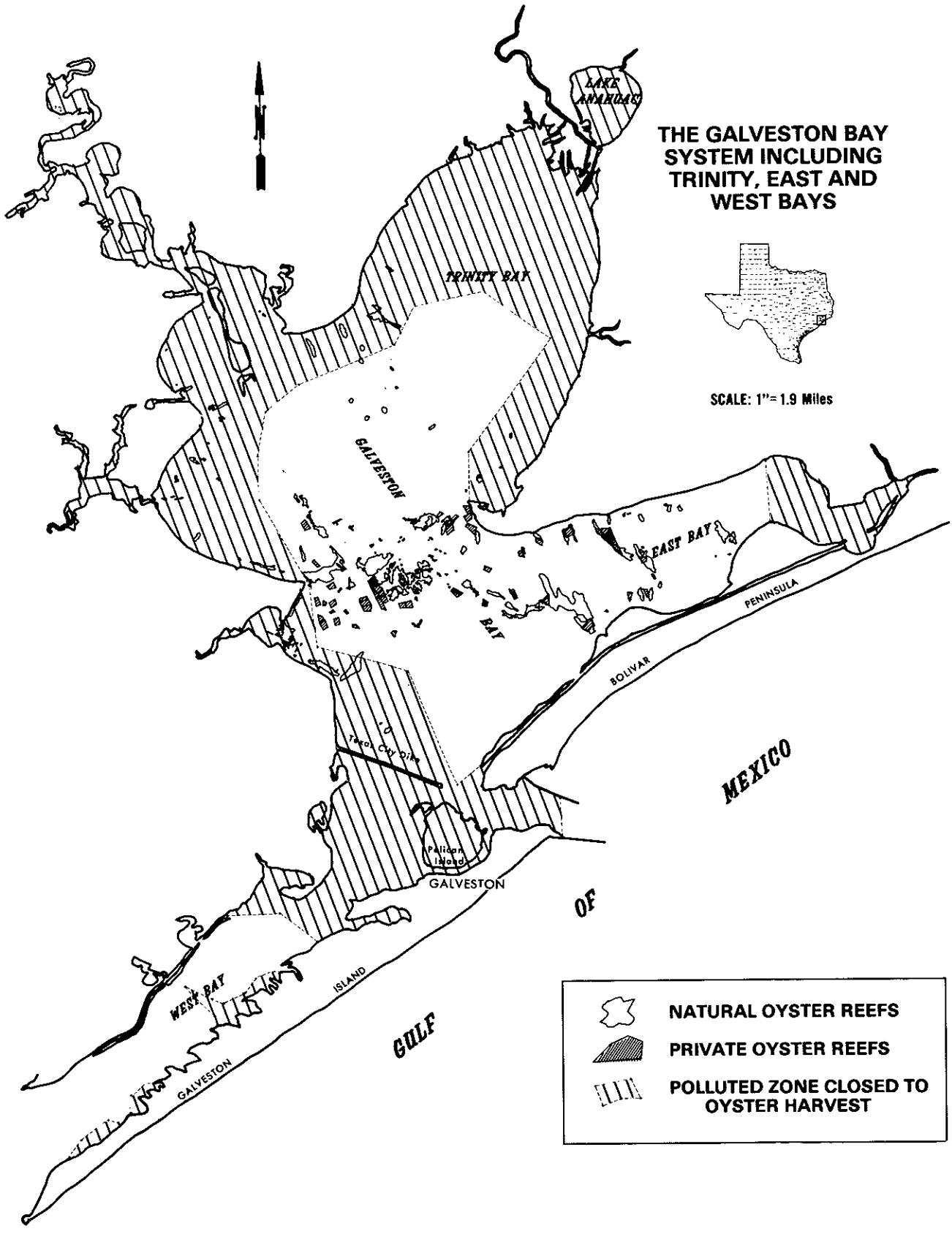
SENSITIVE CULTURAL RESOURCES



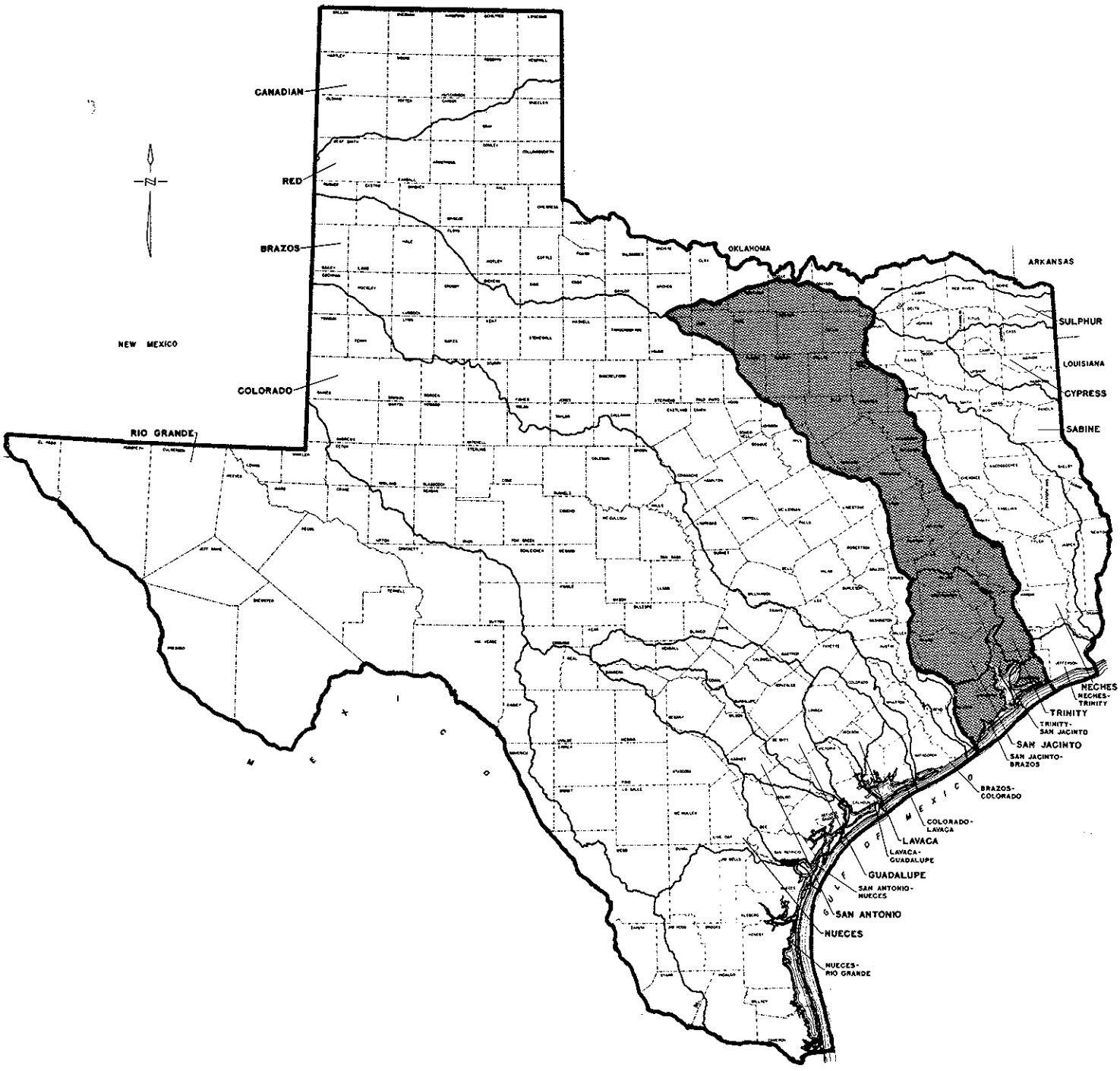
SENSITIVE BIOLOGICAL RESOURCES



OYSTER FISHERIES RESOURCES OF GALVESTON BAY



GALVESTON BAY SYSTEM WATERSHED



FRESH WATER FLOWS AND POINT SOURCE DISCHARGES

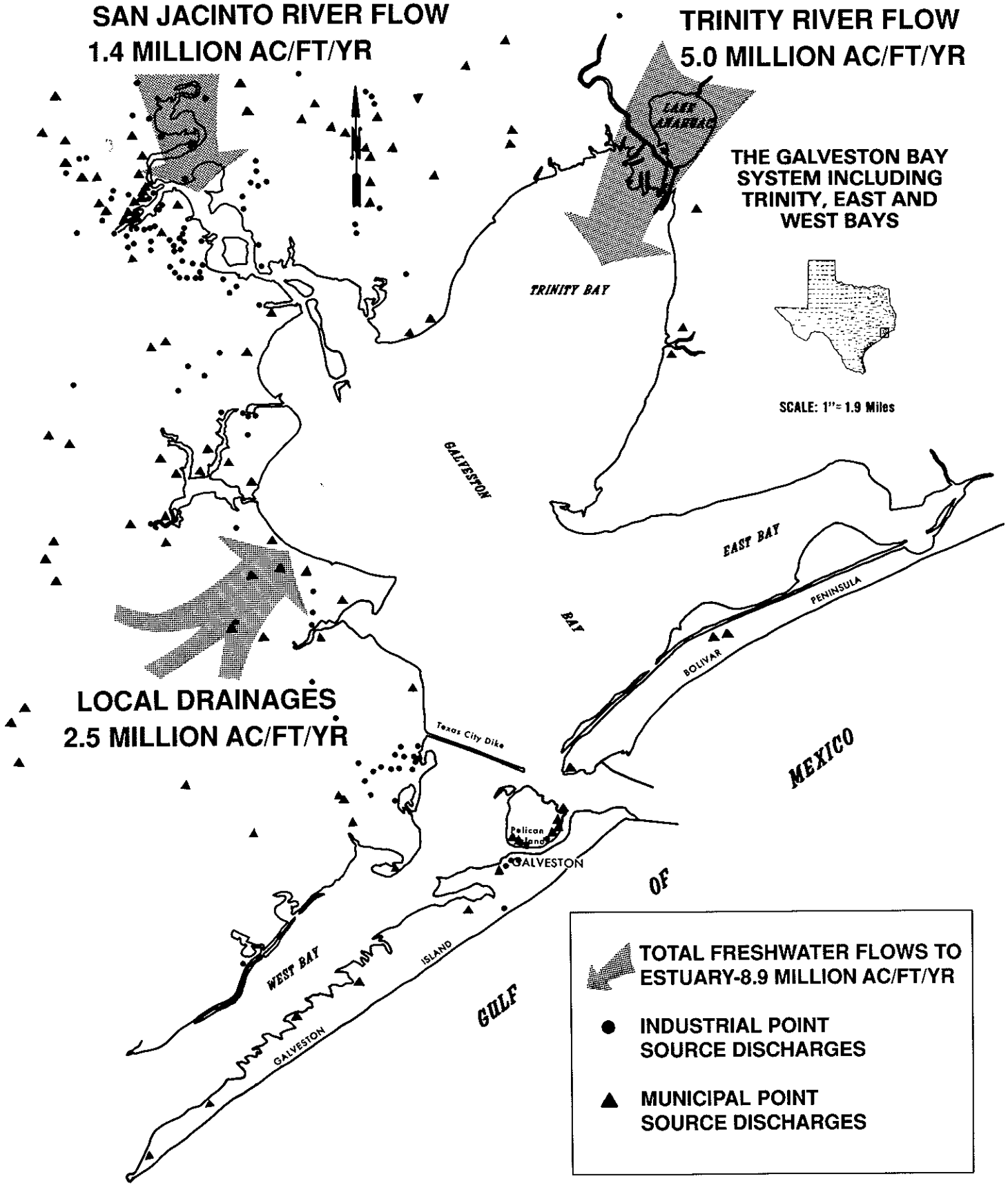


Table 1. Distribution of Population Along Texas Coast and Percent Accounted for by the Galveston Bay Complex for the Years 1960, 1970, 1980, 1990 and 2000.

	1960[a]	1970[b]	1980[c]	1990[d]	2000[d]
Jefferson	245,659	244,937	250,938	266,664	272,346
Chambers	10,379	12,187	18,538	21,310	22,955
Harris	1,243,158	1,741,908	2,409,547	3,078,356	3,584,883
Galveston	140,364	169,812	195,940	228,833	246,490
Brazoria	72,204	108,312	169,587	206,657	235,848
Matagorda	25,744	27,913	37,828	37,869	34,057
Jackson	14,040	12,975	13,352	14,392	14,330
Calhoun	16,592	17,831	19,574	24,694	28,580
Refugio	10,975	9,494	9,289	9,087	8,309
Aransas	7,006	8,902	14,260	20,012	24,608
San Patricio	45,021	47,288	58,013	66,780	70,685
Nueces	221,573	237,542	268,215	324,410	380,285
Kleburg	30,052	33,173	33,358	37,268	39,501
Kenedy	884	699	534	534	586
Willacy	20,084	15,570	17,495	19,845	20,668
Cameron	151,098	140,368	209,727	270,524	318,384
TOTAL	2,254,833	2,828,911	3,726,195	4,627,235	5,302,515
Percent of coastal strata contained in four-county area	65.0%	71.8%	75.0%	76.4%	77.1%
Percent of state population contained in four-county area	15.3%	18.2%	19.6%	20.0%	20.1%

Source:
[a]Dallas Morning News. 1961.
[b]U.S. Department of Commerce. 1972.
[c]U.S. Department of Commerce. 1983a.
[d]Texas Department of Health. 1986.

Table 2. Estimated Commercial Harvest of Finfish and Shellfish from Galveston Bay During 1986.

	Pounds Harvested	% of all bays total weight	Ex-vessel value	% of all bays ex-vessel value
Finfish	424,495	28	206,491	21
Shellfish				
Shrimp	6,152,860	30	6,839,741	27
Oyster	3,538,808	63	6,951,738	67
Blue crab	3,018,315	32	1,028,097	33

Source: Osburn, Quast and Hamilton, 1987.

Table 3. **Direct and Total[a] Economic Impacts of the Inshore and Offshore Commercial Fishery in the Galveston Bay Complex (Trinity-San Jacinto Estuary), 1986.**

	Landings		Total			
			Inshore		Inshore/Offshore	
	Inshore	Inshore/ Offshore	Regional*	State	Regional*	State
Output (Million $)	12.5	63.6	32.9	41.1	167.6	209.3
Income (Million $)	3.5	18.0	7.3	10.4	37.2	52.7
State Tax Revenues (Million $)	0.1	0.3	[b]	0.6	[b]	2.8
Local Tax Revenues (Million $)	0.1	0.4	[b]	0.9	[b]	4.4

[a]Total = direct, indirect and induced
[b]Data not available

*Four-county area (Brazoria, Chambers, Galveston, Harris)
Source: Fesenmaier and Jones, 1987.

Table 4. **Annual Weight of Finfish Landed by Recreational Boat Fishermen from Galveston Bay during 1984, 1985 and 1986.**

Year	Galveston Bay	All Texas Bays	% of total weight from Galveston Bay
1983-1984	1,391,100	4,316,900	32
1984-1985	940,700	2,922,000	32
1985-1986	1,121,400	3,205,400	35

Source: Osburn and Ferguson, 1987.

Table 5. **Direct and Total[a] Economic Impact from Sport Fishing Expenditures, Galveston Bay Complex (Trinity-San Jacinto Estuary), 1986[b].**

	Direct[c]		Total	
	Regional*	State	Regional*	State[d]
Output (Million $)	171.5	181.2	433.2	576.7
Income (Million $)	53.6	66.1	104.0	154.5
State Tax Revenues (Million $)	[e]	0.8	7.4	7.8
Local Tax Revenues (Million $)	[e]	2.3	13.1	13.9

[a]Total = direct, indirect and induced
[b]Values in 1986 dollars
[c]Direct impacts for the region and state differ due to the travel expenditure adjustment
[d]Statewide expenditures include the regional impacts
[e]Data not available

*Four-county area (Brazoria, Chambers, Galveston, Harris)
Source: Fesenmaier and Jones, 1987.

Table 6. Number of Marinas and Wet Slips in Galveston Bay and for the Texas Coast, 1976-1987.

	Galveston Bay		Galveston Bay as % of Total Coastal		Coastal Texas	
	# of Marinas	Wet Slips	Slips	Marinas	# of Marinas	Wet Slips
1976	18	3,066	56.1	27.3	66	5,469
1981	21	4,151	58.1	25.6	82	7,150
1985	26	6,579	61.5	28.9	90	10,706
1987	40	9,171	62.9	29.9	134	14,573

Source: Dewayne Hollin, Texas A&M University Sea Grant College Program, 1988.

Table 7. Direct and Total[a] Economic Impact from Other Recreation[b] Expenditures, Galveston Bay Complex (Trinity-San Jacinto Estuary), 1986[c]

	Direct[d]		Total	
	Regional	State	Regional	State[e]
Output (Million $)	122.4	131.8	311.0	425.2
Income (Million $)	38.2	48.5	74.5	113.3
State Tax Revenues (Million $)	[f]	0.6	5.3	5.7
Local Tax Revenues (Million $)	[f]	1.6	9.5	10.1

[a]Total = direct, indirect and induced
[b]Activities include hunting, picnicking, swimming, camping, pleasure boating and sightseeing
[c]Values in 1986 dollars
[d]Direct impacts for the region and state differ due to the travel expenditure adjustment
[e]Statewide expenditures include the regional impacts
[f]Data not available

Source: Fesenmaier and Jones, 1987.

Table 8. Number of Wastewater Permittees in Galveston Bay Watershed.

Area	Number of Permits[a]		
Trinity Basin (above Lake Livingston Dam)	519		
San Jacinto Basin (above Lake Houston Dam)	262		
Galveston Bay (below Livingston and Houston Dams)	1,151		(719)[b]
Domestic		674	(484)
Industrial		477	(235)
Total Galveston Bay Watershed	1,932		
Total Permittees in Texas	3,756		

[a]These include both active and inactive permits. "No discharge" permits are not included.
[b]These include only discharging active permittees.

Source: Kolb, 1987.

Table 9. Direct and Total[a] Economic Impact from the Ports of Houston, 1986 and Galveston, 1981[b].

	Direct		Total	
	Port of Galveston	Port of Houston	Port of Galveston	Port of Houston
Revenue (Million $)	638	2,976	N/A	N/A
Employment (Man-years)	4,138	28,650	6,993[c]	47,781
Income (Million $)	184	712	405[d]	1,567

[a]Total = direct and indirect
[b]Values in 1986 dollars
[c]Secondary employment derived using a 1.69 employment multiplier for waterborne transportation (TDWR, 1983)
[d]Secondary income derived using a 2.2 income multiplier recommended by the U.S. Department of Commerce Maritime Adminstration (1980)

Source:
1) Port of Galveston figures were derived from U.S. Army Corps of Engineers, Galveston District, 1987.
2) Port of Houston figures from Martin O'Connell Associates, 1987.

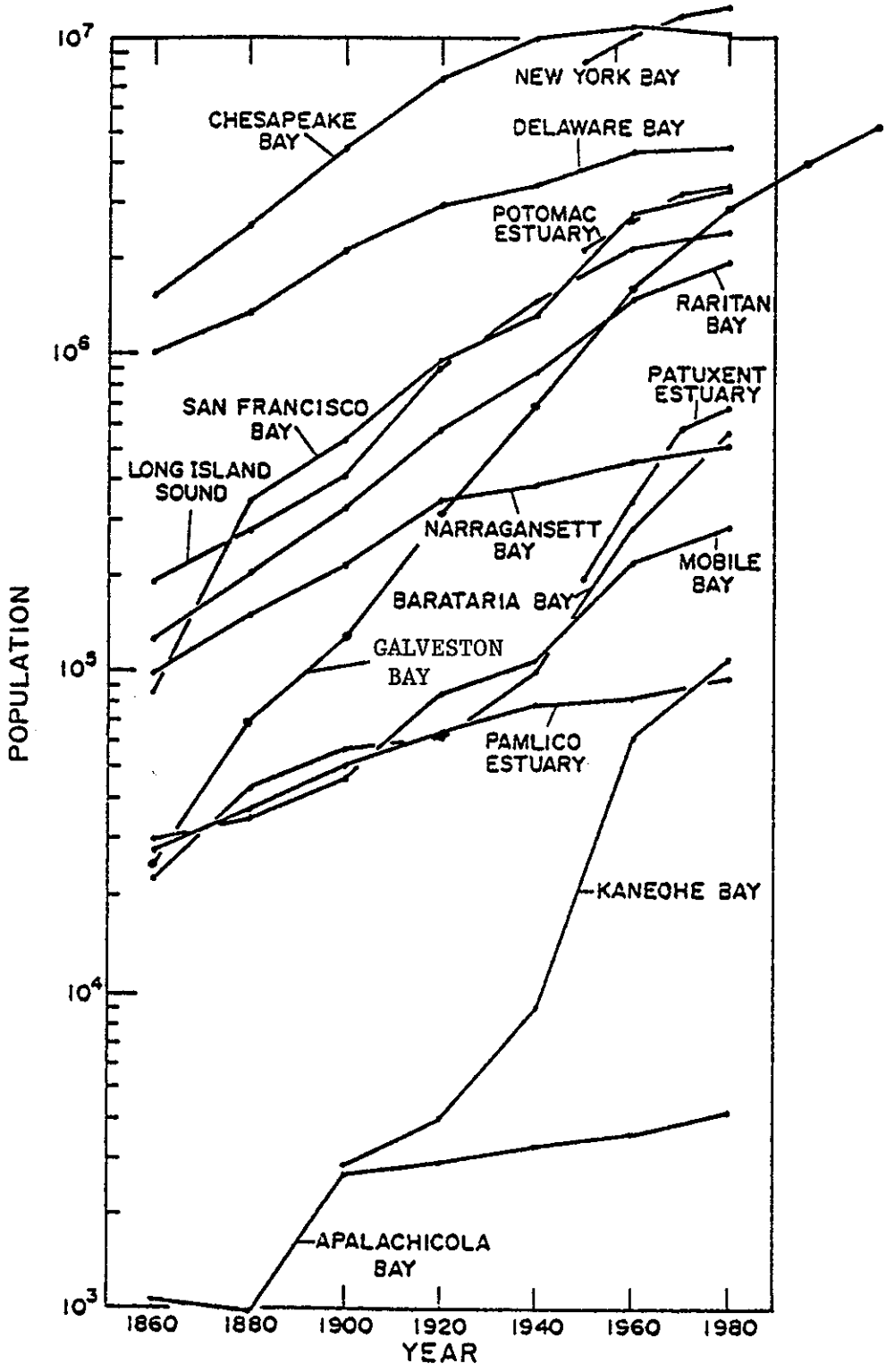


Figure 1. Human Population Adjacent to Selected Estuarine Study Areas

Source—
All data except for Galveston Bay were derived from Nixon, 1983. Data for Galveston Bay Counties are from Dallas Morning News, 1951.

Appendix II
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Galveston Bay Description

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