Water Resources of Southwestern Louisiana

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1364

Prepared in cooperation with the Louisiana Department of Public Works and the Louisiana Geological Survey, Department of Conservation

Water Resources of Southwestern Louisiana

By PAUL H. JONES, E. L. HENDRICKS, BURDGE IRELAN, *and others*

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1364

Prepared in cooperation with the Louisiana Department of Public Works and the Louisiana Geological Survey, Department of Conservation

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1956

UNITED STATES DEPARTMENT OF THE INTERIOR

Fred A. Seaton, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C.

PREFACE

The field work on ground-water investigations was under the direction of Paul H. Jones, district geologist, Ground Water Branch. In this phase of the investigation, A. N. Turcan and Leslie J. Whaley, hydraulic engineers, William W. Whitesides, Thomas B. Buford, Everett E. Richardson, Terrence A. Bell, and Kirby L. Cockerham, Jr., geologists, and Allen B. Jones and Ira W. Thrasher, engineering aids, assisted in the collection of data. Ground-water studies were under the direction of V. T. Stringfield, chief, Section of Ground Water Geology, and A. N. Sayre, chief, Ground Water Branch. Field work on the surface-water phase was under the direction of E. L. Hendricks, hydraulic engineer, and under the general administrative supervision of F. N. Hansen, district engineer, and J. V. B. Wells, chief, Surface Water Branch. Assistance in the collection of data was given by Donald R. Aertker, Hirsch C. Meyer, and Miles L. Eddards, hydraulic engineers. Field work on the quality-of-water phase was under the direction of Burdge Irelan, district chemist, and under the general administrative supervision of S. K. Love, chief, Quality of Water Branch. Assistance was given in the collection of data by James R. Avrett and Samuel J. Rutherford, chemists.

The principal authors were assisted in basic analyses and compilation of data by A. N. Turcan, Herbert E. Skibitzke, Donald R. Aertker, Miles L. Eddards, and James R. Avrett. A. N. Turcan prepared subsections on "Hydraulic characteristics of the aquifers," "Withdrawals," "Effects of withdrawals," and "Wells." Herbert E. Skibitzke prepared the subsection on "Ground-water movement," and part of the subsections on "Recharge" and "Discharge." Miles L. Eddards prepared part of the subsection on "Current methods of rice culture." Donald R. Aertker and Miles L. Eddards contributed to the subsection on "Determination of water requirements." F. N. Hansen prepared the "Introduction" and the section on "Climate" and subsections on "Historical notes" and "Engineering developments."

This report, dependent in large part on the collection of data, was made possible by the cooperation of many individuals and organizations. Without such help and cooperation the investigation would have been very limited in scope. Lack of space prohibits listing individually all those who provided assistance, but their contribution is no less appreciated.

The U. S. Weather Bureau at Fort Worth, Tex., lent an automatic rain gage for the field studies. The Corps of Engineers, New Orleans district, supplied gage records on streams and lakes and numerous data on salinity and other subjects from their files. Charles R. Kolb, of the Waterways Experiment Station at Vicksburg, Miss., gave valuable assistance in geological investigations. The U. S. Public Health Service lent six can-type rain gages.

The Rice Experiment Station at Crowley, through R. K. Walker, director, provided two experimental fields for detailed study. Louisiana State University lent two can-type rain gages and made available its hydraulic laboratory, and much helpful advice was given by its present head, T. M. Lowe, and by the former head of the laboratory, the late C. S. Camp.

The State Department of Highways furnished many parish maps, and its Soils Testing Laboratory, under H. L. Lehman, determined the moisture content of some soil samples.

The writers are indebted to F. E. Everett of Crowley for advice, access to salinity data collected by the Acadia-Vermilion Rice Irrigating Co., Inc., and help in collecting pumpage records at the various plants operated by the company. B. W. Freeland, of the Louisiana Irrigation and Milling Co., Crowley, made it possible to rate pumps and obtain records at the various plants operated by the company. H. G. Chalkley, of the American Rice Milling Co., Lake Charles, rendered assistance at plants operated by that company. S. Arthur Knapp supplied considerable salinity data collected by the Lake Charles Association of Commerce. The American Rice Growers Cooperative Association, Inc., and the Louisiana State Rice Milling Co. provided data on the acreages harvested annually and on the sources of water.

Lucius Vidrine of Fenton, John LaHaye of Vidrine, Jimmie Miller of Church Point, and Joe D. Russo of Abbeville permitted the use of wells for pumping tests. Charles Houssiere of Jennings constructed a well to be used for observation purposes.

Water-well contractors, The Layne-Louisiana Co., Lake Charles; E. M. Stokes, Abbeville; F. J. Fredericks, Abbeville; the Coastal Water Well Corp., Welsh; the Eunice Iron Works, Eunice; H. Brown, Eunice; P. Granberry, De Ridder; Stamm-Scheele, Inc., Rayne; and W. K. Banker, Lake Charles, provided drillers' logs and well-construction data.

The Gulf States Utilities Co., Lake Charles; the United Gas Corp., Lake Charles; and the Central Louisiana Electric Co., Ville Platte, provided power-consumption figures to be used in computation of pumpage for rice irrigation. The Cit-Con Corp., Continental Oil Co., Cities Service Refining Corp., Columbia Southern Corp., Mathieson Chemical Corp., Firestone Tire and Rubber Co., Newport Industries, Magnolia Oil Co., Humble Oil Co., Sunray Oil Co., and Stanolind Oil Co. provided well-construction data and pumpage information. The Calcasieu Paper Co., Elizabeth, and the Texas Co., Erath, provided pumpage figures and permitted use of their wells for pumping tests.

Acknowledgment is made to the individual farmers and well owners who allowed use of their wells for observation purposes and to individual farmers who permitted installation of staff and rain gages within their fields and who collected daily records on these gages. Thanks are due city officials and water-plant operators for information on well construction, pumping rates, and water treatment.

CONTENTS

ILLUSTRATIONS

[All plates in box]

TABLES

WATER RESOURCES OF SOUTHWESTERN LOUISIANA

By Paul H. Jones, E. L. Hendricks, Burdge Irelan, and others

ABSTRACT

In southwestern Louisiana large quantities of fresh water are available for agricultural, municipal, domestic, and industrial purposes. However, local and regional problems resulting from salt-water encroachment in the streams and persistent declines of the ground-water levels in certain areas during drought periods have caused some concern regarding the future water supply of the region. In order to appraise the situation, to provide hydrologic information basic to development of the area, and to provide a basis for sound plans for alleviating recurrent dry-year losses, a study of the ground-water resources of the area was begun in 1938 through cooperation with the Louisiana Geological Survey, Department of Conservation. An intensive investigation comprising ground-water, surface-water, and quality-of-water studies was authorized in 1948 in cooperation with the Louisiana Department of Public Works, and was completely under way before the 1949 irrigation season. The studies were carried through the irrigation season of 1951.

The investigation was designed principally to determine the amounts of water used for irrigation and the relation of these amounts to present supplies of water for all uses.

Southwestern Louisiana is underlain by vast deposits of sand and gravel which yield very large quantities of water to wells. The best aquifers (water-bearing formations) generally range in thickness from 200 to 600 feet, but in south-central Acadia Parish one massive gravel-bearing aquifer is more than 800 feet thick. The aquifers have a gentle gulfward slope, are overlain by a widespread deposit of impermeable clay at the land surface, and are exposed to rainfall and recharge from streams in the broad rolling uplands to the north of the rice-farming area.

The geology and climate of southwestern Louisiana combine to form one of the largest sources of fresh ground water in North America. The annual withdrawal for the past several years has exceeded 600,000 acre-feet, and in some years it has been greater than 800,000 acre-feet. Individual wells commonly yield 2,000 to 4,000 gpm, and several wells yielding as much as 6,000 gpm have been recorded. These yields are very large for wells tapping sand and gravel beds.

Ground-water levels fluctuate seasonally. For the past 9 years there has been a downward trend also, as shown by measurements of the highest stages to which the ground-water levels have recovered each year, in the early spring months. However, the net decline for that period has been less than 10 feet in the most seriously affected areas. Although well failures have been common as a result of falling water levels, the cause is attributable to shallow pump settings required by shallow pits, rather than to a shortage of ground water. Pumping levels have fallen 20 to 50 feet in some areas as a result of withdrawals locally increased by the installation of additional wells or by the modernization of pumping equipment.

The widespread increase in the use of ground water has been made possible mainly because of the good market for rice during recent years, which has enabled farmers to pay for new wells. No doubt water-rent policies are in part responsible for a trend toward increasing use of ground water for irrigation. Cheap power for pumping in the form of natural gas has become almost universally available in southwestern Louisiana, and this has further favored water-well installation.

Many farmers who irrigate with surface water have provided themselves with wells as an alternative source for use in drought years when surface supplies are short. As a result, the acreage irrigated by wells is about one-third the total acreage, depending upon the weather.

The surface-water investigation includes determination of the volumes of streamflow available and the volumes of water diverted for irrigation from the three principal streams in southwestern Louisiana—namely, the Vermilion, Mermentau, and Calcasieu Rivers. Movements of salt water from the Gulf of Mexico into the streams during periods when withdrawal exceeded fresh-water supply are delineated. Requirements for water in growing rice are shown.

The 2 years 1948 and 1951 were years of critical water-supply shortages, approaching, if not exceeding, any of record. Fortunately, records of irrigation pumpage collected by private groups in 1948 could be utilized in the study. Most of the pertinent surface-water facts presented in this report concern these 2 years.

Diversions of water from the streams for the irrigation of rice were estimated on the basis of the measurement of diversion volumes at pumping plants serving about 37 percent of the total acreage irrigated with surface water in southwestern Louisiana. Runoff from large areas in each river basin was estimated on the basis of headwater gaging-station records. Water requirements for growing rice were determined for 42 ricefields through a program of daily stage and precipitation measurements. Data on water requirements for two fields were measured with flumes and weirs supplemented by automatic rain gages. Volumes of irrigation water required to satisfy soil-moisture storage and seepage losses were determined from a series of 17 infiltration tests. No losses by deep seepage were found in the areas tested.

From data collected in fields irrigated with surface water the average water requirement for growing rice was determined to be about 32 inches. This water-depth requirement includes that part which inevitably will be supplied in any season by rainfall and also that which must be supplied by irrigation. Of these 32 inches, it is estimated that 27 inches would need to be supplied by irrigation in a year of critically low rainfall. During the period 1948–51 the average seasonal depth of water applied to the fields was about 22 inches. Losses of surface water between points of diversion from the supply streams and points of delivery to the ricefields average about 35 percent. The maximum diversion requirement from surface sources in a critical year thus is estimated to be about 42 inches, or 3.5 acre-feet per acre.

During the period 1946–51 the average seasonal depth of well water applied to the fields was about 22 inches, the minimum was 16 inches, and the maximum was about 32 inches.

In the Vermilion River basin, total supplementary supplies of 180,000 and 125,000 acre-feet of water would have been required in 1948 and 1951, respectively, to prevent encroachment of salt water. If 70,000 acres of rice were irrigated with surface water in the basin in a critically dry year, it is estimated that a supplementary water supply of about 215,000 acre-feet would be required, and this supply would have to be furnished at a maximum rate of 1,500 cfs.

Because the Mermentau River and the large coastal lakes through which it flows were converted into a closed reservoir system by the completion in 1951 of a system of control structures on all outlets, analyses of water-supply problems in that basin were made with the channel and lakes considered as a reservoir. Greatest demands for water from storage for irrigation diversions for any 2 years were 314,000 and 166,000 acre-feet during the

1948 and 1951 irrigation seasons, respectively. Including surface evaporation and rainfall on the reservoir system, it is estimated that the demand for water from storage in the system reached a maximum of about 425,000 acre-feet in 1948. It is estimated that in a critically dry water-supply year the maximum storage demand would be about 795,000 acre-feet if 250,000 acres of rice were irrigated in the basin with surface water. Comparison of the possible maximum demand on storage with an estimated potential storage capacity of 740,000 acre-feet at maximum controlled elevation leads to doubt that, even if conditions prior to the irrigation season were ideal, serious crop losses could be averted in a dry year if rice plantings were at a maximum. Consideration of possible low between-season runoff into the storage area indicates inevitable losses if two dry seasons should follow each other without the benefit of high runoff between the seasons.

Results of the study indicate that water supplies in the Calcasieu River basin would have been sufficient to meet the diversion requirements for rice irrigation upstream from Lake Charles in the two dry seasons studied if the supplies had been protected from contamination by salt water. Because high rates of excess flow are required to prevent salt-water encroachment into the Calcasieu River from reaching diversion points, appreciable damage to rice crops was experienced in 1948 and 1951. Results indicate, however, that supplies in dry years will not support great increases in irrigation demands; and during dry periods, continuous for as long as 3 months, little water in excess of present irrigation demands is available for other purposes.

The investigation shows that, except during flood periods, the water in the Calcasieu River from Lake Charles downstream is too saline for rice irrigation and most industrial purposes.

Fresh ground water occurs to a maximum depth of about 3,100 feet in southwestern Louisiana, but in the principal (Chicot) reservoir it is present below a depth of 1,100 feet in a few places. The chloride content of water in this reservoir grades upward in the areas of maximum withdrawal and is least in the recharge areas in the northern and eastern parts of the region. There are only two localities in which the chloride content of water from existing wells would be damaging to rice at its most sensitive stage of growth. One of these is in the lower basin of the Vermilion River and the other is a few miles southeast of Lake Charles in Calcasieu Parish. There is good evidence that salt-water contamination of the Chicot reservoir occurs whenever the Vermilion River is intruded by salty water.

The water in the Chicot ground-water reservoir ranges in hardness from less than 50 to about 400 parts per million, grading from moderately soft to very hard eastward, southeastward, and southward from the recharge area in Beauregard and Allen Parishes.

The potential ground-water supply available in southwestern Louisiana is at least several times as great as the maximum recorded withdrawal, provided that steps are taken at an early date to prevent salt-water contamination through the channel of the Vermilion River. Elsewhere along the margin of the Gulf of Mexico there appears to be a sufficient thickness of impermeable clay above the aquifers to prevent the encroachment of gulf water.

The report contains tables of temperatures and chemical analyses of water samples collected from wells and daily sampling stations on the rivers. During periods of salt-water encroachment, area-wide stream surveys and special surveys were made to determine salinity changes; the results of the surveys appear in the report. Salt water in the Vermilion River moves as a front; salt water in the Calcasieu River moves as a wedge. These separate phenomena are discussed in detail.

387601 O - 56 - 2

INTRODUCTION

By F. N. Hansen

Louisiana has an average annual rainfall of 56 inches. Part of the water from these rains finds ready access to and ideal storage in the thick sands that have been laid down in the geologic past. In addition, the excess waters from more than 40 percent of the land area of the United States find an exit to the Gulf of Mexico through Louisiana. These physical conditions have given to Louisiana an abundance of water that is not equaled in any other State.

Considerable volumes of surface water run off during floods. As a consequence, flood control and drainage have been the paramount water problems in Louisiana for more than 200 years. Up to the present time (1952), thousands of acres of land have been reclaimed. Flood control has protected lands and works of man from loss from frequent floods, and drainage systems have placed in useful productivity lands that once were submerged most of the time.

The general abundance of water has tended to create a belief that there is an inexhaustible supply. If surface waters were evenly distributed in time, problems of control and utilization would be simplified. Because the important problems of the past have been drainage and flood control, little attention has been given to occasional water shortages. Water-supply deficiencies that have appeared now and then have excited alarm only in recent years.

Today there are several serious regional water-supply deficiencies. The problems created by these deficiencies must be met with the same energy given to the problems of drainage and flood control. The continued welfare and prosperity of the State, the continued growth of industry, and a stable agriculture free from periodic losses from water shortages are dependent upon greater use of excess waters and a safeguarding of existing water resources so that the need in time of drought may be met.

PURPOSE AND SCOPE

Louisiana's water resources have been put to far greater use in southwestern Louisiana than in any other area of the State.

Ground- and surface-water supplies have been tapped heavily to irrigate the rice crops, to meet the many needs of industry, and to provide water for public supply. Users of surface water for agriculture and industry have placed almost complete reliance upon current streamflow, and few storage facilities have been built. The demand for water has increased as agriculture and industry have responded to the call for more goods to supply the Nation's and the world's markets. Particularly, in recent years, industrial expansion has placed great demands on existing supplies. Consequently, this region and its citizens have been the first in the State to experience widespread inconvenience from droughts. Local monetary losses have been too frequent and upsetting to the economy of the area.

Water levels in wells in southwestern Louisiana have shown a downward trend for many years. Some wells in certain localities have been abandoned during the last few years as a result of salt-water encroachment. The depth of pump setting in existing wells has been increased where possible to maintain submergence. Where this has not been possible, new wells have been installed. Pumping and operating costs have increased as the water levels have declined. The threat of further losses resulting from the effects of heavy ground-water withdrawals has disconcerted and alarmed the people.

During periods of subnormal rainfall, sea water has moved up the channels of the streams and has contaminated surface supplies. In turn, some streams have been the direct source of contamination of adjacent ground-water supplies. The natural flow of the streams and bayous will not meet present-day demands during times of drought. River pumps have remained idle when crops needed water of good or tolerable quality. In some localities in Louisiana industry has had to use saline waters overheated by reuse. Threatened and actual salt-water encroachment into the channels of streams and into the ground-water reservoirs, dry and withering crops, and a threatened slowdown in manufacturing have all contributed to a call for action.

The Louisiana Department of Public Works and the Louisiana Department of Conservation, Louisiana Geological Survey, in cooperation with the U. S. Geological Survey, as a first step to corrective action, have provided for an inventory of available supplies and a determination of the water requirements of the area. Supply-and-demand data, related to time, provide the basis for planning the necessary alleviating works—whether they are in the form of salt-water barriers, dams for upstream storage, diversion from other streams, artificial recharge of ground-water reservoirs, or some other step. Any attempt to solve the problems without such a basic inventory would be likely to end in only partial relief or in haphazardly planned projects that would provide unsure results at greater cost.

This report is basically intended to give an appraisal of water supply and demand. To make this appraisal, many phases of the problem must be considered, and these are covered herein.

Phases of the ground-water study are: The geology of the area; the location of ground-water reservoirs and the occurrence of water in them; the quality and rates of movement of the water within these aquifers; the source of recharge; the relation of ground-water conditions to low-flow supplies in the surface streams; the rate of withdrawal and its effect; and the danger of salt-water encroachment directly from the Gulf of Mexico or from portions of the aquifers or associated strata now containing salty water, or by influent seepage from surface streams.

Phases of the surface-water study are: The occurrence and availability of waters in the streams; the movement of salt water within the streams; the probable extent of relief afforded by existing water-control structures; the quality of water in the streams; determination of the rice-crop requirement and of its various components; and determination of the diversion requirements for irrigation.

Other material indirectly related to the water resources is included within the report to present a better understanding of the problems and of the importance of the region to the State and Nation.

LOCATION AND EXTENT OF AREA

Southwestern Louisiana, as referred to in this report and as shown in figure 1, includes nearly all the region lying within 12 parishes: Acadia, Allen, Beauregard, Calcasieu, Cameron, Evangeline, Iberia, Jefferson Davis, Lafayette, St. Landry, St. Martin, and Vermilion. A general map of the region (fig. 1) includes St. Mary Parish because it is a part of the geographic region, but no rice is grown there. The region covers an area of nearly $6\frac{1}{2}$ million acres, of which nearly $1\frac{3}{4}$ million acres is cultivated. It is estimated that at least 1 million acres at present is adapted for rice culture.

Southwestern Louisiana comprises about 22 percent of the land area and about 18 percent of the population of the State. In the marshland areas of Cameron Parish, the population density is

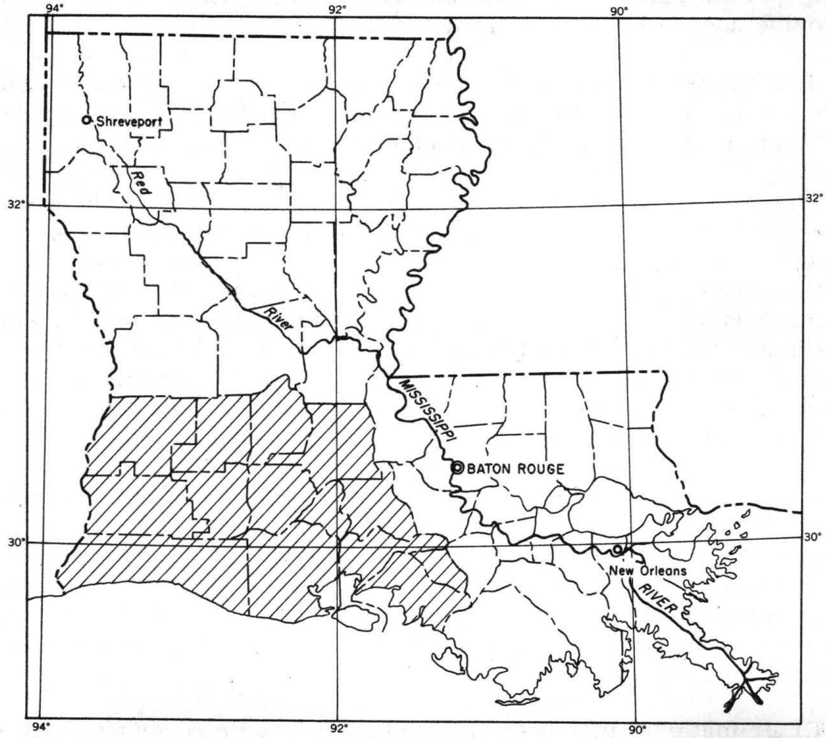


Figure 1.—Location map of southwestern Louisiana.

less than five persons per square mile. Lafayette Parish, the smallest in land area, has the highest population density, more than 100 per square mile.

Lake Charles, with a population of 41,000, is the largest city in southwestern Louisiana. Oil refining, synthetic-rubber and chemical manufacturing, lumber milling, and rice milling are the principal industries. The deepwater port at Lake Charles is the nearest to the gulf of the three deepwater ports in Louisiana. Sixty-eight percent of the Nation's export rice is shipped from here. The city of Lafayette, on the Vermilion River, is second to Lake Charles in population and likewise has many industries. The largest industries of this city are those making processed foods, lumber products, and farm implements.

Southwestern Louisiana has followed the trend of rapid growth in the gulf-coast region in recent years. The population increased 15 percent in the 10 years 1940–50. This is somewhat greater than the 12.8-percent increase for the State as a whole in the same period.

The Intracoastal Waterway crosses the southern part of the area from east to west. Barge traffic plies the main rivers and tributaries. Several paved highways, north to south and east to west, provide ready access between main population centers within the State and into Texas. The area is served by two buslines and several motor-freight lines. Lines of the Southern Pacific, Missouri Pacific, Texas and Pacific, Rock Island, Sante Fe, and Kansas City Southern railroads provide rail service. Eastern Air Lines provides air-freight and passenger service.

Oil and natural gas are being produced in every parish. Consequently, the entire area is crisscrossed with oil and gas pipelines leading from producing fields to refineries and centers of population. The network extends to New Orleans, Atlanta, Memphis, St. Louis, and other distant cities.

The flat terrain of the area does not lend itself to hydroelectric power development. Nevertheless, the need for power has been amply met at low cost with natural gas and refinery waste oil.

Salt and sulfur are found in structurally upwarped areas called domes. Sulfur deposits now being worked are in a dome near Starks about 30 miles west of Lake Charles. A large salt mine is located on Avery Island. Nearly 100-percent pure sulfur and salt are produced from structural domes.

Shell deposits at or near the land surface are mined extensively for use by chemical industries and as road metal; in many places in the coastal marshland, these deposits are as much as 10 feet thick.

Shrimp, oyster, and crab abound in the coastal waters, and fishing is a profitable industry. The region contributes greatly to the shrimp catch, helping to place Louisiana first in the Nation in shrimp production.

Many fur pelts come from the coastal area of southwestern Louisiana.

Much of the area of southwestern Louisiana is well suited by nature to the profitable production of rice. For that reason, rice has been the major crop for many years. By 1950 rice farming had become more than a 50-million-dollar industry. Its importance to the agricultural economy of the State is tremendous and second only to that of cotton. The rice industry is described more fully in a following section.

The soil, climate, and terrain of southwestern Louisiana are conducive to the profitable growing of a great variety of crops. Some diversification of agriculture has been under way in recent years. In this region, cotton is of secondary importance to rice. Sweet potatoes, livestock and byproducts, and sugarcane, in the order given, follow cotton closely in money value. Corn and poultry raising are increasing in importance year by year.

Southwestern Louisiana is rich in natural resources. Knowledge of and wise development of the water resources will do much to stabilize the economy of this production area.

PREVIOUS INVESTIGATIONS

Ground-water investigations in southwestern Louisiana have been carried on since 1938 by the U. S. Geological Survey, in cooperation with the Louisiana Department of Conservation, Louisiana Geological Survey. Results of the regular stream-gaging program, carried on for a number of years by the U. S. Geological Survey, were available to the writers of this report. Since 1943 the investigations have included cooperation with the Louisiana Department of Public Works. The data from earlier investigations were utilized extensively in the present investigation. This report would not have been possible if records of past years had not been available.

THE RICE INDUSTRY IN LOUISIANA

By F. N. Hansen and others

HISTORICAL NOTES[1]

Rice, as a native plant, has been known in Louisiana since earliest historical times. Records left by the survivors of the DeSoto expedition revealed that wild rice grew in marshy spots and was gathered by the Indians by shaking the grain into their canoes.

The first cultivated rice was a white Creole variety introduced by the early colonists. Its cultivation dates to 1718, soon after a settlement was established on the Mississippi River. As early as 1719 the French began building levees and constructing drainage ditches for the protection of the farm lands in the area surrounding the present site of New Orleans. By 1720 rice was being grown at many points along the Mississippi River. The lands back from the river were flooded by openings in the levees during the periods of high water. Cutting of the levees was discontinued within a few years in favor of siphons. The water was removed from the flooded lands through ditches to points lower down the river or by way of a secondary drainage system through the inland swamps. By 1726 rice was commercially important enough for some export to Europe. However, before the Civil War the industry was confined chiefly to Plaquemine Parish, and rice cultivation was mainly for home consumption.

Rice was first grown in the southwestern part of Louisiana by the Acadian settlers after their expulsion from Nova Scotia in 1755. Only small plots in low-level fields along the bayous were planted in rice. This rice was dependent entirely on local rainfall for water supply and was known as Providence rice. Methods of culture were primitive, as the crop was sown by hand, cut with a sickle, and threshed with a flail. The fields were too small for very profitable cultivation, and commonly crops failed in years of deficient rainfall. Little advance was made over the Acadian methods until near the end of the last century.

In 1885, J. B. Watkins, working mostly with English capital, attempted reclamation and irrigation of 4,000 acres of coastal

[1]These notes are based on information obtained from many published sources, Federal, State, and private.

marsh. On the east bank of Calcasieu Lake about 30 miles below Lake Charles, levees about 4 feet above the surface of the marsh were constructed. The area enclosed by the levees was low and flat, and the water in Calcasieu Lake generally stood about 6 inches above the reclaimed marsh surface. The idea was to flood the marsh from the lake at high tide, hold the water within the levee area during the growing period, and pump it off before harvest. The first crop was a failure because salty water from the Gulf of Mexico contaminated irrigation supplies during a dry period, and high water that occurred in the autumn could not be handled by the pumps.

The Southern Pacific Railroad crossed the prairies in 1882. The first twine binder was introduced in 1884. In 1888, in Acadia Parish, the Abbott brothers rigged a crude endless chain, with buckets at intervals, to raise the water to the prairie land above the bayou. They were so successful in this venture that the following year they expanded it and others imitated them. No doubt each of these developments is due some credit for the rapid growth of the industry that followed and made Louisiana the leading rice-producing State by 1889. The first canal to be built for the purpose of supplying water on a rental basis was built by the Abbotts in 1894 in the vicinity of Crowley. Prairie-land culture became well established in the decade from 1889 to 1899, and the acreage increased from 24,000 in 1889 to 147,000 in 1899.

For a few years the bayous furnished an adequate supply of water. However, it early became apparent that in years of subnormal rainfall the flow of the bayous would not be sufficient. A few wells had been drilled before 1901 to help supplement the water supply from the bayous. The dry year of 1901 emphasized the inability of the bayous to supply all demands for water, and by the close of 1903 several hundred wells were in use.

The rice industry continued to flourish and expanded to an acreage peak in 1920. Thereafter planted acreage declined slightly until the start of World War II. Acreage planted in rice has remained reasonably stable over the past decade, and Louisiana has managed to retain the lead in acres planted.

ACREAGE RECORDS

During the years 1946 to 1951, inclusive, rice plantings in southwestern Louisiana totaled 3,577,906 acres, or an average of 596,317 acres each year. The largest acreage was planted in 1948—about 627,000 acres. The total rice acreage for the State has exceeded this figure only once since 1904 and that was in 1920 when more than 700,000 acres was planted (fig. 2). It is apparent that the total rice acreage in cultivation has remained nearly constant during the past 10 years. This graph, for the period 1904–46, inclusive, is based upon figures obtained from several sources in the U. S. Department of Agriculture reports: For the years 1904–33, inclusive, from the Yearbook of Agriculture; for the

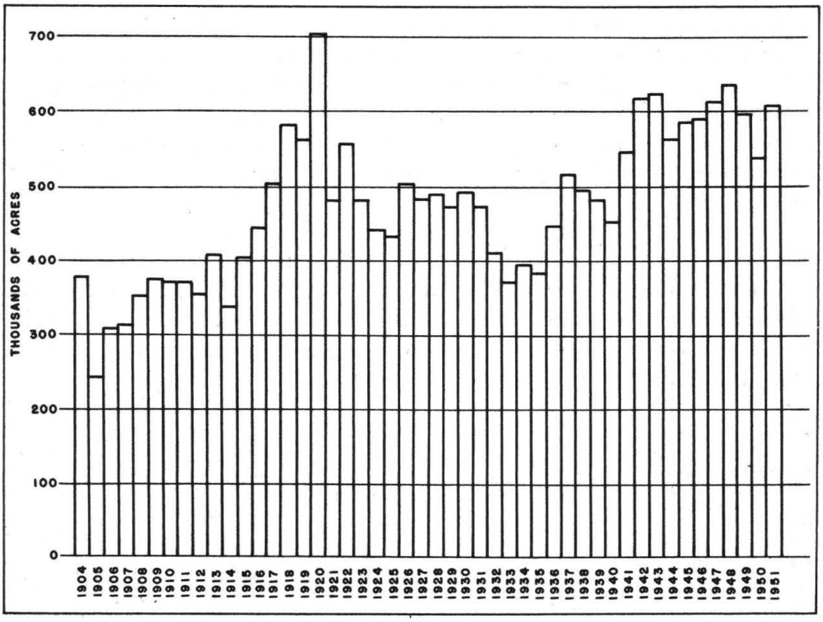


Figure 2.—Total acreage of rice harvested in Louisiana, by years, 1904–51.

years 1934–45, inclusive, from the publication Agricultural Statistics; and for the year 1946, from a mimeographed report of the Bureau of Agricultural Economics. The figures for 1947 through 1951 are acreages planted in rice in southwestern Louisiana only, which constitute at least 98 percent of the total for the State. The figures for these later years were obtained through the courtesy of the Louisiana State Rice Milling Co. and the American Rice Growers' Cooperative Association.

VARIETIES

Rice varieties and variety trends have a bearing on irrigation-water requirements. Although little is known of the inherent differences in rate of water consumption by the several varieties, it is reasonable to assume that, because early-maturing varieties are irrigated over shorter periods of time, the total water consumption by these varieties is less than that by the late-maturing varieties.

The acreages sown to the different varieties of rice change significantly from year to year. Shifts in variety preferences are usually the result of development of new varieties that have better milling quality, improved disease resistance, increased yield, or greater adaptability to mechanical harvesting methods. The shift in recent years from binder-thresher and hand methods of harvesting to the use of combines and driers has greatly influenced the selection of varieties for planting. Consumer preference, reflected in market demand and prices, determines the selection of grain types.

Growers and millers usually classify rice by groups on the basis of time of maturity and grain type. The following table, adapted from Jodon and de la Houssaye (1949), shows the general classification system and some of the varieties in each group. Practically no short-grain rice is now grown in Louisiana.

Grain type	Approximate length of growing period (days from seeding to maturity)			
	Early-maturing, 125	Medium-early, 140	Medium-late, 155	Late-maturing, 170
Medium........	Zenith Magnolia	....	Blue Rose	....
Long............	Century Patna[1]........	Bluebonnet Fortuna	....	Rexoro (Texas Patna)

[1]New variety.

Table 1 shows percents of Louisiana rice acreage in different varieties from 1895 to 1951 and indicates shifts in preference for varieties and grain types. This table was compiled and furnished through the courtesy of Nelson E. Jodon, associate agronomist, U. S. Department of Agriculture, Rice Experiment Station, Crowley, La., from information furnished to him by the Rice Millers Association.

Table 1 indicates the shift toward the use of early-maturing varieties that has been taking place in recent years. This shift is significant as it may reduce the volume of water used.

Table 1.—*Percent of Louisiana rice acreage in different varieties, 1895–1951*

Variety	Percent of acreage										
	1895	1905	1915	1925	1935	1940	1944	1948	1949	1950	1951
Long grain											
Honduras......	45.00	70.00	35.70	10.98	....	....	....	....	....	....	....
Edith..........	....	....	....	....	0.83	0.03	....	....	....	....	....
Lady Wright..	....	....	....	....	.26	.06	....	....	....	....	....
Fortuna........	....	....	....	....	5.00	2.46	8.28	12.11	9.00	3.40	1.10
Rexoro........	....	....	....	....	4.16	11.95	19.01	17.48	19.50	24.20	21.11
Nira............	....	....	....	....	2.95	1.46	.80	1.52	1.30	.96	.35
Bluebonnet....	....	....	....	....	....	....	....	4.14	5.30	17.50	29.18
Carolina.......	45.00	....	....	....	....	....	....	....	....	....	....
Medium grain											
Blue Rose.....	....	....	46.90	78.20	75.06	71.53	50.06	11.83	7.00	1.40	.56
Early Prolific.	....	....	....	9.47	11.63	11.03	16.84	3.90	1.00	.15	....
Zenith..........	....	....	....	....	....	....	4.92	42.59	48.30	47.70	43.42
Magnolia......	....	....	....	....	....	....	....	6.35	8.60	4.30	3.97
Short grain											
Japan..........	10.00	30.00	17.40	1.35	.11	1.36	.01	.04	....	....	....
Others..........	....	....	....	....	....	.12	.08	.04	....	....	....

CURRENT METHODS OF RICE CULTURE

In rice farming, a pasture-rice rotation plan improves the yield of rice and is currently being used where proceeds from livestock and from rice assume equal importance. One rotation plan that has proved highly successful consists of a rice crop for 2 successive years, then stubble or improved or natural pasture for 3 years. The majority of ricegrowers in southwestern Louisiana, however, use a 2-year plan with 1 year of rice followed by 1 year of either natural stubble or improved pasture. Where the acreage cultivated is small and is the main source of income, rice may be planted continuously year after year. Yields are lower, however, when this plan is followed.

Early-maturing varieties of rice generally are planted from April 1 to May 1, approximately, but owing to the shorter growing season these varieties may be planted at later dates. Late-maturing varieties are planted from April 1 to May 15, approximately. Intermediate varieties are planted from April 1 to June 1. A wet or dry soil is not readily workable, and in either wet or dry years, plantings are delayed because of unfavorable conditions.

Rice is planted by either the broadcast or the drill method. Most rice acreage is seeded with grain-fertilizer drills. In only a small proportion of farms is the broadcast method used; it consists of sowing by airplane into a flooded field.

In normal years the soil moisture is usually sufficient for germination of seed. Occasionally, however, the fields must be lightly irrigated to produce germination or to soften the soil crust for plant emergence.

A field in which rice has been planted with a drill is flooded for the first time 10 to 35 days after planting, depending on climatic conditions and the necessity for flooding to control weeds. During this first flooding the land is covered to a depth of 3 to 6 inches, depending on the height of the rice seedlings. The general practice in southwestern Louisiana is to keep water on the fields continuously throughout the growing season. Additional irrigation water is added at intervals as needed to replace evapotranspiration losses. Usually a large part of the precipitation falling on a field is retained and serves to reduce the volume of irrigation water that must be added.

For several reasons some farmers drain their fields once or more during the growing season. After unwanted grasses and weeds have been destroyed by the first flooding, the water may be drained off and the land allowed to dry to induce new root growth on the rice. Fields also are drained, or sometimes partly drained, to permit application of fertilizer or to induce better development at some stages of plant growth.

After the rice is fully headed, the fields are drained. In 7 to 10 days the land is dry enough to support harvesting machines and the moisture content of the rice kernels is at a proper level to permit harvesting to begin.

The seeding of fields by airplane is becoming more common in the area but as yet accounts for only a small proportion of the plantings. When rice is planted by this method, the cultural practices are essentially the same as with the other methods, except that the fields are flooded before planting and drained soon after germination of the seed.

Rice is harvested by methods similar to those commonly used in other parts of the country in harvesting grains. Often a reaper-binder is used that cuts and ties the rice in bundles which are then stacked in the field to dry. When dry, the grain is separated from the stalks by a mechanical thresher and sacked in bags which are transported to either a warehouse or a mill, depending on whether the rice is to be sold immediately or placed in storage. But the most common practice, and one becoming even more widely adopted, is to use combines which cut and thresh the rice in one operation.

ENGINEERING DEVELOPMENTS

The rice industry in Louisiana has kept pace with technological advances. In general, scientific farming is practiced to the utmost. The following description is based on a paper by Shutts (1953).

The larger irrigation-canal systems are designed to serve 10,000 to 25,000 acres of rice land annually. The earliest practice of the irrigation companies was to construct wide canals with beds near the elevation of the natural land surface. Such construction meant shallow canals which tended to become choked with weeds and marsh grass. The common practice today is to construct deeper, narrower channels. Levees are constructed from the material dug from the channels. Relift pumps are required for only the larger irrigation systems. Water is delivered to the edge of the field at such an elevation that the field can be flooded by gravity. The Mixflo pump has been adopted almost universally. This type of impeller combines the characteristics of the centrifugal and axial-flow units and results in a nearly flat horsepower curve under variable heads. The largest units in use have rated capacities of 125,000 gpm. Greater flexibility and dependability can be obtained from multiple units, and in practice these factors limit the maximum capacity of any one unit. Most new pumping units use the gas-engine drive because of its low operating cost.

Technological advances in well-drilling equipment, especially the development of the hydraulic rotary method and the development of the deep-well turbine pump, have made it economical to install and operate irrigation wells to any depth required in southwestern Louisiana under any conditions of pumping lift. Deep wells in the area discharge as much as 6,000 gpm and range in depth from about 100 to 900 feet.

The prairie lands of southwestern Louisiana are spotted with many pimple mounds generally 1 to 5 feet high and 30 to 50 feet across. Within the past 3 to 4 years farmers have made considerable use of land-leveling machinery to smooth out these irregularities. Before the introduction of land-leveling machinery, the mounds were a great hinderance to irrigation.

Low, flat contour levees are now generally constructed. These low levees have vertical intervals as small as 0.15 foot. Such levees can be plowed over, seeded, and later harvested, thus saving much of the land formerly lost to higher, more widely spaced levees. The use of low contour levees provides for a more uniform distribution and a more economical utilization of irrigation water. Increased use is being made of the airplane in seeding, fertilizing, and spraying. The building of large rice-storage driers made it possible to utilize combines in harvesting the crop.

WATER-RENT POLICIES

Growth of the rice industry in Louisiana was accelerated in the latter part of the last century. The investment of private capital in large surface-water pumping plants and extensive distribution systems designed to supply independent landowners with water no doubt contributed largely to the growth of the industry. The irrigation companies agreed to furnish water and the farmers agreed to pay a part of their crop for the water; this arrangement has become recognized as a water-rent policy. Water-rent policies in southwestern Louisiana are well established by precedent and have been subject to little change.

Farmers who irrigate with surface water furnished by an irrigation company pay a rent of one-fifth of their crop to the company. A few farmers whose farm lands in the outlying and higher areas require the lifting of the water to higher elevations than usual, are charged one-fourth of their crop as water rent. The irrigation companies maintain the pumping plants and distribution systems and deliver the water to the growers' fields. Distribution of the water over the field is the responsibility of the farmer. No restriction is placed on the amount of water to be delivered in return for the crop share collected as water rent, but the irrigation company determines when water will be furnished. The amount of water delivered to individual farmers is not measured in any way. The part of the crop due the irrigation company is collected as rough rice at the time of harvest. The irrigation company handles the milling and marketing of its share of the crop.

Water-rent policies of ground-water users are not so uniform as for users of surface water but generally fall into about the same pattern. Farmers who contract with neighbors to supply ground water for irrigation usually pay one-fifth to one-fourth of the rice crop as water rent. Farmers who rent lands having a supply well pay one-fifth of the crop for water rent if the landowner operates the well. If the tenant operates the well, he usually pays a cash sum for its use.

In addition to water rent, tenant farmers pay one-fifth of their rice crop for land rent. This share of the crop, however, covers the rent for lands not seeded in rice, dwelling houses, outbuildings, fences, and other improvements. According to Mullins (1951) approximately 70 percent of the rice acreage surveyed was rented by farmers who paid one-fifth of the crop as land rent. About two-thirds of the rice acreage was operated under contracts requiring one-fifth of the crop in payment for water.

No doubt water-rent policies are responsible, in part, for a trend toward increasing use of ground water for irrigation. During the war years and the postwar period market prices were high. The dollar value of one-fifth of a crop has been great enough to permit many farmers to amortize the cost of their own supply wells in a few years by the savings effected in water rent.

387601 O - 56 - 3

CLIMATE

By F. N. Hansen

Louisiana has a humid temperate climate that is remarkably uniform over large areas. The principal influences that determine the climate of southwestern Louisiana are its subtropical latitude and its proximity to the Gulf of Mexico. The marine tropical influence is evident from the fact that the average water temperature of the gulf along its northern shore ranges from 64°F in February to 84°F in August. Average midwinter and midsummer air temperatures are about 53° and 82°F, respectively. The average year-round air temperature is about 68°F. Extreme temperatures for the area are 107° and 2°F, recorded at Rayne. Temperatures at 32°F, or lower, are recorded every year. However, extremely hot weather in summer and severely cold weather in winter seldom occur. Although the growing season in the southernmost section is more than a month longer than that in the northern section, the greater part of southwestern Louisiana has on the average about 270 frost-free days extending from February 28 to November 25.

In summer the prevailing southerly winds provide a moist tropical climate. When the atmospheric pressure decreases westward from the Atlantic Ocean, a condition favorable for afternoon thundershowers develops whenever the oceanic high-pressure area is not too far west. When the pressure area is altered so as to bring easterly to northerly winds, periods of hotter and drier weather interrupt the usual moist weather.

Although south of the usual track of the larger cyclonic storms, southwestern Louisiana is occasionally visited by winter storms requiring storm warnings, and its position on the gulf coast brings it within the path of occasional tropical storms. Local storms, including hailstorms, tornadoes, and other windstorms of small area, have occurred in all seasons but are somewhat more frequent in spring. Aside from tornadoes, the highest wind velocities have occurred in hurricanes. The most severe hurricane in recent years occurred in August 1940 when high winds, torrential rains, and subsequent floods caused widespread losses. During the 4-day period August 6–9, 1940, a record of 33.71 inches of rain was recorded at Crowley. During this same month nearly 38 inches of rain fell at Lafayette. Fortunately for the area, storms that create widespread havoc tend to pass to the east of the mouth of the Mississippi River. Snow is rare and, whenever it falls, usually amounts to no more than a few flakes that melt as they touch the ground. Glaze and sleet are even less frequent than snow.

The average annual rainfall decreases from east to west and ranges from 59 inches in the eastern part of the area to 52 inches along the western rim. Droughts occur at times during the growing season. From records at Crowley, annual rainfall extremes range from about 31 inches to about 107 inches.

The U. S. Weather Bureau obtained a 40-year record on evaporation from a sunken pan at the Rice Experiment Station at Crowley. Data on evaporation at this location and precipitation records for three selected stations are given in table 2.

Table 2.—*Average monthly, annual, and seasonal (April to September) precipitation and evaporation, in inches*

	Precipitation			Evaporation
	De Ridder	Jennings	Jeanerette Experiment Station	Crowley
January	5.82	5.25	5.02	2.21
February	4.22	4.20	4.32	2.57
March	4.58	3.52	3.73	3.69
April	5.08	3.93	4.32	4.79
May	4.65	5.22	4.01	5.94
June	4.12	4.68	6.28	6.21
July	3.50	5.81	8.36	5.83
August	4.38	5.55	6.13	5.78
September	2.75	4.14	4.93	5.14
October	3.42	3.62	3.70	4.44
November	4.15	4.08	3.92	3.04
December	6.67	5.92	4.67	2.42
Annual	53.34	55.92	59.39	52.06
April to September	24.48	29.33	34.03	33.69

PHYSIOGRAPHY

By Paul H. Jones

GENERAL FEATURES

Southwestern Louisiana lies within the physiographic region known as the West Gulf Coastal Plain. The area comprises parts of three physiographic belts which lie roughly parallel to the margin of the Gulf of Mexico (Doering, 1935, p. 651–688) in eastern Texas and Louisiana and a fourth belt transverse to them, the western margin of the Mississippi Valley. Where the oldest of these belts approach the Mississippi Valley, their boundaries trend northeastward. The principal surface features that distinguish these belts are the degree of dissection by streams and the regional slope of the land surface.

The gulf shoreline of southwestern Louisiana has an eastward trend, and the general slope of the region described in this report (also called the project area) is gulfward. The northernmost east-trending topographic belt (pl. 1) is formed by the outcrop area of two geologic formations, the Bentley and the Montgomery (Fisk, 1948). It rises farthest above gulf level and has the greatest relief and the steepest gulfward slope. Its surface is gently undulating, and it can be described as an upland plain. The gulf-marginal belt, on the other hand, is a marshland of low relief only slightly above sea level, and sloping imperceptibly gulfward. Between the two is a broad, nearly flat prairie.

The prairie belt includes most of the cultivated land of southwestern Louisiana. It extends almost without a break from the Sabine River on the west to the Bayou Teche and Bayou Cocodrie drainage system on the east. East of the Calcasieu River it is roughly triangular in shape, with the apex in northern Evangeline Parish and the base lying parallel to the gulf shoreline. Its maximum width from west to east is about 130 miles, and from north to south, about 70 miles. Its northern and eastern boundaries generally are marked by a low but conspicuous escarpment or line of hills, and its gulfward margin grades almost imperceptibly into marshland.

The altitude of the land surface in the marshland is generally less than 5 feet above sea level. Only the narrow beach ridges of sand and shell rise higher, up to altitudes of about 25 feet. The prairie lands range in altitude from about 5 feet to about 100 feet. The upland plains area slopes relatively steeply and rises from altitudes of about 40 feet in northwestern Calcasieu Parish to about 300 feet in northwestern Beauregard Parish near De Ridder. (See pl. 2.)

These physiographic belts are recognized as terraces, although their origin is a subject of controversy. They are considered by some authors to be of marine origin—that is, formed under the sea (Harris and Fuller, 1904, p. 17; Deussen, 1914, p. 78–80; Cooke, 1931, p. 503–513); and by others to be of fluviatile origin—formed by stream deposition (Barton, 1930a, p. 359–382; Doering, 1935, p. 675–677; Russell, 1936, p. 10; Fisk, 1940, p. 58).

UPLAND PLAINS

The oldest, most dissected, and perhaps least studied physiographic unit of the region is the upland plains section which comprises all of Beauregard Parish, approximately the northern two-thirds of Allen Parish, and the northwestern one-fourth of Evangeline Parish. (See pl. 1.) Between the principal streams of this area the plains are gently rolling, and the relief is seldom more than 20 feet where the plains are well preserved from erosion. The slope of the plains' surface is a few degrees east of south.

The upland plains consist of two roughly parallel topographic belts. A northern belt of plains—by far the largest part of the upland plains section—has a gently rolling surface sloping gulfward about 5 feet per mile. This area has been correlated with the Bentley terrace of central Louisiana (Holland, Hough, and Murray, 1952; Fisk, unpublished map). The local relief is generally no more than 15 to 20 feet, and the nearly flat expanses of this plain favor the cultivation of rice. Small areas, mostly west of De Ridder (pl. 3), were changed to rice cultivation during the years immediately after World War II.

A rather narrow belt of plains, ranging in width (north to south) from about 6 to about 20 miles, has been termed the Lissie surface (Deussen, 1914, p. 78; Doering, 1935, p. 684). It is adjacent to and south of the Bentley terrace and is dissected noticeably only near the southern and eastern margins where it merges with the prairie lands mentioned above. It lies across southern Beauregard and northern Calcasieu Parishes. Northeastward, it includes most of the upland area east of the Calcasieu River in Allen and Evangeline Parishes. Although these plains have a gulfward slope ranging from about 3 to 3.8 feet per mile, much of their surface is so flat that drainage is poor. Low, swampy areas of this belt of plains are called "flatwoods" (Doering, 1935, p. 684). This belt has a local relief generally less than 20 feet. It has been correlated with the Montgomery terrace in Grant and La-Salle Parishes (Fisk, 1938, p. 56) and Rapides Parish (Fisk, 1940, p. 98). Much of this terrace is suited to rice farming, but at present only a small part is under cultivation.

The upland plains area was largely forest at the time of earliest settlement in the latter part of the nineteenth century. The timber, mostly pine, has since been stripped from the land. The features of the surface are obscured only by stumps and low brush throughout most of the area. The general flatness of the land now is obvious to the most casual observer.

Several surface features characterize the upland plains. Perhaps the most apparent are the pimple mounds, the bagols, and the long, regular swells or ridges present in a few places, generally lying parallel to the trend of the belt of plains.

Pimple mounds (fig. 3) are circular mounds of earth, generally from about 30 to about 50 feet in diameter and ranging in height from about a foot to about 5 feet. The nature of their alinement in

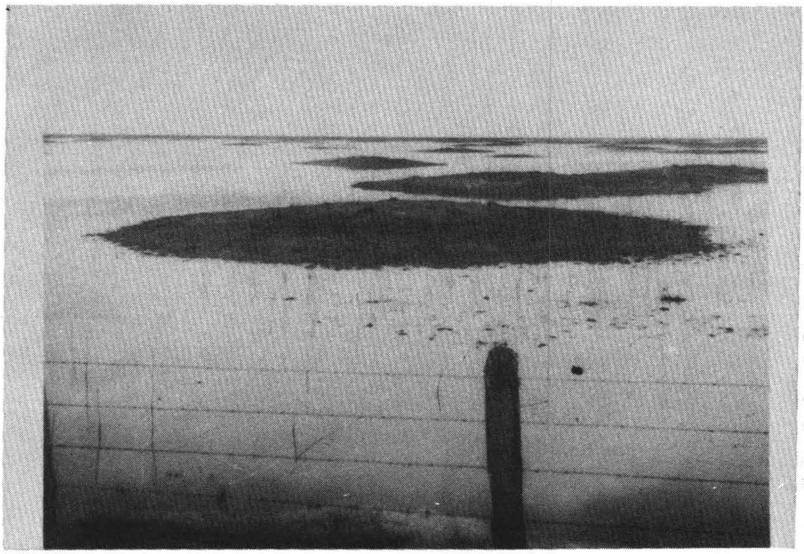


Figure 3.—Pimple mounds about one-half mile north of the intracoastal canal on State Route 25 east of Calcasieu Lake, Cameron Parish.

rows parallel to the drainage (Fisk, 1948, fig. 2) suggests that they may be of erosional origin. Their abundance gives the surface upon which they occur a mottled appearance. No fewer than 40 theories as to their origin have been advanced (Harris and Veatch, 1899, p. 192–195), but none has been proved. The most comprehensive recent discussion of their origin is presented by Holland (in Holland, Hough, and Murray, 1952, p. 50), who concludes that no single theory is adequate to explain all occurrences. Pimple mounds are known to occur only west of the Mississippi River and to be present upon land surfaces ranging in geologic age from early Tertiary to late Pleistocene. They are called mima mounds in the Pacific Northwest.

Bagols are low, swampy areas usually round or elliptical in shape, rarely more than one-fourth mile in greatest width, and generally marked by a growth of pin oaks and bay trees, for which they are named. As they do not favor the growth of pines their timber was left standing by lumbermen, and the bagols now dot the barren upland plains as small islands of woods in an expanse of grassland and stumps (fig. 4).

The long, regular swells (there are no scarps) that make up the principal topographic "highs" within the upland plains give a semblance of beach ridges, where they are not eroded by modern

Figure 4.—Bagol in northwestern Beauregard Parish about one-third mile north of U. S. 190, 4 miles east of De Ridder.

drainage. They generally lie parallel to the adjacent downslope line of hills or gulfward-facing escarpment. Between the long swells, in a poorly defined channel, a tiny stream may be present. The relief in the vicinity of these low, rolling swells may be as great as 50 or 60 feet.

The upland plains are drained almost entirely by the Calcasieu River and its tributaries (pl. 1). The Sabine River, which adjoins the plains on the west, receives only one significant stream (Anacoco Bayou) in the project area, and its flow is derived almost entirely from outside the area. Cypress Creek, a tributary of Bayou Nezpique, drains the extreme eastern tip of the upland plains.

The principal tributaries of the Calcasieu River, from the standpoint of streamflow, are Bundick, Whiskey Chitto, Six Mile, and Ten Mile Creeks. Their valley floors are 50 to 60 feet below the general level of the adjacent upland plains, and their broad flood plains (1 to 3 miles or more wide) indicate that their pre-Recent scour trenches were cut to a much greater depth into the upland. The streams are flanked by benches that are continuous with the Montgomery and Prairie terrace surfaces. Although the stream valleys are rather straight, following the regional slope of the plains, the streams themselves meander intricately within their flood plains. Valley scarps are commonly of sand or sand and gravel, and spring-fed branches are abundant.

Perhaps a third of the area of the upland plains is drained by Barnes Creek, the West Fork Calcasieu River, and the Houston River. None of these streams has a large low-water flow, perhaps because their tributaries do not cut deeply enough into the plain to tap water-bearing sands which underlie the near-surface clay and silt. Bear Head, Beckwith, and Hickory Creeks have similar low-flow characteristics. They trend almost due south to join the Houston River, which flows almost due east along the southern margin of the upland to join the Calcasieu River. In this part of the region the drainage approaches the right-angle or trellis pattern (Fenneman, 1938, p. 202), and the indication is that Bear Head Creek may have joined the Sabine River in the past but has since been captured as a result of headward erosion by the Houston River.

All the streams of the upland plains area are transverse in that they cross successively younger geologic formations at right angles in their course toward the gulf. Their gradients are decidedly less steep than the seaward slope of the land throughout the area. The swamp vegetation of their flood plains is in sharp contrast to the vegetation of the adjacent upland. Cypress and gum are the predominant trees, and tangled vines and palmetto thickets give the valleys the aspect of a jungle. In many places they are still in their primeval state, never having been exploited for lumber.

PRAIRIE

Although not entirely treeless, the broad triangular plain constituting about half of southwestern Louisiana can be considered a true prairie. Generally the only trees visible are those growing on the flood plains or on the marginal slopes of streams. Where it is not under cultivation the prairie is essentially grassland. Most of the rice farming of southwestern Louisiana is done on this prairie, partly because of its low altitude, low relief, and gentle slope, and partly because of its impervious subsoil.

According to Doering (1935, p. 684), the original depositional surface of the prairie, which he correlates with the Beaumont plain of east Texas (Fisk, 1940, p. 65), was never as smooth as that of the next higher (older) terrace (Deussen's and Doering's Lissie and Fisk's Montgomery terrace). The relief on the prairie, where untouched by erosion, ranges from 10 to 20 feet, between the tops of the plentiful distributary ridges or meander-belt natural levees of ancient streams (pl. 1) and the bottoms of their flanking back-swamp lowland. Because the prairie slopes very gently gulfward ($1\frac{1}{2}$ to 2 feet per mile), rises no more than about 100 feet above sea level at its northern extremity in the region described in this report (in northern Evangeline Parish), and has been exposed to erosion for a relatively short time, the maximum relief is generally less than about 30 feet.

Between the northern tip of Evangeline Parish and the southeastern boundary of Iberia Parish, the eastern edge of the prairie is marked by an eastward- or northeastward-facing escarpment. In some places the escarpment has been dissected by streams to form a narrow belt of hills. The height of this escarpment, between the prairie surface and the western margin of the Mississippi Alluvial Plain, is greatest to the north, gradually decreasing gulfward until the escarpment is barely perceptible at its southeastern extremity in the vicinity of Franklin in St. Mary Parish—where the prairie slopes beneath the Mississippi Alluvial Plain at its junction with the coastal marshland. In Evangeline Parish the height of the escarpment is as great as 80 feet; at the latitude of Opelousas in St. Landry Parish it is about 50 feet; at Lafayette in Lafayette Parish it is about 25 feet; at New Iberia in Iberia Parish it is about 10 to 15 feet; and southeast of Franklin it is not perceptible.

Except along the principal streams the relief on the prairie is almost imperceptible. The crests of the low natural levees of ancient streams which crossed and recrossed the prairie are better drained than the back-swamp areas between them, and as a result, these levees are the principal locations of roads, dwellings, and railroads. However, the drainage has been much improved by dredging, and spoil banks mark the courses of many small streams. Pimple mounds are plentiful in several parts of the prairie and are the most common and perhaps the most conspicuous feature of the relief. Along the southern margin of the prairie, where the prairie surface slopes beneath the coastal marshland, the pimple mounds protrude through the thin veneer of marsh deposits. In preparing the land for rice cultivation it has been found necessary to scrape off the mounds with land-leveling machinery. With the mounds goes much of the soil so that, in the fields of growing rice, the circular pattern of the mounds is apparent because of the contrast in appearance of the rice plants growing where the mounds previously stood and those growing in the intermound areas—the latter are greener.

The valleys of the transverse streams of the prairie are conspicuous because of the contrast of their plant cover—pines on the low flanking benches and gum, cypress, and willow on the flood plains. Evergreen oaks, commonly called live oaks, are abundant in the towns and about the homesteads on the prairie. Their original habitat, however, is the marshland to the south.

Except for the Calcasieu and the Vermilion Rivers, streams that cross the prairie (such as the Mermentau River and Bayou Nezpique) generally do not cut through the clay that forms the land surface, and therefore their dry-weather flow is very small. This is an important factor in their rôle as sources of irrigation water.

COASTAL MARSHLAND

The coastal marshland is, as the name implies, an area of very low relief. It is an expanse of hydrophytic grasses which in few places rises more than 5 feet above sea level. Except for the cheniers (Russell and Howe, 1935, p. 449–461), which are old beach ridges deposited in the marsh (pl. 1), there is no perceptible relief west of the Vermilion River.

East of the Vermilion River there are no cheniers, but the flatness of the marsh is broken by a series of broad mounds from 2 to 4 miles across and 75 to about 175 feet high, marking the location of salt domes. Five mounds, commonly called islands

(Veatch, 1899), lie along a line trending northwestward from the mouth of the Atchafalaya River. Four of the five islands lie in the coastal marshland and are its most conspicuous relief.

The marshland of Cameron and Vermilion Parishes has been estimated to include 2,321 square miles of the 2,771 square-mile total area of those parishes (Howe, Russell, and McGuirt, 1935, p. 12). Toward the north the marsh is quite firm, being underlain by silt and hard clay. In its central and southern parts, however, the organic content of the mud is high, and the surface of the marsh is really not a land surface, as anyone attempting to cross it on foot will find.

The most conspicuous topographic feature of the coastal marshland is the chenier. A chenier is a beach ridge, composed mostly of sand and shells thrown up by the waves during storms. In the marshland the cheniers, which were so named by their Creole inhabitants, form the principal areas of habitation and comprise most of the arable land near the gulf. Their total area in coastal southwestern Louisiana is about 70 square miles (Howe, Russell, and McGúirt, 1935, p. 12). They rise as much as 25 feet above sea level (Grand Chenier) and extend for many miles, trending roughly parallel to the present coastline (pl. 1). They are generally narrow, seldom more than a few hundred feet wide, although the larger ones near the present shoreline are more than a mile wide. In transverse section the cheniers are steep on the gulfward side, because of their wave origin, and slope gently inland. The gentle backslope is the product of "wash-over fans," the cones of sand and shell carried down the backslope by the water spilled over the crest of the ridge by the highest waves.

The cheniers farthest from the present shoreline have the least relief because they are oldest and have had ample opportunity to sink into the soft marsh muds on which they rest. Extensive boring records show that their original form is preserved. To the east even the youngest of the cheniers merge with the level of the marshland, probably because of regional subsidence toward the axis of the Mississippi structural trough. (See "Geology" which follows.)

One of the most conspicuous features of the coastal marshland is the abundance of lakes. Although some of these owe their origin to peat "burn-outs" (for example, part of Lake Arthur), most of them are estuaries formed by wave erosion along the margins of natural watercourses, especially the coastal streams. Perhaps Grand Lake, White Lake, and Vermilion Bay are the best examples. The regional subsidence mentioned above has increased the advantage of the waves, and enlargement of lakes and bays is active today.

The gulf shoreline now is moving inland at the expense of the coastal marshland, probably because insufficient detrital material is being derived from the Terrebonne delta of the Mississippi River (Russell and Russell, 1939, p. 160) by the alongshore currents to build gulfward rapidly enough to compensate for regional subsidence or rise in sea level. (See "Geology.") That the shoreline has been moving inland for a long time is indicated by the transection of the meander pattern of an ancestral Mississippi River in the vicinity of Cameron and Mud Lake in Cameron Parish, near the mouth of the Calcasieu River (pl. 1).

MISSISSIPPI RIVER FLOOD PLAIN

The flood plain of the Mississippi River merges with the coastal marshland along an indefinite line trending southeastward from Franklin in St. Mary Parish. Northwest from Franklin the western margin of the flood plain is marked by the course of Bayou Teche (pl. 1). This part of the Mississippi River flood plain is identified by Russell (1936) and Fisk (1944) as the deltaic plain.

The part of the deltaic plain lying west of the Atchafalaya River is composed principally of forested swamps. A relatively narrow belt of natural levees runs along its western fringe. The total relief, from the crest of the natural levees to the floor of the swamps, may be less than 15 feet, but in this flat terrain it is sufficient to differentiate the lands very effectively. The swamp lands, with their poor drainage and heavy soils, are almost worthless by comparison with the well-drained natural levees where the soil is generally silt loam.

An interesting feature of the flood plain along the Atchafalaya River is the filling of Grand Lake through which it passes. Since 1932 about 40 square miles of its area have been changed from lake bottom to dry land.

GEOLOGY

By Paul H. Jones

PURPOSE AND SCOPE OF GEOLOGIC STUDIES

The occurrence, origin, quality, and availability of ground water in southwestern Louisiana are related to the late Tertiary and Quaternary geology of the region. Because older deposits do not contain fresh water in the region studied and their geologic features seldom bear direct relation to the ground water, they are treated only briefly in this report.

The geology of an aquifer—a formation or structure that transmits water in sufficient quantity to supply pumped or flowing wells or springs—comprises the aquifer's texture, mineral composition, thickness, and structure, its areal continuity, facies changes within it, the nature of its extremities, and its stratigraphic position and age. All these factors may have important bearing upon its ability to yield water and upon the quality of the water it contains. The geology of an aquifer is therefore an important factor in its evaluation as a source of water supply.

PREVIOUS STUDIES

Although the geology of Louisiana has received a great deal of study during the past 100 years and especially since the discovery of oil near Jennings in Jefferson Davis Parish in 1901, relatively little study had been devoted previously to the subsurface deposits of Pleistocene age in southwestern Louisiana, which include the principal aquifers. Detailed investigations of the geology of their updip equivalents in central Louisiana have been made in recent years by Fisk (1938, 1940), with special attention to their topographic features. However, results of these investigations have provided little assistance in the interpretation of the subsurface stratigraphy and structure in the region covered by this report (pl. 4). In fact, formation descriptions and structural relations of the deposits inferred from study of their areas of outcrop have provided no usable basis for their differentiation in the subsurface.

In southwestern Louisiana, fresh ground water does not occur in formations older than the Catahoula formation of Miocene age, and there is little evidence that the stratigraphy of older deposits has a direct bearing upon the ground-water resources. Reference therefore is made only to those investigations that treat directly with Miocene or younger rocks.

Southwestern Louisiana is underlain in large part by deltaic deposits of the Mississippi River, and important studies of the geology of these deposits that contribute to an understanding of deltaic sedimentation deserve mention here. The earliest significant contribution to an understanding of the Mississippi Delta was made by Sir Charles Lyell (1847), in a study in which the rate of delta building of the modern river is discussed and gravelly outcrops at Port Hudson on the east bank of the river about 18 miles above Baton Rouge are described. Raymond Thomassy (1860) inferred that large amounts of Mississippi River water enter the alluvial deposits along its banks, as evidenced by lateral springs and lakes. In chapter 8 of his book he postulated a theory of hydrothermal and volcanic origin for the Five Islands of southwestern Louisiana (Jefferson Island, Avery Island, Weeks Island, Cote Blanche Island, and Belle Isle) which now are known to be surface uplifts due to rising salt "plugs."

The first detailed study of the hydrography and geology of the whole Mississippi Basin was made by Humphreys and Abbott (1861, 1876). Among the important findings of their work were two geologic factors that have had a profound influence upon the water resources of southwestern Louisiana. The river alluvium was found to be a comparatively thin deposit filling an older erosional channel, or scour trench; the tough clays underlying the alluvium were found to form a buried "bar" or "ridge" transverse to the course of the lower Atchafalaya River near Franklin in St. Mary Parish (pl. 5). Accurate records of the rate of the advance of the passes at the mouth of the Mississippi River are also presented in this report.

The interpretations of E. W. Hilgard (1869), based upon a reconnaissance of 30 days' duration in 1867, resulted in the publication of a report in 1873 described by Harris and Veatch (1899, p. 29) as the "most complete statement of the geology of the State heretofore published." Hilgard made reference to and identified formations penetrated by water wells west of the Calcasieu River near Bayou Choupique in Calcasieu Parish. The beds that occur beneath the surface to a depth of 160 feet along the Calcasieu River were correlated with deposits that lie between depths of 120 and 630 feet at New Orleans and were identified as marine deposits laid down in Port Hudson time (Pleistocene).

The emphasis of Hilgard's work cited above was on the geology of rocks of Tertiary age in central and northern Louisiana, but he recognized the great importance of geosynclinal subsidence along the gulf shoreline, which he judged to have "suffered a depression to the extent of at least 900 feet (perhaps more) in the late Quaternary, and during the Terrace epoch a contrary motion of about half that amount" (Hilgard, 1869). His correlation of the sand and gravel bed penetrated in the Bayou Choupique well between depths of 160 and 333 feet with the Orange Sand group of Safford (1856) and of Hilgard (1869)—lower Pleistocene or upper Pliocene equivalent of the Lafayette formation of McGee (1891)—was the first significant subsurface interpretation of the relation between the gravelly aquifer of southwestern Louisiana and the gravel exposures in the uplands of central Louisiana.

The first geologic map of the State was prepared by F. V. Hopkins (1871). Hopkins (1872) devotes considerable attention to the deposits of Quaternary age and includes perhaps the first attempt in the gulf region to correlate formations on the basis of similarities in the chemical quality of their contained water. He correctly states, on page 168, "It is evident, therefore, that by testing the water of the deepest wells dug in the [Recent] alluvium, it is possible to tell whether they pass through it into the underlying Port Hudson [Pleistocene] group or not." He was perhaps the first to correlate the upland Pleistocene terrace deposits along the Red River with the beds of the Port Hudson group east of the Mississippi River, a correlation widely accepted today (1952). He also identified Paleozoic fossils in the chert gravels of Pleistocene age and suggested that they were transported from the Hudson Bay region by an "Arctic current."

During the summers of 1894 and 1895, W. W. Clendenin examined areas in southern Louisiana (1896). It was he who substituted the names Lafayette formation of McGee (1891) and Columbia formation of McGee (1888) for Hilgard's Orange Sand and Port Hudson group, which he considered to constitute the Pleistocene deposits of the area. He was able to prove, by detailed study of well records, that uplift of the Five Islands described on page 95 of this report had continued through the period of deposition of McGee's Lafayette formation, and in this respect he was perhaps the first to realize that detailed study of subsurface conditions in southwestern Louisiana is necessary to sound interpretation of its geology.

Harris and Veatch (1899) give an excellent review of past investigations of the geology of Louisiana, from which the above historical discussion is largely derived. Their contribution to an understanding of the geology of Louisiana, especially the Quaternary geology, was considerable, and their deductions, which were of necessity based upon few subsurface data, have proved to be

387601 O - 56 - 4

remarkably accurate. They concluded (p. 109–111) that a three-phase sequence of events took place in the Quaternary: subsidence, uplift, and subsidence continuing today. Excellent evidence of recent subsidence is presented, and the extensive gravel deposits of the region are attributed to outwash from Pleistocene glaciers. It is not surprising that they failed to recognize regional tilting, involving simultaneous landward uplift and coastward downwarp as an important factor of deposition, and that the effect of ice accumulation on the continents was a lowering of sea level and rejuvenation of coastal streams.

The name Port Hudson was assigned by Harris and Veatch (1899, p. 114) to the deposits forming the pine flats of Calcasieu Parish and the whole prairie region of southern Louisiana. The lithology and fauna of the Port Hudson show two facies, marine and fresh water, although the type locality shows only fresh-water deposits of fluviatile origin. In the vicinity of Lake Charles, Harris and Veatch estimated their Port Hudson to be about 200 feet thick, although one water well was said to show a thickness of 354 feet. As shown on plate 32 in this report, the thickness of the fine-grained sediments above the principal aquifer is generally between 200 and 400 feet in east-central Calcasieu Parish. It is therefore evident that Harris and Veatch believed the clay, silt, fine sand, and marine shells that overlie the principal aquifer in southwestern Louisiana to compose their Port Hudson, which they considered to be of earliest Quaternary (oldest Pleistocene) age.

The Lafayette formation of Hilgard (1891) was recognized by Harris and Veatch on the basis of the Paleozoic fossils that occur in the chert gravels. They agreed with McGee (1891) on its Pliocene age and noted that the formation is not nearly so widespread in northern Louisiana as was previously believed because of its confusion with deposits of the Claiborne group of Eocene age, which have the same colors and in places the same textures. The southernmost outcrops of gravel of Hilgard's Lafayette formation noted by Veatch (in Harris and Veatch, 1899, p. 102) are in southern Rapides Parish and near Bayou Chicot in northern Evangeline Parish. Gravel deposits in these two localities are definitely outcrops of the sediments that compose the principal aquifer of southwestern Louisiana. A thickness of 442 feet of "material presumably of Lafayette age" (Harris and Veatch, 1899, p. 105) was noted from records of a boring at Jefferson Island in Iberia Parish, and it is further stated, "The band of pebbles which appears along the southern edge of the Grand Gulf [Fleming formation of Fisk (1940) of Miocene age] seems to pass beneath the Port Hudson and to be the gravel which is struck in deep wells sunk in the Port Hudson territory" (1899, p. 106).

Harris (in Harris and Fuller, 1904, p. 17) ascribes the origin of the prairies and "long leaf pine hill lands" of southwestern Louisiana to "sea bottom" deposition. In his discussion of the stratigraphy of southern Louisiana, Harris' Grand Gulf group [Catahoula formation and the Fleming formation of Fisk (1940)] are mistakenly identified as deposits of Oligocene age. However, the deposits of gravel, sand, and clay of Quaternary age are shown to crop out from a point a few miles south of Oakdale northward across the hills to the bluffs south of Alexandria (1904, p. 18), which is approximately correct, although the thickness and dip of the formations given are in error. Harris fully appreciated the extreme complexity of the Quaternary stratigraphy of southern Louisiana and admittedly was baffled by it (1904, p. 21). He placed great emphasis upon the importance of study of depositional processes now in progress and believed that a correct interpretation of Quaternary stratigraphy required a good knowledge of present conditions. He described in detail many of the features of the modern coastline and the Mississippi Delta. Of special note is his discussion of the role of the Mississippi River in Quaternary deposition in Louisiana (in Harris, Veatch, and others, 1905, p. 19).

Deussen (1914) named all of the gravelly beds in the Quaternary deposits beneath the prairie lands of the gulf coast the Lissie gravel, after the town of Lissie in Wharton County, Tex., where typical exposures occur. He considered that they represent "coalescing alluvial fans" of streams that emptied into the Gulf of Mexico during early and middle Pleistocene time. The overlying fine-grained deposits, which he called the Beamount clay, were considered to represent a later phase of the same depositional cycle, formed as stream gradients became lower and the sea encroached upon the land.

Dall (1914) identified a Pliocene fauna in the fine-grained calcareous clays and silts that underlie the chert gravels in southern Rapides Parish. There is thus support for identification of a series of Pliocene deposits in southwestern Louisiana between the *Rangia johnsoni* (a fresh-water clam) zone (Dall, 1898), generally believed to mark the top of the Miocene, and the base of the chert gravels.

Hilgard's (1891) Lafayette formation was discarded by many gulf coast geologists after Eocene leaves were found by Berry (1911) in the type locality in Lafayette County, Miss., and the name "Citronelle formation" was applied to a part of the deposit by Matson (1916) on the basis of exposures at Citronelle, Ala. The Citronelle formation was assigned by Matson to the Pliocene, and his reasons for this age reference are given in the following quotation (Matson, 1916, p. 173).

The sediments included in the Citronelle formation have sometimes been referred to the Pleistocene because of their physiographic resemblance to the terraced deposits of Pleistocene age. They differ from the Pleistocene deposits of the gulf coast, however, by being more sandy and containing more gravel. The evidence of their greater age is shown by their mature dissection, which in general exceeds that of the coast Pleistocene and glacial deposits, and by the weathered condition of the pebbles, many of which are composed of chert so completely decomposed as to break or even crumble easily in the hand. The Pliocene age is further shown by the presence of the Pliocene fossil plants, those at Red Bluff showing that the deposition was originally extended some distance beyond the southern margin of the general area shown in figure 15 (p. 168), and that the Pleistocene material was later deposited upon the eroded surface of the Citronelle. The line between the Pliocene and Pleistocene plains is drawn between the 150-foot and 200-foot terraces. The Pleistocene age of the plains at lower levels is shown by their slight dissection and by the presence of crystalline pebbles in the fluviatile portion of the 150-foot terrace at Natchez, Miss.

The Pliocene age identification was based largely on the fossil plants. Their association with these deposits at Citronelle, Ala., was indicated by Roy (1939) to be in error. However, the position of the fossil plants at Red Bluff, Ala., which V. T. Stringfield (oral communication, 1952) believes to be in the Citronelle formation, apparently was not examined by Roy. Matson identified a series of four terraces, the St. Elmo, Port Hickey, Hammond, and Pensacola (oldest to youngest), but he considered only the younger two to be of Pleistocene age, as the Port Hickey and St. Elmo were found in terrane of Citronelle age.

As summarized by Fisk (1940, p. 55), changes in the nomenclature and age classification of these deposits since they were defined by Matson were these:

In 1925 Barton used Matson's Pleistocene terrace terms for southwestern Louisiana, but apparently the terms were not acceptable since no further use of them was made. In a subsequent report Barton (1930b) applied the terms Lissie and Beaumont to sedimentary groups comparable to the Pliocene Lafayette and Pleistocene Port Hudson. Doering (1935) retained the term Beaumont and subdivided the Lissie into the Willis (Pliocene) and Lissie (early Pleistocene) formations. He referred to the terrains of these sediments as plains. Barton (1937) later introduced a fourth plain, the Oakdale, into Doering's sequence. This plain occupies a position between the Beaumont and Lissie and is divided into the upper and lower Oakdale (Barton, correspondence).

A generalized geologic map of Louisiana was published by the American Association of Petroleum Geologists in 1930, on which the areas of gravelly exposures in southwestern Louisiana (fig. 5) were identified as the Citronelle formation of Pliocene age. (A copy of this map appeared in the General Bulletin Handbook of the Louisiana Department of Conservation for 1933.) The same gravelly areas are shown as the Citronelle formation of Pliocene age on the geologic map of the United States published by the U. S. Geological Survey in 1932.

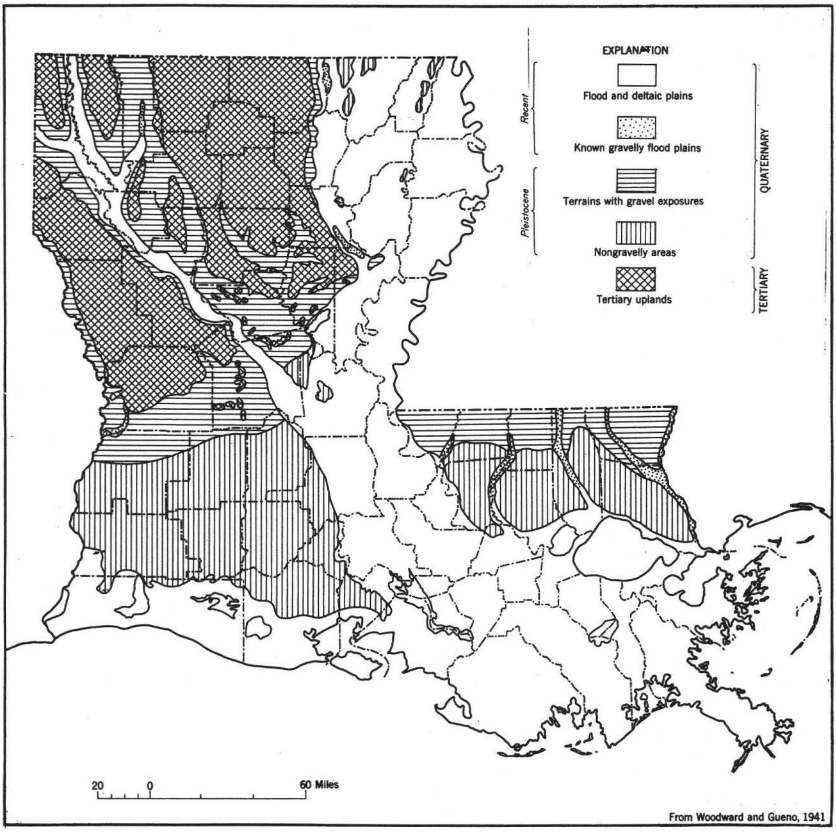


Figure 5.—Generalized map of Louisiana showing regions of gravel exposure.

Howe and Moresi (1931, p. 97) identified gravelly beds to a depth of 3,300 feet in wells drilled on the flanks of the Jefferson Island salt dome in Iberia Parish and judged them to be of Pliocene age or Pleistocene. This is more than 1,000 feet deeper than they would be expected to occur on the basis of the findings of the present writer; it may be attributed to downwarp of the "rim syncline" of the salt-dome structure.

Howe (1933, p. 652) believes that most of the beds referred by Matson to the Citronelle formation in his subsurface correlations "should in reality be referred to the Pleistocene." Howe's statement that "the Citronelle(?) gravel horizon tends to become marine in the extreme southern part of Louisiana, . . . between the line of the Southern Pacific Railroad [Lake Charles to Lafayette through Crowley] and the Gulf" is abundantly evident in the records available to the writer, and the principal structural and stratigraphic problems of the fresh-water section can be attributed to this downdip facies change.

Barton (in Barton, Ritz, and Hickey, 1933), in one of the early well-documented articles on the gulf coast geosyncline, estimated the depth to the basement rocks (igneous or metamorphic) at Jennings in Jefferson Davis Parish to be more than 25,000 feet. He also contributed (1933) to an understanding of salt-dome structure, which is one of the principal factors in oil accumulation in southwestern Louisiana, and is also an important factor in the occurrence of fresh ground water. The faulting associated with salt-dome structures has controlled ground-water movement locally, and in the vicinities of domes fresh ground water may occur at either greater or less depth than elsewhere. Records available do not indicate that salt-water encroachment of ground water has resulted from solution of the salt plugs.

Howe and Moresi (1933) were able to interpret the late Pleistocene and Recent geology of Lafayette and St. Martin Parishes by detailed study of topographic and soil features. They present records of the rapid growth of the land area in eastern St. Martin Parish as a result of the deposition of sediments in Grand Lake by the Atchafalaya River.

Howe, Russell, and McGuirt (1935) traced some of the physiographic features of Lafayette and St. Martin Parishes into Cameron and Vermilion Parishes. Terraces considered in the earlier report to be of marine origin were demonstrated in the later to be of deltaic origin.

By far the most detailed studies and most comprehensive interpretations of the geology of the gravelly terrace deposits of Louisiana have been made by, or under the direction of, H. N. Fisk (1938, 1940). Although his subdivision of the deposits into four formations, Williana, Bentley, Montgomery, and Prairie (oldest to youngest) is based largely upon analysis of topographic features, there is abundant evidence that the series of four terraces of the same names reflect a depositional sequence and therefore identify at least a part of the deposits that underlie them. The areas mapped by Fisk as Pleistocene terraces include much of the Lafayette formation of Hilgard (1891), most of the Port Hudson group of Hilgard (1869, p. 78–88), the Port Hudson formation of Harris and Veatch (1899, p. 111–115), and nearly all the area mapped in Louisiana by Matson (1916) as the Citronelle formation. On the basis of excellent physiographic control, the existence of at least four terraces is firmly established; and because their sequence agrees well with the events of the Pleistocene epoch, accurately detailed on worldwide evidence, there is good reason to accept their Pleistocene age assignment. On a textural basis, the deposits that underlie the terraces represent a marked contrast to those outside the terrace areas, as the terrace deposits consist generally of a coarse, gravelly basal member grading into fine-grained fluvial deposits, reflecting the type of deposition one might expect during a receding glacial hemicycle. Three of the Pleistocene terraces of Fisk (the three youngest and lowest) are shown on the map of southwestern Louisiana (pl. 1).

Maher (1940) described the ground-water geology of the Miocene and Pliocene(?) formations of Rapides Parish, which lies north of and adjacent to the region described in this report. He discussed briefly the occurrence of gravel of the Citronelle sandstone in the southern part of the parish, where it is more than 100 feet thick (Maher, 1940, p. 17), and correlated it with the principal aquifer in southwestern Louisiana. Further detail has been added to the geology of the gravel deposits in his unpublished report of 1942 on ground-water conditions at Camp Claiborne, and he has presented a detailed analysis of the local geology of the upper Miocene deposits [Fleming formation(?) of Fisk (1940)] at Camp Polk (1945) near Leesville in northern Vernon Parish which is north of and adjacent to Beauregard Parish.

In their report on the sand and gravel deposits of Louisiana, Woodward and Gueno (1941) provide detailed textural analyses of the deposits identified as Pleistocene sediments and provide a map showing their areal distribution. As the most extensive terrain of gravel exposures lies in and adjacent to the northern part of southwestern Louisiana and is an important factor in the occurrence of ground water, their map is reproduced in this report (fig. 5). A geochronic synonymy, showing age classifications and nomenclature used by 39 writers since 1833, is included following page 28 in their report.

Frink (1941) mapped the subsurface equivalents of the Pleistocene formations identified by Fisk on the basis of gravel recordings on oil-well drillers' logs. His published maps and geologic cross sections for southwestern Louisiana cannot be substantiated by the findings of the writer.

Perhaps the most pertinent published discussions of the near-surface geology of the deposits that compose the aquifers of southwestern Louisiana are to be found in Fisk (1940), Welch (1942), and Holland, Hough, and Murray (1952). The stratigraphy of Fisk's Fleming formation (1940) in Rapides Parish is presented in detail with a comprehensive discussion of its members, and the same terminology is applied in Vernon Parish (Welch, 1942). Throughout this report the term Fleming is used as defined by Fisk. The subsurface (downdip) equivalents in Allen and Beauregard Parishes (Holland, Hough, and Murray, 1952) are known to have many of the characteristics found at the surface in Rapides and Vernon Parishes.

These bulletins also provide excellent discussions of the gravelly deposits, the formations of Quaternary (Pleistocene) age. However, the descriptions and postulates with regard to the beds, based upon evidences at their outcrop, cannot be applied universally to their downdip equivalents which constitute the principal aquifer of southwestern Louisiana.

The most comprehensive previous report on the subsurface geology of the gravelly deposits of southwestern Louisiana is that by Stanley and Maher (1944) on Jefferson Davis and Acadia Parishes. It is a direct forerunner of this report.

Fisk (1944) has presented detailed descriptions of regional structural and physiographic features of southwestern Louisiana and has provided an excellent analysis of the late Pleistocene and Recent history of the central West Gulf Coastal Plain, of which southwestern Louisiana is a part. Evidence of pre-Recent erosion of the gulfward margin of the prairie by coastal streams (pl. 3) and the excellent detail of a broad Mississippi River meander belt of late Pleistocene age are given in his report on the geology of the Mermentau River Basin (1948). Both of these geologic features are of great importance in the analysis of the ground-water geology of the region.

There are a great many other important writings on the geology of the late Tertiary and Quaternary deposits of southwestern Louisiana, but the above have been described because of their bearing upon the occurrence of fresh ground water in the project area.

STRATIGRAPHY

ORIGIN OF THE DEPOSITS

Southwestern Louisiana has been an area of low relief for tens of millions of years. The gulf shoreline has moved northward many times as the land subsided into the deep structural trough known as the gulf coast geosyncline (Barton, Ritz, and Hickey, 1933, p. 1446–1458; Howe and Moresi, 1931, p. 86–92); as many times it has retreated southward before the delta of an ancestral Mississippi River (Harris and Fuller, 1904, p. 26; Howe, Russell, and McGuirt, 1935, p. 42). That the site of deposition of the beds forming the thick mass of sediments beneath southwestern Louisiana was never more than a few tens of feet above or below sea level is indicated by their texture, faunal content, lithology, and structure.

The depositional capacity of ancient river systems that emptied into the Gulf of Mexico in the region covered by this report has been very large since Mesozoic time (Howe, Russell, and McGuirt, 1935, p. 48). The modern Mississippi River drains about 40 percent of the land area of the continental United States, and the average suspended load of detritus it transports to the gulf is believed by R. J. and R. D. Russell (1939, p. 153) to be about 2 million tons per day. In an earlier report, R. J. Russell (1936, p. 162) states that the suspended load is at least 2 million tons per day. Referring to the estimates by the Russells and similar estimates by others, the Mississippi River Commission (Fisk, 1947, p. 11–15) states, "Such estimates when considered in broad view are inaccurate and probably much smaller than the actual amount carried by the river. Figures are based on sampling in the lower river near New Orleans, and do not take into account the load carried through the Atchafalaya River nor the sediment which is deposited in flood-basins during its periodic stage variation." The average bed load is not known but Howe (in Howe, Russell, and McGuirt, 1935, p. 42) stated that it is perhaps twice as great as the suspended load. His statement was based on informal statements made by personnel of the Mississippi River Commission (H. V. Howe, oral communication to A. N. Turcan, February 1953).

During periods of flood the load is many times greater than average (Russell, R. J., 1936, p. 159–160). The Mississippi's principal distributary, the Atchafalaya River, has transformed an area of 40 square miles in upper Grand Lake from water bottom to dry land since 1932, and the depth of fill in that period is more than 8 feet in parts of the area.

Some (Harris and Veatch, 1899, p. 110) believe that the volume and transporting capacity of ancient rivers entering the Gulf of Mexico through southern Louisiana was many times as great as that of the modern Mississippi, but it can be demonstrated that, to deposit the mass of sediments known to be present during the time that has elapsed, such a condition would not have been necessary. The total thickness of the deposits is no less than 30,000 feet (Howe, Russell, and McGuirt, 1935, p. 41) along the margin of the gulf, and some 120 million years was spent in their deposition.

Climatic changes during the Pleistocene epoch (commonly called the Ice Age) resulted in sea-level fluctuations amounting to several hundred feet (Fisk, 1944, p. 68). Accompanying lowered sea levels, which rejuvenated streams and resulted in channel scour, there was prolonged destruction of the terranes of the continent by Pleistocene glaciers. As the glacial ice melted, vast quantities of rock debris were released with the water. The two main tributaries of the modern Mississippi River, the Ohio and the Missouri, formed along the ice front and carried outwash sand and gravel gulfward. A great deal of residual mantle rock from the unglaciated areas also was transported into the Mississippi valley and thence gulfward.

The Pleistocene depositional history described by Fisk (1938) begins with decline of sea level as ice accumulated on the continents. Rejuvenation of coastal and trunk streams resulted, and they scoured their channels to form deep trenches. Glaciation provided melt waters and rock debris which the Mississippi and its principal tributaries transported gulfward to spill them into the margin of the gulf, to fill their scour channels, and to spread them widely over an expanse of braided-stream network. The depositional cycle was completed as the gradient of the streams flattened in response to rising sea level, and the gravelly blanket was covered in turn by back-swamp and natural-levee deposits of meandering streams. The areal structure of the deposit was fan-like, with the apex up the Mississippi valley. In longitudinal section, along a line parallel to the axis of the Mississippi structural trough, the deposit was wedge shaped, its thickest part lying at the gulf margin, its featheredge far to the north. After deposition, downwarp along the gulf margin tilted the mass, steepening the gulfward slope.

Three times more this process was repeated and each time the locus of maximum deposition shifted gulfward; each time, too, the landward featheredge lay gulfward of the older one. Thus a series of wedge-shaped deposits was formed, and these compose the Pleistocene deposits of southwestern Louisiana.

The importance of events of the Pleistocene epoch to the ground-water geology of southwestern Louisiana cannot be stressed too greatly. The depth of occurrence, the distribution, and the textural changes within the massive beds of sand and gravel that form the aquifer tapped by all irrigation wells in the coastal prairies of Louisiana are features of the vast delta complex of a Pleistocene Mississippi River.

OCCURRENCE OF THE DEPOSITS

Oil-test wells in coastal southwestern Louisiana, some of which have been drilled to depths greater than 18,000 feet, log a sequence of medium- to fine-grained sands interbedded with organic clays or silts, with infrequent zones of marine shells and marl. Few dense limestone beds are recorded, and coarse-grained deposits—coarse sand and gravel—generally do not occur below depths of about 1,000 feet. The character of most of the deposits indicates a deltaic or nearshore marine origin. Recent detailed sedimentary stratigraphic analysis (Murray, unpublished manuscript) has made possible the preparation of lithofacies maps of the region for the most important formations and faunal zones that occur in the sediments of Tertiary age.

The "near-surface" deposits of southwestern Louisiana (the upper 1,000 feet) consist of extensive beds of clay, sand, or sand and gravel. The sands are generally massive, and although lenticular, are interconnected almost everywhere. Usually they are separated by beds of laminated clay. The medium- to fine-grained sands (table 3) are composed largely of subangular to well-rounded grains of milky quartz, but the gravels are composed principally of angular to subangular pieces of chert, indicated by their fossil content to be derived, at least in part, from rocks of Mississippian age (Schuchert and Dunbar, 1933, p. 223–240).

Chert gravels seldom are recorded at depths greater than 1,000 feet by reliable drillers' logs. The depth of vertical transition from gravelly to nongravelly beds has been taken commonly as the base of the Pleistocene deposits, and in much of southwestern Louisiana this is a mappable "contact." However, gulfward from the imaginary line formed by intersection of the base of the gravels and the 1,000-foot subsea datum plane this textural break generally is lost. Gravel is common above that datum in the gulf-marginal area and has been recorded above it in many offshore wells. Thick beds of sand and gravel can be unmistakably correlated downdip with nongravel-bearing beds of similar thickness. The gulfward stratigraphic equivalents of the gravels are typical marine-marginal or coastwise offshore deposits (Howe, 1933, p. 654), and often they contain fresh or brackish water that could occur in them only by virtue of their continuity with the updip gravel-bearing deposit.

In the northern and north-central parts of southwestern Louisiana (in Beauregard, Allen, Evangeline, and northern St. Landry Parishes) the gravel-bearing deposits are underlain by a thick series of fine- to medium-grained deltaic deposits which cannot be identified definitely with the Fleming formation of Fisk (1940) of Miocene age, because they lie far above the *Rangia johnsoni* faunal zone (pl. 6) that generally is considered to mark the upper limit of the Miocene deposits of Louisiana (Dall, 1898, p. 905). Extensive study of this series of beds has not been made, largely be-

Table 3.—*Grain-size definitions of sedimentary materials*

[After National Research Council, 1947]

Phi value	Grain diameter		Description
	Millimeters	Inches	
-12	4,096	161.3	Very large boulders
-11	2,048	80.63	Large boulders
-10	1,024	40.31	Medium boulders
-9	512	20.16	Small boulders
-8	256	10.08	Large cobbles
-7	128	5.04	Small cobbles
-6	64	2.52	Very coarse gravel
-5	32	1.26	Coarse gravel
-4	16	.630	Medium gravel
-3	8	.315	Fine gravel
-2	4	.157	Very fine gravel
-1	2	.079	Very coarse sand
0	1	.0394	Coarse sand
+1	.5	.0197	Medium sand
+2	.25	.0098	Fine sand
+3	.125	.0049	Very fine sand
+4	.0625	.0025	Coarse silt
+5	.0313	.0013	Medium silt
+6	.0156	.00062	Fine silt
+7	.0078	.00031	Very fine silt
+8	.0039	.00015	

cause there are few paleontologic or lithologic markers within it and because they lie above the *Rangia johnsoni* zone and below the gravel-bearing beds. These deposits are considered by the writer to be of Pliocene age. A convenient geographic name can be assigned to them on the basis of detailed lithologic and hydrologic studies made of them at Oakdale in Allen Parish, where they occur between depths of about 120 and 1,400 feet, and at Mamou in Evangeline Parish, where they lie between depths of about 320 and 1,500 feet. As Oakdale previously has been used as a formation name these deposits will be referred to collectively as the Foley formation in this report, for the locality of Foley in central Allen Parish, in T. 4 S., R. 4 W.

Deposits in and immediately below the *Rangia johnsoni* zone, where they are penetrated by wells in Beauregard, Allen, and Evangeline Parishes, consist of hard blue-green clay in places interbedded with thin laminae of yellow or red clay and, in other places, containing lime nodules. The clay deposits separate beds of fine- to medium-grained sand. These deposits comprise the upper part of Kennedy's Fleming beds (Kennedy, 1892, p. 62–63; Veatch, 1906, p. 40) of Miocene age in southwestern Louisiana. The formation is predominantly sand, and although some beds are more than 100 feet thick, they generally range from 20 to 50 feet. Many of the thin beds contain much lignite and yield straw-colored fresh water. Effective interconnection is proved by the great depth to which they contain fresh water (pl. 7).

Because, in southwestern Louisiana fresh water does not occur in deposits older than the Fleming formation of Fisk (1940), little attention has been given such deposits in this report. They lie at or near the land surface where they are uplifted by piercement-type salt domes (Pine Prairie, Avery Island, Jefferson Island), and near these structures the older deposits influence the occurrence of ground water. Their uplift caused thinning of the younger beds and resulted in the shallow occurrence of the salty water they contain.

GEOLOGIC FORMATIONS

It is the purpose of this writer to follow the simplest and most coherent interpretation of the geology of southwestern Louisiana, without regard to the arguments for or against specific features of the nomenclature or age assignments of the deposits. The usage of formation names common in Louisiana will serve to identify the formations mapped or recorded in the subsurface by previous writers. The accompanying stratigraphic column is adapted from Fisk (1938, p. 118), with modifications of the nomenclature of units above the Grand Gulf group of Hilgard (1860). Pliocene deposits are assigned to the Foley formation and Pleistocene deposits to the formations named by Fisk. His Pleistocene nomenclature is followed, not only because its validity is well demonstrated in the terrace areas but also because the subsurface deposits in southwestern Louisiana along the axis of the Mississippi Embayment lend themselves to a fourfold, or perhaps a fivefold, formation subdivision (pl. 10). It might be pointed out also that the work of the Geological Survey in southeastern Texas shows that serious difficulties remain to be resolved before the Pliocene and Pleistocene sections of Texas and Louisiana can be correlated satisfactorily.

Stratigraphic column of southwestern Louisiana

[Sources of fresh ground water]

System	Series	Group	Formation	Member		Zone
Quaternary.	Recent.		LeMoyen.	Lebeau.	Mermentau.	
	Pleistocene.		Prairie. Montgomery. Bentley. Williana.			
Tertiary.	Pliocene.		Foley.	Mamou. Steep Gully.		
	Miocene.	Grand Gulf (of Hilgard).	Fleming (of Fisk).	Blounts Creek (of Fisk). Castor Creek (of Fisk). Williamson Creek (of Fisk). Dough Hills (of Fisk). Carnahan Bayou (of Fisk). Lena (of Fisk).		*Rangia johnsoni.* *Potamides matsoni.*
			Catahoula.			*Discorbis.* *Heterostegina.* *Marginulina.*

MIOCENE SERIES

GRAND GULF GROUP (HILGARD)

Exposures of sandstone beds at Grand Gulf, Claiborne County, Miss., were named the Grand Gulf sandstone by Wailes (1854). His Grand Gulf is used by most gulf coast geologists to designate the entire Miocene sequence of the West Gulf Coastal Plain. As identified by Hilgard (1860) all sediments between the Vicksburg formation of Oligocene age and the Williana formation (a part of the deposits called the Orange Sand by Hilgard) of Pleistocene age were included in the Grand Gulf group. Beds considered by the writer as representing deposition during Pliocene time do not crop out in Louisiana and therefore were missed by the early investigators.

The sediments of the Grand Gulf group, as indicated by Fisk, at the outcrop in Louisiana are described in the following excerpt (Fisk, 1940, p. 139).

Viewed, as a unit, the surface exposures present a monotonous series of silty clays, lenticular bodies of sand and silty sand, tongues of clays, and pyroclastic debris. Most of the sediments are poorly indurated; but resistant beds, formed by silty clays and sands, shape the topography in the Miocene terrain. The silty clays give evidence of deposition in widespread marsh areas. They are poorly sorted and contain abundant grass-root tubes and some well-preserved or slightly carbonized plant remains. The sand lentils are most abundant in the basal part of the surface section. Oak, willow, and other fossil leaves, and palm fronds and boles, as well as the lenticular character of these deposits, point to a flood-plain origin. The clay tongues have a high content of calcium carbonate and contain brackish-water fossils but no true marine forms. Their lithology and fossil content indicate that they were deposited in bays or brackish-water lakes near the coast.

The complexity of the depositional pattern of the beds apparent at the outcrop is demonstrated further by studies of records of subsurface conditions. Although detailed drillers' logs of water wells in central Rapides Parish were available to Maher and tentative correlations of water-bearing sands and indurated zones are shown on his geologic section (1940, p. 14), there is little assurance that long-range (20–30 miles) correlation of the unfossiliferous beds will ever be possible on a lithologic basis. It will be shown later in this report that hydrologic conditions can be used to substantiate or even to establish long-range correlations of sand members in the Grand Gulf group of Fisk, under certain conditions.

With reference to subsurface conditions Fisk (1940, p. 139) continues.

Subsurface information adds to the picture of the Miocene stage of deltaic deposition. Deep borings in Rapides and adjacent parishes show not only that the lenticular sands are distributed throughout the mass of sediment but also along any line down dip the sands interfinger with silty clays. In southern Rapides Parish the first marine equivalents of the nonmarine sediments are found at a depth of approximately 3,000 feet, but marine beds are not everywhere present at that depth. Although beds exposed at the surface rarely can be followed for more than a few feet, dips can be accurately determined because the tops of key fossil zones in the subsurface section serve as a basis of computation. Dips determined from subsurface information indicate that the Miocene sediments can be separated into great seaward-thickening wedges. In western Rapides Parish where the Miocene beds are exposed the following generalized dips have been traced into the subsurface; on base of Catahoula, 100 to 125 feet per mile; on base of Fleming, 60 to 75 feet per mile; on top of *Potamides matsoni* zone, 45 to 55 feet per mile.

Although the Grand Gulf sandstone of Wailes has been divided into a lower formation, the Catahoula sandstone of Veatch (1906), and an upper formation, the Fleming beds of Kennedy (1892), the line of demarcation between them and the upper limit of the latter are poorly defined. The nature of the contact of the Catahoula and the Fleming of Kennedy perhaps has been discussed best by Haase (1932). The principal identifying characteristics of the Fleming beds of Kennedy in and near the outcrop are their occasional beds of clay liberally filled with calcareous nodules, and the absence of sandstone beds which are common in the basal part of the Catahoula formation. Downdip the entire Grand Gulf of Wailes exhibits a considerably stronger marine character.

Fleming formation.— Throughout this report the term Fleming is used as defined by Fisk (1940). All information obtained for the Fleming formation of Fisk in the project area was obtained from borings, as no outcrops were found nor are any expected. If the top of the *Rangia johnsoni* faunal zone is taken as the top of the Fleming formation, as commonly is done by geologists of the gulf coast (Fisk, 1944, fig. 68) because it is the youngest known paleontologic marker, then records have been obtained on the lithology of the Fleming formation in only two deep water-well test holes in southwestern Louisiana, one at Oakdale in Allen Parish and one at Mamou in Evangeline Parish. (See records for wells Al–108 and Ev–142 in tables 6 and 7.)

At Oakdale the *Rangia johnsoni* zone was not identified but the top of the Fleming formation of Fisk is probably marked by the first salt-water sand, which lies between depths of about 1,185 and 1,400 feet. In the beds disclosed by this well between the depths of 1,420 and 1,738 feet, there is an abundance of marine-shell fragments, a well-preserved gastropod fauna that has not been identified, and some glauconite. A massive uniform-textured gray water-bearing sand (containing fresh water between depths of 1,738 and 1,770 feet) was penetrated between depths of 1,738 and 1,870 feet, and the records (electric logs) of oil-test wells in northern Allen Parish and southern Rapides Parish indicate that this and three other massive fresh-water sand members that underlie it above a depth of 3,000 feet are present throughout the area.

At Mamou the top of the *Rangia johnsoni* zone has been mapped between depths of 1,400 and 1,500 feet (Fisk, 1944, fig. 68), but the writer believes that the top of the zone is deeper, probably below a depth of 2,000 feet. It is believed, therefore, that well Ev–142 (1,500 feet deep) did not penetrate the Fleming formation of Fisk. The lithology of the deposits between depths of 250 and 1,500 feet at Mamou is very similar to that of the beds between depths of about 140 and 1,200 feet at Oakdale, assigned by the present writer to the Pliocene Foley formation.

Although detailed information is not available now on the lithology and continuity of the unconsolidated sands of the Fleming formation of Fisk in southwestern Louisiana, there is reason to believe that a thorough study of the deposits will be necessary as they are tapped in the future by water wells and as their importance as a source of water supply is realized. The map showing the depth of occurrence of fresh ground water (pl. 15) indicates that Fisk's Fleming formation is an important potential source of ground water in southwestern Louisiana, although aquifers in it are not as well suited to development of large supplies for rice irrigation as are those in the overlying Pliocene and Pleistocene deposits.

PLIOCENE SERIES

FOLEY FORMATION

First named in this report for beds penetrated by several water wells in the vicinity of the city of Oakdale, in T. 3 S., R. 3 W., in Allen Parish, La., about 35 miles southwest of the city of Alexandria, the Foley formation consists of a sequence of fine- to medium-grained sands interbedded with soft to moderately hard gray-green to brown laminated clays. It is named for the town of Foley in central Allen Parish because the name Oakdale has been previously used for other deposits. The mineral composition and lithology of the Foley formation are similar to those of the underlying Fleming formation of Fisk, except that the sands are more commonly lignitic, the clays are less calcareous, the deposits are thinner bedded, and the proportion of sand is generally greater. The Foley formation thickens rapidly downdip, with no marked change in its lithology. At Oakdale the beds composing the upper 300 feet of the formation are finer grained than those below, and this upper fine-grained sequence thickens to about 1,200 feet in the vicinity of the town of Mamou.

The Foley formation is overlain by coarse-grained deposits of the Williana formation of Pleistocene age and underlain by a faunal zone characterized by the fresh-water clam *Rangia johnsoni*, which marks the top of the Fleming formation of Fisk, of Miocene age. The thickness of the Foley formation at Oakdale is about 1,050 feet; but at Mamou in Evangeline Parish, about 18 miles downdip, its thickness is about 2,500 feet.

Although beds of the Foley formation lie near the surface in northern Beauregard, Allen, and Evangeline Parishes, the writer has seen no outcrops, and it is doubtful that there are any. A thin veneer of Pleistocene deposits covers their beveled edge, and perhaps this is the reason the formation has not been identified previously. However, it underlies all southwestern Louisiana and often has been incorrectly correlated with Pleistocene deposits as it bears a marked similarity to them in their downdip facies.

In the Foley formation thus defined (as a rock unit), there are no known lithologic marker beds or distinctive faunal zones; therefore, accurate member subdivision cannot be made at this time. There is, however, a gradational change in lithology upward, and on its basis two members are named (see p. 54, 56).

Only a small number of scattered water wells in southwestern Louisiana tap the Foley formation, and reliable records on the geology of the deposits are scanty. It is expected that the rate of

387601 O - 56 - 5

development of ground water from them will increase rapidly during the next several years, for reasons given in the section on ground water; as more information on the geology of the formation becomes available, it may be possible to subdivide the formation further with confidence.

The beds of sand of the Foley formation are typically fine- to medium-grained, as shown by the mechanical analyses in table 7. Representative textures are shown for samples obtained from depths of 611 to 1,183 feet in well Al–108; from 494 to 1,197 feet in well Al–109; for all samples in wells Al–120, Al–138, and Al–144; from 588 to 1,000 feet in well Al–157; from 193 to 307 feet in well Al–158; and from 319 to 1,500 feet in well Ev–142.

The sedimentary petrography of the deposits of the upper part of the Foley formation has been studied in detail by Kirby L. Cockerham, using samples collected from a well (Al–157) that penetrates the upper 562 feet of the formation at Kinder in Allen Parish. His description of the petrography of the deposits is given in table 4, and the frequency of occurrence of certain of the heavy minerals is shown in table 5.

In spite of certain indicated petrographic anomalies with depth, it is the opinion of the writer that good evidence is lacking for a differentiation of the deposits of the Foley formation from the overlying sediments on the basis of heavy-mineral studies. It is, of course, too much to expect that studies of samples from a single well might provide conclusive results. Although extreme care was exercised in collecting samples from well Al–157, the fact remains that the well was drilled by the hydraulic-rotary method, and first occurrences are therefore the most reliable determinations that can be made. On this basis the most apparent change in the mineral assemblage occurred between depths of 449 and 454 feet.

Comparison of the depth of occurrence of this anomaly with the depth at which the principal textural change occurs (table 7) indicates that the deposits between depths of 399 feet (the base of the Pleistocene gravels) and 454 feet are more closely related to the sediments above than to those below. Use of texture alone to differentiate the Foley formation from the overlying gravelly deposits is not likely to result in reliable interpretations. The top of the Foley formation in well Al–157 was determined on the basis of the electric log to be at a depth of 438 feet (pl. 11).

Perhaps the most conspicuous lithologic differences, other than texture, between the sediments of the Foley formation and those that overlie it are the color of sediments and the presence of

Table 4.—*Lithologic character of deposits penetrated by a test well (Al-157) at Kinder in Allen Parish, La., with petrography by Kirby L. Cockerham*

Depth (feet)	Description
	Pleistocene series
0 - 20.........	Silt, some clay, buff to tan. Quartz grains mainly clear, stained brown, angular; some milky, subangular to well-rounded, ½ mm diam. Nodules of ferruginous clay ("buckshot clay") abundant, ½ mm diam. Carbonized wood. Magnetite fairly abundant.
20 - 50.........	Same as 0 - 20, but magnetite more abundant, and some mica.
50 - 60.........	Same as 20 - 50; magnetite, and mica less abundant.
60 - 70.........	Same as 50 - 60; larger (¼ to ½ mm diam.) quartz grains more abundant. Mica, green and brown, more abundant. Clay nodules less abundant.
70 - 80.........	Sand, very fine-grained (⅛ to ½ mm diam.), mainly clear to milky subangular to rounded quartz, stained buff to tan. Magnetite and mica. Clay nodules absent.
80 - 131.........	Sand, fine- to medium-grained (¼ to 1 mm diam.), mainly clear quartz, larger grains rounded to well rounded. Ferruginous stain less common. Magnetite and mica absent; other dark minerals abundant and some chert and feldspar.
131 - 164.........	Sand, medium- to very coarse-grained (¼ to 2 mm diam.), mainly clear quartz, gray to tan from stains, subangular to rounded. Dark minerals, brown chert, and feldspar less abundant than 80 - 131.
164 - 175.........	Sand and gravel, gray, and brown chert gravel. Gravel composes about 25 percent of sample. Dark minerals and feldspar sparse.
175 - 187.........	Same as 164 - 175, but gravel about 40 percent of sample.
187 - 198.........	Same as 175 - 187, but some gravel comprised of sandstone fragments.
198 - 221.........	Same as 187 - 198, but gravel about 25 percent of sample.
221 - 243.........	Same as 198 - 221, but occasional grains of marcasite and few quartz grains having ferruginous stain.
243 - 254.........	Same as 221 - 243, some quartz grains coated with siderite.
254 - 265.........	Same as 243 - 254, but gravel reduced to about 10 percent of sample. Some grains clustered with marcasite cement and some siderite lumps present.
265 - 287.........	Sand, buff to gray, quartz grains occasionally coated by siderite, dark minerals more abundant, with marcasite and pyrite common. Flesh-colored feldspar occasional.
287 - 298.........	Sand and gravel, gravel about 25 percent of sample. Buff-gray, with many sand grains (milky quartz) spotted with siderite crust; gravel pebbles subrounded to subangular. Occasional grains of dark minerals, marcasite, feldspar.
298 - 320.........	Gravel and sand. First pebbles of honey-colored chert. Gravel comprises 60 percent of sample, siderite encrustation common on grains of all sizes. Marcasite, pyrite, and dark minerals common; feldspar rare.
320 - 331.........	Same as 298 - 320, gravel about 50 percent of sample; marcasite, feldspar, and dark minerals more abundant, and some milky quartz grains stained with limonite.
331 - 336.........	Sand and gravel, gravel about 25 percent of sample.
336 - 350.........	Gravel and sand, gravel about 65 percent of sample, some pebbles 15 to 20 mm diam.; siderite abundant.
350 - 360.........	Clay, red and buff to light blue, sandy.
360 - 365.........	Gravel and sand, some sand grains stained by red ferruginous crust; siderite, dark minerals sparse; feldspar and marcasite common.
365 - 376.........	Sand and gravel, with clay lumps. Gravel pebbles small, about 25 percent of sample, clay lumps red to buff, sandy. Feldspar, marcasite, and dark minerals common; siderite a trace.
376 - 388.........	Clay, gravel, and sand, clay lumps, white to buff, comprise 60 percent of sample, otherwise same as 365 - 376.
388 - 399.........	Sand, milky quartz with ferruginous or sideritic stains.
399 - 438.........	Clay and sand. Clay blocky—blue, yellow, red and gray; silt in the yellow clay. Limonite stain on milky quartz grains rare, marcasite common.
	Pliocene series Foley formation Mamou member
438 - 449.........	Clay, similar to clay 399 - 438.
449 - 467.........	Sand, medium- to coarse-grained, gray to buff, some ferruginous stain on grains, larger grains more rounded. Feldspar, pyrite, and dark minerals (including magnetite) abundant; chert sparse.

Table 4.—*Lithologic character of deposits penetrated by a test well (Al–157) at Kinder in Allen Parish, La., with petrography by Kirby L. Cockerham*— Continued

Depth (feet)	Description
	Pliocene series—Continued
467 - 493.......	Clay, blocky to fissile; blue, buff, gray, and red silt in the buff clay; some clay lumps stained black by manganite or pyrolusite.
493 - 512.......	Sand, and a scattering of very fine gravel (probably from above), light-yellow-gray; some grains of sand (milky quartz) stained with ferruginous material; magnetite and other dark minerals common; feldspar and pyrite present; chert particles sparse.
512 - 588.......	Clay, blocky to fissile; blue, buff-yellow, red, and dark gray; lignite or carbonized wood; manganite or pyrolusite; yellow clay silty.
588 - 623.......	Sand, very fine-grained, grading downward into medium-grained; subangular to rounded, clear to milky quartz, with some grains of calcite or limestone (secondary?); carbonized wood, lignite, and dark minerals abundant.
623 - 643.......	Clay, blocky to thinly laminated; tan to buff and blue, tan clay silty; marcasite and manganite common.
643 - 674.......	Clay and sand, clay blocky, yellow and buff to blue-gray, some lumps black from manganite stain; sand largely clear to milky quartz, fine- to medium-grained; dark minerals common, with marcasite and pyrite; carbonized wood or lignite abundant.
674 - 697.......	Sand, fine- to medium-grained, angular to rounded, milky to clear quartz, some with ferruginous stain; dark minerals (green and black) abundant; pyrite and feldspar sparse.
697 - 729.......	Clay, sandy, buff to yellow and gray, buff clay with silt; some ferruginous clay lumps ("buckshot clay").
729 - 741.......	Sand, fine-grained, milky to clear quartz (no chert) generally subangular to rounded, lignite abundant, magnetite and marcasite less abundant.
741 - 752.......	Sand and clay, sand like that above, except some chert present; clay mostly red or buff.
752 - 788.......	Sand, fine to medium grains, angular to subangular, coarse grains well rounded; dark minerals common, lignite sparse; chert fragments occasional. Shells at 763 feet.
788 - 818.......	Sand and clay, similar to that at 741 - 752 feet.
818 - 850.......	Sand, medium-grained to very coarse grained, mostly clear quartz, chert fragments common, shell fragments more abundant than above, some ferruginous stain on grains.
850 - 870.......	Clay, blocky to fissile, red, yellow, gray, and blue. Manganite and carbonized wood abundant.
870 - 930.......	Clay and sand, similar to deposits below depth of 818 feet above.
930 - 974.......	Sand, medium-grained to very coarse grained, clear to milky quartz, some chips of chert; dark minerals, including magnetite, common; shells, siderite, and carbonized wood occasional; pyrite and marcasite abundant; ferruginous stain on grains of all kinds very abundant.
974 - 1,000.......	Clay and sand; clay fissile, somewhat sandy, brown to buff; sand principally clear to milky quartz, fine-grained.

finely divided lignite. The overlying sediments are predominantly brown and buff to red; those below are blue and gray to black. Lignite particles are abundant in the upper part of the Foley formation and rather uncommon above it. That is not to say that partially decayed wood, often excellently preserved, is absent in the overlying deposits. On the contrary, wood—even logs—commonly is penetrated in the gravelly sequence.

Steep Gully member.—First named in this report, the Steep Gully member of the Foley formation comprises the basal deposits of the Foley formation penetrated below a depth of 200 feet by water wells and oil-test wells in the vicinity of the town of Elizabeth in T. 2 S., R. 4 W., in Allen Parish, La., about 8 miles northwest

Table 5.— *Frequency of occurrence of certain heavy mineral grains in samples from a test well (Al–157) at Kinder in Allen Parish, La., with petrography by K. L. Cockerham*

Depth of samples (feet)	10-20	80-98	109-120	243-254	343-354	388-399	449-454	454-465	493-509	520-542	588-599	643-654	675-695	974-985
Augite...........	2	5	4	3	1	3	4	1	1	3	3	3	.....	1
Epidote..........	3	5	14	8	8	12	12	6	11	10	15	8	7	19
Garnet...........	2	23	17	29	18	21	17	18	12	19	10	11	12	17
Hornblende......	8	45	35	34	44	48	43	42	51	42	40	34	35	35
Kyanite..........	....	....	2	3	2	1	....	1	.....	2	.....	2	1	2
Rutile...........	2	1	2	1	1	1	....	1	.....	1	2	.....	....	.....
Staurolite........	....	1	2	3	1	1	2	....	2	3	2	5	2	3
Tourmaline......	....	2	2	.....	.....	2	3	3	1	.....	6	2	9	1
Titanite..........	4	3	3	.....	5	1	3	4	1	5	1	2	1	.....
Zircon...........	13	2	4	8	5	7	3	9	4	3	7	12	9	5
Anatase..........	....	1	.....	2	1	.....	2	.....	.....	.....	.....	.....	2	.....
Brookite..........	....	....	1	.....	1	.....	1	1	1	....	.....	.....	.....	.....
Andalusite.......	....	....	1	.....	.....	.....	1	.....	1	.....	.....	.....	.....	2
Monazite.........	....	1	2	4	4	1	2	3	1	1	.....	1	2	.....
Sillimanite.......	....	....	.....	.....	1	.....	.....	1	.....	2	1	1	1	.....
Topaz............	....	....	.....	.....	.....	.....	.....	1	3	.....	4	5	5	3
Zoisite...........	....	....	.....	.....	.....	1	.....	1	1	.....	.....	1	.....	.....
Axinite..........	....	....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	2	.....
Clinozoisite.....	....	....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....
Vesuvianite......	....	....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....
Opaque...........	32	45	30	30	31	34	46	31	44	61	83	66	55	43
Unknown.........	17	10	13	5	9	3	7	7	10	7	8	13	12	12
Total number of particles in sample...	83	144	132	130	133	136	146	130	144	160	183	166	155	143

of Oakdale. It is named for the nearby stream known as Steep Gully Branch because the name Elizabeth has been assigned to other deposits by previous writers. The most reliable records in which this member is identified were obtained during the drilling of wells at Oakdale. Between depths of about 450 and 1,185 feet those wells penetrated a sequence of medium- to fine-grained sands interbedded with light-gray, gray-green, and blue structureless to thinly laminated clays. Although the driller's log of well Al–120 (see table 6) is lacking in descriptive detail, it is typical of the record commonly made of these deposits by drillers in the area. There are few identifying characteristics that serve to differentiate the beds. Even the texture of the sands is monotonously uniform, as indicated by the mechanical analyses of samples from wells Al-108, Al-109, Al-120, Al-138, and Al-144, which are representative.

Fisk (1944, fig. 68) maps the top of the *Rangia johnsoni* zone (top of the upper Miocene beds) at a depth of about 600 feet at Oakdale; but in his report on Rapides and Avoyelles Parishes (1938, pl. 6, p. 140) he includes a geologic section that passes through Oakdale and shows the top of the *Rangia johnsoni* zone at a depth of about 1,300 feet. His section, with modifications, is reproduced in this report as plate 6. Study of the samples from well Al-108 tends to confirm the depth of about 1,300 feet indicated on the geologic section. A zone of hard fine-grained sands somewhat consolidated by limy material and containing salty water occurs between depths of 1,185 and 1,400 feet at Oakdale. The base of that sand zone may mark the top of the *Rangia johnsoni* zone, as the mollusk for which the zone is named lived only in fresh or brackish (slightly salty) water.

Detailed study of the electric logs of wells in the Oakdale area shows that, in spite of the extreme lenticularity of the beds, they can be correlated with good accuracy for distances of at least 2 to 4 miles. Their dip or slope is south-southeastward at rates ranging from about 60 to about 80 feet per mile. On this basis it is estimated that the bottom of the formation is at a depth of about 2,500 feet at Mamou in Evangeline Parish, about 18 miles directly downdip.

Although the thickness of individual beds of sand in the Steep Gully member is more than 50 feet in few places, the part of the member composed of sand is generally in excess of 50 percent and in places as great as 80 percent. The areal continuity of the beds of sand and their lateral and vertical interconnection with one another are excellently demonstrated by the fact that they contain fresh water to a depth of 1,184 feet at Oakdale. Electric logs of oil-test wells to the south and east show that the character of the formation changes little in a distance of 15 to 20 miles, and it is believed that the member underlies all southwestern Louisiana, thickening gulfward.

Mamou member.—The Mamou member of the Foley formation, a sequence of fine-grained beds, is first named in this report for the town of Mamou in Evangeline Parish, about 45 miles south of Alexandria, near which it occurs typically in deposits penetrated by a water-well test hole, in T. 5 S., R. 1 E. Beneath the Mamou member are the less lignitic, coarser textured deposits of the Steep Gully member; above it lie gravelly deposits of early Pleistocene age.

Table 6.—*Drillers' logs of representative wells in southwestern Louisiana*

Material	Thickness (feet)	Depth (feet)

ACADIA PARISH

Ac-282. Acadia Parish Courthouse.
6th St. and N. Parkerson Ave. in Crowley.
Sec. 33, T. 9 S., R. 1 E.

Material	Thickness (feet)	Depth (feet)
Clay	12	12
Sand	8	20
Clay	85	105
Sand; water	95	200
Gravel; water	89	289

ALLEN PARISH

Al-120. Town of Oakdale.
On 6th St. in Oakdale.
Sec. 4, T. 3 S., R. 3 W.

Material	Thickness (feet)	Depth (feet)
Soil, silty	16	16
Sand, fine-grained	12	28
Clay	26	54
Sand and gravel	86	140
Shale and sand, mixed	145	285
Shale, sandy	10	295
Sand, medium-grained	21	316
Shale	88	404
Sand	9	413
Shale	27	440
Sand	9	449
Shale	85	534
Sand, coarse-grained	4	538
Shale	98	636
Shale, sandy	18	654
Sand, medium-grained	25	679
Shale	22	701
Sand	5	706
Shale	26	732
Sand	49	781
Shale	16	797
Sand	5	802
Shale	20	822
Rock	2	824
Sand	50	874
Shale	3	877
Sand	4	881
Shale	2	883
Sand	33	916
Shale	146	1,062
Sand	38	1,100
Shale	45	1,145
Sand	11	1,156
Shale, sandy	24	1,180
Sand	10	1,190
Shale	2	1,192
Sand	32	1,224
Shale	12	1,236

Al-157. Town of Kinder.
On U. S. 165 in Kinder.
Sec. 35, T. 6 S., R. 5 W.

Material	Thickness (feet)	Depth (feet)
Soil	1	1
Silty, clay, buff	59	60
Sand, medium- and coarse-grained; water	30	90
Sand and gravel; water	309	399

Table 6.—*Drillers' logs of representative wells in southwestern Louisiana*—Continued

Material	Thickness (feet)	Depth (feet)

ALLEN PARISH—Continued

Al-157. Town of Kinder—Continued

Clay and some sand	50	449
Sand, gray, medium-grained; water	18	467
Clay	26	493
Sand, fine- to medium-grained	16	509
Clay	79	588
Sand, gray, fine-grained	35	623
Clay, blue, sandy	51	674
Clay, and some sand, fine-grained	78	752
Sand, gray, medium-grained, and shells	44	796
Clay, sandy	22	818
Sand, gray, medium-grained	52	870
Clay, fissile	20	890
Sand and clay, lenticular	110	1,000

BEAUREGARD PARISH

Be-5. Town of De Ridder.
At 8th and Bon Ami Sts. in De Ridder.
Sec. 33, R. 2 S., R. 9 W.

Clay, sandy	4	4
Shale, sandy	87	91
Sand, blue	19	110
Sand, gray, fine-grained	5	115
Sand, coarse-grained, and gravel	68	183
Gumbo	5	188

Be-75. W. Girouard.
Twelve miles north of Lake Charles.
Sec. 6, T. 7 S., R. 8 W.

Soil	8	8
Clay	6	14
Sand, loosely packed	6	20
Clay	75	95
Sand, fine-grained	20	115
Sand, coarse-grained	110	225
Gravel	35	260

CALCASIEU PARISH

Cu-496. Central Louisiana Electric Co.
South of U. S. 190 in De Quincy.
Sec. 18, T. 7 S., R. 10 W.

Clay	97	97
Clay, sandy	53	150
Clay, blue	85	235
Sand, fine-grained	55	290
Rock	10	300
Sand, fine-grained, and gravel	40	340
Clay and some rock	20	360
Gravel	10	370
Clay	30	400
Gravel	20	420
Clay and some rock	70	490
Sand, fine-grained	10	500
Rock	1	501
Clay	9	510
Sand, fine-grained, and gravel	50	560

Table 6.— *Drillers' logs of representative wells in southwestern Louisiana*— Continued

Material	Thickness (feet)	Depth (feet)

CALCASIEU PARISH—Continued

Cu-496. Central Louisiana Electric Co. —Continued

Gravel; water	25	585
Sand, fine-grained; water	65	650
Sand, fine-grained; clay and gravel	100	750

Cu-553. Gulf States Utilities Co.
On N. Ryan St. in Lake Charles.
Sec. 31, T. 9 S., R. 8 W.

Clay, silty, and some sand	45	45
Shale, sandy	50	95
Sand and some shale	44	139
Shale	81	220
Gumbo	30	250
Shale	78	328
Shale, sandy	78	406
Sand; water	100	506
Shale	54	560
Sand; water	111	671

Cu-556. Columbia-Southern Chemical Corp.
Six miles west of Lake Charles.
Sec. 4, T. 10 S., R. 9 W.

Clay and sand	30	30
Shale	92	122
Shale, sandy	47	169
Shale, hard	16	185
Sand; water	69	254
Gumbo	31	285
Shale	66	351
Sand; water	163	514
Shale	16	530
Sand	23	553
Shale	19	572
Sand; water	128	700

CAMERON PARISH

Cn-27. Sweetlake Land and Canal Co.
Sixteen miles southeast of Lake Charles.
Sec. 4, T. 12 S., R. 7 W.

Clay, soft, sticky	10	10
Sand, loosely packed	14	24
Shale, sandy	23	47
Clay, soft, sticky	53	100
Shale	30	130
Clay, soft, sticky	20	150
Shale	40	190
Shale, gummy	15	205
Shale, sandy	65	270
Sand, fine-grained	23	293
Sand, medium-grained	31	324
Shale, gummy	8	332
Sand, medium-grained; water	50	382
Sand, fine-grained; water	24	406
Sand, coarse-grained; water	23	429
Sand, medium-grained; water	45	474
Sand, fine-grained; water	16	490

Table 6.—*Drillers' logs of representative wells in southwestern Louisiana*—Continued

Material	Thickness (feet)	Depth (feet)

CAMERON PARISH—Continued

Cn-44. Magnolia Petroleum Co.
At Cameron Meadows.
Sec. 23, T. 15 S., R. 13 W.

Material	Thickness (feet)	Depth (feet)
Shale and some sand	22	22
Shale	74	96
Shale, gummy	24	120
Shale, sandy	130	250
Shale, gummy	50	300
Shale, hard	82	382
Sand, medium-grained; salt water	42	424
Shale	77	501

EVANGELINE PARISH

Ev-142. Magnolia Petroleum Co.
Two miles northeast of Mamou.
Sec. 6, T. 5 S., R. 1 E.

Material	Thickness (feet)	Depth (feet)
Soil	2	2
Clay	6	8
Sand, red	7	15
Shale	115	130
Sand; water	98	228
Sand, coarse-grained, and gravel	22	250
Shale	25	275
Sand, fine-grained	21	296
Shale, gummy	9	305
Shale	24	329
Sand, white, fine-grained	40	369
Shale, sandy	40	409
Shale, gummy	101	510
Sand, medium-grained	53	563
Shale, sandy	35	598
Shale	54	652
Sand	13	665
Shale, gummy	244	909
Sand, medium-grained	31	940
Sand	49	989
Shale	17	1,006
Shale, sandy	16	1,022
Sand	4	1,026
Shale	6	1,032
Sand	11	1,043
Shale	3	1,046
Sand	7	1,053
Shale	15	1,068
Sand and some shale	41	1,109
Shale	4	1,113
Sand	5	1,118
Shale	44	1,162
Sand, fine-grained	31	1,193
Shale and some sand	70	1,263
Sand	14	1,277
Shale and some sand	76	1,353
Sand	29	1,382
Shale and some sand	118	1,500

Table 6.—*Drillers' logs of representative wells in southwestern Louisiana*—Continued

Material	Thickness (feet)	Depth (feet)
IBERIA PARISH		
I-19. Jefferson Island Salt Co. Seven miles southwest of New Iberia. Sec. 59, T. 12 S., R. 5 E.		
Soil	6	6
Clay, yellow	26	32
Sand, silty	11	43
Clay, yellow	88	131
Gumbo	22	153
Sand, gray, fine-grained	88	241
Sand, gray, coarse-grained	60	301
Sand, gray, fine-grained	19	320
Sand, gray, coarse-grained	20	340
Sand, gray, fine-grained	13	353
Sand, gray, coarse-grained	124	477
JEFFERSON DAVIS PARISH		
JD-224. T. J. Heinen. Twelve miles southeast of Kinder. Sec. 10, T. 8 S., R. 4 W.		
Clay	85	85
Sand, fine-grained	59	144
Sand, coarse-grained	46	190
Sand and gravel	67	257
Sand, fine-grained	17	274
Shale	9	283
Sand, fine-grained	19	302
Sand and gravel	142	444
Sand, packed	28	472
Shale	38	510
Shale, sandy	23	533
Sand, fine-grained	22	555
Sand, coarse-grained	24	579
Gravel	33	612
Shale	10	622
Sand and some shale	25	647
Shale	5	652
Sand and some shale	17	669
Sand and gravel	45	714
Shale	46	760
JD-343. Town of Jennings. On Church St. in Jennings. Sec. 27, T. 9 S., R. 3 W.		
Soil	26	26
Sand, silty	54	80
Clay	20	100
Sand, fine-grained	40	140
Sand, coarse-grained, and gravel	131	271
LAFAYETTE PARISH		
Lf-488. Southwestern Louisiana Institute. On campus in Lafayette. Sec. 73, T. 9 S., R. 4 E.		
Clay, silty brown	27	27
Sand, medium- to coarse-grained	85	112
Sand, and gravel, fine- to medium-grained	69	181

Table 6.—*Drillers' logs of representative wells in southwestern Louisiana*—Continued

Material	Thickness (feet)	Depth (feet)
LAFAYETTE PARISH—Continued		
Lf-488. Southwestern Louisiana Institute—Continued		
Clay	16	197
Gravel and sand	11	208
Sand, coarse-grained, and gravel	56	264
Gravel and sand	9	273
Sand, interbedded with clay	10	283
Gravel, medium- to fine-grained, and sand	57	340
Shale, blue, green, and brown	29	369
Sand, medium- to coarse-grained	103	472
Sand, fine-grained, interbedded with clay	31	503
Shale, or clay, blue, green, and brown	78	581
Sand, medium- to coarse-grained, some gravel	91	672
Shale	32	704
Sand, medium- to coarse-grained	71	775
Shale or clay, blue	32	807
Sand, coarse-grained, and gravel, fine- to medium-grained	188	995
Sand, interbedded with clay	8	1,003
Sand, coarse-grained, and gravel, fine- to medium-grained	27	1,030
Shale, hard, gray	2	1,032
ST. LANDRY PARISH		
SL-84. Village of Krotz Springs. Two blocks north of Missouri Pacific Railroad in Krotz Springs. Sec. 9, T. 6 S., R. 7 E.		
Clay	90	90
Sand; water	291	381
Shale	33	414
Sand	78	492
Shale	64	556
Sand	70	626
Shale	84	710
Sand	20	730
Shale	42	772
Sand	68	840
Shale	34	874
Sand	12	886
Shale	64	950
Sand	45	995
Shale	19	1,014
Sand	54	1,068
Shale and some sand	76	1,144
Shale	140	1,284
Sand, interbedded with clay	151	1,435
Shale	161	1,596
Sand	18	1,614
Shale	8	1,622
Sand	138	1,760
Sand and some shale	52	1,812
Sand	93	1,905
Shale	2	1,907
SL-91. Humble Oil and Refining Co. Two miles south of Opelousas. Sec. 101, T. 6 S., R. 4 E.		
Clay	40	40
Sand	5	45
Clay	10	55
Shale, fissile	45	100
Clay	25	125

Table 6.— *Drillers' logs of representative wells in southwestern Louisiana*— Continued

Material	Thickness (feet)	Depth (feet)
ST. LANDRY PARISH—Continued		
SL-91. Humble Oil and Refining Co. —Continued		
Sand	85	210
Shale, sandy	30	240
Shale	50	290
Sand; water	145	435
Gumbo	56	491
Sand; water	59	550
Shale, hard	20	570
Sand	8	578
Shale	2	580
Sand	105	685
Gumbo	114	799
SL-129. R. Horecky. Two miles southeast of Morrow. Sec. 5, T. 3 S., R. 4 E.		
Soil	1	1
Clay and some sand	43	44
Sand, fine- and medium-grained	26	70
Sand, medium- and coarse-grained	20	90
Sand, coarse-grained, and gravel	40	130
Clay, sandy	55	185
Gumbo	24	209
Sand, gray, fine- to coarse-grained	20	229
Gumbo	59	288
Clay, sandy	2	290
ST. MARTIN PARISH		
SMn-46. Town of Arnaudville. In Arnaudville. Sec. 44, T. 7 S., R. 5 E.		
Clay, yellow	18	18
Sand, fine-grained	6	24
Clay, yellow	76	100
Sand; water	114	214
Sand, coarse-grained	30	244
SMn-37. Gordy Salt Co. Six miles northeast of Lafayette. Sec. 71, T. 9 S., R. 5 E.		
Soil	1	1
Clay	10	11
Sand, fine-grained	39	50
Sand, coarse-grained, and gravel	110	160
Gravel and some clay	7	167
ST. MARY PARISH		
SM-42. Town of Franklin. At City Park in Franklin. Sec. 2, T. 15 S., R. 9 E.		
Soil	25	25
Clay	68	93
Shale, sandy	22	115
Sand, fine-grained	45	160

Table 6.—*Drillers' logs of representative wells in southwestern Louisiana*—Continued

ST. MARY PARISH—Continued

SM-42. Town of Franklin—Continued

Material	Thickness (feet)	Depth (feet)
Sand; water	52	212
Shale	60	272
Shale, sandy	28	300
Sand, fine-grained	17	317
Sand, medium-grained	83	400

VERMILION PARISH

Ve-136. The Texas Co.
Seven miles southeast of Abbeville.
Sec. 21, T. 13 S., R. 4 E.

Material	Thickness (feet)	Depth (feet)
Soil	10	10
Clay, yellow	25	35
Clay, blue	79	114
Sand, brown, fine-grained	56	170
Sand, brown, coarse-grained	40	210
Sand, coarse-grained, and gravel	60	270
Shale, sandy	46	316
Shale, gummy	7	323
Sand, shaly	15	338
Sand, gray, medium-grained	50	388
Sand, white, coarse-grained	67	455
Sand, white, medium-grained	20	475
Sand, coarse-grained, and gravel	43	518
Gravel	59	577
Sand, coarse-grained	8	585

Table 7.—*Mechanical analyses of sand samples from wells in southwestern Louisiana*

Well no.	Depth of sample (feet)	Mechanical analysis of sand fraction (cumulative percent retained by weight)						
		4 mm	2 mm	1 mm	½ mm	¼ mm	⅛ mm	1/16 mm
				ALLEN PARISH				
Al-108	611- 622	0	0	0	1.37	22.26	91.41	100.00
	622- 632	0	0	0	24.14	77.24	98.51	100.00
	632- 640	0	0	3.44	39.84	87.38	98.08	100.00
	640- 653	0	0	1.34	7.39	37.78	99.94	100.00
	738- 759	0	0	0	16.51	92.78	99.96	100.00
	1120-1141	0	0	.79	8.45	29.36	99.18	100.00
	1162-1183	0	0	.27	5.52	47.63	99.10	100.00
	1738-1761	0	0	.74	26.77	85.35	98.91	100.00
	1761-1773	0	0	.07	19.78	83.31	99.51	100.00
	1773-1785	0	0	1.21	20.80	84.07	99.11	100.00
	1785-1796	0	0	.56	2.56	62.77	99.50	100.00
	1796-1807	0	0	.34	7.33	78.13	99.48	100.00
	1807-1818	0	0	1.61	24.29	82.81	99.59	100.00
	1818-1830	0	0	1.98	6.47	78.46	99.41	100.00
	1830-1841	0	0	0	3.21	89.32	99.72	100.00
	1841-1852	0	0	.31	15.12	94.89	99.96	100.00
	1852-1870	0	0	.50	11.84	76.98	98.57	100.00
Al-109	494- 504	0	.20	1.16	4.48	53.86	94.72	100.00
	504- 516	0	0	0	4.01	69.96	97.44	100.00
	516- 526	0	0	.28	1.80	63.66	97.65	100.00
	595- 605	0	0	.19	2.58	45.36	94.41	100.00
	605- 627	0	0	0	.24	49.30	97.91	100.00
	627- 639	0	0	.18	.54	17.74	80.49	100.00
	639- 651	0	0	.23	.77	18.10	74.20	100.00
	983-1028	0	.02	29.97	89.73	96.70	99.37	100.00
	1082-1104	0	0	2.96	65.72	95.92	99.80	100.00
	1104-1128	0	0	1.45	49.12	84.90	97.00	100.00
	1128-1151	0	0	0	2.03	31.67	87.54	100.00
	1151-1168	0	0	0	3.49	34.14	95.03	100.00
	1168-1173	0	0	0	9.16	57.82	96.94	100.00
	1173-1183	0	0	0	1.39	35.35	98.50	100.00
	1183-1197	0	0	0	9.00	59.74	95.38	100.00
Al-120	683- 705	0	.01	.06	62.40	85.65	96.76	100.00
	705- 716	0	4.42	23.28	67.56	85.83	97.42	100.00
	728- 739	0	0	1.08	36.13	86.92	99.56	100.00
	739- 751	0	.20	.81	23.40	80.04	98.59	100.00
	751- 763	0	0	.16	4.26	60.13	98.98	100.00
	858- 879	.26	1.27	2.63	13.21	82.34	99.28	100.00
	879- 900	.13	.48	1.56	12.87	86.34	99.63	100.00
	920- 940	.16	.25	.84	36.07	76.97	95.48	100.00
Al-138	734- 742	0	0	2.12	15.12	49.23	92.08	100.00
	742- 763	0	0	2.44	20.36	75.97	97.43	100.00
	810- 820	0	0	.10	8.56	69.38	97.41	100.00
	820- 831	0	0	.19	8.11	55.02	98.23	100.00
	831- 855	0	0	.90	15.46	63.95	95.38	100.00
	864- 876	0	0	1.46	12.11	57.92	93.32	100.00
	881- 899	0	0	3.16	32.50	76.21	97.81	100.00
	899- 906	0	0	5.06	35.25	73.38	96.79	100.00
	916- 931	0	0	1.62	10.88	35.95	77.57	100.00
Al-144	391- 414	0	.03	.52	4.04	8.81	85.96	100.00
	611- 635	0	.06	.12	.28	6.53	85.69	100.00
	635- 658	0	0	1.48	56.25	90.36	98.98	100.00
	728- 738	0	0	.64	53.29	92.09	99.93	100.00
	738- 746	0	0	.89	59.12	93.57	99.92	100.00
	746- 756	0	0	.60	42.76	84.34	99.78	100.00
	756- 767	0	.03	.28	19.01	80.22	99.85	100.00
	767- 775	0	.03	.19	11.45	69.73	99.91	100.00

Table 7.—*Mechanical analyses of sand samples from wells in southwestern Louisiana*—Continued

Well no.	Depth of sample (feet)	Mechanical analysis of sand fraction (cumulative percent retained by weight)						
		4 mm	2 mm	1 mm	½ mm	¼ mm	⅛ mm	1/16 mm
				ALLEN PARISH—Continued				
Al-157	60- 70	0	0	0	2.36	4.43	24.14	100.00
	70- 80	0	0	0	1.60	8.75	34.81	100.00
	80- 98	0	0	.94	10.63	67.65	99.95	100.00
	98-109	0	0	1.08	9.34	49.98	97.38	100.00
	109-120	0	2.55	6.78	28.70	82.21	99.96	100.00
	120-131	0	1.97	6.00	19.72	72.74	98.92	100.00
	131-142	0	2.86	12.40	43.35	90.06	99.62	100.00
	142-153	0	.46	5.78	42.44	91.64	99.48	100.00
	153-164	0	.38	5.53	34.41	91.22	99.96	100.00
	164-175	0	10.99	33.85	64.95	95.63	99.99	100.00
	175-187	.46	24.45	57.83	86.64	98.89	99.98	100.00
	187-198	5.29	50.25	67.28	87.99	99.15	99.99	100.00
	198-210	9.80	46.14	60.40	82.47	97.91	99.96	100.00
	210-221	2.49	21.82	38.31	67.19	95.33	99.97	100.00
	221-232	3.14	21.82	39.55	67.06	94.26	99.96	100.00
	232-243	2.37	14.41	24.31	48.60	88.42	99.99	100.00
	243-254	2.79	24.45	33.63	55.69	91.09	99.99	100.00
	254-265	0	3.05	19.30	45.94	89.14	99.86	100.00
	265-276	.33	1.48	6.83	18.49	83.93	99.78	100.00
	276-287	0	4.68	24.59	59.42	89.09	99.83	100.00
	287-298	0	5.86	28.78	65.42	90.01	99.84	100.00
	298-309	16.92	73.44	79.89	88.76	95.58	99.76	100.00
	309-320	21.79	41.15	50.09	69.54	92.63	99.76	100.00
	320-331	15.11	47.99	63.22	79.70	94.98	99.80	100.00
	331-343	41.28	71.05	86.29	95.01	98.79	99.90	100.00
	343-354	41.19	57.67	66.67	81.57	92.04	99.92	100.00
	354-365	77.07	92.02	95.97	98.33	99.47	99.92	100.00
	365-376	9.57	14.15	19.80	41.26	76.55	99.07	100.00
	376-388	82.93	94.33	96.75	98.44	99.55	99.93	100.00
	388-399	.30	2.98	6.37	23.49	67.46	99.93	100.00
	449-465	0	0	19.66	23.95	44.11	92.81	100.00
	493-509	0	0	39.14	46.99	72.06	97.96	100.00
	600-620	0	0	1.54	2.64	9.26	71.22	100.00
	674-697	0	0	8.44	10.82	21.45	80.34	100.00
	763-774	0	0	1.09	1.88	7.22	70.92	100.00
	774-784	0	0	.79	1.38	6.43	82.89	100.00
Al-158	86- 96	0	0	.53	10.50	79.26	98.28	100.00
	96-107	.38	4.82	9.86	28.56	92.27	99.25	100.00
	107-117	.25	5.48	12.41	34.00	93.24	99.04	100.00
	117-127	31.61	40.62	46.10	60.42	92.27	99.31	100.00
	127-137	13.21	20.84	29.54	53.14	93.47	99.64	100.00
	137-147	13.80	21.69	30.08	52.94	92.87	99.39	100.00
	147-157	51.26	74.26	81.80	90.38	98.08	99.61	100.00
	157-167	44.00	73.21	84.77	93.82	99.39	99.89	100.00
	193-203	0	.10	1.45	10.00	40.22	90.68	100.00
	203-213	0	1.28	5.29	16.09	63.87	93.09	100.00
	213-223	0	.97	4.07	20.33	63.39	92.79	100.00
	223-233	0	.25	2.05	15.74	57.44	92.25	100.00
	268-277	0	0	.83	8.19	41.72	85.13	100.00
	277-287	0	.15	1.13	8.96	45.57	86.59	100.00
	287-297	0	.87	3.47	18.41	63.58	94.46	100.00
	297-307	0	1.03	3.39	14.41	54.58	92.60	100.00
				CALCASIEU PARISH				
Cu-452	140-160	33.82	97.66	98.43	98.98	99.64	99.64	100.00
	202-222	0	0	0	.58	70.81	97.77	100.00
	305-315	0	0	0	.35	2.31	70.70	100.00
	315-335	0	0	0	0	8.43	89.04	100.00
	335-358	0	0	0	.08	9.19	94.24	100.00

Table 7.— *Mechanical analyses of sand samples from wells in southwestern Louisiana*—Continued

Well no.	Depth of sample (feet)	Mechanical analysis of sand fraction (cumulative percent retained by weight)						
		4 mm	2 mm	1 mm	½ mm	¼ mm	⅛ mm	$\frac{1}{16}$ mm
				CALCASIEU PARISH—Continued				
Cu-452—Continued	358-379	0	0	0	0.91	32.91	98.24	100.00
	379-404	0	0	0	3.87	82.67	99.10	100.00
	404-424	0	0	.82	30.85	87.25	99.60	100.00
	424-435	0	9.08	40.93	68.36	96.07	96.69	100.00
Cu-496	550-560	14.80	20.78	23.70	28.48	51.23	89.10	100.00
	560-570	12.71	17.97	20.90	25.79	48.87	87.96	100.00
	570-580	19.77	26.51	29.97	35.35	60.79	94.36	100.00
Cu-553	329-361	0	0	2.00	7.19	45.81	91.18	100.00
	361-384	0	.14	.65	1.71	29.81	94.50	100.00
	384-406	0	.32	1.09	2.55	43.55	95.00	100.00
	406-429	0	.13	.55	1.52	65.15	95.75	100.00
	429-452	0	.42	2.64	12.10	73.75	96.46	100.00
	453-474	0	.11	19.35	36.11	75.63	97.11	100.00
	474-496	0	1.79	19.41	44.89	77.27	96.81	100.00
	560-584	0	.14	.93	5.62	48.34	90.54	100.00
	584-606	0	.61	2.08	6.33	53.96	92.93	100.00
	606-628	0	.87	3.16	8.92	59.56	93.82	100.00
	628-650	0	.33	6.30	24.28	68.57	94.53	100.00
	650-676	0	.37	1.96	9.53	51.67	89.23	100.00
Cu-555	410-421	0	0	0	1.31	23.73	84.23	100.00
	421-436	0	0	0	54.34	85.30	95.73	100.00
	436-452	0	0	.05	8.08	45.74	90.62	100.00
	452-481	0	3.89	3.89	12.78	52.82	93.50	100.00
	481-491	0	.20	1.10	11.21	66.46	96.89	100.00
	511-542	0	.34	1.16	9.53	51.90	92.03	100.00
	557-574	.13	.69	2.32	15.65	67.58	97.31	100.00
	574-590	0	.49	1.57	15.05	73.34	97.15	100.00
	590-598	.13	4.34	11.35	27.54	79.73	98.38	100.00
Cu-560	438-460	0	0	.10	.26	43.26	98.34	100.00
	460-482	0	0	.03	.69	56.57	99.57	100.00
	482-504	0	0	.03	.16	35.99	98.50	100.00
	504-526	0	0	.66	24.16	82.14	99.47	100.00
	526-548	0	.17	24.67	82.49	93.99	99.82	100.00
	548-570	0	0	1.34	42.88	93.63	99.76	100.00
	570-593	0	35.91	78.30	89.35	96.83	99.82	100.00
				EVANGELINE PARISH				
Ev-142	120-180	0	0.47	2.42	35.99	90.46	99.92	100.00
	180-218	0	1.38	16.07	58.55	92.84	99.98	100.00
	218-240	8.60	17.83	23.45	41.89	83.70	99.70	100.00
	265-286	.15	.32	1.17	5.11	35.85	94.15	100.00
	319-349	0	.07	.24	1.03	11.49	87.07	100.00
	510-545	0	0	.04	.48	46.31	98.08	100.00
	545-563	0	.80	.91	11.31	83.02	99.54	100.00
	614-637	0	.03	.14	.69	32.68	99.21	100.00
	659-682	0	.15	.42	1.45	17.56	92.11	100.00
	682-705	0	.03	.16	1.05	16.35	81.17	100.00
	705-728	0	.02	.17	1.11	17.63	75.48	100.00
	728-750	0	.03	.31	1.81	21.49	91.25	100.00
	772-795	0	.02	.17	.66	15.63	86.43	100.00
	795-818	0	.05	.54	2.71	19.78	90.05	100.00
	818-841	0	.05	.33	1.52	16.59	82.84	100.00
	841-865	0	.02	.26	1.61	25.80	92.30	100.00
	865-888	0	.11	.52	2.31	20.17	88.26	100.00
	888-911	0	.07	.39	4.35	54.68	88.18	100.00

Table 7.—*Mechanical analyses of sand samples from wells in southwestern Louisiana*—Continued

Well no.	Depth of sample (feet)	Mechanical analysis of sand fraction (cumulative percent retained by weight)						
		4 mm	2 mm	1 mm	½ mm	¼ mm	⅛ mm	1/16 mm
				EVANGELINE PARISH—Continued				
Ev-142—Continued	911- 934	0	0.06	0.48	8.93	65.47	93.95	100.00
	934- 940	0	0	.02	12.22	75.71	99.21	100.00
	940- 957	0	0	.36	35.02	89.11	99.58	100.00
	957- 969	0	0	.01	.37	15.94	92.86	100.00
	979- 989	0	0	.02	.27	59.09	98.64	100.00
	989-1001	0	0	.01	.20	29.04	95.58	100.00
	1001-1024	0	.02	.13	6.83	54.04	95.23	100.00
	1024-1047	0	0	.08	9.66	42.18	97.09	100.00
	1047-1070	0	0	.03	4.54	36.34	96.34	100.00
	1070-1092	0	.01	.04	5.51	46.02	96.25	100.00
	1092-1115	0	0	.02	4.04	28.24	87.05	100.00
	1115-1137	0	.03	.11	5.81	48.34	95.88	100.00
	1137-1159	0	0	.01	.96	47.55	96.24	100.00
	1159-1182	0	0	.01	2.05	56.93	90.90	100.00
	1182-1205	0	0	.01	1.64	40.17	96.87	100.00
	1205-1229	0	0	.01	.99	44.43	98.34	100.00
	1229-1252	0	0	.03	5.23	63.34	98.15	100.00
	1252-1262	0	0	.04	4.34	69.55	98.28	100.00
	1262-1275	0	.13	.22	14.63	55.67	97.98	100.00
	1275-1297	0	0	.04	5.49	42.82	93.70	100.00
	1297-1321	0	0	.06	15.53	52.54	93.95	100.00
	1321-1343	0	.10	1.74	40.89	65.79	96.06	100.00
	1343-1366	0	0	.01	9.29	36.52	94.78	100.00
	1366-1389	0	0	0	1.55	45.21	98.54	100.00
	1389-1410	0	.04	.54	10.04	52.21	96.35	100.00
	1410-1433	0	1.48	18.88	43.41	70.95	98.58	100.00
	1433-1456	0	.14	6.50	17.17	53.04	97.96	100.00
	1456-1478	0	.16	2.86	9.53	45.84	97.62	100.00
	1478-1500	.05	.91	8.08	15.53	44.96	97.42	100.00
				JEFFERSON DAVIS PARISH				
JD- 88	64- 106	0	0.37	1.05	5.47	38.63	94.68	100.00
	106- 125	0	.01	.73	9.87	70.17	97.31	100.00
	125- 145	0	.08	2.57	7.87	44.69	95.24	100.00
	145- 165	0	.08	5.24	26.11	69.97	95.90	100.00
	165- 186	0	.25	3.70	11.42	52.24	96.05	100.00
	186- 205	1.56	48.88	99.39	99.96	99.98	99.99	100.00
	205- 225	6.19	70.34	99.54	99.94	99.98	100.00	100.00
	225- 267	4.31	24.62	36.09	61.16	93.85	100.00	100.00
	267- 287	8.09	69.52	84.63	93.13	99.18	99.98	100.00
	287- 288	13.82	85.88	99.81	99.90	99.94	99.97	100.00
JD-224	122- 144	.39	1.93	5.98	16.26	50.05	98.00	100.00
	144- 166	0	2.22	8.33	22.08	75.19	98.04	100.00
	166- 190	1.98	13.10	29.91	50.83	79.39	98.86	100.00
	190- 212	1.29	20.98	41.16	68.93	91.17	99.81	100.00
	212- 234	4.58	35.63	55.11	80.59	97.81	99.92	100.00
	234- 257	2.02	17.46	30.66	55.85	90.40	99.47	100.00
	257- 274	6.29	28.43	47.23	74.79	95.31	99.82	100.00
	274- 293	11.43	46.32	60.98	79.42	93.59	99.80	100.00
	302- 323	45.57	72.70	84.55	94.59	99.08	99.94	100.00
	323- 344	52.37	76.08	83.95	93.32	97.69	99.90	100.00
	344- 365	14.15	38.75	55.88	77.15	96.94	99.60	100.00
	365- 388	34.05	58.14	67.95	82.27	95.77	99.86	100.00
	388- 407	87.17	96.85	97.72	98.62	99.57	99.92	100.00
	407- 428	83.56	96.40	97.26	98.01	99.13	99.89	100.00
	428- 450	18.18	45.80	60.60	74.70	94.06	99.90	100.00
	450- 460	19.91	26.31	43.84	61.53	90.80	99.72	100.00
	473- 495	22.25	45.96	56.48	71.41	93.89	99.81	100.00

Table 7.—*Mechanical analyses of sand samples from wells in southwestern Louisiana*—Continued

Well no.	Depth of sample (feet)	Mechanical analysis of sand fraction (cumulative percent retained by weight)						
		4 mm	2 mm	1 mm	$\frac{1}{2}$ mm	$\frac{1}{4}$ mm	$\frac{1}{8}$ mm	$\frac{1}{16}$ mm
				JEFFERSON DAVIS PARISH—Continued				
JD-224—Continued	495–513	22.48	43.27	52.84	69.81	93.15	99.73	100.00
	513–532	0	.71	2.73	5.93	30.01	94.17	100.00
	532–555	0	0	0	2.85	60.60	96.55	100.00
	555–579	0	0	2.01	26.77	88.41	98.85	100.00
	579–602	0	12.56	29.93	66.65	95.76	97.44	100.00
	602–612	.87	15.19	32.76	62.71	95.41	99.92	100.00
	612–622	0	0	6.31	34.16	77.95	95.34	100.00
	622–647	0	13.84	33.02	64.37	95.89	99.69	100.00
	647–669	0	.49	2.19	8.08	62.00	94.47	100.00
	669–692	5.32	31.38	50.38	73.38	93.39	99.66	100.00
	692–714	.36	13.76	33.87	65.79	91.77	96.46	100.00
JD-406	93–117	0	.10	.96	15.37	76.12	99.69	100.00
	387–403	0	3.82	19.23	58.24	98.03	99.85	100.00
	426–433	0	.33	2.06	23.84	85.03	99.05	100.00
	433–453	0	1.47	19.32	49.07	87.84	99.28	100.00
	735–750	0	0	0	.31	33.68	77.48	100.00
	880–887	0	0	.01	.63	11.83	55.27	100.00
	887–905	0	0	.01	.76	22.70	87.48	100.00
				LAFAYETTE PARISH				
Lf-488	27– 45	0	0	0	13.94	89.15	98.89	100.00
	45– 67	0	0	0	5.11	76.93	99.46	100.00
	67– 90	0	0	.11	1.75	89.05	99.89	100.00
	90–112	0	0	1.36	24.81	93.56	99.50	100.00
	112–135	12.24	19.52	31.88	56.84	93.93	99.79	100.00
	135–157	11.88	22.57	40.46	73.22	98.22	99.96	100.00
	157–167	10.86	27.21	41.34	65.62	95.44	99.94	100.00
	167–177	12.96	29.90	45.50	69.24	96.26	99.88	100.00
	197–208	25.47	52.75	72.60	90.63	99.03	99.97	100.00
	208–219	19.89	34.84	48.28	70.45	94.95	99.77	100.00
	219–230	12.32	22.79	33.31	60.38	93.00	99.67	100.00
	230–242	13.30	26.90	38.56	64.30	92.95	99.58	100.00
	242–253	27.08	39.39	47.83	66.69	93.38	99.78	100.00
	253–264	25.80	39.82	49.43	68.46	93.78	99.86	100.00
	264–273	50.46	64.50	72.67	84.46	97.33	99.99	100.00
	283–294	45.58	64.91	73.51	85.18	97.51	99.87	100.00
	294–305	38.87	57.54	66.67	79.70	95.21	99.41	100.00
	305–317	35.66	59.47	71.29	85.36	97.79	99.92	100.00
	317–328	63.61	82.92	87.36	91.86	97.24	99.79	100.00
	328–340	63.91	82.27	86.89	91.13	96.74	98.83	100.00
	369–380	0	2.44	5.42	16.65	62.71	98.43	100.00
	380–391	0	1.37	3.98	14.82	60.47	99.39	100.00
	391–403	0	.44	2.13	10.99	51.88	97.31	100.00
	403–415	0	.16	.79	6.45	55.14	96.96	100.00
	415–426	.30	.94	2.33	10.31	53.98	97.94	100.00
	426–437	0	.15	.68	5.47	45.99	96.53	100.00
	437–449	0	0	.22	2.32	36.37	94.06	100.00
	449–472	0	.26	.73	5.58	49.29	96.28	100.00
	581–593	0	.96	2.72	10.59	49.62	96.47	100.00
	593–604	.41	5.54	12.73	26.90	71.37	98.44	100.00
	604–615	0	3.19	8.71	19.51	63.84	97.69	100.00
	615–627	0	0	.54	4.64	47.87	96.75	100.00
	627–638	0	1.23	3.07	10.63	54.19	95.61	100.00
	638–650	0	.69	2.20	9.22	58.28	95.03	100.00
	650–662	0	1.51	3.74	10.33	50.92	93.35	100.00
	662–672	0	1.77	4.59	11.80	56.02	94.04	100.00
	704–715	.14	1.75	5.57	15.58	61.38	95.89	100.00
	715–728	0	3.13	6.69	16.18	61.66	95.39	100.00

Table 7.—*Mechanical analyses of sand samples from wells in southwestern Louisiana*—Continued

Well no.	Depth of sample (feet)	Mechanical analysis of sand fraction (cumulative percent retained by weight)						
		4 mm	2 mm	1 mm	½ mm	¼ mm	⅛ mm	1/16 mm
				LAFAYETTE PARISH—Continued				
Lf-488—Continued	728- 740	0	0.28	1.05	5.80	44.51	92.60	100.00
	752- 762	0	.16	.99	4.77	36.09	91.46	100.00
	762- 772	0	.54	1.48	5.10	52.27	99.25	100.00
	772- 782	.48	1.71	2.57	5.43	43.35	94.67	100.00
	807- 829	.92	2.94	5.02	9.10	45.43	88.84	100.00
	829- 851	1.26	11.95	23.39	33.48	71.23	96.80	100.00
	851- 874	.69	3.14	14.58	27.18	70.60	97.62	100.00
	874- 896	2.91	21.59	35.93	44.27	76.10	95.99	100.00
	896- 919	2.39	15.30	24.13	32.51	73.96	98.19	100.00
	919- 942	1.34	10.09	17.52	26.10	69.71	97.80	100.00
	942- 964	7.59	20.65	26.64	35.37	78.04	98.84	100.00
	964- 987	1.19	4.23	7.25	15.32	64.33	96.69	100.00
	987-1009	4.40	13.26	19.96	29.42	74.98	97.79	100.00
	1009-1032	1.01	19.10	36.76	54.39	89.38	99.50	100.00
				ST. MARY PARISH				
SM- 39	120- 135	0	0	0.04	0.12	4.77	78.07	100.00
	135- 146	0	0	0	.07	23.21	92.67	100.00
	146- 157	0	0	3.72	46.00	95.90	99.90	100.00
	157- 168	0	0	.89	15.51	73.27	96.67	100.00
	168- 180	0	0	3.90	39.98	94.45	99.83	100.00
	180- 191	0	0	2.67	24.63	84.75	98.96	100.00
	191- 202	0	0	2.21	20.70	81.03	99.04	100.00
	202- 213	0	0	3.83	32.56	84.94	99.36	100.00
	213- 225	0	0	1.66	25.28	58.57	99.57	100.00
	225- 236	0	0	1.80	18.83	47.43	99.67	100.00
	236- 246	0	0	1.20	11.34	43.31	99.19	100.00
	299- 304	0	0	1.81	12.95	47.75	99.74	100.00
	304- 315	0	0	1.26	9.57	44.96	98.87	100.00
	315- 326	0	0	1.25	8.92	53.72	98.58	100.00
	326- 337	0	0	1.57	11.26	49.98	99.10	100.00
	337- 348	0	0	1.12	14.13	56.90	99.07	100.00
	348- 360	0	0	.87	12.20	47.83	98.95	100.00
	360- 371	0	0	1.84	18.69	35.91	99.34	100.00
	371- 382	0	0	1.17	15.19	68.22	99.05	100.00
	382- 393	0	0	.80	14.28	52.31	99.52	100.00
	393- 405	0	0	.78	13.60	47.23	99.41	100.00
	405- 416	0	0	.38	13.95	62.75	99.57	100.00
	416- 427	0	0	.52	11.72	47.40	99.37	100.00
	427- 438	0	0	2.13	15.43	48.42	99.82	100.00
	438- 442	0	0	.65	8.70	55.07	99.76	100.00
SM- 43	80- 93	0	.04	.34	.82	1.40	65.64	100.00
	93- 105	0	.01	.08	.30	.86	57.48	100.00
	105- 116	0	0	.33	.53	.80	56.97	100.00
	116- 127	0	0	.12	.23	.41	72.60	100.00
	127- 140	0	0	.01	.03	.22	67.23	100.00
	140- 150	0	0	.06	.12	2.95	79.42	100.00
	150- 165	0	0	.02	.17	12.40	83.51	100.00
	165- 176	0	1.61	7.36	28.97	87.27	99.91	100.00
	188- 200	0	.33	1.87	20.62	82.50	98.52	100.00
	200- 214	0	2.61	4.24	19.99	80.75	97.19	100.00
	214- 230	0	.17	.55	11.83	76.28	96.74	100.00
	305- 312	0	0	.32	5.26	53.67	89.78	100.00
	312- 320	0	.09	1.90	13.86	69.85	96.70	100.00
	320- 330	0	.38	1.89	16.24	75.85	99.37	100.00
	332- 344	0	1.02	9.18	30.72	86.47	99.24	100.00
	344- 353	0	1.38	7.83	32.98	89.72	99.34	100.00
	353- 367	0	.54	.86	15.00	75.94	98.15	100.00

Table 7.—*Mechanical analyses of sand samples from wells in southwestern Louisiana*—Continued

Well no.	Depth of sample (feet)	Mechanical analysis of sand fraction (cumulative percent retained by weight)						
		4 mm	2 mm	1 mm	$\frac{1}{2}$ mm	$\frac{1}{4}$ mm	$\frac{1}{8}$ mm	$\frac{1}{16}$ mm
				ST. MARY PARISH—Continued				
SM-43—Continued	367-380	0	0.57	0.69	11.08	80.54	98.97	100.00
	380-390	0	.61	.96	10.49	76.15	96.85	100.00
				VERMILION PARISH				
Ve-136	180-190	0	0	1.75	11.56	51.30	97.55	100.00
	190-203	0	0	6.41	22.73	50.10	99.23	100.00
	203-225	1.47	14.43	37.08	68.58	92.80	99.72	100.00
	225-248	1.25	16.52	31.22	64.26	92.41	99.60	100.00
	248-270	0	8.12	24.57	57.26	93.48	99.83	100.00
	270-293	2.02	14.14	17.04	21.43	38.82	77.51	100.00
	293-315	4.71	10.86	17.55	24.45	35.38	67.64	100.00

Notes to table 7

Well no.	*Location*	*Owner*
Al-108	Sec. 10, T. 3 S., R. 3 W.	City of Oakdale
Al-109	Sec. 3, T. 3 S., R. 3 W.	Do.
Al-120	Sec. 4, T. 3 S., R. 3 W.	Do.
Al-138	Do	Do.
Al-144	Do	Do.
Al-157	Sec. 35, T. 6 S., R. 5 W.	Town of Kinder
Al-158	Sec. 20, T. 2 S., R. 4 W.	Calcasieu Paper Co.
Cu-452	Sec. 23, T. 8 S., R. 12 W.	Raymond Royer
Cu-496	Sec. 18, T. 7 S., R. 10 W.	Central-Louisiana Electric Co.
Cu-553	Sec. 31, T. 9 S., R. 8 W.	Gulf States Utilities
Cu-555	Sec. 15, T. 10 S., R. 12 W.	Town of Vinton
Cu-560	Sec. 19, T. 10 S., R. 9 W.	Cities Service Refining Co.
Ev-142	Sec. 6, T. 5 S., R. 1 E.	Magnolia Petroleum Co.
JD- 88	Sec. 35, T. 7 S., R. 4 W.	Union Sulphur Co.
JD-224	Sec. 10, T. 8 S., R. 4 E.	T. J. Heinen
JD-406	Sec. 34, T. 6 S., R. 3 W.	Town of Elton
Lf-488	Sec. 43, T. 9 S., R. 4 E.	Southwest Louisiana Institute
SM-39	Sec. 46, T. 14 S., R. 10 E.	Town of Franklin
SM-43	Sec. 43, T. 14 S., R. 10 E.	Do.
Ve-136	Sec. 21, T. 13 S., R. 4 E.	The Texas Co.

The thickness of the Mamou member at Mamou is about 1,200 feet. As the contact with the Steep Gully member is apparently gradational, thickness figures are likely to be misleading. The sands of the Mamou member are generally more micaceous and contain a greater abundance of lignite than those of the Steep Gully member, and the clays and sandy shales have a characteristically darker hue.

Except for the northernmost parts of Beauregard, Allen, and Evangeline Parishes, all southwestern Louisiana is underlain by the Mamou member. Beds of sand in it are probably in contact with the basal gravels of the Pleistocene series in many places in the project area.

Deposits of the Mamou member have been penetrated by water wells at Kinder in Allen Parish, Elton in Jefferson Davis Parish, Fenris and Mamou in Evangeline Parish, and Washington in St. Landry Parish. Their character is excellently demonstrated by conditions at Mamou, where the deepest penetration of the deposits by water wells has been made (see log of well Ev–142, table 6). However, the most detailed study of the lithology ~~in~~ heavy-mineral assemblage of deposits of the member ~~have~~ been made of samples from a test well (Al–157) at Kinder. (See tables 4 and 5.) Organic remains in these samples indicate a coastal-marsh or back-swamp origin such as prevails today along the margin of the Gulf of Mexico. Both the structure of the deposits and their texture are in conformity with such a mode of origin, as the beds are typically thin, lenticular, and fine grained. Abundant pyrite and marcasite indicate deposition below water level.

PLEISTOCENE SERIES

No group name has been assigned to the thick mass of sediments of Pleistocene age in southern Louisiana. Their maximum thickness along the gulf coast is probably greater than 2,000 feet (Schuchert, 1935, p. 221). Fisk (1944, fig. 70) indicates that their thickness exceeds 3,000 feet in St. Mary Parish, near the axis of the Mississippi structural trough. (See p. 95.)

The line of demarcation between the base of the Pleistocene series and the top of the underlying Foley formation is not readily definable in the area south of the latitude of Crowley in Acadia Parish where gulfward facies changes complicate the downdip correlation of beds. Efforts of the writer to map the base of the series in the gulf-marginal areas have been unsuccessful (pl. 8). Previous references in this report to the occurrence and character of the deposits indicate the nature of the difficulties. Where it is gravelly to its base, the Pleistocene series is easily distinguished, and the map of the base is reliable.

The maximum thickness of gravelly sediments, where their base has been mapped by the writer, occurs in southern Acadia

Parish. This is probably the result of structural controls that established an area of downwarp along a north-south axis through Acadia Parish during much of Pleistocene time and so provided for the accumulation and preservation of the deposits. The line of geologic section *B-B'* (pl. 10) lies parallel to the axis of this trough, as shown on the map, plate 9. As one might expect, the correlation of beds along this section is less subject to question than correlations indicated on other sections prepared in this investigation. The gulfward extent of gravelly beds of Pleistocene age is greatest along this line. They form a thick "lobe" that crosses Vermilion and eastern Cameron Parishes and extends southward beneath the margin of the gulf.

Mapping the base of the Pleistocene series is complicated by lateral (east-west) gradation of gravelly beds into sand, silt, and clay. These fine-grained equivalents probably are partly lake and bay deposits, partly natural-levee and back-swamp deposits, and in Cameron and St. Mary Parishes which are farthest from the north-south axis of graveliferous deposition, they probably are deposits of marine origin interbedded with coastal marsh sediments. Although the continuity and areal distribution of the fine-grained sediments are highly important to a comprehensive analysis of the hydrology of southwestern Louisiana, the scope of this investigation did not provide for intensive detailed study of the stratigraphy of these deposits. It is evident that they include important water-bearing sands, and their structural and textural features have an important relation to the problem of salt-water encroachment. Further study of these deposits will be necessary to a full understanding of the ground-water hydrology of southwestern Louisiana.

WILLIANA FORMATION

Named and defined by Fisk (1940, p. 176), the Williana formation is the basal part of the Pleistocene deposits of Louisiana (see stratigraphic column). Although the outcrop area of the formation lies in southern Vernon and Rapides Parishes north of the project area (pl. 4), the formation is an important part of the deposits in southwestern Louisiana. The formation name is derived from the terrace surface developed upon it in Grant and LaSalle Parishes named by Fisk (1938) for the town of Williana on the terrace. Because the terrace is believed to be deltaic, the deposits immediately beneath it are regarded as of contemporaneous and related origin and thus can be identified by the same name.

The Williana formation was deposited upon a pre-Pleistocene erosion surface, and as a result its thickness is somewhat irregular. However, the pre-Williana surface in general was not dissected deeply and probably formed a rather smooth regional terrane, as indicated by the map, plate 8. Structural changes—uplift or downwarp—during and after deposition probably are responsible for most of the irregularities.

Correlation of deposits downdip from the outcrop of the Williana is not well established. The outcrop area forms a belt about 4 to 6 miles wide from north to south, extends west to east across southern Vernon Parish, and its southern margin is not more than 6 to 10 miles north of the Beauregard Parish line. Because it is north of the area described in this report, it is not shown on the geologic map, plate 1. Where they are exposed, the sediments exhibit a three-phase sequence considered by Fisk (1938, p. 155) to represent cycles of fluvial to deltaic deposition. As described by Fisk, these deposits in Grant Parish are composed of the following phase.

> . . .a coarse [basal] phase, consisting of lenticular masses of sands and gravels; a central, predominantly sandy phase with local lenses of gravels; and an upper silty clay phase with local sand lenses.

With reference to the work of Fisk in Grant Parish, Welch (1942, p. 64–66) describes the sediments of the Williana formation at their outcrop in Vernon Parish as follows:

> These phases may also be distinguished in Vernon Parish but are not always present as distinct units. There is considerable transition laterally as well as vertically. Sand and gravel may occur throughout this section. Gravel may occur in lenses anywhere in the section or may be absent altogether; however, it is rare in the upper part of the section, which usually consists of clay and sandy clay, and occurs commonly in the lower half of the formation, frequently at the base. . . .
>
> The central or sandy phase normally makes up at least half of the formation. No clay was recorded in the Williana in the lower half of any of the geophysical borings.

Because the age of the Williana and the altitude of its outcrop have favored erosion and dissection by streams and perhaps because the upper stratum of silt or clay may never have been thick, exposures of gravel in this terrane are more common than elsewhere in southwestern Louisiana. Gravel pits are scattered across the outcrop area of the Williana formation in southern Vernon Parish (fig. 5), and it is likely that there are few parts of the outcrop area where permeable beds are not at or near the land surface (pl. 31).

The maximum thickness of the Williana formation in Vernon Parish, based upon records of beds penetrated by boreholes, is given by Welch (1942, p. 64) as 142 feet. If, as believed, the basal formation of the Pleistocene series shown on plate 10 represents the downdip equivalent of the Williana formation, its maximum thickness in the subsurface is about 200 feet. However, south of the latitude of Lake Charles and Crowley, it is composed of medium- to fine-grained sand and includes a marine fauna. In the vicinity of Washington in St. Landry Parish it is a massive fine-grained gray sand.

BENTLEY FORMATION

Named by Fisk (1938) for exposures in the vicinity of the town of Bentley in Grant Parish, the Bentley formation crops out in a broad expanse of upland plains in Beauregard and western Allen Parishes (pl. 1). Its surface generally is well preserved except along its eastern margin where tributaries of the Calcasieu River have scoured trenches about 80 to 100 feet deep, perhaps somewhat deeper. These trenches (for example, the valley of Bundick Creek) have been partially backfilled to form flat-bottomed flood plains along the lower courses of the streams.

Along the marginal slopes of the small valleys cut into the Bentley terrace there are excellent exposures of the sediments that comprise the Bentley formation (figs. 6 and 7). The three-phase sequence described by Fisk for each of the Pleistocene formations appears to be verified by the driller's log of well Be–5 (table 6) at De Ridder in Beauregard Parish.

Whether the deposits are all of the Bentley formation, or perhaps represent the Williana formation with a thin veneer of clay or shale of the Bentley at the land surface, cannot be determined from boring records. Because the area has been mapped as Bentley on the basis of the topography, it is assumed that deposits of the Williana might be present beneath it. According to the three-phase, four-cycle theory of deposition (p. 47) there should be, at De Ridder, two complete sequences, one above the other: gravel overlain by sand overlain by clay and silt; gravel overlain by sand overlain by clay and silt. However, only one sequence is present where information on the subsurface conditions is available. Where post-Bentley erosion has removed the clay-silt top stratum in several localities (fig. 6), very coarse grained gravel deposits have been exposed (fig. 7). The gravel occurs in a matrix of ferruginous sand and is composed principally of honey-colored chert. The gravelly deposit where penetrated by boreholes is massive, contains few clay or shale zones, and is about 70 feet thick at De Ridder. At Elizabeth, in Allen Parish, the base of the gravel is at a depth of about 167 feet, and the deposit is about 71 feet thick. The top of the gravel bed is near the land surface over broad areas (fig. 5), and gravel is taken from many pits. The texture of the deposit where penetrated by wells,

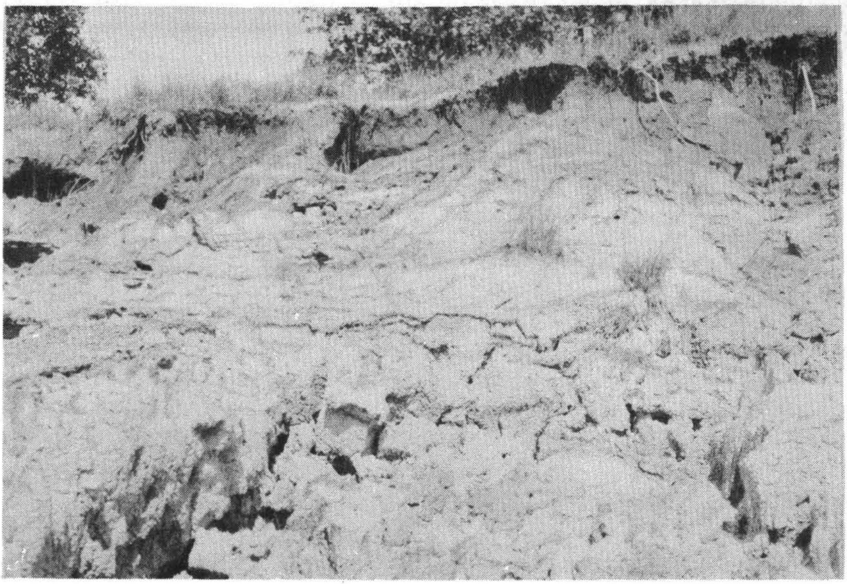


Figure 6.—Exposure of beds in the upper part of the Bentley formation. Ferruginous silty sand underlain by a fossiliferous zone of platy siderite (middle ground). Bentonitic "buckshot" clay underlies the fossil zone. Locality about 6½ miles southeast of De Ridder, Beauregard Parish.

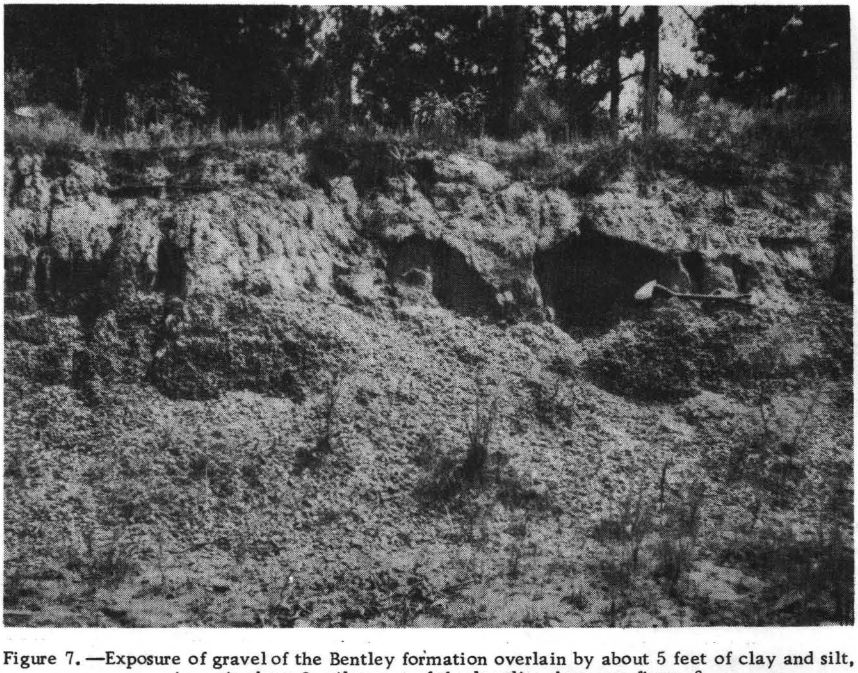


Figure 7.—Exposure of gravel of the Bentley formation overlain by about 5 feet of clay and silt, in a pit about 3 miles east of the locality shown on figure 6.

is illustrated by the analysis of samples from well Al-158 shown on table 7. The area of gravel exposures in the outcrop of the Williana and Bentley formations is the principal area of recharge, from rainfall, of ground water in the Chicot reservoir (p. 223).

The clay-silt top stratum of the Bentley formation is almost identical in texture and mineral content to that of the Prairie formation, described in detail in table 4, from drill cuttings obtained from a well at Kinder in Allen Parish. The character of the Bentley's surface exposures is shown by the photographs (figs. 8, 9, 10) taken in the Bundick Creek area near De Ridder in Beauregard Parish. These show a sequence of thinly laminated,

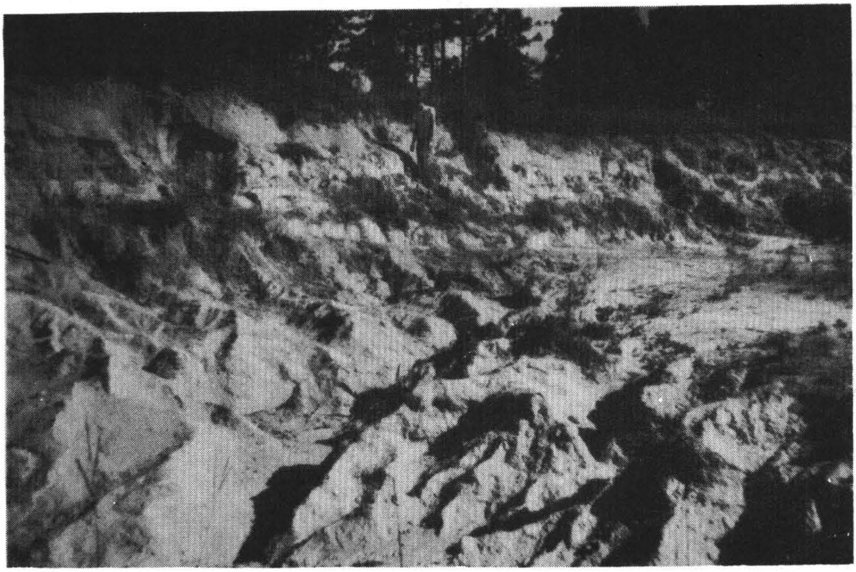


Figure 8.—Outcrop of the Bentley formation on south side of State Route 252 about 2½ miles southeast of De Ridder, Beauregard Parish.

tan silty sand overlain by 6 to 10 feet of white structureless, very fine sand that is, in turn, overlain by about 3 feet of clay, in part silty, in which sideritic (iron carbonate) concretions are very abundant and fossils occur. Ferruginous clay pellets, locally called "buckshot clay," occur abundantly in this zone and in the dense clays above. Where it is exposed to rainwash, the surface of the top stratum often is dotted with sideritic concretions on little pedestals of ferruginous clay.

Figure 9. —Thin-bedded silty sand in a road cut near the locality shown on figure 8. Separation of thin cemented laminae in about 1 to 2 inches.

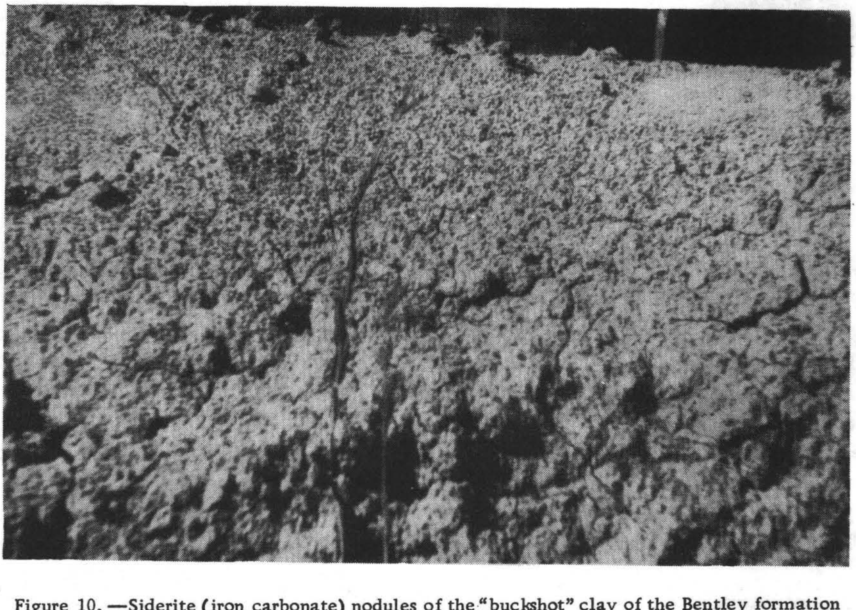


Figure 10. —Siderite (iron carbonate) nodules of the "buckshot" clay of the Bentley formation near the locality shown on figure 9.

Fossils collected by A. B. Jones from the Bentley at the locality near De Ridder were identified by J. P. E. Morrison, assistant curator of the Division of Mollusks, U. S. National Museum. Following are his identifications:

Quadrula cf. *Q. pustulosa* Lea group or possibly *Fusconaia* sp.; 9 specimens
Quadrula sp.; 2 specimens
Plectomerus dombeyana (Valenciennes); 5 specimens
Tritigonia tuberculata (Barnes); 1 specimen, female
Elliptio crassidens (Lamarck)?; 2 specimens
Proptera capax; 1 specimen
Lampsilis cf. *L. ventricosa* Lea group; 1 specimen
Lampsilis sp.; 3 specimens
Unidentified; 15 specimens

All the fossils identified represent forms still living in coastal Louisiana today.

The area of outcrop of the Bentley formation (pl. 1) covers most of Beauregard Parish and parts of northwestern Allen Parish. Because of its great areal extent, the relatively deep dissection of its margin by streams, its altitude, and its nearness to the rice-irrigation area, the geology of the outcrop area of the Bentley is vitally important to this investigation. As indicated on plate 31, the clayey top stratum is relatively thin throughout the outcrop area, which is the principal recharge area for ground-water supply from rainfall in southwestern Louisiana.

In the subsurface, the massive beds of sand and gravel of the Bentley formation extend gulfward at least as far as the northern boundary of Vermilion Parish (pl. 1). The clay top stratum is generally less than 50 feet thick (pl. 31) in the area of outcrop, partly as a result of postdepositional scour. Farther downdip, however, in central Jefferson Davis Parish and south-central Acadia Parish, the clayey top stratum is present, and available records indicate that it gradually thickens gulfward. Beneath the coastal marshlands the texture of the formation is fine grained, the clays compose a larger part of the formation thickness, and marine shells often occur in the fine-grained sands.

MONTGOMERY FORMATION

Named by Fisk (1938) for well-preserved surface exposures near the town of Montgomery in Grant Parish, the outcrop area of the Montgomery formation forms a belt of flat to gently rolling plains about 6 to about 20 miles wide which extends across southern Beauregard and northern Calcasieu Parishes, the northern part of Allen Parish, and the northwestern part of Evangeline Parish (pl. 1).

The near-surface deposits of the Montgomery formation are similar to those of the Williana and Bentley formations discussed previously, although evidences of weathering are less abundant. Montgomery deposits exposed on the west banks of Bayou Cocodrie in northwestern Evangeline Parish (fig. 11) are similar to the upper beds of the Bentley formation. Except where structural uplift has occurred over salt domes, as at Pine Prairie in Evangeline Parish, the gravelly substratum of the Montgomery formation is not exposed. However, the clayey top stratum is less than 50 feet thick in a narrow belt trending northwestward from Elton in Jefferson Davis Parish to near the Calcasieu River valley (pl. 31) and along the east margin of that valley northeast of Oberlin.

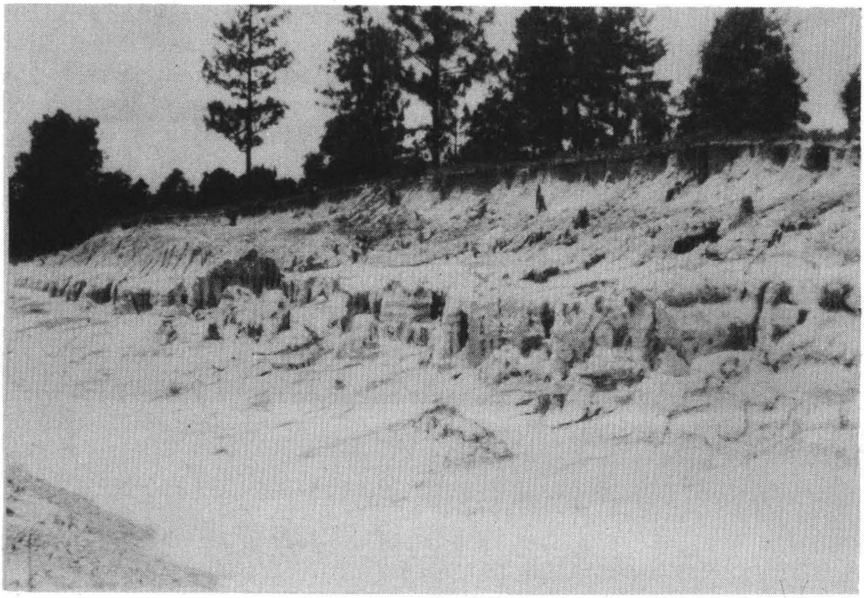


Figure 11.—Exposure of beds of silty clay in the upper part of the Montgomery formation on the west bank of Bayou Cocodrie, northwestern Evangeline Parish. Note similarity to the deposits of the Bentley formation shown on figure 8.

The character of the subsurface deposits of the Montgomery formation is illustrated by the records for a test well (Al–108) at Oakdale in Allen Parish. From the land surface to a depth of about 3 feet the deposit is dark-red to brown silty sand. This is underlain by soft buff clay and silty clay to a depth of 15 feet which in turn is underlain by a bed of fine-grained buff sand to a depth of 28 feet. Hard structureless blue clay interbedded with thin layers of yellow clay and coarse sand occurs between depths of 28 and 54 feet. A bed of blue fissile shaly clay 16 feet thick marks the base of the top stratum of the Montgomery formation at Oakdale, where it occurs at a depth of 70 feet. This sequence represents very well the lithology of the upper part of the formation throughout its area of outcrop in southwestern Louisiana, although there is wide difference in the thickness of the individual beds from place to place, and sometimes the blue shaly clay is overlain by a few feet of fine- to medium-grained blue sand.

Between depths of 70 feet and 145 feet at Oakdale the sand and gravel phase of the Montgomery formation is present, the upper 35 feet consisting of fine-grained blue-gray sand. The lower part of the deposit, about 40 feet thick, is coarse blue and gray sand with abundant chert gravel. The top of the Foley formation of Pliocene age, which immediately underlies the Montgomery formation at Oakdale, is marked by a bed of hard sandy shale.

PRAIRIE FORMATION

Named by Fisk (1938) for the broad, flat expanse of the prairie of southwestern Louisiana, this formation is at the land surface in most of the rice-farming area under study. As it is the youngest Pleistocene formation, its surface is best preserved, and interpretation of the geologic history of Pleistocene deposition is based largely upon study of the terrane of the Prairie formation.

Aerial photographs show that the near-surface deposits of the Prairie formation throughout most of its extent in southwestern Louisiana are stream-channel or flood-plain deposits (pl. 1). The abandoned channels of many streams are present, although they are somewhat altered and inconspicuous. Borehole records show the thickness and texture of stream deposits identified on the aerial photographs. On the basis of channel width and radius of curvature of meanders, and of the height width, texture, and color of the natural-levee deposits, it is possible to identify the streams that formed the deposits. The youngest (uppermost) deposits in the area between Lake Charles in Calcasieu Parish and Lafayette in Lafayette Parish are deposits of the Red River (pl. 1). During the period of the deposition the Red River probably entered the Gulf of Mexico without joining the Mississippi River.

Trending southwest toward the gulf from the city of Lafayette is a belt of meanders of considerably larger proportions. These resemble, in geometry and sediments, meanders of the modern Mississippi River and, without doubt, are good evidence that an ancestral Mississippi River crossed the eastern part of the Prairie terrace during late Pleistocene time, just prior to the last great stage of glaciation. It is quite likely that the thick impermeable clays that form the "hardpan" beneath most of the rice-farming lands on the Prairie formation have their origin as back-swamp clays formed during the development of this well-established Pleistocene Mississippi River meander belt. The channel and natural-levee deposits of the Red River which blanket the prairie area probably form only a thin veneer on the dense back-swamp clays laid down by the ancestral Mississippi River.

The map showing the thickness of the surficial clay in southwestern Louisiana (pl. 31) tends to support this theory. Along the meander belt of the ancestral Mississippi River the clay is thin, being less than 50 feet thick almost everywhere. Although not shown on the map, many borings show only 6 to 20 feet of clay at the surface in the meander-belt area. However, on both the western and eastern margins of the meander belt the thickness of the surface clay is much greater. This is in accord with the distribution and thickness of meander-belt and flood-plain deposits in the valley of the modern river.

The geologic cross section in figure 12 shows the profile of flood-plain deposits of the Mississippi River near Mayersville, Miss. As discussed by Fisk (1938), all these deposits are channel-fill materials, deposited by the Mississippi River in a broad scour trench cut into a terrane of Tertiary rocks, and the sequence of fill after scour is shown below.

1. Braided channels of a postglacial Mississippi River (similar to those of the modern Platte River in Nebraska) spread a broad blanket of sand and gravel down the valley. Gradients were steep, stream velocities were high, and the fine-grained sediments were carried gulfward from the area. Deposition of this type continued until an altitude of about 40 feet above sea level was reached on the profile.

2. The braided channels carried a progressively less vigorous flow as sea level continued to rise, and stream velocities in the lower valley eventually became insufficient to transport gravels. However, the velocities were still sufficient to transport and deposit sands and to carry silts and clays gulfward.

3. As the depth of fill reached a level about 60 feet above sea level on the Mayersville profile, the braided stream channels were suddenly abandoned and a single thread of channel was formed This stream followed a meandering course to the Gulf of Mexico, and because its stage had a wide seasonal variation—perhaps 40 feet or more—it formed a deep U-shaped channel. During periods

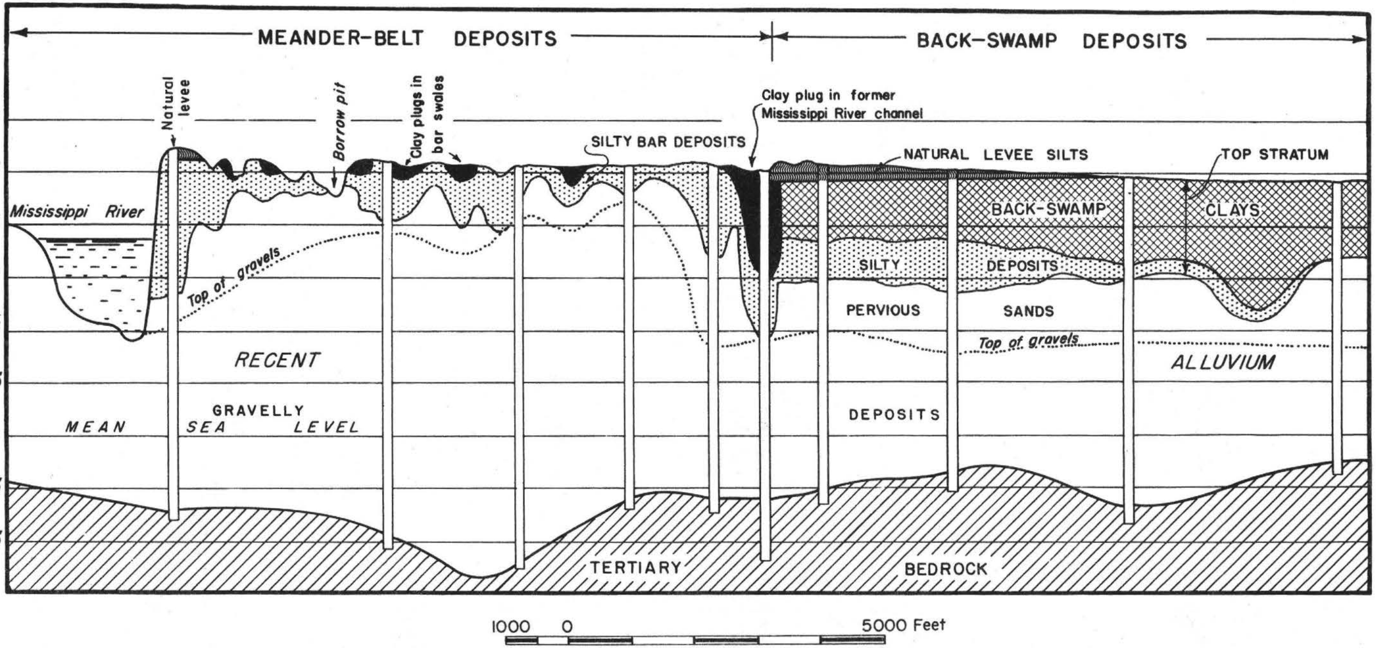


Figure 12. —Profile of deposits transverse to a Mississippi River meander belt.

387601 O - 56 - 7

of flood it readily scoured its channel into the sands and gravels below it and tossed them up to the surface on the insides of its bends. At the same time its floodwaters spread widely across the gently undulating surface of the older braided-stream deposits.

4. The thread of the current in time of flood was in the deep part of the channel, and as the waters spread thinly away from it over the valley flats, the velocity was lost, the transporting power was dissipated, and the sediments in suspension were dropped—the coarser (silt) near the channel margin, the finer (clay) at greater distance from the channel. With falling stage large areas of still water were left isolated from the trunk stream, and even the finest colloidal sediments were precipitated in the so-called back-swamp areas. Because the velocity decrease was most pronounced just outside the channel margin, the largest part of the suspended-sediment load was dropped there, forming a natural ridge or levee.

5. As this process continued over many hundreds or even thousands of years, the deposits of dense clay in the back-swamp areas gradually thickened. Meanwhile the river scoured its outer banks on the bends, spread sand and gravel on its point bars (the deposits on the insides of bends), and eroded away the natural-levee deposits along its flanks. But when its scour banks reached the thick mass of back-swamp clays, it could go no farther laterally, as the clays were difficult to erode. Thus the river channel was trapped between flanking deposits of back-swamp clays; and from then on the stream did nothing but rework, time and again, the coarse-grained deposits of the meander belt. This is the history of the relict meander belt of the ancient Mississippi River that trends southwestward from the town of Lafayette in Lafayette Parish and disappears beneath the Recent marshland northeast of White Lake in Vermilion Parish.

The map, figure 13, is an enlargement of a part of the relict meander belt described above. The area included on the map extends from Milton in southwestern Lafayette Parish to the northern end of Vermilion Bay. The regional relations of the area, which lies at the southeastern margin of the rice-farming area, are shown on plate 9 as well as on plate 1.

From Milton almost to Vermilion Bay the Vermilion River follows an abandoned channel of the meander-belt system. The channel of the modern stream is deep enough to cut entirely through the thin layer of clay that blankets the relict channels and point-bar deposits.

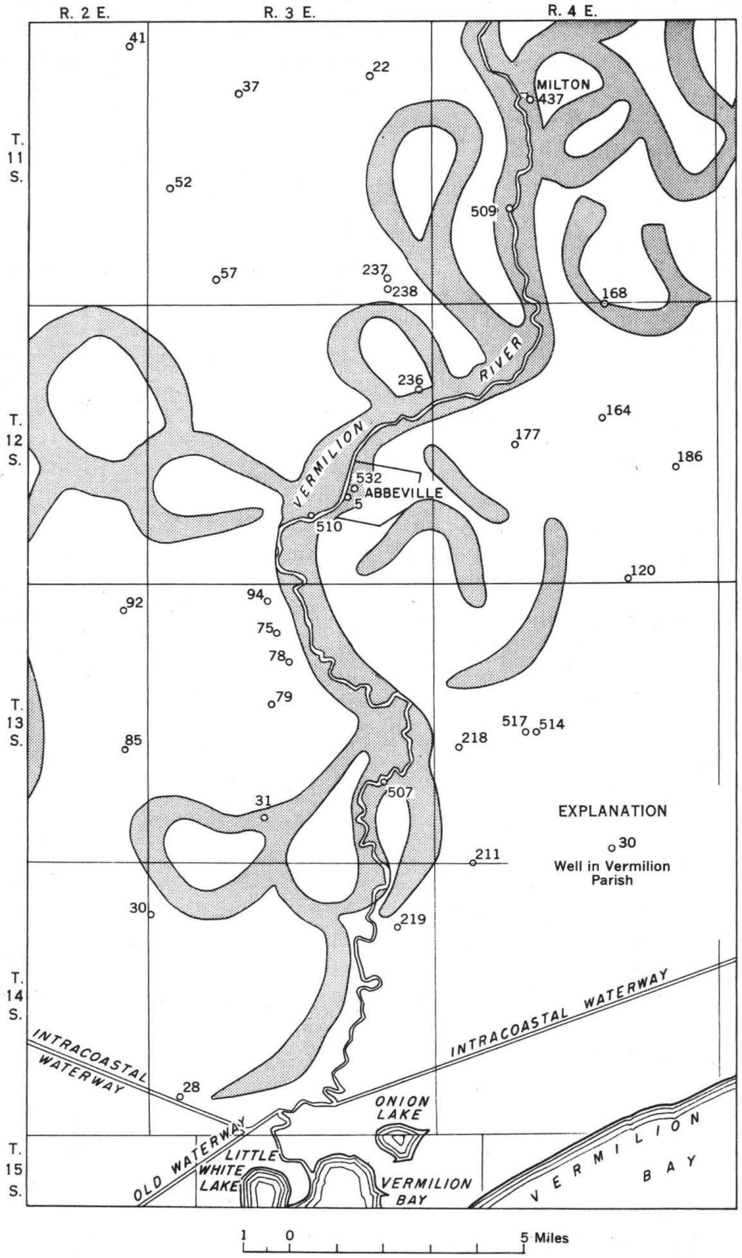


Figure 13. —Map showing the effect of the meander belt of a Pleistocene Mississippi River upon the modern course of the Vermilion River.

The land surface of the meander-belt area is dotted with small circular ponds and arcuate swamps. The ponds on the prairie probably have the same origin as the bagols (Holland, Hough, and Murray, 1952, p. 64) of the upland plains (fig. 4). R. J. Russell (oral communication, 1950) has suggested that they may have been formed by compaction of sediments that filled the scour pools ("blue holes") of the buried river channels.

The lithology of the Prairie formation is similar to that of the older Pleistocene deposits described above, except that oxidation of the clay-silt top stratum rarely extends below depths of about 40 to 60 feet. Zones of marine shells are common below the oxidized zone, both *Ostrea* and *Rangia* being abundantly represented. At the land surface, lime concretions are very common, especially near the margin of the coastal marsh. Cypress logs have been penetrated at different depths in the clay-silt top stratum, not only in that of the Prairie formation but also in those of the older Pleistocene deposits as well.

Beneath the bed of clay-silt and shells there is generally a fine-grained blue-gray sand which grades downward into hard blue-green shale, seldom more than 30 feet thick, or into medium-grained brown or yellow sand. This in turn grades downward into coarse sand and then into sand and gravel. Most water-well contractors drill 50 to 100 feet into the "pea gravel" and stop, but test-hole drill cuttings show that many of the pebbles in the lower parts of the formations are as large as walnuts, perhaps larger. If they are larger, the hydraulic-rotary method of drilling is not capable of lifting them to the land surface.

The character of the subsurface deposits of the Prairie formation at Kinder in Allen Parish is excellently portrayed in the detailed lithologic description in table 4. The nature of its mineral content is shown in table 5. It cannot be stated with certainty that the entire gravelly sequence logged by the test well at Kinder belongs to the Prairie formation; nevertheless, the general nature of the deposits cannot be mistaken.

The top stratum of the Prairie formation at Kinder is silt, probably of natural-levee origin. Surface features indicate that the near-surface deposits of this area were formed by meandering streams, and the texture and mineral content of the silty top stratum here resembles natural-levee deposits of the Mississippi River. That this locality lay within the meander belt of a major stream for a long time is indicated by the considerable thickness (70 feet) of the silt deposit.

At Kinder, between depths of 70 and 175 feet, there is a deposit of sand beneath the silt. The texture of the sand becomes coarser downward, from very fine grained at the top to medium grained in the middle and coarse to very coarse grained at the bottom. This textural sequence is comparable to that of the deposits of Recent age that underlie the flood plain of the Mississippi River.

Chert gravel is abundant at Kinder from a depth of 175 feet to about 388 feet. The writer believes that this thick deposit of gravel is composed of the basal parts of the Williana, Bentley, and Montgomery formations as well as of the basal part of the Prairie formation. However, there is apparently no reliable lithologic basis for differentiating the massive deposit of sand and gravel into formations; and, until further study provides a method of recognizing the beds of each formation where they thus occur, they must be lumped together. To the east, west, and south of Kinder there are beds of clay that divide the gravel into separate beds (see cross sections *A-A'* and *E-E'*, pls. 7 and 11), and these are believed to mark the formational changes of the Pleistocene deposits with depth. Although a rather tentative identification of the four Pleistocene formations defined by Fisk has been made on the geologic cross sections that accompany this report, the writer finds it impossible to correlate them throughout the area, as indicated by the statements above.

The deposits of the Prairie formation are thickest and have the coarsest texture along a north-south line through Crowley in Acadia Parish. This is believed to indicate that the axis of deposition of the Prairie was along this line and that the apex of the delta of the Prairie formation was in the Avoyelles hills northwest of Marksville in Avoyelles Parish. Available records on formation thickness and texture show that in southwestern Louisiana, the Prairie formation has the thickest gravelly section and the maximum gulfward extent of gravelly beds of the Pleistocene formations. Gravel of the Prairie alone has a maximum thickness greater than 400 feet and extends beyond the gulf shoreline between Creole, a few miles east of Cameron in Cameron Parish, and South Bend, at the east end of West Cote Blanche Bay, in St. Mary Parish, an east-west distance greater than 100 miles. Throughout this entire distance the gravelly bed is less than 300 feet thick in few places. This gravelly deposit has been logged by offshore oil tests at depths greater than 1,000 feet (R. J. Russell, personal communication).

Although the coarse-textured phase of the Prairie formation has excellent continuity along the gulf shoreline and throughout the central part of southwestern Louisiana, westward through the Lake Charles area in Calcasieu Parish and eastward through

Franklin in St. Mary Parish, its marginal facies change results in very complicated problems of correlation. Toward the flanks of the delta of the Prairie formation the texture of the deposits becomes finer, the granular deposits become thinner, and the bedding becomes lenticular.

The eastern margin of the delta of the Prairie was deeply incised in late Pleistocene time by the Mississippi River during the period of lowered sea level that accompanied late Wisconsin glaciation. Parts of the scour channel reached a depth some 250 feet below modern sea level (Fisk, 1944, pl. 3, sheet 2), removing not only the clayey top stratum but also a considerable thickness of the basal gravel.

As a result of the regional gulfward slope of the deposit, a slope that no doubt increased in steepness even as the beds were laid down, the clayey top stratum generally increases in thickness gulfward (pl. 31). Beneath the margin of the Gulf of Mexico the top of the basal coarse-textured member is less than 150 feet below sea level in few places. West of Cameron in Cameron Parish and east of South Bend in St. Mary Parish the thickness of the clay above the sand (or sand and gravel) member increases locally to 400 feet or more. It should be noted that the original thickness of the clayey top stratum was least along the axis of the Prairie delta described above (pl. 31).

RECENT SERIES

Extensive deposits of Recent age in southwestern Louisiana have been described in detail in previous reports, but no group name has been assigned. The thickest and most extensive deposits of Recent age lie beneath the Atchafalaya River basin. The gulfward margin of these deposits has been under wave attack for thousands of years, and it is the detrital material derived from them that has been carried westward along the gulf shoreline of Louisiana and redeposited there to form the vast coastal marshland. Thus all the deposits of Recent age in southwestern Louisiana are related, although their structure, texture, faunal content, and mineral assemblage differ greatly.

LE MOYEN FORMATION

The Le Moyen formation, first named in this report, is penetrated by water wells near the town of Le Moyen in T. 3 S., R. 4 E., in St. Landry Parish, La., on U. S. 71 about 43 miles southeast of Alexandria. The formation consists of two essentially equivalent members, one containing a large amount of sand or sand and gravel in the lower part and the other consisting mainly of silty clay or clay. It underlies all the modern flood plain of the Mississippi River and the broad coastal marshland along the gulf shoreline of southwestern Louisiana. Its upper surface is the land surface, and its base in Louisiana lies on rocks ranging in age from Eocene to late Pleistocene.

The Le Moyen formation is partly a channel-fill and partly a deltaic deposit beneath the Mississippi River flood plain, and principally an alongshore deposit in the coastal marshland. Its maximum thickness increases gulfward, but locally its thickness depends upon the configuration of the pre-Recent surface (pl. 2) and upon the structural subsidence that has occurred since the end of Pleistocene time. The maximum known thickness of the Le Moyen formation in Louisiana is about 300 feet, but at the type locality it is only about 260 feet thick. The basal sand and gravel is about 115 feet thick at Le Moyen and is overlain by dark organic clay.

Lebeau member.— First named in this report for deposits of the Le Moyen formation typically represented beneath the town of Lebeau, in T. 4 S., R. 5 E., in St. Landry Parish, on U. S. 71 about 6 miles southeast of Le Moyen, the Lebeau member of the Le Moyen formation underlies all the modern flood plain of the Mississippi River. Its basal part, a coarse-grained channel-fill deposit is entirely of fluviatile origin. Its upper fine-grained beds are silt and clay derived from floodwaters, and deposition of the Lebeau member continues to the present day.

Although the base of the clayey top stratum of the Lebeau member is not nearly so smooth as the present flood plain, it is much more uniform than the buried pre-Recent topography. The top of the gravelly (basal) stratum has been mapped by Fisk (1944, pl. 12), and its appearance in profile is shown by the geologic cross section from McCrea in Pointe Coupee Parish to Atchafalaya Bay (pl. 5).

The thickness of the clayey top stratum in general increases gulfward, although there are local differences. From its head at Naples in Avoyelles Parish southward to the latitude of Arnaudville (near the south boundary of St. Landry Parish), the bottom of the channel of the Atchafalaya River is cut into the basal sand and gravel deposits of the Lebeau. The thalweg of the river (the line of the deepest part of the channel) is shown in profile on plate 5, and it is apparent from this geologic section that the river is deep only where it can breach the surficial bed of clay. That it has cut through the surficial clay in its upper course more effectively than downstream may indicate that channel scour, in this instance, is progressing downstream. The volume and rate of flow of the Atchafalaya River have increased, not as a result of lowered base level at the downstream end but rather as a result of an increased rate of diversion from the Red and Mississippi Rivers, for which it is the only distributary. This channel scour is very important to the ground-water hydrology of southwestern Louisiana, for it provides an avenue of recharge to ground-water supplies of the project area.

As stated above, the Lebeau member lies in a pre-Recent channel cut into the Pleistocene terrane to depths that are as great as 300 feet and commonly are greater than 200 feet. The gravelly deposits of the Lebeau member therefore lie in direct contact with gravelly deposits of the underlying Pleistocene formations, a factor also vitally important to the ground-water hydrology of southwestern Louisiana because it enables ground-water movement from a line source of recharge to the areas of heavy pumping in the project area to the west.

Mermentau member.—First named in this report for deposits penetrated by water wells and boreholes in the vicinity of the town of Cameron, in T. 14 S., R. 9 W., in Cameron Parish, La., the Mermentau member of the Le Moyen formation consists of dark-colored marine muds, beach deposits of sand and shell (fig. 14), organic clays of the coastal marsh, and sediments formed in lakes and bays—all complexly interlaminated (fig. 15). These deposits are typically less consolidated than the underlying deeply oxidized clay of Pleistocene age, from which they are readily distinguishable on the basis of color. Their thickness increases gulfward and eastward, as a result of subsidence into the gulf coast geosyncline and the Mississippi structural trough. Their upper surface is the modern land surface, and their gulfward margin is offshore. Deposition of the Mermentau member continues today in the marshes where floodwaters of coastal streams are trapped with their suspended sediments, along the coast where sand and shell are thrown up during storms, and along the shore where detritus eroded from the deltaic beds of the Lebeau member farther east are redeposited. Landward the Mermentau member thins to a featheredge against the emergent Pleistocene deposits, near the northern boundaries of Cameron and Vermilion Parishes (pl. 1).

There is no exact line of demarcation between the deltaic deposits of the Lebeau member and the coastwise marine, beach, and marsh deposits of the Mermentau member. They are essentially contemporaneous and merge into one another approximately along a line drawn southeastward from Franklin in St. Mary Parish toward Atchafalaya Bay.

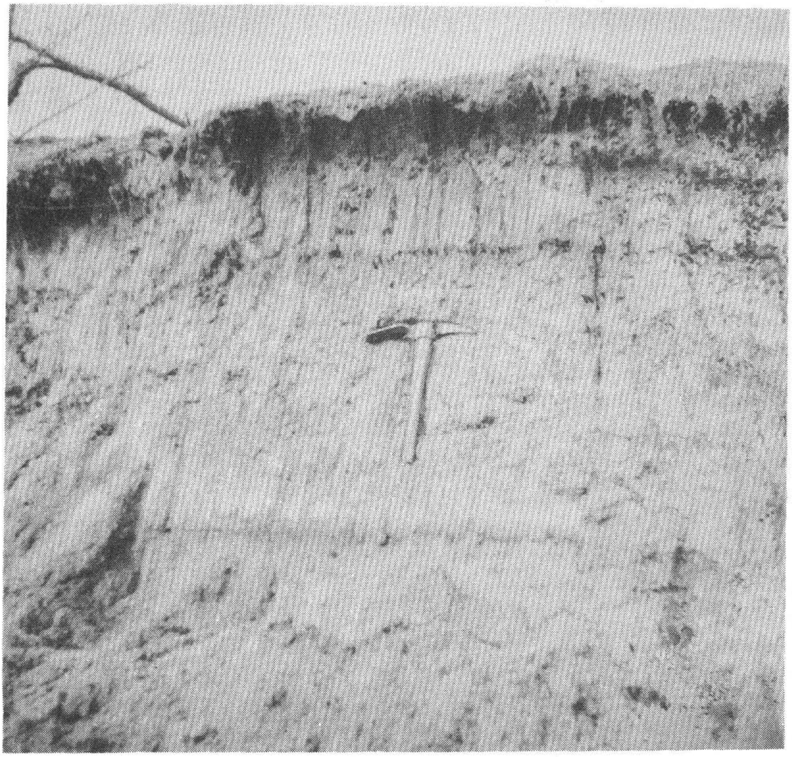


Figure 14. —Exposure of deposits of the Mermentau member of the Le Moyen formation forming Oak Grove Ridge, the eastward extension of Grand Chenier, near the mouth of the Mermentau River.

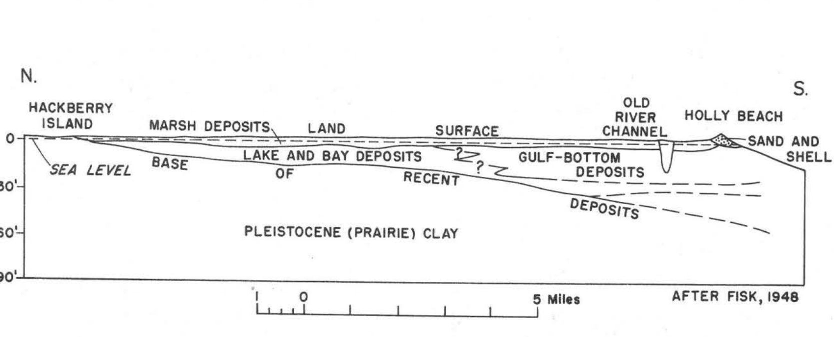


Figure 15. —Profile sketch from Hackberry Island to Holly Beach, Cameron Parish, showing type and distribution of Recent deposits.

The base of the Mermentau member lies upon the eroded gulf-marginal surface of the Prairie formation of Pleistocene age. The principal features of this buried topography (pl. 2) are the scour trenches of the coastal streams and their tributaries, described in considerable detail by Fisk (1948).

It is evident from these studies that the marsh deposits of the Mermentau member are more than 40 feet thick in few places along the margin of the Gulf of Mexico. However, the coastal streams deepened their channels during the pre-Recent decline of sea level, and borings show the bottoms of their scour trenches to be commonly 60 feet or more below the modern level of the gulf. Because few borings extend to the bottoms of the scour channels and because it is to be expected that at least the principal coastal streams would have cut their channels to the lowest position of the late Pleistocene sea level, these figures are, of course, minimum values. Perhaps the most significant feature of the pre-Recent surface beneath the Mermentau member is the scour trench of the Sabine River, the bottom of which lies no less than 200 feet below sea level. This is important to the ground-water hydrology of southwestern Louisiana, as it is probably responsible for the presence of salty water in all aquifers in southwestern Cameron Parish.

The character of the deposits of the Mermentau member and their vertical distribution along a line of profile from Hackberry Island, at the northern end of Calcasieu Lake in Cameron Parish, to Holly Beach, on the gulf shoreline about 8 miles west of Cameron, are shown on figure 15 (after Fisk, 1948). The marked predominance of fine-grained deposits in the section should be noted.

Perhaps the best-known features of the coastal marsh area are the Five Islands (pl. 1). Although these mounds are surrounded by marsh instead of water, they are islands nevertheless. They are composed, at their surface, of weathered Pleistocene clay and silt that have been uplifted by rising salt masses, or plugs. These, and Hackberry Island to the west of the same origin, are the only localities in the marsh in which the continuity of the Recent deposits is interrupted.

GEOLOGIC STRUCTURE

The dominant feature of the structural geology of southwestern Louisiana is geosynclinal subsidence. This structural control, and the repeated periods of accelerated deposition accompanying it, have resulted in movement of the shoreline alternately gulfward and landward for distances of several hundred miles; it has challenged the depositing power of streams to keep pace with it; and it has resulted in the preservation of perhaps the most complete sequence of Mesozoic and Cenozoic rocks in the world. Since Early Cretaceous time the structural keynote of the central part of the West Gulf Coastal Plain has been subsidence.

The almost universal gulfward slope or dip of the beds is altered locally where stable areas developed, of which perhaps the most important is the Sabine "uplift" of northwestern Louisiana. Others include the Jackson dome and Hatchitigbee anticline in the State of Mississippi and the Monroe uplift of north-central Louisiana. The Angelina-Caldwell flexure (Veatch, 1906, p. 67) has controlled the strike of the beds of southwestern Louisiana.

In southwestern Louisiana the salt dome is one of the most important structural anomalies in the gigantic monocline of gulfward-dipping beds. This type of structure, which is attributed by most authorities to the rise of a salt mass (a "plug") from some deeply buried "mother salt bed," is typically a local doming of beds over the salt mass, with pierced beds dragged steeply upward around the flanks (Barton, 1933, p. 1025–83; Bates and Bornhauser, 1938, p. 285–305). Where the salt mass is at great depth (6,000 feet or more), a graben structure is formed in the overlying beds (Wallace, 1944). The greatest diameter of salt-dome structures is seldom more than 3 miles, although radial faults may extend several miles away from the dome.

Because most of the beds in the Tertiary sequence of southern Louisiana are of deltaic origin and are poorly cemented and incompetent, compressional structures, such as anticlines and reverse faults, are rare. The most common regional fracture is the high-angle normal fault, which generally is parallel to or at right angles to the trend of the Appalachian fault system (Fisk, 1944, fig. 71). Several regional normal faults cross southwestern Louisiana from west to east almost parallel to the gulf shoreline, and these faults, which are almost invariably downthrown to the south, have a profound effect upon the migration not only of oil but of ground water as well.

THE GULF COAST GEOSYNCLINE

The deep structural trough that lies along the northern rim of the Gulf of Mexico has formed largely since the beginning of Mesozoic time. Although it was recognized by early investigators of gulf coast geology (McGee, 1892, p. 177–192), the immensity of its dimensions was not appreciated until late in the 1920's

(Howe, 1933, p. 39). The magnitude of downwarp was determined not only from geological evidence but also by geophysical means (Barton, Ritz, and Hickey, 1933, p. 1446–58), and it was soon recognized that the thickness of the Tertiary and Quaternary deposits present beneath the coast of southern Louisiana must be 30,000 feet or more.

The axis of the gulf coast geosyncline—the line that joins points of maximum downwarp of this trough—trends eastward along the Louisiana coast (pl. 8) and crosses the southern part of Marsh Island. West of the Sabine River it trends southwestward along the Texas coast.

The effect of downwarp continuing with deposition is to produce a gulfward thickening of the beds. Thus the older deposits dip southward more steeply than the younger beds that overlie them, and all the deposits thin northward. Viewed in north-south profile, the Tertiary and Quaternary sequences of beds would appear almost fanlike.

Although subsidence has nearly kept pace with deposition, the locus of maximum downwarp has shifted progressively gulfward with each great influx of rock debris. Each new flood of deposits has "leapfrogged" the previous mass of fill to form a new center of deposition, a new locus of downwarp gulfward from that of the previous cycle. This has been true, not only of the great Tertiary delta masses—the Wilcox formation, the Sparta sand, the Cockfield formation, the Catahoula formation, the Fleming formation of Fisk, and the Foley formation—but also of the Quaternary deltas. As described above, the delta complex of the Prairie formation (the youngest Pleistocene deposit) can be traced farther gulfward than any of the older formations of the Pleistocene series.

The structural control exercised by the gulf coast geosyncline upon Pleistocene deposition is shown on plate 8. Contours on the base of the Pleistocene deposits lie parallel in a general way to the axis of the syncline. Steepening of the dip gulfward is quite apparent south of the latitude of Opelousas in St. Landry Parish.

With further reference to plate 8, tentative correlation by the writer of the basal members of the Williana formation (oldest Pleistocene) penetrated by wells along the gulf margin south of Grand Lake in Cameron Parish and White Lake in Vermilion Parish indicates that the base of the Pleistocene deposits in that area is at a depth of about 2,100 to 2,200 feet.

THE MISSISSIPPI STRUCTURAL TROUGH

The axis of the Mississippi structural trough trends roughly northward beneath Opelousas in St. Landry Parish. This trough has had a profound influence upon the deposition of formations in southwestern Louisiana ranging in age from Early Cretaceous through late Miocene. Its effect upon the Pleistocene deposits is indicated on plate 8 by the northeastward swing of some of the contours, and although the downwarp along this axis has been marked, it is almost insignificant by comparison with that of the coast geosyncline. The gentle northeastward trend of the contours may be a reflection of slight regional downwarp toward the axis of the Mississippi structural trough. No doubt the relative importance of the trough increases greatly with distance from the gulf shoreline.

SALT DOMES

As indicated above, the most important secondary structural feature of southwestern Louisiana geology is the salt dome with its accompanying structural discontinuities. The map (fig. 16) shows the locations of 32 salt domes in the area covered by this report. The contours on the map, plate 8, depict regional conditions and do not show the marked local anomalies caused by the salt domes.

The effect of a salt dome upon the beds that overlie it depends upon the type and distribution of faulting produced. Deep-seated domes produce a broad gentle upwarp. Continued rise of the salt may cause upward and outward movement of the beds above the periphery of the plug, resulting in the development of a steeply dipping fault or system of faults radiating upward from the top of the salt "plug." The wedge of deposits thus formed, with its apex pointed downward toward the salt mass, slides downward relative to the rising beds on the flanks. Displacement may be only a few feet, or it may be several hundred feet.

Continued upward movement of the salt eventually causes rupture and piercement of all the overlying beds, as has occurred over two of the Five Islands (pl. 1). The effect of uplift over the Hackberry dome in northern Cameron Parish is shown on the geologic cross section *A-A'* (pl. 11). Displacement of beds in the freshwater section has exceeded 300 feet, and there has been a marked effect on the movement of the ground water. Rim synclines, caused by subsidence resulting from thinning of the "mother salt bed" as salt moved into the "plug," circle many of the piercement-type domes.

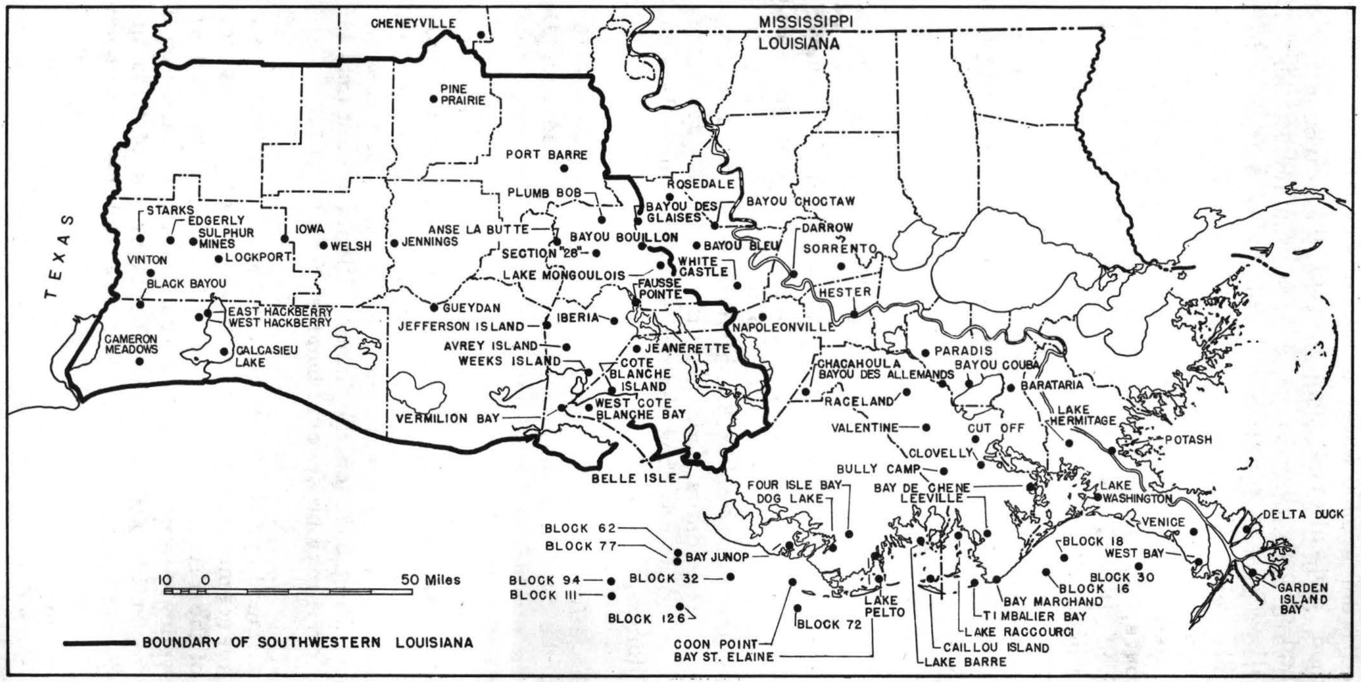


Figure 16.—Map showing location of south Louisiana salt domes.

The salt mass of a piercement-type dome generally is tightly sealed from ground water in the beds penetrated. Fault gouge and crushed and altered rock blanket the plug. Steeply upturned pinched-off beds abut it. Therefore, the principal hydrologic effect of salt domes is a function of the thinning of overlying beds and the faulting and folding they produce, rather than an effect on the quality of the water in the adjacent beds.

It should be noted that the line across Beauregard, Allen, Evangeline, and St. Landry Parishes, north of which there are few salt domes (fig. 16), conforms excellently to the line along which the base of the Pleistocene deposits begin to dip more steeply (pl. 8). South of that line, which is about on the latitude of Opelousas, the domes are abundant.

REGIONAL FAULTS

In an area of great structural movement the development of regional faults or fault zones should be expected. In southwestern Louisiana there is abundant evidence that major readjustments of the sediments have occurred along preferred lines as gulfward subsidence continued. Although the pattern of regional fracture generally reflects the continental fault-line pattern (Fisk, 1944, fig. 71), probably dictated by established lines of weakness in the crystalline basement rocks, there is a strong tendency for faulting along lines parallel to the axis of the gulf coast geosyncline. This is especially true along the margin of the zone of active subsidence.

The nature of the regional faults is related to the incompetence of the beds and to the shear mechanism resulting from gulfward downwarp and landward uplift. Not only is there a positive action causing normal faulting, with fault planes dipping southward and the beds displaced downward to the south, but there is also a maze of tension fractures resulting from flexure of the beds over the edge of the stable synclinal margin. Resulting branch faults in the downthrown block produce graben structures all along the fault zone, the branch fault planes dipping steeply northward into the plane ot the major fault. Although the writer has not shown as faults the apparent displacements of beds on the geologic cross sections accompanying this report, there can be little doubt that the displacements are faults. Regional faulting is evidenced between wells 4 and 5 on geologic section *A-A'* (pl. 11) and between wells 10 and 13 on section *E-E'* (pl. 7). It is also shown near and parallel to a line from Opelousas in St. Landry Parish southwestward to the Houston River area in Calcasieu Parish (see pl. 8). Whether or not the fault shown across the northern part of Calcasieu Lake on plate 8 is regional cannot be proved by means of drilling records, but the ground-water hydrology indicates that the fault extends westward to the Sabine River.

Movement along the regional faults is still active, and detailed study of the physiography of southern Louisiana has been used to excellent advantage by Howe, Russell, and McGuirt (1935) and Fisk (1944) to trace them. Such studies, supplemented with adequate drilling records, should enable a better analysis of the ground-water hydrology of southwestern Louisiana. The effect of faulting upon the occurrence of fresh ground water, upon salt-water encroachment, and upon the ground-water hydraulics cannot be overemphasized.

SURFACE-WATER RESOURCES

By E. L. Hendricks

The greatest surface-water problem in southwestern Louisiana is that supplies are insufficient to meet the needs for water to irrigate rice. When the volumes diverted for irrigation exceed streamflow, water is drawn upstream from the direction of the Gulf of Mexico. If periods of deficiency persist, saline waters move up the stream channels and ultimately reach the irrigation pumps. Farmers then do without irrigation water, use water having salt concentrations that (depending on the stage of plant development) may be injurious to their crops, or begin pumping from wells, if they have supplementary ground-water supplies.

The initial purpose of the surface-water investigation was to determine quantitatively the water-supply deficiencies by measuring the available water supply and the requirements for water by diversion from streams. In addition to fundamental inventories of supply and demand, the investigation was expanded to provide data on conveyance losses, consumptive use by rice plants, volumes of rainfall retained for crop use, and other components of the total water requirement. Consideration of specific plans for providing the additional water supplies required was not within the purpose or scope of this investigation.

The inventories of supply and demand were limited to the three areas in which critical problems exist; namely, the Vermilion, Mermentau, and Calcasieu River basins. The areas drained by these three streams and their tributaries are shown on plate 12. Although there are diversions from Bayou Teche and from the Sabine River for irrigation of rice in their respective basins, no problems have arisen in those basins that require, at this time, investigation on the same scale as in the three principal basins named.

The observational program covered three ricegrowing seasons, those of 1949, 1950, and 1951. Pumping records obtained from local irrigation companies made it possible to include data on diversions in each river basin for the 1948 season in the analyses presented in this report. The 4 years for which detailed analyses were made include two critically dry water-supply years, 1948 and 1951.

387601 O - 56 - 8

INVESTIGATIONAL METHODS AND PRESENTATION OF DATA

RECORDS OF STREAMFLOW

Records of flow at Geological Survey gaging stations, in operation before the beginning of this investigation, and many supplementary discharge measurements and stage records collected by the Corps of Engineers were used in this report. Because of tidal influences, daily gaging-station records are available only for the headwater areas of the principal streams. Gaging flow in the tidal reaches of the rivers was not practicable because of high operating cost and the limitations of available funds. It was necessary, therefore, to estimate runoff from large areas in each river basin.

Gaging stations in the area of study and the drainage area and period of record of each are listed in the following table.

Station	Basin	Drainage area (square miles)	Period of record
Bayou Bourbeau at Shuteston...	Vermilion..........	19.0	Oct. 1942 to date
Bayou Carencro near Sunset....	......do..............	37.1	Oct. 1943 to date
Bayou Nezpique near Basile....	Mermentau.........	527	Oct. 1938 to date
Cypress Creek near Pine Prairie	......do..............	56.0	Sept. 1948 to Dec. 1951
Bayou des Cannes near Eunice.	......do..............	131	Oct. 1938 to date
Bayou Plaquemine Brule near Crowley.	......do..............	252	Oct. 1942 to Sept. 1947
Calcasieu River near Glenmora.	Calcasieu..........	499	Aug. 1943 to date
Calcasieu River near Oberlin..	......do..............	753	Aug. 1922 to Jan. 1925 Sept. 1938 to date
Calcasieu River near Kinder...	......do..............	1,700	Aug. 1922 to Jan. 1925 Oct. 1938 to date
Whiskey Chitto Creek near Oberlin.	......do..............	510	Jan. 1939 to date
Bundick Creek near Dry Creek.	......do..............	238	Jan. 1939 to date
Beckwith Creek near De Quincy.	......do..............	148	Aug. 1945 to date
Hickory Branch at Kernan......	......do..............	82.2	Aug. 1945 to date

Runoff from the ungaged area in the Vermilion and Mermentau River basins and part of the Calcasieu River basin was computed by adjusting the rate of runoff from the gaged area by a variable part of the difference in rainfall on the gaged and ungaged areas. The method of determining this adjustment took into account infiltration rates and soil-moisture storage capacities and deficiencies. Monthly precipitation depths for each subarea were determined from isohyetal maps based on records from all possible sources. For further details, see determinations and estimates of flow in each river basin. The exact details of the methods of estimation used are not included in these discussions. Estimated monthly runoff volumes were apportioned into daily flow volumes on the assumption that the gaged and ungaged daily flow volumes were in the same relation to each other as the corresponding gaged and ungaged monthly flow volumes. Total runoff volumes thus derived represent the water reaching a river channel simultaneously at many points along the channel during a given period, rather than the flow past a specified point on the river during that period. This is advantageous inasmuch as withdrawals also are taking place along the stream channels simultaneously at many points.

Measured and computed daily flows were combined into 7-day volumes to facilitate analysis and to smooth irregularities inherent in shorter time intervals. The period in each year that requires detailed analysis is the growing season, April through October, and the 7-day volumes have been computed for only those months. For the other months in each year, monthly volumes were computed and tabulated.

It is unfortunate that so large a part of the available water supply had to be computed by indirect methods. This was necessary, however, because of the urgency of deriving useful deficiency criteria and because of the impracticability of any other method. To have measured the flow in the downstream reaches of the streams would have involved measurement of flow in both upstream and downstream directions in channels that are affected by tide and that have cross-section areas so large that water velocities are unmeasurable by any instruments yet available.

Although the utmost care and the best hydrologic knowledge were used in making the computations of flow included in this report, the limitations of the methods used must be recognized. Interpretation and application of the results should be made in full light of the knowledge that probable errors may be large and are inherent in water-supply problems where estimates of streamflow are necessary.

VERMILION RIVER BASIN

Gaging stations on Bayous Bourbeau and Carencro measure the runoff from an area of 56.1 square miles, or 8.6 percent of the 652 square miles of the Vermilion River basin above the Intracoastal Waterway. To compute the total fresh surface-water supply in the Vermilion River basin, it was necessary to estimate the runoff from about 596 square miles of the basin.

Flow records for Bayous Bourbeau and Carencro indicate that the flow measured at these two stations is almost entirely surface runoff. The computations of runoff from the ungaged area based on records for these gaging stations are, therefore, essentially estimates of surface runoff. Quantities of ground water in the basin, either flowing from or into the Vermilion River channel, are not included in the estimates that have been made. Computations given on pages 163, 164, however, indicate that the volumes of exchange between ground and surface water are small by comparison with other flow volumes in the Vermilion River.

Flow is diverted from Bayou Teche into the Vermilion River through the Ruth Canal (see pl. 12). For use in this report a rating of flow through the control structure on the Ruth Canal near Bayou Teche was developed on the basis of 18 measurements of flow made by the Geological Survey. This rating and daily records of head and gate openings at the control structure, furnished by the Corps of Engineers, were used to compute daily flow through the canal.

Bayou Fusilier connects Bayou Teche with the Vermilion River near the north end of the basin. Flow through Bayou Fusilier may be either to or from the Vermilion River, depending on the relative elevations of the river and of Bayou Teche. Daily flow through Bayou Fusilier was computed from approximate rating curves based on a slope-rating method described by Corbett and others (1943). The rating curves are defined by measurements of flow through Bayou Fusilier, made by the Corps of Engineers, and include fall, computed from the differences in elevation between Bayou Teche and the Vermilion River, as a factor.

The computed flows through Bayou Fusilier may not be very accurate, because the gages used in determining fall were not well located for use in developing slope ratings. The resulting records, however, represent about the best computations of flow in Bayou Fusilier that can be made from existing data.

A tabulation of the monthly flow volumes for the Vermilion River basin for the period October 1947 through October 1951 is given in table 8. Weekly runoff volumes for the 7-month period April through October in the 4 years 1948–51 are given in table 9.

MERMENTAU RIVER BASIN

The drainage area of the Mermentau River basin above the Intracoastal Waterway prior to the construction of Calcasieu Lock (see pl. 12) was about 2,610 square miles. After the lock was

Table 8.—*Monthly streamflow, in acre-feet, Vermilion River basin, 1947–51*

Month	Bayou Bourbeau	Bayou Carencro	Ruth Canal	Bayou Fusilier	Ungaged area	Total
1947						
October......	0	0	8,100	70	10	8,200
November....	600	1,400	20,000	200	49,800	72,000
December....	4,700	5,400	31,500	-8,300	98,300	132,000
1948						
January.......	3,200	3,900	26,000	-2,600	74,600	105,000
February......	2,800	2,600	20,400	-200	64,600	90,200
March.........	4,600	7,900	14,600	-5,200	78,600	100,000
April..........	1,400	6,000	22,600	-100	47,600	77,500
May...........	40	50	22,900	3,600	800	27,400
June...........	20	10	13,700	1,800	600	16,100
July...........	70	200	8,100	80	4,800	13,200
August........	100	200	13,100	80	10,800	24,300
September....	200	400	4,400	60	10,500	15,600
October......	0	0	4,200	60	1,000	5,300
November....	2,000	3,900	3,900	-100	82,500	92,200
December....	1,400	4,200	9,700	14,200	90,400	120,000
1949						
January.......	2,100	4,500	14,000	10,600	49,900	81,100
February......	2,600	5,600	12,000	3,900	58,600	82,700
March.........	6,000	12,000	10,700	2,600	149,000	180,000
April..........	3,500	5,600	11,000	4,500	50,500	75,100
May...........	600	2,200	29,800	14,700	29,800	77,100
June...........	2,900	2,700	31,300	4,500	71,700	113,000
July...........	5,900	6,800	14,600	5,800	141,000	174,000
August........	1,400	800	31,900	6,500	23,300	63,900
September....	80	200	11,700	200	4,100	16,300
October......	4,200	11,300	11,900	-11,700	158,000	174,000
November....	90	200	13,700	400	2,800	17,200
December....	700	1,800	8,800	2,700	25,000	39,000
1950						
January.......	9,400	15,300	8,900	-11,200	160,000	182,000
February......	2,400	4,800	13,000	4,100	46,100	70,400
March.........	4,100	9,000	19,700	5,000	113,000	151,000
April..........	1,400	4,400	21,600	7,300	52,200	86,900
May...........	2,000	5,100	30,500	9,200	82,000	129,000
June...........	3,600	5,900	20,600	-500	190,000	220,000
July...........	1,600	2,200	29,600	6,200	41,700	81,300
August........	400	400	15,400	1,000	6,500	23,700
September....	30	100	12,400	500	3,400	16,400
October......	0	10	7,700	200	50	8,000
November....	0	30	5,100	200	1,600	6,900
December....	2,000	5,500	4,200	3,900	72,400	88,000
1951						
January.......	2,800	4,400	7,700	8,700	64,300	87,900
February......	3,400	4,700	4,300	12,400	60,700	85,500
March.........	3,400	6,500	17,600	6,400	62,200	96,100
April..........	30	1,300	21,900	12,400	2,400	38,000
May...........	10	10	16,500	1,600	300	18,400
June...........	300	400	7,300	30	4,100	12,100
July...........	2,100	700	14,000	700	47,300	64,800
August........	30	10	13,300	400	2,000	15,700
September....	2,200	1,700	5,900	800	81,500	92,100
October......	20	10	5,900	300	500	6,700

placed in operation in January 1951, the effective drainage area was increased to about 2,760 square miles. The two principal gaging stations in the basin, Bayou des Cannes near Eunice and Bayou Nezpique near Basile, gage the runoff from a combined area of 658 square miles, or about one-fourth of the total area.

Table 9.—*Weekly streamflow, in acre-feet, Vermilion River basin, 1948–51*

Week ending	Bayou Bourbeau	Bayou Carencro	Ruth Canal	Bayou Fusilier	Ungaged area	Total
1948						
Apr. 8	10	10	5,000	900	70	6,000
15	500	3,700	5,300	-800	27,000	35,700
22	20	40	5,500	800	400	6,800
29	900	2,200	5,300	-1,200	20,200	27,400
May 6	10	30	5,300	800	300	6,400
13	20	20	5,200	900	500	6,600
20	0	0	4,800	800	20	5,600
27	0	0	4,800	700	20	5,500
June 3	0	10	5,700	700	60	6,500
10	0	10	5,300	600	100	6,000
17	20	0	4,200	500	400	5,100
24	0	0	1,100	300	20	1,400
July 1	0	0	800	80	30	900
8	0	0	100	0	0	100
15	0	0	1,500	10	0	1,500
22	60	200	2,900	40	4,500	7,700
29	10	0	2,900	20	300	3,300
Aug. 5	0	0	2,600	20	0	2,600
12	10	0	3,200	20	500	3,700
19	40	20	4,000	30	2,300	6,400
26	10	10	2,600	20	700	3,300
Sept. 2	50	100	1,800	0	7,300	9,200
9	0	0	1,000	0	0	1,000
16	200	400	700	10	10,200	11,500
23	20	0	1,100	30	300	1,400
30	0	0	1,200	20	0	1,200
Oct. 7	0	0	800	0	0	800
14	0	0	400	10	0	400
21	0	0	1,600	30	900	2,500
28	0	0	1,200	20	70	1,300
Season total	1,880	6,750	87,900	5,360	76,190	178,000
1949						
Apr. 8	1,000	600	500	-1,900	9,000	9,200
15	900	1,300	2,500	1,500	12,300	18,500
22	700	1,900	4,300	3,600	14,000	24,500
29	800	1,500	3,100	900	12,600	18,900
May 6	20	90	5,000	5,200	800	11,100
13	0	10	6,000	4,800	60	10,900
20	0	0	6,900	3,400	0	10,300
27	50	300	8,200	3,200	3,500	15,200
June 3	600	1,900	7,300	-400	26,000	35,400
10	1,400	800	7,800	1,700	27,800	39,500
17	1,500	1,800	6,600	-1,100	41,700	50,500
24	40	70	7,400	1,200	1,300	10,000
July 1	0	30	7,600	2,200	400	10,200
8	40	300	6,300	700	3,500	10,800
15	800	1,400	4,900	-100	24,400	31,400
22	3,200	3,300	400	-6,500	72,100	72,500
29	1,800	1,800	800	-600	40,400	44,200
Aug. 5	20	20	5,900	2,100	400	8,400
12	30	20	7,800	2,000	500	10,400
19	1,400	800	7,200	600	22,200	32,200
26	30	10	7,800	1,700	400	9,900

Table 9.—*Weekly streamflow, in acre-feet, Vermilion River basin, 1948–51*—Continued

Week ending	Bayou Bourbeau	Bayou Carencro	Ruth Canal	Bayou Fusilier	Ungaged area	Total
1949–Con.						
Sept. 2	0	0	5,600	500	30	6,100
9	0	0	3,000	40	0	3,000
16	60	200	2,500	30	3,300	6,100
23	10	40	2,900	40	800	3,800
30	0	0	2,200	30	40	2,300
Oct. 7	1,600	3,800	1,300	-2,900	54,600	58,400
14	2,200	6,400	400	-9,600	88,500	87,900
21	70	100	3,900	400	2,200	6,700
28	10	30	4,600	500	400	5,500
Season total	18,280	28,520	140,700	13,240	463,230	664,000
1950						
Apr. 8	250	1,200	4,600	400	12,700	19,200
15	0	10	4,700	3,100	100	7,900
22	0	30	4,600	3,000	300	7,900
29	300	1,300	6,000	2,500	14,200	24,300
May 6	1,000	2,500	4,800	-1,400	31,100	38,000
13	100	800	7,000	4,100	10,300	22,300
20	900	1,400	7,600	1,500	26,700	38,100
27	30	90	7,700	2,400	1,400	11,600
June 3	1,400	3,800	7,800	-300	76,600	89,300
10	1,200	1,800	400	-1,600	61,600	63,400
17	0	20	7,500	2,900	500	10,900
24	1,200	2,300	3,600	-200	71,200	78,100
July 1	700	200	6,700	-700	18,700	25,600
8	60	100	7,200	2,600	2,500	12,500
15	300	1,200	6,700	1,300	16,600	26,100
22	80	200	6,600	1,600	3,500	12,000
29	900	600	6,100	500	15,600	23,700
Aug. 5	200	100	5,900	600	3,400	10,200
12	0	40	4,600	400	300	5,300
19	10	0	2,600	50	100	2,800
26	300	100	2,400	50	3,000	5,800
Sept. 2	100	200	2,800	100	2,300	5,500
9	20	60	3,900	200	2,200	6,400
16	0	0	2,200	60	60	2,300
23	0	10	2,800	80	400	3,300
30	0	20	2,400	50	500	3,000
Oct. 7	0	0	3,200	50	20	3,300
14	0	0	1,600	20	0	1,600
21	0	0	900	20	20	900
28	0	0	1,300	50	10	1,400
Season total	9,050	18,080	136,200	23,430	375,910	563,000
1951						
Apr. 8	10	70	3,700	4,700	400	8,900
15	0	10	5,800	3,600	20	9,400
22	0	10	5,600	1,400	10	7,000
29	10	1,200	5,800	1,400	1,500	9,900
May 6	0	10	6,000	1,700	10	7,700
13	0	0	3,700	200	100	4,000
20	0	0	3,200	100	20	3,300
27	0	0	3,200	50	200	3,400

Table 9.—*Weekly streamflow, in acre-feet, Vermilion River basin, 1948–51*—Continued

Week ending	Bayou Bourbeau	Bayou Carencro	Ruth Canal	Bayou Fusilier	Ungaged area	Total
1951–Con.						
June 3	0	0	2,300	20	60	2,400
10	10	20	1,700	0	200	1,900
17	20	90	1,700	0	700	2,500
24	200	100	1,800	20	2,000	4,100
July 1	30	200	1,400	0	2,000	3,600
8	90	30	3,300	200	2,100	5,700
15	0	0	3,100	100	10	3,200
22	300	50	2,700	50	5,600	8,700
29	1,700	500	3,400	200	37,500	43,300
Aug. 5	70	10	4,500	300	1,500	6,400
12	0	0	3,700	200	10	3,900
19	0	0	2,700	30	0	2,700
26	0	0	2,400	20	300	2,700
Sept. 2	20	0	1,600	0	1,600	3,200
9	0	0	1,300	0	100	1,400
16	10	10	1,500	0	300	1,800
23	20	20	1,100	10	900	2,000
30	2,200	1,600	1,600	800	80,200	86,400
Oct. 7	10	0	2,600	290	200	3,100
14	0	0	1,500	40	20	1,600
21	0	0	800	0	20	800
28	10	10	600	0	300	900
Season total	4,710	3,940	84,300	15,420	137,880	246,000

To calculate the total fresh surface-water supply in the basin, it was necessary to estimate the runoff from about 1,950 square miles during 1948–50 and from about 2,100 square miles during 1951. Measured and estimated monthly flow volumes are given in table 10. Weekly runoff volumes for the 7-month period April through October in each of the 4 years covered by this report are given in table 11.

Table 10.—*Monthly streamflow, in acre-feet, Mermentau River basin, 1947–51*

Month	Bayou des Cannes	Bayou Nezpique	Ungaged area	Total
1947				
October	100	400	36,400	36,900
November	25,900	49,700	113,000	189,000
December	30,400	93,400	263,000	387,000
1948				
January	20,100	67,600	146,000	234,000
February	32,200	132,000	396,000	560,000
March	26,600	88,400	250,000	365,000
April	10,000	7,800	94,300	112,000
May	1,000	900	28,100	30,000

Table 10.—*Monthly streamflow, in acre-feet, Mermentau River basin, 1947–51*—Con.

Month	Bayou des Cannes	Bayou Nezpique	Ungaged area	Total
1948— Continued				
June	20	20	15,300	15,300
July	2,700	6,300	45,300	54,300
August	2,300	2,600	63,100	68,000
September	3,600	4,400	51,100	59,100
October	100	200	12,100	12,400
November	9,500	22,000	38,400	69,900
December	20,500	70,100	276,000	367,000
1949				
January	23,600	98,300	294,000	416,000
February	29,900	121,000	434,000	585,000
March	27,800	125,000	388,000	541,000
April	38,500	191,000	293,000	522,000
May	5,300	49,000	62,200	116,000
June	5,500	3,700	53,300	62,500
July	13,700	46,300	322,000	382,000
August	10,900	18,600	114,000	144,000
September	3,000	7,300	55,900	66,200
October	39,500	51,700	584,000	675,000
November	500	2,500	26,200	29,200
December	8,300	32,900	174,000	215,000
1950				
January	40,900	63,200	593,000	697,000
February	37,900	145,000	256,000	439,000
March	34,200	112,000	316,000	462,000
April	1,600	5,100	10,900	17,600
May	14,600	69,900	241,000	326,000
June	40,400	114,000	401,000	555,000
July	14,400	19,500	90,900	125,000
August	5,800	12,800	79,900	98,500
September	1,800	6,400	57,500	65,700
October	600	700	14,000	15,300
November	500	600	28,700	29,800
December	4,500	5,300	87,900	97,700
1951				
January	9,300	39,800	306,000	355,000
February	27,600	85,700	480,000	593,000
March	12,500	23,500	68,600	105,000
April	3,100	31,000	82,400	116,000
May	300	400	16,700	17,400
June	3,100	5,000	62,900	71,000
July	2,600	2,100	77,000	81,700
August	3,700	3,200	51,200	58,100
September	7,200	11,200	131,000	149,000
October	600	1,800	30,600	33,000

Table 11.—*Weekly streamflow, in acre-feet, Mermentau River basin, 1948–51*

Week ending		Bayou des Cannes	Bayou Nezpique	Ungaged area	Total
1948					
Apr.	8	20	200	400	600
	15	200	200	1,800	2,200
	22	200	300	2,800	3,300
	29	8,200	6,300	77,900	92,400
May	6	1,900	1,300	17,200	20,400
	13	300	200	14,700	15,200
	20	40	80	3,400	3,500
	27	30	10	1,100	1,100
June	3	100	40	3,800	3,900
	10	10	0	4,800	4,800
	17	0	0	5,500	5,500
	24	0	0	2,800	2,800
July	1	0	0	2,000	2,000
	8	200	1,500	9,200	10,900
	15	1,500	3,100	22,800	27,400
	22	400	1,200	7,700	9,300
	29	300	300	3,100	3,700
Aug.	5	500	700	9,400	10,600
	12	1,300	900	29,000	31,200
	19	400	300	9,600	10,300
	26	100	300	5,200	5,600
Sept.	2	500	1,000	17,400	18,900
	9	500	700	8,100	9,300
	16	1,800	1,300	18,500	21,600
	23	1,000	1,800	16,900	19,700
	30	100	300	2,300	2,700
Oct.	7	20	70	600	700
	14	20	30	1,800	1,800
	21	40	100	6,600	6,800
	28	20	30	2,400	2,400
Season total		19,700	22,260	308,800	351,000
1949					
Apr.	8	5,500	45,900	119,000	170,000
	15	9,400	29,400	39,500	78,300
	22	2,600	25,800	24,400	52,800
	29	17,000	69,000	73,200	159,000
May	6	7,300	55,100	53,100	116,000
	13	90	4,800	4,100	9,000
	20	50	200	800	1,000
	27	40	50	800	900
June	3	300	1,600	28,900	30,800
	10	400	100	3,500	4,000
	17	3,300	400	17,400	21,100
	24	700	900	7,600	9,200
July	1	1,100	1,500	12,000	14,600
	8	700	1,000	9,000	10,700
	15	1,400	3,100	24,200	28,700
	22	6,400	13,800	109,000	129,000
	29	4,900	24,700	159,000	189,000
Aug.	5	600	6,400	37,300	44,300
	12	3,000	2,900	22,200	28,100
	19	4,300	5,800	37,200	47,300
	26	2,600	5,400	29,600	37,600

Table 11.—*Weekly streamflow, in acre-feet, Mermentau River basin, 1948–51*—Continued

Week ending	Bayou des Cannes	Bayou Nezpique	Ungaged area	Total
1949—Continued				
Sept. 2	800	2,100	10,900	13,800
9	600	1,000	7,900	9,500
16	800	3,400	23,700	27,900
23	1,200	1,600	15,800	18,600
30	300	800	6,000	7,100
Oct. 7	6,600	10,600	110,000	127,000
14	22,300	29,200	330,000	382,000
21	10,000	10,600	132,000	153,000
28	500	900	8,600	10,000
Season total	114,780	358,050	1,456,700	1,930,000
1950				
Apr. 8	100	400	900	1,400
15	80	300	600	1,000
22	100	900	1,600	2,600
29	200	900	1,700	2,800
May 6	8,700	34,600	100,000	143,000
13	300	20,600	67,100	88,000
20	3,800	14,400	59,900	78,100
27	400	1,200	5,200	6,800
June 3	10,700	10,500	63,400	84,600
10	18,600	64,100	213,000	296,000
17	1,000	21,800	58,300	81,100
24	8,400	11,500	50,800	70,700
July 1	5,000	9,100	36,200	50,300
8	3,000	3,400	17,100	23,500
15	1,600	1,200	7,700	10,500
22	4,200	3,500	20,900	28,600
29	2,700	4,700	20,100	27,500
Aug. 5	4,200	10,900	42,800	57,900
12	1,700	1,800	17,500	21,000
19	800	1,500	12,400	14,700
26	700	2,400	16,600	19,700
Sept. 2	700	2,000	14,900	17,600
9	700	3,600	30,700	35,000
16	200	900	7,900	9,000
23	400	900	9,300	10,600
30	200	400	4,400	5,000
Oct. 7	100	300	3,500	3,900
14	60	100	2,100	2,300
21	200	80	3,600	3,900
28	100	200	4,000	4,300
Season total	78,940	228,180	894,200	1,201,000
1951				
Apr. 8	900	21,200	41,600	63,700
15	40	500	1,800	2,300
22	20	200	1,200	1,400
29	300	3,000	22,500	25,800
May 6	90	200	1,900	2,200
13	70	100	4,500	4,700
20	100	200	8,100	8,400
27	20	30	1,300	1,400

Table 11.—*Weekly streamflow, in acre-feet, Mermentau River basin, 1948–51*—Continued

Week ending		Bayou des Cannes	Bayou Nezpique	Ungaged area	Total
1951—Continued					
June	3	40	20	1,900	2,000
	10	800	10	6,200	7,000
	17	600	200	6,400	7,200
	24	1,400	4,400	43,600	49,400
July	1	500	600	9,600	10,700
	8	1,200	800	32,700	34,700
	15	300	300	10,600	11,200
	22	200	200	5,900	6,300
	29	500	500	17,200	18,200
Aug.	5	700	1,100	20,800	22,600
	12	600	800	9,900	11,300
	19	900	400	8,700	10,000
	26	1,400	700	14,400	16,500
Sept.	2	300	700	6,900	7,900
	9	1,100	1,500	17,900	20,500
	16	2,100	2,800	35,200	40,100
	23	800	2,100	20,900	23,800
	30	3,100	4,600	54,900	62,600
Oct.	7	400	1,400	14,600	16,400
	14	90	200	4,800	5,100
	21	50	50	3,300	3,400
	28	60	60	4,800	4,900
Season total		18,680	48,870	434,100	501,700

CALCASIEU RIVER BASIN

To compute the fresh surface-water supplies in the Calcasieu River basin, only that part of the basin above Lake Charles was considered. The total area of the basin above Lake Charles is about 3,170 square miles. There are five gaging stations measuring flow from independent areas within the basin: Calcasieu River near Oberlin, Whiskey Chitto Creek near Oberlin, Bundick Creek near Dry Creek, Hickory Branch at Kernan, and Beckwith Creek near De Quincy. Flow measured by the gaging station on the Calcasieu River near Kinder is affected by irrigation withdrawals above the station. The five key stations gage the flow from a combined area of 1,730 square miles, or nearly 55 percent of the total drainage area.

It was necessary to compute the runoff from a total ungaged area of about 1,440 square miles in the Calcasieu River basin. Upon the suggestion of the Ground Water Branch, the ungaged area was divided into three subareas labeled *A*, *B*, and *C* on plate 12. The sizes of these areas are 498, 578, and 362 square miles, respectively.

Ungaged area *A* is thought to be similar to the Bundick Creek and Whiskey Chitto Creek area in runoff characteristics. These streams receive large contributions of ground-water flow because their channels cut through the capping clay into the underlying sand and gravel aquifer. The daily flow from this area was computed by multiplying the combined daily flow of Whiskey Chitto and Bundick Creeks by the ratio of the ungaged area to the combined drainage areas of the gaging stations on Whiskey Chitto and Bundick Creeks (approximate ratio 0.67).

It is believed that drainage channels in ungaged area *B* do not cut into the aquifer. In this area, therefore, the unmeasured runoff is principally surface drainage. Examination of runoff records for Beckwith Creek and Hickory Branch indicates that the flow of these streams includes only very small volumes of ground-water flow. Runoff from ungaged area *B* was computed from the records for Beckwith Creek and Hickory Branch.

Ungaged area C lies east of the Calcasieu River and is similar in geology to the ungaged area in the Mermentau River basin. Runoff from ungaged area C was computed from records of flow at the gaging stations in the Mermentau River basin.

Measured and estimated monthly flow volumes are given in table 12. Weekly runoff volumes for the period April through October in each of the 4 years covered by this report are given in table 13.

Table 12.—*Monthly streamflow, in acre-feet, Calcasieu River basin, 1947–51*

Month	Beckwith Creek	Hickory Branch	Bundick Creek	Whiskey Chitto Creek	Calcasieu River at Oberlin	Ungaged area *A*	Ungaged area *B*	Ungaged area *C*	Total
1947									
October	100	30	4,300	10,000	3,100	9,500	300	4,000	31,300
November	2,300	1,300	18,400	37,100	26,200	37,000	37,800	40,600	201,000
December	12,800	7,700	36,100	71,900	136,000	71,900	46,700	39,500	423,000
1948									
January	14,200	13,000	27,700	53,900	92,400	54,300	79,000	46,500	381,000
February	26,500	19,700	45,500	94,700	198,000	93,400	123,000	100,000	701,000
March	8,600	6,800	20,400	56,400	111,000	51,100	39,400	28,400	322,000
April	2,600	800	8,500	21,500	40,500	19,900	11,800	13,100	119,000
May	500	50	7,400	20,000	11,900	18,200	1,700	3,600	63,400
June	200	30	4,600	11,100	4,300	10,400	800	600	32,000
July	900	100	4,700	11,100	4,200	10,500	5,400	7,700	44,600
August	100	10	4,000	8,800	3,000	8,500	1,400	8,200	34,000
September	80	20	4,800	10,200	3,200	10,000	600	9,300	38,200
October	200	10	4,300	7,900	2,800	8,100	300	2,400	26,000
November	12,200	6,600	45,500	90,300	106,000	90,400	30,200	6,600	388,000
December	8,500	6,600	20,200	60,100	120,000	53,400	32,900	34,400	336,000
1949									
January	23,500	19,100	41,300	95,500	157,000	91,100	93,200	42,400	563,000
February	38,300	26,200	45,600	90,900	189,000	90,800	170,000	126,000	777,000
March	51,900	36,800	66,200	130,000	228,000	130,000	241,000	77,000	961,000
April	61,500	34,000	83,300	216,000	348,000	199,000	186,000	91,800	1,220,000
May	9,100	2,900	25,900	37,300	77,700	42,000	25,200	22,900	243,000
June	5,500	1,200	10,100	22,400	9,300	21,600	22,600	12,300	105,000
July	5,900	3,700	10,600	32,300	31,100	28,600	25,200	53,200	190,600
August	500	200	7,400	20,000	24,600	18,200	2,300	17,200	90,400
September	200	400	6,500	13,500	5,600	13,300	1,400	11,400	52,300
October	12,100	11,000	20,200	37,700	30,700	38,500	99,800	99,500	350,000
November	600	500	6,600	17,000	11,100	15,700	4,400	4,600	60,500
December	21,700	14,800	36,000	65,400	98,400	67,500	97,800	39,300	441,000

1950									
January	17,800	8,500	35,700	81,400	158,000	78,000	56,600	59,300	495,000
February	48,400	28,800	98,700	165,000	329,000	176,000	133,000	86,400	1,065,000
March	28,500	23,000	41,300	94,400	180,000	90,300	122,000	86,600	666,000
April	8,000	7,100	15,500	51,500	33,100	44,600	23,200	2,300	185,000
May	27,400	9,400	53,100	137,000	192,000	127,000	85,100	45,000	676,000
June	50,200	26,900	77,700	151,000	257,000	152,000	274,000	98,800	1,088,000
July	3,800	2,000	15,200	33,900	23,900	32,700	19,400	13,700	145,000
August	1,000	90	6,400	19,400	11,700	17,100	2,800	13,400	71,900
September	1,000	200	6,500	17,900	11,600	16,200	3,000	12,700	69,100
October	400	20	5,700	13,900	6,400	13,100	1,800	4,700	46,000
November	600	50	6,100	14,500	14,600	13,800	2,300	7,300	59,200
December	700	70	7,000	18,200	14,600	16,800	4,000	12,700	74,000
1951									
January	8,100	6,100	24,300	60,400	166,000	56,400	10,200	29,700	361,000
February	8,200	5,100	16,900	48,000	91,200	43,200	48,600	53,800	315,000
March	7,900	3,500	15,700	37,400	42,400	35,300	41,000	27,400	211,000
April	4,900	400	12,600	33,200	113,000	30,500	14,900	26,600	236,000
May	400	50	5,800	15,900	46,800	14,400	1,200	2,800	87,400
June	200	10	4,600	11,300	8,000	10,600	400	7,500	42,600
July	1,100	2,400	5,000	12,500	8,000	11,700	11,800	10,500	63,000
August	400	200	4,100	8,700	4,700	8,500	2,200	7,200	36,000
September	6,200	9,200	14,900	17,400	4,600	21,500	29,800	15,500	119,000
October	1,000	200	4,800	10,700	6,400	10,300	2,500	3,400	39,300

Table 13.—*Weekly streamflow, in acre-feet, Calcasieu River basin, 1948–51*

Week ending	Beckwith Creek	Hickory Branch	Bundick Creek	Whiskey Chitto Creek	Calcasieu River at Oberlin	Ungaged area *A*	Ungaged area *B*	Ungaged area *C*	Total
1948									
Apr. 8	200	50	1,700	5,200	5,100	4,600	700	20	17,600
15	1,100	400	2,100	4,800	3,500	4,600	5,500	200	22,200
22	600	100	2,500	5,900	14,700	5,600	2,700	400	32,500
29	600	200	1,600	4,200	15,900	3,900	2,500	10,800	39,700
May 6	200	30	1,400	3,900	3,300	3,500	700	2,400	15,400
13	100	20	2,800	7,300	4,300	6,700	500	1,900	23,600
20	80	10	1,500	4,100	2,600	3,700	300	400	12,700
27	60	0	1,200	3,000	1,500	2,800	200	100	8,900
June 3	100	10	1,400	3,600	1,300	3,300	400	500	10,600
10	50	0	1,100	2,800	1,200	2,600	200	200	8,200
17	50	10	1,100	2,600	1,000	2,400	200	200	7,600
24	30	0	1,000	2,400	900	2,200	100	100	6,700
July 1	60	20	1,000	2,200	800	2,100	300	70	6,600
8	90	50	1,000	2,500	900	2,400	700	1,500	9,100
15	400	50	1,300	3,300	1,300	3,100	2,700	3,900	16,000
22	300	20	1,000	2,400	900	2,200	1,600	1,300	9,700
29	40	10	900	2,000	800	2,000	300	500	6,600
Aug. 5	20	0	900	2,300	800	2,100	200	1,400	7,700
12	50	10	900	2,000	700	1,900	600	3,700	9,900
19	20	0	800	1,700	700	1,700	200	1,200	6,300
26	10	0	800	1,800	600	1,700	100	700	5,700
Sept. 2	20	0	1,100	2,200	800	2,200	300	2,300	8,900
9	20	0	1,300	2,000	700	2,200	200	1,400	7,800
16	20	20	1,400	3,200	800	3,100	200	3,500	12,200
23	20	0	1,000	2,400	800	2,200	100	3,200	9,700
30	10	0	900	2,000	700	1,900	40	400	6,000
Oct. 7	10	0	900	1,800	700	1,800	30	100	5,300
14	100	10	1,200	1,900	600	2,110	200	400	6,500
21	40	0	900	1,800	600	1,800	70	1,300	6,500
28	20	0	900	1,700	600	1,700	30	500	5,400

387601 O - 56 - 9

Season total	4,420	1,020	37,600	89,000	69,100	84,100	21,870	44,590	352,000
1949									
Apr. 8	11,900	2,500	20,000	47,700	110,000	45,100	32,600	23,100	293,000
15	15,400	11,000	16,800	40,700	65,800	38,300	48,400	15,100	252,000
22	4,300	4,000	6,700	15,400	18,200	14,700	15,200	10,800	89,300
29	24,500	13,700	31,700	93,100	110,000	83,100	69,800	32,700	459,000
May 6	8,200	3,200	18,400	23,200	57,700	27,700	23,100	23,700	185,000
13	600	100	4,000	7,500	25,300	7,700	1,500	1,800	48,500
20	300	40	2,400	5,200	4,300	5,100	600	200	18,100
27	300	90	1,900	4,300	2,200	4,100	900	100	13,900
June 3	1,700	400	2,900	5,100	1,800	5,300	4,900	4,700	26,800
10	200	70	1,600	3,800	1,500	3,600	700	700	12,200
17	3,600	500	4,200	6,800	2,400	7,300	14,600	4,500	43,900
24	900	500	1,900	5,500	2,500	4,900	4,800	2,000	23,000
July 1	100	60	1,700	4,900	2,500	4,400	600	3,100	17,400
8	200	40	1,700	4,000	2,100	3,800	800	1,600	14,200
15	800	400	1,800	4,900	4,100	4,500	3,200	4,000	23,700
22	3,300	1,100	2,400	9,300	11,200	7,800	11,600	17,900	64,600
29	1,500	2,100	3,800	11,800	11,000	10,400	9,200	26,100	75,900
Aug. 5	100	70	2,800	5,600	8,800	5,600	600	6,100	29,700
12	300	20	1,900	4,500	4,100	4,300	1,000	3,300	19,400
19	60	10	1,400	5,600	8,900	4,600	200	5,600	26,400
26	50	50	1,200	3,700	3,900	3,300	400	4,400	17,000
Sept. 2	80	100	1,400	3,100	1,700	3,000	600	1,600	11,600
9	40	100	1,600	3,400	1,500	3,300	300	1,500	11,700
16	60	200	1,700	3,300	1,300	3,400	500	4,900	15,400
23	30	70	1,400	3,300	1,200	3,200	200	3,300	12,700
30	20	10	1,100	2,600	1,100	2,500	50	1,200	8,600
Oct. 7	3,400	6,500	7,800	12,600	7,300	13,600	42,800	18,800	113,000
14	5,800	2,400	3,700	10,400	9,600	9,400	35,400	56,200	133,000
21	900	500	2,400	5,000	7,100	4,900	6,000	22,500	49,300
28	1,600	1,500	5,200	7,300	3,400	8,300	13,400	1,500	42,200
Season total	90,240	51,330	157,500	363,600	492,500	347,200	343,950	303,000	2,150,000

Table 13.—*Weekly streamflow, in acre-feet, Calcasieu River basin, 1948–51*—Continued

Week ending	Beckwith Creek	Hickory Branch	Bundick Creek	Whiskey Chitto Creek	Calcasieu River at Oberlin	Ungaged area *A*	Ungaged area *B*	Ungaged area *C*	Total
1950									
Apr. 8	300	100	2,900	11,000	9,300	9,200	900	200	33,900
15	1,200	600	2,100	6,800	5,500	5,900	2,900	100	25,100
22	2,000	1,700	3,100	10,400	6,300	9,000	5,500	300	38,300
29	1,200	600	2,800	7,400	5,000	6,800	2,700	400	26,900
May 6	21,900	9,300	38,700	104,000	86,000	95,200	59,700	19,300	434,000
13	1,400	400	3,800	13,500	57,900	11,600	4,500	12,300	105,000
20	2,600	900	7,600	21,200	26,700	19,200	9,800	11,000	99,000
27	1,000	200	4,300	8,000	21,700	8,200	3,200	1,000	47,600
June 3	11,800	12,800	14,600	21,600	17,700	24,100	82,000	13,200	198,000
10	29,600	13,400	47,900	99,000	185,000	97,800	153,000	53,200	679,000
17	5,000	1,100	6,300	14,400	37,900	13,800	21,700	14,600	114,800
24	6,200	2,100	9,000	13,800	13,900	15,200	29,700	12,800	103,000
July 1	1,500	200	3,900	8,300	7,800	8,100	5,800	9,100	44,700
8	400	100	3,700	7,600	5,100	7,500	1,900	3,100	29,400
15	1,000	800	2,800	6,600	5,200	6,200	5,900	1,100	29,600
22	2,100	1,000	5,400	10,000	6,700	16,300	10,400	2,800	54,700
29	200	60	1,800	6,000	4,400	5,200	800	2,700	21,200
Aug. 5	200	20	1,700	6,100	4,400	5,100	600	5,800	23,900
12	100	10	1,600	4,600	2,700	4,100	400	3,100	16,600
19	90	0	1,400	3,600	2,200	3,300	300	2,200	13,100
26	90	30	1,400	4,800	2,600	4,100	300	3,000	16,300
Sept. 2	1,000	50	1,400	3,800	2,000	3,400	2,500	2,800	17,000
9	300	10	1,600	5,300	3,500	4,600	700	6,800	22,800
16	90	0	1,200	3,300	3,800	3,000	200	1,800	13,400
23	80	60	1,300	3,600	1,800	3,200	400	2,100	12,500
30	100	100	2,000	4,500	1,900	4,300	700	1,000	14,600
Oct. 7	100	10	1,700	3,500	1,800	3,400	500	900	11,900
14	60	0	1,100	2,900	1,200	2,700	200	700	8,900
21	70	0	1,200	3,000	1,100	2,700	300	1,300	9,700
28	90	0	1,300	3,400	1,700	3,100	600	1,400	11,600

Season total	91,770	45,650	179,600	422,000	533,800	406,300	408,100	190,100	2,276,000
1951									
Apr. 8	2,500	200	3,800	10,300	65,700	9,400	7,400	16,800	116,000
15	800	60	3,000	7,800	18,700	7,200	2,300	400	40,300
22	200	20	1,700	5,000	14,200	4,500	700	200	26,500
29	200	40	1,600	5,100	7,500	4,400	600	3,100	22,500
May 6	200	40	1,600	4,800	3,600	4,200	500	300	15,200
13	100	10	1,400	4,000	32,900	3,600	300	800	43,100
20	80	10	1,200	3,400	7,500	3,100	200	1,400	16,900
27	50	0	1,100	2,900	2,400	2,600	200	200	9,400
June 3	40	0	1,100	2,600	2,300	2,400	100	300	8,800
10	40	0	1,100	2,700	2,000	2,500	100	700	9,100
17	30	0	1,200	2,800	1,600	2,700	80	800	9,200
24	40	0	1,100	2,700	1,800	2,500	80	5,200	13,400
July 1	50	0	1,100	2,400	1,500	2,300	100	1,200	8,600
8	40	0	1,400	4,400	2,400	3,900	100	4,500	16,700
15	30	0	1,000	2,300	2,600	2,200	90	1,400	9,600
22	30	0	1,000	2,000	1,300	2,000	90	800	7,200
29	200	1,600	1,000	2,400	1,200	2,300	6,300	2,400	17,400
Aug. 5	900	900	1,200	2,900	1,800	2,800	6,200	2,900	19,600
12	70	20	900	2,000	1,100	2,000	300	1,400	7,800
19	60	0	1,000	1,800	900	1,900	200	1,200	7,100
26	70	60	800	1,700	800	1,700	600	2,000	7,700
Sept. 2	30	0	800	1,600	700	1,600	200	1,000	5,900
9	100	20	900	1,800	700	1,800	300	1,200	7,800
16	1,500	1,700	5,200	4,400	800	6,400	6,200	4,100	30,300
23	600	2,000	1,900	3,600	1,300	3,700	5,100	2,400	20,600
30	3,900	5,500	6,600	7,200	1,600	9,200	18,200	6,400	58,600
Oct. 7	800	200	1,600	3,100	1,800	3,100	1,900	1,700	14,200
14	90	30	1,000	2,400	1,200	2,200	200	500	7,600
21	60	10	900	2,100	1,100	2,000	100	400	6,700
28	50	10	900	2,200	1,700	2,100	100	500	7,600
Season total	12,860	12,430	49,100	104,400	184,700	102,300	58,840	67,200	591,000

RECORDS OF DIVERSIONS FOR IRRIGATION

There are hundreds of pumps in southwestern Louisiana that divert water from the streams that flow through the area. Their powerplants range in size from farm tractors to large stationary engines of several hundred horsepower. Many of the small pumps are on drainage ditches (fig. 17). The larger ones pump from the

Figure 17. —Tractor-powered pump diverting water from a drainage canal for irrigation of rice. (Photograph by Raymond Sloss.)

major stream channels (fig. 18). Pumping capacities range from about 1,000 gpm for the tractor-powered pumps to about 300,000 gpm for the large plants having several pumps. There are no canals in the area that can divert water from the streams by gravity flow.

In this investigation it was impracticable to measure the volume of water pumped from the streams by each plant in the three river basins. Instead, records of diversion were obtained for 15

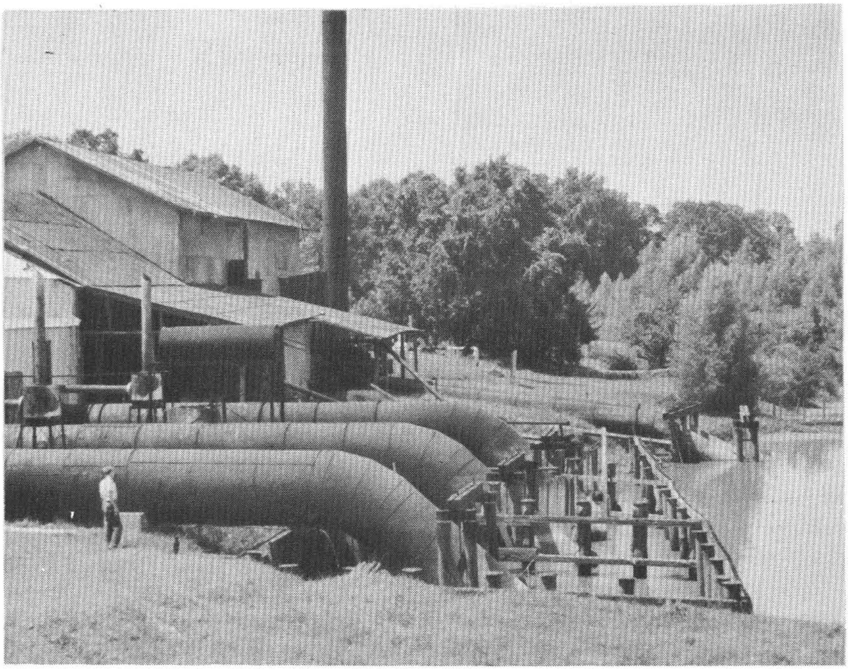


Figure 18.—Large pumping plant diverting water from the Vermilion River for irrigation of rice. (Photograph by Raymond Sloss.)

of the larger plants scattered widely over the area (for location, see pl. 12). Records were obtained also for one plant pumping from the Sabine River. These constituted a sample from which to compute the average rates of diversion. The total diversions in each basin were computed on the assumption that the average rate of diversion determined from the sample plants in each river basin represented the average rate for the entire basin. The following table gives the number of sample plants used in each year, the acreages irrigated by these plants, the total acreages irrigated in each river basin, and the percent of the total acreages irrigated by the plants sampled.

River basin	Number of sample plants	Acreages irrigated by sample plants	Total acreages irrigated in basin	Percent of area sampled
1948				
Vermilion	2	34,400	54,500	63
Mermentau	6	36,200	189,500	19
Calcasieu	....	....	51,000	....

River basin	Number of sample plants	Acreages irrigated by sample plants	Total acreages irrigated in basin	Percent of area sampled
1949				
Vermilion	2	28,700	51,500	56
Mermentau	11	63,600	188,500	30
Calcasieu	2	19,300	52,000	37
1950				
Vermilion	2	27,200	49,500	55
Mermentau	11	56,800	162,000	35
Calcasieu	2	17,500	49,000	36
1951				
Vermilion	2	31,400	47,000	67
Mermentau	10	56,700	157,000	36
Calcasieu	2	19,000	43,000	44

To obtain diversion records during the 3-year period of observation, it was necessary to solicit, from the major irrigation companies in the area and from many plant operators employed by these companies, cooperation in collecting daily records of hours of operation, pump speeds, and lift. Where gages were not already in use, staff gages were set to measure the level of the source stream and of the irrigation canals. These gages were set to a common datum to facilitate the computation of static lifts. Plant operators read these gages about twice daily and recorded the gage readings, the number of hours of operation, and the pump speeds in revolutions per minute during the periods of operation for each pump in the plant.

Ratings showing the rate of discharge under various combinations of speed and static lift were not available for the pumps. Personnel of the Geological Survey obtained several series of discharge measurements for each pump in the sample plants to determine their ratings. In order to simplify the rating procedure, static lifts were used in the ratings in place of dynamic lifts.

Wherever practicable, pump discharges were measured by current meter in canals or flumes. Because most of the sample plants have more than one pump discharging into the same canal, another method of measurement was required that would permit measurement of discharge from individual units. This necessitated measuring the flow in either the discharge or the suction pipe of each pump. Because the discharge pipes of most pumps were inaccessible, nearly all measurements of flow were made in suction pipes, which are under negative pressure.

Measurements of flow in the pipes were made by use of a pitot tube. This tube was inserted into the pipe through a valve in the wall of the pipe that would permit observations of water velocity at several points across the diameter of the pipe. The pitot tube was connected to a manometer containing a colored liquid heavier than water for measuring the difference between the dynamic and static pressures—this difference is the velocity head. By the use of appropriate formulas, readings of the manometer-column differences were converted into velocities of the water. Two pitot tubes were used in this investigation—one for pipes up to 48 inches in diameter and the other, reinforced to withstand high velocities, for pipes up to 72 inches in diameter.

Measurements of discharge were made by inserting the pitot tube into a pipe and measuring velocities at several points across the pipe. Usually 12 to 30 point-velocity determinations were made in order to compute the weighted mean velocity of the water. The diameter of each pipe at the measuring section was carefully determined by use of a pipe caliper. The product of the area of a pipe, computed from its measured diameter, and of the mean velocity of the water flowing in it gives the rate of flow through it.

The use of pitot-tube equipment in pipes under negative (less than atmospheric) pressure caused many difficulties. For accurate transmission of pressure to the manometer, all connecting tubes had to be completely filled with liquid. In pipes under positive pressure, water under pressure was allowed to flow through the tube ends until all air was displaced and then the tube ends were closed. To fill the manometer-tube system with water when measuring in pipes under negative pressure, it was necessary to exhaust the air from the system by use of a vacuum pump. When all air had been displaced by water rising from the pipe, the tube ends were closed. All parts of the system had to remain airtight.

An ordinary tire pump, with the valves reversed, was used to exhaust air from the tubes. The use of clear plastic tubing from the tube to the glass manometer enabled the operator to detect immediately the presence of air in the manometer system.

From 10 to 25 measurements of flow were made for each pump to determine its discharge rating. Together with the plant records of lift, hours, and speed, these ratings were used to compute the volume of water discharged by each pump during each day of the irrigation seasons. These daily diversion volumes were combined for all pumps measured in each basin and grouped into 7-day totals. The 7-day volumes pumped by the sample plants in each basin were increased in the proportion of the total acreage irrigated in the basin to the acreage irrigated by the sample plants, to compute the total diversion for irrigation in the basin.

These diversions are given in table 14 for the irrigation seasons 1948, 1949, and 1951.

Diversions by the plant on the Sabine River were computed for 2 years, 1950 and 1951. As these records were not used in any of the analytical phases of the investigation, the volumes diverted by this plant are omitted from this report.

The diversion records computed for each plant are believed to be accurate within a maximum error of about 10 percent. Acreages served by the plants are compiled from reports made by the farmers to the irrigation companies at the time contracts are drawn. The farmers probably know the acreages they are farming within a close margin of error, even though many of these acreages undoubtedly are estimated. The figures for total diversion, listed in table 14, are affected by these possible sources of error.

Records were not available for plants in the Calcasieu River basin during 1948. Estimated diversions in this basin during 1948, listed in table 14, are based on records for five pumping plants in the Mermentau River basin that were unaffected by the water shortage that developed in parts of the Mermentau River basin. Diversions computed in this way represent estimates of what would have been diverted in the Calcasieu River basin during 1948, if an ample supply of fresh water had been available to all irrigators in the basin. Because shortages of fresh water developed in the lower areas of the basin, the volumes of water actually pumped in 1948 cannot be accurately estimated. In subsequent analyses of the 4-year period, 1948–51, each year of diversion record will be appraised as to whether or not the records for that year fairly represent the actual volumes of water pumped (see p. 156, 171, 173, 178, 187, 190).

Table 14.—*Weekly diversions for irrigation, in acre-feet, Vermilion, Mermentau, and Calcasieu River basins, 1948–51*

[Diversions during 1948 from the Calcasieu River basin based on records for five pumping plants in the Mermentau River basin where pumping was not affected by water shortage]

Week ending	Vermilion River	Mermentau River	Calcasieu River
1948			
Apr. 8	0	0	0
15	300	3,400	300
22	0	8,500	2,100
29	6,900	11,000	2,800
May 6	11,400	36,800	9,000
13	13,100	35,400	9,600
20	16,200	51,000	12,700
27	15,500	47,000	13,000

Table 14.—*Weekly diversions for irrigation, in acre-feet, Vermilion, Mermentau, and Calcasieu River basins, 1948–51*—Continued

Week ending	Vermilion River	Mermentau River	Calcasieu River
1948—Continued			
June 3	11,200	28,400	8,000
10	16,900	53,400	13,100
17	11,300	38,200	9,800
24	16,600	47,700	11,500
July 1	13,500	46,800	13,700
8	8,600	18,400	6,900
15	2,700	15,900	5,100
22	7,100	44,000	9,000
29	13,800	29,200	8,100
Aug. 5	12,500	19,000	3,900
12	7,900	20,100	6,600
19	4,400	13,000	4,200
26	5,200	12,100	2,500
Sept. 2	700	700	300
9	1,400	4,400	1,700
16	700	4,600	1,700
23	0	3,900	0
30	200	1,500	600
Oct. 7	400	1,100	400
14	0	1,200	400
21	100	600	200
28	0	0	0
Season total	199,000	597,000	157,000
1949			
Apr. 8	0	0	0
15	0	600	0
22	50	100	0
29	0	800	0
May 6	1,600	4,000	80
13	5,100	12,600	300
20	6,300	16,800	1,000
27	7,500	24,600	4,200
June 3	6,600	16,500	2,600
10	10,600	37,900	5,100
17	6,200	22,800	6,900
24	11,200	39,900	11,500
July 1	13,000	43,800	10,200
8	8,700	19,200	3,400
15	8,900	26,600	4,000
22	1,100	1,200	900
29	6,200	6,500	100
Aug. 5	10,300	35,800	5,100
12	2,400	22,200	8,800
19	9,600	26,100	9,400
26	10,200	21,900	7,400
Sept. 2	5,900	8,200	6,600
9	2,900	12,400	2,500
16	4,900	11,400	6,900
23	600	2,100	1,000
30	100	1,000	2,400
Oct. 7	0	50	100
14	0	0	0

Table 14.—*Weekly diversions for irrigation, in acre-feet, Vermilion, Mermentau, and Calcasieu River basins, 1948–51*—Continued

Week ending	Vermilion River	Mermentau River	Calcasieu River
1949—Continued			
Oct. 21	0	0	0
28	0	0	0
Season total	140,000	415,000	100,000
1950			
Apr. 8	0	0	0
15	0	0	0
22	0	4,200	0
29	3,200	5,600	0
May 6	3,800	13,000	200
13	6,400	27,600	4,300
20	4,500	20,900	8,000
27	6,300	30,100	9,100
June 3	5,800	12,200	4,200
10	3,100	11,100	1,200
17	7,300	35,900	9,000
24	3,400	11,400	3,900
July 1	11,500	40,000	7,000
8	11,200	29,100	9,500
15	8,200	19,500	6,000
22	10,600	24,800	5,600
29	12,500	40,300	11,500
Aug. 5	10,300	22,100	8,100
12	7,600	30,900	8,200
19	12,700	20,200	6,900
26	10,800	20,600	6,700
Sept. 2	7,500	10,700	7,000
9	7,000	15,400	5,000
16	8,100	15,300	6,700
23	5,900	6,100	500
30	300	6,100	0
Oct. 7	0	2,300	0
14	1,400	600	0
21	1,600	700	0
28	0	0	0
Season total	171,000	477,000	129,000
1951			
Apr. 8	0	2,200	0
15	0	1,600	0
22	1,800	4,700	0
29	5,900	9,100	0
May 6	8,200	17,100	1,100
13	6,000	25,200	5,400
20	7,800	25,900	9,300
27	10,800	34,300	10,100
June 3	7,600	32,700	8,100
10	0	24,100	8,900
17	8,900	32,600	9,300
24	6,400	30,700	9,000
July 1	3,000	34,500	6,800
8	4,400	32,600	9,900
15	15,300	40,200	9,100

Table 14.—*Weekly diversions for irrigation, in acre-feet, Vermilion, Mermentau, and Calcasieu River basins, 1948–51*—Continued

Week ending		Vermilion River	Mermentau River	Calcasieu River
	1951—Continued			
July	22	11,400	37,800	10,100
	29	6,800	12,500	6,100
Aug.	5	0	5,800	4,400
	12	12,700	33,700	9,400
	19	13,200	21,800	8,600
	26	7,100	10,700	4,100
Sept.	2	9,000	20,600	2,400
	9	1,300	7,300	4,600
	16	0	5,300	1,100
	23	4,600	4,200	0
	30	0	500	0
Oct.	7	0	1,400	0
	14	400	1,500	0
	21	0	0	0
	28	0	0	0
Season total		153,000	511,000	138,000

DETERMINATION OF WATER REQUIREMENTS

In order to compute the possible maximum diversion rates in the years of most critical water supply, it was necessary first to determine the actual volumes of water used to grow rice in southwestern Louisiana. Determination of the parts of the total water requirements supplied by rainfall and by irrigation provided the means by which to compare variations in irrigation-season pumping with variations in seasonal rainfall and thus to determine the maximum irrigation requirements in years of critically low rainfall. Only in this way could the irrigation requirements measured during the relatively short (3-year) period of investigation be compared with the streamflow that likely would be available during the driest periods to be expected.

Water requirement, as used in this report, includes all water supplied to the ricefields by rainfall and by irrigation during the period the fields are submerged. It should be noted that the term "water requirement," as defined above, throughout this report on surface-water resources refers to the total volumes of water used on the ricefields, whereas the term "diversion requirement" refers to the volumes of water pumped from the streams for irrigation. The term "irrigation requirement" refers to that part of the water used on ricefields that is supplied by irrigation. That part of the water requirement furnished at the fields by irrigation (irrigation requirement) is less than that diverted from the streams at the pumping plants (diversion requirement) by the amount of the conveyance losses between the plants and the fields. With reference to rice culture, water requirements, as defined, include the following items.

1. Water entering soil-moisture storage and that lost by deep seepage.

2. Evaporation and transpiration (hereinafter called evapotranspiration or consumptive use). In the following analyses the water in the grain and straw at the time of harvest, although not evaluated separately, is included in the volumes assigned to evapotranspiration.

3. Water lost from the fields by the overflowing of levees or by accidental levee breaks.

4. Water intentionally drained from the fields during the growing season because of cultural practices.

5. Water drained from the fields at the end of the growing season.

As the determination of the amount of moisture required to germinate seed and to support plant growth before flooding and between final draining and harvest was outside the scope of this investigation, water needed for those purposes has not been included as part of the water requirement. Occasionally it is necessary for farmers to irrigate lightly to germinate seed or to soften the soil crust for plant emergence. The volumes of water used for this purpose, however, are small compared with the other components of the water requirement. Water remaining in soil-moisture storage after the fields are drained is adequate to supply the evapotranspiration demand during the period between draining and harvest.

Because investigation of water-resources problems in southwestern Louisiana was not planned to include an exhaustive investigation of the disposition of water on ricefields, the information obtained relative to the various components of the water used on ricefields was collected with the least possible expenditure of effort. This was done by enlisting the cooperation of many farmers in the collection of data. These farmers served without pay. The data-observation program made use of the simplest of measuring devices. The program was divided into three related phases: Determination of water entering soil-moisture storage in the upper soil stratum and that lost by deep seepage; determination of the other components of the water requirements by means of daily water-level readings and measurements of precipitation on selected ricefields; and more detailed determination of water requirements on two of the fields by use of flow-measuring devices and automatic water-stage and rain recorders.

SOIL-MOISTURE STORAGE AND SEEPAGE

The type and sequence of sediments that form the terrane of southwestern Louisiana make the area nearly ideal for the culture of rice. Crowley silt-loam ranging in depth from 6 to 24 inches lies upon a stratum of relatively impermeable clay, or hardpan, without a perceptible line of demarcation. The substratum of impermeable clay impedes water losses by deep seepage and makes possible the retention of water in surface storage. The surface soils in southwestern Louisiana range from sandy loam to loam. Soil-moisture storage and seepage tests were made over a broad geographic area to determine the range in amount of this component of the water requirement.

A trial step in the measurement of soil-moisture storage involved collection of soil samples from dry and from flooded fields and the determination of moisture content in soil in these two extreme conditions. The difference in moisture content of dry and saturated samples provided an approximation of the increment of soil moisture added by flooding with irrigation water. The term "dry field" as here used refers to a field not currently planted in rice and hence not artificially flooded. A "dry sample" refers to a soil sample taken from a field that is not currently flooded with water.

On September 1, 1950, soil samples from cultivated dry fields were obtained with a soil auger from two locations at the Rice Experiment Station, Crowley, at depths approximately 2, 6, and 10 inches below the surface. These are designated as samples 5A, 5B, and 5C and 6A, 6B, and 6C in table 15. On the same date, samples 3 and 4 were collected from a dry field that was in pasture by driving a thin-walled brass cylinder, 2 inches in diameter and 24 inches in length, into the soil. In the month preceding the taking of the dry-field samples, there was a total of 2.08 inches of rain, 0.44 inches of which occurred on the day before the samples were taken.

Two core samples were obtained from a flooded ricefield at the Rice Experiment Station on September 1, 1950. This field had been under water continuously since May 29, 1950. The flooded-field samples are listed as samples 1 and 2 in table 15.

Table 15.—*Moisture content of soil samples collected in vicinity of Crowley, La.*

[Samples 1 and 2 are from submerged fields and the rest are from dry fields]

Sample	Depth below land surface (inches)	Weight of dry soil (grams)	Weight of water (grams)	Water content (percent)
1	2	23.816	9.240	38.8
	6	31.661	7.116	22.5
	10	32.231	7.812	24.2
2	2	36.820	11.736	31.9
	6	27.268	5.368	19.7
	10	37.349	9.473	25.4
3	2	24.332	4.617	19.0
	6	29.010	5.616	19.4
	10	31.285	7.139	22.8
4	2	29.472	5.509	18.7
	6	27.122	5.889	21.7
	10	28.523	6.623	23.2
5A	2	18.902	3.435	18.2
5B	6	21.492	4.571	21.3
5C	10	20.704	5.547	26.8
6A	2	21.403	3.886	18.2
6B	6	20.247	3.878	19.2
6C	10	24.256	7.098	29.3

In preparation for moisture analysis, all samples at the time of collection were sealed with paraffin wax to prevent loss of moisture in transit. All samples were analyzed for water content by the Soils Laboratory of the Louisiana Department of Highways as soon as practicable after collection. In the laboratory, sections were cut from the core samples in order to determine moisture content at depths of about 2, 6, and 10 inches below ground surface. The results of the laboratory analyses are given in table 15.

These analyses indicate that in the dry fields on the day sampled there was an increase in moisture content with increasing depth. Percents of moisture averaged 18.5, 20.4, and 25.5 at depths of 2, 6, and 10 inches, respectively. The samples taken from the submerged fields averaged 35.4, 21.1, and 24.8 at depths of 2, 6, and 10 inches, respectively. At the 6- and 10-inch depths the samples taken from the dry and the flooded fields show nearly identical moisture content at corresponding depths. The results of these tests indicate, therefore, that the increase in moisture content caused by flooding was confined to the upper 5 or 6 inches of the soil stratum, despite the fact that the field from which the saturated samples were taken had been submerged continuously for 95 days prior to sampling. As the normal depth of cultivation is 5 to 6 inches, it would appear that, in the Crowley area at least, moisture changes resulting from flooding are confined to about the depth of cultivation.

The soil-moisture analyses discussed in the foregoing paragraphs were used to compute approximate soil water increments added by flooding. Soil water was computed in inches of depth to which the soil water if extracted from the soil, would fill a cylinder having a cross-section area equal to that of the column of soil from which the water was removed. Columns of soil 6 inches long of unit cross-sectional area having void ratios and water content as determined at the 2-inch-depth points in samples 1 and 2 (from flooded fields) were computed to contain 3.0 and 2.8 inches of water, respectively, or an average of 2.9 inches. If, for samples 1 and 2, the water content of a 6-inch column is taken as the average of the 2- and 6-inch depths, the computed amounts are 2.4 and 2.2 inches, respectively, or an average of 2.3 inches of water.

A similar computation of the water in the dry field samples (samples 3–6, table 15) gives an average of 1.6 inches. Subtracting this amount from the 2.9- and 2.3-inch averages computed for the flooded-field samples gives 1.3 inches and 0.7 inch, respectively, as estimates of the amount of the water applied to the flooded field that went into soil-moisture storage in the samples tested.

There is evidence in these analyses that little, if any, irrigation water was lost to deep seepage. It is probable that the moisture content measured at the 2-inch depths in the flooded fields represents conditions in the top 6 inches of soil more nearly than does the average of the 2- and 6-inch depth measurements. Therefore, 1.3 inches of water is probably nearer the correct measurement, in these samples, of the soil-moisture storage increment resulting from flooding.

The principal program for determining soil storage and seepage losses from ricefields involved simulation, on a small scale, of the flooding of a ricefield. Tests were made on 17 ricefields scattered widely over the ricegrowing area of southwestern Louisiana. These fields were, as nearly as possible, the same ones used as test areas in the determination of the other components of water requirement (for location, see pl. 12).

The equipment for each test consisted of a pair of cylindrical tubes 8 inches in diameter and made of 18-gage galvanized iron. One tube, hereafter called an infiltration tube, was 36 inches in length and open at both ends. The other tube in each pair, hereafter called an evaporation tube, was 18 inches in length with the lower end sealed by a metal cap.

The infiltration tubes were driven to a depth of about 24 inches. By driving them to this depth, it was expected that they would be seated in the dense clay substratum and that lateral seepage would be reduced to a minimum. One such tube was placed in each test field 1 or 2 days before the first flooding, and water was placed in it to a depth of 6 to 8 inches to simulate flooding of the field. Observations of water level in the tubes with hook gages were begun within a few seconds after water was added. During the first hour after adding water, readings were made at 5- or 10-minute intervals. After that, the time between observations was lengthened gradually to a maximum of 1 week. Readings during the first 2 or 3 days usually were made by the field engineer. Subsequent readings usually were made by cooperating observers.

Although the infiltration tube was covered and evaporation losses were very low, an evaporation tube was set into the ground within a few feet of each infiltration tube to enable adjustment of the apparent infiltration depths for the small effect of evaporation. Both tubes were set to about the same height above ground level (about 12 inches) and filled with water to about the same depth. Both were covered with wooden lids to prevent entrance of precipitation. The tubes were set in each field so as to be within the submerged area when the field was flooded.

The difference between two successive water-level readings in each infiltration tube represented the depth of water which had infiltrated into the soil plus that which had evaporated during the interval between readings. Because of the similarity of external exposure between each infiltration tube and its companion evaporation tube, evaporation from companion tubes was assumed to be identical. Thus to determine the infiltration depth, over a period of time or between observations, the water-level change in the evaporation tube was subtracted from the corresponding water-level change in its companion infiltration tube.

A pair of these tubes were left in place in eight fields throughout the growing season. In the other nine fields, the equipment was removed within a few days after the field was flooded. These nine short-duration tests are hereafter called partial tests. A sample of one of the records of infiltration is given in figure 19. This sample was selected in preference to others because of its completeness and relative accuracy.

The equipment used in these tests was relatively simple but served well in giving the approximations desired. Some difficulties were encountered which may have affected to a limited degree the accuracy of the results. Several of the wooden covers may have permitted some rain water to enter the tubes. Errors

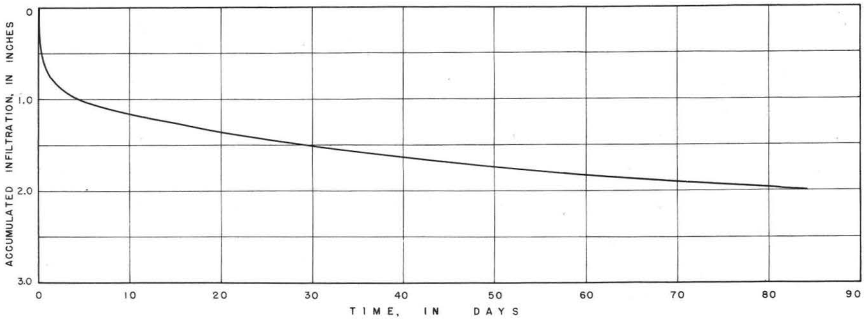


Figure 19.—Sample curve of infiltration of irrigation water into soils of southwestern Louisiana.

from this source, however, probably were very small. One tube may have leaked at a seam. Hook-gage readings were estimated to the nearest 0.001 foot, but the probable maximum error in reading was about 0.005 foot. Sufficient field personnel were not available to make an adequate number of accurate readings, and the cooperating observers experienced considerable difficulty in reading the gages. The results obtained in these tests will be only summarized here.

The greater part of the observed infiltration occurred during the first 2 days after the tests began. Sometime within the first 15 days of all tests, the infiltration rate decreased to about the rate that continued to the end of the test. For the eight tests that extended through the greater part or all of the growing season, the periods of observation ranged from 42 to 102 days. Total infiltration ranged from 0.7 inch to 2.9 inches of water, averaging 1.8 inches. Of the seven partial records that were analyzed, five gave results similar to those from the complete tests. One partial test made near Kinder, the northernmost area tested, indicated a total infiltration of about 3.5 inches. In another set of observations made near the coastal marsh area, an infiltration of 4.5 inches in 26 days was measured.

The total infiltration during a ricegrowing season, based on all tests, ranged from 0.7 inch to 3.5 inches of water and averaged about 2 inches. Inasmuch as the soil was extremely dry at the beginning of all tests, these results represent about the maximum depths of irrigation water that may be expected to go into soil-moisture storage in southwestern Louisiana during an irrigation season. When allowance is made for the effect of antecedent precipitation, the 1.3 inches of water absorption computed from the laboratory soil analyses is in reasonable agreement with these results.

387601 O-56-10

About half of the infiltration tests that extended over the entire irrigation season showed a small rate of infiltration continuing to the end of the test period (see fig. 19). In the other tests there was no measurable rate of infiltration during the latter part of the period. At the time each infiltration tube was removed from the fields, the soil core was examined carefully for evidences of moisture saturation. Saturation was not detected below a depth of 6 or 8 inches in any of the cores examined. On the basis of this evidence it does not appear that there is a separate water loss that can be called a deep-seepage loss in any of the areas in which tests were made. Thus it can be assumed reasonably that all irrigation water that infiltrates into the soil in this region is retained in soil-moisture storage.

The results summarized in the foregoing paragraphs represent only a small sample of the different soil conditions in the area. The figures given, however, serve to demonstrate the range in magnitude of these infiltration losses. The volume of water placed on ricefields that goes into soil-moisture storage differs from place to place and varies with the amount of precipitation preceding the first flooding.

EVAPOTRANSPIRATION AND DRAINAGE FROM RICEFIELDS

To determine the losses of water from ricefields by evapotranspiration and by drainage from the fields during the irrigation season and at the end of the season, measurements of these factors were made on test fields in each of the areas served by the pumping plants at which surface-water diversions were measured (see pl. 12). It was assumed that the early- and late-maturing varieties of rice require different quantities of water, depending on the length of period flooded; therefore, test fields were selected to include representative varieties of rice.

With the assistance of irrigation-company officials and canal managers, the field engineer selected a farmer in each test area to act as an observer. In some areas the canal managers themselves served as observers. These observers served without remuneration and, with few exceptions, their services were conscientiously performed and of great value to the investigation.

A standard nonrecording rain gage of the U. S. Weather Bureau type was installed in each test field as near to the field as was convenient for the observer. None of the rain gages were located more than about 2, 000 feet from the test field and most of them were set on the levees of the field or adjacent to them. In conjunction with each rain gage, a staff gage was used to measure

Figure 20.—General view of rain gage and staff gage used to measure components of water use on ricefields.

water-level changes in the flooded field (see figs. 20, 21). These gages are graduated to 0.02-foot intervals and may be read to an accuracy of 0.01 foot. The general plan of this program was to

Figure 21.—Closeup of staff gage. (Photograph by Raymond Sloss.)

obtain daily water-level measurements during the period each test field was submerged. The records of rainfall, the notes by the observers, and water-level changes were used to compute the various components of water requirement.

A ricefield is divided into several subareas, called cuts, each bounded by levees. In this investigational program, water-level measurements were made on only one cut in each field. The size of the test areas ranged from 1 to 10 acres. In each local area, records were obtained during the irrigation seasons in 1949–51. A total of 42 field records were obtained in this manner during the 3 years of observation. Most of the cooperating observers served throughout the investigational period.

Each observer recorded rainfall, staff-gage readings, the date of planting, date and duration of initial flooding, date and duration of subsequent floodings, accidental or intentional draining, date of final draining, and date of harvesting. The rain gages remained at about the same sites from March 1949 to October 1951. Records of rainfall from these gages were used in this report to supplement records available from other sources.

Soon after the test fields were flooded for the first time, the depth of water in the cut being observed was measured at 50 to 100 points to obtain the average depth. By relating the average depth of water to the gage reading at the time of measurement, it was possible to determine the average depth at any subsequent time from the gage reading at that time.

The average depth of water was computed from a water-level reading, obtained immediately after the first flooding was completed and was adjusted by subtracting the measured precipitation and by adding the estimated evapotranspiration during the flooding period. This average provided a measure of the depths of water furnished by irrigation during the first flooding. Depths added during subsequent floodings were computed from the measured change in water level, similarly adjusted. The total depth of water added to a field by irrigation, hereinafter called the irrigation requirement, was computed from the total of the water-depth increments added by irrigation adjusted upward by the volume estimated to have gone into soil-moisture storage. The soil-moisture storage adjustments were estimated from the test results (see the preceding section) in each field, adjusted according to the estimated effect of antecedent precipitation.

Depths of water intentionally or accidentally drained from the fields were computed from the change in water levels. If a field was completely drained, either during the season or at the end of the season, the depth of water drawn off was computed from the gage reading immediately before draining. Periods of accidental or intentional draining and of flooding, not recorded or detected by the observers, were easily identified from the daily gage readings.

During a few periods in several field records, the addition of water by irrigation and precipitation and additions or subtractions by overflowing of levees occurred simultaneously. During those periods, the assignment of depth changes to the various factors was necessarily approximate.

Adjustments for evapotranspiration during the periods of flooding were computed from records of pan evaporation by the following method. Before May 1950 a record of pan evaporation was collected by the Rice Experiment Station at Crowley. This pan was of the sunken type, 6 feet in diameter and about 35 inches deep, set with the rim projecting about 4 inches above the ground. Using records for the 1949 season, a compilation was made of water-level changes for all days during the submergence period in all test fields in which water-level changes resulted only from evapotranspiration. Evaporation from the Crowley pan for the same days was tabulated also. The ratio of the sum of all field water-level changes to the sum of the Crowley pan-evaporation losses was 1.23. This ratio represents the average seasonal ratio of evapotranspiration losses from ricefields in southwestern Louisiana to pan evaporation at Crowley. To compute the evapotranspiration adjustment for a period of flooding, the sum of the daily pan-evaporation depths during the period was multiplied by 1.23.

Records were not available for the Crowley pan after May 1950, necessitating the use of records after that time for a pan of different type at another location and requiring the use of a different coefficient. Subsequent to May 1950, the U. S. Weather Bureau collected records at Hackberry for a land pan (Class A) 4 feet in diameter by 10 inches deep and set on a timber grillage with the bottom of the pan about 6 inches above the ground. These records provided the basis for computing evapotranspiration adjustments. Evaporation-pan records at Hackberry were multiplied by a coefficient of 0.99 to estimate evapotranspiration losses. This coefficient was based on correlations between evaporation from the Hackberry pan and that from the Crowley pan during overlapping periods of record.

Interpretation of the results from the water-requirement investigation described above necessitated consideration of the depths of precipitation intercepted by the rice plants. The portion of the precipitation intercepted by plant foliage and returned to the atmosphere by evaporation does not affect water levels in the fields. To determine how much of the precipitation occurring during the submergence period was utilized by the crop, it was necessary to adjust the measured seasonal rainfall on a field by an estimated depth of interception. To arrive at a method of estimating interception, a tabulation was made of precipitation on each day of rain during all years of record on all test fields, water-level changes resulting from each rainfall, and the elapsed time in days between the time each field was first flooded and the time each rainfall occurred. Data were tabulated for a total of 243 days of rainfall. For analysis of the effect of plant-development stage on interception, these data were grouped by 10-day intervals based on time of rainfall occurrence with respect to the time of first flooding. For each 10-day occurrence interval, the average precipitation depth and the average water-level change, adjusted for evapotranspiration, were computed. In any 10-day interval, the average water-level change subtracted from the average precipitation depth represented the average depth of interception.

This method of computing interception showed a range from no measureable interception during the early stages of the rice (0 to 20 days after first flood) to a maximum of about 35 percent of the precipitation during the late stages (80 to 100 days after first flood). Interception for the entire growing season averaged about 10 percent. Analysis of the variation of interception with amounts of rainfall in individual storms did not produce meaningful results.

In computing the precipitation retained on each test field, the total rainfall during the period of submergence was adjusted by 10 percent for interception and further adjusted for depths of precipitation lost by levee breaks or overflow, if any. Inasmuch as totals for an irrigation season were being sought in the analysis of these data, use of an average seasonal adjustment for interception was considered sufficiently accurate.

In addition to the 42 field records described in the foregoing paragraphs, two 1-year records were obtained by more accurate methods. Through the courtesy of the Rice Experiment Station, Crowley, the Geological Survey was permitted to install measuring and recording devices on two fields, one in each of the years 1950 and 1951.

The largest available field that could be irrigated from only one point of diversion from the supply canal was selected in each year. The field used in 1950 was 23.5 acres in size, and the one used in 1951 was 8.0 acres. It was possible to obtain accurate measurements of all the water received by both fields, either from rainfall or by irrigation, and of the water drained from them.

The methods of measurement used in each year were essentially the same. The flow of water from the supply canal onto the cut of highest elevation was measured by means of a metal Venturi flume (Parshall, 1945) as shown in figure 22. Small breeches

Figure 22.—Venturi flume and associated water-level gages used to measure volumes of water placed upon and removed from ricefields.

were made in the interior levees, and the water was allowed to flow by gravity from the higher elevation cuts to the lower elevation cuts until the entire field was flooded. Two sharp-crested V-notch weirs (fig. 23) were installed in the outside levee of the cut having the lowest ground-surface elevation. All water leaving the field by drainage or by overflow was measured by means of these weirs. Water-stage recorders measured the heads of water flowing through the flume and weirs. A staff gage was placed in each cut in the field, and after the field was flooded, the average depth of water in each cut was referenced to its respective staff gage. The staff-gage readings were used in conjunction with the area of each cut to compute the volumes of water drained from the field or added to the field by irrigation. The use of the volumetric computation methods was a precautionary step taken in case the weirs or the flumes were bypassed by accidental levee breaks. It also served as a means of verifying the computations of flow through the weirs and flume.

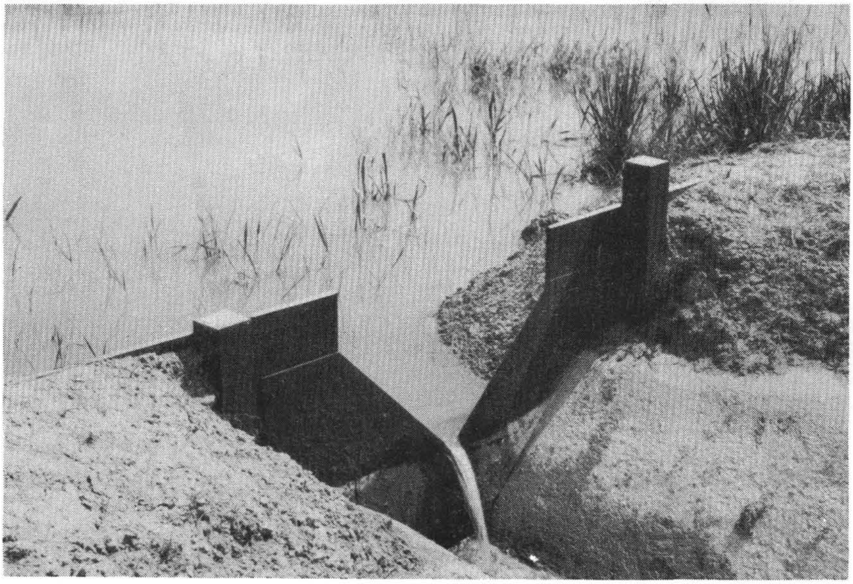


Figure 23.—View of V-notch wier.

To measure the rainfall, a recording rain gage of the weighing type was placed on the levee bounding the field. The field studied in 1950 had, in addition to the recording rain gage, two standard U. S. Weather Bureau nonrecording rain gages placed inside the field.

Flow through the flume was computed from standard tables for the Parshall-type measuring flume. Flow through the weirs was computed by the formula $Q = 2.52H^{2.47}$, in which H is the height of the water above the vertex of the weir. Because of the nature of the installations, it was impracticable to obtain measurements of flow to check the assumed ratings for these measuring devices. As indicated above, flow registrations by the flumes and weirs were checked by comparison with volume changes in the fields.

An accurate map was made of each of the two fields by plane-table methods. A map made of the field used in 1950 is shown on figure 24. Areas used in making computations of volumes of water on the fields were measured on these maps.

The results of the water-requirement studies described in the preceding discussions are presented in table 16. With a few exceptions, the data included in this table are self-explanatory.

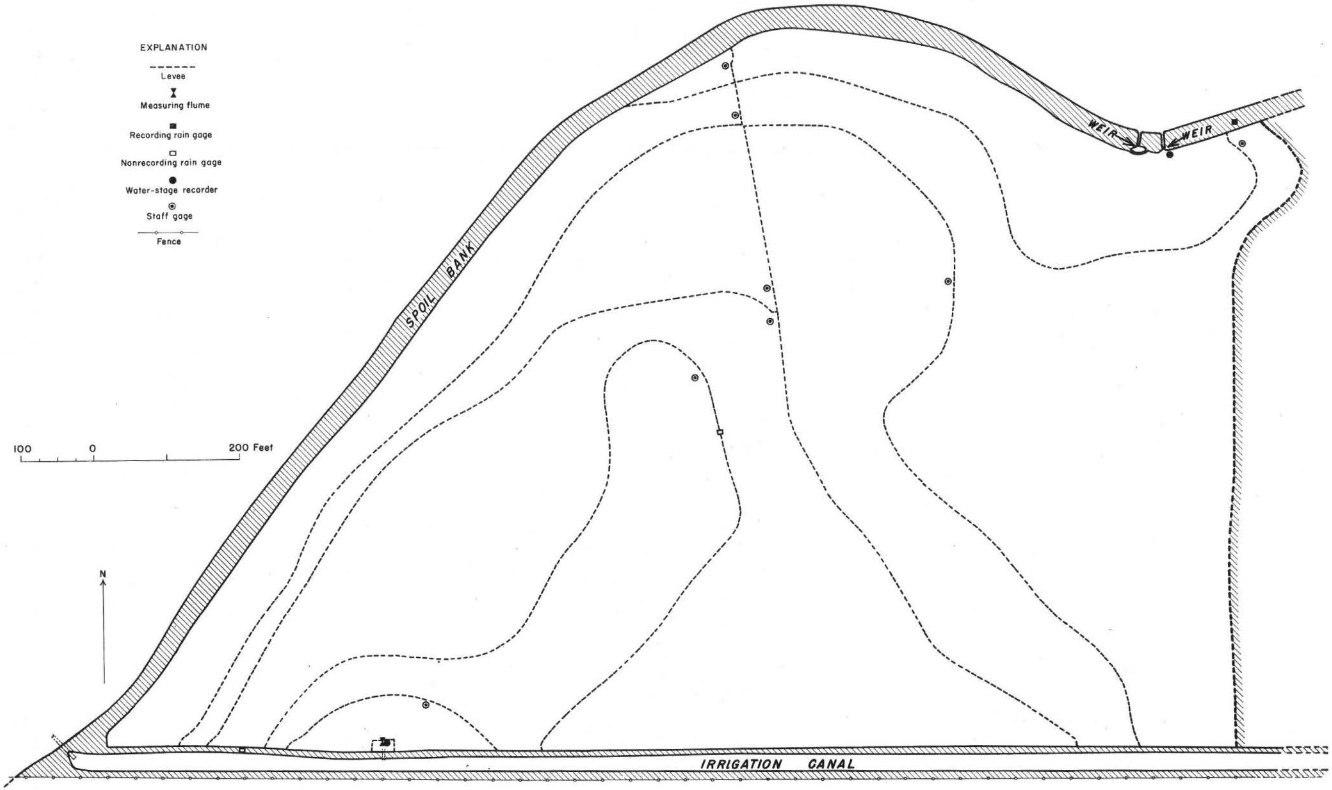


Figure 24.—Map of a ricefield for which water requirements were measured.

Table 16.—*Water requirements, in inches of depth, and other pertinent data for selected ricefields*

Field no.	Date of planting	Date of first flooding	Date of final draining	Days field under water	Estimated soil-moisture storage deficiency	Rainfall			Irrigation water added	Drainage			Consumptive use[1]
						Planting to first flooding	During flooded period	Retained on field		During season	End of season	Total	
						1949							
2	May 29	June 23	Sept. 3	72	2.0	5.76	18.13	11.1	14.6	4.6	3.8	8.4	15.3
3	9	5	Aug. 24	80	2.0	11.70	19.10	6.8	17.4	0	2.8	2.8	19.4
4	9	3	27	85	1.8	2.64	17.26	11.1	16.9	1.2	6.7	7.9	18.3
5	22	25	Sept. 22	89	2.5	8.55	17.71	11.2	19.7	2.8	5.3	8.1	20.3
6	Apr. 24	May 30	Aug. 4	66	.4	1.35	15.66	4.9	18.9	.4	5.0	5.4	18.0
7	28	June 1	Sept. 7	98	1.5	5.48	25.97	13.8	22.3	3.9	7.2	11.1	23.5
7A	9	May 13	July 30	78	1.8	4.59	21.98	11.6	17.2	0	6.7	6.7	20.3
8	May 13	June 4	Sept. 10	98	1.3	2.47	19.72	11.2	16.9	0	1.0	1.0	25.8
9	June 21	July 6	20	76	1.3	1.87	13.72	8.8	16.3	3.4	4.8	8.2	15.6
10	May 16	June 18	23	97	3.5	6.06	16.71	13.7	22.4	4.1	1.8	5.9	26.7
11	28	19	6	80	3.5	4.10	16.01	14.1	13.5	2.6	3.9	6.5	17.6
12	June 4	July 3	28	87	1.5	3.94	12.57	11.3	19.6	0	6.5	6.5	22.9
13	May 28	June 6	Aug. 31	86	1.7	.76	20.25	11.1	20.4	3.4	5.5	8.9	20.9
14	10	17	Sept. 1	76	.7	.95	17.89	14.2	11.2	0	5.8	5.8	18.9
15	26	May 21	Aug. 30	101	3.2	....	22.95	16.1	20.5	5.1	3.3	8.4	25.0
16	Apr. 22	23	25	94	1.8	1.14	17.58	10.8	15.7	2.7	3.8	6.5	18.2
1949 season average				85	....	....	18.33	11.4	17.7	2.1	4.6	6.7	20.4
						1950							
1	Apr. 17	May 11	Aug. 2	83	1.5	2.00	25.19	13.5	14.4	2.4	4.7	7.1	19.3
2	11	11	16	97	2.2	3.30	25.93	18.0	40.7	20.4	9.4	29.8	26.7
3	23	13	8	87	2.0	2.20	15.91	10.6	22.1	1.1	3.6	4.7	26.0
3A	23	13	8	87	2.0	2.20	15.91	11.4	16.7	0	2.3	2.3	23.8
4	May 9	June 8	22	75	1.6	11.75	14.28	7.4	20.6	4.6	5.5	10.1	16.3
5	Apr. 20	May 26	Sept. 19	116	2.3	8.24	21.58	9.5	33.2	4.3	7.7	12.0	28.4
6	Mar. 28	3	Aug. 1	90	.4	2.53	18.81	7.2	22.6	3.4	2.8	6.2	23.2
8	Apr. 15	9	23	106	1.3	2.26	20.65	12.9	18.2	0	3.8	3.8	26.0
9	15	4	July 28	85	1.6	3.43	19.05	13.4	11.5	0	4.2	4.2	19.1
10	21	31	Sept. 16	108	2.2	8.82	17.32	15.3	24.1	.4	7.6	8.0	29.2
11	14	8	7	122	3.5	....	19.36	12.7	25.0	0	8.5	8.5	25.7

13......	1	4	Aug. 5	93	1.5	3.29	15.54	6.6	25.2	3.0	6.5	9.5	20.8
14......	May 23	June 20	22	63	.4	6.88	12.77	11.2	11.2	2.1	5.5	7.6	14.4
15......	11	2	Sept. 1	91	3.0	6.69	11.23	9.6	19.1	0	5.3	5.3	20.4
16......	27	20	5	77	.8	....	14.44	11.2	24.0	0	9.2	9.2	25.2
17......	8	May 29	Oct. 5	129	1.9	3.68	17.49	15.8	24.8	7.8	4.3	12.1	26.6
1950 season average......................				94	....		17.84	11.6	22.1	3.1	5.7	8.8	23.2
1951													
2......	Apr. 10	May 10	Aug. 7	89	2.2	2.09	9.83	7.3	36.1	7.2	8.0	15.2	26.0
3......	4	8	July 30	83	1.9	.80	5.84	4.0	24.8	.6	7.0	7.6	19.3
4......	....	Aug. 7	Oct. 4	58	1.8	....	7.91	6.1	16.3	0	4.7	4.7	15.9
5......	May 7	June 4	Sept. 3	91	1.5	1.82	4.31	3.9	32.9	0	5.4	5.4	29.9
6......	June 11	27	12	77	.6	1.04	7.73	6.2	15.8	0	7.2	7.2	14.2
8......	Apr. 25	May 21	1	103	1.6	.80	8.04	5.0	31.2	0	5.3	5.3	29.3
9......	June 9	June 27	15	80	1.6	.40	15.12	7.5	18.3	0	5.0	5.0	19.2
11......	Apr. 23	May 18	Aug. 19	93	3.5	0	2.20	2.0	30.0	1.3	2.8	4.1	24.4
13......	13	2	11	101	1.7	0	9.01	8.1	31.2	0	6.8	6.8	30.8
14......	11	15	July 27	75	.7	3.31	7.09	5.7	22.1	0	6.7	6.7	20.4
15......	....	June 29	Oct. 6	99	2.8	....	20.26	12.0	21.7	0	3.0	3.0	27.9
17......	Apr. 23	May 14	Aug. 21	99	1.9	.68	6.17	5.6	29.2	0	2.3	2.3	30.6
1951 season average......................				87	....		8.63	6.1	25.8	.8	5.3	6.1	24.0
Average three seasons....................				89	....					2.1	5.2	7.3	22.4

[1]During period of submergence.

Note.—Ricefields were made available and daily observations of rainfall and water levels were made by: Wilson Ardoin, J. H. Dennison, August Domment, Harry Doucet, James E. Foreman, S. W. Flournoy, Rene Guidry, A. Hanks, Ellis Hoffpauer, H. M. Hoffpauer, C. N. LaCombre, Joseph B. Landry, Evence Manuel, Placide Mouton, O. L. Pollingue, Curley Regan, Clyde Trahan, Jake White, and E. E. Wild.

Data for field 17 for the two seasons of water-requirement measurements at the Rice Experiment Station are listed in the tabulations for 1950 and 1951.

The number of days each field was submerged was computed from the dates of first flooding and final draining without regard to the occasional short periods during which several of the fields were drained and reflooded during the growing season. The soil-moisture storage deficiency recorded for each field represents the depth of the water added by irrigation which is estimated to have gone into soil-moisture storage. These depths were derived from the soil-moisture storage depths observed at the various sites in the test program, reduced by a depth based on an estimate of the moisture remaining from antecedent precipitation.

The tabulated depth of irrigation water added to the fields represents the measured irrigation requirement of each field. The figures for consumptive use (evapotranspiration losses), listed in the last column of table 16, were computed by subtracting the total depths drained from the fields and the estimated depths in soil-moisture storage from the total depths of water placed on the fields (rainfall retained plus irrigation requirement). The depths listed as consumptive use represent the depths of water used by evapotranspiration (not including rainfall intercepted and lost to evaporation) during the periods the fields were submerged. Evapotranspiration losses prior to the first flooding and after the final draining are not included in the consumptive-use depths. It should be noted that the data in table 16 were collected on fields irrigated with surface water. Data similar to that shown in table 16 are not available for fields irrigated with ground water. The consumptive use in either case should be about the same. Other items may vary where cultural practices may be different.

Further summary and analyses of the results of the water-requirement-measurement program are given in the next section of this report.

ANALYSES OF SEASONAL WATER REQUIREMENTS FOR RICE CULTURE

Measurements of the water depths consumed by evapotranspiration during the period of submergence (consumptive use) were found to range widely. The primary factor affecting total consumptive use is the number of days in the submergence period (table 16). Figure 25 shows, graphically, the relationship between consumptive use and period of submergence. The open circles plotted on this diagram represent the 44 test-field results. The line of relationship, as sketched, is intended only to indicate the

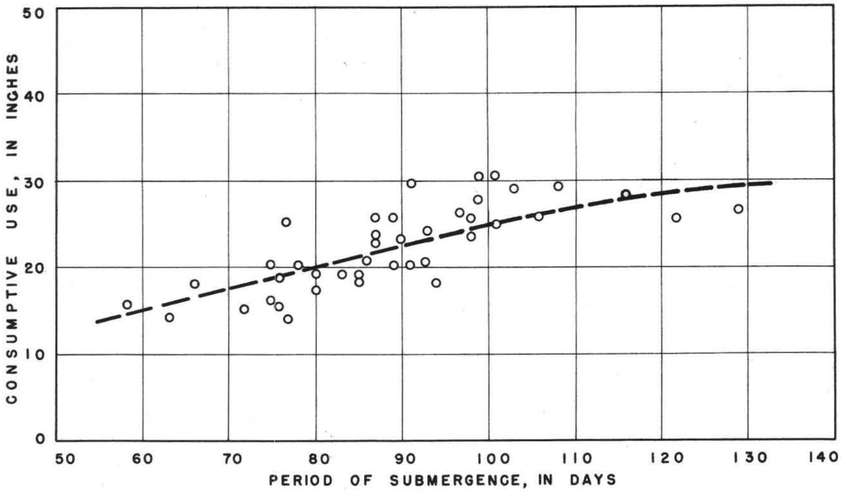


Figure 25.—Approximate relation between period of submergence and consumptive use of water by rice.

approximate relation. This line shows that the average consumptive use by rice in southwestern Louisiana is about 0.25 inch per day during the period of submergence.

In addition to the normal sources of error in measurement and in analysis of data, there are other factors that may influence the scatter of the points plotted on figure 25. If there is a significant difference in the consumptive-use rate of the several varieties, the relation between consumptive use and period of submergence should not be generalized as in figure 25. However, results of the 44 measurements of consumptive use, when statistically analyzed by varieties, do not indicate significant differences. Climatic variations between a given length of submergence period in different years or in different parts of the same year would result in varying consumptive-use rates.

One of the most important factors influencing the volumes of water that must be supplied to the fields in any season is the amount of precipitation during the season. The precipitation falling on the fields during a season reduces the volumes of water to be supplied by irrigation in direct proportion to the volumes of precipitation that are retained on the fields for crop use. As explained in a preceding section, part of all precipitation is intercepted by the plant foliage and returned to the atmosphere by evaporation. Of the precipitation that does reach water storage on the fields, some may be lost by the overflowing of levees or by levee breaks. When heavy precipitation occurs, sometimes levees are breached as a result of overtopping, causing loss of all precipitation volumes and loss of water that was already in storage on the fields. Thus it would be expected that, in low-rainfall seasons, greater proportions of the precipitation would be retained for crop use than in high-rainfall seasons. The results of the water-requirement observations during three irrigation seasons, listed in the table below tend to substantiate this conclusion.

Year	Number of field records	Precipitation during submergence period (inches)	Precipitation retained for crop use (inches)	Percent of precipitation retained
1949	16	18.33	11.4	62
1950	16	17.84	11.6	65
1951	12	8.63	6.1	71

In the year of lowest rainfall of the three studied (1951), the highest percentage of precipitation was retained (71 percent) on the fields for crop use. Inasmuch as the summer of 1951 was a season of record-low rainfall in the Mermentau River basin and possibly the lowest year of record for southwestern Louisiana as a whole and only 71 percent of the precipitation falling on the fields in that season was effective for crop use, it may be assumed that, in the most extreme dry season likely in southwestern Louisiana in the future, the average percentage of retention for crop use would be no more than about 75 percent. This percentage was used in the computations that are given below.

Of the various cultural practices in growing rice, none affect the volumes of water to be supplied by irrigation as much as the practice of draining water from the fields. The results of the three-season investigation, reported in table 16, reveal some important facts regarding drainage volumes. The results indicate a wide range in the practice of individual farmers of draining water from their fields during the growing season. Some manage entire seasons without losing water accidentally and without intentionally draining for any purpose. Many farmers do not drain intentionally during the season but occasionally lose water because of muskrat or crayfish holes in the levees or by levee breaches from other causes. As mentioned in "Current methods of rice culture," some farmers drain water from their fields during the season because they consider such drainage beneficial to their crops. The averages for depths drained during the season, however, are rather consistent. The average depths observed were 2.1, 3.1, and 0.8 inches, respectively, in the years 1949–51. It is significant to observe from the records obtained that in the year of lowest rainfall, 1951, an average of only 0.8 inch of water was drained from the fields. In the years of plentiful rainfall, 1949 and 1950, farmers were more inclined to follow the practice of draining their fields during the growing season. The volumes cited as water drained from the fields during the submergence period are in addition to the volumes of precipitation lost from the fields, which were discussed in the preceding paragraph.

Depths of water drained at the end of the growing season, just prior to the harvest, averaged 4.6, 5.7, and 5.2 inches in the years 1949–51, respectively. Results indicate that farmers do not anticipate the time of maturity of the rice and do not let evapotranspiration dry their fields prior to the time of maturity of the crop. On the contrary, the records indicate that many farmers apply water by irrigation only a few days prior to the time of final draining. The three-season average for water depth drained at the end of the irrigation season is 5.2 inches.

It should be observed that the data on water requirements discussed in the foregoing paragraphs were collected on fields irrigated with surface water. Except for the depths of water drained from the fields during or at the end of a season the data should be applicable to fields irrigated with ground water. Farmers irrigating with surface water usually pay one-fifth of the crop as water rent regardless of the amount of water used. That they are actually less conservative in the use of water than farmers irrigating with ground water, who usually own their pumps, has not been revealed by this investigation.

On the basis of all water-requirement measurements discussed in preceding sections of this report, the average seasonal water requirement for growing rice irrigated with surface water in southwestern Louisiana is computed in the following tabulation.

	Water depth (inches)
Consumptive use (evapotranspiration) during period of submergence	22.4
Drained from fields during period of submergence	2.1
Drained from fields at end of season	5.2
Soil-moisture storage	2
Total water requirement	31.7

The total water requirement, about 32 inches, is computed from the averages obtained in the three-season measurement program. This water-depth requirement includes that part which inevitably will be supplied in any season by rainfall and also that which must be supplied by irrigation. In a year of extremely low rainfall, the requirement may be slightly lower because of the apparent tendency toward a more conservative practice in draining water from fields during the growing season. Trends in the choice of rice varieties with longer or shorter growing seasons, with consequent longer or shorter periods of submergence, will affect the water requirement. The trend toward seeding rice by airplane onto flooded fields is too recent to permit accurate evaluation of this factor with respect to its effect on water requirement. Only 1 of the 44 fields for which records were obtained was planted in this manner (field 15, 1949, table 16).

The preceding computation of water requirement was based on an average soil-moisture storage of 2 inches. The test results constitute a sample that is too small to indicate reliably all the possible geographical variations in this part of the water requirement. On the basis of the available data, however, water requirements in the three major river basins of the study area do not appear to be greatly different. Although the water requirement undoubtedly differs slightly from place to place in the area, the average water requirement as determined for the entire southwestern Louisiana area, 31.7 inches, will be used in all subsequent computations.

ANALYSES OF SEASONAL DIVERSION RATES

CONVEYANCE LOSSES

Losses of water between points of diversion from the supply streams and points of delivery to the fields generally are called conveyance losses. These losses can be determined only indirectly from the available data. Comparison of the water volumes diverted by the pumping plants in southwestern Louisiana with the volumes delivered at the fields may be made for the 3 years covered by the water-requirement investigation. In the table below, the diversion depths are averages computed from records for all pumping plants throughout the area for which records were obtained. For convenience, diversion volumes have been expressed in inches of depth over the irrigated area. Expressing these volumes as inches of depth is equivalent to expressing the rates of diversion in acre-inches per acre. Depths of water delivered to the fields are the averages recorded in table 16.

Year	Average diversion depth (inches)	Average depth delivered to fields (inches)	Conveyance losses	
			Inches	Percent of diversion depth
1949	27.5	17.7	9.8	35.6
1950	36.3	22.1	14.2	39.1
1951	38.9	25.8	13.1	33.7

The average conveyance loss computed from available data for the 3 years 1949–51 is about 36 percent of the water diverted at the source streams. Because of the possible inaccuracy of this figure for conveyance loss (and for convenience), an average conveyance loss rounded off to 35 percent will be used in subsequent computations.

Conveyance losses include evaporation from canal surfaces, transpiration by native vegetation on canal banks, seepage through the bed and banks of the canal channels, and such losses as may occur naturally or inadvertently or as may be necessary in operating the distribution system. Volumes of water lost by leakage at headgate structures, flumes over drainage canals, culverts under roadways, and other canal structures and by spilling over field boundary levees during the application of irrigation water also are considered as elements of conveyance losses. Muskrats and crayfish cause many breaks in canal banks and considerable water loss, which is included in the conveyance losses.

The average conveyance loss computed for southwestern Louisiana not only includes all water diverted from the streams that is not ultimately retained on the fields for use, but also is affected by errors in reported acreages and by the pirating of water from the canals by farmers who have not contracted with the irrigation companies for water supply. There is no way to estimate the probable magnitude of these effects. The effect of the size of a canal system on conveyance losses cannot be evaluated from the data available. The acreages irrigated by the pumping plants for which records were obtained range from 2,500 to 25,000 acres, and the length of the canals in the systems range from 25 to 115 miles. Considering all possible variables, the conveyance-loss percentages for the three seasons are in remarkably close agreement.

RETURN FLOW

In general, the return flow from an irrigation project is the part of the diverted water that eventually returns to the stream channel. Water drained from ricefields which subsequently is pumped out of drainage ditches for reuse on other fields may be considered as part of the return flow even though it does not reach the main stream channel. Direct measurement of return-flow volumes represented a problem too complex to be attempted in this investigation.

In southwestern Louisiana essentially all return flow is surface drainage reaching the stream channels through drainage ditches.

387601 O - 56 - 11

This flow is derived from leakage through canal structures and from drainage of ricefields. Many farmers cultivating small acreages of rice depend upon the supply available in drainage ditches from return flow and from surface runoff from rainfall. Because the supply is not dependable, many of these farmers have wells for supplementary supply; others purchase water during critical periods from neighbors who have wells or from irrigation companies. In seasons of plentiful rainfall, farmers depending on drainage ditches for supply usually manage to get all the water they need. During critically dry seasons, however, the drainage-ditch supply is very limited. As indicated previously in this report, drainage from ricefields during critical seasons is very low. The average drainage during the 1951 season was only 0.8 acre-inch per acre. Much of this part of the return flow is consumed by evapotranspiration in the drainage canals and is not available for reuse. The water comprising ricefield drainage comes both from the lands irrigated with surface water and from those irrigated with ground water.

Although drainage from the fields at the end of the season is large, averaging about 5 inches, this water is available too late in the season to meet an appreciable part of the need for water in the periods of heaviest demand. Thus, omission of return flow does not seriously affect the total water budget for southwestern Louisiana, particularly in a dry year. Neglecting return flow in the determination of supplementary water-supply needs for the area introduces a factor of safety in the planning of remedial works.

MAXIMUM SEASONAL DIVERSION RATES

An estimate of probable maximum seasonal diversion during an irrigation season may be computed from the data on water requirements and conveyance losses presented in the preceding sections and estimated precipitation during the flooded period. The average seasonal water requirement was computed to be 31.7 inches of depth. A part of this total water requirement is furnished by rainfall, the remainder must be delivered to the fields by irrigation. During the 1951 season an average of only 8.6 inches of precipitation fell on the fields during the periods of their submergence (see table 16). It should be noted that this average rainfall is not that for a specific calendar period. One field may have been submerged during the months of April through June and thus received its rainfall in that period, whereas another field may have been submerged during the months June through August and thus received its rainfall in those months. Therefore, the periods of submergence of the numerous fields for which the average of 8.6 inches of rainfall during the 1951 irrigation season was computed were not exactly concurrent periods. Thus, the average rainfall during the submerged periods represents a sampling for shorter periods throughout the overall irrigation season extending approximately from April through August.

For the purpose of computing the maximum probable diversion rate, the assumption is made that in a season of extreme drought throughout the ricegrowing area, the average precipitation during the submergence periods might be as low as 6 inches. Of this 6 inches of rainfall about 75 percent, or 4.5 inches, would be available for crop use (see p. 144). Reducing the 31.7-inch total requirement by the 4.5 inches of effective precipitation leaves 27.2 inches to be delivered to the fields by irrigation. As conveyance losses in southwestern Louisiana average 35 percent of the water diverted at the supply streams, the total diversion would be 42 inches of depth, or 3.5 acre-feet per acre. According to this computation, 3.5 acre-feet per acre per season represents about the maximum seasonal rate of diversion required in a season of severest drought. This rate of diversion may be compared to the rates listed in the following table which shows the average rate for each year for southwestern Louisiana. Diversion rates for 1949–51 were computed from records collected during the period of this field investigation (see p. 118). Rates for the years 1939–48 were computed on the basis of records available for a few pumping plants in the area for which records of speed, lift, and hours of operation were maintained as a usual part of the operation records. Pump ratings determined during the period of investigation (1949–51) were assumed to apply during these earlier years.

Year	Acreage served by sample plants	Seasonal diversion (acre-feet per acre)
1939	59,500	3.00
1940	56,200	2.01
1941	62,800	2.14
1942	70,400	2.22
1943	67,300	2.91
1944	61,100	3.20
1945	58,800	2.76
1946	58,200	2.84
1947	55,500	3.31
1948	70,600	3.39
1949	111,600	2.29
1950	101,500	3.03
1951	107,100	3.24

The seasonal rates of diversion in 1948 and 1951 were only slightly below the computed probable maximum. Because the variation in seasonal average rate of diversion is primarily a function of rainfall depths occurring during the irrigation season, April through August, the natural inference from these data is that these periods in 1948 and 1951 were seasons of nearly record-low rainfall. The average precipitation in southwestern Louisiana during the period April through August is listed below for the five seasons of lowest rainfall since 1900.

	Precipitation in the months April through August (inches)
1902	15.4
1924	14.2
1925	12.7
1948	14.6
1951	12.7

In the above table, the precipitation for 1948 and 1951 is the average over the Mermentau, Calcasieu, and Vermilion River basins computed from isohyetal maps drawn on the basis of all available records. For the 3 earlier years, 1902, 1924, and 1925, the precipitation was computed as an average of a small group of precipitation stations scattered widely over southwestern Louisiana. Thus the data in this table are roughly comparable, although the average figures for the early years are considerably less reliable than those for the later years.

Inasmuch as this table shows the 1948 and 1951 seasons to be among the 5 years having the lowest precipitation of record, it is not surprising that the diversion rates during these 2 years were near the maximum rate computed above. It should be noted here, however, that in computing the probable maximum diversion rate, an average of 6 inches of precipitation during the periods of submergence was used instead of the average of 8.6 inches observed during 1951. This resulted in a computed maximum of 3.5 acre-feet per acre instead of 3.2 acre-feet per acre as would have been obtained by using the precipitation figure of 1951. Because of possible contingencies, use of the higher maximum figure seems to be justified.

The possibility that seasonal diversion rates may vary in different parts of southwestern Louisiana has been discussed briefly in a preceding section. Diversion rates, in acre-feet per acre per season, for the seasons 1948–51 based on records for pumping plants in each major river basin of the area, are listed in the following table.

Year	Vermilion River basin	Mermentau River basin	Calcasieu River basin
1948	3.64	3.15	....
1949	2.72	2.20	1.93
1950	3.46	2.94	2.63
1951	3.24	3.25	3.21

The differences in the measured diversion rates in the Mermentau and Calcasieu River basins are no greater than would be expected to result from averages obtained by a sampling procedure or from differences in rainfall. There is, therefore, no reason to assume that the two basins are essentially different in diversion requirements. Except for 1951, the pumping plants in the Vermilion River basin show higher diversion rates than those in the other two basins during the years listed in the preceding table. Rate comparisons for years prior to 1948, however, do not indicate the diversions in the Vermilion River basin are consistently higher than those in the other basins. Records of diversion by pumps in the Calcasieu River basin are not available for years prior to 1949.

The diversion-rate comparisons that have been made appear to justify the use of a maximum probable-diversion rate of 3.5 acre-feet per acre for the entire southwestern Louisiana area.

ANALYSES OF RIVER-BASIN PROBLEMS

The three major river basins in southwestern Louisiana have the same general surface-water problem. When periods of low rainfall coincide with the irrigation season, streamflow is either less than withdrawals for the irrigation of rice or does not exceed withdrawals by amounts sufficient to prevent encroachment of saline waters from the Gulf of Mexico. The encroachment of salt water causes crop losses and presents the hazard of ground-water contamination which is discussed in the section on ground water. Inasmuch as the encroachment of saline water into the streams is dependent on the day-to-day or week-to-week relation of stream discharge to rates of diversion, the analyses of river-basin problems that follow are based primarily on the relations of supply and demand as revealed by a study of the hydrographs of weekly river discharge and weekly diversions. The factors peculiar to each river basin that affect its water-supply budget are discussed in the section of this report devoted to that basin. Analyses of the effects of existing works designed to improve the water-supply problems are made only briefly.

VERMILION RIVER BASIN

The Vermilion River basin (see pl. 12) is about 55 miles long and about 23 miles wide at its widest section at the latitude of St. Martinsville. The total area of the basin above the Intracoastal Waterway is about 652 square miles.

The principal physiographic features of the area are the coastwise plains, or prairies, and the coastal marsh. The prairie lands constitute the higher and northernmost part of the area. They are eroded remnants of a former delta of the Mississippi River system. The altitude of the prairie lands increases from approximately 2 feet at their junction with the coastal marsh to slightly above 70 feet near Opelousas. The coastal marsh is an area of very low relief, the surface elevations generally being less than 2 feet above mean gulf level.

The prairie lands in the basin present a wide, flat expanse of lands particularly suited to the culture of rice. The light, loamy surface soil is closely underlain by dense and nearly impervious subsoils. In general, surface drainage channels are small, having depths of only a few feet below the general land surface.

The Vermilion River is formed by the confluence of Bayous Fusilier and Carencro and traverses a total distance of about 73 river miles to its mouth at Vermilion Bay. Bayou Fusilier interconnects with Bayou Teche. Another connection is through Ruth Canal. Although above the latitude of Lafayette the stream is known as Bayou Vermilion and as the Vermilion River below Lafayette, for convenience the entire stream will be referred to as the Vermilion River in this report. Channel improvements for flood control and navigation cause the river to be tidal about to the mouth of Bayou Fusilier. The range in stage of normal tides at the mouth of the Vermilion River is about 10 inches.

The estuary of the river is formed by three connecting bays: Vermilion Bay, West Cote Blanche Bay, and East Cote Blanche Bay, East Cote Blanche Bay, at its outlet to the Gulf of Mexico, is adjacent to Atchafalaya Bay which is the estuary of the Atchafalaya River. Southwest Pass also connects Vermilion Bay with the Gulf of Mexico. (See pl. 12.)

ACREAGE IRRIGATED

Acreages of rice irrigated by diversions from the Vermilion River during the 4 years included in this report were:

	Acres		Acres
1948	54,500	1950	49,500
1949	51,500	1951	47,000

The acreages include all areas irrigated by diversion from the main Vermilion River channel and from drainage channels tributary to the river or to the Intracoastal Waterway within the drainage boundary of the basin and include an arbitrarily assigned portion of the acreage irrigated in the basin by farmers having both a surface- and a ground-water supply. Diversions from the river for uses other than irrigation of rice are negligible.

It is not possible to determine from available records the area in the basin irrigated by surface water prior to 1948. Acreage records for earlier years are available, however, for the two pumping plants in the basin at which diversions were measured during this investigation. These plants served a maximum of about 43,000 acres of rice in each of the years 1942 and 1943. If the acreage served by these plants in past years was about 60 percent of the total acreage, as is currently true, the maximum area irrigated with surface water in the Vermilion River basin in previous years was about 70,000 acres. The trend in the past few years has been toward a lower acreage. However, if an adequate fresh surface-water supply were assured, the area irrigated with surface water in the basin in subsequent years possibly again would approach 70,000 acres or more.

SOURCES OF AVAILABLE SURFACE-WATER SUPPLY

The natural flow of the Vermilion River in seasons of low runoff is small by comparison with diversion requirements. A small volume of water enters the Vermilion River through Bayou Fusilier, a natural channel (see pl. 12). Flow through Bayou Fusilier may be either to or from the Vermilion River, depending on the relative water-surface elevations of Bayou Teche and the Vermilion River. Since about 1920 supplementary supplies have been diverted from Bayou Teche into the Vermilion River through the Ruth Canal. Water available from Bayou Teche, however, has not been sufficient in critical years to meet the needs for supplementary water in the Vermilion River basin.

The following table lists flow in the Vermilion River, by sources during the irrigation-season months, April through August, in the years 1948–51.

Year	Vermilion River basin (acre-feet)	Bayou Fusilier (acre-feet)	Ruth Canal (acre-feet)	Total (acre-feet)
1948	72,700	5,500	80,400	159,000
1949	349,000	24,400	119,000	492,000
1950	400,000	23,200	118,000	541,000
1951	61,000	15,100	73,000	149,000

This table shows that, in low-flow years, more water now is being brought into the basin from outside sources than originates as runoff from within the basin. The experience with salt-water encroachment in the 1948 and 1951 seasons, as well as in other years of past record, demonstrate that supplementary water supplies are needed in addition to those now available. Tabulations of monthly and weekly flow in the Vermilion River, by sources, during the 4 years 1948–51, were presented in tables 8 and 9 in a preceding section.

SOURCE, NATURE, AND CAUSE OF SALINITY ENCROACHMENT

During periods when diversions for irrigation exceed the available upstream supply in the Vermilion River, water from Vermilion Bay is drawn into the channel. If a period of deficient flow persists, saline waters from the bay encroach many miles up the channel. The ultimate source of the contaminating water is the Gulf of Mexico. The saline waters that enter the Vermilion River, however, never have been observed to have salt concentrations as high as those of gulf water, which averages about 19,000 ppm. (Throughout this report salinity is stated in terms of chloride concentrations in parts per million.)

Vermilion Bay may contain water from at least three sources: Vermilion River water from antecedent periods of flow in excess of diversions; water from the Atchafalaya River, a major distributary of the Mississippi River that enters by way of East and West Cote Blanche Bays or through the Intracoastal Waterway; and water from the Gulf of Mexico. At the same time Vermilion Bay also may have volumes of water from rainfall directly on the water surface or from runoff on areas contiguous to the bay, and it may receive water from Bayou Teche through the Intracoastal Waterway. Water in the bay from these sources may be mixed completely at a given time. Tidal action, velocity and direction of wind movement, and duration of these diffusive influences determine the extent of mixing. Data presented in subsequent parts of this report indicate that the water which enters the bay from the Vermilion River, under favorable circumstances, may remain pocketed near the mouth of the river for at least several weeks.

It was not possible to make extensive surveys during this investigation to determine salinity changes in the various bays. However, many records collected by the Corps of Engineers and by the Acadia-Vermilion Rice Irrigating Co. were available and have been examined. These records indicate that, during periods of high flow in the Atchafalaya River, the water in East and West Cote Blanche Bays is often considerably fresher than that in Vermilion Bay. During this investigation, the Geological Survey made only one set of observations in Vermilion Bay (see table 29). A sample taken at the mouth of Vermilion Bay, at its junction with West Cote Blanche Bay, had a chloride concentration of 92 ppm, whereas samples taken in other parts of Vermilion Bay had chloride concentrations of slightly above or below 2,000 ppm. F. E. Everett of the Acadia-Vermilion Rice Irrigating Co. (unpublished memorandum) has presented a logical explanation of these phenomena. He points out that water from the Atchafalaya River sweeps in a general westerly direction toward and across the mouth of East Cote Blanche Bay, following the usual direction of the alongshore currents. These fresh waters at times enter West Cote Blanche Bay and provide a barrier to the entry of gulf water. The effectiveness of the barrier presumably depends, in part at least, upon the rate of Atchafalaya River flow. The maximum depth across the mouth of East Cote Blanche Bay is about 6 feet. Because fresh water from the Atchafalaya River is of lower density than gulf water and tends to remain near the surface, the shallow depths across the mouth of East Cote Blanche Bay limit the entry of water into the bay to that part of the gulf water which is diluted with fresh water.

Intermittent records indicate that the principal point of entry of the more saline gulf water into Vermilion Bay is through Southwest Pass. The water entering through the pass is not all gulf water because of the westward course of Atchafalaya River flow into the gulf. The fresh-water barrier, however, is less effective in preventing encroachment of salt water at this point than it is at the mouth of East Cote Blanche Bay. The maximum measured chloride concentration of water entering Southwest Pass during 1951 was 5, 700 ppm, which is about one-third the concentration of undiluted gulf water.

As a result of the combination of factors described in the preceding paragraphs, chloride in the water entering the Vermilion River from the bay during periods of excessive withdrawal for irrigation is variable in quantity but rarely exceeds 2, 600 ppm. This water, however, may have chloride concentrations of about 2, 000 ppm over extended periods of time. The chloride concentrations of the upstream fresh-water supply during the pumping season is 50 ppm or less. Because of the diluted character of the saline water entering the Vermilion River, the difference in density between it and the fresh-water supply is not great enough to cause the encroachment to follow the usual wedge pattern (see discussion and illustrations in "Quality of water").

RELATIONS OF SUPPLY TO DEMAND

Streamflow and diversion for irrigation during the growing seasons of 4 years, 1948–51, are presented graphically in figures 26–29. Weekly streamflow and diversion are shown in the upper half of each illustration. Volumes of diversion in excess of current streamflow, hereinafter called deficiencies, are indicated by the crosshatched areas. The lower half of each illustration shows volumes of flow, diversion, and deficiency accumulated from the first week of diversion. The difference between accumulated diversion and accumulated streamflow on any date represents the accumulated net deficiency or excess in streamflow from the beginning of pumping to that date. The accumulated deficiency line in the lower section of each figure represents the cumulative total of the crosshatched areas in the upper section, or the accumulated gross deficiency.

Total diversions from the basin as computed from the sample plants are probably representative of actual diversions during the years 1948, 1949, and 1951. The measured diversion rate for 1950 (see fig. 28) is inexplicably high for a year of plentiful rainfall, but the possible discrepancy is of no consequence in these analyses because salt-water encroachment was not serious in that year. During the 1948 and 1951 seasons, pumping schedules were affected by salt-water encroachment at the two plants for which diversion records were available. Thus, the diversion rates by the two sample plants were probably representative of those for the entire basin.

A comparison of figures 26–29 shows that the 1948 and 1951 irrigation seasons were more critical than the other two of the four for which records are presented, with 1948 being the year of greatest deficiency. Although streamflow in 1949 and 1950 was slightly deficient during short periods, there was no salt-water encroachment of consequence in those years. The gross deficiency for the entire 1948 season was 118,000 acre-feet as compared with 75,000 acre-feet in 1951 (figs. 26, 29). These deficiencies would have been greater had not supplementary supplies been diverted from Bayou Teche.

For the 5-month period April through August which covers nearly the entire irrigation season, the lowest precipitation of

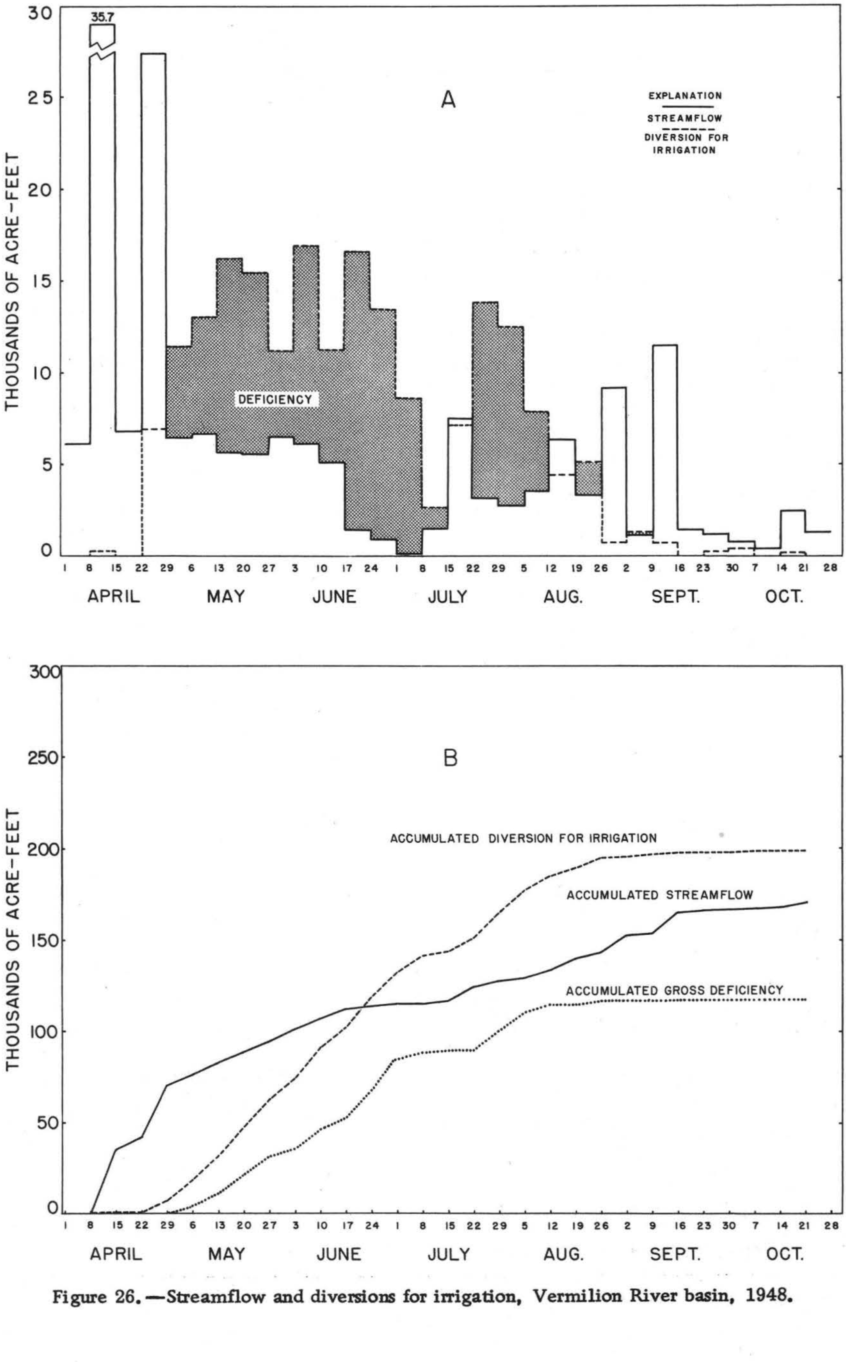


Figure 26.—Streamflow and diversions for irrigation, Vermilion River basin, 1948.

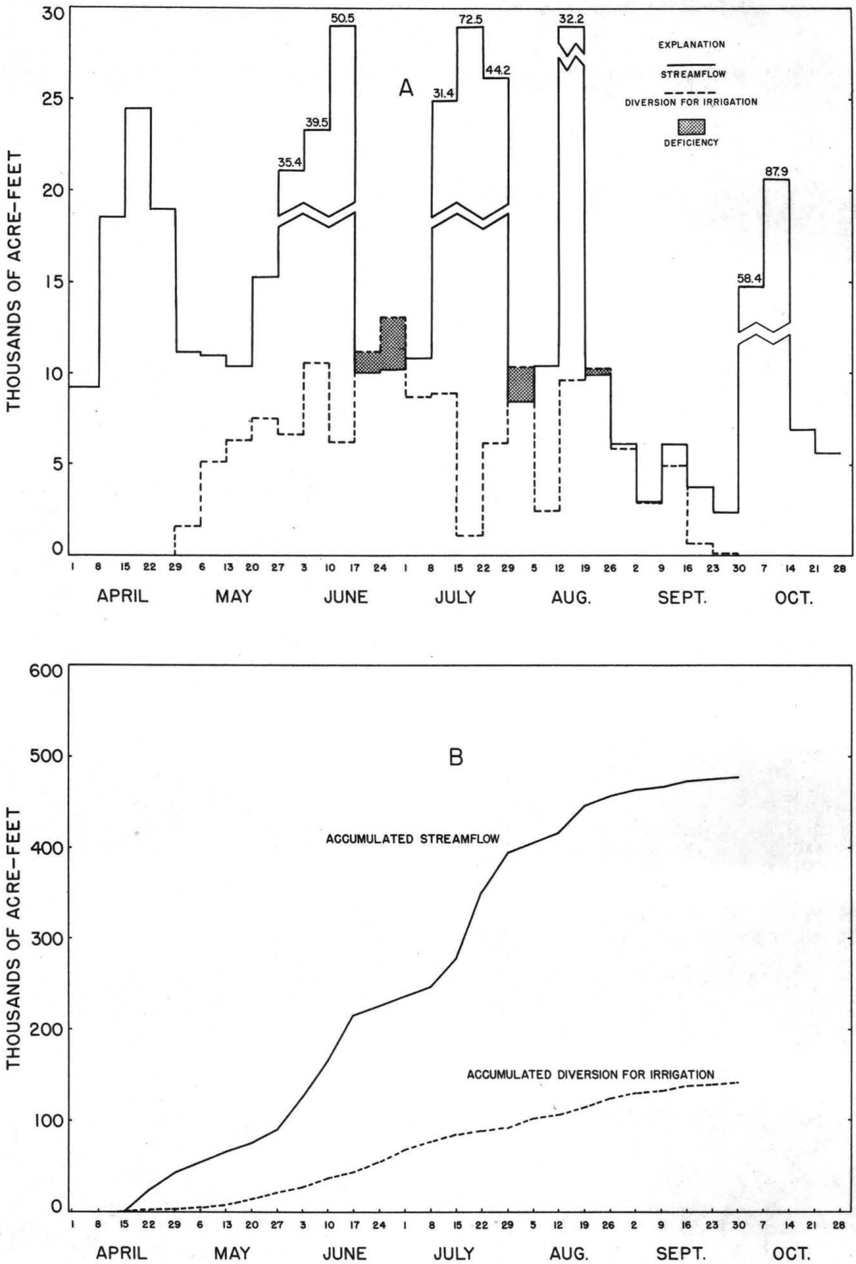


Figure 27.—Streamflow and diversions for irrigation, Vermilion River basin, 1949.

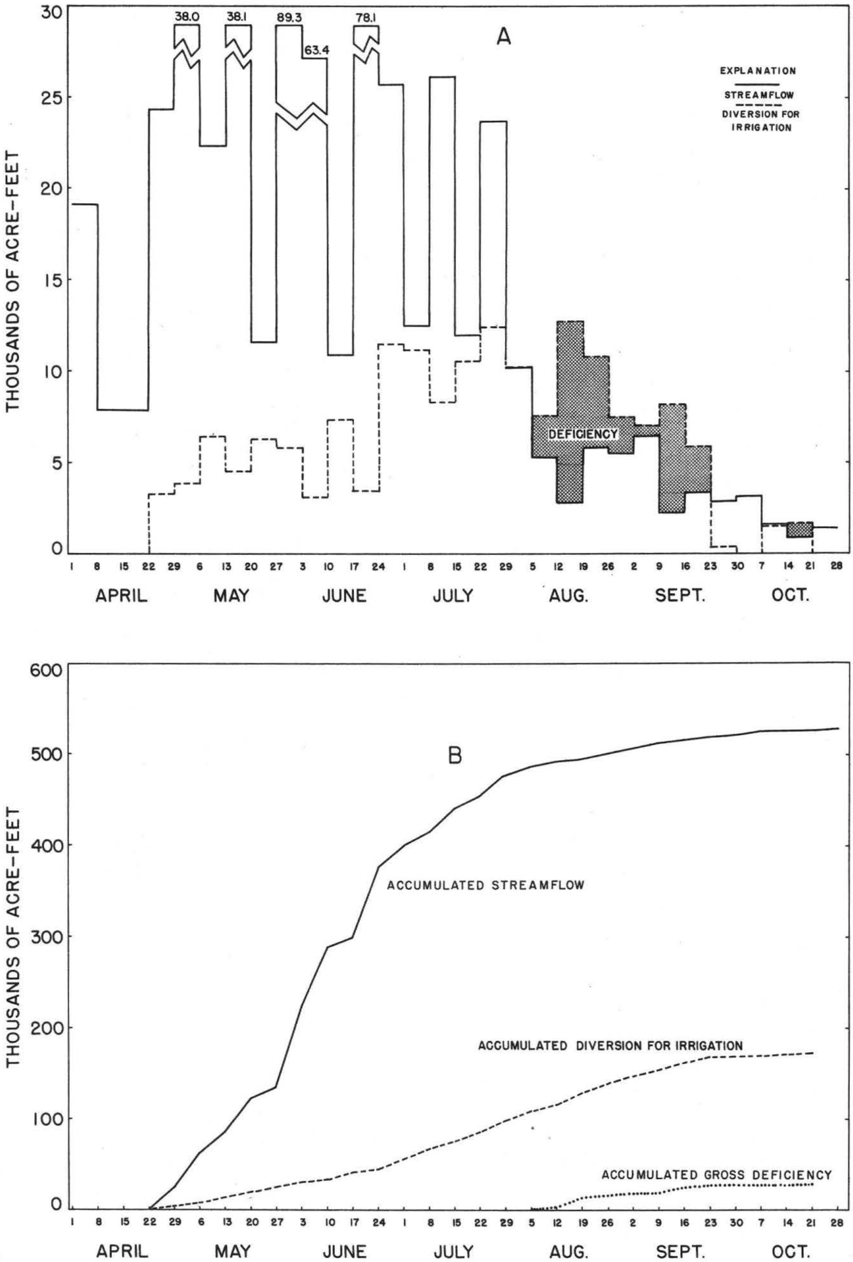


Figure 28.—Streamflow and diversions for irrigation, Vermilion River basin, 1950.

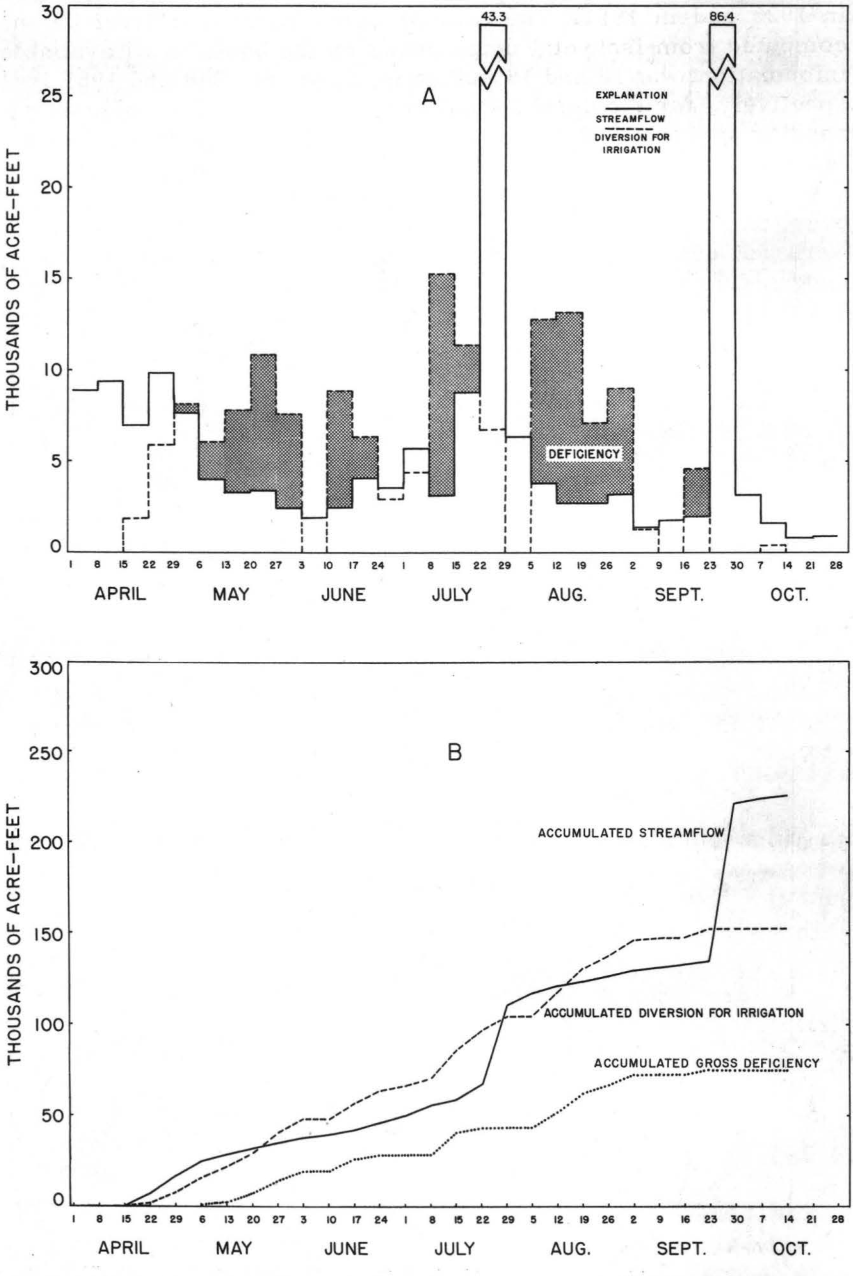


Figure 29.—Streamflow and diversions for irrigation, Vermilion River basin, 1951.

record for the southwestern Louisiana area as a whole occurred in 1925 and in 1951. The rainfall on the Vermilion River basin, computed from isohyetal maps drawn on the basis of all available information, was 16 and 18 inches in the years 1948 and 1951, respectively, for the period April through August. For the corresponding period in 1925, the average precipitation at three stations in the basin was 13.7 inches. Furthermore the 1925 season was preceded by 12 months of critically subnormal rainfall. However, according to available acreage records, plantings in 1925 were considerably less than in 1948. Thus, although 1925 was undoubtedly a year of serious salt-water encroachment, the disparity between water supply and demand in the Vermilion River basin in 1948 was probably the greatest of record.

Figure 30 shows the approximate location in the river channel of water having a salinity concentration of 500 ppm during the 1948 and 1951 seasons. A detailed comparison of figure 30 with figures 26 and 29 shows a very close relation between periods of excess and deficiency and the resultant movement of saline water in the channel. Although diversions in relation to streamflow were much greater in 1948 than in 1951, figure 30 shows that critical salinity conditions developed much earlier in 1951 than in 1948. The large volume of runoff that went into Vermilion Bay during April 1948 probably became pocketed in the bay near the mouth of the river. Much of it probably was reclaimed during the subsequent weeks of excessive pumping, thus delaying the encroachment of salt water.

The diversion requirement during the 1948 irrigation season was high, and streamflow was low. Because of the great demand for water, plants on the river were forced to continue heavy pumping despite the unsatisfactory quality of the water. Thus, as shown on figure 30, when salinities became critical in 1948 they remained so throughout the irrigation season. In 1951, when only 47,000 acres was irrigated with surface water, supply and demand were not so critically out of balance; the pumping plants were shut down for several periods to allow the fresh-water flow to accumulate in channel storage. This storage was pumped back in subsequent periods. Usually the salt-water front did not recede as far downstream as Vermilion Bay.

CONSIDERATION OF EFFECT OF GROUND WATER ON SURFACE-WATER SUPPLY

As explained in the preceding discussions, the estimates of flow from the Vermilion River basin are essentially estimates of surface runoff. Thus there is the possibility that these estimates of flow were too low and that inflow from ground water may have

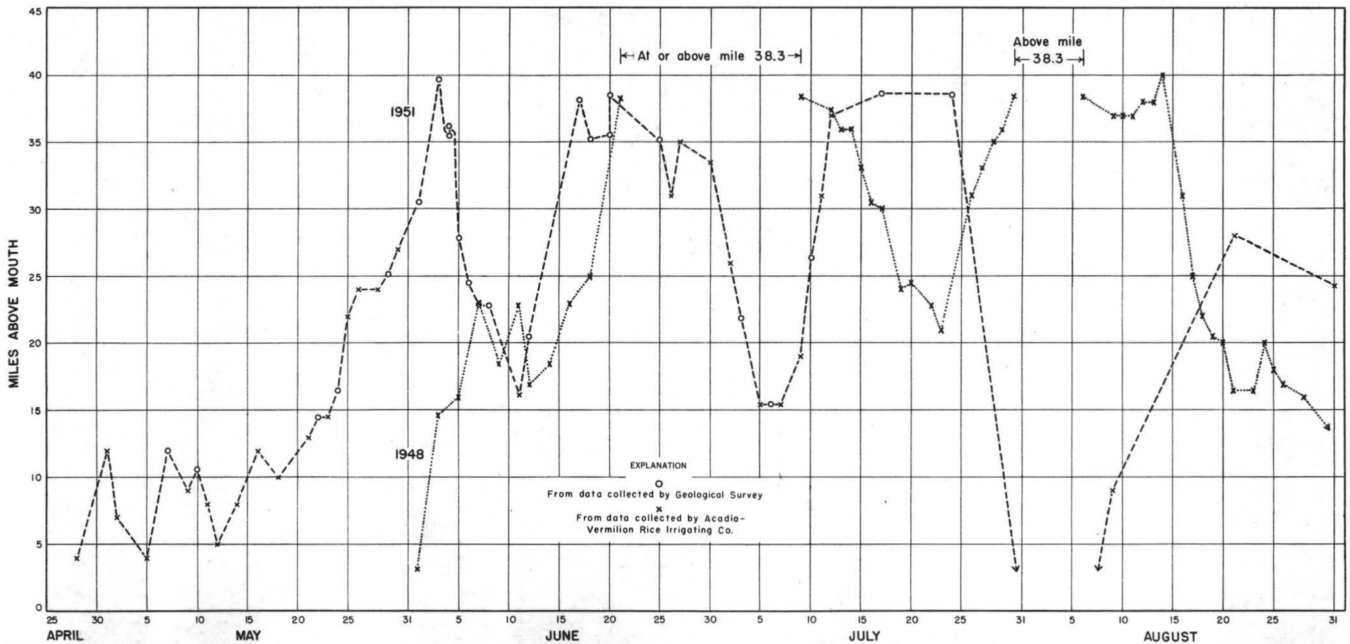


Figure 30.—Channel location of water having a chloride concentration of 500 ppm during periods of diversion for irrigation, Vermilion River, 1948 and 1951.

increased the actual supply. On the other hand these estimates may be high because of river water that might have infiltrated to ground water. It, therefore, becomes important to examine the data for evidence of the amount of the exchange between ground and surface water in the basin. This exchange is discussed on pages 236–241.

During the period April 30 to August 12, 1948, 178,000 acre-feet of water was diverted from the Vermilion River. The available supply from upstream sources during this period was about 63,000 acre-feet. Thus, 115,000 acre-feet of water was pumped which did not originate as current runoff from the Vermilion River basin or by diversions from Bayou Teche. This water represented ground-water inflow, Vermilion Bay water made usable by dilution, excess streamflow in antecedent periods subsequently withdrawn from storage in Vermilion Bay, return flow from irrigated fields, channel storage, or water entering from adjacent basins through the Intracoastal Waterway. The volumes of water contributed by each of these sources cannot be determined to any high degree of accuracy, but it is possible to compute fair estimates of them. As diversions exceeded supply in the Mermentau River basin during this period in 1948, it is improbable that water was drawn into the Vermilion River basin from that basin. It is possible, however, that water entered the Vermilion River basin from Bayou Teche or the Atchafalaya River through the Intracoastal Waterway.

To compute the volume of Vermilion Bay water originating from Atchafalaya Bay and the gulf that was made usable by dilution, the assumption is made that water from Atchafalaya Bay and water entering Southwest Pass, when mixed in Vermilion Bay, averages 2,000 ppm of chloride. Records collected by the Acadia-Vermilion Rice Irrigating Co. have been used to compute the mean salinity of the diverted water. During the period April 30 to August 12, 1948, the chloride in the water pumped by the two sample plants in the basin averaged about 450 ppm. If all water pumped during this period (178,000 acre-feet) averaged 450 ppm, Vermilion Bay water averaged 2,000 ppm, and the fresh-water supply from all sources contained 50 ppm, and then out of the 178,000 acre-feet pumped, about 37,000 acre-feet was Vermilion Bay water made usable by dilution. This volume of water derived from Vermilion Bay was computed by use of the dilution equation:

$$450(178,000) = 50(178,000 - X) + 2,000\,X$$

in which X equals the volume of Vermilion Bay water made usable by dilution. Accounting for this volume reduces the deficiency from 115,000 acre-feet to 78,000 acre-feet.

387601 O - 56 - 12

Consideration now will be given to the volume of fresh water drawn from storage in Vermilion Bay or from adjacent basins through the Intracoastal Waterway. Records show that the salinity at Intracoastal City, near the mouth of the Vermilion River, increased from 950 ppm of chloride on June 18 to 1,850 ppm on June 23. The salinity had been much lower before June 18 and was higher after June 23. By June 25 the river channel was filled with high-salinity water up to about 38 miles above the mouth. All fresh water in storage in the bay and in the channel, therefore, was exhausted by June 25. The total deficiency in streamflow prior to June 24 (see fig. 26) was 69,000 acre-feet, which may be assumed to have been the approximate volume of water available from preseason runoff reclaimed from storage in Vermilion Bay and in the river channel and of that drawn from other basins through the Intracoastal Waterway. It is probable, however, that the greater part of this water had its origin as preseason runoff from Vermilion River basin.

Accounting has now been made for 37,000 acre-feet of water, which originated in the bay and gulf area, and 69,000 acre-feet of preseason runoff reclaimed from storage. Of the 115,000 acre-feet of excess pumpage during the period being considered, 106,000 acre-feet has been approximately identified as to source. This leaves 9,000 acre-feet to be accounted for as ground-water inflow and return flow by drainage from ricefields. As all errors in estimating the water-budget components heretofore computed are reflected in this figure (9,000 acre-feet), further breakdown of the excess pumpage as to source is not practicable.

Computations for a like period during the 1951 season produced results similar to those outlined for the period in 1948 and, therefore, are not reported in detail. The computations for both years indicate that the exchange between ground and surface water in the Vermilion River basin is of such small magnitude in comparison with the other quantities involved in the water budget for an irrigation season that accurate computation of the exchange volumes cannot be made from the data presented in this section. These computations also indicate that return-flow volumes do not figure importantly in the water-supply budget for an irrigation season.

SUPPLEMENTARY WATER-SUPPLY REQUIREMENTS

Although during the season in 1951 the total water supply in Vermilion River from all sources was nearly equal to the need (fig. 29), there were several weeks when deficiencies developed that resulted in salt-water encroachment in the channel. The ground-water investigation made in the Vermilion River basin indicates clearly that, to prevent contamination of the ground-water aquifer, the encroachment of salt water in the Vermilion River channel must not be allowed at any time (see p. 287–293). Also, encroachment by salt water of any part of the channel at any time should be prevented so that all farmers in the basin may be supplied with fresh water. This means that the deficiencies in streamflow should be counterbalanced week by week, as they occur, by supplementary supplies. It should not be assumed that an excess of flow in 1 week may be available from storage for use in a subsequent week of deficient flow.

The crosshatched areas on figures 26 and 29 represent the additional volumes of water that would have been needed during each week to prevent encroachment of saline water into the channel during 1948 and 1951. Supplementary supplies of 118,000 and 75,000 acre-feet, in addition to those available from Bayou Teche, would have been needed in 1948 and 1951, respectively, to prevent encroachment of salt water.

It is a well-recognized fact that, to prevent salt-water encroachment in streams entering highly saline waters, supply rates in excess of demand rates are required if artificial barriers are not used. Even if supply exceeds the demand, encroachment will result from the reverse gradient created by the density difference between fresh and salt water. There is no evidence in the data for the Vermilion River to indicate that the density difference between the fresh-water supply and the Vermilion Bay water is great enough to be an important consideration. A study of the movement of the salt-water front (fig. 30) in relation to the flow balance (figs. 26 and 29) reveals that large excesses of fresh water are not required to cause the zone of contact between fresh water and salt water to move downstream. For reasons previously stated, the effect of return flow is neglected in the computations of supplementary water-supply needs.

Heretofore in this report, all computations of deficiency have been based on Vermilion River flow, including that diverted from Bayou Teche. The gross deficiency during the 1948 and 1951 seasons was given as 118,000 and 75,000 acre-feet, respectively. If the only flow available during these years had been that originating within the basin, the gross deficiencies would have been about 180,000 and 125,000 acre-feet, respectively, during those years.

Although provision for a total supplementary supply of 180,000 acre-feet per season probably would have prevented salinity encroachment in all years of past experience, consideration of a possible maximum future requirement is desirable.

For the period April through August 1925, the runoff from the Vermilion River basin is estimated to have been about 30,000 acre-feet, not including flow through the Ruth Canal or Bayou Fusilier. At a maximum diversion rate of 3.5 acre-feet per acre on 70,000 acres, a total diversion volume of about 245,000 acre-feet would have been required. If this volume of diversion should be required in a year like 1925 and if it is assumed that the 30,000 acre-feet of runoff is distributed during the season so that all is usable, a total of about 215,000 acre-feet of water would be needed from outside sources to prevent drawing water from Vermilion Bay.

The probability of maximum diversion demand coinciding with the worst of water-supply years cannot be predicted accurately. It is probable, however, that those making plans designed to eliminate the water-supply problem in the Vermilion River basin should consider the possibility that a total supplementary supply of as much as 215,000 acre-feet of water may be needed.

The maximum rate at which supplementary water must be delivered to the basin is also an important factor. In the week of maximum diversion during the 4 years of which records have been studied, the diversion rate was 0.3 acre-foot per acre. To irrigate 70,000 acres at this rate would require the delivery of water from a supplementary source at a rate of about 1,500 cubic feet per second. As there were 7 weeks during the 1948 season in which there was no runoff from the Vermilion River basin, it is reasonable to assume that at the time of maximum demand the flow originating within the basin would be negligible.

MERMENTAU RIVER BASIN

The Mermentau River is formed by the confluence of Bayous Nezpique and des Cannes and flows in a general southwesterly direction to the Gulf of Mexico, a distance of about 69 miles by river (see pl. 12). The major tributary streams other than Bayous Nezpique and des Cannes, are Bayou Plaquemine Brule, which is tributary to Bayou des Cannes about 2 miles above its mouth; Bayou Queue de Tortue, which enters the Mermentau River at about mile 55; and Bayou Lacassine, which flows into a northwestern arm of Grand Lake, an integral part of the lower Mermentau drainage system.

The main Mermentau River channel differs greatly in width and depth throughout its length. Except where it passes through the several lakes, channel widths range from 200 to 1,200 feet and depths range from about 3 to 50 feet.

Land-surface elevations range from 2 feet above mean gulf level, or less, near the mouth of the river to slightly above 125 feet in the extreme upper parts of the basin. Below the latitude of Eunice, land-surface elevations are generally under 50 feet.

The Mermentau River basin consists of prairie uplands in the northern sector, with gently undulating topography; flatter prairie in the central part where the agricultural industry is largely rice farming; and coastal marsh in the lower area, which is used largely for stock raising and wildlife conservation but is being increasingly developed for rice farming. The central and lower parts of the area are an almost featureless plain except for the wooded fringes of the natural drainage channels.

As would be expected in an area of flat terrain, the natural drainage is rather poorly developed. Drainage in the southern part of the area, however, has been improved through a system of artificial drainage channels.

A notable feature of the Mermentau River system is the series of large interconnected inland lakes. Channels have been dredged for navigation and flood control which connect Grand and White Lakes. White Lake, in turn, is connected with Vermilion Bay. The Intracoastal Waterway, a navigation channel 125 feet wide and maintained at a 12-foot depth, traverses the basin from east to west near the northern fringe of the coastal marsh. The waterway crosses the Mermentau River at about mile 35.

With the completion, on April 19, 1951, of the Catfish Point Control Structure on the Mermentau River between Grand Lake and the gulf, the entire Mermentau River basin, including the inland lakes, became a controlled system. Exchange of water between the Calcasieu and Mermentau River basins is controlled by the Calcasieu Lock on the Intracoastal Waterway. The lock was completed January 8, 1951. Control of water exchange between Vermilion Bay and the Mermentau River system is accomplished by the Vermilion Lock (completed in 1934) on the Intracoastal Waterway and by the Schooner Bayou Lock and Control Structure. Schooner Bayou Lock was completed in 1913 and the control structure early in 1951.

With the Mermentau River system in a controlled condition, winter runoff can be impounded in the lake-storage areas and conserved for use during the summer irrigation season. The locks and control structures also function to protect the impounded water from contamination by saline water from the Gulf of Mexico, the Calcasieu River, and Vermilion Bay. The total water-surface area in the Mermentau River system is about 110,000 acres, including lakes and stream channels (Corps of Engineers, 1948).

The total storage capacity in the system, below mean low gulf level, is estimated to be about 575,000 acre-feet. The greater part of this storage is in Grand and White Lakes, which have maximum depths at mean low gulf level of about 5 or 6 feet.

The total drainage area of the basin above the Intracoastal Waterway is about 2,100 square miles. Completion of the Calcasieu Lock moved the terminus of the drainage divide at the Intracoastal Waterway about 16 miles northwestward from its natural position to the position of the lock. Before the completion of the Calcasieu Lock, the drainage area above the Intracoastal Waterway was about 1,950 square miles.

ACREAGE IRRIGATED

Acreages of rice irrigated by diversions from the Mermentau River or its tributaries during the 4 years included in this report were:

	Acres		*Acres*
1948	189,500	1950	162,000
1949	188,500	1951	157,000

The acreages include areas irrigated by diversions from channels in the Mermentau River basin that are tributary to the Intracoastal Waterway and also include arbitrarily assigned portions of the acreage irrigated by farmers having both a surface- and a ground-water supply. Diversions from the river for uses other than irrigation of rice are negligible.

Records are not available from which to determine the maximum acreage irrigated with surface water in the Mermentau River basin in any previous year. Several methods of extrapolating present acreages, however, indicate that as much as 250,000 acres of rice may have been irrigated with surface water in the Mermentau River basin in one or more of the past years.

SOURCES OF AVAILABLE SURFACE-WATER SUPPLY

The only fresh surface-water supply now available in the Mermentau River basin is runoff from rainfall within the basin. Available records indicate that there is no appreciable contribution of ground water to any of the channels in the basin. All tributary streams flow intermittently, depending on surface runoff from rainfall.

Tabulations of monthly and weekly streamflow in the basin, gaged or estimated, are given in tables 10 and 11. Streamflow has been estimated for the entire basin area above the Intracoastal Waterway. Flow estimates include that in drainage channels tributary to the Intracoastal Waterway on the assumption that during the irrigation season the greater part of this flow will be intercepted for irrigation use before reaching the waterway. When the Intracoastal Waterway contains saline water, as it has frequently in the past, the water reaching that channel is rendered unfit for irrigation use.

Rainfall or runoff into, and evaporation from, the lake system below the Intracoastal Waterway is considered to be a part of the problem to be studied in connection with determinations of availability of storage in the system for use in periods when current streamflow is insufficient to meet diversion requirements. The acreage of rice planted south of the Intracoastal Waterway is negligible. The basic objective of this investigation was to determine quantitatively the deficiencies in streamflow. The problem of determining just what additional remedial work, if any, is needed is outside the scope of this report.

SOURCE, NATURE, AND CAUSE OF SALINITY ENCROACHMENT

Prior to the completion of the Catfish Point Control Structure, salt water from the Gulf of Mexico could encroach into Grand Lake through the lower Mermentau channel, impeded only by the volumes of fresh-water flow. During periods when diversions were excessive and water was being drawn from Grand Lake, some of the replacement water came from the gulf through the lower Mermentau River channel. Entry and diffusion of this highly saline water probably was greatly accelerated by tidal action. Similarly, water of very high salinity was brought into the Mermentau River system through the Intracoastal Waterway from the Calcasieu River. Water having lower salinity (see "Vermilion River basin") but having great enough salinity to be damaging to rice crops, entered from Vermilion Bay to the east. (See pl. 12.)

Under conditions existing prior to 1951, the potentialities for fresh-water storage in Grand Lake were negated to a great extent by these unimpeded encroachments of saline water. With the completion of the control structures and the dredging of a channel between Grand and White Lakes designed to effectively integrate White Lake into the Mermentau River system, the effective storage of large volumes of water has been made possible.

The general plan of operation is to let one or more of the control structures remain open during the winter runoff season for the passage of excess flood waters. Control gates are operated so as to maintain a maximum controlled elevation of 1.5 feet above mean low gulf level in Grand and White Lakes. Beginning early in the 1951 irrigation season all structures were kept closed, except for passage of boats through Calcasieu and Vermilion Locks, until withdrawals reduced the water levels enough to hinder boat traffic in the Intracoastal Waterway. The Schooner Bayou Control Structure was then opened to let the system refill with water from Vermilion Bay.

When the control structures are closed, the entry of saline water is limited to that entering through the Intracoastal Waterway while the boats pass through the Vermilion and Calcasieu Locks. Although the volumes of water introduced by the lockages are relatively small, they are sufficient to contaminate water in many miles of the Intracoastal Waterway within a few weeks after flow deficiencies develop. Concentrations of saline waters introduced into the Intracoastal Waterway through the Calcasieu Lock are significantly higher than those introduced through the Vermilion Lock. This contamination is a matter of great concern to farmers who divert water from drainage channels tributary to the Intracoastal Waterway.

By the opening of the Schooner Bayou Control Structure, water is introduced from Vermilion Bay into the lake system to replace excessive withdrawals. This water is considerably less saline than that which would be introduced into the lakes by the opening of either the Catfish Point Control Structure or the Calcasieu Lock and has a much greater distance to travel through the lakes before reaching the principal points of withdrawal in the channels upstream from Grand Lake.

At the start of the 1951 irrigation season, some salinity encroachment into the lakes had occurred before the structures were completed and placed in operation. After the structures were closed, the salinity in the lakes continued to increase as heavy withdrawals were made. With the system operating as a vast reservoir, heavy losses of the stored water took place through water-surface evaporation. This evaporation may have been a very important factor in increasing the salinity of the lakes. If water in the lake system had been fresh at the beginning of the 1951 season, the effect of evaporation on salinity would have been unimportant. During 1951 some contamination resulted from lockage of highly saline water through the Calcasieu and Vermilion Locks.

A comparison of salinities in Grand Lake during the two seasons 1948 and 1951 demonstrates, to some degree at least, the effectiveness of the control structures in preventing salt-water encroachment. Although records indicate that the average salinity in Grand Lake was about the same (400 ppm of chloride) at the beginning of the 1948 and 1951 seasons, on July 11, 1948, and July 12, 1951, the mean salinities in Grand Lake were about 5,300 and 1,100 ppm, respectively. Although withdrawals for irrigation were greater in 1948 than in 1951, the difference in the July salinities in the 2 years is largely the result of the effectiveness of the control system in preventing buildup of the salt-water content in Grand Lake.

Further comparison of salinities in the Mermentau system is shown in figures 31 and 32. These diagrams show that the maximum salinity at Lacassine Refuge on the Mermentau River (mile 38.2) was about 6,200 ppm of chloride in 1948 whereas the maximum in 1951 at that point was about 1,400 ppm of chloride. Comparison of salinities at upstream locations gives similar results.

Figures 31 and 32 also illustrate the advance of salt water upstream in the river channel. Increases in salinity began at the downstream station and progressed in order to the upstream station.

RELATIONS OF SUPPLY TO DEMAND

Streamflow and diversion for irrigation during the growing seasons of the 4 years, 1948–51, are presented graphically in figures 33–36. Weekly streamflow and diversion volumes are shown in the upper half of each illustration. Volumes of diversions in excess of current streamflow are indicated by the crosshatched areas. The lower half of each illustration shows volumes of flow, diversion, and deficiency accumulated from the first week of diversion. The difference between accumulated diversion and accumulated streamflow on any date represents the accumulated net deficiency or excess in streamflow from the beginning of pumping to that date or the net volume of withdrawal from lake storage for irrigation. The accumulated deficiency line on the lower half of each figure represents the cumulative total of the crosshatched areas in the upper section or the accumulated gross deficiency.

As previously explained, total diversions were determined by measuring diversions at selected pumping plants and applying the measured rate per acre to the total acreage irrigated in the basin. In years of adequate water supply, as in 1949 and 1950, the sampling process resulted in computed total diversion volumes for the

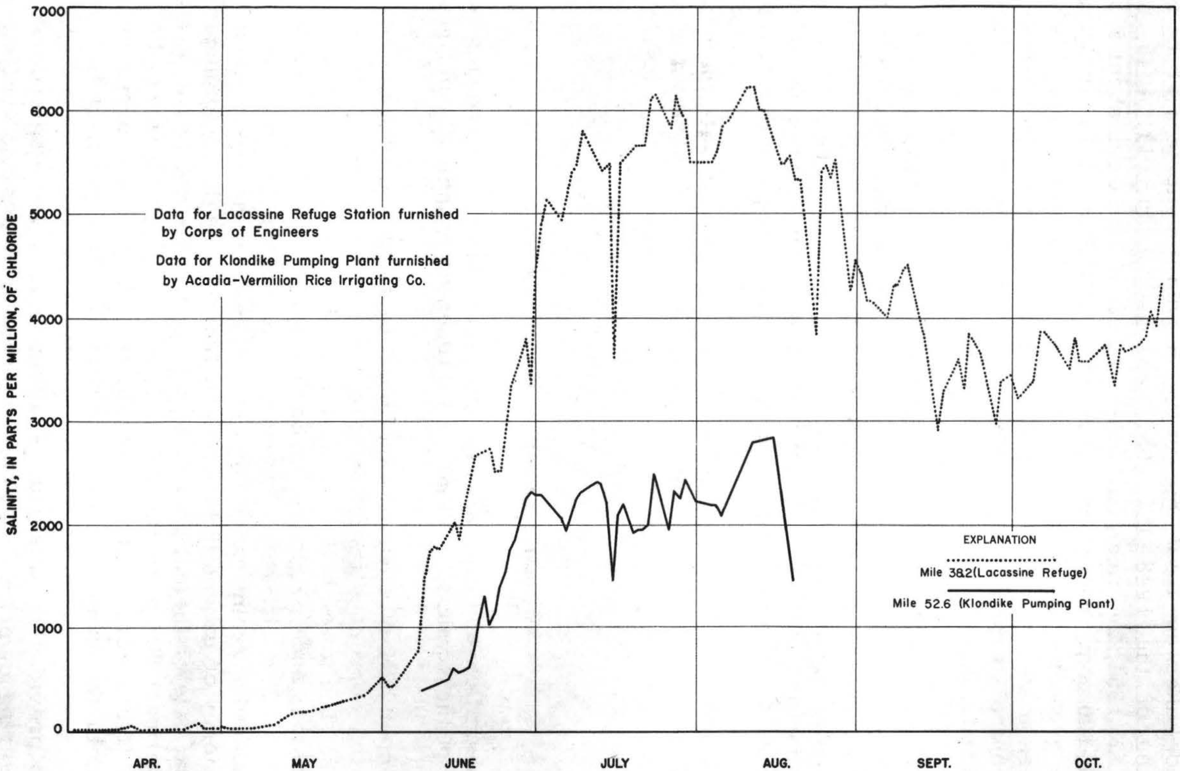


Figure 31.—Salinities at selected sites, Mermentau River, 1948.

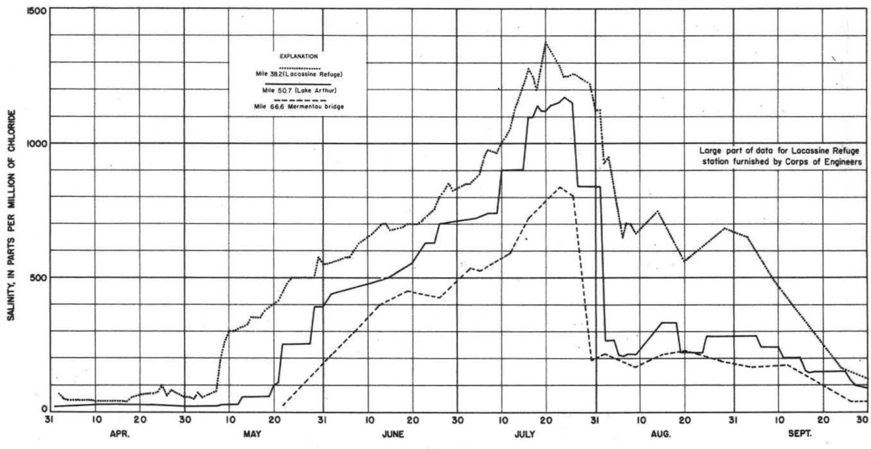


Figure 32.—Salinities at selected sites, Mermentau River, 1951.

Mermentau River basin which probably are very nearly correct. In years like 1948 and 1951, however, plants pumping from the sites farthest downstream in the basin were forced to modify pumping schedules because of salinity encroachment. There was some loss of, or damage to, crops in the lower parts of the basin in both years. Water was not pumped onto all acreage in the basin at the same rate in these years. Obviously, the only way to have determined the exact total of diversions in 1948 and 1951 would have been to measure the diversions by all units pumping from the channels in the basin, but this was impracticable.

Of the six pumping plants in the Mermentau River basin for which diversion records are available for the 1948 season, only one was affected seriously by salinity encroachment. It is probable, then, that the extrapolation of records for these plants produces figures for total diversion slightly less than those that would have resulted if ample fresh water had been available and possibly slightly greater than the actual volumes of diversion. The difference between computed diversions and actual diversions during 1948, however, probably is too small to be of practical significance.

All plants for which records were obtained during the 1951 season pumped water to the limit of their needs. Extrapolation of these records produces diversion-volume estimates for 1951 that represent fairly accurately the volumes that would have been diverted in the basin if adequate supplies had been available for all acreage in the basin. There were a few farmers in the area, particularly those pumping from channels tributary to the Intracoastal Waterway, who were not able to pump all the water they needed.

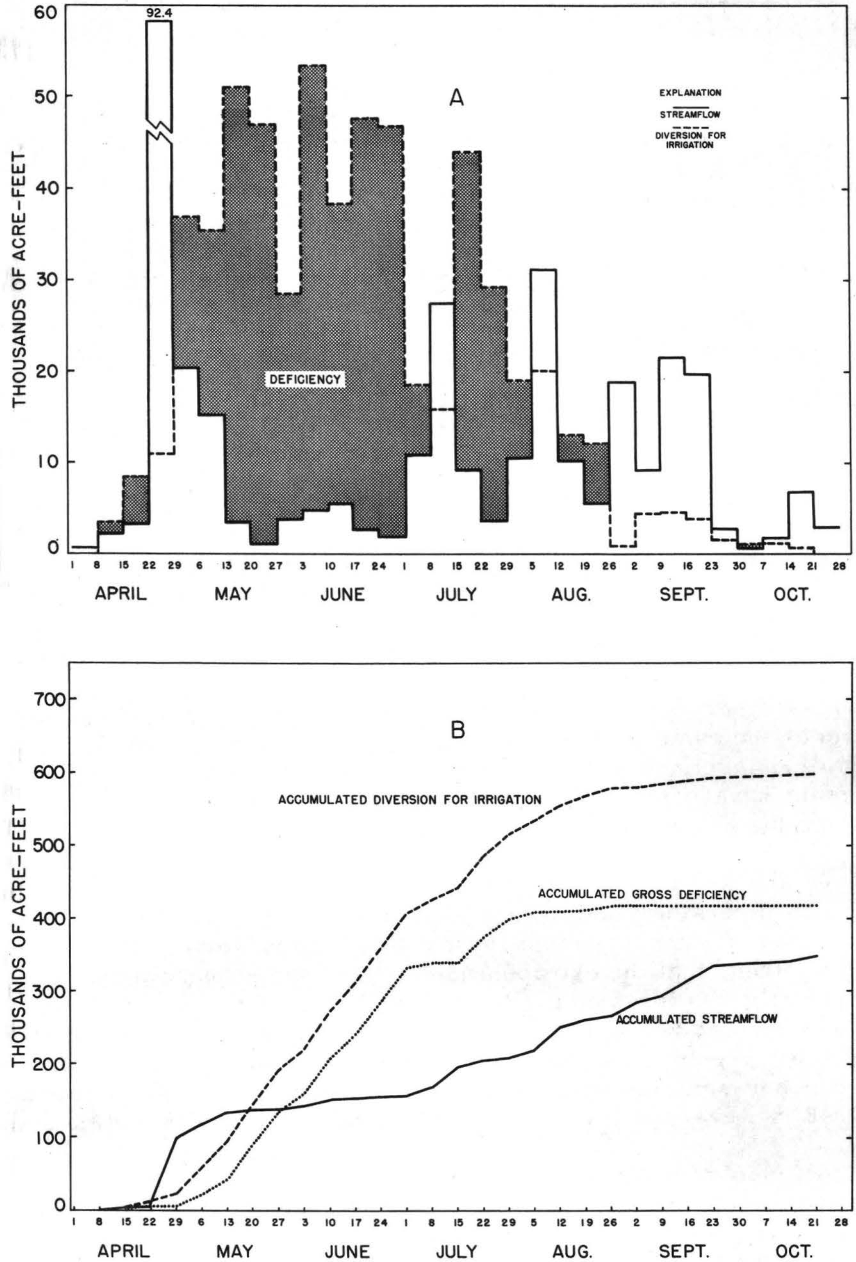


Figure 33. —Streamflow and diversions for irrigation, Mermentau River basin, 1948.

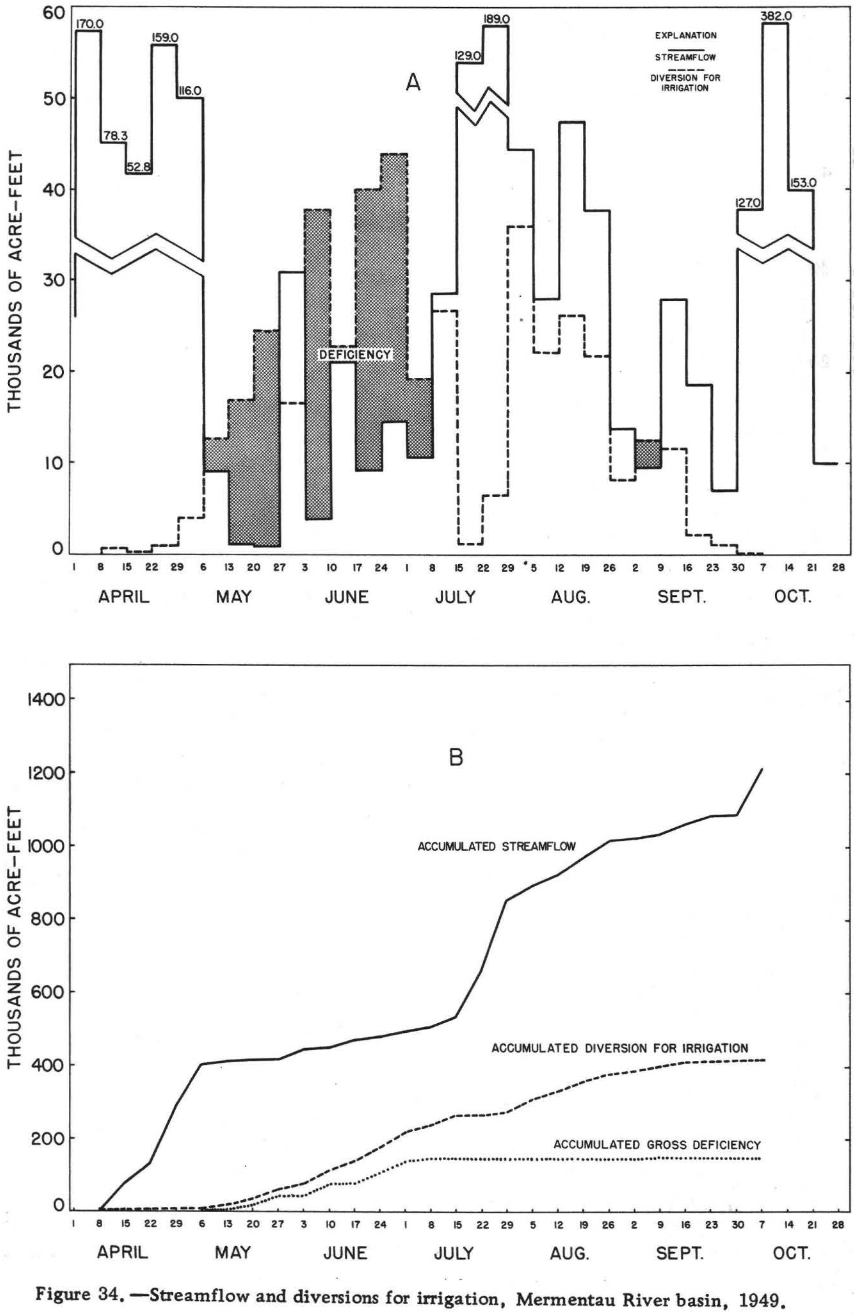


Figure 34. —Streamflow and diversions for irrigation, Mermentau River basin, 1949.

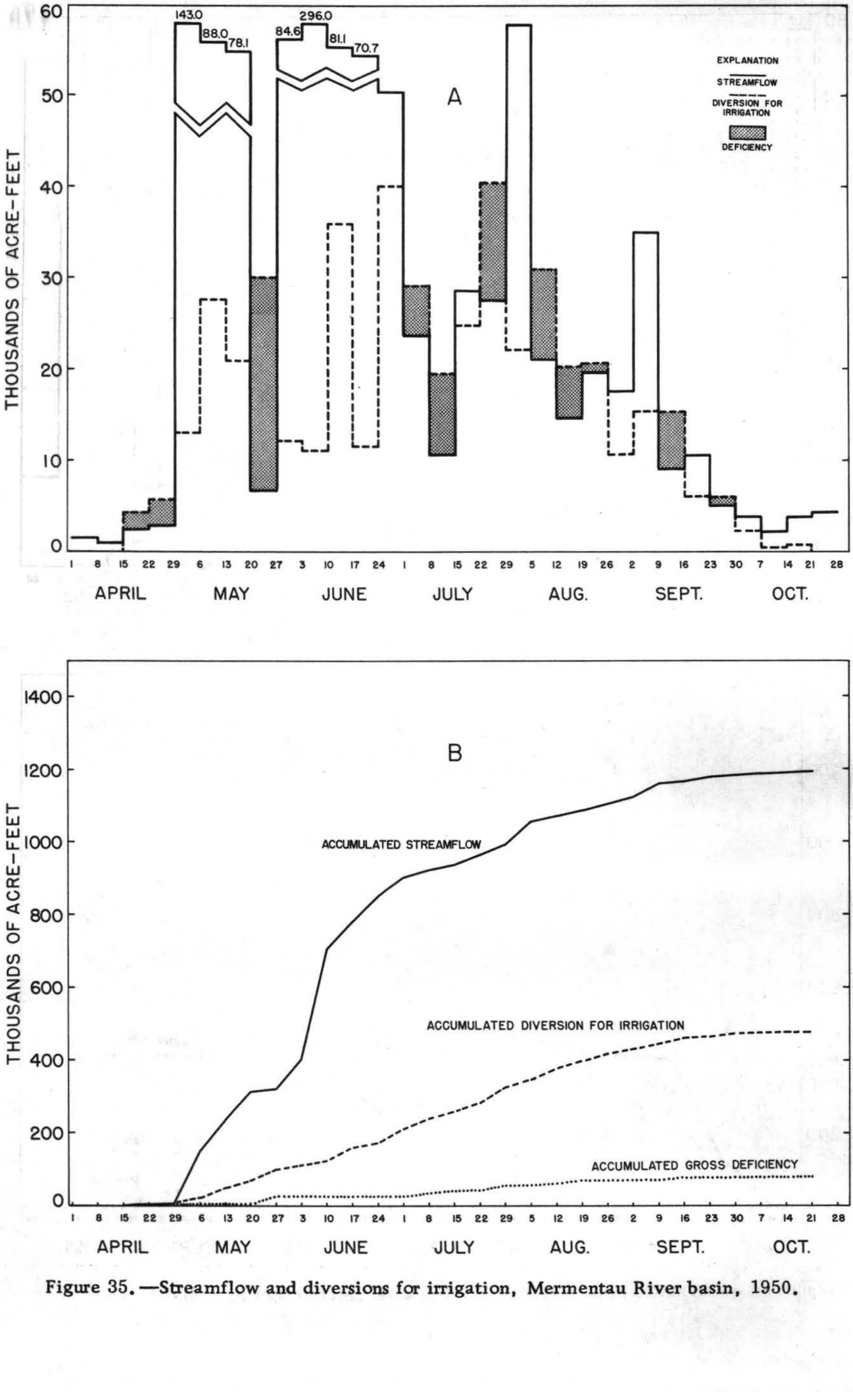
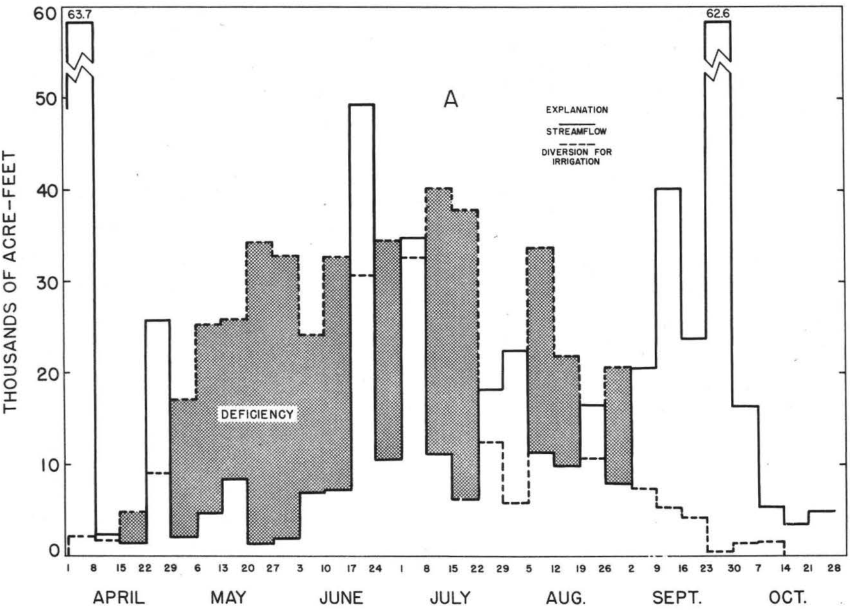


Figure 35.—Streamflow and diversions for irrigation, Mermentau River basin, 1950.



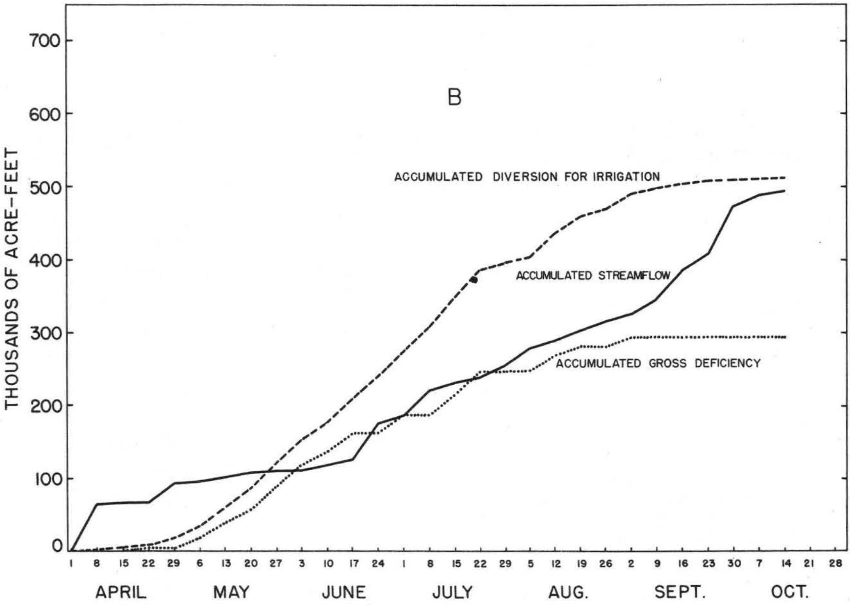


Figure 36.—Streamflow and diversions for irrigation, Mermentau River basin, 1951.

The acreage so affected, however, was small in comparison with the total acreage irrigated in the basin. As in 1948, the deviation of the computed diversions from actual diversions during 1951 probably is too small to be of practical significance.

Of the 4 years for which records are presented, the years of greatest flow deficiency were 1948 and 1951. The gross deficiencies in the 2 years were 418,000 and 294,000 acre-feet, respectively. Although there were gross deficiencies in streamflow in 1949 and 1950 amounting to 150,000 and 79,000 acre-feet, respectively, the encroachments of salt water were not serious in those years.

With the Mermentau system now controlled, primary interest in the records for 1948 and 1951 centers in the maximum volumes of water withdrawn from lake storage. The maximum net deficiency had accumulated by August 5 in 1948 and by September 2 in 1951. From April 9 to August 5, 1948, total diversions exceeded total streamflow by about 314,000 acre-feet. From April 2 to September 2, 1951, total diversions exceeded total streamflow by about 166,000 acre-feet. These deficiencies represent the net volumes of water withdrawn from lake and channel storage up to the time when the total net withdrawals reached their maximums. Thus it is seen that the maximum requirement for water from storage for irrigation was nearly twice as great in 1948 as in 1951.

Consideration of the critical period in 1948 (April 9 to August 5) will serve to demonstrate the probable total demand for water from storage in that critical year. Water-surface evaporation depth during the period is estimated to have been about 25 inches over the storage area. Of this evaporation depth, about 13 inches was supplied by rainfall on the water-surface area, leaving a net loss to evaporation of about 12 inches. Over the estimated water-surface area of 110,000 acres, the evaporation loss thus is estimated as about 110,000 acre-feet. This volume added to the estimated withdrawal for irrigation gives a total withdrawal during the period of 425,000 acre-feet, or a volume sufficient to have reduced the stage in the Mermentau system almost 4 feet, if the system had been controlled then as it is now. Except for the fortuitous occurrence of about 81,000 acre-feet of excess streamflow in the week April 23–29, the computed total withdrawal would have been about 500,000 acre-feet. This computation is illustrative of the storage requirements in a year like 1948 with the lake system operated as it is now. It neglects runoff from areas contiguous to the lake and possible recovery of water from bank storage along the shorelines.

Control of the lake system was in effect during the 1951 season, but supply and demand were not as greatly out of balance as in

1948, principally because of the reduced acreage irrigated. The Mermentau system was closed effectively for the first time on April 19, 1951, just after the beginning of the irrigation season. By July 12 the water level in the Intracoastal Waterway was low enough to hinder boat traffic seriously, and the Schooner Bayou Control Structure was opened to admit water to restore the level in the Mermentau system.

During the period April 23 to July 8, 1951, records indicate that the net withdrawal from storage was 145,000 acre-feet. According to stage records collected by the Corps of Engineers, the average stage of the lake system receded from 1.5 feet on April 23 to -0.7 foot on July 8, or a total recession of about 2.2 feet. From pan records reduced by an approximate coefficient, evaporation from the reservoir system is estimated to have been about 12 inches. Average precipitation on the lake system during the period was about 3 inches. Therefore, the net change in stage resulting from evaporation and rainfall was a recession of about 9 inches. Assuming the reservoir area to be about 110,000 acres, the withdrawal for irrigation (145,000 acre-feet) lowered the stage about 16 inches. The computed total stage recession, then, is about 25 inches compared with an observed stage change of 2.2 feet or 26 inches. This computation illustrates the importance of evaporation in reducing the storage in the reservoir system. During the period April 23 to July 8, 1951, evaporation losses accounted for about three-fourths as much stage recession in the lakes as did the diversion for irrigation.

The foregoing computations indicate clearly that, in a future year having diversion requirements as great as in 1948, it will be necessary to open the Schooner Bayou Control Structure very early in the irrigation season in order to maintain navigation depths. How much of the fresh-water storage remaining in the system at the time of opening the structure can be used in subsequent periods of deficient streamflow before serious salinity concentrations develop cannot be determined accurately on the basis of available data.

MAXIMUM PROBABLE WATER-SUPPLY DEFICIENCY

Of great concern in connection with the water-supply problem in the Mermentau River basin is the question of the streamflow deficiency in a year of maximum diversion requirements and minimum streamflow. In "Maximum seasonal diversion rates," it was computed that the maximum probable diversion rate is about 3.5 acre-feet per acre. It has been indicated, also, that the maximum acreage in the basin irrigated with surface water in past

387601 O - 56 - 13

years was about 250,000 acres. This acreage, at maximum rate, would require about 875,000 acre-feet of diversions from the water supply of the Mermentau River basin.

Any estimates of available streamflow and of evaporation from the storage area in a critical year are of necessity very approximate. These estimates are necessary, however, if any idea is to be gained as to the most critical problem that may be faced in the future in the Mermentau River basin.

The total precipitation in the Mermentau River basin in the months April through August in several of the most critically dry years of record is given in the following tabulation.

	Precipitation in months April through August (inches)
1902	14.6
1924	14.1
1925	14.1
1931	16.4
1948	15.9
1951	11.9

This tabulation shows that there was less rainfall on the Mermentau River basin in the period April through August in 1951 than in any corresponding period of record since 1900. Because of high runoff during the first part of April 1951 which resulted from rainfall the last few days in March, the total streamflow in the 5-month period April through August in 1951 was greater than for the same period in 1948. However, the runoff from the 15.9 inches of rainfall in the period in 1948 was about 285,000 acre-feet, and the runoff from the 11.9 inches of rainfall in 1951 was about 265,000 acre-feet.

Assuming that the fortuitous carryover from March may not be available in another year as critical as 1951, the runoff of 265,000 acre-feet in 1951 may be used as a probable record-low volume of streamflow in the Mermentau River basin. Thus, in a year of maximum acreage, requiring about 875,000 acre-feet of water for irrigation, the net deficiency in current streamflow would be about 610,000 acre-feet in a year of minimum water supply. Water to overcome this deficiency, if available, would have to come from storage in the lake system or from a supplementary source of supply outside the basin.

Further withdrawals from storage would result from evaporation losses. Pan evaporation at Crowley from April through August in 1948 was 35.3 inches (records are not available for this pan for 1951). Using a coefficient of 0.90 (Harding, 1942) to approximate lake evaporation from pan evaporation (pan of sunken type, 72 inches in diameter and 35 inches deep) gives an estimate of 32 inches of evaporation from the lake system during an irrigation season in that dry year. Allowing for about 12 inches replacement by rainfall leaves a net estimated withdrawal by evaporation of about 20 inches. Twenty inches of withdrawal on 110,000 acres is equivalent to about 185,000 acre-feet. The total demand for water from storage in a runoff season like 1951, if 250,000 acres of rice were planted, would be about 795,000 acre-feet (610,000 acre-feet deficiency in streamflow plus 185,000 acre-feet loss by evaporation).

During the interval between irrigation seasons, the availability of water to flush or refill the storage area is of great importance. Estimates of total flow from the entire basin for the months September through March preceding the four irrigation seasons included in this report are given in the following tabulation.

	Acre-feet		*Acre-feet*
1947–48	1,810,000	1949–50	2,583,000
1948–49	2,050,000	1950–51	1,262,000

The years for which volumes of preseason flow are listed in this tabulation, however, do not include the lowest runoff seasons of record.

The lowest total precipitation in the Mermentau River basin in the months September through March recorded since 1900 was about 17 inches in 1903–4. The runoff during this period in 1903–4 is estimated to have been about 600,000 acre-feet. This runoff estimate, of course, is quite unreliable but is probably in about the right order of magnitude. The next lowest September-through-March rainfall occurred in 1917–18 and was slightly less than 18 inches. The runoff during this period in 1917–18 is estimated to have been about 700,000 acre-feet.

Between-season runoff as tabulated includes September, but it should be remembered that a small volume of the September flow in each year is diverted for irrigation. The effectiveness of the replenishing runoff will be reduced by evaporation from the storage area. Evaporation from the water-surface area during the months September through March is estimated to average about 20 inches of depth or about 180,000 acre-feet. Therefore, in a dry winter season like that of 1903–4, the minimum net volume of water remaining in storage at the beginning of the following irrigation season would be about 420,000 acre-feet.

The computations presented in the foregoing discussions are intended only to illustrate the various factors affecting the water budget for the Mermentau River basin and the relative magnitude of these factors. Several important facts, however, appear evident from the data presented and the illustrative computations that have been made.

If the lake and channel reservoir system is full at the beginning of an irrigation season, the storage volume would be about 575,000 acre-feet below and about 165, 000 acre-feet above mean low gulf level (to maximum controlled elevation of 1.5 feet above mean low gulf level), or a total of about 740,000 acre-feet. By comparison, the total storage demand in a critically dry water-supply year, if 250, 000 acres of rice is irrigated in the basin, would be about 795, 000 acre-feet. Although the total storage volume appears to be nearly great enough to satisfy the water-supply requirements in a critically dry year, the effective availability of the total storage volume is seriously in question. A model study probably would be required to determine what portion of the total storage volume could be utilized effectively under various plans of operation of the control structures to maintain necessary navigation depth. However, it is possible that, if the storage areas were full of fresh water at the beginning of a season, a large part of the water required for irrigation could be withdrawn before the water reaching the pumping plants would be salty enough to injure the rice crops. Water having the highest salinity utilized would be pumped in the late part of a season, a time when the rice generally is at a stage of maturity such that it would tolerate moderate concentrations of salt.

Although the storage system possibly might prevent serious damage to a rice crop in one critically dry season, if storage conditions were ideal at the beginning of the season, the prospects of preventing damage in a second successive critically dry season are dim. If, between the two critically dry irrigation seasons, there should occur a critically dry winter-runoff season in which the net volume of water available for storage might be as low as 420, 000 acre-feet, there would be a considerable residual volume of salty water in the storage area at the beginning of the second irrigation season. In the second season salinity concentrations sufficient to damage rice undoubtedly would develop early in the irrigation season. Such a sequence of low-runoff seasons occurred in 1924–25.

CALCASIEU RIVER BASIN

The Calcasieu River has its source in Vernon Parish in western Louisiana and follows a tortuous course of about 215 miles in a general southerly direction to the Gulf of Mexico (see pl. 12). The drainage area above Lake Charles is about 3,170 square miles.

The extreme upper part of the basin is in the outcrop area of Miocene sedimentary rocks. The surficial beds are tightly cemented sand and doughy clay. Probably nearly all the flow from this area is surface runoff. The topography is characterized by relief contrasts commonly as great as 60 feet. The highest land-surface elevations are slightly more than 400 feet above mean sea level.

A belt of delta-gravel exposures crosses the basin in a generally east-west direction in the vicinity of De Ridder. This gravel exposure is the principal area of ground-water recharge for the entire southwestern Louisiana area. Streams originating within or crossing this area receive large contributions of ground-water flow. Bundick and Whiskey Chitto Creeks are the principal Calcasieu River tributaries that carry large volumes of ground-water runoff. Effluent ground water also constitutes a large portion of the flow from the area drained by the Calcasieu River as it crosses the gravel belt. (For a more complete delineation of this and other physiographic regions of the Calcasieu River basin, see pl. 1.) The gravel-outcrop area is generally termed the upland plains.

Below the upland plains the prairie slopes rather gradually into the relatively flat portions of the coastwise plain. In this area the surface clays are relatively impervious, greatly retarding percolation of rainfall. Because stream channels generally do not cut entirely through the bed of these clays, the flow carried by streams in this area is very largely surface runoff. The principal Calcasieu River tributaries that drain this area are Barnes Creek, Hickory Branch, Beckwith Creek, and the Houston River and its tributaries.

The Intracoastal Waterway traverses the Calcasieu River basin in a generally east-west direction near the northern fringe of the coastal marsh area. As in the other parts of southwestern Louisiana, land elevations are extremely low in the coastal marsh.

In the northern part of the basin the Calcasieu River and its tributaries are clear swiftly running streams. Below the latitude of Kinder, the Calcasieu River channel widens and deepens as it approaches Lake Charles. In this reach the river changes from a swiftly flowing stream into a sluggish tidal stream typical of the bayous of southwestern Louisiana. The river is considered navigable to a distance of about 66 miles above its mouth and is tidal throughout this reach. The normal tidal variation at the mouth of the Calcasieu River is from 10 to 14 inches. Under the influence of strong winds, this variation frequently is 3 feet or more.

A deepwater ship channel, first completed in 1941 and subsequently enlarged to its present (1952) size of 250 by 35 feet, connects Lake Charles with the Gulf of Mexico by a route that approximates the natural Calcasieu River channel. Lake Charles is connected with the gulf also through Sabine Lake by the Intracoastal Waterway.

ACREAGE IRRIGATED

The acreages of rice irrigated by diversions from the Calcasieu River or its tributaries during the 4 years covered by this report were:

	Acres		*Acres*
1948	51,000	1950	49,000
1949	52,000	1951	43,000

The acreages include arbitrarily assigned portions of the acreage irrigated by farmers having both a surface- and a ground-water supply.

Records are not available from which to determine the maximum acreage irrigated with surface water in the Calcasieu River basin in years before 1948. After completion, in 1941, of the ship channel from Lake Charles to the Gulf of Mexico through Calcasieu Lake, increased salt-water encroachment into the lower Calcasieu River resulted in a shift from the use of surface-water supplies to ground-water supplies on much of the rice acreage below the latitude of Lake Charles. Because of the effect of the ship channel, industrial water requirements and wastes, and oilfield brines on the quality of surface water in the lower part of the river, there are at present no diversions for irrigation from the Calcasieu River or its tributaries below Lake Charles.

During the 4 years for which accurate records are available, the maximum acreage irrigated with surface water in the Calcasieu River basin was 52,000 acres in 1949. As this acreage was planted in a year subsequent to completion of the ship channel, it is reasonable to expect that an acreage at least as great as that in 1949 may be irrigated with surface water in the Calcasieu River basin in some future year. There is the distinct possibility that expansion of the use of surface water for irrigation in the upper parts of the basin may occur in future years. A large area in the Calcasieu River basin, near the western drainage-basin divide, is served by water from the Sabine River. Should water-supply problems become critical in the Sabine River basin and conditions in the Calcasieu River be improved, at least a part of this area may be increasingly dependent on water from the Calcasieu River or its tributaries. It is not unreasonable to suppose that an additional 10,000 to 15,000 acres in this area may become dependent eventually on water from the Calcasieu River basin.

SOURCES OF AVAILABLE SURFACE-WATER SUPPLY

No supplementary water supplies are being diverted into the Calcasieu River or its tributaries from outside sources. Neither are there any reservoirs in the basin through which to redistribute the annual flow for more effective use during periods of heavy withdrawal.

Water-supply problems in the Calcasieu River basin below the city of Lake Charles are complicated by the requirements of many interests, mainly agriculture, industry, navigation, and mining (sulfur and salt). To solve the problems of the lower basin would require extensive studies beyond the contemplated scope of the investigation leading to this report. The problems of the lower basin, therefore, are considered only superficially herein. Runoff data for the basin above Lake Charles are given in tables 12 and 13.

SOURCE, NATURE, AND CAUSE OF SALINITY ENCROACHMENT

The principal source of salt-water contamination in the Calcasieu River is the Gulf of Mexico. Encroachment occurs through the ship channel in the typical wedge pattern (see "Quality of water"). Except during periods of high runoff rates, this wedge of salt water extends far up the Calcasieu River and its tributaries.

During 1951, encroachment of salt water in the main river channel was observed to reach slightly more than 61 miles above the mouth of the river. Chloride concentrations as high as 900 ppm were observed at a pumping plant on Bayou Serpent about 66 miles by channel from the mouth of Calcasieu River. According to local reports, the maximum chloride concentrations at this point on Bayou Serpent were much higher during the 1948 irrigation season than during the 1951 season.

At the Geological Survey's daily-sampling station on the Calcasieu River at the Naval Training Station at Lake Charles (mile 44.0), the maximum top and bottom chloride concentrations observed during the 1951 irrigation season were 4,900 and 7,750 ppm, respectively. At the sampling station near Hecker (mile 59.0), the maximum top and bottom chloride concentrations observed in 1951 were 1,040 and 6,680 ppm, respectively. These chloride concentrations are cited to illustrate the seriousness of the salt-water encroachment problem to the rice farmers in the Calcasieu River basin.

With regard to the cause of salinity encroachment in the Calcasieu River channel and the effects of the dredged ship channel that links Lake Charles with the gulf through Calcasieu Lake, a Corps of Engineers report (U. S. Army, 1950) on a model study by the Waterways Experiment Station, Vicksburg, Miss., states:

> Prior to the dredging of this channel, the shallow depths throughout Calcasieu Lake and Calcasieu Pass (controlling depth about 5.5 ft) constituted a natural barrier to the movement of salt water up the Calcasieu River. Density flow of salt water in any channel is controlled primarily by the salt-water head at the entrance. It is to be expected, therefore, that the rate and extent of salt-water intrusion into and through a 30-ft channel would be more serious than would occur in a channel having a controlling depth of less than 6.0 ft. Moreover, a given river discharge would be more effective in combatting salinity intrusion in the shallow channel than in the comparatively deep channel.

The channel was deepened to 35 feet in 1948.

When diversions are being made for irrigation, the river discharge available for combatting salinity encroachment is greatly reduced. As a general principle, the lower the river discharge the farther upstream the salt-water wedge penetrates. At times, diversion for irrigation exceeds total streamflow. This causes the wedge to advance upstream very rapidly. Other sources of salt-water contamination in the Calcasieu River are described in the model study report referred to above:

> In addition to the Gulf of Mexico, the sources of salt which may contribute to contamination of the waters of the Calcasieu River and tributary streams are the numerous oil and gas fields throughout the area and industrial wastes dumped into the streams for disposal. Data supplied by the State of Louisiana Department of Conservation indicate that oil wells in the Calcasieu River area produce approximately twice as much salt water as oil, the total salt-water production amounting to about 302,000 cu ft per day and having salinities ranging from 42,000 to 143,000 parts per million chloride. Also, the Mathieson Alkali Works produce about 200,000 cu ft of waste per day which, when dumped into the river for disposal, has an average salinity of approximately 40,000 parts per million chlorides. The above-discussed wastes are not dumped directly into the stream as they are produced; instead, the wastes are impounded and released into the stream only during favorable conditions of flow and, if possible, during times at which pumping for irrigation purposes is at a minimum.

RELATIONS OF SUPPLY TO DEMAND

Streamflow and diversion for irrigation during the growing seasons of 2 years, 1948 and 1951, are presented graphically in figures 37 and 38. Weekly streamflow and diversion volumes are shown in the upper half of each illustration. Volumes of diversions in excess of current streamflow are indicated by the crosshatched areas. The lower half of each figure shows volumes of flow, diversion, and deficiency accumulated from the first week of diversion. The difference between accumulated diversion and accumulated streamflow on any date represents the accumulated net deficiency or excess in streamflow from the beginning of pumping to that date. The accumulated deficiency line in the lower half of each figure represents the cumulative total of the crosshatched areas in the upper section, or the accumulated gross deficiency.

Streamflow and diversion volumes for 1949 and 1950 are not shown graphically because there were no weeks in either year in which diversions for irrigation exceeded current streamflow. Tabulations of streamflow volumes for the years 1948–51 were presented in tables 12 and 13 in a preceding section. Diversion volumes for the same years were presented in table 14.

As previously explained in this report, total diversions were determined by measuring diversions at selected pumping plants and applying the measured rate per acre to the total acreage irrigated in the basin. Diversion records were not available for pumping plants in the Calcasieu River basin during the 1948 season. Diversion from the Calcasieu River during 1948 was computed from the rate of diversion measured at five plants in the Mermentau River basin that were unaffected by salt-water encroachment. Thus, diversion volumes computed for 1948 in the Calcasieu River basin essentially are estimates of the volumes that would have been diverted had there been no salt-water encroachment. The two plants in the Calcasieu River basin at which diversions were measured in 1951 were not affected appreciably by salt water. Thus the computed diversions during 1951 also are estimates of the total volumes of water that would have been diverted had there been no salt-water encroachment. The plant on English Bayou (see pl. 12) at which diversions were measured is protected from salt-water encroachment by a control structure just below the plant. Water pumped by the plant is diverted from the Calcasieu River at a point about 2 miles below the mouth of Bayou Serpent and brought to the plant through a privately owned canal.

Pumping schedules of a number of plants were affected seriously by salt water in both the 1948 and 1951 seasons. The estimates

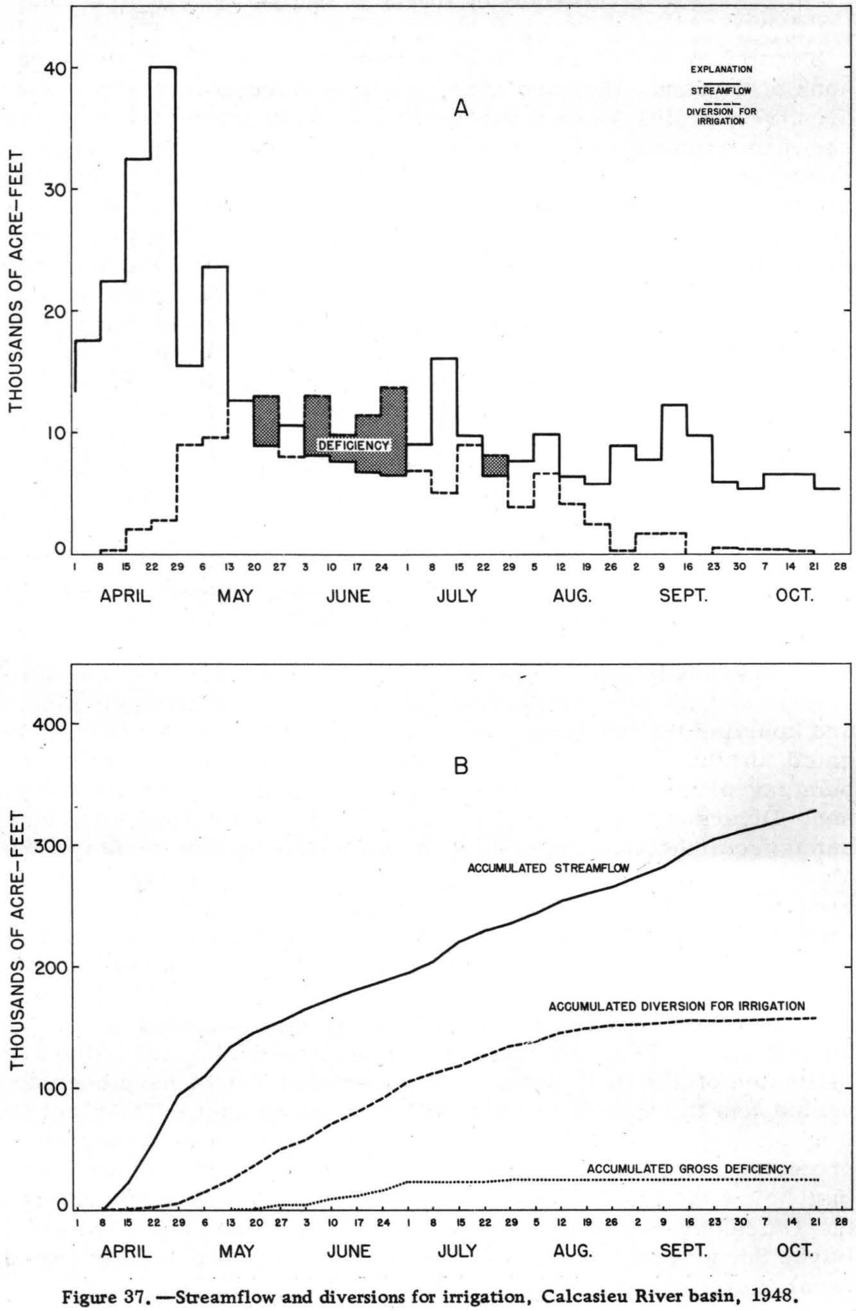


Figure 37.—Streamflow and diversions for irrigation, Calcasieu River basin, 1948.

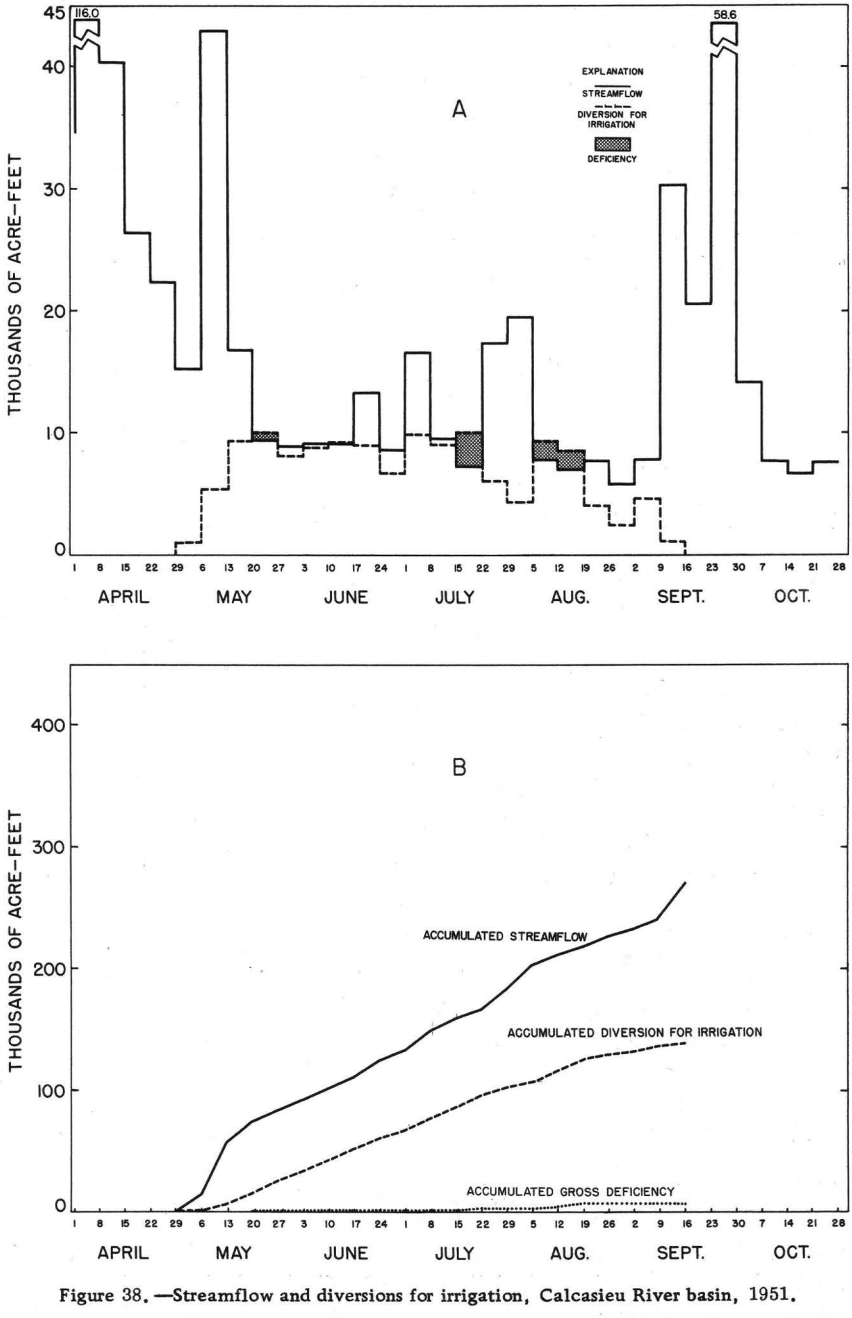


Figure 38. —Streamflow and diversions for irrigation, Calcasieu River basin, 1951.

of total diversions from the Calcasieu River and its tributaries in those years undoubtedly are somewhat higher than the actual diversions although probably not more than 10 to 20 percent.

An important observation to be made from a study of figures 37 and 38 is that the deficiencies in current streamflow were not very large in either 1948 or 1951, indicating that there would have been no serious water-supply problem for irrigation purposes in either year if the available supply could have been protected from contamination by the salt-water wedge encroaching from the gulf.

The total gross deficiencies in 1948 and 1951 were about 25,000 and 7,000 acre-feet, respectively. The maximum net deficiency was accumulated during the period May 21 to July 1, 1948, and was about 20,000 acre-feet.

A significant feature to be observed in figures 37 and 38 for 1948 and 1951 is that water supply and demand were quite closely in balance for about 3 months during the irrigation season in each year. Thus, for extended periods in these years there was very little excess streamflow to combat the encroachment of salt water.

A study of means of preventing salt-water encroachment involves the determination of rates of fresh-water flow necessary to prevent encroachment from reaching farther upstream than a given point. Only indirect inferences as to the effects of rates of flow on encroachment into the Calcasieu River may be drawn from the available data. Although estimates of total weekly flow have been made for the period April through October in the years 1948–51, no data are available as to the actual rates of flow on particular days at specific points along the river. Some insight into the problem, however, may be gained by examination of salt-water movements in the channel during April 1951. Other periods might have been chosen, but this one will serve to illustrate the factors involved in the encroachment problem. References are made to salinity data collected under the sponsorship of the Lake Charles Association of Commerce.

The mean rate of flow during March 1951 was about 3,500 cubic feet per second. During the last half of March, the maximum top and bottom salinities at mile 26 (Shell Terminal) reached about 3,800 and 12,000 ppm of chloride, respectively. During the same period at mile 46 (just above the mouth of the West Fork Calcasieu River) the maximum top and bottom salinities were about 450 and 5,000 ppm, respectively. As a result of flow during the week of April 2–8, averaging about 8,000 cfs, bottom salinities at mile 26 were reduced to a minimum of about 2,660 ppm on April 13. Top salinities at that point reached a minimum of about 380 ppm of chloride several days prior to that date. On April 2, top and bottom salinities at mile 46 were down to about 50 ppm. The water at that point remained nearly fresh until April 18, but thereafter salinities increased rapidly so that, on April 23, chloride concentrations were about 1,400 and 8,000 ppm at top and bottom, respectively. Thus it is seen that the salt-water wedge had encroached beyond the mouth of the West Fork Calcasieu River in 1951 before the irrigation season had begun (see fig. 38), despite fairly high rates of flow. The average flow during the week of April 16–22 was about 1, 800 cfs.

Although the foregoing discussion has presented only sketchy and inconclusive data, it is apparent that, with a rate of flow of about 8,000 cfs, there is encroachment upstream at least 26 miles from the mouth of the river and that the wedge will advance beyond the mouth of the West Fork Calcasieu River in the face of flows ranging somewhere between 2, 000 and 8, 000 cfs.

More conclusive evidence is to be found in the results of the model study by the Corps of Engineers referred to in a preceding part of this section. The following is taken from the published report on the model study (insertions by the present writer express salinity and location as they are used in this report):

The results of tests 21–25, which were concerned with salinity intrusion in the upper Calcasieu River, Houston River, and English Bayou, are shown on plates * * * The results of these tests indicate that with the proposed 34 ft channel installed, water of very high salinity would intrude upstream past stations 13 [mile 51.7 on Calcasieu River] and 14 [on Houston River 51.6 mi. above mouth of Calcasieu River], the uppermost stations at which salinity samples were obtained. With a river discharge of 7,000 cfs, the salinity at station 14 in the Houston River was quite low; however, that at station 13 in the Calcasieu River reached a maximum of almost 27,000 ppm [about 16,500 ppm of chloride, bottom sample]. For river discharges of 5,000 cfs or less, maximum salinities at all stations exceeded 26,000 ppm [about 16,000 ppm of chloride].

As a large acreage of rice is irrigated with water from the West Fork Calcasieu River and its tributaries, salinities of water in the Calcasieu River at the mouth of the West Fork are of great interest. Records for Beckwith Creek and Hickory Branch indicate that the West Fork and its tributaries drain an area of relatively low runoff. For this reason, a considerable part of the water diverted from the West Fork and its tributaries undoubtedly comes from the Calcasieu River. As has been pointed out previously, salt-water encroachment reached upstream beyond the mouth of the West Fork immediately prior to the 1951 irrigation season. Irrigators in the West Fork and Houston River areas were affected earlier and more severely than those in any other part of the Calcasieu River basin.

The seriousness of the encroachment problem has given rise to a proposal by local interests that a salt-water barrier be placed across the Calcasieu River below the mouth of the West Fork. The foregoing discussion contains water-supply and salinity data pertinent to the proposal for a salt-water barrier. No doubt, these data will be of interest to those whose function it is to pass on the economic justification for remedial works and to design and construct them. It has been shown, for example, that current streamflow in the 2 critically dry years 1948 and 1951 was sufficient to have met all irrigation needs in the basin in those years, with need for only very small storage volumes, if the streamflow had been protected from contamination. In those years very little acreage was irrigated by diversions from the Calcasieu River or its tributaries below the mouth of the West Fork.

The discussion on the relation of salt-water encroachment to rates of river flow leads to the conclusion that a rate of flow above 8,000 cfs would be required to prevent encroachment beyond the mouth of the West Fork Calcasieu River. To have supplied a rate of flow of 8,000 cfs in excess of irrigation withdrawals during the 1951 pumping season would have required about 2,100,000 acre-feet of water in excess of natural river flow during the 1951 season. Between the close of the 1950 irrigation season and the beginning of the 1951 irrigation season the computed total flow of the Calcasieu River at Lake Charles was 1,300,000 acre-feet. Therefore, even if it were possible to control completely the flow of the Calcasieu River at Lake Charles there is insufficient flow in the basin, in a year such as 1951, to supply a rate of flow necessary to prevent salt-water encroachment.

Although it is impossible for upstream reservoirs to supply the rate of flow necessary to prevent salt-water encroachment, the probable need for such reservoirs should not be overlooked. It has been shown that, on the basis of current acreages, in years like 1948 and 1951 there are extended periods in which water-supply and diversions for irrigation are closely in balance. If the natural river flow were protected from contamination by a barrier, it is probable that diversions from above the barrier would be made to supply an increased acreage in the southern part of the basin and possibly to supply certain industrial needs. If this should occur, supplementary supplies from upstream storage would be required. The continued availability of those supplies will be dependent to some extent on future ground-water developments (see p. 231).

The scope of this investigation did not include the needs for surface water by industry in the Lake Charles area. The data presented herein make it clear, however, that in critical irrigation seasons there are only small volumes of excess flow that are available for use by industry. Diversion points for irrigation are upstream from those for industry. If the need for surface water by industry in the Lake Charles area should require diversion of appreciable supplies of fresh water and water demands for irrigation should remain at the present level or increase, the necessity for supplementing natural river flow by releases from upstream storage would be inevitable. The water-supply needs of industry in the Calcasieu River basin will have to be known more accurately than at present before comprehensive conclusions regarding storage requirements can be drawn.

Owing to the complexity of the factors that may affect future acreages irrigated by diversions from the Calcasieu River or its tributaries, extrapolation to the maximum probable seasonal diversion requirement is not made for the Calcasieu River basin. However, some discussion as to the probable relation of river flow in 1948 and 1951 to that in earlier years is desirable. Although rainfall comparisons are never a very good index to streamflow, such comparisons are helpful in drawing general conclusions. The average rainfall on the Calcasieu River basin during the period April through August in several of the most critical years since 1900 is listed in the following tabulation.

	Precipitation in the months April through August (inches)
1902	15.2
1924	15.4
1925	11.0
1931	13.6
1948	13.5
1951	12.2

This indicates that both 1948 and 1951 were years of nearly record-low rainfall on the Calcasieu River basin.

Total flow in the basin during the years 1948–51 has been estimated for use in this report. The total streamflow from the area above Lake Charles in the months April through August of those years is listed in the following tabulation.

	Streamflow April through August (acre-feet)
1948	293,000
1949	1,849,000
1950	2,166,000
1951	465,000

The data in this tabulation indicate that the runoff during the 1948 season was less than that in 1951, although the rainfall was slightly greater in 1948. For a stream like the Calcasieu River, which has large contributions of ground-water flow, antecedent hydrologic conditions have so great an influence on runoff in subsequent periods that current rainfall alone is an unsatisfactory index to current streamflow.

The total streamflow measured at three gaging stations in the basin during the 5-month period April through August in the years 1939–51 is listed in the following table. The three gaging stations are Calcasieu River near Oberlin, Whiskey Chitto Creek near Oberlin, and Bundick Creek at Dry Creek. The combined drainage area for these stations is about 1,500 square miles, or about 47 percent of the Calcasieu River basin above Lake Charles. The tabulation shows that streamflow in Calcasieu River basin was lower during the 1948 irrigation season than during any other of the 13 years for which records are available.

	Streamflow April through August (acre-feet)
1939	248,000
1940	1,414,000
1941	1,325,000
1942	567,000
1943	208,000
1944	599,000
1945	965,000
1946	966,000
1947	528,000
1948	166,000
1949	956,000
1950	1,078,000
1951	294,000

From the preceding comparisons of rainfall and streamflow, it may be concluded that the 1948 irrigation season was one of the periods of lowest water supply on record in the Calcasieu River basin.

When upstream-storage possibilities are being studied, river flow during the period between irrigation seasons is of great interest. Although no effort is made here to analyze storage possibilities in the Calcasieu River basin, total runoff volumes for the months September through March are listed in the following tabulation for the gaging station on the Calcasieu River near Kinder that measures the runoff from about 1,700 square miles, or about 54 percent of the total area of the Calcasieu River basin above Lake Charles. This station could not be used as an index to irrigation-season water supply because of large withdrawals for irrigation above the station, but it can be used for analysis of flow during the nonirrigation months. Records for this season are presented in the following tabulation.

	Streamflow September through March (acre-feet)
1922–23	1,308,000
1923–24	2,201,000
1939–40	486,000
1940–41	1,747,000
1941–42	1,424,000
1942–43	488,000
1943–44	1,236,000
1944–45	1,253,000
1945–46	1,842,000
1946–47	1,667,000
1947–48	1,135,000
1948–49	1,603,000
1949–50	1,687,000
1950–51	667,000

These records give the yield from that part of the Calcasieu River basin above Kinder. Any critical appraisal of runoff from areas in the basin below Kinder should make allowances for the widely varying runoff characteristics of the Calcasieu River basin.

387601 O - 56 - 14

GROUND-WATER RESOURCES

By P. H. Jones, A. N. Turcan, Jr., and H. E. Skibitzke

Ground water is defined as the water in the zone of saturation—the zone beneath the earth's surface in which all the interstices of the rocks are filled with water which is free to move under the influence of gravity. The upper surface of the zone of saturation is known as the water table, except where it is formed by a bed of impermeable rock. Where this condition exists, the water will rise in tightly cased wells above the top of the water-bearing bed and is said to be artesian or confined water. Connate water is water trapped in the interstices of a rock formation as it was deposited; it may be either fresh or salty.

An aquifer is a geologic formation, a group of formations, or a part of a formation that is capable of yielding water to pumped wells or to springs. In this report a group of interconnected aquifers, all in the same stratigraphic unit and having the same general lithologic and hydrologic characteristics, is called a ground-water reservoir. Additions to the body of ground water are called recharge, and withdrawals—either natural or by man—are called discharge.

Ground water always exists under hydrostatic pressure, and its movement is from places of higher potential or head to places of lower head. Its head at any point can be expressed as the altitude above a fixed datum to which it will rise in a tightly cased well. The rate of movement between two points in an aquifer depends upon the difference in head and the distance between the points, and the permeability of the aquifer. It also depends upon the viscosity (the resistance to flow) of the water, which is a function of its temperature.

The difference in head in the aquifer between two given points is generally expressed in feet of water, and the slope of the profile of head change between them is called the hydraulic gradient, generally expressed in feet per mile. The pressure gradient in an aquifer is determined by measuring the water level (in feet above or below a common datum) in wells tapping the aquifer. Contours—lines joining points of equal altitude on the potential surface of water in a given aquifer—enable a three-dimensional analysis of head distribution. Such water-level contour maps are known as piezometric maps (Meinzer, 1923, p. 38). They show not only the distribution of pressure head in the aquifer but also where the water is coming from, where it is going, and the route it is following. Piezometric maps can be used to determine the rate of ground-water flow if the permeability and thickness of the aquifer are known.

The availability of ground-water supplies in any area is determined by the geology of the area, the abundance of recharge water, and the physical laws that govern ground-water storage and motion.

PREVIOUS STUDIES

As stated by Harris (Harris, Veatch, and others, 1905, p. 1), the serious study of the underground waters of Louisiana was begun during the winter of 1899–1900 by members of the Louisiana Geological Survey. The first report of progress (Harris and Pacheco) appeared in 1902. Participation of the United States Geological Survey in the investigations was begun in the summer of 1903 and resulted in a publication in 1904 (Harris and Fuller). The work was continued partly under State and partly under Federal financing and supervision through 1904.

It is significant that the emphasis in these early investigations was placed on southwestern Louisiana in recognition of the abundance and growing importance of ground water in that part of the State. The rapidly expanding rice-farming industry placed a growing demand on water supply, and the development of pumps, engines, and water-well drilling techniques was given a strong impetus.

One of the first procedures of study adopted by Harris and Veatch was the periodic measurement of water levels in selected wells. It is the availability of reliable water-level records for many scattered wells, most of which were referred to sea-level datum, or "tide," that forms the basis for important comparisons of conditions then with conditions now. These records provide the basis for preparation of a generalized water-level contour map for the year 1903 (pl. 13).

The general extent and character of the aquifers are discussed in the early reports, along with records of well construction, quality of the ground water, and water-use practices. Of particular interest is the section on rice irrigation by M. L. Fuller (Harris and Fuller, 1904) in which the role of wells as an alternative source of supply in times of drought is described. Salt-water encroachment of surface sources from the Gulf of Mexico had already become a factor to be reckoned with in 1901, and by 1903 several hundred irrigation wells were in operation (Harris and Fuller, 1904, p. 84).

Between 1905 and 1938 no investigations of ground water in southwestern Louisiana were made under State or Federal auspices. Records available for that interval are of little value, except those pertaining to the geology of beds penetrated in well drilling. Water-level notes made by drilling contractors on well-construction records serve in a general way to indicate the gradual downward trend of levels during that period; but well locations are sketchy, names of owners have changed, and the datum of reference of water-level depth is seldom recorded.

During the period 1915–18 there was a great increase in the number of irrigation wells, as evidenced by dates on completion records obtained from the files of drilling contractors. Many of the wells drilled at that time were in use during the early part of the present investigation which was begun in the spring of 1939. However, most of the older wells have been abandoned during the past few years (1948–51) as a result of water-level declines— seldom because of screen failure. (See p. 299.)

The field studies leading to this report were begun in 1939 by T. B. Stanley, Jr., of the U. S. Geological Survey, under the supervision of J. C. Maher, through cooperation with the Louisiana Geological Survey, Department of Conservation. Detailed investigations during the period 1939–41 were made principally in Jefferson Davis and Acadia Parishes, which include most of the rice-farming area, and a report on the ground-water conditions in these parishes was published in 1944 (Stanley and Maher). The report includes the first published water-level contour maps for these parishes, showing water levels in the principal aquifer tapped by irrigation wells. Maps, based upon seasonal measurements of water level in 80 wells in Acadia Parish and 74 wells in Jefferson Davis Parish to which spirit levels had been run, provided the basis for evaluation of water-level fluctuations over the area, interpretation of the direction of ground-water movement, and delineation of the areas of heavy withdrawals from wells. The report also presents in the form of geologic cross sections the first results of regional correlation of the aquifers tapped; locations and construction records for 441 wells in the two parishes are provided in the tables.

Although the report on Jefferson Davis and Acadia Parishes was a real contribution to an understanding of ground-water conditions in southwestern Louisiana, its authors realize that a sound analysis of the ground-water reservoirs and an evaluation of their ability to yield large supplies of water, would require a study of regional scope (Stanley and Maher, 1944, p. 34) and that such a study must include detailed hydraulic tests to determine the ability of the aquifers to transmit and store water.

As a part of the statewide cooperative program of ground-water studies the first steps of the regional project were taken in 1943 and 1944 by W. J. Drescher and L. W. Youngquist, under the supervision of J. C. Maher, and later under George C. Taylor, Jr. Well inventories were made in Calcasieu Parish by Drescher and in Lafayette, St. Martin, and St. Landry Parishes by Youngquist. Together Drescher and Youngquist prepared the first regional water-level contour map in April 1944 (pl. 14). The next regional map, for September 1944, was made by G. C. Taylor, Jr., using a broader network of observation wells.

The emphasis of the statewide ground-water investigations, intensified in 1943 through the combined cooperation of the Louisiana Geological Survey, Department of Conservation, and the Louisiana Department of Public Works, was properly placed on southwestern Louisiana in 1945, not only because the supply problems faced were of major importance but also because it is the most heavily settled part of Louisiana. Studies of limited scope in the rice-farming area in 1945–47 provided data that prompted the Louisiana Department of Public Works to propose a detailed regional investigation of the ground-water resources. Work on the project, begun in 1948, is described in this report.

This report presents information and interpretations based upon some 12½ years of study. However, it is not a final report, as there are many problems yet to be solved.

GENERAL FEATURES

Fresh ground water in bedded deposits of sand or gravel in southwestern Louisiana occurs to depths of about 3,100 feet (pl. 15). All the aquifers are composed of unconsolidated granular rock materials, and the ground water is present in the interstices between the grains. Because the beds that comprise the aquifers are laterally continuous for many miles or are interconnected locally with aquifers above or below that do not have great areal extent, the ground water can move great distances underground. Gulfward and at great depth all water-bearing formations of the project area contain salty water.

The regional dip or slope of the aquifers is gulfward. In the updip area which lies at altitudes ranging from a few tens of feet to about 200 feet above sea level (pl. 2), erosion has exposed the beds to recharge from rainfall or from streams that cross their beveled edges. The aquifers that crop out in areas having an altitude of 100 feet or more may contain fresh water at depth because the water is under considerable head in the recharge area. However, those that crop out in areas of low altitude are not so likely to contain fresh water far downdip, at considerable depth, because the hydraulic head is less, the outcrops have been submerged by the gulf in relatively recent geologic time, and there has been less opportunity for complete flushing of the aquifers by fresh water.

The aquifers of southwestern Louisiana are underlain and in many places overlain by relatively impermeable beds of clay or shale which confine the water within each aquifer. Thus the hydraulic head and quality of the water in and the yield of a well tapping a certain aquifer may differ greatly from those characteristics of a nearby well tapping a different aquifer, although the two aquifers may be separated vertically by no more than a few feet of clay or shale.

The texture of the granular rock materials composing the aquifers determines their permeability—their ability to transmit water under a given hydraulic gradient. In granular rock such as sand or gravel, permeability is a function of the number, size, and shape of the pores, which are determined by the size and uniformity of the grains, their shape, and the way they are packed together. Cementing material between the grains reduces permeability, but in general the sand and gravel aquifers of southwestern Louisiana are unconsolidated.

There is often a pronounced, though gradual, change in the texture and permeability of an aquifer with depth and distance from its outcrop. This is especially true of the Pleistocene deposits between the outcrop and a depth of about 1,200 feet in southwestern Louisiana. Textural changes are important in the area of study, but changes in the thickness and continuity of beds comprising the aquifers are apparently the more important considerations in analysis of the ground-water hydrology.

Structural features—faults and folds—control the movement of ground water. Faults do so by offsetting aquifers and abutting them against less permeable clay or shale or by bringing two different aquifers into hydraulic interconnection. Folds do so by upwarping beds and facilitating their exposure to recharge, as a result of accelerated local stream erosion, or by downwarping the aquifer and bringing the fresh water into contact with highly mineralized water in the downdip part of the aquifer. The highly mineralized water resists further movement due to its greater density head.

Withdrawals from wells lower the water table in unconfined aquifers and lower the pressure head in artesian aquifers. The hydraulic gradients that result cause ground water to move toward the locality of withdrawal. In response to this movement, water levels in the recharge area are lowered, perhaps increasing recharge by reducing ground-water seepage into streams or even inducing influent seepage from streams; or water is withdrawn from downdip storage, reducing natural discharge in that direction and perhaps inducing salt-water encroachment.

The development of a dependable ground-water supply hinges upon many geologic and hydrologic factors. The evaluation of the supply and prediction of future ground-water conditions requires a thorough knowledge of geologic controls, the locus and magnitude of ground-water withdrawals, and the hydraulic effects caused by them.

OBJECTIVES AND METHODS

Ground-water studies in southwestern Louisiana have four main objectives: To determine the depth and thickness of aquifers and their extent; to determine the sources of the ground water and the hydraulic factors that govern its movement from areas of recharge to areas of discharge; to determine the present rate of ground-water withdrawal and its effect upon the total perennial ground-water supply; and to determine the chemical quality of the ground water and to interpret differences or changes in quality in the aquifer as to area, depth, and time.

Although the project objectives outlined above have been partially gained, and much information on the ground-water resources of southwestern Louisiana is presented in this report, the writers are able to provide only qualified answers to many of the problems that confront ground-water users in the project area. Important conclusions have been reached, however, with regard to regional conditions, and problem areas have been identified. This report provides a basis for detailed locality studies for which arrangements have not yet been made (for example, in the Vermilion River basin); the results of these studies should complete the over-all analysis of the ground-water resources of southwestern Louisiana.

In the early stages of this study, information was collected on the characteristics of selected wells in each of the 13 parishes of the project area, together with information on the geology of the deposits (drillers' logs and electric logs) from well contractors. Water samples were collected from wells for chemical analysis, and periodic measurements of water level were made in selected wells. Information recorded on forms (well schedules) for each well included the following: the owner, location, depth, diameter, driller, date drilled, screen setting, geologic formation tapped, water level, yield and specific capacity, owner's estimate of pumpage rate, owner's oral statement of water quality, measured water temperature, and miscellaneous data.

After a preliminary canvass of well owners and analysis of data from well schedules, in the light of geologic and hydrologic information obtained from previously prepared reports and drillers' logs, key wells were selected for periodic water-level measurement for preparation of water-level contour maps. Spirit levels were run to the measuring points of the wells, and measurement routes were established over the area. Water levels in all such key wells were measured within the short period of 3 or 4 days to enable preparation of a contour map showing approximately the relief of the entire piezometric surface at relatively the same time. Ground water always moves down the hydraulic gradient, at right angles to the contours on the piezometric map. The water-level contour maps (piezometric maps) therefore identified not only the areas of lowest water level but also the areas from which the water was being derived. Plates 14 and 16–29 are maps of the project area showing the piezometric surface of the principal aquifer, designated the Chicot reservoir, at selected times during the investigation. Maps made in the spring before irrigation began, when compared with maps made in the fall, after the irrigation season, provided the most valuable basis for evaluating the effects of ground-water withdrawals.

Determination of the hydraulic characteristics of the Chicot reservoir was necessary to interpretation of piezometric maps in terms of rate of ground-water flow and of withdrawals from ground-water storage. The hydraulic characteristics of the reservoir were determined locally by pumping selected wells at known discharge rates for controlled periods of time and by observing the rate of water-level decline in nearby wells tapping the aquifer. Engineering studies of this type were made in four scattered localities. One steady-state aquifer-performance test was made, in the Lake Charles area, by analysis of the shape of the cone of depression in the piezometric surface caused by a measured steady withdrawal from industrial and public-supply wells.

Rates of pumping from selected irrigation wells flooding a known acreage were measured periodically during the irrigating season to obtain an acreage water-requirement figure. This figure, when applied to the total acreage flooded by wells, gave the total withdrawal from irrigation wells, by season. Rice-acreage figures, by water source, were provided through the courtesy of the American Rice Growers Cooperative Association and the Louisiana State Rice Milling Co. Data on pumpage from industrial and public-supply wells in the area were obtained from well owners. Domestic requirements of necessity were estimated, but these requirements are small in comparison to others and any error in estimation is negligible.

During the period of this investigation, water samples were collected for chemical analysis from about 300 wells scattered throughout the project area. Complete analyses of water from 69 wells, believed to be representative of the quality of ground water in the project area, are given in table 30. The chloride content and specific conductance of water from about 180 scattered wells were determined from samples collected in July 1948 and again in June 1949. On the basis of all these data, the areal distribution of chloride in ground water from wells in the project area tapping the principal aquifer is shown on plate 36. Partial or preliminary analyses (see "Quality of water") of water from many other wells were made but are not included in this report because they conform to the general pattern of chemical quality shown by the complete analyses and are useful primarily in making interpretations of local conditions.

The geology of the aquifers was interpreted largely by use of water-well drillers' logs, and electric logs of oil-test holes. A few water-well test holes were drilled by municipalities and private interests in the area during the course of the study, and efforts were made to obtain accurate information on these. Geological Survey personnel were assigned to collect and describe formation samples taken from wells during drilling, and detailed textural and lithologic studies were made of them in the laboratory. Several of the most important geologic and hydrologic interpretations in this report could not have been made without the use of electric logs of oil-test wells. An electric log is a graph of the electrical characteristics (generally the electrical resistivity and spontaneous potential) of the rocks penetrated by a well plotted against depth.

In the following sections the hydrology of the three principal ground-water reservoirs of southwestern Louisiana is described. These are, from oldest to youngest in geologic age, the Evangeline, Chicot, and Atchafalaya reservoirs, formed by the Foley formation of Pliocene age, the Williana, Bentley, Montgomery, and Prairie formations of Pleistocene age, and the Le Moyen formation of Recent age, respectively.

THE EVANGELINE RESERVOIR

GEOLOGIC CHARACTERISTICS

The name Evangeline reservoir is assigned to the system of aquifers that occur in deposits of Pliocene age, the Foley formation, in southwestern Louisiana. As indicated in the Geology section of this report, the lowest beds of the Foley formation lie immediately above the *Rangia johnsoni* faunal zone which occurs at a depth of about 1,400 feet at Oakdale in Allen Parish and probably about 2,500 feet in south-central Evangeline Parish. No map of the base of the reservoir has been prepared, partly because information is scanty and partly because the main objective of this study has been the investigation and evaluation of ground-water supply for irrigation. There is little likelihood that irrigation wells will tap aquifers of the Evangeline reservoir during the next decade, because the relatively low permeability and limited thickness of the aquifers, and their considerable depth below the land surface, would make the cost of installing wells and pumping water several times greater than those costs for wells tapping the overlying gravel-bearing aquifers of the Chicot reservoir.

The map of the base of the Pleistocene deposits, the Williana, Bentley, Montgomery, and Prairie formations (pl. 8), of course, is also a map of the top of the Evangeline reservoir. Thus, to tap aquifers of the Evangeline reservoir at a selected locality, it is necessary to drill wells deeper than the depth shown on plate 8. There can be no assurance, however, that aquifers suitable for development will be found immediately below that depth, as the depth of occurrence of aquifers in the Evangeline reservoir having a favorable thickness and texture is almost unpredictable. It should be possible, with detailed study, to delineate areas in which aquifers are relatively thick and coarse textured and thus to select locations for well fields. This has been done with good results at Oakdale in Allen Parish.

It is evident from the mechanical analyses of sand samples from aquifers of the lower part of the Evangeline reservoir (table 7, wells Al–120, Al–138, Al–144, Al–158 below a depth of 167 feet, and well Ev–142 below a depth of 265 feet), that in the Oakdale area they are typically coarse to medium grained, seldom more than 5 percent, by weight, of the sample being retained on the 1-millimeter screen and generally less than 50 percent on the 0.5-millimeter screen. In the Mamou area the aquifers, which are in the upper part of the reservoir, are finer grained; there were only 3 samples of which more than 5 percent was retained on the 1-millimeter screen and only 3 samples of which more than 20 percent was retained on the 0.5 millimeter screen. The well at

Mamou disclosed a thickness of about 1,250 feet of beds comprising the upper part of the Evangeline reservoir, of which more than 65 percent was sand.

At Kinder in Allen Parish the texture of the sands in the upper part of the Evangeline reservoir between depths of about 450 and 1,000 feet was comparable to that at Mamou, and aquifers of the upper part of the reservoir have a similar texture at Elton in northern Jefferson Davis Parish and Fenris in southern Evangeline Parish. It is apparent from these records that aquifers in the upper part of the Evangeline reservoir are typically finer textured than those in the basal part of the reservoir.

Although individual aquifers of the Evangeline reservoir in places are more than 75 feet thick, they are generally much less. At Oakdale in Allen Parish 29 beds of sand in the lower part of the reservoir between depths of 400 and 1,300 feet range from 3 to 54 feet in thickness and have a cumulative thickness of 290 feet, for an average thickness of 10 feet. At Kinder in Allen Parish 13 beds of sand in the upper part of the reservoir between depths of 450 and 1,000 feet range from 5 to 28 feet in thickness and have an average thickness of 17 feet. At Ville Platte in Evangeline Parish 38 beds of sand in the upper part of the reservoir between depths of 535 and 1,530 feet range from 2 to 35 feet in thickness and have an average thickness of 11 feet. At Mamou in Evangeline Parish 42 beds of sand in the upper part of the reservoir between depths of 250 and 1,500 feet range from 3 to 90 feet in thickness and have an average thickness of 20 feet. Near De Ridder in Beauregard Parish 18 beds of sand in the lower part of the reservoir between depths of 300 and 1,000 feet range from 3 to 115 feet in thickness and have an average thickness of 27 feet.

The descriptions above are believed to be typical. Although they show a range of average sand thickness from 10 to 27 feet, no pattern of thickness distribution is apparent from these few control points. A detailed study of sand thickness, cumulative sand thickness, and percent of total thickness of the reservoir composed of sand should be made, as such studies would lead to a better appraisal of available ground-water supplies in this series of aquifers.

Relatively poor continuity of individual aquifers in the Evangeline reservoir has been, and no doubt will continue to be, a deterrent to development of ground-water supplies from it. However, there can be no doubt that each bed of sand that constitutes an aquifer is connected above, below, and laterally with other such beds. They are interfingered and effectively joined to provide a continuous hydraulic system from the outcrop area at least as far downdip as they contain fresh water. That artesian pressures in aquifers when they are first tapped are uniform over a range of depth of several hundred feet is further proof of interconnection. And, finally, the sustained yield of wells that tap the aquifers would not be possible if the series of beds did not in reality constitute an immense underground reservoir and conduit.

Correlations of individual aquifers in the Evangeline reservoir over distances of a few miles have been made at Oakdale in Allen Parish on the basis of a careful study of electric logs. Correlation of aquifers for distances of 30 to 50 miles should be possible by applying the same technique to large numbers of records of closely spaced wells. However, at present electric logs are not available for sufficient closely spaced wells to enable regional studies of this kind.

HYDRAULIC CHARACTERISTICS

The hydraulic characteristics of aquifers of the Evangeline reservoir have not been determined by systematic pumping tests. The hydraulic characteristics that are significant to this study are the transmissibility and storage coefficients of the aquifer, and knowledge of these values (defined on p. 217) enables prediction of the hydraulic behavior of the aquifer tapped under a given set of withdrawal conditions. Extensive use of hydraulic tests was made in a study of the aquifers of the Chicot reservoir discussed later in this report.

On the basis of estimates made by determination of the specific capacity (yield per unit of drawdown of water level) of wells, it is believed that the permeability of water-bearing sands of the Evangeline reservoir ranges from about 250 to 1,000 Meinzer's units (C. V. Theis, unpublished report in files of U. S. Geol. Survey). Permeability in Meinzer's units may be defined as the number of gallons of water, at 60°F, that would be conducted in 1 day through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow) for each foot of thickness of the bed and for each foot per mile of hydraulic gradient. There are about 20.50 Meinzer's units in 1 darcy, the conventional unit of permeability used by petroleum engineers. For field studies the field coefficient of permeability is used. It is the same as the permeability in Meinzer's units, except that it is measured at the ground-water temperature prevailing in the area rather than at 60°F.

Specific capacities of 10 wells tapping aquifers of the Evangeline reservoir range from about 2 to 20 gpm per foot of drawdown of water level. As specific capacity is a function of transmissibility (the product of permeability and aquifer thickness), it has a greater range in value than the permeability.

RESERVOIR OPERATION

By definition, a reservoir is a natural or artificial place where water is collected and stored for use. Implied in this definition are the three phases of reservoir operation: Recharge, or the addition of water to the reservoir; storage, or static retention of the water; and discharge, the diversion of water. In neither surface nor underground storage is there true static retention; water in an underground reservoir is in constant motion, although that motion may be so slow as to be imperceptible; and water in a surface reservoir is subject to convection currents, wind action, and evaporation effects as well as the mass movement from points of inflow from tributaries to spillways and other points of exit. Thus an essential function of a reservoir is its property of transmitting water as a conduit.

The Evangeline ground-water reservoir is composed of a maze of interconnected broadly lenticular conduits, the beds of sand that constitute the aquifers. The walls of the conduits are composed of relatively impermeable clay which serves to confine the water in the beds of sand. The confining beds of clay separating or overlying the aquifers are called aquicludes. As described in "Geology," the deposits slope gently gulfward, and therefore the zone of exposure of the aquifers to recharge is, or was during the geologic past, at their northward extension.

RECHARGE

After deposition, the series of aquifers and aquicludes was beveled by erosion, and no doubt the opportunities for recharge of ground water were thus greatly increased. The eroded outcrop area is now almost entirely blanketed by the Pleistocene deposits in the region of gravel exposures. It is not possible to reconstruct the factors of terrain, climate, drainage, and altitude that influenced recharge during the period of erosion and exposure, as this cycle of events closed about a million years ago, at the beginning of the Pleistocene epoch.

During the first great ice accumulation of Pleistocene time there was a marked lowering of sea level, and this no doubt increased by several hundred feet the effective hydrostatic head in aquifers of the Evangeline reservoir, enabling the fresh ground water to drive saline connate water many miles down the dip of the beds. As the first Pleistocene glaciation waned, glacial meltwaters spilled across the outcrop areas of the Evangeline reservoir, burying them beneath thick deposits of coarse-textured alluvium. The sand and gravel deposits that blanketed the outcrop area of the Evangeline reservoir at that time were water saturated, and there is good reason to believe that seldom, if ever, since they were laid down have they failed to be saturated through at least a part of their thickness.

Thus, since the beginning of Pleistocene time there has been an essentially continuous source of recharge to the Evangeline reservoir. During much of the geologic past the altitude of the recharge area has been relatively greater than at present, as sea level has seldom been higher than it now is. Under these circumstances it is not surprising that aquifers of the Evangeline reservoir contain fresh water to depths greater than 2,000 feet.

The availability of recharge to the Evangeline reservoir has not lessened during the period of this investigation, as indicated by the water levels in shallow wells tapping the Pleistocene deposits of sand and gravel that blanket the outcrops of its aquifers. In fact, there has been a persistent upward trend in the water levels in some shallow wells in the recharge area over a period of several years coinciding with a period of years that were wetter than normal (see records for well R-347, fig. 39). Conditions, therefore, are favorable for replenishment of supplies that may be withdrawn from the Evangeline ground-water reservoir, provided that the withdrawals do not exceed the transmission capacity of the reservoir.

MOVEMENT

The direction of ground-water movement is the same as the direction of the hydraulic gradient in an aquifer. On this basis water in the Evangeline reservoir is moving gulfward. Exactly where it is going, where and how it escapes down the dip, and how rapidly it moves are questions that cannot be answered with information available. No water-level contour maps for the Evangeline reservoir have been prepared because the points of control are too few and too widely scattered. This does not detract from the statement above that the hydraulic gradient is gulfward, for that fact is evident from all water-level records, but a contour map of southwestern Louisiana prepared on the basis of 10 control points would be no more than a sketch.

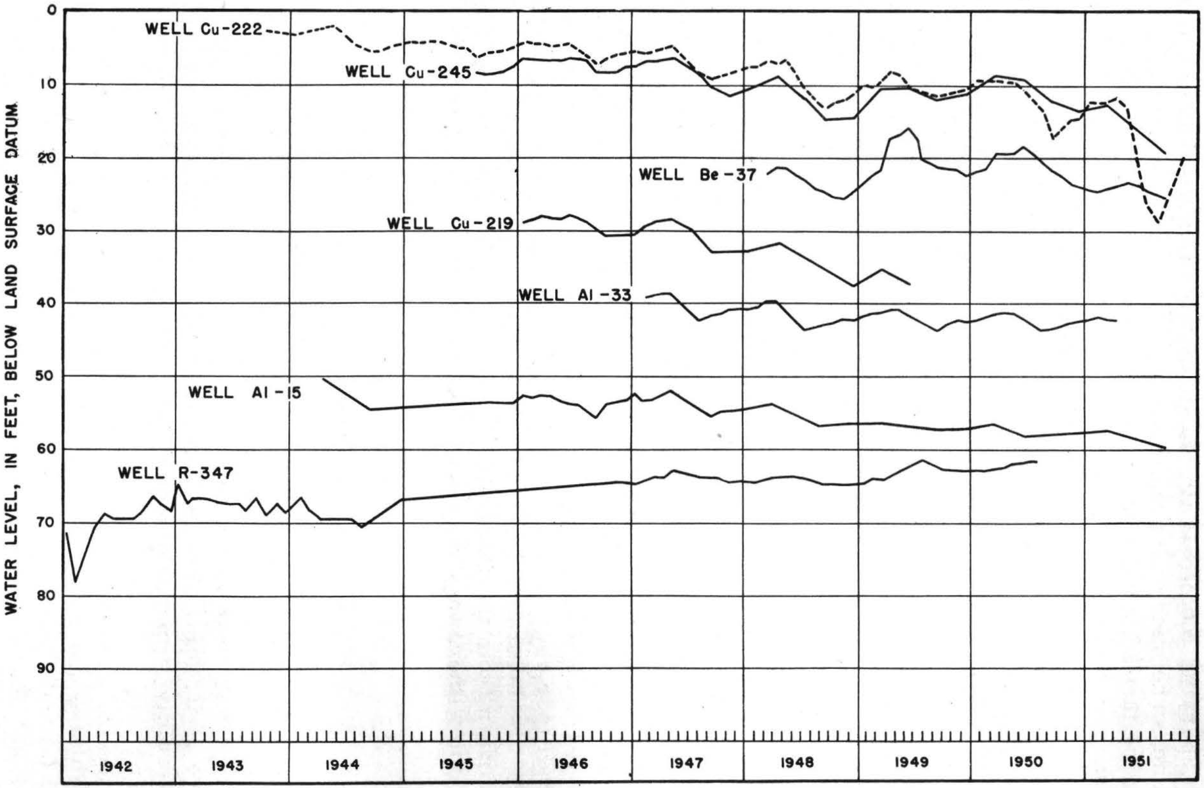


Figure 39. —Hydrographs of water levels in or near the recharge area at the outcrop of the gravelly aquifers of the Chicot reservoir.

Many hydraulic tests of the Evangeline reservoir, and many more water-level measurements, will have to be made before the first piezometric map can be prepared and interpreted in terms of the rate of ground-water flow.

DISCHARGE

It is quite likely that natural withdrawals (diversions not attributable to the effects of the works of man) from the Evangeline reservoir are by far the major item of withdrawal. This is inferred from a knowledge that existing withdrawals from wells have produced almost insignificant changes in the piezometric surface of water in the reservoir.

Natural withdrawals occur by upward movement from aquifers in the downdip areas of the reservoir, perhaps even in areas south of the shoreline of the Gulf of Mexico. There must be escape of water from the aquifers down the dip to provide space for additions up the dip if they are to contain fresh water and if movement is to continue. The escape does not necessarily occur in that part of an aquifer where it contains fresh water, but escape in fresh-water areas is thought to be important.

Natural downdip withdrawal may occur as a result of two main reservoir conditions, one structural (faulting) and one depositional (lateral and vertical gradation of texture and interbedding). It cannot be judged accurately at this time which of these conditions is most important, but the writers believe that faulting ultimately may be proved to be very important, and perhaps the most important. This opinion is based largely upon conditions evident on the map (pl. 15) showing the depth of occurrence of fresh ground water in southwestern Louisiana.

Upward escape of artesian water as a result of faulting in the unconsolidated deposits of southwestern Louisiana probably is accomplished, not by movement of water up the fault plane itself, but by flow across the fault plane into an offset aquifer, thence vertically through the aquifer, and back across the fault plane into a shallower aquifer hydraulically joined by the offset. Although the course may be devious, and the cross section of flow restricted, such an avenue of escape could be very significant in geologic time. And, as discussed in "Geologic structure," a number of regional normal faults, downthrown toward the gulf, cross southwestern Louisiana in several directions.

Upward escape of artesian waters across fault planes in the complexly faulted peripheries of salt-dome structures may be a

387601 O -56 -15

very significant factor in southwestern Louisiana. Reference to the map (fig. 16) showing the locations of salt domes in southwestern Louisiana, when compared with plate 15 referred to above, shows undeniable influence of salt-dome structures. Perhaps detailed piezometric maps of the Evangeline reservoir would serve to locate regional faults or salt-dome structures and enable evaluation of their role in ground-water discharge.

Discharge of ground water upward through natural channels from the Evangeline reservoir probably contributes significantly to the supply of fresh ground water in the overlying gravelly Pleistocene deposits in the north-central part of the project area. The rate of upward discharge may be indicated by the computations of withdrawals from the Chicot reservoir and analysis of the rate of lateral recharge to it. These computations indicate that in 1946 almost twice as much ground water was pumped from the Chicot reservoir as entered the area of withdrawal laterally through its boundaries. Only a small part of this water could have been derived from dewatering of the Chicot reservoir, as no significant net decline of water level occurred in that year. Plate 30 shows the average rate of ground-water movement into the area of withdrawal in 1946 and the graph, figure 51, gives the total annual withdrawal. Unless the total recharge to the Chicot reservoir downward through breaks in the surface clay is very great, upward leakage, or discharge, from the Evangeline reservoir constitutes an important source of recharge to the Chicot reservoir. This source is discussed later in the report. That withdrawal from the Evangeline reservoir is in part induced by pumping from the Chicot reservoir cannot be doubted, but a quantitative evaluation of such withdrawal cannot be made from available data.

Withdrawals in the form of discharge from wells tapping aquifers of the Evangeline reservoir are very small. Probably the average total daily withdrawal from wells in southwestern Louisiana does not exceed 5 million gallons.

The effects of withdrawals from wells tapping aquifers of the Evangeline reservoir can be appraised only at Oakdale in Allen Parish, where 5 wells tap water-bearing sands between depths of about 700 and 950 feet. Pumping at the rate of about 3 million gpd for about 5 years has caused a static water-level decline (decline of the nonpumping water level) of about 30 feet in the aquifers. Nearly steady-state conditions of drawdown and discharge probably have been established in these aquifers in the vicinity of the well field.

CHEMICAL QUALITY OF THE GROUND WATER

Water from the Evangeline reservoir is generally better than that from the overlying Chicot reservoir for uses other than irrigation. In general the water from the Evangeline reservoir is of the sodium bicarbonate type, very soft, slightly alkaline on the pH scale, low in chloride content, and free of excessive quantities of dissolved iron. The water therefore requires little or no treatment and is desirable for public supply. Most wells tapping the Evangeline reservoir have been drilled as public-supply wells. Complete chemical analyses of water from wells at Oakdale in Allen Parish and Mamou in Evangeline Parish are included in the tables of analyses in "Quality of water," where the chemical character of the ground water is described in more detail.

Water from certain thin lignitic fine-grained aquifers of the Evangeline reservoir commonly has a yellowish or brownish color, probably owing to colloidal organic matter, and in some places it contains undesirable quantities of dissolved iron. In some localities the fluoride content is greater than 1.5 ppm, the maximum concentration specified by the U. S. Public Health Service for water used on interstate carriers.

Where they are tapped by wells at Oakdale and Kinder, the uppermost aquifers of the Evangeline reservoir contain water similar to that in the overlying deposits of the Chicot reservoir. That the aquifers of the Evangeline dip more steeply than those of the overlying Chicot reservoir, which lie across their beveled buried outcrop, indicates that much of the water in the Evangeline aquifers was derived from the Chicot reservoir. Down the dip, a part of it probably returns to the Chicot reservoir, as described above. It would be expected that the quality of water in the uppermost aquifers of the Evangeline near their buried outcrops would resemble the quality of water of the Chicot reservoir because the distance traveled in the Evangeline reservoir is short and the exposure to base-exchange minerals in the Evangeline beds has been relatively brief.

This interpretation is based upon the belief that beds of the Evangeline reservoir contain minerals (so-called natural zeolites) that have the property of exchanging sodium and potassium in the particles for calcium and magnesium ions in water. This reaction removes the principal ions that cause hardness in water, resulting in natural softening. A progressive decrease with depth in the hardness of water from aquifers of the Evangeline reservoir has been noted, and the effectiveness of natural softening agents in them is thus indicated.

The southern limit of fresh water in the Evangeline reservoir is indicated as the line of intersection of the base of the Chicot reservoir (pl. 8) and the base of fresh water (pl. 15). This line of intersection trends northeastward from Lake Charles in Calcasieu Parish to Opelousas in St. Landry Parish.

THE CHICOT RESERVOIR

GEOLOGIC CHARACTERISTICS

The name Chicot reservoir is assigned to the system of aquifers that immediately overlies the Evangeline reservoir and is formed by deposits of Pleistocene age, the Williana, Bentley, Montgomery, and Prairie formations, in southwestern Louisiana. The depth to the base of the reservoir has been mapped in the part of the project area where differentiation of beds of Pleistocene age from those of pre-Pleistocene age is possible (pl. 8). Correlation of the massive beds of sand or sand and gravel that compose the aquifers is shown on three geologic cross sections (pls. 7, 10, and 11). Because the Chicot reservoir is the principal source of ground water in southwestern Louisiana, the occurrence of aquifers in it is of great importance.

The map referred to above (pl. 8) shows the depth to the base of a massive sand and gravel aquifer throughout most of the project area. In parts of the project area the basal unit is finer grained. (See p. 72, 73.) The massive water-bearing bed is the principal aquifer of the Chicot reservoir; its top is generally less than 200 feet below the land surface in the northern part of the project area where it is composed of sand and gravel (see the map, pl. 31). In those areas down the dip, where the principal aquifer includes much fine- to medium-grained sand, the top may be at depths of 700 feet or more. As shown on plate 31, there are two extensive areas in which the principal aquifer lies at depths of less than 50 feet, the larger one being the area of outcrop. The other, which follows the course of the Vermilion River, is perhaps equally important from a hydrologic standpoint and is discussed in detail in "Recharge" and "Chemical quality of the ground water" which follow.

A conspicuous feature of the top of the principal aquifer is its uniform depth (about 100 feet) throughout most of Evangeline, Jefferson Davis, and Acadia Parishes, western St. Landry Parish, and western and southwestern Vermilion Parish.

Aquifers of the Chicot reservoir have been tapped by offshore wells and are known to contain fresh water near the shoreline beneath the Gulf of Mexico between Cameron, in Cameron Parish, and the mouth of the Atchafalaya River in easternmost St. Mary Parish.

The principal identifying geologic characteristic of aquifers of the Chicot reservoir is their gravelly texture. As discussed in "Geology," the coarseness of texture and the composition of the gravel pebbles are the principal criteria for differentiation of these deposits from those beneath and for assigning them to the Pleistocene series. Gravel is not everywhere present in these formations, as facies change down the dip and along the strike of the beds. However, the name Chicot reservoir is applied to the entire system of aquifers formed by the Pleistocene series in southwestern Louisiana.

The texture of a granular aquifer is indicated by mechanical analyses of formation samples obtained from wells penetrating it. Although such analyses provide no information on grain shape and packing—which play a major role in determining the hydraulic characteristics of the aquifer—they are the only quantitative textural criteria obtained for aquifers studied in this investigation. Because of the relation of grain size and uniformity of grain size to permeability, mechanical analyses of formation samples are valuable aids in identifying beds and appraising their probable relative permeability. Also, they provide information of practical value to the well driller, enabling him to select the proper screen-slot opening for his well.

The texture of formation samples from many wells that tap aquifers of the Chicot reservoir is shown in table 7. It should be noted that as much as 30 percent (by weight) of the sample commonly is retained on the 4-millimeter screen; more than 80 percent of some samples was retained on it. Of the analyses shown, those for wells in Allen, Jefferson Davis, and Lafayette Parishes were consistently the coarsest grained. Although no analyses are presented for wells in Acadia Parish, it is known that the aquifers are similarly coarse there.

Mechanical analyses of samples from aquifers of the Chicot reservoir in south-central Calcasieu Parish and southeastern St. Mary Parish show the texture in those areas to be generally medium to fine grained, although some gravel does occur in the Lake Charles area. The scope of this report did not enable the preparation of detailed textural maps of the Chicot aquifers in southwestern Louisiana, but such maps would be a valuable aid to interpretation of the geology and hydrology of the region. A great many samples are now available (from the Geological Survey) for textural analysis.

A rough index map of cumulative aquifer thickness for the Chicot reservoir could be made by a comparison of the maps (pls. 31, 8) referred to above, one showing the depth to the base of the Chicot reservoir and the other showing the depth to the top of the principal aquifer of the reservoir. It would, of course, be necessary to adjust the contours for altitude. Such a map was not made as a part of this study because a more accurate one would be required to be of quantitative value. Actual cumulative thicknesses of permeable beds between the top and bottom of the reservoir should be recorded for several hundred wells penetrating the full thickness of the reservoir. Work is in progress on such a map.

As a general statement on aquifer thickness, it can be said that some of the sand and gravel aquifers of the Chicot reservoir of southwestern Louisiana are among the thickest uniformly permeable granular water-bearing beds in the United States.

The thickness of individual beds of sand and gravel ranges from a few feet to about 800 feet, the thickest beds occurring in southern Acadia Parish and northern Vermilion Parish. Elsewhere aquifer thicknesses of 200 to 400 feet are commonplace; in many places there are two or three such aquifers in the section separated by beds of clay not more than 50 feet thick. The best understanding of aquifer thickness throughout the project area can be gained from the geologic cross sections *A–A'*, *B–B'*, and *E–E'* (pls. 11, 10, and 7).

The thickness of aquifers updip is limited by thinning of the reservoir, and in the area of outcrop the reservoir is generally composed of a single aquifer 50 to 70 feet thick—depending upon the topographic setting and the distance from the featheredge of the Pleistocene deposits.

Downdip (gulfward), the aquifers in the central part of the reservoir are thin, and some of them pinch out. However, the basal aquifer of the reservoir, even where its texture is sandy rather than gravelly, persists gulfward and to the east and west with a thickness of about 200 feet, disregarding the few thin shale or clay beds that it includes. The uppermost aquifer of the reservoir extends an unknown distance gulfward from the coastline of eastern Cameron Parish and from the full length of the Vermilion Parish coastline, where it has a minimum thickness of about 300 feet.

All the aquifers of the Chicot reservoir are laterally continuous throughout southwestern Louisiana. Furthermore, all of them join in the approximate geographic center of the region to form an immensely thick aquifer. Thus, in the same general area where withdrawals are greatest, the hydraulic features of the reservoir are most favorable for development of large supplies.

This coalescing of aquifers near the locus of greatest thickness of permeable deposits also provides an excellent opportunity for reservoir balance. Withdrawals from any aquifer in the reservoir are replenished by flow from all the others—although both the hydraulic gradients generated and the rates of movement may be imperceptible.

The aquifers of the reservoir are continuous for more than 100 miles from west to east and equally as far from north to south. No aquifer of the reservoir suitable for development of supply wells will fail to provide moderate to large perennial supplies, because of the aquifer's great areal continuity and effective hydraulic interconnection with other aquifers of the reservoir.

HYDRAULIC CHARACTERISTICS

As a part of the investigation of the ground-water resources in southwestern Louisiana, four detailed pumping tests were made by the Geological Survey to determine the coefficients of storage and transmissibility of the Chicot reservoir, which is the main source of ground water for irrigation, public-supply, industrial, and domestic uses in this area. The results of these tests were reviewed and checked by H. E. Skibitzke and J. G. Ferris, district engineer (GW), Lansing, Mich.

The ability of an aquifer to transmit water is expressed by a coefficient of transmissibility, which is defined (Theis, 1938, p. 889–902) as the number of gallons of water that will move in 1 day through a vertical strip of an aquifer 1 foot wide, having the full height of the aquifer, under a hydraulic gradient of 100 percent, or 1 foot per foot. The transmissibility is equal to the field permeability multiplied by the thickness of the aquifer, in feet.

The storage capacity of an aquifer under artesian conditions is expressed (Theis, 1938, p. 889–902) by a coefficient of storage, which is defined as the volume of water, measured as a fraction of a cubic foot, released from storage in each column of the aquifer having a base of 1 square foot and a height equal to the thickness of the aquifer, when the artesian head is lowered 1 foot.

The amount and rate of decline of water levels caused by pumping from wells depend upon the transmissibility of the aquifer and its storage coefficient. These factors can be used in computing the theoretical drawdown in an infinite aquifer at various radii from a well yielding a constant and known quantity of water, as shown graphically in figure 40 for the area in the vicinity of Fenton in northwestern Jefferson Davis Parish.

In all the tests, measurements of the quantity pumped from the discharging wells were made with a circular orifice designed specifically to measure within the range of the quantity pumped. The "wetted-tape" method as described by Wenzel (1942, p. 115) was used to measure the water levels in the observation wells.

The derivations of the various formulas used to compute the results are omitted to simplify the presentation of the data. For those who are interested, the bibliography contains a number of articles related to the determination of the hydraulic characteristics of an aquifer.

The nonequilibrium formula as developed by Theis (1935, p. 519–524) was applied to the observational data to determine the hydraulic characteristics of the aquifer in a selected locality.

This formula is:

$$s = \frac{114.6Q}{T} \int_{\frac{1.87r^2S}{Tt}}^{\infty} \frac{e^{-u}}{u}\, du \qquad (1)$$

in which s = the drawdown (or recovery) of the water level, in feet, at any point in the vicinity of a well pumped at a uniform rate;

Q = the discharge of the well, in gallons per minute;

T = the coefficient of transmissibility of the aquifer, in gallons per day per foot;

r = the distance, in feet, from the pumped well to the point of observation;

S = the coefficient of storage of the aquifer;

and t = the time, in days, that the well has been pumped, or for recovery, the time in days since it was shut off.

This formula assumes that the aquifer is infinite in extent, that it is homogeneous, that its transmissibility is the same at all places, and that it is confined between impermeable beds above and below. The nonequilibrium formula further assumes that the coefficient of storage is constant and that the water is released from storage instantaneously with a decline in artesian head. This formula may be applied in either of two ways: To the amount

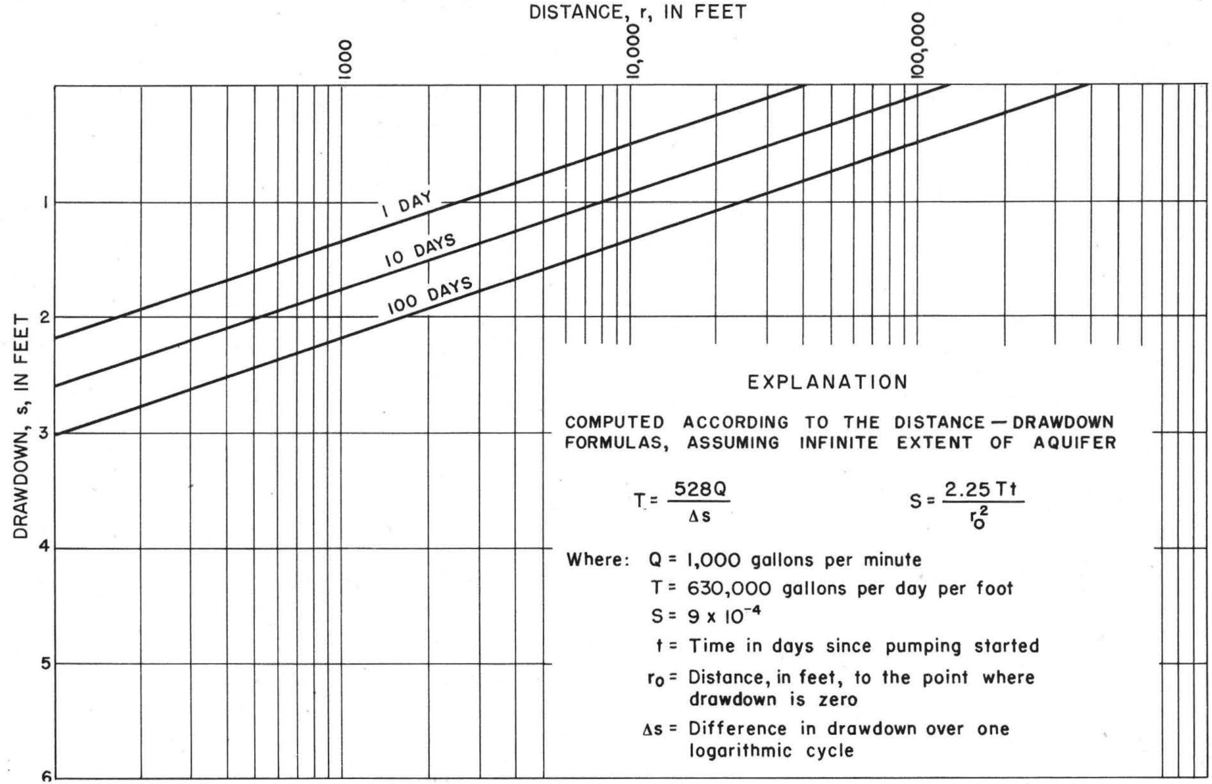


Figure 40. —Graph showing the duration of water level at any distance from a pumped well at any time after pumping has begun.

and rate of drawdown or recovery in a single observation well; or to the rate of recovery in the pumped well itself after the pumping ceases.

Table 17 gives the coefficients of transmissibility, T, and storage, S, obtained by application of this formula to the data obtained from the pumping tests. Along with these results, the table shows also the test-well number and its location, the number of observation wells used, the effective thickness of the aquifer, the date and duration of the test, the calculated field permeability (P_f), and the rate of discharge from the pumped well.

After a recovery period of 17 hours, the test well, Ve-134, was pumped and measurements were made of the water-level decline in the observation wells for a period of about 5 hours. The data confirmed that obtained during the first 5 hours of the recovery portion of the test. Because of mechanical difficulties, the test well was released to the owner and measurements discontinued. (See table 17.)

A pumping test is made primarily to obtain the coefficients of transmissibility and storage of the aquifer in order that they may be used to predict future drawdowns of water levels. A test and the use of its results are, therefore, essentially a process of determining the equation of a water-level drawdown curve for a short period of time and extending the curve over a longer period of time by means of the same or another equation. In applying an equation over a long period, consideration usually must be given to boundaries and changes in character of the aquifer that are not taken into account by the equation for the short-term curve.

The curves in figure 40 were computed by means of the straight-line method as outlined by Cooper and Jacob (1946, p. 526–534) who described the use of the distance-drawdown graph to determine the hydraulic characteristics of an aquifer. The result for a typical test, that on well JD-242 as shown in figure 40, is a graph of the drawdown with time, t, after the discharge begins, plotted against r, the distance in feet, on semilogarithmic paper, with r on the logarithmic scale.

The formula for transmissibility, using any set of consistent units, as presented by Cooper and Jacob is

$$T = \frac{-2.303Q}{2\pi \Delta s} \qquad (2)$$

in which T = the transmissibility;
Q = the discharge;

Table 17.—*Summary of results of pumping tests made*

Test well no.	Location	Date of test	Duration of test (days)		Number of observation wells used	Rate of pumping (gpm)	Effective thickness of aquifer (feet)	T	P_f	S
			Drawdown	Recovery						
JD-242	Sec. 24, T. 8 S., R. 6 W., about 9 miles southwest of Kinder.	Feb. 14-18, 1950	1.9	1.1	4	2,740	[1]250	630,000	2,520	9×10^{-4}
Ev-1	Sec. 20, T. 4 S., R. 1 E., about 8 miles west of Ville Platte.	Feb. 17-22, 1950	3.0	3.0	2	1,525	100	150,000	1,500	9×10^{-4}
Ve-134	Sec. 21, T. 13 S., R. 4 E., near Erath.	Jan. 31 to Feb. 1, 1951	.2	.7	3	1,050	150	260,000	1,733	4×10^{-4}
Ve-236	Sec. 40, T. 12 S., R. 3 E., about 2 miles north of Abbeville.	Mar. 20-21, 1951	1.0	1.3	5	1,520	600	900,000	1,500	3×10^{-3}

[1]600 feet thick 5 miles away.

and Δs = the drawdown over one log cycle of distance from the pumped well.

The minus sign indicates that s, the drawdown, decreases as the logarithm of distance from the pumped well increases. Converting this formula to units as described by Theis we have the following formula:

$$T = \frac{528\,Q}{\Delta s} \tag{3}$$

in which Δs = the difference in drawdown, in feet, over one logarithmic cycle;

Q = the discharge, in gallons per minute;

and T = the transmissibility, in gallons per day per foot.

The equation for storage coefficient S, as expressed by Cooper and Jacob is:

$$S = \frac{2.25\,Tt}{r_o^2} \tag{4}$$

in which r_o = the distance from the pumped well to the point at which the drawdown is zero;

T = the transmissibility;

S = the coefficient of storage, a dimensionless quantity;

and t = time of pumping.

Again converting the units to those used by Theis, we have:

$$S = \frac{0.3\,Tt}{r_o^2} \tag{5}$$

in which t = time of pumping, in days;

T = the transmissibility, in gallons per day per foot;

and r_o = the distance, in feet, from the pumped well to the point at which the drawdown is zero.

As described in the discussion of the geology and shown by geologic cross section *A–A'* (pl. 11), the aquifer drawn upon by the wells in the vicinity of well JD-242 is uniform in thickness and character. Therefore, it is believed that the distance-drawdown graph as computed for well JD-242 is representative for wells affected by pumping in this vicinity. The results plotted indicate that a well discharging 1,000 gpm for 100 days will cause a drawdown of about 2 feet in a well 1,000 feet from the pumped well.

If the required data are available—total withdrawals from an aquifer for a known period and water-level measurements for the preparation of a detailed water-level contour map—it is possible to determine the transmissibility of an aquifer without making a detailed pumping test. However, it is important that the piezometric map be constructed from measurements made at a time when the water levels in wells in the area under consideration are virtually at a steady state. If these conditions are satisfied, the coefficient of transmissibility can be determined by application of the following formula derived from Darcy's fundamental law (Wenzel, 1942, p. 76–80):

$$T = \frac{0.366\,Q}{\Delta s} \log \frac{r_1}{r_2}$$

in which T = transmissibility, in gallons per day per foot;

Q = pumpage, in gallons per day;

r_1 = distance to geometric contour from the center of pumping;

r_2 = distance to geometric contour from the image of the center of pumping;

and Δs = interval between contours described by r_1/r_2.

By application of this theory (see discussion, p. 257) the transmissibility of the principal aquifer in the Lake Charles area was determined, using data obtained from the map on plate 34. The values of r_1/r_2 shown on figure 41 are plotted on semilogarithmic paper as the logarithmic ordinate against the altitude of the piezometric surface. (By using values of r_1/r_2 across one log cycle, the value of log r_1/r_2 becomes 1 and Δs is the r_2 difference in altitude of the piezometric surface across one log cycle.) Values should be plotted for all the contours affected by the pumping.

By substituting, in the above formula, the daily pumpage figure of 40 million gallons and data obtained from the graph of plotted points (fig. 41), which shows a difference in altitude (Δs = 50 feet) as described by r_1/r_2 over one log cycle, the coefficient of transmissibility for the aquifer in the Lake Charles area is computed to be 300,000 gallons per day per foot.

RESERVOIR OPERATION

RECHARGE

INFLUENT SEEPAGE FROM RAINFALL IN THE OUTCROP AREA

Recharge of the Chicot reservoir occurs in several areas, the largest of which is immediately northwest of the rice-farming area where the aquifers crop out. The southern boundary of this

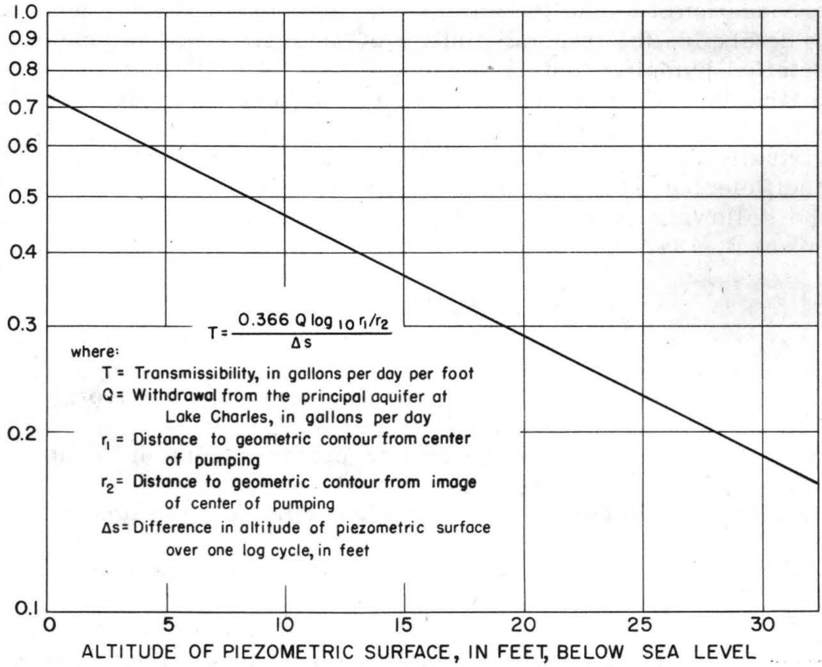


Figure 41.—Graph showing the altitude of the piezometric surface with relation to distances from centers of actual and theoretical (image) pumping at Lake Charles, Calcasieu Parish.

recharge area trends southeastward across Beauregard Parish to the vicinity of Kinder in Allen Parish and thence northeastward into Evangeline Parish to the headwater area of Cypress Creek (see stippled area on pl. 31). It comprises an area of some 2,000 square miles. Topographically it is an area of broad, poorly drained plains crossed by belts of low, rolling hills separated by many small streams. To the north, in south-central Rapides Parish, the relief is greater and dissection by streams is more advanced; in that area only scattered remnants of the plains remain.

In parts of this recharge area, the sand and gravel deposits are overlain by clay and silt of low permeability. These fine-grained deposits generally thicken toward the southern margin of the area. Where the beds of sand and gravel are exposed at the land surface much of the rainfall makes its way into the aquifer. Where the surface is covered by thin beds of relatively impermeable materials, recharge occurs principally along stream channels that cut through this cover.

A drainage area of 238 square miles, lying on either side of Bundick Creek above the stream-gaging station, Bundick Creek near Dry Creek, in Beauregard Parish (pl. 12), typifies the recharge area as a whole. Streamflow records for Bundick Creek have been obtained since 1939 (U. S. Geol. Survey Water-Supply Papers, Surface water supply of the United States, part 8, Western Gulf of Mexico basins, for 1939 and subsequent years). Since 1948, water levels have been measured monthly in a large number of wells in the drainage basin of Bundick Creek above Dry Creek. Continuous records of water-level fluctuation are available for one well (Be-37) for the period since 1948.

The relation of rainfall in the basin to streamflow and water levels in water-table wells (wells tapping unconfined aquifers) is shown on figure 42, which shows conditions in 1948 and 1949. Peak streamflow, as in November and December 1948, results principally from surface runoff (overland flow). Low flow, however, such as that between the middle of March and the middle of November in 1948, is derived almost exclusively from ground-water seepage. The amount of streamflow derived from ground water is shown approximately by the dashed line on figure 42. The minimum rate of flow during the period of record (1939–51) was 49 cfs in September 1939, and the minimum flow during the prolonged drought in the summer of 1948 was 55 cfs.

The water table slopes toward the creek and conforms in a general way to the topography of the basin. A profile of the water table, transverse to the axis of the basin near the Dry Creek gaging station, is shown on figure 43, and the apparent range of fluctuation of the water table between June 15 and October 17, 1951, is shown. The sustained dry-weather flow of Bundick Creek, the slope of the water table toward the stream, and geologic conditions favorable to effluent ground-water seepage are evidence that a part of the recharge to the aquifer is lost to the stream.

Recharge to the Chicot ground-water reservoir in the Bundick Creek drainage basin thus is sufficient not only to replenish quantities transmitted into the artesian area to the south and east, where large supplies are withdrawn for rice irrigation, but also to maintain streamflow in the creek during dry weather, by hydraulic discharge of gravity ground water. If the water table were lowered significantly (perhaps 20 to 50 feet below the present average level at the crest of the water-table divide between drainage basins) by heavy withdrawals from wells in the irrigation area, there would be less seepage into streams that cross the intake area of the aquifer. This would decrease the dry-weather flow available to rice farmers using surface-water sources but would increase greatly the rate and quantity of recharge to the Chicot reservoir. Some of the water that now is lost as overland

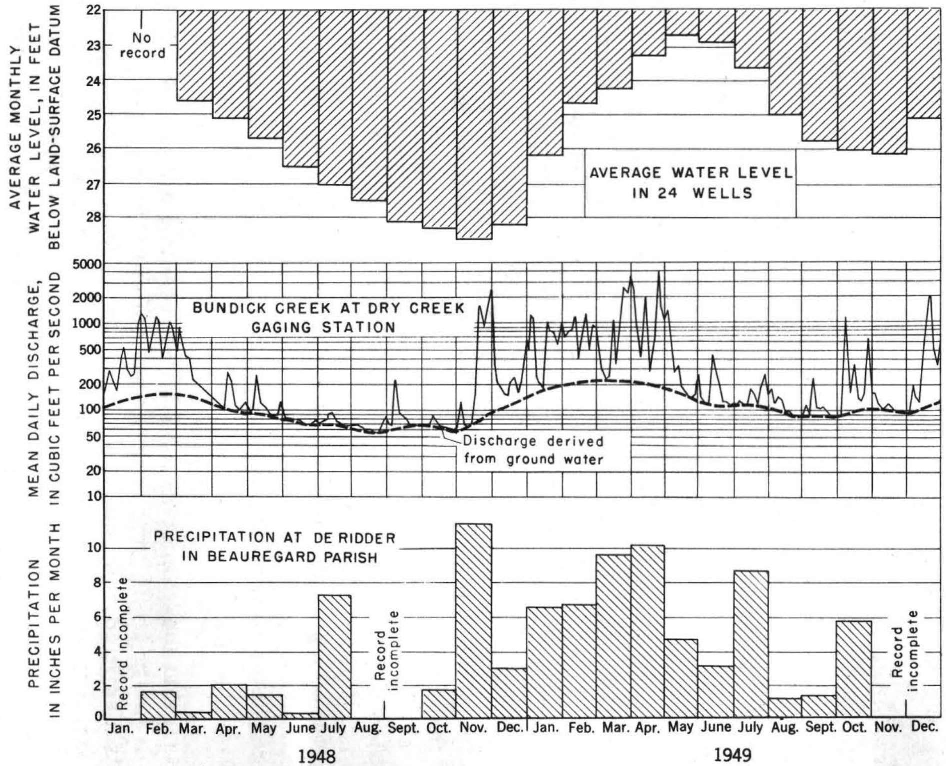


Figure 42.—Hydrographs showing the relation of precipitation at De Ridder, Beauregard Parish, to the average monthly water level in observation wells in the Bundick Creek drainage basin above the Dry Creek stream-gaging station and the flow of Bundick Creek past the station.

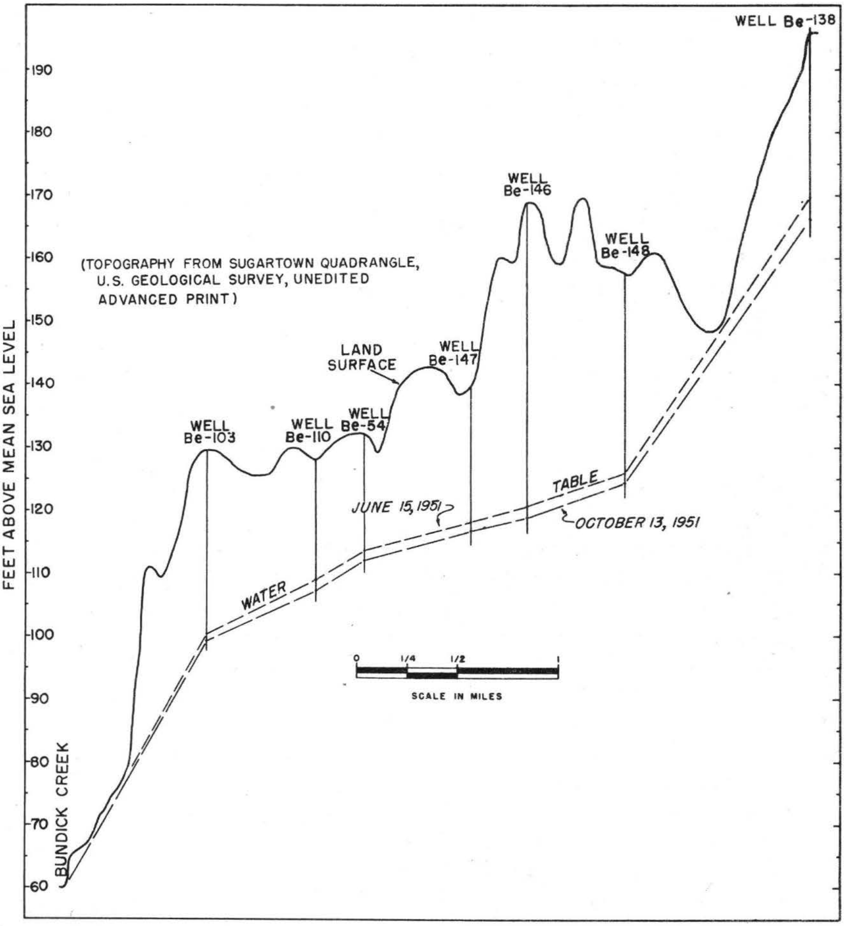


Figure 43. —Profile of water table at wells in the Bundick Creek drainage basin.

flow in the winter and spring months because the ground-water reservoir is too full to hold it would go into ground-water storage if the water table were lowered. This would tend to conserve for use a greater part of the available water supply.

Available water-level records for wells tapping aquifers in the recharge area of the Chicot reservoir in the Bundick Creek drainage basin show no indication of the net annual decline one might expect as a result of withdrawals from wells to the south and east. This is true throughout most of the recharge area where water-level records are available. (See fig. 39.)

387601 O -56 -16

On plate 32 are shown the locations of the observation wells used in compiling the graphs shown on figure 39. Some of the wells are not in the recharge area but lie between it and the region of heavy pumping; for example, wells Cu-245, Cu-222, and Cu-219 in Calcasieu Parish. The slight declines of water level shown on their hydrographs are evidence of the development of the regional hydraulic gradients in the marginal areas required to induce large-scale movement of ground water from recharge areas into the irrigated region. In spite of steepened hydraulic gradients from the recharge area to the areas of withdrawal, there have been no general declines of water level in wells in the recharge area. There is no indication of incremental depletion of ground-water storage in the recharge area, and thus available recharge is more than sufficient to meet present requirements.

The hydrograph of average water level in 24 wells, shown on figure 42, indicates that water levels in wells in the part of the recharge area included in the Bundick Creek drainage basin decline during the summer months and rise during the winter months. Declines are due partly to ground-water movement southward into the irrigated area, partly to effluent seepage into streams that cross the recharge area, and partly to evapotranspiration.

The hydraulic gradient in the Chicot reservoir near the juncture of Bundick and Whiskey Chitto Creeks is southeastward and roughly parallel to the trend of Bundick Creek. The rate of ground-water flow southeastward from this recharge area through a cross section of the aquifer 6 miles wide (the approximate width of the drainage basin) has been about 10,000 acre-feet a year during the period 1946–51 (see p. 261). The net recharge necessary to supply this quantity from the 238 square miles of area in the drainage basin above the Dry Creek gaging station—if the 10,000 acre-feet of water originated in the basin area—amounts to about 0.8 inch of rainfall each year. That the water was derived from rainfall in the basin is likely, for the drainage basin transects the outcrop of the sand and gravel aquifers of the Chicot reservoir.

The net retention of rainfall as recharge to the Chicot reservoir was about 1 percent of the total rainfall, on the basis of computation of the total rainfall in the Bundick Creek drainage basin, the total streamflow from the basin, and the total ground-water movement from the basin area from January 1949 to January 1951, during which period there was no net loss or gain of ground-water storage in the basin. Streamflow carried away about 52 percent of the precipitation during the 2-year period and, thus, evapotranspiration accounted for about 47 percent. The average annual rainfall in the Bundick Creek drainage basin during the period was about 60 inches.

If the disposition of the total annual precipitation in the Bundick Creek drainage basin can be regarded as typical of conditions throughout the approximately 2,000 square miles in which Pleistocene sand and gravel aquifers of the Chicot reservoir crop out or lie near the surface in south-central Louisiana, then the approximate total annual net recharge (not later lost by evapotranspiration or effluent seepage to streams) to the reservoir from this source is at least 85,000 acre-feet. Because most of the 2,000-square-mile area is less dissected by streams than is the Bundick Creek basin and thus is less subject to natural diversions from the ground-water reservoir by effluent seepage to streams, the disposition of precipitation available for ground-water recharge is probably somewhat different. Evapotranspiration losses probably account for considerably more than 50 percent of the precipitation in the upland-plains areas, whereas the net retention of rainfall as recharge to the Chicot reservoir may be somewhat greater than 1 percent of the total annual precipitation.

Although it is not possible to make a reliable estimate of the amount of ground water that may have been withdrawn from storage by a small decline of the water table in the 2,000-square-mile area, the volume of water involved is very large and its appraisal is highly important. A representative figure for the storage coefficient (defined on p. 217) of granular water-table aquifers of the type we are considering is about 0.20. This means that, as the water table falls 1 foot over an area of 1 acre, 0.20 acre-foot of water is withdrawn from storage. Thus, an average water-level decline of 5 feet over the 2,000 square miles of the recharge area would indicate a withdrawal of 1,280,000 acre-feet of water from ground-water storage. Actual declines of this magnitude measured in the area are attributable largely to evapotranspiration or effluent seepage, but the potential supply available for withdrawal by wells is indicated.

However, the coefficient of storage of the water-table aquifer is essentially equivalent to its specific yield, which varies with the texture of the aquifer. The water-table aquifer in the recharge area grades downward from clayey sand near the land surface into fine-grained sand, and then into coarse-grained sand or gravel. There is, therefore, a wide range in the specific yield, or storage coefficient, of the water-table aquifer with change of depth to water; and a unit decline of water level at shallow depth indicates a much smaller withdrawal from storage than a unit decline at greater depth. Computations of withdrawals from storage in the recharge area based upon measurement of water-table decline, therefore, are subject to considerable error. Detailed study of aquifer characteristics—texture gradation, thickness, and structure—will be needed before withdrawals can be related to water-table declines. As shown later in this report (table 18), the estimated maximum recorded annual withdrawal by wells from the Chicot reservoir was about 890,000 acre-feet in 1951.

Because this area of recharge to the Chicot reservoir is a broad belt extending from the Sabine River to the valley of the Red River, because it is underlain by a highly permeable bed of sand and gravel having an average water-saturated thickness of 100 feet or more, and because it is in an area of relatively heavy precipitation well distributed with respect to time, it provides an excellent and dependable source of recharge to the artesian part of the Chicot reservoir, where almost all wells tap it. During 1946 the total volume of ground water that moved from the intake area at the outcrop into the area of withdrawal was about 160,000 acre-feet, on the basis of figures shown on plate 30. That this quantity was restored to the aquifer by recharge within a matter of a few months is indicated by the complete recovery of water levels in key wells in the area during the following winter.

The ability of the recharge area discussed above to accept and store water is not at present a function of its capacity to hold water but rather a function of the degree to which it is dewatered by evapotranspiration, effluent seepage, and underground flow into the area of withdrawal during the summer months. In the spring months it is generally "brim full," or as near to that condition as a water-table aquifer in a rolling terrain can be. And during the spring months much of the precipitation that could be caught and stored in the ground-water reservoir for use during the summer months therefore flows into the streams and in large part is discharged to the Gulf of Mexico without use at present, but the probable need for surface-water reservoirs for storage of spring runoff should not be overlooked (see p. 192).

Evapotranspiration losses are much greater in areas where the water table is close to the land surface than where it is several feet or tens of feet below it. If the zone of soil water is in contact with the capillary fringe (the belt that overlies the zone of saturation and contains water held by capillarity above it but in hydraulic continuity with it), the discharge of ground water into the atmosphere begins (Meinzer, 1923, p. 27). If a zone of aeration exists between the two, evaporation and transpiration are both reduced. Thus, lowering the water table in the recharge area of the Chicot reservoir by increased withdrawals from wells to the south not only provide more storage space for the catchment and retention of precipitation but also would decrease evapotranspiration losses from the recharge area. There would be, of course, an accompanying decline in effluent seepage to streams like Bundick Creek, and their dry-weather flow would be greatly reduced. However, much of the recharge area, especially that part lying in northwestern Beauregard Parish, at present does not contribute significantly to the dry-weather flow of local streams, and a lowered water table, therefore, would not decrease stream-water supplies in proportion to the gain in the ground-water supply.

INFLUENT SEEPAGE FROM STREAMS

Calcasieu River. —The southeastern margin of the recharge area described above is followed by the Calcasieu River and its tributaries. The river follows a flood plain formed by the filling of a scour trench, a valley cut through the surface clays by the ancestral Calcasieu River in late Pleistocene time. The valley-fill deposits, principally of sand, lie in contact with the sand and gravel aquifers of the Chicot reservoir. The depth of the ancient scour trench is great enough to provide hydraulic interconnection of the river and the aquifers of the Chicot reservoir as far downstream as the mouth of Barnes Creek. From that point to the Gulf of Mexico the channel of the Calcasieu River lies in clay.

The Calcasieu River, therefore, serves not only as a source of recharge to the Chicot reservoir but also as a line of escape for ground water moving southeastward from the outcrop area of aquifers of the reservoir. This dual function of the river is shown by the hydrographs on figure 44. At high stage the river recharges the aquifer and at low stage drains it. The river maintains high water levels in the aquifer, and the maximum rate of recharge from the river in the reach between Oberlin and Kinder probably is not exceeded anywhere else in southwestern Louisiana. This is true not because

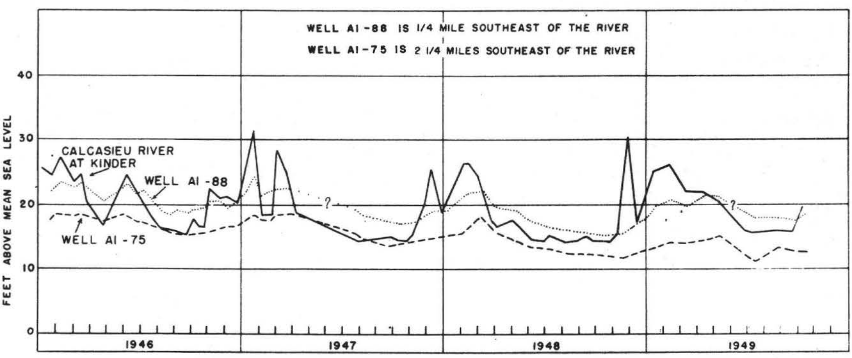


Figure 44. —Hydrographs showing the relation between fluctuations in river stage and water well levels in wells nearby in the Kinder area.

the conditions for influent seepage are most favorable but rather because the locus of heavy withdrawals is nearby in Jefferson Davis Parish and southern Allen Parish (see pl. 33 showing locations of irrigation wells). The piezometric maps (pls. 14, 16–23) show a persistent "high" east and southeast of the river in northern Jefferson Davis Parish and southern Allen Parish with contours forming a broad arc convex down the gradient. Recharge from the river probably is responsible for the presence of this "high." Recovery of water levels in wells at the end of the irrigating season in the area south and east of this reach of the Calcasieu River is more rapid than elsewhere in the region.

The effectiveness of recharge of fresh soft water from the Calcasieu River and in the outcrop area to the northwest is further indicated by the contour of the chloride (pl. 36) and hardness content (pl. 35), both of which show arcuate contours convex down the gradient.

Although the influent reach of the Calcasieu River consists of only about 10 percent of the length of the periphery of the area irrigated by wells (see pl. 33), recharge across this boundary, whether derived from rainfall on the outcrop of the aquifers to the northwest or from the river by influent seepage, constituted at least 25 percent of the total recharge entering the area of withdrawal in 1946. Probably an even greater proportion of the effective recharge came from this area during the drought years of 1948 and 1951. The proportion derived from the river by influent seepage, compared with that which crossed this boundary as underflow from the recharge area to the northwest, cannot be computed from available data.

Atchafalaya River.—In 1903 the basin of the Atchafalaya River was an important area of natural ground-water discharge (see pl. 13). Since 1944, and probably for several years prior to that date, it has been a very important source of recharge to the ground-water supplies of southwestern Louisiana. All piezometric maps showing hydrodynamic conditions in the Chicot reservoir since 1944 (pls. 14, 16–23) give evidence of westward movement of the ground water from the Atchafalaya River basin. Although the hydraulic gradient is not steep, it is very stable; and, because the thickness of the aquifer is less than about 400 feet in few places along the eastern boundary of the irrigation area between Ville Platte in Evangeline Parish and New Iberia in Iberia Parish, the rate of recharge from this direction is very great. The length of the boundary crossed by ground water from the Atchafalaya River basin constitutes at least 30 percent of the periphery of the irrigation area, and it is estimated that in 1946 at least 30 percent of the recharge to ground-water supplies in the area of heavy withdrawal crossed this portion of the boundary.

Evidence that the Atchafalaya River is an effective source of recharge is available from both geologic and hydrologic data. The geologic section, plate 5, shows that the channel of the river lies in clay, and sand and gravel deposits of Recent age. The deposits of Recent age (the Lebeau member of the Le Moyen formation) lie in a scour trench carved in deposits of Pleistocene sand and gravel. There is hydraulic interconnection between the Recent sand and gravel and the gravelly aquifers of the Chicot reservoir.

The hydrographs of water levels in wells east of the Vermilion River show a better conformity to the stage hydrograph of the Atchafalaya River than to the cyclic pattern characteristic of most wells elsewhere in the project area. This relationship is evident in the hydrograph of well Lf-164 on figure 45 which shows hydrographs for that well which is about 4 miles east of the Vermilion River, for well Lf-437 about ⅓ mile east of the Vermilion River, and for well Ve-127 about 20 miles west of the Vermilion River (see pl. 32). The hydrograph for well Ve-460 (see fig. 46), less than 8 miles west of the Vermilion River, is very similar to that for well Ve-127: Both wells show a sharp decline of water level as pumping for irrigation begins in the early spring, the decline continues until the middle of the irrigating season, and then, as wells are shut down, a gradual recovery occurs.

The sharp response of water level to pumping is typical of wells tapping the part of the Chicot reservoir where the water is under artesian conditions (confined). Because little water is available in storage locally where artesian conditions prevail, water levels in wells tapping artesian aquifers in the vicinity of pumped wells decline immediately, to produce from surrounding areas a hydraulic gradient sufficient to cause flow to the pumped wells approximately equivalent to the rate of withdrawal. The stabilizing influence of the water-table area along the Vermilion River (see graph for well Lf-437) reduces fluctuations due to withdrawals from wells located to the west and makes more evident the relation between the stage of the Atchafalaya River and ground-water levels in the artesian part of the aquifer between the Vermilion and Atchafalaya Rivers.

The most compelling evidence of recharge from the Atchafalaya River is the westward hydraulic gradient shown on the piezometric maps mentioned above. The eastward swing of water-level contours near the latitude of Lafayette in Lafayette Parish no doubt results from a reduction in or a lack of influent seepage from the river in the area downstream. It should be noted that, except for one short reach in the lower Grand Lake area, the channel of the river does not completely penetrate the clayey top stratum of the Recent deposits southward from the latitude of Bayou Fusilier, approximately at the southern boundary of St. Landry Parish.

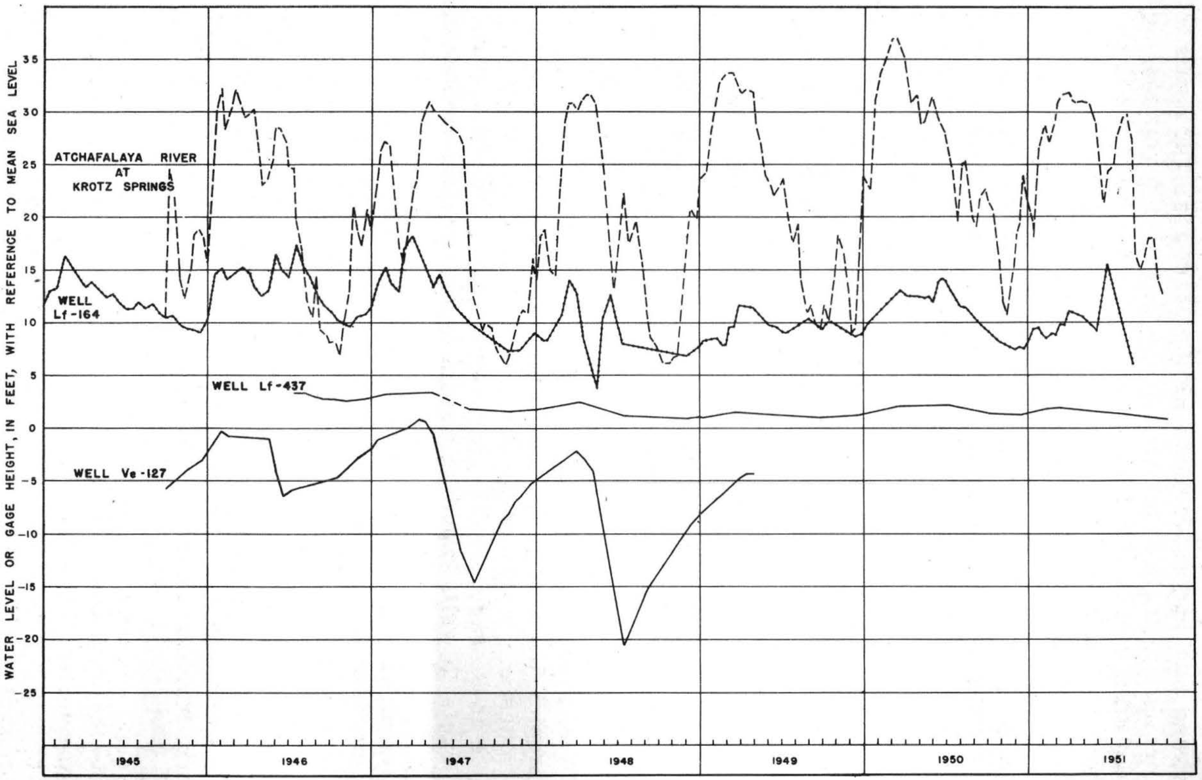


Figure 45.—Hydrographs showing the relation of water levels in wells to the gage height of the Atchafalaya River at Krotz Springs.

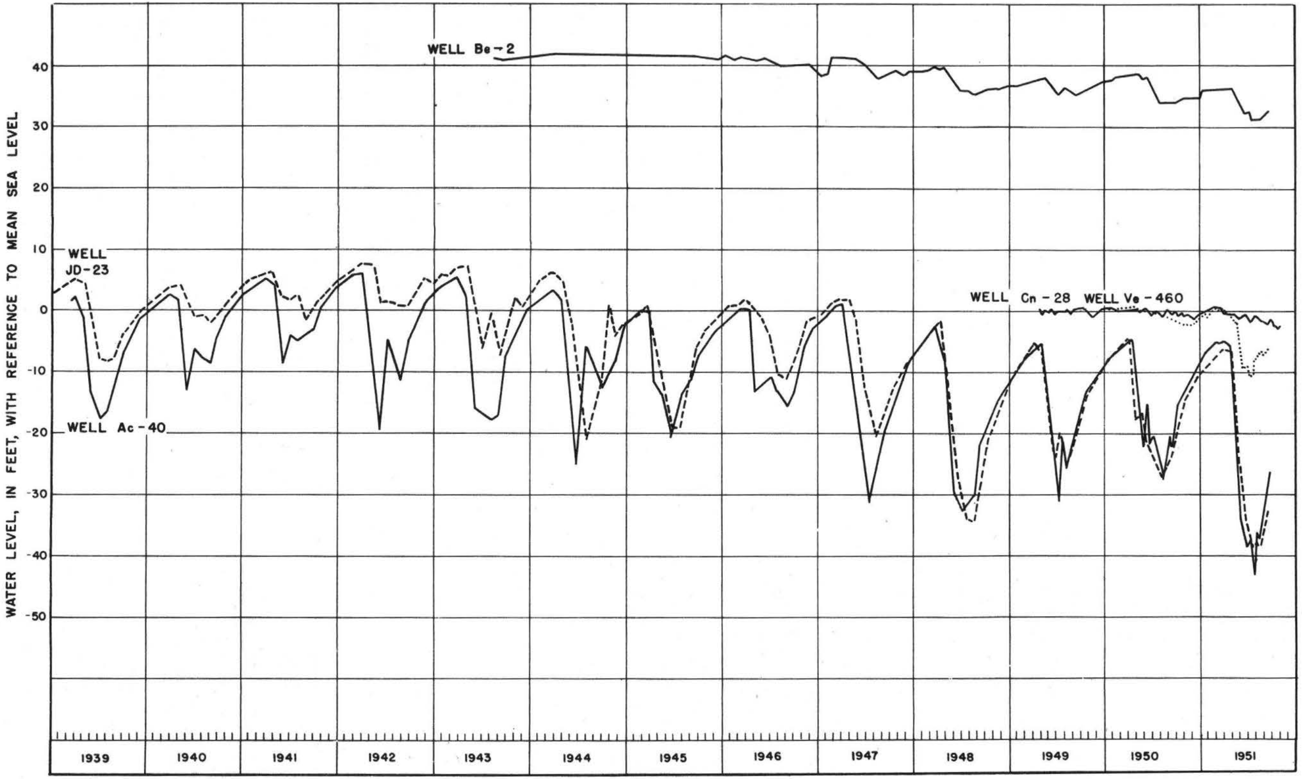


Figure 46.—Hydrographs showing fluctuations of water levels in wells near the centers of heavy withdrawal for irrigation compared with fluctuations in wells near the margin of the irrigated areas.

Vermilion River. —One of the most noticeable anomalies on the piezometric map of southwestern Louisiana for 1903 (pl. 13) is the slope of the hydraulic gradient in the aquifer from the west, north, and east toward the lower basin of the Vermilion River. That, in 1903, the channel of the Vermilion River was a line of escapement for water in the aquifer is evident; and even today (1952) the river is effluent along part of the channel during part of the year. However, the regional hydraulic gradients in the western and northern parts of the Vermilion River basin have been reversed (compare pl. 13 with pl. 16), and the important role of the Vermilion River today is its recharging function. All piezometric maps showing conditions during this investigation give evidence of the stabilizing influence of the river on ground-water levels, as shown by the contours.

To confirm the belief that the Vermilion River is a source of recharge—further indicated by study of the geology of the basin—a hydraulic test was made in 1951 about 2 miles above Abbeville, using a pumped well and five observation wells. Analysis of test results indicated that the river and aquifer are interconnected hydraulically in that reach. (See p. 256.)

The Vermilion River is a tidal stream having a rather narrow range of stage variation, and it is alternately influent and effluent. During the early spring months when ground-water levels are at their highest, the river receives effluent seepage from the aquifer throughout most of the lower basin, as shown by the water-table map (fig. 47), and by profiles *A–B, C–D, E–F, G–H,* and *I–J* in figure 48. Profiles of the water table show that the hydraulic gradients in the aquifer are dissipated largely near the stream channel or in the water-table zone of the meander-belt deposits on either side.

During the late summer and early fall, when water levels in wells decline markedly as a result of heavy withdrawals for rice irrigation, the river recharges the aquifer along at least a part of its course. The map and profiles of the water table, figures 49 and 50, show the nature of this seasonal reversal of flow. Influent seepage amounted to at least 25 cfs along a 10-mile reach of the stream near Abbeville in November 1951. This determination was made for conditions some $2\frac{1}{2}$ months after pumping for irrigation had ceased, and recharge rates in this reach during the pumping season probably were several times as great.

It is evident that the profiles of the water table should conform almost exactly with the level of the Vermilion River where they cross it, if hydraulic interconnection is direct and head loss is negligible. However, measured water levels in wells indicate that

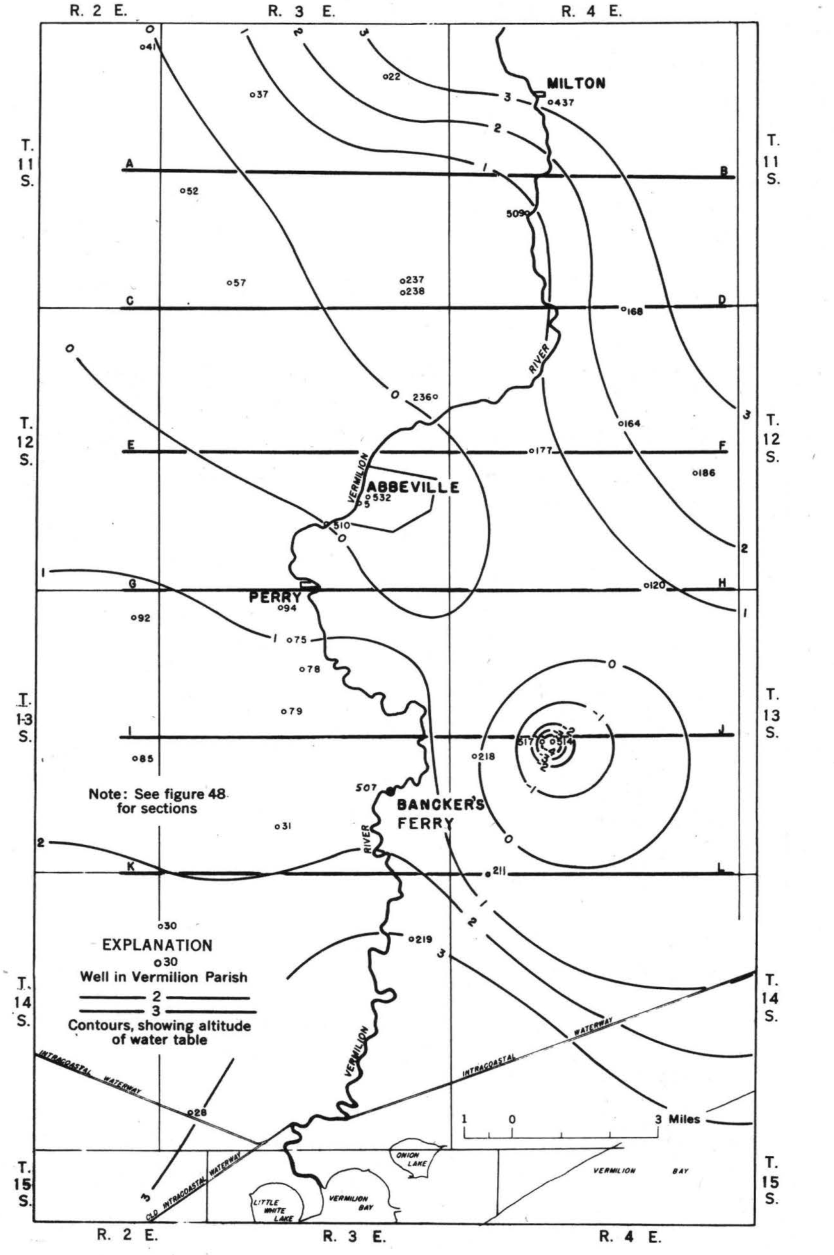


Figure 47. —Map of the lower part of the Vermilion River basin showing the altitude of the water table in the principal aquifer, March 1951.

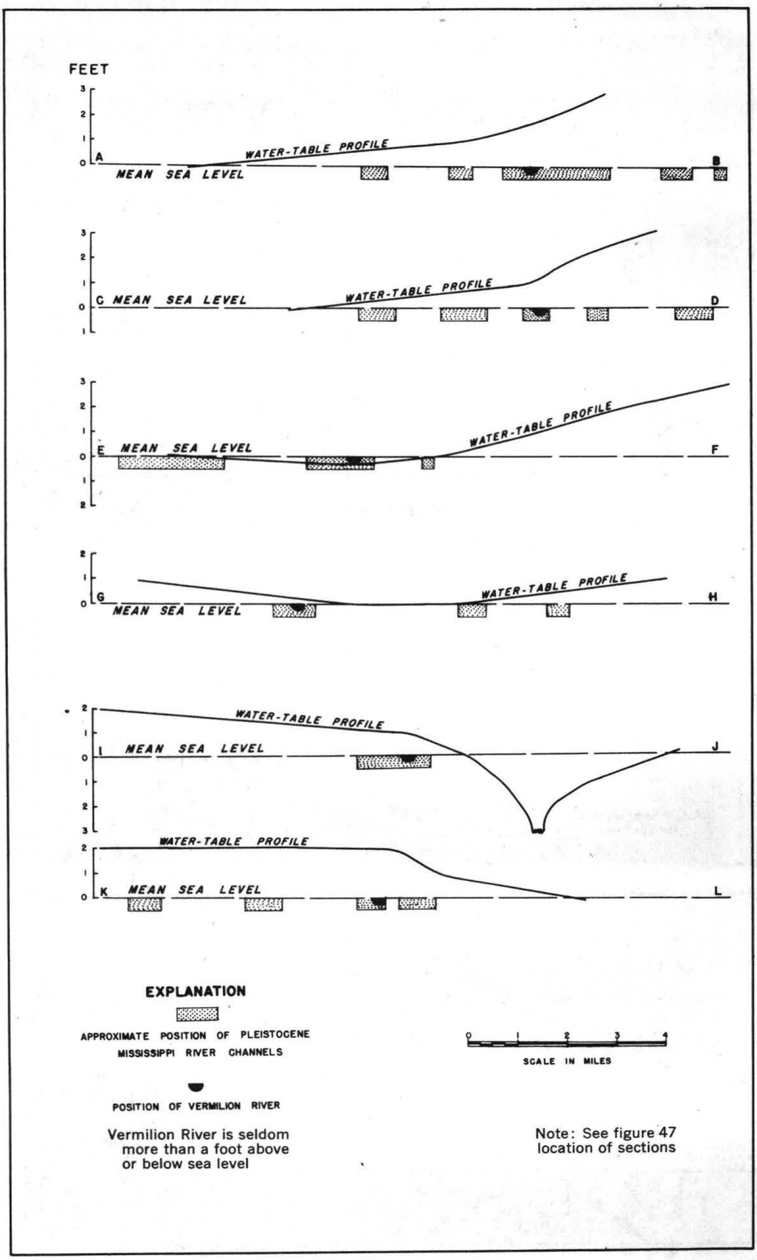


Figure 48. —Transverse profiles across the lower part of the Vermilion River basin, showing the effect of the Vermilion River on the water table in the principal aquifer.

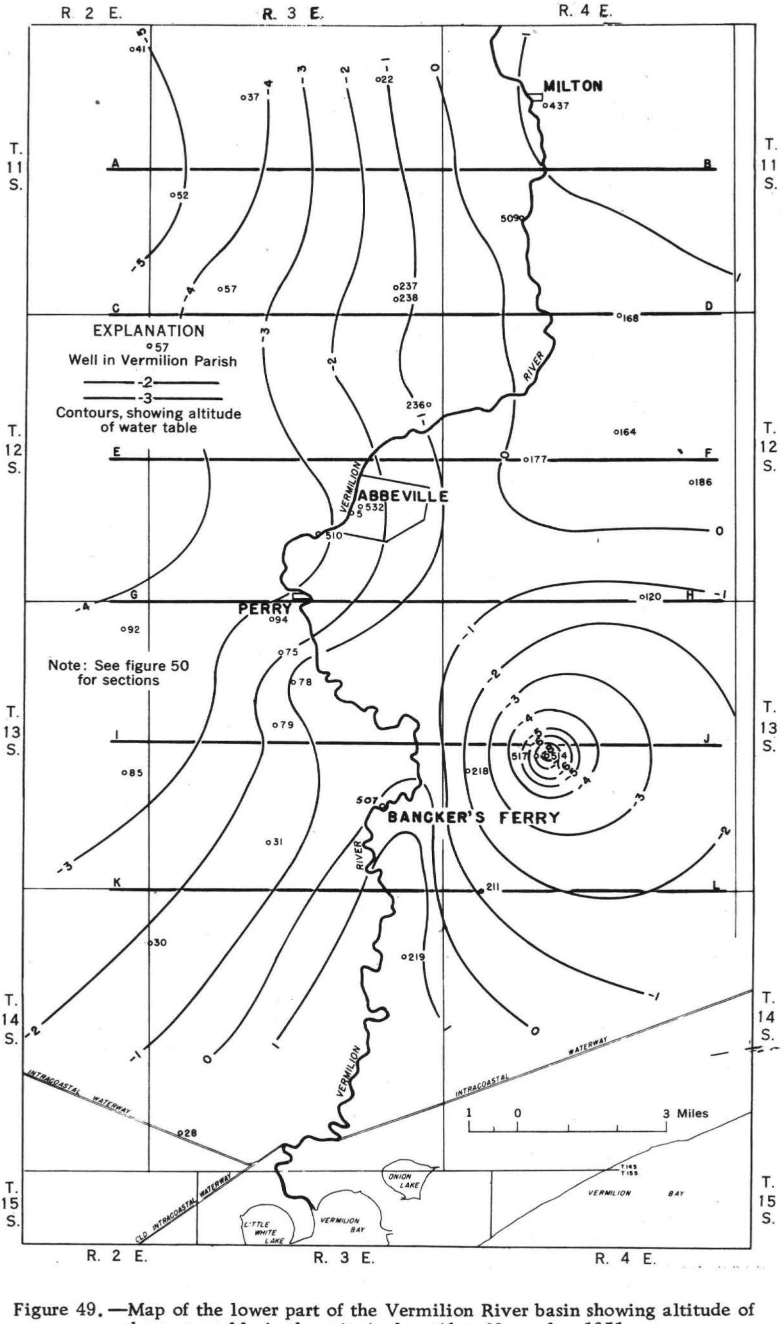


Figure 49. —Map of the lower part of the Vermilion River basin showing altitude of the water table in the principal aquifer, November 1951.

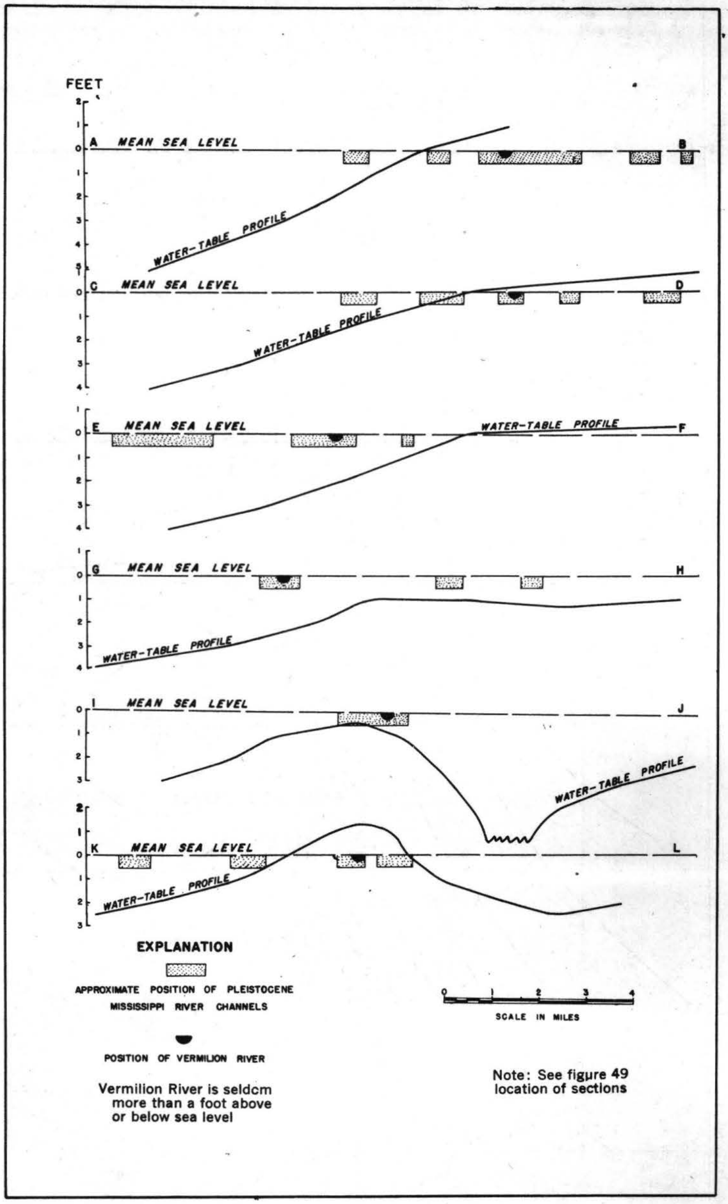


Figure 50. —Transverse profiles across the lower part of the Vermilion River basin showing the effect of the Vermilion River on the water table in the principal aquifer.

the hydraulic interconnection between the river and the Chicot reservoir in some reaches is through beds of low permeability and in general is related more closely to the distribution of the meander-belt deposits than to the position of the stream channel on a given water-table profile.

It should be noted that, in the lower basin, influent-seepage gradients in the fall are considerably steeper than effluent-seepage gradients during the spring, especially below Abbeville, indicating that the rate of recharge from the river in the summer and fall is greater than the rate of loss to it during the spring. The effect of a steady withdrawal of about 8 mgd from industrial wells a few miles southeast of Abbeville is the most noticeable anomaly on the maps, but such withdrawal could never produce the regional declines of water level that induce large-scale recharge from the river throughout most of the lower basin during the summer and fall months. Pumping at a rate greater than a billion gallons per day from many rice-irrigation wells tapping the aquifer to the west and northwest is largely responsible for the reversal of flow.

It should be noted also that the net effect of the stream as an influent or effluent channel cannot be established at any time without a detailed water-table map for the basin, for it is simultaneously influent in some reaches and effluent in others. And its function changes with regional fluctuations of water level in the aquifer caused by seasonal large-scale withdrawals. Steady pumping at an industrial plant east of the river induces continual recharge from a reach of the channel below Abbeville. Future regional declines of water levels in the irrigation area to the west and northwest may result in very large increases in recharge rates from the Vermilion River. For this reason it is very important that the Vermilion River be maintained as a fresh-water stream. It is vital that plans for providing an adequate water supply in the Vermilion River basin take these conditions into account.

PERCOLATION FROM ABOVE OR BELOW THROUGH AQUICLUDES

The sand and gravel aquifers that underlie the rice-farming areas of southwestern Louisiana are in general separated by thick beds of clay which have very low permeability and act as aquicludes restricting ground-water movement. Because of the low permeability, there are pressure differences between the upper and lower sides of each clay bed. When the head difference between the top and bottom of a confining clay bed is zero, there is no tendency for water to move through it; however, when the head difference is considerable, there will be a tendency for water to move through the clay. If there are no permeable channels or "short cuts" through the clay layer as a result of depositional irregularities, erosion, or faulting, the rate of water movement through the boundaries of the aquifer is very small.

The permeability of a number of samples of clay tested in the Hydrologic Laboratory of the U. S. Geological Survey ranged from approximately 0.2 gpd/ft^2 to 0.0002 gpd/ft^2 (Wenzel, 1942, p. 13). Below is a table showing the rate of flow through different thicknesses of clay for a hydraulic-head differential of 1 foot through the clay layer. For larger pressure differentials the quantities would be proportionately greater. These appear to be very small

Seepage rates through beds of low permeability with a range of thickness from 5 to 100 feet

Bed thickness (feet)	Flow in gallons per day through a cross section of 1 square foot, under a hydraulic head of 1 foot	
	Bed permeability 0.2	Bed permeability 0.0002
5	0.04	0.00004
10	.02	.00002
15	.013	.000013
20	.010	.000010
25	.008	.000008
30	.007	.000007
50	.004	.000004
100	.002	.000002

flow rates, but if the number of square feet in a square mile (nearly 28 million) is considered, it is evident that the quantities moving through the clay layers may be quite large over a long period of time. If the lower limit of 0.0002 is used as the permeability of an extensive clay bed 50 feet thick, approximately 100 gpd would flow through each square mile of a clay layer for each 1 foot of head difference. It should be noted that movement upward from underlying salt-water aquifers can occur as readily as movement downward from overlying aquifers. The sands of the Evangeline reservoir beneath the principal aquifer of the Chicot reservoir are filled with salt water throughout a large part of the rice-farming area.

As indicated above, movement through the clay layers can be important when large areas are involved. As an example, the clay layer beneath the Gulf of Mexico allows water to move from the aquifer into the Gulf of Mexico when ground-water levels in the aquifer are above gulf level, whereas the reverse movement takes place when water levels are below the surface of the gulf. To determine the exact pressure-head relationship, it is necessary to consider the densities of fresh water and sea water. To maintain a dynamic balance of head, the water levels in the aquifer would have to be somewhat above gulf level to prevent water movement from the gulf into the aquifer. The necessary fresh-water head to balance the system is equal to approximately 0.025 the thickness of fresh water in the aquifer, if sea water of average density is to be considered the source of recharge (Brown, 1925, p. 49). The density of gulf water along the Louisiana coast is generally less than that of an average sea water (see table 24).

After the sands were deposited beneath salt water in the gulf and were buried beneath thick clays, the fresh-water head was considerably increased. It was more than sufficient to balance the density head during much of Recent geologic time, and the salt water was flushed from the landward parts of the aquifers. As ground-water levels have been lowered somewhat in the past 50 years, the direction of the hydraulic gradient has been reversed, the density balance disturbed, and recharge from the gulf-marginal area begun. The rate of water movement northward from the gulf region is shown on plate 30, but this is not intended to indicate the rate of recharge from the gulf; on the contrary, it is believed that almost all water movement from the gulf region occurs as a result of arcuate flow. Water whose southward movement has been reversed and which is now moving northward across the shoreline is largely replaced in the aquifer by water from its eastward extensions, which in turn derive water from the north—from beneath the flood plain of the Atchafalaya River. Because the structural and stratigraphic discontinuities between Calcasieu Lake and the Sabine River are intricate and because the surficial clays are thick beneath most of the lower course of the Sabine River, it is likely that the quantity of water now moving gulfward or southeastward from that area is very small by comparison with the quantities moving gulfward from the region of the Atchafalaya River basin. Although there are few water-level observation wells west of Calcasieu Lake, the contours on the piezometric maps (pls. 14, 16–23) show no gulfward movement whatsoever. The presence of salty water in the Chicot reservoir in this area may reflect a "static" condition resulting from structural and stratigraphic barriers to movement, effective ever since deposition of the beds.

Before heavy pumping began in southwestern Louisiana, large quantities of ground water moved southward toward the gulf. From the few data available it appears that, if there are exposures of the aquifer to waters of the Gulf of Mexico, they are at a considerable distance offshore, except possibly in the area south of Franklin, in Atchafalaya Bay.

387601 O -56 -17

Recharge from the Gulf of Mexico south of White Lake may be occurring at a considerable distance offshore, and northward hydraulic gradients in this part of the area are extremely small. The northward rate of movement of water in the aquifer is probably no more than 50 to 100 feet per year. At present there is fresh water in the upper part of the aquifer for a distance of 5 to 10 miles offshore along the coast of Vermilion Parish and eastern Cameron Parish.

Throughout southwestern Louisiana there is ground water in the silt, shell, and fine sand above or within the extensive clay bed that confines the water in the principal aquifer. Where the level of this water stands above the level of water in the principal aquifer, it moves along the top of the clay layer below until it reaches a structural or depositional break, where it gains access downward into the principal aquifer; also, it seeps slowly through the clay itself. Conversely, where and when water levels in the principal aquifer are above the top of the confining clay, these shallow aquifers receive recharge from below. In the past, when water levels were higher, this condition probably resulted in effluent seepage to streams where their channels were cut into the shallow aquifers in the clay-silt top stratum.

Possibly the most important structural control of recharge by percolation in southwestern Louisiana is that of the salt dome. There are at least 32 of these in the area of study, and although their areal dimensions are not large—few of the salt masses or "plugs" are more than 3 miles in diameter—the vertical displacement of aquifers by peripheral or radial faults may amount to several hundred feet. In some places this is sufficient to bring two different aquifers into hydraulic interconnection and to provide an avenue of recharge or escape of ground water.

The map showing the depth of occurrence of fresh ground water (pl. 15) reveals many anomalies that are known to be related to salt-dome structures (see "Geology"). In some places the depth of fresh water is increased by dome faulting in the graben over a deep-seated dome (Wallace, 1944); in others it is decreased markedly by uplift over a piercement-type dome (for example, at Port Barre in St. Landry Parish); and in still others the faulting allows salty water to encroach upon a fresh-water aquifer.

Faulting joins aquifers that are heavily drawn upon to aquifers that are tapped by few wells and thus enables flow from one to the other. An example of this is indicated on the map of the greater Lake Charles area (pl. 34) in the vicinity of the Hackberry dome at the northern end of Calcasieu Lake. The thickness of the clay that overlies the principal aquifer in this area (pl. 31) is so great that recharge from Calcasieu Lake does not appear likely, but salt-water encroachment from upthrown aquifers probably is now taking place (see pl. 11).

The line of recharge northwest of Lake Charles, shown on plate 34, probably is caused by an effective thickening of the aquifer, either by depositional features or by faulting. Regional faults having about the same trend as the line of recharge are known to occur to the northeast, approximately along the southern boundary of Allen and Evangeline Parishes, and it is possible that the hydraulic conditions shown are related to their southwestward extension.

The amount of recharge to the Chicot reservoir through its lateral boundaries in 1946 has been computed using the data on plate 30. The total withdrawal that year is shown on figure 51. Comparison of these figures indicates that as much as half the recharge that year was derived by percolation from above or below, and this is probably representative of continuing conditions.

The fact that a considerable amount of this recharge was brackish or salty water will be a very important factor in the future

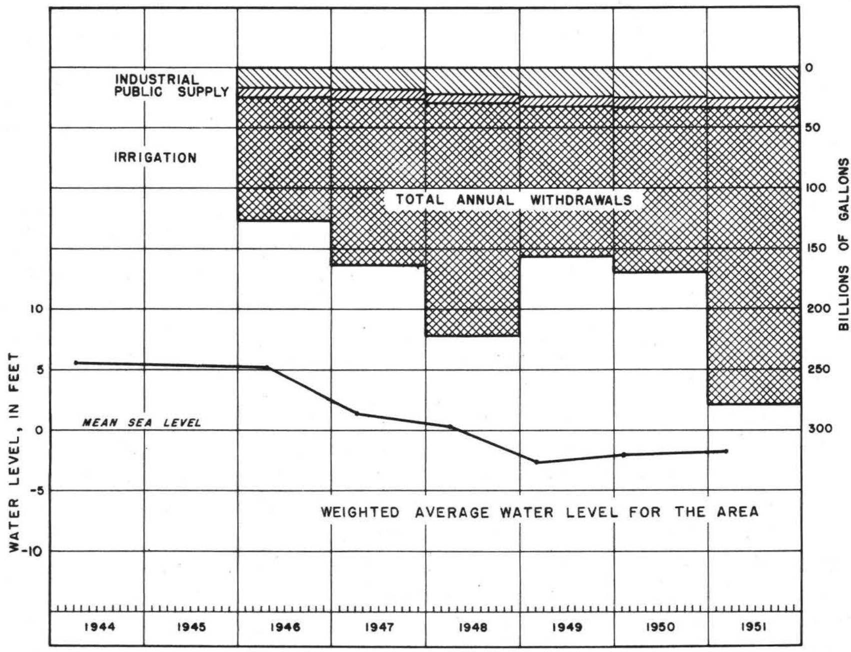


Figure 51.—Graphs showing the effect of withdrawals on water levels in the Chicot reservoir.

development of ground-water supplies from the Chicot reservoir. Important avenues of salt-water encroachment from above or below must be located and steps taken to reduce their effectiveness; and similar avenues of fresh-water recharge should be identified and recharge from them increased.

METHODS OF LOCATING AREAS OF RECHARGE

Hydraulic tests. —The nonequilibrium formula developed by Theis assumes that the aquifer is infinite—without boundaries or any changes in its hydraulic characteristics. In recent years, study has been given to methods for estimating the degree or manner in which an observed aquifer diverges from the idealized aquifer (Ferris, 1948). The application of the image method in problems of ground-water hydraulics, as described by Ferris, was made in a detailed pumping test at the Erath Cycling Plant near Erath, in Vermilion Parish, in an effort to determine the possible occurrence and location of a geologic boundary. The plant, operated by the Texas Co., is about 7 miles southeast of the town of Abbeville and about $2\frac{1}{2}$ miles east of the Vermilion River, which was believed to be interconnected with this aquifer.

A supply of about 8 mgd is pumped for cooling purposes from five wells located on company property. Pertinent data concerning these supply wells are presented in table 22 which lists the wells owned by the major industrial water users in southwestern Louisiana. All the wells in this area are screened in sand and gravel of the Chicot reservoir, the geologic characteristics of which were discussed before.

One of the supply wells, Ve-134, located in the western part of the plant area, was used as the test well, and three unused oilfield supply wells at different distances from Ve-134 and tapping the same aquifer at depths of about 250 feet were used as observation wells. The map of the test area, figure 52, shows the location of these wells and the other supply wells used by the Texas Co.

The test well, Ve-134, had been pumped continuously at a rate of about 1,050 gpm for at least a month prior to the time of the test, and when it was shut down, measurements were made of the water-level rise in the observation wells for a period of 17 hours. Because of the high transmissibility and relatively small storage coefficient of the aquifer tested, which is under artesian conditions, the effects became stabilized in observation wells after a period of 14 hours of discharging or recharging the aquifer at a rate of 1,000 gpm.

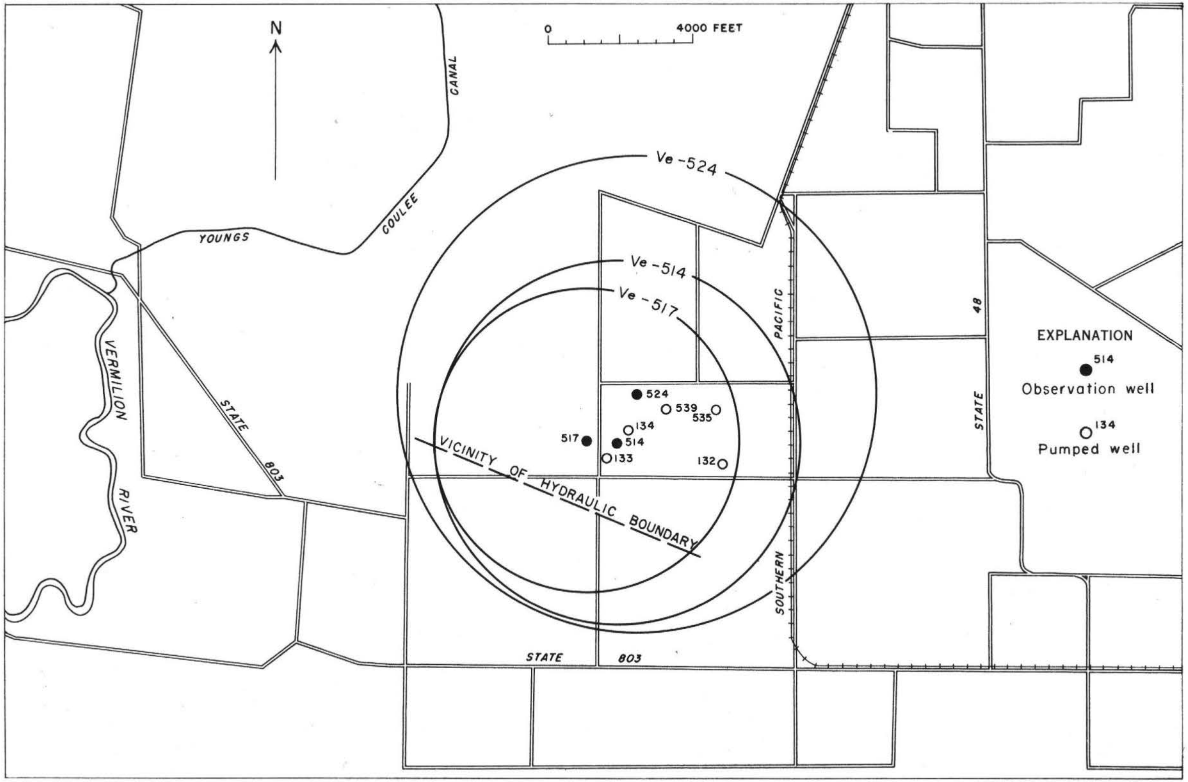


Figure 52.—Map showing location of pumping test site near Erath, Vermilion Parish, with radii to image recharge wells defining a hydraulic boundary.

The logarithmic plots of the observed water-level data against values of r^2/t for both drawdown and recovery phases are shown in figures 53 to 59. For purposes of computation the graphs of the observed data are superposed on the type curve (fig. 53), and with the coordinate axes of the two curves parallel, a position is found by trial for which most of the plotted points fall on the type curve. With the curves in this position, an arbitrary point (generally unity, for convenience) is chosen on one graph, and from the corresponding points on the other graph, values are derived for use in computing the coefficients of storage and transmissibility. By use of this method, these values were determined to be 4×10^{-4} and 250 mgd per foot, respectively.

If a geologic or hydrologic boundary is not present, the extrapolated observed-data curves should correspond for their full length with the type curve. However, if a boundary is present within the effective radius of the area tested, the curves will deviate above or below the type curve. The deflection of the curves in one direction or the other indicates the type of boundary present—recharging or barrier. The divergence of the curve described by observed data from the type curve is determined for a series of points on the curves, and these values are plotted in the same manner as the original data. If a single curve conforming to the type curve is described by these points, there is only one image affecting the results. After agreement between the type curve and these replotted curves is effected, it is possible to calculate the distance to the image from each observation well, using the formulas derived by Ferris. The calculated image distance for each observation well at Erath is shown in the following table.

Distance from observation well to image well and test well at Erath, La.

Observation well no.	Distance to image well (feet)		Distance to test well (feet)
	Recovery	Drawdown	
Ve-514	4,800	5,200	490
Ve-517	4,200	4,200	1,170
Ve-524	7,900	....	1,190

These calculated distances are circumscribed by means of a compass from each observation well as shown on the map, figure 52. The center of the circle is located at the appropriate observation well, and the intersection of arcs theoretically pinpoints the locus of the image well. As indicated on the map, the image arcs for observation wells Ve-514 and Ve-517 intersect to the west of the plant area. The arcs for wells Ve-514 and Ve-524 nearly intersect south-southwest of the well field. The arcs for wells Ve-517 and Ve-524 nearly intersect southwest of the plant

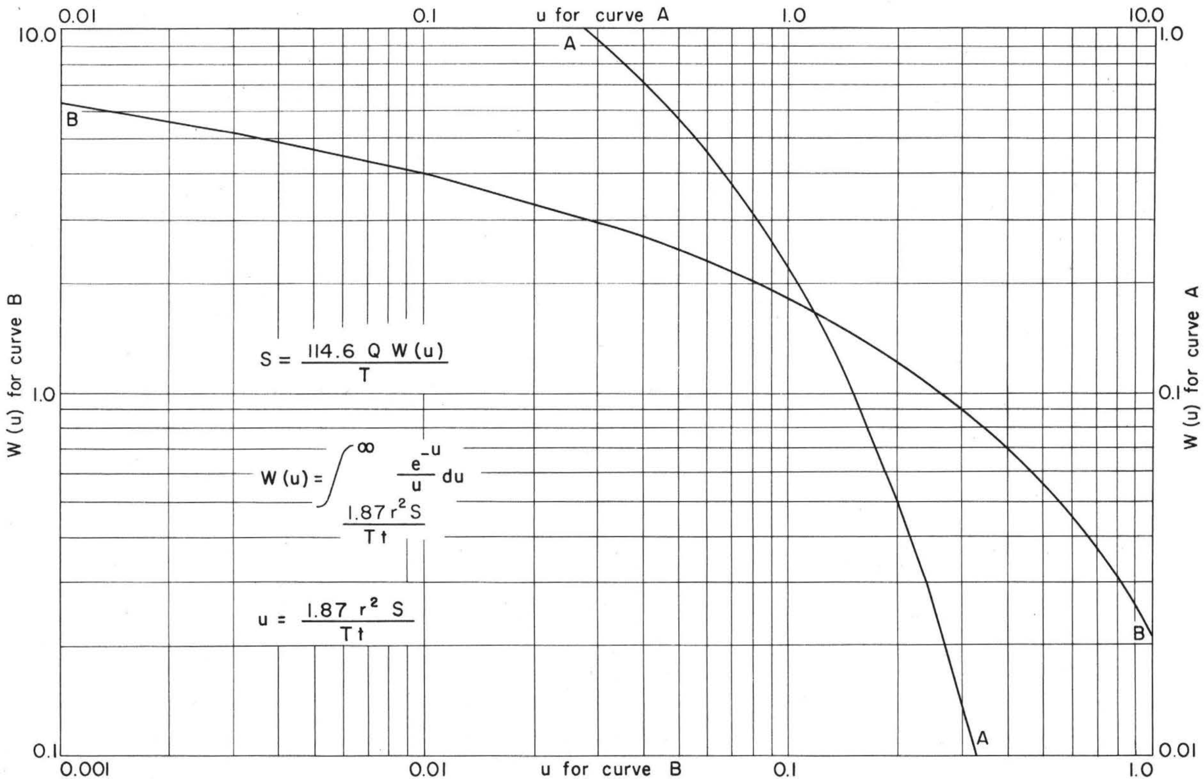


Figure 53. —Logarithmic graph of the well-function type curve.

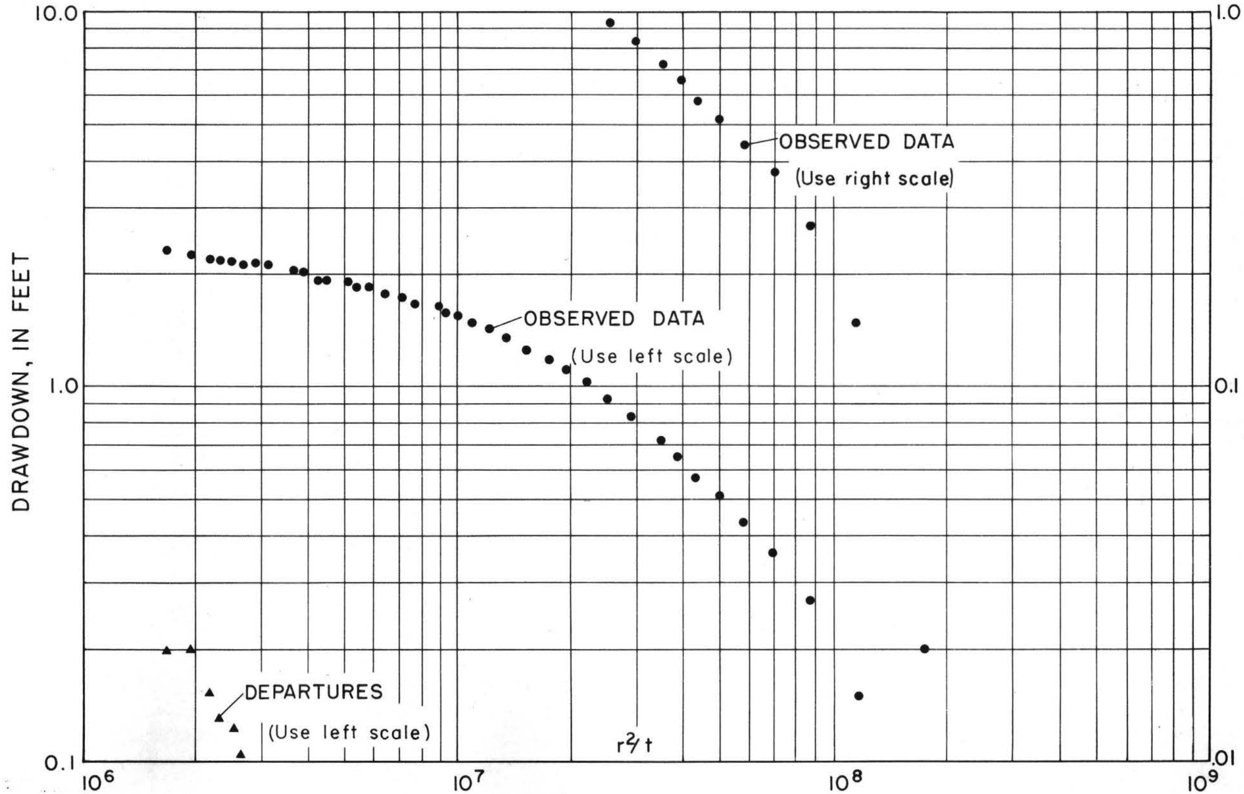


Figure 54.—Logarithmic graph of drawdown of water level in well Ve-514 near Erath, Vermilion Parish.

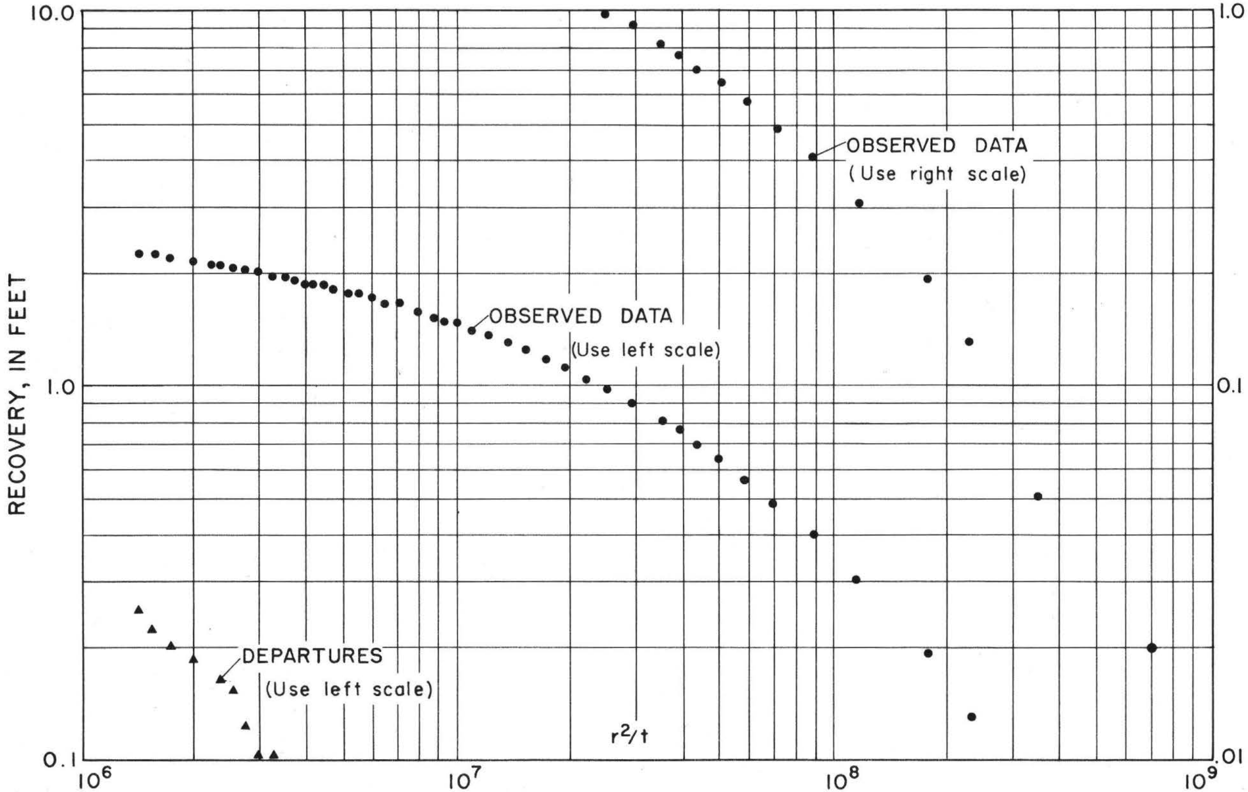


Figure 55.—Logarithmic graph of recovery of water level in well Ve-514 near Erath, Vermilion Parish.

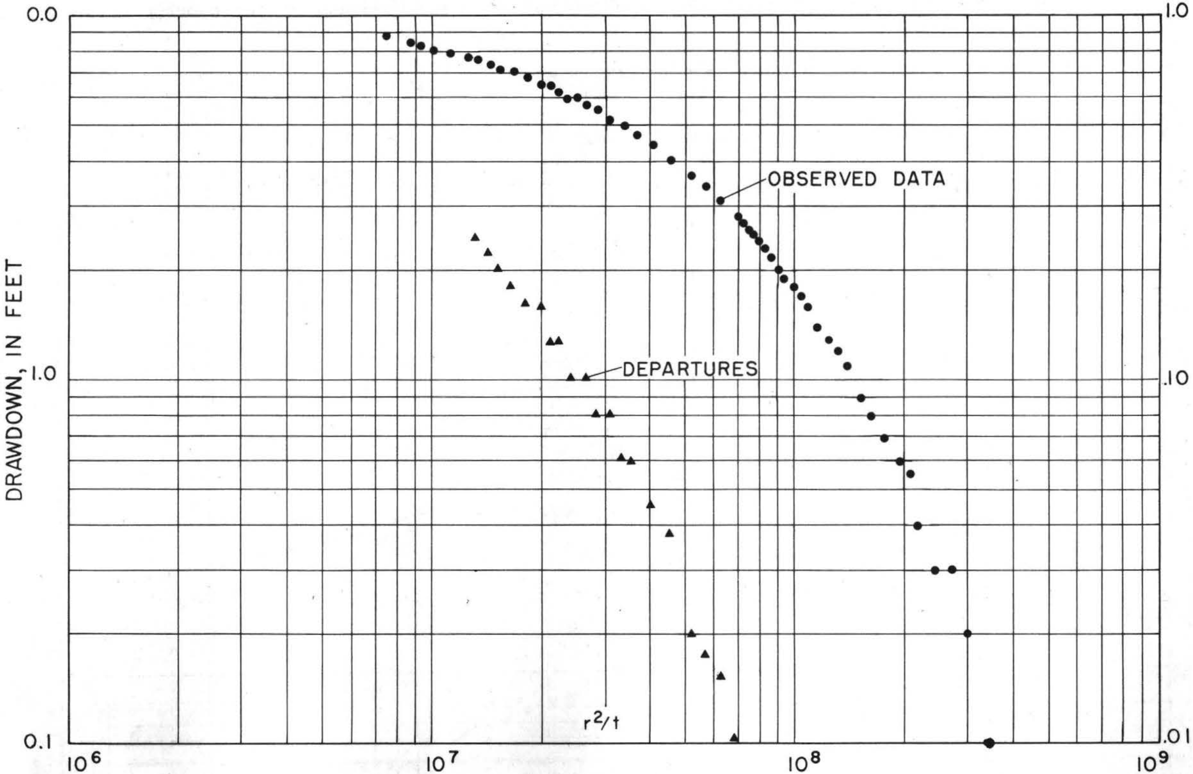


Figure 56.—Logarithmic graph of drawdown of water level in well Ve-517 near Erath, Vermilion Parish.

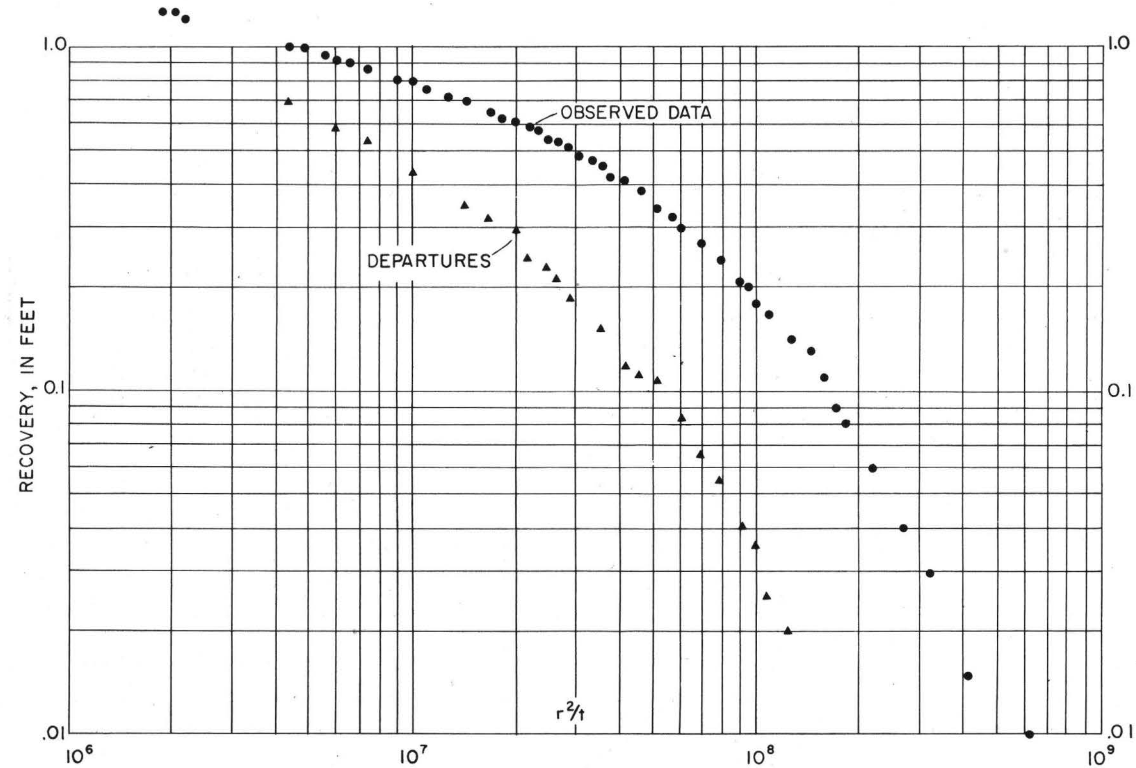


Figure 57.—Logarithmic graph of recovery of water level in well Ve-517 near Erath, Vermilion Parish.

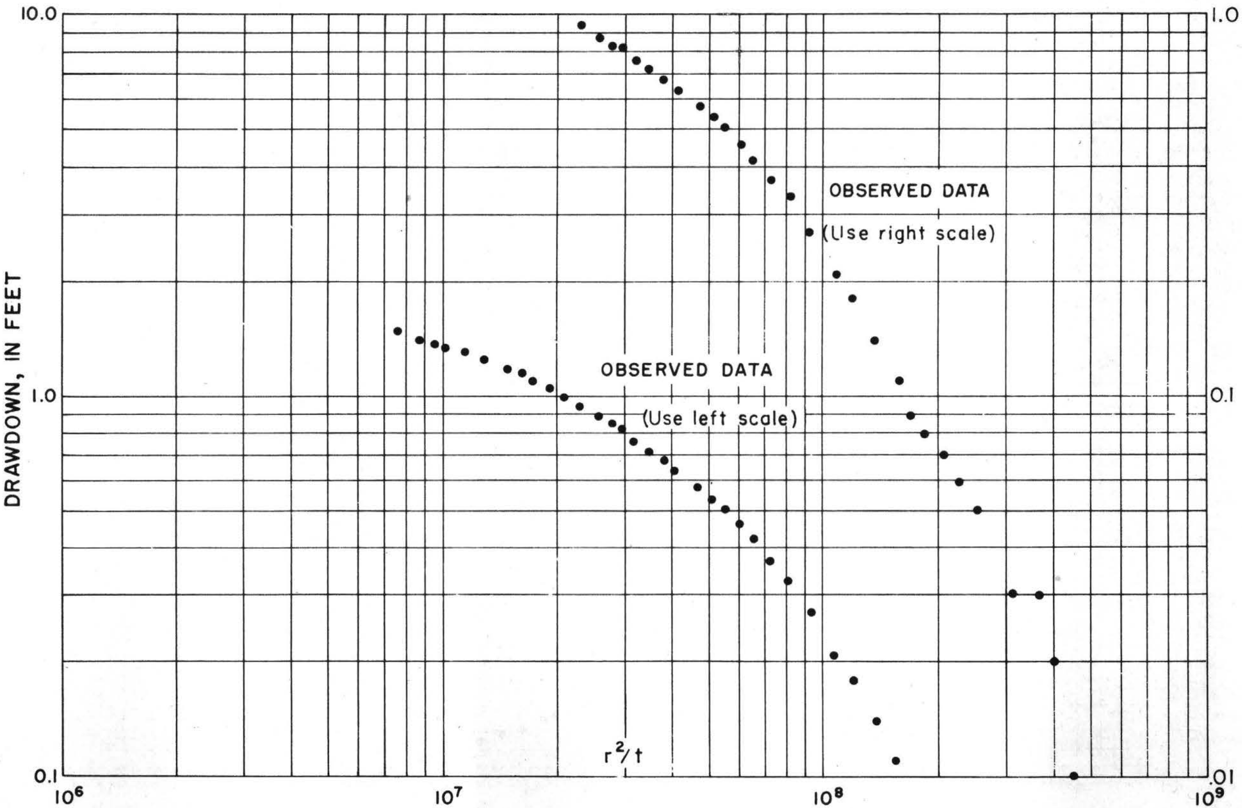


Figure 58.—Logarithmic graph of drawdown of water level in well Ve-524 near Erath, Vermilion Parish.

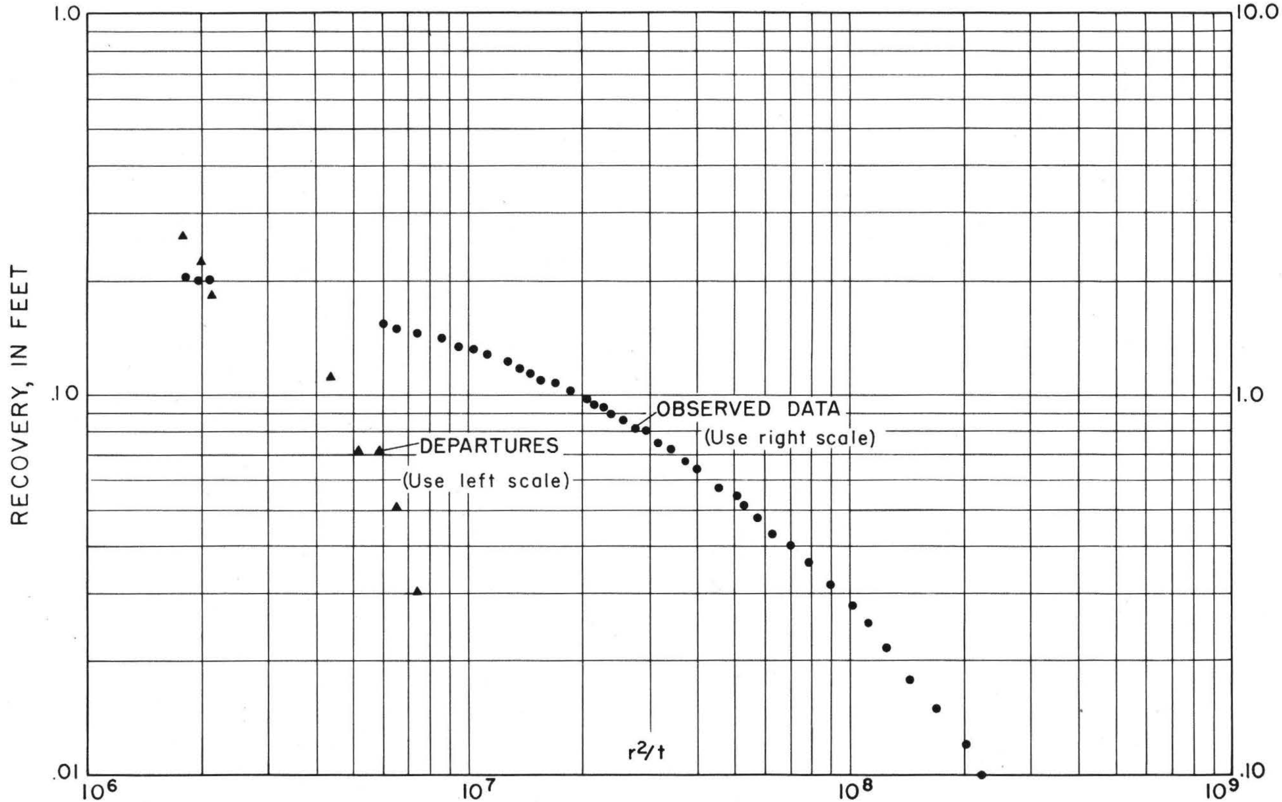


Figure 59.—Logarithmic graph of recovery of water level in well Ve-524 near Erath, Vermilion Parish.

area. This dispersion of arcs and their near intersections is the result of a gradual thinning of the clay above the aquifer, causing the behavior of water in the real aquifer to deviate from that in a vertically bounded aquifer such as is assumed in using the method of images.

In general, the results of this test indicate that a recharging image is situated about a mile southwest of the plant site. By construction, one point on the hydraulic boundary is located midway between the test well and the image-well location, or about 2,500 feet southwest of well Ve-134. Thus, the aquifer which is tapped by all wells used in this test receives water from a deeper one indirectly, probably by thinning of the clay bed between them. Because the deeper aquifer contains water of poor quality (the chloride content of water near the bottom exceeds 500 ppm and the hardness exceeds 300 ppm), the location and hydraulic nature of the interconnection southwest of the recycling plant is of great importance to ground-water users in the area east of the Vermilion River.

The results of the pumping test indicate a recharging boundary, and this is in agreement with the geologic conditions of the area. Examination of drillers' logs and electric logs of oil and water wells within and in the vicinity of the plant area shows a bed of clay or shale from a depth of 270 to 316 feet at the location of well Ve-134. This shale bed separates the aquifer tapped by the well from an underlying aquifer about 150 feet thick. However, to the south and southwest this shale bed does not exist, and the two sands form a single aquifer having a much greater transmissibility, which affects the hydraulic conditions in the same manner as a recharging boundary.

Another application of the image theory as described by Ferris was made during a pumping test conducted in the area north of Abbeville in order to determine the extent of interconnection between the Vermilion River and the aquifer. Six observation wells at an average depth of about 80 feet were installed at this site and arrangements were made to pump a rice-irrigation well in the center of the observation wells at an average rate of about 1,500 gpm. Owing to pump failure the drawdown phase of the test was limited to a period of about 1,300 minutes. The recovery phase lasted for a total of 1,900 minutes. The results of this test were analyzed by J. G. Ferris. He stated (October 23, 1951, written communication) "that the locus of the image lies across the Vermilion River, as would be expected if interconnection occurs between the aquifer and the stream." Mr. Ferris's interpretation of the data indicates that the coefficient of transmissibility of the aquifer in this area is 900 mgd per foot and the storage coefficient has a range of 2.3 to 4.0×10^{-3}.

Geometric analysis of piezometric maps and the theory of the line source of recharge.— The chemical plants and refineries west of Lake Charles in Calcasieu Parish pump large quantities of ground water throughout the year. Pumpage during the winter of 1950–51 averaged 40 mgd and the pumping was confined to an area about 5 miles in diameter. In addition to industrial withdrawals there was heavy pumping during the summer and fall for rice irrigation in the adjoining areas. During the month of September pumping for irrigation generally ceases, and a recovery of water levels owing to reduced pumping begins. By late spring the residual drawdowns in the vicinity of Lake Charles are due primarily to industrial pumping. As the water levels at this time are virtually in a steady state, the configuration of the piezometric surface is due almost solely to geologic and hydrologic conditions.

Contours of the piezometric surface near a well field of small diameter form concentric circles if the aquifer is of large extent and if there are no geologic discontinuities. If there is recharge to the aquifer in the vicinity of the well field, the centers of the circles formed by the contours do not lie at the locus of pumping but rather to one side of it, in a direction opposite to the direction to the recharge area. A source of influent seepage nearby or a zone of higher transmissibility in the aquifer will produce this effect.

A detailed water-level contour map of the Lake Charles area for the spring of 1951 is shown as plate 34. There is a noticeable shift of the circular contours to the southeast, indicating the presence of an area of ground-water recharge a short distance northwest of Lake Charles.

Considerable data on the theory of a line source of recharge have been compiled by Muskat (1937, p. 175–181). This theory, applied on plate 34, assumes a completely adequate and penetrating line of recharge in the vicinity of the locus of pumping. The effective line of recharge is located an unknown distance from the center of the pumped area. The rate of recharge is the same as the rate of withdrawal. A configuration of contours identical to that on the pumped side of the line of recharge is obtained in the recharge area by assuming the recharge area to be at an image point located at twice the distance from the center of the pumped area to the line of recharge. The loci of the points describing the theoretical contours in polar coordinates are given by the equation:

$$h = \frac{0.366\,Q}{T} \log \frac{r_1}{r_2}$$

in which h = elevation of the contour, in feet below the initial surface;

Q = quantity being pumped, in gallons per day;

T = transmissibility of the aquifer, in gallons per day per foot;

r_1 = distance from the center of pumping, in feet;

and r_2 = distance from the hypothetical recharging well, in feet.

D' = distance of the center of pumping and recharging from the line of recharge;

and D = distance from the line of recharge to the center of the circular contours.

The centers of the circles would be at a distance D from the line of recharge equal to:

$$D = D' \left[\frac{1 + e^{\frac{4\pi h T}{Q}}}{1 - e^{\frac{4\pi h T}{Q}}} \right]$$

The flow lines, actual and hypothetical, form nearly perfect circles with centers on the line of recharge. The circles intersect both the actual center of pumping and the image of the center of pumping. Using this method, it is possible to match the actual contours to hypothetical contours, to calculate the transmissibility of the aquifer, and to locate the effective line of recharge.

The first step in this procedure is to locate the centers of the observed contours of equal hydrodynamic pressure. The areas of these nearly perfect circles should be found by a planimeter. The radii of the equivalent circles are then determined by the equation:

$$R = \sqrt{\frac{A}{\pi}}$$

in which A = planimetered area of actual circle;

and R = radius of theoretical circle.

Circles of these radii are drawn on a piece of transparent drafting paper. The transcribed circles are placed over the map, obtaining the best matching possible, and the centers are marked on the map. It should be noted that these centers fall on a straight line, D–D'. The contours then may be redrawn with the above radii.

The next step is to locate the line of recharge. One of the constructed contours is chosen, and a radial line is drawn from the center to the circumference in any direction except along *D–D'*. A perpendicular to this line is erected tangent to the circle. Along this tangent line a circle is located, by trial and error, that has a center on the tangent line and a circumference that goes through both the center of pumping and the point of tangency. The arc of the circle is continued until it intersects the projection of the line *D–D'*. As stated above, the line *D–D'* is drawn so that it goes, as nearly as possible, through all centers of circles describing the constructed contours. The arc intersects of the inscribed circles with the projection of the line of centers *D–D'* forms the locus of the image well field; and the perpendicular bisector of the line joining the centers of the real and image well fields is the effective line of recharge.

The distance to and location of the effective line of recharge to an aquifer with respect to a well field tapping it are factors that combine to determine the depth and shape of the cone of pressure decline in the aquifer that results from a withdrawal of ground water at a specified rate. The transmissibility and storage coefficients are the other principal factors.

As indicated before, the hydraulic effect caused by an adequate line source of ground-water recharge may also result from a pronounced thickening of a homogeneous aquifer or a marked increase in its permeability within the area influenced by withdrawals. The line source of recharge apparent on plate 34 is not evident at the land surface, but it may be the result of a rapid thickening of the aquifer—indicated by thinning of the surface clay (pl. 31)—or of interconnection with aquifers of the Evangeline reservoir as a result of regional faulting.

Whatever the cause of the recharging boundary, it is very important to the ground-water supply of central Calcasieu Parish. Development of additional large supplies from the Chicot reservoir is favored by conditions in the crosshatched area north of Lake Charles, shown as a "high" on plate 34. In future developments it would not be advisable, however, to place major well fields where they would intercept flow between existing well fields and the line of recharge.

MOVEMENT OF THE GROUND WATER

DIRECTIONS

Ground water always moves in the direction of the hydraulic gradient. Therefore, the best means of determining the direction of movement is to prepare a water-level contour, or piezometric,

387601 O -56 - 18

map. The direction of the hydraulic gradient is derived from the piezometric map by drawing lines perpendicular to the contours, from high to low head, as shown on plate 13. As indicated on the map, the path from a given source to a given point of withdrawal may be circuitous, but it is always down the gradient.

In 1903, and perhaps until 1941, ground water in the Chicot reservoir west of Bayou Nezpique (between Jefferson Davis and Acadia Parishes) moved southward toward natural outlets beneath the Gulf of Mexico. A cone of depression in the piezometric surface had been formed in 1903 by withdrawals from some 50 irrigation wells in northwestern Vermilion Parish, but to the south, near White Lake in Vermilion Parish, the gulfward slope of the surface and the movement of the water were reestablished. The effect of the Vermilion River as a line of escape is apparent on plate 13, and ground water moved toward it from the west, north, and east. North of the Vermilion River basin the effect of the Atchafalaya River and the Atchafalaya reservoir upon the direction of flow in the Chicot reservoir is apparent. The direction of ground-water flow was almost parallel to the Atchafalaya River, indicating that a line or point of escape lay beneath Grand Lake, in St. Martin or Iberia Parishes, or perhaps farther north.

The dominant direction of movement in 1903 was gulfward; and this direction probably prevailed for thousands of years before 1903.

By 1944 (see pls. 14, 16–29) two important changes in the direction of ground-water flow had occurred. Along a line between Ville Platte in Evangeline Parish and New Iberia in Iberia Parish the direction of flow had changed radically. Under native conditions the flow was southeastward across this line, whereas since 1944 it has been westward or southwestward. And across a line from the northern end of Calcasieu Lake in Cameron Parish to Abbeville in Vermilion Parish the direction of flow had reversed. Whereas flow across this line was gulfward in 1903 and for some time thereafter, by 1944 it had turned landward; and throughout most of the length of the line the flow has been approximately north-northwestward, directly up the dip of the beds. The direction of movement offshore is believed to be arcuate, water sweeping southward beneath the Atchafalaya River basin, passing southwestward beneath Atchafalaya, East Cote Blanche, West Cote Blanche, and Vermilion Bays, westward offshore from Marsh Island and the eastern coast of Vermilion Parish, and thence northward back across the shoreline. It is believed that movement from the Sabine Lake area has been negligible, for the reasons given on page 243.

Other notable changes in the direction of ground-water flow have occurred immediately east and west of Lake Charles in Calcasieu Parish, where movement is now almost at right angles to that of the native conditions. The water now moves toward the Lake Charles area from all directions, and therefore there is a neutral point at the center of that area, where there is no continued movement in any specific direction. The same condition exists in a broad, elongate area in the southern part of Jefferson Davis Parish, and in an elliptical area of comparable size that occupies parts of south-central Evangeline Parish, western St. Landry Parish, and northern Acadia Parish. A smaller circular area southeast of Abbeville in southeastern Vermilion Parish shows similar conditions.

There are, of course, a great many local features of ground-water movement that are of real significance, and some of these are discussed under "Recharge." There are seasonal reversals of flow that are related to pumping, and during the irrigating season it is likely that the pattern of flow in the Chicot reservoir is extremely complicated, with local vortexes about each of the pumped wells or groups of wells

RATES OF GROUND-WATER FLOW

The rate of ground-water flow is directly proportional to the hydraulic gradient, other things being constant. It can be assumed that the flow is laminar, except in the immediate vicinity of pumping wells. Interpretation of piezometric maps in terms of rates of ground-water flow is possible, if the transmissibility (the product of permeability and thickness) of the aquifer is known.

A detailed map showing the cumulative thickness of the aquifer throughout the project area would be necessary for accurate over-all analysis of piezometric maps in terms of rate of ground-water flow. Such a map is in preparation but could not be completed in time for use in this report. However, aquifer thickness in a peripheral belt about the project area has been determined, and the flow rates across its boundaries have been computed for the year 1946, using estimated figures for permeability and average annual hydraulic gradients derived from monthly piezometric maps. On the basis of pumping-test results and sample studies an average permeability of 1,500 Meinzer units was chosen as representative. The flow rates are shown on plate 30. The map shows velocity vectors, with numerical values of rate of movement in feet per day, as well as the quantity of water in gallons crossing the boundary in 1 day through a section of the aquifer

1 mile long perpendicular to and bisected by the velocity vector at its base.

On the basis of this map the relative contribution of underflow from each of the recharge areas has been calculated, and the rate of flow from areas in which the aquifer is known to contain salty water has been computed. The vector representing maximum observed velocity (vector no. 8) is not the one showing maximum quantity of daily flow (vector no. 36) because of a difference in aquifer thickness.

The maximum average annual rate of flow across the peripheral boundary shown on plate 30 is 0.95 foot per day (vector 8). The maximum average monthly rate of flow across the boundary was observed to be about 3 feet per day. Velocities southward, eastward, and westward into the area of withdrawal are generally 10 to 100 times greater than velocities northward from the gulf margin.

The rate of ground-water movement undergoes a sharp change across the line of transition from artesian conditions, which prevail throughout most of the irrigation area, to the area of water-table conditions in the recharge area at the outcrop. The change in slope of hydraulic gradients along a profile parallel to the direction of ground-water movement best illustrates this, and such a profile is shown on figure 60. As mentioned above, the rate of

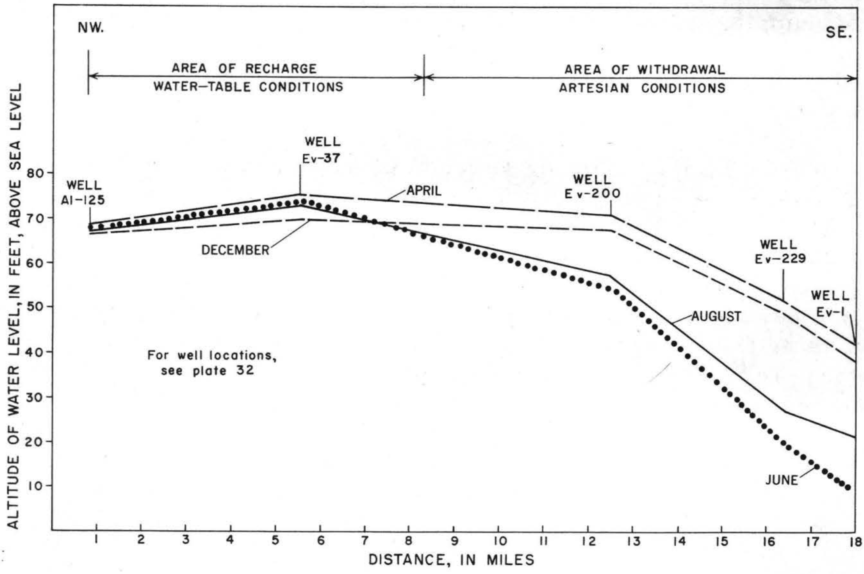


Figure 60. —Seasonal changes in the profile of the water level in the Chicot reservoir from the area of recharge to the area of withdrawal.

flow is proportional to the hydraulic gradient under uniform conditions; but under the same gradient the quantity of flow is proportional to aquifer thickness and permeability. As the aquifer thins rapidly northwestward along this profile and is perhaps less than half as thick at well Ev-37 as it is at well Ev-1, the volume of flow past well Ev-37 is far less than that past well Ev-1. Increments of flow between these wells are derived from ground-water storage (see "Hydraulic characteristics"). The withdrawal from storage resulting from a unit decline of water level in the water-table area (fig. 39) is perhaps 100 times as great as that caused by the same decline in the artesian area. The storage coefficient of a water-table aquifer is a large fraction of its porosity, but that of an artesian aquifer is believed to be a function of its compression and is very small. Therefore, the spread of the cone of pressure decline resulting from pumping in the artesian area is rapid until it reaches the zone of transition to water-table conditions. Each unit strip of water-table aquifer along the margin of the cone gives up some water from storage, as the cone spreads across it, and transmits the remainder of the required water from the adjacent unit strip of water-table aquifer up the gradient. Thus, during a given period of declining water level, the profile of the gradient flattens across the zone of transition from artesian to water-table conditions, and accordingly the rate of ground-water flow decreases up the gradient.

The series of profiles of the water level, figure 60, show that the rate of flow in the area southeast of well Ev-37 is everywhere most rapid during the summer (June profile) but that, during the latter part of the pumping season (August profile), the rate of change of the rate of flow in the zone of water-table transition is less than the rate of change of the rate of flow in the artesian area. This can be attributed to the damping effect of water-table storage on spread of the cone of depression. Rapid withdrawals from water-table storage occur during and immediately after the pumping season and continue at a slower rate into the winter. These withdrawals are restored slowly during the late winter and spring months, but gradients from the recharge area to the area of withdrawal never are erased, and ground-water flow from the water-table area to the artesian area is continuous.

The zone of transition from artesian to water-table conditions is therefore a zone of maximum flow-velocity contrast. Movement is more rapid in the part of the area under artesian conditions. It is evident that the zone of transition from artesian to water-table conditions moves toward the area of pumping as the cone of water-level depression goes down. That is, water in a strip of aquifer along the northwestern side of the project area is confined by the overlying clay beds during the winter and spring months, when water levels are high, and is not confined during the summer and fall, when the water level is below the base of the confining clay beds. The effect of this cyclic transition is shown on the hydrograph for well Ev-37 (fig. 61). It is especially

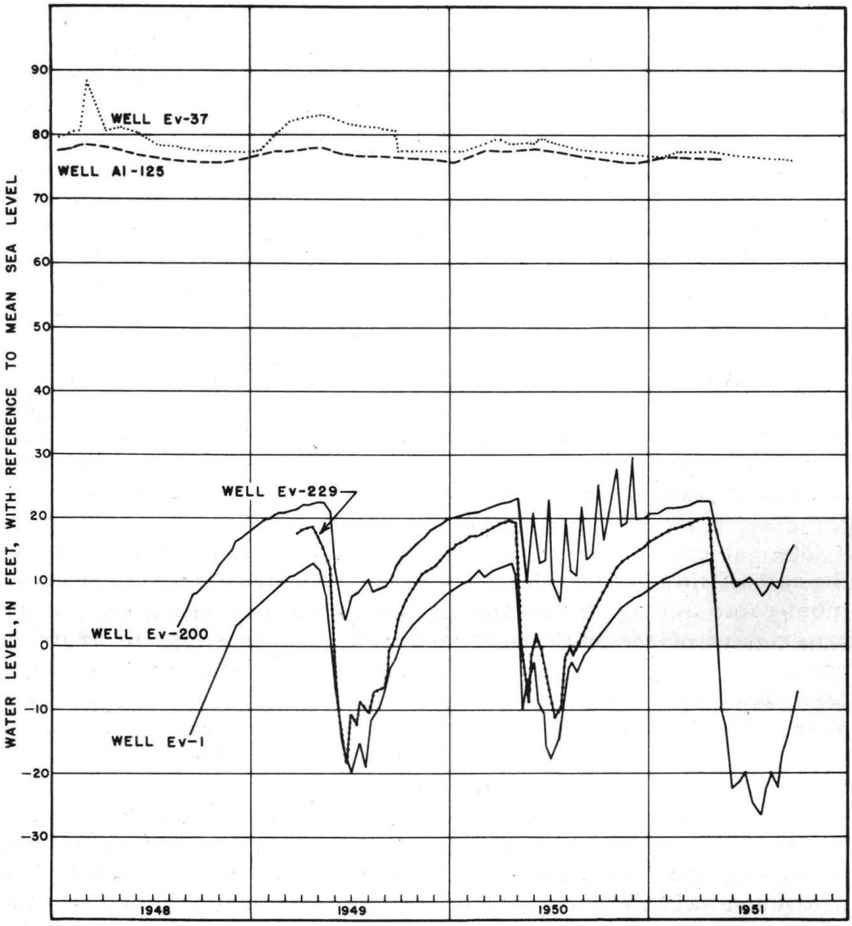


Figure 61. —Hydrographs showing the contrast between the water-level fluctuations in wells in the water-table area and in the artesian area of the Chicot reservoir.

noticeable in September 1949. The water level in the well fell about 4 feet in less than 2 weeks, then stopped abruptly, and very little change in water level was noted during the next 5 months. This well is equipped with a continuous water-level recorder that gives a reliable record.

The nature of water-level fluctuations in the other wells used in preparation of the water-level profile (fig. 60) are shown on figure 61 which demonstrates graphically the marked difference in change of hydraulic head in the aquifer where it is under artesian and where it is under water-table conditions. As water levels are functions of hydraulic gradients, these graphs also show the general contrast in rates of ground-water flow under the two conditions in the project area.

Because of the lag in the spread of the cone of water-level decline into the water-table area and the "cushioning" effect of withdrawals from water-table storage, water levels in the outcrop area reach their lowest position, not at the time of heaviest pumping, but some months later, in the winter, when precipitation and streamflow are most conducive to replenishment of the ground-water supplies. This permits the most efficient operation of the Chicot ground-water reservoir.

DISCHARGE

Discharge of fresh ground water from the sand and gravel aquifers of the Chicot reservoir occurs both naturally and by induced methods. Induced discharge includes withdrawals from wells by pumping and by natural flow under artesian conditions. Natural discharge was important in the geologic past when ground water moved southward and eastward to the Vermilion and Atchafalaya Rivers, which then acted as lines of escape. The basis for this conclusion is the water-level contour map for the year 1903 (pl. 13) prepared on the basis of records compiled by Harris and Fuller (1904). This map shows the directions of ground-water flow and represents the approximate hydrodynamic balance of recharge and discharge of the aquifer before pumping began.

As a result of heavy withdrawals from wells the hydraulic gradients in the aquifer have now been reversed and the natural discharge is now periodic and small in volume. The Atchafalaya River now is providing recharge, as evidenced by the water-level contour maps (pls. 14, 16–29) which show a pronounced hydraulic gradient westward from the Atchafalaya River basin. The Vermilion River is now alternately influent and effluent, and there is evidence that this condition exists in parts of the Calcasieu River basin. (See fig. 44.)

Almost all discharge of ground water in the area occurred by natural processes before the introduction of large-capacity deep-well pumps, near the turn of the century. Induced discharge (pumping) has steadily increased, and in recent years it has constituted nearly all the discharge. In 1903 artesian flow from uncapped wells was common throughout much of the area. Now (1952) the only wells tapping the Chicot reservoir with sufficient artesian pressure to flow are along the gulf shoreline.

Until about 1890 irrigation-water supply was generally dependent upon the availability of stream water. With the development of the deep-well turbine pump and efficient drilling methods the acreage under irrigation by ground water in southwestern Louisiana increased rapidly. This is indicated by records (Harris and Fuller, 1904, p. 91) which show that, of 373,442 acres of rice harvested in 1902, 308,744 acres (83 percent) were flooded by water from streams and only 48,648 acres (13 percent) by well water; whereas, of 608,216 acres of rice grown in 1951, about 277,495 acres (about 46 percent) were irrigated by well water, 262,706 acres (about 43 percent) were irrigated by stream water, and 68,015 acres (about 11 percent) were irrigated by a combination of well and stream water. The map, plate 3, shows the distribution of the rice land flooded by ground water in 1951. Comparison of the total acreage records for 1902 and 1951 indicates that a large part of the growth of the rice industry in southwestern Louisiana has been dependent upon the availability of ground-water supplies for irrigating the rice.

The agricultural growth of the area was accompanied by development of related industries and increase in population. In addition, there was an expansion of industries related to petroleum after the discovery of oil in southwestern Louisiana and as a result of the development of Lake Charles as a port for seagoing vessels.

For the entire area of southwestern Louisiana, the average daily ground-water withdrawal for all purposes—agricultural, domestic, industrial, and municipal—has more than doubled during the past 6 years. This is indicated by the increase in ground-water requirements from about 377 mgd in 1946 to an average daily use of 793 million gallons in 1951, as shown in table 18. Based on these pumpage records the calculated average daily ground-water withdrawal from the Chicot reservoir for the 6-year period is about 539 million gallons, and it can be expected that the demand for ground water will continue to increase for the next several years to accompany industrial and agricultural development and expected municipal expansion.

IRRIGATION SUPPLIES

The methods used for estimating quantities of water pumped for irrigation necessarily are indirect because no water meters are in use to determine directly the quantity pumped. Early in this investigation it was decided that the most accurate method available for determining the pumpage was to calculate, for each of the farms having electrically operated well pumps, the yearly water requirement in acre-feet per acre. Wells using electric power constitute about 8 percent—about 105—of the 1,300 irrigation wells in the project area.

Periodic measurements of the quantity of water pumped by each key well were made by the trajectory method (J. F. Hostetter, unpublished report in files of U. S. Geol. Survey), and figures for the total kilowatt-hours of power consumed were furnished by the Gulf States Utilities Co. and the Central-Louisiana Electric Co. Using these data, the quantity of water pumped during the year was determined by the following formulas used by the Ground Water Branch of the U. S. Geological Survey in Arizona (Russell, 1934).

$$\text{Acre-feet} = \frac{1.98 \times Q \times \text{kwhr}}{24 \times \text{kw}}$$

in which 1.98 = acre-feet per day for 1 cfs;
Q = discharge in cubic feet per second;
kwhr = total kilowatt-hours used;
and kw = kilowatts used by the motor as computed by the following formula:

$$\text{kw} = \frac{3.6Kn}{t}$$

in which n = number of revolutions of the meter disk;
t = time in seconds for n revolutions;
and K = meter constant = $K_n \times K_r$ in which
K_n = watt-hour constant
K_r = register constant

The constants K_n and K_r for each meter were furnished by the electric-power companies and the factors t and n were determined when the discharge of the well was measured.

It was found that, during each year of the period 1946–51, the average total depth of water pumped onto the irrigated land by the approximately 100 wells for which records were obtained varied in a general way with rainfall. As shown in table 18, the total amount of ground water pumped onto the fields from these wells each irrigation season ranged from 1.3 to 1.8 acre-feet per acre during years of above-average rainfall, whereas during years of below-average rainfall the quantity of water pumped ranged from 2.3 to 2.7 acre-feet per acre. Thus, the average seasonal requirement of ground

Table 18.—*Ground-water use for irrigation, industrial, rural, and municipal supply, 1946–51*

	1946	1947	1948	1949	1950	1951
Total acreage irrigated	600,000	606,100	626,700	596,500	540,400	608,200
Acreage irrigated by ground water	240,000	263,000	255,600	254,500	232,100	277,500
Acre-feet of ground water pumped per acre based on sample area	1.3	1.6	2.3	1.5	1.8	2.7
Total amount used for rice irrigating, in million gallons	101,680	137,153	191,581	124,416	136,178	244,292
Total amount used for industrial purposes, in million gallons	17,267	18,241	21,928	23,838	24,738	25,500
Total amount used for rural supply purposes, in million gallons	11,000	11,000	11,000	11,000	11,000	11,000
Total amount used for municipal supply purposes, in million gallons	7,712	7,782	7,989	8,041	8,182	8,465
Total ground-water withdrawal during year:						
In million gallons	137,762	175,278	232,600	167,398	180,200	289,360
In acre-feet	422,806	534,878	713,873	513,763	553,053	888,045
Average daily withdrawal:						
In million gallons	377	477	636	458	494	793
In acre-feet	1,158	1,465	1,950	1,299	1,515	2,433

water for rice irrigation was about 1.9 acre-feet per acre during the period of study. Using this average seasonal water requirement as a basis, it is possible to estimate in a general way the pumpage as far back as records of the acreage irrigated by ground water are available.

Table 18 shows both the total ground-water withdrawal and the total pumpage for irrigation for each of the 6 years, 1946–51. Pumpage during the 1951 season was the greatest on record. This was due in large part to the relatively low and poorly distributed rainfall that occurred during the year. It is estimated that in 1951 about 749,000 acre-feet, or 244 billion gallons, of ground water was required to flood 277,500 acres of rice. In 1946, a year of above-average rainfall, about 312,000 acre-feet, or 100 billion gallons, of ground water was pumped to irrigate 240,000 acres.

INDUSTRIAL SUPPLIES

The growth of the area has resulted in a great increase in the rate of industrial ground-water withdrawal. The estimate of pumpage for industrial supply is based on reported and inferred capacities of pumps and their operating schedules. The principal industrial uses of ground water are in oil refining, gas recycling, manufacture of chemicals (principally soda ash and related compounds), synthetic rubber, and naval stores, and electric-power generating. A total of 110 industrial wells were operated in the project area by the larger industries in 1951. These are listed in table 22. Most of the plants operate 24 hours a day and the wells are pumped continuously, with an average yield per well of approximately 500 gpm. In 1951 the yearly pumpage for industrial use (table 18) in southwestern Louisiana is estimated to have been 78,000 acre-feet or about 25.5 billion gallons. On a daily basis this amounts to about 70 million gallons.

The demand for ground water for industrial purposes in southwestern Louisiana has been greatest in the Lake Charles industrial area, which may be defined as six townships in east-central Calcasieu Parish. The total withdrawal of ground water in this area for industrial purposes has increased from about 2 mgd in 1935 to about 60 mgd in 1951, an increase of about 3,000 percent. Records of withdrawal and resultant decline of water level are shown on figures 62 and 63.

For the entire area of southwestern Louisiana withdrawals of ground water for industrial supply have increased about 50 percent during the past 6 years. The total annual ground-water

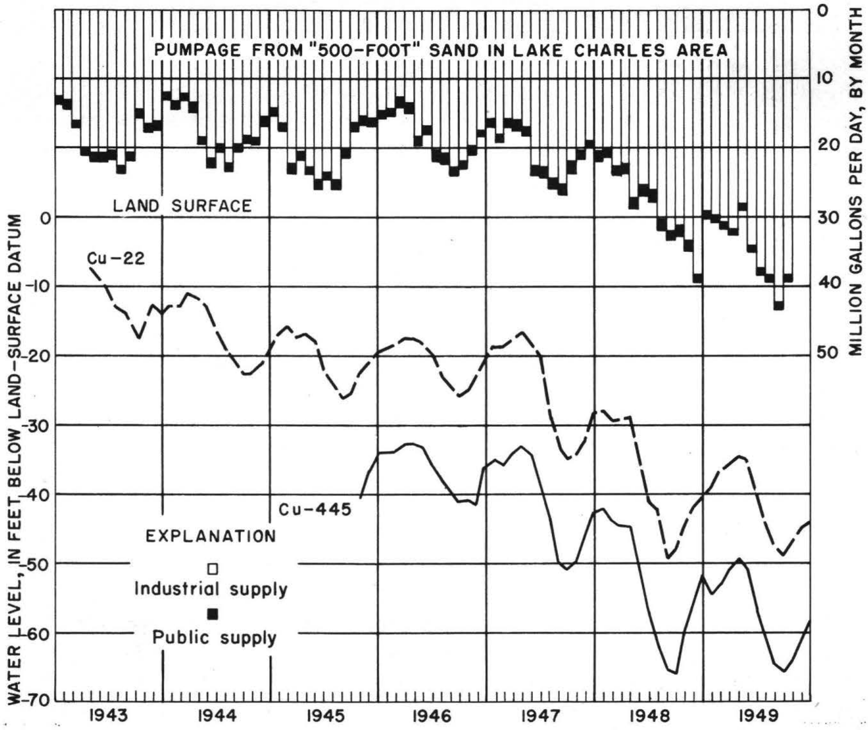


Figure 62. —Graphs showing the relation of pumpage from the "500-foot" sand to water levels in wells in the Lake Charles area.

requirement for industrial use has increased from 17 billion gallons in 1946 to 25.5 billion gallons in 1951, as shown in table 18.

PUBLIC SUPPLIES

With the exception of the town of St. Martinville, whose water supply is obtained from Bayou Teche, all municipalities in southwestern Louisiana are dependent upon wells which tap aquifers of the Evangeline reservoir of Pliocene age or the Chicot reservoir of Pleistocene age. An average of about 21 mgd of ground water is used by 46 municipalities in southwestern Louisiana. Table 19 lists these municipalities, their daily water requirement, and their storage facilities.

Of the municipalities, Lake Charles ranks first in the amount of ground water pumped, with an average daily requirement of about 3.5 million gallons in 1951. The city of Lafayette is second with a daily requirement of about 2.5 million gallons in the same

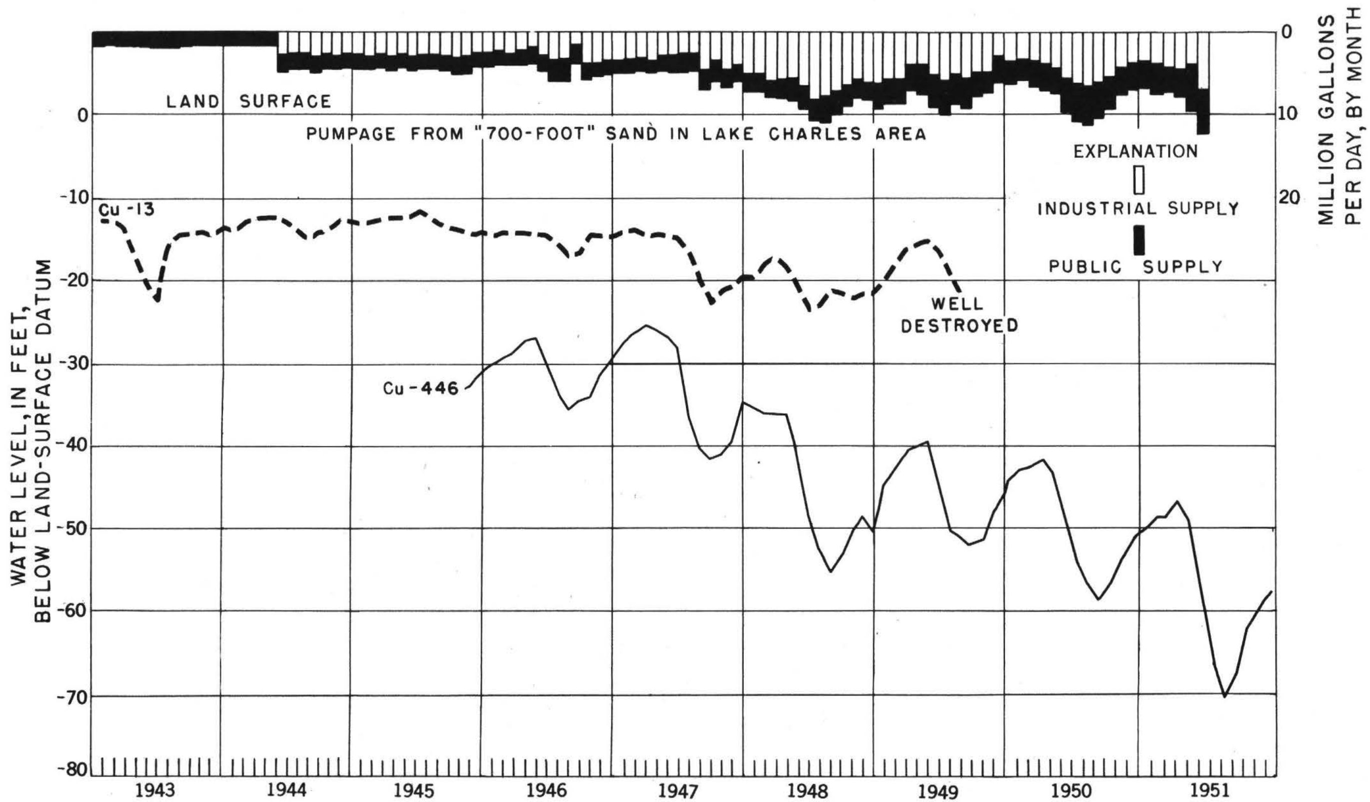


Figure 63.—Graphs showing the relation of pumpage from the "700-foot" sand to water levels in wells in the Lake Charles area.

Table 19.—*Public water supplies obtained from ground water*

Municipality	Population (1950)	Average daily pumpage (gallons)	Storage	
			Ground (gallons)	Elevated (gallons)
Acadia Parish				
Church Point	2,897	150,000	125,000	50,000
Crowley	12,784	1,200,000	1,000,000	165,000
Iota	1,162	75,000	....	75,000
Rayne	6,485	750,000	300,000	50,000
Allen Parish				
Elizabeth	1,113	500,000	100,000	100,000
Kinder	2,003	75,000	....	50,000
Oakdale	5,598	200,000	212,000	50,000
Oberlin	1,544	100,000	50,000	25,000
Beauregard Parish				
De Ridder	5,799	750,000	225,000	....
Merryville	1,383	50,000	....	21,500
Calcasieu Parish				
De Quincy	3,837	400,000	200,000	75,000
Lake Charles	41,272	3,500,000	1,000,000	500,000
Maplewood	2,671	100,000	....	100,000
Sulphur	5,996	500,000	170,000	65,000
Vinton	2,597	250,000	250,000	....
Westlake	1,871	100,000	....	20,000
Cameron Parish				
Cameron	....	24,000	120	....
Evangeline Parish				
Basile	1,572	180,000	....	25,000
Mamou	2,254	75,000	15,000	35,000
Ville Platte	6,635	280,000	200,000	80,000
Iberia Parish				
Jeanerette	4,692	440,000	300,000	100,000
Jefferson Island	....	45,000	....	20,000
Loreauville	478	25,000	....	20,000
New Iberia	16,467	1,200,000	500,000	....
Weeks Island	1,499	105,000	30,000	30,000
Jefferson Davis Parish				
Elton	1,434	70,000	52,000	30,000
Jennings	9,663	1,000,000	90,000	300,000
Lake Arthur	2,849	100,000	....	50,000
Welsh	2,416	175,000	100,000	50,000

Table 19.—*Public water supplies obtained from ground water*—Continued

Municipality	Population (1950)	Average daily pumpage (gallons)	Storage	
			Ground (gallons)	Elevated (gallons)
Lafayette Parish				
Broussard	1,237	50,000	30,000	50,000
Carencro	1,587	80,000	....	55,000
Lafayette	33,541	2,500,000	1,000,000	500,000
St. Landry Parish				
Eunice	8,184	500,000	208,000	75,000
Krotz Springs	866	....	....	....
Melville	1,901	275,000	125,000	50,000
Opelousas	11,659	1,750,000	310,300	250,000
Port Barre	1,066	35,000	35,000	50,000
Sunset	1,080	500,000	....	50,000
Washington	1,291	100,000	....	55,000
St. Martin Parish				
Arnaudville	872	62,000	35,000	45,000
Breaux Bridge	2,492	100,000	....	75,000
Vermilion Parish				
Abbeville	9,338	1,750,000	165,000	85,000
Delcambre	1,463	105,000	75,000	50,000
Erath	1,514	210,000	30,000	50,000
Gueydan	2,041	200,000	....	60,000
Kaplan	4,562	500,000	50,000	50,000

year. It is expected that the demand for ground water as a source of public water supply will increase in future years along with industrial development and agricultural expansion. A summary of well-construction data and well ownership is presented in table 21 which lists the public-supply wells in southwestern Louisiana. As shown by this table, the wells range from $2\frac{1}{2}$ to 18 inches in diameter and have yields ranging from 80 to about 4,000 gpm.

RURAL SUPPLIES

As shown by the census taken in 1950, the population of the rural part of the project area not supplied by municipal facilities was 243,352. The quantity of water consumed in these areas is based on an estimated per capita use of 125 gpd. This allows for gardening, stock supply, use by small businesses, and other uses. It is reasonable to assume that essentially all the water required for rural supply is obtained from wells because of the availability and easy accessibility of a potable ground-water supply in this area. Thus, the ground water pumped for rural supply is estimated to have been about 11 billion gallons in 1950, or an average daily use of about 30 million gallons. It seems practicable and is considered safe (in view of the relatively small change in rural population in the past 6 years) to assign this pumpage figure for rural use to each of the 6 years 1946–51.

RETURN OF GROUND WATER

The total quantity of ground water pumped for all purposes in this area may be assumed to be removed permanently from the aquifers. Because of the methods used in rice culture and the presence of a thick, impervious clay hardpan underlying the rice-fields, very little water used for rice irrigation seeps into the ground and returns to the aquifers (see "Surface-water resources"). Nearly all the irrigation water is drained into the streams, escapes into the air by evaporation or transpiration, or is carried away in the harvested crop. Water used for rural and municipal supply is disposed of by the users into a network of drainage canals or ditches which, in turn, discharge the water into streams which flow to the Gulf of Mexico. A large part of the ground water used by industries is lost in processing or is discharged as waste water into the coastal streams.

There is periodic influent seepage from some of the coastal streams, and the water so recharged may include small quantities of used ground water. However, this amount is probably negligible and is not considered in the over-all computation of ground-water use.

EFFECT OF WITHDRAWALS

Withdrawals of ground water in southwestern Louisiana cause a widespread seasonal fluctuation of water levels in wells, largely because pumpage for irrigation from April through September constitutes the bulk of the withdrawal. The rate of withdrawal and length of the pumping season are dependent to a large degree upon the distribution and intensity of rainfall, but in general, the maximum declines in water level and about 90 percent of the total annual withdrawal occur during this period.

The effects of ground-water withdrawals upon water levels have been serious in some parts of the area but hardly noticeable in others (see figs. 39, 46). The most noticeable effects of the water-level decline have been the decrease in the yields of wells and the increase in pumping cost. It has been necessary to install larger engines on many pumps, and a number of wells have had to be replaced because the upper, or "pit," casings did not extend deep enough to permit the pumps to be lowered. (See fig. 71.)

Another important effect of water-level decline is the reversal of the direction of ground-water flow in coastal areas. This may result in salt-water encroachment from the gulfward margin and influent seepage from streams that are periodically intruded by sea water. As the water levels in an aquifer continue to decline in an area of heavy pumping, the cone of depression eventually reaches areas in which the aquifer contains salty water, encroachment begins, and salt-water contamination results. This condition is known to occur in several parts of southwestern Louisiana (p. 284–293), although hydraulic gradients are small and movement generally slow—no more than about 2 to 20 feet per year.

In contrast to the general seasonal decline of water levels each year because of induced discharge, there is a corresponding seasonal rise of water levels due to cessation of pumping and to recharge. The fluctuations of the water levels are graphically shown by the hydrographs (fig. 46) for observation wells Ac-40, JD-23, and Ve-460 which are in areas of heavy pumping and reflect local conditions. (See pl. 32 for locations.) As indicated by these graphs the water levels in wells in the vicinity of Crowley (Ac-40), Iowa Junction (JD-23), and Kaplan (Ve-460) declined to the lowest level on record in 1951 as a result of heavy withdrawals. The water levels in wells Ac-40 and JD-23 were about 10 feet below the previous low in 1948, and because of increased demands for ground water in an area that formerly depended upon surface-water sources, the water level in well Ve-460 declined about 8 feet below the previous recorded low which occurred in 1949.

The great increase in the demand for ground water in the Lake Charles area during the past 17 years has resulted in gradual declines of water levels in wells tapping the "500-foot" and "700-foot" sands in that area. This is indicated by the graphs (figs. 40 and 41) which show the relationship between pumpage from the "500-foot" and "700-foot" sands and water levels in wells in the Lake Charles area. Ground-water users should expect still greater water-level declines with continuing industrial and municipal expansion.

In the foregoing paragraphs the magnitude of water-level fluctuations has been discussed and illustrated for certain areas. These local effects reflect a regional composite effect which may result in a rise, in a decline, or in no net change in the average water level of an area over a selected period. To enable a better analysis of the conditions, graphs (fig. 51) were prepared showing the total annual pumpage and the weighted average water levels for the area calculated for the period of maximum recovery, usually in March or April. Weighted average water levels for the area were computed by planimetry of areas on the piezometric maps between adjacent contours, multiplying by the average of the altitudes of the two contours, totaling the products for successive contour intervals (algebraically), and dividing the sum by the total area contoured. The plotted points reflect conditions caused by total withdrawals during the preceding year and exemplify the direct relationship between pumpage and water levels. That there have been no large withdrawals from ground-water storage is shown by the weighted average water-level graph for the area based upon records for the artesian part of the Chicot reservoir (where all significant water-level declines have occurred). (See p. 217, table 17, fig. 60.) In the early spring in 1950 and 1951 the water levels showed a net rise (fig. 51), indicating that the total recharge was greater than the total discharge for the previous 12-month period, and the net gain remained in storage. When total annual recharge was less than annual discharge, as shown for the years 1946, 1947, 1948, and 1951, water was withdrawn from storage, and a net decline of water levels occurred.

The piezometric maps (pls. 14, 16–29) show for each year since 1944 the configuration of the artesian-pressure surface in the Chicot reservoir tapped by all rice-irrigation wells in southwestern Louisiana, at times of maximum recovery and maximum drawdown. To prepare these maps, water levels in 160 wells scattered through 12 parishes were measured at the time indicated on each map. The altitude of the measuring point above mean sea level previously had been established by spirit leveling. The depth to water in each well was subtracted from the altitude of the measuring point, and the difference, representing the altitude of the piezometric surface, was plotted on the map. Water-level contours then were drawn through points of equal elevation of the piezometric (pressure) surface. If the altitude of the land surface at a well is known, any well owner can determine, by using these maps, the approximate depth to the nonpumping water level in his well at the time the water-level measurements were made.

Comparison of the spring map (showing maximum recovery of water levels) with the map prepared from measurements made in the fall (showing maximum drawdown) indicates the amount of the decline in water levels throughout the area during the 6-month period of pumping for rice irrigation. These maps show a close relationship between water levels and pumpage, as evidenced by the map for

September 1951 (pl. 29), which was constructed for a period that followed the heaviest pumping of ground water on record. As shown by a comparison of this map with the one for March 1951 (pl. 28), the areas in which declines were most significant were central and southeastern Calcasieu Parish, western St. Landry Parish, southern Evangeline Parish, northern and southern Acadia Parish, and almost all of Jefferson Davis Parish. In these areas the water level declined 20 feet or more below mean sea level during the irrigating season.

In addition to their value in outlining areas of heavy pumping, these maps enable determination of the direction and rate of ground-water flow, if the hydraulic characteristics of the aquifer are known.

The area in which well owners noted the most critical decrease in the yields of their wells was in south-central Evangeline Parish. The discharge rate of one well about 2 miles northeast of Reddell decreased from 1,880 gpm on May 17, 1949, to 1,560 gpm on August 5, 1949, a decrease of 17 percent. This condition was reflected throughout the south-central part of the parish and can be attributed to close spacing of wells, which results in excessive mutual interference, especially as the permeability of the aquifer in this area is low—only about 900 gpd/ft^2—and it is relatively thin. (See pls. 2, 8.) However, well failures and decreased discharge rates were not confined to Evangeline Parish, although their effects were more critical there.

As the regional piezometric surface declines, the yields of wells decrease, unless the horsepower rating of the pump engines is increased. This was indicated in 1947 when records for 52 wells in Jefferson Davis Parish showed that the average yield per horsepower was 19 percent less in 1947 than in 1946, owing to lower water levels in the wells.

CHEMICAL QUALITY OF THE GROUND WATER

The chemical characteristics of ground water from the Chicot reservoir are described in detail in "Quality of water." Therefore, the following discussion is confined to interpretation of changes in hardness and chloride content areally with depth in the reservoir and with time. The effect of base-exchange reactions upon the hardness of water in the Chicot reservoir is noted, and reference is made to the increase of the dissolved-solids content of the water with distance from the areas of recharge. There are, no doubt, a number of other chemical changes in the water as it moves through the reservoir, but data to serve as a basis for describing them are not available, and their interpretation was not necessary in this investigation.

All fresh ground water in the Chicot reservoir is believed to have originated as rain or snow. Differences in its chemical quality noted in samples from wells are attributed largely to changes that have occurred since it entered the aquifers. It dissolved some gases, of course, and perhaps even soluble smoke particles, from the air in its descent. It is believed that analysis of the occurrence of ground water in southwestern Louisiana on the basis of its hardness and its chloride content provides valuable keys to its points of origin, its direction of movement, and the quality to be expected in the future in specific localities.

The quality of water in aquifers tapped by wells was determined by chemical analysis for those areas in which water wells exist. The quality of water—specifically, its chloride content and hardness—in aquifers not tapped by water wells, or at considerable distance from the nearest water well, was estimated by interpretation of the electric log of some conveniently located oil-test well, including those shown on the geologic cross sections *A–A'* and *B–B'* on plates 11 and 10. The method of interpretation has been described in detail by Jones and Buford (1951). It is based upon the relation between the dissolved-solids content of a water and its electrical conductance. As resistivity, the reciprocal of conductance, is the value conventionally expressed on electric logs, it should be noted that resistivity decreases as the dissolved-solids content increases. Water from a selected artesian aquifer of great areal extent (many hundreds of square miles) usually has a characteristic "family" of dissolved constituents, with a characteristic relative concentration of each.

HARDNESS

The hardness of water is due to the ions of calcium, magnesium, iron, aluminum, and other cations that combine with the fatty acids of soap to form an insoluble greasy precipitate; in effect, soap added to a hard water softens it by removing calcium, magnesium, and the other hardness formers from solution. When the water has been softened, the excess soap forms suds and cleanses by emulsifying oils and dirt.

Minerals containing calcium and iron, which are relatively soluble in the presence of dissolved carbon dioxide, are very common in the Pleistocene deposits of southwestern Louisiana. Minerals containing magnesium (these are also relatively soluble in the presence of dissolved carbon dioxide) are not abundant, and thus the magnesium content of ground water in the Chicot reservoir is never large, seldom being more than 30 ppm.

Water that enters the outcrop (the intake area) of the aquifers that comprise the Chicot reservoir dissolves carbon dioxide present in the soil zone and perhaps certain organic material. Pine-covered hills characterize the outcrop area, where soils are generally sandy. Where the reaction of water from wells in the outcrop area has been measured, the pH is commonly as low as 6.4, and the water is found to be somewhat corrosive.

Water with carbon dioxide in solution is very effective in dissolving calcium carbonate and siderite (iron carbonate), and during the geologic past these minerals apparently have been removed almost entirely from the zone of saturation below the water table in the recharge area. Evidence of this is the low dissolved-solids content of the ground water in the recharge area. Soluble minerals, if present, surely would be dissolved, and it can be assumed that the water is essentially in equilibrium with its environment.

In accordance with the hydraulic gradient in the Chicot reservoir, the direction of ground-water movement was southward and southeastward for thousands of years. This condition was probably true until about 1940. At that time there occurred a reversal of the hydraulic gradient in the coastal part of the project area which has persisted to the present. But the effect of the reversal has not yet been evident in the distribution of hardness in the ground water.

With the slow movement of ground water the more soluble constituents of the aquifers in the recharge area have been picked up and carried down the gradient. The water has moved along flow lines evident from the piezometric map of 1903 (pl. 13). As the southeasternmost part of the project area is farthest from the area of recharge, the dissolved-solids content of ground water there should be a maximum. The map (pl. 35) showing the hardness of water from wells in southwestern Louisiana tapping the Chicot reservoir conforms very well to the above theory of hardness gradation. It also shows that there probably is local recharge in the upper basin of the Vermilion River, indicated by the presence of softer water.

The hardness-gradation pattern described above reflects movement of the ground water over distances ranging from less than a mile to 100 miles or more. It does not appear unreasonable to assume that water in the lower part of the reservoir, at maximum depths of 900 to 1,000 feet, might be somewhat harder than water from depths of 100 to 200 feet in the same reservoir, assuming that opportunity for vertical flow is restricted, because water in the shallow aquifers probably has traveled a much shorter distance from its point of origin or recharge. A dip of 10 feet per mile is representative of the beds at the bottom of the reservoir, and on this basis water at a depth of 1,000 feet theoretically has traveled 50 miles farther in the reservoir than water at a depth of 500 feet. Therefore, its opportunity to dissolve mineral matter has been much greater, and it should be harder. Data on the cross sections (pls. 10, 11) show that this is not true everywhere. Vertical movement through the full thickness of the reservoir is possible in the central part of the project area, and local recharge is known to occur in the southeastern part of the area.

Detailed chemical analyses of ground water from a wide range of depths at selected localities have not been made by the Geological Survey. Chemical analyses made by consulting chemists indicate that there is some basis for the above interpretation in the few localities for which data have been obtained. However, the hardness of the water does not increase in proportion to the dissolved-solids content. (See "Quality of water.") This indicates that there are natural zeolite minerals in the aquifer which cause softening by base exchange.

Changes in the hardness of water from individual wells tapping aquifers of the Chicot reservoir have been recorded, but they are almost invariably associated with changes in the chloride content and probably are related to salt-water encroachment. There is no reason why hardness encroachment could not occur as a result of the hydraulic gradient westward from the Bayou Teche region, and this may be a notable feature of ground-water developments in the eastern and southeastern parts of the project area in future years. It probably would be a slow process, as it is related to the rate of ground-water movement.

With reference to the areal distribution of hardness in water from wells tapping the Chicot ground-water reservoir, as shown on plate 35, it should be noted that wells in Beauregard and Allen Parishes generally yield water having a hardness ranging from 50 to 100 ppm; wells in southern Calcasieu Parish, southern Jefferson Davis Parish, most of Cameron Parish, northwestern Acadia Parish, central Evangeline Parish, Lafayette Parish, and northeastern Vermilion Parish yield water having a hardness ranging from 100 to 200 ppm; wells in north-central Vermilion Parish, central Iberia Parish, most of Acadia Parish, central St. Landry Parish, and western St. Martin Parish yield water having a hardness ranging from 200 to 300 ppm; and wells in northeastern St. Landry Parish, eastern Iberia Parish, northern

St. Mary Parish, and southern Vermilion Parish yield water having a hardness ranging from 300 to 400 ppm.

CHLORIDE

Chloride salts generally are very soluble in water and, unlike the hardness-causing compounds, generally are not removed from solution by natural processes in the aquifers. Once in solution, chloride in nature remains in solution unless there is a loss of solvent and the saturation point is exceeded. However, the salinity of ground water obtained from wells in southwestern Louisiana is far below the saturation point and in few localities is it too high to be tolerated by growing rice.

The origin of the Chicot reservoir has been described. A broad, thick mass of sand and gravel was deposited by braided streams that spread fanwise southward from an apex somewhere in north-central Louisiana. The fan of gravel and sand covered most of southwestern Louisiana, extending from eastern Calcasieu Parish to the Atchafalaya River. At least four times during this period of deposition the sea level rose and fell, and each time, as the gulf shoreline moved inland (northward), these gravelly deposits were filled with salty water. On the bottom of the shallow arm of the Gulf of Mexico thus formed were deposited mud, shells, and fine-grained sands. During the last advance of the shoreline northward, the deposits were formed that compose the basal part of the relatively impervious top stratum of the project area. Eventually the gulf margin retreated southward before the late Pleistocene deltas of the Mississippi and Red Rivers, whose natural-levee silts and back-swamp clay deposits form the upper 20 to 60 feet of the top stratum.

Thus, near the end of Pleistocene deposition in the project area the Chicot reservoir was filled with salty gulf water. Residual salty water was trapped in lenticular beds of sand and shells in the clay top stratum, the chloride content ranging up to about 2,000 ppm (Stanley and Maher, 1944, p. 41). Pre-Recent scour of coastal streams and of the Mississippi River to the east, during late Wisconsin glaciation when sea level declined, cut deeply into the clay top stratum and in many places removed it entirely. Erosion by coastal streams during this period was most effective near the gulf margin, and openings in the clay top stratum probably were formed there early in the erosional cycle. As these openings were at much lower altitude than the updip exposures of the gravelly aquifer formed by the braided-stream deposits, rain water entering their outcrops in the hills of south-central Louisiana moved gulfward to them and escaped. The saline water left in the Chicot reservoir at the end of Pleistocene deposition was flushed out gradually in this manner; and as the rise of sea level during Recent time caused filling of the pre-Recent scour trenches (the lines of ground-water escape mentioned above), the rate of flushing no doubt decreased. But at no time since the late Pleistocene has sea level been high enough to offset the natural fresh-water head in the reservoir, partly because of the favorable altitude of the recharge areas, partly because of abundant rainfall (recharge), and partly because the pressure head in the aquifer in the areas of escape is maintained partially by the fine-grained deposits of Recent age that fill the pre-Recent scour trenches and retard effluent seepage.

Areal distribution. —The areal distribution of chloride in water from wells tapping the Chicot ground-water reservoir is shown on plate 36. Comparison of this map with the hardness-distribution map (pl. 35) indicates that, in general, the areas in which wells yield water having a low chloride content are also areas in which the water has low hardness. The most notable exception to this rule occurs along the eastern margin of the project area, where the reverse is true.

Comparison of the chloride-distribution map with the piezometric maps (pls. 14, 16–29), especially those for the fall months, shows an unmistakable similarity of contour pattern and gradients. It is evident, therefore, that the chloride content of the water may be a more reliable key than hardness to interpretation of the origin and direction of movement of the ground water. Neither should be ignored, however, and it is likely that the best interpretations will require the use of both. The isochloride map is based upon chemical analyses of water from about 180 water wells, few of which are more than 400 feet deep. The chloride distribution shown, therefore, is affected by both dilution from local recharge and concentration due to the upward movement of salty water present beneath pumping wells (see p. 285).

Vertical distribution. —Late Pleistocene fresh-water flushing of the Chicot reservoir did not remove all the salty water in it, nor was the fresh-water flushing effective through the full depth and areal extent of the reservoir. The map showing the maximum depth of occurrence of fresh ground water in southwestern Louisiana (pl. 15) indicates the three-dimensional extent of fresh-water flushing; and the geologic cross sections (*A–A'* and *B–B'*, pls. 11 and 10) show the nature of the profile. For the purposes of the map and cross sections, water having more than 250 ppm of chloride in solution is considered salty. This is the maximum limit of of chloride content in drinking water for use on interstate carriers and public supplies in general as set up in drinking water standards by the U. S. Public Health Service (1946, p. 383).

Fresh-water aquifers were identified on electric logs of oil-test wells using the method described by Jones and Buford (1951), and interpretations based upon these identifications provided the basis for preparation of the map (pl. 15) showing the maximum depth of occurrence of fresh water in the project area. It is apparent from the map that salty water was flushed from the Chicot reservoir most effectively where its base occurs above a depth of about 1,000 feet (see pl. 8). Southward from the latitude of Jennings in Jefferson Davis Parish and Lafayette in Lafayette Parish there generally is salty water in the lower part of the reservoir, and in the gulf-marginal belt the structural and depositional characteristics of the reservoir influence greatly the occurrence of fresh water.

Fresh ground water generally is present to depths of about 700 to 1,000 feet in the broad area between Calcasieu Lake in Cameron Parish and the Atchafalaya River above Grand Lake, which forms the eastern boundary of St. Mary Parish. The eastern limit of the belt of deep fresh ground water follows a line trending southward from the head of Grand Lake to the eastern margin of East Cote Blanche Bay. It should be noted that this broad area coincides with the great lobe of thick gravelly deposits described before (p. 56).

The effect of salt-dome structures upon the depth of occurrence of fresh ground water in the project area is very important, although their effects are believed to be due solely to faulting. There is no evidence whatsoever that direct solution of salt from the "plugs" is a source of contamination. If such conditions do exist, they probably are of local extent and probably do not pose a serious threat to the regional ground-water supply.

Comparison of the map (pl. 15) showing the depth of occurrence of fresh water with the map (fig. 16) showing the locations of salt domes in southern Louisiana indicates that domes may cause the depth of occurrence to be either less than or greater than in the interdome areas. Faulting (described on p. 97) explains this surprising feature.

Two broad areas in which the small thickness of fresh ground water is not related to structural features are shown on plate 15. One of these is an elongate salt-water mound beneath the lower basin of the Vermilion River, and the other is a similar mound beneath the lower basin of the Atchafalaya River. Both these features are related to the late Pleistocene fluviatile deposition and erosion described in the Geology section of this report (p, 88, 89). Both areas were important ground-water outlets from the Chicot and Atchafalaya reservoirs in the geologic past, and today

(1952) they are very important inlets to these reservoirs under the reversed hydraulic gradients.

SALT-WATER ENCROACHMENT

CONNATE WATER

As indicated above, salty connate water (water deposited or entrapped concurrently with the sediment deposition) has been partially flushed from the Chicot reservoir. The distribution of water of high chloride content remaining in the reservoir is shown in section on plates 7, 10, and 11. The dotted-line salt-water "fronts" drawn on sections *A–A'* and *B–B'* are essentially profiles of equilibrium interfaces, the fresh-water component consisting of unit-density head plus artesian-pressure head (with reference to sea level) and the salt-water component consisting of density head only, the density being greater than unity.

In any system of two fluids of different density, there is a tendency for the interface between the fluids to become a horizontal plane. The principal factor opposing this, in the fresh-water—salt-water system in the aquifers of southwestern Louisiana, is the action of fresh ground water moving against and rising up the interface to a near-surface point of escape from the ground water reservoir. Where escape of fresh water is by way of slow upward seepage through confining beds over a widespread area, the salt-water interface is almost a horizontal plane. The downdip extent of fresh water, under this condition, is marked by a wedge-out against the upper confining bed, as shown in the Prairie aquifer (pl. 10) under the margin of the Gulf of Mexico.

In the southern part of southwestern Louisiana, where there appears to be no easy avenue of escape of water from the aquifer, the development of existing relations between fresh water and salt water has required thousands of years. During this long period it is likely that a steady artesian-pressure head has been applied gulfward from the outcrop and upward from the gulf marginal part of the aquifers. Had there been an easy local way of escape, it is likely that the existing pattern of fresh-water occurrence in the gulf marginal area would not have developed. The broad "front" of fresh ground water, forming an arc at least 120 miles in length along the coast, lies southward from the gulf shoreline; this fact is excellent evidence that no important local avenues into the Gulf of Mexico are present offshore. Conversely, no important local avenues of easy entry of gulf water appear to be present offshore.

It should be noted that the artesian-pressure head of fresh water in aquifers beneath the gulf shoreline was not more than a few feet above sea level in 1903, under virtually natural conditions (pl. 13). Today there is only one sector of the coastline beneath which aquifers of the Chicot reservoir do not have a pressure head above sea level and that is between Mud Lake and the mouth of the Mermentau River in Cameron Parish. Seasonal fluctuations of water level in wells along the coast perhaps are as much as 1.5 feet; and tidal fluctuations—which have occurred for thousands of years—range from 0.3 to 0.5 foot in wells on the coast. Therefore it is believed that, in spite of a reversal of the regional hydraulic gradient, the rate of ground-water flow northward is very slow—probably not more than 50 feet a year across the shoreline of eastern Cameron Parish and not more than 10 feet a year across most of the shoreline of Vermilion Parish.

Salty connate water is present in the lower part of the aquifers in the southern part of the project area, as shown on the geologic sections *A–A'* and *B–B'* (pls. 11 and 10). However, there are few water wells in the parts of the area where this condition exists, and flow lines in the aquifer in these areas probably are almost horizontal. Because the fresh-water—salt-water interface is almost horizontal in the massive aquifers, except where altered by structural discontinuities, and the dip of the aquifers is southward at a rate of about 8 to 10 feet per mile, the updip movement of the salt-water wedge tends to become negligible when the intersect of the top of the salt-water wedge with the base of the aquifer reaches a level equivalent to the maximum height of the interface downdip.

If the pressure head in the fresh-water zone is reduced by pumping, the salt-water interface rises in response to the density head of the salt water; but if the equilibrium level of the interface resulting is below the bottoms of wells tapping the fresh-water zone, then fresh water is skimmed off. But the presence of a salt-water mound or ridge beneath pumped wells poses a constant threat of encroachment and may require ingenious and perhaps costly methods of withdrawal to avoid further salt-water encroachment. Steady pumping at low rates from widely spaced wells might be one way of obtaining the required supply.

Figure 64 shows the cone of brackish or salty water formed in an aquifer beneath a pumped well partially penetrating the aquifer and demonstrates an ingenious device (Pennink, 1905, p. 179) used to detect the source of the highly saline water proved to be entering only through the bottom of the well screen. This is a condition that would be common if connate salt water were to encroach upon wells in the central part of the project area.

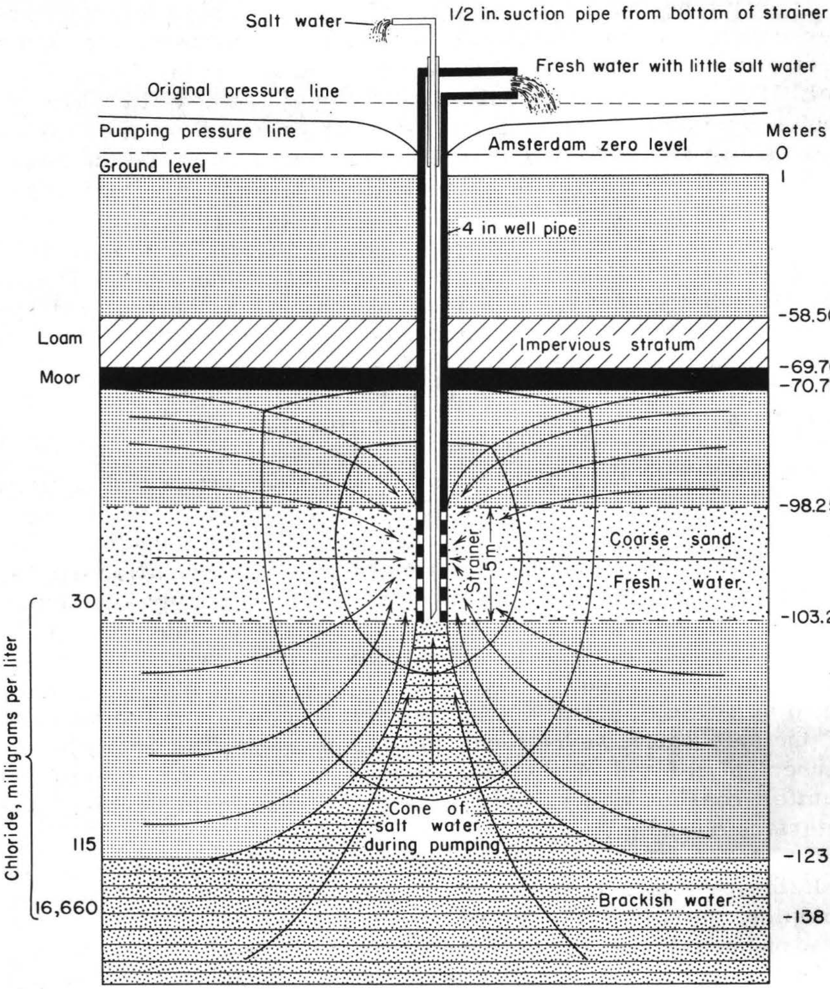


Figure 64.—Cone of salt water induced by pumping overlying fresh water.

As indicated on the geologic cross sections, aquifers below the Chicot reservoir in the southern part of the project area contain salty water. Without doubt, there is some movement of salty water upward into the basal aquifers of the Chicot reservoir under the pressure-head differentials resulting from widespread pumping from wells. However, this movement probably is very slow and of relatively little consequence. The salt-water aquifers beneath the Chicot reservoir are generally much less permeable, less continuous, and not nearly as thick as the aquifers in it. Furthermore, those aquifers immediately beneath the Chicot reservoir are either hydraulically connected with it where their beveled edges lie in contact with the overlying Pleistocene deposits updip and, like it, have been flushed of their salty water or they are not continuous updip (see pl. 11). Therefore the water in them is moving downdip under the same, or perhaps even less, natural hydraulic gradient than water in the aquifers of the Chicot reservoir, and salt-water movement from them therefore is believed to be of negligible consequence.

Structural discontinuities (principally faults) that allow salty water to escape from aquifers of the Evangeline reservoir into aquifers of the Chicot reservoir probably have been effective for thousands of years. Because the deeper aquifers of the Evangeline reservoir crop out and are recharged at higher altitudes and because their water is confined almost immediately after entry, the pressure head in them is greater than that in the Chicot reservoir, thereby creating conditions conducive to ground-water movement into aquifers of the Chicot reservoir wherever interconnections exist. This possible movement of salty water into the Chicot reservoir, from aquifers incompletely flushed of salty water during the past, could be facilitated also by heavy pumping and consequent lowered artesian-pressure head in the Chicot reservoir. However, no specific examples of salt-water encroachment of this type are known at the present time.

It appears likely that movement of salty connate water in dangerous quantity would have given evidence of its existence by this time (1952) if it is occurring; that there is no evidence of such movement at this time indicates that it is not likely to constitute a serious threat within the next few decades.

STREAMS SUBJECT TO SALT-WATER ENCROACHMENT

The occurrence and origin of salty water in the coastal streams of southwestern Louisiana are described in detail in "Surface-water resources" and "Quality of water." The geologic features of coastal southwestern Louisiana, with specific reference to river-channel deposition are described in "Geology." The hydrologic features of the lower Vermilion River basin are described in detail above, as the basin has characteristics favorable to recharge of the ground-water supply in its lower reaches through its channel walls and bottom.

If the Vermilion River were perennially a fresh-water stream, there would be no serious present problem of salt-water encroachment in the Chicot ground-water reservoir. However, in drought years since 1902, gulf water has been drawn into the river many miles inland from Vermilion Bay as a result of withdrawals in excess of streamflow. In the summer of 1951 the river was filled with salty water for a total of about 13 weeks through a channel distance of about 38 miles. This encroachment occurred during the period of heavy withdrawals from irrigation wells and maximum decline of ground-water levels. Because the Prairie formation of the Chicot reservoir is interconnected hydraulically with the Vermilion River throughout most of this distance, water recharged to the ground-water reservoir beneath this reach was salty during that period.

As a result of this condition, the water from several pumped wells along the course of the Vermilion River increased in salinity during the summer and fall of 1951. The salinity graphs shown on figure 65 indicate the relation between change of salinity of water in the Vermilion River at Banckers' Ferry and Perry (fig. 47), a few miles below Abbeville in Vermilion Parish, and change of salinity of water from well Ve–75 located about 4,000 feet west of the river 1 mile south of Perry. There is an evident timelag in salinity increase in the well, and at maximum values, the salinity of well water is seldom more than one-fourth as great as that of river water. The timelag under such conditions is explained by Muskat (1937, p. 470). On the basis of his discussion, theoretical lines of progress and the rate of movement of the fresh-water–salt-water interface are shown in a diagrammatic sketch on figure 66. That the salinity of water from the well is never as high as that of river water can be explained by means of the principles illustrated in figure 64. At least a part of the intake of the well is through the upper section of the screen, where the aquifer contains fresh water.

The effectiveness with which the Vermilion River has recharged the aquifer with salty water is shown on the geologic section, plate 10. Moderately salty water (probably having a chloride content less than 3,000 ppm except in the bottom 30 feet) fills the aquifer from its base (at a depth of about 600 feet) up to a depth of about 220 feet. Thus there is a salt-water mound or ridge about 380 feet high beneath the Vermilion River at Abbeville, from which salty water spreads outward in all directions (see pl. 15).

The variety of methods by which salt-water encroachment can occur under conditions found along the lower Vermilion River is shown graphically by profile sketches, figures 67–69. For the condition shown on figure 67 to be effective, the density head of river water resulting from salinity and the depth of the river perhaps would have to be greater than is common in the Vermilion River. The free interchange of river and ground water has been discussed above, and only the mechanics of salt-water encroachment under these circumstances need be considered here.

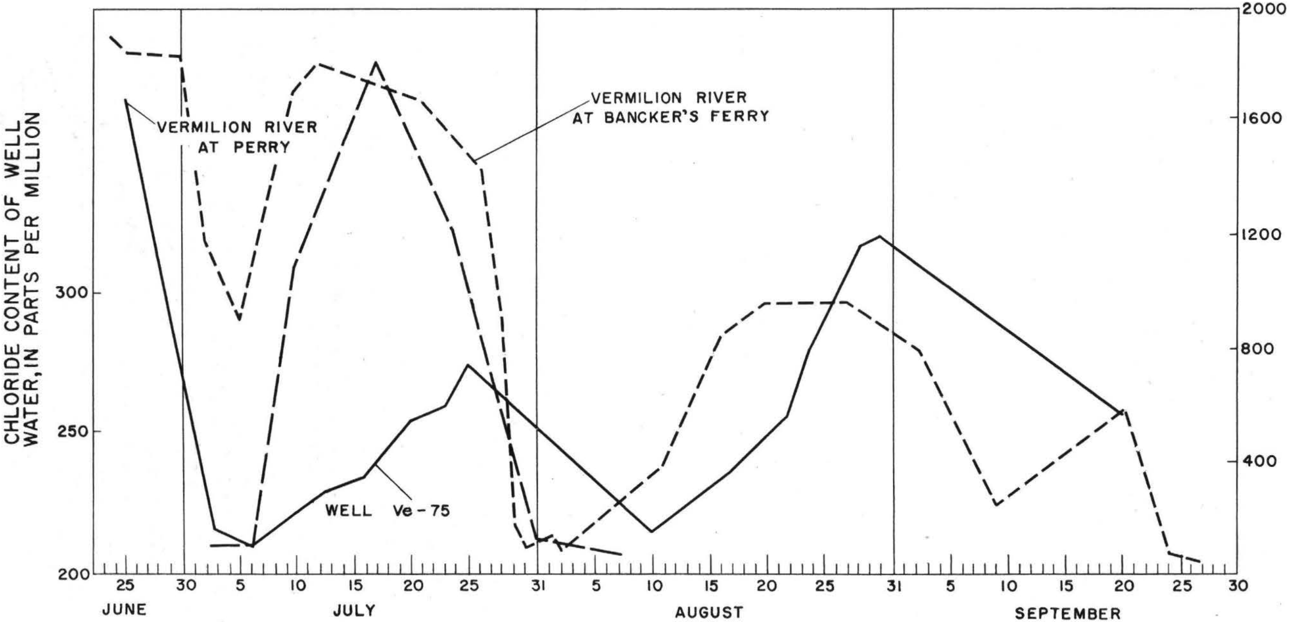


Figure 65.—Graphs showing the relation between the salinity of water in the Vermilion River at Perry and at Bancker's Ferry and the salinity of water from well Ve-75.

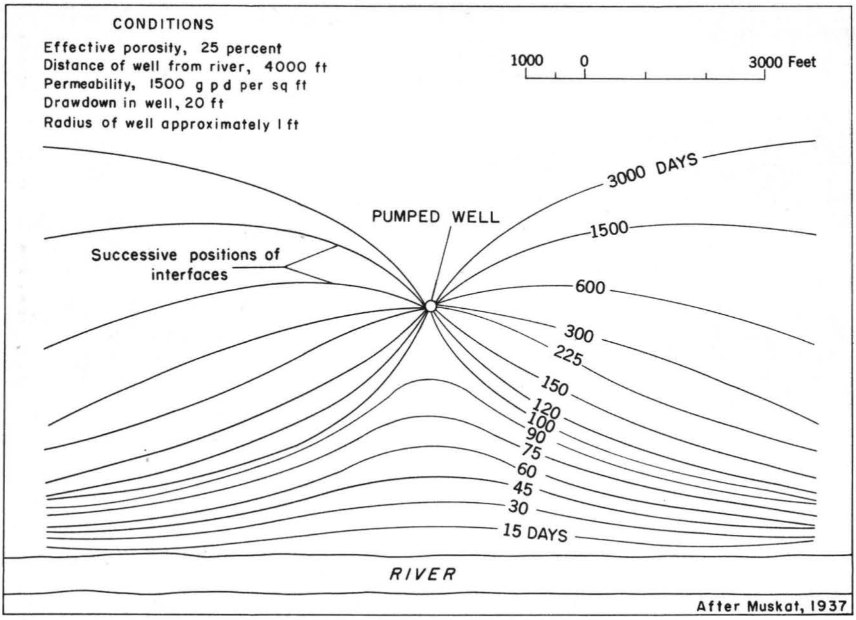


Figure 66.—Movement of salt-water and fresh-water interface toward a pumped well near a river, showing position as a function of days after salt water appears in river channel.

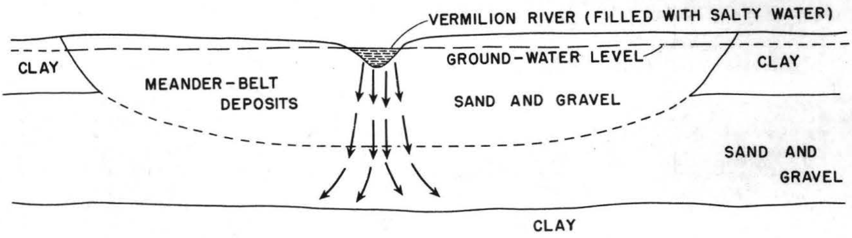


Figure 67.—Diagrammatic cross section showing salt-water movement into the aquifer due to gravitational settling when ground-water levels and river stage are at the same elevation.

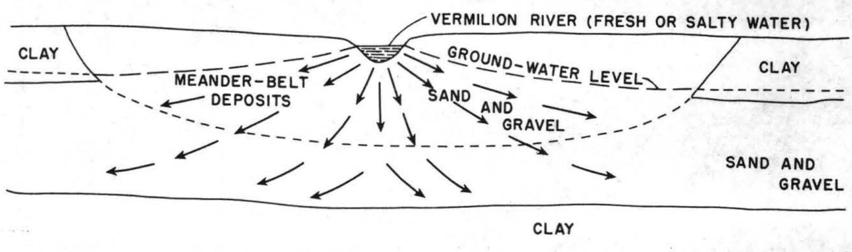


Figure 68.—Diagrammatic cross section showing recharge to the aquifer from the river when ground-water levels are below river stage.

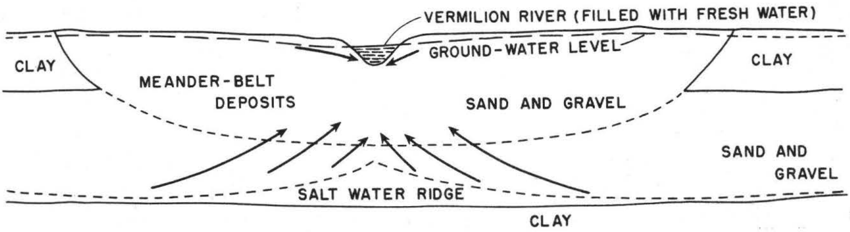


Figure 69.—Diagrammatic cross section showing ground-water seepage to the river and the resultant salt-water ridge formed in the base of the aquifer beneath the river.

For simplicity, river stage may be considered constant. The Vermilion River is a tidal stream having a deep, U-shaped channel, and tidal flow is accomplished with relatively small head loss. At Abbeville the tidal range of stage generally is less than 1.3 feet. Ground-water levels, on the other hand, rise and fall with an annual cycle, being highest in the early spring and lowest in the early fall. The range is several feet in wells near the western margin of the lower part of the Vermilion River basin (see fig. 45) and less near the river. Ground-water levels are above river stage in the early spring and below it in the early fall.

When river stage and ground-water level are at the same elevation (fig. 67) and the river is filled by salty water having a density of about 1.001 (the density of water having a chloride content of about 2,000 ppm, which is common in the Vermilion River during periods of severe encroachment), the density head tending to cause salt water to enter the aquifer is equal to $0.001h$, where h is the depth of the river in feet. At Abbeville the bottom of the Vermilion River is about 18 feet below mean sea level, and when ground-water level and river stage are at sea level, the density head tending to cause influent seepage of salty water into the aquifer is about 0.018 foot or about $\frac{1}{4}$ inch. Whether this head of water is sufficient to cause appreciable influent seepage through the river bottom is debatable. Probably the controlling factor is the permeability of the river bottom which may be considerably less than the permeability of the aquifer in general. However, unless the river bottom is completely impermeable, water must flow downward from the river into the aquifer. As the salt-water column reaches the base of the aquifer or a layer of salty water having a density equal to or greater than its own, it spreads laterally in all directions.

When river stage is above ground-water levels (fig. 68), influent seepage occurs regardless of the salinity of the river water, This condition is common during the late summer and fall along the Vermilion River, and the fact that the water recharged (influent seepage) is often salty, but of low density, probably is a minor

387601 O-56-20

factor in the hydraulic system inducing recharge. However, as the salty water that enters the aquifer in drought years moves downward and away from the river along the general flow lines shown on figure 68, it tends to move to the bottom of the aquifer. Its movement is streamline and very slow, and it flows as a body, or mass, through the aquifer. There is little mixing with the fresh water in the aquifer except along the boundaries of the salt-water mass. Fresh water beneath this mass is displaced horizontally until the mass rests upon water of equal or greater density. The salty water may have moved a considerable distance horizontally before sinking to its proper depth in the aquifer to provide a vertical density profile that persistently decreases upward, but this is the equilibrium condition that is reached eventually. Salty ground water is never found above fresh ground water in the same aquifer where free movement is possible throughout and sufficient time has elapsed to enable the development of an equilibrium density profile, regardless of the magnitude of the density contrast.

When the ground-water level is above river stage the aquifer loses water to the river, as shown on figure 69. Water throughout the aquifer moves horizontally and upward as indicated by the flow lines. The river acts somewhat as a line sink, the ground-water flow lines and salt-water movement, as viewed through a transverse vertical section, adopting a pattern quite similar to that shown by figure 64. This tends to facilitate development of a salt-water ridge if salty water is present in the aquifer. The salt-water ridge may rise toward the stream bottom in response to the steepened vertical pressure gradient caused by lower stream stage, but its movement upward is retarded by its density head. Under a given set of conditions of effluent seepage from the aquifer, the salt-water ridge will have a predictable height and form. The shape and height of the existing salt-water ridge beneath the Vermilion River (see pl. 15) may be determined at least in part by the mechanics of such a pressure-density system.

Conditions shown on the diagrammatic cross sections (figs. 67–69) represent behavior in an aquifer in which the water is not under a prevailing regional hydraulic gradient. Water in the aquifer beneath the Vermilion River basin is for the most part moving westward or northwestward under a regional gradient (see piezometric maps, pls. 14, 16–29), and water derived from the Vermilion River does not remain beneath it. Recharge to the aquifer, whether of fresh or salty water, for the most part moves westward. When water levels in the aquifer rise above river stage, the ground water lost to the river by effluent seepage is not the water obtained from it during previous periods of influent seepage. Therefore, salty water derived from the Vermilion River is stored in the aquifer, incrementally, and moved westward or northwestward toward the centers of heavy pumping from wells.

The Vermilion River is a very important source of recharge to the Chicot reservoir. Because the water recharged is periodically salty, the Vermilion River is probably the principal source of salt-water encroachment to the Chicot reservoir. To avoid further salt-water encroachment upon the ground-water supply of southwestern Louisiana it would be necessary to maintain the Vermilion River as a fresh-water stream to its mouth at all times.

THE ATCHAFALAYA RESERVOIR

GEOLOGIC CHARACTERISTICS

The name Atchafalaya reservoir is assigned to the single gravelly aquifer formed by sediments that partly fill the pre-Recent scour trenches of the Mississippi River and its western tributaries where they underlie the eastern margin of the project area. The configuration of the scour trenches, and thus of the aquifer, is shown on plate 1, which was drawn after Fisk (1944 and 1948). Although the highly permeable deposit of gravel and sand only partly fills the scour trenches and is blanketed by a thick deposit of clay, it constitutes an important aquifer. The thickness of the surface clay has been mapped in detail by Fisk (1944, pl. 12).

The shape of the Atchafalaya reservoir is dendritic in plan, the channels coalescing southward and eastward toward the trunk channel of the pre-Recent Mississippi River. In transverse section, each of the "limbs" of the reservoir is roughly V-shaped, the sides and bottom formed in Pleistocene deposits, the top composed of Recent silts and clays. The depth to the base of individual conduits thus formed ranges to about 300 feet below sea level at the latitude of Lafayette in Lafayette Parish. However, as shown on plates 2 and 7, the Atchafalaya reservoir occurs only beneath the Recent flood plain of the Mississippi River—the western margin of which is occupied by the Atchafalaya River in the project area.

Along much of their length in the project area, the "limbs" of the Atchafalaya reservoir (the branch conduits) lie in direct contact with aquifers of the Chicot reservoir. The hydraulic continuity established by this intimate occurrence of the aquifers is a factor of major importance to the ground-water resources of the project area because it provides an excellent opportunity for recharge waters to move from the Atchafalaya reservoir into the heavily pumped Chicot reservoir.

The depth to the top of the principal aquifer of the Atchafalaya reservoir has been mapped by Fisk, as mentioned above, and the geologic section C–C' (pl. 5) drawn after Fisk (1952, pl. 17), shows a profile of the reservoir and its overlying deposit of clay from McCrea in Pointe Coupee Parish to Atchafalaya Bay.

No mechanical analyses have been made of formation samples from wells penetrating the Atchafalaya reservoir in the project area. However, mechanical analyses of formation samples from wells tapping it near Baton Rouge show very coarse texture, and samples from wells in the project area show that the aquifer consists of sand and gravel having a texture comparable to that of the coarsest deposits of the Chicot reservoir.

Because of its origin as a channel-fill deposit, the Atchafalaya reservoir differs in thickness from place to place. Along the axis of a scour trench its thickness is rather constant, but transverse to the trench the thickness decreases rapidly in either direction, and the aquifer pinches out against the trench wall. Minimum thicknesses generally are recorded over buried interfluvial areas.

Along the axes of buried pre-Recent scour trenches in the project area, the aquifer that composes the reservoir has a maximum thickness of about 250 feet.

Along the axes of the "limbs" of the buried dendritic pre-Recent drainage, the continuity of the aquifer is unbroken. Because of the arboreal pattern of the reservoir, no part of it is isolated from the remainder, and thus it forms an integrated hydraulic system of aquifers.

HYDRAULIC CHARACTERISTICS

No systematic hydraulic tests have been made of the aquifer in the project area, but the specific capacities (yield per unit of drawdown) of wells tapping it are comparable to those of wells tapping aquifers of the Chicot reservoir. On this basis and because yields of large-diameter wells (10 to 18 inches) tapping the Atchafalaya reservoir compare favorably with those of similar wells tapping the Chicot reservoir, the hydraulic characteristics of the two are believed to be in the same order of magnitude.

RESERVOIR FUNCTION

RECHARGE

Ground water in the Atchafalaya reservoir now is derived largely, if not entirely, from the channels of major streams cut into it.

As shown on plate 5, the thalweg (the line of the deepest part of the channel) of the Atchafalaya River lies in sand and gravel deposits of the reservoir for many miles in the project area.

During the geologic past, and probably within the past century, the ground-water flow was largely from the aquifer to the stream—as effluent seepage—during most of the year. At that time recharge to the Atchafalaya reservoir was largely through underground interconnections with aquifers of the Chicot reservoir, which contained water under a higher artesian pressure during most of the year, as shown by the map, plate 13.

Today (1952) the principal, if not only, source of recharge to the Atchafalaya reservoir in southwestern Louisiana is the Atchafalaya River. Because the river is the outlet for the Red River and a major distributary of the Mississippi River, the Atchafalaya is a very large stream and is able to supply all diversions to ground-water recharge with imperceptible effect upon its flow.

MOVEMENT

As a result of decline of artesian pressure in the Chicot reservoir hydraulic gradients are generally away from the Atchafalaya River most of the time. Only during low stages of the river does ground water flow into it from the Atchafalaya reservoir (see fig. 45). During the late summer when the river is at a low stage, there is a water-table ridge running parallel to the trend of the river, its axis lying to the west of the Atchafalaya River, near the center of the meander belt of Bayou Teche. This water-table ridge flattens, and its axis moves eastward during the fall. Ground water moves both westward and eastward from this ground-water ridge. The hydrographs of figure 45 show the change in hydraulic head across the mound along a line transverse to it a few miles southeast of Lafayette in Lafayette Parish.

Because of the complex shape of the Atchafalaya reservoir and the indeterminate nature of interconnections between it and the Chicot reservoir, it is difficult to evaluate reservoir gradients in terms of flow rates. In the broad belt of swamp that lies between Bayou Teche and the Atchafalaya River, there are few water wells in which to measure water levels for the preparation of piezometric maps. However, the very stable water levels in wells tapping the Chicot reservoir along the course of Bayou Teche provide excellent evidence that recharge from the Atchafalaya River and reservoir is approximately equivalent to ground-water flow rates westward into the Chicot reservoir.

DISCHARGE

As indicated above, the principal withdrawal from the Atchafalaya reservoir is not from wells which tap it but rather from water loss across the buried interface between the Atchafalaya and Chicot reservoirs. As shown on plate 30, some 28 percent of all ground-water recharge to the Chicot reservoir in 1946, or about 40 billion gallons of water, entered that reservoir from the east. Probably most of this was derived from the Atchafalaya reservoir.

Few wells in the project area tap the Atchafalaya reservoir. One of these well SL–129, is shown on geologic cross section *B–B'* (pl. 10). The well yields about 2, 500 gpm, but some of this comes from an aquifer of the Evangeline reservoir screened near the bottom of the well.

Discharge from the Atchafalaya reservoir into the Atchafalaya River, during low summer-month stages, probably far exceeds direct withdrawals by wells; but, because there is no information on water levels in the aquifer within a few miles of the river on either side, no estimates of effluent seepage can be made at this writing. This seepage is probably so small a percentage of the total flow of the river, even at low stage, that standard stream-gaging equipment used to measure river flow would not be sufficiently accurate to detect it. This does not mean, however, that effluent seepage from the Atchafalaya ground-water reservoir is negligible at such times.

CHEMICAL QUALITY

The chemical quality of water from the Atchafalaya ground-water reservoir has been determined for very few wells in the project area. Samples of water have been collected from a number of wells tapping this source in the area east of the Atchafalaya River, and chemical analyses show the water to be very hard, to contain large quantities of iron in solution, and to have a high dissolved-solids content. The water is generally alkaline in reaction but contains about 10 to 40 ppm of carbon dioxide in solution. The analysis shown for well SL–104 in "Quality of water" is representative of water from the Atchafalaya reservoir.

WELLS

CONSTRUCTION

Wells now in use for irrigation, public-supply, and industrial purposes in southwestern Louisiana were drilled by the hydraulic-rotary method. This method, which originated in the oil fields of Louisiana about 1890, came into prominence in 1901 with the development of the Spindletop oil district of eastern Texas (Tolman, 1937, p. 402–406) and has been used successfully during the past 50 years in the drilling of water wells in Louisiana (Harris and Fuller, 1904, p. 68–70).

For the drilling of water wells, rotary-drilling equipment has been designed to provide portability and ease of assembly and disassembly at well sites. Portable equipment is of two general types: Truck-mounted self-propelled rigs and skid-mounted rigs (Uren, 1946, p. 376–378). The truck-mounted self-propelled rig (fig. 70) is the more commonly used rig and comprises a draw works, a mud pump, a collapsible mast, and an internal-combustion engine mounted on the truck body. The regular truck motor furnishes power for moving from one location to another and also may be used in hoisting drill pipe and in operation of the mud pump. By means of specially designed transmission gearing, the engine that drives the truck can be compounded with the engine mounted on the bed of the truck for handling drill pipe and other heavy loads. In rigging up, the truck simply is parked at the well location, the mast legs set on timbers, and the front end raised so that all weight is taken off the truck springs. The collapsible mast is drawn into place with the power unit, secured with guy lines, and adjusted vertically by hydraulic jacks.

The parts of the skid-mounted portable drilling rig are assembled in units for convenience in rigging and transport but are not attached permanently to the vehicle on which they are moved. However, they are arranged on skid slides so that they may be put in place and the drilling mast may be set up without difficulty. The rig-up time with this type of equipment is necessarily somewhat longer than with truck-mounted rigs, but the driller has the advantage of being able to drill a larger diameter hole to a greater depth because skid-mounted rigs generally are heavier and more strongly built.

The drilling is done by rotating a fishtail bit on the end of a drill-stem pipe which is screwed onto the kelly, a square section of drill pipe that fits into the square-drive bushing in the rotary table on the derrick floor. A mud fluid sufficiently viscous to seal up the walls of the hole and to carry the cuttings to the surface is

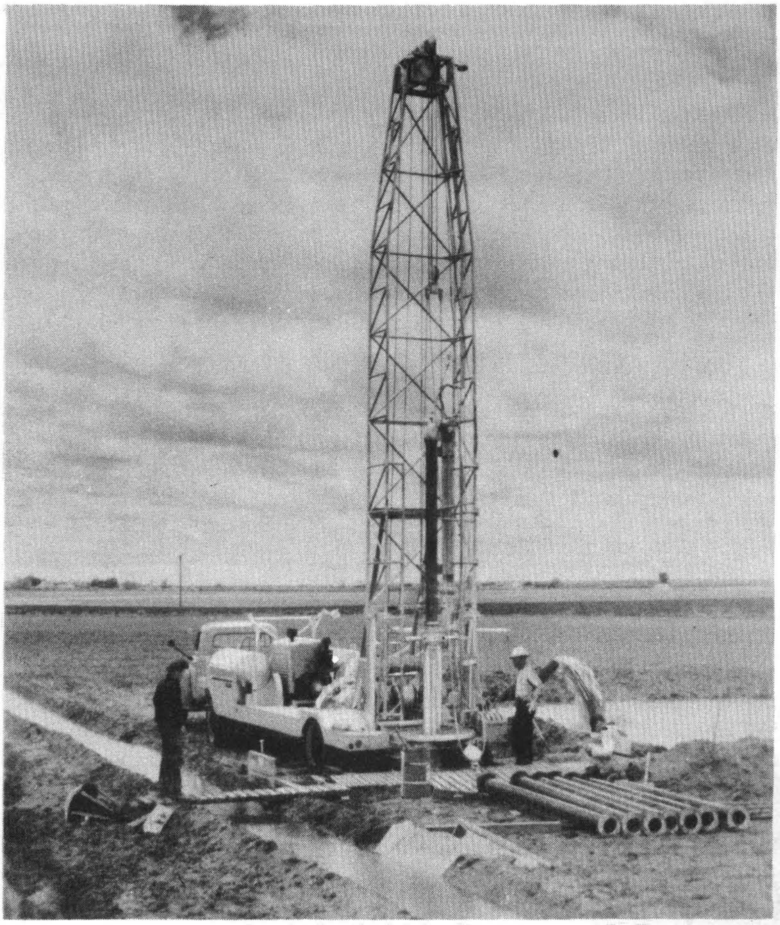


Figure 70. —Truck-mounted self-propelled hydraulic drilling rig. (Photograph courtesy of the Winter-Weiss Co.)

pumped, under pressure, down the drill pipe and out through holes in the bit. Both natural mud and substances such as Aquagel, a processed commercial drilling mud containing the mineral bentonite, are used in drilling.

A "pilot" hole usually is drilled to determine the geologic and hydrologic character of the formations. A record of the beds penetrated in this hole is made, formation samples are collected, drilling time is recorded, and notes are made of the action of the mud pump and rotary table. If an electrical survey is desired after the pilot hole has been made, the hole is conditioned by circulating the drilling mud for a period of 1 to 3 hours to insure uniformity of mud in all parts of the hole and to build up a heavy mud cake in the water sands to prevent caving upon withdrawal of the drilling tools. As soon as possible after the removal of the drilling tools an electric log of the formations is made by one of the several commercial firms specializing in such services for oil and water wells. The information obtained from the pilot hole determines the future development of the well or the abandonment of the hole if conditions seem unfavorable. If a supply well is to be constructed, the pilot hole is reamed to a larger diameter or a larger diameter hole is drilled to the desired depth.

After the hole is reamed and cleaned, the screen, pit casing (casing large enough to accommodate a pump of the desired size, set to a depth below the lowest expected pumping level), and well casing are set. The lower end of the screen is equipped with a back-pressure valve; many of these valves are designed by the water-well contractor. The pit casing is generally of welded or riveted sheet steel; the well casing is heavy steel line pipe. After the casing and screen have been put in place, clear water is circulated down from the surface, out through the back-pressure valve, and up through the annular space, between the casing and the hole walls, thus clearing away accumulated clay and detrital material from the wall of the well, breaking down the mud cake on the hole wall, and allowing the sand of the aquifer to collapse against the screen.

The selection of the well screen is an important factor in proper construction of a well; along with proper size and depth of pit casing, it usually determines the "life span" of the well. The screen size should not be decided haphazardly but should be based upon the results of mechanical analyses of samples of the water sand. It is from these data that the screen is selected so that the slot opening will be suitable to the texture of the sand to be screened. The proper size of the screen openings is not, as is commonly thought, the size capable of holding out all the sand, but rather it is the size that will permit the smaller particles of sand around the well—commonly the particles making up the finest grained 40 to 70 percent of the sand—to pass through the screen and out of the well.

The primary purpose of the pit casing is to allow ample space for installation and submergence of the pump and its component parts (fig. 71) to provide the amount of water desired. Before deciding on the diameter and length of the pit casing to be used, the yield characteristics of the well to be installed—specific capacity, discharge rate, and static water level—should be determined or estimated. In an area of declining water levels, such as southwestern Louisiana, the depth of setting of the pit casing

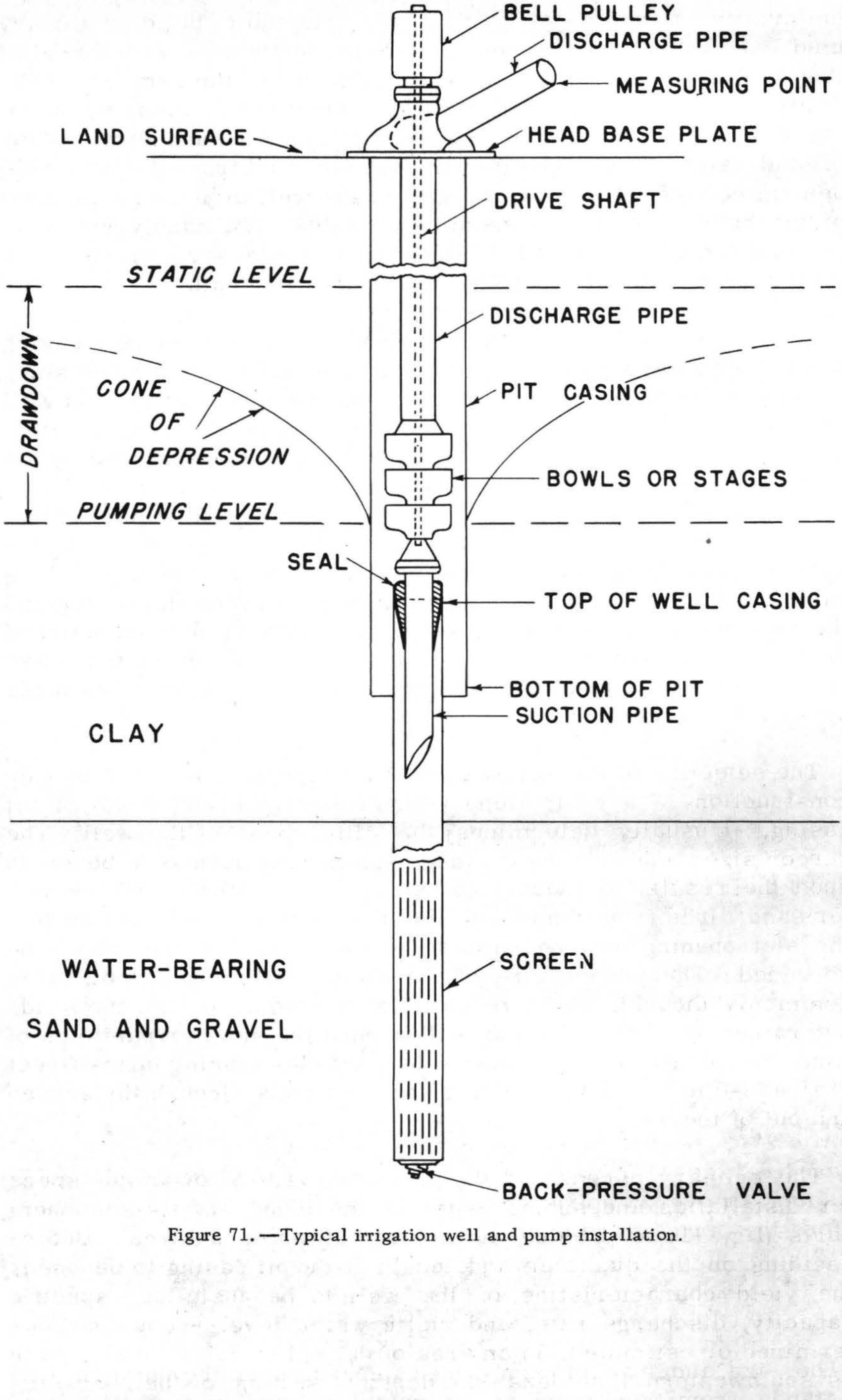


Figure 71. —Typical irrigation well and pump installation.

is an important factor in the life span of a well. Once the pumping level declines below the pump bowls, the quantity of water delivered will decrease until eventually the pump loses suction. Such loses have been common during the rice-irrigating season in recent years. When such a loss occurs, a smaller pump of less capacity must be installed in the well casing below the pit casing. If time is available and the quantity delivered by the smaller pump is insufficient, a new well is constructed. Well failure of this type has been the principal factor necessitating well replacement in southwestern Louisiana.

When a well is to be used to provide water for industrial and public-supply purposes, surface casing usually is set and cemented in the upper section of the hole to shut off contaminated surface waters or to provide additional support for the walls of the well. Fluid cement is forced into the annular space between the walls of the hole and the casing and allowed to harden.

In southwestern Louisiana a specialized type of well, known as a gravel-packed well, commonly is used. In a gravel-packed well, the hole is reamed out to large diameter (as much as 28 to 32 inches) in the sand bed to be tapped, and carefully sized gravel is placed around the screen. When the entire hole is reamed out and the gravel is placed around the casing as well as the screen, from top to bottom, the well is referred to as a "gravel-wall" well. Gravel-wall or gravel-packed wells are constructed in an effort to increase the specific capacity of the well. This is based on the theory that, by increasing the effective diameter of the well, the velocity of the water entering from the formation is reduced and the head loss through the sand particles about the screen is decreased; consequently the specific capacity of the well is increased. However, this does not indicate that all gravel-wall or gravel-packed wells will yield more water per unit of drawdown of water level than a properly developed "natural" sand well. Coarseness and uniformity of texture of the aquifer tapped, thickness of aquifer, screen-slot opening used, and method of well development, all have an important bearing upon the specific capacity of a well.

After the screen is set and the gravel placed around it, the gravel-packed well is ready for development by surging, backwashing, or overpumping, or by a combination of these processes, before the permanent installation of a pump.

PUMPING PRACTICES

The size and type of pump used depends upon the pumping lift (distance from land surface to pumping level in the well), the quantity of water desired, and the diameter of the pit casing. In turn, the type and power of the engine used to operate the pump are determined by the capacity and speed of rotation of the pump and by the lift. Rice-irrigation wells commonly are equipped with 16- or 18-inch turbine pumps, 1 to 4 stages being used, and are usually constructed with 80 feet of screen; however some wells are reported to have as much as 145 feet of screen. (See table 23.)

The engines installed on rice-irrigation wells are powered by diesel oil, natural gas, electricity, gasoline (tractors and stationary engines), and butane. Of 1,061 rice-irrigation wells in southwestern Louisiana for which records are available, 450 are equipped with diesel or semidiesel engines, 212 with natural-gas engines, 105 with electric motors, 43 with butane-gas engines, and 19 by stationary gasoline engines. Farm tractors, temporarily installed, are used on 81 wells. (See table 20.) The type of power used to operate the other 151 irrigation wells was not recorded.

Table 20.—*Summary of rice irrigation wells, showing the type of power used and number of each type*

Parish	Diesel	Natural gas	Electric	Tractor	Stationary gasoline	Butane	Power unknown	Total
Acadia	163	31	6	4	1	1	10	215
Allen	23	11	....	4	9	5	5	57
Beauregard	....	....	....	4	....	....	3	7
Calcasieu	26	6	4	4	....	4	23	67
Cameron	3	....	1	1	....	....	2	7
Evangeline	35	104	9	3	....	21	27	199
Iberia	3	1	1	2	....	....	1	8
Jefferson Davis	98	33	84	8	3	5	66	297
Lafayette	22	2	....	....	....	....	1	25
St. Landry	5	21	1	1	3	....	5	36
St. Martin	1	....	....	....	2	....	1	4
Vermilion	71	3	....	50	1	7	7	139
Total	450	212	105	81	19	43	151	1,061

Whereas diesel-, natural-gas-, and electric-powered engines are now the types most commonly used to operate irrigation-well pumps, the main source of power in the earlier years of rice irrigating was steam (Harris and Fuller, 1904, p. 73).

As shown by tables 21 and 22, which list those wells used for industrial and public-supply purposes, the main source of power for the operation of these wells, with a few exceptions, is electricity.

A total of 959 well-discharge measurements was made during the period 1945–51 as a part of the quantitative investigation. The yields measured ranged from 600 to 6,100 gpm. The maximum discharge measured was that of well Al–156 near Kinder in Allen Parish. The average discharge of the wells measured was 1, 775 gpm. Some of these measurements may have been made when the pump was not operating at full speed, but rather at a rate which, through experimentation and time, was considered by the well owner to be most efficient.

Table 21.— *Records of public-supply wells of*

[Screen diameter in most wells same as well diameter; water level shown is that at date pumped by electric power except those

Well no.	Owner	Location	Driller	Depth (feet)
				ACADIA
Ac-166	People's Water Service, Inc.	Church Point	Layne-Louisiana	250
Ac-241	.......do	.......do	Coastal Water Well Co.	243
Ac-169	Gulf Public Service, Inc	Crowley	Layne-Louisiana	280
Ac-170	.......do	.......do	Stamm-Scheele	247
Ac-280	.......do	.......do	....do	257
Ac-168	Municipal	Iota	Layne-Louisiana	300
Ac-279	.......do	.......do	Stamm-Scheele	302
Ac-247	.......do	Rayne	....do	288
Ac-259	.......do	.......do	....do	308
				ALLEN
Al-121	Calcasieu Paper Co	Elizabeth	Fred Getty	155
Al-154	Municipal	Kinder		170
Al-157	.......do	.......do	Stamm-Scheele	706
Al- 2	.......do	Oakdale	Layne-Louisiana	365
Al-120	.......do	.......do	G. C. Blevins	910
Al-138	.......do	.......do	....do	906
Al- 31	.......do	Oberlin	J. F. Ritter	120
Al-141	.......do	.......do	Coastal Water Well Co.	142
				BEAUREGARD
Be- 4	Municipal	De Ridder	Coastal Water Well Co.	186
Be- 5	.......do	.......do	....do	188
Be- 82	R. L. Fortenberry	Merryville		378
Be- 83	.......do	.......do		378
				CALCASIEU
Cu- 6	Gulf Public Service, Inc	De Quincy	Layne-Louisiana	654
Cu-495	.......do	.......do	Stamm-Scheele	655
Cu-496	.......do	.......do	Eunice Iron Works.	750
Cu- 3	Gulf States Utilities Co	Lake Charles	Layne-Louisiana	700
Cu- 31	.......do	.......do	....do	680
Cu-457	.......do	.......do	....do	696
Cu-501	.......do	.......do	....do	690
Cu-553	.......do	.......do	....do	674
Cu-447	Municipal	Maplewood	....do	493
Cu-448	.......do	.......do	....do	496
Cu-118	.......do	Sulphur	....do	510
Cu-119	.......do	.......do	....do	497
Cu-502	.......do	.......do	Coastal Water Well Co.	573
Cu- 1	.......do	Vinton	Layne-Louisiana	560
Cu-555	.......do	.......do	Eunice Iron Works.	602
Cu-486	.......do	Westlake	Coastal Water Well Co.	537
				CAMERON
Cn- 32	Richard McCullen	Cameron		460
Cn- 33	.......do	.......do		300

municipalities, by parish and municipality

of completion. Pump setting and water level in feet below land-surface datum. All wells indicated by * which are flowing wells]

Casing				Length of screen (feet)	Pump setting	Yield (gpm)	Drawdown (feet)	Date of completion	Water level
Pit		Well							
Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)						
PARISH									
....	....	....	....	....	....	170	....	1926	....
170	10	54	6	60	90	400	....	Jan. 1949	53
....	26	....	12	57	60	1,250	....	July 1925	....
91	24	95	10	80	73	1,550	....	Aug. 1939	34
100	12	94	10	50	85	900	....	July 1942	29
....	....	....	6	....	....	....	....	....	....
127	10	99	8	70	100	580	....	July 1949	....
109	16	87	10	84	109	2,000	....	May 1948	36
125	24	112	16	80	100	3,000	52	Mar. 1950	35
PARISH									
....	16	....	10	....	....	1,421	....	Nov. 1934	....
....	....	....	....	....	....	....	....	....	....
151	8	473	6	40	....	....	....	July 1951	36
....	....	....	10	40	160	250	....	1935	52
....	....	840	18	70	147	1,000	....	June 1948	6
....	18	....	10	112	....	425	83	Feb. 1949	35
....	8	....	6	....	....	....	....	1930	....
....	....	130	8	16	....	....	....	Oct. 1949	....
PARISH									
120	12	....	8	63	120	750	13	May 1942	25
123	12	....	8	60	120	750	12	June 1942	33
....	....	....	2½	40	....	150	....	1919	+11
....	....	....	6	40	....	150	....	1947	....
PARISH									
580	12	....	....	....	....	360	....	May 1940	82
584	12	393	6	60	155	375	....	May 1948	....
587	12	404	6	60	170	460	....	July 1949	....
....	....	....	....	....	140	1,500	....	1940	....
....	18	....	10	80	84	1,500	....	Mar. 1942	12
575	16	121	10	80	140	1,500	....	Aug. 1946	....
....	16	....	10	80	140	1,760	....	July 1949	55
563	20	93	12	86	140	1,500	55	Aug. 1950	60
195	10	235	6	60	105	680	47	June 1943	26
200	10	280	6	63	105	600	25	Aug. 1943	31
....	....	....	10	....	....	....	....	1929	....
....	10	....	6	49	....	325	25	Feb. 1936	....
520	10	68	6	40	105	800	37	Aug. 1949	....
536	8	45	6	49	....	....	....	1939	....
502	12	73	8	80	....	....	....	1950	....
430	10	101	6	70	....	670	....	Feb. 1949	50
PARISH									
....	....	....	4	....	....	....	....	....	....
....	....	....	4	....	....	....	....	....	....

Table 21.—*Records of public-supply wells of*

Well no.	Owner,	Location	Driller	Depth (feet)
				EVANGELINE
Ev-348	Municipal	Basile	Layne-Louisiana	215
Ev-344	do	Mamou	Stamm-Scheele	219
Ev-377	do	do	Coastal Water Well Co.	245
Ev- 5	Central Louisiana Elec. Co.	Ville Platte	C. K. White	200
Ev-345	do	do	do	234
Ev-346	do	do	do	200
Ev-375	do	do	B. M. Crooks	220
				IBERIA
I- 53	Municipal	Jeanerette	Layne-Louisiana	208
I- 54	do	do	do	208
I- 71	do	do	do	202
I- 11	Jefferson Island Salt Co.	Jefferson Island	J. F. Ritter	380
I- 67	do	do	Stamm-Scheele	382
I- 13	Municipal	Loreauville	do	229
I- 1	Central Louisiana Elec. Co.	New Iberia		266
I- 12	do	do	Stamm-Scheele	250
I- 18	do	do		250
I- 63	do	do	Eunice Iron Works.	288
I- 6	Bay Chemical Co.	Weeks Island	Blakemore	225
I- 7	do	do	do	243
I- 65	do	do	Stamm-Scheele	251
				JEFFERSON DAVIS
JD-373	Municipal	Elton	Stamm-Scheele	191
JD-406	do	do	Layne-Louisiana	450
JD-220	do	Jennings	F. I. Getty	300
JD-339	do	do	Coastal Water Well Co.	280
JD-343	do	do	Layne-Louisiana	271
JD- 5	do	Lake Arthur	do	293
JD-204	do	do	do	253
JD-350	do	Welsh	Coastal Water Well Co.	238
JD-363	do	do	do	237
				LAFAYETTE
Lf-166	Municipal	Broussard	Layne-Louisiana	151
Lf-489	do	do	Stamm-Scheele	116
Lf-496	do	Carencro	do	157
Lf-499	do	do	do	165
Lf- 1	do	Lafayette	do	215
Lf-433	do	do	do	212
Lf-491	do	do	do	214
Lf-492	do	do	do	213
Lf-503	do	do	Eunice Iron Works.	212
Lf- 35	do	Scott	Stamm-Scheele	153
Lf- 36	do	do	do	150

municipalities, by parish and municipality— Continued

Casing				Length of screen (feet)	Pump setting	Yield (gpm)	Drawdown (feet)	Date of completion	Water level
Pit		Well							
Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)						
PARISH									
...	...	...	6	70	100	300	...	Feb. 1945	70
127	10	15	6	70	104	490	...	....do......	44
175	12	18	8	60	145	750	14	Oct. 1951	104
...	...	...	10	80	...	500	...	Sept. 1938	...
...	...	...	...	...	...	...	...	1944	...
...	...	...	...	...	...	...	...	1930	...
...	...	...	...	...	...	...	...	Oct. 1950	...
PARISH									
169	12	58	6	30	60	350	...	Jan. 1945	...
...	...	...	6	...	...	...	...	1939	...
161	12	45	6	32	...	320	20	Oct. 1950	...
...	...	...	6	...	...	200	...	1917	...
108	18	183	12	80	...	3,999	...	June 1944	6
62	8	122	6	42	...	100	...	July 1939	...
...	...	...	...	...	...	700	...	...	...
...	12	...	10	73	...	1,500	...	May 1939	...
...	12	...	...	...	...	...	...	...	...
119	24	60	10	60	...	1,760	...	Oct. 1949	...
...	...	...	...	...	...	...	...	...	...
...	...	...	10	72	...	576	41	Sept. 1941	10
121	22	57	12	80	106	...	...	Dec. 1943	8
PARISH									
...	...	...	8	...	118	600	...	Mar. 1941	...
...	...	...	...	...	...	...	...	Feb. 1950	...
...	...	...	12	60	...	...	...	1910	...
190	16	52	10	80	140	...	...	Apr. 1948	...
160	18	69	10	62	...	...	...	Feb. 1941	...
...	...	...	8	80	...	...	...	1922	...
...	...	...	8	40	...	400	...	1927	...
180	12	24	8	52	120	600	...	May 1949	42
200	12	...	8	...	80	...	...	1938	...
PARISH									
...	...	...	6	...	...	400	...	1935	17
...	...	82	8	30	50	300	...	Apr. 1948	23
80	10	12	6	60	70	300	36	June 1944	30
...	...	101	10	60	80	...	...	Sept. 1950	32
...	...	...	10	79	...	250	...	June 1936	...
...	20	...	12	60	...	...	...	Nov. 1943	31
109	16	20	12	79	90	1,870	40	July 1949	37
109	16	20	12	79	103	...	...	July 1946	36
122	24	25	16	80	110	1,800	...	July 1951	37
...	...	...	6	...	...	125	...	1941	30
...	8	...	6	20	...	...	...	1939	...

387601 O -56 -21

Table 21.— *Records of public-supply wells of*

Well no.	Owner	Location	Driller	Depth (feet)
				ST. LANDRY
SL- 61	Central Louisiana Elec. Co..	Eunice...........................	Layne-Louisiana..	190
SL- 62	........do........................	........do........................	F. I. Getty.........	200
SL- 99	........do........................	........do........................	Eunice Iron Works.	428
SL- 6	Municipal........................	Krotz Springs..................	D. K. Summers...	1,666
SL- 84	........do........................	........do........................	......do.............	1,907
SL- 4	........do........................	Melville..........................	I. B. White........	963
SL- 89	........do........................	Opelousas.......................	Layne-Louisiana..	288
SL- 2	........do........................	........do........................	Stamm-Scheele...	217
SL-122	........do........................	........do........................	......do.............	326
SL-123	........do........................	........do........................	......do.............	326
SL- 5	........do........................	Port Barre.......................	I. B. White........	250
SL- 12	........do........................	Sunset............................	Layne-Louisiana..	216
SL-124	........do........................	........do........................	E. Watson..........	200
SL- 29	Central Louisiana Elec. Co..	Washington.....................	....	155
SL- 30	........do........................	........do........................	....	155
				ST. MARTIN
SMn- 46	Municipal........................	Arnaudville.....................	Stamm-Scheele...	242
SMn- 1	........do........................	Breaux Bridge..................	A. G. Broussard...	179
SMn- 90	........do........................	........do........................	Layne-Louisiana..	283
				VERMILION
Ve-532	Municipal........................	Abbeville........................	Stamm-Scheele...	209
Ve-122	........do........................	Delcambre.......................	J. F. Ritter........	375
Ve-137	........do........................	Erath..............................	Stamm-Scheele...	219
Ve-497	........do........................	........do........................	Coastal Water Well Co.	224
Ve-107	........do........................	Gueydan.........................	Layne-Louisiana...	226
Ve-496	........do........................	........do........................	Stamm-Scheele...	225
Ve- 2	........do........................	Kaplan............................	......do.............	325
Ve-498	........do........................	........do........................	......do.............	283

municipalities, by parish and municipality— Continued

Casing				Length of screen (feet)	Pump setting	Yield (gpm)	Drawdown (feet)	Date of completion	Water level
Pit		Well							
Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)						

PARISH

....	....	....	10	....	100	500	....	1919	....
....	....	....	12	....	....	1,000	....	1926	....
126	20	382	12	84	146	1,000	17	June 1945	85
....	....	1,626	4	40	....	*	....	May 1940	+40
....	....	1,867	4	40	....	*250	....	Oct. 1947	+55
....	....	....	16	73	....	450	....	Sept. 1930	....
....	....	....	....	....	70	....	....	Aug. 1929	....
....	....	....	10	....	....	....	....	May 1944	....
226	26	....	10	100	....	2,000	....	1942	55
139	20	80	12	100	135	2,300	....	Aug. 1950	57
....	....	....	8	50	....	200	....	1936	20
....	....	....	8	40	....	450	....	....do......	....
....	....	....	....	....	....	....	....	1945	....
....	....	....	6	....	....	80	....	....	....
....	....	....	6	....	....	80	....	....	....

PARISH

127	8	70	6	40	....	164	....	June 1939	13
....	....	....	10	....	....	385	....	1910	....
....	....	....	8	....	....	....	....	Sept. 1947	....

PARISH

107	15	41	12	60	93	1,900	....	June 1951	10
....	....	....	8	....	....	300	....	1930	....
64	8	107	6	39	40	....	....	May 1943	4
176	12	97	8	40	60	....	....	June 1949	7
....	....	....	12	40	....	500	....	1928	....
104	10	36	6	80	60	....	....	May 1945	10
....	10	....	....	....	....	....	....	....	....
....	....	242	8	36	....	....	....	Aug. 1937	17

Table 22.—*Records of wells of major*

[Screen diameter in most wells same as well diameter. Pump setting and water level in feet by electric power except those indicated by * for

Well no.	Owner	Location	Driller	Depth (feet)
				ACADIA
Ac-286	Evangeline Refining Co......	Sec. 12, T. 9 S., R. 2 W...	....	165
				ALLEN
Al-116	Calcasieu Paper Co...........	Sec. 20, T. 2 S., R. 4 W....	F. I. Getty........	163
Al-117	.......do........................	.......do........................	...do...............	163
Al-118	.......do........................	.......do........................	I. B. White........	168
Al-145	.......do........................	.......do........................	Stamm-Scheele...	170
Al-158	.......do........................	.......do........................	...do...............	167
Al-110	Newport Industries	Sec. 9, T. 3 S., R. 3 W.....	Layne-Louisiana..	970
Al-130	.......do........................	.......do........................	...do...............	840
				BEAUREGARD
Be- 76	Crosby Chemical Co..........	Sec. 4, T. 3 S., R. 9 W.....	Layne-Louisiana..	204
Be- 77	.......do........................	.......do........................	...do...............	218
Be- 78	.......do........................	Sec. 3, T. 3 S., R. 9 W.....	...do...............	211
Be- 79	.......do........................	.......do........................	...do...............	224
				CALCASIEU
Cu-462	Cit-Con Corp..................	Sec. 13, T. 10 S., R. 9 W..	Layne-Louisiana..	724
Cu-463	.......do........................	.......do........................	...do...............	533
Cu-464	.......do........................	.......do........................	...do...............	532
Cu- 93	Cities Service Refining Corp.	Sec. 19, T. 10 S., R. 9 W..	...do...............	522
Cu- 94	.......do........................	.......do........................	...do...............	520
Cu- 95	.......do........................	.......do........................	...do...............	534
Cu-454	.......do........................	.......do........................	...do...............	540
Cu-560	.......do........................	.......do........................	...do...............	574
Cu- 96	Cities Service Butadiene Plant	Sec. 18, T. 10 S., R. 9 W..	...do...............	736
Cu- 97	.......do........................	.......do........................	...do...............	519
Cu- 98	.......do........................	.......do........................	...do...............	767
Cu-461	.......do........................	.......do........................	...do...............	522
Cu- 99	Columbia-Southern Chem. Corp.	Sec. 3, T. 10 S., R. 9 W...	...do...............	667
Cu-100	.......do........................	.......do........................	...do...............	685
Cu-556	.......do........................	.......do........................	...do...............	697
Cu-580	.......do........................	Sec. 30, T. 9 S., R. 10 W..	...do...............	469
Cu-581	.......do........................	.......do........................	...do...............	469
Cu-582	.......do........................	.......do........................	...do...............	609
Cu-583	.......do........................	Sec. 3, T. 10 S., R. 9 W...	...do...............	670
Cu- 86	Continental Oil Co...........	Sec. 27, T. 9 S., R. 9 W...	...do...............	529
Cu- 88	.......do........................	.......do........................	...do...............	275
Cu- 89	.......do........................	.......do........................	...do...............	508
Cu- 90	.......do........................	.......do........................	...do...............	253
Cu- 91	.......do........................	.......do........................	...do...............	526
Cu- 92	.......do........................	.......do........................	...do...............	701
Cu-561	.......do........................	Sec. 34 T. 9 S., R. 9 W.....	...do...............	264
Cu- 74	Firestone Tire and Rubber Co.	Sec. 18, T. 10 S., R. 9 W..	...do...............	545
Cu- 75	.......do........................	.......do........................	...do...............	751
Cu- 76	.......do........................	.......do........................	...do...............	527
Cu-574	Gulf States Utilities Co.......	Sec. 3, T. 10 S., R. 9 W...	...do...............	707
Cu-575	.......do........................	.......do........................	...do...............	715
Cu- 77	Mathieson Chemical Corp...	Sec. 35, T. 9 S., R. 9 W...	...do...............	512

industrial water users, by parish and industry

below land-surface datum; water level shown is that at date of completion. All wells pumped gasoline, ** for steam, and *** for compressed air]

Casing				Length of screen (feet)	Pump set-ting	Yield (gpm)	Draw-down (feet)	Date of comple-tion	Water level
Pit		Well							
Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)						
PARISH									
....	....	145	4	40	60	70	30	1938	14
PARISH									
75	24	20	12	70	....	2,000	40	1938	46
75	24	20	12	70	....	2,000	40	1926	46
75	30	20	12	73	....	1,700	40	1933	46
92	20	....	....	75	83	2,400	42	1950	53
109	18	1	12	61	103	2,080	....	Sept. 1950	77
913	10	91	6	....	170	440	110	Nov. 1946	5
790	10	72	6	....	290	390	214	....do......	20
PARISH									
134	16	....	8	43	126	500	....	Nov. 1944	31
140	16	....	8	45	120	500	....	Mar. 1945	....
145	16	....	8	38	120	500	....	...do.......	....
140	16	....	8	37	120	500	....	...do.......	....
PARISH									
620	18	71	10	84	260	1,280	....	July 1948	....
400	18	51	10	124	200	1,620	....	....do......	61
406	18	49	10	95	200	....	....	....do......	....
402	18	68	10	112	165	1,500	62	Feb. 1943	13
399	18	87	10	107	145	1,500	85	Jan. 1943	12
399	18	91	10	120	248	1,500	84	Nov. 1942	12
426	18	93	10	110	260	1,500	....	June 1945	40
421	20	81	12	130	300	1,500	48	Apr. 1951	60
612	18	63	10	95	125	1,500	41	Oct. 1942	12
388	18	65	10	108	125	1,500	38	...do.......	12
579	18	96	10	138	125	1,500	38	Dec. 1942	12
414	18	89	10	80	207	1,500	....	Dec. 1945	....
562	18	....	12	80	200	1,500	86	Sept. 1951	87
572	18	....	10	96	160	1,500	63	Apr. 1942	11
576	18	....	10	100	200	1,500	84	Oct. 1950	76
396	12	80	8	60	100	600	34	Oct. 1946	31
400	12	80	8	60	100	600	34	Nov. 1946	31
475	18	208	8	100	160	1,000	52	Dec. 1951	44
550	18	....	10	100	200	1,500	61	...do.......	85
415	18	71	10	100	100	1,250	....	Sept. 1940	....
161	24	64	12	80	100	1,950	37	July 1940	5
329	18	97	10	80	219	1,470	....	Aug. 1940	....
161	24	180	12	70	140	1,200	40	Sept. 1940	8
412	18	66	10	100	100	900	41	July 1940	7
610	18	63	12	78	160	1,300	....	June 1942	21
188	26	200	16	60	120	2,000	....	Jan. 1951	....
390	18	64	10	130	200	1,000	17	Nov. 1942	12
641	18	62	10	94	143	1,500	98	Jan. 1943	11
385	18	64	10	130	200	1,000	19	...do.......	8
....	12	....	8	81	200	800	64	Aug. 1947	40
....	12	....	8	79	145	800	67	Jan. 1947	38
....	10	....	6	64	125	500	....	June 1943	32

Table 22.— *Records of wells of major industrial*

Well no.	Owner	Location	Driller	Depth (feet)
				CALCASIEU
Cu- 78	Mathieson Chemical Corp	Sec. 35, T. 9 S., R. 9 W	Layne-Louisiana	513
Cu- 79	do	Sec. 34, T. 9 S., R. 9 W	do	499
Cu- 80	do	Sec. 35, T. 9 S., R. 9 W	do	512
Cu- 81	do	do	do	525
Cu- 83	do	do	do	505
Cu-449	do	Sec. 34, T. 9 S., R. 9 W	do	517
Cu-450	do	Sec. 35, T. 9 S., R. 9 W	do	523
Cu-458	do	Sec. 34, T. 9 S., R. 9 W	do	509
Cu-459	do	Sec. 35, T. 9 S., R. 9 W	do	511
Cu-460	do	Sec. 18, T. 10 S., R. 9 W.	do	512
Cu-465	do	Sec. 34, T. 10 S., R. 9 W.	do	520
Cu-552	do	do	do	517
Cu-576	do	do	do	508
Cu-215	Newport Industries	Sec. 18, T. 7 S., R. 10 W.	do	365
Cu-216	do	do	do	608
Cu-217	do	do	do	610
Cu-579	do	do	do	652
Cu-126	Swift Packing Co	Sec. 1, T. 10 S., R. 8 W	do	510
Cu-127	do	do	do	517
				EVANGELINE
Ev-316	Anchor Gasoline Corp	Sec. 36, T. 3 S., R. 1 W	Amy Drilling Co.	160
Ev-317	do	do	Eunice Iron Works.	330
Ev-318	do	do	Amy Drilling Co.	175
Ev-338	Cabot Carbon Co	Sec. 47, T. 3 S., R. 2 E	Eunice Iron Works.	206
Ev-339	do	do	do	201
Ev-340	do	do	do	215
Ev-241	Continental Oil Co	Sec. 44, T. 4 S., R. 10 E	do	202
Ev-242	do	do	do	214
Ev-243	do	do	do	214
Ev-244	do	do	do	237
Ev-245	do	do	do	316
Ev-246	do	do	do	223
Ev-247	do	do	do	230
Ev-380	do	do	Unknown	230
Ev-142	Magnolia Oil Co	Sec. 6, T. 5 S., R. 1 E	Layne-Louisiana	960
Ev-378	do	do	do	960
				IBERIA
I- 6	Bay Chemical Co	Sec. 42, T. 15 S., R. 7 E	Blakemore	225
I- 7	do	do	do	243
I- 65	do	do	Stamm-Scheele	251
I- 11	Jefferson Island Salt Co	Sec. 58, T. 12 S., R. 5 E	J. F. Ritter	380
I- 67	do	Sec. 59, T. 12 S., R. 5 E	Stamm-Scheele	382
I- 26	International Salt Co	Sec. 53, T. 13 S., R. 5 E	I. B. White	500
I- 27	do	do	do	500
I- 28	do	do	do	650
I- 64	McIlhenny Co	Sec. 55, T. 13 S., R. 5 E	do	502
I- 66	M. A. Patout and Son	Sec. 33, T. 13 S., R. 5 E	Coastal Water Well Co.	369

water users, by parish and industry— Continued

Casing				Length of screen (feet)	Pump setting	Yield (gpm)	Drawdown (feet)	Date of completion	Water level
Pit		Well							
Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)						
PARISH—Continued									
...	16	...	10	80	207	1,560	76	Feb. 1934	...
...	16	...	10	80	207	1,500	...	Mar. 1934	...
...	18	...	10	70	207	1,400	86	Mar. 1940	...
...	18	...	10	70	207	1,440	75	....do.......	...
399	18	63	10	80	207	1,400	65	July 1943	...
303	18	123	10	129	206	1,840	72	Aug. 1945	58
300	18	121	10	130	206	1,820	58	....do.......	59
359	18	96	10	81	206	1,700	55	Dec. 1947	39
250	18	205	10	81	206	1,700	40	July 1948	39
250	18	204	10	80	206	1,680	...	....do.......	...
252	18	200	10	83	206	1,800	45	Aug. 1947	36
416	18	104	10	88	207	1,500	40	July 1950	96
416	18	89	10	80	239	1,500	28	Oct. 1951	88
...	12	...	8	60	80	1,000	...	Apr. 1937	...
545	10	83	10	60	220	700	...	Aug. 1937	60
508	16	66	4	80	200	1,100	...	Dec. 1939	...
530	18	86	10	82	308	1,000	...	Aug. 1947	...
425	12	64	8	160	80	750	...	June 1937	...
...	12	...	8	160	...	750	...	Jan. 1943	...
PARISH									
...	...	...	12	40	...	***	...	Aug. 1947	...
...	...	...	8	60	...	***	...	....do.......	65
...	...	...	8	40	...	***	...	Mar. 1948	...
...	...	...	10	84	...	...	...	June 1943	...
...	...	...	10	82	...	...	...	Apr. 1945	...
...	...	...	10	80	...	...	...	Apr. 1946	...
93	12	22	10	63	...	725	...	Mar. 1942	...
88	12	22	10	48	...	666	...	....do.......	...
121	12	22	10	48	...	664	...	....do.......	...
...	...	143	12	76	...	**480	...	June 1948	...
...	...	165	12	81	...	715	...	Dec. 1947	...
125	16	12	10	90	...	*472	...	June 1943	...
120	16	9	10	80	...	536	...	Aug. 1943	...
...	...	150	12	80	165	912	...	Dec. 1951	82
905	8	92	5	37	125	125	62	May 1948	...
905	8	92	5	37	...	...	...	Dec. 1948	...
PARISH									
...	...	...	...	...	...	...	...	...	...
...	...	...	10	72	...	576	41	Sept. 1941	10
121	22	57	12	80	106	...	...	Dec. 1943	8
...	...	...	6	...	...	200	...	1917	...
108	18	183	12	80	...	3,999	...	June 1944	6
...	...	...	12	80	...	1,900	50	1932	2
...	...	...	12	80	...	1,500	55	1932	...
...	...	...	12	100	...	1,100	...	1941	...
...	...	457	8	45	...	450	...	Jan. 1949	flow
260	18	...	12	80	80	3,000	35	June 1950	5

Table 22.—*Records of wells of major industrial*

Well no.	Owner	Location	Driller	Depth (feet)
				JEFFERSON DAVIS
JD-403	Sunray Oil Corp................	Sec. 38, T. 7 S., R. 3 W....	Coastal Water Well Co.	305
JD-404	........do..........................	........do..........................	......do...............	285
JD-405	........do..........................	........do..........................	......do...............	290
JD-435	Stanolind Oil and Gas Co....	Sec. 15, T. 10 S., R. 3 W..	......do...............	285
JD-436	........do..........................	........do..........................	......do...............	263
				ST. LANDRY
SL- 91	Humble Oil Co................	Sec. 101, T. 6 S., R. 4 E...	Layne-Louisiana...	433
SL- 92	........do..........................	........do..........................	......do...............	424
				ST. MARTIN
SMn- 76	Anse LaButte Co...............	Sec. 43, T. 9 S., R. 5 E.....	Stamm-Scheele....	180
SMn- 77	........do..........................	........do..........................	......do...............	180
SMn- 73	Evangeline Pepper and Food Co.	Sec. 56, T. 10 S., R. 6 E...	Layne-Louisiana...	225
SMn- 74	........do..........................	........do..........................	....	225
SMn- 95	........do..........................	........do..........................	A. W. Eggleston..	215
SMn- 37	Gordy Salt Co...................	Sec. 71, T. 9 S., R. 5 E......	Stamm-Scheele....	160
SMn- 38	..........do........................	........do..........................	C. L. Bond..........	240
SMn- 92	..........do........................	........do..........................	Stamm-Scheele....	195
				VERMILION
Ve-132	The Texas Co..................	Sec. 21, T. 13 S., R. 4 E...	Stamm-Scheele....	414
Ve-133	........do..........................	........do..........................	......do...............	291
Ve-134	........do..........................	........do..........................	......do...............	291
Ve-135	........do..........................	........do..........................	......do...............	291
Ve-535	........do..........................	........do..........................	......do...............	275
Ve-539	........do..........................	........do..........................	......do...............	260

water users, by parish and industry— Continued

Casing				Length of screen (feet)	Pump setting	Yield (gpm)	Drawdown (feet)	Date of completion	Water level
Pit		Well							
Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)						
PARISH									
...	...	...	8	...	...	750	...	1947	...
...	...	...	6	...	...	10	...	1947	...
...	12	...	8	...	...	1,000	...	1948	...
192	18	60	10	80	120	2,000	...	Nov. 1950	34
183	12	70	8	70	120	2,000	...	Oct. 1951	34
PARISH									
330	12	67	7	82	100	430	...	Feb. 1949	56
330	12	64	7	84	100	440	...	Mar. 1949	52
PARISH									
...	...	...	8	40	80	300	...	1949	19
...	12	...	6	40	80	300	...	1946	19
...	...	...	6	30	...	**150	...	1936	...
...	...	...	6	20	...	200	...	1938	...
140	16	20	10	60	...	2,000	...	Sept. 1951	12
...	12	...	...	60	...	2,200	...	1942	...
...	10	...	...	20	...	250	...	1924	5
82	24	66	12	59	...	...	...	Aug. 1946	...
PARISH									
211	22	150	10	80	100	*1,200	...	Aug. 1943	...
...	22	211	10	80	100	*847	...	Sept. 1943	...
...	...	...	...	80	100	*594	...	Oct. 1943	...
...	...	...	...	80	100	*1,451	...	Nov. 1943	...
224	20	21	12	49	100	*1,192	...	Oct. 1951	16
155	20	56	12	69	...	...	...	Nov. 1951	...

Table 23.—*Records of representative*

[Screen diameter in most wells same as well diameter. Pump setting and water

Well no.	Owner	Location	Driller
			ACADIA
Ac- 94	J. B. Stokes	Sec. 33, T. 8 S., R. 1 E.	Stamm-Scheele
Ac-217	A. Loewer	Sec. 32, T. 7 S., R. 1 E.	Coastal Water Well Co.
Ac-218	J. A. Frey	Sec. 2, T. 8 S., R. 1 W.	F. I. Getty
Ac-236	La. Irrigation and Mill Co.	Sec. 44, T. 7 S., R. 2 E.	Layne-Louisiana
Ac-237	R. Daigle	Sec. 54, T. 7 S., R. 1 E.	Stamm-Scheele
Ac-261	T. Fuselier	Sec. 9, T. 7 S., R. 1 W.	Layne-Louisiana
Ac-271	D. Andrus	Sec. 50, T. 8 S., R. 2 E.	Stamm-Scheele
Ac-276	M. and A. Petitjean	Sec. 48, T. 9 S., R. 2 E.	do
Ac-277	L. Leonards	Sec. 24, T. 9 S., R. 1 W.	Coastal Water Well Co.
			ALLEN
Al- 33	M. Carroll	Sec. 35, T. 4 S., R. 4 W.	Coastal Water Well Co.
Al-107	F. Rostrum	Sec. 19, T. 6 S., R. 4 W.	do
Al-112	H. Guidry	Sec. 38, T. 6 S., R. 2 W.	do
Al-114	G. W. Reese	Sec. 23, T. 6 S., R. 3 W.	Layne-Louisiana
Al-134	A. LaPoint	Sec. 33, T. 6 S., R. 6 W.	Unknown
Al-135	M. Walker	Sec. 33, T. 5 S., R. 6 W.	Coastal Water Well Co.
Al-143	A. Richard	Sec. 21, T. 6 S., R. 4 W.	do
Al-146	C. Meaux	Sec. 19, T. 5 S., R. 3 W.	do
Al-150	H. Dear	Sec. 31, T. 4 S., R. 3 W.	do
Al-151	C. Kuntz	Sec. 15, T. 7 S., R. 4 W.	do
Al-152	Quartre Parish Co.	Sec. 15, T. 7 S., R. 6 W.	do
			BEAUREGARD
Be- 61	H. Buck	Sec. 22, T. 7 S., R. 8 W.	Coastal Water Well Co.
Be- 75	W. Girouard	Sec. 6, T. 7 S., R. 8 W.	do
			CALCASIEU
Cu-144	M. Chataignier	Sec. 32, T. 9 S., R. 6 W.	Stamm-Scheele
Cu-151	E. Daugenbaugh	Sec. 29, T. 10 S., R. 7 W.	Coastal Water Well Co.
Cu-451	Stanolind Oil and Gas Co.	Sec. 3, T. 11 S., R. 7 W.	Unknown
Cu-452	R. Boyer	Sec. 23, T. 8 S., R. 12 W.	Layne-Louisiana
Cu-453	C. Patterson	Sec. 34, T. 10 S., R. 10 W.	Coastal Water Well Co.
Cu-494	A. Gayle	Sec. 22, T. 10 S., R. 8 W.	Layne-Louisiana
Cu-515	M. Ellender	Sec. 8, T. 11 S., R. 10 W.	do
Cu-517	Helms and Steward	Sec. 12, T. 8 S., R. 9 W.	do
Cu-520	D. Lavoi	Sec. 8, T. 11 S., R. 6 W.	do
Cu-532	M. Gray	Sec. 22, T. 11 S., R. 11 W.	Coastal Water Well Co.
Cu-534	W. Corbello	Sec. 6, T. 10 S., R. 12 W.	do
Cu-550	C. Miller	Sec. 15, T. 8 S., R. 8 W.	do
Cu-568	Dripps and Rauser	Sec. 6, T. 9 S., R. 13 W.	Layne-Louisiana
Cu-569	A. Cormier	Sec. 23, T. 8 S., R. 13 W.	do
Cu-570	J. Johnson	Sec. 33, T. 8 S., R. 11 W.	do
Cu-578	F. Vail	Sec. 17, T. 11 S., R. 8 W.	Coastal Water Well Co.
			CAMERON
Cn- 10	Hebert, Helms and Co.	Sec. 28, T. 12 S., R. 7 W.	Layne-Louisiana
Cn- 21	Precht and Hebert	Sec. 4, T. 12 S., R. 8 W.	do
Cn- 37	A. Benoit	Sec. 14, T. 12 S., R. 3 W.	Coastal Water Well Co.

irrigation wells, by parish

level in feet below land-surface datum; water level is that of date of completion]

Depth (feet)	Casing				Length of screen (feet)	Pump setting	Yield (gpm)	Date of completion	Water level
	Pit		Well						
	Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)					

PARISH

305	....	....	....	12	....	....	1,417	1926	....
273	120	20	71	12	80	106	1,477	Mar. 1945	....
292	....	....	....	12	....	....	....	....	....
253	160	18	27	12	76	140	....	June 1948	80
241	128	18	48	8	78	109	....	Feb. 1947	....
275	100	24	106	10	80	....	....	1945	....
265	....	18	....	8	80	....	....	1944	46
299	120	22	....	10	105	107	....	July 1947	....
286	120	14	95	10	80	....	2,000	Dec. 1947	....

PARISH

287	102	16	108	8	94	80	2,200	Jan. 1942	35
242	108	14	72	8	80	70	....	Apr. 1946	....
267	119	20	80	12	80	100	....	May 1946	....
241	125	18	48	8	80	100	....	Apr. 1946	51
242	120	20	44	12	88	105	3,000	Apr. 1948	25
234	110	20	56	10	80	90	3,200	Apr. 1946	23
254	100	20	10	12	86	90	....	Jan. 1949	40
265	120	14	93	8	62	105	....	Apr. 1948	50
245	100	18	70	10	80	80	2,750	May 1947	....
274	150	14	86	8	80	105	....	Mar. 1948	35
244	101	20	73	10	80	80	....	Nov. 1947	....

PARISH

370	102	20	25	10	80	....	....	Dec. 1945	....
259	120	16	20	10	145	80	....	May 1945	....

PARISH

312	....	....	....	10	....	....	2,500	July 1943	....
849	99	18	661	10	100	82	2,750	Aug. 1943	30
380	....	....	....	10	....	....	3,100	Feb. 1944	....
433	....	....	....	8	....	....	....	May 1946	....
352	101	20	178	10	84	....	....	Nov. 1948	....
577	160	20	384	12	80	100	....	July 1949	....
573	120	18	399	10	85	....	....	June 1948	30
439	105	18	265	10	82	85	....	1943	....
414	129	18	200	14	80	120	2,000	Aug. 1948	....
568	....	....	....	....	100	....	....	May 1948	....
550	100	18	358	10	60	80	2,800	Mar. 1947	12
447	135	14	262	18	84	120	2,500	Mar. 1949	35
450	....	22	....	10	80	120	3,000	Sept. 1951	31
453	....	20	....	10	80	100	....	Mar. 1951	23
400	....	26	....	12	80	100	....	Apr. 1951	37
697	....	....	....	14	....	....	3,800	Aug. 1947	20

PARISH

376	....	24	....	10	80	61	2,700	July 1937	6
383	84	18	228	12	83	60	3,000	Feb. 1943	12
287	98	12	92	8	80	....	....	June 1948	....

Table 23.— *Records of representative*

Well no.	Owner	Location	Driller
			EVANGELINE
Ev-153	W. Brandt	Sec. 9, T. 6 S., R. 2 E	Stamm-Scheele
Ev-160	C. Rozas	Sec. 20, T. 5 S., R. 2 E	Layne-Louisiana
Ev-172	V. Morein	Sec. 25, T. 4 S., R. 2 E	Coastal Water Well Co
Ev-194	C. Landreaneau	Sec. 10, T. 6 S., R. 1 W	Layne-Louisiana
Ev-203	J. Stockwell	Sec. 41, T. 6 S., R. 2 W	Coastal Water Well Co
Ev-226	Fuselier and Hebert	Sec. 14, T. 5 S., R. 1 W	Layne-Louisiana
Ev-356	Perron and Perron No. 2	Sec. 59, T. 5 S., R. 2 E	H. Brown
Ev-358	L. Wade	Sec. 24, T. 4 S., R. 1 W	Eunice Iron Works
Ev-359	Comeaux and Reed	Sec. 22, T. 5 S., R. 1 W	Stamm-Scheele
Ev-371	J. Fuselier	Sec. 59, T. 5 S., R. 2 E	Coastal Water Well Co
Ev-372	A. Fontenot	Sec. 37, T. 4 S., R. 1 E	Layne-Louisiana
Ev-379	A. Vidrine	Sec. 58, T. 4 S., R. 3 E	H. Brown
			IBERIA
I- 19	Jefferson Island Salt Co	Sec. 59, T. 12 S., R. 5 E	Layne-Louisiana
I- 62	E. Duhon	Sec. 65, T. 12 S., R. 5 E	Stamm-Scheele
			JEFFERSON DAVIS
JD-141	T. Plunket	Sec. 17, T. 7 S., R. 3 W	Layne-Louisiana
JD-218	Cline Estate	Sec. 36, T. 9 S., R. 5 W	do
JD-259	R. Hayes	Sec. 2, T. 10 S., R. 5 W	Coastal Water Well Co
JD-239	S. Lejeune	Sec. 15, T. 8 S., R. 4 W	do
JD-251	Treme Bros	Sec. 35, T. 7 S., R. 4 W	do
JD-290	M. Augustine	Sec. 2, T. 9 S., R. 6 W	do
JD-298	C. Guidry	Sec. 28, T. 10 S., R. 3 W	do
JD-309	R. Monger	Sec. 28, T. 8 S., R. 5 W	Unknown
JD-313	Wolverton and Johnson	Sec. 12, T. 8 S., R. 4 W	do
JD-329	J. Campbell	Sec. 20, T. 9 S., R. 4 W	Coastal Water Well Co
JD-331	Lockmoor Co	Sec. 1, T. 8 S., R. 7 W	do
JD-344	A. Peloquin	Sec. 15, T. 9 S., R. 3 W	do
JD-352	M. Augustine	Sec. 2, T. 8 S., R. 6 W	do
JD-384	T. Strohe	Sec. 15, T. 10 S., R. 4 W	do
JD-386	F. Lyons	Sec. 19, T. 11 S., R. 4 W	do
JD-387	R. Fontenot	Sec. 20, T. 7 S., R. 5 W	do
JD-389	R. Arceneaux	Sec. 9, T. 11 S., R. 3 W	do
JD-397	H. Langlinois	Sec. 35, T. 6 S., R. 4 W	do
JD-411	R. Fontenot	Sec. 16, T. 10 S., R. 6 W	do
			LAFAYETTE
Lf-129	C. Hanks	Sec. 2, T. 10 S., R. 3 E	Stamm-Scheele
Lf-478	C. Bradford	Sec. 31, T. 9 S., R. 3 E	do
Lf-494	A. LaCroix	Sec. 1, T. 10 S., R. 2 E	do
			ST. LANDRY
SL- 82	J. Miller	Sec. 58, T. 5 S., R. 4 E	Stamm-Scheele
SL- 93	E. Simmons	Sec. 42, T. 6 S., R. 2 E	do
SL- 97	L. Richard	Sec. 11, T. 7 S., R. 2 E	do
			ST. MARTIN
SMn- 80	E. Choplin	Sec. 7, T. 11 S., R. 7 E	Layne-Louisiana

irrigation wells, by parish— Continued

Depth (feet)	Casing: Pit, Length (feet)	Casing: Pit, Diameter (inches)	Casing: Well, Length (feet)	Casing: Well, Diameter (inches)	Length of screen (feet)	Pump setting	Yield (gpm)	Date of completion	Water level
PARISH									
258	124	20	54	10	83	116	3,000	May 1948	....
236	140	18	20	10	85	120	....	Apr. 1948	57
240	131	20	32	12	84	....	2,900	Jan. 1948	67
260	122	16	84	8	64	100	1,500	1944	56
249	120	18	50	10	88	100	3,000	Feb. 1948	50
263	140	18	39	10	85	128	....	Apr. 1948	....
250	....	24	....	12	....	125	....	1946	....
214	....	....	....	12	61	130	1,460	July 1948	....
270	151	22	33	12	104	....	3,200	July 1947	56
206	136	10	....	6	60	120	....	Dec. 1948	....
215	145	18	5	14	60	....	....	Oct. 1948	100
225	....	....	....	12	60	....	2,400	Dec. 1950	....
PARISH									
477	....	....	....	....	80	....	3,000	Aug. 1917	....
419	70	24	284	12	83	47	2,821	Mar. 1949	4
PARISH									
307	....	....	....	12	53	....	....	July 1925	....
380	....	....	....	10	....	....	....	1918	....
279	106	16	89	8	80	....	....	Mar. 1946	....
357	121	20	140	12	100	100	3,600	Apr. 1947	46
258	103	16	70	8	80	....	....	Feb. 1945	....
322	....	16	....	8	79	100	2,500	June 1946	....
297	100	16	....	8	80	80	....	Jan. 1943	....
285	....	....	....	....	....	....	....	Apr. 1925	34
333	....	....	....	....	....	....	....	Apr. 1917	....
300	106	18	90	12	100	94	2,800	July 1943	....
183	100	18	22	10	64	85	....	Apr. 1947	30
339	100	20	159	12	80	90	....	Feb. 1946	....
329	....	16	....	8	85	80	....	May 1946	....
343	100	20	170	12	80	80	....	June 1946	....
265	100	18	75	12	100	80	2,700	....do........	15
296	102	16	100	8	90	80	2,500	Jan. 1942	35
288	120	14	86	8	90	100	....	May 1948	....
265	105	18	85	10	85	80	....	Jan. 1947	....
406	120	20	104	10	82	....	....	Oct. 1948	....
PARISH									
350	....	....	....	8	50	....	2,265	1926	....
282	....	....	....	....	65	....	2,000	May 1943	....
279	149	12	....	8	61	93	....	June 1948	49
PARISH									
282	....	22	....	10	....	97	2,000	Mar. 1947	62
265	152	16	64	12	....	....	3,000	Feb. 1949	73
242	149	22	20	10	83	109	....	Nov. 1948	63
PARISH									
236	80	24	84	10	80	....	....	Apr. 1937	....

Table 23.—*Records of representative*

VERMILION

Well no.	Owner	Location	Driller
Ve- 58	O. Vincent	Sec. 21, T. 11 S., R. 3 E.	J. Ritter
Ve-298	H. Abadie	Sec. 4, T. 12 S., R. 3 E.	Stamm-Scheele
Ve-322	A. Adam	Sec. 19, T. 11 S., R. 2 E.	do
Ve-354	A. Hair	Sec. 10, T. 12 S., R. 1 W.	Coastal Water Well Co.
Ve-370	J. Zaunbrecher	Sec. 35, T. 11 S., R. 2 W.	Stamm-Scheele
Ve-442	R. Simon	Sec. 36, T. 13 S., R. 1 W.	Coastal Water Well Co.
Ve-458	A. Hebert	Sec. 29, T. 12 S., R. 2 E.	H. Brown
Ve-489	G. Leger	Sec. 34, T. 11 S., R. 1 W.	Stamm-Scheele
Ve-501	G. Bares	Sec. 1, T. 12 S., R. 4 E.	do

irrigation wells, by parish— Continued

PARISH

Depth (feet)	Casing				Length of screen (feet)	Pump setting	Yield (gpm)	Date of completion	Water level
	Pit		Well						
	Length (feet)	Diameter (inches)	Length (feet)	Diameter (inches)					
301	....	....	....	8	80	....	....	1920	....
291	102	22	86	10	111	87	....	Feb. 1947	12
255	79	22	94	10	89	66	....	Mar. 1947	20
278	79	25	137	12	81	52	....	Feb. 1943	....
314	....	12	....	10	80	42	....	1940	10
284	80	20	231	10	82	66	....	July 1948	30
236	....	....	....	8	60	60	2,000	Aug. 1948	20
250	80	20	92	8	86	65	....	Sept. 1946	10
227	80	18	84	8	65	67	....	Feb. 1950	17

QUALITY OF WATER

By Burdge Irelan

GENERAL FEATURES

This investigation of the water resources of southwestern Louisiana originally was intended to show the quantity of water that could be developed from surface and underground sources and to point out deficiencies in present supplies to meet current and expected needs. However, as soon as the study was begun, it became evident that any quantitative information would be incomplete unless the quality of water—that is, the amounts and kinds of minerals present in well and stream waters at various times, places, and depths—was determined also. These data are essential for determining the fitness of the waters for various uses. Because of insufficient time to study slow changes that might be occurring, the scope of the quality-of-water studies necessarily was limited to surveys of present conditions and examination of readily available records, both past and current.

MEANING OF THE TERM "QUALITY OF WATER"

Although chemically pure water is a compound of hydrogen and oxygen, the word water as used in this report includes the solid, liquid, and gaseous materials that it holds in solution or suspension. In surface and ground waters, the dissolved minerals are generally the same, although their amounts and proportions may differ widely. Surface water always contains some suspended inorganic sediment and varying amounts of biological material such as algae, bacteria, and other micro-organisms, whereas ground water generally is nearly free from these impurities. Ground water usually contains more dissolved gases than surface water because it is under more pressure. In its broadest meaning the term "quality of water" includes all factors—whether physical, chemical, or biological—that affect the fitness of water for use. The term is used widely to include the bacterial or sanitary condition of water. In this report, however, only the temperature and chemical characteristics are included in the term "quality of water." The quality of surface water changes rapidly with rainfall and streamflow, but the quality of ground water from a specific source normally changes rather slowly; in many places no changes in the quality of ground water are detectable over long periods.

387601 O - 56 - 22

For these reasons and because methods of development and treatment required frequently are different, ground and surface water are considered separately in some of the discussion that follows.

IMPORTANCE OF WATER ANALYSES

Chemical analyses furnish the basic data from which quality-of-water interpretations are made. These data are tools by which water sources and supplies are evaluated. They are helpful in tracing geologic relations and have been used in determining the source and movement of ground waters. They can be used as indices of salt-water encroachment and stream pollution.

In southwestern Louisiana, analyses are used to show the extent to which the highly mineralized sea water is drawn up the rivers during periods of heavy pumping and to follow the movement of salt-water during periods of rapid change in salinity.

TYPES OF ANALYSES

In theory, a complete chemical analysis should include determination of all substances present in any amount. As such an analysis would be prohibitively expensive, ordinarily only the amounts of those substances are determined that materially affect the utility of a water for a specific purpose, that can be helpful in showing geologic relations, or that can give information on sources and movement of water.

All but the simplest chemical analyses are made up of individual tests. Analyses used in this study have been divided into four general classifications, depending upon the number and type of separate determinations. In this report these classifications are designated complete, partial, preliminary, and test analyses.

Most of the analyses were made in the Geological Survey laboratory at Austin, Tex., by methods regularly in use (Collins, 1928, Am. Public Health Assoc., 1946). The field tests were made by Survey personnel using modifications of these methods.

Complete analyses, as used in this report, include the following determinations: Specific conductance, pH, silica, iron, calcium, magnesium, sodium, potassium, carbonate and bicarbonate, sulfate, chloride, fluoride, nitrate, boron, and dissolved solids. Hardness, sum of determined constituents, and percent sodium are computed values generally reported with complete analyses. In addition, some of the complete analyses included aluminum, manganese, phosphate, or other special determinations. Complete analyses were made of samples collected from many public- and industrial-supply wells, irrigation wells, and several streams.

Partial analyses included a smaller number of determinations. As a rule, such analyses did not include determinations of iron, sodium, potassium, fluoride, or boron. In partial analyses, sodium was calculated from the equivalent weights of the positive and negative ions. Partial analyses were made of many single and composite samples of surface waters and of a few samples of ground water.

Preliminary analyses consisted of the minimum number of determinations to outline the general water quality. They usually included only specific conductance, pH, carbonate and bicarbonate, chloride, and hardness, but occasionally they included silica and iron. In this investigation preliminary analyses were made of small samples transmitted by mail. Preliminary analyses also were made of a single sample from each of many inventoried wells that were not sampled for complete analysis.

Test analyses included analyses in which only chloride or specific conductance or both were determined. Most test analyses were made in the field instead of the laboratory. Some of the tests made in the field surveys were verified in the laboratory. Samples from key wells were collected for repeated tests to determine changes in quality of ground water that occurred as a result of prolonged pumping.

UNITS OF MEASUREMENTS AND EXPRESSION OF RESULTS

The tables of analyses included with this report give the chemical concentrations in parts per million by weight.

Water temperatures are reported in degrees Fahrenheit. Hardness is reported as parts per million of calcium carbonate. Specific conductance is reported as micromhos per centimeter at 25°C. Determinations of pH are reported on a numerical scale extending from 1 to 14, 7.0 being neutral, less than 7.0 increasingly acidic, and greater than 7.0 increasingly alkaline. Percent sodium is the ratio multiplied by 100 of the sodium to the total of calcium, magnesium, sodium, and potassium (if determined), all ions being expressed in equivalents per million.

The significance of the various constituents is discussed in the annual water-supply papers "Quality of the surface waters of the United States" (Water-Supply Paper 1022, 1030, and 1050).

In this investigation the specific conductance and chloride concentrations of the waters were of major importance. Methods of determining specific conductance and chloride concentration are discussed briefly in the following paragraphs because they were used extensively in salinity observations.

SPECIFIC CONDUCTANCE

The ionizable solids dissolved in water have the ability to conduct an electric current. This property of electrical conductance makes it possible to measure the approximate concentration of solids in solution by means of suitable electrical equipment. The determination is made in the laboratory by placing the water sample in a standard cell equipped with two fixed platinum electrodes between which an alternating current is passed. The resistance of the water to the passage of the current is measured by means of a Wheatstone bridge. The value obtained is adjusted for difference in temperature from the standard temperature of 25°C. The reciprocal of this adjusted resistance is the specific conductance in reciprocal ohms, more commonly called mhos. The conductance in mhos is multiplied by the factor 1,000,000 or 10^6 to eliminate inconvenient decimals and is expressed in micromhos.

The relation between specific conductance and dissolved solids is variable, depending upon the concentration and nature of the dissolved solids. A fairly close approximation of the dissolved solids in parts per million can be obtained by multiplying the specific conductance in micromhos by the factor 0.6.

Specific conductance was determined on all samples collected in southwestern Louisiana, which were authorized by the Austin laboratory.

A portable conductivity apparatus, developed commercially, is calibrated to read directly in approximate chloride or sodium chloride (salt) concentrations. Some of the salinity measurements furnished by the irrigation companies were obtained with this type of apparatus. Salinity measurements obtained with the portable conductivity apparatus usually are somewhat high in the lower concentrations (below 100 ppm of chloride) and low in the higher concentrations (above 700–800 ppm of chloride).

An attempt was made to find a more rapid method of following salt-water movement than was possible by collection of individual samples for chloride determination. A commercial resistivity instrument used to locate salt-water leaks in water wells was purchased and used on several surveys. This instrument, an adaptation of the Wheatstone bridge, used a high-frequency electric current in resistivity measurements. Although a few successful surveys were made with the instrument, it was found to be unreliable electrically.

CHLORIDE

The determination of chloride concentration is the most widely accepted single determination used in measuring the salinity of waters. Many irrigators make their own chloride determinations. They commonly use some modification of the Mohr method (Hillebrand and Lundell, 1929, p. 590), although some use is made of the conductivity apparatus previously mentioned.

In the Mohr method for determining chloride concentration, a sample of water of known volume, to which has been added a few drops of yellow potassium chromate indicator, is titrated to a red end point with a solution of silver nitrate of known concentration.

Although more accurate results are obtained when the titration is done under a yellow light, as is done in the laboratory, results obtained by the irrigators generally are good measures of salinity.

METHOD OF REPORTING ANALYSES

Analyses of water samples require the determination of quantities of substances which generally are present in minute amounts. Water analyses have been expressed in a variety of ways, depending on the methods employed and the uses to be made of the analyses. The most common method of expression, used by the Geological Survey in this and most other reports, is as parts per million of the substances determined. This has the advantage that few decimals are required and, for most analyses, not more than three or four figures are needed. One part per million equals one ten-thousandth of 1 percent.

It is desirable sometimes to illustrate results of water analyses by means of diagrams. This is done most conveniently when the analyses are expressed in equivalents per million. Equivalents per million are computed by dividing the concentration in parts per million for each constituent by its equivalent weight. Analyses of irrigation water frequently are reported by the Department of Agriculture in equivalents per million. This system facilitates the evaluation of the effects of the dissolved salts on the soil.

Methods commonly used in water analysis give the concentrations determined for the various ions or radicals but do not show how these ions or radicals were previously combined into mineral salts. Formerly, it was common practice to report ions or radicals together in "hypothetical combinations" in grains per gallon. This method of reporting still is used rather widely by industrial engineers, water-plant operators, and rice irrigators.

The unit grains per gallon is a member of the English system of measurements and is an expression of weight in volume. This unit gradually is being abandoned in favor of reporting in terms of parts per million. Parts per million is independent of volumes and holds regardless of the weight units used. Grains per gallon of any constituent may be converted to parts per million by multiplying by the factor 17.12. The rice irrigators customarily report their analyses as grains of sodium chloride (common salt) per gallon. For exact computations, concentrations expressed as grains of salt per gallon may be converted to concentrations in parts per million of chloride by multiplying by the factor 10.4. Field analyses commonly lack some of the refinements attainable in a well-equipped laboratory, so that the factor 10 ordinarily can be used in making this conversion. Conversely, analyses expressed in parts per million chloride can be converted to grains of salt per gallon by dividing by 10.

SOURCE OF CHEMICAL ANALYSES

Much information on the quality of water in southwestern Louisiana was available when the present investigation was begun. For many years the rice farmers and irrigation companies have used chloride determinations to determine the suitability of available water for irrigation. The Corps of Engineers has collected a mass of chemical data as a part of its salinity surveys in the coastal areas of southwestern Louisiana. The Lake Charles Association of Commerce has amassed salinity data for the Calcasieu River. The Geological Survey had included some analyses of stream waters from the area in an earlier survey of stream waters of the State. Many analyses were available in Survey files of samples collected in connection with its statewide water investigational program.

Plans were made to use as much of this information as possible. In addition, a new program of systematic collection of ground- and surface-water samples was begun to supplement the old data and the data being collected by others.

The ground-water sampling program included complete analyses of samples collected from all the public water supplies and many industrial wells. In addition, many samples were collected from irrigation wells and analyzed sufficiently to show general quality-of-water changes as well as changes in the chemical character of the water that were occurring during pumping.

The surface-water sampling consisted of daily sampling programs at key points on the three principal rivers in the area and an extensive spot sampling program throughout the area. It was planned to collect and analyze a sufficient number of samples to give an over-all picture of conditions during periods when streamflow is adequate to meet needs for water and when streamflow is inadequate.

RELATION OF CHEMICAL QUALITY TO USE OF WATER

INDUSTRIAL

The chemical quality of available water supplies is one of the most important considerations in planning and locating an industry. The rapid growth of industry in the Lake Charles area is an indication that water available there has been of suitable quality. The quality-of-water requirements for industries differ greatly, but the natural quality of water in streams and in the principal aquifers in southwestern Louisiana seems to have been satisfactory for most industrial purposes.

DOMESTIC

Water for domestic use preferably should be soft and should be low in dissolved solids. It should be free from unpleasant taste and odors, and from harmful bacteria. Ground waters available in the area meet most of these requirements. For that reason, ground water is used for almost all the public supplies in southwestern Louisiana. Although generally safe bacterially, public supplies of ground water in this area sometimes are chlorinated to insure safety.

U. S. Public Health Service standards are used most widely in evaluating water supplies for domestic use (U. S. Public Health Service Reports, 1946). To meet these standards, drinking water should contain no more than 250 ppm of chloride, 250 ppm of sulfate, and 125 ppm of magnesium. According to suggested standards, the dissolved solids should not exceed 500 ppm, although 1,000 ppm is permissible where water of better quality is not available.

Cities and towns in southwestern Louisiana in the past have been able to comply with these standards. Salt-water encroachment into the aquifers that are dependable sources of drinking water may at some future time force some communities to change the source of their water supplies if they are to continue to meet these standards.

RICE IRRIGATION

The suitability of water for rice irrigation depends not only on the concentration of its chemical constituents but also upon the stage of growth of the rice, the nature of the soil (porosity, permeability, drainage, and other factors), and the concentrations of harmful salts present in the soil prior to the application of the irrigation water.

Published standards of water quality for irrigation use were developed for arid regions where rainfall is not sufficient to prevent salt accumulation in the soil. Salt accumulation in the soil probably occurs very infrequently in southwestern Louisiana as the high rainfall normally leaches excess salts from the soil during periods when the land is not in cultivation. It is now recognized generally that quality-of-water requirements are much less rigid in regions of high rainfall (Staebner, 1940).

It is well known to the rice farmers in Louisiana that the concentration of salts in the irrigation water has an important effect upon the growth of rice. Salt-water damage to rice crops ranges from slight reductions in quality and yield to complete loss, depending upon the salinity of the applied water, the age of the rice when irrigated with the salty water, and the length of its application.

Data given in various publications on salt tolerance of rice differ widely. It generally seems to be agreed, however, that water containing less than 600 ppm of sodium chloride (35 grains of sodium chloride, salt, per gallon or 350 ppm of chloride) is not harmful to rice at any stage of growth.

The following is a digest of instructions issued by the Acadia-Vermilion Rice Irrigation Co., Inc., in 1937 in regard to salinity of irrigation water.

Water with more than 40 grains of salt per gallon should not be used to wet young rice for the first time.

The soil should not be allowed to dry after the first wetting.

No more than the following maximum salinities should be permitted. Salinity can be increased during stages as shown.

Permissible salinity of water for irrigation of rice in grains (salt) per gallon of water

[Multiply by 10 to give limits as parts per million of chloride]

Plant growth		Salinity	
		Variety of rice	
Stage	Age (days)	Blue Rose	Prolific
Stooling	25–30	75–100	75–100
Jointing	30–80	150–200	140–175
Booting	80–90	200–250	175–200
Heading	100–110	250–275	200–225

THE COMPOSITION OF SEA WATER

Ascertaining the presence or absence of sea water is one of the most important problems in the study of well and stream waters in coastal areas.

Sea water has been found to contain nearly all the elements, although most are present in very small amounts. Analyses of samples of sea water from various sources, including some from the Gulf of Mexico, are given in table 24. Minor constituents are omitted, and the analyses have been recalculated to the same form. Although the absolute amounts of the various constituents vary somewhat, the relative proportions are nearly constant.

The salinity of waters in the streams and wells of southwestern Louisiana may be due to contamination by industrial wastes or oilfield brines, to upward migration of underlying ground water of high salinity, or to encroachment of sea water from the gulf. As sea water has nearly constant ratios of its principal constituents, which is not true generally of salty water from the other sources, it is possible to determine by chemical analysis whether or not a source has been affected by salt-water encroachment from the Gulf of Mexico. If mixing of fresh waters with sea water has occurred, as in the rivers of southwestern Louisiana, it is possible to determine, with reasonable accuracy, the fraction of sea water present.

Significant ratios (constituents in parts per million), which may be used as indicators of the presence or absence of sea water are:

$$\frac{\text{Chloride}}{\text{Sulfate}} = 7.2 \qquad \frac{\text{Sodium}}{\text{Magnesium}} = 8.3 \qquad \frac{\text{Chloride}}{\text{Magnesium}} = 14.8$$

Table 24.—*Analyses of sea water collected by various investigators, in parts per million*

	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Density	Dissolved solids
1	423	1,324	10,970	429	147	2,750	19,770	....	35,800
2	419	1,304	10,710	390	146	2,690	19,350	....	35,000
3	400	1,272	10,561	380	142	2,650	18,980	....	....
4	420	1,316	10,722	382	151	2,696	19,324	....	....
5	426	1,258	10,220		149	2,560	18,200	1.022	32,700
6	343	1,060	8,760		133	2,200	15,500	1.019	27,900
7	371	1,118	9,382		148	2,268	16,625	....	....
8	423	1,240	10,440		161	2,532	18,500	....	....
9	241	728	5,650	241	117	1,500	10,300	1.011	18,700

1. Average concentrations of Gulf of Mexico as determined by Dale, K. B., 1914, Some chemical characteristics of sea water at Tortugas and around Biscayne Bay, Fla.; Carnegie Inst.; Washington, D. C., v. 5, rept. 182.
2. Analyses of sea water from 77 samples collected by Dittmar from different parts of the world. U. S. Geol. Survey, Water-Supply Paper 258, p. 82, 1911. Also Water-Supply Paper 557, p. 12.
3. Dissolved elements most prevalent in sea water. Original source: Sverdrup, H. U., Johnson, M. W., and Fleming, R. H., 1942, The oceans, their physics, chemistry, and general biology: 1807 p., New York, Prentice-Hall, Inc. Lange, N. A., 1946, Handbook of chemistry, p. 1237, Sandusky, Ohio, Handbook Publishers, Inc. Recomputed by Lange, reported as elements when originally published.
4. Nordell, Eskel, 1951, Water treatment, p. 347, New York, Reinhold Publishing Corp.
5. Field no. 60, about 1 mile south of Brazos Santiago Pass, 1 mile off Padre Island, Gulf of Mexico. Integrated from top to bottom. Depth: 25 ft, Date of collection: May 14, 1942, Collector: W. W. Hastings.
6. Gulf of Mexico near New Calcasieu Pass. Date of collection: March 8, 1944. Collector: Ambrose De Launey.
7. Analysis of water from Galveston surf, Gulf of Mexico. Collected and analyzed by W. W. Curtis, July 15, 1950, 5 miles west of Fort Crockett. Analyses of settled water—clear and colorless.
8. Analysis of water from Galveston surf, Gulf of Mexico. Collected and analyzed by W. W. Curtis, July 30, 1950, 10 miles west of Fort Crockett. Analyses of settled water—clear and colorless.
9. Sea water from Gulf of Mexico at Cameron, La., used by W. E. Edens in M. S. thesis investigation, La. State University. Date of collection: April 1950. This sample shows dilution from coastal streams.

For example, from table 25 it is readily seen that the chloride concentration of the water of Vermilion River usually is less than 100 ppm. On March 16–17, 1949, the chloride concentration was 247 ppm. Since none of the index ratios was approached, the water at that time contained no sea water. On October 2–3, 1949, the chloride was 620 ppm. All three index ratios approached the sea water values. Hence, it is obvious that the Vermilion River contained sea water on that date.

THE GENERAL QUALITY-OF-WATER PROBLEM IN SOUTHWESTERN LOUISIANA

The quality-of-water phase of this investigation was planned to yield such information as would be most useful in the quantitative appraisals of the available ground- and surface-water supplies. It was not expected that a complete picture of the quality of the available water would be achieved.

Considerations of water supply indicated that a quality-of-water investigation might furnish information upon the following subjects:

1. The extent and nature of the encroachment of salt water from the Gulf of Mexico up the stream channels and into the many canals.
2. Movements of salt water into the ground-water reservoirs from the stream channels during periods of salt-water encroachment.
3. Movement of salt water from the Gulf of Mexico into the water-bearing beds owing to the lowering of ground-water levels.
4. Movement of salt water—caused by heavy pumping of the fresh water—from lower to higher levels of the aquifers.

The first problem primarily concerned surface-water supplies, and the last three concerned the ground-water supplies. As the investigation proceeded, it became apparent that, although pertinent information was being collected touching on all the above problems, only the first could be treated in a comprehensive manner. A longer period of investigation involving different methods of study would be needed to obtain answers to the last three problems.

CHEMICAL CHARACTER OF SURFACE WATER

METHOD OF INVESTIGATION

For a detailed study of the quality of the stream waters of an area as large as southwestern Louisiana, a large number of samples must be collected and analyzed. The quality of water in the streams depends on various factors, the most important of which are stream discharge and quantity of water being pumped from the streams. Depth of channels and ease of access of salt water from the Gulf of Mexico also have a marked bearing on quality of water.

A single sample from a stream is not likely to show the quality of water that passes the sampling point for a very long period of time. Also, the single sample may not be representative of the stream and its tributaries for more than a few miles above or below the sampling point at certain times, whereas at other times it may be representative of the stream water from the mouth nearly to the source.

Early in the investigation it was apparent that detailed information could not be collected at all points that might be of interest. Although considerable fragmentary chemical information was available when the investigation began, no daily records were available and the information did not show what changes in chemical quality might be expected to occur from point to point in the streams. Accordingly, the quality-of-water investigation was divided into two parts: Collection of daily records at key points and stream or area surveys in which spot samples were collected from one or many points, either incidental to other work or at times of intensive study of salt-water occurrence and movement.

DAILY SAMPLING STATIONS

Daily water-sampling stations were established in January 1949 on the Vermilion River at Bancker's Ferry, Mermentau River at Lake Arthur, and Calcasieu River at the Naval Training Station at Lake Charles. Locations of the daily sampling stations are shown on plate 37. These points were selected for daily samples because it was believed that they were located where salt water could be detected before it reached the intakes for irrigation pumping plants. Also, the station locations would best indicate conditions in the individual basins and would show the differences in quality of water available during both the pumping and the nonpumping seasons.

At each station, top and bottom samples were collected in the deep part of the river channel by local observers. Samples were collected in 8-ounce bottles with a weighted sampler so arranged that the stopper could be removed when the bottle was on the bottom of the stream. Temperatures of the individual samples were taken at the time of collection. The samples were marked as to depth, temperature, date and hour of collection, and were shipped to the Survey laboratory at Austin at approximately monthly intervals for chemical analysis. An additional daily sampling station was operated on the Calcasieu River near Hecker, La., from March to September 1951. This station was established in order to determine whether significant changes in quality of water occurred upstream from the Lake Charles sampling station at points where highly saline water had been observed for considerable periods.

Daily samples were taken at these stations continuously for the period of the active investigation, except at the Lake Charles station. A gap in the record occurred there when there was a personnel change at the Naval Training Station in the summer of 1949. However, as there were no water shortages that year, this gap did not seriously affect the utility of the record as an index to river conditions.

Complete chemical analysis of each sample collected at the daily stations was not attempted because the additional information was considered unnecessary for this study. Instead, samples were grouped together on the basis of specific conductance, and partial analyses were made of composite samples.

Specific conductance provides a useful indication of the chloride concentration or total amount of dissolved material in a water sample but gives no information as to the exact amounts present. In order to define general relations, some chloride determinations also were made on the daily samples. These formed a basis for estimating chloride concentrations on individual samples on which only conductance was determined.

Following the determination of conductance on the individual samples, samples of similar conductivity were assembled for chemical analysis. The usual practice was to assemble composite samples for 10-day periods. When a considerable variation in concentration was indicated by the conductances, the samples were assembled for shorter periods.

The program of making analyses of composite samples, except for occasional short periods, was discontinued after one year, as it was felt that a sufficient number of analyses were then available to indicate the normal quality of water at the sampling points. Daily sampling, with specific conductance and occasional chloride determinations of the samples, was continued throughout the investigation, with occasional analysis of composite samples. The analyses of composite samples, by stations, are given in table 25. The individual conductance and chloride determinations are given in table 26.

AREAL SAMPLING SURVEYS

Southwestern Louisiana contains many hundreds of miles of river and ship channels and irrigation canals. A large number of water samples were collected and analyzed in order to determine the general pattern of water quality in the channels and to follow changes which occurred during periods of deficient streamflow and heavy pumping. These samples were collected both in areal surveys covering many streams and in single salinity surveys on individual streams designated hereafter as field surveys. Samples collected in surveys over the area were for the most part analyzed in the Survey laboratory at Austin, but the samples that were collected in connection with the river field surveys to give information on movement of salt water were tested only for chloride by engineers and chemists in the field.

The first river survey was made by automobile in May 1949 with stops at bridges and ferries. Serious streamflow deficiencies did not occur in 1949, and no further surveys were made that year. A comprehensive quality-of-water survey was made, however, in August 1949. During this survey samples were collected at more than 150 separate points in every parish in southwestern Louisiana.

Table 25.—*Chemical analyses of water from Vermilion, Mermentau, and Calcasieu Rivers*

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium + potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
													Parts per million[a]	Tons per acre-foot	Total	Noncarbonate	

VERMILION RIVER AT BANCKER'S FERRY, NEAR ABBEVILLE, LA.

[At Bancker's Ferry, 14.5 miles from mouth, and about 6 miles south of Abbeville, Vermilion Parish. Top and bottom samples were collected at this station and composited. Chemical analyses of composite samples in parts per million]

Date of collection	Specific conductance	pH	Silica	Iron	Calcium	Magnesium	Sodium + potassium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate	Dissolved solids, ppm	Tons per acre-foot	Hardness, total	Noncarbonate	Percent sodium
Jan. 18-21, 23-24, 28-31, 1949	211	7.3	8.2	0.50	4.8	7.3	24	35	8.2	40	0.0	1.5	112	0.15	42	13	56
Jan. 22	561	7.3	6.8	......	11	5.0	95	29	12	153	....	1.5	299	.41	48	24	81
Jan. 25-27	408	7.2	7.5	1.6	9.4	7.2	63	35	17	101	....	1.5	225	.31	53	24	72
Feb. 1-4, 8-10	183	7.3	8.6	.80	5.8	6.6	22	37	6.3	36	.0	1.0	105	.14	42	11	53
Feb. 5-7	310	7.2	8.8	1.4	7.0	7.1	41	35	6.1	71	....	1.0	161	.22	47	18	66
Feb. 11-14, 19	374	7.2	7.8	.05	10	4.4	57	37	5.2	92	....	1.0	196	.27	43	13	74
Feb. 15-18	136	7.3	6.2	.10	5.3	4.1	15	25	5.6	25	....	1.5	75	.10	30	10	52
Feb. 20-28	145	7.2	8.0	.10	7.7	4.2	14	36	4.7	22	....	.8	79	.11	36	7	45
Mar. 1-10	193	7.1	14	......	10	5.1	20	50	3.7	31	....	1.2	110	.15	46	5	49
Mar. 11-15	173	7.4	10	......	8.2	4.5	18	41	3.5	29	....	1.2	95	.13	39	5	51
Mar. 16-17	883	7.1	6.2	......	14	9.4	139	28	3.0	247	....	1.2	434	.59	74	50	80
Mar. 18-21, 24-25, 30	232	7.5	8.1	......	6.5	7.1	26	26	3.3	54	....	1.2	119	.16	45	24	55
Mar. 22-23	53	6.7	3.0	......	1.1	1.5	7.9	11	2	10	....	1.2	32	.04	9	0	66
Mar. 26-29, 31	121	7.1	4.8	......	4.7	2.2	16	23	2.8	23	....	1.2	66	.09	21	2	62
Apr. 1-10	129	7.1	5.4	......	6.3	5.5	11	28	3.0	25	....	2.2	72	.10	38	15	39
Apr. 11-13, 16-20	169	7.2	7.4	......	8.2	5.9	15	34	3.4	31	....	2.2	90	.12	45	17	42
Apr. 14-15	381	7.1	6.2	......	10	6.3	54	31	5	96	....	2.2	195	.27	51	25	70
Apr. 21-22, 24-30	174	7.0	7.2	......	6.5	3.3	23	30	4	35	....	1.8	96	.13	30	5	63
May 1-10	170	7.6	11	......	8.9	4.5	19	46	4.2	27	....	2.2	100	.14	41	3	50
May 11-19	160	7.5	11	......	8.7	4.1	19	46	3.5	26	....	1.5	96	.13	39	1	51
May 21-31	162	7.8	12	......	7.5	3.5	22	44	2.7	28	....	2.5	100	.14	33	0	59
June 2-4, 7-10	203	7.7	11	......	6.8	3.6	28	35	4.9	40	....	3.0	114	.16	32	3	66
June 12-15, 20	168	7.3	12	......	7.0	3.2	22	37	4	30	....	1.8	98	.13	31	0	61

June 16-19	302	7.3	12	....	8.7	4.1	45	38	4.0	71	....	1.5	165	.22	39	7	72
June 21-25	128	7.4	9.5	....	5.7	2.7	20	31	9	23	....	1.8	87	.12	25	0	63
June 26-30	223	7.4	13	....	12	5.3	23	53	4	36	....	3.0	122	.17	52	8	49
July 1-2, 4-10	243	7.4	13	....	14	6.0	26	70	6.0	36	....	1.8	137	.19	60	2	49
July 11-13	259	7.4	13	....	6.6	6.6	36	74	4	40	....	2.2	145	.20	44	0	64
July 15-20	126	7.3	7.2	....	5.5	2.5	16	30	2	23	....	.8	72	.10	24	0	60
July 21-28	125	7.1	8.4	....	6.4	3.3	13	35	3.0	17	....	1.8	70	.10	30	1	48
July 29-31	213	7.6	13	....	8.8	4.4	26	41	2.6	42	....	1.8	119	.16	40	6	59
Aug. 1-10	173	7.6	13	....	8.7	4.6	19	47	4.9	26	....	1.8	101	.14	41	2	50
Aug. 11-14	194	7.6	13	....	11	5.2	18	48	8.0	28	....	1.2	108	.15	49	10	45
Aug. 15	667	7.6	16	....	14	7.8	103	45	4	176	....	1.8	345	.47	67	30	77
Aug. 16-20	327	7.2	12	....	9.7	4.8	46	40	6.0	73	....	1.8	173	.24	44	11	69
Aug. 21-31	223	7.6	18	....	8.8	4.2	29	43	4.8	42	....	2.2	130	.18	39	4	61
Sept. 1-10	253	7.7	20	....	12	5.6	30	62	7.4	40	....	4.0	150	.20	53	2	55
Sept. 11-20	262	7.3	13	....	13	9.2	21	59	6.9	42	....	2.0	136	.18	70	22	40
Sept. 21-30	282	7.3	13	....	12	8.1	28	58	5.2	50	....	1.5	146	.20	63	16	49
Oct. 1, 4-6	260	7.4	9.2	....	8.9	5.9	31	39	7.2	52	....	2.0	135	.18	46	14	59
Oct. 2-3	2,210	6.9	10	....	28	45	345	53	82	620	....	1.0	1,160	1.58	255	212	75
Oct. 7-10	120	7.2	5.5	....	4.4	3.0	15	22	5	22	....	1.5	67	.09	23	5	58
Oct. 11, 14-15, 20	166	7.0	8.1	....	6.6	2.9	21	32	3.0	30	....	1.8	89	.12	28	2	61
Oct. 12-13, 16-19	255	7.0	9.8	....	8.4	2.8	37	38	3.4	54	....	1.2	135	.18	32	1	71
Oct. 21-31	160	7.4	12	....	7.6	3.8	19	42	3.9	25	....	1.5	94	.13	35	0	54
Nov. 1-2	119	7.2	9.4	....	6.2	3.9	12	34	5.8	16	....	1.2	71	.10	32	4	45
Nov. 3-5	342	7.2	11	....	8.8	5.8	50	39	5.9	82	....	1.2	184	.25	46	14	70
Nov. 6-11	689	7.1	12	....	14	7.8	107	36	5.8	186	....	1.5	352	.48	67	38	78
Nov. 12-20	288	7.6	16	....	13	5.7	37	64	6.8	54	....	1.2	165	.22	56	3	59
Nov. 21-25, 28-30	282	7.7	20	....	12	5.9	37	66	5.6	52	....	1.0	166	.23	54	0	60
Dec. 1-9	283	7.7	20	....	12	6.1	38	67	5.1	54	....	1.2	169	.23	55	0	60
Dec. 11-20	313	7.4	14	....	7.8	7.8	44	66	7.8	59	....	1.8	175	.24	52	0	65
Dec. 21-22, 30-31	234	.....	16	....	9.3	4.5	28	44	8.9	40	....	1.5	130	.18	42	6	59
Dec. 23-25, 27-29	535	.....	15	....	14	5.6	80	46	9.4	129	....	1.8	277	.38	58	20	75
Jan. 1-5, 7-8, 1950	262	.....	15	....	7.9	4.2	34	30	7.0	56	....	1.2	140	.19	37	12	67
Jan. 6, 9-10	143	.....	15	....	5.5	3.5	16	18	5	29	....	1.5	84	.11	28	13	55
Jan. 11-20	204	.....	14	....	4.2	3.3	31	26	5.6	45	....	1.5	117	.16	24	3	74
Jan. 21-27, 29-31	206	.....	15	....	6.2	3.7	29	34	4.7	42	....	1.8	119	.16	31	3	67
July 1-8, 10	158	7.0	13	....	8.1	5.9	14	43	3.1	24	....	2.5	92	.13	44	9	40
Sept. 21-30	428	7.5	21	....	21	9.3	50	95	7.5	78	....	4.0	238	.32	91	13	54
Apr. 5-10, 1951	229	7.4	9.2	....	9.8	8.8	20	41	7.3	43	....	1.5	120	.16	61	27	41
May 4-7, 10	916	6.9	14	....	11	11	150	66	13	234	....	2.5	468	.64	72	18	82

See footnotes at end of table.

Table 25.—*Chemical analyses of water from Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium + potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
													Parts per million[a]	Tons per acre-foot	Total	Noncarbonate	
MERMENTAU RIVER AT LAKE ARTHUR, LA.																	
[At bridge on State Route 25, 50.7 miles from mouth, about ½ mile east of Lake Arthur, Jefferson Davis Parish. Top and bottom samples were collected at this station and composited. Chemical analyses of composite samples in parts per million]																	
Jan. 19-20, 1949	192	7.2	6.0	...	3.8	3.1	33	24	13	42	...	0.8	114	0.16	22	3	76
Jan. 21-31	125	7.0	6.0	0.90	2.1	6.9	11	23	3.8	24	0.0	.8	67	.09	34	15	41
Feb. 1-5, 10	127	6.6	6.5	1.6	5.8	2.4	13	22	3.4	22	.0	.5	66	.09	24	6	54
Feb. 6-9	206	6.8	7.9	1.5	3.6	1.8	34	28	4.8	44	.0	.5	112	.15	16	0	82
Feb. 11-19	110	6.6	6.3	1.5	3.6	1.9	15	22	3.0	20	.0	.5	63	.09	17	0	66
Feb. 20-28	114	6.9	7.2	.15	4.2	3.6	10	22	3.5	18	...	1.0	58	.08	25	7	47
Mar. 1-10	104	7.6	8.8	...	3.9	2.8	13	26	2.9	17	...	.5	62	.08	21	0	56
Mar. 16-20	127	7.7	6.6	...	2.6	2.9	19	25	4.7	24	...	.0	72	.10	18	0	69
Mar. 21-31	111	6.8	5.0	...	3.2	6.2	7.5	20	3.5	21	...	.2	56	.08	34	17	33
Apr. 1-4, 6, 8-10	91	7.0	5.0	...	3.6	2.3	11	20	3.0	16	...	1.2	52	.07	18	2	57
Apr. 11-20	86	...	5.3	...	3.4	2.1	9.9	20	1.5	14	...	1.2	47	.06	17	1	56
Apr. 21-30	84	7.2	5.3	...	3.1	1.8	12	20	1.5	16	...	1.2	51	.07	15	0	63
May 1-10	80	6.8	5.3	...	3.2	1.9	11	20	2.0	14	...	.8	48	.07	16	0	59
May 11-20	70	6.8	4.8	...	2.8	1.9	9.9	20	1.5	12	...	1.8	45	.06	15	0	59
May 21-25, 27-31	90	7.2	6.5	...	3.2	2.2	15	24	3.8	18	...	1.0	62	.08	17	0	66
June 1, 3-10	125	7.1	8.1	...	3.8	2.6	20	22	5.2	27	...	1.5	79	.11	20	2	68
June 11-20	140	7.1	7.5	...	4.2	2.9	21	26	5.6	28	...	1.8	84	.11	22	1	27
June 21-30	180	7.2	8.4	...	4.6	3.4	27	28	6.7	38	...	1.2	103	.14	26	3	70
July 1-10	315	7.2	7.5	...	6.1	5.5	46	26	11	74	...	1.2	164	.22	38	17	73
July 11, 15-17	215	...	6.2	...	5.4	3.6	43	54	8	47	...	2.8	143	.19	28	0	77
July 18-20	145	...	7.5	...	5.2	2.3	29	60	2	23	...	2.8	101	.14	22	0	74
July 21-30	131	...	9.2	...	5.8	3.6	25	63	2.2	20	...	.8	98	.13	29	17	65
Aug. 12, 14-15, 18-20	150	...	8.4	...	6.5	4.4	26	67	2	24	...	.8	105	.14	34	0	63

Aug. 21-31	204	7.7	13	....	8.5	4.5	27	60	2.3	32	....	3.0	120	.16	40	0	60
Sept. 1-10	192	7.7	9.9	....	6.8	4.3	27	53	2.6	32	....	1.8	110	.15	35	0	63
Sept. 11-20	209	7.5	13	....	7.4	4.4	28	50	2.8	36	....	3.5	120	.16	37	0	62
Sept. 21-30	232	7.5	11	....	8.4	5.2	31	56	2.3	42	....	1.8	129	.18	42	0	61
Oct. 1-10	218	7.5	9.2	....	7.8	4.9	28	52	2.6	38	....	1.0	117	.16	40	0	60
Oct. 11-20	139	7.2	9.5	....	5.0	2.7	18	32	2.6	24	....	1.0	78	.11	24	0	63
Oct. 21-31	128	7.6	8.2	....	5.0	2.9	17	34	2.8	21	....	.5	74	.10	24	0	60
Nov. 1-10	164	7.4	9.2	....	6.0	3.5	22	40	2.4	29	....	.5	92	.13	29	0	62
Nov. 11-20	165	7.3	9.0	....	5.9	3.4	23	40	2.4	30	....	.2	94	.13	29	0	63
Nov. 21-25, 28-30	195	7.7	10	....	6.6	4.0	31	50	3.2	38	....	2.2	120	.16	33	0	67
Dec. 1-10	194	7.7	10	....	6.3	3.9	31	50	3.4	38	....	1.0	118	.16	32	0	68
Dec. 11-13, 16-19	247	7.0	6.5	....	7.8	5.4	31	36	4.4	50	....	4.2	127	.17	42	12	61
Dec. 14-15	60	6.5	.0	....	6.2	1.5	2.1	12	4	7.0	....	2.8	30	.04	22	12	17
Dec. 20-23	544	6.9	7.2	....	13	8.3	78	40	6.1	139	....	1.8	273	.37	67	34	72
Dec. 24-31	266	6.8	5.1	....	4.8	6.7	36	26	6.2	63	....	1.5	136	.18	40	18	66
Jan. 1-10, 1950	175	6.7	3.7	....	4.1	5.7	21	18	6.0	40	....	1.2	91	.12	34	19	57
Jan. 11-20	110	6.8	3.4	....	5.6	6.3	6.3	19	4.4	23	....	1.2	60	.08	40	24	26
Jan. 21-30	130	7.2	5.1	....	3.4	7.1	10	26	4.2	24	....	1.2	68	.09	38	16	38
June 21-30	110	6.8	6.4	....	4.4	4.4	11	32	1.9	16	....	2.2	62	.08	27	3	45
Sept. 11-13, 15-20	458	7.4	14	....	12	8.8	62	74	7.2	93	....	2.5	236	.32	66	6	67
Oct. 21-27	988	7.2	13	....	16	19	151	69	28	254	....	1.5	517	.70	118	62	74
Apr. 1-10, 1951	125	6.9	6.4	.31	3.7	2.4	18	18	4.7	25	....	3.0	72	.10	19	4	67

CALCASIEU RIVER AT LAKE CHARLES, LA.

[At foot of Ryan St., 42.4 miles from mouth, Lake Charles, Calcasieu Parish. Samples collected at U. S. Naval Reserve Training Station at foot of Nichols St., 44.0 miles from mouth, beginning September 1949. Unless noted as top (T) or bottom (B), samples are a composite of top and bottom. Chemical analyses of composite samples in parts per million]

Jan. 20-31, 1949	79	6.9	6.5	0.15	0.9	2.9	9.8	13	4.4	14	0.0	0.5	46	0.06	14	4	60
Feb. 1-10	75	6.5	7.8	.47	2.2	1.3	10	10	3.3	15	.0	.2	45	.06	11	3	67
Feb. 11-19	61	6.6	6.2	....	2.0	1.3	7.6	10	2.9	11	.0	.2	36	.05	10	2	61
Feb. 20-28	59	6.5	6.6	.50	2.0	1.7	7.1	12	3.3	10	.0	.0	37	.05	12	2	56
Mar. 1-10	66	7.3	8.1	....	2.1	2.2	7.4	16	3.2	10	....	.0	41	.06	30	17	53
Mar. 11, 15-20	67	7.1	6.8	....	2.3	2.1	8.2	16	3.0	12	....	.2	42	.06	32	20	54
Mar. 12-14	114	7.4	11	....	3.8	2.6	17	23	5.8	23	....	.0	75	.10	20	1	65
Mar. 22-28	39	6.6	3.0	....	1.2	1.7	4.6	8	3	7.0	....	.5	25	.03	10	3	50
Apr. 4-10	38	6.6	4.7	....	1.2	1.6	4.9	10	2.0	7.0	....	.2	26	.04	10	1	53

See footnotes at end of table.

Table 25.—*Chemical analyses of water from Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium + potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
													Parts per million[a]	Tons per acre-foot	Total	Noncarbonate	
CALCASIEU RIVER AT LAKE CHARLES, LA.—Continued																	
Apr. 11-20	38	6.3	4.5	....	1.4	1.0	4.8	10	1	6.0	....	0.5	24	0.03	8	0	58
Apr. 21-30	29	6.9	3.6	....	1.1	.9	4.1	10	1	4.0	....	.5	20	.03	6	0	58
May 1-10	47	6.7	7.1	....	1.4	1.4	4.9	12	1	6.0	....	.8	28	.04	9	0	54
May 11-20	73	6.9	12	....	2.4	1.6	11	18	1	14	....	.5	51	.07	13	0	65
May 21-27(T), 28, 29 (B), 31	165	7.0	15	....	3.6	3.8	23	23	4.9	35	....	1.2	98	.13	25	6	67
May 21-22(B), 24(B).	649	7.4	13	....	6.4	13	97	22	24	168	....	1.2	333	.45	70	52	75
May 23 (B), 26 (B)	1,140	7.4	13	....	9.2	22	172	23	42	300	....	1.8	571	.78	114	94	77
May 25 (B)	336	7.7	15	....	....	....	48	20	11	78	....	1.2	....	....	35	19	75
May 27(B)	1,950	7.6	18	....	....	....	306	28	65	540	....	1.2	....	....	204	181	78
May 29 (T)	3,860	8.8	32	....	18	12	255	1,730	50	435	....	.2	[b]2,100	2.86	94	0	27
June 1-5	124	....	20	....	4.0	3.3	26	54	2	24	....	.8	107	.15	24	0	71
June 11-16(T)	955	....	17	....	10	19	155	60	37	250	....	1.0	519	.71	103	54	77
June 11(B), 15-16(B)	7,370	....	22	....	58	155	1,260	79	322	2,220	....	....	4,080	5.55	782	718	78
June 12-14(B)	14,600	....	18	....	121	324	2,670	106	680	4,710	....	....	8,580	11.67	1,630	1,550	78
Aug. 25 (T)	1,620	7.1	15	....	15	38	239	21	67	442	....	2.8	914	1.24	194	176	73
Aug. 25 (B)	3,240	6.8	13	....	48	80	469	25	148	915	....	2.8	1,690	2.30	449	428	69
Sept. 3 (T), 5-10(T).	3,930	6.9	15	....	28	79	646	30	160	1,140	....	1.0	2,080	2.83	395	370	78
Sept. 3 (B), 5-10(B)	18,900	6.9	11	....	147	461	3,660	75	943	6,510	....	....	11,800	16.05	2,260	2,200	78
Sept. 11-19 (T)	5,360	7.0	16	....	37	110	894	35	224	1,580	....	.2	2,880	3.92	545	516	78
Sept. 11-19 (B)	21,600	7.2	12	....	171	558	4,330	83	1,110	7,740	....	....	14,000	19.04	2,720	2,650	78
Sept. 21-23, 25-28, 30 (T)	4,360	7.0	17	....	31	94	706	33	173	1,270	....	1.5	2,310	3.14	464	437	77
Sept. 21, 23, 25-28, 30 (B)	22,500	7.5	14	....	186	582	4,590	89	1,170	8,180	....	....	14,800	20.13	2,860	2,780	78
Oct. 1	27,900	7.8	15	....	232	699	5,410	103	1,400	9,700	....	....	17,500	23.80	3,450	3,370	77

Oct. 2	6,500	7.6	15	....	50	135	1,080	42	270	1,920	....	1.0	3,490	4.75	680	646	78
Oct. 3-5	12,900	7.6	16	....	106	301	2,260	62	580	4,090	....	....	7,380	10.04	1,500	1,450	77
Oct. 7	942	....	15	....	7.5	18	141	20	42	240	....	1.5	475	.65	92	76	77
Oct. 10-11, 14-18, 20	184	6.9	15	....	7.2	2.5	22	14	6.7	40	....	1.2	102	.14	28	17	63
Oct. 23, 25, 27, 29	177	....	14	....	7.0	3.2	21	18	6.8	38	....	1.2	100	.14	31	16	60
Nov. 1-2	138	....	13	....	3.8	2.4	20	16	6	30	....	1.8	85	.12	19	6	69
Nov. 6	297	....	14	....	....	....	44	16	12	72	....	1.5	....	....	32	....	75
Nov. 8	660	....	15	....	7.2	12	100	18	28	170	....	1.0	342	.47	68	53	76
Nov. 10, 15, 18(T)	1,470	....	13	....	13	27	216	18	53	385	....	1.8	718	.98	144	129	77
Nov. 10 (B)	18,800	....	14	....	171	422	3,540	74	883	6,290	....	....	11,400	15.50	2,160	2,100	78
Nov. 15, 18(B)	8,310	....	13	....	68	173	1,430	38	346	2,550	....	....	4,600	6.26	881	850	78
Nov. 21-22(T & B), 23, 30 (T)	2,430	....	13	....	20	46	384	26	96	675	....	1.2	1,250	1.70	239	218	78
Nov. 23, 30(B)	9,820	....	15	....	82	207	1,720	52	431	3,050	....	....	5,530	7.52	1,060	1,010	78
Dec. 2-3, 11-12(T)	1,910	....	15	....	16	35	300	20	75	525	....	1.0	977	1.33	184	168	78
Dec. 2-3 (B)	11,800	....	14	....	110	250	2,120	52	524	3,770	....	....	6,810	9.26	1,300	1,260	78
Dec. 4	5,780	....	13	....	46	116	991	34	240	1,750	....	1.0	3,170	4.31	592	564	78
Dec. 11 (B)	17,700	....	16	....	181	409	3,420	68	884	6,090	....	....	11,000	14.96	2,130	2,080	78
Dec. 12 (B)	2,930	....	14	....	....	....	473	24	120	832	....	1.0	....	....	290	....	78
Dec. 17, 19	1,300	....	13	....	9.2	23	188	14	50	328	....	.8	619	.84	118	106	78
Dec. 31	58	....	13	....	....	....	7.8	8	4	11	....	.8	....	....	10	....	63
Jan. 10-11, 13, 22, 24, 26, 1950	68	....	13	....	2.8	1.6	9.6	12	3.9	14	....	1.0	52	.07	14	4	61
July 27-31	1,180	6.6	11	....	9.4	23	185	17	45	325	....	.8	608	.83	118	104	77
Sept. 11-14 (B)	6,520	7.3	17	....	51	143	1,120	41	293	1,990	....	1.5	3,640	4.95	715	682	77
Apr. 12, 14, 17, 1951	1,270	6.5	15	....	12	23	193	14	55	335	....	3.0	643	.87	124	113	77
May 11-12, 17-18 (T & B), 19(T), 20 (B)	6,710	6.8	12	....	50	134	1,150	31	313	2,010	....	....	3,680	5.00	676	650	79

See footnotes at end of table.

Table 25.—*Chemical analyses of water from Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium + potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
													Parts per million[a]	Tons per acre-foot	Total	Noncarbonate	
CALCASIEU RIVER NEAR HECKER, LA.																	
[At Calcasieu Park near Hecker, Calcasieu Parish, 66.2 miles from mouth. Top and bottom samples were collected at this station and composited. Chemical analyses of composite samples in parts per million]																	
Mar. 21, 23-27, 29-30, 1951.........	84	7.0	17	....	3.2	2.7	10	26	4.4	11	....	0.5	62	0.08	19	0	54
Apr. 11-20.............	52	6.8	14	....	2.4	1.4	6.0	15	3.9	5.5	....	1.0	41	.06	12	0	53

[a]The sum of the mineral constituents, rather than residue on evaporation, is reported owing to the large amount of organic matter present.
[b]450 parts per million ammonia as NH_4.

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*

[Specific conductance (micromhos) at 25°C and chloride (parts per million)]

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January–December 1949																
1	...	...	...	...	218	217	...	...	208	202	...	...	162	166	...	...
2	...	...	...	...	156	155	...	...	204	202	...	...	161	165	...	...
3	...	...	...	...	139	139	...	...	196	198	...	...	117	124	...	...
4	...	...	...	...	144	144	...	...	196	196	...	...	141	119	...	...
5	...	...	...	...	308	294	...	...	180	180	...	...	111	112	...	...
6	...	...	...	...	312	295	...	...	179	176	...	...	105	106	...	...
7	...	...	...	...	311	297	...	...	179	179	...	...	111	111	...	...
8	...	...	...	...	139	138	...	...	174	179	...	...	116	116	...	...
9	...	...	...	...	212	210	...	...	190	190	...	...	127	127	...	...
10	...	...	...	...	235	235	...	...	196	217	...	...	127	127	...	...
11	...	...	...	...	344	340	...	...	195	193	...	...	153	159	...	...
12	...	...	...	...	571	571	...	...	195	195	...	...	155	167	...	...
13	...	...	...	...	316	320	...	...	192	192	32	...	164	159	...	...
14	...	...	...	...	306	311	...	...	163	164	28	...	455	458	...	...
15	...	...	...	...	174	184	...	...	73	97	9	16	299	302	...	...
16	...	...	...	...	126	128	...	...	877	875	244	...	174	174	...	...
17	...	...	...	...	102	106	...	...	880	880	...	...	172	171	...	...
18	166	162	...	...	128	128	...	...	383	384	94	...	172	171	...	...
19	138	136	...	...	303	306	...	...	196	191	...	...	181	174	...	...
20	258	260	...	...	150	146	...	...	186	187	...	...	181	166	...	...
21	233	257	...	...	148	146	...	...	189	191	...	...	158	154	...	...
22	554	568	...	...	146	146	...	...	47	47	...	...	156	154	...	...
23	176	177	...	...	142	143	...	...	56	58	10	...	...	...	...	...
24	181	182	...	...	121	122	...	...	234	230	...	...	145	146	...	...
25	465	462	...	...	142	151	...	...	236	246	...	...	145	146	...	...
26	399	390	...	...	143	144	...	...	119	114	22	...	228	228	...	...
27	337	338	...	...	129	129	...	...	139	138	...	...	226	228	...	...
28	228	229	...	...	146	147	...	...	144	137	...	...	163	162	...	...
29	210	211	...	...	...	...	...	...	108	106	18	...	162	160	...	...
30	217	215	...	...	...	...	...	...	192	189	44	...	176	176	...	...
31	216	219	...	...	...	...	...	...	87	83	16	...	...	...	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January–December 1949—Continued																
1	181	181	...	...	...	146	...	...	232	238	...	...	170	169	...	...
2	181	181	...	...	241	248	...	...	249	231	...	...	147	164	...	...
3	176	177	...	...	251	254	...	...	...	250	...	...	143	154	...	...
4	174	181	...	...	252	249	...	...	191	193	...	...	139	137	...	...
5	169	165	...	...	...	...	...	...	248	231	...	...	161	170	...	...
6	166	164	...	...	...	...	...	...	276	242	...	...	173	163	...	...
7	167	164	...	...	159	149	...	...	229	229	...	...	182	180	...	...
8	154	160	...	...	159	160	...	...	234	227	...	...	182	182	...	...
9	150	157	...	...	171	163	...	...	231	227	...	...	192	194	...	...
10	158	182	...	...	175	186	...	...	346	361	...	...	212	211	...	...
11	161	162	...	...	...	...	...	...	266	267	...	...	215	213	...	...
12	152	152	...	...	165	166	...	...	249	249	...	...	217	217	...	...
13	163	168	...	...	165	...	...	...	249	267	...	...	175	177	...	...
14	167	166	...	...	150	187	...	...	...	...	...	...	163	168	...	...
15	152	151	...	...	152	177	...	...	89	86	...	...	666	669	...	...
16	149	151	...	...	371	355	...	...	88	...	...	...	336	345	...	...
17	158	160	...	...	341	342	...	...	145	147	...	...	313	315	...	...
18	163	...	...	...	286	283	...	...	146	147	...	...	365	313	...	...
19	160	165	...	...	214	210	...	...	132	131	...	...	321	315	...	...
20	...	...	...	...	171	174	...	...	133	130	...	...	315	319	...	...
21	156	156	...	...	137	133	...	...	121	114	...	...	332	329	...	...
22	156	163	...	...	97	93	...	...	114	114	...	...	265	256	...	...
23	156	148	...	...	116	119	...	...	114	114	...	...	254	272	...	...
24	151	156	...	...	135	134	...	...	117	118	...	...	216	226	...	...
25	156	164	...	...	127	185	...	...	117	116	...	...	215	238	...	...
26	159	155	...	...	196	191	...	...	131	118	...	...	200	199	...	...
27	170	166	...	...	256	...	...	...	133	145	...	...	175	178	...	...
28	154	152	...	...	253	...	...	...	136	136	...	...	193	183	...	...
29	178	185	...	...	205	220	...	...	218	239	...	...	191	192	...	...
30	180	181	...	...	271	184	...	...	244	248	...	...	190	192	...	...
31	127	115	...	...	...	...	...	...	156	161	...	...	198	197	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	September				October				November				December			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January–December 1949—Continued																
1	197	219	...	...	262	257	...	...	113	115	...	...	285	285	...	...
2	247	261	...	...	1,840	2,250	...	...	122	124	...	...	286	284	...	...
3	247	248	...	...	2,070	2,590	...	...	302	293	...	...	300	286	...	...
4	247	251	...	...	315	326	...	...	328	344	...	...	292	268	...	...
5	245	249	...	...	296	338	...	...	384	384	...	...	263	258	...	...
6	259	267	...	...	183	176	...	...	662	663	...	...	258	263	...	...
7	257	260	...	...	105	115	...	...	680	712	...	...	265	305	...	...
8	261	262	...	...	93	91	...	...	691	708	...	...	282	283	...	...
9	260	269	...	...	138	153	...	...	704	698	...	...	280	282	...	...
10	266	265	...	...	126	126	...	...	656	643	...	...	...	...	...	...
11	255	...	...	...	206	191	...	...	470	491	...	...	327	319	...	...
12	242	249	...	...	264	251	...	...	258	262	...	...	318	319	...	...
13	244	240	...	...	241	236	...	...	254	257	...	...	338	337	...	...
14	244	239	...	...	141	142	...	...	262	264	...	...	368	309	...	...
15	236	234	...	...	136	135	...	...	262	264	...	...	291	293	...	...
16	272	292	...	...	231	255	...	...	264	264	...	...	302	309	...	...
17	300	293	...	...	225	225	...	...	249	255	...	...	376	384	...	...
18	268	375	...	...	270	270	...	...	260	263	...	...	297	301	...	...
19	237	268	...	...	252	251	...	...	268	266	...	...	268	236	...	...
20	210	229	...	...	174	185	...	...	268	266	...	...	237	332	...	...
21	224	228	...	...	157	157	...	...	275	272	...	...	...	330	...	...
22	244	242	...	...	157	157	...	...	290	283	...	...	329	326	...	...
23	277	298	...	...	171	175	...	...	290	283	...	...	804	808	...	...
24	283	288	...	...	173	187	...	...	284	279	...	...	682	674	...	...
25	298	305	...	...	176	176	...	...	283	281	...	...	494	505	...	...
26	300	305	...	...	151	151	...	...	...	...	...	...	...	...	...	...
27	...	320	...	...	180	174	...	...	...	...	...	...	454	461	...	...
28	278	279	...	...	167	168	...	...	255	253	...	...	448	457	...	...
29	274	276	...	...	180	179	...	...	279	285	...	...	486	503	...	...
30	267	271	...	...	116	116	...	...	281	280	...	...	213	225	...	...
31	...	...	...	...	114	118	...	...	...	...	...	...	188	192	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau and Calcasieu Rivers*— Continued

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January-December 1950																
1	234	221	...	...	189	188	39	...	192	192	...	...	210	206	39	...
2	281	243	...	...	203	197	...	...	172	168	...	...	139	134	...	...
3	228	233	...	...	209	210	...	...	189	187	...	...	...	156	...	...
4	...	269	...	...	212	214	...	...	110	111	18	...	124	129	...	...
5	...	234	...	...	209	215	...	...	221	214	...	...	156	159	...	...
6	86	124	...	...	213	219	...	...	363	336	...	...	204	203	...	...
7	285	271	...	...	216	219	...	...	367	368	...	...	163	174	...	...
8	292	285	...	...	205	208	...	...	207	215	...	...	171	163	...	...
9	157	160	...	...	180	182	...	...	172	175	...	...	164	181	...	...
10	164	156	...	...	178	179	...	...	196	199	...	...	183	186	...	...
11	156	159	...	...	266	264	45	...	195	196	...	...	157	172	...	...
12	186	176	...	...	96	99	...	...	211	211	...	...	...	...	...	...
13	266	270	...	...	...	94	...	...	200	202	...	...	195	183	...	...
14	234	240	...	...	94	106	...	...	199	200	...	...	189	184	...	...
15	209	214	...	...	82	83	10	...	380	384	...	97	219	222	...	...
16	208	212	...	...	171	164	...	...	148	157	...	...	219	222	...	...
17	218	221	...	...	204	214	...	...	...	...	...	...	218	219	...	...
18	173	176	...	...	196	199	...	...	296	301	...	...	221	219	...	...
19	173	178	...	...	203	200	...	...	301	301	...	...	176	180	...	...
20	194	194	...	...	196	195	...	...	301	296	...	...	163	163	24	...
21	202	195	...	...	201	203	...	...	179	199	37	...	178	172	...	...
22	182	185	...	...	201	201	...	...	192	189	...	...	192	191	...	...
23	223	222	...	...	201	200	...	...	177	176	...	...	286	283	...	...
24	221	222	...	...	226	229	...	...	183	178	...	...	261	263	...	...
25	182	186	...	...	226	227	...	...	177	176	...	...	269	263	...	...
26	158	159	...	...	232	229	...	...	178	183	...	...	267	264	...	...
27	162	158	...	...	216	214	...	...	179	175	...	...	294	282	...	...
28	...	...	...	...	178	180	31	...	187	192	...	...	261	286	...	...
29	268	257	...	...	...	...	...	...	189	192	...	...	262	266	...	...
30	275	265	...	...	...	...	...	...	189	200	...	...	288	283	41	...
31	187	185	...	...	...	...	...	...	189	189	...	...	...	...	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January–December 1950—Continued																
1	154	164	......	27	157	152	......	......	177	171	......	......	......	......	......	......
2	164	175	......	......	158	155	......	......	169	161	......	......	249	220	42	......
3	494	486	128	......	116	102	......	......	174	167	......	......	214	223	......	......
4	428	429	......	......	92	97	14	......	174	174	......	......	......	......	......	......
5	323	331	......	......	108	102	......	......	168	165	......	......	......	......	......	......
6	251	250	......	......	127	126	......	......	169	159	......	......	......	......	......	......
7	225	256	......	......	125	123	......	......	146	146	......	......	......	......	......	......
8	225	231	44	......	171	170	......	......	139	134	......	......	......	......	......	......
9	227	229	......	......	171	183	......	......	......	......	......	......	191	189	......	......
10	230	232	......	......	......	......	......	......	114	113	......	......	175	174	......	......
11	242	234	......	......	147	150	......	......	99	99	14	......	201	167	32	......
12	......	......	......	......	157	171	25	......	133	143	......	......	160	167	......	......
13	......	......	......	......	154	155	......	......	164	168	......	......	190	188	......	......
14	89	108	15	......	193	188	......	......	116	110	......	......	216	218	......	......
15	372	369	......	93	198	180	......	......	......	......	......	......	239	221	......	......
16	376	395	......	......	169	178	......	......	99	138	......	......	209	217	......	......
17	860	849	......	237	169	169	......	......	138	138	......	......	200	228	......	......
18	860	856	......	......	159	167	......	......	178	177	......	......	177	180	......	......
19	372	374	......	......	99	100	......	......	645	651	172	......	271	250	......	......
20	......	......	......	......	102	105	......	......	286	295	......	......	263	252	......	......
21	......	......	......	......	53	60	......	......	220	274	......	......	310	308	......	......
22	173	173	28	......	67	63	......	......	204	201	......	......	354	342	......	......
23	155	167	......	......	84	70	......	......	206	208	......	......	402	372	......	......
24	152	186	......	......	401	410	......	......	170	171	......	......	378	383	82	84
25	163	162	......	......	221	227	......	......	183	195	......	......	357	345	......	......
26	168	162	......	......	218	224	......	......	198	177	......	......	354	339	......	......
27	167	172	......	......	176	194	......	......	226	232	......	......	396	397	......	......
28	167	199	......	......	176	180	......	......	257	261	......	......	396	390	......	......
29	164	170	23	......	177	177	......	......	253	263	......	......	354	328	......	......
30	152	154	......	......	166	171	......	......	160	204	......	......	363	360	......	......
31	156	179	......	......	......	......	......	......	154	154	......	26	270	257	......	......

Table 26.— *Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*— Continued

Date	September				October				November				December			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January–December 1950—Continued																
1	294	268	52	......	307	308	......	......	443	449	......	......	677	633	147	......
2	293	287	......	......	302	302	......	......	444	451	......	......	741	724	......	......
3	262	259	......	......	348	271	72	58	447	444	......	......	751	729	......	......
4	243	237	......	......	244	254	50	......	512	511	......	......	723	714	......	......
5	280	288	......	......	327	324	......	......	......	......	......	......	......	......	......	......
6	334	320	61	......	331	324	......	......	552	531	......	......	......	124	......	......
7	360	358	......	......	332	325	......	......	878	894	205	......	114	122	......	......
8	354	358	......	......	345	348	......	......	734	675	......	......	125	132	......	......
9	360	356	......	......	347	345	......	......	743	739	......	......	324	320	82	......
10	319	318	......	......	342	349	......	......	740	740	166	......	954	957	273	......
11	331	332	......	......	342	353	......	......	......	......	......	......	922	888	......	......
12	340	340	......	......	356	354	......	......	762	760	......	......	......	......	......	......
13	364	355	......	......	384	378	......	......	1,860	1,960	498	......	522	510	136	......
14	373	406	......	......	345	342	......	......	1,770	1,810	......	......	516	508	......	......
15	368	375	......	......	420	418	......	......	1,360	1,320	......	......	......	......	......	......
16	857	866	......	......	362	362	......	......	1,210	1,220	309	......	287	286	......	......
17	465	461	......	......	362	362	......	......	1,210	1,250	......	......	......	......	......	......
18	524	586	120	137	601	853	142	525	971	983	......	......	312	320	......	......
19	387	377	......	......	413	409	......	......	538	536	106	......	218	220	......	......
20	357	354	......	......	392	393	......	......	538	561	......	......	215	225	......	......
21	350	368	......	......	419	393	79	......	534	535	......	......	......	......	......	......
22	469	459	......	......	465	465	......	......	522	526	......	......	259	248	......	......
23	458	460	......	......	460	451	......	......	484	486	......	......	250	246	......	......
24	460	465	......	......	468	448	......	......	484	486	......	......	......	......	......	......
25	469	476	......	......	453	448	......	......	477	475	94	......	216	215	......	......
26	465	469	......	......	456	535	......	......	600	595	136	......	221	216	43	......
27	465	463	......	......	488	450	......	......	515	516	......	......	......	......	......	......
28	454	458	......	......	460	456	......	......	515	514	......	......	......	......	......	......
29	350	351	......	......	447	448	......	......	573	577	......	......	......	......	......	......
30	312	307	......	......	444	444	......	......	......	......	......	......	......	......	......	......
31	......	......	......	......	457	448	......	......	......	......	......	......	......	......	......	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January—September 1951																
1	185	173							321	310	62	61	624	665	169	182
2	381	384							312	313			444	440	114	118
3	248	270							327	326			381	386		
4	307	310			234	233			312	313			332	338		
5	210	212			237	237			309	314			284	285		
6	295	296			239	252			305	306			252	254		
7	195	192			233	239			309	306			225	217		
8	163	161			220	230			231	229			201	199		
9	160	167	30		222	249			269	261			207	206		
10	255	262			202	184	42		279	280	49	49	207	210		
11	278	261	62		180	180			331	324			217	210		
12					222	220			343	324			196	195		
13	262	265			218	216			323	334			290	293		
14	291	300			217	218			328	336			299	299		
15	238	329			122	121			319	319			260	257		
16	237	240			117	119			263	263			281	244	54	44
17	237	243			105	106	17		261	258				405		88
18					270	289							255	255	46	46
19					274	270	65		250	253			182	183	32	32
20					383	383	100		188	195	25	28	196	197		
21					727	727	206		483	476	118	117	193	194		
22					524	524			503	471	124	117	237	233		
23					520	520	138		370	364			220	215	36	35
24					391	384	98		339	339			220	215		
25					328	328			312	315			219	218		
26					330	344			312	315			222	224		
27					326	338			303	286			255	324	44	63
28	260	260	63		350	326			229	230				258		
29									231	230			263	289		
30	260	260							131	110	21	18	262	263		
31									649	631	179	174				

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January-September 1951—Continued																
1	263	274	......	......	6,700	6,880	......	......	3,950	4,180	......	......	536	538	130	......
2	295	292	......	......	7,140	7,300	2,180	2,200	4,060	4,130	1,180	......	403	414	89	......
3	323	321	......	......	7,180	7,260	......	......	3,880	4,040	......	......	400	412	......	......
4	846	851	......	......	7,180	7,260	......	......	3,910	4,050	......	......	407	412	......	......
5	764	755	......	......	6,630	6,700	2,000	2,000	2,820	3,290	800	920	442	440	......	......
6	1,080	1,070	......	......	6,190	6,260	......	......	3,190	3,350	......	......	439	444	......	......
7	1,040	1,040	......	......	5,800	5,880	1,720	1,720	2,900	3,070	......	......	438	437	......	......
8	576	558	......	......	6,160	6,240	......	......	3,410	3,510	......	......	440	470	......	......
9	648	700	......	......	5,800	5,930	......	......	4,150	4,200	......	......	454	464	......	......
10	806	804	......	......	3,370	3,490	960	1,000	5,710	5,790	1,700	......	497	471	......	......
11	692	760	190	190	4,330	4,570	1,270	1,320	5,880	5,950	......	......	1,500	1,520	402	......
12	376	369	61	61	5,130	5,280	1,540	1,540	6,070	6,090	1,800	......	......	......	......	......
13	371	369	......	......	6,210	6,260	1,880	1,880	6,090	6,110	......	......	1,560	1,560	......	......
14	589	589	......	......	6,450	6,500	......	......	6,250	6,260	......	......	......	......	......	......
15	550	546	......	......	6,640	6,720	......	......	6,250	6,260	......	......	2,700	2,610	......	......
16	444	453	......	......	6,410	6,500	......	......	......	......	......	......	3,000	3,030	850	......
17	380	377	61	60	6,480	6,540	......	......	6,260	6,310	......	......	......	......	......	......
18	373	377	......	......	6,480	6,590	1,920	1,960	6,290	6,390	......	......	3,090	3,120	......	......
19	363	392	......	......	6,430	6,520	......	......	6,310	6,390	......	......	3,180	3,210	......	......
20	513	523	102	101	6,810	6,620	......	......	5,850	5,890	......	......	3,360	3,360	950	......
21	2,040	2,080	580	570	6,340	6,430	......	......	5,690	5,750	1,680	......	......	......	......	......
22	1,160	1,210	298	300	6,340	6,410	......	......	5,640	5,720	......	......	......	......	......	......
23	3,280	3,340	940	950	6,310	6,320	1,900	1,900	5,610	5,720	......	......	3,330	3,350	......	......
24	3,810	3,810	1,120	1,100	5,960	6,030	......	......	5,630	5,720	......	......	3,330	3,370	......	......
25	5,930	6,080	......	......	6,120	6,200	1,830	1,840	4,910	4,980	......	......	3,350	3,360	......	......
26	6,020	6,200	1,840	1,860	6,370	6,430	......	......	4,960	4,950	1,420	......	3,360	3,380	......	......
27	6,360	6,440	......	......	6,120	6,160	......	......	2,700	2,610	......	......	3,380	3,380	950	......
28	......	......	......	......	6,020	6,120	......	......	2,870	2,930	820	......	3,380	3,370	......	......
29	6,430	6,510	......	......	6,020	6,120	......	......	747	718	178	......	3,360	3,370	......	......
30	6,240	6,710	......	......	6,090	6,210	1,810	1,820	435	452	96	......	3,360	3,370	......	......
31	6,760	6,860	2,030	2,040	......	......	......	......	426	435	......	......	3,360	3,360	......	......

Table 26.— *Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*— **Continued**

Date	September			
	Conductance		Chloride	
	Top	Bottom	Top	Bottom
Vermilion River at Bancker's Ferry, near Abbeville, La., January-September 1951—Continued				
1	3,250	3,090	....	....
2	2,830	2,830	790	....
3	2,830	2,830	....	....
4	3,090	3,090	....	....
5	2,830	2,830	....	....
6	2,710	2,710	....	....
7	......	....	....	....
8	2,620	2,620	....	....
9	985	985	240	....
10	1,030	1,020	....	....
11	965	943	....	....
12	......	....	....	....
13	994	985	....	....
14	1,020	982	....	....
15	......	....	....	....
16	659	675	....	....
17	692	692	....	....
18	668	664	....	....
19	639	644	....	....
20	1,680	2,050	468	570
21	979	1,040	....	....
22	......	....	....	....
23	334	359	....	....
24	332	346	71	....
25	353	351	....	....
26	357	360	....	....
27	248	258	45	....
28	......	....	....	....
29	300	342	....	....
30	315	311	....	....
31	......	....	....	....

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mermentau River at Lake Arthur, La., January-December 1949																
1	...	...	...	...	126	125	...	...	102	103	...	...	101	102	...	...
2	...	...	...	...	110	110	...	...	109	109	...	...	94	95	...	...
3	...	...	...	...	95	95	...	...	112	112	...	...	99	83	...	...
4	...	...	...	...	102	100	...	...	109	109	...	...	78	73	...	...
5	...	...	...	...	131	131	...	...	104	102	...	...	...	...	...	...
6	...	...	...	...	208	219	...	...	92	97	...	...	74	73	...	...
7	...	...	...	...	238	235	...	...	92	92	...	...	...	...	...	...
8	...	...	...	...	188	186	...	...	99	97	...	...	89	96	...	...
9	...	...	...	...	163	163	...	...	102	98	...	...	95	97	...	...
10	...	...	...	...	114	113	...	...	104	102	...	...	86	84	...	...
11	...	...	...	...	147	134	...	...	...	...	...	...	76	76	...	...
12	...	...	...	...	103	103	...	...	...	...	...	...	71	70	...	...
13	...	...	...	...	92	91	...	...	...	...	...	...	82	81	...	...
14	...	...	...	...	97	97	...	...	...	...	...	...	106	103	...	...
15	...	...	...	...	101	96	...	...	...	...	...	...	93	91	...	...
16	...	...	...	...	90	91	...	...	164	157	...	...	92	93	...	...
17	...	...	...	...	89	89	...	...	124	124	...	...	88	86	...	...
18	...	...	...	...	130	131	...	...	124	125	...	...	79	79	...	...
19	179	178	...	...	100	99	...	...	119	123	...	...	77	76	...	...
20	201	198	...	...	108	105	...	...	117	113	...	...	77	78	...	...
21	131	130	...	...	119	119	...	...	107	126	...	...	67	68	...	...
22	102	102	...	...	101	102	...	...	105	105	...	...	72	65	...	...
23	104	104	...	...	96	138	...	...	92	91	...	...	82	79	...	...
24	120	120	...	...	96	97	...	...	118	118	...	...	77	82	...	...
25	114	113	...	...	101	101	...	...	92	91	...	...	123	124	...	...
26	110	109	...	...	100	100	...	...	90	90	...	...	93	92	...	...
27	103	104	...	...	93	94	...	...	81	84	...	...	104	104	...	...
28	106	106	...	...	125	126	...	...	70	71	...	...	80	82	...	...
29	107	107	...	...	...	...	...	...	124	121	...	...	69	70	...	...
30	151	149	...	...	...	...	...	...	120	120	...	...	70	72	...	...
31	154	161	...	...	...	...	...	...	95	83	...	...	...	...	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mermentau River at Lake Arthur, La., January–December 1949—Continued																
1	92	93	...	...	99	102	...	...	330	366	...	...	...	...	...	...
2	94	98	...	...	...	...	...	...	324	350	...	...	...	...	...	...
3	80	78	...	...	102	104	...	...	328	357	...	...	...	...	...	...
4	70	81	...	...	106	104	...	...	340	341	...	...	...	...	...	...
5	75	83	...	...	115	113	...	...	342	347	...	...	...	...	...	...
6	69	70	...	...	113	136	...	...	289	288	...	...	...	...	...	...
7	74	75	...	...	126	146	...	...	283	286	...	...	...	...	...	...
8	72	71	...	...	126	129	...	...	298	256	...	...	...	...	...	...
9	...	...	...	...	154	153	...	...	304	252	...	...	...	...	...	...
10	...	...	...	...	153	153	...	...	297	263	...	...	...	...	...	...
11	66	67	...	...	141	138	...	...	308	257	...	...	...	...	...	...
12	73	74	...	...	141	137	...	...	...	...	...	...	128	123	...	...
13	74	61	...	...	141	155	...	...	...	...	...	...	...	...	...	...
14	59	60	...	...	132	152	...	...	...	...	...	...	117	119	...	...
15	63	63	...	...	131	151	...	...	199	193	...	...	114	121	...	...
16	66	83	...	...	134	134	...	...	192	194	...	...	...	...	...	...
17	65	66	...	...	143	132	...	...	202	192	...	...	...	...	...	...
18	69	78	...	...	126	138	...	...	142	140	...	...	183	181	...	...
19	71	...	...	...	138	125	...	...	145	165	...	...	179	185	...	...
20	72	69	...	...	141	147	...	...	147	133	...	...	186	192	...	...
21	84	75	...	...	140	127	...	...	125	134	...	...	206	226	...	...
22	81	79	...	...	154	150	...	...	123	127	...	...	213	209	...	...
23	80	78	...	...	153	154	...	...	123	127	...	...	209	212	...	...
24	84	80	...	...	182	179	...	...	123	125	...	...	213	200	...	...
25	96	95	...	...	191	180	...	...	125	159	...	...	201	204	...	...
26	...	...	...	...	182	202	...	...	132	133	...	...	206	206	...	...
27	93	93	...	...	178	209	...	...	134	133	...	...	203	203	...	...
28	93	93	...	...	170	223	...	...	146	133	...	...	185	190	...	...
29	93	92	...	...	184	223	...	...	118	118	...	...	184	219	...	...
30	95	91	...	...	184	223	...	...	118	118	...	...	182	203	...	...
31	102	101	...	...	...	...	...	...	...	...	...	...	196	198	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	September				October				November				December			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
	Mermentau River at Lake Arthur, La., January-December 1949—Continued															
1	181	184	......	......	229	227	......	......	163	160	......	......	187	184	......	......
2	181	186	......	......	230	229	......	......	161	160	......	......	186	183	......	......
3	183	197	......	......	232	229	......	......	162	161	......	......	187	187	......	......
4	185	203	......	......	232	239	......	......	162	190	......	......	193	187	......	......
5	191	190	......	......	266	265	......	......	170	163	......	......	190	195	......	......
6	190	190	......	......	267	265	......	......	163	167	......	......	198	195	......	......
7	192	190	......	......	188	192	......	......	163	163	......	......	192	189	......	......
8	188	187	......	......	190	190	......	......	164	164	......	......	191	213	......	......
9	191	186	......	......	161	161	......	......	164	163	......	......	193	194	......	......
10	215	196	......	......	163	159	......	......	157	157	......	......	202	202	......	......
11	218	194	......	......	146	146	......	......	156	159	......	......	218	204	......	......
12	196	213	......	......	160	141	......	......	174	159	......	......	210	208	......	......
13	187	187	......	......	141	141	......	......	156	156	......	......	227	206	......	......
14	193	193	......	......	140	135	......	......	159	159	......	......	55	62	......	......
15	189	198	......	......	137	144	......	......	165	165	......	......	53	53	......	......
16	193	199	......	......	138	168	......	......	163	163	......	......	284	295	......	......
17	199	197	......	......	126	127	......	......	165	164	......	......	294	287	......	......
18	224	193	......	......	126	132	......	......	165	167	......	......	236	251	......	......
19	230	240	......	......	122	122	......	......	168	167	......	......	238	234	......	......
20	230	235	......	......	124	137	......	......	168	168	......	......	532	569	......	......
21	221	221	......	......	128	146	......	......	172	170	......	......	537	525	......	......
22	221	221	......	......	125	125	......	......	190	193	......	......	541	538	......	......
23	221	221	......	......	146	125	......	......	257	191	......	......	541	541	......	......
24	221	221	......	......	123	120	......	......	191	192	......	......	284	308	......	......
25	241	230	......	......	119	123	......	......	190	194	......	......	311	284	......	......
26	236	244	......	......	119	117	......	......			......	......	291	284	......	......
27	233	238	......	......	125	125	......	......	......	......	......	......	285	282	......	......
28	245	236	......	......	125	125	......	......	183	192	......	......	283	282	......	......
29	243	236	......	......	127	133	......	......	209	185	......	......	287	284	......	......
30	235	237	......	......	131	137	......	......	185	185	......	......	184	185	......	......
31	......	......	......	......	127	127	......	......	......	......	......	......	184	184	......	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mermentau River at Lake Arthur, La., January–December 1950—Continued																
1	184	206	......	......	92	93	16	......	106	99	......	......	75	79	11	......
2	188	186	......	......	112	102	......	......	100	98	......	......	75	79	......	......
3	192	195	......	......	111	105	......	......	151	160	......	......	82	75	......	......
4	196	213	......	......	112	115	......	......	160	153	......	......	88	79	......	......
5	193	192	......	......	118	118	......	......	153	152	......	......	......	......	......	......
6	193	192	......	......	118	119	......	......	152	153	31	......	82	76	......	......
7	193	......	......	......	122	121	......	......	73	73	12	......	76	92	......	......
8	120	124	......	......	123	123	......	......	76	81	......	......	83	102	......	......
9	134	123	......	......	125	124	......	......	76	73	......	......	......	......	......	......
10	123	123	......	......	125	124	......	......	76	84	......	......	75	81	......	......
11	126	126	......	......	125	126	23	......	76	90	12	......	81	75	13	......
12	104	110	......	......	127	127	......	......	79	76	......	......	80	82	......	......
13	106	105	......	......	127	128	......	......	77	77	......	......	79	113	......	......
14	105	108	......	......	127	127	......	......	102	111	......	......	80	89	......	......
15	104	104	......	......	89	86	......	......	......	......	......	......	80	87	......	......
16	107	106	......	......	90	86	......	......	105	105	......	......	82	83	......	......
17	109	108	......	......	94	88	......	......	114	107	......	......	86	79	......	......
18	110	108	......	......	88	88	......	......	108	108	......	......	86	98	......	......
19	110	110	......	......	69	68	......	......	100	104	......	......	91	95	......	......
20	110	110	......	......	72	72	......	......	103	103	......	......	98	92	......	......
21	118	123	......	......	73	72	12	......	119	107	21	......	96	89	18	......
22	......	123	......	......	73	73	......	......	125	104	......	......	81	88	......	......
23	126	125	......	......	84	84	......	......	75	78	......	......	83	83	......	......
24	129	127	......	......	88	91	......	......	78	78	......	......	87	83	......	......
25	113	114	......	......	94	92	......	......	78	77	......	......	83	83	......	......
26	116	115	......	......	94	94	......	......	78	93	......	......	83	83	......	......
27	116	116	......	......	93	94	......	......	64	65	......	......	84	86	......	......
28	138	138	......	......	95	93	......	......	65	66	......	......	84	85	......	......
29	154	152	......	......	......	......	......	......	81	65	......	......	87	91	......	......
30	148	150	......	......	......	......	......	......	65	66	......	......	89	88	......	......
31	......	......	......	......	......	......	......	......	65	66	......	......	......	......	......	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu River*—Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mermentau River at Lake Arthur, La., January-December 1950—Continued																
1	88	87	......	13	......	......	......	......	113	115	15	......	......	......	......	......
2	172	168	......	......	......	......	......	......	120	111	......	......	......	......	......	......
3	179	177	......	......	......	......	......	......	114	119	......	......	......	......	......	......
4	179	183	......	......	......	......	......	......	......	......	......	......	......	......	......	......
5	184	193	......	......	......	......	......	......	......	......	......	......	......	......	......	......
6	185	189	......	......	123	114	15	......	......	......	......	......	......	......	......	......
7	190	190	......	......	113	113	......	......	......	......	......	......	......	......	......	......
8	192	193	......	......	115	128	......	......	......	......	......	......	......	......	......	......
9	195	193	......	......	143	113	......	......	......	......	......	......	......	......	......	......
10	145	145	......	......	113	117	......	......	......	......	......	......	......	......	......	......
11	145	145	25	......	98	94	......	......	......	......	......	......	......	......	......	......
12	145	147	......	......	100	97	......	......	130	130	17	......	......	......	......	......
13	141	151	......	......	93	104	......	......	152	130	......	......	......	......	......	......
14	149	148	......	......	103	100	......	......	146	139	......	......	......	......	......	......
15	148	148	......	......	98	94	......	......	132	136	......	......	......	......	......	......
16	141	......	......	......	108	283	18	67	131	131	......	......	175	167	32	......
17	150	......	......	......	108	108	......	......	135	131	......	......	175	177	......	......
18	144	138	......	......	107	110	......	......	131	142	......	......	214	167	......	......
19	140	138	......	......	111	117	......	......	131	152	......	......	179	166	......	......
20	174	132	......	......	124	121	......	......	......	......	......	......	175	164	......	......
21	133	131	......	......	124	117	......	......	......	......	......	......	192	244	35	47
22	126	125	21	......	126	114	......	......	......	......	......	......	203	186	......	......
23	133	125	......	......	105	104	......	......	......	......	......	......	179	216	......	......
24	130	126	......	......	104	109	......	......	......	......	......	......	198	190	......	......
25	128	130	......	......	105	104	......	......	......	......	......	......	180	216	......	......
26	129	128	......	......	107	109	......	......	......	......	......	......	182	183	......	......
27	133	127	......	......	106	109	......	......	......	......	......	......	182	185	......	......
28	133	128	......	......	110	109	......	......	......	......	......	......	404	425	......	......
29	153	153	......	......	109	110	......	......	......	......	......	......	404	423	......	......
30	160	163	......	......	112	114	......	......	......	......	......	......	442	408	......	......
31	158	161	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Mermentau River at Lake Arthur, La., January-December 1950—Continued

Date	September				October				November				December			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
1	...	...	...	...	531	532	...	...	1,280	1,250	346	...	1,400	1,370	...	...
2	...	...	...	...	492	561	...	...	1,280	1,280	...	...	1,370	1,370	...	...
3	...	...	...	...	494	492	...	...	1,280	1,290	...	...	1,370	1,470	...	...
4	...	...	...	...	504	492	...	...	1,280	1,280	...	...	1,370	1,370	...	...
5	...	...	...	...	490	492	...	...	1,250	1,250	...	...	1,370	1,370	...	...
6	428	423	95	...	510	494	...	...	1,260	1,250	...	...	1,370	1,370	382	...
7	420	452	...	...	497	523	...	...	1,250	1,250	...	...	350	380	88	97
8	431	484	...	...	494	496	...	...	1,290	1,250	...	...	346	346	...	...
9	418	420	...	...	786	790	...	...	1,240	1,250	...	...	346	346	...	...
10	417	417	...	...	786	786	202	200	1,230	1,260	...	...	350	...	...	...
11	424	425	...	...	805	792	...	...	66	99	6.5	...	348	386	88	...
12	415	411	...	...	781	...	...	...	58	70	6.8	...	345	349	...	...
13	409	414	...	...	786	792	...	...	1,340	1,250	361	...	341	...	...	...
14	...	...	...	...	786	792	...	...	1,290	1,310	...	...	469	351	...	...
15	425	434	...	...	786	786	...	...	1,430	1,420	...	...	...	...	...	...
16	436	437	...	...	793	792	...	...	...	...	...	...	455	456	...	...
17	590	452	...	...	...	...	...	...	1,430	1,430	...	...	455	456	...	...
18	441	481	...	...	...	...	...	...	1,420	1,430	...	...	...	...	...	...
19	449	438	...	...	...	...	...	...	1,420	1,430	...	...	...	...	...	...
20	436	438	...	...	977	977	258	...	1,420	1,430	...	...	455	455	...	...
21	441	438	...	...	985	1,000	...	...	1,430	1,430	402	392	456	451	118	...
22	441	438	...	...	985	994	...	...	1,400	1,380	...	...	456	459	...	...
23	440	441	...	...	1,000	983	...	...	1,380	1,380	...	...	455	457	...	...
24	440	451	...	...	985	974	...	...	1,380	1,380	...	...	569	573	...	...
25	440	433	...	...	985	985	...	...	1,320	1,310	...	...	456	460	...	...
26	504	534	...	...	974	991	...	...	1,320	1,310	...	...	570	575	...	...
27	493	500	...	...	974	985	...	...	1,320	1,300	...	...	570	576	...	...
28	493	498	113	...	1,300	1,360	...	...	1,260	1,220	337	336	570	576	...	...
29	515	504	...	...	1,310	1,350	...	...	1,270	1,230	...	...	568	571	...	...
30	499	499	...	...	1,290	1,350	...	...	1,230	1,230	...	...	566	571	...	...
31	...	...	...	...	...	...	...	...	...	...	...	...	568	576	152	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mermentau River at Lake Arthur, La., January–September 1951																
1	573	573	......	......	279	279	......	......	158	165	......	......	117	123	......	......
2	570	560	......	......	285	277	70	......	162	156	......	......	123	125	......	......
3	439	481	......	......	109	104	22	......	162	157	......	......	121	121	......	......
4	439	443	......	......	108	114	......	......	166	208	34	42	124	135	......	......
5	439	441	......	......	107	103	......	......	168	173	......	......	148	128	......	......
6	441	441	111	......	104	103	......	......	171	166	......	......	139	110	......	......
7	183	189	41	......	104	104	......	......	168	167	......	......	119	113	......	......
8	172	172	......	......	105	104	......	......	167	173	......	......	113	114	......	......
9	173	173	......	......	105	103	......	......	168	171	......	......	113	113	......	......
10	175	174	......	......	130	144	......	......	169	172	......	......	157	113	......	......
11	141	167	......	......	147	145	......	......	171	173	......	......	115	114	......	......
12	146	145	......	......	184	174	......	......	187	173	......	......	114	116	......	......
13	215	214	......	......	......	......	......	......	154	165	......	......	122	133	......	......
14	216	212	......	......	......	......	......	......	161	161	......	......	121	116	......	......
15	240	213	......	......	......	......	......	......	194	172	......	......	143	116	......	......
16	218	228	......	......	......	......	......	......	175	172	......	......	140	120	27	21
17	215	216	......	......	......	......	......	......	171	170	......	......	......	......	......	......
18	242	234	......	......	......	......	......	......	177	171	......	......	......	......	......	......
19	236	224	......	......	......	......	......	......	181	232	......	......	......	......	......	......
20	224	217	45	......	......	......	......	......	182	171	35	32	......	......	......	......
21	174	171	......	......	......	......	......	......	201	172	......	......	......	......	......	......
22	201	170	......	......	......	......	......	......	180	172	......	......	130	135	......	......
23	184	170	......	......	......	......	......	......	193	179	......	......	134	131	24	23
24	191	189	......	......	......	......	......	......	190	179	......	......	132	132	......	......
25	174	169	......	......	......	......	......	......	176	173	......	......	136	134	......	......
26	191	184	......	......	......	......	......	......	177	179	33	34	128	123	......	......
27	182	203	41	......	......	......	......	......	279	280	64	64	123	124	......	......
28	248	272	67	......	......	......	......	......	287	282	......	......	124	124	22	21
29	273	279	......	......	......	......	......	......	282	284	......	......	124	121	......	......
30	277	274	......	......	......	......	......	......	288	282	......	......	123	123	......	......
31	260	285	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mermentau River at Lake Arthur, La., January-September 1951—Continued																
1	123	124	...	...	1,480	1,460	...	...	...	...	...	...	2,930	2,960	...	...
2	124	125	...	...	1,620	1,620	...	...	...	...	...	...	1,030	1,010	265	...
3	126	127	...	...	1,610	1,660	...	...	...	...	...	...	1,010	1,030	...	...
4	126	126	...	...	...	...	...	...	2,420	2,500	...	...	1,020	1,020	...	...
5	126	128	...	...	1,640	1,640	...	...	2,440	2,500	...	...	853	858	212	...
6	124	128	...	...	1,630	1,640	...	440	2,560	2,650	...	...	858	853	...	209
7	128	128	22	22	...	...	...	...	2,560	2,650	740	740	853	908	...	...
8	153	155	28	28	...	...	...	...	2,600	2,650	...	...	...	...	...	...
9	157	156	...	...	...	...	...	...	2,600	2,650	...	...	880	867	...	...
10	157	156	...	...	...	...	...	...	3,140	3,140	900	900	35	31	2	...
11	157	158	...	...	1,690	1,750	475	482	3,160	3,140	...	...	967	982	248	...
12	157	160	28	29	1,740	1,750	...	...	3,160	3,140	...	...	...	...	...	...
13	256	258	57	57	1,690	1,770	...	...	3,110	3,140	...	...	...	...	...	...
14	260	258	...	...	1,760	1,800	...	...	3,170	3,140	900	...	...	...	...	...
15	258	262	...	...	1,800	1,800	500	495	3,110	3,140	...	...	1,200	1,200	...	...
16	268	263	...	...	1,790	1,800	...	...	3,850	3,850	...	...	1,200	1,200	...	...
17	263	263	...	...	1,790	1,810	...	...	3,850	3,870	...	...	1,210	1,210	...	...
18	263	261	...	...	1,850	1,810	...	...	3,920	3,920	1,140	...	1,210	1,210	330	...
19	269	261	58	58	2,020	2,020	...	...	3,870	3,900	...	...	876	876	...	...
20	443	392	107	92	2,020	2,020	552	555	3,870	3,920	...	...	880	876	223	...
21	453	369	...	...	2,010	2,030	...	...	3,900	3,890	...	...	878	873	...	...
22	974	974	...	...	2,030	2,030	...	...	4,000	4,030	...	...	890	873	...	...
23	970	987	...	...	2,220	2,290	622	635	4,020	4,060	...	...	876	873	...	...
24	964	977	...	...	2,260	2,260	...	...	4,030	4,060	1,170	...	876	873	220	...
25	964	997	...	...	2,260	2,260	...	...	4,030	4,030	...	...	1,060	1,040	...	...
26	970	983	...	...	...	...	...	...	4,010	4,030	...	...	1,050	1,040	...	...
27	964	983	...	...	2,480	2,480	695	700	2,930	2,960	...	...	1,040	1,040	...	...
28	970	983	252	...	2,480	2,480	...	...	2,960	2,990	...	...	1,040	1,050	...	...
29	1,460	1,470	390	...	2,480	2,480	...	...	2,930	2,960	840	...	1,050	1,040	280	...
30	1,460	1,470	...	...	...	...	...	...	2,930	2,990	...	...	1,040	1,050	...	...
31	1,460	1,480	...	...	...	...	...	...	2,930	2,990	...	...	...	...	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	September			
	Conductance		Chloride	
	Top	Bottom	Top	Bottom
Mermentau River at Lake Arthur, La., January-September 1951—Continued				
1	1,140	1,120	......	......
2	1,040	1,010	......	......
3	1,020	1,040	......	......
4	1,020	1,010	......	......
5	1,060	1,020	280	......
6	903	903	......	......
7	913	903	......	......
8	903	919	......	......
9	891	942	......	......
10	891	926	......	......
11	838	822	......	......
12	838	822	......	......
13	856	828	......	......
14	834	828	......	......
15	834	828	203	......
16	644	626	......	......
17	632	632	147	......
18	654	632	......	......
19	648	649	......	......
20	644	644	......	......
21	644	644	......	......
22	......	......	......	......
23	644	649	......	......
24	644	649	......	......
25	644	649	......	......
26	512	534	......	......
27	487	481	102	......
28	......	......	......	......
29	......	......	......	......
30	......	......	......	......
31	......	......	......	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La., January-December 1949																
1	......	......	......	......	78	83	......	......	57	57	......	......	......	......	......	......
2	......	......	......	......	70	67	......	......	60	55	......	......	......	......	......	......
3	......	......	......	......	71	71	......	......	59	68	......	......	......	......	......	......
4	......	......	......	......	94	95	......	......	60	55	......	......	33	34	......	......
5	......	......	......	......	79	81	......	......	53	53	......	......	35	35	......	......
6	......	......	......	......	65	64	......	......	59	54	......	......	35	34	......	......
7	......	......	......	......	61	62	......	......	61	59	......	......	36	36	......	......
8	......	......	......	......	61	83	......	......	60	62	......	......	36	35	......	......
9	......	......	......	......	69	69	......	......	60	60	......	......	36	35	......	......
10	......	......	......	......	69	77	......	......	67	71	......	......	39	39	......	......
11	......	......	......	......	70	72	......	......	67	69	......	......	40	40	......	......
12	......	......	......	......	52	52	......	......	111	113	......	......	39	40	......	......
13	......	......	......	......	51	67	......	......	111	125	......	......	36	37	......	......
14	......	......	......	......	53	59	......	......	111	114	......	......	35	44	......	......
15	......	......	......	......	60	60	......	......	64	64	......	......	......	32	......	......
16	......	......	......	......	60	64	......	......	64	67	......	......	40	35	......	......
17	......	......	......	......	60	61	......	......	68	56	......	......	38	35	......	......
18	......	......	......	......	61	60	......	......	63	66	......	......	38	38	......	......
19	......	......	......	......	58	61	......	......	63	64	......	......	38	38	......	......
20	97	92	......	......	57	56	......	......	73	66	......	......	30	30	......	......
21	74	76	......	......	59	59	......	......	......	......	......	......	27	26	......	......
22	67	74	......	......	50	52	......	......	47	46	......	......	26	26	......	......
23	57	57	......	......	50	49	......	......	46	46	......	......	26	27	......	......
24	64	68	......	......	46	47	......	......	40	39	......	......	33	35	......	......
25	60	61	......	......	63	65	......	......	39	38	......	......	38	37	......	......
26	76	81	......	......	63	62	......	......	34	33	......	......	30	31	......	......
27	60	62	......	......	62	62	......	......	32	31	......	......	26	25	......	......
28	73	74	......	......	62	65	......	......	32	41	......	......	23	23	......	......
29	76	76	......	......	......	......	......	......	......	......	......	......	28	27	......	......
30	76	76	......	......	......	......	......	......	......	......	......	......	32	35	......	......
31	76	80	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Calcasieu River at Lake Charles, La., January–December 1949—Continued

Date	May				June[a]			
	Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
1	34	37	...	...	115	115	...	...
2	34	36	...	...	114	112	...	...
3	33	34	...	...	111	113	...	...
4	40	46	...	...	118	124	...	...
5	45	44	...	...	123	125	...	...
6	45	44	...	...	...	...	...	...
7	50	50	...	...	...	...	...	...
8	50	50	...	...	...	...	...	...
9	51	50	...	...	...	...	...	...
10	50	50	...	...	...	...	...	...
11	57	57	...	...	1,100	12,300	...	...
12	56	57	...	...	1,030	7,300	...	...
13	55	57	...	...	1,030	7,390	...	...
14	58	60	...	...	980	7,390	...	...
15	78	77	...	...	955	15,400	...	...
16	80	77	...	...	652	15,900	...	...
17	78	79	...	...	...	...	...	...
18	80	78	...	...	...	...	...	...
19	79	78	...	...	...	...	...	...
20	78	79	...	...	...	...	...	...
21	167	784	42	202	...	...	...	...
22	111	520	22	131	...	...	...	...
23	114	1,200	22	345	...	...	...	...
24	114	662	21	166	...	...	...	...
25	108	335	21	76	...	...	...	...
26	221	1,050	54	265	...	...	...	...
27	225	1,950	51	530	...	...	...	...
28	235	238	55	56	...	...	...	...
29	3,860	111	435	21	...	...	...	...
30	...	...	...	...	...	...	...	...
31	130	122	22	23	...	...	...	...

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*— Continued

Date	September				October				November				December			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La., January-December 1949—Continued																
1					29,000	26,400			138	131						
2					7,500	5,240			134	132			2,070	14,100		
3	3,110	22,000			11,300								2,280	8,890		
4					15,100	16,200							4,340	6,970		
5	3,970	4,140			10,600	10,700										
6	3,910	15,100							278	316						
7	4,120	27,800			912	920										
8	3,750	19,700							537	809						
9	4,090	16,000														
10	4,230	21,600			288	279			1,470	18,800						
11	3,970	27,800			184								1,340	17,700		
12	5,830	27,500											1,820	2,930		
13	5,330	23,000														
14	5,080	14,400			205	208										
15	4,860	20,300			149	163			1,330	9,820						
16	5,410	20,800			134											
17	6,330	17,200			135	149							1,280	1,730		
18	6,470	21,800			142	142			1,550	6,760						
19	4,670	18,600											922	927		
20					185	141										
21	3,520	23,600							2,280	2,320						
22	3,520								2,460	2,770						
23	4,190	18,700			133	131			2,750	12,100						
24																
25	3,890	21,600			158	160										
26	3,760	26,300														
27	4,540	27,000			197	197										
28	5,580	22,200														
29					197	197										
30	5,510	17,200							1,940	7,280						
31													52	56		

See footnotes at end of table.

Table 26.— *Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*— Continued

Date	January				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La., January–December 1950—Continued																
1									57	48	10					
2									48	48						
3									43	44						
4					103	96	21		43	53						
5																
6									38	39						
7																
8					71	70			36	37						
9									35	31						
10	95	76														
11	79	74							48	56			80	80		
12									34	43	5.2		106	106		
13	74	89			84	81			39	40			74	88		
14									44	42			106	106		
15					50	50			47	49			106	106		
16													181	178		
17									111	42			195	197	45	
18					32	37	5.2		52	73			194	191		
19									47	48			82	82		
20									43	45			105	106		
21						30			48	51			82	80	12	
22	47	46			37	37	8.0		49	48			108	108		
23					39	39			66	63			108	108		
24	45	44			43	41			47	62			108	108		
25					50	47							107	107		
26	58	54			47	50			39	36			69	68		
27						32							54	54		
28					38	40							54	51		
29									51	48	8.2		61	65		
30													60	52		
31																

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La, January-December 1950—Continued																
1	67	66	...	12	62	69	8.2	...	75	75	...	...	615	713	...	...
2	64	52	...	...	68	69	...	...	76	75	...	...	568	609	...	...
3	55	51	...	...	70	36	...	...	104	81	...	...	421	467	...	...
4	54	55	...	...	40	39	...	...	205	235	...	...	300	389	71	...
5	36	42	...	...	38	56	...	...	175	286	...	...	1,000	2,000	...	...
6	35	39	...	...	36	38	...	...	179	177	...	...	1,580	2,170	...	...
7	37	49	...	...	38	39	...	...	321	382	...	...	2,670	8,180	760	2,580
8	34	37	4.0	...	40	56	...	...	1,010	1,030	...	...	592	719	110	181
9	208	39	51	...	38	38	...	...	174	217	...	...	751	929	...	...
10	42	39	...	...	39	40	...	...	334	372	77	...	1,000	1,790	...	500
11	49	39	...	...	36	35	5.1	...	895	1,020	262	...	1,570	1,910	...	...
12	66	65	...	9.0	34	34	...	...	700	808	...	...	2,530	4,380	...	...
13	71	67	...	...	34	35	...	...	749	1,020	...	...	2,550	5,320	740	1,570
14	69	68	...	...	56	...	...	...	778	1,110	...	...	3,050	3,920	...	...
15	70	69	...	...	44	49	...	...	1,060	1,160	...	...	2,800	5,480	...	...
16	70	72	...	...	46	46	...	...	626	675	159	...	...	12,000	...	...
17	74	79	...	...	45	45	...	...	1,090	1,130	...	...	5,740	...	1,730	...
18	74	74	...	...	52	43	...	...	965	965	...	...	...	...	...	...
19	73	67	...	...	40	45	...	...	687	646	...	...	...	7,490	...	2,320
20	69	65	...	...	47	46	...	...	360	368	87	...	2,800	...	...	...
21	69	83	...	...	61	63	...	...	254	249	...	...	2,780	...	...	...
22	81	76	...	...	60	57	...	...	214	210	...	...	...	...	...	...
23	58	55	...	...	202	250	43	...	611	766	...	...	3,550	10,800	1,040	3,520
24	54	54	...	...	211	255	...	...	331	379	...	...	4,530	8,010	1,340	2,520
25	55	54	...	...	237	281	...	...	446	...	...	...	4,530	8,370	...	...
26	80	77	...	...	90	57	...	...	596	711	156	...	5,730	14,500	1,750	...
27	79	76	13	...	67	59	...	...	1,080	1,190	...	...	5,730	12,900	...	...
28	50	75	...	...	60	102	...	...	1,260	1,320	...	...	4,960	11,900	...	...
29	43	56	7.4	...	71	65	...	...	1,220	...	...	...	5,470	15,900	...	5,450
30	66	91	...	...	67	65	...	...	1,150	1,200	...	...	5,470	15,300	...	...
31	57	75	...	...	...	...	...	...	1,110	1,130	...	...	...	...	...	...

See footnotes at end of table.

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	September				October				November				December			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La., January-December 1950—Continued																
1	4,860	14,200	...	...	...	...	...	...	4,670	18,900	...	...	5,060	22,300	...	...
2	6,110	18,400	...	...	...	...	...	...	5,570	11,600	...	...	3,010	20,300	...	...
3	5,190	20,000	1,590	7,170	7,210	17,800	...	...	5,520	17,600	...	...	3,740	27,100	...	...
4	5,620	16,600	1,730	5,810	4,340	14,100	...	...	3,950	14,400	1,200	...	3,870	19,700	...	...
5	5,840	13,400	...	...	4,180	23,400	1,260	8,800	5,680	10,700	...	...	3,010	21,600	...	...
6	5,370	8,840	...	...	6,160	14,600	...	...	5,600	20,700	...	...	5,960	6,740	...	...
7	4,720	10,200	...	...	4,340	4,350	1,290	1,320	4,260	23,200	...	...	1,850	2,030	522	570
8	4,720	13,500	1,410	4,600	5,220	11,600	...	...	5,370	18,100	...	...	4,300	23,200	...	...
9	6,140	19,200	...	...	5,220	11,800	...	...	5,780	20,200	...	...	1,850	...	...	...
10	7,100	16,100	...	...	4,230	12,000	...	...	5,530	...	...	...	1,850	22,000	520	2,120
11	3,490	6,090	...	...	4,290	11,800	...	...	5,370	...	...	...	4,470	24,300	...	...
12	2,240	6,270	...	...	9,180	4,500	...	...	5,170	19,400	1,620	...	...	22,500	...	...
13	3,240	5,750	...	...	5,120	14,300	...	...	4,930	22,800	...	...	2,980	20,500	870	...
14	3,270	7,730	...	...	6,460	15,500	2,000	5,460	5,750	15,300	...	...	1,850	2,290	522	...
15	7,050	17,100	...	...	6,500	14,000	2,020	4,780	5,370	23,200	...	...	3,800	25,900	...	...
16	4,560	4,450	...	...	6,470	15,100	...	...	4,670	17,800	...	...	3,800	25,900	...	...
17	5,040	5,110	...	...	6,550	18,800	...	...	4,610	19,000	...	...	...	25,900	...	...
18	4,270	4,650	...	...	...	17,900	...	...	4,870	23,400	...	...	3,740	24,700	...	...
19	4,160	5,070	...	...	6,130	16,500	...	...	8,250	22,800	...	...	3,010	19,400	...	...
20	3,920	3,930	...	...	4,930	16,200	...	...	8,250	13,500	...	...	1,790	2,110	515	580
21	4,240	16,000	...	...	5,140	16,100	...	...	4,780	20,800	...	...	...	...	...	...
22	...	...	...	...	5,120	14,300	...	...	4,820	21,900	...	...	...	...	...	...
23	...	...	...	...	5,380	14,800	...	...	3,010	23,700	880	...	...	...	...	...
24	3,420	3,670	...	...	4,190	15,200	...	...	6,100	19,600	1,930	...	...	...	...	...
25	4,150	9,710	...	...	4,260	17,300		...	3,010	25,400	...	...	...	...	...	...
26	3,090	16,100	910	5,720	4,650	18,500	...	...	4,440	22,800	...	...	...	...	...	...
27	4,220	22,700	1,260	8,500	4,630	18,300	1,450	6,580	4,540	20,400	...	...	...	...	...	...
28	4,140	16,100	...	...	4,100	16,500	...	...	4,360	21,000	...	...	...	...	...	...
29	...	...	...	...	4,070	15,900	...	...	3,990	23,700	...	...	...	...	...	...
30	...	...	...	...	4,070	23,000	...	...	3,980	21,000	...	...	...	...	...	...
31	...	...	...	...	4,240	24,200	...	9,050	...	...	...	...	...	...	...	...

Table 26.— *Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*— Continued

Date	January[b]				February				March				April			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La., January-September 1951																
1	...	...	...	...	...	...	...	...	291	285	...	...	177	192	...	...
2	...	...	...	...	...	...	...	...	451	427	...	...	167	155	37	34
3	...	...	...	...	...	...	...	...	455	433	...	...	77	83	18	18
4	...	...	...	...	...	...	...	...	455	435	...	...	75	1,230	17	330
5	...	...	...	...	...	...	...	...	453	436	...	...	75	78	...	...
6	...	...	...	...	...	...	...	...	295	290	...	...	1,210	1,190	...	...
7	...	...	...	...	...	...	...	...	288	288	...	...	77	79	...	...
8	...	...	...	...	...	...	...	...	452	436	...	...	74	74	...	...
9	...	...	...	...	...	...	...	...	288	325	72	82	75	78	17	16
10	...	...	...	...	...	...	...	...	453	437	112	110	1,240	1,200	332	325
11	...	...	...	...	98	88	18	...	455	439	...	...	91	86	...	...
12	...	...	...	...	73	71	...	...	448	380	114	98	1,360	1,230	...	...
13	...	...	...	...	73	71	...	...	456	437	...	...	104	100	...	...
14	...	...	...	...	105	90	16	17	432	407	105	...	1,250	1,290	...	...
15	...	...	...	...	97	91	...	...	926	935	246	250	1,390	543	372	139
16	...	...	...	...	143	139	28	...	761	829	202	...	132	135	28	28
17	...	...	...	...	...	...	...	...	926	1,000	...	...	1,240	1,230	...	...
18	...	...	...	...	73	75	...	...	167	167	38	...	148	185	...	...
19	...	...	...	...	75	72	...	...	473	452	119	...	216	166	...	...
20	...	...	...	...	74	89	...	...	168	169	...	...	539	2,050	144	580
21	...	...	...	...	133	132	...	...	825	845	...	...	1,250	1,240	...	...
22	...	...	...	...	130	135	...	...	946	951	250	253	1,250	1,230	...	...
23	...	...	...	...	130	131	...	...	172	169	40	40	810	836	212	224
24	...	...	...	...	...	...	...	...	180	174	...	...	991	1,090	264	292
25	...	...	...	...	...	...	...	...	172	173	...	...	1,250	1,240	...	...
26	...	...	...	...	132	135	...	...	1,650	2,230	450	630	1,640	1,570	...	...
27	...	...	...	...	132	331	30	84	172	185	40	42	1,320	1,520	...	...
28	...	...	...	...	359	148	90	32	1,250	1,230	...	...	997	1,240	...	...
29	...	...	...	...	...	...	...	...	1,240	1,230	350	340	1,640	1,830	455	520
30	...	...	...	...	...	...	...	...	171	178	39	40	6,690	3,710	2,000	1,100
31	...	...	...	...	...	...	...	...	170	175	...	...	...	...	...	...

See footnotes at end of table.

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*— Continued

Date	May				June				July				August			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La., January-September 1951—Continued																
1	6,670	3,940	2,000	1,150	6,820	7,210	2,100	2,200	16,900	16,800	5,650	5,700	9,600	9,870	3,080	......
2	1,860	1,980	......	......	13,900	14,300	......	......	16,600	16,500	......	......	8,590	9,480	......	......
3	1,630	1,660	......	......	14,000	14,500	......	......	5,910	6,990	1,770	2,120	5,900	7,360	1,740	2,250
4	1,650	1,860	......	......	14,000	14,500	......	......	......	......	......	......	5,850	6,750	......	......
5	6,240	7,140	1,900	2,200	14,000	14,400	......	......	12,900	13,800	4,280	4,580	11,500	13,900	......	4,550
6	979	967	252	250	14,300	14,200	......	......	5,860	6,800	......	......	6,030	6,680	......	......
7	955	950	......	......	14,400	14,200	4,720	......	5,860	6,470	......	......	6,300	6,350	......	......
8	6,250	7,190	1,900	2,200	14,400	14,200	......	......	9,160	7,150	2,950	......	8,310	8,990	......	......
9	2,110	3,270	......	......	14,400	14,200	......	......	11,100	13,100	......	......	8,960	10,100	......	3,150
10	6,250	7,110	......	......	14,400	14,200	......	......	11,300	13,600	......	......	9,010	9,600	......	......
11	6,250	7,140	......	......	14,200	14,600	......	......	9,870	7,320	3,120	2,260	11,600	15,700	......	......
12	6,250	7,140	......	......	9,320	14,600	2,950	4,720	9,160	7,320	......	......	7,440	8,380	......	2,600
13	1,840	1,880	......	......	14,400	14,600	......	......	8,140	10,100	......	3,250	7,110	15,500	2,190	......
14	1,840	1,870	......	......	......	......	......	......	5,830	6,040	1,760	......	11,500	15,900	......	......
15	1,850	1,940	......	......	14,400	14,600	......	......	5,800	6,310	......	......	9,380	16,300	......	5,480
16	1,660	1,840	460	510	14,200	14,600	......	......	5,780	7,860	......	......	9,330	15,500	2,950	......
17	6,240	7,160	......	......	14,500	14,600	......	......	11,300	12,300	......	......	11,600	16,100	......	......
18	6,240	7,160	......	......	14,500	14,700	......	......	11,300	14,900	3,680	5,000	11,800	15,100	......	......
19	6,240	......	......	......	14,500	14,800	......	......	11,300	15,800	......	......	11,800	15,700	......	......
20	3,600	7,100	1,080	......	12,900	14,800	4,120	......	11,300	15,500	......	......	12,700	19,600	4,180	6,700
21	3,670	14,700	1,060	4,780	14,600	14,500	4,700	4,780	11,200	15,700	3,650	......	13,000	20,500	......	7,030
22	3,920	14,400	......	......	14,500	14,500	......	......	11,200	15,500	......	......	12,900	20,800	......	......
23	3,900	4,140	......	......	5,910	7,230	1,760	2,190	14,600	16,800	4,920	5,600	10,700	19,300	......	......
24	14,000	3,740	4,520	1,090	13,900	14,500	......	......	11,400	16,400	......	......	10,600	18,100	......	......
25	14,000	14,300	......	......	11,700	13,000	......	......	13,800	14,600	......	......	10,600	18,100	......	......
26	14,000	14,300	......	......	5,860	7,570	......	......	11,600	15,700	......	......	13,100	18,600	......	......
27	14,000	14,400	......	......	5,860	6,780	......	......	13,000	14,200	......	......	13,100	18,400	......	......
28	14,000	14,200	......	......	11,400	13,800	3,650	......	11,700	16,700	......	......	15,000	18,100	4,900	......
29	14,000	14,200	......	......	13,000	15,300	......	......	11,600	16,000	......	......	14,500	22,500	......	7,750
30	14,000	13,800	......	......	5,900	7,150	......	......	10,800	11,000	......	......	14,300	15,400	......	4,980
31	6,750	14,000	2,040	......	......	......	......	......	10,100	10,500	......	3,300	11,900	16,300	3,800	......

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	September			
	Conductance		Chloride	
	Top	Bottom	Top	Bottom
Calcasieu River at Lake Charles, La., January-September 1951—Continued				
1	...	...	...	...
2	11,900	12,000	...	...
3	12,800	13,900	...	...
4	...	...	...	...
5	11,400	13,100	...	...
6	13,400	15,500	...	...
7	11,900	15,800	...	...
8	4,910	5,020	1,390	1,410
9	4,730	5,000	...	...
10	11,000	17,200	...	6,200
11	13,000	20,600	4,200	7,050
12	4,650	4,980	...	...
13	13,300	13,600	...	...
14	5,940	5,940	...	...
15	5,940	5,940	...	...
16	4,690	5,040	...	...
17	2,700	2,720	750	...
18	2,350	2,630	...	...
19	2,570	3,130	...	...
20	3,290	6,780	950	2,070
21	4,710	5,210	...	...
22	4,710	5,210	...	...
23	4,710	5,200	...	...
24	3,070	3,600	...	...
25	3,550	3,600	...	...
26	3,390	3,620	...	...
27	3,290	3,580	...	...
28	...	...	...	...
29	...	...	...	...
30	...	...	...	...
31	...	...	...	...

See footnotes at end of table.

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	March				April				May				June			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
	Calcasieu River near Hecker, La., March–September 1951[c]															
1	56	56	...	...	44	45	6.8	6.8	58	62	...	...	85	144	...	...
2	56	57	...	...	41	42	...	...	68	66	...	...	149	128	...	...
3	58	57	...	...	...	...	...	...	66	68	...	...	112	210	18	51
4	60	85	8	15	42	39	...	...	...	...	...	...	102	120	...	...
5	62	64	...	7.5	37	37	...	...	105	72	20	7.5	89	...	...	...
6	62	63	...	...	36	36	...	...	...	72	...	...	95	189	13	42
7	...	...	...	...	41	39	...	...	76	99	7.5	15	321	447	75	110
8	67	68	...	...	39	42	...	...	76	73	...	...	552	1,020	141	270
9	66	68	...	...	39	40	...	...	70	...	...	...	445	1,760	114	500
10	...	...	...	...	43	42	...	...	65	68	...	...	399	1,540	80	420
11	96	69	15	7	44	46	...	...	39	83	5.0	17	640	1,640	160	460
12	...	...	...	...	47	46	...	...	40	44	...	...	110	3,460	32	870
13	73	77	...	...	49	49	...	...	39	42	...	...	209	3,000	44	1,100
14	74	72	...	...	52	52	...	...	35	49	...	...	584	3,700	144	900
15	...	...	...	...	53	52	...	...	36	36	...	...	297	3,000	66	1,120
16	...	...	...	...	52	53	...	...	41	41	...	...	851	3,800	218	825
17	90	78	10	7.5	...	...	...	...	42	43	...	...	452	2,920	108	825
18	78	78	8.5	...	48	48	...	...	47	49	...	...	181	2,490	38	725
19	89	68	...	...	48	47	...	...	52	50	...	...	858	3,000	220	850
20	67	84	...	...	52	65	...	...	58	58	...	...	1,010	2,380	320	675
21	72	65	...	...	51	51	6.0	6.5	67	78	...	...	792	1,810	201	490
22	...	...	...	...	62	58	...	...	66	67	...	...	939	2,710	250	735
23	74	63	...	...	59	57	...	...	66	66	...	...	224	1,190	47	310
24	81	65	...	...	60	70	...	...	76	81	...	...	1,540	3,430	415	942
25	63	63	...	...	61	64	...	...	71	69	...	...	632	4,800	157	1,420
26	64	65	...	...	65	67	...	...	81	80	...	...	494	6,070	120	1,840
27	71	80	...	...	76	71	7.5	7.5	83	75	...	...	475	5,640	114	1,680
28	...	...	...	...	73	73	...	...	74	102	11	11	2,340	6,940	635	2,050
29	44	55	...	...	57	88	6.0	6.5	78	78	...	...	3,290	7,610	925	2,320
30	49	99	...	...	62	56	...	...	83	79	...	...	3,210	7,010	905	2,100
31	...	...	...	...	...	...	...	...	81	82	...	...	...	...	...	...

387601 O - 56 - 25

Table 26.—*Specific conductance and chloride content of water from sampling stations on Vermilion, Mermentau, and Calcasieu Rivers*—Continued

Date	July				August				September			
	Conductance		Chloride		Conductance		Chloride		Conductance		Chloride	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calcasieu River near Hecker, La., March-September 1951—Continued												
1	3,720	7,740	1,070	2,380	611	3,340	147	970	3,710	16,300	....	....
2	4,230	7,820	1,230	2,180	266	1,910	65	555	2,050	18,900	....	....
3	....	....	....	....	129	488	....	....	1,610	18,900	....	....
4	....	....	....	....	120	1,050	....	282	1,250	18,500	....	....
5	318	7,300	76	2,250	215	438	41	103	1,320	18,700	....	....
6	145	7,590	32	2,320	146	2,040	....	....	1,260	17,000	....	....
7	124	7,700	20	2,280	117	2,460	19	700	1,280	6,460	348	1,840
8	406	7,370	88	2,280	148	5,840	....	1,750	671	17,700	162	6,000
9	494	1,550	116	450	218	6,080	....	....	1,280	17,000	....	....
10	398	7,490	88	2,300	244	6,770	....	....	1,170	9,940	....	....
11	210	7,570	68	2,350	674	7,020	....	....	1,610	17,200	410	5,750
12	459	7,320	85	2,300	152	6,320	24	1,920	1,460	16,600	....	....
13	660	7,570	165	2,320	286	5,800	....	....	772	1,150	202	....
14	888	2,480	230	725	755	7,410	199	2,270	123	113	18	18
15	716	8,240	178	2,520	1,340	2,440	365	688	95	128	....	....
16	1,180	8,150	315	2,480	1,670	4,880	462	....	90	122	....	....
17	951	8,650	240	2,680	2,250	10,200	635	3,220	77	79	....	11
18	1,490	8,880	400	2,700	2,440	13,200	....	....	74	78	10	....
19	1,120	9,690	290	2,980	1,620	14,000	....	....	74	82	....	....
20	2,460	8,370	688	2,520	1,320	15,500	....	5,150	130	118	....	....
21	2,050	9,620	560	....	1,090	16,400	....	....	85	82	13	....
22	1,880	10,500	....	....	906	15,600	....	....	85	82	....	....
23	1,880	10,800	....	....	1,070	15,400	290	5,080	110	122	....	....
24	1,650	11,400	480	3,600	804	18,800	204	6,400	146	304	22	68
25	1,690	10,900	....	....	1,350	19,400	....	....	94	109	....	....
26	1,720	11,400	....	....	1,480	19,600	408	6,680	70	67	....	....
27	1,460	7,940	400	2,440	2,000	19,600	568	....	61	60	8.0	....
28	1,810	11,400	....	....	2,710	19,600	770	....	70	70	....	....
29	1,370	10,900	....	....	3,570	19,600	1,040	....	....	....	....	....
30	484	8,260	116	....	2,760	19,300	....	....	67	51	....	6.0
31	591	6,120	....	....	2,930	19,600	....	....	....	....	....	....

[a]No samples collected for the period June 17 to September 2, 1949.

[b]No samples collected January 1 to February 11, 1951.

[c]Station established March 1, 1951.

Table 27.—*Channel distances used in salinity survey*

Vermilion River basin

Vermilion River

Sampling points	*Miles from mouth*
Intracoastal City	3.0
Bancker's Ferry (daily sampling)	14.5
Abbeville pumping plant	24.2
Abbeville, State Route 25 bridge	26.0
Hunter pumping plant	38.3
Milton, State Route 175	38.7
U. S. 90 crossing near Lafayette	50.1
State Route 422 crossing (Pinhook Bridge)	56.1
State Route 43 crossing (Long Bridge)	59.6
State Route 675 crossing (Pont des Mouton)	63.8
State Route 988 crossing (Tontons Bridge)	70.0

Mermentau River basin

Mermentau River

Sampling points	*Miles from mouth*
Grand Chenier	8.2
Catfish Point Locks	24.0
At Intracoastal Waterway	34.5
Mouth Bayou Lacassine (in Grand Lake)	35.0
Above Intracoastal Waterway	35.7
Lacassine Refuge	38.2
Lowery (Bill Meyer's Camp)	42.2
Lake Arthur at State Route 25 bridge (daily sampling)	50.7
Klondike pumping plant	52.6
Mouth Bayou Queue de Tortue	54.8
In Mermentau U. S. 90 bridge	66.6
Confluence of Bayou Nezpique and Bayou des Cannes forming Mermentau River	68.8
Mouth Bayou Plaquemine Brule (tributary Bayou des Cannes)	70.5
Mouth Bayou Mallet (tributary Bayou des Cannes)	92.4
Mouth Bayou Wikoff (tributary Bayou Plaquemine Brule)	95.7

Tributaries of Mermentau River

Sampling points	*Miles from mouth of tributary*
Bayou Nezpique	
State Route 371 crossing	6.5
Riverside pumping plant	14.0
Grand pumping plant	21.8
Mamou pumping plant	33.2
Gaging station on U. S. 190 near Basile, La	41.2
Bayou Des Cannes	
Mouth of Bayou Plaquemine Brule	1.7
Abbot Duson pumping plant	6.8
State Route 1045 crossing	10.4
Acadia pumping plant	16.8
State Route 370 crossing	17.2
Mouth of Bayou Mallet	23.6
State Route 222 crossing	27.0
State Route 580 crossing	34.2
Gaging station on U. S. 190 near Eunice, La	35.6

Table 27.— *Channel distances used in salinity survey*— Continued

Tributaries of Mermentau River—Continued

Sampling points	*Miles from mouth of tributary*
Bayou Mallet	
State Route 222 crossing	2.9
Bayou Plaquemine Brule	
Quibodeaux ferry on State Route C-1393	4.9
Estherwood pumping plant at State Route 1017	12.1
Roller pumping plant	19.0
State Route 370 crossing northwest of Crowley, La	22.1
State Route 26 crossing north of Crowley, La	22.9
Mouth of Bayou Wikoff	25.2
State Route 365 crossing northwest Rayne, La	36.0
State Route 376 crossing west of Branch, La	42.2
Bayou Wikoff	
State Route 1024 crossing north of Crowley, La	0.3
State Route 365 crossing north of Rayne, La	9.0
Bayou Queue de Tortue	
Primeaux pumping plant	6.5
Ferre pumping plant	11.1
State Route 128 crossing	14.7
State Route 26 crossing	27.6
State Route 369 crossing	32.7
State Route 366 crossing	36.2
State Route 367 crossing	39.5
Bayou Lacassine	
State Route 98 crossing	15.9
East Bayou Lacassine at U. S. 90 crossing	36.4

Calcasieu River basin

Calcasieu River

Sampling points	*Miles from mouth*
State Route 25 crossing, near Cameron, La	2.0
Near Hackberry, La	17.0
At Moss Lake, east of State Route 104	24.0
Port of Lake Charles	35.2
Old U. S. 90 bridge	35.5
Kansas City Southern R. R. crossing, West Lake, La	37.2
Foot Ryan Street in Lake Charles (daily sampling)	42.4
Foot Nichols Street in Lake Charles (daily sampling)	44.0
Two O'Clock Point	45.3
Mouth West Fork	45.9
Perkins ferry (bridge junction)	46.2
Mouth English Bayou	47.3
U. S. 171 crossing	50.2
Goss' ferry	54.2
Old Town Bay	56.1
Calcasieu Parish Park (daily sampling)	59.0
Mouth Bayou Serpent	59.8
Hecker, La	66.2
Indian Village, La	80.6

Table 27.— *Channel distances used in salinity survey*— Continued

Calcasieu River basin—Continued

Calcasieu River— Continued

Sampling points	*Miles from mouth*
Gaging station on U. S. 90 near Kinder, La	90.8
Mouth Indian Bayou (tributary West Fork)	50.9
Mouth Houston River (tributary West Fork)	54.1
Confluence Beckwith Creek and Hickory Branch (head of West Fork)	62.2

Tributaries of Calcasieu River

Sampling points	*Miles from mouth of tributary*
West Fork Calcasieu River	
Mouth Indian Bayou	5.0
Mouth Houston River	8.2
West Fork ferry	13.3
Indian Bayou	
At bridge 2 miles east of West Fork ferry	4.7
Houston River	
At ferry near Kansas City Southern R. R. crossing	4.3
State Route 104 crossing	8.3
Bayou Serpent	
Mouth Bayou Arceneaux	5.0
State Route 386 crossing	6.0
Pumping plant near State Route 386 crossing	6.1
Bayou Arceneaux	
State Route 386 crossing	1.2
English Bayou	
U. S. 171 crossing	1.0
Road crossing near Chloe	7.1

Intracoastal Waterway

Sampling points	*Miles from Harvey, La.*
Bayou Ivanhoe	130.9
Intracoastal City	160.0
Vermilion Locks Center	162.8
Forked Island ferry (State Route 26)	169.7
Spencer ditch (Gueydan Canal)	192.8
West of Mermentau River north of Grand Lake	203.2
State Route 25 crossing	219.7
State Route 931 crossing	231.3
State Route 211 crossing	238.0
State Route 104 crossing north of Hackberry	243.7

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*

[Chemical analyses, in parts per million]

MAIN TECHE DRAINAGE BASIN

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
Bayou Cocodrie at bridge on State Route 224															
Aug. 12, 1949	60	...	...	...	...	...	...	...	5.0	...	...	...	...	...	...
Bayou Courtableau at Washington at bridge on State Route 5															
Aug. 13, 1949	121	7.5	...	...	...	...	48	...	12	...	...	...	...	...	...
Bayou Courtableau near Washington at bridge on State Route 487															
Aug. 13, 1949	149	...	...	...	...	...	...	...	20	...	...	...	...	...	...
Bayou Teche at Arnaudville at bridge on State Route 25															
Aug. 15, 1949	174	...	...	...	...	...	...	...	12	...	...	...	...	...	...
Bayou Teche at Cecelia at bridge on State Route 25D															
Aug. 16, 1949	194	...	...	...	...	...	...	...	19	...	...	...	...	...	...
Bayou Teche at bridge in Breaux Bridge															
Aug. 16, 1949	171	...	...	...	...	...	...	...	12	...	...	...	...	...	...

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*— Continued

MAIN TECHE DRAINAGE BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
Bayou Teche at bridge in St. Martinville															
Aug. 16, 1949........	210	7.7	....	....	....	....	74	....	24	....	....	....	....	....	....
Bayou Teche at New Iberia at bridge on State Route 56															
Aug. 19, 1949........	187	7.7	....	....	....	....	38	....	11	....	....	....	....	....	....
Bayou Teche at Olivier at bridge on State Route 1181															
Aug. 19, 1949........	167	.....	....	....	....	....	....	....	11	....	....	....	....	....	....
Canal 2 miles south Tate Cove on State Route 224															
Aug. 12, 1949........	498	.....	....	....	....	....	....	....	32	....	....	....	....	....	....
Bayou Carron at Washington at bridge on State Route 5															
Aug. 13, 1949........	303	.....	....	....	....	....	....	....	21	....	....	....	....	....	....
Bayou Tesson near Opelousas at bridge on U. S. 167															
Aug. 15, 1949........	509	.....	....	....	....	....	....	....	18	....	....	....	....	....	....
Bayou Bourbeaux at Sunset at bridge on State Route 167															
Aug. 15, 1949........	108	.....	....	....	....	....	....	....	10	....	....	....	....	....	....

Bayou Carencro at St. Landry-Lafayette Parish line at bridge on U. S. 167

Aug. 15, 1949........	1,130	7.7	....	....	....	....	83	....	296	....	....	....	....	....	....

Ruth Canal near Ruth at bridge on State Route 43

Aug. 16, 1949........	161	.....	....	....	....	....	....	....	11	....	....	....	....	....	....

Ruth Canal to west of lock near State Route 43

Aug. 16, 1949........	170	7.6	....	....	....	....	66	....	14	....	....	....	....	....	....

Bayou Petite Anse at bridge on State Route 25

Aug. 19, 1949........	267	7.9	....	....	....	....	55	....	43	....	....	....	....	....	....

Lake Peigneur near Delcambre at State Route 448

Aug. 19, 1949........	1,790	.....	....	....	....	....	....	....	510	....	....	....	....	....	....

Delcambre Bayou at Delcambre at bridge on State Route 25

Aug. 19, 1949........	1,420	.....	....	....	....	....	....	....	392	....	....	....	....	....	....

Bayou Tigre at Erath at bridge on State Route 25

Aug. 19, 1949........	178	.....	....	....	....	....	....	....	28	....	....	....	....	....	....

VERMILION RIVER BASIN

Vermilion River just below junction of Bayou Fusilier and Bayou Carencro (mile 72.5)

Aug. 15, 1949........	171	.....	....	....	....	....	....	....	13	....	....	....	....	....	....

Vermilion River at bridge near Lafayette on State Route 43 at Parish line (mile 59.6)

May 11, 1949..........	185	.....	14	8.3	2.9	36	70	4	34	1.2	138	0.19	33	0	70
Aug. 15.................	466	.....	....	....	....	....	....	....	99	....	....	....	....	....	....

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*—Continued

VERMILION RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_4)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
Vermilion River at bridge near Lafayette on U. S. 90 (mile 50.1)															
Aug. 15, 1949	143	6.8	8.8	7.8	4.8	10	39	3.0	18	1.0	107	0.15	39	7	36
Sept. 14 (top)	198	...	...	...	...	...	...	...	23	...	...	...	...	...	...
Sept. 14 (bottom)	189	...	...	...	...	...	...	...	23	...	...	...	...	...	...
Vermilion River at bridge at Milton on State Route 175 (mile 38.7)															
Aug. 19, 1949	317	...	...	...	...	...	...	...	72	...	...	...	...	...	...
Sept. 14 (top)	246	...	...	...	...	...	...	...	29	...	...	...	...	...	...
Sept. 14 (bottom)	182	...	...	...	...	...	...	...	24	...	...	...	...	...	...
Vermilion River at Abbeville on State Route 25 (mile 26.0)															
Aug. 19, 1949 (top)	624	...	...	...	...	...	...	...	160	...	...	...	...	...	...
Aug. 19 (bottom)	642	...	...	...	...	...	...	...	164	...	...	...	...	...	...
Sept. 14 (top)	276	...	...	...	...	...	...	...	46	...	...	...	...	...	...
Sept. 14 (bottom)	282	...	...	...	...	...	...	...	47	...	...	...	...	...	...
Vermilion River at Bancker's Ferry on State Route C-1846 (mile 14.5)															
Aug. 19, 1949 (top)	179	...	...	...	...	...	...	...	28	...	...	...	...	...	...
Aug. 19 (bottom)	184	...	...	...	...	...	...	...	26	...	...	...	...	...	...
Sept. 14	241	...	...	...	...	...	...	...	35	...	...	...	...	...	...
Vermilion River above Intracoastal Waterway off State Route 43 (mile 3.5)															
Aug. 19, 1949	146	...	...	...	...	...	...	...	18	...	...	...	...	...	...
Sept. 14	1,670	...	...	...	...	...	...	...	452	...	...	...	...	...	...

Vermilion River, common channel with Intracoastal Waterway on State Route 43 (mile 3.0)

Aug. 19, 1949.........	346	7.5	....	....	....	....	50	....	69	....	....	....	....	....	....
Sept. 14.................	4,490	.....	....	....	....	....	....	....	1,350	....	....	....	....	....	....
Apr. 30, 1951..........	4,640	7.7	10	39	94	764	48	193	1,350	2.0	2,480	3.37	484	444	77

Bayou Capucin at bridge on State Route 422

Aug. 16, 1949.........	184	.....	....	....	....	....	....	....	40	....	....	....	....	....	....

Canal halfway between St. Martinville and Cade at bridge on State Route C-1491

Aug. 16, 1949.........	227	.....	....	....	....	....	....	....	39	....	....	....	....	....	....

Coulee Mine near Scott at bridge on U. S. 90

Aug. 15, 1949.........	57	7.2	....	....	....	....	17	....	5.0	....	....	....	....	....	....

Bayou Ile des Cannes near Scott at bridge on U. S. 90

Aug. 15, 1949.........	207	.....	....	....	....	....	....	....	48	....	....	....	....	....	....

Grande Coulee in Maurice at bridge on U. S. 167

Aug. 19, 1949.........	165	.....	....	....	....	....	....	....	28	....	....	....	....	....	....
Sept. 14.................	167	.....	....	....	....	....	....	....	17	....	....	....	....	....	....

Hunter Canal near Maurice at bridge on U. S. 167

Aug. 19, 1949.........	361	.....	....	....	....	....	....	....	83	....	....	....	....	....	....
Sept. 14.................	170	.....	....	....	....	....	....	....	23	....	....	....	....	....	....

Hunter Canal northeast of Kaplan at bridge on State Route 177

Aug. 22, 1949.........	329	.....	....	....	....	....	....	....	75	....	....	....	....	....	....

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*—Continued

VERMILION RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
											Parts per million	Tons per acre-foot	Total	Noncarbonate	
Coulee Kinney at bridge on State Route C-1349															
Aug. 19, 1949	158	...	...	...	...	...	...	...	29	...	...	...	...	...	...
Bayou Galleque near Abbeville at bridge on State Route C-1997															
Aug. 19, 1949	148	...	...	...	...	...	...	...	23	...	...	...	...	...	...
Abbeville Canal at bridge on State Route C-1997															
Aug. 19, 1949	685	...	...	...	...	...	...	...	180	...	...	...	...	...	...
Abbeville Canal at bridge on State Route 26															
Aug. 22, 1949	204	...	...	...	...	...	...	...	28	...	...	...	...	...	...
Marrone Canal at bridge on State Route 516															
Aug. 22, 1949	193	...	...	...	...	...	...	...	29	...	...	...	...	...	...
Young's Coulee Canal at Rose Hill at bridge on State Route 803															
Aug. 19, 1949	204	...	...	...	...	...	...	...	36	...	...	...	...	...	...

Little Bayou at bridge on State Route 43

Aug. 19, 1949	179	...	...	...	...	...	...	...	32	...	...	...	...	...	...

Kaplan Canal at bridge on State Route 292

Aug. 22, 1949	211	...	...	...	...	...	...	...	33	...	...	...	...	...	...

Seventh Ward Canal at bridge on State Route 292

Aug. 22, 1949	165	...	...	...	...	...	...	...	30	...	...	...	...	...	...

Touchets Canal at bridge on State Route 26

Aug. 22, 1949	167	...	...	...	...	...	...	...	28	...	...	...	...	...	...

MERMENTAU RIVER BASIN

Mermentau River at Mermentau at bridge on U. S. 90 (mile 66.6)

Aug. 17, 1949 (top)	215	...	...	...	...	...	...	...	37	...	...	...	...	...	...
Aug. 17 (bottom)	245	...	...	...	...	...	...	...	43	...	...	...	...	...	...
Sept. 14 (top)	214	...	...	...	...	...	...	...	39	...	...	...	...	...	...
Sept. 14 (bottom)	308	...	...	...	...	...	...	...	57	...	...	...	...	...	...

Mermentau River at Lake Arthur at bridge on State Route 25 (mile 50.7)

Aug. 22, 1949 (top)	202	...	...	...	...	...	...	...	31	...	...	...	...	...	...
Aug. 22 (bottom)	200	...	...	...	...	...	...	...	30	...	...	...	...	...	...
Sept. 14 (top)	176	...	...	...	...	...	...	...	29	...	...	...	...	...	...
Sept. 14 (bottom)	176	...	...	...	...	...	...	...	29	...	...	...	...	...	...

Mermentau River just below Lake Arthur

Aug. 24, 1949	184	...	...	...	...	...	...	...	33	...	...	...	...	...	...

Mermentau River at Lacassine Migratory Waterfowl Refuge (mile 38.2)

Aug. 22, 1949	158	...	...	...	...	...	...	...	28	...	...	...	...	...	...
Sept. 14	225	...	...	...	...	...	...	...	42	...	...	...	...	...	...

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*— Continued

MERMENTAU RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
											Parts per million	Tons per acre-foot	Total	Noncarbonate	
Mermentau River north of Intracoastal Waterway crossing (mile 34.5)															
Aug. 24, 1949	144	...	...	...	...	...	...	...	22	...	...	...	...	...	...
Mermentau River south of Intracoastal Waterway (mile 34.0)															
Aug. 24, 1949	200	...	...	...	...	...	...	...	36	...	...	...	...	...	...
Grand Lake at Grassy Point															
Aug. 24, 1949	870	...	...	...	...	...	...	...	220	...	...	...	...	...	...
Grand Lake at entrance to Mallard Bay															
Aug. 24, 1949	917	...	...	...	...	...	...	...	232	...	...	...	...	...	...
Grand Lake at Umbrella Point															
Aug. 24, 1949	1,600	...	...	...	...	...	...	...	422	...	...	...	...	...	...
Grand Lake at southeast corner near Chenier Dufond															
Aug. 24, 1949	1,890	...	...	...	...	...	...	...	510	...	...	...	...	...	...
Grand Lake near outflow into lower Mermentau River															
Aug. 24, 1949	2,360	...	...	...	...	...	...	...	655	...	...	...	...	...	...

Mermentau River just below outlet of Catfish Lake

Aug. 24, 1949........	2,370	7.4	19	22	46	376	49	95	652	2.8	1,240	1.69	244	204	77

Mermentau River at Grand Chenier at bridge on State Route 292 (mile 8.2)

Aug. 23, 1949 (top)..	2,580	7.4	....	....	....	....	....	....	718	....	....	....	....	....	....
Aug. 23 (bottom)......	2,580	7.3	....	....	....	....	36	....	718	....	....	....	....	....	....
Apr. 28, 1951........	4,580	6.8	9	28	94	757	47	193	1,320	2.0	2,430	3.30	456	418	78

Gulf of Mexico at mouth of Mermentau River

Aug. 23, 1949........	42,400	.....	....	....	....	....	....	....	15,700	....	....	....	....	....	....

Bayou Nezpique

At mouth of canal running into Miller's Lake 1 mile north State Route 575

Aug. 12, 1949........	56	.....	....	....	....	....	....	....	1.0	....	....	....	....	....	....

East Fork Bayou Nezpique on State Route 26

Aug. 12, 1949........	77	.....	....	....	....	....	....	....	8.0	....	....	....	....	....	....

Bayou Nezpique just below confluence East and West Forks at bridge on State Route 220

Aug. 12, 1949........	200	.....	....	....	....	....	....	....	32	....	....	....	....	....	....

Bayou Nezpique on Allen-Evangeline Parish line at bridge on State Route 120

Aug. 12, 1949........	161	.....	....	....	....	....	....	....	24	....	....	....	....	....	....

Bayou Nezpique near Basile at gaging station on U. S. 190 (mile 41.2)

Aug. 10, 1949........	151	7.0	11	6.7	4.8	14	45	1.0	20	1.5	117	0.16	36	0	46

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*—Continued

MERMENTAU RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
***Bayou Nezpique*—Continued**															
Bayou Nezpique at bridge on State Route 371 (mile 6.5)															
Aug. 18, 1949	104	...	...	...	...	...	...	...	15	...	...	...	...	...	...
Sept. 16 (top)	141	...	...	...	...	...	...	...	22	...	...	...	...	...	...
Sept. 16 (bottom)	147	...	...	...	...	...	...	...	22	...	...	...	...	...	...
Bayou Blue on State Route 25															
Aug. 12, 1949	72	7.3	...	...	...	...	28	...	7.0	...	...	...	...	...	...
Bayou des Cannes and Plaquemine Brule															
Bayou des Cannes at bridge on State Route 575															
Aug. 12, 1949	49	7.3	...	...	...	...	22	...	2.0	...	...	...	...	...	...
Bayou des Cannes at pumping station 1 mile west Point Blue on State Route 219															
Aug. 12, 1949	266	...	...	...	...	...	...	...	18	...	...	...	...	...	...
Bayou des Cannes near Eunice at gaging station on U. S. 190 (mile 35.6)															
Aug. 10, 1949	225	7.3	18	17	8.0	16	102	1.0	17	2.0	150	0.20	75	0	32
Bayou des Cannes toward Redich (Northwest of Iota) 2 miles west State Route 222 (mile 27.0)															
Aug. 18, 1949	175	...	...	...	...	...	...	...	27	...	...	...	...	...	...

Bayou des Cannes at bridge on State Route 370 (mile 17.2)

Aug. 18, 1949........	239	7.6	......	....	....	....	46	....	47	....	....	....	....	....	....
Sept. 16 (top)..........	511	.....	......	....	....	....	....	....	73	....	....	....	....	....	....
Sept. 16 (bottom).....	473	.....	......	....	....	....	....	....	68	....	....	....	....	....	....

Coulee de Manuel at bridge on State Route 119

Aug. 12, 1949........	393	.....	......	....	....	....	....	....	35	....	....	....	....	....	....

Bayou Marron L'anse at bridge on State Route 119

Aug. 12, 1949........	445	.....	......	....	....	....	....	....	30	....	....	....	....	....	....

Irrigation canal near Chataignier at bridge on State Route 119

Aug. 12, 1949........	321	.....	......	....	....	....	....	....	24	....	....	....	....	....	....

Bayou Mallet at Lawtell at bridge on U. S. 190

Aug. 13, 1949........	266	.....	......	....	....	....	....	....	13	....	....	....	....	....	....

Bayou Mallet at bridge on State Route 222 (mile 2.9)

Aug. 18, 1949........	180	.....	......	....	....	....	....	....	20	....	....	....	....	....	....
Apr. 3, 1951..........	15,000	7.9	12	233	88	2,970	134	7.4	5,160	....	8,540	11.61	944	834	87

Bayou Doza at bridge on U. S. 190

Aug. 13, 1949........	351	.....	......	....	....	....	....	23	....	....	....	....	....	....	....

West Fork Bayou Plaquemine Brule at bridge on U. S. 190

Aug. 13, 1949........	260	.....	......	....	....	....	....	13	....	....	....	....	....	....	....

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*—Continued

MERMENTAU RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
											Parts per million	Tons per acre-foot	Total	Noncarbonate	
***Bayou des Cannes and Plaquemine Brule*—Continued**															
Bayou Plaquemine Brule at bridge on State Route 767															
Aug. 13, 1949	130	...	...	...	...	...	...	...	4.0	...	...	...	...	...	...
Bayou Plaquemine Brule at bridge on State Route 365 (mile 36.0)															
Aug. 17, 1949	163	...	...	...	...	...	...	...	11	...	...	...	...	...	...
Bayou Plaquemine Brule near Crowley at bridge on State Route 26 (mile 22.9)															
Aug. 17, 1949	135	7.1	8.8	7.6	5.0	12	53	2.0	13	1.0	96	0.13	40	0	39
Bayou Plaquemine Brule at Estherwood pumping plant at ferry on State Route 1017 (mile 12.1)															
Aug. 17, 1949	122	...	...	...	...	...	...	...	10	...	...	...	...	...	...
Sept. 14 (top)	265	...	...	...	...	...	...	...	23	...	...	...	...	...	...
Sept. 14 (bottom)	274	...	...	...	...	...	...	...	26	...	...	...	...	...	...
Bayou Plaquemine Brule at Quebodeaux ferry on State Route C-1393 (mile 4.9)															
Aug. 17, 1949	218	...	...	...	...	...	...	...	21	...	...	...	...	...	...
Grand Coulee at Mowata at bridge on State Route 26															
Aug. 17, 1949	189	...	...	...	...	...	...	...	19	...	...	...	...	...	...

Long Point Gully at bridge on State Route 26

Aug. 17, 1949	226	...	...	...	...	...	...	...	23	...	...	...	...	...	...

Bayou Wikoff at bridge on State Route 365 (mile 9.0)

Aug. 17, 1949	61	...	...	...	...	...	...	...	5.0	...	...	...	...	...	...

Canal 1.2 miles west of Crowley near Rice Experiment Station on U. S. 90

Aug. 17, 1949	173	...	...	...	...	...	...	...	15	...	...	...	...	...	...

Bayou Blanc at bridge on U. S. 90

Aug. 17, 1949	192	...	...	...	...	...	...	...	14	...	...	...	...	...	...

Bayou Queue de Tortue

Bayou Queue de Tortue at bridge on State Route 26 (mile 27.6)

Aug. 22, 1949	192	8.2	...	...	...	...	93	...	13	...	...	...	...	...	...

Bayou Queue de Tortue at bridge on State Route 128 (mile 14.7)

Aug. 18, 1949	158	7.7	...	...	...	...	63	...	18	...	...	...	...	...	...
Sept. 14 (top)	331	...	...	...	...	...	...	...	60	...	...	...	...	...	...
Sept. 14 (bottom)	206	...	...	...	...	...	...	...	27	...	...	...	...	...	...

Canal at Primeaux pumping plant on Bayou Queue de Tortue (mile 6.5)

Aug. 18, 1949	149	...	...	...	...	...	...	...	18	...	...	...	...	...	...

Indian Bayou at bridge on State Route 367

Aug. 22, 1949	303	...	...	...	...	...	...	...	13	...	...	...	...	...	...

387601 O - 56 - 26

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*— Continued

MERMENTAU RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
Bayou Queue de Tortue— Continued															
Bayou Grande Marais at bridge on State Route 26															
Aug. 22, 1949	289	......	......	......	......	......	......	......	53	......	......	......	......	......	......
Sledge Canal at bridge on State Route 516															
Aug. 22, 1949	204	......	......	......	......	......	......	......	24	......	......	......	......	......	......
Robins Canal at bridge on State Route 516															
Aug. 22, 1949	190	......	......	......	......	......	......	......	43	......	......	......	......	......	......
Feeder canal near junction Warren and Gueydan Canals about 6 miles southeast Gueydan															
Aug. 22, 1949	255	......	......	......	......	......	......	......	36	......	......	......	......	......	......
Warren Canal about 6 miles southeast Gueydan															
Aug. 22, 1949	229	......	......	......	......	......	......	......	31	......	......	......	......	......	......
Gueydan Canal at bridge on State Route 518															
Aug. 22, 1949	315	......	......	......	......	......	......	......	73	......	......	......	......	......	......

Mitchell Bayou at bridge on Lowry Road

Aug. 22, 1949........	234	...	...	...	...	...	...	...	39	...	...	...	...	...	...

Bayou Lacassine

East Bayou Lacassine at Welsh at bridge on U. S. 90 (mile 36.4)

Aug. 20, 1949........	226	...	...	...	...	...	...	...	28	...	...	...	...	...	...

Tributary to East Bayou Lacassine at Welsh at bridge on State Route 105 (mile 36.0)

Aug. 18, 1949........	269	...	...	...	...	...	...	...	25	...	...	...	...	...	...

West Bayou Lacassine at bridge on U. S. 90

Aug. 18, 1949........	658	8.2	...	...	...	...	80	...	155	...	...	...	...	...	...

Bayou Lacassine at bridge on State Route 98 (mile 15.9)

Aug. 18 1949 (top)...	203	...	...	...	...	...	...	...	30	...	...	...	...	...	...
Aug. 18 (bottom).....	165	...	...	...	...	...	...	...	26	...	...	...	...	...	...

Bayou Grand Marais near Hathaway School at bridge on State Route C-2030

Aug. 20, 1949........	212	...	...	...	...	...	...	...	35	...	...	...	...	...	...

Bayou Grand Marais at bridge on U. S. 90

Aug. 20, 1949........	350	...	...	...	...	...	...	...	48	...	...	...	...	...	...

Bayou Chene at bridge on State Route 105

Aug. 18, 1949........	174	...	...	...	...	...	...	...	26	...	...	...	...	...	...

South Bayou Chene at bridge on State Route 105

Aug. 18, 1949........	203	...	...	...	...	...	...	...	30	...	...	...	...	...	...

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*—Continued

MERMENTAU RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium
											Parts per million	Tons per acre-foot	Total	Noncarbonate	
***Bayou Lacassine*—Continued**															
Indian Bayou Canal at bridge on dirt road 2 miles east of State Route 1156															
Aug. 18, 1949	204	...	...	...	...	...	...	...	33	...	...	...	...	...	...
CALCASIEU RIVER BASIN															
Calcasieu River near Oberlin at gaging station on State Route 52															
Aug. 10, 1949	53	6.8	14	2.3	1.4	5.5	18	2.0	4.2	0.8	39	0.05	12	0	51
Calcasieu River at Le Blanc at gaging station on U. S. 190 (mile 90.8)															
Aug. 10, 1949	63	6.7	21	2.5	1.9	6.0	20	1.0	6.5	0.5	49	0.07	14	0	48
Calcasieu River at bridge on U. S. 171 (mile 50.2)															
Aug. 20, 1949 (top)	64	...	...	...	...	...	...	...	8.0	...	...	...	...	...	...
Aug. 20 (bottom)	97	...	...	...	...	...	...	...	9.0	...	...	...	...	...	...
Aug. 25 (top)	604	...	...	...	...	...	...	...	153	...	...	...	...	...	...
Aug. 25 (bottom)	14,900	7.4	14	124	347	2,690	60	691	4,830	...	8,730	11.87	1,740	1,690	77
Sept. 16 (top)	2,900	...	...	...	...	...	...	...	860	...	...	...	...	...	...
Sept. 16 (bottom)	26,900	...	...	...	...	...	...	...	10,500	...	...	...	...	...	...
Nov. 30	310	...	...	...	...	...	...	...	74	...	...	...	...	...	...

Calcasieu River at Perkins ferry (bridge junction) (mile 46.2)

Aug. 25, 1949........	1,400	......	......	......	......	......	......	......	370	......	......	......	......	......	......
Sept. 13 (top)..........	4,480	......	......	......	......	......	......	......	1,320	......	......	......	......	......	......
Sept. 13 (bottom).....	27,700	......	......	......	......	......	......	......	10,800	......	......	......	......	......	......
Sept. 16 (top)..........	4,330	......	......	......	......	......	......	......	1,310	......	......	......	......	......	......
Sept. 16 (bottom).....	27,400	......	......	......	......	......	......	......	10,800	......	......	......	......	......	......
Nov. 30..................	1,210	......	......	......	......	......	......	......	332	......	......	......	......	......	......

Lake Charles at pier off U. S. 90

Aug. 25, 1949	3,170	......	......	......	......	......	......	......	915	......	......	......	......	......	......

Calcasieu River at old bridge on U. S. 90 (mile 35.5)

Aug. 20, 1949........	1,640	......	......	......	......	......	......	......	448	......	......	......	......	......	......

Moss Lake 1 mile east State Route 104 (mile 24.0)

Aug. 23, 1949........	9,140	......	16	70	201	1,570	58	379	2,820	......	5,080	6.91	1,000	954	77
Sept. 16.................	21,100	......	......	......	......	......	......	......	7,780	......	......	......	......	......	......

Calcasieu River below Moss Lake

Nov. 30, 1949........	12,500	......	......	......	......	......	......	......	4,230	......	......	......	......	......	......

Calcasieu Lake near Hackberry (mile 17.0)

Aug. 23, 1949........	18,300	......	......	143	434	......	......	871	6,020	......	......	......	......	......	......

Calcasieu River near Cameron at bridge on State Route 25 (mile 2.0)

Aug. 23, 1949 (top)..	45,500	7.8	......	372	1,230	9,610	76	2,450	17,200	......	30,900	42.02	5,990	5,920	78
Aug. 23 (bottom)......	45,400	7.5	......	392	1,230	9,660	72	2,480	17,300	......	31,100	42.30	6,040	5,980	78

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*—Continued

CALCASIEU RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
Canal cutting off bend in Calcasieu River on State Route 292															
Aug. 23, 1949	45,500	7.1	...	...	...	...	57	...	17,300	...	...	...	...	...	...
Whiskey Chitto Creek near Mittie at gaging station on State Route 52															
Aug. 10, 1949	60	6.8	20	2.2	2.2	5.8	20	1.0	6.0	1.5	52	0.07	15	0	46
Bundick Creek at gaging station Dry Creek on State Route 251															
Aug. 10, 1949	63	6.7	21	2.4	1.8	7.2	19	2.0	7.2	1.5	52	.07	13	0	54
Junction of Clear and Mud Creeks at Reeves on U. S. 190															
Aug. 13, 1949	87	7.6	...	...	...	...	37	...	10	...	...	...	...	...	...
Tributary to Bayou Serpent 2 miles south Kinder on U. S. 165															
Aug. 13, 1949	42	...	...	...	...	...	...	...	5.0	...	...	...	...	...	...
Bayou Serpent between Fenton and Edna on U. S. 165															
Aug. 20, 1949	105	7.3	...	...	...	...	24	...	17	...	...	...	...	...	...
Bayou Serpent at bridge on State Route 386 (mile 6.0)															
Aug. 20, 1949	82	7.4	...	...	...	...	28	...	10	...	...	...	...	...	...

Canal at Serpent near pumping plant on State Route 386 (mile 6.1)

Aug. 20, 1949	83	...	...	...	...	...	...	...	11	...	...	...	...	...	...

Bayou Arceneaux on State Route 386

Aug. 20, 1949	163	...	...	...	...	...	...	...	27	...	...	...	...	...	...

English Bayou at bridge on U. S. 171 (mile 1.0)

Aug. 20, 1949	307	...	...	...	...	...	...	...	72	...	...	...	...	...	...
Aug. 25 (top)	763	...	...	...	...	...	...	...	196	...	...	...	...	...	...
Aug. 25 (bottom)	8,660	6.9	20	72	197	1,470	44	395	2,650	...	4,830	6.57	990	954	76
Sept. 13 (top)	2,440	...	...	...	...	...	...	...	700	...	...	...	...	...	...
Sept. 13 (bottom)	25,000	...	...	...	...	...	...	...	9,520	...	...	...	...	...	...
Sept. 16 (top)	3,220	...	...	...	...	...	...	...	930	...	...	...	...	...	...
Sept. 16 (bottom)	24,400	...	...	...	...	...	...	...	9,480	...	...	...	...	...	...
Nov. 30	793	...	...	...	...	...	...	...	207	...	...	...	...	...	...

Hickory Branch at bridge on State Route 7 (mile 6.5)

Aug. 11, 1949	347	7.2	...	...	...	...	19	...	92	...	...	...	...	...	...

West Fork Calcasieu at West Fork ferry (mile 13.3)

Aug. 20, 1949	70	...	...	...	...	...	...	...	13	...	...	...	...	...	...

West Fork Calcasieu River and Indian Bayou Junction at Southerland ferry (mile 5.0)

Aug. 20, 1949	211	...	...	...	...	...	...	...	51	...	...	...	...	...	...
Sept. 16 (top)	3,080	...	...	...	...	...	...	...	900	...	...	...	...	...	...
Sept. 16 (bottom)	28,700	...	...	...	...	...	...	...	11,500	...	...	...	...	...	...
Nov. 30	1,660	...	...	...	...	...	...	...	478	...	...	...	...	...	...

Indian Bayou 2 miles east of West Fork ferry at bridge on dirt road (mile 4.7)

Aug. 20, 1949	94	...	...	...	...	...	...	...	19	...	...	...	...	...	...

Table 28.—*Miscellaneous analyses of water from streams in southwestern Louisiana*—Continued

CALCASIEU RIVER BASIN—Continued

Date of collection	Specific conductance (micromhos)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium + Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
Houston River at bridge on State Route 380															
Aug. 25, 1949	75								13						
Houston River at bridge on State Route 104 (mile 8.3)															
Aug. 11, 1949	53								9.0						
Contraband Bayou at bridge on State Route C-1947															
Nov. 30, 1949	5,350								1,610						
Choupique Bayou at bridge on State Route 104															
Aug. 23, 1949	2,880								818						
Nov. 30	8,270								2,700						
Black Bayou on State Route C-1382															
Aug. 20, 1949	861	7.4					62		211						
Sept. 16 (top)	1,970								530						
Sept. 16 (bottom)	18,100								6,540						
Nov. 30	303								56						
Canal 4 miles south Black Bayou at bridge on State Route C-1382															
Nov. 30, 1949	285								57						

INTRACOASTAL WATERWAY

Intracoastal Waterway at ferry (Forked Island ferry) on State Route 26 (mile 169.7)

Aug. 22, 1949 (top)...	914	7.5	......	......	......	......	36	......	232	......	......	......	......	......	......
Aug. 22 (bottom)......	896	......	......	......	......	......	......	......	232	......	......	......	......	......	......
Sept. 14 (top).........	371	......	......	......	......	......	......	......	95	......	......	......	......	......	......
Sept. 14 (bottom)......	367	......	......	......	......	......	......	......	90	......	......	......	......	......	......

Intracoastal Waterway at Gueydan Canal (Spencer ditch) crossing (mile 192.8)

Aug. 24, 1949.........	299	......	......	......	......	......	......	......	64	......	......	......	......	......	......

Intracoastal Waterway west of Mermentau River crossing (mile 203.2)

Aug. 24, 1949.........	148	7.7	......	......	......	......	40	......	21	......	......	......	......	......	......

Intracoastal Waterway at ferry on State Route 25 (mile 219.7)

Aug. 23, 1949 (top)...	348	......	......	......	......	......	......	......	82	......	......	......	......	......	......
Aug. 23 (bottom)......	375	......	......	......	......	......	......	......	89	......	......	......	......	......	......

Intracoastal Waterway at ferry on State Route 931 (mile 231.3)

Nov. 30, 1949.........	963	......	......	......	......	......	......	......	262	......	......	......	......	......	......

Intracoastal Waterway at ferry on State Route 211 near Calcasieu Lock (mile 238.0)

Aug. 20, 1949.........	521	......	......	......	......	......	......	......	128	......	......	......	......	......	......
Sept. 16 (top)..........	24,200	......	......	......	......	......	......	......	9,260	......	......	......	......	......	......
Sept. 16 (bottom)......	24,700	......	......	......	......	......	......	......	9,530	......	......	......	......	......	......
Nov. 30.................	1,130	......	......	......	......	......	......	......	318	......	......	......	......	......	......

Intracoastal Waterway at ferry on State Route 104 (mile 244.0)

Aug. 23, 1949.........	11,800	7.4	15	102	268	2,070	62	545	3,710	......	6,740	9.17	1,360	1,310	77
Sept. 16 (top)..........	22,400	......	......	......	......	......	......	......	8,410	......	......	......	......	......	......
Sept. 16 (bottom)......	27,200	......	......	......	......	......	......	......	10,800	......	......	......	......	......	......
Nov. 30.................	12,000	......	......	......	......	......	......	......	4,190	......	......	......	......	......	......

Table 29.—*Salinity field surveys*

VERMILION RIVER

[The salinity of Vermilion River usually was observed to be nearly the same from top to bottom at any station. Many of the results for chloride reported in this table are averages of the chloride content of top and bottom samples. Others are single observations of top, bottom, or integrated samples. Where significant differences were found, both top and bottom values are given. Salinity, in parts per million of chloride, 1949-51]

Station (miles from mouth)	Time	Chloride
	May 11, 1949	
5.0	9:00 a.m.	45
14.5	11:00 a.m.	28
22.8	12:30 p.m.	30
38.7	1:40 p.m.	20
50.1	....	32
59.6	4:30 p.m.	40
63.8	4:00 p.m.	8
	Mar. 27, 1950	
50.1	....	46
56.1	....	45
59.6	....	92
63.8	....	15
70.0	....	20
	Mar. 28, 1950	
14.5	....	36
24.2	....	52
26.0	....	26
38.7	....	32
	May 15, 1950	
14.5	2:45 p.m.	6
24.2	2:00 p.m.	15
26.0	1:45 p.m.	16
38.7	1:00 p.m.	130
50.1	12:20 p.m.	350
56.1	11:20 a.m.	330
59.6	11:40 a.m.	250
70.0	10:40 a.m.	24
	May 23, 1950	
50.1	9:30 a.m.	30
56.1	10:15 a.m.	50
59.6	10:05 a.m.	130
	Aug. 14, 1950	
3.0	.... (top)	60
	(bottom)	125
	Aug. 21, 1950	
3.0	7:45 a.m.	155
3.0	1:30 p.m.	155
24.2	12:30 p.m.	28
26.0	12:20 p.m.	30
38.7	11:40 a.m.	70
50.1	11:15 a.m.	85
56.1	10:40 a.m.	92
59.6	10:30 a.m. (top)	280
	(bottom)	1,300
	Aug. 28, 1950	
3.0	8:00 a.m.	242
	Sept. 4, 1950	
3.0	8:15 a.m. (top)	860
	(bottom)	550
	Sept. 11, 1950	
3.0	10: a.m.	1,350
	Sept. 18, 1950	
3.0	8:00 a.m.	1,250
	Sept. 25, 1950	
3.0	8:00 a.m.	1,400
	Oct. 10, 1950	
3.0	4:10 p.m.	1,300
26.0	3:20 p.m.	87
	Apr. 2, 1951	
3.0	7:30 a.m.	190
	Apr. 9, 1951	
3.0	7:00 a.m.	55
	Apr. 16, 1951	
	8:00 a.m. (top)	365
	(bottom)	450
	Apr. 19, 1951	
14.5	....	35
24.2	....	40
26.0	....	35
38.7	....	32
50.1	....	38
59.6	....	128
63.8	....	22
70.0	....	18
	Apr. 23, 1951	
3.0	8:30 a.m.	52
	Apr. 30, 1951	
3.0	8:00 a.m.	1,320
	May 7, 1951	
3.0	1:15 p.m.	1,300
14.5	12:00 m. (top)	235
	(bottom)	295
24.2	10:50 a.m.	50
26.0	11:05 a.m.	70
38.7	9:50 a.m.	48
50.1	9:25 a.m.	52
56.1	9:05 a.m.	70
59.6	8:50 a.m. (top)	85
	(bottom)	130
	May 10, 1951	
3.0	10:20 a.m.	1,100
14.5	10:45 a.m.	200
24.2	11:00 a.m.	50
26.0	11:25 a.m.	50
38.7	12:25 p.m.	48
50.1	1:00 p.m.	35
56.1	1:40 p.m	78
59.6	1:45 p.m.	300

Table 29.—*Salinity field surveys*—Continued

VERMILION RIVER—Continued

Station (miles from mouth)	Time	Chloride
	May 14, 1951	
3.0	7:00 a.m.	2,020
	May 16, 1951	
14.5	12:30 p.m.	88
24.2	10:25 a.m.	50
26.0	10:50 a.m.	45
38.7	10:05 a.m.	70
50.1	9:50 a.m.	58
56.1	8:40 a.m.	55
59.6	8:30 a.m.	218
	May 21, 1951	
3.0	7:00 a.m.	1,920
	May 23, 1951	
3.0	....	1,900
5.5	....	1,900
11.0	....	1,350
14.5	....	500
16.0	....	195
17.2	....	75
22.8	....	60
24.2	8:15 a.m.	60
25.7	8:00 a.m.	50
	May 24, 1951	
6.6	....	2,000
10.2	....	1,850
10.4	....	1,850
11.0	....	1,800
12.3	....	1,600
13.0	....	1,800
13.4	....	1,500
13.5	....	1,600
14.4	....	1,320
15.1	....	1,200
15.8	....	900
16.0	....	700
17.1	....	225
17.3	....	200
17.5	....	215
17.7	....	155
18.3	....	110
19.8	....	95
20.8	....	70
22.5	....	65
24.1	....	45
25.9	....	45
	May 28, 1951	
3.0	8:00 a.m.	2,230
	May 29, 1951	
3.0	11:20 a.m.	2,180
4.1	11:05 a.m.	2,300
5.1	10:45 a.m.	2,220
6.1	10:35 a.m.	2,210
8.2	10:25 a.m.	2,250
9.3	10:15 a.m.	2,250
10.2	9:40 a.m.	2,200
10.3	9:30 a.m.	2,250
	May 29, 1951—Con.	
11.0	9:20 a.m.	2,200
11.9	9:15 a.m.	2,120
13.0	9:05 a.m.	2,020
13.5	9:00 a.m.	2,000
14.1	8:50 a.m.	1,950
14.5	8:40 a.m.	1,950
15.2	8:35 a.m.	1,950
15.7	8:30 a.m.	1,880
16.3	8:30 a.m.	1,900
16.8	8:20 a.m.	1,800
17.4	8:15 a.m.	1,700
18.0	8:05 a.m.	1,700
18.2	7:55 a.m.	1,600
18.7	7:50 a.m.	1,580
19.6	7:45 a.m.	1,580
20.1	7:35 a.m.	1,500
20.6	7:30 a.m.	1,500
21.8	7:15 a.m.	1,320
22.8	7:00 a.m.	1,250
24.2	6:25 a.m.	880
26.0	1:45 p.m.	190
38.7	2:05 p.m.	65
50.1	2:30 p.m.	70
56.1	3:30 p.m.	175
59.6	3:35 p.m.	440
14.5	6:30 a.m.	1,960
	7:30 a.m.	1,960
	8:30 a.m.	1,940
	9:30 a.m.	1,940
	10:30 a.m.	1,920
	11:30 a.m.	1,910
	12:30 a.m.	1,920
	1:30 p.m.	1,920
	2:30 p.m.	1,920
	3:30 p.m.	1,940
	4:30 p.m.	1,980
	5:30 p.m.	1,970
	6:30 p.m.	1,980
	June 1, 1951	
3.0	3:35 p.m.	2,140
5.1	3:10 p.m.	2,040
7.2	2:45 p.m.	2,030
9.3	2:25 p.m.	2,020
11.0	1:55 p.m.	2,160
13.0	1:40 p.m.	2,150
14.8	1:05 p.m.	2,120
16.3	12:35 p.m.	2,040
18.7	12:20 p.m.	1,910
20.6	12:00 m.	1,810
22.8	11:25 a.m.	1,660
24.2	11:00 a.m.	1,500
24.9	10:55 a.m.	1,500
26.0	10:30 a.m.	1,350
27.0	10:20 a.m.	1,220

Table 29.—*Salinity field surveys*—Continued

VERMILION RIVER—Continued

Station (miles from mouth)	Time	Chloride	Station (miles from mouth)	Time	Chloride
	June 1, 1951—Con.			June 3, 1951—Con.	
28.1	10:00 a.m.	1,080	44.2	4:05 p.m.	70
29.2	9:45 a.m.	866	45.2	3:55 p.m.	65
30.2	9:35 a.m.	585	46.3	3:50 p.m.	52
31.2	9:35 a.m.	290	38.7	7:10 a.m.	71
32.3	9:10 a.m.	146	38.7	10:35 a.m.	328
33.4	8:55 a.m.	78	38.9	9:45 a.m.	74
34.5	8:05 a.m.	61	40.0	9:50 a.m.	76
35.6	7:45 a.m.	58	41.0	10:00 a.m.	84
36.6	7:30 a.m.	55	42.3	10:10 a.m.	80
37.8	7:15 a.m.	65	26.0	6:20 a.m.	1,820
38.2	7:10 a.m.	52	26.0	7:15 a.m.	1,870
38.4	7:00 a.m.	47		8:25 a.m.	1,850
				9:25 a.m.	1,880
	June 3, 1951			11:55 a.m.	1,880
27.0	3:05 p.m.	1,900		1:50 p.m.	1,950
28.1	2:55 p.m.	1,900		3:15 p.m.	1,960
29.2	2:50 p.m.	1,900		4:20 p.m.	1,950
30.2	2:40 p.m.	1,800		5:50 p.m.	2,000
31.2	2:35 p.m.	1,750			
				June 4, 1951	
32.3	2:30 p.m.	1,700	3.0	7:30 a.m.	2,190
33.4	2:25 p.m.	1,600	24.9	11:20 a.m.	1,850
35.6	2:15 p.m.	1,500	26.0	11:15 a.m.	1,880
36.6	2:05 p.m.	1,350	27.0	11:05 a.m.	1,750
37.8	2:55 p.m.	1,250	28.1	11:00 a.m.	1,650
38.1	11:30 a.m.	1,200	29.2	10:50 a.m.	1,600
38.5	1:55 p.m.	1,150	30.2	10:45 a.m.	1,550
38.9	2:00 p.m.	1,010	31.2	10:40 a.m.	1,400
40.0	2:15 p.m.	315	32.3	10:30 a.m.	1,300
41.0	2:25 p.m.	80	33.4	10:30 a.m.	1,200
42.1	2:35 p.m.	92	34.5	10:25 a.m.	1,150
43.2	2:45 p.m.	80	35.6	10:15 a.m.	500
44.2	2:55 p.m.	80	36.6	10:05 a.m.	90
45.2	3.05 p.m.	55	38.3	9:30 a.m.	78
46.3	3:15 p.m.	52	38.9	9:25 a.m.	68
3.0	2:40 p.m.	2,200	38.9	10:00 a.m.	85
14.8	2:10 p.m.	2,100	39.4	9:20 a.m.	68
26.0	3:15 p.m.	1,960	40.0	9:15 a.m.	65
27.0	3:30 p.m.	1,900	40.5	9:15 a.m.	48
28.1	3:35 p.m.	1,850	41.0	9:05 a.m.	55
29.2	3:40 p.m.	1,850	26.0	1:15 p.m.	1,850
30.2	3:50 p.m.	1,850	27.0	1:30 p.m.	1,700
31.2	3:55 p.m.	1,800	28.1	1:35 p.m.	1,750
32.3	3:55 p.m.	1,750	29.2	1:40 p.m.	1,650
33.4	4:00 p.m.	1,750	30.2	1:45 p.m.	1,620
34.5	4:05 p.m.	1,700	31.2	1:50 p.m.	1,520
34.9	4:15 p.m.	1,550	32.3	2:00 p.m.	1,400
36.3	4:10 p.m.	1,450	33.4	2:05 p.m.	1,250
37.2	4:25 p.m.	1,350	35.0	2:10 p.m.	850
38.5	4:45 p.m.	1,150	35.6	2:15 p.m.	1,050
38.9	3:55 p.m.	1,000	36.6	2:25 p.m.	220
40.0	4:45 p.m.	450	37.8	2:30 p.m.	95
41.0	4:35 p.m.	75	38.3	2:35 p.m.	76
42.1	4:25 p.m.	80	26.0	7:20 a.m.	1,750
43.2	4:15 p.m.	80	26.0	9:20 a.m.	1,550

Table 29.—*Salinity field surveys*—Continued

VERMILION RIVER—Continued

Station (miles from mouth)	Time	Chloride	Station (miles from mouth)	Time	Chloride
	June 4, 1951—Con.			June 6, 1951—Con.	
38.3	3:05 p.m.	100	17.4	10:15 a.m.	1,600
26.0	8:00 a.m.	1,760	18.7	10:20 a.m.	1,300
	9:00 a.m.	1,730	19.2	10:25 a.m.	1,200
	10:00 a.m.	1,760	19.6	10:30 a.m.	1,150
	12:00 m.	1,780	20.1	10:30 a.m.	1,000
	1:00 p.m.	1,800	20.6	10:35 a.m.	950
	2:00 p.m.	1,800	21.2	10:40 a.m.	925
	3:00 p.m.	1,770	21.8	10:40 a.m.	950
	4:00 p.m.	1,690	22.3	10:45 a.m.	962
			22.8	10:50 a.m.	1,025
	June 5, 1951				
14.8	11:50 a.m.	2,000	23.3	....	925
16.3	11:30 a.m.	1,870	23.8	11:05 a.m.	825
17.4	11:25 a.m.	1,710	24.2	11:10 a.m.	750
18.7	11:25 a.m.	1,580	22.8	10:25 a.m.	980
19.6	11:10 a.m.	1,440	23.8	10:15 a.m.	750
20.6	11:05 a.m.	1,360	24.9	10:05 a.m.	461
21.8	11:00 a.m.	1,240	25.4	10:00 a.m.	292
22.8	10:55 a.m.	1,240	26.0	9:55 a.m.	175
23.8	10:45 a.m.	960	26.5	9:45 a.m.	75
24.9	10:35 a.m.	1,220	27.0	9:40 a.m.	70
26.0	10:30 a.m.	995	27.6	9:35 a.m.	66
27.0	10:25 a.m.	760	28.1	9:30 a.m.	60
27.6	10:20 a.m.	670	28.5	9:25 a.m.	65
28.1	10:15 a.m.	430	22.8	6:50 a.m.	820
29.2	10:10 a.m.	74	26.0	6:40 a.m.	100
31.2	10:00 a.m.	52			
				June 7, 1951	
33.4	9:45 a.m.	46	21.2	....	775
35.6	9:30 a.m.	44	22.8	....	545
37.8	9:10 a.m.	34	23.3	....	352
26.0	7:20 a.m.	1,080	23.8	....	421
22.8	7:45 a.m.	1,250	24.2	8:25 a.m.	180
22.8	9:00 a.m.	1,180	24.3	8:15 a.m.	125
	10:00 a.m.	1,220	24.9	8:10 a.m.	88
	11:00 a.m.	1,220	26.0	8:05 a.m.	66
	12:00 m.	1,220	26.5	8:00 a.m.	62
	1:00 p.m.	1,260	27.0	7:55 a.m.	62
	2:00 p.m.	1,250	27.5	7:50 a.m.	58
	3:00 p.m.	1,260	28.1	7:45 a.m.	50
	4:00 p.m.	1,250	28.5	7:40 a.m.	52
	5:00 p.m.	1,280	28.9	7:35 a.m.	52
	6:00 p.m.	1,280	26.0	6:00 a.m.	75
	7:00 p.m.	1,280			
				June 8, 1951	
	June 6, 1951		14.5	8:30 a.m.	1,720
3.0	8:50 a.m.	2,050	15.2	8:35 a.m.	1,550
5.1	9:00 a.m.	2,050	15.7	8:40 a.m.	1,420
7.2	9:15 a.m.	2,100	17.0	8:40 a.m.	1,350
9.3	9:25 a.m.	2,150	17.4	8:45 a.m.	1,250
10.2	9:35 a.m.	2,100			
			18.0	8:50 a.m.	1,100
11.0	9:40 a.m.	2,050	18.7	8:50 a.m.	1,000
11.9	9:45 a.m.	1,950	19.2	8:55 a.m.	950
13.0	9:50 a.m.	1,980	19.6	9:00 a.m.	950
14.1	9:55 a.m.	1,900	20.1	9:05 a.m.	950
14.5	9:55 a.m.	1,900			
15.2	10:00 a.m.	1,800	20.6	9:05 a.m.	850
16.3	10:10 a.m.	1,590	21.2	9:10 a.m.	850

Table 29.—*Salinity field surveys*—Continued

VERMILION RIVER—Continued

Station (miles from mouth)	Time	Chloride
	June 8, 1951—Con.	
21.8	9:10 a.m.	750
22.3	9:15 a.m.	650
22.8	9:20 a.m.	500
23.3	9:20 a.m.	405
23.8	9:25 a.m.	290
24.3	9:30 a.m.	180
24.9	9:30 a.m.	105
25.4	9:35 a.m.	90
26.0	9:35 a.m.	80
27.0	9:45 a.m.	60
28.1	9:55 a.m.	60
26.0	6:00 a.m.	62
26.0	11:05 a.m.	95
	June 11, 1951	
3.0	7:00 a.m.	1,960
3.5	2:40 p.m.	2,050
	June 12, 1951	
3.3	3:15 p.m.	2,050
5.1	2:30 p.m.	2,000
7.2	2:15 p.m.	2,050
9.3	2:10 p.m.	2,100
11.0	1:55 p.m.	2,100
13.0	1:45 p.m.	1,920
14.5	1:40 p.m.	1,780
15.2	1:30 p.m.	1,520
16.3	1:20 p.m.	1,350
17.4	1:10 p.m.	1,050
18.7	1:05 p.m.	900
19.6	12:55 p.m.	750
20.6	12:50 p.m.	500
21.8	12:45 p.m.	250
22.8	12:35 p.m.	125
24.2	12:25 p.m.	60
24.9	12:20 p.m.	58
26.0	11:50 a.m.	62
27.0	11:45 a.m.	62
28.1	11:35 a.m.	66
29.2	11:30 a.m.	53
30.2	11:25 a.m.	46
31.2	11:20 a.m.	41
32.3	11:10 a.m.	40
33.4	11:05 a.m.	43
34.5	11:00 a.m.	48
35.6	10:40 a.m.	64
36.6	10:20 a.m.	86
37.8	10:10 a.m.	95
38.3	10:00 a.m.	98
	June 17, 1951	
38.3	9:00 a.m.	120
38.3	6:00 p.m.	320
38.3	8:00 p.m.	520
	June 18, 1951	
38.3	5:30 a.m.	36
3.0	9:00 a.m.	1,800
4.1	9:05 a.m.	1,720
	June 18, 1951—Con.	
5.1	9:10 a.m.	1,720
7.1	9:20 a.m.	1,700
9.2	9:30 a.m.	1,650
11.0	9:40 a.m.	1,780
13.0	9:45 a.m.	1,920
14.5	9:55 a.m.	2,000
16.3	10:10 a.m.	1,900
17.4	10:15 a.m.	1,850
18.7	10:20 a.m.	1,850
19.6	10:25 a m.	1,850
20.6	10:30 a.m.	1,850
21.8	10:35 a.m.	1,800
22.8	10:45 a.m.	1,700
23.8	10:50 a.m.	1,650
24.2	10:55 a.m.	1,700
24.9	11:00 a.m.	1,650
26.0	11:30 a.m.	1,600
27.0	11:35 a.m.	1,450
28.1	11:40 a.m.	1,350
29.2	11:50 a.m.	1,450
30.2	11:55 a.m.	1,300
31.2	12:00 m.	1,250
32.3	12:05 p.m.	1,020
33.4	12:10 p.m.	900
34.5	12:20 p.m.	800
35.6	12:25 p.m.	358
36.6	12:35 p.m.	90
37.8	12:40 p.m.	65
38.3	12:45 p.m.	21
	June 20, 1951	
24.2	12:05 p.m.	1,620
24.9	12:05 p.m.	1,520
26.0	11:45 a.m.	1,350
27.0	11:40 a.m.	1,350
28.1	11:30 a.m.	1,300
29.2	11:25 a.m.	1,280
30.2	11:15 a.m.	1,340
31.2	11:10 a.m.	1,150
32.3	11:00 a.m.	1,050
33.4	10:55 a.m.	900
34.5	10:50 a.m.	850
35.6	10:45 a.m.	500
36.6	10:35 a.m.	110
37.8	10:25 a.m.	350
38.1	10:25 a.m.	450
38.3	10:00 a.m.	532
38.4	10:00 a.m.	520
38.7	9:55 a.m.	480
38.8	9:55 a.m.	388
38.9	9:55 a.m.	320
40.0	9:45 a.m.	84
	June 25, 1951	
22.8	8:50 a.m.	1,690
24.2	8:40 a.m.	1,580
26.0	11:05 a.m.	1,540

Table 29.—*Salinity field surveys*—Continued

VERMILION RIVER—Continued

Station (miles from mouth)	Time	Chloride
	June 25, 1951—Con.	
27.0	11:10 a. m.	1,500
28.1	11:20 a. m.	1,420
29.2	11:25 a. m.	1,300
30.2	11:30 a. m.	1,300
31.2	11:35 a. m.	1,220
32.3	11:45 a. m.	1,150
33.4	11:50 a. m.	1,160
34.5	11:55 a. m.	832
35.6	12:05 p. m.	352
36.6	12:10 p. m.	128
37.8	12:20 p. m.	92
38.1	....	72
	July 3, 1951	
3.0	9:45 a. m.	1,700
3.5	9:50 a. m.	1,750
4.1	9:50 a. m.	1,700
5.1	9:55 a. m.	1,650
6.1	10:00 a. m.	1,700
7.2	10:05 a. m.	1,800
8.3	10:10 a. m.	1,750
9.3	10:15 a. m.	1,780
10.2	10:20 a. m.	1,800
11.0	10:25 a. m.	1,620
11.9	10:30 a. m.	1,400
13.0	10:35 a. m.	1,220
14.1	10:40 a. m.	1,220
14.8	10:45 a. m.	1,220
15.2	10:50 a. m.	1,150
16.3	10:55 a. m.	1,220
17.4	11:00 a. m.	1,200
18.7	11:15 a. m.	1,020
19.6	11:20 a. m.	1,020
20.6	11:25 a. m.	1,100
21.8	11:30 a. m.	488
22.8	11:40 a. m.	162
24.2	11:50 a. m.	90
26.0	12:15 p. m.	68
	July 6, 1951	
3.0	....	1,790
3.5	....	1,720
5.1	1:35 p. m.	1,690
6.1	1:30 p. m.	1,700
7.2	1:25 p. m.	1,340
9.3	1:15 p. m.	1,520
10.6	1:10 p. m.	1,250
11.9	1:00 p. m.	1,230
13.6	12:50 p. m.	1,060
15.2	12:45 p. m.	520
16.3	12:40 p. m.	250
17.4	12:35 p. m.	90
18.7	12:25 p. m.	80
19.6	12:20 p. m.	80
20.6	12:15 p. m.	100
21.8	12:05 p. m.	105
	July 6, 1951—Con.	
22.8	12:00 m.	85
23.8	11:55 a. m.	80
24.9	11:45 a. m.	158
26.0	11:25 a. m.	154
27.0	11:20 a. m.	182
28.1	11:10 a. m.	240
29.2	11:00 a. m.	256
30.2	10:55 a. m.	200
31.2	10:50 a. m.	144
32.3	10:45 a. m.	84
33.4	10:40 a. m.	58
34.5	10:35 a. m.	50
35.6	10:25 a. m.	26
36.1	10:20 a. m.	21
36.6	10:20 a. m.	43
38.1	10:15 a. m.	77
	July 10, 1951	
3.0	9:50 a. m.	1,880
3.5	9:55 a. m.	1,850
5.1	10:00 a. m.	1,820
7.2	10:10 a. m.	1,750
9.3	10:20 a. m.	1,720
11.0	10:30 a. m.	1,750
13.0	10:40 a. m.	1,680
14.8	10:50 a. m.	1,650
16.3	11:00 a. m.	1,580
17.4	11:05 a. m.	1,400
18.7	11:10 a. m.	1,350
19.6	11:15 a. m.	1,320
20.6	11:20 a. m.	1,200
21.8	11:30 a. m.	1,180
22.8	11:00 a. m.	1,100
24.9	11:55 a. m.	875
26.0	12:25 p. m.	590
27.0	12:50 p. m.	340
28.1	1:00 p. m.	210
29.2	1:05 p. m.	110
30.2	1:10 p. m.	91
31.2	1:15 p. m.	138
32.3	1:20 p. m.	198
33.4	1:30 p. m.	146
34.5	1:35 p. m.	97
35.6	1:45 p. m.	75
36.6	1:50 p. m.	55
37.8	2:00 p. m.	54
38.2	2:05 p. m.	54
	July 17, 1951	
3.5	3:15 p. m.	1,710
5.1	3:10 p. m.	1,680
7.2	3:00 p. m.	1,630
9.3	2:50 p. m.	1,720
11.0	2:35 p. m.	1,810
13.0	2:25 p. m.	1,860
15.2	1:55 p. m.	1,880

Table 29.—*Salinity field surveys*—Continued

VERMILION RIVER—Continued

Station (miles from mouth)	Time	Chloride
	July 17, 1951—Con.	
17.4	1:40 p.m.	1,900
18.7	1:35 p.m.	1,910
19.6	1:30 p.m.	1,900
21.8	1:10 p.m.	1,780
22.8	1:00 p.m.	1,810
23.8	12:55 p.m.	1,820
24.9	12:45 p.m.	1,790
26.0	12:25 p.m.	1,760
27.0	12:15 p.m.	1,690
28.1	12:05 p.m.	1,710
29.2	12:00 m.	1,700
30.2	11:50 a.m.	1,660
31.2	11:40 a.m.	1,660
32.3	11:35 a.m.	1,700
33.4	11:25 a.m.	1,790
34.5	11:15 a.m.	1,620
36.6	10:55 a.m.	1,660
38.1	10:40 a.m.	1,610
38.9	10:30 a.m.	,187
40.0	10:25 a.m.	46
41.0	....	55
	July 24, 1951	
3.0	10:15 a.m.	1,500
3.5	10:25 a.m.	1,440
5.1	10:30 a.m.	1,460
7.2	10:45 a.m.	1,530
9.3	10:50 a.m.	1,550
11.0	11:05 a.m.	1,540
13.0	11:15 a.m.	1,590
14.8	11:25 a.m.	1,680
16.3	11:35 a.m.	1,520
17.4	11:45 a.m.	1,580
18.7	11:55 a.m.	1,660
19.6	12:00 m.	1,700
20.6	12:10 p.m.	1,720
21.8	12:15 p.m.	1,560
22.8	12:20 p.m.	1,180
23.8	12:30 p.m.	821
24.9	12:40 p.m.	990
26.0	12:55 p.m.	1,290
27.0	1:05 p.m.	1,590
28.1	1:10 p.m.	1,530
29.2	1:20 p.m.	1,620
30.2	1:25 p.m.	1,650
31.2	1:30 p.m.	1,700
32.3	1:40 p.m.	1,600
33.4	1:45 p.m.	1,480
34.5	1:50 p.m.	1,550
35.6	2:00 p.m.	1,600
36.6	2:10 p.m.	1,460
38.2	2:20 p.m.	1,000
38.9	2:25 p.m.	44
	July 31, 1951	
3.0	2:45 p.m.	105
3.5	2:40 p.m.	170
	July 31, 1951—Con.	
5.1	2:35 p.m.	78
7.2	2:20 p.m.	69
9.3	2:10 p.m.	69
11.0	2:00 p.m.	76
13.0	1:50 p.m.	93
14.8	1:40 p.m.	98
16.3	1:20 p.m.	94
17.4	1:10 p.m.	90
18.7	1:05 p.m.	91
19.6	1:00 p.m.	94
20.6	12:55 p.m.	102
21.8	12:45 p.m.	116
22.8	12:35 p.m.	130
23.8	12:30 p.m.	126
24.9	12:15 p.m.	50
26.0	11:50 a.m.	56
27.0	11:40 a.m.	54
28.1	11:35 a.m.	50
29.2	11:30 a.m.	45
30.2	11:25 a.m.	46
31.2	11:15 a.m.	57
32.3	11:10 a.m.	58
33.4	11:00 a.m.	52
35.6	10:55 a.m.	54
36.6	10:45 a.m.	54
37.8	10:30 a.m.	51
	Aug. 7, 1951	
3.0	9:30 a.m.	168
3.5	9:35 a.m.	278
5.1	9:45 a.m.	358
7.2	10:05 a.m.	102
9.3	10:15 a.m.	90
11.0	10:25 a.m.	88
13.0	10:35 a.m.	85
14.8	10:45 a.m.	92
16.3	10:55 a.m.	88
17.4	11:00 a.m.	120
18.7	11:10 a.m.	88
19.6	11:20 a.m.	92
20.6	11:30 a.m.	109
21.8	11:35 a.m.	79
22.8	11:40 a.m.	72
24.2	11:55 a.m.	62
24.9	12:00 m.	96
26.0	12:35 p.m.	60
27.0	12:40 p.m.	50
28.1	12:50 p.m.	46
29.2	12:55 p.m.	46
30.2	1:00 p.m.	40
31.2	1:10 p.m.	43
32.3	1:15 p.m.	45
33.4	1:20 p.m.	52
34.5	1:30 p.m.	50
35.6	1:35 p.m.	52
36.6	1:45 p.m.	45
37.8	1:50 p.m.	43

Table 29.—*Salinity field surveys*—Continued

VERMILION RIVER BASIN

[Many of the results for chloride reported for this basin are averages of the chloride content of top and bottom samples. Others are single ovservations of top, bottom, or integrated samples. Salinity, in parts per million of chloride at miscellaneous sites, 1951]

Location	Date	Time	Chloride
Vermilion River and Bay cutoff:			
Just south of Intracoastal Waterway	May 29	11:10 a.m.	2,050
Just south of Intracoastal Waterway	June 1	3:25 p.m.	2,110
At mouth of Bebe Bayou	June 11	3:25 p.m.	2,000
Onion Bayou:			
Just east of Vermilion River and Bay cutoff	June 11	3:35 p.m.	2,000
Just west of Vermilion River and Bay cutoff	June 11	3:35 p.m.	2,050
Vermilion Bay:			
At mouth of Onion Bayou	June 5	1:30 p.m.	1,770
At mouth of Onion Bayou	June 11	3:45 p.m.	2,050
Near Shell Island	June 11	3:50 p.m.	1,880
At mouth of Vermilion River	June 15	10:00 a.m.	2,150
Off Redfish Point	June 15	10:45 a.m.	1,450
Halfway between Redfish Point and Southwest Pass	June 15	11:00 a.m.	1,750
At north end of Southwest Pass	June 15	11:50 a.m.	1,800
At south end of Southwest Pass	June 15	12:20 p.m.	2,425
Between Cypremort Point and Marsh Island	June 15	1:40 p.m.	92
At mouth of Weeks Bay	June 15	4:30 p.m.	1,350
West Cote Blanche Bay:			
Three miles south of Louisa	June 15	2:25 p.m.	500
At mouth of Ivanhoe Canal	June 15	3:10 p.m.	550
Coulee Kinney:			
State Route 43	May 7	11:00 a.m.	55
State Route 43	May 10	....	55

MERMENTAU RIVER BASIN

[Many of the results for chloride reported for this basin are averages of the chloride content of top and bottom samples. Other are single observations of top, bottom, or integrated samples. Where significant differences were found, both top and bottom values are given. Salinity, in parts per million of chloride, 1949–51]

Mermentau River

Station (miles from mouth)	Chloride	Station (miles from mouth)	Chloride	Station (miles from mouth)	Chloride
May 12, 1949		July 18, 1950—Con.		Aug. 21, 1950	
42.2	12	38.2	46	38.2	60
50.7	8				
66.6	5	July 26, 1950		Aug. 27, 1950	
		8.2	123	8.2	7,900
Mar. 29, 1950					
52.6	16	Aug. 10, 1950		Aug. 28, 1950	
		8.2	680	38.2	555
Mar. 31, 1950					
66.6	10	Aug. 14, 1950		Sept. 4, 1950	
		8.2	8,300	8.2	13,300
May 4, 1950		38.2	30	38.2	(top) 950
52.6	10				(bottom) 4,400
66.6	16	Aug. 20, 1950			
		8.2	(top) 6,250		
July 18, 1950			(bottom) 7,600		
8.2	122				
33.6	68				

Table 29.—*Salinity field surveys*—Continued

MERMENTAU RIVER BASIN—Continued

Station (miles from mouth)	Chloride
Mermentau River—Continued	
Sept. 9, 1950	
38.2	1,300
Sept. 18, 1950	
8.2	(top) 4,050
	(bottom) 7,300
38.2	(top) 1,450
	(bottom) 3,050
Sept. 25, 1950	
8.2	3,450
38.2	1,220
Oct. 10, 1950	
66.6	60
Apr. 2, 1951	
38.2	75
Apr. 7, 1951	
8.2	1,250
Apr. 9, 1951	
38.2	42
Apr. 16, 1951	
8.2	1,180
38.2	42
66.6	18
Apr. 23, 1951	
38.2	65
Apr. 28, 1951	
8.2	1,310
Apr. 30, 1951	
38.2	41
May 4, 1951	
24.0	550
34.5	180
35.7	150
42.2	28
May 7, 1951	
38.2	75
May 12, 1951	
8.2	3,500
May 14, 1951	
38.2	350
May 21, 1951	
8.2	7,780
38.2	450
May 22, 1951	
66.6	25
May 28, 1951	
38.2	500
June 2, 1951	
52.6	412
66.6	208
June 4, 1951	
38.2	560
June 7, 1951	
42.2	600
52.6	460
66.6	300
June 11, 1951	
38.2	675
June 13, 1951	
66.6	400
June 18, 1951	
38.2	700
June 19, 1951	
42.2	700
52.6	525
66.6	450
June 25, 1951	
38.2	765
June 26, 1951	
42.2	750
52.6	650
66.6	425
July 3, 1951	
52.6	720
66.6	535
July 5, 1951	
38.2	895
42.2	845
52.6	695
66.6	525
July 9, 1951	
38.2	950
July 12, 1951	
34.5	1,070
38.2	1,040
42.2	970
49.3	865
66.6	590
July 16, 1951	
38.2	1,280
42.2	1,270
52.6	958
66.6	720
July 23, 1951	
38.2	1,160
July 23, 1951—Con.	
42.2	1,300
52.6	1,140
66.6	838
July 26, 1951	
34.5	1,470
38.2	1,270
42.2	1,290
49.3	1,160
52.6	1,080
66.6	805
July 30, 1951	
38.2	1,170
42.2	1,150
52.6	920
66.6	195
Aug. 2, 1951	
38.2	800
42.2	975
66.6	219
Aug. 9, 1951	
38.2	632
42.2	460
52.6	200
66.6	165
Aug. 14, 1951	
38.2	750
Aug. 15, 1951	
66.6	215
Aug. 20, 1951	
38.2	560
Aug. 21, 1951	
66.6	230
Aug. 28, 1951	
66.6	190
Aug. 29, 1951	
38.2	682
Sept. 3, 1951	
38.2	650
Sept. 4, 1951	
66.6	165
Sept. 9, 1951	
38.2	490
Sept. 12, 1951	
66.6	175
Sept. 24, 1951	
38.2	165

Table 29.—*Salinity field surveys*—Continued

MERMENTAU RIVER BASIN—Continued

Station (miles from mouth)	Chloride
Mermentau River—Con.	
Sept. 26, 1951	
66.6	40
Oct. 1, 1951	
38.2	115
Oct. 2, 1951	
66.6	40
Oct. 7, 1951	
66.6	50
Oct. 8, 1951	
38.2	101
Oct. 15, 1951	
38.2	105
Oct. 22, 1951	
38.2	136
Bayou Lacassine	
July 16, 1951	
15.9	782
22.9	747
July 23, 1951	
15.9	850
22.9	734
36.4	38
July 30, 1951	
15.9	725
Aug. 9, 1951	
15.9	175
22.9	160
Bayou Queue de Tortue	
May 12, 1949	
6.5	15
Mar. 28, 1950	
27.6	8
32.7	8
39.5	9
Mar. 29, 1950	
6.5	9
11.1	10
14.7	18
May 2, 1951	
11.1	7
14.7	6
27.6	2
32.7	2
39.5	2
Bayou Queue de Tortue—Con.	
May 5, 1950	
6.5	4
Apr. 18, 1951	
11.1	18
14.7	18
32.7	20
36.2	10
39.5	10
June 2, 1951	
6.5	32
14.7	56
June 7, 1951	
6.5	300
14.7	140
June 19, 1951	
6.5	505
14.7	60
27.6	40
June 26, 1951	
6.5	575
14.7	50
27.6	52
July 3, 1951	
6.5	618
14.7	58
27.6	21
July 5, 1951	
6.5	85
11.1	45
14.7	55
July 16, 1951	
6.5	868
14.7	120
July 17, 1951	
36.2	32
July 23, 1951	
6.5	985
14.7	770
July 30, 1951	
6.5	215
14.7	195
Aug. 9, 1951	
6.5	128
14.7	128
Aug. 15, 1951	
6.5	147
14.7	165
Bayou Queue de Tortue—Con.	
Aug. 20, 1951	
6.5	172
Aug. 27, 1951	
6.5	224
Sept. 3, 1951	
6.5	185
Sept. 10, 1951	
6.5	215
Sept. 24, 1951	
6.5	117
Oct. 1, 1951	
6.5	53
Oct. 9, 1951	
6.5	52
Bayou Nezpique	
May 12, 1949	
6.5	8
Mar. 30, 1950	
14.0	6
33.2	11
41.2	8
Mar. 31, 1950	
6.5	1
21.8	5
May 4, 1950	
6.5	2
14.0	4
21.8	2
33.2	4
41.2	1
Apr. 16, 1951	
33.2	20
Apr. 17, 1951	
6.6	10
21.8	12
Apr. 18, 1951	
41.2	15
June 2, 1951	
6.5	60
33.2	34
June 7, 1951	
6.5	186

Table 29.—*Salinity field surveys*—Continued

MERMENTAU RIVER BASIN—Continued

Station (miles from mouth)	Chloride
Bayou Nezpique—Con.	
June 13, 1951	
6.5	281
33.2	34
June 19, 1951	
6.5	235
14.0	125
23.3	35
33.2	8
June 26, 1951	
6.5	242
14.0	28
23.3	30
33.2	25
July 5, 1951	
6.5	417
14.0	254
23.3	24
33.2	28
July 16, 1951	
6.5	553
14.0	422
23.3	142
33.2	28
July 23, 1951	
6.5	685
14.0	545
23.3	333
33.2	83
July 30, 1951	
6.5	555
14.0	255
23.3	142
33.2	30
Aug. 9, 1951	
6.5	360
14.0	186
23.3	51
33.2	33
Aug. 15, 1951	
6.5	290
14.0	267
Aug. 20, 1951	
14.0	165
Aug. 27, 1951	
14.0	130
Sept. 3, 1951	
14.0	88
Sept. 17, 1951	
14.0	28

Station (miles from mouth)	Chloride
Bayou Nezpique—Con.	
Sept. 24, 1951	
14.0	21
Oct. 1, 1951	
14.0	21
Bayou des Cannes	
May 12, 1949	
6.8	41
Mar. 30, 1950	
6.8	30
16.8	(top) 68
	(bottom) 445
May 4, 1950	
6.8	26
16.8	13
34.2	2
36.5	2
Apr. 16, 1951	
27.0	485
Apr. 18, 1951	
6.8	65
10.4	102
16.8	345
34.2	45
35.6	30
May 3, 1951	
10.4	172
17.2	256
27.0	77
June 2, 1951	
10.4	65
17.2	188
June 7, 1951	
10.4	76
June 13, 1951	
10.4	107
17.2	90
June 19, 1951	
6.8	290
10.4	105
17.2	112
27.0	38
June 26, 1951	
6.8	120
10.4	75
17.2	75
27.0	55

Station (miles from mouth)	Chloride
Bayou des Cannes—Con.	
July 5, 1951	
6.8	64
10.4	48
17.2	40
27.0	30
July 16, 1951	
6.8	580
10.4	485
17.2	62
27.0	52
July 23, 1951	
6.8	559
10.4	505
16.8	83
27.0	60
July 30, 1951	
6.8	110
10.4	107
17.2	207
27.0	55
Aug. 9, 1951	
6.8	137
10.4	123
17.2	73
27.0	87
Aug. 15, 1951	
6.8	100
10.4	75
Aug. 20, 1951	
6.8	70
Aug. 27, 1951	
6.8	64
Sept. 3, 1951	
6.8	120
Sept. 17, 1951	
6.8	72
Sept. 24, 1951	
6.8	68
Oct. 1, 1951	
6.8	47
Oct. 8, 1951	
6.8	142
Oct. 15, 1951	
6.8	130

Table 29.—*Salinity field surveys*—Continued

MERMENTAU RIVER BASIN—Continued

Station (miles from mouth)	Chloride
Bayou Mallet	
Mar. 30, 1950	
2.9	(top) 80
	(bottom) 130
May 4, 1950	
2.9	39
Apr. 18, 1951	
2.9	2,750
May 3, 1951	
2.9	(top) 5,280
	(bottom) 5,730
June 19, 1951	
2.9	140
June 26, 1951	
2.9	98
July 5, 1951	
2.9	44
July 16, 1951	
2.9	46
July 23, 1951	
2.9	118
July 30, 1951	
2.9	177
Aug. 9, 1951	
2.9	75
Bayou Plaquemine Brule	
May 12, 1949	
4.9	19
Mar. 30, 1950	
22.1	6
Mar. 31, 1950	
4.9	6
12.1	6
19.0	12
42.2	12
May 2, 1950	
4.9	4
12.1	3
19.0	3
22.1	3
Bayou Plaquemine Brule—Con.	
June 2, 1950	
4.9	71
Apr. 16, 1951	
4.9	21
12.1	18
36.0	50
42.2	75
Apr. 18, 1951	
22.1	15
June 7, 1951	
12.1	96
June 13, 1951	
4.9	280
June 19, 1951	
4.9	320
12.1	270
22.1	80
June 26, 1951	
4.9	372
12.1	360
22.1	95
July 3, 1951	
12.1	210
22.1	65
22.9	68
July 5, 1951	
4.9	350
12.1	300
22.1	64
July 16, 1951	
4.9	596
12.1	511
22.1	104
July 23, 1951	
4.9	675
12.1	581
22.1	125
July 26, 1951	
12.1	385
July 30, 1951	
4.9	85
Bayou Plaquemine Brule—Con.	
July 30, 1951—Con.	
12.1	85
22.1	32
Aug. 9, 1951	
4.9	135
12.1	125
22.1	68
Aug. 15, 1951	
4.9	165
Aug. 20, 1951	
4.9	158
Aug. 27, 1951	
4.9	154
Sept. 3, 1951	
4.9	160
Sept. 10, 1951	
4.9	98
Sept. 17, 1951	
4.9	68
Sept. 24, 1951	
4.9	66
Oct. 1, 1951	
4.9	31
Oct. 8, 1951	
4.9	36
Bayou Wikoff	
Mar. 31, 1950	
0.3	19
9.0	35
May 2, 1950	
0.3	2
9.0	4
Apr. 17, 1951	
0.3	50
Apr. 18, 1951	
9.0	185

Table 29.—*Salinity field surveys*—Continued

MERMENTAU RIVER BASIN—Continued

Grand Lake

[Stations are: 1, Nigger Island; 2, Grassy Point; 3, outside Catfish Point; 4, Chenier Du Fond; 5, Umbrella Point; 6, Mallard Bay; and 7, Mallard Bay near Spencer ditch]

Station	Chloride	Station	Chloride	Station	Chloride
May 4, 1951		July 12, 1951		July 26, 1951	
2	325	1	1,060	1	1,500
3	625	2	1,100	2	1,110
4	575	4	1,230	4	1,140
5	525	5	1,100	5	1,080
6	425	6	935	6	940
7	298				

CALCASIEU RIVER BASIN

[Salinity, in parts per million of chloride, 1949–51]

Calcasieu River

Station (miles from mouth)	Time	Top	Bottom
May 13, 1949			
35.5	10:30 a.m.	32	30
90.8	2:15 p.m.	1	1
Mar. 21, 1950			
50.2	....	5	7
56.1	....	4	6
66.2	....	5	2
80.6	....	4	4
90.8	....	3	4
May 11, 1950			
35.5	12:15 p.m.	2	2
37.5	12:30 p.m.	1	1
44.0	2:50 p.m.	1	2
50.2	10:45 a.m.	1	2
56.1	10:15 a.m.	2	2
66.2	9:50 a.m.	1	1
80.6	9:00 a.m.	2	2
90.8	8:35 a.m.	1	1
July 18, 1950			
0.7	....	3,280	11,100
Aug. 7, 1950			
50.2	1:20 p.m.	16	20
Aug. 17, 1950			
44.0	9:45 a.m.	800	1,550
50.2	10:15 a.m.	300	7,000
56.1	11:00 a.m.	15	75
66.2	11:15 a.m.	15	15
80.6	11:45 a.m.	15	15
Oct. 10, 1950			
50.2	8:30 a.m.	700	6,000
56.1	8:45 a.m.	35	35

Station (miles from mouth)	Time	Top	Bottom
Apr. 17, 1951			
50.2	9:20 a.m.	10	15
56.1	9:30 a.m.	5	5
59.0	9:45 a.m.	10	10
66.2	10:10 a.m.	10	15
80.6	10:35 a.m.	10	20
May 10, 1951			
44.0	....	1,150	2,250
50.2	....	550	550
56.1	....	10	10
59.0	....	10	10
June 4, 1951			
35.5	6:15 p.m.	3,950	4,450
37.5	5:50 p.m.	3,650	7,080
46.2	2:10 p.m.	2,060	7,640
50.2	1:50 p.m.	1,500	4,540
59.0	12:30 p.m.	14	22
66.2	11:45 a.m.	....	10
80.6	11:00 a.m.	....	10
90.8	10:15 a.m.	....	34
June 6, 1951			
35.5	....	4,150	4,350
37.5	....	3,780	5,550
50.2	....	1,480	5,430
54.8	....	250	1,450
56.1	....	77	130
59.0	....	12	10
June 8, 1951			
51.1	12:15 p.m.	1,600	4,280
52.1	12:05 p.m.	1,300	5,020
53.0	11:55 a.m.	1,120	3,500
54.1	11:40 a.m.	460	2,180
55.1	11:25 a.m.	410	1,640

Table 29.—*Salinity field surveys*—Continued

CALCASIEU RIVER BASIN—Continued

Station (miles from mouth)	Time	Top	Bottom	Station (miles from mouth)	Time	Top	Bottom
	Calcasieu River—Continued						
	June 8, 1951—Con.				July 18, 1951—Con.		
56.1	11:15 a.m.	290	620	57.0	11:25 a.m.	700	2,820
57.0	11:00 a.m.	199	563	57.9	11:15 a.m.	520	2,650
57.9	10:45 a.m.	47	115	59.0	11:00 a.m.	520	2,250
59.0	10:35 a.m.	24	42	60.1	10:40 a.m.	300	1,120
				61.1	10:30 a.m.	46	90
	June 21, 1951						
37.5	4:15 p.m.	5,250	5,900		July 25, 1951		
50.2	1:50 p.m.	2,750	4,700	35.5	3:40 p.m.	6,250	9,960
55.1	12:00 m.	1,100	1,650	46.2	12:30 p.m.	4,150	8,280
56.1	11:45 a.m.	850	1,180	50.2	2:50 p.m.	3,420	6,500
57.0	11:25 a.m.	425	1,400	54.8	10:45 a.m.	1,600	4,220
57.9	11:15 a.m.	300	1,150	56.1	11:10 a.m.	1,280	3,820
59.0	10:35 a.m.	100	250	57.0	11:25 a.m.	950	3,500
				57.9	11:35 a.m.	790	3,100
	June 27, 1951			59.0	12:00 m.	470	2,660
37.5	12:00 m.	5,050	....	60.1	12:15 p.m.	235	2,440
55.1	10:30 a.m.	700	2,680	61.1	12:25 p.m.	70	305
56.1	10:45 a.m.	550	2,380				
57.3	10:55 a.m.	375	1,900		Aug. 2, 1951		
57.8	11:05 a.m.	400	1,780	35.2	1:25 p.m.	6,175	10,220
58.4	11:20 a.m.	250	1,500	37.5	1:15 p.m.	4,450	9,890
59.0	11:50 a.m.	110	1,350	46.2	12:40 p.m.	2,200	8,050
60.1	12:00 m.	50	750	50.2	12:25 p.m.	1,650	6,200
61.1	12:10 p.m.	12	10	54.8	10:15 p.m.	690	3,160
62.1	12:55 p.m.	12	12	56.1	10:00 a.m.	585	2,910
63.1	12:40 p.m.	10	10	57.0	9:45 a.m.	410	2,740
				57.9	9:35 a.m.	220	2,440
	July 3, 1951			59.0	9:05 a.m.	68	386
37.5	3:00 p.m.	6,480	7,750	60.1	8:45 a.m.	18	25
50.2	2:20 p.m.	3,800	4,700	61.1	8:35 a.m.	20	15
54.1	11:15 a.m.	2,520	3,380				
55.1	11:05 a.m.	2,100	2,680		Aug. 8, 1951		
56.1	10:55 a.m.	1,600	3,300	35.2	2:10 p.m.	5,900	10,500
57.0	10:40 a.m.	1,000	2,180	37.5	1:45 p.m.	4,320	10,680
57.9	10:30 a.m.	650	2,000	46.2	11:25 a.m.	1,780	9,580
59.0	10:20 a.m.	185	800	50.2	11:10 a.m.	1,250	7,100
60.1	10:10 a.m.	45	55	53.0	12:50 p.m.	585	4,350
61.1	10:00 a.m.	14	16	54.1	12:40 p.m.	305	3,300
62.1	9:50 a.m.	10	12	54.8	12:00 m.	310	3,500
63.1	9:30 a.m.	10	9	56.1	1:30 p.m.	195	4,000
64.1	9:20 a.m.	10	13	57.0	1:45 p.m.	150	3,250
				57.9	1:55 p.m.	96	2,880
	July 11, 1951			59.0	2:05 p.m.	56	1,690
35.2	4:10 p.m.	5,760	9,125	60.1	2:20 p.m.	19	22
37.5	3:55 p.m.	4,800	8,220	61.1	2:30 p.m.	11	11
46.2	12:10 p.m.	2,500	7,550				
50.2	11:55 a.m.	1,600	5,280		Aug. 21, 1951		
54.8	8:05 a.m.	440	2,700	35.2	4:40 p.m.	6,550	14,850
56.1	8:20 a.m.	290	2,920	37.5	4:20 p.m.	4,800	15,200
57.0	8:35 a.m.	270	2,130	46.2	2:20 p.m.	3,700	13,550
57.9	8:50 a.m.	140	2,020	50.2	2:00 p.m.	2,700	11,750
59.0	9:05 a.m.	48	1,750	54.8	11:50 a.m.	1,020	6,800
60.1	9:20 a.m.	10	320	56.1	11:30 a.m.	690	6,050
				57.0	11:15 a.m.	590	5,450
	July 18, 1951			57.9	11:05 a.m.	350	4,950
35.2	3:10 p.m.	5,520	7,950	59.0	10:45 a.m.	284	4,580
37.5	2:55 p.m.	5,180	7,950	60.1	10:30 a.m.	192	3,320
46.2	2:15 p.m.	3,000	7,350	61.1	10:20 a.m.	100	2,280
50.2	1:50 p.m.	2,450	6,650				
54.8	12:10 p.m.	1,200	3,620		Sept. 5, 1951		
56.1	11:50 a.m.	785	3,120	35.2	4:05 p.m.	7,100	13,000

Table 29.—*Salinity field surveys*—Continued

CALCASIEU RIVER BASIN—Continued

Station (miles from mouth)	Time	Top	Bottom
	Calcasieu River—Con.		
	Sept. 5, 1951—Con.		
37.5	3:45 p.m.	4,900	13,450
46.2	12:55 p.m.	3,350	15,250
50.2	4:25 p.m.	2,700	10,850
54.8	10:20 a.m.	1,070	6,500
56.1	10:35 a.m.	815	5,400
57.0	10:50 a.m.	715	6,300
57.9	11:05 a.m.	520	6,250
59.0	11:20 a.m.	450	5,400
60.1	11:55 a.m.	285	4,400
61.1	12:10 p.m.	180	3,200
62.1	12:25 p.m.	60	78
63.1	12:50 p.m.	47	62
64.1	1:05 p.m.	10	12
65.1	1:15 p.m.	15	20
	Sept. 19, 1951		
35.2	2:00 p.m.	2,300	12,100
37.5	1:45 p.m.	1,300	9,300
46.2	10:55 a.m.	430	11,800
50.2	10:35 a.m.	150	9,450
54.8	1:15 p.m.	40	1,150
56.1	12:55 p.m.	21	4,425
57.0	12:40 p.m.	18	40
57.9	12:25 p.m.	14	14
59.0	10:50 a.m.	10	12
60.1	11:05 a.m.	7	8
61.1	11:15 a.m.	5	7
62.1	11:30 a.m.	5	5
	Oct. 2, 1951		
35.2	12:15 p.m.	1,350	9,500
37.5	12:00 m.	900	9,300
46.2	7:45 a.m.	550	11,100
50.2	1:25 p.m.	115	8,250
52.1	9:35 a.m.	65	170
53.0	9:20 a.m.	31	105
54.1	9:10 a.m.	18	52
54.8	8:20 a.m.	14	22
56.1	8:45 a.m.	16	11
59.0	12:00 m.	7	7
	West Fork Calcasieu River		
	June 4, 1951		
5.0	2:35 p.m.	900	7,700
13.3	3:00 p.m.	600	2,820
	June 6, 1951		
5.0	....	1,100	7,750
13.3	5:10 p.m.	650	4,700
	June 11, 1951		
1.8	11:20 a.m.	2,000	5,700
2.8	11:30 a.m.	1,680	3,500
4.3	....	1,500	4,980
5.0	12:05 p.m.	1,450	4,800
6.7	12:15 p.m.	1,450	3,520
8.2	12:25 p.m.	1,420	4,200
	West Fork Calcasieu River—Con.		
	June 21, 1951		
5.0	2:40 p.m.	1,950	2,900
13.3	2:25 p.m.	1,000	4,750
	July 11, 1951		
5.0	12:45 p.m.	3,300	6,420
13.3	1:30 p.m.	1,920	5,720
	July 25, 1951		
5.0	1:00 p.m.	3,560	7,920
13.3	1:30 p.m.	3,050	5,750
	Aug. 2, 1951		
5.0	1:00 p.m.	800	6,050
	Aug. 3, 1951		
5.0	9:25 a.m.	700	7,300
13.3	9:55 a.m.	50	5,000
	Aug. 8, 1951		
5.0	11:45 a.m.	745	8,250
13.3	12:10 p.m.	210	5,700
	Aug. 21, 1951		
5.0	2:40 p.m.	2,800	12,050
13.3	3:05 p.m.	1,720	8,750
	Sept. 5, 1951		
5.0	1:30 p.m.	1,000	14,000
13.3	1:55 p.m.	2,920	11,350
	Sept. 19, 1951		
5.0	11:15 a.m.	725	7,150
13.3	12:00 m.	65	11,350
	Oct. 2, 1951		
5.0	8:00 a.m.	205	11,750
13.3	8:35 a.m.	10	11,700
	Indian Bayou		
	June 21, 1951		
4.7	2:15 p.m.		[a]128
	June 27, 1951		
4.7	11:10 a.m.		[a]800
	July 11, 1951		
4.7	1:10 p.m.	370	370
	July 25, 1951		
4.7	1:20 p.m.		[a]325
	Aug. 3, 1951		
4.7	9:45 a.m.		[a]290
	Aug. 8, 1951		
4.7	11:55 a.m.		[a]636

Table 29.—*Salinity field surveys*— Continued

CALCASIEU RIVER BASIN—Continued

Station (miles from mouth)	Time	Top	Bottom
	Indian Bayou—Con.		
	Aug. 21, 1951		
4.7	2:55 p. m.		[a]1,075
	Sept. 5, 1951		
4.7	1:50 p. m.		[a]200
	Sept. 19, 1951		
4.7	11:50 a. m.		[a]110
	Oct. 2, 1951		
4.7	8:25 a. m.		[a]48
	Beckwith Creek		
	June 21, 1951		
13.0	3:00 p. m.		[a]16
	Hickory Branch		
	June 21, 1951		
6.5	2:45 p. m.		[a]21
	Houston River		
	June 4, 1951		
4.3	3:45 p. m.	2,140	5,120
8.3	4:20 p. m.	980	1,060
	June 6, 1951		
4.3	....	2,130	5,050
8.3	....	1,050	1,250
13.2	....	38	28
	June 11, 1951		
1.0	12:30 p. m.	1,450	3,900
1.7	12:40 p. m.	2,100	4,300
2.7	12:50 p. m.	2,400	3,650
3.3	12:55 p. m.	2,480	3,780
4.3	1:15 p. m.	2,400	3,350
8.3	1:40 p. m.	1,200	1,650
9.5	1:50 p. m.	825	925
9.7	2:00 p. m.		[a]750
11.2	2:10 p. m.	300	300
12.2	2:20 p. m.	150	110
	June 21, 1951		
4.3	3:50 p. m.	2,900	4,450
8.3	3:35 p. m.	950	1,350
	June 27, 1951		
4.3	1:00 p. m.	2,250	....
8.3	12:20 p. m.		[a]900
	July 11, 1951		
4.3	2:00 p. m.	2,790	4,620
8.3	2:20 p. m.	1,700	2,450
13.2	2:40 p. m.	20	20
	Houston River—Con.		
	July 25, 1951		
4.3	2:00 p. m.	3,360	4,820
8.3	2:25 p. m.	1,650	1,940
13.2	2:45 p. m.		[a]10
	Aug. 3, 1951		
4.3	10:15 a. m.	1,900	5,060
8.3	10:30 a. m.	740	750
13.2	10:50 a. m.		[a]6
	Aug. 8, 1951		
4.3	12:45 p. m.	1,650	5,750
8.3	12:55 p. m.	500	2,470
	Aug. 19, 1951		
4.3	12:15 p. m.	1,120	11,300
8.3	12:25 p. m.	1,720	3,800
13.2	12:45 p. m.		[a]28
	Aug. 21, 1951		
4.3	3:25 p. m.	3,500	8,200
8.3	3:45 p. m.	2,220	5,900
	Sept. 5, 1951		
4.3	2:20 p. m.	3,650	11,050
8.3	2:30 p. m.	4,250	8,200
13.2	2:50 p. m.		[a]30
	Oct. 2, 1951		
4.3	9:00 a. m.	425	11,400
8.3	9:10 a. m.	65	75
	English Bayou		
	May 13, 1949		
1.0	12:00 m.	22	22
	June 4, 1951		
1.0	1:30 p. m.	1,360	2,880
7.1	12:50 p. m.	1,080	1,080
	June 6, 1951		
7.1	....	675	1,100
9.5	....	210	212
	June 21, 1951		
1.0	2:05 p. m.	2,500	4,000
7.1	1:50 p. m.	1,300	1,900
	June 27, 1951		
1.0	10:25 a. m.	2,680	4,280
	July 3, 1951		
1.0	2:10 p. m.	2,900	4,980
7.1	1:25 p. m.	2,020	3,120
	July 11, 1951		
1.0	11:45 a. m.	2,710	4,720
7.1	11:05 a. m.	2,480	2,820

Table 29.—*Salinity field surveys*—Continued

CALCASIEU RIVER BASIN—Continued

Station (miles from mouth)	Time	Top	Bottom
	English Bayou—Con.		
	July 18, 1951		
1.0	2:00 p.m.	2,850	5,720
7.1	1:10 p.m.	2,600	2,720
	July 25, 1951		
1.0	2:25 p.m.	3,440	6,050
7.1	2:00 p.m.	2,480	2,750
	Aug. 2, 1951		
1.0	2:15 p.m.	2,400	5,810
7.1	11:35 a.m.	2,540	2,900
	Aug. 8, 1951		
1.0	10:55 a.m.	1,820	6,000
7.1	4:05 p.m.	2,210	3,150
	Aug. 21, 1951		
1.0	1:50 p.m.	3,300	11,150
7.1	1:20 p.m.	2,550	4,750
	Sept. 5, 1951		
1.0	4:05 p.m.	3,700	9,600
7.1	3:25 p.m.	3,100	5,300
	Sept. 19, 1951		
1.0	10:45 a.m.	365	9,320
7.1	2:30 p.m.	220	180
	Oct. 2, 1951		
1.0	1:15 p.m.	410	7,600
7.1	12:15 p.m.	105	130
	Bayou Serpent		
	May 13, 1949		
6.0	12:30 p.m.	5	5
	Bayou Serpent—Con.		
	June 4, 1951		
6.0	12:00 m.	14	12
6.1	June 6, 1951		
6.1	....	12	....
	June 27, 1951		
.5	1:20 p.m.	180	810
	July 3, 1951		
6.0	....	925	900
6.1	....		[a]597
	July 11, 1951		
6.0	10:25 a.m.	222	225
6.1	10:45 a.m.	29	30
	July 25, 1951		
6.0	1:25 p.m.	630	680
6.1	1:40 p.m.	45	41
	Aug. 8, 1951		
6.0	3:40 p.m.	76	37
6.1	3:30 p.m.	28	27
	Aug. 21, 1951		
6.0	12:55 p.m.	60	75
6.1	12:50 p.m.	90	92
	Sept. 5, 1951		
6.1	10:55 a.m.		[a]48
	Sept. 19, 1951		
6.1	2:10 p.m.		[a]25

INTRACOASTAL WATERWAY

[Many of the results for chloride reported for the Waterway are averages of the chloride content of top and bottom samples. Others are single observations of top, bottom, or integrated samples. Where significant differences were found, both top and bottom values are given. Salinity, in parts per million of chloride, 1950-51]

Station (miles from Harvey, La.)	Chloride
Mar. 21, 1950	
203.2	52
Mar. 28, 1950	
162.8	35
July 18, 1950	
203.2	48
219.7	112
243.7	1,560
Aug. 9, 1950	
169.7	140
Aug. 10, 1950	
219.7	82
Aug. 14, 1950	
231.3	3,780
Aug. 21, 1950	
162.8	70
231.3	(top) 2,750
	(bottom) 3,750
Aug. 28, 1950	
231.3	7,500

See footnote at end of table.

Table 29.—*Salinity field surveys*—Continued

INTRACOASTAL WATERWAY—Continued

Station (miles from Harvey, La.)	Chloride	Station (miles from Harvey, La.)	Chloride	Station (miles from Harvey, La.)	Chloride
Sept. 4, 1950		June 1, 1951		July 21, 1951	
231.3	7,900	158.8	2,130	231.3	9,480
Sept. 11, 1950		June 5, 1951		July 26, 1951	
231.3	6,300	158.8	2,100	192.8	1,480
				201.0	1,460
Sept. 18, 1950		June 15, 1951		203.2	1,360
231.3	(top) 4,500	130.9	158		
	(bottom) 5,250	155.0	1,340	July 28, 1951	
				231.3	9,620
Sept. 25, 1950		June 27, 1951			
231.3	2,900	231.3	7,720	Aug. 4, 1951	
		238.0	8,620	231.3	9,380
May 4, 1951					
192.8	375	June 31, 1951		Aug. 11, 1951	
201.0	325	231.3	8,000	231.3	9,090
203.2	178				
		July 7, 1951			
May 7, 1951		231.3	8,850		
162.6	1,720				
163.0	1,500	July 12, 1951			
		192.8	1,050		
May 29, 1951		199.5	1,050		
158.8	2,080	203.2	2,070		

[a]Integrated sample.

As a matter of expediency, most of the samples collected in 1950 and 1951 were analyzed in the field for chloride alone at the time of collection.

Early in the 1951 season there was a marked deficiency in streamflow. The Department of Public Works made available a powerboat, with an operator, which was used in many surveys on the Vermilion River and one survey in Vermilion Bay. Surveys on the Calcasieu River during 1951 were made both by automobile and by a small boat powered by an outboard motor.

Table 27 gives the channel distances, in miles from the mouth, for the important points where samples were taken. Plate 37 also gives stream mileages which can be used in locating sampling points. Table 28 gives the analyses of miscellaneous samples, arranged by basins, and table 29 gives the results of field surveys by basins.

PATTERNS OF SALT-WATER ENCROACHMENT

The problem of salinity in coastal streams and encroachment of salt water in river channels has been studied in various places in the United States by the Geological Survey, the Corps of Engineers, and others. The factors that govern the extent of encroachment are well known, and no reference will be made here to other studies. However, a brief explanation of the manner in which salt-water encroachment occurs is given in the following paragraphs in order to aid in the understanding and interpretation of the data collected in southwestern Louisiana.

In any stream flowing into the sea there is some point or region where the salinity changes from that of the fresh-water characteristic of that stream to that of the open sea. Usually the contact between fresh water and salt water is not characterized by a sharp line of demarcation. Rather, there is a moving zone of mixing or diffusion, where the water is intermediate between sea water and fresh river water. During periods of flood discharge the zone of mixing may be pushed away from the shore out into the open sea, and during periods of low discharge it may move many miles inland.

Factors that affect the amount of mixing and the location of the fresh-water—salt-water contact in a stream include: stream discharge, width, depth, and shape of the channel, sinuosity of the channel, tidal movements and alongshore currents, wind velocity and direction, and disturbances due to navigation.

Salt water is heavier than fresh water and tends to move beneath the fresh water whenever physical agitation is not sufficient to result in mixing. Mixing of sea water and fresh water occurs in the zone of contact. Whenever turbulence is small or absent, this zone may be sharp, and the mixing caused principally by diffusion, a relatively slow process.

Frequently vertical stratification occurs in deep channels having large cross-sectional areas. In these channels fresh water may move downstream on the surface at the same time that salt water moves up the channels on the bottom. The zone of contact between fresh water on top and saltier water on the bottom moves up or down vertically from day to day, the change of position depending chiefly on the river discharge and tidal action. Accompanying this vertical movement of the contact zone is an advance or retreat of the salt water in the stream channel. As salt water often is detectable on the bottom for distances as much as several miles upstream from the point where the fresh water is found on the surface, the salt water sometimes is said to move in a "wedge" beneath the fresh water. Usually both the top and bottom of the stream show higher salinity at downstream points than at upstream points.

In shallow channels stratification is much less likely to occur because wind, tides, and turbulence caused by river traffic result in more complete mixing. In these channels the absence of vertical difference in density results in sharper zones of transition perpendicular instead of parallel to the stream bottoms. As a result, the movement of salt water appears to occur in fronts.

GENERAL QUALITY OF SURFACE WATER

In areas of high rainfall, as in Louisiana, soluble minerals produced by weathering of rocks and soils are carried away in solution at about the rate they are formed. Where they are not affected by oilfield or industrial wastes or encroachment of sea water, the stream waters of southwestern Louisiana are very much alike in chemical characteristics. They usually contain less than 100 ppm of dissolved solids, are soft, and have pH values of about 7.

Although calcium and magnesium bicarbonates normally are present, the amounts are less than are usually found in streams flowing in areas where limestones crop out.

The small amounts of sodium chloride present probably are derived partly from sea spray and partly from rock sources. Generally only very small amounts of sulfate are present. Silica seldom exceeds 20 to 25 ppm and is frequently much less, although it may represent one-fourth to one-half the dissolved solids present in the more dilute waters.

In that part of southwestern Louisiana in which gulf water enters the streams, higher-than-normal concentrations of chloride may be found for varying periods after the encroachment. After runoff has been sufficient to flush out the sea water, there is no significant difference in quality from the normal.

The streams of southwestern Louisiana generally are regarded as being relatively free of suspended sediment. No effort was made to study the sediment loads of the streams. However, it was observed that very little sediment was present in the samples collected for chemical analysis.

Although the southwestern Louisiana area covers small sections outside of the Vermilion, Mermentau, and Calcasieu River basins, the quality-of-water data can best be understood by considering the basins separately. The data presented in the table are divided by basins with separate parts for the Intracoastal Waterway and the Bayou Teche basin where separate data are available.

QUALITY OF WATER IN VERMILION RIVER BASIN

Records collected during the southwestern Louisiana investigation do not show any significant source of salinity in the Vermilion River basin other than diluted gulf water. No evidence of serious contamination from oilfield brines was found. The Vermilion River basin differs from the Mermentau and Calcasieu River basins in that water quality in the Vermilion River basin has been little affected by engineering improvements. Although some water moves into the Vermilion River from Bayou Teche by way of the Ruth Canal and Bayou Fusilier, the analyses of the miscellaneous samples collected in the Bayou Teche and Vermilion River basins indicate that these diversions do not materially affect the quality of water in the Vermilion River.

During periods of water shortage, as in 1948 and 1951, pumping plants on the Vermilion River withdraw more water than the river's natural flow. As a result, water is drawn into the river from Vermilion Bay.

A few chloride determinations of Vermilion Bay water are included in the field survey table (see table 29). These determinations and records obtained from the Corps of Engineers show that Vermilion Bay is normally a body of brackish water representing a mixture of water from flows of the Vermilion River during periods of excess runoff and from flows from the Atchafalaya River, mixed with a small proportion of gulf water. It appears from the data that Vermilion Bay water has a chloride concentration rarely greater than about 2,000 ppm and more rarely greater than 2,600 ppm.

The various records collected on the Vermilion River show that, with few exceptions, there is very little difference in salinity in top and bottom samples (see table 26). The buffer effect of the Atchafalaya River water, which prevents ready access of the saltier gulf water into Vermilion Bay, and the comparatively shallow channel both act to prevent vertical density gradations. As a result, salt water moves into the Vermilion River in fronts rather than as a wedge under the fresh water. The location of the front depends principally on the amounts of runoff and pumping.

Typical salinity profiles, which clearly show the comparatively sharp break from fresh to brackish water, are given in figure 72. Data collected on the field surveys during the period of deficient runoff extending from May to September 1951 also show the movement of the fronts during the period. Some of the analyses indicate changes at particular points from hour to hour resulting from tidal actions. The data show that normally the salinity in the Vermilion

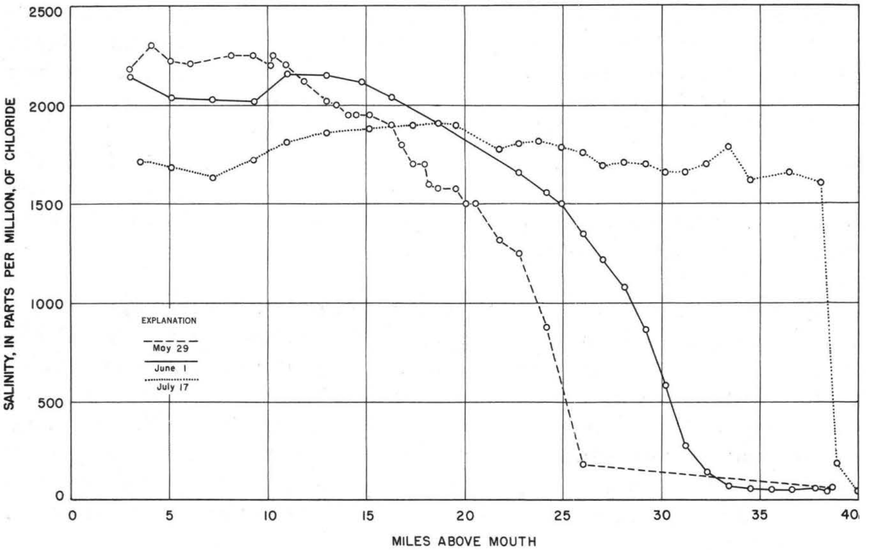


Figure 72.—Typical salinity profiles in Vermilion River, 1951.

River did not change greatly at points on the river located above or below the frontal zone.

Infiltration may occur from the Vermilion River into the aquifers from which the rice-irrigation wells obtain water. (See "Ground-water resources.") The record of daily samples shows that, for periods totaling about 12 weeks between January 1949 and September 1951, water in the Vermilion River was more highly mineralized than the water obtained from the rice-irrigation wells. During these periods, water in the river would have been harmful to young rice. Any wells intruded by the salty river water could have been used safely for irrigation only during the later stages of crop growth.

For further discussion of the factors affecting the quality of water in the Vermilion River see "Surface-water resources." Analyses of water samples from the Vermilion River are given in tables 25, 26, 28 and 29.

QUALITY OF WATER IN MERMENTAU RIVER BASIN

As pointed out in "Surface-water resources," the lower Mermentau River and lake system has been altered into a controlled system. Completion of the control structures has decreased the accessibility of salt water so that data collected before 1951 may not be pertinent to conditions in the future.

Data tabulated from the miscellaneous analyses and field surveys show that the normal discharges of the Mermentau River and its tributaries are low in salinity and the quality of water has deteriorated only during periods of heavy demand, such as occurred in 1951 (see table 25). Analyses of samples collected from Bayou Mallet near its mouth in April and May 1951 give some evidence of contamination from oilfield brines. These were the only samples collected in the Mermentau River basin that indicated this type of contamination.

Because a large part of the water pumped from the Mermentau River and its tributaries is derived from storage in Grand and Whites Lakes, information on the salinity of these lakes is helpful in understanding upstream conditions. The Corps of Engineers and several irrigation companies made records available to the Geological Survey, and a few samples were collected in the lakes by Survey personnel. However, because of a limitation of personnel and facilities, detailed studies of salt-water movement in the lakes were not made.

A sample survey made in 1949 is included in the miscellaneous analyses (table 28), and analytical data for three surveys in the lakes in 1951 are included in the table of field surveys (table 29). Study of the data from these surveys shows that the salinity in Grand Lake on May 4, 1951, at the start of the irrigation season, was about the same as on August 24, 1949, near the close of an irrigation season when water supply had been ample. By July 12, 1951, the salinity in Grand Lake had more than doubled but was still much less than that in Vermilion Bay.

In this investigation no evidence was collected of any danger to the ground waters by encroachment of saline waters in the Mermentau system. Analyses of water samples from the Mermentau River basin are given in tables 25, 26, 28, and 29.

QUALITY OF WATER IN CALCASIEU RIVER BASIN

The quality of water available for irrigation and industrial use in the lower reaches of the Calcasieu River has been greatly affected by navigation improvements. The deep channel to Lake Charles has given the river downstream from the city the salinity characteristics of a tidal estuary. Formerly, a considerable acreage of rice was irrigated by diversion downstream from Lake Charles, but it does not appear that this will be possible again unless some measure is taken to prevent free movement of salt water up the ship channel or upstream supplies are augmented and brought to the area by way of auxiliary channels. For quantitative analysis of the water supply see "Surface-water resources."

The quality of water present in the upper reaches of the Calcasieu River and its tributaries at all times was found to be satisfactory for irrigation. During periods of high flow, such as occurred during the winters of 1949 and 1950, the river channel was swept clean of salt water so that there was no difference in salinity between top and bottom samples collected at the Naval Training Station at Lake Charles. However, when the irrigation pumping began, it was not many weeks, even in those favorable years, until salt water moved above the sampling station, where it remained for considerable periods after pumping ceased.

Field surveys made on the Calcasieu River in 1951 show that on May 10 some salt was present in the river as far upstream as U. S. 171, and by June 4 the salinity at that point was too great for the water to be used.

The salt water in the Calcasieu River moves in the typical wedge pattern. The data from the field surveys nearly always showed higher salinity on the bottom of the channel than near the water surface. Figure 73 shows a typical salinity cross section on the Calcasieu River at Two O'Clock Point, mile 45. 3, taken August 22, 1951.

Pollution from the industries at Lake Charles sometimes has been blamed for the presence of the salt water. Although some salt water does get into the river from industrial sources, on the basis of samples collected upstream from the industries it does not appear that the industrial contamination significantly affected the waters upstream. In any event, the effect of industrial contamination is insignificant in comparison with and is obscured by gulf-water encroachment. One sample collected at mile 42. 4, given in the table of composite analyses (table 25, May 29, 1949), evidently was contaminated badly by some waste product as shown by the very high bicarbonate content and the presence of 450 ppm of ammonia ion. This ion is normally found only in very small amounts in stream waters.

As the Calcasieu River contains saline water in its bed for many months of each year, at least as far upstream as Lake Charles, there is a distinct hazard to heavily pumped groundwater sources. Much additional study is needed, but is is possible that some of the municipal and industrial wells in the Lake Charles area could be damaged by induced infiltration of the saline water.

Analyses of water samples from the Calcasieu River are given in tables 25, 26, 28 and 29.

387601 O -56 -28

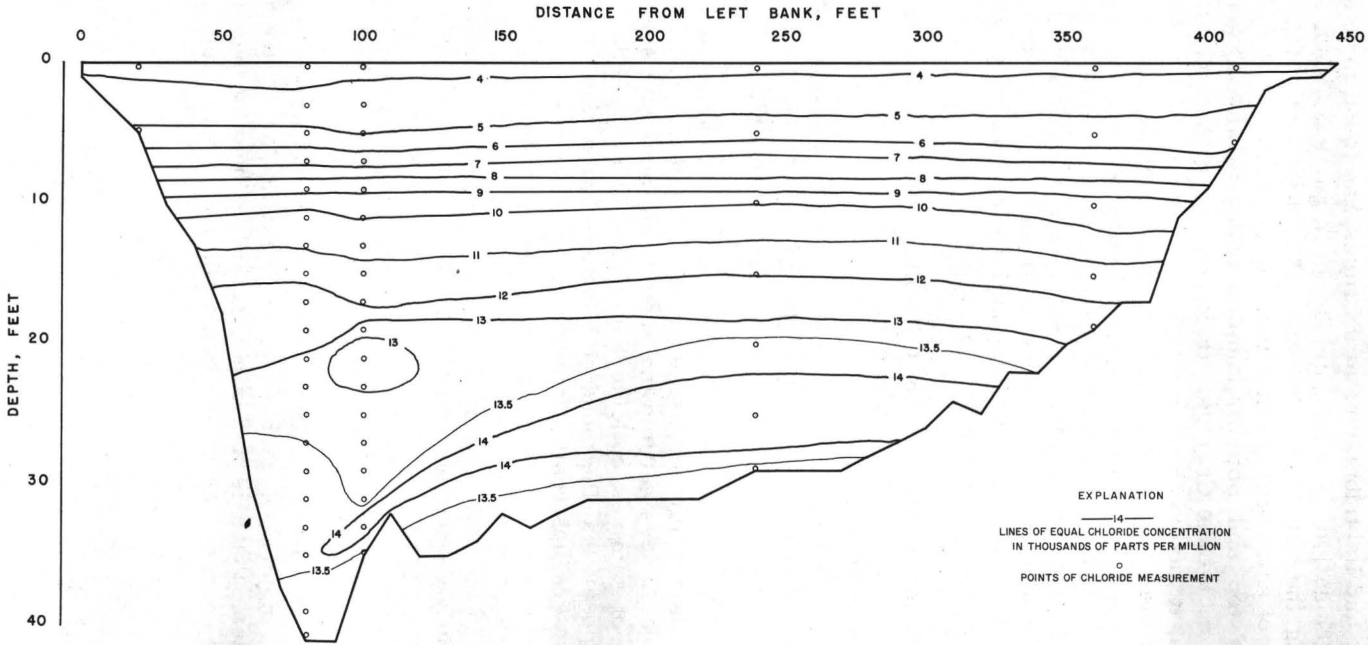


Figure 73. —Typical salinity cross section, Calcasieu River.

CHEMICAL CHARACTER OF GROUND WATER

The quality of ground water in any area is related to the geologic formation through which it moves, the depth below the land surface from which it is obtained, and the distance from areas of recharge. In an effort to determine, on a regional basis, the quality of water available from aquifers of pre-Pleistocene and Pleistone age, a large number of water samples were collected from wells scattered throughout southwestern Louisiana. Complete analyses of samples collected from 69 selected wells are presented in table 30. Plate 38 shows locations of the wells listed in table 30. All the analyses in the table represent the quality of the water from the Pleistocene sand and gravel except those for samples from wells Al–138, Ev–142, SL–4, and SL–84, which represent waters from beds of Pliocene or late Miocene age.

Water of satisfactory quality for many uses is available in formations of Pleistocene age in nearly all of southwestern Louisiana. In some places, chiefly in the coastal area near the Sabine River, potable water is lacking in the Pleistocene deposits. Here the sand and clay were deposited in salty water, and there has been no effective flushing by fresh water. However, in some parts of the coastal region small quantities of potable water are present on barrier beaches, where it occurs to a depth of a few feet as a lens floating on salt water. This water is used for household purposes in some places but is relatively unimportant and is not represented by any of the tabulated analyses.

Most of the wells used for irrigation, public water supply, and industrial purposes in southwestern Louisiana obtain water from the Pleistocene sand and gravel—the Chicot reservoir in this report. Wells drilled in formations of Pleistocene age range in depth from a few feet near the formation outcrop to 800 or 900 feet in a few localities. Many wells drilled into the Pleistocene deposits do not reach the bottom of the fresh-water section. Drilling generally is stopped when a sufficient thickness of the aquifer has been penetrated to supply the amount of water desired. Many of the wells pass through several water-bearing beds and the water pumped from them is a mixture of that present at various depths. The quality of water pumped from these wells depends to a considerable extent on the location of the well screens, consequently, it is not always easy to generalize about the quality of water available in selected areas. The transition from fresh to salt water in the Pleistocene aquifers usually occurs in a fairly sharp zone; although the water above this zone may vary somewhat in quality, generally it is usable for irrigation.

Table 30.—*Chemical analyses of typical ground waters in southwestern Louisiana*

[Parts per million except as explained on page 325. Well identifications listed at end of table]

	Well Al-2	Well Al-31	Well Al-138	Well Al-154	Well Al-156
Silica (SiO_2)	16	52	12	56	50
Iron (Fe)	.42	.05	.06	1.5	4.4
Calcium (Ca)	1.2	9.0	.5	7.2	11
Magnesium (Mg)	2.3	4.5	.3	3.4	3.2
Sodium (Na)	68	12	70	26	18
Potassium (K)	1.2		.4		2.8
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	173	60	168	64	63
Sulfate (SO_4)	13	1.0	7.1	3.0	4.1
Chloride (Cl)	5.9	12	7.5	24	18
Fluoride (F)	.4	...	.2	.0	.1
Nitrate (NO_3)	.0	.2	.0	.0	.2
Boron (B)	.20	...	.16	...	.11
Carbon dioxide (CO_2), calculated	6.9	1.2	5.3	2.6	20
Dissolved solids	193	120	184	151	139
Total hardness as $CaCO_3$	12	41	2	32	41
Specific conductance (micromhos at 25°C)	304	135	284	180	161
Color	20	...	0	...	...
pH	7.6	7.9	7.7	7.6	6.7
Temperature (°F)	74	...	74	72	...
Date of collection	2-13-51	10-27-49	2-13-51	10-27-49	5-17-50
Depth (in feet)	365	120	904	127	280

	Well Al-158	Well Ac-10	Well Ac-166	Well Ac-168	Well Ac-247
Silica (SiO_2)	34	32	35	38	35
Iron (Fe)	.07	1.4	1.6	4.7	...
Calcium (Ca)	2.2	54	63	52	48
Magnesium (Mg)	1.2	20	21	16	20
Sodium (Na)	8.9	57	43	53	62
Potassium (K)	1.6	8.8			
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	28	382	362	286	360
Sulfate (SO_4)	2.0	4.0	.8	.9	2.1
Chloride (Cl)	8.0	24	27	53	26
Fluoride (F)	.0	.0	...	...	.05
Nitrate (NO_3)	.0	1.2	1.0	1.5	3.2
Boron (B)	.19	.40	...	...	...
Carbon dioxide (CO_2), calculated	18	19	9.1	7.2	14
Dissolved soldis	72	396	369	355	373
Total hardness as $CaCO_3$	10	216	244	196	202
Specific conductance (micromhos at 25°C)	72.9	672	622	607	600
Color	...	...	...	...	...
pH	6.4	7.5	7.8	7.8	7.6
Temperature (°F)	69	70	70	71	72
Date of collection	11-9-50	5-10-50	9-13-50	9-13-50	10-25-49
Depth (in feet)	167	300	396	300	288

	Well Ac-280	Well Be-4	Well Be-47	Well Be-48	Well Be-83
Silica (SiO_2)	32	34	6.8	8.2	20
Iron (Fe)	1.7	.06	.00	.00	.04
Calcium (Ca)	54	3.3	14	12	6.4
Magnesium (Mg)	20	1.2	2.7	3.1	.9
Sodium (Na)	65	11	60	1.8	56
Potassium (K)	6.0	5.6			6.8
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	396	37	28	42	164
Sulfate (SO_4)	.5	.8	9.5	2.0	7.2
Chloride (Cl)	26	9.0	70	6.0	7.0

Table 30.—*Chemical analyses of typical ground waters in southwestern Louisiana*—Con.

	Well Ac-280	Well Be-4	Well Be-47	Well Be-48	Well Be-83
Fluoride (F)	0.2	0.0	0.0	0	0.3
Nitrate (NO_3)	8.2	.0	56	2.0	.0
Boron (B)	.08	.02	...	...	.05
Carbon dioxide (CO_2), calculated	32	19	18	6.7	6.5
Dissolved solids	407	95	270	60	186
Total hardness as $CaCO_3$	216	13	46	43	20
Specific conductance (micromhos at 25°C)	691	86	430	95	285
Color	...	...	...	...	...
pH	7.3	6.5	6.4	7.0	7.6
Temperature (°F)	...	70	62	66	72
Date of collection	9-16-50	9-1-50	4-12-48	4-12-48	9-1-50
Depth (in feet)	257	186	22	20	378

	Well Cu-1	Well Cu-83	Well Cu-92	Well Cu-97	Well Cu-98
Silica (SiO_2)	46	65	58	64	58
Iron (Fe)	.64	1.6	1.9	1.1	1.1
Calcium (Ca)	27	36	32	34	51
Magnesium (Mg)	8.5	8.7	9.0	7.8	16
Sodium (Na)	99	35	95	30	190
Potassium (K)	6.4	.4	1.6	2.0	2.0
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	193	168	182	182	202
Sulfate (SO_4)	2.8	4.2	2.0	4.9	1.9
Chloride (Cl)	113	44	120	21	306
Fluoride (F)	.4	.0	.0	.2	.1
Nitrate (NO_3)	.0	.0	.0	.0	.0
Boron (B)	.08	.06	.06	.04	.21
Carbon dioxide (CO_2), calculated	12	1.3	1.5	1.1	1.6
Dissolved solids	398	276	407	253	740
Total hardness as $CaCO_3$	102	126	117	117	193
Specific conductance (micromhos at 25°C)	659	417	677	355	1,300
Color	10	...	...	...	...
pH	7.4	8.3	8.3	8.4	8.3
Temperature (°F)	73	74	76	75	78
Date of collection	10-25-49	7-18-50	7-18-50	7-18-50	7-18-50
Depth (in feet)	560	505	701	519	767

	Well Cu-118	Well Cu-215	Well Cu-447	Well Cu-486	Well Cu-495
Silica (SiO_2)	58	56	48	54	50
Iron (Fe)	2.4	2.4	.74	1.5	.86
Calcium (Ca)	20	13	28	30	9.7
Magnesium (Mg)	7.9	4.2	7.0	9.0	2.0
Sodium (Na)	28	22	37	37	36
Potassium (K)			6.0		9.2
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	139	85	176	161	115
Sulfate (SO_4)	2.0	5.9	3.0	3.0	2.5
Chloride (Cl)	20	21	26	40	16
Fluoride (F)	.0	.0	.2	.0	.2
Nitrate (NO_3)	.0	.0	.2	.0	.0
Boron (B)	...	.47	.15	...	.18
Carbon dioxide (CO_2), calculated	5.5	27	8.8	2.6	15
Dissolved solids	204	175	243	252	184
Total hardness as $CaCO_3$	82	56	99	112	32

Table 30.—*Chemical analyses of typical ground waters in southwestern Louisiana*—Con.

	Well Cu-118	Well Cu-215	Well Cu-447	Well Cu-486	Well Cu-495
Specific conductance (micromhos at 25°C)	276	221	356	371	244
Color	....	....	....	....	....
pH	7.6	6.7	7.5	8.0	7.1
Temperature (°F)	....	71	74	....	74
Date of collection	10-25-49	7-27-49	4-6-51	10-25-49	9-12-50
Depth (in feet)	510	340	493	537	660

	Well Cu-550	Well Cn-10	Well Cn-28	Well Cn-32	Well Cn-33
Silica (SiO_2)	58	26	25	25	28
Iron (Fe)	4.9	.12	.14	2.0	.27
Calcium (Ca)	17	27	16	27	29
Magnesium (Mg)	6.5	8.7	12	16	18
Sodium (Na)	32	219	283	394	343
Potassium (K)	4.4	17	7.6	6.8	8.4
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	106	305	436	420	416
Sulfate (SO_4)	6.6	.3	1.6	.3	.3
Chloride (Cl)	33	241	250	470	400
Fluoride (F)	.3	.1	.2	.3	.3
Nitrate (NO_3)	.0	1.0	.0	2.0	.2
Boron (B)	.08	.14	.26	.05	.27
Carbon dioxide (CO_2), calculated	27	12	17	....	....
Dissolved solids	214	690	810	1,150	1,030
Total hardness as $CaCO_3$	69	104	90	134	146
Specific conductance (micromhos at 25°C)	291	1,210	1,390	2,030	1,810
Color	....	....	5	10	10
pH	6.8	7.6	7.6	7.6	7.6
Temperature (°F)	73	73	74	....	....
Date of collection	5-17-50	5-25-50	11-9-50	10-24-49	10-24-49
Depth (in feet)	100	376	282	460	300

	Well I-53	Well I-56	Well I-62	Well JD-5	Well JD-210
Silica (SiO_2)	46	36	37	40	52
Iron (Fe)	6.8	1.0	.68	.15	1.6
Calcium (Ca)	102	63	57	39	27
Magnesium (Mg)	39	23	14	14	11
Sodium (Na)	32	50	43	73	53
Potassium (K)	8.8	8.0	8.0		4.4
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	613	340	314	252	177
Sulfate (SO_4)	.6	1.0	1.5	1.0	5.1
Chloride (Cl)	5.0	58	28	75	58
Fluoride (F)	.5	.1	.3	.05	.3
Nitrate (NO_3)	.0	2.8	.0	.8	.0
Boron (B)	.00	.25	.11	....	.11
Carbon dioxide (CO_2), calculated	61	27	13	2.5	14
Dissolved solids	535	409	344	367	310
Total hardness as $CaCO_3$	415	252	200	155	113
Specific conductance (micromhos at 25°C)	871	697	572	600	477
Color	20	....	....	....	....
pH	7.2	7.3	7.6	8.2	7.3
Temperature (°F)	73	72	71	72	72
Date of collection	10-19-49	4-18-50	5-16-50	10-31-49	5-9-50
Depth (in feet)	210	340	419	273	300

Table 30.—*Chemical analyses of typical ground waters in southwestern Louisiana*—Con.

	Well JD-327	Well Ev-142	Well Ev-344	Well Ev-345	Well Ev-348
Silica (SiO_2)	53	25	44	42	48
Iron (Fe)	2.1	.6	1.1	.78	2.1
Calcium (Ca)	7.7	.6	46	54	21
Magnesium (Mg)	4.2	.7	17	22	10
Sodium (Na)	86	195	67	30	33
Potassium (K)	8.8	5.2		4.8	
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	150	397	288	290	150
Sulfate (SO_4)	3.6	1.1	23	.4	1.0
Chloride (Cl)	76	66	49	39	29
Fluoride (F)	.2	5.2	.2	.4	.3
Nitrate (NO_3)	.0	1.2	.8	.0	.0
Boron (B)	....	1.3	....	.10	....
Carbon dioxide (CO_2), calculated	.12	4.0	3.6	18	1.5
Dissolved solids	311	508	389	335	220
Total hardness as $CaCO_3$	36	4	185	225	94
Specific conductance (micromhos at 25°C)	488	809	614	549	315
Color	....	70	....	0	....
pH	7.3	8.2	8.1	7.4	8.2
Temperature (°F)	....	74	70	70	....
Date of collection	6-8-49	2-7-50	10-27-49	10-27-49	10-26-49
Depth (in feet)	710	989	219	234	215

	Well I-1	Well I-13	Well JD-343	Well JD-363	Well JD-406
Silica (SiO_2)	42	42	50	50	52
Iron (Fe)	1.7	11	.62	2.6	4.6
Calcium (Ca)	99	64	42	24	20
Magnesium (Mg)	36	23	13	13	5.9
Sodium (Na)	20	17	43	40	32
Potassium (K)	12	14	2.0	2.4	4.8
Carbonate (CO_3)	0	0	0	0	....
Bicarbonate (HCO_3)	540	342	226	165	126
Sulfate (SO_4)	.5	1.2	.5	4.9	5.4
Chloride (Cl)	8.5	5.3	49	40	29
Fluoride (F)	.8	.2	.2	.4	.3
Nitrate (NO_3)	.0	5.2	.2	.0	.8
Boron (B)	.13	.44	.09	.18	.10
Carbon dioxide (CO_2), calculated	54	4.3	11	21	4.0
Dissolved solids	485	340	318	256	212
Total hardness as $CaCO_3$	395	254	158	113	74
Specific conductance (micromhos at 25°C)	785	537	495	390	306
Color	10	....	10	20	....
pH	7.2	8.1	7.5	7.1	7.7
Temperature (°F)	74	70	72	....	70
Date of collection	10-19-49	9-28-50	10-18-49	10-20-49	3-20-50
Depth (in feet)	266	229	271	237	450

	Well Lf-36	Well Lf-129	Well Lf-166	Well Lf-491	Well Lf-496
Silica (SiO_2)	40	42	40	46	48
Iron (Fe)	.54	1.2	.16	3.6	.42
Calcium (Ca)	42	52	11	36	20
Magnesium (Mg)	15	14	4.4	8.0	10
Sodium (Na)	21	37	11	9.8	9.0
Potassium (K)		3.6	1.2	1.2	
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	247	302	56	151	115

Table 30.—*Chemical analyses of typical ground waters in southwestern Louisiana*—Con.

	Well Lf-36	Well Lf-129	Well Lf-166	Well Lf-491	Well Lf-496
Sulfate (SO_4)	0	0.5	7.7	9.3	4
Chloride (Cl)	7.0	14	9.9	8.2	8.0
Fluoride (F)	.1	.0	.1	.5	....
Nitrate (NO_3)	.2	.0	4.0	.0	1.2
Boron (B)	....	.09	.10	.19	....
Carbon dioxide (CO_2), calculated	9.9	1.9	22	24	12
Dissolved solids	247	313	127	195	164
Total hardness as $CaCO_3$	166	187	46	123	91
Specific conductance (micromhos at 25°C)	380	502	154	278	215
Color	....	30	....	....	....
pH	7.6	8.4	6.6	7.0	7.2
Temperature (°F)	70	70	69	68	69
Date of collection	10-25-49	6-27-50	10-25-50	10-25-49	8-7-50
Depth (in feet)	150	350	151	212	157

	Well Lf-501	Well Lf-502	Well SL-4	Well SL-5	Well SL-30
Silica (SiO_2)	42	42	21	50	38
Iron (Fe)	.07	.96	.06	4.8	1.6
Calcium (Ca)	11	16	.8	88	106
Magnesium (Mg)	4.9	4.5	.7	30	33
Sodium (Na)	15	9.8	97	26	59
Potassium (K)	2.8	.4	3.2	2.8	4.0
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	78	93	244	449	462
Sulfate (SO_4)	5.0	2.0	9.7	.8	.6
Chloride (Cl)	9.8	4.0	3.8	23	110
Fluoride (F)	.2	.1	.5	.0	.2
Nitrate (NO_3)	1.8	.0	.8	4.0	.0
Boron (B)	.21	.17	.19	.26	.09
Carbon dioxide (CO_2), calculated	31	12	4.9	3.6	12
Dissolved solids	131	152	269	446	608
Total hardness as $CaCO_3$	48	58	5	343	400
Specific conductance (micromhos at 25°C)	170	169	415	783	1,040
Color	....	15	....	120	40
pH	6.6	7.1	7.9	8.3	7.8
Temperature (°F)	70	....	....	69	69
Date of collection	6-6-51	7-4-51	9-11-50	7-13-50	9-11-50
Depth (in feet)	96	90	983	200	155

	Well SL-48	Well SL-84	Well SL-99	Well SL-104	Well SL-124
Silica (SiO_2)	42	25	44	34	34
Iron (Fe)	.85	.46	.40	3.8	.54
Calcium (Ca)	40	1.8	43	98	47
Magnesium (Mg)	8.4	1.3	14	42	16
Sodium (Na)	65	144	69	113	23
Potassium (K)	4.4	.8	5.6	10	2.8
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	257	366	286	572	268
Sulfate (SO_4)	1.7	10	.5	13	.4
Chloride (Cl)	51	6.6	63	128	6.8
Fluoride (F)	.1	.6	.1	.2	.2
Nitrate (NO_3)	.2	1.5	1.0	.0	2.0
Boron (B)	.11	.41	.07	.00	.03
Carbon dioxide (CO_2), calculated	16	1.2	11	57	13
Dissolved solids	339	377	388	719	264
Total hardness as $CaCO_3$	134	10	165	417	183

Table 30.—*Chemical analyses of typical ground waters in southwestern Louisiana*—Con.

	Well SL-48	Well SL-84	Well SL-99	Well SL-104	Well SL-124
Specific conductance (micromhos at 25°C)	563	590	649	1,260	443
Color	....	40	....	5	40
pH	7.4	8.7	7.6	7.2	7.5
Temperature (°F)	70	87	72	66	70
Date of collection	5-10-50	7-13-50	9-12-50	6-15-50	9-13-50
Depth (in feet)	279	1,910	426	230	200±

	Well SMn-46	Well SMn-90	Well Ve-2	Well Ve-7	Well Ve-110
Silica (SiO_2)	36	45	32	34	33
Iron (Fe)	2.9	5.8	1.5	1.6	3.3
Calcium (Ca)	58	62	50	68	98
Magnesium (Mg)	20	20	21	20	34
Sodium (Na)	62	15	91	150	114
Potassium (K)	1.6	2.4			8.8
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	383	317	420	342	360
Sulfate (SO_4)	.8	1.0	2.1	2.6	1.9
Chloride (Cl)	29	8.2	43	206	243
Fluoride (F)	.2	.1	.2	....	.1
Nitrate (NO_3)	3.5	4.0	2.8	5.5	3.8
Boron (B)	.10	.08	....	....	.20
Carbon dioxide (CO_2), calculated	48	32	21	14	23
Dissolved solids	402	314	449	654	786
Total hardness as $CaCO_3$	226	236	212	252	388
Specific conductance (micromhos at 25°C)	675	504	739	1,140	1,300
Color	....	....	....	....	5
pH	7.1	7.2	7.5	7.6	7.4
Temperature (°F)	....	70	70	71	68
Date of collection	12-12-50	10-25-50	10-26-49	10-25-49	11-17-50
Depth (in feet)	242	283	325	180	400

	Well Ve-137	Well Ve-370	Well Ve-496	Well Ve-533	
Silica (SiO_2)	36	28	29	36	
Iron (Fe)	.89	1.1	.81	1.4	
Calcium (Ca)	54	64	58	70	
Magnesium (Mg)	13	20	21	29	
Sodium (Na)	25	97	121	97	
Potassium (K)		13		.8	
Carbonate (CO_3)	5	0	0	0	
Bicarbonate (HCO_3)	267	438	442	400	
Sulfate (SO_4)	1.6	.2	1.2	.7	
Chloride (Cl)	10	72	88	121	
Fluoride (F)	.1	.0	....	.0	
Nitrate (NO_3)	.2	8.8	9.2	2.5	
Boron (B)	....	.12	....	.25	
Carbon dioxide (CO_2), calculated	1.7	35	7	25	
Dissolved solids	276	522	545	558	
Total hardness as $CaCO_3$	188	242	231	294	
Specific conductance (micromhos at 25°C)	425	875	907	990	
Color	....	....	....	....	
pH	8.4	7.3	8.0	7.4	
Temperature (°F)	70	72	72	71	
Date of collection	10-26-49	5-24-50	10-26-49	7-26-51	
Depth (in feet)	238	314	225	280	

Identification of wells.

[P, public supply; Irr, irrigation; Ind, industrial; S, stock; D, domestic; A, air conditioning]

U.S.G.S. well no.	*Owner*	*Location*	*Use*
Al-2	City of Oakdale	Sec. 10, T. 3 S., R. 3 W.	P
Al-31	Town of Oberlin	Sec. 15, T. 5 S., R. 4 W.	P
Al-138	City of Oakdale	Sec. 4, T. 3 S., R. 3 W.	P
Al-154	Town of Kinder	Sec. 35, T. 6 S., R. 5 W.	P
Al-156	J. S. Kingrey	Sec. 8, T. 6 S., R. 4 W.	Irr
Al-158	Calcasieu Paper Co.	Sec. 20, T. 2 S., R. 4 W.	Ind
Ac-10	Rice Experiment Station	Sec. 5 T. 10 S., R. 1 E.	Irr
Ac-166	Town of Church Point	Sec. 54, T. 7 S., R. 2 E.	P
Ac-168	Town of Iota	Sec. 29, T. 8 S., R. 1 W.	P
Ac-247	Town of Rayne	Sec. 28, T. 9 S., R. 2 E.	P
Ac-280	Gulf Public Service	Sec. 4, T. 10 S., R. 1 E.	P
Be-4	Town of De Ridder	Sec. 33, T. 2 S., R. 9 W.	P
Be-47	Ohros Cooley	Sec. 8, T. 3 S., R. 8 W.	D
Be-48	G. S. Bailey	Sec. 5, T. 3 S., R. 8 W.	D
Be-83	R. L. Fortenberry	Sec. 36, T. 3 S., R. 12 W.	P
Cu-1	Town of Vinton	Sec. 15, T. 10 S., R. 12 W.	P
Cu-83	Mathieson Chemical Corp.	Sec. 35, T. 9 S., R. 9 W.	Ind
Cu-92	Continental Oil Co.	Sec. 34, T. 9 S., R. 9 W.	Ind
Cu-97	Cities Service Refining Corp.	Sec. 18, T. 10 S., R. 9 W.	Ind
Cu-98	..........do........................	..........do........................	Ind
Cu-118	Town of Sulphur	Sec. 34, T. 9 S., R. 10 W.	P
Cu-215	Newport Industries	Sec. 18, T. 7 S., R. 10 W.	Ind
Cu-447	Maplewood Housing Corp.	Sec. 31, T. 9 S., R. 9 W.	P
Cu-486	Town of West Lake	Sec. 26, T. 9 S., R. 9 W.	P
Cu-495	Town of De Quincy	T. 7 S., R. 10 W.	P
Cu-550	Clarence Miller	Sec. 15, T. 8 S., R. 8 W.	Irr
Cn-10	Hebert & Helms	Sec. 28, T. 12 S., R. 7 W.	Irr
Cn-28	Judge A. M. Barb	Sec. 31, T. 15 S., R. 10 W.	S
Cn-32	Dick McCullen	Sec. 37, T. 14 S., R. 9 W.	P
Cn-33	.......do......................	..........do........................	P
I-53	Town of Jeanerette	Sec. 17, T. 13 S., R. 8 E.	P
I-56	M. A. Patout	Sec. 33, T. 13 S., R. 7 E.	D
I-62	Eugene Duhon	Sec. 65, T. 12 S., R. 5 E.	Irr
JD-5	Gulf Public Service	Sec. 14, T. 11 S., R. 3 W.	P
JD-210	Mr. Krielow	Sec. 36, T. 9 S., R. 4 W.	Irr
JD-327	United Gas Pipeline Co.	Sec. 25, T. 8 S., R. 6 W.	D, Ind
Ev-142	Magnolia Petroleum Co.	Sec. 6, T. 5 S., R. 1 E.	Ind
Ev-344	Town of Mamou	Sec. 12, T. 5 S., R. 1 W.	P
Ev-345	Louisiana-Central Electric Co.	Sec. 21, T. 4 S., R. 2 E.	P
Ev-348	Town of Basile	Sec. 32, T. 6 S., R. 2 W.	P
I-1	Gulf Public Service	Sec. 47, T. 12 S., R. 6 E.	P
I-13	Town of Loreauville	Sec. 23, T. 11 S., R. 7 E.	P
JD-343	Town of Jennings	Sec. 34, T. 9 S., R. 3 W.	P
JD-363	Town of Welsh	Sec. 30, T. 9 S., R. 4 W.	P
JD-406	Town of Elton	Sec. 34, T. 6 S., R. 3 W.	P
Lf-36	Town of Scott	Sec. 30, T. 9 S., R. 4 E.	P
Lf-129	Claude Hanks	Sec. 2, T. 10 S., R. 3 E.	Irr
Lf-166	Town of Broussard	T. 10 S., R. 5 E.	P
Lf-491	City of Lafayette	Sec. 24, T. 9 S., R. 4 E.	P
Lf-496	Town of Carencro	T. 8 S., R. 4 E.	P
Lf-501	Town of Youngsville	Sec. 7, T. 11 S., R. 5 E.	P
Lf-502	Cyril K. Moresi	Sec. 47, T. 10 S., R. 4 E.	D, A
SL-4	Town of Melville	Sec. 16, T. 4 S., R. 7 E.	P
SL-5	Village of Port Barre	Sec. 3, T. 6 S., R. 5 E.	P
SL-30	Town of Washington	Sec. 27, T. 5 S., R. 4 E.	P

Identification of wells—Continued

U.S.G.S. well no.	*Owner*	*Location*	*Use*
SL-48	Sadie Fuselier	Sec. 24, T. 6 S., R. 1 W.	Irr
SL-84	Village of Krotz Springs	Sec. 9, T. 6 S., R. 7 E.	P
SL-99	Gulf Public Service	Sec. 30, T. 6 W., R. 1 E.	P
SL-104	Joe A. Fontenot	Sec. 6, T. 3 S., R. 4 E.	Irr
SL-124	Town of Sunset	Sec. 59, T. 7 S., R. 4 E.	P
SMn-46	Town of Arnaudville	Sec. 44, T. 7 S., R. 5 E.	P
SMn-90	Town of Breaux Bridge	Sec. 105, T. 9 S., R. 6 E.	P
Ve-2	Town of Kaplan	Sec. 17, T. 12 S., R. 2 E.	P
Ve-7	City of Abbeville	Sec. 49, T. 12 S., R. 3 E.	P
Ve-110	U. S. Army, Corps of Engineers	Sec. 9, T. 15 S., R. 2 E.	D
Ve-137	Town of Erath	Sec. 35, T. 12 S., R. 4 E.	P
Ve-370	Joseph Zaunbrecher	Sec. 35, T. 11 S., R. 2 W.	Irr
Ve-496	Town of Gueydan	Sec. 6, T. 12 S., R. 1 W.	P
Ve-533	Edes Stelly	T. 14 S., R. 1 E.	Irr

Although most of the wells in use yield water from the Pleistocene sand and gravel, a few municipal and industrial wells located in the northern part of the area are screened in sands of Pliocene or late Miocene age. Fresh water is available in these formations to a maximum depth of about 3,100 feet. Water from these formations is not being used for irrigation to any great extent.

The most important quality consideration in evaluating the suitability for irrigation of the water in the Pleistocene sediments is the chloride concentration. Wells Cn–32 and Cn–33, which are used as supply wells for the coastal community of Cameron, are the only wells listed in the table which yield water with chloride concentrations that might be harmful to rice at any stage.

It has been observed frequently that water produced from a formation tends to be softer with increased depth and distance from the outcrop. In the Pleistocene sand and gravel that yield water in southwestern Louisiana, this softening is obscured somewhat by an increase in dissolved solids. At or near the outcrop, the quality of ground water is very much like that of stream water. Increase of pressure and temperature downdip results in further solution of the rock materials. Changing proportions of calcium and sodium concentrations to bicarbonate concentrations indicate that, even though at some points the deeper water is harder than that at the outcrop, at most places it is softer, suggesting that considerable softening by base exchange has occurred as the water moved through the Pleistocene deposits.

Difficulty has been experienced in making use of water from the Pleistocene sand and gravel for industrial and municipal supplies. Many of the wells yield water containing excessive quantities of iron. Some of the well waters also contain relatively large amounts of free carbon dioxide. Iron-bearing waters are usually scale forming, and waters containing free carbon dioxide may be corrosive. Although waters containing these objectionable substances can be used for irrigation where the water is pumped directly from well to ditch, aeration or some other treatment is required where the waters are used for municipal or industrial supplies.

Water from many of the wells tapping Pleistocene aquifers contains silica in excess of 30 ppm, and occasionally concentrations of 50 to 60 ppm are present. This quantity of silica may contribute to formation of boiler scale but is not objectionable otherwise.

The water from the underlying Pliocene or late Miocene sands is somewhat different in composition from that obtained from the Pleistocene deposits. Sodium bicarbonate forms most of the dissolved minerals, the chloride concentration is relatively low, and the silica content varies from about 10 to 25 ppm. Only small amounts of free carbon dioxide are generally present. In northwestern Allen Parish the water is soft, generally free of excessive quantities of iron in solution, and alkaline in reaction (see well Al–138, table 30). This water is excellent for most industrial uses and is acceptable, without treatment, for public supply. Although soft fresh water is available from these deposits in the north-central part of the area, this water is straw colored in many places (probably because of organic materials in solution), contains considerable dissolved iron, and in some places contains fluoride in excess of the United States Public Health Service recommended maximum concentration of 1.5 ppm (see well Ev–142, table 30).

The salinity of water from a number of wells in the region has increased markedly during the past 25 years, notably at Abbeville and Lake Charles. This increase has caused abandonment of some wells as a source of water for irrigation and public supply. Salt-water encroachment is a continuing threat and may increase with further development of the ground-water supplies.

WATER TEMPERATURES

Collection of information on temperatures of surface water may be termed one of the dividends of the southwestern Louisiana investigation. Information on surface-water temperatures has little bearing on the problems of how much water is available or needed for irrigation purposes. However, as temperature data on surface water could be collected at very small cost during the gathering of other necessary data, it was included in the general investigation.

Information on daily variation of temperatures of surface waters, particularly during the summer months, is most important in planning new industrial plants. Where large amounts of water are used for cooling purposes, the temperature of the raw water may be one of the factors controlling plant location. In addition, water temperatures have an important bearing on the propagation of fish and in controlling the type of aquatic life that exists in various streams. The sediment-carrying capacity of streams is affected considerably by water temperature. Also affected is the amount of influent seepage to ground water, where it occurs.

The relation between surface-water temperature and air temperature is variable. During months when the air temperature is above the freezing point, the mean monthly air temperature is a reasonable index of the mean monthly temperature of the surface water.

Ground water is preferred for many industrial purposes because of its relatively constant temperature. The coolest ground water in most areas in the United States has a temperature about equal to the average annual air temperature. As pointed out by Collins (1925), the usual water temperature at depths of 30 to 60 feet below the surface of the ground is 2° to 3°F above the average annual air temperature.

Water temperatures, for the most part, were taken with the armored red-liquid pocket-type thermometers that customarily are used by the Geological Survey and are calibrated in single degree divisions. As the pocket thermometers are considered accurate to ± 1°F, the temperatures normally were read to the nearest degree. Readings that were reported to a fraction of a degree were rounded to the nearer degree during the preparation of the tables.

Temperature measurements were made by Geological Survey field personnel and by the water samplers. The thermometer was immersed in the sample bottle immediately after collection of the sample or in the discharge stream of the well and read after about a minute or as soon as the reading was relatively constant.

Surface-water temperatures obtained at the time of collection of the daily water samples are given in table 31. The table shows that temperatures of the stream water vary from about the freezing point in winter to about 99°F in summer. The extreme summer temperatures were somewhat higher than previous spot measurements had indicated they might be.

Water temperatures were recorded at the time of collection of many ground-water samples and at the time of many discharge measurements. Some of these temperature data are included in the table of analyses of ground waters (table 30). The temperature of water from supply wells ranges from about 62° to 87°F. The temperatures also indicate that ground waters in the region increase about 1°F for each 90 feet of increase in depth.

Table 31.—*Temperature of stream waters*

[Temperature (°F) of water]

Vermilion River at Bancker's Ferry, near Abbeville, La.

1949

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	...	48	58	60	60	84	85	88	85	78	65	60
2	...	46	58	55	60	82	88	87	85	87	68	65
3	...	52	58	55	78	84	88	88	88	87	64	60
4	...	51	62	55	80	84	87	86	85	84	62	60
5	...	58	60	58	78	...	88	88	85	78	58	60
6	...	58	65	60	78	...	92	87	84	78	60	60
7	...	58	60	70	78	82	88	88	85	82	65	60
8	...	58	62	70	78	83	90	87	88	79	60	60
9	...	61	68	70	76	81	90	87	86	77	65	65
10	...	60	60	65	76	79	90	88	86	79	68	...
11	...	60	65	70	78	...	78	88	...	81	65	58
12	...	60	48	61	81	86	92	87	85	80	60	58
13	...	68	52	78	78	88	88	88	85	78	62	60
14	...	68	50	81	82	84	...	88	85	78	60	60
15	...	58	50	68	80	85	88	86	85	78	60	58
16	...	64	55	68	76	88	...	88	85	76	60	40
17	...	60	52	76	80	85	88	88	85	78	60	70
18	61	58	52	78	...	...	88	88	87	78	58	60
19	58	60	48	68	82	86	88	90	88	78	62	60
20	58	56	60	60	...	77	88	88	84	78	78	60
21	56	65	52	68	80	87	88	88	85	78	60	65
22	56	65	55	68	82	88	86	86	78	78	60	55
23	57	65	55	...	82	87	88	87	88	77	60	50
24	65	68	60	76	82	85	86	86	80	77	60	60
25	65	68	60	78	86	82	86	87	85	72	60	60
26	65	65	60	68	84	85	86	85	85	70	...	...
27	65	65	52	78	84	88	88	85	80	70	...	55
28	64	65	55	68	82	85	88	86	87	70	60	60
29	56	...	55	70	84	80	85	88	78	70	70	60
30	46	...	55	70	84	88	87	88	75	76	68	60
31	46	...	66	...	86	...	88	87	...	64	...	50
Average	...	60	57	68	79	84	88	87	84	77	63	59

1950

1	50	70	60	60	75	82	95	....	85	78	80	70
2	50	60	62	70	65	78	90	....	88	80	80	88
3	65	65	65	70	70	78	90	....	86	80	78	70
4	65	70	65	65	....	78	90	....	90	80	65	70
5	60	60	68	68	70	80	....	....	85	75	....	....
6	31	60	65	60	78	78	85	....	88	74	70	....
7	58	60	68	60	68	80	85	....	85	85	82	....
8	60	60	60	62	85	80	83	....	80	88	82	....
9	65	60	69	60	80	80	....	....	82	80	82	....
10	60	60	60	60	82	....	80	....	85	80	60	....
11	60	65	60	60	80	85	85	....	85	82	....	....
12	60	65	62	....	....	88	84	....	84	80	60	....
13	68	65	62	65	....	78	85	....	85	80	70	....
14	60	65	50	60	78	82	80	....	88	80	76	....
15	60	60	60	60	80	90	....	....	84	80	85	....
16	60	65	65	60	80	90	88	....	88	82	82	55
17	60	65	....	65	80	92	80	88	85	82	78	....
18	60	60	62	65	80	92	88	81	85	85	78	48
19	60	60	60	65	80	90	88	88	84	85	85	44
20	60	60	60	70	....	90	88	80	85	85	70	44
21	60	65	60	70	....	90	90	84	84	88	65	....
22	65	65	60	70	80	85	85	85	80	84	70	48
23	60	65	69	60	80	94	....	85	88	88	70	70
24	60	65	88	60	80	88	....	....	88	88	60	....
25	60	60	66	65	80	96	....	88	84	85	50	58
26	60	65	65	60	82	95	....	85	80	88	54	55
27	65	65	60	75	82	95	....	88	82	80	70	....
28	....	60	75	70	80	95	....	85	80	80	72	....
29	60	....	68	68	82	88	....	82	80	84	78	....
30	65	....	60	70	80	95	....	85	75	80	....	....
31	60	....	60	....	80	....	....	85	....	80	....	....
Average	60	63	64	65	78	87	....	....	84	82	72	....

Table 31.—*Temperature of stream waters*—Continued

Vermilion River at Bancker's Ferry, near Abbeville, La.—Continued

1951												
Day	January	February	March	April	May	June	July	August	September	October	November	December
1	....	....	60	65	80	....	88	88	88			
2	....	....	62	60	80	85	88	88	92			
3	....	....	65	62	80	88	88	85	98			
4	....	48	65	65	80	88	83	85	88			
5	....	52	60	58	75	85	90	90	88			
6	....	52	68	60	75	85	88	92	88			
7	....	52	66	60	75	85	88	85	....			
8	....	54	62	68	74	85	....	88	86			
9	....	55	65	68	68	85	90	98	90			
10	....	60	....	65	75	88	88	89	85			
11	....	58	68	65	80	88	90	88	85			
12	....	60	60	62	75	88	88	....	....			
13	....	58	42	60	80	88	90	95	85			
14	....	60	48	60	78	85	88	....	80			
15	....	55	60	60	85	85	88	90	....			
16	....	54	68	60	80	85	....	90	80			
17	....	65	66	65	85	85	88	....	85			
18	....	58	....	65	85	85	88	85	85			
19	....	58	54	60	80	86	88	86	80			
20	....	....	60	60	84	88	88	90	80			
21	....	54	56	60	80	85	88	....	80			
22	....	58	60	68	80	85	88	....	....			
23	....	56	60	65	80	85	88	86	80			
24	....	....	60	60	84	85	82	90	80			
25	....	58	65	70	85	88	85	90	80			
26	....	58	62	75	80	88	85	86	80			
27	....	58	68	75	80	88	85	90	85			
28	54	65	60	78	....	85	84	88	....			
29	....	....	65	70	85	85	85	88	80			
30	38	....	....	75	85	85	88	88	80			
31	....	....	64	....	85	....	85	88	....			
Average	....	57	61	65	80	86	87	89	84			

1949

1	...	50	61	67	76	78	83	...	78	85	43	48
2	...	50	61	66	75	...	82	...	78	87	46	43
3	...	53	60	65	78	77	82	...	79	80	48	45
4	...	52	62	64	79	...	82	...	80	60	47	44
5	...	50	64	...	76	82	83	...	80	65	46	43
6	...	50	65	60	79	79	82	...	90	60	42	46
7	...	49	62	...	79	82	82	...	88	63	43	42
8	...	53	65	70	72	83	82	...	88	70	45	41
9	...	55	66	70	...	82	82	...	76	70	43	43
10	...	54	60	68	...	83	81	...	79	73	43	42
11	...	58	...	67	78	82	82	...	80	70	45	43
12	...	60	...	65	78	81	...	79	70	73	45	45
13	...	61	...	66	79	82	...	...	78	78	47	46
14	...	63	...	70	80	82	...	78	78	77	43	40
15	...	66	...	70	80	83	78	80	79	75	42	31
16	...	62	65	70	89	82	78	...	80	78	40	38
17	...	61	...	65	87	83	87	...	82	76	42	37
18	...	60	63	68	89	82	81	79	96	78	43	31
19	54	60	60	67	...	83	80	80	80	79	42	33
20	55	62	60	67	88	81	80	79	85	76	44	38
21	54	63	66	70	76	82	79	76	75	77	45	37
22	55	66	66	69	79	83	81	77	77	78	45	39
23	55	65	61	70	78	83	82	76	79	78	43	40
24	58	67	48	71	78	82	80	79	78	77	47	43
25	60	62	69	65	76	81	82	80	79	71	46	31
26	61	67	75	76	...	82	82	79	80	71	...	47
27	64	65	68	75	78	82	80	79	78	70	...	46
28	60	65	67	76	78	82	79	80	78	70	48	48
29	56	...	70	77	81	82	78	81	75	73	48	48
30	54	...	70	76	82	82	79	79	80	71	46	43
31	54	...	69	...	80	...	...	77	...	65	...	42
Average	...	59	64	69	80	82	81	...	80	73	45	41

387601 O - 56 - 29

Table 31.—*Temperature of stream waters*—Continued

Mermentau River at Lake Arthur, La.—Continued

Day	1950											
	January	February	March	April	May	June	July	August	September	October	November	December
1	47	35	32	42	57	...	84	...	...	83	68	64
2	44	32	34	42	53	...	85	...	...	86	72	63
3	43	33	43	45	57	...	87	...	...	86	76	67
4	39	32	44	43	60	...	...	...	...	88	81	68
5	42	34	44	...	61	...	...	...	...	88	87	54
6	45	32	45	47	56	73	...	...	83	62	88	68
7	40	35	42	46	58	75	...	...	79	60	76	64
8	39	36	37	41	61	77	...	...	81	59	79	66
9	39	37	43	...	61	77	...	...	84	73	84	68
10	37	38	45	46	57	78	...	...	92	77	86	69
11	34	39	47	44	59	82	...	...	95	79	87	72
12	32	40	42	48	61	84	90	...	92	82	91	77
13	34	31	38	44	63	81	91	...	92	85	68	73
14	36	31	32	36	62	90	93	...	...	87	64	74
15	34	45	...	42	60	93	89	...	84	90	73	...
16	33	43	34	42	65	89	92	82	85	94	...	...
17	35	42	36	45	67	91	95	87	85	...	71	...
18	33	46	37	47	67	93	97	84	87	...	65	...
19	37	34	34	46	68	94	97	86	87	...	68	...
20	38	35	38	57	70	95	...	85	89	66	78	...
21	33	36	33	53	72	96	...	87	86	69	81	68
22	34	38	32	48	71	97	...	73	88	72	68	73
23	33	45	32	52	73	93	...	78	88	76	76	69
24	37	36	33	56	76	94	...	80	89	78	78	54
25	38	37	34	44	77	97	...	83	87	81	68	69
26	37	38	37	57	76	95	...	86	85	84	66	58
27	38	30	38	58	78	99	...	83	87	87	64	58
28	33	30	41	48	75	98	...	85	88	69	66	61
29	32	...	40	50	66	97	...	85	94	72	67	62
30	34	...	45	53	68	83	...	85	94	75	67	68
31	...	...	49	...	67	...	...	...	...	...	...	59
Average	37	36	39	47	65	89	...	...	...	78	75	66

1951

1	62	...	63	44	83	82	...	78	74			
2	61	...	61	46	87	88	...	72	67			
3	59	37	51	52	83	90	...	74	71			
4	61	38	43	52	87	...	86	77	68			
5	62	42	44	57	85	85	89	78	68			
6	63	43	47	62	87	87	89	78	67			
7	44	44	49	64	88	...	88	80	69			
8	46	54	42	59	84	...	87	...	72			
9	39	60	60	65	87	...	88	77	73			
10	69	62	62	62	92	...	88	67	71			
11	35	62	62	59	96	90	85	78	63			
12	36	64	42	42	88	92	85	...	67			
13	42	...	39	44	79	88	88	...	63			
14	44	...	41	60	82	73	84	...	61			
15	39	...	52	62	83	77	88	77	68			
16	42	...	54	63	87	80	81	79	59			
17	42	...	57	...	83	78	83	71	61			
18	46	...	59	...	85	81	85	69	58			
19	43	...	42	...	88	84	82	68	56			
20	43	...	44	...	88	87	81	71	68			
21	42	...	46	...	89	81	86	75	56			
22	43	...	61	59	78	84	85	79	...			
23	45	...	63	60	81	87	84	70	60			
24	47	...	66	63	82	84	87	69	63			
25	48	...	67	65	83	81	86	70	62			
26	43	...	67	62	83	...	81	73	68			
27	44	...	46	61	86	81	82	75	66			
28	44	...	41	62	81	85	81	74	...			
29	45	...	42	64	84	91	79	79	...			
30	38	...	45	65	81	...	77	79	...			
31	35	...	...	...	85	...	81	...	...			
Average	47	...	52	58	85	...	84	74	65			

Table 31.—*Temperature of stream waters*—Continued

Calcasieu River at Lake Charles, La.

1949

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	...	49	62	...	72	78	...	...	...	77	68	...
2	...	48	62	...	75	78	...	...	...	76	70	65
3	...	47	62	...	76	80	...	...	84	77	...	64
4	...	47	59	61	76	80	...	...	...	74	...	65
5	...	47	59	63	76	82	...	...	86	76	...	...
6	...	50	63	63	74	...	...	...	90	...	63	...
7	...	51	63	62	76	...	...	...	87	75	...	...
8	...	52	63	63	76	...	...	...	86	...	68	...
9	...	52	63	63	75	...	...	...	80	...	...	...
10	...	54	63	62	77	...	...	...	86	77	68	...
11	...	60	62	62	76	82	...	...	85	76	...	63
12	...	61	63	61	76	82	...	...	85	...	...	64
13	...	59	61	65	76	82	...	...	87	...	...	...
14	...	65	62	66	...	81	...	...	83	80	...	...
15	...	65	63	64	77	85	...	...	86	76	65	...
16	...	64	64	63	77	82	...	...	84	...	...	...
17	...	65	64	64	76	([a])	...	...	86	78	...	60
18	...	62	56	66	76	...	...	...	77	78	64	...
19	...	60	62	70	76	...	...	...	85	...	...	59
20	55	60	62	71	77	...	...	...	...	79	...	...
21	53	63	...	71	79	...	...	...	80	...	64	...
22	55	64	65	70	79	...	...	...	84	...	63	...
23	57	65	64	70	81	...	...	...	81	72	62	...
24	57	65	67	72	83	...	...	...	...	...	...	...
25	59	65	68	70	82	...	...	...	83	71	...	...
26	63	65	68	70	76	...	...	...	84	...	...	...
27	61	62	60	71	77	...	...	...	84	75	...	...
28	60	63	64	70	79	...	...	...	81	...	...	...
29	54	...	...	71	80	...	...	...	...	68	...	...
30	54	...	...	71	...	...	...	...	77	...	67	...
31	53	...	...	...	79	...	...	...	77	...	...	57
Average	...	58	63	66	77	...	...	...	84	...	...	...

1950

1	...	...	64	...	72	78	86	97	87	...	79	65
2	...	...	64	...	75	78	87	90	84	...	70	61
3	...	...	68	...	75	78	84	87	83	86	70	61
4	...	65	70	...	75	78	90	87	86	78	89	61
5	...	...	...	...	74	78	80	89	86	77	72	52
6	...	...	73	...	76	78	84	86	85	79	71	55
7	...	...	...	...	74	78	87	92	83	79	72	56
8	...	68	64	...	76	77	83	94	85	77	69	58
9	...	...	63	...	76	79	91	89	87	78	70	60
10	57	...	...	...	75	79	85	92	87	80	65	59
11	59	...	64	70	77	79	82	80	86	79	67	59
12	...	...	71	75	76	80	88	89	86	78	67	62
13	52	65	62	69	76	80	87	87	86	78	65	60
14	...	...	65	77	76	88	84	88	88	80	63	65
15	...	57	62	77	76	81	84	88	85	81	65	68
16	...	...	...	63	77	85	87	88	86	79	68	56
17	...	...	62	68	77	85	86	92	87	80	67	64
18	...	59	62	68	77	85	82	...	81	76	69	57
19	...	...	64	70	77	85	88	88	83	75	65	58
20	...	...	67	77	77	83	84	85	...	70	68	51
21	...	66	74	72	78	81	84	87	83	75	68	...
22	64	60	68	77	79	81	94	...	...	75	64	...
23	...	61	70	77	79	79	91	91	...	76	62	...
24	68	62	68	77	78	84	89	88	82	80	63	...
25	...	54	...	77	78	84	84	96	82	79	60	...
26	69	57	66	80	79	86	84	92	80	81	67	...
27	...	60	...	81	79	90	81	89	87	79	65	...
28	...	63	...	82	78	90	87	86	83	90	63	...
29	...	...	72	80	78	92	86	87	...	88	61	...
30	...	...	...	75	78	87	90	86	...	80	64	...
31	...	...	...	...	78	...	89	...	...	76	...	...
Average	...	...	...	...	77	82	86	89	85	79	68	...

See footnote at end of table.

Table 31.—*Temperature of stream waters*—Continued

Calcasieu River at Lake Charles, La.—Continued

Day	1951								
	January	February	March	April	May	June	July	August	September
1	([b])	...	...	67	71	87	88	89	...
2	...	...	79	65	72	89	85	90	90
3	...	...	76	67	71	80	89	90	89
4	...	...	74	66	69	78	...	89	...
5	...	...	76	67	80	80	92	90	88
6	...	...	78	65	79	80	89	93	88
7	...	...	77	66	75	78	90	91	86
8	...	...	77	65	81	87	91	92	87
9	...	...	76	66	79	85	90	90	88
10	...	...	59	69	82	80	91	88	85
11	...	...	58	66	81	78	89	88	89
12	...	...	63	70	82	85	90	91	88
13	...	...	63	70	75	86	89	92	84
14	...	...	65	68	76	...	90	89	87
15	...	...	64	70	78	88	88	91	78
16	...	...	66	67	75	88	88	90	77
17	...	...	66	72	83	88	90	93	80
18	...	...	64	67	85	85	91	90	79
19	...	...	65	68	85	84	88	89	82
20	...	...	66	67	80	88	90	89	81
21	...	...	67	78	86	88	90	90	81
22	...	...	67	72	86	88	90	89	82
23	...	...	67	73	82	87	89	90	82
24	...	...	63	75	81	85	91	89	83
25	...	...	63	72	80	88	90	90	80
26	...	...	62	74	78	88	91	89	81
27	...	...	63	79	82	88	86	89	80
28	...	...	64	72	82	87	89	91	...
29	...	...	66	69	89	88	90	91	...
30	...	...	65	71	86	89	90	92	...
31	...	...	66	...	85	...	90	90	...
Average	...	...	68	69	80	85	89	90	84

Day	March	April	May	June	July	August	September
				1951			
1	......	74	78	82	88	90	86
2	......	65	78	84	87	88	90
3	70	......	76	84	......	88	......
4	70	65	......	83	......	92	90
5	74	65	78	84	90	90	88
6	72	64	78	84	90	92	88
7	......	64	78	82	90	90	88
8	72	64	76	82	90	90	88
9	72	64	82	82	84	90	88
10	......	65	82	88	88	88	83
11	72	62	76	86	88	84	82
12	......	61	74	83	88	90	82
13	67	64	76	86	88	90	79
14	65	64	72	86	88	90	78
15	......	65	76	88	88	86	77
16	......	68	76	88	88	88	78
17	72	......	70	88	94	92	74
18	62	68	80	88	90	88	76
19	60	70	76	88	90	88	78
20	58	65	78	88	92	90	80
21	62	74	84	89	88	90	78
22	......	72	78	88	88	88	81
23	62	74	80	87	90	88	86
24	60	74	76	86	90	90	78
25	65	78	78	88	90	88	82
26	62	78	78	......	86	88	82
27	67	76	82	90	90	88	82
28	......	72	82	86	86	90	79
29	65	76	82	86	88	88	......
30	64	78	82	84	88	92	79
31	......	......	82	......	88	94	......
Average	......	69	78	86	89	89	82

[a]No samples collected for period June 17 to September 2.
[b]No temperature measurements made for period January 1 to March 1.

SUMMARY

For the convenience of the reader, the general conclusions drawn from the data in the entire report are summarized below by item.

1. The geologic formations of southwestern Louisiana that contain fresh water range in age from late Miocene to Recent, but the oldest beds tapped by water wells in the area are believed to be of Pliocene age.

2. Upper Miocene strata contain fresh water at depths greater than 3,000 feet in the northwestern part of the area. Pliocene strata contain soft fresh water in the northwestern one-third of the area, and Pleistocene strata contain water ranging from soft to moderately hard southward throughout almost all the area.

3. In general, fresh water obtained from wells screened in the sands of Recent, Pleistocene, and pre-Pleistocene ages is satisfactory in quality for irrigation, domestic, municipal, and most industrial purposes.

4. As Pliocene strata do not occur at the surface in Louisisna, they probably derive their ground water from gravelly deposits of Pleistocene age which lie upon their beveled outcrops. The individual aquifers of Pliocene age are typically fine- to medium-grained sands less than 50 feet thick, horizontally and vertically interconnected to form a hydraulic unit termed the Evangeline reservoir. The dip of these water-bearing beds is generally 45 to 75 feet per mile, steepening gulfward and with depth.

5. A coarse-grained deposit of Recent age, called the Atchafalaya reservoir, partially fills late Pleistocene scour channels of an ancient Mississippi River system which underlies the eastern part of southwestern Louisiana. This gravelly bed, generally not more than 150 feet thick and overlain by mud or clay, lies in contact with water-bearing beds of Pleistocene age. The channel of the Atchafalaya River for much of its length cuts into the Recent deposit of sand and gravel. Similar beds occupy late Pleistocene scour channels of certain minor streams draining directly into the Gulf of Mexico.

6. The principal source of ground water now tapped by most of the wells throughout southwestern Louisiana is a thick deposit of sand and gravel of Pleistocene age named the Chicot reservoir.

7. The massive beds of Pleistocene sand and gravel, ranging from 50 to about 800 feet in total thickness, overlain by an extensive impervious bed of clay throughout southwestern Louisiana, are comparable in productivity to the best water-bearing formations of other parts of North America.

8. The dip, or slope, of the sand and gravel beds of the Chicot reservoir is about 5 to 15 feet per mile. The recharge area of the reservoir is some 2,000 square miles in the project area, and its regional continuity is unbroken.

9. The structure of the Chicot reservoir is monoclinal, with gulfward dip. Its thickness increases rapidly downdip, so that it forms a wedge-shaped mass.

10. The total thickness of deposits of Pleistocene age is perhaps 100 feet in the northern part of the area and not less than 1,500 feet along the margin of the Gulf of Mexico.

11. The most important structural controls on the occurrence of ground water in southwestern Louisiana, other than the regional gulfward slope of the beds, are the many salt-dome structures which produce local faults and folds and the regional normal faults which follow the strike of the beds. By cutting off water-bearing beds or altering their interconnections, these structures have controlled the flow of ground water in the past and today must be considered in planning development of supplies.

12. Results of tests in scattered localities indicate that the water-bearing sediments of the Chicot reservoir in the artesian area have storage coefficients ranging from 0.0009 to 0.003 and transmissibilities ranging from 90,000 to 900,000. The aquifers of the Atchafalaya reservoir are believed to have comparable hydraulic characteristics.

13. On the basis of their thickness and texture, it is estimated that the ability of the late Miocene or Pliocene strata in the project area to store and transmit water is only about one-fifth to one-tenth that of the Pleistocene strata.

14. Replenishment of water withdrawn from the Pleistocene ground-water reservoir in 1946 occurred approximately as follows: In the recharge area in the upper basin of the Calcasieu River (north of the northern boundary of Calcasieu Parish), about 37 percent; in the recharge area in the basin of Bayou Cocodrie (in northern Evangeline Parish), about 7 percent; in the basins of the Atchafalaya and Vermilion Rivers, about 28 percent; and from the direction of the Gulf of Mexico, about 28 percent. It is believed

that most of the last amount was derived from recharge in the Atchafalaya River basin and moved in an arcuate course southward beneath the margin of the Gulf of Mexico and thence northward into the area of withdrawal.

15. Withdrawals from irrigation wells tapping beds of Pleistocene age ranged from about 380,000 acre-feet in 1946 (a wet year) to about 700,000 acre-feet in 1951 (a dry year). About 240,000 acres of rice is flooded by ground water from about 1,300 large-capacity irrigation wells yielding 1,500 to 6,000 gpm. The cumulative depth of ground water applied to the ricefields in a single season ranged from about 1.3 to 2.3 feet (about 16 to 27 inches) during the period 1946–51.

16. Withdrawals from industrial wells, most of which tap the Chicot reservoir, increased from about 65,000 acre-feet in 1946 to 95,000 acre-feet in 1951. Municipal supplies that are obtained largely from the same source increased from about 29,000 acre-feet in 1946 to 32,000 acre-feet in 1951. Thus, in 1951, in southwestern Louisiana the total withdrawal of ground water, including rice irrigation, was about 890,000 acre-feet.

17. There is no evidence that the ground-water resources of southwestern Louisiana are being depleted in quantity or that declines of water level, in themselves, threaten to restrict continued development of supplies on an areal basis. Local problems of water-level decline resulting from close spacing of wells can be solved by relocation based upon hydraulic-test results or, in some localities, by tapping different sands. The principal threat to the ground water is not reduction of quantity, but impairment of quality by salt-water encroachment. (See item 26 and following ones.)

18. Results of soil-moisture storage and seepage tests indicate that an average of about 2 inches of water enters soil-moisture storage if ricefields in southwestern Louisiana are flooded with irrigation water when the fields are in an extremely dry condition. No loss by deep seepage was detected.

19. The average seasonal depth of water consumed by evapotranspiration in ricefields was found to be about 25 percent greater than that measured in an evaporation pan of the sunken type and about equal to that measured in a standard U. S. Weather Bureau land pan.

20. Approximate determinations of precipitation intercepted by rice plants showed a range from no measurable interception during the earliest stages of plant growth to about 35 percent during the nearly mature stages. Average seasonal interception was about 10 percent of the precipitation.

21. The components of the average seasonal water requirement for rice in southwestern Louisiana were determined as follows:

	Water depth (inches)
Consumptive use during period of submergence	22.4
Drained from fields during period of submergence	2.1
Drained from fields at end of season	5.2
Soil-moisture storage	2.0
Total water requirement	31.7

22. In a critically dry year only about 4.5 inches of the total water requirement would be supplied by rainfall, leaving about 27 inches to be supplied by irrigation. Loss of water between points of diversion from the supply streams and points of delivery to the ricefields (conveyance losses) were found to average about 35 percent of the volumes diverted from the streams.

23. The maximum probable irrigation-water requirement for growing rice in southwestern Louisiana was estimated to be about 27 acre-inches per acre. As conveyance losses are approximately 35 percent, the maximum probable diversion requirement would be about 42 acre-inches, or 3.5 acre-feet, per acre.

24. Average rates of seasonal diversion from streams in southwestern Louisiana were determined as follows:

	Seasonal diversion (acre-feet per acre)		*Seasonal diversion (acre-feet per acre)*
1948	3.39	1950	3.03
1949	2.29	1951	3.24

Measured differences in diversion rates among the three major river basins in southwestern Louisiana were not significant.

25. Stream waters in southwestern Louisiana are normally fresh except where they have been deepened for navigation or made saline by reversed flow from the Gulf of Mexico induced by heavy pumping upstream.

26. During drought years, brackish water from Vermilion Bay is drawn many miles up the Vermilion River, resulting in considerable loss to rice crops and potentially serious encroachment into the ground-water reservoirs.

27. To have prevented the withdrawal of potentially salty water from Vermilion Bay during the 1948 and 1951 irrigation seasons,

supplementary supplies of 118,000 and 75,000 acre-feet, respectively, would have been required, in addition to those received from Bayou Teche.

28. If the only flow available during the 1948 and 1951 seasons had been that originating within the Vermilion River basin, the supplementary requirement would have been 180,000 and 125,000 acre-feet during the 1948 and 1951 irrigation seasons, respectively.

29. A maximum of about 70,000 acres of rice has been irrigated in past years with water from the Vermilion River. If this acreage should be irrigated in a critical water-supply season requiring maximum diversions (3.5 acre-feet per acre), a total supply of 245,000 acre-feet would be required. Only about 30,000 acre-feet of runoff could be expected from the Vermilion River basin in such a season, leaving a total of about 215,000 acre-feet to be supplied from sources outside the basin.

30. The maximum observed weekly diversion-demand rate in the Vermilion River basin was 0.3 acre-foot per acre. In critically dry seasons there are usually several weeks during which there is no runoff from the basin. Therefore, a supplementary water supply would need to be delivered to the basin at a rate of about 1,500 cubic feet per second in order to supply water to irrigate 70,000 acres of rice.

31. The salinity of water entering the Vermilion River from Vermilion Bay seldom is greater than about 2,500 ppm expressed as chloride. The difference in density between this water and the fresh-water supply in the Vermilion River is not great enough to require a fresh-water supply rate appreciably more than the diversion-demand rate in order to prevent the encroachment of salt water into the stream channel.

32. The water-level contour maps indicate that the lower basin of the Vermilion River is a very important source of recharge of the ground-water supplies, partly because there is good hydraulic interconnection between the river and the Pleistocene ground-water reservoir, and partly because the river is relatively near the center of ground-water pumping. As the river is encroached by salty water from the Gulf of Mexico for periods of several weeks during the rice-irrigation season, when ground-water levels are lowest and recharge rates highest, this condition poses a serious threat of salt-water encroachment to the Chicot ground-water reservoir. Chemical analyses of water from wells near the river and electric logs of oil-test and water wells in the basin tend to confirm the belief that salt-water encroachment occurs periodically. The threat of salt-water contamination of ground-

water resources from the channel of the Vermilion River is of utmost importance and early steps must be taken to prevent its recurrence. This can be accomplished only by maintaining the river as a fresh-water stream to its mouth at all times.

33. Control structures in the Mermentau River basin have nearly eliminated the dangers from salt-water encroachment but have not eliminated the surface-water supply problems that will arise during extremely dry years.

34. Records collected in the Mermentau River basin during this investigation indicate that the total demands for irrigation water from storage in the lake system reached a maximum of about 314,000 acre-feet from April 9 through August 5, 1948 and about 166,000 acre-feet from April 9 through September 2, 1951. These were the 2 most critically dry years of the 4 for which records are presented in this report.

35. Evaporation losses from the lake and channel storage system during the period between the beginning of the 1948 irrigation season and the time when net withdrawals from storage reached their maximum are estimated to have been about 110,000 acre-feet in excess of the volumes supplied by rainfall on the system. Thus the maximum total storage requirement for the Mermentau River basin during the 1948 irrigation season was about 424,000 acre-feet.

36. Based on plantings of 250,000 acres of rice in the Mermentau River basin, in a critically low runoff season the maximum probable storage requirement is estimated as about 795,000 acre-feet.

37. The Calcasieu River from Lake Charles downstream cannot be developed for water-supply purposes because of recurring high salinity. Upstream from Lake Charles, miles of the Calcasieu River and its tributaries also will become unusable during dry years.

38. Although the irrigation seasons in the years 1948 and 1951 were periods of extremely low runoff, current streamflow in the Calcasieu River basin was sufficient to have supplied the needs for irrigation in those years if the water had been protected from contamination. Diversions for irrigation exceeded streamflow by only small volumes and only during a few weeks in those critical years.

39. For a period of about 3 months in both the 1948 and 1951 seasons however, supply and demand for surface water were closely in balance. Thus the available supply in critically dry

seasons is not sufficient to support an appreciable expansion of rice planting in the Calcasieu River basin, nor do significant volumes remain for other uses after irrigation needs are met.

40. Results of this investigation and a previous model study by the Corps of Engineers indicate that it would be impossible to supply rates of flow from reservoir storage in the Calcasieu River basin sufficient to prevent salt-water encroachment into the Calcasieu River channel. A rate of flow somewhat greater than 8,000 cfs would be required to prevent encroachment of salt water beyond the mouth of the West Fork of the Calcasieu River.

BIBLIOGRAPHY

Am. Public Health Assoc., 1946, Standard methods for the examination of water and sewage, 9th ed.

Baden-Ghyben, W., 1889, Nota in verband met de voorgenomen put boring nabij Amsterdam: K. inst. ing Tijdschr., p. 21, The Hague.

Barton, D. C., 1925a, Pine Prairie salt dome: Am. Assoc. Petroleum Geologists Bull., v. 9, p. 738–755.

———1925b, American salt-dome problems in the light of the Romanian and German salt domes: Am. Assoc. Petroleum Geologists Bull., v. 9, p. 1227–1268.

———1930a, Deltaic coastal plain of southeastern Texas: Geol. Soc. America Bull., v. 41, no. 3, p. 359–382.

———1930b, Surface geology of coastal southeast Texas: Am. Assoc. Petroleum Geologists Bull., v. 14, no. 10, p. 1301–1320.

———1933, Mechanics of formation of salt domes with special reference to gulf coast salt domes of Texas and Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 9, p. 1025–1083.

———1937, Post-Recent plains and shorelines of southern Texas and southwestern Louisiana: Geol. Soc. America Proc., p. 63–64.

Barton, D. C., Ritz, C. H., and Hickey, Maude, 1933, Gulf coast geosyncline: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 12, p. 1446–1458.

Berry, E. W., 1911, The age of the type exposures of the Lafayette formation: Jour. Geol. v. 19, p. 249–256.

———1916, The flora of the Citronelle formation: U. S. Geol. Survey Prof. Paper 98, p. 193–208.

Bates, F. W., and Bornhauser, Max, 1938, Geology of Tepetate oil field, Acadia Parish, La.: Am. Assoc. Petroleum Geologists Bull., v. 22, no. 3, p. 285–305.

Brown, J. S., 1925, A study of coastal ground water, with special reference to Connecticut: U. S. Geol. Survey Water-Supply Paper 537, p. 49.

Clendenin, W. W., 1896, Florida parishes of east Louisiana and the bluff, prairie, and hill lands of southwest Louisiana: Geology and Agriculture of Louisiana, pt. 3, Baton Rouge, La., La. State Univ. rept.

Collins, W. D., 1925, Temperature of water available for industrial use in the United States: U. S. Geol. Survey Water-Supply Paper 520-F.

———1928, Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 596-H.

Cooke, C. W., 1931, Seven coastal terraces in the Southeastern States: Wash. Acad. Sci. Jour., v. 21, no. 21, p. 503–513.

Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating and summarizing well-field history: Am. Geophys. Union Trans., v. 27, no. 4, p. 526–534.

Corbett, D. M., and others, 1943, Stream-gaging procedure: U. S. Geol. Survey Water-Supply Paper 888, p. 135–139.

Dall, W. H., 1898, Contributions to the Tertiary fauna of Florida: Wagner Free Inst. Sci. Trans., v. 3, pt. 4, p. 905.

———1914, On a brackish water Pliocene fauna of the southern Coastal Plain: U. S. Nat. Mus. Proc., v. 46, p. 225–237.

Darton, N. H., 1902, Deep borings in the United States: U. S. Geol. Survey Water-Supply Paper 57.

———1905, Deep borings in the United States: U. S. Geol. Survey Water-Supply Paper 149.

Deussen, Alexander, 1914, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335.

Doering, John, 1935, Post-Fleming surface formations of coastal southeast Texas and south Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 19, no. 5, p. 651–688.

Everett, F. E., 1946, Quantity and quality of water required for rice irrigation in Louisiana: La. State Univ. Eng. Expt. Sta. News, v. 2, no. 1, p. 23–28.

Fenneman, N. H., 1906, Oilfields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 282.

387601 O - 56 - 30

Fenneman, N. H., 1938, Physiography of Eastern United States: 714 p., New York, McGraw-Hill Book Co., Inc.

Ferris, J. G., 1948, Ground-water hydraulics as a geophysical aid: Mich. Dept. Conserv., 11 p. [Processed.]

Fisk, H. N., 1938, Geology of Grant and LaSalle Parishes: La. Dept. Conserv. Geol. Bull. 10, 246 p.

———1940, Geology of Avoyelles and Rapides Parishes: La. Dept. Conserv. Geol. Bull. 18, 240 p.

———1944, Geological investigation of the alluvial valley of the lower Mississippi River: U. S. Dept. Army, Mississippi River Comm., 78 p.

———1946, Geological history and the water resources of Louisiana: La. State Univ. Eng. Expt. Sta. News, v. 2, no. 1, p. 17–22.

———1947, Fine-grained alluvial deposits and their effects on Mississippi River activity: U. S. Dept. Army, Mississippi River Comm., p. 11–15.

———1948, Geological investigations of the lower Mermentau River basin and adjacent areas in coastal Louisiana: U. S. Dept. Army, Mississippi River Comm., 41 p.

———1952, Geological investigation of the Atchafalaya Basin and the problem of Mississippi River diversion: U. S. Dept. Army, Mississippi River Comm., 2 v., 145 p.

Frink, J. W., 1941, Subsurface Pleistocene of Louisiana: La. Dept. Conserv. Geol. Bull. 19, p. 369–419.

Haase, F. M., 1932, Catahoula-Fleming contact, Vernon Parish: Am. Assoc. Petroleum Geologists Bull., v. 16, no. 6, p. 608–609.

Harding, S. T., 1942, Evaporation from free water surfaces, *in* Physics of the Earth, pt. 9, Hydrology, edited by O. E. Meinzer, p. 76; New York, McGraw-Hill Book Co., Inc.

Harris, G. D., 1902, The geology of the Mississippi embayment: La. Geol. Survey Special Rept. 1, 39 p.

———1907, Cartography of southwestern Louisiana with special reference to the Jennings sheet: La. Geol. Survey Bull. 6, 24 p.

Harris, G. D., and Fuller, M. L., 1904, Underground waters of southern Louisiana with discussion of their uses for water supplies and for rice irrigation: U. S. Geol. Survey Water-Supply Paper 101, 98 p.

Harris, G. D., and Pacheco, J., 1902, The subterranean waters of Louisiana: La. Geol. Survey Special Rept. 6, pt. 6.

Harris, G. D., and Veatch, A. C., 1899, A preliminary report on the geology of Louisiana: La. State Expt. Sta., 5 pts., 138 p.

Harris, G. D., Veatch, A. C., and others, 1905, Underground waters of southern Louisiana: La. Geol. Survey Bull. 1, 79 p., pt. 1.

Herzberg, Baurat, 1901, Die Wasserversorgung einiger Nordseebader: Jour. Gasbeleuctung und Wasserversorgung, Jahrg. 44, Munich.

Hilgard, E. W., 1860, Discussion of Grand Gulf group: Am. Jour. Sci., 2d ser., v. 41, p. 311–325.

———1869, Summary results of late geological reconnaissance of Louisiana: Am. Jour. Sci., 2d ser., v. 47, p. 78–88.

———1891, Communication to The American Geologist: v. 8, no. 2, p. 129–131.

Hillebrand, W. F., and Lundell, G. E. F., 1929, Applied inorganic analysis: 929 p., New York, John Wiley & Sons.

Holland, W. C., Hough, L. W., and Murray, G. E., 1952, The geology of Allen and Beauregard Parishes: La. Dept. Conserv. Geol. Bull. 27, 224 p.

Hopkins, F. V., 1872, Third annual report of the Geological Survey of Louisiana: La. State Univ., Ann. Rept. 1871, p. 168.

Howe, H. V., 1933, Review of Tertiary stratigraphy of Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 17, p. 613–655.

Howe, H. V., and Moresi, C. K., 1931, Geology of Iberia Parish: La. Dept. Conserv. Geol. Bull. 1, 182 p.

———1933, Geology of Lafayette and St. Martin Parishes: La. Dept. Conserv. Geol. Bull. 3, 238 p.

Howe, H. V., Russell, R. J., and McGuirt, J. H., 1935, Reports on the geology of Cameron and Vermilion Parishes: La. Dept. Conserv. Geol. Bull. 6, 242 p.

Humphreys, A. A., and Abbott, H. L., 1861, Report upon the physics and hydraulics of the Mississippi River: U. S. Dept. Army, Corps of Topographical Engineers, 146 p.

———1876, Physics and hydraulics of the Mississippi River, republished with additions: U. S. Dept. Army, Corps of Topographical Engineers, Prof. Paper 13, 691 p.

Ideker, R. A., 1949, Arkansas plans ahead; growers join forces with government to provide a steady supply of irrigation water: Rice News, v. 16, no. 2, p. 3–4.
Jodon, Nelson E., and de la Houssaye, D. A., 1949, Rice varieties for Louisiana: La. Agr. Expt. Sta. Bull. 436.
Jones, P. H., and Buford, T. B., 1951, Electric logging applied to ground-water exploration: Geophysics, v. 16, no. 1, p. 115–139.
Kennedy, William, 1892, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Tex. Geol. Survey 3d Ann. Rept., p. 62–63.
Lyell, Charles, 1847, On the delta and alluvial deposits of the Mississippi and other points [abs.] *in* The geology of North America observed in the years 1845–46: Am. Jour. Sci., 2d ser., v. 3, p. 34, 118.
McGee, W J, 1888, The Columbia formation: Am. Assoc. Adv. Sci., Proc. 36, p. 221–222.
———1891, The Lafayette formation: U. S. Geol. Survey 12th Ann. Rept., p. 347–521.
———1892, The Gulf of Mexico as a measure of isostasy: Am. Jour. Sci., 3d ser., v. 44, p. 177–192.
Maher, J. C., 1940, Ground-water resources of Rapides Parish: La. Dept. Conserv. Geol. Bull. 17, 100 p.
———1945, Ground-water geology of Camp Polk and North Camp Polk, La.: Am. Assoc. Petroleum Geologists Bull., v. 29, no. 8, p. 1169–1188.
Matson, G. C., 1916, The Pliocene Citronelle formation of the Gulf Coastal Plain: U. S. Geol. Survey Prof. Paper 98, p. 167–192.
Meinzer, O. E., 1923, Outline of ground-water hydrology: U. S. Geol. Survey Water-Supply Paper 489, 71 p.
———1933, Geophysical interpretation of ground-water levels: Am. Geophys. Union Trans., 14th Ann. Mtg., p. 36–37.
Mullins, Troy, 1951, Farm management aspect of variety selection in rice production in Louisiana: La. Rural Economist, v. 13, no. 3.
Muskat, Morris, 1937, The flow of homogeneous fluid through porous media: 763 p., New York, McGraw-Hill Book Co., Inc.
———1946, The flow of homogeneous fluid through porous media: 763 p., Ann Arbor, Mich., J. W. Edwards, Inc.
Parshall, R. L., 1945, Improving the distribution of water to farmers by use of the Parshall measuring flume: U. S. Dept. Agr., Soil Conserv. Serv. Bull. 488.
Pennink, J. M. K., 1905, Investigations for ground-water supplies: Am. Soc. Civil Engineers Trans., v. 54, pt. 4, p. 179.
Roy, C. J., 1939, Type locality of Citronelle formation, Citronelle, Ala.: Am. Assoc. Petroleum Geologists Bull., v. 23, no. 10, p. 1553–1559.
Russell, G. H., 1934, Measurements of flow of water from pipe discharge by trajectory method: Federal Land Bank Memorandum.
Russell, R. J., 1936, Physiography of lower Mississippi [River] delta: La. State Dept. Conserv. Geol. Bull. 8, 199 p.
Russell, R. J., and Howe, H. V., 1935, Cheniers of southwestern Louisiana: Geog. Rev., v. 25, no. 3, p. 449–461.
Russell, R. J., and Russell, R. D., 1939, Mississippi River delta sedimentation: Recent Marine Sediments Bull., Am. Assoc. Petroleum Geologists Symposium, p. 153–177.
Safford, J. M., 1856, A geological reconnaissance of the State of Tennessee; being the author's first biennial report: 164 p. (legislative ed., 120 p.), map, Nashville, Tenn.
Schuchert, Charles, 1935, Historical geology of the Antillean-Caribbean region: 811 p., New York, John Wiley & Sons, Inc.
Schuchert, Charles, and Dunbar, C. O., 1933, A textbook of geology, pt. 2, Historical geology: p. 223–240, New York, John Wiley & Sons, Inc.
Shutts, E. E., 1953, Rice irrigation in Louisiana: Am. Soc. Civil Engineers Trans., v. 118, p. 871–884.
Staebner, F. E., 1940, Supplementary irrigation: U. S. Dept. Agr. Farmers' Bull. 1846, p. 3.
Stanley, T. B., Jr., and Maher, J. C., 1944, Ground-water resources of Jefferson Davis and Acadia Parishes, La.: La. Dept. Public Works, 93 p.
Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pt. 2, Aug., p. 519–524.
———1938, The significance and nature of the cone of depression in ground-water bodies: Econ. Geol., v. 33, p. 889–902.
Thomassy, Raymond, 1860, Geologie pratique de la Louisiane: 263 p., New Orleans, La.
Tolman, C. F., 1937, Ground water: 593 p., New York, McGraw-Hill Book Co., Inc.

U. S. Dept. Army, Corps of Engineers, 1948, Definite project report, Mermentau River, La. [Processed.]

———1950, Salt-water intrusion, Calcasieu River, La., and connecting waterways: Waterways Expt. Sta. Tech. Mem. 2-310.

U. S. Geol. Survey, 1947, Quality of surface waters of the United States, 1944: U. S. Geol. Survey Water-Supply Paper 1022, 311 p.

———1949, Quality of surface waters of the United States, 1945: U. S. Geol. Survey Water-Supply Paper 1030, 335 p.

———1950, Quality of surface waters of the United States, 1946: U. S. Geol. Survey Water-Supply Paper 1050, 486 p.

———Surface-water supply of the United States, Lower Mississippi River Basin: U. S. Geol. Survey Water-Supply Papers 547, 567, 587, 607, 877, 897, 927, 957, 977, 1007, 1037, 1057, 1087, 1117, and 1147, for the years 1922 to 1949.

———Surface-water supply of the United States, Western Gulf of Mexico Basins: U. S. Geol. Survey Water-Supply Papers 548, 568, 588, 608, 878, 898, 928, 958, 978, 1008, 1038, 1058, 1088, 1118, and 1148, for the years 1922 to 1949.

———Water levels and artesian pressure in observation wells in the United States: U. S. Geol. Survey Water-Supply Papers 114, 845, 886, 909, 939, 947, 989, 1019, 1026, 1074, 1099, 1129, and 1159, for the years 1905 to 1949.

U. S. Public Health Service, 1946, Public Health Service drinking standards and manual of recommended water sanitation practice: Reprint 2697, U. S. Pub. Health Serv. Repts., v. 61, no. 11, p. 371–384.

Uren, L. C., 1946, Oil-field development, *in* Petroleum production engineering, 3d ed., New York, McGraw-Hill Book Co., Inc.

Veatch, A. C., 1899, The five islands, report for 1899: La. Geol. Survey Special Rept. no. 3, p. 209–262.

———1906, Geology and underground water resources of northern Louisiana and adjoining districts: La. Geol. Survey Rept. for 1905, Bull. 4, p. 248–514.

Wailes, B. L. C., 1854, Report on the agriculture and geology of Mississippi: Jackson, Miss.

Wallace, W. E., 1944, Structure of south Louisiana deep-seated domes: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 9, p. 1249–1312.

Welch, R. N., 1942, Geology of Vernon Parish: La. Dept. Conserv. Geol. Bull. 22, 86 p.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 887, 192 p.

Woodward, T. P., and Gueno, A. J., Jr., 1941, The sand and gravel deposits of Louisiana: La. Dept. Conserv. Geol. Bull. 19, 365 p.

Note.—Many of the preliminary or examination surveys made by the Corps of Engineers, U. S. Army, have been reported and published as House and Senate Documents. The latest of these published reports are as follows: H. Doc. 1032-65-2, H. Doc. 465-77-1, S. Doc. 190-79-2, H. Doc. 1032-65-2, H. Doc. 1230-65-2, H. Doc. 1398-65-3, H. Com. 36-72-1, S. Doc. 231-79-2, H. Doc. 75-73-1, H. Doc. 594-78-2, H. Doc. 418-64-1, H. Doc. 741-65-2, H. Doc. 93-77-1.

INDEX

D

E

U.S. GOVERNMENT PRINTING OFFICE : 1956 O - 387601