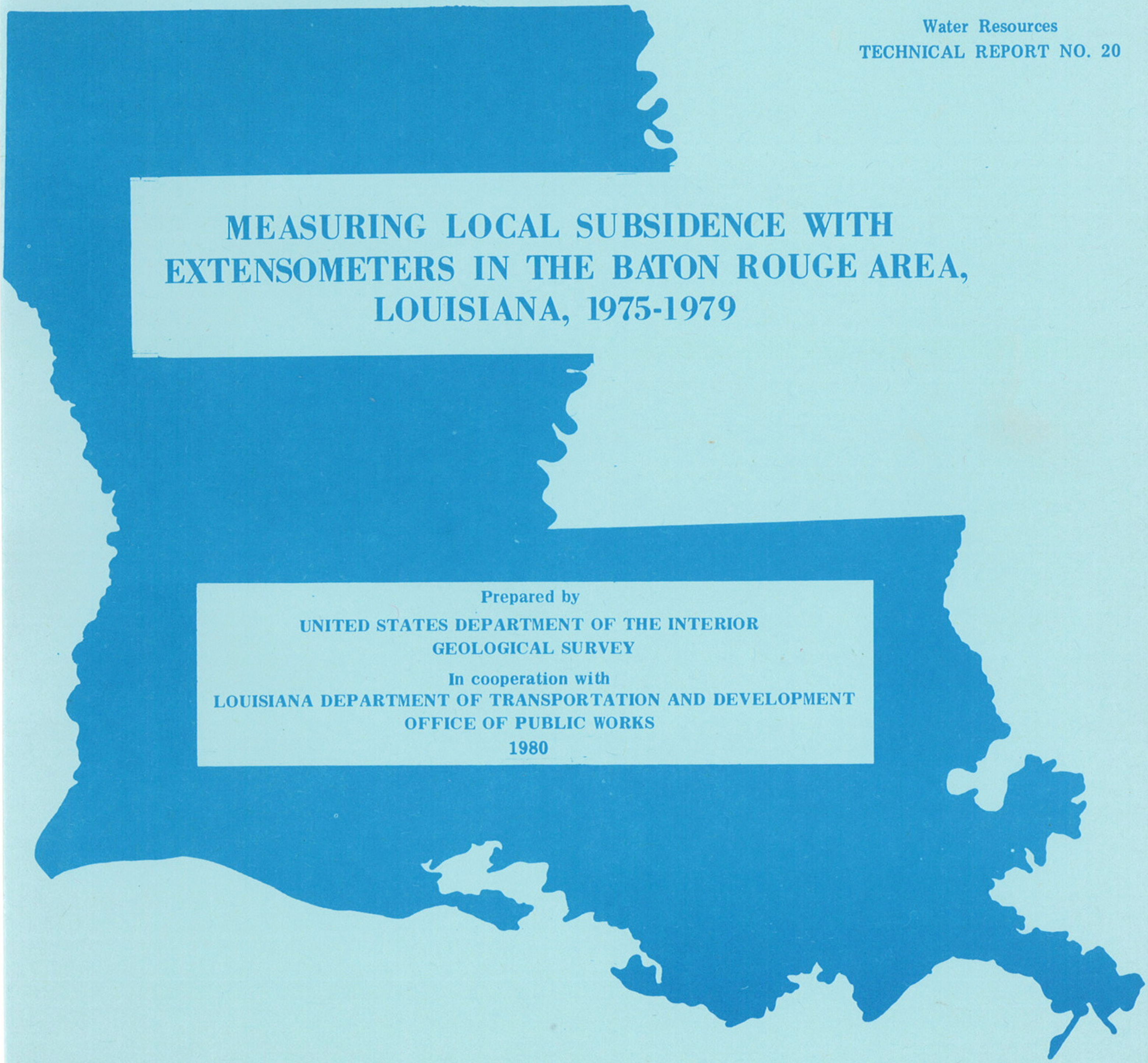
STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS

Water Resources
TECHNICAL REPORT NO. 20



MEASURING LOCAL SUBSIDENCE WITH EXTENSOMETERS IN THE BATON ROUGE AREA, LOUISIANA, 1975-1979

Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
In cooperation with
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS
1980

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By

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U.S. Geological Survey

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) OF METRIC UNITS

Multiply inch-pound units	By	To obtain SI units
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/year)
inch (in.)	2.540	centimeter (cm)
mile (mi)	1.609	kilometer (km)
pound-force per square inch (lbf/in^2)	6.895	kilopascal (kPa)

MEASURING LOCAL SUBSIDENCE WITH EXTENSOMETERS IN THE BATON ROUGE AREA, LOUISIANA, 1975-79

By C. D. Whiteman, Jr.

ABSTRACT

Substantial water-level declines caused by pumping ground water in the Baton Rouge, La., area have resulted in a local cone of land-surface subsidence. Local subsidence of at least 1.26 feet occurred during the period 1935-76, and subsidence averaged 0.035 feet per year, 1964-76.

Three extensometers have been operated since October 1975 at a site near the center of local subsidence in the Baton Rouge industrial district. The extensometers record compaction of the sediments within each of three zones in a 3,000-foot section of alternating sand and clay. The deepest monitor probably records more than 90 percent of the compaction that causes local subsidence. If so, the average rate of subsidence from October 1975 to April 1979 has been less than 0.014 foot per year.

A sharp reduction in industrial pumping in late 1974 allowed water levels of most of the principal aquifers to rise well above levels reached in 1973 and 1974. Water levels of most aquifers in early 1979 are still above the lowest levels reached in previous years, so little permanent compaction is occurring now. A slow decline in the water level of the "2,800-foot" sand and the gradual adjustment of excess pore pressures in thick clays below a depth of about 900 feet are responsible for the small amount of compaction and land-surface subsidence observed since late 1975.

Results of tests on clay cores indicate that the clays of the area are predominantly montmorillonite and mixed-layer clays. Pore water squeezed from the clay cores is more mineralized that water in the freshwater-bearing aquifers but does not appear to threaten significant contamination of the aquifers.

INTRODUCTION

More than 1 ft of land-surface subsidence has been detected in the Baton Rouge, La., area. This subsidence has been caused primarily by pumping ground water for industrial and public-supply uses and is in addition to an average regional tectonic subsidence of about 0.01 ft/yr. As water levels of the major aquifers decline in response to pumping, water drains from interbedded clay beds; and the weight of overlying sediments causes the clays to compact. Most of the observed subsidence is the result of irreversible compaction of clay beds, though a small amount of reversible, elastic compaction also occurs in both the clays and the sands. Thick clay beds between the major aquifers have a high potential for additional compaction if water levels decline farther.

As a result of the observed subsidence, a program was started in 1974 to install monitors to determine the rate and vertical distribution of the compaction that causes subsidence. The study was made by the U.S. Geological Survey in cooperation with the Louisiana Department (now Office) of Public Works and by the East Baton Rouge City-Parish Council through the efforts of the East Baton Rouge Parish Water Conservation Commission.

The current ground-water program in the Baton Rouge area is conducted in cooperation with the Louisiana Department of Transportation and Development, Office of Public Works, and the Capital Area Groundwater Conservation Commission. Monitoring of subsidence in the Baton Rouge industrial area is continuing under this program.

The purpose of this report is to describe the compaction monitors installed--the specifications and construction details of the monitors, the relations of the monitors to the principal aquifers of the area, and the results of tests on core material collected from the wells--and to present the results of the first 4 years of operation of the monitors. The monitors consist of three free-pipe extensometers designed to measure compaction between land surface and depths of 833, 1,700, and 2,997 ft at a site near the center of local subsidence. Compaction and rebound observed since the installation was completed in October 1975 are discussed in relation to water-level trends of the principal aquifers of the area.

Location

The extensometers are located in the east-central part of the Baton Rouge industrial district on property of Exxon Company, U.S.A. The site is on the south side of Gulf States Road about 750 ft west of Scenic Highway and is near the center of land-surface subsidence and pumping in the area. (See fig. 1.)

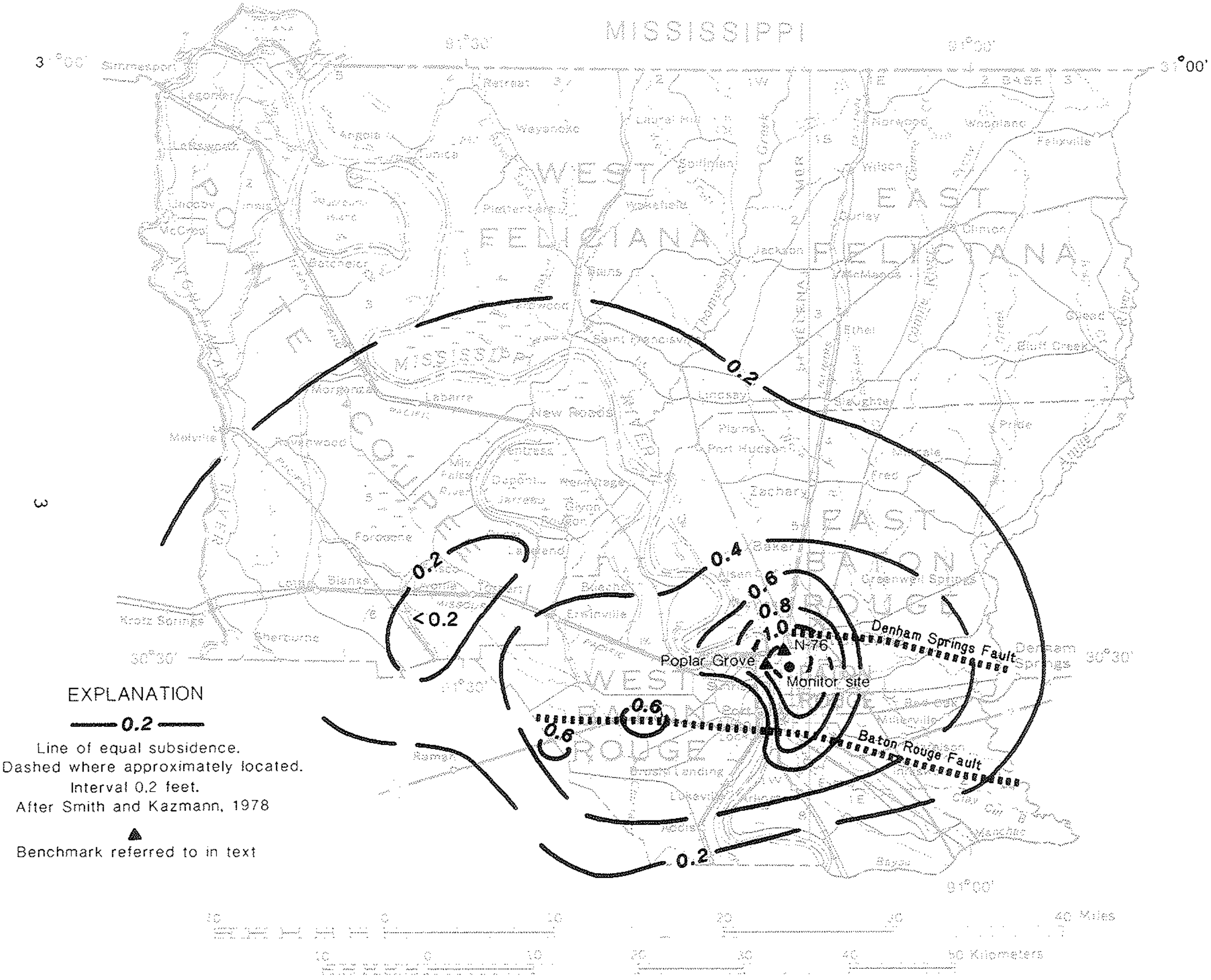

Figure 1.--Location of the extensometer installations and lines of equal subsidence for the period 1934-76.

Previous Work

Land-surface subsidence caused by ground-water pumping in the Baton Rouge area was first reported by Davis and Rollo (1969), who reported a maximum of about 1 ft (30 cm) of subsidence during the period 1900-1965. Kazmann (1970) discussed observed subsidence in general terms and made some estimates of future subsidence. Wintz, Kazmann, and Smith (1970) presented a more detailed discussion of subsidence in the Baton Rouge area, which included the results of extensive releveling work done in 1969, estimates of subsidence that had occurred during various periods including 1964-69, and projections of future subsidence. Smith and Kazmann (1978) compared results of 1976 leveling by the National Geodetic Survey with earlier leveling work and profiles of subsidence for earlier periods given by Davis and Rollo (1969) and Wintz, Kazmann, and Smith (1970). Smith and Kazmann (1978) show local subsidence of at least 0.42 ft in the northern part of the industrial district during the period 1964-76 and 1.26 ft in the industrial district for the period 1935-76. The methods used in each of these reports to determine changes in elevations of benchmarks with time eliminate the effects of uniform regional subsidence, so that only local subsidence is considered. When regional subsidence is mentioned, it is in terms of an assumed average rate--generally considered to be about 0.01 ft/yr.

The reports described above have been aimed primarily at the areal aspect of local subsidence--how much subsidence has occurred at various points in the area and the relation of subsidence to pumping centers. Kazmann (1970) and Wintz, Kazmann, and Smith (1970) speculated on theoretical grounds that most of the observed subsidence was the result of compaction of clays below a depth of 1,000 ft but presented no data to confirm this conclusion or to indicate the depth zones of greatest compaction.

Acknowledgments

Exxon Company, U.S.A. generously provided not only a secure site for the monitor installation but also protective fencing, shell walkways, and continuing maintenance of the grounds at the site. Special thanks are due Mr. M. R. Aubin of Exxon, whose liaison was most helpful at all stages of the design, installation, and operation of the monitors.

THE AQUIFER SYSTEM

Local land-surface subsidence in the Baton Rouge area is occurring in response to pumping ground water from a very thick--more than 3,000 ft--section of alternating sand and clay. Within this section, seven major and five minor aquifers have been designated in the Baton Rouge area. Except for the Mississippi River alluvial aquifer and lenticular shallow Pleistocene sands, the aquifers are named for their approximate depth below land surface in the industrial district near the monitor site. (See pl. 1.) The "400-foot," "600-foot," "1,200-foot," "2,000-foot," and "2,400-foot" sands are the principal aquifers of the industrial district. The "1,500-foot" sand is thin or absent beneath most of the industrial district, but to the southeast it is a major source of water for public supply. The "2,800-foot" sand yields brackish water to two wells in the industrial district, but it is the principal aquifer for both industrial and public-supply uses north of the industrial district through the Felicianas and Pointe Coupee Parish.

Individual sand and clay beds range from a few inches to several hundred feet thick. Although the aquifers vary in thickness across the area and pinch out in places, most are at least 75 ft thick and may be more than 200 ft thick. Clay intervals between aquifers are generally at least 100 ft thick and attain thicknesses of 400 to 500 ft where one or more aquifers pinch out. Although most wells are screened in a single aquifer, some are screened in two aquifers; and a few are screened in three. Water levels in wells in each aquifer fluctuate mostly in response to pumping from that aquifer, though there are some natural hydraulic connections between aquifers and some interactions because of the multiscreened wells.

Water levels in wells in the principal aquifers have been lowered significantly by pumping. Water levels of all aquifers below the "600-foot" sand were above land surface before pumping began. The greatest decline has been in wells in the "2,000-foot" sand, where water levels have been more than 400 ft below prepumping levels for several years. The "2,800-foot" sand--the deepest and most recently developed aquifer--has shown the least decline, with water levels 100-120 ft below prepumping levels. Water levels of the "400-foot" and "600-foot" sands had declined more than 200 ft by the mid-1950's; but pumping from these aquifers has decreased, and water levels have recovered to an average of about 100 ft below prepumping levels.

MONITORING TECHNIQUE

The installation described in this report is designed to divide the sediments affected by pumping ground water into four zones and to obtain continuous records of compaction in three of those zones. Compaction in the deepest zone, below 3,000 ft, can be obtained periodically when level lines are run across the area. The deepest monitor, set in well EB-944 at 2,997 ft, covers about 85-90 percent of the total section undergoing compaction in response to pumping. Because pumping from the zone below this is relatively limited and distant, the deepest monitor should be recording at least 90 percent, and probably more than 95 percent, of the total compaction resulting from ground-water pumping. Natural regional subsidence is generally estimated to average about 0.01 ft/yr in this area. Most of the regional subsidence probably occurs far below the deepest monitor anchor and would not affect the observed compaction. However, any component of regional subsidence occurring above a depth of 3,000 ft would be included in the compaction recorded by the monitors.

The shallowest monitor, set in well EB-945 at 833 ft below land surface, monitors compaction between land surface and 833 ft. Although it is believed that little permanent compaction is occurring in this zone under present conditions, monitoring of this zone is necessary to determine the amount of compaction in the deeper zones. The intermediate-depth monitor, set in well EB-946 at 1,700 ft below land surface, divides the interval 833-2,997 ft into two zones. The difference in the amount of compaction shown by the shallow and the intermediate-depth monitors is the amount of compaction within the 833- to 1,700-foot zone. Similarly, the difference in compaction shown by the intermediate and deep monitors is the amount of compaction within the 1,700- to 3,000-foot zone.

The installation is designed to provide information on the rate of compaction of the sediments within each zone in response to water-level declines in that zone before land subsidence becomes a serious problem. If subsidence does increase to the point that problems develop, knowledge of the response of the sediments within each zone to changes in water levels will be vital for successful resolution of the problems at minimum cost.

No additional monitor installations are planned at the present time (1979) because subsidence is not great enough or rapid enough to justify additional monitoring. If future water-level declines are sufficient to cause a sharp increase in subsidence, or if the area affected by large water-level declines increases significantly, additional monitors may be installed to provide areal coverage.

SITE SELECTION

An extensometer installation was desired near the center of maximum observed subsidence in order to measure the maximum rate and amount of compaction. Maximum compaction will probably occur in the area of greatest water-level decline. The long-term nature of the project required a site as secure as possible from vandalism, accidental damage, or disturbance by nearby construction.

After it was decided that the most favorable site, on the basis of observed subsidence and maximum water-level decline, was in the east-central part of the industrial district, officials of Exxon Company, U.S.A. were asked if their company could provide a suitable site. They responded by providing a site in the northeast corner of the refinery property. This site is in a nearly ideal location, is protected by the plant-security system, and is well away from any probable future construction.

THE TEST HOLES

The first hole, EB-944, was drilled and logged through the entire freshwater-bearing section and into the saltwater-bearing lower part of the "2,800-foot" sand. A contact-caliper log was made for detailed resolution of thin sand and clay beds; spontaneous potential, single-point resistance, and gamma-ray logs were made for correlation purposes. Conventional cores for laboratory analysis were taken during the drilling of the lower part of this hole, below the expected depth of the intermediate monitor, using a double-tube core barrel. Core recovery was poor, in part because of the lack of a nearby electrical log to guide selection of optimum coring points. Core recovery from the upper part of the section in the intermediate-depth hole, EB-946, was much better. No cores were taken in the shallowest hole, EB-945. In all, 13 conventional cores were attempted, and seven cores were obtained. Unfortunately, most of the cores were later found to have been damaged by rotation of the inner core barrel, and the complete suite of intended tests could be run on only one core.

Sidewall cores were taken in the first test hole, following the logging, to provide additional coverage of clay-mineral composition of both the thick clay sections between aquifers and the thin clay interbeds within the aquifers.

A prime requirement of a free-pipe extensometer installation is that the inner pipe be free to move within the outer pipe with a minimum of friction or interference. To reduce interference to a practical minimum, the specifications called for a maximum deviation of the hole of 1° from vertical. Inclination surveys were made at intervals of not more than 100 ft during the drilling of each hole. Although doubts had been expressed about being able to maintain less than 1° deviation, no problems were encountered in maintaining this standard. The maximum observed inclination was 3/4°, and most surveys showed inclinations of less than 1/2°.

THE WELLS

Each of the three extensometer wells is completed as a combination free-pipe extensometer and water-level observation well. Free-pipe extensometers were chosen in preference to the anchored-cable type because experience in other areas of the country indicated that they give more reliable records and have a longer trouble-free life.

Construction details of the monitor wells are shown in figure 2. A 16-inch hole was first drilled, and 12-inch welded pipe was cemented in place as surface casing. The original intent was to remove the surface casing after the well was completed, but none of the surface casings could be pulled with the equipment available. An 8 3/4-inch hole was then drilled to slightly below the anticipated final depth of each well, and a cement plug was set at the bottom of the hole to provide a solid footing for the extensometer pipe. After allowing time for the cement to set, the hole was cleaned out and drilled down to hard cement.

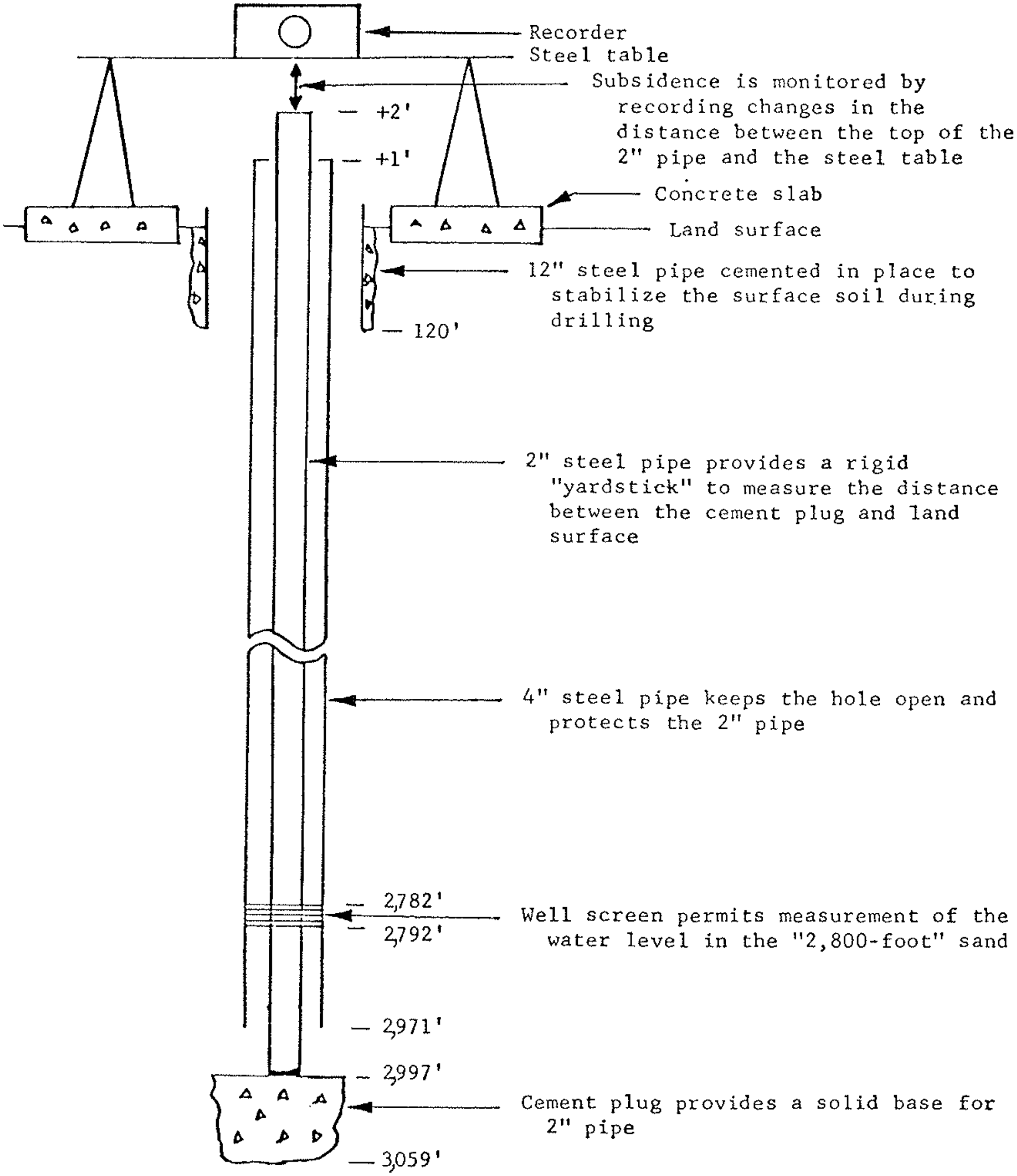

Figure 2.--Construction diagram of extensometer well EB-944.

Galvanized 4-inch pipe was used for the outer casing of each well with 10 ft of 4-inch stainless steel well screen positioned opposite one of the major aquifers. A back-pressure valve was loosely installed at the bottom of the 4-inch pipe to aid in development of the observation well. The bottom of the 4-inch casing was suspended several feet above the top of the cement plug to avoid any downward pressure on the plug. After the observation-well screens were developed by backwashing, surging, and pumping, a water sample was collected for chemical analysis. The completed installation and the relationships of the extensometer and observation wells to the major aquifers of the area are shown on plate 1.

Next, the 2-inch galvanized pipe for the extensometer was lowered into the well until the back-pressure valve was contacted. The back-pressure valve was then unscrewed or driven out, and the 2-inch pipe was lowered to contact the cement plug. Solid contact with the plug was assured by repeatedly dropping the pipe a short distance until it was hitting solidly and would not go deeper. Heavy-duty collars were used on the 2-inch pipe for strength and to reduce clearance between the 2- and 4-inch pipes. The reduced clearance keeps the 2-inch pipe as straight as possible within the 4-inch pipe and reduces the tendency of the inner pipe to wedge or bind against the outer pipe.

After work on the wells was completed, the site was restored and allowed to settle for several months. A 10-inch-thick reinforced concrete slab was then poured around each well, with care being taken to isolate the slab from the surface casing. The recorder shelters were then constructed and the recorders were installed. The wells were drilled and completed during the period October 1974 to March 1975, and the recorders were installed in October 1975.

THE RECORDER INSTALLATION

The recorders are bolted to steel tables that are rigidly attached to the concrete slabs. The slabs are free to move as the land surface subsides or rebounds. The 2-inch pipe, on the other hand, is supported only by the cement plug at its base, so the top of the 2-inch pipe remains at a fixed height above the plug. When the land surface subsides, the top of the 2-inch pipe appears, in effect, to rise in relation to everything around it. Compaction and rebound are monitored by recording changes in the distance between the top of the 2-inch pipe and the recorder, which moves with the concrete slab.

Temperature changes do not measurably affect the operation of the system. Expansion or contraction of the steel 2-inch pipe in response to a change in temperature is negligible and partly compensated by expansion or contraction of the steel table legs. Any uncompensated difference in expansion or contraction is less than the sensitivity of the recorder and, in any event, would produce only a low level of "noise" in the system and no cummulative error.

The recorders are Stevens[1] type F water-level recorders that have been modified to increase their sensitivity. Movement to be recorded is amplified by a factor of 10, and backlash is eliminated from the recorder gear train by an added counterweight. The resulting charts can be read to 0.0001 ft with an overall accuracy of about 0.001 ft.

THE CORES AND TEST RESULTS

Although most of the conventional cores were found to have been damaged by twisting or shearing from rotation of the core barrel, the clays and pore water in the interior of the cores were not affected by contact with mud or mud filtrate. The sidewall cores, though much smaller, likewise contain clay unaffected by mud or mud filtrate in the interior of the core. Tables 1, 3, and 4 give the results of tests on the core material obtained from the monitor wells.

Soon after the monitor installation was completed, an opportunity arose to obtain sidewall cores from a deep, privately drilled, test well (EB-972), about 3 mi to the south. Sidewall cores were taken in the interval 410-2,685 ft to determine if the clay composition of the cores from the monitor site was representative of the composition in the general area. Mineralogic determinations for these sidewall cores are given in table 2.

The principal point of interest regarding the mineralogy of the samples is the high percentage of montmorillonite and mixed-layer (illite-montmorillonite) clay minerals. (See tables 1 and 2.) These are "swelling" clays that can be expected to have a much higher potential for compaction under load than nonswelling clays such as illite and kaolinite. The samples also contain a high proportion of quartz, which is consistent with the observation that most of the samples contained relatively large amounts of silt and very fine sand.

The pore-water analyses (table 3) indicate the quality of the water that is being squeezed from the clays. Although the water is more highly mineralized and has a much higher concentration of sulfate than normal water from the principal aquifers of the area, pore water from the clays does not appear to represent a potential source of significant contamination of the freshwater-bearing aquifers. The three most highly mineralized samples were all squeezed from pieces of the deepest core, taken between 3,052 and 3,059 ft below land surface, where the overlying and underlying sands contain brackish to salty water.

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[1] The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

MONITORING RESULTS

Compaction and rebound measured during the first 4 years of operation of the monitor installation are shown by the graphs on plate 2A. The graphs indicate that earlier assumptions made on theoretical grounds (Davis and Rollo, 1969, p. 184; Wintz and others, 1970, p. 13) are correct, and that most of the recent subsidence has been the result of compaction of clays below a depth of 800 ft. On plate 2A the records for each monitor were started from a common point, and the divergence of the curves shows the differential movement (compaction or rebound) in each zone.

Nearly 0.1 ft of elastic compaction and rebound and little or no long-term compaction are shown by the shallowest monitor well, EB-945, for the zone between land surface and 833 ft. The zone between 833 and 1,700 ft below land surface has undergone about 0.02 ft of compaction, probably mostly permanent. The deepest monitored zone, 1,700 to 2,997 ft below land surface, has undergone slightly more than 0.03 ft of compaction.

OUTLOOK FOR THE FUTURE

The most significant finding of the first 4 years of monitoring is the relatively low rate of permanent compaction that is occurring. The indicated rate for the entire monitored section is a little more than 0.01 ft/yr. If the assumption stated earlier is correct--that the deepest monitor is responding to more than 90 percent of the total compaction resulting from pumping water from the area--the average rate of local subsidence at the monitor site has been less than 0.014 ft/yr during the period of record.

The indicated rate of subsidence of less than 0.014 ft/yr, 1975-79, is significantly less than rates calculated for earlier periods on the basis of releveling of benchmarks. Davis and Rollo (1969) indicate average subsidence rates of 0.015 ft/yr at benchmark Poplar Grove for the 1900-1964 period and 0.029 ft/yr at benchmark N-76 for the 1935-65 period.[2] They also suggest a strong possibility that subsidence was concentrated near the end of the period, which would indicate a higher rate than the average during the 1960's. An average subsidence rate of 0.046 ft/yr at benchmark N-76 is indicated by Wintz, Kazmann, and Smith (1970) for the period 1964-69. Smith and Kazmann (1978, p. 21) calculate an average subsidence rate of 0.035 ft/yr at benchmark N-76 for the 1964-76 period.

The present low rate of compaction indicated by the monitors can be explained by an examination of recent water-level changes in the area

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[2] Benchmark N-76 is about 1.5 mi northwest of the monitor site, and benchmark Poplar Grove is about 2 mi west of the monitor site on the west bank of the Mississippi River. (See fig. 1.)

(pl. 2B). The rates of subsidence determined by releveling of benchmarks include periods in which water levels in most of the principal aquifers of the area were declining sharply. The compaction monitors, on the other hand, have been operating during a period when water levels have been relatively stable. In late 1974 and early 1975 a sharp reduction in pumping for industrial use led to a rise or stablization of water levels in wells in most of the principal aquifers. The decrease in industrial pumping has been large enough to offset continued increases in pumping for public supply since 1975, and water levels in wells in most of the major aquifers of the area are higher now than in the early 1970's.

With water levels relatively stable, the observed compaction is probably primarily the result of continued adjustment of pore pressures in the very thick clays of the area to water-level declines that occurred before the monitors were installed. Although no measurements have been made of the pore pressures in the interior of the thick clays separating major aquifers, it is certain that the pressure in the clays below about 800 ft is still much higher than the water levels in the adjacent aquifers. A small amount of compaction may result from a gradual--about 3 ft/yr--continuing decline in the water level of the "2,800-foot" sand. If water levels stabilize at their present levels, compaction should continue at a gradually decreasing rate for many years until the excess pore pressures dissipate. If water levels resume their declining trend, which seems likely to happen as a result of population growth, even if industrial pumping remains relatively low, the rate of compaction will increase again as water levels fall below their earlier levels.

Previous reports on subsidence in the Baton Rouge area discussed preconsolication of the clays and emphasized that water levels in some of the principal aquifers were reaching levels approaching the probable level of preconsolidation stress. Preconsolidation stress is the maximum stress to which a deposit has been subjected in the past. Changes in stress below the preconsolidation stress cause small elastic deformations of the deposit. Stress increases beyond the preconsolidation stress produce large inelastic (nonrecoverable) deformations in fine-grained materials. If water levels do decline to the preconsolidation level, additional water-level decline could lead to an abrupt increase in the rate of subsidence. One of the objectives of taking cores from the test wells was to determine the preconsolidation stress by laboratory tests, but damage to the cores prevented these tests. Thus the preconsolidation stress is still unknown, but the monitor installation should be able to detect the increase in the rate of compaction that will occur if water levels decline below the preconsolidation level in the future.

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HYDROLOGIC DATA

Tables 1-4

Table 1.--Mineralogy of core material from the extensometer wells

[All analyses by U.S. Geological Survey Hydrologic Laboratory, Denver, Colo.]

Depth (ft)	Type of core[1]	Percentage by weight										
		Quartz	Potassium feldspar	Plagioclase feldspar	Calcite	Dolomite	Chlorite	Kaolinite	Illite	Montmorillonite	Mixed-layer clay minerals	Total
447- 455	C	38	3	3	0	0	0	6	8	12	39	109
530	S	32	5	9	--	--	--	5	8	22	20	101
821	S	34	5	7	--	--	--	3	4	36	10	99
843- 854	C	35	5	5	0	0	0	2	2	20	36	105
1,285-1,291	C	44	0	3	0	0	0	5	3	36	21	112
1,394	S	42	5	5	--	--	--	5	11	16	25	109
1,499	S	27	3	5	0	0	0	5	2	19	40	101
1,660-1,665	C	35	3	3	0	0	0	4	6	14	29	94
1,665-1,670	C	24	4	2	7	0	0	5	5	9	41	97
2,113-2,116	C	38	4	3	0	0	0	6	6	14	34	105
2,113-2,116	C	39	4	4	0	0	0	5	6	12	30	100
2,116-2,119	C	32	2	4	0	0	0	6	5	10	32	91
2,116-2,119	C	29	1	4	1	0	<1	6	9	5	26	81
2,130	S	14	0	2	--	--	--	9	8	14	44	91
2,459-2,464	C	34	0	5	0	0	<1	6	9	8	26	88
2,497	S	40	5	7	--	--	--	5	6	16	24	103
2,549-2,559	C	8	0	1	50	0	0	2	3	7	18	89
2,657	S	12	4	4	--	--	--	9	15	20	41	105
2,816	S	28	5	5	0	0	0	3	4	16	33	94
2,991	S	19	0	3	0	0	0	7	7	15	34	85
3,052-3,059	C	27	5	6	0	2	0	2	3	11	37	93

[1] C, conventional core; S, sidewall core.

Table 2.--Mineralogy of sidewall cores from well EB-972, about 3 miles south of the extensometer installation

[All analyses by U.S. Geological Survey Hydrologic Laboratory, Denver, Colo.]

Depth (ft)	Percentage by weight								
	Quartz	Potassium feldspar	Plagioclase feldspar	Calcite	Kaolinite	Illite	Montmorillonite	Mixed-layer clay minerals	Total
410	25	3	3	0	4	6	16	37	94
750	34	3	4	0	5	4	18	37	105
1,030	33	4	9	0	3	3	23	27	102
1,100	47	4	8	0	4	3	19	22	107
1,246	38	2	2	0	4	3	14	29	92
1,295	34	2	4	0	5	3	23	29	100
1,385	36	2	4	0	6	5	18	28	99
1,670	41	3	5	0	5	4	24	25	107
1,725	26	1	4	0	4	4	19	26	84
1,775	40	1	3	0	6	3	24	25	102
1,905	35	2	3	0	4	2	29	19	94
2,075	28	2	4	0	4	4	16	26	84
2,282	34	2	6	0	6	3	19	24	94
2,366	26	2	4	0	6	3	13	26	80
2,456	34	2	4	4	4	1	24	24	97
2,685	28	<1	2	0	8	6	15	40	99

Table 3.--Chemical composition of water squeezed from cores

[Analyses by U.S. Geological Survey Central Laboratory]

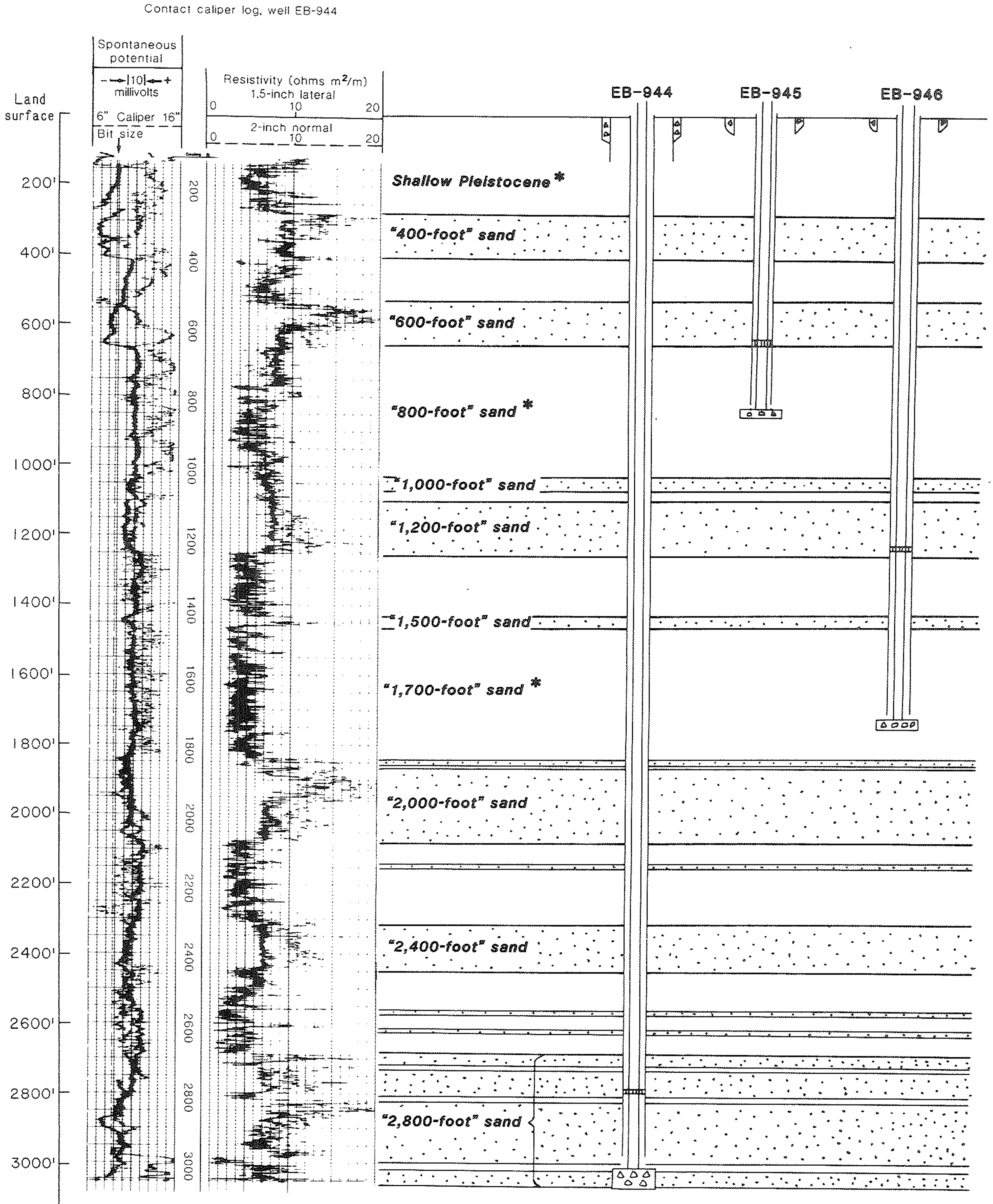
Depth interval (ft)	Specific conductance (micromhos/cm at 25°C)	Dissolved constituents, in milligrams per liter							
		Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Iron[1/]
447- 455	590	22	3.0	92	2.7	160	69	49	<10
447- 455	520	16	3.0	85	1.7	130	50	40	<10
843- 854	890	16	.0	210	4.8	312	160	56	400
843- 854	1,000	16	1.4	200	6.4	281	120	110	600
1,660-1,665	------	47	.0	310	10	---	210	130	1,000
2,116-2,119	2,350	19	4.5	590	10	670	590	195	600
2,549-2,559	2,300	6.6	2.5	540	10	670	530	80	950
2,549-2,559	2,100	3.8	1.5	470	8.9	580	500	72	600
2,549-2,559	------	33	5.0	690	13	---	1,200	100	500
2,549-2,559	2,480	9.4	2.5	590	8.0	450	850	75	250
3,052-3,059	14,200	240	41	3,000	43	610	2,000	3,900	200
3,052-3,059	13,300	134	32	1,500	35	530	2,200	1,600	100
3,052-3,059	------	118	32	7,400	30	530	2,400	8,600	<10

[1/] Micrograms per liter.

Table 4.--Vertical hydraulic conductivity and specific storage of clay cores

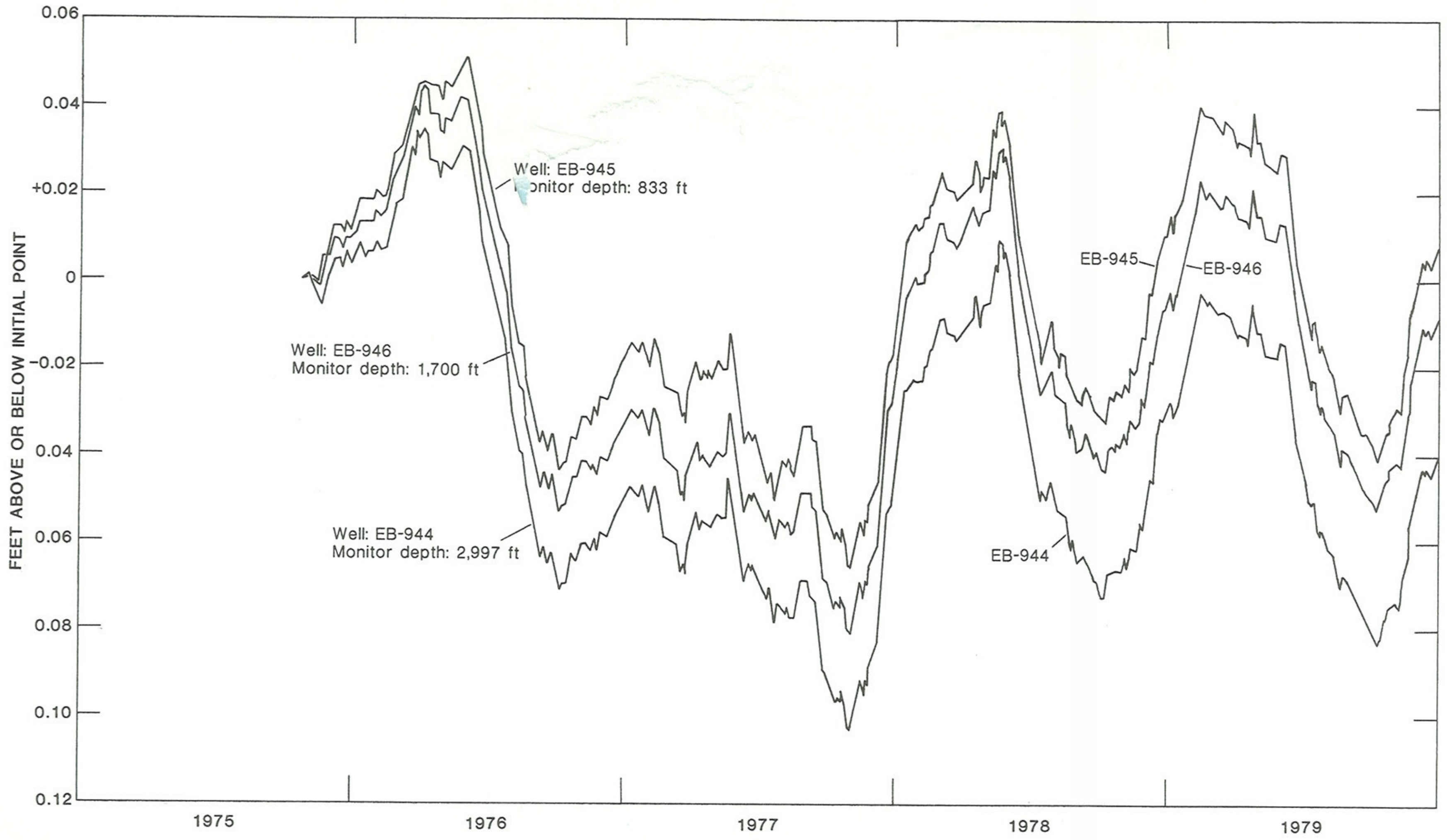
[Analyses by U.S. Geological Survey Hydrologic Laboratory, Denver, Colo.]

Depth interval (ft)	Vertical hydraulic conductivity (m/d)	Field effective stress, calculated (lbf/in^2)	Specific storage, elastic range (ft^{-1} at indicated lbf/in^2)	Specific storage, inelastic range (ft^{-1} at indicated lbf/in^2)
447- 455	$3.3x10^{-7}$	335	$3.5x10^{-5}$ at 330	$6.3x10^{-5}$ at 377
2,113-2,116	$5.1x10^{-6}$	1,130	$1.6x10^{-5}$ at 1,120	--------------
2,549-2,559	--------	1,340	$3.3x10^{-5}$ at 1,340	--------------
3,052-3,059	--------	1,580	$3.6x10^{-5}$ at 1,180	--------------

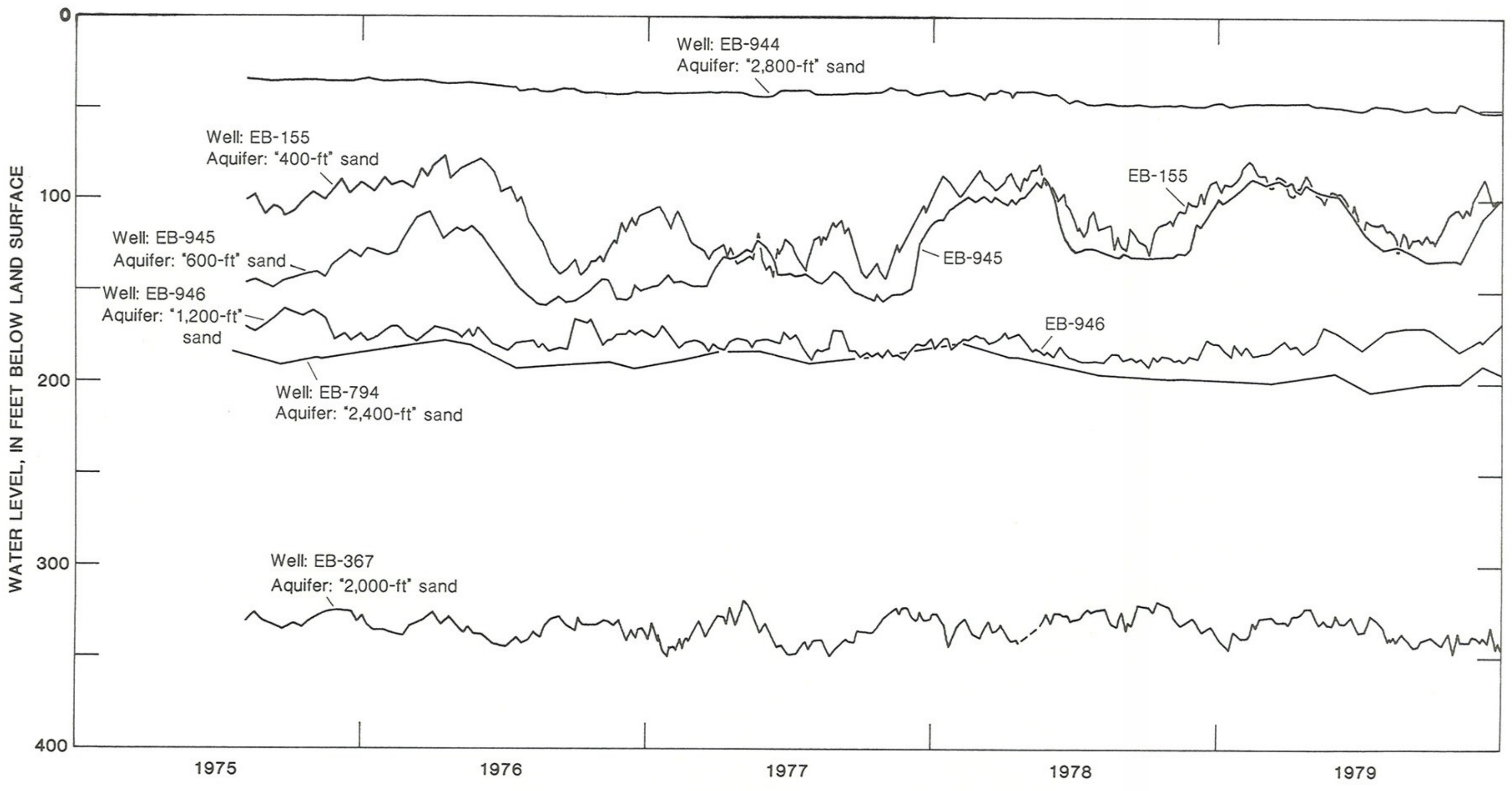


* Sand missing at this location

PLATE 1. THE RELATION OF THE EXTENSOMETERS AND WELL SCREENS TO THE AQUIFERS OF THE BATON ROUGE AREA.



A. Measured compaction and rebound at the monitor site.



B. Water levels of the principal aquifers present at the monitor site.

PLATE 2. GRAPHS SHOWING COMPACTION AND WATER LEVELS AT THE MONITOR SITE.