GALVESTON BAY WATER QUALITY STUDY --

Historical and Recent Data

Prepared

for

THE TEXAS WATER POLLUTION CONTROL BOARD

Austin, Texas

by

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THE UNIVERSITY OF TEXAS
AUSTIN 12, TEXAS

DEPARTMENT OF CIVIL ENGINEERING
ENVIRONMENTAL HEALTH ENGINEERING
ENGINEERING LABORATORIES BUILDING 305

March 1, 1964

Mr. Joe D. Carter
Chairman
Texas Water Pollution Control Board
Austin, Texas

Dear Sir:

We are transmitting herewith our report which you authorized under Interagency Contracts 4413-752 and 4413-899 dated May 15, 1963, and November 1, 1963, respectively.

This report for the first time assembles and compares much of the data which describes the quality of the water in Galveston Bay. Information has been obtained from historical files, current surveys on quality evaluations, and reports on projected developments. Some of the important factors which influence the quality of the water are delineated. The changes in water quality, the general hydrological characteristics of the Bay area, biological productivity of the Bay, the various water development plans that influence the usefulness of the Bay, and the public health aspects of the Bay waters have been reviewed.

This report will be of assistance to those who must plan for the future and direct studies of the maximum beneficial use of Galveston Bay. It is hoped that this report will serve as the beginning of a coordinated and comprehensive program to assure the maximum utilization of the State's water resources. It is evident that a high degree of coordination will be required in data collection, research, and planning, if the Bay is to continue to function as a multi-use system.

Respectfully submitted,

Earnest F. Gloyna

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SYNOPSIS

This report describes the Galveston Bay area, summarizes some of the projections which may influence the domestic and industrial growth of the area, depicts the quality of the waters as observed by various survey groups, and relates various ecological aspects of the Galveston Bay system. In the spirit of the study public records and files were reviewed, data were obtained from current surveys, and comparisons were made. Notably, most of the data represent historical information.

As shown herein, a vast amount of material is available which reflects the projected use of the resources around and in Galveston Bay. Increased water demands, sources of water supplies, and return flows point to the expanded use and reuse of the water resources in the Galveston Bay area. Traditionally, the harvest of marine products from the Bay has been an important and significant item. Also, the growing recreational demands on the Bay system are worthy of serious consideration.

In this report, consideration of the chemical characteristics of the Bay is limited primarily to oxygen demand, available oxygen, and salinity. Historical survey data and information derived from permits as issued by the Texas Water Pollution Control Board are presented. From these data, although incomplete, the sources of wastes and the ability of the Bay system to assimilate various wastes becomes quite evident.

Through a comparison of bacteriological data, it has been possible to establish a relative concept of the local and areal extent of sewage contamination. Relative coliform densities for various parts of the Bay system are shown. Included are preliminary data from a water-quality survey initiated in 1963.

Similarly, a comparative study of the biochemical and chemical oxygen demand of the various wastes has been made. Localized areas are readily apparent where the waste loads have exceeded the dilution capacity of the receiving body of water.

Additional reviews have been included which may help to indicate the presence or extent of pollution. As shown, a very limited amount of public information is available on bottom sediments, diversity and distribution of marine forms, and general ecological characteristics.

CONCLUSIONS AND RECOMMENDATIONS

1. The available data, though limited, point out the large dilution capability of the Galveston Bay system and the ability of these waters to assimilate waste materials. However, the ultimate assimilative capacity of the Bay has not been established. It is therefore recommended that appropriate engineering studies be undertaken to determine the mixing and transport characteristics of the Bay, the major tributaries, and the embayments. Model studies, field monitoring, and model evaluations are necessary to determine the residence time of wastes, to evaluate the influence of return flows on dilution and mixing, to establish the transport of nutrients, to study the effects of coastal construction on water quality, and to determine the extent and effect of the interchange of Gulf waters with Bay waters.

2. The public data presently available indicate that the coliform concentration in the water is still the most reliable index for estimating the extent of human waste releases into the Galveston Bay system. A comparison between the 1951 and 1963 survey data shows that based on coliform concentrations there is considerable improvement in the condition of that portion of Lower Galveston Bay contiguous to Galveston County. However, in 1963 such areas as the Houston Ship Channel, Clear Creek, and Highland Bayou contained high concentrations of coliform organisms. To assure improvement of such conditions in these areas it is imperative that all human wastewaters be effectively

treated and chlorinated before being discharged.

3. Aside from the areas mentioned above and occasional high coliform concentrations at a few stations in Trinity and Galveston Bays, the coliform counts were generally less than 100 organisms per 100 ml. The data from the 1963 survey are insufficient in number to statistically evaluate the coliform information, and therefore important guides such as "median values" have not been tabulated in this report. It is recommended that the collection of coliform data be continued with particular emphasis at selected stations, and that this information be subjected to appropriate statistical analyses.

4. The areas exhibiting the greatest concentrations of organic wastes as measured by the biochemical oxygen demand test are the Houston Ship Channel, Clear Creek, Texas City area, and Highland Bayou. Notably there were virtually no COD data available for inclusion in this report. Much of the five-day BOD data are believed to be low and do not reflect the actual oxygen requirements. It is proposed that the COD test be used except when domestic wastes are suspected and where checks are to be made on the relative biodegradability of industrial wastes. In the latter case acclimated seed organisms should be used.

5. There are virtually no data available which describe the diurnal fluctuations in dissolved oxygen concentrations in the Bay.

Diurnal oxygen data can be helpful in determining the respiration and photosynthetic activity. This information reflects the relative nutrient load, bacterial activity, and algal concentration. It is recommended that at least six stations be established to obtain diurnal oxygen data.

6. Permits have now been issued which allow the discharge of about 468 million gallons per day of domestic and industrial effluents into the Galveston Bay system. On the basis of these permit data, almost 68 per cent of this volume enters Galveston Bay via the Houston Ship Channel at Morgan's Point and about 27 per cent of the total waste flow originates near the Texas City area. The data indicate that about 72 and 27 per cent of the BOD originates in the Houston Ship Channel above Morgan's Point and in the Texas City area, respectively. On the basis of the industrial permits, about 63 per cent of the COD can be discharged into the Houston Ship Channel above Morgan's Point and 37 per cent can be released near Texas City.

7. No data are available on the refractory and toxic characteristics of the materials that are in the Bay waters. Identification of such materials, estimates of persistence, and concentrations in aquatic forms should be made.

8. Projections of the amount of runoff, return wastewater flows, and trans-basin diversions have been made, but no estimates of the quality of these return flows or diverted waters are available. These studies, together with an evaluation of the interchange of Bay and Gulf

waters, must be made.

9. The general nutirent load introduced into the Bay will increase if present conventional treatment methods are utilized. However, neither the short- nor long-term effects of this nutrient-rich environment on the ecological system are known. Studies should be initiated which would provide basic ecological and productivity information for various schemes of treatment and flow conditions.

10. The total recreational use of the Galveston Bay area (man-days or dollars spent) is not known. Data on the expenditures for recreation by both residents and non-residents are needed to help establish the economic value of these waters as a recreational facility.

11. It is apparent that the anticipated influx of people and industry into the Galveston Bay area will contribute to the growing waste load on the Galveston Bay system. These waste discharges into the Bay do not imply the misuse of a valuable body of water. However, there are many complex problems which must be solved if this multipurpose system is to be utilized most effectively and if regulatory actions are to be meaningful. It is therefore recommended that the studies and surveys suggested herein be initiated and the utmost effective use of all available data be made. As one means of accomplishing this objective, the development of a Galveston Bay Water Quality Survey Center, or possibly a Galveston Bay Water Quality Authority, could be formed encompassing Federal, State, industrial, and municipal groups having associated

interests in this field of activity. The establishment of such a survey center would have the capability of coordinating survey programs and sample collections, standardizing analytical techniques, and reducing data.

12. This report represents the initial compilation of information relating to the factors affecting the use and quality of the Galveston Bay system. Annual supplements should be prepared to keep this report current.

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CHAPTER 1

INTRODUCTION

The Galveston Bay complex is unique in many respects. This bay is the largest on the Texas Coast, and it is of considerable economic importance. The environs are undergoing a spirited industrialization and an accompanying urbanization. Galveston Bay includes several deep water ports, a vibrant economy, a large labor pool, valuable marine resources, and an attraction for those seeking recreational outlets. The area has unique water resources as well as other natural resources. All of these assets have made the City of Houston the largest municipality in the State as well as the center of the petrochemical industry in the United States. The entire Galveston Bay area is destined to grow in a similar manner, and this growth will be reflected in the characteristics of Galveston Bay.

The Bay and its tributaries must serve this rapidly expanding industrialization and at the same time maintain its aesthetic posture. The Bay represents a water resource and must therefore be used to the fullest extent possible. However, the use and reuse of the water is not an *a priori* right which can be established by a few users. The use of water for navigation, dilution of industrial and domestic effluents, chemical raw material, power production and other manufacturing processes is justified and should be encouraged. Yet, such use must in all probability be in line with other uses such as the maintenance of a balanced aquatic environment which will sustain the production of marine products and recreational activities.

The equitable distribution of benefits from a resource such as the waters of Galveston Bay and surrounding tributaries is not easy nor necessarily conclusive. The speed with which water management must come into play will be a result of marketplace pricing, in which new uses of water and waste-water treatment will have their impact. Thus, in order to obtain facts for managerial decisions, it is necessary to have ready access to historical data. It is equally desirable to receive a continuous supply of current information from properly planned studies.

The multiple use of Galveston Bay and its contributing watershed has made it apparent that a close surveillance of the water quality must be maintained. Such an undertaking in itself without the benefit of all of the previous investigations would be virtually impossible.

Objective

The primary purpose of this report was to summarize all of the available data dealing with the quality of the water in Galveston Bay, as well as its tributaries, and to relate all the factors that may influence the future quality of the Bay water.

Secondarily, the objective was to compare historical data.

Finally, the objective was to establish the direction of future test programs that may be required and thereby hopefully stimulate a high degree of coordination.

Scope

The organization of this study led to a comprehensive review of the historical literature. Published reports, files of various regulatory agencies, and personal interviews were the primary sources of information. The compilation of data includes the results obtained by the Water Pollution Control Board through cooperating State Agencies, mainly the Texas State Department of Health and the Parks and Wildlife Department.

The State and Federal agencies that have been involved in the collection of water quality data have been contacted. Much of the relevant data from various agencies have been tabulated, and attempts have been made to evaluate the information in terms of both historical and present significances. Additional information collected sporadically through the years has been included in this report, partly to establish the paucity of certain data and the general lack of coordination in obtaining "base-line" information.

Although it is not the express objective of this report to establish the future plans of each regulatory agency in regard to the respective individual data collection program, some expression of future objectives is included herein.

Acknowledgments

Special acknowledgment is directed to Dr. B. J. Copeland, Research Scientist of the Institute of Marine Science, University of Texas, for his assistance in preparing Chapters 9 and 10. The assistance of a number of students, especially, Mr. Peter Williams and Mr. Arnold Ott, is appreciated.

Valuable assistance was furnished by numerous individuals and many interested agencies. Some are listed below.

State of Texas

Texas State Department of Health
  Environmental Sanitation Services Section
  Water Pollution Control Division
  Laboratory Division
Texas Parks and Wildlife Department
Texas Water Commission

U. S. Government Agencies

U. S. Army, Corps of Engineers (Galveston District)
U. S. Bureau of Commercial Fisheries (Galveston, Texas)
U. S. Bureau of Reclamation (Area Engineering Office, Austin, Texas)
U. S. Geological Survey (Austin, Texas)
U. S. Public Health Service (Region VII)

Local Public Agencies

Brazoria County Health Department
City of Houston Health Department
Galveston County Health Department
Harris County Health Department
Public Works Division, City of Houston

Other Agencies

Committee on Industrial Wastes, Houston, Texas
Environmental Sciences Division, Rice University
Geology Department, Rice University
Houston Chamber of Commerce, Houston, Texas
Lockwood, Andrews, and Newnam, Consulting Engineers, Houston, Texas
Oceanography Department, Texas A & M University
Southwest Research Institute
Turner and Collie, Consulting Engineers, Houston, Texas

The University of Texas

Environmental Health Engineering Laboratories
Institute of Marine Science
The Bureau of Business Research

Acknowledgments of additional sources of assistance and specific sources of data have been included as references.

The Technical Advisory Committee of the Texas Water Pollution Control Board reviewed a draft of this report and provided suggestions. Committee members are as follows:

Mr. A. W. Busch, Associate Research Professor, William Marsh Rice University, Houston, Texas
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Dr. D. F. Leipper, Chairman, Department of Oceanography, Texas A & M University, College Station, Texas
Dr. E. F. Gloyna (Chairman), Director, Center for Research in Water Resources, The University of Texas, Austin, Texas

CHAPTER 2

GEOGRAPHY OF THE GALVESTON BAY AREA

The Galveston Bay area is in the West Gulf Coastal Plain and is a nearly smooth, featureless depositional plain. Galveston Bay is the largest inland bay that lies behind the barrier islands. The Galveston Bay area has about 100 miles of actual seacoast and has many times this length of shoreline along the various bays and channels.

The discussion which follows includes:

- General Description
- Physical Characteristics
- Climate
- Geology
- Houston Ship Channel
- Major Cities and Counties

General Description

The general area considered in this report includes Galveston Bay and the immediate contributing watershed. The relative position of the study area is shown in Fig. 2-1. More specifically, the area includes:

Houston Ship Channel
Turning Basin in Houston to Morgan's Point
Ship Channel from Morgan's Point to Gulf of Mexico

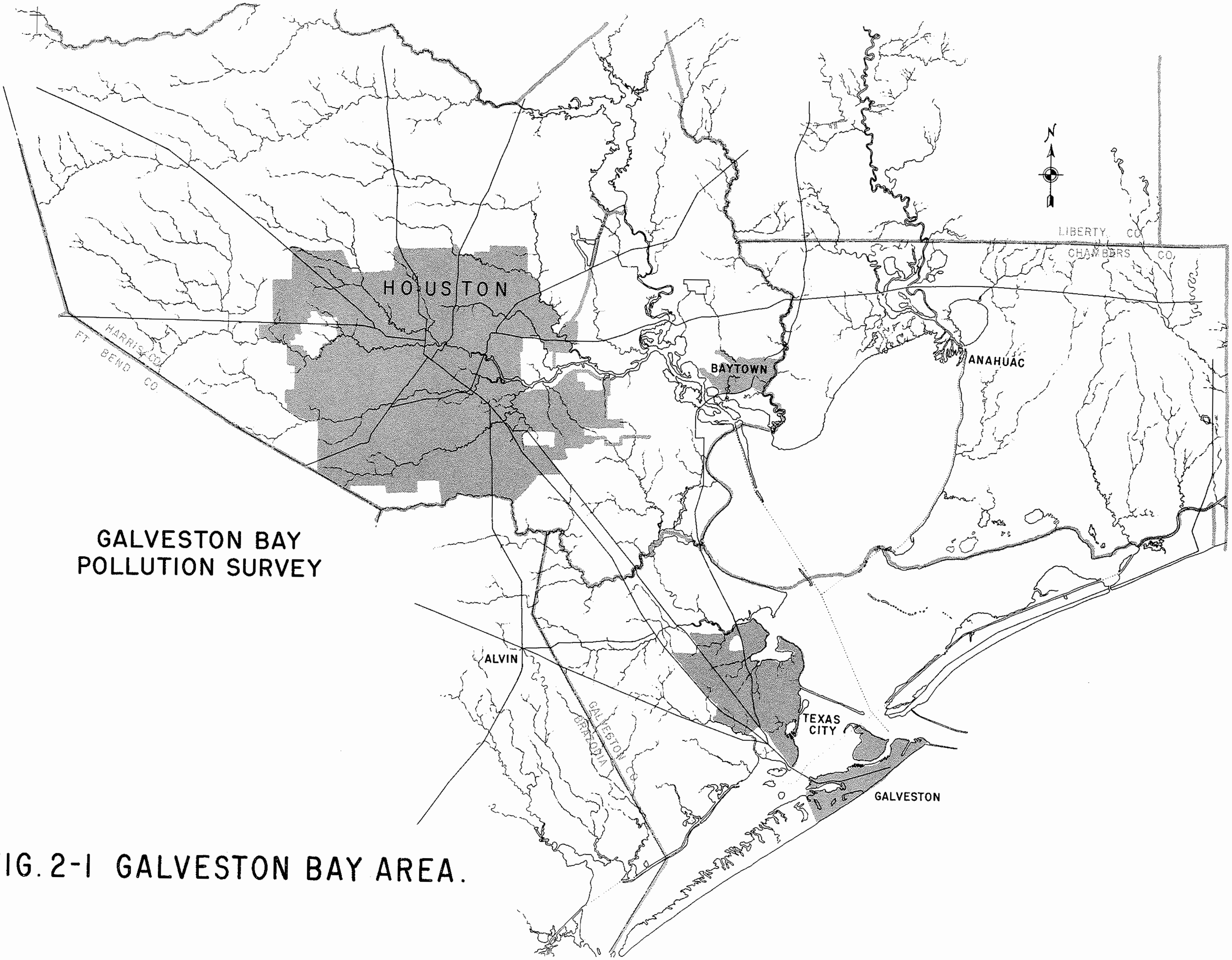


FIG. 2-1 GALVESTON BAY AREA.

Galveston Bay
- Trinity Bay
- Upper Galveston Bay, including the Clear Creek area
- Lower Galveston Bay
- East Bay
- West Bay

The contiguous land area includes:

Harris County
Chambers County
Galveston County
Brazoria County

The major municipalities of the Bay-Channel region include:

Houston
Texas City
Galveston
Baytown
Clear Creek Complex

The Houston Trading Area extends over 15 counties of the south-eastern Gulf Coast, namely:

Harris
Galveston
Brazoria
Liberty
San Jacinto
Montgomery
Walker
Polk
Fort Bend
Waller
Austin
Washington
Colorado
Wharton
Matagorda

Other terms used to describe the Houston area are Urban Houston (Harris County), Houston Orbit (development concept), Houston Zone (radial development concept), and Houston or Galveston Nodes (resource use concept).

The latter subdivisions include:

Houston Node	Galveston Node
Houston	Galveston
Baytown	La Marque
Bellaire	Texas City
Galena Park	
San Jacinto City	
Pasadena	
River Oaks	
West University	

If a zone having a 75-mile radius centered at Houston, Texas, is drawn, it will include four of the principal rivers of Texas:

Trinity
San Jacinto
Brazos
Colorado

The Bay area is rich in resources such as oil, gas, sulfur, agriculture, timber, marine foodstuffs, and fresh water. Abundant ground water supplies underlie the entire area. Four of the principal rivers of Texas flow into the Gulf of Mexico within a 75-mile radius. The flow from these four rivers constitutes approximately 43 per cent of the unused stream flow from all of Texas.

Physical Characteristics

Galveston Bay is a shallow body of water containing numerous

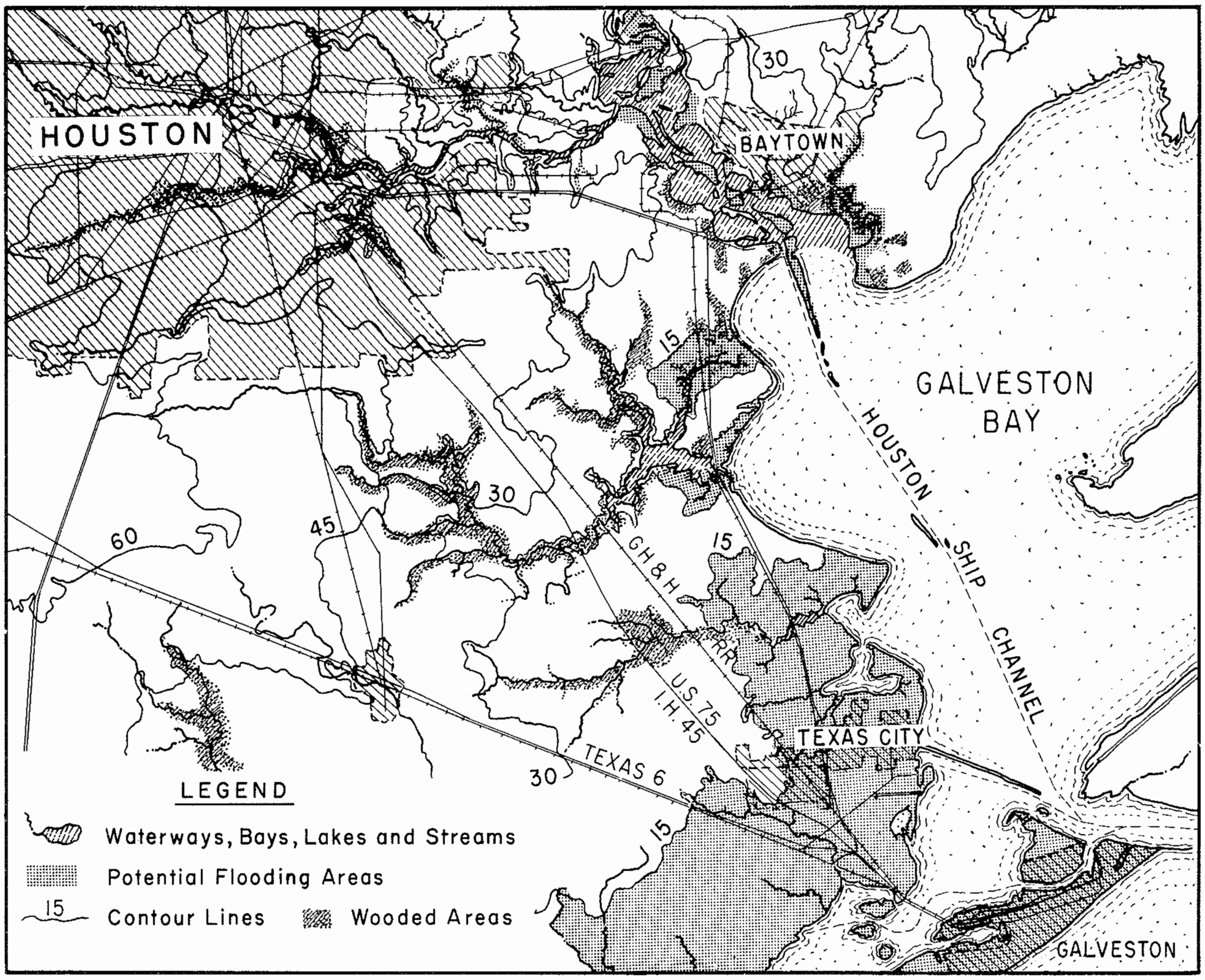


FIG. 2-2. PHYSICAL CHARACTERISTICS (3)

small, low-lying islands and shell reefs. Galveston Bay lies north of the City of Galveston and generally extends northward into Chambers County. West Bay forms a narrow arm approximately three miles wide, extending southwestward into Brazoria County. East Bay is a narrow body of water extending eastward paralleling the coast and ending near High Island. Trinity Bay receives the discharge of the Trinity River while the Houston Ship Channel receives the flow from the San Jacinto River, Buffalo Bayou, Sim's Bayou, Brays Bayou, and various smaller bayous, streams, and creeks. Buffalo Bayou and associated bays receive the flow from the San Jacinto River.

Figure 2-2 shows some of the waterways, contour lines, potential flooding areas, and wooded areas. In general, the contour lines parallel the shape of the Galveston Bay. Most of the immediate surrounding area lies within the thirty foot contour. The potential flooding areas are above the coastline, and the nearer the Gulf the more likelihood of flooding.

Lack of available frontage along Galveston Bay and recent rulings by the Federal Housing Administration that no more commitments will be made for construction on any land that lies at an elevation less than eight feet above sea level may limit the residential growth to within approximately 3/4 mile from the Bay. The acquisition of land for expansion of Galveston Island may be costly because of the required protection from high water and wave action caused by storms.

Some of the land lying southwest of Texas City is subject to inundation and will be expensive to reclaim for development purposes. Future developments to the north of Texas City along the Bay may be impeded by waterways and possibly a lack of adequate routes.

Climate

Climatologically, the Galveston Bay area is humid. The range in average annual rainfall is from approximately 42 inches to over 50 inches at Liberty and Anahuac. The average monthly temperature varies from 53°F to 84°F. (At Galveston the mean annual temperature is 69.7°F, and a 58-year record shows the mean annual temperature is 64.8°F.) Table 2-1 shows a comparison of the climate among the contiguous counties.

Geology

In general, the Galveston Bay area is characterized by formations which may be designated as fertile, alluvial sandy loams; chocolate loams; and black, waxy clay soils intermixed in some localities with variegated loams and clays.

The Bay area is underlain by sequences of unconsolidated sands and clays. Along the coastal islands the sediments are mostly of alluvial or deltaic origin. Some of the material has been reworked by littoral currents to form beach deposits. In general, the strata outcrop in belts parallel to the coast and dip gently toward the coast.

Table 2-1. Rainfall and Temperature[2]

Item	Harris	Galveston	Chambers	Liberty	Brazoria
Ann. rainfall (in.)	45.26	41.81	51.19	51.16	49.16
Jan. temp. avg. (°F)	55	55	53	54	55
July temp. avg. (°F)	84	83	82	83	82
Mean avg. temp. (°F)	69	69	68	69	69
Growing season (days)	309	341	289	232	276

The dip of the strata is greater than the slope of the land surface so that the formations lie at depths that increase toward the southeast.

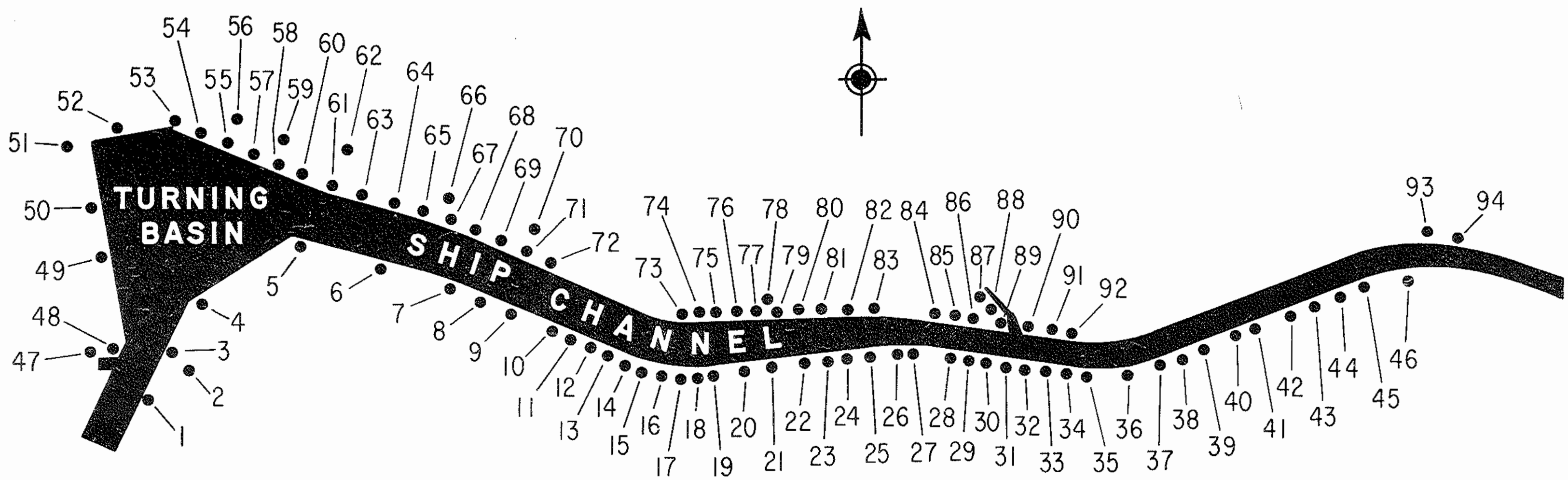
The older formations outcrop at successively higher altitudes. These formations with interbedded permeable sands and relatively high impermeable clays provide ideal conditions for supplying artesian water. In order from oldest to youngest formations, the lissie formation, the "Alta Loma" sand at the base of the Beaumont clay, and the upper part of the Beaumont clay are all of Pleistocene age, while beach and dune sands of coastal marsh deposits are of recent age.

Houston Ship Channel

The Houston Ship Channel was developed by dredging a channel from Galveston through Galveston Bay and inland to the City of Houston. This channel serves as the access route for ocean-going vessels to the Port of Houston, one of the world's busiest ports. Numerous streams and bays empty into the Houston Ship Channel. In addition, the City of Houston, towns and communities along the banks, and numerous industries discharge effluents into the Houston Ship Channel. Figure 2-3 shows a list of most industries.

The Channel receives a tidal exchange, depending upon the distance up the Channel from Galveston Bay. The fresh water from the San Jacinto River and the shallow bays adds to the recuperative powers of the water coming down the Ship Channel. Since the upper

FIG. 2-3. INDUSTRIAL MAP OF THE PORT OF HOUSTON'S FABULOUS FIFTY MILES



INDUSTRIES ALONG HOUSTON SHIP CHANNEL

1-PORT HOUSTON IRON WORKS (SHIP REPAIRS)
2-PATRICK SHIPSIDE WAREHOUSE
3-WHARF 4
4-
5-WHARF 2
6-WHARF 1
7-PACIFIC MOLASSES CO.,LTD.
8-ARMOUR FERTILIZER WORKS
9-GULF ATL. WHSE. CO. (LONG REACH DOCKS)
10-SPRUNT DOCKS
11-COMMERCIAL BARGE LINES (BRADY ISL.)
12-STAUFFER CHEM. CO., CONSOLIDATED CHEM. INDS. DIV.
13-SIGNAL OIL & GAS CO.
14-LONE STAR CEMENT CORP.
15-NAV. DIST. MANCHESTER WHARVES
16-CONTINENTAL GRAIN CO.(ELEVATOR)
17-FIRE BOAT STATION (MANCHESTER)
18-SOUTHWEST SUGAR & MOLASSES CO.
19-COLONY WINE CO.
20-SIGNAL OIL & GAS CO.
21-MANCHESTER TERMINAL CORP. (WHARVES)
22-SINCLAIR REFINING CO.
23-SINCLAIR-KOPPERS CHEM. CO.
24-HOUSTON LIGHTING AND POWER CO.
25-CHAMPION PAPER & FIBRE CO.
26-CROWN CENTRAL PETR. CORP. (REFINERY)
27-GEN. AMERICAN TANK STRGE. TERMINALS
28-HORTON & HORTON (MATERIAL & SHIPYARD)
29-OLIN MATHIESON CHEMICAL CORP.
30-KAISER GYPSUM CO.
31-ADAMS TERMINAL (PHILLIPS)
32-PHILLIPS CHEMICAL CO. (ADAMS TERMINAL)
33-ETHYL CORPORATION
34-TENNESSEE GAS TRANS.CO.
35-SHELL OIL CO.(REFINERY)
36-SHELL CHEMICAL CORP.
37-LUBRIZOL CORP.
38-DIAMOND ALKALI CO. (DEER PARK)
39-ROHM & HAAS CO.
40-CELANESE CORP. OF AMERICA
41-SAN JACINTO BATTLEGROUND & MONUMENT
42-PHILLIPS CHEMICAL CO.
43-NATIONAL PETROCHEMICALS CO.
44-U.S. INDUSTRIAL CHEMICALS CO.
45-TEXAS ALKYLS, INC.
46-DUPONT, E.I., de NEMOURS & CO.
47-VISITORS' PARKING LOT
48-SAM HOUSTON, INSPECTION BOAT
49-WHARF 8
50-WHARF 9 OBSERVATION PLATFORM
51-VISITORS' PARKING LOT
52-WHARF 10
53-WHARF 11
54-WHARF 12
55-WHARF 13
56-TERMINAL OFFICE
57-WHARF 14
58-WHARF 15
59-NAV. DIST. PUBLIC GRAIN ELEVATOR
60-WHARF 16
61-WHARF 17
62-SEA-LAND SERVICE, INC.
63-WHARF 18
64-WHARF 19
65-WHARF 20
66-NAVIGATION DIST.SHIPSIDE WAREHOUSE 21-A
67-WHARF 21
68-WHARF 22
69-WHARF 23
70-NAVIGATION DIST.SHIPSIDE WAREHOUSE 24-A
71-WHARF 24
72-WHARF 25
73-COAST GUARD
74-DICKSON GUN PLANT
75-TENNESSEE COAL & IRON DIV. (U.S. STEEL)
76-SOUTHERN PACIFIC RR CO. WHARF
77-IDEAL CEMENT CO.(GULF DIVISION)
78-MAYO SHELL CORP.
79-U.S. GYPSUM CO.
80-GULF OIL CORP.
81-GEN. AMERICAN TANK STRGE. TERMINALS
82-TEXACO, INC.(STORAGE TERMINAL)
83-WASHBURN TUNNEL
84-WARREN PETR. CORP. (WARREN GAS TERMINAL)
85-HESS TERMINAL CORPORATION
86-SHEFFIELD DIV.,ARMCO STEEL CORP.
87-A.O. SMITH CORP.
88-TENN-TEX ALLOY & CHEM. CORP.
89-TODD SHIPYARDS CORP.(HOUSTON DIV.)
90-NAVIGATION DIST. BULK MATERIALS HANDLING PLANT
91-SAN JACINTO CHEMICAL CORP.
92-SAN JACINTO ORDNANCE DEPOT
93-HUMBLE OIL & REFG. CO. (REFINERY)
94-STAUFFER CHEM. CO., CONSOLIDATED CHEM. INDS. DIV., BAYTOWN

part of the Houston Ship Channel receives a considerable quantity of effluent material there is, at best, a delicate balance between the conditions that sustain an aerobic aquatic life.

The salinity in the Houston Ship Channel fluctuates in a cyclic fashion and in a seasonal pattern because of the variation in the amounts of rainfall and evaporation. It should be noted that the flow of the San Jacinto River has been decreased by the construction of dams on the river, and thus this fresh water contribution ceases during periods of low rainfall. Tidal differences caused by meteorological and astronomical factors influence the chlorinity in a seasonal pattern. It has been reported that the tide which affects the Channel is largely diurnal with a single high and low tide. The annual tidal fluctuations result in a higher sea level during the second half of the year than in the first. Winter winds in this area are from the north causing the tidal exchange to be lessened at the same time that the greatest dilution by runoff occurs. Conversely, the prevailing winds in the summer are from the south, intensifying the effects of the tide.

Major Cities

The cities of Houston and Galveston are located in the Bay-Channel region. Other cities are shown in Fig. 2-4.

Houston: The Houston complex can best be described by the

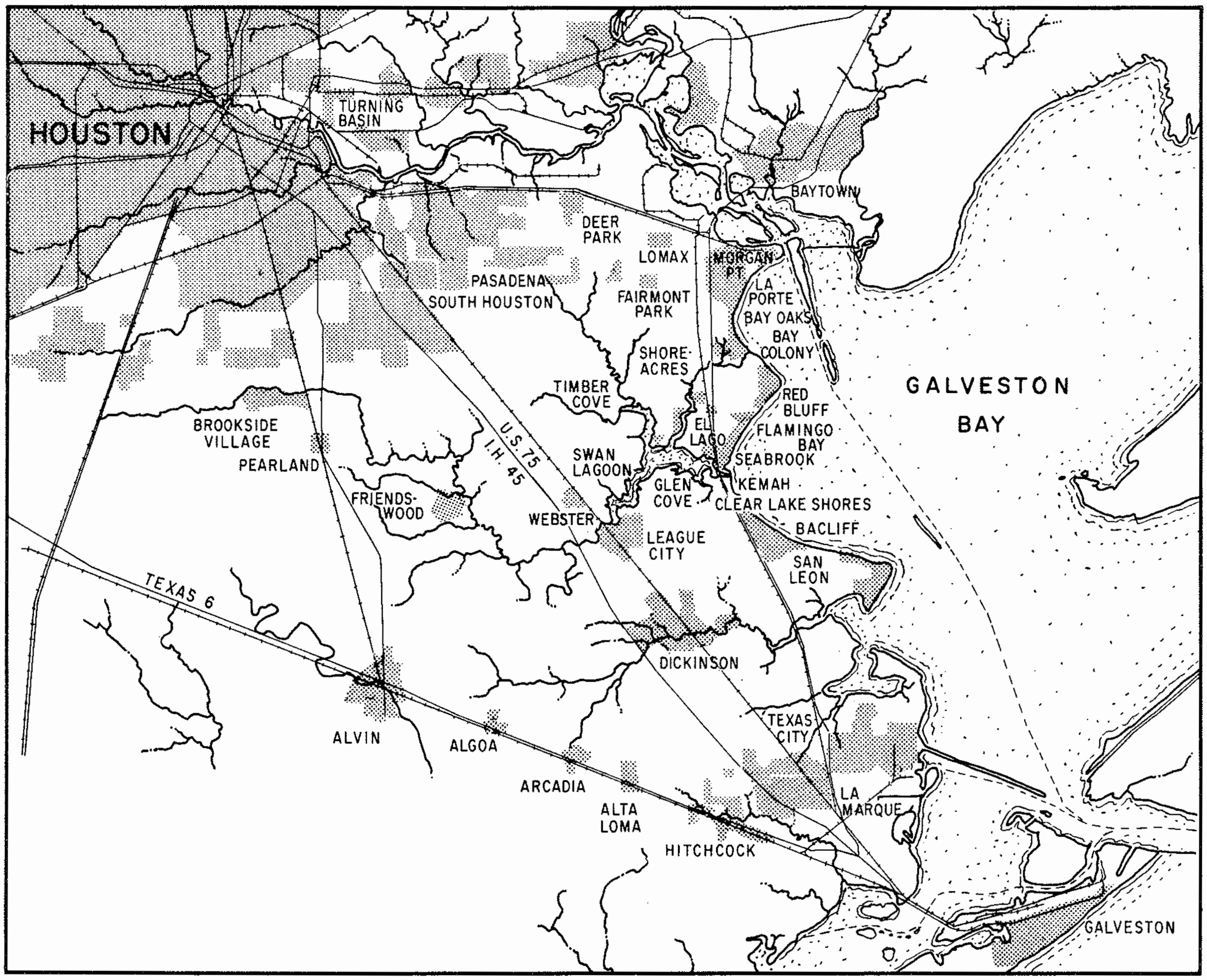


FIG. 2-4. EXISTING POPULATION CENTERS.(3)

the jetties and about 1.5 feet at Galveston. The tides are irregular and are controlled mostly by the force and direction of the winds.

Texas City: Texas City is the fourth port in Texas in total tonnage. The outer harbor affords safe anchorage throughout the year in 35 to 50 feet of water protected by breakwaters extending over five miles long and two miles apart. The channel leading from Bolivar Roads to Texas City is 300 feet wide at the bottom and six miles long with a depth of 34 feet. The harbor is 875 to 1,100 feet wide and 5,300 feet long. The channel will be improved to a width of 400 feet and a depth of 35 feet at mean low tide. Also, the existing turning basin will be widened to 1,000 feet.

Counties

The counties produce natural gas, oil, salt, sulphur, and shell and have extensive ground and surface water resources, agricultural activity, inland seaports, access to domestic and foreign resources, markets, and space for growth. As shown in Table 2-2, Harris County leads in population and area.

Brazoria County: Brazoria County has a population (1960) of 76,204 people and has experienced rapid economic growth in recent years. Approximately one-third of the area is covered with coastal grasses and another one-third is covered with timber. Chocolate Bayou, a stream of importance in this survey, flows into West Bay of

Houston Urban area, primarily in the San Jacinto Basin, and the Houston Zone, which includes an area having a 75-mile radius with the City of Houston as the center. The City of Houston directly influences the counties of Harris, Brazoria, Galveston, and Chambers. The urban population of the city in the year 2000 is expected to be more than three times the current population. The city is the nation's second port in tonnage. A total of 4,375 ships called at this port in 1963 and moved 56,474,299 short tons of cargo. The Gulf-Intracoastal Waterway gives Houston access to 6,500 miles of navigable inland waterways.

The Houston-Gulf Coast lists 30 refineries and accounts for 32 per cent of the U. S. refining capacity. A major part of the nation's petrochemical industry is located in the Houston Gulf Coast region.

Six major rail systems operating over 15 separate lines radiate from the city. The Houston International Airport generates more than one per cent of the U. S. traffic. Thirty-four common carrier motor freight trucklines operate from Houston.

Galveston: Galveston's proximity to the open sea is a natural physical advantage that is enjoyed by no other major port in America. The channel depth is about 35 feet and at the narrowest point is 1,200 feet wide. The distance from the docks to the open sea is about ten miles.

The maximum normal tidal action is about two feet at the end of

Table 2-2. Counties Contiguous to Galveston Bay and Houston, Texas[4]

Item	Harris	Galveston	Chambers	Liberty	Brazoria
Area (sq.mi.)	1,711	429	617	1,173	1,422
1962 Pop. (est.)	1,347,816	145,652	10,779	31,738	81,247
1960 Pop.	1,243,158	140,364	10,379	31,595	76,204
1960 Urban Pop.	1,174,710	125,819	---	15,332	44,760
Alt. (ft.)	s.l.*-300	s.l.*-50	s.l.*-50	20-200	s.l.*-60

* sea level

Galveston Bay. The City of Alvin (5,643) is the major municipality in the immediate vicinity of Galveston Bay. Alvin is the center of the farming and truck growing areas which service the Houston market. The surfside beach from San Luis Pass to the Brazos River is described as one of the finest recreational areas in Texas.

Brazoria County has some of the wealthiest mineral deposits in the State. Mineral values average about $150 million yearly. Oil production for a 58-year period (1902-1960) was reported to be 675,770,395 barrels. Mineral production in order of value was: oil, gas, gas liquids, bromine, magnesium chloride, salt, Frasch sulfur, magnesium compounds, and lime. The Chocolate Bayou oil field in Brazoria County was discovered in 1956, and an estimated ultimate recovery of crude oil is in excess of 100 million barrels. Brazoria County is one of the leading counties in agricultural produce, which includes the production of rice from about 50,000 acres yearly. This county is also among the leading counties in beef cattle production. Fishing and hunting are important business of this county.

Harris County: This county, in addition to the corporate City of Houston, had 24 industrial, suburban, and commercial centers with more than 1,000 population according to the 1960 census. In addition, the newly located National Aeronautics and Space Administration Manned Spacecraft Center will have a major impact on the Gulf

Coast region.

<u>Galveston County</u>: The economy of Galveston County is dominated by the metropolitan Galveston-Texas City complex. Shipping, petrochemicals, tourist trade, fishing, and other occupations are major factors in the over-all economy. Farming is limited to rice, truck crops, poultry, and dairying.

Sulfur, sand, gravel, and shell production are important factors in the economy. Petroleum is produced on the mainland and offshore, and during a 38-year period (1922-1960) almost 200 million barrels of oil were recovered from this county.

<u>Chambers County</u>: Chambers County is located on the southeast Gulf Coast and borders on part of the Trinity, Galveston, and East Bays. It is a pioneer oil-producing county, having produced nearly 443 million barrels of oil during the period 1902-1960. Natural gas, sulfur, and sulfur deposits are located in this county. Fishing, hunting, and the tourist trade are lively. Approximately four-fifths of the crop acreage is rice and the remainder is occupied by truck crops. The City of Anahuac is a major fishing and recreation center.

CHAPTER 3

GROWTH STATISTICS

The anticipated growth of the industrial and domestic complex between Houston and Galveston will put new demands on Galveston Bay and adjacent waterways. As a result of the expanding Ship Channel and Baytown industries, the concentration of space programs around Clear Lake, the developments at Texas City, and the building of new plants throughout the area, it appears that there will be an almost continuous urban area between Houston and Galveston. The complex will consist of many small communities with separate governments, possibly with conflicting ideas and policies, but nevertheless, each one affecting the character of the Bay. Common problems will include water supply, sewage treatment, water pollution, traffic regulation, land use, housing, blight, recreation, schools, air pollution, finance, and maximum use of Galveston Bay.

Summaries of previous estimates are as follows:

- Population estimates
- Industrial growth of Texas and Galveston Bay Area
- Waste-water treatment facilities
- Water supplies
- Water requirements
- Return flows
- Recreational and sports activities
- Commercial fishing

Population Estimates

The population of the Galveston Bay survey area has increased rapidly in the last century, from approximately 120,000 in 1900 to over 1,400,000 in 1960. The rate of growth can be expected to increase. The large employment opportunity afforded by the space industry will make most previous population estimates seem quite conservative. In addition, the various chemical industries, particularly those in the non-petroleum related fields, should continue to expand and provide new employment opportunities.

The Houston Orbit, Table 3-1, is expected to have 9 million people within fifty years. The Bay-Channel region around Clear Lake may have a population of a million people. The Houston urban population, Harris County, is expected to grow from an estimated 1.36 million to 7.8 million.

Table 3-1. Population Predictions[(1)]

Population Centers	Time		
	1960[a]	1962[b]	2010[c]
Houston Orbit Counties of Harris, Galveston, Brazoria, Chambers	1,470,000	1,620,000	9,000,000
Harris County	1,240,000	1,360,000	7,800,000
Bay-Channel Region	27,000	33,000	1,000,000

(a) U.S. Census
(b) Caudill, Rowlett, Scott estimate
(c) Estimate Furnished the U.S. Study Commission and U.S. Corps of Engineers by U.S. Department of Health, Education, and Welfare.

By comparing Table 3-1 and Fig. 3-1, it becomes apparent that growth predictions are likely to be widely divergent, although rapid growth is anticipated by everyone. Most estimates for the Houston area seem to have been conservative. In a report released by the U. S. Study Commission-Texas, it has been predicted that the population in the San Jacinto watershed area will reach 3,190,000 by year 2010 with 99 per cent of this population residing in the major cities such as Houston. Similarly, the lower and adjoining Brazos River watershed, which includes Galveston Island and Texas City, will have 850,000 people by year 2010 with 81 per cent of this population residing in two major cities.

These projections are substantially the same as provided by studies made by the Bureau of Business Research of The University of Texas. Figure 3-1 shows historical population estimates for the Houston and Galveston Nodes, the Houston Trading Area, and Harris and Galveston Counties where most of the growth may be expected to occur.

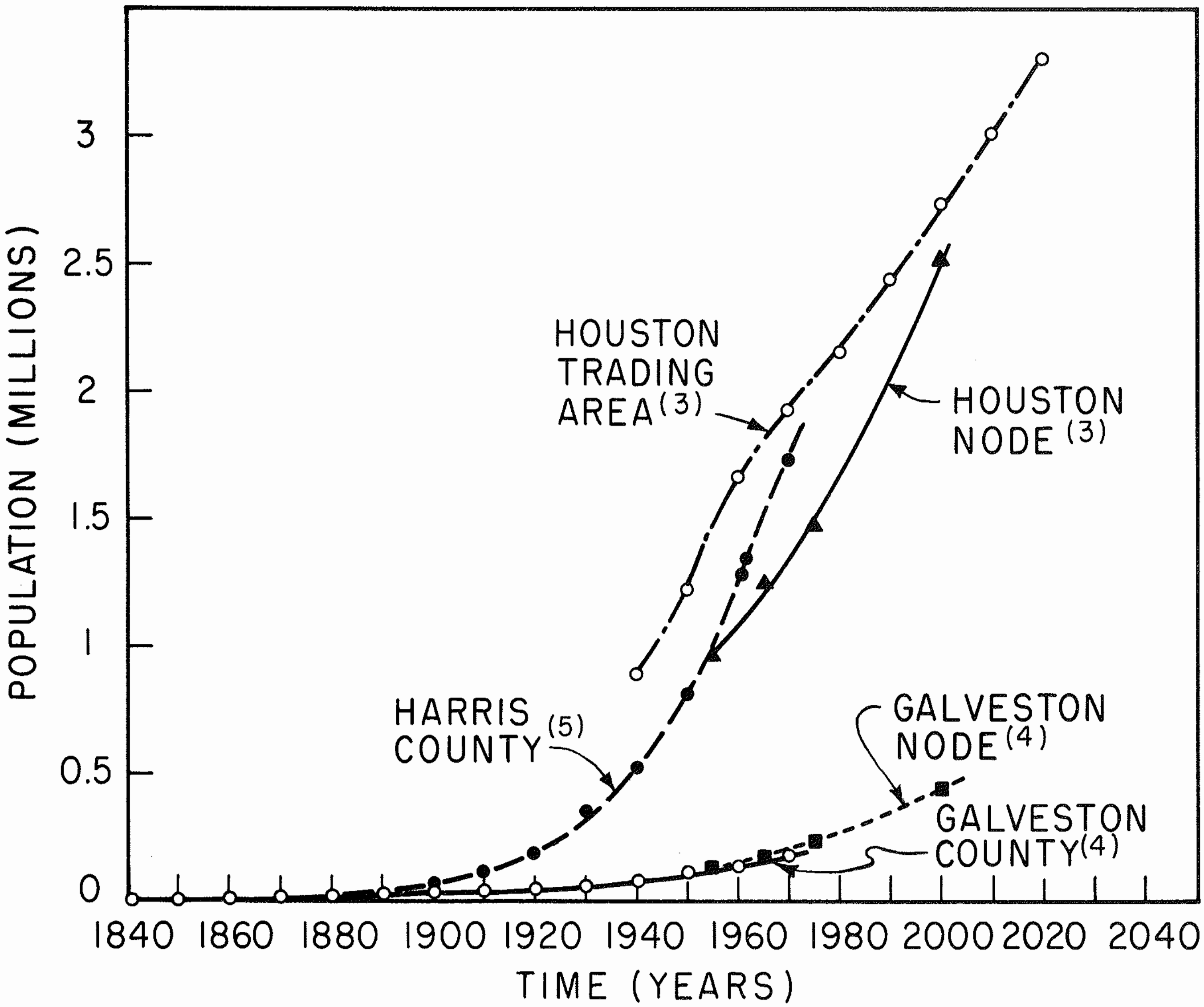


FIG. 3-1. POPULATION ESTIMATES

Industrial Growth of Texas and Galveston Bay Area

The Galveston Bay Area is the industrial empire of the Southwest. This region and the State of Texas have grown more rapidly than has the rest of the nation as a whole. Houston's 57.4 per cent population increase during the 1950-1960 decade made it the seventh largest U. S. city. Houston ranks ninth in the nation in new investment for manufacturing.

The Houston Gulf Coast area has the world's largest refinery concentration consisting of about 30 plants exceeding 32 per cent of the total U. S. capacity. The refinery investment is estimated to be $1.2 billion, and the capacity is projected as 2,990,000 barrels of crude oil daily.

A major fraction of the nation's petrochemical industry is located in the Houston-Gulf Coast area. Table 3-2 gives major new petrochemical plants completed or under construction in the Galveston Bay area in 1962. Table 3-3 shows the increased employment and capacity for the Texas Gulf Coast. There are approximately 125 chemical plants in the Houston-Gulf Coast area. By the construction of two new ethylene plants in 1962, the production of ethylene was increased by one-seventh of the total U. S. output. This increased Texas' capacity about 25 per cent, maintaining its nearly 60 per cent proportion of the U. S. total.

Table 3-2. New Chemical Industries in the Galveston Bay Area[6]

Product	Plant Location	Capacity	Company
Ethylene/propylene	Cedar Bayou	500 million lb/yr	Gulf Oil Corp.
	Chocolate Bayou	550 million lb/yr	Monsanto Chemical Co.
	Houston	85 million lb/yr	Signal Oil & Gas Co.
Phenol	Chocolate Bayou	50 million lb/yr	Diamond Alkali Co.
Acetylene	Deer Park	40 million lb/yr	Celanese Corp. of America
Ammonia	Texas City	600 tons/day	American Oil Co.
Benzene	Chocolate Bayou	42 million gal/yr	Monsanto Chemical Co.
Lactic Acid	Texas City	10 million lb/yr	Monsanto Chemical Co.
Naphthalene	Chocolate Bayou	85 million lb/yr	Monsanto Chemical Co.
Polyethylene	Houston	60 million lb/yr	National Petro-chemical Corp.
Polypropylene	Houston	n.a.	Alamo Polymer Corp.
	Texas City	50 million lb/yr	Monsanto Chemical Co.
Styrene	Baytown	75 million lb/yr	Marbon Chemical Co.
Synthetic Rubber	Baytown	n.a.	United Rubber & Chemical Co.
Vinyl acetate	Texas City	45 million lb/yr	Monsanto Chemical Co.
Xylene	Baytown	100 million lb/yr	Enjay Chemical Co.

n.a. - not available

Table 3-3. Increased Employment and Capacity in Texas Gulf Coast Petrochemical Industry, 1954-1975[7]

Product	Total employment increase to 1975	Capacity increase to 1975
Acetaldehyde		1,500 mill. lbs.
Acetic acid	3,000	1,400 mill. lbs.
Acetic anhydride		590 mill. lbs.
Acetone	350	200 mill. lbs.
Nylon intermediates	3,000	n.p.
Polyester intermediates	4,000	n.p.
Acrylonitrile	4,500	520 mill. lbs.
Hydrogen cyanide		340 mill. lbs.
Phenol	900	250 mill. lbs.
Formaldehyde	800	825 mill. lbs.
Glycerol	1,900	480 mill. lbs.
Styrene[1]	3,500	700 mill. lbs.
Ethylbenzene		850 mill. lbs.
Polyvinyl chloride	2,000	590 mill. lbs.
Polyvinyl acetate		
Urea	150	n.p.
Vinyl chloride	2,000	1,000 mill. lbs.
Vinyl acetate		
Polyethylene	1,000	270 mill. lbs.
Ethanolamines	150	36 mill. lbs.
Pesticides	600	n.p.
Butadiene	5,250	1,400 mill. lbs.
GR-S	5,400	720,000 tons
Butyl rubber	675	45,000 tons
Neoprene	800	80,000 tons
Ammonia	1,500	440,000 tons
Methanol	1,200	800 mill. lbs.
Methyl chloride and methylene chloride	400	70 mill. lbs.
Ethyl chloride	950	530 mill. lbs.
Ethylene dichloride	850	570 mill. lbs.
Ethyl alcohol	2,400	1,600 mill. lbs.
Ethylene oxide	1,500	550 mill. lbs.
Ethylene glycol		250 mill. lbs.
Miscellaneous	12,700*	
Total	61,475	

n.p. - not projected

* - rounded

[1]Includes styrene monomer and polystyrene

According to the Manufacturing Chemists' Association about 88 firms expended \$719,530,000 during 1961 in Texas for 188 projects. This estimate of expenditures is three times that invested in any other state. In 1962 new plant locations of all industries in Texas totaled 240, which was exceeded only by Pennsylvania and New York.

The Houston metropolitan area (Harris County) lists 1,542 manufacturing plants in the 1963 Directory of Texas Manufacturers.[8] This number is exceeded only by that of the Dallas metropolitan area.

In 1963, one of the largest construction developments under way in the United States was the \$360 million Houston-New York pipeline in which 9 major oil firms were associated.[9] The manned spacecraft center and associated enterprises in the Galveston Bay area (Clear Lake) will undoubtedly accelerate industrial expansion. Texas ranks tenth among states in space spending.

A breakdown of employees, production workers, and wages is given in Table 3-4. The Houston area in 1961 had a payroll of over \$555 million.

The wholesale trade for this particular area is also significant, Table 3-5. Harris County had about 15 per cent of all of the wholesale establishments in Texas in 1958, and the total sales were in excess of \$14 billion.

Texas export value estimates for the calendar years 1961 and 1962 are shown in Table 3-6. These estimates were first made

Table 3-4. Manufacturing: Standard Metropolitan Statistical Areas With 40,000 or More Manufacturing Employees by Industry Groups (10)

Standard metropolitan statistical area and industry group	1961							1960	
	All Employees		Production Workers						
	Number	Payroll ($1000)	Number	Man-hours (1000)	Wages ($1000)	Value added by manufacture, adjusted ($1000)	Capital Expenditures, new ($1000)	Total Employment	Value added by manufacture, adjusted ($1000)
Dallas, Total	103,110	$525,138	68,777	144,398	$294,181	$1,018,316	$41,970	97,837	$ 969,732
Ft. Worth, Total	53,529	307,836	35,277	71,658	172,157	537,649	14,838	55,495	556,004
Houston, Total	91,056	555,363	60,891	125,248	327,069	1,359,358	120,305	92,641	1,318,267

Table 3-5. Wholesale Trade in the Galveston Bay Area (1958) (11)

County and City	Establishments (Number)	Sales ($1,000)	Payroll Year ($1,000)	Paid Employees (Number)
Galveston County	131	105,766	4,256	1,777
Galveston	101	94,626	3,520	1,029
Texas City	20	8,655	646	116
Remainder of County	10	2,485	90	32
Harris County	2,421	3,640,365	168,515	34,025
Baytown	23	15,476	592	152
Bellaire	9	1,625	*	*
Galena Park	8	10,955	783	131
Houston	2,290	3,499,463	163,294	33,007
Jacinto City	1	*	*	*
Pasadena	27	6,496	348	77
West University Place	1	*	*	*
Remainder of County	62	105,862	3,354	631

*Withheld to avoid disclosure.

Table 3-6. Foreign and Domestic Commerce Through Galveston Bay Ports (tons) (12)

Item	Total	Foreign		Domestic					
				Coastwise		Internal			
		Imports	Exports	Receipts	Shipments	Receipts	Shipments	Local	Intra-port
Calendar Year 1962									
Houston	58,604,886	3,435,473	6,634,362	2,414,494	24,794,938	6,505,418	5,944,575	8,785,232	90,394
Texas City	18,576,203	11,422	161,642	680,222	8,618,212	6,900,205	2,202,346	2,154	----
Galveston	4,220,634	150,691	3,636,625	166,764	90,320	127,776	48,449	9	----
Calendar Year 1961									
Houston	56,474,299	2,787,441	7,434,496	1,058,054	25,727,908	5,702,385	5,844,081	7,828,071	91,836
Texas City	16,418,556	109,590	251,054	363,549	7,380,504	6,475,355	1,833,812	4,692	----
Galveston	5,361,179	144,980	4,733,858	151,046	110,606	161,780	58,904	5	----

available in 1960 by the U. S. Department of Commerce.

Texas is the leading state and the Galveston Bay area is the leading area in Texas in export of chemicals and petroleum. The state ranks fourth among states in exports of food and eighth in value of exports of manufactures. Only California exceeds Texas in the export value of agricultural products. Houston exports twice the tonnage of any other Texas port.

Harris County leads the state in a significant number of categories. As shown in Table 3-7, Harris County leads in population, manufacturing values, retail sales, total motor vehicles, poll tax receipts, and scholastic population. The county also leads in the production of beef cattle, it is second in dairying, and among the first in total farm income which includes hogs, poultry, and rice production.

The county has an economic index of 15.413 which is the highest in the State. The following weighted factors are used to compile this economic index: assessed property evaluation of county, weighted by 20; population of county, weighted by 8; income of county, as measured by value added by manufacturing; value of minerals produced, value of agricultural products, payrolls for retail establishments, payrolls for wholesale establishments, and payrolls for service establishments--weighted collectively by 72.(13)

Comparisons of the data depicting the economic strength of Houston and the surrounding cities are shown in Tables 3-8 through 3-10. The

Table 3-7. Comparative Data for Harris County[13]

Rank	Topic	Source of Information
1	Population	U. S. Census, 1960
1	Manufacturing Values	U. S. Bureau of Census, 1958
8	Mineral Values	U. S. Bureau of Mines, 1960
1	Retail Sales	U. S. Bureau of Census, 1958
2	Wholesale Sales	U. S. Bureau of Census, 1958
6	Livestock and Products	U. S. Census, 1960
4	Total Oil Production (to January 1, 1961)	Mid-Continent Oil & Gas Association
1	Total Motor Vehicles, 1962	Texas Highway Department
7	Total Number of Farms	U. S. Bureau of Census, 1960
1	Poll Tax Receipts	Comptroller of Public Accounts, 1962
1	Scholastic Population	Texas Education Agency, 1962-63
2	Dairy Cows	U. S. Bureau of Census, 1960

Table 3-8. Metropolitan Houston and Galveston-Texas City Data[15]

Item	Houston	Galveston-Texas City
Effective Buying Income	$2,937,281,000	$269,980,000
Retail Sales	$1,840,359,000	$162,259,000
Labor Force	548,300	57,690
Wages Paid	$1,852,893,840	$144,728,960
Number Employed	526,200	52,570
Mfg. Values	$1,153,967,000	$270,107,000
Wholesale Sales	$3,640,365,000	$105,766,000
Building Permits	$376,078,532	$34,902,495
Nonresidential Permits	$119,066,964	$14,914,930
New Dwelling Permits	$215,145,995	$6,694,876
Bank Deposits	$3,002,119,000	$169,275,000
Bank Assets	$3,322,925,000	$250,235,000
Vehicles Registered	655,969	64,955
Economic Index	14,413	1,991

Table 3-9. Houston and Galveston-Texas City Statistics[16]

Item	Houston	Galveston-Texas City
Assessed Property Value	$2,455,710,000	$131,852,000
Adjusted Municipal Tax Rate	$0.77	$1.40
Gross Post Office Receipts	$22,384,102	$1,384,892
Passengers Enplaned	776,920	740
Common Carrier Airlines	11	1
Mainline Railroads	8	8
Common Carrier Trucklines	35	10
Telephones	607,669	31,464
Government	Council	Council-Manager

Table 3-10. Income in Counties Contiguous to Galveston Bay[17]

Item	Harris	Galveston	Chambers	Liberty	Brazoria
No. farms	2,414	518	483	1,189	1,276
Farm income	$21,184,317	$4,654,060	$7,975,600	$7,191,012	$12,106,626
Auto. reg.	515,830	50,386	4,454	10,149	28,897
Poll taxes	287,567	37,831	3,176	6,864	21,004
No. employed	348,203	29,395	1,543	3,607	17,665
Wages paid	$1,852,893,840	$144,728,960	$9,176,484	$14,140,248	$110,816,556
Mfg. value	$1,153,967,000	$270,107,000	----a	$2,399,000	----a
Retail sales	$1,840,359,000	$162,259,000	$9,443,000	$33,601,000	$101,167,000
Whl. sales	$3,640,365,000	$105,766,000	----a	$14,630,000	$22,898,000
Bank dep.	$3,002,119,000	$169,275,000	$7,133,000	$26,274,000	$68,254,000
Tax values	$1,840,154,119	$266,492,446	$40,631,745	$56,706,246	$263,087,665
Income	$2,937,381,000	$269,980,000	$17,628,000	$46,917,000	$151,228,000
Mineral value	$104,684,791	$37,859,325	$56,546,869	$44,906,579	$127,332,159
1960 Oil (bbls)	18,075,092	10,177,848	13,778,716	10,915,424	18,278,857

a. Withheld to avoid disclosures.

effective buying income and other measures of wealth show that Houston truly is the hub of domestic and industrial growth. The assessed property value for this area is higher than that for any other city in Texas.

Waste-Water Treatment Facilities

As of December 1, 1962, permits were issued for a total of 336 domestic and industrial waste-water discharges. Of this number 242 and 94, respectively, were industrial and domestic permits.

Permits have not been issued for all of the domestic and industrial waste treatment systems, but a list of the domestic and industrial waste-water treatment plants or discharges for which permits have been issued are given in Appendix Tables F-1 to H-1. Approximately 468 million gallons per day of waste are released, of which about 114 million gallons per day represent domestic effluents.

As a relative index of the number of domestic waste-water treatment plants in 1961, there were 65 sewage treatment plants inside the City of Houston and 59 additional plants outside the City in Harris County. Similarly, there were 11 sewage treatment plants in Galveston County.

The disposal of sewage in Harris County has been rather uncoordinated. In the metropolitan area the number of sewage disposal plants in 1945 numbered 16, operated as follows: by cities, 13; by water districts, 1; by private persons, 2. This number had increased by 1956 to a total of 104: 28 municipal plants, 25 plants operated by water districts, 51 operated by private persons. In 1945 it was estimated that on the average there was one plant for 39,400 people, and in 1956 there were 10,000 people per plant.

Water Supplies

The existing and proposed storage facilities will, when operated at maximum capacity, regulate the tributary drainage into the Galveston Bay area during the period critical to downstream use.

The rivers near Houston are already fairly well developed by means of reservoirs. Additional reservoirs are either under construction or are scheduled for construction by 1966, as shown in Table 3-11.

Houston's own surface water supply will be increased six-fold within the next five years, Table 3-12. The supply of water around Houston will be more than doubled by 1966.

As shown in Fig. 3-2, the surface water supply yields an average flow of 15,390 MGD. The present use is 1000 MGD and one projection for the planned supply is 3,730 MGD.

Water available for new uses is shown in Fig. 3-3. This supply includes both surface and ground water for the year 1966.

The ground water supplies around the Houston zone are

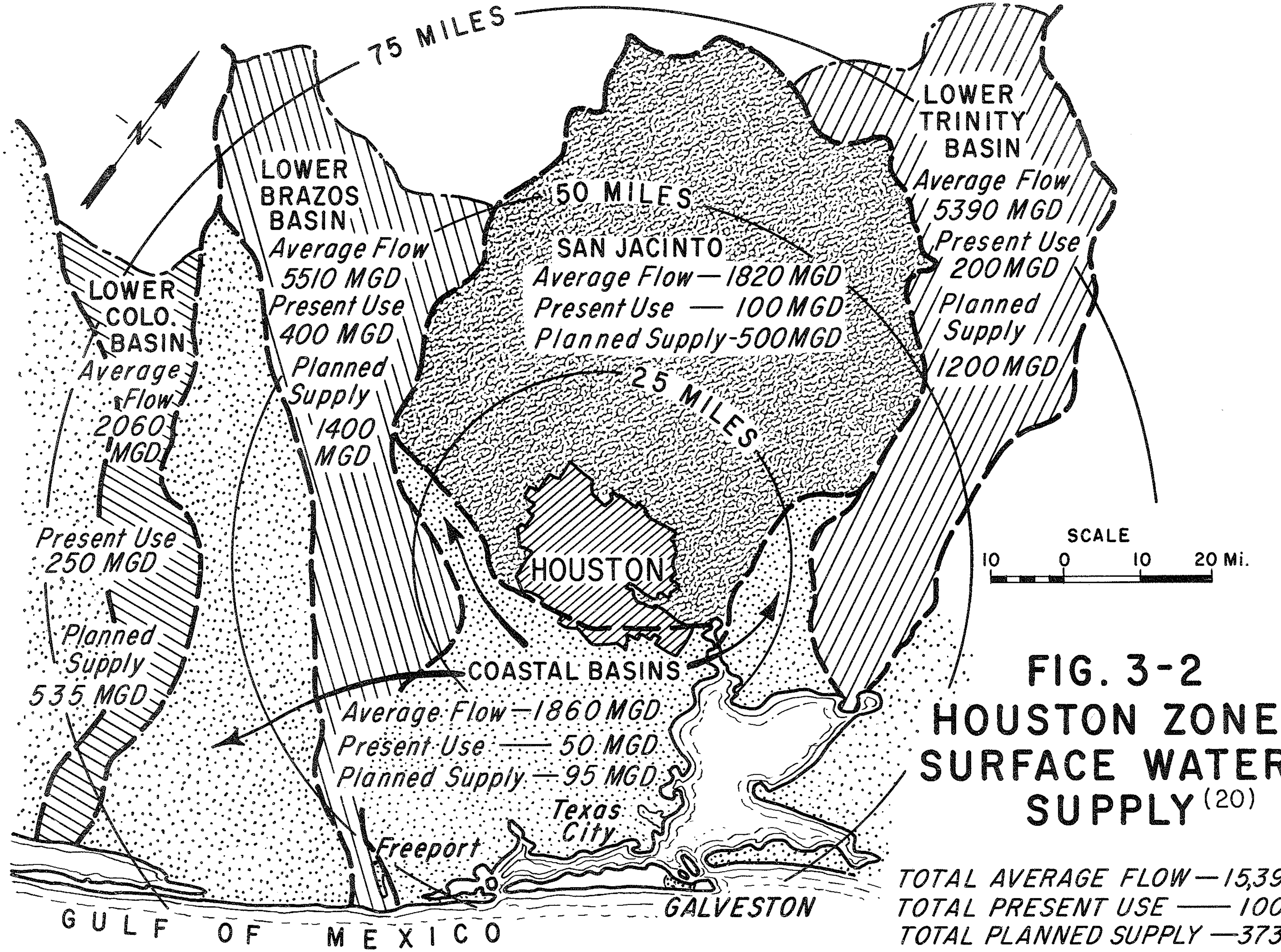


FIG. 3-2
HOUSTON ZONE
SURFACE WATER
SUPPLY [20]

TOTAL AVERAGE FLOW — 15,390 MGD
TOTAL PRESENT USE — 1000 MGD
TOTAL PLANNED SUPPLY — 3730 MGD

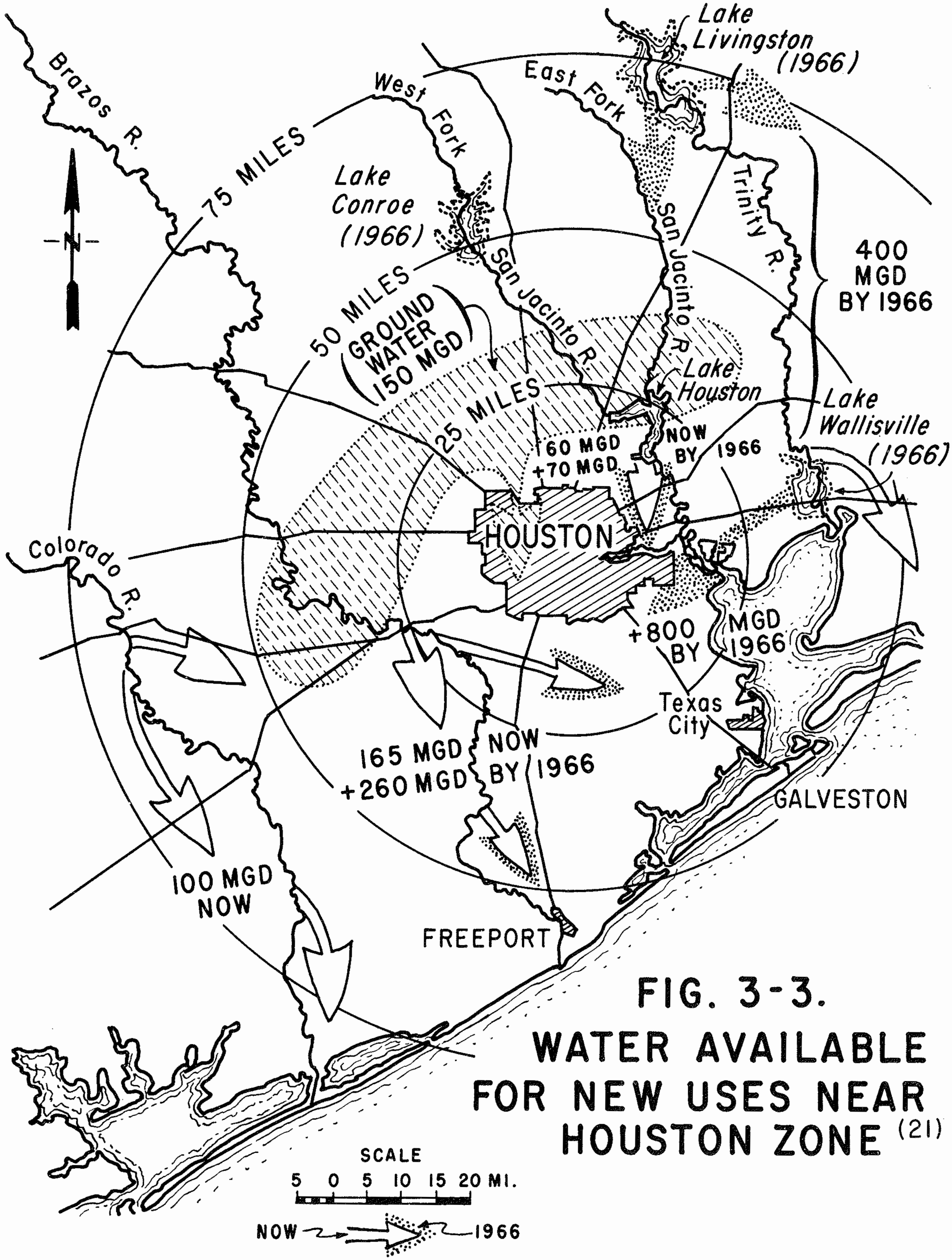


FIG. 3-3. WATER AVAILABLE FOR NEW USES NEAR HOUSTON ZONE (21)

Table 3-11. Major Reservoirs on Rivers Near Houston[18]

Reservoirs	Trinity River	San Jacinto River	Brazos River	Colorado River	Total
Existing	14	1	16	8	39
Acre-Feet of Storage	1,440,000	160,000	1,400,000*	2,060,000*	5,060,000*
Under Construction or Planned Soon	3	1	5	2	11
Acre-Feet of Storage	1,550,000	360,000	730,000	185,000	2,825,000
Total Existing and Planned**	41	8	31	13	93
Acre-Feet of Storage	9,650,000	2,000,000	4,700,000	3,250,000	19,600,000

*Includes storage used for hydroelectric power but providing incidental low flow regulation.

**Approximate, based upon best information available.

Table 3-12. Water Supply Reservoirs Within Houston Zone[19]

Location	Effective Storage Acre-Feet	Firm Yield MGD
Existing Lake Houston-San Jacinto River	160,000	160
Planned Honea Reservoir-San Jacinto River	360,000	72
Planned Livingston Reservoir-Trinity River	1,750,000	1,120
Planned Lake Wallisville-Trinity River	22,000	80
TOTAL	2,292,000	1,432

currently producing approximately 465 million gallons daily from over 100 wells. The major centers of ground water production are shown in Fig. 3-4. It is noted that the water level has dropped 100 feet, and it has been reported that some surface subsidence has occurred.

Water Requirements

The Houston area is, and will continue to be, the largest water-using complex in the Texas Gulf Coast area. All of the major water-using industries are presently located in this area, and all of the industries are expected to experience growth during the next fifty years. The present annual industrial fresh water use in Urban Houston alone is about 200,000 acre-feet.

Projected water use for Urban Houston is shown in Fig. 3-5. The assumed industrial expansion in water use for the year 2010 is mainly in chemicals, paper, and primary steel. The water requirements for the steel industry are expected to grow from 6,300 acre-feet in 1954 to 225,000 acre-feet in 2010, implying a steel ingot capacity in 2010 of 30 million tons annually. Further development of industry in Urban Houston to more than five times the current water use has been assumed. An allowance for the chemical industries of 282,000 acre-feet has also been assumed.

Fresh water use in the Galveston-Texas City area in 1958

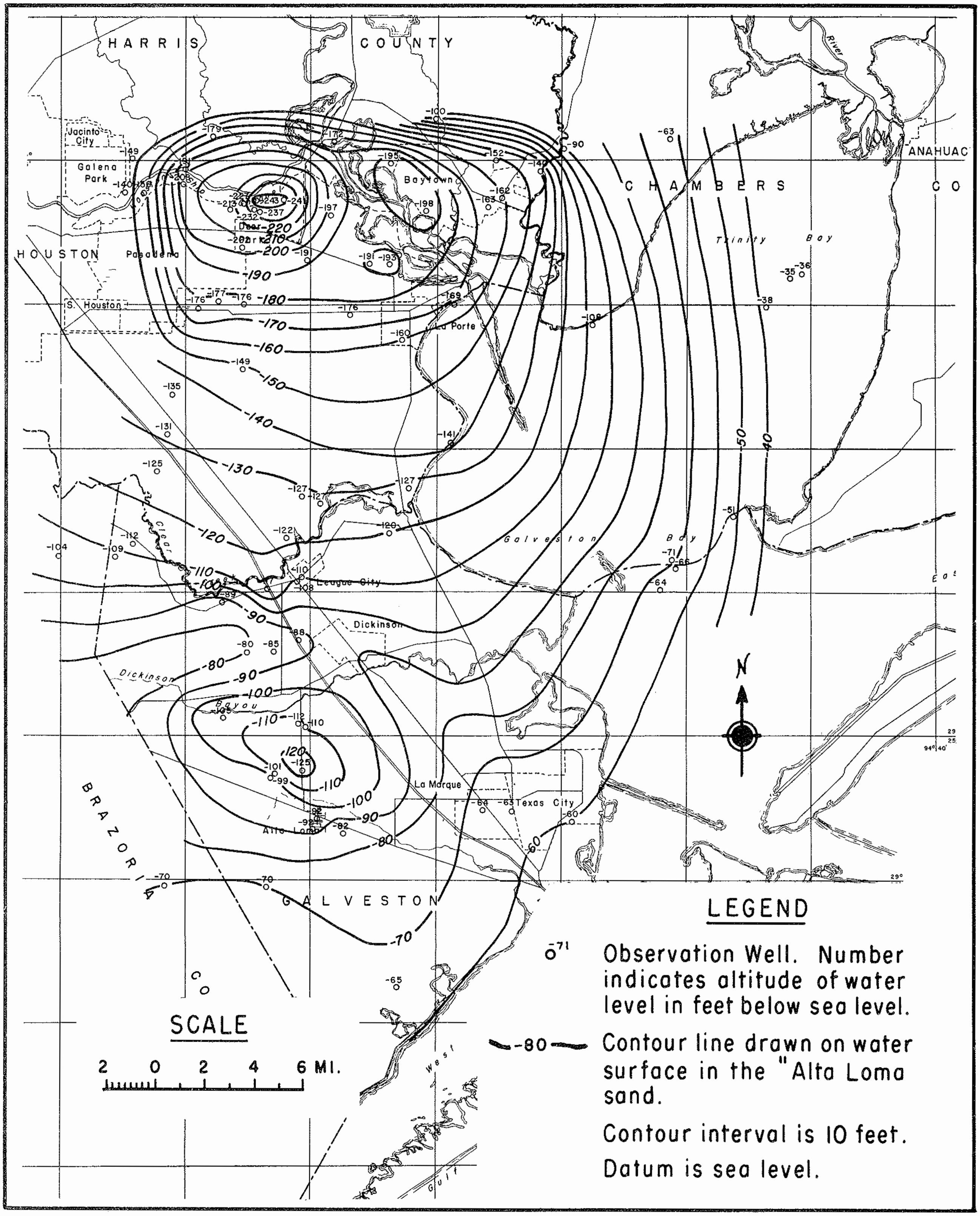


FIG. 3-4. APPROXIMATE ALTITUDES OF WATER LEVELS, IN FEET, IN WELLS SCREENED IN THE "ALTA LOMA SAND," GALVESTON, HARRIS, BRAZORIA, AND CHAMBERS COUNTIES, MAY 1962.[22]

amounted to about 75,000 acre-feet of which 52,500 acre-feet were used in the petroleum refineries and chemical plants at Texas City. For this area a base projection for the year 2010 indicates about 395,000 acre-feet, Fig. 3-6. Interestingly enough, these projections which were adopted by the U. S. Study Commission-Texas indicate that by the year 2010 the chemical industry at or near the Texas City complex will double that of the present Houston-Baytown area or will be approximately 22 times that of the 1958 level for Texas City.

Historical water requirement projections for the Houston Node are given in Fig. 3-7. They reflect a general development in anticipated growth of this area.

It is anticipated that the municipal and domestic demand will increase, as will the industrial demand, while the irrigation demand will gradually decrease. These projections are shown in Table 3-13 and Fig. 3-8.

Table 3-13. Water Use in Houston Zone, Present and Projected[26]

Use	Present MGD	Est. 1966 MGD	Est. 1980 MGD	Est. 2000 MGD
Irrigation	860	790	610	435
Municipal and Domestic	185	240	405	715
Industrial	430	720	1,420	2,530
Total	1,475	1,750	2,435	3,680

FIG. 3-5.
WATER USE TRENDS, HOUSTON(23)

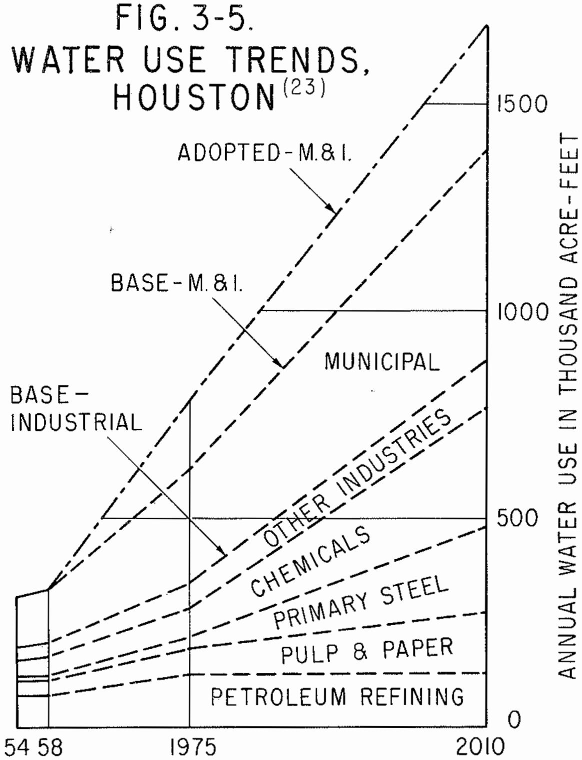


FIG. 3-6.
WATER USE TRENDS
GALVESTON-TEXAS CITY(24)

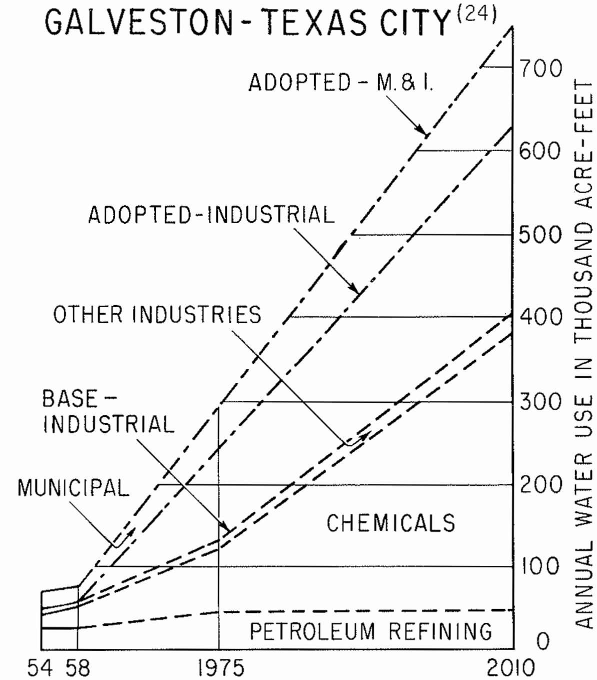
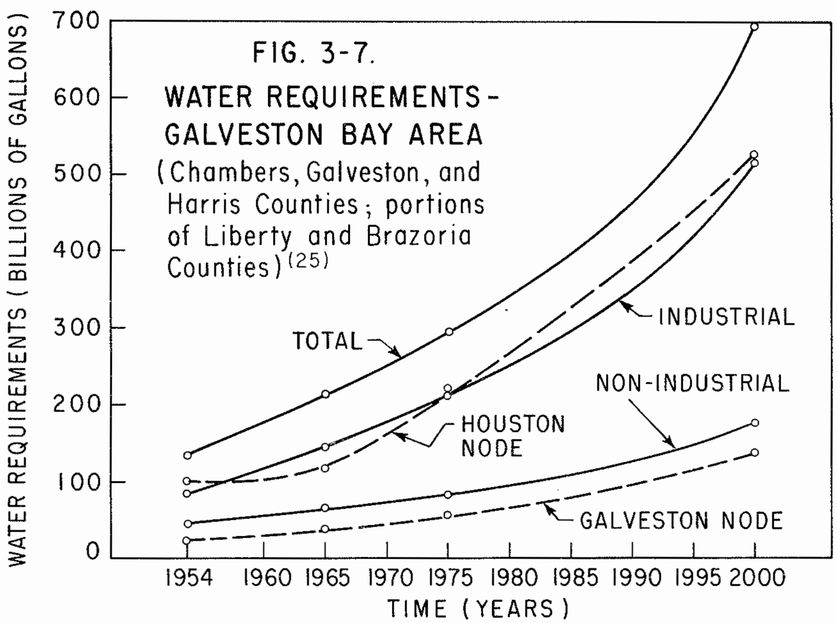


FIG. 3-7.
WATER REQUIREMENTS - GALVESTON BAY AREA
(Chambers, Galveston, and Harris Counties; portions of Liberty and Brazoria Counties)(25)



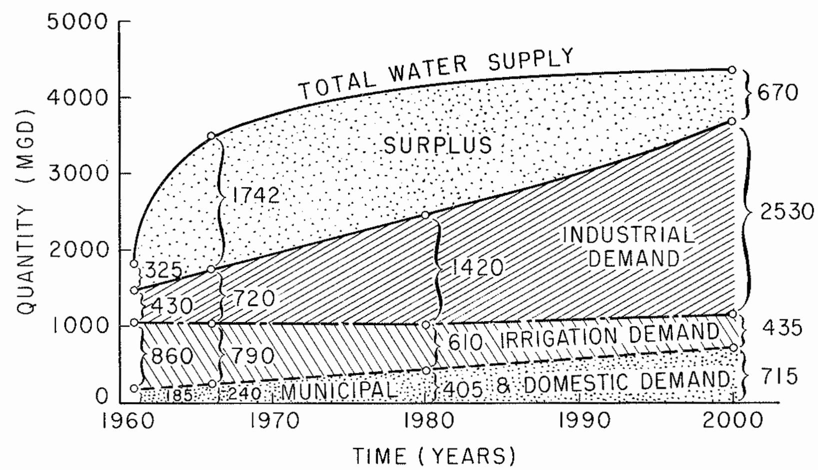


FIG. 3-8. COMPARISON OF FUTURE WATER SUPPLY AND DEMAND FOR THE HOUSTON ZONE(27)

The estimated total water demand for the year 2000 for the Houston Zone is 3,680 million gallons per day. As a comparison, the total water intake for the United States in the year 2000 is estimated to be 168.7 billion gallons per day and for the Western Gulf Region 31.7 billion gallons per day. By this time the Western Gulf Region will be the number-one water consuming region in the United States.

Approximately 1.8 billion gallons of water daily are now used or are available within this 75-mile zone, Table 3-14. Of this amount about 465 million gallons per day come from a thousand deep wells. In addition, by 1966 another 1.5 billion gallons can be added to this supply through the addition of currently planned surface reservoirs and another 150 million gallons a day from new wells.

The water development and requirements in the Clear Lake area as a result of the space center and other related activities are not as yet clearly defined. However, the increased use in future water requirements is obvious.

The use of the saline water around the Galveston Bay area has been increasing during the last decade, and this trend is likely to rise sharply in the future.

Table 3-14. Water Supply for the Houston Industrial Zone[28]

Source	Water Used or Available Now (MGD)				Additional Water Available Within 5 Years (MGD)			Total Supply Presently Planned (MGD)
	Irrig.	Mun.	Indus.	Tot.	Mun.	Indus.	Tot.	
Surface Water								
Trinity River	176	1	16	193		1200*	1200*	1200*
San Jacinto River	4	80	76	160	20	52	72	500
Brazos River	232	--	300	532	10	250	260	1400
Colorado River	265	--	100	365				535
Coastal Streams	85	--	--	85		10	10	95
Subtotal - Surface Water	762	81	492	1335	30	1512	1542	3730
Ground Water	207	140	118	465	10	140	150	620
TOTAL	969	221	610	1800	40	1652	1692	4350

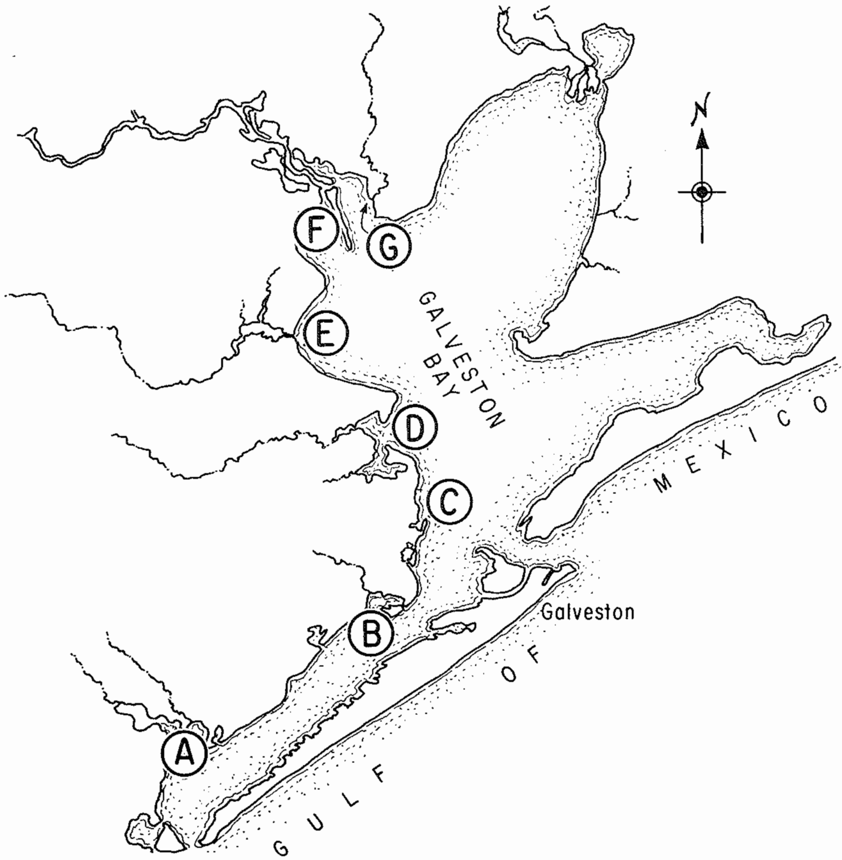
*Includes water for use near Lake Livingston and east of Trinity River.

Return Flows

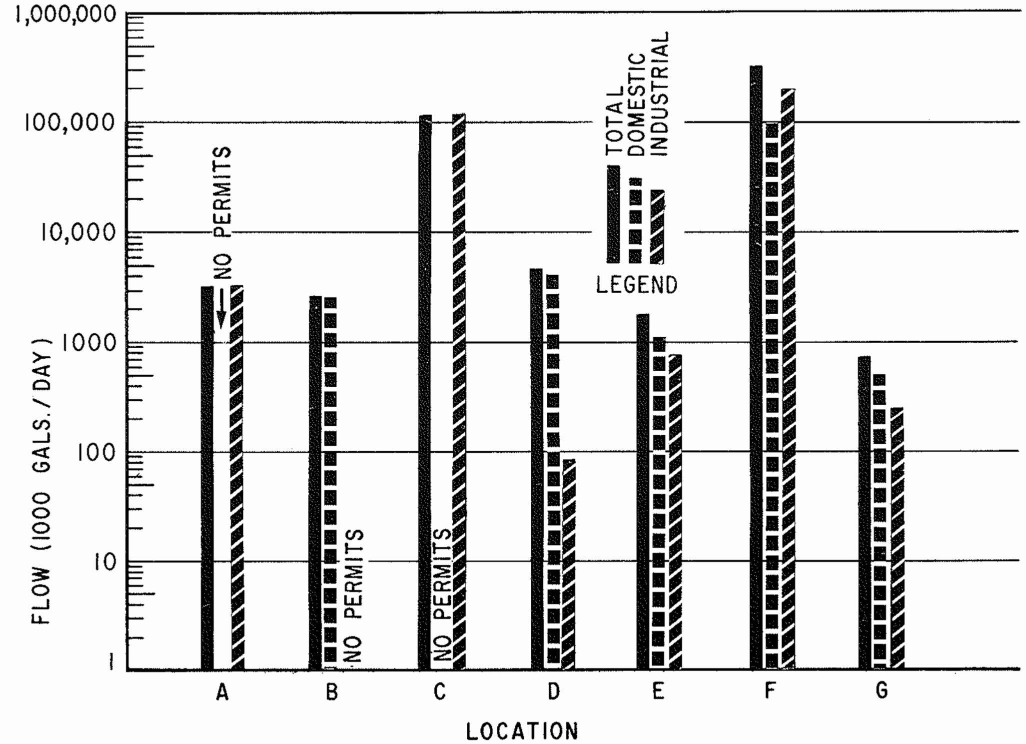
There are a lesser number of estimates available regarding return flows than there are on the water demands, and this is to be expected since the reuse of water after it has been diluted with the brackish bay water is not very likely. However, return flows to Galveston Bay from diverted waters of various river basins may be of major significance, and the contaminants in the return flows from domestic and industrial treatment plants may affect the entire ecology of Galveston Bay.

Return flows can be calculated from the discharges of the major domestic sewage treatment plants and industrial waste treatment plants. Figure 3-9 shows the return flow based on waste permits. It is noted that there are approximately 114 million gallons per day of domestic waste and 354 million gallons per day of industrial effluent being discharged into the Galveston Bay or tributaries. Based on the same ratio of water use to waste water produced, the return flows for the year 2000 would be a total of 2222 million gallons per day for the area under consideration. However, this prediction based on a ratio of use to waste flow is not likely to be as precise as projections based on qualities. A better relationship would be a total solids, total organic, and nutrient load.

A projection, Fig. 3-10, made by The University of Texas



GALVESTON BAY AREA



RETURN FLOWS PERMIT

FIG. 3-9. RETURN FLOWS (BASED ON PERMITS)
(Dec. 1, 1963)

(Environmental Health Engineering) for the Houston trading area in 1957, has shown that possibly by the year 2010 the reclaimed waste water may be as much as 450 billion gallons per year, of which roughly 350 billion gallons per year will be industrial water. It can be assumed, however, as the quality of the surface water supplies deteriorates with prior and more extensive use, the water intake will probably decrease; and such measures would have a material effect on the percentage of return flow.

Additional return flow studies have been made by the U. S. Bureau of Reclamation for Galveston and Trinity Bays. Tabulations have been made which depict the historic inflows into Trinity and Galveston Bays, the return flows based on historic runoff, the return flows based on future reservoir operations, and the return flows based on future reservoir operations which include the Texas Basins Project. These estimates are shown in Table 3-15. The firm return flows without the canal and with the Texas Basins Canal, respectively, are estimated to be 1.097 and 1.240 million acre-feet per year.

Much of the urban development around the large cities is not too well defined in terms of sewerage systems. Septic tanks are commonly used, and there have been no estimates as to the number of septic tanks within the Galveston Bay watershed. It can be assumed that as the domestic and industrial development continues to increase, more of these houses will join the central waste-water

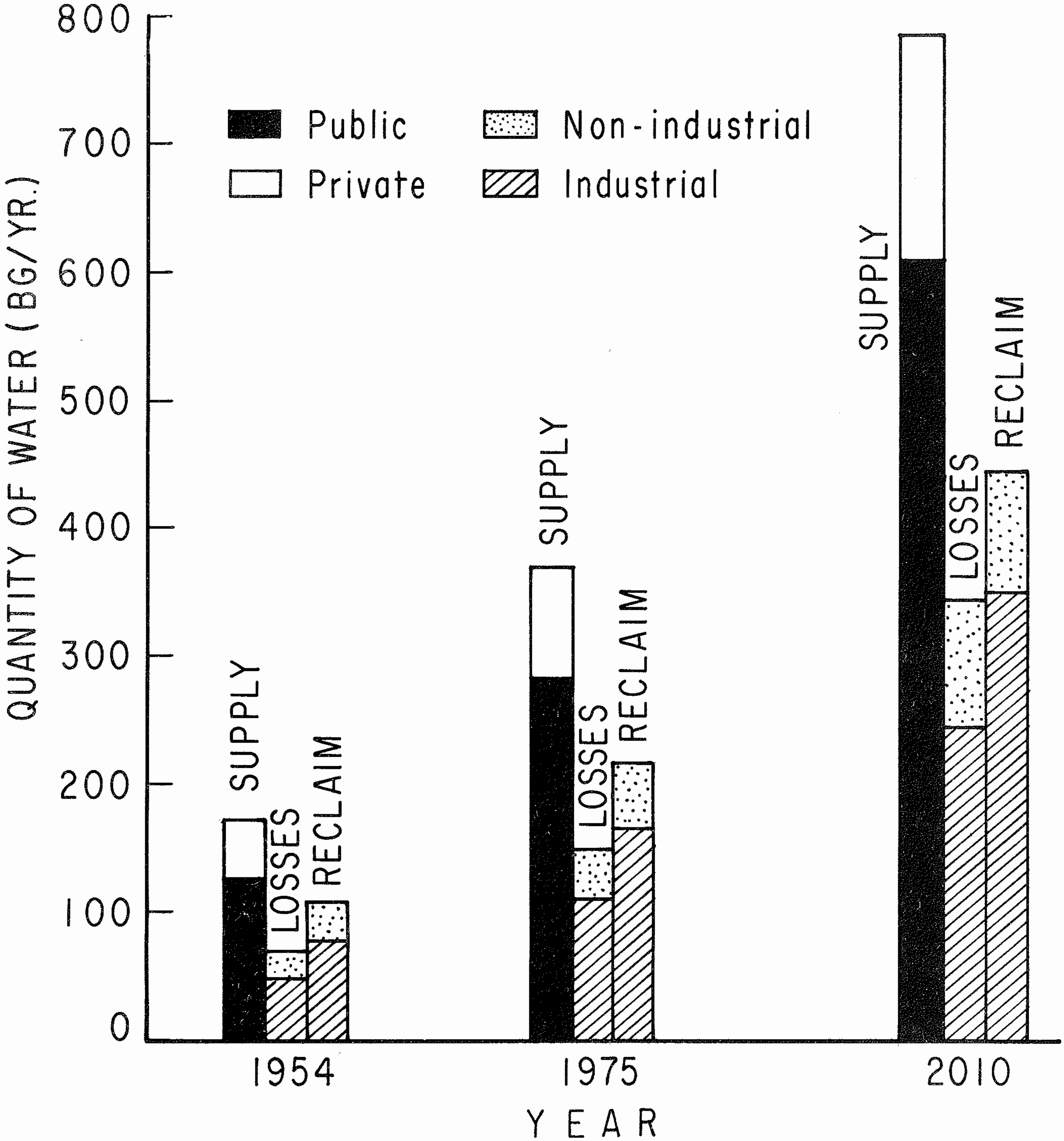


FIG. 3-10. WATER QUANTITIES, HOUSTON TRADING AREA (BILLION GAL/YEAR)[29]

Table 3-15. Galveston and Trinity Bay[25]

Unit: 1000 acre-feet

	Historic					Future							
1 Year	2 Recorded Trinity at Romayor & San Jacinto at Huffman Gages	3 Below Gages plus Buffalo Bayou & Other Streams	4 Return Flow	5 Rainfall on Bay	6 Total Fresh-water Inflow	7 Natural Below Reservoirs plus Buffalo Bayou & Other Streams	8 Rainfall on Bay	9 Spills from Wallisville & Houston Reservoirs plus Wallisville Navigation Release	10 Return Flow	11 Total Fresh-water Inflow	12 Spills from Wallisville & Houston Reservoirs plus Wallisville Navigation Release	13 Return Flow	14 Total Fresh-water Inflow
1941	13345	4696	113[a]	2123	20277	4192	2123	6197	1097	13609[b]	4646	1240	12201[c]
1942	10567	2044	119	1423	14153	1808	1423	6768	1097	11096	5422	1240	9893
1943	4672	1647	128	1705	8152	1507	1705	1694	1097	6003	734	1240	5186
1944	9746	2843	158	1514	14261	2418	1514	5680	1097	10709	4324	1240	9496
1945	14679	3409	164	1904	20157	2963	1904	10897	1097	16861	9030	1240	15137
1946	13286	4853	172	2021	20332	4367	2021	10165	1097	17650	8699	1240	16327
1947	6456	1801	179	1033	9469	1524	1033	3872	1097	7526	3197	1240	6994
1948	4227	606	189	644	5666	506	644	1495	1097	3742	383	1240	2773
1949	7249	2116	198	1682	12245	2834	1682	2226	1097	7839	806	1240	6562
1950	8659	1996	204	1132	11991	1722	1132	5418	1097	9369	3663	1240	7757
1951	1674	254	212	1200	3340	259	1200	70	1097	2626	70	1240	2769
1952	2883	858	225	1314	5280	786	1314	78	1097	3275	70	1240	3410
1953	5083	1747	236	1517	8583	1555	1517	292	1097	4461	70	1240	4382
1954	1577	457	249	910	3193	631	910	75	1097	2713	70	1240	2851
1955	2211	718	274	1161	4364	648	1161	130	1097	3036	70	1240	3119
1956	1064	246	291	657	2258	297	657	70	1097	2121	70	1240	2264
1957	13231	2315	321	1718	17585	2041	1718	2786	1097	7642	232	1240	5231
1958	6885	436	264		7585								
1959	6028	830	268		7126								
1960	7896	1201	272		9369								
1961	8351	1294	276		9921								
1941-56 Total				21940		28017	21940	55127	17552	122636	41324	19840	111121
1941-61 Total	136538	35052	4192		197722								
1941-56 Avg.				1371		1751	1371	3446	1097	7665	2583	1240	6945
1941-61 Avg.	6502	1669	200		9415								

[a]Does not include rice irrigation which has not been computed. Historic and 2010 condition rice return flow assumed to be approximately the same.

[b]Without canal and associated reservoirs. Total = Col. 7 + Col. 8 + Col. 9 + Col. 10.

[c]With Texas Basin Project. Total = Col. 7 + Col. 8 + Col. 12 + Col. 13.

collection systems, and these will contribute to the over-all return flow pattern.

Recreational and Sports Activities

The Galveston Bay area is striving to become the vacation center of the State and possibly the Southwest. Many of the local residents utilize Galveston Bay, Clear Lake, and tributary waters as year-round recreation and fishing facilities.

Galveston Island with its 32 miles of white, sandy beaches is one of the main attractions for tourists during the long summer months. A $2 million pleasure pier is currently an attraction for the City of Galveston. It is estimated that more than three million tourists visit the Galveston beaches annually.[31]

The main part of Galveston Bay is used extensively for boating and pleasure fishing, but it is not used to any great extent for duck hunting. East and West Bay are used as routes to and from many small bayous and sloughs which lie in the north bank where ducks can be found in great numbers.

Boating: Boating on Galveston Bay has become a timely recreation and is no longer the exclusive province of the sportsman or the week-end fisherman. The combination of the boat and the large protected bodies of water such as Clear Lake give the members of the urban population an opportunity to water ski, to find the best swimming holes possible, or to explore. Boating has taken on the characteristics of an ideal family sport.

The total dollar expenditure for pleasure boats in the United States from 1958 to 1959 showed an increase of 18.7 per cent. Similarly, the increase in the number of pleasure boats for the period of 1947 to 1959 showed an increase of 220 per cent.[32]

Estimates of the total number of boats in Texas are probably well in excess of a half million. In 1959 about 4.9 per cent of the boats in the nation were located in Texas. In the sale of outboard motors in 1959, Texas ranked sixth, while the City of Houston ranked fifteenth in the nation.

Fishing: Both recreational and commercial fishing are conducted in Galveston Bay and surrounding bodies of water, Fig. 3-11. However, commercial fishing is restricted to means other than the use of nets in the Galveston Bay area.

The recreational salt water fishing habits have been studied by Belden Associates and are abstracted in Tables 3-16 through 3-20. For each of the five listed species the activities of salt water fishermen on the Texas Gulf Coast, the comparative salt water catches, the total projection of fish caught, average number of days fished, and percentage of salt water fishermen, are depicted.

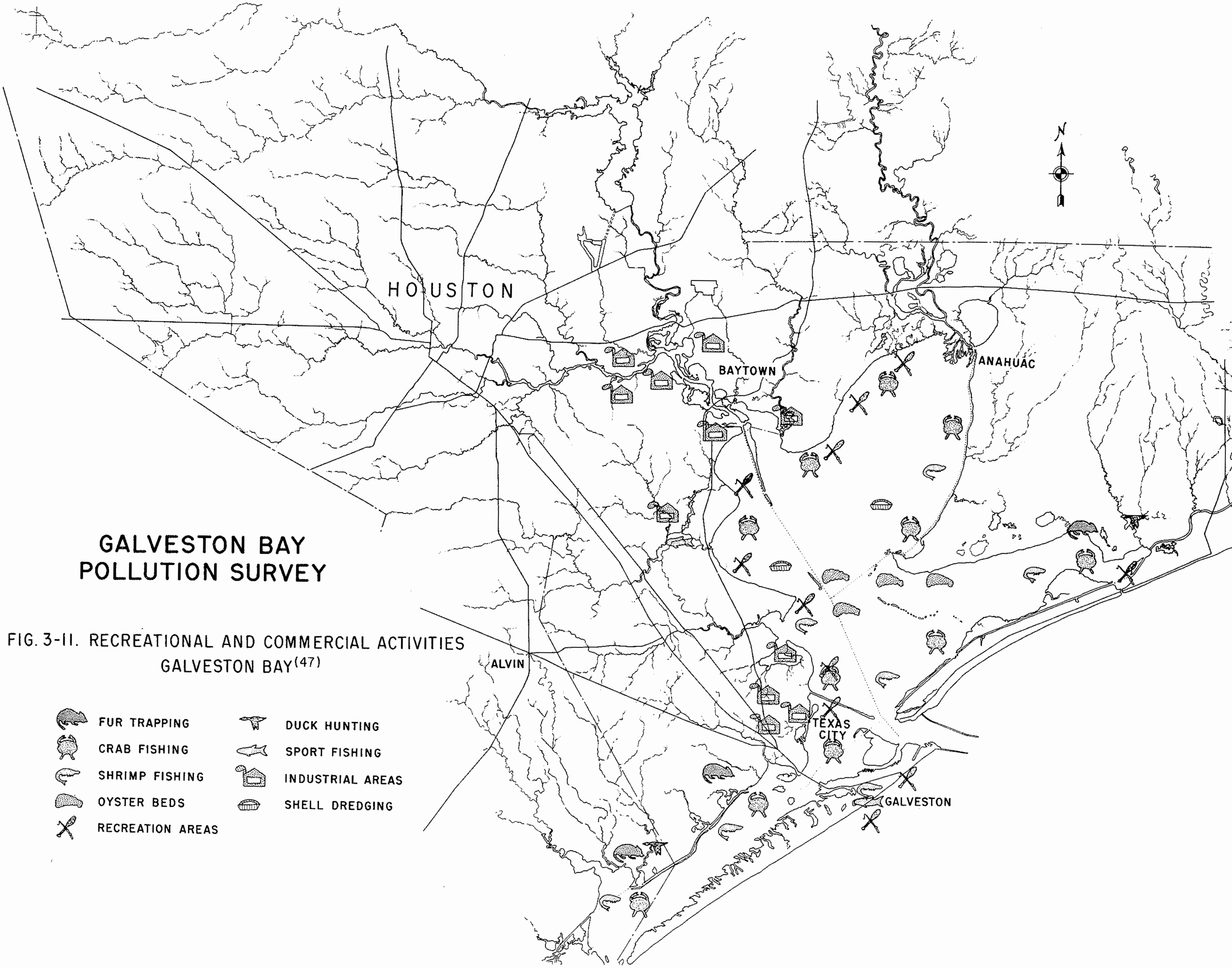


FIG. 3-11. RECREATIONAL AND COMMERCIAL ACTIVITIES GALVESTON BAY(47)

Notably, the Galveston-Freeport area produced more flounder and redfish than any area along the Texas Gulf Coast during the 1959-1960 period. However, a lesser proportion of the same fish were caught in this area during the 1957-1958 period. The Galveston-Freeport area also leads in both speckled trout and drum.

The 1959-1960 harvest was substantially less than the 1957-1958 harvest (Table 3-17), and this decrease was caused by an almost equal decrease in the amount of total hours spent by Texas sportsmen in quest of salt water fish (Table 3-18). Commercial and out-of-state fishermen are excluded. It is estimated that the decrease in catch has been attributed to both number of days, number of hours spent fishing, and number of fishermen. Table 3-19 shows that there was a decline in fishing activity in both coastal and inland fishing in this period.

Prior to June 10, 1962, the Texas Game and Fish Commission had conducted no creel census for Galveston Bay. However, a census was begun on June 10, 1962. It has not been completed, but the area known as Dollar Reef is probably the most heavily fished area in Galveston Bay. In Upper Trinity Bay, the area known as Fisher's Shoals is very popular.(38)

Tourism: The value of tourist expenditures around Galveston Bay waters is not known. First, there is the problem of estimating the increased value of tourism to the area under study, and second

Table 3-16. Salt Water Fishing Activity[33]

Salt-water Fishermen State-wide	Redfish % 1960	Redfish % 1958	Speckled Trout % 1960	Speckled Trout % 1958	Flounder % 1960	Flounder % 1958	Drum % 1960	Drum % 1958	Shrimp % 1960	Shrimp % 1958
Per cent who ever caught	52	51	70	68	47	39	45	40	16	16
Usually caught:										
From boat	57	67	60	66	42	50	52	60	56	66
From pier or jetty	27	29	32	30	29	27	36	32	23	11
While wading or surf fishing	24	22	17	19	34	32	16	18	19	24
Usually used:										
Rod and reel	90	90	91	90	64	66	88	87	--	--
Pole and line	6	7	8	7	7	4	10	8	--	--
Trotline	3	2	1	2	--	--	1	1	--	--
Gig	--	--	--	--	31	29	1	1	--	--
Drag seine	--	1	--	--	--	1	--	1	41	41
Trawl	3	--	2	1	--	--	1	1	33	39

Table 3-17. Comparative Salt Water Catches[34]

Type of Fish	1959-1960 Harvest Number Caught	1959-1960 Harvest Pounds Caught	1957-1958 Harvest Number Caught	1957-1958 Harvest Pounds Caught
Redfish	3,397,000	5,978,000	6,916,000	9,199,000
Speckled	10,085,000	13,211,000	17,135,000	20,905,000
Flounder	1,749,000	2,640,000	1,621,000	2,139,000
Drum	1,493,000	2,897,000	2,250,000	4,343,000

Table 3-18. Total Projection of Fish Caught[35]

Catch	1959-1960	1957-1958
Projected pounds caught (redfish, speckled trout, flounder, drum, shrimp)	26,322,000	39,586,000
Projected number of fishermen	665,200	748,000
Average number fishing days per fisherman	7.7	9.4
Average number hours fished per day	4.7	5.2
Average catch per unit of effort (pounds per man-hour of fishing)	1.09	1.08

Table 3-19. Average Number of Days Fished Per Fisherman[36]

Item	1960	1958
Coast	8.8	12.0
Inland	5.1	5.3
State	7.7	9.4

Table 3-20. Percentages of Salt-Water Fishermen Who Caught Each of the Five Species During the Twelve-Month Periods of the Two Surveys[37]

Type	During 9/59-8/60 %	During 9/57-8/58 %
Speckled Trout	56	58
Redfish	37	39
Drum	29	26
Flounder	29	24
Shrimp	8	9

there is the problem of determining how much of the estimated tourism can be attributed to the marine environment. The value of tourism, or at least of fishing, can be estimated to a limited extent by comparing Galveston and Corpus Christi Bays. Estimates made for the Corpus Christi area indicate that local residents spend about $91.00 per year for fishing equipment and other goods and services related to fishing.(39)

Commercial Fishing

Commercial fishing in the Galveston Bay area is an important segment of the economy as suggested in Table 3-21. The total fish catch is fairly large because menhaden exists in large numbers and is caught for its oil, with fertilizer being a by-product.

Table 3-22 shows the commercial catch, less shrimp, for Galveston, Trinity, East, and West Bays for the period 1959-1962. It is interesting to note the increased total catch between 1959 and 1962. The spotted sea trout is by far the largest catch in the Bay proper. It should be noted that netting of fish in Galveston Bay is prohibited.

Shrimp

The shrimp catch varies, but in 1962 over four million pounds were taken from the Bay area. It is noted from Table 3-23 that the total pounds of shrimp caught in the Bay have increased

Table 3-21. Pounds of Marine Products Taken from Galveston Bay Area
May, 1952 - May, 1963(40)

Species	1952-1953	1953-1954	1954-1955	1955-1956	1956-1957	1957-1958	1958-1959	1959-1960	1960-1961	1961-1962	1962-1963
Fish											
Buffalo, Fresh Water	--	--	--	--	--	--	--	--	14	7,588	85
Catfish, Fresh Water	--	--	--	--	--	--	--	725	6,735	13,202	9,518
Croaker	233	--	385	--	--	1,500	--	6,362	981	4,192	5,398
Drum (Black)	1,463	655	1,147	4,573	37,222	15,641	40,101	14,696	6,502	40,683	15,667
Flounders	16,349	9,778	13,933	7,802	7,297	12,039	12,877	16,033	16,879	37,155	9,808
Gafftopsail (seacatfish)	263	1,766	662	537	--	4,280	8,597	3,683	5,340	5,912	3,593
Gaspergou	--	--	--	--	--	--	--	--	659	757	564
Grouper	56,895	24,268	22,078	9,585	12,328	28,876	38,362	13,890	22,377	18,450	--
Jewfish	2,637	4,620	1,044	--	--	--	--	33	--	2,824	--
Ling (cabio)	1,251	100	10	--	--	--	--	994	984	5,819	--
Mackerel (Spanish)	270	156	199	10	--	1,210	289	67	1,304	933	--
Menhaden	61,397,380	67,290,320	53,290,560	55,118,427	60,470,170	59,575,326	99,084,290	133,380,250	15,573,950	98,616,603	--
Mullet	104	--	--	50	245	33,569	14,150	14,960	1,276	1,559	--
Pompano	12	17	--	72	--	395	368	228	194	9	2
Redfish (Red drum)	8,866	12,015	6,926	13,848	15,856	21,700	23,229	25,723	10,701	19,010	10,526
Redsnapper	742,612	570,604	846,162	631,558	618,240	853,274	737,707	253,618	600,285	845,007	--
Sheepshead	6,560	8,896	14,608	4,689	9,344	12,156	22,804	12,230	27,349	46,482	18,159
Trout, Spotted Sea	27,332	40,127	48,464	22,914	39,759	46,831	58,562	60,275	86,616	110,615	111,145
Tuna	--	--	--	--	--	--	60	--	--	--	--
Warsaw	16,344	8,711	8,908	22,786	5,147	20,565	23,792	14,810	26,281	52,035	--
Whiting (King Whiting)	32,574	38,799	37,272	27,151	11,721	13,405	22,369	15,588	15,908	59,175	2,271
Unclassified (scrapfish)	1,857	9,908	12,720	5,267	6,538	6,784	44,451	31,675	76,222	202,790	--
SUBTOTAL FISH	62,313,105	67,970,774	54,305,177	55,869,269	61,233,834	60,647,916	100,132,008	133,865,840	158,480,557	--	--
Shellfish											
Crabs (Blue)	27,419	50,378	64,951	262,610	149,419	148,954	145,930	254,868	249,810	275,838	42,556
Oysters*	102,339	468,729	246,896	619,642	1,117,678	72,602	172,160	262,515	231,792	418,337	1,070,652
Shrimp	6,995,952	7,799,062	8,643,000	11,864,643	--	--	--	--	--	--	--
Brown	--	--	--	--	7,578	13,639,011	9,827,534	19,337,804	20,991,109	8,382,140	556,975
Pink	--	--	--	--	11,941,526	--	--	--	--	--	1,627
Rock	--	--	--	--	--	--	993	--	--	--	--
Royal Red	--	--	--	--	--	--	--	10,062	1,103,509	--	400
Seabobs	--	--	--	--	--	--	--	--	--	--	2,418
White	--	--	--	--	1,573,919	--	2,140,963	4,071,376	2,080,056	5,009,110	2,365,742
Squid	--	--	--	--	--	--	3,938	10,062	9,458	16,717	17
SUBTOTAL SHELLFISH	7,125,710	35,768,928	8,954,847	12,746,895	14,790,120	16,001,530	15,555,718	24,557,752	24,665,734	14,102,142	--
GRAND TOTAL	69,438,815	36,694,619	63,260,024	68,616,164	76,023,954	76,649,446	115,687,726	158,423,565	183,146,291	114,192,429	--

*Converted to pounds of meat on basis of 8.75 pounds per gallon

Table 3-22. Commercial Catch--Galveston, Trinity, East and West Bays[41]

Type	1959 Wt (lb)	1959 Value ($)	1960 Wt (lb)	1960 Value ($)	1961 Wt (lb)	1961 Value ($)	1962 Wt (lb)	1962 Value ($)
Buffalo fish	---	---	---	---	---	---	7,600	950
Catfish and bullheads	12,900	3,856	11,700	2,925	15,200	5,320	14,200	4,260
Black drum	4,900	486	6,400	448	14,700	3,648	11,900	711
Red drum	9,500	1,727	2,100	378	500	90	2,600	575
Flounders	5,400	1,340	9,800	2,450	9,500	2,353	11,400	2,850
Sea Catfish	3,600	356	600	42	300	25	200	14
Spotted Seatrout	13,000	3,250	2,200	484	4,300	989	17,000	4,180
Freshwater Sheepshead	100	8	500	75	800	85	1,000	100
Saltwater Sheepshead	5,000	600	9,200	736	15,500	772	16,800	1,683
Food, unclassified	---	---	---	---	63,900	3,192	59,700	4,780
Bait & animal food	---	---	---	---	---	---	18,400	368
Crabs, blue, hard	107,600	5,391	102,400	5,836	128,600	7,012	311,300	15,569
Oysters, all	555,500	174,202	1,162,600	362,501	410,200	130,260	749,900	306,642
Croaker	6,400	614	1,200	84	200	10	---	---
King Whiting	2,200	216	---	---	---	---	---	---
White Seatrout	1,000	100	---	---	---	---	---	---
TOTAL	727,100	192,146	1,308,700	375,959	663,700	153,756	1,222,000	342,682

Table 3-23. Shrimp Harvest--Biological Year Totals[42]

Type	1956	1957	1958	1959	1960	1961	1962
Biological Year							
Brown	6,604	1,016	0	24,291	9,003	86,145	906,268
White	170,765	743,032	988,920	1,002,034	1,571,801	1,207,890	3,643,100
Total	177,369	744,048	988,920	1,026,325	1,580,804	1,294,035	4,549,368
Pounds Per Day							
Brown	24.6	1.0	0	33.6	6.8	70.6	236.1
White	663.7	729.3	917.4	1,634.1	1,122.8	600.2	1,053.1
Total	688.3	730.3	917.4	1,667.7	1,129.6	670.8	1,289.1
% Estuarine Catch							
Brown	1.9	--	0	11.1	10.6	15.0	48.9
White	13.1	26.9	26.6	29.0	29.3	31.5	53.7

considerably. Of interest is the fact that in 1962 the Galveston Bay catch for shrimp was about 50 per cent of the total estuarine catch.

The bait shrimp business for Galveston Bay for 1962 is shown in Table 3-24. The most activity takes place during June and the summer season.

The monthly distribution of catches is shown in Table 3-25. The white shrimp are the most predominant and the months during the summer and fall are most productive. The catches are reported on a heads-on basis in lb./day of trawling.

Some indication of the variation in brown and white shrimp catches near Galveston Bay is shown in Table 3-26. The brown shrimp constitutes by far the largest catch in the offshore areas.

Table 3-26. Commercial Production (thousands of pounds) of Penaeid Shrimp From Offshore Areas Adjacent to Galveston Bay(45)

Type	1956	1957	1958
Brown (*Penaeus aztecus*)	11,155	14,777	10,644
White (*Penaeus setiferus*)	2,974	1,025	4,871
Pink (*Penaeus duorarum*)	1	4	17

Table 3-24. Bait Shrimp Survey Galveston Bay (1962) (43)

Month	Total Prod. in Pounds	Estimated Total Effort in Hours
January	2,000 ± 500	200 ± 20
February	200 ± 10	50
March	1,400 ± 500	710 ± 270
April	2,400 ± 700	1,430 ± 480
May	71,200 ± 13,300	2,340 ± 600
June	191,700 ± 28,200	4,180 ± 700
July	180,400 ± 27,000	6,320 ± 830
August	189,800 ± 33,300	7,920 ± 930
September	138,100 ± 25,400	4,830 ± 670
October	160,200 ± 30,000	3,450 ± 640
November	93,500 ± 24,700	1,740 ± 340
December	31,400 ± 8,100	420 ± 110
Totals	1,062,900	33,610
1962 x total yield in lbs/unit effort = 31.6		

Table 3-25. Monthly Catches of Shrimp in Galveston Bay (Heads on basis in lb/day) (44)

Type and Month	1956	1957	1958	1959	1960	1961	1962	1963
BROWN								
January	--	--	--	--	--	--	--	--
February	--	--	--	--	--	--	--	--
March	--	--	--	--	--	--	--	--
April	--	353.0	--	--	--	--	--	--
May	--	--	--	--	--	359.6	521.6	819.3
June	638.7	--	--	618.0	--	1517.5	1504.0	1021.2
July	2403.0	--	--	687.0	548.0	716.4	803.7	--
August	--	--	--	176.1	28.5	86.6	76.2	--
September	--	0.9	--	62.2	0.9	0.2	--	--
October	6.0	--	--	44.9	--	--	1.4	--
November	--	--	--	--	--	--	--	--
December	--	--	--	--	--	--	--	--
Total	24.6	1.0	--	91.9	6.8	70.6	236.1	
WHITE								
January	--	--	--	--	--	1265.1	1483.3	663.3
February	--	--	--	--	--	680.0	--	--
March	504.0	--	--	--	--	396.9	--	--
April	314.7	--	--	293.3	--	--	77.0	88.0
May	--	--	--	258.2	--	383.5	3.6	78.0
June	323.3	--	--	--	282.5	0.1	3.6	5.9
July	59.0	--	--	1213.6	188.0	101.7	42.1	--
August	--	857.4	1037.3	1956.8	1062.1	601.1	1175.8	--
September	915.6	768.4	914.8	2228.4	1299.1	984.5	992.3	--
October	558.1	605.3	696.0	1447.3	1036.5	1101.5	2294.4	--
November	501.2	392.7	507.5	1077.2	1436.1	1307.8	811.4	--
December	--	--	717.7	--	894.1	922.9	837.4	--
Total	650.6	728.6	805.5	1440.1	1175.5	989.3	945.4	
COMBINED								
January	--	--	--	--	--	1265.1	1483.3	663.3
February	--	--	--	--	--	680.0	--	--
March	504.0	--	--	--	--	396.9	--	--
April	314.7	353.0	--	293.3	--	--	77.0	88.0
May	--	--	--	258.2	--	600.8	525.1	897.4
June	962.0	--	--	618.0	282.5	1517.6	1507.6	1026.6
July	2462.0	--	--	1955.0	736.0	818.1	845.8	--
August	--	857.4	1037.3	2132.9	1090.5	687.6	1252.0	--
September	915.6	769.3	914.8	2290.6	1300.1	984.9	992.3	--
October	564.2	605.3	696.0	1492.1	1036.5	1101.5	2294.4	--
November	501.2	392.7	307.5	1077.1	1436.1	1307.8	811.4	--
December	--	--	717.7	--	894.1	922.9	337.4	--
Total	675.2	729.6	805.5	1514.3	1182.3	1059.9	1181.5	

Oysters

Over a million pounds of oysters (Table 3-21) were taken from the Galveston Bay Area during the period September 1962 to May 1963. The oyster production for each biological year has increased since 1957 when the total oyster harvest was only 72,602 pounds.

Historical data for the period from 1936 to 1953 are presented in Table 3-27. These data indicate that oyster production in the Galveston Bay Area was much less than that reported during the last five years. It should be noted, however, that oyster harvesting was prohibited in Lower Galveston Bay around Galveston and Texas City during 1944 because no adequate sewage treatment facilities were available. After sewage treatment was initiated in 1951, these areas of the Bay were opened for oyster harvesting. The harvesting of oysters from the Bay has continued to increase annually since 1951.

Table 3-27. Production of Oysters in The Galveston Bay Area (46)
(Pounds Shucked Oysters)

Year	Texas Total	Galveston Bay
1936-37	690,648	32,346
1937-38	1,249,912	32,338
1938-39	938,798	810
1939-40	959,504	12,707
1940-41	1,203,424	9,693
1941-42	664,404	10,746
1942-43	511,574	37,100
1943-44	471,511	38,910
1944-45	577,642	2,421
1945-46	594,367	1,080
1946-47	712,873	2,999
1947-48	467,572	2,064
1948-49	230,065	——
1949-50	69,195	263
1950-51	75,435	5,688
1951-52	176,455	20,148
1952-53	292,852	102,339

CHAPTER 4

CHEMICAL AND BIOCHEMICAL CHARACTERISTICS (HISTORICAL)

Galveston Bay is typical of many coastal bodies of water. The Bay periodically receives variable influxes of fresh water and waste materials. Factors which influence the chemical composition of the Bay also affect the ecology, and the net result may be reflected in the benefits which are derived from these waters. Benefits may be expressed in terms of economic value and the well-being of man.

A discussion of the effects of effluents will be presented as follows:

- General Effects
- Houston Ship Channel (Morgan's Point to Turning Basin)
- Trinity Bay
- Upper Galveston Bay (including Clear Lake)
- Lower Galveston Bay
- East Bay
- West Bay

General Effects

Chemical characteristics of the Bay can conceivably be changed through several means:

1. Regulation of fresh water inflow will change the salinity.

2. Control of tidal exchanges through the construction of hurricane walls, flood control structures, harbor facilities, and shipping channels may possibly change the aquatic environment and assimilative capacity.

3. Degradation of the water through use or direct pollution of the clean waters may stimulate the growth of undesirable aquatic systems.

All of these considerations can materially affect the natural transport mechanism, dilution capacity, and productivity of the Galveston Bay system.

A body of water as large as Galveston Bay has a considerable capacity to transport and dilute waste substances. The Bay also has the facility to support a vast variety of marine life. In addition, large amounts of organic material can be assimilated because of factors which sustain an active microbiological population. The water in the Bay is shallow, providing an opportunity for considerable photosynthetic reoxygenation. However, the capacity of Galveston Bay to assimilate waste materials is not unlimited.

Some of the chemical parameters which are important in the evaluation of the quality of water include:

- Biochemical oxygen demand (BOD, 5-day, 20°C)
- Chemical oxygen demand (COD)
- Dissolved oxygen (DO)
- Salinity
- Surface active agents
- Refractory organic compounds
- Toxic Compounds
- Settleable, suspended, and dissolved solids
- Oil-like substances

This report is limited primarily to a discussion of the oxygen demand, available oxygen, and salinity. Very little information is available on the amount of toxic or refractory materials in the water.

Table 4-1. Total Effluent Characteristics as Depicted by Permits
(December 1, 1963)

Location and Source	Flow 1000 gal/ Day	BOD lb/Day	COD lb/Day	Suspended Solids lb/Day
Cedar Bayou:				
a. Domestic	535	90	-----	5
b. Industrial	222	8	46	30
c. Sub-total	757	98	46	35
Ship Channel				
a. Domestic	104,068	35,596	-----	75,620
b. Industrial	209,616	236,633	288,066	264,193
c. Sub-total	313,684	272,229	288,066	339,813
Clear Lake:				
a. Domestic	1,163	221	-----	327
b. Industrial	748	-----	-----	-----
c. Sub-total	1,911	221	-----	327
Dickinson Bay & Moses Lake				
a. Domestic	4,700	784	-----	1,184
b. Industrial	86	34	-----	34
c. Sub-total	4,786	818	-----	1,218
Texas City:				
a. Domestic	-----	-----	-----	-----
b. Industrial	135,201	103,677	170,187	3,746
c. Sub-total	135,201	103,677	170,187	3,746
Highland Bayou:				
a. Domestic	2,740	457	-----	695
b. Industrial	-----	-----	-----	-----
c. Sub-total	2,740	457	-----	695
Chocolate Bay:				
a. Domestic	-----	-----	-----	-----
b. Industrial	3,337	798	-----	-----
c. Sub-total	3,337	798	-----	-----
Others:				
a. Domestic	835	139	-----	138
b. Industrial	4,618	-----	-----	8
c. Sub-total	5,453	139	-----	146
Total Domestic	114,041	37,287	-----	77,969
Total Industrial	353,828	341,150	458,299	268,011
GRAND TOTAL	467,869	378,437	458,299	345,980

A summary of flow and waste quality information is shown in Fig. 4-1 and Table 4-1. These data represent the information obtained from permits dated prior to December 1, 1963. Almost all of the existing plants are included in this tabulation. The total average effluent is about 468 million gallons per day. The total average daily quantity of BOD and COD, respectively, are about 378 and 458 thousand pounds. Almost 67 per cent of the total permitted effluent discharged from domestic and industrial sources entering Galveston Bay originates in the Houston Ship Channel above Morgan's Point. Similarly, industrial and domestic contributions above Morgan's Point are 45 and 22 per cent, respectively, of the total discharge into Galveston Bay. About 29 per cent of the total waste flow into Galveston Bay originates around the Texas City area and represents only industrial waste discharges.

A complete listing of the domestic and industrial permits are given in Appendix Tables F-1 and G-1, respectively. Summary data of the permits are tabulated for each receiving stream in Appendix Table H-1.

Special attention is directed to the fact that chemical, biochemical, and bacteriological data have been collected by a variety of people, and numerous sampling and analytical techniques have been employed. No attempt has been made in this report to evaluate the various techniques, although it must be recognized that some discrepancies may exist.

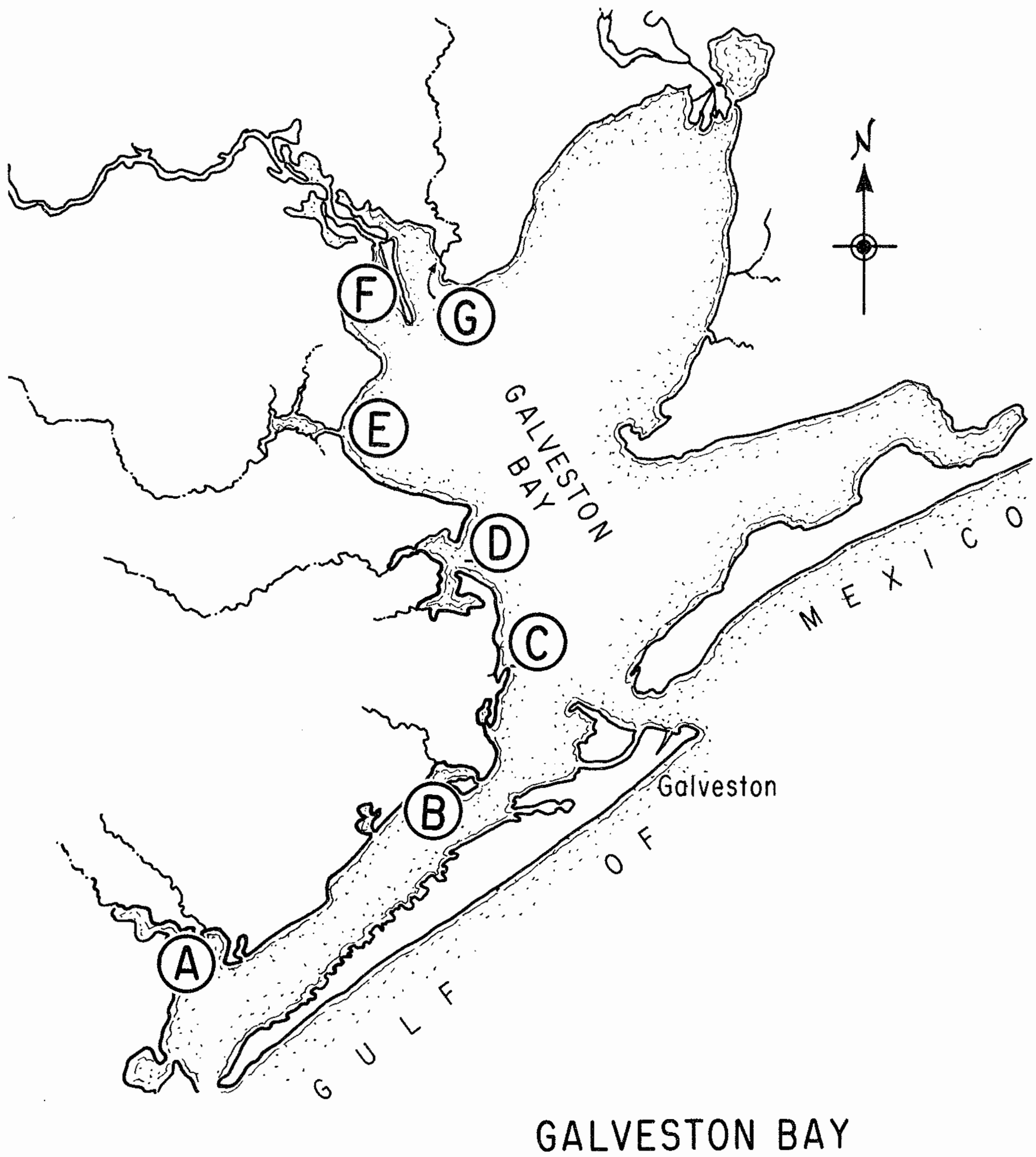


FIG. 4-1. SUMMARY OF WASTE TREATMENT PLANT EFFLUENTS (BASED ON PERMITS) (DEC 1, 1963)

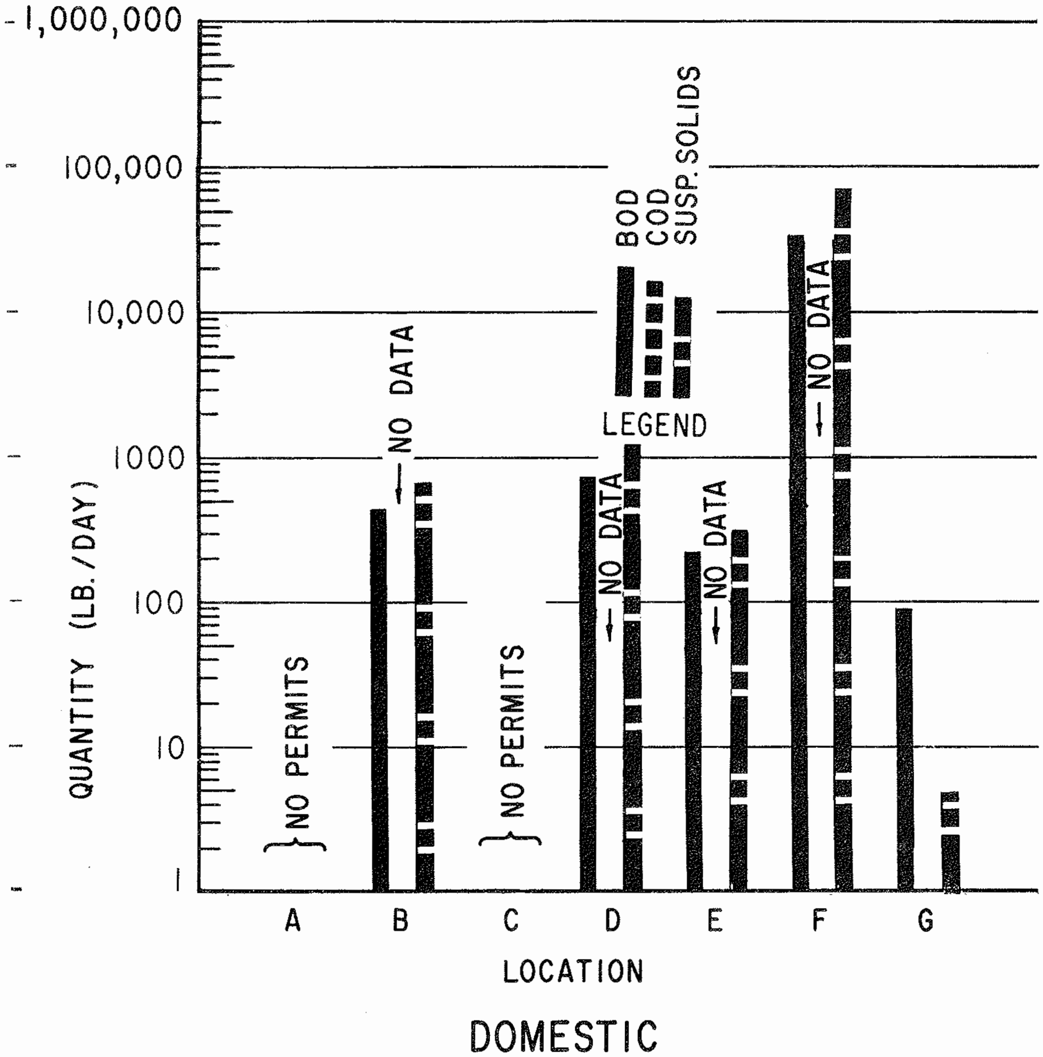


FIG. 4-1. SUMMARY OF WASTE TREATMENT PLANT EFFLUENTS (BASED ON PERMITS) (DEC 1, 1963)

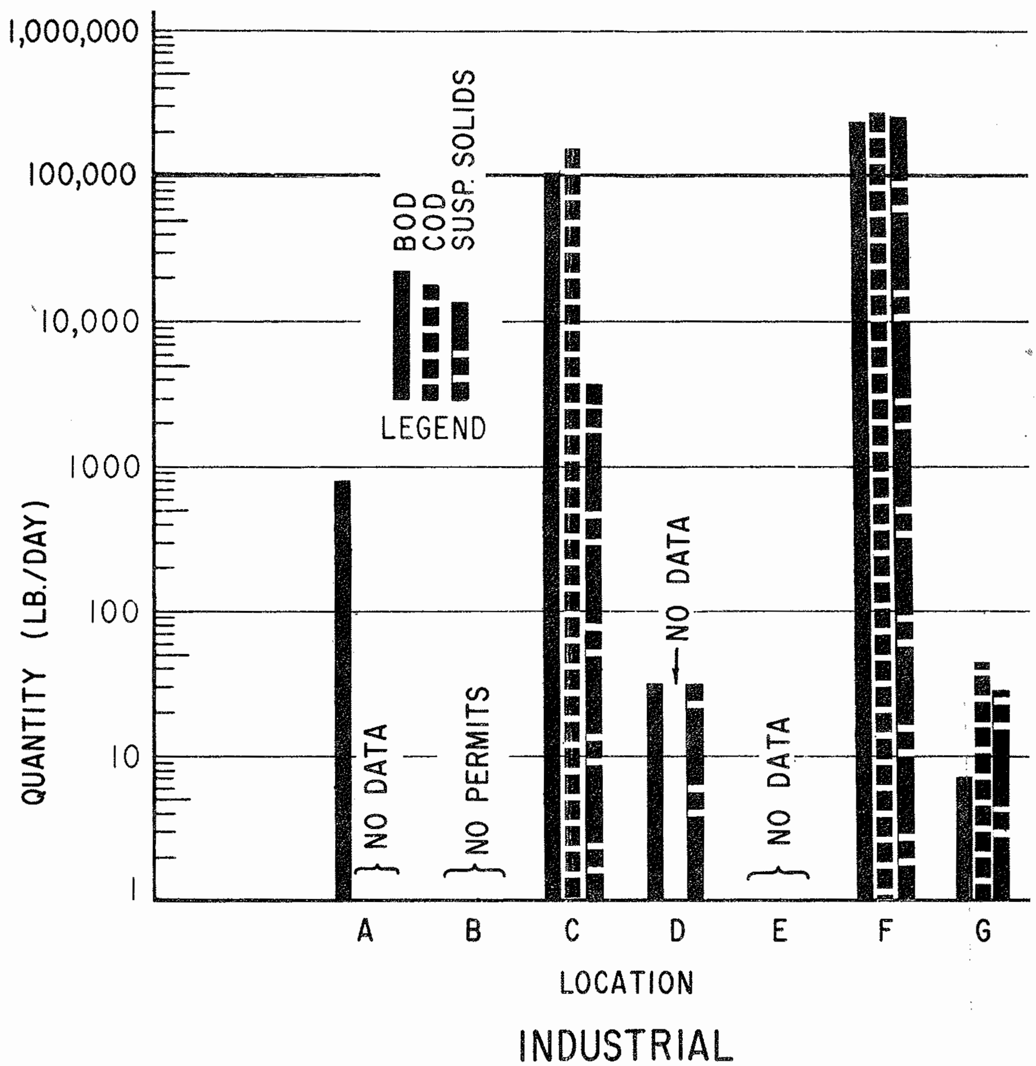


FIG. 4-1. SUMMARY OF WASTE TREATMENT PLANT EFFLUENTS (BASED ON PERMITS) DEC 1, 1963)

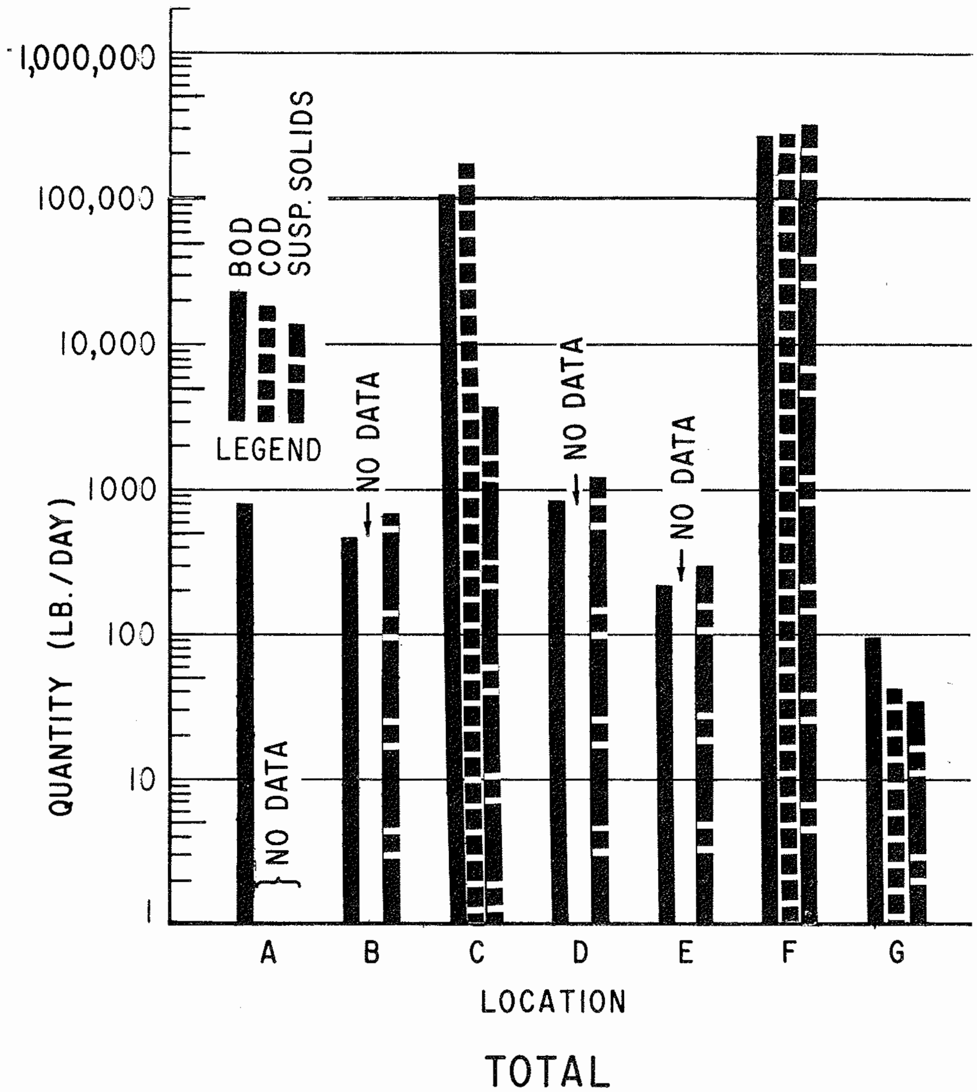


FIG. 4-1. SUMMARY OF WASTE TREATMENT PLANT EFFLUENTS (BASED ON PERMITS) (DEC 1, 1963)

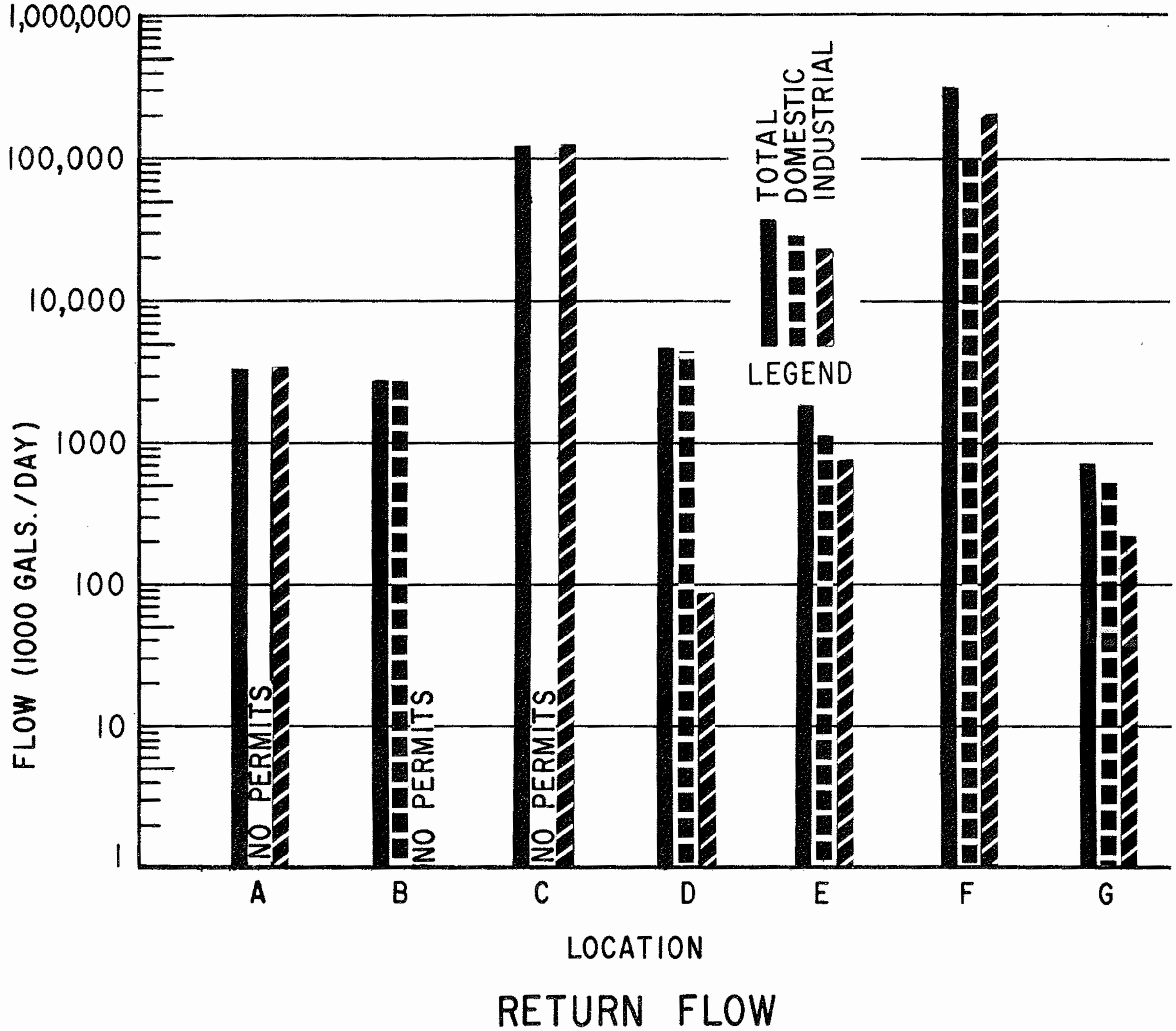


FIG. 4-1. SUMMARY OF WASTE TREATMENT PLANT EFFLUENTS (BASED ON PERMITS) (DEC 1, 1963)

Houston Ship Channel (Morgan's Point to Turning Basin)--Chemical Indicators

Biochemical Oxygen Demand: The biochemical oxygen demand test reflects the oxygen consumption of microorganisms during the degradation of organic materials. This test is therefore important in evaluting pollution. The laboratory test for BOD usually involves an incubation of a prepared sample for five days at 20°C; however, the validity of the result is dependent on the manner in which the sample was collected, the mode of transportation of the sample to the laboratory, the microorganisms used as seed, the dilution water used in the test, as well as the temperature and time of incubation.

The average industrial discharges into the Houston Ship Channel account for about 236,633 pounds of BOD per day, and the total average BOD is 272,229 pounds per day. This total BOD load was calculated from the waste-water discharge permit records. The above BOD values constitute about 72 per cent of the total BOD, based on permits, discharged into the Galveston Bay system.

The results of the recent Texas State Department of Health (TSDH) Survey are given in Fig. 4-2. These results were obtained during the period June 1 to December 1, 1963. Maximum, average, and minimum BOD values are plotted for about 25 stations. In general, average BOD values were relatively low (1 to 11 mg/l). During this survey, a

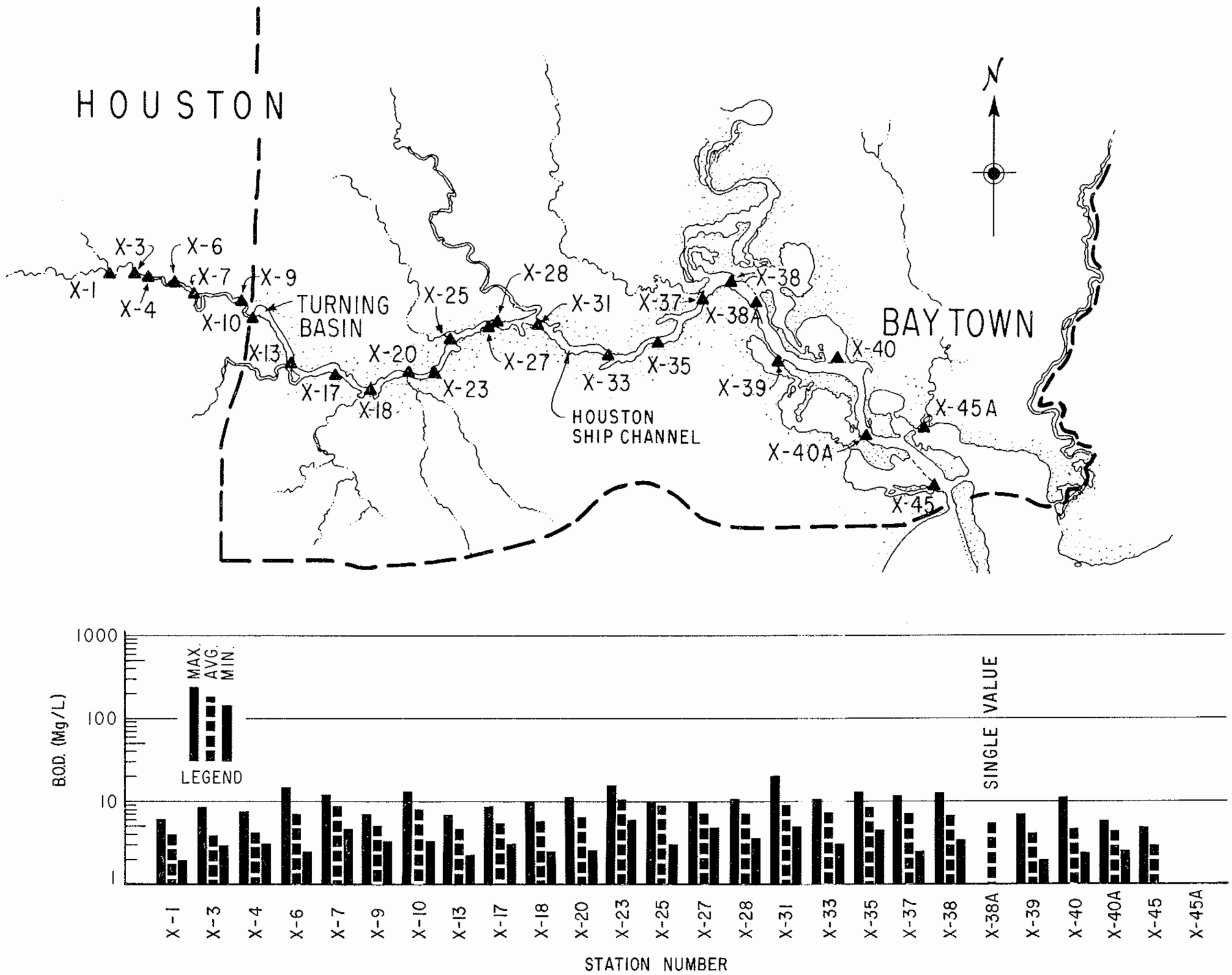


FIG. 4-2. BIOCHEMICAL OXYGEN DEMAND - HOUSTON SHIP CHANNEL
(June 1 - Dec. 1, 1963)

maximum BOD of 21 mg/l was found at Station X-31. Station X-23 indicated both the greatest average (10.7 mg/l) and minimum (6.0 mg/l) BOD values.

Monthly BOD data reported by the City of Houston for a period 1933 to 1941 are shown in Table 4-2. Additional data for the period 1951 to 1963, inclusive, are available but were not supplied for inclusion in this report. Table 4-2 provides annual average BOD data as well as ranges of BOD at 20 typical stations along the Houston Ship Channel. The City of Houston through these monthly surveys has contributed significantly to the historical pattern of pollution.

Chemical Oxygen Demand: According to the industrial permits, the average daily amount of COD discharged into the Houston Ship Channel is approximately 288,066 pounds. This quantity of COD represents about 63 per cent of the total industrial contribution to the Galveston Bay System. Data are not available for COD contributions from domestic sewage treatment plants.

As noted in Table 4-1 the COD load is considerably larger than the BOD load. It should be pointed out that all industrial wastes were not characterized by BOD and COD. However, on the basis of available data the COD:BOD ratio is 10:8 for the industrial wastes released to the Houston Ship Channel. Although both tests represent an oxygen demand, the BOD and COD figures need not necessarily be the same.

It has been reported by others that both the COD and BOD loads are greater in the upper section of the Houston Ship Channel than

Table 4-2. BOD in Houston Ship Channel (1)

Station[a]	1933		1937		1938		1939		1940		1941	
Buffalo Bayou, Shepherd Drive	15.1[b]	0-30[c]	9.4	6-18	6.7	2-21	6.8	4-12	5.4	0-17	5.8	2-16
Little White Oak Bayou, 4.6 miles from White Oak Bayou	16.8	0-24	9.0	2-18	5.6	0-12	6.5	1-34	6.7	4-8	6.4	2-14
Little White Oak Bayou, 0.8 mile from White Oak Bayou	8.4	2-34	9.8	2-26	8.7	2-40	5.7	1-20	4.3	0-14	8.4	2-34
White Oak Bayou, 8.6 miles from Channel	17.8	0-52	8.3	2-14	4.1	0-10	37.8	6-82	4.4	1-18	4.8	0-6
White Oak Bayou, Confluence with Little White Oak Bayou	23.0	0-38	26.7	2-156	7.4	0-12	6.0	2-12	5.9	2-12	7.8	4-16
White Oak Bayou, 1.2 miles from Channel	51.5	10-160	29.5	19-156	49.9	8-116	37.8	6-82	49.9	2-83	23.3	4-64
Buffalo Bayou, White Oak Bayou Entrance	30.0	0-46	30.3	6-72	18.5	8-56	18.9	4-35	25.3	0-58	8.7	2-16
Buffalo Bayou, Turning Basin	25.5	14-40	12.0	4-20	16.5	4-34	12.7	2-44	10.9	0-27	9.1	0-22
Brays Bayou, First Station	10.7	0-28	9.5	4-18	13.8	1-31	5.4	0-24	5.5	0-11	5.4	3-8
Brays Bayou, at Houston Ship Channel	27.5	6-52	32.5	6-72	14.3	7-22	17.6	6-36	13.2	4-25	12.9	3-32
Buffalo Bayou, Mouth of Brays Bayou	23.6	6-42	16.2	4-40	15.3	0-42	11.7	0-34	8.6	0-16	9.6	2-18
Sims Bayou, First Station	16.7	0-38	12.2	4-24	5.9	0-16	7.7	0-42	2.0	0-8	2.8	2-4
Sims Bayou, 1.2 miles from Channel	15.3	0-28	19.8	6-40	6.7	2-22	2.3	0-8	7.0	0-22	4.1	2-8
Buffalo Bayou, 500' below Sims Bayou	23.5	0-44	20.4	4-58	10.8	0-22	9.1	2-22	7.2	0-16	9.3	4-18
Buffalo Bayou, 500' below Greens Bayou	18.7	4-38	10.3	4-14	8.6	0-28	7.7	4-14	6.8	0-14	9.3	2-16
Buffalo Bayou, ¼ mile below Shell Refinery	17.8	0-32	15.9	4-28	12.1	4-26	9.1	0-17	5.8	0-14	8.9	0-26
Buffalo Bayou, San Jacinto River	18.9	0-40	10.6	6-18	5.9	0-24	6.5	0-22	4.0	0-10	3.5	0-10
Buffalo Bayou, below Humble Refinery	18.8	0-44	12.3	2-26	20.5	2-36	16.3	0-82	5.0	0-11	6.7	0-18
Buffalo Bayou, Morgan's Point	13.5	0-28	14.4	2-28	8.7	0-20	4.5	0-18	4.6	0-17	4.0	1-8
Buffalo Bayou, ¼ mile in Galveston Bay	12.7	0-28	13.8	4-60	6.9	2-28	1.1	0-4	5.8	0-88	4.4	1-10

[a] Annual operating reports of sewage treatment plants - Bayou Pollution Survey, City of Houston, Texas.

[b] Average annual data, mg/L.

[c] Range of monthly data, mg/L.

in the lower section of the Channel.[2] In support of this work, a number of water samples taken at mid-channel and at a depth of about six inches from the water surface were analyzed for COD, phenol, and sulfide content. The results of these analyses are presented in Table 4-3. The hydrocarbon content of the water at the upper channel station was surprisingly low considering the large amount of organic material that enters the Channel. It is not known whether the analytical technique, involving chloride corrections, was responsible for the low COD values. A reduction in hydrocarbon content at Station 137 (not TSDH number) was reported as a result of dilution from the San Jacinto River and tidal waters. Also, some biological degradation probably occurred.

Dissolved Oxygen: Stations X-37 and X-38, during the period August 20 to September 24, 1963, indicated a zero level of dissolved oxygen. However, increasing amounts of oxygen were found at stations located nearer Galveston Bay, Fig. 4-3.

Similarly,[3] during 1957 and 1958 there was almost always a greater concentration of dissolved oxygen at the lower end of the area under study than at the upper end of the Houston Ship Channel. These results have been reduced and dissolved oxygen isopleths have been plotted as shown in Fig. 4-4. The effects of the warm summer periods and low stream flows are dramatic in that the dissolved oxygen along the length of the channel dropped to very low values during the warmer

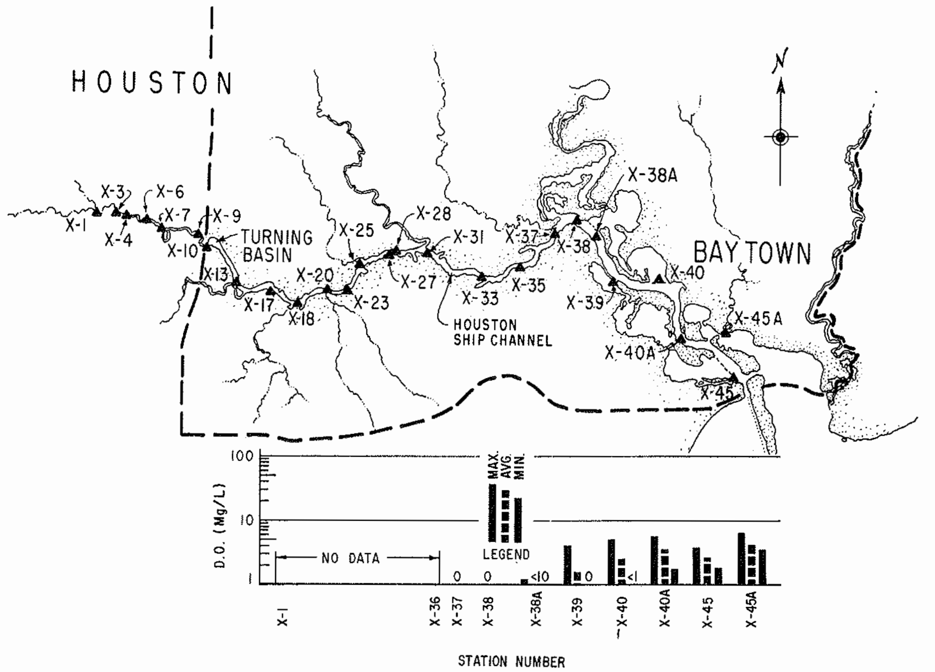
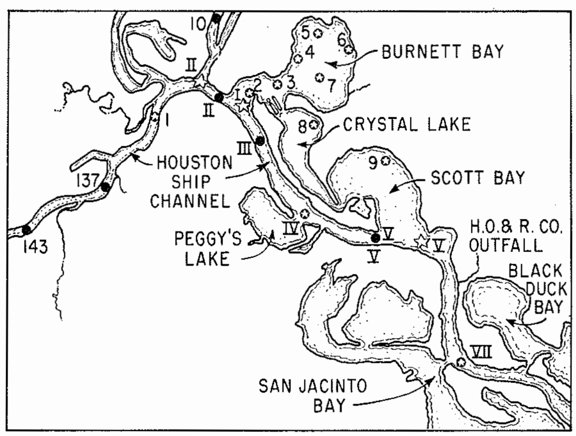


FIG. 4-3. DISSOLVED OXYGEN- HOUSTON SHIP CHANNEL (June 1 - Dec. 1, 1963)



SAMPLING STATIONS.[5]
Stars indicate stations sampled on September 1, 1957; black circles indicate stations after January 30, 1958.

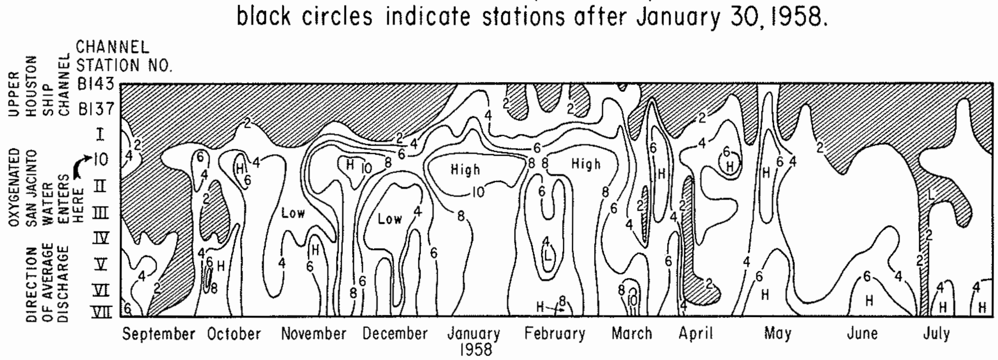


FIG. 4-4. CONCENTRATIONS OF DISSOLVED OXYGEN OF THE HOUSTON SHIP CHANNEL IN PARTS PER MILLION (ppm) AND DISSOLVED OXYGEN ISOPLETHS AT 2 ppm INTERVALS.[6]

Table 4-3. Chemical Analysis of Channel Water[4]

Date	Mid-channel Location	Sulfides ppm	Hydro-carbons ppm	Phenol ppm	pH	COD ppm
10/16/57	Station #1	---	5.0	1.0	---	---
12/16/57	Station #1	0.0	0.0	0.0	---	---
12/17/57	Dock #1	0.0	1.0	0.0	---	---
1/9/58	Buoy 141	0.0	4.0	1.0	7.10	---
1/9/58	Buoy 134	0.0	0.0	---	---	---
1/16/58	Buoy 141	0.0	1.0	4.0	7.10	---
1/27/58	Station #1	---	5.9	2.8	---	---
1/29/58	Buoy 133	---	2.0	4.0	---	---
1/30/58	Buoy 143	---	7.0	14.0	6.86	---
2/3/58	Buoy 143	---	0.0	11.0	7.03	10.0
2/6/58	Buoy 143	0.0	4.0	13.0	7.06	---
2/13/58	Buoy 143	---	3.0	7.0	7.09	1.0
2/13/58	Buoy 137	---	0.0	5.0	---	---
2/17/58	Buoy 143	---	0.0	1.0	---	12.0
2/17/58	Buoy 137	---	---	---	---	0.5
2/20/58	Buoy 143	---	1.0	4.0	7.06	2.0
2/20/58	Buoy 137	---	1.0	0.0	---	---
2/24/58	Buoy 143	---	2.0	1.0	6.92	4.0
2/27/58	Buoy 143	---	1.0	0.0	6.92	0.5
2/27/58	Buoy 137	---	1.0	0.0	7.02	---
3/10/58	Buoy 143	---	0.0	0.0	7.06	4.0
3/10/58	Buoy 137	---	2.0	1.0	7.07	---
3/13/58	Buoy 143	0.085	2.0	0.0	7.10	2.0
3/13/58	Buoy 137	0.085	0.0	0.0	7.32	---
3/17/58	Buoy 143	0.68	13.0	0.0	7.16	4.0
3/17/58	Buoy 137	0.25	1.0	0.0	6.98	2.0
3/20/58	Buoy 143	1.0	2.0	3.0	7.05	---
3/20/58	Buoy 137	0.5	3.0	1.0	7.07	---
3/21/58	Buoy 160	0.4	4.0	0.0	6.88	7.0
3/21/58	Buoy 137	0.8	1.0	0.0	6.97	5.0
3/24/58	Buoy 143	0.0	---	---	---	---
3/27/58	Buoy 143	0.0	---	---	---	---

and drier periods.

The partial reoxygenation of Houston Ship Channel water with Galveston Bay water and fresh water becomes very apparent. The San Jacinto River, especially during periods of heavy rainfall, greatly increased the dissolved oxygen content of the Houston Ship Channel area below the mouth of the river and frequently even for a considerable distance above the point of entry. The mixing of Houston Ship Channel water with the less polluted Galveston Bay water through tidal exchanges was also obvious. Otherwise it is difficult to establish a seasonal picture of dissolved oxygen concentration in the upper channel or to correlate the dissolved oxygen with rainfall and salinity because of heavy oxygen demands.

The dissolved oxygen picture would be much better if diurnal oxygen data were available. It has been reported that the dissolved oxygen content in the upper channel probably fluctuates independently of seasonal conditions; the dissolved oxygen at Station 10, Fig. 4-3, is dependent on the flow from the Lake Houston spillway and is highest in the winter, lowest in the summer months, and intermediate in the fall and spring.[7] It should be noted that the oxygen solubility increases with cooler temperatures.

Figures 4-5 through 4-12 show the effect of stream flows on dissolved oxygen and chlorinity. Figure 4-5 shows the dissolved oxygen and chlorinity in the Houston Ship Channel on January 16, 1958. This was a period of heavy rain and runoff. After the first mile there was a steady increase in the concentration of dissolved oxygen from the upper to the lower boundaries of this portion of the Ship Channel. Notably at this time there was a slight chlorinity gradient. Conversely, Fig. 4-6 shows a high chlorinity and low flow situation with an entirely different dissolved oxygen pattern. Figure 4-7 depicts a pattern of high dissolved oxygen similar to that shown in Fig. 4-5, except that high dissolved oxygen values are noted in the upper reaches of the Channel. In contrast to the period of heavy rainfall, the dissolved oxygen content for July 8, 1958, Fig. 4-8, was representative of the Houston Ship Channel in the poorest condition encountered. Reportedly the condition described in Fig. 4-8 was seldom encountered.[12]

The distribution of oxygen across Burnett Bay on April 2, 1958, a day typical of those when the salinity was higher in the Channel, showed that the oxygen content rapidly increased as the chlorinity dropped, Fig. 4-9. The chlorinity of the Ship Channel and Burnett Bay were very nearly the same on July 31, 1958, and as shown the dissolved oxygen changed markedly across a transition zone, Fig. 4-10. A period of high rainfall and heavy runoff on December 26, 1957, is described in Fig. 4-11. Notably the dissolved oxygen continued to increase across the Bay during the period of high rainfall. On October 16, 1958, also a period of heavy rainfall, the pattern

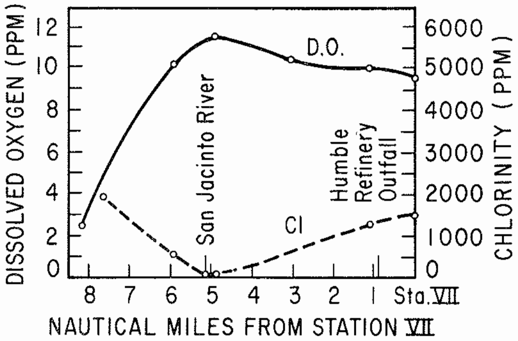


FIG. 4-5. DISSOLVED OXYGEN AND CHLORINITY. (Jan. 16, 1958)

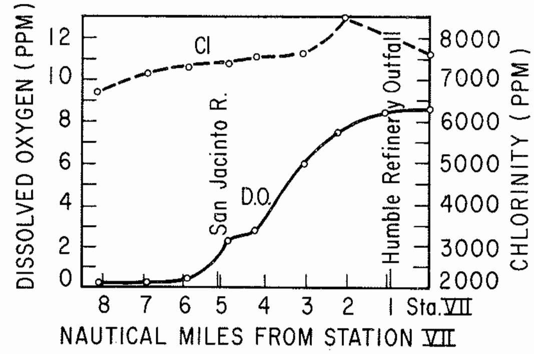


FIG. 4-6. DISSOLVED OXYGEN AND CHLORINITY (April 2, 1958)

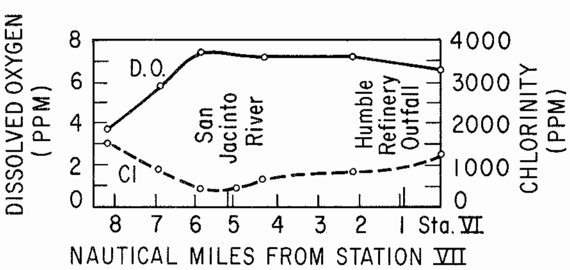


FIG. 4-7. DISSOLVED OXYGEN AND CHLORINITY (May 8, 1958)

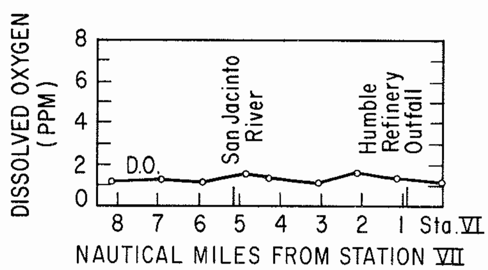


FIG. 4-8. DISSOLVED OXYGEN AND CHLORINITY. (July 8, 1958)

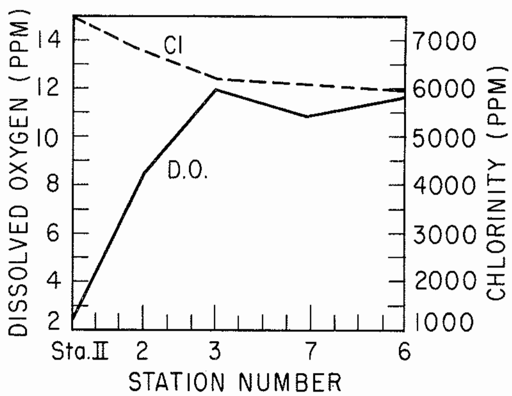


FIG. 4-9. DISSOLVED OXYGEN AND CHLORINITY IN BURNETT BAY (April 2, 1958)[13]

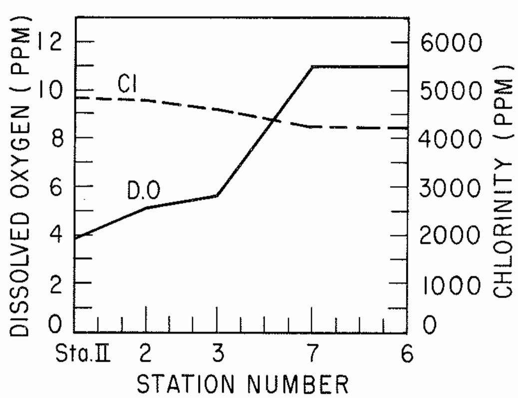


FIG. 4-10. DISSOLVED OXYGEN AND CHLORINITY IN BURNETT BAY (July 31, 1958)[14]

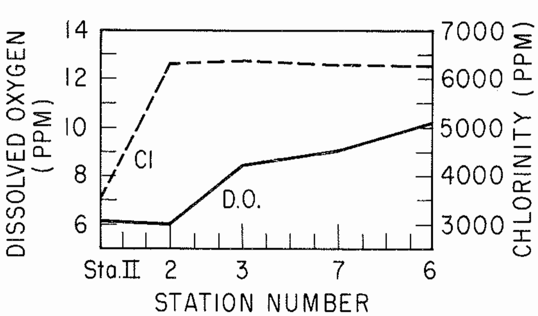


FIG. 4-11. DISSOLVED OXYGEN AND CHLORINITY IN BURNETT BAY (Dec. 26, 1957)[15]

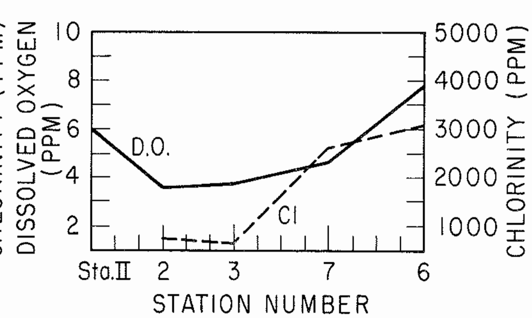


FIG. 4-12. DISSOLVED OXYGEN AND CHLORINITY IN BURNETT BAY (Oct. 16, 1957)[16]

shows a high oxygen content in the Channel, low in the transition zone, and then high again across the Bay, Fig. 4-12.

In a study undertaken by the Texas Game and Fish Commission for the period November 1959, to November 1960,[17] it was reported that the lowest dissolved oxygen concentration at Station MK122, Fig. 4-13, occurred from June to October 1960. During this time the area of lowest dissolved oxygen concentration for Area M-2, consisting of Upper Galveston Bay, Trinity Bay, and Clear Lake, was Station MK122 in the Houston Ship Channel. Reportedly the lowest dissolved oxygen concentration occurred during a period of high water temperatures and a time of flooding.

Additional studies[19] have shown a decided variation in the dissolved oxygen content at several stations in the Houston Ship Channel. The studies were made primarily to establish the factors influencing diurnal metabolism. Oxygen measurements were made in four strata on a cloudy day and the results were plotted in Fig. 4-14. A diurnal curve on an area basis was obtained by summing the three vertical columns. Regular diurnal curves for both oxygen and pH were observed in the surface layers. There was some indication that vertical stratification occurred.

Salinity: Virtually every study has indicated a considerable amount of chlorinity in the Houston Ship Channel. There are fluctuations in chlorinity which occur in a cyclic fashion and in a seasonal pattern because of variations in the amounts of rainfall and evaporation. Some of these aspects have been covered in the previous section.

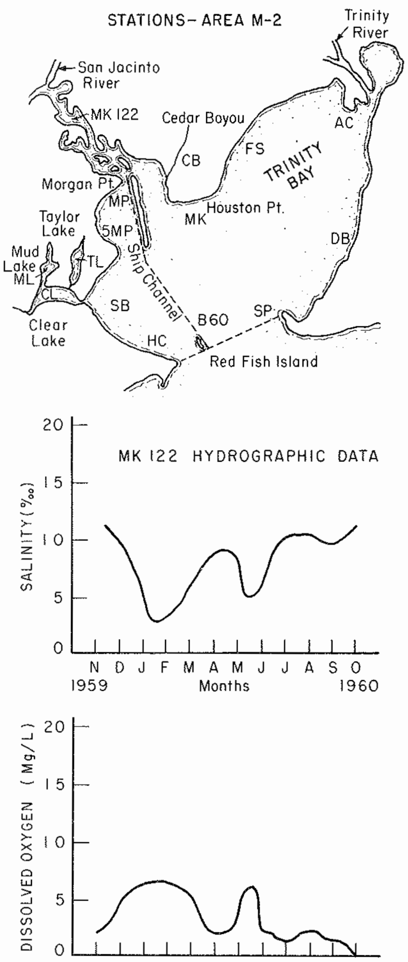


FIG. 4-13. DISSOLVED OXYGEN AND SALINITY[18]

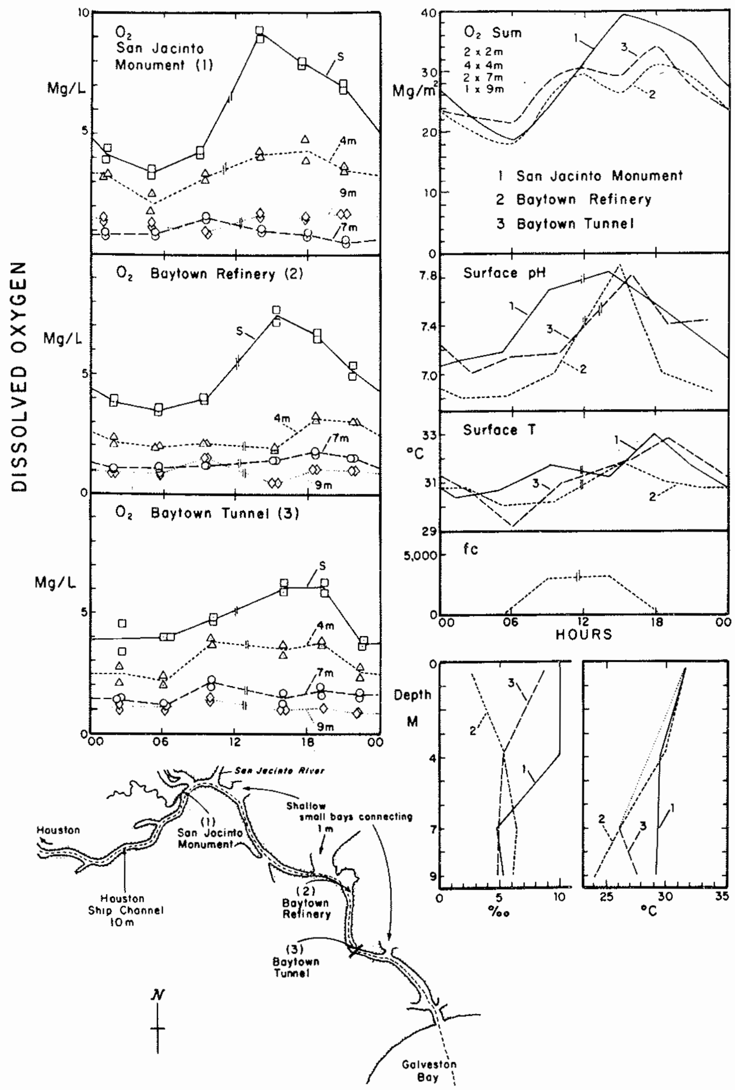


FIG. 4-14. DIURNAL VARIATIONS (July 17-18, 1961)[20]

Both meteorological and astronomical tidal differences influence the chlorinity in a seasonal pattern. During a considerable part of the winter season the winds are from a northerly direction causing the tidal exchange to be lessened. However, during the winter the greatest discharge occurs from the San Jacinto River, and consequently the greatest dilution factor is obtained. In essence, the entire area of the Houston Ship Channel is affected by major fluctuations in chlorinity.

Figures 4-15 and 4-16 depict the chlorinities in the upper and lower channels, respectively, of the San Jacinto River. It should be noted that whereas the salinity in the ship channel varies considerably from the upper to the lower parts of the channel, there is not such a pronounced difference in the bays. This is an important aspect because water of either high or low salinity, possibly polluted, can become trapped in the bays and thus may not be transferred readily into the open waters.

In a study reported by the Texas Game and Fish Commission for the period including November, 1959, to November, 1960, a vertical salinity stratification was observed in the Houston Ship Channel during every month of the study.[23] The bottom salinity would frequently be more than double the surface salinity. More information on these studies may be found in Chapter 6.

Refractory and Toxic Materials Analysis: There appears to be little public information available that specifically describes the

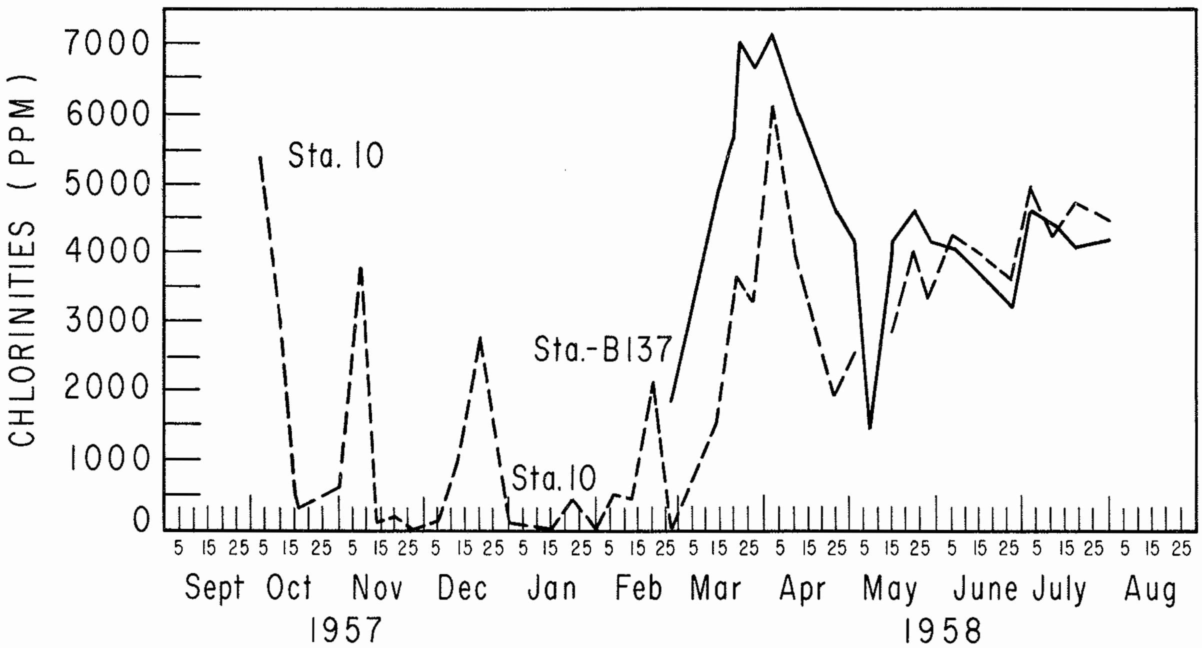


FIG.4-15. CHLORINITIES OF THE UPPER CHANNEL AND SAN JACINTO RIVER (Sept. 1957–Aug. 1958)[21]

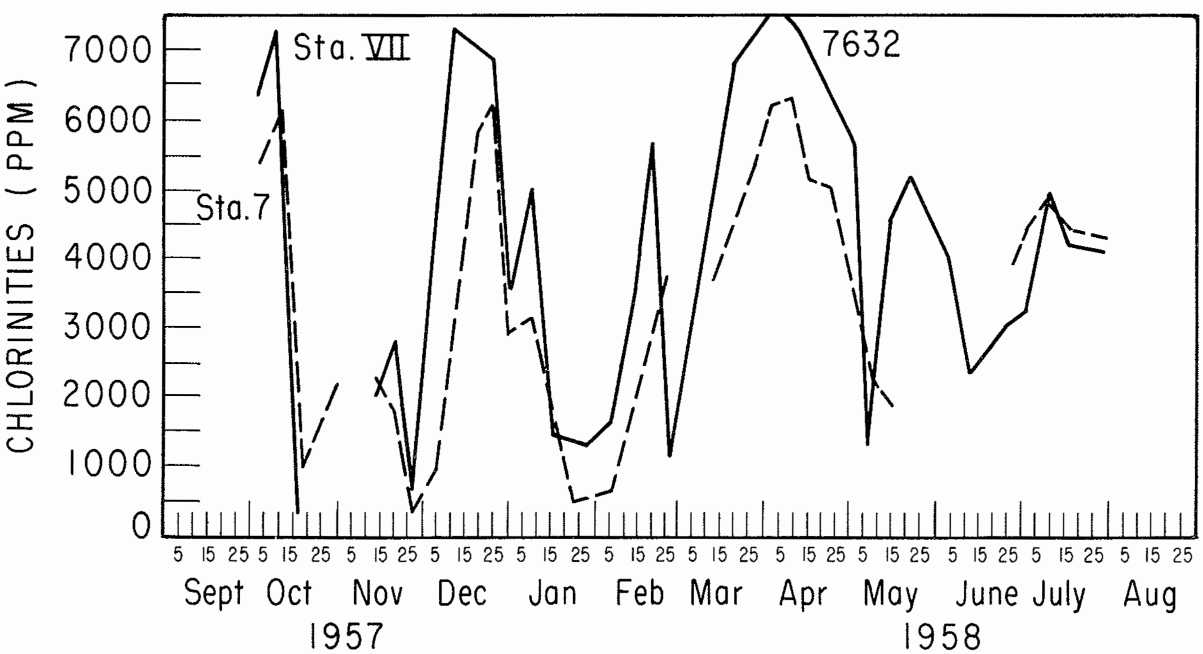


FIG.4-16. CHLORINITIES OF THE LOWER CHANNEL (STATION VII) AND OF BURNETT BAY (STATION 7).[22]

toxicity of the channel waters to either fresh water or marine organisms. Yet numerous fish kills have occurred, and at times reports have indicated that fish have been killed due to industrial waste releases or low dissolved oxygen contents. Table 4-4 shows where some of the recent fish kills occurred. For the period June 1962 to November 1963, 18 out of 29 fish kills occurred in Galveston County.

Long-range ecological studies involving the actual effects of waste discharges on typical flora and fauna are needed as well as more detailed analyses on the identification of general chemical categories.

Trinity Bay

According to the permits issued by the Water Pollution Control Board, there are no major industrial and domestic developments around Trinity Bay similar to the Houston Ship Channel and Texas City. The major chemical and biochemical information on record for this particular area seems to be that which is being collected currently by the Texas State Department of Health.

Biochemical Oxygen Demand: Fourteen stations have been established by the Texas State Department of Health and these are shown in Fig. 4-17. The maximum BOD value reported during the period of June to December, 1963, was 5 mg/l. The average value appeared to be less than 3 mg/l. A fairly uniform distribution of decomposable

Table 4-4. Fish Kills in Galveston Bay Area[24]

Date		Area
1962 -	June	Halls Bayou, Galveston County
	July	Swan Lake, Galveston County
		Galveston Bay, Chambers County
		Lake Charlotte, Chambers County
		Highland Bayou, Galveston County
	August	Green Bayou, Harris County
	September	Old River (San Jacinto), Harris County
		Clear Creek, Galveston County
	October	Galveston Bay, (Texas City Area), Galveston County
1963 -	March	San Jacinto River, Harris County
	May	San Jacinto Bay, Harris County
		Lake Houston, Harris County
	June	Galveston Bay (Texas City Dike), Galveston County
	July	Anahuac Channel, Chambers County
		Galveston Bay, Galveston County
		Galveston Bay, Galveston County
		Galveston Bay, Galveston County
	August	Turtle Bayou, Chambers County
		Swan Lagoon Boat Slip, Harris County
		Galveston Bay, Galveston County
	September	Swan Lake, Galveston County
		Swan Lake, Galveston County
		Dickinson Bayou, Galveston County
	October	Fresh water ponds, Galveston County
	November	Halls Bayou, Galveston County
		Texas City Harbor Area, Galveston County
		West San Jacinto River, Harris County
		Offatts Bayou, Galveston County
		Galveston Bay (Texas City Area), Galveston County

organic matter exists. Probably much of the BOD is associated with algal cell debris, etc.

As the flushing action of the Trinity River is curtailed, most of the exchange occurring with this Bay will have to result from meteorological and astronomical tidal exchanges.

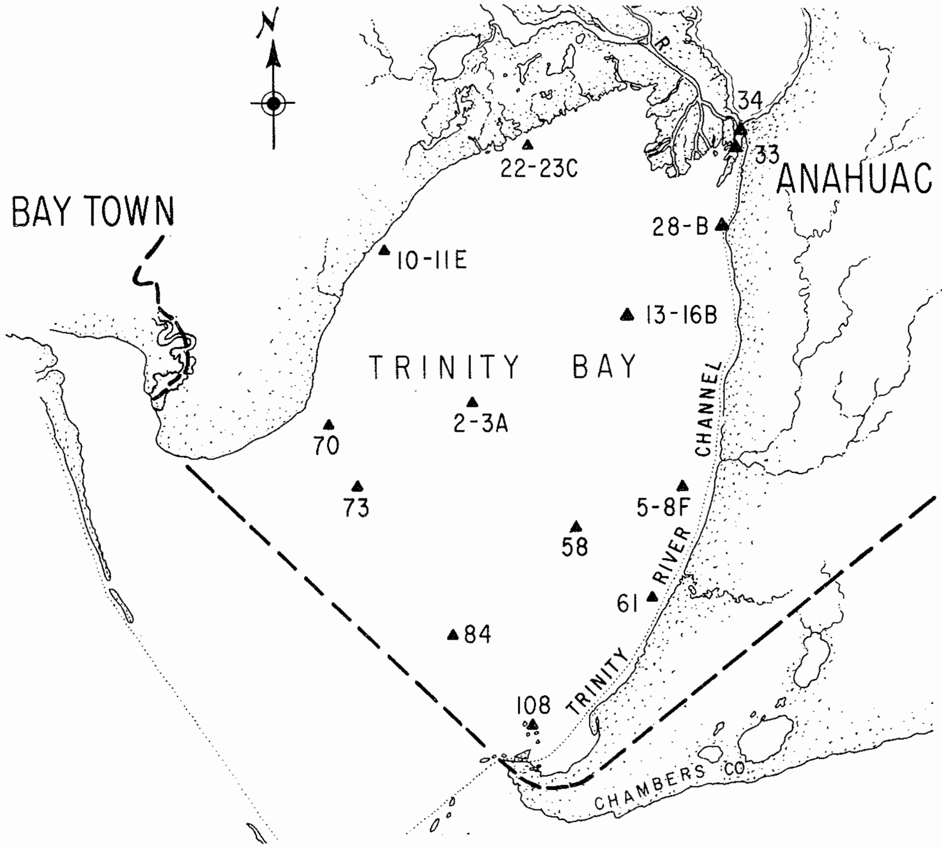
Dissolved Oxygen: In Trinity Bay the dissolved oxygen values reported by the current Texas State Department of Health survey (Fig. 4-18) are all relatively high. Maximum values for the period June to December 1963, were in excess of 9 and minimum values were in excess of 6 mg/l.

It will be highly desirable to obtain some diurnal oxygen data and observe these with seasonal fluctuations. With such productivity measurements, estimates of the future behavior of the Bay can be made. This information will be particularly important if the outflow of the Trinity River is rigidly curtailed.

At present there seems to be no major pollution nor problems of public health significance with Trinity Bay. Its use as a nursery ground for different fauna is well known, and future manipulations of the water into and out of the Bay should be evaluated in light of the beneficial use of this Bay as a nursery area.

Upper Galveston Bay and Clear Lake Area

A number of studies have been made along the section of the



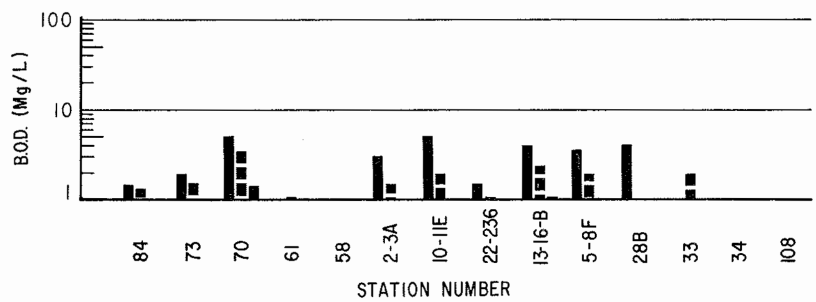


FIG. 4-17. BIOCHEMICAL OXYGEN DEMAND - TRINITY BAY (June 1 - Dec. 1, 1963)

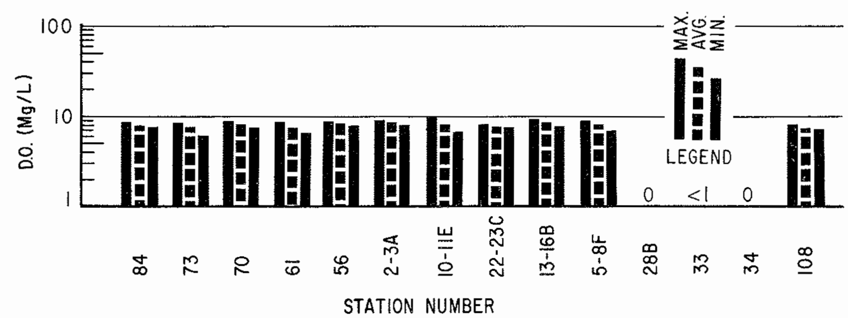


FIG. 4-18 DISSOLVED OXYGEN - TRINITY BAY (June 1 - Dec. 1, 1963)

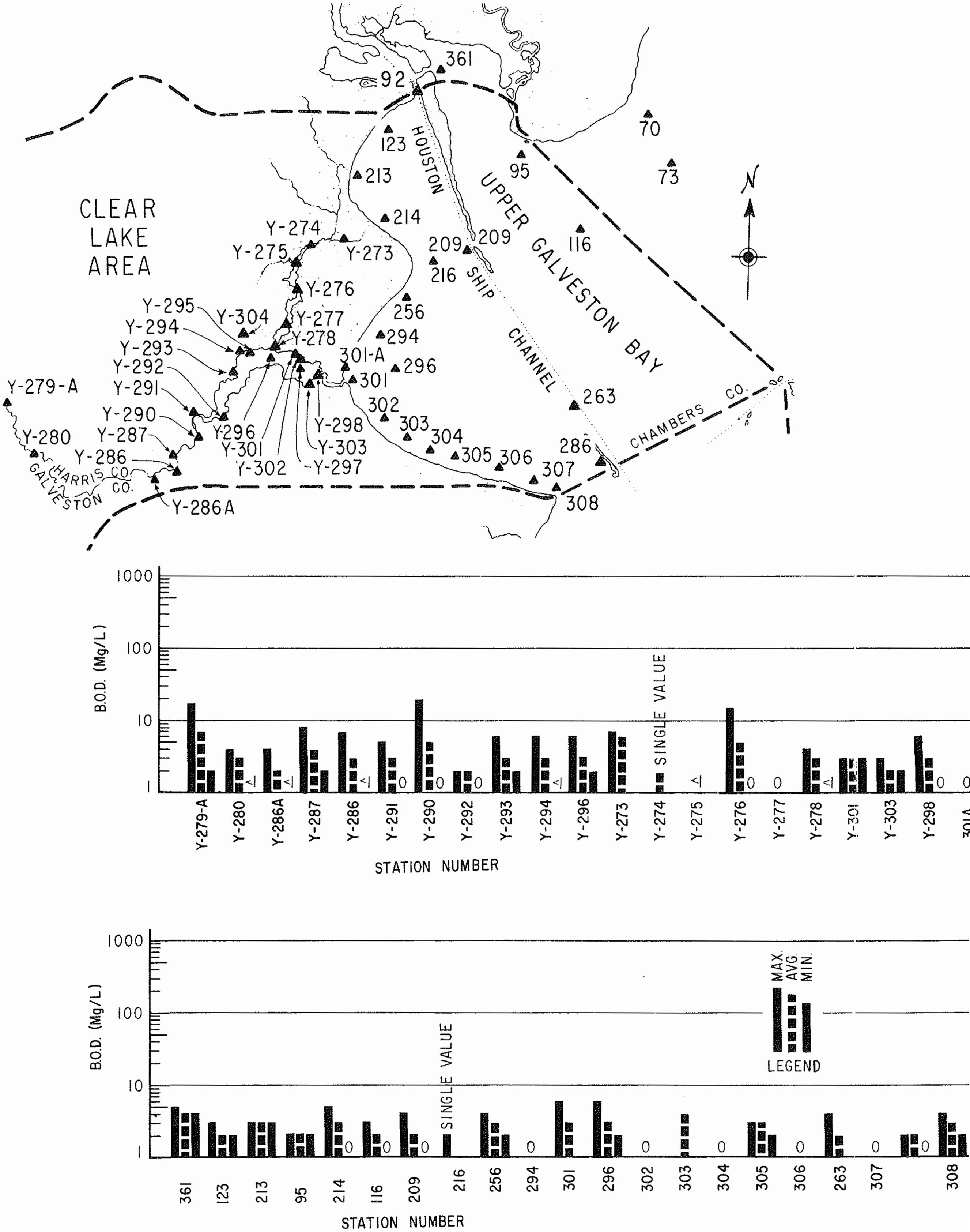
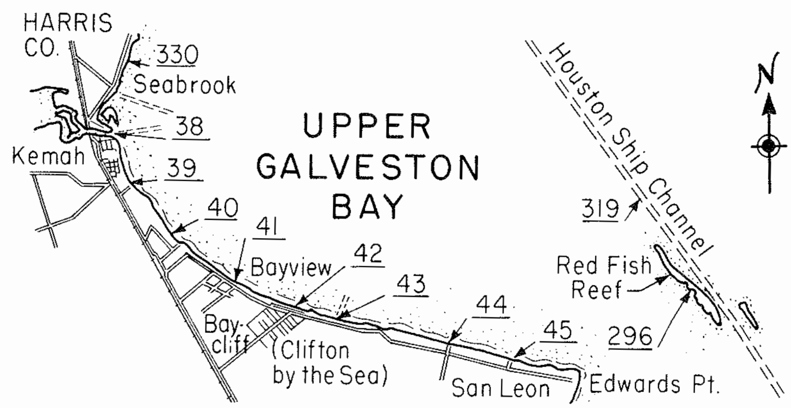


FIG. 4-19. BIOCHEMICAL OXYGEN DEMAND-UPPER GALVESTON BAY AND CLEAR LAKE AREA (June 1 - Dec. 1, 1963)



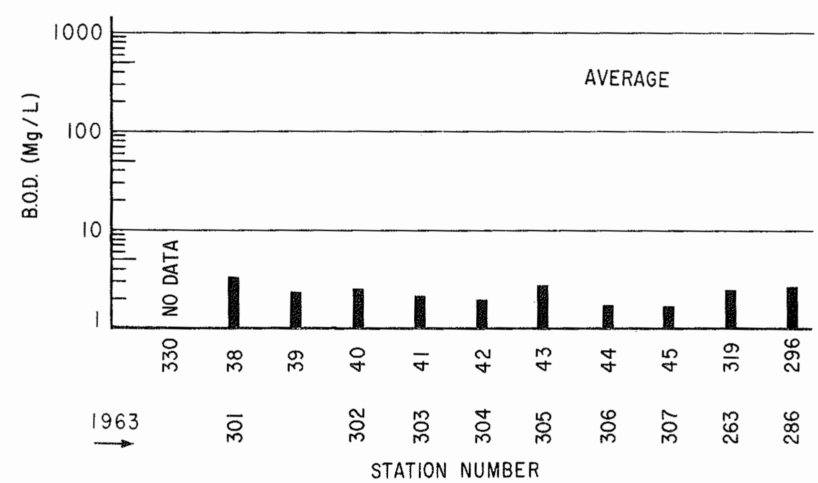
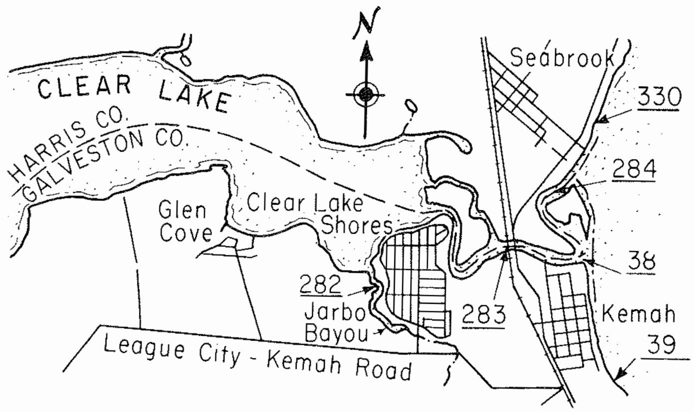


FIG. 4-20. BIOCHEMICAL OXYGEN DEMAND-UPPER GALVESTON BAY[25]
(Feb. 17, 1950-Feb. 28, 1951)



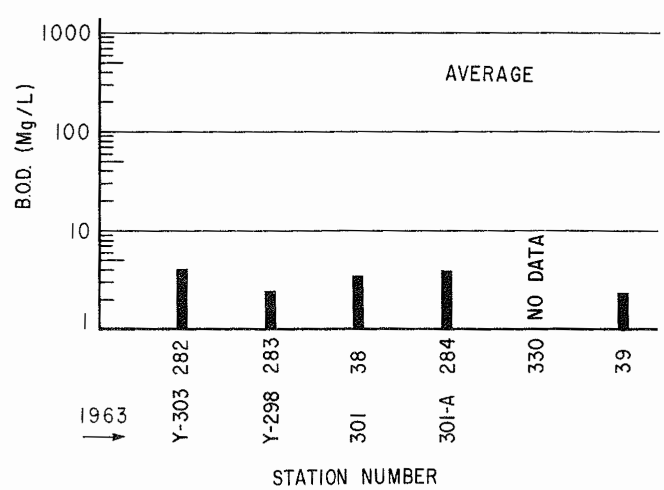
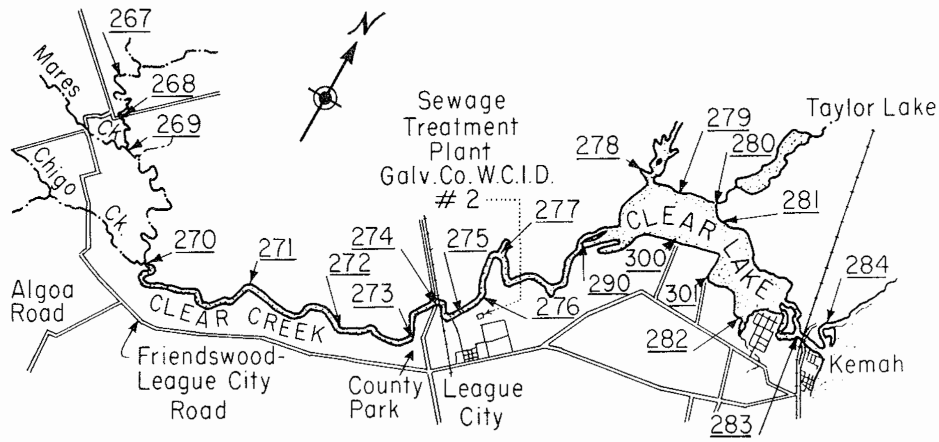


FIG. 4-21. BIOCHEMICAL OXYGEN DEMAND- KEMAH (Feb. 17, 1950-Feb. 28, 1951)[26]



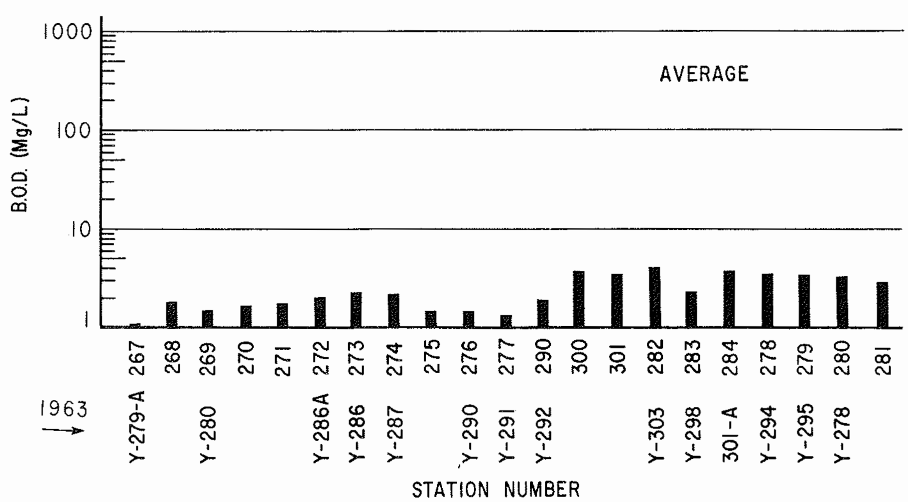


FIG. 4-22. BIOCHEMICAL OXYGEN DEMAND-CLEAR LAKE (Feb. 17, 1950 - Feb. 28, 1951)[27]

Houston Ship Channel in what is referred to as Upper Galveston Bay, along the western shores of the Bay area and in the Clear Creek area. At the present time, there is some residential and commercial development, but the projected growth for this area as previously depicted is almost astronomical. In terms of waste effluents, this growth is a significant factor in the future quality of Galveston Bay.

Biochemical Oxygen Demand: As shown in Fig. 4-19, the maximum BOD measured by the Texas State Department of Health survey was 18 mg/l (Station Y-290). The average measurements were in the neighborhood of 3 mg/l.

The Clear Creek area had the highest BOD (Fig. 4-19). Station Y-279A recorded the greatest average value which was 7 mg/l. The organic load in the water at stations in Galveston Bay was 5 mg/l or less.

On the basis of Figs. 4-20 through 4-22 which show the results of the 1950-1951 survey, there has not been an appreciable increase in the average BOD values of the Clear Lake-Upper Galveston Bay area. The average BOD values for this area reported in the February 17, 1950 - February 28, 1951 survey were generally less than 4 mg/l.

Chemical Oxygen Demand: At this time there are no public data that depict the chemical oxygen demand for this area.

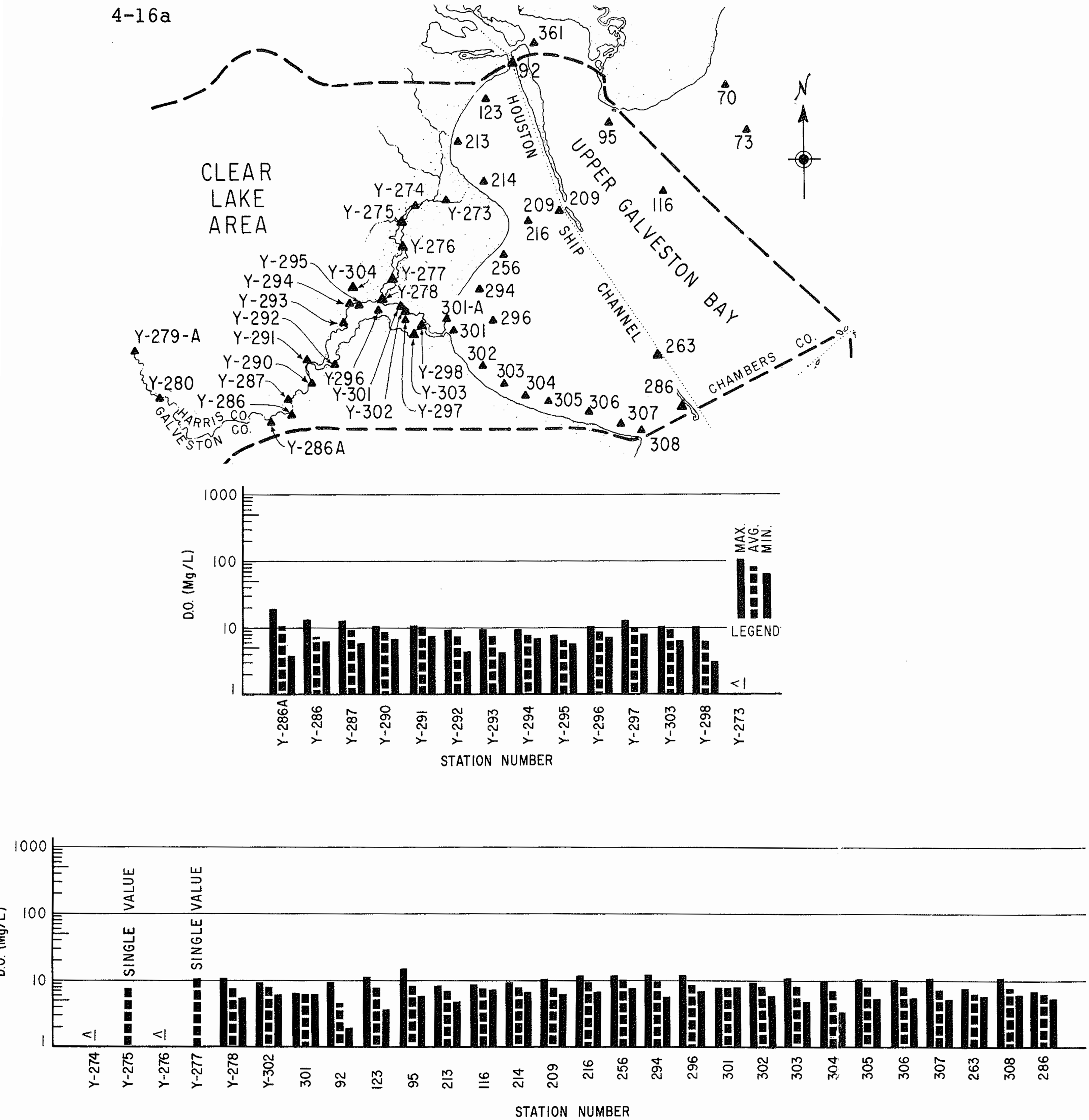
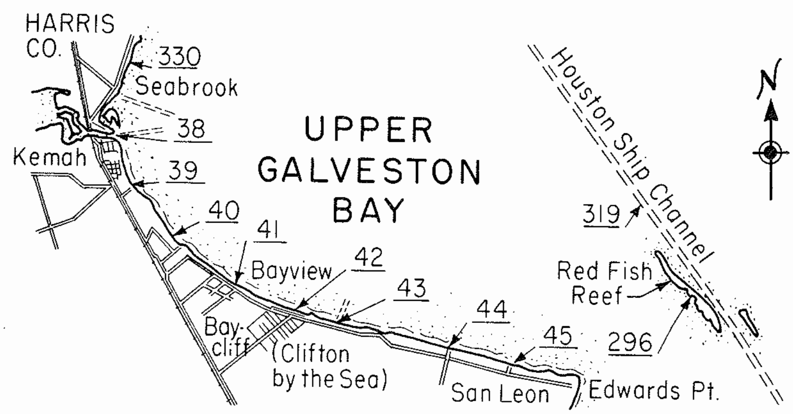


FIG. 4-23. DISSOLVED OXYGEN-
UPPER GALVESTON BAY AND CLEAR LAKE
AREA (June 1 - Dec. 1, 1963)



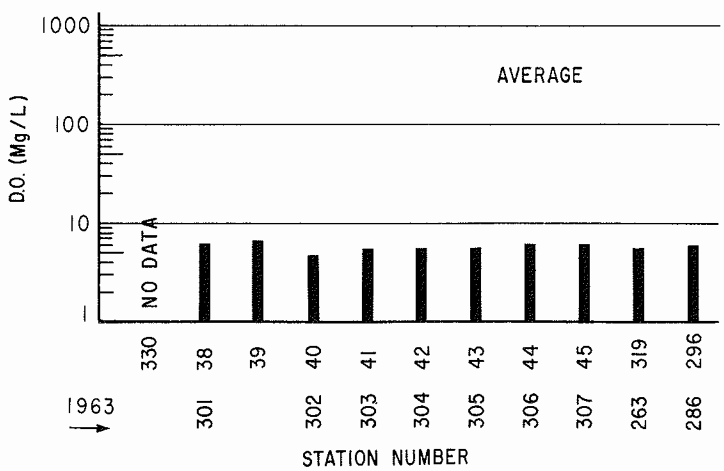
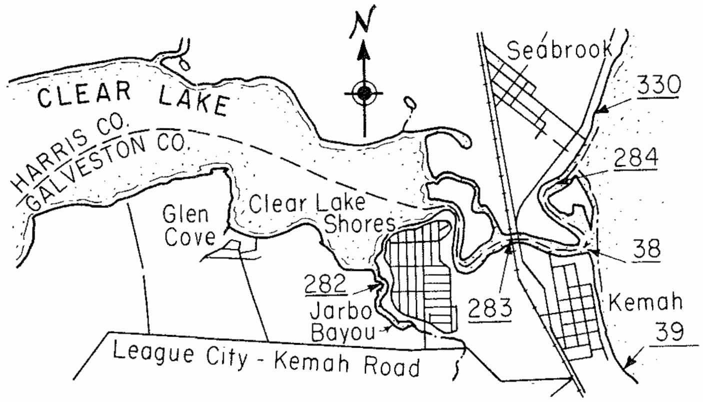


FIG. 4-24. DISSOLVED OXYGEN - UPPER GALVESTON BAY[28]
(Feb. 17, 1950 - Feb. 28, 1951)



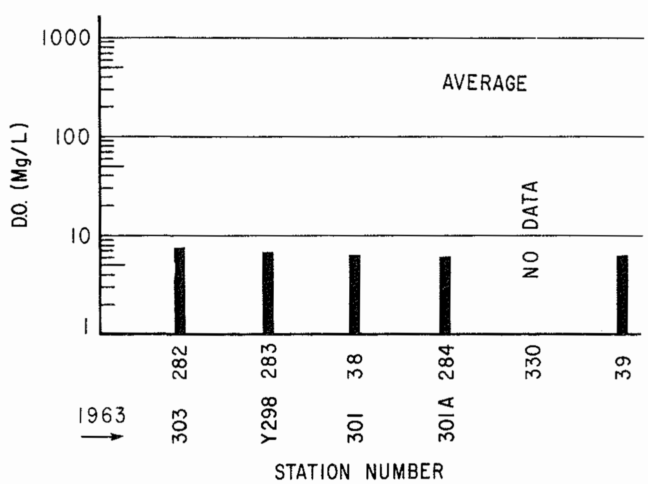
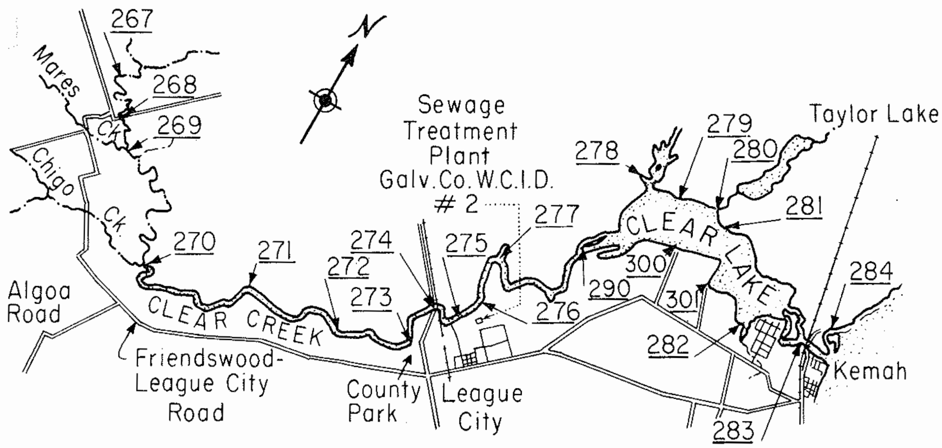


FIG. 4-25. DISSOLVED OXYGEN - KEMAH (Feb. 17, 1950 - Feb. 28, 1951)[29]



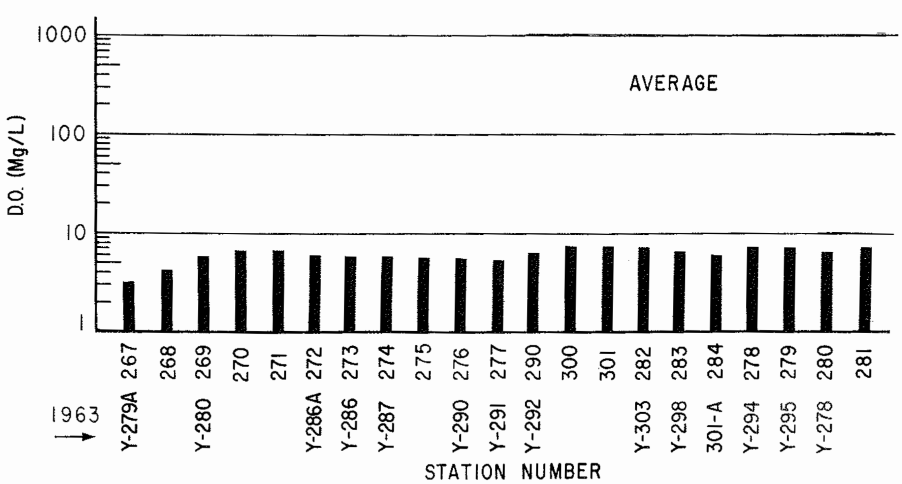


FIG. 4-26. DISSOLVED OXYGEN - CLEAR LAKE (Feb. 17, 1950-Feb. 28, 1951)[30]

<u>Dissolved Oxygen:</u> The dissolved oxygen indicates a high degree of photosynthetic productivity since some of the stations show average values that are in excess of saturation. These dissolved oxygen values as measured from June to December, 1963, seem to be comparable with those reported in the 1950-1951 survey.

The photosynthetic activity in the more polluted areas such as Station Y-286A is very apparent. The maximum dissolved oxygen value recorded at this station was 18.7 mg/l, Fig. 4-23. This station also registered the greatest average values during the period June 1 - December 1, 1963. Since all of these stations were sampled during periods of sunshine or daylight hours it can be expected that there would be minimum values on the reverse part of the diurnal curve. The fertilization in the Clear Creek area is quite evident.

As shown in Figs. 4-24 through 4-26, the dissolved oxygen during the 1950-1951 survey was fairly high except in the upper reaches of the Clear Creek area. These data reflect daytime oxygen concentrations and do not show the minimum which might be expected during diurnal fluctuations. In general, the historical data reflect adequate oxygen supplies; however, spot checks for evaluating dissolved oxygen may at times be misleading.

The productivity of upper Galveston Bay for the period August 22-23, 1962, shows a considerable diurnal oxygen pattern. If these data are considered typical, significant oxygen concentrations exist even at night. Furthermore, the oxygen concentration is sufficient for most varieties of fish, for the recommended minimum for marine fish is 4 mg/l.[31] In Fig. 4-27 the mean oxygen content in six Bay stations ranges from about 5 mg/l to 8 mg/l. Temperature, wind, light, and rate of oxygen use or production are also given. In Fig. 4-28 the ratio of CO_2 to O_2 further helps to define some of the inter-relationships between photosynthesis and respiration.

Lower Galveston Bay

The Lower Galveston Bay area seems to be marked for additional growth. Even now most of the organic load added to Galveston Bay originates in this area. Heavy industrial development around the Texas City complex is likely to increase significantly. Similarly the Chocolate Bayou Area appears to be attractive to industries.

Biochemical Oxygen Demand: Increasing amounts of BOD near the Texas City area indicate relatively large industrial and domestic waste discharges. As shown in Fig. 4-29 the average BOD values along the immediate Texas City coastal area were in the neighborhood of 6 mg/l. The maximum value reported was 12 mg/l. However, most of the data obtained during the 1963 survey showed average values of less than 2 mg/l. Permits have been issued allowing an average discharge of about 103,677 pounds of BOD per day by the industrial community near Texas City. This

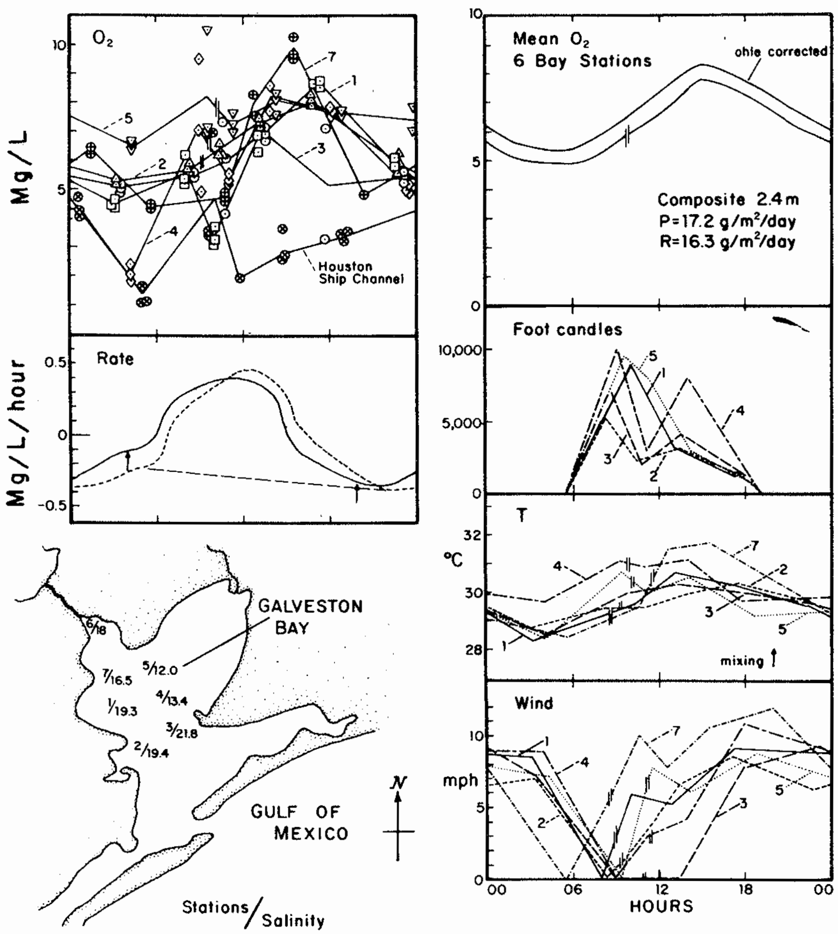


FIG. 4-27. OXYGENATION IN UPPER GALVESTON BAY (Aug. 22-23, 1962)(32)

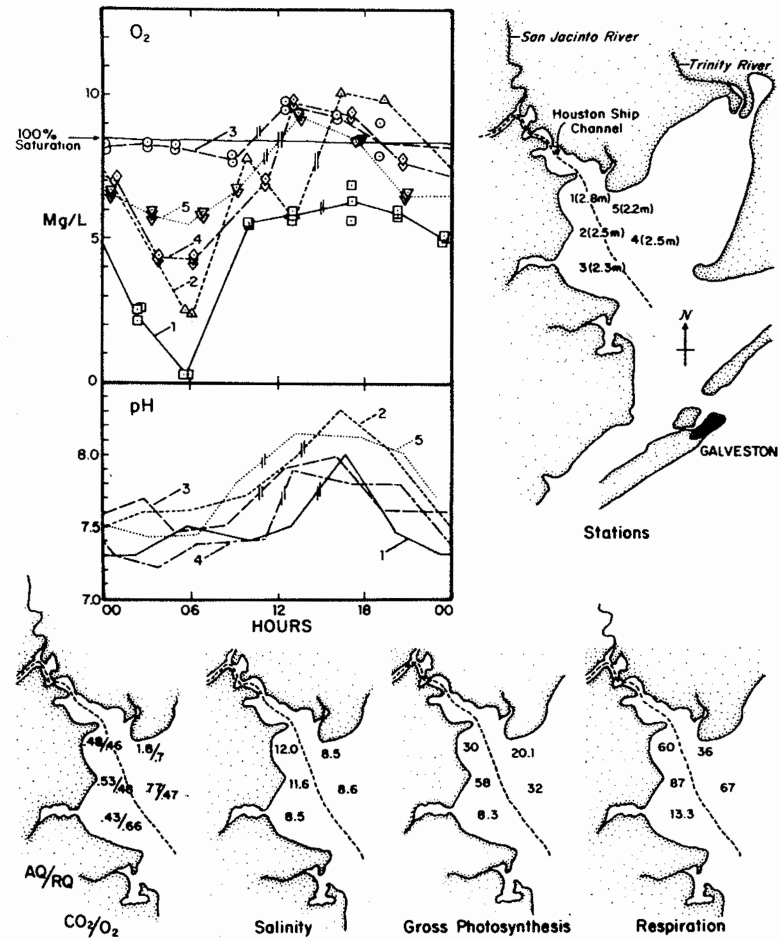


FIG. 4-28. PRODUCTIVITY IN UPPER GALVESTON BAY (April 18-19, 1961)(32)

even at night. Furthermore, the oxygen concentration is sufficient for most varieties of fish, for the recommended minimum for marine fish is 4 mg/l.[31] In Fig. 4-27 the mean oxygen content in six Bay stations ranges from about 5 mg/l to 8 mg/l. Temperature, wind, light, and rate of oxygen use or production are also given. In Fig. 4-28 the ratio of CO_2 to O_2 further helps to define some of the inter-relationships between photosynthesis and respiration.

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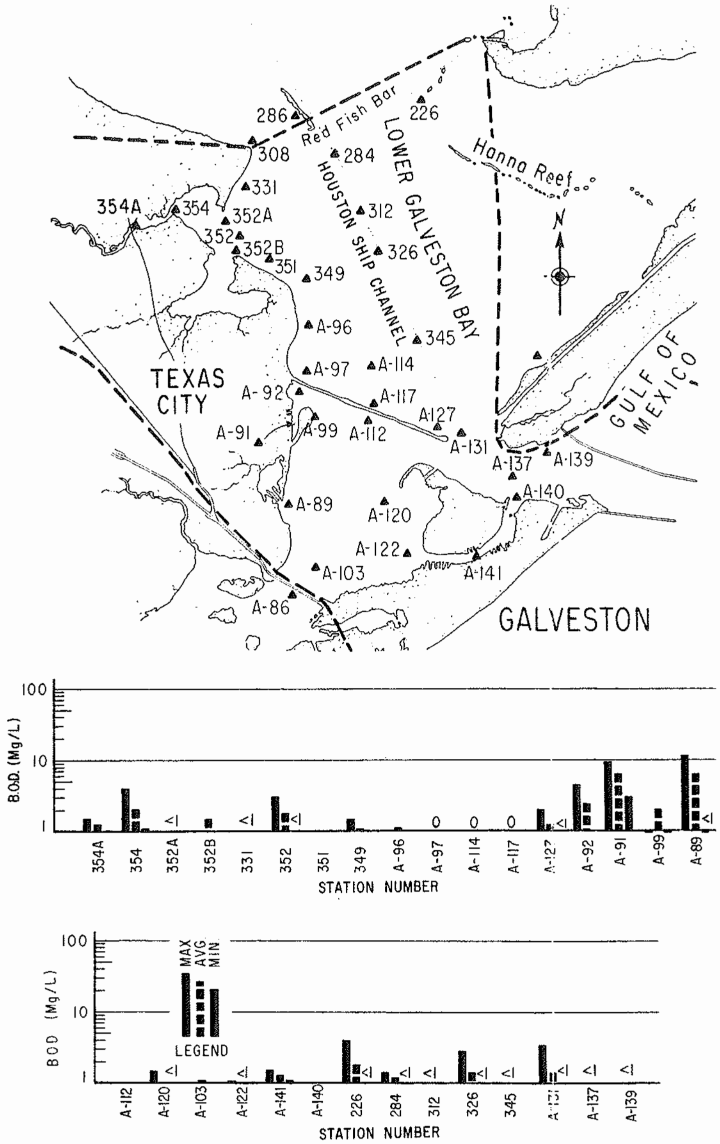


FIG. 4-29. BIOCHEMICAL OXYGEN DEMAND-LOWER GALVESTON BAY (June 1 - Dec.1, 1963)

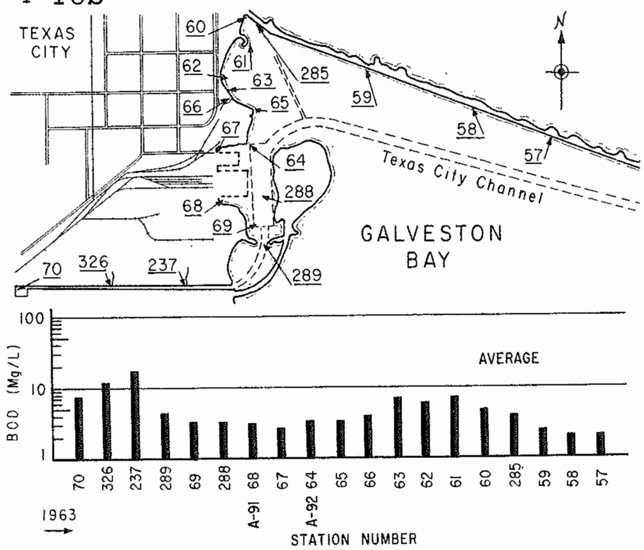


FIG. 4-30. BIOCHEMICAL OXYGEN DEMAND-TEXAS CITY (Feb. 17, 1950-Feb. 28, 1951)[33]

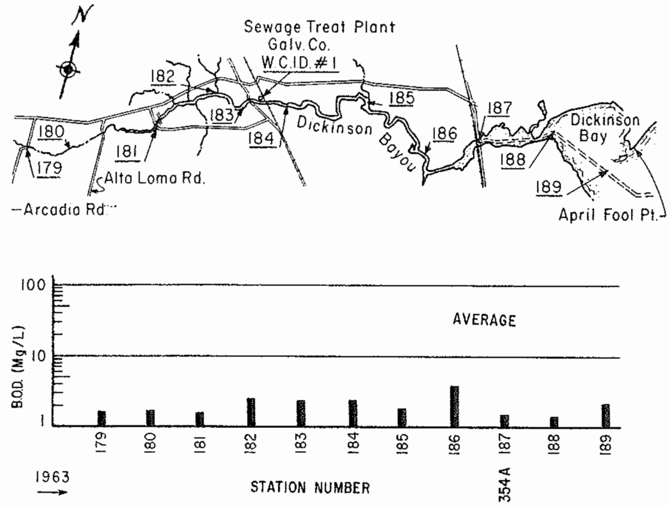


FIG. 4-31. BIOCHEMICAL OXYGEN DEMAND-DICKINSON BAYOU (Feb. 17, 1950-Feb. 28, 1951)[34]

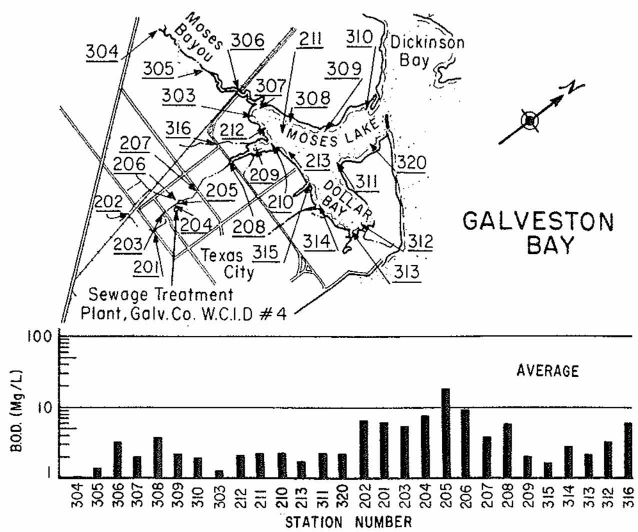


FIG. 4-32. BIOCHEMICAL OXYGEN DEMAND-CARBIDE DITCH AND MOSES LAKE (Feb. 17, 1950- Feb. 28, 1951)[35]

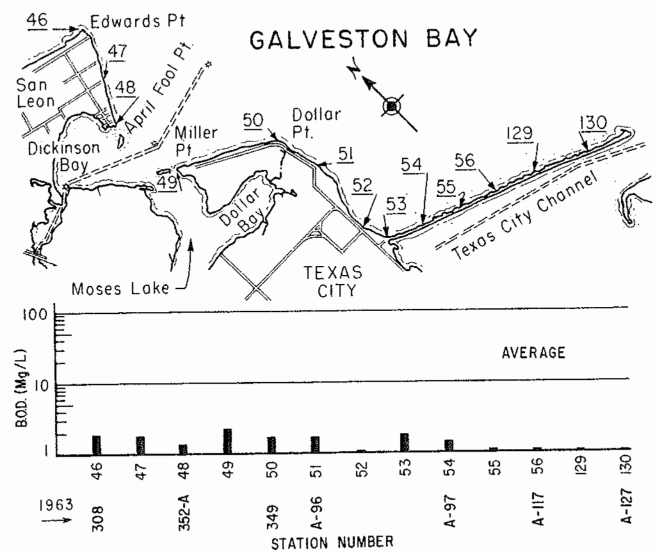


FIG. 4-33. BIOCHEMICAL OXYGEN DEMAND-TEXAS CITY DIKE (Feb. 17, 1950-Feb. 28, 1951)[36]

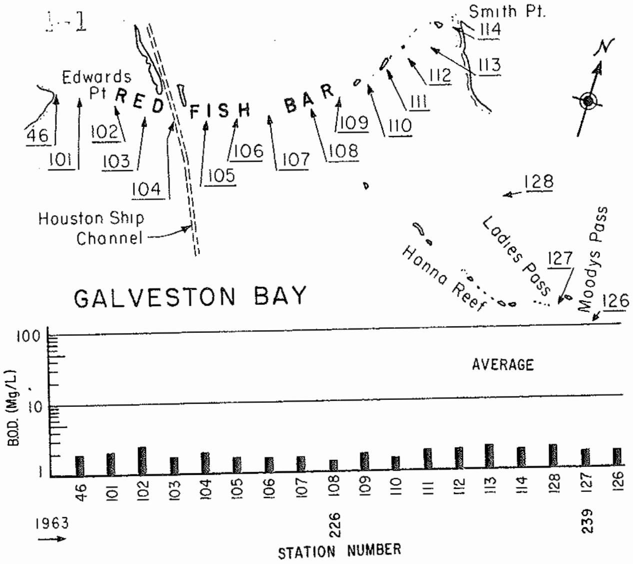


FIG. 4-34. BIOCHEMICAL OXYGEN DEMAND-RED FISH BAR (Feb. 17, 1950 - Feb. 28, 1951)(37)

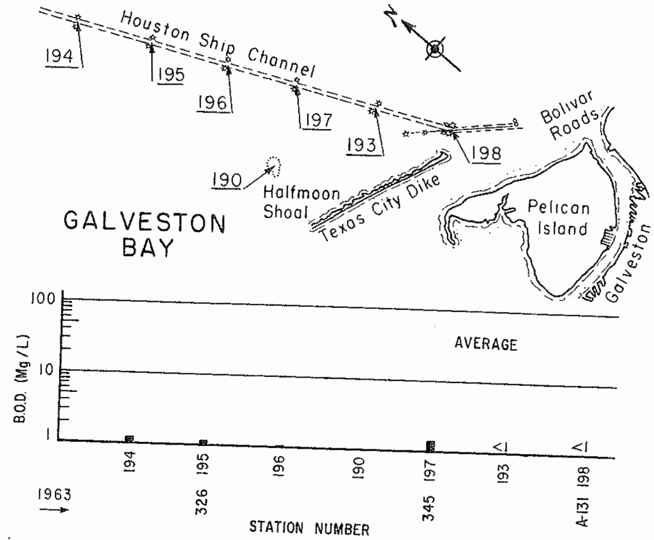


FIG. 4-35. BIOCHEMICAL OXYGEN DEMAND-SHIP CHANNEL (Feb. 17, 1950 - Feb. 28, 1951)(37)

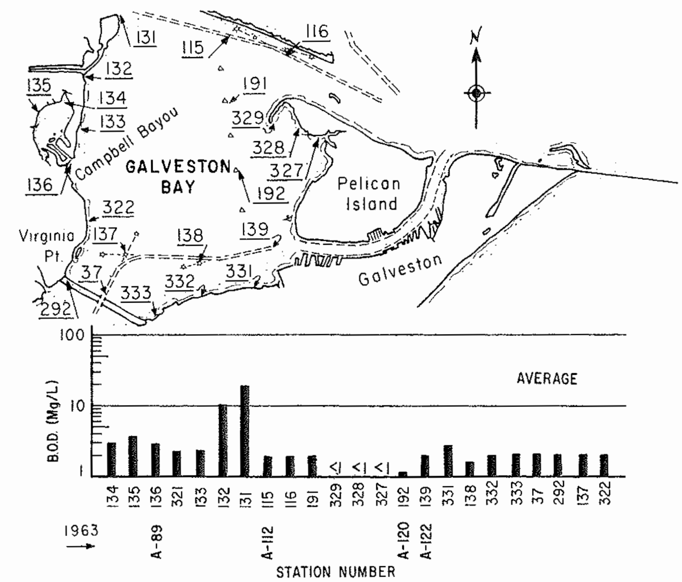


FIG. 4-36. BIOCHEMICAL OXYGEN DEMAND-GALVESTON AREA (Feb. 17, 1950 - Feb. 28, 1951)(39)

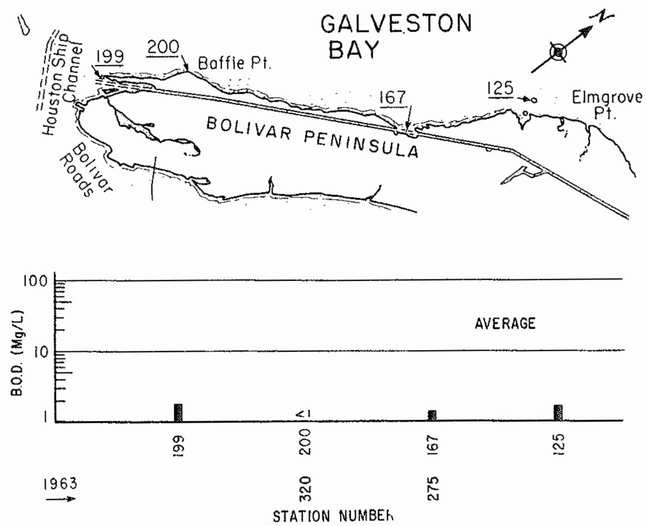


FIG. 4-37. BIOCHEMICAL OXYGEN DEMAND-BOLIVAR AREA (Feb. 17, 1950 - Feb. 28, 1951)(40)

BOD load represents about 37 per cent of the total load discharged to Galveston Bay.

The 1950-1951 survey collected a vast amount of data in the general area from Dickinson Bayou to Galveston Island. These results are shown in Figs. 4-30 through 4-37. Station 237 in the Texas City area showed an average BOD of about 18 mg/l. Similarly, stations 205 and 131 showed an equal degree of pollution. In general, data obtained from Moses Lake and Dickinson Bay, Red Fish Bar and the lower sections of Galveston Bay were relatively low. BOD values of less than 3 mg/l were common.

Chemical Oxygen Demand: It has been estimated from the permits that the average industrial releases for the Texas City area may produce a COD load of approximately 170,187 pounds per day. This figure is higher than the BOD load. Most of the oxygen demand must be satisfied by biological action. If for some reason the waste cannot be transferred to a large diluting body of water containing numerous biota and oxygen, unsatisfactory conditions may result.

Dissolved Oxygen: Fig. 4-38 depicts the dissolved oxygen of the recent Texas State Department of Health survey. The data are fairly uniform, and the average values are roughly 6.5 mg/l.

Table 4-5 shows biweekly dissolved oxygen data for the area referred to as M-2 (Fig. 4-13). Monthly variations are significant.

Table 4-5. Dissolved Oxygen Area M-2
(November 1959 - November 1960)[49]

Item		November	December	January	February	March	April
Surface	Maximum	15.3*	9.3	18.9	10.8	11.0	10.6
	Minimum	1.5	4.0	4.6	6.0	2.3	1.5
	Average	10.5	7.9	9.5	9.0	9.4	7.7

Item		May	June	July	August	September	October
Surface	Maximum	11.5	8.7	11.9	9.7	9.8	10.3
	Minimum	5.9	1.0	1.2	1.0	0.5	0
	Average	8.0	6.7	6.4	6.5	7.2	7.6

*Values are mg/L

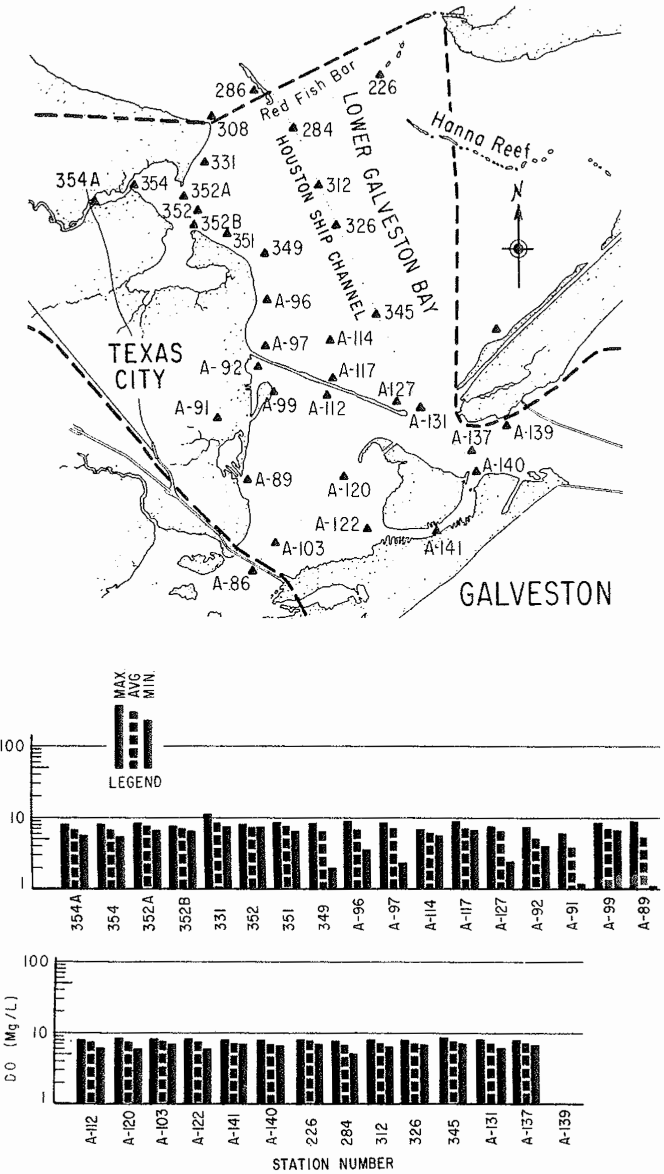


FIG. 4-38. DISSOLVED OXYGEN
LOWER GALVESTON BAY
(June 1 - Dec. 1, 1963)

The minimum dissolved oxygen values varied from 6.0 mg/l in February to 0 mg/l in October.

The effect of aquatic blooms on the dissolved oxygen is clearly shown in Tables 4-6 through 4-8. For example, on September 21, 1960, the dissolved oxygen content ranged from 12.8 mg/l to 2.1 mg/l. During another bloom, conditions were such that the dissolved oxygen concentration reached 16.3 mg/l (Table 4-8). It should be noted that this bloom occurred in January during which time the light energies were relatively low. Minimum BOD values of near 2 mg/l were reported at several sampling stations, particularly near Moses Lake. Without information on the diurnal fluctuations, it is impossible to fully assess the full significance of these dissolved oxygen data.

In comparison with the results of the 1950-1951 survey the dissolved oxygen values obtained in the 1963 survey indicated that the Bay as a whole was in better shape than it was 12 years ago. The 1950 and 1951 data on dissolved oxygen are shown in Figs. 4-38 through 4-46.

The total respiration oxygen, gross photosynthesis, and diurnal fluctuation for the lower Galveston Bay and Texas City areas vary considerably.[(53)] As shown in Fig. 4-47 total respiration varied from 4.6 at the Texas City area to 31.7 in the Galveston Bay itself. The gross photosynthesis at the same two

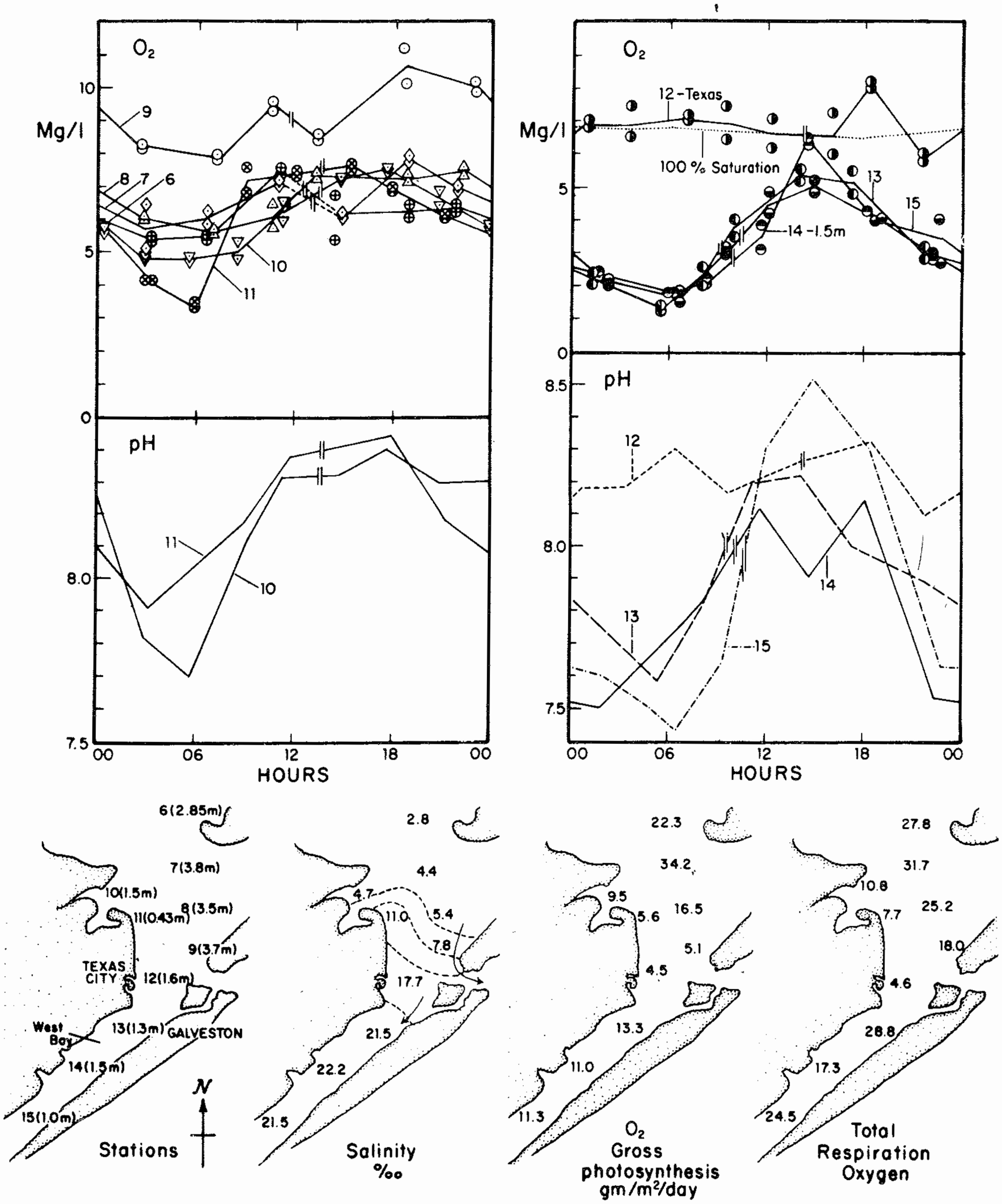


FIG. 4-47. PRODUCTIVITY - LOWER GALVESTON BAY(54)
(JULY 15-19, 1961)

Table 4-6. Diurnal Oxygen Curve
Laboratory Bulkhead during <u>Gymnodinium splendens</u> Bloom (50)

Date	Time	Temp. C° Air	Temp. C° Water	DO mg/L	pH	Turb. mg/L	Sal. °/oo	Cloud °/o	Wind Rate	Wind Dir.	Bar. Pressure	Tide ft	Comments
9-21-60	0800	26.0	29.0	2.2	7.6	95	11.5	20	0-5	E-NE	29.95	1.8	Foggy
	0900	29.0	29.5	2.9	7.6	95	11.7	30	5-10	NE	29.96	1.9	
	1000	29.0	29.5	4.1	7.7	95	11.7	30	0-5	E-NE	29.97	1.8	
	1100	29.0	30.0	5.7	7.8	94	11.7	20	5-10	E-NE	29.98	1.7	
	1200	29.5	30.2	9.8	8.3	90	11.8	20	10-12	E	29.97	1.7	pH meter erratic
	1300	29.2	30.8	12.5	8.3	88	11.8	20	12-14	E	29.96	1.6	Water getting rougher
	1400	29.0	30.5	12.8	8.4	88	11.8	20	8-16	E-NE	29.94	1.6	
	1500	29.5	30.0	11.3	8.4	87	11.7	15	10-20	E-SE	29.94	1.6	
	1600	29.5	31.0	11.3	8.3	87	11.7	10	10-20	E-SE	29.90	1.5	
	1700	29.5	31.0	10.0	8.3	87	11.8	0	14	SE	29.90	1.7	
	1800	29.5	30.6	9.9	8.3	89	11.9	0	13	SE	29.90	1.8	Sunset 1815
	1900	28.8	30.8	8.6	8.2	89	11.8	0	6	SE	29.91	1.8 or 1.9	
	2000	27.5	30.8	6.1	8.1	91	12.1	0	5	SE	29.91	1.9	
	2100	27.0	30.0	4.9	8.0	92	12.0	0	0-5	SE	29.92	1.9	
	2200	27.0	29.5	3.4	7.9	95	11.9	0	0-5	SE	29.92	1.9	
	2300	27.0	29.5	2.9	7.75	93	11.7	0	0-5	SE	29.92	1.8	
	2400	25.0	29.0	2.1	7.7	95	11.7	0	0-5	SE	29.92	1.8	Calm
9-22-60	0100	24.5	29.0	1.7	7.7	95	11.8	0	0-5	SE	29.92	1.7	Calm
	0200	24.0	29.0	1.3	7.55	95	11.7	0	0-5	SE	29.92	1.6	Calm, mist over water
	0300	23.8	29.0	1.2	7.4	95	11.6	0	0-5	SE	29.91	1.6	Calm
	0400	23.5	29.0	1.4	7.4	95	11.5	0	0-5	SE	29.91	1.6	
	0500	20.2	29.0	1.3	7.5	93	11.7	0	0-5	SE	29.91	1.7	
	0600	22.0	29.0	1.2	7.5	93	11.6	5	0-5	NW	29.91	1.8	
	0700	23.0	29.0	1.4	7.6	93	11.7	5	0-5	NW	29.91	1.9	
	0800	27.0	28.5	1.3	7.7	95	11.6	5	0-5	N	29.94	2.0	

Table 4-7. Diurnal Oxygen Curve
Laboratory Bulkhead - November 1959 during _Gymnodinium_ and _Exuviella_ Bloom [51]

Date	Time	Water Temperature C°	pH	DO mg/L	Turb. mg/L	Air Temperature C°
1959						
20 November	1200	13.4	8.7	18.7	86	15.2
	1300	14.3	9.1	19.3	69	15.2
	1400	14.2	9.2	19.5	37	14.9
	1500	14.1	8.9	18.9	77	14.5
	1600	14.0	9.0	18.0	65	14.5
	1700	13.9	8.9	17.8	72	14.0
	1800	13.8	8.9	17.0	80	14.0
	1900	13.8	8.9	16.9	78	14.0
	2000	13.7	8.9	16.7	91	14.0
	2100	13.7	8.7	12.4	77	13.5
	2200	13.7	8.6	11.6	84	13.0
	2300	13.9	8.5	11.7	89	13.0
	2400	13.5	8.4	9.8	43	12.5
1959						
21 November	0100	13.2	8.5	9.8	48	12.0
	0200	13.2	8.5	11.3	55	12.0
	0300	13.0	8.4	10.0	61	11.5
	0400	12.9	8.4	9.6	63	12.0
	0500	13.0	8.4	10.0	82	12.0
	0600	13.0	8.4	9.3	82	11.3
	0700	12.8	8.4	10.4	87	10.6
	0800	12.9	8.4	10.7	86	12.8
	0900	13.3	8.8	13.0	80	15.5
	1000	13.7	8.8	14.7	75	16.5
	1100	14.7	8.8	17.1	83	17.6
	1200	18.0	9.2	17.9	52	18.5

Table 4-8. Diurnal Oxygen Curve
Laboratory Bulkhead during Eutreptia and Gymnodinium Bloom (52)

Date	Time	Temp. C° Air	Temp. C° Water	DO mg/L	pH	Turb. mg/L	Sal. °/oo	Cloud	Wind Rate	Wind Dir.
1960										
28 January	0800	12.0	---	10.7	7.9	95	---	H. Fog	0-5	S
	0900	---	13.7	11.9	8.1	--	---	H. Fog	---	---
	1000	---	13.8	12.8	8.1	97	---	H. Fog	---	---
	1100	---	14.1	14.0	8.2	97	8.7	H. Fog	---	---
	1200	14.2	15.0	14.9	8.2	96	8.7	H. Fog	---	---
	1300	15.6	16.8	16.3	8.5	94	8.6	Fog Lifting	5-10	S
	1400	15.0	16.7	15.5	8.6	92	8.6	Sun Spotty	5-17	S
	1500	16.8	16.8	15.5	8.6	93	8.6	100% Cloud	15	S
	1600	20.0	16.9	14.2	8.6	94	8.3	Sun Spotty	15-17	S
	1700	19.3	16.8	14.3	8.6	94	8.2	Sun Spotty	15	S
	1800	19.0	17.5	13.3	8.4	96	8.3	100% Cloud	0-5	---
	1900	18.0	16.5	14.4	8.3	95	7.7	Rain	0-5	---
	2000	18.0	16.4	13.7	8.3	92	8.0	Rain	5-10	S
	2100	18.0	16.7	11.1	8.3	95	7.7	Rain	5-10	N
	2200	18.0	16.4	11.9	8.3	97	7.7	Clear	5-10	N
	2300	16.0	15.8	11.9	8.3	97	7.6	Clear	10-15	N
	2400	13.0	14.9	12.2	8.3	96	8.0	Clear	13-17	N
1960										
29 January	0100	11.0	14.8	11.5	8.3	96	8.3	Clear	12-17	N
	0200	9.0	14.2	11.2	8.4	98	8.0	Clear	17-25	N
	0300	8.0	13.7	12.3	8.4	98	8.9	Clear	12-17	N
	0400	7.0	13.6	12.2	8.5	96	9.0	Clear	14-16	N
	0500	6.0	13.4	11.9	8.4	97	9.2	Clear	15-18	N
	0600	6.0	13.2	11.9	8.4	98	8.9	Clear	12-18	N
	0700	6.0	12.9	11.5	8.5	97	9.6	Pt. Cloudy	12-15	N-NW
	0800	6.0	12.3	11.7	8.5	97	9.3	Pt. Cloudy	15	N
	0900	8.0	13.0	12.4	8.4	97	8.9	Pt. Cloudy	16	N
	1000	8.5	13.0	12.0	8.6	97	8.4	Pt. Cloudy	15-20	N
	1100	10.0	14.3	12.7	8.5	95	8.5	Sl. Cloudy	15	N
	1200	12.5	15.2	12.5	8.6	93	8.0	Clear	20-25	N

Tide ft	1-29-60		
		0600	+0.7
		0800	+0.4
		1200	0

stations varied from 4.5 to 34.2 gm. per square meters per day. The pH variations during night and day substantiate the large amount of photosynthetic activity. The low biological activity in the Texas City area indicated a certain ecological disturbance.

Salinity: In Fig. 4-47 the salinity gradients for the period July 15-19, 1961, depict the potential exchange of fresh and salt waters. The salinity values varied from about 4.4 parts per thousand (o/oo) opposite Moses Lake to about 20 o/oo opposite Pelican Island.

East Bay

There is little activity in the East Bay area at the present time, and there is no indication of a major pollution problem.

Biochemical Oxygen Demand: No permits of significance have been issued for the East Bay area. Maximum BOD values for this bay during the recent 1963 survey showed only 2 mg/l. This information is shown in Fig. 4-48. Similar results obtained from the 1950-1951 survey are shown in Fig. 4-49.

Dissolved Oxygen: There was some fluctuation in the 1963 dissolved oxygen between maximum and minimum values, Fig. 4-50. However, in most cases there was little difference in values. At Station 320 the minimum value for dissolved oxygen was near 2 mg/l, indicating considerable utilization of oxygen. Typical

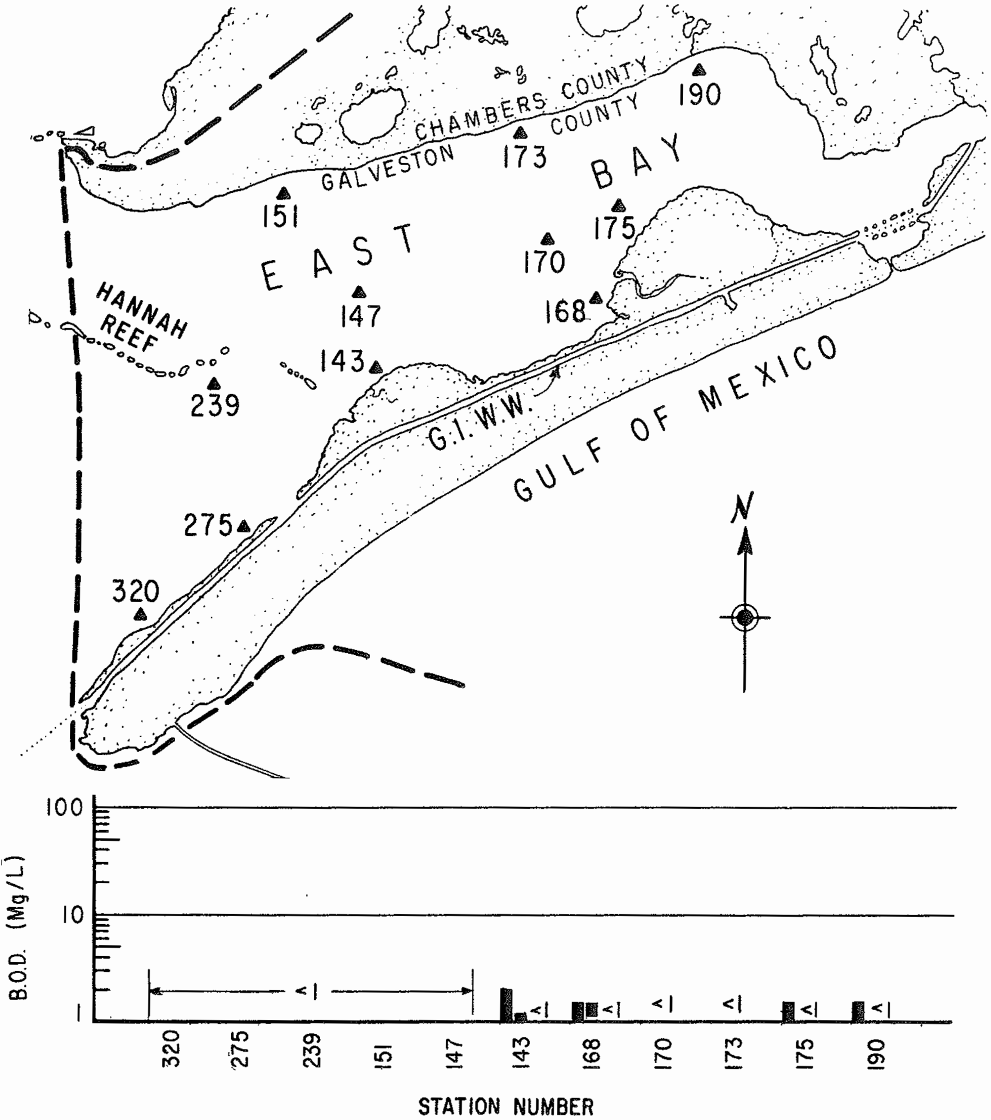


FIG. 4-48. BIOCHEMICAL OXYGEN DEMAND-EAST BAY (June 1- Dec. 1, 1963)

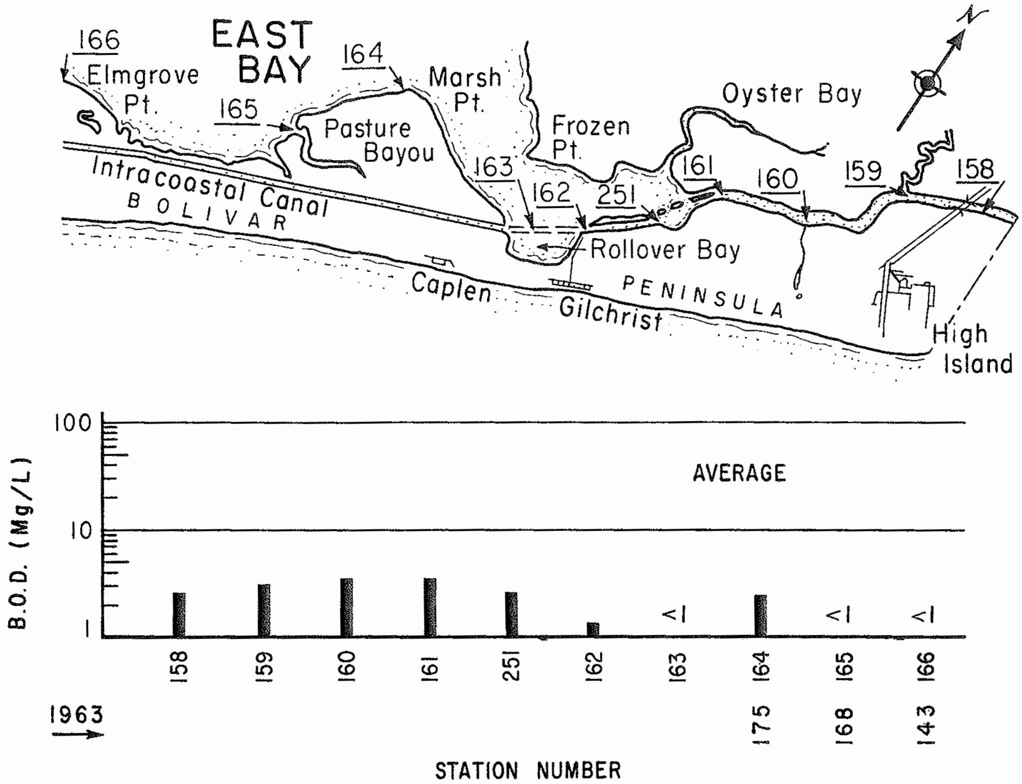


FIG. 4-49. BIOCHEMICAL OXYGEN DEMAND-EAST BAY (Feb. 17, 1950-Feb. 28, 1951)[55]

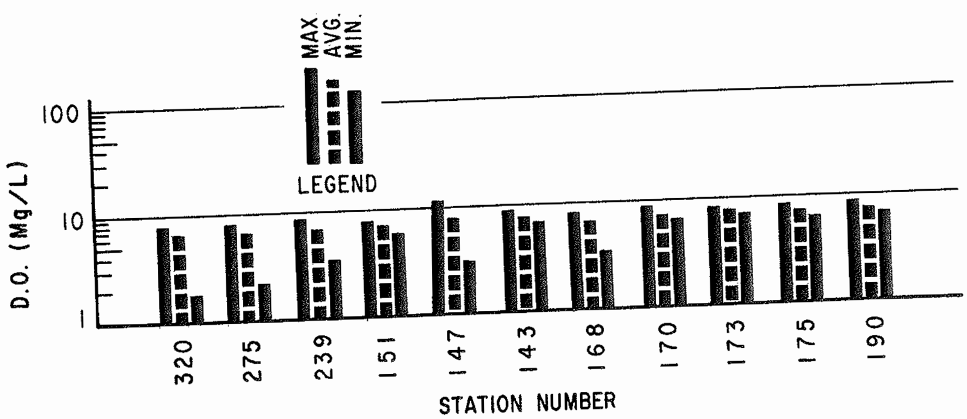


FIG. 4-50. DISSOLVED OXYGEN - EAST BAY (June 1 - Dec. 1, 1963)

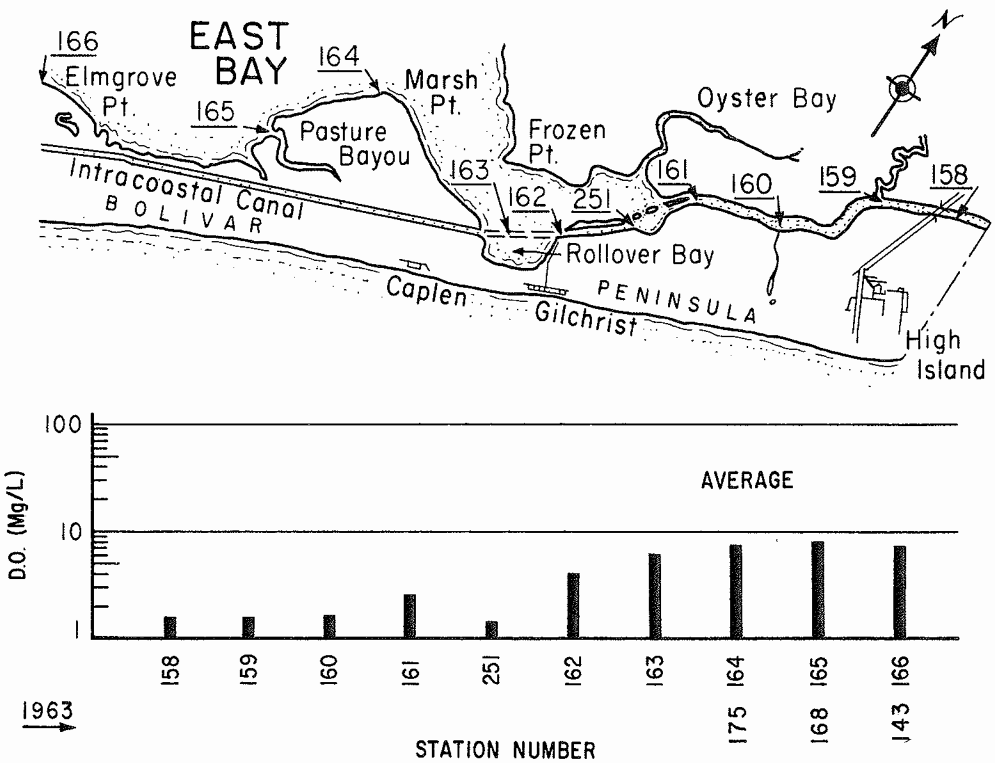


FIG. 4-51. DISSOLVED OXYGEN - EAST BAY (Feb. 17, 1950 - Feb. 28, 1951)[56]

examples of the dissolved oxygen conditions are given in Fig. 4-51. The dissolved oxygen during 1950-1951 appeared to be somewhat less than that found during the 1963 survey.

West Bay

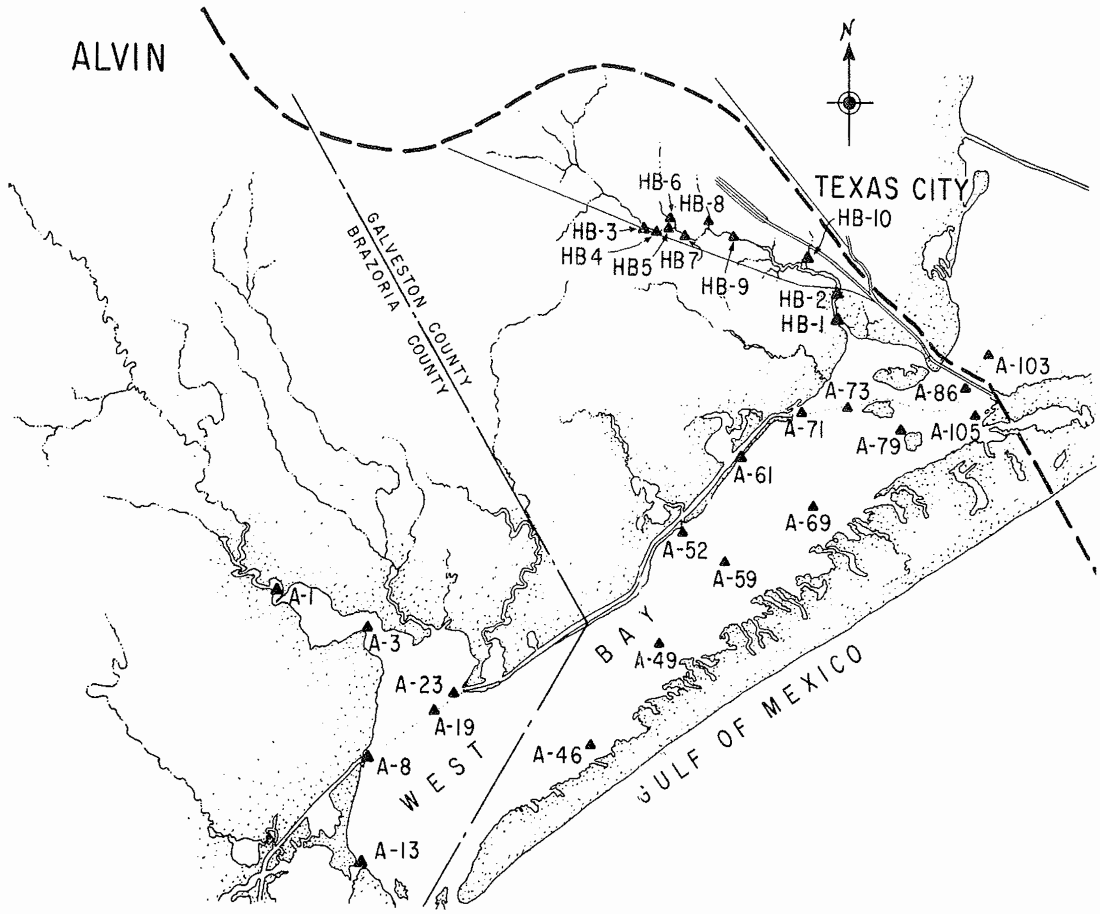
The West Bay Area contains West Lake, Highland Bayou, and Chocolate Bayou. Some industrial activity is beginning to develop in this area.

Biochemical Oxygen Demand: From the permits it has been estimated that about 457 and 798 pounds of BOD, respectively, will be released into Highland Bayou and Chocolate Bay. Virtually all of the BOD in the Highland Bayou area is due to domestic discharges, whereas the reverse is true for the Chocolate Bay area.

The upper portion of the Highland Bayou is presently receiving a significant waste load. At station HB9 the maximum BOD was 18 mg/l. The same locations were receiving considerable amounts of sewage during the 1950-1951 survey. The results of the 1963 survey are shown in Fig. 4-52 and the earlier data are given in Figs. 4-53 through 4-56. West Bay itself showed no significant pollution.

Chemical Oxygen Demand: At this time no permits have been issued which show an anticipated COD value.

Dissolved Oxygen: The dissolved oxygen in the Highland Bayou



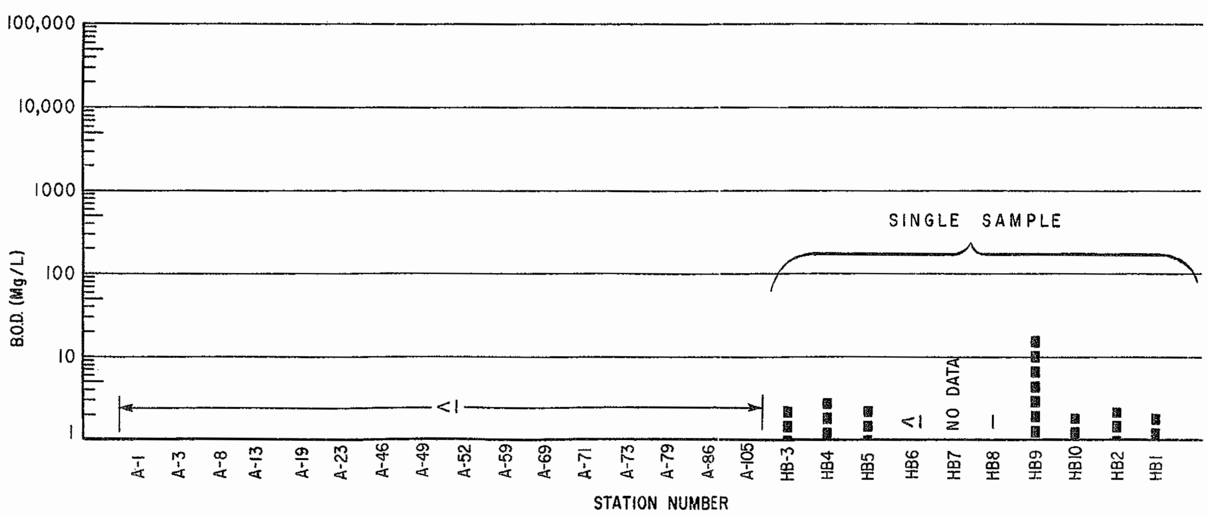


FIG. 4-52. BIOCHEMICAL OXYGEN DEMAND-
WEST BAY (June 1 - Dec. 1, 1963)

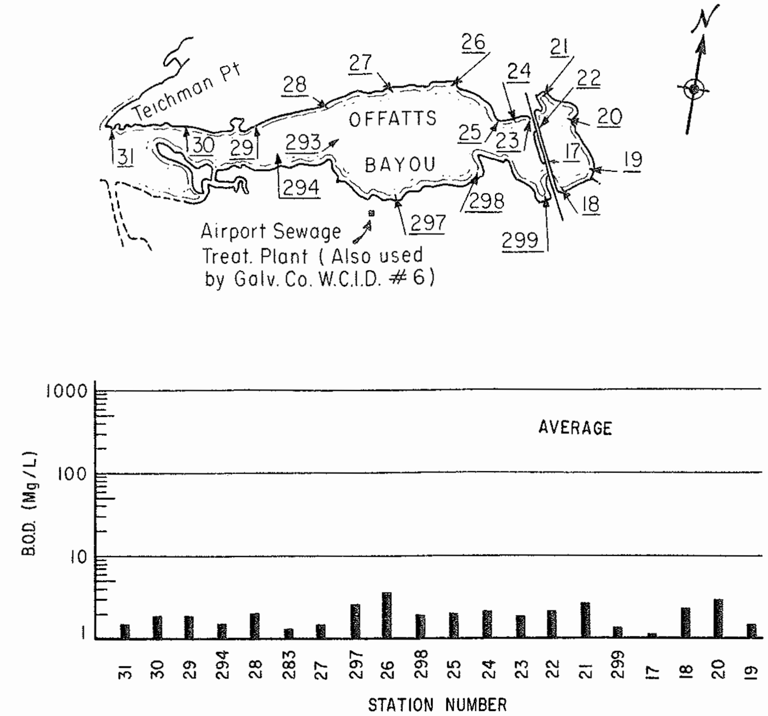


FIG. 4-53. BIOCHEMICAL OXYGEN DEMAND-OFFATTS BAYOU (Feb. 17, 1950-Feb. 28, 1951)[57]

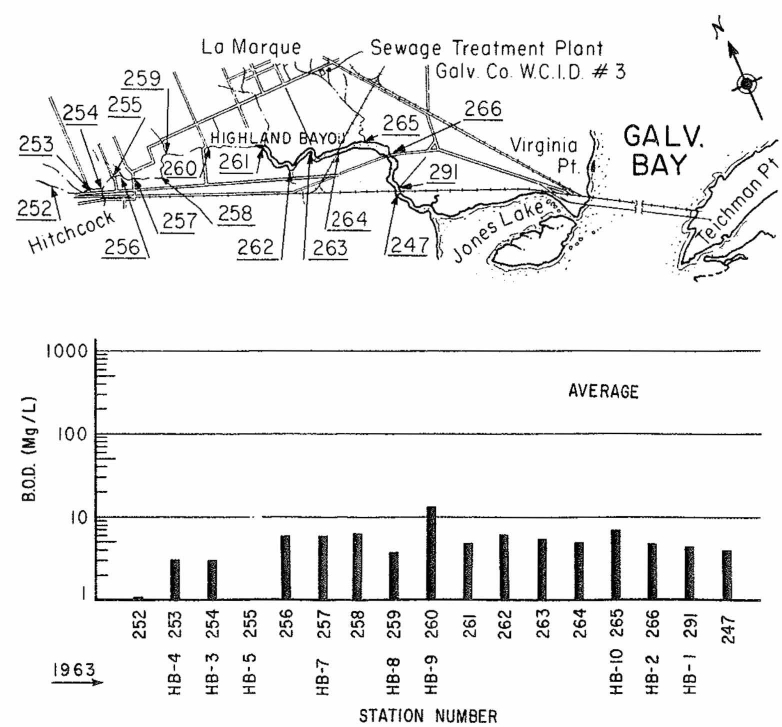


FIG. 4-54. BIOCHEMICAL OXYGEN DEMAND-HIGHLAND BAYOU (Feb. 17, 1950-Feb. 28, 1951)[58]

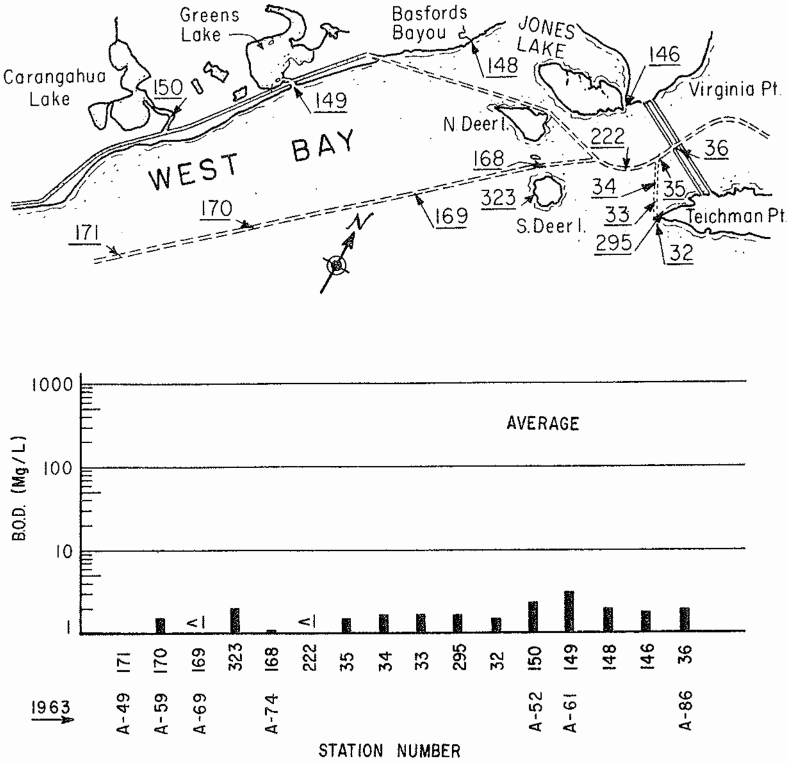


FIG. 4-55. BIOCHEMICAL OXYGEN DEMAND-
WEST BAY (Feb. 17, 1950 - Feb. 28, 1958)[59]

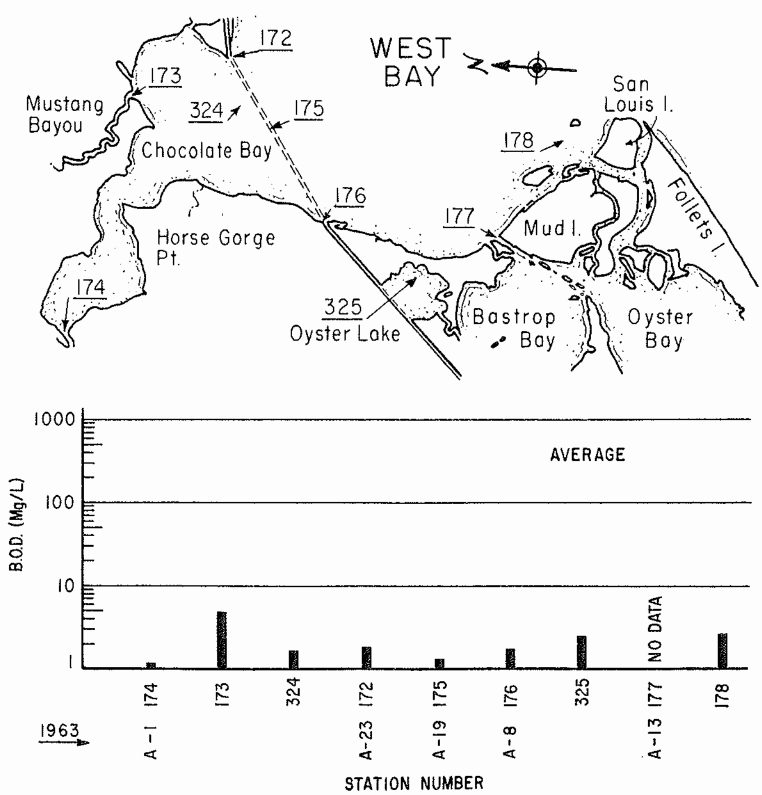
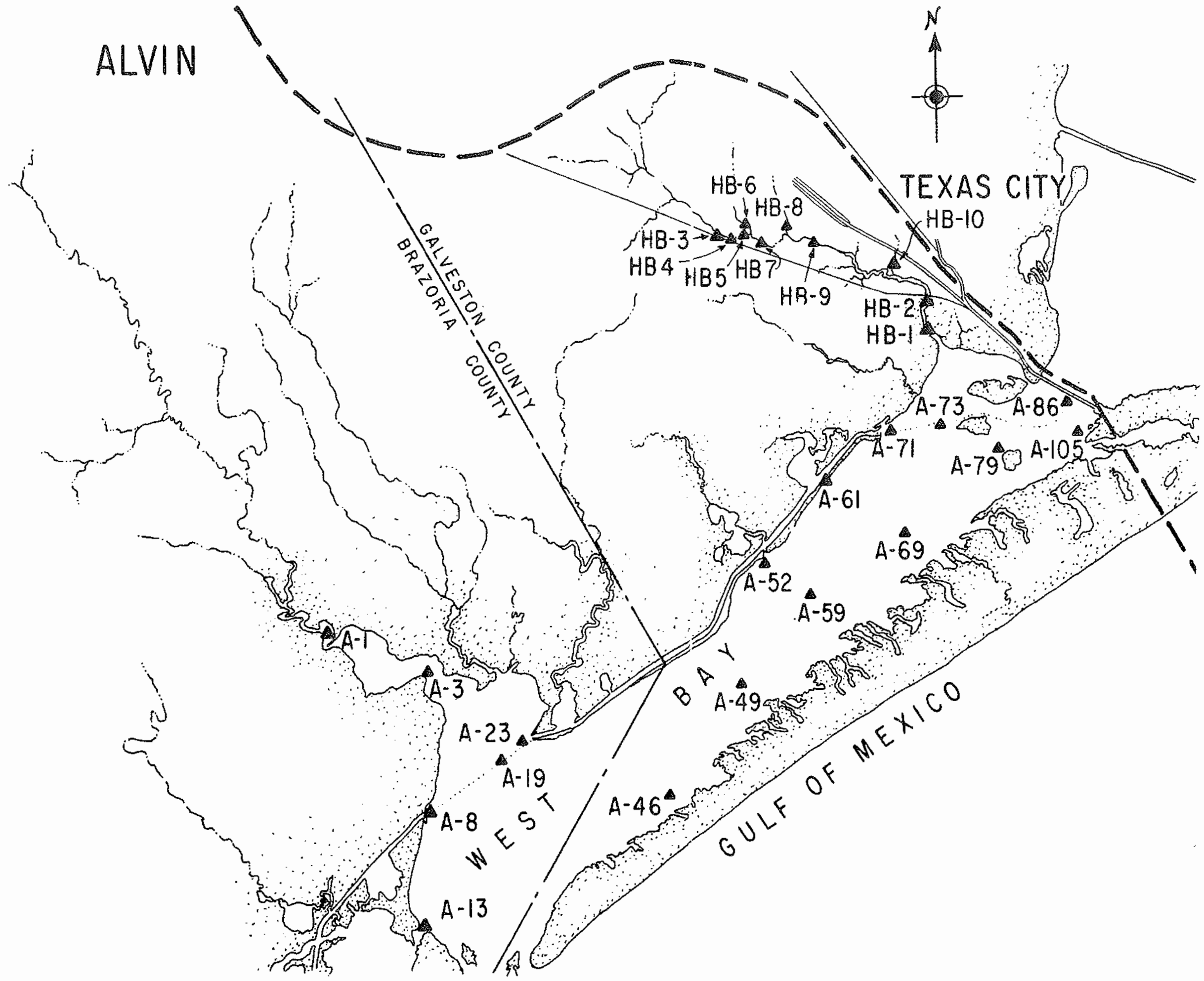


FIG. 4-56. BIOCHEMICAL OXYGEN DEMAND -
CHOCOLATE BAY (Feb. 17, 1950 - Feb. 28, 1951)[60]

area, in the vicinity of Station H-B4, reflects pollution, Fig. 4-57, At this station the maximum dissolved oxygen recorded was only 1.7 mg/l. Supersaturation of oxygen was found to exist at some of the stations, indicating considerable photosynthesis. Large variations were found between maximum and minimum values of dissolved oxygen in other areas as well. Such variations would seem to indicate excessive fertilization. The dissolved oxygen values obtained during the 1950-1951 survey were about the same as those obtained during the 1963 survey. Samples collected at Station HB3 and HB4 in the upper portion of Highland Bayou presently indicate relatively low values of dissolved oxygen.



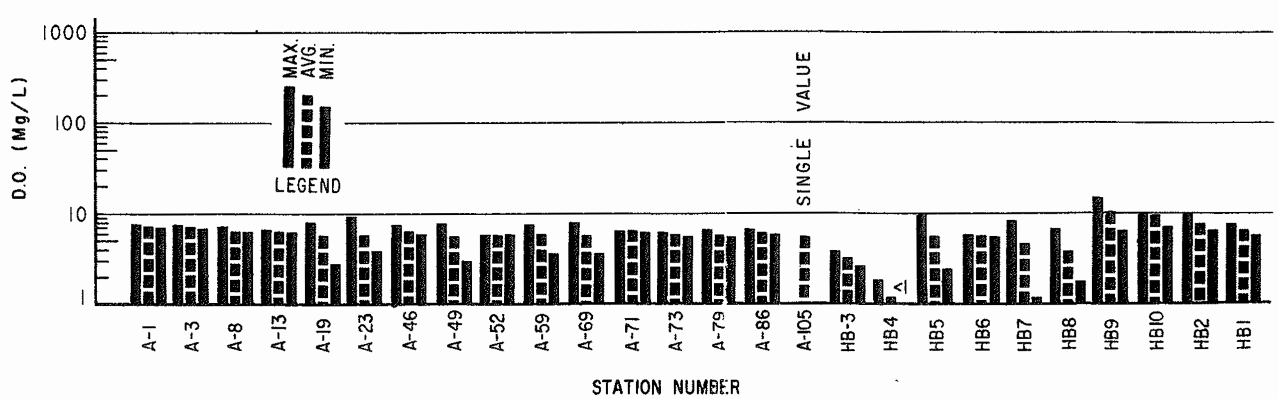


FIG. 4-57. DISSOLVED OXYGEN-WEST BAY-
(June 1 - Dec.1, 1963)

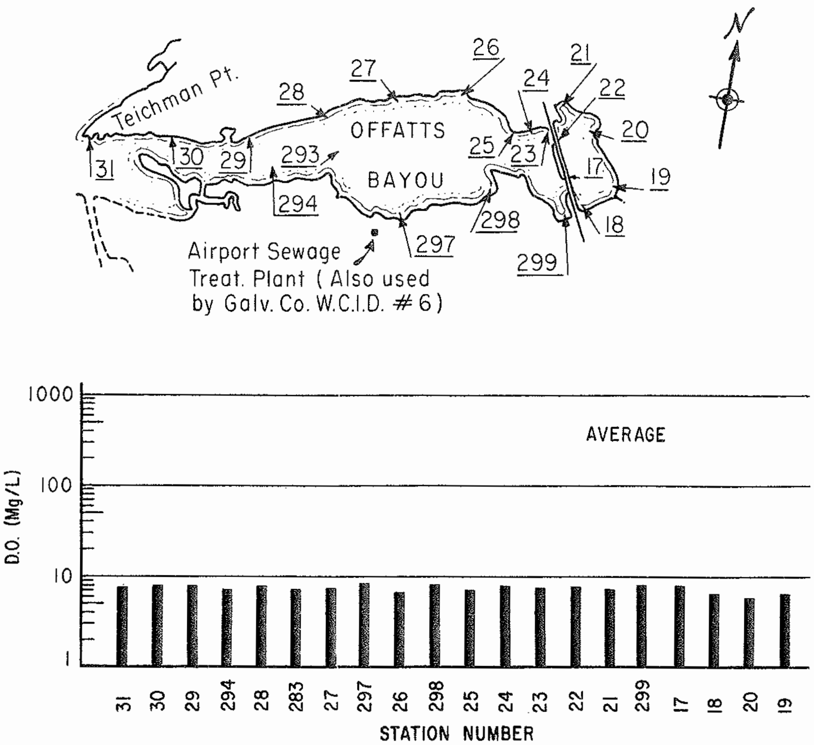


FIG. 4-58. DISSOLVED OXYGEN-OFFATTS BAYOU
(Feb. 17, 1950 - Feb. 28, 1951)[61]

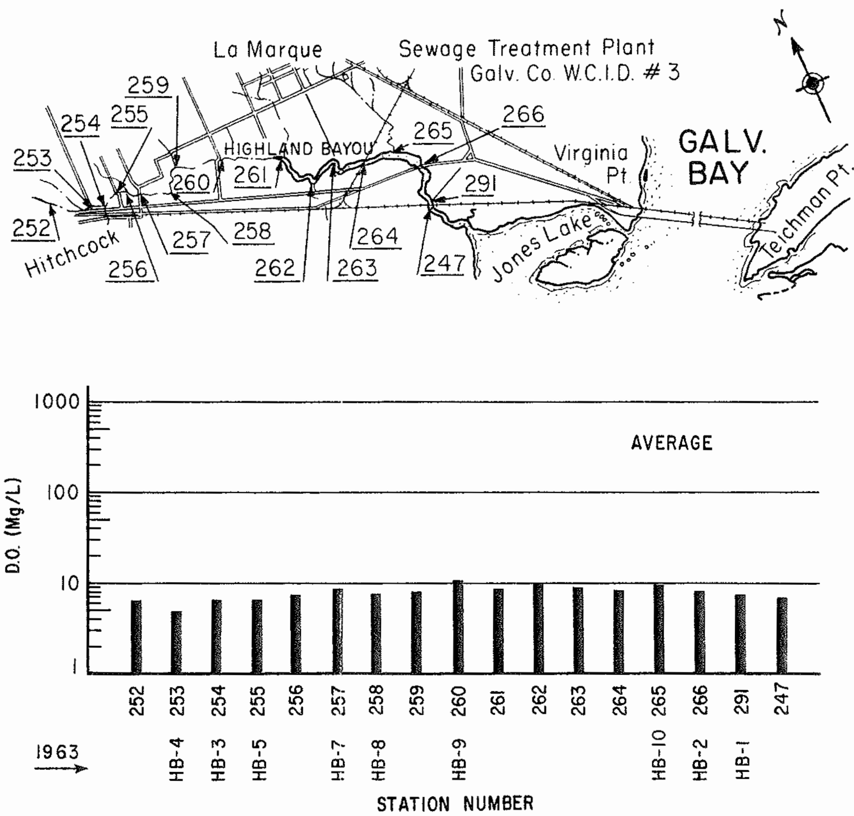


FIG. 4-59. DISSOLVED OXYGEN-HIGHLAND BAYOU
(Feb. 17, 1950 - Feb. 28, 1951)[62]

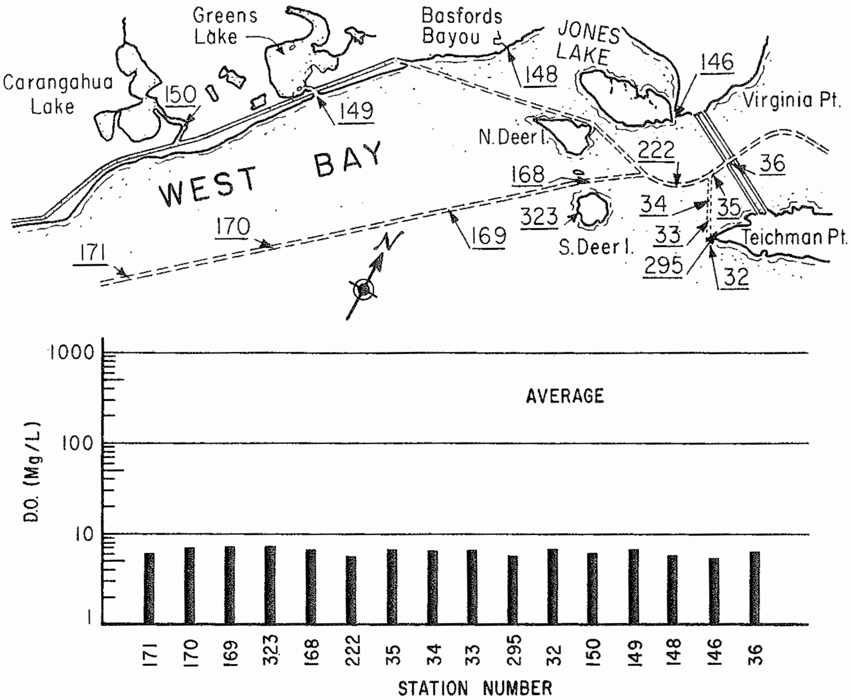


FIG. 4-60. DISSOLVED OXYGEN - WEST BAY (Feb. 17, 1950 - Feb. 28, 1951)[63]

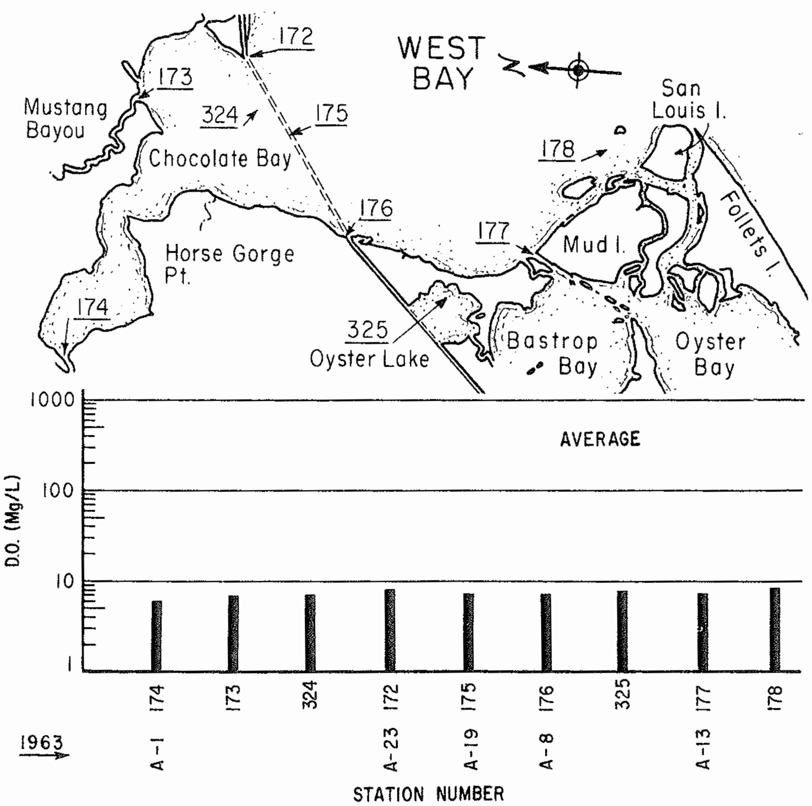


FIG. 4-61. DISSOLVED OXYGEN - CHOCOLATE BAY (Feb. 17, 1950 - Feb. 28, 1951)[64]

CHAPTER 5

BACTERIOLOGICAL CHARACTERISTICS (HISTORICAL)

A number of studies have been made to establish the local and areal extent of sewage contamination in Galveston Bay and its tributaries. Various county and city health units, industrial organizations, U. S. Bureau of Commercial Fisheries (USBCF), Institute of Marine Science (The University of Texas), Texas State Department of Health (TSDH), Texas Parks and Wildlife Department (TPWD), City of Houston, and other agencies have made contributions to the historical collection of bacteriological data. In this connection, the index of pollution by sewage is a group of microorganisms commonly referred to as coliforms.

The following discussion describes:

- General Background
- Houston Ship Channel
- Trinity Bay
- Upper Galveston Bay and Clear Lake
- Lower Galveston Bay
- East Bay
- West Bay

General Background

The results of two studies of major significance from a public health point-of-view have been reported. The first investigation culminated in a report for the period February 17, 1950, to February 28, 1951,

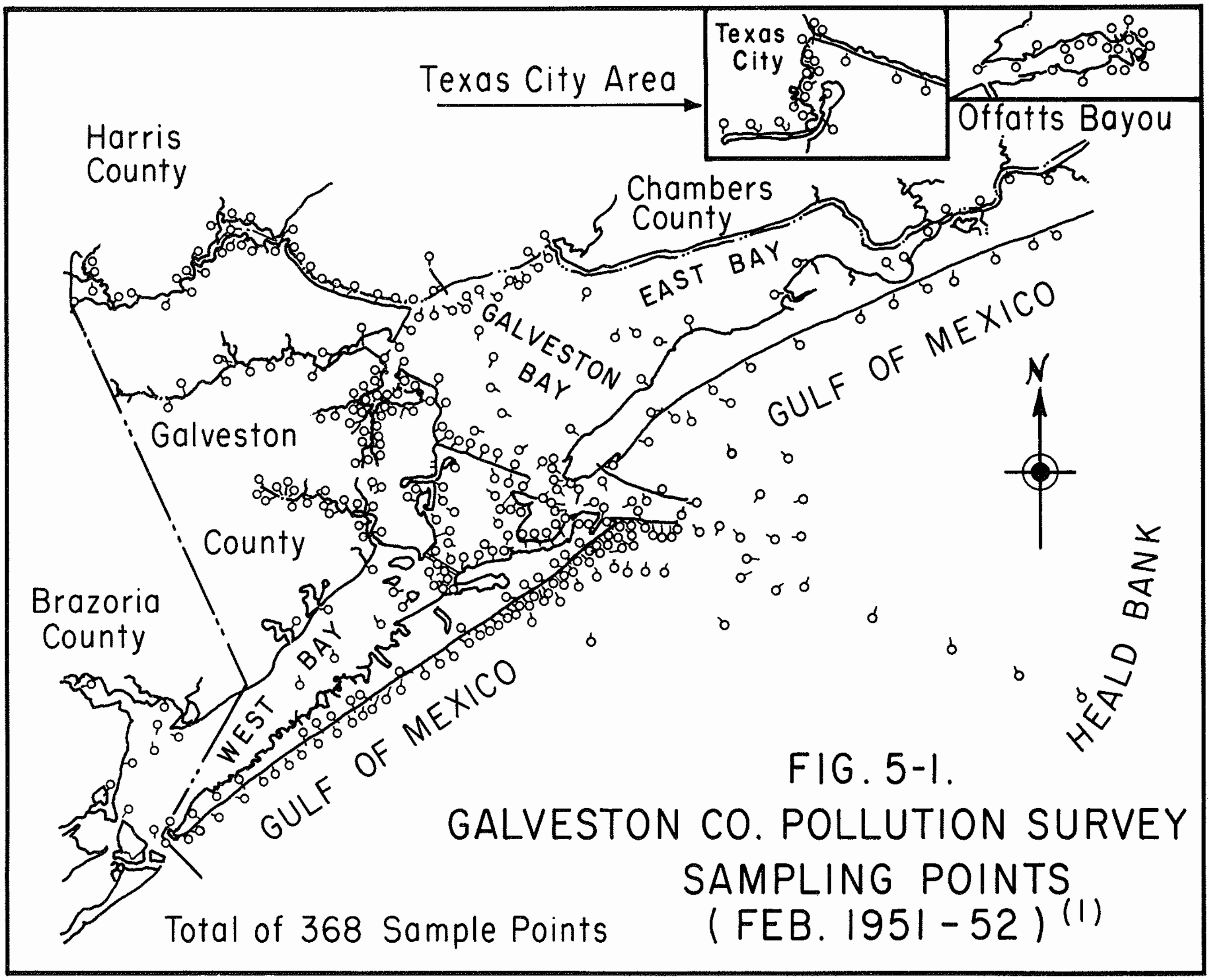


FIG. 5-1.
GALVESTON CO. POLLUTION SURVEY
SAMPLING POINTS
(FEB. 1951 - 52) (1)

entitled Galveston County Pollution Survey, dated March, 1951. The second of these surveys is currently under way and is conducted by the TSDH and TPWD for the Texas Water Pollution Control Board.

A third survey of a shorter duration was conducted between February 24, 1958, and June 4, 1958. The purpose of this survey was to evaluate the sanitation conditions affecting the quality of the oysters.

A fourth source of public information on coliform contamination can be found in the extensive files of the Department of Public Works in the City of Houston. Detailed data for the Houston Ship Channel are available for the period 1933-1941 and for the post World War II period. However, only the 1933-1941 data were made available for this report.

Galveston County Pollution Survey: The Galveston County Pollution Survey (1950-1951) was a cooperative investigation by the Texas State Department of Health and the Galveston County Commissioner's Court. The sampling stations are given in Fig. 5-1 and the locations are described in Appendix Table A-1. A total of 368 sampling points were established covering the following specific areas:

Upper Galveston Bay
Middle Galveston Bay
Lower Galveston Bay
East Bay

West Bay
Offatts Bayou
Galveston Channel and Bolivar Roads
West Galveston Beach
City of Galveston Beach
Gulf of Mexico
Texas City Area
Carbide Ditch and Moses Lake
Clear Creek
Dickinson Bayou
Highland Bayou
Bolivar Beach

It should be noted that the information contained in this report is not necessarily subdivided according to the above listing. However, many of these areas are used in the comparisons which follow.

A total of 2,500 samples were analyzed during the 1950-1951 survey. The stations were located where pollution was anticipated and the frequency of sampling was varied. A greater frequency of sampling was conducted in those areas in which pollution existed. Some sampling stations were established along the Gulf side of Galveston Island at intervals of approximately 1,500 feet along recreational waters, and samples were collected in water two to four feet deep; however, these data are not discussed herein.

A summary of the report is as follows:(2)

> "1. It has been conclusively proven that sewage pollution from the communities to the north does not affect the waters of Galveston County.
>
> "2. It has been observed that in all areas there is a tendency toward natural recovery of polluted waters due to the bactericidal effects of normal sea water, as well as dilution by tidal action.

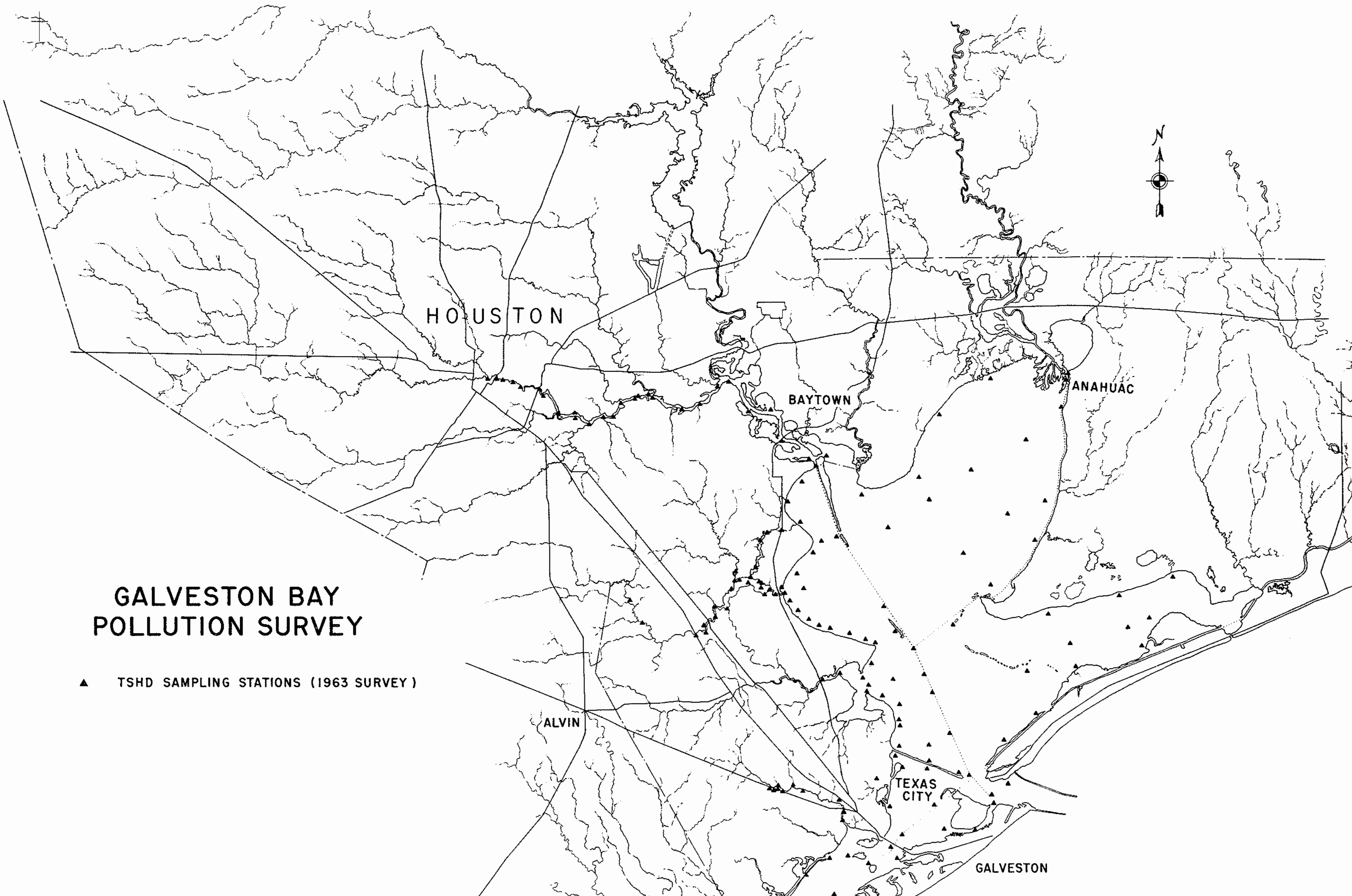


FIG. 5-2. TEXAS STATE DEPARTMENT OF HEALTH SURVEY STATIONS (1963)

"3. Although this phenomena was substantiated many times over, some areas were receiving such high sewage loads that this recovery procedure was nullified. This is particularly evident in Texas City, Galveston Channel, Bolivar Roads, and Gulf of Mexico areas.

"4. The actual areas of gross pollution are designated on the accompanying county map. It can be seen that concentrations are of a shoreline nature with practically the entire western shoreline of Galveston Bay involved; Lower Galveston Bay, Galveston Channel, and Bolivar Roads are polluted in their entirety.

"5. It has been determined that the Gulf of Mexico beaches from approximately 61st St. north to about 7 Mile Road on Bolivar Beach are subject to intermittent sewage pollution from the City of Galveston.

"The degree of this pollution exceeds the suggested standard for Grade A beaches as suggested by the Joint Committee on Bathing Places of the American Public Health Association.

"6. During the process of this survey, excellent cooperation has been received from various industries in the county. Industry in general is aware of its responsibility in controlling and eliminating pollution by industrial wastes. Tremendous strides are being taken in this regard. The survey will continue working with industry in these problems."

TSDH and TPWD Survey: The 1963-1964 Galveston Bay survey is not confined to the surrounding environs of Galveston and does not encompass the Galveston beach area on the Gulf of Mexico side of Galveston Island. These sampling stations are shown in Fig. 5-2, and a description of each location is given in Appendix Table C-1. Although the survey is scheduled to span one year, the data included herein is approximately for the period June 1, 1963, to December 1,

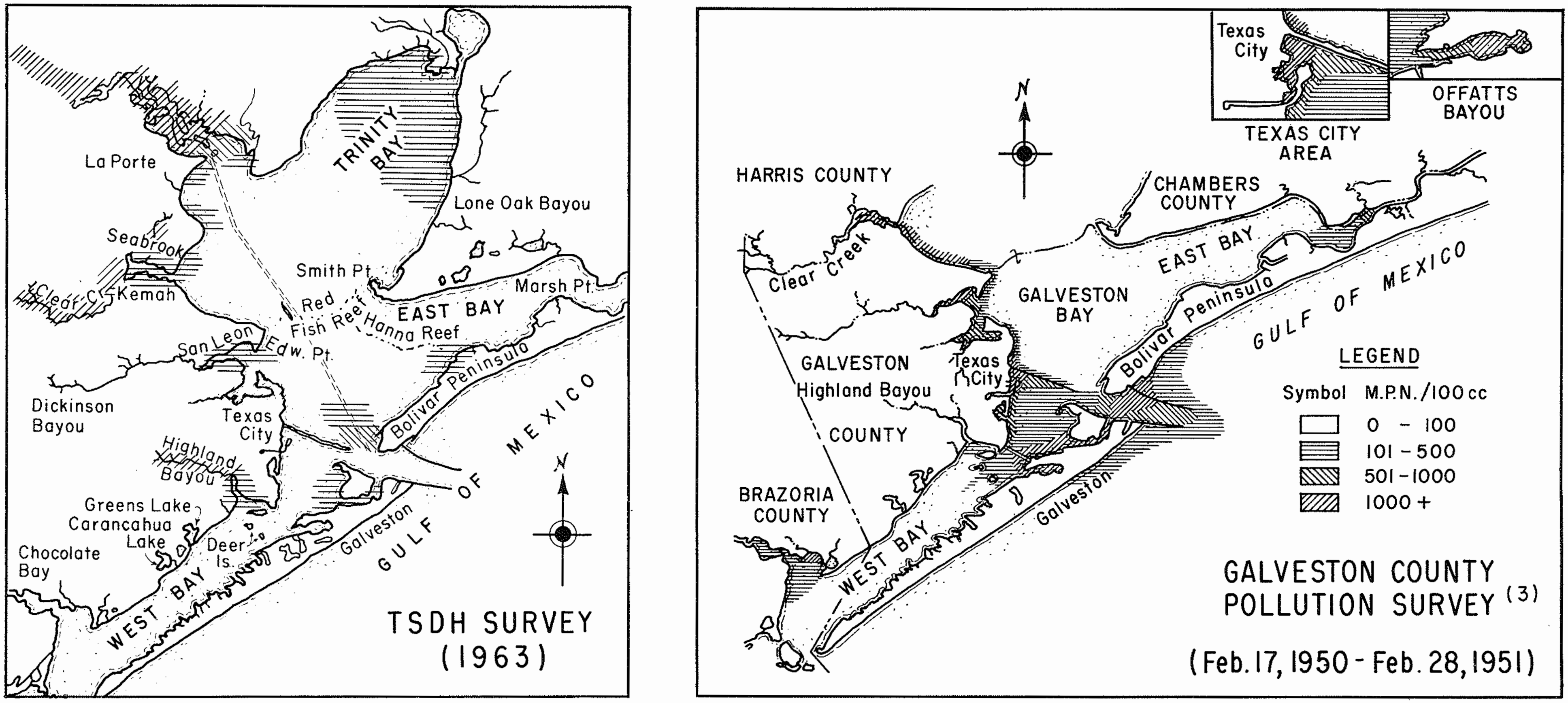
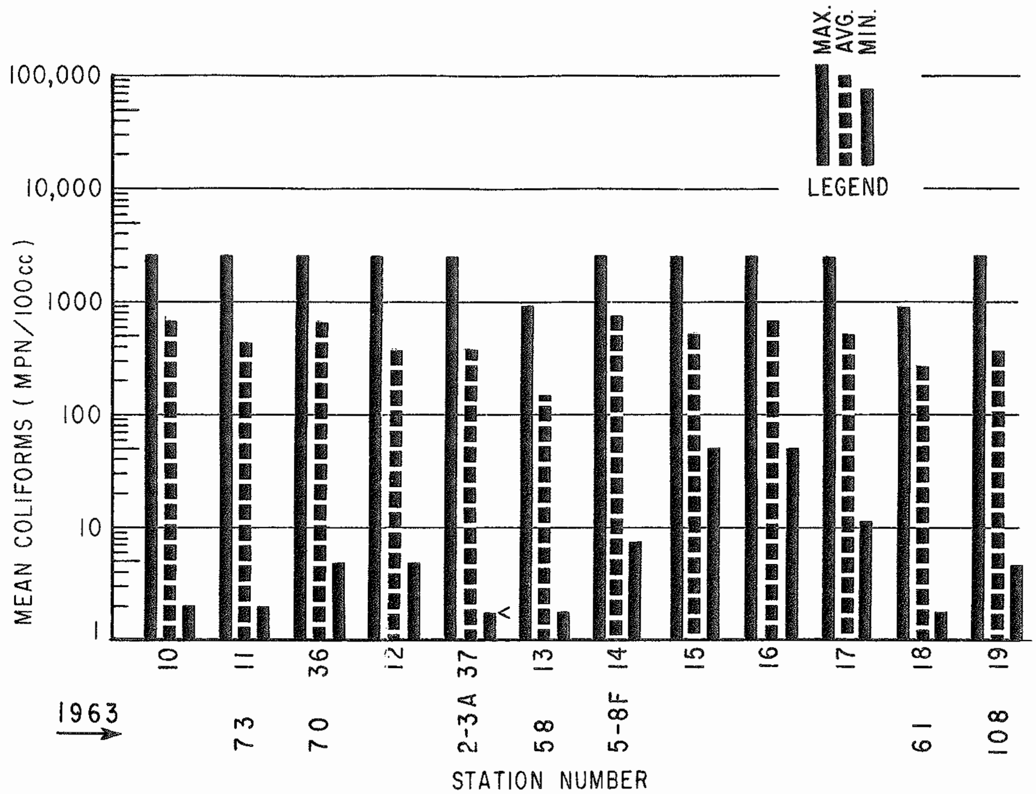


FIG. 5-3. COLIFORM COMPARISONS

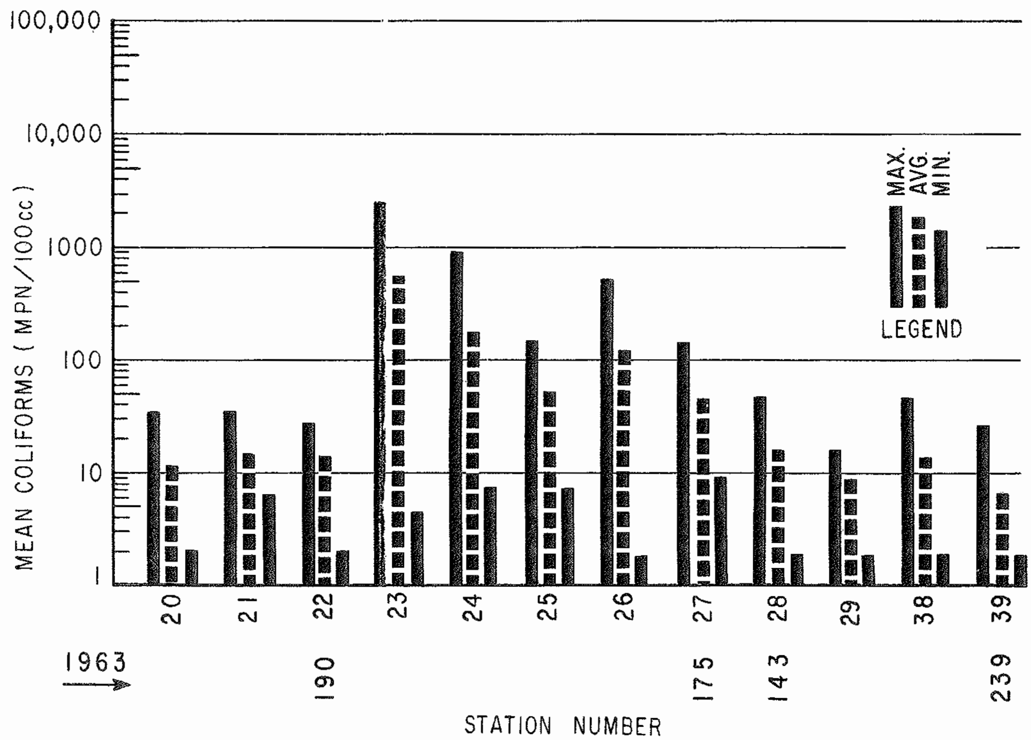
1963, and referred to herein as the 1963 data.

Figure 5-3 shows a more general comparison of the 1963 and the 1950-1951 results. In 1963, water samples taken from the Houston Ship Channel above Morgan's Point, Clear Creek, parts of Clear Lake, and Highland Bayou, contained more than 1,000 coliform microorganisms per 100 ml. The data represent average values. The water in sections of the Houston Ship Channel near Morgan's Point and opposite the Texas City Dike in 1963 contained 500 coliforms per 100 ml. The results of the 1963 sampling indicated that parts of Trinity Bay, Galveston Bay, Clear Lake, West Bay, and East Bay contained coliforms in excess of 100 per 100 ml. Apparently a considerable number of areas such as the shoreline of Galveston Bay above Dickinson Bayou and the area around Galveston are not polluted as badly with domestic sewage now as in previous years. The 1950-1951 survey was limited to the Lower Bay; therefore, complete comparisons are impossible. The comparison is illustrative but not necessarily statistically valid. No conclusions can be drawn from this comparison.

Additional comparisons are shown in Fig. 5-4. These data include the results of the 1958 survey. Coliform counts in Upper Galveston Bay and Trinity Bay in 1958 were generally higher than in Lower Galveston Bay and East Bay.[23] At most stations, the count ranged from two to over 1,000 coliform organisms per 100 ml.

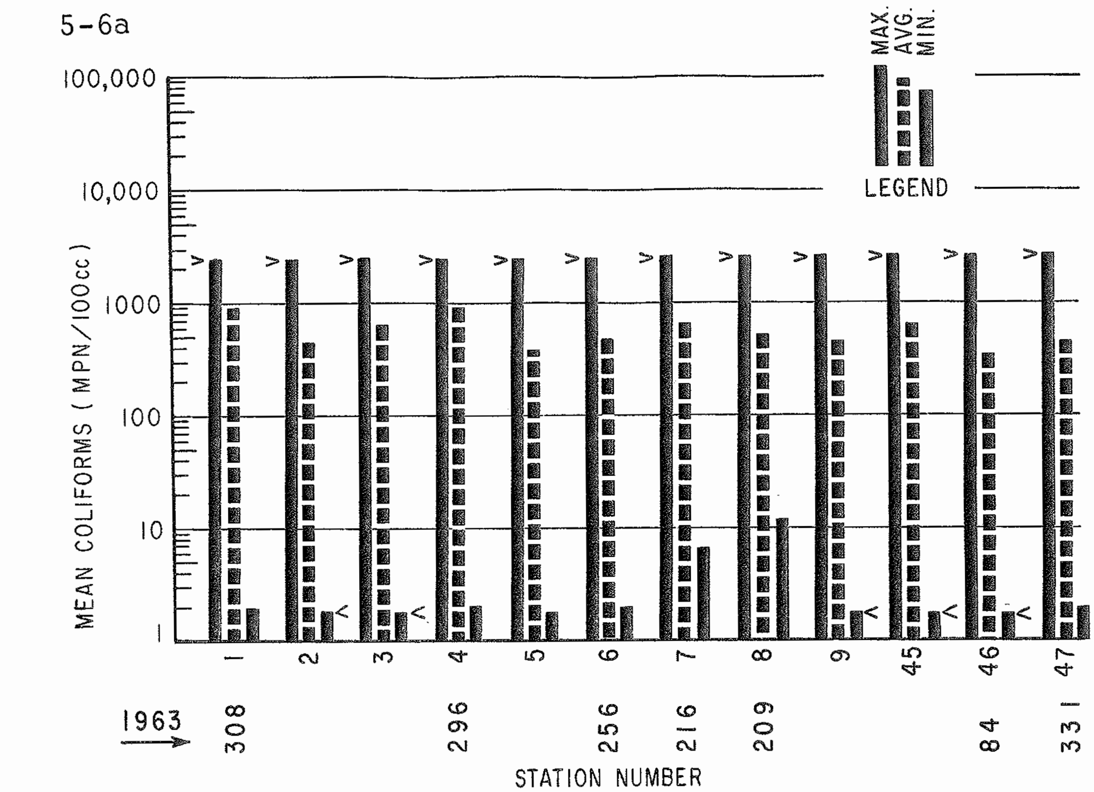


TRINITY BAY (1958)[23]

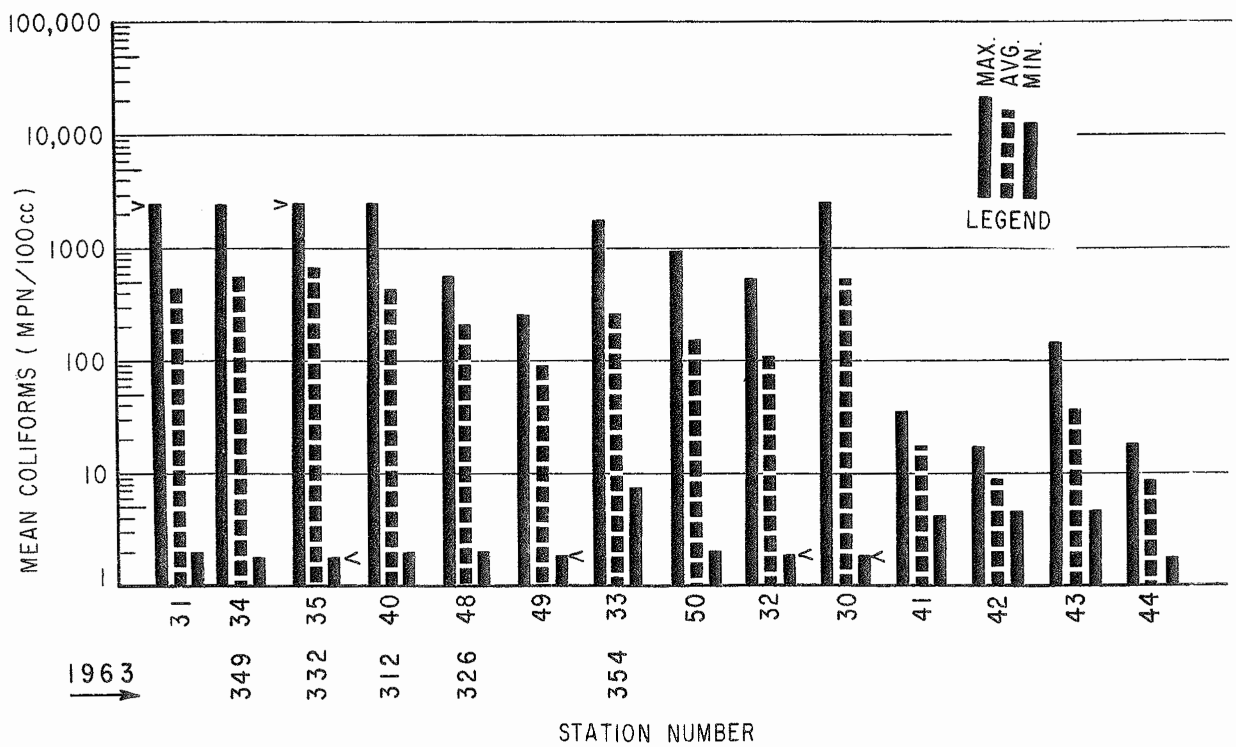


EAST BAY (1958)[23]

FIG. 5-4. COMPARISON OF COLIFORM DENSITIES



UPPER GALVESTON BAY (1958)[23]



LOWER GALVESTON BAY (1958)[23]

FIG. 5-4. COMPARISON OF COLIFORM DENSITIES

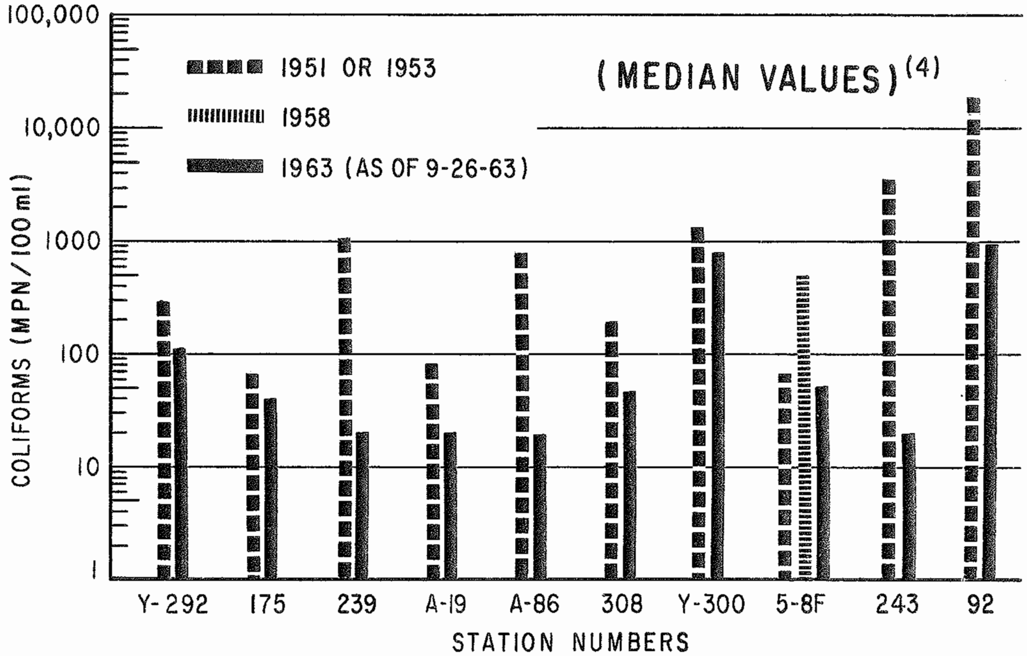


FIG. 5-4. COMPARISON OF COLIFORM DENSITIES

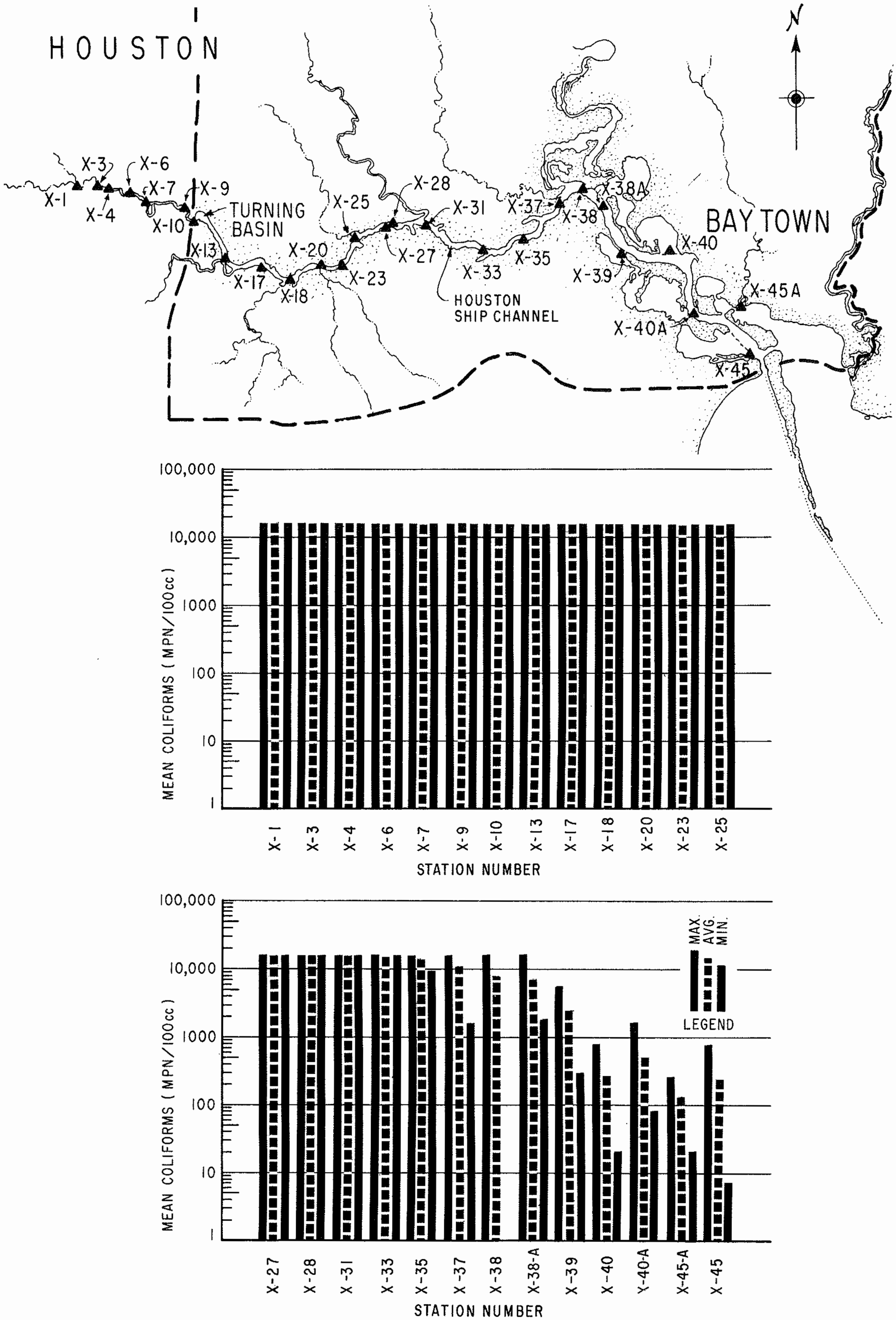


FIG. 5-5. COLIFORMS-HOUSTON SHIP CHANNEL
(June 1 - Dec. 1, 1963)

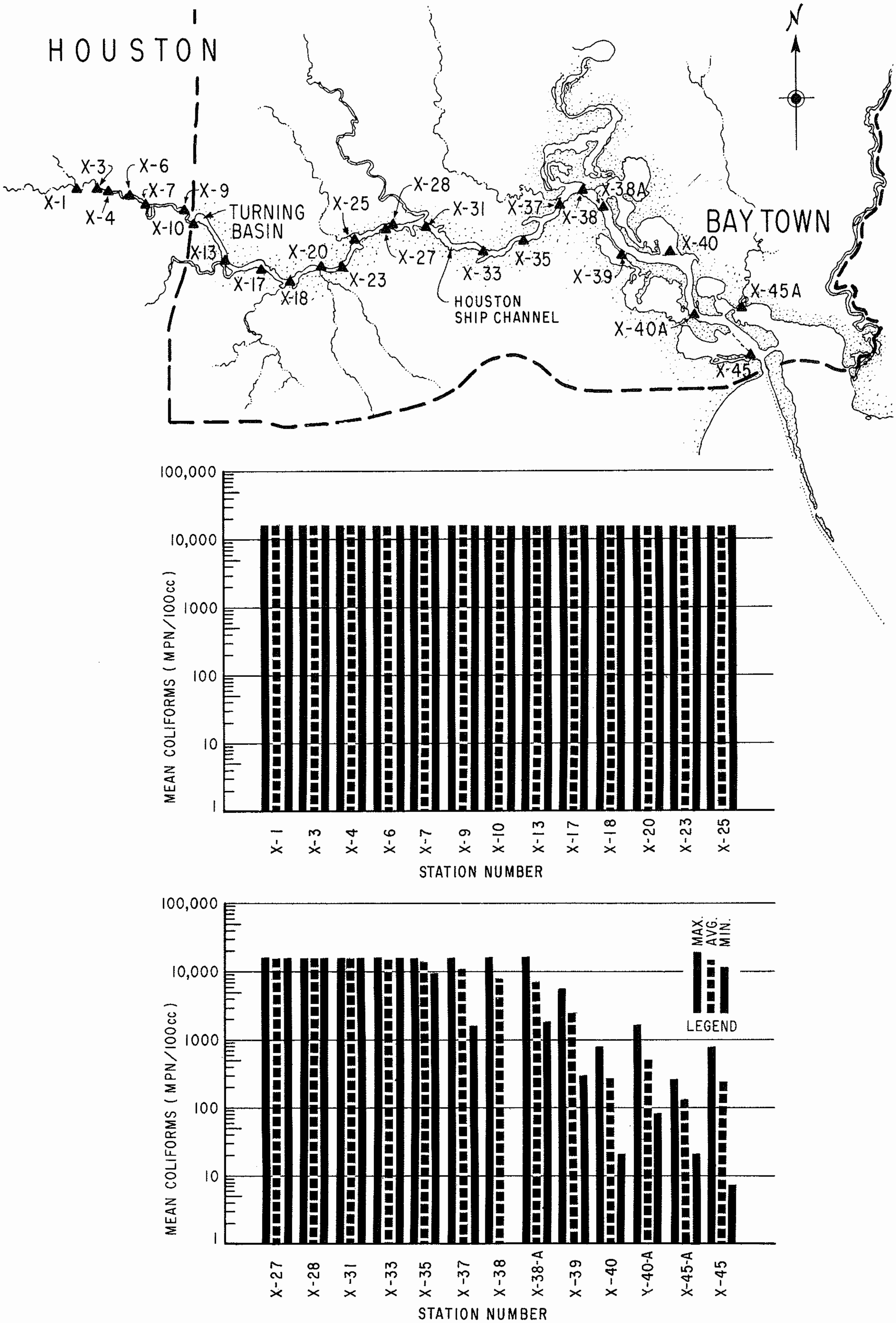


FIG. 5-5. COLIFORMS-HOUSTON SHIP CHANNEL
(June 1 - Dec. 1, 1963)

Houston Ship Channel--Coliforms

The State of Texas, City of Houston, and Harris County have routinely sampled sections of the Houston Ship Channel to estimate coliform densities. However, only the data from the State and some of the data from the City of Houston have been made available for this report. Figure 5-5 shows the Texas State Department of Health and Texas Parks and Wildlife Department sampling stations and the results of the 1963 survey, whereas Table 5-1 lists the coliform count as determined by the City of Houston.

The available information, including the 1963 data, indicate a considerable amount of sewage pollution. As shown in Fig. 5-5, the most probable number of coliform organisms per 100 ml (MPN/100 ml) on the average was greater than 10,000 between stations X-1 and X-37. Usually, when the coliform count is greater than 1,000 per 100 ml, there is reason to suspect considerable or recent sewage pollution.

The effect of these high coliform counts and associated pollution on this body of water has not been fully evaluated, but the bulk of the coliform count must be the result of domestic wastes. Seasonal adjustments on dilution have not been studied. Similarly, movement of sewage effluent into shallow bays along the channel is not fully known. Of equal interest is the influence of industrial wastes on the die-away of coliforms. It is of course possible that the coliform count would be greater if there were no industrial waste releases.

Table 5-1. Coliforms (#/100 ml.) in Houston Ship Channel[5]

Station	1933		1937		1938		1939		1940		1941	
Buffalo Bayou, Shepherd Drive	[a]51,400	10^3-10^5[b]	11,258	0-10^5	33,142	10^3-10^5	16,286	10^3-10^5	29,125	10^3-10^5	55,000	10^4-10^5
Little White Oak Bayou, 4.6 mi. from White Oak Bayou	31,000	10^3-10^5	30,250	10^3-10^5	21,700	10^3-10^5	17,750	1-10^5	—	—	73,000	10^3-10^5
Little White Oak Bayou, 0.8 mi. from White Oak Bayou	53,425	10-10^5	37,675	10^2-10^5	27,000	10^3-10^5	44,600	10^2-10^5	41,388	10^2-10^5	41,376	1-10^5
White Oak Bayou, 8.6 mi. from Channel	43,750	10^3-10^5	11,350	10^2-10^5	14,888	10^3-10^5	57,430	10-10^5	4,375	10^3-10^4	30,250	10^3-10^5
White Oak Bayou, Confluence with Little White Oak Bayou	37,000	10^3-10^5	46,000	10^3-10^5	12,590	10-10^5	15,388	0-10^5	28,000	10^3-10^5	66,250	10^4-10^5
White Oak Bayou, 1.2 mi. from Channel	76,750	10^2-10^5	69,175	10^2-10^5	62,110	10^2-10^5	53,750	0-10^5	77,500	10^4-10^5	66,250	10^4-10^5
Buffalo Bayou, White Oak Bayou entrance	73,000	10^4-10^5	66,373	10-10^5	30,250	10^3-10^5	60,014	10^2-10^5	70,000	10^4-10^5	88,750	10^4-10^5
Buffalo Bayou, Turning Basin	62,110	0-10^5	58,273	10^3-10^5	63,887	10^2-10^5	47,286	10^3-10^5	89,000	10^3-10^5	77,500	10^4-10^5
Brays Bayou, First Station	27,168	10-10^5	40,626	0-10^5	91,818	10^4-10^5	29,555	10^2-10^5	60,000	10^4-10^5	74,636	10^3-10^5
Brays Bayou, Houston Ship Channel	69,250	10^3-10^5	92,500	10^4-10^5	91,818	10^4-10^5	90,100	10^3-10^5	90,000	10^4-10^5	91,818	10^4-10^5
Buffalo Bayou, Mouth of Brays Bayou	48,365	10-10^5	83,636	10^4-10^5	64,000	10^2-10^5	60,142	10^3-10^5	57,889	10^3-10^5	88,750	10^4-10^5
Sims Bayou, First Station	2,431	10-10^4	18,085	10-10^5	2,013	10^2-10^4	18,871	10^2-10^5	5,350	10^2-10^4	29,142	0-10^5
Sims Bayou, 1.2 mi. from Channel	14,320	10^2-10^5	21,175	10^2-10^5	5,500	10^3-10^4	16,400	10-10^5	19,000	10^3-10^5	34,429	10^3-10^5
Buffalo Bayou, 500' below Sims Bayou	15,310	10^2-10^5	13,845	10^2-10^5	15,164	10-10^5	18,871	10^2-10^5	3,669	10-10^4	20,125	10^3-10^5
Buffalo Bayou, 500' below Greens Bayou	2,033	0-10^4	1,213	10-10^4	12,801	10-10^5	16,030	10-10^5	1,479	0-10^4	15,625	10^3-10^5
Buffalo Bayou, $\frac{1}{4}$ mi. below Shell Refinery	190	10-10^3	410	10-10^3	12,677	10-10^5	1,743	0-10^4	1,459	0-10^4	6,625	10^3-10^4
Buffalo Bayou, San Jacinto River	352	0-10^3	1,048	0-10^4	301	0-10^3	1,630	10-10^4	267	0-10^3	15,513	10^2-10^5
Buffalo Bayou, below Humble Refinery	2,033	0-10^4	285	0-10^3	227	0-10^3	601	10-10^3	248	0-10^3	1,888	10-10^4
Buffalo Bayou, Morgan's Point	16,870	10-10^5	312	0-10^3	317	10-10^3	29	0-10^2	139	0-10^3	15,400	10^2-10^5
Buffalo Bayou, $\frac{1}{4}$ mi. in Galveston Bay	622	10-10^3	295	0-10^3	177	10-10^3	1,616	0-10^4	1,237	0-10^4	3,025	10^2-10^4

[a]Annual average

[b]Range of monthly data

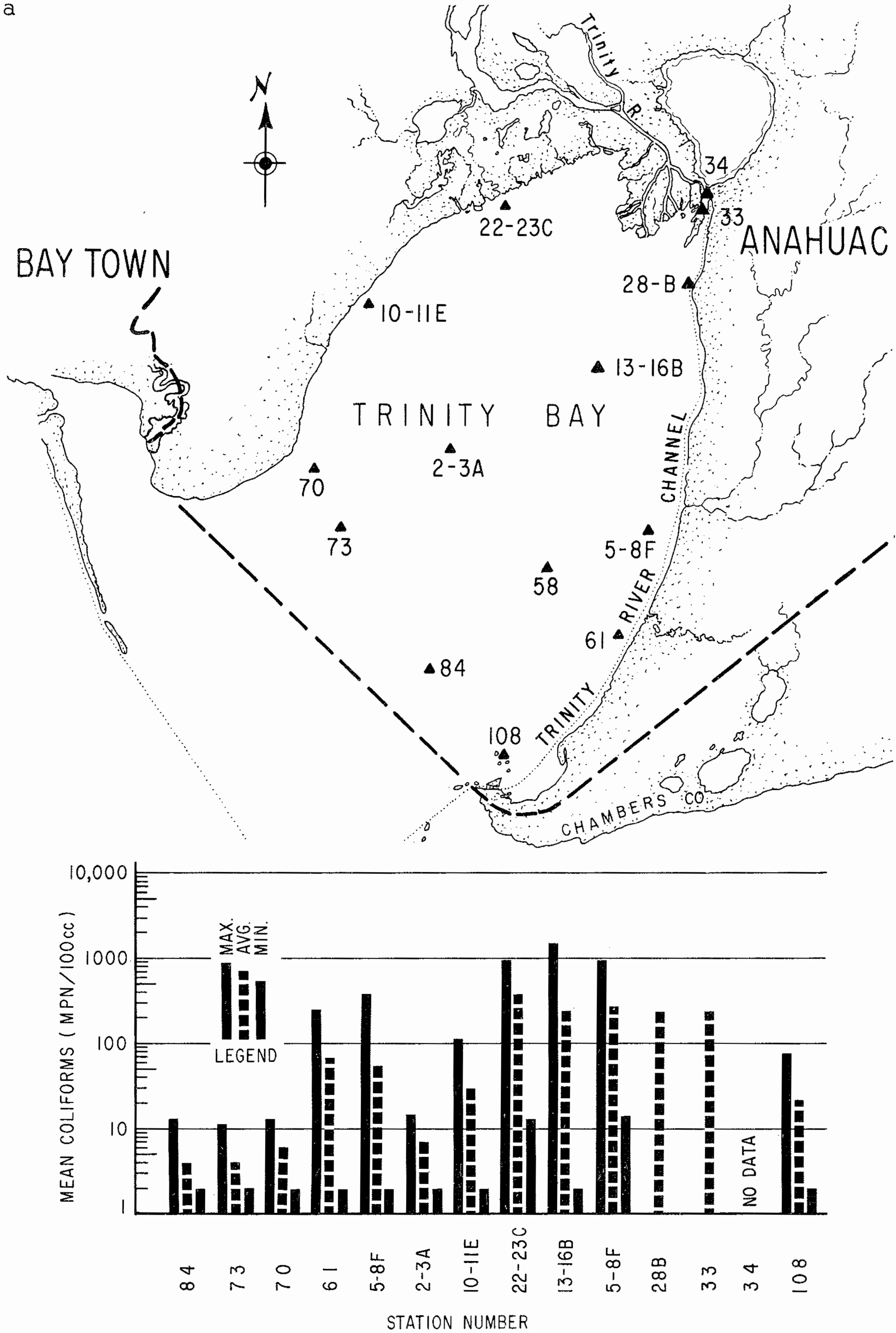


FIG. 5-6. COLIFORMS - TRINITY BAY
(June 1 - Dec. 1, 1963)

Table 5-1 shows the average, minimum, and maximum values of coliforms (MPN/100 ml) for the Houston Ship Channel, as well as bayous that receive sewage treatment plant effluents. Virtually all MPN values for the bayous indicate excessive numbers of coliforms as based on recreational water standards. The average coliform counts recorded at some of the stations near Morgan's Point were greater than 10,000 (MPN/100 ml).

Trinity Bay—Coliforms

As shown in Fig. 5-6, the average coliform count (MPN/100 ml) in Trinity Bay ranged from about four to 400. The average value (MPN/100 ml) for Station 22-23C was 376 while the maximum value at Station 13-16B was 1,600. Stations near the entrance to Galveston Bay showed relatively lower coliform counts.

It must be recognized that the coliform count in the upper reaches of Trinity Bay during the 1963 survey was as high as the counts in the lower reaches of the Houston Ship Channel at Morgan's Point. Agricultural runoff and domestic wastes apparently account for the relatively high coliform counts. However, little if any information is available about the dilution and flushing action of Trinity Bay.

Upper Galveston Bay and Clear Lake—Coliforms

Figure 5-7 shows the relative density of coliform organisms in the upper sections of Galveston Bay and the Clear Lake system as found in 1963. A comparison can be made between the earlier 1950-1951 survey and the 1963 data. There is little doubt about the source of domestic pollution and the dilution capacity of Galveston Bay. However, it is difficult to arrive at statistically valid conclusions based on the 1963 data.

In general, the Galveston Bay stations around Red Fish Reef, San Leon, Bacliff, Kemah, and Seabrook, Fig. 5-8, indicated better quality water in 1963 than in 1950-1951. The coliform count around Bacliff during 1950-1951 showed a mean value of 10,000 per 100 ml, whereas the maximum value in 1963 was only 540 per 100 ml.

Stations in the Clear Lake Channel connecting Clear Lake and Galveston Bay are shown in Fig. 5-9. It appears that the more recent samples contained fewer numbers of coliforms than those samples collected during 1950-1951. Notably, the mean values shown in the 1950-1951 survey were somewhat greater than the maximum values reported in 1963.

Presently, one of the most polluted sections of the Galveston Bay area, as shown in Fig. 5-7, is Clear Creek. This stream has maximum coliform counts in excess of 16,000 (MPN/100 ml). At Station Y-279-A on Clear Creek the minimum coliform concentration was in excess of 16,000 organisms per 100 ml. In the 1950-1951 survey, Fig. 5-10, the mean coliform content for Station Y-279-A was about 5,000 per 100 ml. The mean coliform densities in Clear Lake were

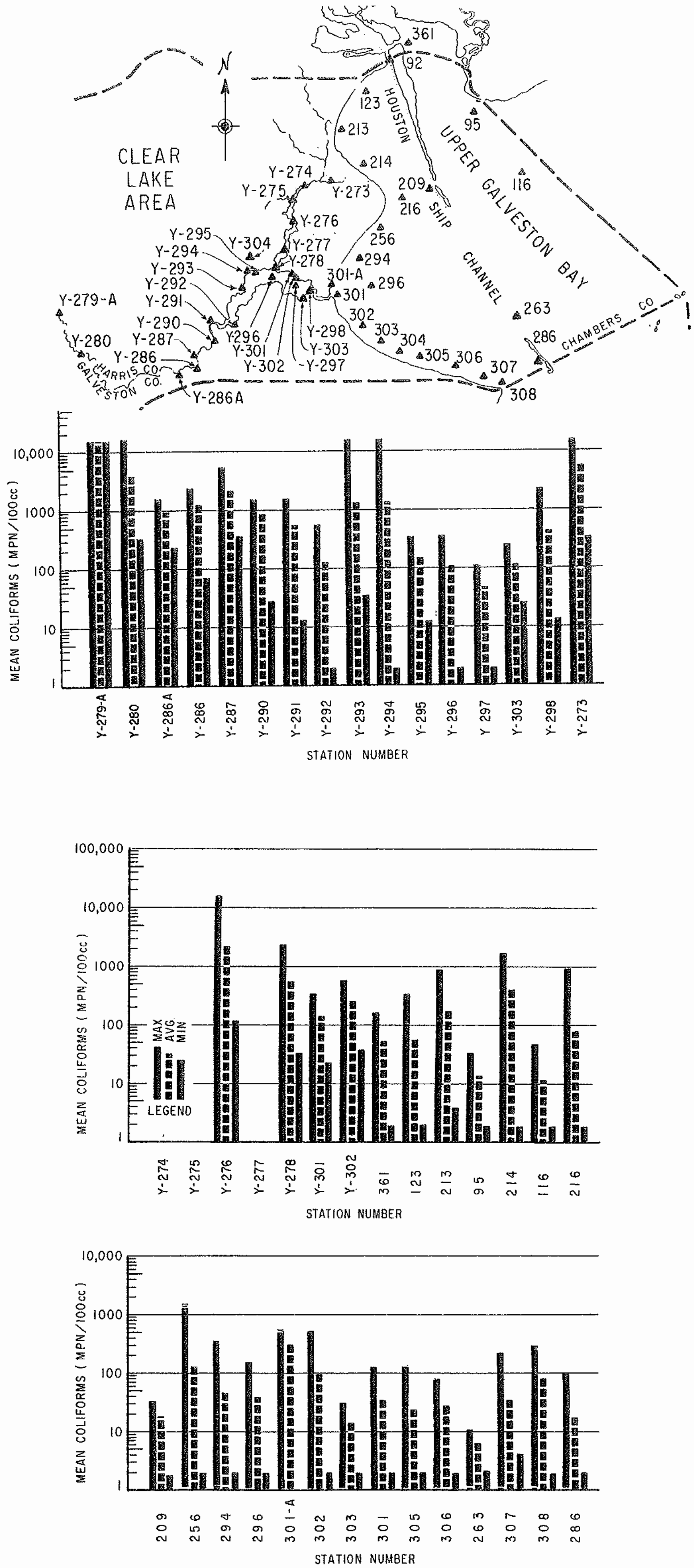


FIG. 5-7. COLIFORMS - UPPER GALVESTON BAY AND CLEAR LAKE AREA (June 1 - Dec. 1, 1963)

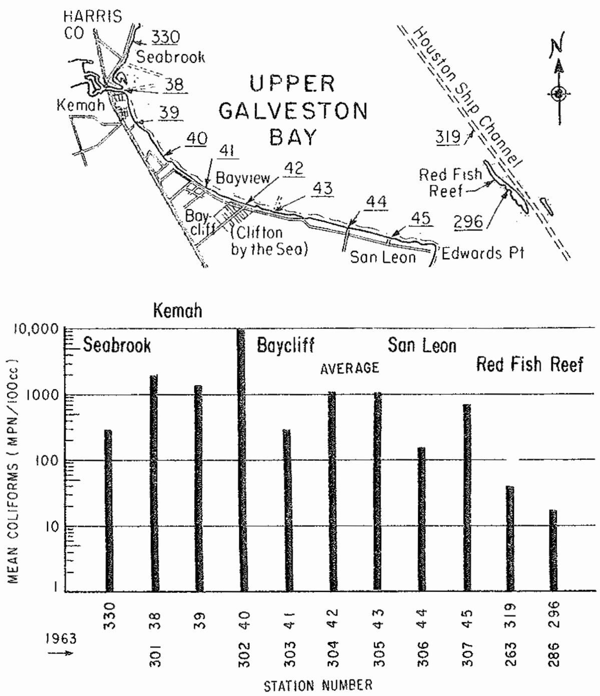


FIG. 5-8. COLIFORMS - UPPER GALVESTON BAY (Feb. 17, 1950 - Feb. 28, 1951)(6)

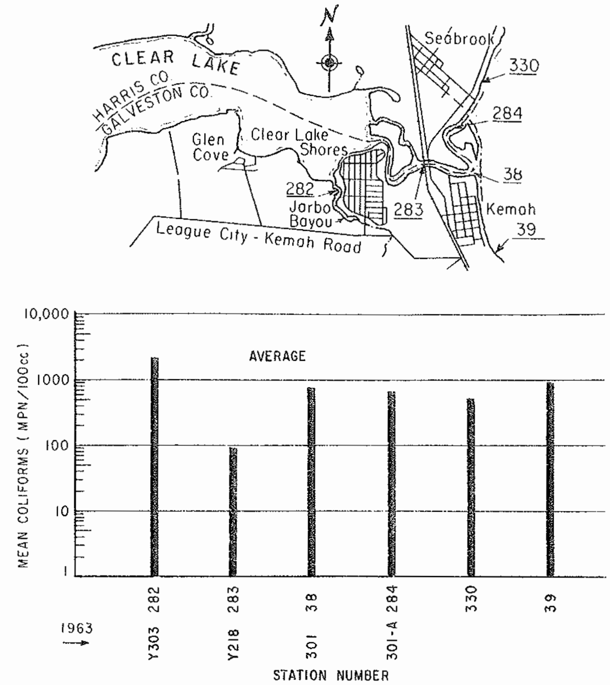


FIG. 5-9. COLIFORMS - KEMAH (Feb. 17, 1950 - Feb. 28, 1951)(7)

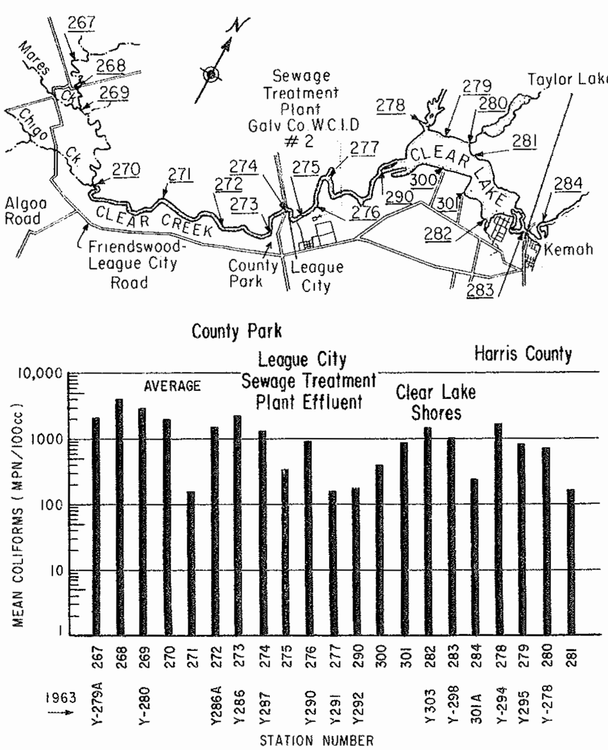


FIG. 5-10. COLIFORMS - CLEAR LAKE (Feb. 17, 1950 - Feb. 28, 1951)(8)

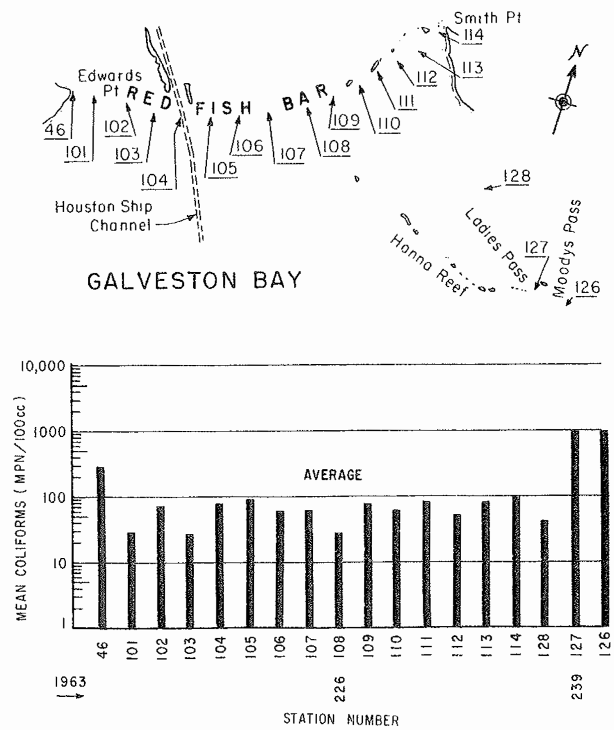


FIG. 5-11. COLIFORMS - RED FISH BAR (Feb. 17, 1950 - Feb. 28, 1951)(9)

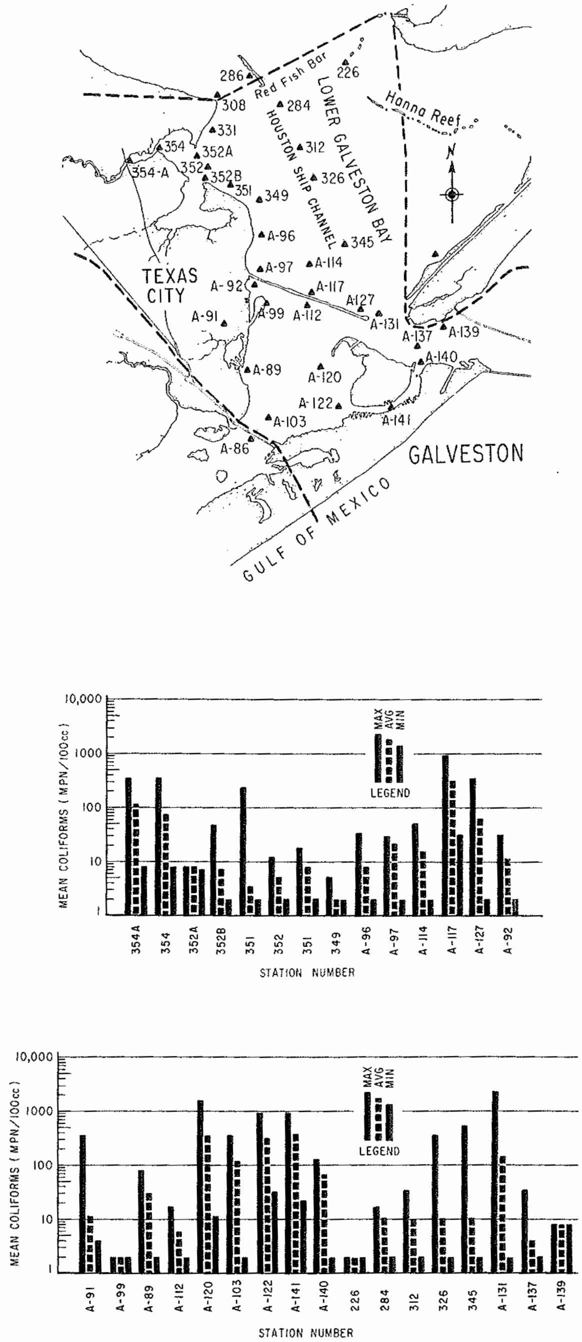


FIG. 5-12. COLIFORMS - LOWER GALVESTON BAY
(June 1 - Dec. 1, 1963)

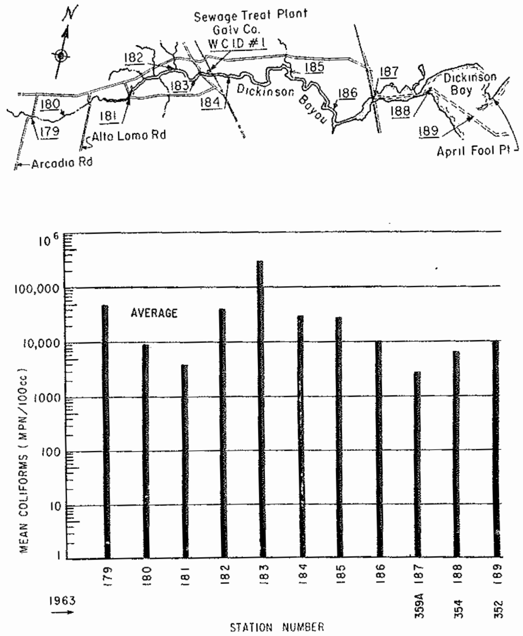


FIG. 5-13. COLIFORMS - DICKINSON BAYOU
(Feb. 17, 1950 - Feb. 28, 1951)[10]

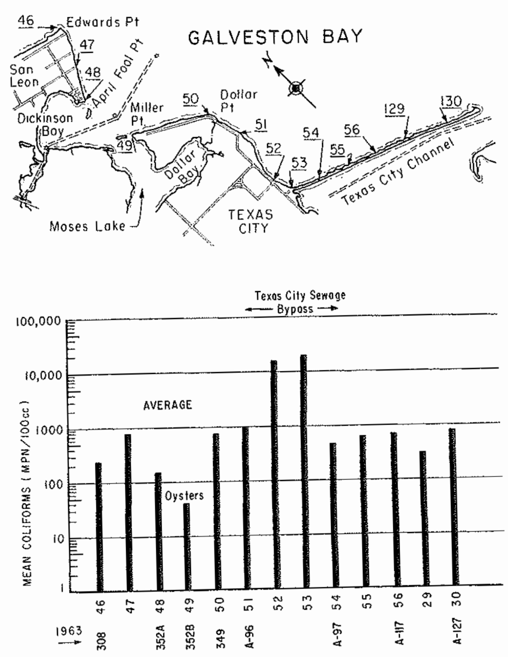


FIG. 5-14. COLIFORMS - TEXAS CITY DIKE
(Feb. 17, 1950 - Feb. 28, 1951)[11]

5-11b

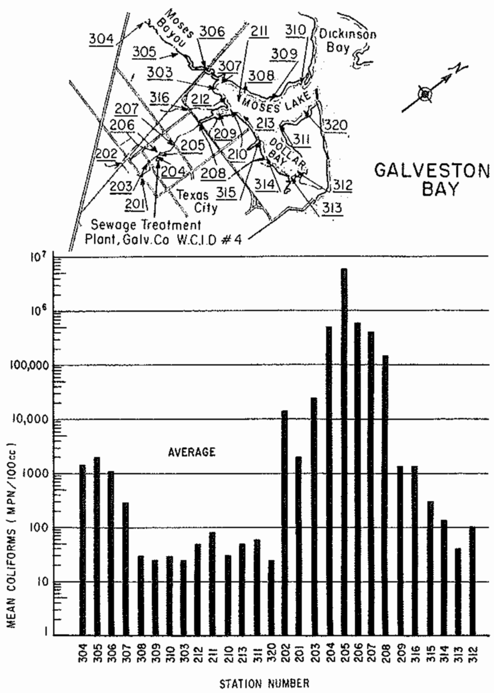


FIG. 5-15. COLIFORMS - CARBIDE DITCH AND MOSES LAKE (Feb. 17, 1950 - Feb. 28, 1951)[12]

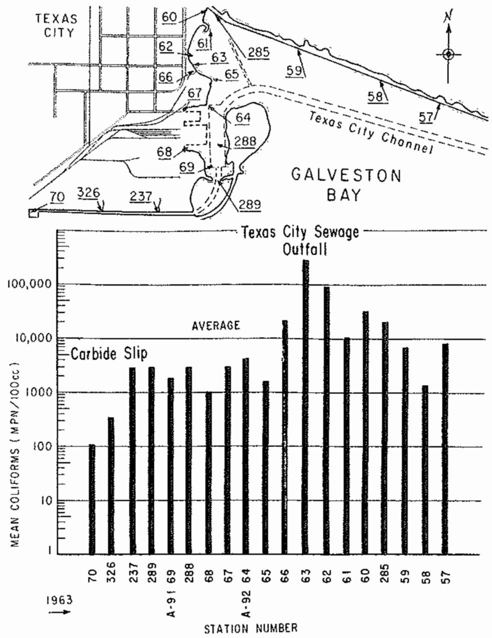


FIG. 5-16. COLIFORMS - TEXAS CITY (Feb. 17, 1950 - Feb. 28, 1951)[13]

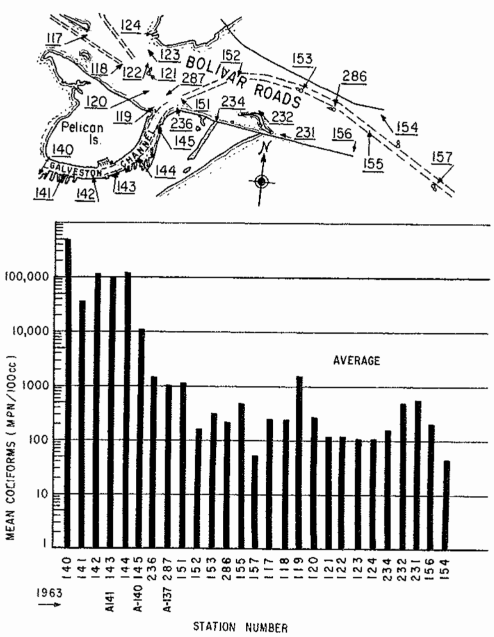


FIG. 5-18. COLIFORMS - BOLIVAR ROADS (Feb. 17, 1950 - Feb. 28, 1951)[15]

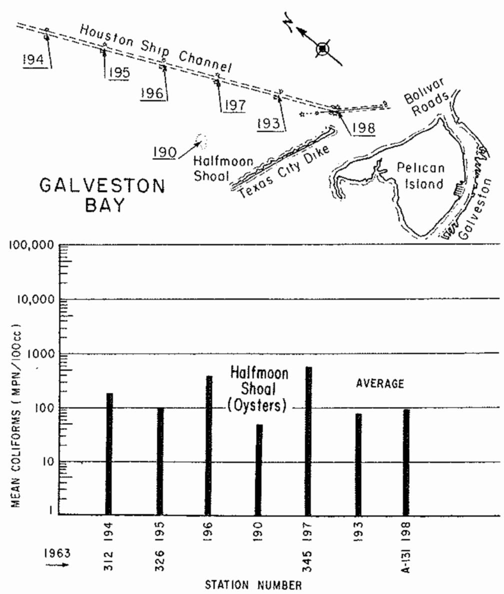


FIG. 5-17. COLIFORMS - GALVESTON BAY CHANNEL (Feb. 17, 1950 - Feb. 28, 1951)[14]

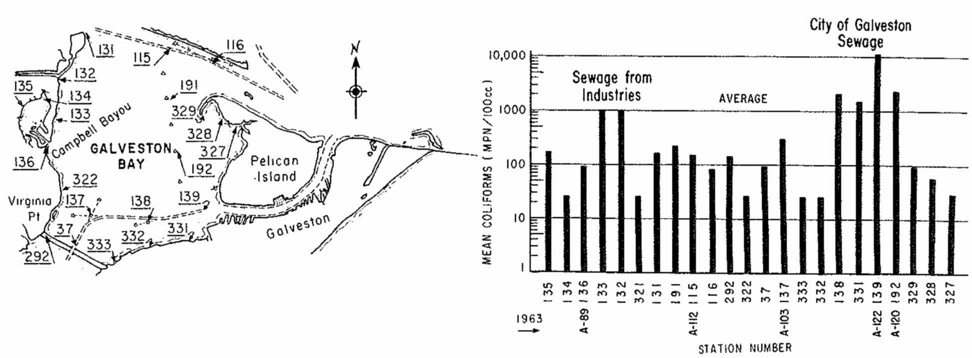


FIG. 5-19. COLIFORMS - LOWER GALVESTON BAY (Feb. 17, 1950 - Feb. 28, 1951)[16]

less in 1963 than in 1950-1951. However, the maximum values for some of the same stations were considerably more than the mean values.

Red Fish Bar and Hanna Reef areas are shown in Fig. 5-11. The coliform counts as determined at stations located across Galveston Bay during 1950-1951 were fairly uniform. The counts at Hanna Reef and Edwards Point were exceptions, where much higher counts were reported. All of these comparisons are based on mean values.

Lower Galveston Bay--Coliforms

Lower Galveston Bay as defined herein includes the area north of Dickinson Bay to Bolivar Roads. The results of the 1963 survey are shown in Fig. 5-12. The data for the 1950-1951 study are shown in Figs. 5-13 through 5-19.

Stations from Dickinson Bay to Bolivar Roads generally contained less than 100 coliforms per 100 ml. However, stations A-117 and A-131 along the Texas City Dike, as well as stations near Galveston, showed high maximum counts. Compared with the 1950-1951 results, the Lower Galveston Bay has improved in quality.

As shown in Fig. 5-13, Dickinson Bayou was heavily polluted during the 1950-1951 survey. Results from a limited number of stations in 1963 showed some improvement.

The stations along the shoreline north of Dickinson Bay and along the Texas City jetty had mean coliform densities in 1950-1951 which ranged from about 200 to 1,000 (MPN/100 ml), whereas the 1963 averages were considerably less, Fig. 5-14. However, in the 1963 survey the maximum value recorded was at Station A-131. At this station a high of 1,600 coliforms per 100 ml was found.

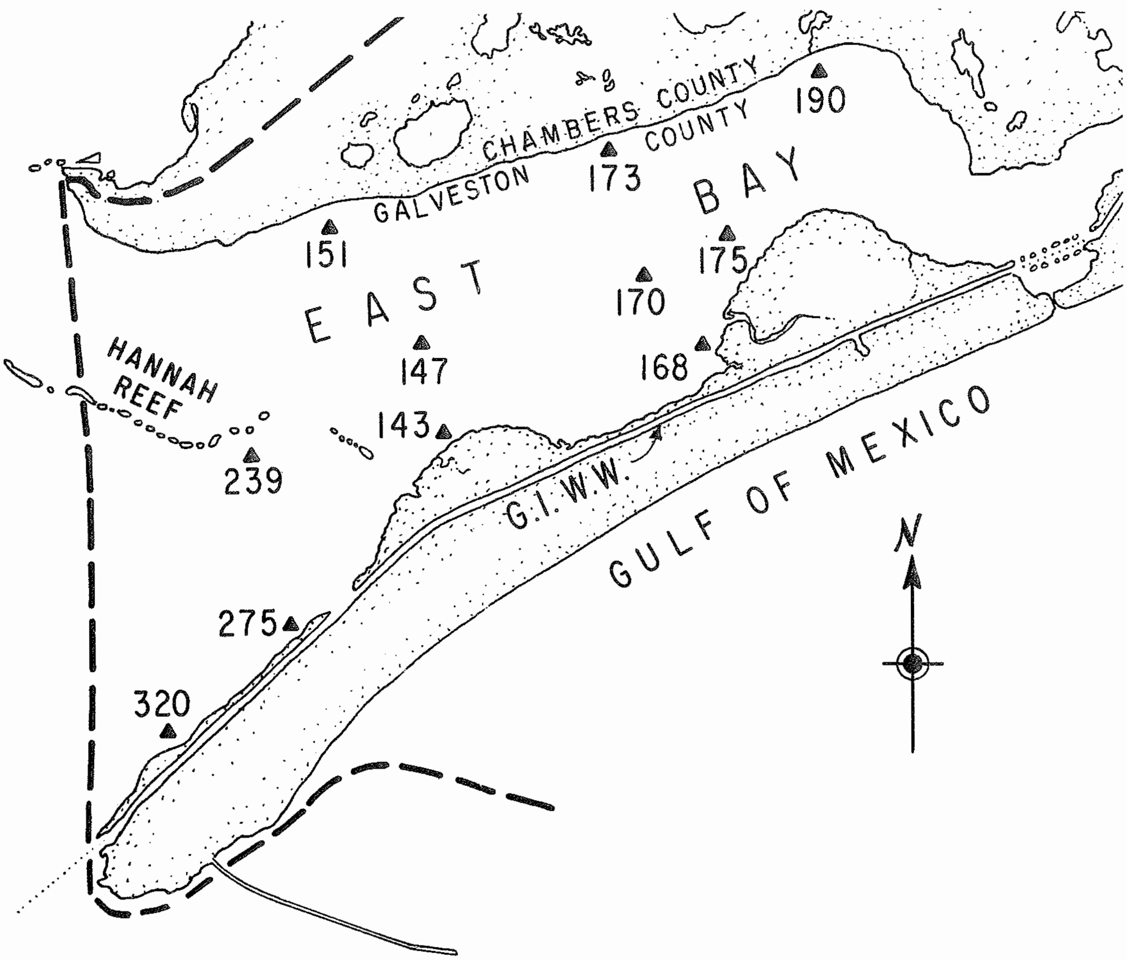
In general, the samples taken in the Houston Ship Channel of Galveston Bay during 1963 indicated a mean coliform density of less than 100, with the exception of Station A-131 which reported a mean value of 156.

Figure 5-15 shows a high coliform count in the Moses Lake area during the 1950-1951 survey. Unfortunately, no samples were obtained from the Carbide Ditch, Moses Lake, or Dallas Bay during 1963.

A comparison of the water quality with respect to coliforms around the Texas City area, Fig. 5-16, shows a marked decrease in coliform density; whereas, the coliform count at the outfall of the Texas City Sewage Treatment Plant ranged from 10,000 to 300,000 organisms per 100 ml. in 1950-1951. The count in a similar area during 1963 was less than 100 coliform organisms per 100 ml.

Station locations along the Houston Ship Channel of Middle Galveston Bay and results are given in Fig. 5-17. The 1950-1951 results appear to be similar to the 1963 data.

The area between Pelican Island and Galveston Island, Fig. 5-18, shows considerable improvement. The 1950-1951 information



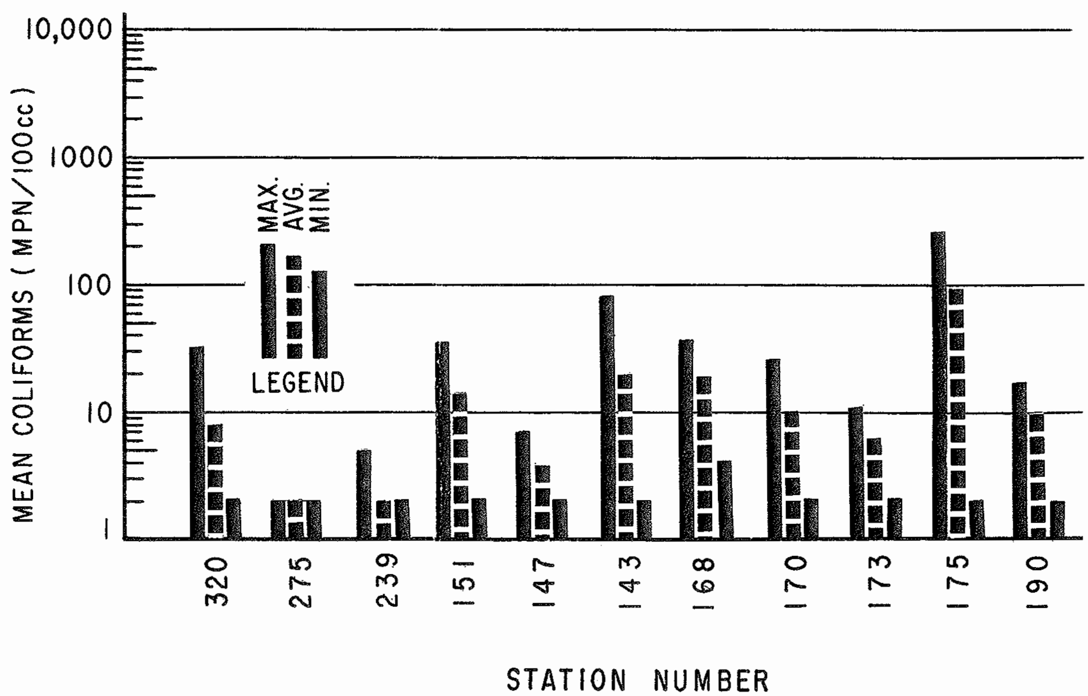
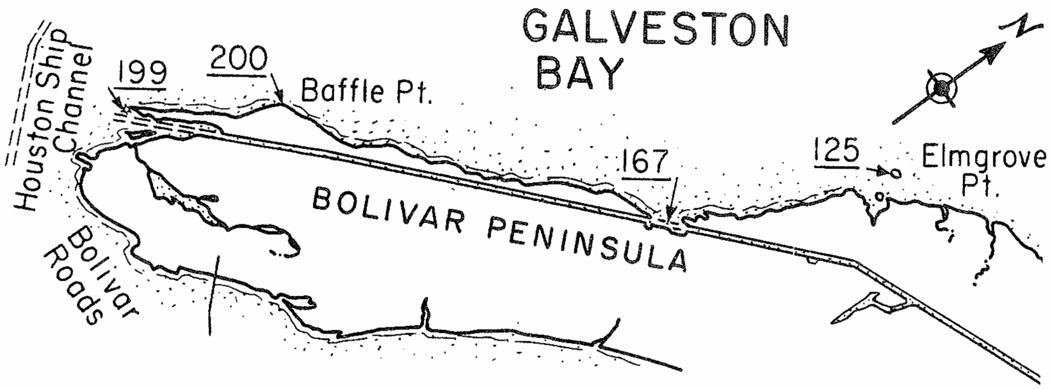


FIG. 5-20. COLIFORMS - EAST BAY (June 1-Dec. 1, 1963)



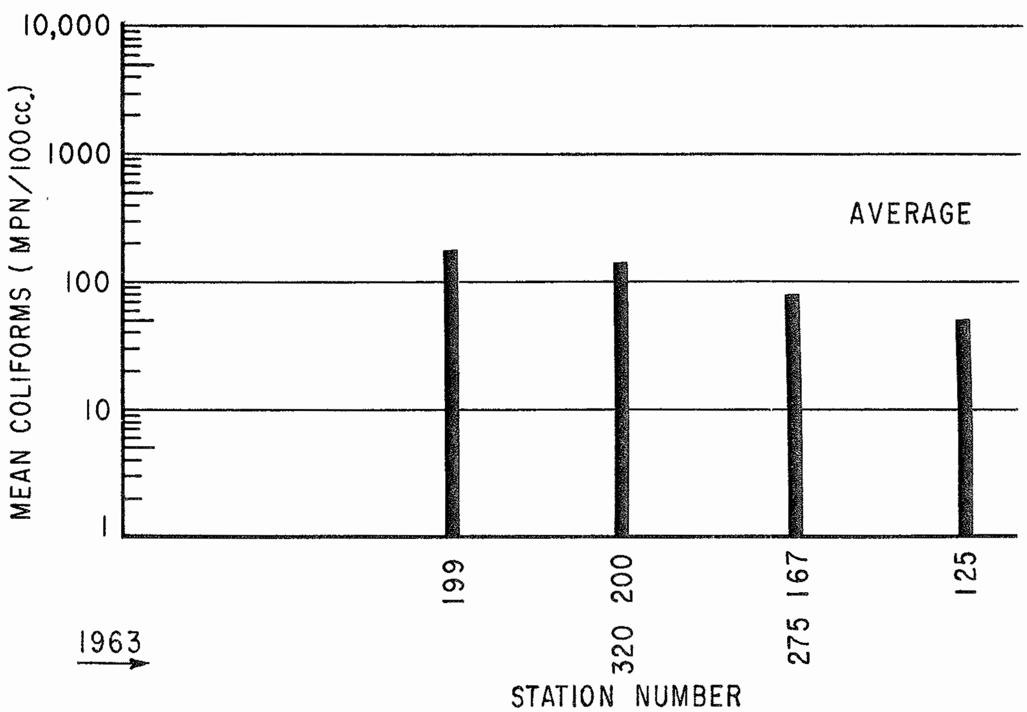


FIG. 5-21. COLIFORMS - BOLIVAR PENINSULA - (Feb. 17, 1950 - Feb. 28, 1951)[17]

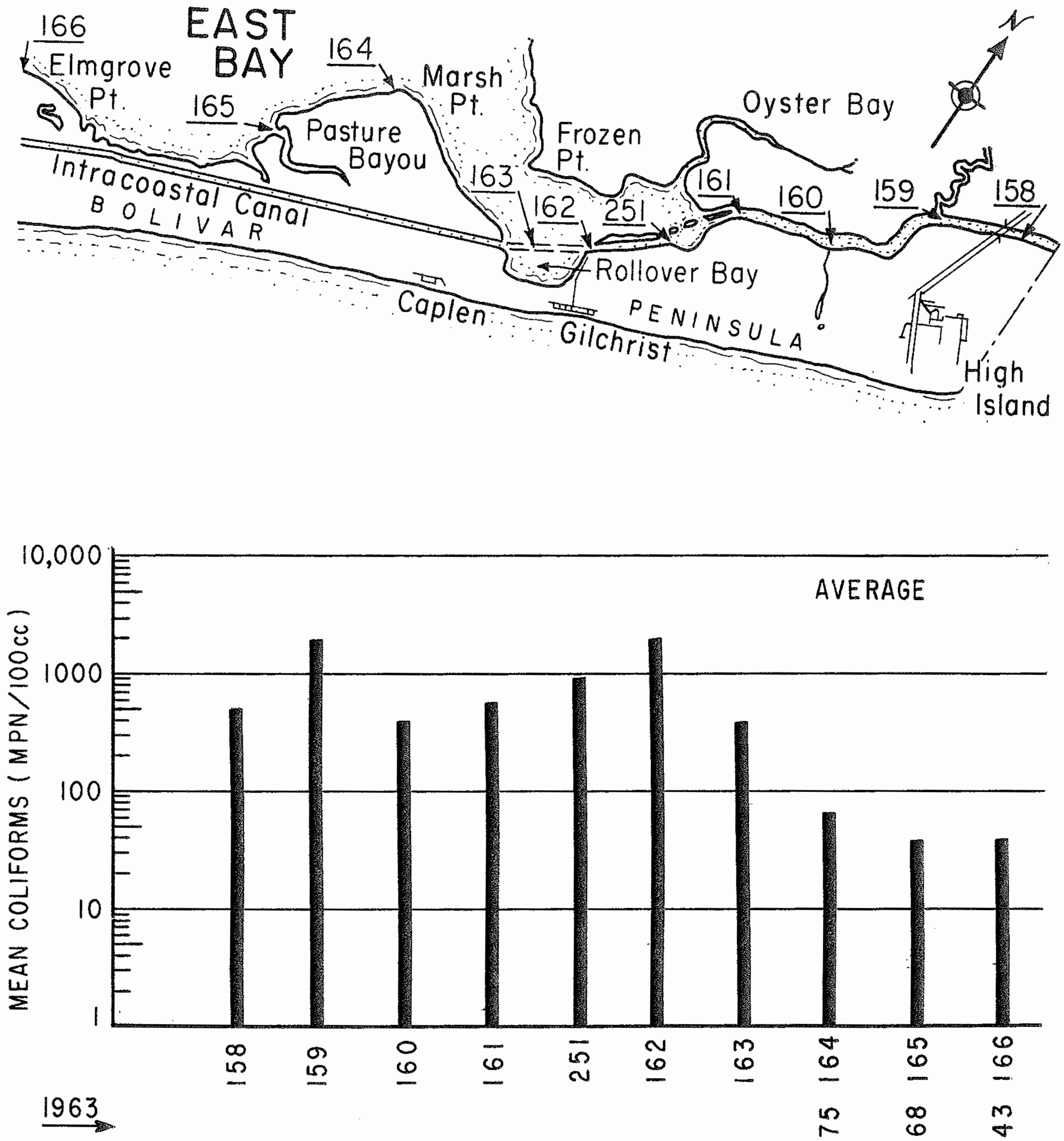


FIG. 5-22. COLIFORMS - EAST BAY
(Feb. 17, 1950 - Feb. 28, 1951)[18]

indicated that the mean coliform density was in excess of 1,000 per 100 ml, and at Station 141 the mean coliform density per 100 ml was 40,000 per 100 ml. According to the 1963 survey, the coliform density was less than 400 per 100 ml at the same station. In the 1950-1951 survey, virtually all of the stations along Bolivar Roads had mean coliform densities in excess of 100 coliforms per 100 ml. In 1963, this vicinity revealed coliform densities that were considerably less, having only registered maximum values of 130 organisms per 100 ml.

The Lower Galveston Bay, between Pelican Island and Virginia Point, Fig. 5-19, has remained about the same in regard to coliform densities. Perhaps some improvement can be noted.

East Bay--Coliforms

The results of the 1963 survey are shown in Fig. 5-20. These data indicate that the highest average coliform count occurred at Station 175 in East Bay, namely, 100 organisms per 100 ml. The mean coliform count at the stations in East Bay other than Station 175 was less than 20 organisms per 100 ml. A maximum count of 300 organisms per 100 ml was reported at Station 175.

The coliform data reported in 1951 are presented in Figs. 5-21 and 5-22. The samples were collected along the southerly shore of East Bay and in the Intracoastal Waterway. Average coliform counts ranged between 50 and 70 organisms per 100 ml at the sampling stations in East Bay. The data reported for the two stations in the immediate

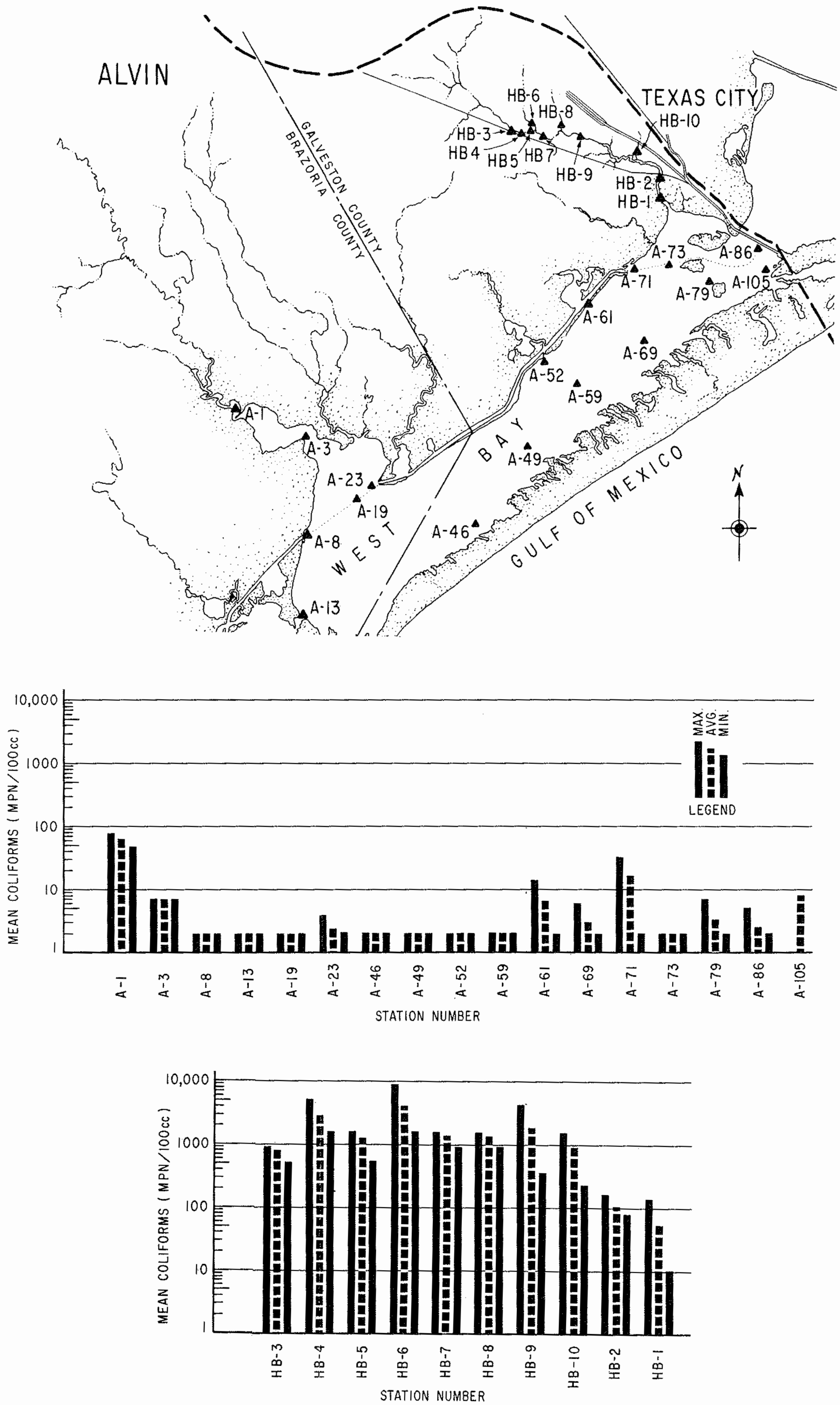


FIG. 5-23. COLIFORMS - WEST BAY
(June 1 - Dec. 1, 1963)

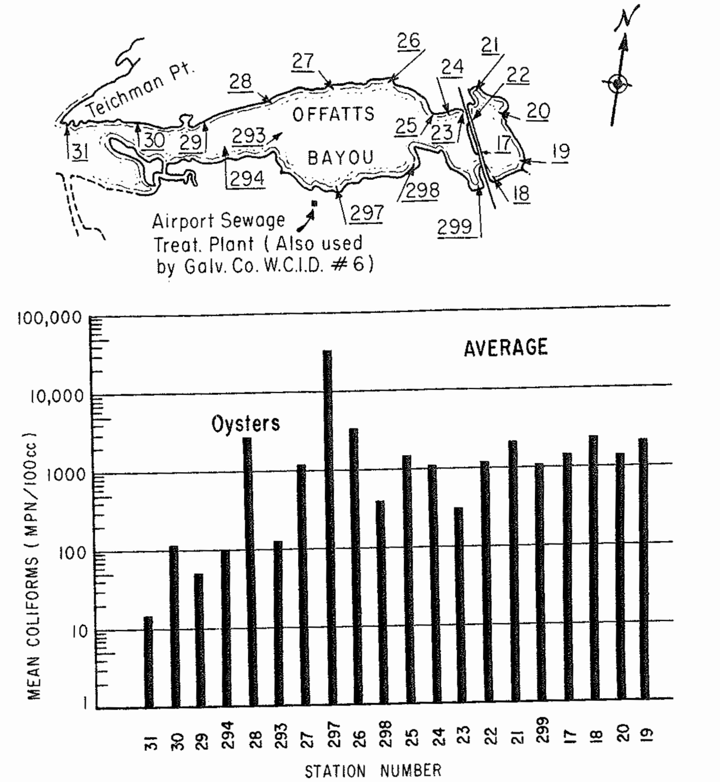


FIG. 5-24. COLIFORMS - OFFATTS BAYOU (Feb. 17, 1950 - Feb. 28, 1951)[19]

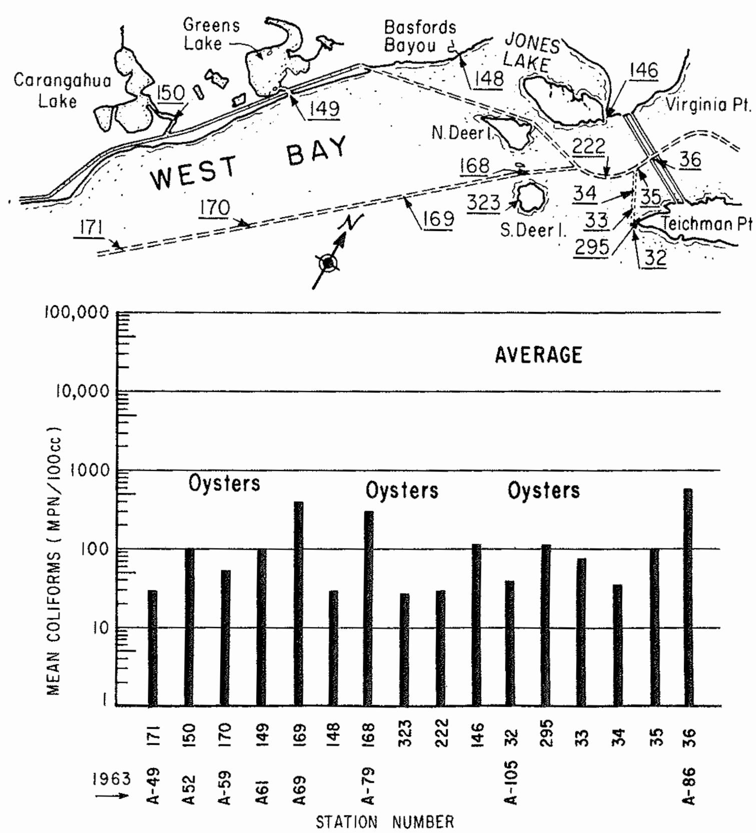


FIG. 5-25. COLIFORMS - WEST BAY (Feb. 17, 1950 - Feb. 28, 1951)[20]

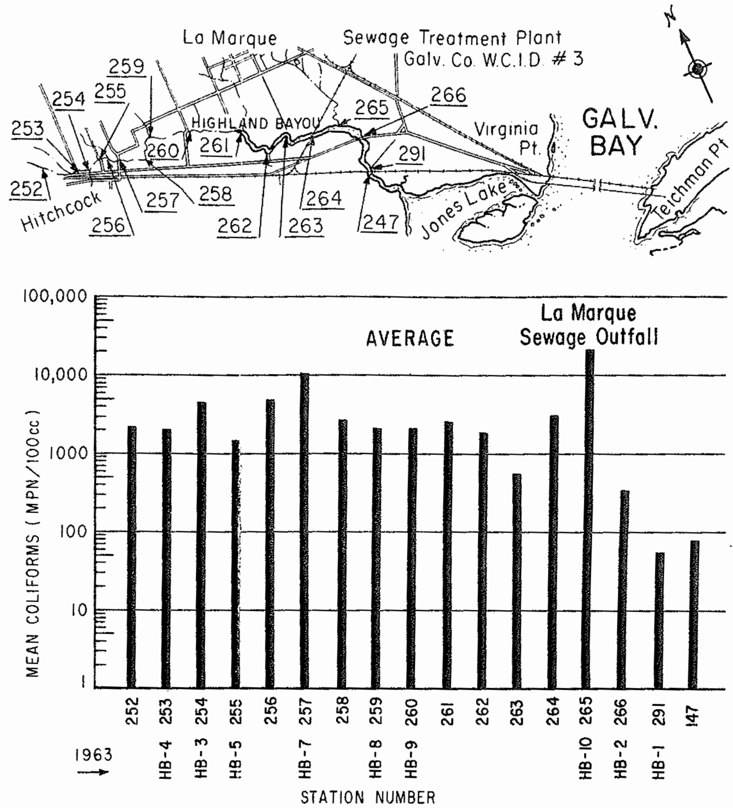


FIG. 5-26. COLIFORMS - HIGHLAND BAYOU
(Feb. 17, 1950 - Feb. 28, 1951)[21]

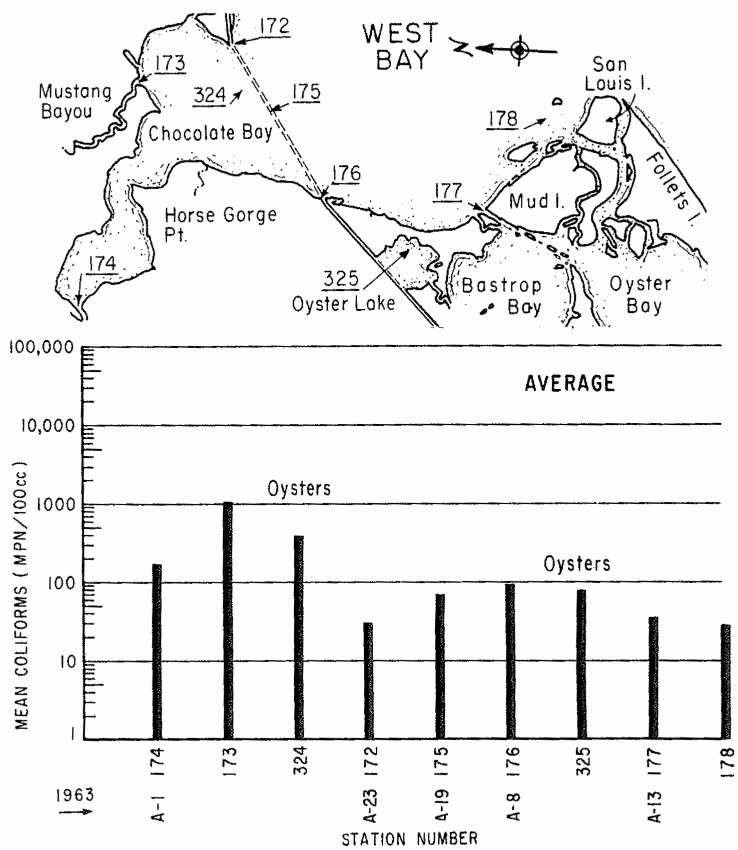


FIG. 5-27. COLIFORMS - CHOCOLATE BAY
(Feb. 17, 1950 - Feb. 28, 1951)[22]

vicinity of the Galveston Bay at the southern tip of the Bolivar Peninsula indicate that the coliform count ranged between 100 and 200 organisms per 100 ml. The coliform density in the Intracoastal Waterway were higher than those in East Bay (Fig. 5-22); namely, between 400 and 2,000 organisms per 100 ml compared with 50 to 70 organisms per 100 ml in East Bay. A comparison of the data reported for the 1950-1951 survey and the present survey indicates that the coliform density in East Bay was less in 1963 than in 1950-1951. The maximum coliform counts reported in East Bay in 1963 were lower than those reported in 1950-1951.

West Bay—Coliforms

The 1963 coliform data for the West Bay area is shown in Fig. 5-23. These data indicate that West Bay itself had low coliform counts. Average coliform densities of less than 10 organisms per 100 ml were reported for all stations in West Bay proper. In fact, throughout most of West Bay the coliform count was less than 2 per 100 ml. However, higher coliform counts were reported at those stations located at the entrance of varous bayous into West Bay, namely, Station A-1 at the mouth of Chocolate Bayou and Station A-71 at the Intracoastal Canal near Green's Lake. The average coliform count at Station A-1 was about 60 organisms per 100 ml, and at Station A-71 the average count was about 15 per 100 ml.

The coliform counts at Highland Bayou were much higher than those in West Bay. Average counts in the upper reaches of the Bayou ranged between 800 and 5,000 organisms per 100 ml at Stations 4B-3 and 4B-6, respectively. It is interesting to note that the coliform count dropped markedly between Station HB-10 and HB-2, namely, from an average count of 900 per 100 ml to 100 per 100 ml. Station HB-2 is near the entrance of Highland Bayou to West Bay.

The coliform data reported for the West Bay area in the 1950-1951 survey are presented in Fig. 5-24 through Fig. 5-26. These data indicate that the coliform count in West Bay ranged from 30 to 600 organisms per 100 ml.

The coliform counts in Offatts Bayou in 1950-1951 ranged from 15 to 24,500 coliform organisms per 100 ml. This minimum count occurred at Teichman Point where Offatts Bayou enters West Bay, while the maximum count was reported near the point at which the Airport Sewage Treatment Plant discharges effluent into Offatts Bayou. The coliform counts for all but three of the sampling stations in the main section of the Bayou were between 1,100 and 3,300 organisms per 100 ml.

The coliform data reported for Highland Bayou in 1950-1951 (Fig. 5-26) followed a pattern similar to that recorded for the 1963 survey. However, the magnitude of the coliform counts in 1950-1951 were higher than those in 1963. The counts in 1950-1951 ranged from 2,200 to 20,000 organisms per 100 ml in the upper reaches of the Bayou compared to the range of 800 to 6,000 reported in 1963. A marked reduction in coliform counts was reported at the stations in Highland Bayou immediately upstream of the point where the Bayou discharges into West Bay. In 1950-1951 the counts dropped from 20,000 to less than 100 coliform organisms per 100 ml. A similar phenomenon was reported during the 1963 survey.

A comparison of the data reported in the 1950-1951 and 1963 surveys indicates that the coliform counts in the West Bay area were lower in 1963 than in the earlier survey.

CHAPTER 6

PHYSICAL CHARACTERISTICS (HISTORICAL)

The physical characteristics of Galveston Bay are best described by the temperature, salinity, and suspended sediments in the water near the surface and at the bottom. The current and tidal fluctuations affect the temperature and salinity at various parts of Galveston Bay and at different depths at the same location. Therefore, it is necessary to discuss these four interrelated factors simultaneously in order to evaluate the physical characteristics of Galveston Bay and associated bodies of water. These factors will be discussed as follows:

- Interrelationships
- Available Data
- Galveston Bay--includes Upper and Lower Galveston Bay, Trinity Bay and East Bay
- Ship Channel--Morgan's Point through the Tidal Pass to the Gulf of Mexico
- Houston Ship Channel--Turning Basin to Morgan's Point

Interrelationships

The temperature of the water is affected by the air temperature, and the salinity of the water is affected by the interchange of bay water with the waters in the Gulf of Mexico, as well as fresh water discharges into the Bay. The uniformity of the temperature and salinity throughout Galveston Bay and in the Houston Ship Channel appears to be controlled by the tidal currents, wind action, and other mixing features.

The movement and interchange of water within the bay systems are important considerations in evaluating the quality of the water in Galveston Bay. The tidal fluctuations in the bay system are influenced by various uncontrollable factors, namely, the lunar cycle, meteorological conditions, winds, etc. The direction of the currents is controlled by the tidal cycle for the most part; however, fresh-water discharge from the streams, as well as masses of water at different temperatures, may influence the currents. The littoral movement of water is affected by the magnitude and direction of the prevailing winds. During the winter months periodic strong winds from the north push the waters out of the bay system into the Gulf of Mexico. However, in the spring and summer the prevailing winds are from the south and southeast; therefore, the water is kept within the bay system, and the Gulf waters tend to prevent extensive interchange of waters. The effects of the winds combined with the lack of fresh water inflow during the summer months can have a marked effect on the quality of the water in Galveston Bay.

Available Data

The physical characteristics of Galveston Bay and the Houston Ship Channel have been investigated extensively. Considerable temperature and salinity data are available; however, data on turbidity, color, and the general appearance of the Bay water are limited. Almost every study involving Galveston Bay has included temperature measurements, although in many cases the recorded temperatures are only representative of surface water and thus are not particularly useful.

It appears that the most detailed temperature measurements have been reported by the U. S. Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas. The locations of the sampling points for these studies are shown in Fig. 6-1, and descriptions of the stations are given in Appendix Table E-1. The current survey of Galveston Bay undertaken by the Texas State Department of Health includes temperature measurements at various positions and depths of the Bay. The sampling stations are presented in Fig. 4-3 and are listed in Appendix Table C-1.

The City of Houston has surveyed the quality of the water in the Houston Ship Channel and the contributing bayous.(2) The data derived from these studies include monthly temperatures and chloride concentrations for more than 80 sampling stations. The initial surveys began in 1932 and continued uninterrupted until 1941. The monthly sampling of these waters resumed in 1951 and is currently continuing. The sampling stations are listed in Appendix Table D-1.

Temperature, chlorinity, and turbidity were estimated by laboratory analyses of samples collected from various sampling stations in Galveston Bay during the 1950-1951 survey conducted by the Texas State Department of Health and the Galveston County Commissioner's

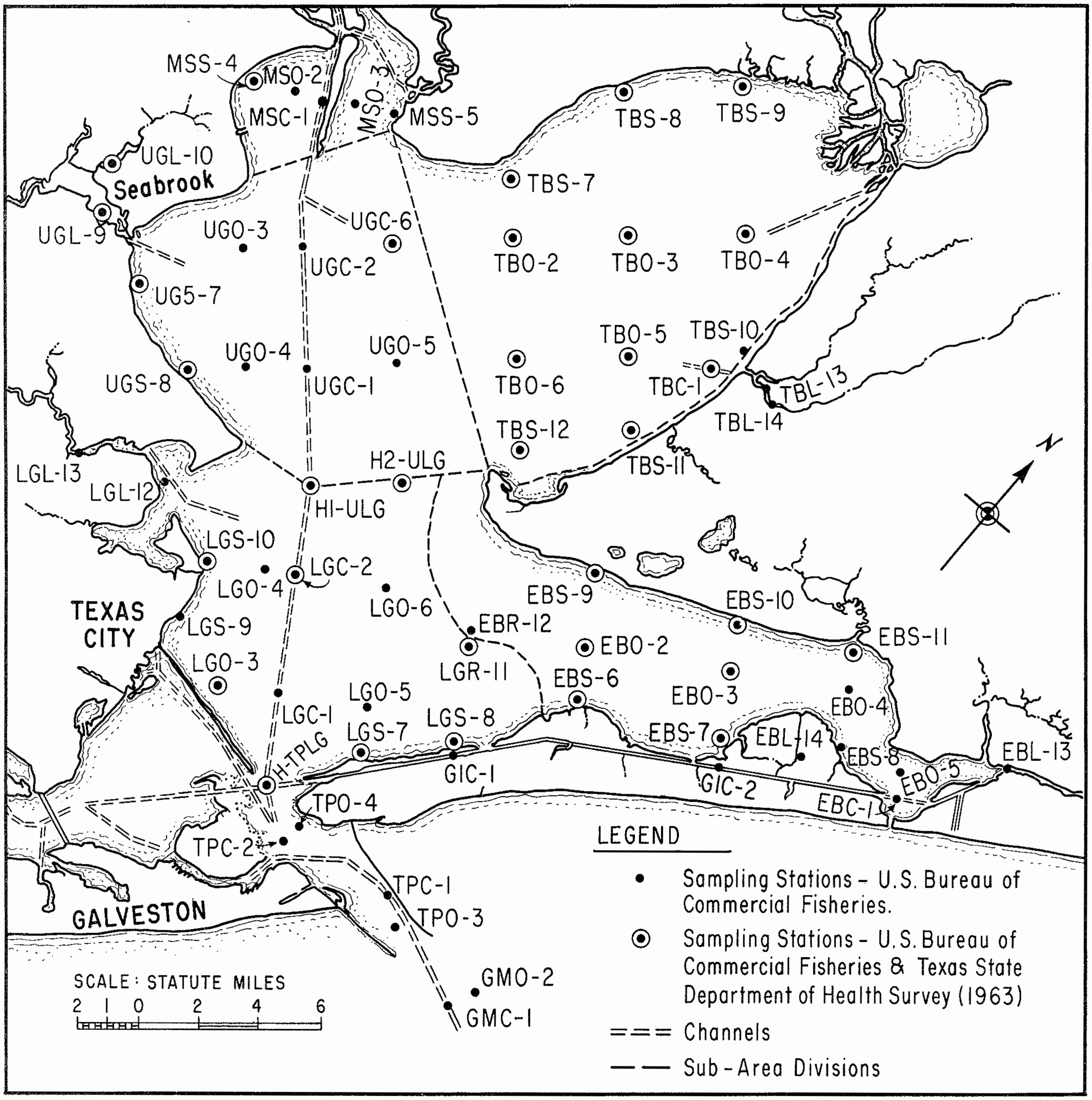


FIG. 6-1. GALVESTON BAY ESTAURINE SYSTEM.[1]

Court.[3] Locations of these sampling stations are given in Appendix Table A-1. The temperature data were not shown in the final report of this survey.

A survey of the quality of water in Galveston Bay was conducted by the Texas Game and Fish Commission during 1959-1960.[4] Temperature of the air and water, as well as salinity and turbidity, have been reported. The sampling stations used during this survey are shown in Fig. 4-13.

The U. S. Corps of Engineers established thirteen stations in the Houston Ship Channel at which locations the direction and magnitude of the current, as well as salinity and the concentration of suspended sediments, were recorded at various depths. A boat was used to collect these data during one tidal cycle after or during a continuous rainfall of relatively high intensity.

The bulk of the current and tidal information available for the Galveston Bay area has been collected by the U. S. Corps of Engineers. Continuous recording of the tidal fluctuations has been in progress at 23 tide gage stations in the Houston Ship Channel and Galveston Bay for more than one year. The location of the current and tide gage stations are shown in Fig. 6-2.

Galveston Bay

The temperature of the water in Galveston Bay varied considerably from season to season, as well as from station to station in a given

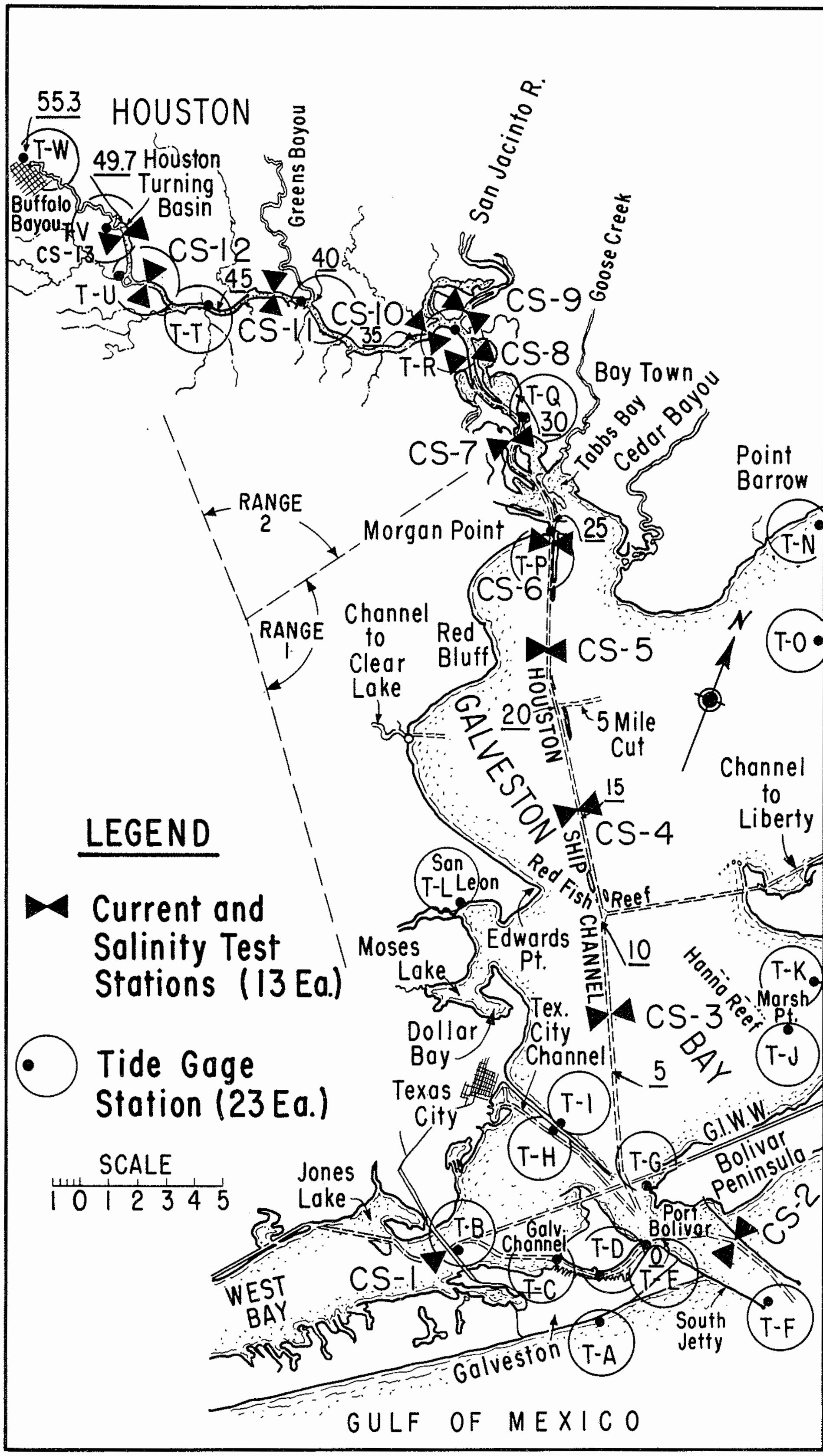


FIG. 6-2. LOCATION OF TIDE GAGE AND CURRENT-SALINITY STATIONS, U.S. CORPS OF ENGINEERS (5)

area of the Bay during a single season. Some temperature gradients from surface to bottom have been reported. Table 6-1 presents a summary of the temperature data reported by the U. S. Bureau of Commercial Fisheries for the period January 1963 to December 1963. The average semi-monthly temperature of Galveston Bay was based on the values recorded during a period of two to three days at 57 stations, not including those stations located in the Ship Channel from Morgan's Point to the Gulf of Mexico. The data for this portion of the Ship Channel are discussed separately.

The seasonal temperature variation in Galveston Bay ranged from 6.5° C to 32.2° C during 1963. There was a slight variation in the temperature of the surface water at the different stations during a given season; however, this variation was only 1° C to 4° C. There was very little difference in the temperature of the surface and bottom waters at most of the sampling stations. The maximum temperature gradient from surface to bottom was 1° C to 1.5° C; however, the depth of water throughout most of Galveston Bay was between two and eight feet. The variation of temperature from the surface to the bottom in the deep waters was greatest when there was a rapid change in air temperature.

The temperature of the surface waters in Galveston Bay was recorded during the Texas State Department of Health survey from March 1963 to October 1963 and these average temperatures are tabulated in Table 6-2. These data are similar to those reported in Table 6-1.

Table 6-1. Temperature (°C) Variation in Galveston Bay[6]
(1963)

Station	Depth	January[a]		February		March		April		May		June		July		August		September		October		November	
Mouth of San Jacinto River	2-6'	[b]15.4	10.6	7.6	13.2	15.3	----	21.5	25.2	26.3	28.3	30.5	29.8	32.0	32.8	32.3	29.5	32.3	29.0	27.0	24.1	20.5	21.3
		[c]15.5	9.0	7.7	11.2	15.4	----	21.2	25.1	26.0	28.0	29.3	29.6	31.5	31.9	31.8	29.3	31.4	28.1	26.1	24.1	20.5	20.5
Upper Galveston Bay	2-8'	15.0	5.0	9.5	12.2	14.8	19.7	22.5	25.0	26.4	28.0	30.4	29.6	32.6	31.1	32.0	29.5	31.5	26.8	26.4	24.7	20.3	20.4
		14.6	5.3	7.9	11.2	14.6	19.4	22.6	25.0	26.3	28.1	29.7	29.4	31.0	31.0	31.7	29.2	31.1	26.1	26.1	24.6	20.2	20.3
Trinity Bay	2-8'	15.9	5.9	7.3	12.8	15.1	18.5	23.0	27.0	26.8	28.3	29.6	29.3	31.1	31.4	31.3	30.1	31.1	26.2	26.4	24.2	21.6	21.9
		15.6	4.5	6.7	11.7	14.7	18.7	22.8	26.5	26.4	27.7	29.3	28.8	30.9	30.6	30.5	29.5	30.3	25.9	25.7	23.9	21.1	20.9
Taylor Lake	2'	15.2	2.9	5.3	13.4	16.2	21.7	21.8	26.6	----	29.0	31.0	31.0	33.0	34.0	31.5	31.0	31.0	29.0	27.0	25.0	20.5	22.0
		15.2	2.9	5.3	13.4	16.2	21.7	21.7	26.4	----	29.0	31.0	31.0	32.0	34.0	32.0	30.0	31.0	29.0	27.0	25.0	20.5	22.0
Clear Lake Channel	2'	14.0	2.9	----	12.8	16.9	21.4	21.4	26.1	27.0	28.0	31.0	31.0	32.0	34.0	33.0	30.5	32.0	29.0	27.0	24.0	20.0	21.5
		14.0	2.9	----	12.8	16.2	21.4	21.8	26.1	27.0	28.0	31.0	31.0	31.0	34.0	33.0	30.0	31.5	29.0	26.5	24.0	20.1	21.5
Lower Galveston Bay	2-8'	12.9	6.5	11.6	9.6	15.6	20.3	23.6	25.4	26.5	26.6	29.5	28.7	31.8	31.0	30.8	30.4	30.7	26.5	26.0	24.2	20.8	21.7
		13.0	6.3	10.9	9.5	15.7	20.2	23.5	25.4	25.9	26.3	29.3	28.7	31.1	30.4	30.7	30.0	30.4	26.3	25.8	23.8	21.0	21.1
East Bay	2-12'	12.5	6.9	10.5	12.8	20.2	21.1	25.5	24.3	26.6	26.1	29.8	29.3	32.0	30.8	31.9	32.2	31.1	25.4	26.3	24.0	23.3	22.6
		12.8	7.0	10.3	12.7	19.6	19.6	25.6	24.1	26.4	26.2	29.3	29.4	31.7	30.5	31.0	31.6	30.4	23.8	26.1	23.8	23.1	22.4
Tidal Pass	3-52'	14.6	11.2	13.1	13.2	15.9	20.1	24.0	26.5	26.5	27.2	29.0	28.9	32.5	29.9	30.6	29.7	30.8	24.6	25.3	25.5	21.6	18.8
		13.7	9.4	10.7	10.8	13.9	19.4	23.3	26.0	25.5	26.2	28.8	29.2	31.0	29.6	30.3	29.2	30.6	24.0	25.8	25.0	21.8	18.7
Gulf of Mexico	32-42'	14.9	----	8.7	9.3	14.4	18.2	22.7	27.8	25.4	25.6	31.6	28.2	32.5	30.0	30.5	29.0	31.0	27.0	25.0	25.5	23.1	18.4
		15.2	----	8.7	9.7	12.8	18.5	23.0	26.2	24.8	24.5	30.0	28.5	30.3	30.0	30.0	29.0	31.0	27.0	26.0	25.5	23.0	18.2
Average		14.2	6.5	9.2	12.1	16.0	20.1	22.9	26.0	26.4	27.4	30.3	29.5	32.2	21.7	31.5	30.2	31.3	27.0	26.3	24.6	21.3	21.0
		14.4	5.9	8.5	11.4	15.4	19.9	22.8	25.6	26.0	27.1	29.7	29.5	31.2	31.3	31.2	29.8	30.8	26.6	26.1	24.4	21.2	20.6

[a]One value recorded during first two weeks of each month - Second value recorded during second two weeks of each month.
[b]Surface Temp.
[c]Bottom Temp.

Table 6-2. Average Surface Water Temperature (°F) in Galveston Bay and Houston Ship Channel[a] (March 1963 - October 1963)

Location	March	April	May	June	July	August	September	October
Houston Ship Channel		82 (11)[b]	82 (18)	82 (11)	84 (23)	89 (28)	84 (32)	80 (12)
Upper Galveston Bay	70 (6)	77 (6)	81 (18)	85 (26)	88 (9)	86 (4)	88 (10)	80 (1)
Trinity Bay			77 (1)		86 (10)	88 (5)	89 (8)	79 (4)
Clear Lake	74 (3)	73 (10)	84 (10)	84 (30)	85 (56)	86 (37)	80 (39)	78 (54)
Lower Galveston Bay			80 (10)	84 (6)	88 (12)	87 (11)	83 (2)	76 (10)
East Bay					86 (11)			78 (7)
West Bay					87 (5)	86 (5)		78 (3)
Highland Bayou							87 (8)	81 (5)
Cedar Bayou							85 (5)	
Average (°F)	71.3	77.6	81.6	84.0	85.6	87.2	83.5	77.6
Total Samples	(9)	(27)	(57)	(73)	(126)	(90)	(104)	(96)
Average (°C)	21.8	25.3	27.6	28.9	29.8	30.7	28.6	25.3

[a] Data from Texas State Department of Health Survey (1963).

[b] Numbers in ( ) are number of samples used to compute average values.

Temperature data recorded in Galveston Bay during the 12-month period from November 1959 to November 1960 are presented in Table 6-3. The seasonal variations and temperature gradients at a given station were of the same magnitudes as those reported during 1963 by the U. S. Bureau of Commercial Fisheries.

The monthly average concentrations of salinity in Galveston Bay reported by the U. S. Bureau of Commercial Fisheries for 1963 are presented in Table 6-4. The salinity in the Bay varied much more than did the temperature of the water. The seasonal variation in salinity was in the order of 15 to 25 parts per thousand (‰). Salinity as low as 0.4 part per thousand was observed in Trinity Bay during 1963. The variation in salinity among the various stations in Galveston Bay during a given season was also considerable and at times was almost as great as the seasonal variations; however, the extreme salinity concentrations in the Bay usually ranged between 5 and 35 parts per thousand. There was a difference in salinity of the surface and bottom waters at most points in Galveston Bay during each sampling period. The more saline waters were at the bottom. For the most part the salinity gradients usually coincided with the temperature gradient; however, the magnitude of the salinity gradient was also affected by the fresh water inflow to the Bay system from the San Jacinto and Trinity Rivers.

The salinity data recorded during a survey of Upper Galveston Bay and Trinity Bay by the Texas Game and Fish Commission in

Table 6-3. Average Temperature, Upper Galveston Bay and Trinity Bay (1959-1960)[7]

Value		November	December	January	February	March	April
Water Temperature °C							
Surface	Maximum	16.7	16.4	16.2	14.3	22.5	26.0
	Minimum	7.9	9.8	6.5	8.8	7.5	16.3
	Average	13.2	13.4	10.5	12.0	13.5	21.4
Bottom	Maximum	16.2	16.2	12.2	12.6	22.2	25.2
	Minimum	7.4	8.9	5.0	8.5	7.4	16.0
	Average	12.5	12.5	9.4	10.0	12.8	21.0

Value		May	June	July	August	September	October
Water Temperature °C							
Surface	Maximum	30.8	31.9	35.0	33.5	32.5	29.0
	Minimum	31.2	27.1	28.8	29.0	24.5	16.0
	Average	25.0	29.6	31.0	30.4	28.4	24.4
Bottom	Maximum	30.8	31.8	34.2	32.6	30.6	28.2
	Minimum	20.8	26.2	28.3	28.6	23.8	23.0
	Average	25.4	28.9	30.0	30.0	27.2	26.0

Table 6-4. Salinity Variation in Galveston Bay
January 1963 to November 1963
(parts per thousand) (6)

Station	Depth (Feet)	January		February		March		April		May		June		July		August		September		October		November	
Mouth of San Jacinto River	2-6	[a] 10.7	13.7	18.3	11.7	12.9	14.7	17.5	17.0	17.6	15.8	16.0	11.6	16.7	15.5	18.6	20.4	23.3	23.0	23.6	23.9	23.5	22.1
		[b] 10.7	16.0	18.3	17.3	12.9	14.8	17.5	17.0	17.7	16.9	16.5	11.5	17.0	15.7	18.7	20.4	23.5	23.3	23.7	24.1	23.6	22.5
Upper Gal- veston Bay	2-8	12.6	18.1	16.6	15.9	14.2	17.1	17.4	19.3	19.3	17.0	17.4	16.2	17.6	17.9	20.2	23.2	25.1	24.4	24.6	25.0	25.0	23.8
		13.3	18.0	16.9	16.6	15.2	17.1	17.4	19.2	19.4	17.3	17.5	14.6	26.2	18.1	20.6	23.4	25.4	24.6	24.7	25.0	25.2	24.1
Trinity Bay	2-8	7.8	8.6	9.9	8.8	9.9	11.1	12.3	13.1	11.0	5.0	8.9	8.9	9.8	11.2	10.2	13.4	15.7	18.8	18.3	20.1	21.7	21.0
		7.9	11.5	9.2	10.6	13.9	11.4	12.3	13.5	14.0	8.2	9.7	9.6	10.0	11.8	12.0	14.0	17.9	19.7	19.7	21.7	22.2	21.9
Taylor Lake	2	2.2	12.0	12.2	5.9	7.1	11.8	13.7	15.4	----	16.3	16.1	16.8	8.9	12.0	13.7	15.8	18.4	18.2	20.9	21.8	22.4	25.4
		2.2	12.0	12.2	5.9	7.1	11.8	13.7	15.7	----	16.3	16.2	16.8	8.6	12.2	13.7	15.9	19.4	18.7	21.0	21.9	22.5	16.4
Clear Lake Channel	2	6.8	13.6	----	9.0	13.8	14.0	17.4	18.6	18.1	17.3	18.3	18.5	15.6	15.6	17.9	18.7	22.5	22.2	22.9	23.4	23.7	19.5
		7.0	13.6	----	9.0	13.8	14.0	17.4	18.6	18.2	17.3	18.4	18.7	16.2	15.6	18.3	21.1	23.1	22.3	21.0	23.4	23.7	19.5
Lower Gal- veston Bay	2-8	14.6	21.2	18.1	17.7	18.4	22.4	24.2	24.2	22.4	23.5	25.4	18.8	22.0	25.7	26.0	27.7	28.4	22.8	23.4	25.3	25.9	24.8
		16.3	21.6	18.7	18.8	20.0	22.4	25.1	25.0	22.7	23.2	26.7	18.9	23.5	26.5	27.1	28.7	28.8	23.4	24.6	26.3	26.9	25.2
East Bay	2-12	13.9	10.1	12.5	11.9	16.2	19.6	20.0	19.8	20.8	21.8	21.4	19.7	19.2	20.8	19.8	21.9	23.3	14.3	15.0	18.6	19.6	15.6
		15.6	11.3	13.8	12.7	16.8	18.9	20.2	20.1	20.9	22.3	22.5	20.4	19.7	21.3	20.6	21.9	23.7	15.5	15.6	18.9	19.9	16.9
Tidal Pass	3-52	25.9	27.0	23.1	15.5	19.7	23.4	23.9	24.3	22.7	29.7	32.7	32.6	31.2	34.9	35.6	35.7	35.7	26.8	29.0	30.8	30.0	30.1
		27.4	28.7	27.6	26.2	26.8	25.6	26.9	25.3	25.9	32.1	32.8	33.2	32.8	35.7	35.8	36.1	35.8	27.8	29.6	31.0	30.6	30.3
Gulf of Mexico	32-42	28.0	----	29.9	26.8	26.7	25.5	26.2	22.9	20.5	34.4	30.8	35.1	32.5	36.2	36.2	35.9	36.1	27.1	30.7	32.2	31.4	31.8
		33.5	----	32.0	31.1	32.3	29.1	28.7	25.5	30.2	34.8	31.6	34.4	33.4	36.5	36.6	36.2	36.1	27.1	21.7	32.2	32.1	31.7

[a] Surface Temp.
[b] Bottom Temp.

1959-1960 are presented in Table 6-5. These data indicated that a horizontal salinity gradient existed in these two bays. The gradient was directly influenced by the fresh water inflow from the rivers, creeks, and bayous discharging into the bays. The salinities in Trinity Bay were generally low at the mouth of the Trinity River and increased as the location of the sampling stations approached Upper Galveston Bay. Summary temperature and salinity data are graphically illustrated in Figs. 6-3 through 6-9.

Temperature and salinity measurements made in the Clear Lake area for the period January 1958 to January 1959 indicated considerable seasonal changes. It has been reported that seasonal changes in the fauna were associated with seasonal changes in temperature but were independent of fluctuations in salinity. Figure 6-6 depicts the temperature and salinity changes. The locations of the sampling stations are shown in Fig. 6-7. During the warmer periods the ranges in both salinity and temperature were considerably less than in the cooler periods indicating more uniform heating and mixing. The temperature fluctuations in the Clear Lake system were very similar to those observed in Galveston Bay in the 1959-1960 survey, as well as in the surveys of 1963. However, the salinity of Clear Lake during 1958-1959 was much lower than that recorded in Galveston Bay during 1963. The salinity variations were also less in Clear Lake in 1958-1959 than in Galveston Bay.

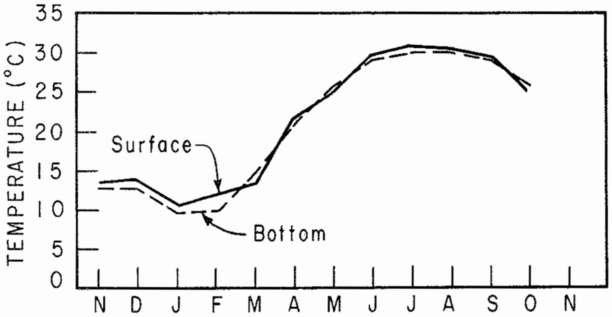


FIG. 6-3. SURFACE AND BOTTOM TEMPERATURES, UPPER GALVESTON BAY AND TRINITY BAY[4] (1959-1960)

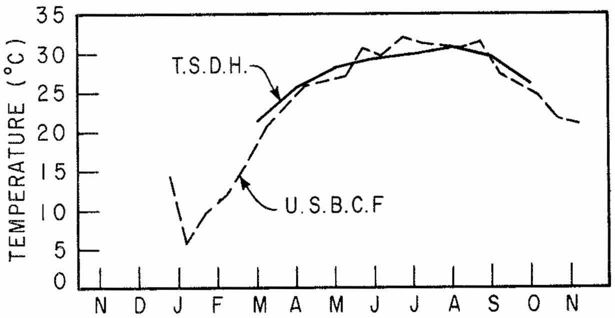


FIG. 6-4. SURFACE TEMPERATURES, GALVESTON BAY (1963)[6]

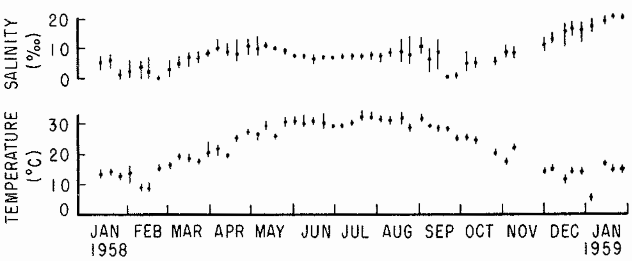


FIG. 6-6. WEEKLY CHANGES IN THE AVERAGE SALINITY AND TEMPERATURE. MEAN VALUES INDICATED BY DOTS AND RANGES SHOWN BY VERTICAL LINES.[8]

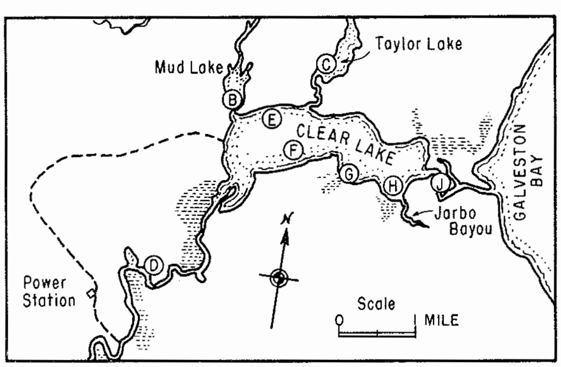


FIG. 6-7. LOCATIONS OF SAMPLING STATIONS.[9]

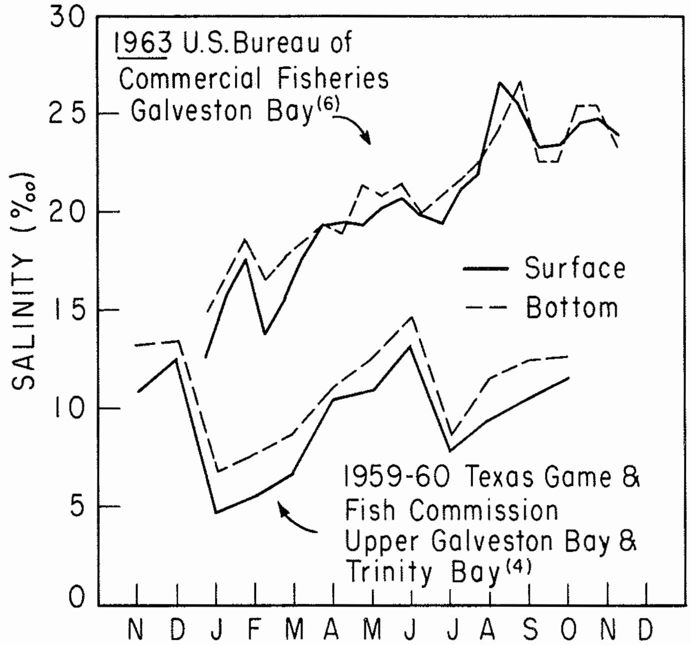


FIG. 6-5. SURFACE AND BOTTOM SALINITY, GALVESTON BAY.

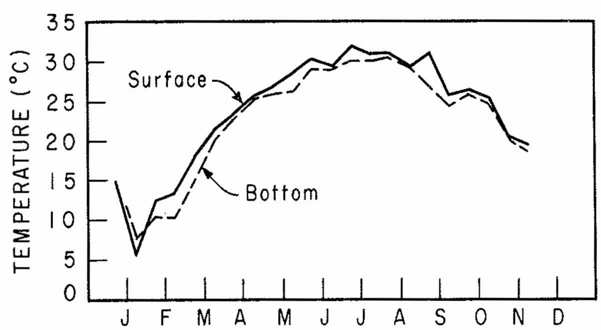


FIG. 6-8. SURFACE AND BOTTOM TEMPERATURES IN SHIP CHANNEL (1963)[6]

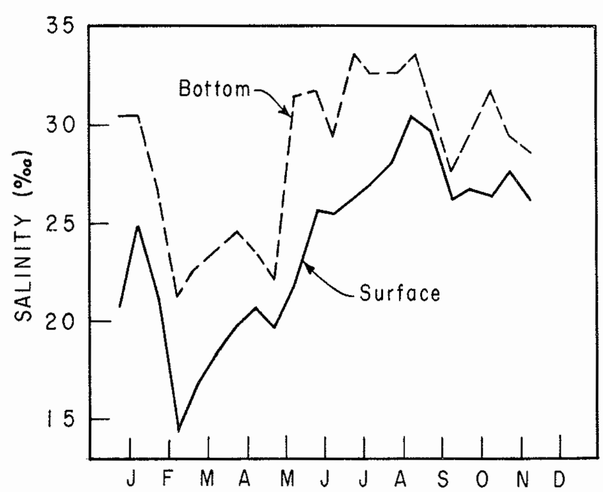


FIG. 6-9. SURFACE AND BOTTOM SALINITY IN SHIP CHANNEL (1963)[6]

Table 6-5. Average Salinity, Upper Galveston Bay and Trinity Bay (1959 - 1960)[7]

Item		November	December	January	February	March	April
Salinity °/oo							
Surface	Maximum	16.74	23.21	12.72	12.90	17.44	19.84
	Minimum	2.90	0.40	0.20	0.20	0.20	0.30
	Average	10.90	12.50	4.80	5.50	6.90	10.50
Bottom	Maximum	21.73	25.49	22.12	30.52	24.90	28.15
	Minimum	2.90	1.50	0.20	0.20	0.20	0.30
	Average	13.10	13.20	6.80	7.60	8.90	11.00

Item		May	June	July	August	September	October
Surface	Maximum	18.24	21.24	14.03	19.91	17.14	19.04
	Minimum	1.05	5.64	0.30	1.15	3.60	1.50
	Average	10.93	13.15	7.86	9.35	10.30	11.54
Bottom	Maximum	24.80	26.58	24.90	31.60	26.38	23.08
	Minimum	2.55	5.64	0.90	1.15	3.60	1.50
	Average	12.30	14.70	8.30	11.50	12.35	12.50

The concentration of chlorides and turbidity at various stations in Galveston Bay were recorded during the 1950-1951 survey which was conducted by the Texas State Department of Health. Turbidity of the water in Upper Galveston Bay and Trinity Bay was estimated in terms of light transmissibility during the 1959-1960 survey which was conducted by the Texas Game and Fish Commission. The temperature and salinity data discussed above characterize Galveston Bay in sufficient detail; therefore, the chloride and turbidity data are not presented in this report.

Typical tidal data recorded in Upper Galveston Bay for a one-year period (1959-1960) are presented in Table 6-6. These data indicate that the maximum difference between ebb tide and flood tide (about 3.2 feet) occurred in the late fall or early winter, while the minimum tidal fluctuations (1.3 feet) occurred in the summer months. The magnitude of the tidal fluctuation between ebb and flood tides in all portions of the bay system was the same even though narrow channels connect some of the bayous and lakes with Galveston Bay. The tidal fluctuation recorded at the Humble Tide Station on Taylor Lake was of the same magnitude as that in Galveston Bay. However, the times at which the flood and ebb tides occurred in Taylor Lake were displaced by a number of hours as compared to those observed in Galveston Bay.

Table 6-6. Maximum and Minimum Tides Area M-2 (Upper Galveston Bay)[10]

Date		Maximum Tide, ft.	Minimum Tide, ft.	Tidal Change
November	1959	2.8	-0.4	3.2
December	1959	2.0	-0.6	2.6
January	1960	1.9	-1.1	3.0
February	1960	2.3	-0.1	2.4
March	1960	2.5	-0.3	2.8
April	1960	2.9	0.1	2.8
May	1960	2.5	0.4	2.1
June	1960	3.0	0.7	2.3
July	1960	2.1	0.8	1.3
August	1960	2.5	1.0	1.5
September	1960	2.6	1.2	1.4
October	1960	2.4	-0.2	2.6

Ship Channel

The Ship Channel from Morgan's Point to the Gulf of Mexico must be considered separately from the more shallow parts of Galveston Bay. The depth of water in the Ship Channel is about 42 feet, and the water in Galveston Bay ranges between two and eight feet. This difference in depth of water resulted in vertical gradients of temperature and salinity in the Ship Channel.

The temperature variations near the surface and at the bottom of the Ship Channel are presented in Table 6-7. Vertical temperature gradients of as much as 6°C were recorded in the Ship Channel during February 1963. The greatest difference in the temperature of the surface and bottom water at a given station was observed when the surface water was rapidly cooled or heated by sudden changes in air temperature. During the winter months it was not uncommon to find that the water on the bottom of the channel was warmer than the surface water. However, during most of the year the temperature at the bottom of the channel was lower than that recorded for the surface water.

Table 6-8 presents the variations in the concentration at the surface and at the bottom of the Ship Channel as well as the seasonal variations in the salinity of the channel. During 1963 the average salinity of the surface water ranged between 14.5 and 30.4 parts per thousand, while the average salinity of the bottom waters varied from 21.2 to 33.7 parts per thousand. These data indicated that the salinity at the bottom

Table 6-7. Temperature (°C) Variation in Ship Channel January 1963 to November 1963 (6)

Station	Depth	January		February		March		April		May		June		July		August		September		October		November	
Mouth of San Jacinto River	40'	[a]17.6	4.8	11.8	16.0	14.4	22.9	22.7	25.9	26.6	28.4	30.0	30.6	32.9	33.3	32.0	30.0	32.0	26.0	26.0	25.0	20.8	20.5
		[b]----	6.6	13.5	10.9	14.9	21.3	23.2	25.7	26.4	26.3	28.6	30.0	30.0	31.5	32.0	30.0	31.9	24.0	25.5	25.0	20.2	19.1
Upper Galveston Bay #1	42'	15.4	4.2	13.0	13.4	14.8	23.5	23.7	25.0	28.6	28.8	32.0	29.0	33.4	32.0	32.0	30.0	31.2	24.0	26.0	25.0	20.4	20.4
		14.1	7.0	----	10.0	15.1	20.8	23.6	25.2	26.4	26.3	29.3	29.3	31.1	30.5	32.0	30.0	31.1	24.0	26.0	25.0	20.6	19.6
#2	42'	12.4	4.4	9.9	16.7	14.6	23.8	23.1	25.2	26.9	29.0	30.6	29.0	35.9	32.4	32.0	30.0	32.0	26.0	26.0	25.0	20.4	20.6
		14.1	7.0	9.3	10.3	14.6	21.4	23.0	25.4	26.0	26.5	28.8	29.7	30.9	30.5	32.0	30.0	31.0	25.0	26.0	25.0	20.5	19.2
(HI-ULG) #3	42'	15.4	7.1	13.5	15.9	19.2	23.1	24.1	25.7	27.2	30.1	31.0	28.3	31.2	31.0	32.0	29.0	32.0	26.0	26.0	26.0	20.3	20.0
		14.5	7.0	10.5	10.5	16.3	20.3	23.1	25.6	25.8	26.5	29.5	29.3	31.1	31.0	32.0	29.0	31.0	24.0	26.0	25.0	20.3	19.5
Lower Galveston Bay #1	42'	14.4	7.5	13.9	11.3	17.0	19.6	23.8	25.1	27.7	29.1	30.0	28.3	30.7	32.3	31.0	30.0	31.5	25.0	26.0	25.0	21.0	19.8
		14.1	7.6	10.8	9.7	15.4	19.6	22.9	25.2	26.0	26.3	29.0	28.6	30.4	30.8	31.0	30.0	31.2	23.0	26.0	25.0	21.2	19.9
#2	42'	14.4	6.4	14.8	13.0	18.4	19.6	23.8	25.4	27.7	30.9	30.8	28.3	30.8	32.0	32.0	30.0	32.0	26.0	28.0	26.0	20.6	19.9
		14.3	6.8	11.9	10.5	16.3	20.1	23.0	25.6	25.8	26.9	29.2	28.8	31.0	30.8	31.5	30.0	31.0	24.0	26.5	25.0	20.6	19.7
Tidal Pass (H-TPLG)	42'	14.9	7.3	14.4	11.1	17.8	20.4	23.5	25.1	27.3	27.5	29.5	28.5	30.8	30.8	31.0	29.0	31.2	25.0	26.0	25.0	20.9	20.0
		14.0	---	10.5	9.8	15.2	19.8	23.1	25.3	26.0	26.1	28.9	29.6	30.2	30.0	31.0	29.0	31.5	24.0	26.0	25.0	21.4	19.8
Gulf of Mexico	42'	14.5	9.8	8.8	8.7	13.6	18.8	23.4	27.7	25.6	25.2	31.6	28.8	32.9	30.0	31.0	30.0	31.0	27.0	25.0	25.0	22.7	18.1
		14.8	10.8	8.7	9.7	12.6	18.2	23.1	26.2	24.8	24.2	29.1	28.4	30.4	30.0	30.5	30.0	31.0	27.0	26.0	25.0	22.6	18.6
Average		14.9	6.4	12.5	13.3	16.2	21.5	23.5	25.6	27.2	28.6	30.7	28.8	32.3	31.7	31.6	29.8	31.6	25.6	26.1	25.2	20.9	19.9
		14.3	7.5	10.7	10.2	15.0	20.2	23.1	25.5	25.9	26.1	29.0	29.2	30.6	30.6	31.5	29.8	31.2	24.4	26.0	25.0	20.9	19.4

[a]Surface Temp.

[b]Bottom Temp.

Table 6-8. Salinity Variation in Ship Channel(6)
January 1963 to November 1963
(parts per thousand)

Station	Depth (Feet)	January		February		March		April		May		June		July		August		September		October		November	
Mouth of San Jacinto River	40	[a]12.1	16.8	20.4	10.9	15.0	16.2	17.2	17.0	17.7	17.9	17.7	19.7	18.1	19.2	19.9	22.3	26.5	25.1	24.6	23.7	22.8	22.7
		[b]26.0	28.4	24.7	21.6	19.4	22.1	19.6	17.5	18.5	28.8	31.3	26.4	19.2	28.9	29.5	27.8	26.4	27.4	25.8	25.1	25.2	25.6
Upper Gal-veston Bay #1	42	13.6	18.6	18.8	14.5	16.1	15.2	18.1	20.9	19.0	16.3	19.7	19.7	20.5	21.5	23.1	25.7	28.2	24.1	25.2	26.2	26.4	24.6
		29.7	30.0	25.8	22.5	24.0	24.0	23.6	22.3	20.5	30.8	30.6	28.6	27.4	32.2	23.2	30.6	33.8	27.4	28.1	28.2	28.1	27.1
#2	42	13.6	18.1	18.8	16.7	14.0	14.6	18.0	18.0	18.5	18.2	17.8	19.8	20.7	19.8	21.8	24.7	25.8	24.3	25.3	25.8	24.4	24.4
		26.0	29.9	25.6	23.0	20.8	23.6	20.8	17.6	19.7	30.3	30.0	27.6	25.4	31.2	31.3	24.6	33.0	27.4	26.9	27.5	27.8	25.8
(HI-ULG) #3	42	15.4	25.4	17.0	9.5	12.8	16.8	17.0	24.8	18.8	18.7	27.9	24.6	21.4	21.8	26.4	28.9	27.4	26.8	24.0	25.4	27.4	26.1
		31.4	30.2	27.1	16.0	24.4	19.4	24.6	26.1	20.7	30.8	31.7	29.9	28.4	32.6	33.6	33.6	35.7	27.5	29.7	29.3	28.5	28.0
Lower Gal-veston Bay #1	42	30.0	30.9	19.8	14.4	18.8	19.6	19.9	25.0	20.8	22.2	32.4	31.6	32.5	35.0	34.4	35.4	29.0	27.4	28.2	23.8	30.3	29.3
		31.6	30.9	26.4	17.5	21.8	21.7	26.1	26.3	22.7	31.4	32.8	33.6	33.5	36.6	36.3	35.4	35.6	27.6	30.2	30.7	31.0	30.6
#2	42	22.1	30.6	18.3	10.2	14.2	18.2	18.6	25.8	20.2	20.2	26.6	26.0	28.0	30.0	29.3	34.0	29.3	27.3	25.9	25.0	27.9	27.7
		32.0	30.6	26.0	15.5	25.4	22.8	26.9	26.4	22.2	31.4	32.4	32.8	31.3	35.1	35.7	35.0	36.1	27.6	30.1	30.5	29.7	30.1
Tidal Pass H-TPLG	42	30.6	29.7	17.7	16.3	19.5	20.8	21.9	23.4	22.6	25.4	31.7	28.5	30.5	31.9	32.9	35.0	35.2	26.8	29.2	28.4	30.2	29.9
		31.4	30.5	25.7	22.7	25.1	25.4	24.4	25.0	22.9	31.8	32.6	31.5	34.2	36.2	33.8	36.4	35.7	27.2	29.8	30.1	31.0	30.3
Gulf of Mexico	42	30.7	29.1	30.4	23.8	24.6	25.6	27.4	21.6	20.8	34.7	31.4	34.2	32.9	36.5	36.2	36.8	35.8	27.3	30.6	31.7	31.9	31.3
		34.2	31.9	31.4	30.6	31.5	30.0	28.2	27.6	30.7	35.2	32.8	34.6	33.4	36.5	36.6	36.5	36.1	27.4	32.7	32.2	32.1	32.0

[a]Surface
[b]Bottom

of the Channel was more uniform than at the surface. The flow of the high-salinity water from the Gulf of Mexico into the Ship Channel accounts for the high salinity at the bottom of the Channel. Naturally, the fresh water inflow from the San Jacinto River tends to lower the salinity of the surface water. In general, the fresh water flows above the more saline waters. The monthly temperature and salinity variations are summarized in Figs. 6-8 and 6-9.

The U. S. Corps of Engineers has four current gaging stations located in the Ship Channel at which the vertical variations in current, salinity, and concentration of suspended sediments were recorded. The tidal fluctuations do not markedly affect the salinity of the water at various depths; however, the magnitude and direction of the current varied considerably from ebb to flood tide. The suspended sediment concentration increased with depth; however, there was a wide variation in the concentration of sediments during the tidal cycle. The salinity and suspended sediment content of the water in the Ship Channel increased as the water flowed from Morgan's Point to the Tidal Pass. The maximum concentration of salinity and suspended sediments was recorded at the Tidal Pass (CS-2). Table 6-9 contains a summary of the data recorded at selected current-salinity gage stations in the Ship Channel.

Houston Ship Channel

The Houston Ship Channel as defined in this section extends from the Turning Basin in Houston to Morgan's Point. The salinity

Table 6-9. Current, Salinity, and Suspended Sediments in Ship Channel (April 2-3, 1963)[5]

Station	Depth Feet	Salinity[a] ‰	Current Flood fps	Current Ebb fps	Suspended[b] Sediment ppm
CS-2	1	26 - 29.5	2.25	2.40	4 - 52
	10	27.5 - 29.5	1.80	1.85	3 - 59
	20	28 - 29.5	1.65	1.60	0 - 150
	30	28 - 29.5	1.50	1.70	1 - 322
	40	28.5 - 29.5	1.35	1.80	---
CS-3	1	19.5 - 28	2.7	3.20	5 - 135
	9	20 - 29.5	3.0	2.80	6 - 273
	17.5	20 - 29.5	3.1	2.85	12 - 336
	26.5	20.5 - 29.5	2.7	2.40	10 - 411
	34.0	22 - 29.5	2.1	1.95	7 - 680
CS-4	1	16.5 - 18	2.15	1.65	2 - 65
	10	16.5 - 18	2.0	1.6	1 - 103
	19	16 - 18	2.0	1.65	2 - 155
	27	16.5 - 19	2.0	1.8	6 - 388
	36	16.5 - 19	1.50	1.65	10 - 2850
CS-5	1	16 - 17	1.95	1.70	26 - 76
	10	16 - 17	1.80	1.55	26 - 107
	19	16 - 17.5	2.05	1.60	44 - 1005
	28	16 - 18	1.95	1.50	12 - 164
	34	16 - 17.5	2.20	1.30	53 - 176

[a]Extreme recorded values.

[b]Lowest and highest concentration recorded.

and temperature in the Houston Ship Channel have been measured by the City of Houston on a monthly basis since 1932. These results for the period 1932-1941 are tabulated in Table 6-10. The data indicated that the temperature and salinity concentration increased as the water flowed from the Turning Basin to the confluence of the Houston Ship Channel and the San Jacinto River at which the temperature and salinity decreased. However, as the flow continued toward Galveston Bay the temperature and salinity increased. The surface temperature usually ranged between 50°F and 90°F, but the average annual temperature was between 70°F and 75°F. The range of salinities reported at the Turning Basin was from 0.05 part per thousand to more than 20 parts per thousand. The annual average salinity of the Houston Ship Channel was about 3 to 5 parts per thousand; however, at Morgan's Point the concentration of salinity ranged from 9 to 13 parts per thousand.

Temperature variations in the Houston Ship Channel were recorded during 1958.[11] The data showed that there was considerable variation in the temperature of the Channel waters from a point near the Baytown Tunnel crossing to Buoy 143, approximately seven miles above Humble's waste outfall. This variation in temperature was about 7°F. This considerable range of temperature occurred on March 20, 1958, although the data almost always exhibited this trend. The upper part of the Channel was always a few degrees warmer than other locations. This particular study involved routine measurements of temperature of the Ship Channel and Bay. Most of the data were

Table 6-10. Temperature (°F) and Chlorides (°/oo) in Houston Ship Channel(2)

Station[c]	1933		1937		1938		1939		1940		1941	
	Temp.	Chlorides	Temp.	Chlorides	Temp.	Chlorides	Temp.	Chlorides	Temp.	Chlorides	Temp.	Chlorides
Buffalo Bayou,	74.0[a]	0.15[a]	69.8	0.07	70.7	0.14	70.1	0.13	67.6	0.09	70.2	0.04
No. 49	61-86[b]	0.07-0.24[b]	51-85	0.02-0.11	54-86	0.17-0.93	57-88	0.05-0.17	52-82	0.02-0.14	55-81	0.02-0.09
L. White Oak	72.6	0.12	69.6	0.07	71.8	0.10	73.6	0.18	43.0	0.07	70.3	0.12
Bayou, No.6	56-84	0.05-0.20	50-88	0.02-0.21	50-88	0.02-0.24	52-89	0.06-0.29	32-49	0.05-0.09	51-85	0.08-0.17
L. White Oak	69.8	0.26	70.7	0.16	72.7	0.18	75.2	0.28	67.4	0.17	71.3	0.18
Bayou, No.1	56-82	0.10-0.44	50-84	0.06-0.34	52-86	0.02-0.30	54-87	0.12-0.72	38-87	0.05-0.30	54-86	0.06-0.32
White Oak	70.2	0.11	69.3	0.08	70.8	0.13	72.8	0.17	65.2	0.12	69.1	0.16
Bayou, No.6	46-86	0.02-0.20	49-86	0.02-0.19	54-88	0.02-0.59	53-86	0.06-0.29	33-85	0.05-0.19	50-85	0.05-0.31
White Oak	69.8	0.18	66.7	0.12	69.5	0.11	72.2	0.23	66.6	0.13	69.0	0.13
Bayou, No.2	46-82	0.05-0.34	49-84	0.03-0.23	56-84	0.02-0.22	52-85	0.10-0.46	42-82	0.05-0.28	51-84	0.05-0.21
White Oak	71.9	0.35	68.7	0.16	73.5	0.23	74.3	0.38	67.6	0.16	69.7	0.18
Bayou, No.1	46-86	0.05-1.40	50-84	0.02-0.33	56-86	0.02-0.53	55-86	0.16-0.58	43-84	0.07-0.29	53-84	0.05-0.36
Buffalo Bayou,	73.7	0.24	70.6	----	71.7	0.61	69.3	1.57	67.7	0.91	71.5	0.48
No. 43	61-86	0.08-0.83	50-85	----	56-86	0.03-4.64	54-85	0.17-6.44	47-86	0.04-2.90	56-83	0.02-2.32
Buffalo Bayou,	74.2	1.90	71.4	2.86	74.1	4.06	71.9	7.90	69.8	8.50	72.5	3.03
No. 23	63-86	0.17-4.81	51-88	0.11-6.68	60-88	0.05-12.76	56-86	2.32-15.08	48-89	0.04-12.80	57-86	0.02-9.86
Brays Bayou,	74.5	0.24	71.3	0.08	75.5	0.20	74.0	0.23	70.3	0.14	73.3	0.09
No. 11	43-90	0.09-0.86	52-90	0.05-0.13	53-88	0.02-1.10	55-92	0.14-0.37	49-88	0.06-0.22	59-87	0.03-0.18
Brays Bayou,	73.3	0.95	70.9	0.72	73.7	2.01	75.4	2.44	70.5	2.34	73.3	0.88
No. 1	43-86	0.13-3.52	52-87	0.10-2.11	53-87	0.28-4.36	59-87	0.81-4.09	50-87	0.09-5.13	58-87	0.03-2.90
Buffalo Bayou,	74.5	3.14	72.5	2.67	73.4	5.32	72.2	8.08	69.7	8.98	73.1	3.74
No. 19	61-88	0.48-8.82	56-88	0.16-8.75	56-88	0.08-15.66	58-88	2.90-14.50	46-89	0.07-17.98	57-87	0.03-11.02
Sims Bayou,	70.9	4.98	73.0	----	71.9	2.27	74.3	11.54	65.0	6.96	74.7	5.41
No. 8	35-87	0.29-14.50	52-90	----	46-90	0.29-7.08	56-89	2.20-18.56	38-92	2.32-13.92	57-91	2.32-23.20
Sims Bayou,	72.6	6.09	72.9	6.83	73.0	6.40	73.6	6.99	66.5	10.95	74.2	8.48
No. 3	44-87	2.18-12.80	52-89	0.92-15.66	48-87	0.87-19.72	52-91	3.25-13.50	44-88	2.32-18.56	57-90	1.74-17.40
Buffalo Bayou,	75.4	5.75	73.6	5.76	75.6	7.87	72.7	12.31	72.2	13.14	76.2	5.77
No. 15	64-89	0.63-10.44	57-90	0.23-14.52	60-90	0.66-16.24	58-89	4.18-19.72	48-92	0.06-19.14	57-95	0.08-13.44
Buffalo Bayou,	76.3	6.22	74.4	7.29	76.0	9.88	74.4	13.60	71.9	13.65	74.5	5.57
No. 10	61-91	0.81-12.18	57-92	0.26-16.30	60-92	0.78-33.06	60-91	5.80-22.62	47-92	0.09-19.72	58-91	0.06-15.69
Buffalo Bayou,	76.4	6.91	74.6	8.75	75.8	10.23	73.9	13.52	71.0	12.98	74.1	6.23
No. 9	60-91	1.05-13.34	58-92	0.28-16.85	58-94	1.15-30.10	59-90	6.38-22.62	46-92	0.29-19.14	58-91	0.06-16.24
Buffalo Bayou,	75.7	6.98	73.5	7.11	74.5	8.84	71.1	12.21	70.8	12.56	72.9	4.26
No. 8	60-91	0.93-13.92	53-90	0.27-17.45	57-93	0.35-28.42	57-89	4.64-19.72	45-92	0.09-20.30	56-90	0.07-15.69
Buffalo Bayou,	76.0	8.17	73.4	8.75	73.6	9.95	71.2	13.76	70.7	15.08	73.5	5.33
No. 6	56-95	1.28-14.50	54-90	0.30-18.58	58-90	1.40-19.72	58-91	5.80-22.04	46-90	1.03-20.88	57-89	0.06-15.08
Buffalo Bayou,	74.5	9.25	71.7	9.54	72.8	11.07	70.3	14.81	70.0	16.39	72.6	5.87
No. 2	58-92	2.90-15.49	49-86	0.35-18.12	58-90	0-22.04	58-88	8.12-23.78	46-88	1.94-23.20	58-89	0.08-13.92
Buffalo Bayou,	74.0	9.66	72.0	10.18	72.8	11.59	70.2	14.98	69.4	16.80	72.0	5.89
No. 1	56-85	4.07-15.66	49-88	0.35-19.72	58-89	3.38-23.20	57-88	9.28-23.79	45-88	2.03-23.20	57-83	0.08-12.11

[a] Annual average; [b] Range of monthly data; [c] Exact location of stations listed in Appendix E-1

obtained by recording the temperature of the upper one foot of water. On two occasions, April 5, 1958, and May 6, 1958, vertical sampling was conducted. Although the reported data were not necessarily typical, they demonstrated the non-homogeneous nature of the Ship Channel and characteristics which are the reverse of those found in Galveston Bay.

The data indicated that a salt-water wedge occasionally lies under the fresh water in the Houston Ship Channel. On May 6, 1958, the fresh water inflow appeared to be lens shaped and located in the upper layer of the Channel. The data recorded during January, 1958, showed that the San Jacinto River water, upon entering the Channel, rode over the Channel water, then continued downstream in the upper layer of the Channel for two or three miles. Interestingly enough, it appeared that at times the fresh water was removed by intakes of industrial plants.

The San Jacinto River apparently affects the chlorinities of the Channel materially. There appeared to be an appreciable effect over a distance greater than two or three miles downstream, and there was some effect for a short distance upstream as well.

Because of the influence of the Lake Houston Dam on the San Jacinto River and the withdrawal of nearly 100 million gallons of water per day by the City of Houston and the San Jacinto River Authority, the flow rate of the River into the Channel does not increase proportionately with rainfall. There was essentially no flow in the river through the dry portions of the year.

It has been reported that during the winter months water of low salinity and high dissolved oxygen flowed into the Channel and was highly beneficial since it raised the dissolved oxygen content of the Channel. In the past, even during the summer period, the San Jacinto River flow has been beneficial since the ebb flow had a higher dissolved oxygen content than the flood flow. Significantly enough, after a lapse of time for surface reaeration and bacteriological activity, a higher quality water apparently returned to the Channel.[11]

The currents resulting from the tidal cycle affected the salinity and concentration of suspended sediments in the Houston Ship Channel. Typical data are shown in Figs. 6-10 and 6-11. Station CS-6 is near Morgan's Point, and Station CS-7 is near Baytown.

The salinity of the water at various depths at a given station did not vary a great deal during a tidal cycle. The concentration of suspended sediment fluctuated a good bit during the tidal cycle, and the data indicated that the suspended sediment content increased with depth at a single station. The salinity and suspended sediment content recorded for the water at the various stations increased from a minimum value at Station CS-13 to a maximum value at Station CS-2. Station CS-13 is near the Houston Turning Basin, and Station CS-2 is at the Tidal Pass in the Gulf of Mexico. The magnitude and direction

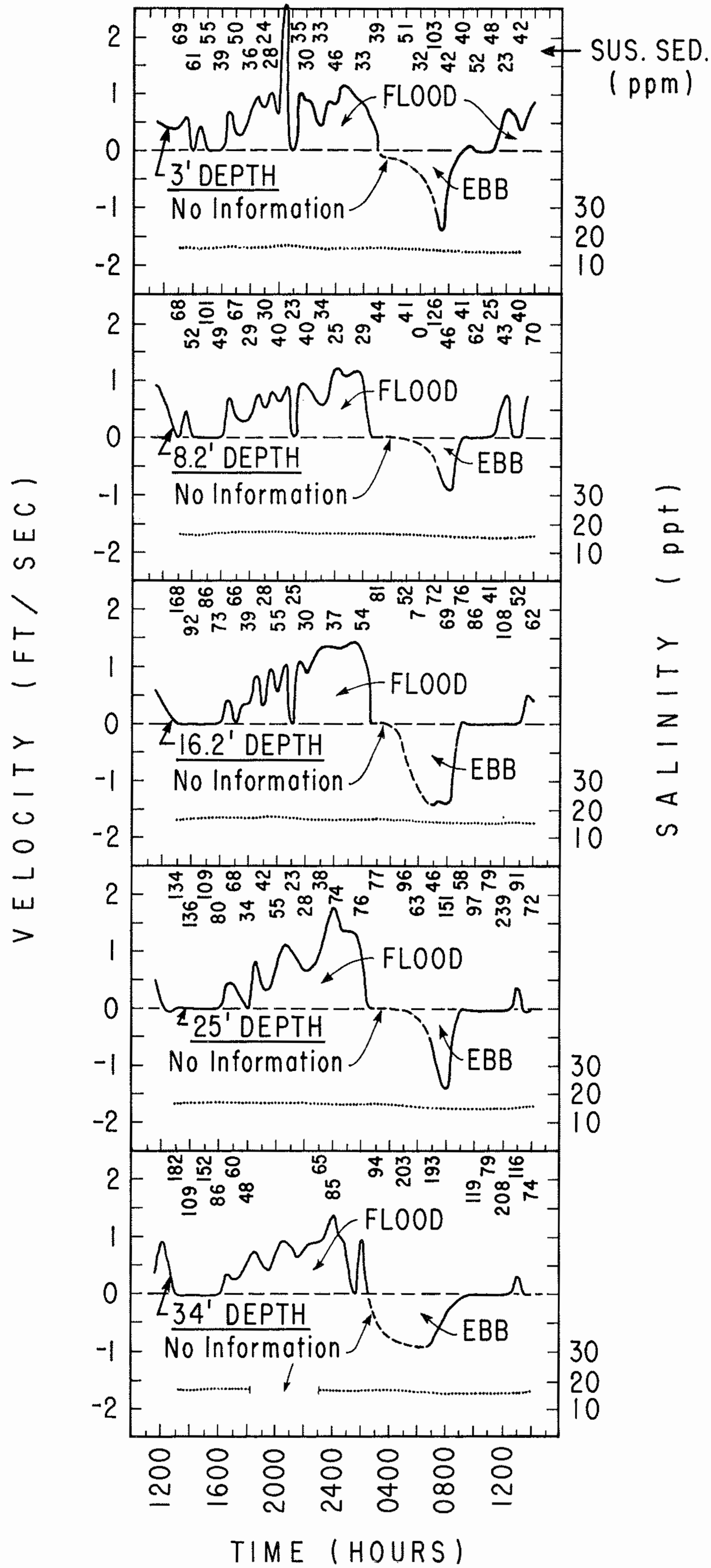


FIG. 6-10. TIDAL DATA, HOUSTON SHIP CHANNEL STATION C-S 6, APRIL 2-3, 1963.[5]

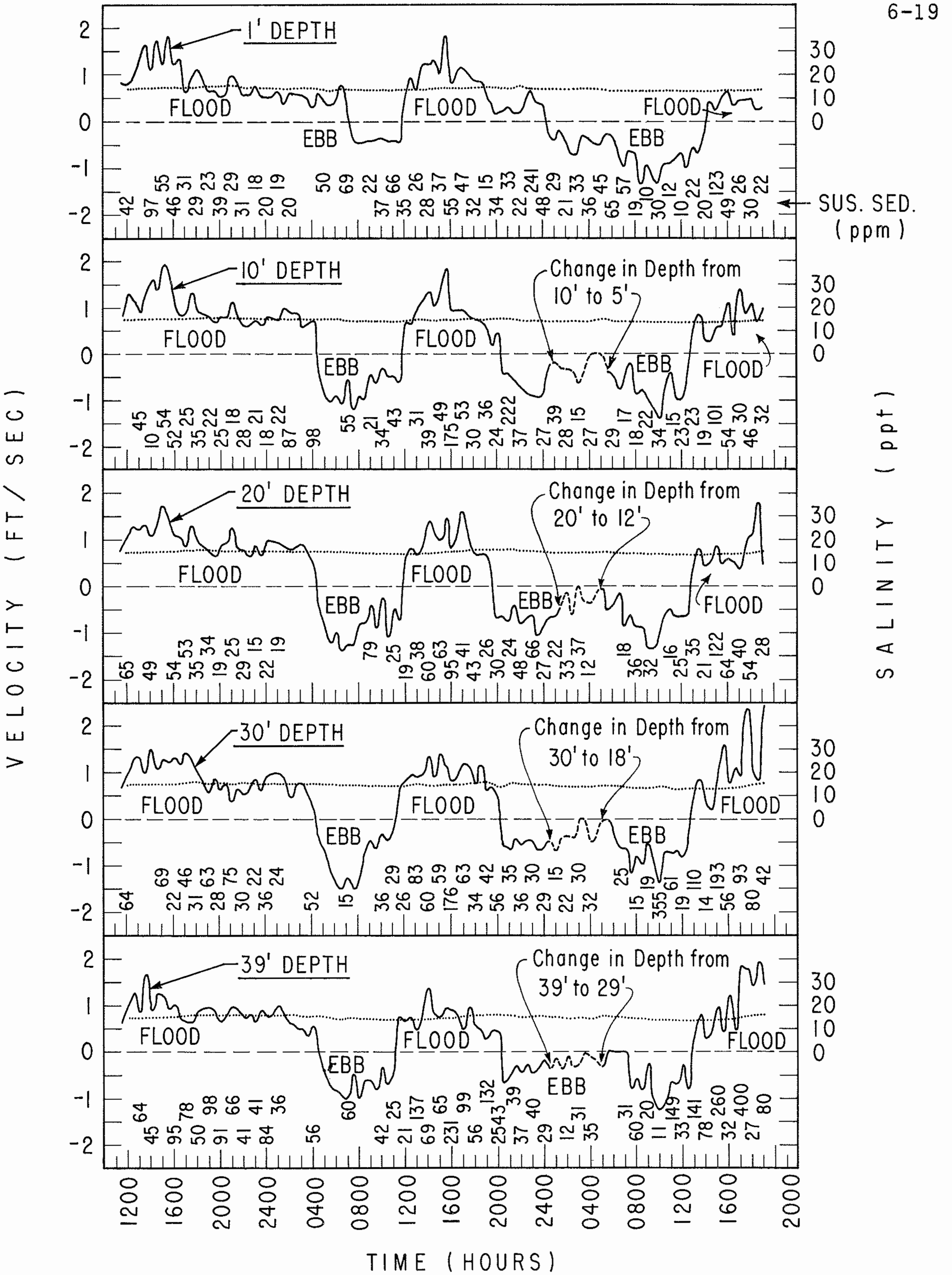


FIG. 6-11. TIDAL DATA, HOUSTON SHIP CHANNEL STATION C-S 7, APRIL 2-4, 1963.(5)

of the current varied much more at Stations CS-2 to CS-5, which are located in the Bay and at the Tidal Pass, than at Stations CS-5 to CS-13 in the Houston Ship Channel.

CHAPTER 7

HYDROLOGICAL CHARACTERISTICS (HISTORICAL)

Galveston Bay is influenced greatly by fresh water inflows, tidal fluctuations and hurricane tides. A brief description follows of:

- Hurricanes
- Rainfalls
- Inflows
- Diversions
- Upstream Reservoirs

Hurricanes

The cities of Galveston and Texas City as well as certain other low-lying areas are susceptible to flooding during hurricanes. A number of localized projects designed to alleviate this problem are either in the planning stage or under construction. In addition to these projects, the erection of a hurricane wall across the entrance to Galveston Bay is under consideration. The installation of this wall will leave only a controlled opening for ocean traffic. Presently, model tests are planned to facilitate the study of the effects of large hurricanes on the control facilities. These studies are under the direction of the U. S. Army Corps of Engineers.

The impact of large hurricane control structures on the transport of water into and out of Galveston Bay is not known at this time. There is a possibility that such a structure would reduce the potential assimilative capacity of the Bay for domestic and industrial discharges. These facilities may also materially change the ecological environment of the entire Galveston Bay system.

Rainfall on the Bay

The average annual rainfall on the Bay during the period 1941-1956 was 1,371,000 acre-feet. The rainfall data are presented in Table 3-15. The minimum and maximum annual rainfalls for this period were 644,000 (1948) and 2,123,000 acre-feet (1941), respectively.

Fresh Water Inflow

A salient characteristic of Galveston Bay is the quantity of fresh water delivered to the Bay by the two main tributaries. The recorded average flows of the Trinity River at Romayor and San Jacinto River at Hoffman gages for 1941-1961 were 6,502,000 acre-feet per year. For the same period the average flow below these gages plus that of Buffalo Bayou and other streams was 1,669,000 acre-feet per year.

The results of field studies indicated that in addition to these runoffs the watershed of the Trinity River below Romayor probably produced an average runoff of 19.5 per cent of the gaged flow at Romayor during the drought period of 1954-1956.[1] Therefore, a minimum average runoff of 258,000 acre-feet per year can be expected below the Romayor Station. This assured fresh water supply to Trinity Bay appears to be a significant factor.

Four major water appropriators, namely, the Richmond Canal Co., the Devers Canal Co., the Southern Canal Co., and the Chambers-Liberty Navigation District, have water rights below Lake Livingston. These water consumers use an estimated total of 230,000 acre-feet per year. About 213,000 acre-feet are used for irrigation and 17,000 acre-feet are used for mining and industrial purposes. There is an allowance of an estimated 2,000 acre-feet of water per month for riparian rights, navigation, seepage, and stream flushing, according to one study.(2)

Future changes in the use, reuse, local diversion, or multiple trans-basin diversion would certainly have an effect on the present ecology. However, this influence would not necessarily be disastrous in terms of net benefits derived from the use of the waters. A more uniform release of water via a complex reservoir system may actually help to stabilize the Bay. On the other hand, if the regulated flow of fresh water is reduced drastically the transport of pollutants may not be possible. Thus, there is a possibility of materially affecting the natural aquatic system.

<u>Texas Basins Diversion</u>

Various proposals have been made to provide water for different locations along the Gulf Coast. One of these plans involves the Texas Basin concept which proposes to divert water from the eastern rivers of Texas to the western areas of need. The future regulated return flow as estimated by the U. S. Bureau of Reclamation is 1,200,000 acre-feet per year. The effect of this trans-basin diversion on the assimilative capacity is not known. The effects of such diversions on the ecology of Trinity Bay and the Houston Ship Channel could conceivably be advantageous. Trinity Bay would not receive massive amounts of fresh water, and the Ship Channel would receive a firm amount of dilution water.

<u>Upstream Reservoirs</u>

The impact of upstream use and reuse of water, regulation of flow and interbasin diversion will be considerable. The amount and quality of the water released to the Bay will change, but no completely integrated study of flow and water quality has been made to date.

The magnitude of the upstream plans is depicted in the following summaries.

<u>Trinity River</u>: In 1957 there were 17 major reservoirs on the Trinity River with a water conservation storage of 1,233,000

acre-feet. This flow came from a drainage area of 6,198 square miles. Most of these reservoirs were in the upper fan of the Trinity River and all of these reservoirs except Lavon and Waxahachie are located above Dallas, Texas.

Eight additional reservoirs and the enlargement of one existing reservoir have been proposed by agencies other than the Trinity River Authority. It is estimated that ultimately these additional projects will increase the water conservation storage in the Trinity River Basin to approximately 4,868,000 acre-feet. The total yield of the upstream reservoirs will be increased to 2,800 acre-feet per day, and the total drainage area contributing to these reservoirs will be 9,455 square miles.[(3)] The proposed reservoir system of the Trinity River Authority includes 14 tributary reservoirs and a main stem reservoir at the Tennessee Colony site. With the exception of the Tehuacana reservoir, all of the tributary reservoirs have apparently been included in the proposed master plan of the Trinity River Authority upon the recommendation of local agencies. However, the construction of all of these reservoirs is not assured.

The water conservation storage in the Trinity River basin will be increased to 7,513,000 acre-feet after the City of Houston completes the Lake Livingston reservoir and the Trinity River Authority completes the Tennessee Colony reservoir. If all the contributing reservoirs are added, the water conservation alone will amount to a grand total of 8,375,000 acre-feet. If the main stem reservoirs are operated for both water conservation and navigation, all estimates must be reduced by 343,000 acre-feet.[4]

The proposed Lake Livingston reservoir and Lake Wallisville are both within the 75-mile zone of the City of Houston. The latter will act as the salt water barrier. Lake Livingston is located 128 river miles from the mouth of the river. This reservoir is designed to impound about 1,750,000 acre-feet of water and has a diversion capacity of 1,254,000 acre-feet per year. The salt water barrier is located between river miles 3 and 4, is designed to impound 22,000 acre-feet, and is planned to have a diversion capacity of 89,600 acre-feet per year.

Of the amount of water diverted from Lake Livingston 800 acre-feet per day are reserved for use in the Trinity basin. The entire 250 acre-feet per day to be diverted from the salt water barrier are reserved for use in the Trinity River basin, according to one study.[5]

Significantly enough, all of the estimates on flow include the return flows from upstream uses. The records for the five-year period for the cities of Fort Worth and Dallas (1952-1956) indicated that an average of 61.4 per cent of all water diverted by the cities was returned to the stream. All of this return water contained additional solids, organic matter, and nutrient materials. Figures

7-1 and 7-2 show the possible build-up of dissolved solids and chlorides in Livingston Reservoir for several modes of river management.

San Jacinto River: Lake Houston has an effective storage of 160,000 acre-feet, and the planned Honea reservoir on the San Jacinto River has a capacity of 360,000 acre-feet. However, the firm yield of Lake Houston is 495 acre-feet per day whereas that of the Honea reservoir is 223 acre-feet per day. It is to be noted that one-half of the present Lake Houston yield has been sold for industrial use. The remainder, plus the yield from the future Honea reservoir of the San Jacinto River, is planned for municipal use.[6]

The influx of water from the San Jacinto River to the Bay will be changed if the planned reservoirs are constructed or if the Texas Basins Project as proposed by the U. S. Bureau of Reclamation is put into effect. Certainly the further use of all fresh waters will change the immediate dilution characteristics of Buffalo Bayou. However, the effect of use, i.e., solids build-up, etc., is an exceedingly complex problem. To date neither actual nor mathematical models have been constructed which could provide much-needed information on the operational behavior of the river-reservoir-bay complex.

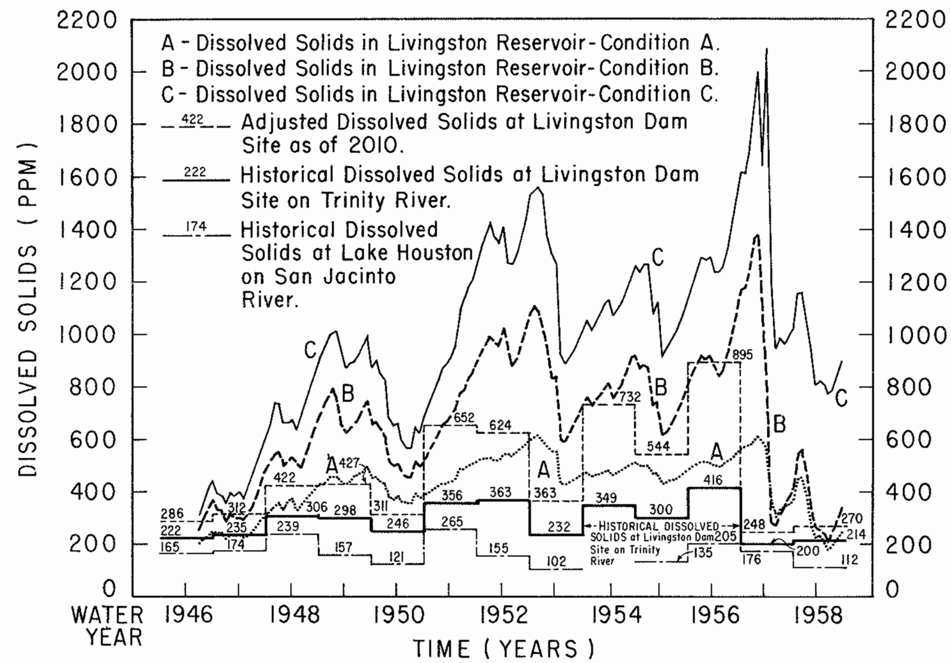


FIG. 7-1. DISSOLVED SOLIDS.(5)

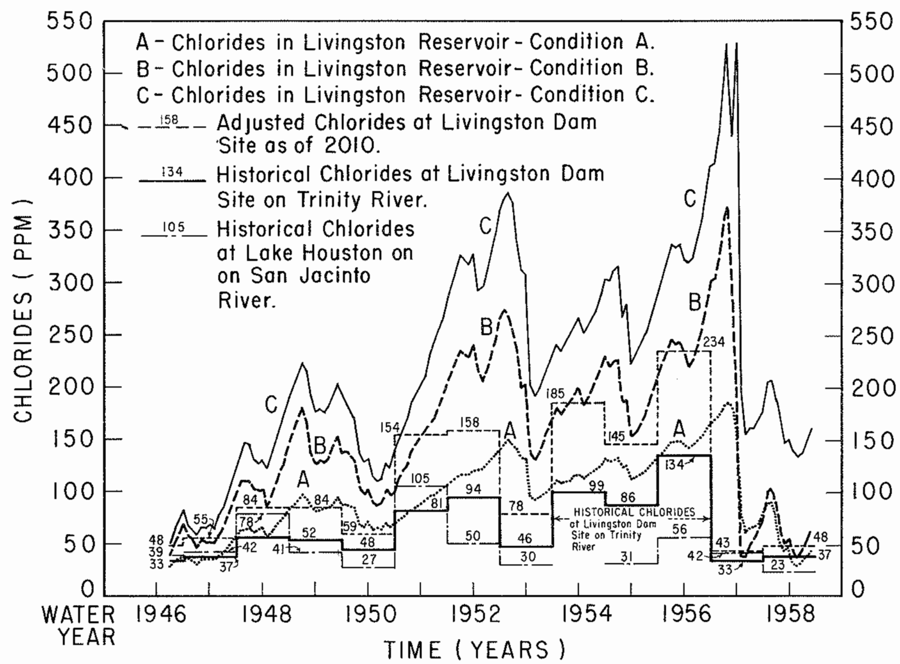


FIG. 7-2. CHLORIDES.(5)

CHAPTER 8

BOTTOM SEDIMENTS (HISTORICAL)

The sediments that accumulate at the bottom of a water course can be helpful in the development of a thorough understanding of the historical condition of a body of water. Similarly, the chemical composition of these sediments and debris can provide some insight into the ability of the body of water to assimilate pollutants. A limited number of geological and ecological studies have been conducted on the sediments in Galveston Bay and the Houston Ship Channel. However, the periodic dredging of the Houston Ship Channel from the Houston Turning Basin to the Tidal Pass has affected the natural movement and deposition of the sediments.

The available information which discusses the geological and ecological conditions of the sediments will be presented in the following order:

- Houston Ship Channel (Turning Basin to Morgan's Point)
- Galveston Bay
- East Bay

Houston Ship Channel

The results of geological investigations of the sediments along the banks of Buffalo Bayou, White Oak Bayou, and Brays Bayou indicate that the sediments are non-marine and probably deltaic and fluvial in origin. The sediments contain a combination of fine-grained clastics, cross-bedding, channel sands, etc. Red clay is abundant, and red sand strata at the surface are traced laterally to light brown sand not exposed to the surface. A large amount of black organic clay containing undecomposed wood was found in some locations.[1]

The sands and clays mentioned above were carried into the Houston Ship Channel and into Galveston Bay during the period of erosion resulting from the flow of the streams in the bayous.

Figure 8-1 shows a series of sketches depicting the condition of the Houston Ship Channel on December 17, 1957. The locations at which these samples were collected are shown in Fig. 4-3. There are thick strata of fine-grained deposits in some of the samples, indicating that the bays were used as settling basins. The Channel has been subjected to periodic flushing action by fresh-water streams, industrial and domestic waste discharges, and repeated dredging. No living organisms were observed in these samples, and a very limited number of forams, shells, bivalves, and other deposit forms were reported. These biological forms are normally found in typically healthy aquatic environments. Such normal environments would certainly include annelids which were found only in the shallow areas of the Channel in the vicinity of Peggy's Lake. Particles in the form of black conglomerates were

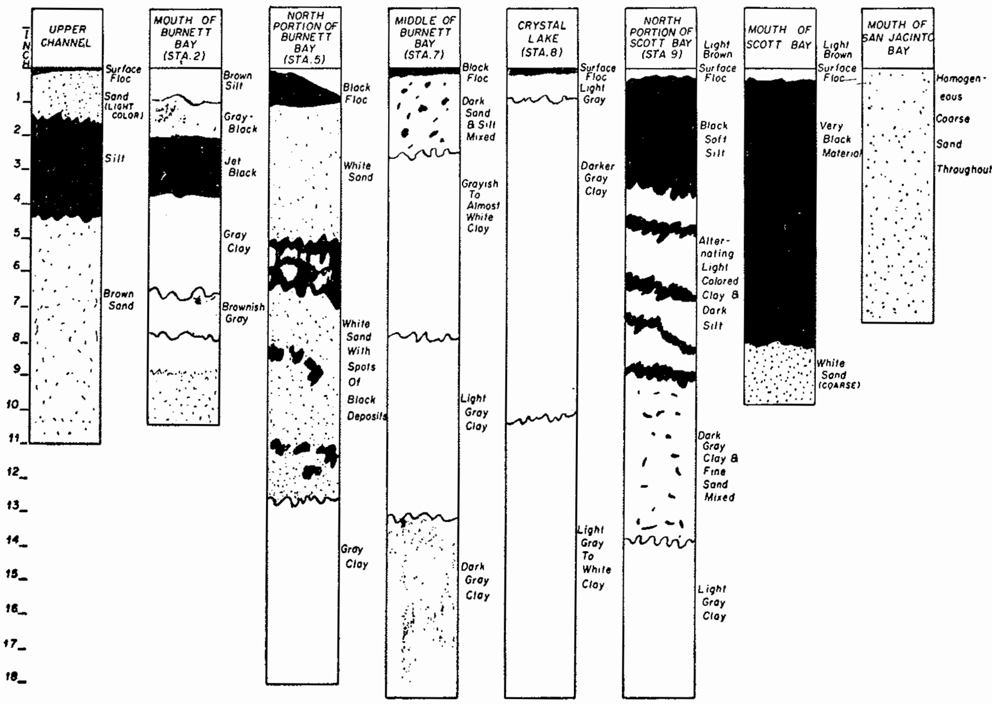


FIG. 8-1. SKETCH OF GROSS APPEARANCE OF CORES.[2]

also commonly found in the middle of the Houston Ship Channel near the Humble outfall and above this point. These chunks of material were possibly oil-coated solids or iron sulfide bodies. There seems to have been some correlation between the frequency of the black conglomerates and the organic content of the samples.[3]

The sediments in the Channel contain varying concentrations of organic materials. Table 8-1 presents the chemical analysis of some channel sediments. The settleable solids from waste streams and general runoff, as well as from some oily substances which settle to the bottom of the Channel, accumulate with the sediments. As movement or turbulence such as that caused by ocean-going ships is produced, some net transport is provided in the general direction of Galveston Bay. This added turbulence has probably been one of the factors in the elimination of oil deposits and sludge banks.

Table 8-1. Chemical Analysis of Channel Sediments, June 17, 1958[4]

Location	Organic Content ppm
Mid-channel, 0.75 mile below refinery outfall	3,200
Mid-channel, 0.30 mile below refinery outfall	2,390
Mid-channel, 0.0 mile from refinery outfall	2,390
Mid-channel, 2.20 miles above refinery outfall (Station IV)	1,920
Mid-channel, 6.06 miles above refinery outfall (Station 137)	4,780
50 yards above outfall and 15 yards from eastern shoreline	11,800
50 yards below outfall and 15 yards from eastern shoreline	21,720

Galveston Bay

The characteristics of the sediment in Galveston Bay have not been reported in sufficient detail to establish a pattern of pollution. A complete description and characterization of the sediments in Galveston Bay are the objectives of a project conducted at the Biological Laboratory of the U. S. Bureau of Commercial Fisheries in Galveston, Texas. The locations of the sampling stations are shown in Fig. 6-1. The analysis of the sediments includes classification of soils, organic content, and enumeration and identification of bottom fauna. All stations are being sampled five times, namely, in the winter, spring, early summer, late summer, and fall.

East Bay

During the summer of 1951, 21 samples of the bottom sediments in East Bay were collected and analyzed. The locations of the sampling points are shown in Fig. 8-2. The grain size distribution of the sediments is presented in Table 8-2. These sediments contained primarily fine silts and clays which passed through the 200 mesh sieve. The clay fraction of the sediments was separated into three categories, namely, montmorillonite, illite, and kaolinite. The relative amount of each clay in a given area of East Bay is presented in Fig. 8-3. Montmorillonite is most abundant in the area north of Hanna Reef and along the northern shore of East Bay. Illite is a

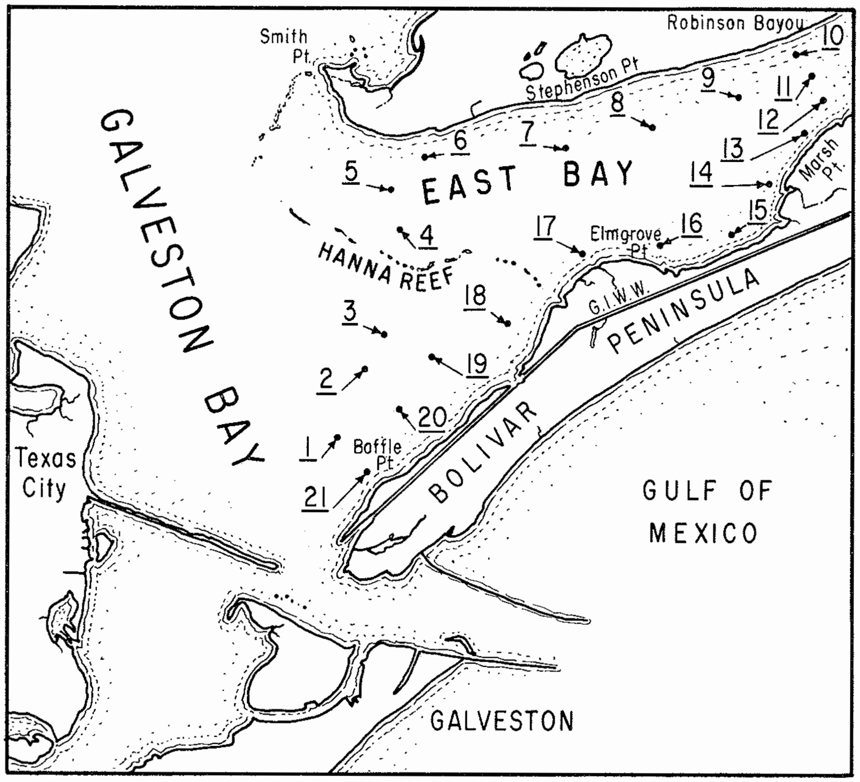


FIG. 8-2. LOCATIONS OF SEDIMENT SAMPLING POINTS - EAST BAY (1951)[5]

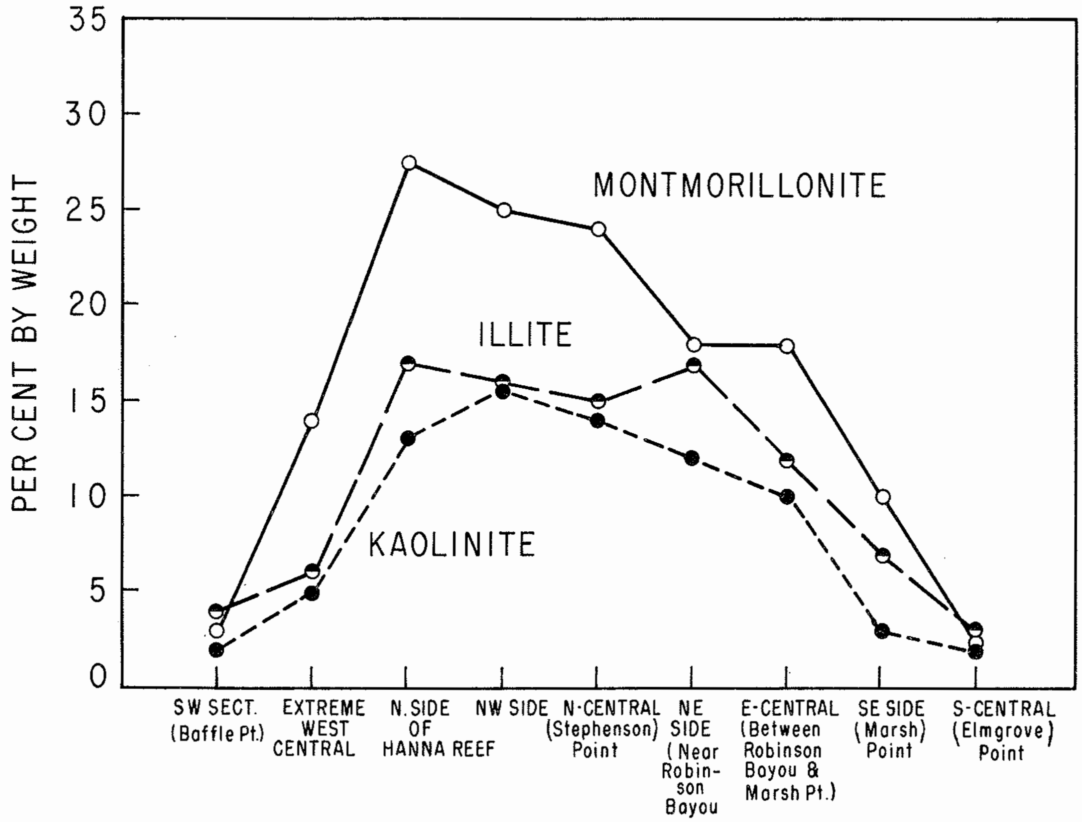


FIG. 8-3. DISTRIBUTION OF CLAY FRACTION IN SEDIMENTS - EAST BAY (1951)[7]

Table 8-2. Weight-Size Distribution of Sediments (per cent), East Bay, (1951) [6]

Sample	Particle Size in Microns				
	-840[a] to +149[b]	-149 to +74	-74 to +44	-44 to +2	-2
1	20.92	62.84	7.45	3.86	4.94
2	9.77	46.64	14.99	11.84	16.76
3	2.53	29.33	11.12	22.40	34.61
4	0.31	5.14	8.71	30.80	55.03
5	0.14	2.10	5.11	31.91	60.73
6	0.15	1.13	4.30	31.95	62.47
7	1.59	5.59	4.19	26.03	62.60
8	0.55	12.19	17.80	25.09	44.36
9	0.34	8.04	12.32	30.66	48.63
10	0.42	20.50	15.24	19.28	44.56
11	1.15	23.88	14.62	20.46	39.88
12	1.36	35.86	12.37	14.12	36.29
13	3.63	60.96	8.72	8.12	18.57
14	5.34	58.37	15.66	8.84	11.79
15	24.35	59.19	6.71	3.95	5.80
16	26.92	46.74	8.15	6.94	11.26
17	17.37	61.09	8.11	4.38	9.06
18	3.14	23.13	9.56	25.85	38.32
19	4.80	8.97	4.77	26.03	55.44
20	1.64	19.41	24.03	22.20	32.71
21	16.78	35.22	21.26	11.97	14.78
Average	6.83	29.82	11.20	18.41	33.74

[a](-) passed through sieve.

[b](+) retained by sieve.

marine-formed clay and is found in all samples. The amount of illite is relatively uniform throughout East Bay. This condition is typical of small lagoon areas not directly fed by fresh water continental streams; however, these data do not sufficiently establish this fact, namely, that the illite was formed in place and not carried into the Bay by fresh water streams.

CHAPTER 9

DIVERSITY AND DISTRIBUTION OF ECONOMICALLY IMPORTANT FISHES AND INVERTEBRATES

The abundant marine life in Texas waters is a major resource which provides an annual harvest of food products important in the economy of many coastal areas. Texas ranks first among the Gulf states in this regard.

Little is known about the diversity and distribution of economically important marine life in Galveston Bay. However, available data will be discussed under the following topics:

- Fish
- Oysters
- Crabs
- Shrimp
- Bay as a Nursery Grounds

Fish

The results of studies on the ecology of the Houston Ship Channel[1] indicate that the per cent of the catch for certain species of fish in the middle region of the Channel was quite different from the adjacent bays. Similarly, this difference existed for the lower region as shown by the data in Table 9-1. It is readily apparent that the resident population cannot be maintained in the middle region of the Houston Ship Channel because of the

Table 9-1. Variation in Per cent of Catch for Certain Species in the Bays and Channel[2]

Date	Station	Brevoortia sp. including B. patronus	Leiostomus xanthurus per cent	Micropogon undulatus per cent	Galeichthys felis per cent	Others per cent	All fish catch per trawl
May 2	III	0	87	17	0	0	70
	VII	10	26	52	2	10	50
May 8[a]	III	1	82	17	0	0	311
	VII	1	85	12	0	2	276
	6-7	0.3	0.3	98	0	1	648
May 15	III	8	71	18	0	3	38
	VII	19	39	36	0.4	6	220
	4-5	2	2	84	0.26	13	386
	6-7	1	1	58	0	38	66
	8	13	1	72	0	12	282
June 12	III	48	52	0	0	0	21
	VII	78	9	13	0.3	0.9	333
	4-5	34	32	23	0	12	197
	8	4	22	62	0	12	94

[a]Station 137, L. xanthurus, 96% , M. undulatus, 4%

Note: Locations of stations are shown in Fig. 4-4.

environmental conditions. Wide fluctuations of dissolved oxygen occur seasonally, daily, and hourly. All of the fish reported in Table 9-1, including menhaden (Brevoortia), prefer dissolved oxygen concentrations greater than 4.0 ppm. In light of this information, it should be noted that menhaden were caught in greater abundance near the outlet of the Houston Ship Channel.

The sports fishing in the upper Galveston Bay and Trinity Bay is fairly great. To support the life history studies of the major game fish in this area, the Texas Parks and Wildlife Commission determined the vertebrate forms present, periods of presence, and relative seasonal abundance for the Upper Galveston Bay area.[3]

During the period 1959 to 1960 only eight speckled trout, Cynoseion nebulosus, were caught. It is to be noted that the black drum, Pogonias cromis, was collected every month of the study except February 1960. The juvenile specimens were taken while seining around Spartina in the marsh habitats.

Southern flounder, Paralichthys lethostigma, were taken during eight months of the year. Juvenile flounder first appeared in the latter part of May 1960 and continued to show up in the collections all summer. These specimens were found in Clear Lake, Mud Lake, and Taylor Lake, indicating that young flounder prefer shallow nursery grounds with muddy bottoms.

Red fish, Sciaenops ocellatus, were very limited in the upper Galveston Bay area. Only three were caught.

Sheepshead, Archosargus probatocethalus, were found in limited numbers around oyster reefs and vegetated areas.

Sand trout, Cynoscion arenarius, was the only game fish collected every month of the study. Specimens under 100 millimeters were taken every month except February 1960. The peak months of spawning, according to the collection records, occurred from May through August in upper Galveston and Trinity Bay areas. Juvenile sand trout were not restricted to any particular type of habitat as other juvenile species seemed to be.

Oysters

The approved oyster-harvesting areas of Galveston Bay (1963 approved area) are shown in Fig. 9-1. The approved areas include West Bay (from Deer Island, southwest to San Luis Pass, but excluding Chocolate Bay), East Bay (from the Houston Ship Channel, east to a point where a straight line may be drawn from the entrance of Robinson Bayou, due south to Marsh Point), Galveston Bay (from Smith Point north to a point 1,500 yards west of the mouth of Lone Oak Bayou—located on a straight line drawn from Lone Oak Five-Mile Pass and a line drawn from Houston Point to Houston Ship Channel marker No. 63 intersect; thence, south along a line from this point to channel marker No. 44, and south

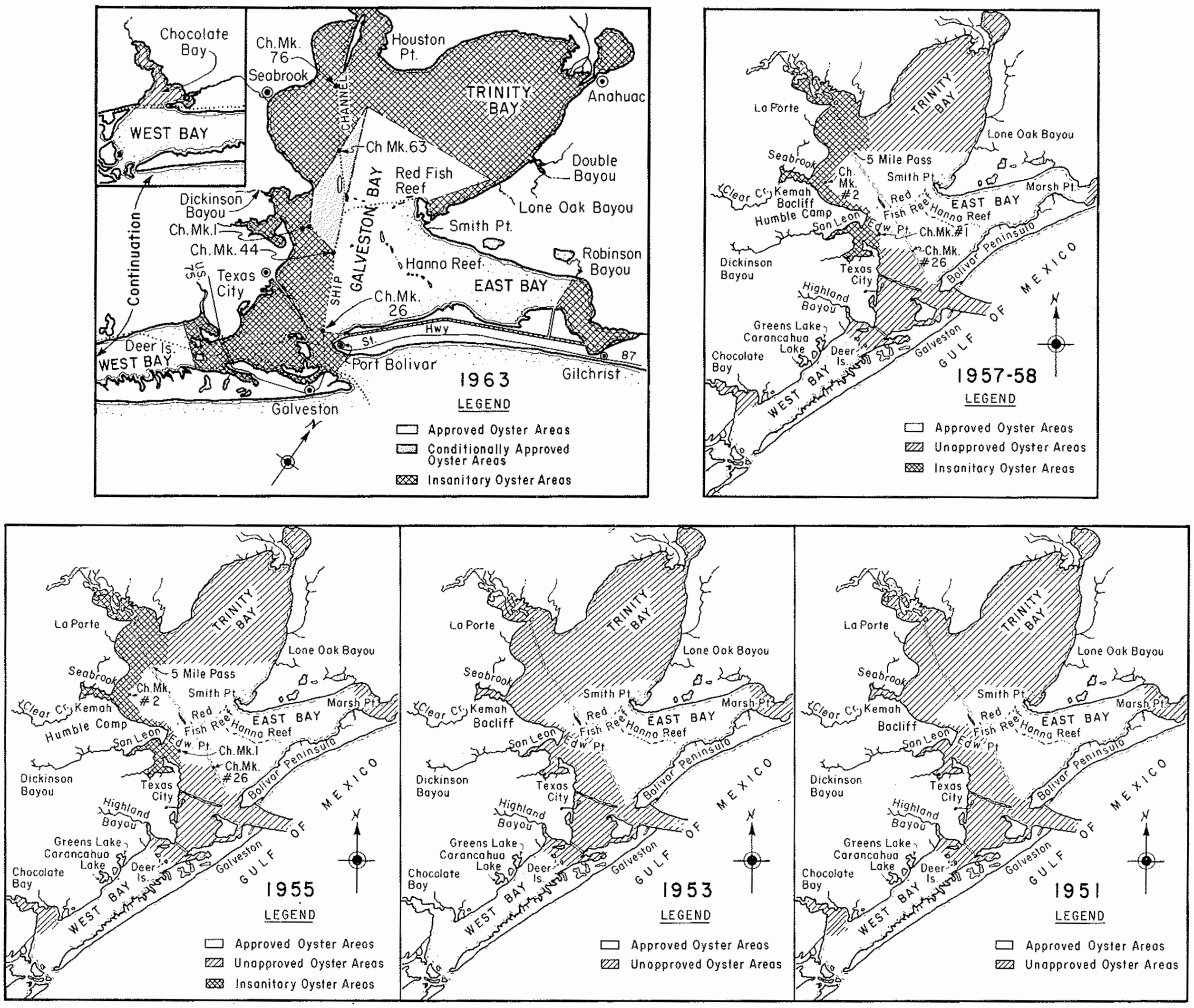


FIG. 9-1. GALVESTON BAY OYSTER AREAS - TEXAS STATE DEPARTMENT OF HEALTH

along the east side of the Houston Ship Channel marker No. 26, and thence, east to a marker No. 12 on the Intracoastal Waterway). Conditionally approved oyster harvesting areas are subject to the runoff and discharge of major tributaries. During the periods of high runoff, the area may be polluted. However, during periods of low runoff the water quality may be satisfactory for harvesting of oysters.

Fishing effort for oysters in the Galveston Bay is particularly heavy on Hanna's Reef in East Bay and on Todd's Dump in middle Galveston Bay. Other reefs were fished infrequently, chiefly because the oysters were thickly clustered or heavily fouled by mussels.

It is to be noted that all areas are open to the public, and the reefs are not privately leased from the State.

The harvesting of oysters in Galveston Bay prior to 1951 had all but disappeared, and the area had been closed for the removal of oysters on a commercial scale. A continuous sampling program by the Texas State Department of Health has been in effect since February 1950, and as a result of abatement, certain sections of Galveston Bay have been opened, beginning with the commercial harvesting of oysters in the 1951 season. Additional areas were opened in the 1952 season and a larger area in 1955. The areas were re-evaluated in 1958 and 1963, with a resulting larger area for permissible oyster harvesting. Exact location of sampling points and analytical data can be found in the files of the Texas State Department of Health.

Crabs

Blue crabs have become increasingly important to fishermen in the Galveston Bay areas during recent years, and more attention is being given to them. They are particularly important in the upper Galveston and Trinity Bay areas. The collection of crabs from the Galveston Bay area is shown in Table 3-21. Although the reason is not clear, the weight of crabs per individual has been decreasing since the peak in 1961-1962.

Shrimp

Production of shrimp in Galveston Bay is shown in Table 9-2. These data indicate an increase in the total shrimp catch during the period from 1956 to 1962.

The white shrimp, *Penaeus setiferus*, and the brown shrimp, *Penaeus aztecus*, have been investigated extensively. As shown in Tables 9-3 and 9-4 for the period 1959-60, migrations of these two types are somewhat different. The first record of juvenile white shrimp in tertiary waters was made in the latter part of April. As the shrimp reached 50 to 60 millimeters in size, they began to migrate to the secondary area, where they reached about 70 milli-

Table 9-2. Shrimp Taken From Galveston Bay[4]
(Heads-on basis, pounds)

Biological Year	Brown	White	Total
1956	6,604	170,765	177,369
1957	1,016	743,032	744,048
1958	0	988,920	988,920
1959	24,291	1,002,034	1,026,325
1960	9,003	1,571,801	1,580,804
1961	86,145	1,207,890	1,294,035
1962	906,268	3,643,100	4,549,368
1963			

Table 9-3. Length-frequency Data (*Penaeus setiferus* 1959-1960)[5]

(Total number measured: 8,786) (Total number caught: 16,744)

Size mm	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
5-10												
11-15												
16-20								2		3	13	1
21-25	2					7		10	15	30	50	25
26-30								1	48	63	37	77
31-35	2						1	3	78	94	27	54
36-40	3	4				1	1	2	116	93	35	44
41-45	10	17	1					2	135	88	55	61
46-50	15	10	3						90	105	88	65
51-55	15	7	3			2			115	123	92	69
56-60	10	7	2						171	120	109	56
61-65	5								203	119	104	80
66-70	14	8	3						190	93	111	82
71-75	20	15				1			141	104	82	80
76-80	34	18	1		1				154	86	89	102
81-85	50	21	2						146	94	76	114
86-90	57	34	4		1				141	97	84	153
91-95	81	33	3						101	74	82	132
96-100	59	22	2	2		1			94	82	84	179
101-105	63	32	3	4					73	82	86	114
106-110	50	28		1			1		55	80	74	107
111-115	39	25	1		1	1			66	61	71	107
116-120	34	25	1						64	66	58	78
121-125	18	6		1		2	2		34	71	42	70
126-130	7	3				1	2		20	45	22	49
131-135	3					1	2		3	24	18	24
136-140	1	1				1	2			21	14	19
141-145						1	2			9	10	1
146-150	1						6				13	1
151-155	1						3			1	5	2
156-160							3			1	3	
161-165							1			1	3	
166-170							1				2	
171-175												
176-180											2	
Tot/Mo.	594	316	29	8	3	19	27	20	2,253	1,930	1,641	1,946
No/Col.	19	9	1	0.3	0.07	0.6	0.8	0.5	73	57	43	55

Table 9-4. Length-frequency Data (<u>Penaeus aztecus</u> 1959-1960)[6]

(Total number measured: 5,286) (Total number caught: 6,443)

Size mm	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
5-10												
11-15												
16-20						3	2			1	1	
21-25	2					7	53	1	2	6	16	1
26-30						18	166		2	12	20	17
31-35	1					33	154	6	7	27	50	21
36-40	1					39	166	7	4	36	29	23
41-45	2	1				24	200	23	1	39	10	11
46-50	4					11	215	57	3	27	14	8
51-55	4	1				2	206	78	3	51	9	13
56-60	36						205	118	4	38	7	9
61-65	25	4					230	180	4	43	4	12
66-70	18	4					214	200	22	41	6	21
71-75	11	1					176	234	24	24	5	21
76-80	12		1				170	293	47	20	9	30
81-85	6						134	292	47	20	9	30
86-90	5						184	287	110	5	7	13
91-95	4						28	149	101	6	3	11
96-100							8	115	69	4		3
101-105							3	61	21	2		
106-110								21	6	1		1
111-115								12	4	2		
116-120								5	4			
121-125	1							4				
126-130									1			
Tot/Mo.	132	11	1	0	0	137	2,514	2,143	516	391	195	246
No/Col.	4.2	0.3	0.03	0	0	4.1	79	52	16.6	11.5	5.1	7

meters and then moved to the primary area. When they had reached the length of about 100 millimeters they began their migration to the Gulf. The larger shrimp seemed to be stragglers in the area. There were white shrimp in the bay all year, and young shrimp appeared all through the shrimp season. The brown shrimp precede the white shrimp in entering and leaving the Texas bays. The juvenile brown shrimp appeared in tertiary waters about the first of April. They remained there until they reached 70 to 80 millimeters. Then they moved into the primary area and remained there until they reached 80 to 90 millimeters at which size they moved out of the upper Galveston Bay area. The brown shrimp for the period 1959-1960 was caught 10 out of the 12 months of the year, and the young shrimp seemed to be present all through the shrimp season.

A most detailed report on the movement of shrimp in the Clear Lake area has been made.(7) Size correlations between the white and the brown shrimp have been made; relative abundance of various shrimp with changes in temperature and salinity have been shown; monthly changes in size composition of shrimp have been demonstrated; monthly changes in relative abundance have been plotted; monthly changes in sex ratio have been noted; and numbers of uncommon species correlated to temperature and salinity have been reported.

Bay as a Nursery Grounds

Much of the commercial fisheries product that makes up the vast export of sea food from Texas is caught outside the beach line. However, the bays are essential nursery grounds for principal parts of the life history of the shrimp, menhaden, and other products. Pollution or other unnatural modifications of the bay environment modify the population of harvest-size marine products. The dollar value of the commercial harvest has reportedly been prorated on the basis of necessary bay acreage and is valued at $20 per acre.

Texas shrimping fleets are now ranging as far as Yucatan and Campeche Bay off the coast of Mexico. It has been suggested that a reason for these shrimping habits is the paucity of shrimp off the Texas coast, at least during certain seasons. It has been speculated, presently without scientific data, that pollution and droughts have lowered the efficiency of the Texas Bays (Galveston is the major one) as a nursery grounds.

The majority of the vertebrate collections for the period 1959-1960 were generally made up of croakers, spot, menhaden, anchovies, and sand trout. On the basis of the data collected during this period for the Upper Galveston Bay area, it is apparent that this section of the Bay is more important as a nursery area for juvenile fish than as a habitat for the larger game fish.

The value of a bay as a nursery grounds may be reflected in its species diversity, and the species diversity for the Galveston

Bay complex has been reported.[8] It was shown that the species diversity increased from four species per thousand individuals in the Houston Ship Channel at the San Jacinto monument, 6 in the mouth of the Channel south of Baytown, 8 to 11 in upper Galveston Bay, 23 in Lower Galveston Bay, to more than 25 in the Gulf of Mexico. This lowered species diversity in the Houston Ship Channel and Upper Galveston Bay indicated that a lesser number of animals utilize the area as nursery grounds.

CHAPTER 10

ECOLOGICAL STUDIES (HISTORICAL)

Reportedly, many of the bayous of Galveston Bay are vital as nursery areas for both sports and commercial species of marine life, i.e., trout, redfish, sheepshead, flounder, commercial shrimp, and blue crabs. The food for the higher marine forms is supplied by intricate food webs based on the abundant growth of marine algae. Shorelines are very shallow, the bottoms are mainly sand and firm clays, and the turbidities are generally low.

The following summaries describe some of the concepts and investigations:

- Concepts
- Concurrent Regulatory Investigations
- Diatom Population
- Nutrient
- Photosynthesis and Respiration
- Marine Flora
- Marine Fauna

Concepts

A satisfactory understanding of the aquatic life of the Galveston Bay and its environs requires a knowledge not only of the organisms themselves but also of those external influences which directly or indirectly affect the natural flora and fauna. In this sense, a study of the interactions between organisms and their environments is commonly known as ecology. Therefore, a review of the effects of wastes on the assimilative capacity of Galveston Bay would be incomplete without including the ecological system.

The use of various portions of the Bay by marine organisms for reproduction, growth, and survival is important in considering the over-all system. The natural environment can be degraded or changed by the depletion of existing organisms, the increase in predator population, the addition of toxic pollutants, the erection of physical barriers, the modification of normal transport and exchange mechanisms, the increase in turbidity, and the increase in temperature.

A number of physical and chemical conditions, in a variety of combinations and intensities, make up the fundamental environmental structure upon which the occurrence, distribution, and success of aquatic organisms depend. Inorganic conditions exert an influence upon the organisms; the organisms exert an influence upon each other; and thereby to a great extent, the conditions are mutually dependent. Many factors are always operating in the presence of others, and it must be understood that any consideration of the influence of a single condition or factor on all organisms is merely a necessary method of approach.

Concurrent Regulatory Investigations

Both the Texas Parks and Wildlife Department and the U. S. Bureau of Commercial Fisheries are continuing ecological studies of the Galveston Bay area. The Texas Parks and Wildlife Department is currently conducting a creel census. This Department tabulates catches of shrimp and other invertebrates, including commercial harvests. Fish kills are reported to the Texas Water Pollution Control Board. Also, ecological studies are conducted to obtain various data on marine flora and fauna. The correlation of these findings with other parameters such as BOD, COD, phosphorus, or respiration may be very useful at a later date.

Diatom Populations

In at least one study a drastic change in the shape of the diatom population in polluted environments was shown to exist. A close correlation was observed between the diatom population and the change in species diversity of the flora and fauna.[1]

The stations that were selected in the above-mentioned report are as follows:

Station 1 — In the vicinity of Red Flasher Beacon 70, 2-1/2 miles up the Houston Ship Channel from the San Jacinto Monument.

Station 2 — Galveston Bay in the vicinity of Red Beacon 66, at the southern tip of Atkinson Island, and approximately 1-1/2 miles southeast of Morgan's Point.

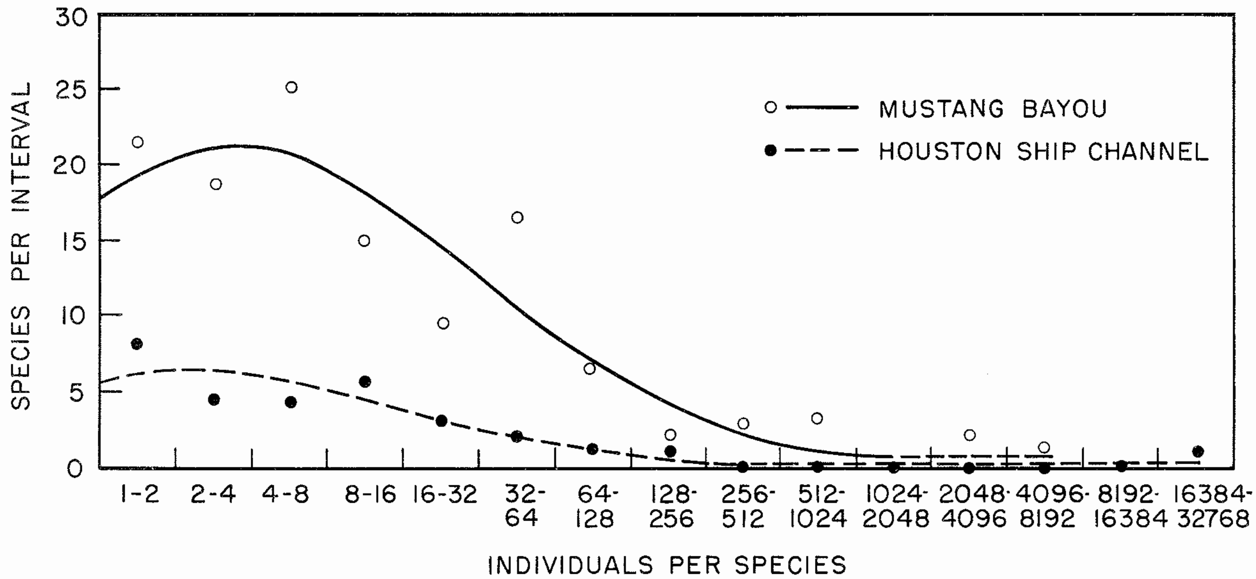


FIG. 10-1. TRUNCATED LOG NORMAL CURVES FOR THE DIATOM POPULATIONS OF MUSTANG BAYOU AND HOUSTON SHIP CHANNEL.[4]

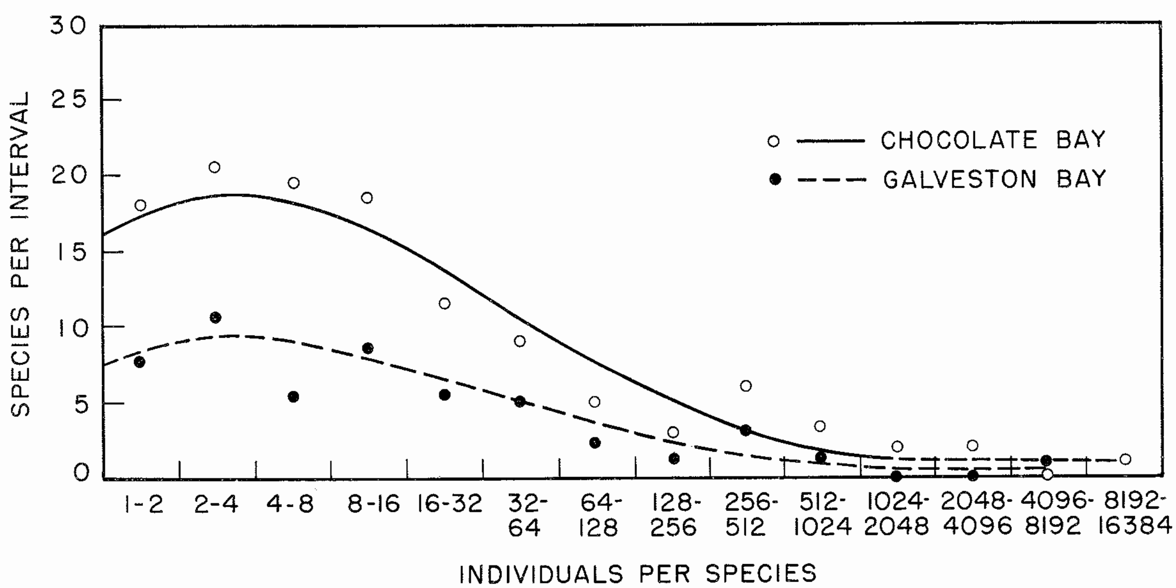


FIG. 10-2. TRUNCATED LOG NORMAL CURVES FOR THE DIATOM POPULATIONS OF CHOCOLATE BAY AND UPPER GALVESTON BAY.[5]

Station 3 In Mustang Bayou approximately 200 yards from its mouth where it enters Chocolate Bay.

Station 4 Several small islands in the vicinity of Red Nun Buoy 22 in Chocolate Bay, approximately 1-1/2 miles west of Horse Grove Point.

Table 10-1 shows a striking difference between the two stations in the Chocolate Bay area and those in the upper portion of Galveston Bay.

The Chocolate Bay and Mustang Bayou areas are classified as "healthy" and may be referred to as natural brackish water areas. Chocolate Bay represents an open bay environment while Mustang Bayou represents a protected estuary, river-type environment. The total species diversity was high and quite similar (163 and 165 species, respectively), and these findings were reported to be in agreement with results obtained in the surveys of natural streams with water of good quality.[3]

As shown in Table 10-1, the flora and fauna at Station 1 on the Houston Ship Channel were very restricted in their species diversity. There was a notable absence of fish and invertebrates, as well as a sparse diversity of other groups. The diatom flora from Station 1 indicated a drastic shift in population balance, for one species made up 97 per cent of the total specimens observed.

Figures 10-1 and 10-2 show that the upper Galveston Bay exhibited a greater diversity than that found in the Houston Ship Channel;

Table 10-1. Species Numbers of the Flora and Fauna Taken on Biological Survey (July 27-30, 1954)[2]

Biota	Stations 1	2	3	4
Blue-green algae	4	2	5	7
Green and red algae	2	3	3	4
Diatoms	10	22	62	51
Fish	0	15	26	26
Protozoa	8	29	48	68
Invertebrates				
Foragers	0	8	9	5
Burrowers	0	2	6	0
Sessile Forms	0	2	4	4
Totals	24	83	163	165

Table 10-2. Total Phosphorus for Abnormal Marine Systems[6] (Lower Galveston Bay--July 15-19, 1961) (Upper Galveston Bay--April 18-19, 1961)

Location	Station	Total Phosphorus (ppb)	
Upper Galveston Bay	1	215	
	2	8,	
	3	178,	315
	4	4,	19
	5	112	
Lower Galveston Bay	1	494,	500
	2	1116,	1302
	5	2000+	
	6	1222,	1295
	7	830,	890
	8	568,	569
	9	431,	488
	10	487,	497
	11	385,	346
	12	298	345

however, it was considerably lower than that found in the comparably healthy area of Chocolate Bay. The diatom survey indicated that the Upper Galveston Bay must have been polluted.

Nutrient

Phosphorus is a sensitive indicator of abnormal imbalances of respiration over photosynthesis. There is little question that total phosphorus can be used as a waste tracer in shallow marine bays. Therefore, nutrient releases, including the important phosphorus load from multiple pollution sources, is important. This factor is particularly important in the phosphorus-rich domestic wastes.

Table 10-2 shows that the phosphorus levels were indeed high below the Baytown Tunnel on July 16, 1961, with 1,222 and 1,295 ppb (parts per billion). The effect of the industrial waste load at the Baytown Refinery on August 22, 1962, is also apparent because the Ohle anomalies were reducing (Table 10-3) from a minus 0.6 to a minus 1.22 mg/l.

The effect of dilution on the phosphorus, however, is very apparent. When the San Jacinto River was discharging considerable quantities of water, the phosphorus content was 0 to 13 ppb, and the content in the Channel and Bays leading to Galveston Bay ranged from 2 to 43 ppb.

As shown in Table 10-2, phosphorus values decreased from the Upper Bay to the Lower Bay. However, measurements taken near the Galveston jetties and in the Gulf of Mexico indicated a fairly high phosphorus content. Measurements made on October 14, 1961, showed that phosphorus concentrations at the Galveston jetties were 182 and 172 ppb. On November 17-19, 1961, a series of measurements showed that the total phosphorus in Galveston Harbor was 112, 107, 93, and 75 ppb. Similarly, the concentration at the mouth of the Galveston jetties was 32, 36, 30, and 54 ppb. Concentration diminished 50 miles offshore to 14 and 17 ppb. All of this indicates that the waters of Galveston Bay at the time of measurement, at least, were rich in phosphorus. The Ohle anomalies for Galveston Bay on August 22, 1961, were reducing as shown in Table 10-3. It is reported that not only were the waters in Galveston Bay rich in phosphorus, but they were also restricted in species diversity and patchy in metabolism and Ohle anomaly, with some of the highest and lowest rates of respiration observed in Texas bays during the summer.

<u>Photosynthesis and Respiration</u>

Through the use of the diurnal oxygen method, a number of studies have been made to depict the characteristics of metabolism of the planktonic and grassy bays along the Texas coastline. In

Table 10-3. Ohle Anomaly Data for Galveston Bay(7)

Location		Winkler	Ohle plus Winkler	Ohle	Corrected Winkler[a]	Anomaly[b]
Houston Ship Channel						
August 22, 1962						
Baytown Refinery						
1000	Surface	3.52		2.16		
		3.52	6.98	2.04		
		3.52	2.10		4.58	-1.06
1910	Surface	3.36	7.10	2.98		
		3.48	7.58	2.67		
		3.42	7.32	2.82	4.50	-1.08
	3.3M	3.43	6.60	2.74		
		2.30	5.70	2.57		
		2.86	6.15	2.65	3.50	-0.64
	6.1M	0.48	4.56	2.78		
		1.34	5.23	2.74		
		0.91	4.89	2.76	2.13	-1.22
Galveston Bay						
August 22, 1962						
Station 1	0755	6.06	9.12	3.49		
		5.30	8.92	3.55		
		5.63	9.02	3.52	5.50	0.10
	1710	8.55	12.67	(3.5)		
		8.64	12.67			
		8.59	12.67	----	9.17	-0.58
Station 2	0820	5.59	9.60	3.56		
		5.78	9.90	3.79		
		5.69	9.65	3.67	5.98	-0.29
	1730	8.05	12.50	3.31		
		7.98	12.85	3.17		
		8.01	12.27	3.24	9.03	-1.02
Station 3	0840	5.59	9.70	3.60		
		5.53	9.70	3.71		
		5.56	9.65	3.65	6.00	-0.44
	1750	7.06	11.52	3.36		
		6.72	10.56	----		
		6.89	10.55	3.36	7.19	-0.30
Station 4	1810	7.74	11.25	3.46		
		7.79	11.60	3.07		
		7.76	11.42	3.52	7.90	-0.14
Station 5	0925	10.55	10.71	2.82		
		7.10	10.93	3.23		
		8.82	10.82	3.02	7.80	1.02
	1835	7.60	11.39	3.25		
		7.82	11.38	3.15		
		7.71	11.38	3.20	8.18	-0.47
Station 7	1030	4.66	8.60	2.91		
		4.84	8.45	2.95		
		4.75	8.52	2.93	5.59	-0.84
	2010	4.85	8.65	2.91		
		4.85	9.00	2.91		
		4.85	8.82	2.91	5.91	-1.06

[a]Difference between (Ohle plus Winkler) and (Ohle).
[b]Difference between Winkler and Corrected Winkler.

general, photosynthesis and respiration were similar and often in phase, although the annual metabolism in single bays along the Texas coast ranges from 0.5 grams per meter^2 per day, minimum, in winter to 40 grams per meter^2 per day, maximum, in summer.[(8)] Respiration generally exceeds photosynthesis during dredging operations, and respiration is also increased when strong winds stir the bottom of the bays. It was reported that maximum total photosynthesis can be obtained by reducing turbidity, eliminating irregular flushing of flood waters, developing grass bottoms, retaining wind-driven circulation, and adjusting water depths of shallow and deep areas toward an average depth of 0.5 meter.[(9)]

Photosynthesis and respiration at three stations in the Houston Ship Channel, at five stations in Upper Galveston Bay, and at ten stations in Lower Galveston Bay, respectively, are shown in Figs. 4-14, 4-28, and 4-47. Respiration exceeded photosynthesis at all stations in the Houston Ship Channel, with photosynthesis being low (Fig. 4-14).

Respiration was high in Upper Galveston Bay, ranging from 13 to 87 grams of oxygen per meter^2 per day (Fig. 4-28). Photosynthesis ranged from 8 to 58 grams of oxygen per meter^2 per day, considerably less than respiration. The inflow of organic wastes from the shores of the Bay and the Houston Ship Channel undoubtedly contributed to the high respiration values. The only way a biological system can burn more energy through respiration than it can make through its own photosynthesis is to have an inflow of labile organic material.

In lower Galveston Bay, respiration and photosynthesis were more nearly balanced. At some stations photosynthesis slightly exceeded respiration, while the opposite occurred at other stations. Also, these two parameters were generally lower than the values observed in Upper Galveston Bay and higher than those observed in the Houston Ship Channel. The only exception to the above generalization occurred at Texas City, where biological activity was very small. As shown in Fig. 4-47, a diurnal pulse of oxygen concentration was almost non-existent at Texas City. This oxygen pattern was in contrast with the usually large diurnal change in oxygen concentration observed at other stations.

Marine Flora

A check list of marsh marine flora in the Upper Galveston Bay including Trinity Bay has been undertaken by the Texas Parks and Wildlife Department.[10]

Marine Flora

Kingdom Plantae

Subkingdom Thallophyta

Phylum Canophyta

Lyngbya sp. A blue-green algae that was commonly found in the summer months attached to mud and shell in the marsh areas. This algae was observed in a water temperature of 27 to 33°C and salinity of 9 to 10 o/oo.

Enteromorphia sp. This green algae was observed during the spring, summer, and fall in Area M-2. It was collected in a water temperature of 9 to 33°C and a salinity of 2 to 15 o/oo. Its normal habitat was on sand and mud from the shore to a depth of approximately two feet in the bay.

Ulva lactuca. Another of the green algae that was common during the latter part of the winter through the early spring of the year. This plant was collected in a water temperature of 10 to 27°C and a salinity of 10 to 15 o/oo. Ulva was collected on clay, mud, and shell bottoms from the shore to a depth of approximately two feet in the bay.

Phylum Rhodophyta

Polysiphonia sp. A red algae that was commonly found attached to stalks of Spartina or to pilings and piers. The algae was common during the summer months in a water temperature of 27 to 34°C and a salinity of 10 to 19 o/oo.

Subkingdom Spermatophyta

Division Angiosperma

Ruppia maritima. This is the only submerged aquatic spermatophyte found in Area M-2. Beds of this marine grass were found in only three areas of the Bay this year. The areas of plant growth are shown in Fig. 1. Ruppia was observed from spring to fall growing on a sandy substratum from about one foot to a three-foot depth in a water temperature of 13 to 33°C and a salinity of two to 19 o/oo.

Marsh Flora

Monanthochloe littoralis. A perennial salt grass commonly found on the muddy-sandy beach in the salt marsh habitat.

Spartina alterniflora. This cord grass, a perennial plant, is commonly found growing in the salt marsh. Plants that grow in the shallow bay offer a protective nursery area for juvenile fish and shrimp.

Spartina patens. Another perennial cord grass of the marsh habitats. This plant is not as abundantly distributed as Spartina alterniflora.

Distichlis spicata. A common perennial salt marsh plant of Area M-2.

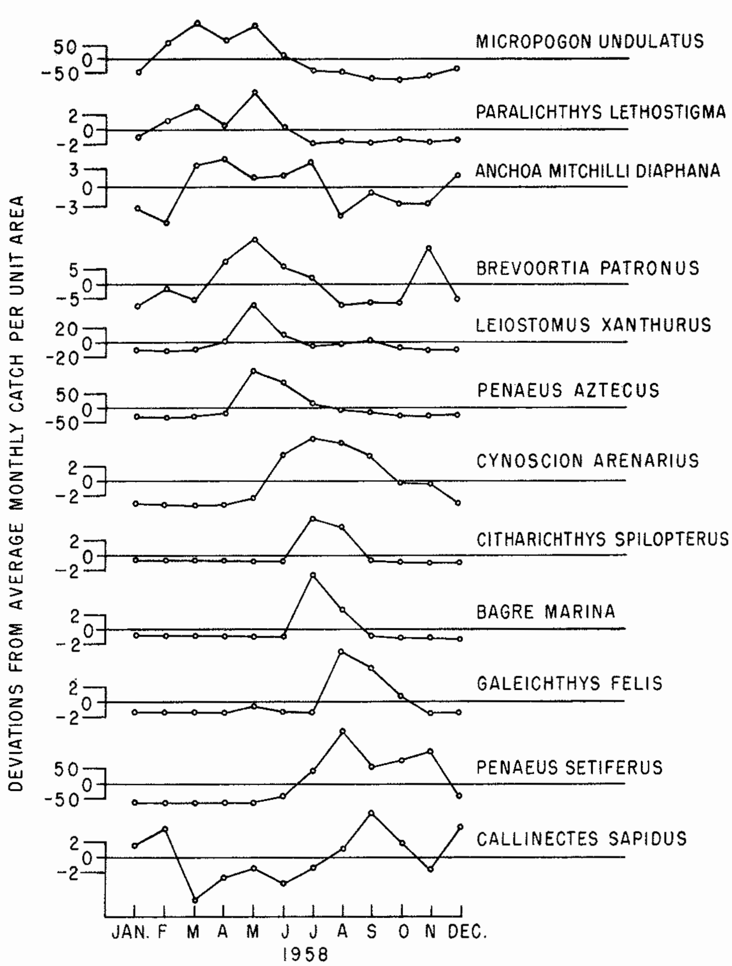


FIG. 10-3. PATTERN OF SEASONAL SUCCESSION MANIFESTED BY MAJOR AND MINOR SPECIES.[13]

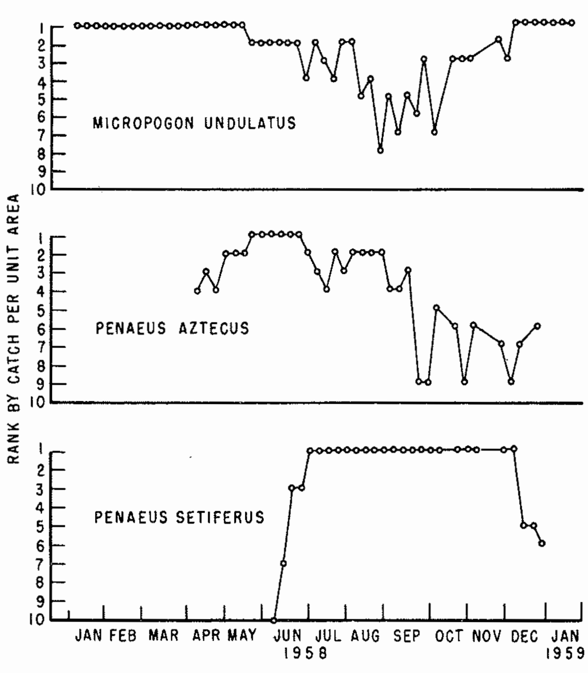


FIG. 10-4. WEEKLY CHANGES IN RANK (BY CATCH PER UNIT AREA) OF THE THREE DOMINANT SPECIES.[14]

Scirpus robustus. The rush plant is a perennial that is commonly found in the salt marsh habitats of Area M-2.

Marine Fauna

Table 10-4 shows some of the data collected by the Texas Parks and Wildlife Department. It is of interest to note the numbers of invertebrates found in the Upper Galveston Bay Area (Area M-2). There is a considerable variation in both numbers and species throughout the year. A correlation of abundance with other parameters such as BOD or respiration would be very useful.

A grouping of species according to the number taken in Clear Lake in 1958 is very revealing. As shown in Table 10-5, the major species are fairly well grouped. It was reported that there was a larger list of species in the Clear Lake area than in Upper Galveston Bay.

Figure 10-3 shows a pattern of seasonal variations by major and minor species. Figure 10-4 shows the weekly changes in rank of the three dominant species found in the Clear Lake area. These results are fairly significant since the data help establish base-line trends.

Table 10-4. Check-List of Invertebrates Found in Upper Galveston Bay and Trinity Bay (1959-1960)[11]

Biota	Month N	D	J	F	M	A	M	J	J	A	S	O	°/oo Sal. Range	C° Temp. Range
Phylum Protozoa														
Class Mastigophora														
Order Cryptomonadidae														
Unidentified sp.	C[a]												12-13.0	13-18.0
Order Dinoflagellida														
Exuviella sp.	A												12-13.0	13-18.0
Gymnodinium splendens (Lebour)	C										A		11.5-13.0	10-31.0
Order Euglenoidida														
Eutreptia sp.			A										7-9.0	6-18.0
Phylum Coelenterata														
Class Hydrozoa														
Bougainvillia spp.										C	C	C	2-9.0	25-31.0
Hydractinia echinata Fleming												S	23.08	26.2
Unidentified Hydromedusa							A	A	A				14-24.0	23-26.0
Class Scyphozoa														
Chiropsalmus quadrumanus L. Agassiz											S		11-25.0	29-30.0
Dactylometra quinquecirrha L. Agassiz											S		16.24	29.6
Stomolophus meleagris L. Agassiz		C		C				S		S			13-31.0	13-31.0
Phylum Ctenophora														
Class Tentaculara														
Mnemiopsis mccradyi Mayer	A	C	C	C	C	C	A	A	C	C	C	C	4-14.0	10-31.0
Class Nuda														
Peroë ovata Chamisso & Eysenhardt	C	C		C	C					S	S		5-11.0	10-31

[a] A = Abundant; C = Common; S = Scarce

Table 10-4 (Continued)

Biota	N	D	J	F	M	A	M	J	J	A	S	O	°/oo Sal. Range	C° Temp. Range
Phylum Platyhelminthes														
Class Cestoda														
Poecilancistrium robustum Chandler						(Found in Drum during the winter)								
Phylum Annelida														
Class Polychaeta														
Unidentified						(Associated with oysters)								
Phylum Mollusca														
Class Pelecypoda														
Order Filibranchia														
Brachidontes recurvus Rafinesque	C	C	C	C	C	C	C	C	C	C	C	C	5-19.0	6-35.0
Crassostrea virginica Gmelin	C	C	C	C	C	C	C	C	C	C	C	C	6-30.0	6.5-30.0
Macoma mitchelli Dall	S	S	S	S	S			S	S				8-14.0	11-25.0
Modiolus demissus granossimus Gray	C	C		C		(Found in mud at roots of Spartina in marsh)								
Mulinia lateralis Gray	S												9.0	14.0
Rangia cuneata Gray	C	C	C	C	C	C	C	C	C	C	C	C	2.9-16.74	6.5-35.0
Rangia flexuosa Conrad	S	S	S	S	S	S	S	S	S	S	S	S	2.90-16.74	6.4-35.0
Class Gastropoda														
Order Aspidobranchia														
Neritina reclivata Say					S	(Found in marsh area)								
Order Mesogastropoda														
Littoridina sphinctostoma Abbott and Ladd	C	C											2.90-13.00	10.0-14.0
Polinices duplicatus Say	S		S	S	S	S	S		S	S			3.5-25.0	7-31.0
Order Neogastropoda														
Thais haemastoma Conrad	S					S			S		S		17.0-30.0	14.0-30.0
Class Cephalopoda														
Lolliguncula brevis Blainville	S	S	S		S	S			S		C	C	13-29.0	13.8-32.0

Table 10-4 (Continued)

Biota	N	D	J	F	M	A	M	J	J	A	S	O	^{o}/oo Sal. Range	C^{o} Temp. Range
Phylum Arthropoda														
Class Eucrustacea														
Subclass Copepoda														
Order Californida														
Lernaeenicus radiatus Leseur						S							11.0-16.0	16.0-22.0
Subclass Cirripedia														
Order Thoracica														
Balanus eburneus Gould	C	C	C	C	C	C	C	C	C	C	C	C	2.9-16.74	6.50-35.0
Balanus improvisus Darwin	C	C	C	C	C	C	C	C	C	C	C	C	2.9-16.74	6.50-35.0
Chelonibia patula Ranzani (Epizotic on crabs)												S	10.0	21.0
Loxothylacus panopaei Boschma									S				8.30	31.0
Subclass Malacostraca														
Order Isopoda														
Anilocra acuta (Parasite on gar)								S					15.94	27.6
Ligyda exotica Roux (Isopod found around piers and bulkheads)														
Olencira praegustator (Latrobe) (Parasite to Menhaden)										S			12.82	30.4
Subphylum Mandibulata														
Class Crustacea														
Subclass Malacostracea														
Division Eucarida														
Order Decapoda														
Suborder Natantia														
Tribe Penaeidea														
Unidentified Sergestid										A	A	A	10-18.0	23-32.0
Penaeus aztecus Ives	S	S	S			C	A	A	S	S	S	S	0.20-21.24	6.5-35.0
Penaeus setiferus Linnaeus	A	C	S	S	S	S	S	S	A	A	A	A	0.20-21.24	6.5-35.0
Sicyonia dorsalis Kingsley												S	17.30	24.0

Table 10-4 (Continued)

Biota	N	D	J	F	M	A	M	J	J	A	S	O	°/oo Sal. Range	C° Temp. Range
Tribe Penaeidea (Continued)														
Trachypeneus constrictus (Stimpson)												S	21.0	23.0
Trachypeneus similus Smith						S						S	21-24.0	23-26.0
Xiphopeneus krøyeri Heller									S	S	C	C	6-32.0	29-31.0
Tribe Caridea														
Crangon heterochelis Say		S	S		S		S					S	9-25.0	8-23.0
Hippolysmata wurdemanni (Gibbes)												S	11.50	31.0
Macobrachium ohione Smith	C		C	C	C	C	C	C	C				0.3-14.0	7-30.0
Palaeomanetes spp.											S	S	10-17.0	25-30.0
Palaeomanetes pugio Holthuis	C	C	C	C	C	C	C	C	C	C	C	C	0-30.0	5-35.0
Tribe Anomura														
Callianassa jamaicensis louisianensis Schmitt										C	C		13.0	28.8
Clibinarius vittatus Bosc	C							C		C	C	C	10-24.0	12-29.0
Pagurus longicarpus Say												S	23.08	26.2
Tribe Brachyura														
Callinectes sapidus Rathbun	C	A	A	A	C	C	C	A	A	A	A	A	0.20-31.25	6.5-35.0
Menippe mercenaria Say								S	S				22.92-24.9	27.8-30.3
Eurypanopeus depressus Smith			S		S		S	S	S	S	S	S	5-29.0	8-30.0
Panopeus herbsti Milne-Edwards		C		C	C	C						C	19-25.0	10-25.0
Rhithropanopeus harrisi Gould			S			S	S	S	S	S			3-29.0	9-30.0
Uca pugnax rapax Smith				A			A	A	A (Field crab found abundantly burrowing in mud of salt marshes)					
Order Stomatopoda														
Family Squillidae														
Squilla empusa Say	C	C	C	C			C				S	A	12-28.0	12-26.0

Table 10-5. Grouping of Species According to Number Taken[12] (1958)

Species	1958	January 1959	Total
MAJOR SPECIES			
Micropogon undulatus	17,380	1,082	18,462
Penaeus setiferus	13,840		13,840
Penaeus aztecus	7,121		7,121
Brevoortia patronus	2,846	79	2,925
Anchoa mitchilli diaphana	2,726	352	3,078
Callinectes sapidus	2,134	411	2,545
Leiostomus xanthurus	1,600	64	1,664
MINOR SPECIES			
Cynoscion arenarius	674	1	675
Galeichthys felis	322		322
Paralichthys lethostigma	272	11	283
Bagre marina	266		266
Citharichthys spilopterus	150		150
UNCOMMON SPECIES			
Trinectes maculatus	120		120
Achirus lineatus	105	10	115
Prionotus tribulus	71	2	73
Mugil cephalus	39	6	45
Opsanus beta	35		35
Gobiosoma bosci	26		26
Symphurus plagiusa	25		25
Bairdiella chrysura	23		23
Lagodon rhomboides	21		21
RARE SPECIES			
Cynoscion nebulosus	11		11
Pogonias cromis	9		9
Chaetodipterus faber	8		8
Gobioides broussonneti	5		5
Menidia beryllina	4	74	78
Polydactylus octonemus	4		4
Spheroides nephelus	4		4
Scianops ocellata	3		3
Gobiesox strumosus	2		2
Lepisosteus oculatus	2		2
Lepisosteus spatula	2		2
Urophycia floridanus	2		2
Archosargus probatocephalus	1		1
Stellifer lanceolatus	1		1
Synodus foetens	1		1
Astrascopus y-graecum	1		1
Fundulus similis	1	1	2
Larimus fasciatus	1		1
Orthopristis chrysopterus	1		1
Syngnathus scovelli	1		1
Myrophis punctatus	1		1
Gobionellus shufeldti	1		1
Cyprinodon variegatus	0	18	18
Dorosoma petenense } Dorosoma cepedianum	24	0	24
TOTAL	49,886	2,111	51,997

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TABLE A-1

SAMPLING STATIONS USED DURING 1950-1951

GALVESTON COUNTY POLLUTION SURVEY

UPPER GALVESTON BAY

SAMPLE POINT NUMBER	DESCRIPTION
38	Pier at mouth of Clear Creek at Kemah.
39	Large unpainted house surrounded by trees at edge of Kemah, 100 yards offshore and 1,500 yards south of Clear Creek entrance.
40	At end of long pier, first road off Highway #146.
41	Front Bayview near longest pier.
42	At pier of Reef Cafe.
43	Humble tank dock.
44	Off pier at Smith's Camp and Edward's Point.
45	Halfway between Smith's Camp and Edward's Point.
319	Channel Markers #39 and #40 in Houston Ship Channel.
330	Off end of pier in back of the "Wagon Wheels" cottage about ½ mile north of Muecke's Place in Seabrook.
296	Todd's Dump.

KEMAH - SEABROOK AREA

38	Pier at mouth of Clear Creek at Kemah.
39	Large unpainted house surrounded by trees at edge of Kemah, 100 yards offshore and 1,500 yards south of Clear Creek entrance.
282	Mouth of bayou from Clear Lake Shores.
283	Railroad bridge between Kemah and Seabrook.
284	Front of Muecke's Place in Seabrook.
330	Off end of pier in back of the "Wagon Wheels" cottage about ½ mile north of Muecke's Place in Seabrook.

MIDDLE GALVESTON BAY

46	At Edward's Point.
47	Near Twin Piers, halfway between Edward's Point and April Foot Point, 8 houses close together.
48	At April Fool Point.
49	At Miller Point.
50	At Dollar Point.
51	At gate to Dollar Point.
52	At outfall-center of school ground, into Bay.
53	Texas City Dike, back of Shorty's Place.
54	North side of dike at sign, "No Cars Beyond This Sign."
55	At old pier on north side of dike.
56	At end of usable road on dike.
129	North side of dike opposite fourth F. G. Marker from end of dike.
130	North side of dike opposite second F. G. Marker from end of dike.
101	¼ way between Edward's Point and Houston Ship Channel Buoys #35 and #36, Red Fish Bar.
102	½ way between Edward's Point and Houston Ship Channel Buoys #35 and #36.
103	3/4 way between Edward's Point and Houston Ship Channel Buoys #35 and #36.
104	Between Buoys #35 and #36 in the Houston Ship Channel.
105	1,200 yards east of Marker Buoys #35 and #36 in Houston Ship Channel.
106	Red Fish Bar, 2,400 yards east of Houston Ship Channel Buoys #35 and #36.
107	Red Fish Bar, 3,600 yards east of Houston Ship Channel Buoys #35 and #36.
108	Red Fish Bar, 4,800 yards east of Houston Ship Channel Buoys #35 and #36.
109	Red Fish Bar, 6,000 yards east of Houston Ship Channel Buoys #35 and #36.
110	Red Fish Bar 7,200 yards east of Houston Ship Channel Buoys #35 and #36, at Marker #12.

111	1/2 way between Markers #12 and #24 on Red Fish Bar.
112	Red Fish Bar Marker #24.
113	South of small island off Smith's Point.
114	Off Smith's Point.
128	2/3 way between Smith's Point and Hanna Reef going southeast.
127	At Ladies' Pass in Hanna Reef.
126	At tripod in Moody's Pass in Hanna Reef.
125	At pilings near Pepper Cove.
167	At mouth of Seiver's Cut.
200	At Baffle Point.
199	At Marker #12 in mouth of Intracoastal Canal from Galveston Bay.
198	1st black marker buoy in Houston Ship Channel from end of dike.
193	Channel Marker #14 in Houston Ship Channel.
197	Channel Markers #17 and #18 in Houston Ship Channel.
196	Channel Markers #21 and #22 in Houston Ship Channel.
195	Channel Markers #25 and #26 in Houston Ship Channel.
194	Channel Markers #29 and #30 in Houston Ship Channel.
190	Halfmoon Shoal.

LOWER GALVESTON BAY

116	In Texas City Channel opposite 2nd F. G. Marker from end of dike.
115	In Texas City Channel opposite 4th F. G. Marker from end of dike.
131	East of northeast corner of Snake Island.
132	Mouth of Carbide Drainage Ditch south of Snake Island.
133	1, 500 yards north of Campbell Bayou entrance.
136	Entrance to Campbell Bayou.
137	At 2nd F. R. Marker east of Virginia Point.
37	By cable crossing signs, 100 yards northeast of old Causeways.
138	In channel opposite 2nd F. G. light east of Causeways.
139	1st marker buoys west of Pelican Island.
192	At #4 Reef west of the center of Pelican Island.
191	At #8 Reef west of the north end of Pelican Island.
135	Mouth of Tin Smelter ditch into Swan Lake.
134	Mouth of large cut in north end of Swan Lake.
292	Between Causeways (NW).
327	Oyster beds in cove on west side of Pelican Island.
328	Oyster bed off point in cove west side of Pelican Island.
329	Oyster beds off point of Pelican Island.
331	East of Causeways. Even with second water tower.
332	Out from beached steel barge.
333	By first point east of Causeways.
321	Oyster reef due east of Campbell Bayou.
322	1/2 way between Campbell Bayou and Causeway.

EAST BAY

158	Slip at U. S. Engineers, Highway 124 & R. R. trestle in the Intracoastal Canal.
159	Mouth of Elm Bayou into Canal.
160	Mouth of Hills Bayou into Canal, sign on N. side Canal says, "Ferry 1/2 mile."
161	At end of East Bay Bayou.
251	At Channel Marker #7 where Canal crosses the tip of East Bay.
162	Where Canal enters into east side of Rollover Bay at Gilchrist.
163	Channel Marker #14 in Rollover Bay.
164	Marsh Point entrance to Straight Bayou.
165	Mouth of Pasture Bayou.
166	At Elm Grove Point.

WEST BAY

146	Entrance to Jones Lake, 1000 yards west of Causeway.
148	Mouth of Brasford Bayou into Jones Lake.
149	Entrance to Green's Lake from Intracoastal Canal.
150	At sharp bend in bayou from Carancahua Lake to Intracoastal Canal.
172	Alligator Point.
173	Mouth of Mustang Bayou.
174	Mouth of Chocolate Bayou.
175	Between Markers S11 and S12 in Intracoastal Canal.
176	Between Markers S27 and S28 in Intracoastal Canal.
177	At entrance to Gaidon's Cut at tip of Mud Island.
178	In San Luis Pass.
32	Between Markers #1 and #2 off Teichman Point.
33	In line from #2 channel marker and a black F. G. marker.
34	At #4 channel marker north of Teichman Point.
35	By black channel Marker #1.
36	Under new Causeway bridge.
222	By Marker Buoy #62 at center of curve in channel west of Causeways.
168	In channel between North and South Deer Islands.
169	At #17 marker southwest of Deer Islands.
170	At #27 marker in channel.
171	At Marker #4 on north side of channel southwest of Carancahua Reef.
324	Chocolate Lake.
325	Oyster Lake.
323	Oyster Reef west of west side of South Deer Island.
295	Teichman Point.

OFFATTS BAYOU

22	Off pier of Duke's Place near bridge.
17	East side of 61st Street at north end of Seabreeze Cafe (Offatts' Bayou).
18	Southwest corner of east section of Offatts' Bayou.
19	Outfall in the southeast corner of east section of Offatts Bayou.
20	Outfall in the northeast corner of east section of Offatts Bayou.
21	In pocket in north end of east section of Offatts Bayou.
23	Northeast corner of west section of Offatts Bayou.
24	Off pier at end of 62nd Street.
25	Off point at intersection of 64th Street and Avenue L.
26	1st outfall into Offatts Bayou west of Hi-Grade Packing Company.
27	2nd outfall into Offatts Bayou west of Hi-Grade Packing Company.
28	Behind John's Oyster Resort.
29	Off pier behind Moody Memorial Building on Teichman Point.
30	Between channel Marker #8 and shore in Offatts Bayou.
31	Off pier at end of Teichman Point.
293	South of John's Oyster Resort.
294	South of Roger's Oyster Farms.
297	Mouth of outfall from Galveston Airport sewerage disposal.
298	In pocket, south side Offatts Bayou near steel bridge.
299	Off Woodward's pier south end.

GALVESTON CHANNEL AND BOLIVAR ROADS

140	Sewage outfall at west end of Galveston Channel, south side.
141	Front of Pier #38.
142	Front of Grain Elevator.

143	In Galveston Channel between 18th and 19th Streets.
144	At 9th Street outfall into channel.
145	At ferry slip.
287	1st F. L. W. buoy northeast of the quarantine station.
151	Buoy #11 at entrance to Inner Bar Channel from Galveston Channel.
152	Buoy #9 in the Inner Bar Channel.
153	Buoy #7 in the Inner Bar Channel.
286	Buoy #5 of the Outer Bar Channel.
154	Buoy #2A of the Outer Bar Channel.
155	Halfway between tips of north and south jetties.
157	F. L. W. #1 at end of the Outer Bar Channel.
117	Halfway between end of the Dike and Texas City Channel.
118	At entrance to Texas City Channel directly opposite concrete ship.
119	Northwest corner of the quarantine station on Pelican Island.
120	Halfway between quarantine station and F. L. W. "14" bell.
121	At the (F. L. R.) "14" bell halfway between Pelican Island and Bolivar Peninsula.
122	Due east of (Occ. R) "2" (entrance to Houston Ship Channel) in line between (F. L. R.) "14" bell and entrance to the Intracoastal Canal.
123	Due west of (FW) "2" bell off Bolivar Peninsula in line between (F. L. R.) "14" bell and entrance to Intracoastal Canal.
124	At light opposite the two slips on Bolivar Peninsula.
236	By abandoned lighthouse near channel Buoy #11.
234	Mouth of Lagoon in Bolivar Roads north of South Jetty.
232	Northmost point of small island north of the South Jetty in Bolivar Roads.
231	$\frac{1}{4}$ the way out on the South Jetty on north side in Bolivar Roads.
156	Lighthouse at end of South Jetty.

WEST GALVESTON BEACH

71	Tip of Galveston Island in San Luis Pass.
72	0.7 mile east of sample point #71.
73	0.7 mile east of sample point #72.
74	0.7 mile east of sample point #73.
75	0.7 mile east of sample point #74.
76	0.7 mile east of sample point #75.
77	0.7 mile east of sample point #76.
78	0.7 mile east of sample point #77.
79	0.7 mile east of sample point #78.
80	0.7 mile east of sample point #79.
81	0.7 mile east of sample point #80.
82	0.7 mile east of sample point #81.
83	At thirteen mile road.
84	0.7 mile east of sample point #83.
85	0.7 mile east of sample point #84.
86	0.7 mile east of sample point #85.
87	0.7 mile east of sample point #86.
88	0.7 mile east of sample point #87.
89	0.7 mile east of sample point #88.
90	0.7 mile east of sample point #89.
91	0.7 mile east of sample point #90.
92	0.7 mile east of sample point #91.
93	0.7 mile east of sample point #92.
94	0.7 mile east of sample point #93.
95	0.7 mile east of sample point #94.
96	0.7 mile east of sample point #95.

97	0.7 mile east of sample point #96.
98	0.7 mile east of sample point #97.
99	Foot of 1st road to beach west of Lake Sweetwater.
100	Foot of 1st road to beach east of Lake Sweetwater.
214	0.7 mile east of Sunset Camp.
215	Front of Sand Dunes Cafe.
216	Front of Beachcomber Cafe.
217	Front of Pelican Cafe.
218	0.2 mile east of Pelican Cafe.
219	0.4 mile east of Pelican Cafe.

CITY OF GALVESTON, BEACHFRONT--61st STREET TO SOUTH JETTY

1	Foot of 61st Street.
2	Halfway between 1st and 2nd Groin.
3	Halfway between 2nd and 3rd Groin.
4	Halfway between 3rd and 4th Groin.
5	Halfway between 4th and 5th Groin.
6	Halfway between 5th and 6th Groin.
7	Halfway between 6th and 7th Groin.
8	Halfway between 7th and 8th Groin.
9	Halfway between 8th and 9th Groin.
10	1st steps to beach west of Pleasure Pier.
11	Under Murdock's Pier.
12	Foot of 17th Street under Free Fishing Pier.
13	Foot of 14th Street.
14	Foot of 10th Street.
15	At end of fence near Zig Zag Inn and playground.
16	Front of Stewart Beach Pavilion.
220	End of east fence at Stewart Beach.
221	0.3 mile east of fence at Stewart Beach.
223	0.6 mile east of fence at Stewart Beach.
224	0.9 mile east of fence at Stewart Beach.
225	1.2 miles east of fence at Stewart Beach.
226	1.5 miles east of fence at Stewart Beach.
227	1.8 miles east of fence at Stewart Beach.
228	2.1 miles east of fence at Stewart Beach.
229	Corner east beach makes with South Jetty.
233	Mouth of Lagoon, south side of South Jetty.
235	North shore of Lagoon where road leads down from Seawall.

GULF OF MEXICO

334	On Bearing 298° from South Jetty Lighthouse and 7 miles from center of ends of jetties.
335	On Bearing 287° from South Jetty Lighthouse and 7 miles from center of ends of jetties.
336	On Bearing 270° from South Jetty Lighthouse and 7 miles from center of ends of jetties.
337	On Bearing 245° from South Jetty Lighthouse and 7 miles from center of ends of jetties.
338	On Bearing 210° from South Jetty Lighthouse and 7 miles from center of ends of jetties.
339	On Bearing 185° from South Jetty Lighthouse and 6½ miles from center of ends of jetties near large green house.

340	On Bearing 210° from South Jetty Lighthouse and 5 miles from center of ends of jetties.
341	On Bearing 245° from South Jetty Lighthouse and 5 miles from center of ends of jetties.
342	On Bearing 270° from South Jetty Lighthouse and 5 miles from center of ends of jetties.
344	On Bearing 344° from South Jetty Lighthouse and 7 miles from center of ends of jetties.
345	On Bearing 13° from South Jetty Lighthouse and approx. 8 miles from center of ends of jetties and on Bearing 315° from W. Edge of Buccaneer Hotel.
346	Out from 1st Groin east of 61st Street at end of Seawall.
347	Between 1st and 2nd Groins west of end of Pleasure Pier.
348	Out from Free Fishing Pier at foot of 18th Street.
349	Out from Stewart Beach.
350	On Bearing 61° to South Jetty Lighthouse and on Bearing 230° from Buccaneer Hotel and on Bearing 297° on Radio Tower (Galv. Beach, E.)
351	On Bearing 63° from South Jetty Lighthouse and on Bearing 273° from Radio Tower.
352	On Bearing 65° from South Jetty Lighthouse and on Bearing 261° from Radio Tower.
353	On Bearing 244° from Radio Tower, approximately 500 yards south of jetty.
354	Approximately halfway between South Jetty Lighthouse and 1st Fishing Camp on Beach (approximately 2000 yards from Lighthouse).
355	1000 yards west of Lighthouse.
356	By South Jetty Lighthouse south of jetty.
357	By Heald Bank Marker Buoy, 30 miles from end of jetties on Bearing 130°.
358	5 miles northwest of Heald Bank Buoy on Bearing 310°, 25 miles from end of jetties.
359	10 miles northwest of Heald Bank Buoy on Bearing 310°, 20 miles from end of jetties.
360	15 miles northwest of Heald Bank Buoy on Bearing 310°, 15 miles from end of jetties.
361	20 miles northwest of Heald Bank Buoy on Bearing 310°, 10 miles from end of jetties.
362	25 miles northwest of Heald Bank Buoy on Bearing 310°, 5 miles from end of jetties on Bearing 325° from South Jetty Lighthouse.
364	3 miles from center of ends of jetties on Bearing 270° from South Jetty Lighthouse in line with sample point #336.
365	Halfway between sea buoy and South Jetty Lighthouse.
366	Approximately 1 mile east of sample point #350 on Bearing 85° from point #350. Bearing 54° to Lighthouse; 281° to tower.
367	Approximately 1 mile east of sample point #366 on Bearing 85°. Bearing 38° to South Jetty and Bearing 276° from tower.
368	Approximately 1 mile east of sample point #367 on Bearing 85°. Bearing 12° to South Jetty and Bearing 273° from tower.
369	Approximately 1 mile east of sample point #368 on Bearing 85°. Bearing 342° to South Jetty and Bearing 272° to tower.
230	¼ way out on South Jetty.

TEXAS CITY AREA

70	Off end dock at west end of Carbide Slip.
237	At Republic and Stone outfall into Carbide Slip.
289	North of Carbide Slip at mouth into turning basin.
69	Southwest corner of turning basin, extreme southwest corner of Pan American Dock.
288	Middle of turning basin at Republic Slip.
68	Northeast corner of Petrol Docks walkway.
67	Outfall in southwest corner of Seatrain Slip.
64	Southeast corner of Monsanto.

65 Northeast corner of Monsanto between light and corner.
66 Texas City Sewage outfall from northwest corner of Monsanto.
63 By-pass outfall at Texas Avenue and Bay Street.
62 Outfall of Texas City drainage ditch at 3rd Avenue North and Bay Street.
61 At old sewage outfall behind shell supply near Texas City Dike.
60 Corner of south side of dike.
285 Off Lee Cain's Fishing Pier.
59 South side of dike at sign "No Cars Past This Sign."
58 South side of dike opposite old pier on north side of dike.
57 At end of usable road on south side of dike.
326 Outfall into Carbide Slip, 400 yards east of Newman's Boathouse.

CARBIDE DITCH AND MOSES LAKE

202 Outfall from the northwest corner of Carbide Corporation Plant.
201 Outfall from the northeast corner of Carbide Corporation Plant.
203 Drainage ditch at intersection of Moore and 1st Avenue North.
204 Raw sewage outfall into ditch from Texas City Heights Sewage Treatment Plant.
206 100 yards west of outfall of Carbide Ditch into drainage ditch from LaMarque Area.
205 50 yards north of Texas City Heights Sewage Treatment Plant.
207 Off Palmer Highway Bridge.
208 Where old Highway #146 crosses Carbide Ditch west of airport.
209 Most southern tip of Moses Lake.
210 Tip of reef in mouth of inlet in south side of Moses Lake.
212 1000 yards west of sample point #210.
211 1000 yards north of sample point #210.
213 1000 yards east of sample point #210.
303 By pier at west end of Moses Lake.
304 Wooden bridge at end of bayou.
305 At old pipe line crossing. Only pilings left.
306 Highway #146 bridge.
307 Mouth of Moses Bayou.
308 Mouth of ditch.
309 Off point near drilling rig.
310 Off point (sand spit due west of Dollar Point).
311 Off point at North Mouth of Dollar Bay.
312 30 yards west of mouth of North Bayou at east end of Dollar Bayou.
313 At mouth of South Bayou at east end of Dollar Bayou.
314 Mouth of 14th St. drainage ditch into Dollar Bay.
315 At mouth of channel to Dollar Bay Fishing Camps.
316 At bridge on old Highway #146, near Wage's Airport.
320 At 2 stakes over oyster bed equal distance between Miller Point and oyster bed and windmill on Miller Point.
267 At end of Clear Creek about $1\frac{1}{4}$ to $1\frac{1}{2}$ miles east of Turkey Creek.
268 At Friendswood Bridge.
269 Mouth of Mare's Creek into Clear Creek.
270 Mouth of Chigo Creek into Clear Creek.
271 At pilings left from old Galveston-Houston road bridge.
272 Gulf Freeway Bridge.
273 Galveston County Park Pier.
274 U.S. Highway #75 bridge.
275 $\frac{1}{2}$ mile west of League City Sewage Treatment Plant at shell pile.
276 Outfall from south just east of League City Sewage Treatment Plant.
277 In mouth of Cow Bayou Gully.
290 Halfway between the two white houses at the fork of Cow Bayou Gully.
278 At bridge over entrance to Mud Lake.

279 At Harris County Park Pier.
280 At mouth of bayou leading to Taylor Lake.
281 Front of Country Club Building (large white building with several large columns in front).
282 Mouth of bayou from Clear Lake Shores.
283 Railroad bridge between Kemah and Seabrook.
284 Front of Muecke's Place in Seabrook.
300 Private pier at end of road.
301 Off pier in corner of Clear Lake.

DICKINSON BAYOU

179 At Arcadia Bridge.
180 At irrigation pump and side ditch.
181 1st bridge before Gulf Freeway Bridge, going east.
182 Mouth of Benson's Bayou into Dickinson Bayou.
183 Mouth of small creek into Dickinson Bayou near pipe line crossing right before Dickinson Bridge, going east.
184 After sewage outfall W. C. I. D. #1 at railroad trestle near shell dump.
185 At mouth of Gum Bayou into Dickinson Bayou.
186 At "Standard-Oilwell #6" on south side of Bayou.
187 At Highway #146 bridge.
188 Marker #27 at entrance to Dickinson Bayou.
189 At 5th Marker in channel between house and island.

HIGHLAND BAYOU

252 At head of bayou near pilings on south side.
253 1st bridge west of Hitchcock-Dickinson road bridge.
254 At mouth of drainage ditch from south.
255 Hitchcock-Dickinson road bridge.
256 1st outfall from north, east of the Hitchcock-Dickinson road bridge.
257 1st bridge east of Hitchcock-Dickinson road bridge.
258 At sharp bend in bayou near pier of two-story white house.
259 Small Bayou at eastern end of Galveston Memorial Cemetery.
260 At Perthuis Bridge.
261 Mouth of bayou from the north (see map).
262 Mouth of bayou from the south (see map).
263 Mouth of a straight drainage ditch from the north.
264 Texas City Terminal railroad bridge.
265 LaMarque sewage outfall from the north.
266 Highway #6 bridge.
291 Drainage ditch coming from the wye.
147 At Santa Fe railroad bridge.

BOLIVAR BEACH

238 At "S" turn in road 1 mile northeast of junction of Highways #87 and #124.
239 At junction of Highways #87 and #124.
240 Road to beach 4.5 miles southwest of sample point #239.
241 In back of Windy's Place at Gilchrist.
242 1st road to beach northeast of Gulf Filling Station at Rollover.
243 In front of white house on pilings, 1 mile northeast of Sun Oil Co. Station.
244 3 miles southwest of Sun Oil Co. Station, opposite radar antenna.
245 Tar and gravel road to beach, $2\frac{1}{2}$ miles southwest of sample point #244.
246 At outfall of small body of water 0.6 mile northeast of large white house with green roof and windows, 2 miles from crossroads (see map).
247 At end of tar and gravel road to beach.
248 At outfall into Gulf, 0.7 mile southwest of sample point #247.
249 At outfall into Gulf, 0.7 mile northeast of road to beach.
250 In corner of north jetty and the beach.
302 At first bend in road west of sample point #239.

TABLE B-1

LOCATIONS OF SAMPLING STATIONS USED IN

TEXAS STATE DEPARTMENT OF HEALTH SURVEY, 1958

LOCATIONS OF SAMPLING STATIONS

Stations No. 1 through No. 4 are located along a line starting at a point 1, 000 yards north of Eagle Point and traveling in a straight line to Kemah-Seabrook Channel Markers #2. Sample stations are located as follows:

No. 1 1, 000 yards north of Eagle Point.
No. 2 One third of way to Kemah Marker #2.
No. 3 Two thirds of way to Kemah Marker #2.
No. 4 Kemah Marker #2.

Stations No. 5 through No. 8 are located along a line starting from Kemah-Seabrook Channel Marker #2 to Houston Ship Channel Marker #55. Sample stations are located as follows:

No. 5 One fourth of way to Ship Channel Marker #55.
No. 6 One half of way to Ship Channel Marker #55.
No. 7 Three fourths of way to Ship Channel Marker #55.
No. 8 Houston Ship Channel Marker #55.

Stations No. 9 through No. 14 are located along a line starting from Houston Ship Channel Marker #55 and extending in an easterly direction to Double Bayou Marker #2. Stations No. 36 and No. 37 are located north of this line. Sample stations are located as follows:

No. 9 One sixth of way to Double Bayou Marker #2.
No. 10 One third of way to Double Bayou Marker #2.
No. 11 One half of way to Double Bayou Marker #2.
No. 36 North of station No. 11 approximately 3, 500 yards.
No. 12 Two thirds of way to Double Bayou Marker #2.
No. 13 Five sixths of way to Double Bayou Marker #2.
No. 37 North of station No. 13 approximately 3, 000 yards.
No. 14 Double Bayou Marker #2.

The following stations are located along the east side of Trinity Bay:

No. 15 Located at Trinity River Channel Marker #116.
No. 16 Located at Trinity River Channel Marker #94.
No. 17 1, 500 yards west of Trinity River Channel Marker #86.
No. 18 1, 000 yards west of Trinity River Channel Marker #66.
No. 19 1, 000 yards north of Trinity River Channel Marker "A" located at Smith Point.

The following stations are located in the East Bay area:

No. 20 3, 000 yards south of Channel Marker "A" at Smith Point.
No. 21 2, 000 yards east of Stephenson's Point and 700 yards from shore.
No. 22 1, 000 yards south of Robinson Bayou.
No. 23 500 yards south of Frozen Point.
No. 24 2, 700 yards north of Gilchrist Pass.
No. 25 1, 700 yards north of Gilchrist Pass.
No. 26 1, 500 yards east of station No. 27 and 500 yards from shore.
No. 27 1, 000 yards north of the northern-most portion of Marsh Point.
No. 28 500 yards north of northern-most portion of Elm Grove Point.
No. 29 3, 000 yards east of Ladies Pass.
No. 30 3, 500 yards in a northeasterly direction from Baffle Point and 500 yards from shore.

The following stations are located along and in the Ship Channel areas:

No. 31 500 yards west of Ref. Marker #10 (south of Texas City Channel Marker #12).
No. 32 1 500 yards east of Houston Ship Channel Marker #8.
No. 50 500 yards east of Houston Ship Channel Marker #14.
No. 33 500 yards east of Houston Ship Channel Marker #18.
No. 49 500 yards east of Houston Ship Channel Marker #22.
No. 48 500 yards east of Houston Ship Channel Marker #26.
No. 34 4, 000 yards west of Houston Ship Channel Marker #23.
No. 35 1, 000 yards east of Dickinson Bayou Channel Marker #1.
No. 40 100 yards northwest of Houston Ship Channel Marker #29.

The following stations are along Hanna Reef and the surrounding area:

No. 38 500 yards south of Moody's Pass.
No. 39 2 000 yards in westerly direction from station No. 38 and 100 yards from reef.
No. 41 2, 000 yards in westerly direction from station No. 39 and 100 yards from reef.
No. 42 3, 000 yards in northwesterly direction from station No. 41 and 200 yards from reef.
No. 44 200 yards from northern-most breakers of Hanna Reef.
No. 43 One half of way between stations No. 44 and No. 20.

The following stations are located along a line from station No. 19 (north of Smith Point) to Houston Ship Channel Marker #40.

No. 47 One fourth of way to Channel Marker #40 from station no. 19.
No. 46 One half of way to Channel Marker #40.
No. 45 Three fourths of way to Channel Marker #40.

TABLE C-1

SAMPLING STATIONS USED BY

TEXAS STATE DEPARTMENT OF HEALTH

NOVEMBER 1, 1963

BAY CODE INDEX OF GALVESTON BAY

Symbol	Area
MLK	Mud Lake
CCK	Clear Creek
CLK	Clear Lake
WES	West Bay
UG	Upper Galveston Bay
LG	Lower Galveston Bay
TRI	Trinity Bay
EAS	East Bay
HSC	Houston Ship Channel
TLK	Taylor Lake
CB	Cedar Bayou
HB	Highland Bayou
CHB	Chocolate Bayou

GALVESTON BAY PROJECT STATION LOCATIONS
AS OF NOVEMBER 1, 1963

Station Number	Bay	Latitude	Longitude	State Tract	Corresponds With These Stations Fish & W	Corp. Eng.	Tex G&F	TSDH	Description
256	UG	29°35.2'	94°59'	256				1958 #6 1963-B-6	Surf Oaks
263	UG	29°31.6'	94°53.7'	263				1950 #319 1958 #51 1963 #S-319	Marker # 59 Houston Ship Channel
275	EAS	29°25.7'	94°43.5'	275	LGS-8			1950 #167 1958 #30	Between Baffle Point & Elm Grove Point
284	LG	29°29.5'	94°52.2'	284	H-ULG			1958 #55	Marker #53 Houston Ship Channel
286	UG	29°30.6'	94°53.2'	286				1950 #296 1958 #52 1963 #S-296	Marker #57-55 Houston Ship Channel
294	UG	29°34.1'	95°00.0'	294				1963 #B-5	Todville
296	UG	29°33.2'	94°59.4'	296				1958 #4	Kemah Marker #2
301	UG	29°32.9'	95°00.9'	301		T-M		1950 #38 1963 #301 #Y-300 #S-38	Kemah Marker #7
302	UG	29°31.9'	94°59.9'	302	UGS-7			1950 #40 1963 #S-40	Kemah - Bayview
303	UG	29°31.3'	94°58.1'	303				1950 #41 1963 #S-41	Bayview
304	UG	29°30.9'	94°58.4'	304				1950 #42 1963 #S-42	Bacliff
305	UG	29°30.9'	94°57.7'	305	UGS-8			1950 #43 1963 #S-43	Bacliff Marker #2
306	UG	29°30.5'	94°56.3'	306				1950 #44 1963 #S-44	Bacliff - San Leon
307	UG	29°30.3'	94°55.4'	307				1950 #45 1963 #S-45	San Leon
308	UG	29°30.1'	94°54.5'	308				1958 #B-1 1950 #46	Eagle Point
301-A	UG	29°33.2'	95°01.2'	301				1950 #284 1963 #S-284	Seabrook
116	UG	29°36.7'	94°53.8'	116					3 mi. E. of Houston Ship Channel Marker #76
123	UG	29°39.7'	94°59.6'	123				1963 B-LP	Bayridge Park

Station Number	Bay	Latitude	Longitude	State Tract	Corresponds With These Stations Fish & W	Corp. Eng.	Tex G&F	TSDH	Description
143	EAS	29°23.6'	94°40.8'	143	EBS-6			1958 #28	Elm Grove Point
147	EAS	29°30'	94°41.4'	147	EBO-2				Elm Grove Point - Stephenson Point
151	EAS	29°31.9'	94°42.4'	151	EBS-9				1 mi. E. of Stephenson Point
168	EAS	29°29.9'	94°36.1'	168	EBS-7				Yates Bayou - Big Pasture Bayou
170	EAS	29°31.7'	94°37'	170	EBO-3				Marsh Point - Elm Grove Point
173	EAS	29°33'	94°37.5'	173	EBS-10				Stephenson Point - Robinson Bayou
175	EAS	29°32'	94°35.6'	175		T-K		1950 #164 1958 #27	Marsh Point
190	EAS	29°34.1'	94°33.9'	190	EBS-11			1950 #166 1958 #22	Robinson Bayou
209	UG	29°36.3'	94°57.3'	209				1958 #8 1963 B-8	Marker #75 Hou. Ship Channel
213	UG	29°38.6'	95°00.6'	213	MSS-4			1963 B-SB	Sylvan Beach
214	UG	29°37.4'	94°59.7'	214				1963 B-HYC 1963 SA-1	Shore Acres
216	UG	29°36.1'	94°58.1'	216				1958 #7 1963 B-7	Red Bluff - Marker #75 Houston Ship Channel
226	LG	29°31.3'	94°49.4'	226	H-2UGL				Smith Point - Eagle Point (Tri. River Channel)
239	EAS	29°28.2'	94°44.7'	239	LGR-11			1958 #39	Hanna Reef
2-3A	TRI	29°40.6'	94°47.4'	2-3A	TBO-3			1958 #37	Between Umbrella Point & Double Bayou
5-8F	TRI	29°38.7'	94°42.7'	5-8F	TBC-1	T-O		1958 #14	Marker #6 Double Bayou
10-11E	TRI	29°44'	94°50'	10-11E	TBS-8	T-N			Point Barrow
13-16B	TRI	29°42.5'	94°44.2'	13-16B	TBO-4			1958 B-37+	Marker #1 Anahuac
22-23C	TRI	29°45.9'	94°46.9'	22-23C	TBS-9				Cross Bayou
28-B	TRI	29°44'	94°41.7'	28B					Round Point

Station Number	Bay	Latitude	Longitude	State Tract	Corresponds With These Stations Fish & W	Corp. Eng.	Tex G&F	TSDH	Description
33	TRI	29°45.4'	94°41.4'	33					N. of Round Point
34	TRI	29°46.3'	94°41.3'	34					Marker #34 Anahuac
58	TRI	29°37.8'	94°45.2'	58	TBO-5			1958 #13	Lone Oak Bayou - Umbrella Point
61	TRI	29°36'	94°43.8'	61	TBS-11			1958 #18	Lone Oak Bayou - Vingtune Island
70	TRI	29°40'	94°51.6'	70	TBS-7			1958 #36	Umbrella Point
73	TRI	29°38.6'	94°50.6'	73	TBO-2			1958 #11	Umbrella Point - Vingtune Island
84	UG	29°35.9'	94°48.4'	84	TBO-6			1958 #46	Smith Point - Red Bluff
92	HSC	29°40.7'	94°58.8'	92		T-P CS-6		1963 #X-46 1963 #B-90+	Morgan Point
95	UG	29°39'	94°55.3'	95					Houston Point
108	TRI	29°33.7'	94°46.8'	108	TBS-12			1958 #18	Vingtune Island
312	LG	29°28.3'	94°51.3'	312				1958 #40 1950 #194	Marker #49 Hou. Ship Channel
320	EAS	29°24.1'	94°45.8'	320	LGS-7			1950 #200	Baffle Point
326	LG	29°27.3'	94°50.7'	326	LGC-2	CS-3		1950 #195 1958 #48	Marker #43 Hou. Ship Channel
331	LG	29°29.0'	94°54.7'	331				1958 #47	Eagle Point - April Fool Point
332	LG	29°27.7'	94°53.4'	332				1958 #35	Marker #2 Dick-inson Bay Channel
345	LG	29°24.6'	94°49.4'	345				1950 #197 1958 #33	Marker #35 Hou. Ship Channel
349	LG	29°26.4'	94°52.9'	349	LGS-10			1958 #34 1963 #S-50	Dollar Point
351	LG	29°26.8'	94°54'	351					Miller Point - Dollar Point
352	LG	29°27.4'	94°55.1'	352		T-L		1958 #35A	Marker #14 Dick-inson Bay Channel
352-A	LG	29°28.0'	94°55.5'	352				1958 #48	April Fool Point
352-B	LG	29°27'	94°55.2'	352				1958 #49	Miller Point
354	LG	29°28.2'	94°57.1'	354				1950 #48	Marker #27 Dick-inson Bay Channel

Station Number	Bay	Latitude	Longitude	State Tract	Fish & W	Corp. Eng.	Tex G&F	TSDH	Description
354-A	LG	29°27.6'	94°58.3'	354				1950 #187	S. P. R. R. Bridge Dickinson Bay Channel
361	UG	29°41.3'	94°58'	361					Marker #14 Cedar Bayou Channel
A-1	WES	29°12.5'	95°11.6'	1A				1950 #174	Marker #2 Chocolate Bayou
A-3	WES	29°11.7'	95°09.4'	3A				1958 #D-3	Horse Grove Point
A-8	WES	29°08.8'	95°09.4'	8A				1958 #C-16 1950 #176	Marker #28 Intracoastal Waterway
A-13	WES	29°06.3'	95°09.5'	13A				1958 #C-15 1950 #177	Mud Island
A-19	WES	29°09.7'	95°07.8'	19A				1950 #175	Marker #11 Intracoastal Waterway
A-23	WES	29°10.2'	95°07.1'	23A				1958 #C-17 1950 #172	Marker #1 Intracoastal Waterway
A-46	WES	29°09.1'	95°03.2'	46A				1958 #C-12	San Luis Pass - Carancahuac Reef
A-49	WES	29°11.6'	95°01.9'	49A				1958 #C-11	Alligator Point - Carancahuac Point
A-52	WES	29°14.6'	95°01'	52A				1950 #150	Carancahuac Lake - Intracoastal Waterway
A-59	WES	29°13.3'	94°59.7'	59A				1958 #C-10 1950 #170	Carancahuac Reef
A-61	WES	29°16.0'	94°59.3'	61A				1958 #C-9 1950 #149	Green's Lake - Intracoastal Canal
A-69	WES	29°14.8'	94°57.4'	69A				1958 #C-8 1950 #169	Green's Lake - Hoeckers Point
A-71	WES	29°16.9'	94°57.8'	71A				1958 #C-7	Green's Lake - N. Deer Island
A-73	WES	29°17.2'	94°56.4'	73A				1958 #C-6	N. Deer Island
A-79	WES	29°16.6'	94°55'	79A				1958 #C-5 1950 #168	N. Deer Island - S. Deer Island
A-86	WES	29°17.6'	94°53.4'	86A		T-B CS-1		1958 #C-3 1950 #36	Galveston Causeway-Intracoastal
A-89	LG	29°20.1'	94°53.6'	89A					Campbell Bayou
A-91	LG	29°22.2'	94°54.2'	91A					Texas City Turning Basin

Station Number	Bay	Latitude	Longitude	State Tract	Corresponds With These Stations Fish & W	Corp. Eng.	Tex G&F	TSDH	Description
A-92	LG	29°22.8'	95°52.9'	95A				1950 #131	Texas City Turning Basin
A-96	LG	29°24.9'	94°52.6'	96A				1950 #51 1963 S-52A	Dollar Point - Texas City Dike
A-97	LG	29°23.7'	94°52.6'	97A				1950 #54 1963 #S-54	Texas City Dike
A-99	LG	29°22.4'	94°52.6'	99A					Snake Island
A-103	LG	29°18.5'	94°52.5'	103A					Intracoastal Waterway off Virginia Point
A-105	WES	29°16.8'	94°53'	105A				1950 #32	Teichman Point
A-112	LG	29°22.4'	95°51.0'	112A		T-H		1950 #115	Texas City Channel
A-114	LG	29°24.0'	95°50.8'	114A					Half Moon Shoal
A-117	LG	29°22.8'	94°50.9'	117A		T-I		1950 #56 1963 #S-56	Texas City Dike
A-120	LG	29°20.1'	95°50.5'	120A				1950 #192	Intracoastal Waterway West of Pelican Island
A-122	LG	29°18.7'	95°49.8'	122A		T-C		1950 #139	Pelican Is. Causeway
A-127	LG	29°22.2'	94°48.9'	127A	HTPLG			1950 #130 1963 #S-130	End of Texas City Dike
A-131	LG	29°21.9'	94°48'	131A				1950 #198 1963 #S-198	Hou. Ship Channel Marker #25
A-137	LG	29°20.7'	95°46.6'	137A				1950 #287	Hou. Ship Channel Marker #16
A-140	LG	29°20.2'	95°46.5'	NA		T-E		1950 #145	Pelican Island Quarantine Station
A-141	LG	29°18.7'	94°47.5'	NA		T-D			Galveston Channel Todd Shipyard
X-1	HSC	29°45.8'	95°21.5'	NA					San Jacinto Bridge
X-3	HSC	29°45.8'	95°20.6'	NA					I.&G.N.R.R. Bridge
X-4	HSC	29°45.7'	95°20.2'	NA					Paige St. Gully
X-6	HSC	29°45.6'	95°19.6'	NA					Ingrams St. Gully
X-7	HSC	29°45.4'	95°19.2'	NA					Lockwood St. Bridge
X-9	HSC	29°45.2'	95°17.9'	NA					69th St. Bridge
X-10	HSC	29°44.8'	95°17.0'	NA					So. Pac. R. R. Bridge

Station Number	Bay	Latitude	Longitude	State Tract	Fish & W	Corp. Eng.	Tex G&F	TSDH	Description
X-13	HSC	29°43.7'	95°16.6'	NA					End Houston Compress
X-17	HSC	29°43.6'	95°15.7'	NA					Fire Boat Station Manchester
X-18	HSC	29°43.2'	95°14.5'	NA					Below Sims Bayou
X-20	HSC	29°43.5'	95°13.4'	NA					Vinces Bayou
X-23	HSC	29°43.6'	95°12.8'	NA					Over Washburn Tunnel
X-25	HSC	29°44.2'	95°12.2'	NA					Cotton Patch
X-27	HSC	29°44.5'	95°11.7'	NA					Mathieson Chem. Co.
X-28	HSC	29°44.6'	95°11.3'	NA					Sheffield Steel
X-31	HSC	29°44.6'	95°10.0'	NA					Below Green's Bayou
X-33	HSC	29°44.1'	95°08.0'	NA					Above Boggy Bayou and Shell Slip
X-35	HSC	29°44.4'	95°06.5'	NA					Patrick Bayou
X-37	HSC	29°45.5'	95°05.5'	NA					San Jacinto State Park off Battleship Texas
X-38	HSC	29°45.8'	95°04.8'	NA					Lynchburg Ferry
X-39	HSC	29°44.2'	95°03.3'	NA					Lynchburg - St. Mary Pt. Marker #118
X-40	HSC	29°43.8'	95°02.1'	NA					St. Mary Point
X-45	HSC	29°40.2'	95°58.7'	NA					Morgan Point
X-46	UG	29°40.7'	95°58.8'	NA					Marker #89 Hou. Ship Channel
X-38A	HSC	29°45.2'	95°04.0'	NA					Marker #123 Hou. Ship Channel
X-40A	HSC	29°42.3'	95°01.2'	NA					Baytown Tunnel
X-45A	HSC	29°42.0'	95°00.2'	NA					Near Mouth of Goose Creek
Y-273	TLK	29°36.7'	95°01.1'	NA				1963-TL273	Hwy 146 & Boggy Bayou
Y-274	TLK	29°36.6'	95°02.1'	NA				1963-TL274	S. P. R. R. Bridge & Taylor Bayou
Y-275	TLK	29°36.1'	95°02.6'	NA					Taylor Bayou

Station Number	Bay	Latitude	Longitude	State Tract	Corresponds With These Stations Fish & W	Corp. Eng.	Tex G&F	TSDH	Description
Y-276	TLK	29°34.7'	95°02.8'	NA				1963 CL-276 TL-280A CL-280A	Red Bluff Rd. & Taylor Bayou
Y-277	TLK	29°34.3'	95°02.9'	NA	UGL-10			1963 TL-277A TL-277B	Middle of Taylor Lake
Y-278	TLK	29°33.9'	95°03.2'	NA				1963 CL-280 CL-278 1950-280	Hwy 528 & Taylor Lake
Y-279	CCK	NA	NA	NA					North Choate Rd. & Clear Creek
Y-279A	CCK	29°32.8'	95°11.6'	NA				1963 CL-267 1950 -267	Choate Rd. & Clear Creek
Y-280	CCK	29°31.7'	95°10.1'	NA				1963 CL-269 1950 -269	Friendswood Bridge & Clear Creek
Y-286	CCK	29°30.8'	95°06.7'	NA				1963 CL-273 CL-286 1950 -273	Galveston County Park Pier
Y-287	CCK	29°31.3'	95°06.1'	NA				1963 CL-274 1950 -274	Hwy 3 & Clear Creek
Y-290	CCK	29°32.5'	95°05.6'	NA				1963 CL-276 CL-290 1950 -276	East of League City S. T. P.
Y-291	CCK	29°32.1'	95°05.5'	NA				1963 CL-277 1950 -277	Mouth of Cow Bayou Gully
Y-292	CCK	29°32.8'	95°04.5'	NA				1963 CL-290 CL-292 1950 -290	Junction of Clear Creek & Clear Lake
Y-293	CLK	29°33.4'	95°04.4'	NA				1963 CL-278A	Clear Lake & Houston Light & Power Co. Ditch
Y-294	CLK	29°33.8'	95°04.3'	NA				1963 CL-278 1950 -278	Hwy 528 & Mud Lake
Y-286A	CCK	29°30.8'	95°06.1'	NA					Interstate Hwy 45 & Clear Creek
Y-295	CLK	29°33.9'	95°03.9'	NA				1963 CL-279 1950 -279	Harris County Park Pier
Y-296	CLK	29°33.4'	95°03.1'	NA				1963 CL-280B CL-296(4-2-63) CL-301A (5-29-63)	Middle Clear Lake, South of Taylor Lake Entrance

Station Number	Bay	Latitude	Longitude	State Tract	Corresponds With These Stations Fish &W	Corp. Eng.	Tex G&F	TSDH	Description
Y-297	CLK	29°33.1'	95°01.9'	NA					Middle Clear Lake, Due South of Houston Country Club
Y-298	CLK	29°32.9'	95°01.4'	NA				1963 CL-283 CL-298 (4-2-63) S-283 (3-12-63) 1950 -283	East End of Clear Lake at Exit
Y-300	UG	29°32.9'	95°00.9'	NA				1963 CL-301 S-38 (4-24-63)	Edgewater Cafe Pier (Kemah)
Y-301	CLK	29°33.2'	95°02'	NA					South of New Boat Basins of Houston Country Club - Inshore
Y-302	CLK	29°33.1'	95°02.5'	NA	UGL-9				Glen Cove - Inshore
Y-303	CLK	29°33.2'	95°02.4'	NA				1963 CL-282 S-282 (3-13-63) 1950 -282	Mouth of Jardo Bayou
Y-304	MLK	29°34.9'	95°04.1'	NA					Mouth of Horsebend Bayou Into Mud Lake
HB-1	HB	29°20.6'	94°56.7'	NA					Santa Fe R. R. Bridge
HB-2	HB	29°19.8'	94°56.7'	NA					Hwy 6 Bridge Near Gulf Freeway
HB-3	HB	29°21.1'	95°01.2'	NA					Cow Gully
HB-4	HB	29°21.4'	95°01.8'	NA					Bridge on Fm Road 2004
HB-5	HB	29°21.2'	95°01.1'	NA					First Bridge North on Al West Road
HB-6	HB	29°21.4'	95°01.1'	NA					Second Bridge North on Al West Road
HB-7	HB	29°21.0'	95°00.8'	NA					Bridge on Hwy 519 North of Hitchcock
HB-8	HB	29°21.4'	95°00.2'	NA					Bridge on Hwy 519 at Carbide Park
HB-9	HB	29°21.0'	94°59.6'	NA					Fairwood Rd. Bridge
HB-10	HB	29°20.4'	94°56.9'	NA					Gulf Freeway Culvert Near Santa Fe R. R. Spur

Station Number	Bay	Latitude	Longitude	State Tract	Corresponds With These Stations: Fish &W	Corp. Eng.	Tex G&F	TSDH	Description
CHB-1	CHB	NA	NA	NA					Chocolate Bayou & Entrance to Monsanto Channel
CHB-2	CHB	NA	NA	NA					Choc. Bayou & Lutes Marine Service Docks
CB-1	CB	29°51'	95°55.0'	NA					Hwy 146 & Cedar Bayou Northeast of Baytown
CB-2	CB	29°49.5'	95°54.5'	NA					Interstate Hwy 10 & Cedar Bayou
CB-3	CB	29°46.2'	95°57.0'	NA					F. M. Hwy 1942 & Cedar Bayou

TABLE D-1

SAMPLING STATIONS USED BY

CITY OF HOUSTON (1932-1941)

BUFFALO RIVER - HOUSTON SHIP CHANNEL

STATION NUMBER	MILE POST	LOCATION
1	0.00	¼ mile in Galveston Bay.
2	0.75	Morgan's Point.
3	1.25	Opposite Tobb's Bay Bridge.
4	2.00	¼ mile east of Goose Creek.
5	2.50	¼ mile west of Goose Creek.
6	4.20	Below Humble Refining Co. Spillway.
7	4.95	Power Line across Channel at Baytown.
8	9.10	Lynchburg Ferry.
9	12.50	¼ mile below Shell Refinery.
10	15.90	500 feet below Green's Bayou
11	16.10	500 feet above Green's Bayou.
12	18.00	Hunting Bayou.
13	19.00	Crown Refinery.
14	19.85	Vincents Bayou.
15	21.00	500 feet below Sims Bayou.
16	21.20	500 feet above Sims Bayou.
17	21.65	Southern Pacific Terminal Dock.
18	22.00	Opposite Fireboat Wharf.
19	23.40	Mouth of Brays Bayou.
20	23.60	Above Brays Bayou.
21	24.10	Lower end of Houston Compress Co.
22	25.00	Wharf #2 and opposite Wharf #13.
23	25.60	Southern Pacific Railroad Bridge.
24	25.80	Above Magnolia Park Sewage Treatment Plant.
25	26.30	69th Street Bridge.
26	26.70	H. B. and T. Railroad Bridge.
27	27.20	Cypress tree.
28	28.10	Milby Street sewer.
29	28.45	Lockwood Street Bridge.
30	28.55	At North Side Sewage Treatment Plant.
31	28.65	Above North Side Sewage Treatment Plant.
32	29.10	Ingrams Gully.
33	29.45	Below Houston Packing Company.
34	29.55	Houston Packing Company.
35	29.65	S. A. and A. P. Railroad Bridge.
36	29.80	Paige Street Gully.
37	30.35	Hill Street Bridge.
38	30.55	I. and G. N. Railroad Bridge.
39	30.80	H. B. and T. Railroad Bridge.
40	31.15	McKee Street Bridge.
41	31.35	G. H. and H. Railroad Bridge.
42	31.75	San Jacinto Street Bridge.
43	31.90	Main Street Viaduct. White Oak Bayou enters.
44	32.25	Smith Street Bridge.
45	32.40	Preston Avenue Bridge.
46	32.80	Capitol Avenue Bridge.
47	33.20	Sabine Street Bridge.
48	35.30	Waugh Drive Bridge.
49	36.00	Shepherd Drive Bridge.

BRAYS BAYOU

1	0.00	Harrisburg Bridge.
2	0.85	Pineview Wharf (Private).
3	1.85	Forest Hill Bridge.
4	2.65	Lawndale Avenue Bridge.
5	4.05	Telephone Road Bridge.
6	4.80	Lidstone Bridge (Kensington).
7	5.60	H. B. and T. Railroad Bridge.
8	6.50	Calhoun Road Bridge.
9	6.75	Below South Side Sewage Treatment Plant.
10	6.90	Above South Side Sewage Treatment Plant.
11	7.65	Scott Street Road Bridge.

SIMS BAYOU

1	0.00	Mouth of Sims Bayou.
2	0.90	Haden Gravel Dock.
3	1.20	La Porte Road Bridge.
4	3.70	Galveston Road Bridge.
5	5.80	Interurban Bridge (G. H. E. RY.)
6	7.80	Alvin Airline (Telephone) Road Bridge.
7	10.80	City Farm Road Bridge.
8	13.80	Chocolate Bayou Road Bridge.

WHITE OAK BAYOU

1	1.20	Elder Street Bridge.
2	1.80	Houston Avenue Bridge (Little White Oak Bayou enters).
3	2.75	Taylor Street Bridge.
4	4.00	Heights Boulevard Bridge.
5	5.40	Shepherd Drive Bridge.
6	8.60	18th Avenue Bridge.

LITTLE WHITE OAK BAYOU

1	.80	North Main Street Bridge.
2	1.90	Trimble Street Bridge.
3	2.55	Janssen Street Bridge.
4	3.45	Sylvester Road Bridge.
5	4.10	H. B. and T. Railroad Bridge.
6	4.60	Above disposal of Houston Textile Mills.

TABLE E-1

SAMPLING STATIONS USED BY

U. S. BUREAU OF COMMERCIAL FISHERIES

BIOLOGICAL LABORATORY, GALVESTON, TEXAS

STATION

GMC-1 Gulf of Mexico - Latitude 29°19.2' N., Longitude 94°39.2' W. - Offshore State Tract #102. Trawl and plankton samples are collected at the #1 sea buoy in the Outer Bar Channel. The average water depth is 42 feet. Bottom type is sandy with some mud. The normal trawl direction is 33° true toward station GMO-2.

GMO-2 Gulf of Mexico - Latitude 29°20' N., Longitude 94°38.6' W. - Offshore State Tract #102. No visible landmarks. After trawling at GMC-1 run 5 minutes at 1750 RPM ("Tommy Box") 33° true (approximately 1¼ miles). Diaphone on south jetty bears 262° true from this station. The average water depth is 32 feet. Bottom type is sand with some mud. The normal trawl direction is 277° true.

TPC-1 Tidal Pass - Latitude 29°21' N., Longitude 94°42.6' W. - State Tract #202. A trawl sample is collected between buoys # 7 and 9 in the Outer Bar Channel. The average depth is 52 feet. Bottom type is hard sand. The normal trawl direction is 290 °true.

TPC-2 Tidal Pass - Latitude 29°20.7' N., Longitude 94°46.4' W. - State Tract unknown. Trawl and plankton samples are collected at the red and black Inner Bar Channel buoy (1 QKFL). The average depth is 38 feet. Bottom type is hard sand. Trawl direction is normally against the tide.

TPO-3 Tidal Pass - Latitude 29°20.4' N., Longitude 94°41.9' W. - State Tract #202. A trawl sample is collected between black buoys #5 and 7 on the Outer Bar Channel, south of the channel. Average depth is 22 feet. Bottom type hard sand. Normal trawl direction is 318 °true.

TPO-4 Tidal Pass - Latitude 29°21.4' N., Longitude 94°46.3' W. - State Tract #137A. Trawl and plankton samples are collected on the sand flats north of buoy #18. The average depth is 15 feet. Bottom type is mud. Normal trawl direction is 197° true toward station TPC-2.

TPL-5 Tidal Pass - Latitude 29°19.5' N., Longitude 94°45.4' W. - State Tract unknown. A trawl sample is collected in East Beach Lagoon approximately 100 yards northeast of the USFWS Seawater Laboratory. Average depth is 3 feet. Bottom type is sandy mud. Normal trawl direction is northeast.

LGC-1 Lower Galveston Bay - Latitude 29°24.1' N., Longitude 94°49.1' W. - State Tract #345. A trawl sample is collected in the Houston Ship Channel between buoys #33 and 34. Average depth is 42 feet. Bottom type is hard sand. Trawl direction is usually against the tide.

LGC-2 Lower Galveston Bay - Latitude 29°27.2' N., Longitude 94°50.7' W. - State Tract #326. Trawl and plankton samples are collected in the Houston Ship Channel approximately 600 yards northwest of buoys #43 and 44. Average depth is 42 feet. Bottom type is clay and mud. Direction of trawl is normally against the tide.

LGO-3 Lower Galveston Bay - Latitude 29°23.5' N., Longitude 94°51' W. - State Tract #114A. Trawl and plankton samples are collected approximately 0.5 of a mile south of Half Moon Shoal and 0.7 of a mile north of the Texas City Dike. Average depth is 8 feet. Bottom type is mud. Normal trawl direction is parallel to the Dike against the tide.

LGO-4 Lower Galveston Bay - Latitude 29°26.9' N., Longitude 94°51.7' W. - State Tract #334. A trawl sample is collected 1 mile southeast of the Houston Ship Channel marker #47 and 0.9 of a mile due west of the Houston Ship Channel marker #43. Average depth is 8 feet. Bottom type is mud. Normal trawl direction is against the tide.

STATION	
LGO-5	Lower Galveston Bay - Latitude 29°25.3' N., Longitude 94°46.4' W. - State Tract #318. Trawl and plankton samples are collected 1.6 miles north-northwest of Baffle Point. The old Bolivar lighthouse bears 175° true and Texas City bears 247° true from this station. Average depth is 7 feet. Bottom type is mud. Normal trawl direction is south-southeast.
LGO-6	Lower Galveston Bay - Latitude 29°28.4' N., Longitude 94°48' W. - State Tract #270. Trawl and plankton samples are collected approximately $2\frac{1}{2}$ miles east of the Houston Ship Channel marker #50. Average depth is 7 feet. Bottom type is mud. Normal direction of trawl is 100° true.
LGS-7	Lower Galveston Bay - Latitude 29°24.1' N., Longitude 94°45.8' W. - State Tract #320. A trawl sample is collected approximately 300 yards from the north shore of Bolivar Peninsula 0.5 of a mile northeast of Baffle Point. Average depth is $2\frac{1}{2}$ feet. Bottom type is sandy mud. Normal trawl direction is parallel to shore against the tide.
LGS-8	Lower Galveston Bay - Latitude 29°25.7' N., Longitude 94°43.5' W. - State Tract #275. Trawl and plankton samples are collected approximately 300 yards offshore from the north shore of Bolivar Peninsula, 1 mile southwest of Flake's Pass. Average depth is 2 feet. Bottom type is mud. Normal trawl direction is parallel to shore against the tide.
LGS-9	Lower Galveston Bay - Latitude 29°24.5' N., Longitude 94°53.3' W. - State Tract #94A. A trawl sample is collected approximately 300 yards offshore 1.4 miles south of Dollar Point. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to shore against the tide.
LGS-10	Lower Galveston Bay - Latitude 29°26.3' N., Longitude 94°53.5' W. - State Tract #350. Trawl and plankton samples are collected approximately $\frac{1}{4}$ mile north-northwest of Dollar Point 300 yards from shore. The station is 1.6 miles from the Dickinson Channel outer beacon which bears .002° north. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to the shore against the tide.
LGR-11	Lower Galveston Bay - Latitude 29°28.2' N., Longitude 94°44.7' W. - State Tract #239. Trawl and plankton samples are collected approximately 800 yards southeast of the western visible edge of Hanna's Reef, 3/4 mile southwest of Ladies' Pass. Depth is $4\frac{1}{2}$ feet. Bottom type is mud. Normal direction of trawl is southeast.
LGL-12	Lower Galveston Bay - Latitude 29°27.6' N., Longitude 94°56.2' W. - State Tract #353. A trawl sample is collected in Dickinson Bay south of Dickinson Bayou Channel 300 yards from shore, halfway between markers #27 and 15. Average depth is 2 feet. Bottom type is mud. Normal direction of trawl is parallel to shore against the tide.
LGL-13	Lower Galveston Bay - Latitude 29°27' N., Longitude 94°58.9' W. - State Tract unknown. Trawl and plankton samples are collected 0.8 of a mile upstream from the railroad bridge and Highway 146 bridge. Average depth is 6 feet. Bottom type is mud. Normal direction of trawl is against the current.
UGC-1	Upper Galveston Bay - Latitude 29°32.5' N., Longitude 94°54.1' W. - State Tract #262. A trawl sample is collected in the Houston Ship Channel between markers #61 and 62. Average depth is 42 feet. Bottom type is hard mud. Normal direction of trawl is against the tide.
UGC-2	Upper Galveston Bay - Latitude 29°35.3' N., Longitude 94°56.3' W. - State Tract #218. Trawl and plankton samples are collected in the Houston Ship Channel between markers #71 and 72. Average depth is 42 feet. Bottom type is mud with some shell. Normal direction of trawl is against the tide.

STATION

UGO-3 Upper Galveston Bay - Latitude 29°34.3' N., Longitude 94°57.9' W. - State Tract #257. Trawl and plankton samples are collected midway on a line between the Houston Ship Channel marker #71 and the outer beacon of the Seabrook Channel. When on station, Red Bluff bears 334° true, and the concrete water tower at Surf Oaks bears 298° true. The average depth is 6 feet. Bottom type is mud. Normal direction of trawl is 229° true.

UGO-4 Upper Galveston Bay - Latitude 29°31.6' N., Longitude 94°55.8' W. - State Tract #289. A trawl sample is collected halfway on a line between the Houston Ship Channel marker #60 and the outside marker of the Clifton Channel (Humble Oil Company Camp). Average depth is 7 feet. Bottom type is mud. Normal direction of trawl is against the tide.

UGO-5 Upper Galveston Bay - Latitude 29°33.9' N., Longitude 94°51.7' W. - State Tract #203. There are no landmarks to determine the exact station location. It is normally located by running a course of 230° true from station TBO-6 for 3½ miles. Average depth is 8 feet. Bottom type is mud. Direction of trawl is determined by the tide.

UGO-6 Upper Galveston Bay - Latitude 29°36.7' N., Longitude 94°53.8' W. - State Tract #116. Trawl and plankton samples are collected 1.2 miles east-northeast of the Five Mile Pass Channel buoy #4. The exact location of this station is determined by running a course of 80° true after leaving the buoy. Average depth is 7 feet. Bottom type is mud. Direction of trawl is 57° true.

UGS-7 Upper Galveston Bay - Latitude 29°32' N., Longitude 95°0.2' W. - State Tract #302. Trawl and plankton samples are collected 300 yards offshore near the Corinthian Yacht Club, approximately 1 mile north of Bayview. Average depth is 3 feet. Bottom type is mud. Normal direction of trawl is parallel to shore against the tide.

UGS-8 Upper Galveston Bay - Latitude 29°30.7' N., Longitude 94°57.4' W. - State Tract #305. A trawl sample is collected approximately ½ mile east of the entrance to the Humble Camp Channel at Bacliff, ¼ mile offshore. Depth is 2 feet. Bottom type is sandy mud. Direction of trawl is parallel to shore against the tide.

UGL-9 Upper Galveston Bay - Latitude 29°33.2' N., Longitude 95°2.7' W. - State Tract unknown. Trawl sample is collected near the south shore of Clear Lake approximately 0.7 of a mile east of the Clear Lake Channel beacon #11. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to shore against the current.

UGL-10 Upper Galveston Bay - Latitude 29°34.3' N., Longitude 95°2.9' W. - State Tract unknown. Trawl and plankton samples are collected in Taylor Lake. Average depth is 2 feet. Bottom type is soft mud. Direction of trawl is generally north.

MSC-1 Mouth of the San Jacinto River - Latitude 29°39.2' N., Longitude 94°58.2' W. - State Tract #121. Trawl and plankton samples are collected in the Houston Ship Channel between markers #85 and 86. Average depth is 40 feet. Bottom is mud. Direction of trawl is against the tide.

MSO-2 Mouth of the San Jacinto River - Latitude 29°38.9' N., Longitude 94°59.2' W. - State Tract #124. Trawl sample is collected in Upper Galveston Bay 0.8 of a mile west-southwest of the Houston Ship Channel beacon #85 and 1.3 miles east-southeast of the Bayshore Park. Average depth is 6 feet. Bottom type is mud. Trawls are normally pulled against the tide.

STATION

MSO-3 Mouth of the San Jacinto River - Latitude 29°39.5' N., Longitude 94°57.3' W. - State Tract #93. Trawl sample is collected in Upper Galveston Bay 0.5 of a mile east of Atkinson Island and 1.8 miles south-southeast of the Cedar Bayou Channel marker #14. Average depth is 5 feet. Bottom type is mud. Direction of trawl is against the tide.

MSS-4 Mouth of San Jacinto River - Latitude 29°38.6' N., Longitude 95°0.5' W. - State Tract #213. Trawl and plankton samples are collected approximately 300 yards offshore ¼ mile south of the Sylvan Beach Pavilion. Average depth is 2 feet. Bottom type is mud. Trawl parallel to shore against the current.

MSS-5 Mouth of San Jacinto River - Latitude 29°39.9' N., Longitude 94°56' W. - State Tract #94. Trawl and plankton samples are collected in Upper Galveston Bay about 300 yards offshore at Mesquite Knoll. This station is 0.8 mile south-southeast of the Cedar Bayou Channel beacon #31. Average depth is 2 feet. Bottom type is mud. Normal trawl direction is parallel to the shore against the tide.

TBC-1 Trinity Bay - Latitude 29°38.7' N., Longitude 94°42.7' W. - State Tract #5-8F. A trawl sample is collected in the Double Bayou Channel at marker #6. Average depth is 6 feet. Bottom type is mud. Direction of trawl is against the current.

TBO-2 Trinity River - Latitude 29°38.5' N., Longitude 94°50.6' W. - State Tract #73. A trawl sample is collected 0.8 mile north of Yellow Sun Oil separator platform. This station is approximately 2 miles southeast of Fisher's Shoals. Average depth is 7 feet. Bottom type is mud. Direction of trawl is 57° true.

TBO-3 Trinity Bay - Latitude 29°40.6' N., Longitude 94°47.4' W. - State Tract #2-3A. Trawl and plankton samples are collected at a station approximately 4 miles 57 true from TBO-2. This station is about 0.9 mile due north of Humble's C-1 separator platform. Average depth is 7 feet. Bottom type is mud. Direction of trawl is 57° true.

TBO-4 Trinity Bay - Latitude 29°42.5' N., Longitude 94°44.2' W. - State Tract #13-16B. Trawl and plankton samples are collected about 600 yards south of the black and white Anahuac outer channel buoy. Average depth is 6 feet. Bottom type is mud. Normal trawl direction is 170° true.

TBO-5 Trinity Bay - Latitude 29°37.8' N., Longitude 94°45.2' W. - State Tract #58. Trawl sample is collected at a station 1.9 miles 240 true from outer beacon of the Double Bayou Channel. Average depth is 6 feet. Bottom type is mud. Trawl direction is 240° true.

TBO-6 Trinity Bay - Latitude 29°35.9' N., Longitude 94°48.4' W. - State Tract #84. Trawl and plankton samples are collected at a station 700 yards northeast of Tidewater Well #102. Average depth is 8 feet. Bottom type is mud. Trawl direction is 236° true.

TBS-7 Trinity Bay - Latitude 29°40' N., Longitude 94°51.6' W. - State Tract #70. Trawl and plankton samples are collected at a station 0.6 of a mile southeast of Umbrella Point and 0.5 of a mile southwest of Fisher's Shoals. This station is approximately 300 yards offshore. Average depth is 2 feet. Bottom type is mud and shell. Direction of trawl is parallel to shore against the tide.

TBS-8 Trinity Bay - Latitude 29°44' N., Longitude 94°50' W. - State Tract #10-11E. A trawl sample is collected approximately 300 yards offshore 0.4 of a mile south of the Humble docks at Point Barrow. Average depth is 2 feet. Bottom type is mud. Trawl direction is parallel to shore against the tide.

STATION

TBS-9	Trinity Bay - Latitude 29°45.9' N., Longitude 94°46.9' W. - State Tract #22-23C. Trawl and plankton samples are collected at a station approximately 0.5 of a mile south of the entrance to Cross Bayou. Average depth is 2 feet. Bottom type is hard sand. Direction of trawl is parallel to shore against the tide.
TBS-10	Trinity Bay - Latitude 29°39.7' N., Longitude 94°42.3' W. - State Tract #9E. Trawl and plankton samples are collected 400 yards offshore about 1½ miles northeast of the Double Bayou Outer Channel marker. Average depth is 2 feet. Bottom type is hard sand. Direction of trawl is parallel to the shore against the tide.
TBS-11	Trinity Bay - Latitude 29°36' N., Longitude 94°43.8' W. - State Tract #61. Trawl and plankton samples are collected 500 yards offshore approximately 1 mile southeast of the Lone Oak Bayou entrance. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to shore against the tide.
TBS-12	Trinity Bay - Latitude 29°33.7' N., Longitude 94°46.8' W. - State Tract #108. A trawl sample is collected 300 yards north of Vingtune Island. Average depth is 3 feet. Bottom type is hard sand. Normal direction of trawl is against the current.
TBL-13	Trinity Bay - Latitude 29°39.1' N., Longitude 94°40.9' W. - State Tract unknown. A trawl sample is collected ½ mile up the east fork of Double Bayou. Average depth is 5 feet. Bottom type is mud.
TBL-14	Trinity Bay - Latitude 29°38.9' N., Longitude 94°40.5' W. - State Tract unknown. Trawl and plankton samples are collected 1 mile up the east fork of Double Bayou. Average depth is 5 feet. Bottom type is mud.
EBC-1	East Bay - Latitude 29°31.1' N., Longitude 94°30.3' W. - State Tract #183. A trawl sample is collected in the Intracoastal Canal at Rollover Pass. Piles marking East Bay Channel on north side of the station. Average depth is 12 feet. Bottom type is mud. Normal direction of trawl is against the tide.
EBO-2	East Bay - Latitude 29°30' N , Longitude 94°41.4' W. - State Tract #147. Trawl and plankton samples are collected 1.6 miles northwest of Elm Grove Point and 2.1 miles south of Stephenson Point. The Bolivar lighthouse bears 206° true from the station. Average depth is 5 feet. Bottom type is mud. Direction of trawl is normally against the tide.
EBO-3	East Bay - Latitude 29°31.7' N., Longitude 94°37' W. - State Tract #170. A trawl sample is collected 1 3/4 miles northwest of Pasture Bayou. Average depth is 4 feet. Bottom type is mud. Direction of trawl is normally against the tide.
EBO-4	East Bay - Latitude 29°33.1' N., Longitude 94°33.4' W. - State Tract #179. Trawl and plankton samples are collected 1½ miles southeast of the mouth of Robinson Bayou and 1 mile north of Marsh Point. Average depth is 3½ feet. Bottom type is mud. Direction of trawl is against the tide.
EBO-5	East Bay - Latitude 29°31.9' N., Longitude 94°30.6' W. - State Tract #187. A trawl sample is collected approximately 1 mile north of Rollover Pass. Average depth is 3 feet. Bottom type is mud. Direction of trawl is against the tide.

STATION

EBS-6 East Bay - Latitude 29°23.6' N., Longitude 94°40.8' W. - State Tract #143. Trawl and plankton samples are collected 400 yards offshore at Elm Grove Point opposite a small bayou. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to shore against the tide.

EBS-7 East Bay - Latitude 29°29.9' N., Longitude 94°36.1' W. - State Tract #168. A trawl sample is collected 200 yards offshore approximately 300 yards northwest of Yates Bayou. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to shore against the tide.

EBS-8 East Bay - Latitude 29°31.5' N., Longitude 94°32.6' W. - State Tract #180. A trawl sample is collected 1.4 miles southwest of Frozen Point, approximately 200 yards off the shore of Marsh Point Peninsula. This station is opposite a small bayou. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to shore against the tide.

EBS-9 East Bay - Latitude 29°31.9' N., Longitude 94°42.4' W. - State Tract #151. A trawl sample is collected approximately 300 yards off the north shore of East Bay 1.1 miles south-southeast of Stephenson Point. The Old Bolivar lighthouse bears 200° true from this station. Average depth is 2½ feet. Bottom type is mud. Direction of trawl is parallel to shore against the tide.

EBS-10 East Bay - Latitude 29°33' N., Longitude 94°37.5' W. - State Tract #173. A trawl sample is collected approximately 200 yards offshore 3¼ miles east-northeast of Stephenson Point and 3¼ miles west-northwest of Robinson Bayou. Average depth is 2½ feet. Bottom type is mud. Direction of trawl is parallel to shore against the current.

EBS-11 East Bay - Latitude 29°34.1' N., Longitude 94°33.9' W. - State Tract #190. Trawl and plankton samples are collected approximately 700 yards southeast of the mouth of Robinson Bayou. Average depth is 2 feet. Bottom type is mud. Direction of trawl is parallel to shore against the current.

EBR-12 East Bay - Latitude 29°28.7' N., Longitude 94°45' W. - State Tract #232. Trawl and plankton samples are collected ¼ mile northwest of the visible western edge of Hanna's Reef, 1 mile west-southwest of Ladies' Pass. Average depth is 4½ feet. Bottom type is sand. Normal direction of trawl is southwest.

EBL-13 East Bay - Latitude 29°33.6' N., Longitude 94°27.9' W. - State Tract unknown. A trawl sample is collected in East Bay Bayou 500 yards from its junction with the Intracoastal Canal. Average depth is 2 feet. Bottom type is soft mud. Direction of trawl is against the current.

EBL-14 East Bay - Latitude 29°30.7' N., Longitude 94°33.7' W. - State Tract unknown. A dredged channel runs in a southeast direction from Marsh Point to the Intracoastal Waterway. Approximately 1.2 miles from March Point a small channel angles off the main channel in a north-northeast direction. Approximately 200 yards up the small channel from its junction with the main channel, plankton and trawl samples are collected. The average depth is 3 feet. Bottom type is mud. The trawl direction is against the tide.

GIC-1 Gulf Intracoastal Waterway - Latitude 29°25.7' N., Longitude 94°43.3' W. - State Tract unknown. A trawl sample is collected in the Intracoastal Canal, Bolivar Peninsula, 1 mile southwest of Flake's Launching Ramp. Average depth is 12 feet. Bottom type is mud. Direction of trawl is against the current.

STATION

GIC-2	Gulf Intracoastal Waterway - Latitude 29°29.2' N., Longitude 94°35.7' W. - State Tract unknown. A trawl sample is collected in the Intracoastal Canal 0.6 mile west of Stingaree Fishing Camp. Average depth is 12 feet. Bottom type is mud. Direction of trawl is against the current.
H-TPLG	Hydrological Station - Junction of Tidal Pass and Lower Galveston Bay - Latitude 29°21.8' N., Longitude 94°47.8' W. - State Tract #131A. Hydrographic data are collected at buoy #22 at the junction of the Houston Ship Channel and the Intracoastal Canal. The Texas City Dike bears 272° true from this station. Average depth is 42 feet. Bottom type is mud.
H-1UGL	Hydrological Station - Junction of Upper and Lower Galveston Bay - Latitude 29°29.7' N., Longitude 94°52' W. - State Tract #285. Hydrographic data are collected in the Houston Ship Channel between markers #53 and 54. The average depth is 42 feet. Bottom type is hard sand and shell.
H-2UGL	Hydrological Station - Junction of Upper and Lower Galveston Bay - Latitude 29°31.3' N., Longitude 94°49.4' W. - Hydrographic data are collected $2\frac{1}{4}$ miles south-southwest of Smith Point, approximately 100 yards south of the small Humble separator platform. Average depth is 12 feet. Bottom type is hard mud.

TABLE F-1

DOMESTIC WASTE-WATER TREATMENT PLANTS

IN GALVESTON BAY AREA

GALVESTON BAY
POLLUTION SURVEY
SEWAGE PLANTS
N
HOUSTON
BAYTOWN
ANAHUAC
ALVIN
TEXAS CITY
GALVESTON

Domestic Waste-Water Treatment Plants in Galveston Bay Area*

Ident. No. and Name	Ident. No. and Name
Brazoria County	12. 10395(4) City of Baytown
1. 10134 Brazoria Co. WC&ID #3	13. 10419 Durkee Manor Sewage Treatment Plant
Chambers County	14. 10436 Crest Sanitary Corp.
1. 10396 City of Anahuac	15. 10450 Harris Co. WC&ID #73
2. 10400 Chambers Co. WC&ID #1	16. 10451 Harris Co. WC&ID #76
Galveston County	17. 10452 Harris Co. FIUSD #50
1. 10173(1) Galveston Co. WC&ID #1	18. Salco Utilities Co.
2. 10173(2) Galveston Co.	19. 10495(1) North Side Plant
3. 10174 Galveston Co. WC&ID #8	20. 10495(2) Sims Bayou Plant
4. 10175 Galveston Co. WC&ID #15	21. 10495(3) Almeda Plaza Plant
5. 10375(1) City of Texas City (Plant #1)	22. 10495(5) Braeburn Terrace Plant
6. 10375(2) City of Texas City (Plant #2)	23. 10495(6) Campbell Woods Plant
7. 10410 City of La Marque	24. 10495(7) Chadwick Manor Plant
8. 1 Municipal Airport	25. 10495(8) Chatwood Plant
9. 2 Galveston 51st St. Plant	26. 10495(9) Chocolate Bayou Plant
10. 5 Hitchcock	27. 10495(10) Clinton Park Plant
11. 8 Galveston Co. WC&ID #2	28. 10495(11) Cole Creek Manor Plant
12. 10 Galveston Co. WC&ID #12	29. 10495(12) Crestmont Plant
Harris County	30. 10495(13) Ella Lee Forest Plant
1. 10144 Bay Colony Utility Co.	31. 10495(14) Fontaine Place Plant
2. 10184 Harris Co. Fresh Water Supply District #6	32. 10495(15) FWSD #17
3. 10185 Harris Co. WC&ID #56	33. 10495(16) FWSD #23
4. 10195 City of Jacinto City	34. 10495(17) FWSD #28
5. 10206 City of La Porte	35. 10495(18)
6. 10236 Oakwilde Water Co.	36. 10495(19) FWSD #41
7. 10272 San Jacinto Junior College	37. 10495(20) Gulf Meadows Plant
8. 10333 Arcadian Land & Utilities Co.	38. 10495(21) Gulf Palms Plant
9. 10395(1) City of Baytown Woodlawn Plant	39. 10495(22) Gulfway Terrace Plant
10. 10395(2) City of Baytown West Main Plant	40. 10495(23) Homestead Plant
11. 10395(3) City of Baytown Cedar Bayou Plant	41. 10495(24) Huntleigh Place Plant
	42. 10495(25) Lake Forest Plant
	43. 10495(26) Lakeview Plant
	44. 10495(27) Langwood Plant
	45. 10495(28) Longpoint Woods Plant
	46. 10495(29) Longwoods Plant

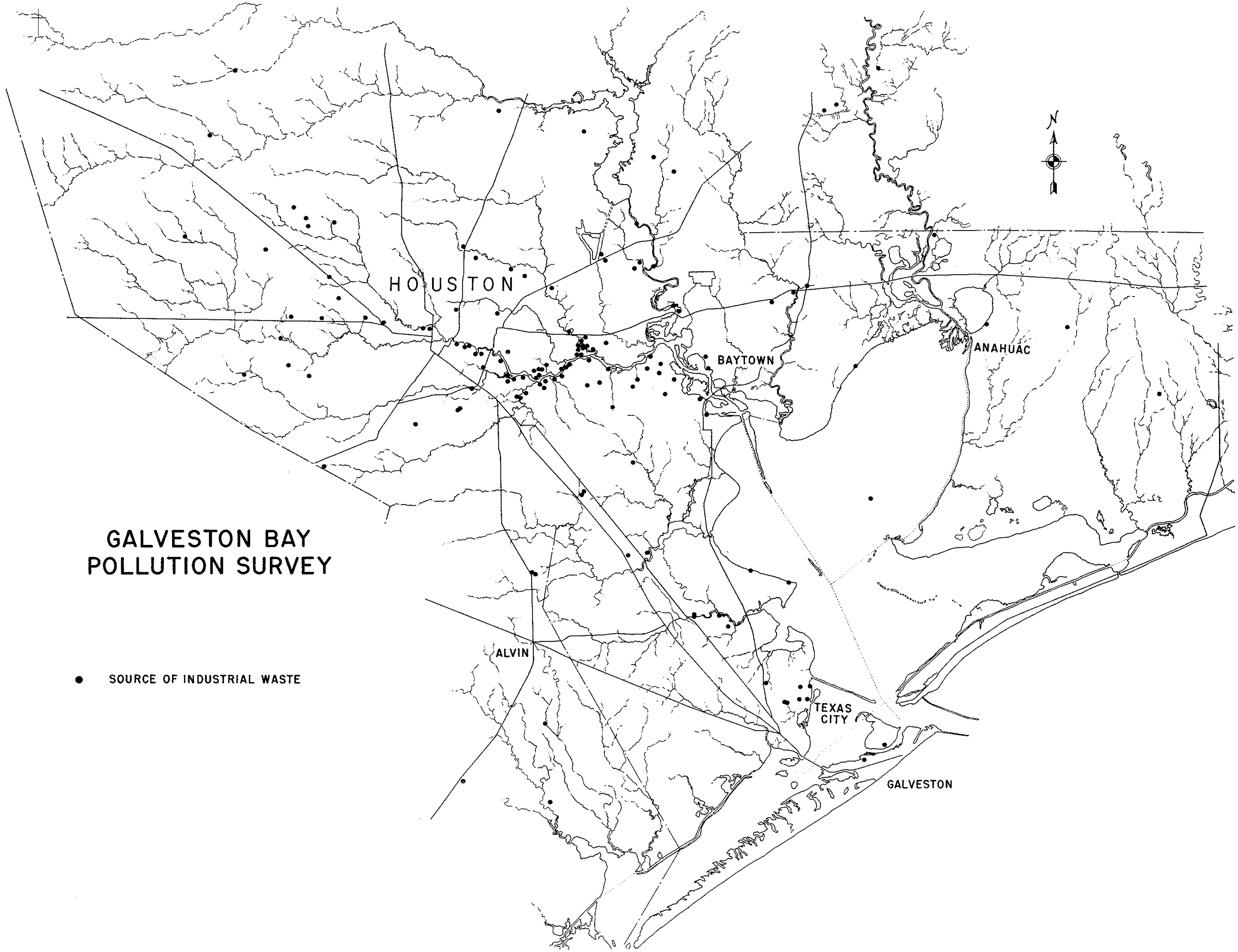
	Ident. No. and Name
47.	10495(30) Memorial Bend Plant
48.	10495(31) North Park Plant
49.	10495(32) Pinewood Village Plant
50.	10495(33) Post Oak Manor Plant
51.	10495(34) Saddlebrook Plant
52.	10495(35)
53.	10495(36) Shenandoah Plant
54.	10495(37) Southwest Plant
55.	10495(38)
56.	10495(39)
57.	10495(40) Timber Creek
58.	10495(41) WC&ID #20
59.	10495(42) WC&ID #24
60.	10495(43) WC&ID #32
61.	10495(44) WC&ID #34
62.	10495(45) WC&ID #39
63.	10495(46) WC&ID #42
64.	10495(47) WC&ID #44-1
65.	10495(48) WC&ID #44-2
66.	10495(49) WC&ID #44-3
67.	10495(50) WC&ID #47-1
68.	10495(51) WC&ID #47-2
69.	10495(52) WC&ID #49
70.	10495(53) WC&ID #51
71.	10495(54) WC&ID #52
72.	10495(55) WC&ID #53
73.	10495(56)
74.	10495(57) WC&ID #57
75.	10495(58) WC&ID #62
76.	10495(59) Wild Rose Plant
77.	10495(60) Willow Bend Plant
78.	10495(61) Charnwood Plant
79.	10495(62) Spring Branch Utility Co. Plant
80.	10495(63) Martin Utility Co. Plant
81.	10495(64) Glen Oaks Utility Co.
82.	10496(64-A) Greenfield Utility Co. Plant
83.	10495(65)
84.	10495(66) GPM Utility Co. Plant
85.	10495(67)
86.	10495(68) City of Houston

* The data recorded on the permit applications listed above were used in calculating the return flows, BOD load, COD load, and suspended solids load to the Galveston Bay system. Permits not listed in this table were not available.

TABLE G-1

INDUSTRIAL WASTE-WATER TREATMENT PLANTS

IN GALVESTON BAY AREA


GALVESTON BAY
POLLUTION SURVEY
SOURCE OF INDUSTRIAL WASTE
N
HOUSTON
BAYTOWN
ANAHUAC
ALVIN
TEXAS
CITY
GALVESTON

Industrial Waste-Water Treatment Plants in Galveston Bay Area*

Permit No.

Brazoria County

1. 00001
2. 00589
3. 00598
4. 00691
5. 00976

Chambers County

1. 00173
2. 00527 (Spillway #1)
3. 00527 (Spillway #2)
4. 00590 (Outlet #1)
5. 00590 (Outlet #2)
6. 00625
7. 00863

Galveston County

1. 00180
2. 00377
3. 00448 (Outlet #1)
4. 00448 (Outlet #2)
5. 00448 (Outlet #3)
6. 00448 (Outlet #4)
7. 00448 (Outlet #5)
8. 00448 (Outlet #6)
9. 00448 (Outlet #7)
10. 00448 (Outlet #8)
11. 00448 (Outlet #9)
12. 00448 (Outlet #10)
13. 00448 (Outlet #11)
14. 00448 (Outlet #12)
15. 00448 (Outlet #13)
16. 00448 (Outlet #14)
17. 00449
18. 00450
19. 00451
20. 00452
21. 00575 (Outlet #1)
22. 00575 (Outlet #2)
23. 00575 (Outlet #3)
24. 00575 (Outlet #4)
25. 00575 (Outlet #5)
26. 00591
27. 00600 (Outlet #1)
28. 00600 (Outlet #2)
29. 00601
30. 00665
31. 00742 (Outlet #1)
32. 00742 (Outlet #2)
33. 00779
34. 00800
35. 00990

Harris County

1. 00002
2. 00072
3. 00073
4. 00074
5. 00075
6. 00076
7. 00077
8. 00078
9. 00082
10. 00100
11. 00109
12. 00111
13. 00112
14. 00113
15. 00119
16. 00127
17. 00128
18. 00130
19. 00146
20. 00192
21. 00193
22. 00195
23. 00209
24. 00255
25. 00258
26. 00259
27. 00263
28. 00312
29. 00345
30. 00347
31. 00347
32. 00353
33. 00357
34. 00364
35. 00391
36. 00392 (Outlet #1)
37. 00392 (Outlet #2)
38. 00392 (Outlet #3)
39. 00392 (Outlet #4)
40. 00392 (Outlet #5)
41. 00392 (Outlet #6)
42. 00392 (Outlet #7)
43. 00392 (Outlet #8)
44. 00392 (Outlet #9)
45. 00392 (Outlet #10)
46. 00392 (Outlet #11)
47. 00393
48. 00402 (No. 1)
49. 00402 (No. 2)
50. 00402 (No. 3)
51. 00413
52. 00427
53. 00440
54. 00458 (Outlet #1)
55. 00458 (Outlet #2)
56. 00469
57. 00472 (Outlet #1)
58. 00472 (Outlet #2)
59. 00472 (Outlet #3)

	Permit No.		Permit No.		Permit No.
60.	00474 (Outlet #1)	101.	00544	142.	00683
61.	00474 (Outlet #2)	102.	00545	143.	00684
62.	00474 (Outlet #3)	103.	00548	144.	00686
63.	00477	104.	00549	145.	00687 (Outfall #1)
64.	00485	105.	00574 (Outlet #1)	146.	00687 (Outfall #2)
65.	00492	106.	00574 (Outlet #2)	147.	00687 (Outfall #3)
66.	00509 (Outfall #1)	107.	00574 (Outlet #3)	148.	00733 (Outlet #1)
67.	00509 (Outfall #2)	108.	00574 (Outlet #4)	149.	00733 (Outlet #2)
68.	00509 (Outfall #3)	109.	00580 (Outlet #1)	150.	00737 (Outlet #1)
69.	00509 (Outfall #4)	110.	00580 (Outlet #2)	151.	00737 (Outlet #2)
70.	00509 (Outfall #5)	111.	00587 (Outlet #1)	152.	00749
71.	00509 (Outfall #6)	112.	00587 (Outlet #2)	153.	00753
72.	00509 (Outfall #7)	113.	00587 (Outlet #3)	154.	00761
73.	00509 (Outfall #8)	114.	00587 (Outlet #4)	155.	00776
74.	00509 (Outfall #9)	115.	00592	156.	00777
75.	00509 (Outfall #10)	116.	00592	157.	00785
76.	00509 (Outfall #11)	117.	00605	158.	00785
77.	00509 (Outfall #12)	118.	00606	159.	00786
78.	00509 (Outfall #13)	119.	00610	160.	00797
79.	00509 (Outfall #14)	120.	00631 (Outlet #1)	161.	00799
80.	00509 (Outfall #15)	121.	00631 (Outlet #2)	162.	00801
81.	00509 (Outfall #16)	122.	00635	163.	00802
82.	00520 (Outlet #1)	123.	00639 (Outlet #1)	164.	00803
83.	00520 (Outlet #2)	124.	00639 (Outlet #2)	165.	00804
84.	00534	125.	00640 (Outlet #1)	166.	00806
85.	00535 (Outfall #1)	126.	00640 (Outlet #2)	167.	00807
86.	00535 (Outfall #2)	127.	00640 (Outlet #3)	168.	00815 (Outlet #1)
87.	00535 (Outfall #3)	128.	00640 (Outlet #4)	169.	00815 (Outlet #2)
88.	00535 (Outfall #4)	129.	00640 (Outlet #5)	170.	00815 (Outlet #3)
89.	00535 (Outfall #5)	130.	00640 (Outlet #6)	171.	00815 (Outlet #4)
90.	00535 (Outfall #6)	131.	00640 (Outlet #7)	172.	00815 (Outlet #5)
91.	00535 (Outfall #7)	132.	00648 (Outlet #1)	173.	00815 (Outlet #6)
92.	00535 (Outfall #8)	133.	00648 (Outlet #2)	174.	00815 (Outlet #7)
93.	00535 (Outfall #9)	134.	00655	175.	00815 (Outlet #8)
94.	00535 (Outfall #10)	135.	00660	176.	00815 (Outlet #9)
95.	00535 (Outfall #11)	136.	00662	177.	00815 (Outlet #10)
96.	00535 (Outfall #12)	137.	00663	178.	00815 (Outlet #11)
97.	00535 (Outfall #13)	138.	00667	179.	00815 (Outlet #12)
98.	00535 (Outfall #14)	139.	00668	180.	00815 (Outlet #13)
99.	00541	140.	00671	181.	00815 (Outlet #14)
100.	00542	141.	00672	182.	00815 (Outlet #15)

Permit No.	Permit No.	Permit No.
183. 00818	188. 00960	Liberty County
184. 00839	189. 00975	1. 00014
185. 00841	190. 00992	2. 00156
186. 00951	191. 00998	3. 00262
187. 00960		4. 00952 (Outlet #1)
		5. 00952 (Outlet #2)

*The data reported on the permit applications listed above were used in calculating the return flows, the BOD load, the COD load, and the suspended solids load to the Galveston Bay system. Permits not listed in this table were not available.

TABLE H-1

SUMMARY DATA OF WASTE EFFLUENTS

BY BASINS

SUMMARY DATA OF WASTE EFFLUENTS

Receiving Body of Water	Domestic				Industrial			
	Flow 1000 gal/day	BOD lb/day	COD lb/day	Susp. Solids lb/day	Flow 1000 gal/day	BOD lb/day	COD lb/day	Susp. Solids lb/day
Cedar Bayou	535.0	90.4	---	5.0	222.0	8.3	46.4	30.0
Goose Creek	1,100.0	183.5	---	---	---	---	---	---
Black Duck Bay	560.0	93.4	---	---	---	---	---	---
San Jacinto River	398.0	56.3	---	56.3	1,276.6	767.3	---	527.5
Carpenter's Bayou	62.5	10.4	---	---	---	---	---	---
Greens Bayou	3,865.0	1,229.9	---	1,970.7	2,628.0	31.7	47.7	1,353.1
Hunting Bayou	2,284.0	222.0	---	651.4	8.1	0.2	---	0.7
Upper Buffalo Bayou	45,715.0	19,580.3	---	44,820.0	2,633.9	17.5	362.7	102,203.4
Brays Bayou	8,525.0	2,291.3	---	5,640.3	222.7	2.7	---	2.9
Sims Bayou	40,809.0	11,804.1	---	22,280.8	7,367.0	524.2	19,492.2	1,064.2
Bayou G 108-00-00	---	---	---	---	14,700.0	1,103.4	1,839.0	---
Boggy Bayou	---	---	---	---	1,000.6	---	---	15,679.2
Patrick Bayou	---	---	---	---	12,545.0	84,553.8	164,354.7	7,463.9
Directly into Houston Ship Channel	750.0	125.1	---	200.2	167,234.1	149,631.8	101,969.6	135,898.2
Little Cedar Bayou	723.0	120.6	---	120.6	---	---	---	---
Directly into Galveston Bay	108.0	18.0	---	18.0	---	---	---	---
Clear Lake	1,163.0	221.1	---	327.1	747.9	---	---	---
Dickinson Bayou	1,700.0	283.6	---	283.6	85.9	34.2	---	34.2
Moses Lake	3,000.0	500.4	---	900.7	---	---	---	---
Galveston Bay (at Texas City)	---	---	---	---	135,200.9	103,676.6	170,186.8	3,746.3
Swan Lake	---	---	---	---	30.0	---	---	7.5
Highland Bayou	2,740.0	457.0	---	694.7	---	---	---	---
Galveston Bay (Galveston Ship Channel)	---	---	---	---	38.4	---	---	---
Chocolate Bay	---	---	---	---	3,337.4	798.5	---	---
Trinity River	---	---	---	---	4,541.4	---	---	---
Directly into Trinity Bay	---	---	---	---	0.6	---	---	---
Lake Anahuac	3.6	---	---	---	---	---	---	---
Double Bayou	---	---	---	---	7.3	---	---	---
East Bay Bayou	---	---	---	---	---	---	---	---

TABLE J-1

IBM DATA

SEWAGE TREATMENT PLANT INVENTORY

COLUMNS 1-55 IDENTIFICATION

Column 1 - Regional Office Number

____

Columns 2-3 - River Basin (Basin Location of Plant)

01 Brazos
02 Canadian
03 Colorado
04 Devils
05 Guadalupe
06 Lavaca
07 Lower Gulf Coast
08 Lower Rio Grande
09 Mission
10 Neches
11 Nueces
12 Pecos
13 Red
14 Sabine
15 San Bernard
16 San Jacinto
17 Trinity
18 Upper Rio Grande

Columns 4-6 - County (write in County Location of Treatment Plant)

____

Columns 7-8 - City or Location

____

Columns 9-10 - Plant Number (eg. #1, New, Old, North, South, etc.)

____

Column 11 - Ownership

1 Home Rule City
2 General Law City
3 State and/or County owned
4 Federally owned
5 WC&ID and/or FWSD
6 Sewer District
7 River Authority
8 Industry - domestic only
9 Private Corporation
9 Non Profit Organization or Corporation

Columns 12-17 - Date (by number)

Month________________ Date_____ Year_____

Columns 18-22 - Census Population (X 100)

____

Columns 23-27 - Estimated Population Served (X 100)

____

Columns 28-34 - Design Load M. G. D. (000.0000)

____

Columns 35-41 - Actual Load M. G. D. (000.0000)

____

Columns 42-45 - Raw BOD ppm (00.00 X 1,000)

____

Columns 46-49 - Raw Total Suspended Solids ppm (00.00 X 1,000)

____

Columns 50-52 - Final BOD ppm (0.00 X 100)

____

Columns 53-55 - Final Total Suspended Solids ppm (0.00 X 100)

____

COLUMNS 56-80 - INVENTORY ITEMS AND STATUS

Column 56 - <u>Screens</u>

0 None
1 Bar screen - (hand cleaned)
2 Bar screen - (mech. cleaned)
3 Disc screen
4 Drum screen
5 Bar-minutor
6 Communitor
7 Communitor and bar screen (hand cleaned)
8 Communitor and bar screen (mech. cleaned)
9 Basket screen

Column 57 - <u>Grit Removal</u>

0 None
1 Grit channel - manual
2 Dual grit channels - manual
3 Grit channel - mech.
4 Grit channel - mech. with grit washer
5 Grit removed by aeration
6 Grit removed by aeration with grit washer
7 Grit pocket at screen
8 Cyclone separators
9

Column 58 - <u>Chemical Treatment and Aeration</u>

0 None
1 Chemical precipitation
2 Chemical precipitation with pre-aeration
3 Chemical precipitation with aeration in primary
4 Chemical precipitation and effluent aeration
5 Chemical precipitation, pre-aeration and effluent aeration

6 Pre-aeration
7 Aeration in primary
8 Pre-aeration and effluent aeration
9 Effluent aeration

Columns 59-60 - Primary Clarifiers

00 None
01 Septic tank
02 Earthen open septic tank
03 Raw sewage oxidation pond
04 Raw sewage oxidation ponds in parallel
05 Raw sewage oxidation ponds in series
06 Raw sewage oxidation ponds in series and parallel
07 Rectangular Imhoff tank
08 Circular Imhoff tank - rectangular flow through chamber
09 Circular Imhoff tank - circumferential flow through chamber
10 Mechanical Imhoff tank
11 Mechanical Imhoff tank with recirculation
12 Rectangular clarifier - hopper bottom
13 Rectangular clarifier - hopper bottom with skimmer
14 Rectangular clarifier - mechanical scraper
15 Rectangular clarifier - mechanical scraper with skimmer
16 Circular clarifier - hopper bottom
17 Circular clarifier - hopper bottom with skimmer
18 Circular clarifier - mech. scraper
19 Circular clarifier - mech. scraper with skimmer
20 Circular clarifier - tangential flow - hopper bottom
21 Circular clarifier - tangential flow - hopper bottom with skimmer
22 Circular clarifier - tangential flow - mech. scraper
23 Circular clarifier - tangential flow - mech. scraper with skimmer
24

Column 61 - Intermediate Clarifiers

0 None
1 Imhoff tank
2 Rectangular clarifier - hopper bottom
3 Rectangular clarifier - mech. scraper
4 Circular clarifier - hopper bottom
5 Circular clarifier - mech. scraper
6 Circular clarifier - tangential flow - hopper bottom
7 Circular clarifier - tangential flow - mech. scraper
8
9

Columns 62-63 - Final Clarifiers

00 None
01 Imhoff tank
02 Imhoff tank with skimmer
03 Rectangular clarifier - hopper bottom
04 Rectangular clarifier - hopper bottom with skimmer
05 Rectangular clarifier - mech. scraper
06 Rectangular clarifier - mech. scraper with skimmer
07 Circular clarifier - hopper bottom

08 Circular clarifier - hopper bottom with skimmer
09 Circular clarifier - mech. scraper
10 Circular clarifier - mech. scraper with skimmer
11 Circular clarifier - tangential flow - hopper bottom
12 Circular clarifier - tangential flow - hopper bottom with skimmer
13 Circular clarifier - tangential flow - mech. scraper
14 Circular clarifier - tangential flow - mech. scraper with skimmer
15 Oxidation pond
16 Oxidation ponds in parallel
17 Oxidation ponds in series
18 Oxidation ponds in series and parallel
19 Rectangular clarifier - hopper bottom plus oxidation pond or ponds
20 Rectangular clarifier - mech. scraper plus oxidation pond or ponds
21 Circular clarifier - hopper bottom plus oxidation pond or ponds
22 Circular clarifier - mech. scraper plus oxidation pond or ponds
23 Circular clarifier - tangential flow - hopper bottom oxidation pond or ponds
24 Circular clarifier - tangential flow - mech. scraper oxidation pond or ponds
25 Circular clarifier - mech. scraper plus sand filter with mech. filter wash

Columns 64-65 - Secondary Treatment
00 None
01 Oxidation pond
02 Oxidation ponds in parallel
03 Oxidation ponds in series
04 Oxidation ponds in series and parallel
05 Standard rate trickling filter - fixed nozzle - single stage
06 Standard rate trickling filter - fixed nozzle - two stage
07 Standard rate trickling filter - rotary distributor - single stage
08 Standard rate trickling filter - rotary distributor - two stage
09 Standard rate trickling filter - traveling distributor - single stage
10 Standard rate trickling filter - traveling distributor - two stage
11 High rate trickling filter - fixed nozzle - single stage
12 High rate trickling filter - fixed nozzle - two stage
13 High rate trickling filter - rotary distributor - single stage
14 High rate trickling filter - rotary distributor - two stage
15 High rate trickling filter - traveling distributor - single stage
16 High rate trickling filter - traveling distributor - two stage
17 Standard rate trickling filter - fixed nozzle - single stage - forced draft
18 Standard rate trickling filter - fixed nozzle - two stage - forced draft
19 Standard rate trickling filter - rotary distributor - single stage - forced draft
20 Standard rate trickling filter - rotary distributor - two stage - forced draft
21 Standard rate trickling filter - traveling distributor - single stage - forced draft
22 Standard rate trickling filter - traveling distributor - two stage - forced draft
23 High rate trickling filter - fixed nozzle - single stage - forced draft
24 High rate trickling filter - fixed nozzle - two stage - forced draft
25 High rate trickling filter - rotary distributor - single stage - forced draft
26 High rate trickling filter - rotary distributor - two stage - forced draft
27 High rate trickling filter - traveling distributor - single stage - forced draft
28 High rate trickling filter - traveling distributor - two stage - forced draft
29 Activated sludge - diffused air
30 Activated sludge - mech. aeration
31 Modified activated sludge diffused air
32 Modified activated sludge mech. aeration
33 Contact aeration

34 24 hour aeration
35 Modified activated sludge - package plant
36 Roughing filter
37 Contact beds
38 Dunbar beds
39 Two stage trickling filter - rotary distributor - high rate followed by standard rate filter
40 Roughing filter - followed by activated sludge

Column 66 - Recirculation

0 None
1 Effluent to head of plant
2 Bottom of final to head of plant
3 Ahead of final to head of plant
4 Effluent to secondary treatment units
5 Bottom of final to secondary treatment units
6 Ahead of final to secondary treatment units
7 Stage recirculation around filters
8 Stage recirculation after passing through clarifiers
9

Column 67 - Chlorination

0 None
1 Chlorination in final clarifier
2 Chlorination in contact chamber
3 Chlorination in effluent line
4 Pre chlorination
5 Pre chlorination and chlorination in final clarifier
6 Pre chlorination and chlorination in contact chamber
7 Pre chlorination and chlorination in effluent line
8 Chlorination following trickling filter
9

Columns 68-69 - Separate Sludge Digestion - First Stage or Single Stage

00 None
01 Fixed cover
02 Fixed cover with mech. mixing
03 Fixed cover with gas mixing
04 Fixed cover with recirculation
05 Fixed cover with internal heating
06 Fixed cover with internal heating and mech. mixing
07 Fixed cover with internal heating and gas mixing
08 Fixed cover with internal heating and recirculation
09 Fixed cover with external heating
10 Fixed cover with external heating and mech. mixing
11 Fixed cover with external heating and gas mixing
12 Fixed cover with external heating and recirculation
13 Floating cover
14 Floating cover with mech. mixing
15 Floating cover with gas mixing
16 Floating cover with recirculation
17 Floating cover with internal heating
18 Floating cover with internal heating with mech. mixing
19 Floating cover with internal heating with gas mixing

20 Floating cover with internal heating with recirculation
21 Floating cover with external heating
22 Floating cover with external heating with mech. mixing
23 Floating cover with external heating with gas mixing
24 Floating cover with external heating with recirculation
25 Open top
26 Open top with recirculation
27 Open top with surface sprays
28 Open top with surface sprays and recirculation
29 Aerobic digester

Columns 70-71 - Separate Sludge Digestion - Second Stage

00 None
01 Fixed cover
02 Fixed cover with mech. mixing
03 Fixed cover with gas mixing
04 Fixed cover with recirculation
05 Fixed cover with internal heat exchanger
06 Fixed cover with internal heat and mech. mixing
07 Fixed cover with internal heat and gas mixing
08 Fixed cover with external heat exchanger
09 Fixed cover with external heat and mech. mixing
10 Fixed cover with external heat and gas mixing
11 Floating cover
12 Floating cover with mech. mixing
13 Floating cover with gas mixing
14 Floating cover with recirculation
15 Floating cover with internal heat exchanger
16 Floating cover with internal heat and mech. mixing
17 Floating cover with internal heat and gas mixing
18 Floating cover with external heat exchanger
19 Floating cover with external heat mech. mixing
20 Floating cover with external heat gas mixing
21 Open digester
22 Open digester with recirculation

Column 72 - Sludge Handling

0 None
1 Vacuum filter
2 Vacuum filter and dryer
3 Sludge centrifuge
4 Incinerator
5 Open drying beds
6 Covered drying beds
7 Sludge pit
8 Sludge lagoon
9

Column 73 - Sludge Disposal

0 None
1 Liquid sludge used as fertilizer
2 Dried sludge used as fertilizer
3 Dried sludge used as fill
4 Barged to sea

5 Sold as commercial fertilizer
6 Burn
7 Discharge to stream
8 Sludge transported to another plant for processing
9

Column 74 - Thickeners
0 None
1 Mechanical
2 Flotation
3 Centrifugal
4
5
6
7
8
9

Column 75 - Gas Handling and Disposal
0 None
1 Separate gas burner
2 Gas used for heating and/or power
3 Separate gas holder with gas burner
4 Separate gas holder with utilization for heating and/or power with gas burner
5 Gas used for heating and/or power with gas burner
6 Gas allowed to escape to atmosphere
7
8
9

Column 76 - Flow Measuring and Recording Equipment
0 None
1 Weir available ahead of plant
2 Weir available for effluent
3 Pumping records
4 Continuously recording equipment at influent
5 Continuously recording equipment at effluent
6 Flow measuring device at influent
7 Flow measuring device at effluent
8 Multiple measuring and recording devices
9

Column 77 - Laboratories and Offices
0 None
1 Office
2 Office and small laboratory
3 Office and complete laboratory
4 Office and complete laboratory including bacterial laboratory
5 Small laboratory
6 Complete laboratory
7 Complete laboratory including bacterial laboratory
8 Laboratory at another location
9

Column 78 - Effluent

0 Percolation
1 Recharge
2 Irrigation
3 Stream flow less than average sewage flow
4 Stream flow more than average sewage flow
5 Lake
6 Bay, Bayou, Gulf
7 Dry water course
8 Roadside ditch
9 Industrial reclamation

Columns 79-80 - Pollution Status

Complete Plant, i.e. primary and secondary treatment facilities

00 Plant below design load - Satisfactory operation and maintenance
01 Plant below design load - Unsatisfactory operation and maintenance
02 Primary overloaded - Satisfactory operation and maintenance
03 Primary overloaded - Unsatisfactory operation and maintenance
04 Secondary overloaded - Satisfactory operation and maintenance
05 Secondary overloaded - Unsatisfactory operation and maintenance
06 Entire plant overloaded - Satisfactory operation and maintenance
07 Entire plant overloaded - Unsatisfactory operation and maintenance
08 Plant grossly overloaded - Useless
09 Plant grossly overloaded - Renovation possible

Primary Treatment Only

10 Primary below design load - needs secondary facilities - Satisfactory operation and maintenance
11 Primary below design load - needs secondary facilities - Unsatisfactory operation and maintenance
12 Primary overloaded - needs secondary facilities - Satisfactory operation and maintenance
13 Primary overloaded - needs secondary facilities - Unsatisfactory operation and maintenance
14 Primary obsolete - needs secondary facilities - Useless
15 Primary obsolete - needs secondary facilities - Renovation possible
16 Septic tank - no secondary facilities - Useless

Primary with Trickling Filter, but no Final Clarifier (or oxidation pond)

17 Primary and filter - below design load - Satisfactory operation
18 Primary and filter - below design load - Unsatisfactory operation
19 Primary overloaded and filter below design - Satisfactory operation
20 Primary overloaded and filter below design - Unsatisfactory operation
21 Primary below design and filter overloaded - Satisfactory operation
22 Primary below design and filter overloaded - Unsatisfactory operation
23 Primary overloaded and filter overloaded - Both useless
24 Primary overloaded and filter overloaded - Primary useless
25 Primary overloaded and filter overloaded - Filter useless
26 Primary overloaded and filter overloaded - Renovation possible
27
28
29

Raw Sewage Ponds

30 Ponds adequate for secondary treatment - needs primary facilities - Satisfactory operation and maintenance

31 Ponds adequate for secondary treatment - needs primary facilities - Unsatisfactory operation and maintenance
32 Ponds not adequate for secondary treatment - needs primary facilities and additional secondary facilities - Satisfactory operation and maintenance
33 Ponds not adequate for secondary treatment - needs primary facilities and additional secondary facilities - Unsatisfactory operation and maintenance
34 No treatment plant - Discharge raw sewage

99 Plant abandoned