Water-Supply and Irrigation Paper No. 101 Series O, Underground Waters, 23

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

UNDERGROUND WATERS

OF

SOUTHERN LOUISIANA

BY

GILBERT DENNISON HARRIS

WITH DISCUSSIONS OF THEIR USES FOR WATER SUPPLIES AND FOR RICE IRRIGATION

BY

M. L. FULLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

The publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topographic Atlas of United States, folios and separate sheets thereof; (8) Geologic Atlas of United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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The following Water-Supply Papers are out of stock, and can no longer be supplied: Nos. 1-16, 19, 20, 22, 29-34, 36, 39, 40, 43, 46, 57-65, 75. Complete lists of papers relating to water supply and allied subjects follow. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.)

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WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles, Wyoming, by G. I. Adams. 1902. 50 pp., 11 pls.
WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.
WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1902. 151 pp., 14 pls.
WS 87. Irrigation in India (second edition), by H. M. Wilson. 1903. 238 pp., 27 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Pt. II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Pt. III.

SERIES J—WATER STORAGE.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.
WS 40. The Austin dam, by Thomas U. Taylor. 1900. 51 pp., 16 pls.
WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.
WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and Reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.
WS 58. Storage of water on Kings River, California, by J. B. Lippincott. 1902. 100 pp., 32 pls.
WS 68. Water storage in Truckee Basin, California-Nevada, by L. H. Taylor. 1902. 90 pp., 8 pls.
WS 73. Water storage on Salt River, Arizona, by A. P. Davis. 1902. 54 pp., 25 pls.
WS 86. Storage reservoirs on Stony Creek, California, by Burt Cole. 1903. 62 pp., 16 pls.
WS 89. Water resources of Salinas Valley, California, by Homer Hamlin. 1904. 91 pp., 12 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Pt. IV.

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., December 4, 1903.

SIR: I have the honor to transmit herewith a manuscript by Prof. G. D. Harris on the "Underground Waters of Southern Louisiana," to which has been added short discussions of certain economic features, including the uses of underground waters for water supplies and for rice irrigation, by Mr. M. L. Fuller. The part by Professor Harris is an elaboration of a portion of an earlier paper published in the reports of the geological survey of Louisiana, and by means of its descriptions and illustrations brings out clearly the nature of the occurrence and the importance of the underground water resources of the region considered. It is believed that the discussion of water supplies, by reiterating the importance of pure sources, will hasten their introduction. The irrigation of rice, though yet in its earlier stages, has already increased tenfold the value of land over large areas, and the publication of information which will in any way call attention to the importance of underground waters in its development will be of considerable value. I would recommend that the report be published in the series of Water-Supply and Irrigation Papers.

Very respectfully,

F. H. NEWELL, *Chief Engineer.*

HON. CHARLES D. WALCOTT,
Director, United States Geological Survey.

UNDERGROUND WATERS OF SOUTHERN LOUISIANA.

By Gilbert D. Harris.

PREFATORY REMARKS.

In the writer's studies of the geology of southern Louisiana during the last three years, opportunities have presented themselves for collecting data relating to the underground waters of this section of the State. A brief summary of the data so collected was given in Part VI of the report of the State geological survey for the year 1902, in Special Report No. 6, "The Subterranean Waters of Louisiana." Since the publication of this work one winter season has been spent in southern Louisiana in general geological work, and one month (June 20 to July 20, 1903) has been devoted to field work bearing exclusively on water supplies. This report, therefore, may be considered as an enlarged and revised edition of the special report named, based, in large measure, on facts gathered by the writer while he was employed by the State of Louisiana. After this explanation it seems scarcely necessary to use quotation marks or to give precise references in every case where facts have been taken from the earlier report.

In many instances the height above tide (mean sea level) of stations along the Southern Pacific Railroad will be found to vary as much as 8 feet in the two reports. This is due to the fact that early elevations furnished by this road to the United States Geological Survey, and published in Bulletin 160, were different from those now posted on the stations along the line throughout southern Louisiana (see Pl. I).

ORIGIN OF ARTESIAN AND DEEP-WELL WATERS IN SOUTHERN LOUISIANA.

PRECIPITATION.

Last year's Weather Bureau report gives the following figures regarding precipitation at several stations in southern Louisiana:[a]

Precipitation at stations in southern Louisiana.

Station.	1902.	Average.
Alexandria	45.24	55.95
Amite	41.44	60.41
Cheneyville	40.74	53.18
Clinton	52.29	55.01
Hammond	47.01	58.13
Lafayette	36.35	53.48
Lake Charles	41.19	54.94
Opelousas	39.77	54.64
Sugartown	48.12	54.52

From this it appears that the average annual precipitation in this part of the State is about 55 inches. This means that each acre of land receives more than double enough rain water to irrigate it properly if planted in rice. But much of this water is lost, so far as agricultural purposes are concerned, by flowing away in surface streams to the Gulf. Much, too, that descends into the soil and lower strata of the earth, doubtless leaches out into the Gulf underground. Unfortunately for our present study, the main local streams of southern Louisiana have never been gaged, and consequently the amount of water that reaches the sea, even by surface streams, is not known. The extent, therefore, to which the total amount of rainfall may be utilized as deep-well water can not at present be even approximately estimated. That much rain water is absorbed and transported to distant places through underground porous layers is evident from the existence of many satisfactory deep and artesian wells throughout the southernmost parishes of the State. Yet it is often held that the supply of deep waters may be derived from large bodies of neighboring water—for example, from lakes and rivers and small streams that have a greater altitude than the surface of the water in the deep wells. This may, indeed, be the case in a region in which there are limestone formations, or in a region where the gradient of the streams is considerable and erosion is scouring and cleaning the sides and bottom of the channels and where practically no silt is being deposited, but in

[a] U. S. Dept. Agr., Ann. Summary, 1902, Louisiana Section, Weather Bureau Office, New Orleans, La.

Louisiana none of these conditions exist, so far as the larger streams and other large bodies of water are concerned. However, we will consider with all necessary detail two of the common theories advanced to account for the presence of water in such apparently immense quantities beneath the surface in southern Louisiana.

GULF WATER AS A SOURCE OF SUPPLY OF DEEP WELLS.

It is frequently asserted that the continuance of southerly winds or high tides causes an appreciable rise in the level of the water in wells not far from the coast; that when wells are vigorously pumped the water level descends below tide; that therefore there is an intimate connection between the waters of the Gulf and those encountered so abundantly in deep wells.

That there is more or less connection between the fresh water under the ground and the salt water of the Gulf there can be no doubt. A variation in the height of the water in a few wells coincident with that in a neighboring body of water in which there is a perceptible tide was long ago recorded by members of the Louisiana State geological survey and others. That there is no underground current from the Gulf landward is evident from the facts (1) that when pumping ceases for a few hours the water level in the wells quickly rises above tide, and (2) that any water derived from the Gulf would possess a saltiness that has not thus far been recorded in any deep irrigation well. Any impediment tending to retard the escape of the underground waters Gulfward, as the weight of water collected from long-continued heavy showers or the backing up of the Gulf's waters from the south, will necessarily raise the level of the water in the deep wells or cause the artesian wells to flow more strongly.

RIVER WATERS AS A SOURCE OF SUPPLY.

In 1860 Raymond Thomassy[a] published his Géologie pratique de la Louisiane. He seems to have been greatly captivated with the idea that a large amount of the water flowing into the Mississippi from its various tributaries never reaches the Gulf by surface streams, but is absorbed by the pervious layers that form the banks and bottom of the river, and is carried thence through underground passages and porous layers to the Gulf coast, or beneath its waters.

Thomassy was of course not aware of the great possibilities of irrigation in southern Louisiana, but had he lived to see hundreds of 10 or 12 inch wells yielding almost rivers of deep, cool water, he would doubtless have felt that his absorption theory was at last fully proved, else whence could all this underground water come?

[a] Géologie pratique de la Louisiane, par R. Thomassy (accompagné de 6 planches), chez l'auteur, à la Nouvelle-Orléans et à Paris, 1860.

No definite statements can be made regarding the amount of water furnished by the rivers of Louisiana to the general underground supply until the topography and stratigraphy have been determined in detail. Yet it may be shown here that the oft-repeated popular statement that waters of the Mississippi River supply the wells in southern Louisiana is but partly, if at all, correct. Certainly no "veritable river" is leaving the Mississippi in its lower reaches to force its way laterally for long distances underground. The process of transferring discharge measurements from one point on the river to another, as employed by Humphreys and Abbot[a] in their delta survey, has shown that the difference in discharge at two stations at equal stages in the river is due to increment of water from tributaries and loss in distributary bayous and crevasses between the two places. Daily discharge measurements made at Vicksburg were compared with discharge measurements made at stations up and down the river, and these agreed in a remarkable way.

In other words, there is no difference in the amounts of discharge at Vicksburg and Carrollton, for example, that can not be explained by taking into account the difference between water received and that given up by surface channels. The absorption, therefore, of the Mississippi's waters by underground porous layers is a subject that is of no importance in the present report.

The impropriety of assuming that variations in "head" noticed in deep wells located at any considerable distance from the Mississippi are due to difference in the stage or height of the river, is evident from facts presented farther on in this report. It is fortunate that the measurements of well stages here recorded were made mostly in the spring of 1901, especially in April and May. The wells showed a slight temporary rise about April 22, due to local showers, but thereafter the usual marked decline for the summer went steadily on. Not so the river; it gradually rose till it reached the highest point of the season on the dates which follow, at the localities designated:[b] May 16, Vicksburg, Miss.; May 15–16, St. Joseph, La.; May 16–17, Natchez; May 17, Red River Landing; May 17, Bayou Sara; May 17, Baton Rouge; May 16, Plaquemine; May 19, Donaldsonville; May 15, College Point; May 17 and 20, Carrollton. After these dates, at the stations named, the river began to decline.

The cross sections presented in figs. 8 and 9 (pp. 29, 30) show clearly the behavior of deep waters in the vicinity of large stream channels. There is therefore reason to suppose that the Mississippi and other large streams serve as drains on the underground-water supply rather than as feeders.

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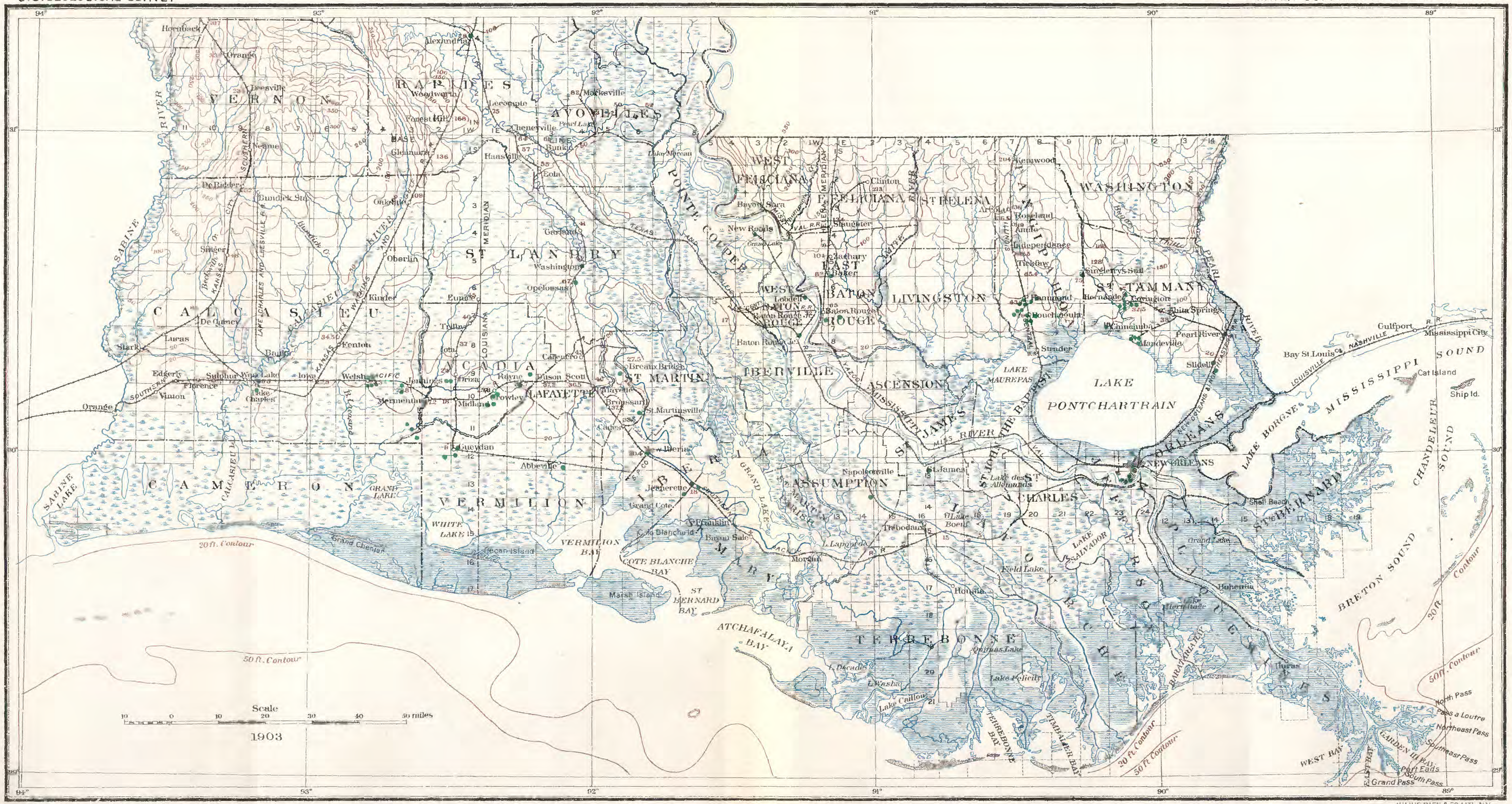
[a] Report upon the physics and hydraulics of the Mississippi River; upon the protection of the alluvial region from overflow, etc.: Professional Paper No. 13, Corps of Engineers, U. S. Army, 1861. See reprint of 1876, pp. 280, 358–363.

[b] Stages of the Mississippi, etc.: Miss. Riv. Comm., 1901, St. Louis, Mo., Mississippi River Commission Print, 1902.



Compiled from maps of the U.S. Land Office, U.S. Engineers Report
U.S. Coast and Geodetic Survey, Railroad profiles
State Geological Survey of Louisiana, and U.S. Geological Survey

JULIUS BIEN & CO. LITH. N.Y.

MAP OF SOUTHERN LOUISIANA SHOWING TOPOGRAPHIC FEATURES AND IMPORTANT WELLS

By G. D. Harris

TOPOGRAPHY OF SOUTHERN LOUISIANA.

Since the cause of flow of underground waters must be due mainly to the action of gravity, it follows that the surface features of the land have a marked influence on the rate of underground as well as of overground flow. Southern Louisiana has only just begun to cooperate with the General Government in the construction of detailed topographic maps, so it is not possible to show the surface features as well as could be desired; yet private individuals, corporations (such as railroad and canal companies), United States engineers, and members of the State geological survey have done a large amount of spirit leveling throughout the area, and from such data it has been found

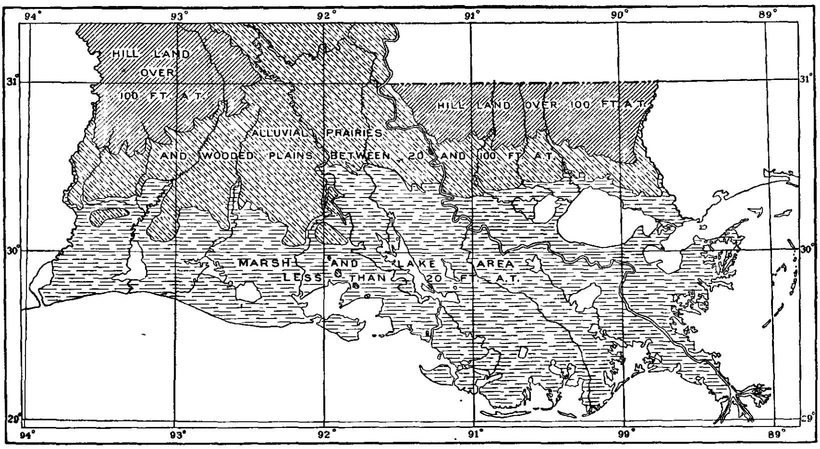


FIG. 1.—Map showing topographic subdivisions of southern Louisiana.

possible to compile a small-scale contour map (Pl. I) and a still smaller index map (fig. 1) to the topography of this part of the State.

TOPOGRAPHIC SUBDIVISIONS.

SWAMP-LAKE AREA.

To this subdivision may be assigned in general that portion of the State having an elevation above tide of less than 20 feet (see fig. 1). Its size is surprisingly great when compared with that of the more elevated areas. Pl. I represents an area in Louisiana, exclusive of large lakes, bays, etc., covering 28,900 square miles, of which 15,800 are below the 20-foot contour. The Five Islands in Iberia and St. Mary parishes are the only areas furnishing what might be called notable relief in this subdivision of southern Louisiana. One "island" rises to a height of 150 feet above the surrounding marsh land; others are but two-thirds or half as high. Since, however, the diameter of the largest is only approximately 2 miles, their total area is extremely insignificant when compared with the vast extent of low land shown on the map. Southern Cameron and Vermilion parishes contain extensive swamp tracts that lie several miles back from the Gulf border, but close to the Gulf there are several remarkably persistent dry, sandy ridges that rise from 5 to 10 feet above mean tide (see Pl. I). In the swampy areas there are several broad and very shallow lakes or bays, as may be seen by consulting the same plate. They rarely show a depth of more than 15 or 20 feet, usually much less. The bayous and rivers, however, have cut very deep channels through these lowlands. Depths of 30 to 40 feet are by no means unusual, while the Mississippi has long stretches of channel that range in depth from 72 to 90 feet, and occasional pools 200 feet deep. The manner in which the ground slopes above and below Gulf level, the basin-like character of the lakes, and the deepness of the river channels are typically shown in fig. 2.

FIG. 2.—North-south section from the Kansas City Southern Railroad, in Texas, through Sabine Lake and southwestern Cameron Parish, La. Length, 35 miles; extreme elevations, −30 to +30 feet.

The topography of the region lying between Lake Pontchartrain and the Atchafalaya River—the so-called delta region of the Mississippi—deserves a few additional remarks.

Large areas in this tract are scarcely above sea level. The figures shown on Pl. I, along the Southern Pacific Railroad from New Orleans to Morgan City, indicate feet above tide. Here, as in all mature river flood plains, there is a tendency to deposit sediment along the immediate banks of the streams so as to form low, natural levees. This feature is indicated to some extent by the figures just referred to, but in the lower delta region it is clearly seen along the sea-level line. Nearly all the streams are leveed, as it were, out into the Gulf, especially the Mississippi.

The large quantities of water that have passed over this delta region in comparatively recent geologic times have kept its surface from rising above sea level at the same rate as did adjoining portions of the State lying north, east, and west. The result is that this region has been eroded by waters coming from nearly all the middle Western States, whereas the adjoining tracts have been worn down only by the results of the precipitation upon their own area. Now, river action is gradually building up this delta region, whereas to the east and west the land surface is being gradually degraded.

REGION OF PRAIRIES AND LOW, ROLLING HILLS.

There is naturally no sharp line of demarcation between this topographic division and the one just described. The swamp and lake regions gradually become drier to the north, and the former Gulf, lake, or swamp bottoms assume the rôle of "crawfish" prairies. This is specially true of the low plains west of the Atchafalaya. In general, this region may be approximately defined as extending from the 20-foot to the 100-foot contour line. For a stretch of about 40 miles in width west of the Mississippi the general appearance of this region is somewhat changed by the erosion and the alluvial deposits of this great stream and its tributaries or distributaries. East of the Mississippi, however, the prairies again appear here and there, though the forests often descend to the very edge of the swamp lands. As the 100-foot contour is approached, the land becomes dissected by numerous small streams, and when cleared of its forest growth presents a decidedly rolling surface. East of the Mississippi the plains lying near the level of the 20-foot contour are still in places thickly studded with graceful, palm-like "long-leaf" pines. Their years are numbered, though, as the many huge sawmill plants in their midst will attest.

The soil of the region or zone that lies nearly at the level of the 20-foot contour is decidedly clayey and "tight-bottomed," a feature of great economic importance to the rice planter. Farther up, toward the 100-foot contour, the soil is more sandy and is, therefore, more pervious to surface waters. This, too, as we shall see later on, is an extremely fortunate circumstance so far as the supply of underground water farther south is concerned.

HILL LANDS.

As the low lake and swamp lands pass gradually into the prairies, so the upper undulating prairie and timber lands pass gradually into the more abrupt dissected area. The chief difference to be noted is that in this last subdivision the streams are so numerous and their valleys so deep that there is little left of the old sea-bottom plain out of which this rugged topography was carved. As the surface of the land in this area rises from 100 feet to over 400 in a distance usually less than from the sea margin to the 20-foot contour, it is no wonder that the effects of erosion are well marked. Here the soil is still more gravelly or sandy than in the belt below the 100-foot contour. This fact, too, has much to do with the rapid erosion that is apparent on every hand. A small exception to the general appearance of these "long-leaf pine hill lands" is to be seen in the calcareous prairies (Anacacho) near Leesville, Vernon Parish.

STRATIGRAPHY OF SOUTHERN LOUISIANA.

GENERAL CONSIDERATIONS.

So far as underground waters are concerned the stratigraphy of southern Louisiana is very simple, for nearly all of the wells discussed in this report are in very young or Quaternary deposits.

Here and there, to be sure, peaks and uplifts of the older beds approach the surface, or even protrude above the general level of the land, but such uplifts are generally of extremely local nature. The Five Islands, for example, stretch along the coast for a distance of over 35 miles, but the greatest diameter of the largest one is only 2 miles.

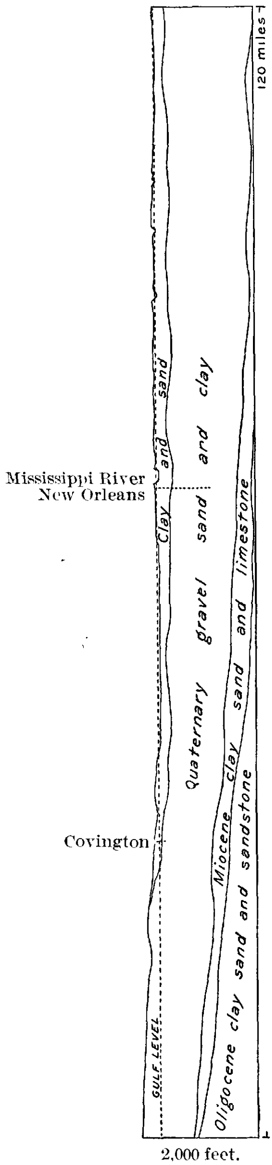


FIG. 3.—North-south section from the Mississippi line, through Covington and New Orleans and Baratara Bay, to the Gulf.

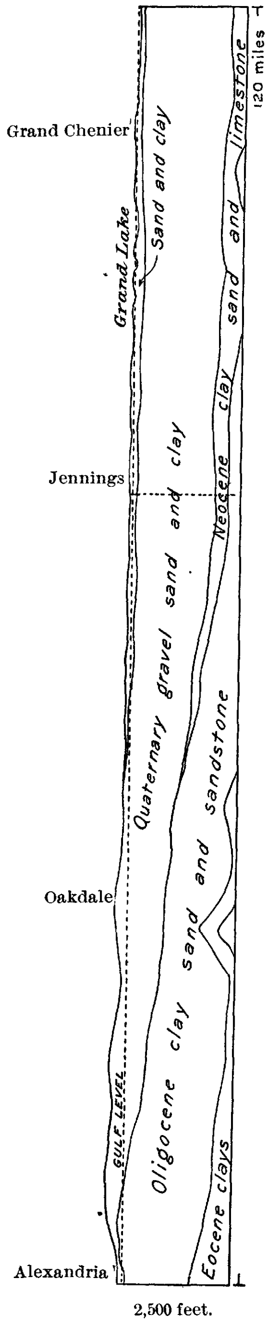
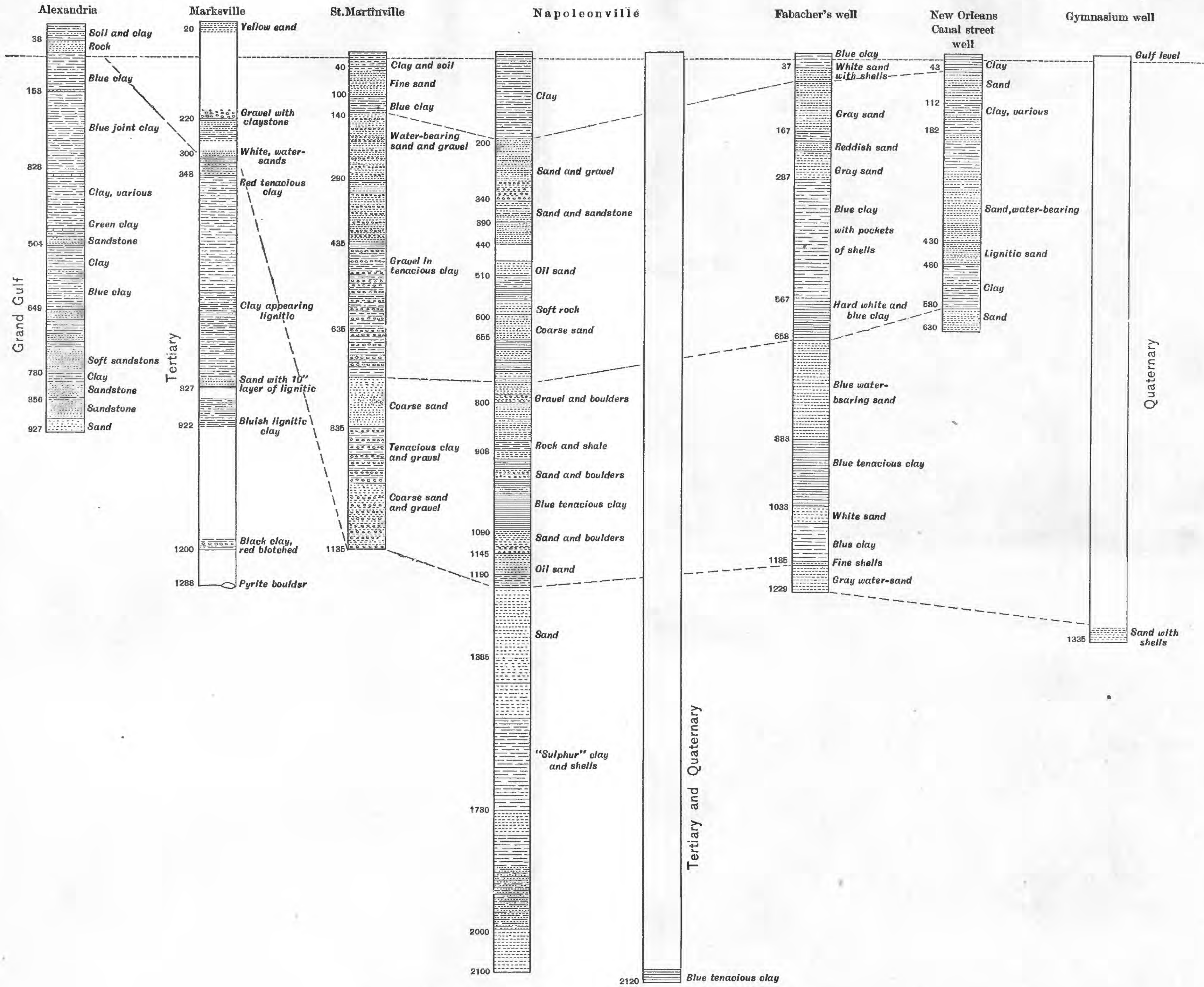


FIG. 4.—North-south section, starting 12 miles west of Alexandria, passing through Oakdale, Jennings, and Grand Lake, to the Gulf.

Again, these Five Islands are separated by a stretch of 25 miles from the truncated cone at Anse la Butte, or by 75 or 80 miles from simi-



WELL SECTIONS FROM ALEXANDRIA TO NEW ORLEANS.

lar structures at Sulphur and Vinton. The Cretaceous limestone of Bayou Chicot is 60 miles north of the northernmost island. There are doubtless other and undiscovered irregularities in the underlying rocks in southern Louisiana, but they are so evenly blanketed over by Quaternary clays and sands that there is no evidence of their existence.

The two cross sections herewith given show the general stratigraphy of the water-bearing sands in southern Louisiana (see figs. 3 and 4). Other sections can be constructed by placing in juxtaposition well sections that have been taken along some one general trend. On Pl. II is shown the stratigraphic relation of the beds encountered in well sec-

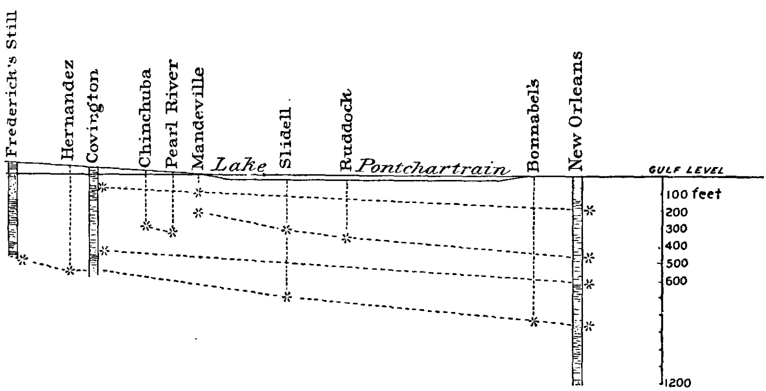


FIG. 5.—Correlation of water-bearing sands north and south of Lake Pontchartrain.

tions at Alexandria, Marksville, St. Martinville, Napoleonville, and New Orleans. Fig. 5 is a similar section, extending from a point 9 miles northwest of Covington to New Orleans.

TERTIARY.

OLIGOCENE.

In considering the Quaternary sands of this region, it seems proper to take some notice of the beds upon which they lie. Again, if the country around Alexandria, for example, be included in the region here called southern Louisiana, this discussion should embrace a consideration of the outcrops of Tertiary (Oligocene) rocks in that neighborhood, which are of considerable importance in connection with the supply of underground potable waters of the State. The well of the Alexandria Ice and Storage Company, recently put down, will give a fair idea of the character of the Oligocene (Grand Gulf) material in this part of the State. Its section is as follows:

Section of well of Alexandria Ice and Storage Company, Alexandria, La.

	Thickness in feet.	Depth in feet.
Surface ground clay	21	21
Sand	2	23
Clay	15	38
Rock	27	65
Blue clay	88	153
Hard rock	2	155
Blue clay	20	175
Rock	8	183
Blue joint clay	145	328
Limestone	3	331
Clay	43	374
Hardpan	90	464
Hard limestone	2.5	466.5
Green clay	12	478.5
Hard rock	1.5	480
Blue clay	10	490
Sandstone	14	504
Clay	30	534
Sand	3	537
Rock	2	539
Clay	10	549
Sand	1	550
Clay	8	558
Sand	2	560
Blue clay	89	649
Sand	16	665
Clay	28	693
Sand	10	703
Blue clay	24	727
Soft sandstone	53	780
Clay	24	804
Sand	5	809
Soft sandstone	42	851
Clay	2	853
Sandstone	44	897
Sand	30	927

This well is provided with a 70-foot strainer, and before it was cleaned had a flow of 125 gallons a minute, according to the report of a local paper.

The somewhat misleading information received at Alexandria two years ago regarding the material passed through in sinking the water-works well would have inclined one to place the water-bearing sands here at a horizon that is manifestly far too low. The great thickness of the Grand Gulf beds here is surprising, but the description of the material penetrated certainly places it in this division of the Tertiary.

The several fine flowing wells at Boyce are evidently mainly if not wholly in this horizon, though perhaps the one 810 feet deep, which yields gas with the water, may have a somewhat lower origin than the shallower ones.

Similar water-bearing Grand Gulf sands on the Ouachita River near Catahoula Shoals have already been described.[a]

It is doubtful whether these beds have ever been encountered in drilling for water or oil farther south in Louisiana, except perhaps around some of the local upheavals or buried cones already referred to. The most probable exception is the Spring Hill oil well, not far east of Kinder, where, at a reported depth of 1,500 feet (probably about 1,200), the writer observed that the drill was passing through sharp quartz sand, mixed with flakes of green clay. It was reported that a soft sandstone, about 14 feet thick, was penetrated by the drill just before the writer's visit.

MIOCENE.

There is little if anything in the stratigraphy of these rocks that concerns us here. Their position must be such (see figs. 3 and 4) that their water supply would be very uncertain, both as to quantity and quality. They probably contain salt water, and this has been found in them by many of the oil-well drillers. From samples of well borings already studied, it seems probable that where there are no local disturbances these beds in southern Louisiana, say along the thirtieth parallel, scarcely ever rise above a plane that lies 2,000 feet below sea level.

QUATERNARY.

SUBDIVISIONS.

The longer the geology of southern Louisiana is studied the more futile appears the attempt to make satisfactory subdivisions in the Quaternary deposits—subdivisions that have any definite time or structural limits. Differences in conditions of deposition during the same period of time have produced results that vary greatly in different localities. The same differences in conditions of deposition that we see to-day at different places in southern Louisiana, producing the sea-marsh clays with vegetable and brackish-water organic inclusions,

[a] Report Geol. Survey Louisiana for 1902, p. 214.

the yellow sand ridges with an abundance of purely marine life, the purely fresh-water alluvium, and the alluvium intermingled with marine sands at the mouths of the larger rivers, all seem to have existed throughout Quaternary times. The mistake that has been made in assigning to the "Port Hudson group" a special place in geologic time may well be illustrated by the case of the casual theater-goer who drops in on a play on the last evening of the season and observes with care and interest the personæ, costumes, etc., throughout the different acts and scenes of the performance and afterwards records the fact that this particular play was given at this place at this particular time. The inveterate theater-goer, on the other hand, may see nothing of special interest in these facts, for he may know that that play had been running at that place not only that particular night but during the whole season. The swamp condition of the "Port Hudson" has been truly reproduced, with its clays, "black muck," and logs, to a depth of over 800 feet in the wells of southwestern Louisiana; the estuarian clay condition (Pontchartrain clay) is accurately reproduced at depths of 80, 500, 1,200, and is best of all at 1,800 feet beneath the surface; the marine sands may be found at various depths. Thick beds of so-called Lafayette gravel are often interspersed with these "Port Hudson" elements.

It seems, therefore, that if there is anything to be gained by applying a name to clays that were evidently deposited in brackish-water bays, estuaries, and lakes along the Gulf border, some such term as "Pontchartrain clays" may be used, with the understanding, however, that the name shall denote a particular kind of deposit or phase of deposition having no special time value. So, too, the deposits, mainly alluvial, containing a large amount of vegetable matter, especially stumps and trunks of trees, may, if necessary, be classed as Port Hudson clays; and marine sands may be referred to as Biloxi sands; but in all cases the terms must be understood as denoting mere phases of deposition, not stratigraphic units.

But the names that may be applied to the different portions of the Quaternary deposits of this State are of little importance so far as the present work is concerned. The important facts are these: Pervious material, such as sand (coarse and fine) and gravel, alternate with impervious clay beds of various thicknesses throughout the Quaternary deposits of southern Louisiana; these beds vary greatly as regards inclosed organic remains and products of decomposition and in different localities are inclined at different angles, the "dip" being, roughly speaking, in the same general direction as the slope of the surface of the land, though somewhat greater in amount; the character of the water is greatly modified by the medium through which it passes; the position or state of the water, i. e., whether "deep well" or artesian," is dependent largely on local topography.

A. REMNANT OF GRAND CHENIER RIDGE AT THE FERRY LANDING ON MERMENTAU RIVER.

B. LOCATION OF SPRINGS AMONG THE LIVE OAKS ON THE BORDER BETWEEN THE SEA MARSH AND THE SOUTH SIDE OF GRAND CHENIER ISLAND ABOUT 2 MILES EAST OF THE VILLAGE.

In the generalized sections here given, running north and south across this portion of the State (see figs. 3 and 4), no attempt has been made to show the many and various clay, sand, and gravel beds that form the Quaternary series of this region. The fact has been indicated, however, that generally, where the land is flat and erosion has been slight, the latest (uppermost) layers consist of fine sand and clays.

GENESIS OF DEPOSITS.

The statistics upon which the above-mentioned general statements are based are mainly of two kinds—first, well sections and the fossils and rock material accompanying them, and second, facts noted in a somewhat detailed study of present areas of deposition along the southern border of the State. Well statistics will form an important section of this report. Their interpretation, however, depends on an accurate knowledge of present conditions of sedimentation. The following remarks and illustrations will therefore serve to throw light on the general statements already made and give a meaning to the detailed well records which follow.

The shore line of southern Louisiana is generally sandy, and there are often sand and shell ridges extending for miles parallel to the shore, either in close proximity to the Gulf or some distance inland. Those more distant from the present southern border of the land often show axial directions not in accord with those nearer the Gulf, as may be seen by observing the direction of the ridges toward the eastern portion of Pecan "Island." These peculiar forms are not due to any considerable extent to erosion. Ridges of the same character are now being formed along the Gulf border, just above and just below mean tide. Off Cameron and Mud lakes, for example, one can see how, during storms, the waves have beaten up the sand and shells in ridges rising in some places to a height of 10 feet above mean tide. Out in the Gulf some distance from the land the same force is at work making the Sabine Shoals (see Pl. I.) The curve of Point au Fer, off Atchafalaya Bay, gives a strong hint as to the formation of ridges with a trend somewhat at variance to the general direction of the shore line. Isle Dernière, Timbalier, Ship, and Cat islands, and the Chandeleurs will probably become inland ridges like Pecan and Grand Chenier, in southwest Louisiana, or like the less elevated and less conspicuous shell ridge encountered in sinking the foundation for pumping station No. 7 for the drainage of New Orleans.

The dimensions and general character of these ridges are well shown by fig. 6*A*. Pl. III, *A*, taken from the Louisiana report of 1902 (op. cit., Pl. IX), shows Mermentau River flowing in a westerly direction for some distance before it finally breaks through the ridge on its way to the Gulf. To the right the sea marsh stretches away to the east and south, with its waters practically at Gulf level. At the border of the Gulf, another though less important ridge is being formed at the present day. This statement, however, is not meant to imply that the large ridge shown in Pl. III, *A*, is of any other than late Pleistocene origin. In fact, the white objects shown in the foreground of the view are remains of large molluscan species similar to those now living in the Gulf and along the Atlantic coast. Notice should be taken of the fact, however, that these shells are all of marine origin. The few *Rangia* mixed with them show considerable river and wave erosion, and have evidently been washed into this marine assemblage by Gulfward flowing streams.

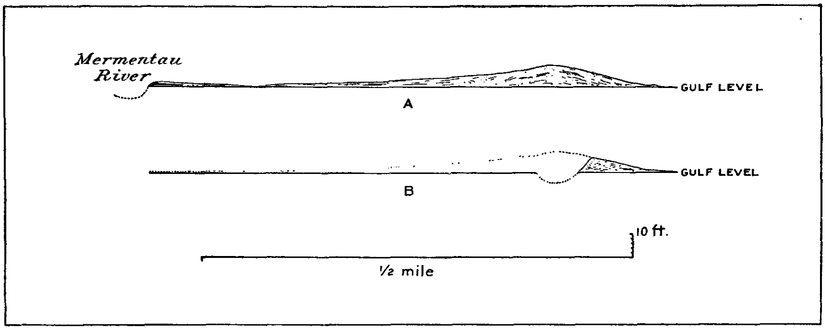


FIG. 6.—Sections across Grand Chenier Island; A, 3 miles west of village; B, one-half mile west of village.

The sands and shells forming these ridges absorb enough rain water to furnish a continuous supply to many springs that flow out at sea level on either flank. Pl. III, *B*, shows the location of such springs along the line of and between the great live oaks that have given the name of Chenier to this island.

The abrupt transition from the firmer ridge material to the softer marsh ground to the south is well shown by the fact that the aged oaks nearly always incline toward and finally fall into the marsh (to the left in the plate). In drilling for water similar abrupt changes are often met with in wells but a short distance apart.

On the north or opposite side of the ridge, scarcely three-fourths of a mile away, the character of the vegetation and deposition is very different (see Pl. IV, *A*). The marshy land is less even or is slightly undulating, showing accordingly all stages of transition from moist to wet lands through occasionally inundated swamps to areas nearly always beneath the water. These areas are receiving sediment from the flood stages of the bayous and hence are gradually filling in and presumably rising, irrespective of any uplifting movement that may be affecting the coast as a whole.

Such areas explain the way that the deposits encountered in the various wells to the north were formed. The occurrence of decayed

A. NORTH SIDE OF GRAND CHENIER ISLAND.

The Mermentau River in the background to the right, near the trees.

B. SOUTH SHORE OF LAKE PORTCHARTRAIN, $1\frac{1}{2}$ MILES WEST OF WEST END.

Black clay soil with occasional heaps of white weathered *Rangia* shells.

leaves, wood, fresh-water and land shells, together with fragments of marine shells in many borings, thus receives a natural explanation.

Equally interesting and important in the formation of this portion of the State are the shallow lakes, reference to which has been made in discussing fig. 2, such as Sabine, Calcasieu, Grand, White, Maurepas, Pontchartrain, and Borgne lakes, as well as the bodies of water called bays simply because they are not so completely surrounded by land. Of these bays Vermilion, Côte Blanche, Atchafalaya, Caillou, Terrebonne, Timbalier, as well as the still more open Chandeleur and Mississippi sounds, are good examples. In these there is a complete series of beds showing transition from purely marine to brackish or even fresh water. The fulgurs, naticas, arcas, oysters, tellinas, and mactras in the open sounds give place in the more inclosed bays to oysters, mactras, and rangias, while in the still more inland lakes the rangias lose their fellowship with the salt-water forms and live in comfort and harmony with the purely fresh-water unios. This condition may be seen in Lake Charles, a small swelling in Calcasieu River about 60 miles from the coast.

Marks of wave action and heaps of brackish-water *Rangia* shells may be seen along the low shore of Lake Pontchartrain, shown in Pl. IV, *B*. The characteristics of this vast expanse of shallow brackish water deserve more than passing notice by one who would understand the general geological history of southern Louisiana. It would scarcely be an exaggeration to assert that during some period of Pleistocene time practically all of the land area of this part of the State passed through a Pontchartrain stage. By this it is not meant that the whole of this area was one great brackish, inland lake at the same time; far from it. There are now in this region open sounds, more inclosed bays, still more landlocked lakes, growing smaller, usually, the farther inland the body of water lies. North of Lake Charles there is an extensive swamp area that has the appearance of being an old lake bed from which the waters are nearly drained off. Little Lake Charles is a remnant of a corner of this former extensive body of water. Still farther up are The Bays, low, flat, level, hard, wet-bottomed areas, embracing several thousand acres of land. The water and oil wells that have been drilled during recent years in southern Louisiana seldom fail to encounter masses of *Rangia* shells at some depth. Water wells, at Jennings for example, sometimes pass through a bed of such shells 10 feet thick, lying at depths ranging from 50 to 100 feet below the surface. On the shores of Lake Charles, Lake Arthur, Grand Lake, Berwick Bay, Lake Pontchartrain, and elsewhere in countless localities the same recent *Rangia* can be seen heaped up in ridges. At Jennings again similar Pontchartrain clays, with the same *Rangia*, are generally encountered just above the oil in wells, at a depth of about 1,800 feet.

EFFECT OF THE MISSISSIPPI ON STRATIGRAPHY OF SOUTHERN LOUISIANA.

The Quaternary material of Louisiana was evidently brought to its present place by Mississippi River and other smaller streams emptying into the Gulf, as it then was, throughout a stretch of perhaps 250 miles. In Tertiary as well as Quaternary times the Mississippi has had a marked influence on the character of deposition and the character of life to be found in this section. In several stages of the Eocene the deposits along the Mississippi axis are decidedly lignitic; farther to the east and west they are more marine. Certain stages in the Oligocene show similar conditions and differences. It must not surprise us, then, to find that the greater part of the Quaternary deposits of southern Louisiana are composed of beds that bespeak clearly the proximity of brackish or fresh water or land conditions. We attribute the presence of tenacious clays in the wells of southern Louisiana, to a depth of 1,800 feet in places, indirectly to the rapid filling in of the Gulf border by the Mississippi sedimentation. In some places there has been a continual loading and consequent depression of the Gulf's border; this has given rise to uplifts in regions not far distant. The shifting of the mouth of the river and the consequent change of loading point has caused a shifting of regions of depression and upheaval. If the region of uplift is some distance from the coast, then shallow sounds, bays, or lakes result, according to the extent of the uplifting. These, when finally filled with Pontchartrain clays derived from the sediment of inflowing rivers, pass through the sea-marsh stage into "crawfish" prairies, when the region in which they occur has been elevated a few feet.

Wave action, to be sure, performs a significant part in the formation of certain ridges that will eventually act as temporary borders to these landlocked bodies of water; but, after all, it is mainly the action of the Mississippi that causes the many changes of level that are so well recorded in the Quaternary deposits throughout south Louisiana.

In the immediate vicinity of the present course of the larger rivers, especially the Mississippi, Biloxi conditions can scarcely be expected to prevail. Here and there will be ridges of sand containing a purely marine fauna, but they will be notably local. Perhaps no better example of such a marine oasis in beds generally of a somewhat brackish water origin can be referred to than the sands containing beautifully preserved seashells at pumping station No. 7 of the New Orleans Drainage Works. This is evidently one of those ridges caused by wave action and slight upheaval that have served to cut off portions of the Gulf in the manner described above. The mouth of the Mississippi was at that time doubtless as far up as Bayou Sara, and its waters would not materially modify the life at a point then so far out at sea. So, too, at Napoleonville, the fauna at a depth of 2,100 feet seems purely marine. When this fauna lived doubtless the mouth of the Mississippi was as far north as the point named above, hence no great modification was brought about by the fresh waters of that great stream. Later, however, the fauna became brackish, with a preponderance of *Rangia* at 1,200 feet, and the drillers brought out a large tooth, equine in appearance, from a depth of 800 feet. Large quantities of *Rangia* have been found in a well near Morgan City at a depth of about 500 feet, and specimens of the same species were obtained at 400 feet at the Istrouma Hotel well at Baton Rouge.

SUBDIVISIONS OF SOUTHERN LOUISIANA, BASED ON UNDERGROUND WATER CONDITIONS.

MODIFICATION OF KIND AND CONDITIONS OF WATER BROUGHT ABOUT BY LOCAL TOPOGRAPHY AND STRATIGRAPHY.

For a somewhat detailed exposition of the topographic features of the southern part of Louisiana the reader is referred to the map herewith published as Pl. I, but a clearer and more general idea of the subject can be obtained more quickly by referring to fig. 1. Topography alone may have little bearing on the subject of underground water supplies, but when considered in connection with stratigraphy its significance may be great. Where the different formations or beds slope coastwise at an angle slightly greater than that of the surface of the land, where there are more or less extended beds of pervious material alternating with impervious, and where there is an abundant rainfall back in the country the conditions are favorable for an underground supply of water. The pressure head of this supply will depend largely upon the topography and stratigraphy, while the kind of water will depend upon the kinds of rock the water has to penetrate and the length of time consumed in its penetration. Kind of water is, therefore, indirectly more or less influenced by topography and stratigraphy. As a result of all these influences underground water occurs in southern Louisiana approximately as indicated by the accompanying fig. 7.

The influence of topography on pressure head will be evident to anyone who will study the outline cross section given in fig. 8 in connection with the topographic map, Pl. I. The section extends from Pearl River to Oberlin, passing through Covington, Hammond, Baton Rouge, Opelousas, and the country lying westward, to Oberlin. The situation at Opelousas is interesting. Here the surface of the ground is 67 feet above the Gulf level, but water rises only 22 feet above that level. A glance at the topographic map will show the cause of this low pressure head. Northward, in the direction of the uprising strata or bedding planes, there is no higher ground than at Opelousas. The water there present must work sidewise along the pervious strata from the somewhat distant hill land lying west and northwest. East of the Mississippi the conditions are different, for only a few miles

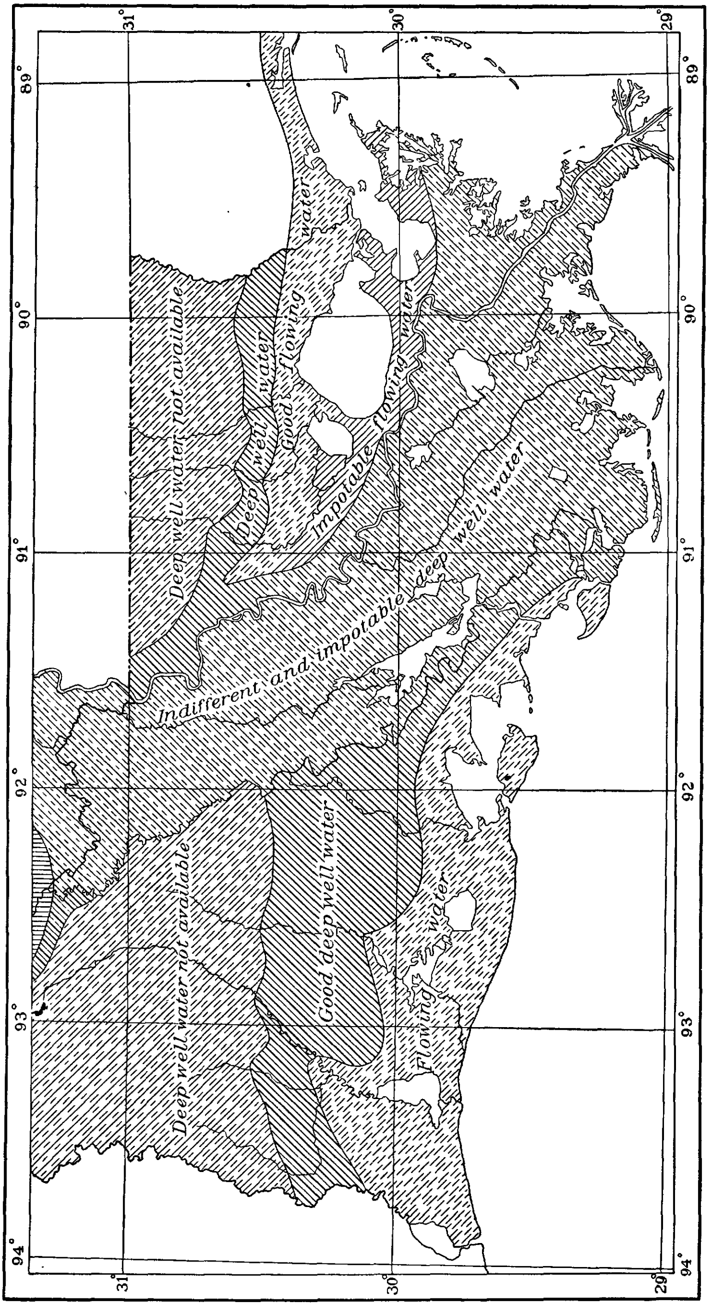


FIG. 7.—Subdivisions of southern Louisiana in accordance with the underground water conditions.

east of Baton Rouge the pressure head is considerably above the surface of the ground, the hill land to the north being close by. The marked decrease in pressure head shown at Baton Rouge is evidently due to the nearness of the Mississippi River Valley. Doubtless, too, this same valley has something to do with the low stand of the water at Opelousas.

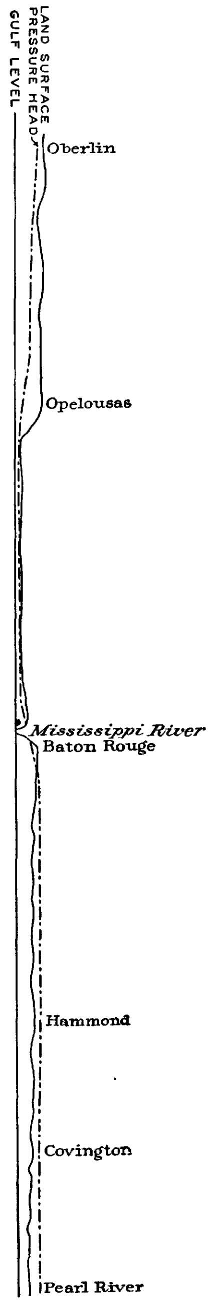


FIG. 8.—Relations of land surface to pressure head of artesian and deep-well waters approximately along parallel 30° 27'.

Lesser depressions than the Mississippi Valley have their influence on the head of subterranean waters, as may be seen by the section along the line of the Southern Pacific Railroad from Lafayette west, shown in fig. 9. Mermentau River, with its tributaries, has degraded this central portion of southwest Louisiana, and the pressure head of the deep-well waters responds to this topographic feature. Calcasieu River seems to have the opposite effect on the pressure head about Lake Charles. Here, however, we are dealing with a region that is immediately south of some of the highest land in the State, and it is doubtless this condition that counteracts any reverse influence the Calcasieu Valley might possess.

East of the Mississippi, in the neighborhood of New Orleans, the low pressure shown by the various water-bearing layers penetrated in wells less than 1,300 feet deep is probably due to the wide, low stretch just to the north—i. e., the Lake Pontchartrain depression. On Ship Island good water flows freely, and with much more force than is exhibited by the New Orleans wells. The narrowness of Mississippi Sound, as compared to Lake Pontchartrain, offers a ready explanation of this fact.

REMARKS ON SPECIAL AREAS.

On the small map (fig. 7) there is indicated a small artesian area about Alexandria. The extent of this area must of necessity be very limited, for the Grand Gulf formation usually dips rapidly Gulfward, so that the water-bearing strata would soon be below practicable depths so far as ordinary water supply and irrigation are concerned (see stratigraphy indicated by fig. 4).

To what extent water would flow close to the Gulf border from Sabine River to Atchafalaya Bay can scarcely be conjectured, though from the fact that in the neighborhood of Lake Charles, Gueydan, and places farther east fairly good water does flow from wells not over 200 feet deep, one may expect to find some kind of artesian water all along the coast in the region mentioned.[a]

North of the artesian area lying north of Lake Pontchartrain a belt of country has been marked on fig. 7 as a probable deep-well area. As water in this region will flow readily from wells situated at elevations between sea level and the 50-foot contour, or even above the latter in some instances, there seems to be no reason why it will not rise to the surface or to points between the surface and 50 feet below the surface at localities situated at elevations lying between the 50- and 100-foot contours.

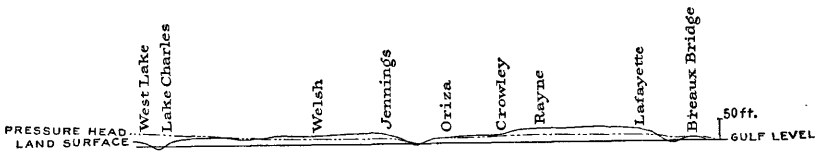


FIG. 9.—Relation of land surface to pressure head of artesian and deep-well waters approximately along parallel 30° 12′.

Mammoth Spring, near Franklington, Washington Parish, would lead one to suppose that deep wells may eventually prove successful in some parts of these northern parishes where on the small map (fig. 7) no sign of the fact is indicated.

So far as the other areas are concerned, little need be said. The deep-well area in southwest Louisiana is well understood. Sand and gravel beds that seem saturated with water are encountered at various depths, ranging from 150 to 500 feet. Near the coast the water overflows; farther northward as a rule it stands lower and lower below the surface, so that north of Oberlin the expense of lifting water to the surface would more than equal the profits of irrigated crops. The map (fig. 7) does not indicate that no deep-well water can be found in much of the northern region. It implies rather that such waters would generally stand say 30 or more feet beneath the surface of the soil; and hence their value for irrigation and general purposes would be materially lessened, owing to the increased cost of pumping.

WELL STATISTICS.

ARTESIAN WELLS IN SOUTHERN MISSISSIPPI, FROM BILOXI WESTWARD.

This part of Mississippi is justly famous for its fine artesian wells. Not only does the water seem good and wholesome, but the pressure is strong and the supply is ample.

As will be seen from the statistics given below, there are shallow sands from which pumping water may be had, and deeper ones from

[a] Good water has recently been obtained in this region.—G. D. H., April, 1904.

which a fair quantity of flowing water may be obtained, but as a rule the best wells are sunk to a much greater depth here than in southern Louisiana.

HARRISON COUNTY.

BILOXI.

Section of well one-half mile east of railroad station.

[Section by Brown.]

Soil.	Thickness in feet.	Depth in feet.
Soil and clay	4	4
Sand, bearing good pumping water	61	65
Whitish clay	35	100
Greenish clay	390	490
Sand, extremely fine at first, becoming coarser below, coarse gravel	428	918

Pipe, 6 and 4 inches; flow, at surface of the ground, 1,000 gallons per minute; 500 gallons at elevation of 35 feet, 250 gallons at elevation of 55 feet. This indicates that the pressure head is not far from 75 feet above tide.

City waterworks wells.—No notes were obtained regarding the depths of these wells. It was observed, however, that the large 6-inch pipes carried the water up rapidly and filled the elevated tanks to a height of 40 feet above the general surface of the ground.

Ice-factory wells.—At these wells the difference in temperature of the shallow and deep well was specially noted, viz: Water (flowing) from 500-foot stratum, 79.5° F.; from 900-foot stratum, 82.5° F.

SHIP ISLAND.

Quarantine station well.—Depth, 730 feet; mouth of well about 10 feet above tide.

Section of well at Quarantine station, Ship Island.

[Section by Dr. P. C. Kallock.]

Soil.	Thickness.		Depth.	
	Feet.	*In.*	*Feet.*	*In.*
White sand	45	0	45	0
Soft clay and mud	155	0	200	0
Hard blue clay	100	0	300	0
White sand	5	0	305	0
Blue clay	60	0	565	0
Sandstone		5	565	5
Blue clay	156	0	721	5
Water-bearing sand	9	0	730	5

Light-house well.—Mouth of well perhaps 10 feet above tide; flow, vigorous; estimated at 50 gallons per minute from a 2-inch pipe; depth, 750 feet.

Section of well at light-house on Ship Island.

[Section by Dr. Murdock.]

Soil.	Thickness in feet.	Depth in feet.
Sand	250	250
Yellow clay	100	350
Blackish mud	50	400
Fine sand, with shells	50	450
Blue clay	250	700
Water-bearing sand	50	750

MISSISSIPPI CITY.

C. Clemenshaw's well.—Depth, 925 feet; mouth of the well about 18 feet above tide. Regarding the well Mr. Clemenshaw remarks:

Passed through no hard rock, no quicksand, but clay and blue sand, the latter often highly micaceous. A 60-gallon per minute flow was found at a depth of 600 feet, a 200-gallon flow at 925 feet.

E. P. Ellis's well.—Depth, 850 feet; 3-inch pipe; flow, 80 gallons per minute; 55 feet above tide.

Court-house well.—Pipe, 2½ inches; reduced to 1½ inches; flow, 20 gallons per minute; 28 feet above ground, or about 50 feet above tide.

GENERAL SECTION FROM PASS CHRISTIAN TO BILOXI.

According to Mr. A. Dixon, who has accompanied a well-drilling outfit for several years in this part of the State, the majority of the wells show approximately the following section:

General section of wells between Pass Christian and Biloxi.

Soil.	Thickness in feet.	Depth in feet.
Sand	80	80
Clay	....	125
Sand, and clay	....	425
Light-gray fine sand	....	500
Clay	....	600
Water-bearing sand	....	685

BAY ST. LOUIS.

Mr. N. H. Darton[a] gives the following data for this locality:

Many wells; temperature of deeper, 78°; depth, 400 to 600 feet; size, from 2 to 4½ inches; yield per minute, 100 to 105 gallons.

ARTESIAN AND DEEP WELLS IN LOUISIANA EAST OF THE MISSISSIPPI.

ST. TAMMANY PARISH.

COVINGTON AND VICINITY.

Court-house well.—In yard in front of the court-house; April, 1901, flow, 2½ gallons per minute; temperature, 73° F.; June 26, 1903, flow, 1 gallon per minute; temperature, 72.4° F. Elevation of ground, 32 feet; of flow, 35.6 feet above tide.

Dixon Academy well.—One-half mile west of Covington; pipe, 2½ inches; flow, 25 gallons per minute, 1901; temperature, 72.6° F., June 26, 1903; elevation of flow, 26.7 feet above tide.

Dummet well.—On Holmesville road; depth, 572 feet; pipe, about 2 inches; flow, according to driller, Robert Wallbillick, 1901, when first put down, 2 feet from ground, 21 gallons per minute. Record by G. D. Harris, 1903, 15 gallons per minute, about 3 feet above ground; temperature, 74° F.

Section of Dummet well, St. Tammany Parish.

[Section furnished by Mr. Wallbillick.]

	Thickness in feet.	Depth in feet.
White clay	15	15
Yellow clay	6	21
White clay	35	56
Coarse white sand	25	81
Fine gravel	12	93
Coarse white sand	6	99
Coarse white sand and gravel	14	113
Coarse yellow sand and gravel	6	119
Coarse yellow sand	8	127
Gravel	10	137
Red clay	1	138
Gravel	10	148
Red clay	2	150
Gravel	10	160

[a] Water-Supply and Irrigation Paper No. 57, 1902, United States Geological Survey.

Section of Dummet well, St. Tammany Parish—Continued.

	Thickness in feet.	Depth in feet.
Red sand and gravel	20	180
Gravel	32	212
Red sand	38	250
Coarse gravel	25	275
Coarse white sand	4	279
White clay	18	297
Blue clay	183	480
Fine bluish and greenish water-bearing sand	7	487
Blue clay	71	558
Gray sand	6	564
Fine blue and greenish sand	8	572

John Dutch's well.—In north-central part of Covington; depth, 600 feet; flow, 20 gallons per minute; temperature, 74° F., April 17, 1901; elevation of flow, 35.6 feet above tide.

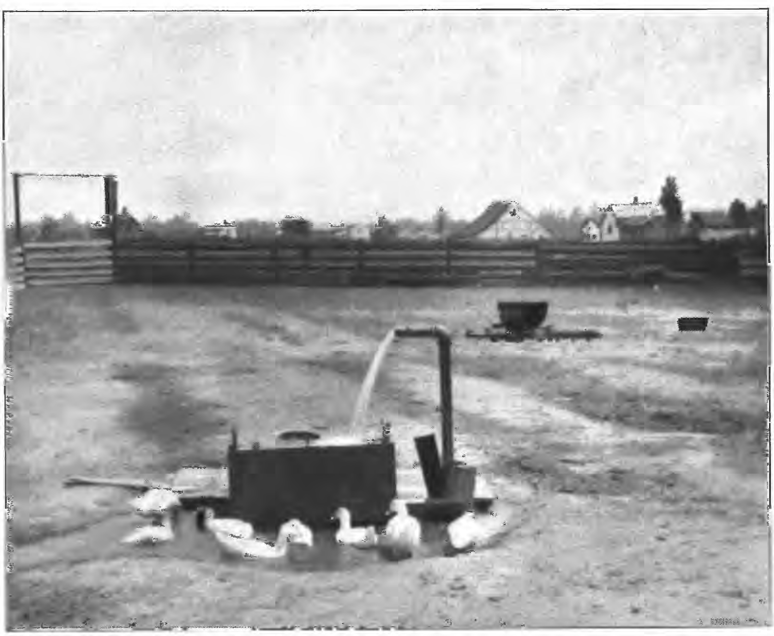
Mrs. Flower's wells.—These records were furnished by Mr. Wallbillick, and show that here, as elsewhere, there are sandy strata bearing water at far less depths than the beds furnishing the water that will flow above the surface of the ground. Such wells are termed shallow or pumping wells.

Sections of Mrs. Flower's wells, St. Tammany Parish.

	Thickness.		Depth.	
Well No. 1:	*Ft.*	*in.*	*Ft.*	*in.*
White clay	30	6	30	6
Blue clay	18	6	49	0
White sand	2	0	51	0
Blue clay	17	0	68	0
Shells mixed with blue clay	1	6	69	6
Fine white sand	27	6	97	0
Coarse white sand (pumping stratum)	6	0	103	0
Well No. 2:				
White clay	40	0	40	0
Blue clay	2	0	42	0
White clay	21	0	63	0
Shells mixed with black clay	0	6	63	6
Dark clay	9	6	73	0
White sand	21	0	94	0

These wells are but 300 feet apart.

A. WELL IN BARN LOT OF THE HERNANDEZ PLACE, 2½ MILES NORTH OF COVINGTON, LA.



B. WELL IN MR. ANDERSON'S BARNYARD, THREE-FOURTHS OF A MILE NORTH-WEST OF HAMMOND STATION, LA.

H. Haller's well.—Southwestern part of Covington; depth, 520 feet; pipe, 2 inches; flow, 30 gallons per minute; temperature, 72° F., June, 1903.

Hernandez place, well by house.—About 2 miles north of Covington; depth, 610 feet; pipe, 2.5 inches; flow from 1-inch pipe, January, 1901, 38½ gallons per minute; April, 1901 (from whole pipe?), 60 gallons per minute; temperature, 1901, 73° F.; elevation of ground, 46.1 feet above tide; top of basin, 47.3 feet; of pipe, 48.5 feet.

Hernandez well, by barn.—About 2½ miles north of Covington; depth approximately as in last well; pipe, 2½ inches; flow, January, 1901, 35⅓ gallons per minute; March, 1902, 54⅓ gallons per minute; June, 27, 1903, 40 gallons per minute; temperature, 72.25°; elevation of ground, 47.4 feet; of pipe, 52; pressure head considerably above 60 above tide.

This is the well shown in Pl. V, *A*, and is usually considered one of the best in this part of the State, but it has not the capacity of the well by the house, which is so piped that satisfactory measurements of its flow are hard to obtain. This beautiful summer residence is now the property of Louis P. Rice, of Covington and New Orleans.

Ice factory wells.—Three wells of the "shallow" type before mentioned, two 2 inch and one 2½ inch, furnish, when pumped, sufficient water for the ice factory. The water rises to within about 8 feet of the surface.

Lyon well.—At Claiborne, 1 mile east of Covington; depth, 630 feet; pipe, 2 inches; flow, 30 gallons per minute; temperature, 73°, April, 1901; flow, 26 gallons per minute; temperature, 74°, June 26, 1903; elevation, 26.6 feet above tide.

Maison Blanche.—Depth, 480 feet; pipe, 2 inches, reduced to 1 inch; flow per minute, April, 1901, 20½ gallons; March, 1902, 23½ gallons; June 26, 1903, 16½ gallons; temperature, 72.25°; elevation of ground, 31 feet 6 inches of top of basin, 33.6 feet of flow, 35.5 feet above tide.

Other wells.—There are many other flowing wells about Covington, but the data presented above will give a fair idea of their general character. It will be seen that as the depth increases the temperature also increases, as might well be expected. For a 600-foot well a temperature of 74° is about normal here. Compare these in this respect with the Hammond and Ponchatoula wells.

There is a flow about Covington at present, within a radius of 3 miles, of about 300 gallons per minute; and as is generally the case the water is mainly wasted, i. e., allowed to flow to no purpose.

ABITA SPRINGS.

Abita Hotel and Cottage Company well.—Half mile east of Abita Springs Station (elevation of station 38.3 feet above tide); depth, given by some as 545, by others, 525 feet; pipe, 2 inches; flow through stopcock, 54 gallons per minute; temperature, 73°; no screen. This is a new well, put down this season (1903). When allowed to flow freely it reduces the pressure of neighboring wells materially, especially those to the west and south.

Aubert Hotel well.—About one-third mile southeast of station; depth, 585 feet; pipe, 1½ inches; flow from a faucet, 2½ feet above the ground; 38.3 feet above tide January, 1901; 12½ gallons per minute through a network of pipes 60 feet long; June 26, 1903, 22 gallons per minute, direct from well at a height of about 38 feet above tide.

See analysis given on p. 78. Pressure head at least 50 feet above tide.

Frank Brinker's well.—One-fourth mile northwest of the station; pipe, 2 inches; depth, 574 feet; flow through stopcock about 2 feet above the surface of the ground, 27 gallons per minute; no screen; temperature, 73° F.

Labat Hotel well.—One-fourth mile north of the station; depth, 526 feet; pipe, 1½ inches; original flow, seven or eight years ago, said to be 45 gallons per minute; flow, January, 1901, from faucet, 45.2 feet above tide, 37 gallons; flow from pipe with stopcock but without faucet, June 26, 1903, 56 gallons per minute; temperature, 74°. When the size of the pipe is taken into consideration this is the most freely flowing well in St. Tammany Parish.

Chas. W. Schmidt's well.—A few yards south of the station; depth supposed to be 800 feet; pipe, 1½ inches; flow through a one-half inch faucet, in 1901 and 1903, 4 gallons per minute; temperature, 72°; elevation of ground, 35.6 feet; of faucet, 36.6 feet above tide. This was perhaps the earliest artesian well in this vicinity. It was not decidedly successful, doubtless on account of the novelty of the undertaking. The temperature indicates that its flow of water comes from a depth much short of 800 feet.

Simon's Hotel well.—Just east of the station; hotel building burned; pipe, 1½ inches; flow through two elbows and a horizontal pipe 2 feet in length, January, 1901, 12 gallons per minute; April, 1901, 11 gallons; June, 1903, 10 gallons; temperature, 1901, 72°; 1903, 73°; elevation of ground, 38.3 feet of top of basin, 41.7 feet of top of pipe, 43.6 feet above tide.

Limit of supply.—The present flow of water from artesian wells about Abita Springs is not far from 200 gallons per minute. The sensitiveness, especially on the part of the smaller wells, to the flow from the new, large well would seem to indicate that the supply, though ample for all legitimate uses, should not be unduly drawn upon, else pumping in some instances will have to be resorted to.

PEARL RIVER JUNCTION.

When compared with most of the wells in this part of the State the well at Pearl River Junction appears remarkable for the great amount of water it furnishes at a shallow depth. The water is not regarded as suitable for boiler and drinking purposes, though for common household uses it serves excellently. Depth, 350 feet; pipe, 2½ inches; flow through a stopcock at the rate of 72 gallons per minute; flow from open 2½-inch pipe said to be 90 gallons per minute; pressure head, 54 feet above tide. The elevation of station is 31 feet above tide.

MANDEVILLE JUNCTION.

At Mandeville Junction there is an excellent well that furnishes the railroad tank with water, flowing up freely 27 feet above the ground. Since no levels have ever been run over this road it is not possible to state the exact height of the well above tide.

MANDEVILLE.

The elevation of station at Mandeville is 6.8 feet above tide.

Dessome well.—Northeastern part of the village, in flower garden; depth, 217 feet; pipe, 2 inches; flow per minute, March, 1901, 28.1 gallons; March, 1902, 26 gallons; June 27, 1903, 28 gallons; temperature in 1902, 69.5°; in June, 1903, 69.8° F. Flows from pipe 9 feet above tide; pressure head, 14½ feet above tide.

Mrs. John Hawkins's well.—Western part of the village; pipe, 2 inches, reduced to 1¼ inches; flow per minute, 1902, 40 gallons; in 1903, 13 gallons; temperature in 1902, 68.5°; in 1903, 70° F. Flow from a pipe 7.35 feet above tide.

C. H. Jackson's well.—Depth, 135 feet; pipe, 1½ inches, reduced to 1 inch; flow, 0.97 gallon per minute; height of flow, 13.8 feet above tide.

Dr. Paine's well.—Flow, open 2-inch pipe, 10.6 gallons per minute; reduced to 1 inch, 10½ gallons per minute; through inch pipe with stopcock attached, 9.1 gallons per minute. Elevation of ground, 3.85 feet; of flow, 6.80 feet above tide.

Ribava well.—Depth, 247 feet; flow, from open 1¼ inch pipe, 12 gallons per minute, 1901; through stopcock, 9¼ gallons per minute in 1902; through stopcock, 1903, 7 gallons per minute; temperature, 71°, February, 1902; 72°, June, 1903; elevation of ground, 3.42 feet; of flow, 4.9 feet above tide.

Rush well.—North of station, perhaps one-third mile; depth, 252 feet; pipe, 2 inches, reduced to 1 inch; flow, 7 gallons per minute; 4 feet above the general level of the ground.

Depths.—As in several other regions already described, there are here to be found beds yielding water at a depth considerably less than that attained by most of the artesian wells. The water in the shallower wells usually stands, in the vicinity of Covington, as well as about Hammond, from 2 to 10 feet below the surface. Here such shallow wells, about 90 feet deep, actually flow, though not vigorously.

It will be noticed that the wells about Mandeville are very much shallower than at Covington, 9 miles to the north. They are about 3° cooler, and have a less ferruginous taste and appearance. The wells about Slidell have not been examined, but Mr. Blakemore, of New Orleans, says that there the Mandeville water (300 feet), and a decidedly bad "yellow" water (perhaps 700 feet down), are met with. The latter is described as the same water that is found at the same depth in the city of New Orleans.

CHINCHUBA.

Depth, 325 feet; pipe, 2 inches; flow reduced to one-third inch pipe, hence with pressure head of but 7.3 feet; temperature, 72° F.; elevation of ground, 19 feet above tide.

Other wells at a brickyard to the north, and at a locality 4 miles to the northwest, are reported to have satisfactory artesian wells, but they were not visited.

TANGIPAHOA PARISH.

SINGLETRY'S STILL.

This well is about 9 miles northwest of Covington, or in the SW. ¼ NW. ¼ sec. 31, 5 S., 10 E. It is so distant from any other flowing well that the following statistics and section, though imperfect, will be of considerable interest to landowners and well men in this section of the State.

Section of well at Singletry's still.

[Section given by E. P. Singletry.]

	Thickness in feet.	Depth in feet.
Sand and clay	100	100
Quicksand	120	220
Red clay	170	390
Pipe clay	160	550
Blue sand	10	560

Depth, 560 feet; pipe, about 2 inches; flow, 18 gallons per minute, with several small leaks; height of pipe where measured, 78 feet above tide. (See analysis, p. 78.) The elevation was determined in 1901 by J. Pacheco and G. D. Harris, who ran a spirit-level line out from Covington.

HAMMOND.

The elevation of the railroad station at Hammond is 43.3 feet above tide.

Captain Anderson's well.—For general appearance of the well see

Pl. V, *B;* depth, 272 feet; size, 2 inches; flow, 20 gallons per minute; temperature of water, 70.5°; strainer or point, 10 feet.

Section: Sand to 40 feet, a thick bed of blue clay, then sand and gravel to the bottom.

Well sunk and cased with galvanized pipe for 55 cents per foot; hence total cost of well, approximately, $150.

Baltzell & Thomas livery stable well.—Depth, 330 feet; size, 2 inches; temperature, 71.5°; flow, 24 gallons per minute, June 23, 1903; screen, 7 feet long.

B. F. Bauerle's well.—One and one-half miles south-southwest of Hammond; depth, 212 feet; size, 2 inches; temperature, 69°; flow, June 23, 1903, 8¾ gallons per minute.

Durkee well.—Depth, 297 feet; size, 2 inches reduced to 1¼ inches; flow in March, 1901, 24 gallons per minute, besides two small distributing pipes that could not be closed; flow, same conditions, June 23, 1903, 24 gallons per minute.

Eastman well.—One and one-half miles south of Hammond; depth, 309 feet; pipe, 2 inches; flow, 30 gallons per minute, in 1901; pressure, 5½ pounds per square inch; temperature, 72° F.

Forbes well.—One mile east of Hammond, NE. ¼ NW. ¼, section 30; depth, 250 feet; flow, June 23, 1903, 7½ gallons per minute; size, 1½ inches; pressure head, 17 feet above surface of ground; age, 8 years.

Three water-bearing beds were encountered in sinking this well: (1) Depth, 52 feet, water coming to within 2 feet of surface; (2) 150 feet, coming to within 8 feet of surface; (3) 250 feet, with head of 17 feet.

Hermann well.—Two miles south-southwest of Hammond. Impossible to obtain accurate data, except pressure, 8½ pounds per square inch.

Hammond Ice Company's well.—Depth, 340 feet; pipe, 2 inches; flow in 1901, about 50 feet above tide, 15 gallons per minute; same conditions, June, 1903, 11 gallons per minute; temperature, both years, 72° F.

Hammond Mineral Water Company (Limited).—Well, 460 feet deep; pipe, 3 inches; flow, about 46 feet above tide, 65 gallons per minute.

C. H. Hommel's well.—One-half mile southeast of Hammond; depth, 318 feet; flow, impossible to measure now; said to have been, when well was first put down, 45 gallons per minute; temperature, 70.5° F.

Alfred Jackson's well.—Depth, 265 feet; pipe, 1¼ inches; flow, 3 feet above surface of the ground, June, 1903, 6¾ gallons per minute; temperature, 71° F.

June Brothers' sawmill well.—Depth, 377 feet; pipe, 2 inches; flow, at a point 5 feet above the ground, open pipe with one elbow, June 22, 1903, 24 gallons per minute; temperature, 71° F.

Kate well.—In western part of the village, on Morris avenue; size of pipe, 2 inches; free flow, perhaps 3 feet above the general surface of the ground, 30 gallons per minute, June 23, 1903; temperature, 70.6° F. A new well, just finished.

Fred Karlton's well.—One-half mile southeast of Hammond; depth, 302 feet; pipe, 2 inches below, reduced to 1½ above surface of ground; screen, 10 feet; flow, June, 1903, 24 gallons per minute; cost, $150; temperature, 70.5° F.

Kemp well.—Three-fourths mile southeast of Hammond; pipe, 1¼ inches; flow, June, 1903, 5 gallons per minute; temperature, 70° F.

Merritt Miller's well.—Depth, 265 feet; pipe, 2 inches, reduced to 1¼; flow in 1901, 28¼ gallons per minute; elevation of flow, 44 feet above tide; pressure head, 56.6 feet above tide; temperature, 71° F.

Morrison well.—Pipe, 2 inches; flow, 46 feet above tide, 1901, 20 gallons per minute; June, 1903, same flow; pressure head, 51.7 feet above tide; temperature, 72° F.

Oaks Hotel well.—Depth, 300 feet; pipe, 2 inches; flow, 25 gallons per minute; age, ten years; temperature, 71° F. See analysis, p. 78.

Oil well.—The following section was obtained from samples in 1901:

Section of oil well at Hammond, Tangipahoa Parish.

	Depth in feet.
Clay	45–55
Sand and gravel	85–100
Yellow loam	173
Water-bearing sand	294
Coarse sand	368
Coarse sand and gravel	475
The same, more sandy	500–512
5-foot bed of hard blue clay, about	570
"Pepper and salt sand"	570+

The new well, June, 1903, was over 760 feet deep. It was generally understood that its section tallied with the old one fairly closely so far as the latter went down. The "5-foot bed of clay" of the old well showed only 3 feet in the new. From approximately 570 feet in the new, gravel was abundant to 760. Below, a hard bed of clay had been encountered, light colored above, but growing much darker below.

Pushee well.—One mile south of Hammond; west of the railroad; depth, 380 feet; 340 feet of 1½-inch pipe, 40 feet of 1¼-inch pipe; no screen; flow recorded by Mr. Pacheco March, 1901, 14½ gallons per minute; April, 1901, 15½ gallons; by G. D. Harris, June 23, 1903, 11 gallons per minute; temperature, 70.6° F.

Robinson well.—Northwest quarter of the town (see analysis, p. 78); depth, 356 feet; size of pipe, 2 inches; flow not ascertained because it is piped to various places quite inaccessible.

Rogers's (Ben) well.—West of Hammond, ⅞ mile; depth, 284 feet; 2-inch pipe reduced to 1 inch; flow, 17 gallons per minute; temperature, 70.5° F.; cost, $142.

Section of Rogers's well, Hammond, Tangipahoa Parish.

Clay.
Quicksand to 75 feet.
Clay.
Sand, last 50 feet.
Lower end of screen (10 feet) stuck in clay bed.

Erastus Rogers's well.—Depth, 225 feet; pipe, 1¼ inches; flow, 5 feet from ground, 2½ gallons per minute; temperature, 70°; strainer (screen), 8 feet.

J. T. Smith's well.—One mile east of Hammond; depth, 235 feet; temperature, 69° F.; pipe, 1½ inches; flow, 6.5 feet above ground, 7½ gallons per minute; age, one year; cost, $108.

W. B. Smith's well.—One-half mile southeast of Hammond; depth said by some to be 260, by others 305, feet; pipe, 2 inches reduced to 1¼; temperature, 70.5°; flow, 11½ gallons per minute; age, eight years.

Tigner well.—Two miles southeast of Hammond; flow, 20 gallons per minute; pipe, 2 inches; temperature, 70° F.

W. J. Wilmot's well.—Depth, about 370 feet; pipe, 2 inches reduced to 1 inch; flow, said to be 40 gallons per minute; pressure, 2 feet above the ground, 7.7 pounds per square inch; flows readily 14 feet above ground, with small leaks in pipe; would doubtless flow 20 feet above ground.

H. Walsh's well.—One and one-half miles south-southeast of Hammond, in section 31; depth, 298 feet; pipe, 1½ inches reduced to 1 inch; flows through 30 feet horizontal pipe, with stopcock, 5½ gallons per minute; temperature, 70.75° F.; age, five years.

Way well.—One and one-half miles south-southwest of Hammond; depth, 140 feet; flow, 3 gallons per minute; temperature, 69° F.

Summary of wells about Hammond.—Water may be had by pumping, from wells ranging in depth from 30 to 100 feet; a sand, or quicksand, furnishes a slight flow generally at 140 to 150 feet, flow or not depending on topography; temperature, 69° F.; after passing more clay, to depths ranging from 230 to 380 feet, coarser sand or gravel is encountered, furnishing an artesian flow above the ground of from 10 to 20 feet, according to topography; temperature, 69° to 72° F.

The well of the Mineral Water Company, with 3-inch pipe, and a depth of about 460 feet, with a flow of 65 gallons per minute, as well as the log of the oil well, shows conclusively that better and larger wells may be expected in this vicinity. The Morrison and Durkee wells, some distance apart, in the central portion of the town, have shown no change whatever in flow for the past two years. Since they are of the normal size and depth, it is evident that the available supply is as yet far greater than the demand.

In a radius of two miles of Hammond there are already about 50 flowing wells, yielding about 1,000 gallons of water per minute, or half a billion gallons annually, nearly all of which is wasted.

Decrease in the flow of certain wells in this neighborhood is due solely to increased obstruction in the lower end of the pipe.

The cost of these wells is not far from 50 cents a foot, labor, casing, etc., being furnished by the driller. The usual size pipe is 2 inches in diameter; in case smaller pipe is used the cost of the well is somewhat less. See notes on J. T. Smith's well, above.

Age of the wells examined, from two months to ten years. When properly screened, or put down into coarse gravel, these wells seem to flow as freely now as when first put down.

Local well drillers: Bacon and Gamble, Edwin Way, John Blumquist.

PONCHATOULA.

The elevation of the railroad station at Ponchatoula is 29 feet above tide.

Alber well.—Two hundred feet from the town well; depth, 413 feet; pipe, 2 inches; flow, 25 gallons per minute; head about 30 feet above the surface of the ground. Bacon and Gamble, drillers.

G. H. Biegel's well.—At Pelican Hotel; depth, 232 feet; flow, 4¾ gallons per minute, 1901; 2¾ gallons per minute, 1903; temperature, 71° in 1901; 69.5° in 1903; pipe, 1½ inches; height of flow about 31 feet above tide.

Mrs. Bishop's well.—Old, deserted place, 3 miles north of Ponchatoula, 2 miles south of Hammond; depth, 170 feet; pipe, 1½ inches; temperature, 69.5° F.; flow, 10 gallons per minute; age, about nine years.

The section of this well, according to John Blumquist, who drilled it, is as follows:

Section of Bishop well, Ponchatoula.

	Thickness in feet.	Depth in feet.
Clay	50	50
Sand, with some water	20	70
Blue clay	94	164
Coarse sand	6	170

C. A. McKinney's well.—About ½ mile southwest of Ponchatoula; depth, 199¾ feet; flow said to be variable, caving in evidently taking place below; on June 24, 1903, 12 gallons per minute; pipe, 1½ inches; age, four years.

Moon well.—Same general vicinity as preceding; depth, 200 feet; pipe, 1¼ inches; flow, 12 gallons per minute; age, seven years. Near by this is the Fisher well with a flow of 10 gallons per minute.

Railroad well.—At Chester, 100 feet north of fiftieth milepost from New Orleans, west of track and 5 feet below the level of rails; flow, 3¾ gallons per minute; pipe, 1¼ inches; temperature, 70° F.

Town well.—In public square; flow, 1901, 2½ gallons; in 1903, 2⅔ gallons per minute; temperature, 71°, 1901; 70°, 1903. See table of analyses for further information regarding this and the Biegel well.

Sawmill well.—Depth, 332 feet; flow, 5 gallons per minute.

Section of sawmill well, Ponchatoula.

[Section given by Bacon and Gamble.]

	Thickness in feet.	Depth in feet.
Yellow and gray blue clay	75	75
Gray sand and gravel	15	90
Blue clay, about	35	125
Fine blue sand	105	230
Coarse white sand	30	260
Fine blue sand, with thin beds of clay	40	300
Sand a little coarser, weak flow of water	32	332

ORLEANS PARISH.

The fact that there are two well-defined water-bearing strata[a] under New Orleans has already been mentioned. A number of additional facts can now be presented.

The old Canal street well of 1854, so often referred to in geological literature, both on account of its great depth, as borings then went, and, more especially, on account of the careful record kept by Mr. Blanchard of the beds passed through, including many fossils, still remains the type section for this general region of the country down to a depth of 630 feet. No recent boring has been recorded with the interest and painstaking care that was displayed in this well. This is most seriously to be regretted, as the number of wells sunk has been very large, and their records, if carefully kept, would furnish material for an interesting chapter in the geological history of the

[a] Rept. Geol. Survey Louisiana for 1902, p. 221.

southern Mississippi Valley. The records of the deeper wells, ranging from 1,200 to 1,400 feet, have been wanting altogether. The record of the Fabacher well, given below, will therefore be of unusual interest to those who are interested in the geology of New Orleans, either from a purely economic or scientific point of view. Fortunate, too, from a geological standpoint, is the collapsing of the screen at the base of the casing in the Young Men's Gymnasium well, at a depth of about 1,300 feet, allowing the sand and fine shells to enter the pipe and be brought to the surface by the force of the flowing water.

DEEP SALT-WATER WELLS.

Young Men's Gymnasium Club well.—Depth supposed to be 1,356 feet, though some claim that 1,250 is nearer the truth; natural flow, 40 gallons per minute; forced, 125 gallons; gas escapes at the rate of 830 cubic feet in twenty-four hours; specific gravity, 1.016.

Analysis of water of well at Young Men's Gymnasium Club.

[Ordway and Kirchoff, analysts.]

	Parts in 100,000.	Grains per gallon.
Chloride sodium	2,115.9	[a]2.82
Chloride calcium	138.2	81.2
Chloride magnesium	75.7	44.9
Chloride ammonia	1.3	.8
Chloride potash	Trace.	Trace.
Carbonate calcium	86.8	40.8
Oxides of Fe and Al	4.7	2.8
Phosphate	Trace.	Trace.

[a] Ounces.

Fabacher's well.—At Fabacher's "Casino," corner Nashville avenue and St. Charles street; depth, 1,229 feet; pipe, 4 inches; flow 1 foot above ground, 55 gallons per minute; flow, reduced to 2 inches and raised 10 feet above the ground, 6 gallons per minute; flow stops at 12 feet above ground; temperature, 81.5° F.

Section of Fabacher's well, New Orleans.

[Furnished by Mr. Blakemore.]

Character of material.	Thickness in feet.	Depth in feet.
Blue clay	37	37
White sand with shells	20	57
Yellowish-white clay	5	62
Gray sand	105	167
Blue clay	20	187
Reddish sand	20	207
Gray sand	80	287
Blue clay, with pockets of shells	280	567
Gray sand	2	569
Blue clay	40	609
Hard white clay	19	628
Hard blue clay	30	658
Blue water sand (fresh water)	225	883
Blue tenacious clay	150	1,033
White sand (resembling white sugar)	40	1,073
Blue clay	85	1,158
Fine shells	6	1,164
Gray water sand	65	1,229

A forthcoming report will deal with the fossil remains saved from this well by Mr. Fabacher, and similar ones preserved by Mr. John Kracke, from the gymnasium well. They appear to be of Pleistocene or Quaternary age.

THE COMMON "YELLOW-WATER" WELLS.

These include the 600 to 900 foot wells bored at frequent intervals over the city. One of the earliest wells of this class sunk in New Orleans was in the neutral grounds on Canal street, between Carondalet and Baronne streets, in the year 1854. A colored section of this well, as originally kept by A. G. Blanchard, C. E., of New Orleans, appears in the report of the board of health of Louisiana for 1890–91.[a] From this it will be observed that the strata penetrated to a depth of 630 feet consist of light yellowish and bluish sands and clays with some light greenish layers and occasional shell sands.[b]

One of the most recent wells of this class is that at the Marine Hospital, Audubon Park. This is 765 feet deep. The first 600 feet are reported as sand, silt, and clay beds; a bed of yellow sand, perhaps

[a] Biennial Rept. Board of Health to the general assembly of the State of Louisiana for 1890–91, plate opposite p. 148. Baton Rouge, 1892.

[b] Rept. Geol. Survey Louisiana for 1903, p. 221.

40 feet thick, was encountered some distance below, and continued to 705 feet. From there on for 60 feet the material consists of white sand. The water rises to within about 3 feet of the surface at present. This 6-inch well is capable of furnishing 300 gallons per minute. The water is classed as excellent for washing purposes, requiring but half as much soap as the river water. It is also excellent for boiler purposes, but is impotable.

The flow from this shallower class of wells has always been weak, and the large number of such wells has still further weakened the flow. There is a tendency now, when more water is required, to seek the lower level. This water is excellent for bathing purposes, containing, as the above analysis shows, a large amount of common salt.

The great range in depth here given really includes two or more water-bearing horizons, though at various localities but one may be represented.

THE 400-FOOT SANDS.

In the old well on the neutral grounds, just referred to, a sand bed was passed through from 335 to 480 feet below the surface that furnished artesian water at the rate of 350 gallons an hour.

SHALLOW WELLS.

Very close by Mr. Fabacher's deep well, above described, is a well but 180 feet in depth, fitted with a 3-inch casing, that flows 12 gallons per minute 1 foot above the surface of the ground. It is brackish. Temperature, 70° F.

Small driven wells in the city limits, at varying shallow depths, reach sandy, coarse material that bears water, evidently closely connected with the river.

BONNABEL WELL.

One of the most interesting wells that has ever been put down in the vicinity of New Orleans is that on the shore of Lake Pontchartrain, about 1 mile west of West End. An attempt was here made to start a summer resort under the name of Lake City, and this well was sunk for a supply of fresh water. According to Mr. Bonnabel, the well is 1,200 feet deep, but a letter from the driller indicates that it is not over 900 feet deep. It now flows from a 2¾-inch pipe, standing about 8 feet above tide, 12 gallons per minute, with a temperature of 79° (measured July 5, 1903).

Mr. Bonnabel makes the following remarks regarding the well section:

> Five-inch casing to 600 feet, hitting rock; 3-inch casing to 700 feet; then 1½-inch casing to 1,200 feet. Compact, ferruginous conglomerate, 60 feet thick, was passed through about 700 feet down; then a black, hard clay was encountered, giving way to bluish sand; water in pale blue clay.

The analysis of the water by Mr. Joseph Albrecht, as given in a handbook regarding "Lake City," is as follows:

Analysis of water from Bonnabel well.

	Grains per gallon.
Sodium chloride	27.74
Sodium carbonate	34.39
Potassium carbonate	4.49
Silica carbonate	1.69
Organic matter free of nitrogen	0.46
Carbonic acid combined as bicarbonates	13.33
Total	82.10

The features of the section outlined by Mr. Bonnabel are in some ways remarkable, and if it were certain that there is no error in the matter there might be grounds for supposing that there had been some orogenic movement in this region that brought up rocks belonging to a horizon beneath the Pleistocene to an elevation of but 600 feet below tide level. It is probable that the water comes from the same stratum that is found at a depth of 500 to 600 feet about Covington and Abita Springs, and that it is the same as the 600 to 900 foot sand beds penetrated and so largely drawn from throughout the city of New Orleans. The fact that the water may be potable at Covington, barely so at Lake City, and quite impotable in New Orleans, is readily explained by the very slight slope of the water-bearing stratum, and hence the very slow movement of the underground waters. A slope of perhaps 150 feet in 35 or 36 miles can scarcely give an appreciable daily motion through sand that is generally very fine. When we consider also the rapid formation of this coastal region of Louisiana, and the great amount of organic matter that was brought Gulfward then as well as now and deposited along in the sand and clay beds of Pliocene times, it is no wonder that the slowly moving waters should become strongly impregnated with various salts and so-called impurities as they pass Gulfward (see fig. 4).

Since such is the condition of affairs in and about New Orleans, there seems to be no valid reason for supposing that the city will ever be supplied with potable artesian water derived from local wells.

ST. JOHN THE BAPTIST PARISH.

RUDDOCK.

Mr. John Blumquist, of Hammond, says that the well at this place opposite the railroad station is 338 feet deep. It flows strongly, but the water stains everything red, even glass.

EAST BATON ROUGE PARISH.

BATON ROUGE AND VICINITY.

Waterworks, two wells.—Old well put down in 1892; depth, 758 feet; water rises to within 6 feet of surface, i. e., approximately 30 feet above tide; capacity given as 500,000 gallons daily.

Analysis of water of waterworks well at Baton Rouge.

[B. B. Ross, analyst.]

	Grains per gallon.
Total solid matter	14.3175
Mineral matter	12.1597
Organic and volatile matter	2.1578
Silica	1.3413
Potash	.2251
Soda	5.9929
Lime	.5009
Magnesia	.2939
Oxides of Fe and Al	.5056
Phosphoric acid	.03196
Sulphuric acid	1.8819
Chlorine	.4655
Oxygen oxidizing organic matter	.04228
Nitrogen, albuminoid ammonia	.00676
Nitrogen as free ammonia	.00519
Nitrogen as nitrates	.00192
Sulphuric acid and chlorine combined as—	
Potassium sulphate	.4171
Sodium sulphate	3.0022
Sodium chloride	.7494

This well has an 8-inch pipe for 386 feet; 6-inch pipe for 304 feet; 4¼-inch pipe for 68 feet. New well starts with 10-inch pipe, and is 6 inches the rest of the way down; depth, 800 feet; flow at surface about 35 feet above tide.

The two wells are said to have a capacity of 1,000,000 gallons a day. Pumped with compressed air.

Istrouma Hotel well.—Depth, according to the Blakemore Well Company, of New Orleans, 770 feet; water stands 18 feet below the surface of the ground. It is of the same quality as the water obtained at the waterworks, and pumps with a suction pump at the surface about 80 gallons per minute.

Well 4 miles east of Baton Rouge.—Pipe 4-inch, flow from 2-inch hole 4½ feet above ground, 5 gallons per minute; from 2-inch hole 1½ feet above ground, 30 gallons per minute; temperature 71° F. Pressure head about 50 feet above tide.

BAKER.

Well at old mill, one-fourth mile south of station.—Depth, 850 feet; 2-inch pipe; has flowed freely 16 feet above present faucet. It now furnishes large quantities of water.

Elevation of pressure head, about 100 feet above tide. (Elevation of Baker station given by Gannett as 82 feet above tide.)

Driven wells, 150 feet deep, furnish fair water. Bored wells, 25 to 40 feet deep, yield very impure water.

ZACHARY.

Wells here, some as deep as 200 feet, have to be pumped. Most of the water used is from shallow bored wells.

WEST FELICIANA PARISH.

BAYOU SARA.

Well just southeast of railroad station, 240 feet deep; passed through gravel at 100 feet. It is pumped. Darton gives the following data from one well at this place: Depth, 736 feet; pipe 4-inch; yield, 347 gallons; height of water [above mouth of well?] +2 feet; temperature 63°. For another he gives simply depth 450 feet and "height" +1 foot.

ARTESIAN AND DEEP WELLS IN LOUISIANA WEST OF THE MISSISSIPPI.

LA FOURCHE PARISH.

THIBODAUX.

Ice factory well.—Depth, 225 feet; passes through moderately fine bluish sand all the way down; water impotable on account of various salts; stands 13 feet below the surface of the ground; used for condensing.

ASSUMPTION PARISH.

NAPOLEONVILLE.

City waterworks.—Two wells, an 8-inch, 190 feet deep; a 6-inch, 210 feet deep. Both said to furnish 25,000 gallons per hour; the smaller, and deeper, with 9-foot strainer, furnishes more water than the larger, with 20-foot strainer.

Several such wells around the town furnish a similar water, i. e., very ferruginous, staining bath tubs and connections an orange yellow.

ST. JAMES PARISH.

St. James well.—Mr. Weasel, contractor for well drilling on the Texas and Pacific Railroad, says that at St. James he found good water at a depth of 285 feet, passing through a bed of shells (probably *Rangia* shells).

Convent well.—Mr. C. Oley, of the Blakemore Well Drilling Company, states that here he put a well down to the depth of 190 feet and procured good water. It rises and falls with the Mississippi.

ST. MARY PARISH.

MORGAN CITY.

Well penetrated a very coarse gravel bed at a depth of 500 feet.

GLENCOE.

Clendenin[a] gives a section of an artesian well at this place furnished by Doctor Simmons. It shows coarse sand and water at a depth of 615 feet.

Section of well at Glencoe, St. Mary Parish.

	Thickness in feet.	Depth in feet.
Soil	1	1
Yellow clay	11	12
Quicksand	12	24
Blue clay	100	124
Shale	Undetermined.	------
Tough, gray clay		------
Coarse sand and gravel and water at	---------	615

IBERIA PARISH.

JEANERETTE AND VICINITY.

Moresi's barnyard well.[b]—Depth, 140 feet; pipe, 1½-inch; flow, February 16, 1901, 7½ gallons per minute; temperature, 70°. See table of analyses given on page 78.

Elevation of station, 18 feet above tide; well, 13.2 feet below station; hence flow is about 5 feet above tide.

Moresi's foundry well.—Depth, 700 feet. See table of analyses given on page 78. Section given as follows:

Section of Moresi's foundry well at Jeanerette, Iberia Parish.

	Thickness in feet.	Depth in feet.
Clay	40	40
Sand and gravel	160	200
Blue and gray clay, shells, and red water	460	660
Gravel	40	700

[a] Part III, Geol. and Agric. State Exp. Sta., 1896, p. 213.
[b] Rept. Geol. Survey Louisiana for 1902, p. 232.

Elevation, 5.5 feet below railroad station; water stands within 5 or 6 feet of the surface; hence water is about 8 feet above tide.

Ice factory well.—Pipe, 8-inch. Clendenin gives this well section as follows:

Section of well at ice factory, Jeanerette.

	Thickness in feet.	Depth in feet.
Red clay	15	15
Mottled clay and sand	80	95
Organic bed	10	105
Sand and gravel	70	175
Yellow clay	175	350

Flow from base of cap, 7.69 feet below railroad station or about 10.5 feet above tide.

Old Moresi plantation.—One mile southeast of Jeanerette; depth, 180 feet; flows freely about 8 feet above tide; stains pipes and connections bright reddish yellow.

S. B. Roane's well.—Three miles south of Jeanerette; depth, 420 feet; pipe, 10-inch; water flows over the top of pipes perhaps 10 feet above tide when wells are not pumped for a time; water seems good for general family use; potable; wells pumped for rice irrigation. This is known as the Kilgore plantation. The section is as follows:

Section of Roane's well at Kilgore plantation, near Jeanerette, Iberia Parish.

	Thickness in feet.	Depth in feet.
Clay	80	80
Gravel	6	86
Clay, full of shells	150	236
Gravel and sand	184	420

NEW IBERIA.

Ice works wells.—Depth, about 230 feet; quality and quantity not as desired for general use; pipes soon cake and clog up.

John Emms's well.—Depth, about 260 feet; extremely ferruginous; not potable; rises 5 feet above the bayou at mid-stage.

Oil well.—North of New Iberia; depth, said to be about 500 feet, with pockets of oil, and one "rock" 2 feet thick; good water also reported at a depth of about 400 feet.

The quality of the water at the Roane well, mentioned above, is such as to seem to bear out ex-Mayor Moresi's statement that good water is to be found only at the usual depths some distance back from the bayou. It is probable that the problem of furnishing New Iberia with good water will be solved by pumping it from a station a few miles to the west. Mr. Caldwell, the machinist, vouches for the statement that good water was found in the "Oil" well.

ST. MARTIN PARISH.

ST. MARTINVILLE AND VICINITY.

Oil well.—About 1½ miles northwest of St. Martinville.

Section of oil well near St. Martinville, St. Martin Parish.

[According to Mr. William Kennedy.]

	Thickness in feet.	Depth in feet.
Clay and soil	40	40
Fine sand	60	100
Blue clay	40	140
Water-bearing sand and gravel	150	290
Tenacious clay and gravel	25	315
Water-bearing sand and gravel	120	435
Tenacious clay, with gravel	200	635
Coarse sand	200	835
Tenacious clay and gravel	150	985
Coarse sand and gravel	150	1,135

It will be observed that two beds of water-bearing sand and gravel are mentioned. Doubtless other sand and gravel beds, like the lowest penetrated, would furnish an ample supply of water, though very likely to be salty.

The Southern Pacific Railroad station is marked 25 feet above tide; a spirit-level line to the well shows that the floor of the derrick is 16.3 feet above tide. For diagram of this well see Pl. II.

In an irrigation well close by the water surface stood at a height of 11.6 feet above tide January 13, 1903.

Labbe's well.—Four miles south of St. Martinville; spirit-level line from St. Martinville showed surface of water to be 11.13 feet above tide; surface of the land 17.3 feet above tide January 14, 1903.

BREAUX BRIDGE.

Gilbeaux place.—Three-fourths mile west of station, on Gilbeaux plantation; elevation of railroad station 27.5 feet above tide; well pipe 12 feet above tide; water said to have flowed over the top of this pipe when well was first put down.

LAFAYETTE PARISH.

LAFAYETTE AND VICINITY.

Waterworks wells.—We have here an instance of lack of care in leaving the orifice of the wells accessible, so that the wells may at any time be cleaned, or rather flushed, when clogged with sand. Three wells have been put down here in succession, because, after a few years, they became clogged np. The depth of the new and consequently best well was given as 226 feet. Its casing is 6 inches; screen, 35.5 feet long. This well supplies Lafayette, besides 220,000 gallons to the Southern Pacific Railroad daily; height of surface of ground, reckoning Lafayette station as 40 feet, about 34.6 feet; water said to be between 20 to 25 feet below, hence about 10 or 15 feet above tide; when cleaned occasionally it is as good as when first put down; screen in very coarse gravel; C. H. Melchert, engineer in charge.

Lafayette Compress and Storage Company's well.—Depth, 125 feet; water surface about 25 feet below surface of the ground, i. e., about 10 feet above tide.

ST. LANDRY PARISH.

OPELOUSAS.

Waterworks well.—Depth, 184 feet; pipe, 10 inches; screen, 64 feet; has been pumped to the extent of 300 gallons per minute, guaranteed 600; elevation of water in well, 22.28 feet above tide, i. e., considering the station as 67.5 feet, as given by the Southern Pacific Railroad.

Section of waterworks well at Opelousas, St. Landry Parish.

	Thickness in feet.	Depth in feet.
Clay	83	83
Fine sand	37	120
Gravel to bottom of well	64	184

Oil Mill well.—Depth, 208 feet; pipe, 8 inches, with 40 feet of screen.

WASHINGTON.

Washington well.—The following section was given for the well at Washington:

Section of well at Washington, St. Landry Parish.

	Thickness in feet.	Depth in feet.
Quicksand	18	18
Sand	52	70
Gravel	124	194

Water said to rise to within 11 feet of surface of ground, or about 30 feet above tide.

WEST BATON ROUGE PARISH.

BATON ROUGE JUNCTION.

Mr. Weasel says he found good water here at 160 feet.

LOBDELL.

The same authority just quoted says that good water is found here at a depth of 150 feet. The surface of the water is 21 feet below the general level of the ground.

POINTE COUPEE PARISH.

NEW ROADS.

Mr. Weasel reports poor water at 120 feet.

BATCHELOR.

The same condition exists here as at New Roads.

AVOYELLES PARISH.

BUNKIE.

Railroad wells.—One 90, the other 142 feet deep; the water from both impotable. Water stands in both about 13 feet below station.

W. D. Haas's well.—One 4-inch well, 180 feet deep, furnishes enough water to run four large boilers in Haas's cotton compress works; water stands about 10 feet below surface of ground or about 11.5 feet below the station.

Gannett gives Bunkie an elevation of 66 feet. Hence water stands in these wells about 52 or 54 feet above tide.

MARKSVILLE.

Court-house well.—This well is reported to have a depth of 800 feet, encountering salt water. At a depth of 230 feet a 5-foot stratum of lignite was penetrated. Mouth of well 0.3 foot above railroad station, hence approximately 82 feet above tide.

VERMILION PARISH.

ABBEVILLE AND VICINITY.

Court-house well.—Well about 16.6 feet above tide with section as follows:

Section of well at court-house, Abbeville, Vermilion Parish.

	Thickness in feet.	Depth in feet.
Clay	15	15
Fine sand	65	80
Clay	2	82
Hard layers of clay alternating with sand	57	139
Coarse white sand with white pebbles	21	160
Reddish clay and "rock"	60	220

The upper bed here alone furnishes water. Exact height of water could not be told; certainly it lacks several feet of overflowing.

Well 9 miles west of Abbeville.—On Mr. John Waltham's place W. ½ SE. ¼ sec. 32, 12 S., R. 3 E., are several wells. The land is here 10 feet above tide and the general well section, according to Mr. Moresi, is about as follows:

Section of well on Waltham's place, 9 miles west of Abbeville, Vermilion Parish.

	Thickness in feet.	Depth in feet.
Clay	30	30
Gray sand	10	40
Clay	5	45
White sharp sand and gravel	30+	75+

Even at this low level the water does not overflow.

SHELL BEACH.

Wells that have a feeble flow above the surface of the ground were heard of at this place, but were not visited.

GUEYDAN.

Wilkinson's well, 3 miles southwest of Gueydan.—Depth, 190 feet; pipe, 8-inch; flow, 8+ gallons per minute; temperature, 73°. Elevation of flow, 6.9 feet above tide, determined by spirit-level line from Gueydan; bench mark on station; according to Southern Pacific Railroad, 9.07 feet above tide.

Donnelly place, 6 or 7 miles east of Gueydan.—Two 8-inch and two 6-inch wells. Water said to rise 8 inches above the surface.

ACADIA PARISH.

RAYNE AND VICINITY.

Chapuis's well.—Depth, 210 feet, with 10-foot strainer; water stands 16 feet below surface. Elevation of station, according to Southern Pacific Railroad, 37.5 feet above tide, well about 2 feet below; hence, water in well about 19.5 feet above tide.

Hippolite Richard's well.—This is 3 miles east-northeast of Rayne. Depth, 200 feet; water stands within 17.5 feet of surface. Elevation of surface of water in well about 20 feet above tide, based on spirit-level line run from Rayne to mouth of well.

CROWLEY AND VICINITY.

Railroad well.—Depth, 173 feet. Water usually rises to within 5 or 6 feet of surface. Elevation of water, about 19 feet above tide.

Ice factory well.—Depth, 600 feet; water unsatisfactory; pipe withdrawn to the usual depth, 170–180 feet.

Long Point, 15 miles northeast of Crowley.—One 8-inch and three 6-inch wells. Water at 180 feet; rises to within 26 feet of the surface.

Three miles east of Crowley.—Two wells pass through logs at depth of 168 and 202 feet. In the first, beneath the 168-foot log, 7 feet of water-bearing sand was encountered, water rising to within 7 feet of surface.

Sol Wright's well.—About 3 miles southwest of Crowley, or in center of sec. 19, T. 10 S., R. 1 E.; depth, 293 feet; surface of ground, 19.37 feet above tide; of water, 9.37 feet above tide January 29, 1903. Strainer, 70 feet long.

L. J. Bowen's well.—Middle of NE. ¼ sec. 19; depth, 196.6 feet; top of pipe, 21.39 feet above tide; of water, 9.49 feet above tide.

MIDLAND.

Water stands in this well, February 5, 1903, 10.5 feet below station; hence 7.5 feet above tide.

ORIZA AND VICINITY.

John Wendling's well, 1 mile southwest of Oriza.—Pipe, 6-inch; flow, 1.2 feet above surface; 20 gallons per minute. Elevation of Oriza (Southern Pacific Railroad), 24 feet above tide. By spirit-level line, top well is 11.4 feet above tide.

D. J. Scanlin's well, 2 miles southwest of Oriza.—Elevation of surface of water, 12.2 feet above tide; line from Oriza.

F. Scanlin's well, 2 miles south-southwest of Oriza.—Elevation of surface of water, 12 feet above tide; leveled from Oriza.

CALCASIEU PARISH.

It is in the eastern half of this parish that perhaps two-thirds of all the large irrigation wells of southwestern Louisiana are located. Not that this particular area is better adapted to the growing of rice than many other sections of southern Louisiana, but by a glance at any map of this part of the State it will be seen that east Calcasieu has comparatively few large rivers, creeks, or bayous from which water may be had for irrigation purposes. The result is that here are found the most advanced methods of sinking wells and lifting the water from them.

It is entirely out of the question to refer to even a tenth part of the wells now in operation in this section; of late years their number has gone up into the hundreds, and will soon reach a thousand or more. A few statistics regarding some of these wells will show the general characters of all of them. Welsh may be taken as the central point of interest in deep-well activity.

WELSH AND VICINITY.

E. L. Bower's well.—About one-half mile northeast of Welsh, center of sec. 30, called in the last report of the Geological Survey of Louisiana (1902) "E. L. Brown's well;" depth, 130 feet; pipe, 8 inches; strainer, 38 feet; surface of water above tide February 26, 1901, 16.68 feet; March 21, 1903, 13.92; July 13, 1.18 feet. The section shows clay to 65 feet and sand, growing coarser below, to 130 feet.

Mr. Bower has recently put down another well 92 feet north of this well; it has a 10-inch casing, is 175 feet deep, and has a 56-foot strainer. From top of pipe to water surface, March 21, 1903, 6.73 feet of the water stood 13.26 above tide; July 13, 1903, 0.5 foot above tide.

Cooper's well, ½ mile east of Welsh.—The section shows clay to 90 feet, coarse sand, clay, sand, and finally blue sand at a depth of 140–145 feet.

Field's well, ¾ mile east of station.—The section shows clay to 90 feet; sand, clay, coarse below, to 164 feet.

Welsh planing mill well.—Pipe, 3 inches; top of pipe, 20.33 feet; surface of water, March 19, 13.86 feet; March 21, 13.93 feet above tide.

Section of well at Welsh planing mill, Welsh, Calcasieu Parish.

	Thickness in feet.	Depth in feet.
Clay	12	12
Sand	4	16
Clay	182	198
Coarse, light sand	40	238

S. R. May's well, ¼ mile north of station.—Top of flume 20.3 feet above tide, of water; March 19, 1903, 14.3 feet; March 21, 15.16 feet; July 12, 1903, 0.8 foot above tide; July 13, after pump had been working 1 hour, but had stopped 5 minutes before the measurement was taken, 1.7 foot above tide; same conditions except pump had been stopped for about 20 minutes, 1.1 foot above tide; lowest level in 1902 said to be −8 feet; depth, 190 feet; pipe, 8 inches; temperature of water, 71.5° F.; supplies 1,200 gallons per minute when pumped by a 20-horsepower Erie engine.

Abbot's well, 2 miles southeast of Welsh.—Elevation of water surface, February 26, 1901, 16.42 feet above tide; that is, 7.08 feet below the railroad station.

Herald's well, perhaps 1½ miles east-southeast of the station.—Elevation of water, February 26, 1901, 16.6 feet above tide, or 6.9 feet below the railroad station.

Well 9 miles north-northwest of Welsh.—The section shows clay to 192 feet and sand to 235 feet.

LAKE ARTHUR.

Wells at mills reported as flowing 5 feet above tide.

R. E. Camp's well, 1½ miles northwest of Lake Arthur.—Southeast ¼ sec. 8, 11 S, 3 W.; depth, 215.7 feet, water-bearing sand 40 feet thick; elevation of top of pipe as determined by a spirit-level line from the lake, 17.5 feet above tide; elevation of water surface, 8 feet above tide.

JENNINGS AND VICINITY.

Anderson's wells, about 1 mile west-southwest of Jennings.—Three 10-inch wells, connected to a 14-inch main and pumped with a 50 horse-power engine. Depth, approximately, 300 feet; wells about 20 feet apart, furnishing, with engine running at perhaps half-rated power, 1,800 gallons per minute.

These wells are furnishing now (1903) about half as much water as they did last year owing to clogging of the strainer with fine sand. The fireman at the plant says the 150-foot well, about 50 feet north of the three, is capable of furnishing nearly as much as these three are furnishing now. Though so various in depth, when the deeper wells are pumped, the amount obtainable from the shallower one is materially diminished.

Carey's wells.—In this same vicinity are the three Carey wells, a general log of which is herewith given:

General section of three wells near Jennings, La.

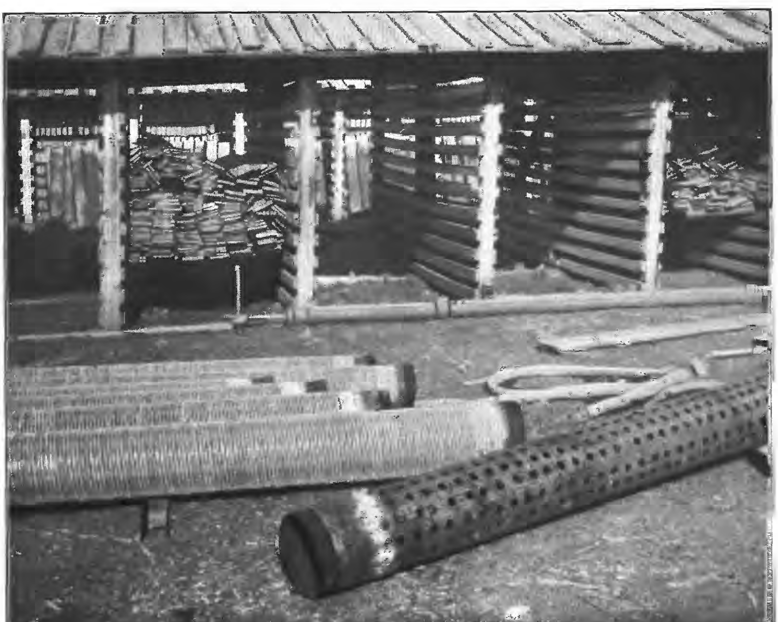
	Thickness in feet.	Depth in feet.
Clay, with shells at about 50 feet, and with vegetable matter and a log below	115	115
Quicksand above, gravelly below	45	160
Bluish, sandy gravel	20	180
Sandy clay	50	230
Gravel	30	260

City waterworks well.—When measured, March 19, 1903, the water in this new well stood 18 feet below the mouth of the pipe or, perhaps, 12 feet above tide. The capacity of the tank is 65,000 gallons. The engineer informed us that the well seemed to lower none while the tank was being filled, the operation lasting about three hours.

Well 3 miles east-southeast of Jennings.—This well was being sunk on February 24, 1900, by the Brechner outfit. The beds penetrated showed reddish, yellow, and gray mottled clay for 30 feet, becoming

A. ARTESIAN WELL OF BRADLEY AND RAMSAY LUMBER COMPANY, 1 MILE NORTH OF LAKE CHARLES, LOUISIANA.

Flow in March, 1901, 210 gallons a minute.



B. SCREEN WOUND AT THE MORESI BROTHERS' SHOP, JEANERETTE, LA.

less tenacious, with fossil fragments, *Rangia*, *Helix*, *Balanus*, etc., until a depth of 90 feet was reached, when blue sand, with thickness undetermined, was struck.

KINDER AND VICINITY.

McRill's well, 1 mile north of Kinder.—Depth, 150 feet; elevation of water surface as determined by leveling, from Kinder Station, March 8, 1902, 27.1 feet above tide, assuming that the station is 49.3 feet above tide.

Tillotson's well.—Depth, 138 feet; depth of water from top of pipe, 21 feet, 10 inches; temperature, 68° F.; elevation of water surface March 7, 1902, 25.4 feet above tide.

CHINA.

McBirney's wells.—A number of wells in this vicinity, ranging in depth from 140 to 175 feet and in size from 6 inches to 8 inches, in which water rises to within 14 to 23 feet of surface, depending on local topography.

OBERLIN.

Mr. Dennis Moore says that the railroad tank well is 190 feet in depth, and that water rises to within 10 feet of the surface, or about 60 feet above tide.

In general the water level would probably be somewhat lower than this. No hopes can be entertained of obtaining a flowing well at this comparatively shallow depth.

LAKE CHARLES.

Well 1 mile north of lake.—The Bradley and Ramsay Lumber Company's well, about 500 feet deep, has the greatest flow of any well measured in the State, 210 gallons per minute; pipe, 6 inches. See analysis given below. (See Pl. VI, *A*, for view at well.) Elevation, 10.5 feet above tide. Based on tide gage reading at Lake Charles, by G. D. Harris.

Reiser's machine-shop well.—The following is a section of the well:

Section at well at Reiser's machine shop, near Lake Charles.

	Thickness in feet.	Depth in feet.
Sand	96	96
Red sand with pebbles	6	102
Gray sand and clay alternating	98	200

Water with iron taste. See analysis given below. Elevation of well about 13 feet; known to flow to 17 feet and said to have flowed to 27 feet above tide.

Judge Miller's well.—Pressure of 5.25 pounds per square inch; flows 12 gallons per minute. Elevation of present flow, 12.72 feet above tide; would flow at 24.79 feet above tide.

WEST LAKE.

Perkins and Miller Lumber Company's well.—Pipe, 4 inches; elevation of flow, 10 feet above tide, and would doubtless flow to 16 feet or more above tide.

Well 3 miles northwest of lake.—Pipe, 8 inches. Following is a partial section of this well:

Partial section of well at West Lake, Calcasieu Parish.

	Feet.
Hard clay between	250–350
Shells	300
Gravel	360

This is a very strong flowing well.

RAPIDES PARISH.

BLOWING WELLS.

It would doubtless be an unpardonable omission, if in enumerating the various classes of wells in southern Louisiana, with their depths, kinds of water, and other characteristics, no mention were made of the "blowing" wells of Rapides Parish, that have attracted much attention, at least locally.

Judge Blackman, of Alexandria, has frequently called attention to a certain well of this character, and has recently sent, through Mr. Kennedy, of the Southern Pacific geological survey, a clipping from the Alexandria Town Talk, of September 19, 1903, relating to this subject.

Though Judge Blackman knows of two other wells having similar characteristics, the one best known is located on the farm of Mr. Frank Melder, Melder post-office, between Spring Creek and Calcasieu River, 2 miles east of the river, and 3 miles east of Strothers Crossing, on the Calcasieu.

It was in 1892 that Mr. Frank Melder started to bore a 12-inch well, but had to give it up after reaching a depth of 80 feet. The air would come rushing from the well, sometimes for a period of three or four days, and again at shorter periods. When the air was not rushing from the well, it would turn the other way and be sucked into the well with great force * * * The force of the air coming from the well would keep a man's hat suspended over it.

In boring the well a stratum of about 1 foot of pipe clay was penetrated, and for the remainder of the distance, over 75 feet, a bed of yellow sand was penetrated.

While boring it was discovered that every foot deeper the well was sunk, the harder the air would blow from it. When the well was first completed, it would blow a day and then air would be sucked in for a day. No water ever appeared in the well at any period.

The subject of "blowing wells" has been discussed in Water-Supply and Irrigation Paper No. 29, by Mr. Barbour.[a] He attributes such phenomena, doubtless correctly, to changes of atmospheric pressure at the surface of the earth. Those interested in this subject will find, without doubt, that when the wells are "blowing," the barometer reading as recorded by the nearest weather station is low; when the wells are "sucking in," the barometer is rising.

It seems from the above statement regarding the section of the Melder well that its great capabilities as a "blowing" well are due to the absence of water between the grains of sand.

When such interstices are mainly filled with water, as is usually the case, the phenomenon of "blowing" is much less noticeable.

VARIATION IN FLOW AND PRESSURE HEAD SHOWN BY WELLS IN SOUTH LOUISIANA.

WELLS EAST OF THE MISSISSIPPI.

As a result of investigations already carried on, it is safe to say that the total amount of water obtained from deep and artesian wells in this part of the State north of Lake Pontchartrain does not exceed 3,000 gallons per minute. South of the lake, in the city of New Orleans, there are a number of 6-inch wells, but they are pumped so irregularly, both as to time and amount, and are so "connected up," that no safe estimate can be given as to their total yield. The water-bearing sands, ranging from 600 to 900 feet below the surface throughout the city, have been penetrated in so many places that the water rarely overflows from these wells. All admit that the head has been gradually lowered somewhat in proportion to the number of new wells put down. (For a record of the present stand of the waters in these wells, see pp. 44–47.)

There seems to have been a slight decline in the waters of the Mandeville region, if we may trust occasional measurements, yet by referring to the data presented under Mandeville (p. 37), it will be seen that some of the important wells are flowing now almost as much as two years ago. Some have become practically clogged up and of little or no value. The presumption is that, were new wells put down or were those now in existence occasionally flushed, the supply would be as great as ever from each well. Very few new wells have been put down in this vicinity during recent years.

[a] Barbour, E. H., Wells and windmills in Nebraska: Water-Sup. and Irr. Paper No. 29, U. S. Geol. Survey, 1899, pp. 78–82.

About Covington the new wells seem to show the same head as those put down two or more years showed at that time. Here, too, there is a suspicion that the marked falling off of head in several of the wells is to be accounted for by the clogging of the pipes.

At Abita Springs it has been noticed that the flowing of the last new large well put down decreases to a marked extent the head in the wells close by, especially to the south and west. Some of the better wells, however, have shown an increase rather than a decrease, so that with care in properly spacing the wells and judgment in using the water no one need expect to be obliged to resort to pumping for a long time to come.

At Hammond the better wells have shown no decrease of flow or pressure head for the last two years, even though their number has greatly increased during this interval.

When the extent of catchment area is taken into account, reaching, as it must, northward as far as Crystal Springs, Miss., and when the total amount of waters obtained from deep sources in this section of the State is considered, it is no wonder that there seems to be no general variation in flow or pressure head thus far recorded. Two moderate-sized rice plantations in southwest Louisiana would call for more water during the summer months than flows from all these wells combined. Until irrigation is practiced far more generally in this section of the country there will probably be no marked decline in the flow of the carefully constructed artesian and deep wells.

WELLS WEST OF THE MISSISSIPPI.

The statement is often made that the wells along the Mississippi and in the alluvial or delta region to the west vary as to head according to the different stages of the river. In the lowest regions, close to the river channel, this probably means that when the river is very high, held far above the wells by the great levee system, some of the river water gradually seeps through the intervening soils and enters the wells. Many instances are on record of the pressure of the river water becoming so great as to cause a spring to burst forth from the ground several hundred yards from the river's border. When such waters are welled up to a height corresponding to that of the surface of the river, they cease to flow.

However, if it is assumed that the motion of most underground waters is but a few feet a day, or only a mile or two a year, it is evident that the underground transmission of water from the Mississippi eastward, westward, or Gulfward is not sufficiently rapid to be detected and correlated with stages of the river except for a distance of a few hundreds yards from the channel.

It is obvious, however, that there may be a transmission of pressure, affecting the flow of wells more promptly and at a greater distance than would the actual translation of the water itself. Data touching upon this interesting question are in the delta region unfortunately lacking, and this for two reasons: (1) Since the water there obtained from wells is usually of poor quality, their number is not great, and (2) when they are put down they are nearly always on the bank of some navigable bayou where the villages and sugarhouses are to be found. The fluctuations of such wells may be due, as explained above, mainly to the lateral transmission of river or bayou water, and not to the simple transmission of pressure.

Wells farther west, some distance from the Mississippi and its distributaries, show, as will be seen below, no appreciable effect of transmission of either water or pressure from the Mississippi.

No observations continuing throughout the whole year have been made, so far as the writer is aware, of the height of water in the various deep wells in the southwest part of the State. As explained in the prefatory notice to this paper, the facts upon which this report is based were collected by the writer during the winter months, while engaged in general work of the State geological survey. However, several short series of observations have been made, covering intervals in three successive years. In 1901 Mr. Pacheco, of the State survey, was kept in the field nearly two months for the sole purpose of making such observations. The results of his observations, as published by the State survey, are as follows:

Variation of height of water in Hammill's well, 2½ miles south of station, Jennings, La.

1901.	Hour.	Feet.	Inches.	1901.	Hour.	Feet.	Inches.
Feb. 21	....	13	4.0	Apr. 29	a. m.	13	7.2
Apr. 20	....	13	9.5		p. m.	13	7.0
21	a. m.	13	9.0	30	a. m.	13	7.16
	p. m.	13	8.5		p. m.	13	7.12
22	9 a. m.	13	7.25	May 1	2 p. m.	13	7.0
	11 a. m.	13	7.0		4 p. m.	13	6.9
	12 m.	13	6.9		5 p. m.	13	6.8
	2 p. m.	13	6.87	5	....	13	7.75
	3 p. m.	13	6.75	6	a. m. / p. m.	13	7.75
	5 p. m.	13	6.75				
24	....	13	8.75	14	....	13	10.25
25	....	13	8.0	15	....	13	11.0
26	a. m.	13	8.33	16	....	13	11.75
	p. m.	13	8.25	17	....	14	0.125
27	10 a. m.	13	8.5	18	....	14	2.0
	11 a. m.	13	8.4	20	....	14	2.0
28	....	13	7.0	Water dropped below pump.			

Variation of height of water in Lawson's well, 1 mile east of station, Jennings, La.

1901.	Hour.	Feet.	Inches.	1901.	Hour.	Feet.	Inches.
Apr. 21	10 a. m.	6	5.75	May 2	10 a. m.	6	6.25
	6 p. m.	6	4.12	5	3 p. m.	6	7.25
22	8 a. m.	6	4.0		3.30 p.m.	6	7.0
	6 p. m.	6	3.9		6 p. m.	6	6.8
23	8–11 a.m.	6	4.0	6	....	6	6.83
24	p. m.	6	4.37	18	....	7	5.25
25	7 a. m.	6	4.2	19	....	7	3.5
26	a. m.	6	4.37	20	....	7	2.87
	p. m.	6	4.33	22	....	8	....
27	....	6	4.75	24	....	8	....
28	{ 9 a. m.– 4 p. m. }	6	5.33	1902.			
29	8 a. m.	6	5.8	Feb. 22	....	7	10.25
	2 p. m.	6	5.75	23	....	7	10.25
	6 p. m.	6	5.66	25	....	7	9.75
30	....	6	6.0	26	....	7	8.5
May 1	9 a. m.	6	6.12	27	....	7	8.25
	11 a. m.	6	6.12	Mar. 11	....	7	9.25
2	8 a. m.	6	6.12	13	....	7	9.125

Variation of height of water in Bower's well, Welsh, La.

1901.	Hour.	Feet.	Inches.	1901.	Hour.	Feet.	Inches.
Feb. 26	....	4	6.0	May 12	....	4	2.5
Mar. 21	....	4	3.0	13	....	4	2.75
Apr. 20	....	4	1.25	14	....	4	2.75
23	....	4	1.5	15	....	4	3.5
24	8 a. m.	4	1.4	16	....	4	3.75
	10 a. m.	4	1.5	17	....	4	3.75
	11 a. m.	4	1.6	18	....	4	4.0
	12 m.	4	1.75	19	....	4	4.25
May 3	....	4	1.75	20	....	4	4.5
5	....	4	2.0	21	....	4	5.0
6	....	4	2.0	22	....	4	5.0
7	....	4	1.75	25	....	4	7.0
8	....	4	2.12	26	....	4	9.0
9	....	4	2.12	28	....	5	5.0
10	....	4	2.12	30	....	5	9.0
11	....	4	2.25				

Variation of heighth of water in Hawkeye rice mill well, Fenton, La.

1901.	Hour.	Feet.	Inches.	1902.	Hour.	Feet.	Inches.
Mar. 31	....	14	10	Mar. 7	....	18	3
May 5	....	15	....	8	....	18	2

It will be observed that in these measurements the numbers under feet and inches indicate distances downward from some datum plane, generally the top of the casing or the floor of the discharge trough. As the season advances, the surface of the water in the wells gradually lowers. The rate of lowering is not constant, but the total result of the various fluctuations is to materially lower the water surface as summer approaches. The noticeable acceleration in the rate of lowering after May 15 is due to the beginning of pumping for rice irrigation. Perhaps there is nothing new or unexpected in these results thus far. The variations shown throughout different hours of the day are much more difficult of explanation. Very possibly, though, carefully kept barometric readings would give a clew to their meaning.

By far the most interesting and unexpected variations are those of about April 22, 1901, and February 25 to 27, 1902. Instead of the gradual downward course, there is indicated for these dates a noticeable rise. The Weather Bureau reports show that heavy showers were abundant on the 16th, 17th, and 18th of April, 1901, in this part of the State, and from the 19th to the 26th of February, 1902.

Again, these same tendencies toward a lowering in summer and a quick response to local showers has been observed this year (1903), as is shown by the following table:

Date.	May well.	Rice mill.	Planing mill.	Bower's wells.	
				North.	South.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Mar. 19....	6.00	....	6.4	....	....
21....	5.14	....	6.33	6.73	6.26
25....	5.85	6.70	6.50	6.87	6.63
July 12....	19.5	18.8	....	19.5	....
13....	19.2	....	....	....	....

Over 2 inches of rain fell on the 19th and 20th of March in this vicinity, and from the changes in level noted in the foregoing tables for previous years it is only to be expected that these wells would show a similar change for a similar cause. Observe especially in the May well how the water level rose on the 21st, but went back again on the 25th. Notice, too, the effect of the summer with its pumping season, under July 12.

The marked effect of copious showers on the water level in the deep wells of southwestern Louisiana has not escaped the general observation of planters.[a]

The extent to which very local heavy showers affect the territory just without their limits is an interesting topic that thus far has not been investigated, nor have time and circumstances permitted the observation of effects produced by local or extensive rainfall in different directions from any given well or group of wells, though the importance of such observations, when a full explanation of the occurrence and conditions of the underground waters of this part of the State is attempted, can not be too much emphasized.

From what has already been said, it is evident that in some respects the waters of this section behave like the common "ground water" of this or any other well-watered land; but that, ordinarily, there is no very direct connection between the water of these deep wells and the ordinary soil supply is evident from the fact that at a number of places the deep waters flow several feet above the surface of the soil for miles around; and, again, the water in the casing of the deep wells never, so far as observed, stands at the same level as the water in the pit outside. Again, the supply of deep water is not obtained until one or, more generally, several, thick, impervious layers of clay have been penetrated.

Since the thickness and character of the sand and clay beds encountered in sinking wells but a short distance from one another may vary greatly, and since the position of a clay bed in one well may be taken by a sand bed in another it is very evident that, in southern Louisiana, the artesian and deep-well conditions are somewhat different from those encountered in regions where there is one great extensive underlying formation, sharply defined from overlying and underlying beds, and alone transmitting the deep underground flow. Yet some typical or ideal artesian features are represented in this part of the State. The first hundred or two hundred feet passed through in sinking deep wells contains comparatively few very porous layers; below, the sand usually becomes coarser, and sometimes thick beds of gravel are found. Gravel deposits are by no means uncommon to a depth of 1,000 feet, as will be seen by inspecting the logs of the wells put down in search for oil or deep artesian water and published herewith as Pl. II. Very coarse gravel is reported in the bottom of many of the best water wells throughout the Gulf border. As will be seen by referring to the record of a well just completed in Biloxi, Miss., the casing, over 900 feet down, is in extremely coarse gravel (see p. 31).

[a] For remarks on this point, see Rept. Geol. Survey Louisiana for 1902, p. 246.

Water naturally flows much more readily through coarse than through fine material. The best flowing or deep wells of southwest Louisiana obtain their waters from very coarse sand or gravel beds. Such beds are generally below 150 or 200 feet from the surface. Ground-water features or characteristics decrease in this region downward, according as those more typically artesian increase.

There is one more somewhat interesting fact connected with variation in pressure head as noticed in the May well at Welsh, though probably it is common to all others in this part of the State. On the 12th of July no pumping was done, and from all appearances none had been done for several days. At 5 o'clock in the evening the water stood 19.5 feet below the top of the mouth of the casing. Next morning the pump had run but an hour when, at the writer's request, it was stopped in order that the stage of the water might be measured. The surface of the water, after dropping suddenly, balanced up and down for a moment and then appeared to have come to rest. Five minutes after the pump had ceased working, the water stood 18.6 feet below the mouth of the casing. After the pump had been stopped for twenty minutes the water stood at 19.2 below the same datum plane. It thus appears that the pumping, which was equivalent to a flow of 1,200 gallons per minute, or 72,000 gallons per hour, had not in one hour's time materially lowered the water level--in fact, had actually raised it temporarily.

That long-continued pumping does lower the level of the water in wells is understood by all who are connected with deep-water supplies. For example, in July, 1903, Mr. Roanes's place was visited, and, although under ordinary circumstances his wells are flowing, at that time, owing to several hours of intermittent pumping, continuing for a period of several days, the water stood just below the tops of the pipes.

The Fabacher well in New Orleans (see p. 44), which ordinarily flows continuously from a 4-inch pipe but 2 feet or less above the general level of the ground, will, if suddenly turned into a smaller pipe, rise up and overflow for a few minutes to a height of 11 or 11.5 feet above the ground. Then the water gradually descends to a permanent head of about 10 feet above the ground. The cause of the temporary, unusually high head in the above-mentioned cases is doubtless attributable to the momentum of the water in the porous sand or gravel bed below. What seems worthy of special note is the length of time required for the water to descend to its normal head, especially in the case of wells that have just been pumped.

WELL DRILLING AND PUMPING.

METHODS OF DRILLING.

In southern Louisiana practically but one method is used in sinking wells, either for water or oil. This consists primarily of loosening the earth with a hollow revolving bit and bringing it to the surface by the upward current of water obtained by forcing water down through the hollow bit. There are, to be sure, many different devices for producing the necessary rotating motion, many differently shaped bits, and many different sized and shaped derricks used; but the fundamental principle of drilling is the same with all.

Preferences as to kind and size of well desired differ considerably in different localities. East of the Mississippi and north of Lake Pontchartrain most of the wells are furnished with a 2-inch casing, and the water is expected to flow at the surface of the ground or even some feet above. The wells are used for dairy or ordinary household purposes. West of the delta region the wells are usually 6, 8, 10, or 12 inches in diameter, the water is not expected to rise to the surface, and irrigation is the main object for which the wells are put down. As a result of the number, kind, and size of wells required in different sections of the State, methods of drilling varying somewhat in detail are resorted to by local drillers.

JETTING.

Fig. 10 shows what is usually called the jetting process. The traction engine furnishes steam to run the small force pump (A), which obtains water from a local source and pumps it through a strong hose (B) to the drill pipe (C). The rotating of the pipe with bit attached is here accomplished by the simple method of temporarily attaching a Stilson wrench (H) and moving it to and fro. The pipe carrying the downward current of water with the bit is held up by a block (D) and ropes (E) and is moved up and down every few seconds by power from the engine transmitted by a rope and the force of gravity. The rope going to the engine in this case simply passed over a drum or large spool about 6 inches in diameter, on the outer end of the fly-wheel shaft. Two or three turns only were made around this drum, and when no work was required of the rope the engine continued turning, but the coils were allowed to slip loosely on the drum. By tightening the coils the drill pipe was immediately raised. The drill pipe in this instance is about 1¼ inches in diameter, while the casing is about 2½ inches. The casing is sunk nearly as far as the drill has penetrated, and the return water, laden with drillings, comes up between the pipes. Its exit is shown at F.

By turning back and forth on the long-handled wrench at K the casing is loosened from the outside sand and clay and ordinarily readily descends by its own weight about as rapidly as the jet clears the way, but in some instances is forced down by driving.

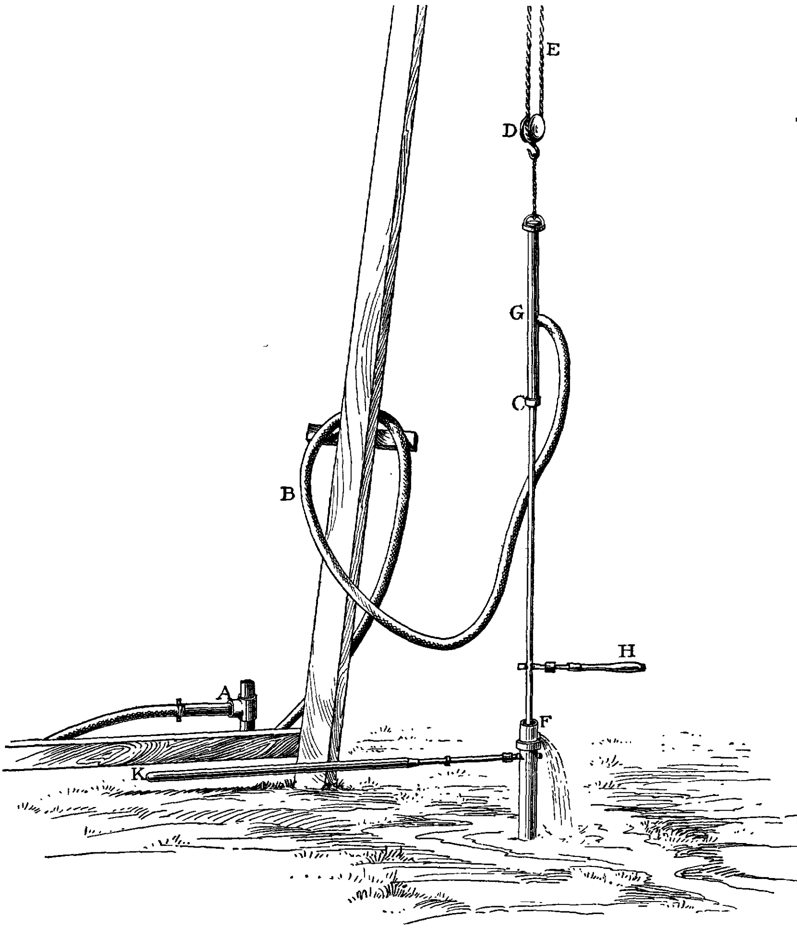


FIG. 10.—Portion of well-drilling outfit of Bacon and Gamble, sinking a well at Ponchatoula by the jetting process.

As the drill descends and the swivel coupling (G) approaches the top of the casing, the coupling is unscrewed and another length of drill pipe, 12 to 20 feet long, is put in, and the drilling is continued.

ROTARY PROCESS.

Where many wells of large diameter are to be put down, as in the southwestern part of the State, much of the manual labor required by the above-described process is done away with by the use of a mechanism for rotating the pipe by steam power. This method is substantially as follows:[a]

A long pit, perhaps 10 feet wide by 20 long, is dug or scraped for a temporary reservoir. This is divided into two compartments, connected, however, in one or two places.

The derrick having been erected and engine placed, a 3-inch pipe with a broad bit attached to one end is hoisted up by rope and drum, and the water hose, of equal size, is attached to the upper end. By a simple device, this pipe is rotated by power from the engine while water is pumped from the pit just described through the hose, down the pipe into the ground. As the pipe descends, the matter disengaged by the bit is washed out and brought to the surface by the jet. When the pipe, say 12 feet long, is sunk into the ground nearly its whole length, another section from 12 to 20 feet long is attached and the rotating and pumping is continued till it too is sunk almost to the surface of the ground. And so the 3-inch pipe is put down till, by the appearance of the sand or the feeling of the pipe when rotated, there is an indication that the water-bearing sand is reached.

Mention should be made here of the care shown in one of the compartments of the pit or pool referred to above, to see that plenty of earth or clay is mixed with the water just before it is pumped through the hose into the pipe. The pressure from the engine pumps is sufficient to force this muddy water into the sandy layers and cause them to stand firmly and not cave as they would be sure to do if only clear water was used. It usually occupies the attention of one man to keep the ingoing waters well stirred up and turbid. The other compartment of the pit contains that portion of the water that has just come out from the well, hence contains the drillings, if such they may be called, derived from the well. The same water as it flows into the first compartment is again used after being properly roiled or mixed with soil.

After the desired depth has been attained, the 3-inch pipe is removed, section by section, and the 6-inch, 10-inch, or 12-inch casing is hoisted up and sunk into the hole made by the 3-inch pipe and its arrow-head bit. The hole is often nearly 14 inches in diameter.

The first one, two, or three sections of this large pipe or "casing" are perforated and form the strainer, near the bottom of the completed well. If the strainer is to be three lengths long, say 60 feet, care is taken to insert in the casing three lengths of 3-inch pipe and to fill the space between this inner and the outside pipe with shavings so that it can not fill with earthy matter while descending. Length after length of casing is screwed on and lowered until the desired amount is sunk into the ground. In case it does not descend readily of its own accord, resort is had to rotating the casing by machinery precisely as the 3-inch pipe was rotated in the beginning. The lower margin of the casing is cut with points like saw teeth, so that it answers fairly well as a drill or auger.[b] The upper end of the 3-inch pipe within carries a conical sleeve, so that it can be caught readily by the thread end of other lengths that are lowered afterwards and coupled up with the three lengths already spoken of as being in the strainer part of the casing. The shavings can now be jettied out, the interior pipe withdrawn, and the well "pumped" to withdraw all the muddy impurities forced down while drilling, as well as fine sand that might eventually fill up the strainer.

One of the most satisfactory methods of drilling is by portable outfits, in which the derrick, traction and dummy engines, pumps, etc.,

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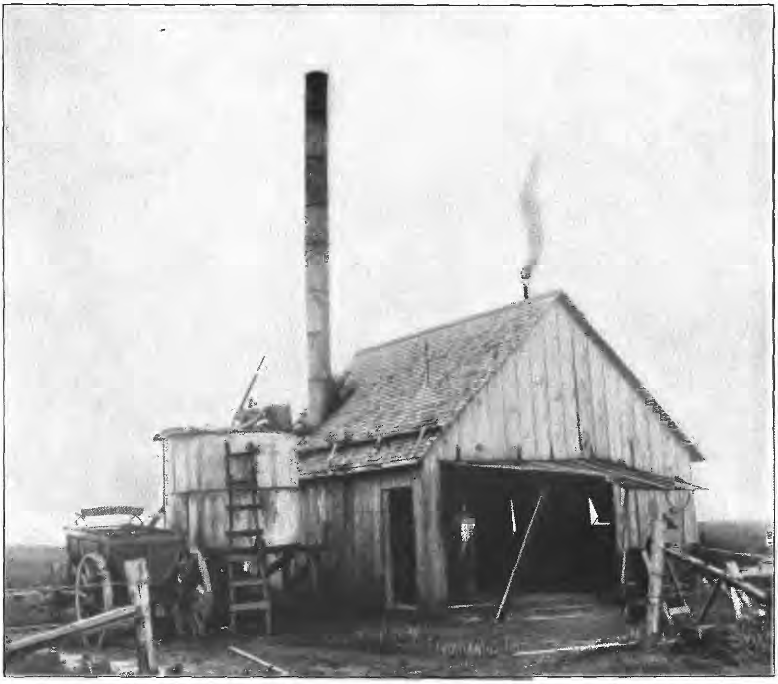
[a] Harris, G. D., and Pacheco, J., The subterranean waters of Louisiana: Rept. Geol. Survey Louisiana for 1902, pt. 6, Special Report No. 6, pp. 236–238.

[b] Bond, Frank, Irrigation of rice in the United States: U. S. Dept. Agr. Exp. Sta. Bull. No. 113, p. 47.



A. MAY PUMPING PLANT, WELSH, LA.

Shows general appearance of small stations throughout the rice district of southwestern Louisiana.

B. PUMPING FROM A 12-INCH WELL ON THE FARM OF A. E. LEE, 8 MILES NORTHWEST OF CROWLEY, LA.

are loaded on special carriages. The lightness of this rig and the consequent facility with which it can be moved from place to place tend to make it popular in regions where depths no greater than 300 feet are to be drilled. For various styles of light derricks see the State survey report already referred to (Pls. XLII and XLIII).

If it is expected that drilling will be carried to a depth of 500 or 1,000 feet, larger, stronger outfits are called for. The great advantage of the taller form of derrick is that in hoisting the drill pipe or casing, whenever necessary, it can be uncoupled two lengths at a time instead of length by length, so that nearly half the labor required to remove or replace the pipe is thus avoided.

Oil wells that reach depths of 1,000, 2,000, or even 3,000 feet are put down by similar but heavier outfits. The derrick is sufficiently high to allow the pipes and casing to be removed three lengths at a time.

SCREENS.

Nearly every driller has his own ideas as to the proper manner of treating or placing the lower end of the casing so that a well may have a free inflow of water and at the same time may not be liable to clog up. Many assert that all ordinary screens are liable to give out and ruin the wells they are in. No screen at all is most satisfactory if the lower end of the pipe is set in very coarse gravel with no mixture of clay or fine sand. Some advocate the pumping out of several tons of finer material from around the bottom of the pipe and the forcing down, in its stead, of several wagonloads of gravel, so as to make a pebble screen.

As a rule, however, some kind of metallic screen is used. Mr. Bond, in the bulletin referred to above, thus describes a common type in use in southwestern Louisiana:

> In the screens now generally used perforations in the well casing are three-fourths to seven-eighths of an inch in diameter, and the distance between centers averages about 1½ inch, the perforated portion being carefully wound with galvanized-iron wire. On 10-inch pipe No. 14 wire is wound nine wires to the inch; on 18-inch pipe No. 16 wire is wound eleven wires to the inch; on 6-inch pipe No. 17 wire is wound fourteen wires to the inch. A common machine-shop lathe is used for winding the wire upon the casing, and the wire is not only wound on tightly, but is soldered in place to prevent its sliding, so as to close openings between strands. Seven rows of solder are placed upon a 10-inch pipe, the number increasing with larger pipe and decreasing with smaller pipe.

Fig. 11 is taken from Bond's work, and represents the casing, holes, wire, rows of solder as he has just described them.

Pl. VI, *B*, shows a different method of constructing a screen. The wires are wound much farther apart than in the type above described. Over the wires is placed fine brass gauze. The pipe is then wound again over the gauze in the opposite oblique direction. The outside coarse wire is mainly to protect the brass gauze, while the inner coarse wire is to hold the same from fitting down tight upon the exterior of the pipe, thus shutting out all ingress of water except immediately over the bored holes.

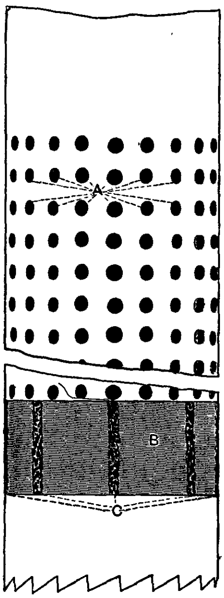


FIG. 11.—A common method of constructing a screen.

Machinists very quickly find it to their advantage to have three to five strands winding at once, side by side, not simply one at a time, as represented in Bond's figure.

The lower end of these pipes is generally closed by a ball valve that is so constructed as to allow the jet of water to pass down and out, but immediately closes against any pressure from below. This is to prevent the entrance of fine sand or other foreign substance.

PUMPING.

As would naturally be supposed, water is pumped from deep wells of southwestern Louisiana by steam power. Formerly the fuel used for generating steam was wood from the nearby lowlands or banks of the bayous or coal brought from Alabama or Kansas City by rail. Since the discovery of oil in such quantities at Beaumont, Tex., nearly all the pumping plants have

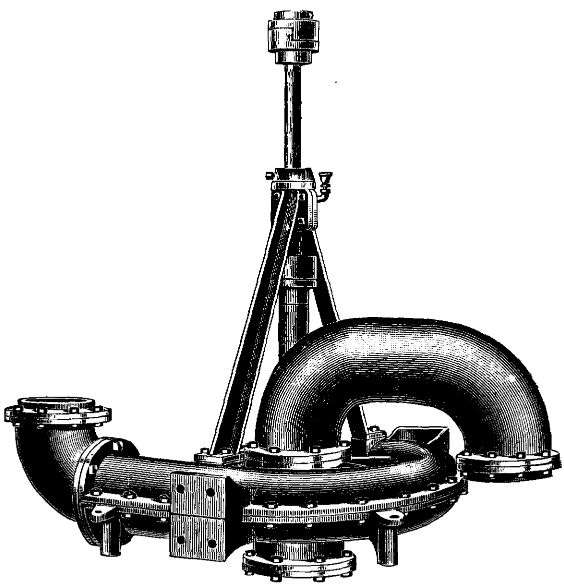


FIG. 12.—Common form of rotary pump. Van Wie model.

erected tanks at an elevation of from 8 to 10 feet above the boiler furnace, and so are able to store and use oil in a very easy and economical manner. However, as the price of oil gradually rises above 80 cents per barrel there is a tendency to return to the old methods and materials for making steam. Pl. VII, *A*, shows a typical small pumping plant of to-day, with its fuel tank and cheap board structure with engine inside.

Pl. VII, *B*, shows the rear of a similar plant. A centrifugal pump (see fig. 12) is on the lower end of the same shaft that carries the band wheel. It is placed in a wooden-curbed well sufficiently low to be beneath the surface of the water at the driest season of the year. When it is not so placed resort must be had to priming every time the pump is started. Around Kinder and China, where the usual head of the water is 25 feet below the surface of the ground, the pumps are depressed to a depth of 25 or 30 feet.

WATER SUPPLIES FROM WELLS IN SOUTHERN LOUISIANA.

By M. L. Fuller.

INCREASED USE OF UNDERGROUND WATER.

The past decade has witnessed a great impetus to well drilling in southern Louisiana, and as the advantages of underground water supplies become better understood, more and more attention will be given to such sources. The use of underground waters for the irrigation of rice has led to the sinking of an unusually large number of wells, especially in the region along the coast, where values in some localities have increased five to ten fold within the last ten years through the reclamation of the land by irrigation. The use of water for this purpose will be considered in detail in the section on "Rice irrigation in southern Louisiana," the present discussion being limited to town, domestic, farm, railroad, and manufacturing supplies.

TOWN AND DOMESTIC SUPPLIES.

Increasing attention is always given to the quality of water supplies as a country becomes older. In the early stages of development the settlements are of small size, and are more or less remote from one another. Even within the villages themselves the houses are generally scattering. Under such conditions a sufficient water supply can usually be had near at hand, either from surface streams, or from springs, or shallow wells, though in some instances a deep supply must be sought from the start. As the country develops and the villages and towns become more crowded the original sources of supply are frequently either exhausted or become too contaminated for use.

Contamination of the shallow wells, where arising from local sources, can frequently be prevented by proper systems of drainage or sewage disposal, but in small communities such systems are often more expensive than a new and deeper system of water supply. Moreover, shallow wells of the open type are not only liable to pollution by the entrance of surface water or of ground water of the surface zone, both of which are often charged with matter derived from stables, privies, cesspools, etc., but receive more or less refuse blown in by the wind from the adjoining yards or streets, while small animals not uncommonly fall into such wells and the water is contaminated by their decaying bodies. The odor and taste of the water in some instances, and the odorous masses of muck removed in cleaning in others, attest the occurrence of large amounts of decaying organic matter. In fact, an open well can seldom be so guarded as to entirely prevent pollution, and although often not especially deleterious to health, the water is rarely equal to that of a driven well of the same depth, from which it is possible to shut out all waters from or near the surface.

In the case of streams, the contamination may not, and in fact usually does not, rest with the community using the water, but with other villages or cities farther up the stream, perhaps in another State. Little can be done in such cases toward removing the sources of pollution, and to secure even a moderately pure supply resort must be had to filtration or other processes of purification, or to deep wells.

In many parts of the country little water can be obtained from deep wells, but in southern Louisiana the conditions are exceptionally favorable for obtaining satisfactory supplies in this manner. Fig. 7, page 28, shows graphically the subdivisions of this portion of the State as regards the occurrence of underground water. It will be noted that there are three definite east-west belts, each of which is bisected by the northwest-southeast belt along Mississippi River. The latter belt, which in area is the largest of them all, is made up of lands consisting mainly of materials deposited by the river in recent geological times, though older deposits sometimes show at the surface. In general it consists of alternations of sands and mucks, all of which carry more or less organic matter. In this area water can be obtained at almost any depth, but it carries a large amount of iron and organic matter, and although used for drinking purposes and for watering stock, has a decidedly deleterious action on health and is a great hindrance to the proper development of the region, especially as the available surface supplies except along Mississippi, Red, and Atchafalaya rivers, Bayou Lafourche, Bayou Teche, etc., are mainly from sluggish streams and bayous (Pl. VIII), which are generally equally bad. Certain of the waters of this belt are, however, sometimes placed on the market as mineral waters, and are used for bathing at several resorts.

The most southerly of the three east-west belts affords the best underground supplies. In this area the water can be obtained at a moderate depth, flows without pumping, and is of good quality. Most of the towns depending for their public supplies on wells (see table on p. 77) are located in this belt. In the middle east-west belt pure supplies are also obtained at no great depths, but in general the wells do not flow. The towns listed in the table mentioned and not situated in the southern belt occur in the middle belt. In the northern belt the land is hilly and abounds in surface streams and springs. Water can be obtained almost everywhere by shallow wells, but does not occur in definite and persistent beds, and is not found in as large quantities as in the more southern belts. It does not often rise to the surface.

The great advantage of the deeper underground supplies is their general freedom from pollution from human sources. A great majority of the cases of typhoid fever, one of the great scourges of this country, appears to be due to impure drinking water. In some instances the number of cases has decreased 75 per cent on the substitution of a pure supply. Malaria, so prevalent in its various forms throughout the South, is believed by many to be largely due to the unsatisfactory quality of the domestic water supplies, although it is probable that poor food and the general unsanitary surroundings have much to do with its prevalence. Whether due to the direct transmission of germs or to a general injurious effect on the constitution, the use of many of the relatively stagnant surface waters certainly adversely affects the health. The substitution of pure underground supplies almost always results in an immediate and marked improvement in health.

To secure a pure underground water supply it is necessary to sink the well to a depth sufficiently great to prevent the possibility of contamination by seepage from the surface zone of the groundwater. The depth will depend largely on local conditions. In general, water obtained from beneath a bed of clay of sufficient thickness to form a barrier to the passage of surface waters, will be entirely satisfactory as far as freedom from contamination is concerned. In flat areas a source of supply 20 to 30 feet below the nearest source of pollution would probably be safe to use if all access to surface waters were cut off by proper casing.

Among the disadvantages of underground supplies are (1) their uncertain distribution and depth, (2) their uncertain quality, (3) the cost of deep wells, (4) the cost of pumping nonflowing wells, and (5) the insufficiency of supply in certain crowded communities and in some irrigable areas. The first two objections are of great importance. The conditions of the occurrence of waters are, however, well understood by those who have investigated them, and valuable information can usually be obtained from the numerous State or national bureaus engaged in the study of the subject. The cost of drilling and pumping deep wells is nearly always greater than the cost of obtaining surface supplies where the latter are at hand, but this is offset in many parts of southern Louisiana by the greater purity and the consequent greater number of uses to which well water can be put, and by the greater number of points at which it can be obtained. Good wells can frequently be obtained at localities far removed from surface sources and in such instances afford the only means of development of the country. The fifth objection is one that is less readily met, but

A CHARACTERISTIC BAYOU OF THE MORE SLUGGISH TYPE IN THE GULF COASTAL REGION.

surface supplies are often subject to the same drawbacks and fail where wells succeed.

In the following table is given a list of the towns and cities in southern Louisiana depending in whole or in part on deep wells for their supplies. Doubtless all of the inhabitants of a given community do not draw upon the public supply; but, on the other hand, the waters are frequently piped beyond the corporate limits. The total number of persons using water from the deep wells in the localities mentioned is, therefore, probably not far from the number indicated by the figures of population, aggregating about 45,000. To these must be added the large but unknown number living in the smaller towns, or scattered throughout the country, who draw their supplies from deep private wells. Many of the more important hotels possess such wells. When it is borne in mind that the amount of sickness and number of deaths is much lower among those using deep waters, and that the productiveness of the State is thereby increased by hundreds of thousands of dollars, the importance of pure water supplies will be appreciated.

Cities and towns depending on deep wells for public water supplies.

[Compiled from Insurance Maps of Sanborn Map Company and other sources.]

Town.	Parish.	Date of information.	Population, 1900.	Number of wells.	Depth of wells.	Method of storage.
Alexandria	Rapides	1900	5,640	2	560, 760	Standpipe.
Baton Rouge	East Baton Rouge.	1903	11,269	2	758, 800	Do.
Crowley	Acadia	1902	4,214	2	170, 270	Do.
Franklin	St. Mary	1899	2,692	2	....	Do.
Jeanerette	Iberia	1898	1,905	1	....	Tanks 60 feet deep.
Jennings	Calcasieu	1903	1,539	1	240	Steel tank on trestle.
Lafayette	Lafayette	....	3,314	3	150, 150, 226	Brick reservoir.
Lake Charles	Calcasieu	1903	6,680	2	....	Standpipe.
Opelousas	St. Landry	1899	2,951	2	(?), 184	Standpipe and reservoir.
Plaquemine	Iberville	1900	3,590	2	....	Elevated tank.
Rayne [a]	Acadia	1903	1,007	1	250	Steel tank on trestle.

[a] System proposed.

The interest exhibited in the problems of pure water supplies is made manifest by a constantly increasing number of analyses, especially those of a sanitary character. A number of analyses, in part sanitary and in part purely chemical, made by the State experiment station [a] are given in the following table:

[a] Rept. Geol. Survey Louisiana for 1902, pt. 6, special report No. 6, pp. 251-252.

Analyses of artesian waters from southern Louisiana.

[Parts per million.]

Name of well.	Locality.	Solid matter.	Ash.	Organic matter.	Albuminoids.	Freeammonia.	Nitrites.	Nitrates.	CaO.	K_2O.	P_2O_5.	Remarks.
A. A. Bayer	Mandeville	208.40	178.4	30.0	0.14	0.04	Trace.	0.8	4.0	4.14	1.19	Colorless, with little suspended matter.
Moresi	Jeanerette	480.0	400.0	80.0	.96	.10	.02	.50	39.40	6.62	.64	Very cloudy.
Moresi (barnyard)	do	417.8	366.8	51.0	.02	1.66	Trace.	1.0	91.0	7.95	4.84	Cloudy.
E. Dessome, at flower garden.	Mandeville	179.4	150.4	29.0	.06	.09	Trace.	.2	2.40	6.46	.59	Perfectly clear.
Mrs. Aubert	Abita Springs	184.0	154.0	30.0	None.	.05	.06	.24	.7	4.80	.74	Do.
Hernandez, by house	Covington	161.6	133.0	28.6	None.	.08	Trace.	.4	15.4	8.27	.69	Colorless, with little suspended matter.
Singletry's still	do	139.0	117.0	22.0	None.	.01	None.	.72	....	7.34	.48	Colorless, with suspended matter.
Lockmore & Co	West Lake / Lake Charles	268.0	214.0	54.0	.10	.01	None.	.20	44.0	3.16	.42	Colorless, with suspended matter (fishy smell).
Bradley & Ramsay Co.	Lake Charles	245.0	219.0	26.0	None.	.09	None.	.20	36.0	4.33	.21	Whitish cloudiness.
Reiser machine shop	do	260.0	235.0	25.0	None.	.08	Trace.	.52	46.5	3.94	.25	Do.
Menafee Lumber Co.	do	271.4	235.0	36.4	None.	.18	None.	.32	33.3	2.52	.42	Slightly cloudy.
Judge E. D. Miller	do	277.0	229.0	48.0	None.	.11	None.	.32	48.2	2.56	.42	Do.
Oaks Hotel	Hammond	185.0	144.6	40.4	.16	.14	.001	.80	5.0	6.98	(a)	Colorless, with suspended matter.
Doctor Robinson	do	187.0	152.0	35.0	.10	.014	Trace.	.28	6.0	.216	3.49	

Owl Bayou Cypress Co.	Strater station	619.0	533.4	85.6	.50	3.08	Trace.	.38	43.30	2.90	3.91
Ponchatoula town well.	Ponchatoula	205.0	179.0	26.0	None.	.07	Trace.	.48	2.0	1.28	1.02
Biegel's overflow (232 feet deep).	do	237.0	198.0	39.0	.205	Trace.	.60	.80	11.50	1.48	6.40
Biegel's pump well (100 feet deep).	do	512.6	450.0	62.6	.20	1.98	.40	1.0	2.0	10.24	11.64

[a] Not enough to determine.

In the above analyses the total amount of solid matter held by the water is indicated in the third column. This solid matter is the residue which is left after the water has been evaporated to dryness, and includes both the suspended matter noted in the last column and matter held in solution. The waters of the table show less foreign matter than is generally found in ground waters, except in the New England States. Iowa ground waters, for example, usually contain from 1,000 to 12,500 parts of residue per million; Illinois waters run from 300 to 1,200, while those of Kansas vary from 1,000 to 7,000 parts. The "ash" column indicates the amount of residue left after the solid matter of the previous column has been heated to a red heat. In the table the difference between the amounts of the ash and the solid matter is given in the third column as organic matter. In reality this is not all organic matter, but includes the volatile parts of carbonates, nitrates, etc., the amounts being, therefore, considerably too large. The figures in the sixth or albuminoid column indicate the amount of ammonia in actual organic combination, while the figures in the free ammonia, nitrite, and nitrate columns represent the amounts in each of the progressive stages through which organic matter passes during its oxidation to mineral matter. No single determination is an absolute indication of the quality of the water, but in general an association of high ammonia and nitrites, especially when associated with high chlorine, indicates pollution by sewage. Most of the waters of the table seem to be of excellent quality, but it is apparent that in a few cases the oxidation of the organic matter has been arrested, while in the case of the 100-foot well in Ponchatoula there are certain evidences pointing to recent pollution. The amounts of calcium oxide do not indicate that the waters are especially hard, and they would probably give rise to only a small amount of scale if used in boilers, even if all of the calcium were in the form of sulphate.[a]

FARM SUPPLIES.

A considerable number of cattle are pastured on the prairies or in the more or less open pine lands throughout southern Louisiana, where they feed on the rich grass which abounds in such places, especially where recently burned over. These cattle find the necessary drinking water in the streams and bayous, artificial provision seldom being necessary. For horses and such cattle, sheep, hogs, etc., as are confined within narrow limits on the scattered farms, however, an artificial supply must often be provided. In a large part of the area this is a simple matter, good water, either flowing or nonflowing, being obtained within a moderate distance of the surface. Pl. V shows typical examples of flowing wells, such as are obtained in the southern portion of the State.

[a] Acknowledgments are due to Mr. M. O. Leighton for portions of the discussion of analyses.

RAILROAD SUPPLIES.

One of the most common and important uses of underground water is for the locomotive supplies of railroads. On every line, usually but a few miles apart, are located the familiar water tanks, each of some hundreds or thousands of barrels capacity. For these, pure supplies must be had. The waters of the bayous and streams are in many instances unsatisfactory for locomotive use, and wells are commonly resorted to. Relatively little difficulty is encountered in southern Louisiana in obtaining water in this way. Except in the Mississippi lowlands, water of a satisfactory quality may usually be obtained in ample amounts at moderate depths. In general, the waters give only slight amounts of boiler scale.

MANUFACTURING SUPPLIES.

Under this head are included both the boiler supplies of manufacturing establishments and the supplies used directly in manufacturing processes. The statements in regard to waters required for railroad locomotives apply equally to boiler waters in other lines. Taken as a whole, such supplies are of great importance, the very existence of the industries of certain localities being largely dependent upon them. The lumber business, with its numerous saw and planing mills, demands supplies of pure water at a great number of points. This water is generally obtained from deep wells. Well waters are also of great importance in many other industries, and as these increase in number, variety, size, and output the economic value of water will proportionally increase.

Of the processes in which water plays a direct and leading part the manufacture of ice is the most important. Many of the cities and towns, including Baton Rouge, Crowley, Covington, Hammond, Jeanerette, and New Iberia, employ well water for this purpose.

RICE IRRIGATION IN SOUTHERN LOUISIANA.

Compiled by M. L. FULLER.

DEVELOPMENT OF RICE IRRIGATION.

One of the newest and most successful applications of irrigation is its use in the cultivation of rice. In 1888 lowlands near the bayous suitable for growing sugar cane, corn, and cotton could be purchased for $3.50 per acre, while the prairie lands back from the bayous could be bought for $1 per acre. With almost the first crop under irrigation the values showed a marked rise, and have continued to increase to the present time. In the first five years the value of the best rice lands rose to $10 per acre, while in 1901 the values reached $30 to $50 per acre.

The productiveness of the crops and the increased values of the land have led to a rapid development, which is still in its earlier stages. Rice land at a distance from railroads and not under canals may still be had for about $15 an acre, and will doubtless yield fair profits if carefully developed. It is with a view of calling attention to the possibilities of rice irrigation that the present description has been prepared. Many of the main facts here presented are taken from the descriptions of Mr. Frank Bond, who investigated the subject for the Office of Experiment Stations, United States Department of Agriculture, and published a report of his investigations as Bulletin 113 of that Bureau. The statistics of the use of wells for rice irrigation, which are brought up to the end of 1902, are presented through the kindness of the Bureau of the Census, Department of Commerce and Labor.

The first people to plant rice in southern Louisiana were the Acadians, who, after their expulsion from Nova Scotia by the English in 1755, settled in considerable numbers in Louisiana and planted small areas to rice. The cultivation, primitive in its methods, was confined to the lowlands along the bayous, the prairies affording pasturage for their herds of cattle. The lowland areas seldom admitted of satisfactory drainage and were too small for profitable cultivation. The crops frequently failed in years of deficient rainfall. Attempts were made to create additional water supplies by building levees across low sags

A. PUMPING STATION ON ONE OF THE LARGER STREAMS OF THE GULF COASTAL REGION.

B. DISCHARGE OF A HEAVY PUMP SYSTEM.

or coulees at points higher than the cultivated areas, but in most cases either the rainfall proved deficient or the capacity of the reservoirs too limited.

Little advance was made over the Acadian methods until a very recent date. Experiments in unusually wet years had served to show that the soils of the prairies were adapted to the growth of rice if sufficient water was at hand. This led to the trial of pumps as a means of raising water from the bayous to the rice fields. So successful was the test that pumps were at once installed at many points, and in a few years tens of thousands of acres of previously nearly worthless land lying from 10 to 70 feet above the bayous were put under cultivation.

The first important pump was installed in 1894. It was a vacuum pump of the pattern used in the mining camps of the Northwest, and was established on the Bayou Plaquemine, in Acadia Parish, near Crowley. Although its failure at a critical time involved the partial loss of the crop, it showed the possibilities of pumping methods. In the following year a centrifugal pump was introduced, but was too small to meet the demands made upon it, and was succeeded in 1896 by a pump having a capacity of 5,000 gallons per minute, which by its success opened a new era in rice cultivation. Still larger pumps have since been introduced, both of the centrifugal and rotary types. These have discharge pipes ranging from 12 to 60 inches in diameter, and raise 20 to 100 cubic feet of water per second through a distance of several feet. In the larger plants batteries of pumps operated by compound Corliss engines of 400 to 800 horsepower are in common use. Pl. IX, *A*, shows the surroundings of a typical pumping plant drawing its supply from a stream or bayou, while *B* of the same plate gives a good idea of the volume of discharge from a powerful battery of pumps.

SOURCES OF WATER.

Bayous.—In the early stages of rice irrigation practically all the water was drawn from the bayous. In the portion of Louisiana devoted to the cultivation of rice these are the channels of the sluggish streams draining the prairies or marshes and not the abandoned or distributary channels of a river, such as those near the Mississippi. In physical aspect, however, they are very similar. The current, though fairly strong at certain seasons, is very weak at others; the slow moving waters resting in channels sunk below the prairies are more or less clogged in many instances by snags of waterlogged stumps, logs, trees, etc., and bordered by dense vegetation, including the constantly encroaching cypress. Notwithstanding the sluggishness of the currents throughout the greater part of the year, however, the bayous maintain deep channels, the bottoms of which, in the region near the coast, are often many feet below the level of the sea.

Wells.—The bayous for a number of years furnished an adequate supply of water for the areas under cultivation, but the increase of acreage, combined with a deficiency of rainfall, as in 1901, brought to the attention of everyone the inadequacy of the supply under such conditions. In that year considerable areas planted to rice had to be abandoned, as the water supply failed, and in many localities the bayous were so lowered that salt water entered and by rendering the supply brackish still further reduced the production. Emphasis was added to the fact already predicted that in dry years considerable areas remote from the bayous would either have to be abandoned or a new supply obtained. Deep wells, however, had already yielded abundant supplies at several points and were now regarded as the key to the situation. A number of the early wells are indicated on a map issued by the Office of Experiment Stations of the Department of Agriculture, and in part reproduced as Pl. XI. To these have been added a number of new wells.[a] The wells shown, however, should be regarded as indicating the locations rather than the exact number, as at the close of 1903 several hundred wells existed where only a few are shown on the map.

IRRIGATION SYSTEMS IN OPERATION.

The following tables give an idea of the extent and importance of the use of well and combined well and bayou systems for the irrigation of rice in Louisiana:

Owners, acreage, and cost of rice irrigation from wells in 1902.

[As reported to the Bureau of the Census.]

ACADIA PARISH.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Cromwell, Wm.	Abbott	160	1	$\frac{1}{4}$	$25.00
Scanlan, Denis J.	do	225	1	1	26.00
Barousse, E.	Branch	200	1	1	24.30
Burns, J. W.	do	200	1		50.00
Edgar, H. F.	do	100	1	$\frac{1}{2}$	26.00
Prosper Bros. & Edgar	do	40	1		18.00
Allen, Robie	Crowley	200	1	2	42.00
Black, R. J.	do	550	2		50.00
Carper, Benjamin F.	do	450	1	$\frac{1}{2}$	67.63
Cromwell, E.	do	450	2		32.00
Cullumber, Chas.	do	300	1		25.00
Ginters, Oscar	do	170	2	$\frac{1}{4}$	19.48
Hoag, Philip H.	Jennings, Calcasieu Parish.	150	1	1	23.20
Jamison, Thomas	Crowley	130	1		10.00
Kraus, George	do	120	1		18.00
Lee, Alonzo E	do	200	1		27.01
Lineberger, Jacob	do	120	1		20.00
Linscombe, John (manager)	do	80	1		30.00
Minga, J. A.	do	430	2	1	42.00
Omealy, Geo. H.	do	520	2	$\frac{1}{4}$	25.25

[a] Information furnished by Mr. A. C. Veatch.

PUMPING PLANT, BAYOU DES CANNES.

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

ACADIA PARISH—Continued.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Portis, J. E.	Crowley	550	3	2½	$52.00
Stokes, Joseph	do	140	1	½	26.50
Waugh, Wm. E.	do	200	1	2	45.00
Wendling, J. and D.	do	200	1		33.00
Wilsey, George W.	do	90	1	½	21.88
Williams, Floyd	do	500	1		40.00
Zambeecher, Wm.	do	300	2		30.00
Shoemaker, J. F. (manager Crowley Farming Co.).	do	480	1	2	58.50
Williams, Thomas and Walter	do	300	1		44.00
Hays, Alton B. and Isaac	do	218	2		35.00
Klumpps, John	Gervais	220	2	½	7.75
Hays, Frank	Iota	150	1		24.00
Nordyke, Harley J	do	160	1		25.00
Robertson, Burrell	do	130	1		6.00
Robinson, Wm. S. and J. J	do	275	2	1	53.00
Romero, A.	Mermenton	80	1		24.45
Bailey, J. F.	Rayne	100	1	1	36.75
Chappuis, A. S	do	200	1	½	24.00
Dupont, Z. N	do	150	1		1.15
Deboral, Emil	do	515	5	1	47.00
Hinen, Wm	do	300	4	1	26.00
Hains & Dumenie	do	450	4	2	25.20
Hensgens, Conrad	do	275	4		25.00
Langdoc, S. N	do	100	1	½	35.00
Lacroix, Francois	do	152	1		24.00
Lege, Lizee	do	300	3	1	21.00
Porter, Leroy	do	475	1	1¼	20.50
Theois, Alois	do	60	1		8.22
Theseis, Jerhard	do	100	1		30.68
Zambeecher, N. J	do	200	1	1	31.80
Bradford, Geo. K	do	100	1		48.00
Snyder, V. (W. K. Andrews, tenant)	Moweaqua, Ill	300	1	1	50.00
Fabacher, Jas. H	Santo	30	1	1	68.25
Frey, John	do	200	1	½	32.00
Girerd & Mouton	do	150	1	2	37.00
Kramer, K	Star	150	2	1	27.00
McNeil, M. W	do	140	1	½	25.50
Remers, Frank	do	125	1		31.00
Hosea & Guidry	Duson, Lafayette Parish.	100	1	½	24.00
Gow, David	Crowley	400	1	1½	55.00
McCormack, Robert	do	200	1	2¾	82.00
Leger, Martin	Eunice	250	3	½	34.00
Simons, H. B	Mermenton	800	4	3	18.00
Bernard & Chappius	Rayne	1,000	1	4	45.00
Gossen, Joseph	do	150	1		26.00
Heinen, D	do	500	4	2	19.00
Heinen, Joseph	do	700	1	3	70.00
Staunn, John F.	do	480	4	1½	.35.00
Jones, W	Star	200	1	1	5.00
McCormic, B	do	200	1	1	5.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

CALCASIEU PARISH.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Gerouard, M. I	Calcasieu	320	1	½	$27.52
Boller, E. L	China	200	1	....	17.46
Bruchaus, William	.....do	50	1	....	21.27
Hebert, M. A	.....do	50	1	....	2.00
Bucklin, S. C	.....do	140	1	½	15.00
Nutt, J. M	Elton	200	1	1	22.50
Pilgrim, John M	.....do	100	1	½	17.00
Baker & Fenton	Fenton	250	1	....	24.00
Day, A. F	.....do	307	1	1	51.00
Fenton, S. J	.....do	220	1	¾	29.00
Miles, C. K	.....do	140	1	½	19.15
Monger, Eliza J	.....do	200	1	....	30.00
Mills, I. J	.....do	250	1	1	28.00
Nicholas, James P. and Rock	.....do	150	1	1¼	39.50
Cluguston, James	Glen	100	1	1	26.03
Peabody, Frank	Fenton	120	1	....	7.00
Webers, A	Iowa	158	1	....	15.50
Arthur, A. M	Jennings	800	1	....	85.00
Bliss, F. E	.....do	75	1	½	24.50
Bryne, Maurice	.....do	100	1	....	21.00
Carr, A. G	.....do	340	1	....	48.00
Cooper, E. W	.....do	220	1	....	45.00
Curtis, C. C	.....do	220	2	1	24.69
Maund, George E	.....do	360	2	....	20.00
Eastman, W. W	.....do	65	1	....	25.00
Garlick, Geo. W	.....do	200	1	½	36.50
Harris, W. E	.....do	300	1	....	37.00
Anderson, Albert	.....do	830	2	1	85.00
Jones, Augustus	.....do	175	1	....	25.50
Jones, Perry B	.....do	320	2	⅛	40.50
Kenny, J. A. (manager)	.....do	600	1	¼	39.00
Marsh, Martin V	.....do	50	1	2	25.00
Maund, James	.....do	150	1	....	26.00
Meyers, John R	.....do	120	1	1½	22.30
Pearl, John	.....do	375	3	....	82.00
Remage, Dr. G. W	.....do	140	1	1	29.00
Roberts, John H	.....do	120	1	....	20.00
Twitchell, V. M	.....do	130	1	....	20.00
White, H	.....do	300	1	....	30.50
Oden, R. E	Kinder	600	3	1	59.00
Cary, Howard L	Jennings	600	5	4	103.50
Garlick, G. W	.....do	240	1	....	27.00
Braden, John E	Lake Arthur	300	1	½	55.00
Camp, R. E	.....do	200	2	....	23.56
Traham, Euzebe	.....do	150	3	½	20.36
Winn, T. H	.....do	850	1	3	150.00
Baker, M. S	.....do	120	1	....	20.50
Wilcason, Dr	Jennings	200	1	....	15.00
Demeist, John B	.....do	122	1	....	33.93
Hamond	Lake Charles	240	1	1¼	43.00
Harlan, A. D	.....do	200	1	....	23.00
Sherman, Mark	.....do	90	1	....	20.05
Raymond, Charles	Raymond	100	1	....	19.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

CALCASIEU PARISH—Continued.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Berry, J	Roanoke	300	1	....	$29.00
Booze, J. M	.....do	300	1	....	75.00
Cary, Dr. C. A. (Auburn, Ala)	.....do	100	1	½	20.00
Clayton, Thomas	.....do	300	1	....	25.00
Diener, John	.....do	150	1	....	27.00
Firestone, O. R	.....do	145	1	....	30.00
Bowers, J. H	.....do	100	1	....	17.45
Firestone, L. N	.....do	155	1	....	31.00
Firestone, J. B	.....do	80	1	....	33.00
Gabbert, W. B	.....do	110	1	....	18.00
Minnix, J. C	.....do	200	2	....	25.00
Robinson, E. T	.....do	130	1	....	12.00
Miller & Sanders Plantation (W. H. Smith, manager).	.....do	200	1	....	35.00
Thomas, David and John	.....do	125	1	1	22.25
Zwick & Son, C. H	.....do	850	1	1	135.00
Abbott, E. S	.....do	500	1	....	57.00
Coffman, J. M	.....do	740	1	1½	95.00
Austin, C. A	Welsh	450	1	....	65.00
Bower, Elmer	.....do	250	2	1⅛	37.00
Cooper, J. W	.....do	90	2	½	19.90
Calkins & Spaulding	.....do	200	1	....	25.00
Coleman, Geo	.....do	160	2	....	16.70
Davis, N. C., and Patterson, A. D	.....do	110	1	....	18.00
Ellis, James	.....do	300	1	....	47.25
Fontenot, J. B	.....do	100	1	....	28.00
Field, C. M	.....do	30	1	....	10.00
Fontenot, H. A	.....do	80	1	....	21.00
Glick Bros	.....do	350	1	1	47.18
Gravel & Sons, M	.....do	100	1	¼	25.55
Heald, Ernest	.....do	200	1	2	42.00
Jeeter, Charles	.....do	140	1	....	31.00
Kelly, N. L	.....do	300	1	....	26.00
Kelley & Prentice	.....do	320	1	½	29.40
McBurney, Wm. and A. R	.....do	900	1	2½	18.50
Moore, F. H	.....do	450	2	1	36.02
Saxby, C. A	.....do	180	2	....	25.00
Scharff, Edward	.....do	500	1	1	47.00
Targart, L	.....do	65	1	....	24.00
Winterton, S. A	.....do	200	3	½	24.28
Whitney, Fred	.....do	200	1	....	22.00
Fox, E. P	Lake Arthur	3,300	10	3	80.00
Krause & Managan	West Lake	150	1	3	42.00

VERMILION PARISH.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Bondreau, Adam	Abbeville	150	1	....	$22.93
Dore, J. O	.....do	300	2	....	33.00
Graham, Wm	.....do	207	3	....	16.25
Le Blanc, Hon. R. P	.....do	240	1	....	41.00
Marchessawe, Edmond	.....do	225	1	1	21.35
Rushmere Planting and Milling Co. (Limited).	.....do	1,200	1	4	100.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

VERMILION PARISH—Continued.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Sirmon, R. G	.....do	125	1	....	16.95
Yantis, W. M	.....do	496	4	3	49.87
Burgon Bros	Gueydan	300	1	....	40.00
Bense & Arnold, Greencastle, Ind	.....do	150	1	7/8	26.50
Fisher, Walter F	.....do	200	1	1	31.80
Freeland, Wm. T	.....do	600	2	....	50.00
Estate of J. P. Gueydan (Henry L. Gueydan, manager).	.....do	1,200	4	....	98.00
Quereaux, Worthy	.....do	240	1	2	30.00
Spencer, W. D	.....do	500	2	....	64.00
McClure Bros. and Taylors	.....do	800	1	....	120.00
Wilkinson, Roy	.....do	200	1	....	25.00
Smith, Alvin	.....do	70	1	1½	12.00
Jones, J. P	Henry	100	1	....	27.00
Stauffer, Chas	.....do	80	1	....	23.00
Romaine & Son, Howard	Kaplan	700	1	2	57.00
Surver, Henry	Indian Bayou	225	5	....	22.50
Broussard, Cæsar	Laurents	150	1	1	9.00
Deihl, Jacob J	Shellbeach	200	1	1½	32.00
Hemingson, Mrs. I	.....do	250	1	½	30.00
Hair, Hausford	Wright	240	2	½	40.50
Peterson, M. W	.....do	100	1	....	20.00
Wright, J. E	Esther	815	4	2½	39.00
Gilmore, Craig	Gueydan	900	3	....	51.50
Laurents, Mrs. G	Laurents	100	1	½	25.50
Laurents, Jules G	.....do	600	3	3½	45.00
Laurents, P	.....do	100	1	....	28.50
Huber, J. F	Perry	700	5	....	60.00

Owners, acreage, and cost of rice irrigation from wells in 1902.

[As reported to the Bureau of Census.]

MISCELLANEOUS PARISHES.

Parish.	Owner of system.	Post-office.	Acreage.	Farms.	Length of main canal.	Total cost.
					Miles.	
Cameron	Hamblin, Albert F	Laurents	60	1	....	$12.00
Do	Bridgeford, Walter F	Lakeside	200	1	....	24.00
Do	Pomeroy and Sons	.....do	100	1	....	28.00
Do	Monroe Rice Plantation	.....do	800	2	5	104.53
Do	Lakeside Irrigation Co	Jennings	3,000	12	12	420.00
Iberia	Loard, Mrs. M	New Iberia	150	1	¾	29.10
Do	Poirson and Roane	Jeanerette	400	1	1¼	54.40
Do	Poirson and Hebert	.....do	200	1	½	41.05
Lafayette	Avant, Berr	Duson	50	1	¼	21.90
Orleans	Funk, John	New Orleans	3	1	....	3.00
Do	Sarradet, J. M	.....do	4	1	....	1.00
Do	Schenck and Son, Michael	.....do	6	1	....	2.70
Do	Seyer, Chas	.....do	1	1	....	.25
Do	Witzel, Mrs. Chas	.....do	3	1	....	2.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

MISCELLANEOUS PARISHES—Continued.

Parish.	Owner of system.	Post-office.	Acreage.	Farms.	Length of main canal.	Total cost.
					Miles.	
St. Landry	Fruge, Azalier	Mamon	405	6	4	52.50
Do	Lafleur, Dorvile	Chataignier	60	3	....	20.00
Do	Bordelon and E. B. Dubuson	Opelousas				
Do	Gus Fusilier and Gaumay	Eunice	200	1	....	40.00
Do	Helms, Lafayette A	.....do	100	1	....	20.00
Do	Miller, Durel	.....do	160	1	....	26.00
Do	Tate, Theodore	.....do	150	1	....	25.00
Do	Woolf, Leon	Washington	130	1	....	21.00
St. Martin	Smedes, C. E	Cades	160	1	....	27.55
Do	Long and Son	St. Martinsville	100	1	¼	16.00
Do	Martin, Dr. J. S	.....do	80	1	....	3.50
Tangipahoa	Hammel, C. H	Hammond	12	1	....	1.85

Number of rice irrigation systems.

[As reported to the Bureau of the Census.]

Parish.	Number of irrigation systems— Supplied with water from— Streams.	Wells.	Streams and wells.	Total.
Acadia	37	59	11	107
Calcasieu	37	93	2	132
Iberia	16	3	....	19
Plaquemines	413	....	....	413
Vermilion	13	27	6	46
Cameron	95	1	4	118
Lafayette		1	....	
Orleans		5	....	
St. Landry		6	1	
St. Martin		3	....	
Tangipahoa		1	....	
All other parishes		1	....	
Total	611	200	24	835

Cost of rice irrigation systems.

Parish.	Supplied with water from—			Total.	Average per acre irrigated, 1902.
	Streams.	Wells.	Streams and wells.		
Acadia	$1,148,630	$182,600	$39,400	$1,370,630	$12.93
Calcasieu	1,482,778	318,880	12,200	1,813,858	13.12
Iberia	89,917	12,455	....	102,372	10.11
Plaquemines	97,077	....	....	97,077	6.93
Vermilion	981,000	105,965	24,950	1,111,915	16.76
Cameron		1,200	57,653		
Lafayette		2,190	....		
Orleans		895	....		
St. Landry	143,199	15,200	5,250	229,457	4.35
St. Martin		4,705	....		
Tangipahoa		185	....		
All other parishes		....	....		
Total	3,942,601	644,275	139,453	4,725,309	12.20

Farms under irrigation for rice.

[As reported to the Bureau of the Census.]

Parish.	Streams.	Wells.	Streams and wells.	Total.
Acadia	543	86	22	651
Calcasieu	419	116	11	546
Iberia	54	3	....	57
Plaquemines	432	....	....	432
Vermilion	450	43	17	510
Cameron		1	16	
Lafayette		1	....	
Orleans		5	....	
St. Landry	186	8	6	237
St. Martin		3	....	
Tangipahoa		1	....	
All other parishes		11	....	
Total	2,084	278	72	2,433

Acreage under irrigation for rice.

Parish.	Streams.	Wells.	Streams and wells.	Total.
Acadia	87,666	13,460	4,880	106,006
Calcasieu	111,636	23,117	3,450	138,203
Iberia	9,376	750	....	10,126
Plaquemines	14,015	....	....	14,015
Vermilion	53,875	9,248	3,215	66,338
Cameron	46,191 (Cameron to All other parishes)	60	4,100	52,769 (Cameron to All other parishes)
Lafayette		50	....	
Orleans		17	....	
St. Landry		800	405	
St. Martin		340	....	
Tangipahoa		12	....	
All other parishes		794	....	
Total	322,759	48,648	16,050	387,457

Lengths of rice canals and ditches in 1902.

[As reported to the Bureau of the Census.]

Parish.	Total length in miles of main canals from well and well and streamsystems.	Total length in miles of ditches of all systems.
Acadia	53	239
Calcasieu	47	291
Iberia	3	12
Plaquemines	....	8
Vermilion	25	108
Cameron	17	50 (Cameron, St. Landry, All other parishes)
St. Landry	4	
All other parishes	....	
Total	149	708

PUMPING.

The different types of pumps in common use have already been mentioned. The centrifugal, which is the prevailing type, is lighter, simpler, more readily established, and cheaper than the rotary pumps, although the latter are more efficient when carefully installed. The total lift of such pumps in raising waters from the bayous to the canals varies from 7 to 35 feet, 20 feet being an average lift. Higher levels require supplementary lifts. Pl. X shows a typical pumping plant on the Bayou des Cannes, Louisiana.

In the case of some of the flowing wells the water can be turned directly into the canals for distribution, but where applied at a higher level than the wellhead, pumps are used for lifting the supply. Where the water rises within a few feet of the surface an excavation is made to such depth that the pump is submerged by the water. In the case of wells of small bore the pumping is generally conducted on batteries of wells located 12 to 20 feet apart, though single wells are sometimes pumped. Great numbers of such batteries have been installed in Calcasieu Parish, where their success has been very marked. Much trouble is caused by sand entering the wells, but this can be largely remedied by screening devices, such as are described on pages 71–72.

The fuel used in pumping is of three kinds: Coal, wood, and oil. In 1901 bituminous coal cost as high as $4.75 per ton; wood, $1.50 to $3 per cord, and oil from 48 to 62½ cents per barrel. The cost of oil was at that time said to be about $1 per acre for the season, while that of coal and wood was from $2 to $3 per acre. Oil now commands a much higher price and there is much less money saved through its use. Coal will doubtless continue to be extensively used in the plants near the railroads, but in localities remote from transportation facilities wood will probably afford the most available supply. Pl. X shows the process of unloading wood from a flatboat by means of a moving belt.

APPLICATION OF THE WATER.

CANALS.

The water received from the pumps or directly from the flowing wells is conducted to the rice fields by canals. These consist of two parallel levees constructed of wet, impervious clays, or clayey loams, free from roots and twigs, between which the water is conducted. Fig. 13 is a cross section of the type of canal which has

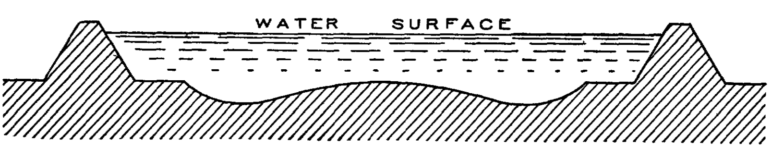
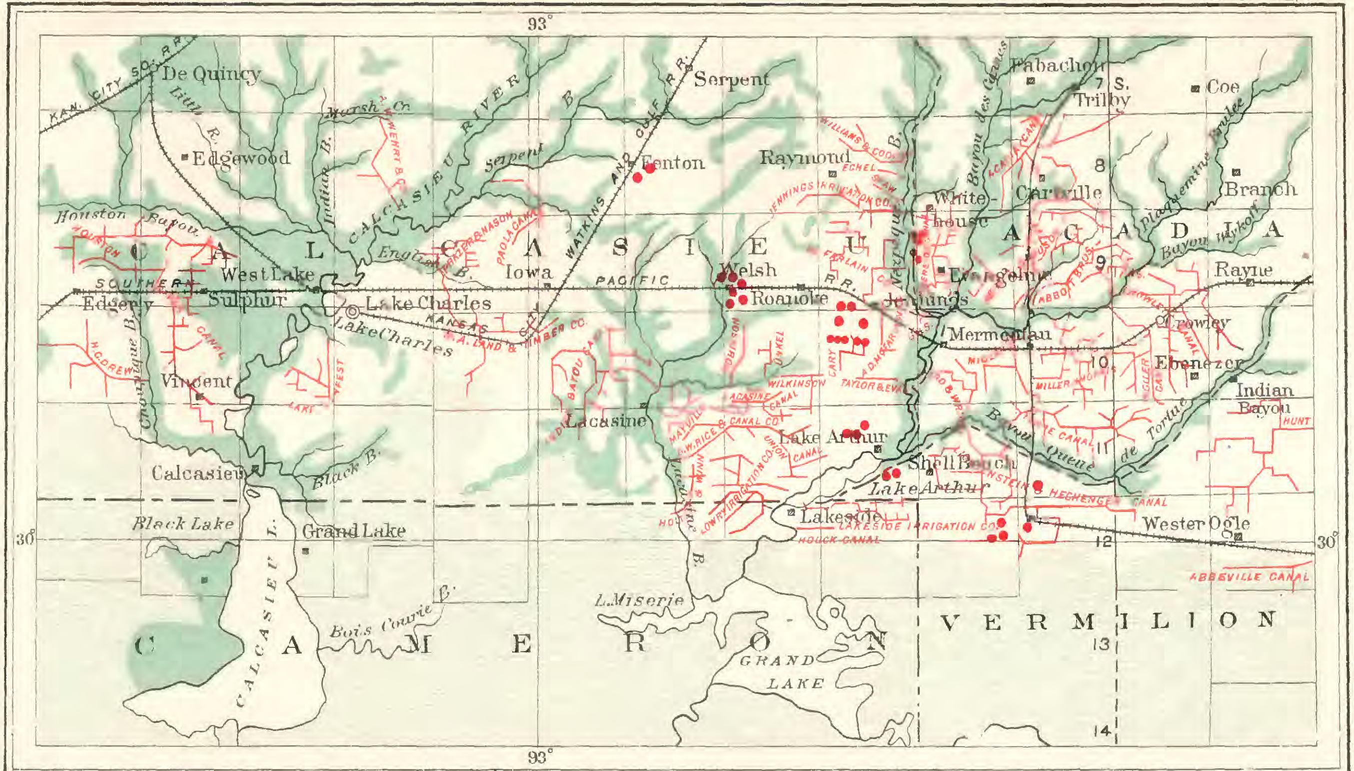


FIG. 13.—Cross section of rice canal.

been found to yield the best results. Care should be taken to remove stumps and to keep out all growth of weeds or other sources of obstruction to the flow of the water. Pl. XI shows the distributary system in the leading rice district of Louisiana.

FIELD LEVEES.

The best form of field levees are low swells, from 15 to 20 feet in width, having the shape shown in fig. 14. They are used to regu-



JULIUS BIEN & CO. N.Y.

CANAL AND WELL SYSTEMS IN SOUTHWESTERN LOUISIANA

Scale

10 0 10 20 miles

Rice canals — Rice wells — Marsh lands — Timbered flood plains — Open prairies

1903

Compiled from Plate I, Bulletin 113, Department of Agriculture late the application of water in irrigation. The advantages of levees of this type over the old high and narrow variety are: (1) They are easily crossed, and without damage, by farm machinery; (2) no land is withdrawn from cultivation by them; (3) the growth of the worthless red rice and of undesirable grasses and plants is largely prevented because of the cultivation of the entire area; (4) they are adapted to the varying slopes of the different types of rice fields.

This kind of levee is more difficult to construct, and before its introduction the fields developed under the old system must be releveled. More levees are also required on sloping ground. In the end, however, its use will probably prove the most economical of the various types.

METHODS OF FARMING.

The type of soil best adapted for the growing of rice is a medium loam, the materials of which are clayey enough to form resistant levees and to support heavy harvesting machinery. Organic matter tends to render the material more porous, and is undesirable where it is to be used for levees.

The land is plowed with gang plows in the fall or spring, sometimes both, then disked and harrowed thoroughly. Planting is done with the broadcast machine attached to an ordinary farm wagon, or the

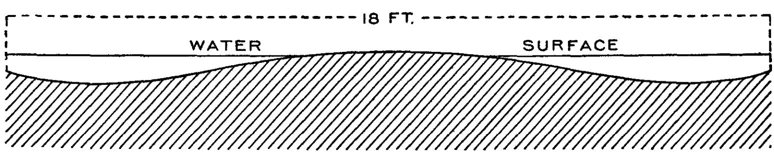


FIG. 14.—Cross section of correct form of field levee.

seed is drilled in rows from 7 to 8 inches apart, the latter method insuring a better crop. During the planting season, which extends from April 1 to June 15, or later, no water is put upon the land, dependence being placed upon rainfall to sprout the seed and promote the growth of the plant for a period varying between one and two months, depending upon the season and water supply. Flooding usually begins when the rice reaches a height varying between 6 and 10 inches, and from this time on until the grain is in the milk and well formed—a period of about seventy days—the fields are kept flooded. In other cases much less water is used. The accompanying diagram (fig. 15) shows the depths of water and dates of flooding of such a field at Crowley.

About ten days before harvest the levees are cut and the fields are drained. The grain rapidly hardens and matures, and by the time it is ready to cut the field is sufficiently dry to permit the use of the reaper and binder. This machine is identical with that used in the grain fields elsewhere in the United States. The sheaves of rice are shocked in the field immediately after the binder, ten sheaves to a shock being the rule, in order that there may be a free circulation of air to dry the straw. When harvesting begins the stalks and leaves of the rice are still green, in the main, but the head is golden yellow on the terminal two-thirds. The green straw properly cured is a valuable substitute for hay, and is baled and fed to live stock, including the work horses and mules, which become accustomed to it, often preferring it to prairie hay. Harvesting begins in September and continues through October and part of November, often until the 1st of Decem-

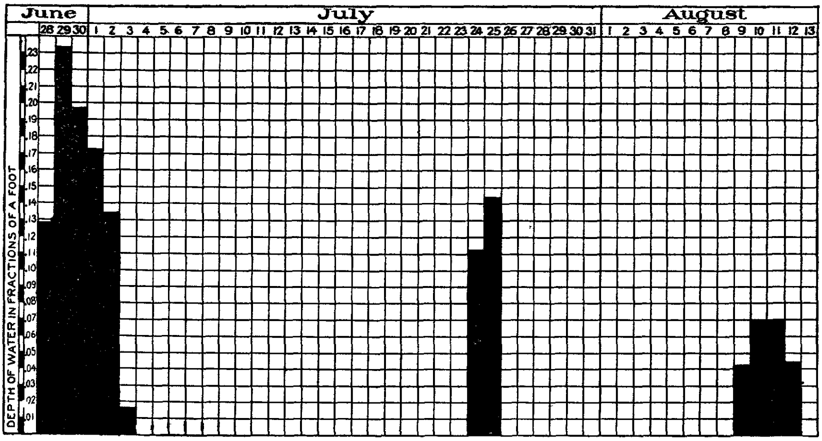


FIG. 15.—Diagram showing depths of water used on rice field at Crowley and dates of irrigation.

ber, and thrashing the rice from the shock begins after it has been allowed to cure and dry for a period of two weeks at least. The machines used are the modern styles of wheat thrashers using steam power, revolving knives for cutting the binding twine, and a blower to remove and stack the straw. The rough rice as it comes from the thrasher is put in large gunny sacks, weighing, when filled, an average of 185 pounds each. The sacked rice is hauled either to the warehouses or directly to the mills.

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O

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but the additional numbers should be added, as received, to the first entry.]

Author.

Harris, Gilbert Dennison.

. . . Underground waters of southern Louisiana, by Gilbert Dennison Harris; with discussions of their uses for water supplies and for rice irrigation, by M. L. Fuller. Washington, Gov't print. off., 1904.

98 p., 1 l. illus., 11 pl. (incl. map). $23\frac{1}{2}^{cm}$. (U. S. Geological survey. Water-supply and irrigation paper no. 101.)

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Water-supply and irrigation papers

no. 101. Harris, G. D. Underground waters of southern La., by G. D. Harris; with discussions of their uses for water supplies and for rice irrigation, by M. L. Fuller. 1904.

Reference.

U. S. Dept. of the Interior.

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WS 60. Development and application of water in southern California, Pt. II, by J. B. Lippincott. 1902. 96–140 pp.
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The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton, Bulletin No. 138.

Series P—Hydrographic Progress Reports.

Progress reports may be found in the following publications: For 1888–89, Tenth Annual, Pt. II; for 1889–90, Eleventh Annual, Pt. II; for 1890–91, Twelfth Annual, Pt. II; for 1891–92, Thirteenth Annual, Pt. III; for 1893–94, B 131; for 1895, B 140; for 1896, Eighteenth Annual, Pt. IV, WS 11; for 1897, Nineteenth Annual, Pt. IV, WS 15, 16; for 1898, Twentieth Annual, Pt. IV, WS 27, 28; for 1899, Twenty-first Annual, Pt. IV, WS 35–39; for 1900, Twenty-second Annual, Pt. IV, WS 47–52; for 1901, WS 65, 66, 75; for 1902, WS 82–85.

Correspondence should be addressed to

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