Water for the Growing Needs of Harrison County Mississippi

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1856

Prepared in cooperation with the Harrison County Development Commission and the Harrison County Board of Supervisors

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By ROY NEWCOME, Jr., D. E. SHATTLES, *and* C. P. HUMPHREYS, Jr.

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An evaluation of the potential of streams and aquifers to satisfy the growing industrial and municipal water needs of an expanding economy on Mississippi's gulf coast

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WATER FOR THE GROWING NEEDS OF HARRISON COUNTY, MISSISSIPPI

By ROY NEWCOME, JR., D. E. SHATTLES, and C. P. HUMPHREYS, JR.

ABSTRACT

The potential for water-supply development in Harrison County is almost unlimited. During an average year, more than 350 billion gallons of water flow into the Gulf of Mexico from the streams of the county. With storage reservoirs these streams have a potential sustained supply of hundreds of millions of gallons per day. Recreation uses and flood-control benefits could also be considered in reservoir design.

Upstream from the zones of salt-water penetration, mineral content is low and fairly constant. Water in the streams generally has high color and low pH; treatment would be required for most municipal and industrial uses. Impoundment in reservoirs normally would have little effect on the quality of the surface water. However, impoundment would trap most of the suspended-sediment load of the streams.

Flooding along the major streams of Harrison County is a minor hazard at present (1966), but with further industrial development and urbanization, flooding in these now rural areas could become serious. Intense rainfall from thunderstorms and hurricanes causes serious local flooding in the populous areas near the coast. Tidal flooding, a result of tropical storms, is an ever-present hazard in areas near the coast.

The ground-water reservoir, which at present provides all fresh-water supplies, is capable of supporting many times the 25 million gallons per day withdrawal through existing wells. Fresh water occurs to depths as great as 2,500 feet in sand aquifers of Pliocene and Miocene age. Many of the aquifers have high transmissibility; most of those tested have transmissibility in the range of 50,000–100,000 gallons per day per foot. Although few wells produce more than 1,000 gallons per minute, several of the aquifers can yield two to three times that amount to wells designed for the higher production.

Artesian water levels along the coast are declining at a rate of 1 foot per year on the average; however, water levels are still above or only slightly below the land surface in most places, and considerable additional drawdown is economically available. Newly discovered deep aquifers (1,700–2,500 ft) have water levels 100 feet above the surface and probably will provide flowing yields of 2,000 gallons per minute or more. The temperature of this deep water is nearly 100°F.

Nearly all the ground water is of good quality and requires little or no treatment for most uses. It is soft, and total mineral content is usually less than 250 parts per million. Color is seldom a problem, although it may have to be con-

sidered in the undeveloped deep aquifers. The pH ordinarily is greater than 7.0, but it is slightly less than 7.0 in most places in the shallow aquifers.

INTRODUCTION

NEED FOR INVESTIGATION

An evaluation of the water resources of Harrison County was made necessary by the rapid growth of the industrial complex along the Mississippi gulf coast. As a center of population and commerce, the Gulfport-Biloxi area must have facilities to support a greatly increased economy as industrial development gains impetus. Construction of the Harrison Industrial Seaway has drawn the attention of many industries. Several plants were in operation or under construction during the 2-year period of this water-resources study.

Because all existing municipal water supplies and practically all industrial supplies have been obtained from the ground-water reservoir, the potential effect of increased withdrawals on the slowly declining artesian pressure has caused increasing concern. A potential problem corollary to declining water levels is saline-water encroachment from downdip regions of the aquifers. Therefore, the attention of local planners has been directed toward development of surface-water reservoirs to provide a water supply to meet the anticipated increase in water use.

Knowledge of Harrison Countys' water resources will be a major factor in planning new water supplies or expanding existing ones. Large additional withdrawals from wells may entail the development of previously untapped aquifers or the redistribution of present pumpage. Surface-water impoundments will require adequate source streams, reliable damsites, and quality control. The information needed for these alternative developments can be obtained only by thorough study of the hydrologic system.

COOPERATION AND ACKNOWLEDGMENTS

The investigation of Harrison County's water resources was sponsored jointly by the Harrison County Development Commission and Board of Supervisors and the Water Resources Division of the U.S. Geological Survey. Many individuals and organizations cooperated with the project team by furnishing information, access to records and property, and aid in field operations. The courtesy and patience of water-supply managers at Biloxi, Gulfport, Pass Christian, Long Beach, the Army and Navy bases, and various industries are greatly appreciated. Well drillers, as usual, provided invaluable service by "filling in the gaps" in many records.

PURPOSE AND SCOPE OF REPORT

This report is intended to serve as a guide for water-supply developers and managers in Harrison County. By informing them as to where the water is, how much is there, what its quality is, and the effects of its development, the report will contribute to wise and efficient use of the resource. The information presented is urgently needed as the gulf coastal region moves farther into the industrial community.

The scope of the investigation and report involves streamflow and basin analysis, aquifer hydraulics, quality and treatment of water, and the effects of changes imposed on the hydrologic regimen. Several alternatives of water-supply development are considered. They may be summarized as (1) additional withdrawal from presently used aquifers, (2) development of deeper, recently discovered aquifers, and (3) proposed and potential reservoir construction. Ultimate development probably will call for utilization of all three.

SETTING

LOCATION AND DEVELOPMENT OF AREA

Harrison County is the central of three counties that compose the Mississippi gulf coast. Jackson County, on the east, separates Harrison County from Alabama, and Hancock County, on the west, separates it from Louisiana. Stone County lies to the north, and the shallow Mississippi Sound to the south. Cat Island and Ship Island, 8 and 12 miles from the coastline, respectively, are lowlying barrier islands that separate the sound from the Gulf of Mexico (fig. 1).

Harrison County is an area of 585 square miles. Much of the county is pine forested, and most of the population lives in a 3-mile-wide strip along the coast. The county is the second most populous in Mississippi. Total population in 1960 was 119,489, with municipal population divided among Biloxi (44,053), Gulfport (30,204), Long Beach (4,770), Mississippi City (4, 169), Pass Christian (3,881) North Gulfport (3,323), D'Iberville (3,005), and Handsboro (1,577). Thus, only 20 percent of the inhabitants live in rural areas. The county's entire coastline is residential and comercial in development; there is no open land.

Construction of the Harrison County Industrial Seaway will bring about an increase in population, and probably shifts in concentration of the populace will accompany the increase. As new industries enter the area and are added to the plants already located or under construction, the economic structure of the area will also undergo a change. Whereas the emphasis has been primarily on recreational and tourism

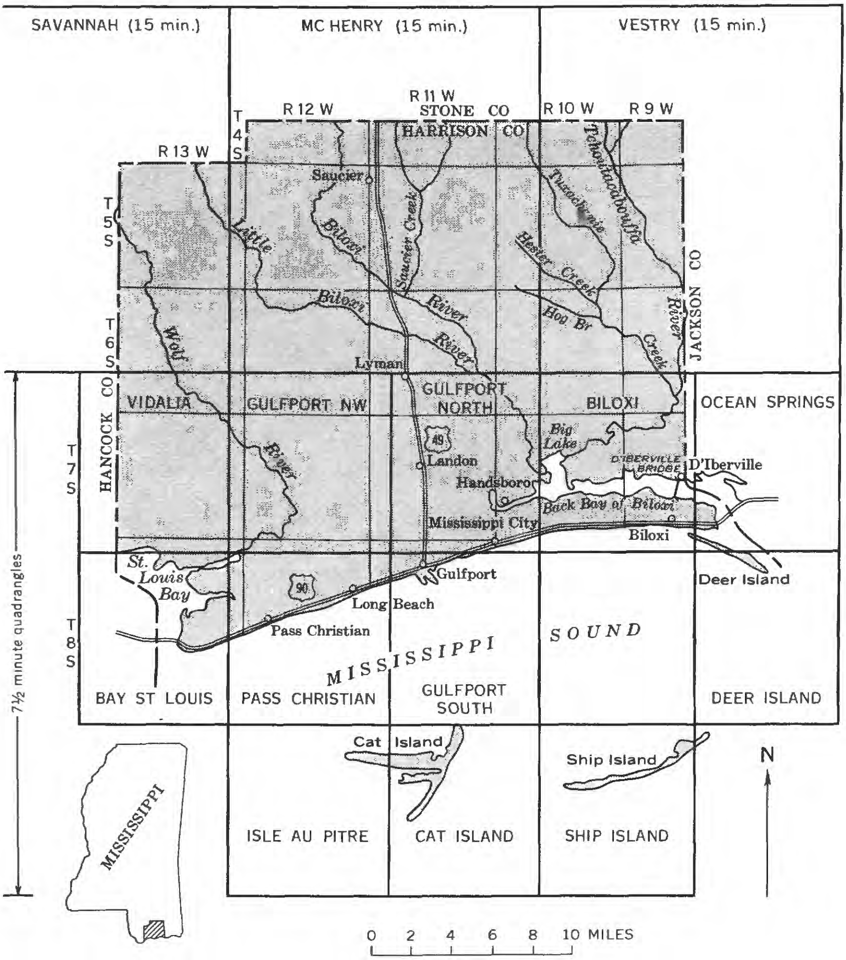

FIGURE 1.—Location map and topographic quadrangles, Harrison County.

aspects of the environment, industrial development and supporting activities will claim attention.

The role of water in the changing setting just described is one that cannot be disregarded. Ever-increasing demands will be made on the water resources—for industrial use, for municipal supply, and for recreation.

HYDROLOGIC ENVIRONMENT

CLIMATE

The climate of the Mississippi gulf coast is humid subtropical. Summers are long and warm, and the winters, short and mild. Annual rainfall averages 60 inches on the coast; July is normally the wettest month, and October the driest. Torrential showers, sometimes accompanying hurricanes, have produced as much as 12 inches of rain in a 24-hour period. Extreme floods, though infrequent in this region, generally follow such rains, particularly when the rains occur in April. Temperatures seldom exceed 100°F or fall below 25°F. The average annual temperature is 68°F. July and August are the hottest months, and January, the coldest. The average air temperature is a major influence on temperature of shallow ground water, and air temperature, wind, and humidity are the controlling factors in evaporation from surface-water bodies. The frost-free season on the coast lasts about 270 days, from late February to late November. This season is somewhat shorter for the inland part of the county.

The following table contains average rainfall and temperature data for two coastal stations of the U.S. Weather Bureau at the east and west margins of Harrison County.

TOPOGRAPHY AND DRAINAGE

Most of Harrison County is gently rolling terrain with well-established stream valleys. The drainage pattern is dendritic. A strip of flat land parallels the coastline and terminates in a manmade seawall and a white-sand beach constructed with dredged material from Mississippi Sound. Elevations range from sea level on the coast to 230 feet above sea level in the north-central part of the county. Relief is nowhere pronounced, although considerable contrast exists between the topography of the seashore and that in the upper reaches of the streams.

Harrison County is drained principally by three major streams which rise outside the county and flow generally southeastward through the project area to bays that open onto Mississippi Sound. The Wolf River is the largest of these streams and drains the western section of Harrison County. The Biloxi and Tchoutacabouffa Rivers, which have nearly equal drainage areas, drain the central and eastern sections of the county, respectively. Smaller streams drain parts of the county near the coast.

The Tchoutacabouffa River drains an area of about 250 square miles and flows into Big Lake at the west end of Back Bay of Biloxi. The headwaters of Tuxachanie Creek, the major tributary to the Tchoutacabouffa River, lie in Stone County, Miss., at an elevation of 300 feet. The flood plain of the Tchoutacabouffa River is heavily wooded throughout the upper and middle reaches but consists of swamps and marshland as the river nears the coast. The river channel is well defined and meanders widely on its flood plain. Many lakes and bayous are on the flood plain below the mouth of Tuxachanie Creek; most are

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Average rainfall (in.)							
Biloxi	3.85	4.00	6.10	4.75	4.71	5.09	7.33	5.71	6.50	2.52	3.29	4.73	58.58
Bay St. Louis	4.33	4.57	5.95	5.79	4.63	4.73	7.86	5.96	6.24	2.68	3.43	5.25	61.42
						Average temperature (°F)							
Biloxi	53.6	55.4	60.1	67.3	74.8	80.6	81.9	81.9	78.1	69.9	59.6	58.0	68.1
Bay St. Louis	53.2	55.6	60.4	67.9	75.3	80.9	82.1	82.1	78.6	69.9	59.3	54.4	68.3

connected to the main channel and are subject to overflow at intermediate river stages.

The Biloxi River flows out of the hills of Stone County on the north and meanders south and east in a well-defined channel to Big Lake and Back Bay of Biloxi. The drainage area of the Biloxi River is about 280 square miles. Elevations of the land surface in the basin range from sea level along the coast to 360 feet above sea level in Stone County. The major tributaries to the Biloxi River are Saucier Creek (drainage area, 45 sq mi) and the Little Biloxi River (drainage area, 78 sq mi).

Headwaters of the Wolf River lie in Lamar County at an elevation of 420 feet above sea level. Where the stream enters Harrison County, near the northwest corner, the drainage area is 253 square miles, and the total drainage area at St. Louis Bay is about 360 square miles. The flood plain is heavily wooded and is occupied on the lower reaches by many lakes and bayous which are connected to the main channel.

GEOLOGY

The gulf coastal area has been slowly subsiding for millions of years, forming a vast sinking trough, or geosyncline. As the trough has sunk, streams emptying into the Gulf of Mexico have kept the trough nearly full by depositing into it huge quantities of mud, sand, and gravel. According to Howe (1936, p. 82), "these sediments have been concentrated along a narrow zone paralleling the present shore, and, since the beginning of the Eocene, have accumulated to a thickness which probably exceeds 30,000 feet (south of the Mississippi River) * * * the region of the present coastline has been depressed under the weight of these deposits to almost three times the present maximum depth of the Gulf of Mexico. The major axis of the Gulf Coast geosyncline approximately parallels the Louisiana coastline." This circumstance made it possible for rivers and streams to deposit the deltaic sand and gravel which make up the principal ground-water aquifers in Harrison County.

Geologic units containing fresh water in Harrison County are of Miocene to Recent age. Water-bearing sands, or aquifers, occur irregularly throughout the 1,500- to 2,500-foot-thick fresh-water section. There are no thick, consistently traceable clay beds. The same is true for the sand beds; they are irregular in thickness and extent, and many are apparently lenticular. However, sandy zones—intervals in which sand constitutes a dominant part of the material—are reasonably traceable and, along with fossils, have been used by some geologists as a basis for stratigraphic subdivision. The Catahoula Sandstone and the Hattiesburg and Pascagoula Formations have been named in the Miocene and the Graham Ferry and Citronelle Formations in the Pliocene.

Detailed examinations of electric logs and water-quality analyses during this investigation failed to reveal mappable horizons in the fresh-water section that could be reliably considered as formation contacts. The authors conclude, therefore, that, at least geohydrologically, all rocks from the base of Miocene (fig. 2) to within about 100 feet of the land surface should be designated Miocene and Pliocene rocks, undifferentiated, and that the sediments above an irregular depth of 40 to 100 feet be designated Citronelle Formation except where they have been eroded and replaced by Pleistocene terrace deposits and Recent alluvium and beach deposits.

Water-bearing beds of the Miocene and Pliocene Series are composed chiefly of clean quartz sand, are tan or light gray, and range in grain size from very fine to very coarse. Both the bed thickness and the grain size vary considerably within short distances, typical effects of deltaic and estuarine deposition. Many beds are more than 100 feet thick.

Strike of the beds is east-southeast across Harrison and Stone Counties. Dip of the base of the Miocene rocks is south-southwest and increases from 50 feet per mile in northern Stone County to 90 feet per mile at the coast (fig. 2). Although stratigraphic points are difficult to correlate in the Miocene and Pliocene Series, the dip of the beds probably is less in the shallower zones owing to normal seaward thickening of the section. The dip of sediments above an elevation of 1,000 feet below sea level on the coast probably is about 30 feet per mile. Except for the regional strike and dip described above, the structures are not pronounced in the fresh-water section.

WATER USE

The largest single user of water in Harrison County—300 mgd (million gallons per day)—is the Mississippi Power Co., generating plant at Handsboro; most of the water used is for cooling and is saline surface water obtained from the Back Bay of Biloxi. Practically all of the water supplies in the county are obtained from wells. The total amount of fresh water pumped is about 25 mgd. Municipalities, industries, and Keesler Air Force Base—in that order—are the heaviest users of fresh water (fig. 3).

Water-supply development is fairly well distributed among the various aquifers. The distribution and approximate rate of withdrawal, in millions of gallons per day, along the coast are given in table 1.

TABLE 1.—*Approximate pumpage from aquifers supplying coastal wells in Harrison County*

[Pumpage in million gallons per day. Aquifer depths refer to each locality individually; the various aquifers do not have the same depth along the coast]

Aquifer depth (ft)	Locality				
	Pass Christian	Long Beach	Gulfport	Keesler AFB	Biloxi
600	----------	0.5	--------	3.6	---------
650	----------	--------	0.5	----------	0.5
700	----------	--------	--------	----------	1.0
750	----------	--------	3.0	----------	---------
800	----------	--------	2.0	----------	---------
850	0.2	--------	1.0	----------	2.0
900	.2	.5	.1	----------	
950	----------	--------	.5	----------	.5
1,000	.2	--------	.2	----------	1.0
1,100	.1	--------	--------	----------	---------
1,200	----------	--------	2.0	----------	3.0

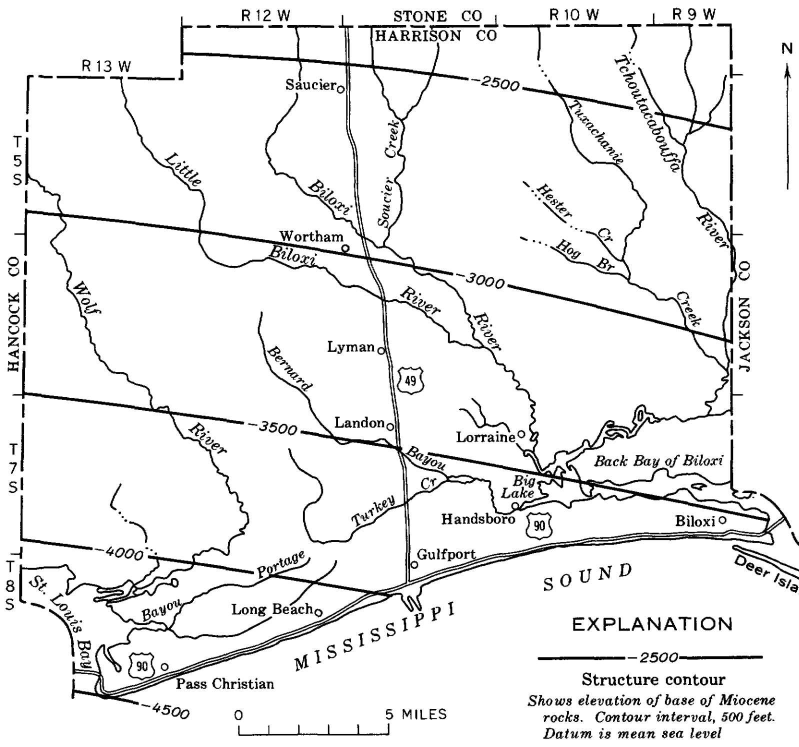

FIGURE 2.—Elevation of the base of the Miocene rocks.

Future use of water will be several times the present use in Harrison County. Each new industry that locates on or near the industrial seaway brings with it both an industrial water requirement, large or small according to the type and size of industry, and municipal water requirement proportional to the number of people that the industry attracts to the area.

To provide adequate supplies for future use it will be necessary to consider the following alternatives of development:

1. Distribution of ground-water withdrawals, both areally and stratigraphically, in a manner that will produce the maximum quantities of water with a minimum effect on water levels.
2. Development of supplies from deep-lying aquifers that are presently untapped.
3. Location of surface reservoirs so that maximum benefits will accrue to water supply, recreation, and flood control.

WATER PROBLEMS

No substantial water-supply problems exist at present in Harrison County. Declines in artesian pressure have necessitated installation or lowering of pumps in many wells, but a large amount of available

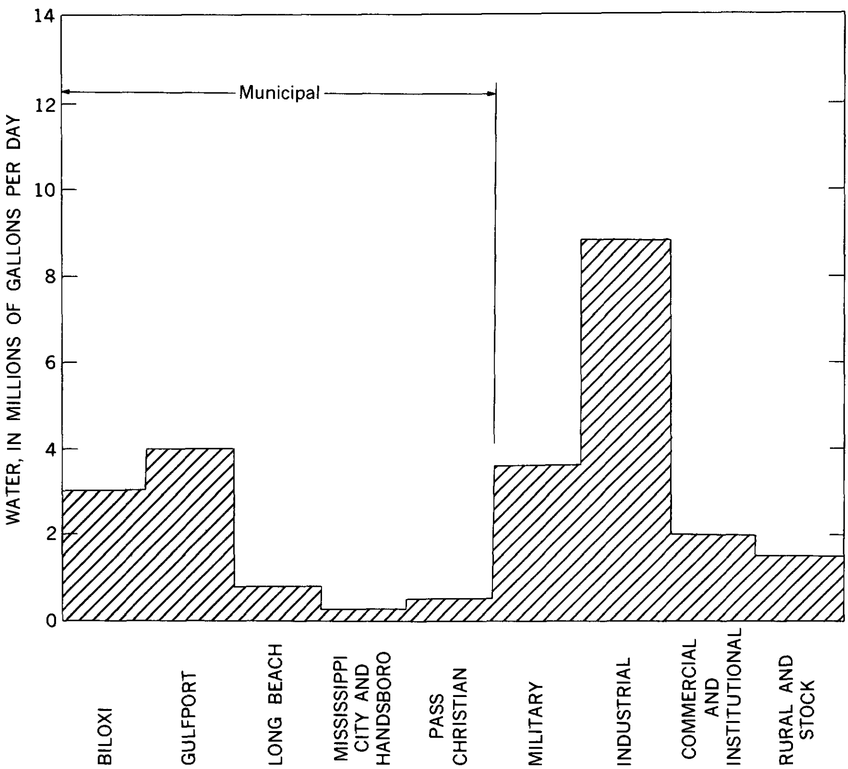

FIGURE 3.—Distribution of fresh-water use during 1966, according to locality or type of use.

drawdown remains. Water-quality problems are rare. Deep-well supplies at Biloxi have had high chloride concentrations since the early days of their development, but long-term records of water quality for nearly all the aquifers tapped along the coast reveal no increase in chloride content in the county (Lang and Newcome, 1964).

If a problem exists, it is the future prospect of supplying greatly increased quantities of water for industrial needs. Water adequate in quantity or quality for some industrial needs probably cannot be obtained economically from the ground-water reservoir, and surface water will have to be considered. During drought periods, the sustained flow of several streams in the county will not satisfy large demands, and surface impoundment may be necessary to sustain desired supplies.

Flooding along streams is a problem which affects a fairly small part of the population at present (1966), but, as the economy grows, industrial and urban encroachment upon the flood plains and reclamation of marshes will create many problems. Planning and zoning before these problems arise are necessary to the wise management and orderly development of the area.

In the past 20 years several hurricanes have caused flooding and considerable property damage in Harrison County. If the frequency and extent of these tropical storms were understood, proper site selection and design could greatly reduce or could prevent future damage.

Urban development in Harrison County will undoubtedly affect the quality of the streams. As communities grow, the amount of pollutants from stormwater runoff that enters streams will increase. Further urbanization of the basins may introduce a potential sediment problem. The high concentrations of suspended sediment during floods would interfere with the use of stream water by industries and municipalities.

STREAMS

A large potential supply of surface water of good mineral quality suitable for most municipal and industrial needs is available from streams in the county. During an average year, more than 350 billion gallons of water flows into Mississippi Sound from the Tchoutacabouffa, Biloxi, and Wolf Rivers—enough to supply the present needs of 20 cities the size of Jackson, Miss. Streamflow and stream quality vary with time and place, and this variability requires continual collection and interpretation of many items of data to make an adequate appraisal of the surface-water resources in the county. Steamflow and water-quality data have been collected and analyzed from a network of continuous-record gaging stations, supplemented with data collected at partial-record sites (pl. 1; table 2).

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TABLE 2.—*Descriptions of stream-gaging stations and water-sampling sites*

Period of streamflow record: Dates followed by an open dash (1964–) indicate continuous record from the date shown.
Type of record: 1, continuous-record gaging station; 2, low-flow partial-record station; 3, miscellaneous flood-data site; 4, periodic chemical quality sampling site; 5, sediment sampling site.

Identification No.	Station	Drainage area (sq mi)	Period of streamflow record	Type of record: Streamflow	Type of record: Quality	Location
2-4803.5	Tchoutacabouffa River near Biloxi.	[1] 58	1964–	2	4, 5	SE¼ sec. 33, T. 5 S., R. 9 W., on county road 3 miles east of State Highway 15, 10 miles north of Biloxi.
2-4804	Hester Creek near Biloxi	10.5	1952–56, 1958, 1965–	2		SE¼ sec. 2, T. 6 S., R. 10 W., at bridge on county road 3 miles northeast of State Highway 67, 10 miles north of Biloxi.
2-4804.5	Hog Branch near Biloxi	8.5	1952–56, 1958, 1965–	2		NE¼ sec. 11, T. 6 S., R. 10 W., at bridge on county road 2 miles northeast of State Highway 67, 9 miles north of Biloxi.
2-4805	Tuxachanie Creek near Biloxi	92.4	Oct. 1952–	1	4, 5	NW¼ sec. 20, T. 6 S., R. 9 W., at bridge on State Highway 15, 7 miles north of Biloxi.
2-4806	Tchoutacabouffa River near Wool Market.	[1] 220	1957, 1964	3		SW¼ sec. 33, T. 6 S., R. 9 W., at bridge on State Highway 67 and 15, 5 miles north of Biloxi.
2-4810	Biloxi River at Wortham	98.3	Oct. 1952–	1	5	SE¼ sec. 31, T. 5 S., R. 11 W., at bridge on U.S. Highway 49, ¾ mile east of Wortham.
2-4810.5	Saucier Creek at Wortham	[1] 40	1952–55, 1958, 1963–	2	5	NW¼ sec. 33, T. 5 S., R. 11 W., at bridge on county road 1½ miles east of U.S. Highway 49, 2¼ miles east of Wortham.
2-4811	Little Biloxi River near Lyman	[1] 71	1942–43, 1952–55, 1958, 1964–.	2	5	NE¼ sec. 17, T. 6 S., R. 11 W., at bridge on U.S. Highway 49, 2 miles north of Lyman.
2-4811.3	Biloxi River near Lyman	[1] 250	Aug. 1964–	1	4, 5	SE¼SE¼ sec. 25, T. 6 S., R. 11 W., at bridge on county road 1.2 miles downstream from the Little Biloxi River, and 4.6 miles east of Lyman.
2-4811.5	Biloxi River near Lorraine	264	Nov. 1959–	3		NW¼ sec. 8, T. 7 S., R. 10 W., at bridge on county road at Lorraine, 4 miles north of Mississippi City.
2-4812	Bayou Bernard near Gulfport	[1] 16	1942–43, 1953–58	2		SW¼ sec. 9, T, 7 S., R. 11 W., at bridge on U.S. Highway 49, 4 miles north of Gulfport.
2-4812.5	Turkey Creek near Gulfport	24.3	1942, 1953–55, 1958	2		On line between sections 21 and 28, T. 7 S., R. 11 W., at bridge on U.S. Highway 49, 2½ miles north of Gulfport.
2-4815	Wolf River near Lyman	253	1942–43, 1944–48,[2] 1952–53, 1958, 1963, Sept. 1964–[2]	1, 2	4, 5	SW¼ sec. 19, T. 5 S., R. 13 W., at bridge on State Highway 53, 15 miles northwest of Lyman.
2-4815.1	Wolf River near Landon	[1] 306	1964–	2	4, 5	NE¼ sec. 34, T. 6 S., R. 13 W., at bridge on county road 11 miles northwest of Landon.
2-4815.2	Wolf River near Long Beach	353	Nov. 1959–Aug. 1965.	3		SE¼ sec. 28, T. 7 S., R. 12 W., at Noel Cornibe residence, on east bank of Wolf River 5 miles north of Long Beach.

[1] Approximate.
[2] Operated as a continuous-record gaging station.

During periods of low streamflow, water shortages can occur that will adversely affect present and future water supplies and recreational facilities, increase pollution problems, and allow salt water from estuaries to penetrate farther upstream. Deficient flow often coincides with a time of maximum water demand, and without storage, serious conditions may result. Too much water (during periods of flooding or periods of inundation from hurricane tides), however, may cause loss of life and property damage.

QUANTITY OF WATER AVAILABLE

FLOW DURATION

Analysis of flow-duration data provides a means of appraising streamflow variability. A flow-duration curve is a cumulative-frequency curve showing the percentage of time during which specified discharges were equaled or exceeded in a given period. If streamflow during the period represented by the curve is typical of the long-term flow pattern of the stream, the curve can be regarded as representing the long-term average distribution of future streamflow for water supply, waste dilution, recreation, and water power.

Flow-duration data for continuous-record gaging stations in Harrison County were computed from the daily discharges by the total-period method. These data show, without regard to chronological order, the flow characteristics of the streams throughout the range of discharge. Estimates of the duration of flows at short-term continuous-record stations were obtained by using methods described by Searcy (1959).

Flow-duration data for stream-gaging stations in Harrison County, adjusted to the base period October 1928–September 1957, are given in table 3 and can be plotted on logarithmic-probablity paper if graphic presentation is desired. These data are reliable long-term predictions of the future flow patterns of the streams, provided no unusual climatological or manmade changes occur; however, values for individual years will deviate, sometimes considerably, from the long-term average predicted.

Flow-duration curves for Tuxachanie Creek near Biloxi, Biloxi River at Wortham, and Wolf River near Lyman are shown in figure 4. A direct comparison of these streams can be made, since the effect of the size of drainage basin has been removed by dividing discharge by drainage area. Because streamflow represents the integrated effects of climate, geology, and topography on runoff, the shape of the curve is determined by these characteristics of a drainage basin. The slope of the lower end of the duration curve is an index of the base-flow yield. Duration curves for Tuxachanie Creek and the Biloxi and Wolf

TABLE 3.—*Duration of daily flow at stream-gaging stations in Harrison County*

[Based on the period 1929-57]

Identification No.	Station	Drainage area (sq mi)	Flow, in cubic feet per second, which was equaled or exceeded for indicated percent of time																
			99.5	99	98	95	90	80	70	60	50	40	30	20	10	5	2	1	0.5
2-4805	Tuxachanie Creek near Biloxi	92.4	3.6	4.2	5.0	7.0	9.8	16	24	37	56	86	138	233	480	850	1,630	2,500	3,720
2-4810	Biloxi River at Wortham	98.3	3.1	3.7	4.6	6.6	9.5	16	26	41	63	95	147	241	474	820	1,500	2,250	3,260
2-4811.3	Biloxi River near Lyman	[1] 250	----	25	29	38	50	74	107	150	208	----	----	----	----	----	----	----	----
2-4815	Wolf River near Lyman	253	18	21	25	35	48	73	102	141	190	262	370	570	1,050	1,710	3,080	4,500	6,500
2-4815.1	Wolf River near Landon	[1] 306	----	30	36	50	67	100	137	188	250	----	----	----	----	----	----	----	----

[1] Approximate.

Rivers are similarly shaped in the lower ends. These relatively flat curves indicate that fairly large amounts of ground water are released to the streams during rainless periods.

The information shown in figure 4, although expressed as discharge per square mile, is not meant to imply that each drainage basin has uniform discharge. The streamflow yields of segments of individual streams vary because of differences in topography, surficial geology, urban development, land use, and channel incision. Therefore, care should be exercised in the extrapolation of flow-duration data to an ungaged site solely on the basis of size of drainage area. One can reasonably assume that the duration curve for a gaging station is usable for a limited distance upstream or downstream from the site where streamflow data were collected. However, where the site under study is in a different geologic environment and there is a considerable difference in drainage area, a careful study of the site, using several base-flow measurements, is required.

Flow-duration data in this report should aid the water manager or design engineer in making estimates for water supply, reconnaissance studies, selection of sites worthy of detailed investigation, stream-pollution studies, and other hydrologic analyses.

The following example (Searcy, 1959, p. 29) illustrates one use of flow-duration data in the design of treatment facilities for sewage:

Assume—

1. No contamination above point under investigation.
2. Allowable BOD (biochemical oxygen demand) for stream below the disposal plant is 4 ppm (parts per million).
3. The allowable BOD (4 ppm) may be exceeded not more than 1 percent of the time, on the average.
4. Flow equals or exceeds 10 cfs (cubic feet per second) 99 percent of the time.
5. Sewage flow is 1 million gallons per day (1.55 cfs).
6. BOD of untreated sewage is 200 ppm.

Compute the degree of treatment required:

The allowable BOD below disposal plant outlet=4 ppm (10 cfs+1.55 cfs).

The BOD of the sewage=200 ppm×1.55 cfs.

The degree (D) of BOD not removed by treatment ($D\times200\times1.55$) must not exceed the allowable (4×11.55),

or $D=\dfrac{4\times11.55}{200\times1.55}=0.15$, or 15 percent.

Thus, 85 percent of the BOD must be removed by the sewage disposal plant.

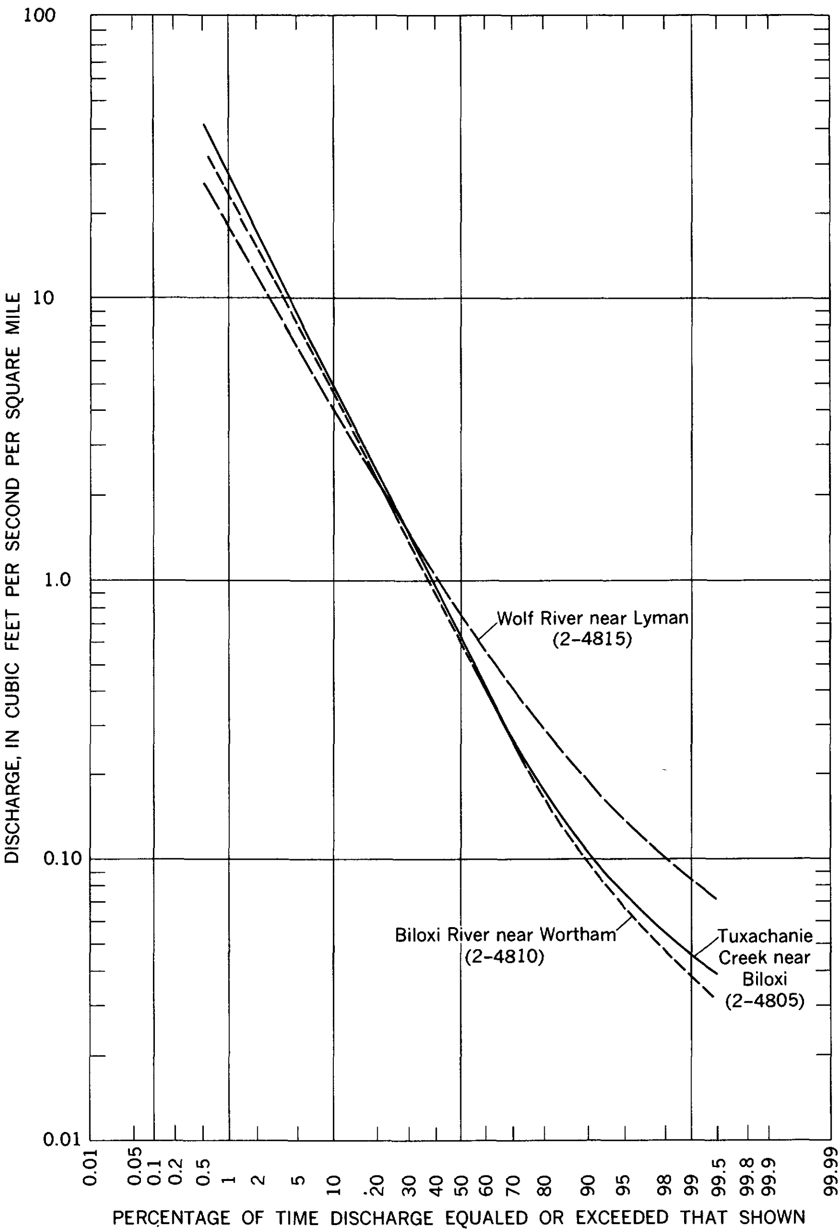

FIGURE 4.—Duration curves of daily flow for three streams (based on data adjusted to the period 1929–57).

The above discussion is not intended to imply that dilution of waste by streamflow is a substitute for adequate treatment. Rather, it illustrates a means of insuring adequate waste treatment before release into a stream, for it is desirable to have the water of our streams as clean as possible, not as unclean as admissible.

LOW-FLOW FREQUENCY

The probable low flow of a stream is of major concern to many users and is often the controlling factor in determining the dependable supply of water available for industrial or municipal development. The quantity, duration, and probability of occurrence of low flows is necessary for intelligent water planning, design, and management. Statistical analyses of past records of low flows, adjusted to the base period 1929–57, are used in this report to predict the probable frequency of low flows in the future. Data from continuous-record gaging stations in and adjacent to Harrison County were used to determine the lowest mean discharge for periods of 7, 15, 30, 60, 120, and 183 consecutive days and the recurrence interval between these discharges. The low-flow frequency data and estimated minimum discharges for gaging stations, given in table 4, are estimates of the probable frequency of low flows at the indicated locations, provided no appreciable climatological or manmade changes occur upstream from these locations. For the short-term continuous-record gaging stations and the low-flow partial-record stations, where only base-flow discharge measurements were made, estimates are confined to the 7-day Q_2, 7-day Q_{20}, and the minimum discharge during the period 1938–65.[1]

Good base-flow yields can be expected from most streams in Harrison County. Major streams in the area produce between 0.06 and 0.25 cfs per sq mi during the normal low-flow period (table 4). The high base flow of the Wolf, Tchoutacabouffa, and Biloxi Rivers and their headwater tributaries is sustained by seepage from areally extensive surficial deposits of the Citronelle Formation, which is composed chiefly of sand and gravel. Streamflow data indicate that the smaller streams near the coast and bedded entirely in Recent deposits have very low yields during extended rainless periods. Many local drainage channels are in and near the urban centers. Manmade changes in these water courses have so altered the regimen of the streams that a hydrologic study of these streams and ditches is beyond the scope of this

[1] The 7-day Q_2 is defined as the lowest average flow for 7 consecutive days occurring at an average interval of 2 years. The 7-day Q_2 has a 50 percent probability of being exceeded in a given year and is used as an index of normal annual low flow. The 7-day Q_{20} is defined as the lowest average flow for 7 consecutive days occurring at an average interval of 20 years and is used as an index of flow for a 20-year drought.

TABLE 4.—*Magnitude and frequency of annual low flow and estimated minimum discharge at stream-gaging stations in Harrison County*

Identification No.	Station	Drainage area (sq mi)	Period (days)	Annual low flow (cfs) for indicated recurrence interval (years) (adjusted to base period 1929–57)						Estimated minimum discharge (cfs) 1938–65	7-day Q_2 (cfs per sq mi)
				1.03	1.2	2	5	10	20		
2-4803.5	Tchoutacabouffa River near Biloxi	[1] 58	7	-----	-----	7.8	-----	-----	2.5	2.6	0.13
2-4804	Hester Creek near Biloxi	[1] 10.5	7	-----	-----	2.5	-----	-----	1.1	.9	.25
2-4804.5	Hog Branch near Biloxi	[1] 8.5	7	-----	-----	1.0	-----	-----	.3	.3	.12
2-4805	Tuxachanie Creek near Biloxi	92.4	7	35	16	7.5	4.0	2.8	2.0	[2] 1.6	.08
			15	41	19	8.9	4.6	3.2	2.3	-----	-----
			30	51	23	11	5.5	3.8	2.7	-----	-----
			60	76	34	16	7.8	5.4	3.8	-----	-----
			120	157	65	30	16	12	8.7	-----	-----
			183	320	123	54	27	19	14	-----	-----
2-4810	Biloxi River at Wortham	98.3	7	28	13	6.2	3.3	2.3	1.7	[2] 1.1	.06
			15	33	15	7.3	4.4	2.7	1.9	-----	-----
			30	40	18	7.6	4.6	3.2	2.3	-----	-----
			60	60	27	13	6.5	4.6	3.2	-----	-----
			120	133	59	28	15	10	7.9	-----	-----
			183	243	114	54	29	21	16	-----	-----
2-4810.5	Saucier Creek at Wortham	[1] 40	7	-----	-----	4.3	-----	-----	1.5	1.0	.11
2-4811	Little Biloxi River near Lyman	[1] 71	7	-----	-----	6.3	-----	-----	2.0	1.3	.09
2-4811.3	Biloxi River near Lyman	[1] 250	7	-----	-----	36	-----	-----	14	10	.14
2-4812	Bayou Bernard near Gulfport	[1] 16	7	-----	-----	1.0	-----	-----	.3	.2	.06
2-4812.5	Turkey Creek near Gulfport	[1] 24.3	7	-----	-----	.2	-----	-----	-----	<.1	.01
2-4815	Wolf River near Lyman	253	7	-----	-----	40	-----	-----	14	12	.16
2-4815.1	Wolf River near Landon	[1] 306	7	-----	-----	56	-----	-----	21	18	.18

[1] Approximate.
[2] Based on observed data.

study. The potential water supply from these small streams is negligible.

A 20-year drought flow is defined as the 7-day low flow (7-day Q_{20}) which has a 95 percent probability of being exceeded, or a 5 percent probability of not being available, in a given year. A graphic presentation of the minimum flow to be expected during a 20-year drought along the gaged reaches of the coastal streams of Harrison County (fig. 5) reveals that the 7-day Q_{20} for the Wolf River increases from 9 mgd at the western county line to about 14 mgd at Wolf River near Landon (Old Cable Bridge) gaging station.

The data on low-flow frequency (table 4) can be used for estimates of potential water supply, for justification of future, more detailed studies, or for calling attention to areas where surface supplies are limited and development of ground-water supplies may be necessary.

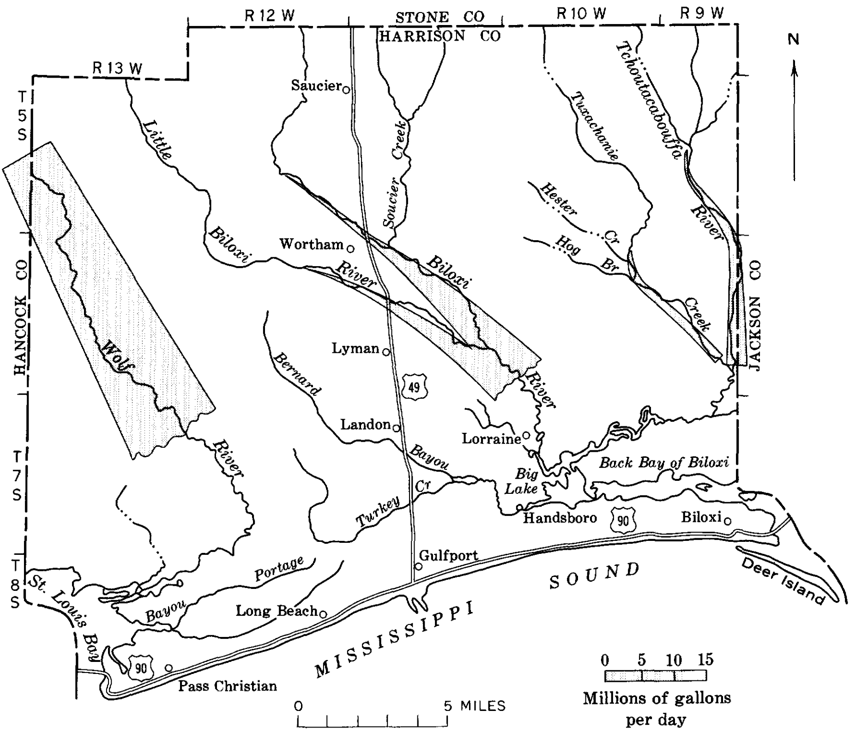

FIGURE 5.—Minimum flow in streams during 20-year drought. Width of shaded area at any point on any stream indicates the minimum flow to be expected at that point during drought.

STORAGE REQUIREMENTS

Storage of water in surface reservoirs can often satisfy water demands that exceed minimum streamflow. The final design of a water-supply reservoir entails a study of the flow characteristics of the stream, the pattern of withdrawals, topography, soil conditions, evaporation and seepage losses, sediment deposition, flood potential, and legal restrictions. Many surface reservoirs serve several functions, such as water supply, flood control, and recreation. These multipurpose reservoirs require additional consideration as to flood capacity and effect of pool fluctuations.

General storage requirements to sustain 50 and 100 mgd of uniform withdrawal during a 20-year drought are given in table 5 for selected sites in Harrison County. Seepage and evaporation losses vary according to conditions at the specific reservoir site and are not included in this analysis.

TABLE 5.—*Estimated water storage requirements for selected sites in Harrison County*

Identification No.	Stream	Drainage area (sq mi)	Acre-feet of water required in storage [1] to maintain indicated sustained flows during a 20-year drought	
			50 million gallons per day	100 million gallons per day
2-4803.5	Tchoutacabouffa River	58	25,000	60,000
2-4805	Tuxachanie Creek	92.4	24,000	60,000
2-4811.3	Biloxi River	250	8,000	30,000
2-4815.1	Wolf River	306	6,000	23,000

[1] Storage estimates do not allow for evaporation and seepage losses. Evaporation losses from a reservoir surface can be as much as 10 inches per month in periods of extended drought.

According to Kohler, Nordenson, and Fox (1959), the annual evaporation loss from a reservoir in the study area would be about 48 inches, or only about 12 inches less than the average annual rainfall. During dry years losses from evaporation would exceed the rainfall on the reservoir. Evaporation losses may be as much as 10 inches per month during summers of dry years.

Sediment deposition is a major design factor in the planning of impoundment projects. From sediment studies of streams in Harrison County an average sedimentation rate of 0.15 acre-feet per square mile per year can be expected under existing conditions. (See section entitled "Fluvial Sediment.") With further development of Harrison County (such as land clearing and urbanization) higher sedimentation rates can be expected.

LEGAL RESTRICTIONS ON USE

The Mississippi water law of 1956 established the Board of Water Commissioners and gave it powers to issue water permits, to protect existing water rights, and to control the future additional appropriation of water so as to insure its most advantageous use. The law declares that surface water in any watercourse, lake, or other natural water body of the State is subject to appropriation in accordance with the provisions of the law.

The Board of Water Commissioners has the authority to permit the appropriation of water of any stream only in excess of the established average minimum flow. The average minimum flow of a stream is defined in the Mississippi water law as follows: "the average of the minimum daily flow occurring during each of the five (5) lowest years in the period of the preceding twenty (20) consecutive years. Such determinations shall be based upon available streamflow data, supplemented, when available data are incomplete, by reasonable calculations." The board may authorize an appropriator to use the established minimum flow for industrial purposes when such water shall be returned within a reasonable time—as specified by the board in its authorization—to the stream at a point downstream from its place of withdrawal. This appropriation is made only if the board determines that such action will not result in any substantial detriment to the property owners affected thereby or to the public interest.

Average minimum flows calculated for streams in Harrison County are given in table 6. Data for the period April 1946–March 1966 were used for the determination of average minimum flows.

TABLE 6.—*Average minimum flows of streams in Harrison County*

[Based on period April 1946–March 1966]

Identification No.	Station	Average minimum flow (mgd)
2–4803.5	Tchoutacabouffa River near Biloxi	2.3
2–4804	Hester Creek near Biloxi	.9
2–4804.5	Hog Branch near Biloxi	.3
2–4805	Tuxachanie Creek near Biloxi	1.9
2–4810	Biloxi River at Wortham	1.7
2–4810.5	Saucier Creek at Wortham	1.4
2–4811	Little Biloxi River near Lyman	1.9
2–4811.3	Biloxi River near Lyman	12
2–4812	Bayou Bernard near Gulfport	.3
2–4815	Wolf River near Lyman	12
2–4815.1	Wolf River near Landon	18

MINERALIZATION

Water that falls on the earth as rain or snow is nearly devoid of dissolved constituents except for small amounts of dissolved gases, such as carbon dioxide. The water in precipitation, streams, ground-water reservoirs, and oceans contains dissolved solids in variable amounts, as shown in the following table (results in parts per million except as indicated).

	Sample				
	1	2	3	4	5
Calcium	------	4. 6	1. 1	0. 8	355
Magnesium	------	4. 7	. 3	. 0	1, 010
Sulfate	------	13	. 6	8. 8	2, 260
Chloride	6. 0	76	4. 5	5. 2	14, 900
Specific conductance (micromhos at 25°C)	35	286	24	299	39, 800

1. Rain sample collected northeast of Pascagoula, Miss., Aug. 23, 1960. Wind south-southwest at 5–15mph
2. Composite sample of rain and blowing spray collected at Biloxi, Miss., Sept. 15, 1960. Wind east at 30 mph. Sample taken at 10:00 a.m. before arrival of the eye of Hurricane Ethel.
3. Biloxi River near Lyman, Sept. 9, 1965. Water discharge 355 cfs.
4. Keesler Air Force Base, well 1 (M64), June 1, 1965.
5. Mississippi Sound near Horn Island, Aug. 7, 1960.

The dissolved minerals in streams and ground water are derived from the rocks and soils with which the water has been in contact. Differences in the chemical composition and dissolved-solids concentration of water on and in the ground are due to differences in the mineral composition of rocks and in the solubility of the minerals. Dissolved minerals in rain are derived from particles of dust that adhere to droplets of water in the atmosphere.

Water in the Biloxi, Wolf, and Tchoutacabouffa Rivers is made up of varying proportions of direct runoff and ground-water discharge. At high flow most of the discharge consists of direct runoff, but at low flow the discharge consists chiefly of ground-water discharge. Usually the dissolved-solids concentration of the water is lowest during periods of high flow and highest when the flow is mostly from ground water. Rainfall that runs off directly has relatively little opportunity to dissolve mineral matter, and thus to increase the slight chemical content of the rainwater itself. However, water that enters the soil and percolates down to the ground-water reservoir reacts with mineral matter in the soil and the underlying rocks and dissolves part of the soluble minerals, thereby increasing its dissolved-solids content.

Figure 6 shows semilogarithmic plots of dissolved-solids content against discharge for streams for which adequate analyses are available. The graphs show lower dissolved-solids concentrations with increases in discharge. In samples collected in the fresh-water reach of the Biloxi, Tchoutacabouffa, and Wolf Rivers, the dissolved-solids content ranged from 14 to 30 ppm in the Biloxi River, from 14 to 33 ppm in the Tchoutacabouffa River, and from 14 to 27 ppm in the Wolf River. Combination of these data, which are based on the period

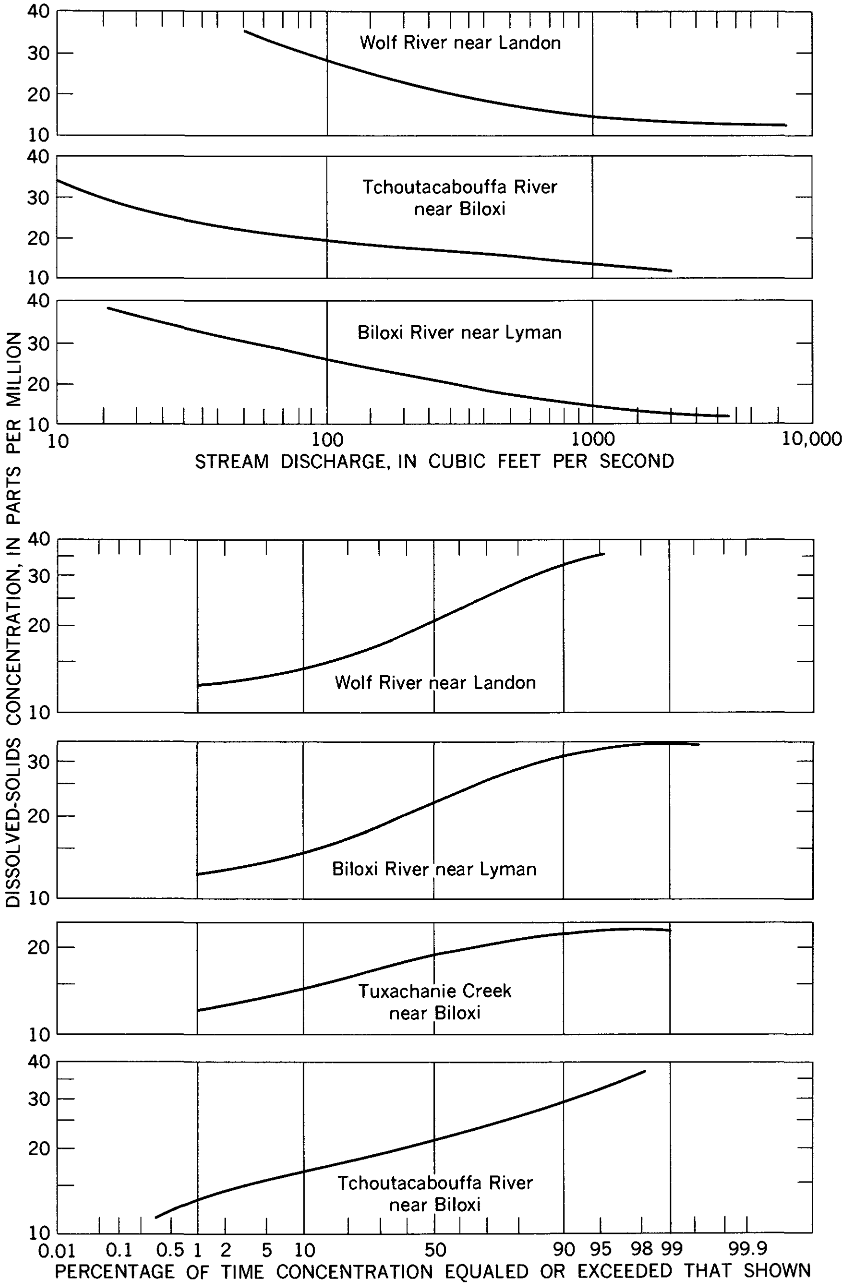

FIGURE 6.—Relation of dissolved-solids concentration to stream discharge and duration of dissolved-solids concentration.

July 23, 1964–January 7, 1966, with flow-duration curves for Wolf River near Landon permits the preparation of a dissolved-solids concentration-duration graph (fig. 6). Although this graph may differ from the long-term relation, it is of value in estimating the percentage of time that the concentration of dissolved solids is equal to or less than any certain value. For example, figure 6 shows that during the 1965 water year the dissolved-solids concentration was less than 25 ppm for 75 percent of the time. Because the character of the flow-duration curve is different from year to year and because the relation of water discharge to dissolved-solids concentration also shows some variation, a concentration-frequency curve for this short period is only an approximation of what the long term curve may be. The curves in figure 7 have been extrapolated to include a wider range of discharge rates than were actually measured.

The principal dissolved constituents in the Biloxi, Tchoutacabouffa, and Wolf Rivers are silica, sodium, chloride, and bicarbonate, as shown by the analyses data in table 7. Figure 7 shows semilogarithmic plots of sodium and chloride against discharge for the rivers named. The graph shows decreases in sodium and chloride concentration with increases in discharge. Analyses of samples collected in the fresh-water reach of the rivers show that the sodium content ranged from 0.9 to 4.1 ppm in the Biloxi River, from 1.4 to 3.7 ppm in the Tchoutacabouffa River, and from 1.2 to 3.4 ppm in the Wolf River. The chloride content ranged from 1.6 to 5.9 ppm in the Biloxi River, from 3.0 to 5.2 in the Tchoutacabouffa River, and from 3.2 to 5.8 in the Wolf River.

Of 97 stream samples taken from the Wolf, Biloxi, and Tchoutacabouffa River basins and analyzed for iron, only 1 sample—from Tuxachanie Creek near Biloxi—contained more than 0.3 ppm, the maximum recommended for domestic use. The fluoride concentration was also low; fluoride was detected in only 53 of the 97 samples, and in these it was only 0.1 ppm, considerably less than the 0.8 ppm upper limit recommended for drinking water in this climatic region. All samples had a pH of less than 7.0. Water having a pH of less than 7.0 is acidic and generally corrosive. Water from these streams probably would corrode water pipes and take iron into solution.

FLUVIAL SEDIMENT

The amount of sediment transported and deposited by streams is a reflection of the degree of soil erosion. High concentrations of suspended sediment interfere with the use of stream water by industries and municipalities. Excessive concentrations are also harmful to fish and wildlife. Stream sediment is deposited in reservoirs and reduces their capacities.

Ordinarily, two separate but related types of sediment data are needed. Many users of stream water are concerned almost exclusively with variations in concentration of suspended sediment; others are concerned only with the magnitude of the sediment load. For example, most industries and municipalities are interested in the concentration of suspended sediment in the water they withdraw from a stream—they are not concerned about the total sediment load carried by the stream. Those interested in storing water in reservoirs, however, are not as interested in the suspended-sediment concentration in streams as they are in the potential loss of reservoir capacity owing to the sediment load transported by the stream.

Complete information on the fluvial sediment of a basin or stream would include all the physical and chemical properties of the sediment as well as the quantities of sediment in a basin or stream. Complete information is always desirable though not often obtained. The information given in this report will provide a general understanding of the physical quality of the water. Because of the reconnaissance nature of the sediment study, conclusions, especially those regarding sediment yield, are tentative.

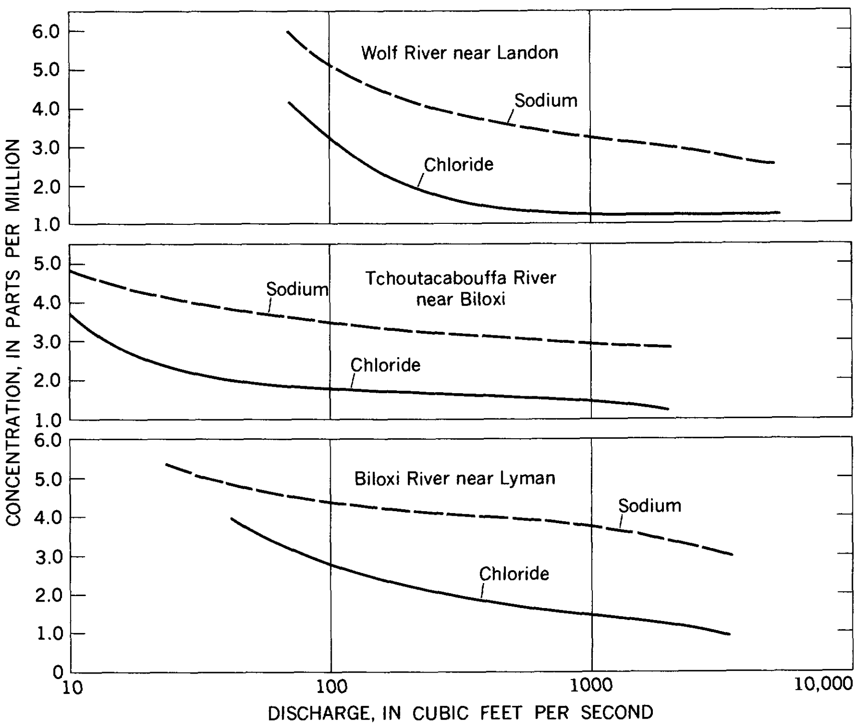

FIGURE 7.—Relation of sodium and chloride concentrations to stream discharge.

TABLE 7.—*Chemical analyses of water from streams in Harrison County*

[Results in parts per million except as indicated]

Date of collection	Water discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
Biloxi River near Lyman																		
7-23-64	130	9.5	0.02	1.2	0.5	2.3	0.5	2	2.4	3.8	0.0	0.5	22	5	3	25	5.3	10
10-27-64	43	13	.06	2.4	.0	3.7	.5	6	1.2	4.1	.1	.2	28	6	1	32	6.0	10
11- 9-64	52	13	.01	1.9	.8	4.1	.4	7	2.6	4.2	.1	.2	30	8	2	36	5.7	5
12- 1-64	501	8.0	.00	1.5	.1	2.1	.7	2	.0	5.1	.1	.4	19	4	2	31	5.1	10
1-21-65	124	11	.06	1.6	.0	2.8	.3	2	.0	5.9	.1	.3	23	4	2	29	5.6	10
2-25-65	856	6.3	.05	1.5	.1	1.6	.3	2	.0	4.2	.1	.3	15	4	2	24	5.3	5
3-31-65	632	6.8	.20	1.3	.4	1.6	.4	2	.2	3.9	.0	.5	16	5	3	25	5.6	70
5-13-65	23	12	.25	2.0	.7	3.2	.5	7	2.4	4.5	.0	.1	29	8	2	36	6.3	30
7-14-65	456	7.6	.03	1.1	.3	.9	.4	2	.4	1.6	.0	.3	14	4	2	24	5.8	40
8- 3-65	98	11	.06	1.4	.4	2.1	.4	3	.0	4.6	.0	.5	22	5	3	25	5.4	30
8-17-65	432	7.5	.10	1.2	.0	1.4	.3	0	.0	3.5	.0	.6	15	7	3	27	4.5	40
9- 9-65	200	9.5	.09	1.1	.3	2.1	.4	3	.6	4.5	.0	.4	20	4	2	24	5.2	40
9-21-65	362	8.6	.03	.6	.4	2.1	.5	1	1.2	4.1	.0	.5	18	3	2	25	4.8	50
10-14-65	110	14	.10	1.0	.9	2.3	.2	4	.8	4.8	.0	.4	26	6	3	28	5.5	30
10-27-65	56	14	.09	1.5	.3	3.2	.4	6	.6	5.0	.1	.4	28	5	0	30	6.2	20
11-17-65	118	13	.13	1.4	.4	2.5	.6	3	.8	5.5	.1	.4	26	5	2	29	5.4	40
12- 1-65	80	13	.12	1.3	.4	2.3	.5	4	.0	4.3	.1	.4	24	5	2	30	5.3	30
1- 7-66	3,240	5.9	.08	.8	.5	1.4	.4	1	.0	3.1	.1	.2	12	4	3	21	4.9	50
Tchoutacabouffa River near Biloxi																		
10-27-64	12	15	0.06	1.5	1.0	3.7	0.6	4	5.2	4.0	0.1	0.2	33	8	5	37	6.0	10
11- 9-64	11	15	.02	1.6	1.0	3.4	.6	5	4.4	3.5	.1	.3	32	8	4	37	5.7	5
12- 1-64	85	9.9	.02	1.6	.5	3.0	.4	1	3.0	4.4	.0	.2	23	6	5	33	4.9	20
1-20-65	22	12	.07	1.2	.5	2.3	.5	4	.0	4.9	.1	.2	24	5	2	32	5.8	20
2-25-65	154	7.3	.12	1.2	.0	2.3	.7	2	.2	4.7	.1	.4	18	3	1	25	5.1	10

3-30-65	159	6.6	.13	1.0	.4	1.4	.3	1	.0	3.3	.1	.5	14	4	3	25	4.9	70
5-13-65	9.7	13	.08	2.2	.6	3.2	.5	6	3.4	4.7	.0	.1	31	8	3	34	6.3	30
6-30-65	52	9.0	.06	1.0	1.1	1.4	.2	2	2.4	3.0	.0	.2	19	7	5	26	4.9	50
7-14-65	42	11	.15	1.1	.8	2.1	.4	2	4.0	3.0	.0	.2	24	6	4	30	5.0	60
8- 3-65	33	11	.05	1.1	.8	1.8	.3	2	2.4	4.0	.1	.6	23	6	4	28	4.9	30
8-16-65	189	8.2	.08	1.1	.3	1.8	.2	2	1.2	3.0	.0	.8	18	4	2	23	4.7	40
9- 9-65	20	13	.13	1.1	.0	2.5	.4	2	1.6	4.2	.0	.4	24	3	1	29	5.1	50
9-21-65	53	11	.14	1.1	.5	2.3	.4	3	.2	5.2	.0	.5	22	5	3	28	5.1	50
10-14-65	20	13	.05	1.0	.6	2.5	.1	3	3.6	4.7	.0	.3	27	5	3	30	5.3	30
10-27-65	85	14	.05	1.4	.6	3.5	.6	6	3.0	3.8	.1	.2	30	6	1	32	5.7	20
11-17-65	100	14	.16	1.4	.4	3.5	.7	5	2.4	4.2	.1	.4	29	5	1	31	5.8	40
12- 1-65	85	14	.08	.9	.8	3.0	.6	5	2.6	4.1	.1	.4	29	6	2	30	5.5	30
12-21-65	107	9.8	.08	.8	.7	2.8	.2	1	3.0	5.1	.1	.2	23	5	4	31	4.7	50
1- 7-66	346	7.0	.04	.9	.4	2.8	.5	4	2.6	4.1	.1	.2	21	4	1	31	5.4	60

Tuxachanie Creek near Biloxi

11-24-59	77	6.4	0.44	3.1	1.4	4.7	1.3	15	5.2	5.0	0.0	0.1	35	14	2	53	6.6	20
4-20-60	1,930	1.5	.08	1.3	.0	2.3	.0	1	2.0	2.5	.1	1.2	12	3	2	18	4.7	60
5-25-60	56	4.0	.15	1.0	.6	2.5	.2	3	2.2	3.8	.1	1.3	17	5	2	24	6.0	40
7-23-64	64	9.5	.02	.9	.7	2.8	.4	2	2.6	4.6	.0	.3	23	5	3	26	5.3	10
10-27-64	22	12	.02	1.1	.3	3.2	.4	4	.2	4.2	.1	.2	24	4	1	28	5.3	5
11- 9-64	19	11	.04	1.8	.4	3.4	.4	4	2.0	4.5	.1	.2	24	6	3	30	5.6	15
12- 1-64	177	7.7	.03	1.5	.3	2.5	.3	0	1.4	3.7	.1	.3	18	5	5	29	4.7	40
1-20-65	35	10	.09	1.0	.4	2.3	.1	2	.0	5.0	.1	.3	20	4	2	26	5.7	10
2-25-65	277	6.8	.07	1.2	.0	2.1	.5	2	.0	4.3	.1	.3	16	3	1	24	4.9	20
3-31-65	255	5.9	.15	.3	.3	1.8	.2	1	.0	2.9	.0	.5	12	2	1	23	5.2	60
5-13-65	13	8.9	.16	1.0	.0	3.2	.6	3	1.4	4.9	.1	.1	21	3	1	29	5.8	30
6-17-65	637	6.1	.11	1.6	.0	1.2	.2	0	.4	3.6	.1	.9	14	4	4	23	4.5	40
7-14-65	85	8.0	.09	1.2	.2	1.4	.1	0	.0	3.4	.0	.3	15	4	4	24	4.7	50
8-18-65	204	11	.00	1.2	.2	1.2	.2	0	.4	3.6	.1	.7	19	4	4	24	4.6	30
9- 9-65	66	9.8	.09	.8	.0	1.6	.3	1	.2	3.0	.0	.4	16	2	1	24	4.7	40
9-21-65	92	8.9	.12	.8	.0	2.1	.3	0	.6	4.5	.0	.4	18	2	2	24	4.6	50
10-14-65	35	11	.06	1.0	.4	2.3	.1	1	.0	4.9	.0	.4	20	4	3	25	4.9	30
10-27-65	22	11	.09	.9	.4	2.3	.1	2	.2	4.3	.0	.3	20	4	2	24	5.5	30
12- 1-65	22	11	.25	.5	.4	1.8	.2	1	.0	4.5	.0	.2	19	3	2	24	5.0	40
1- 7-66	645	6.0	.10	.2	.9	1.4	.1	0	.4	3.6	.1	.2	13	4	4	23	4.6	50

TABLE 7.—*Chemical analyses of water from streams in Harrison County*—Continued

[Results in parts per million except as indicated]—Continued

Date of collection	Water discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
Wolf River near Landon																		
7-23-64	126	12	0.03	1.5	0.3	2.8	0.5	4	3.6	3.6	0.0	0.3	27	5	2	30	5.7	15
10-26-64	98	12	.05	2.0	.2	3.4	.5	4	2.8	3.7	.1	.2	27	6	3	31	5.8	5
11-10-64	112	11	.02	1.5	.3	3.0	.6	4	1.2	3.8	.1	.4	24	5	2	30	5.6	20
12- 2-64	433	10	.02	2.0	.0	1.2	.4	2	.0	4.1	.1	.3	19	5	3	28	5.3	5
12-18-64	521															26		
1-21-65	228	11	.05	1.3	.2	2.3	.8	4	.0	4.7	.1	.2	23	4	1	27	5.8	5
2-26-65	842	6.3	.06	1.7	.2	1.2	.3	3	.0	3.3	.1	.3	14	5	3	23	5.5	5
4- 1-65	470	7.7	.13	1.0	.6	1.6	.4	2	.0	3.6	.0	.5	17	5	3	25	5.3	50
5-12-65	67	11	.13	1.9	.5	2.1	.7	5	1.0	4.5	.1	.1	24	7	3	32	5.9	30
6-17-65	299	8.4	.06	2.0		1.6	.4	2	2.0	3.8	.1	.6	20	6	4	29	5.0	20
7-14 65	246	9.5	.06	1.9	.0	1.4	.4	2	2.2	3.2	.0	.3	21	8	6	29	5.0	40
8- 2-65	190	10	.02	2.1	.4	1.8	.4	3	1.0	4.9	.0	.4	22	7	5	30	5.2	30
8-17-65	430	8.9	.05	1.7	.2	1.8	.3	2	1.0	3.9	.0	.8	20	5	3	28	4.9	40
9- 9-65	121	15	.07	1.1	.5	1.8	.5	4	.6	4.0	.0	.4	26	5	2	27	5.2	30
9-21-65	237	10	.07	1.4	.1	2.3	.5	1	.4	5.8	.0	.4	21	4	3	21	5.4	30
10-14-65	126	13	.06	2.0	.7	2.3	.2	4	.8	4.8	.0	.3	26	8	5	30	5.5	15
10-26-65	110	13	.07	1.6	.2	3.0	.5	6	.6	5.0	.1	.2	27	5	0	31	5.7	20
11-16-65	421	9.4	.13	1.5	.5	1.4	.7	2	.8	4.0	.1	.4	20	6	4	28	5.1	50
12- 1 65	155	13	.14	.9	.7	1.8	.5	4	.2	4.2	.0	.2	24	5	2	27	5.4	30
12-21-65	1,310	8.4	.05	.8	.7	3.4	.4	5	1.8	4.2	.1	.2	22	5	1	28	5.9	50
1- 6-66	5,270	5.1	.11	1.1	.1	1.4	.5	1	1.0	2.5	.1	.2	12	3	2	20	4.8	40

Wolf River near Lyman

7-23-64	146	11	0.02	0.9	0.7	2.3	0.5	5	0.2	3.8	0.1	0.3	22	5	1	26	5.7	20
10-28-64	66	11	.02	1.4	.6	2.3	.6	6	.2	3.5	.1	.2	23	6	1	29	6.0	15
11-10-64	77	12	.04	2.0	.2	2.3	.7	5	.0	3.8	.1	.2	23	6	2	29	5.8	5
12- 2-64	324	10	.03	2.1	.2	2.8	.7	4	2.0	3.2	.1	.4	23	6	2	32	5.3	5
1-21-65	191	11	.06	1.6	.0	2.1	.7	4	.2	4.2	.1	.2	22	4	1	26	5.9	5
2-26-65	641	7.0	.07	1.4	.1	1.4	.2	2	.0	3.5	.1	.3	15	4	2	23	5.9	5
4- 1-65	383	7.2	.13	.8	.7	1.8	.4	4	.0	3.1	.0	.5	17	5	2	24	5.6	5
5-12-65	47	9.4	.12	2.1	.4	2.1	.6	6	.2	4.5	.0	.1	23	7	2	33	5.8	20
6-17-65	180	9.8	.08	2.0	.0	2.3	.5	2	1.8	4.6	.1	.5	23	5	3	29	5.2	15
7-14-65	112	10	.08	2.0	.7	1.8	.4	3	1.4	4.1	.0	.3	22	8	6	31	5.2	50
8- 2-65	109	10	.05	2.0	.5	1.4	.5	2	.2	4.7	.0	.6	21	7	5	30	5.2	40
8-17-65	63	12	.06	1.9	.3	1.8	.4	4	.0	4.5	.0	.4	23	6	3	28	5.5	30
9- 9-65	73	10	.04	.8	.7	2.5	.5	6	.8	4.0	.0	.4	23	5	0	26	5.7	40
9-21-65	168	10	.13	1.0	.4	2.3	.5	2	.4	5.2	.0	.4	21	4	2	27	5.3	50
10-14-65	85	13	.10	1.2	.5	2.3	.4	4	.6	4.9	.0	.4	25	5	2	32	5.6	40
10-26-65	45	13	.04	1.5	.3	2.5	.6	5	.4	4.9	.1	.4	26	5	1	29	5.5	20
11-16-65	242	9.5	.12	1.4	.4	1.4	.7	2	.6	3.8	.1	.2	19	5	2	28	5.0	50
12- 1-65	72	12	.07	1.4	.4	2.3	.5	4	.4	4.8	.0	.1	24	5	2	28	5.5	30
12-21-65	1,000	8.9	.04	1.0	.6	2.3	.5	5	1.8	3.9	.1	.2	21	5	1	27	6.1	50
1- 6-66	4,370	5.2	.11	.6	.6	1.4	.4	2	.0	2.5	.1	.2	12	3	1	22	5.0	50

GENERAL FACTORS AFFECTING SEDIMENT YIELD

The amount and type of sediment transported by a stream at any point are the net result of the interaction of all the many factors capable of affecting sediment movement. Kennedy (1964, p. 6) listed eight factors which should be considered in estimating sediment yield. (Sediment yield is defined as the total sediment outflow from a watershed or drainage basin.) The factors listed are: Soils, covering vegetation, precipitation, drainage area and topographic features, channel types, runoff, soil and cover management practices, and conservation practices and watershed-treatment measures. These factors can be considered the result of the interaction of geology, climate, and man's activities. Some factors influencing sediment yield in Harrison County are discussed below.

Runoff and precipitation.—Average runoff reported for Harrison County streams ranges from a low of 0.397 mgd per sq mi (million gallons per day per square mile; 1 mgd=1.547 cfs) to a high of 2.231 mgd per sq mi. The amount of sediment carried is dependent upon the rate of flow as well as the volume. A short period of heavy rainfall causes greater sediment yield than a longer period of gentle rainfall, even though the runoff or total rainfall may be the same for the periods.

Soils.—The characteristics of the soil in an area are always significant in determining the amount of erosion from the land. Sandy soils absorb precipitation rapidly and reduce the water available for transportation of soil particles. Clayey soils, however, tend to shed water and thereby cause a large part of the rainfall to run off over the land surface.

Detention reservoirs.—The presence of dams and reservoirs in a drainage basin can be a major factor in the control of sediment yield from the basin. The efficiency with which the various reservoirs trap sediment is related to the ratio of the reservoir capacity to the rate of inflow. Proposed reservoirs in Harrison County would reduce the sediment yield by about 90 percent.

Channel characteristics.—The sediment yield from a drainage basin represents the material eroded from the land surface as modified by the effects of gains or losses in the stream channel. If a stream is near equilibrium, about as much sediment will leave a drainage basin annually as is washed into the stream channels.

Soil-conservation practices.—Reduced land erosion in Harrison County in recent years has followed improved soil-conservation practices, and the supply of stream sediment has decreased.

SUSPENDED-SEDIMENT DISCHARGE

Biloxi River basin.—The concentration of suspended sediment in samples collected from Biloxi River near Lyman ranged from about 15 ppm to 402 ppm (table 8). In general, the concentration increased with increasing stream stage, as indicated in figure 8. Although suspended-sediment concentration generally increases with increasing discharge, the correlation is affected—particularly during floods—by

TABLE 8.—*Concentration of suspended sediment in Harrison County streams*

Date	Instantaneous discharge (cfs)	Suspended-sediment concentration (ppm)	Date	Instantaneous discharge (cfs)	Suspended-sediment concentration (ppm)
Biloxi River near Lyman					
3- 2-65	5,120	15	11-20-65	2,130	120
9- 9-65	848	15	12-21-65	1,260	75
9-10-65	1,740	18	1- 5-66	4,810	402
12-19-65	2,910	180	1- 6-66	6,790	134
12-20-65	2,660	83	1- 6-66	6,090	117
Biloxi River at Wortham					
3- 2-65	1,300	8	1- 5-66	3,180	332
9-10-65	176	15	1- 5-66	3,410	186
12-19-65	1,320	100			
12-20-65	865	115	1- 6-66	1,730	235
12-20-65	749	119	1- 6-66	[1] 5,770	[2] 124
			1- 7-66	[1] 3,200	[2] 65
12-21-65	347	52	1- 8-66	[1] 1,560	[2] 35
1- 3-66	[1] 723	[2] 75	1- 9-66	[1] 912	[2] 15
1- 4-66	[1] 1,420	[2] 135	1-10-66	[1] 723	[2] 10
1- 5-66	[1] 4,070	[2] 280			
Wolf River near Lyman					
9-10-65	129	43	12-21-65	1,020	70
12-19-65	2,030	250	1- 6-66	4,370	256
12-20-65	1,690	179			
Wolf River near Landon					
9-10-65	198	52	1- 6-66	5,220	331
12-19-65	2,540	220	1- 6-66	5,130	427
12-21-65	1,400	59			
Tuxachanie Creek near Biloxi					
3- 2-65	------------	7	1- 5-66	1,730	168
12-19-65	1,110	124	1- 6-66	2,100	120
12-20-65	880	81	1- 6-66	1,760	98
12-21-65	320	50	1- 7-66	551	25
Tchoutacabouffa River near Biloxi					
3- 1-65	------------	37	1- 5-66	1,290	885
12-19-65	630	462	1- 6-66	1,120	564
12-20-65	485	417	1- 6-66	755	600
12-21-65	140	46			

[1] Mean daily discharge.
[2] Mean daily suspended-sediment concentration.

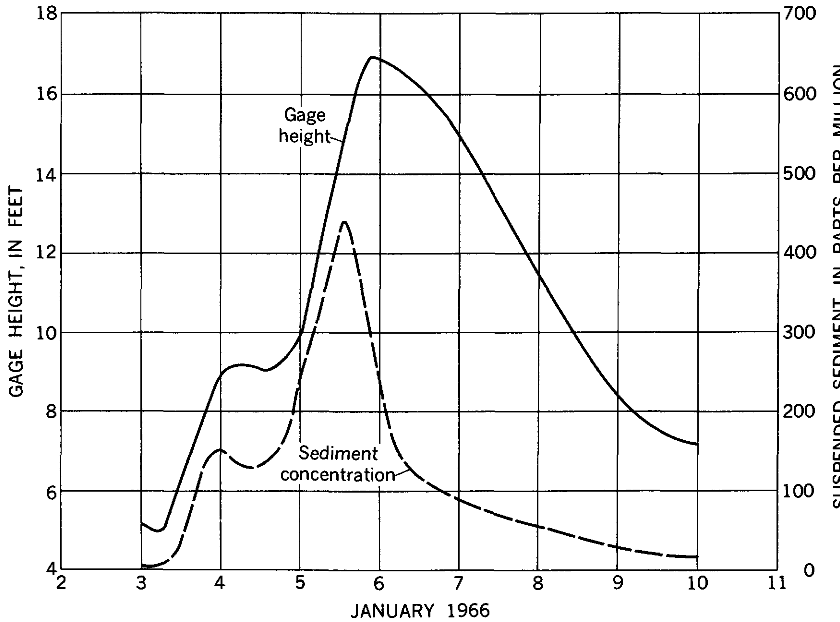

Figure 8.—Variation in gage height and concentration of suspended sediment at Biloxi River near Lyman, Miss., January 2–10, 1966.

the tendency of sediment concentration to reach a maximum before the discharge peak and then to decrease rapidly, as shown. The relation of stream discharge to concentration of suspended sediment is shown in figure 9. The lines represent the most probable concentration for each given discharge.

Daily suspended-sediment loads for the period January 3–10, 1966, were calculated. The total suspended-sediment load is about 6,660 tons for the sampled period. The total suspended-sediment load corresponds to an annual sediment yield for the Biloxi River basin of about 215 tons per square mile, or about 20,000 tons per year.

Analyses of samples collected from the Biloxi River at Wortham indicate that the concentrations of suspended sediment ranged from 8 to 332 ppm (table 8). In general, the concentration of suspended sediment increased with increasing water discharge (fig. 9).

Wolf River basin.—Suspended-sediment samples collected from the Wolf River near Lyman and Landon indicate that the concentration of sediment ranged from 43 to 256 ppm near Lyman, and from 52 to

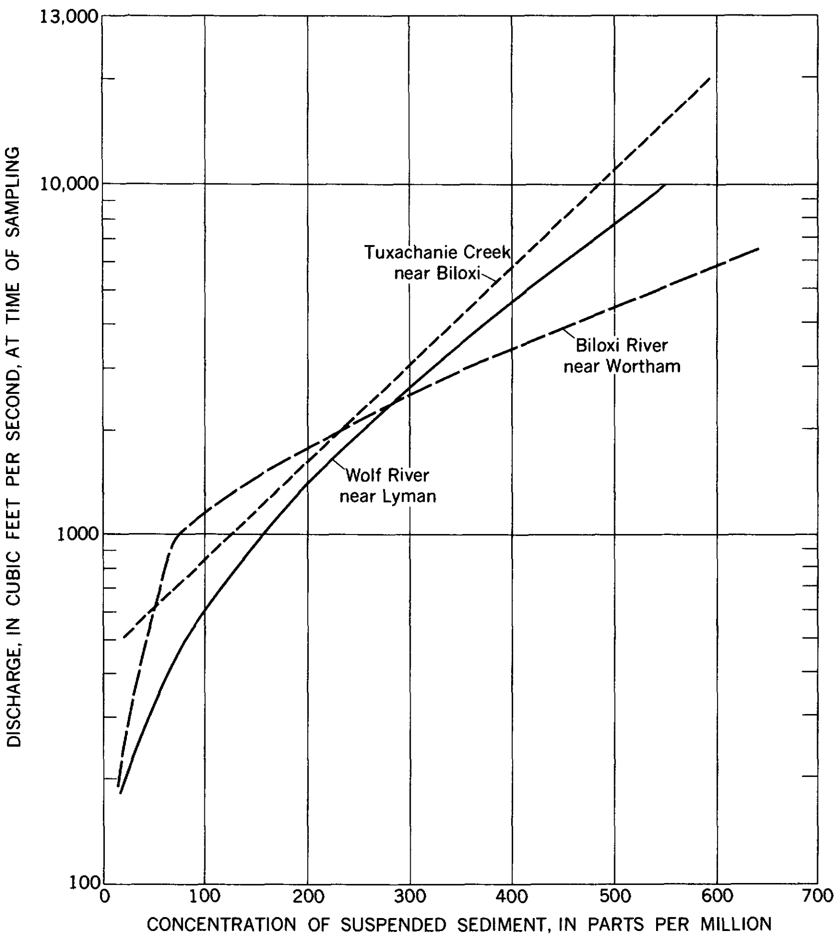

FIGURE 9.—Relation of stream discharge to concentration of suspended sediment.

427 ppm near Landon. Concentration of suspended sediment generally increased with increasing water discharge (fig. 9). Correlation of water-discharge and sediment-concentration data indicate an annual sediment yield for the Wolf River basin of about 210 tons per square mile, or about 64,000 tons per year.

Tchoutacabouffa River basin.—Suspended-sediment samples collected from Tuxachanie Creek and the Tchoutacabouffa River near Biloxi are considered to be representative of conditions in the Tchoutacabouffa River basin. Suspended-sediment concentrations in samples taken from Tuxachanie Creek and the Tchoutacabouffa River from March 1, 1965–January 7, 1966, ranged from 7 to 168 ppm and 37 to 885 ppm, respectively (table 8). Concentration of suspended sediment generally increased with increasing water discharge (fig. 9), and the data indicate an annual sediment yield from the Tuxachanie Creek basin of about 190 tons per square mile, or about 18,000 tons per year.

TEMPERATURE

Temperature changes in streams and nonflowing bodies of water may result from natural climatic phenomena, from the introduction of industrial wastes, such as distillery effluents or discharged cooling water, or from municipal waste. The temperature is important, and sometimes critical, for many uses of water. It affects the palatability of water, the treatment processes, the value of water for many industrial uses, including cooling processes, and its suitability as a habitat for aquatic life. An increase in stream temperature causes a direct decrease in dissolved oxygen and an indirect increase in oxygen demand.

Water temperatures of the Biloxi and Wolf Rivers and Tuxachanie Creek (Tchoutacabouffa River basin) were measured by the U.S. Geological Survey during the period 1944–47 and from 1954 to date. As temperature data are generally obtained at the time discharge measurements are made at the various stations, the observations vary in frequency from a few hours to 6 weeks and usually are made just below the surface of the water near the center of the stream.

Analyses of water-temperature data show that the temperature ranged from 40° to 87°F in the Biloxi River and Tuxachanie Creek and from 43° to 86°F in the Wolf River. Water-temperature records for these streams (table 9) were collected in conjunction with streamflow measurements and the chemical-quality sampling program. The data do not necessarily show either the maximum or the minimum temperatures that occurred; however, they are indicative of the range in water temperature for various times of the year.

TABLE 9.—*Temperature of water in Harrison County streams*

Biloxi River at Wortham

Date	Time a.m.	Time p.m.	Temperature (°F)	Date	Time a.m.	Time p.m.	Temperature (°F)
2-24-44	9:05	--------	63	7-31-45	11:15	--------	77
5-15-44	--------	2:25	81	9-21-45	8:45	--------	78
8- 2-44	--------	1:05	83	12-13-45	--------	12:45	51
9-12-44	--------	12:05	75	1-24-46	11:45	--------	47
10-30-44	--------	2:45	62	3- 7-46	--------	2:50	64
1-17-45	9:15	--------	48	4-11-46	--------	12:15	77
3- 1-45	11:20	--------	58	6-19-46	8:25	--------	82
4-14-45	--------	3:00	78	7-24-46	--------	12:15	78
5-17-45	--------	4:55	73	1- 9-58	--------	12:10	42
6-20-45	--------	4:45	79	2-20-58	9:05	--------	40

TABLE 9.—*Temperature of water in Harrison County streams*—Continued

Biloxi River at Wortham—Continued

Date	Time a.m.	Time p.m.	Temperature (°F)	Date	Time a.m.	Time p.m.	Temperature (°F)
4- 3-58	--------	12:05	61	2- 7-63	11:30	--------	52
5-19-58	--------	2:45	69	3-21-63	--------	3:15	64
6- 3-58	10:30	--------	85				
10-17-58	11:45	--------	72	5- 1-63	--------	1:20	78
10-28-58	--------	12:25	64	5-22-63	9:55	--------	72
				7- 4-63	--------	2:05	83
3-19-59	11:00	--------	48	8-22-63	7:25	--------	83
4-23-59	10:15	--------	56	10- 3-63	--------	2:35	80
5- 6-59	10:25	--------	75				
7- 2-59	9:50	--------	67	10-16-63	9:20	--------	70
8-13-59	11:25	--------	65	11-22-63	6:55	--------	63
				12-19-63	--------	2:10	43
9-17-59	9:10	--------	73	3-27-64	8:40	--------	54
11-24-59	11:05	--------	60	5- 4-64	--------	12:40	73
1- 5-60	9:20	--------	49				
4- 2-60	10:55	--------	65	5-19-64	10:25	--------	77
4-25-60	--------	1:45	78	6-11-64	--------	2:15	86
				7-16-64	9:00	--------	78
5-20-60	10:40	--------	79	8- 4-64	--------	12:10	86
6-15-60	9:45	--------	84	8-14-64	--------	2:05	83
8- 3-60	10:00	--------	77				
10-19-60	11:10	--------	74	10-13-64	11:35	--------	67
12-24-60	11:50	--------	43	10-26-64	--------	3:55	63
				11- 9-64	10:45	--------	64
1-26-61	10:50	--------	44	12-17-64	--------	3:50	53
24-61	11:45	--------	79	1-21-65	9:40	--------	50
12- 7-61	11:15	--------	61				
1- 3-62	10:05	--------	45	2-26-65	7:55	--------	46
2-13-62	7:45	--------	56	3-31-65	--------	4:45	66
				5-12-65	--------	12:35	83
3-30-62	7:55	--------	67	7- 1-65	9:05	--------	81
5-10-62	--------	3:10	84	7-15-65	8:30	--------	79
5-31-62	7:15	--------	80				
7-10-62	8:10	--------	83	8-17-65	--------	1:00	86
8-17-62	6:30	--------	87	9-21-65	--------	12:55	81
				10-27-65	7:30	--------	55
10-11-62	--------	3:35	77	12- 1-65	11:50	--------	52
11-20-62	8:55	--------	59	1- 6-66	--------	1:35	59
12-30-62	11:45	--------	56				

Tuxachanie Creek near Biloxi

Date	Time a.m.	Time p.m.	Temperature (°F)	Date	Time a.m.	Time p.m.	Temperature (°F)
3-25-44	--------	5:30	64	3-19-59	8:45	--------	47
5-16-44	--------	12:15	80	4-23-59	--------	1:15	56
8- 3-44	9:55	--------	79	5- 6-59	9:00	--------	75
9-12-44	--------	6:05	77	7- 2-59	7:05	--------	72
10-30-44	--------	4:45	65	8-13-59	9:25	--------	63
1-17-45	--------	12:05	51	11-24-59	9:30	--------	61
3- 1-45	--------	3:20	61	1- 5-60	11:20	--------	49
4-14-45	--------	4:30	77	2-11-60	--------	3:00	58
6-20-45	--------	12:20	81	4- 2-60	9:00	--------	64
7-31-45	--------	5:05	81	4-22-60	--------	1:35	76
9-20-45	--------	4:10	86	5-20-60	9:05	--------	78
12-13-45	8:40	--------	52	5-25-60	9:35	--------	77
1-24-46	8:55	--------	43	6- 6-60	--------	4:55	87
3- 7-46	9:30	--------	64	6-15-60	8:00	--------	78
4-11-46	9:35	--------	74	10-19-60	--------	1:10	74
5-15-46	--------	2:50	65	11-16-60	--------	2:35	67
6-20-46	8:25	--------	82	12-24-60	9:15	--------	43
7-24-46	8:35	--------	76	1-26-61	8:50	--------	44
10-22-57	--------	2:40	68	3- 8-61	9:05	--------	62
2-20-58	10:35	--------	40	12- 7-61	9:30	--------	61
4- 3-58	--------	2:55	61	1- 3-62	11:50	--------	47
6-13-58	9:25	--------	82	2-13-62	11:00	--------	60
9- 6-58	10:55	--------	77	3-29-62	--------	3:50	67
10-17-58	10:10	--------	71	5-10-62	10:10	--------	82
10-28-58	10:25	--------	64	5-30-62	5:00	--------	85

TABLE 9.—*Temperature of water in Harrison County streams—Continued*

Tuxachanie Creek near Biloxi—Continued

Date	Time a.m.	Time p.m.	Temperature (° F)	Date	Time a.m.	Time p.m.	Temperature (° F)
7-10-62	6:30		80	11- 9-64		2:20	65
8-16-62		5:35	86	12- 1-64	8:20		51
9- 6-62		5:40	83	1- 1-64		7:20	51
10-11-62	11:35		76	1-17-64	9:20		51
11-20-62		12:50	61	1-20-65		4:30	50
12-30-62		1:40	56	2-25-65		12:50	51
2- 7-63		2:10	54	3- 2-65	8:30		60
3-22-63	7:20		56	3-31-65	9:45		66
5- 1-63	10:00		75	5-13-65	10:30		81
7- 4-63	10:55		82	6-17-65	8:45		77
8-22-63	10:20		80	7-14-65		3:45	80
10- 3-63	11:35		79	8-18-65	10:00		79
10-16-63		2:55	75	9-21-65		2:40	81
11-21-63		1:20	65	10-27-65		12:40	62
12-19-63	11:20		42	11-13-65	7:40		65
2- 6-64	7:30		52	12- 1-65		3:00	53
3-26-64		3:25	62	12-19-65		4:45	52
5- 5-64		2:45	75	12-20-65	7:30		50
5-19-64	7:35		73	12-20-65		3:30	53
6-11-64	10:05		85	12-21-65	11:15		52
7-16-64	6:40		76	1- 5-66		4:30	59
8- 5-64	10:45		80	1- 6-66	6:30		58
8-14-64	10:25		80	1- 6-66		12:30	58
10-13-64	7:55		65	1- 7-66		2:00	58
10-27-64	7:25		63				

Wolf River near Lyman

Date	Time a.m.	Time p.m.	Temperature (° F)	Date	Time a.m.	Time p.m.	Temperature (° F)
2-25-44		2:15	68	8-15-64	8:30		81
3-25-44		1:00	60	9- 2-64		1:15	86
5-15-44		4:35	79	9- 9-64		1:20	80
8- 2-44		4:25	85	10-13-64		1:30	67
9-12-44		2:50	76	10-28-64	8:40		65
10-31-44	9:15		60	11-10-64		1:00	63
1-16-45		3:10	51	12- 2-64	11:50		52
3- 1-45	8:25		57	12-18-64	11:35		51
4-14-45		12:15	72	1-21-65		2:15	52
5-17-45		7:15	70	2-26-65	10:15		48
6-19-45		5:05	81	4- 1-65	8:00		64
7-13-45		2:15	79	5-12-65		3:20	81
12-13-45		3:50	79	6-17-65		3:10	81
1- 8-46	9:00		64	7-14-65	10:50		81
1-24-46		4:30	48	8- 2-65		5:10	85
3- 7-46		3:50	64	8-17-65	11:00		85
4-11-46		3:25	77	9- 9-65	9:45		76
6-19-46	10:40		82	9-21-65	8:00		78
7-25-46		1:40	80	10-14-65	9:25		70
10- 1-46		6:10	70	10-26-65		12:55	62
10-31-46	9:25		70	11-16-65		3:35	64
12-12-46	11:15		64	12- 1-65	9:45		49
1-16-47		2:10	64	12-21-65	9:05		52
4- 3-47		12:05	64	1- 6-66	10:30		58
5-15 47	11:30		70	1-25-66	8:50		43
7-23-64	11:00		82	2- 8-66	7:07		49
8- 8-64	9:15		86	3-29-66		12:15	60

QUALITY PROBLEMS

LOW pH

The pH of a raw-water source for domestic water is significant in that it affects taste, corrosiveness, efficiency of chlorination, and many treatment processes, such as coagulation and floculation.

The pH of the 97 samples analyzed ranged from 4.5 to 6.3 in the Biloxi basin, from 4.7 to 6.3 in the Tchoutacabouffa basin, and from 4.8 to 6.1 in the Wolf River basin. All samples analyzed had a pH less than 7.0. Recommended limiting values of pH for various industrial-process waters are given in the following table (California State Water Quality Control Board, 1963).

Industrial process	Recommended pH values	
	Minimum	Range
Boiler-feed water:		
0–150 psi [1]	8.0	---------
151–250 psi	8.4	---------
251–400 psi	9.0	---------
>400 psi	9.6	---------
Brewing	--------	6.5–7.0
Confectionary	7.0	---------
Food canning and freezing	7.5	---------
Laundering	--------	6.0–6.8
Oil-well flooding	7.0	---------
Rayon manufacturing	--------	7.8–8.3
Steel making	--------	6.8–7.0
Tannery operations	--------	6.0–8.0

[1] Pounds per square inch.

Water with a pH of 3.9 or below has a sour taste. The optimum dosage of coagulating chemicals is influenced by the pH as well as by the buffering action of the water. However, the effectiveness of chlorine in reducing bacteria diminishes with increasing pH values, and it is economically advantageous to apply chlorine to water having a pH value of 7 or less. Nonetheless, high pH values favor corrosion control.

COLOR

Color is observed mainly in surface water, although water from some deep wells is noticeably colored. Color is undesirable in water for many industrial uses, as in laundries, in making ice, dairy products, and bottled beverages, and in photography. Table 10 shows color maximums permissible in water for the listed industrial uses.

The 1962 U.S. Public Health Service Drinking Water Standards limit the color of acceptable water to 15 units. Analyses of samples collected in the fresh-water reach of the stream show a color range from 5 to 70 units in the Biloxi and Tchoutacabouffa Rivers and from

5 to 50 units in the Wolf River (table 7). The variation in color is not related to discharge but has a seasonal relation (fig. 10). In the period July 1964–December 1965, about 65 percent of the samples from the Biloxi River, 75 percent from the Wolf River, and 85 percent from the Tchoutacabouffa River contained color greater than 15 units. Industries and municipalities using water from these streams would require treatment for the removal of color.

TABLE 10.—*Color limits permissible in water for industrial use*

[California State Water Quality Control Board (1963, table 6-3)]

Use	*Units of color (Platinum-cobalt scale)*	*Use*	*Units of color (Platinum-cobalt scale)*
Baking	10	Pulp and paper—Continued	
Boiler-feed water	[1] 2–80	High-grade paper	5
Bottled beverages	5–10	Special papers (such as tissue and filter)	5
Brewing	0–10	Bleached kraft papers	25
Dairy industry	0	Unbleached kraft papers	100
Food-equipment washing	5–20	Groundwood papers	30
Food processing	5–10	Tanning	10–100
Food products	10	Textiles:	
Nitrocellulose production	1	Cotton	50
Pulp and paper:		Rayon	5
Alkaline pulps	5	General	0–70

[1] According to pressure.

SALT-WATER INTRUSION

In the tidal reaches of the Biloxi, Tchoutacabouffa, and Wolf Rivers, the downstream flow is interrupted periodically by flood tides. Until the tide ebbs, saline water from the Mississippi Sound flows upstream—because of its greater density—as a wedge under the fresh river water.

The degree of salt-water intrusion upstream in the three rivers depends principally upon fresh-water discharge, tidal stage, and configuration of the river channel. Of these factors, the effect of fresh-water discharge is dominant. As a result of these turbulence-producing factors, mixing along the fresh-water interface of a tidal stream causes changes in the composition of water in vertical and horizontal planes. The salt front, or wedge, advances or retreats, depending on the extreme range of fresh-water discharge and tide.

The maximum penetration of salt water up the Biloxi, Tchoutacabouffa, and Wolf Rivers occurs during extreme drought conditions. Salinity surveys were made on the Biloxi and Tchoutacabouffa Rivers in October 1963 and on the Wolf River in August 1965 to determine the maximum penetration of salt water up these three coastal rivers (pl. 2). Partial chemical analyses of samples collected at these stations are given in table 11.

Changes in fresh-water flow generally will cause the salt front to advance or retreat, the distance of the advance or retreat depending

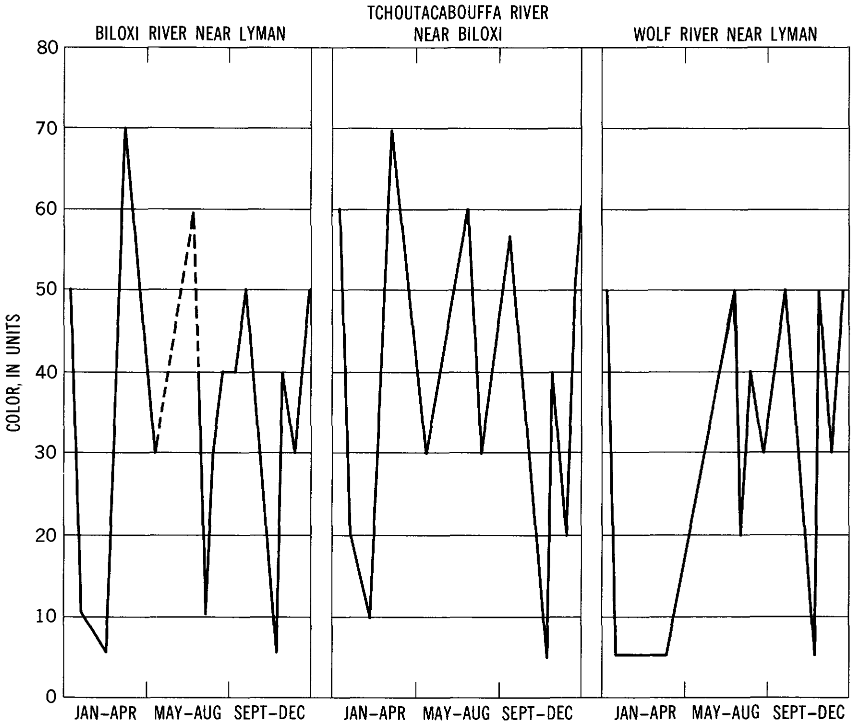

FIGURE 10.—Variation of color with time in the Biloxi, Tchoutacabouffa, and Wolf Rivers.

upon the magnitude and duration of the change. During flood tide, the salt front moves upstream; as the tide ebbs, the front moves downstream. During spring tide the differences between high and low tide may be as much as 3 feet, and during neap tide the differences may be only a few tenths of a foot. Thus, for a given river discharge, the salt front moves back and forth through a greater distance during a spring tidal cycle than during a neap tidal cycle.

The thalweg of the Wolf River is irregular; for example, it ranges in elevation from 2 to 17 feet below sea level between mile 3 and mile 4. A graphic plot of the thalweg (pl. 2) indicates that the bed of the Wolf River is a series of depressions separated by ridges of various length.

Maximum penetration of the salt front in Wolf River under normal tidal conditions during this study reached mile 6.5, when the discharge at Landon was about 70 cfs. Specific conductance, chloride data, and study of the stream-bed profile (pl. 2) in the reaches upstream from mile 6.5 indicate that salt water did not penetrate beyond mile 7.0.

TABLE 11.—*Specific conductance and chloride determinations for selected points on the Biloxi, Tchoutacabouffa, and Wolf Rivers*

[Upper value for each sampling point represents surface sample; lower value represents river-bottom sample; single value, surface sample]

Sampling point on map (pl. 2)	Specific conductance (mircomhos)	Chloride (ppm)	Sampling point on map (pl. 2)	Specific conductance (mircomhos)	Chloride (ppm)
		Biloxi River			
2	10,600	3,620	10	7,030	2,320
	24,400	9,300		20,000	----
4	9,500	----	11	300	----
	24,400	9,200		3,040	942
5	10,000	----	13	65	4.4
	23,600	8,830			
		Tchoutacabouffa River			
1	6,440	2,120	7	712	200
	16,600	5,940		----	----
2	3,230	1,000	10	55	6.9
	13,400	4,720		55	----
6	1,000	263			
	10,000	----			
		Wolf River			
0	13,700	4,410	4.5	946	240
	15,100	4,740		4,400	1,300
1	10,600	3,300	5	354	81
	14,000	4,450		9,560	2,880
2	8,670	2,660	5.5	131	28
	13,500	4,300		1,440	386
3	4,010	1,160	6	44	6.1
	10,900	3,420	6.5	39	5.6
3.5	1,930	506		42	6.4
	11,600	3,610			
4	1,530	410			
	8,890	2,760			

Salt-water penetration beyond mile 7.0 would be a rare event that would result from the simultaneous occurrence of low river discharge and high tide.

The downstream flow of fresh water erodes and diffuses the salt-water wedge, thus increasing the dissolved-solids content of the water from the fresh-water reaches to the gulf. Consequently, the quality of water in the zone of salt-water intrusion varies between the quality in the fresh-water reaches of the streams and that in Mississippi Sound. The variation in specific conductance with depth and distance below the salt front and the effects of the ridges in the thalweg of the Wolf River, especially the ridge at mile 7, are shown on plate 2.

Analyses of samples collected from Mississippi Sound show the dissolved-solids content to be variable and lower than the dissolved-solids content of ocean water. Undiluted ocean water contains about 35,000 ppm of dissolved solids, including about 19,000 ppm of chloride. The analyses of Mississippi Sound water show a dissolved-solids content of 19,900–27,100 ppm and a chloride content of 10,600–14,900 ppm.

EFFECTS OF STORAGE ON WATER QUALITY

Water on the land surface can be stored in two types of reservoirs, manmade and natural; in either type of reservoir the effects of storage on the chemical quality of water would be about the same in Harrison County.

Storage of large volumes of surface water in reservoirs in Harrison County would improve the overall chemical quality of the surface water. The pH of the Biloxi, Tchoutacabouffa, and Wolf Rivers would be increased from the low range, 4.5 to 6.3, to a range of 6 to 7.

Impoundment of water in open reservoirs without first cleaning the land areas leads to temporary deterioration of water quality. When the reservoir area is flooded, the vegetation dies, and organic matter is released to the water. Algae and other micro-organisms flourish. Odor, taste, and color are imparted to the water, rendering it unsuitable for most domestic and some industrial uses. The stabilization rate in shallow reservoirs is greater than in deep reservoirs. Ninety percent reduction of color and micro-organisms in shallow uncleaned reservoirs is effected in 12–16 years; whereas, the same reduction in deep reservoirs under the same conditions will take as long as 20–24 years (Fair and Geyer, 1965, p. 235). Reservoirs which have been cleaned properly do not need a stabilization period prior to use of the water.

Reducing conditions at the bottom of deep reservoirs durings summer seasons tend to hold in solution undesirable chemicals, such as iron and manganese, that may be present. Water withdrawn from the bottom of a reservoir can contain these impurities.

In general, the water of a lake is less subject to rapid variation in composition than river water, and many large lakes are remarkably constant over long periods of time. Because of relative quiescence, lakes serve as very efficient settling basins, and their turbidities are usually low for the greater part of the time.

LEGAL RESTRICTIONS ON QUALITY CHANGES

The Mississippi law controlling disposal of industrial waste into the streams of the State is administered by the Game and Fish Commission. Regulations established by the Commission state that the stream waters shall have the following characteristics after the addition of industrial effluent:

1. There shall be no noticeable floating solids, scum, oil, or grease slick.
2. The pH values shall average in the range of 6.0 to 8.4, and a sample shall not be below pH 5.0 nor above pH 9.5.
3. The salt concentration shall not be increased by more than 1,000 ppm sodium chloride.

4. The dissolved oxygen shall not be reduced below an average of 3.0 ppm, and no sample shall contain less than 2.5 ppm.
5. No poisons or deleterious substances shall be present in sufficient quantities to cause injury or death to fish or wildlife.
6. No substances shall be present which could cause distinct foreign tastes in fish.

The Mississippi State Board of Health has regulatory control of waste disposal by municipalities with a population in excess of 5,000.

WATER TREATMENT

To present specific water-quality requirements for all industrial uses would be impossible. The general classifications of industrial uses of water are as follows: cooling, processing, power generation, sanitary services, fire protection, and miscellaneous. Of these uses, the demands for cooling water far exceed all others.

Chemical analyses of water for municipal and industrial uses are necessary to determine whether the water is suitable for specific purposes and, if not, to determine the type and cost of treatment necessary to make it satisfactory. Analyses can also be used to determine the cost of softening water, its scale-forming properties, or its tendence to corrode plumbing.

Chemical analyses of the Biloxi, Tchoutacabouffa, and Wolf Rivers indicate that treatment would be necessary to remove color if the water is to be used for municipal and most industrial purposes. However, if the water is to be used for cooling, no treatment would be required. For example, the Mississippi Power and Light Co. uses some 300 million gallons of very saline water (dissolved solids about 25,000 ppm) each day for cooling. Table 10, showing color limits permissible in water for industrial use, contains only four uses for which the colored water in the Biloxi, Tchoutacabouffa, and Wolf Rivers would qualify in their natural state.

Most industries and municipalities would have to employ some method of treatment to adjust the low pH values (4.5–6.3) from the Biloxi, Tchoutacabouffa, and Wolf Rivers. There are many acceptable methods for neutralizing acid waters. Some of these methods are (1) mixing acid water from the streams with high-alkaline ground water so that the net effect is a near-neutral pH; (2) passing acid water through trays of limestone; (3) mixing acid water with lime slurries; and (4) adding the proper proportions of concentrated solutions of caustic soda or soda ash to acid stream water.

The concentration of iron is low in streams in Harrison County and would require no treatment for most industrial and municipal requirements.

FLOODS

HEADWATER FLOODS

Harrison County, because of its geographic location, is often subjected to periods of excessive precipitation and resulting floods. Intense rainfall can occur as a result of tropical storms during the summer and fall and of thunderstorm activity in the spring.

Records of discharge and stage of outstanding floods that have occurred on streams in Harrison County can be of inestimable value in the design and location of structures on and adjacent to the streams. Discharge data, as well as stage data, are of significance to the designer in planning water-supply, flood-control, recreation, or transportation facilities.

Two noteworthy floods in recent years have contributed much to the understanding of flood patterns along the Tchoutacabouffa, Biloxi, and Wolf Rivers. The highest flood on Tuxachanie Creek since streamflow records were begun in 1952 occurred in September 1957 and produced a peak discharge of 17,700 cfs (fig. 11) at the gaging station at State Highway 15. The flood of April 1964 crested at a stage 2.50 feet lower. According to local residents, a flood that exceeded the 1957 flood by 1 foot occurred during the period 1907–09 at the same site (fig. 12).

Downstream at the State Highway 67 crossing of the Tchoutacabouffa River, the September 1957 flood produced a peak discharge of

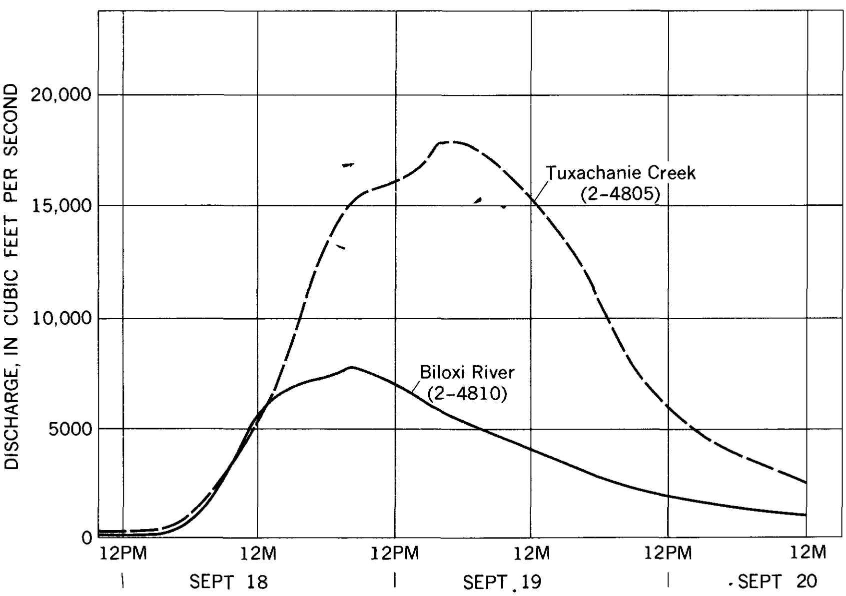

Figure 11.—Discharge hydrographs at gaging stations in Harrison County.

36,000 cfs, and the April 1964 flood produced a peak discharge of 26,400 cfs at a stage 2.68 feet lower than the September 1957 flood (fig. 12). On the Biloxi River at the gaging station at U.S. Highway 49, the flood of April 1964 crested at 42.12 feet above mean sea level. The peak discharge was 8,420 cfs. The discharge of this flood was slightly greater than the discharge of the outstanding flood of September 1957 (7,740 cfs), but the crest elevation of the September 1957 flood was 0.14 feet higher (42.26 ft above mean sea level). Great floods which occurred prior to establishment of the gaging station at U.S. Highway 49 were the floods of 1916, 1928, and 1948. The floods in 1916 and 1928 were approximately the same stage and were at least 8.5 feet higher than the 1957 flood at a point about 1 mile upstream from U.S. Highway 49. The 1948 flood peaked at 44.5 feet above mean sea level at U.S. Highway 49.

The flood of March 14, 1947, crested at 86.5 feet above mean sea level at the gaging station on Wolf River at State Highway 53. The peak discharge of this record flood was 18,500 cfs. The second highest flood at State Highway 53 occurred April 27, 1964, and reached a peak of 86.26 feet above mean sea level (fig. 12).

FLOOD FREQUENCY

Flood data represent past events and can be used in the form of flood-frequency curves to predict future events. Curves by Wilson and Trotter (1961) that are applicable to streams in Harrison County are shown herein. The magnitude and frequency of floods can be estimated from these curves by using the size, shape, and location variables of the drainage basin.

Peak discharges of floods at 174 sites on streams in Mississippi were correlated with drainage areas and basin-shape factors by using graphic multiple-correlation techniques. The basin-shape factor used is a ratio of the distance that floodwaters must flow divided by the average width of the basin. The ratio was computed by using the formula $r=\frac{L^2}{A}$, or $r=\frac{L}{W}$,

where

r=ratio (the basin-shape factor);
L=maximum length, in miles, that floodwaters flow;
A=drainage area, in square miles, of the basin; and
W=average width, in miles, of the basin, equivalent to $\frac{A}{L}$.

A study of the correlations indicated that, after both drainage area and basin shape had been considered, significant errors in estimate of the peak discharges remained. Some of the scatter undoubtedly can be attributed to chance and to errors in method; however, a large

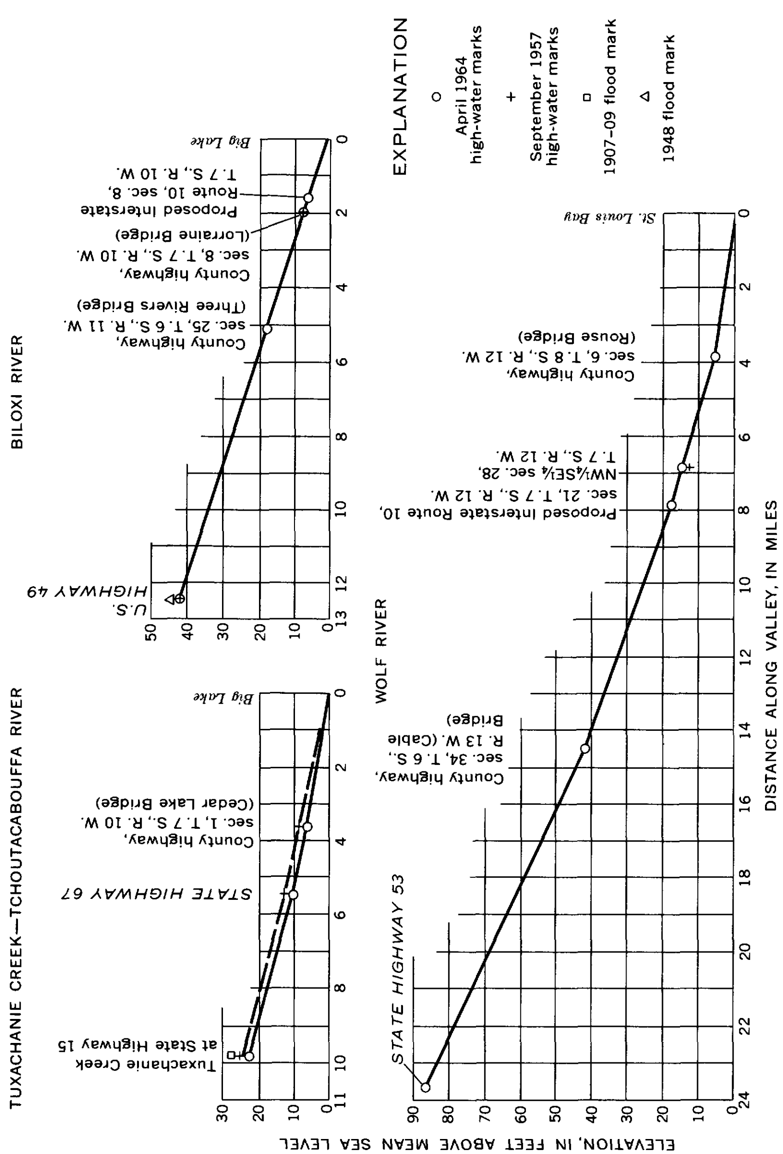

FIGURE 12.—Flood profiles of streams in Harrison County.

part of it is a result of factors such as geographic location, slope, geology, and soil types not evaluated in the correlations. Many of these factors are similar in other areas of Mississippi. Largely through trial and error, the State was divided into five hydrologic areas; parts of two of the areas are in Harrison County (fig. 13).

The groups of curves applicable to the hydrologic areas in Harrison County are shown in figures 14 and 15. To incorporate the effect of basin shape into these curves was impractical; therefore, the curve showing that effect is presented separately in figure 16. In Harrison County the larger floods generally overtop the banks and flow along the valleys; accordingly, the length of floodwater flow is measured as valley length, rather than channel length.

USE OF FLOOD-FREQUENCY CURVES

Flood-frequency curves can be used to estimate the magnitude and frequency of floods on most streams in Harrison County. Methods presented herein are not applicable to regulated streams or to extremely small drainage areas. Neither do the curves apply to estuarial sites

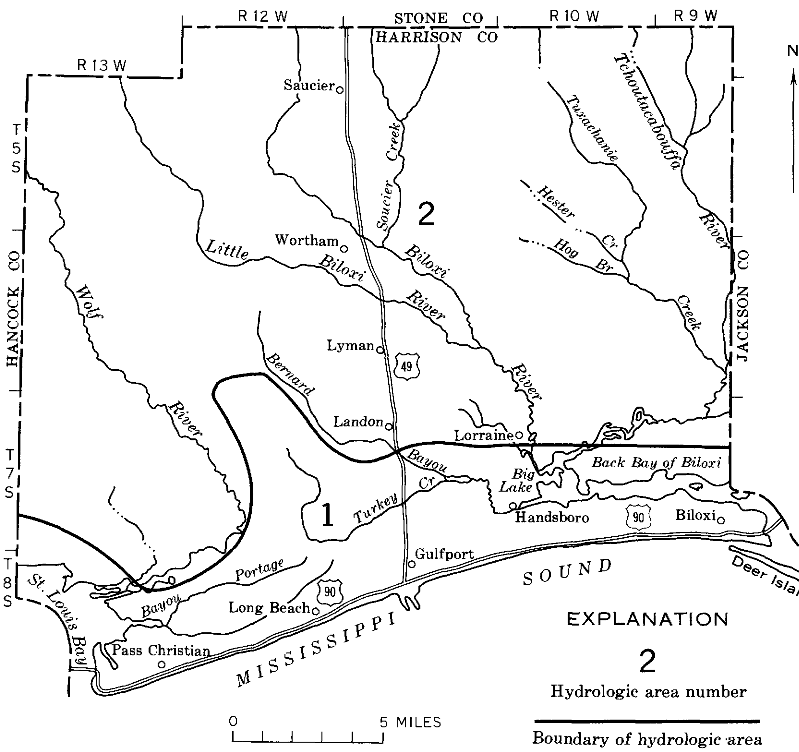

FIGURE 13.—Location of hydrologic areas in Harrison County.

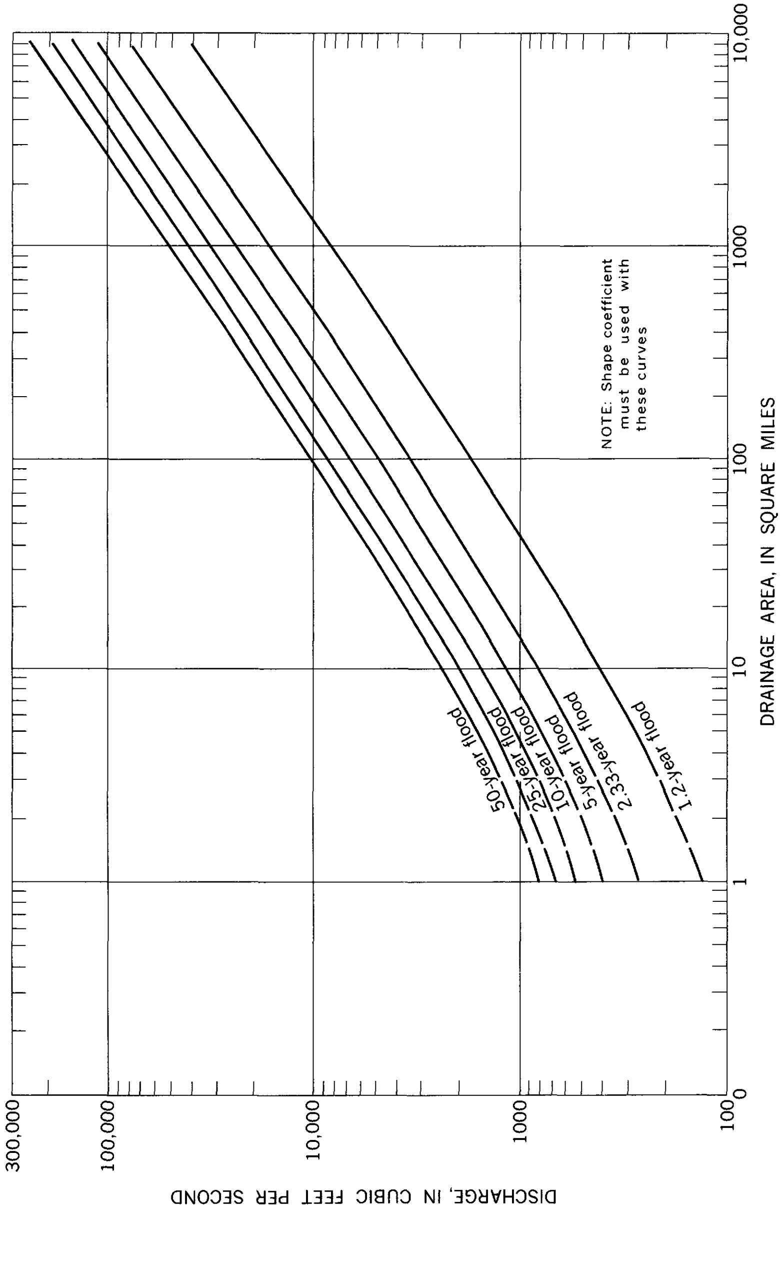

FIGURE 14.—Flood-frequency curves for hydrologic area 1.

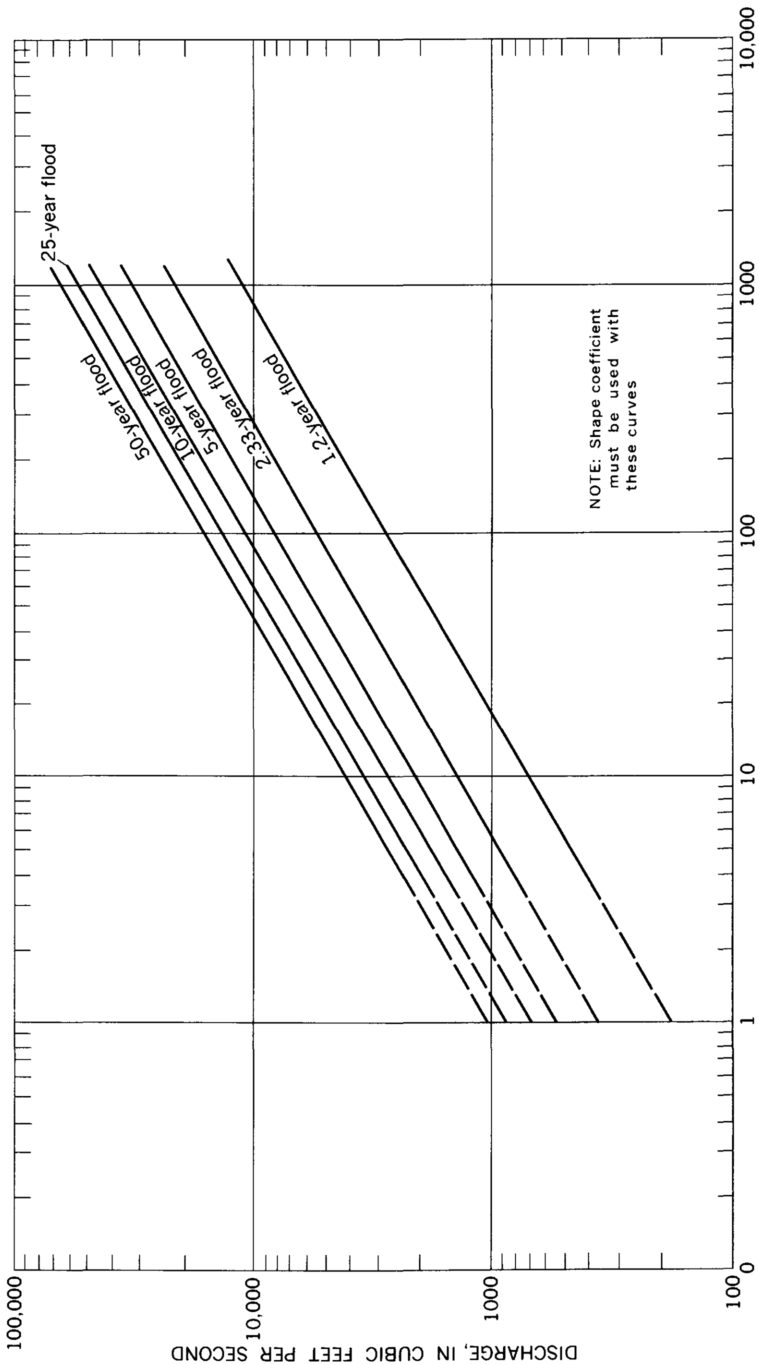

FIGURE 15.—Flood-frequency curves for hydrologic area 2.

near the mouths of coastal streams, where unusual flood discharges result from hurricane tides moving water either into or out of storage. Similarly, the curves are not applicable near the mouths of streams draining into larger streams because the rate of rise or fall of the larger streams may cause variable amounts of backwater and storage at the places in question.

To illustrate the use of these curves, assume that the user is concerned with the design of a drainage structure on the Biloxi River at U.S. Highway 49 at Wortham. The economics of the situation dictate that the structure be designed to pass a 25-year flood. The peak discharge of April 27, 1964, was 8,420 cfs. The user needs to know the frequency of a similar occurrence.

The following steps would be necessary to determine the magnitude of the 25-year flood:

1. The drainage area would be determined from the best available map. In this example the area was 98.3 square miles.
2. The maximum distance floodwater must travel would be measured on the same map. For the station at Wortham, the length of the basin was determined to be 26 miles.
3. Determine from figure 13 the hydrologic area in which the drainage basin lies. Biloxi River at Wortham is in area 2.

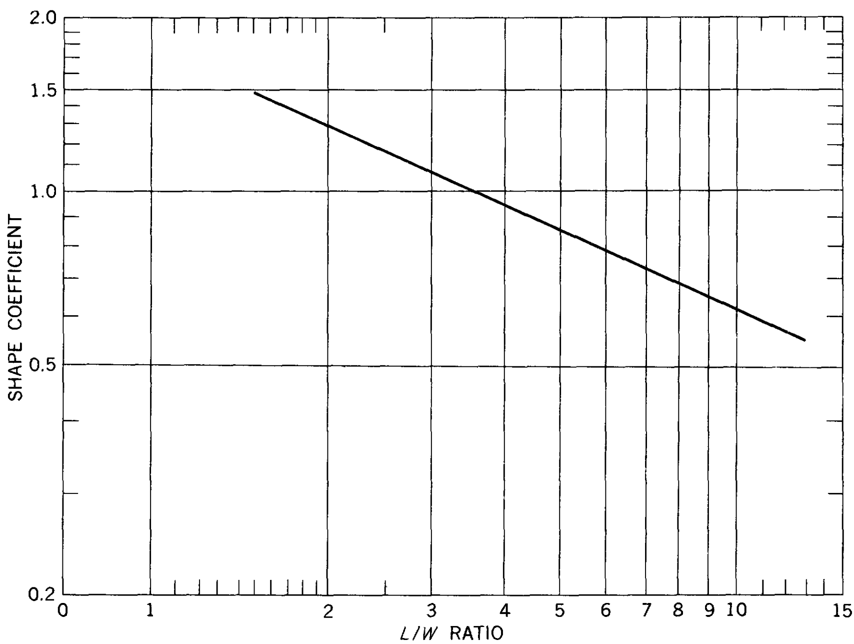

FIGURE 16.—Shape-coefficient curve for hydrologic areas 1 and 2.

4. From figure 15 (flood-frequency curve for area 2) and by use of the drainage area factor determined in step 1, the magnitude of the 25-year flood is seen to be 13,900 cfs. This value is for an average-shaped basin and must be adjusted for the shape of the Biloxi River drainage basin above the point in question.
5. Compute the length-width ratio by the formula $r=\frac{L^2}{A}$. For the Biloxi River, $r=\frac{(26)^2}{98.3}=6.88$.
6. Determine the shape coefficient using figure 16. A length-width ratio of 6.88 corresponds to a shape coefficient of 0.74.
7. Adjust the 25-year flood discharge found in step 4 for shape by multiplying the unadjusted value by the shape coefficient. For the Biloxi River, $Q_{25}=13{,}900$ cfs $\times 0.74=10{,}300$ cfs.

To determine the probable frequency of a known flood, the procedure is the reverse of that shown above. Again, referring to the hypothetical problem on the Biloxi River, the following steps would be taken to determine the probable frequency of a flood of 8,420 cfs.

1. The drainage area, length-width ratio, and shape coefficient would be the same as those determined previously.
2. Adjust the measured discharge to a value for an average-shaped basin by dividing by the shape coefficient for that basin. The adjustment for the Biloxi River would be as follows:

$$\frac{8{,}420}{0.74}=11{,}400 \text{ cfs.}$$

3. Determine the approximate frequency from the areal frequency curve. By use of figure 15 for hydrologic area 2 and the drainage area of 98.3 square miles, the 11,400 cfs flood (equivalent to 8,420 cfs on the Biloxi River) is found to occur on the average of once in about 12 years.

TIDAL FLOODS

One of the major natural hazards to Harrison County is the gulf hurricane. High winds, storm waves and tides, and extreme river floods due to torrential rains cause great damage when hurricanes unleash their fury.

Since 1866 the Mississippi coast has been affected by 23 storms of full hurricane intensity. The most recent detailed study of hurricanes affecting Mississippi is presented in the U.S. Army Corps of Engineers, Mobile District, report (1965), which contains summaries of hurricane distribution, storm damage, climatological data, protective measures, and related subjects. The report includes all recorded hurricanes and tropical storms that affected the area prior to the September 1965 storm and presents maps showing the areas along the coast that were inundated by a 10-foot tide.

Inundation due to hurricane storm tides is a major hazard along the Harrison County gulf coast. High-water marks more than 13 feet above mean sea level were observed at several places along the coast after recent hurricane storm tides. Figure 17 is a map of the coastal area of Harrison County showing the location and elevation of hurricane-tide marks recorded by the U.S. Geological Survey and the U.S. Army Corps of Engineers after the storms of September 1947 and September 1965. The map also shows that the effect of the high tides extends several miles inland up coastal streams.

The hurricane-tide-frequency curve in figure 18 is applicable to the coastal area of Harrison County; it shows the number of times that any given tide can be expected to be equaled during a 100-year period. As an example of how this curve can be used, consider the tide elevation of 10.70 feet above mean sea level observed at the Gulfport recording gage during the September 1965 hurricane. From the curve (fig. 18) this elevation can be expected to have a normal occurrence of about three times in 100 years.

Inundation is not the only hazard associated with tidal floods. During storm tides, salt water penetrates several miles farther up coastal streams than it would during normal high tide. After the tide has subsided, the salt water can be expected to retreat to its normal limit of penetration. However, small pockets of brackish water may persist in some streams for a considerable length of time after the storm. If this water entered industrial water intakes, serious damage can result.

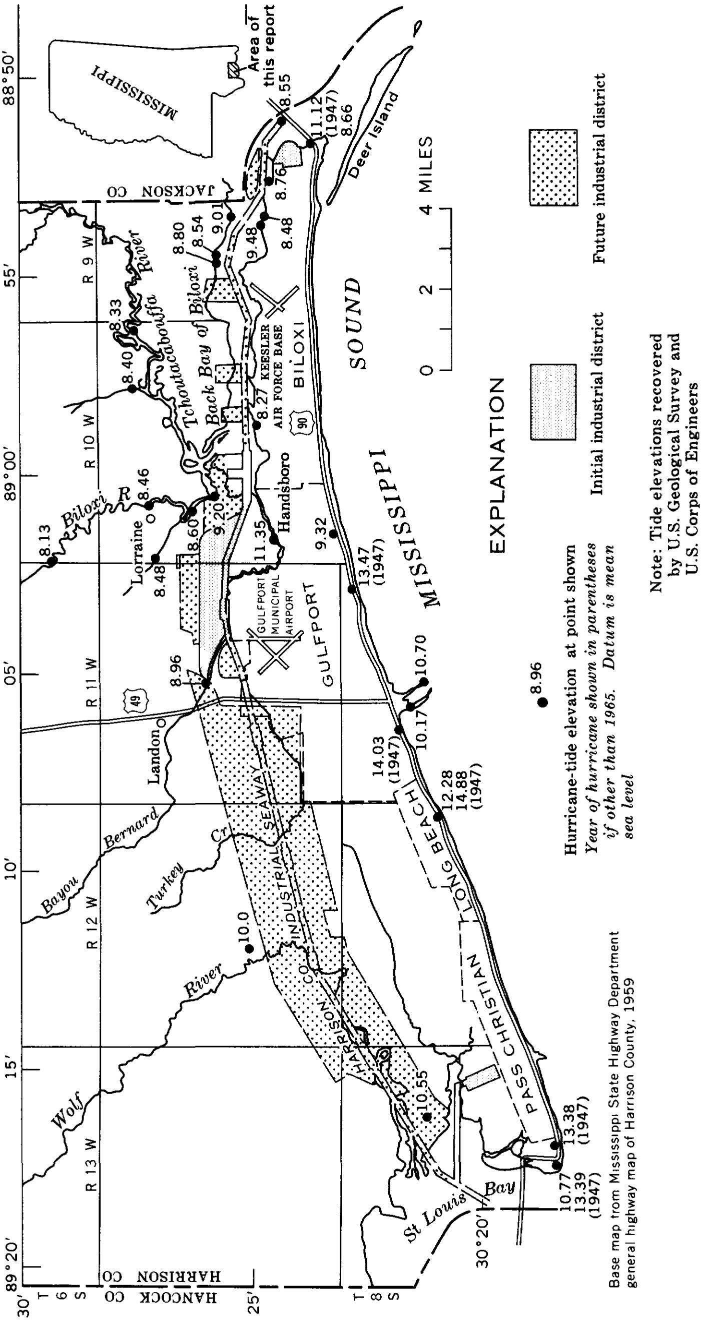

FIGURE 17.—Location of hurricane-tide elevations, September 1947 and September 1965.

Hurricane-tide elevations in Harrison County

Elevation (feet)	Date	Location
13.39	1947	At Gulfshore Baptist Assembly, Henderson Point, lat 30°18′20″, long 89°17′30″.
10.77	1965	
13.38	1947	At residence ½ mile east of Gulfshore Baptist Assembly.
10.55	1965	At residence in DeLisle, lat 30°21′15″, long 89°16′20″.
10.0	1965	Wolf River at proposed Interstate Route 10, lat 30°25′00″, long 89°12′00″.
14.88	1947	At first residence west of Kit Carson's Tourist Court, Long Beach.
12.28	1965	At Hatem Texaco Service Station, Long Beach, lat 30°20′45″, long 89°08′35″.
14.03	1947	At residence across street from Gulf Haven Tourist Home, West Beach, Gulfport.
10.17	1965	At White Star Fish Co., Gulfport, lat 30°21′30″, long 89°05′55″.
8.96	1965	Bayou Bernard at proposed Interstate Route 10, lat 30°26′00″, long 89°05′20″.
10.70	1965	Gulfport recording gage, West Pier, lat 30°21′11″, long 89°05′29″.
13.47	1947	At residence 500 feet west of Court House Road, Mississippi City.
8.48	1965	Fritz Creek at proposed Interstate Route 10, lat 30°27′00″, long 89°02′15″.
8.13	1965	Biloxi River recording gage near Lyman, lat 30°29′18″, long 89°02′09″.
11.35	1965	At tavern, corner Cowan Road and Magnolia St., Handsboro, lat 30°24′25″, long 89°01′40″.
9.32	1965	At trailer sales office on U.S. Highway 90 at Cowan Road, Mississippi City, lat 30°23′05″, long 89°01′30″.
8.46	1965	Biloxi River near Loraine, lat 30°27′10″, long 89°00′50″.
8.60	1965	At Mississippi Powerplant intake canal near Mississippi City, lat 30°26′10″, long 89°00′40″.
9.20	1965	At Mississippi Powerplant discharge canal near Mississippi City, lat 30°25′30″, long 89°00′35″.
8.27	1965	At Pops Ferry Bridge, Biloxi, lat 30°24′50″, long 88°58′35″.
8.40	1965	Parker Creek at proposed Interstate Route 10, lat 30°27′35″, long 88°57′40″.
8.33	1965	Tchoutacabouffa River at Redmond's Camp, Cedar Lake, lat 30°27′30″, long 88°56′20″.
8.80	1965	At Mr. Loney's residence off Brodie Road, D'Iberville, lat 30°25′45″, long 88°54′30″.
8.54	1965	At Brodie Nursery on Bay Shore Road, D'Iberville, lat 30°25′45″, long 88°54′15″.
9.48	1965	Near south end of D'Iberville Bridge, Biloxi, lat 30°24′50″, long 88°53′40″.
8.48	1965	At Biloxi Canning Co., lat 30°24′50″, long 88°53′30″.
9.01	1965	At north end of D'Iberville Bridge, Biloxi, lat 30°25′30″, long 88°53′30″.
8.76	1965	At Bill's Curb Market, Bayview Drive, Biloxi, lat 30°24′40″, long 88°52′40″.
11.12	1947	At Coast Guard Station, Biloxi, lat 30°23′30″, long 88°51′25″.
8.66	1965	
8.55	1965	Biloxi recording gage at railroad bridge, Biloxi, lat 30°23′59″, long 88°51′02″.

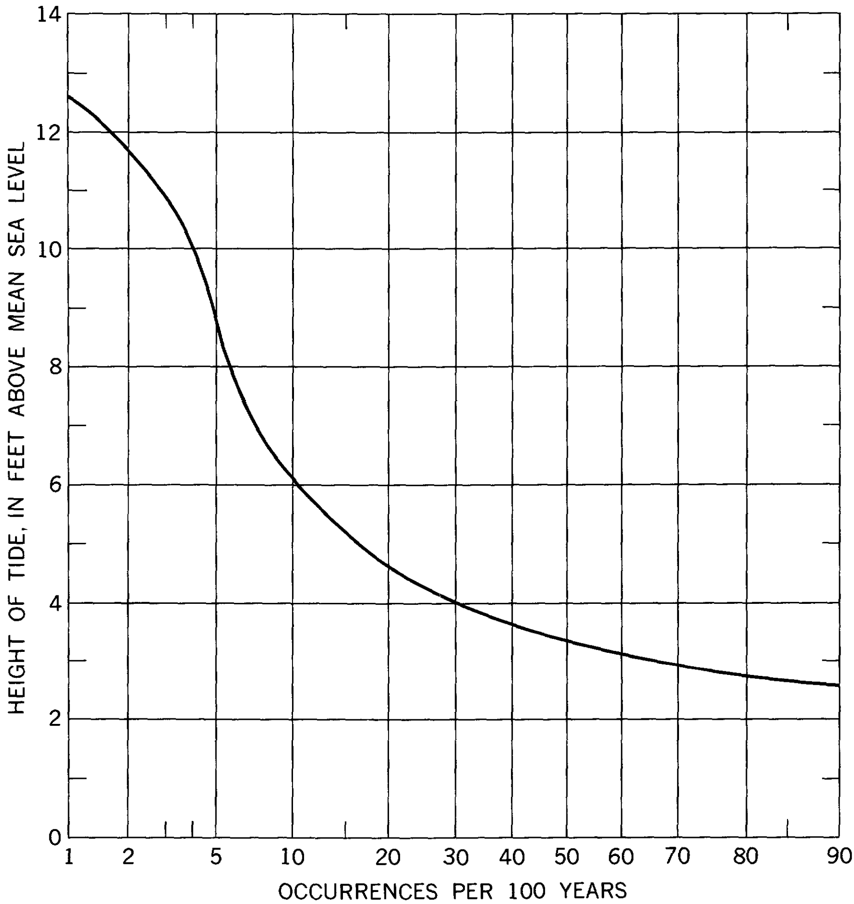

FIGURE 18.—Hurricane-tide-frequency curve (from U.S. Army Corps of Engineers, Mobile District, 1965).

GROUND WATER

DEPTH AND THICKNESS OF AQUIFERS

Fresh-water aquifers are available in Harrison County to depths ranging from 1,850 feet (1,700 ft below sea level) in the northeast corner to 2,500 feet near Gulfport, where land-surface elevations are only a few feet above sea level (fig. 19). The upper half of the fresh-water zone is tapped by wells in the coastal cities; however, in most inland places probably less than a quarter of the fresh-water zone has been penetrated by water wells. Some of the thickest and potentially most productive aquifers have not been tapped for water supplies.

The deepest water wells in the county, about 1,400 feet deep, are near Landon. The deepest of the major supply wells are screened at about 1,200 feet (table 12). Most major supply wells along the coast tap aquifers that are 600–1,200 feet deep. In the interior of the county, aquifers may exist at any depth within the fresh-water zone, depending upon location. The aquifers, which are beds of sand that dip gently south-southwest, commonly are lenticular and cannot be delineated over large areas. Electric logs of oil tests are the chief source of information on aquifer thickness, particularly for those parts deeper than existing water wells. Although electric-log data are lacking for large parts of Harrison County, the available logs are of great value in appraising the potential ground-water supply. Fresh-water sand intervals (table 13) indicated by these logs range in thickness from 10 to 270 feet and have a median thickness of 65 feet. Locations of the electric logs summarized in table 13 are shown on plate 1, which also shows cross sections constructed from the log data.

Nearly everywhere along the coast, as elsewhere in the county, water can be obtained from two or more aquifers. The following table gives the general depth of aquifers, in feet, tapped by wells in the towns and military installations from Pass Christian, on the west, to Biloxi, on the east. See also geohydrologic section *A–A′* (pl. 1) and the city maps (pl. 3).

Pass Christian	Long Beach	Navy base (CB)	Gulfport	Mississippi City	Keesler AFB	Biloxi
800	900	750	----------	----------	600	600
1,100	----------	850	900	800	----------	1,200
----------	----------	1,200	1,200	----------	----------	----------

TABLE 12.—*Descriptions of major wells in the coastal region of Harrison County*

Type of test: C, chemical analysis; P, pumping test.

Owner	Well: U.S. Geol. Survey No.	Well: Owner No.	Location	Year drilled	Depth (ft)	Casing diameter (in.)	Screen length (ft.)	Water level: Above (+) or below (−) land surface (ft)	Water level: Date of measurement	Discharge (gpm)	Temperature (°F)	Remarks
Biloxi												
Municipal Supply:												
City of Biloxi	M2	1	Biloxi Water Works	1954	1,207	18, 12, 10	80	+19	Dec. 1964	1,600		P
Do	M3	2	do	1945	905	12, 8	86	−4	Nov. 1964	600		C
Do	M4	3	Maple St	1945	1,200	12, 10	80	+4	Dec. 1964	460		P
Do	M5	6	Iberville St	1952	865	12, 8, 6	80			1,000		
Do	M6	7	Hospital on Bayview Dr	1963	463	14, 10	79	−6	Nov. 1964	550		
Do	M115	5	Father Ryan St	1942	1,226	12, 10		+19	Dec. 1964	900		C, P
Do	M119	4	Porter St	1927	1,182	12, 10	68	+19	Dec. 1964	800	86	C, P
Military Supply:												
Keesler Air Force Base	M64	1	B St. between 3d and 4th St.	1942	620	18, 12, 10	40	−26	Nov. 1964	620	77	C, P
Do	M65	4	E St. between 3d and 4th St.	1942	631	18, 10	40	−25	Nov. 1964	600		C
Do	M66	3	H St. between 3d and 4th St.	1942	639	12, 10	40	−25	Nov. 1964	600	77	C
Do	M67	2	E St. between 1st and 2d St.	1942	634	12, 10	40		Nov. 1964	580		C
Do	M68	5	H St. west of 1st St	1942	618	10	40	−24	Nov. 1964	560		C, P
Do	M75	7	West end of Service Dr	1951	610	24, 18, 12	40	−21	Nov. 1964	700		C,P
Do	M76	8	East end of G St	1951	630	24, 18, 12	40	−23	Nov. 1964	740		C,P
Do	M77	9	West Howard Ave. near Q St.	1951	638	24, 18, 12	40		Nov. 1964	700		C
Do	M78	10	Near Pass Rd. and Ploesti Dr.	1951	641	24, 18, 12	40	−25	Nov. 1964	720		C,P
Do	M79	11	Southwest corner of military reservation.	1951	640	24, 18, 12	40	−25	Nov. 1964	800		C,P
Miscellaneous:												
Buena Vista Hotel	M9		U.S. Highway 90 near Cuevas St.	1958	946	16, 10	60	+10	1958	565	82	C
Coast Water Works	M14		Beachview Ave	1958	830	6, 4	40	+1	Oct. 1958	80		
Do	M33		Bay View Dr., near Pops Ferry Rd.	1957	700	8	40	+1	1957	475	80	
Do	M40		Tanglewood subdivision	1960	654	12, 8	50	−17	Apr. 1966	350		P
Jefferson Davis Junior College.	M48		Switzer Rd	1964	670	6, 4	60	−18	Aug. 1964	100		
New Ice Co	M58		Bowen St. near Back Bay	1934	935	6	40	+13	May 1964	150	82	C

U.S. Veterans Hospital	M80	1	Pass Rd. and Pat Harrison Ave.	1940	1,245	10, 6	58		1966	250		
Do	M81	2	At hospital	1948	1,282	10, 6	60		1966	300		
Keesler AFB Housing Unit.	M82		Pat Harrison Ave., near Pass Rd.	1961	684	24, 18, 10	60	−13	1961	1,000		C
Mavar Shrimp and Oyster Co.	M147		Maple St., near beach	1966	1,002	12, 8	60	+8	Apr. 1966	950	83	P
Dejean Packing Co	M148		Foot of Pine St	1966	733	6, 4	40	+8	Feb. 1966	200		
				Gulfport								
Municipal Supply (Gulfport):												
City of Gulfport	L2		30th Ave	1964	815	24, 16, 10	60	−8	Oct. 1964	1,100		P
Do	L14	5	Airport	1956	763	24, 16, 10	60	−3	Oct. 1964	965		P
Do	L15		East Railroad St	1963	752	24, 16, 10	63	−19	Aug. 1964	960	78	P
Do	L16		34th St	1959	815	16, 10	70	−3	Apr. 1966	975		P
Do	L17		Mills Ave	1952	848	18, 10	80	−8	Mar. 1966	500	80	P
Do	L84	2	Airport	1942	645	12, 6	86	−10	Oct. 1964	900	77	C, P
Do	L147		18th St. and 24th Ave	1937	953	10	71	−30	Mar. 1966	665	81	C, P
Do	L149		do	1927	1,242	12, 10		−3	Mar. 1966	710	85	C, P
Municipal Supply (Mississippi City—Handsboro):												
Mississippi City Water Co.	L4		Victory and Ebony Sts	1958	1,179	4	30	+4	June 1964	75		C
Do	L8		Railroad St. near Walston St	1959	1,199	4	30	+10	June 1964	75	82	C
Do	L9		16th St	1947	1,219	3	40	0	June 1964	75	80	C
Do	L10		Wood Glen subdivision	1961	858	6, 4	40	−6	1961	150	79	C
Do	L11		Teagarden Rd	1946	1,193	3	40	+2	June 1964	75	80	C
Handsboro Water Works.	L31		Singwood subdivision	1962	818	6, 4	20	−4	1962	100	78	
Mississippi City Water Co.	M27		Sherwood Dr	1962	802	6, 4	30	−18	Sept. 1962	125	79	C
Do	M28		Township Rd	1950	890	4	40	+8	June 1964	75	81	C
Handsboro Water Works.	M29		Pass Rd. near Pine St	1964	825	6, 4	20	−9	1964	75	77	C
Do	M30	1	Commerce St	1952	920	4	40			75	81	C
Mississippi City Water Co.	M142		Township Rd. near Martin Ave.	1911	915	4				75	80	C
Miscellaneous:												
Phillips Co	L6		U.S. Hwy. 49 near 34th St	1946	1,174	10, 6	40	−19	Jan. 1966	350		C
Coca Cola Bottling Co	L13		do	1963	860	6	30			200	79	C

TABLE 12.—*Descriptions of major wells in the coastal region of Harrison County*—Continued

Owner	Well: U.S. Geol. Survey No.	Well: Owner No.	Location	Year drilled	Depth (ft)	Casing diameter (in.)	Screen length (in.)	Water level: Above (+) or below (−) land surface (ft)	Water level: Date of measurement	Discharge (gpm)	Temperature (°F)	Remarks
Gulfport—Continued												
Orange Grove Utilities	L18		Dedeaux Rd. and Klein Rd.	1962	765	8, 6	50	+22	Oct. 1962	300	80	C
U.S. Veterans Hospital	L141		Railroad St. near Arkansas St.	1956	1, 098	10, 6	80			533	82	C
U.S. Naval base (CB)	L160	1	U.S. Naval Base (CB)	1942	1, 196	10, 6	29	+1	Nov. 1965	833		C, P
Do	L161	2	do	1942	850	10, 6	30			526		C, P
Do	L162	3	do	1943	757	10, 6	60			500		C, P
Broadwater Beach Golf Club.	M7		Anniston Ave. and L&N RR.	1963	1, 036	12, 8	60	−8	May 1963	500		
Mississippi Power Co.	M23	1	Pat Watson Steam Plant	1956	755	24, 16, 10	60	+9	Dec. 1964	380	79	C, P
Do	M24	2	do	1956	845	24, 16, 10	60	+4	Dec. 1964	317		P
Harrison County Develop. Comm.	M26		Lorraine Rd	1962	752	16, 10, 6	60	+4	Dec. 1964	500	81	
Handsboro Water Works.	M32		Fernwood Heights	1962	840	6, 4	30	14	1962	100		C
Reichhold Chemical Co.	M49		Reichhold Rd	1964	745	10, 6	60	+1	Jan. 1965	600		
Gulf Coast Military Academy.	M101		U.S. Hwy. 90 and Anniston Ave.	1937	900	4	40	−9	Sept. 1965	500		C
Gulf Homes Water Corp.	M149		College Park subdivision	1964	1, 033	12, 8	60	−2	1964	350		
Long Beach												
Municipal Supply:												
City of Long Beach	L5		Wright Ave	1958	880	10, 6	80	−6	1964	500		
Do	O1		Lang Ave	1963	926	12, 8	60	+3	May 1964	585	80	C, P
Do	O172		Jeff Davis Ave	1947	848	10, 6	80			385	79	P
Do	O174		Waterworks (2d St.)	1956	962	10, 6	80	+6	Jan. 1965	500	79	C
Miscellaneous:												
Coast Water Works	O8		Royal Grove subdivision	1960	611	8, 6	40	−5	Apr. 1966	340		P
Do	O11		Daugherty Park subdivision	1964	590	12, 8	40	+3	Apr. 1966	330		P

Pass Christian												
Municipal Supply:												
City of Pass Christian	N2	--------	Brown St.	1953	1,002	6	40	----------	----------	300	--------	
Do.	N3	--------	Fire station	1948	1,111	6	60	+22	Mar. 1966	90	84	C,P
Do.	N191	--------	do.	1937	880	6	60	----------	----------	300	--------	C
Do.	O6	--------	Lang Ave. and 2d St.	1954	891	8	50	+6	Mar. 1966	435	81	P
Miscellaneous:												
Portage Estates subdivision.	N6	--------	1 mile north of Bayou Portage bridge.	1965	810	6, 4	30	+20	June 1965	150	--------	

TABLE 13.—*Fresh-water sand intervals from electric logs of oil tests*

Oil test No. shown on pl. 1	1	2	3	4	5	6
Location (sec., T., R.)	26, 4 S.–10 W.	20, 5 S.–13 W.	13, 6 S.–11 W.	30, 4 S.–10 W.	17, 5 S.–13 W.	33, 4 S.–11 W.
Elevation (ft)	148	112	65	145	169	156
Top of log (ft)	1,400	50	1,079	906	90	156
Sand intervals (ft)	1,430–1,560	240–440	1,260–1,300	910–990	120–155	190–300
	1,770–1,850	470–550	1,510–1,525	1,050–1,095	230–255	400–430
	2,035–2,150	960–1,070	1,560–1,580	1,110–1,190	270–360	710–750
		1,300–1,410	1,655–1,880	1,220–1,415	390–470	790–890
		1,500–1,510	1,970–2,130	1,460–1,575	565–575	910–940
		1,975–2,100	2,215–2,240	1,625–1,635	900–930	1,270–1,410
		2,120–2,210	2,305–2,350	1,825–1,850	965–1,075	1,440–1,475
			2,470–2,585	1,990–2,025	1,285–1,305	1,490–1,565
				2,075–2,195	1,500–1,615	1,870–2,010
				2,220–2,310?	2,020–2,170	2,100–2,300?

Oil test No. shown on pl. 1	25	26	27	51	13
Location (sec., T., R.)	28, 5 S.–10 W.	26, 5 S.–11 W.	17, 5 S.–9 W.	32, 4 S.–12 W.	St. Louis Bay
Elevation (ft)	103	195	78	150	18
Top of log (ft)	1,686	1,821	1,622	1,690	1,962
Sand intervals (ft)	1,810–1,820	1,830–2,015	1,650–1,680	1,900–1,950	2,070–2,100
	1,850–1,885	2,120–2,135		2,005–2,160	
	2,010–2,030	2,265–2,285		2,260–2,310	
	2,110–2,140	2,330–2,345			
	2,200–2,470	2,400–2,430			

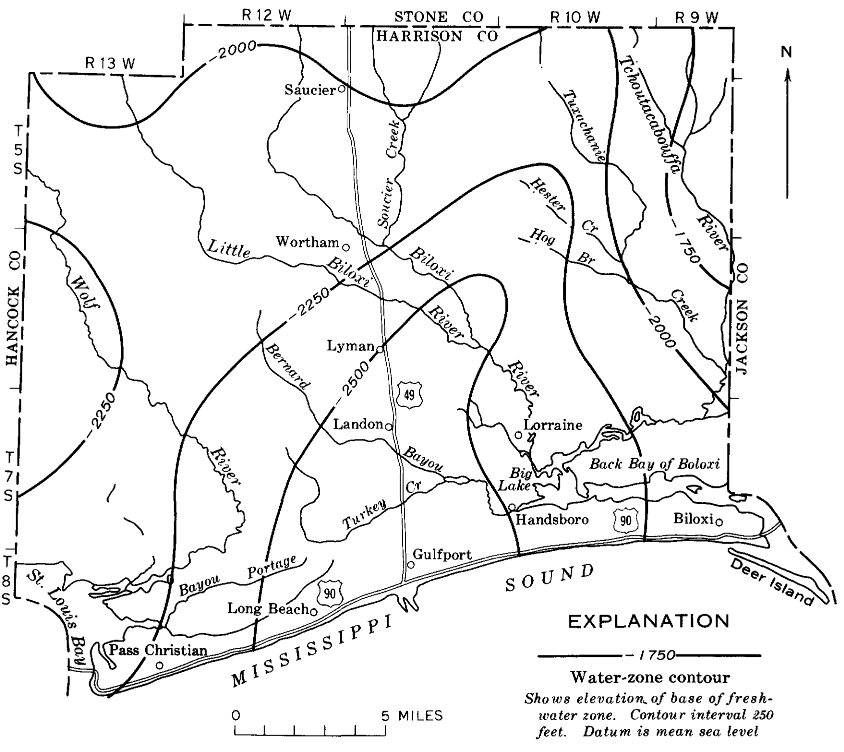

FIGURE 19.—Configuration of the base of the fresh-water zone.

Electric-log coverage for deep aquifers along the coast was nonexistent prior to this water-resources investigation. As a result, test drilling, which is described next, was done to supplement available information.

TEST DRILLING

Two deep test wells were drilled during the project. The first, on Reichhold Road in Gulfport's Industrial District 1, resulted in the discovery and sampling of two aquifers between the depths of 2,150 and 2,500 feet. Artesian pressure in the aquifers forced water nearly 100 feet above the land surface. A detailed description of procedures and findings in connection with this test well was included in the report of the first year's progress on the project (Newcome and others, 1965). The findings are summarized in geohydrologic section *B–B′* (pl. 1), and chemical analyses are given in table 18.

Findings from the second test well are summarized on geohydrologic section *A–A′* (pl. 1) and in table 18. This well was drilled at the north end of Market Avenue in Pass Christian. Three previously unknown fresh-water aquifers and one saline-water aquifer between the depths of 1,700 and 2,200 feet were discovered and sampled. Artesian pressures sufficient to force water 100 feet above the surface were measured in this test also.

The aquifers revealed by the deep test wells represent potentially major sources of water supply for industrial and municipal uses in the coastal area. These two wells, together with electric-log data from several oil tests made farther north in Harrison and Stone Counties and the recent deep water-supply development at Mississippi Test Facility in Hancock County, provide reliable evidence that deep-lying fresh-water aquifers are available for development throughout Harrison County.

Shallow test drilling along the proposed route of the industrial seaway canal provided data on the sand thickness and the contained water in the thin section, comprising the Citronelle Formation and Recent alluvium, which overlies the older Pliocene-Miocene sediments. Although as much as 15 feet of sand and gravel were penetrated in a few places, the deposits are irregular in thickness and composition and probably do not represent a potential source of substantial water supplies. Knowledge of the hydrology of these deposits is of value, however, in the planning of excavations for industrial plants or other large structures. The depths given in table 14 are the approximate limits of sandy or gravelly material; underlying this material is firmer clay of the pre-Pleistocene rocks. Water levels fluctuate seasonally and are probably highest in January. Samples of water are collected periodically for chloride determination to provide background data for analysis of potential quality-of-water changes that may accompany completion of the seaway and development of industry. The temperatures measured are near the average annual air temperature, which determines shallow ground-water temperature under normal conditions. The temperature in these shallow deposits is more readily affected by extraneous factors than that in the deeper aquifers, a fact that should be considered if water supplies are developed in the sand-and-gravel sections.

TABLE 14.—*Water-level and quality data for the shallow aquifer along the Harrison County industrial seaway*

[Wells are shown on well-location maps]

Well	Depth (ft)	Water level and date of sampling (feet above (+) or below (−) land surface)	Chloride concentration (ppm)	Temperature (° F)
K8	22	−4.5 (Sept. 1965)	----------	--------
K9	60	−2.0 (Aug. 1965)	----------	--------
K10	21	−1.2 (Jan. 1966)	6.0	68
K11	39	−2.3 (Jan. 1966)	8.7	67
K12	22	−8.0 (Aug. 1965)	----------	--------
K14	30	−6.2 (Jan. 1966)	6.0	68
L26	18	+1.0 (Jan. 1966)	16	69
L27	60	−7.0 (Aug. 1965)	----------	--------
L29	35	−4.5 (Jan. 1966)	6.0	70
L30	20	−7.4 (Aug. 1965)	----------	--------
M84	34	−11.8 (Jan. 1966)	28	68
M85	25	−15.3 (Aug. 1965)	----------	--------
M86	58	−16.6 (Aug. 1965)	----------	--------
M87	38	−10.8 (Jan. 1966)	6.2	69
M88	30	−11.1 (Jan. 1966)	5.9	69
O7	34	−6.2 (Jan. 1966)	----------	67

RECHARGE AND WATER LEVELS

Aquifers at depths of more than 500 feet along the gulf coast contain sufficient artesian pressure to support flowing wells, except in localities where withdrawals have reduced the head to a nonflowing condition. Pressure in the aquifers is a result of confinement of the water-saturated sand between overlying and underlying beds of relatively impermeable clay as the water flows southward down the dip from areas where it enters the ground.

Main recharge to the aquifers that supply wells on the coast occurs several miles to the north, where the aquifer systems are at or near the surface. The deeper the aquifer on the coast, the farther north is its surface intake. Although accurate correlation of individual sand beds is not possible for long distances in this region, probably none of the commonly used aquifers on the coast receive much of their recharge in Harrison County. For example, the 600-foot sand that supplies wells at Keesler Air Force Base probably is replenished in an east-west band that crosses the south end of Stone County, passing through the McHenry area. The recharge area for the sand that supplies 1,200-foot wells at Biloxi, Mississippi City, and Gulfport probably crosses Stone County in the Wiggins area.

Recharge to these aquifers occurs by infiltration of rain that falls directly on the outcrops, by percolation through overlying sandy deposits, and by intermovement between aquifers where conditions of permeability and head permit. Water quality is similar for all the artesian aquifers in Harrison County, and individual sand beds are not continuous over large areas. The authors therefore conclude that the sand beds or lenses are sufficiently interconnected hydraulically to permit interflow but not to create a stabilized pressure common to all the aquifers. This condition could be accounted for by a high transmissibility in a horizontal direction and a contrastingly low transmissibility in a vertical direction.

As water moves slowly down the hydraulic gradient (probably only a few hundred feet per year), it loses some head owing to friction with the aquifer material and to seepage into partially confining beds. However, the water that entered the ground at an elevation of 250 feet near Wiggins retained sufficient pressure in the 1,200-foot sand at Gulfport to rise 70 feet above the surface—before intensive development lowered aquifer pressures along the coast. Ordinarily, at a given location each aquifer has greater artesian pressure than the next higher one because the elevations of recharge areas are greater with increasing distance inland. Exceptions occur where withdrawal from wells has altered natural conditions.

Ground-water levels (artesian pressure) in the coastal region of Harrison County declined an average of 1 foot per year in the period 1939–66. The net decline varied considerably in different localities and in different aquifers, depending on aquifer transmissibility and on the magnitude and concentration of pumpage. A record of water levels measured in wells in 1939 and in the present investigation is given in table 15. A few wells in the county may have had greater water-level declines than the table shows, but most have had declines corresponding to, or smaller than, those listed. Hydrographs of observation wells (fig. 20) illustrate year-to-year fluctuations in water levels and the net change.

A graphic analysis of ground-water levels along the Harrison County coast (fig. 21) reveals the degree to which artesian pressure in the various aquifers has been reduced by withdrawals over the years. Normal pressure-depth relations have been considerably altered, espe-

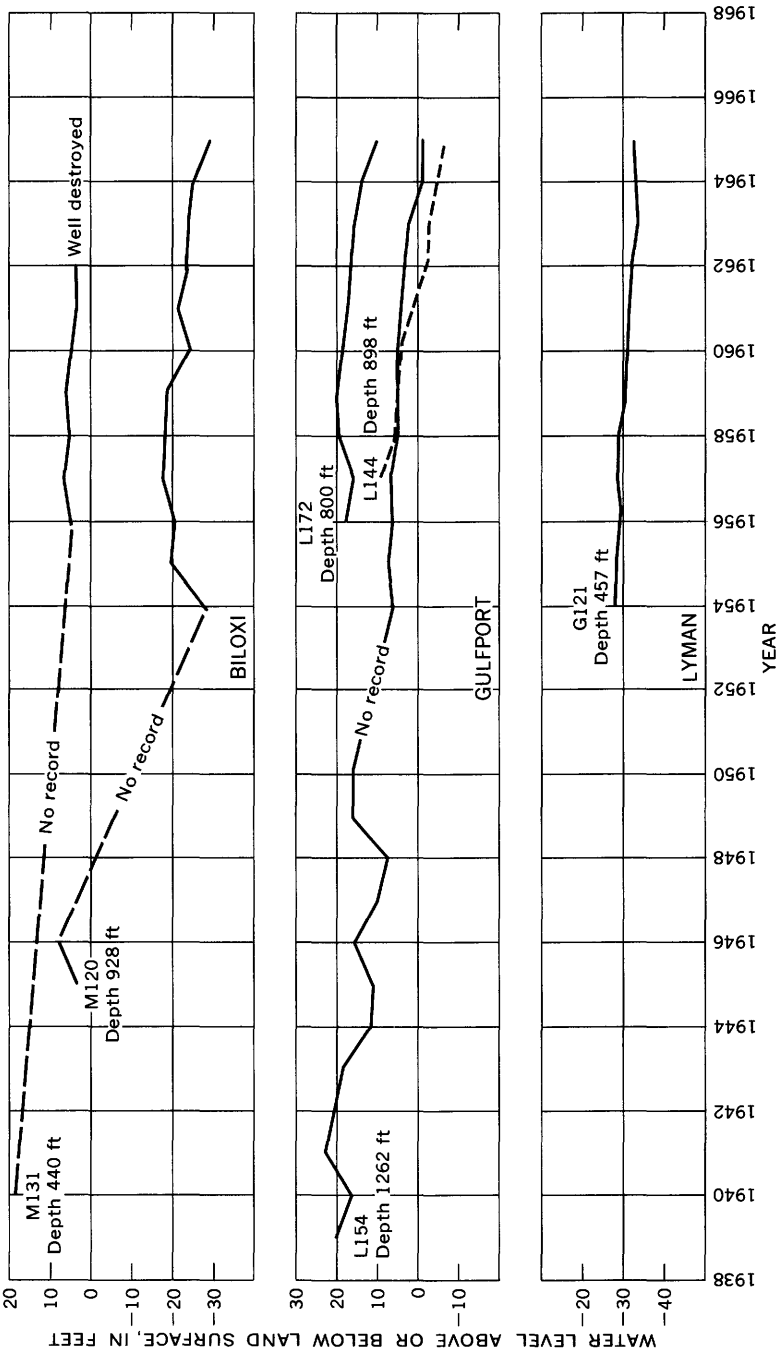

FIGURE 20.—Water-level trends in observation wells.

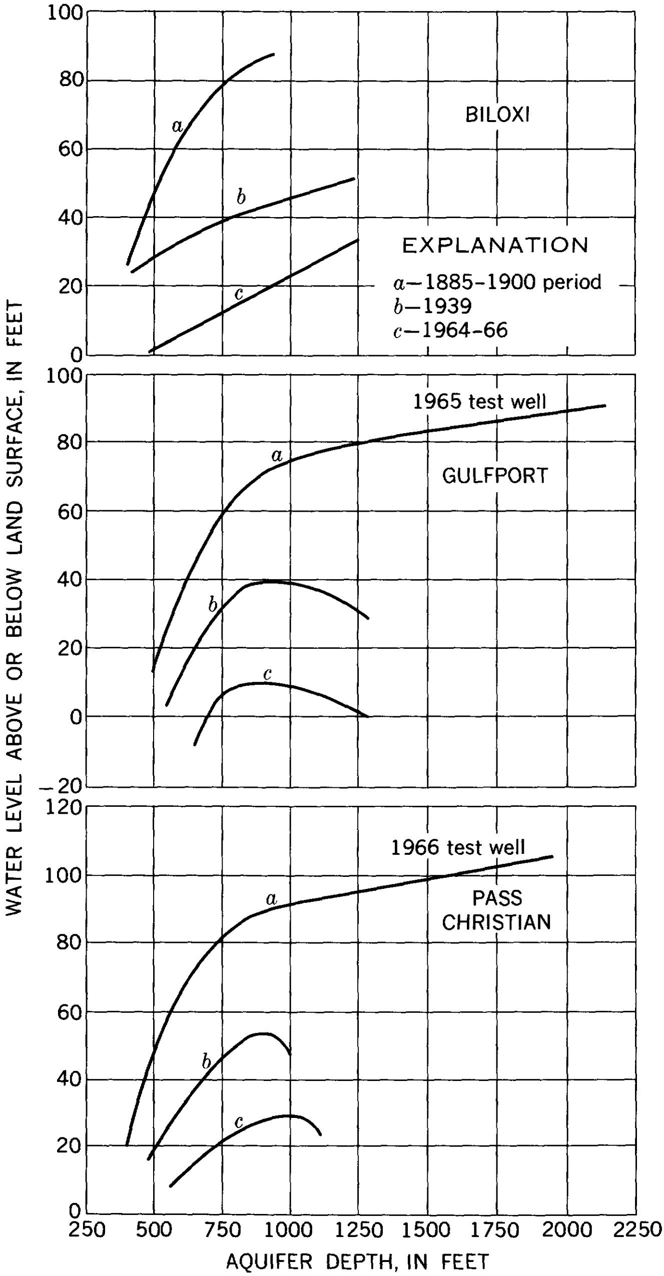

FIGURE 21.—Comparative water levels in Harrison County along the gulf coast.

cially in the centers of pumping—Biloxi, Gulfport, and Pass Christian. Oldest available records indicate that water levels were highest at Pass Christian and lowest at Gulfport, and that water levels at Biloxi were slightly less than those at Pass Christian. Water levels remained lower at Gulfport in 1939 and in 1965 than in the areas to the east and west. Thus, ground-water gradients have been toward Gulfport from every direction since the turn of the century.

TABLE 15.—*History of water levels in wells of Harrison County*

Locality	Well	Well depth (ft)	Water level above (+) or below (−) measuring point (ft)			
			Earliest measurement	1939	1940–63 period	1964-66
Biloxi	M4	1,200			+8 (1945)	+4
	M8	1,263			+22 (1945)	+20
	M12	944			+25 (1958)	+5
	M58	935	+42 (1934)		+14 (1956)	+14
	M61	865	+34 (1935)			+8
	M65	631			−8 (1942)	−26
	M75	610			−8 (1952)	−23
	M76	630			−10 (1952)	−26
	M79	640			−24 (1952)	−26
	M119	1,182		+45	+16 (1956)	+25
	M120	928	+44 (1919)	+23	+15 (1943)	−30
	M131	440		+20	+3 (1962)	
Cedar Lake	M34	764	+50 (1937)		+48 (1943)	+30
	M45	828	+25 (1928)	+12		+5
Cuevas	K89	550		+24		0
	O88	548		+35		+12
	O163	569	+40 (1921)	+25		−5
DeLisle	N166	684		+61	+54 (1943)	+37
D'Iberville	M46	911	+40 (1928)		+31 (1943)	
Edgewater Park	M71	690		+18	−1 (1950)	−23
Gulfport	L91	900		+9		−25
	L144	898	+58 (1919)	+28	+9 (1957)	−7
	L147	965		+9		−31
	L154	1,262	+65 (1911)	+26	+6 (1954)	−1
	L160	1,196			+15 (1942)	+1
	L169	890		+39	+21 (1956)	+8
	L172	800±		+38	+17 (1956)	+9
Landon	L48	789		+24		0
Long Beach	L173	830		+37		+16
	L174	832		+35		+6
	O175	883	+58 (1926)	+30		+4
Lorraine	M41	522	+40 (1924)	+24		+11
Lyman	G19	429		+15		−8
	G20	431		+13		−7
	G24	790		+6		+2
	G25	801			+12 (1949)	0
	G121	457		−10	−28 (1954)	−33
Mississippi City	M72	680	+35 (1925)	+24		−9
Pass Christian	N3	1,111			+39 (1948)	+24
	N182	861		+53		+26
	O6	891			+18 (1954)	+8
	O178	600±			+30 (1943)	+11
	O179	591	+26 (1928)		+11 (1943)	+11
	O183	677		+39		+19
	O185	714		+43		+20
Ship Island	M1	727			+23 (1958)	+14
Woolmarket	H32	700		+23		−7
	H33	512		+28		0
Wortham	C13	590		+28		+15
	F15	598		+9		−12

Eastward movement of ground water toward Gulfport has created no problem; in fact, it has helped to prevent updip movement of saline water from a seaward direction. Westward movement, however, has resulted in slightly saline water occupying the 1,200-foot sand and a few shallower aquifers at Biloxi and the area just north of that city. The immediate source of this water is in the Ocean Springs area east of Biloxi Bay, where high-head wells in the 1,200-foot sand produce water having more than 750 parts per million of chloride. The quality of ground water at Biloxi has remained fairly uniform since the early years of the 20th century, even though the aquifers at Biloxi have been heavily pumped and water-level decines have been substantial. Water in the Biloxi aquifers possibly will not become significantly more saline than it is at present—even with additional water-level decline—because the water-level decline that induces saline-water flow toward Biloxi also induces inflow of diluting water from other directions. Chloride histories provide the basis for this conclusion. (See table 19.)

The commonly expressed fear that the lowering of water levels in coastal aquifers will induce salt-water encroachment from the downgradient or seaward direction does not always take into account the fact that water-level declines induce inflow from all directions. Because heads immediately outside the pumping centers are nearly always substantially higher in a landward direction than seaward, it follows that flow gradients are steeper in the landward direction and that, consequently, more water moves to the pumping centers from the landward side.

Although increased withdrawals will induce some landward movement of the fresh-water–salt-water interface in the aquifers, the authors believe that the rate of such movement will not increase in proportion to the additional amount of water pumped. The present position of the fresh-water–salt-water interface is not accurately known; however, wells as deep as 730 feet on Ship Island produce water with a low chloride content. (See table 19.) Also, the electric log of an oil test on Horn Island shows fresh-water-bearing sand to a depth of 1,500 feet. This indicates that the interface in the aquifers used on the Harrison County coast is more than 12 miles offshore; how much more is not known.

Declining artesian pressure produces undesirable economic effects for the water user wherever it occurs. On the gulf coast, however, the problem usually can be alleviated readily and cheaply compared with most other areas. Many of the wells that have undergone substantial water-level decline still retain sufficient head to flow; others have water levels within 10–20 feet of the land surface. Installation or lowering of pumps, although costly, is not the major expense that it is in the region north of Harrison County, where deep-well pumps have been required for many years.

AQUIFER AND WELL CHARACTERISTICS

Only through knowledge of aquifer hydraulics can quantitative values be assigned to the ground-water resource. The production of wells often provides no more than a hint of aquifer potential because of the great variation in well efficiencies.

Aquifer and well characteristics can both be ascertained by means of pumping tests. A test involves pumping a well and observing the effect on the water level in the well being pumped and in nearby wells that tap the same aquifer. The aquifer characteristics obtained are transmissibility, permeability, and storage coefficient. Well characteristics are production, specific capacity, and well efficiency.

Transmissibility (T) is the rate of flow of water through a vertical strip of the aquifer 1 foot wide under a hydraulic gradient of 1 foot per foot. Units are gallons per day per foot. Transmissibility is the index of an aquifer's ability to transmit water. An aquifer having low transmissibility has a high resistance to the flow of water; hence, wells tapping such aquifers generally have low specific capacities. Wells tapping aquifers having high transmissibility generally have large specific capacities.

Permeability (P) is the rate of flow of water through a 1-foot-square section of the aquifer under the unit hydraulic gradient. Its units are gallons per day per square foot. It is commonly obtained by dividing the transmissibility by the aquifer thickness, in feet.

Coefficient of storage (S) is a dimensionless figure that relates the volume of water an aquifer releases from storage per unit of surface area to the unit decline in the component of head normal to that surface. The coefficient of storage is an index of the amount of water released from storage in the aquifer. In conjunction with T, it can be used to estimate the long- or short-term relation between well yield and the consequent drawdown of the artesian surface. Storage coefficients of the artesian aquifers in Harrison County range from 0.0002 to 0.002.

Well discharge (Q) is the pump discharge or flow of a well, in gallons per minute

Specific capacity ($\frac{Q}{s}$) is the number of gallons per minute a well produces for each foot of drawdown, or lowering, of the water level. It is obtained by dividing into the discharge rate the difference between static water level and pumping water level and is usually calculated for a 1-day period to provide comparative values.

Well efficiency is the ratio of the measured specific capacity to the calculated specific capacity of a 100-percent efficient well. Known or estimated aquifer characteristics are necessary for calculating the ideal specific capacity. Well efficiency is expressed as a percentage. A 100-percent-efficient well is one in which the water level during pumping is the same as the water level immediately outside the well.

The hydraulic characteristics of aquifers determine how much water can be withdrawn and the effects of the withdrawal; also, well characteristics affect the economics of ground-water supplies. Consequently, it is important to know the potential of aquifers and to construct efficient wells that take optimum advantage of the aquifer potential.

Thirty-five pumping tests were made in Harrison County during the water-resources investigation. Nearly all these tests were made in the coastal area, where most of the large production wells are located. However, the U.S. Fish Hatchery wells at Lyman and the Harrison Experimental Forest well near Saucier were also tested. Aquifer and well characteristics obtained in the tests (table 16) represent all the aquifers in use along the coast. The values of transmissibility and permeability for a particular aquifer or well depth vary from place to place. This is a typical effect of the stratigraphic conditions in the gulf coastal plain, where deposits are irregular in extent, thickness, and grain-size distribution.

Many of the aquifers in the coastal region of Harrison County have high transmissibility. They have supported large withdrawals through wells for many years and are capable of providing much larger quantities of water in properly engineered development programs. In addition, presently untapped aquifers on the coast and throughout the rest of the county are estimated to have high transmissibility.

The most productive aquifers appraised by means of pumping tests in the investigation are the 900-foot sand at Long Beach and the 1,200-foot sand at Biloxi. These aquifers are of substantial areal extent and have transmissibilities of about 600,000 and 100,000 gpd per ft (gallons per day per foot), respectively. Highly efficient large-diameter wells constructed in these aquifers will have specific capacities of 200 gpm per ft (gallons per minute per foot) and 40 gpm per ft. When one considers that present water levels in both aquifers are within a few feet of the land surface, it is apparent that pumped wells could each produce several thousand gallons of water per minute.

The newly discovered deep aquifers at Gulfport and Pass Christian are believed to be capable of yielding large amounts of water to properly constructed wells. This applies particularly to the 1,700- and 1,900-foot sands in the Pass Christian test well. Estimated transmissi-

TABLE 16.—*Aquifer and well characteristics as determined from pumping tests*

Location of test	Well	Depth (ft)	Aquifer thickness (ft)	Transmissibility (gpd per ft)	Permeability (gpd per sq ft)	Storage coefficient	Specific capacity (gpm per ft)	Well efficiency (percent)
Biloxi								
Biloxi Water Works	M2	1,207	116	105,000	900	--------	9	20
Maple St	M4	1,200	*100	103,000	1,030	--------	26	55
Tanglewood subdivision	M40	654	80	125,000	1,550	--------	20	35
Father Ryan St	M115	1,226	124	98,000	780	--------	12	30
Porter St	M119	1,182	*100	94,000	940	--------	29	70
Maple St. near beach	M147	1,002	80	84,000	1,050	--------	17	45
Keesler Air Force Base								
Keesler Air Force Base:								
Well 1	M64	625	*100	100,000	1,000	0.0003	18	40
Well 5	M68	618	57	55,000	970	.0004	10	40
Well 7	M75	610	64	62,000	970	--------	19	65
Well 8	M76	630	54	67,000	1,240	--------	22	70
Well 10	M78	641	100	73,000	730	--------	16	50
Well 11	M79	640	*80	80,000	1,000	--------	25	75
Gulfport								
30th Ave	L2	815	60	51,000	850	--------	19	85
Airport well 5	L14	763	90	85,000	940	--------	12	30
East Railroad St	L15	752	76	65,000	860	--------	32	100
34th St	L16	815	82	55,000	670	0.0002	25	100
Mills Ave	L17	848	123	37,000	300	--------	13	80
Airport well 2	L84	645	100	27,000	270	.0002	15	100
18th St. and 24th Ave	L147	953	92	18,000	195	.0003	--------	---------
Do	L149	1,242	80	96,000	1,200	--------	--------	---------
U.S. Naval Base (CB)	L160	1,196	*50	66,000	*1,300	--------	12	40
Do	L161	850	38	16,000	420	--------	5	65
Do	L162	757	88	75,000	850	--------	23	70
Pat Watson steam plant	M23	755	175	110,000	620	.0005	14	30
Do	M24	845	175	110,000	620	.0005	27	55
Long Beach								
Lang Ave	O1	926	--------	570,000	----------	--------	--------	---------
Royal Grove subdivision	O8	611	50	56,000	1,100	--------	11	50
Daugherty Park subdivision	O11	590	57	100,000	1,750	--------	18	45
Jeff Davis Ave	O172	848	240	630,000	2,600	0.0021	--------	---------
Pass Christian								
Fire station	N3	1,111	57	24,000	430	--------	6	50
Lang Ave. and 2d St	O6	891	95	137,000	1,450	--------	--------	---------
Lyman								
U.S. Fish Hatchery	G19	429	85	64,000	750	--------	10	40
Do	G20	431	85	61,000	720	--------	6	20
Do	G24	790	120	110,000	900	0.0003	31	60
Harrison County Experimental Forest								
U.S. Forest Service Headquarters	C18	638	50	75,000	1,500	--------	17	50

*Estimated.

bilities and predicted well performance for all aquifers penetrated by the test wells at Gulfport and Pass Christian are given in table 17.

Predictions of well production can be made by using known relations between transmissibility, storage coefficient, well size, and specific capacity. The graph (fig. 22) illustrates the relations and can be used to make well-production predictions where the other parameters are known or estimated.

PUMPING EFFECTS

WELL INTERFERENCE

Distribution of ground-water withdrawals should be such that wells do not unduly interfere with one another. Well interference is a current or potential problem in all ground-water-supply developments. It cannot be avoided entirely so long as there are two or more wells producing from the same aquifer. Well interference can be minimized, however, by placing wells optimum distances apart consistent with economy and by planning pumping schedules that distribute withdrawals among aquifers and well fields and thus permit recovery of lowered water levels.

TABLE 17.—*Potential production of wells tapping sands at Gulfport and Pass Christian test-hole sites*

Location	Sand interval (ft)	Estimated transmissibility (gpd per ft)	Specific capacity (gpm per ft)		Predicted natural flow (gpm)	Predicted production with pump at 50 ft (gpm)
			Full efficiency	75 percent efficiency		
Gulfport	675–770	[1] 55,000	26	19	0–200	750–1,300
	1,110–1,160	15,000	7	5	0–50	150–200
	2,170–2,270	50,000	24	18	1,500–2,000	2,500–3,000
	2,375–2,525	40,000	19	14	1,200–1,700	2,000–2,500
Pass Christian	410–460	15,000	7	5	0	200–300
	800–880	[1] 80,000	36	27	0–500	1,200–1,700
	1,015–1,075	[1] 25,000	12	9	200–250	650–850
	1,685–1,795	55,000	26	19	2,000–2,500	3,000–4,000
	1,860–2,010	75,000	34	25	2,500–3,500	4,000–5,000
	2,080–2,225	20,000	10	8	650–850	1,000–1,300

[1] Based on permeability values calculated from pumping tests of nearby wells.

Since the predicted effects of pumping can be calculated when certain parameters are known or estimated, a graph is again appropriately used as a guide. Time, distance, and drawdown bear a relation to transmissibility, storage coefficient, and production rate. This relation (fig. 23) has application in the planning of well fields and selection of withdrawal rates.

WELL EFFICIENCY

Well efficiency—or the effectiveness of the individual well—is of great economic importance. A well in which the screen opening and

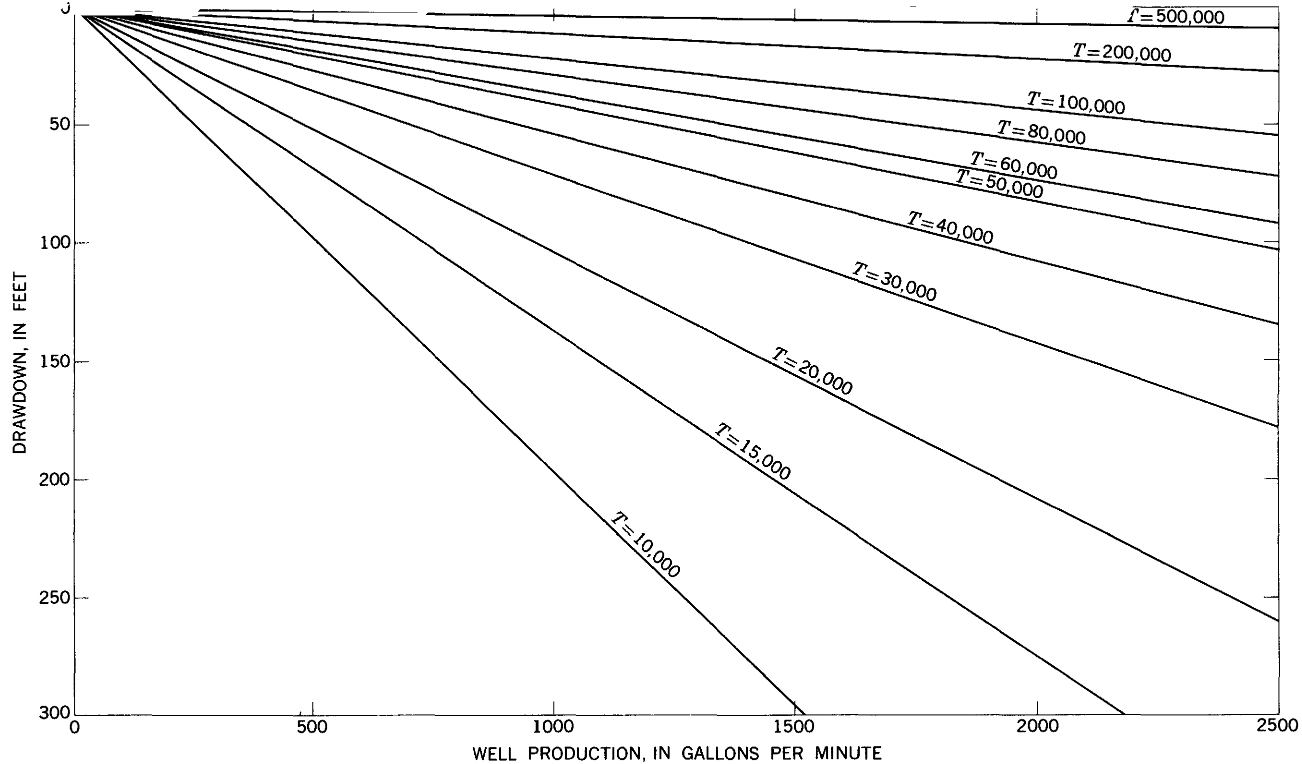

FIGURE 22.—Transmissibility-drawdown-production relation. Where transmissibility (T) is known or estimated, the graph will indicate the drawdown caused by various pumping rates or the well production for various amounts of drawdown. Values are based on artesian conditions and on a 100-percent-efficient 12-inch well; for well efficiencies less than 100 percent, either the production will be decreased or the drawdown will be increased proportionately. No allowance is made for head loss, and consequent production loss, caused by pipe friction. However, a well 16 inches in diameter will have only one-fourth the friction of a 12-inch well.

screen length are properly selected and from which all traces of drilling mud have been washed is a highly efficient well—that is, the water level (or pressure) immediately outside the well is nearly the same as that inside the well during pumping or flowing. The degree to which the levels inside and outside the well differ during pumping is a function of well efficiency (fig. 24). It costs more to pump a given amount of water from an inefficient well than from an efficient well in the same aquifer; obviously, then, it is uneconomical when two wells are required to provide a water supply that should be available from one well.

Many of the wells in Harrison County, as elsewhere, have low efficiency. The average efficiency of those tested is 55 percent (table 16). Several wells are highly efficient; some are very inefficient. Chief causes of inefficiency are incomplete well development and improper sizing of well-screen opening or gravel-pack material to the aquifer. In a few wells the casing is of insufficient size to accomodate the flow of water without substantial head loss due to pipe friction. Pipe fric-

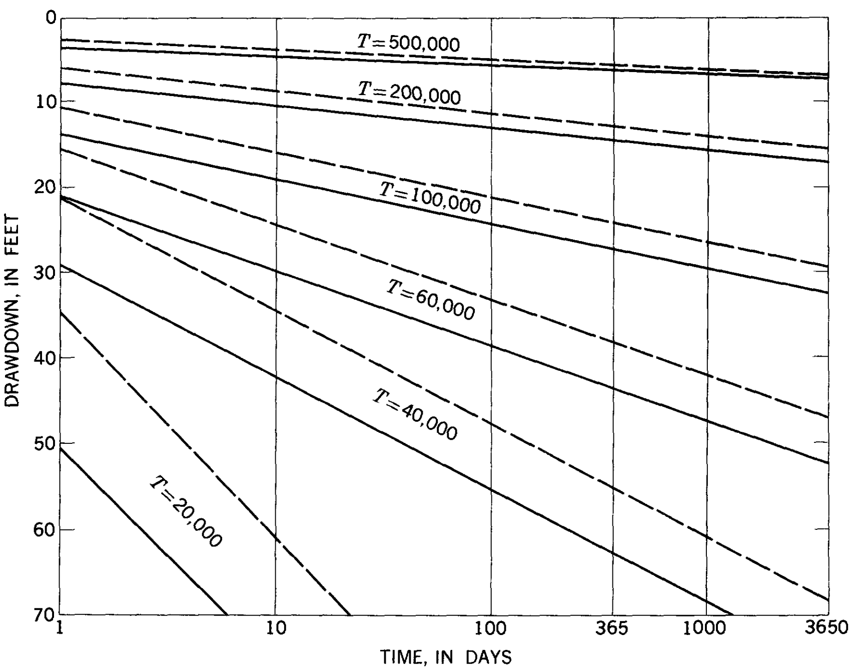

FIGURE 23.—Time-drawdown relation for aquifers. Pumping rate is 2,000 gpm; for other rates, drawdown will be proportional. Solid line represents drawdown at a distance of 500 feet from well; dashed line represents drawdown at a distance of 1,000 feet from well. *T*, transmissibility, in gallons per day per foot. Storage coefficient is 0.0003, median value based on several pumping tests.

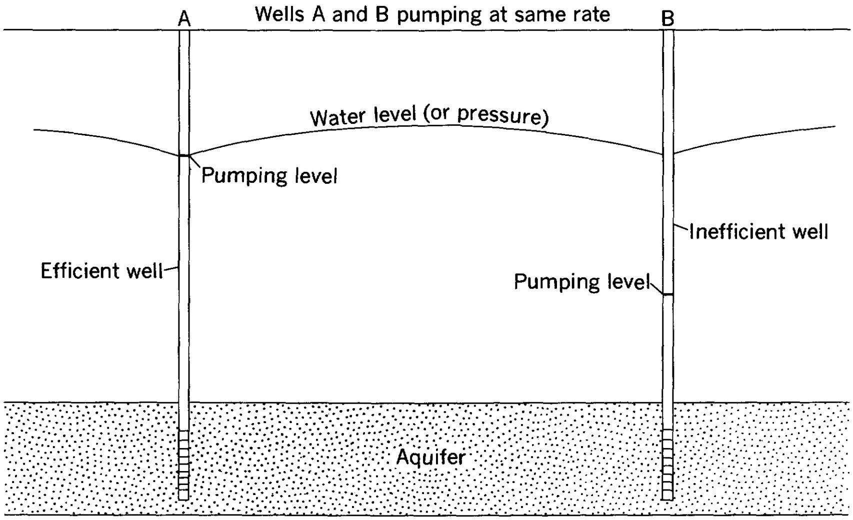

FIGURE 24.—Effect of well inefficiency.

tion, in combination with pump pressure, decreases well production by an amount equal to the head loss multiplied by the specific capacity of the well.

QUALITY OF THE GROUND WATER

Water that moves through underground formations comes into contact with, and dissolves minerals from, the rocks, thereby changing the chemical quality of the water. Differences in the quality of ground water reflect differences in the geologic environment in the water-bearing formations (table 18, wells N199a and N199d). Formations lying at considerable depth below the surface and those that yield water derived from distant sources usually contain water that is more highly mineralized than those which lie at shallow depths or which obtain water from nearby sources (pl. 1).

DISSOLVED SOLIDS

The measured dissolved-solids content of water from aquifers in Harrison County ranged from 51 ppm in the northern part of the county to 1,570 ppm at Pass Christian in the southern part of the county. Plate 1 contains data on the concentration of dissolved solids in ground water from the northern boundary of Harrison County to the Gulf of Mexico, along the coast from Hancock County to Jackson County, and across northern Harrison County. The dissolved-solids content increases generally with depth and along the dip toward the gulf, which is the direction of regional water movement.

Because specific conductance depends on the quantity and degree of ionization, it is indicative of the dissolved-solids content of water. The mineral content, in parts per million, of the ground water in this area can be estimated by multiplying specific conductance by 0.59. Figure 25 shows the graphic relation between specific conductance and dissolved solids in ground water.

Most ground water used in Harrison County contains less than 250 ppm of dissolved solids, but in the Biloxi area water from a few wells contains more than 500 ppm.

At some locations or in some aquifers, mineralization in a water supply increases as pumping proceeds or increases. Pumping results in a lowering of ground-water levels which induces flow from more mineralized water zones as the effect of pumping expands. A graph of pumpage and dissolved-solids variation (fig. 26) shows that minor changes occurred in the dissolved-solids concentration in water from wells in the 600-foot sand at Keesler Field as pumpage fluctuated during the 1948–65 period.

Changes in concentration of the various ions in solution occur as the total ion concentration increases (fig. 27). Increases in total concentration are due principally to increases in the concentration of bicarbonate, chloride, and sodium. The individual concentrations of

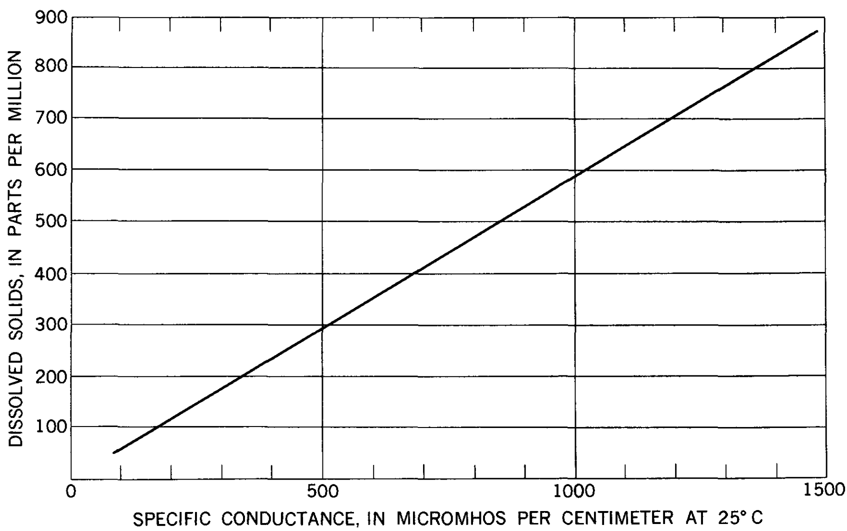

FIGURE 25.—Relation of dissolved solids to specific conductance in ground water.

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TABLE 18.—*Chemical analyses of water*

[Results in parts per million

Well	Date of collection	Depth (ft)	Silica (SiO_2)	Total iron (Fe)	Iron (Fe) in solution at time of analysis	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
A1	2- 9-65	190	52	------	--------	7.5	1.8	12	3.0	53
A3	2- 9-65	500	41	------	0.31	11	3.0	13	2.4	81
A6	2- 9-65	187	51	------	.02	21	6.7	14	4.2	128
B2	2- 9-65	70	10	------	.00	4.0	3.4	3.9	1.0	22
B10	2-10-65	200	51	------	.01	2.0	.7	33	.8	82
B12	2- 9-65	230	49	------	.25	7.8	2.1	11	2.3	46
C2	5-20-64	300	--------	------	--------	--------	--------	--------	--------	---------
C13	5-20-64	590	20	------	.02	.0	.0	72	.8	167
C14	2-10-65	205	53	------	.07	4	1.2	12	2.1	38
C23	2-10-65	226	41	------	--------	4.1	1.2	9.2	2.3	40
D5	2-10-65	236	30	------	--------	3.0	.6	39	1.1	102
D12	2-10-65	190	.0	------	--------	5.5	3.7	6.7	1.7	51
F2	2- 9-65	800	24	------	.06	.0	.0	55	.4	132
F3	2- 9-65	405	24	------	.03	.6	.4	57	.2	137
F7	2- 9-65	446	23	------	.02	.8	1.5	49	.8	120
G19	6-27-39	429	--------	------	--------	--------	--------	--------	--------	81
	6-30-42	429	--------	------	--------	--------	--------	--------	--------	---------
	12-26-42	429	--------	------	--------	--------	--------	--------	--------	---------
	7-23-43	429	--------	------	--------	--------	--------	--------	--------	---------
G22	2-10-65	794	36	------	--------	.0	.0	46	.2	109
H8	2- 9-65	240	37	------	.07	4.5	.9	51	2.0	140
H9	2- 9-65	835	17	------	.02	.0	.0	78	.2	170
H21	3- -52	505	48	------	.03	2.6	1.1	30	2.0	88
	2-28-53	505	46	------	4.2	4.5	1.0	30	2.7	89
	2- 2-54	505	38	------	4.2	2.5	.8	29	3.0	87
	12- 6-54	505	34	------	.45	4.4	.7	31	2.4	84
	10- 4-55	505	34	------	2.1	4.0	.8	30	1.4	86
	10- 3-56	505	18	------	.00	3.9	.9	29	2.3	83
	10- 9-57	505	23	2.0	--------	4.0	.8	29	2.9	88
	10-30-58	505	29	------	.48	4.6	.6	28	2.3	87
	8-13-59	505	27	------	.19	5.1	2.0	29	2.2	84
	9- 1-60	505	30	------	.18	3.8	.8	29	2.6	86
	9-21-61	505	43	------	.30	4.5	.7	28	1.8	80
	5-28-62	505	45	------	.27	4.4	.5	29	2.0	84
	5- 8-63	505	45	------	2.4	4.9	.4	28	2.0	86
	5-16-64	505	59	5.9	1.0	4.0	.5	31	2.1	88
	6- 1-65	505	56	------	1.3	4.0	1.2	28	1.6	85
H27	2-10-65	900	28	------	.04	1.5	.5	47	.7	118
H32	6-27-39	700	--------	------	--------	--------	--------	--------	--------	116
J1	2- 9-65	551	34	------	.10	6.0	1.2	38	1.7	115
J2	2- 9-65	220	59	------	.00	6.8	2.7	9.0	2.1	50
J87	6-27-39	617	--------	------	--------	--------	--------	--------	--------	98
K2	2- 9-65	212	58	------	.04	.8	.5	54	1.1	132
K3	2- 9-65	955	23	------	.02	1.2	.0	76	.2	179
K4	12-17-65	785	36	------	.21	.6	.1	59	.5	147
K10	12-17-65	21	--------	------	--------	--------	--------	--------	--------	---------
K11	12-17-65	39	--------	------	--------	--------	--------	--------	--------	---------
K14	12-17-64	30	--------	------	--------	--------	--------	--------	--------	---------
L4	6-12-65	1,179	--------	------	--------	--------	--------	--------	--------	---------
L6	6- 9-64	1,174	--------	------	--------	--------	--------	--------	--------	---------
L8	6-10-64	1,199	20	.11	--------	1.0	.6	149	1.9	342
L9	6-12-64	1,219	--------	------	--------	--------	--------	--------	--------	---------
L10	6-12-64	858	--------	------	--------	--------	--------	--------	--------	---------
L11	6-12-64	1,193	--------	------	--------	--------	--------	--------	--------	---------
L13	6-23-64	860	--------	------	--------	--------	--------	--------	--------	---------
L18	8-14-64	765	--------	.18	--------	1.1	.1	53	.2	127
L19	8-13-64	229	29	.38	--------	1.6	.0	69	.2	173
L20	8-14-64	380	42	.00	--------	.6	.1	43	.3	101
L26	12-16-65	--------	--------	------	--------	--------	--------	--------	--------	---------
L29	12-16-65	--------	--------	------	--------	--------	--------	--------	--------	---------
L48	6-27-39	789	--------	------	--------	--------	--------	--------	--------	134
	5-30-42	789	--------	------	--------	--------	--------	--------	--------	---------
	12-26-42	789	--------	------	--------	--------	--------	--------	--------	---------
	7-24-43	789	--------	------	--------	--------	--------	--------	--------	---------

from wells in Harrison County

except as indicated]

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
0	10	2.8	0.0	0.3	115	26	0	123	6.8	15	------
0	3.2	3.2	.1	.1	117	40	0	151	6.9	10	------
0	5.4	5.4	.0	.0	171	80	0	225	6.7	0	------
0	.4	5.3	.2	12	51	24	6	90	6.0	5	------
0	6.6	4.0	.1	.1	138	8	0	159	7	5	------
0	9.2	3.1	.2	.1	108	28	0	111	6.9	20	------
------	------	3.0	------	------	------	------	------	------	----	------	------
0	9.4	2.9	.2	.1	187	0	0	285	7.7	5	72
0	4.0	4.7	.2	.1	100	5	0	90	7.0	10	------
0	2.8	3.2	.0	.1	84	15	0	85	6.6	5	------
0	7.2	2.7	.3	.1	134	10	0	188	7.3	5	------
0	.0	3.9	.1	.1	67	29	0	98	6.9	5	------
0	11	2.8	.1	.0	158	0	0	229	7.7	5	------
0	7.4	7.0	.1	.0	164	3	0	239	7.3	0	------
0	8.2	4.6	.0	.0	147	8	0	213	7.1	0	------
0	6.0	3.0	------	------	------	------	------	------	----	------	------
------	------	5.0	------	------	------	------	------	------	----	------	------
------	------	4.0	------	------	------	------	------	------	----	------	------
------	------	4.0	------	------	------	------	------	------	----	------	------
0	6.4	2.3	.2	.1	145	0	0	205	7.5	5	------
0	9.0	3.8	.3	.1	178	5	0	252	7.0	5	------
9	11	4.4	.2	.1	204	0	0	327	8.5	5	------
0	4.8	3.0	.0	.3	149	11	0	150	7.1	80	65
0	2.4	3.5	.0	.7	157	15	0	145	7.2	80	73
0	6.6	4.0	.1	.5	158	10	0	161	7.1	23	72
0	2.8	4.0	.3	.9	158	14	0	161	7.0	70	------
0	1.6	3.5	.2	.3	156	13	0	154	7.4	50	76
0	6.4	3.2	.1	.5	105	13	0	153	7.3	50	------
0	5.2	3.0	.1	.7	114	13	0	153	7.2	80	------
0	2.0	3.5	.1	.1	114	14	0	149	7.0	70	------
0	4.6	8.8	.2	.6	121	20	0	162	7.0	45	------
0	2.4	3.8	.1	1.2	116	13	0	147	7.2	80	------
0	5.2	3.2	.0	.7	126	14	0	154	6.7	70	------
0	4.8	2.2	.2	.7	130	13	0	159	6.8	50	------
0	1.0	2.8	.1	.3	129	14	0	159	6.8	60	76
0	1.2	3.5	.1	.0	144	12	0	159	6.8	80	74
0	.0	3.6	.1	.0	136	15	0	153	6.6	80	78
0	6.8	5.3	.2	.1	148	6	0	215	7.4	5	71
0	10	3.0	------	------	------	------	------	------	----	------	75
0	2.8	4.2	.1	.0	145	20	0	195	7.0	0	------
0	.0	6.6	.1	.1	111	28	0	124	6.5	5	------
0	4.0	2.0	------	------	------	------	------	------	----	------	------
0	4.0	4.0	.1	.0	192	4	0	232	7.3	5	------
3	9.0	4.6	.2	.1	205	3	0	311	8.3	5	76
0	8.6	3.8	.3	.1	181	2	0	259	7.9	5	75
------	------	------	------	------	------	------	------	115	----	------	68
------	------	------	------	------	------	------	------	34	----	------	62
------	------	------	------	------	------	------	------	100	----	------	69
------	------	3.2	------	------	328	------	------	505	----	------	------
------	------	2.3	------	------	290	------	------	447	----	------	------
9	6.2	18	.7	.3	375	5	0	610	8.4	40	82
------	------	4.0	------	------	198	------	------	304	----	------	80
------	------	3.1	------	------	192	------	------	295	----	------	79
------	------	3.2	------	------	298	------	------	460	----	------	80
------	------	3.3	------	------	240	------	------	368	----	------	------
0	8.6	3.4	.1	.1	162	3	0	223	6.6	5	80
0	7.8	3.8	.3	.1	197	4	0	290	7.3	15	72
0	9.0	2.9	.1	.1	147	2	0	184	7.3	5	80
------	------	------	------	------	------	------	------	110	----	------	70
------	------	------	------	------	------	------	------	150	----	------	70
7	11	2.0	------	------	------	------	------	------	----	------	78
------	------	4.0	------	------	------	------	------	------	----	------	------
------	------	3.0	------	------	------	------	------	------	----	------	78
------	------	4.0	------	------	------	------	------	------	----	------	------

TABLE 18.—*Chemical analyses of water*

Well	Date of collection	Depth (ft)	Silica (SiO_2)	Total iron (Fe)	Iron (Fe) in solution at time of analysis	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
L81	6-14-51	658	41	0.23	0.01	0.8	0.2	55	4.3	131
L83	6-14-51	668	41	.16	.02	.9	.5	53	2.4	125
L84	6-14-51	645	42	.30	.01	.4	.5	51	3.0	120
	8-18-64	645	------	------	------	------	------	------	------	------
L85	7-23-43	659	------	------	------	------	------	------	------	------
L141	6-20-56	1,098	24	.03	.00	2.1	.3	112	1.8	268
L143	9-3-19	537	28	------	.04	.4	.3	67		117
	12-2-20	537	------	------	------	------	------	------	------	117
	5-29-42	537	------	------	------	------	------	------	------	------
	12-26-42	537	------	------	------	------	------	------	------	------
	7-24-43	537	------	------	------	------	------	------	------	------
L144	5-30-42	898	------	------	------	------	------	------	------	------
	1-2-43	898	------	------	------	------	------	------	------	------
	7-23-43	898	------	------	------	------	------	------	------	------
	5-21-47	898	30	------	.02	2.7	.8	89		191
	8-18-64	898	------	------	------	------	------	------	------	------
L147	8-18-64	953	------	------	------	------	------	------	------	------
L149	6-14-51	1,242	19	.09	.01	.6	.7	124	5.1	270
L150	8-30-19	1,173	34	------	.09	.2	.3	139		174
L152	8-30-19	862	28	.09	------	.3	.7	77	3.2	127
L154	9-2-19	1,262	32	------	.08	.6	1.0	103		193
L155	9-1-19	840	27	------	.06	.3	.4	72		115
L157	9-1-19	865	39	------	.08	.5	.4	67		117
L160	9-18-42	1,196	26	------	.04	1.4	.9	147	.4	306
	1-17-51	1,196	32	.06	.01	.8	.6	61	5.3	146
	6-14-51	1,196	24	.08	.01	.6	.5	72	4.7	151
	1-30-52	1,196	24	.04	.00	.8	.4	70	.8	138
	2-16-53	1,196	23	.02	.01	1.0	.6	71	.6	155
	8-18-64	1,196	------	------	------	------	------	------	------	------
L161	9-8-42	850	29	------	0.02	2.2	0.8	80	0.3	150
	1-17-51	850	24	0.05	.01	1.2	1.0	140	8.0	305
	6-14-51	850	20	.06	.01	.5	.4	135	5.8	300
	1-30-52	850	22	.08	.06	.8	1.0	141	1.0	304
	2-16-53	850	19	.03	.02	1.2	.7	133	1.3	293
	8-18-64	850	------	------	------	------	------	------	------	------
L-162	1-17-51	757	23	.09	.00	.7	.8	71	5.3	167
	1-14-51	757	34	.12	.03	.6	.4	60	5.0	144
	1-30-52	757	40	.15	.02	1.0	1.6	59	.8	146
	2-16-53	757	37	.08	.08	1.0	.9	59	.9	145
L169	6-1-39	890	------	------	------	------	------	------	------	133
	7-23-43	890	------	------	------	------	------	------	------	------
	8-18-64	890	------	------	------	------	------	------	------	------
L171	9-1-19	800	39	------	.08	.6	.3	74	74	119
	5-30-42	800	------	------	------	------	------	------	------	------
	12-31-42	800	------	------	------	------	------	------	------	------
	7-1-43	800	------	------	------	------	------	------	------	------
	8-18-64	800	------	------	------	------	------	------	------	------
L174	5-26-64	832	------	------	------	------	------	------	------	------
L201	4-23-65	1,430	18	------	.09	1.5	.1	91	.7	224
M1	10-12-65	727	29	.05	------	.0	.0	92	.3	224
M3	6-14-51	905	20	.09	.01	1.5	.8	138	6.2	251
M8	6-26-64	1,263	21	.44	------	2.6	.6	225	1.6	313
M9	7-16-64	946	------	------	------	------	------	------	------	------
M12	5-19-64	944	21	.09	------	2.1	.2	133	.8	245
M13	2-10-65	734	21	------	------	2.4	.0	75	.7	181
M21	5-19-64	1,215	12	.11	.00	5.8	1.3	375	3.5	310
M22	6-22-64	1,200	------	------	------	------	------	------	------	------
M23	2-10-65	755	22	------	.00	.5	.2	84	.3	201
M27	6-12-64	802	------	------	------	------	------	------	------	------
M28	6-12-64	890	------	------	------	------	------	------	------	------
M29	6-12-64	825	------	------	------	------	------	------	------	------
M30	7- -64	920	------	------	------	------	------	------	------	------
M31	6-12-64	510	------	------	------	------	------	------	------	------
M32	6-12-64	840	------	------	------	------	------	------	------	------
M34	5-19-64	764	22	.11	.01	1.1	.5	124	.9	264
M45	8-19-64	828	------	------	------	------	------	------	------	------

from wells in Harrison County—Continued

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
0	9.3	5.2	0.1	2.7	188	3	0	235	8.0	7	78
0	9.1	5.2	.0	.7	174	4	0	219	7.9	6	78
0	10	7.2	.0	2.4	171	3	0	214	7.9	5	78
--	--	3.7	--	--	152	--	--	233	--	--	--
--	--	4.0	--	--	--	--	--	--	--	--	--
12	9.0	4.2	.3	.4	289	6	0	462	8.7	25	82
17	11	8.0	--	Trace	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--
--	--	37	--	--	--	--	--	--	--	--	--
--	--	4.0	--	--	--	--	--	--	--	--	--
--	--	4.0	--	--	--	--	--	--	--	--	--
--	--	3.0	--	--	--	--	--	--	--	--	--
--	--	3.0	--	--	--	--	--	--	--	--	--
--	--	4.0	--	--	--	--	--	--	--	--	--
17	10	4.5	.5	.6	248	--	--	379	8.9	--	--
--	--	3.1	--	--	208	--	--	320	--	--	--
--	--	3.8	--	--	204	--	--	314	--	--	81
20	8.5	6.8	.5	2.5	317	4	0	500	8.8	23	85
16	9.0	9.0	--	Trace	361	--	--	--	--	--	--
32	11	6.0	--	Trace	148	--	--	229	--	--	--
--	11	5.0	--	Trace	292	--	--	--	--	--	--
23	11	8.0	--	Trace	208	--	--	--	--	--	--
19	10	6.0	--	Trace	200	--	--	--	--	--	--
34	8.2	7.8	.5	.0	372	7.2	0	--	9.1	--	--
0	9.8	5.8	.1	.3	189	4	0	257	7.8	6	74
9	9.1	6.5	.0	2.8	285	4	0	296	8.6	6	79
16	11	5.0	.2	.3	198	4	0	296	8.8	7	76
7	9.5	5.8	.0	.0	195	5	0	280	8.6	7	78
--	--	14	--	--	364	--	--	560	--	--	--
22	11	7.8	0.2	0.1	222	9	0	--	9.0	--	--
24	13	11	.6	.5	374	7	0	572	8.8	20	74
18	7.7	6.0	.5	1.7	345	2	0	539	8.8	30	84
22	8.4	4.8	.8	.1	352	6	0	508	8.9	25	78
22	7.8	6.8	.3	1.2	337	6	0	527	9.0	25	78
--	--	4.7	--	--	192	--	--	294	--	--	--
0	15	8.5	.1	.6	208	5	0	298	8.5	4	74
0	8.2	4.8	.0	2.5	188	3	0	249	7.8	5	78
0	8.8	4.8	.1	.1	189	9	0	236	7.7	6	72
0	8.6	4.2	.1	.3	183	6	0	239	8.0	5	76
21	8	5.0	--	--	--	--	--	--	--	--	--
--	--	6.0	--	--	--	--	--	--	--	--	--
--	--	5.3	--	--	186	--	--	287	--	--	--
--	9.0	6.0	--	Trace	221	--	--	--	--	--	--
--	--	8.0	--	--	--	--	--	--	--	--	--
--	--	6.0	--	--	--	--	--	--	--	--	--
--	--	6.0	--	--	--	--	--	--	--	--	--
--	--	6.0	--	--	192	--	--	294	--	--	--
--	--	4.0	--	--	171	--	--	--	--	--	80
0	9.0	2.1	.3	.1	233	4	0	386	7.4	30	85
0	13	5.6	.6	.0	250	0	0	393	7.6	10	79
8	5.8	56	.2	1.8	364	7	0	583	8.4	18	83
0	.0	178	.4	.3	584	9	0	1,030	8.0	30	72
--	--	311	--	--	--	--	--	1,380	--	--	82
0	5.8	58	.4	.2	343	6	0	565	7.9	15	73
0	12	5.9	.4	.3	208	6	0	325	7.9	10	--
0	.0	425	.4	.4	976	20	9	1,770	7.7	15	82
--	--	334	--	--	--	--	--	1,540	--	--	73
0	10	2.8	.4	.1	219	2	0	341	7.9	15	--
--	--	15	--	--	--	--	--	457	--	--	79
--	--	17	--	--	346	--	--	534	--	--	81
--	--	--	--	--	250	--	--	388	--	--	77
--	--	5.2	--	--	337	--	--	469	--	--	81
--	--	3.0	--	--	214	--	--	329	--	--	78
--	--	33	--	--	243	--	--	374	--	--	80
0	3.4	35	.1	.2	317	5	0	523	7.9	20	75
--	--	179	--	--	670	--	--	1,030	--	--	--

TABLE 18.—*Chemical analyses of water*

Well	Date of collection	Depth (ft)	Silica (SiO_2)	Total iron (Fe)	Iron (Fe) in solution at time of analysis	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
M56	5-29-42	850	--------	------	--------	--------	--------	--------	--------	--------
	12-28-42	850	--------	------	--------	--------	--------	--------	--------	--------
	7-23-43	850	--------	------	--------	--------	--------	--------	--------	--------
	8-19-64	850	--------	------	--------	--------	--------	--------	--------	--------
M57	5-29-42	868	--------	------	--------	--------	--------	--------	--------	--------
	12-28-42	868	--------	------	--------	--------	--------	--------	--------	--------
	7-23-43	868	--------	------	--------	--------	--------	--------	--------	--------
	8-19-64	868	--------	------	--------	--------	--------	--------	--------	--------
M58	5-29-42	935	--------	------	--------	--------	--------	--------	--------	--------
	12-28-42	935	--------	------	--------	--------	--------	--------	--------	--------
	7-24-43	935	--------	------	--------	--------	--------	--------	--------	--------
	5-19-64	935	21	0.16	--------	2.0	0.0	136	1.3	27
M63	7-24-43	620	--------	------	--------	--------	--------	--------	--------	--------
	6- -48	620	53	------	.01	1.7	.4	51	1.8	110
	4-26-49	620	41	------	.01	1.6	.8	52	.4	126
	5- 6-50	620	55	------	.10	1.0	.2	54	4.9	126
	2- -51	620	58	------	.01	.9	.9	54	3.8	130
	3- -52	620	47	------	.02	1.3	.5	65	.9	155
M64	5-24-42	620	--------	------	--------	--------	--------	--------	--------	136
	5-26-42	620	--------	------	--------	--------	--------	--------	--------	--------
	8- 7-42	620	48	------	.04	1.0	.9	55	.4	128
	12-29-42	620	--------	------	--------	--------	--------	--------	--------	--------
	7-24-43	620	--------	------	--------	--------	--------	--------	--------	--------
	6- -48	620	45	------	.01	1.8	.7	72	1.6	158
	4-26-49	620	46	------	.01	1.0	.7	75	.6	162
	4- 6-50	620	47	------	.03	1.6	.4	75	5.4	178
	2- -51	620	49	------	.04	1.0	.4	77	3.8	187
	3- 2-52	620	45	------	.02	1.2	.5	71	.9	172
	2-28-53	620	40	------	.01	1.0	.9	74	1.1	180
	2- 2-54	620	29	------	.52	4.2	.1	66	.8	147
M64	6-12-54	620	24	------	.00	.8	.1	72	.8	162
	12- 6-54	620	24	------	.00	.8	.1	72	.8	162
	10- 3-56	620	11	------	.00	.8	.1	70	1.5	170
	10- 9-57	620	25	------	.04	.5	.1	70	2.0	165
	8-13-59	620	27	------	.01	.8	.5	74	1.3	180
	9- 1-60	620	24	------	.00	.8	.2	69	1.5	170
	8-21-61	620	36	------	.04	.0	.0	69	.6	163
	5-28-62	620	35	------	.04	1.2	.0	72	.7	174
	5- 8-63	620	32	------	.04	.8	.0	70	.5	164
	5-26-64	620	46	.14	.01	.0	.0	73	.9	171
	6- 1-65	620	42	.19	--------	.8	.0	71	.6	166
M65	5-26-42	631	--------	------	--------	--------	--------	--------	--------	--------
	9- 7-42	631	55	------	.14	1.6	.9	58	.7	147
	12-29-42	631	--------	------	--------	--------	--------	--------	--------	--------
	7-24-43	631	--------	------	--------	--------	--------	--------	--------	--------
	4-26-49	631	45	------	.02	.6	.5	52	.4	106
	4- 6-50	631	50	------	.04	2.0	.4	63	4.6	150
	2- -51	631	57	------	.14	1.1	1.0	66	3.9	157
	3- -51	631	41	------	.01	1.0	.7	65	.8	157
	2-28-53	631	40	------	.06	1.6	.9	64	1.3	157
	2- 2-54	631	34	------	.47	2.3	.6	58	.7	132
M65	12- 6-54	631	35	------	.17	1.4	.4	60	.8	136
	10- 4-55	631	25	------	.30	1.3	.1	66	1.3	162
	10- 9-57	631	27	------	.18	1.1	.2	60	2.3	149
	10-30-58	631	23	------	.07	1.2	.1	58	.8	144
	8-13-59	631	26	------	.06	1.2	.3	62	1.0	156
	9- 1-60	631	25	------	.09	.8	.2	55	1.4	134
	8-21-61	631	37	------	.05	.0	.0	62	.7	145
	5-28-62	631	37	------	.07	1.1	.3	67	.8	163
	5- 8-63	631	34	------	.05	.8	.0	71	.3	169
	5-26-64	631	50	------	.21	.7	.1	60	.9	138
	6- 1-65	631	48	.15	--------	1.2	.0	60	.6	144

from wells in Harrison County—Continued

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
------	------	65	------	------	------	------	------	------	----	------	------
------	------	62	------	------	------	------	------	------	----	------	81
------	------	63	------	------	------	------	------	------	----	------	------
------	------	50	------	------	370	------	------	570	----	------	------
------	------	64	------	------	------	------	------	------	----	------	------
------	------	64	------	------	------	------	------	------	----	------	81
------	------	66	------	------	------	------	------	------	----	------	------
------	------	50	------	------	372	------	------	573	----	------	------
------	------	53	------	------	------	------	------	------	----	------	------
------	------	53	------	------	------	------	------	------	----	------	82
------	------	53	------	------	------	------	------	------	----	------	------
0	4.8	57	0.4	0.6	356	5	0	605	7.8	30	74
------	------	4	------	------	------	------	------	------	----	------	------
7.9	7.2	4.5	.2	1.0	189	90	0	231	7.6	------	79
0	6.8	5.5	.1	1.6	187	7	0	221	7.8	5	78
0	8.1	6.5	.0	.6	183	3	0	225	7.8	------	71
0	7.1	5.2	.2	.2	170	6	0	219	7.8	3	72
0	9.4	8.2	.0	.3	208	5	0	265	7.5	------	68
20	7	4	------	------	------	9	0	------	----	------	------
------	------	5	------	------	------	------	------	------	----	------	------
3.9	11	4.2	.1	.0	185	6.2	0	------	8.3	------	------
------	------	------	------	------	------	------	------	------	----	------	------
------	------	4	------	------	------	------	------	------	----	------	------
12	8.6	4.5	.1	1.0	231	------	------	318	8.5	------	78
10	9.2	4.5	.1	2.0	228	5	0	304	8.6	5	78
2	9.6	4.5	.0	.7	226	6	0	307	8.3	------	71
0	9.2	4.8	.1	.2	229	4	0	305	8.2	3	72
0	9.6	6.0	.1	.7	220	5	0	296	7.7	5	67
0	8.8	4.5	.1	.8	230	6	0	296	8.2	5	------
0	11	6.0	.3	.8	------	11	0	305	7.9	20	72
0	13	6.8	.2	1.2	222	2	0	301	7.9	10	72
0	13	6.8	.2	1.2	222	2	0	301	7.9	10	72
0	9.2	4.5	.2	1.1	225	2	0	288	8.2	5	------
3	9.2	4.5	.1	.7	218	2	0	294	8.5	6	------
0	11	5.5	.6	.1	247	4	0	290	8.0	10	------
0	8.4	4.0	.3	1.1	200	3	0	274	8.1	5	------
0	8.0	4.1	.6	.2	198	0	0	302	7.3	5	------
0	9.0	3.8	.2	.6	209	3	0	302	7.9	5	------
0	8.2	5.5	.4	.7	199	2	0	294	7.6	5	79
0	17	3.7	.1	.0	225	0	0	289	7.2	5	79
0	8.8	5.2	.4	.0	211	2	0	299	7.2	10	80
------	------	8.0	------	------	------	------	------	------	----	------	------
0	11	7.0	.1	.4	208	8	0	------	7.9	------	------
------	------	7.0	------	------	------	------	------	------	----	------	------
------	------	6.0	------	------	------	------	------	------	----	------	------
10	9.0	4.5	.1	1.7	184	3	0	222	7.9	5	75
0	9.3	10	.0	.6	205	7	0	268	7.8	------	70
0	9.2	7.2	.3	.9	219	7	0	265	7.9	4	71
0	15	5.5	.0	.2	------	5	0	262	7.4	5	71
0	8.8	5.8	.1	.6	212	8	0	264	7.8	5	71
0	10	14	.3	.2	210	8	0	268	7.7	17	72
2	7.6	6.5	.3	.5	204	5	0	257	8.3	5	72
0	4.8	7.0	.3	.5	222	4	0	279	7.9	15	80
0	8.0	6.0	.2	.3	178	4	0	240	8.0	5	------
0	8.4	5.2	.0	.2	168	4	0	237	7.8	5	------
0	7.2	5.8	.4	.1	181	4	0	259	7.6	5	------
------	7.6	5.0	.5	.3	162	3	0	237	7.5	10	------
0	9.6	4.0	.5	.5	185	0	0	271	7.1	5	------
0	8.6	4.5	.4	.5	200	4	0	288	7.6	5	------
0	8.8	6.0	.4	.5	204	2	0	304	7.4	5	79
0	7.8	5.0	.6	.4	194	2	0	261	7.2	10	79
0	7.8	4.7	.3	.1	194	3	0	261	7.4	0	------

TABLE 18.—*Chemical analyses of water*

Well	Date of collection	Depth (ft)	Silica (SiO_2)	Total iron (Fe)	Iron (Fe) in solution at time of analysis	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
M66...	5-26-42	639	------	------	------	------	------	------	------	------
	12-29-42	639	------	------	------	------	------	------	------	------
	7-24-43	639	------	------	------	------	------	------	------	------
	6- -48	639	55	------	0.01	2.0	1.6	51	1.6	130
	4-26-49	639	51	------	.01	1.0	1.7	53	.4	116
	4- 6-50	639	59	------	.02	1.0	.3	56	2.5	132
	2- -51	639	57	------	.01	.8	.5	56	3.4	134
	3- 2-52	639	45	------	.01	.8	.6	55	.8	134
	2-28-53	639	48	------	.92	1.7	.7	57	1.3	137
	2- 2-54	639	40	------	.19	1.6	.1	55	.8	132
M66...	12- 6-54	639	32	------	.00	1.0	.2	56	.8	128
	10- 4-55	639	21	------	.08	1.2	.1	58	1.2	133
	10-30-58	639	26	------	.04	.9	.2	53	.8	130
	8-13-59	639	29	------	.07	1.0	.2	60	1.1	144
	9- 1-60	639	24	------	.22	1.3	.3	54	1.5	128
	9-21-61	639	40	------	.04	.0	.0	52	.7	118
	5-28-62	639	40	------	.07	1.2	.0	52	.6	129
	5- 8-63	639	34	------	.30	1.5	.1	59	.5	143
	5-26-64	639	51	0.16	.05	1.6	.2	63	1.0	151
	6- 1-65	639	50	.16	------	1.0	.1	50	.7	125
M67...	5-26-42	634	------	------	------	------	------	------	------	------
	12-29-42	634	------	------	------	------	------	------	------	------
	7-24-43	634	------	------	------	------	------	------	------	------
	6- -48	634	48	------	.01	3.0	.5	74	1.8	162
	4-26-59	634	44	------	.01	1.4	.3	76	.6	164
	4- 6-50	634	45	------	.02	1.6	.4	77	2.7	184
	2- -51	634	21	------	.01	.7	.7	78	3.5	191
	3- 2-52	634	47	------	.01	.4	.3	77	.8	192
	2-28-53	634	40	------	.01	2.3	1.1	79	1.1	189
	2- 2-54	634	26	------	.01	.8	.2	75	.5	180
M67...	12- 6-54	634	27	------	.00	.5	.1	79	.7	186
	10- 4-55	634	15	------	.00	.6	.1	78	1.6	174
	10- 3-56	634	14	------	.00	.4	.2	74	1.4	180
	5-10-57	634	18	------	.00	.2	.1	76	2.1	186
	10- 9-57	634	29	------	.04	.5	.1	74	2.0	186
	10-30-58	634	23	------	.04	1.1	.5	70	.8	174
	8-13-59	634	27	------	.00	.8	.1	78	.9	188
	4- 4-60	634	21	------	.00	.5	.2	66	1.2	160
	9- 1-60	634	24	------	.01	.8	.2	72	1.4	176
	8-21-61	634	35	------	.02	.0	.0	73	.5	175
	5-28-62	634	37	------	.06	1.4	.1	72	.6	171
	5- 8-63	634	36	------	.09	2.0	.0	76	.5	188
	5-26-64	634	45	.58	.05	1.2	.2	71	.7	169
	6- 1-65	634	44	.06	------	.7	.1	71	.6	178
M68...	5-26-42	618	------	------	------	------	------	------	------	142
	12-29-42	618	------	------	------	------	------	------	------	------
	7-24-43	618	------	------	------	------	------	------	------	------
	6- -48	618	43	------	.01	1.3	1.1	67	1.9	150
	4-26-49	618	37	------	.01	1.0	.3	69	.4	154
	4- 6-50	618	46	------	.02	1.6	.3	76	1.0	168
	2- -51	618	47	------	.01	.9	.7	73	4.6	178
	3- -52	618	50	------	.02	1.0	.5	57	.9	134
	2-28-53	618	32	------	.04	1.0	.7	74	1.3	180
	2- 2-54	618	33	------	.31	1.0	.1	68	.6	165
	12- 6-54	618	27	------	.17	.9	.2	74	.8	180
M68...	10- 4-55	618	12	------	.00	.6	.1	75	1.2	178
	10- 3-56	618	15	------	.00	.5	.1	74	1.4	182
	10- 9-57	618	19	------	.21	1.0	.2	59	2.2	147
	10-30-58	618	24	------	.11	1.2	.2	60	.8	148
	8- 3-59	618	26	------	.03	1.0	.6	73	1.0	180
	9- 1-60	618	24	------	.14	1.0	.2	61	1.5	148
	8-21-61	618	35	------	.02	.0	.0	75	.8	180
	5-28-62	618	36	------	.02	1.2	.5	79	.7	192
	5- 8-63	618	35	------	.00	.7	.1	77	.7	188
	5-26-64	618	49	.27	.22	1.0	.1	62	1.1	146
	6- 1-65	618	48	.11	------	.8	.0	57	.6	138

from wells in Harrison County—Continued

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
-------	------	5.0	------	--------	--------	--------	--------	--------	----	------	-------
-------	------	4.0	------	--------	--------	--------	--------	--------	----	------	-------
-------	------	4.0	------	--------	--------	--------	--------	--------	----	------	-------
0	9.3	5.0	0.2	0.3	196	12	0	239	8.2	------	79
8	8.7	5.5	.1	1.6	191	10	0	231	8.1	5	78
0	8.6	5.5	.0	.0	189	4	0	233	8.0	------	71
0	8.8	4.5	.2	.2	190	4	0	216	8.1	4	71
0	8.5	5.2	.1	.2	188	4	9	223	7.6	5	70
0	8.8	7.2	.1	.2	202	7	0	241	7.5	25	68
0	9.6	5.0	.2	.7	200	4	0	233	7.8	10	78
2	7.8	5.0	.2	.9	189	3	0	238	8.3	5	76
0	8.8	6.2	.3	.3	196	3	0	236	7.9	6	80
0	6.8	4.2	1	.4	156	3	0	215	7.6	4	-------
0	8.0	6.0	.2	.0	177	4	0	242	7.6	5	-------
0	7.8	7.0	.7	.3	160	4	0	232	7.6	10	-------
0	7.6	7.0	.0	.5	166	0	0	232	7.5	5	-------
0	7.4	3.9	.2	.5	170	3	0	234	7.4	5	-------
0	7.8	5.8	.2	.3	180	4	0	260	7.2	10	79
0	9.0	3.7	.2	.4	204	5	0	243	7.0	10	79
0	7.2	4.5	.1	.0	176	3	0	229	6.8	10	80
-------	------	5.0	------	--------	--------	--------	--------	--------	----	------	-------
-------	------	5.0	------	--------	--------	--------	--------	--------	----	------	-------
-------	------	4.0	------	--------	--------	--------	--------	--------	----	------	-------
14	8.8	4.5	.1	.3	244	10	0	330	8.5	------	78
12	7.0	5.0	.1	2.0	233	5	0	310	8.6	5	78
2	9.5	4.0	.0	.4	237	6	0	318	8.3	------	71
0	9.4	3.8	.1	.2	234	5	0	313	8.4	2	71
0	9.5	4.2	.1	.0	231	2	0	310	8.1	5	71
1	14	4.5	.1	.7	241	10	0	308	8.3	6	72
3	10	4.0	.3	.7	238	3	0	315	8.4	8	76
0	9.0	2.8	.3	1.0	236	2	0	322	8.2	5	76
2	11	6.5	.3	.5	232	2	0	295	8.3	7	80
0	7.6	4.0	.2	.6	191	2	0	305	8.2	5	-------
0	10	4.0	.0	1.3	226	1	0	316	8.2	5	-------
0	10	3.5	.2	.8	212	2	0	287	8.1	6	-------
0	10	5.0	.1	.6	197	4	0	283	8.0	4	-------
0	9.0	4.5	.2	.1	214	2	0	298	7.9	2	-------
0	10	5.0	.1	.0	183	2	0	269	7.8	4	-------
0	8.6	4.5	.5	.5	200	3	0	296	7.9	10	-------
0	10	4.3	.0	.7	210	0	0	317	7.5	5	-------
0	8.8	4.9	.5	.5	210	4	0	304	7.8	5	-------
0	9.2	4.7	.2	.1	223	5	0	324	8.0	5	80
0	8.8	5.1	.7	.0	216	4	0	298	7.9	5	80
0	9.2	4.9	.2	.0	219	2	0	315	6.9	10	80
16	------	4.0	------	--------	--------	12	0	--------	----	------	-------
-------	------	4.0	------	--------	--------	--------	--------	--------	----	------	-------
-------	------	4.0	------	--------	--------	--------	--------	--------	----	------	-------
9.8	8.4	5.0	.2	.3	216	8	0	306	8.3	------	79
10	8.8	4.5	.1	2.0	216	4	0	286	8.5	5	78
2	9.0	4.5	.0	.0	213	5	0	297	8.3	------	70
0	9.5	5.0	.1	.2	217	5	0	295	8.3	3	72
0	9.3	6.0	.1	.8	191	5	0	236	7.7	3	68
0	8.1	7.0	.0	.6	233	5	0	301	8.1	5	66
1	10	6.0	.2	.7	224	3	0	287	8.3	15	74
0	8.2	5.0	.3	1.1	224	3	0	314	8.2	20	-------
6	9.2	5.5	.2	.1	238	2	0	316	8.5	6	80
0	7.2	3.5	.2	.4	193	2	0	303	8.3	5	-------
0	8.6	6.0	.2	.3	169	3	0	257	7.6	5	-------
0	7.2	5.5	.1	.4	172	4	0	243	7.8	5	-------
0	8.2	5.2	.2	.3	204	5	0	291	8.0	2	-------
0	8.4	5.0	.4	.4	175	4	0	257	7.7	10	-------
0	8.8	4.2	.0	.7	214	0	0	319	7.7	5	-------
0	8.8	2.5	.2	.6	225	5	0	325	7.9	5	-------
0	7.8	3.1	.2	.9	216	2	0	321	7.9	0	79
0	7.8	5.4	.6	.0	199	3	0	255	7.5	5	78
0	7.0	5.1	.4	.1	187	2	0	248	6.8	0	80

TABLE 18.—*Chemical analyses of water*

Well	Date of collection	Depth (ft)	Silica (SiO_2)	Total iron (Fe)	Iron (Fe) in solution at time of analysis	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
M69	5-26-42	720	--------	------	--------	--------	--------	--------	--------	---------
	12-29-42	720	--------	------	--------	--------	--------	--------	--------	---------
	8-19-64	720	--------	------	--------	--------	--------	--------	--------	---------
M74	9- 2-19	825	18	------	0.03	1.9	0.8	90	--------	176
	12-28-20	825	18	------	--------	--------	--------	--------	--------	176
M75	2-28-53	610	48	------	.19	1.5	.9	61	1.1	144
	2- 2-54	610	33	------	.17	1.2	.2	58	.8	142
	12- 6-54	610	18	------	.12	1.2	.3	60	1.0	143
	10- 4-55	610	21	------	.21	.9	.2	58	1.2	144
	10- 3-56	610	14	------	.00	1.4	.1	56	1.6	138
	10- 9-57	610	22	------	.21	1.2	.1	57	2.2	142
	10-30-58	610	28	------	.10	2.1	.4	59	.8	150
M75	8-13-59	610	30	------	.02	1.0	.4	58	1.1	144
	9- 1-60	610	25	------	.19	1.1	.2	57	1.5	140
	8-21-61	610	38	------	.19	.0	.0	58	.7	136
	5-28-62	610	38	------	.08	2.2	.4	58	.6	145
	5- 8-63	610	36	------	.25	1.5	.1	58	.5	144
	5-26-64	610	51	0.20	.12	.8	.2	62	.9	144
	6- 1-65	610	50	.51	--------	1.5	.0	49	.5	124
M76	2-28-53	630	48	------	.04	2.6	.9	50	1.1	128
	2- 2-54	630	34	------	.14	.6	.3	52	.5	127
	12- 6-54	630	28	------	.00	1.0	.3	54	.8	127
	10- 4-55	630	24	------	.23	.9	.1	52	.9	130
	10- 3-56	630	12	------	.00	.7	.2	51	1.2	126
	10- 9-57	630	21	------	.54	.6	.2	52	1.7	129
	10-30-58	630	22	------	.13	1.0	.1	53	.7	130
M76	8-13-59	630	28	------	.14	.8	.2	51	.9	128
	9- 1-60	630	26	------	.16	.9	.2	52	1.3	126
	9-21-61	630	36	------	.21	.0	.0	62	1.7	144
	5-28-62	630	37	------	.10	1.7	.2	61	.6	147
	5- 8-63	630	32	------	.25	.8	.0	53	.6	124
	5-26-64	630	45	.64	.24	.6	.1	56	.9	131
	6- 1-65	630	47	------	.21	.8	.0	52	.6	127
M77	2-28-53	638	40	------	.08	1.3	.9	71	1.1	172
	2- 2-54	638	30	------	.07	1.1	.1	69	.6	166
	12- 6-54	638	26	------	.00	.8	.2	72	.8	164
	10- 4-55	628	25	------	.00	.6	.2	73	1.2	166
	10- 3-56	638	15	------	.00	.9	.1	65	1.3	160
	10- 9-57	638	14	------	.20	.8	.1	66	1.9	163
	8-13-59	638	31	------	.01	1.4	.2	66	.9	164
	9- 1-60	638	25	------	.10	1.2	.2	62	1.3	152
	8-21-61	638	35	------	.02	.0	.0	64	.7	150
	5-28-62	638	35	------	.03	1.2	.0	67	.8	162
	5- 8-63	638	34	------	.01	.8	.0	69	.5	158
	5-26-64	638	45	0.21	.07	.8	.0	70	.7	160
	6- 1-65	638	41	------	.12	.8	.0	68	.5	164
M78	3-17-53	641	56	------	.33	1.8	1.0	69	1.1	163
	2- 2-54	641	22	------	.04	.5	.1	66	.4	150
	12- 6-54	641	20	------	.00	.4	.1	66	.7	149
	10- 4-55	641	18	------	.00	.4	.1	64	.9	142
	10- 3-56	641	5.2	------	.00	.8	.2	60	1.4	144
	10- 9-57	641	13	------	.07	.3	.1	61	1.6	142
	10-30-58	641	13	------	.01	.6	.1	62	.6	148
	8-13-59	641	14	------	.00	.3	.1	59	.7	144
	9-11-60	641	16	------	.00	.6	.1	59	1.5	142
	8-21-61	641	22	------	.03	.0	.0	60	.5	138
	5-28-62	641	23	------	.01	.8	.0	60	4.7	147
	5- 8-63	641	21	------	.00	.0	.0	63	.2	139
	5-26-64	641	29	.14	.02	.0	.0	65	.5	149
	6- 1-65	641	25	.72	--------	.8	.0	60	.7	142

from wells in Harrison County—Continued

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$ Calcium, magnesium	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
--------	------	5.0	------	--------	--------	--------	--------	--------	----	------	-------
--------	------	3.0	------	--------	--------	--------	--------	--------	----	------	-------
--------	------	4.2	------	--------	206	--------	--------	317	----	------	-------
24	11	5.5	------	Trace	238	--------	--------	--------	----	------	-------
24	------	--------	------	--------	--------	--------	--------	--------	----	------	-------
0	8.6	6.5	0.1	0.4	202	7	0	251	7.6	8	68
0	10	5.5	.3	.2	208	4	0	252	7.6	9	78
0	7.6	5.0	.2	.7	198	4	0	257	7.7	15	76
0	7.2	5.5	.3	.1	203	3	0	251	7.7	6	80
0	10	4.8	.2	.5	157	4	0	242	7.8	10	-------
0	9.6	4.5	.2	.3	167	3	0	247	7.7	5	-------
0	8.4	5.0	.2	.2	178	6	0	240	7.9	5	-------
0	8.2	5.5	.3	.1	176	4	0	243	7.7	2	-------
0	8.6	4.8	.2	.8	168	4	0	242	7.5	10	-------
0	7.6	4.3	.0	.7	176	0	0	254	7.2	10	-------
0	9.2	3.7	.2	.1	183	7	0	259	7.5	5	-------
0	8.4	4.2	.2	.2	180	4	0	255	7.2	5	80
0	9.0	4.7	.1	.2	200	3	0	249	7.2	5	80
0	6.8	4.6	.1	.0	174	4	0	231	6.7	5	80
0	6.1	4.5	.1	.4	182	10	0	216	7.9	5	69
0	9.0	4.2	.2	.1	186	3	0	218	7.8	10	76
0	7.2	4.8	.3	.7	180	4	0	229	7.9	5	-------
0	5.6	4.0	.3	.1	187	3	0	222	8.1	6	78
0	5.6	4.0	.1	.6	137	3	0	216	8.2	5	-------
0	7.2	4.0	.1	.2	152	2	0	221	7.8	6	-------
0	7.6	5.0	.1	.2	154	3	0	214	7.8	5	-------
0	5.4	4.2	.2	.1	154	3	0	215	7.7	5	-------
0	7.0	4.2	.3	.8	155	3	0	216	7.8	5	-------
0	9.2	5.6	.7	.3	186	0	0	271	7.4	10	-------
0	8.0	5.3	.7	.4	187	5	0	272	7.4	5	-------
0	7.0	3.9	.2	.1	159	2	0	222	7.2	10	79
0	8.8	3.7	.1	.0	180	2	0	220	7.1	10	76
0	6.4	3.1	.2	.0	173	2	0	228	6.9	10	78
0	9.0	5.8	0.1	0.6	225	7	0	290	8.0	10	71
0	12	5.8	.3	.2	222	3	0	288	7.5	8	76
0	9.8	6.0	.4	.8	223	3	0	295	8.2	5	76
0	11	6.5	.	.3	224	2	0	285	8.2	6	80
0	10	5.2	.1	.7	177	3	0	276	7.9	5	-------
0	8.8	5.0	.1	.3	177	2	0	280	7.8	5	-------
0	8.0	5.5	.4	.2	195	4	0	272	7.8	5	-------
0	9.4	5.0	.3	.9	180	4	0	268	7.8	5	-------
0	9.6	5.6	.2	.7	190	0	0	283	7.2	5	-------
0	10	4.9	.3	.6	200	3	0	289	7.8	5	-------
0	9.0	5.6	.3	.1	197	2	0	287	7.6	5	79
0	11	5.1	.2	.0	212	2	0	273	7.2	5	78
0	8.8	5.8	.6	.1	207	2	0	293	7.5	15	78
3	8.3	7.8	.1	.7	210	9	0	293	8.4	23	72
3	12	7.0	.4	.3	197	2	0	277	8.3	14	76
0	10	6.2	.2	1.2	191	1	0	278	8.2	5	76
4	11	6.0	.3	.4	192	1	0	267	8.4	6	80
0	11	5.2	.1	.8	156	3	0	257	8.1	10	-------
2	11	5.5	.2	.7	165	1	0	260	8.3	5	-------
0	9.0	5.8	.2	.0	164	2	0	249	7.9	4	-------
0	5.0	5.5	.4	.2	156	1	0	251	8.2	5	-------
0	9.8	5.2	.4	.8	163	2	0	249	7.6	10	-------
0	10	4.8	.1	.7	166	0	0	262	7.8	5	-------
0	9.4	3.6	.3	.2	174	2	0	269	8.0	5	-------
0	9.2	5.7	.6	.3	168	0	0	263	7.9	5	80
0	11	4.9	.2	.0	184	0	0	255	7.6	10	80
0	10	3.8	.4	.1	171	2	0	262	7.1	5	79

TABLE 18.—*Chemical analyses of water*

Well	Date of collection	Depth (ft)	Silica (SiO_2)	Total iron (Fe)	Iron (Fe) in solution at time of analysis	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
M79	2- 2-54	640	21	------	0.00	0.5	0.1	58	0.4	112
	12- 6-54	640	30	------	.00	1.2	.2	58	.6	120
	10- 4-55	640	18	------	.07	.8	.2	58	.6	109
	10- 3-56	640	5.1	------	.00	.6	.2	55	1.1	122
	10- 9-57	640	15	------	.04	.4	.1	56	1.4	120
	10-30-58	540	13	------	.04	.9	.3	59	.5	120
	9-13-59	640	18	------	.00	.5	.3	57	.6	118
	9- 1-60	640	15	------	.04	.6	.1	56	1.2	116
	8-21-61	640	23	------	.03	.0	.0	57	.5	129
	5-28-62	640	21	------	.00	.5	.2	56	.5	130
	5- 8-63	640	20	------	.06	.0	.0	59	.2	122
	5-26-64	640	29	0.06	.04	.2	.1	63	.5	139
	6- 1-65	640	26	.08	--------	.5	.2	55	.2	134
M82	10- 3 56	684	8.2	------	.00	.5	.1	83	1.3	192
	10- 9-57	684	13	------	.12	.9	.7	80	1.7	192
	10-30-58	684	9.1	------	.03	2.5	.2	86	.7	192
	8-13-59	684	21	------	.00	.5	.2	60	1.2	160
	9- 1-60	684	11	------	.00	.8	.2	79	1.5	192
	8-21-61	684	15	------	.02	.0	.0	80	.5	193
	5-28-62	684	16	------	.00	1.2	.0	86	.6	206
	5- 8-63	684	15	------	.00	.6	.1	87	.3	204
	5-26-64	684	20	.30	.01	.0	.0	84	.6	209
	6- 1-65	684	19	.10	--------	.5	.2	80	.4	200
M83a	5- 1-65	* 2,460	19	------	.23	1.2	.7	276	2.0	328
M83b	5-10-65	* 2,255	20	.08	--------	2.4	.0	144	1.4	260
M84	12-16-65	34	--------	------	--------	--------	--------	--------	--------	--------
M87	8-11-65	38	--------	------	--------	--------	--------	--------	--------	--------
M88	12-16-65	30	--------	------	--------	--------	--------	--------	--------	--------
M101	2- 2-54	900	18	------	.00	.9	.2	104	.4	212
	12- 6-54	900	16	------	.13	1.3	.2	105	.9	212
	10- 4-55	900	10	------	.12	.9	.2	101	1.0	223
	8-21-61	900	17	------	.02	.0	.0	100	.5	230
M102	6-27-39	970	--------	------	--------	--------	--------	--------	--------	201
	5-30-42	970	--------	------	--------	--------	--------	--------	--------	--------
	12-26-42	970	--------	------	--------	--------	--------	--------	--------	--------
	7-23-43	970	--------	------	--------	--------	--------	--------	--------	--------
M109	5-30-42	1,450	--------	------	--------	--------	--------	--------	--------	--------
	12-31-42	1,450	--------	------	--------	--------	--------	--------	--------	--------
	7-24-43	1,450	--------	------	--------	--------	--------	--------	--------	--------
	8-18-64	1,450	--------	------	--------	--------	--------	--------	--------	--------
M114	5-26-42	750	--------	------	--------	--------	--------	--------	--------	--------
	7-24-43	750	--------	------	--------	--------	--------	--------	--------	--------
M115	9- 7-42	1,226	--------	------	--------	--------	--------	--------	--------	262
	7-24-43	1,226	--------	------	--------	--------	--------	--------	--------	--------
	8-19-64	1,226	--------	------	--------	--------	--------	--------	--------	--------
M118	6-27-39	825	--------	------	--------	--------	--------	--------	--------	179
M119	5-26-42	1,182	--------	------	--------	--------	--------	--------	--------	--------
	12-28-42	1,182	--------	------	--------	--------	--------	--------	--------	--------
	7-23-43	1,182	--------	------	--------	--------	--------	--------	--------	--------
	6-14-51	1,182	21	.08	.01	2.8	1.0	212	6.7	294
	8-19-64	1,182	--------	------	--------	--------	--------	--------	--------	--------
M120	9- 5-19	928	51	------	.09	1.0	.4	60		130
	1-25-21	928	51	------	--------	--------	--------	--------	--------	139
M121	5-29-42	1,220	--------	------	--------	--------	--------	--------	--------	--------
	12-28-42	1,220	--------	------	--------	--------	--------	--------	--------	--------
	7-23-43	1,220	--------	------	--------	--------	--------	--------	--------	--------
	6-14-51	1,220	18	.03	.00	6.5	1.0	391	14	335
M128	9- 5-19	727	25	------	Trace	2.6	.9	95		170
	11-29-20	727	25	------	--------	--------	--------	95		170
	5-29-42	727	--------	------	--------	--------	--------	--------	--------	--------
	12-26-42	727	--------	------	--------	--------	--------	--------	--------	--------
M131	9- 5-19	440	16	------	Trace	2.6	1.5	80		146
	11-11-20	440	16	------	--------	--------	--------	80		146
	5-29-42	440	--------	------	--------	--------	--------	--------	--------	--------
	12-26-42	440	--------	------	--------	--------	--------	--------	--------	--------
	7-23-43	440	--------	------	--------	--------	--------	--------	--------	--------

See footnote at end of table.

from wells in Harrison County—Continued

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
13	11	4.5	0.3	0.1	174	2	0	249	9.1	10	76
8	7.6	4.2	.2	1.2	187	4	0	250	8.7	5	76
14	12	4.0	.3	.4	177	3	0	242	8.9	7	80
6	10	4.0	.1	.8	143	2	0	237	8.8	5	-------
8	10	4.0	.2	.3	154	1	0	238	8.7	5	-------
10	10	5.2	.2	.0	158	3	0	229	8.8	5	-------
8	9.8	5.0	.3	.8	158	2	0	235	7.0	45	-------
8	9.2	5.2	.6	.9	154	2	0	237	8.6	5	-------
0	10	4.8	.8	.8	161	0	0	254	8.0	5	-------
2	9.4	3.5	.3	.7	159	2	0	247	8.4	5	-------
6	9.4	3.5	.2	.1	158	0	0	247	8.6	5	80
0	9.6	6.0	.6	.1	177	1	0	255	7.7	10	80
0	8.8	3.6	.2	.0	160	2	0	245	7.0	5	80
4	13	3.5	.2	1.4	210	2	0	329	8.7	10	-------
7	11	3.5	.2	.2	212	5	0	336	8.6	10	-------
0	10	18	.5	.1	222	7	0	352	7.4	5	-------
0	10	5.0	.1	.0	183	2	0	332	7.8	4	-------
4	10	2.8	.5	1.0	206	3	0	333	8.4	10	-------
0	11	2.4	.4	.9	206	0	0	346	8.0	10	-------
0	11	2.8	.5	.7	220	3	0	353	8.2	10	-------
0	11	3.7	.5	.1	218	2	0	350	8.2	5	79
0	10	3.3	.4	.1	221	0	0	336	7.9	10	77
0	10	2.7	.4	.0	221	2	0	347	7.0	10	82
0	.4	254	.7	.5	716	6	0	1,330	7.9	60	90+
0	2.6	74	.3	.3	373	6	0	650	7.9	15	96+
------	------	--------	------	--------	--------	--------	--------	110	----	------	68
------	------	6.2	------	--------	--------	--------	--------	185	----	------	69
------	------	--------	------	--------	--------	--------	--------	500	----	------	69
16	12	12	.4	.2	280	3	0	425	9.0	15	78
15	10	13	.2	1.2	270	4	0	439	8.7	30	78
11	9.6	12	.5	.1	280	3	0	423	8.7	22	82
0	10	11	.3	.8	253	0	0	421	8.2	10	-------
22	7.0	9.0	------	--------	--------	--------	--------	--------	----	------	80
------	------	14	------	--------	--------	--------	--------	--------	----	------	-------
------	------	12	------	--------	--------	--------	--------	--------	----	------	80
------	------	12	------	--------	--------	--------	--------	--------	----	------	-------
------	------	5.0	------	--------	--------	--------	--------	--------	----	------	-------
------	------	5.0	------	--------	--------	--------	--------	--------	----	------	-------
------	------	4.0	------	--------	--------	--------	--------	--------	----	------	-------
------	------	6.5	------	--------	--------	--------	--------	362	----	------	-------
------	------	7.0	------	--------	--------	--------	--------	--------	----	------	-------
------	------	6.0	------	--------	--------	--------	--------	--------	----	------	-------
35	0	162	------	.0	--------	--------	--------	--------	----	------	84
------	------	170	------	--------	--------	--------	--------	--------	----	------	-------
------	------	142	------	--------	570	--------	--------	875	----	------	-------
0	12	3	------	--------	--------	--------	--------	--------	----	------	77
------	------	151	------	--------	--------	--------	--------	--------	----	------	-------
------	------	152	------	--------	--------	--------	--------	--------	----	------	86
------	------	152	------	--------	--------	--------	--------	--------	----	------	-------
0	1.6	170	.3	2.0	--------	11	0	938	7.2	15	85
------	------	148	------	--------	577	--------	--------	--------	----	------	-------
6.0	.1	5.3	------	Trace	197	--------	--------	--------	----	------	-------
.0	------	--------	------	--------	196	--------	--------	--------	----	------	-------
------	------	390	------	--------	--------	--------	--------	--------	----	------	-------
------	------	355	------	--------	--------	--------	--------	--------	----	------	86
------	------	395	------	--------	--------	--------	--------	--------	----	------	-------
0	.4	432	.3	1.2	1,050	20	0	1,850	8.0	40	87
23	10	20	------	.7	--------	--------	--------	--------	----	------	-------
23	------	--------	------	--------	311	--------	--------	--------	----	------	-------
------	------	137	------	--------	--------	--------	--------	--------	----	------	-------
------	------	111	------	--------	--------	--------	--------	--------	----	------	-------
23	10	4.0	------	Trace	209	--------	--------	--------	----	------	-------
23	------	--------	------	--------	--------	--------	--------	--------	----	------	-------
------	------	6.0	------	--------	--------	--------	--------	--------	----	------	-------
------	------	5.0	------	--------	--------	--------	--------	--------	----	------	-------
------	------	6.0	------	--------	--------	--------	--------	--------	----	------	-------

TABLE 18.—*Chemical analyses of water*

Well	Date of collection	Depth (ft)	Silica (SiO_2)	Total iron (Fe)	Iron (Fe) in solution at time of analysis	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
M132	6-27-39	1,000	--------	------	--------	--------	--------	--------	--------	253
	5-29-42	1,000	--------	------	--------	--------	--------	--------	--------	--------
	12-28-42	1,000	--------	------	--------	--------	--------	--------	--------	--------
	7-24-43	1,000	--------	------	--------	--------	--------	--------	--------	--------
	8-19-64	1,000	--------	------	--------	--------	--------	--------	--------	--------
M142	9- 3-19	915	21	------	0.06	2.6	1.4	73		177
	11-11-20	915	--------	------	--------	--------	--------	73		177
	6-12-64	915	--------	------	--------	--------	--------	--------	--------	--------
M201	8-31-19	770	39	------	.04	1.6	.9	94		175
	12- 5-20	770	38	------	--------	--------	--------	94		175
	1- 2-43	770	--------	------	--------	--------	--------	--------	--------	--------
	7-24-43	770	--------	------	--------	--------	--------	--------	--------	--------
M202	8-31-19	730	47	------	.08	.6	.4	102		190
	1-24-21	730	56	------	--------	--------	--------	--------	--------	215
	12-30-42	730	--------	------	--------	--------	--------	--------	--------	--------
	7-23-43	730	--------	------	--------	--------	--------	--------	--------	204
	6-12-58	730	23	0.27	.04	.6	.5	93	.6	226
N1	2- 9-65	220	58	------	.73	5.4	1.1	44	2.4	124
N3	1-19-66	1,111	21	.05	--------	1.0	.6	175	1.6	400
N166	5-27-64	684	50	.68	.06	8.4	1.5	49	1.5	143
N182	2-11-65	861	23	------	--------	4.5	.2	124	.8	276
N191	9- 4-19	880	50	------	.02	.6	.4	144		227
	6-27-39	880	--------	------	--------	--------	--------	--------	--------	258
	6-19-56	880	--------	------	--------	--------	--------	--------	--------	--------
N192	2-11-65	660	31	------	.00	.2	.0	62	.5	154
N195	5-26-64	985	--------	------	--------	--------	--------	--------	--------	--------
N196	5-26-64	800	27	.34	--------	.7	.1	69	.5	173
N197	7-13-64	840	--------	------	--------	--------	--------	--------	--------	--------
N199a	1-10-66	*2,460	18	.84	--------	12	1.2	598	12	378
N199b	1-14-66	*2,200	16	.33	--------	3.7	.2	285	2.3	480
N199c	1-17-66	*1,937	18	.34	--------	4.0	.5	143	3.1	230
N199d	1-19-66	*1,745	18	.35	--------	2.1	1.2	94	1.6	167
O1	5-29-64	926	45	------	.03	3.2	.0	50	.6	126
O3	5-28-64	535	42	2.4	.12	.2	.1	50	1.5	117
O7	12-17-65	34	--------	------	--------	--------	--------	--------	--------	--------
O88	7-13-64	548	--------	------	--------	--------	--------	--------	--------	--------
O163	5-28-64	569	--------	------	--------	--------	--------	--------	--------	--------
O164	5-28-64	±500	--------	------	--------	--------	--------	--------	--------	--------
O165	5-28-64	1,000	--------	------	--------	--------	--------	--------	--------	--------
O174	2- 9-65	962	37	------	.02	2.2	.6	56	.5	140
O175	6-27-39	883	--------	------	--------	--------	--------	--------	--------	136
O178	5-28-64	±600	51	.80	--------	4.4	1.0	52	2.7	146
O179	5-28-64	591	--------	------	--------	--------	--------	--------	--------	--------
O185	7-13-64	714	--------	------	--------	--------	--------	--------	--------	--------
O189	9- 4-19	665	40	------	.04	.8	.4	58		143
	1-25-21	665	40	------	--------	--------	--------	--------	--------	143
O190	9- 4-19	700	43	------	.03	.8	.4	62		122
	12-15-20	700	43	------	--------	--------	--------	--------	--------	130

*Drill-stem sample. Iron concentration may be less than indicated. Sample collected from a nearby well, completed in same sand as N199d, contained 0.04 ppm iron

from wells in Harrison County—Continued

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
18	3	72	------	------	------	------	------	------	----	------	------
------	------	73	------	------	------	------	------	------	----	------	------
------	------	73	------	------	------	------	------	------	----	------	------
------	------	72	------	------	------	------	------	------	----	------	------
------	------	49	------	------	------	------	------	566	----	------	------
8	11	5.0	------	Trace	317	------	------	------	----	------	------
8.4	------	------	------	------	------	------	------	------	----	------	------
------	------	3.0	------	------	------	------	------	374	----	------	80
24	12	10	------	Trace	268	------	------	------	----	------	------
25	------	10	------	------	------	------	------	------	----	------	79
------	------	10	------	------	------	------	------	------	----	------	79
------	------	10	------	------	------	------	------	------	----	------	------
29	29	8.0	------	Trace	303	------	------	------	----	------	------
14	------	------	------	------	316	------	------	------	----	------	------
------	------	6.0	------	------	------	------	------	------	----	------	------
24	7.0	6.0	------	1.2	------	------	------	------	----	------	------
4	11	6.2	0.5	1.1	------	4	0	392	8.5	22	------
0	7.0	4.4	.3	.1	84	8	0	226	7.4	5	73
0	.0	46	.7	.4	443	5	0	721	8.2	40	83
0	9.4	3.2	.1	.1	193	27	0	253	7.4	10	77
0	3.6	41	.4	.3	334	12	0	554	8.0	20	------
38	3.0	51	------	Trace	410	------	------	620	----	------	------
21	1.0	42	------	------	------	------	------	------	----	------	------
------	------	26	------	------	324	------	------	497	----	------	79
0	8.0	5.0	.3	.1	184	3	0	270	7.8	5	75
------	------	43	------	------	348	------	------	577	----	------	81
0	7.2	5.9	.1	.1	196	2	0	299	7.4	0	78
------	------	5.3	------	------	187	------	------	288	----	------	------
0	.6	743	.5	.2	1,570	35	0	2,800	7.5	30	100+
19	.2	161	.9	.1	724	10	0	1,210	8.5	60	98+
0	1.2	94	.2	.2	377	12	0	652	8.2	40	97
17	11	29	.3	.2	256	10	0	439	8.8	30	92
0	9.2	3.7	.1	.1	174	8	0	226	6.9	5	80
0	9.8	3.4	.1	.0	165	1	0	212	7.3	15	73
------	------	------	------	------	------	------	------	140	----	------	69
------	------	3.0	------	------	109	------	------	168	----	------	74
------	------	3.0	------	------	129	------	------	198	----	------	72
------	------	3.7	------	------	140	------	------	216	----	------	74
------	------	3.3	------	------	144	------	------	221	----	------	74
0	8.4	4.6	.1	.0	178	8	0	239	7.4	0	79
5	8.0	3.0	------	------	------	------	------	------	----	------	80
0	9.4	2.9	.1	.1	196	15	0	249	6.9	0	79
------	------	3.2	------	------	162	------	------	248	----	------	74
------	------	3.7	------	------	------	------	------	232	----	------	74
0	8.7	8.0	------	Trace	213	------	------	------	----	------	------
0	------	------	------	------	204	------	------	------	----	------	------
13	8.1	11	------	Trace	198	------	------	------	----	------	------
7.2	------	------	------	------	------	------	------	------	----	------	------

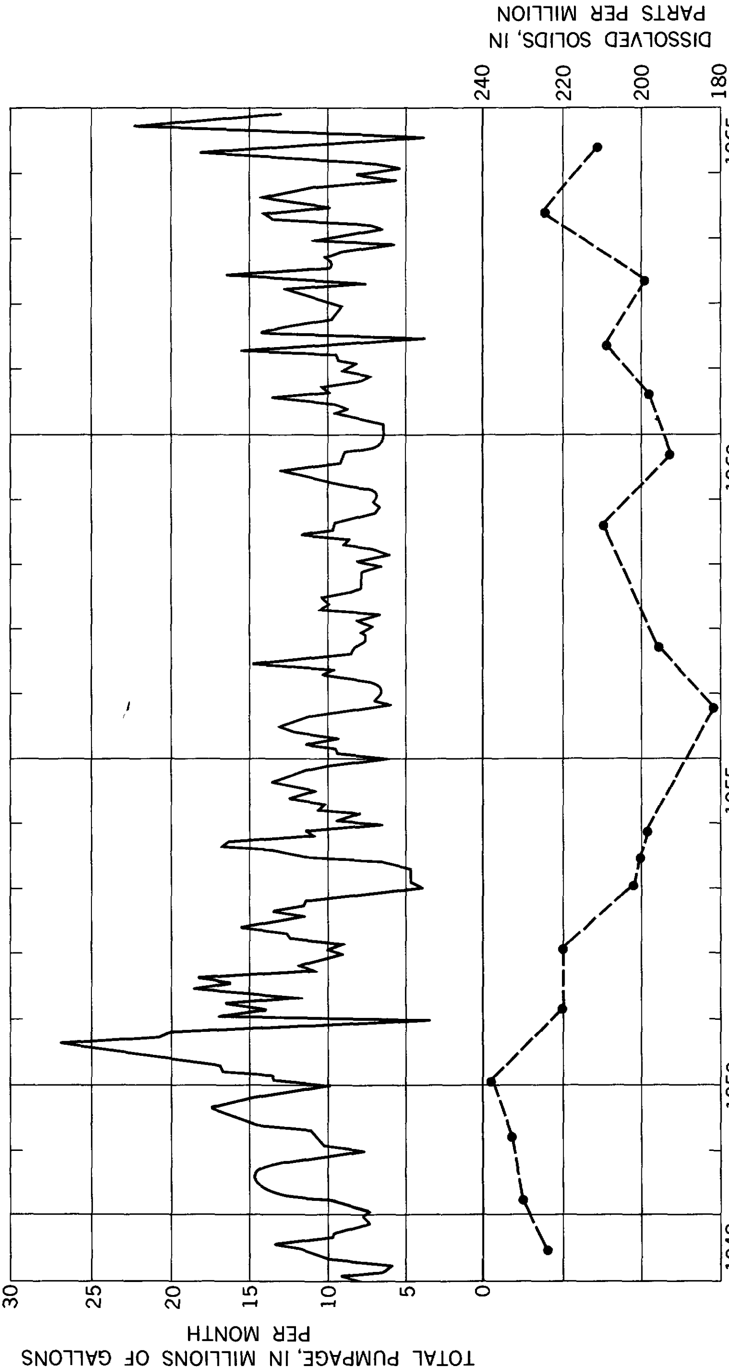

FIGURE 26.—Relation of well pumpage to dissolved-solids concentration, shown by comparison of the total pumpage from the 600-foot sand to the amount of dissolved solids in well water, Keesler Air Force Base, 1948–65.

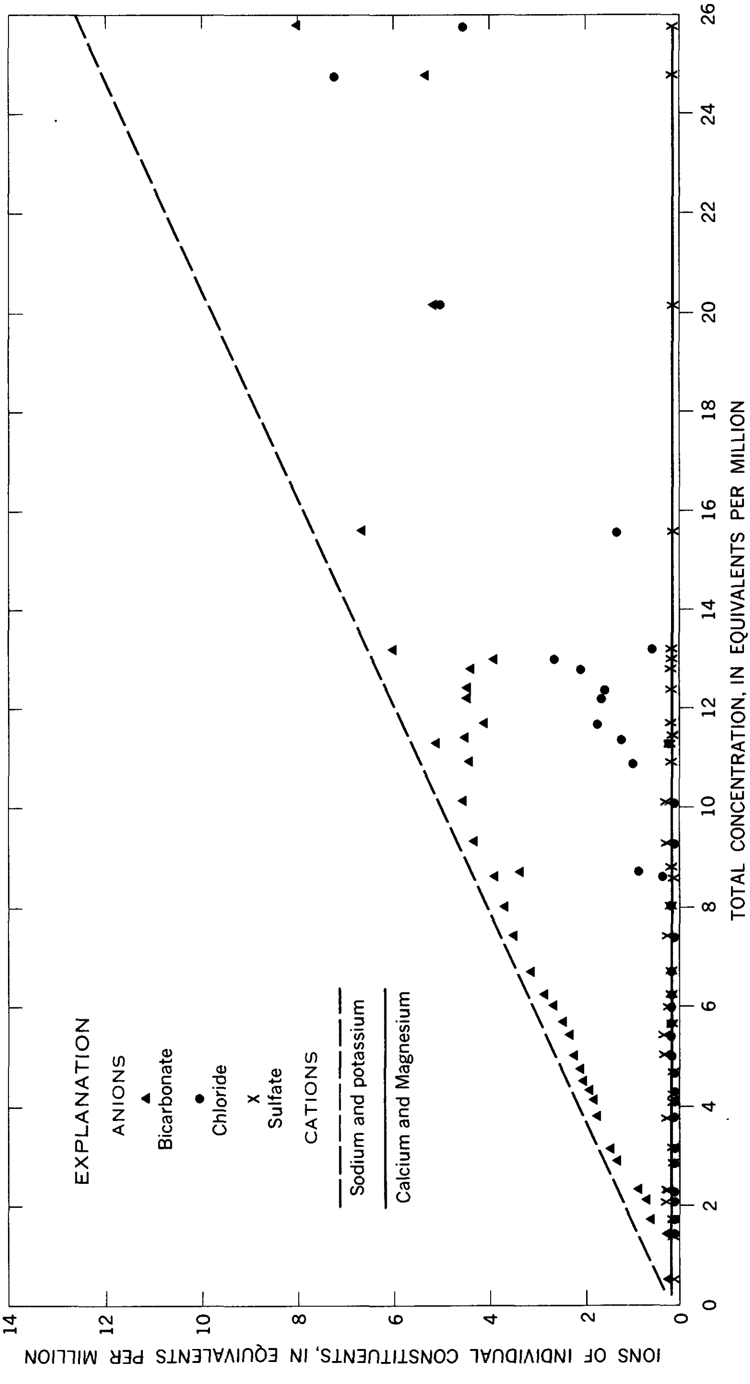

FIGURE 27.—Relation of ions of individual constituents to total concentrations in ground water.

calcium, magnesium, potassium, and sulfate remain fairly constant throughout the range of total concentration and with depth below land surface; they seldom exceed 10 ppm in Harrison County. On the basis of analyses of water from wells in Harrison County (table 18) the observed maximum and minimum concentrations of dissolved solids and the predominant constituents are given in the following summary table.

Constituent	Concentration (ppm) Maximum	Concentration (ppm) Minimum
Dissolved solids	1, 570	51
Sodium (Na)	598	3. 9
Alkalinity (HCO_3, CO_3)	499	22
Chloride (Cl)	743	2. 0

SODIUM

The sodium content in ground water ranged from 3.9 to 598 ppm. Sodium enters the ground water from two sources—from the sea and from the minerals in the aquifer. Particularly during storms, salt spray is carried aloft from ocean waves by the wind; and when the spray droplets evaporate, tiny salt particles are left as dust in the atmosphere. This dust is brought down by rain, much of it near the coast, but some of it many miles inland. Therefore, the rain at times contains all the ions present in sea water. Ordinarily, only sodium and chloride are present in amounts sufficient to noticeably affect the chemical content of ground water. Sodium ions having their source in rain, in sodium-bearing minerals in the soil and aquifer material, and in unflushed saline water give the ground water an average sodium content of about 80 ppm.

As water moves downgradient from the recharge area, the acid ground water tends to decompose silicate minerals in the soil and aquifers, setting free the sodium ion to go into solution in the ground water. Because most sodium salts are extremely soluble in water, any sodium that is leached from the soil or rocks will remain in solution unless the ground water passes through certain soils which remove the sodium ion by the process of ion exchange. The quantity of sodium so derived may be estimated independently because the sodium, unlike that which comes from the sea, is not necessarily accompanied by chloride.

A good correlation exists between the amount of sodium in a sample and the total concentrations of the ionized constituents (fig. 27). A general correlation exists between the amount of sodium in the aquifer and the depth at which it occurs below land surface (fig. 28). In general the sodium concentration increases gradually with depth to 2,200 feet and tends to increase rapidly thereafter.

Sodium concentrations as great as 200 ppm in drinking water may be harmful to persons suffering from cardiac, renal, and circulatory diseases. More than 50 ppm of sodium plus potassium in boiler waters may cause foaming. High concentrations of sodium (106–212 ppm) in water used for sprinkler irrigation can, under certain conditions and with a few kinds of plants, cause discoloration of the foliage and stunting of growth.

CHLORIDE

The chloride content of ground water in Harrison County is low, and it does not exhibit any particular horizontal distributional pattern. The source of the chloride is probably atmospheric precipitation, as some storm rains containing sea spray may contain as much as 76 ppm. Many wells produce water having a chloride content of less than 5 ppm, and only a few wells produce water having a chloride content more than 10 ppm. A few aquifers in the Biloxi area show some degree of contamination. Possibly the area adjacent to Mississippi Sound in Biloxi will be subject to salt-water encroachment in the future.

The chloride content of the ground water ranged from 2.0 to 743 ppm in the samples analyzed. The average chloride content of ground water is about 5 ppm, the same figure determined for this area 25 years ago. Only in the 800-foot sand north of Biloxi have comparatively large increases in the chloride content been observed. At Biloxi, the analysis records for municipal supply wells in the 1,200- to 1,300-foot depth zone indicate that there has been a slight decrease in chloride.

Declining chloride concentrations ordinarily follow redistribution of pumpage; however, increased withdrawals from individual aquifers may be followed by a rise in chloride content. At Biloxi, water in the 1,200-foot aquifer contains many times more chloride than water in the deeper, 1,450-foot aquifer and the shallower 400- and 600-foot aquifers.

Chloride analyses given in table 19 indicate that the concentration of chloride in ground water along Mississippi Sound in Harrison County is low (except in a few localities) and is of little concern to most municipal and industrial users.

BICARBONATE

The areal distribution of bicarbonate in ground water in Harrison County is similar to that of the sodium content. The great majority of the 313 samples analyzed in the 1919–66 period had between 100 and 150 ppm of bicarbonate. Where more than one sample had been collected from the same well (M64 at the Keesler Air Force Base) the bicarbonate content generally had a wide variation (128–187 ppm).

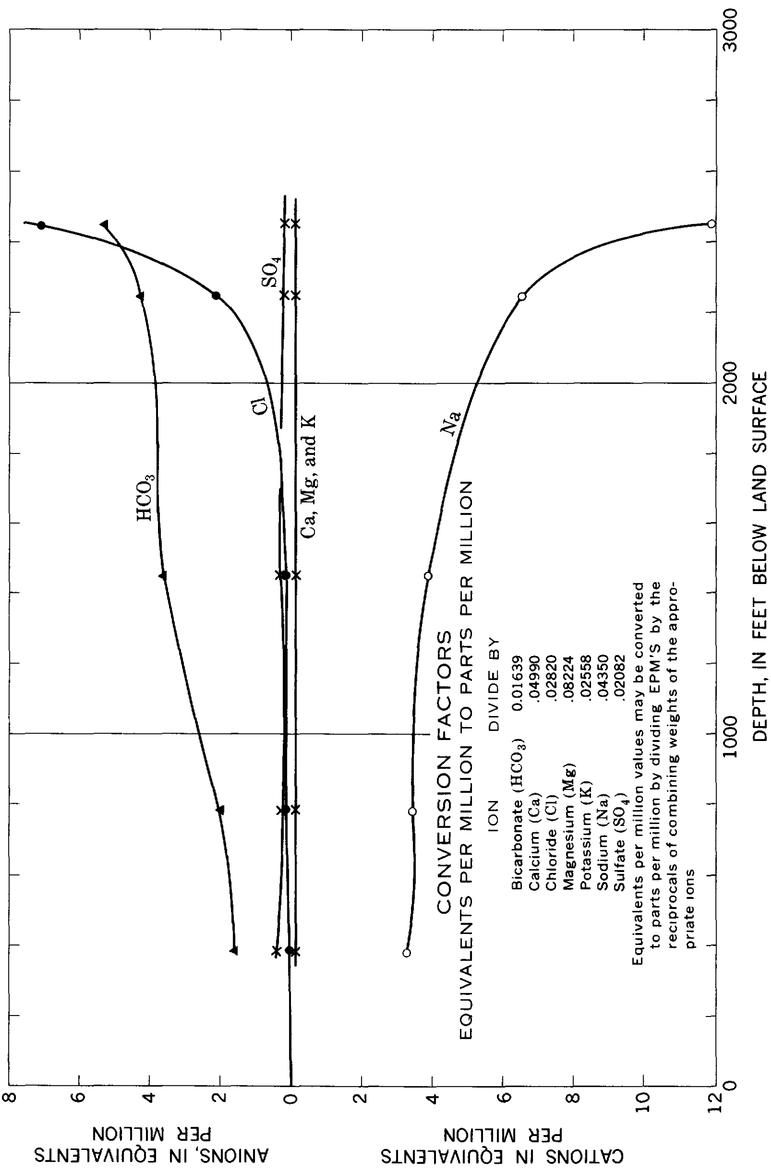

FIGURE 28.—Relation of anions and cations to depth below land surface at the Gulfport test-hole site.

TABLE 19.—*Chloride in ground water from wells along Mississippi Sound in Harrison County*

Well	Depth (ft)	Date		Chloride (ppm)
L84	645	Sept.	1942	4.0
		June	1951	7.2
		June	1956	9.0
		Aug.	1964	3.7
L144	898	May	1939	12
		May	1942	3.0
		Dec.	1942	3.0
		Jan.	1943	3.0
		July	1943	4.0
		May	1947	4.5
		June	1956	6.0
		Aug.	1964	3.1
L147	953	July	1937	6.0
		Sept.	1940	6.0
		June	1956	6.0
		Aug.	1964	3.8
L160	1,196	Aug.	1919	5.0
		Sept.	1942	7.9
		Jan.	1951	5.8
		June	1951	6.5
		Jan.	1952	5.0
		Feb.	1953	5.8
		June	1956	21
		Aug.	1964	14
L161	850	Sept.	1942	7.8
		Jan.	1951	11
		June	1951	6.0
		Jan.	1952	4.8
		Feb.	1953	6.8
		June	1956	14
		Aug.	1964	4.7
L169	890	June	1939	5.0
		July	1943	6.0
		June	1956	8.0
		Aug.	1964	5.3
		July	1943	6.0
L171	800	Sept.	1919	6.0
		May	1939	18
		May	1942	8.0
		Dec.	1942	6.0
		July	1943	6.0
		June	1956	10
		Aug.	1964	6.0
M45	828	Sept.	1940	96
		June	1942	37
		June	1956	175
		Aug.	1964	179
M56	±850	Sept.	1940	74
		May	1942	65
		Dec.	1942	62
		July	1943	63
		June	1956	54
		Aug.	1964	50
M57	868	Sept.	1940	76
		May	1942	64
		Dec.	1942	64
		July	1943	66
		Aug.	1964	50
M58	935	Sept.	1940	56
		May	1942	53
		Dec.	1942	53
		July	1943	53
		June	1956	60
		May	1964	57
M64	620	May	1942	5.0
		Aug.	1942	4.2
		Dec.	1942	4.0
M64	620	July	1943	4.0
		June	1944	7.0
		July	1944	5.0
		Aug.	1944	6.0
		June	1948	4.5
		Apr.	1949	4.5
		Apr.	1950	4.5
		Feb.	1951	4.8
		Mar.	1952	6.0
		Feb.	1953	4.5
		Feb.	1954	6.0
		June	1954	6.8
		Dec.	1954	6.8
		Oct.	1956	4.5
		Oct.	1957	4.5
		Aug.	1959	5.5
		Sept.	1960	4.0
		Aug.	1961	4.1
		May	1962	3.8
		May	1963	5.5
		May	1964	3.7
		June	1965	5.2
M69	720	May	1942	5.0
		Dec.	1942	3.0
		June	1956	13
		Aug.	1964	4.2
M109	±1,450	May	1939	14
		Sept.	1940	6.0
		May	1942	5.0
		Dec.	1942	5.0
		July	1943	4.0
		June	1956	7.0
		Aug.	1964	6.5
M115	1,226	Sept.	1942	162
		July	1943	170
		June	1956	154
		Aug.	1964	142
M119	1,182	Sept.	1940	176
		May	1942	151
		Dec.	1942	152
		July	1943	152
		June	1951	170
		June	1956	166
		Aug.	1964	148
M131	440	Sept.	1919	4.0
		May	1939	14
		Sept.	1940	6.0
		May	1942	6.0
		Dec.	1942	5.0
		July	1943	6.0
		June	1956	12
M132	1,000	June	1939	72
		Sept.	1940	82
		May	1942	73
		Dec.	1942	73
		July	1943	72
		June	1956	92
		Aug.	1964	49
M202	730	Aug.	1919	8.0
		Dec.	1942	6.0
		July	1943	6.0
		June	1944	9.0
		June	1958	6.2
N191	880	Sept.	1919	51
		June	1939	42
		June	1956	26
O175	883	June	1939	3.0
		June	1956	5.0

This wide variation is caused by heavy pumping, which lowers the water level and induces water of different quality from different directions. A general correlation exists between the amount of bicarbonate and depth below land surface (fig. 31).

As there is no limestone in the area, the increase in bicarbonate occurs where there are calcareous shell fragments, ion-exchange material, and lignitic material. Foster (1950, p. 33–48) has shown that where an aquifer contains these three materials, dynamochemical processes result in the generation of water rich in sodium and bicarbonate. In such a process, carbon dioxide is generated by alteration of carbonaceous material in the sediment; the water then dissolves calcium carbonate, the calcium thus taken into solution being replaced by sodium through the action of ion-exchange materials. The end result of these reactions is an increase in the sodium bicarbonate content of the water (Foster, 1950, p. 41).

In general, the concentration of bicarbonate in ground water increases with depth along dip from the outcrop area in northern Harrison and Stone Counties to Mississippi Sound.

HARDNESS

The term "hardness" is applied to the soap-neutralizing power of water and is attributable principally to calcium and magnesium ions. Hardness of the water may be caused by the natural accumulation of calcium and magnesium from contact with the soil and geological formations, or from direct pollution by industrial wastes. The Geological Survey gages hardness according to the following classifications.

Hardness (ppm)	*Rating and usability*
0–60	Soft. Suitable for many uses without further softening.
61–120	Moderately hard. Usable except in some industrial applications. Softening profitable for commercial laundries.
121–180	Hard. Softening required by laundries and some other industries.
>180	Very hard. Requires softening for most purposes.

This classification is only a general guide, for industries differ in their tolerance of hardness. Water from the principal aquifers in Harrison County is soft to moderately hard (0–80 ppm) and is of a sodium bicarbonate type. In general, hardness decreases from the outcrop area along the dip toward Mississippi Sound.

pH

Some of the principal compounds that help to determine the pH of ground water are formed by gases in the atmosphere or are subject to reactions with them; consequently, the pH of water is subject to change if the sample is exposed to the air. Determinations of pH, therefore, are not easily reproducible, especially if the samples stand for some time before being tested, even if the containers are tightly closed. The pH tends to migrate toward neutrality (7.0) with time. Two readings were made on some of the samples collected in Harrison County as part of the sampling program: one reading on the fresh sample at time of its collection, and the other after the sample had been shipped to the laboratory for detailed analysis. The following table of pH values, measured in the laboratory and field, are for water samples from the test well at Pass Christian.

Well	Depth below land surface (ft)	pH tests	
		Lab.	Field
N199d	1,745	8.8	9.1
N199c	1,937	8.2	8.9
N199b	2,211	8.5	8.8
N199a	2,460	7.5	8.2

In general, the most significant changes in pH of a ground-water sample exposed to the air occur with the loss of carbon dioxide (CO_2). The water moving through soil and aquifer material picks up more carbon dioxide than it contained as rain and the immediate effect is to increase the acid content of the water and thus lower the pH. The carbonic acid, meanwhile, reacts with the mineral grains in the aquifer material, and the product of this attack includes sodium, calcium, magnesium, potassium, and bicarbonate ions. Bicarbonate ions tend to make the water alkaline. The carbon dioxide makes the water acid, but some of the ions that form during solvent action of the water in the aquifer material make the water alkaline. The result is that a typical sample of ground water along the coast in Harrison County might have a pH of 8.2 when freshly pumped out of a well and change to 7.5 on standing owing to loss of gases from the sample or gain of carbon dioxide from the atmosphere. The difference between these pH values is largely due to changes in the bicarbonate ion.

The pH of water, simple as it may appear by definition, is actually the resultant of a complexity of factors, some closely related and others quite distinct. Therefore, any interpretation of pH values of ground water that are reported by the laboratory must be made cautiously, unless there are adequate field data to substantiate the suggested conclusion.

The pH of 272 samples of ground water in Harrison County analyzed in the period 1942–66 ranged from 6.0 to 9.1. In general, the pH of the water increases with depth and along the dip toward the Gulf of Mexico.

WATER TREATMENT

The nature of raw water in its relation to the required standards of water quality determines the method of treatment to be employed. Ground-water supplies at Biloxi, Gulfport, Pass Christian, and Bay St. Louis require little treatment, and the only treatment presently used is chlorination, an operation by which potentially infectious organisms are killed.

The color is usually less than 15 units; however, deep aquifers contain as much as 80 units and would need some treatment for most municipal and industrial uses. A few wells in the Biloxi area produce water having concentrations of chloride and dissolved solids above the recommended limits for drinking water. Mixing this water with water having low salinity results in a composite water that is generally acceptable.

The pH of ground water is above 7.0 except in the shallow aquifers in northern Harrison County, where the pH ranges from 6.0 to 6.9. The concentration of iron is higher in the shallow aquifers in northern Harrison County, and most industries and municipalities would have to use some method of treatment to remove iron from water supplies developed in those aquifers.

SALT-WATER ENCROACHMENT

Salt water occurs naturally in deposits laid down in a deltaic or marine environment, but over many centuries it may be flushed from the aquifers and replaced by fresh water. The fresh water enters the aquifers in their uplifted areas of outcrop and is thus under sufficient artesian pressure to force the salt water farther down the gradient. A system of aquifers under equilibrium conditions would exhibit a wedgelike relation between the salt water and the fresh water. The heavier salt water would occur in the lower part of an aquifer, and the fresh water would occur in the upper part, the interface sloping landward beneath the fresh water. A wedgelike relation exists between the base of the Miocene rocks and the base of fresh water (pl. 3).

The position of the salt-water–fresh-water interface along the gulf coast in Harrison County was relatively static before development of ground water began. Heavy withdrawals of fresh water possibly have changed the interface.

A few wells in the 800-foot sand north of Biloxi show some degree of contamination by having comparatively large concentrations of chloride. However, analysis records of the 1,200- to 1,300-foot-deep municipal-supply wells in the Biloxi area show a slight decrease in chloride.

TEMPERATURE

Annual variations in the temperature of ground water under ordinary conditions are almost negligible, because the earth's crust dampens out the extreme temperature variations found at ground surface. The temperature of ground water in Harrison County is a function of the mean annual air temperature and the geothermal gradient. The mean annual air temperature for the coastal area of Mississippi is 68°F, and the geothermal gradient on the coast of Harrison County is 1°F increase in temperature for every 62 feet of depth (fig. 29).

The temperature of the water discharged from a well in Harrison County depends largely on the well discharge rate and the depth of the aquifer. Temperature declines are caused by water passing through a progressively cooler environment as it ascends in a well. The greater the discharge rate, the closer will be the measured temperature at the well head to the temperature of the formation.

For some of the test-hole samples collected in Harrison County, two temperature readings were made—one on the water sample at time of collection at the surface and the other by lowering a recording thermometer in the well and recording the change in temperature of the

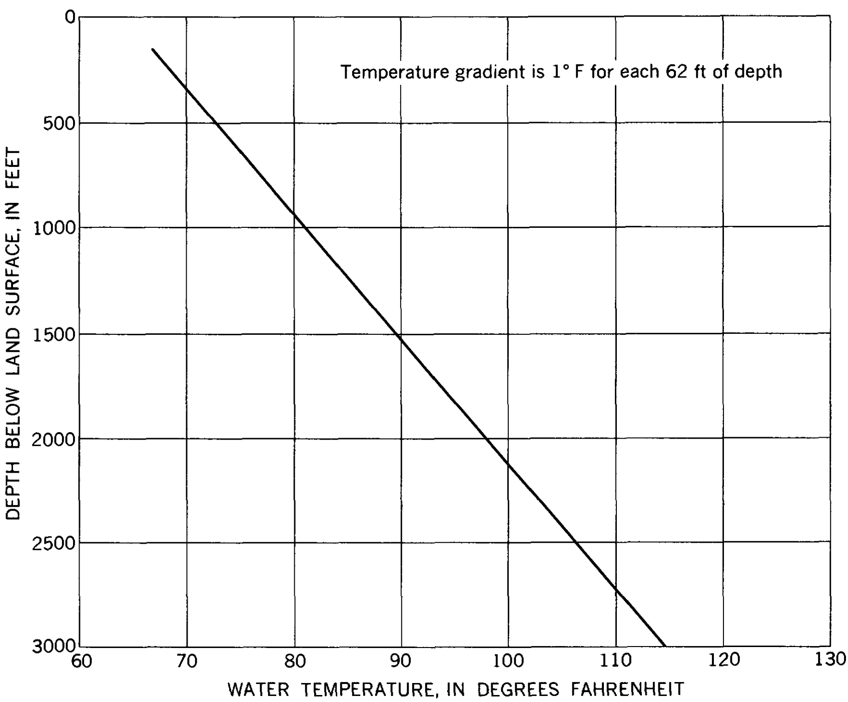

FIGURE 29.—Depth-temperature relation for ground water.

water as the thermometer descended. The following temperature values were measured at the surface and at the bottom of the test well at Pass Christian.

Well	Depth below land surface (ft)	Temperature (°F)		Natural flow (gpm)
		Surface	Bottom	
N199d	1,745	83	92	17
N199c	1,937	83	97	30
N199b	2,211	83	98+	1
N199a	2,460	84	100+	20

The water temperature has a marked effect on the efficiency of water treatment and purification. Filtration for example, is more effective at low temperatures than at high temperatures. Flocculation and sedimentation rates are increased as the temperature increases. At temperatures of 57°–75°F, less alum is required to reduce color in water than at temperatures above 75°F and below 57°F.

SUMMARY OF CONCLUSIONS

Harrison County is amply supplied with water. Its streams, undeveloped as yet, provide water of good to fair quality to all parts of the area. Hardly a place in the county is beyond the benefit of potential reservoir sites. Beneath the surface lie untapped reserves of ground water. Despite the fact that all fresh-water supplies, totaling 25 mgd, are derived from the ground-water reservoir, the resource has been developed substantially only in the coastal cities, and even there considerably greater development is feasible.

The major streams of Harrison County are the Wolf, Biloxi, and Tchoutacabouffa Rivers. Of these streams any one can furnish sufficient water, with storage, to sustain a draft of more than 100 mgd. With ultimate development, many hundred millions of gallons per day would be made available for the growing industrial and municipal needs of the county.

The largest fresh-water supply from streams in their natural state can be obtained from the Wolf River just above the point of maximum salt-water penetration, where the 20-year drought flow, or the 7-day Q_{20}, exceeds 13 mgd. The 20-year drought flow in the Biloxi River at Lyman gaging station is expected to be 9 mgd and that for the Wortham station is expected to be about 1 mgd. Corresponding flow for Tuxachanie Creek and the Tchoutacabouffa River at their gaging stations north of Biloxi is about 1.5 mgd each. An inexhaustible supply of brackish water is available from the bays and estuarine streams.

The tidal-flood hazard is serious in the low-lying areas near the coast. Recent hurricane tides and winds have caused severe damage to commercial and private property in the Gulfport-Biloxi area. Damage as a result of headwater floods along the principal streams in Harrison County has not been severe in the past owing to sparse development on the flood plains. However, with both industrial and urban development near the streams, the problem of flooding may become serious.

Legal restrictions by the State of Mississippi concerning the use of streams for water supply and waste disposal must be considered in the design of surface-water-utilization projects. Authorization to use water from streams must be obtained from the State Board of Water Commissioners. Regulations of the State Game and Fish Commission require that stream waters meet certain standards after the addition of industrial wastes.

The mineral content and pH of the Biloxi, Wolf, and Tchoutacabouffa Rivers are low and the color is rather high. Dissolved solids, chloride, and sodium concentrations generally decrease as the water discharge increases, but these constituents do not vary over a wide range. Most tributaries of the major streams are of good quality and could be used for municipal water supply after some treatment. Principal treatment required would be disinfection, turbidity and color removal, and adjustment of pH.

Samples collected from the Biloxi, Wolf, and Tchoutacabouffa Rivers contained more suspended sediment as the water discharge increased. The estimated annual total sediment yield for these streams for the period of study was about 215, 210, and 190 tons per square mile, respectively. Water during high river stage generally contains lower concentrations of dissolved mineral matter than during low stage. However, the concentration of suspended sediment is greater at high stage than at low stage.

Observed water temperatures ranged from 40° to 87°F in the Biloxi River and Tuxachanie Creek, and from 43° to 86°F in the Wolf River. These are not necessarily the maximum and minimum temperatures that occurred; however, they are indications of the range in water temperature throughout the year.

Aquifers are irregular in thickness and continuity, but several of substantial thickness are available for development at any place in the county. High transmissibility is common for these aquifers; most of the aquifers have transmissibilities ranging from 50,000 to 100,000 gpd per ft, and one has a transmissibility of 600,000 gpd per ft. A great many untapped aquifers appear, from electric logs, to have sufficient thickness to guarantee high transmissibility even with conservative estimates of permeability.

Test wells at Gulfport and Pass Christian penetrated the fresh-water section at 2,500 and 2,250 feet, respectively. Each test revealed two or more previously unknown aquifers having sufficient artesian pressure to force the water 100 feet above the land surface. These aquifers are each at least 100 feet thick and are believed capable of supporting individual well production of 2,000 gpm or more. In addition to these untapped aquifers, many of those supplying current water needs are capable of much more development with proper consideration for distribution of withdrawals.

The average artesian water-level decline of 1 foot per year along the coast during the past 25 years has reduced levels to near land surface in many places, but this is only the point at which water-supply development begins in most regions. Considerably more drawdown is economically available for nearly every aquifer and in nearly every place in Harrison County.

Soft fresh water of a sodium bicarbonate type occurs to depths as great as 2,500 feet in the aquifers of Harrison County. Except for a gradual increase in dissolved solids with depth, there is little variation in the quality of ground-water areally or stratigraphically. In general, sodium, bicarbonate, and chloride increase with depths while calcium, magnesium, and sulfate remain unchanged. The pH of ground water increases downdip from the outcrop areas toward Mississippi Sound. Most of the aquifers contain water of good quality that could be used for municipal water supply after little or no treatment other than chlorination. However, shallow aquifers in northern Harrison County would need treatment for removal of iron and adjustment of pH. The color of ground water is usually less than 15 units.

The geothermal gradient in Harrison County is 1°F for each 62-foot increase in depth. Temperatures in near-surface aquifers are about 68°F. Well-discharge temperatures are relatively constant and are determined by depth of aquifer and rate of discharge.

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Describes various methods for correlating and presenting data from quality-of-water surveys of tidal rivers. Points out some of the natural forces and physical factors which must be considered in planning water-quality investigations of tidal rivers, and shows how these factors may affect the chemical quality of river water.

Kennedy, V. C., 1964, Sediment transported by Georgia streams: U.S. Geol. Survey Water-Supply Paper 1688, 101 p.

Contains reconnaissance data from 33 sites on the variation of sediment concentration, particle-size analysis, and suspended sediment load with stream discharge during the period December 1957–June 1959.

Kohler, M. A., Nordenson, T. J., and Fox, W. E., 1959, Evaporation maps for the United States: U.S. Weather Bur. Tech. Paper 37, 13 p.

Presents brief discussion of evaporation and evaporation-study methods. Maps showing average annual class A pan evaporation, average annual lake evaporation average annual class A pan coefficients, average May–October evaporation, and standard deviation of annual class A pan evaporation for the Nation are presented.

Lang, J. W., and Newcome, Roy, Jr., 1964, Status of salt-water encroachment in aquifers along the Mississippi Gulf Coast—1964: Mississippi Board Water Comm. Bull. 63–4, 17 p.

A tabulation of chloride measurements made over the years for wells in the coastal counties. Also contains a general description of ground-water development and the significance of water-quality trends. A contour map of the base of the fresh-water section along the coast is included.

Morgan, C. O., 1961, Ground-water conditions in the Baton Rouge area, 1954–59, with special reference to increased pumpage: Louisiana Geol. Survey Water-Resources Bull. 2, 78 p.

A status report of ground-water conditions at Baton Rouge. It updates previous reports and presents a timely analysis of pumpage effects. Distribution of withdrawals among the various aquifers—from the alluvium to the 2,800-foot sand—is tabulated. The report has application to Harrison County's water resources in that the aquifers discussed are of similar age, origin, and composition; the water is of similar type and quality; and high-temperature water used at Baton Rouge has a counterpart in the newly discovered deep aquifers on the Harrison County coast.

Newcome, Roy, Jr., 1965, Configuration of the base of the fresh-ground-water section in Mississippi: Mississippi Board Water Comm. Water Resources Map 65–1.

A map showing, by contours at 500-foot intervals, the elevation of the base of fresh water in Mississippi. It shows that the fresh-water section thickens westward along the Mississippi gulf coast and extends to depths of 1,500–2,500 feet below sea level in Harrison County.

Newcome, Roy, Jr., 1966, Test well exploration for fresh aquifers on the Mississippi Gulf Coast, *in* Mississippi Water Resources Conf. Proc., 1966: Water Resources Research Inst., Mississippi State Univ., p. 149–154.

Describes methods and findings of test-well exploration at Gulfport and Pass Christian, and deep-well development at Mississippi Test Facility (National Aeronautics and Space Administration). Deep testing was undertaken because maps based on oil-well electric logs indicated the existence of fresh ground water to depths as great as 3,000 feet along the Mississippi gulf coast. The test holes and water wells verified the good quality, high head, and large yield of the deep water zones.

——— 1967a, Development of ground-water supplies at Mississippi Test Facility, Hancock County, Mississippi: U.S. Geol. Survey Water-Supply Paper 1839–H, 28 p.

Describes test drilling and development of deep aquifers at the National Aeronautics and Space Agency's rocket-testing facility in Hancock County. Provides details of aquifer and well testing, including transmissibility and specific-capacity values, and a discussion of well efficiency.

——— 1967b, Pumping tests: Mississippi Soc. Prof. Engineers Water Well Symposium Proc., November 1965, Jackson, Miss. (in press).

Brief explanation of a procedure for well and aquifer testing, with accent on well efficiency. Purpose is to provide consulting engineer with a simple method of testing and evaluating water wells. Contains formulas and examples of graphs and solutions.

Newcome, Roy, Jr., Humphreys, C. P., Jr., Shattles, D. E., and Callahan, J. A., 1965, Harrison County, Mississippi, water study—interim report: U.S. Geol. Survey open-file report, 25 p.

This report on the first year's activities in the Harrison County water-resources investigation summarizes preliminary findings and outlines the work planned for the second and final year of the project. Streamflow data and the electric log of a deep test well at Gulfport are included.

Robinson, W. H., and Skelton, John, 1960, Minimum flows at stream-gaging stations in Mississippi: Mississippi Board Water Comm. Bull. 60–1, 91 p.

A tabulation of annual low flow for the years 1953–57 in Tuxachanie Creek and the Biloxi River and for the years 1945–47 in the Wolf River. Contains lowest mean discharge for 7, 15, 30, 60, 120, and 183 days.

Searcy, J. K., 1959, Flow duration curves: U.S. Geol. Survey Water-Supply Paper 1542–A, 33 p.

Presents basic methods of developing and interpreting flow-duration curves for long-term record stations and for correlation of short-term record stations with long-term stations, with examples of application.

Skelton, John, 1961, Low-flow measurements at selected sites on streams in Mississippi: Mississippi Board Water Comm. Bull. 61–1, 135 p.

Discharge measurements made during base flow conditions on Hester Creek, Hog Branch, Tuxachanie Creek, Saucier Creek, Flat Branch, the Little Biloxi River, Bayou Bernard, Turkey Creek, and the Wolf River.

Stephenson, L. W., Logan, W. N., and Waring, G. A., 1928, Ground-water resources of Mississippi: U.S. Geol. Survey Water-Supply Paper 576, p. 189–199.

Briefly describes general features and local water supplies. Contains drillers' logs for several communities, a well-record table, and a chemical-analysis table. The treatment of the coastal area is updated by Brown and others (1944).

Swenson, H. A., and Baldwin, H. L., 1965, A primer on water quality: Washington, U.S. Geol. Survey, 27 p.

Describes what "water quality" means generally and contains a basic explanation on how the quality is changed as water moves through the hydrologic cycle. Emphasis is on man and the effect of his wastes on the quality of the Nation's surface and ground waters.

U.S. Department of the Army, Corps of Engineers, Mobile District, 1965, Report on hurricane survey of Mississippi Coast, 49 p.

A comprehensive report of gulf hurricanes affecting the Mississippi coast, with discussion of hurricane characteristics, storm damage, history of gulf hurricanes, storm tides, hurricane protective measures, and related subjects. Maps showing areas inundated by storm tides of 10 feet and charts of hurricane paths are included.

U.S. Geological Survey, issued annually, Surface water records of Mississippi—1961, 1962, 1963, 1964, 1965.

Records of average daily discharge for Tuxachanie Creek near Biloxi and Biloxi River at Wortham. Also, discharge measurements at low-flow partial-record stations on Saucier Creek, Little Biloxi River, and Wolf River and miscellaneous discharge of the Tchoutacabouffa River, the Biloxi River, and Bayou Bernard. Records for the period 1952–60 are in U.S. Geological Survey Water-Supply Paper Series entitled Surface Water Supply of the United States.

——— 1964, Water quality records in Alabama, Louisiana, and Mississippi—1964.

Contains chemical quality data for Tuxachanie Creek and the Tchoutacabouffa and Wolf Rivers in Harrison County.

Wilson, K. V., 1959, Mississippi floods of 1957: U.S. Geol. Survey open-file report, p. 19–29.

This is a detailed report of the September 18–19, 1957, flood in Harrison County, giving rainfall data, peak discharges, and flood history.

Wilson, K. V., and Trotter, I. L., Jr., 1961, Floods in Mississippi, magnitude and frequency: Mississippi State Highway Dept., 326 p.

Presents data on floods that have occurred in Mississippi and explains methods of estimating the magnitude of future floods for selected recurrence intervals. Hydrologic areas are outlined for the State, and flood frequency curves and shape coefficient curves for each area are presented.

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