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Biological Services Program

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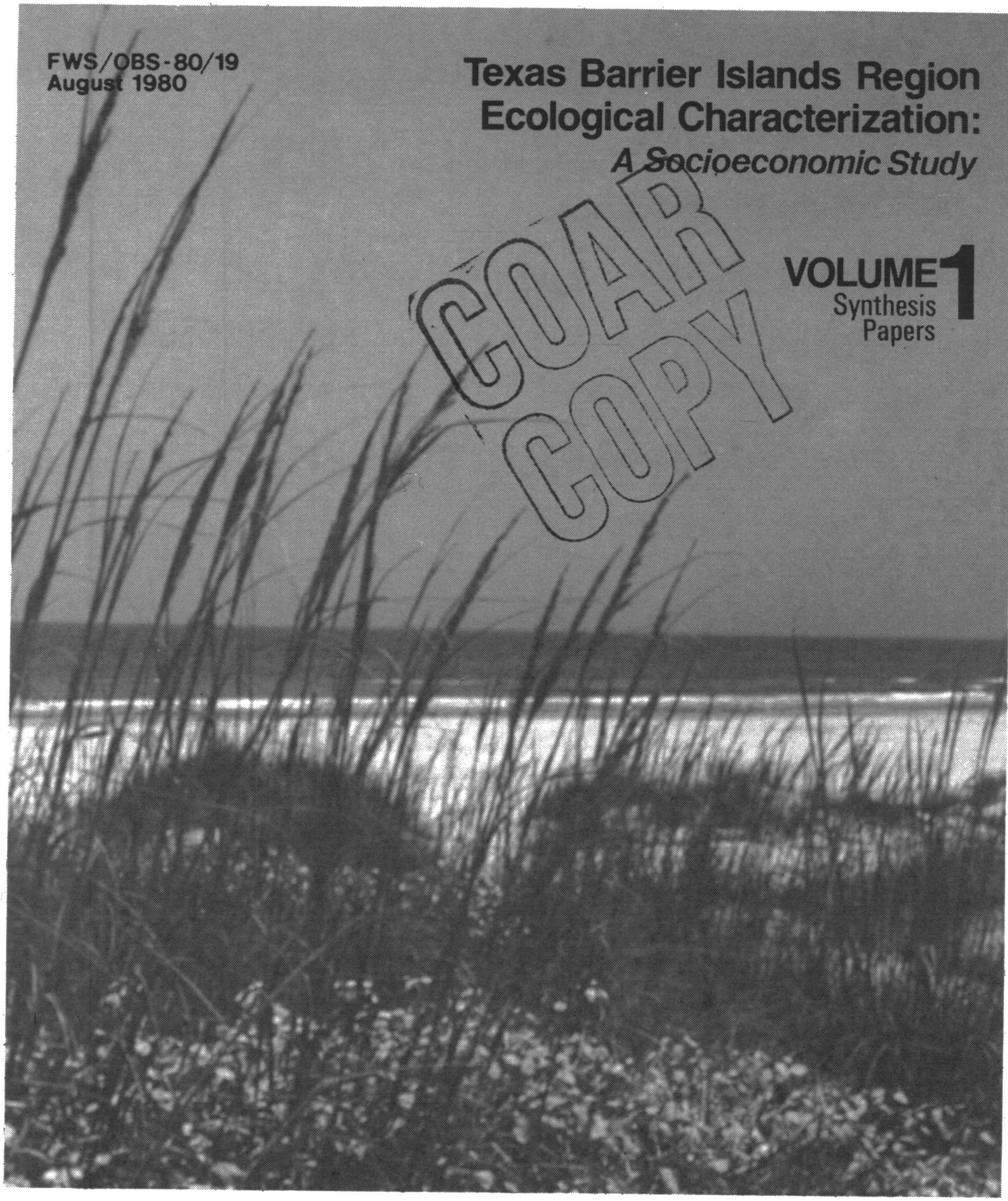
Texas Barrier Islands Region Ecological Characterization:

A Socioeconomic Study

VOLUME 1
Synthesis Papers



Bureau of Land Management
Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.

- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.

- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on an analysis of the issues, a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

Projects have been initiated in the following areas: coal extraction and conversion; power plants; geothermal, mineral and oil shale development; water resource analysis, including stream alterations and western water allocation; coastal ecosystems and Outer Continental Shelf development; and systems inventory, including National Wetland Inventory, habitat classification and analysis, and information transfer.

The Biological Services Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staffs, who provide a link to problems at the operating level; and staffs at certain Fish and Wildlife Service research facilities, who conduct in-house research studies.

FWS/OBS-80/19
AUGUST 1980

TEXAS BARRIER ISLANDS REGION ECOLOGICAL CHARACTERIZATION: A SOCIOECONOMIC STUDY

Volume I: Synthesis Papers

by

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DISCLAIMER

PREFACE

The purpose of the socioeconomic characterization study is to compile and synthesize information from existing sources concerning the natural, physical, and social components of the ecosystems within the Texas Barrier Islands Region. Decisionmakers, among others, should find this report and its data base useful for coastal resource planning and management. This is one of a series of characterizations of coastal ecosystems that is being produced by the U.S. Fish and Wildlife Service. This series describes the relationships between complex growth processes and the availability of natural resources in the Nation's coastal areas.

This project was conducted under Contract FWS 14-16-0009-79-103. Funding was provided by the Bureau of Land Management and the Fish and Wildlife Service. Any questions or suggestions regarding this publication should be directed to:

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The cover photograph was taken by Kent Butler, University of Texas at Austin.

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ABBREVIATIONS

BLM	Bureau of Land Management
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
DOE	Department of Energy
EPA	Environmental Protection Agency
FWPCA	Federal Water Pollution Control Act
FWS	Fish and Wildlife Service
GIWW	Gulf Intracoastal Waterway
HCRS	Heritage Conservation and Recreation Service
ICC	Interstate Commerce Commission
IPM	Integrated Pest Management
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OBS	Office of Biological Services
OCS	Outer Continental Shelf
OCZM	Office of Coastal Zone Management
OPEC	Organization of Petroleum Exporting Counties
OWOCRS	Open Water Oil Containment and Recovery System
PAD	Petroleum Administration for Defense
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SIC	Standard Industrial Classification
SMSA	Standard Metropolitan Statistical Area
SPR	Strategic Petroleum Reserve
STCC	Standard Transportation Commodity Classification
TBIE	Texas Barrier Islands Ecosystems
TDPA	Texas Deepwater Port Authority
TDWR	Texas Department of Water Resources
TEC	Texas Employment Commission
TGLO	Texas General Land Office
TORP	Texas Outdoor Recreation Plan
TPWD	Texas Parks and Wildlife Department
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USGS	United States Geological Survey

ac	acre
bbl	barrel
DWT	deadweight ton
gal	gallon
gpd	gallons per day
mt	metric ton
N.D.	no data
ppm	parts per million
t	short ton

METRIC AND ENGLISH UNITS OF MEASUREMENT

Distance

1 cm = 0.39 in	1 in = 2.54 cm
1 m = 39.38 in	1 ft = 0.30 m
1 km = 0.62 mi	1 yd = 0.91 m
	1 mi = 1.61 km

Area

1 m^2 = 1.2 yd^2	1 ft^2 = 0.09 m^2
1 km^2 = 0.39 mi^2	1 yd^2 = 0.83 m^2
1 ha = 2.5 ac	1 ac = 0.40 ha
	1 mi^2 = 2.59 km^2

Weight

1 g = 0.035 oz	1 oz = 28.35 g
1 kg = 2.20 lb	1 lb = 453.60 g
1 mt (1000 kg) = 1.1 t (2,204.6 lb)	1 lb = 0.45 kg
	1 t = 0.91 mt

Volume

1 ml = 0.03 fl oz	1 fl oz = 29.57 ml
1 liter = 2.1 pt	1 pt = 0.47 liter
1 liter = 1.06 qt	1 qt = 0.95 liter
1 bbl = 42 gal	1 gal = 3.79 liter
1 m^3 = 35 ft^3	1 ft^3 = 0.03 m^3
1 m^3 = 1.3 yd^3	1 yd^3 = 0.76 m^3

Temperature

$C^o = 5/9\ F^o - 32$	$F^o = 9/5\ C^o + 32$

INTRODUCTION

By Presidential proclamation, 1980 has been designated the "Year of the Coast." The Texas Barrier Islands Ecosystems (TBIE) characterization study area comprises some of the Nation's more pristine coastal landscape and some of the more intensively developed urban industrial areas found in the United States (Figure 1). Rapid development and public interests must be delicately balanced to manage coastal area resources and establish effective resource management policies for the future. Socioeconomic data collection and synthesis will be important tools equipping the public to identify what is known about the TBIE study area, and the range of consequences attributable to alternative resource management practices in the area.

In 1953, the Outer Continental Shelf Lands Act (67 Stat. 62) was passed by Congress, establishing Federal jurisdiction over the submerged lands of the continental shelf seaward of state boundaries. The Act charged the Secretary of the Interior with the responsibility for administrating Outer Continental Shelf (OCS) mineral exploration and development. The Secretary was empowered to formulate regulations so that the provisions of the Act might be met. In conjunction with this authority, the Department adopted three overall minerals management goals: 1) receipt of fair market value for the minerals leased; 2) orderly development of resources; and 3) protection of the environment.

Subsequent to the passage of the OCS Lands Act of 1953, the Secretary of the Interior designated the Bureau of Land Management (BLM) as the administrative agency for leasing submerged Federal lands, and the U.S. Geological Survey (USGS) for supervising production. The BLM was also designated by the Secretary as lead agency for all environmental actions pertaining to development of OCS mineral resources.

The Submerged Lands Act (67 Stat. 29) set the inner limit of authority of the Federal government by giving coastal states jurisdiction over mineral rights in the seabed and subsoil of submerged lands adjacent to their coastline out to a distance of three nautical miles (5.6 km). There are two exceptions, Texas and the Gulf coast of Florida, where State jurisdiction extends to nine nautical miles (16.7 km) based on terms for admission to statehood.

The National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4371 et seq.) requires that all Federal agencies utilize a systematic, interdisciplinary approach that will insure the integrated use of the natural and social sciences in any planning and decisionmaking which may have an impact on the human environment. Subsequent changes in the regulations guiding the implementation of NEPA procedures (40 CFR 1500-1508) call for a greater emphasis on issue identification and on "scoping" in the environmental planning process, to avoid the excessive informational burden that had characterized previous impact assessment efforts.

The U.S. Fish and Wildlife Service (FWS) has developed an ecological characterization approach for describing coastal areas of the United States and its territories to assist in natural resource planning policy in conjunction with OCS oil and gas development. "Characterizations provide descriptions of the socioeconomic features, biological resources, and physical processes that comprise a particular coastal ecosystem. Descriptions, where possible, are both quantitative

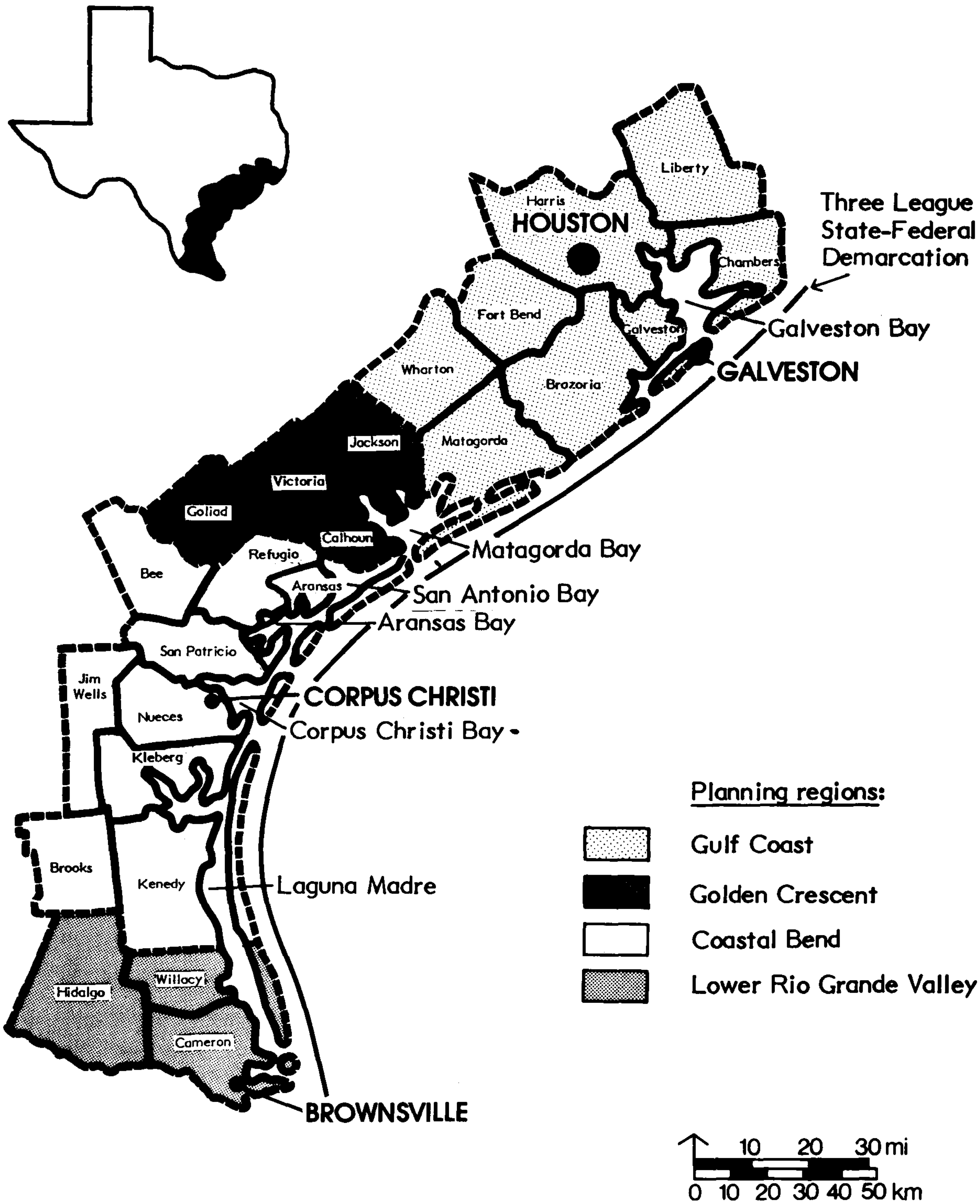

Figure 1. Texas Barrier Islands Ecosystems study area and subregions (Lay and Culbertson 1978).

and qualitative in nature. This information is integrated into a functional framework to provide an understanding of the interrelationships of the ecosystem" (Johnston 1978: 692). In an interagency memorandum of understanding, the Bureau of Land Management and the Fish and Wildlife Service agreed that in the course of the Ecological Characterization project for the TBIE study area, socioeconomic components of the ecosystems should receive special attention because of extensive oil and gas activities and their impact on the area (personal communication, Elaine Bunce, FWS, Memorandum of Understanding between BLM and FWS No. AA551-MU9-14).

THE TEXAS BARRIER ISLANDS ECOSYSTEMS STUDY AREA

The 24-county study area contains approximately 58,300 km^2 (22,500 mi^2) encompassing several distinct resource zones and many overlapping governmental jurisdictions. Characterization of the region as a whole, while permitting a broader range of generalizations than would be provided by county-level discussion, would eliminate an emphasis on some of the distinctive characteristics that are peculiar to subareas within the barrier islands ecosystems. Therefore, for maximum sensitivity to the needs of the area and to the needs shared by several adjacent counties, an intermediate level of characterization refinement has been selected. The study area has been divided into four subregions, corresponding to the regional council of government jurisdictions in the area. County-level data, as well as regional data and statewide characteristics, have been reported where they are appropriate.

Because of the array of resources located in the Texas Barrier Islands, many diverse demands are placed on the area. Industry finds it advantageous to locate near coastal water transportation routes. Agriculture, fisheries, and cattle ranching are important to coastal food-producing activities. The mineral and oil resources of the coast generate substantial economic activity, and there are numerous recreation and tourism attractions as well. This range of demands placed on the region's resources is a continuing source of concern to those persons responsible for the management and protection of our living resources. Responsible government agencies may be subjected to economic and political pressures stemming from the paradoxical responsibilities of natural resource protection and resource use.

The production of crude oil, although still representing an important economic activity for the region, as well as a vital resource for the Nation, has been steadily declining during the past two decades. Recent international developments and national policy decisions, however, have resulted in an increase in the exploration and recovery of these resources, particularly in offshore locations. There has also been an increased interest in the potential utilization of geopressured and geothermal resources that occur in the northern portions of the Gulf of Mexico basin. The area has developed a concentration of petroleum and associated support industry activities that is equal to concentrated industrial development in any coastal area of the world. Although economically attractive supply sources for crude oil and gas in the area are limited, the petroleum-related industries in the area may be expected to stabilize by importing crude oil.

A number of environmental concerns are created by the oil and gas activities in the TBIE study area. There are hazards for marine life and estuarine productivity resulting from spillage and waste disposal, yet there has been virtually no attempt to distinguish between actual and perceived impacts to the coastal area's renewable resource base. Localized subsidence from petroleum withdrawals and conflicts in land use that result from petrochemical facility siting decisions are additional causes for concern. Management and regulation of oil and gas activities are undertaken by State and Federal agencies, and the future of the oil and gas industry is, to a great extent, determined by national and international events that are outside the sphere of local influence.

Approximately 155 km^2 (60 mi^2) of the TBIE area are occupied by industrial facilities, while urban development occupies approximately 2,590 km^2 (1,000 mi^2). One-third of the entire State's industrial activities and a similar share of the State's population are concentrated in the study area, which comprises only 8.1% of the land area in Texas. According to the University of Texas Bureau of Business Research, the rapid rate of economic growth is likely to continue. As a result, the population of the study area is expected to grow to approximately 5.6 million by 2000, reflecting a 46.5% average growth rate for the period between 1980 and 2000. The Houston-Galveston area will have accounted for more than 80% of that increase (Texas Department of Water Resources 1979). Elsewhere on the coast, urban areas with port access will have the greatest growth.

Urban and industrial development affect coastal resources in many ways. Increasing subjugation of wetlands and agricultural lands for urban uses can damage fish and wildlife habitats without displacing them. For example, in 1975 more than 1,300 km^2 (500 mi^2) of Texas' bays were closed to oyster harvest because of sewage discharge (Kier et al. 1977). Lavaca Bay has been contaminated by mercury pollution from industrial activities, and fish and shellfish harvests from that area have been curtailed since 1970.

Additional impacts caused by industrial and related urban expansion include increased diversion and consumption of surface and groundwater supplies, which are essential to the maintenance of the fragile coastal ecosystems. Water development projects have generally resulted in fish and wildlife resource losses by inundating riparian habitats (such as hardwood bottomlands), by reducing instream fisheries below damsites, by reducing the replenishment of delta marshes, and by decreasing freshwater inflows within the coastal bays. Flood control projects that do not impound water (i.e., channelization, concrete lining of channels, clearing of riparian vegetation) allow rapid and radical changes in salinity for shorter durations and seriously damage fish and wildlife resources. Other environmental concerns associated with industrial and urban expansion include increased use of herbicides and pesticides and oil or grease in untreated storm sewer runoff.

One of the study area's more important economic assets is its waterborne transportation network. Improvements to natural waterways have contributed greatly to the attractiveness of the coast for industrial development. To maintain this valuable network, however, demands attention and effort. Continuous maintenance dredging is required to keep routes navigable because of seasonal variations in currents and in response to an ever-increasing fleet of larger and more expensive cargo haulers. Controversy surrounds maintenance dredging activities and the location of spoil disposal sites, the resilience of near-shore and offshore habitats, and future transportation industry growth.

Serious consideration is being given to several proposed deepwater facilities for waterborne transportation. Economic uncertainties and the unprecedented interest rates that have occurred during the 1980's have left private industry with difficult decisions regarding the risks of meeting capital cost requirements.

Environmental concerns have included the contributions of these facilities to deteriorating air and water quality in the most heavily developed portions of the study area. Each of these proposed facilities will result in tremendous amounts of dredged material; the location of spoil sites may be critical to the study area's wetland habitats.

Other forms of transportation, vital to the growth of the area, have had their ecological impacts. A total of 33 airport facilities exist in the region today and an additional 13 facilities have been proposed (Texas Aeronautics Commission 1979). A steady growth of airborne passenger, freight, and mail services has occurred, particularly in the Houston area. There have been fluctuations in the use of railroad transportation over the past three decades, but some areas (Corpus Christi for example) have shown steady growth in railroad usage. Motor vehicle registrations have increased throughout the study area.

The coastal area's intangible, aesthetic values are enjoyed by millions of people. These intangible benefits may be more significant than the economic benefits, although the rewards of fishing, hunting, birdwatching, or merely escaping from the urban environment are impossible to measure. The same distinctive qualities of the natural environment that attract tourists and new residents--clean air, clean water, a diversity of plant and animal life, and open spaces--also support wildlife. The study area's recreation/tourism industry is responsible for a multi-billion dollar contribution to the State economy each year. However, many jobs in this industry are seasonal and low-paying. Additionally, recreational activities may compete with industrial development for developable land and, on a purely economic level, industrial development can usually win.

Fisheries, cattle ranches, and agricultural activities are important to the coastal economy. The coastal bays and their associated wetlands, which comprise such small portions of Texas' land resources, provide huge dividends for a small investment in fishing. Sport fishing has taken, in one year's time, almost 2.7 million kg (6 million lb) of finfish from coastal bays. This harvest afforded approximately 13 million man-hours of recreation. The commercial fisheries harvest in Texas was 40.6 million kg (89 million lb), valued at more than $105 million in 1977; the economic impact upon the State's economy was conservatively estimated at $260 million (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979). Future extension of fisheries' jurisdictions by international treaty may further affect the coastal economy, while national policies may have an even more pervasive impact.

In addition to its contribution to the economy of the region, agriculture has added to the general problems of coastal area resource management. Much of the coastal agriculture is water intensive. This has affected the adequacy of freshwater flows to the estuaries and wetlands that are necessary to maintain the marine nurseries essential to commercial and sport fisheries. Extensive agricultural areas in monoculture may be detrimental to or incompatible with certain types of wildlife.

The amount of land in agricultural uses today, the kinds of crops grown, and livestock supported are nearly the same as they were 25 years ago, although there has been an increase in irrigated land over the past quarter century. The market value of field crops, vegetables, and livestock from commercial farms has more than doubled, however. Some areas have remained dependent on agriculture. For example, the Lower Rio Grande Valley economy is based on agriculture and tourism, with extractive and manufacturing sectors contributing little by regional standards. The Coastal Bend area has historically been known for its agricultural production, although growth in mineral production and manufacturing have outstripped agricultural activities in recent years.

THE TEXAS BARRIER ISLANDS ECOSYSTEMS SOCIOECONOMIC CHARACTERIZATION

The TBIE Ecological Characterization project includes three concurrent studies to be synthesized into one major characterization for the study area. The Fish and Wildlife Service, Office of Biological Services staff is conducting a bibliographic and literature search. An ecological atlas of wetlands, uplands, and other coastal area resources is being developed by faculty and staff at Texas A&M University using aerial photography and the results of the bibliographic and socioeconomic characterization studies. The socioeconomic characterization study has been conducted by Willdan Associates of Phoenix, Arizona, in conjunction with the University of Texas at Austin.

The results of the socioeconomic study are contained in two volumes: Volume I, the Synthesis Papers, presents a synthesis of the study's data collection effort. Volume 2, the Data Appendix, is presented as a companion document to the Synthesis Papers volume for users who are interested in more detailed information.

Consistent with legislative intent and with the understanding reached by the BLM and the FWS, socioeconomic data collection and synthesis for the TBIE study area have been guided by four overriding considerations:

- Systematic data collection and evaluation procedures, as well as the uses to which data will be put, were established at the outset of the process.
- The uses to which the data will be put have been the basis for defining the study's data categories and the relative analytical emphasis that each data category has received.
- Criteria that have been used in evaluating the reliability and consistency of the study area's data base include the comparability of data sources in generating a time series, geographic relevance to the study area and its planning regions, and appropriateness of data source methodology.
- Data synthesis reflects an interdisciplinary team effort, with provisions for peer and agency review, to insure that characterizations of separate socioeconomic sectors contribute to a valid characterization of the ecosystems' complex interactive processes.

Four general tasks have been completed in the course of the TBIE socioeconomic characterization study. The first task involved a series of meetings with Federal, State, regional, and local agency representatives to identify specific data requirements and to specify the form in which study results would be presented.

The second task involved data collection and evaluation. One of the critical objectives to be fulfilled as a result of the data collection and evaluation task was to identify problems with data gaps and inconsistencies, and to recommend ways in which these problems could be resolved. The product of the data collection effort is the Data Appendix (Volume 2). Categories for which data have been compiled within the appendix include: population characteristics; employment and income; agricultural production; mineral production; fish and wildlife production; transportation; recreation and tourism industries; industrial and residential development and point source pollution discharge; public utilities; and land use practices.

The third and fourth tasks involved the data synthesis and final report production. Information sources collected in the course of the study were evaluated to select those key references required for a basic understanding of each of the topics to be included in the synthesis papers. Source documents, including maps, diagrams, statistical tables and other publications so selected, have been combined into synthesis papers for each of six topics: (1) Oil and Gas Production; (2) Recreation/Tourism Industry; (3) Commercial Fishing Industry; (4) Industrial and Residential Development; (5) Transportation Systems; and (6) Agricultural Production.

SYNTHESIS PAPERS

The Oil and Gas synthesis paper, written by Kent S. Butler, University of Texas at Austin, characterizes historical and current petroleum industry development trends and discusses oil and gas reserves in the TBIE study area. Support industries, land use, and industrial infrastructures are discussed. Environmental concerns for the Texas coastal area are identified in the context of oil and gas activities. Resource management and regulatory jurisdictions are also identified. Additional data needs are suggested in the context of planning decisions which resource management agencies are likely to face in the future.

The Recreation/Tourism Industry synthesis paper, written by Terry D. Kahn, University of Texas at Austin, characterizes the general significance of the industry to the TBIE study area economy and describes the historical and current patterns of resource use. Facilities and services available are identified for the study area as a whole and for those areas in which the industry plays a particularly important economic role. Factors that are likely to influence the future of the recreation/tourism industry are identified, and a number of scenarios, ranging from optimistic to pessimistic, are created to describe likely alternative futures with which the industry is faced. Policy issues and resource management practices that will influence the industry's future are also described, and additional data requirements that should be met to better address such issues are identified.

The Commercial Fishing synthesis paper, written by Victor L. Arnold, University of Texas at Austin, examines historical and current trends in the Texas commercial fishing industry by habitat, catch and value, and by changes in harvesting and processing technologies. Factors that influence the commercial fishing harvest are described, including natural ecosystem characteristics, resource management considerations, market conditions, and ways in which habitat modifications have resulted from human activity. Jurisdictional controls of commercial fishing resources are described and additional data requirements are suggested in the context of probable resource management decisions to be made in the next several years.

The Transportation synthesis paper, written by Michael A. Klein and George H. Ford, Willdan Associates, presents an historical overview of the study area's transportation system development and characterizes present system functions, usage rates, and capacities. The effects that facility developments may have on coastal area resources are described. Major planned or proposed facilities are identified, noting particularly the planned waterway and port facility improvements. Jurisdictional controls over transportation system components are described, including financial control, operation and maintenance responsibilities, planning authority, and transportation management as a recreation resource protection tool. Further data needs are suggested to facilitate future resource management decisions.

The Industrial and Residential Development synthesis paper, written by Thomas R. Plaut, University of Texas at Austin, examines general growth trends in the study area economy with a major emphasis on the relationships between industrial growth in energy-related sectors, natural resource availability, and population growth. Physical effects of industrial and residential developments are described in terms of point source discharge, groundwater withdrawals, air quality changes, and other effects. Future growth patterns are considered, including projections of population and industrial growth in terms of limiting and growth-inducing factors. Additional data requirements are suggested for addressing issues which study area planning agencies are likely to encounter in the coming decades.

The Agricultural Production synthesis paper, written by Edward B. Liebow, Willdan Associates, examines changes that have taken place in agricultural activities, their contributions to the regional and local economy, and factors that are likely to influence the industry's contributions to the economy in the future. Regional concentrations of field crops, livestock production, and specialty products are described, along with specific production constraints and opportunities by which the study area can be characterized. Agricultural futures are explored in terms of market dislocations and the industry's ability to respond to market fluctuations, and also in terms of the social consequences of agriculture's changing role in the regional and national economy. Additional data requirements are identified.

These synthesis papers are intended to provide a brief overview of a wide range of topics, using selected key references to describe general trends and region-wide factors influencing the relationships between complex growth processes and the availability of natural resources. For a more detailed basis for these discussions, the reader is referred to the Data Appendix, Volume 2.

INTRODUCTION: LITERATURE CITED

Johnston, J.B. 1978. Ecological characterization--an overview. Coastal zone '78, the proceedings of the symposium on technical, environmental, socioeconomic and regulatory aspects of coastal zone management; 1978 March 14-16, San Francisco, CA: American Society of Civil Engineers; 1978: 692-710.

Kier, R.S.; Garner, L.E.; Brown, L.F. Jr. Land resources of Texas. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1977; 42 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Lay, D.W.; Culbertson, K.F. Wildlife of the Texas coastal zone. Austin, TX: Texas Parks and Wildlife Dept.; May 1978; 72 p. Available from: Texas Parks and Wildlife Dept., Austin, TX.

Texas Aeronautics Commission. Texas airport system plan: 1979. Austin, TX: 1979.

Texas Dept. of Water Resources. Unpublished population projections, Austin, TX: 1979.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Fisheries of the United States, 1978. Current fishery statistics no. 7800. Washington, DC: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; April 1979. Available from: National Marine Fisheries Service, Washington, DC.

OIL AND GAS PRODUCTION

INTRODUCTION

Oil and gas production activites in Texas have created an industry of national and global significance during the past eight decades. The State has produced one-fourth of all the energy ever produced in the United States, and today accounts for more than one-third of the Nation's oil and gas production. In 1978, crude oil production in the TBIE area accounted for 16% of the statewide total, and the area's natural gas production was of similar magnitude.

In addition to development and production concerns, the TBIE petroleum industry complex includes refineries, petrochemical plants, and a vast array of logistic support facilities. The area's hydrocarbon resources and ready access to water and pipeline transport have resulted in an industrial complex that is equal to that of any coastal area in the world. The impact of oil and gas development on growth in the TBIE area is difficult to measure accurately, although the strengthening and stabilizing influence of the petroleum industry on the State economy is apparent. The tendency is to attribute a great deal of significance to oil and gas development, if for no other reason than that the pipelines, processing plants, drilling rigs, and refineries have such high visibility. It is one thing to say that the petroleum industry has touched the lives of many TBIE area residents, but it is quite another to identify the actual number of people in the area who would either not be there, or who would be doing something else, were it not for oil and gas. Extraction, transportation, and refinery activities that make up the petroleum industry itself are characterized by a sophisticated technology that requires relatively few labor inputs. The direct support provided by welders, fabricators, mud suppliers, tool and die manufacturers, and shipyard workers represents a much higher level of labor intensity. But the local supermarkets, office supply firms, architects, construction contractors, and dozens of other types of business concerns are also a consequence, to some extent, of the petroleum industry.

Trends in the production of crude oil and natural gas changed dramatically in recent years, with attendant effects upon the TBIE area economy. Both oil and gas production rose to all-time high levels in 1972, and then declined steadily as economically attractive recoverable resources diminished. Recent international events, however, and our own national responses to these events, have created a resurgence in exploration and development activity. Staggering increases in the price of imported petroleum from Organization of Petroleum Exporting Countries (OPEC) cartel members since 1973, a gradual price deregulation program for domestic products, and contemplated limits on the amount of foreign imports permitted annually are factors that have contributed to recent increases in exploration and development in the TBIE area. These exploratory and developmental efforts have recently been concentrated in the offshore area, and development of natural gas resources has received the greatest attention. Offshore production increases for both oil and gas may be anticipated, at least in the short run.

Support industries are not solely dependent on local production. The TBIE coastal area is considered a world headquarters for petroleum corporations and high-technology service industries. These corporations and services are expected to maintain a commanding world position through the import of hydrocarbon resources. Although these industrial activities may not continue to increase indefinitely at their present pace, they should provide a stabilizing element of diversity to the TBIE's predominantly natural resource-based economy.

The short-term and long-term future of the oil and gas industry in the TBIE area will depend on four factors:

- The international petroleum market and its effects on supply and demand;
- Facility siting decisions of the petroleum industry;
- The regulations, policies, and energy needs of the United States; and
- Environmental protection concerns and policies, and the cost of providing mitigation and enhancement measures to address such concerns.

The implications that each of these factors presents for the area's petroleum industry are explored in the following discussion. In the first section, "Historical and Current Development Trends," a brief overview of the industry's early history in Texas is accompanied by a discussion of exploration, development, and production trends through the late 1970's. Technological changes that have affected these trends are also identified. In the second section, "Energy Reserves and Resources," proven reserves are identified, and the relationship between reserves and drilling and production levels is explored. Logistic support facilities, trends in land use and support services, storage and transport facilities, and the processing and petrochemical industries are discussed in the third section, "Infrastructure, Land Use, and Related Industries." The fourth section, "Environmental Concerns," places a special emphasis on factors that are likely to play an important role in resource management and planning in the future. Operational hazards of drilling, production, transport, and brine discharges, are described along with a distinction that must be made between actual and perceived locational conflicts between oil and gas operations and shipping, fishing, recreation, and other shorefront activities. In the fifth and sixth sections, management jurisdictions are described and major policy issues that resource management planners are likely to encounter are identified. A final section identifies additional data needed to guide future resource management planning activities, primarily in those areas where meeting such data requirements would help to design mitigation and enhancement measures.

HISTORICAL AND CURRENT DEVELOPMENT TRENDS

Early History of Oil and Gas Production in Texas

Oil has been the key to prosperity for many Texas communities since the early 1900's. The first small fields were discovered near Nacogdoches in 1866 and Corsicana in 1895. Extensive well drilling operations were underway by the 1880's (Texas almanac 1979). The famous Lucas gusher at the Spindletop field (near Beaumont) in 1901 demonstrated the potentials of the industry to the rest of the Nation. Speculation followed the openings of this and other new fields, and thousands of Texans began to accrue great wealth with the development and production of the State's vast reserves (Steen 1960). After Spindletop, Beaumont became a bustling industrial center. And the "boom" story was repeated as major discoveries, especially by today's standards, were made at the fields of Sour Lake (1902), Humble and Dayton (1905), Blue Ridge and Goose Creek (1908), Electra (1911), Ranger (1917) and Burkburnett (1918).

The early days of oil exploration were rather different from today's experience. Maximum drilling depths were much shallower than most of today's completed wells. Surface oil seeps and near-surface geologic indications were the historical equivalents of modern geophysical surveys and test drillings. Even so, drilling adjacent to producing wells in the vast fields found 60 years ago was perhaps as likely to produce oil as modern drilling into the typically smaller reservoirs found today. Wildcatters, however, certainly earned their trade name a half century ago. When they occasionally struck the right location and depth, the ensuing "gushers" (now more ominously called "blowouts") would set off a speculative economic boom unmatched in recent decades. Wildcatters were extremely fortunate to be in a state with such vast fields because, just as today, the oil business did not profit by exploration alone.

The prosperous years that surrounded the first World War affected every state in the Nation and marked the beginning of the Texas petroleum industry. The largest oil field ever discovered in the continental United States is the famous East Texas field, which began producing in 1930.

Texas has consistently led all other states in annual oil production since 1928. California, Oklahoma, and Louisiana were early contenders for the highest ranking state in oil production, but only Alaska is potentially capable of surpassing Texas. Texas' highest share of national production occurred in 1951 at 45% (1.0 billion bbl), or 24% of world production. The level of production peaked in 1972 at approximately 1.3 billion bbl, and has since steadily declined. Approximately 1.07 billion bbl were produced in 1978, representing 34% of total domestic production (American Petroleum Institute 1979).

Natural gas production trends have corresponded very closely to oil production trends. In 1918, Texas produced and marketed only 2% (381 million m^3 or 13.4 billion ft^3) of the national output. But by 1930 the level had soared to 27% (14.7 billion m^3 or 518 billion ft^3) and reached a peak of 44% (48.5 billion m^3 or 1.71 trillion ft^3) of United States production in 1945. Production began declining in 1972, and by 1978 the State's share of national production was only 35% (DeGolyer and MacNaughton 1978). By 1978, however, the volume of natural gas produced in the State had increased more than four-fold since 1945 (200 billion m^3 or 7.1 trillion ft^3). Gas is shipped by pipeline from Texas to at least 40 other states.

The early drilling in the open Gulf of Mexico could hardly be called an art, but it certainly was not then the science that it is today. Transportation was one of the more critical problems when Texas offshore activities began in the early 1950's. Wooden-hull Coast Guard cutters and Navy landing craft were pressed into service as supply boats. Mud and cement were loaded and unloaded by hand. Radar and air conditioning were unheard of and helicopters were considered unsafe (Boynton 1969).

The Standard Oil Company of Texas was the first to produce oil in the Texas Gulf, from a well drilled offshore from Padre Island, Kleberg County. Building on the Louisiana experience in offshore drilling, which had begun in 1947, a four-well platform and barge tender-rig were used on this State lease in 1954. The first Federal offshore lease sale occurred in November 1954. Once again, Standard Oil held the distinction of producing the first oil in Texas Federal waters from a well drilled offshore from Jefferson County in 1959, which later became the High Island Block 52 field (Boynton 1969).

Prior to establishment of the Federal jurisdiction in lands under territorial waters in 1953, all offshore leases had been awarded by the State. In 1941, Texas attempted to extend its seaward sovereign boundary to 27 nautical miles from shore, and in 1947 extended it to the edge of the continental shelf. If not for the reassertion of dominant sovereignty by the Federal government in the ensuing Tidelands controversies, involving literally dozens of Supreme Court decisions and major Federal legislation (Submerged Lands Act of 1953), Texas and virtually all other coastal states would have realized tens of billions of dollars in offshore lease royalties and bonuses.

The resulting Supreme Court decision in 1960, which granted rights to Texas and Florida out to the three-league line in the Gulf of Mexico, was a significant and hard-fought achievement for Texas, relative to the three-mile zones granted to all other coastal states (Butler 1977). For example, Texas had rights to 37% of the oil and 63% of the gas produced in its offshore areas in 1975. On the other hand, the State of Louisiana's share was only 11% for oil and 13% for gas (U.S. Department of the Interior, Geological Survey 1978). The Gulf of Mexico has been the site of at least 95% of all domestic offshore petroleum production since 1953. Even though there are clear indications that offshore activity will increase substantially, Louisiana has accounted, and will likely continue to account, for overwhelming proportions of the national offshore production (U.S. Department of the Interior, Geological Survey 1978).

Exploration

The exploration process. The complex exploration segment of the oil and gas industry can be divided into the following three phases: regional mapping, detailed surveying, and exploratory drilling. Regional mapping is actually a pre-exploratory phase that serves to clarify regional geologic trends and identify potentially productive sedimentary basins. Geophysical surveys utilizing magnetic, gravity, and seismic sensing instrumentation are the primary activities during this phase. Available geological and geophysical surveys are used whenever possible. Resolution of ownership boundaries and various charted information is also accomplished at an early date. This latter task is especially important in offshore exploration, where good surveying control is essential for reliable application of the survey information.

The detailed surveying phase is a finer analysis of the information described above. Site-specific tests are run to identify key drilling sites. Some shallow coring and even selected deep stratigraphic testing may be undertaken in frontier areas (e.g., offshore) or in sites having extremely complex structures. Oil and gas companies will undertake joint ventures where there are large structures or when the survey costs involve several millions of dollars. There are usually no permanent installations in this phase, and the environmental impacts are believed to be insignificant for offshore exploration. Impacts may be significant, however, for inshore (estuarine) seismic testing. Reefs and marshes can be seriously damaged if exploration activities are not carefully controlled.

The exploratory drilling program begins with relative uncertainty, especially in areas where little prior testing was done. As drilling proceeds, sediment cores are analyzed and the well is periodically "logged" to determine the sonic, electric, and radiation characteristics of the strata. If potentially commercial finds are made, other wells are drilled nearby to confirm the discovery, estimate the size and yield of the reservoir, and determine the number and location of production wells needed to drain the field economically (U.S. Department of the Interior, Fish and Wildlife Service 1978).

Geographic distribution. The geographic distribution of onshore oil and gas exploration activity in the Texas coastal area can be characterized as widespread and very uniform. Drilling of exploratory wells and dry holes since 1955 has included all 24 TBIE counties to a considerable degree. Exploratory gas well drilling consistently exceeded oil well drilling from 1955 to 1978 due to the much greater likelihood of finding new commercial gas reservoirs in coastal basins. In 1979, 1,451 wildcat wells were drilled in the three coastal districts of the Texas Railroad Commission representing 33% of the statewide level of exploratory drilling (Beck 1980). These three coastal districts comprise 54 counties, including the TBIE study area.

The distribution of Texas offshore exploration has also been widespread, but the greatest concentration of activity leading to production has consistently been along the Louisiana border, outside the TBIE study area (Figure 2). Operators have historically been interested in staying close to familiar geologic features, looking for greater sand accumulations in shallower water and relying on the successes of nearby Louisiana offshore explorations. Most of the Federal OCS lease tracts off the Texas coast are in the upper Texas coastal area, particularly the High Island South Addition and the High Island East Addition-South Extension. The Brazos, Matagorda Island, and Mustang Island areas also contain several leased tracts.

The offshore fields found in northern Texas waters usually correlate structurally with onshore geology found in adjacent fields. Sands deposited during the Miocene period have produced much of the gas and oil found offshore thus far. On a site-specific basis, deep-seated or piercement-type salt intrusions have created the highly faulted anticlinal strata in which producible quantities of petroleum are trapped.

There was concern two decades ago about potential problems with oil and gas exloration in the rougher waters and stronger currents of less explored reaches of the lower Texas coast, but the excessive costs and time delays that were anticipated never really materialized. Sizable investments were made, however, in exploratory drilling in the southern waters. Discoveries were frustratingly scarce and dry holes were plentiful. The most obvious conclusion about early

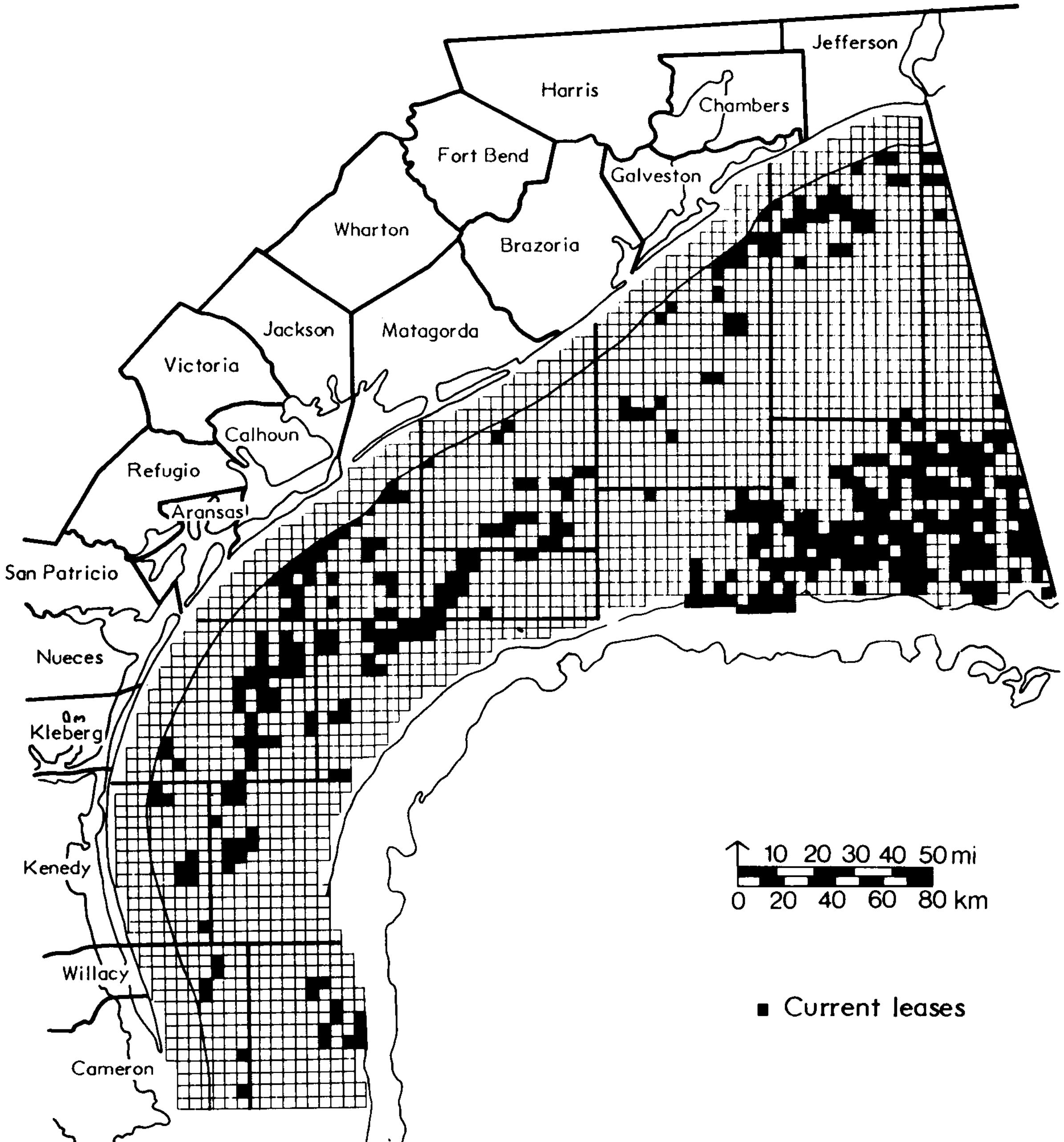

Figure 2. Leased tracts in Texas Federal Outer Continental Shelf (Research and Planning Consultants, Inc. 1977 ; U.S. Dept. of the Interior, Bureau of Land Management 1979).

offshore activity in south Texas was that companies held back on the Texas offshore in general, preferring to exploit the proven fields on Louisiana leases first (Scott 1969).

Exploration and investment. The level of investment, commitment, and risk in oil and gas exploration in the TBIE study area can be ascertained by examining indicators, such as rotary drilling rig activity, drilling footage, average cost of wells, employment in geophysical exploration, and the number of exploratory wells drilled in proportion to new development wells. The average annual number of active rotary rigs in Texas hit an all-time high in 1951 with 1,230 rigs, and then declined steadily to 291 rigs in 1971. Since then, drilling has increased steadily except for a slight decline in 1979 (Table 1). Activity in the three coastal Railroad Commission districts followed the same trend, increasing to 197 rigs in 1978 (representing 10% of all national activity) but declining slightly in 1979. The Texas share of offshore activity has also increased significantly over earlier levels. Activity from 1970 to 1973 represented only 7% of national activity (Beck 1980). In contrast, an average of 50 rigs were operating offshore in 1979, accounting for 27% of national offshore activity.

Table 1. Average annual rotary drilling rig activity in Texas and the United States, 1970 through 1979 (Beck 1980).

Year	Railroad Commission Districts 2[a], 3[b], and 4[c]	Offshore[d]	State	United States
1970	73	6	302	1,208
1971	79	5	291	976
1972	95	6	338	1,107
1973	109	9	376	1,194
1974	128	21	508	1,471
1975	142	21	637	1,660
1976	160	36	653	1,658
1977	175	42	779	2,001
1978	197	47	855	2,259
1979	141	50	770	2,177

[a]Aransas, Bee, Calhoun, DeWitt, Goliad, Jackson, Karnes, Lavaca, Live Oak, Refugio, and Victoria Counties.

[b]Austin, Brazoria, Brazos, Burleson, Chambers, Colorado, Fayette, Fort Bend, Galveston, Grimes, Hardin, Harris, Jasper, Jefferson, Lee, Liberty, Madison, Matagorda, Montgomery, Newton, Orange, Polk, San Jacinto, Trinity, Tyler, Walker, Waller, Washington, and Wharton Counties.

[c]Brooks, Cameron, Duval, Hidalgo, Jim Hogg, Jim Wells, Kenedy, Kleberg, Nueces, San Patricio, Starr, Webb, Willacy, and Zapata Counties.

[d]State and Federal waters.

Estimates of the level of investment in exploratory well drilling in the TBIE study area can be made on the basis of nationwide averages of drilling costs and footage drilled, and the number of wells drilled in the TBIE study area. In 1978, nationwide average well drilling costs for all types of wells (oil, gas, dry) were about $144/m ($44/ft) for onshore wells, and $200/m ($61/ft) for offshore wells (American Petroleum Institute 1979, Leonard 1979). The average depth of all wells drilled in the Texas coastal area in 1978 was 2,050 m (6,727 ft) for onshore wells and 2,912 m (9,551 ft) for offshore wells (1979 should set... 1979). On the basis of these figures, the total cost of onshore exploratory well drilling in 1978 in the TBIE study area can be inferred as $112 million for onshore drilling and $555 million for offshore drilling. The statewide cost of exploratory drilling in 1978 alone is estimated at $1.15 billion, while nationwide costs were $10.7 billion. In Victoria and Wharton Counties, which accounted for the largest numbers of exploratory wells in the TBIE area during 1978, these estimates would indicate that $9.8 million was spent on drilling in each county. Lease agreements, geophysical surveying, and other activities must also be considered in assessing the total financial commitment in oil and gas exploration.

Employment in geophysical exploration in the TBIE study area can be inferred from national and State data. The total United States employment in seismic, gravity, magnetic, and other methods of geophysical exploration in 1977 was 3,183 crew-months (American Petroleum Institute 1979). If we assume that the level of geophysical surveying in any given area is roughly proportional to rotary drilling employment in the TBIE area, then there would have been approximately 350 crew-months of surveying work in the TBIE area in 1977 (Beck 1980).

TBIE employment in the mining industry, and the oil and gas sector in particular, can be estimated for 1978. Using statewide data for oil and gas extraction employment and TBIE area data for mining industry employment (Texas Employment Commission 1979; U.S. Department of Commerce, Bureau of Economic Analysis, Regional Information System 1979), it is estimated that 63,000 persons were employed in oil and gas extraction in the TBIE area during 1978. On the basis of statewide averages, the total wages for TBIE employment in this sector in 1978 were approximately $1.1 billion. These employment and wage figures encompass most, but not all, of the operations involved in oil and gas exploration, development, and production.

Well drilling is the most important exploration activity, as indicated by the very sizeable investments involved. The proportion of exploratory wells to total wells completed in the TBIE area rose from 31% in 1955 to 47% in 1975, and declined markedly to 18% by 1978. At the same time, exploratory drilling throughout the State maintained a fairly even rate of 21% to 26% of all well completions. The rate of success of exploratory drilling for oil and gas wells in the study area has varied considerably from 65% to 90%; these ranges are quite comparable to State and national averages of successful drilling.

The greater exploration activity for natural gas compared to crude oil is a distinctive characteristic of the TBIE study area. Until 1973, when natural gas prices began to increase rapidly, more wells were drilled in search of oil than for gas in Texas and in the United States. In the TBIE area, however, natural gas exploration levels consistently exceeded oil exploration levels since before 1960.

The significant risks and costs incurred in Texas offshore oil and gas exploration are clearly indicated by the large labor requirements and the ratios of exploratory wells to developmental wells. The typical exploratory drilling rig employs about 110 workers. Each rig can drill from four to six wells per year (U.S.

Department of the Interior, Bureau of Land Management 1979). Only 43% of all wells drilled from rigs off the Texas coast in 1979 were exploratory (Beck 1980), a significant reduction from the frontier days of Texas offshore exploration. In the Louisiana offshore, by contrast, only 17% of all wells drilled in 1978 were exploratory. Indications are that Texas offshore exploration will remain at relatively low levels while developmental activity will continue at a high pace, at least until 1985.

Offshore leases and exploration. Gulf of Mexico lease sales conducted by the BLM and the Texas General Land Office (TGLO) are of great significance in shaping offshore exploration and development ventures. Their complex environmental assessment and protection requirements as well as bidding procedures are major determinants of the timing, extent, and manner of offshore exploration. By the end of 1977, 1,777 Federal OCS lease tracts off the Texas coast had been offered to petroleum companies; 703 were leased, comprising a total of 1.4 million ha (3.3 million ac). Between 1963 and 1977, 1,267 exploration permits were issued. The total value of bonuses paid on these leases was $4.46 billion, representing an average price of $3,300/ha ($1,336/ac). Texas Federal lease tracts comprised 22% of all leased acres and bonuses in the Nation from 1954 through 1977 (Table 2).

Individual lease sales have varied enormously in bidding levels, bonuses paid and area leased. The May 1968 sale of 219,063 ha (541,304 ac) brought $594 million in bonuses. The average price of tracts leased in this sale was $2,710/ha ($1,097/ac), the second highest price level in United States history. Two sales, one in 1973 of $5,735/ha ($2,321/ac) and one in 1974 of $6,437/ha ($2,605/ac) dwarfed all earlier figures; one tract lease in 1973 sold for $33,336/ha or $13,491/ac (Table 2).

Lease Sale Number 58A in the central and western Gulf of Mexico was made in November 1979. It brought in high bids of $1.9 billion from 24 companies--the second highest amount ever paid on Gulf leases.

The 124 tracts offered in this sale were estimated to be capable of yielding 50 million bbl of oil and 19 billion m^3 (685 billion ft^3) of gas (U.S. Department of the Interior, Bureau of Land Management 1979). A legal boundary dispute in this lease involving reservoirs that straddle the Texas-Louisiana border continues to be litigated in Federal courts. Resolution of the matter by the Department of the Interior and the two states will likely yield sizable royalties for State of Texas coffers (Boundary dispute could... 1979).

Lease sales in State waters by the TGLO have taken place in a smaller area, but with much higher activity over a considerably longer period. All submerged lands held in the State's public trust--estuarine areas, bays, lagoons, and the open Gulf out to the three-league line--are potentially leasable for mineral exploration and development. The leasing schedule and the increasingly rigorous environmental management programs led by the TGLO (with cooperation from other agencies) are largely responsible for determining the location and extent of nearshore petroleum ventures. On the basis of historical averages, about one-half of the tracts leased will ultimately be explored (Research and Planning Consultants, Inc. 1977).

The estimated State-owned coastal area on which oil and gas related activities could take place in 1979 was 23,500 km^2 or 9,060 mi^2 (Texas General Land Office 1979). Total receipts taken by the TGLO from Texas tidelands

Table 2. Texas Federal OCS lease sales, 1954 through 1979 (U.S. Department of the Interior, Fish and Wildlife Service 1978; Research and Planning Consultants Inc. 1979; U.S. Department of the Interior, Bureau of Land Mangement 1980).

Date	Tracts offered	Acres offered	Tracts leased	Acres leased	Bonus paid	Average price per acre
a	93	125,090	93	125,090	N.D.	N.D.
November 9, 1954	38	111,788	19	67,149	$ 23,357,029	$ 348
July 12, 1955	39	216,000	27	149,760	8,437,462	56
January 26, 1960	97	437,760	48	240,480	35,732,031	149
March 16, 1962	30	90,720	10	28,800	557,720	19
May 21, 1968	169	728,551	110	541,304	593,899,046	1,097
June 19, 1973	124	672,643	96	527,173	1,537,495,671	2,321
May 29, 1974	245	1,355,678	102	565,112	1,471,851,831	2,605
July 30, 1974	143	787,821	10	53,253	22,264,900	418
February 4, 1975	515	2,870,344	113	626,587	274,690,955	378
May 28, 1975	36	192,660	9	51,840	25,337,000	489
July 29, 1975	176	963,832	23	132,480	44,852,318	339
February 18, 1976	30	157,269	12	63,427	37,382,176	589
November 16, 1976	7	28,828	4	17,308	31,111,244	1,798
June 23, 1977	35	207,360	26	150,723	356,102,428	2,363
April 25, 1978[b]	145	709,727	90	438,756	733,656,893	1,672
December 19, 1978[b]	128	643,987	81	412,416	874,464,998	2,113
July 31, 1979[c]	123	577,517	81	391,183	1,247,489,022	3,189
November 27, 1979[c]	124	588,601	90	421,519	1,913,337,938	4,539
Total[d]	1,777	8,946,344	702	3,340,486	$4,463,071,811	$1,336

[a]1947 through 1954, leases awarded by State prior to Federal jurisdiction.

[b]Figures are for lease sales in both the Texas and Louisiana OCS (sales #45 and #51).

[c]Figures are for lease sales in the Gulf of Mexico (sales #58 and #58A).

[d]Totals are for Texas Federal OCS lease sales through June 23, 1977.

between June 1922, and September 1977, amounted to almost $522 million (Table 3). These values have risen dramatically in the past few years, with income from royalties doubling about every two years. The most lucrative lease areas for the State have clearly been in the open Gulf, especially those lying between the three-mile line and the three-league line. In February 1979, the TGLO sold 665 new oil and gas leases at the largest sale in Texas history.

There is every indication that lease sales in the Texas Federal offshore area will continue at high levels of activity for several years. Secretary of the Interior, Cecil Andrus, has executed a policy of accelerated leasing in the Federal OCS

Table 3. Receipts by Texas from tidelands, 1922 through 1978 (Texas alamanac 1980).

Date		Bonus (dollars)	Rental (dollars)	Royalty (dollars)	Total (dollars)
From	To				
6- 9-1922	9-28-1945	814,055.70	61,973.75	48,334.36	924,363.81
9-29-1945	6-23-1947	272,700.00	7,680.00	16,020.30	296,400.30
6-24-1947	6- 5-1950	7,231,755.48	375,915.00	86,441.74	7,694,112.22
6- 6-1950	5-22-1953	N.D.	9,176.00	45,919.04	55,095.04
5-23-1953	6-30-1958	49,788,639.03	3,852,726.98	623,187.10	54,264,553.11
7- 1-1958	8-31-1959	N.D.	143,857.00	627,207.75	771,064.75
9- 1-1959	8-31-1960	257,900.00	98,226.00	627,209.32	983,335.32
9- 1-1960	8-31-1961	3,228,639.51	68,578.00	593,582.64	3,890,800.15
9- 1-1961	8-31-1962	297,129.88	127,105.00	697,690.21	1,121,925.09
9- 1-1962	8-31-1963	2,617,057.14	177,174.91	781,656.59	3,575,888.64
9- 1-1963	8-31-1964	2,435,244.36	525,315.00	695,677.39	3,656,236.75
9- 1-1964	8-31-1965	53,114,943.63	755,050.12	784,583.21	54,654,576.96
9- 1-1965	8-31-1966	18,223,357.84	3,163,475.00	761,992.60	22,148,825.44
9- 1-1966	8-31-1967	3,641,414.96	3,711,092.65	1,117,173.25	8,469,680.86
9- 1-1967	8-31-1968	1,251,852.50	1,683,732.50	2,370,266.00	6,305,851.00
9- 1-1968	8-31-1969	1,838,118.33	1,491,592.50	3,042,557.45	6,372,268.28
9- 1-1969	8-31-1970	5,994,666.32	618,362.50	3,698,001.66	10,311,030.48
9- 1-1970	8-31-1971	4,326,120.11	726,294.15	4,917,214.91	9,969,629.17
9- 1-1971	8-31-1972	1,360,212.64	963,367.60	5,234,746.97	7,558,327.21
9- 1-1972	8-31-1973	3,701,737.30	920,121.60	4,646,116.78	9,167,975.68
9- 1-1973	8-31-1974	32,981,619.28	1,065,516.60	7,670,534.16	41,717,670.04
9- 1-1974	8-31-1975	5,319,762.85	2,932,415.60	19,066,478.17	27,318,656.62
9- 1-1975	8-31-1976	6,197,853.00	3,222,535.84	29,326,685.25	38,747,074.09
9- 1-1976	8-31-1977	41,343,114.81	2,404,988.80	40,448,124.66	84,196,228.27
9- 1-1977	8-31-1978	49,807,750.45	4,484,064.52	63,427,305.82	117,719,120.79
Total		296,045,645.12	34,591,777.62	191,354,707.33	521,992,130.07

(continued)

Table 3 (concluded).

Area	Bonus (dollars)	Rental (dollars)	Royalty (dollars)	Total (dollars)
Inside three-mile line	74,385,190.25	9,399,125.34	48,447,561.00	132,231,876.59
Between three-mile line and three marine-league line	219,008,370.49	25,019,371.09	142,907,146.33	386,934,887.90
Outside three marine-league line	2,652,084.39	173,281.19	N.D.	2,825,365.58
Totals	296,045,645.12	34,591,777.62	191,354,707.33	521,992,130.07

in concert with President Carter's goal of decreasing reliance on imported oil. Some critics of the proposed final leasing schedule issued in March 1980 argued that exploration in frontiers such as Alaska and OCS margin areas were not given enough emphasis (Rogers 1979). Clearly, the center of exploratory activity will remain in its historical place of origin--the Gulf of Mexico. The proposed schedule includes 12 major sales in Gulf waters over the five-year period from September 1980 through May 1985.

Summary. Oil and gas exploration in the Texas coastal region should remain at stable levels or even increase over the next few years. The Texas-Louisiana border area has been the site of most of the offshore drilling in recent years, and is likely to continue to hold that position. Many of the indicators of exploratory activity showed gradual declines over the last three decades, but upward trends were apparent soon after the Arab oil embargo and relaxation of natural gas price controls. The costs of exploration today are staggering, especially in the offshore zone. Were it not for the recent changes in the economics of world energy, a larger part of the exploration effort in Texas would have shifted to the more reliable and less risky arena of development drilling in and adjacent to proven fields.

Development

The development phase begins once exploratory drilling has located enough petroleum reserves to make production an economical venture. Field development basically involves drilling, casing the well, preparation of equipment for production, and handling of all other relevant matters leading to pumping.

Economic investment and risk. Offshore oil and gas development is perhaps the most expensive and dynamic of all oil and gas related activities. Company strategies are continually reoriented and redefined as development drilling reveals new information on field characteristics and as final plans for onshore support facilities are completed.

The decision by a company to proceed with field development is guided or constrained by the following series of economic and environmental factors (U.S. Department of the Interior, Fish and Wildlife Service 1978):

- installation and operating costs of wells at particular locations (e.g., in certain water depths)
- level of risk in drilling dry holes (as much as $3 million each)
- land lease and royalty costs
- expected capital outlays relative to expected returns on investment
- size and physical characteristics of the reservoir
- capability of operating in areas constrained by technological problems (e.g., deep water or harsh weather)
- local marketing considerations, including access to refineries and processing plants

- o time lags and costs of financing between the time of initial development and initial production

- o other factors.

Drilling is clearly the most expensive and important facet of development. It proceeds much more slowly than exploratory operations because of the need to install casings, perforate the well at appropriate strata, and sometimes directionally drill the well hole. Directionally drilled wells are sometimes deviated as much as 2 km (1.2 mi) horizontally. Costs have risen substantially in recent years; between 1968 and 1978, average drilling costs across the Nation rose 170% (Leonard 1979). Offshore well drilling costs increased in the same period by almost 270% (American Petroleum Institute 1979). The average annual materials requirements for offshore rigs that drill four development wells per year to a 4,575-m (15,000-ft) depth is presented in Table 4.

Table 4. Materials requirements for rigs that drill four 15,000-foot wells per year.

Item	Quantity per rig year	
Mud	2,568 to 5,970	t[a]
Cement	1,260	t[b]
Fresh water and drilling water	5,200,000	gal[b]
Drill cuttings	3,070	m^3[a]
Drill pipe, casing and tubing	1,820	t[b]
Fuel for drilling	13,272	bbl[b]
Fuel for all puposes	61,200	bbl[a]
Total quantity of required material	38,430	t

[a]U.S. Department of the Interior, Bureau of Land Management 1979.
[b]Ellis 1978.

Labor requirements and total employment generated in the development stage of a petroleum field can also be quite substantial, and the levels vary considerably through different phases of development. The total number of persons employed depends on the number of drilling sites and the operator's planned development schedule. These factors are used to determine the number of drilling rigs required to meet the schedule and, in turn, the labor requirements for drilling, support services, and other indirect needs.

Development scenarios for offshore operations indicate that exploration and development activities take place over a seven to nine year period. A typical drilling rig requires about 65 workers for development operations, and each rig can drill from four to six wells per year. Employment rises steadily during the development phase, peaking near the end as production platforms are brought into service. If the proposed 1980 OCS Lease Sales A62 and 62 are held and exploration/development/production takes place in a manner consistent with previous experience, then the "peak year" employment levels indicated in Table 5 might be generated in Texas coastal counties in each of the specified years (U.S. Department of the Interior, Bureau of Land Management 1979).

Table 5. Estimated peak year employment generated by proposed Outer Continental Shelf Lease Sales A62 and 62 (U.S. Department of the Interior, Bureau of Land Management 1979).

Employment type	Number of persons
Direct employment	
Exploration/development (1984)	662
Development (1987 and 1988)	389
Platform operations (1988)	207
Other (1988)	24
Total employment (1987)	2,599
New resident employment (1987)	1,040
New resident population (1987)	2,396

Geographic distribution. The distribution of development and production operations in TBIE counties can be inferred by examining the arrangement of oil and gas fields along the coast (Texas Gulf coast... 1979). Paralleling the coast from the Louisiana border to Kenedy County are two or more linear swaths of tightly clustered petroleum fields. These bands of activity lie between the Gulf shoreline and the landward boundary of Miocene age deposits; one is about 16 to 40 km (10 to 25 mi) inland and another is 40 to 65 km (25 to 40 mi) inland. The following counties, listed in decreasing order of importance, have experienced the greatest development drilling activity during the last 25 years: Harris, Nueces, Liberty, Wharton, Jackson, Refugio, Brazoria, and Victoria (Texas Mid-Continent Oil and Gas Associaton 1979). The Lower Rio Grande Valley planning region had the least amount of development activity.

Development and production in State-owned waters also appear to be widely distributed, based on the locations of proved oil and gas fields. Galveston, Trinity, and Corpus Christi Bays contain the majority of oil and gas fields, but gas fields are found in almost every bay system. Gas fields in Gulf waters out to the three-league line are most prevalent off Galveston, Brazoria, and Matagorda Counties (Table 6). Again, the southernmost areas have experienced the least amount of activity.

Table 6. Oil- and gas-producing fields in Texas tidelands, 1979 (Texas Gulf coast...1979).

Nearest county[a]	Fields in bay systems		Fields in the Gulf to three-league line	
	Oil	Gas	Oil	Gas
Aransas	9	16	0	3
Brazoria	1	3	0	13
Calhoun	15	25	0	5
Cameron	0	4	0	0
Chambers	14	28	0	1
Galveston	6	20	4	14
Harris	1	1	0	0
Jackson	2	5	0	0
Kenedy	2	8	0	0
Kleberg	2	13	2	7
Matagorda	3	8	0	23
Nueces	14	26	2	6
Refugio	1	1	0	0
San Patricio	3	3	0	0
Willacy	0	0	0	3
Total	73	161	8	75

[a]Fields that overlap county boundaries are tabulated for both jurisdictions. Fields confined to barrier islands are not tabulated. Onland fields that extend into State waters are tabulated, as are those that overlap the three-league boundary.

The distribution of Federal OCS development operations has generally tracked the experiences of exploratory drilling--intensive gas field development in the upper regions near Louisiana (High Island and Galveston areas) and progressively less activity southward. The south Texas area presented some hope to exploration geologists, but inconsequential seismographic tests and numerous dry holes dimmed their hopes by the mid-1970's. Some notable exceptions to this trend are the gas fields developed in the Mustang Island and North Padre Island areas.

Drilling Completions

A useful indicator of trends in development activity is the number of well completions in proved fields. Important new trends were established in Texas offshore areas as development drilling surged in recent years. Between 1967 and 1975, only 14% of Texas offshore wells were developmental. But the number of development well completions mushroomed from 10 to 79 between 1975 and 1976, marking the beginning of a major effort to exploit more fully the gas fields already leased (Table 7). And in 1979, development drilling activity surpassed exploratory drilling in the Texas offshore for the first time.

Table 7. Texas offshore drilling, 1954 through 1979: State and Federal jurisdictions (American Petroleum Institute 1979, Beck 1980).

Year	Exploratory	Development	Total
1954-1966	199	175	374
1967	61	41	102
1968	40	13	53
1969	103	11	114
1970	51	9	60
1971	38	6	44
1972	47	6	53
1973	66	6	72
1974	150	13	163
1975	162	10	172
1976	147	79	226
1977	195	143	338
1978	147	143	290
1979	129	173	302
All time to January 1980	1,479	874	2,353

Similarly striking changes have become apparent in the TBIE counties. Development drilling accounted for about 55% to 70% of all drilling activity until 1975, and then rose to 82% in 1978. Although State and national trends are also on the rise, they are not nearly as prominent.

A large component of the proportional increase in development drilling is the net increase in activity. From 1971 to 1978 (the low point of the decade in drilling activity), completion of development wells nationally had increased by 93%, compared with an overall well completion increase of 82%. Completion of development wells in gas fields increased by 138% during that period (American Petroleum Institute 1979). Within the TBIE study area, gas well completions rose by an unprecedented 300% from 1970 (196 wells) to 1978 (786 wells).

Summary. Oil and gas field development is the intermediary activity that bridges successful exploration with production, and has been of tremendous economic significance to the Texas coastal area. The many tiers of service and supply operations that have been sited along the Texas (and Louisiana) coasts have made the region a world center for petroleum development.

Much of the future activity will likely occur in and adjacent to proven fields, both onshore and offshore. The probability of discovering very large new fields is becoming highly unlikely; this fact combined with the escalating costs of exploration will dampen the willingness of most oilmen to make large risks in the near future. On a national scale, the TBIE study area is in fact a "proven" area. The next few years of Federal OCS lease sales will steer a large share of the offshore development back into the western Gulf of Mexico.

Production

Production is the "mature" phase of oil and gas exploitation. It begins as drilling and other development operations end, although it can overlap with earlier phases when other portions of an oil or gas field are subsequently explored and developed. Special production equipment is installed after development drilling equipment is disassembled, and the level of employment drops radically at that time. In the offshore zone, fixed production platforms and other specialized types of equipment are installed so that oil or gas can be treated and pumped to onshore terminals.

The production phase of a given well usually spans 20 or 30 years, depending on the size of the field, rate of recovery, operating condition of the well, and the ability to improve the percentage of petroleum that can be recovered. Periodically, a producing well is put through a "workover" cycle to modify the well hole and increase the rate of recovery. As an oil or gas field is depleted, certain wells are discontinued and plugged.

Geographic distribution. The regional distribution of oil and gas production in the TBIE study area is heavily concentrated in the Gulf Coast planning region. Brazoria, Chambers, Fort Bend, and Harris Counties were the site of almost half of all the crude oil and liquid condensate produced in the study area in 1978. Jackson, Refugio, Jim Wells, and Kleberg Counties have historically been important oil-producing counties as well (Table 8). With the exception of Jim Wells and Kleberg Counties, all of these counties have at least one large oil field which has produced at least 100 million bbl (Texas almanac 1979).

Natural gas production is concentrated in two areas--in the northeast counties of Galveston, Brazoria, and Matagorda, and in the south-central counties of Jim Wells, Nueces, Kleberg, and Brooks. These seven counties collectively account for approximately two-thirds of the natural gas produced in the study area.

Distribution of natural gas production in the offshore regions is heavily concentrated in the northeast portion of the study area, especially near the Louisiana border. The Brazos, Galveston, and various High Island lease areas account for most of the historical production in Federal waters, although several producing wells are also found in the central and south-central lease areas. In State waters, most of the production (and royalty income) is in the zone situated between 4.8 and 14.5 km (3 and 9 mi) offshore.

Table 8. Cumulative oil production statistics (through 1978) and date of discovery (Texas almanac 1979).

Region and county	Cumulative oil production to date (bbl)	Date of discovery
GULF COAST		
Brazoria	1,117,431,887	1902
Chambers	796,152,594	1916
Fort Bend	568,516,705	1919
Galveston	385,389,679	1922
Harris	1,218,827,122	1905
Liberty	455,150,430	1905
Matagorda	231,865,339	1904
Wharton	256,334,471	1925
Total	5,029,668,227	
GOLDEN CRESCENT		
Calhoun	76,351,598	1935
Goliad	62,805,559	1930
Jackson	579,043,423	1934
Victoria	213,761,332	1931
Total	931,961,912	
COASTAL BEND		
Aransas	69,332,057	1936
Bee	87,385,820	1930
Brooks	141,406,152	1936
Jim Wells	441,697,402	1933
Kenedy	24,099,512	1947
Kleberg	293,729,170	1926
Nueces	502,191,692	1930
Refugio	1,007,705,065	1928
San Patricio	432,434,470	1930
Total	2,999,981,340	
LOWER RIO GRANDE VALLEY		
Cameron	385,853	1944
Hidalgo	37,311,552	1934
Willacy	85,615,991	1936
Total	123,313,396	
TBIE STUDY AREA	9,084,924,875	
STATE	43,724,695,223	

Mainland production. Levels of crude oil and natural gas production have shifted dramatically in recent years. Crude oil production in the TBIE study area and the entire State rose to all-time high levels in 1972 and declined steadily over the next seven years. In 1970, crude oil production in the TBIE area accounted for 20% (254 million bbl) of the statewide total; by 1978, its share (163 million bbl) had dropped to 16% (Texas Railroad Commission 1971, 1976, 1979a).

Brazoria, Harris, and Refugio Counties have consistently been the site of a major part of the area's crude oil production. Between 1975 and 1978, these counties accounted for half of all production in the 24-county area. At the national level, Texas has accounted for more than one-third of total national production since 1928, although its share has declined somewhat in recent years (DeGolyer and MacNaughton 1978).

Natural gas production (gas well and casinghead gas) has followed the same general trends as crude oil. Statewide production peaked in 1972 at 245 billion m^3 (8.6 trillion ft^3) and declined to about 198 billion m^3 (7.0 trillion ft^3) in 1978 (Texas Railroad Commission 1976, 1979a). Casinghead gas, which is produced from oil wells and separated for marketing, has accounted for 20% to 25% of all marketed gas production in the State. Like crude oil, gas production in the State has been of major importance to national output; its share between 1950 and 1955 was one-half of total national production, although it declined and represented only 35% in 1977 (American Petroleum Institute 1979).

There were 163,746 producing oil wells in Texas in 1977, representing one-third of all wells in the United States. More than half of these are "stripper wells," which produce less than 10 bbl/day. (The average stripper well in Texas produces 4 bbl/day.) Their contribution to statewide production is only about 10% to 12% annually (DeGolyer and MacNaughton 1978). At the national level, stripper wells account for three-fourths of all producing wells, but only about 13% of total crude oil production (American Petroleum Institute 1979).

Offshore production. Crude oil has not been a major component of production in the gas-prone Texas offshore area (Table 9). In the last few years, oil production has risen to all-time high levels (4,565,000 bbl in 1978). Natural gas production has always been more significant than oil production offshore in both State and Federal waters. In the early peak production year of 1971, some 11 billion m^3 (387 billion ft^3) of gas were produced; 67% of this was in State waters and 33% was in Federal waters. Outputs declined radically from 1971 until 1974, when a significant new upward trend began. By 1978, outputs had reached an all-time high level of 11.4 billion m^3 or 402 billion ft^3 (Table 10). The State share of output in 1978 was 58%. Future production volumes should rise, both in Texas and in all Federal waters, as exploration activity remains strong and greater emphasis is given to development of proven fields. However, the Texas share of national offshore gas production will likely remain quite low. As of 1978, Texas offshore gas accounted for less than 8% of national production.

Economic value. The gross value of oil and gas production has soared with rising wellhead prices in spite of the gradual declines in production. In 1965, gas produced from gas wells in the TBIE study area was valued at $351 million. By 1977, yearly production value had increased to $1,633 million ($888 million in constant 1965 dollars) and represented one-third of the value of statewide production. Until the early 1970's, wellhead gas prices in Texas were about 20% lower than national averages. Actual prices then rose rapidly. In the period between 1965 and 1977, prices in Texas rose from $4.60/1,000 m^3 to $31.90/1,000 m^3, or from $0.13/1,000 ft^3 to $0.90/1,000 ft^3 (American Petroleum Institute 1979).

Table 9. Crude oil production in Texas offshore waters (U.S. Department of the Interior, Geological Survey 1979).

Year	Texas (1,000 bbl)	State(%)	Federal(%)	Gulf of Mexico (1,000 bbl)
Pre-1954	0	0	0	54,803
1954	10	100	0	15,936
1955	156	99	1	25,887
1956	140	90	10	41,046
1957	256	98	2	53,091
1958	470	100	0	57,851
1959	499	100	0	73,292
1960	567	100	0	88,689
1961	292	100	0	103,489
1962	803	100	0	127,604
1963	669	92	8	149,756
1964	578	99	1	174,287
1965	557	99	1	199,850
1966	1,246	29	71	244,326
1967	3,400	16	84	287,433
1968	3,400	9	91	333,322
1969	3,109	11	89	368,800
1970	3,046	26	74	401,424
1971	2,885	42	58	447,248
1972	3,035	43	57	455,619
1973	2,285	29	71	431,750
1974	1,869	26	74	391,545
1975	2,136	37	63	355,396
1976	1,761	40	60	341,119
1977	4,035	77	23	328,621
1978	4,565	54	46	315,064
TOTAL	41,769	43	57	5,867,142

Table 10. Natural gas production in Texas offshore waters (U.S. Department of the Interior, Geological Survey 1979).

Year	Texas (million ft^3)	State(%)	Federal(%)	Gulf of Mexico (million ft^3)
Pre-1954	0	0	0	91,675
1954	3,440	100	0	84,765
1955	6,880	100	0	128,159
1956	6,880	100	0	143,407
1957	13,765	100	0	174,237
1958	24,080	100	0	258,047
1959	24,080	100	0	353,360
1960	30,960	100	0	439,348
1961	13,760	100	0	472,241
1962	41,280	100	0	629,641
1963	30,960	100	0	737,505
1964	30,960	100	0	814,834
1965	27,520	100	0	898,644
1966	59,259	29	71	1,325,158
1967	127,473	22	78	1,782,696
1968	154,631	29	71	2,211,922
1969	240,212	47	53	2,718,957
1970	264,420	50	50	3,064,524
1971	387,245	67	33	3,606,445
1972	156,772	6	94	3,637,603
1973	250,338	41	59	3,865,230
1974	254,338	37	63	4,126,302
1975	332,862	63	37	4,154,608
1976	206,043	55	45	4,209,851
1977	354,531	75	25	4,449,315
1978	402,000	58	42	5,311,206
TOTAL	3,444,689	53	47	49,689,280

The value of crude oil in Texas has always been slightly higher than the national average. As the national average price per barrel rose from $2.86 in 1965 to $9.00 in 1978, so did the gross value of oil produced in the TBIE area (in spite of declining production). Yearly production value at the wellhead rose from $562 million in 1965 to $1,463 million in 1978 ($816 million in constant 1965 dollars), representing approximately 15% of the 1978 statewide value of crude oil at the wellhead.

Recent (post-1977) data on the value of Texas offshore petroleum production were not available. However, the cumulative production value from the Texas Federal OCS from 1954 through 1977 was $431 million (U.S. Department of the Interior, Geological Survey 1979). As the volume of natural gas produced offshore increases and the price of gas at the wellhead continues to escalate sharply, the economics of offshore development are certain to improve.

The cumulative royalty value of production on the Federal OCS from 1954 to 1977 was $69 million. On State submerged lands, royalty rate schedules are being assigned to new lease tracts which should bring staggeringly large receipts to the Permanent School Fund[1]. Royalty income to the State is approaching $200 million per year (Table 3). A single gas field adjacent to the Louisiana border is expected to produce more than $72 million in receipts for the State in the coming year alone (Reaves 1980). Federal OCS royalty receipts may also soar in the near future as leased tracts in the Gulf of Mexico are given closer scrutiny for development potential.

Summary. Unprecedented challenges confront the Texas oil and gas industry as it faces the next decade. Even if per capita energy consumption declines gradually over the next few years, the country will probably not decrease its reliance on petroleum at a significant pace. Meanwhile, OPEC production and other import sources will probably decrease. The industry will therefore be called upon to invest enormous sums in exploration and development.

Some experts say, however, that production levels will continue to decline on the basis of physical limitations, no matter what the investment. A recent editorial in the Oil and Gas Journal presents this dilemma quite lucidly:

> The decline in the worldwide petroleum discovery rate is a consequence of the fact that most of the world's crude oil is in a few very large fields, and that in the exploration of a petroleum province the large fields are usually discovered early.
>
> Because exploration of frontier areas has moved almost exclusively offshore, we can reasonably conclude that prospects in accessible onshore areas are significantly poorer than prospects offshore. The existence and durability of

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[1] The Permanent School Fund was established in the 1850's as a land and monetary endowment for the public schools of the State. It has accrued tremendously in value over the years. In 1978, the total investment value was more than $1.8 billion and annual income earned was more than $100 million (Texas almanac 1979). In addition to prior endowments, the Legislature in 1939 dedicated to the Fund the mineral estate in river beds and channels and in all areas within the tidewater limits, including islands, lakes, bays, and the seabed out to the limit of State jurisdiction (approximately 2 million ha, or 5 million ac). The Commissioner of the TGLO and the School Land Board are responsible for the management, lease, and sale of the public school lands.

the oil cartel (OPEC) is evidence that crude oil is found in large quantities in only a few places (Oil in the...1979:169).

Three future needs are made evident from this analysis of the Texas oil and gas industry: (1) attainment of maximum rates of recovery from producing fields; (2) accelerated exploration for new reserves in OCS frontiers; and (3) development of continually more sophisticated exploration/development technology. The latter priority is the essential mechanism for accomplishing enhanced recovery and for probing deepwater frontiers.

Technological Trends in the Industry

Few industries are as directly dependent on technological advancement and refinement for long-term viability as the energy industry. The mere disclosure of technological breakthroughs can stimulate large scale plans for new exploration or development. Most of the recent technology developments in the industry can be classified as either improving the economic efficiency of ongoing activities, facilitating new activity in areas where it was not formerly possible to operate, or reducing the environmental hazards involved in equipment failures.

Onshore. Onshore petroleum operations are experiencing rapid technology development in geophysical exploration, drilling, and production. Seismic and other geophysical surveys are aided tremendously by computer processing. Three-dimensional survey analyses and plotting systems aid geologists in deciphering complex structures with great precision. Major breakthroughs in drill bit design are increasing the speed of drilling operations. Better knowledge of bit hydraulics and computer planning of drilling programs are enabling drilling supervisors to optimize their numerous control decisions (New methods and... 1979). Microprocessor technology advancements will soon move into the drill hole to achieve "real time" monitoring of all facets of drill bit penetration, direction, and cutterhead condition. These achievements in drilling technology become readily apparent when comparing drilling depth records of 25 years ago (6,860 m or 22,500 ft) to those made recently (10,060 m or 33,000 ft) (Wood 1979). A variety of methods for enhancing oil recovery from producing reservoirs are being tested for larger scale deployment in fields approaching exhaustion. Steam injection, water flooding, chemical flooding, and artificially increased permeability by use of explosives and chemicals are some examples of enhanced recovery techniques.

Offshore. In the offshore environment, important technology developments are unfolding in the areas of drilling, production, transportation, and accident prevention/response. In particular, drilling technology for deepwater environments is experiencing a design revolution.

The types of drilling platforms in use now or being prepared for use in the near future are so diverse that virtually every continental shelf environment in the Gulf of Mexico is potentially accessible. Drillships equipped with dynamic-position referencing systems have recently drilled in open waters more than 1,460 m (4,800 ft) deep. This technology is almost ready for safe and economical drilling in waters to depths of 2,440 m (8,000 ft) with no fixed mooring and with the ability to raise, lower, and re-guide the drill stem repeatedly into the same template on the ocean floor (New methods and... 1979). New modular, multi-well templates allow for deepwater drilling of up to 60 wells from a single site, and a single production riser or pipeline system can be shared among all wells during production. Single-well satellite templates are also providing alternative advantages (Walther 1978a).

Semi-submersible drilling rigs continue to offer new advantages over other rig types. Some are self-propelled, dynamically positioned, and very large; equipment dimensions include hollow legs 8 m (26 ft) in diameter, mounted on floodable pontoons 110 m (360 ft) long, and supporting work platforms greater than 60 m (200 ft) on a side. They can drill in waters over 610 m (2,000 ft) deep and remain properly moored in 18-m (60-ft) storm waves (U.S. Department of the Interior, Fish and Wildlife Service 1978). Another semi-submersible platform concept is the concrete caisson drilling and production system. This massive type of facility would be capable of simultaneously drilling in very deep water, producing up to 100,000 bbl/day, storing 600,000 bbl in the caisson, and dynamically positioning itself over the drilling template (Koonce 1977).

In the area of production, new fixed-platform designs continue to extend the maximum potential depths of production. The Brown and Root fabrication yard at Port Aransas, Texas, recently constructed the world's largest and tallest one-piece platform jacket. The entire platform rises 235 m (772 ft) off the Gulf of Mexico seabed and will have the capacity to support 20 wells (Brown and Root, Inc. 1980).

Exxon U.S.A. has developed, built, and tested (at a cost of $500 million) a prototype guyed tower secured by radially oriented cables in the Gulf of Mexico. The tower will function in water depths to 610 m (2,000 ft). It is ingeniously moored so that it rests on a spud and can sway up to one or two degrees in severe winds without damaging or interrupting drilling operations (Koonce 1977). The company recently announced plans to install a full-scale tower (the largest in the world) off the Louisiana coast in 1983 (Oil company to... 1980). It will stand approximately 400 m (1,300 ft) tall and will support a three-level, 7,000 m^2 (75,000 ft^2) deck, altogether weighing 40,800 mt (45,000 t). It appears that the 610-m (2,000-ft) water depth may be the economic and technological limit for above-water fixed platforms.

In still deeper waters, a rapidly developing assortment of subsea production systems will allow for petroleum pumping, processing, transport, and routine equipment maintenance to take place on the ocean floor. Highly specialized maintenance equipment such as one-atmosphere deep-sea submersibles, remotely controlled "smartie" submarines, and fully automated maintenance robots attached to subsea templates are being designed and tested for long-term serviceability in Gulf waters and other ocean environments (Maintenance of production... 1980).

Transportation has always been a technological challenge in the offshore zone. Some of the more recent improvements that may have important effects on the industry have been made in barge design for pipeline laying and platform installation, and for pipeline monitoring and repair equipment. Very large derrick barges and semi-submersible pipeline lay barges are installing pipes in record water depths. The largest lay barges are more than 125 m (410 ft) long; they can install up to 2 km/day (1.2 mi/day) of pipe, burying it in a trough which is "jetted" through 3 m (10 ft) of sand. One new derrick barge designed for installing large platforms supports a crane with an 87 m (285 ft) boom and is capable of lifting 1,090 mt (1,200 t) over the stern (Matheny 1980).

New technology for accident prevention and response is also being developed. Better monitoring of offshore pipelines and pipe flow rates, using automated flow meters and submersible inspection capsules, may give onshore service bases sufficient advanced notice to detect cracks and flow losses before major spills occur. Transport of offshore oil and gas in the same pipeline, called multi-phase pipeline flow, could reduce the total number of pipelines stemming from an offshore field.

Improved "real time" monitoring of downhole drilling conditions and improved mud circulation and cementing techniques should reduce the hazard of a blowout or other major failure (New methods and... 1979). Similarly, advances in directional drilling offer obvious advantages in terms of accident prevention and response. By clustering well holes at the surface (i.e., on a single offshore platform), there is less surface area affected and potentially less ecological disturbance from drilling. However, the hazard of fire or explosion is far greater in large clusters of wellheads.

Many other innovative technologies will soon be implemented. Rapid-response electric blowout preventer valves are being developed for deepwater drilling operations. Large hovercraft platforms which measure 14 by 17 m (45 by 55 ft) and which are capable of carrying 50-ton payloads, including drilling rigs, may soon be available for use in environmentally restricted (wetland) or remote areas (Leonard 1979). Specialized training schools and certification programs for OCS operators are offering sophisticated simulation training for dealing with crisis situations. Attendance at these schools is mandated by the BLM for technicians working on Federal lease tracts.

ENERGY RESERVES AND RESOURCES

Several important trends are evident in the accounting of oil and gas resources in Texas. Some trends have very obvious implications while others are subtle and complex. The relationships between current reserves, current rates of production, and exploratory drilling activity can be observed in all of them.

Resource Classification

Petroleum resources and reserves are classified on the basis of economics and level of discovery. Undiscovered oil resources are potential supplies. Undiscovered oil resources are considered as economically recoverable, subeconomic, or non-recoverable (Masters 1977), while undiscovered gas resources are often termed probable, possible, or speculative (Grow 1977).

Identified resources are also classified as recoverable, subeconomic (potentially recoverable) or non-recoverable. Those identified resources that are economically recoverable are considered as reserves. Specifically, measured proved reserves represent the amount of petroleum that the industry believes is now available for production and can be recovered economically under existing prices and technology. Considering the frequency of Federal audits, industry estimates of measured reserves are considered generally reliable.

Measured proved reserves, however, cannot be pumped from the ground at any arbitrary rate. Physical constraints will generally limit annual production from a field to one-tenth of the measured reserves. Production-to-reserve ratios greater than 1:10 are attainable in some fields, but higher ratios can lead to significantly less efficient rates of recovery. In fact, a 60% rate of recovery from a reservoir is considered as an ultimate attainable limit of reservoir depletion (Masters 1977).

In any given year, reserve estimates are adjusted on the basis of discoveries, reserve revisions and extensions, and production during the previous year. Net changes in the annual accounting of these variables will reflect depletion of the measured proved reserves and can be indicated by a reduction of the estimated number of years of remaining supply.

Crude Oil Trends

Texas crude oil measured reserves account for almost one-third of the United States crude oil reserves (DeGolyer and MacNaughton 1978). The three coastal districts of the Texas Railroad Commission (see footnotes, Table I) have accounted for 20% of statewide reserves in recent years (U.S. Department of the Interior, Bureau of Mines 1978). Crude reserves in Texas began declining in 1951 while production continued to increase until 1972. The breakeven point at which annual production consistently began exceeding reserve additions and extensions occurred in 1971. This triggered an even steeper rate of decline of proved reserves (Figure 3). In January 1978, measured reserves of crude oil in Texas were estimated as slightly less than 7.7 billion bbl (Table II). This represented slightly more than 7 years of remaining supply at the 1978 annual rates of production and new additions to reserves, the lowest level since the early days of oil development in Texas, and precisely one-half of the peak level of 1951.

Table II. Estimated proved reserves of hydrocarbons in Texas Railroad Commission districts (U.S. Department of the Interior, Bureau of Mines 1975; American Petroleum Institute 1979).

Year	Crude oil (1,000 bbl)	Natural gas liquids (1,000 bbl)	Natural gas (million ft^3)
1955	14,933,502	3,045,361	108,287,548
1960	14,758,492	3,596,174	119,489,393
1965	14,303,058	4,059,557	120,616,760
1970	13,195,476	3,330,159	106,352,993
1975	10,080,035	2,660,668	71,036,854
1978	7,689,991	2,268,284	54,600,235

National crude oil production and reserve accounts have followed the same basic trends. Proved reserves in 1978 amounted to 27.8 billion bbl, or 5 years of remaining supply at the 1978 rate of production and addition to reserves (DeGolyer and MacNaughton 1978).

No matter how aggressive the search for major new additions to our declining national reserves, it will be extremely difficult to balance annual production with new reserve additions. One reason for this is the production-to-reserve ratio, which dictates that for every barrel of increased production, an average of 10 bbl of new reserves must be found. Another reason is that major new discoveries cannot be anticipated or expected. The last discovery of the magnitude of Prudhoe Bay was the East Texas field, discovered more than 50 years ago.

Recent estimates of economically recoverable crude oil resources for the United States suggest that 18 billion bbl of "indicated" and "inferred" reserves and 50 to 127 billion bbl of "undiscovered" resources could some day be added to "proved" reserves (Masters 1977). A large share of Texas' undiscovered but economically recoverable resources appear to lie offshore, primarily in Federal waters. Between 1.3 billion and 2.2 billion bbl are believed to lie in Federal and

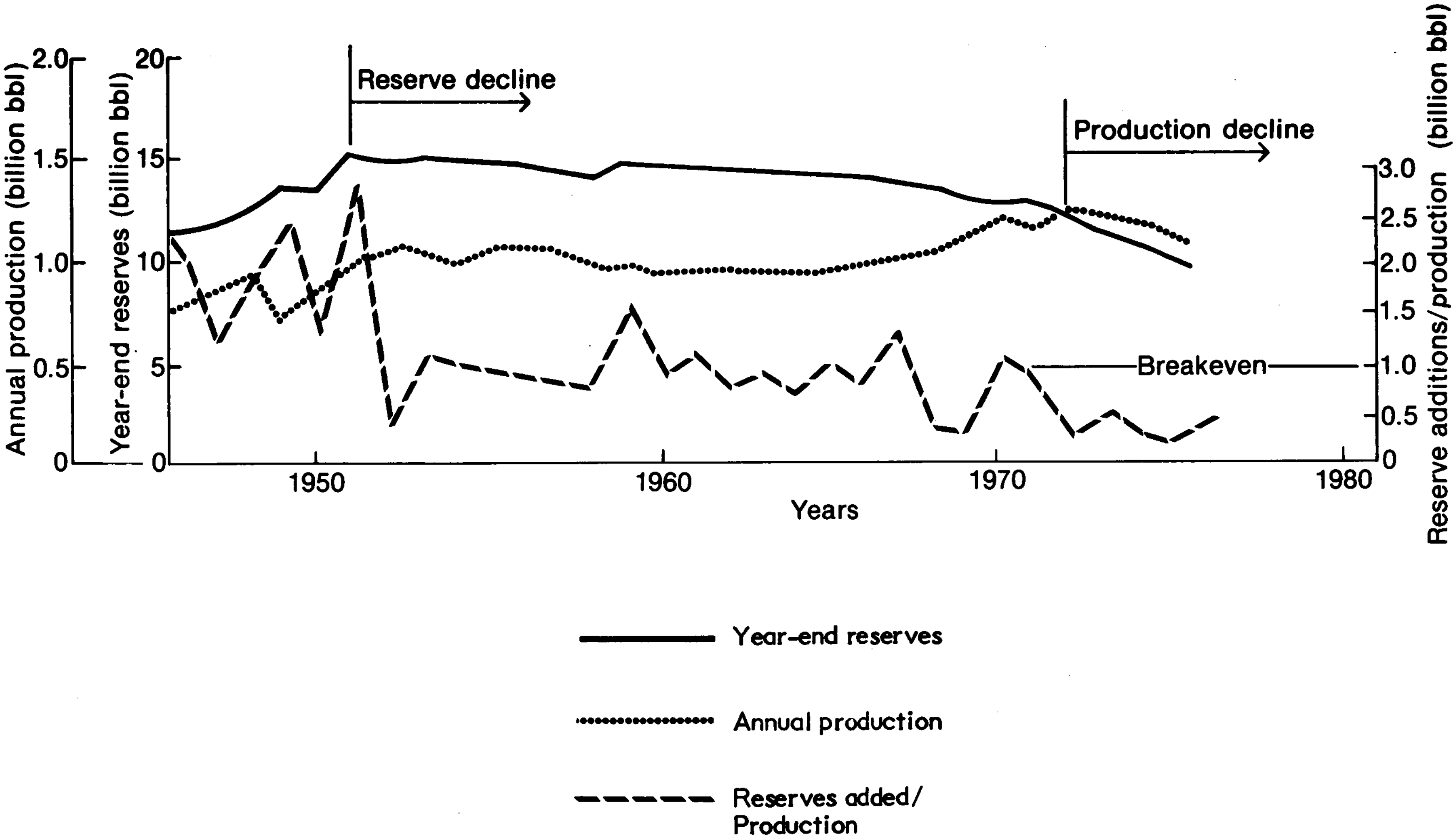


Figure 3. Texas crude oil production and reserve trends, 1946 through 1977 (Fisher 1978).

State waters less than 200 m (650 ft) deep, and another 300 million to 700 million bbl may be recoverable in waters up to 2,500 m (8,200 ft) deep (Miller et al. 1975).

Natural Gas Trends

Measured natural gas reserves in the three coastal districts of the Texas Railroad Commission have recently accounted for one-third of statewide reserves (U.S. Department of Interior, Bureau of Mines 1978). Statewide reserves increased each year from the date of discovery until 1966. The annual rate of natural gas production began to exceed the annual additions to reserves that year, and a steady decline has since ensued (Table 11). Annual production continued to increase through 1972, thereby diminishing year-end reserves by even greater margins (Figure 4). As of 1977, proved natural gas reserves in the State were 1.76 trillion m^3 (62.2 trillion ft^3), having declined in each of the previous few years by 7% to 8%. At the 1977 rate of production and reserve additions, this estimate represented about 9 years of future supply (DeGolyer and MacNaughton 1978).

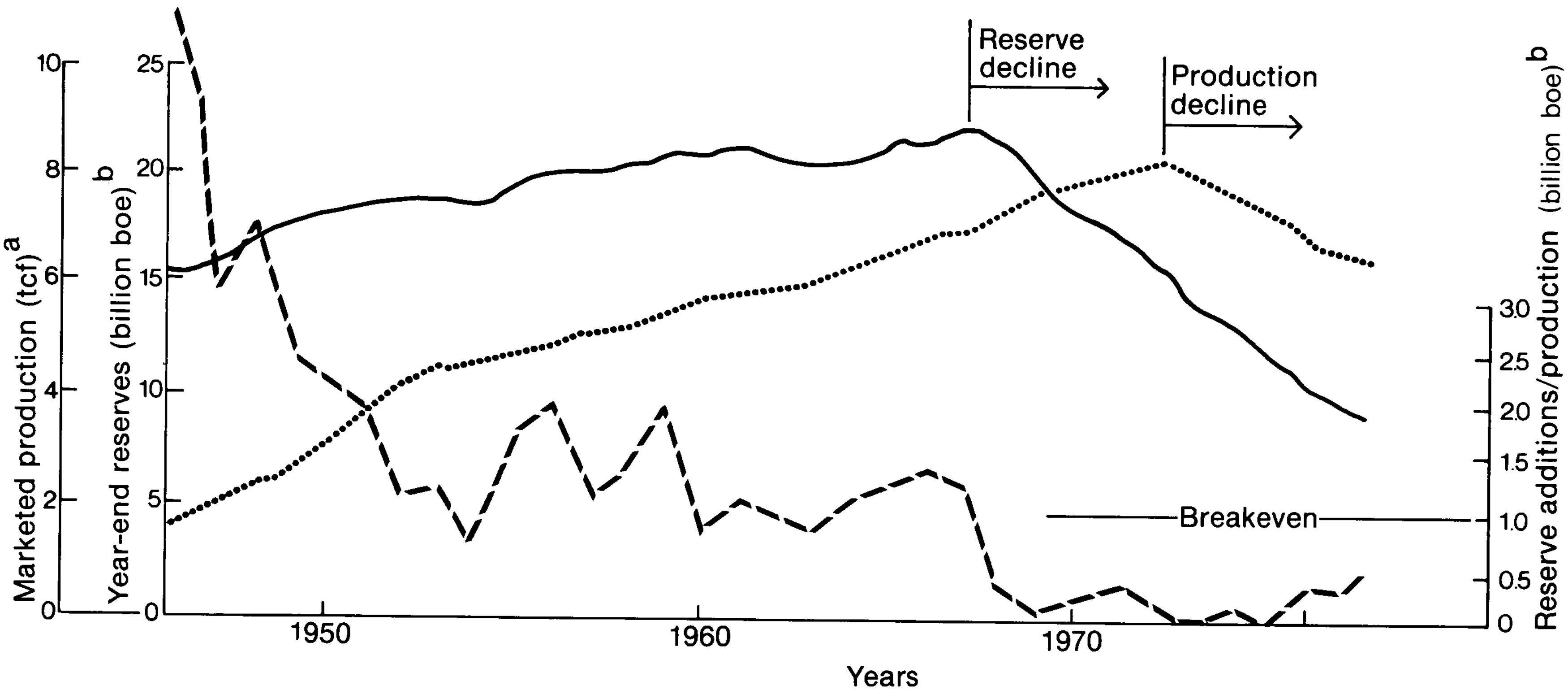
At the national level, proved natural gas reserves peaked in 1967 and have since declined steadily, except for the 1970 Prudhoe Bay addition. The 1978 proved reserves amounted to 5.67 trillion m^3 (200 trillion ft^3), or about 10 or 11 years of remaining supply at 1978 rates. Texas has accounted for 30% to 33% of the United States reserves for the past several years (DeGolyer and MacNaughton 1978).

Vast amounts of unproved recoverable gas resources are believed to exist in the Texas coastal region. The Potential Gas Committee, an autonomous national advisory group comprised of 120 geologists and engineers, has prepared estimates of probable, possible, and speculative resources for south Texas and the coastal plains region. They concluded that this part of the State holds 0.5 trillion m^3 (19 trillion ft^3) of "probable" reserves which can be expected to be found in known producing formations or adjacent to existing fields (Grow 1977). Another 0.45 trillion m^3 (18 trillion ft^3) are believed to exist as "possible" or "speculative" sources in areas where no prior drilling has been made. The Committee further estimated that the Texas offshore zone contains 0.6 trillion m^3 (20 trillion ft^3) of probable resources and 0.74 trillion m^3 (26 trillion ft^3) of speculative resources (Table 12). Collectively, these resources would amount to about 14 additional years of natural gas supply for Texas, assuming 1977 rates of production.

Geopressured-geothermal Resources

The Texas coastal basin province contains vast amounts of geothermal energy. It appears that some of this energy is recoverable from deep, highly pressured water-bearing strata. As a result of a series of complex geologic events, water temperatures and pressures much higher than expected are found in certain strata lying at depths of 1,500 m (5,000 ft) or greater beneath the surface (Dorfman and Kehle 1974). Petroleum explorers have traditionally avoided these geopressured-geothermal zones because of their poor petroleum-bearing potential and the stresses imposed by high temperatures and pressures on conventional well-drilling equipment (Figure 5).

It appears, however, that steam energy recovery and extraction of methane gas dissolved in the geo-pressured waters may be approaching the point of economic feasibility. The world's first test well in a geopressured-geothermal



[a]Trillion cubic feet.
[b]Barrels of oil equivalent.

Figure 4. Texas natural gas production and reserve trends, 1946 through 1977 (Fisher 1978).

Table 12. Estimated proved and unproved natural gas resources and reserves in Texas, 1977, in trillion ft^3 (Grow 1977).

Region	Proved reserves	Probable reserves	Possible resources	Speculative resources
South Texas and Coastal Plains Region[a]				
0-15,000 ft	N.D	17	9	2
15,000-30,000 ft	N.D.	2	5	2
Offshore (State and Federal jurisdictions)	N.D.	20	26	0
State	62	N.D.	N.D.	N.D.
United States	209	215	363	370

[a]Potential Natural Gas Committee district, representing about one-fourth of the State.

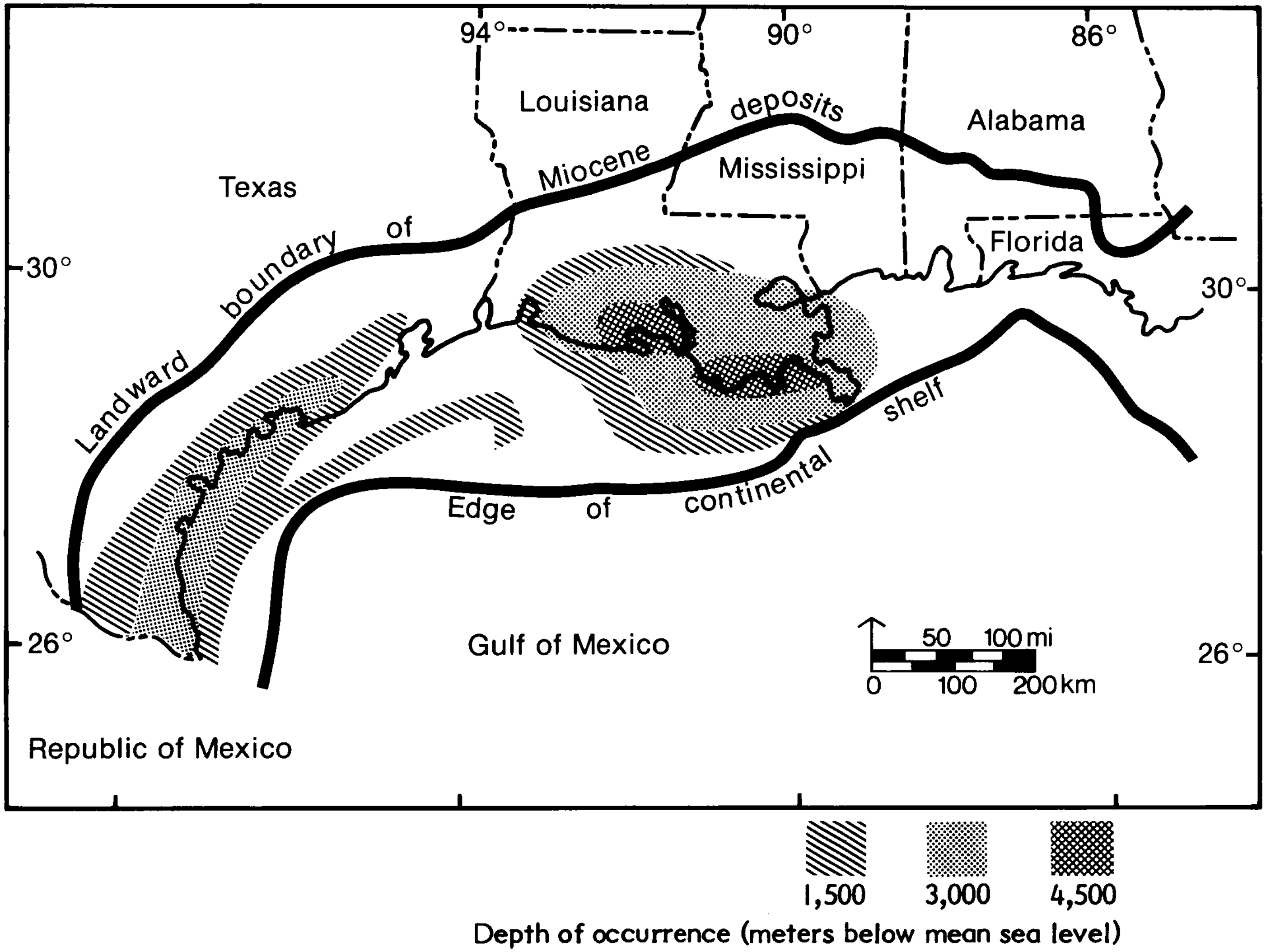


Figure 5. Location and depth of occurrence of the geopressured zone in the northern Gulf of Mexico basin (Dorfman and Kehle 1974).

formation was recently drilled in the Pleasant Bayou area, Brazoria County, Texas. The test was conducted by the Bureau of Economic Geology at the University of Texas and the U.S. Department of Energy as part of a research program on the viability of producing thermal water for electrical generation. Initial tests from a depth of approximately 4,470 m (14,660 ft) indicated a possible steady flow of 30,000 bbl/day of water at about 149°C (300°F), and methane gas content of 0.57 to 0.71 m^3/bbl (20 to 25 ft^3/bbl) of water (Leonard 1979). Considerable further testing will be needed to determine the project's feasibility.

It appears that the Brazoria fairway has the highest potential for economical reserves in the Texas coastal area. Selection of optimum well locations and depths will likely be based on tradeoffs between the advantages of higher temperatures (at deeper levels) and greater permeability (at shallower levels), and on a number of environmental constraints unique to this type of energy production (office visit 17 January 1980 to Dr. Robert Morton, Bureau of Economic Geology, University of Texas at Austin).

Recent estimates of Texas geopressured-geothermal resources and recovery estimates were made by the USGS and the Bureau of Economic Geology. The more conservative estimates of the Bureau indicate that a 3.3% recovery rate for the entire region would yield 95 quadrillion British thermal units (95 Quads) of thermal energy (equal to 2.6 trillion m^3, or 92 trillion ft^3 of natural gas) and 55 Quads of methane gas (1.4 trillion m^3 or 51 trillion ft^3 of natural gas) (Fisher 1978). Collectively, these resource estimates are greater than the State's combined proved reserves of crude oil and conventional natural gas. It is questionable, however, whether geothermal resources along the Texas coast will be economically recoverable.

INFRASTRUCTURE, LAND USE, AND RELATED INDUSTRIES

The infrastructure of the oil and gas industry in the United States is geographically organized around historical and reliable sources of oil and gas. Areas having the largest concentrations of producing fields have had a greater share and a more diverse mix of service facilities and allied industries. The Gulf coast, and the TBIE study area in particular, is one of the best known examples. Pipelines and refineries in this region have been transporting and processing petroleum from local fields for more than 60 years. The complex infrastructure of support and service operations along the Texas coast should continue to operate and expand as more expensive and advanced techniques of petroleum exploration and recovery are applied.

Logistical Support

Pipeline yards. Pipelines are usually the preferred mode of petroleum transportation because they require fewer transfer operations and operate more efficiently and safely in all types of weather than other modes of transport. As of 1977, there were 106,000 km (66,000 mi) of petroleum pipelines in Texas (Table 13). The typical pipeline yard serves in part as a storage facility, but primarily as a site for coating pipe prior to installation. The major site requirements are a 30- to 80-ha (75- to 200-ac) tract with good navigational and rail access. Up to 95% of the yard is storage space. A typical 40-ha (100-ac) yard can store approximately 480 km (300 mi) of pipe sections (U.S. Department of the Interior, Fish and Wildlife Service 1978). Major yards are found in the Houston-Galveston and Corpus Christi areas (Research and Planning Consultants, Inc. 1977).

Table 13. Miles of petroleum pipeline in Texas for selected years, 1950 through 1977 (U.S. Department of Energy, Energy Information Administration 1979).

Type pipeline	1950	1956	1962	1968	1974	1977
Trunk lines						
Crude	26,409	29,642	26,439	26,004	27,490	27,811
Products	2,625	3,726	9,875	10,608	14,026	14,130
Gathering lines	20,149	26,018	26,962	23,704	24,794	24,025
Texas total	49,183	59,386	63,276	60,316	66,310	65,966
U.S. total	152,814	188,540	200,543	209,478	223,535	227,066

The principal operations in a pipeline yard are application of anti-corrosion coatings (mastic) on all pipes, application of weighted coatings (concrete) for underwater pipelines, curing and storage of coated sections, and transport of sections into and out of the yard. A standard 12.2-m (40-ft) section of large diameter coated pipe may weigh 36 mt (40 t). The staggering raw material requirements for coated pipes and the high cost of pipe laying, especially offshore (more than $2 million/km), make this activity one of the most expensive in the petroleum industry (U.S. Department of the Interior, Fish and Wildlife Service 1978).

Pipeline yards generate moderate amounts of employment and economic benefit for surrounding areas. A pipe-coating facility which processes 320 km (200 mi) of pipe per year might employ up to 200 people. These yards also cause certain adverse environmental impacts which are associated with construction of the yard, use of corrosive chemicals, navigational improvements, and grading and filling in coastal areas. The noise and dust levels during intensive operations can also be significant (U. S. Department of the Interior, Fish and Wildlife Service 1978).

Platform fabrication yards. Fabrication yards on the Gulf coast are busy servicing the world market in oil and gas production. These yards require more labor, waterfront, and land area than any other oil and gas development activity. A typical facility on the Texas coast may include a jacket fabrication area, pile fabrication racks, assembly buildings for decks and other modules, a pipe-rolling mill, plate and pipe shops, painting and sandblasting shops, electrical shops, warehouses, and open storage areas (U.S. Department of the Interior, Fish and Wildlife Service 1978). These activities require a cleared, level yard of 60 to 400 ha (150 to 1,000 ac). Environmental impacts associated with the yard construction can include wetland filling and devegetation, surface contaminant runoff, channel dredging, and noise during operations.

Employment varies greatly, depending on the number of platforms and jackets under construction at any time. Large yards working at full capacity may employ 1,200 people, mostly as fabricators and welders, of which the majority would be local semi-skilled residents (U.S. Department of the Interior, Fish and Wildlife Service 1978). The indirect and induced economic effects can be equally large.

The major yards in the Texas coastal area are found near Houston (2 yards), Corpus Christi (3 yards) and Brownsville (1 yard). Smaller yards in Texas and Louisiana are generally confined to the fabrication of shallow-water units. The most recent developments have included a major expansion at the Chicago Bridge and Iron Works yard in Ingleside and completion of a new 65 ha (160 ac) yard at Ingleside, owned by ETPM U.S.A. (Sumpter 1980).

Shipyards and marine vessel service facilities. The longstanding involvement of Texas and Louisiana in outer continental shelf development has made the upper Gulf coast the petroleum boat-building center of the world. Associated with this industry are the numerous marine repair and maintenance facilities used to keep the vessels in good operating condition.

Many types of offshore vessels are used by the petroleum industry. Crew boats are high-speed vessels used for personnel transport, capable of carrying 30 to 50 passengers at speeds in excess of 20 knots. Supply boats and utility boats are used for bulk cargo transport (pipe, drilling mud, cement, and tools) and maintenance work. The largest supply boats may exceed 70 m (230 ft) in length and have below-deck mud storage capacities of 125 m^3 (4,400 ft^3). Some are specially designed and equipped with elaborate technology for use as survey vessels. Tug boats and push boats, which are used for light to heavy towing and transport of portable equipment, can deliver as much as 8,000 horsepower with adequate fuel capacity (600,000 liters or 160,000 gal) to tow drilling rigs across the open ocean (U.S. Department of the Interior, Fish and Wildlife Service 1978). Pipe laying barges, derrick barges, and platform launching barges are equipped with highly specialized devices for handling and assembling heavy equipment in open waters. Some of the new barges operating in the Gulf exceed 135 m (440 ft) in length and contain two or more below-surface decks (Matheny 1980). Tankers and petroleum barges are used primarily for import/export through Texas ports and transhipment of petroleum products through the Gulf Intracoastal Waterway. The controlling water depths of Texas ports (11 to 14 m, or 36 to 45 ft) limit tanker sizes to less than 100,000 dead weight tons (90,700 mt).

As of 1976, approximately 13% of all petroleum vessels under construction in the United States were being made in Texas ports (Ocean industry's report... 1976). In addition, of the ten shipyards in the United States that were capable of constructing or servicing mobile offshore drilling rigs at that time, half were located in Texas (Brownsville, Ingleside, Galveston, Beaumont, and Orange) (U.S. Department of the Interior, Fish and Wildlife Service 1978). A corresponding proportion of the construction and maintenance of support craft, including several very highly specialized vessels, are clustered in ports along the Texas coast, particularly in the Brownsville, Corpus Christi Bay, and Galveston Bay areas (Research and Planning Consultants, Inc. 1977).

Onshore service and support centers. Service and shore support facilities are the vital links between onshore and offshore activities. There is probably no other coast in the world that exceeds the Texas coast in the diversity and number of petroleum service and support operations, or that serves as headquarters for more major international service-related companies (such as Brown and Root, Hughes Tool, Schlumberger, and Dresser, all located in Houston). The range of activities aided by service industries includes virtually every stage of petroleum development. Some service facilities are owned and built by oil companies, while others are operated by specialized, independent firms under contract to oil companies.

Site requirements for service and support facilities vary considerably with the type of activity. Offshore services require close proximity to drilling activities and direct access to navigable channels or rail lines, but do not cover large areas. Service bases for offshore drilling may contain berths for supply boats and crew boats, dock space for loading, warehouses, a machine shop, and other facilities. Some bases contain facilities for offshore telecommunications, preparation and storage of drilling muds, and helicopter landing areas. Additional support services in the area may include anything from mud suppliers and cement suppliers to food catering establishments.

The major service centers in the TBIE study area are concentrated in the Houston-Galveston-Brazosport area, Corpus Christi-Ingleside-Aransas Pass area, and Brownsville-McAllen area (Research and Planning Consultants, Inc. 1977). One of the more critical problems confronting these firms is the chronic shortage of qualified labor. Estimates of the current shortages of mariners in the offshore petroleum industry indicate that current labor demand is about 50% greater than the available supply. There is every indication that even more critical shortages will develop as OCS activity increases in the coming decade (U.S. Department of Commerce, Maritime Administration 1979).

Offshore Drilling Rigs and Production Platforms

There are five basic types of offshore drilling and production platforms that operate in the Gulf of Mexico at the present time. They include the following: drillships, semi-submersibles, jackups, submersible barges, and fixed platforms. Drillships are highly advanced and expensive units, designed for use in deep waters. They have the advantages of being self-propelled and dynamically positioned (using thrusters on all sides) for drilling over extended periods without mooring. The four ships recently operating off the Texas coast can drill wells up to 7,600 m (25,000 ft) deep in waters 910 m (3,000 ft) deep (Table 14). They can carry more than 7,256 mt (8,000 t) of drilling equipment and 15,000 bbl of fuel.

Semi-submersibles are also self-contained vessels, with massive floodable caissons that allow a portion of the rig to rest below sea level during drilling. An operating semi-submersible is virtually unaffected by most wave action and is far more stable than a drillship in high seas. Some of the 13 semi-submersibles recently active in Texas waters are capable of drilling 9,100-m (30,000-ft) wells in 610 m (2,000 ft) of water using dynamic positioning.

Jackups are mobile drilling platforms with extendable/retractable legs that allow them to be floated out to drilling sites in moderately deep waters and yet stand rigidly during drilling. The platform may measure 60 m (200 ft) on a side and contain two or more decks for equipment storage, crew quarters, and the like. They are not self-propelled, but are favored for their speed in setting up and ability to remain virtually stable during drilling. Some of the 47 jackups recently operating off the Texas coast can drill 9,100-m (30,000-ft) wells in waters up to 115 m (375 ft) deep.

Table 14. Drilling rigs and platforms in Texas waters, February 1980 (Offshore rig locator... 1980a, 1980b).

Type of platform or rig	Active	Idle	Rated water drilling depth			
			0-30 m	30-100 m	100-300 m	>300 m
Drillships	4	0	X	X	X	X
Semi-submersibles	13	0	X	X	X	X
Drilling barges	9	4	X	X	X	
Jackups	47	1	X	X		
Submersibles	11	4	X			
Tenders	3	0				
Fixed platforms[a]	22	0				
Total mobile rigs	75	5	30	32	10	17
Total production platforms	22	0				

[a]Actively drilling.

Certain platforms are referred to as submersibles, best described as shallow water rigs that are floodable to the extent that the hull rests on the bay or ocean bottom. The 11 submersible barges recently operating in Texas waters are able to drill very deep wells, but only in waters less than 6 m (20 ft) deep. The barges are floated to drilling sites (almost always in bay waters), the bases are flooded and allowed to settle on the bottom, and the entire structure is secured in place with pilings on all sides until drilling is completed. After drilling, the platform is again floated and moved to another location. An additional type of drilling barge, known as a "posted barge," is characterized by large legs that facilitate stationary drilling in shallow offshore or bay waters too deep for submersible barges.

Bay drilling with submersible barges is usually accomplished with the use of shell pads which provide a highly stable foundation for the barge during drilling. The pad is laid on the bay mud in a rectangular configuration slightly larger than the barge dimensions, commonly 30 m by 60 m (100 ft by 200 ft). The thickness of the pad is determined by the water depth and the draft of the barge and may vary from 0.5 to 1.5 m. Pads are used exclusively with submersible barges and almost always for drilling in bay waters.

The principal suppliers of shell for drilling pads in Texas waters (as well as for concrete, road construction, and other uses) are Parker Brothers of Houston and

Anahuac Shell of Baytown. A minor amount is also procured from Louisiana sources. Parker Brothers serves petroleum companies along the central and southern Texas coast almost exclusively and is clearly the largest supplier of shell in the State. The company operates the only active shell dredge in the State (in San Antonio Bay), although four other permits have been issued by the Texas Parks and Wildlife Department (TPWD) (telephone call 22 May 1980 from Chester Harris, Fisheries Division, Texas Parks and Wildlife Department, Austin, Texas). The volume and value of shell used in constructing a drilling pad can vary from 1,200 m^3 (1,600 yd^3) at a cost of $12,000, to 3,000 m^3 (3,900 yd^3) at a cost of $31,000 (telephone call 22 May 1980 from Robert Parker, Parker Brothers, Houston, Texas). The total volume of shell dredged in Texas has declined from approximately 7 million m^3 (9.1 million yd^3) in 1970 to 1.2 million m^3 (1.6 million yd^3) in 1979 (telephone call from Chester Harris, Fisheries Division, Texas Parks and Wildlife Department, Austin, Texas). Recent sales values for shell have been approximately $9/ton ($6/m^3).

Fixed production platforms installed in the Gulf of Mexico are usually large, two-piece steel structures. The submerged piece is a multiple pile framework (jacket) welded to tubular steel legs. The working surface (deck) is built separately and fitted atop the jacket after pilings have been driven through the jacket legs for permanent anchoring. In the development drilling stage, one or more drilling derricks are erected on the platform deck; up to several dozen production wells may be directionally drilled through the base of the platform, or even through the jacket legs. When the wells are completed, the deck facilities are changed from drilling to production equipment (pumps, separators, scrubbers, compressors).

Until 1958, there were no mobile offshore rigs in Texas; fixed platforms (usually constructed on wooden pilings) were used for all drilling and production operations (Scott 1969). The typical configuration in Gulf of Mexico production systems has been a master production platform with satellite platforms for crew and equipment, all interconnected by walkways (Crosby 1969).

There were 76 fixed platforms in Texas Federal waters in January 1977, representing a very sizeable increase over the 29 present in the previous year (Research and Planning Consultants, Inc. 1977). The Platforms Approval Section of the USGS recorded the installation of 117 platforms in the Gulf of Mexico in 1977, 158 units in 1978,and 135 platforms and caissons in 1979. An end-of-year 1979 survey by the Oil and Gas Journal accounted for installations of 100 single-well platforms and caissons and 75 three-well or larger platforms that year (Sumpter 1980). Twenty-two fixed platforms were actively drilling production wells off the Texas coast as of February 1980 (Table 14).

Petroleum Storage and Transport Facilities

Tank farms. Petroleum storage facilities, or tank farms, are used to receive, measure, segregate, store, and distribute crude and refined products that are destined for either refineries or tankers. They are essentially surge tanks, accepting a constant inflow from pipelines and providing variable outflows to tankers and refineries. Their primary purpose is to speed the process of tanker loading and unloading for economic as well as safety reasons (New England River Basins Commission 1978).

Storage terminals are always sited near refineries or between the refinery and the tanker offloading terminal. Land area requirements are rather substantial, and the site constraints are rigorous. A 2 million bbl tank farm servicing a 500,000 bbl/day refinery would require about 16 ha (40 ac). Individual oil storage tanks are surrounded by retention dikes, access roads, and pumping equipment. Foundation support for the massive tanks (up to 88 m, or 290 ft in diameter) must have a load bearing capacity of 34 mt/m^2 (7,000 lb/ft^2). The tank farms in the TBIE study area are sited adjacent to refineries, 95% of which are in Harris, Galveston, and Nueces Counties.

Strategic petroleum reserves. A recent action of the Federal government, arising from the need for a fuel allocation in the event of a national emergency, is the development of the Strategic Petroleum Reserve (SPR) system. Underground caverns are being artificially created in salt domes along the Texas and Louisiana coasts as part of this massive and ambitious undertaking. Piercement-type salt domes are giant pillars of salt that may cover several hectares in surface area and penetrate thousands of meters into the ground. Caverns are leached out of the center areas of the domes with jetted water, and are used to store petroleum for future use. The highly concentrated brine is pumped from the domes and discharged into the Gulf. Proposed locations in the TBIE area include Nash Salt Dome in Fort Bend County, and Bryan Mound Salt Dome, Allen Salt Dome, Damon Mound Salt Dome, and West Columbia Salt Dome, all in Brazoria County (Greenwalt 1979). Four large caverns at the Bryan Mound site have been created and partially filled with crude oil, and ten more caverns are planned at the site. The total planned capacity of the SPR is 750 million bbl.

Pipelines. The principal mode of both onshore and offshore petroleum transport is the pipeline. It is considerably safer and usually more economical than tankers or rail transport. Ideally, corridors are sited along the shortest routes, but diversions are often required as a result of engineering or environmental constraints. Onshore and offshore pipelines are constructed of the same materials, except that offshore sections are usually coated with concrete for ballast and corrosion protection. Onland corridor rights-of-way range from 15 to 25 m (50 to 80 ft) in width. The pipeline is usually buried 1.2 to 2 m (4 to 6 ft) deep except where rivers or lakes cannot be avoided. (In rivers or lakes the pipeline is buried at least 3 ft.) Except for installation in wetlands (which is more like an offshore pipelaying operation), onland pipelaying is not very different from electrical transmission line construction or other corridor activities.

Offshore corridors may approach 30 m (100 ft) in width at the point of landfall. Federal regulations require that pipelines be buried at least 3 ft in water depths less than 60 m (200 ft). Highly specialized pipelaying equipment is used offshore, especially in very deep waters. Pipe sections are welded, treated and tested on pipe laying barges immediately prior to laying. Semi-submersible sleds are used on bury barges as a means of easing the intact pipeline onto the sea floor. A jetting sled which digs a trench by shooting water at high pressures into the sediments is dragged in advance of the bury barge. All barges and equipment are stabilized and moved forward with the use of intricate multi-anchor mooring, winching and navigation systems (Woods Hole Oceanographic Institute 1978).

Texas has more than three times the pipeline length of any other state and accounts for almost one-third of the total pipeline length in the United States. Most of the pipelines are used for crude or natural gas transport or as gathering lines from producing fields (Table 13). Beginning in 1947 with the conversion of the famous "Big Inch" and "Little Inch" pipelines into pressurized natural gas lines to service the Atlantic coast, Texas has been serving more than 40 other states with natural gas and refined petroleum products. More than a dozen major transport lines extend along the entire Texas coast (Texas Gulf coast... 1979). More than 60 major gathering lines bring oil and gas into mainland terminals (Research and Planning Consultants, Inc. 1977), and several more are proposed or under construction. An example of the significant investment in pipeline laying and operation is the new High Island gathering system. It will connect seven fields in Federal waters (various High Island lease areas) to an onshore metering station near Texas City, 206 km (120 mi) to the northwest. A total of 270 km (168 mi) of pipe will be laid in water depths up to 100 m (330 ft). Nineteen oil companies will be owners of the $62 million system (Seaton 1980).

Interindustry Relationships of Oil and Gas Production

Although Texas has the distinction of being the national hub of petroleum activity, it did not acquire that title solely by having contributed 25% of all the energy ever produced in the 50 states. It is the multitude of highly interdependent petroleum-related industries, in concert with the State's petroleum production, that has caused petroleum activity in Texas to grow and endure. It is a well-known fact that the infrastructure of the United States petroleum industry is organized around the historical sources of oil and gas, especially in areas with the largest concentration of producing fields. In fact, the concentration of petroleum-related enterprises in the TBIE study area is unmatched throughout the world.

A selected number of petroleum-related industries and facilities are described briefly in this section to identify their interindustry relationships and the high level of dependence of other regions in this Nation on Gulf coast petroleum activity.

Ports and waterways. Several Texas ports are internationally significant in terms of the volume of transported petroleum and related products. The Port of Houston is the busiest petroleum port in the western hemisphere in terms of annual volume. In 1977, a total of 471 million bbl of crude oil, petroleum products and allied chemicals passed through the port (U.S. Department of the Army, Corps of Engineers 1977), amounting to more than one-third of the petroleum products handled in all Texas ports and waterways. The shipments of petroleum and coal products alone (202 million bbl) were valued at $2.7 billion in 1978 (U.S. Department of Commerce, Bureau of the Census 1979).

Corpus Christi, Texas City, and Freeport are also large petroleum ports in Texas. Like Houston, they handle a significant portion of the crude oil imported into Texas for refining and processing. About one-fifth of all the crude oil imported into the United States enters through Texas ports.

Interdistrict movement of petroleum (especially refined products) is facilitated by the Gulf Intracoastal Waterway (GIWW). In 1977, 88 million bbl of chemicals and allied products and 154 million bbl of petroleum and coal products were shipped on the Texas reaches of the waterway (U.S. Department of the Army, Corps of Engineers 1977).

At the present time, the maximum channel depths of Texas ports range from 11 to 14 m (36 to 45 ft), which prevents very large crude carriers from entering nearshore waters or ports. As a result, "lightering" of crude oil onto shallower draft vessels takes place routinely in designated areas from 25 to 80 km (15 to 50 mi) offshore from the port areas of Houston-Galveston-Texas City and Corpus Christi. Several transshipment ports located in the Caribbean Sea and southwest Atlantic Ocean are also used for transferring petroleum to shallower draft vessels.

Several large and controversial navigational improvement projects have been proposed in recent years by various port authorities and industries, primarily as a means of securing a greater share of the imported oil entering the Gulf of Mexico. These projects could significantly affect the volume of crude oil entering Texas ports. They may also have profound effects on local and regional economics, on industrial location, and on various coastal ecosystems. Some of the proposals in the TBIE study area are:

- o Galveston Ship Channel/Northville Industries, channel deepening to 16 m (55 ft)
- o Texas City Channel, channel deepening to 14 to 15 m (45 to 50 ft)
- o Texas Deepwater Port Authority, single point mooring facilities and pipelines off the coast of Brazosport
- o Port of Freeport, channel deepening in Old Brazos River to 14 m (45 ft)
- o Liquified natural gas facility on Matagorda Bay, and channel deepening to 12 to 14 m (40 to 45 ft)
- o Deeport, inshore supertanker port at Harbor Island, channel deepening to 23 to 25 m (75 to 80 ft)
- o Dow chemical monobuoy facility, near Port O'Connor
- o Coscol Marine Corporation, monobuoy facility 35 km (22 mi) offshore Padre Island
- o Port of Brownsville, channel deepening to 12 to 13 m (40 to 42 ft)
- o Houston Ship Channel, channel deepening to 14 to 15 m (45 to 50 ft).

Oil refineries and gas processing plants. The historical growth of the refining and processing industries in Texas was inspired by the heavy concentration of producing fields in the immediate area. However, these plants are increasingly supplied from imports entering the petroleum terminals at Texas ports. Important market advantages, such as proximity to major ports, availability of pipeline systems, steady supply of crude oil and natural gas, and all manner of essential resources (water supply, access to water transport, labor, favorable economic climate) serve to reinforce the unusual concentration of refineries and gas processing plants along the Texas coast.

As of 1978, there were 28 major oil refineries in the TBIE study area (Texas Railroad Commission 1979a), amounting to a maximum daily refining capacity of more than 2.8 million bbl. Three-fourths of this refining capacity was located in the Houston-Baytown-Galveston area. The regional significance of this capacity is indicated by the fact that refineries in the TBIE area account for 68% of the entire State capacity and approximately 20% of the United States capacity.

As of 1973, two-thirds of the crude oil refined in Texas was also produced in Texas, which has allowed for the capture of a large share of the indirect and induced benefits of oil production. In addition, some of the oil refined in Texas (15% in 1973) is produced elsewhere in the United States, giving the State an additional benefit relative to other producing states (U.S. Department of the Interior, Bureau of Mines 1975).

Gas processing plants are the "refineries" of natural gas. They are principally responsible for separating natural gas liquids and various impurities from methane gas. There were 86 gas processing plants in the TBIE area in 1977 (Directory of Texas Manufacturers 1977). Most are located in the vicinity of producing gas fields.

Petrochemical plants. The massive petrochemical complex along the Texas coast is the most vivid example of interindustry relationships with oil and gas production. Most of the feedstocks for the petrochemical industry are obtained from nearby refineries. Texas has continually produced 55% to 60% of the entire domestic supply of feedstocks, so it is not surprising that an overwhelming majority of corporate leaders would rank "nearness to raw materials" as their primary reason for building a plant in Texas (Whitehorn 1973).

In the early 1970's, there were 82 firms operating 130 petrochemical plants in Texas, representing 40% of all basic petrochemical capacity in the United States. Approximately 88% of the State's capacity was located in the coastal counties. The value of petrochemical shipments in 1970 was $4.4 billion, and the combination of direct, indirect, and induced impacts amounted to $10.5 billion (in 1970 dollars) (Whitehorn 1973).

In spite of the tremendous dependence of the Texas petrochemical industry on in-state production and refining, the refining and gas processing operations in Texas are not nearly so closely related to petrochemical manufacturing. Only about 5% of the national refinery output is used as feedstocks for petrochemical plants, while the other 95% is required for energy production.

Interregional relationships. The economic interdependence of the various regions of the Nation is exemplified by the flow of oil, gas, and petroleum products. Using data collected by multi-state regions called Petroleum Administration for Defense (PAD) districts, the Department of the Interior has documented shipments of petroleum from Gulf and south-central states (PAD III) to the Atlantic coast (PAD I), the Midwest (PAD II), and other regions (U.S. Department of the Interior, Bureau of Mines 1975). All shipments by pipeline from PAD III in 1973 amounted to approximately 800 million bbl. About 75% of these pipeline shipments went to PAD I, and about 22% went to PAD II.

Similar magnitudes of interdistrict movement are evident in tanker and barge shipments of crude oil and petroleum products. Of the 567 million bbl shipped by water from PAD III to other regions, about 85% went to PAD I ports and 14% went to PAD II ports. The overwhelming majority of shipments were gasoline, jet fuel, or distillate fuel oil (U.S. Department of the Interior, Bureau of Mines 1975).

Short-term Expectations for Oil- and Gas-related Industries

Most of the experts who monitor oil and gas operations are predicting that the early 1980's will witness very strong, if not record-breaking, levels of exploration and development activity in Texas. In particular, the 1980 drilling forecasts of the Oil and Gas Journal anticipate increased activity throughout the Texas coastal area, including a 60% increase in offshore drilling (Beck 1980).

Increased exploration and development of the accelerated offshore lease sales should lead to moderate increases in the activity of related service and support industries. Gulf coast drilling and platform fabrication yards may experience record numbers of orders and installations in 1980 and 1981. Fabricators have predicted between 60 and 120 new orders each year (Sumpter 1980). Scenarios of continued offshore oil development in Texas were used by the TGLO to assess future requirements for drilling rigs and many other support services; the magnitudes portrayed in the "high impact" scenarios have already been exceeded with the current flurry of drilling activity (Research and Planning Consultants, Inc. 1977).

The mix of logistical support and service industries in the TBIE study area is so well developed that nearly all anticipated increases in exploration and development activity for the next few years can be handled by existing firms. Any foreseeable growth would likely be expansions of existing facilities.

The increasing shortages of skilled and semi-skilled labor create a potentially stifling problem for future drilling activity. Drilling rig supervisory personnel, geologists, and service employees are in short supply (Sumpter 1980). The mariners and crews that cater to offshore petroleum exploration may also be in short supply throughout the 1980's (U.S. Department of Commerce, Maritime Administration 1979).

The petroleum refineries, gas processing plants, tank farms, and petrochemical industries in Texas should remain busy in the coming years, but the years of growth are probably over. Imported oil and new discoveries resulting from accelerated exploration will only serve as a stopgap for the continual decline in production from existing fields. Moreover, the expected yield of petroleum for each new increment in depth to which exploratory wells are drilled in Texas has declined substantially over the past several decades. The prospects of discovering major new fields only grow dimmer.

Episodic growth in petroleum transportation facilities can be expected in the next decade. A few major pipeline gathering systems may be installed offshore and in shoreland areas as more offshore fields are brought into production. And perhaps a few of the channel deepening projects and offshore terminal projects will be started in the next decade.

In summary, the near-term prospects for oil and gas industries in the TBIE study area might include stepped up exploration and development and continued stability, but no expansion in the allied refining, processing, and petrochemical industries.

ENVIRONMENTAL CONCERNS

Literally every oil- and gas-related activity has the potential to cause adverse environmental impacts. Some, such as gas production from a properly functioning offshore platform, have extremely mild adverse impacts and even some beneficial effects. Other activities, such as the collision or rupture of a large tanker, are unmatched in their potential for injury to coastal environments. In the following section, those concerns that are unique to oil and gas operations are discussed. They include: operational hazards of drilling, production, and transportation; brine discharges; marine oil pollution; and actual versus perceived locational conflicts between oil and gas operations and other unrelated activities. Impacts that are not particular to oil and gas production (dredging, filling, air pollution) are addressed in other sections of this volume.

Drilling, Production, and Transportation

Operations performed during oil and gas drilling, production, and transport have certain predictable adverse impacts and carry a certain risk of major damage. Offshore activities are particularly hazardous because of periodic adverse weather conditions and the harsh saltwater environment. The disruption of the ocean bottom environment as a platform is installed, or the accumulation of drill cuttings adjacent to the well, usually involves only nominal, temporary disturbances. However, the improper handling of drilling equipment or monitoring of downhole conditions can result in a major blowout and spill. The prevalence of multi-well drilling and production platforms carries the added risk of platform fires or explosions in one well spreading to adjacent wells. In spite of careful precautions against the obstruction of shipping lanes, several accidental collisions with platforms have occurred in the Gulf. Hurricane winds and storm waves also pose a certain hazard to offshore drilling, but clearly the majority of impacts and hazards are attributable to human error during the drilling operation.

Improvements in the design, installation, and operation of blowout prevention equipment are needed. Drilling in deeper waters requires the use of faster, more automated shutoff systems because the standard hydraulic designs are too slow in responding to sudden changes in downhole conditions. More rigorous training and simulation of emergencies will be required of offshore technicians to reduce the risks of accelerated offshore activity. The USGS requires this training, and there are many schools along the Texas coast that have been developing improved programs to meet new Federal requirements (Walther 1978b). In the future, increased installation of subsea production systems that do not require the installation of fixed platforms may mitigate some of the hazards associated with adverse offshore conditions.

Production operations are generally much less risky than drilling. Fixed platforms and fully completed wells require only moderate amounts of supervision and maintenance. The major environmental risks are accidental equipment failures, fires or explosions on multiple-well platforms, and vessel collisions. Low-level, chronic impacts are sometimes caused by oily brines that are continually separated and discharged during production. These occurrences can be particularly damaging in shallow brackish or freshwater environments.

Transportation is perhaps the most hazardous activity in the context of adverse weather and offshore conditions. Bulk carriers account for a large proportion of major petroleum spills, usually as a result of hull ruptures, leaks, or vessel collisions. Intentional bilge and ballast discharges, transfers during offshore lightering, and terminal loading and unloading provide many opportunities for small incidental spills.

Pipeline systems offer many obvious advantages as a means of transport. Virtually all production in State and Federal waters off the Texas coast is shipped to land stations via pipelines. Installation of pipelines may cause only temporary impacts although wetlands and landfall sites can be severely degraded by channelization or transport of heavy equipment. Federal regulations require burial of pipelines in waters less than 61 m (200 ft) deep and in shipping lanes to avoid breaks from anchor dragging. Ruptures and leaks are still a potentially calamitous problem, however. Internal pipe corrosion, settling, faulty installation, or a combination of these events has occurred in the Gulf on numerous occasions.

Rigorous automated monitoring of pipeline pressures and flow rates (at both sending and receiving ends), surface and airborne surveillance of external leaks, and installation of timely shutoff systems must be carried out on a frequent schedule. The current state of the art in pipeline leak detection and repair includes subsurface patrolling and detection, complete shut-off of flow in limited portions of the line, and rapid repair while petroleum remains in adjacent sections of the pipeline.

The oil industry must continue its efforts to advance technological capabilities, such as directional drilling, and to implement exploration and development techniques that minimize environmental disturbance.

Brine Discharges

Most of the wells that produce oil and gas in the Texas coastal area also produce a certain amount of brine. The brine is separated from oil and gas and is usually discharged at the site. Some brines are reinjected into the ground. The salt concentration in brine varies considerably, but it is often at least as high as in seawater (35,000 ppm). Some oily residues usually remain in the brines as a result of incomplete separation. Further, there is the potential hazard that some brines contain heavy metals that may enter the food chain and become concentrated in species that are used for human food. The Texas Railroad Commission is the principal permitting and regulatory agency for brine disposal in Texas. The volume, quality, method of disposal, and location of disposal are all regulated in the State program.

Potential adverse impacts. Environmental impacts of brine discharges will vary considerably with the volume and chemical composition of the liquid and the environment on or into which it is discharged. The most severe impacts would likely result from discharge of hypersaline solutions into freshwater aquifers, fragile freshwater wetlands or upland environments (Research and Planning Consultants, Inc. 1979), or contamination of bay sediments with toxic hydrocarbon residues associated with the brine (Armstrong et al. 1979). Loss of vegetation, long-term soil alterations, and mortality of benthic organisms in open water bodies are the major associated impacts of excessive discharges.

Gustavson et al. (1977) evaluated some long-term effects of oilfield brine discharges. The investigators identified exposed areas in east Texas that were barren 30 to 80 years after discharges had been discontinued. Research and Planning Consultants, Inc. (1979) investigated several studies and available data to assess the potential impacts of geothermal well discharges along the Texas coast. They noted potential, but inestimatable, adverse effects resulting from geothermal well blowouts, contamination of shallow freshwater aquifers, and interference with other petroleum reservoirs at different depths. They also concluded that many of the potential impacts could endure for decades, especially in upland areas.

Armstrong et al. (1979) monitored oilfield brine discharges emanating from an oil separator platform in the shallow, brackish water environment of Trinity Bay. Napthalenes and other highly toxic fractions of the oil were found in sediments at concentrations that were several orders of magnitude greater than in overlaying waters. Sampling stations several hundreds of meters away from the platform had much higher than normal accumulations. Severely depressed benthic populations were observed as far away as 150 m (490 ft).

Recent, current, and future discharges. Use of injection and disposal wells is the most prevalent means of discharging brine along the Texas coast. As of 1979, there were more than 634 licensed injection wells and 1,527 licensed disposal wells in the TBIE study area (Texas Railroad Commission 1979b). Although they are widely distributed in association with producing field operations, Brazoria, Chambers, Harris, Victoria, and Refugio Counties have the largest share. Actual discharge volumes are not known, but historical experience in the East Texas Field Salt Water Disposal facility (the largest operation in the State) may give an indication of potential magnitudes. The average injection rate (into injection wells) in the East Texas Field facility has been approximately 6,000 bbl/day (Dorfman and Kehle 1974). If this rate were applied to the entire TBIE study area, potential discharge into injection wells alone would amount to 3.8 million bbl/day.

Discharges into bays and estuaries are another widespread means of disposal. As of 1979, there were 121 tidal discharge permits (Office visit 10 December 1979 to George Singletary, Texas Railroad Commission, Oil and Gas Division, Austin, Texas). The total permitted discharge was 766,000 bbl/day (Texas Railroad Commission 1979c). Salinity concentrations in these effluents usually ranged between 8,000 and 40,000 ppm.

Offshore discharges from production platforms are usually not a problem because of comparable salinities found in seawater and the dilution capacity of the Gulf. However, a highly controversial and as yet unstudied offshore discharge involves the leaching and disposal of salt from salt domes as part of the Department of Energy's SPR program. After a hotly contested review of proposals to create massive oil storage caverns out of the salt at Bryan Mound near Freeport, Texas, the Army Corps of Engineers and Department of Energy created four caverns. The concentrated brines were discharged in 23 to 24 m (75 to 80 ft) of water via pipeline some 20 km (12 mi) offshore. Local shrimpers, fishermen, and environmentalists persuaded the agencies to extend the pipeline farther and begin conducting research on the effects of such concentrated discharges. A series of instruments to measure salinity, temperature, and currents are being installed on a buoy at the discharge site and will be monitored by the Naval Ocean Research and Development Authority. Additional brine disposal will commence in the spring of 1980 as 12 additional caverns are completed. The permitted discharge through the pipeline will be 680,000 bbl/day (Whitley 1980).

The most significant potential discharge of brine in the TBIE study area is that generated from production in geopressured-geothermal wells. It is presumed that much of the saline water produced from the wells would be safely reinjected into the ground or converted into useable water. High levels of boron have been found in brines south of Corpus Christi and in Louisiana, however. Further, the sheer volume of water would be staggering. Dorfman and Kehle (1974) estimated that the well water required to operate just ten 100-megawatt plants (about 3 million bbl/day) would be equivalent to the total daily production of oil in Texas. Moreover, the risk of a blowout (potentially as high as 1 blowout for every 15 wells drilled) is much greater in drilling into geopressured strata. A typical blowout well might discharge 40,000 bbl/day of 149°C (300°F), highly saline water at a wellhead pressure of 5,900 kg/cm² (2,000 lb/in²) (Research and Planning Consultants, Inc. 1979). Thus, the seemingly pollution-free production of geothermal energy could have unprecedented impacts on surrounding environments.

Alternative disposal practices. Four principal alternatives for oilfield brine disposal along the Texas coast are as follows:

- reinjection into formations that contain similar water
- discharge into tidal or offshore waters
- discharge into artificial basins for evaporation or infiltration
- processing to make freshwater with discharge of residuals either in a solid waste disposal site or in one of the above sites.

Specific modifications of these methods will enhance their effectiveness and reduce their environmental impact. For example, reinjection wells may be drilled and cased in a manner that would repressurize the producing zone and enhance the petroleum recovery. Nearby water wells could be closely monitored to ensure that faulty well casings or inadvertent lateral displacement of brines do not contaminate overlying freshwater aquifers. These operations will be monitored and regulated as part of the Federal Underground Injection Control Program (U.S. Environmental Protection Agency 1979).

The impacts of discharges into open waters could be mitigated in a variety of ways. Pipelines extending into deeper, less productive offshore zones or barge transport to such zones would avoid disturbing the nearshore environment. If outfall facilities are located in enclosed bays and estuaries, they should be carefully sited in areas where maximum water circulation and diffusion are likely to occur. Alternative practices that are environmentally sound usually require larger capital outlays.

Regardless of the means of disposal, oil and gas field operators should take every precaution to ensure that excessive hydrocarbons are not discharged with brines. Separator technologies should be carefully operated, maintained, and monitored by skilled technicians.

Land Surface Subsidence

The deep sandy and shaley sediments along the Texas coast are highly susceptible to compactional subsidence and surface faulting. Although these are natural processes, excessive withdrawals of water and petroleum liquids have accelerated the rate in many areas. As fluid is extracted from porous reservoirs of sand and sandstone, sandwiching layers of shale tend to expel water into the reservoir to adjust for the loss in reservoir pore pressure. The "dewatered" shales are thus compacted in an essentially irreversible manner (Kreitler and Gustavson 1978). Fault activation and expression at the surface can result in damage to buildings, pipelines, roads, and other structures.

The primary human-induced cause of compactional subsidence and faulting along the Texas coast is groundwater withdrawal. Subsidence related to hydrocarbon production is usually confined to the producing field. However, there are so many fields in certain areas that regional subsidence (on the order of a few square kilometers) can be a problem (telephone call 30 November 1979, from Dr. Charles Krietler, Bureau of Economic Geology, University of Texas at Austin).

The prediction and simulation of subsidence as a result of fluid withdrawal is still a very inexact science (Research Planning Consultants, Inc. 1979). In areas where groundwater as well as hydrocarbons have been withdrawn, it would be extremely difficult to predict or distinguish the effects attributable to hydrocarbon production.

Oil Spills

Exploratory drilling, production, and transport of oil pose a limited, but very real and chronic risk that a blowout or major spill will occur. In addition, small but continuous amounts of oil are released into nearby environments as a result of routine handling and processing operations. Both major and incidental spills can cause harm and disruption of marine life, and create economic dislocations for other marine-related activities. The following section includes a brief characterization of the potential risks to marine life and coastal resource use, and documents the incidence of oil spills in the Texas coastal region.

Hazards for marine life and coastal resource use. Marine organisms and birds can be affected by oil in several ways. Highly toxic petroleum fractions, such as the low boiling point aromatic compounds, can be lethal at relatively low concentrations (as low as 0.1 ppm), especially for larval and juvenile species. Sublethal effects may include disruption of behavioral activities, such as feeding, mating, and sensing abilities of fish species. Direct coating of oil can destroy the waterproofing and insulating properties of fur and feathers, and oil can be ingested by animals as they try to clean themselves (Moore and Dwyer 1974). The habitats of marine life, especially of burrowing organisms that depend on characteristic substrates, can be severely disrupted for long periods. Eventually, the impacts on marine life can be felt by humans if hydrocarbons are incorporated and concentrated in the food chain, tainting edible organisms or causing health hazards that are not yet understood (Figure 6).

Water supplies and vegetation can be affected by spills on land. Blowouts, pipeline breaks, equipment failures, and other accidents can release oil and brine into surface waters. Faulty well casings may allow oil or other hydrocarbons to enter and contaminate shallow freshwater aquifers. Even contamination of well water by natural gas is possible; one case was reported in a shallow water well in Jackson County following two gas well blowouts (Ginn 1979).

There are two major unresolved issues related to the effects of oil spills on marine life and resource use. One issue that might be resolvable with more research is the question of relative importance of major spills versus chronic, low-level releases of hydrocarbons in the marine environment. The data on spillage volumes clearly indicate that most of the oil spilled each year is caused by a relatively few catastrophic accidents. Studies have been conducted that indicate that major spills can have subtle adverse effects for protracted periods of time (Blumer 1971, Farrington 1978).

On the other hand, some investigators have concluded that low-level chronic oil pollution is ecologically more serious than catastrophic pollution events. Arm

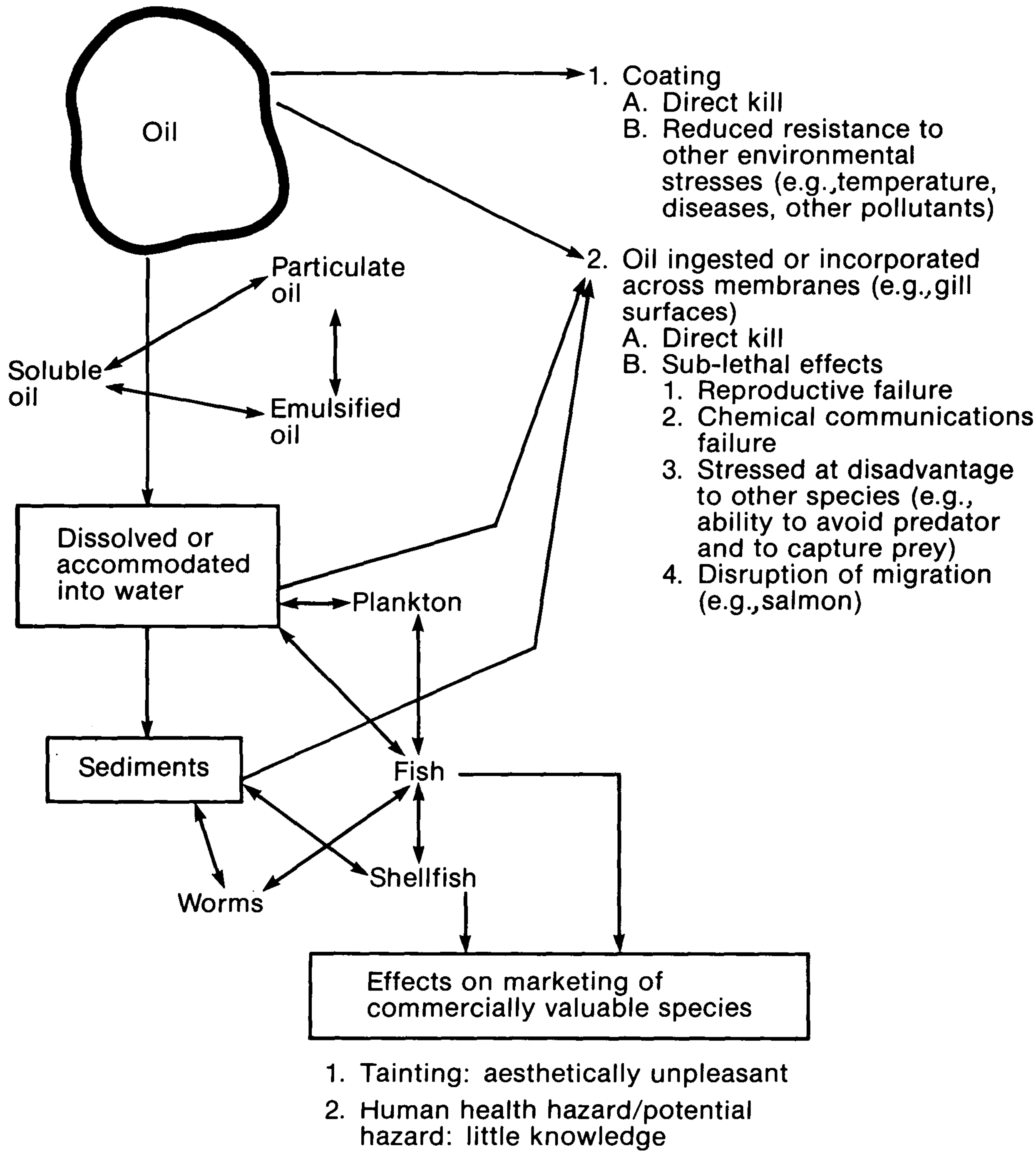


Figure 6. Pathways of oil incorporation into marine ecosystems (Banta 1978).

strong et al. (1979) cite their own research and 10 other investigations performed in the past 9 years that show that continuous introductions of low levels of oil result in long-term effects, such as hydrocarbon accumulations in sediments that kill benthic organisms and disrupt higher levels in the food chain. Given the facts that neither major nor minor spills have been reduced markedly in recent years, and that regulatory agencies are not adequately staffed, equipped, or funded to control the causes of both major and minor spills simultaneously, more specific priorities may be required for oil spill prevention containment.

A second issue not easily resolved is the distinction between actual and perceived impacts of oil pollution. Marine and coastal recreation economies are unquestionably affected by both types of impacts, as illustrated in the claims following the Burmah Agate and Ixtoc I[2] spills of 1979 and 1980. Liability for perceived adverse effects has not yet been addressed to any extent in the courts, but the results may be very significant. Moreover, passage and implementation of the proposed Oil Spill Liability Superfund or a comparable State fund will require much more concise treatment of this ambiguous problem.

Extent of marine oil pollution. Oil pollution incidents are commonly the result of: ruptures and leaks in tankers, barge hulls, storage tanks, and pipelines; valve, pump and other equipment failures; improper handling and other personnel errors on all vessels and onland facilities; bilge and ballast pumping and other intentional discharges on marine vessels; water runoff, slush pit and levee overflows; natural phenomena; and unknown causes (U.S. Department of Transportation, Coast Guard 1973, 1974, 1975, 1977a, 1977b, 1978).

Blowouts are caused by improper handling or, less commonly, by valve and other equipment failures. Kash and White (1973) have investigated the causes and significance of well blowouts, platform fires, explosions, and other accidents. They calculated a ratio of one blowout for every 2,575 wells drilled on land and one per 500 on the continental shelf. Pipeline ruptures and leaks are also very probable causes of spills. In 1976 and 1977, 960 pipeline breaks accounted for 155,000 bbl of spilled oil and other substances in coastal areas of the United States (U.S. Department of Transportation, Coast Guard 1977b, 1978). In 1977 and 1978, 11 large spills (greater than 50 bbl) in the TBIE area were reported as attributable to pipeline ruptures or leaks (Texas Department of Water Resources 1979).

Historically, petroleum tankers have accounted for most of the marine oil discharges in United States waters. Tank cleaning, terminal loading and offloading, and incidental discharges have accounted for 82% of this discharge, while casualties represented only 18% (U.S. Department of the Interior, Fish and Wildlife Service 1978). Most routine tanker discharges occur far from shore and do not pose significant hazards for coastal resources.

Inland and nearshore spills have become a major problem in the Gulf of Mexico. In 1976 and 1977, 252,000 bbl of oil and other substances were reported as

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[2]The recent Ixtoc I blowout and oil spill was perhaps predictable from the very beginning. Petroleos Mexicanos (Pemex) always names wells in the Campeche area after Mayan gods. In this case, "Ix" is a prefix which can be translated into "the damned," and "Toc" is either the god of fire or the god of explosions. Together they mean "the damned fire" or "the damned exploder" (Stewart-Gordon 1979).

spill incidents in the Gulf. More than 84% of this volume was spilled in rivers and channels, ports and harbors, or on beaches and non-navigable waters (U.S. Department of Transportation, Coast Guard 1977b, 1978). Vessel unloading accidents, heavy rainfall runoff, and overflow of slush pits are some of the more common causes of coastal spills in the TBIE area (Texas Department of Water Resources 1979). The improper pumping (emptying) of slush pits allows oil to overflow and enter streams and estuaries when it rains. Also, waterfowl land in the pits, particularly in areas that have limited surface waters.

Between 1972 and 1979, more than 2 million bbl of oil and other substances were reported spilled within the United States jurisdictional limits of the Gulf of Mexico (Table 15). The number of spills reported each year has been surprisingly consistent, ranging from 4,131 in 1975 to 4,623 in 1978.

In the TBIE study area, 3,695 spills reported between January 1977 and December 1979 accounted for 671,000 bbl of spilled oil and other substances. The Burmah Agate collision off Galveston Island was responsible for approximately 610,000 bbl of spilled oil. The Houston Ship Channel-Galveston Bay area is usually the most prolific in terms of spills in the TBIE study area. This area has encountered an average rate of 28 spills, or 880 bbl each month for the past three years (Table 15).

Table 15. Oil-hydrocarbon polluting incidents in TBIE, Gulf of Mexico, and United States waters, 1972 through 1979 (U.S. Department of Transportation, Coast Guard 1973, 1974, 1975, 1977a, 1977b, 1978, 1979, 1980).

Year/location of spill	Number of incidents	% of U.S. total	Volume of spill (gal)	% of U.S. total
1972				
Gulf coast	4,375	44.0	3,385,828	18.0
United States	9,931	100.0	18,805,732	100.0
1973				
Gulf coast	4,422	33.2	3,789,136	15.6
United States	13,328	100.0	24,314,918	100.0
1974				
Gulf coast	4,470	32.0	3,864,219	23.0
United States	13,996	100.0	16,916,308	100.0
1975				
Gulf coast	4,131	34.3	5,545,714	37.1
United States	12,057	100.0	14,967,895	100.0
1976				
Gulf coast	4,482	35.4	7,639,623	22.6
United States	12,655	100.0	33,851,830	100.0

(continued)

Table 15 (concluded).

Year/location of spill	Number of incidents	% of U.S. total	Volume of spill (gal)	% of U.S. total
1977[a]				
Houston	251	2.0	82,229	0.4
Galveston	394	3.1	137,476	0.7
Corpus Christi	474	3.7	299,680	1.5
TBIE study area	1,119	8.7	519,385	2.6
Gulf coast	4,347	33.8	19,952,140	9.8
United States	12,844	100.0	19,899,988	100.0
1978				
Houston	389		273,294	
Galveston	388		97,298	
Corpus Christi	582		50,470	
TBIE study area	1,359		421,062	
Gulf coast	4,623		28,814,937	
United States		100.0		100.0
1979				
Houston	366		960,058	
Galveston	240		26,136,949	
Corpus Christi	611		171,402	
TBIE study area	1,217		27,268,409	
Gulf coast	4,367		31,223,047	
United States		100.0		100.0

[a]Breakdown of data by major port did not begin until after 1976.

In June 1979, an extensive oil spill occurred in the southern Gulf of Mexico off the Mexican coast. The Pemex well, Ixtoc I, blew out and the drilling rig subsequently caught fire and collapsed, destroying the wellhead and the rig and all hopes for recapping the original well. An estimated 30,000 bbl of oil flowed daily for the first seven weeks, soon becoming the largest oil spill in history. (The previous record spill was the 1978 Amoco Cadiz disaster off the coast of France, which spilled 1.3 million bbl of crude oil.) By mid-December, Pemex indicated that it had reduced the flow to 2,000 bbl/day, using a variety of novel but only moderately successful techniques. Two directional relief wells were drilled to intercept the flow, and the blowout was finally brought under control in March 1980, after nine months and more than three million bbl of spilled oil.

Major containment and cleanup efforts were taken as the oil from Ixtoc I arrived at Texas beaches. As of September 1979, approximately 9,560 m^3 (12,500 yd^3) of oiled sand were removed from the beaches, and 11,200 kg (24,700 lb) of oil and debris were removed from the water along the south Texas coast. Cleanup crews numbered as many as 250 at the height of the pollution (Oil cleanup team... 1979). Much of the oil was deposited in the subtidal zone, mixing with sand and organic matter to form beds of asphaltic material or "tar mats." Removal of these deposits may be impossible, even though pieces are expected to continue to break off and wash ashore for some time. Class action suits filed on behalf of Texas spill victims against the Mexican oil agencies and Sedco, Inc. have claimed more than $350 million in damages (Oil spill intelligence report 1980).

Oil spill response and contingency plans. To implement the Federal Water Pollution Control Act Amendments of 1972 (FWPCA), the President's Council on Environmental Quality (CEQ) developed the National Oil and Hazardous Substances Pollution Contingency Plan, which directed various agencies to adopt pollution control programs. Section 311 of the FWPCA requires that discharges of oil or other hazardous substances be reported to the appropriate Federal agency. Executive Order 11735 designated the U. S. Coast Guard (USCG) as the lead agency for spill reporting, spill containment, and contingency planning for discharges in or adjacent to navigable waters. Implementing regulations are found in the Code of Federal Regulations (CFR), Title 33, Sections 150, 154, 155 and 156, and Title 40, Section 1510. The Pollution Incident Reporting System, administered by the USCG, is used to catalogue 41 variables on every reported incident, including discharge characteristics, clean-up responses, and penalty actions.

The USCG requires that parties responsible for spills take all necessary actions to clean up the spill to the agency's satisfaction. If the party fails to respond, the USCG initiates a clean-up program (often contracting with nearby firms) and pays for the work with Federal Pollution Fund monies (telephone call 8 March 1980 from Lieutenant Ann Bennett, USCG, Galveston, Texas). The party is then charged for the costs incurred. The USCG also requires that many companies install containment devices of varying degrees of sophistication. Some petroleum-related companies have continuing contracts with local pollution clean-up firms to handle routine or small incidental spills.

Responsibility for routine spill containment and contingency planning in the TBIE study area is delegated to the USCG Port Captain of each major port. For example, the Captain of the Port of Galveston is responsible for patrolling, reporting, and ensuring clean-up of spills between High Island and upper Matagorda Bay and in Trinity Bay and lower Galveston Bay. Moderate amounts of equipment (boats, sorbants, and small booms) are available at individual ports. The seaward jurisdiction of USCG operations is 12 mi (22.3 km) for penalty assessment and 3 mi (5.6 km) for clean-up operations.

Major spills are handled by the USCG Gulf Coast Strike Team, which is headquartered at NSTL Station, Mississippi. In addition, an interagency Regional Response Team is convened in the event of a major spill to coordinate State, local, and volunteer assistance.

Many criticisms of the USCG oil spill program have been aired in the past year. Fire-fighting equipment, tug boats, and seaworthy containment booms were needed but not available in adequate supply during the Burmah Agate incident in the Houston Ship Channel. Individuals affected by recent oil spills realized that the only viable sources of financial recovery assistance were low-interest Small Business Administration loans. Members of the Texas Senate have proposed a State liability fund for certain waste discharges, and a more direct role for the Texas Department of Highways and Public Transportation in transporting equipment rapidly to spill sites. At this time, the State has no oil spill contingency planning authority independent of the Regional Response Team. Certainly, every critic or proponent of USCG operations must have some sympathy for the past years' challenges.

Oil spill containment techniques. Technology for the containment and cleanup of oil spills has developed at a rapid rate in the past decade. Many problems and constraints on effective containment are not yet resolved, however, and pose a challenge for improvement on the part of developers and operators of this technology. A variety of response and containment methods are presently employed, depending on the spill location, magnitude, type, age, and the availability of equipment and skilled operators. At least four types of technology are used in the Gulf of Mexico: dispersants, sorbants, skimmers, and open beach methods. Floating booms are generally used in conjunction with these technologies to contain the oil or deflect its path to more quiescent waters where skimmers and sorbants are effective.

Chemical oil dispersants are used routinely throughout the world, but are rigidly controlled and usually discouraged in the United States. Only a few of the products that are available have been officially tested and approved for use by the Environmental Protection Agency. The conventional type consists of a surfactant, hydrocarbon solvent, and a chemical stabilizer. Newer products have less aromatic hydrocarbons in the solvent and the surfactant is more biodegradable than older types. The advantages and disadvantages of dispersants were recently summarized at a conference sponsored by the FWS:

> Dispersants remove oil from the water surface, prevent the formation of water-in-oil emulsions, reduce the ability of oil to adhere to objects, and permit accelerated deterioration of the oil. However, chemically dispersed oil also has a greater short-term toxicity and a greater ability to penetrate sand and gravel beaches than does nondispersed oil. In addition, chemical dispersants seldom work as well as expected and, from a biologist's viewpoint, they are an undesirable method of oil spill control. Decisions on the use of dispersants should be made carefully on a case by case basis (Albers 1979).

Sorbants operate by a process of physical adsorbtion of oil onto a reusable sorbent medium; the oil is subsequently separated and collected for disposal. A commonly used type, produced by Oil Mop, Inc., utilitizes a polypropylene rope or mop-like structure that is mechanically pulled across a spill, usually in front of a containment boom. The sorbant eventually becomes saturated with oil and is passed through a wringer and reused (telephone call 30 May 1980, from David Barker, Spill Response Coordinator, Texas Dept. of Water Resources, Austin, TX).

Skimmer devices operate by separating and collecting the surface layer of oil or emulsion from a water body with the use of weir gates or vacuum pumps. Fully self-contained skimmers include a storage barge and booms in addition to the separation and collection devices. The most successful skimmer-boom combination for open water containment is the Open Water Oil Containment and Recovery System (OWOCRS), which was specifically designed for the USCG. It includes a special V-shaped boom and a control gate-weir system to regulate the depth of oil and water that is skimmed off and removed. A skimmer barge (Marco Class 5) used by the U.S. Navy has a catamaran hull and a flat belt that is mechanically pulled across the underside of the hull. The belt is continuously cleaned of accumulated oil. This type of barge was used extensively at tidal inlets along the south Texas coast during the Ixtoc I oil spill response. Other skimmers (eg., Slurp) are lightweight and can be connected to onshore vacuum pumps for oil removal and disposal (telephone call 30 May 1980, from David Barker, Spill Response Coordinator, Texas Dept. of Water Resources, Austin, TX).

Open beach methods are used when large amounts of oil are washed onshore. Hay straw or other disposable sorbent materials are sometimes placed at the high tide line and later collected. Front-end loaders, beach combing equipment, and other heavy equipment are used occasionally to remove large amounts of tar or emulsified oil on the dry beach. Trenches and pits are sometimes dug with a back hoe to funnel the oil into the depression with the force of the tides. Vacuum pumps and tanker trucks are then used to pump the pits.

The effectiveness of current techniques for oil spill containment is limited by several factors. High winds and heavy seas are the principal problems on open waters. No containment or collection device can hold or retrieve oil in greater than two knots of current. Availability of equipment and skilled personnel is a problem in isolated areas or in the event of a major spill or multiple simultaneous spills. Current technology is not adequate for spills that catch fire, especially offshore. The Burmah Agate collision posed dangerous challenges to the spill response crews as continuous fires and episodic explosions occurred on the ship. Finally, the environmental harm caused by oil spilled far offshore has not been thoroughly investigated. Dispersants, which are not favored in nearshore areas, may be the best spill response technique for such areas.

Locational Conflicts With Other Marine Activities

Drilling, production, and service functions in the oil and gas industry require land, water, and other resources that conflict and compete with other coastal uses. Certain petroleum-related uses also complement the particular needs of other coastal activities. These relationships can be characterized according to economic, aesthetic, and ecological functions, but cannot be readily quantified or completely resolved. The following list includes a selection of these actual and perceived conflicts of coastal resource use:

Onshore facilities (pipelines, refineries, service bases)	Wetland uses (hunting, birding, research), shorefront uses (recreational, residential)
Offshore pipelines	Shipping, commercial fishing
Production platforms	Shipping, commercial fishing, beach recreation
Spills and other discharges	Commercial fishing, water supply, beach recreation, coastal tourism, wetland uses, endangered species

Onshore petroleum facilities can be particularly injurious when sited in wetland or estuarine locations. Channelization for drainage and pipeline installation and land filling for foundation support have displaced many wetland and bayshore environments. As of 1975, there were 1,760 km (1,095 mi) of navigation channels and 31,600 ha (78,000 ac) of filled areas in the Texas coastal area, a large part of which was created specifically to meet the needs of petroleum industry activities (Lindall and Saloman 1977).

Offshore pipelines have been known to rupture as a result of anchor dragging or fouling from commercial fishing gear. Even though Federal laws require burial of any line in shipping lanes or in waters less than 61 m (200 ft) deep, offshore pipelines still present a serious hazard for other coastal uses. On the other hand, there can be no question that pipelines are the safest and least obstructive means of petroleum transport.

Production platforms have been the cause of numerous vessel collisions and pose a serious, continual hazard for nearby shipping lanes. Before the vessels in the recent Burmah Agate collision came to rest, one of the ships circled a platform while out of control for an hour or more. Many beach recreationists feel that platforms that are readily visible from land are aesthetic blights on the seascape. On the other hand, there is overwhelming evidence that deep sea sport fishing, scuba diving, and possibly commercial finfishing opportunities are greatly enhanced by the presence of these artificial reefs. Almost immediately after being placed in the water, platform legs and templates become covered with algae and are eventually encased with mollusks, barnacles, and tunicates. Fish of all sizes and species are then attracted to the platforms in concentrations that would otherwise never occur (U.S. Department of the Interior, Fish and Wildlife Service 1978).

Spills and other discharges are unfortunate consequences of oil and gas production; they present acute conflicts with almost every other coastal use. Actual versus perceived impacts and damages to other uses are very difficult to distinguish. The recent experiences along the Texas coast are a testament to this problem. Resolution of liability and compensation claims will require a much clearer assessment of economic and aesthetic impacts of spills.

In summary, the potential environmental impacts of oil and gas production of the TBIE area are quite severe. The massive volumes of oil spilled in major and minor incidents along the Gulf coast are indicators of the hazards of accelerated exploration and production. Fortunately, most of the fields expected to be discovered on the Texas OCS will be gas-producing. Fishing, swimming, beachcombing, and other oil-sensitive activities have co-existed with oil production for many years and will undoubtedly continue. Increased use of safeguards, improved technology, and more conscientious handling by skilled technicians will be a requirement for a compatible mix of coastal uses in the future.

MANAGEMENT AND REGULATION

Federal and State agencies in Texas have adopted hundreds of specific regulations and management objectives directly relating to oil and gas activities. The underlying rationales for these complex, rapidly evolving rules are that 1) petroleum is a limited, precious resource requiring efficient allocation, and 2) the environmental and economic effects of petroleum production are important to the State and the entire Nation.

The Federal government maintains exclusive control over oil and gas operations on the Federal OCS and on Federally owned lands. However, Texas agencies are often consulted and given opportunity to comment on matters affecting State, local, and private resources. The State manages and regulates activities in the submerged lands seaward to the three-league line although its responsibility is shared with several Federal agencies and even some local governments that have annexed bay and Gulf waters. Oil and gas operations in upland areas are managed and regulated intensively by all levels of government (Texas Railroad Commission 1979d). The following list indicates the Federal and State agencies that have primary responsibilies for oil and gas management and regulation.

United States Government

Management

Department of Interior
- Bureau of Land Management
- Geological Survey

Department of Energy

Regulation

Environmental Protection Agency

Department of Interior
- Fish and Wildlife Service
- Bureau of Land Management

Department of Transportation
- Coast Guard

Army Corps of Engineers

Department of Commerce
- National Marine Fisheries Service

Department of Energy
- Federal Energy Regulatory Commission

Texas Government

Management

Railroad Commission

General Land Office
- School Land Board

Regulation

Department of Water Resources

Air Control Board

General Land Office

Department of Health

Parks and Wildlife Department

Railroad Commission

A governmental concern that crosscuts all specific management and regulatory issues is the overlapping responsibility of State and Federal governments. The Federal government has exercised an increasing amount of authority in areas that formerly were left for states to address. The Natural Gas Policy Act of 1978 and Section 404 of the FWPCA are recent examples. This issue is particularly sensitive in Texas because of the State's longstanding experience in oil and gas management and regulation.

Federal agencies have become increasingly involved in oil and gas activities in at least three ways. Minimum Federal standards are sometimes established for state adoption and implementation. This procedure has often been applied when a few states lagged behind national norms in adopting state laws. The Federal government has also enacted laws regulating the use of scarce resources that were considered to be of paramount national importance, especially when individual states' activities became competitive with one another. Finally, incentive measures have been provided to states to arouse their concern for a resource and to strengthen their capabilities to manage the resource effectively.

Improvements in oil and gas management and regulation at both State and Federal levels can be achieved by sharing data and information as well as by cooperating on mutually valuable research programs. Regulatory permitting programs could be streamlined and combined where overlapping state and Federal authorities exist. The agencies might strengthen their communication and cooperation by establishing ad hoc committees to review their respective plans and objectives. Adequate funding for administrative and regulatory programs and autonomy from political pressures are also required if state and Federal agencies are to monitor the industry and enforce rules dutifully.

LONG-TERM EXPECTATIONS AND POLICY ISSUES

Changes in governmental policies will generally affect either the rate or location of exploration and development. Certain shifts in price or environmental regulation, for example, could conceivably make the difference between rapid expansion and shut-down of a given activity. Depending on the mix of policies in effect, location of development might be concentrated in proven, producing areas or be extended into frontier areas.

International Petroleum Markets

Alterations in the price or quantity of foreign petroleum production may have both direct and indirect impacts on domestic production and refining. If an oil import quota or the President's targeted reduction in dependence on imports is to be achieved, then domestic wellhead prices and the level of domestic exploration will probably increase markedly. An embargo by a major foreign oil supplier would have a similar effect, but the timing would be different. The rapid price increases for OPEC oil are already affecting domestic exploration and dependence on imports.

Tax Policies and Price Controls

While petroleum demand and production have begun to decline, the potential for recordbreaking increases in exploration and new development is very real. Alternative allocation schemes under the Windfall Profits Tax could have subtle effects on the future level of investment in risky, capital-intensive exploration and development ventures. If Congress proceeds to pass most of these revenues on to disadvantaged energy consumers rather than return them for energy development, exploration in frontier areas, such as the deep waters of the Texas coast may become less active. However, if large revenues are used to encourage development of unconventional petroleum sources, such as enhanced oil recovery projects, then the outcome might be substantially different. Policy alternatives in regulating domestic oil and gas prices may have similar repercussions.

Environmental Quality Standards

The adoption of stricter or looser environmental standards and regulations will directly affect the location and rate of future development. For example, environmental conditions are used by the BLM as criteria for selecting offshore tracts and blocks before a lease sale. Exclusion of some blocks from a sale and inclusion of others are potentially a major determinant of marine environmental quality. Specific standards imposed on operations in a lease block are equally significant. A challenge to agencies that implement environmental policies affecting oil and gas development is to impose strong, enforceable control measures in a manner that does not suppress the industry's willingness to continue taking large economic risks.

Implementation and enforcement of air and water quality standards will continue to be the subject of considerable debate, especially as they relate to petroleum refining, energy facility siting, and energy production. For example, the production of "sweet" crude oil, which contains relatively low amounts of sulfur and other residuals, is declining, while "sour" Middle Eastern oils and newer domestic sources gradually dominate the inputs to United States refineries. The "sour" crudes require elaborate and very expensive scrubber technology for sulfur removal. Many small refineries may be forced to close if they are required to install the new air pollution control technology.

Energy Impact Planning and Assistance

Now that Texas offshore activity is approaching peak levels, some coastal communities are becoming aware of the need for local planning and assessment of growth-related impacts. The Coastal Energy Impact Program is a Federal revenue-sharing measure designed to offset the impacts of accelerated OCS development by providing local governments with loans, grants, and technical assistance.

Some critics of the Program in Texas feel that State revenues gained from accelerated Federal offshore development will represent only a fraction of the State's public costs required to service new residents (Grubb and McCray 1974). Others are of the opinion that Texas' three-league jurisdiction gives it a distinct advantage over less plentiful State lands to the east in terms of lease bonuses and royalty payments. Many local Texas governments are nevertheless learning about energy impacts and making tentative plans to accommodate new growth. As a result, Federal and State agencies must plan for and allow more local participation in coastal energy development decisions.

Alternative Energy Resources and Technologies

In the coming decades, we will experience more shifts to coal and unconventional energy sources as the volume of petroleum production steadily declines. A nationwide trend in improved energy conservation and efficiency is just becoming evident. But these shifts will not be rapid. Coal has increased 2% in its share of national energy consumption since 1972. Nuclear energy use will be increasing substantially in Texas, but nationally it accounts for a relatively small portion of energy supplies. The synthetic fuels industry appears to be favored by the energy industry, but it will take many years for it to account for a sizable share of the energy market. Unclear Federal energy policies, excessive water requirements, unattainable air pollution standards, and exceedingly high investments in unproved technology still stand in the way of economic feasibility for synthetic fuels. While these and other trends in the energy production mix are being established, crude oil continues to rise in relative importance; crude oil consumption represented a record 49% of national energy consumption in 1979.

Geopressured-geothermal Energy Production

Full-scale production of geopressured-geothermal energy is still many years away. The likelihood of production depends largely on the results of more feasibility testing and the interest of cautious energy companies. Although the technological requirements of drilling and production are achievable at the present time, the inordinately harsh downhole conditions will call for highly resistant materials and extreme caution in avoiding blowouts. Dorfman and Kehle (1974) estimated that the risk of blowouts in geopressured reservoirs could be considerably higher than in normally pressured strata. The anticipated high costs of full-scale production will also make potential users carefully scrutinize the economic feasibility of this source versus alternative sources.

Enhanced Oil Recovery

As the cost of oil exploration rises to much higher levels, companies will begin to look more earnestly at the oil remaining in producing reservoirs which is retrievable by "enhanced oil recovery" techniques. The outlook for these ventures is expensive and not very lucrative. On the average, an estimated 68% of the oil that has been sought is left in an underground reservoir after routine primary and secondary recovery. Estimates of the ultimate average limit of reservoir depletion indicate that only about 25 billion bbl nationwide might be recovered by enhanced recovery processes, at a price of $25/bbl (in 1977 dollars). Such a yield represents only 4 years of supply at the present rate of consumption (Masters 1977), but market conditions may improve to a point that this alternative looks increasingly attractive.

Drilling and Production on the Outer Continental Shelf

Exploration for oil and gas in frontier areas has moved almost exclusively offshore. The level of activity during the 1980's is expected to surpass all previous statistics. Many Federally imposed restraints are being relaxed, especially on lease sale activities in the Gulf of Mexico. Several more lease sales are planned for the next few years, and if recent experience is an indication, the industry will set more records in the depth of waters explored and the proportion of tracts offered to those leased, explored, and developed. Fortunately for Texas, most of the necessary infrastructure is already in place and can readily accept new contracts upon demand. The debates and procedural delays that postponed lease sales in the middle and north Atlantic areas are not likely to occur at Gulf of Mexico sales (except, perhaps, when exploration is attempted in coral reef buffer areas), because the people of Texas and Louisiana have now lived with offshore oil activity for three decades.

If giant fields are not found in deep waters within a few years, the industry may refrain from further frontier exploration. The dismal experience of exploration activities in south Texas waters in the late 1950's is still a vivid memory for many companies. Staggering long-range capital investments are required to develop the giant deepwater reservoirs, if they materialize at all. Of 281 wells drilled in waters deeper than 185 m (600 ft) during the past 15 years, only

2 have undergone development. Shell Oil's Cognac platform in the Gulf of Mexico cost $300 million. Exxon's recently announced plans to install a guyed tower platform carries an initial price tag of $500 million. If and when petroleum is found on the deeper portions of the OCS, the price for delivery will set a new trend for domestic petroleum prices.

ADDITIONAL DATA AND RESEARCH NEEDS

Additional data and research that can guide future resource management planning activities are suggested primarily where such data would help to design mitigation and enhancement measures. One recommended information requirement is the effect of brine discharges into tidal waters as a result of drilling operations. At the present time, the Texas Railroad Commission issues discharge permits indicating maximum allowable discharge volumes, and maintains an accounting of actual volumes discharged by permitted parties. The salinity models used to set maximum volumes have various limitations, however. It is difficult to establish mathematical accuracy, and the problem is further complicated by the possibility of unpermitted brine discharges or excessive discharges above permitted volumes. At the present time, mitigation of adverse environmental impacts attributable to brine discharge is largely limited to a permitting process by which potentially sensitive habitats are avoided. The cumulative effects of discharges into surface waters could be more carefully monitored.

An additional area in need of further study is the potential for avoiding accidental petroleum discharges or mitigating the effects of accidents by applying performance and specification standards to offshore drilling activities. The specific characteristics of alternative error detection and blowout prevention systems could be considered in greater detail, along with a consideration of other accident inspection and prevention systems.

Although the number of worker injuries and accidents on rigs in Texas waters has been low in comparison to Louisiana experiences, the expected future increases in offshore drilling will likely include exposure of a greater number of workers to hazardous situations. More rigorous monitoring of occupational injuries and their causes should be conducted to aid in anticipating and preventing future accidents.

An area in which additional environmental research would be helpful is the synthesis of background and baseline monitoring studies concerned with the effects of oil spills on marine ecosystems in Texas, with a special focus on research that has been conducted in nearshore zones and bay bottom sediments. As in the case of the Ixtoc I blowout, the uncontained oil has settled into sediments laden with microorganisms that form the first link in the submarine food chain. Relevant existing data collected by State institutions (eg., University of Texas) and Federal institutions have not yet been fully compiled, reviewed or integrated with other studies.

One final area for which further study is recommended would be the long-term channel deepening requirements anticipated to meet petroleum industry activity projections for the next several decades. There were more than 10 channel deepening proposals being considered for the Texas coastal area as of 1980, and there have been few indications of the adequacy or demand for these proposed facilities to meet projected activity levels in the decades to come. Channel deepening studies should also include the quantity and areal extent of estuary to be dredged, areas to be filled, the related environmental impacts, and the cumulative effects of such activities.

SUMMARY

Texans have lived closely with oil and gas operations for several decades. They have developed a respect for the opportunities that these operations have provided and for the beneficial impacts they have had on coastal communities. Texans have also developed an awareness of the adverse impacts of oil and gas development on sensitive natural areas. Many Texas industries are closely dependent on in-state petroleum production. The concentration of refineries, petrochemical plants, transport facilities, and all manner of petroleum service industries within the TBIE area is attributable to the longstanding productivity

Albers P.H. Oil dispersants and wildlife. In Proceedings of the 1979 U.S. Fish and Wildlife Service pollution response workshops; 1979; Available from: U.S. Government Printing Office, Washington, DC: 67-72; proceedings edited by U.S. Fish and Wildlife Service, Washington, DC.

American Petroleum Institute. Basic petroleum data book; petroleum industry statistics. 5th printing, Washington, DC: American Petroleum Institute; 1979.

Armstrong, H. W.; Encik, K.; Anderson, J. W.; Neff, J. M. (Dept. of Biology, Texas A & M Univ., College Station, TX). Effects of oilfield brine effluent on sediments and benthic organisms in Trinity Bay, Texas. Marine Environmental Research 2(1): 55-69; 1979.

Banta, J.S. (The Conservation Foundation, Washington, DC). Environmental planning for offshore oil and gas. Vol. 4. NSTL Station, MS: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services; FWS/OBS-77/15; 1978; 126 p. Available from: U. S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services, Slidell, LA.

Beck, R. J., ed. Production flat; demand, imports off. Oil and Gas Journal 78(4): 108-125; 1980.

Blumer, M. Scientific aspects of the oil spill problem. Environmental Affairs 1(1): 54-73; 1971.

Boundary dispute could trim Gulf sale. Oil and Gas Journal 189(6): 136-137; 1979.

Boynton, J. D. (Standard Oil Co. of Texas, Houston, TX). Drilling is engineering challenge. Petroleum Engineer 41(1): 65-68; 1969.

Brown and Root, Inc. We built the tallest one-piece jacket in the world. Offshore 40(2): 89; 1980.

Butler, K. S. Delineating shore and landward coastal boundaries. Madison, WS: Univ. of Wisconsin; 1977; 279 p. Dissertation.

Crosby, G. E., ed. Shell's buccaneer sets design pace. Petroleum Engineer 41(1): 57-61; 1969.

DeGolyer and MacNaughton. Twentieth century petroleum statistics: 1978. Dallas, TX: DeGolyer and MacNaughton; November 1978; 105 p. Available from: DeGolyer and MacNaughton, Dallas, TX.

Developing new oil production may cost $70 billion annually. World Oil 189(6): 129-138; 1979.

Directory of Texas Manufacturers: 1977-1978. Austin, TX: Bureau of Business Research, Univ. of Texas at Austin; 1977. 2 vol.

Dorfman, M.; Kehle, R.O. Potential geothermal resources of Texas. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1974; 33 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Ellis, R. H. Coastal zone management system: a combination of tools. Washington, DC: Marine Technological Society, 1972. Taken from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services. Environmental planning for offshore oil and gas. 5 vol. NSTL Station, MS; March 1978. Available from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services, Slidell, LA.

Exxon designs for production in 5,000 feet of water. World Oil 189(7): 139-144; 1979.

Farrington, J. W. Oil pollution in the coastal environment. Estuarine pollution control and assessment. Vol II: proceedings of a conference; 1975 February 11-13; Pensacola, FL. Washington, DC: U.S. Environmental Protection Agency; 1977. Taken from: Clark, J.; Terrell, C. (The Conservation Foundation, Washington, DC). Environmental planning for offshore oil and gas. Vol III. NSTL Station, MS: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services; March 1978; 220 p. Available from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services, Slidell, LA.

First base for exploration - acreage under lease. World Oil (Energy Management Report) 50(2): EM6-EM7; 1980.

Fisher, W. L. Texas energy reserves and resources. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1978; 30 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Ginn, R. F. Groundwater contamination from natural gas, W. H. Baner Ranch near Carancahua Bay, Jackson County, Texas. Unpublished Texas Dept. of Water Resources file report. Taken from: Research and Planning Consultants, Inc. An analysis of ecological effects of geopressured-geothermal resource development. Geopressured-geothermal technical paper no. 4. Austin, TX: Texas General Land Office; July 1979; 129 p. Available from: Texas General Land Office, Austin, TX.

Greenwalt, L. A., Director of Fish and Wildlife Service. (Memorandum to Frank Gregg, Bureau of Land Management, U.S. Dept. of the Interior). 1979 April 10. FWS/DES 375.4.

Grow, G. C., Jr. (Potential Gas Committee, Westfield, NJ). Natural gas: U.S. energy source for years to come. Petroleum Engineer 49(13): 22-36; 1977.

Grubb, H. W.; McCray, W. C. Benefits and costs to State and local governments in Texas resulting from offshore petroleum leases on Federal lands. Austin, TX: Office of the Governor, Office of Information Services; 1974; 340 p. Available from: Texas Coastal and Marine Council, Austin, TX.

Gustavson, T.C.; McGraw, M. M.; Tandy, M.; Parker, F.; Wohlschag, D. G. Ecological implications of geopressured-geothermal energy development Texas-Louisiana Gulf Coast region; 1977. Taken from: Research and Planning Consultants, Inc. Analysis of ecological effects of geopressured-geothermal resource development (draft). Austin, TX: Texas General Land Office; July 1979; 129 p. Available from: Texas General Land Office, Austin, TX.

Kash, D. E.; White, I. L. Energy under the ocean. Norman, OK: Univ. of Oklahoma Press; 1973; 400 p.

Koonce, K. T. (Production Department, Exxon Company, U.S.A., Houston, TX). Advances in offshore technology. Petroleum Engineer 49(1): 22-30; 1977.

Kreitler, C. W.; Gustavson, T.C. Geothermal resources of the Texas Gulf coast -- environmental concerns arising from the production and disposal of geothermal waters: proceedings of the second geopressured-geothermal energy conference; vol. 5, report 3. Taken from: Kreitler, C. W. Faulting and land subsidence from groundwater and hydrocarbon production, Houston - Galveston, Texas. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1978; 22 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Leonard, J. G., ed. What's happening in drilling. World Oil 189(7): 15; 1979.

Lindall, W. L.; Saloman, C. H. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. Mar. Fish. Rev. 39(9): 1-7; 1977.

Maintenance of production the key to growth. Offshore 40(2): 31-34; 1980.

Masters, C. D. (Office of Energy Resources, U.S. Geological Survey, Reston, VA). U.S. oil resources; the critical years. Petroleum Engineer 49(13): 40-44; 1977.

Matheny, S. L., Jr., ed. Big new derrick barge goes to work in Gulf of Mexico. Oil and Gas Journal 78(6): 93-98; 1980.

Mc Caslin, J. C., ed. 1980: Biggest drilling year since 1957. Oil and Gas Journal 78(4): 126-130; 1980.

McNally, R., ed. Turnaround seen for U.S. production. Petroleum Engineer 49(13): 48-49; 1977.

McNally, R., ed. Drilling paces oilfield activity. Petroleum Engineer 50(1): 19-21; 1978.

Miller, B.; Thompson, H.L.; Dalton, G.L.; Coury, A.B.; Hendricks, T.A.; Lennart, F.E.; Powers, R.B.; Sable, E.G.; Varnes, C.L. Geological estimates of undiscovered recoverable oil and gas resources in the United States; 1975; U. S. Geological Survey Circular 725; U.S. Dept. of the Interior, Geological Survey; Available from: U.S. Government Printing Office, Washington, DC: 78 p.

Moore, S. F.; Dwyer, R. L. Effects of oil on marine organisms: a critical assessment of published data. Water Research 8: 819-827; 1974.

New England River Basins Commission. Onshore facilities related to offshore oil and gas - factbook; 1976. Taken from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services. Environmental planning for offshore oil and gas; vol. I. Slidell, LA: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services; March 1978; 225 p. Available from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services, Slidell, LA.

New methods and equipment improve drilling operations. World Oil 189(7): 83-90; 1979.

Next decade will see birth of U.S. synfuels industry. Oil and Gas Journal 189(6): 189-198; 1979.

Ocean industry's report on construction activities. Ocean Industry 11(1): 61-83; 1976.

Offshore rig locator. Offshore 40(2): 179-180; 1980a.

Offshore rig locator. Petroleum Engineer 52(2): R17-R19; 1980b.

Oil cleanup team being phased out. Houston Post. 1979 October 13. Taken from: Texas Coastal and Marine Council. Clips and Briefs 6(7):3; 1979.

Oil company to install unusual platform. Dallas Morning News. 1980 February 10. Taken from: Texas Coastal and Marine Council. Clips and Briefs 6(22): 2; 1980.

Oil in the eighties: tight supply, soaring capital outlays. Oil and Gas Journal 189(6): 163-169; 1979.

Oil spill intelligence report. Weekly newsletter of the Center for Shortlived Phenomena 3(2): 1; 1980 January 11.

Page, J. (Vetco Offshore, Inc., Ventura, CA). A diverless subsea completion system. Petroleum Engineer 50(1): 10-12; 1978.

Reaves, G. Schools expect to pump $72 million from gas field. Austin American Statesman. 1980 February 11.

Research and Planning Consultants, Inc. Offshore oil: its impact on Texas communities. 4 vol. Austin, TX: Texas General Land Office, Texas Coastal Management Program; June 1977; 900 p. Available from: Texas General Land Office, Austin, TX.

Research and Planning Consultants, Inc. An analysis of ecological effects of geopressured-geothermal resource development (draft). Austin, TX: Texas General Land Office; July 1979; 129 p. Available from: Texas General Land Office, Austin, TX.

Rogers, F. W. Oil and Gas in Washington. World Oil 189(7): 29; 1979.

Scott, J., ed. Texas offshore: breakthrough in the making. Petroleum Engineer 41(1): 53-56; 1969.

Seaton, E., ed. High Island gathering system nears completion. Oil and Gas Journal 78(6): 101-104; 1980.

Steen, R. W. The Texas story. Austin, TX: Steck Co.; 1960: 470 p.

Stewart-Gordon, T. J. A world of oil. World Oil 187(7): 25; 1979.

Sumpter, R., ed. Gulf coast platform work looks up. Oil and Gas Journal 78(6): 88-90; 1980.

Texas almanac 1980-1981. Dallas, TX: A. H. Belo Corporation; 1979; 704 p.

Texas Department of Water Resources, Enforcement and Field Operations Division. Unpublished data on coastal oil spills over 50 barrels, Austin, TX; 1979.

Texas Employment Commission. Unpublished employment data, 1978. Taken from: Texas almanac. Dallas, Texas: A. H. Belo Corporation; 1979; 444-445.

Texas General Land Office, Energy Resources Program. Unpublished lease sales revenue data, Austin, TX; 1979.

Texas Gulf coast and continental shelf showing natural gas pipelines (Cadastral): M. F. Stanley and R. W. Evans, Cartographers. Houston, TX: Transco Companies, Inc., 1979. Sept. 1: 443, 520; 56 X 40 in.; colored. Prepared for the Transco Companies, Inc.

Texas Mid-Continent Oil and Gas Association. Unpublished county data, Dallas, TX; 1979.

Texas Railroad Commission, Oil and Gas Division. Annual report: 1970. Austin, TX: Texas Railroad Commission; 1971; 700 p. Available from: Texas Railroad Commission, Austin, TX.

Texas Railroad Commission, Oil and Gas Division. Annual report: 1975. Austin, TX: Texas Railroad Commission; 1976; 101 p. Available from: Texas Railroad Commission, Austin, TX.

Texas Railroad Commission, Oil and Gas Division. Annual report: 1978. Austin, TX: Texas Railroad Commission; 1979a; 613 p. Available from: Texas Railroad Commission, Austin, TX.

Texas Railroad Commission, Oil and Gas Division. Unpublished county data on brine injection and disposal wells. Austin, TX; 1979b.

Texas Railroad Commission, Oil and Gas Division. Unpublished computer file of waste disposal into Texas waters by disposal point. Austin, TX; 1979c.

Texas Railroad Commission, Oil and Gas Division. Rules having statewide general application to oil, gas, and geothermal resource operations within the State of Texas. Austin, TX: Railroad Commission of Texas, Oil and Gas Division; October 1979d; 208 p. Available from: Railroad Commission of Texas, Oil and Gas Division, Austin, TX.

U.S. Dept. of the Army, Corps of Engineers. Waterborne commerce of the United States: 1977. Part 2. Waterways and Harbors Gulf Coast, Mississippi River System and Antilles. Washington, DC: U.S. Government Printing Office; 1978; 179 p. Available from: U.S. Dept. of the Army, Corps of Engineers, New Orleans, LA.

U.S. Dept. of Commerce, Bureau of the Census. United States export and import trade; March 1978. Taken from: U.S. Dept. of the Interior, Bureau of Land Management. Proposed 1980 outer continental shelf oil and gas lease sales A62 and 62. Washington, DC: U.S. Government Printing Office; 1979; 193 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of Economic Analysis, Regional Information System. Unpublished estimates of county employment; 1979; Washington, DC.

U.S. Dept. of Commerce, Maritime Administration, Office of Maritime Labor and Training. Workforce supply and demand study for the offshore oil and gas exploration support craft industry, 1979-1988. Washington, DC: U.S. Government Printing Office; September 1979. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Energy, Energy Information Administration. Crude oil and refined products pipeline mileage in the United States (triennial reports). Taken from: American Petroleum Institute. Basic petroleum data book: petroleum industry statistics. Washington, DC: American Petroleum Institute; 1979. unpaginated. Available from: American Petroleum Institute, Washington, DC.

U.S. Dept. of the Interior, Bureau of Land Management. Proposed 1980 outer continental shelf oil and gas lease sales A62 and 62. Environmental impact statement. Washington, DC: U.S. Government Printing Office; 1979; 193 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of the Interior, Bureau of Land Mangement. Unpublished data on outer continental shelf lease sales 45, 51, 58, and 58A: New Orleans, LA; 1980.

U.S. Dept. of the Interior, Bureau of Mines. Minerals Yearbook: 1973. Washington, DC: U.S. Government Printing Office; 1975. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of the Interior, Bureau of Mines. Minerals Yearbook: 1975. Washington, DC: U.S. Government Printing Office; 1978. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services. Environmental planning for offshore oil and gas. 5 vol. NSTL Station, MS: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services; March 1978; 1,004 p. Available from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services, Slidell, LA.

U.S. Dept. of the Interior, Geological Survey. Outer continental shelf statistics, calendar year 1975; 1976. Taken from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services. Environmental planning for offshore oil and gas; vol. I. Slidell, LA: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services; March 1978. Available from: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services, Slidell, LA.

U.S. Dept. of the Interior, Geological Survey. Outer continental shelf statistics: 1953-1978. Reston, VA: U.S. Dept. of the Interior, Geological Survey; June 1979; 100 p. Available from: U.S. Dept. of the Interior, Geological Survey, Conservation Division, Reston, VA.

U.S. Dept. of Transportation, Coast Guard. Polluting incidents in and around United States waters: 1972. Washington, DC: U.S. Dept. of Transportation; Coast Guard; 1973; 11 p. Available from: U.S. Dept. of Transportation, Coast Guard, Washington, DC.

U.S. Dept. of Transportation, Coast Guard. Polluting incidents in and around United States waters: 1973. Washington, DC: U.S. Dept. of Transportation, Coast Guard; 1974; 11 p. Available from: U.S. Dept. of Transportation, Coast Guard, Washington, DC.

U.S. Dept. of Transportation, Coast Guard. Polluting incidents in and around United States waters: 1974. Washington, DC: U.S. Dept. of Transportation, Coast Guard; 1975; 16 p. Available from: U.S. Dept. of Transportation, Coast Guard, Washington, DC.

U.S. Dept. of Transportation, Coast Guard. Polluting incidents in and around United States waters: 1975. Washington, DC: U.S. Dept. of Transportation, Coast Guard; February 1977a; 24 p. Available from: U.S. Dept. of Transportation, Coast Guard, Washington, DC.

U.S. Dept. of Transportation, Coast Guard. Polluting incidents in and around United States waters: 1976. Washington, DC: U.S. Dept. of Transportation, Coast Guard; December 1977b; 31 p. Available from: U.S. Dept. of Transportation, Coast Guard, Washington, DC.

U.S. Dept. of Transportation, Coast Guard. Polluting incidents in and around United States waters: 1977. Washington, DC: U.S. Dept. of Transportation, Coast Guard; July 1978; 30 p. Available from: U.S. Dept. of Transportation, Coast Guard, Washington, DC.

U.S. Dept. of Transportation, Coast Guard. Unpublished polluting incidents data. New Orleans, LA; 1979.

U.S. Dept. of Transportation, Coast Guard. Unpublished polluting incidents data. New Orleans, LA; 1980.

U.S. Environmental Protection Agency, Office of Drinking Water. A guide to the underground injection control program. Washington, DC: U.S. Environmental Protection Agency, Office of Drinking Water, June 1979; 29 p. Available from: U.S. Environmental Protection Agency, Office of Drinking Water, Washington, DC.

Walther, E., ed. Templates, trees, and controls. Petroleum Engineer 50(13): 26-30; 1978a.

Walther, E., ed. OCS training requirements may be attainable. Petroleum Engineer 50(12): 21-24; 1978b.

Whitehorn, N. C. Economic analysis of the petrochemical industry in Texas. College Station, TX: Texas Engineering Experiment Station, Texas A & M Univ. May 1973; 78 p. Available from: Industrial Economics Research Division, Texas Engineering Experiment Station, Texas A & M Univ., College Station, TX.

Whitley, G. Louisiana shrimpers gear for fight over DOE brine disposal plan. Brazosport Facts. 1980 March 2. Taken from: Texas Coastal and Marine Council. Clips and Briefs 6(24): 2; 1980.

Wood, P. W. J. There's a trillion barrels of oil awaiting discovery. World Oil 188(7): 141-148; 1979.

Woods Hole Oceanographic Institute. Effects on commercial fishing of petroleum development off the northeastern United States. Woods Hole, MA; 1976. As referenced in U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services. Environmental planning for offshore oil and gas; vol. I. Slidell, LA: U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services; March 1978; 226 p. Available from: U.S. Dept. of the Interior, Fish and Wildlife Services, Office of Biological Services, Slidell, LA.

Wright, T. R., ed. What's happening in production. World Oil 189(4): 15; 1979.

1979 should set some records. World Oil 189(3): 67-72; 1979.

RECREATION/TOURISM INDUSTRY

INTRODUCTION

With concern for a large, concentrated population and abundant natural resources, planning for the use and management of resources in the TBIE study area requires a rigorous grasp of complex interacting processes. As the area residents' mobility, disposable income, and leisure time have increased, so have the demands for recreation and tourism opportunities. Throughout the TBIE area, these increasing demands have resulted in a multitude of potential interest groups competing for the use of the same resource. In some cases, this competition is the result of conflicts between short-term and long-term use considerations. In other cases, there is a competition for use of the same resource among incompatible user groups. As the different interest groups attempt to deal with increasing demands, more analyses and plans are being completed, shelved, and forgotten, as implementation becomes an impossible task. As a way to introduce planners, scientists and decisionmakers to the TBIE area recreation/tourism industry, this synthesis paper briefly characterizes the historical, present, and likely future industry trends as they are understood with existing information.

The Texas Outdoor Recreation Plan (TORP) is one of the more outstanding examples of comprehensive state outdoor recreation resource plans in the United States. Consisting of ten volumes, and supported by an extensive computerized data base with a full contingent of recreation planning professionals, the plan cannot be adequately summarized in this discussion. Particularly noteworthy is Volume V, which describes the coastal area of Texas in detail. Tourism information is not nearly so plentiful. No comprehensive data base is available with which to characterize the TBIE area. Indirect measures of the magnitude of this part of the industry must be utilized, including travel expenditures, population, employment, and total economic productivity.

General Significance of the Industry

Within the TBIE area, there are nearly 155,000 ha (382,000 ac) of recreation park land, approximately 2.7% of the total TBIE land area. Within all of Texas, only 1% of the land area is used for parks and recreation activities. This provides an indication of the relative concentration of recreation/tourism resources within the TBIE study area. Approximately 5.6% of the area's recreation land is developed, while 8% is considered prime undeveloped land, and 86.4% is in a variety of other undeveloped classifications (Texas Parks and Wildlife Department, Comprehensive Planning Branch 1979). Because the planning regions identified in the TORP are not identical to the TBIE study area boundaries, actual recreation resources available in the TBIE area cannot be accurately specified. Using the Texas Parks and Wildlife Department (TPWD) Regions 24, 25, 26, 28, 32, 33, and 34, which contain all of the TBIE counties, the general significance of rural and urban recreation resource supply can be identified. Facilities include 18,134 m (19,927 yd) of linear fishing parks and 1,613 boat slips and stalls in the 7 TPWD regions. There are 63 camping parks, and 2,914 campsites; 95% of the parks are in rural settings, and 99.9% of all campsites are located in rural settings as well.

Included among these facilities are the Padre Island National Seashore, 6 national wildlife refuges, and 18 State parks and recreation areas (Table 16). The

Table 16. Location and size of Federal and State parks within the TBIE study area, 1979 (Texas Parks and Wildlife Department, Comprehensive Planning Branch 1979).

Park name	County	Acreage[a]
Federal		
Brazoria National Wildlife Refuge	Brazoria	10,321.5
San Bernard National Wildlife Refuge	Brazoria	24,455.0
Anahuac National Wildlife Refuge	Chambers	10,022.0
Aransas National Wildlife Refuge	Calhoun	1,700.0
Aransas National Wildlife Refuge	Aransas	53,120.0
Padre Island National Seashore	Kenedy	88,669.0
Padre Island National Seashore	Kleberg	36,127.0
Padre Island National Seashore	Hidalgo	9,122.0
Laguna Atascosa National Wildlife Refuge	Cameron	49,190.0
Santa Ana National Wildlife Refuge	Hidalgo	3,865.0
State		
Hale Ranch State Park	Fort Bend	4,597.0
Galveston Island State Park	Galveston	1,952.0
San Jacinto Battleground State Park	Harris	327.2
Sheldon Wildlife Management Area	Harris	2,503.0
Port Lavaca Fishing Pier	Calhoun	1.8
Fannin Battleground State Historical Park	Goliad	13.0
Goliad State Historical Park	Goliad	184.5
Palmetto Bend Reservoir State Park	Jackson	575.0
Copano Bay Causeway State Park	Aransas	6.0
Fulton Mansion State Historical Park	Aransas	2.3
Goose Island State Park	Aransas	307.0
Mustang Island State Park	Nueces	3,570.0
Lipantitlan State Park	Nueces	5.0
Lake Corpus Christi State Park	San Patricio	350.0
Brazos Island State Recreation Area	Cameron	217.0
Port Isabel Lighthouse State Park	Cameron	0.5
Queen Isabella Causeway State Park	Cameron	7.0
Resaca De La Palma State Park	Cameron	1,055.0
Los Palmos Wildlife Management Area	Cameron	266.6
Bentsen State Park	Hidalgo	587.7
Los Palmos Wildlife Management Area	Hidalgo	110.7
Los Palmos Wildlife Management Area	Willacy	35.0

[a]2.471 ac = 1 ha.

TBIE region supports an abundance of fish and wildlife, providing recreational opportunities for naturalists, hunters, and fishermen alike. Bird watchers find the area is frequented by a variety of endangered bird species, most notably the whooping crane (Grus americana), brown pelican (Pelecanus occidentalis), and Attwater's prairie chicken (Tympanachus cupido attwateri). Bird hunters' interests center around the migratory species of geese, ducks, doves, and the indigenous turkey and quail. Game hunters focus on white-tailed deer (Odocoileus virginianus texanus), javelina (Pecari angulatus), and numerous smaller animals such as rabbits, squirrels, and coyotes (more commonly known as varmints).

Recreational fishing focuses primarily on saltwater species, although pursuit of freshwater gamefish is also significant throughout the region. Principal inshore saltwater gamefishes are the spotted seatrout (speckled trout) (Cynoscion nebulosus), red drum (redfish) (Sciaenops ocellata), southern flounder (Paralichthys lethostigma), and Atlantic croaker (Micropogonias undulatus). Offshore gamefishes of note are the king mackerel (kingfish) (Scomberomorus cavalla), cobia (ling) (Rachycentron canadum), sailfish (Istiophorus platypterus), tarpon (Megalops atlantica), marlin (Makaira sp.), and red snapper (Lutjanus campechanus). Freshwater fishing is for largemouth black bass (Micropterus salmoides), white bass (Morone chrysops), and several species of panfish and catfish.

The economic significance of tourist activities is considerably more difficult to identify, due to the lack of available data. One important, albeit indirect, measure of activity levels is derived from travel-related expenditures. Per capita travel expenditures in the TBIE area were approximately 7% greater in 1977 than in the rest of Texas (Table 17). Economic impacts attributable to the recreation/tourism industry's travel expenditures range from less than $300 per capita in Bee County to nearly $2,000 per capita in Aransas County, a six-fold difference in expenditure levels. A range of similar magnitude is indicated in employment data, where 23% of the Aransas County employment is travel-related, in contrast with only 2.9% in Bee County. Aransas County has a long, attractive coastline, providing access to the considerable barrier islands recreation/tourism resources. Bee County is located inland, with an economy based on oil and gas activities, agricultural production, and a naval air station.

Data Sources

The principal sources of data for this paper are limited in their coverage. While the TORP presents a complete analysis of historical, present, and projected participation levels for a wide spectrum of recreation activities and facilities, this analysis does not make any distinction between participation and demand for facilities. Failure to make such a distinction is not at all unusual, but it does make conceptual facility planning more difficult by not addressing special interests of those who may have been systematically excluded from participation because of past planning considerations. Where appropriate, key statistics have been identified from the TORP to provide a generalized description of the physical setting, participation rates, and the management framework within which complex resource planning decisions are being developed. Other major sources of industry characteristics include the time series data from the Texas Employment Commission, U.S. Bureau of the Census, U.S. Department of Commerce, and the U.S. Travel Data Center. All of these sources provide indirect measures of industrial activity by marking changes in population, employment, travel expenditures, and the broad scope of the TBIE area economy. A more detailed assessment of the data gaps, inconsistencies, and recommended requirements for additional research is presented in the final section of this discussion.

Table 17. Travel economics in the TBIE study area, Texas, and selected counties, 1977.

Region and county	Population[a]	Employment[b]	Travel expenditures[c] (dollars)	Travel employment[c]	Per capita travel expenditures (dollars)	Travel employment as a percentage of total employment
Texas	12,830,000	5,974,688	6,257,807,000	229,497	488	3.8
TBIE Study Area	3,621,677	1,743,521	1,853,999,000	68,986	512	4.0
Texas without TBIE	9,208,400	4,231,167	4,403,808,000	160,511	478	3.8
Harris County	2,138,300	1,168,265	1,195,173,000	46,389	559	4.0
Galveston County	195,400	76,541	118,615,000	5,014	607	6.6
Victoria County	60,600	37,032	22,918,000	997	378	3.7
Aransas County	11,100	4,194	22,015,000	964	1,983	23.0
Bee County	22,800	10,168	6,724,000	292	295	2.9
Nueces County	250,700	111,939	122,462,000	4,673	489	4.2
Cameron County	176,500	63,074	82,912,000	3,007	470	4.8

[a]U.S. Department of Commerce, Bureau of the Census 1979.
[b]U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979.
[c]U.S. Travel Data Center 1977.

Two factors have strongly influenced the methods and techniques used in characterizing the TBIE recreation/tourism industry--available information and standard, state-of-the-art analytical techniques. The result has been the selection of several secondary variables for use as estimates of the levels and types of recreation/tourism in the study area, including: total population (for use in generating per capita and extra-TBIE comparisons), total employment, travel related expenditures, travel generated employment, trip time and length of stay (to define the travelers), and tax receipts (accumulated within various subcategories relevant to the recreation/tourism industry).

Definition of Recreation/Tourism

While the general characteristics of the TBIE study area can be summarized according to the recreation resources and tourism industry, a more detailed analysis of the recreation/tourism industry does not reveal a sharp distinction between the two. A tourist is any person pursuing an activity outside of the normal locus of daily life, for either recreational or business purposes. A technical definition of recreationist is much more difficult because of the broad spectrum of perceptions of leisure activities. Recreation for one individual may be considered work for another. Rather than offer a rigorous distinction, this essay presents a series of examples that can be used to demonstrate the similarities and differences between the two portions of the industry.

The distinction may be based on the purpose of the facilities rather than the purpose of the family or individual involved. First, consider the case of a waterfront condominium development on one of the bays along the Texas coast. The family that owns a condominium unit as a second residence and uses it periodically for weekend and vacation trips is obviously participating in the recreation/tourism industry. The family that lives in the dwelling unit year-round and whose principal wage earner is the local doctor is not part of the industry. Yet, the condominium complex would not exist but for the recreation/tourism demand in the first place. Hence, the doctor's family's impact, as well as the second home owner's impact, may be viewed as being more closely related to recreation/tourism than to another industry. More difficult to identify in this example is the distinction between recreation and tourism activities. The second home owner could fall into either category, depending on the specific operational definition. The doctor would not fall directly into either, yet (s)he is clearly a component of the industry itself.

The importance of measuring industrial activity on a facility or resource-specific basis, in contrast to activity measurements with the participant as the focus, is emphasized in another example. Consider a local beachfront park. The out-of-town visitor sunbathing on the beach is both a tourist and a recreationist. The hometown person using the same beach for the same purpose may be categorized in the same context.

The same type of case can be made using a business traveler and a vacationer as the basis of comparison. Since both use the same hotels, restaurants, and entertainment facilities, both may be considered as part of the recreation/tourism industry. Imagine a visitor from Dallas who reserves space on a charter boat in the coastal community of Freeport for fishing red snapper. On the same trip is a person who lives in Freeport and works at one of the local chemical plants, who also rents the charter boat for the same purpose. The facilities being used and the services being offered on that charter are identical for both parties. Creating an analytical or heuristic distinction to refine our classification of charter boat users would require an extensive increase in primary data collection efforts, and may yield some limited data concerning the origin of demands for charter fishing boats, while not yielding any data concerning other more important factors that result from charter operations.

Observing a typical coastal village boat launch ramp suggests a similar reason for not retaining an arbitrary distinction between different portions of the industry. On a given day the ramp is likely to be used by any or all of the following people: the sport fisherman; the professional guide with a client (who will sell any of the day's catch that the client does not want); a commercial finfisherman; a commercial shellfisherman; a family shrimping for fun but intending to sell some of the catch to defray their expenses; and a game warden. To distinguish each of these activities on the basis of distance traveled by participants would require a detailed primary data collection effort, and this type of distinction is not warranted by most of the major recreation/tourism issues with which resource management planning agencies are faced.

There are, of course, issues for which such information could be useful. Anticipating effects of new or improved highways on recreation resource use could depend on identification of user groups, as could allocation of costs among users of public beaches. These data are not readily available, however, and for this study, recreation and tourism are combined.

The remainder of this paper presents the results of the characterization of the recreation/tourism industry, beginning with an overview of the industry's socio-economic and environmental impacts. Growth trends within the study area are described, along with a range of alternative futures that may result from both regional and national policy considerations. Pertinent issues are delineated for planners, scientists, and decisionmakers when considering the place of the recreation/tourism industry in the broad socioeconomic environment of the TBIE area. Finally, the most critical data gaps and research needs are suggested to provide the additional information required to address the problems of an uncertain future.

SOCIOECONOMIC AND ENVIRONMENTAL IMPACTS OF THE TBIE RECREATION/TOURISM INDUSTRY

Socioeconomic Impacts

Travel expenditures, population growth, and employment serve as useful indirect measures of the recreation/tourism industry's socioeconomic consequences. As indicated in Table 17, the per capita travel expenditures in the TBIE study area exceed those for the State as a whole. These expenditures are being made by TBIE area residents and by visitors to the area--tourists using regional recreation facilities and services. Table 18 summarizes the socioeconomic characteristics of the study area in terms of population and employment changes from 1970 to 1977.

The TBIE area population is growing at a faster rate than the State as a whole. Harris, Galveston, and Aransas Counties, which had relatively high per capita travel expenditures (Table 17), are also experiencing very rapid growth. Although the data for Cameron County (in the Lower Rio Grande Valley) do not reflect relatively high expenditures (Table 17), that area is, nevertheless, known as a prime tourist attraction. In other words, those counties that have the greatest recreation/tourism industry orientation also tend to be growing at faster rates. This tendency reflects an aspect of migrant influx that is stimulated by a resource base already at a relatively mature stage in its development. Those areas in which recreation/tourism facilities are already developed present greater opportunities for further industrial growth than would be present in areas where little or no development has taken place.

Of particular interest in the TBIE study area is the transient population, colloquially known as "snowbirds." These persons travel to the Texas coast, especially to the Rockport, Aransas Pass, and Lower Rio Grande Valley areas, to escape the cold winters of their permanent homes in the Midwest. The median length of stay is about 4 months, with the full "snowbird" season ranging from Thanksgiving to Easter. Almost three-fourths of these winter visitors live in their own travel trailers, motor homes, or mobile homes. Their average age tends to be between 60 and 75 years old, and their median per capita expenditure is slightly more than $100 per week (Bureau of Business and Economic Research, Pan American University 1977; 1978; 1979).

Approximately 4% of the employment in the State and in the TBIE study area is a result of the recreation/tourism industry. Table 19 segregates tourist-related employment into subcategories. Food service employment is often considered to be less important than other industry employment subcategories, although it accounts for as much as 20% of the industry's total employment. Unlike lodging and transportation-related jobs, which are often associated with national service franchises, food service employment is more often associated with locally owned and operated enterprises. The data presented in Table 19 are somewhat dated and statewide in aggregation, although they may serve as an approximate indication of TBIE industry employment since the ratio of tourism employment to statewide employment (4%) is consistent with current estimates. Moreover, there is little reason to believe that the industry employment mix would vary from one part of the State to another.

Table 18. Socioeconomic characteristics, TBIE study area, Texas, and selected counties, 1970 and 1977 (U.S. Department of Commerce, Bureau of the Census 1973; 1979; U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979).

Region and county	Population		Change in population 1970-1977 (%)	Employment		Change in employment 1970-1977 (%)
	1970	1977		1970	1977	
Texas	11,196,730	12,830,000	13.58	4,770,013	5,998,604	25.76
TBIE study area	3,009,953	3,609,000	18.48	1,266,826	1,743,521	37.63
Harris County	1,741,912	2,138,000	20.43	817,225	1,168,265	42.96
Galveston County	169,812	195,400	14.02	63,485	76,541	20.57
Victoria County	53,766	60,600	12.07	19,860	27,032	36.11
Aransas County	8,902	11,100	22.00	3,373	4,194	23.01
Bee County	22,737	22,800	0.44	9,790	10,168	3.86
Nueces County	237,544	250,700	5.37	99,991	111,939	11.95
Cameron County	140,368	176,500	22.79	46,310	63,074	36.20

Table 19. Employment in the Texas tourist industry, third quarter 1973 and 1974 (Kahn 1976).

Industry	1973 Employment	1973 % of tourist industry employment	1973 % of Texas employment	1974 Employment	1974 % of tourist industry employment	1974 % of Texas employment
Tourist industry						
Transportation						
Auto	8,108	6.4		8,439	5.1	
Air	21,499	17.0		23,270	13.9	
Bus	3,894	3.1		4,147	2.5	
Lodging	41,452	32.8		42,268	25.3	
Food	23,471	18.6		33,460	20.0	
Entertainment etc.	27,808	22.0		55,504	33.2	
Total tourist industry	126,232	100.0	3.88	167,088	100.0	4.46
Total Texas (all sectors)	3,337,182		100.0	5,016,000		100.0

Public employment in the tourist industry, although seldom acknowledged and virtually impossible to delineate because of its tourist and non-tourist orientation, should not be ignored. Game wardens, park rangers, the highway patrol, Federal Aviation Administration employees, city parks department employees, and some members of the U.S. Army Corps of Engineers planning staff represent a wide range of public sector involvement in the recreation/tourism industry.

Table 20 shows the tax revenues generated by basic travel expenditures. For every dollar spent by a tourist in the study area in 1978, approximately three cents was generated in State tax revenue. The tax return to the local level was approximately one cent. The expenditure volume in the recreation/tourism industry can be conceptualized in terms analogous to export commodities. The more "export" dollars the community can receive, the better off it is because it does not have to provide traditional community infrastructural and social services for visitors to the same degree that is required by resident taxpayers.

Environmental Impacts

There is a relatively small empirical foundation on which a description of relationships between recreation/tourism industry activities and the environment can be based. The TPWD, Resource Protection Branch, has in its files a detailed case history for each of the recreation facility siting cases under its jurisdiction where environmental consequences were potentially significant. No public catalogue of these cases is available although the Resource Protection Branch is so well regarded that when El Paso Natural Gas Company was first considering construction of a Liquified Natural Gas plant at Port O'Connor, the company's first State agency contact was to the Branch to insure that sensitive areas were avoided.

Several relationships can be observed in the TBIE area on the basis of isolated cases:

1. Those parts of the TBIE area that are experiencing rapid economic growth are also growing rapidly in terms of recreation/tourism activities. Ongoing industrial, commercial, and residential development may not necessarily be in conflict with growth in the recreation/tourism industry.

2. Where recreation/tourism developments have posed environmental threats, measures have sometimes been taken to mitigate potentially adverse consequences. A major impact of the recreation/tourism industry on the environment has been the construction of hotels, motels, and residential units in dune areas, bayshores, and wetlands. Of particular concern are the covering of shallow water nurseries as a result of dredge and fill operations and disruption of water flows by canal developments. Some areas, such as Galveston Island and Mustang Island (Port Aransas), are taking strong steps to minimize the potential adverse impacts of development although compensation will still be necessary for unavoidable impacts.

3. As the demand for space in the TBIE area increases, so does the probability of further degradation of some environmentally sensitive areas. Demands for recreational opportunity and facilities are depleting some coastal physical resources. Overcrowding of the beaches

Table 20. Tax receipts and expenditures in the TBIE study area, Texas, and selected counties, 1978 (U.S. Travel Data Center 1978).

Region and county	Travel expenditures ($1,000)	State tax receipts ($1,000)	State tax revenues generated per dollar of total travel expenditures (dollars)	Local tax receipts ($1,000)	Local tax revenues generated per dollar of total travel expenditures (dollars)
Texas	7,032,369	213,914	0.030	60,675	0.009
TBIE Study Area	2,074,700	63,880	0.031	18,760	0.009
Harris County	1,340,067	43,204	0.032	12,861	0.010
Galveston County	132,218	4,784	0.036	1,369	0.010
Victoria County	25,556	1,023	0.040	281	0.011
Aransas County	24,546	925	0.038	119	0.005
Bee County	7,502	300	0.040	82	0.011
Nueces County	136,262	4,640	0.034	1,352	0.010
Cameron County	91,673	2,834	0.031	774	0.008

causes spill-over traffic onto dune areas disrupting the vegetation and thus eventually destabilizing the dune. Overfishing the redfish has been partially responsible for a sharp decrease in supply. The demand for recreational access to pristine natural areas increases pressure for roads to be constructed in those areas.

It appears that, on the whole, attempts have been made to achieve a relative balance between the environment, development, and recreation/tourism demands for space, services, and facilities in the TBIE region. Resort development, condominiums, yacht basins, hotels, and restaurants are, however, intruding on fish and wildlife habitats. The National Environmental Policy Act (section 10 and section 404) provides a mechanism for reviewing proposed coastal development. Other legislation has provided for dune protection, floodplain development planning, dredge and fill limitations, regulation of oyster harvest areas because of sewage, and other constraints on development, not only for recreation and tourism, but also for other coastal activities.

TBIE RECREATION/TOURISM INDUSTRY: A GROWTH TREND

The recreation/tourism industry in the TBIE area has grown markedly over the past two decades. Detailed data on the size of the industry are not available prior to 1960, but the evolution of employment types can be traced. In this section, the discussion begins with a brief history of the economy of the TBIE area, describes the presence of the facilities and services that comprise the recreation/tourism industry, and concludes with a presentation of those activities that the recreation/tourism industry supports.

History of the TBIE Area Economy

Data in Table 21 show that between 1950 and 1977, the TBIE economy experienced the greatest rates of employment growth in contract construction; finance, insurance, and real estate; and other services. Wholesale and retail trade and manufacturing grew rapidly between 1950 and 1970 although the rate of growth tapered off somewhat from 1970 through 1977. The only economic sector with a decrease in employment over the period was agriculture, forestry, and fisheries. In absolute terms, the largest employment sectors were wholesale and retail trade, services, manufacturing, and government, in that order.

Most of the employment in the region is centered in Harris County (Houston), Nueces County (Corpus Christi), Cameron and Hidalgo Counties (Lower Rio Grande Valley), and Galveston County (Galveston). See Data Appendix, Population Table 1.

Travel-related Employment

The growth of the recreation/tourism industry in the TBIE area has been greater than for the State as a whole. Between 1974 and 1978, employment in the State increased by about 9%. Travel industry employment in the TBIE area increased by slightly more than 20% between 1975 and 1978. Most TBIE counties underwent changes over the same period of 15% to 20% (U.S. Travel Data Center 1975, 1978; U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979).

Table 21. Percent change in employment in the TBIE study area, 1950 through 1970 and 1970 through 1977 (U.S. Department of Commerce 1975; U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979).

Economic sector	Change in employment 1950-1970 (%)	Change in employment 1970-1977 (%)	1977 employment
Agriculture, agricultural services, forestry and fishing	-46.3[a]	-9.8[b]	20,466
Mining	56.2	52.0	60,188
Contract construction	67.5	70.2	152,017
Manufacturing	90.5	31.9	248,514
Transportation, communications and public utilities	35.6	25.8	107,144
Wholesale and retail trade	83.7	36.1	357,813
Finance, insurance and real estate	154.2	52.2	84,833
Services	143.9	40.7	313,587
Government	107.5	27.1	239,748
Industry not reported	783.5	N.D.	N.D.
Proprietors	N.D.	15.9	122,466
Total TBIE employment	77.9	37.6	1,743,521

[a]Includes farm employment only.
[b]Includes farm, agricultural services, forestry and fishing employment.

Table 22 shows estimated employment in the recreation/tourism sector of the TBIE economy for 1978. There are several points to be made from the data in Table 22. First, the absolute magnitude of the industry can be appreciated on the basis of lodging units. At an estimated ratio of one lodging employee per room, there were almost 19,000 rooms in the TBIE area in 1978.

A second point is that the entertainment category has the largest number of employees in the industry. This category includes live entertainment, theater, and amusement park employment, as well as jobs at such facilities as country clubs, public parks, museums, and other activities normally thought of as local recreation. The difficulties involved in distinguishing these facilities on the basis of tourist use versus recreationalist use require that the classifications be combined.

Finally, the distribution of transportation employment in Table 22 is misleading. Although the air travel industry is the largest employer in this sector, it should be emphasized that the TBIE area is dependent upon the private automobile to a greater extent than any other transit mode for intercity travel. Commercial air carriers service Houston, Galveston, Corpus Christi, and the Lower Rio Grande

Table 22. Estimated employment in the TBIE recreation/tourism industry, 1978 (Kahn 1979).

Sector	Employment
Transportation	
Auto	3,742
Air	10,198
Bus	1,834
Lodging	18,561
Food	14,673
Entertainment, etc.	24,357
Recreation/tourism industry total	73,365

Valley. With the exception of flights originating or terminating in Houston, however, the volume of service is relatively low. Virtually all flights into and out of the smaller TBIE cities originate and terminate in Houston or Dallas, necessitating time consuming transfers. Because of the low air passenger volumes within the region, there was a time in the recent past when it cost more to fly round trip between Austin and Corpus Christi, a highway distance of about 300 km (200 mi), than to fly round trip from Houston to Cancun in southern Mexico. Bus service is available between most cities in the TBIE area, but carrying capacity is low. Limited passenger rail service is available (see Transportation synthesis paper).

There is no information on types of trips and accommodations for the auto traveler in the TBIE area. Data are available on a statewide basis, however (refer to Data Appendix, Recreation and Tourism Tables 22 and 23), and there is little reason to believe that the statewide numbers would not hold true for the TBIE area. In 1978, about 40% to 50% of all auto travelers were on vacation; approximately 35% were visiting friends; between 10% and 20% were just passing through; and approximately 10% were on business (Texas Department of Highways and Public Transportation 1979).

In terms of accommodations, short-term visitors traveling by auto in 1978 tended to stay in hotels and motels (about 65%); long-term visitors stayed in a combination of hotel-motel and other accommodations (40%-50%); both long- and short-term visitors stayed in private homes (15%-25%); and numerous long-term visitors stayed in recreational vehicles or camped (20%-30%). There is some double counting in these data, but choice of accommodations seems to depend on trip length. Essentially, the short-term traveler is likely to stay in a hotel or motel, while the long-term visitor is more likely to stay in a recreational vehicle or camp. Many long-term visitors do stay in hotels and motels, but the facilities used most often are the recreational vehicles, camps, or mobile homes.

A growing source of accommodations in the TBIE region is the condominium complex. Many units are owned and used as second homes (vacation homes) for both short- and long-term purposes. Increasing numbers are being purchased, however, with a view toward occasional use, tax write-offs, appreciation potential, and more importantly, income from rental of the unit to tourists when the unit is not in use by the owner.

MAGNITUDE OF THE TBIE RECREATION/TOURISM INDUSTRY

This section characterizes the facilities and activities that comprise the TBIE recreation/tourism industry. Private and public developments are identified, along with a description of recreation/tourism activities.

Recreation/Tourism Development

The study area includes 1,102 parks within its boundaries. Included in this total are 7 Federal, 23 State, 860 local, and 212 private park facilities (Texas Parks and Wildlife Department, Comprehensive Planning Branch 1979). Table 23 shows the types of facilities available within or near the TBIE area as of 1975. Park facilities are largely water-oriented with numerous piers, marinas, and boat ramps. The facilities listed in Table 23 represent items available in total and may include more than one item at a park.

The private development sector of the recreation/tourism industry consists of hotels, motels, and other lodging facilities; amusement parks; recreational vehicle parks; and marinas. As mentioned earlier, the location of lodging accommodations, and the choice of the traveler depends to a large extent on the trip length. Secondary data on number and size of amusement and recreational vehicle parks are not available. Observations, however, indicate that amusement parks are more likely to be found in large communities in the TBIE area, possibly because the smaller communities cannot generate sufficient demand to warrant the considerable investment required. Conversely, recreational vehicle parks in the region have tended to be located in or on the periphery of the small but popular tourist-oriented communities.

There were 65 marinas in the TBIE area in 1976 (Crompton et al. 1976). Of these, 22 were in the Galveston Bay area; 8 were near Freeport and Matagorda; 4 were near Port Lavaca; 19 were in the Coastal Bend region (Rockport, Aransas Pass, Port Aransas, Corpus Christi); and 12 were located in the Laguna Madre in the area between Kingsville and Brownsville. Although the number of marinas tends to be commensurate with the size of the surrounding population, the size and quality of facilities at a given marina exhibit no such relationship. Some of the larger and better equipped marinas in the TBIE area are located in the small communities of Freeport, Rockport, and Port Aransas. There were 88 charter boat operators working out of marinas on the coast in 1975 (Ditton et al. 1978).

Table 24 depicts changes in population and building permits in the TBIE area. Building permit data are subject to possible flaws in interpretation without discussion of the economic climate of the county or region and the Nation over the period in question. The data indicate overwhelmingly, however, that construction is occurring beyond the level required to keep up with population growth. The TBIE area is growing in terms of construction activity, and some of this construction activity is a response to the recreation/tourism industry.

Recreation/Tourism Activities

The TBIE region offers the following recreation/tourism activities:

Fishing: inshore and offshore

Hunting: game animals, waterfowl, upland birds

Table 23. Rural and urban parks and recreation facilities by TPWD Planning Region (Texas Parks and Wildlife Department 1975).

Facilities	TPWD region[a]							Total
	24	25	26	28	32	33	34	
RURAL								
Parks with water associated	10	17	14	41	2	15	10	109
Park - lake	0	4	17	7	0	7	6	41
Park - river or stream	10	10	4	30	2	16	6	78
Camping - parks	5	7	10	9	1	21	7	60
Campsites	171	342	351	570	20	960	482	2,896
Fishing - parks	5	5	1	47	0	22	16	96
Piers, barges and marinas	4	2	1	34	0	20	15	76
Total linear yards	2,687	225	84	9,195	0	6,138	1,238	19,567
Boating - parks	16	8	4	61	3	27	17	136
Ramps	16	9	5	66	3	28	17	144
Lanes	21	26	8	89	3	40	21	208
Slips and stalls	45	10	0	941	39	445	133	1,613

(continued)

Table 23 (concluded).

Facilities	TPWD region[a] 24	25	26	28	32	33	34	Total
URBAN								
Boating								
Parks	1	1	0	2	0	2	0	6
Ramp lanes	2	1	0	2	0	6	0	11
Fishing								
Parks	1	1	0	4	0	2	0	8
Piers/barges/marinas (yd)	0	300	0	0	0	60	0	360
Camping								
Parks	0	1	0	1	0	1	0	3
Campsites	0	0	0	8	0	10	0	18

[a] Region 24: Austin, Calhoun, Colorado, DeWitt, Fort Bend, Goliad, Jackson, Victoria, Waller, and Wharton Counties
Region 25: Harris County
Region 26: Liberty, Montgomery, and Walker Counties
Region 28: Matagorda and Brazoria Counties
Region 32: Bee, Brooks, Duval, Jim Wells, Live Oak, and McMullen Counties
Region 33: Aransas, Kenedy, Kleberg, Nueces, Refugio, and San Patricio Counties
Region 34: Cameron, Hidalgo, and Willacy Counties

[b] Length measurement includes the total length of areas specifically designated as available for fishing (e.g., piers, barges, bulkheads, and marinas).

Table 24. Percent change in population and residential building permits in the TBIE study area and selected counties, between 1970 and 1977 (U.S. Department of Commerce, Bureau of the Census 1973, 1979; Building Construction in Texas 1971; 1978).

Region and county	Change in population 1970 to 1977 (%)	Change in residential building permits issued 1970 to 1977 (%)
TBIE study area	20.3	82.7
Harris County	22.8	54.5
Galveston County	15.1	211.3
Victoria County	12.7	249.7
Aransas County	24.7	[a]
Bee County	0.4	405.0
Nueces County	5.5	74.8
Cameron County	25.7	59.7
Texas	14.6	N.D.

[a]No building permits issued in 1970, 97 in 1977.

Boating

Swimming and sunbathing

Camping

Pier fishing

Sightseeing and bird watching

Hiking

Amusement parks

Convention facilities

Participation sports: golf, tennis, playing fields

Table 25 indicates the extent to which the counties on the Texas coast are used for recreation purposes. Although not commensurate with the TBIE study area, the seventeen coastal counties included in Table 25 are representative of TBIE area trends. Fishing, swimming, picnicking, and boating are consistently the more popular activities.

Table 25. Current and projected recreation participation in the coastal region[a] for selected years 1968 through 2000 by type of activity (annual activity days) (Texas Parks and Wildlife Department 1975).

Activity[b]	Total resident, non-resident, and out-of-state participation days					
	Current	Rank	1975	Rank	1980	Rank
Boating	3,402,800	4	5,923,600	4	8,404,400	4
Fishing	12,814,900	1	17,780,800	1	21,797,400	2
Skiing	472,400	10	509,200	10	536,300	10
Surfing	1,429,600	6	2,176,400	7	2,827,900	7
Swimming	9,460,100	2	15,894,100	2	23,214,200	1
Camping	3,267,400	5	4,698,600	5	7,294,900	5
Picnicking	4,688,900	3	7,175,100	3	13,541,100	3
Marsh hunting	145,600	12	361,200	11	466,500	11
Sightseeing	860,300	8	1,118,500	9	1,287,300	9
Walking	1,365,500	7	2,186,900	6	3,180,700	6
Hiking	149,900	11	212,400	12	246,600	12
Nature study	713,900	9	1,243,100	8	1,775,600	8
17 coastal county total	38,771,300		59,274,900		84,572,900	
17 coastal county average	2,280,700		3,487,100		4,974,900	

Activity[b]	Total resident, non-resident, and out-of-state participation days			
	1990	Rank	2000	Rank
Boating	12,817,500	4	18,107,600	4
Fishing	31,154,600	2	42,554500	2
Skiing	577,700	11	633,900	11
Surfing	4,331,200	7	6,101,900	7
Swimming	32,812,000	1	46,645,800	1
Camping	9,685,200	5	13,628,800	5
Picnicking	18,712,200	3	27,812,200	3
Marsh hunting	588,200	10	776,900	10
Sightseeing	1,649,100	9	2,080,400	9
Walking	5,487,400	6	8,442,900	6
Hiking	317,700	12	399,200	12
Nature study	3,006,600	8	4,552,400	8
17 coastal county total	121,139,400		170,736,500	
17 coastal county average	7,125,800		10,043,300	

[a]Aransas, Brazoria, Calhoun, Cameron, Chambers, Galveston, Harris, Jackson, Jefferson, Kenedy, Kleberg, Matagorda, Nueces, Orange, Refugio, San Patricio and Willacy Counties.

[b]Totals for each activity include resident and non-resident participation occurring in rural areas. Boating, fishing, skiing, surfing, swimming, picnicking, walking/hiking, and nature study totals include resident and non-resident participation occurring in urban areas. Boating, fishing, swimming, camping, and picnicking totals include out-of-state participation occurring in rural areas.

[c]For each activity, as "current" includes 1968 rural resident and non-resident participation, 1970 rural out-of-state participation, and 1970 urban resident and non-resident participation.

[d]Walking includes walking occurring in rural areas and walking and hiking in urban areas.

The TORP also reports the following 1970 activity expenditures per trip: camping, $145.56; swimming, $128.26; fishing, $58.73; picnicking, $39.90; and boating, $17.67. These figures include both local and non-local trips.

As shown in Table 17, the TBIE recreation/tourism industry is one of considerable economic impact. Unfortunately, disaggregative value data for the activities listed here are not available for recreational fishing in saltwater, which was estimated at $319 million in 1978 (Texas Parks and Wildlife Department 1978).

Data characterizing the number and size of facilities and participation rates are available for individual sites, for the Texas Gulf coast, and for planning regions, but not for each of the counties that comprise these planning regions. The data presented in the TORP reflect observations made in 1968 and published in 1975 (Texas Parks and Wildlife Department 1975). The data file is updated continuously, but data remain too disaggregated to be presented here for the TBIE study area as a whole.

Table 26 shows hunting and fishing license sales in the State for 1955 through 1978. The total of resident hunting, fishing, and combination hunting and fishing licenses is 2,075,798, which represents 16.2% of the 1978 statewide population. Because licenses can be purchased anywhere in the State, and because Texas outdoorsmen have traditionally been willing to travel long distances to pursue fish and game, regional data on licenses have limited usefulness. On the basis of its portion of the statewide population, however, it can be estimated that about $3,729,000 was spent on hunting and fishing licenses in the TBIE study area in 1979-1978.

Table 26. Hunting and fishing license sales in Texas for selected years 1955 through 1978 (Texas Parks and Wildlife Department, Licenses Section 1979).

Class & type	1955-56	1960-61	1965-66	1970-71	1977-78
Class I					
Resident hunting	398,204	491,176	740,349	980,485	590,930
Non-resident hunting	1,423	2,293	4,395	10,421	14,453
Class II					
Non-resident 5-day migratory game bird	923	1,418	2,066	4,339	6,674
Non-resident migratory waterfowl	N.D.	36	N.D.	N.D.	N.D.
Non-resident shooting resort only	N.D.	224	81	85	37

(continued)

Table 26 (concluded).

Class & type	1955-56	1960-61	1965-66	1970-71	1977-78
Non-resident trapper	N.D.	N.D.	N.D.	4	2
Shooting preserve	5,853	8,553	12,317	15,357	11,250
Shooting resort	17	45	87	91	47
Hunting boat	48	30	13	16	27
Fur-bearing animal permit	46	39	33	107	265
Fishing	458,702	873,859	1,018,913	1,495,845	1,036,028
Fish boat	1,392	1,616	1,147	1,081	650
Fish guide	202	262	249	692	517
Resident trapper	6,266	3,575	2,457	2,641	33,156
Resident combination fishing & hunting[a]	0	0	0	0	448,840

[a]Use of combination licenses did not begin until after 1970-71.

There are several points of special interest in Table 26. First, there is a relatively large increase over time in the number of non-resident hunting licenses. It is likely that a considerable portion of this increase is attributable to growing interest in the unusually large white-tailed deer found in the area known as the South Texas brush country. Several counties in the TBIE area are part of the brush country. The large number of non-resident migratory game bird licenses is attributable primarily to the special white-wing dove (Zenaida asiatica) season, which centers in Cameron, Willacy, and Hidalgo Counties.

Other points of interest include the number of fishing guide licenses and the use of licenses in pursuit of saltwater gamefish. Most of the guide licenses are issued to persons offering services on the coast, and these licenses are therefore held by persons working in the TBIE region. Texas requires a regular fishing license for legal pursuit of saltwater fish species or a special three-day saltwater license. The low cost of a Texas fishing license ($4.50/yr) apparently accounts for the lack of controversy over the saltwater license requirement that has surfaced recently in several other Gulf and eastern seaboard states.

Table 27 shows weekend finfish landings by recreational fishermen using boats for various species found in TBIE waters. The spotted seatrout and red drum (redfish) are by far the most sought after species despite the relative importance in terms of poundage of several other fishes.

Table 28 shows landings, catch rates, and changes in fishing pressures for the selected bays of Galveston, Aransas, and Upper Laguna Madre according to the National Marine Fisheries Service. Speckled trout and redfish were chosen for detailed presentation because of their importance as sport species. These bays were selected as representative of those that showed increases (Aransas) and decreases (Galveston, Upper Laguna Madre) in trout and redfish harvest over the period 1974 to 1977. Catch rates were down in Aransas Bay although a large increase in fishing pressure produced an increase in absolute catch volume. Catch

Table 27. Estimated weekend finfish landings by sport fishermen in boats, 1974-1975 and 1976-1977 seasons (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1978).

Species	1974-1975 (1,000 lb)	1976-1977 (1,000 lb)
Spotted seatrout (Cynoscion nebulosus)	1,124.8	772.4
Red drum (Sciaenops ocellata)	272.1	219.9
Black drum (Pogonias cromis)	186.8	209.1
Southern flounder (Paralichthys lethostigma)	132.9	73.8
Sheepshead (Archosargus probatocephalus)	80.3	90.9
Atlantic croaker (Micropogonias undulatus)	303.7	175.1
Sand seatrout (Cynoscion arenarius)	268.8	157.9
Gafftopsail catfish (Bagre marinus)	193.2	86.2
Other	90.1	57.0
Total	2,652.5	1,836.7

rates and volume were down in the Upper Laguna Madre. In Galveston Bay, the total volume decreased, but the catch rate increased. Fishing pressure decreased in Galveston Bay and Upper Laguna Madre and increased in Aransas Bay. These data appear to indicate generally that recreational fishermen pursuing trout and redfish are becoming less successful. The data are not conclusive, however, and serve to emphasize that each bay system is individualistic, a fact that should be kept in mind regarding policy development on fishing regulations.

Table 28. Weekend finfish harvest data, selected bay systems of the TBIE study area, 1974-1975 and 1976-1977 seasons (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1978).

Activity	Galveston		Aransas		Upper Laguna Madre	
	1974-75	1976-77	1974-75	1976-77	1974-75	1976-77
Estimated landings (1,000 lbs)						
Spotted seatrout	281.6	152.7	82.6	90.5	333.5	178.0
Red drum	45.5	36.3	40.2	42.0	46.6	26.2
Bay total	974.6	583.5	169.6	175.9	545.8	252.5
Catch rates (lb/man/hr)						
Spotted seatrout	0.18	0.21	0.30	0.25	0.57	0.46
Red drum	0.03	0.05	0.17	0.11	0.08	0.07
Bay average	0.61	0.78	0.63	0.48	0.93	0.65
Fishing pressure (1,000 man trip hr)	1,606.9	746.6	270.0	365.5	581.1	389.3
Fishing pressure for total TBIE region bays:						
1974-1975	3,616.3					
1976-1977	2,453.8					
% change	32.1					

To offer an example of the order of magnitude by which sport fishing data may differ, the following results of the first segment of a 2-year study are presented, to contrast with the data found in Tables 27 and 28 (Heffernan et al. 1977). These data summaries borrow heavily from the analysis completed by Heffernan et al. (1977).

A creel survey of the catches made by sport anglers in the Galveston Bay area, the San Antonio Bay area, the Aransas Bay area, and the Upper Laguna Madre area was conducted from September 1974 through August 1975. The catch estimates were derived from completed trip interviews (at specified locations within each area) of anglers who used boats, wade-bank areas and lighted piers. Pressure estimates were obtained by roving counters who traveled through each area during 1 of the 2 randomly selected periods on 26 randomly selected days each quarter (3 mo). The "rover" counted the numbers of fishermen at all access areas and the numbers of boat trailers at all boat ramps within the survey area.

According to this survey, the total sport angler harvest for the four bay systems was estimated to be 5,231,000 fishes which weighed 2,172,150 kg (4,827,000 lb). The harvest by bay area was 1,275,300 kg (2,834,000 lb) in Galveston; 187,200 kg (416,000 lb) in San Antonio; 233,550 kg (519,000 lb) in Aransas; and 476,100 kg (1,058,000 lb) in the Upper Laguna Madre. Sport boat fishermen harvested 81.6% of the total sport harvest (by weight), wade-bank anglers caught 13.3%, and lighted pier fishermen caught 5.1%. Total fishing effort for the four survey areas was 7,183,000 man-hours, of which the Galveston Bay area received 4,226,000 man-hours, the San Antonio Bay area 386,000 man-hours, the Aransas Bay area 998,000 man-hours, and the Upper Laguna Madre area, 1,573,000 man-hours.

Sport fishing pressure was greatest during the summer quarter with 3,114,900 man-hours of effort (43.4% of annual total) which produced a harvest of 894,555 kg (1,987,900 lb) of fish or 41.2% of the total sport catch.

The total sport catch for all areas was comprised of 1,009,350 kg (2,243,000 lb) (46.4% of the total sport harvest) of spotted seatrout; 185,400 kg (412,000 lb) (8.5%) of red drum; 140,850 kg (313,000 lb) (6.5%) of black drum; 111,150 kg (247,000 lb) (5.2%) of southern flounder; 95,400 kg (212,000 lb) (4.4%) of sheepshead; 64,800 kg (144,000 lb) (3.0%) of gafftopsail catfish; and 108,900 kg (242,000 lb) (5.0%) of "other" species.

A total of 1,633,600 sport fishing trips was made in the survey areas by an estimated 100,840 individual fishermen. Texas residents comprised over 98% of the total fishermen in each system except the Aransas Bay area where 20.8% of the 16,830 fishermen were non-resident.

There are no secondary data available on game and bird inventories and harvest for the specific TBIE area. TPWD tabulates the data for regions too large for analysis in this paper. White-tailed deer data are presented in Table 29. As indicated in this table, more than 50,000 hunters spend an average of about six days apiece pursuing deer in the TBIE region. Regardless of home location, those hunters are pouring a large amount of "export" cash into the regional economy. Although not as significant as the white-tailed deer hunting industry, the pursuit of migratory ducks, geese, and white-winged doves in the region generates considerable recreation/tourism activity. Duck and goose hunting is predominant in the coastal prairies and marshes of the upper coast, while the white-winged dove is hunted in the Lower Rio Grande Valley.

Table 29. White-tailed deer hunter and harvest data for the TBIE study area, 1978 (Texas Parks and Wildlife Department 1979).

Category	Number
Estimated deer population	249,563
Number of hunters	50,038
Average number of hunting days/hunter	6.16
Total harvest	19,026
Kills/hunter	0.38

THE FUTURE OF RECREATION/TOURISM IN THE TBIE AREA

With this overview of the recreation/tourism industry, the future of the industry may be considered. Because there are several uncontrollable and therefore unpredictable factors, this look at the future will be offered in terms of several differing sets of assumptions.

Uncontrollable Factors

Three elements of the economy that bear directly on the size of the recreation/tourism industry and that are unpredictable are 1) the relationship between disposable income and the propensity to travel; 2) the availability and price of gasoline; and 3) the availability of alternatives to automobile transportation.

Propensity to travel. Despite apparent decreases in available disposable income in recent years, the travel industry continues to be relatively healthy in terms of demand for facilities and services. Certainly, the traveler seeking air reservations, comfortable car-to-car space on the highway, an unhurried restaurant dinner, or a nice sleeping accommodation is discovering that many others are seeking the same things; demand for these services is high. The paucity of data about the relationship between disposable income and services obtained, however, makes an analysis difficult. It is not known whether disposable income will increase or decrease, and there is uncertainty as well with regard to the impact of a marked change on the demand for recreation/tourism facilities and services.

Availability and price of gasoline. It is not possible to predict what the price and quantity of gasoline available to the traveler will be. Much depends on policy decisions that have historically placed the recreation/tourism industry toward the bottom of the priority list in times of serious economic difficulty. The TBIE area is largely dependent on auto travel as the basis for the recreation/tourism industry, and as long as that dependence exists, the economy will be subject to factors in the gasoline market completely outside of local control.

Availability of alternate transportation sources. Alternatives to the automobile for recreational travel in the TBIE area are restricted in terms of volume and accessibility of service. The development of alternatives is subject to policy decisions that cannot be predicted. The probable cost of local development of alternate sources of transportation places the TBIE region in a passive position with regard to its recreation/tourism economy.

Economic Trends: the Key to the Future of Recreation/Tourism

The future of the recreation/tourism industry in the TBIE region will be considered under several possible economic circumstances. These circumstances are based on the following assumptions: 1) an economic status quo; 2) the unavailability of gasoline or alternative transportation options combined with current levels of disposable income; and 3) available transportation but with a sharp decline in disposable income.

Economic status quo. Continued growth of the TBIE recreation/tourism industry can be expected if economic conditions remain essentially unaltered. Reduced gasoline supplies and increased prices have not yet seriously damaged auto-dependent travel to and within the TBIE region. Disposable incomes are such that many families continue to place a high budget priority on recreation/tourism and the accompanying travel.

The socioeconomic characteristics of the TBIE region would continue to reflect a healthy economy and a growing population. But there is concern over environmental impacts of continued growth of the recreation/tourism industry, not only for those occasions of disregard for the environment on the part of the tourist and/or land developer but because of the sheer volume of persons and vehicles involved, and the infrastructure required to meet the demands of the market as well.

Restricted transportation: current levels of disposable income. If transportation is restricted, a mild recession in the TBIE recreation/tourism industry can be expected. Outside of the major population centers, the industry is dependent upon the traveling visitor; there is insufficient local demand for recreation/tourism services to permit continued operation of the hotels, motels, restaurants, and other facilities catering to out-of-town guests.

A continuation of current levels of disposable income offers some hope for counterbalancing the recession expected for the industry through development of greater stability. Families will continue to want to travel in the TBIE area. Instead of the short-duration trips characteristic of the industry at present, visitors would make fewer trips but stay longer. The travel patterns of in-state visitors to the TBIE area (assuming current levels of disposable income) would become more similar to the travel patterns of the "snowbird," although their length of stay would probably be considerably shorter. The extent to which the winter visitor season would continue to flourish in the area is a function of the severity of the gasoline shortage. Gasoline availability would probably have to approach zero before the typical winter visitors would be unable to secure a sufficient supply to drive from the Midwest to the TBIE area and back once a year.

Should the available transportation be restricted severely enough to inhibit Texans and out-of-state visitors from traveling to the TBIE area, it is likely that part of the future population increase in the region would be of persons who would decide to make a permanent change of residence. The year-round opportunity to pursue recreational activities afforded by the pleasant weather and abundant natural resources of the region would attract increasing numbers of permanent residents who prefer the coastal area to that of their current home. Such residence changes would be made predominantly by retired persons not tied to jobs in their old residence locations, resulting in shifts in the TBIE population distribution toward older age groups.

Another aspect of this scenario is the possibility for marked industrial growth. Historically, industrial growth in this country has shown an affinity for coastal or Great Lakes locations. It may well be that restricted personal transportation opportunities would provide yet another impetus to seek permanent locations in attractive coastal areas. The Gulf coast, and thus the TBIE area, is an obvious candidate for growth with any nationwide shifts in industrial development.

Should the industrial development possibility of this scenario occur, the potential for degradation of the environment in the TBIE area would increase sharply. The consequences of industrial growth in the region thus far have been less serious from an environmental point of view than the projected impacts from the potentially rapid and extensive development, which would present a new set of circumstances for which the region would seem currently unprepared.

Available transportation: declining disposable income. Should inflation continue to decrease disposable income, a point would eventually be reached at which recreation/tourism would lose a position of priority in the family budget. In that case, regardless of the availability of transportation, the TBIE area would suffer a severe recreation/tourism recession. There are, however, two points of relative optimism for the industry under this scenario.

First, because a coastal vacation in the TBIE area tends to be a bargain in terms of price by comparison with similar locations in other states, the area would be the least and last affected. Second, there is the opportunity for a shift in the nature of the industry from the short duration trip (several nights' stay) to the one-day trip to a nearby recreation facility. Provision of recreation/tourism facilities in proximity to much of the population in the TBIE area offers a challenge to the traditional focus of the industry, but an obvious opportunity as well.

Should the recreation/tourism recession be severe, persons displaced from jobs in the industry would seek different types of employment. The TBIE area could then be expected to undergo a population shift from smaller tourist-oriented communities to major population and manufacturing centers. Should the recession be relatively mild, few population shifts would occur, but the unemployment rate could be expected to climb. Many jobs in the recreation/tourism industry require few skills. Rising unemployment in the industry would thus release persons not readily adaptable to other forms of work into an already tight job market.

Environmental concerns would not be markedly different under this scenario than under the status quo assumptions.

ISSUES OF RECREATION/TOURISM CONCERN

Major issues of the TBIE recreation/tourism industry concern aspects of local and State policy, local and State practice in the application of policy, and Federal policy.

Local and State Policy

There is no general policy identifiable at either the local or State level with regard to the role of the recreation/tourism industry in the economy. Policy impacts are felt in the industry as residual effects of decisions made concerning other aspects of the economy. State activities that address the impacts of the recreation/tourism industry are Coastal Zone Management, the Dune Protection Act, and the Coastal Wetlands Acquisition Act. The Texas Coastal Management Program is administered by the Governor's Office, while the Wetlands and Dune Protection acts are administered by the TGLO. In both cases, the TGLO is pursuing identification and classification of environmentally critical areas as required by State law and for the purposes of the Federal Coastal Zone Management Act. Two concerns focusing directly on the industry in the TBIE area are (1) recreational access versus environmental protection; and (2) the complexity of the regulatory framework.

Recreational access vs. environmental protection. The increasing demand for recreation/tourism facilities and services in the TBIE area poses particular problems for that part of the industry dealing with outdoor activities.

Increasing amounts of park space are required to meet the needs of day visitors, campers, hikers, and outdoor enthusiasts. In providing that space, State and local officials are faced with the problem of environmental degradation to the extent that a site is altered from its natural state. Yet, in order to meet the demand, the natural state must be altered if the site is to be anything other than a wilderness area. In most cases development must occur because a wilderness site would satisfy only a very small part of the demand for services. Decisionmakers are caught between the need for facilities and the need to preserve the environment, as illustrated by the following two examples.

Matagorda Island in the San Antonio and Espiritu Santo bay systems was formerly a military gunnery range. A large section of the island has been released by the military and, pending a final determination of jurisdiction between the State of Texas and the Federal government, is available for potential recreational development. The island teems with wildlife, including deer, coyotes, turkeys, and numerous coastal birds. The waters of the estuarine system support large populations of gamefish and migratory waterfowl. The Gulf beaches are clean and uncluttered.

Because access to the island is by boat only, current use of the resources is restricted to the relatively small proportion of the population possessing the time and equipment to travel to the vicinity by water. The dilemma is whether to preserve the natural state of the island, thereby severely restricting the number of users, or to open the island to development through construction of a bridge over a narrow section of the flanking intracoastal canal or through operation of a major ferry service. The development option would meet the demand for outdoor recreational facilities and services at a potentially severe cost to an essentially pristine environment. A set of objectives and goals should be established by which to weigh the various options.

The case of the Padre Island National Seashore is even more illustrative of the access vs. protection issue. Development now extends only as far as the highway pavement at each end of the National Seashore. In between are many miles of unspoiled beaches and dunes, accessible only to backpackers and a very few who travel by highly specialized four-wheel drive vehicles, which are destroying many of the dunes. Inaccessibility protects the natural environment. It would be a simple matter to extend the highway all along the National Seashore, spanning the Port Mansfield Channel, as a means of opening the island to visitors. Again, demand pressures would be addressed, but the environment would suffer, and storm protection afforded by the dunes could be lost.

Complexity of the regulatory framework. Commercial and sportfishing regulations are administered by the TPWD. Policies with regard to oil and gas exploration, transportation development (for example, a new deepwater port), and allocation of economic resources (such as gasoline in time of supply shortage) are developed in the political and industrial arenas. Seldom is there joint effort at development of mutually beneficial policy. The pressures for economic development and the politically popular jobs that such development creates are strong deterrents to application of environmental protection policy.

An example is the proposed deepwater port development near Harbor Island in the Port Aransas, Aransas Pass, and Rockport area. The significant economic implications of the port are obvious: new jobs and revenues of considerable magnitude in the TBIE area. The Harbor Island area is also one of the more fertile and productive shallow water nursery grounds of the entire Texas coast. The deepwater port would severely alter tidal flows and water depths in the nursery grounds and would, therefore, cause serious damage to the estuarine environment.

The problem is that there is no easy solution to the economic versus environmental controversy. Because of the nature of much of the TBIE area as a sensitive if not fragile environment, the decisions on development versus environmental protection are especially critical.

Research conducted in Chambers County during the mid-1970's serves further to illustrate the problem. The county has both a strong growth potential in terms of industrial development and a large amount of environmentally sensitive area. Research into the practice and applicability of development controls and regulations revealed that the agencies involved are so numerous as to be undeterminable. Discussions with agency personnel revealed the regulatory framework to be so complex that some interviewees admitted they knew of no certain path through the development regulations maze (Bilich et al. 1976).

Regulatory Practice

The practical applications of the complex set of regulations governing the recreation/tourism industry are of particular concern in the TBIE area.

Limited use of park facilities. Demand for park facilities and services reaches points well beyond capacity on several occasions each year. The TPWD has instituted a reservations system for some parks that insures that those facilities will not operate at levels beyond capacity. The reservations system helps to protect the environment, but simultaneously excludes many families whose taxes pay for development of the very parks from which they receive no benefit without a reservation. A critical question facing the TPWD is whether its prime function is to maximize use or to minimize adverse environmental impact. The TBIE area, because of its significant recreation/tourism orientation, is perhaps more affected by the trade-offs involved than are other parts of the State.

Commercial vs. recreational fishing. A marked decline in both sportfishing catches and commercial catches of speckled trout and redfish in the TBIE bays over the past 5 years has generated a heated controversy. Each side blames the other for the demise of these popular fish, and the State Legislature and the TPWD are caught in the middle in a regulatory battle.

The TPWD has the authority to set bag and possession limits for both commercial fishing and sportfishing, as well as the authority to close certain parts of bays to commercial and sport fishing. Legislation has recently been passed dealing with licensing, penalties for non-compliance with the regulations, and regulation of the total catch of redfish and speckled trout on a bay-by-bay basis. These regulations also impose bag and size limits on both sport and commercial fishermen.

The redfish and speckled trout are far more important to the TBIE economy as recreation/tourism draws than they are as elements in the food production sector of the economy. Yet severe restrictions on commercial fishing for the species could seriously alter the livelihood of approximately 200 to 300 commercial finfishermen. Additionally, consumers would no longer be able to purchase Texas-caught trout and redfish in seafood and grocery markets. Recent achievements in artificial spawning and raising of speckled trout and redfish give rise to the hope of increasing the numbers of fish through aquaculture as a solution to the problem.

Innovative land use measures. There have been few attempts at imaginative ways to solve the controversy generated by development pressures and the desire to protect the environment. As demands for recreation/tourism development in the TBIE region increase, there are increased pressures for development.

One community in the TBIE region has implemented a development control plan that recognizes the need for both development and protection. The comprehensive plan and zoning ordinance for Galveston Island is concerned with dune structure, erosion, vegetation, setback, height, and design requirements for construction in beach areas. It also restricts paths of access, both vehicular and on foot, to the beach. Although restrictive concerning the development of recreation/tourism facilities, the plan also offers solutions. Special parking and access areas are provided for public use, minimizing environmental impact while meeting the demands for beach facilities. Guidelines are provided for construction design which is attractive and functional, but which also meets all of the requirements of building on the beach areas. Only recently activated, the success of the plan for Galveston's development is uncertain, but the plan itself is an approach to solving the problem which plagues much of the TBIE recreation/tourism industry.

Additionally, the city of Port Aransas has adopted a zoning ordinance and permitting process that requires review by Nueces County prior to any construction affecting dune areas. Nueces County officials forward dune permit applications to the TGLO to make use of evaluative expertise not available at the local level. As a result, development proposals on Mustang Island receive intensive scrutiny from the viewpoint of environmental protection.

Recreation/tourism priority in the local budget. Persons in the community whose livelihoods do not depend upon the existence of the recreation/tourism industry frequently oppose inclusion of funds for the promotion and/or regulation of the industry in public budgets. To the extent that local bias against the recreation/tourism industry persists in some TBIE communities, it will be difficult to plan and implement measures for effective control of development. Because high demand will encourage development to occur, a community lacking the benefit of public attention and dedication to quality development may suffer undesirable results.

Federal Policy Unknowns

The economic and energy policies of the Federal government will determine to a great degree the extent to which the scenarios discussed will be applicable. Those policies are essentially out of the hands of State officials and are almost surely beyond the influence of TBIE local officials. Judging from such practices as weekend closing of gasoline service stations, Federal policy is not likely to attempt protection of the recreation/tourism industry during difficult economic periods. Most proposals for rationing and schedule cutbacks focus on the automobile, leaving alternative forms of transportation largely untouched. This is an especially critical factor for the TBIE area and its automobile based recreation/tourism industry.

The uncertainty concerning changes that might occur places the recreation/tourism developer in an uncomfortable position. As a result, the growth of the industry in the TBIE area suffers from hesitancy on the part of both public and private developers. There is a tendency to achieve a more favorable risk versus return relationship required for development by doing things in a less than optimal fashion. Some recent developments in the TBIE area have been of questionable quality because developers were unwilling to risk the extra investment required for sound, environmentally acceptable projects against the possibility that consumers might not be willing to pay the extra cost.

INFORMATION GAPS

The lack of information that inhibits studies of the recreation/tourism industry has been emphasized. Data available for the TBIE area parallel those available on a general basis throughout the country. There are some specific types of information to be considered that would be particularly helpful in analysis of the TBIE area.

Data Requiring Analytical Research

Two research efforts would be most useful in TBIE recreation/tourism analysis. These concern the propensity to continue to travel and the economic value of recreation/tourism activities.

Propensities to travel. If policies remain less than clearly defined with regard to energy, transportation, and the environment, with resultant effects on disposable income, families face difficult decisions concerning expenditures. Knowledge of the propensity to continue to travel, and thus to participate in the recreation/tourism industry when changes in the economy occur, would remove some of the uncertainties that affect the industry. Aggregate research at the national level is of little value to the TBIE recreation/tourism industry. The characteristics of the region as exemplified by automobile dependency and the winter visitor phenomenon leads to the conclusion that decisions with regard to travel in the region are different from such decisions in other parts of the country. Primary research focused on propensities to travel in the TBIE area is required.

Economic value of recreation/tourism activities. The continuing controversy over the value of a recreation/tourism activity versus another activity (commercial, industrial, or residential) or a preservation activity is difficult to resolve without placing an economic value on recreation/tourism activities. For example, a regulation that prevents fishermen from catching redfish for a living can be evaluated in terms of jobs lost because reasonably accurate data are available on the number of jobs involved (200 to 300 in Texas). By comparison, a regulation that prevents sportfishing for redfish cannot be evaluated in terms of jobs lost because there are no reliable data addressing the relationship between recreational fishing for redfish and jobs. As a result, any economic comparison of the value of the redfish to commercial and sporting interests cannot be made. This prevents the development of a comprehensive redfish preservation policy on an economic basis.

Reasonably reliable estimates of the value of the recreation/tourism industry as a whole are available (See Table 17). Unfortunately, such data cannot, for example, be disaggregated into value for sunbathing, birdwatching, sportfishing, or deer hunting. The necessary primary data have not been collected to develop the expenditure and multiplier data required to accomplish the desired degree of disaggregation.

Data Requiring Collective Research

Data concerning the TBIE recreation/tourism industry are clearly limited. Below are types of information that would be useful in further analysis of the industry. All must be specific to the TBIE area.

Primary data. The following data must be collected through survey, either census or sample:

a. Length of stay and daily expenditures by type of expenditure and type of fish or wildlife for hunters and fishermen

b. Length of stay and daily expenditures by type of expenditure for other travelers, including park and refuge visitation and visitor activities

c. Number of lodging accommodations by county

d. Number of winter visitors ("snowbirds") by county

e. Number of amusement parks by county

f. Number of recreation vehicle parks by county

g. Number of vacation homes by county

h. Distance traveled and daily expenditures for intrastate travelers

i. Volume of intrastate travel by transportation modes other than auto.

Secondary data. These are data already collected but not aggregated in a form suitable for recreation/tourism analysis at the regional level:

a. Park acreage and facilities by county - available from Texas Parks and Wildlife Department records.

b. Employment by county by 4-digit SIC code - available from the records of the Texas Employment Commission.

c. Sales and tax receipts by county by 4-digit SIC code - available from the State Comptroller's Office.

RECREATION/TOURISM INDUSTRY: LITERATURE CITED

Bilich, M. W.; Darbyshire, W. G., Jr.; Pearce, C. L. Land development beyond city limits--a monitoring of problems and procedures in Chambers County, Texas. Austin, TX: Univ. of Texas at Austin; June 1976. 93 p. Unpublished working paper.

Building construction in Texas XLV(2); 1971.

Building construction in Texas LII(3); 1978.

Bureau of Business and Economic Research, Pan American Univ. A survey of winter visitors in the lower Rio Grande Valley: 1977. Edinburg, TX: Bureau of Business and Economic Research, Pan American Univ.; April 1977; 40 p. Available from: Bureau of Business and Economic Research, Pan American Univ., Edinburg, TX.

Bureau of Business and Economic Research, Pan American Univ. A survey of winter visitors in the lower Rio Grande Valley. 1978. Edinburg, TX: Bureau of Business and Economic Research, Pan American Univ.; April 1978; 28 p. Available from: Bureau of Business and Economic Research, Pan American Univ., Edinburg, TX.

Bureau of Business and Economic Research, Pan American Univ. A survey of winter Texans in the lower Rio Grande Valley: 1978-1979. Edinburg, TX: Bureau of Business and Economic Research, Pan American Univ.; 1979; 35 p. Available from Bureau of Business and Economic Research, Pan American Univ., Edinburg, TX.

Crompton, J. L.; Beardsley, D. D.; Ditton, R. B. Marinas on the Texas Gulf coast. College Station, TX: The Texas Agricultural Experiment Station, Texas A & M Univ.; December 1976; 35 p. Available from: The Texas Agricultural Experiment Station, Texas A&M Univ.

Ditton, R.B. The economic impacts of recreational boat fishing in the Houston-Galveston area of the Texas coast. College Station, TX: Texas Agricultural Experiment Station, Texas A & M Univ. September 1979 (draft).

Ditton, R.B.; Stephens, M. Coastal recreation: a handbook for planners and managers. Washington DC: U. S. Dept. of Commerce, Office of Coastal Zone Management, Washington, DC. January 1976.

Ditton, R.B.; Jarman, R.N.; Woods, S.A. An analysis of the charter boat fishing industry on the Texas Gulf coast. Marine Fisheries Review; 40(8): 1-7; 1978.

Ditton, R.B.; Alling, C.E.; Beardsley, D.D.; et al. Barrier islands on the Texas coast: existing and future recreational use and development. College Station, TX: Texas A&M Univ., August 1979.

Heffernan, T.L.; Green, A.W.; McEachron, L.W.; Weixelman, M.G.; Hammerschmidt, P.C.; Harrington, R.A. Survey of finfish harvest in selected Texas bays. 1977; 116 p.; 5 appendices. Available from: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, DC.

Ingram, B.I. Economic inventory of recreation and tourism within the Texas coastal zone. College Station, TX: Texas Engineering Experiment Station, Texas A & M Univ., August 1973.

Kahn, T. Employment in the Texas tourist industry: 1975. Unpublished working paper. Austin, TX: Univ. of Texas at Austin; 1975.

Kahn, T. Measuring the impact of the tourist industry: a hard data deficit. Marketing travel and tourism: seventh annual conference proceedings. The Travel Research Association, Boca Raton, FL; 1976 June 20-23.

Kahn, T. Employment in the Texas tourist industry: 1979. Unpublished working paper. Austin, TX: Univ. of Texas at Austin; 1979.

Texas Dept. of Highways and Public Transportation. 1978 Texas visitor survey. Austin, TX: Texas Dept. of Highways and Public Transportation; 1979; 34 p. Available from: Texas Dept. of Highways and Public Transportation, Austin, TX.

Texas Parks and Wildlife Dept. Texas outdoor recreation plan. December 1975; 10 vol. Available from: Texas Parks and Wildlife Dept., Austin, TX.

Texas Parks and Wildlife Dept. Coastal fisheries plans 1978-1979; 1980-1981. Texas Parks and Wildlife Dept.; 1978; 44 p.

Texas Parks and Wildlife Dept. Texas big game investigations. Job no. 4. Austin, TX: Texas Parks and Wildlife Dept.; 1979; 90 p. Available from: Texas Parks and Wildlife Dept., Austin, TX.

Texas Parks and Wildlife Dept., Comprehensive Planning Branch. Unpublished parks data. Austin, TX; 1979.

Texas Parks and Wildlife Dept., Licenses Section. Unpublished license sales data, 1979. Austin, TX.

U.S. Dept. of Commerce. Regional employment by industry: 1940-1970. Washington, DC: U.S. Government Printing Office; 1975. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of population: 1970. Vol. I, part 45. Washington, DC: U.S. Government Printing Office; 1973. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Current population reports. Series p-25, no. 792. Washington, DC: U.S. Government Printing Office; 1979. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of Economic Analysis, Regional Economic Information System. Unpublished estimates of employment; 1979; Washington, DC.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Survey of finfish harvest in Texas bays. St. Petersburg, FL: U.S. Dept. of Commerce, National Oceanic and Atmospheric

Administration, National Marine Fisheries Service; 1978; 81 p. Available from: U.S. Dept. of Commerce, National Oceanic and Atmospheric Adminstration, National Marine Fisheries Service, St. Petersburg, FL.

U.S. Travel Data Center. 1972 National travel expenditure study: summary report. Washington, DC: U.S. Travel Data Center, 1973. Available from: U.S. Travel Data Center, Washington, DC.

U.S. Travel Data Center. 1973 National travel expenditure study: summary report. Washington, DC: U.S. Travel Data Center, 1974. Available from: U.S. Travel Data Center, Washington, DC.

U.S. Travel Data Center. 1974 National travel expenditure study: summary report. Washington, DC: U.S. Travel Data Center, 1975. Available from: U.S. Travel Data Center, Washington, DC.

U.S. Travel Data Center. 1975 National travel expenditure study: summary report. Washington, DC: U.S. Travel Data Center, 1976. Available from: U.S. Travel Data Center, Washington, DC.

U.S. Travel Data Center. 1976 National travel expenditure study: summary report. Washington, DC: U.S. Travel Data Center, 1977. Available from: U.S. Travel Data Center, Washington, DC.

U.S. Travel Data Center. 1977 National travel expenditure study: summary report. Washington, DC: U.S. Travel Data Center, 1978. Available from: U.S. Travel Data Center, Washington, DC.

COMMERCIAL FISHING

INTRODUCTION

Socioeconomic considerations inform many of the natural resource public management issues in the TBIE area. These considerations will become more important as diverse demands for multiple use of the Texas coastal area increase. The calculation of net economic gains and losses for alternative natural resource management options is increasing in popularity and use at the Federal, State, and local government levels.

Historically, TBIE area commercial fishing management alternatives have been based on biological criteria. While such criteria are still very important, a greater understanding of the socioeconomic characteristics of the Texas commercial fishing industry is in order. Such an understanding could provide additional insight in TBIE multiple-use policy deliberations. The purpose of this chapter is to describe some of the major socioeconomic characteristics of commercial fishing in the TBIE area.

GENERAL OVERVIEW OF TBIE COMMERCIAL FISHING

The most productive TBIE area fish habitats constitute only a small portion of the total land area. Salt marsh accounts for 1%; brackish to fresh marsh, 2.2%; fresh marsh, 0.8%; and marine grassflats, 0.7%. These habitats are relatively scarce and are subject to changes caused by development activities (Kemp 1979). Estuaries are important spawning areas and nursery grounds for the lifestages of a number of commercial species of finfish and shellfish. Estuaries are especially productive because sediments and nutrients from freshwater inflows and from marine sources support an abundance of filter and deposit feeders (Odum 1973). Bryan (1973) estimated that the total annual commercial value of biological products derived from the Texas estuarine complex amounts to approximately $110,433,000. For the 135,000-ha (333,000-ac) estuary complex, this commercial value translates to an investment value of $16,461/ha ($6,632/ac) in fisheries related values alone, based on a 5% annual return rate.

Most of the fish species that are commercially important are estuarine dependent during some stage of their life cycle. Human activities, however, place diverse demands on the Texas coast: waste sink, recreation, transportation, oil and minerals development, urban and industrial development, agriculture, and commercial and sport fishing, to name a few.

Texas commercial fishermen utilize all of the major coastal areas: estuaries and bays, the near-shore margin and the offshore portion of the Gulf. The species of major economic importance include shrimp (Penaeus spp.), American oyster (Crassostrea virginica), blue crab (Callinectes sapidus), red drum (Sciaenops ocellata), spotted seatrout (Cynoscion nebulosus), black drum (Pogonias cromis), flounder (Paralichthys spp.), and Gulf menhaden (Brevoortia patronus). Other species also have economic significance: cobia (Rachycentron canadum), Atlantic croaker (Micropogonias undulatus), striped mullet (Mugil cephalus), Florida pompano (Trachinotus carolinus), and sheepshead (Archosargus probatocephalus) (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1967 through 1979). (Detailed information on catch and value trends for all are contained in the Data Appendix volume.)

Employment statistics in commercial fishing are difficult to ascertain because of reporting practices. Fishing employment is reported in "County Business Patterns" at a level aggregated with agriculture and forestry. Some employment data are available for the processing and wholesale seafood trade sector in Texas. In 1976, total Texas employment in fish processing and wholesale seafood trade was 2,363 for average employment and 3,260 for seasonal employment in 139 establishments. In 1977, the number of establishments remained the same, while the average number of full-time employees was 2,378 and the number of seasonal employees was 3,997 (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979).

Wholesale and retail income reported for all commercial fishery landings in Texas increased by 325% between 1965 and 1977, from $24.8 million in 1965 to $105.4 million in 1977 (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979). It is impossible to differentiate wholesale and retail income from commercial fisheries in the TBIE area because many enterprises are vertically integrated and incorporate aspects of both economic subsectors. These figures may understate the actual volume of business because many financial transactions in fishing are carried out on a cash basis. Prices for all species of commercial fish also increased during this period. Economic estimates have been calculated for the Texas shrimp fishing industry for 1971 (Warren and Griffin 1978). For the purposes of comparison, the Texas A & M University investigators aggregated communities into regions. The regions derived in this manner do not correspond to regional council of governments jurisdictions that provide planning areas for this report. Localized purchases of goods and services were estimated to have been $37.6 million in the Brownsville-Aransas region and $23.6 million in the Port Lavaca-Galveston region.

The economic effect of the shrimp industry's $63.9 million of output for the same period was estimated to have been $197.1 million, or a multiplier of 3.1 for Texas. A multiplier of 3.1 indicates that a one dollar output in the shrimp industry generates $3.10 output in other sectors of the Texas economy. Localized impacts were estimated to have been $92.5 million with a multiplier of 2.5 in the Brownsville-Aransas region and $55.9 million with a multiplier of 2.3 in the Port Lavaca-Galveston region (Warren and Griffin 1978).

Sales of commercial fishing licenses along the Texas coast increased by 245% from 1955 to 1979, with sales of 10,382 in 1955 and 35,826 in 1977. Commercial fishing boat licenses are required by anyone, resident or non-resident, who catches fishes, oysters, or other edible aquatic products from State waters for the purposes of sale, barter, or exchange (Texas Parks and Wildlife Department, Licenses Section 1980). Sales of boat licenses remained relatively constant over the same period: 1,682 in 1955 and 1,726 in 1979. Commercial Gulf shrimp boat license sales increased 73%, from 1,947 in 1960 to 3,364 in 1979. Commercial bay shrimp boat licenses increased by 125% over the 1965 level of 1,969 to 4,444 in 1979 (Texas Parks and Wildlife Department, Licenses Section 1980).

The industry is marked, however, by declines in some categories of licenses; namely, oyster power dredge, wholesale fish dealers, truck and retail fish dealers. It appears that there has been an increase in units in the capture side of the fishing industry, but a decline in processing and marketing probably due to consolidation of dealers.

A tally of Texas fish and seafood processors in 1977 (Bureau of Business Research 1978) identified the following pattern. Brazoria County had 1 processor; Calhoun County, 3; Cameron County, 11; Chambers County, 1; Galveston County, 4; Hidalgo County, 1; Matagorda County, 1; Nueces County, 1; plus 4 processors that were not located within the coastal area.

SHELLFISHES

From the standpoint of both sales and volume, the production of shellfish overwhelms all other commercial fishing in Texas. In 1978, shrimp, blue crab, and oysters accounted for about 95% of the total fish landings of 44.8 million kg (98.7 million lb) and 98% of the total value of $147,865,782. Shrimp accounted for 85.2% of the volume and 95.3% of the value; blue crabs for 7.6% of the volume and 1.4% of the value; and oysters for 1.9% of the volume and 1.5% of the value.

Shrimp

Three commercially important species of shrimp are found in Texas waters: brown shrimp (Penaeus aztecus), white shrimp (P. setiferus) and pink shrimp (P. duorarum). Brown shrimp is the dominant species in landings.

Shrimp in general have four distinct phases in their life cycle: planktonic larval, post-larval, juvenile, and adult. Adult brown shrimp spawn in the open Gulf waters. Spring and early summer are the spawning periods for adults living at depths greater than 18.3 m (10 fathoms). Scientists have also observed that adults living at depths of 46 to 110 m (25 to 60 fathoms) have a tendency to spawn continuously but with peak spawning periods in the late fall and mid-to-late spring (Renfro and Brusher 1965).

Adult female white shrimp spawn at depths of 7 to 31 m (4 to 17 fathoms) in the Gulf throughout spring, summer, and fall (Lindner and Anderson 1965, Renfro and Brusher 1965). Pink shrimp spawn year round at depths of 22 to 48 m (12 to 26 fathoms) with peak spawning periods through spring, summer and fall (Jones et al. 1964).

During the postlarval stage, all three species migrate to the nearshore areas of estuaries and become benthic dwellers. It has been found that the peak postlarval migration of brown shrimp to Galveston Bay occurs in March through mid-April. Postlarval white shrimp migrate to bays and estuaries in Texas from May through October (Baxter and Renfro 1967). Postlarval pink shrimp have a peak migration to the bays and estuaries in August and September (Copeland and Truitt 1966).

The juvenile shrimp seek a substrate of mud that contains a plentiful supply of decaying organic material (Jones 1973). The growth rate in this nutrient-rich environment is rapid. Predation of shrimp in this stage of the life cycle by such finfish species as speckled trout, redfish, and other carnivorous species is intense (Farfante 1969, Gunter 1945, Van Lopik et al. 1979).

Postlarval shrimp are most critically influenced by salinity and temperature. Both influence the size of the habitat to support these juveniles as well as the postlarval rates of growth (Ford and St. Amant 1971). Young brown shrimp survive a salinity range from 8.5 to 42.5 parts per thousand (ppt). The range of salinity that can be tolerated depends on the size of the shrimp, with postlarval shrimp having a higher salinity tolerance than juveniles (Venkataramiah et al. 1974). As the postlarval shrimp grow, they begin to migrate into deeper open water. Brown shrimp, for example, have a peak movement toward open waters during the months of May through August. There is an association between this seaward movement and full moon periods. The resulting spring tides and faster currents trigger seaward migration (Copeland 1965, Trent 1967). Juveniles, or sub-adults, migrate southward along the Texas coast as they move seaward into deeper waters (Gunter 1945). Depending on age, size, and food source, the preferred substrate ranges from mud to silt to sand.

The harvest of brown shrimp begins in the estuaries in May and historical data indicate that the shrimp size is greater than 148 tails/kg (67 tails/lb). At offshore depths of 20 to 37 m (11 to 20 fathoms), the prevalent size is 68 to 88 tails/kg (31 to 40 tails/lb). At a depth of 29-37 m (16-20 fathoms), in September, the catch is predominantly 57 to 66 tails/kg (26 to 30 tails/lb). During January to April, the fishery is concentrated in the open Gulf at depths of 38-73 m (21-40 fathoms) and the tail count per kilogram is less than 46 (21/lb) (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1967 through 1979).

The Texas shrimp fishery became economically important between 1920 and 1948. Throughout this period, the fishery was based predominately in nearshore or inland waters and the catch was marketed as dried shrimp. During the 1950's, the discovery of brown shrimp concentrations off the Texas coast provided a stimulus for growth in offshore shrimp fishing in the State. The older boats were usually open skiffs ranging in size up to 7.6 m (25 ft). Although powered by inboard engines, these boats were too small to exploit the offshore brown shrimp. Larger diesel powered wooden trawlers capable of towing a single 24 to 30.5 m (80 to 100 ft) wide otter trawl were developed. During the 1960's, large vessels were built of steel and powered by 300 to 400 horsepower engines capable of towing double 15 to 24 m (50 to 80 ft) otter trawls. Today, the Texas commercial shrimp fishing industry embraces two distinct elements: relatively large vessels in offshore fishery and smaller vessels for the inshore fishery. During the 1978-1979 shrimp season, 3,364 commercial Gulf shrimp boat licenses were issued--an increase of 73% from the 1960-61 season when 1,947 licenses were issued (Texas Parks and Wildlife Department, Licenses Section 1980). By way of comparison, 4,444 commercial bay shrimp boat licenses were issued in 1978-1979, an increase of 125% over the 1965-1966 level. Table 30 describes the revenues derived by the State of Texas from shrimp fishing license sales and severance taxes for the period 1973 through 1977.

In 1960, the average capacity per Gulf shrimp vessel was 37.5 mt (41.3 t). By 1975, the average capacity had increased to 58 mt (64 t). The cost of vessels increased dramatically. In 1971, a new 16-to 20-m (53-to 65-ft) wood and steel vessel averaged $57,000. By 1977, the average 21-m (68-ft) wooden vessel cost $147,000 and the average steel vessel of the same size cost $195,000. A 20-to 22-m (66-to 72-ft) vessel of wood and steel averaged $76,000 in 1971, and by 1977, a 22-m (73-ft) wooden vessel averaged $164,000, and a steel one of the same size, $220,000 (Warren and Griffin 1978).

Resident vessel shrimpers are the people employed full-time on shrimp vessels and boats. Total full-time employment varied little from 1958 to 1975. The early 1970's were marked by sizeable increases in employment in Texas (Table 31) but that may be due, in large part, to increases in the average vessel price for shrimp.

Table 30. Revenue to Texas from severance taxes and the sale of shrimp fishing licenses 1973 through 1977 (Texas Parks and Wildlife Department, Licenses Section 1980).

Year	Revenue
1973	$644,781
1974	969,899
1975	887,768
1976	845,556
1977	881,085

Table 31. Resident vessel shrimpers for the Gulf of Mexico and for Texas, 1958 through 1975 (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979).

Year	Gulf	Texas
1958	8,171	4,592
1959	8,225	4,222
1960	7,849	4,142
1961	7,186	4,268
1962	6,661	3,406
1963	7,252	3,824
1964	7,121	3,749
1965	7,223	3,657
1966	7,466	3,787
1967	8,219	4,723
1968	8,851	4,932
1969	9,266	4,975
1970	9,386	4,737
1971	9,042	5,247
1972	9,534	5,264
1973	10,573	6,312
1974	9,733	5,415
1975[a]	9,359	4,751

[a]Estimate.

Considering the landings and value of shrimp at Texas ports from Texas waters from 1965 to 1977, it appears that landings have reflected natural variation in availability of the resource and the value of those landings has generally steadily increased (Figure 7). The general trend in place of capture is an increase in the proportion of shrimp caught in the Texas Gulf as compared to the catch in the Texas bay systems (Table 32). In 1965, approximately 53% of the weight of the catch was in the Gulf. By 1977, that figure had increased to approximately 82%.

Average value of shrimp landed at Texas ports from Texas waters was \$0.55/kg (\$0.25/lb) in 1965. The average value per kilogram had increased to \$2.93 (\$1.33/lb) by 1977 (Table 33). Texas, which averages 46% of the value of all northern Gulf of Mexico landings, consistently has the highest vessel shrimp prices in the Gulf of Mexico (Van Lopik et al. 1979).

The allocation of the revenues from shrimp fishing can have many variations. Inshore vessels typically do not divide the revenues, but share expenses of fishing and the net returns. The limited number of offshore vessels that are owned by the operator typically operate on a share basis with the vessel receiving a share to cover fuel, ice, and operating expenses. Offshore vessels not owned by the operator have another allocation arrangement. The captain and crew share between 30% and 40% of the net revenues, less a share of the ice, fuel, and operating expenses (Van Lopik et al. 1979).

<u>The shrimp processing industry</u>. The relationship between the vessel owner and the dockside dealer also has many variations, ranging from no formal relationship to one in which the dockside dealer may advance operating expenses for the vessel. The marketing of shrimp landed in Texas can range from shrimp vessel operators selling directly to the consumer or to many processors, jobbers and wholesalers (Figure 8).

A review of Texas shrimp products and their wholesale dollar values as reported in 1975 showed that 39.6% were sold raw headless, 23.7% were peeled and deveined, and 23.9% were breaded. The remaining 12.8% cannot be accounted for in the data (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1977). The number of fish processing plants located in Texas declined from 88 in 1970 to 55 in 1976, and the yearly average employment decreased from 2,978 in 1970 to 1,720 in 1976. No data are readily available for the number of employees that process shrimp, but from 1978 to 1979 the State of Texas issued 28 shrimp house operators' licenses (Texas Parks and Wildlife Department, Licenses Section 1980). The absence of data precludes observations concerning excess processing capacity or over-capitalization.

Commercial bait-fishing is an element in the Texas shrimp fishing industry that also deserves attention. In 1978, 1,500 commercial bait-shrimp boat licenses were issued, and it has been estimated by the National Marine Fisheries Service that approximately 1.06 million kg (2.34 million lb) of dead and live bait shrimp with a value of \$6.79 million were harvested that year. These figures provide an average price of \$6.40/kg (\$2.90/lb) for bait shrimp and an average revenue per license of \$4,527.

Commercial shrimp fishing is not a major contributor to employment in Texas coastal counties (Van Lopik et al. 1979). At its peak, however, the shrimp industry could have contributed as much as 25% to the employment profile of some Texas coastal counties.

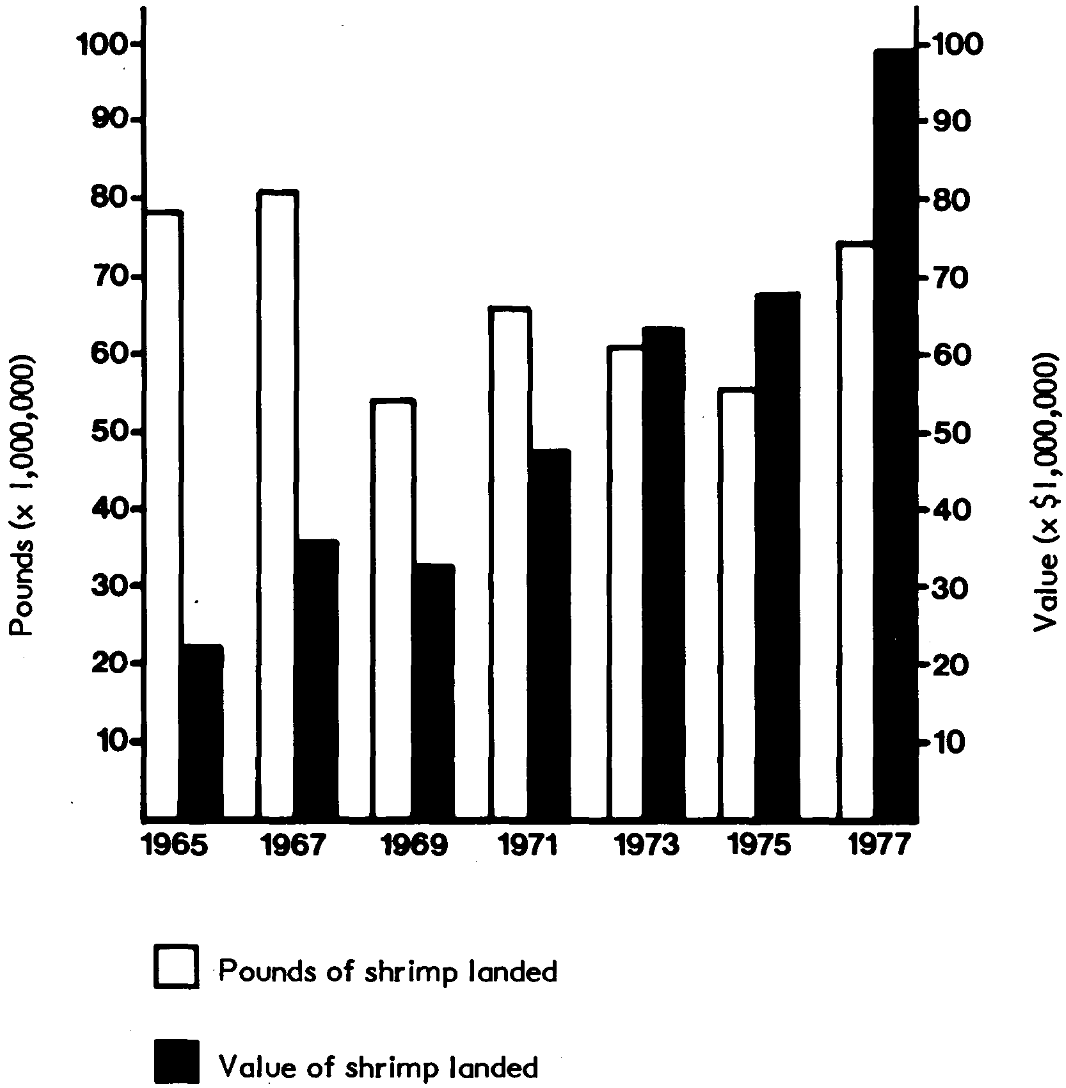


Figure 7. Landings and value of shrimp at Texas ports from Texas waters for selected years 1965 through 1977 (U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979).

Table 32. Texas Gulf of Mexico shrimp catch by grid zone[a], for selected years 1965 through 1977 (heads on, lb) (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979).

Grid zone	Year						
	1965	1967	1969	1971	1973	1975	1977
0180	8,346,700	12,362,300	6,430,800	13,720,100	6,296,200	9,207,800	16,240,030
0181	1,451,983	2,187,400	4,285,100	5,012,900	5,027,600	4,755,600	3,791,017
0190	25,260,500	32,312,800	20,676,700	26,827,500	14,070,400	13,152,800	19,914,257
0191	23,646,000	1,268,400	1,427,700	1,287,200	3,812,100	1,706,100	4,474,489
0192	1,733,600	1,285,700	1,098,600	748,600	1,521,800	1,277,100	1,621,836
0193	945,600	488,100	735,000	422,700	1,870,900	1,184,100	2,313,653
0200	6,886,600	14,742,600	8,986,200	10,939,300	15,322,800	13,065,300	12,500,871
0201	452,800	514,700	327,300	99,300	1,222,000	988,800	1,205,763
0210	5,645,700	15,545,300	10,972,800	7,186,100	11,651,100	10,130,300	11,752,901
0211	0	0	0	0	0	0	0
TOTAL	74,369,483	80,707,300	54,940,200	66,243,700	60,794,900	55,467,900	73,814,817

[a]

Grid Zone	Region	Grid Zone	Region	Grid Zone	Region
0180	Gulf	0191	Matagorda Bay System	0200	Gulf
0181	Galveston Bay System	0192	San Antonio Bay System	0201	Corpus Christi Bay System
0190	Gulf	0193	Aransas Bay System	0210	Gulf
				0211	Lower Laguna Madre

Table 33. Averge value per pound of shrimp landed at Texas ports from Texas waters, for selected years 1965 through 1977 (Van Lopik et al. 1979).

Year	Average value per pound[a]
1965	$ 0.25[b]
1967	0.44
1969	0.59
1971	0.72
1973	1.04
1975	1.22
1977	1.33

[a] 1 lb = 0.45 kg.
[b] current dollars.

Management and policies affecting Texas commercial shrimp industry. Management control of the Texas shrimp fishery is primarily in the hands of the Texas Legislature, with limited responsibility in the hands of the Texas Parks and Wildlife Commission. Texas jurisdiction extends seaward for 16.5 km (three marine leagues) . The Texas Shrimp Conservation Act of 1963 applies to all Texas counties. Legislation and regulatory measures to manage the fishing include legal size and catch limits, licensing of fishermen, the length of the shrimp fishing season, and restricted waters.

The Draft Fishery Management Plan and Draft Environment Impact Statement for Shrimp prepared and adopted by the Gulf of Mexico Fisheries Management Council contains the following objectives (Van Lopik et al. 1979):

1. Optimize the yield from shrimp recruited to the fishery.

2. Encourage habitat protection measures to prevent undue loss of shrimp habitat.

3. Coordinate the development of shrimp management measures by the Gulf of Mexico Fishery Management Council with the shrimp management programs of the several states where feasible.

4. Promote consistency with the Endangered Species Act and Marine Mammal Protection Act.

5. Minimize the incidental capture of finfish by shrimpers, when appropriate.

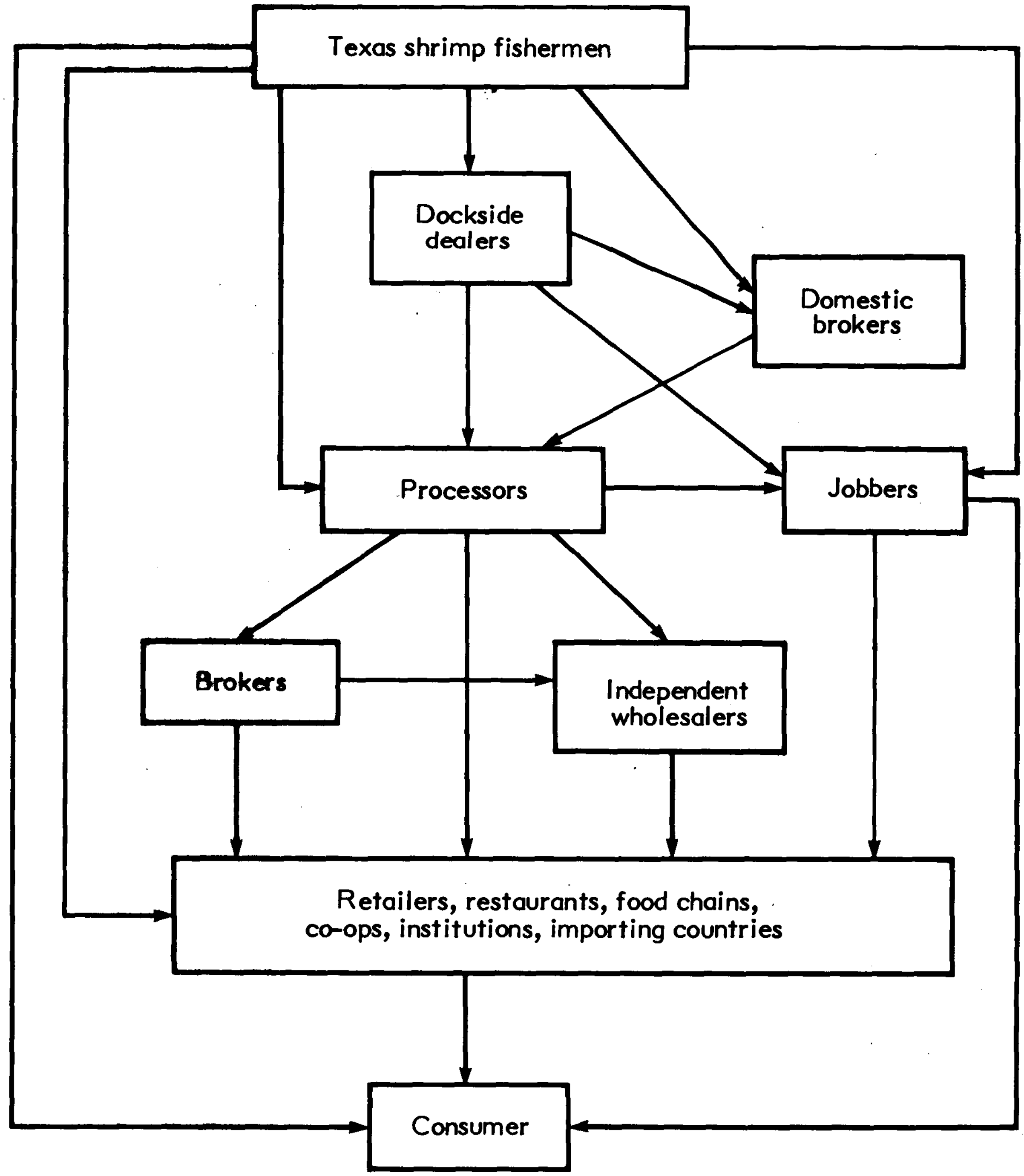


Figure 8. Marketing channels for shrimp products (Van Lopik et al. 1979).

6. Minimize conflicts between shrimp and stone crab fishermen.

7. Minimize adverse effects of underwater obstructions to shrimp trawling.

As of 28 May 1980, the plan was adopted by the Secretary of Commerce.

Oysters

In 1965, the American oyster (Crassostrea virginica Gmelin) accounted for 2.2% of the total volume by weight of commercial fishery landings and 5.4% of the value. In 1977, they accounted for 2.9% of the volume and 2.8% of the value. In dollar value they are second to the shrimp as the State's most important commercial fishery.

The oyster spends its entire life in estuaries. Spawning begins in sexually mature oysters when water temperatures exceed 24°C (75°F). The spawning season usually extends from April to October. The spawning of one oyster stimulates spawning among other mature oysters; thus the spawning for an oyster bed occurs at approximately the same time. The oyster may change its sex during its life, but only before the gonads are fully developed, and is thus incapable of fertilizing its own eggs (Hoffsteter 1959). Each female spawns several times during the season and produces millions of eggs during each spawn. After fertilization of the eggs, larval oysters form. They are free swimming and are widely dispersed by the currents. During this period, they can withstand wide variations in salinity. Optimum temperatures for larval growth range from 30.0° to 32.5°C (86.0° to 90.5°F) and salinities range from 10 to 27 ppt (Davis and Calabrese 1964).

As the larval form matures, it attaches itself to a solid substrate. This process is known as setting, or spat fall. Over time, oyster reefs are formed. As oyster metamorphosis occurs, permanent organs appear. Foods include phytoplankton and zooplankton, but the oyster is a discriminate filter feeder and feeds primarily on diatoms.

Adult oysters are capable of living within wide ranges of salinity, from 5 to 30 ppt. Freshwater inflow is beneficial, as brackish water kills the oysters' major predators--gastropods, flat worms and starfish. Other predators include the blue crab and stone crab (Texas Parks and Wildlife Department, Coastal Fisheries Branch 1975).

In the moderate to warm waters of the Texas bay systems, growth occurs year-round. Eighteen to 24 months are usually required for the oyster to achieve the legal size for harvest (3 inches).

Throughout its life, the oyster is sensitive to environmental variability, for example, changing salinities and water temperature, and disease-causing organisms. As filter feeders, they may concentrate organisms that are subsequently dangerous to man.

Oysters are sometimes harvested by wading in shallow waters and picking by hand. Frequently, however, they are gathered by oyster tongs. Most frequently, oyster dredges are used. Harvesting by the tong and dredging method is indiscriminate, and the legal size oysters must be culled from the remainder.

During the process of culling and throwing back the small oysters, the oyster bed can be expanded by scattering seed oysters and cultch over the reef.

The major commercial oyster beds in Texas occur in the Galveston Bay estuarine system. Other commercially important oyster beds occur in Matagorda Bay, San Antonio Bay, and Aransas Bay. Grid zone 0181 (Galveston Bay) has recently been the system with the overwhelming proportion of the harvest (Table 34). In fiscal years 1978 and 1979, 58 commercial oyster dredging licenses were issued, and the catch amounted to 29,065 barrels of oysters, which is equivalent to 0.57 million kg (1.2 million lb) of oyster meats valued at $1.5 million dollars. The average landing price was $2.76/kg ($1.25/lb).

Oyster landings and values at Texas ports from Texas waters fluctuated widely from 1965 to 1977 (Figure 9). These fluctuations cannot be attributed to a single factor, but dredging, hurricanes, floods, and overfishing are among the causes.

Oystermen sell their catch directly to dealers or, if they are licensed processors, shuck (open) them and distribute oyster meat directly to retail outlets or to the consumer.

Blue Crab

The blue crab (Callinectes sapidus Rathbun) is the third most valuable Texas commercial fishery. In 1965, it accounted for 2.5% of the volume and 0.9% of the value of fishery landings. In 1977, it accounted for 8.8% of the volume and 1.7% of the value.

The blue crab lives for 2 to 3 years. During her lifetime, the female crab may spawn one to three times and produce up to three million eggs each spawn. Spawning in Texas occurs from December through October (Leary 1967). Mating occurs in upper estuaries and the females migrate to the lower bays and Gulf for spawning. The fertilized eggs are carried by the female until they hatch. Once hatched, the young crabs are on their own for survival (Leary 1967). They move to the estuaries during the larval stages and are able to withstand wide ranges in temperature and salinity.

The blue crab can best be described as a scavenger. They eat fresh to putrid flesh of mollusks, 39%; crustaceans, 15%; organic debris, 20%; and fishes, 19.4% (Tagatz 1968). During growth, the crab sheds its shell and develops a new one. Growth rates are quite rapid, from 15 to 18 mm (0.59 to 0.71 in) per month in Galveston Bay (More 1969). The time from hatch to commercial size can be as short as 10 months or as long as 15 (Costlow 1967).

The first blue crab processing plant in Texas, built in Palacios in 1958, caused a rapid growth in commercial fishing by providing a market (More 1969). Today, the predominant commercial crabbing areas in Texas are Galveston, San Antonio, Aransas, and Matagorda Bays and in Lower Laguna Madre. In fiscal year 1979, total blue crab production was 3.2 million kg (7.0 million lb) (Table 35) with a value of $1.8 million (Figure 10). This translates to an average price of $0.57/kg ($0.26/lb). An average 45.4 kg (100 lb) of crabs yield 6.8 kg (15 lb) of meat (More 1969).

Table 34. Texas Gulf of Mexico oyster catch by grid zone[a], for selected years 1965 through 1977 (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979).

Grid Zone	Year 1965	1967	1969	1971	1973	1975	1977
				weight (lb)			
0180	0	0	0	0	0	0	0
0181	2,223,145	2,992,600	3,447,200	3,951,800	743,000	1,237,800	1,947,800
0190	0	0	0	0	0	0	0
0191	123,600	282,300	180,900	294,600	73,700	373,600	139,600
0192	122,500	252,100	11,100	395,000	43,800	124,000	438,400
0193	0	3,800	43,900	30,000	9,900	12,400	65,600
0200	0	0	0	0	0	0	0
0201	0	0	0	0	0	0	0
0202	0	0	0	0	0	0	0
0210	0	0	0	0	0	0	0
0211	5,600	2,100	1,100	0	500	8,200	9,100
0212	0	0	0	0	0	0	0
Total	2,474,845	3,532,900	3,634,200	4,671,500	871,600	1,756,000	2,600,500

[a]See Volume 2, Data Appendix: Figure 1 and Table 3 in the Fish and Wildlife Production (FSH) section.

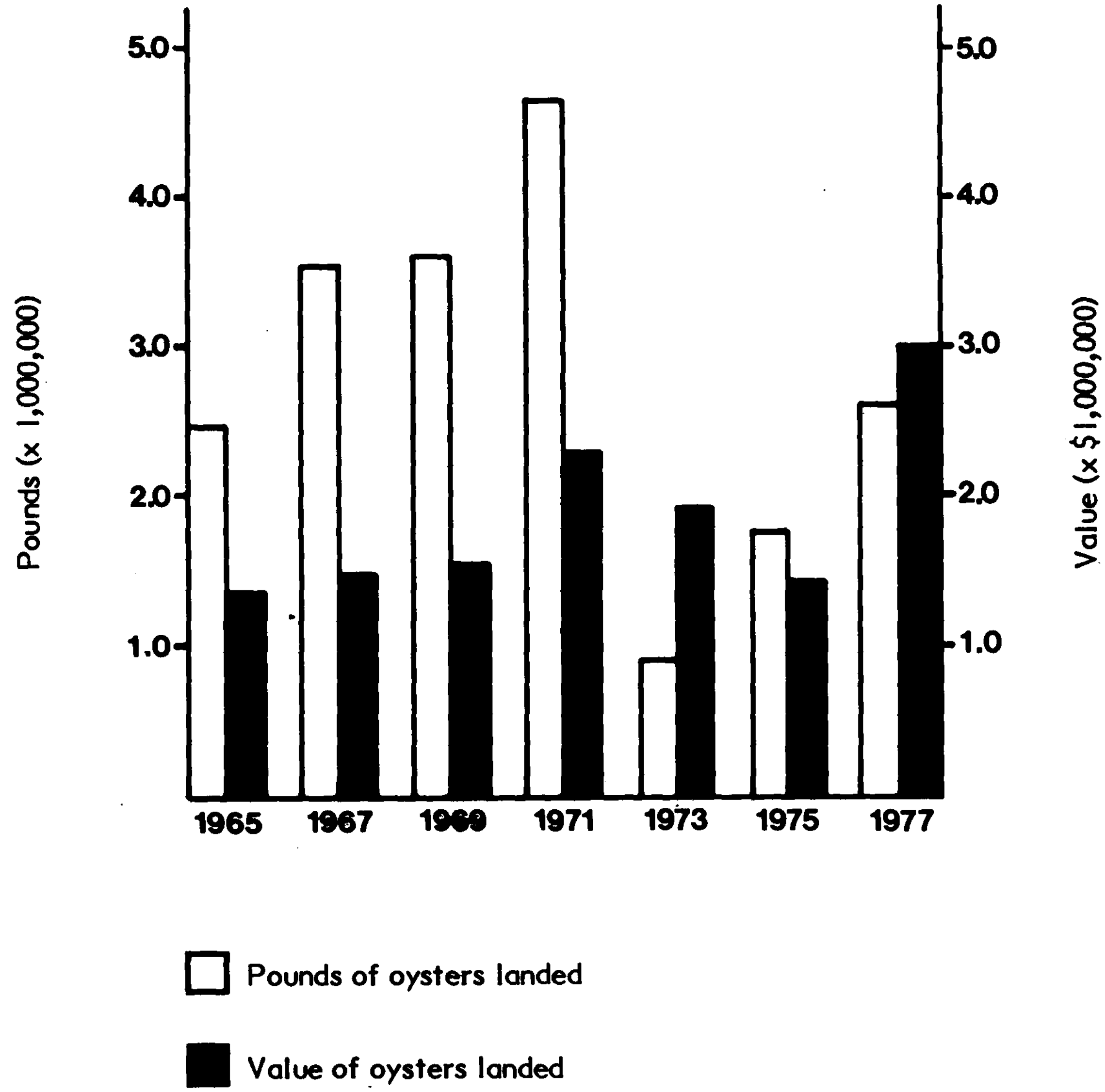


Figure 9. Landings and value of oysters at Texas ports from Texas waters for selected years 1965 through 1977 (U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979).

Table 35. Texas Gulf of Mexico blue crab catch by grid zone[a], for selected years 1965 through 1977 (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1979).

Grid Zone	Year 1965	1967	1969	1971 weight (lb)	1973	1975	1977
0180	0	8,700	30,500	36,800	73,900	37,900	11,000
0181	1,817,900	1,047,900	1,705,700	2,160,800	2,040,000	1,784,700	1,746,000
0190	500	0	0	24,400	1,000	0	0
0191	401,300	360,800	891,000	394,300	1,129,600	1,075,9000	535,400
0192	509,500	269,900	1,328,500	530,000	859,000	1,539,100	2,275,400
0193	39,600	155,600	724,200	591,800	1,272,700	1,272,700	2,150,800
0200	0	0	0	0	0	0	100
0201	113,700	0	152,500	100,500	41,100	134,700	102,800
0202	0	0	528,500	200	1,000	0	126,800
0210	0	0	0	0	0	400	0
0211	0	0	0	0	11,600	3,500	975,200
Total	2,881,500	1,842,900	5,360,900	3,838,800	5,429,900	5,290,500	7,923,500

[a]See Volume 2, Data Appendix: Figure 1 and Table 3 in the Fish and Wildlife Production (FSH) section.

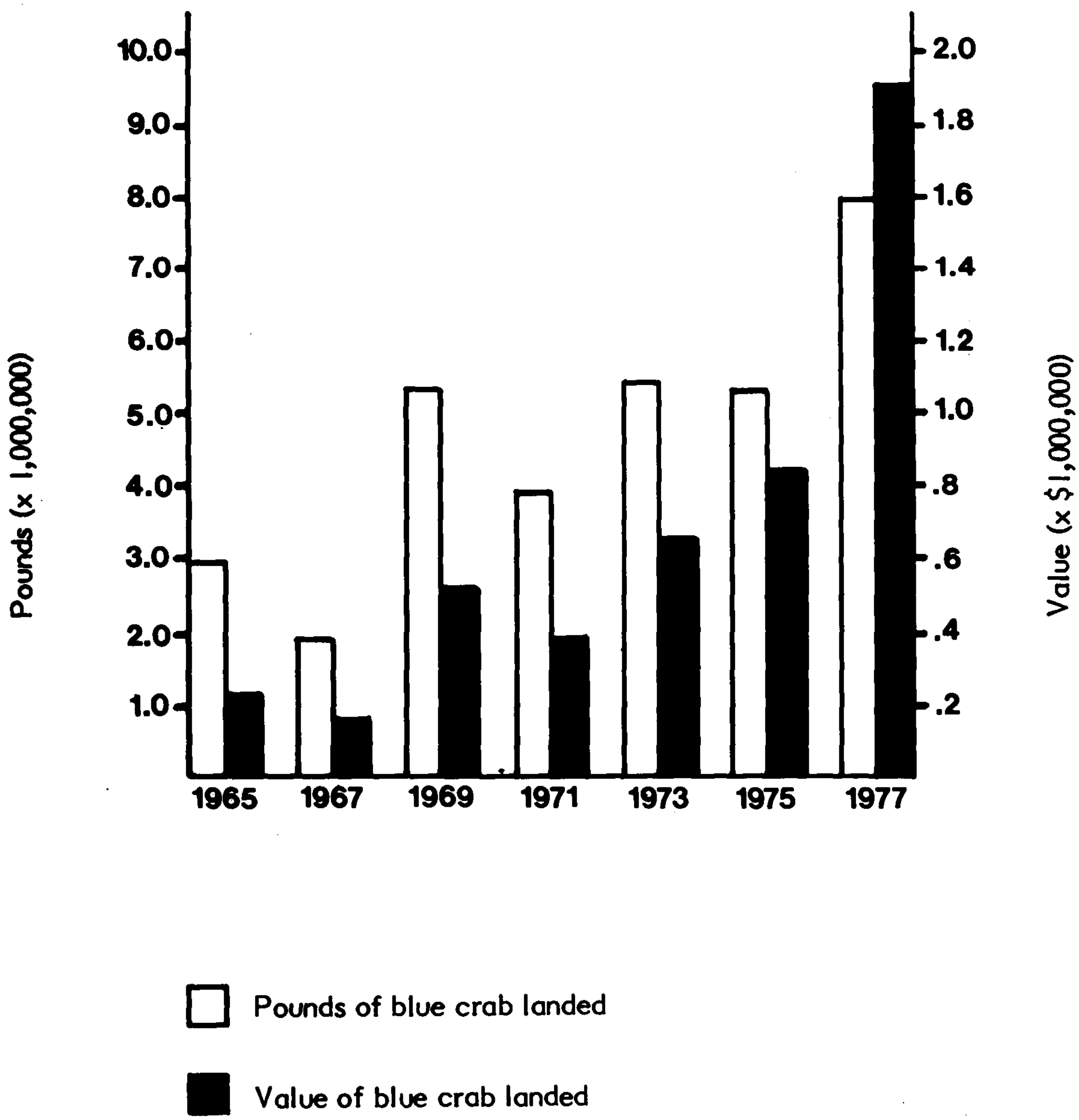


Figure 10. Landings and value of blue crab at Texas ports from Texas waters for selected years 1965 through 1977 (U.S. Department of Commerce, National Oceanic and Atmospheric administration, National Marine Fisheries Service 1979).

Commercial crab fishermen use traps or crab pots, exclusively. The traps and pots are baited and placed on the bottom in estuaries. The traps are retrieved periodically and the crabs collected. Crabbers sell their catch directly to retail outlets and consumers or to processing facilities. The crabs are purged, cooked, and picked at the processing plants and then frozen or canned and marketed.

FINFISHES

There are seven major commercial finfish species in Texas: red drum, spotted seatrout, red snapper, black drum, sheepshead, and two flounder species. The following paragraphs present information about these species and their landings and value trends.

Red Drum (Redfish)

The red drum (*Sciaenops ocellata*), a member of the family Sciaenidae, is euryhaline, occurring in both freshwater (Gunter 1956) and in hypersaline conditions (Simmons 1957). They can tolerate temperatures ranging from 2° to 33°C (36° to 91°F), but are sensitive to sudden cold spells. Catastrophic kills in shallow waters have been observed during periods of rapid temperature declines (Gunter and Hildebrand 1951).

Spawning occurs in the Gulf of Mexico and tidal passes from August through November, usually peaking in October. Juvenile redfish move into the bays and dwell in areas protected by marsh vegetation and sea grasses.

Their food habits change as they grow to adult size: less than 15 mm total length (0.6 in), zooplankton; 15 to 75 mm total length (0.6 to 3.0 in), bottom invertebrates and other young fishes; and larger than 75 mm total length (3.0 in), decapods and fishes (Bass and Avault 1975). Growth rates are an average length of 325 mm total length (12.8 in) for 1 year old redfish and 800 mm total length (31.5 in) for 4 year olds (Texas Parks and Wildlife Department, Coastal Fisheries Branch 1975).

Commercial catch for red drum was 233,600 kg (519,100 lb) in 1965 with a total value of $134,522 and an average price of $0.57/kg ($0.26/lb). Catch had increased to 426,400 kg (947,600 lb) in 1977 with a total value of $509,797 and an average price of $1.19/kg ($0.54/lb).

Spotted Seatrout

The spotted seatrout (*Cynoscion nebulosus*) is a major sport and commercial fish species in Texas. The spotted seatrout spawns in low turbidity estuaries and non-tidal lagoons (Tabb 1966). Spawning begins when the water temperature attains 20°C (68°F) and continues through the summer months with peaks in the months of April and September. Like red drum, the spotted seatrout is euryhaline. The most productive seatrout grounds are those that have a seasonally fluctuating salinity regime (Tabb 1966). They also adapt to water temperatures from 4° to 32°C (40° to 90°F). With sudden drops in temperature, they move to deeper waters where the temperature is more stable. As with the red drum, massive thermal kills of spotted seatrout have been reported when adequate deeper water was not located.

Female seatrout grow faster and live longer than the males. In the Laguna Madre, both sexes reached 130 mm total length (5.1 in) at the end of their first year. At the end of the fifth year, males reached lengths of 410 mm total length (16.0 in) whereas females were 520 mm total length (20.5 in).

Commercial fishing is conducted with trammel nets, gill nets, and drag seines. The 1965 catch was 410,000 kg (910,300 lb), valued at $315,879; average landing price was $0.77/kg ($0.35/lb). By 1977, the catch was 605,300 kg (1,345,200 lb), valued at $672,398, and landing price averaged $1.10/kg ($0.50/lb).

Red Snapper

The red snapper (Lutjanus aya) is a reef fish and there has been recent controversy over whether the red snapper population has been overfished. The catch has fallen from 512,000 kg (1,137,900 lb) in 1965 to 121,000 kg (268,800 lb) in 1977, but the reasons are not clear. During the same time period, the average landing price has increased from $0.61/kg ($0.28/lb) to $2.04/kg ($0.92/lb).

Some biologists do not believe there is sufficient biological information to currently manage the stocks of red snapper (Beaumariage and Bullock 1976). Beaumariage and Bullock reviewed the current red snapper literature and discovered meager findings. The following is a summary of the results of this review.

Red snapper may live at least 9 to 11 years, but neither their effective fishable life span nor theoretical growth rates have been adequately determined. Red snapper have been thought to mature sexually within only one year, but this has not been verified. Observations of spawning activity over level bottom within 20 fathoms off the Texas coast have been reported.

Juvenile red snapper have been captured off Texas over smooth bottom, which is regularly trawled for shrimp. It is generally throught that as red snapper grow older, they seek deeper water, although some evidence indicates juveniles subsequently return to shallower water during spring and summer after the first winter's emigration from such areas. Red snapper also definitely show specific reef residency. This is indicated by seasonal returns to summer forage areas, as well as distinct congregation at reefs in deeper water.

Black Drum

The black drum (Pogonias cromis) is a common bay fish with the highest concentrations usually in Corpus Christi Bay and Laguna Madre (Simmons and Breuer 1962). In fact, they have been so numerous at times that the Texas Parks and Wildlife Department has contracted for drum removal during the winter. Such was the case in the Lower Laguna Madre in 1959 to 1961 when 0.79 million kg (1.75 million lb) were netted.

Black drum are euryhaline and frequently live in brackish and fresh water (Gunter 1956). Adult drum have even been found in the Upper Laguna Madre where the salinity was 80 ppt (Simmons and Breuer 1962). In addition to wide tolerances in salinity, black drum can withstand similar variations in temperature. Temperatures of 35°C (95°F) are tolerated. Black drum, however, are susceptible to sudden decreases in temperatures; when rapid decline occurs, they seek deeper water.

Young black drum prefer very shallow, turbid water and do well along the central Texas coast in habitats such as those in Laguna Madre and Oso and Nueces Bays (Pearson 1929). They frequently use the same habitat for spawning and nursery purposes (Simmons and Breuer 1962).

Reaching sexual maturity by the end of the second year, black drum spawn in or near the passes on the Texas coast, in the open Gulf, and in all parts of bays. While most of the spawning occurs in February and March, ripe male black drum have been found as early as December and as late as June. Such observations have led some to postulate two spawning cycles, the later one occurring in June and July (Texas Parks and Wildlife Department, Coastal Fisheries Branch 1975). Spawning adults as large as 22.7 kg (50 lb) are not uncommon, and a large female may contain as many as six million eggs (Pearson 1929).

Whereas young black drum feed on annelids, soft crustaceans, and small fishes (Simmons and Breuer 1962), adult drum feed on mollusks, shrimp, crabs, and vegetation (Pearson 1929, Miles 1949); the adults are largely benthic feeders.

The commercial catch of black drum commonly involves the use of trotlines and nets. More than half of the commercial take of black drum has historically occurred in the Lower Laguna Madre and Oso and Nueces Bays near Corpus Christi. The catch in 1965 was 661,000 kg (1,469,000 lb), valued at $135,991 with an average price per kilogram of $0.21 ($0.09/lb). In 1977, the catch, essentially unchanged, was 651,000 kg (1,446,600 lb), with a value increase to $397,948, resulting in an average price of $0.61/kg ($0.28/lb).

Flounders

Two species of flounder, southern flounder (Paralichthys lethostigma) and Gulf flounder (Paralichthys albigutta) have commercial significance in Texas. The southern flounder is more abundant and attains a larger size than the Gulf flounder.

Having been spawned in the open Gulf, the postlarval juvenile southern flounder enter the bays during the spring. Adults move seaward in the fall and winter (Simmons and Hoese 1959). Ripe adults have been captured in 30.5 m (100 ft) of water.

Small southern flounder (10 to 150 mm or 0.39 to 5.9 in) feed primarily on invertebrates, whereas large flounder (greater than 150 mm or 5.9 in) feed on fishes, commonly small herring and menhaden (Stokes 1973). The growth rates of flounder have been calculated at 20 mm (0.79 in) per month, based on a length of 305 mm (12 in) at 1.5 years of age (Simmons 1950).

Being euryhaline, flounder have been observed in environments where salinity ranged from 20 to 60 ppt (Gunter 1956). Temperature variations are also tolerated. Flounder have been found in Mississippi River waters where the temperatures ranged from 5° to 34.9°C (41° to 94.8°F) (Perret et al. 1971).

Commercial fishing for flounder is conducted with numerous kinds of gear ranging from hook and line to nets, seines, trawls, and gigs (Stokes 1973). The fishing activity ranges from bays and estuaries to the open Gulf. The Texas commercial landings in 1965 were 529,545 kg (240,200 lb), with a value of $60,309 and an average price of $0.55/kg ($0.25/lb). Figures for 1977 place the Texas catch at 677,474 kg (307,300 lb) with a value of $266,342 and an average price of $1.92/kg ($0.87/lb).

Gulf Menhaden

Gulf menhaden (Brevoortia spp.), an important forage species, receive special mention, not because they are an important commercial species in Texas today, but because commercial processing facilities have not existed in Texas since 1971. It is one of the United States' older and larger fisheries in terms of volume of landings (Christmas and Etzold 1977). Menhaden landings were first recorded in the Gulf of Mexico in 1880.

In 1977, there were 5 harvesting and processing firms in the Gulf area with 11 plants, all of which were located in Mississippi and Louisiana. The fishery is very stable when measured by market structure, entry and exit, and product-exploitation levels (Christmas and Etzold 1977). The processed products are fish meal, condensed fish solubles, and fish oil.

The last menhaden plant permit was issued in Texas during the fiscal year 1970-1971. During fiscal year 1978-1979, 43 menhaden fishing boat licenses were issued and it has to be assumed that the landings were made in Louisiana and Mississippi.

FACTORS INFLUENCING COMMERCIAL FISHING HARVESTS

Natural factors, resource management, costs, and human habitat modification all influence, or have the potential to influence, commercial fish production and harvests in Texas coastal waters. These factors are interdependent, and, working in tandem, they can drastically alter commercial fish production in the short as well as long term.

Natural Factors

Hurricanes certainly alter the physical environment for important commercial species. Storms can disrupt the salinity and the mixing and sedimentation processes in places where species spend any stage in their life cycles. If these disruptions occur at critical stages, a population can be sharply reduced in the short run.

In the late 1960's, Hurricane Beulah was responsible for notable changes (Simmons 1969):

> The most spectacular result appeared in the Lower Laguna Madre soon after the hurricane. Beulah roared in during the season when redfish spawn in the Gulf. Great gashes were torn in barrier islands and tides poured over the dunes. Apparently these tides brought larval fish with them. At any rate, shortly after the storm, small redfish appeared in droves. Not until spring did anyone realize just how many small redfish were in the bays. Commercial fishermen cast-netting for bait caught--little redfish. Trout fishermen, working under lights, caught--little redfish. Trotlines seeking large fish caught--little redfish. Biologists sampling for shrimps, crabs, trout, drum, and even oysters caught--little redfish. ...It was the biggest redfish crop in at least eight years along the lower coast. Probably the biggest in at least 20 years....

Texas rivers commonly discharge very little freshwater into the lower Texas bays and Gulf. The low normal discharge results from small drainage areas of the rivers and the semiarid climate. Peak flows generally occur in the spring and fall. Fall peak flows are noticeable on hydrographs of rivers and streams flowing into Matagorda Bay. Fall peak flows are also noticeable in the San Antonio Bay system and fall flows exceed spring flows from the Aransas Bay region through the Laguna Madre region. The hypersalinity in Laguna Madre is primarily caused by evaporation and by very low flows--from 0.26 to 5.67 m^3/s (9 to 200 cfs).

The upper Texas coast rivers have peak flows in the spring, followed by relatively low flows during the summer and fall. Great variation occurs annually (Van Lopik et al. 1979).

Resource Management

The Gulf of Mexico Fishery Mangement Council is currently drafting and holding hearings on management plans for the major Gulf fisheries. A draft Fishery Management Plan for the shrimp fishery of the Gulf of Mexico, United States Waters, has been prepared and reviewed. The plan was adopted on May 28, 1980 by the Secretary of the U.S. Department of Commerce. Plans for other Gulf fisheries are under consideration or in preparation by the Gulf of Mexico Fishery Management Council.

The State of Texas has two mandated authorities for managing Texas commercial fisheries: the Texas Legislature and the Texas Parks and Wildlife Department. Both have the opportunity for management through setting seasons, identifying areas for the prohibition of fishing, establishing gear regulations, and establishing limits on the size and quantity of fish to be harvested. In addition, the Texas Coastal and Marine Council identifies issues and factors affecting the coastal resources of Texas, conducts policy analyses, and offers management recommendations to the Texas Legislature.

Currently, there are no species of commercial marine fishes in Texas on the endangered or threatened list. The list does, however, contain 23 freshwater noncommercial species. (U.S. Department of the Interior, Fish and Wildlife Service 1979).

There is a problem with depletion of commercial fish populations. This is in part related to actions by fishermen and vessel operators. Increased numbers of licenses imply an increased number of fishing vessels. There may be overexploitation of a fishery if scientific management practices are not followed. There are many other intervening variables, such as natural events and manmade changes, that need to be understood better.

Costs

Commercial shrimp and finfish harvesting are fuel-intensive. Diesel fuel could be purchased in coastal ports in 1973 for \$0.02 to \$0.03/liter (\$0.105 to \$0.115/gal). Current 1980 prices of diesel fuel on the Texas Coast range from \$0.19 to more than \$0.26/liter (\$0.80 to more than \$1.00/gal). Fuel has become the "make-or-break" expense for small operators. Coupled with current levels of double-digit inflation, the marginal operators will more than likely fail, and currently successful operations may become marginal as profits diminish. The fisherman's dockside prices for his catch have not increased as rapidly as his costs for vessel construction and operating expenses. In addition, Mexico's 1980 closure of fish and shrimp grounds traditionally fished by the offshore Texas shrimp fleet may have a deleterious effect on the economy of the South Texas shrimp industry (Fisher 1975; Griffin and Beattie 1978; Swartz and Griffin 1979).

Habitat Modifications

There is consensus that mechanical disruption of habitats and change in freshwater inflow can seriously affect commercial fisheries. Most agree that development cannot be stopped, and responsible agencies are struggling with solutions, compromises, or means of diminishing adverse effects (Gulf South Research Institute 1976).

The major mechanical disruptions of coastal habitats are dredging and filling operations. Approximately 36.7 million m^3 (48 million yd^3) of sediments are dredged and deposited by the U.S. Army Corps of Engineers in achieving their channel maintenance in Texas each year (Lindall and Saloman 1977). Coastal habitats are filled by dredged material for industrial, urban, and recreational developments. It has been estimated that 56,000 ha (138,458 ac) of Gulf estuaries have been filled. Texas accounts for 56% (31,600 ha or 78,000 ac) of these filled Gulf estuaries (Lindall and Saloman 1977).

Estuaries require freshwater inflow to maintain their productivity. Water use upstream can influence the flow of fresh water into estuarine areas, thus diminishing biological productivity. In addition, land subsidence caused by extracting ground water and petroleum has affected freshwater inflow by reducing river inflow.

Another form of detrimental habitat modification is pollution. One measure of pollution effects on commercial fishing is the amount of fishing habitat that is closed to shellfishing. Various indicators of pollutants, such as the presence of coliform bacteria from industrial, residential, and agricultural uses, have closed 322,000 ha (795,609 ac) of Gulf oyster habitat. Statistically, as a result of pollution, 10% of the Gulf estuaries are closed to oyster harvesting. Texas accounts for more than 40% of the total closure or 132,000 ha (325,000 ac), which is 21.2% of the State's estuaries (Lindall and Saloman 1977). It is also reported that these figures are conservative, because when bacterial counts exceed safe levels (after a heavy storm runoff, for example) additional areas are closed. In Texas, total bay systems may be affected, particularly an additional 6,700 ha (16,600 ac) of oyster habitat. Estuaries are classified only as "polluted" or "approved". Heavy storm runoff may temporarily alter classification of several bays or any portion thereof. Texas commercial oystermen are, however, permitted to obtain oysters from closed areas and to transport them to leased oyster beds where the oysters undergo depuration (self-cleaning) before harvesting.

There are insufficient data to determine the short- and long-term consequences of oil pollution. It has been reported that offshore oil platforms act as artificial reefs for epiphytic algae (Humm 1979). Numerous productive oyster reefs also occur in the vicinity of oil platforms.

Fishing Industry Perceptions of Management Issues

A series of public meetings and questionnaires by the Gulf South Research Institute generated the following information regarding Gulf fishing industry members' perception of management issues (Gulf South Research Institute 1976). The issues perceived by this group are not necessarily compatible with the fishery management literature. There is a continuing need for improvements in coordination between the public managers and the affected industry.

Environmental alterations. People in the fisheries industry in the Gulf states say that alterations of the environment such as dams, landfill, and industrial developments are seriously affecting fisheries. They are not opposed to progress, but they are just as confused as everyone else about the appropriate standards for weighing one interest against another. They ask only that their interests be taken into consideration when alterations of the environment are contemplated. There were surprisingly few comments about specific problems in this area.

Mariculture. Mariculture has not yet demonstrated its practical applicability in the Gulf area, but people in the fisheries industry are optimistic and feel that research and development funding should be continued on a limited basis.

Artificial reefs. Sport fishermen in particular feel that more funding is needed for large-scale reef construction. They maintain that restrictions for constructing reefs need to be eased, but unrestricted construction of reefs should not be allowed.

Operating regulations. People in the fisheries industry maintain that because existing regulations at the local, State, and Federal levels are often confusing, overlapping, and sometimes contradictory, the regulations need to be streamlined.

Licenses. Fishermen considered licenses a potential solution to various problems. They would like to have reciprocal licenses that would be recognized across state boundaries. Commercial fishermen would like to have license fees raised as a means of limiting entry into the industry. Commercial fishermen would also like stricter requirements for commercial licenses to sell a catch; it was hoped that new restrictions would eliminate illegal sale of catches by semi-commercial sport fishermen.

Taxes. Fishermen do not like high taxes, and they see large discrepancies between fishermen and farmers with respect to tax bases and collections. They maintain that crewmen are independent contractors rather than employees and do not want to withhold taxes from crew salaries.

Duties. People in the fisheries industry strongly favor duties on imports of seafood products. They say that fisheries subsidies in foreign countries produce artificially low prices for foreign seafood products in the U.S. market. They are also concerned about the adverse impact of market gluts. They are not against imports as such, but feel that market fluctuations should be reduced and that market opportunities should be equalized. Both sport and commercial fishermen strongly oppose duties on fisheries gear and supplies.

Road taxes. Fishermen maintain that they should be totally exempt from road taxes on gasoline. If exemption is not granted, they feel that the rebate system should at least be made more efficient.

Fuel allocation. Fishermen believe that fuel allocation and price control systems, as presently administered by the U.S. Department of Energy, should be dismantled because they disrupt rational patterns of action.

Loans. Fishermen are very concerned about lack of money for equipment, operations, and vessels. They are dissatisfied with Federal loan programs and say that the requirements are unrealistic, the payment schedules are too rigid, too much information is required, and the loans take too long. They also have difficulty obtaining private loans. Bankers say this is because most fishermen have little collateral and do not keep good records. As a solution to their problems, fishermen suggest long-term low interest loans with flexible payment schedules.

Subsidies. Because they are fairly independent, people in the fisheries industry are not in favor of direct subsidies, but they do favor rebates, price ceilings, and price supports.

Insurance. People in the fisheries industry stress the high cost of hull and crew insurance and their inability to obtain it. They request underwriting or subsidies. Large fleet owners say that they are plagued by alleged crew injury problems and suits, which have resulted in insurance premiums of the same magnitude as medical malpractice insurance. To alleviate this problem, they suggest that injury insurance requirements be made inapplicable to fishermen.

Operating costs. The increasing costs of operations and maintenance are seriously affecting production and profits, according to people in the industry. As solutions, they propose greater efficiency, utilization of incidental catches, off-season fishing, relief from foreign competition, marketing assistance, and fair treatment from dealers and processors.

Fuel costs. Fishermen would like to have lower fuel costs and particularly dislike the disproportionate inflation of diesel fuel prices.

Gear and equipment costs. Fishermen have been particularly hard hit by rising prices because much of their gear is made from petroleum products. They favor lower prices, but have no concrete suggestions as to what could be done to accomplish this.

Safety. Fishermen favor a voluntary safety program, possibly administered through the Coast Guard.

Pollution control. People in the fisheries industry favor pollution control insofar as discharges are detrimental to the environment, but they do not like rigid regulations that hurt them economically without improving the environment. Seafood processors claim that their plant discharges are beneficial to the environment and do not understand why they are being penalized for making such discharges.

Quality control. The fisheries industry has suffered from variations in product quality more than most other industries, and this has seriously affected marketing. Each segment of the industry tends to blame the others for poor quality, and each segment claims that the other segments should do something about the problem.

Theft. Fishermen say that the problem of theft of some types of gear and equipment is serious, as is the problem of illegal catch sales by boat captains. Fishermen maintain that increased enforcement would help, but more funds would be needed. Industry people believe that illegal sales could be stopped through prohibition of cash sales.

Bookkeeping. Many fishermen say that accounting and bookkeeping are growing headaches because of the increasing complexity of Federal and State regulations. They feel that they do not have the skills necessary to keep books.

Disaster reserves. Fishermen are very concerned about natural disasters and feel that a relief fund is needed, perhaps a "sea bank" developed with OCS monies. They say that Federal relief does not arrive fast enough and that a single-source point of quick money for disaster relief is needed.

Personnel recruitment. According to people in the industry, the labor shortage in fisheries is endemic because of the hard work and low wages. Recruitment is becoming more difficult because of extensive onshore and offshore opportunities and because of pessimism about the future of the fisheries industry. Seafood processing plants claim that they lose workers to welfare rolls.

Training. Because the industry must take whatever workers are available, qualifications are few. It was reported that training classes have been generally unsuccessful and, given the labor shortage, formal qualifications would only make matters worse. Commercial fishermen and charter and party boat operators feel that safety training programs are needed for casual sport fishermen. These programs could best be implemented as part of a licensing procedure.

Marketing. Study participants felt that little attention has been given to the marketing of seafood. People in the fisheries industry blame this lack of attention to marketing for many of the industry's ills and maintain that a strong, comprehensive marketing program is needed. They feel that the program should include consumer education, development of markets for underutilized and nonutilized species, studies of buying and selling patterns, processing research, assistance for effective competition with foreigners, and suspension of foreign fisheries development aid. Industry personnel claim that such a program should be undertaken by the Federal government because the fisheries industry is not consolidated. They want the National Marine Fisheries Service to pay more attention to marketing problems.

Foreign competition. Commercial fishermen are very concerned about foreign competition for fisheries resources, even though foreign catch statistics for the Gulf indicate that the foreign catch is insignificant. Sport fishermen claim that foreign longliners have depleted the Gulf billfish resources. Commercial fishermen are more concerned about market competition than resource competition, however. It is felt that tariffs and duties are needed to give the U.S. fisherman a fair chance in the U.S. market.

Harbor and ports. Sport fishermen need fishing piers and launching ramps. Access is becoming a major problem for both commercial and sport fishermen because of shore development. Commercial fishermen say they have adequate docking and service facilities in Texas and Florida, but more facilities are needed in Mississippi and Louisiana.

Obstructions. Bottom obstructions such as dredge pipe sections, pipelines, and debris and wrecks from hurricanes are a big problem in the Gulf, according to the commercial fishermen. They would like to see obstructions removed, but the Corps of Engineers claims that it does not have enough money to do so. Sportfishermen, on the other hand, would prefer to see the wrecks permanently marked and left as artificial reefs.

Navigation. Fishermen are satisfied with the Loran A system and do not want the added expense of Loran C. If they must change systems, they would at least like a longer changeover schedule.

Markers. Although private marking systems are inadequate, fishermen are generally satisfied with the Coast Guard navigational marker system. The fishermen say that more markers and buoys are needed, particularly on reefs and obstructions, and port lighting systems need to be modified to avoid confusion.

Extended jurisdiction. Extended jurisdiction is supported by the inshore commercial fishermen and offshore sport fishermen and is opposed by the offshore commercial fishermen (particularly the shrimp and snapper fishermen). Offshore fishermen are very concerned about the potential loss of their historic rights to fish in foreign waters, and they believe that enforcement of a 200-mile zone is impractical. They strongly favor any actions that can be taken to assure them of their historic rights to fish.

Authority. People in the fisheries industry and state fisheries administrators feel that existing authority is inadequate. They maintain that there are too many agencies affecting fisheries at the Federal level, and that the National Marine Fisheries Service has not been able to deliver the services prescribed by law. State regulatory agency officials relate that there is little overall management of fisheries or management strategy. Fishermen find the great number of fisheries-related agencies confusing and would like an organization at the Federal level that could speak for their interests in the same way that the Department of Agriculture speaks for the farmer. A frequent suggestion was that Congress should establish a single fisheries agency (or expand the NMFS), place it in charge of the direction and coordination of all fisheries activities, require a policy, and give the organization the authority and money it would need to do its job. Also, it was suggested that the NMFS laboratory programs might better address the problems of regional concern if the programs were placed in the hands of the regional directors.

Management. Fishermen say that they are opposed to governmental intervention in their affairs, even when they advocate programs that would increase that intervention. Moreover, fishermen do not think in terms of overall management strategies. Comments on the need for management strategies were supplied by state fisheries administrators. Fishermen generally support specific management tools, such as resource allocation and limited entry, but they also feel that other types of management will increase. Many people associated with the fisheries industry, including the state administrators, want management to be left to the states, but most admit that this would require more cooperation among the states than has existed in the past. Others are of the opinion that fisheries management requires Federal direction. Fishermen hope that, whoever is in charge, management decisions will be made on the basis of sound biological data and conservation principles and divorced from "politics." They are worried about the highly politicized nature of fisheries at the state level and feel that Federal intervention will probably make matters worse.

Regulations. People in the fisheries industry say that present regulations are inadequate to protect the industry and its resource base. They maintain that regulations at the state and Federal levels often conflict with each other and that management regulations are needed on at least a regional basis. People in the fisheries industry favor Federal laws based on sound conservation principles. They strongly favor negotiations with foreign countries to confirm historic rights to fish.

Management funds. People involved with the fisheries industry, either directly or indirectly, say that more money is needed for research, management, and enforcement at both the Federal and state levels. Agency personnel were particularly dissatisfied with the handling of P.L. 88-309 funds. They want full funding, an increased funding level, and separation of the 88-309 funds in the NMFS budget. Fishermen would like to see more money for enforcement and for the development of products and markets.

Resource allocation. It was the feeling of the great majority of both sport and commercial fishermen that some form of resource allocation must be instituted insofar as certain species are concerned. Talk of resource allocation centered on those species heavily fished by both sport and commercial fishermen. There was no mention of a need for resource allocation among the commercial fishermen themselves.

Limited catch. Both sport and commercial fishermen want limits placed on sport catches, particularly with respect to the catches taken by semi-commercial sportsmen. Sport fishermen want commercial fishermen to stop using gillnets and purse seines, which sportsmen believe are depleting the resources.

Size restriction. There is a great controversy over the practice of catching small shrimp (also crabs, redfish, and lobsters). Since the authorities are divided among themselves on the issue, people in the industry believe that the dispute can only be settled through research. If it is concluded that small shrimp should not be caught, resource conservation could best be achieved through an agreement between producers and processors.

Limited entry. Fishermen are of the opinion that the size of their catches is being reduced because of too much competition and that the resources are being depleted. Because of this, they tend to favor limited entry. They would like to prohibit unlicensed commercial fishermen and semi-commercial sport fishermen from fishing, and they would like to prohibit wealthy professionals from investing in fishery operations as a tax shelter. The most popular limited entry scheme among Gulf fishermen is to limit the number of licenses issued, with the appropriate number to be issued on the basis of sound biological principles and data. It should be noted that most fishermen would not favor limited entry as a concession to greed. If research indicates that the catch per vessel is not decreasing or that the resources are not in danger of depletion, Gulf fishermen would probably not be in favor of limited entry. They want a management scheme only if it can be demonstrated that one is needed.

Fishermen-Federal cooperation. Fishermen do not think Congress has their best interests at heart. As evidence, they repeatedly cite the fact that Congress generally does not take the opinions of fishermen into consideration when legislation affecting fisheries is contemplated, and claim that fisheries interests are sacrificed in diplomatic negotiations with other countries. They are not pleased with the extent of services provided by NMFS.

Sport-commercial cooperation. The conflict between sport and commercial fishermen has been intense, but the situation seems to be improving with the recognition of common interests. Commercial fishermen claim that sport fishermen are given preferential treatment in the state legislatures because of their wealth. The disputes between sport and commercial fishermen can be resolved only through research.

Communication. Fishermen feel that Federal agencies are distant. Governmental agents say that fishermen are not educated enough to utilize fully the fruits of research. Fishermen do not understand theoretical concepts such as Optimum Sustainable Yield and Maximum Sustainable Yield and do not wish to discuss them unless the concepts are reduced to practical equivalents. Sport and commercial fishermen need to get together more often to reduce the tension between them.

DATA GAPS

There are too many data gaps to provide conclusive answers about many trends. One subject that requires better understanding involves the economic and social characteristics of Texas fishermen. Aggregated data that are currently available do not permit a good basis for drawing any conclusions.

Another subject for which data are sorely absent is that which permits understanding the complex interdependencies between natural events, habitat modifications, and the economics of the commercial fishing industries. Until a better understanding is achieved, the best management practice may be one of informed judgment under great uncertainty and a commitment not to engage in a practice that is completely irreversible in the long term.

Although there are data gaps, the available data are sometimes ignored in decisionmaking. The lack of utilization of existing data may be a greater problem than data gaps.

COMMERCIAL FISHING: LITERATURE CITED

American Institute of Biological Sciences. The proceedings of the conference on assessment of ecological impacts of oil spills. Washington, DC: 1978; 936 p.

Barrett, B.B.; Gillespie, M.C. Primary factors which influence commercial shrimp production in coastal Louisiana. Louisiana Department of Wildlife and Fisheries, Technical bulletin no. 9; 1973; 28 p.

Bass, R.J.; Avault, J.W., Jr. Food habits, length-weight relationship, condition factor and growth of juvenile red drum, Sciaenops ocellata, in Louisiana. Transactions of the American Fisheries Society 104(1):35-45; 1975.

Baxter, K.N.; Renfro, W.C. Seasonal occurrence and size distributions of post-larval brown and white shrimp near Galveston, Texas, with notes on species identification. U.S. Fish and Wildlife Service, Fishery bulletin 66:149-158; 1967.

Beaumariage, D.S.; Bullock, L.H. Biological research on snappers and groupers as related to fishery management requirements. Contribution No. 270, Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg, FL; 1976; 9 p.

Brahtz, J.F., ed. Coastal zone management: multiple use with conservation. John Wiley and Sons, Inc., New York; 1972; 352 p.

Bryan, C.F. Values of marshes and estuaries to sport and commercial fishery resources. Proceedings of Fish and Wildlife Values of the Estuarine Habitats. Atlanta, GA: 66-68; 1973.

Bureau of Business Research, Univ. of Texas at Austin. 1977 Directory of Texas manufacturers; 1978; 225 p.

Christmas, J.Y.; Etzold, D.J. The menhaden fishery of the Gulf of Mexico, United States: a regional management plan. Gulf Coast Research Laboratory, Ocean Springs, MS; 1977; 128 p.

Clark, J. Coastal ecosystems ecological considerations for management of the coastal zone. The Conservation Foundation, Washington, DC; 1974; 178 p.

Copeland, B.J. Fauna of the Aransas Pass Inlet, Texas. I. Emigration as shown by tide trap collections. Publication of the Institute of Marine Science, Univ. of Texas 10:9-21; 1965.

Copeland, B.J.; Truitt, M.V. Fauna of the Aransas Pass Inlet, Texas. II. Penaid shrimp post-larvae. Texas Journal of Science 18:65-74; 1966.

Costlow, J.D., Jr. The effect of salinity and temperature on survival and metamorphosis of megalops of the blue crab Callinectes sapidus. Helgolander Wissenschaftliche Meeresuntersuchungen (15):84-97; 1967.

Davis, H.C.; Calabrese, A. Combined effects of temperature and salinity on development of eggs and growth of larvae of M. mercenaria and C. virginica. U.S. Fish and Wildlife Service bulletin 63:643-655; 1964.

Ewald, J.J. The laboratory rearing of pink shrimp, Penaeus duorarum Burkenroad. Contribution no. 615 from The Marine Laboratory. Institute of Marine Science, Univ. of Miami: 436-449; 1965.

Farfante, I.P. Western Atlantic shrimps of genus Penaeus. Fisheries Bulletin 67:461-591; 1969.

Farrell, D. Benthic communities in the vicinity of producing oil wells on the shallow Louisiana continental shelf. Department of Oceanography, Florida State Univ. (mimeo); 1979.

Fisher, N.P. The future of Texas fisheries. Austin, TX: Research & Program Development Dept., Texas Industrial Commission; December 1975; 59 p.

Ford, T.B.; St. Amant, L.S. Management guidelines for predicting brown shrimp, Penaeus aztecus, production in Louisiana. Proceedings of the Gulf and Caribbean Fisheries Institute, 23rd Annual Session: 149-161; 1971.

Galtsoff, P.S. The American oyster Crassostrea virginica Gmelin. U.S. Fish and Wildlife Service, Fisheries bulletin no. 64. n.p.; 1964.

George, R.Y. Structure and function of oyster reef and sandy shore community in the vicinity of oil platforms in Louisiana coast. Institute of Marine Biomedical Research, Univ. of North Carolina at Wilmington (mimeo); 1979.

Griffin, W.L.; Beattie, B.R. Economic impact of Mexico's 200-mile offshore fishing zone on the U.S. Gulf of Mexico shrimp fishery. Land Economics 54:27-38; 1978.

Gulf South Research Institute. The fisheries industry in the Gulf region. Gulf South Research Institute; 1976; 248 p.

Gunter, G. Studies on marine fishes of Texas. Publication of the Institute of Marine Science, Univ. of Texas 1:1-190; 1945.

Gunter, G. A list of the fishes of the mainland of North and Middle America recorded from both fresh and sea water. American Midland Naturalist 28:205-222; 1956.

Gunter, G. Shrimp landings and production of the State of Texas for the period 1956-1959 with comparison with other Gulf states. Publication of the Institute of Marine Science, Univ. of Texas 8:216-226; 1967.

Gunter, G.; Hildebrand, H.H. Destruction of fishes and other organisms on the south Texas coast by the cold wave of January 28-February 3, 1951. Ecology 32(4):731-735; 1951.

Hite, J.C.; Stepp, J.M. Coastal zone resource management. Praeger special studies in United States economic and social development. Praeger Publishers, New York; 1971; 169 p.

Hoffstetter, R.P. The Texas oyster fishery. Texas Parks and Wildlife Dept.; 1959; 39 p.

Humm, H. The effect of the offshore oil and gas wells on the benthic marine plants of Louisiana: I. Timbalier Bay. Dept. of Marine Science, Univ. of South Florida (mimeo): 2; 1979.

Jones, A.C.; Dimitriou, D.E.; Ewald, J.J.; Tweedy, J.H. Distribution of pink shrimp larvae (Penaeus duorarum Burkenroad) in waters of the Tortugas shelf, Gulf of Mexico. Institute of Marine Science, Univ. of Miami; 1964; 105 p.

Jones, R.R., Jr. Utilization of Louisiana estuarine sediments as a source of nutrition for the brown shrimp, Penaeus aztecus. Dissertation. Louisiana State Univ.; 1973; 125 p.

Kemp, R.J. Potential impacts of industry on the fish and wildlife resources of the Gulf coast. Texas Parks and Wildlife Dept. (mimeo); 1979; 21 p.

Leary, S.P. The crabs of Texas. Texas Parks and Wildlife Dept. bulletin no. 43; 1967; 57 p.

Lindall, W.N.; Saloman, C.H. Alteration and destruction of estuaries affecting fishery resources on the Gulf of Mexico. Marine Fisheries Review 39(9):1-7; 1977.

Lindner, M.J.; Anderson, W.W. Growth, migrations, spawning and size distribution of shrimp, Penaeus setiferus. Fisheries Bulletin 56:555-645; 1965.

Miles, D.W. A study of the food habits of the fishes of the Aransas Bay area. Texas Game, Fish and Oyster Commission, Marine Laboratory annual report 1949; 126-169; 1949.

More, W.R. A contribution to the biology of the blue crab (Callinectes sapidus Rathbun) in Texas, with a description of the fishery. Technical Series no. 1; Texas Parks and Wildlife Dept., Austin, TX.; 1969.

Odum, E.P. A description and value assessment of south Atlantic and Gulf coast marshes and estuaries. Proceedings of Fish and Wildlife Values of the Estuarine Habitats, Atlanta, GA: 30-31; 1973.

Pearson, J.C. Natural history and conservation of redfish and other commercial sciaenids of the Texas coast. Bulletin of the Bureau of Fisheries 44:129-144; 1929.

Perret, W.S.; Barrett, B.B.; Latapie, W.P.; Pollard, J.F.; Mock, W.R.; Adkins, G.B.; Gaidry, W.J.; White, C.J. Cooperative Gulf of Mexico estuarine inventory and study, Louisiana. Louisiana Wildlife and Fisheries Commission, New Orleans, LA.; pp 41-68; 1971.

Renfro, W.C.; Brusher, H.A. Population distribution and spawning. U.S. Fish and Wildlife Service circular no. 183:13-15; 1964.

Renfro, W.C.; Brusher, H.A. Population distribution and spawning. U.S. Fish and Wildlife Service circular no. 230:68-70; 1965.

Simmons, E.G.; Fish trap investigation. Texas Game, Fish and Oyster Commission, Commercial Marine Laboratory annual report 1949-1950; 1950; 27 p.

Simmons, E.G. An ecological survey of the upper Laguna Madre of Texas. Publication of the Institute of Marine Science, Univ. of Texas (2):156-200; 1957.

Simmons, E.G. Beulah's Silver Lining. Texas Parks and Wildlife Dept.; n.p.; 1969.

Simmons, E.G.; Breuer, J.P. A study of redfish, Sciaenops ocellata Linnaeus and black drum, Pogonias cromis Linnaeus. Publication of the Institute of Marine Science, Univ. of Texas (8):184-211; 1962.

Simmons, E.G.; Hoese, H.D. Studies on the hydrography and fish migrations of Cedar Bayou, a natural tidal inlet on the central Texas coast. Publication of the Institute of Marina Science, Univ. of Texas; 1959; 6 p.

Stokes, G.M. Life history studies of Paralichthys lethostigma and P. albigutta in the vicinity of Aransas Pass, Texas. Annual report, Fisheries Division, Texas Parks and Wildlife Dept., Austin, TX.; n.p.; 1973.

Swartz, A.N.; Griffin, W.L. The effect of an increased price in diesel fuel on Gulf shrimp vessel operations. Staff paper series, departmental information report. College Station, TX: The Texas Agricultural Experiment Station, Texas A&M Univ.; May 1979; 7 p.

Tabb, D.C. The estuary as a habitat for spotted seatrout, Cynoscion nebulosus. American Fisheries Society Special Publication 3:59-67; 1966.

Tagatz, M.E. Growth of juvenile blue crabs, Callinectes sapidus Rathbun, in the St. Johns River, Florida. U.S. Fish and Wildlife Service Fisheries bulletin 67:281-288; 1968.

Texas Parks and Wildlife Dept. A guide to Texas commercial fishing regulations. PWD booklet 9000-68; October 1979; 12 p.

Texas Parks and Wildlife Dept., Coastal Fisheries Branch Staff. A program for research and management of finfish on the Texas coast; 1973; 22 p.

Texas Parks and Wildlife Dept. Coastal Fisheries Branch. Information on the biology and the life history of important fish and shellfish of the Texas coast. Preliminary draft. Austin, TX: Coastal Management Project, Texas General Land Office; July 1975; 299 p.

Texas Parks and Wildlife Dept., Licenses Section. Memorandum to Governor William P. Clements from Dicky Travis; 1980; 2 p.

Trent, L. Size of brown shrimp and time of emigration from Galveston Bay system, Texas. Proceedings of the Gulf and Caribbean Fisheries Institute 19th annual session: 7-16; 1967.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Texas landings, annual summary: 1965-1977; annual series 1967 through 1979.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Processed fishery products annual summary 1976; 1977.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Fisheries of the United States: 1-120; 1979.

U.S. Dept. of the Interior, Fish and Wildlife Service. Concept plan unique wildlife ecosystems Texas. U.S. Fish and Wildlife Service Region 2:1-164; February 15, 1979.

Van Lopik, J.R.; Drummond, K.H.; Condrey, R.E. Draft environmental impact statement and fishery management plan for the shrimp fishery of the Gulf of Mexico, United States waters. Center for Wetland Resources, Louisiana State Univ.: 1-1 to 10-19; October 1979.

Venkataramiah, A.; Lashmi, G.J.; Gunter, G. Studies on the effects of salinity and temperature on the commercial shrimp Penaeus aztecus Ives, with special regard to survival limits, growth, oxygen consumption and ionic regulation. U.S. Dept. of the Army, Corps of Engineers, Waterways Experiment Station contract report H-74-2; xi; 1974.

Warren, J.P.; Griffin, W.L. Cost and return trends in the 1970's for the Gulf of Mexico shrimp vessels. Texas A&M Univ. Agricultural Economics Dept., College Station, TX; 1978; 20 p.

TRANSPORTATION

Transportation is perhaps the most important support industry in the TBIE area, although income generated may not be as large as some other support industries. The services provided by the transportation industry are virtually indispensable, and the cost of financing facilities and vehicles providing these services touches the lives of all area residents. Petroleum refining, petroleum production, and agriculture, three of the four leading economic sectors of the area, are to a great extent dependent on transportation for their value. Of the TBIE area's leading economic sectors, only banking activities are not directly dependent on transportation systems.

The transportation industry will play a key role in the future growth and development of the TBIE area because transportation controls access to resources and activities; whether the industry should take an active role in determining the amount and shape of regional growth will depend on a number of factors, including questions of jurisdiction and financial resources.

The industry will need to provide not only for the increases in population and industrial activity that are predicted for the area, but for a change in economic orientation. Until recently the TBIE area could be characterized as an export center. The abundant supply and steady development of petroleum and other natural resources in the area provided the basis of most economic activities. Today the readily accessible natural resources of the area are diminishing, with a consequent need for foreign imports to fuel the industrial activities, while continued urban growth is increasing the need for consumer commodities. The area is thus rapidly changing into a center for import. In 1978, the value of imports nearly equaled the value of exports at the Port of Houston for the first time, and imports have exceeded exports at Galveston since 1975 (Texas almanac 1979). This shift in the balance of import and export activities is an important consideration in transportation planning in the TBIE, particularly for port facilities as the need increases to attract import shipping.

The demand for different types of transportation services in the TBIE area varies with the mix of industrial activity and urban concentration. The energy-related industries and the greater population densities of the Gulf Coast planning region are a contrast to the agricultural activities and relatively low population densities of the southern portions of the study area. Transportation plans and the assessment of the environmental effects of transportation systems must reflect these regional differences. There are trade-offs between transportation modes that depend on the type and level of activity in each region. It may become increasingly necessary to consider these trade-offs if predicted fuel shortages and rising transportation costs become realities.

The transportation industry of the Texas Coast has several major sectors. As of January 1980, six deepwater ports serve the Texas coast, their depths ranging from 11 to 12.2 m (36 to 40 ft) (U.S. Department of Commerce 1978). The Gulf Intracoastal Waterway (GIWW) extends along the entire coast, particularly through lagoons landward of the barrier islands. A total of 578 km (359 mi) of the GIWW is located within the area, which constitutes 32.4% of the GIWW's total length of 1,749 km (1,109 mi) from Brownsville to Tampa Bay. The concentration of pipelines in the area is greater than any similar sized area in the world, with a capacity to transport more than 135 million mt (150 million t) of product per year

(Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973). Ten Class I or II rail lines, with more than 4,100 km (2,500 mi) of track, operate within the study area (Texas almanac 1979). At least 11,265 km (7,000 mi), or 10% of the State's highways are in the TBIE area (Texas almanac 1979). Thirty-three of the State's 265 airports (12.4%) are located there, 9 of which are currently served by scheduled air carriers.

With the exception of pipelines and powerlines, each transportation mode can be considered as a discrete system comprised of terminal facilities, a vehicle type, and an interconnecting medium through which the vehicle travels as it transports people, information, and goods. Considerable capital has been invested in terminal facilities, and their long-term usefulness is a concern to system users and to those who finance their construction and operation.

The vehicles used to transport people, information, or goods between terminal points are specially designed for certain kinds of cargo and for specific travel distances and interconnecting media. Utilization of an airspace between two terminal points involves electronic navigation and avoidance of other airspace users. Waterways, in contrast, present an additional concern for the maintenance of channel depths, approaches, turning basins, and the preservation of valuable natural habitats. Railways and roadways pose a series of other considerations, including corridor maintenance and the proper compatibility with adjacent land uses. These and other issues present a need for the development of comprehensive plans that enable transportation system users easy and economical access to all modes.

To better understand their function, the following sections will characterize the facilities and vehicles of each transportation mode and discuss their characteristics as they relate to the TBIE area.

WATERWAYS

Waterborne commerce accounts for the greatest volume of commercial transportation in the Texas coastal area. Three-fourths of all goods shipped from Texas to other states travel by water (Texas General Land Office 1978). In 1977, 420 million mt (460 million t) of products traveled the waterways of the TBIE area (U.S. Department of the Army n.d.), carried by 382,000 trips. On the average, 1,146,600 mt (1,260,000 t) were shipped daily to another destination or brought into the TBIE area during 1977.

The Houston Ship Channel handled 94,905,053 mt (104,291,267 t) or almost 23% of the total TBIE yearly traffic (U.S. Department of the Army n.d.). The facilities of Corpus Christi handled 50,997,412 mt (56,041,113 t), or 12% of TBIE traffic. These examples of traffic at TBIE ports and harbors indicate the area's continuing dependence on waterborne commerce (Figure 11).

The TBIE area contains six deepwater harbor areas: Houston, Texas City, Galveston, Freeport, Corpus Christi Bay area, and Brownsville (U.S. Department of Commerce 1978).

Major Ports

The Port of Houston, third largest in the Nation, extends along the Houston Ship Channel. Houston is at the head of the channel, 35 km (22 mi) north of

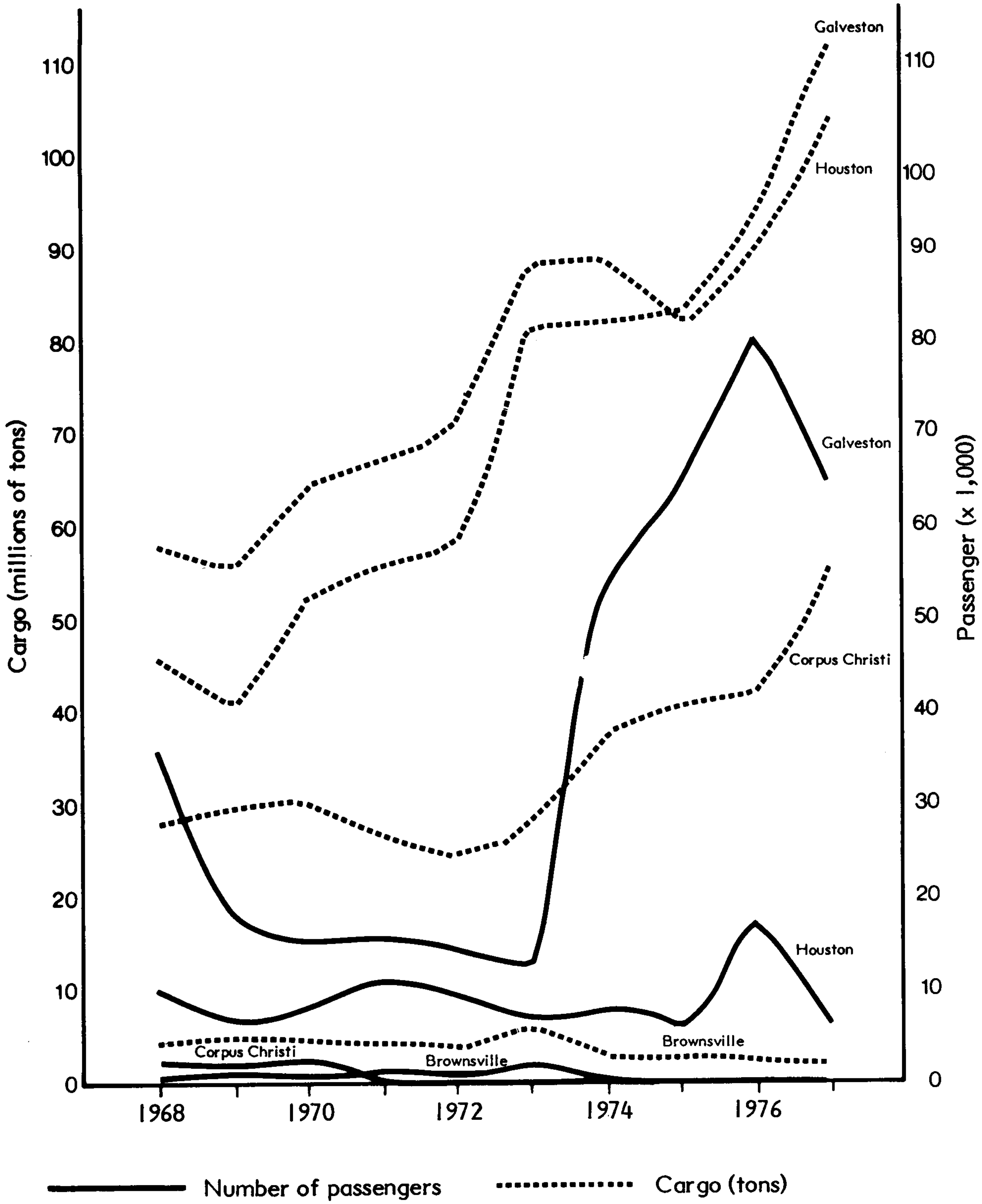


Figure 11. Passenger and cargo for four major harbor and port areas (U.S. Dept. of the Army, Corps of Engineers n.d.).

Galveston and 71 km (44 mi) from the Galveston entrance to the Gulf of Mexico. The port area also encompasses several smaller towns and waterways between Houston and Galveston. The port is managed and controlled by the Port of Houston Authority.

Principal imports at the Port of Houston include coffee, molasses, burlap, lumber, wood products, newsprint, petroleum, various ores and concentrates, steel products, and motor vehicles. Principal exports include wheat, sorghum and various other grains, petroleum products, cotton, synthetic rubber, coke, coal tar products, alcohol, industrial chemicals, and fertilizers (U.S. Department of Commerce 1978). The port has one public and four private grain elevators, with the largest capable of storing more than 8 million bushels of grain. In addition, there are many petroleum refineries, petrochemical and fertilizer plants, cotton compresses with warehouses, shipyards, and steel mills.

More than 200 piers and wharves provide cargo transfer points for ships using the Houston port. Over 4,900 m (16,000 linear ft) of docking facilities are available for deepwater vessels with drafts up to 12.2 m (40 ft). Common cargo handling is generally carried out with the vessels' own loading and tackle equipment, but special handling equipment is available on a limited and pre-arranged basis. Mobile cranes of up to 273 mt (300 t) capacity, and a floating derrick of 728 mt (800 t) capacity are available at the port (U.S. Department of Commerce 1978). There are facilities for the handling of containerized shipments. The port also provides about 80 ha (200 ac) of open storage, 226,400 m^3 (8 million ft^3) of covered storage, and 113,200 m^3 (4 million ft^3) of cooler and freezer storage.

Intermodal connections at the port are provided by six trunk railroad companies, over 30 major motor freight carriers, and many specialized truck lines. Buslines operate from two terminal areas, and there is a local public transit bus service (U.S. Department of Commerce 1978). At least 100 steamship lines serve the Port of Houston, in addition to some 90 tanker operators, 20 specialized cargo operators, and several barge lines.

Galveston Bay is the entrance to East and West Bays, the Houston Ship Channel and the cities of Galveston, Texas City, and Houston, as well as numerous smaller towns and bayous. The bay is approximately 48 km (30 mi) long and 27 km (17 mi) wide, with depths ranging generally from 2.1 to 2.7 m (7 to 9 ft). The bay is divided into two areas by Red Fish Bar, a small chain of islets and shoals through which the Houston Ship Channel is dredged (Port Galveston magazine 1978).

The Port of Galveston is one of the older deepwater facilities in the Gulf of Mexico. Used for shipping since 1820, the principal commodities traded through the port area are wheat, rice, synthetic rubber, petroleum products, scrap iron, lumber, paper products, oil well pipe casing, machinery, alcohol, stone, aluminum, copper, and coal (U.S. Department of Commerce 1978, Port Galveston magazine 1978).

To serve the trading activities in the area, the port has a total berthing area of 8,230 m (27,000 linear ft) along more than 50 wharves and piers. All deepwater craft facilities have potable water supplies, shorepower, railroad, and highway connections. Special handling equipment is available if the ship's equipment cannot unload its cargo. Large cranes, up to 68.3 mt (75 t) capacity, are available, as well as a 455-mt (500-t) floating derrick from Houston.

The port provides more than 12 ha (29.7 ac) of shipside warehousing and more than 74 ha (181.3 ac) of open area for storage and transfer of trade commodities. The Port of Galveston also owns and maintains an 80.5-km (50-mi) terminal railway with 5 diesel engines. Six railroad companies use the port facilities to transfer cargo traffic from rail to ship (U.S. Department of Commerce 1978). Containerized shipment facilities are also available.

The privately owned port of Texas City lies on the west side of Galveston Bay, 11 km (7 mi) northwest of Galveston. Although somewhat smaller than Galveston or Houston, Texas City Port has extensive foreign and domestic trading in petroleum, chemicals, fertilizer, and tin ore. Other major commodities include rice, wheat, flour, hides, naval stores, textiles, lumber, woodpulp, petroleum products, steel products, zinc, copper, coal tar, and scrap iron (U.S. Department of Commerce 1978).

Most Texas City port facilities are owned by the Texas City Terminal Railway Company. The area has more than 35 wharves and piers with over 900 m (3,000 ft) of docking facilities. Various piers with special equipment are available for cargo handling, including a 32-mt (35-t) floating crane and use of the 455-mt (500-t) floating derrick from Houston. The Texas City Terminal Railroad connects seven trunk railroads to the seaside loading docks in the Texas City area.

Freeport Harbor, adjacent to the town of Freeport, lies 64 km (40 mi) southwest of Galveston. Dow Chemical Corporation's two large plants constitute the principal industry in the general region, which is known as Brazosport. Other industries in the Brazosport area deal in oil, sulphur, and shrimp. Oil and chemicals are the principal export commodities (U.S. Department of Commerce 1978).

More than 640 m (2,100 ft) of docking facilities are available at more than 50 wharves and piers in the Brazosport area. Although special cargo handling equipment is available, most handling is accomplished by shipboard equipment. A 319-mt (350-t) floating "stiff-leg" derrick is available (U.S. Department of Commerce 1978). The Brazos River Harbor Navigation District has jurisdiction and control of the navigable waterways in the Brazosport area. The general manager of the district acts as port director and the terminal superintendent assigns berths on application for the facilities operated by the navigation district.

The Port of Corpus Christi, located 303 km (188 mi) southwest of Galveston, includes many waterways and facilities. Corpus Christi Bay is elliptical in shape, about 24 km (15 mi) long and 18 km (11 mi) wide. Within the bay area are Main Harbor, Harbor Island, Port Ingleside, and La Quinta. The Main Harbor includes Corpus Christi Turning Basin, Tule Lake Turning Basin, Viola Turning Basin, and Chemical Turning Basin. Port operations are guided by a commission that oversees the Nueces County Navigation District No. 1, which encompasses all of Nueces County. The 13.7-m (45-ft) depth of many of its channels make the Port of Corpus Christi the deepest inshore port on the Gulf of Mexico (Port of Corpus Christi 1978).

Principal cargos imported at the Corpus Christi port are crude oil, molasses, chrome, zinc, paint and pigments, and petroleum products. Exports include wheat, sorghum, animal feed, flaxseed, aluminum products, industrial chemicals, and canned food (Port of Corpus Christi 1978, U.S. Department of Commerce 1978).

Tonnage at the port more than doubled from 1973 to 1978, primarily due to increased shipments of petroleum-related products.

Approximately 54,600 mt (60,000 t) of cargo were handled at Corpus Christi in 1978. More than 2,530 m (8,300 ft) of deep draft docking facilities are divided among 70 piers and wharves. There are 18 ha (45 ac) of open storage area available, with 19 ha (46 ac) of covered storage, and 2,547 m^3 (900,000 ft^3) of cold storage. Mobile cranes with capacities of up to 32 mt (35 t) and a 91-mt (100-t) stiff-leg derrick are available for the handling of special cargos. Three trunk railroads serve the ship docks for transfer of cargo (Port of Corpus Christi 1978, U.S. Department of Commerce 1978).

The Port of Brownsville, located at the southern tip of Texas is connected to the Gulf of Mexico through the 23.3-km (14.5-mi) Brownsville Ship Channel. The Brownsville Navigation District has jurisdiction and control over the Ship Channel and turning basin. The port contains 17 ha (41 ac) of covered storage, about 38 ha (93 ac) of open storage, and 19 ha (46 ac) of cold storage. More than 40 wharves and piers with more than 2,000 m (6,700 ft) of deep draft dockside facilities serve the users of the port. Two 137-mt (150-t) floating cranes are available for special cargo handling. One Mexican and two United States trunk railroads serve the port transfer requirements (U.S. Department of Commerce 1978). Primary cargo handled at Brownsville includes cotton, zinc, chemicals, petroleum products, citrus fruit, steel products, and manganese.

There are several other ports in the TBIE area that are less significant in terms of waterborne commerce. Bayport, Port Lavaca-Point Comfort, and Port Isabel have deep draft channels and specialize in the handling of various products such as petroleum products, petrochemicals, bauxite, and certain bulk cargos. They also contain berthing and repair facilities for commercial shrimping vessels and small craft. Many shallow draft harbors, sited along the Gulf Intracoastal Waterway, cater to barge traffic, recreational craft, and specialized vessels for the oil and gas industry.

Foreign trade through the ports of the study area increased remarkably from 1970 to 1977, primarily due to the import of crude petroleum (see Volume II, Data Appendix, Transportation tables 4-7, 9, and 10). In 1970, foreign commerce was responsible for only 26.4% of the tonnage handled at the Port of Houston; 7.5% was import traffic and 19.0% export, predominately the export of farm products. In 1977, foreign shipments at Houston had increased to 48.9% of the tonnage, 34.1% of which was imported. Crude petroleum accounted for 78.7% of the import tonnage. Foreign exports at the Port of Houston increased slightly in absolute tonnage during this period, but declined in percentage of port commerce to 14.9% in 1977.

Other TBIE area ports have shown similar increases in foreign trade. At Texas City, foreign commerce increased from 5.2% of tonnage handled in 1970 to 39.0% in 1977. Imports accounted for 36.7% of all trade at Texas City in 1977; 98% of this was in crude petroleum. Foreign trade at Corpus Christi grew from 27.2% of total tonnage in 1970 to 51.6% in 1975; 42.5% was import traffic, largely in crude petroleum. Freeport increased foreign imports from 0.2% in 1970 to more than 66% in 1977, while foreign exports remained relatively steady in absolute tonnage. Crude petroleum accounted for most of the growth in foreign imports at each of these ports.

The import of crude petroleum was not a factor at the Port of Galveston, but this is a port long dominated by foreign commerce, especially the export of farm products. In 1977, foreign trade at Galveston accounted for 74.2% of the total, 17.3% of which was import business and 61.9% export. Approximately 55% of the tonnage handled at the Port of Brownsville is import and export trade with Mexico (Hershman et al. 1978).

Port Financing and Management

Texas coastal ports, with the exception of the city owned Galveston Wharves and the privately owned Texas City Terminal, are owned and administered by local navigation districts (Buchanan 1973). These districts, with powers granted by the State Legislature, have responsibility for the management and development of port facilities. Development capital is generated by direct revenues from port activities, tax revenues, and tax and revenue bonds that the navigation districts have the authority to issue. Revenue bonds are the preferred means of long-term debt financing because, unlike tax bonds, they can be issued without voter approval if they are backed by sufficient revenue potential.

Estimates of the capital improvement programs of 9 Texas ports exceeded $160 million for the period from 1970 to 1980 (Etter and Graham 1974). The estimates for 1980 to 1990 exceed $105 million, and this is undoubtedly understated because it has not taken inflation into account. Projections indicate that requirements for capital cannot be met by most ports under the present means of financing. State support has been suggested as necessary if expansion and development plans are to be realized (Etter and Graham 1974). Indirect financial assistance for the ports is provided by Federal navigation projects and programs of Federal tax exemption.

Most indirect Federal control of port development is provided through the Army Corps of Engineers. The Corps performs both maintenance and expansion dredging of ports and harbors, and of waterways and channels. Texas bays are so shallow that channel dredging is essential to accommodate even shallow draft navigation (Texas General Land Office 1978).

The Corps administers a program for the consideration of environmental impacts associated with dredge and fill operations in navigable waters. This program involves many Federal and State agencies and other interested parties (33 U.S. Code 320 and 322-329; 42 Federal Register 37121, July 19, 1977). Copies of all plans for proposed dredging projects are sent to reviewing agencies. Under the National Environmental Policy Act of 1969 (42 U.S. Code 4341), the Corps must identify environmental impacts of each proposed project and address reviewers' comments on these impacts in an environmental impact statement. The EPA, NMFS, FWS, and TPWS generally make extensive reviews and recommendations on Corps projects.

In the absence of an overall State port authority there is competition for business between the Texas ports that potentially leads to a duplication of costly specialized facilities such as deep-draft ports (Etter and Graham 1974). Texas ports are also in competition with other Gulf ports; a competition that will increase with the opening of the Louisiana Offshore Oil Port (LOOP). The trend toward fewer and deeper ports that is apparent along the Texas Gulf Coast is the result of intense competition and the maximization of local benefits, in a free market, rather than a statewide plan of development. These local benefits, which include existing storage, manufacturing and refining facilities, and infrastructure, provide many Texas ports with their best competitive edge.

The Texas Ports Association is a voluntary, unincorporated association of deepwater ports that convenes periodically to consider matters of mutual interest to all deepwater ports of Texas (Buchanan 1973). This body has no legal status or rule-making or decisionmaking powers. It offers a forum, however, for the discussion of common approaches to common problems, and may represent a step toward collective decisionmaking.

Proposed Superports

The size and draft of ocean-going commercial vessels has increased significantly in the past few decades. Channel depths in the ports of the TBIE area range from 10.8 m (36 ft) at Brownsville, Galveston, and Freeport to 12 m (40 ft) at Houston, Texas City, and Corpus Christi. Nearly 10 years ago, these depths were considered barely adequate to handle the average size tankers of world fleets (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973). In addition to increases in the currently used method of offshore lightering to shallower draft vehicles, additional deepwater port facilities may be essential if the Texas coast is to remain prominent in refining and petrochemical industrial activities. Three major proposals for crude-importing superports in the study area have been made: 1) the Pelican Island project at Galveston; 2) the Texas Deepwater Port Authority (TDPA) monobuoy system off the coast at Freeport; and 3) the Deeport project at Port Aransas-Harbor Island.

The Pelican Island project is designed to handle very large crude carriers with a deepwater channel and new oil terminal (Sumpter 1979). Two crude pipelines would connect the facility with a 12 million bbl tank farm at Texas City. Other pipelines would connect the tank farm with refineries in Beaumont-Port Arthur, Houston-Baytown, and Freeport. The project calls for lengthening the existing channel from 19 km (11.8 mi) to 51.5 km (32 mi) at a depth of 19.5 m (65 ft) outside the Galveston jetties, and deepening the Galveston channel within the port to a depth of 16.2 m (54 ft).

The Pelican Island project was originally estimated to cost $350 million, but it is now apparent that costs will exceed that figure (Sumpter 1980). Galveston Wharves, the city-owned port, has signed an agreement with the Pelican Terminal Corporation, a privately held firm, for financing and construction of the project. In the opinion of the developers, the terminal would not be in competition with LOOP for the same shippers, but would be in competition with the other proposed Texas superports (Sumpter 1979).

The TDPA project would require four single-point mooring buoys and offshore pump facilities (Sumpter 1979). Two 80-km (52-mi) pipelines would move the crude to a 22.5 million bbl tank farm onshore. The deepwater facility, which would be located about 44 km (27 mi) off the coast of Freeport, would have an estimated cost of $1.15 billion. TDPA was created by the State Legislature, and has borrowed $2.9 million from the Texas treasury, but the facility will not be financed directly by the State. Financing must come from the sale of revenue bonds, although to date not enough crude importers have agreed to underwrite these bonds. The port may be built piecemeal, if at all (Sumpter 1980).

Deeport, originally a \$431 million project now estimated at \$600 million, is under the control of the Nueces County Navigation District No. 1. It would be funded by revenue bonds and backed by five private companies. Plans call for the dredging of a 24-m (80-ft) deep, 16-km (10-mi) long approach channel into Harbor Island near Port Aransas, a 22.2-m (74-ft) turning basin and a 22.8-m (76-ft) docking basin. Plans include 13 million bbl of onshore crude tankage and two 122-cm (48-in) crude lines connected to refineries. The completed project would handle fully loaded tankers up to 275,000 dead weight tons (DWT).

All of these projects are being delayed by environmental, permitting, and financial concerns. Safety considerations, particularly fear of fire and explosion, are being voiced in response to the Pelican Island project. The biggest concern of Federal agencies and environmentalists in the Deeport project is the effect of the scheduled disposal of dredged spoil on 1,200 ha (3,000 ac) of wetlands. Deeport also needs an easement from the Texas General Land Office to use submerged lands for the disposal of dredged spoil.

In the opinion of some experts, none of the proposed Texas superports will be approved for construction in the near future (No big improvements...1980). If the EPA's concerns about air quality standards can be satisfactorily addressed, the Pelican Island project appears to have some chance of being constructed. If this takes place, the refining, petrochemical, and associated industrial activities will be sustained along the northern reaches of the Texas Gulf coast, and additional industrial development may be stimulated.

Modal Connections and Vessels

The terminal shape, design, number of wharves and piers, land area, and use are largely dependent upon the type and amount of cargo brought into the port. Type and amount of cargo are determined by the capacity of a ship to transport the goods, and to reach its destination.

Large vessels of specialized design take advantage of the economies of large-scale transport of goods, significantly affecting port operation and development. Larger, faster vessels carry more cargo over a given period and spend less time in port loading and unloading (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973). Costs of shipping bulk cargo have been reduced because of technological improvements in ship design and use.

The tanker and bulk carrier vessel are the largest types in terms of DWT. The transport of considerably more cargo in each ship requires that port facilities increase their capacity for transfer and storage. Most of the impact of the larger ships has been experienced only in the last ten years, mainly in the form of increased port congestion (Hershman et al. 1978).

General cargo vessels have not increased in DWT as much as the tankers and bulk carriers. There have, however, been significant changes on new general cargo vessels in the method of on-board loading and unloading. Specialized cargo handling techniques have substantially reduced the time and cost of a vessel's stay in port. Ships with such specialized equipment constitute less than 20% of the U.S. general cargo fleet, but carry more than two-thirds of the general cargo in vessels of U.S. registry (Hershman et al. 1978).

Three types of special cargo ships are regularly used today: containership, barge-carrying ship, and the roll-on, roll-off (RORO) ship.

Containership. The first generation of containerships was introduced in the 1960's. The ships were approximately 150 m (500 ft) long and carried about 500 containers of the 6.1-m (20-ft) standard size. More recent ships are as much as 274 m (900 ft) long and can carry as many as 3,000 of these standard containers. The drafts of such ships have created problems. Drafts of some new ships are 13.1 m (43 ft), requiring deeper port facilities. Newer designs, not yet operating, will draw even more water when fully loaded.

Standardized containers permit loading and unloading in as little as one-fifth the time required by equivalent loads not shipped in these containers (Hershman et al. 1978). These specialized containers, designed especially for transfer and transport, can be taken directly from the ship to a railroad flatcar. With increased saving of time and labor costs, more and more cargo will probably be shipped by this method, thus requiring additional intermodal ship-rail transfer facilities and deeper port facilities. The ports at Houston, Texas City, Galveston, Corpus Christi and Brownsville have facilities for containerized cargo.

Barge-carrying ships. The barge-carrying ship is designed to supplement inland waterway transportation. Barges are loaded at inland, shallow draft ports (1.8 to 3.7 m, or 6 to 12 ft depth), transported to deeper facilities, and then transferred directly to barge-carrying ships for ocean travel to other countries. This method increases the efficiency of shipping on two inland waterways with an intervening oceanic stage, but is used far less than the containership method of rail-ocean transfer.

RORO ships. These vessels take advantage of the cargo's automotive capability. Loaded trailers, trucks, or cars, are driven on board by way of stern or side ramps, to and from the storage or transfer areas. As with the barge-carrying ship, the RORO is not used as extensively as the containership.

The increasing use of these three types of new special cargo ships prompts many port authorities to request that the Corps of Engineers deepen their channels and harbors. The requests are based on logical ambitions that arise from new ship designs. Depth, however, is only one of the waterway design considerations. Additional attention must be focused on widths of channels for increasing two-way traffic and enhancing safe navigation and maneuvering room in turning basins and bends for capacity and safety needs. Efficient use of ports depends upon the effective disposition of these difficulties. Traffic congestion in some of the channels is already so severe that collisions occur. The Houston Ship Channel is one of 14 in the Nation being considered by the Coast Guard for a traffic control system, if enabling legislation is passed (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973).

Deeper ports, harbors, and channels also require additional dockside facilities. Extensive capital investments have been made in such facilities: new wharves for handling the cargo and containers; additional land (8 to 20 ha, or 20 to 50 ac) needed to support each new ship berth; more specialized cargo handling equipment such as cranes and straddle carriers; and new and extended highway and rail connections (Hershman et al. 1978).

Navigation Districts

In addition to the navigation districts that control the deepwater ports of the Texas coast, there are 16 navigation districts concerned only with the development and maintenance of channels that connect with the GIWW or with the development of facilities for water recreation. These districts have primary responsibility for the improvement, conservation, and preservation of inland and coastal navigable water areas (Buchanan 1973).

The responsibility of navigation districts controlling the channels includes control of vessels of all types on these waterways and the control and distribution of storm water and floodwater of rivers and streams in aid of navigation. Commercial navigation is only a secondary consideration for those districts concerned with developing the area under their control for water recreation and tourism purposes. Not all areas of the Texas coast are within the jurisdiction of a navigation district.

Gulf Intracoastal Waterway

A discussion of waterborne transportation in the TBIE area is not complete without a consideration of the GIWW. One-third of the GIWW, which extends from Brownsville to Tampa Bay, Florida, is located within the TBIE area. The Texas portion handled more than 63% of the total GIWW traffic tonnage recorded in 1977 (U.S. Department of the Army n.d.). Barge shipment of bulky materials is characteristic of GIWW transportation.

When construction on the GIWW was initiated in the mid-1930's, little or no consideration was given to uses other than commercial shipping (Transportation Planning Division, Texas State Departments of Highways and Public Transportation 1978b), or to the effects on the coastal wetlands. Today, the adverse effects of commercial shipping on wetland habitat and function have become major concerns creating substantial development problems.

On a 69-km (43-mi) segment of the GIWW, selected for observation, commercial traffic constitutes about 63% of the average annual traffic (Transportation Planning Division, Texas State Department of Highways and Public Transportation 1978b). The remaining 37% resulted from the activities of small fishing vessels (18%) and recreational craft (19%). The great fluctuation in volume of traffic is accountable to fishing and recreational craft. Movements of fishing vessels vary with the season and the weather; recreational craft activities differ greatly from day to day. For example, on one summer weekend, recreational craft passing an observation point constituted more than 72% of all traffic, an increase of 500% over the daily average for that month (Transportation Planning Division, Texas State Department of Highways and Public Transportation 1978b). Non-commercial traffic seems to be increasing along many reaches of the GIWW. Accommodation for these craft must be considered. Because there are few mooring facilities, recreational craft traveling the GIWW commonly anchor overnight in the main channel, creating a navigation safety hazard (Transportation Planning Division, Texas State Department of Highways and Public Transportation 1978b).

Major commodities handled on the GIWW are petroleum products, chemicals, crude petroleum, shell, and non-metallic minerals. Shipment of these bulky items constituted over 94% of total commodity transport in 1976 (U.S. Army Corps of

Engineers n.d.). While these five items as a group have remained constant in their total share of GIWW traffic, their relative portions have changed significantly. Between 1960 and 1965, crude petroleum and marine shell constituted about 51% of all commodity shipments. By 1970, however, their proportion had declined to 44.1%, and by 1976 to 27.6%. Petroleum products and industrial chemicals increased proportionately during the same period.

While GIWW cargoes increase, so do the costs of transportation by barge. Inadequate channel depths and widths on the GIWW increase the cost to its users, compared to transportation competitors on other navigable waterways. Increased depth would allow more tons per barge, and increased width would enhance safety and decrease transportation time.

Comparing the Mississippi River to the GIWW, the depth of the Mississippi ranges from 4 to 12 m (13 to 40 ft), and its width ranges from 91 to 335 m (300 to 1,100 ft), while the average depth of the GIWW is 3.7 m (12 ft) and the average width is 38 m (125 ft) (U.S. Army Corps of Engineers n.d.). The channel dimensions of the GIWW restrict tows to a maximum length of 360 m (1,180 ft) and a maximum width of 16.8 m (55 ft). These restrictions limit tows to three to five barges. On the Mississippi, by contrast, tows can reach 40 barges in size. Shippers on the GIWW not only have the cost of longer haul routes compared to the Midwest, but must contend with smaller tow sizes.

Texas shippers call for enlarging the GIWW between the Sabine River and Corpus Christi to a depth of 4.9 m (16 ft) and to a width of 76.2 m (250 ft). Figure 12, however, indicates that although there has been an increase in vessels with drafts of 3 m (10 ft) and more, particularly in eastbound traffic, vessels with a draft of 1.8 m (6 ft) continue to dominate traffic in the GIWW. The shippers also recommend that the GIWW be straightened where possible to reduce curve restrictions on traffic. Currently, the Corps of Engineers, Institute of Water Resources is conducting major studies to address these and other improvements to the GIWW. The report is due for completion in October 1980. Widening the GIWW barge canal may gain little, however, unless the capacity of the locks to the Mississippi River system is increased. In 1970, more than half the barge traffic on the GIWW crossed the Texas-Louisiana border and had to pass through the severely congested locks in Louisiana. The restrictions to barge traffic caused by these locks can create delays of 24 to 30 hours, which more than doubles the normal travel time between Texas and the Mississippi River (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973).

Natural Resource and Environmental Concerns

Coastal management concerns revolve primarily around the proper and effective use of natural resources. Waterborne commerce creates an undeniably significant impact upon these natural resources. The TBIE area is only one among many coastal areas where environmental concerns have been expressed, studied, and debated over the past several years. Common to all waterway development programs are these fundamental issues:

1. Management of landfill;
2. Management of dredging and dredged material disposal;
3. Air and water quality degradation, including hydrologic modifications;
4. Mitigation and compensation for environmental damages.

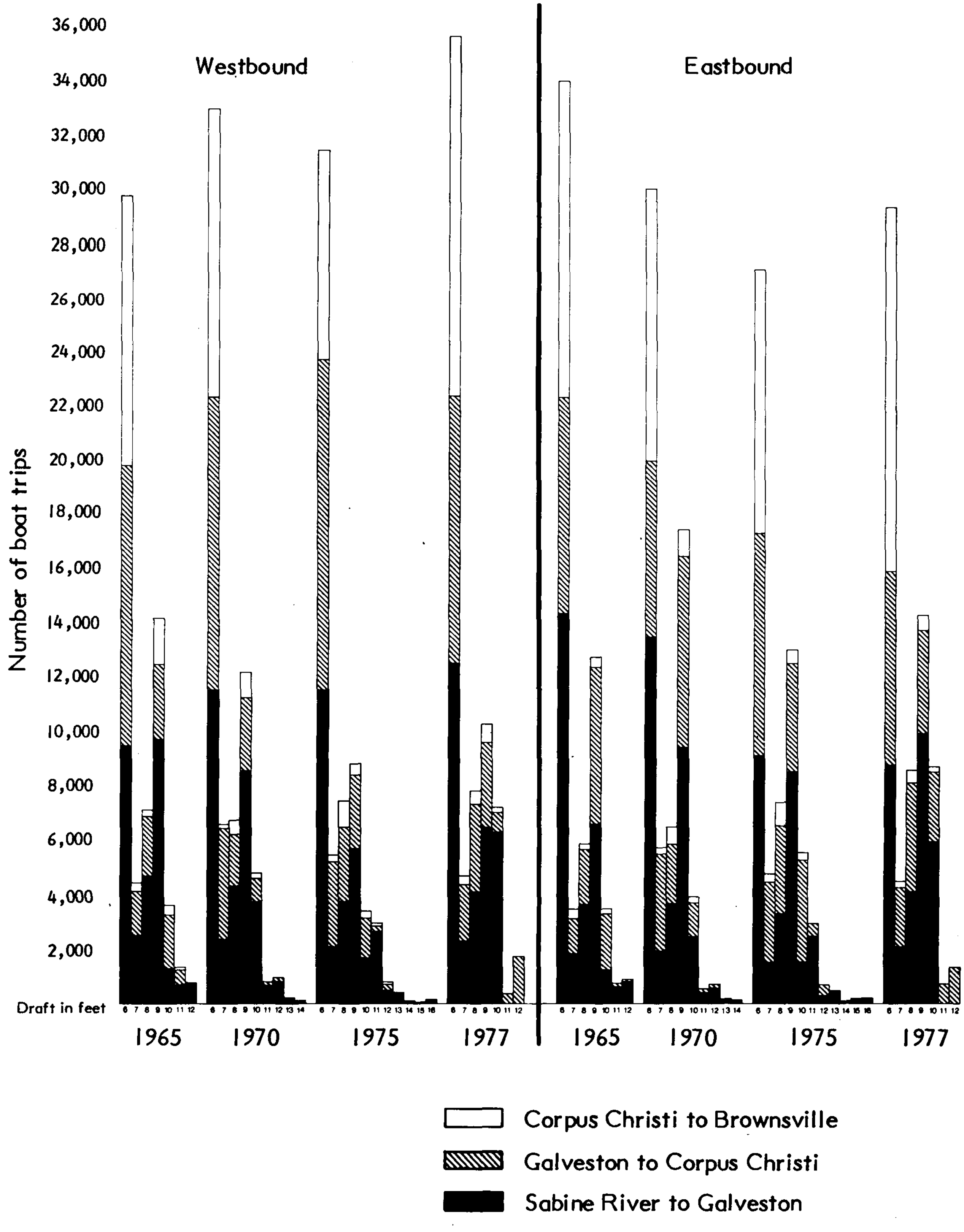


Figure 12. Distribution of GIWW boat traffic by reach, direction, and draft, for selected years 1965 through 1977 (U.S. Dept. of the Army, Corps of Engineers n.d.).

Although these are items of concern for most waterway projects, the specifics of each region must be emphasized in dealing with the issues. In addition, there may be jurisdictional differences in the laws and the regulatory agencies from region to region. The following discussion is not an attempt to offer resolution to these environmental concerns, but to indicate those areas that will require intense study and effort before sound resolution can be effected.

Management of landfill. The owners and administrators of most ports intend to acquire additional waterfront facilities to accommodate increased shipping and larger vessels. Other activities in port areas, such as steel mills and petroleum storage, must be close to the waterfront for the sake of economy. Without available land areas for new developments, port authorities must create new facilities or suffer economic losses in competition with ports that have such facilities; thus, the need for landfill development projects.

Management of dredging and disposal of dredged material. World fleets contain ships exceeding 19.8 m (65 ft) drafts. To remain competitive in world markets, ports must be able to serve these deeper draft vessels. Naturally-occurring deep ports of sufficient depths are virtually non-existent on the Gulf Coast, but artificially creating such ports is possible. Essentially, the removal of the port floor (dredging) is relatively inexpensive when compared with the failure to serve the large ships.

A measure of the magnitude of estuarine alteration resulting from channel dredging is the amount of material removed. From maintenance activities alone, 115.1 million m^3 (151.5 million yd^3) of spoil are dredged annually along the Gulf Coast (Lindall and Saloman 1977). This is equivalent to a roadbed 45.5 m (50 yd) wide, 0.9 m (3 ft) deep, and 2,806 km (1,743 mi) long--the driving distance from Key West, Florida to Brownsville, Texas. Of this volume of dredged material, 51.6 million m^3 (67.9 million yd^3), or 32%, is dredged from Texas waters. When existing channels are expanded to dimensions already authorized, 41.8 million m^3 (55 million yd^3) of material will be removed annually by dredging operations. Authorized new work will produce 67.6 million m^3 (89 million yd^3) of virgin dredged material. This new work and associated maintenance dredging will require nearly 400,000 acre-feet (494 million m^3) of disposal space. This amount of disposal area is not yet available (Texas General Land Office 1978). New pipelines constructed for offshore operations will require additional dredging and disposal space.

The navigation channels are important to the total transportation system in Texas, but their construction and maintenance can be a threat to productive wetlands habitats. Improperly planned placement of dredged material may unnecessarily cover land that is biologically productive or increase the turbidity of waters to a level harmful to marine organisms. In particular, losses and alterations can result from the creation of new spoil islands, the segmentation and isolation of bays, increased shoaling, increased salt water intrusion, increased time required to flush estuarine habitats, alteration of tidal exchange and circulation patterns, increased turbidity, and loss of emergent vegetation (Lindall and Saloman 1977). Changes in salinity levels and suspended sediment distribution may reduce the productivity of oyster reefs, marsh areas, and open bays far from the dredging site. The effects may continue for a long time. In addition, a study conducted by the Texas Coastal Management Program found that nearly 45 percent of material disposed of during Federal dredging on the coast is polluted (Texas General Land Office 1978).

Coastal wetlands are among the most productive lands of the natural world. Wetlands produce seafood and animal fodder, provide habitat for wildlife, aid in flood and erosion control, treat and denature pollutants, and provide for recreation and aesthetic enjoyment. Coastal wetlands also constitute an extremely fragile type of ecosystem that is easily damaged or destroyed. The proposed Texas Coastal Management Program identifies control and planning of dredging and material placement as a major means of protecting wetlands (Texas Coastal Program 1979). Properly placed dredged material can create new marsh areas and new spoil islands may provide rookery sites (Texas General Land Office 1978).

Degradation of air and water quality. The very nature of the industries that commonly locate at port facilities threatens air and water quality. Grain, petroleum, and chemical industries produce the greatest volumes of pollutants (Hershman et al. 1978). Coastal management programs enacted at the Federal level address these conditions, but continued cooperation between Federal and local agencies is necessary in planning and implementing regulations.

In one exemplary instance, the Brownsville Navigation District, which operates the Port of Brownsville and Port Isabel, mitigated local, inherent potential for pollution. The District, without imposing regulations, achieved a satisfactory degree of water quality by building two wastewater aeration lagoons using $4.6 million in port-sponsored bond revenues (Hershman et al. 1978).

Mitigation of, and compensation for, environmental damage. Mitigation is the avoidance or reduction of adverse conditions created by development programs. Specific programs of mitigation have, however, been defined in few port areas. At the national level, California and Oregon have developed standards concerning restoration or replacement of wetland areas affected by landfill and dredging (Hershman et al. 1978). In these two states new areas are set aside for supporting affected biological elements if restoration is not possible. Lack of knowledge concerning habitats and life cycles of the displaced creatures makes it difficult, however, to develop new sites for them. The sources of sedimentation in shoaling waterways are also inadequately understood.

As late as 1979, Texas had not yet specified mitigation techniques appropriate to dredge and fill operations. Continued efforts to do so are expected. The Corps of Engineers has developed environmental impact statements for each of the proposed deepwater port facilities and the GIWW improvement programs; each statement deals with the issues of mitigating the deleterious effects of their proposed development.

Financing mitigation measures presents an additional burden. The purpose of dredging is to create an economically viable port system, but mitigation imposes additional costs of replacing or compensating for the loss of reduced natural resources. These costs often lead to frustration or an actual loss of the economic benefits attributable to port development.

User taxes on cargo, Federal funds, and land banking are methods that may assist in the effort to provide compensation. User taxes and Federal funds are currently being utilized in various projects in the study area; land banking is yet to be used in Texas, although it is being discussed by regional river-basin commissions in other parts of the country.

PIPELINES

Crude petroleum, petroleum products, and natural gas pipelines, ranging up to 91 cm (36 in) in diameter, criss-cross the study area. In 1973, the pipeline capacity was sufficient to transport more than 135 million mt (150 million t) per year (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973). There are over 70 trunk or gathering pipelines extending from the Texas OCS and the Federal OCS to the Texas coast. Twelve of these pipelines, representing a total length of about 235 km (147 mi), extend beyond the three marine league line into the Federal OCS (Research and Planning Consultants, Inc. 1977). Most of the pipelines that are situated wholly within the Texas OCS carry gas and are 6 to 30 cm (2.4 to 12 in) in diameter. A few are larger and carry some oil, but these are relatively rare.

Sizable increases in pipeline capacity will probably be needed as offshore areas are developed. Pipelines require large initial investments and additional rights-of-way may be difficult to obtain. It is reasonable to assume that producers may be drawn to areas currently served by pipelines because significant savings could be made. Recent proposals for pipeline activity in the Gulf Coast have been in areas of already existing pipeline systems (Research and Planning Consultants, Inc. 1977).

Pipelines are well suited for the movement of fluids over relatively short distances when continuous flow in one direction is desired. Operating costs increase drastically if the diameter of the pipe is not optimum for the desired throughput. Pipeline systems, thus, are usually designed to transport a specific commodity at a specific flow rate between two points. Under these conditions, pipelines are the least expensive, but also the least flexible, of the transportation modes. Slurry pipelines for the movement of bulk cargo from offshore areas and coal from the Midwest are being considered, but the costs involved in pipeline systems increase substantially when solids are transported in slurry form (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973).

Construction of new pipelines requires dredging and spoil disposal, but once completed, have the lowest potential for pollution or other environmental impacts of any transportation mode. More information concerning the pipelines of the TBIE area and their impacts are included in the Oil and Gas Production synthesis paper in this volume.

RAILBORNE COMMERCE

Seven Class I line-haul railroads and three Class II line-haul railroads serve the Texas Coast. The TBIE area total track mileage in 1976 was 4,591 km (2,853 mi) (Texas almanac 1979).

Major rail service in Texas is either port-related, particularly concerned with the export of agricultural products, or is located in areas of economic growth (Railroad Commission of Texas 1979). Within the study area, rail traffic is concentrated in the coastal urban and industrial centers of the area, and provides links between these centers (Figure 13). Of the planning regions along the Texas coast, the Gulf Coast planning region has the greatest concentration of population and industry, and contains 62.6% (2,602 km or 1,617 mi), of the area's trackage,

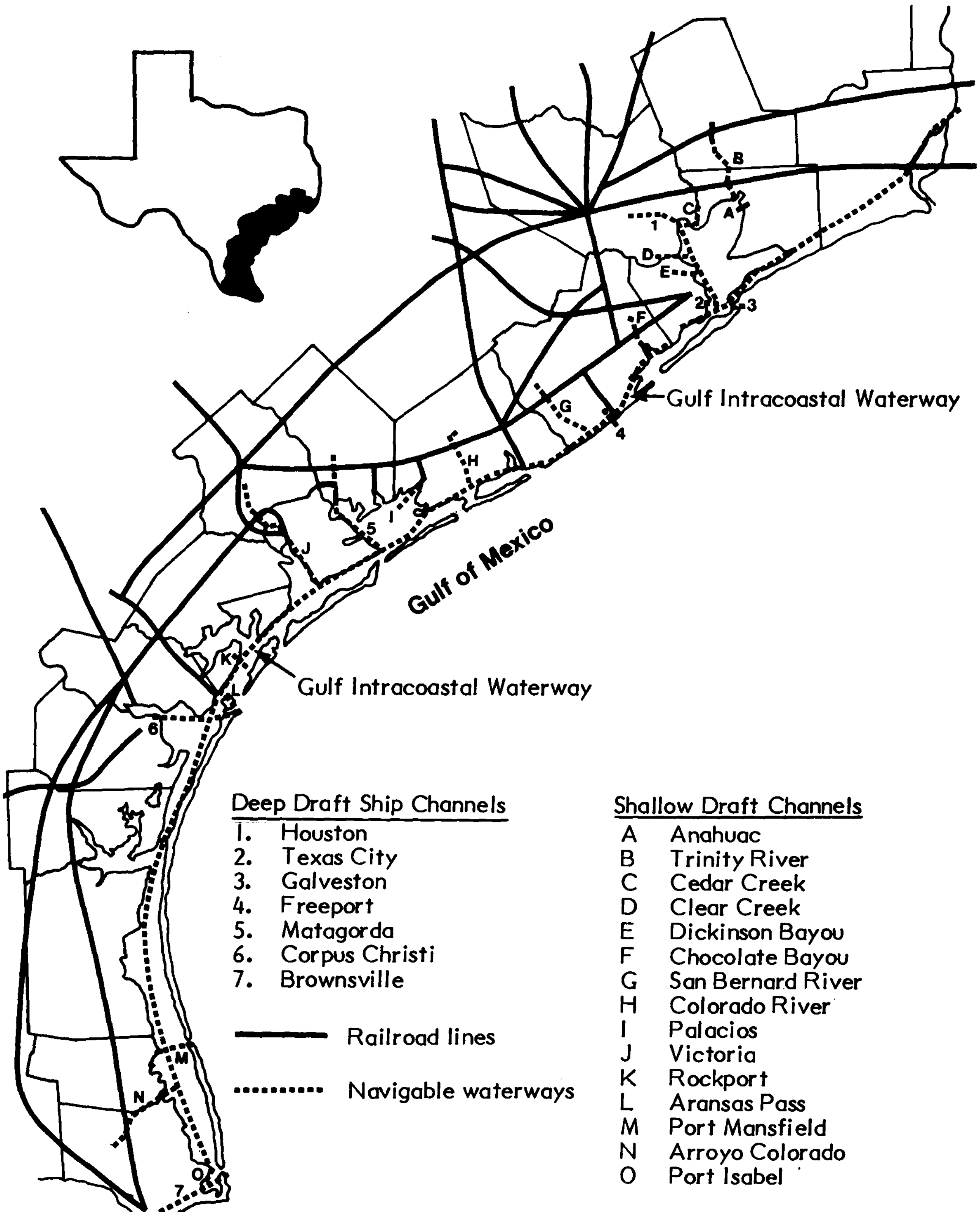


Figure 13. Railroad lines and navigable waterways in the TBIE study area (Texas Dept. of Highways and Public Transportation 1976, Railroad Commission of Texas 1979).

while the more agriculturally oriented Lower Rio Grande Valley has only 10.9% (452 km or 281 mi), and the Golden Crescent planning region has 8.4% (350 km or 218 mi). Houston is a major hub of railroad operations, linking Gulf ports to the rest of Texas and the Nation. In Harris County alone, there were 1,355 km (842 mi) of track in 1976. Important rail centers are also located in Galveston, Victoria, Corpus Christi, and Brownsville.

Rail concentrations in the TBIE area reflect the importance of rail transport to urban and industrial activities, as well as the interface of rail transport with waterborne transportation networks. The railroads provide service to the primary ship channels of the GIWW, as well as a linkage among industrial centers. Railroad use in Texas has been heavily concentrated in three Standard Transportation Commodity Classification (STCC) groups: non-metallic minerals (STCC 14), chemicals and allied products (STCC 28), and farm products (STCC 01). The three largest Class I rail haul lines in the area (Southern Pacific, Missouri Pacific, and the Atchison, Topeka and Santa Fe) have primarily transported these three product categories plus petroleum and coal products (STCC 29), and food and kindred products (STCC 20) (Railroad Commission of Texas 1979).

The history of the railroads in Texas, as measured by track mileage, has been one of early development, but steady decline over the past 30 years (Texas almanac 1979). Throughout the State, mileage increased from the turn of the century until the beginning of World War II, and has decreased steadily since that time as lines and service areas have been abandoned. This decline has been especially marked in passenger traffic, but has also been true in certain types of freight traffic. In 1978, the length of mainline track had declined to that of 1909.

Within the study area, and particularly at the ports, however, the use of rail freight did not decline at every port. Galveston, Houston, and Brownsville have unloaded fewer and fewer rail carloads during the past 30 years, but Corpus Christi has experienced a significant increase (Association of American Railroads 1951, 1961, 1971, 1978).

The use of rail lines for freight hauling has been predicted to double in terms of tonnage, for all of Texas between 1979 and 1990. By 2000, this rate of increase will be even greater (Railroad Commission of Texas 1979). Because the projected levels of population, urban, and industrial growth in the study area exceed the statewide forecasts and because of the types of industry that concentrate in the area, rail traffic in the TBIE area should increase at least to such a level. These increases will be especially concentrated in the coastal urban-industrial centers (Railroad Commission of Texas 1979).

Rail service and truck transport can serve complementary, not conflicting needs, and thus, an increase in one does not necessarily imply a decrease in the other. The largest volume of rail usage is for low-value, heavier, bulkier commodities, where the cost savings per ton-mile is more important than speed and delivery service. Examples include products of the chemical and agricultural industries. Truck traffic, in contrast, is characterized by high-value, lighter products where the needs for service and delivery outweigh shipping costs. These transportation considerations are considered so basic that even rising fuel prices should cause no immediate major shifts in transportation mode, although higher fuel costs will significantly affect economies within the transportation modes, and should drive the more expensive shippers to more efficient means.

The predicted increase in railroad use will be concentrated where there is already rail service--along the present rail corridors and in the principal urban centers. The lack of adequate railroad access has limited the growth of the southern part of the study area, however. A projected program in the Lower Rio Grande Valley planning region may improve this situation. The Brownsville Navigation District is vigorously promoting a major project to relocate rail lines and railyards to the east of Brownsville and Matamoros, on the Mexican side of the international border, and to build a new rail bridge over the Rio Grande River. This new arrangement would remove the major rail yards from the relatively congested areas of the two cities and link the fastest growing industrial areas on each side of the border. There are difficulties, however, in getting the two major railroad companies involved to cooperate.

Most problems and environmental impacts associated with the growth of rail service in the area will probably be localized. Existing equipment, track, and rights-of-way should suffice, although the chronic national shortage of rail cars will limit the capacity of the railroads to expand their business. None of the rail corridors serving the coastal area are operating at more than 20% of their basic capacity at present, and even that capacity could be increased through signalization and centralized traffic control (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973). Technical innovations, such as containerized shipping, should benefit rail transport, especially in its interface with water transportation. Local problems would include those of grade crossings, safety, yard congestion, land use, rail routings, and delivery delays. In Houston, for example, problems may be anticipated in terminal-area congestion, the consequent worsening of service, and competition for land use with urban development (Railroad Commission of Texas 1979).

Among the more severe problems of rail transportation nationwide have been those resulting from the financial and equipment conditions and the management of the railroads themselves. Of the principal railroad companies in the study area, the Missouri Pacific is considered to be in exceptionally good condition, and one of the better performers in the industry (Railroad Commission of Texas 1979). The Atchison, Topeka and Santa Fe is rated very favorably, according to maintenance criteria and moderately well in performance. Only the Southern Pacific appears weak and may require the monitoring of the Texas Railroad Commission. The condition of this line may have been improved as a result of recent expenditures for maintenance.

The study area will probably suffer few service curtailments in the near future. Only 12% of the present service in the Gulf Coast is rated as light-use line, and only about 8% of that faces potential abandonment. There is a greater danger of losses of service in the Rio Grande Valley, but not within the Lower Rio Grande Valley planning region specifically (Railroad Commission of Texas 1979).

The coordination of Federal, State, and local regulation is another difficulty facing railroad companies. Subsidized by the Federal government, railroads are regulated by Federal agencies, primarily the Federal Railroad Administration (FRA) of the Department of Transportation and the Interstate Commerce Commission (ICC). The ICC has the most far-reaching regulatory powers, including approval or disapproval of line abandonment. State railroad commissions aim primarily at influencing Federal agencies and at providing legislation favorable to railroad development. The Texas Railroad Commission is attempting to accomplish a more favorable climate for railroad development through public policy development and comprehensive planning efforts (Railroad Commission of Texas 1979). In the past, some local regulations and taxes have had a repressive effect on the railroads.

HIGHWAY AND MOTOR FREIGHT

The network of Federal, State, and local highways and primary roads is the only transportation mode that serves all of the communities of the TBIE area. For many of the smaller towns, highways provide the only means of access (Texas almanac 1979).

Interstate highways I-10 and I-45 link Houston with Gulf ports on the east and with the rest of Texas and the Nation on the west and north. Interstate highways also serve Corpus Christi. The Federal-aid primary highway network links the urban industrial centers of the area with each other and with the ship channels (Zlatkovich 1970). A proposed Coastal Freeway and a Valley Freeway in the Lower Rio Grande Valley are near completion, using these primary highways.

Within the study area in 1976, the State maintained approximately 11,300 km (7,000 mi) of roads, and an additional 51,500 km (32,000 mi) was maintained by local agencies (Zlatkovich 1976). The length of paved road in Texas grew at a rate of 21% per year from 1929 to 1978 (Texas almanac 1979). Although the highways of the TBIE area constitute less than 11% of the total highway distance in Texas, more than 33% of the State's population resides in the area, which also contains 27% of the State's registered vehicles. Some might suggest that the greater rate of road use in the area requires greater road development, but population density in the study area is greater than in many other regions of the State.

There will be no significant developments in the highways of the rural areas in the near future, except for maintenance and improvement of existing intercity highways and some local building programs. Highways and streets in urban areas will continue to play a role in the growth of the area and in the problems associated with that growth. The urban and industrial development of the study area, which is projected to occur at greater than State or national rates, will depend on the existence of streets and roadways.

The demand for urban travel in Texas has increased about 50% during the past ten years, much faster than the rate of population growth. Improvements in urban transportation would probably be needed even if the population did not increase; if the urban population doubles, as some predict, the coastal area cities will eventually need an additional 4,830 km (3,000 mi) of major arterials and freeways as well as 24,150 km (15,000 mi) of local and collector streets (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973). The larger urban areas may need improved forms of mass transportation to supplement the private automobile. At present, only Houston is pursuing a program of modernizing and expanding its mass transit system (Texas Department of Highways and Public Transportation 1979).

In rural sections of the TBIE area, recreation/tourism opportunities are dispersed and depend heavily on the automobile. The expansion of these opportunities will, in all likelihood, continue to depend on the car. Highway safety can only become an increasing concern.

Throughout Texas, the largest share of shipping costs goes to truck and bus transport (Texas Transportation Institute, Texas A&M University 1977). Not only is the highway the only means of transport that serves many communities, but it also is the freight route for all. It is the best mode for light-weight items when the desire for convenience of delivery and service justifies greater shipping costs. Truck traffic, and thus, highway use are likely to continue to expand with the industrial development of the area.

Local governments and interests have more control over highways and streets than over any other mode of travel. Despite Federal assistance, highways are principally funded by State or local taxes and regulated by State and local agencies. As a consequence of this local control, there is a greater potential for planning for the specific needs of local communities and for reaction to distinctive local problems. The biggest problems to be addressed by transportation planners may be those of congestion and maintenance with a secondary emphasis placed on local problems and inadequacies, rather than the need for major new roads. Some towns, however, have only limited access by road.

No major roadways penetrate the barrier islands chain. Decisions concerning roadway development of these islands and other regions have, in the past, been made on economic grounds--whether the building of roads and bridges could be justified by use (Texas General Land Office 1978). Economic constraints have kept the building of highways that affect bay and estuary sites to a minimum. Approximately 48% (278.5 km or 173 mi) of the Gulf beaches are classified as easily accessible to the public; segments of the remaining 52% (301.1 km or 187 mi) are classified as accessible with difficulty, or inaccessible. There is a need for decisions concerning new road systems along the islands and wetlands to be based on a balancing of the rights of access and resource utililization versus environmental protection.

The automobile and the truck have been identified as principal sources of air pollution, partially due to the prevalence of their use in the movement of people and goods (Transportation Planning Program, Texas Transportation Institute, Texas A&M University 1973). Additionally, the automobile and the truck are principal users of scarce fuels. One study indicates that migration patterns in the coastal area may result in the continuous urban sprawl, with congestion and increased pollution from automobiles, that many migrants to the area are seeking to escape (Texas Transportation Institute, Texas A&M University 1977). Automobile manufacturers have, however, increased fuel efficiencies and decreased emissions in late models. Should these trends continue, they will provide at least some relief from the energy-related economic and environmental problems that may accompany the area's growth.

Streets and highways will not only be essential to the growth of the study area, but they will contribute to the form of that growth. At present, it can be predicted that roadway development will continue to be concentrated in urban and suburban areas. If highway and freeway systems continue to improve, the dispersion of residents that characterizes these areas at present can be expected to continue. With the potential for use of automobiles that consume less fuel and have lower emissions levels, the deconcentration of the cities may be increased. Increasing housing and land development costs, however, could discourage dispersal. Energy problems may soon act as a catalyst to re-activate the more densely populated central cities (Texas Transportation Institute, Texas A&M University 1977). Residential preference patterns alone may not determine population distribution. New and improved roadway facilities and the availability of energy for automobiles and trucks will help to determine the population distribution, growth patterns, and levels of resource utilization in the area (Texas Transportation Institute, Texas A&M University 1977).

AIR TRANSPORTATION

Whereas rail, highway, and water transportation operate within well defined earthbound corridors, air transportation moves over these corridors, and over other land uses as well. The airport is the primary terminal facility, just as ports are for water commerce, but unlike waterborne traffic, aircraft fly over the TBIE coastal resources. Thus, regional settlement patterns are not significantly influenced by the location of air transport corridors, although local development patterns are heavily influenced by the location of airports.

The TBIE area is served by several types of airport facilities, ranging from private, low activity airports to the area's largest intercontinental airport located in Houston (Figure 14). There are 33 airports in the TBIE area that are considered as contributions to the objectives of air service identified by the Texas Airport System Plan (TASP). These 33 facilities represent nearly 13% of the State's 265 TASP airports. Ten of these facilities have scheduled air carrier service. Many other private and public use airports are also located in the study area (Texas Aeronautics Commission 1979). The TASP calls for the development of 13 new, smaller airports within the TBIE area by 1999. They are intended primarily to accommodate developing areas and to replace airports that may be closed.

The airport terminal provides an area of transition from flight to surface transportation. Land areas are set aside for the traditional elements of airport facilities (i.e., runways, taxiways, parking aprons, terminal structures, and safety areas), but within the past several years, new land area requirements have been found necessary for successful airport operations. Public opposition to the noise of aircraft landing and departure makes it prudent for airport operators to acquire buffer areas that will tolerate certain types and levels of noise. This resistance may, in limited instances, require the closing of some airports unless they can be relocated. The cost of relocation sometimes exceeds the reported benefits of such a move.

Airport characteristics generally reflect local industrial needs. Activities of the airport generally harmonize with adjacent commercial and industrial developments, and tend to attract organizations that depend on rapid movement of personnel and materials. Air travel in the TBIE area is characterized more by the movement of people than goods. In 1978 only 65,520 mt (72,000 t) of goods were shipped by air from the area (U.S. Department of Transportation, Federal Aviation Administration, Civil Aeronautics Board 1979).

Five of the 10 airports that have scheduled services are served by airlines that are certified by the Civil Aeronautics Board. From 1962 to 1978, total passenger movement through four airports (Brownsville, Corpus Christi, Houston International, and Houston's Hobby Field) increased by at least 1,177%, which is an average annual compounded rate of 28.6%. In 1978, these 4 airports handled over 49 million passengers, compared with 879,000 in 1962. Cargo and mail carried through these airports had similar growth rates (Figure 15). Galveston airport data are available only through 1970, but during 8 years from 1962 to 1970, the airport experienced an average annual compounded passenger growth rate of over 34%.

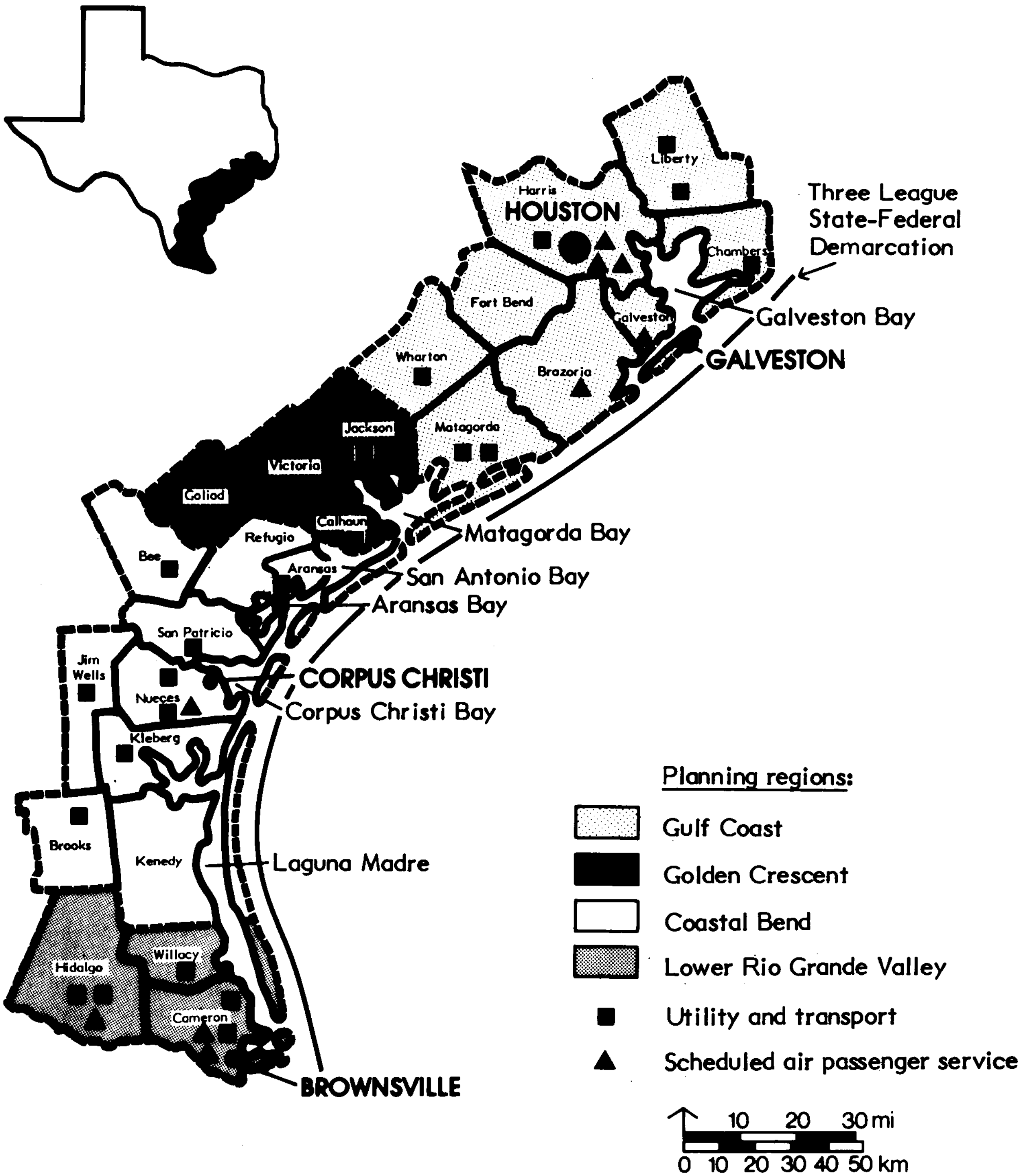
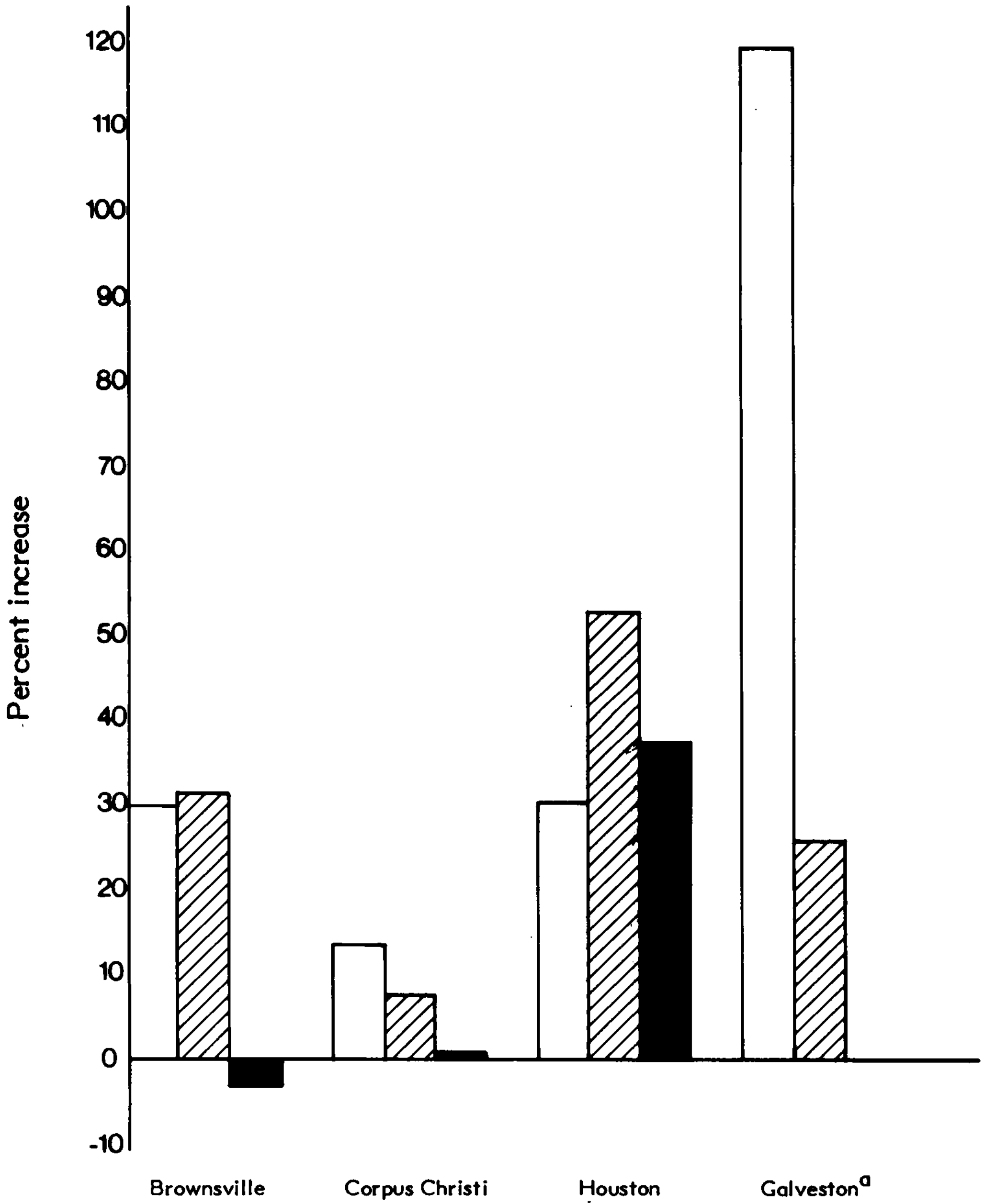


Figure 14. Airports found in Texas Airport System Plan, 1979 (Texas Aeronautics Commission 1979).



[a] Data for Galveston are for period 1962 to 1970.

Passenger

Freight

Mail

Figure 15. Growth rates of air service, 1962 to August 1978 (Civil Aeronautics Board 1963, 1971, 1979).

The remaining five airports that have scheduled service in the TBIE area are served by commuter airlines certified by the Texas Aeronautics Commission. In 1970, only three of these airports received air service: McAllen, Lake Jackson, and the Short Take-off and Landing (STOL) port at Clear Lake City. These airports and the commuter carriers serving them handled more than 316,000 passengers in 1978. This is 623% greater than the passenger departures in 1970, a 28% annual average increase during the eight years (Texas Aeronautics Commission Certificated Carriers 1970-1978 n.d.).

The Texas Airport System Plan lists seven objectives for air transportation:

1. Provide reasonable access to scheduled air passenger transportation;
2. Provide facilities for fast delivery of emergency health services and disaster relief;
3. Preserve and develop smaller towns as viable economic and social entities by assisting their economic development;
4. Provide facilities to meet the growing aviation demands of our metropolitan areas;
5. Make direct air access possible between isolated communities and population centers;
6. Improve communication and coordination between State and local governments;
7. Provide air access to recreational areas.

These objectives apply both to major airline service in the metropolitan areas and to airports providing service for smaller communities.

ADDITIONAL DATA NEEDS

Adequate data are generally available to describe the transportation systems of the TBIE area. The movement of people, information, and goods by all transportation modes is documented in detailed fashion by a number of Federal, State, and local agencies and by the transportation industry. Transportation is among the best reported industrial activities.

Existing data also provide an adequate base for predicting future transportation needs. Such predictions depend particularly on projections of population and industrial growth and on reported transportation industry developments, both of which are generally available. Waterborne transport has received special attention in comparison with the other modes, although additional information and study are needed concerning super-draft ports and coastal waterway problems. The existence of more detailed information concerning the demographic characteristics of the population and a more frequent updating of population and industrial statistics would also improve the planning process.

Although much information is available concerning each of the transportation modes separately, there are relatively few documents published recently that articulate an integrated assessment of comprehensive transportation planning needs for the TBIE area. Economic and environmental tradeoffs for a variety of proposed transportation system improvements have been considered primarily on a piecemeal basis. The need for an integrated assessment of future conditions may be indicated by the distribution of transportation service by mode, where use of pipelines and waterways is currently approaching current system capacities, while railways are being utilized at only a fraction of their ultimate capacity. Decisions concerning large-scale capital improvements for new deepwater port facilities should be made in a broader context than the specific economic considerations that may or may not warrant their construction. The potential adverse environmental effects of pipeline, railway, and roadway linkages to these facilities should be considered at the conceptual planning stage, rather than after the concept of a particular facility has been endorsed.

Problems of equipment age and system maintenance need to be addressed in the context of complementary services that can be provided by separate transport modes. Barges, for example, move goods over long distances and trucks are used for relatively short hauls. Other modes, such as rail transport, provide a substitute service, moving overflow quantities of goods beyond existing barge and truck carrying capacities (Phillips 1976). There may be tradeoffs between modes that could result in more cost effective use of facilities, vehicles, and fuel. The rapidly growing transportation needs of the area might also be better served, and with less detriment to the environment, by the development of multimodal transportation corridors as well as an integrated transportation plan.

The greatest need for additional data concerns the effects of existing and projected transportation activities on the environment. The effects of transportation systems in general, and in particular the effects of dredge and fill operations on wetlands, are in need of additional research. The proposed Texas Coastal Management Plan highlights a specific need for more study of the composition and impact of dredged material placement (Texas General Land Office 1978). This plan also calls for the development of an efficient, integrated assessment and permitting process, involving all relevant State and Federal agencies, to determine the environmental and socioeconomic impacts of proposed activities on bay and estuary systems (Texas Coastal Program 1979).

Finally, additional data are necessary to aid in defining acceptable mitigation techniques. State and Federal guideline development is necessary to provide port developers with the better tools of defined and acceptable mitigation practices. These guidelines could have the effect of reducing governmental review time and define more clearly the costs of the mitigation of impacts of major port programs.

TRANSPORTATION: LITERATURE CITED

Association of American Railroads, Car Service Division. Export and coastal carloads unloaded, excluding coal - Atlantic, Gulf and Pacific ports 1950 vs. 1949; PT report 6-A, sheet 11; 1 p; 9 January 1951. Available from: Manager, Port Traffic, Association of American Railroads, New York, NY.

Association of American Railroads, Car Service Division. Export and coastal carloads unloaded, excepting coal and coke, Atlantic, Gulf, Pacific and Great Lakes ports, 1960 vs. 1959; PT report 6-A, sheet 21-A, 1 p; 17 January 1961. Available from: Manager, Port Traffic, Association of American Railroads, New York, NY.

Association of American Railroads - Car Service Division. Export and coastal carloads unloaded, except bulk liquids, coal, coke and ore - Atlantic, Gulf and Pacific ports year 1970 vs. year 1969; PT report 6-A, sheet 31-A; 1 p; 19 January 1971. Available from: Manager, Port Traffic, Association of American Railroads, New York, NY.

Association of American Railroads - Car Service Division. Export and coastal carloads unloaded, except bulk liquids, coal, coke and ore, Atlantic, Gulf and Pacific ports; year 1977 vs. year 1976; PT report 6A, sheet 38A; 1 p; 13 January 1978. Available from: Manager Port Traffic, Association of American Railroads, New York, N.Y.

Berriman, J.W.; Herbich, J.B. Major port improvement alternatives for the Texas Coast. College Station, TX: Texas A&M Univ. Sea Grant College; March 1977; 45 p. TAMU-SF-77-205 COE rep. 197. Available from: Department of Marine Resources Information, Center for Marine Resources, Texas A&M Univ. College Station, TX.

Buchanan, G.S. Texas navigation districts and regional planning in the Texas Gulf coast area. Houston Law Review; 10(3): 533-597; 1973.

Etter, W.E.; Graham, R.C. Financial planning for the Texas port system. College Station, TX: Texas A&M Univ. Sea Grant College; March 1974; 81 p. TAMU-SG-74-210 Available from: Dept. of Marine Resources Information, Center for Marine Resources, Texas A&M Univ., College Station, TX.

Hershman, M.; Goodwin, R.; Ruotsala, A.; McCrea, M.; Hayuth, Y. Under new management: port growth and emerging coastal management programs. Seattle and London: A Washington Sea Grant Publication distributed by Univ. of Washington Press; 1978; 212 p.

Lindall, W.N.; Saloman, C.H. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. Marine Fisheries Review; 39(9):1-7; 1977.

No big improvements seen for U.S. facilities for VLCC's. Oil and Gas Journal 78(13):55; 1980.

Phillips, C. Cost efficient cargo distribution among transportation modes. College Station, TX: Texas A&M Univ. Sea Grant College; March 1976; 78 p. TAMU-SG-76-206.

Port of Corpus Christi, 1978 annual report. Corpus Christi, TX: Nueces County Navigation District no. 1; 1978; 27 p.

Port Galveston magazine. 1978 Annual report issue. Vol. 31, no. 14, August 1978.

Rail Service Planning Office, Interstate Commerce Commission. Rail rate equalization to and from ports: preliminary report. Washington, DC; July 1978; 100 p.

Railroad Commission of Texas. The outlook for the Texas rail system. Draft prepared by Arthur D. Little, Inc. for the Railroad Commission of Texas, Austin, TX; December 1979; 259 p.

Research and Planning Consultants, Inc. Offshore oil: its impact on Texas communities. 4 vol. Austin, TX: Texas General Land Office, Texas Coastal Management Program; June 1977; 900 p. Available from: Texas General Land Office, Austin, TX.

Sumpter, R. LOOP start-up slated for late 1980. Oil and Gas Journal 77(22): 44-46; 1979.

Sumpter, R. Texas port eyes phased constructions. Oil and Gas Journal 78(3): 32-33; 1980.

Texas Aeronautics Commission Certificated Carriers 1970-1978. Annual enplanement data; n.d.; no pagination.

Texas Aeronautics Commission. Texas Airport System Plan (TASP). Airport operational role 1976-1995 (planning map) included in Texas Airport System Plan: Texas Transportation Institute, Texas Airport System Plan, phase III: summary report. College Station, TX: Texas A&M Univ.; January 1976; revised 1979.

Texas almanac 1980-81. Dallas TX: A.H. Belo Corporation; 1979; 704 p.

Texas Coastal Program. Office of the Governor, State of Texas, Austin, TX; June 1979; 292 p. Available from: Office of the Governor, State of Texas, Austin, TX.

Texas Dept. of Highways and Public Transportation. Plans for public transportation in Texas. Austin, TX; January 1979; 216 p.

Texas General Land Office. State of Texas coastal management program, preliminary hearing draft. Austin, TX: 1978.

Texas Ports Association, Texas Coastal and Marine Council, Sea Grant Program, Texas A&M Univ. Analysis of the role of the Gulf Intracoastal Waterway in Texas. College Station, TX: Texas A&M Univ., December 1974; 246 p. TAMU-SG-75-202.

Texas Transportation Institute, Texas A&M Univ. Texas airport system plan: phase III, summary report. College Station, TX: Texas A&M Univ., January 1976; pagination varies.

Texas Transportation Institute, Texas A&M Univ. Texas population trends and implications for transportation: College Station, TX: Texas A&M Univ., August 1977; 126 p.

Transportation Planning Division, Texas Dept. of Highways and Public Transportation. The Gulf Intracoastal Waterways in Texas: summary 1976. Austin, TX; 1976; 16 p.

Transportation Planning Division, Texas Dept. of Highways and Public Transportation. The Gulf Intracoastal Waterway in Texas: 1978. Austin, TX; 1978a; pagination varies.

Transportation Planning Division, Texas Dept. of Highways and Public Transportation. The Gulf Intracoastal Waterway in Texas: summary 1978. Austin, TX; 1978b; 13 p.

Transportation Planning Program, Texas Transportation Institute, Texas A&M Univ. Transportation in the Texas coastal zone: a conceptual report. March 1973; 168 p.

U.S. Dept. of the Army, Corps of Engineers. Waterborne commerce of the United States calendar year 1977: part 2, waterways and harbors....Gulf Coast, Mississippi River systems and Antilles; n.d.; 179 p. Compiled under the supervision of the Division Engineer, U.S. Army Engineer Division, Lower Mississippi Valley, Corps of Engineers, Vicksburg, Mississippi. Available from: District Engineer, U.S. Army Engineer District, New Orleans, LA.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey. United States coast pilot 5. Atlantic Coast: Gulf of Mexico, Puerto Rico, and Virgin Islands. eleventh ed.; July 1978; 339+ p. Available from: Superintendent of Documents, U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Transportation. A prospectus for change in the freight railroad industry. A preliminary report by the Secretary of Transportation. Washington, DC; October 1978; 186 p.

U.S. Dept. of Transportation, Federal Aviation Agency, Civil Aeronautics Board. Airport activity statistics, 12 months ended December 31, 1962. Washington, DC: U.S. Government Printing Office; 1963; 341 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Transportation, Federal Aviation Agency, Civil Aeronautics Board. Airport activity statistics, 12 months ended December 31, 1965. Washington, DC: U.S. Government Printing Office; 1966; 284 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Transportation, Federal Aviation Administration, Civil Aeronautics Board. Airport activity statistics, 12 months ended June 20, 1970. Washington, DC: U.S. Government Printing Office; 1971; 304 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Transportation, Federal Aviation Administration, Civil Aeronautics Board. Airport activity statistics, 12 months ended December 31, 1978. Washington, DC: U.S. Government Printing Office; 1979; 299 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. General Accounting Office. American seaports changes affecting operations and development; November 1979; 49 p. Reproduced by National Technical Information Service, U.S. Dept. of Commerce, Springfield, VA.

Zlatkovich, C.P. Texas in the seventies: vol. 2. Transportation. Texas Business Review XLV(4); Austin, TX: Bureau of Business Research, Univ. of Texas at Austin; April 1970; (reprint) 6 p.

Zlatkovich, C.P. Texas transportation handbook. Austin, TX: Bureau of Business Research, Univ. of Texas at Austin; 1976; 319 p.

INDUSTRIAL AND RESIDENTIAL DEVELOPMENT

INTRODUCTION: GENERAL DESCRIPTION OF THE STUDY AREA

Socioeconomic Characteristics and Patterns of Development

The popular image of the Texas Gulf Coast is that of an area of extremely rapid growth with an economy dominated by oil and gas production, petroleum refining, petrochemicals, and other energy-related industries. The coast, especially the Houston-Galveston area, is also perceived as an area faced with serious environmental problems, including traffic congestion, air and water pollution, urban sprawl, and generally unplanned development.

In a general sense, the above perceptions are largely correct. The population of the TBIE study area has more than doubled since 1950, growing at an average rate more than twice as great as the national average (Table 36). More than 25% of the Nation's petroleum refining capacity and 40% of the Nation's petrochemical industry are located along the Texas coast (Research and Planning Consultants, Inc. 1975). Mining is almost five times more important as a source of personal income in the TBIE study area than in the Nation (U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979b). In 1972, about two-thirds of the value added by manufacturing in TBIE metropolitan areas was contributed by five energy-related industries: chemicals and allied products, petroleum and coal products, rubber and plastic products, fabricated metals, and non-electrical machinery (U.S. Department of Commerce, Bureau of the Census 1975),[1] and, because of the recent upsurge in oil prices and energy activity along the coast, this figure is certainly even higher today.

Almost 85% of the population growth in the TBIE study area from 1950 to 1977 occurred in the Gulf Coast planning region (containing Houston-Galveston) (U.S. Department of Commerce, Bureau of the Census 1952b; 1979d). The Houston-Galveston Standard Consolidated Area (the Houston Standard Metropolitan Statistical Area plus the Galveston-Texas City SMSA) is now the tenth largest metropolitan region in the United States and the largest in the South and Southwest. The environmental problems resulting from this growth have indeed become quite serious. Major traffic congestion can occur at almost any hour on Houston's freeways. Harris County (Houston) is the only area in Texas that will be unable to meet the U.S. Environmental Protection Agency's ambient air quality standards by 1982 (Texas Air Control Board 1978). Ground subsidence and serious flooding are also common growth-related problems in the Houston-Galveston area.

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[1] Throughout this paper, these five industries will be referred to as energy-related industries. Finer industrial disaggregation would make the identification of energy related industries even more accurate, but unfortunately such information is not available. Petroleum and coal products are obviously highly energy related because of the dependence of petroleum refining on oil and gas inputs. The chemicals and allied products and rubber and plastic products industries, in turn, depend heavily on petroleum feedstocks and natural gas for power. Finally the fabricated metals and non-electrical machinery industries on the Texas coast tend to be highly specialized in the production of oil drilling equipment, platforms, and other infrastructure for the petroleum industry.

Table 36. General growth indicators for the TBIE study area, Texas, and U.S., 1950, 1960, 1962, 1970, 1972, 1977 (U.S. Department of Commerce, Bureau of the Census 1952b; 1962a; 1973a; 1979d; U.S. Department of Commerce 1975; U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979a; 1979b).

	A. Population (1,000)				Average annual growth rate (%)		
Region	1950	1960	1970	1977	1950-1970	1970-1977	1950-1977
TBIE Study Area	1,749.4	2,423.2	3,010.0	3,621.6	2.75	2.68	2.73
Texas	7,711.2	9,579.7	11,196.7	12,830.0	1.88	1.96	1.90
U.S.	151,325.8	179,323.2	203,211.9	216,383.0	1.49	0.90	1.33

	B. Employment (1,000)					Average annual growth rate (%)	
Region	1950[a]	1960[a]	1970[a]	1970[b]	1977[b]	1950-1970[a]	1970-1977[b]
TBIE Study Area	649.2	856.9	1,155.2	1,266.8	1,743.5	2.92	4.67
Texas	2,860.3	3,480.9	4,348.0	4,770.0	5,974.7	2.12	3.27
U.S.	57,474.9	66,372.7	79,307.9	86,799.0	97,848.9	1.62	1.73

	C. Per capita personal income ($)				Average annual growth rate (%)		
Region	1950	1962	1972	1977	1950-1972	1972-1977	1950-1977
TBIE Study Area	1,165	1,791	3,471	6,282	5.09	12.60	6.44
Texas	1,349	2,052	4,053	6,891	5.13	11.20	6.23
U.S.	1,496	2,353	4,493	7,042	5.13	9.40	5.91

[a] Number of workers by place of residence.
[b] Number of jobs by place of work.

Despite the general accuracy of these popular perceptions, however, significant diversity in the coastal area remains. Generally, as one moves south along the coast away from the Houston-Galveston area, the importance of energy-related activity declines and agriculture and low-wage industries (apparel, food processing, and electronics assembly) become more important. The intensity of energy-related activities also drops off quickly as one moves farther inland.

Population and economic growth along the Texas coast has been far from geographically even. Since 1950, population growth in areas other than the Gulf Coast planning region has been at about the same rate as that for the Nation. In addition, the rate of growth in the Lower Rio Grande Valley has fluctuated considerably over the period (U.S. Department of Commerce, Bureau of the Census 1952b; 1962a; 1973a; 1979d).

Income levels and the ethnic structure of the population also differ significantly along the coast. Per capita personal income in the Gulf Coast planning region is greater than the average for the United States, but is only 57% of the national average in the Lower Rio Grande Valley (U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979b). The combination of low wages and high unemployment makes the Lower Rio Grande Valley one of the less prosperous regions in the United States (U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979b). Eleven percent of the Gulf Coast planning region's population is Mexican-American (Spanish surname), while 78% of the Lower Rio Grande Valley's population falls into this category (U.S. Department of Commerce, Bureau of the Census 1973a).

People and businesses along the Texas coast are strongly concentrated in the major metropolitan areas. Seventy-two percent of the study area's population lives in the Houston-Galveston area. Another 20% of the TBIE area population lives in the Corpus Christi (8.4%), Brownsville-Harlingen-San Benito (4.9%), and McAllen-Pharr-Edinburg (6.4%) SMSA's. Actually, the Brownsville and McAllen SMSA's are strongly linked economically and socially so that the entire Lower Rio Grande Valley can be viewed as one metropolitan area (Zlatkovich and Bennett 1977). This would make the Brownsville-McAllen area the second largest metropolitan concentration in the study area. In addition, approximately 275,000 persons lived in the Mexican border cities of Matamoros and Reynosa in 1970. These cities are strongly linked with the Lower Rio Grande Valley economy. Another 1.7% of the TBIE study area's population is located in Victoria County, but this area has not achieved the combination of characteristics necessary to have it designated as a metropolitan area by the Federal government. The remaining 7% are scattered in small towns and rural areas.

Major Historical Developments

The main character of development in most areas arises from a few, often unexpected developments. Before 1900, the TBIE area depended largely on agricultural production, especially cattle ranching. The discovery of oil in 1901, at Spindletop (near Beaumont), however, launched a transformation of the economic structure of much of the coast. Major oil and gas discoveries quickly followed in Brazoria and Harris counties, but occurred much later (late 1920's to early 1930's) in the Golden Crescent and Coastal Bend regions (Texas almanac 1979).

The Houston Ship Channel was completed in 1915 while the Port of Corpus Christi was opened in 1926. Most Texas ports were originally intended to ship agricultural goods and to receive manufactured goods, but they soon acquired even greater importance in industrial development.

Although oil refining soon followed the discovery of oil and gas in the upper coastal areas, the development of an extensive petrochemical complex took considerable time. Many of the major petrochemical operations first located in the Houston-Galveston area during the 1940's (Austin 1978, Marchesini and Austin 1978).

The extension of irrigation systems into the Lower Rio Grande Valley in the early 1900's made intensive crop farming possible. Today, citrus, vegetables and grain sorghum are dominant crops in the area. Agricultural development has supported the growth of a major food processing industry in this part of the coast.

The National Aeronautics and Space Administration's Lyndon B. Johnson Space Center was established near Clear Lake City, 35 km (22 mi) southeast of Houston, in 1962. At its peak, in 1969, the center employed 4,600 persons. Today, the Center employs 3,560 persons and has an annual payroll of $98 million. An additional $182 million is expended on 800 firms located or represented in Texas (Texas almanac 1979).

Finally, it may be too early to take an historical perspective, but it appears that recent energy developments have already significantly affected coastal growth trends. The reasons for this are two-fold. First, in the face of rapidly declining Texas oil production, Gulf coast refiners have turned to foreign imports to offset lost domestic supplies. Many of the recent industrial developments along the coast, including major port improvements and the conversion of refinery operations to handle high sulphur oil, have resulted from increased efforts to handle foreign oil. Secondly, the high price of oil and gas has spurred exploration and development activities in the Texas coastal area and throughout the world. Because of the significant agglomeration of oil and gas exploration and development activities along the Texas coast, the area has an important comparative advantage in serving worldwide markets for petroleum technology. Much of the rapid growth of the Houston-Galveston areas, especially since 1973, can be attributed to rapid expansion in energy-related sectors.

GENERAL GROWTH TRENDS

General growth trends along the Texas coast can be identified by examining three key socioeconomic indicators--population, employment, and per-capita personal income. Population and employment data reveal a strong relationship between economic growth (employment) and demographic growth (population). The extent to which population growth exceeds employment growth, or vice versa, results in excess supply of labor (unemployment) or excess demand for labor (job vacancies). Per-capita personal income is a standard measure of general welfare in the region. In addition, it serves as a rough indicator of per-capita output, given the lack of gross product accounts for regions.

Population

The population of the TBIE study area has grown rapidly since 1950. The average annual growth rate for the area declined only slightly from 2.75% during 1950-1970 to 2.68% during 1970-1977, despite a sharp drop in the national growth rate due to fertility declines (Table 36). This relatively high growth rate indicates a large increase in migration into the TBIE area during the 1970's. One should be careful in inferring migration differentials from comparing regional and national population growth rates, however, because of significant differences in the natural increase (births minus deaths) rate, both between regions within the study area and between the study area and the country.

Significant differences in the population growth rate among regions in the TBIE area are clearly evident (Table 37). The Gulf Coast planning region has grown fairly steadily since 1950. Growth in the Golden Crescent and Coastal Bend planning regions, on the other hand, slowed significantly during the 1970's, paralleling national trends. Population growth in the Lower Rio Grande Valley has been erratic. From 1950 to 1960, the region grew at a moderate rate, but it declined from 1960 to 1970. Much of this decline can be attributed to population losses in Cameron County due to the closing of military bases (Zlatkovich and Bennett 1977). Since 1970, however, population growth in the Lower Rio Grande Valley has been extremely rapid.

Table 37. Population growth by planning region in the TBIE study area, 1950, 1960, 1970, 1977 (U.S. Department of Commerce, Bureau of the Census 1952b, 1962a, 1973a, 1979d).

Planning region	Population (1,000)				Average annual growth rate (%)		
	1950	1960	1970	1977	1950-1970	1970-1977	1950-1977
Gulf Coast	1,089.6	1,606.1	2,182.2	2,677.9	3.53	2.97	3.39
Golden Crescent	59.6	82.5	89.4	96.5	2.05	1.10	1.80
Coastal Bend	293.7	384.2	400.9	421.6	1.57	0.72	1.35
Lower Rio Grande Valley	306.5	352.1	337.5	425.6	0.48	3.37	1.22
TBIE Study Area	1,749.4	2,423.2	3,010.0	3,621.6	2.75	2.68	2.73

The measurement of population in the Lower Rio Grande Valley is not a straightforward process, however. In census years, significant undercounts are possible because of the temporary and hidden nature of much of the population. The Lower Rio Grande Valley population is constantly fluctuating because of the flows of seasonal farm workers, short term and long term tourists, and undocumented workers through the area. In the post-census population estimates that have been available since 1970, measurement errors are even more probable. The estimates are based on 1970 relationships between population and a number of variables that indicate the size of and changes in the population of an area; these relationships are extremely unstable and unreliable in the Lower Rio Grande Valley. For a further discussion of the population estimation techniques used by the Bureau of the Census, see Burghardt and Geraci (1978).

Employment

Employment growth paralleled the strong population growth in the TBIE study area throughout the entire period between 1950 and 1977. As with population growth patterns, there are significant employment growth differences among planning regions in the area.

Employment growth was consistently rapid throughout the period between 1950 and 1977 in the Gulf Coast planning region. Since 1970, employment grew at a rate that was almost three times faster in this region than in the Nation (Tables 36 and 38). Strong demand for labor and low unemployment in the Houston area led to a rapid expansion in job vacancies. The index of help wanted advertising, prepared by the Conference Board (Preston 1977) rose from 100 in 1967 to 435 in 1978, compared to an increase from 100 to 150 in the Nation. Throughout this period, Houston's increase in help wanted advertising was, by far, the greatest of the 51 cities surveyed.

Table 38. Employment growth by planning region in the TBIE study area, 1950, 1960, 1970, 1977 (U.S. Department of Commerce 1975; U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979a).

Planning region	Employment (1,000)					Average annual growth rate (%)	
	1950[a]	1960[a]	1970[a]	1970[b]	1977[b]	1950-1970[a]	1970-1977[b]
Gulf Coast	431.3	594.7	883.0	974.9	1,383.3	3.65	5.13
Golden Crescent	21.8	27.6	31.8	35.6	44.0	1.91	3.07
Coastal Bend	99.7	123.7	142.6	155.0	171.5	1.81	1.46
Lower Rio Grande Valley	96.4	110.9	97.8	101.3	144.8	0.07	5.24
TBIE Study Area	649.2	856.9	1,155.2	1,266.8	1,743.5	2.92	4.67

[a]Number of employed persons by place of residence.
[b]Number of jobs by place of work.

Employment growth in the Golden Crescent and Coastal Bend planning regions was much slower than in the Gulf Coast region during the period from 1950 to 1977. Following TBIE area trends, employment growth in the Golden Crescent region accelerated from the period 1950-1970 to 1970-1977, but the growth rate declined in the Coastal Bend planning region during the 1970's.

Employment increased extremely slowly from 1950 to 1970 in the Lower Rio Grande Valley planning region (actually, employment grew from 1950 to 1960 and then declined from 1960 to 1970). During the 1970's, however, employment in this region grew very rapidly, even a little faster than in the Gulf Coast planning region. Surprising as it may seem, however, this rapid employment growth has been outpaced by population and labor force growth so that the unemployment rate in this planning region increased from 6.2% in 1970 to 9.0% in 1978 (Texas Employment Commission 1978).

Unlike the Lower Rio Grande Valley, employment growth in the three other TBIE planning regions has more evenly kept pace with labor force and population growth. In 1978, the average unemployment rate was 3.3% in the Gulf Coast and Golden Crescent planning regions and 4.3% in the Coastal Bend planning region (Texas Employment Commission 1978).

Per Capita Personal Income

Since 1950, per capita personal income has grown significantly faster in the TBIE study area (537.23%) than in the State (510.82%) or the Nation (470.72%). From 1950 to 1977, TBIE area per capita income, as a proportion of the national average, grew from 78% to 89%. All of the convergence between TBIE area and United States per capita income, however, occurred from 1972 to 1977 (Table 36).

All of the regions in the TBIE area have experienced a growth in per capita personal income at or above the national rate since 1950. From 1950 to 1977, the ratio of regional to national per capita personal income grew from 88% to 101% in the Gulf Coast planning region, 78% to 95% in the Golden Crescent planning region, and 76% to 87% in the Coastal Bend planning region. In the Lower Rio Grande Valley, however, per capita personal income has since 1950 remained at 57% of the national average. Like the TBIE area as a whole, the convergence in per capita personal income between the four planning regions and the Nation occurred from 1972 to 1977 (Table 39).

Table 39. Per capita personal income by planning region in the TBIE study area, 1950, 1962, 1972, 1977 (U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979b).

Planning region	Per capita personal income ($)				Average annual growth rate (%)		
	1950	1962	1972	1977	1950-1972	1972-1977	1950-1977
Gulf Coast	1,310	1,957	3,752	7,141	4.90	13.74	6.48
Golden Crescent	1,160	1,797	3,356	6,659	4.95	14.69	6.69
Coastal Bend	1,142	1,818	3,643	6,108	5.41	10.89	6.41
Lower Rio Grande Valley	852	1,256	2,362	4,009	4.74	11.16	5.90
TBIE Study Area	1,165	1,791	3,471	6,282	5.09	12.60	6.44

TRENDS IN INDUSTRIAL DEVELOPMENT

Changes in Economic Structure

Changes in regional economic structure can be examined through the use of personal income location coefficients. These coefficients show the percentage of personal income derived from a certain sector in the region divided by the percentage of personal income derived from that sector in the Nation. An increasing location quotient reveals that a sector is becoming more important in the regional economy relative to that sector's importance in the Nation.

The personal income location quotients for the TBIE study area show that contract construction and manufacturing are the most rapidly expanding sectors (Table 40). The relative importance of agriculture and, to a much lesser degree, transportation, communication, and public utilities; finance, insurance, and real estate; and government is declining. Mining (almost entirely oil and gas extraction) continues to hold a much more important position in the TBIE area than in the Nation.

Obviously, an understanding of the rapid growth of the construction and manufacturing sectors is of key importance in understanding the growth of the TBIE area over the last 30 years. (Details of manufacturing development will be discussed in the next section.) The growth of the construction sector can be largely explained by the rapid population growth and industrial expansion in the TBIE area which have generated tremendous demands for homes, factories, commercial buildings, roads, schools, and many other forms of private and public infrastructure. Almost all of the rise in the relative importance of the TBIE area construction sector occurred during the most recent growth spurt, between 1972 and 1977, while the growth of the manufacturing sector has been more steady (U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979b).

A sector-by-region analysis of the personal income location quotients reveals growth patterns generally paralleling those in the TBIE area as a whole. The relative importance of agriculture has declined in all of the planning regions, although it remains very important in the Golden Crescent and Lower Rio Grande Valley planning regions.

Mining has declined in the Gulf Coast planning region, but its importance has significantly increased in the three other regions. Mining now plays an especially important role in the Golden Crescent and Coastal Bend economies. The importance of the contract construction sector has increased in all four regional economies, especially in the Lower Rio Grande Valley. Again, rapid population and industrial growth, especially in the Gulf Coast and Lower Rio Grande Valley regions, explain this increase.

The manufacturing sector has grown in all four regions, but this increase has been most dramatic (the location quotients have roughly doubled from 1950 to 1977) in the three less developed planning regions, the Golden Crescent, Coastal Bend, and Lower Rio Grande Valley. As will be seen in the next section, however, the industries that have grown in the manufacturing sector are quite different from region to region.

Table 40. Personal income location quotients[a] for the TBIE study area and the four planning regions, 1950 and 1977 (U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System 1979b).

	TBIE area		Planning Regions: Gulf Coast		Golden Crescent		Coastal Bend		Lower Rio Grande Valley	
Economic sector	1950	1977	1950	1977	1950	1977	1950	1977	1950	1977
Ag., ag.svcs., for. & fish.	1.00	0.54	0.36	0.25	3.42	2.19	1.73	1.30	4.15	3.37
Mining	4.96	4.61	5.43	4.49	3.94	7.79	5.76	7.02	0.56	1.32
Contract construction	1.38	1.99	1.57	2.12	1.61	1.77	1.24	1.44	0.05	1.03
Manufacturing	0.59	0.75	0.70	0.79	0.41	1.00	0.27	0.48	0.22	0.50
Transportation, commun. & pub. util.	1.28	1.08	1.35	1.12	0.74	0.80	1.11	0.92	1.09	0.81
Wholesale & retail trade	1.09	1.16	1.11	1.17	0.88	0.86	1.02	1.07	1.11	1.39
Finance, insurance & real estate	1.12	0.95	1.30	1.00	0.48	0.55	0.62	0.69	0.60	0.75
Services	0.99	0.96	1.03	0.99	0.88	0.68	0.93	0.83	0.77	0.85
Total government	0.76	0.65	0.65	0.54	0.53	0.64	1.45	1.31	0.77	1.30

[a]Percentage of personal income derived by the sector in the region divided by the percentage of personal income derived by the sector in the Nation.

Changes in the relative importance of service-producing sectors (excluding government) have generally been less significant than those for the goods-producing sectors. The service-producing sectors continue to be relatively the most important in the Gulf Coast planning region. Wholesale and retail trade, an increasingly important sector in the Lower Río Grande Valley, provides something of an exception to the regional pattern and reflects the increasing importance of trade with Mexico.

Government clearly plays a relatively unimportant role in the Gulf Coast and Golden Crescent regional economies, but a very important role in the economies of the Coastal Bend and the Lower Rio Grande Valley. The importance of government in the Coastal Bend region is due to the presence of major military bases in Corpus Christi and Kingsville. Government's important and rapidly rising role in the Lower Rio Grande Valley can be explained by the rise of local government to serve the rapid growth in this politically fragmented area (33 municipalities are located in the three counties).

Changes in Manufacturing

Growth in value added. Overall, the rate of manufacturing expansion in the TBIE area relative to the United States has increased since 1972. From 1954 to 1972, manufacturing value added grew 1.42 times faster in TBIE area SMSA's than in the Nation, while from 1972 to 1977 this differential increased to 1.76 (Table 41). Caution is advised, however, in interpreting these figures. Much of the recent increase in manufacturing value added in the TBIE area is due to the rapid increase in oil refining profits due to the increasing price of oil and, thus, does not reflect a real increase in output. This especially affects the value-added figures in the Galveston-Texas City, Houston, and Corpus Christi SMSA's.

Table 41. Growth of manufacturing value added in TBIE SMSA's, Texas, and the United States, 1954 through 1977 (U.S. Department of Commerce, Bureau of the Census 1957, 1975a, 1979b).

Planning region	Average annual growth rate (%)		
	1954-1972	1972-1977	1954-1977
Galveston-Texas City SMSA	8.57	16.70	10.28
Houston SMSA	9.12	18.44	11.08
Corpus Christi SMSA	7.91	22.18	10.87
Brownsville-Harlingen-San Benito SMSA	11.34	16.20	12.38
McAllen-Pharr-Edinburg SMSA	9.83	16.10	11.17

(continued)

Table 41 (concluded).

Planning region	Average annual growth rate (%)		
	1954-1972	1972-1977	1954-1977
Total TBIE area SMSA's	9.02	18.37	10.99
State	8.53	16.61	10.23
United States	6.34	10.44	7.22

Although manufacturing growth has been rapid in all TBIE SMSA's, it has been especially strong in the Lower Rio Grande Valley. From 1954 to 1972, manufacturing value added grew much faster in the two valley SMSA's than in the other SMSA's in the study area. Since 1972, the growth rate has been higher in the upper coastal SMSA's, especially Houston and Corpus Christi, but much of the apparent growth in these areas is due to the rapid increase in refinery profits.

Structure of manufacturing growth. Even at the SMSA level, the statistics given in the Census of Manufacturing for value added by manufacturing industries are fraught with so many disclosure limitations that consistent analyses are impossible. To study the structure of manufacturing growth in the TBIE area, the next best data are the figures on employment by industry, from the Texas Employment Commission. Detailed breakdowns of manufacturing employment are available, however, only from 1972 for TBIE area SMSA's (TBIE Data Appendix Employment and Income Characteristics Table 4 for these data).

The most important manufacturing industries in the Houston-Galveston area are largely energy-related. Fabricated metal products, non-electrical machinery, chemicals and allied products, and petroleum refining and related industries accounted for 58% of the manufacturing employment in the two SMSA's in 1978. In addition, three of these industries have shown very strong growth in recent years (1972 to 1978): fabricated metals (35.4%), non-electrical machinery (73.6%), and chemicals and allied products (28.6%). Two important non-energy-related industries have also shown very strong employment growth in the region during the same period: electrical machinery (208.8%) and printing, publishing, and allied industries (212.2%). Only one important manufacturing industry in the Houston-Galveston area declined between 1972 and 1978: employment in food and kindred products decreased 3.4%.

A majority of the manufacturing activity in the Corpus Christi SMSA is also concentrated in energy-related industries; 56% of the manufacturing employment was in fabricated metal products, non-electrical machinery, chemicals and allied products, and petroleum refining and related industries in 1978. One non-energy-related sector, food and kindred products, accounted for another 16% of the manufacturing employment.

Major fast-growing industries in the Corpus Christi area include three of the energy-related sectors: non-electrical machinery (which grew 178.6% from 1972 to

1978), chemicals and allied products (25.0%), and petroleum refinery and related industries (53.6%). Employment in food and kindred products and in printing and publishing also grew rapidly during this period--33.3% and 30.8%, respectively. Employment in primary metal industries declined by almost 46% between 1972 and 1978, offsetting much of the strong growth in other manufacturing industries. This decline is largely due to the shutdown of the Reynolds Metals aluminum smelting plants in 1975 due to rising energy prices (U.S. Department of the Interior, Bureau of Mines 1979).

None of the major manufacturing industries in the Lower Rio Grande Valley SMSA's are energy-related: electrical machinery, food and kindred products, and apparel and finished textile products accounted for 58% of the manufacturing employment in 1978. Fast-growing industries are difficult to identify because of disclosure limitations in the 1972 data, but non-electrical machinery, electrical machinery, transportation equipment, and apparel and finished textile products appear to be the fastest growing major industries. Employment in food and kindred products increased 57.9% in the McAllen SMSA from 1972 to 1978, but declined 43.7% in the Brownsville SMSA.

Petroleum Refining Development

While oil refining accounts for only a small proportion of TBIE employment (8% of total SMSA manufacturing employment in 1978) (Texas Employment Commission 1979), its overall impact on the area economy is much greater. Because refining is an extremely capital intensive process, a high output-to-worker ratio occurs in this industry and, consequently, wages are also relatively high. Petroleum refining accounted for only 4.2% of Texas manufacturing employment in 1977, but produced 13% of the State's manufacturing value added (U.S. Department of Commerce, Bureau of the Census 1979b).

Closely related to oil refining is the much larger chemicals and allied products industry. Numerous petrochemical feedstocks are produced in the refining process, thus tying the long-run growth of the chemical industry to the growth of refining activity. The chemical industry is also highly capital intensive; refining and chemicals together accounted for only 12.1% of Texas manufacturing employment in 1977, but together produced 34.5% of the value added (U.S. Department of Commerce, Bureau of the Census 1979b). Because 23.9% of TBIE SMSA employment is in refining and chemicals (Texas Employment Commission 1979), perhaps up to two-thirds of the manufacturing value added in the TBIE area is produced by these two industries.

Refining is strongly linked to many other manufacturing and non-manufacturing industries besides chemicals. Increases in refinery output require major inputs from the oil and gas, chemicals, transportation, utility, trade, real estate, and service sectors (Monti 1977). The high wages paid in the refinery industry and strong interindustry linkages result in extremely high multiplier effects. According to the 1972 Texas input-output table, every refinery worker indirectly supports another 9.7 workers in the State (Texas Department of Water Resources 1978). Applying this ratio to the TBIE area indicates that the 20,180 refinery workers in the study area SMSA's in 1977 supported 13.2% of the total metropolitan employment.

Historical statistics show an increasing rate of growth in Texas refining capacity, beginning about 1967 (Table 42). Because 88% of Texas refining capacity is on the Gulf coast (U.S. Department of Energy 1978), Texas refining trends essentially reflect coastal refinery trends. Texas refining capacity increased at an average annual rate of 1.9% from 1953 to 1967, but this rate more than doubled to 4.8% from 1967 to 1978. Consequently, the percentage of United States refining capacity in Texas, which declined from 28.1% in 1953 to 26% in 1967, increased again to 27.3% in 1978 (American Petroleum Institute 1975, U.S. Department of Energy 1978).

Table 42. Texas refinery data, 1953, 1960; 1967 through 1978 (Texas Energy and Natural Resources Advisory Council 1979).

Year	Number of refineries	Crude oil capacity as of Jan. 1 (bbl/day)	Crude oil receipts (thousand bbl)	Receipts from Texas sources (%)	Receipts from foreign sources (%)
1953	62	2,142,537	712,477	81.9	0.3
1960	59	2,631,820	801,634	76.8	0.1
1967	53	2,800,732	961,954	73.9	0.0
1968	53	3,096,464	949,812	73.5	0.0
1969	51	3,143,179	1,018,207	75.3	0.0
1970	51	3,282,542	1,041,094	76.3	0.0
1971	51	3,556,278	1,064,197	74.8	1.7
1972	50	3,555,358	1,112,566	77.4	2.1
1973	46	3,569,858	1,174,310	73.5	11.0
1974	48	3,807,746	1,188,691	67.6	19.1
1975	49	3,995,050	1,212,431	63.2	25.5
1976	51	4,005,550	1,307,826	55.6	34.9
1977	50	4,296,387	1,430,009	49.6	41.6
1978	56	4,695,370	1,463,206	46.0	44.5

The dramatic decline in Texas oil production in the 1970's has clearly affected Texas refiners. While Texas refiners obtained three-quarters of their crude oil supply from in-state sources in 1970, almost half of their crude oil was obtained from foreign sources by 1978. The TBIE area refining industry is now extremely sensitive to the uncertainties of foreign oil supplies and United States policy regarding oil imports. The strong linkages between refining and other regional industries make the entire TBIE economy sensitive to such developments.

TRENDS IN RESIDENTIAL DEVELOPMENT

Components of Population Growth

Migration is the major link between industrial and residential developments because people move from one region to another mainly in response to job opportunities (Biggar 1979, Plaut 1980). Regional employment growth and net migration (in-migration minus out-migration) are highly interrelated: a growing regional economy is characterized by high employment growth and net in-migration, while a declining regional economy is characterized by slow employment growth and net out-migration.

Population growth differences among regions are generally due to differences in net migration. With declining birth rates, migration has also become increasingly important in determining whether a region's population grows or declines absolutely. In most cases, differences in the natural increase rates (births minus deaths) between regions are less than differences in the net migration rates. This is true in the TBIE study area, but substantial differences in the natural increase rate are still evident within the area because of the higher birth rate in its southern part.

The average annual net migration rate for the TBIE study area declined slightly from 0.74% during the 1950's to 0.51% during the 1960's, but it increased sharply during the 1970's to 1.30%. Net migration now accounts for about half of the population growth in the TBIE study area (Table 43).

Net migration patterns have been quite different among planning regions within the TBIE study area. The Gulf Coast planning region has consistently had the highest net migration rates over the entire period between 1950 and 1977. The net migration rate for the region increased only slightly from 1950-1970 to 1970-1977. The other three planning regions underwent a decrease in net migration from 1950-1960 to 1960-1970 and then an increase from 1960-1970 to 1970-1977. The Golden Crescent planning region is now exhibiting slight net in-migration, while the Coastal Bend region continues to have substantial net out-migration. The Lower Rio Grande Valley planning region, which had relatively high net out-migration during the 1960's, is now exhibiting substantial net in-migration. As expected, these net migration patterns closely follow the trends in employment growth.

Following national trends, the rate of natural increase has decreased significantly in the TBIE study area since the 1950's. This decline has also occurred in all four planning regions. Because of the large Mexican-American population, however, the natural increase rate in the southern part of the study area continues to be very high. The natural increase rate in the Lower Rio Grande Valley planning region, for example, is almost twice that in the Gulf Coast planning region.

Age Structure of the Population

The age structure of the population is a significant factor in a region's economy for at least three reasons. First, the working age population is the major determinant of the size of the labor force and associated tax revenues from employed persons. Second, population age structure has a significant effect on buying patterns; the purchase of housing and durable goods, especially, are prevalent among young adults. Finally, demands for governmental services are strongly affected by population age structure; children and older adults, especially, are heavy users of public services.

The age distribution of the TBIE area population has changed significantly since 1950. The percentage of the population under 19 years old increased until 1960 and declined thereafter. The percentage of the population over 65, on the other hand, has been continuously increasing during the period. The percentage of the population of working ages (20-64) declined from 1950 to 1960, but has been increasing since then (Table 44).

Table 43. Components of population growth in the TBIE study area by planning region, 1950 through 1977 (Bowles and Tarver 1965; Bowles et al. 1975; U.S. Department of Commerce, Bureau of the Census 1979d).

	1950-1960				1960-1970				1970-1977			
	NM[a]	%/yr	NI[b]	%/yr	NM	%/yr	NI	%/yr	NM	%/yr	NI	%/yr
Gulf Coast	225,203	1.57	291,312	2.16	295,877	1.56	280,193	1.48	295,300	1.74	200,400	1.18
Golden Crescent	4,565	0.64	18,373	2.59	-6,635	-0.77	13,540	1.58	800	0.12	6,400	0.98
Coastal Bend	-7,401	-0.22	96,163	2.85	-54,143	-1.38	72,566	1.85	-20,900	-0.73	41,500	1.44
Lower Rio Grande Valley	-68,955	-2.09	114,505	3.48	-96,594	-2.80	81,981	2.40	27,600	1.03	60,500	2.27
TBIE Study Area	153,412	0.74	520,353	2.49	138,505	0.51	448,280	1.65	302,800	1.30	308,800	1.32

[a]NM = Net migration.
[b]NI = Natural increase.

Table 44. Age distribution (by percentage) of the TBIE study area population by planning region, 1960, 1970, 1975 (U.S. Department of Commerce, Bureau of the Census 1952b, 1962a, 1973a, 1978b).

Planning region age distribution	Year			
	1950	1960	1970	1975
Gulf Coast				
0-19	34.6	41.0	40.3	37.5
20-34	26.9	21.0	22.6	25.8
35-64	33.5	32.4	30.8	30.0
65 and over	5.0	5.7	6.3	6.7
Golden Crescent				
0-19	39.3	44.7	42.8	38.6
20-34	22.9	19.2	18.5	22.0
35-64	31.7	29.8	30.9	30.5
65 and over	6.2	6.4	7.8	8.9
Coastal Bend				
0-19	42.7	46.8	43.0	39.7
20-34	25.3	20.2	20.8	23.6
35-64	28.0	28.0	29.3	28.8
65 and over	4.1	5.0	6.8	7.9
Lower Rio Grande Valley				
0-19	46.1	49.9	47.7	44.0
20-34	24.2	19.5	17.3	22.5
35-64	25.4	25.2	26.8	25.4
65 and over	4.3	5.4	8.2	8.2
TBIE Study Area				
0-19	38.2	43.3	41.6	38.6
20-34	26.0	20.6	21.7	25.0
35-64	31.1	30.6	30.2	29.3
65 and over	4.8	5.6	6.6	7.1

There are major differences in the population age structure among regions in the TBIE study area. As a consequence of its relatively high birth rate, the Lower Rio Grande Valley has the highest percentage of people under 19 years old (44% in 1975). The highest percentage of people over 65 years old is found in the Golden Crescent and Lower Rio Grande Valley planning regions (8.9% and 8.2%, respectively). Finally, the Gulf Coast planning region has the highest percentage of people of working ages (55.8%), while the Lower Rio Grande Valley has the lowest percentage of residents of working age (47.9%).

Housing Construction

Population growth and the rate of household formation are major determinants of the demand for housing. The resulting housing construction is important because of the significant role of the construction sector in the TBIE area economy and because housing is, by far, the major urban land use in the study area. Residential uses took up approximately three-quarters of the TBIE study area's urban land in 1976 (Fisher et al. 1972, Fisher et al. 1973, Brown et al. 1976, McGowen et al. 1976a, McGowen et al. 1976b, Brown et al. 1977, Brown et al. 1980).

The number of housing units has increased rapidly in the TBIE study area. From 1950 to 1970, housing units increased at an average annual rate of 3.18%. From 1970 to 1978, the increase is estimated at 2.51% per year (Table 45). Caution is advised, however, in interpreting the housing expansion figures in the 1970's: these estimates are based on building permit data which may understate actual housing construction because permits are seldom required for housing construction in unincorporated areas in Texas. In addition, to make the housing expansion figures for the 1970's comparable to those for 1950-1970, the beginning housing stock (in 1970) had to be depreciated. The annual depreciation rate was estimated at 0.73% from data in the 1976 Houston SMSA Annual Housing Survey (U.S. Department of Commerce, Bureau of the Census 1978a), but the actual rate is likely to differ somewhat from region to region because of the different ages of the existing housing stock.

Table 45. Housing units in the TBIE study area by planning region, 1950 through 1978 (Building permits issued... 1971, 1972, 1973, 1974, 1975, 1976, 1977; U.S. Department of Commerce, Bureau of the Census 1952a, 1972, 1978a, 1979c).

Planning region	Total units 1950	Total units 1970	Units permitted 1970-1978	Average annual growth rate in the number of units (%) 1950-1978	1970-1978[a]
Gulf Coast	346,025	739,787	240,810	3.87	2.86
Golden Crescent	18,251	29,535	6,046	2.44	1.63
Coastal Bend	85,572	127,390	21,375	2.01	1.26
Lower Rio Grande Valley	81,081	96,866	23,977	0.89	2.07
TBIE Study Area	530,929	993,578	292,568	3.18	2.51

[a]Estimates based on the number of building permits issued from 1970 to 1978 and assuming a 0.73% annual depreciation rate. The depreciation rate was estimated from U.S. Bureau of the Census (1978a).

It is more appropriate to compare the housing expansion estimates for the 1970's across regions than with the figures for 1950 to 1970. Either comparison, however, is likely to be somewhat risky. The possible errors in the estimates of housing expansion for the 1970's can be appreciated by examining the more accurate statistics in the 1976 Annual Housing Survey for the Houston SMSA. The survey data implies that the number of housing units in the Houston SMSA increased at an average annual rate of 3.8% from 1970 to 1976. The building permit data, on the other hand, indicate an average annual increase in housing units in the Gulf Coast planning region (which is dominated by the Houston SMSA) of only 2.4% during the same period (Building permits issued... 1971; 1972; 1973; 1974; 1975; 1976; 1977). The rate of housing expansion is thus clearly underestimated, at least in the Gulf Coast planning region, during the 1970's.

With these caveats in mind, some idea of the rate of housing expansion in the TBIE study area and for the regions within the area can still be inferred. First, the apparent slowdown in the rate of housing construction in the TBIE study area from 1950-1970 to 1970-1978 probably did not occur. The undercount of units constructed in the 1970's results from units constructed outside city limits without building permits. Second, the fastest rate of housing expansion over the entire 1950-1978 period has probably been in the Gulf Coast planning region. Third, the rate of housing expansion accelerated from 1950-1970 to 1970-1978 in the Lower Rio Grande Valley region. The acceleration closely follows the rapid population growth in the region during the 1970's.

ENVIRONMENTAL EFFECTS OF INDUSTRIAL AND RESIDENTIAL DEVELOPMENT

In the past, industrial and residential development in the TBIE study area has occurred in a generally "free enterprise" regulatory environment. There have been some governmental restrictions on development, such as the traditional tools of zoning and subdivision regulation, but these regulations generally have not been binding. Economic theory predicts that unregulated development can produce socially undesirable environmental effects if firms and people do not take account of the costs that their actions impose on society as a whole. This impact has occurred in the TBIE study area and in many other parts of the country.

During the 1970's, concern about the environment has resulted in a number of new Federal, State, and local restrictions being imposed on industrial and residential development. Whether these restrictions will be effective in avoiding undesirable environmental consequences of future development is unclear at this time.

General Trends in Land Use

Changes in land use in the TBIE study area have taken the forms of increasing urbanization accompanied by a decentralization of development within urban areas. Land area devoted to agricultural uses, particularly cropland, on the other hand, has been declining. From 1958 to 1967, urban and built-up areas in the TBIE study area increased by 17.6% which is well above the State figure of 11.6%. During the same period, cropland declined 7.1% in the study area, but the decline was even larger in the State (14.2%) (Table 46). The loss of cropland in the study area, therefore, cannot be attributed entirely to the conversion to urban uses. Most of this loss is probably due to the retirement of marginally productive farmland from production (Hart 1968).

A direct comparison of urban and agricultural land uses in 1967 and 1977 is not possible because of the lack of comparable data. Some useful information on

Table 46. Changes in land use by planning region in the TBIE study area and in Texas in thousands of ha (ac), 1958 to 1967 (U.S. Department of Agriculture, Soil Conservation Service 1970).

Region	Cropland 1958	Cropland 1967	Cropland % change	Pasture and range 1958	Pasture and range 1967	Pasture and range % change
Gulf Coast	794.9 (1,964.2)	719.1 (1,776.9)	-9.5	674.2 (1,665.9)	705.3 (1,742.0)	4.6
Golden Crescent	208.7 (515.7)	192.5 (475.8)	-7.8	477.7 (1,180.4)	459.5 (1,135.4)	-3.8
Coastal Bend	430.4 (1,063.6)	406.8 (1,003.2)	-5.5	1,335.9 (3,301.0)	1,281.8 (3,167.3)	-4.0
Lower Rio Grande Valley	438.3 (1,083.1)	422.6 (1,044.2)	-3.6	272.8 (674.1)	278.6 (688.4)	2.1
TBIE Study Area	1,872.4 (4,626.6)	1,740.2 (4,300.1)	-7.1	2,760.6 (6,821.4)	2,725.1 (6,733.7)	-1.3
Texas	16,803.4 (41,521.2)	14,419.4 (35,630.3)	-14.2	38,104.9 (94,157.2)	40,342.4 (99,686.1)	5.9

Region	Forest land 1958	Forest land 1967	Forest land % change	Urban and built-up 1958	Urban and built-up 1967	Urban and built-up % change
Gulf Coast	480.7 (1,187.7)	446.7 (1,104.0)	-7.1	205.1 (506.8)	252.9 (624.9)	23.3
Golden Crescent	97.7 (241.5)	108.7 (268.6)	11.3	18.8 (46.5)	20.3 (50.2)	8.0
Coastal Bend	17.6 (43.4)	17.1 (42.2)	-2.8	60.3 (149.0)	68.5 (169.3)	13.7
Lower Rio Grande Valley	0.0 (0.0)	0.0 (0.0)	0.0	46.3 (114.4)	46.9 (115.8)	1.3
TBIE Study Area	596.0 (1,472.6)	572.6 (1,414.8)	-3.9	330.5 (816.7)	388.7 (960.6)	17.6
Texas	9,852.6 (24,345.8)	9,179.2 (22,681.7)	-6.8	1,755.6 (4,338.2)	1,960.0 (4,843.2)	11.6

the growth of incorporated land area and the loss of land in farms during the 1970's can, however, be assembled.

From 1970 to 1977, incorporated land in the TBIE study area increased 55.3% (Table 47). This figure, however, cannot be directly compared to the growth of urban and built-up land during 1958-1967. Incorporated land area includes both developed and undeveloped areas. Aggressive annexation policies during the 1970's have probably expanded many coastal cities beyond their actual developed areas. On the other hand, the expansion of scattered industrial and residential land areas outside of city limits and the expansion of a number of small unincorporated settlements are not included in official incorporated land statistics. Despite the difficulty of stating confidently whether the data on incorporated land overestimate or underestimate the actual rate of urban expansion during the 1970's, it appears that the rate of urban expansion is somewhat overestimated.

From 1969 to 1974 (the latest data available), cropland (not pastured or grazed) declined 5.8% in the TBIE study area. This decline, however, is smaller than the State decline in cropland (not pastured or grazed) of 9.4% during the same period (U.S. Department of Commerce, Bureau of the Census 1977a).

The greatest rate of increase in incorporated land area from 1970 to 1977 occurred in the Coastal Bend and Gulf Coast planning regions--80.6% and 53.8% respectively. Aggressive annexation by Corpus Christi in advance of urban development has greatly raised the rate for the Coastal Bend region, however (see Table 48). Much of the expansion of incorporated land in the Gulf Coast planning region, on the other hand, is probably due to actual expansion of developed land area.

The Lower Rio Grande Valley exhibited a somewhat slower growth of incorporated land (45.2%), despite rapid population growth and strong construction activity during the 1970's. This lower growth rate is probably attributable to extensive annexation prior to 1970, as well as the relatively poor fiscal situation of many cities in the Lower Valley. Finally, the growth of urban land area in the Golden Crescent planning region is probably underestimated due to the rapid increase of very small unincorporated towns in the area.

Table 47. Incorporated land area by planning region in the TBIE study area in mi^2(km^2), 1970 and 1977 (U.S. Department of Commerce, Bureau of the Census 1973a, 1973b, 1979a, 1979d).

	Incorporated land area		
Planning region	1970	1977	% change
Gulf Coast	901.0 (2,334.2)	1,386.0 (3,590.7)	53.8
Golden Crescent	24.1 (62.4)	25.4 (65.8)	5.4
Coastal Bend	137.4 (356.0)	248.1 (642.7)	80.6
Lower Rio Grande Valley	90.5 (234.5)	131.4 (340.4)	45.2
Total TBIE Study Area	1,153.0 (2,987.0)	1,790.9 (4,639.6)	55.3

Table 48. Land area and population density in major TBIE study area cities, 1960, 1970, 1977 (U.S. Department of Commerce, Bureau of the Census 1962b, 1973a, 1973b, 1979a, 1979d).

	1960		1970		1977	
City	Land area (mi^2)	Population density (persons per mi^2)	Land area (mi^2)	Population density (persons per mi^2)	Land area (mi^2)	Population density (persons per mi^2)
Galveston	19.7	3,410	21.0	2,943	28.5	2,111
Texas City	45.0	713	67.1	580	67.1	631
Baytown	17.9	1,573	25.4	1,732	27.9	1,875
Houston	328.1	2,860	433.9	2,841	541.0	2,874
Pasadena	22.0	2,670	35.4	2,522	53.0	1,960
Victoria	12.2	2,709	16.6	2,491	17.8	2,651
Corpus Christi	37.8	4,436	100.6	2,033	176.1	1,222
Kingsville	5.3	4,773	10.8	2,677	11.3	2,573
Brownsville	15.7	3,060	15.2	3,455	25.9	2,745
Harlingen	31.0	1,329	22.5	1,489	23.1	1,770
McAllen	9.5	3,445	13.5	2,788	27.1	1,941
Total	544.2	2,706	762.0	2,448	998.8	2,272

While the incorporated land area of municipalities is increasing, population densities within these cities are generally decreasing (Table 48). This reflects the relatively low density of recent development. Changes in population densities, however, differ greatly from city to city in the study area.

Increasing urbanization in the TBIE study area has resulted in a number of undesirable environmental effects including the loss of rural lands and activities, increased human susceptibility to natural hazards, changes in water quality and supply, and air pollution. The decentralization of development within urban areas has further aggravated these problems.

Loss of Rural Lands and Activities

Agricultural lands. The United States is now losing 364,000 ha/yr (910,000 ac/yr) of prime agricultural land to urban and built-up uses. If, as some expect, it will become desirable to expand the agricultural land base in the future, the continued loss of productive agricultural land to urbanization could exacerbate a possible agricultural land shortage problem in the future (Plaut 1979a, 1979b).

In addition to the conversion of farmland to urban uses, the growth of urban uses can have other detrimental effects on nearby agricultural production. Intense urban pressures may result in the premature idling of otherwise productive farmland because of adverse "spillover" effects from nearby development. Typical urban spillovers include vandalism of farm equipment, restrictive regulations on farming, high taxes, and high land prices. Encroaching urbanization, coupled with the general expectation of future development, may also cause farmers to reduce agriculture investments and to switch from long-term capital investments (e.g. dairying) to shorter-term forms of investment (e.g. field crops). Increasing job opportunities in nearby cities may also result in some farmers converting their lands to easily managed uses so that they can work in the city (Berry and Plaut 1978, Berry 1978, 1979).

In the TBIE study area, conflicts between urban growth and agricultural uses appear to be especially strong in the Houston-Galveston, Corpus Christi, and Brownsville-McAllen areas. All three of these urban areas are largely surrounded by major concentrations of prime farmland (Vining et al. 1977).

In the Houston-Galveston area, cropland has been declining faster than in other parts of the TBIE study area. Cropland (not pastured or grazed) declined 11.5% from 1969 to 1974 in the Houston-Galveston Standard Consolidated area compared to a decline of 5.8% in the study area (U.S. Department of Commerce, Bureau of the Census 1977a). In 1960, 71% of Harris County's land area was in agricultural use; by 1974, this figure had declined to 44%. Agricultural activities in the region are now primarily centered on field crops (Moore 1980).

Cropland (not pastured or grazed) declined by 10.2% from 1969 to 1974 in the Corpus Christi SMSA (U.S. Department of Commerce, Bureau of the Census 1977a). Approximately 3,227 ha (8,100 ac) of agricultural lands are projected to be converted to urban uses in the Corpus Christi area from 1977 to 1995 (Coastal Bend Council of Governments 1977).

The decline in agricultural lands is potentially the most severe in the Lower Rio Grande Valley. The Valley is an extremely important agricultural resource, both for the State and the Nation. It supplies 100% of the State crop of grapefruit and oranges and 20% of the National crop. Eighty percent of the carrots, 75% of the cauliflower, and 92% of the broccoli produced in Texas are grown there (James Veltman and Associates 1977). From 1969 to 1974, cropland (not pastured or grazed) declined 6.7% in the Brownsville and McAllen metropolitan areas (U.S. Department of Commerce, Bureau of the Census 1977a). As much as 10,000 ha (25,000 ac), 3% of the 1974 acreage of agricultural lands, may be withdrawn from production in the Valley by 1983 as a result of scattered urban development. Still more lands may be developed to accommodate additional part-time winter residents (James Veltman and Associates 1977).

Much of the farmland converted to urban uses is irrigated. Easily accessible water supplies have already been appropriated in the Gulf Coast and Lower Rio Grande Valley planning regions. While a decrease in irrigated land area may release water for municipal and industrial uses, water for new irrigation projects to upgrade nonirrigated farmlands may not be available in the face of continued industrial and municipal expansion. Dryland farming for some crops takes almost twice the amount of land to produce the same yield as it does for irrigated acreage. Total farming productivity may thus be lowered, even if additional reserve lands are brought into production (Texas Department of Agriculture 1980).

Wetlands and fish and wildlife habitats. Coastal wetlands occupy 937 km^2 (362.3 mi^2), or 2.2% of the mapped area of the TBIE region (Fisher et al. 1972, Fisher et al. 1973, Brown et al. 1976, McGowen et al. 1976a, McGowen et al. 1976b; Brown et al. 1977; Brown et al. 1980). The total area of submersed seagrass beds is 1,009 km^2 (389 mi^2) (Lindall and Saloman 1977). These areas supply the detrital materials that serve as a substrate for bacteria, fungi, and protozoa--the basic energy sources of the marine food chain. Wetland areas also aid in the maintenance of water quality by filtering upland runoff and tidal waters. Submersed sea grasses and other estuarine habitats support important commercial and sport species such as fish, crabs, oysters, and shrimp (Lindall and Saloman 1977).

One of the more obvious causes of wetland degradation has been the construction of canals in residential developments. Federal restrictions imposed in the past decade will sharply limit new canal developments (Parker 1979). Large-scale residential canal projects were, however, widely built from Galveston to Brownsville during the 1960's and 1970's. The result has been the filling and destruction of wetland vegetation, changes in water quality and sediment type (as a result of increased and poorly filtered runoff and inadequate circulation), and changes in the number and kinds of animal life (Lindall and Trent 1975). As a result of these alterations, the abundance and species composition of benthic organisms decreased (Gillmore and Trent 1974), oysters reproduced less and suffered higher mortality rates, and the number of fishes and crustaceans declined (Lindall and Trent 1975).

Wetland areas within the study area also serve as waterfowl habitats. From 55 to 65% of the total Central Flyway waterfowl population of the United States winters on the Texas coast (U.S. Department of the Interior, Fish and Wildlife Service 1977). Almost 2.5 million ducks winter on the coast. Approximately 700,000 geese winter in the study area, but their number has declined with changing land use (Kemp 1979). An estimated 708 ha (1,750 ac) of coastal wetlands will be destroyed annually through 1982, further reducing the estuarine habitat and feeding areas available to waterfowl (U.S. Department of the Interior, Fish and Wildlife Service 1977).

The tidal flats and wetland areas that still remain in many of the urbanized areas of the coast have been significantly altered with drainage canals. The resulting changes in water quality and decline in productivity have limited their usefulness as feeding sites for birds and marine organisms (Harland Bartholomew and Associates 1975). Urbanization and rural land fragmentation have claimed habitat areas of upland game species and furbearers causing declines in their total populations (Kemp 1979).

Increased Human Susceptibility to Natural Hazards

Barrier islands and shorelines are generally locationally and structurally unstable. Natural winds and waves constantly alter the shapes of these islands or shores. Development along the coast can accelerate the rate of change in shoreline configuration, thereby reducing the effectiveness of the shoreline as a natural defense against storm hazards and erosion.

Storm hazards and flooding. Thirty hurricanes and many more tropical storms have struck the TBIE area since 1900 (U.S. Dept. of the Army, Corps of Engineers 1979a). These storms produce high storm surge and waves, torrential rains, and strong winds. Shores and adjoining lands are eroded by waves and tidal currents. During Hurricane Carla (1961) shorelines eroded as much as 240 m (800 ft) on Matagorda Peninsula and 45 m (150 ft) on Matagorda Island (Brown et al. 1974). Storm surge tides may flood low lying areas up to elevations above 6 m (20 ft). Tidal currents accompanying Hurricane Beulah (1967) flooded 8,200 km^2 (3,164 mi^2).

The torrential rains accompanying and following hurricanes produce runoff of flood proportions, inundating the low lying areas along streams and bays. Accumulated rainfall may stand for days or weeks in areas of poor drainage. More than 90 cm (36 in) of rain fell in a 6½-day period after Hurricane Beulah, leading to freshwater flooding of 5,700 km^2 (2,200 mi^2), in addition to that flooded by tidal currents (Brown et al. 1974, U.S. Dept. of the Army, Corps of Engineers 1979a).

Alteration of beach and dune areas. Barrier islands act as a natural line of defense for the mainland, serving to dissipate some of the destructive force of hurricanes. The beach and foredune areas constitute the barrier islands' last "line of defense" against hurricane storm surge and washover (Morton and Pieper 1975). Dunes also serve as a sediment reserve from which the beach can be naturally reconstituted after a storm. Removal of the dunes eliminates the sediment reserve, thereby contributing to beach erosion and weakening the natural beach protection mechanism.

Although storms, drought conditions, grass fires, and overgrazing have long contributed to dune erosion, recent human activities have accelerated natural beach and dune erosion (Eden 1980). Residential and commercial construction in the foredunes has become common practice along the TBIE coastline and is contributing to beach erosion. Construction of seawalls, groins, and jetties designed to protect property has affected the quantity and type of beach material delivered to the shoreline and has accelerated erosion. Dramatic shoreline changes caused by human activities can be seen at: 1) the west end of the Galveston seawall, where the beach has been entirely removed by wave action, 2) Surfside (Freeport Harbor), where residential construction has obliterated the dunes and shoreline erosion has been so serious that a number of homes have been lost, and 3) the Matagorda Ship Channel and Mansfield Channel (Morton 1977). Artificial maintenance of the Mississippi River in its present channel is considered a major factor causing the erosion of Texas' northern beaches (City of Galveston 1979, Morton 1977).

The most severe hurricane storm damage can be expected when large hurricanes make landfall in areas of low relief, where foredunes are poorly developed or absent, and where the area is densely populated (Brown et al. 1974). As development along the shoreline increases, the probability of loss of life and property associated with hurricanes will increase.

Land-surface subsidence. Heavy pumping of groundwater for municipal and industrial use is a major cause of subsidence in the Houston-Galveston area. Withdrawal of water from Gulf Coast aquifers immediately decreases hydraulic pressure in the water-bearing formation. With this reduction in pressure, an additional load, equal to the lost pressure, is transferred to the solid structure of the aquifer. The difference in pressure causes water to move from the clays to the sands, resulting in compaction of the clay strata and consequential land surface subsidence.

The Gulf Coast planning region, which depends heavily on groundwater for municipal and industrial use (Texas Department of Water Resources 1977), is experiencing a significant subsidence problem; the Corpus Christi area is also affected. The largest subsidence depression in the Gulf Coast planning region is in the vicinity of the Houston Ship Channel at Pasadena. As much as 2.9 m (7.3 ft) of subsidence occurred there between 1943 and 1973. The area of active subsidence is expanding. Between 1943 and 1954, about 900 km^2 (350 mi^2) had subsided 0.3 m (1 ft) or more. By 1973, 6,500 km^2 (2,500 mi^2) had subsided 0.3 m (1 ft) or more. Approximately 12,200 km^2 (4,700 mi^2) subsided 15 cm (0.5 ft) between 1943 and 1973 (Gabrysch and Bonner 1975).

The subsidence problem is aggravated in those areas close to bay waters. Some coastal municipalities have permanently lost land due to inundation by tidal waters. Faulting in the Gulf Coast planning region is also aggravated by subsidence (Kreitler 1977). Faults may act as fluid barriers. Fluid withdrawal on one side of a fault may cause pressure declines and compaction on that side, but not on the other. This pressure difference results in differential land subsidence, which can severely damage structures straddling the fault. Generally, however, the direct physical damage due to subsidence is slight. Tidal and freshwater flooding have caused the highest subsidence-related costs (Warren et al. 1974). Some areas that were formerly not subject to freshwater flooding are now regularly inundated by heavy rains. Over the last 30 to 40 years, an additional 180 km^2 (70 mi^2) are estimated to now be subject to storm-surge flooding in the event of a major hurricane in Galveston Bay (Brown et al. 1974). The towns of Kemah and Seabrook have permanently lost land due to inundation by tidal waters. Subsidence-related flooding in Baytown has become so severe that 456 homes have been scheduled for demolition. Residents are being relocated at Federal expense (U.S. Dept. of the Army, Corps of Engineers 1979b). The direct and indirect costs of subsidence in the Houston-Galveston area have been estimated at $60.7 million and $48.9 million respectively (Warren et al. 1974). Of the $109.6 million in damages, $53.2 million were incurred during Hurricane Delilah in 1973.

Although the U.S. Geological Survey, the Houston-Galveston Area Coastal Subsidence District, and various municipalities within the planning region are planning to arrest the incidence of subsidence by reducing groundwater pumping and increasing the use of surface water supplies, adequate additional sources of surface water have not yet been identified (Office visit 18 December 1979 to Bud Holvschuh, Harris-Galveston Coastal Subsidence District, Houston, TX). Until enough of these sources can be identified and allocated, excessive groundwater production will continue, further aggravating subsidence and increasing potential flooding damage.

Water Use, Salt Water Intrusion, and Point-source Discharge

Increased competition and potential shortages of supply. The availability of water in the Lower Rio Grande Valley is a potential limit to municipal, industrial, and agricultural expansion (James Veltman and Associates 1977). Surface water constitutes the majority of water supply for the Valley. Unlike most rivers in Texas, surface-water rights have been determined in the Rio Grande. The 1969 case of Texas versus Hidalgo County Water Control and Improvement District No. 18 established irrigation, industrial, and domestic water rights in the Valley. Available surface-water rights appear to be 100% appropriated (Hanks 1980).

As Valley municipalities expand, irrigated farmland is converted to urban uses. Because the water rights belong to an irrigation district rather than to the agricultural landowner, the water right cannot be conveyed with the deed. Municipalities may purchase water rights from irrigation districts. Demands, however, generally exceed the supply (James Veltman and Associates 1977). Irrigation districts are sometimes reluctant to sell their rights. Because the price of water rights is set by the private marketplace, many communities find it difficult to purchase additional rights, especially when competing with major industries or power companies.

At present, groundwater is not heavily exploited in the Valley. With the limited availability of surface water, groundwater pumping may increase. This, however, will be an expensive undertaking because extensive treatment of the water will be necessary to remove dissolved solids (Texas Department of Water Resources 1977).

The Gulf Coast planning region may also experience future surface-water supply limitations. The long-range plan for subsidence control calls for an increase in the use of surface water while decreasing groundwater pumping. Additional surface-water sources have not yet been determined, but the most likely possibilities are dams and reservoirs or rivers northeast of Houston. This will increase the available supply of surface water, but will also raise its cost to consumers and further decrease freshwater flows into Galveston Bay.

Salt water intrusion. Salt water has intruded into the freshwater aquifers of the Gulf Coast planning region, particularly around Galveston-Texas City (Texas Department of Water Resources 1977). Freshwater aquifers along the coast are associated with salt water aquifers that occur below, above, or downdip of the fresh water. When heavy pumpage occurs, the reduction of pressure allows saline water to migrate toward the pumping wells, often resulting in deterioration of water quality and loss of storage volume for potential freshwater recharge. Freshwater aquifers underlying the Coastal Bend, Golden Crescent, and Lower Rio Grande Valley planning regions are also subject to saltwater encroachment due to excessive groundwater withdrawal (Texas Department of Water Resources 1977).

Point-source discharges. Point-source discharges are those municipal and industrial effluents that are transported via pipeline or channel to a natural water body. The general effects of point-source discharges on water quality in river and coastal basins in the TBIE study area are summarized below (Texas Department of Water Resources 1979a). Table 49 shows significant water quality problems noted in specific segments of the basins.

No significant water quality problems have occurred in the Trinity river basin (Liberty and Chambers counties). The Trinity-San Jacinto, San Jacinto, and San Jacinto-Brazos river basins, situated in the Gulf Coast planning region, however, have been severely affected by point-source discharges. High bacterial concentrations in inflows from the San Jacinto River have deleteriously affected parts of

Table 49. Significant water quality problems in segments of river and coastal basins[a] in the TBIE study area, 1979 (Texas Department of Water Resources 1979a).

River or coastal basin	Water quality problem: Elevated inorganic nitrogen levels	Elevated phosphorus levels	Elevated herbicide or pesticide levels	Low dissolved oxygen levels	High dissolved oxygen levels	Elevated mercury levels	Elevated manganese levels
Nueces-Trinity		X			X	X	X
Trinity		X	X				
Trinity-San Jacinto	X	X			X	X	X
San Jacinto	X	X	X	X	X	X	X
San Jacinto-Brazos	X	X		X	X	X	X
Brazos	X	X					
Brazos-Colorado	X	X			X		
Colorado-Lavaca			X			X	
Lavaca							
Lavaca-Guadalupe		X	X			X	
Guadalupe			X				
San Antonio							
San Antonio-Nueces		X	X				
Nueces							
Nueces-Rio Grande	X	X	X			X	X

(continued)

Table 49 (concluded).

River or coastal basin	Water quality problem: Elevated dissolved solids, sulfates, and chloride	Elevated fecal coliform levels	Elevated or sporadic chlorophyll levels	Elevated arsenic or heavy metals in sediments	Point-source discharge adversely affects water quality	Non-point-source discharge adversely affects water quality
Nueces-Trinity		X	X			
Trinity						
Trinity-San Jacinto		X	X	X	X	X
San Jacinto		X	X	X	X	
San Jacinto-Brazos	X	X	X	X	X	X
Brazos		X	X	X		
Brazos-Colorado	X	X	X	X	X	X
Colorado-Lavaca		X		X		
Lavaca		X				
Lavaca-Guadalupe				X		
Guadalupe		X				
San Antonio		X		X	X	
San Antonio-Nueces	X	X		X		X
Nueces	X		X			
Nueces-Rio Grande		X		X	X	X

[a]Data are presented only for that portion of the basin system within the TBIE study area.

Galveston Bay. Nearly half of the Bay is now closed to oyster harvesting because of water pollution (Carter 1970). Major fish kills have occurred in parts of the San Jacinto-Brazos Coastal Basin (Texas Department of Water Resources 1979).

The Brazos-Colorado (Gulf Coast planning region), Colorado-Lavaca (portions of Jackson, Wharton and Matagorda counties), Lavaca (portions of Jackson and Wharton counties), Lavaca-Guadalupe, Guadalupe, and San Antonio Basins (Golden Crescent planning region) generally exhibit acceptable water quality throughout, although the Lavaca Basin displays a high incidence of fecal coliform resulting from unconfined livestock operations.

High fecal coliform levels from partially treated municipal wastewater, elevated total dissolved solids due to residual effects of discontinued open-pit discharges of oil field brine, and non-point-source effluents have significantly affected water quality in the San Antonio-Nueces Basin (Coastal Bend planning region). The Nueces Basin in the Coastal Bend region and the Nueces-Rio Grande Basin (Coastal Bend and Lower Rio Grande Valley planning regions) are generally of good water quality. The Arroyo Colorado segment, however, receives much of the municipal, agricultural, and industrial wastes of the Lower Rio Grande Valley area. Flows in the Arroyo are usually maintained by irrigation return flows and municipal effluents, resulting in oxygen depletion and elevated levels of fecal coliforms, nitrogen, phosphorous, and dissolved solids.

Air Pollution

The most serious air pollution problems are in the northern and central sections of the study area. Federal ambient air quality standards for ozone and hydrocarbon concentrations are currently exceeded in Houston, Texas City, Freeport, and Corpus Christi (Texas Air Control Board 1978). Houston will be unable to comply with Federal ozone standards by 1982, the mandatory date of compliance set by the U.S. Environmental Protection Agency.

Unacceptably high concentrations of particulates are found in urbanized parts of the Gulf Coast, Coastal Bend, and Lower Rio Grande Valley planning regions. Portions of Brazoria, Harris, Galveston, Victoria, and Nueces Counties exceed Federal standards for photochemical oxidant concentrations (Texas Air Control Board 1979, U.S. Environmental Protection Agency 1980).

The main sources of polluting emissions in the TBIE study area include petroleum refineries; storage, transportation, and marketing of petroleum products; organic chemical and industrial manufacturing; and automobile, truck, rail, and aircraft emissions (Texas Air Control Board 1979). Automobile emissions and oil industry operations (cracking, storage, tank filling, and transfer) are major sources of hydrocarbon pollution. Hydrocarbons play a major role in the reaction of sunlight and nitrogen dioxide, resulting in the formation of ozone (American Lung Association 1974).

Ozone is an allotropic form of oxygen that can cause coughing, choking, headache, and severe fatigue. Ozone is also a participant in the highly complex series of continuing reactions contributing to the formation of PAN (peroxyacyl nitrate) and formaldehyde. Particulates, including aerosols, smoke, fumes, and dust, can also act as catalysts for further reactions (American Lung Association 1974).

The most dangerous forms of air pollution, however, are nitrogen dioxide, ozone, and other photochemical oxidants. Both the structure and function of the respiratory tract may be changed by these substances. Vegetation growth may be slowed considerably. Livestock and poultry, through ingestion of plants capable of storing large amounts of formaldehyde and other deleterious substances, can become sickened or less productive, generating fewer offspring and smaller eggs. Steel, iron, zinc, brass, copper, nickel, lead, and tin corrode much faster in urban, industrialized areas because of excessive oxidants and acidity (American Lung Association 1974).

Other Effects

Solid waste disposal. A large number of solid waste disposal sites are found in the study area (Texas Department of Water Resources 1979c; U.S. Congress, House of Representatives 1979). Ninety-one percent of the sites are in the Gulf Coast planning region. Of the 49 sites no longer in use, only 8 have been closed. While the contents of many abandoned sites are unknown, it is likely that some contain toxic wastes and are public health hazards, especially if the disposal sites are in areas with high water tables. Only 30% of the coastal solid waste disposal sites in the TBIE study area are capable of holding wastes securely, and 20% are in poor host areas. The balance of waste disposal sites are in marginally suitable disposal areas (Division of Natural Resources and Environment 1973).

Electrical generating stations. There are currently 19 electrical generating plants in the study area (Moody's public utilities manual 1978). One additional facility, the South Texas Nuclear Project (with a capacity of 1,200 megawatts) is expected to begin operating in Matagorda County by 1983.

A variety of environmental problems are associated with the presence of large generating facilities and their associated infrastructures. Ozone and other photochemical oxidants are produced as a byproduct of corona discharge from extra high voltage transmission lines (500 kV and greater) (Smith et al. 1977). Power plants use extremely large amounts of water, both for cooling and for steam generating purposes. This may prove to be a serious problem in the future, especially in the Gulf Coast and Lower Rio Grande Valley regions where water supplies are already short.

Expanded use of salt water for cooling may be an inadequate solution to the problem of competing demands for freshwater supplies because of the potential deleterious effects of thermal pollution in coastal bays and estuaries and the possible entrapment of fish in the intake system. During a one-year period in 1969 and 1970, over seven million fish were caught on the filtering screen of the P.H. Robinson Plant (Galveston Bay) intake system (Clark and Brownell 1973). In addition, the corrosion of power plant equipment from salt water coolant makes this alternative relatively unpopular with facility operators.

FUTURE GROWTH PATTERNS

Growth-limiting and Growth-inducing Factors

In a growing regional economy, like the TBIE study area, rapid expansion in employment opportunities leads to migration and population growth which, in turn, generates further demands in the service sector, leading to further employment growth. Thus, in the short run, rapid growth should be expected to continue in the TBIE area. Over a longer time, however, major factors could limit established growth trends or initiate new growth trends.

It is, of course, difficult to identify what the most important growth-limiting or growth-inducing factors will be in the TBIE study area and it is even harder to predict the exact impacts of these factors on future growth patterns. It is possible, however, at least to discuss some of the factors that may have important effects on future growth in the TBIE study area and generally to indicate the direction and magnitude of these effects.

Energy prices, availability, and production. A large part of the TBIE area economy directly or indirectly depends on energy-related activities. Moreover, much of the recent growth in the TBIE area is due to expansion in energy-oriented sectors. Future growth patterns in the study area, therefore, will be largely shaped by national and world energy developments. Federal energy policy and the reliability of foreign oil imports are particularly important here.

High oil and gas prices are certainly going to continue for some time in the future. As discussed in the Oil and Gas synthesis paper, the associated surge in oil exploration and development activities is likely to continue not only in the TBIE study area, but throughout the world. The comparative advantage of TBIE-area firms in servicing worldwide exploration and development activity should be maintained in the future. Thus, continued growth in the non-electrical machinery, fabricated metals, and associated real estate, finance, transportation, and service sectors is expected.

On the other hand, the oil using sectors in the TBIE study area--refining and the strongly related petrochemicals industry--are a possible weak spot in the area economy. These sectors have now become so dependent on foreign oil supplies that short-run interruptions in oil imports could seriously affect the level of production. In the long-run, refining-petrochemical capacity could gradually move away from the Texas Gulf coast and toward other parts of the United States and the world. The original factor leading to the concentration of refining and petrochemical activities along the Texas coast was the availability of locally produced oil and gas. With oil and gas production falling rapidly in the coastal area, this locational advantage is also diminishing. Future refining capacity may thus be added closer to the traditional East Coast market--along the Louisiana-Mississippi-Alabama coastline, in the Caribbean, and in the Northeast. The Louisiana Offshore Oil Port (LOOP), which will begin operations in 1981, may make southern Louisiana locations look especially attractive (McKie and Niemeyer 1979, Sumpter 1979).

At least three factors may mitigate the projected shift of new refining capacity to areas east of the Texas Gulf coast. First, the cost savings resulting from the existing agglomeration of refineries, petrochemical plants, transport, and other support facilities along the Texas coast may continue to outweigh the additional transportation costs assumed by locating in the area. Present cost considerations make the expansion of existing refinery complexes much more attractive than building entirely new plants, and this will also favor continued expansion on the Texas coast. Second, the shift of people and industry from the Northeast and Midwest to the South and Southwest should continue. This will lead to the further development of Southern markets and decrease the importance of East Coast markets for refined products. Third, a new oil superport may be built on the Texas Gulf Coast. This would lead to significant transportation cost savings on imported oil and make Texas coastal locations appear much more attractive for refineries. (The possible impacts of the construction of a Texas superport are considered separately below.)

The discussion so far has been based on the assumption that imported oil will continue to play an important role in United States energy consumption for some time in the future. Price-induced conservation, the substitution of alternative energy sources, and sluggish economic growth could reduce the rate of growth in national demands for oil imports and slow national refining expansions. This could consequently slow economic growth along the Texas coast.

Water resources. The availability of water has and will continue to be a major factor limiting development along the Texas coast. The severity of the water problem, however, varies significantly in the TBIE study area. Traditionally, the Houston-Galveston area has relied heavily on groundwater sources, especially for residential users. Efforts to deal with subsidence, however, may lead to increased diversion of surface water supplies to the area. Such supplies are limited locally, but are available in areas north and east of Houston. Gaining improved access to East Texas water supplies is possible, but will be expensive (Texas Department of Water Resources 1977). Possible reductions in freshwater inflows into Galveston Bay may be an important environmental constraint to damming East Texas rivers.

South of the Houston-Galveston area, the water supply is more limited. The recent approval of the Choke Canyon Dam northwest of Corpus Christi should guarantee sufficient water for moderate growth in that area, but the short supply of water could significantly limit growth in the Lower Rio Grande Valley. Water rights to the Rio Grande are almost completely allocated and future water demands in the Brownsville area, at least, may exceed the water available under rights held by the city (James Veltman and Associates 1977). The limited supply of water may also retard agricultural expansion in the Valley, which would limit future expansions in food processing and other industries related to agriculture.

Quality-of-life considerations. Recently, the Houston-Galveston area has been experiencing rapid growth, despite the national trend of movement away from large metropolitan areas and toward smaller cities and nonmetropolitan areas (Beale 1977). Unlike other major metropolitan areas, the advantages to people and firms of moving to Houston-Galveston apparently still outweigh the disadvantages. Continued growth, however, especially without effective planning and resource management, may lead to increased pollution, congestion, and other environmental problems in the Houston-Galveston area, with the environmental consequences of continued growth eventually beginning to outweigh the economic advantages. People and firms appear to be increasingly sensitive to quality-of-life considerations in deciding where to locate, and this sensitivity may lead to a growth slowdown in the Houston-Galveston region.

Urban-related environmental problems are less likely to limit growth in coastal areas other than Houston-Galveston. In fact, many smaller communities in the TBIE study area offer numerous recreational and other amenities that make them potentially attractive to firms and people. Consequently, one may see activities that formerly would have moved to the Houston-Galveston area locating in smaller cities and towns farther down the coast.

Deep water ports and other transportation improvements. A deep water port would help maintain the preeminence of the Texas Coast in refining and petrochemical activities. Three major superports have been proposed for the TBIE study area: 1) the Pelican Island project at Galveston, 2) the Texas Deepwater Port Authority project off the Freeport coast, and 3) the Deeport project at Harbor Island (just north of Corpus Christi).

The $350 million (estimated in 1979) Pelican Island project would handle large crude oil tankers that were first "lightered" at the LOOP superport, at Caribbean transshipment terminals, or offshore. A channel 17 m (56 ft) deep would be dredged off the Galveston jetties while the Galveston Channel would be dredged to 16.8 m (54 ft). Major crude oil pipelines would run from Pelican Island to a 12 million bbl tank farm at Texas City. Crude oil would then be piped to refineries at Beaumont-Port Arthur, Houston-Baytown, and Freeport (Sumpter 1979, 1980a).

The Pelican Island project appears to have a fair chance of being built. On 5 April 1980, Galveston voters narrowly defeated a proposal that would have severely limited the size of vessels carrying flammable cargos into Galveston wharves. The Pelican Island project, however, still awaits the approval of dredging permits from the U.S. Army Corps of Engineers. Galveston citizens will also be given a chance to vote directly on the $350 million in revenue bonds needed to build the project, and opponents continue to fight a Texas Air Control Board permit in the courts (Galveston voting...1980).

The Texas Deepwater Port Authority (TDPA) was formed in 1978 to promote the construction of a major monobuoy port 43 km (27 mi) off Freeport after the private consortium on the project collapsed. Plans call for the installation of four single-point mooring buoys and offshore pump facilities. A 22.5 million bbl tank farm would be built onshore. The cost of the project was estimated at $843 million in 1979. The TDPA has been notably unsuccessful in finding enough crude oil importers to underwrite the project. Some attempts were made to scale down the proposed project, but cost savings were not sufficient. The future of the Freeport project, thus, is not bright (Sumpter 1979, 1980b).

The proposed Deeport project is probably the most environmentally controversial of the three proposals for Texas superports. Plans call for the dredging of a 24-m (80-ft) deep, 16-km (10-mi) approach channel into Harbor Island near Port Aransas. A 13 million bbl tank farm would be built on the island and pipelines would run to Corpus Christi. The estimated cost of the project was $431 million in 1979, but may rise to $600 million if construction does not start before 1982. Deeport proponents are now working on a final environmental impact statement for the project, but because 1,200 ha (3,000 ac) of wetlands would have to be used to dump dredging spoil, Federal approval of the project is not likely (Sumpter 1979, 1980a).

Many experts in the oil industry believe that none of the proposed Texas superports will be approved and constructed in the near future (No big improvement...1980). The Pelican Island project does, however, appear to have some chance of being constructed. If it is built, refining, petrochemicals, and associated industrial development may be spurred in the upper Gulf Coast or, at least, their activities will be preserved in the future.

Historically, the lack of good railroad access has been an important factor limiting industrial development in the southern part of the TBIE study area. At least one major railroad improvement, however, may improve this situation, at least in the Lower Rio Grande Valley. Major railroad yards are now located in relatively congested parts of Brownsville and in Matamoros, on the Mexican side of the border. The Brownsville Navigation District, however, is developing plans for a major railroad project that would relocate rail lines and railyards to the east of the two cities and build a new connecting bridge over the Rio Grande. The project would greatly improve intermodal connections at the Brownsville port, and would link the fastest growing industrial areas on both sides of the border. The estimated cost of the project is $45 million. At present, doubts about the feasibility of completing the project arise from the difficulty in getting the two major railroads involved to cooperate with each other.

Mexican oil and gas. Thus far, the United States has been unsuccessful in making any major agreement for the purchase of Mexican oil and gas. Because of the wide divergence between United States energy demands and Mexican supplies, however, some sort of agreement will probably be made. This could have important implications for the growth of the TBIE study area, especially the southern part of the area.

If the United States does start importing major quantities of Mexican oil, it is not exactly clear whether crude oil will be imported to be refined in the United States or whether partially or fully refined products will be imported. If actual crude is imported, this could lead to a major acceleration in the growth of refining capacity and, consequently, overall economic growth in the Brownsville and Corpus Christi areas.

It is much more likely, however, that Mexico will retain part or all of the refining activity on its side of the border so that it can capture the indirect economic effects of this activity. In this case, Mexican oil may still have some economic impacts in the TBIE study area, but the overall effect will be much less than if the refining activity were actually concentrated on this side of the border.

Air pollution regulations. Air pollution regulations, by themselves, will probably have little effect on future growth trends in the TBIE study area. Harris County (Houston) is the only part of the study area that will be unable to meet the Environmental Protection Agency's ambient air-quality standards by 1982, and compliance is expected by 1987. In combination with other factors, however, air pollution regulations could have some effect on TBIE area growth patterns. Quality-of-life considerations, Mexican oil and gas developments, air pollution regulations, and other factors could lead to a general movement of industrial and residential activity away from the Houston-Galveston area and a southerly movement along the coast.

Control of flooding and subsidence. In the future, it appears that there may be some improvement in the subsidence and associated flooding in the Houston-Galveston area because of a reduction in groundwater pumping. This will make the Houston-Galveston area a more desirable place in which to live, but it is questionable if it will significantly affect future growth patterns. One would be hard pressed to argue that either serious flooding or subsidence has slowed growth (or even affected the pattern of development) in the Houston-Galveston area in the past, so there is little reason to believe that an improvement in the situation will accelerate future growth.

State and local land-use controls. In general, land-use controls may be able to affect the spatial distribution of development, but they have relatively little effect on the overall magnitude of growth. In Texas, State and local land use controls are relatively weak, so the effect of such controls on the future magnitude or even the distribution of industrial and residential development will probably not be of major importance. State and local land-use controls, properly employed, however, could be useful in guiding future development in an environmentally desirable form. For example, greater control could be exercised in protecting wetlands, dunes, prime agricultural land, and other especially sensitive environments from urban development. Whether such controls are exercised, however, is a political question. At present, only wetlands seem to be guaranteed some protection from future urban development.

Some land-use controls, unique to Texas, should be mentioned because they have some effects on the pattern of development within urban areas. One is the unusually strong annexation power of cities. Larger Texas cities can annex surrounding unincorporated areas almost at will and can annex other incorporated areas if the affected city agrees. This power has been freely used in the TBIE study area, especially by Corpus Christi and Houston. The other is the power of extraterritorial jurisdiction under which cities can impose some regulations on development in surrounding unincorporated areas up to 9 km (5 mi) outside the city boundaries. This power has also been widely used in the TBIE area. By using these powers, cities can usually apply some control to fringe development, but again, the extent to which these powers are used to effectively control development is a political question.

In contrast to the relatively strong powers of cities, Texas counties have little authority to regulate land use. Texas counties have no general legislative power and can exercise only those powers that have been specifically delegated by State legislation or by the State constitution. Counties are given limited powers in the following areas: taxation, road planning and maintenance, airport acquisition and mangement, park acquisition and management, solid waste disposal, the regulation of private sewage facilities, subdivision regulation, and flood plain management. Texas counties do not have the power to zone or the authority to construct and adopt their own charters (county home rule) (Callaway and Beatty 1977).

Projections of Industrial and Residential Growth

Relevance of recent trends. Whether recent growth trends are relevant for predicting future growth in the TBIE study area depends largely on the length of the projection period. In the short-run (up to five years), recent growth trends should be expected to continue because: 1) expansion in energy-related sectors should continue to be strong and the low-wage industrial growth in the southern part of the study area should continue and 2) strong growth, once it is underway, tends to reinforce itself and generate more growth.

For longer projection periods, however, the relevance of recent trends in predicting the future becomes more questionable. The longer the projection period, the more important growth-limiting and growth-inducing factors will become in determining future growth patterns. For very long range projections (20 to 50 years), recent growth trends are probably of very little relevance for predicting the future and TBIE area growth patterns will be determined almost entirely by factors largely unanticipated today.

Review of relevant projections. The only available projections of future industrial growth in the TBIE study area are the employment projections from the Texas Employment Commission, Economic Research and Analysis Department (1977a, 1978, 1979a, 1979b). These projections give employment by industry and occupation for the five coastal SMSA's. Projections are made from a base year of 1974 and extend to 1985.

Several population projections are available for the TBIE study area. These projections vary greatly, however, in the degree of demographic detail (age, race, and sex), the level of geographic aggregation, and the length of the projection period. For this paper, it is necessary to obtain county level projections with a fairly long forecast period (at least to the year 2000).

Only two sets of population projections that meet the above criteria are available for the study area. These are: 1) the population projections from the Population Research Center (PRC) at the University of Texas (Poston 1973), and 2) the Texas Department of Water Resources (TDWR) population projections (Poston 1979b). Of these two projections, the TDWR projections are much newer and are constantly being revised to reflect recent trends and changed future expectations. The PRC projections, on the other hand, are somewhat older and, thus, do not reflect the most recent trends. The TDWR projections are therefore the most useful here.

Projections of employment growth. The Texas Employment Commission (TEC) projects a slowdown in employment growth in the TBIE study area and Texas from 1974 to 1985 as compared to the period between 1960 and 1974 (Table 50). Given the significant acceleration in employment growth in both the TBIE study area and Texas during the 1970's, however, these projections appear to be questionable. Unless there is major slowdown in TBIE area and Texas employment growth in the 1980's--and there is little reason why this should be expected to occur--the TEC projections are not likely to be realistic.

The validity of the TEC projections becomes even more questionable when one examines the expected employment growth by SMSA. According to the projections, growth in the Houston SMSA is expected to decline dramatically while employment growth in the four other SMSA's, especially Galveston-Texas City, is expected to increase. In the 1970's, however, rapid employment growth has continued in the Houston SMSA, while the Galveston-Texas City and Corpus Christi SMSA's continue to experience relatively slow growth. Growth has accelerated in the Brownsville and McAllen SMSA's, but the increase has been even greater than that anticipated by the TEC (U.S. Dept. of Commerce, Bureau of Economic Analysis 1979a). Thus, unless there is a major shift in growth patterns in TBIE area SMSA's in the 1980's compared to the 1970's, the TEC employment projections will turn out to be fairly inaccurate.

Population projections. The Texas Department of Water Resources projects a slowdown in TBIE area and Texas population growth from 1977 to 2000 compared to 1950 to 1977. This projection parallels the U.S. Census Bureau's prediction of a slowdown in national population growth over the same period because of a continuation of low birth rates (Table 51).

Despite the projected deceleration in population growth, the TBIE area is still expected to continue to grow much faster than the State and the Nation. The gap

Table 50. Actual and projected employment growth for TBIE area SMSA's, 1960 (U.S. Department of Commerce, Bureau of the Census 1962d; Texas Employment Commission, Economic Research and Analysis Department 1977a, 1977b, 1978, 1979a, 1979b).

Region	Employment: Actual 1960[a]	Employment: Actual 1974[b]	Employment: Projected 1985[b]	Average annual growth rate (%) 1960–1974	Average annual growth rate (%) 1974–1985
Galveston-Texas City SMSA	51,442	65,550	106,300	1.75	4.49
Houston SMSA	531,715	1,030,200	1,340,800	4.84	2.77
Corpus Christi SMSA	86,286	104,250	138,300	1.36	2.60
Brownsville-Harlingen -San Benito SMSA	47,195	56,150	72,450	1.25	2.34
McAllen-Pharr-Edinburgh SMSA	57,425	64,300	75,000	0.81	1.41
Total TBIE Study Area SMSA's	774,063	1,320,450	1,782,850	3,89	2.77
Texas	3,480,858	5,016,000	6,307,500	2.64	2.11

[a]Number of workers by place of residence.
[b]Number of jobs by place of work.

between TBIE area and national population growth, in fact, is expected to increase. From 1950 to 1977, the TBIE area grew 2.1 times faster than the Nation; from 1977 to 2000, this figure is expected to increase to 2.4. This difference reflects the expectation that the increased migration into the TBIE area during the 1970's will continue--not an unreasonable assumption. The difference between TBIE area and Texas population growth, on the other hand, is expected to decrease in the future. From 1950 to 1977, the TBIE area grew 1.4 times as fast as Texas; from 1977 to 2000, this figure is expected to decline to 1.2. This projection reflects the expectation that future population growth in Texas will be less concentrated along the coast than in the past. Again, this appears to be a reasonable assumption.

The projected distribution of population growth within the TBIE study area up to the year 2000 is expected to follow recent patterns closely. The Gulf Coast planning region is expected to continue to show very strong growth. The Golden Crescent planning region is predicted to experience somewhat slower growth while the Coastal Bend planning region is expected to continue to be the slowest growing region in the area. The Lower Rio Grande Valley planning region exhibited relatively slow growth over the entire 1950 to 1977 period, but recall that there was a significant acceleration in the Valley's growth in the 1970's and this trend is expected to continue.

Table 51. Actual and projected population of TBIE regions, Texas and the United States, 1950-2030 (U.S. Department of Commerce, Bureau of the Census 1952b, 1977d, 1979d; Texas Department of Water Resources 1979b).

Region	Actual population (1,000) 1950	Actual population (1,000) 1977	Projected population (1,000) 2000	Projected population (1,000) 2030 Low	Projected population (1,000) 2030 High	Average annual growth rate (%) 1950-1977	Average annual growth rate (%) 1977-2000	Average annual growth rate (%) 2000-2030 Low	Average annual growth rate (%) 2000-2030 High
Gulf Coast	1,089.7	2,677.9	4,216.8	6,157.5	7,155.8	3.39	1.99	1.27	1.78
Golden Crescent	59.6	96.5	125.6	172.2	197.6	1.80	1.15	1.06	1.52
Coastal Bend	293.7	421.6	515.3	739.5	853.3	1.35	0.88	1.21	1.70
Lower Rio Grande Valley	306.5	425.6	719.3	1,088.8	1,250.0	1.22	2.30	1.39	1.86
Total TBIE Study Area	1,749.4	3,621.6	5,577.0	8,158.0	9,456.7	2.73	1.90	1.28	1.78
Texas	7,711.2	12,830.0	18,270.7	26,285.2	30,464.9	1.90	1.55	1.22	1.72
United States series II projections	151,325.8	216,383.0	259,655.5	299,913.5[a]		1.33	0.80	0.48[a]	

[a]U.S. Department of Commerce Series II projections are based on a uniform set of assumed natural increase and net migration rates, rather than different rates to yield "Low" and "High" projections.

Projections with longer than a 20-year prediction period are likely to be fairly inaccurate, and the TDWR population projections reflect this uncertainty about the future. Two sets of projections are available: a "low" set that predicts a deceleration in Texas population growth between 2000 and 2030 compared to 1977 through 2000 and a "high" set that predicts an acceleration in the State's growth. Both population projections predict a slowdown in TBIE area population growth after the year 2000.

There are several reasons to consider both TDWR population projections for 2000 to 2030 as overestimates. The projections do not adequately reflect: 1) the expected continued decrease in national natural increase because of a continuing decline in the birth rate and increasingly older population; and 2) the expectation that migration into both the TBIE area and Texas will begin to fall off because of the importance of several growth-limiting factors. For very long-run population projections, however, assumptions about future fertility trends become crucial. Demographers have been surprised by past fertility shifts in this country, and they may well be surprised again. For two exactly opposite predictions of future fertility trends in the United States, for example, see Butz and Ward (1979) and Easterlin et al. (1978).

ADDITIONAL INFORMATION NEEDS

Historical Conditions

In general, growth trends in the TBIE study area can be adequately monitored by using data on population, employment, and personal income. A consistent series on output, by industry, would also be helpful, but a set of regional product accounts (similar to the national income and product accounts) will probably not be available in the foreseeable future.

Linking growth trends in the TBIE area to particular environmental impacts has been more of a problem. A major limitation is the lack of a consistent time-series on land uses. The growth of urban land areas and the loss of agricultural land, wetlands, dune and beach areas, and other environmentally sensitive areas, therefore, cannot be adequately measured. Because of recent monitoring activity, the data on water use and air and water pollution tend to be fairly useful, but again, the link between urban and residential developments and these environmental effects cannot be completely established.

Present Conditions

Probably the biggest problem with monitoring present conditions in the TBIE study area is the lag between data collection and publication. Recent efforts by the U.S. Bureau of the Census and the Bureau of Economic Analysis have greatly improved the quality and timeliness of regional population, employment, and personal income data. Still, when this study was prepared in early 1980, the most recent data available were generally for 1977 and 1978.

A special problem faced in the preparation of this paper was the extremely long time lag between the 1977 Economic Censuses and the availability of the results. The Census of Manufacturers is especially useful, but as of 1 April 1980, only limited results for the State and the Nation had been released.

Construction activity since 1970 can only be monitored through the use of building permit data. Serious coverage problems with these data, however, severely limited their usefulness.

The most serious data gap in measuring the environmental impact of industrial-residential developments has been the lack of consistent land use data. For example, the expansion of urban areas during the 1970's had to be measured using incorporated land area data. This is a very weak and seriously flawed proxy for actual urban expansion.

The 1980 Census of Population and Housing should help to remedy many of the data problems mentioned here. Since this analysis was conducted in the late 1970's, much of the data from the 1970 census were judged largely irrelevant. Because of the failure of the proposed mid-decade census for 1985, similar data problems may again be faced in the late 1980's.

Projections

The Texas Employment Commission's employment projections for coastal SMSA's are so questionable that they are not very useful as guides to future industrial growth in the study area. The Texas Department of Water Resources' population projections, on the other hand, appear to be more reasonable through the year 2000.

A major problem with the employment and population projections for the TBIE study area is that they are not at all integrated. Instead, the two projections were done completely independently, despite the strong linkage between migration and employment growth. Future projections should consider the strong interaction between these two variables in a growing regional economy.

SUMMARY AND CONCLUSIONS

Since 1950, the TBIE study area has consistently experienced very strong growth, with the divergence in the growth of the study area and the Nation becoming even greater in the 1970's. Much of the recent growth in the TBIE area is due to rapid expansion in energy-related sectors. Energy-related growth, however, is much more important in upper coastal areas than in the southern part of the study area. In the Lower Rio Grande Valley, especially, energy-related growth is relatively unimportant, and much of the recent growth has come from the location and expansion of low-wage industries in the area.

Recent growth has also tended to be geographically uneven in the study area. The Gulf Coast and Lower Rio Grande Valley planning regions have experienced, by far, the fastest growth, with the Golden Crescent planning region showing somewhat slower growth and the Coastal Bend planning region lagging far behind.

Industrial and residential development have had significant environmental impacts in the TBIE area. Increasing urbanization and the decentralization of development within urban areas have resulted in increasing losses of rural land to urban uses. Prime agricultural land, wetlands, fish and wildlife habitats, beach and dune areas, and other environmentally important land uses have been affected. Groundwater pumping has resulted in subsidence, especially in the Houston-

Galveston area, while this and other human activities have aggravated the damage potential of major storms. Water quality has been deleteriously affected by point-source discharges and salt-water intrusion in many parts of the study area. Possible water shortages are becoming an increasing concern, particularly in the Gulf Coast and Lower Rio Grande Valley regions. Finally, air pollution has become a problem in urban concentrations along the Texas coast, especially in the Houston-Galveston area.

Future growth patterns in the TBIE study area are difficult to predict. In the short-run, strong growth should continue in those areas now experiencing rapid expansion (i.e., the Houston-Galveston area and the Lower Rio Grande Valley). In the long-run, however, significant shifts from present growth patterns could occur. In particular, growth-generated environmental problems could somewhat slow down TBIE area growth in the future and perhaps, more importantly, lead to a movement of industrial and residential activity away from the Houston-Galveston area and into the southern parts of the study area. National and worldwide energy developments are probably of foremost importance in determining future growth trends in the TBIE area. Economic considerations may lead to a gradual shift in refining-petrochemical capacity away from the Texas coast and toward other parts of the world. This relocation and a possible slowdown in the growth of foreign oil imports could have a dampening effect on the future growth of the TBIE study area.

INDUSTRIAL AND RESIDENTIAL DEVELOPMENT:
LITERATURE CITED

American Lung Association. Air pollution primer. Washington, DC: American Lung Association; 1974; 104 p. Available from: American Lung Association, Washington, DC.

American Petroleum Institute. Basic petroleum data book. Washington, DC: American Petroleum Institute; 1975.

Austin, J. P. (Bureau of Business Research, Univ. of Texas at Austin, Austin, TX). Galveston—Texas City: Industrial and medical center on the Gulf Coast. Texas Business Review 52(8): 165-169; 1978.

Beale, D. L. The recent shift of the United States population to non-metropolitan areas; 1970-1975. International Regional Service Review 2(2): 113-122; 1977.

Berry, D. (Department of Urban and Regional Planning, University of Illinois at Champaign - Urbana, Champaign, IL). Effects of urbanization on agricultural activities. Growth and Change 9(3): 2-8; 1978.

Berry, D. (Department of Urban and Regional Planning, University of Illinois at Champaign - Urbana, Champaign, IL). The sensitivity of dairying to urbanization: a study of northeastern Illinois. The Professional Geographer 31: 170-176; 1979.

Berry, D. (Department of Urban and Regional Planning, University of Illinois at Champaign - Urbana, Champaign, IL); Plaut, T. (Regional Science Research Institute, Philadelphia, PA). Retaining agricultural activities under urban pressures: a review of land use conflicts and policies. Policy Sciences 9:153-178; 1978.

Biggar, J.C. The sunning of America: migration to the sunbelt. Population bulletin 34, no. 1. Washington, DC: Population Reference Bureau; March 1979; 44 p. Available from: Population Reference Bureau, Washington, DC.

Bowles, G.K. (Economic Research Division, U.S. Department of Agriculture, Washington, DC); Beale, C.L. (Economic Research Division, U.S. Department of Agriculture, Washington, DC); Lee, E.F. (Department of Sociology and the Institute of Behaviorial Research, Univ. of Georgia, Athens, Georgia). Net migration of the population, 1960-1970, by age, sex and color. Athens, GA: Univ. of Georgia Printing Department; 1975. Available from the Univ. of Georgia Printing Department, Athens, GA.

Bowles, G.K. (Economic Research Division, U.S. Department of Agriculture, Washington, DC); Tarver, J.D. (Department of Sociology, Okahoma State Univ., Tulsa, OK). Net migration of the population, 1950-1960, by age, sex and color. Washington, DC: U.S. Government Printing Office; 1965. Available from: U.S. Government Printing Office, Washington, DC.

Brown, L.F., Jr.; Brewton, J.L.; Evans, T.J.; McGowen, J.H.; White, W.A.; Groate, C.G.; Fisher, W.L. Environmental geologic atlas of the Texas coastal zone—Brownsville-Harlingen area. Austin, TX: Bureau of Economic Geology, Univ. of

Texas at Austin; (1980); in preparation. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Brown, L.F., Jr.; Brewton, J.L.; McGowen, J.H.; Evans, T.J.; Fisher, W.L.; Groate, C.G. Environmental geologic atlas of the Texas coastal zone--Corpus Christi area. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1976; 123 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Brown, L.F., Jr.; Brewton, J.L.; McGowen, J.H.; Evans, T.J.; Fisher, W.L.; Groate, C.G. Environmental geologic atlas of the Texas coastal zone--Kingsville area. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1977; 131 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Brown, L.F., Jr.; Morton, R.A.; McGowen, J.H.; Kreitler, C.W.; Fisher, W.L. Natural hazards of the Texas coastal zone. Austin, TX: Bureau of Economic Geology; 1974; 20 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Building permits issued in Texas cities, December 1970: annual summary. Building Construction in Texas XLV(2); February 1971; 17 p.

Building permits issued in Texas cities, December 1971: annual summary. Building Construction in Texas XLVI(2); February 1972; 16 p.

Building permits issued in Texas cities, December 1972: annual summary. Building Construction in Texas XLVII(2); February 1973; 18 p.

Building permits issued in Texas cities, December 1973: annual summary. Building Construction in Texas XLVIII(2); February 1974; 19 p.

Building permits issued in Texas cities, December 1974: annual summary. Building Construction in Texas XLIX(2); February 1975; 19 p.

Building permits issued in Texas cities, December 1975: annual summary. Building Construction in Texas L(2); February 1976; 20 p.

Building permits issued in Texas cities, December 1976: annual summary. Building Construction in Texas LI(2); February 1977; 20 p.

Building permits issued in Texas, December 1977: annual summary. Building Construction in Texas LII(3); March 1978; 22 p.

Burghardt, J. A.; Geraci, V. J. Intercensal State and local population estimates: methods, performance and Texas applications. Report No. 1978-4. Austin, TX: Univ. of Texas at Austin, Bureau of Business Research; 1978; 59 p. Available from: Univ. of Texas at Austin, Bureau of Business Research, Austin, TX.

Butz, W.P., (Rand Corporation); Ward, M.P. (Dept of Economics, University of California at Los Angeles, Los Angeles, CA). The emergence of counter-cyclical U.S. fertility. American Economic Review 69:318-323; 1979.

Callaway, G.; Beatty, K. Environmental analysis for development planning: Chambers County, Texas. Technical Report: vol. 4. Houston, TX: Southwest

Center for Urban Research 1977. Available from National Technical Information Service PB-296-520 Washington, DC.

Carter, L.J. Galveston Bay: test case of an estuary in crisis. Science, 20 February 1970, p. 1,102.

City of Galveston, Dept. of Planning and Traffic, Galveston Island beach and dune management plan. Galveston, TX: City of Galveston, Dept. of Planning and Traffic; October 1979; 118 p. Available from: City of Galveston, Dept. of Planning and Traffic, Galveston, TX.

Clark, J. (Conservation Foundation, Washington, DC); Brownell, W. (Fundacion La Salle de Ciencias Naturales, Venezuala). Electric power plants in the coastal zone: environmental issues. Highlands, NJ: American Littoral Society; 1973; 138 p. Available from: American Littoral Society, Highlands, NJ.

Coastal Bend Council of Governments. Existing and projected population, land use and employment. Interim report 2. Corpus Christi, TX: Coastal Bend Council of Governments; 1977.

Division of Natural Resources and the Environment, Univ. of Texas at Austin. Bay and estuarine system management in the Texas coastal zone: phase II. Conceptual report. Austin, TX: Division of Natural Resources and the Environment, Univ. of Texas at Austin; March 1973; 132 p. Available from: Office of the Governor, State of Texas, Austin, TX.

Easterlin, R.A.; Wachter, M.L. (Dept. of Economics, Univ. of Pennsylvania, Philadelphia, PA); Wachter, S. (Dept. of Finance, Univ. of Pennsylvania, Philadelphia, PA). Demographic influences on economic stability: the United States experience. Population and Development Review 4:1-22; 1978.

Eden, D.J. The erosion hazard on the Texas coast: an analysis of dune protection efforts. Austin, TX: Graduate School of the Univ. of Texas at Austin; May 1980; 94 p. Available from: Graduate School of the Univ. of Texas at Austin, Austin, TX.

Fisher, W.L.; Brown, L.F., Jr.; McGowen, J.H.; Groate, C.G. Environmental geologic atlas of the Texas coastal zone--Beaumont-Port Arthur area. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1973; 93 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Fisher, W.L.; McGowen, J.H.; Brown, L.F., Jr.; Groate, C.G. Environmental geologic atlas of the Texas coastal zone--Galveston-Houston area. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1972; 91 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

Gabrysch, R.K.; Bonner, C.W. (U.S. Dept. of the Interior, Geological Survey, Houston, TX). Land Surface Subsidence in the Houston-Galveston Region, Texas. Austin, TX: Texas Water Development Board; 1975; 19 p. Available from: Texas Dept. of Water Resources, Austin, TX; Report 188.

Galveston voting returns. Houston Post. 1980 April 6.

Gilmore, G.; Trent, L. Abundance of benthic macroinvertebrates in natural and altered estuarine areas. NOAA Technical Report. Washington, DC: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; 1974; 13 p. Available from: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, DC; NMFS SSRF-677.

Hanks, H. TWC tells water applicants there isn't anymore to spare. Houston Chronicle. 3 March 1980.

Harland Bartholomew and Associates. Land use plan. Prepared for the City of Brownsville. Brownsville, TX: City Planning Dept.; October 1975; 45 p. Available from: City Planning Department, Brownsville, TX.

Hart, J.F. Loss and abandonment of cleared farmland in the eastern United States. Annals of the Association of American Geographers 58:417-439. 1968.

James Veltman & Associates, Inc. 208 Socio-economic report. McAllen, TX: Lower Rio Grande Valley Development Council; January 1977; 117 p. Available from: Lower Rio Grande Valley Development Council, TX.

Kemp, R.J. Potential impacts of industry on the fish and wildlife resources of the coast. Austin, TX: Texas Parks and Wildlife Dept.; 1979. Available from: Texas Parks and Wildlife Dept, Austin, TX.

Kreitler, C.W. Faulting and land subsidence from ground-water and hydrocarbon production, Houston-Galveston, Texas. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1978; 22 p. Reprinted from: Symposium of Anaheim, 1977. Land subsidence, IAHS Publication no. 121. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX; Research Note 8.

Lindall, W.N.; Saloman, C.H. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. Marine Fisheries Review 39(9):1-7; 1977.

Lindall, W.; Trent, L. Housing development canals in the coastal zone of the Gulf of Mexico: ecological consequences, regulations and recommendations. Marine Fisheries Review 37(10):19-24; 1975.

Marchesini, R.; Austin, J.P. (Bureau of Business Research, Univ. of Texas at Austin, Austin, TX). Houston: growth center of the southwest. Texas Business Review 52(8):159-164; 1978.

McGowen, J.H.; Brown, L.F., Jr.; Evans, T.J.; Fisher, W.L.; Groate, C.J. Environmental geologic atlas of the Texas coastal zone--Bay City-Freeport area. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1976a; 98 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

McGowen, J.H.; Proctor, C.V.; Brown, L.F., Jr.; Evans, T.J.; Fisher, W.L.; Groate, C.J. Environmental geologic atlas of the Texas coastal zone--Port Lavaca area. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1976b; 107 p. Available from; Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX.

McKie, J.W. (Dept. of Economics, Univ. of Texas at Austin, Austin, TX); Neimeyer, E.V. (Electric Power Research Institute, Palo Alto, CA). U.S. oil geography in 1990: scenarios and implications. Texas Business Review 53(3):65-69; 1979.

Monti, L.A. (Bureau of Business Research, Univ. of Texas at Austin, Austin, TX) How oil supports prosperity in Texas. Texas Business Review 51(1):1-3; 1977.

Moody's public utilities manual. New York: Moody's Investors Service; 1978.

Moore, E. Loss of the land: agriculture in county throttled by Houston's growth and escalating value of property. The Houston Post; 11 February 1980. (no page or column number).

Morton, R.A. Historical shoreline changes and their causes, Texas Gulf Coast. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1977; 13 p. Reprinted from Transactions of the Gulf Coast Association of Geological Societies, vol. XXVII; 1977; 352-364. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX; GC 77-6.

Morton, R.A.; Pieper, M.J. Shoreline changes in the vicinity of the Brazos River Delta: an analysis of historical changes of the Texas Gulf shoreline. Austin, TX: Bureau of Economic Geology, Univ. of Texas at Austin; 1975; 47 p. Available from: Bureau of Economic Geology, Univ. of Texas at Austin, Austin, TX; GC 75-4.

No big improvements seen for U.S. facilities for VLCC's. Oil and Gas Journal 78(13):55; 1980.

Parker, V. An analysis of the private land development process within the Texas coastal region: procedures and problems. Austin, TX: Univ. of Texas at Austin; 1979. 102 p. Thesis.

Plaut, T.R. (Bureau of Business Research, Univ. of Texas at Austin, Austin, TX). Urban expansion and the loss of farmland in the United States: implications for the future. Bureau paper 79-5. Austin, TX: Univ. of Texas at Austin, Bureau of Business Research; 1979a; 14 p. Available from: Univ. of Texas at Austin, Bureau of Business Research, Austin, TX.

Plaut, T.R. (Bureau of Business Research, Univ. of Texas at Austin, Austin, TX). Preserving rural uses of the land: why?, where?, how much?, who pays? Bureau paper 79-6. Austin, TX: Univ. of Texas at Austin, Bureau of Business Research; 1979b; 15 p. Available from: Univ. of Texas at Austin, Bureau of Business Research, Austin, TX.

Plaut, T. (Bureau of Business Research, Univ. of Texas at Austin, Austin, TX). Migration and the growth of Texas and the south. Texas Business Review 54(1):11-14; 1980.

Poston, D.L., Jr. Population projections for Texas counties: 1980 to 2020. Austin, TX: Population Research Center, Univ. of Texas at Austin; 1973; 18 p. Available from: Population Research Center, Univ. of Texas, Austin, TX.

Preston, N. L. The help-wanted index: technical description and behavorial trends. New York, NY: The Conference Board; 1977.

Research and Planning Consultants, Inc. The coastal economy: an economic report. Austin, TX: Texas General Land Office; October 1975; 66 p. Available from: Texas General Land Office, Austin, TX.

Smith, T.W.; Jenkins, J.C.; Steinhart, J.S.; Briody, K.A.; Schoengold, D. Transmission lines: environmental and public policy considerations. IES report 79. Madison, WI: Institute for Environmental Studies, Univ. of Wisconsin; June 1977; 165 p. Available from: Institute for Environmental Studies, Univ. of Wisconsin, Madison, WI.

Sumpter, R. LOOP start-up slated for late 1980. Oil and Gas Journal 77(22):44-46; 1979.

Sumpter, R. Texas port eyes phased constructions. Oil and Jas Journal 78(3):32-33; 1980a.

Sumpter, R. Texas port authority taking its last gasps. Oil and Gas Journal 78(13): 55-56; 1980b.

Texas Air Control Board. Biennial report: September 1, 1976 - August 31, 1978. Austin, TX: Texas Air Control Board; 1978; 62 p. Available from: Texas Air Control Board, Austin, TX.

Texas Air Control Board. Revisions: Texas State implementation plan control strategies. Austin, TX: Texas Air Control Board; March 1979; 234 p. Available from: Texas Air Control Board, Austin, TX.

Texas almanac 1980-1981. Dallas, TX: A.H. Belo Corporation; 1979; 704 p.

Texas Dept. of Agriculture. Trends in loss of farmland projected to continue in 1980. Austin, TX: Texas Dept. of Agriculture; news release; 1980; 1 p.

Texas Dept. of Water Resources. Continuing water resources planning and development for Texas. 2 vol. Austin, TX: Texas Dept. of Water Resources. May 1977; 1,145 p. Available from: Texas Dept. of Water Resources, Austin, TX.

Texas Dept. of Water Resources. The Texas input-output model, 1972. Austin, TX: Texas Dept. of Water Resources; March 1978; 447 p. Available from: Texas Dept. of Water Resources, Austin, TX; LP-24.

Texas Dept. of Water Resources. State of Texas water quality assessment. Austin, TX: Texas Dept. of Water Resources; April 1979a; 377 p. Available from: Texas Dept. of Water Resources, Austin, TX.

Texas Dept. of Water Resources. Unpublished population projections; Austin, TX. 1979b; n.p.

Texas Dept. of Water Resources. Unpublished point-source discharge permit data; Austin, TX. 1979c; n.p.

Texas Employment Commission. Unpublished estimates of the labor force; Austin, TX. 1978. n.p.

Texas Employment Commission. Unpublished wage and salary employment data; Austin, TX. 1979; n.p.

Texas Employment Commission, Economic Research and Analysis Dept. Job scene 1985: Houston standard metropolitan statistical area. Austin, TX: Texas Employment Commission, Economic Research and Analysis Dept.; December 1977a; 57 p. Available from: Texas Employment Commission, Austin, TX.

Texas Employment Commission, Economic Research and Analysis Dept. Job scene 1985: State of Texas. Austin, TX: Texas Employment Commission, Economic Research and Analysis Dept.; September 1977b; 62 p. Available from: Texas Employment Commission, Austin, TX.

Texas Employment Commission, Economic Research and Analysis Dept. Job scene 1985: Corpus Christi standard metropolitan statistical area. Austin, TX: Texas Employment Commission, Economic Research and Analysis Dept.; August 1978; 55 p. Available from: Texas Employment Commission, Austin, TX.

Texas Employment Commission, Economic Research and Analysis Dept. Job scene 1985: Brownsville-Harlingen-San Benito, Laredo, McAllen-Pharr-Edinburg standard metropolitan statistical areas. Austin, TX: Texas Employment Commission, Economic Research and Analysis Dept.; January 1979a; 72 p. Available from: Texas Employment Commission, Austin, TX.

Texas Employment Commission, Economic Research and Analysis Dept. Job scene 1985: Bryan-College Station, Galveston-Texas City, Killeen-Temple, Waco standard metropolitan statistical areas. Austin, TX: Texas Employment Commission, Economic Research and Analysis Dept.; May 1979b; 97 p. Available from: Texas Employment Commission, Austin, TX.

Texas Energy and Natural Resources Advisory Council. Texas energy history: 1978 update. Report no. 79. Austin, TX: Texas Energy and Natural Resources Advisory Council; 1979; 156 p. Available from: Texas Energy and Natural Resources Advisory Council, Austin, TX.

U.S. Congress, House of Representatives, Committee on Interstate and Foreign Commerce. Waste disposal site survey. 96th Congress, 1st Session. Report no. 96-IFC 33. Washington, DC: U.S. Government Printing Office; October 1979; 487 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Agriculture, Soil Conservation Service. Conservation needs inventory: Texas. Washington, DC: U.S. Dept. of Agriculture, Soil Conservation Service; 1970; 297 p. Available from: U.S. Dept. of Agriculture, Soil Conservation Service, Austin, TX.

U.S. Dept. of the Army, Corps of Engineers. Texas coast hurricane study main report. Galveston, TX: U.S. Army Corps of Engineers; March 1979a; 176 p. Available from: U.S. Dept. of the Army, Corps of Engineers, Galveston, TX.

U.S. Dept. of the Army, Corps of Engineers. Final environmental supplement: Baytown, Texas. Galveston, TX: U.S. Army Corps of Engineers; June 1979b; 63 p. Available from: U.S. Dept. of the Army, Corps of Engineers, Galveston, TX.

U.S. Dept. of Commerce. Regional employment by industry: 1940-1970. Washington, DC: U.S. Government Printing Office; 1975. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of housing: 1950. vol I, part 43. Washington, DC: U.S. Government Printing Office; 1952a. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of the population: 1950. vol. II, part 43. Washington, DC: U.S. Government Printing Office; 1952b. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of manufacturers: 1954. vol. III, part 2. Washington, DC: U.S. Government Printing Office; 1957. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of the population: 1960. vol. I, part 45. Washington, DC: U.S. Government Printing Office; 1962a. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. County and city data book: 1962. Washington, DC: United States Government Printing Office; June 1962b, 669 p. Available from: United States Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of housing: 1970. vol. I, part 43. Washington, DC: U.S. Government Printing Office; 1972. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of the population: 1970. vol. I, part 45. Washington, DC: U.S. Government Printing Office; May 1973a. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. County and city data book: 1972. Washington, DC: U.S. Government Printing Office; 1973b. 1020 p. Available from: U.S. Government Printing Office, Washington, DC; Stock #8324-00121.

U.S. Dept. of Commerce, Bureau of the Census. Census of manufacturers: 1972. vol. II, part 44. Washington, DC: U.S. Government Printing Office; October 1975; 52 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S Dept. of Commerce, Bureau of the Census. Census of agriculture: 1974. vol. I, part 43. Book I. Washington, DC: U.S. Government Printing Office; September 1977a. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Projections of the population of the United States, 1977-2050. Current population reports. Series p-25, no. 704. Washington, DC: U.S. Government Printing Office; 1977b. 23 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Annual housing survey: 1976 Houston SMSA. Current housing reports. Washington, DC: U.S. Government Printing Office; August 1978a, 456 p. Available from: U.S. Government Printing Office, Washington, DC; H-170-76-49.

U.S. Dept. of Commerce, Bureau of the Census. Unpublished estimates of the population by age, sex and race. April 1978b.

U.S. Dept. of Commerce, Bureau of the Census. Boundary and annexation survey: 1970-1977. Series GE-30-3. Washington, DC: U.S. Government Printing Office; August 1979a. 90 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of manufacturers. Geographic area series. Preliminary report. Washington, DC: U.S. Government Printing Office; September 1979b. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Housing units authorized by building permits and public contracts: annual 1978 construction reports C 40-78-13. Washington, DC: U.S. Government Printing Office; July 1979c; 408 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Population estimates and projections series p-25, no. 867. Washington, DC: U.S. Government Printing Office; November 1979d; 10 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of Economic Analysis, Regional Economic Information System. Unpublished estimates of county employment; 1979a; Washington, DC.

U.S. Dept. of Commerce, Bureau of Economic Analysis, Regional Economic Information System. Unpublished estimates of personal income; 1979b; Washington, DC.

U.S. Dept. of Energy, Energy Information Administration. Petroleum refineries annual. Energy Data Reports. Washington, DC: U.S. Government Printing Office; June 1978; 19 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of the Interior, Bureau of Mines. Minerals in the economy of Texas. Pittsburgh, PA: U.S. Dept. of the Interior, Bureau of Mines, Publications Distribution Branch; 1979; 21 p. Available from: U.S. Department of the Interior, Bureau of Mines, Publications Distribution Branch, Pittsburgh, PA.

U.S. Dept. of the Interior, Fish and Wildlife Service. Wetlands preservation program: Texas Gulf Coast, Category 8. Albuquerque, NM; U.S. Dept. of the Interior, Fish and Wildlife Service; March 1977; 46 p. Available from: U.S. Dept. of the Interior, Fish and Wildlife Service, Albuquerque, NM.

U.S. Environmental Protection Agency. Unpublished air quality data; 1980, Dallas, TX.

Vining, D.R. (Dept. of Regional Science, Univ. of Pennsylvania); Plaut, T. (Dept. of Regional Science, Univ. of Pennsylvania); Bieri, K. (Regional Science Research Institute, Philadelphia, PA). Urban encroachment on prime agricultural land in the United States. International Regional Science Review 2(2):143-156; 1977.

Warren, J.P.; Jones, L.L.; Griffin, W.L.; Lacewell, R.D. Costs of land subsidence due to groundwater withdrawal. College Station, TX: Texas Water Resources Institute, Texas A & M Univ.; July 1974; 79 p. Available from: Texas Water Resources Institute, Texas A & M Univ., College Station, TX; Project No. A-023-TEX.

Zlatkovich, C.P.; Bennett, C.T.F. The lower Rio Grande Valley: an area of rapid growth. Texas Business Review 51(9):204-209; 1977.

AGRICULTURAL PRODUCTION

INTRODUCTION

During the initial stages of this country's economic history, agricultural activities provided a subsistence base and a surplus of agricultural commodities. The surplus generated an investment fund that was a major source of capital for the development of other sectors of the economy. Financing for roads and waterways, for schools, public buildings, and for government itself was generally drawn from taxes paid on agriculture. In later decades of American history, agriculture continued its contribution to economic development, although its relative role declined as the sector came to represent a decreasing share of the national economy. As productivity increased, land, labor and capital resources began to be used in other economic sectors, while agricultural production continued to meet national and international food and fiber requirements.

Increased productivity was the result of a combination of developments, including the improvement of pest and disease control methods, advanced management systems, and rapidly advancing technology, each of which placed a premium on larger, more highly capitalized agricultural operations. This trend toward larger farms accompanied greater crop or livestock specialization, so that machinery could be more fully used.

Technological improvements whose costs require larger farming operations (and which also force smaller operators out of the agricultural sector) have resulted in more intensive agricultural land uses, increasing the value of agricultural lands for agricultural purposes. Because these lands are generally located in level areas that are well-drained and suitable for urban development, the value of agricultural lands is also affected by encroaching urbanization. Reduction of the agricultural political base and a diminished contribution to the local economy are two well-documented results of increasing numbers of non-farm residents in rural and semi-rural areas (Berry and Plaut 1978).

An additional factor that has influenced the use of agricultural lands in the face of urbanization is the political pressure that urban constituents have exerted on routine farming activities that are incompatible with urban residential uses. Restrictions placed on the aerial application of fertilizers and pesticides in field crop operations and restrictions placed on the location of odoriferous feedlots would be included in this category of factors. While such improvements have indirectly benefited farmers, the acquisition of farmland to build roads, power lines, reservoirs, and other elements of an urban physical plant has also disrupted agricultural production to some extent.

Land speculation represents another indirect consequence of urban encroachment on agricultural lands. Where cities grow most rapidly, farmers may actively speculate in their land, holding off on land improvements while anticipating a capital gain from the sale of their land in the near future (Berry and Plaut 1978). Where urban growth is relatively slow, land owners may look forward to retirement and divestiture, which results in a guarantee of savings for retirement years, but also often removes the land from agricultural production.

Property tax reforms have been instigated to attempt to hold off increases in the rate of agricultural conversion. The Texas State Legislature changed the basis upon which open space lands, including agricultural holdings, would be assessed. This legislation (State of Texas 1977) would use the value of agricultural products as the basis of agricultural land values, rather than the fair market value of the land, providing financial incentives to land owners in areas where urban pressures are not overwhelming to maintain the agricultural status of their holdings. Other public programs, ranging from direct payments to low-interest loans established by Commodity Credit Corporations, have also been instituted as ways in which agricultural productivity and the national balance of trade can be at least maintained, if not improved.

Throughout the TBIE area's history, agricultural activities have played an important role in the area's social and economic environment. The favorable climate and fertile soils allow almost every food and fiber crop grown in the western hemisphere to be raised. Vast expanses of coastal prairies and subtropical plains provide prime grazing lands for livestock. The region's agricultural production is, however, subject to much the same economic and public policy forces that confront the industry nationwide.

In what ways can we expect these forces to alter the structure of the TBIE area agricultural production? What are the implications of increasingly consolidated holdings and growing capitalization requirements to sustain competitive yields? How can agricultural water requirements be reconciled with the demands of municipal and industrial water users in the TBIE area? Will changes in property tax evaluation criteria and parity-pricing formulae have any long-term effect on the productivity of the area's farming operations? The following discussion addresses these questions as well as other characteristics of agricultural production in the TBIE area. The compelling conclusion is that a reassessment of the area's farming prospects is required. Urbanization and development of the energy-related industries have pre-empted some prime agricultural lands, but agriculture continues to contribute substantially to the area's economy.

Recent historical trends and future prospects are evaluated in the remainder of this discussion. In Section II, "Agriculture's Contribution to the Regional and Local Economy," historical developments are briefly described, along with a description of the post-World War II movement toward consolidated land holdings, changes in production expenses, and changes in the use of agricultural lands. Section III, "Agricultural Products," details the range of field and specialty crops, the livestock and poultry operations, and timber operations in the TBIE area. Section IV, "Agricultural Futures," explores agriculture's role in maintaining the stability and diversity of regional economic opportunities.

AGRICULTURE'S CONTRIBUTION TO THE REGIONAL AND LOCAL ECONOMY

For the purposes of discussing agricultural development, the TBIE study area may be subdivided into four planning regions, corresponding to regional council of governments jurisdictions. The study area encompasses approximately 58,200 km^2 (22,000 mi^2), most of which is made up of broad expanses of relatively level coastal prairies, chaparral pasture land, and farm lands occurring inland of the numerous bays. The northern portion of the Gulf Coast planning region contains the southernmost extension of the pine forests that cover most of east Texas. The coastal prairie includes sandy loam and clay soils, as well as recent alluvial deposits associated with the many drainages that intersect the area.

The western portions of the Golden Crescent, Coastal Bend, and Lower Rio Grande Valley planning regions lie within the South Texas Plain, with its subtropical dryland vegetation and sandy loam, clay, and clay loam soils. Deep alluvial soils, a product of Rio Grande sequential deposition, characterize much of the area encompassed by the counties in the Lower Rio Grande Valley planning region.

The climate of the study area becomes increasingly warmer and more arid as one moves from the Gulf Coast planning region at the north to the Lower Rio Grande Valley at the south. The growing season, typically measured as the average interval between the last 0°C (32°F) temperature in the spring and the first 0°C (32°F) temperature in the fall, gradually increases from approximately 300 days in Harris County to 327 days in Hidalgo County (Texas almanac 1979). Average annual precipitation decreases, however, from approximately 120 cm (48 in) in Harris County to approximately 50 cm (19.9 in) in Hidalgo County (Texas almanac 1979).

Between 1954 and 1974, the study area as a whole underwent a 9.9% reduction in land area used for agricultural production, while statewide reductions in agricultural land area amounted to 7.9% during the same period. The study area had a total of approximately 5 million ha (12.3 million ac) of agricultural lands in 1954, or 8.4% of the statewide total agricultural area. By 1974, TBIE agricultural lands accounted for approximately 4.5 million ha (11.1 million ac), or 8.3% of the statewide total agricultural area (U.S. Department of Commerce, Bureau of the Census 1957, 1962, 1967, 1977a).

The greatest absolute reduction in agricultural lands occurred in the Gulf Coast planning region, which includes the TBIE area's greatest concentration of sustained urban development since the annexation of Texas. The greatest relative reduction in agricultural lands, however, occurred in the Lower Rio Grande Valley planning region, where nearly 20% of the lands that had been used for agricultural production in 1954 had been converted to other uses by 1974.

Despite the retirement of agricultural lands and the conversion of some agricultural lands to other uses throughout the study area, the average value of remaining agricultural lands increased dramatically between 1954 and 1974, as did the value of farm machinery, and the market value of agricultural products sold. Primarily because of increased farm size, the average value of farms rose from a 1954 value of $61,400 to nearly $270,000 in 1974. The magnitude of increase was particularly significant in the Gulf Coast and Golden Crescent planning regions.

Such dramatic indications of agricultural change have been compressed into a relatively short period, when compared with the 80 years of Texas history from 1820 to 1901, when agriculture developed into a prosperous way of life for newcomers to the TBIE area. Since 1901, while hundreds of thousands of TBIE area residents have depended upon agricultural production for their livelihoods, farming and raising livestock have been relegated to the shadows of the petrochemical era.

Extending the Frontier

In 1820, Texas was a sparsely inhabited area that was under control of the Mexican government. Permanent settlements of notable size included San Antonio de Bexar, (present-day San Antonio), Bahia (Goliad), along the southern banks of the Lower Rio Grande, and along the Sabine River in east Texas. A particularly rapid westward expansion of the frontier occurred early in the 19th century, bringing large new areas within the sphere of influence of Southern cultural and economic activities. The factors that spurred emigration from the older areas of the South are said to be varied and complex; the depletion of soil fertility had probably decreased the attractiveness of many areas although the popularly held impression of a vast sterile wasteland in the wake of an advancing frontier is somewhat misleading (Jordan 1966).

The principal attractive feature of Texas to early 19th century settlers was the relative availability of land. Antecedent French and Spanish land grants in Louisiana required complicated and exacting surveys well into the middle of the century. Lands in Texas, in contrast, were more readily available, without the threat of disputed ownership posed by Louisiana holdings.

The Mexican government established a series of empresario relationships in the 1820's, under which individuals contracted to settle specified numbers of immigrants in areas of Texas where land had been granted by the government to these empresarios. The first such contract was made with Moses Austin, an American who had acquired Spanish citizenship during an earlier residence in Missouri. At his death, the contract was passed on to his son, Stephen F. Austin. In honoring this empresario contract, Austin's colony was established in south-central Texas, including the valleys of the lower Brazos and Colorado Rivers.

The settlement was essentially riverine in character. Nearly every land grant was rectangular in shape, with one of the smaller sides fronting on a river or smaller stream. The settlers were largely yeoman farmers from Tennessee, Missouri, and Kentucky, later to be joined by Louisiana emigrants. According to Jordan (1966), the only major plantation areas of the colony were concentrated along the Brazos and Colorado Rivers.

With the exception of the DeWitt Colony, additional empresario contracts were not nearly so successful as the Austin Colony in introducing large numbers of Anglo-Americans into Texas. A Mexican settlement was established in 1820 along the lower Guadalupe River around the town of Victoria, and other empresarios brought Irish immigrants to the lower Nueces River at San Patricio in the 1830's.

This pattern of localization of immigrant groups, with or without the institutional support of the empresario arrangements, is not difficult to understand. A pioneer might select a site to settle, often by accident (and certainly not always with the keenest of judgment), find it to his liking, and induce relatives and friends to follow. The result was that source regions for settlers were often quite small areas, so that the population of one parish in Louisiana or one small state in central Germany might largely be responsible for settling a particular county or adjacent counties in coastal Texas. By this process, Louisiana, Irish, and German immigrants were the most heavily represented groups in the settlement of coastal counties during the period from 1820 to 1880. Several thousand Germans were induced to migrate by an active promotion in the 1840's that offered free transportation, free land, credit for initial equipment outlays, and a wide variety of public improvements. Galveston served as a port of entry for many, and Indianola on Matagorda Bay was the point of departure for the inland agricultural settlements (Biesele 1946).

One of the more interesting sources of information concerning agricultural development in the Texas coastal area during the second half of the 19th century is the almanac, or immigrant guidebook, that played an important role in describing the opportunities available to prospective newcomers. As was characteristic of this type of publication, every morsel of information that might attract another settler to the area was included. No almanac or guidebook was published regularly, and most appeared only once or twice (Southwestern Immigration Company n.d.; Texas almanac 1870). Editors of pamphlets relied to some extent on census reports, but most of the material was drawn from real or alleged experiences of residents. The almanacs and guides were well salted with success stories of men and women engaged in agriculture and industry. There were articles on the qualities of mesquite bark as a tanning agent; on the phenomenal rise of the impoverished shepherd to the status of a wealthy sheepman; on the farmer and his wife who, by their own labor, raised $900 worth of produce on a small Nueces farm in 1875. The publications repeatedly reminded the immigrant of the availability of free land and emphasized the relatively low land prices in or near existing settlements. All emphatically claimed that any crop successfully grown in the temperate zone could be raised profitably in Texas, and some included plants from the tropics in their claims.

The claims were essentially accurate although land and commodity market forces determined to a large extent the directions that agricultural production would take. In the last quarter of the 19th century, there was explosive population growth accompanied by extensive rail and waterway development and an increase in commercial agriculture in the Texas coastal area. These changes tended to result in an increase in land values, and the increased cost of land resulted in a pressure for added use intensity to increase the return per land unit. As Spratt points out:

> "In the eastern portions of the state, livestock raising became stock farming, stock farmers cultivated fields of feed as supplements to pastures, thereby making it possible to maintain larger herds on a given land area" (1955:39).

Since the mid-1950's, changes in agriculture's contribution to the TBIE area's economy have reflected two significant trends: a major decrease in the number of farming operations, and a relatively minor decrease in the amount of land used for agricultural production.

Number, Size, and Value of Farms

There were nearly 30,000 farms in the TBIE area in 1954, accounting for approximately 10% of the State's farming operations and approximately 8% of the State's farm lands (Table 52). A substantial consolidation of agricultural operations occurred in the TBIE area between 1954 and 1974. The number of farms decreased by approximately 40%, or 12,000 farms by 1974, yet the land area used for agriculture decreased by only 10%, or slightly less than 500,000 ha (1.2 million ac) (U.S. Department of Commerce, Bureau of the Census 1962, 1967, 1972, 1977a).

The decline in TBIE area farming operations has been relatively consistent with agricultural operation declines in the State as a whole. While the number of TBIE farms accounted for approximately 10% of the State's farming operations and approximately 8% of the State's farm lands in 1954, the study area's farms still accounted for 10% of all Texas farms and 8% of all Texas land area in agricultural production in 1974 (Table 53).

In 1954, the average farm size for the TBIE area was approximately 165 ha (411 ac), compared with an average farm size of approximately 200 ha (500 ac) for

Table 52. Number of farms for selected years 1954 through 1974 (U.S. Dept. of Commerce, Bureau of the Census 1957, 1962, 1967, 1972, 1977a, 1977b).

Planning region and county	Year				
	1954	1959	1964	1969	1974
GULF COAST					
Brazoria	1,669	1,276	1,425	1,299	1,038
Chambers	491	483	409	325	284
Fort Bend	2,407	2,002	1,713	1,742	1,251
Galveston	715	518	374	415	295
Harris	3,869	2,414	2,122	2,156	1,478
Liberty	1,361	1,189	900	839	649
Matagorda	1,220	1,037	839	902	753
Wharton	2,466	2,103	1,921	2,005	1,413
Total	14,198	11,022	9,703	9,683	7,161
GOLDEN CRESCENT					
Calhoun	303	259	244	297	253
Goliad	708	560	478	669	546
Jackson	1,074	946	876	925	757
Victoria	1,232	1,118	1,071	1,115	868
Total	3,317	2,883	2,669	3,006	2,424
COASTAL BEND					
Aransas	99	80	52	55	27
Bee	861	727	677	788	631
Brooks	283	181	231	251	216
Jim Wells	720	729	669	766	672
Kenedy	16	13	16	16	23
Kleberg	281	246	209	221	213
Nueces	1,157	1,096	838	993	798
Refugio	270	260	263	294	250
San Patricio	888	816	676	737	598
Total	4,575	4,148	3,631	4,121	3,428
LOWER RIO GRANDE VALLEY					
Cameron	2,836	2,338	1,754	1,750	1,324
Hidalgo	4,072	3,575	2,868	4,124	2,827
Wallacy	865	673	547	550	406
Total	7,773	6,586	5,169	6,424	4,557
TBIE STUDY AREA	29,863	24,639	21,172	23,234	17,570
STATE	292,947	227,071	205,110	213,550	174,068

Table 53. Land area in farms (acres) for selected years, 1954 through 1974 (U.S. Dept. of Commerce, Bureau of the Census 1957, 1962, 1967, 1972, 1977a, 1977b).

Planning region and county	Year 1954	1959	1964	1969	1974
GULF COAST					
Brazoria	673,923	633,166	697,775	598,874	545,048
Chambers	357,120	350,064	347,335	359,001	309,141
Fort Bend	513,196	545,759	506,545	470,932	440,425
Galveston	114,676	125,677	120,645	129,528	103,576
Harris	690,046	667,255	562,295	551,056	483,310
Liberty	350,396	532,575	448,205	457,451	351,859
Matagorda	592,588	727,574	642,495	600,186	602,387
Wharton	658,961	710,574	706,365	701,482	672,636
Total	3,950,906	4,292,644	4,031,660	3,868,510	3,508,382
GOLDEN CRESCENT					
Calhoun	218,690	158,054	162,965	208,361	210,728
Goliad	377,273	332,862	345,165	447,641	387,941
Jackson	419,880	561,188	522,965	506,195	483,094
Victoria	550,559	551,046	589,525	473,867	538,858
Total	1,566,402	1,603,150	1,620,620	1,636,064	1,620,621
COASTAL BEND					
Aransas	68,052	62,060	51,972	51,247	23,980
Bee	477,031	472,491	468,275	562,091	462,792
Brooks	799,983	796,388	731,365	516,606	545,522
Jim Wells	506,908	554,492	562,865	570,477	509,048
Kenedy	652,526	534,707	533,425	545,168	545,071
Kleberg	918,608	947,441	921,685	934,663	931,038
Nueces	554,093	628,263	648,235	485,837	502,329
Refugio	436,660	498,301	567,925	392,785	481,861
San Patricio	433,200	549,114	542,395	434,685	395,429
Total	4,847,061	5,043,257	5,028,142	4,493,559	4,397,070
LOWER RIO GRANDE VALLEY					
Cameron	550,119	486,198	426,215	452,285	403,822
Hidalgo	1,018,819	810,422	736,715	772,792	848,528
Willacy	369,328	373,751	378,715	377,182	309,392
Total	1,938,266	1,670,371	1,541,645	1,602,259	1,561,742
TBIE STUDY AREA	12,302,635	12,609,422	12,222,067	11,600,392	11,087,815
STATE	145,812,733	143,217,559	141,706,309	142,566,826	134,185,289

the State as a whole. By 1974, the average farm size for the TBIE area had increased by more than 50% to approximately 255 ha (630 ac), compared with an increase in the statewide average size of 55%, to 310 ha (770 ac) (U.S. Department of Commerce, Bureau of the Census 1957, 1962, 1972, 1977a). Throughout the period between 1954 and 1974, the largest agricultural operations in the TBIE area were found in Kenedy, Kleberg, and Brooks Counties in the Coastal Bend planning region--the site of some of the larger cattle ranching operations in the country. In this 20-year period, the smallest operations in the TBIE area were found in Cameron and Hidalgo Counties in the Lower Rio Grande Valley, and in Fort Bend and Galveston Counties in the Gulf Coast planning region.

While all four TBIE planning regions experienced an increase in the average size of farming operations, the greatest increases in average farm size between 1954 and 1974 took place in those areas where there were also the greatest decreases in land area used for agricultural production. The Gulf Coast planning region, for example, experienced a 76% increase in the average farm size over the 20-year period (the greatest relative increase of the four regions), while also experiencing a conversion of nearly 180,000 ha (450,000 ac) of agricultural lands to other uses. The Lower Rio Grande Valley planning region experienced a 37% increase in the average size of agricultural operations, while approximately 150,000 ha (375,000 ac) of agricultural lands were converted to other uses. The Coastal Bend and Golden Crescent planning regions, which had the largest average farm size throughout the period between 1954 and 1974, had the least amount of relative increase in average size of farming operations. Jackson and Victoria Counties in the Golden Crescent were the only two counties in which there was actually a net gain in agricultural lands between 1954 and 1974 (Table 53).

Although agricultural lands in the TBIE area decreased by nearly 500,000 ha (1.2 million ac), the dramatic increase in the average size of farming operations was accompanied by an equally dramatic increase in the value of farms over the period from 1954 to 1974 (U.S. Department of Commerce, Bureau of the Census 1957, 1967, 1972, 1977a). While the average size of TBIE farms increased by 53% over this 20-year period, the average value per farm increased by approximately 340% (Table 54). Inflation accounted for 115 percentage points of this increase, and part of this increase in value is attributable simply to larger farm sizes. As calculated on a price per hectare of farmland, however, the average land value increased by approximately 190% over this period, compared with a statewide increase in the value per hectare amounting to almost 320%.

Important factors in the dramatic increase in the value of TBIE farmland are the irrigation systems and improved access to markets. Between 1954 and 1974, irrigated lands increased by 11% in the Gulf Coast planning region (despite a 50% decrease in total agricultural lands), and the average farm value as calculated on a price per hectare increased by 280%. In the Golden Crescent planning region, irrigated lands increased by 37% between 1954 and 1974, and the average land value per hectare increased by 244%. In the Coastal Bend planning region, irrigated lands increased by 212%, and average land values per hectare increased by 210%. In the Lower Rio Grande Valley there was a 156% increase in irrigated lands between 1954 and 1974, accompanied by a 151% increase in the value of a hectare of farmland.

The counties with the highest average value per farm in 1974 were Kenedy, Kleberg, and Refugio Counties in the Coastal Bend planning region, and Chambers, Brazoria, and Harris Counties in the Gulf Coast planning region. Located in these

Table 54. Average value of farms (dollars) for selected years, 1954 through 1974 (U.S. Dept. of Commerce, Bureau of the Census 1957, 1962, 1967, 1972, 1977a, 1977b).

Planning region and county	Year 1954	1959	1964	1969	1974
GULF COAST					
Brazoria	31,540	64,842	117,345	164,803	364,809
Chambers	53,966	80,700	161,995	276,202	431,091
Fort Bend	29,898	52,883	98,558	170,591	284,402
Galveston	27,797	68,114	123,995	215,135	254,684
Harris	39,162	109,677	169,065	213,894	325,000
Liberty	17,150	40,370	75,422	115,476	277,160
Matagorda	36,359	66,746	111,055	139,106	292,448
Wharton	26,313	51,604	82,436	107,784	215,177
Region	45,273	66,867	117,484	175,374	305,596
GOLDEN CRESCENT					
Calhoun	75,942	90,924	135,325	136,905	237,519
Goliad	37,105	48,103	88,400	102,803	184,922
Jackson	25,878	47,960	92,802	118,084	212,044
Victoria	28,276	46,543	77,373	85,540	174,108
Region	41,800	58,383	98,475	110,833	202,148
COASTAL BEND					
Aransas	31,021	70,607	55,349	106,570	179,256
Bee	29,488	44,747	77,091	99,912	174,500
Brooks	46,753	90,338	133,105	127,344	317,984
Jim Wells	41,293	62,953	88,178	118,790	166,720
Kenedy	440,955	229,867	1,208,150	1,373,448	1,158,078
Kleberg	62,493	208,372	203,695	278,809	428,096
Nueces	87,600	140,684	205,215	203,602	293,769
Refugio	93,406	115,207	172,025	171,028	352,665
San Patricio	71,419	126,711	187,375	182,576	274,511
Region	100,492	121,054	258,909	295,787	371,731
LOWER RIO GRANDE VALLEY					
Cameron	44,258	60,765	71,689	87,910	183,667
Hidalgo	49,872	60,126	80,559	65,274	172,756
Willacy	80,203	111,748	132,625	207,654	241,664
Region	58,111	77,546	94,958	120,279	199,361
TBIE STUDY AREA	61,419	80,963	142,457	175,568	269,709
STATE	29,278	48,379	77,756	99,133	187,073

counties were the larger TBIE area farms. The counties with the most valuable farms—as calculated on a price per hectare basis--included those counties that constitute the Houston-Galveston, Corpus Christi, and Brownsville metropolitan areas. If the value of farmland can be taken as an indication of the demand for that land by both agricultural and non-agricultural users, the distribution of TBIE farmland prices confirms the observation that both urban and agricultural uses have nearly identical requirements for suitable development locations.

Market Value of Products Sold: Regional Distribution

Agricultural production in the TBIE area has undergone a remarkable change in the period between 1954 and 1974. Inflation notwithstanding, the average market value of agricultural commodities produced by each farm in the area has increased dramatically. Along with a decrease in the number of farms, 1974 field crop sales for the TBIE area represent a 104% increase over 1954 sales; 1974 TBIE livestock sales represent a 145% increase over 1954 sales; 1974 vegetable sales for the TBIE area increased more than 200% over 1954 sales levels; and 1974 TBIE fruit and nut sales were 825% greater than 1954 sales. Over this 20-year period, inflation accounted for approximately 115 percentage points of the increases in value (Texas almanac 1979).

When changes in the market value of TBIE agricultural products are compared with changes in the value of agricultural products statewide, it is evident that the market value increases in the TBIE area did not keep pace with statewide increases. While the TBIE area market values for all commodity categories increased by 123%, or nearly $400 million between 1954 and 1974, the statewide total market value increased by 160%, or nearly $2.6 billion over this period. Thus, while the TBIE area's total market value for agricultural products sold in 1954 accounted for 19% of the statewide total, by 1974 the TBIE area accounted for only 16.5% of the statewide total market value.

The market value of field crops and fruit and nut products increased more rapidly for the TBIE area than for Texas as a whole, while the area's contribution to Texas livestock and vegetable production declined between 1954 and 1974. The market value of TBIE area field crops amounted to only 23% of the Texas total in 1954, but had increased to represent 74% of the statewide total in 1974. The market value of TBIE fruit and nut products had represented 49% of the Texas total for this commodity category in 1954, but by 1974, the value of TBIE fruit and nut products had increased to represent 75% of the statewide total. The market value of livestock produced in the TBIE area accounted for more than 9% of the Texas total in 1954, but had declined to less than 4% of the statewide total by 1974. The market value of vegetables produced in the TBIE area accounted for 46% of the statewide total in 1954, but had declined to 42% of the Texas total by 1974.

The average value of commodities produced per farm in the TBIE area was consistently higher than the statewide average over the period of 1954 through 1974. In 1954, the statewide average was approximately $5,500 per farm while the TBIE area average was approximately $10,300 in commodities produced per farm. In 1974, the statewide average was approximately $24,100, while the TBIE area average was $39,300 (U.S. Department of Commerce, Bureau of the Census 1957; 1967; 1972; 1977a). Within the TBIE area, in 1954 the Coastal Bend planning region could boast of farms that produced the greatest market values for commodities sold, with an average of $17,700 per farm (or more than three times the statewide average). The Lower Rio Grande Valley planning region had an average of $13,100 per farm while both the Gulf Coast and Golden Crescent planning regions averaged approximately $7,000 per farm in commodities sold that year. By 1974, however, farms in the Lower Rio Grande Valley planning region averaged $51,500 in the market value of commodities sold while the Coastal Bend farms had increased the average market value of their commodities to $42,900. In the Gulf Coast planning region, the average market value per farm had increased to $34,200 while in Golden Crescent, the average had increased to only $26,500 per farm.

In terms of market values, the Gulf Coast and Lower Rio Grande Valley planning regions consistently produced the greatest field crop volumes. The largest absolute increase in the market value of field crops over the period between 1954 and 1974 was experienced in the Gulf Coast planning region, where the total annual market value of field crops sold increased by nearly $130 million. The greatest relative increase in the annual value of field crops sold was experienced in the Golden Crescent planning region, where an increase of $35 million between 1954 and 1974 represented a 216% increase.

While the Coastal Bend planning region consistently generated the greatest revenue from livestock production between 1954 and 1974, livestock production in the Lower Rio Grande Valley increased by nearly 500% over the period, overtaking the aggregate market value of livestock sold in the Gulf Coast planning region. If increases in the revenue from livestock production continue at this rate, the Lower Rio Grande Valley will shortly become the leading livestock producing region in the TBIE area. The reason that the Lower Rio Grande Valley, a vegetable and citrus growing region, is regaining its historical stature as a widely recognized stock raising area has to do with the productive use of non-irrigated lands. Farmers in the valley with more land than their irrigation allotment seek productive alternatives to row crops for that part of their lands that cannot effectively be irrigated even though those lands lie within the irrigated area. Stock raising provides a productive alternative for these lands.

The market value of vegetable products from commercial farms actually declined in the Coastal Bend and Golden Crescent planning regions between 1954 and 1974. A slight increase, however, in the Gulf Coast planning region's vegetable production and a dramatic increase in market value of vegetables produced in the Lower Rio Grande Valley have resulted in a relative increase for the TBIE area as a whole that is comparable in magnitude to increases in the value of other commodities. Commercial vegetable production had been virtually eliminated from the Golden Crescent economy by 1974, whereas the market value of vegetable products in the Lower Rio Grande Valley planning region was actually greater than the market value of livestock produced in that region by 1974.

Fruit and nut production from commercial farms was heavily concentrated in the Lower Rio Grande Valley planning region throughout the period between 1954 and 1974. This planning region's total market value for fruit and nut products sold accounted for at least 90% of the TBIE total over this entire period. The actual market value for fruit and nut products fluctuated wildly over the period of 1954 to 1974, primarily as a result of extreme weather conditions in the Lower Rio Grande Valley, and also as a result of temperature extremes in other citrus production areas of the country that resulted in higher values for products that were able to get to market from the TBIE area.

Production Expenses and Operator Debt

Farm production expenses include all farming operation and maintenance costs, excluding expenditures for land and building improvements. Expenditures for land and building improvements are considered fixed costs by the U.S. Department of Commerce, Bureau of the Census (1977a) and are therefore not considered to be operating expenses. In the following discussion, the Bureau of the Census accounting system is accepted although expenditures for land are recognized as perhaps the single most expensive item on the typical farmer's budget. Data concerning operator debt are included to indicate the magnitude of capital expenditures relative to production expenses. Labor, machinery operations and rentals, liming, seed and feed purchases, livestock and poultry purchases, and animal health care are the major expenditure categories for TBIE area farmers.

Although precise figures concerning production expenses for TBIE area farms were not comparably organized prior to the 1974 Census of Agriculture, production expenses have apparently increased considerably during the period of 1954 to 1974. Since 1974, these expenses have increased almost as much as they did during the preceding 20 years. Agricultural lands in the TBIE area carry production expenses that average slightly below expenses for the average Texas farming operation. In 1974, the average production expenses per farm in Texas totalled approximately $28,600, while the average production expenses per farm in the TBIE area totalled approximately $27,200. Counties varied widely in their average expenses per farm, with Kenedy County in the Coastal Bend planning region (and location of the famed King Ranch) having an average $118,900 per farm. Among those counties where agricultural holdings are not as consolidated as in Kenedy County, the counties with the highest average production expenses—Refugio and Nueces Counties in the Coastal Bend planning region and Matagorda County in the Gulf Coast planning region--tend to have concentrations of irrigated crop lands, especially for the production of grain sorghum, rice, and cotton.

While total production expenses per farm increased substantially between 1954 and 1974, average farm size also increased, and the average production expenses per hectare increased as well. In 1974, major operating costs for agricultural production in the TBIE area were for hired labor ($56.2 million) and for fertilizer ($54.6 million). Livestock and poultry purchases, combined with the costs of feeds and commercial mixed feeds totalled $92.1 million while fuels and oil cost a total of $27.6 million. Nearly $500 million was spent in 1974 in TBIE area farming operations, producing a total of almost $700 million in market value of agricultural products sold by TBIE area agriculturalists.

Equipment and machinery values among TBIE area farming operations represent a sizable capital investment. Such capital requirements have contributed increasingly to the consolidation of landholdings and to a decline in the number of TBIE area farms in the face of uncertain market conditions. That is, as commodity prices fluctuate as wildly as they have over the past decade, under-capitalized and smaller operations have had difficulties in meeting operating costs and storage costs while waiting for prices to stabilize.

The average equipment value per farm for TBIE area counties was estimated at $20,400 in 1974 while the statewide average was an estimated $15,800 per farm (Table 55). There is a wide range in average equipment values per farm, with Kleberg ($49,400 per farm) and Chambers ($38,700 per farm) having the highest average values. Both of these counties have concentrated livestock production

Table 55. Machinery and equipment values and number of farms, 1974 (U.S. Dept. of Commerce, Bureau of the Census, 1977a, 1977b).

Planning region and county	Estimated market value of all machinery and equipment ($1,000)	Number of farms	Average value per farm ($1,000)
GULF COAST			
Brazoria	17,914	1,038	17.3
Chambers	11,000	284	38.7
Fort Bend	19,644	1,251	15.7
Galveston	2,810	295	9.5
Harris	19,655	1,478	13.3
Liberty	14,835	649	22.8
Matagorda	18,916	753	25.1
Wharton	39,131	1,413	27.7
Total	143,905	7,161	20.1
GOLDEN CRESCENT			
Calhoun	5,931	253	23.4
Goliad	4,833	546	8.9
Jackson	18,007	757	23.8
Victoria	9,836	868	11.3
Total	38,607	2,424	15.9
COASTAL BEND			
Aransas	387	27	14.3
Bee	9,307	631	14.8
Brooks	2,985	216	13.8
Jim Wells	10,251	672	15.2
Kenedy	764	23	33.2
Kleberg	10,524	213	49.4
Nueces	22,095	798	27.7
Refugio	6,627	250	26.5
San Patricio	17,584	598	29.4
Total	80,524	3,428	23.5
LOWER RIO GRANDE VALLEY			
Cameron	28,128	1,324	21.2
Hidalgo	54,101	2,827	19.1
Willacy	13,940	406	34.3
Total	96,169	4,557	21.1
TBIE STUDY AREA	359,205	17,570	20.4
STATE	2,749,766	174,068	15.8

activities. Those TBIE counties where vegetable production and labor-intensive field crops are grown tend to have lower average equipment values per farm, and lower average equipment values per hectare as well.

In 1974, the average operator debt for TBIE area farms was somewhat lower than the statewide average. While TBIE farm operators had an average debt of approximately $11,600 per farm, the statewide average was $12,600 per farm. Within the TBIE area, the highest operator debt was found in the Lower Rio Grande Valley planning region, where $14,300 was the average debt per farm. The lowest average debt per farm was found among Golden Crescent planning region counties, where $7,200 was the average.

Agricultural Land Use Changes

Historical changes in agricultural land uses reflect changing market conditions that have made it economical to change emphasis among agricultural production alternatives. The 1974 distribution reflects an increased proportion of harvested croplands within the TBIE area, a decrease in the amount of pasture land, and a substantial increase in the amount of irrigated land. Woodlands and idle cropland remained relatively constant between 1964 and 1974 while the residual category ("All Other Uses") decreased. This category of land uses includes rural house lots, roadways, and wasteland (Table 56).

Table 56. Changes in agricultural land area by land use category, 1964, 1969, and 1974 (acres) (U.S. Dept. of Commerce, Bureau of the Census 1967, 1972, 1977a,1977b).

Land use	1964	Percent of 1964 total	1969	Percent of 1969 total	1974	Percent of 1974 total
Irrigated land	946,830	7.7	1,200,871	10.4	1,042,634	9.4
Woodland	651,849	5.3	561,239	4.8	638,449	5.8
Failed cropland	18,820	0.2	56,987	0.5	36,014	0.3
Pasture land	6,215,673	50.5	6,828,381	58.9	5,920,625	53.4
Idle cropland	129,747	1.1	561,243	4.8	130,339	1.2
Harvested cropland	2,474,135	20.1	2,134,238	18.4	2,800,898	25.3
All other uses	1,865,581	15.2	257,433	2.2	518,856	4.7
Total	12,302,635	100.0	11,600,392	100.0	11,087,815	100.0

There were approximately 1.0 million ha (2.5 million ac) within the TBIE area used for harvested croplands in 1964. These lands accounted for approximately 20% of the total TBIE area's agricultural lands in that year. By 1974, there were approximately 1.1 million ha (2.8 million ac) of harvested croplands in the TBIE area, and these lands accounted for more than 25% of the area's agricultural lands. Hidalgo County in the Lower Rio Grande Valley planning region had more than 160,000 ha (403,000 ac) of harvested cropland, by far the largest expanse of this land use type in the TBIE area.

Irrigated land accounted for 7.7% of all TBIE area agricultural lands in 1964, but had increased to 9.4% of agricultural lands in the area by 1974. Pasture land, while declining in actual total area between 1964 and 1974, increased from representing 50.5% of the 1964 agricultural land total to 53.4% of the 1974 TBIE agricultural land total. Idle, or fallow, cropland never accounted for a significant portion of TBIE agricultural lands in the period between 1964 and 1974, although the TBIE area's share of statewide totals for this land use category has decreased over the period, indicating that the importance of fallow lands outside the area has increased when compared with the TBIE area.

AGRICULTURAL PRODUCTS

Field Crops

The TBIE area makes an increasingly important overall contribution to field crop production in Texas. In 1954, market value of field crops sold from TBIE area farms accounted for 23% of the Texas total. By 1974, the TBIE area accounted for nearly 75% of the Texas total. In 1978, Hidalgo County was the leading crop producing county in Texas, with agricultural receipts totalling more than twice the receipts of the second-ranked Cameron County, which is also in the TBIE area. Wharton County, in the Gulf Coast planning region, was ranked 7th among Texas counties in terms of market value of crops harvested (U.S. Department of Agriculture, Economics, Statistics and Cooperative Service and Texas Department of Agriculture 1979a).

The production of field crops within the TBIE study area varies among regions, reflecting differences in climate, soils, and distances to processing and marketing centers. In the northern counties of the Gulf Coast planning region, rice and soybeans are the principal crops. In the Golden Crescent planning region and in inland Gulf Coast counties, there is a relative emphasis on corn. Cotton and sorghum are grown throughout the study area, but are particularly concentrated in the Coastal Bend and Lower Rio Grande Valley planning regions. Sugar cane is grown only in the Lower Rio Grande Valley in commercial quantities (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1979b, 1979d).

Even within the planning regions, there are variations in the field crops cultivated. In Wharton County, corn, sorghum, rice, cotton, and soybeans are all cultivated. In many counties of the Coastal Bend planning region, including Kenedy, Brooks, and Kleberg, there are relatively few field crops cultivated other than cotton although these counties have extensive livestock operations. The Lower Rio Grande Valley is the agricultural production center of the Texas coastal area, and field crops harvested in commercial quantities include corn, sorghum, cotton, and sugar cane.

Rice. Although the United States produces only a small portion of the total world rice crop, it is one of the leading rice exporters. The principal rice-producing region is in the broad level prairie along the Gulf coast of southwestern Louisiana and southeastern Texas, part of which falls within the TBIE study area. The grand prairies of eastern Arkansas, the Sacramento and San Joaquin Valleys of central California, and the northern lake district of Minnesota are the only other parts of the country that produce rice in commercial quantities.

While rice was first introduced to this continent in the late 17th century (Heyward 1937), it was not until the end of the 19th century that the crop achieved commercial significance in Texas. Upland, or non-irrigated, rice was grown in Texas to a limited extent as early as 1850. Improvements introduced from the Midwest by way of Louisiana in the 1880's demonstrated that rice could be produced on the coastal prairie by mechanized methods then in use for wheat production in the upper Midwest (Efferson 1952). Steam-pumped irrigation systems were constructed, including a series of canals to divert irrigation water to more distant fields, eliminating the need for locating close to freshwater streams. Experimental plots in Jefferson County proved successful, and by the turn of the 20th century, nearly 10,000 ha (24,700 ac) of irrigated rice fields had been cultivated.

The main rice-producing portion of the TBIE study area is the Gulf Coast planning region, where 63% of the total Texas land area planted to rice was located in 1978 (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1979a). An additional 11% of the total Texas land area planted to rice was located in three Golden Crescent planning region counties--Calhoun, Jackson, and Victoria. Wharton County in the Gulf Coast planning region had the greatest land area harvested in 1978, with approximately 31,000 ha (76,300 ac). Wharton County also had the highest yields per land area unit of any TBIE area county with approximately 965 kg/harvested ha (5,245 lb/harvested ac). Colorado and Lavaca Counties (outside the study area) had smaller areas planted to rice in 1978, although yields were greater than in any TBIE county.

Sorghum. Sorghum is grown for livestock feed and for silage throughout the TBIE area, but its cultivation is especially concentrated in the Coastal Bend counties, in the Lower Rio Grande Valley, and in Wharton County in the Gulf Coast planning region. In terms of the total volume of grain sorghum harvested, Nueces, San Patricio, Hidalgo and Wharton Counties led all other Texas counties in 1978. In terms of area harvested, sorghum is the largest field crop in the TBIE study area (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1979d). In 1978, this land area amounted to more than 600,000 ha (1.5 million ac). Sorghum grown in the TBIE area accounted for 25.3% of the total Texas sorghum production in 1978. In general, the yields per unit of land area found in TBIE counties were among the best in the State.

The growing season for grain sorghum in the TBIE area begins earliest and is among the shorter growing seasons in the State. Planting generally begins in late February, and harvesting is generally completed by mid-August.

Corn. While most of the Texas corn crop is harvested in the High Plains of the Texas Panhandle, corn is grown throughout the TBIE area. Major TBIE corn-growing counties include Hidalgo, Cameron, Jackson, Victoria, Bee, Fort Bend, and Wharton Counties. In 1978, a total of 92,400 ha (228,400 ac) were planted to corn in the TBIE area.

Yields per unit of land area are among the higher yields in the State although Texas Panhandle counties are unsurpassed in corn yields. The best yields in the TBIE area are found in Matagorda and Cameron Counties although there is less corn grown in these two counties than in other TBIE counties. In 1978, the statewide total land area planted to corn had decreased more than 10% over the previous year while the study area's contribution to statewide harvests increased from 10% to 14% of the State total between 1977 and 1978.

Corn planting begins in the Lower Rio Grande Valley in February and moves steadily northward. Harvest begins in the Lower Rio Grande Valley in July and is completed in the study area by September.

Cotton. In 1978, a total of 247,000 ha (610,300 ac) were planted in upland cotton within the study area. This was 8.8% of the State's total. Of this land area, 68,000 ha (167,900 ac) were irrigated; 7.3% of Texas' irrigated cotton lands. Texas led the Nation that year in the production of upland cotton, and ranked second in the production of American-Pima cotton.

The area's most productive cotton growing is located in Nueces and San Patricio Counties in the Coastal Bend planning region, in Fort Bend and Wharton Counties in the Gulf Coast planning region, and particularly in the Lower Rio Grande Valley. More than 97% of the irrigated cotton in the TBIE area is grown in the Lower Rio Grande Valley.

Cotton is particularly affected by soil, temperatures, and by fluctuations in precipitation. Drought conditions in 1978 forced the abandonment of many dry land stands outside the study area, as well as limiting the yields in others. In that same year, the yields per planted land unit in the study area were among the best in the State.

In the TBIE counties, the cotton growing season begins the earliest in the year and is the shortest of any growing region in Texas. Planting begins in the Lower Rio Grande Valley as early as late February, and is generally completed in the northern portions of the study area by early May. Harvesting begins in mid-July in the Lower Rio Grande Valley and is completed in the study area by mid-October.

Sugarcane. All of the sugarcane grown in Texas comes from the Lower Rio Grande Valley planning region, and particularly from Hidalgo County. Sugarcane had been a relatively important field crop in the Lower Rio Grande Valley during the early part of the 20th century. In 1923, however, infestation and adverse market conditions forced the abandonment of sugar fields until the late 1960's. Production costs and the initial capital investment required for specialized equipment have dissuaded many operators from entering the market. The only mill still in operation is located in Cameron County, further discouraging operators in other parts of the TBIE area from growing cane. In 1978, Texas ranked fourth among states in the production of sugarcane, supplying 0.9 million mt (1.06 million t), or approximately 4% of the total national production.

The sugarcane harvest begins in late fall and is completed by early spring. Because this crop is particularly vulnerable to freezing temperatures, which limit sugar content, it is only in the Lower Rio Grande Valley that climatic conditions make this a profitable agricultural venture. Even there, for example, in 1978, production was reduced by unfavorable temperatures.

In 1978, a total of 13,800 ha (34,100 ac) of sugarcane were harvested in the Lower Rio Grande Valley, with an average yield of 11.5 mt/ha (31.1 t/ac).

Soybeans. Soybeans have become an increasingly important crop throughout the TBIE area. Soybeans provide a profitable alternative to other field crops. Production costs for soybeans are lower than for corn or cotton, less specialized machinery is required for planting and harvesting, and transportation to processing centers is more readily accomplished. Approximately 46% of the total Texas soybean land in 1978 was located in the Gulf Coast planning region. There is scattered production throughout the Coastal Bend and Golden Crescent planning regions, but no significant amounts are grown in the Lower Rio Grande Valley.

Soybean yields in the study area are among the best in the State. The crop season spans the summer and fall. Planting in the area begins in early May and harvesting is generally completed by December. Successful production depends on moisture, a requirement that is sometimes poorly met because irrigation of soybeans is not as widely used as it is in the High Plains region.

Fruit and Nuts

Citrus fruit. Virtually all of the citrus fruit grown in Texas comes from the Lower Rio Grande Valley, especially from Hidalgo County. Texas ranks second in the Nation in the production of grapefruit, third in early, mid-season, and navel oranges, and fourth in the production of valencia oranges. There is some production of tangerines, tangelos, and lemons in the Lower Rio Grande Valley.

The production of citrus fruit declined sharply from the mid-1940's to the mid-1960's, with one upturn in 1960. Since that time, production has been steadily increasing. Orange yields now exceed those of the 1940's and grapefruit production continues to climb. In 1954-1955, the value of grapefruit production was nearly $3.2 million, and the value of orange production was about $2.4 million. In 1964-1965, grapefruit production had regained some of the disastrous losses of 1961-1963, and the value of grapefruit production amounted to $4.7 million. Orange production accounted for nearly $3.1 million in 1964-1965. By 1975-1976, the value of grapefruit production had increased to $18.6 million, and the value of orange production had increased to $12.3 million.

Citrus fruit, of course, depends heavily on irrigation, a long growing season, and mild temperatures. The heaviest volume of orange shipments from the area occurs in December, and from December through May for grapefruit. More than half of the citrus fruit production is sold through fresh market channels.

Peaches. Peaches are also grown in the study area, although the production volume is relatively small when compared with other portions of the State. Preliminary peach production estimates for 1978 (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1979e) indicate that 20,100 bushels of peaches, or 2.4% of the Texas total, will have come from TBIE farms. Peaches are primarily produced in Brazoria and Harris Counties, and to a lesser extent in Hidalgo, Cameron, Kleberg, Victoria, Wharton, Brooks, and Jim Wells Counties.

Peach trees begin blooming in the Lower Rio Grande Valley in late February, and are thus vulnerable to late freezes. Peaches do best in irrigated orchards. Peach harvest is virtually complete by the end of June in south Texas.

Avocados. The relatively few avocados that are grown in Texas are produced in the Lower Rio Grande Valley. This fruit is sold at roadside stands, is sold to nearby markets, or shipped in gift packs. Avocados bloom in March and are ready for harvest from mid-October to January.

Pecans. Texas ranked second in the Nation in the production of pecans in 1978, but little of this was from the study area. There is, however, scattered production throughout the area, particularly in the counties of the Gulf Coast planning region.

Vegetables

The South Texas region, which includes the Lower Rio Grande Valley and Coastal Bend planning regions, is the principal winter vegetable area of the State. Important winter vegetables include beets, broccoli, cabbage, carrots, cauliflower, lettuce, and spinach. Spring and summer vegetables from this region are snap beans, cantaloupes, carrots, cucumbers, sweet corn, honeydew melons, onions, bell peppers, squash, and tomatoes. Fall crops include cabbage, cucumbers, and bell peppers. The earliest watermelons of the season are shipped from the Lower Rio Grande Valley and from the Coastal Bend planning regions.

Hidalgo County is the leading Texas county in fresh market vegetable area harvested. Cameron County ranks fourth in the State. There are no major vegetable growing areas in Aransas, Kenedy, Calhoun, Jackson, Victoria, Chambers, or Liberty Counties.

The Upper Coast agricultural reporting area, which includes most of the Gulf Coast planning region, produces a wide variety of vegetables. Most of this production is consumed locally with supplies available during the spring, summer, and fall months. Major crops include snap beans, cabbage, cantaloupe, cucumbers, sweet corn, squash, tomatoes, watermelons, okra, potatoes, and sweet potatoes.

Minor Crops

Flaxseed. Approximately 32% of the State's total of flaxseed in 1978 was produced in the study area (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1978). Bee County alone accounted for 16% of the statewide production total, although yields per unit of land area in this county were among the lowest in the State. Other significant areas for flaxseed included Jackson, Kleberg, Jim Wells, and Refugio Counties. Texas' overall production declined sharply from 1975 to 1978. Flaxseed is planted in the late fall, from October through December, and is harvested in May and June.

Oats and Wheat. There is some scattered production of oats and wheat throughout the study area, but the amounts are insignificant when compared with State totals. In 1978, approximately 13,000 ha (32,000 ac) were planted to oats, and slightly more than 8,000 ha (19,700 ac) were planted in wheat. There was little use of irrigation for wheat production in the area, with the exception of 600 ha (1,500 ac) in the Lower Rio Grande Valley.

Rye. Chambers County ranked sixth in the State in rye production in 1978, with 3.4% of the statewide total. Almost as much rye was planted in Brazoria County, but less than 40% was harvested, in comparison with 67% in Chambers County. Rye was also planted in Fort Bend and Liberty Counties, with about a 40%

harvest rate (the ratio of planted to harvested areas was even less throughout the State because rye is grown primarily for grazing in Texas) (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1978).

Timber. Approximately 3.5% of the 1978 statewide timber income of the Piney Woods region of east Texas came from within the TBIE study area. Only Harris, Chambers, and Liberty Counties contributed significantly to that amount (U.S. Department of Agriculture, Economics, Statistics and Cooperatives Service and Texas Department of Agriculture 1979a).

Livestock and Poultry

While more than 60% of the total Texas market value of agricultural products sold came from livestock and poultry products in 1978, livestock operations make a less substantial contribution to TBIE agricultural production. In 1978, the TBIE market receipts from livestock and poultry operations accounted for less than 20% of the total TBIE market value of agricultural products sold (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1979f). According to the Bureau of the Census (1957, 1962, 1967, 1972, 1977a, 1977b), there was a general decline from 1954 through 1974 in the numbers of livestock and poultry on the commercial farms in the study area. There is a discrepancy, however, between these data and estimates provided by the U.S. Department of Agriculture in cooperation with the Texas Department of Agriculture (1979f). For the same reporting periods, the census estimates are significantly lower than the Department of Agriculture estimates.

Cattle. Texas cattle herding and other livestock production activities began with Spanish breeds that were brought to this continent in the 16th and 17th centuries. Generations of breeding Andalusian and English stock left the open range populated with what Spratt termed "a ready-made livestock industry" (1955:85). To become a cattleman, one rounded up mavericks in numbers limited only by one's energy and ability to hold them on the open range. As long as each animal had sufficient range in which to graze, the stock could compound itself in relatively short order. Achieving success in the industry's early days ultimately came to depend on laying claim to as much range land as possible. Informal agreements parceled claims when the range was open, but many cattlemen began to establish land titles in fee simple, laying claim to all the plots that they could in the mid-19th century. With the appearance of barbed wire, potential land owners gained a formidable ally in proving title to vast stretches of range.

The dusty cattle drive, subject of a wealth of romantic folklore (Hansen 1960), was erased from the landscape as fences restricted herd migration, railroads provided an alternative means of transporting livestock, and a reluctance grew on the part of stock breeders to expose their herds to parasites and disease. Fencing was also used to manage herd migration to avoid overgrazing and to maintain livestock populations with densities sufficient to control the cost of decentralized well locations.

Historical developments have combined with the distinctive opportunities and constraints presented by the coastal environment to shape the nature of livestock production in the TBIE area. What distinguishes cattle operations in the TBIE area in particular is the use that is made of grazing lands in contrast with the concentration of herds on feedlots in those areas of Texas where agricultural production is more heavily oriented toward livestock. In many parts of the Texas coastal area, the animal that has most aided livestock operations is the Brahman, or Zebu variety, Bos indicus species (Cavendish 1948). Their size, preadaptation to climatic extremes, disease and insect resistance, calf crop, straight-barreled body, longevity, and thin rind have made the Brahman-hybrid a favorite among coastal cattlemen (Cobb 1946, Massey 1969, Russell 1959). In the grazing lands of the South Texas Plains and inland prairies, cattle breeds vary according to cattle raiser's preferences, but the Brahman-hybrid prevails in the grassland and marsh regions of the TBIE study area.

On an area-wide basis, TBIE vegetational areas can be distinguished into two zones for their relative suitability for grazing: marsh and salt grasses adjacent to tidewater zones, and upland vegetation consisting of six communities, including brush (chaparral), live oak mottes, Spartina spartinae community, and three prairie grass communities. The prairie grass species, with the exception of salt and marsh grasses, make excellent grazing. Hardwoods grow along streambeds, and along with live oak (Quercus virginiana) mottes, these stands create an overstory that effectively shades and prevents the growth of understory prairie grasses (letter dated 10 March 1980 from Thomas Fritts, U.S. Fish and Wildlife Service, Slidell, Louisiana).

Principal grasses that are heavily concentrated in the grazing areas of the TBIE study area include bushy bluestem (Andropogon glomeratus), shortspike windmill grass (Chloris subdolichostachya), seacoast bluestem (Andropogon scoparius littoralis), and gulf cordgrass (Spartina spartinae). Heavy grazing has disturbed the prairie to the point that there is no consistency in the dominant vegetational species. According to the Fish and Wildlife Service, "There is no area of any consequence on the clay prairie which has not been disturbed by grazing" (letter dated 10 March 1980 from Thomas Fritts, U.S. Fish and Wildlife Service, Slidell, Louisiana).

The brush community that characterizes the southern and western portions of the TBIE study area contains heavy concentrations of mesquite (Prosopis juliflora) with spiny hackberry (Celtis pallida), white thorn (Zizyphus obtusifolia), and lime pricklyash (Xanthoxylum fagara) being common. Prior to floodplain clearing practices, the brush community could be found in extensive reaches along the higher elevations of the major drainages in the area. The brush community also includes buneli grass (Sporobolus wrightii), huisache (Acacia farnesiana), several types of prickly pear (Opuntia sp.), bee brush (Aloysia ligustrina), and yucca (Yucca treculeana). According to local ecologists (letter dated 10 March 1980 from Thomas Fritts, U.S. Fish and Wildlife Service, Slidell, Louisiana), the expansion of the brush community is attributed to overgrazing of other prairie grass communities and to the spread of mesquite seed through the digestive tract of cattle.

Although cattle and calf populations decreased in all TBIE planning regions except the Coastal Bend between 1954 and 1974, the value of cattle sold increased by almost 300% during this period. In the Coastal Bend planning region in particular, there was a 30% increase in total cattle and calf population between 1954 and 1974, while there was a 7% decrease throughout the TBIE area as a whole. Kleberg County more than doubled the number of cattle and calves in that 20-year period, based on statistics supplied by the U.S. Department of Commerce, Bureau of the Census (1957, 1962, 1967, 1972, 1977a, 1977b). According to the U.S. Department of Agriculture and Texas Department of Agriculture (1979f), Brazoria, Fort Bend, Harris, Matagorda, Wharton, Bee, Brooks, Jim Wells, Kenedy, Kleberg, and Hidalgo Counties each reported more than 60,000 head of cattle in 1978. The study area accounted for almost 9% of Texas cattle in 1978.

As of 1 January 1979, there were 159 feedlots in Texas, with 9 feedlots located within 5 TBIE area counties: Goliad County had 2 feedlots with a total capacity of 5,000 head; Nueces County had 2 feedlots with a combined capacity of 2,000 head; San Patricio County had 1 feedlot with a capacity of 12,000 head; Matagorda County had 1 feedlot with a capacity of 1,000 head, and Cameron County had 3 feedlots with a combined capacity of 30,000 head. The total TBIE area feedlot capacity of 50,000 head of cattle accounted for approximately 0.5% of the total Texas feedlot capacity as of January 1979.

Dairy cattle. As of 1 January 1979, there were 14,150 dairy cattle in the TBIE area, representing less than 5% of the Texas total. Harris and Jim Wells Counties in the Gulf Coast planning region had 9,600 of these cattle, and the Lower Rio Grande Valley planning region had 2,800. The remaining dairy cattle were sparsely distributed throughout the study area. Texas dairying operations, which ranked 9th among leading agricultural production states in 1979, are concentrated in the northeastern portions of the State, along the Sabine and Red River Valleys.

Hogs and pigs. The census of hogs and pigs on commercial farms indicates a sharp decline in the swine population over the study area from 1954 to 1974 (U.S. Department of Commerce, Bureau of the Census 1957; 1962; 1967; 1972; 1977a; 1977b). There was an overall decrease of almost 80%. Relative stability occurred only in Jim Wells and Nueces Counties.

The estimates of the U.S. Department of Agriculture and Texas Department of Agriculture (1979f) are considerably higher for numbers of hogs and pigs than are those of the Bureau of the Census. Their statistics indicate that swine production is located primarily in the Gulf Coast planning region, particularly in Brazoria and Fort Bend Counties. According to these figures, almost 4% of the statewide total for hogs and pigs are raised in the TBIE study area.

Horses and Mules. With the exception of Kleberg County, the numbers of horses and mules decreased markedly in the study area from 1954 to 1974. This amounted to a 60% reduction, consistent with statewide declines during the same period (U.S. Department of Commerce, Bureau of the Census 1957; 1962; 1967; 1972; 1977a; 1977b).

Sheep. There is no significant sheep raising reported for the study area, even in those portions of the area where these activities were historically important (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service and Texas Department of Agriculture 1979f).

Poultry. Paralleling the decrease in livestock there has been a decline in poultry production, amounting to 73.7% from 1954 to 1974. During this same period, the numbers of poultry on commercial farms statewide decreased only 9.4%.

The Texas Department of Agriculture reported relatively high volumes of poultry and poultry products in 1978 only in Harris County (hens, commercial broilers, and eggs), Kleberg and Nueces Counties (commercial broilers), and Brooks and Jim Wells Counties (turkeys). Overall, the study area contributed less than 2% to the Texas poultry activities.

AGRICULTURAL FUTURES: A DIVERSITY OF OPPORTUNITY

The future of agricultural production in the TBIE area is likely to be determined by three factors: the degree to which urbanization contributes to an agricultural land shortage; the extent of government support for production in the form of price supports, loan guarantees, and international cooperative agreements; and the institutional arrangements around which water uses are organized.

As food and fiber commodity markets change, operating costs and capitalization requirements increase, and increases in agricultural productivity begin to slow, the TBIE area's agricultural sector is likely to be subject to increasing pressure in the future. The major production trends described in previous sections can be understood as responses to changing market conditions. A brief summary of these trends would include:

- Farms have decreased in number, increased in size and specialization, and they have become more expensive to own and operate, but more productive as well.
- Irrigation has become a major factor in crop production, and livestock and poultry production have been greatly increased through feedlot finishing, commercial broiler production, artificial insemination, improved pastures, and brush control.
- The Federal government has increased its role in agricultural production while the political influence of agriculture has declined with urbanization.

Several authors have pointed out that the conversion of agricultural production lands to urban uses has resulted in regional disparities in the availability of agricultural lands, but that, on the whole, a broad ranging agricultural land shortage has yet to emerge (Adkins n.d.).

These conversions are important, however, for several reasons. First, the conversion of agricultural lands to urban uses creates commitment of land resources that is difficult if not impossible to reverse, removing from lands their potential for producing food and fiber. Second, the conversion of productive agricultural lands to urban uses can have deleterious effects on wetlands and estuarine habitat areas where converted lands are located along major drainages and rivers. Estuarine habitats are sensitive to changes in water salinity levels as moderated by freshwater inflows, and such habitats are also sensitive to changes in water temperature, turbidity, and to other aspects of water quality. To the extent that these estuaries have adjusted to upstream agricultural users and the kinds of effluents produced from agriculture (typically including fertilizers, pesticides and nitrogenous wastes, in addition to sediment loadings from erosion), conversion to urban uses can radically alter drainage regimes and alter the quantity, temperature, and quality of estuarine inflows.

Lawmakers, in anticipation of potential agricultural land shortages, have attempted to slow the rate of conversion to urban uses by instituting the use value of agricultural lands as the basis of property tax assessment in lieu of market value of the lands. With this approach, the land owner is offered an incentive to keep his land in agricultural use through a current-use value assessment, rather than a market value assessment of his land. If there are strong urban pressures on the land, the tax savings can be significant, since the land's market value will inevitably contain substantial speculative development value. A stipulation is attached to the new use value assessment criteria, stating that if the land is taken out of eligible uses, four years in back taxes must be paid on the difference between taxes paid on the basis of use value and the tax that would have been levied had the land been appraised at market value for the same period. An additional 5% interest charge is added for each year of taxes, to be paid on the difference between the two types of tax values.

Some critics of this approach to preserving agricultural lands claim that property taxes are not the only considerations that most land owners take into account when deciding whether or not to sell their lands to speculators or to developers (Coughlin et al. 1978). The penalty that is imposed by requiring that back taxes be paid if the land is taken out of agricultural production may, in effect, amount to a low-interest loan to the land owner.

A different sort of incentive to keep agricultural lands from being converted to urban uses is the opportunity presented by Federal price-support programs. Participation in these programs may provide an element of economic stability to marginally profitable enterprises and thereby keep some farmers in business who might otherwise sell off their assets and pursue alternative economic opportunities. The Agricultural Act of 1949 is the basic authority for current price-support programs. The level of price support is related to the "parity" price of the commodity produced. Parity prices are those that would give farm products, collectively, the same per unit purchasing power that they had in a selected base year period—a period when the relationship between prices received and paid was considered to be in good balance. The parity price for each commodity was calculated in direct relation to the period 1910 to 1914 until 1950, when the parity formula was revised to make the pattern of relationships among parity prices dependent upon the pattern of market price relationships that existed among agricultural commodities in the 10-year period immediately preceding the year for which parity is being calculated (Food and Agricultural Organization of the United Nations 1970). This revision was made to adjust for changes in productivity and other factors that occurred after the base period 1910 to 1914. Support levels are established according to legislative designation, requiring that the level of price support for a commodity be within the range of 65% to 90% of parity price if producers have agreed to marketing quotas set by the U. S. Department of Agriculture, and 50% of parity price if producers have disapproved of such quotas. Such price supports are deemed essential, by industry members, to be able to maintain a competitive position in national and international commodity markets, although such supports have had, as an indirect consequence, a huge stockpile of small grains produced that could not be marketed under the authority of subsidy agreements. Because these commodities are relatively stable and non-perishable in nature, they can be transported long distances, and they can also be stored without undue deterioration. As a result, for a commodity like rice, it is the total supply of rice in the country, rather than the amount produced in any one area, that has the most important effect on rice prices.

In addition to land-use and commodity values, the availability of water for livestock and irrigation affects TBIE agricultural production. According to the

U.S. Department of Agriculture (1980), dryland cultivation of such crops as soybeans and small grains may yield only half the volume per area unit as irrigated field crops. Yet, the amount of water used for irrigation and for livestock is decreasing dramatically in the TBIE area. According to the Texas Department of Water Resources projections (1977), water requirements for irrigation and livestock accounted for 71% of all water requirements in the Texas coastal area while municipal and industrial uses accounted for 29% in 1974. Projections for the year 2000 indicate that irrigation and livestock requirements will account for only 36% of total water requirements, and by 2030, irrigation and livestock requirements will account for less than 20% of all water requirements (Texas Department of Water Resources 1977). In view of apparent declines in the rate of productivity increases, those agricultural production activities that use water intensively seem to be destined for dislocation.

Several recent changes that may serve to counteract the trend towards larger, more heavily capitalized farming and livestock operations involve the development of improved production techniques applied to cropping patterns that are characteristics of the TBIE area. These improved operating practices have generally been directed toward increasing production yields and lowering operating costs. To the extent that operating costs can be lowered (primarily by reducing the need for application of soil builders, pesticides, and herbicides), such improvements may permit some operations to sustain competitive yields, rather than forcing many relatively small operations out of the market altogether. A secondary consequence of these technical improvements that is of direct interest to fish and wildlife resource management policy is the long-term improvement in water quality made possible by: 1) decreasing the amount of pesticides and herbicides contained in non-point source agricultural discharges; 2) reducing soil erosion, and thereby reducing sediment loading in surface water supplies; 3) lowering water tables in areas where poor quality groundwater intrudes into crop root zones, thereby allowing surface soils to act more effectively as a water quality treatment agent; and 4) improving soil salinity conditions.

One portion of the study area where growers have been forced to reassess the economic and environmental efficacy of conventional irrigated field crop cultivation is the Lower Rio Grande Valley region, best known for its agricultural production activities. Episodes of heavy precipitation and seepage from irrigation and drainage ditches add to the existing water table, which is predominately very high over most of the Lower Rio Grande Valley groundwater basin. Capillary action causes the water, which is high in salt content, to rise through the soil profile and eventually reach the surface, where the water evaporates and leaves substantial salt accumulations. This salt buildup can reach crop-damaging levels in a relatively short period of time. Some farmers overirrigate their land in an attempt to leach the salt accumulation from the soil. This action can be successful only if the fields have subsurface drainage systems installed. This irrigation method can be self-defeating, however, for a number of reasons. First, the irrigation water, generally diverted from the Rio Grande itself, contains concentrations of total dissolved solids ranging from 400 to 1,200 parts per million, further adding to the soil's saline content. Second, over-irrigation raises the water table, thus pushing it closer to the crop root zone. Third, surface runoff from over-irrigation collects in low-lying areas and ditches. The runoff adds to soil salt content in these depressions and adds to existing storm runoff that collects in these ditches.

Crop damage caused by high soil salinity in the Lower Rio Grande basin has been considerable. It has been estimated that approximately 34% of the land area in Willacy and Hidalgo Counties has been affected by salinity to such an extent that termination or impairment of agricultural production has resulted (U.S. Department of the Army, Corps of Engineers 1980). Reductions in annual yields in the basin have been estimated at 10 to 15% as a result of high soil salt accumulations. Adequate drainage of these affected lands would allow farmers to leach the soil of salt and increase crops with fewer adverse effects than are presently experienced. Increased agricultural production could result in considerable net income gains in this economic sector (U.S. Department of the Army, Corps of Engineers 1980).

The most important technical improvements that have been developed in recent years to resolve these production problems have been within the scope of the Integrated Pest Management (IPM) approach, developed and implemented by the Texas Agricultural Extension Service. In addition, land leveling and the installation of subsurface drains have helped specifically to make more productive uses of water and soil resources.

The practice of land leveling results in an agricultural field with a slope of less than 3 cm per 30 m (0.1 ft per 100 ft), and a border around the field about 25 cm (10 in) in settled height. A "down drain" system is used to drain off excess rainwater into drainage ditches. The system consists of a vertical standpipe with the top at 9 cm (4 in) above the ground elevation connected to a horizontal drain pipe that terminates at the drainage ditch. As an area is flooded with water, the soil is saturated and water begins to pond on the surface. When water depth reaches 9 cm (4 in), all excess would run off through the downdrain. The velocity of water running off the field would be very slow and a ponding area around the standpipe would allow most sediments to fall out of the water column before draining off the field. The design of this system is such that soil erosion is essentially eliminated, and water is conserved to the maximum usable extent.

Subsurface drains are installed in agricultural fields at a minimum depth of 1.5 m (5 ft) and spaced at intervals as prescribed by soil types to remove subsurface water and surface water that percolates down through the soil. The water is then discharged into drainage ditches through these drains. Ditches of adequate depth are vital to the proper operation of these subsurface drains. Borders of approximately 25 cm (10 in) settled height are placed around the field to reduce surface runoff and retard soil erosion. This system is highly desirable for agricultural areas where high groundwater tables and high soil salinity problems occur. The Lower Rio Grande Valley area exhibits the greatest geographic concentration of such problems of any portion of the TBIE study area. The use of subsurface drains lowers the groundwater table, which, in turn, provides a system by which the soil acts as a filter to remove pesticides from water and allows water to leach excess salts from the soil. Agricultural areas served by subsurface drains also serve as reservoirs and detainment facilities for rainwater runoff.

These improvements in drainage and irrigation systems, combined with changes in the timing and duration of growing seasons, have demonstrated a strong potential for reducing costs and improving crop yields. Improved pest control has also resulted from this approach. Techniques developed include monitoring insect pests and beneficials, using the short season crop concept, narrow-row crops, using specific types of insecticides, and reduced insecticide usage. The monitoring of insect pests and beneficial species helps producers in applying pesticides at the proper time for maximum effect and in reducing the number of applications per growing season. The use of the short season crop concept and narrow-row crops has also been incorporated into the IPM approach. Short season crops are rapidly fruiting and maturing varieties and, when planted early, can be harvested before pest populations reach their peak during the growing season. The crowding effect of narrow-row spacing will cause some crops to mature more rapidly, producing a canopy that prevents weed growth and eliminates the need for extra herbicide application for cultivation. Insecticides that are more target-specific have been developed and are being used with excellent results. These materials usually degrade rapidly with minimal effects on non-target terrestrial and aquatic life. The techniques described above have all resulted in reduced insecticide usage, and, as a secondary consequence, have improved the quality of non-point source discharge associated with agricultural practices. Since the initiation of the IPM program, producers have reduced their range of insecticide applications in irrigated cotton from 15 to 20 per season to 6 to 12 per season.

Adjusting agriculture's ability to respond to market changes on the basis of technological improvements will, to a large extent, shape agriculture's role in the area. Leaving agriculture's fate in the hands of inexorable market forces could, however, diminish the economy's stability in light of an ever more volatile international energy market. Moreover, the public has a wide range of social and economic requirements that may best be met by maintaining diversity at the expense of short-term profitability. Explicit planning goals for agriculture's future should be established, with the industry's present social as well as economic contribution serving as a point from which to begin to plan the use of prime agricultural lands in the TBIE area.

AGRICULTURAL PRODUCTION: LITERATURE CITED

Adkins, W.G. Is there an agricultural land shortage? Texas A&M Univ., Texas Real Estate Research Center, College Station, TX. n.d. 3 p.

Adkins, W.G.; Graeber, K.E. Market value versus use value of agricultural land in Texas. College Station, TX: Texas Real Estate Research Center, College of Agriculture, Texas A&M Univ.; January 1978; 15 p. Available from: Texas Real Estate Research Center, Texas A&M Univ., College Station, TX.

Berry, D.; Plaut, T. Retaining agricultural activities under urban pressures: a review of land use conflicts and policies. Policy Sciences 9: 153-178; 1978.

Biesele, R. L. Early times in New Braunfels and Comal County. Southwestern Historical Quarterly 50 (1946-1947): 75-92.

Billington, R. A. Westward expansion: a history of the American frontier. New York: Macmillan Company; 1960; 2nd ed.

Cavendish, R.A.E. About Zebu cattle from India and the U.S.A. Gulf Coast Cattlemen 14(6):5-8, 1948.

Cobb, W. F. Brahman cattle in the South. Southern Agriculture 76 (2):11, 1946.

Coughlin, R. E.; Berry, D.; Plaut, T. Differential assessment of real property as an incentive to open space preservation and farmland retention. National Tax Journal 21(2): 165-179. June 1978.

Efferson, J. N. The production and marketing of rice. New Orleans: Simmons Press. 1952; 534 p.

Food and Agricultural Organization of the United Nations. FAO commodity policy studies: national rice policies 1970. Rome: Food and Agriculture Organization of the United Nations; 1970; 112 p.

Hansen, H., ed. Texas: a guide to the lone star state (revised). Originally compiled by the Federal Writers' Program of the Work Projects Administration. American Guide Series. New York: Hastings House. 1960; 717 p.

Heyward, D. C. Seed from Madagascar. Chapel Hill, NC: Univ. of North Carolina Press; 1937; pages.

Jones, J. W.; Jenkins, J. M. Rice culture in the southern states. Washington, DC; Farmer's Bulletin 1808; 1938.

Jordan, T. G. German seed in Texas soil: immigrant farmers in nineteenth century Texas. Austin: Univ. of Texas Press. 1966; 237 p.

Levi, D. R. Economic implications of land-use planning for agricultural lands. Journal of the American Society of Farm Managers and Rural Appraisers, Inc. 38(2): 57-64; October 1974.

Massey, B. What the Brahman can contribute. Cattlemen 55(9): 42-43; 1969.

Russell, J. Brahman -- the product of necessity. Gulf Coast Cattleman 24(12): 37-38; 1959.

Schmedemann, I. W.; Hascall, W. T. Rural land values in Texas...decade of increase. Texas Agricultural Progress 23(4): 12-16; Fall 1977.

Southwestern Immigration Company, n.d. The state of Texas. 18 p.

Spratt, J. S. The road to Spindletop: economic change in Texas 1875-1901. Dallas: Southern Methodist Univ. Press. 1955; 337 p.

State of Texas. 1977. General and special laws of the state of Texas passed by the regular session of the sixty-fifth legislature convened at the city of Austin, January 11, 1977 and adjourned May 30, 1977; 847-849; 1977.

Texas almanac for 1870, and emigrants guide to Texas. Galveston: Richardson and Company. n.d. 18 p.

Texas almanac 1980-1981. Dallas, TX: A. H. Belo Corporation; 1979; 704 p.

Texas Dept. of Water Resources. Continuing water resources planning and development for Texas. Austin, TX: Texas Dept. of Water Resources; May 1977; 2 vol. 1,145 p. Available from: Texas Dept. of Water Resources, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 Texas small grains statistics; Austin, TX: Texas Dept. of Agriculture; 1978; 48 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 Texas agricultural cash receipts statistics; Austin, TX: Texas Dept. of Agriculture; 1979a; 30 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 Texas cotton statistics. Austin, TX: Texas Dept. of Agriculture; 1979b; 20 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 Texas dairy statistics. Austin, TX: Texas Dept. of Agriculture; 1979c; 16 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 field crop statistics. Austin, TX: Texas Dept. of Agriculture; 1979d; 84 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 Texas fruit and pecan statistics. Austin, TX: Texas Dept. of Agriculture; 1979e; 24 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service, Texas Dept. of Agriculture. 1978 Texas livestock statistics. Austin, TX: Texas Dept. of Agriculture; 1979f; 56 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 Texas poultry statistics. Austin, TX: Texas Dept. of Agriculture; 1979g; 20 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service; Texas Dept. of Agriculture. 1978 Texas vegetable statistics. Austin, TX: Texas Dept. of Agriculture; 1979h; 48 p. Available from: Texas Dept. of Agriculture, Austin, TX.

U.S. Dept. of Agriculture, Soil Conservation Service. Soil and water resources conservation act: summary of appraisal, parts I and II, and program report (review draft). Washington, DC: U.S. Dept. of Agriculture, Soil Conservation Service; January 1980; 35 p. Available from: U.S. Dept. of Agriculture, Washington, DC.

U.S. Dept. of the Army, Corps of Engineers. Final environmental impact statement: Dept. of Army permit application no. 11374 by Hidalgo County Drainage District No. 1 for flood control and major drainage improvements in Willacy and Hidalgo Counties, Texas. Galveston, TX: U.S. Army Engineer District, Galveston, Corps of Engineers; January 1980; 301 p. Available from: U.S. Dept. of the Army, Corps of Engineers, Galveston, TX.

U.S. Dept. of Commerce, Bureau of the Census. Census of agriculture: 1954. Vol. 1, part 26. Washington, DC: U.S. Government Printing Office; 1957; 666 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of agriculture: 1959. Vol. 1, part 37. Washington, DC: U.S. Government Printing Office; 1962; 567 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of agriculture: 1964. Vol. 1, part 37. Washington, DC: U.S. Government Printing Office; 1967; 853 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of agriculture: 1969. Vol. 1, part 37, section 2. Washington, DC: U.S. Government Printing Office; June 1972; 2,040 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of agriculture: 1974. Vol. 1, part 43. Book 1. Washington, DC: U.S. Government Printing Office; September 1977a; 372 p. Available from: U.S. Government Printing Office, Washington, DC.

U.S. Dept. of Commerce, Bureau of the Census. Census of agriculture: 1974. Vol. 1, part 43. Book 3. Washington, DC: U.S. Government Printing Office; September 1977b; 761 p. Available from: U.S. Government Printing Office, Washington, DC.

Vining, D. R., Jr.; Plaut, T.; Bieri, K. Urban encroachment on prime agricultural land in the United States. International Regional Science Review 2(2): 143-156; 1977.