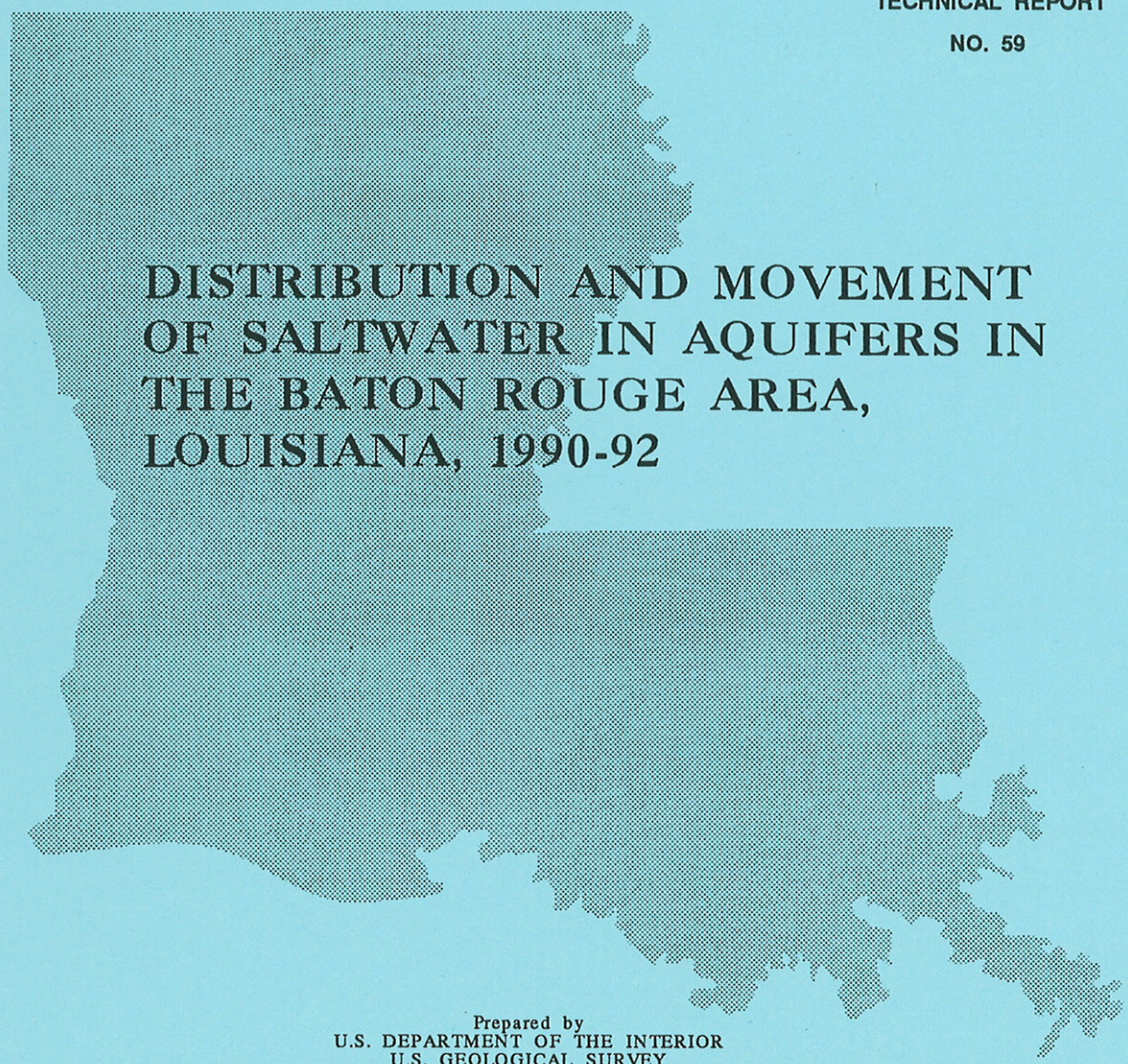
STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
PUBLIC WORKS AND FLOOD CONTROL DIRECTORATE
WATER RESOURCES SECTION

WATER RESOURCES
TECHNICAL REPORT
NO. 59

DISTRIBUTION AND MOVEMENT OF SALTWATER IN AQUIFERS IN THE BATON ROUGE AREA, LOUISIANA, 1990-92



Prepared by
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
In cooperation with
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
and
CAPITAL AREA GROUND WATER CONSERVATION COMMISSION

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By

Dan J. Tomaszewski

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Published by
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
Baton Rouge, Louisiana

1996

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNIT

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per foot (ft/ft)	0.3048	meter per meter
foot per day (ft/d)	0.3048	meter per day
foot per year (ft/yr)	0.3048	meter per year
foot per mile (ft/mi)	0.1894	meter per kilometer
cubic foot (ft3)	0.02832	cubic meter
million cubic feet (Mft3)	0.02832	million cubic meters
mile (mi)	1.609	kilometer
square mile (mi2)	2.590	square kilometer
gallon per day (gal/d)	0.003785	cubic meter per day
gallon per minute (gal/min)	0.06308	liter per second
million gallons per day (Mgal/d)	3,785	cubic meter per day
billion gallons (Bgal)	3,785	billion cubic meters

Transmissivity: In this report, the mathematically reduced form for transmissivity, foot squared per day (ft2/d), is used for convenience. The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [ft3/d)/ft2]ft.

Temperature in degrees Celsius (C) can be converted to degrees Fahrenheit (F) as follows: F = 1.8 X C +32.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality unit:

milligrams per liter (mg/L)

Distribution and Movement of Saltwater in Aquifers in the Baton Rouge Area, Louisiana, 1990-92

By Dan J. Tomaszewski

Abstract

Saltwater encroachment has been detected in the "1,000-foot," "1,500-foot," and "2,000-foot" sands underlying the Baton Rouge area. Saltwater has encroached in response to pumping primarily by industry and public supply. Large withdrawals induce northward leakage of saltwater across the Baton Rouge fault and northward encroachment into freshwater areas. Although areas containing saltwater also exist in the "600-foot," "1,200-foot," and "2,800-foot" sands, no saltwater movement (further encroachment) was detected in 1992.

The "1,500-foot" sand, an important public-supply source, contains saltwater at the base of the aquifer north of the fault in an area of about 1.5 square miles. In 1992 saltwater was estimated to be about 1,600 feet from the nearest pumping station (Government) and was estimated to arrive at the station in about 5 years. Public-supply wells at the Lafayette and Convention stations pumped from a second aquifer, the "2,000-foot" sand, which has been affected (1992) by saltwater encroachment. Concentrations of chloride in water from three public-supply wells were above background levels (10 milligrams per liter). The "2,000-foot" sand supplied about 39 million gallons per day (1990). Saltwater encroachment north of the affected pumping stations was not detected. The affected stations may intercept and discharge the encroaching saltwater. If pumping from these stations is discontinued as chloride concentrations increase and no physical barriers to movement exist, saltwater probably will advance toward the heavily pumped industrial district at a rate of about 2 feet per day and could arrive near the southern edge of the industrial district about 8 years after stations are discontinued.

INTRODUCTION

In 1990, 10 aquifers yielded a combined total of about 135 Mgal/d of freshwater primarily for industry and public supply in East and West Baton Rouge Parishes, Louisiana (George T. Cardwell, Capital Area Ground Water Conservation Commission, oral commun., 1990). The aquifers containing freshwater in East and West Baton Rouge Parishes north of the Baton Rouge fault are the "400-, 600-, 800-, 1,000-, 1,200-, 1,500-, 1,700-, 2,000-, 2,400-, and 2,800-foot" sands. However, in the three most heavily pumped aquifers ("1,500-foot," "2,000-foot," and "2,800-foot" sands) and in five less heavily pumped aquifers ("400-, 600-, 800-, 1,000-, and 1,200-foot" sands), saltwater (water with chloride concentrations greater than 250 mg/L) or water with chloride concentrations exceeding normal background levels (10 mg/L) has been detected and monitored. Although saltwater is present in these aquifers, in 1992 saltwater encroachment (horizontal movement of saltwater into freshwater areas) was detected only in the "1,000-foot," "1,500-foot," and "2,000-foot" sands. No saltwater has been detected in the "1,700-foot" and "2,400-foot" sands.

The "2,800-foot" sand, unlike other aquifers underlying East and West Baton Rouge Parishes, contains saltwater in a broad area north of the Baton Rouge fault. Saltwater initially filled the aquifer; however, natural recharge (rainfall) over geologic time slowly moved downdip from recharge areas and flushed much of the saltwater from the aquifer. Because all of the saltwater was not completely flushed from the aquifer, a large area north of the fault contains less dense freshwater overlying denser saltwater. This area, where freshwater overlies saltwater in the "2,800-foot" sand, has been designated the transitional zone. Background levels of chloride in the "2,800-foot" sand exceed 10 mg/L.

Concentrations of chloride exceeding normal background concentrations in aquifers containing freshwater (except the "2,800-foot" sand) have resulted from northward movement of saltwater across the Baton Rouge fault. This fault is located in the southern half of East and West Baton Rouge Parishes (fig. 1) and is within the southern city limits of Baton Rouge. Baton Rouge and the surrounding cities and towns in East and West Baton Rouge Parishes (fig. 2) use ground water for industry and public supply. An understanding of the distribution, direction, and rate of movement of saltwater in the aquifers containing freshwater is needed for effective management of the freshwater resource. In response to this need, the U.S. Geological Survey (USGS), in cooperation with the Louisiana Department of Transportation and Development (DOTD) and the Capital Area Ground Water Conservation Commission (CAGWCC), has evaluated the rate and direction of saltwater movement across the fault and into freshwater aquifers in East and West Baton Rouge Parishes.

The study area includes East and West Baton Rouge Parishes, about 370 mi^2 (fig. 1). Townships 6 and 7 in these parishes include the location of the Baton Rouge fault, areas where saltwater encroachment has occurred in many aquifers, and the location of the transitional zone in the "2,800-foot" sand.

Purpose and Scope

This report describes the present (1992) distribution (vertical and horizontal extent) of saltwater in freshwater aquifers of East and West Baton Rouge Parishes and provides information on the rate of horizontal saltwater movement (saltwater encroachment) toward pumping stations and areas of withdrawal (fig. 2) in East and West Baton Rouge Parishes. Previously published estimates and present conditions of saltwater movement are summarized and evaluated. Possible strategies for controlling saltwater encroachment in the "1,500-foot" and the "2,000-foot" sands are discussed.

Methods and Approach

Chloride concentrations were used as an indicator to monitor and detect saltwater changes, because chloride ions are the principal constituent of saltwater and are relatively conservative and not affected by chemical reactions or precipitation. Determination of chloride concentration is commonly assumed to be one of the simplest and most dependable procedures in water analysis (Hem, 1985, p. 120). The most common type of water in which chloride is the dominant anion is one in which sodium is the predominant cation (Hem, 1985, p. 120). Chloride concentrations in freshwater from most aquifers (the "2,800-foot" sand is an exception) north of the Baton Rouge fault generally are 10 mg/L (background level) or less. An increase in chloride concentrations above this background level can be a result of saltwater encroachment or the upconing of saltwater below the screened interval. In this report, saltwater is defined as water containing concentrations of 250 mg/L or more chloride. Concentrations of chloride greater than 250 mg/L exceed the secondary maximum contaminant level[1] (SMCL) for drinking water (U.S. Environmental Protection Agency, 1977, 1992).

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1 Secondary drinking-water regulations secondary maximum contaminant level (SMCL): Contaminants that affect the aesthetic quality of drinking water. At high concentrations or values, health implications as well as aesthetic degradation may also exist. SMCL's are not Federally enforceable, but are intended as guidelines for the states.

Figure 1. Location of study area in Louisiana.

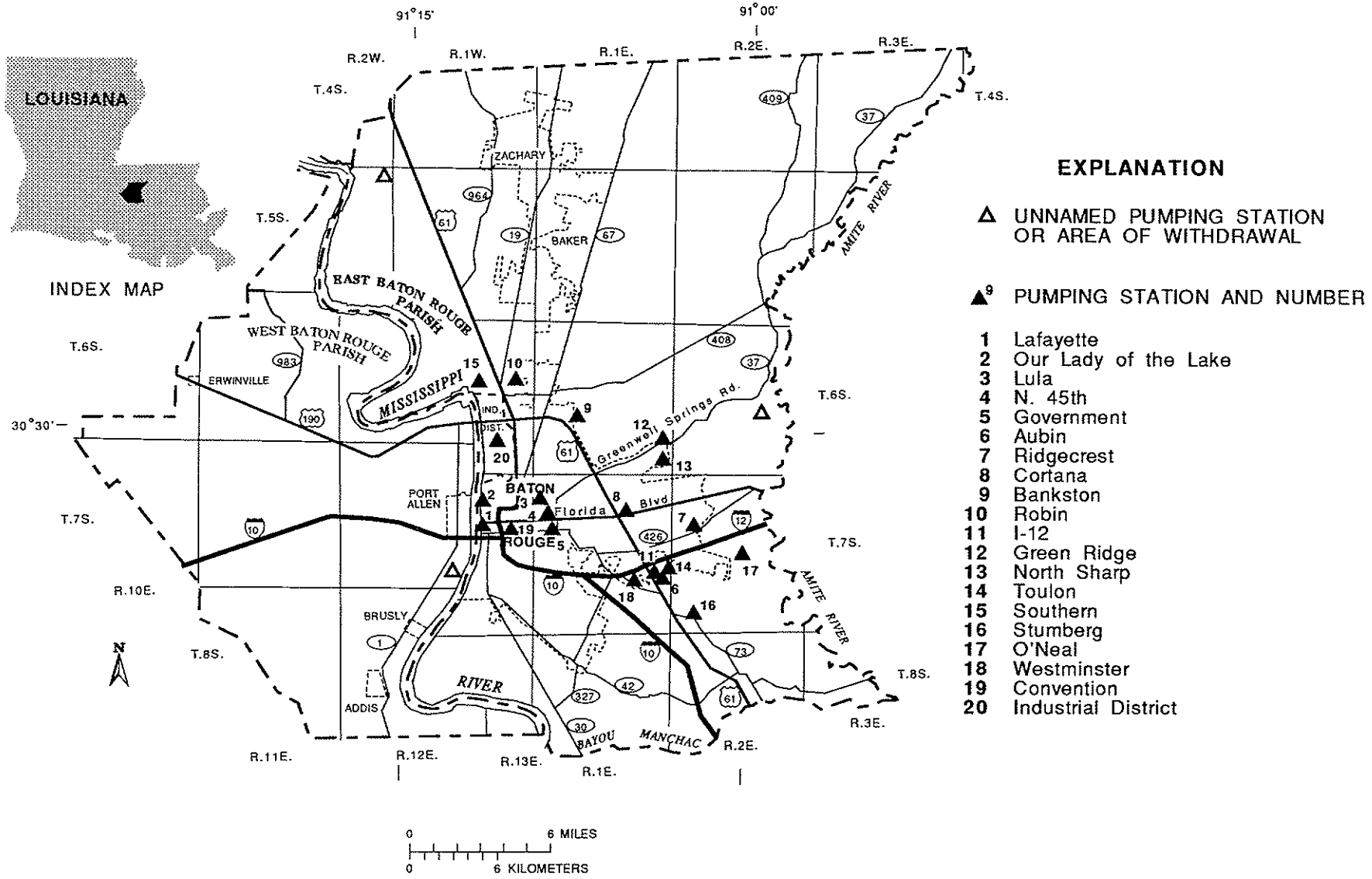


Figure 2. Location of pumping stations and areas of withdrawal in the Baton Rouge area, Louisiana.

Chloride data were collected from 83 wells in East and West Baton Rouge Parishes. Most of these data were collected between 1990 and 1992; however, water-quality data from previous studies were compared with recent data to delineate trends in chloride concentrations. Chloride data and supplemental electric-log data also were used to estimate the spatial location of saltwater in the "1,500-foot" and "2,000-foot" sands.

Water-level data were collected from approximately 100 wells to prepare the potentiometric surface maps and evaluate water-level trends. Corrections in water-level data were made for density differences by calculating water levels that would occur if all wells contained freshwater. Rate and direction of freshwater and saltwater movement were estimated with hydraulic gradients determined from 1990 potentiometric maps. These estimates also were used to refine the 1992 location of saltwater in East and West Baton Rouge Parishes.

Previous Investigations

This study includes data from previous investigations documenting saltwater encroachment in the Baton Rouge area. Before the discovery of the hydrogeologic significance of the Baton Rouge fault, early reports documented hydraulic properties and the possibility of saltwater encroachment in aquifers of the Baton Rouge area (Meyer and Turcan, 1955; Morgan, 1961). These reports include background data used to determine geologic, hydraulic, and water-quality characteristics of the aquifer system. Later, Morgan and Winner (1964) documented known areas of saltwater in aquifers underlying East and West Baton Rouge Parishes. Morgan and Winner estimated the rates of saltwater movement toward areas of heavy withdrawal that included the industrial district and the Bankston, Government, and Lafayette pumping stations (fig. 2); however, the hydrogeologic significance of the Baton Rouge fault was still unknown at that time.

The position and hydrogeologic significance of the Baton Rouge fault were documented by Rollo (1969, p. 11-13). An investigation by Whiteman (1979) includes a report with a detailed discussion of the "600-foot" and "1,500-foot" sands and summaries of the other aquifers. The source of saltwater, and the direction and rate of saltwater encroachment previously were determined or estimated by Whiteman for many of the aquifers discussed in this report.

Acknowledgments

Special thanks are given to Zahir "Bo" Bolourchi of DOTD, and George T. Cardwell of CAGWCC for their cooperation in supplying data, including pumpage records. The Baton Rouge Water Company was very cooperative during this investigation, allowing access to sites and interrupting normal pumping operations to accommodate data collection. Additionally, the assistance and cooperation of individuals who allowed data collection from privately owned wells and well sites is greatly appreciated.

HYDROGEOLOGY

Aquifers in the Baton Rouge area consist of unconsolidated sand that generally thickens and dips in a southward direction (fig. 3). These deposits range from Miocene to Pleistocene age (fig. 4). Although the aquifers vary in thickness and pinch out locally, the aquifers generally are at least 75 ft thick and may be more than 200 ft thick. Confining beds between aquifers, composed of clay and silt, are generally at least 100 ft thick and may be 400 to 500 ft thick in some areas (Whiteman, 1980, p. 5). Aquifers in the Baton Rouge area are named according to the depth of the bottom of each unit in the industrial district (Meyer and Turcan, 1955, p. 12-13). The aquifers discussed in this report include the "400-, 600-, 800-, 1,000-, 1,200-, 1,500-, 1,700-, 2,000-, 2,400-, and 2,800-foot" sands. The shallow Pleistocene age sands are not included in this report.

Freshwater enters the 10 aquifers that comprise the aquifer system in the recharge area north of Baton Rouge (fig. 3). The outcrop or suboutcrop area (recharge area) extends northward from East and West Feliciana Parishes into Mississippi (fig. 1). Freshwater enters the system as rainfall and generally flows southward with the hydraulic gradient. Recharge water entering the system has flushed out saltwater previously contained in the aquifers (Morgan and Winner, 1964, p. 4).

In 1992, the freshwater-saltwater interfaces (boundaries where freshwater intersects saltwater) were near the Baton Rouge fault (except in the "2,800-foot" sand, where the interface is several miles north of the fault). Flushing of saltwater south of the fault has not occurred, because of the decrease in permeability across the fault. The decrease in permeability at the fault is indicated by the differences in water levels in aquifers on the north and south sides of the fault. The freshwater-saltwater interface is in close proximity to pumping stations in Baton Rouge, and large withdrawals north of the fault induce northward movement of saltwater across the fault toward the pumping stations.

The displacement of aquifers at the Baton Rouge fault from a few feet or tens of feet in shallow sands to 350 ft at the top of the "2,000-foot" sand, has been documented in previous studies (Durham and Peeples, 1956, p. 65; Whiteman, 1979, p. 4). As a result of this displacement, aquifers north of the fault are interconnected with stratigraphically overlying aquifers that have been downthrown south of the fault (fig. 3). Test drilling during previous investigations has indicated that the "400-foot" sand south of the fault has been downthrown opposite the "600-foot" sand (Rollo, 1969, p. 27). Thus, the "400-foot" sand south of the fault is a source of saltwater for the "600-foot" sand north of the fault. Aquifer displacements of particular importance to this study include the "1,200-foot" sand which is displaced downward south of the fault and is interconnected with the "1,500-foot" sand to the north, and also the downward displacement of the "1,500-foot" sand which is interconnected with the 2,000-foot" sand north of the fault.

Hydrogeologic factors and the effects of pumping on ground-water gradients determine the rate and direction of saltwater encroachment in all aquifers in the study area. Whiteman (1979, p. 18) determined that the rate and direction of movement of saltwater resulted from the combined effects of hydraulic gradients, hydraulic characteristics of the aquifer, gravity on the relatively dense saltwater, and configuration of the base of the aquifer. The Baton Rouge fault is an important hydrogeologic barrier that restricts or limits the volume of saltwater moving northward. Depressions or ridges at the base, as well as the slope of the base of the aquifer, can further affect saltwater movement. Variability in permeability such as an undiscovered highly conductive channel of sand could allow for a much faster rate of saltwater encroachment toward pumping stations than previously estimated. The density of saltwater affects movement in the aquifer. Because saltwater is denser than freshwater, the saltwater is present as a thin layer at the base of the aquifer. Saltwater previously has been determined to be moving northward across the Baton Rouge fault, then sinking to the base of the aquifer and moving northward in response to heavy pumping.

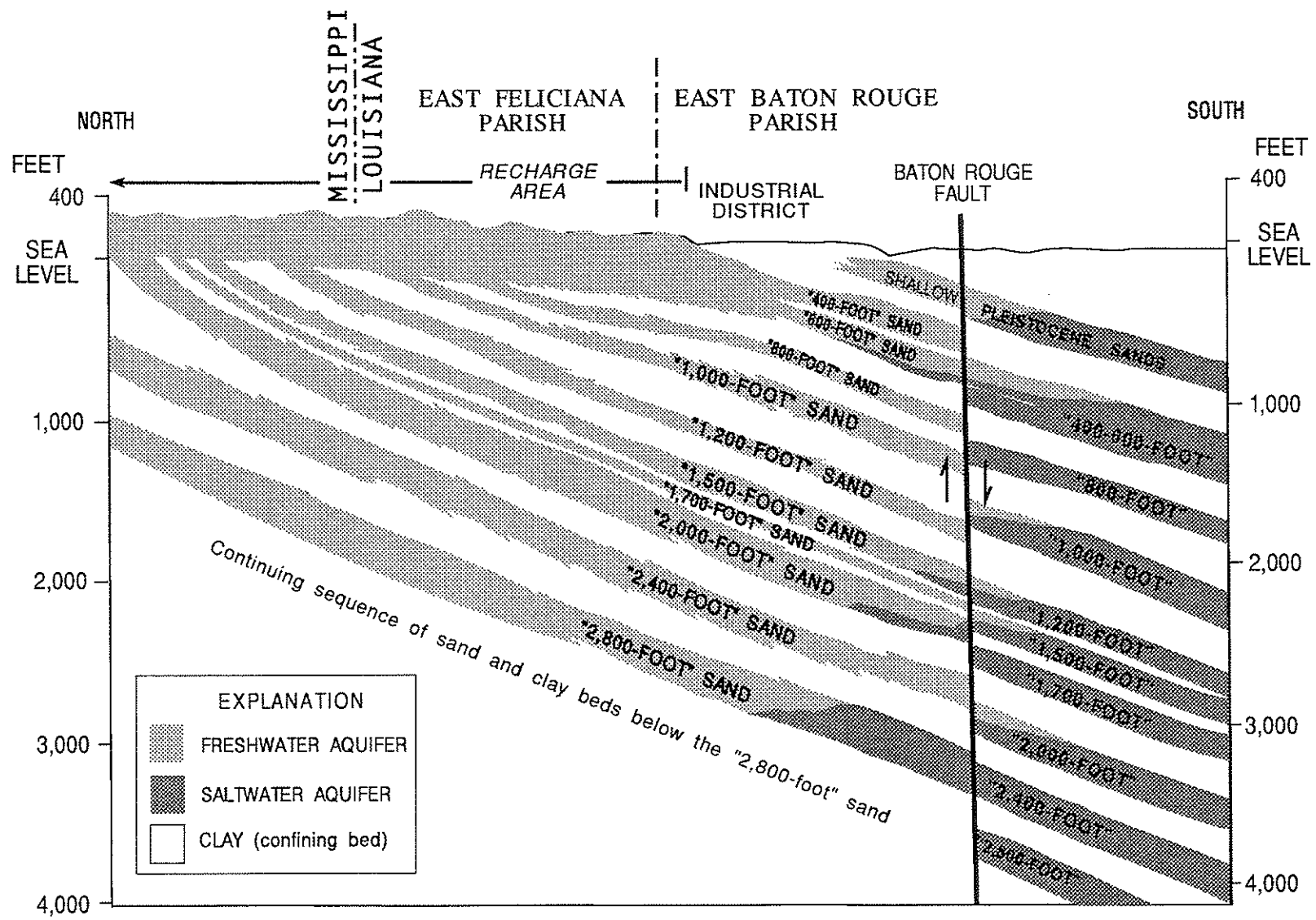


Figure 3. Idealized hydrogeologic section showing the aquifer system in southern Mississippi and southeastern Louisiana.

System	Series	Aquifer (hydrogeologic unit)	Lithologic description	Transmissivity, in feet squared per day	Thickness, in feet
Quaternary	Holocene and Pleistocene	"400-foot" sand and "600-foot" sand	Fine sand to pea gravel	1,700-26,000	75-400
Tertiary	Pliocene	"800-foot" sand	Fine to medium sand	3,400	50-150
		"1,000-foot" sand	Fine to coarse sand	9,500	40-90
		"1,200-foot" sand	Fine to medium sand	10,000-17,000	40-100
		"1,500-foot" sand and "1,700-foot" sand		4,300-12,000	20-300
	?				
	Miocene	"2,000-foot" sand	Medium sand	22,000-39,000	100-300
		"2,400-foot" sand	Fine to medium sand	13,000	50-250
		"2,800-foot" sand	Fine to coarse sand	17,000	50-350

Modified from Huntzinger and others (1985)

Figure 4. Hydrogeologic description of aquifers in the Baton Rouge area, Louisiana.

DISTRIBUTION AND MOVEMENT OF SALTWATER IN THE HEAVILY PUMPED AQUIFERS IN THE BATON ROUGE AREA

The three most heavily pumped aquifers in the Baton Rouge area (1990) are the "1,500-foot," "2,000-foot," and "2,800-foot" sands (fig. 5). Based on the amount of pumpage from these aquifers, which supplied about 65 percent of the ground water used in East and West Baton Rouge Parishes, they are discussed first. The remaining less heavily pumped aquifers are discussed according to depth. For each aquifer the location or distribution of saltwater in areas north of the fault are described, and the direction and rate of encroachment are estimated or calculated. Methods of controlling and monitoring encroachment are discussed for the "1,500-foot" and "2,000-foot" sands.

"1,500-Foot" Sand

In 1990, about 20 Mgal/d were pumped from the "1,500-foot" sand in the Baton Rouge area (George T. Cardwell, Capital Area Ground Water Conservation Commission, written commun., 1990). Principal uses of water from the "1,500-foot" sand were public supply (80 percent) and industrial use (20 percent). The "1,500-foot" sand is the third most heavily pumped aquifer in the Baton Rouge area. The most concentrated pumping in 1990 was at the Lula station (figs. 2 and 6), where about 7.5 Mgal/d was withdrawn from the aquifer. At the Government station, about 2.3 Mgal/d was withdrawn. Pumpage exceeded 2 Mgal/d only in two additional unnamed areas (west of Zachary and south of Port Allen, fig. 2). Throughout the remaining area, pumping from the aquifer was less concentrated. No wells pumped from the aquifer in the industrial district along the Mississippi River south of U.S. Highway 61 (fig. 2) because the aquifer in that area generally is thin or missing.

Distribution of Saltwater

Saltwater has been documented in the "1,500-foot" sand in previous reports (Morgan and Winner, 1964; Rollo, 1969; Whiteman, 1979). A comprehensive discussion of the source of saltwater in the "1,500-foot" sand was given by Whiteman (1979, p. 29-31). Whiteman stated, "salty water in the '1,500-foot' sand is almost certainly the result of leakage across the Baton Rouge fault from the downthrown '1,200-foot' sand." He further stated, "... water levels in the '1,200-foot' sand south of the fault respond in subdued fashion to water-level changes in the '1,500-foot' sand north of the fault, indicating some hydraulic connection between the sands." Additional water-quality data (Whiteman, 1979, table 2) indicated that as salinity north of the fault increased, the differences in relative chemical concentrations in water from the "1,200-foot" and "1,500-foot" sands decreased and became insignificant. Therefore, Whiteman concluded (based on hydraulic head and water-quality data), the probable source of saltwater in the "1,500-foot" sand is northward leakage from the "1,200-foot" sand south of the fault.

The area underlain by saltwater in the "1,500-foot" sand north of the fault totaled about 1.5 mi^2 in 1992 (fig. 6). This includes the approximate area straddling Acadian Thruway south of Clay Cut Road. This area was delineated using chloride data and estimates of the ground-water velocity. The main body of saltwater in the "1,500-foot" sand is near wells EB-782B, EB-807A, and EB-917. Other wells north of the fault (fig. 6) yield water with chloride concentrations at background levels (table 1).

Water from well EB-782B had concentrations of about 250 mg/L chloride when the well was initially completed and sampled in 1965. Chloride concentrations began steadily increasing in water from this well from about 250 mg/L in 1973 to 840 mg/L in 1987 (fig. 7). Sampling was discontinued in 1987 due to a casing leak.

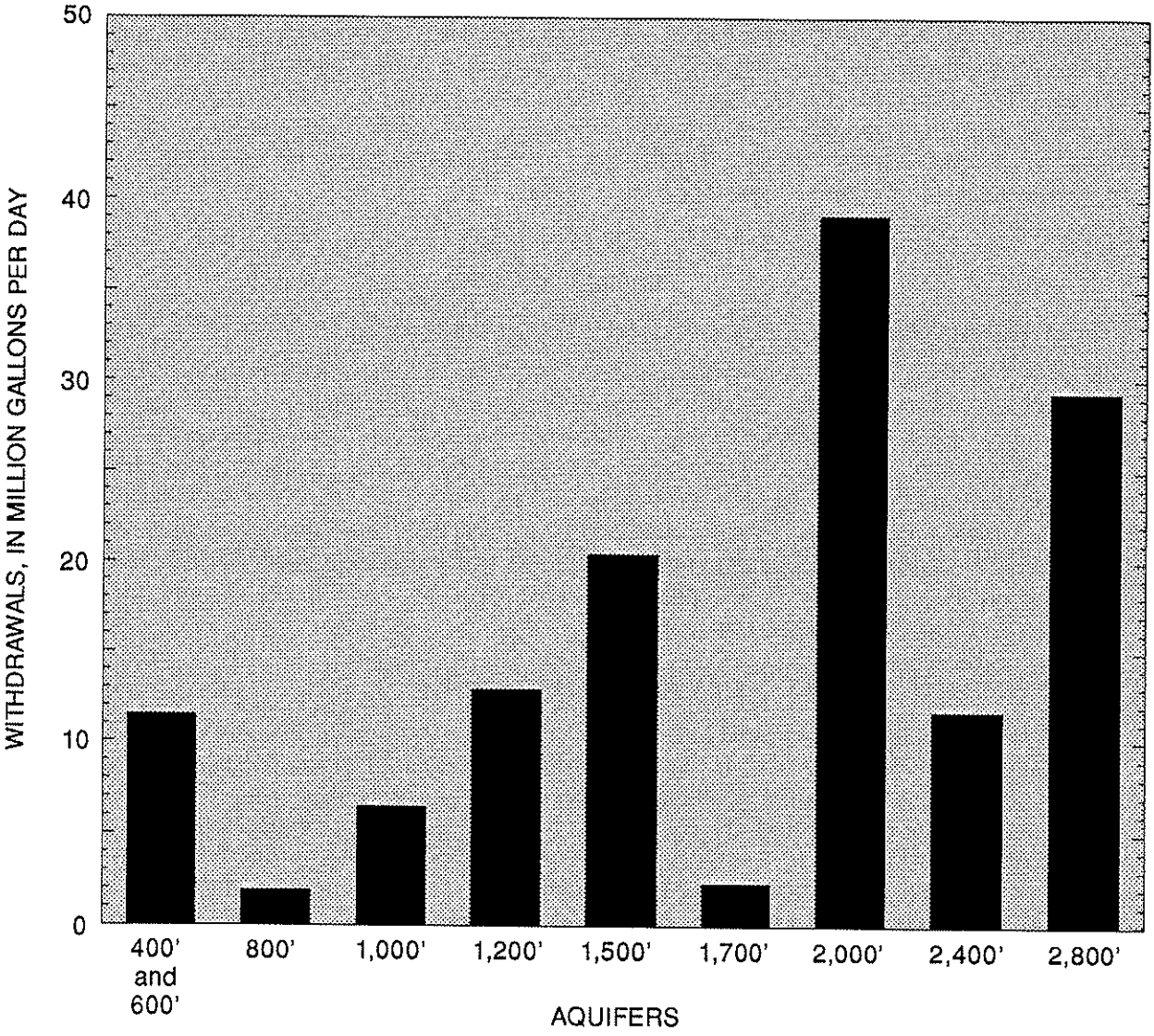
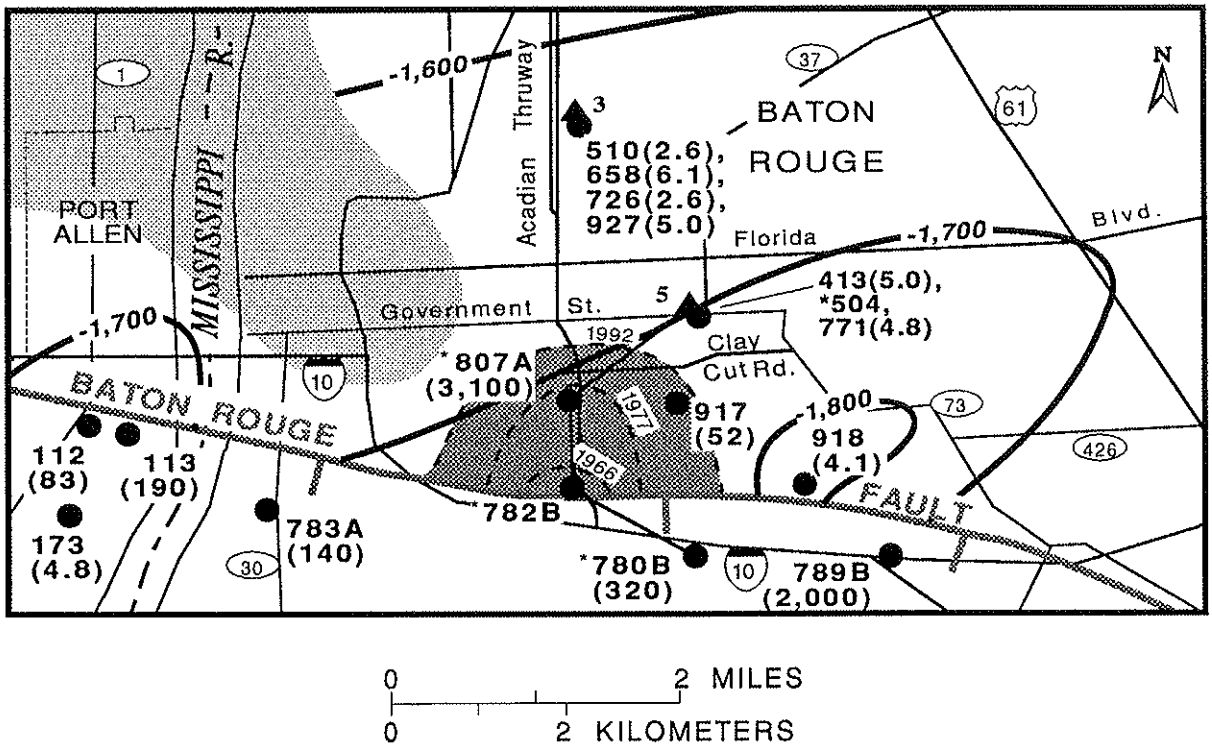


Figure 5. Withdrawals from aquifers in East and West Baton Rouge Parishes, Louisiana, 1990, (Data from: George T. Cardwell, Capital Area Ground Water Conservation Commission, oral commun., 1990).



EXPLANATION

APPROXIMATE AREA WHERE THE AQUIFER CONTAINS SALTWATER NORTH OF THE BATON ROUGE FAULT

APPROXIMATE AREA WHERE THE AQUIFER IS THIN OR ABSENT

1977 — EXTENT AND DATE OF SALTWATER ENCROACHMENT

-1,600 — STRUCTURE CONTOUR--Shows base of the aquifer. Contour interval 100 feet. Datum is sea level (Whiteman, 1979)

917 (52) — CONTROL POINT--Shows location of well sampled for chloride. Top number is well number. Number in parentheses is chloride concentration, in milligrams per liter (see table 1 for sample data)

3 — PUMPING STATION AND NUMBER

3 -- Lula

5 -- Government

5 780B — LINE OF HYDROGEOLOGIC SECTION (see fig. 8). * indicates well on section

Figure 6. Location of saltwater and structure contours in the "1,500-foot" sand north of the Baton Rouge fault in the Baton Rouge area, Louisiana.

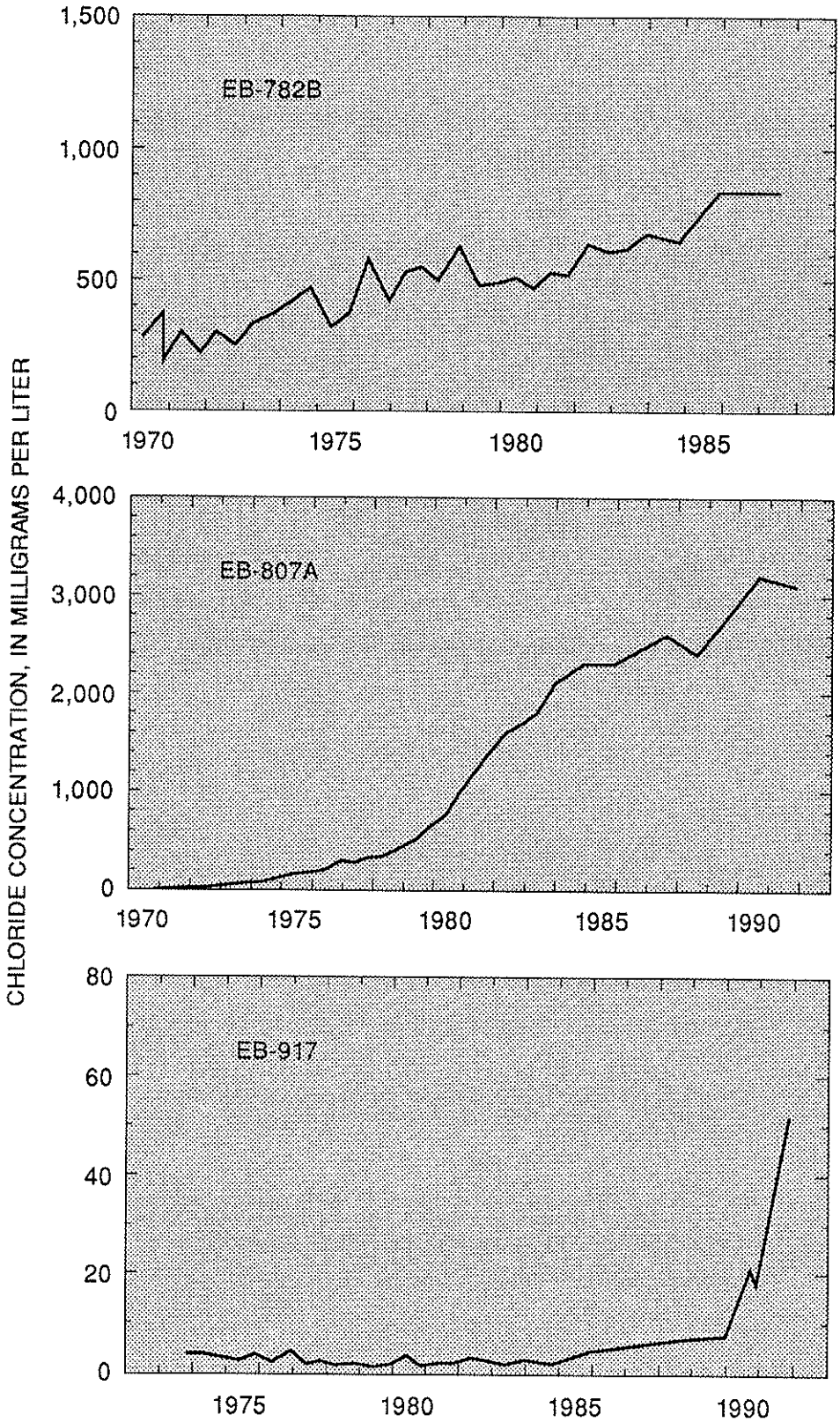


Figure 7. Chloride concentration in water from selected wells screened in the "1,500-foot" sand in the Baton Rouge area, Louisiana (well locations are shown in fig. 6).

Table 1. Selected chloride data for aquifers in the Baton Rouge area, Louisiana

[Well locations are shown in figures 6 and 10]

Well name	Date sampled	Well depth, in feet	Chloride concentration, in milligrams per liter
	"400-foot" sand		
[1]EB-745	9-12-91	503	2.6
[1]EB-816	9-12-91	520	3.6
[1]EB-822	10-24-91	573	800
EB-825	11- 8-91	475	5.8
[1]EB-1017C	9-16-91	567	3.4
EB-1036	6-17-92	549	5.8
EB-1132	5-24-90	590	4.3
	"600-foot" sand		
[1]EB-434	10-23-91	611	68
[1]EB-793	11-12-91	687	6.5
[1]EB-824	11- 8-91	581	2.3
[1]EB-870	10-23-91	692	3.2
EB-879	5-14-90	664	3.4
	"1,000-foot" sand		
WBR-138	6-15-90	958	7.1
WBR-147	11-13-91	1,292	750
	"1,200-foot" sand		
[1]EB-298	11- 5-91	1,387	4.1
[1]EB-621	9-16-91	1,487	5.6
EB-653	5-17-90	1,153	4.3
EB-772	6-17-92	1,214	5.0
[1,2]EB-780A	11- 7-91	1,622	860
EB-925	5- 8-90	1,470	3.4
EB-990	5-17-90	1,450	3.0
[1]WBR-35	9-20-91	1,290	3.2
WBR-101	8-29-90	1,367	4.0
WBR-102A	8-29-90	1,288	5.8
[1]WBR-136	9-17-91	1,305	4.2
WBR-137	1-19-90	1,330	3.0
[1]WBR-148	11-13-91	1,304	3.8

Table 1. Selected chloride data for aquifers in the Baton Rouge area, Louisiana—Continued

Well name	Date sampled	Well depth, in feet	Chloride concentration, in milligrams per liter
	"1,500-foot" sand		
[1]EB-413	6-17-92	1,745	5.0
EB-510	7-29-91	1,605	2.6
EB-658	5- 8-90	1,604	4.2
EB-658	6-17-92	1,604	6.1
EB-726	7-29-91	1,601	2.6
[1]EB-771	6-17-92	1,739	4.8
[1]EB-780B	11- 7-91	1,913	320
[1]EB-783A	11-12-91	2,179	140
[1]EB-789B	11- 6-91	1,721	2,000
[1]EB-807A	11-11-91	1,713	3,100
[1]EB-807A	10-30-92	1,713	3,500
[1]EB-917	11- 6-91	1,736	52
[1]EB-918	11-14-91	1,834	4.1
EB-927	6-17-92	1,511	5.0
EB-1016B	6-17-92	1,465	5.2
[1]WBR-112	6-19-92	2,205	83
[1]WBR-113	6-19-92	2,242	190
WBR-132	7-11-90	2,082	3.8
WBR-132	6-19-92	2,082	5.9
WBR-173	7-10-90	2,194	2.2
WBR-173	6-19-92	2,194	4.8
	"1,700-foot" sand		
EB-73	6-17-92	1,884	6.3
[1]EB-804A	10-24-91	1,950	3.4
[1]WBR-181	9-20-91	1,900	5.1
	"2,000-foot" sand		
[1]EB-444	6-17-92	2,172	7.2
[3]EB-630	8-13-90	2,253	97
EB-630	7-29-91	2,253	100
EB-630	3-25-92	2,253	120
EB-630	6-17-92	2,253	120
EB-674	8- 8-91	2,250	4.6
EB-774	6-17-92	2,143	4.3
[1]EB-778	11- 7-91	2,586	140
[1]EB-781	11-15-91	2,286	2,600
[1]EB-781	10-13-92	2,286	3,000
[1]EB-783B	10-25-91	2,675	740
[1]EB-792B	11- 6-91	2,286	5.5
[1]EB-803B	1-22-92	2,265	550

Table 1. Selected chloride data for aquifers in the Baton Rouge area, Louisiana—Continued

Well name	Date sampled	Well depth, in feet	Chloride concentration, in milligrams per liter
	"2,000-foot" sand--continued		
[1]EB-807B	11-11-91	2,264	13
EB-814	7-29-91	2,168	3.2
EB-814	6-17-92	2,168	5.1
EB-874	6-17-92	2,250	5.9
EB-878	5- 8-90	2,178	3.5
EB-878	6-17-92	2,178	5.9
[1]EB-1028	7-18-90	2,238	210
EB-1150	7-29-91	2,242	11
EB-1150	3-25-92	2,242	13
EB-1150	6-17-92	2,242	16
WBR-102B	8-28-90	2,100	2.6
	"2,000- and 2,400-foot" sands		
[1]EB-151	6-17-92	2,658	3.8
[1]EB-733	6-17-92	2,637	3.9
	"2,400-foot" sand		
EB-654	5-17-90	2,382	5.1
EB-769	5-17-90	2,362	4.8
[1]EB-794	11- 8-91	2,709	13
[1]EB-804B	9-24-90	2,762	4.1
EB-813	6-17-92	2,536	5.3
EB-1025	6-17-92	2,674	4.1
EB-1039	6-17-92	2,697	3.1
EB-1149	3-25-92	2,694	2.0
EB-1149	6-17-92	2,694	3.9
[1]WBR-100B	11-13-91	2,448	3.2
	"2,800-foot" sand		
EB-623	5-24-90	2,652	15
[1]EB-750	6-17-92	2,643	58
[1]EB- 798	6-17-92	2,647	160
EB- 832	5-25-90	2,048	3.5
EB- 995	5-24-90	2,520	5.1
[1]EB-1000	10-22-91	2,926	91
EB-1037	5-24-90	2,682	46
EB-1187	6-19-92	2,405	7.3
WBR-95C	6-13-90	2,640	48

[1] Well is part of 1992 chloride-monitoring network.
[2] Well is located south of the Baton Rouge fault.
[3] Data were collected by Louisiana Department of Environmental Quality.

Although well EB-782B is located at the fault, chloride concentrations in water from the well are relatively low (compared to 1992 chloride concentrations in water from well EB-807A) because well EB-782B was screened near the top of the saltwater interval. Based on analysis of the electric-log data, saltwater was contained below the screened interval at the time of well completion (1965). Electric-log interpretations and well-construction data indicate well EB-782B was screened over a 5-ft interval (screened interval is at the 1965 saltwater line shown on electric log 782B in fig. 8). The bottom of the screened interval is 54 ft above the base of a major unbroken sand interval. The small increase in chloride concentration at well EB-782B may indicate that only a small change in vertical thickness of saltwater has occurred at this site.

Water from well EB-807A (fig. 6) increased in chloride concentration in 1972. Chloride concentrations have increased continually since 1972, reached 250 mg/L in 1976, and have been greater than 3,000 mg/L since 1990 (fig. 7). Well EB-807A is screened between 7 and 12 ft above the base of a unbroken sand interval (near the 1977 saltwater line on electric log 807A, shown in fig. 8).

Chloride concentrations presently (1992) are increasing in water from well EB-917, located about 0.5 mi south of the Government station (fig. 6). Data shown in figure 7 indicate that an increase in chloride concentrations began between 1985 and 1988 at this site. Although chloride concentrations of 52 mg/L have been detected in water sampled at this site, chloride concentrations of 3,000 mg/L have been detected in water sampled from nearby well EB-807A, screened in the same sand. Because well EB-917 is screened in an interval between 9 and 14 ft above the base of the aquifer and very salty water (containing chloride concentrations greater than 3,000 mg/L) has been detected nearby at well EB-807A, it is likely that chloride concentrations exceeding those detected in water from this well are present below the well screen.

Direction and Rate of Saltwater Movement

Based on the distribution of pumping stations, pumping rates, and aquifer characteristics, saltwater is moving in a north to northeasterly direction from the main body of saltwater near the fault. Saltwater encroachment is toward the Government and Lula pumping stations (fig. 6). The direction and rate of saltwater encroachment is controlled by the location and amount of pumpage from the Government and Lula stations. These stations accounted for about half of the total pumpage (1990) from the "1,500-foot" sand (George T. Cardwell, Capital Area Ground Water Conservation Commission, written commun., 1991). The base of the aquifer has a gentle slope (less than 1^{0} from horizontal) from the 1992 location of saltwater to the Lula pumping station. The base of the aquifer is essentially flat between the 1992 location of saltwater and the Government pumping station. This little or no slope will not create a natural boundary for flow of saltwater toward the Government and Lula pumping stations.

Whiteman (1979, p. 33) estimated that the gradient in the vicinity of the 1977 freshwater-saltwater interface averaged 2 to 3 ft/mi and the rate of northward flow of saltwater toward the Government pumping station was about 100 ft/yr. The 1979 distribution of pumping has remained unchanged; however, withdrawals have increased about 5 Mgal/d, chiefly for public supply.

Few observation wells are available in the area south of the Government station for data collection to determine the rate of saltwater encroachment toward the Government and Lula stations. However, water-level data indicate a general northward gradient toward the Government station. Data collected at wells EB-413 and EB-917 indicate a northward gradient between 1.5 and 2 ft/mi toward the Government station. This gradient is consistent with previous estimates by Whiteman (1979, p. 33); therefore, the northward rate of saltwater encroachment then (1977) calculated to be between 80 and 120 ft/yr is still (1992) valid. With this gradient, the saltwater at the base of the aquifer has proceeded northward between 1,200 and 1,800 ft since 1977 (fig. 6). The 1992 freshwater-saltwater interface may be within 1,600 ft of the Government station.

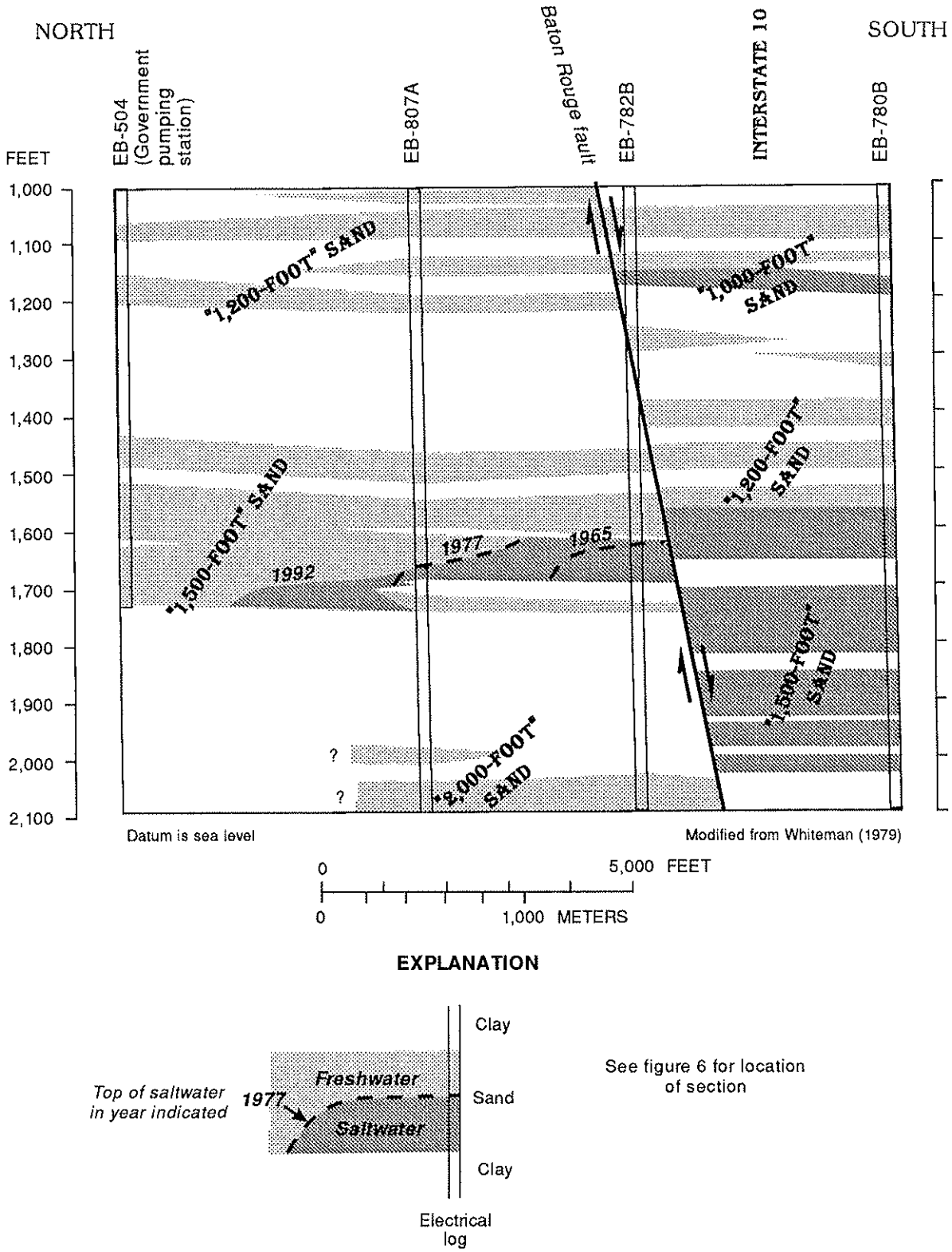


Figure 8. Hydrogeologic section showing saltwater encroachment toward the Government pumping station in the Baton Rouge area, Louisiana.

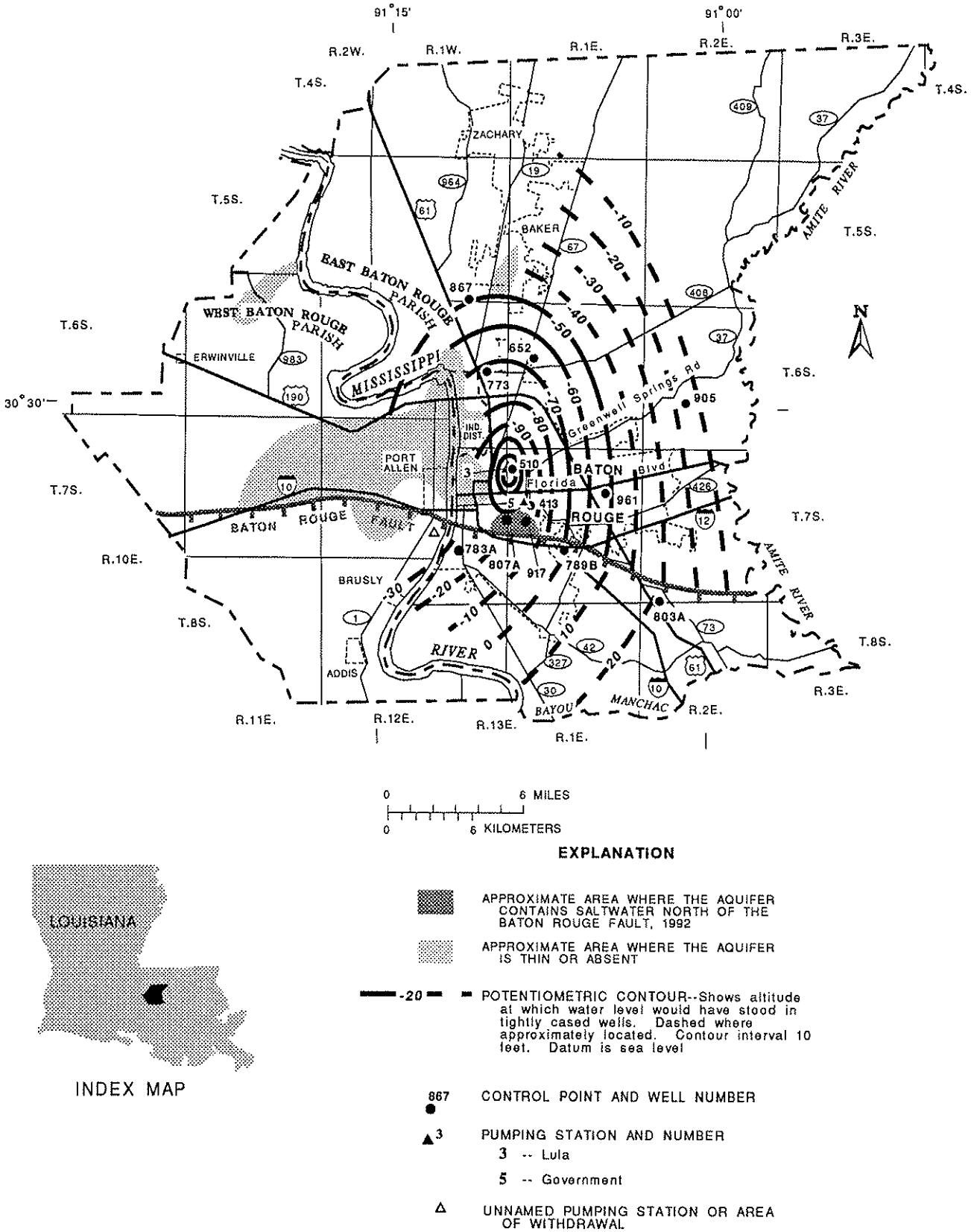


Figure 9. Potentiometric surface of the "1,500-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

If the saltwater were to continue to move northward at an average rate of 120 ft/yr, the saltwater interface would reach at the Government station in 13 years. However, because the local cone of depression steepens toward the Government station, it is likely that the encroachment rate will accelerate as saltwater approaches this station. Thus, it is estimated that the saltwater probably will arrive at the Government station in about 5 years from 1992 (table 2). This is based on an average hydraulic gradient of about 2.5 ft/1,600 ft between the 1992 freshwater-saltwater interface and the Government station. The station is assumed to operate continuously, pumping 2.5 Mgal/d. Additionally, the effective porosity of the aquifer was assumed to be 25 percent and the hydraulic conductivity of the aquifer to be 140 ft/d (Morgan, 1961, p. 39). The velocity of average ground-water flow at the interface was determined to be about 320 ft/yr (0.9 ft/d), based on the following application of Darcy's law:

$$V = \frac{KI}{\Theta},$$

where

V is ground-water velocity, in feet per day;

K is aquifer hydraulic conductivity, in feet per day;

I is hydraulic gradient, in feet per feet; and

Θ is aquifer porosity, dimensionless.

The northward rate of saltwater encroachment toward the Lula pumping station in 1992 was probably minimized or possibly eliminated by withdrawal from the "1,500-foot" sand at the Government pumping station. However, saltwater may be moving past the Government station and northward toward the Lula station. If saltwater is moving with the hydraulic gradient determined from the potentiometric map (fig. 9) toward the Lula station (totally bypassing the Government station), saltwater may reach the Lula station in about 16 years (table 2). This is based on (1) the 1992 estimated location of the freshwater-saltwater interface (about 8,000 ft south of the Lula station, fig. 9), (2) an average hydraulic gradient of 20 ft/8,000 ft between the interface and the Lula station, (3) a porosity of 25 percent, and (4) a hydraulic conductivity of 140 ft/d. Use of Darcy's law for this estimate assumes no dispersion or density effects.

Table 2. Summary of data used to determine saltwater encroachment toward the Government and Lula pumping stations, Baton Rouge, Louisiana

Pumping station	Time for freshwater-saltwater interface to reach pumping station, in years from 1992	Distance to pumping station from 1992 freshwater-saltwater interface, in feet	Average hydraulic gradient between interface and pumping station, in feet per feet	Aquifer porosity, in percent	Hydraulic conductivity, in feet per day
Government	5	1,600	2.5/1,600	25	140
[1]Lula	16	8,000	20/8,000	25	140

[1] Assumes 1992 pumpage from the Government pumping station has no effect on saltwater encroachment.

Because no wells are located between the estimated freshwater-saltwater interface and the Government station, additional sampling and evaluation of water-level and chloride data from public supply wells at the Government station may give early detection of saltwater arriving at the station. The installation of one or two monitor wells between the estimated interface and the Government station would allow saltwater to be detected before affecting the station and would allow collection of water-level and chloride data to refine the estimate of arrival time of saltwater at the station.

Control of Saltwater Encroachment

Potential methods for controlling saltwater encroachment (Todd, 1959, p. 282-287) in coastal areas include reduction or relocation of pumping, direct recharge, development of a pumping trough, development of a freshwater ridge, and construction of artificial subsurface barriers. However, Freeze and Cherry (1979, p. 378) concluded that, of the methods listed by Todd (1959), only a reduction or relocation of pumping has proven effective and economic. Methods of controlling saltwater encroachment in aquifers underlying the Baton Rouge area (discussed by previous investigators) generally include recharge or discharge barrier wells (Rollo, 1969, p. 18-20; Whiteman, 1979, p. 25-29 and 35).

Industry and a local water management agency are considering scavenger wells as an option for controlling saltwater encroachment in the "1,500-foot" sand. Scavenger wells would be designed to pump the denser saltwater from the base of the aquifer. Withdrawal of saltwater by scavenger wells screened at the base of the aquifer seems feasible for two reasons: First, the saltwater is limited in areal extent (less than 1.5 mi^2), and second, the rate of saltwater leakage is relatively small (0.2 to 0.5 Mgal/d). Scavenger wells placed between the fault and major pumping stations could effectively intercept and remove much of the saltwater. If one or more scavenger wells pumped only saltwater, continuous pumpage of 150 to 350 gal/min would be needed to intercept the 1992 saltwater leakage across the fault.

Although a scavenger-well operation to intercept the saltwater may be technically feasible, disadvantages include the costs of well installation, continuous operation of the wells, and saltwater disposal. Additionally, future changes in location of pumping centers and subsequent ground-water flow may alter the effectiveness of scavenger wells.

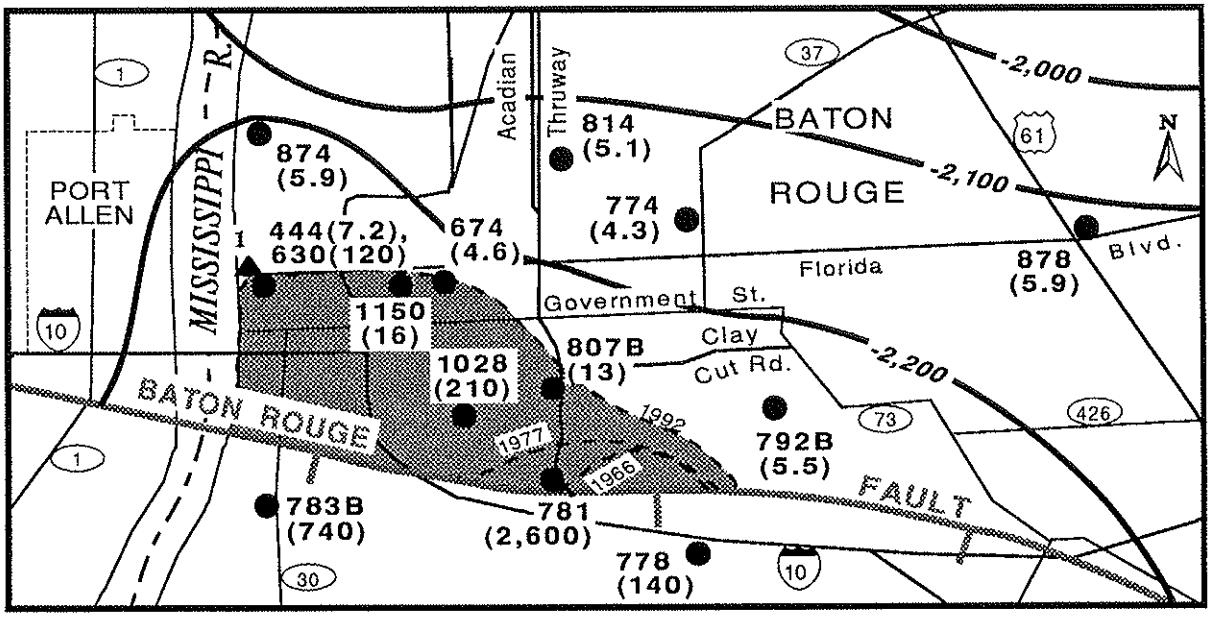
Reduction or relocation of ground-water withdrawals in the "1,500-foot" sand could be used to lessen the gradient across the Baton Rouge fault and thereby reduce flow of saltwater toward freshwater areas. Relocation of pumping centers farther north of the fault would allow more time before saltwater would impact pumping stations due to the longer distance saltwater would have to travel and because the gradient between the fault and the pumping center would decrease.

"2,000-Foot" Sand

In 1990, the "2,000-foot" sand was the most heavily pumped aquifer in the Baton Rouge area; about 39 Mgal/d was pumped from the aquifer. About 80 percent of the pumpage was by industry in East Baton Rouge Parish; no substantial pumpage was in West Baton Rouge Parish. The remaining 20 percent of water pumped was for public supply in East Baton Rouge Parish. Pumpage from the "2,000-foot" sand by industry was concentrated in the industrial district (20 Mgal/d) and about 3 mi west of Zachary (11 Mgal/d) (fig. 2). Additional pumpage was distributed among sites in East Baton Rouge Parish north of Government Street and south to southeast of the industrial district. Withdrawals from these stations ranged from 0.5 to 1.5 Mgal/d.

Distribution of Saltwater

Previous investigators documented saltwater in the "2,000-foot" sand north of the Baton Rouge fault only in a small area (fig. 10) (Rollo, 1969, p. 33; Smith, 1976, p. 3; Whiteman, 1979, p. 42). Saltwater encroachment in the "2,000-foot" sand was thought to be minimal, with saltwater leaking across the fault at a low rate, if at all, and confined to this limited area (Rollo, 1969, p. 34; Smith, 1976, p. 3).



EXPLANATION

APPROXIMATE AREA WHERE THE AQUIFER CONTAINS SALTWATER NORTH OF THE BATON ROUGE FAULT

1977 EXTENT AND DATE OF SALTWATER ENCROACHMENT

-2,100 STRUCTURE CONTOUR--Shows base of the aquifer (modified from Rollo, 1969). Contour interval 100 feet. Datum is sea level

778 (140) CONTROL POINT--Shows location of well sampled for chloride. Top number is well number. Number in parentheses is chloride concentration, in milligrams per liter (see table 1 for sample data)

1 PUMPING STATION AND NUMBER

1 -- Lafayette

Figure 10. Location of saltwater and structure contours in the "2,000-foot" sand north of the Baton Rouge fault in the Baton Rouge area, Louisiana.

Evaluation of chloride and electric log data during this study indicates that the area underlain by saltwater in the "2,000-foot" sand is now (1992) considerably larger than that described by previous investigators (fig. 10). The area of saltwater extends from about a mile east of Acadian Thruway westward to the Mississippi River. The northernmost extent is as far as Florida Boulevard near the Mississippi River.

Analysis of data collected from monitor well EB-781, near the fault, indicates that the concentration of chloride is increasing at this site (fig. 11). When completed in 1970, the chloride concentration in water from this well was less than 2,000 mg/L; however, in 1992 the concentration was about 2,600 mg/L. The increase of chloride concentration may indicate that saltwater south of the Baton Rouge fault continues to move northward.

About 1980, an increase in chloride concentration was detected in water from well EB-807B (fig. 11). Well EB-807B is screened near the base of the aquifer (4 ft of screen in an interval 5 to 9 ft above the base) and still (1992) yields freshwater. However, the increase in chloride concentration in 1983 above background levels indicates that a thin layer of saltwater existed at the base of the aquifer at this site.

Upon the completion of well EB-1028 in 1981, the area underlain with saltwater in the "2,000-foot" sand was known to extend beyond the areas mapped by previous investigators. The installation of this well closed a significant gap in the 1979 monitor network. Well records and interpretation of electric-log data indicate that the well is screened in an interval 10 to 25 ft above the base of the aquifer. Electric-log interpretations indicate higher dissolved-solids concentrations in water at the base of the aquifer (compared to those in water sampled in the screened interval) at the time of well completion. Chloride concentrations in samples from well EB-1028 were about 80 mg/L in 1981 and were about 210 mg/L in 1990 (fig. 11, table 1); however, chloride concentrations below the screened interval most likely exceed 210 mg/L.

Increased chloride concentrations detected in water from wells EB-630 and EB-1150 (table 1) are significant because these are public supply wells for the city of Baton Rouge. The wells, unlike those designed specifically for saltwater monitoring, are screened across most of the aquifer interval (vertical thickness). Consequently, chloride concentrations in water samples obtained from the wells are considered to be a composite representing the entire screened interval. Therefore, chloride concentrations at wells EB-630 and EB-1150, about 120 mg/L and 16 mg/L, respectively (June 17, 1992), represent a mixture of high-chloride water at the base of the aquifer (a few feet to possibly a maximum of 10 ft) diluted by very low chloride water (background level) contained throughout most of the vertical thickness of the aquifer.

Direction and Rate of Saltwater Movement

Rollo (1969) suggested that saltwater present in the "2,000-foot" sand north of the Baton Rouge fault (fig. 10) could move toward the Lafayette station. He estimated that saltwater from this area, located east of Acadian Thruway and adjacent to the fault, would travel with the hydraulic gradient at a rate about 930 ft/yr and arrive at the station within 10 to 15 years. A subsequent investigation by Whiteman (1979, p. 42) indicated that the saltwater area had nearly doubled in size but was still located near the fault straddling Acadian Thruway. The larger area of the aquifer underlain with saltwater was shown to trend in a westward direction. Although no encroachment rate was estimated, Whiteman (1979) reiterated previous concerns of Rollo (1969). In 1981, well EB-1028 was installed to investigate the westward movement of saltwater toward the Lafayette pumping station. As discussed in the preceding section, saltwater was present at this well location in 1981. Thus, the rate of encroachment was greater than previous investigators estimated (Smith, 1976, p.12; Whiteman, 1979, p. 42).

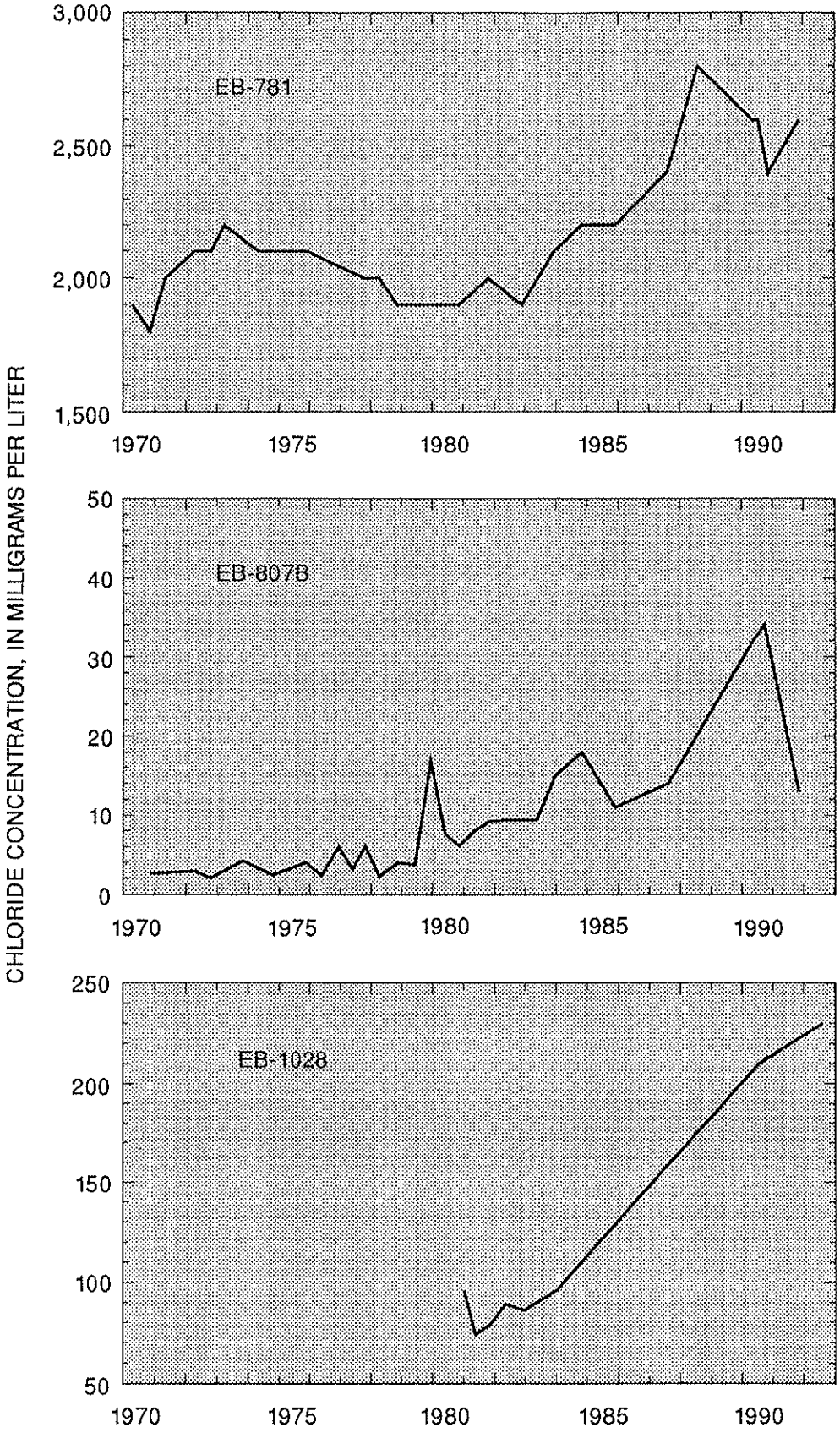


Figure 11. Chloride concentration in water from selected wells screened in the "2,000-foot" sand in the Baton Rouge area, Louisiana (well locations are shown in fig. 10).

Chloride concentrations between approximately 100 and 120 mg/L were detected at the Lafayette station (well EB-630, table 1) from an analysis by the Louisiana Department of Environmental Quality in 1990 and confirmed by USGS analysis in 1991-92. If the saltwater area delineated by Rollo (1969, pl. 5) was correct, the average rate of saltwater encroachment toward the Lafayette station was about 700 ft/yr (2 ft/d) since 1966. Because the base of the aquifer is relatively flat in the area between the Lafayette station and well EB-781, the saltwater proceeded in a westerly to northwesterly direction with the hydraulic gradient (fig. 12). Further northward encroachment of saltwater toward the industrial district may be restricted, if the saltwater is intercepted and discharged by the Lafayette station. Well EB-630 presently (1992) is estimated to be pumping about 20,000 gal/d of saltwater from the aquifer. This estimate is based on (1) withdrawals from well EB-630 total about 0.4 Mgal/d, (2) freshwater in the aquifer contains about 5 mg/L chloride, and (3) maximum chloride concentration in water at well EB-630 is estimated to be 3,000 mg/L (based on the chloride concentration in water at well EB-781, near the fault).

A second well pumping from the "2,000-foot" sand at the Convention station (well EB-1150, fig. 10) could also delay the northward movement of saltwater. This well is located near the northern extent of the saltwater and may eventually pump water containing higher concentrations of chloride. Total withdrawals are about 1.2 Mgal/d from well EB-1150.

If pumping is stopped from wells bordering the northern extent of saltwater at the Lafayette and Convention stations and remedial steps are not taken to reduce or eliminate saltwater encroachment, the saltwater is projected to advance toward the industrial district at a rate of about 2 ft/d. This estimate is based on an average hydraulic conductivity of 170 ft/d, a porosity of 25 percent, and a hydraulic gradient of 45 ft/16,000 ft between the Lafayette station and the center of the cone of depression in the industrial district. However, before reaching the industrial district, water in well EB-874 (a public supply well at Our Lady of the Lake station, fig. 10) will likely become salty. Thus, if pumping from well EB-630 is stopped, the freshwater-saltwater interface may continue northward and arrive at well EB-874 in about 8 years. Well EB-874 is located 1.1 mi north of well EB-630 and 1.2 mi south of the nearest well in the "2,000-foot" sand in the industrial district.

Control of Saltwater Encroachment

Leakage of saltwater across the fault into the "2,000-foot" sand was estimated to be about 450,000 gal/d (Smith, 1976, p. 14). By calculating the 1992 known area underlain with saltwater in the "2,000-foot" sand (4 mi^2) and estimating the average thickness of the saltwater contained in the base of the aquifer (20 ft) and the porosity of the aquifer (25 percent), an estimate can be made of the volume of saltwater contained north of the fault. This volume of saltwater is about 560 Mft^3 (4.2 Bgal). If the area containing saltwater in 1977 was about 1 mi^2 (larger than that described by Whiteman [1979] and estimated with data collected from well EB-1028 test site), the aquifer contained about 140 Mft^3 (1.1 Bgal) of saltwater. From 1977 to 1992, the increase in the volume of saltwater was about 3.1 Bgal; therefore, about 0.57 Mgal/d of saltwater has leaked across the fault.

Industry and a local water agency are considering installing scavenger wells as an option for controlling saltwater encroachment in the "2,000-foot" aquifer. The daily volume of saltwater leaking across the Baton Rouge fault could be removed by one or more scavenger wells pumping about 500 gal/min of saltwater. Discharge wells could be located near the fault in the area straddling Acadian Thruway or south of the northernmost extent of the 1992 freshwater-saltwater interface (near Florida Boulevard, south of wells EB-444 and EB-674). However, disadvantages of a scavenger well operation in the "2,000-foot" sand are the same as those mentioned for the "1,500-foot" sand.

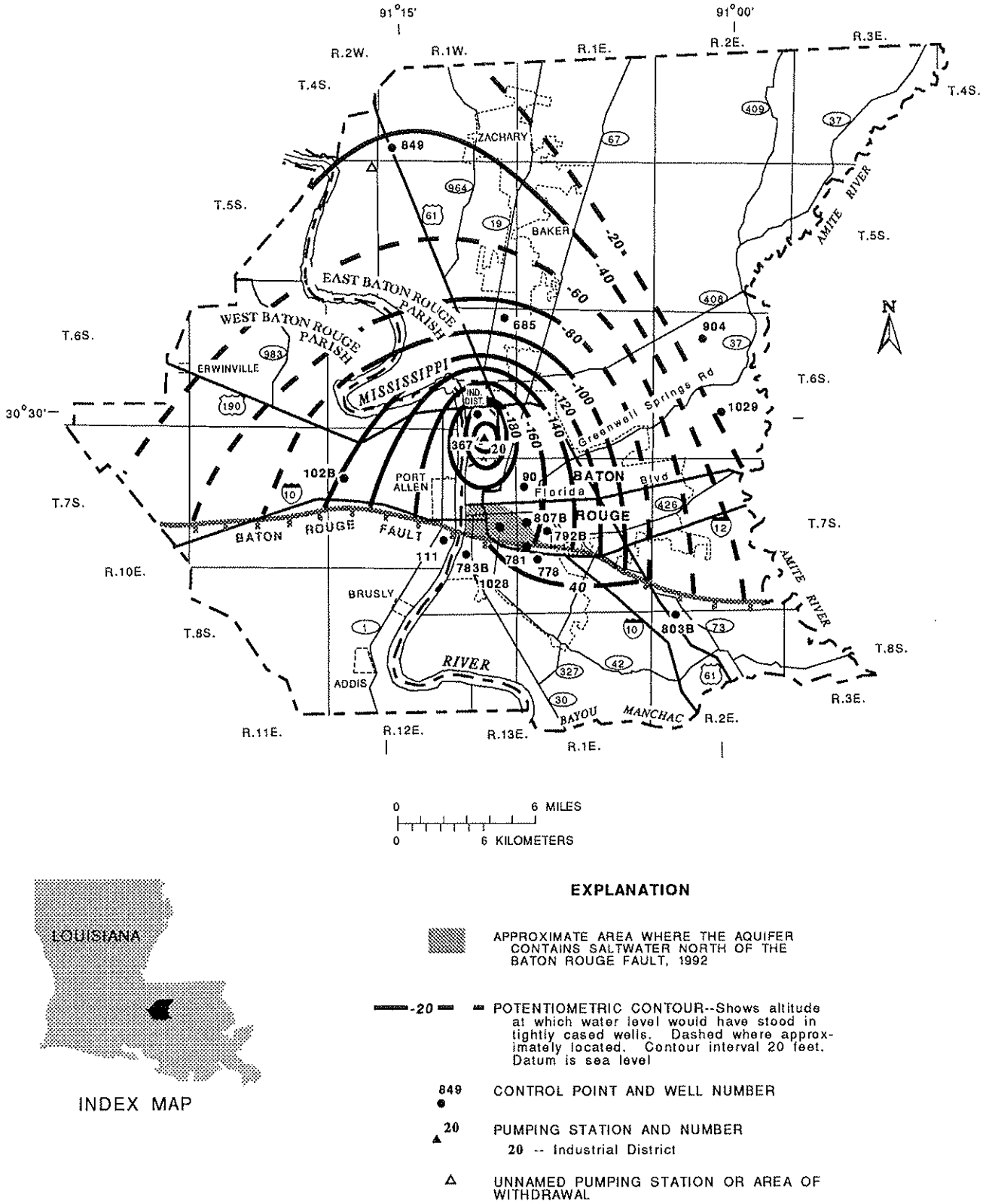


Figure 12. Potentiometric surface of the "2,000-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

"2,800-Foot" Sand

Pumpage from the "2,800-foot" sand, the second most heavily pumped aquifer in the Baton Rouge area, totaled 29 Mgal/d in 1990. Pumping was located primarily in the northern half of East Baton Rouge Parish. About 70 percent of the pumpage is by industry.

Most of the pumpage from the "2,800-foot" sand is concentrated west of Zachary where industry pumped about 15.5 Mgal/d. The remaining pumpage was dispersed throughout the northern part of East Baton Rouge Parish. There is moderate pumpage from this aquifer in the industrial district, north of U.S. 190.

Distribution of Saltwater

An extensive area containing saltwater exists in the "2,800-foot" sand north of the Baton Rouge fault in East and West Baton Rouge Parishes (fig. 13). The aquifer contains saltwater in most of West Baton Rouge Parish and approximately the southern half of East Baton Rouge Parish. Saltwater in the "2,800-foot" sand is the result of incomplete flushing of saltwater which at one time filled the entire aquifer (Rollo, 1969, p. 37; Whiteman, 1979, p. 44). In much of the area containing saltwater, a large amount of overlying freshwater is present. The area containing saltwater and freshwater generally has been referred to as the transitional zone. The transitional zone begins 3 to 5 mi north of the fault and is about 4 mi in width. South of this zone the entire aquifer contains saltwater.

Direction and Rate of Saltwater Movement

No evidence of saltwater encroachment in the "2,800-foot" sand was observed during this study. Data collected at sample sites (fig. 13 and table 1) indicate no substantial movement has been detected. However, analysis of well data (EB-750 and EB-798) indicates wells installed within the transitional zone may yield water with increasing trends in chloride concentrations. The increase in chloride probably is the result of upconing of saltwater in the transitional zone. Chloride concentrations in water from wells EB-750 and EB-798 (fig. 14) show trends in chloride concentrations that occurred in moderately pumped wells in the transitional zone. Chloride concentrations have increased at each well since monitoring began (fig. 14). In 1990, both wells were pumped about 0.5 Mgal/d (1990). Chloride concentrations may continue to increase as moderate pumping continues or as pumpage is increased. In 1992, water from well EB-798 contained concentrations of chloride about 250 mg/L.

Chloride concentrations in water from well WBR-95C have changed very little in comparison to wells EB-750 and EB-798. Chloride concentrations in water from well WBR-95C were 38 mg/L and 42 mg/L when constructed and sampled in 1964. Subsequent chloride concentration in water from well WBR-95C was 48 mg/L when sampled in 1990. Although well WBR-95C is screened in the transitional zone where increasing chloride trends may be expected, only about .1 Mgal/d was pumped from this well in 1990.

Pumping wells near the limit of the transition zone may induce greater flow of freshwater from the north, thereby supplying the wells north of the transition zone with water lower in chloride concentrations than previously yielded. The decrease in chloride concentration at this well may result from pumping near the northern limit of the transition zone. If pumping continues at the northern extent of the transitional zone, wells located north of the zone will continue to yield water low in chloride under present pumping conditions (presuming no large increases in withdrawals north of the transition zone), and northward saltwater encroachment will be minimal. The 1990 potentiometric surface (fig. 15) indicates no northward gradient exists under present conditions to move saltwater into freshwater areas of the aquifer.

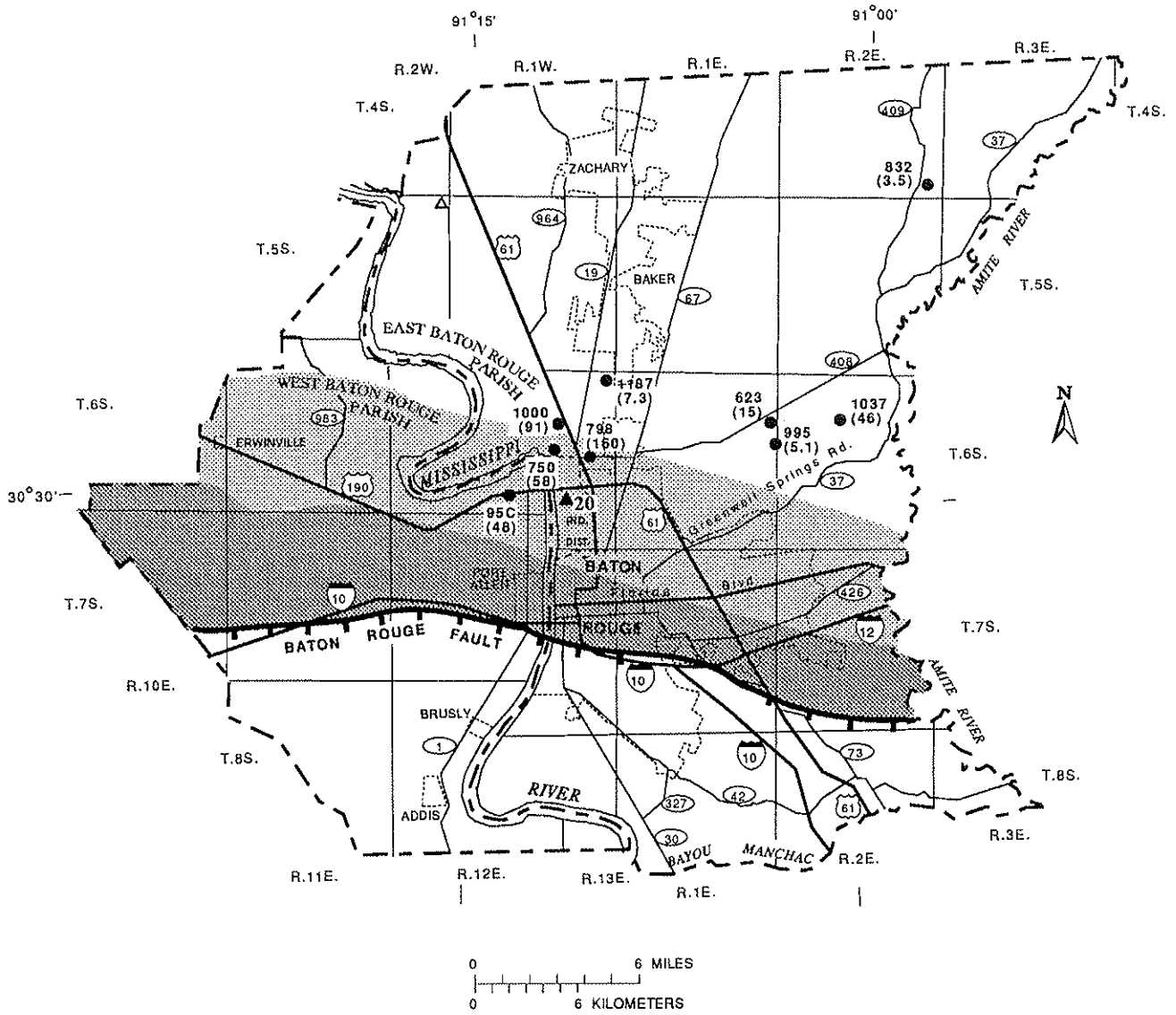


Figure 13. Location of saltwater in the "2,800-foot" sand north of the Baton Rouge fault in the Baton Rouge area, Louisiana.

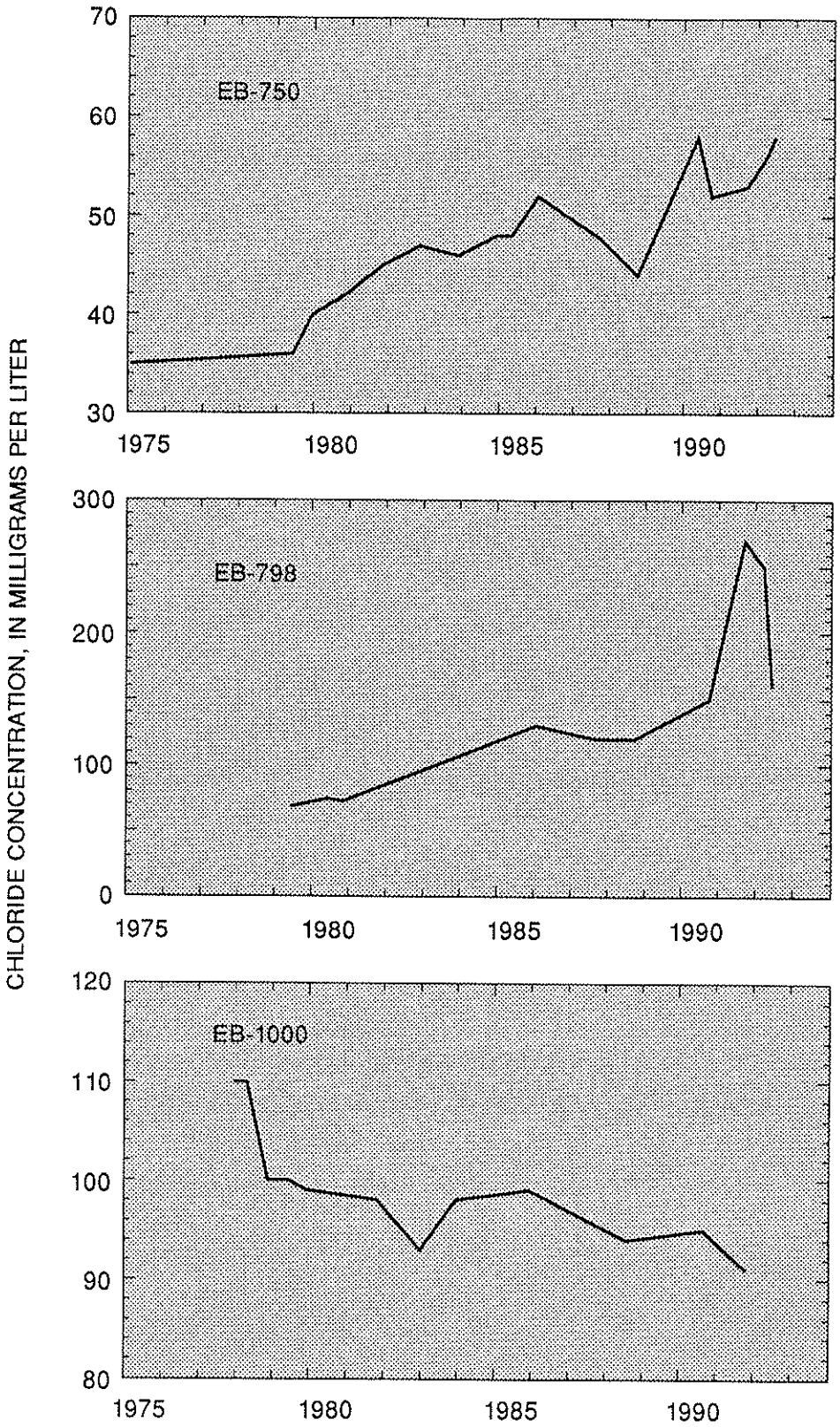


Figure 14. Chloride concentration in water from selected wells screened in the "2,800-foot" sand in the Baton Rouge area, Louisiana. (Well locations are shown in fig. 13.)

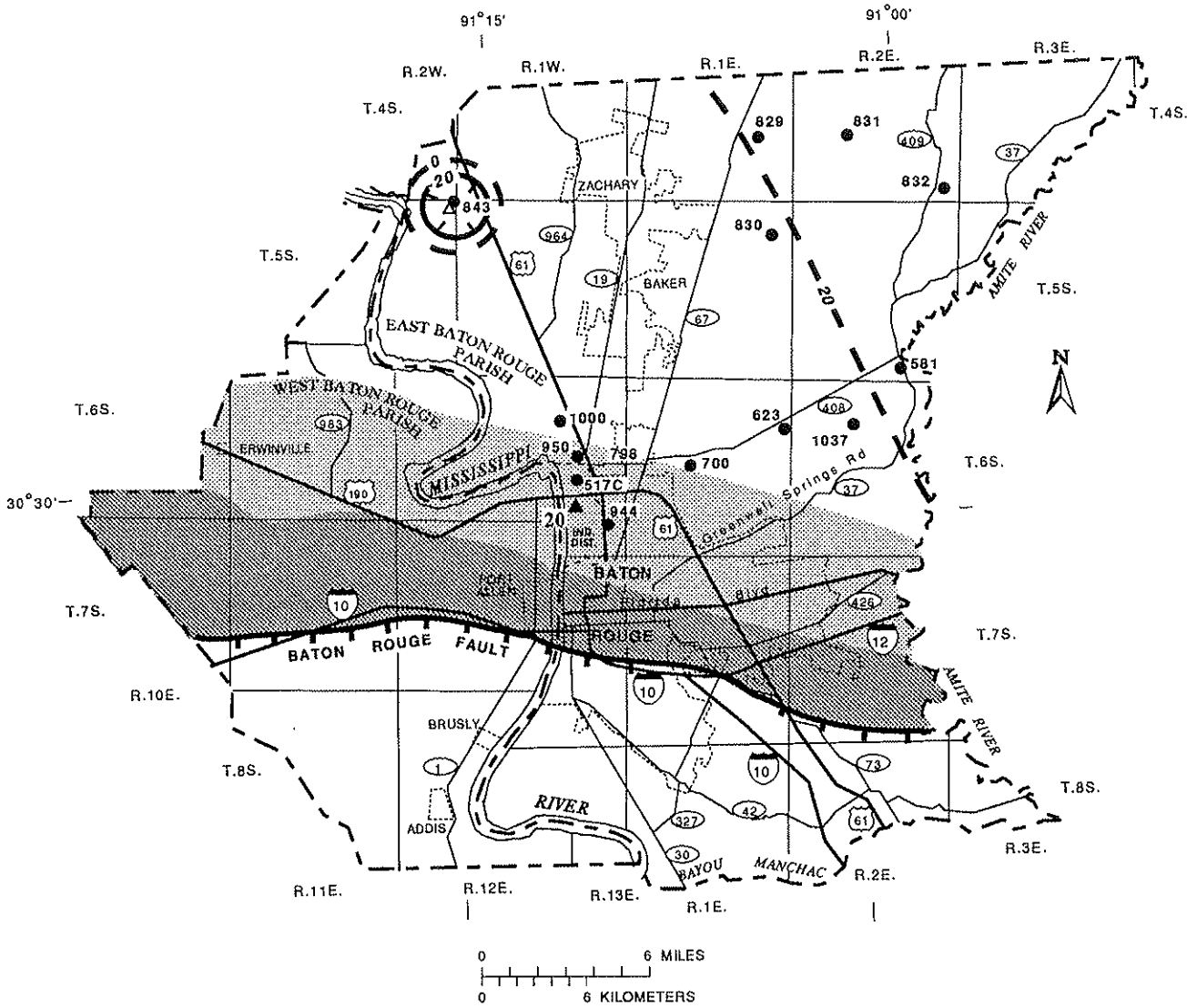


Figure 15. Potentiometric surface of the "2,800-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

DISTRIBUTION AND MOVEMENT OF SALTWATER IN OTHER AQUIFERS IN THE BATON ROUGE AREA

The "400-, 600-, 800-, 1,000-, 1,200-, 1,700-, and 2,400-foot" sands supply about 35 percent of the ground water pumped in East and West Baton Rouge Parishes. Although the percentage of pumpage is relatively low, saltwater has been detected north of the Baton Rouge fault in most of these aquifers.

"400-Foot" Sand

In 1990, about 9 Mgal/d were pumped from the "400-foot" sand in the Baton Rouge area. Pumping is concentrated in three areas: the industrial district (1.5 Mgal/d); an area including the Aubin, Interstate 12, and Toulon pumping stations; and an area west of Zachary. Additional pumping from the aquifer was from wells screened in both the "400-foot" and the underlying "600-foot" sands in the industrial district area. Wells with screens in both aquifers were pumped less than 3 Mgal/d in 1990. It is estimated about 1.5 Mgal/d (half of the total 3 Mgal/d) was pumped from the "400-foot" sand.

Saltwater in the "400-foot" sand does not seem to be moving toward pumping stations. All wells sampled north of the fault yielded water with chloride concentrations near background levels (less than 10 mg/L). Whiteman (1979) documented an area containing saltwater north of the Baton Rouge fault (fig. 16). The area located in western West Baton Rouge Parish is thought to be part of a residual body of saltwater that was never flushed from the aquifer (Whiteman, 1979, p. 36). Because pumpage from the aquifer is relatively low and downthrown sands opposite the "400-foot" sand at the fault contain freshwater, saltwater encroachment is unlikely under present hydrologic conditions; however, saltwater leakage from the underlying "600-foot" sand is possible (Whiteman, 1979, p. 36). The possibility exists for vertical leakage of saltwater through abandoned wells, if saltwater in the "600-foot" sand reaches the industrial district and if water levels in the "400-foot" sand are reduced below levels in the underlying "600-foot" sand. Under 1990 conditions, water-level elevations in the "400-foot" sand were similar to those in the "600-foot" sand (figs. 16 and 17), and saltwater was not present in the "600-foot" sand under the industrial district.

"600-Foot" Sand

The "600-foot" sand is one of the least pumped aquifers in the Baton Rouge area. About 2.5 Mgal/d of water was pumped for industry and public supply (1990) from wells screened only in the "600-foot" sand. Largest withdrawals were for public supply (0.6 Mgal/d) near the Baton Rouge fault at well EB-879 (fig. 17). About 0.5 Mgal/d was pumped in the industrial district. An estimated 1.5 Mgal/d was pumped from the "600-foot" sand by industry in the industrial district and west of Zachary from wells screened in the "400-foot" and "600-foot" sands.

The estimated present (1992) extent of the main body of saltwater in the aquifer is shown in figure 17. The configuration of the saltwater body is about the same as that delineated by Whiteman (1979, pl. 3). No additional wells have been affected by movement of saltwater.

Although northward advance of saltwater in the "600-foot" sand was not detected during this study, saltwater leakage across the fault into the "600-foot" sand is possible. A relation between pumpage in the industrial district, the rate of leakage of saltwater across the fault, and rate of movement of saltwater was documented by Whiteman (1979, p. 21). Total combined pumpage from the "400-foot" and "600-foot" sands decreased about 40 percent between 1977 and 1992. The reduction in pumpage and resultant rise in water levels north of the fault has decreased the rate of saltwater leakage across the fault into the "600-foot" sand and the rate of northward saltwater encroachment in the aquifer. A water-level difference of 20 ft or more across the fault is indicated by a comparison of the potentiometric surface of the "400-foot" sand south of the fault (fig. 16) with the potentiometric surface of the "600-foot" sand north of the fault (fig. 17). Thus, saltwater leakage across the fault may occur.

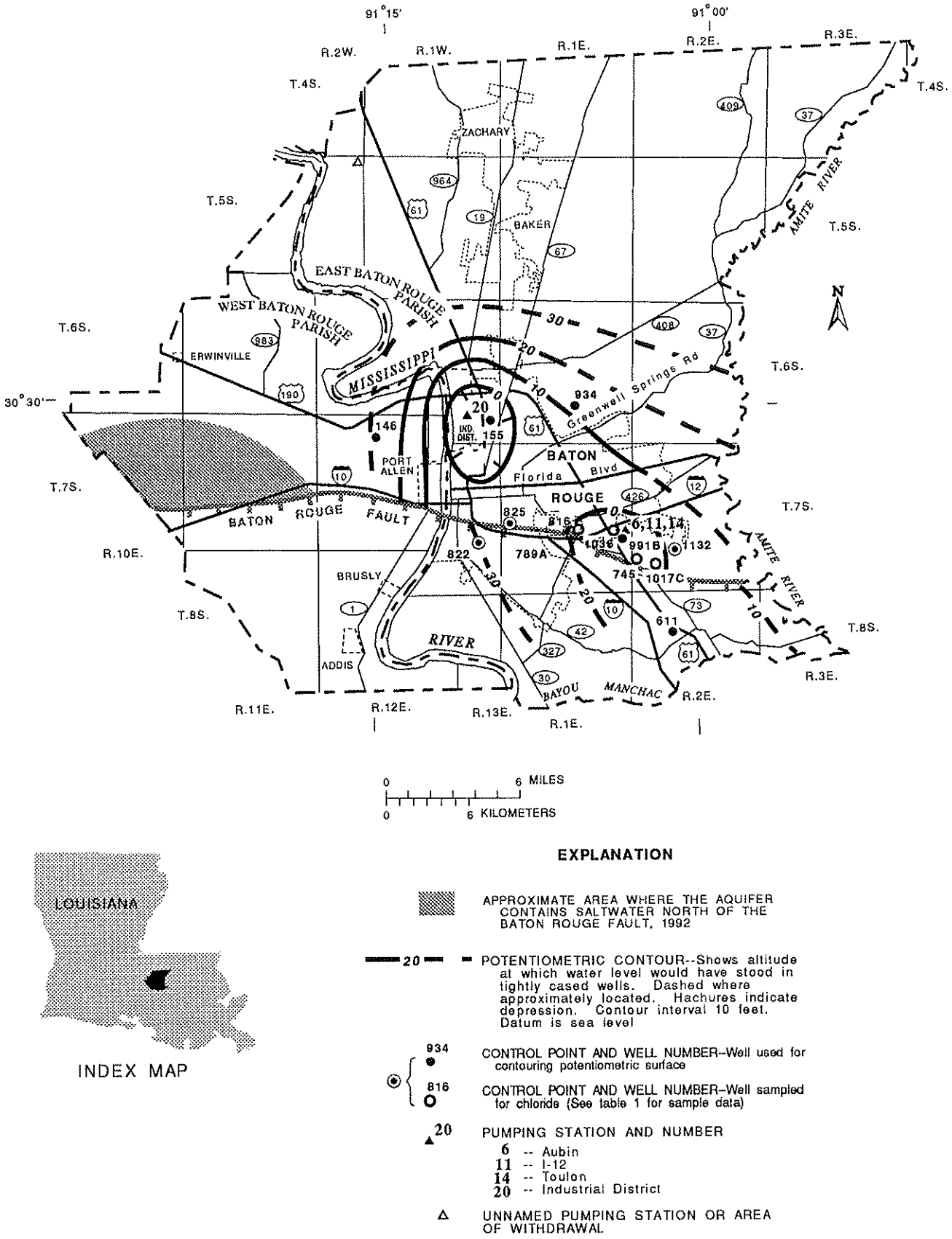


Figure 16. Location of saltwater north of the Baton Rouge fault and potentiometric surface of the "400-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

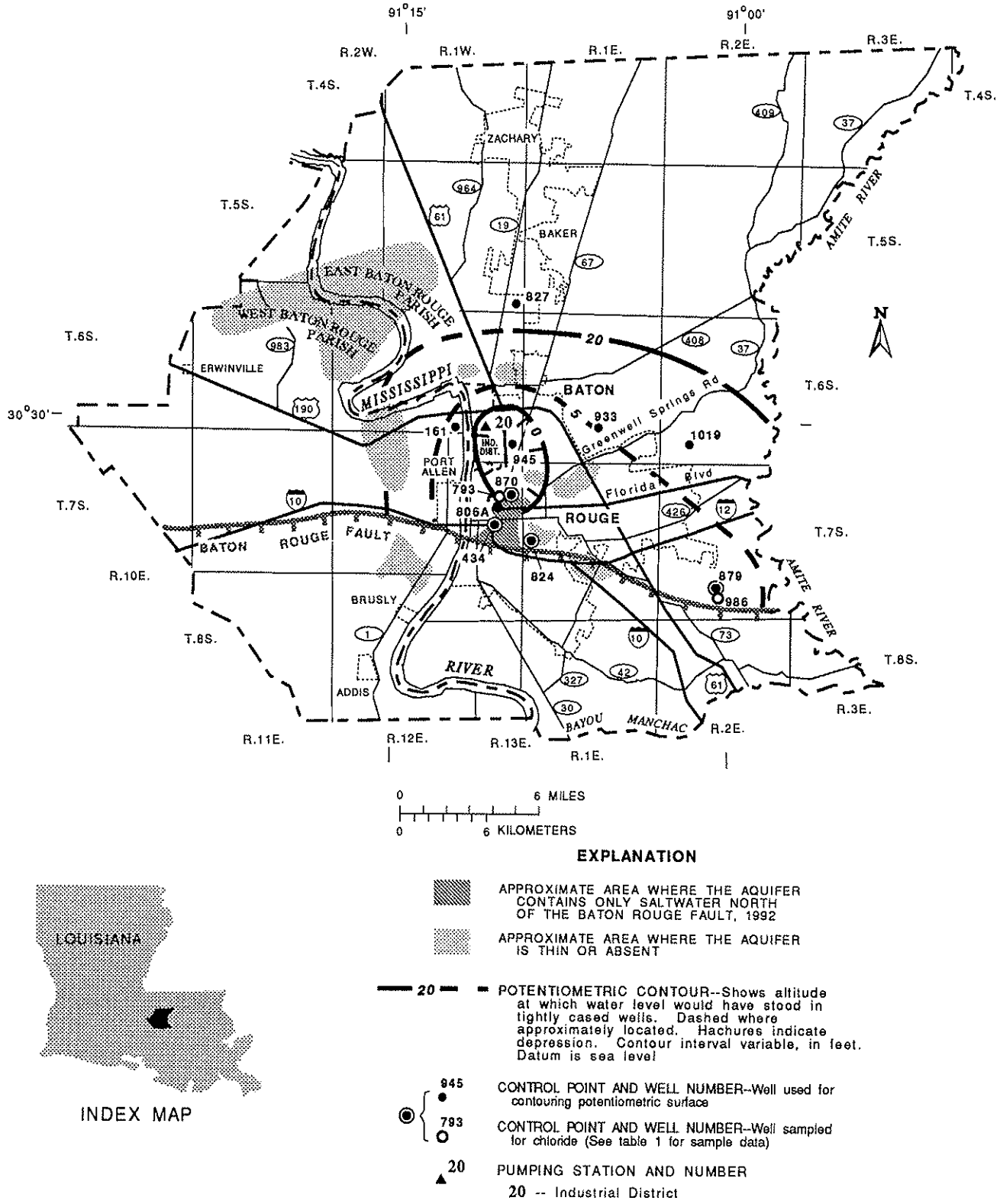


Figure 17. Location of saltwater north of the Baton Rouge fault and potentiometric surface of the "600-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

Saltwater encroachment may be in a northeasterly direction following a low area in the base of the aquifer mapped by earlier investigators (Kuniansky and others, 1989, pl. 17). In addition, saltwater may be leaking vertically into the underlying "800-foot" sand in an area where that aquifer is directly interconnected with the "600-foot" sand. Kuniansky and others (1989, pl. 17) mapped a large area where the "600-foot" and the "800-foot" sands merge. The area includes the central and northern areas occupied by the saltwater body in the "600-foot" sand.

"800-Foot" Sand

In 1990, only 1.9 Mgal/d was pumped from the "800-foot" sand in the Baton Rouge area (fig. 5). About 90 percent of the withdrawal was for public supply. In eastern East Baton Rouge Parish, 1 Mgal/d was pumped; in Port Allen, about 0.6 Mgal/d was pumped. The remaining 0.3 Mgal/d was pumped in the industrial district.

Saltwater encroachment did not seem to be a major problem in the "800-foot" sand in 1992. Although a narrow strip of saltwater along the north side of the fault has been documented previously (Whiteman, 1979, fig. 8), no encroachment was detected during this study. If pumping from the aquifer increases, saltwater leakage from the "600-foot" sand may become significant. A large area north of the fault where the "600-foot" sand contains saltwater may be interconnected with the "800-foot" sand (Kuniansky and others, 1989, pl. 17). If an increase in pumping lowers water levels in the "800-foot" sand below those in the "600-foot" sand, downward flow of saltwater will result. Vertical leakage of saltwater into the "800-foot" sand may occur at present, due to the density of saltwater in the overlying "600-foot" sand; however, no data are available to confirm this.

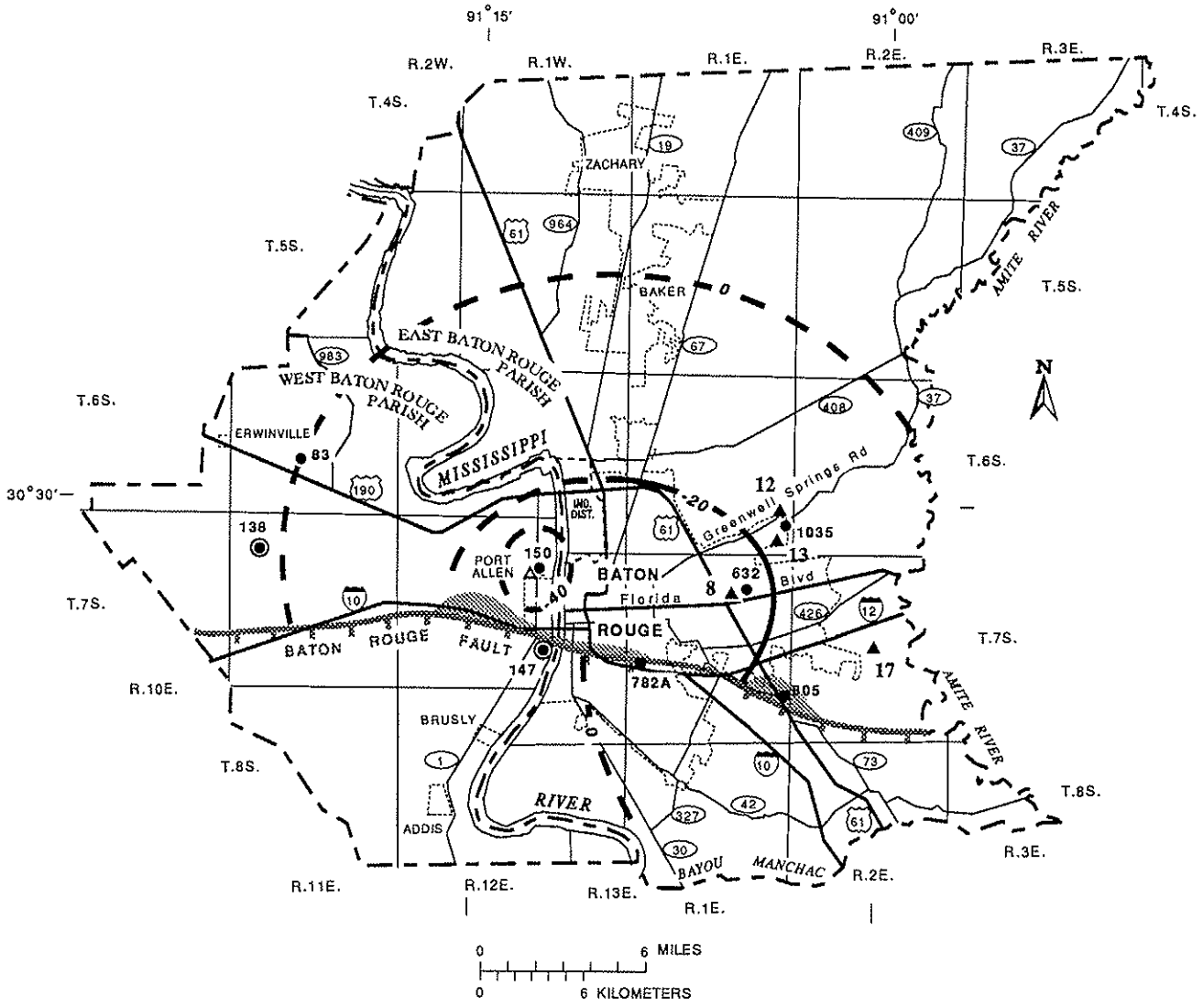
"1,000-Foot" Sand

In 1990, pumpage from the "1,000-foot" sand totaled about 6.5 Mgal/d and all was used for public supply (fig. 5). Pumping stations were distributed north of the fault (the nearest well is 2.0 mi north) and pumpage from each station was relatively small. Pumping stations were located just north of Port Allen, and in eastern East Baton Rouge Parish at Cortana, Green Ridge, North Sharp, and O'Neal stations (fig. 18).

Saltwater has been detected north of the fault (Whiteman, 1979, p. 38) in the area shown around well EB-805 in figure 18. Additional wells have not been completed in the "1,000-foot" sand to monitor saltwater encroachment. Chloride concentrations were monitored in water from well EB-805 from 1966 to 1988 (fig. 19). Chloride concentrations steadily increased during this period from less than 1,000 mg/L to more than 7,000 mg/L. Monitoring was discontinued after 1988; however, from 1984 to 1988 chloride concentrations increased about 200 mg/L per year. If this trend has continued, chloride concentration may now (1992) be 8,000 mg/L at this well.

The continuous increase in chloride concentrations in water from well EB-805 is evidence that saltwater is leaking across the fault in this area. The saltwater leakage is caused by water-level differences across the fault due to pumping from the "1,000-foot" sand in eastern East Baton Rouge Parish. Cones of depression (not indicated in fig. 18 because of the contour interval) now encompass the pumping stations and a northward gradient has developed. In response to the hydraulic gradient across the fault, saltwater is moving northward toward the pumping stations.

The rate of saltwater encroachment cannot be determined directly in the "1,000-foot" sand with available data. No wells have been installed north of the previously delineated saltwater areas to monitor encroachment.



INDEX MAP

EXPLANATION

APPROXIMATE AREA WHERE THE AQUIFER CONTAINS SALTWATER NORTH OF THE BATON ROUGE FAULT, 1992

0 — POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 20 feet. Datum is sea level

632 — CONTROL POINT AND WELL NUMBER--Well used for contouring potentiometric surface

147 — CONTROL POINT AND WELL NUMBER--Well sampled for chloride (See table 1 for sample data)

8 — PUMPING STATION AND NUMBER

8 -- Cortana
12 -- Green Ridge
13 -- North Sharp
17 -- O'Neal

△ UNNAMED PUMPING STATION OR AREA OF WITHDRAWAL

Figure 18. Location of saltwater north of the Baton Rouge fault and potentiometric surface of the "1,000-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

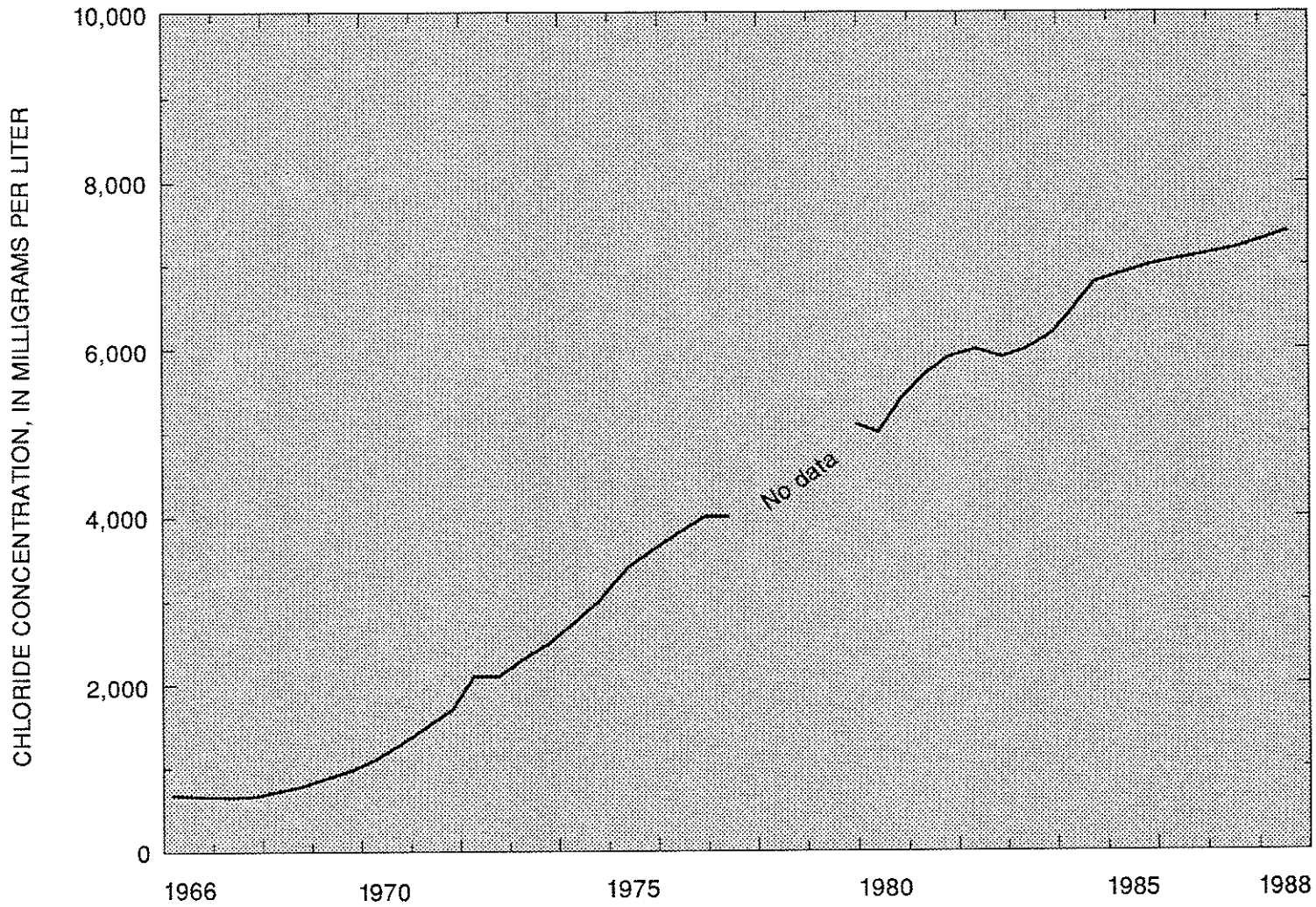


Figure 19. Chloride concentration in water from well EB-805 screened in the "1,000-foot" sand in the Baton Rouge area, Louisiana.

In the saltwater area located near well EB-805, Whiteman (1979, p. 41) estimated the average rate of northward encroachment to be less than 200 ft/yr. At this rate, it was estimated that saltwater would reach the Cortana station in about the year 2050. It is likely that the average rate of saltwater encroachment may be about half the rate suggested earlier, or about 110 ft/yr. This estimate is based on an average hydraulic conductivity of 110 ft/d, porosity of 25 percent, and a hydraulic gradient of about 10.6 ft/16,000 ft (3.5 ft/ft) between the Cortana station and well EB-805. If this calculation is correct, the freshwater-saltwater interface has moved only about 0.3 mi in a generally northward direction since 1977. Based on this calculation, about 140 yrs will be required for saltwater to reach the Cortana station from this position under present pumping conditions.

In West Baton Rouge Parish the rate of saltwater encroachment toward Port Allen cannot be determined without test drilling and the installation of a monitor well for water-quality and water-level data collection. Water sampled from a monitor well (WBR-104) near Port Allen confirmed the presence of saltwater north of the fault (Whiteman, 1979, p. 38) (fig. 18). The monitor well failed soon after completion and could not be sampled.

"1,200-Foot" Sand

In 1990, about 13 Mgal/d was pumped from the "1,200-foot" sand in the Baton Rouge area (fig. 5). The most concentrated pumping was in the industrial district (fig. 20), where nearly 5.5 Mgal/d was pumped by industry. The second largest concentration of pumping, about 2.5 Mgal/d, was at the Bankston station (public supply). Additional stations, mostly in central East Baton Rouge Parish, pumped about 1 Mgal/d or less. In West Baton Rouge Parish, about 1.1 Mgal/d was pumped near the fault west of Port Allen.

An evaluation of data collected during this study indicated the possibility of saltwater encroachment has occurred at only one site. Well EB-621, located at the Westminster station (fig. 20), began yielding water with chloride concentrations above background levels (10 mg/L) in 1978. Highest chloride concentrations (about 60 mg/L) were detected between 1984 and 1987; after 1987, chloride concentrations decreased to near background levels. The increased concentration of chloride from well EB-621 may be due to upconing of saltwater from the base of the aquifer during periods of pumping (0.3 Mgal/d in 1990) or leakage of saltwater across the fault. With the exception of well EB-621, water sampled from wells north of the fault since 1990 contained 5.8 mg/L or less chloride.

Under 1992 pumping conditions, saltwater encroachment in the aquifer is unlikely because most pumpage is not heavily concentrated and is located considerably north of the fault. However, routine collection and evaluation of chloride data from well EB-621 and nearby wells, such as EB-990, could provide early detection of possible saltwater encroachment. If encroachment were detected in the area, alternative pumping distribution and rates may reduce or eliminate the problem.

"1,700-Foot" Sand

In 1990, pumpage from the "1700-foot" sand totaled about 2.5 Mgal/d (fig. 5); the "1,700-foot" sand is considered to be a minor aquifer in the Baton Rouge area. Nearly all pumpage was for public supply (80 percent) and was in East Baton Rouge Parish. The largest withdrawals were at the Cortana station (1.5 Mgal/d). Additional stations are located in Port Allen (0.3 Mgal/d) and in eastern East Baton Rouge Parish (near well EB-614). Additional withdrawals from the aquifer are at the Robin station from a well screened in the "1,700-foot" and "2,000-foot" sands.

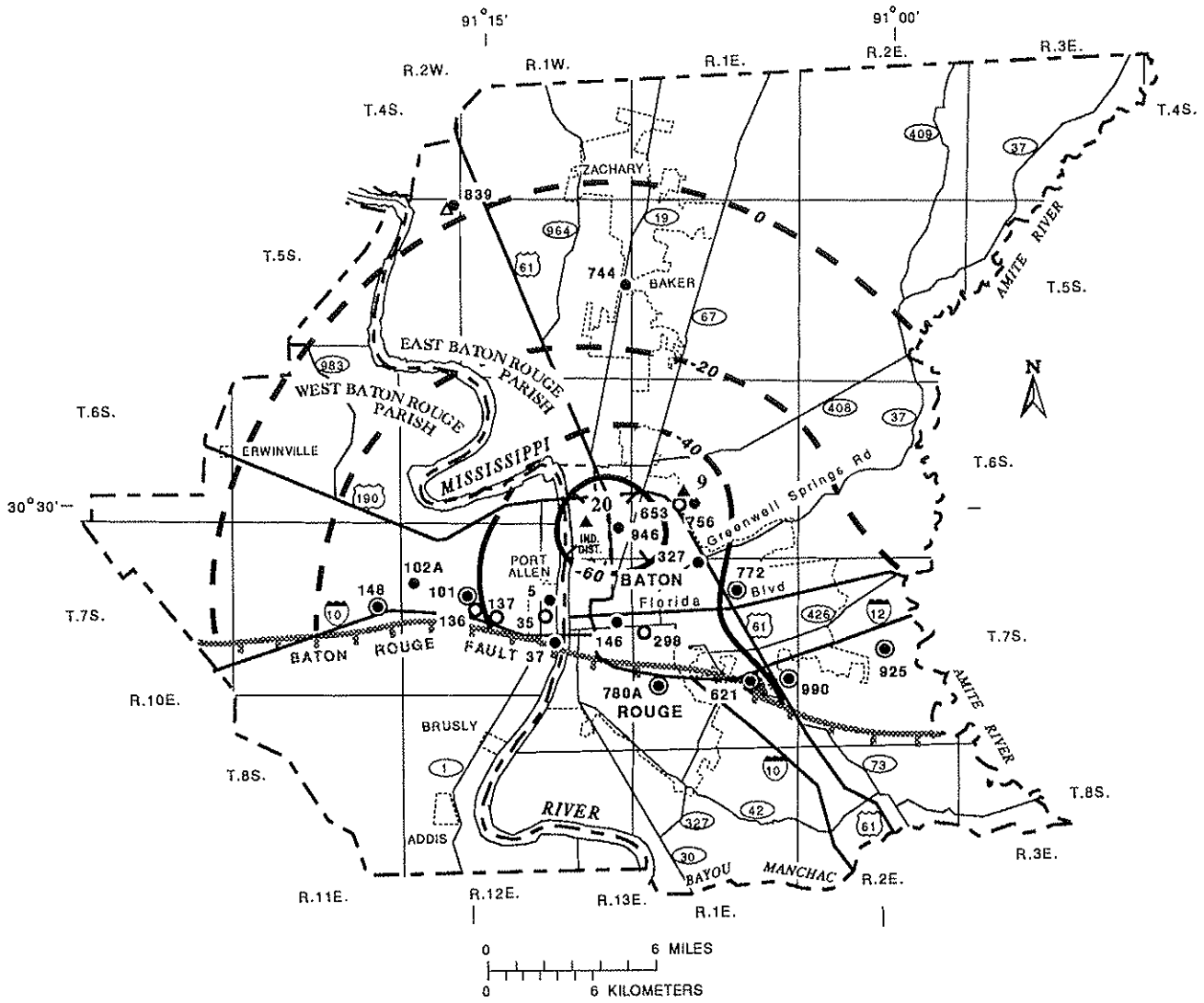


Figure 20. Location of wells sampled for chloride and potentiometric surface of the "1,200-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

Saltwater encroachment was not detected in the "1,700-foot" sand during this study. However, few wells were available for chloride data collection (fig. 21). Water from all wells sampled contained low chloride concentrations (less than 10 mg/L, table 1). Saltwater encroachment is unlikely because pumpage from the aquifer is small and generally located well north of the Baton Rouge fault.

"2,400-Foot" Sand

In 1990, pumpage from the "2,400-foot" sand was about 11.5 Mgal/d (fig. 5); about 85 percent of the pumpage was for public supply. The most concentrated pumpage in central East Baton Rouge Parish was located in the industrial district (2.5 Mgal/d), the Convention station (2.0 Mgal/d), and the Government station (2.8 Mgal/d). Saltwater encroachment is unlikely because the "2,000-foot" sand contains freshwater south of the fault.

Saltwater was not detected in the "2,400-foot" sand in any wells located north of the Baton Rouge fault. Chloride concentrations in water from wells routinely sampled as part of the saltwater monitoring network did not show increasing trends, and water from additional wells sampled were low in chloride concentration. Most water from wells sampled north of the fault in the "2,400-foot" sand has chloride concentrations of 10 mg/L or less (table 1).

The 1990 potentiometric surface (fig. 22) has a cone of depression in the "2,400-foot" sand centered about the Convention pumping station. The position of the cone of depression and the water-level gradient determined from potentiometric contours (fig. 22) indicate that saltwater leaking across the fault will probably flow toward the Convention pumping station. Water from well EB-794 (located near the fault and south of the Convention station) has shown no increasing trend in chloride concentrations.

At the Government station, two wells (EB-151 and EB-733) were installed to each yield water from both the "2,000-foot" and "2,400-foot" sands. However, water-level and temperature data indicate that these dual-screened wells (each screened in the "2,000-foot" and "2,400-foot" sands) are yielding water only from the "2,400-foot" sand. Interpretations of electric-log data at this site indicate the "2,400-foot" sand is located between 2,525 and 2,635 ft below land surface. Temperature data collected at the well site are indicative of water from a depth of about 2,600 ft. Well EB-151 is screened in the intervals from 2,157 to 2,269 ft and from 2,591 and to 2,637 ft below land surface. Well EB-733 is screened in the intervals from 2,070 and to 2,244 ft and from 2,570 to 2,658 ft below land surface. Water-temperature data collected from wells EB-151 and EB-733 (June 17, 1992) were 35.9 and 35.4 ^{o}C, indicating most of the water is pumped from the "2,400-foot" sand. Another indication water is from the "2,400-foot" sand is that the water-level data from both wells, which indicate pumping water levels were above non-pumping levels in the "2,000-foot" sand.

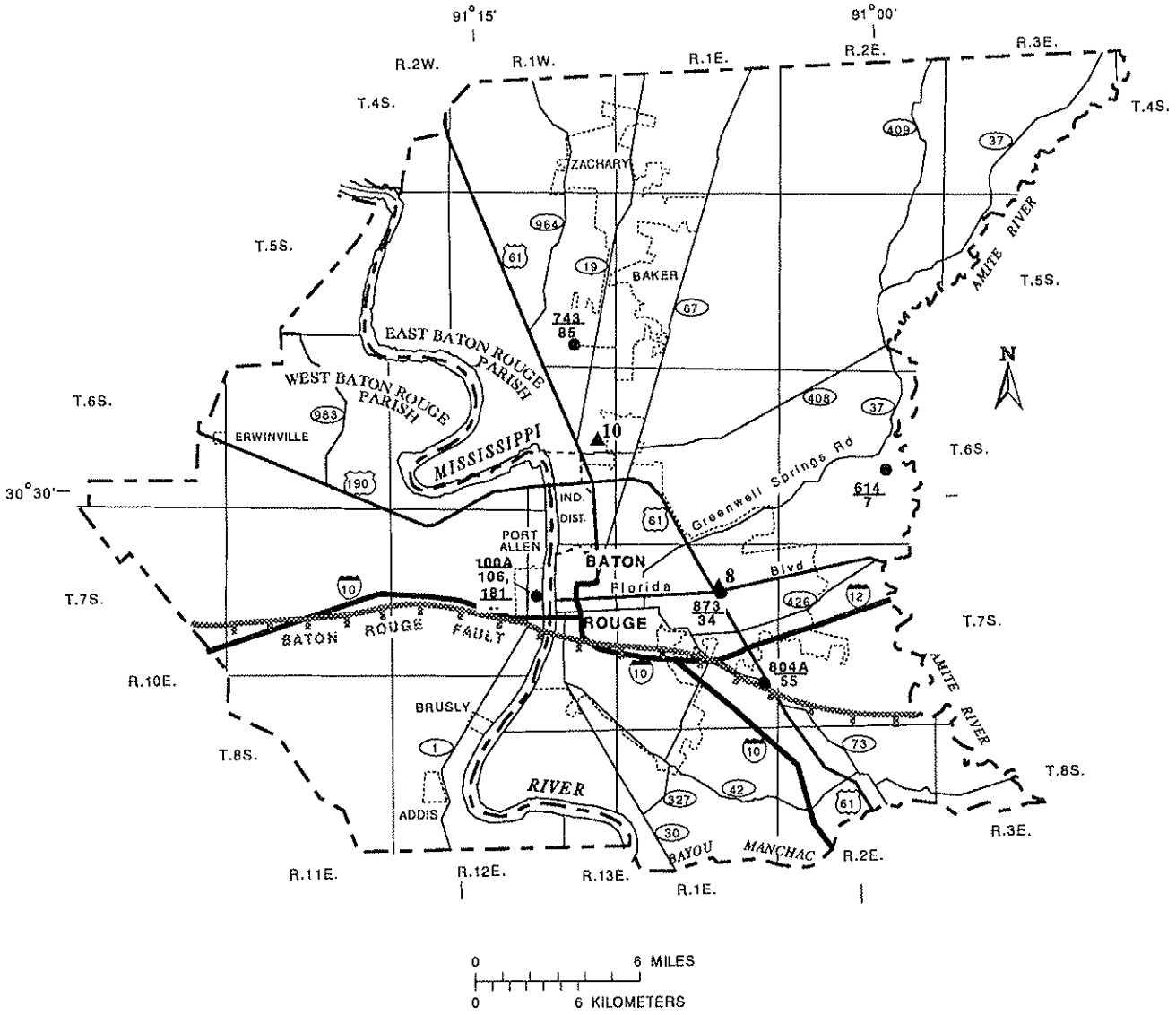


Figure 21. Location of wells sampled for chloride and water-level data collection in the "1,700-foot" sand, spring 1990, in the Baton Rouge area, Louisiana.

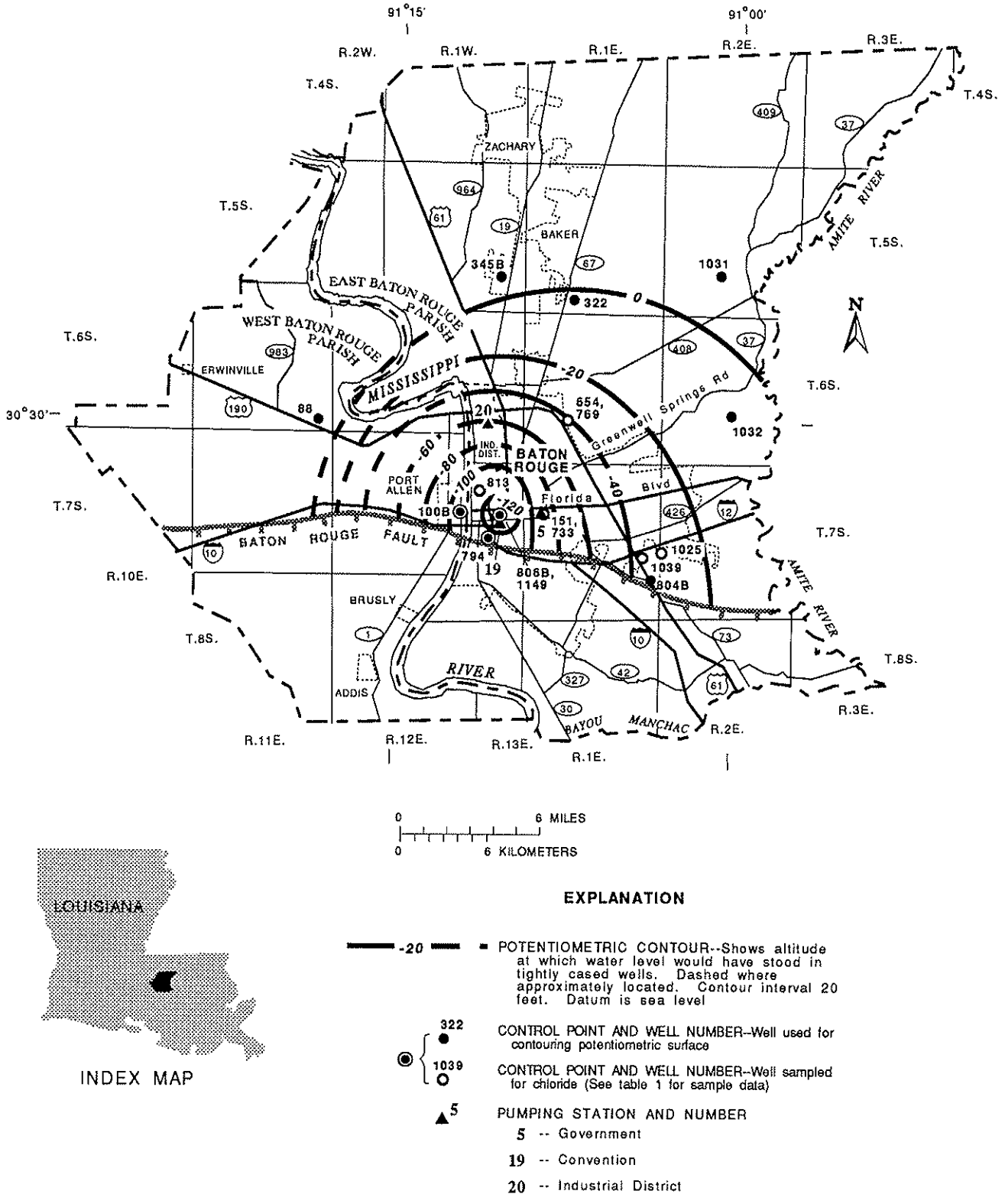


Figure 22. Location of wells sampled for chloride and potentiometric surface of the "2,400-foot" sand, north of the Baton Rouge fault, spring 1990, in the Baton Rouge area, Louisiana.

EVALUATION OF THE CHLORIDE MONITORING NETWORK TO DETECT THE DISTRIBUTION AND MOVEMENT OF SALTWATER

The 1992 chloride monitoring network consists of 36 wells in East Baton Rouge Parish and 7 wells in West Baton Rouge Parish (table 1). Each well in the network is sampled annually for chloride (chloride data for well EB-782B is not shown in table 1). Annual sampling procedures also include field measurements of specific conductance and water levels. Because of changing conditions in the Baton Rouge aquifers, modifications to the network could improve the potential for early detection of saltwater encroachment into well fields or vulnerable areas of the aquifer system.

More frequent (possibly quarterly) sampling at key wells may be beneficial for early detection of saltwater encroachment. The benefits of more frequent sampling are limited; however, early detection of increasing chloride concentrations in one aquifer would allow water users to develop alternative pumping schemes, such as reducing pumpage or using wells screened in other aquifers.

Coupled with more frequent sampling, additional wells could be added to the monitoring network. In some locations, available production wells could be sampled. Some pumping stations are (1992) considered at high risk for saltwater encroachment. Gradient and chemical data to more precisely determine the position and encroachment rate of saltwater may be acquired by drilling test wells for chloride and water-level data collection. Additional geologic and hydrologic information could be obtained by drilling of test wells and installation of monitor wells for the Lafayette and Convention stations in the "2,000-foot" sand and for the Government station in the "1,500-foot" sand. Elevated concentrations of chloride are now (1992) present at the Lafayette and Convention stations. Test drilling at or near these areas may provide information necessary for the selection of suitable sites for scavenger wells. Test-well data collected south of the Lafayette and Convention stations would be valuable in documenting the basal geology of the "2,000-foot" sand as well as in determining the thickness and chloride concentration of saltwater at the base of the aquifer. Installation of a monitor well north of the Lafayette station, between wells EB-444 and EB-874 (fig. 10), for chloride and water-level data collection could help determine if saltwater is presently (1992) moving northward past the Lafayette station and toward the industrial district.

Installation of two monitor wells near the Government station (in the "1,500-foot" and "2,000-foot" sands about halfway between the estimated 1992 freshwater-saltwater interface and the Government station) may allow data collection to refine the 1992 estimates of the location of the interface. Chloride and water-level data may enable a more accurate estimation of direction and rate of saltwater movement in the area of the Government station. The installation of a monitor well west of Government station and north of well EB-807A, may be helpful in monitoring saltwater encroachment toward the Lula station. Installation and data collection from this monitor well may give detailed hydrogeologic data and chloride data helpful in evaluating the effects of pumpage from the Government station. In West Baton Rouge Parish, the installation of a monitor well in the "1,000-foot" sand between the previously mapped saltwater area (Whiteman, 1979) and Port Allen could be helpful to determine location of the interface as well as direction and rate of ground-water movement.

Supply wells are available to add to the chloride monitoring network. In the "1,200-foot" sand, well EB-990 (a public-supply well) could be added to the network and the water sampled annually for chloride. Wells EB-674 and EB-1150 in the "2,000-foot" sand also could be added to the network and sampled for chloride quarterly, if possible. In addition, water in the wells at the Government, Lafayette, and Convention stations may be sampled semiannually, or possibly quarterly, for chloride.

SUMMARY AND CONCLUSIONS

Ten aquifers in the Baton Rouge area contain freshwater north of the Baton Rouge fault. The "600-, 1,200-, 1,500-, 2,000-, and 2,800-foot" sands are the most heavily pumped aquifers in the Baton Rouge area. Saltwater (water containing chloride greater than 250 milligrams per liter) has been detected in all of these aquifers except, the "1,200-foot" sand; however, data collected at well EB-621, screened in this aquifer, indicate that saltwater may be present just north of the fault at the Westminster station. Although saltwater is contained in these aquifers, in 1992 saltwater encroachment was detected only in the "1,000-foot," "1,500-foot," and "2,000-foot" sands.

The Baton Rouge fault, located in the southern half of East and West Baton Rouge Parishes, is within the southern city limits of Baton Rouge. Although the fault restricts ground-water movement, leakage across the fault has been detected. Because pumping stations for industrial use and public supply are near the fault, ground-water withdrawals have reversed the hydraulic gradient across the fault and induced northward movement of saltwater across the fault. Saltwater sinks to the base of the aquifer as it moves across the fault and toward pumping stations in response to the induced gradient and hydrogeologic controls.

In 1992, the area of saltwater in the "1,500-foot" sand occupied about 1.5 square miles. Saltwater is moving in a north to northeasterly direction toward the Government and Lula stations. The saltwater-freshwater interface may be within 1,600 feet of the Government station, and probably will arrive at the station in 5 years. Because the areal distribution of saltwater and the rate of saltwater leakage (0.2 to 0.5 million gallons per day) across the fault are relatively small, scavenger wells located between the fault and pumping stations have been considered as an option for controlling saltwater encroachment.

The "2,000-foot" sand, the most heavily pumped aquifer in the Baton Rouge area, provides about 39 million gallons per day of water that primarily are pumped for industrial supply. An area underlain by saltwater in the "2,000-foot" sand is about 4 square miles. Saltwater leakage across the fault from 1977 to 1992 is estimated to be 0.57 million gallons per day. Saltwater in the "2,000-foot" sand has reached the Lafayette and Convention public supply stations. Saltwater encroachment north of the Lafayette and Convention pumping stations has not been detected. Concentrations of chloride in water from 3 public supply wells were above background levels (10 milligrams per liter). If pumping from these stations is discontinued as chloride concentrations continue to increase and no physical barrier to movement exists, saltwater probably will advance toward the heavily pumped industrial district at a rate of about 2 feet per day and arrive near the southern edge of the industrial district about 8 years after the stations are discontinued. Scavenger wells located near the fault may be effective for controlling saltwater northward encroachment in the "2,000-foot" sand.

Northward saltwater encroachment in the "2,800-foot" sand was not observed during this study. However, the "2,800-foot" sand contains naturally occurring saltwater north of the fault in most of West Baton Rouge Parish and the southern half of East Baton Rouge Parish. Wells installed in areas where freshwater in the upper part of the aquifer is underlain by saltwater and wells installed near the northern edge of the freshwater-saltwater interface may eventually yield water with increasing chloride concentrations.

Although no advance of the interface was detected in the "600-foot" sand, saltwater leakage across the fault may occur, because of the water-level difference across the fault. Chloride concentrations above background levels (10 milligrams per liter) were detected in the "1,200-foot" sand at the Westminster station; however, encroachment toward pumping stations was not detected.

Water-level, chloride, and hydrogeologic data collected from wells added to the 1992 chloride network may be used for refining future encroachment rates and direction for selected aquifers. Data collected from installation of two monitor wells could be used to determine a more precise position of the freshwater-saltwater interface in the "1,500-foot" and "2,000-foot" sands south of the Government station. Saltwater has reached and passed the monitor wells (EB-807B, EB-917) installed for this purpose. A third well located north of well EB-807B and west of the Government station may be used to collect chloride and water-level data for detection of saltwater encroachment in the "1,500-foot" sand toward the Lula station. An additional well in the "2,000-foot" sand located north of the Lafayette station could be installed to detect northward movement of saltwater (beyond the Lafayette station) toward a well field used for public supply and the industrial district.

Sampling of additional wells near the fault (available industrial and public supply wells) also will provide gradient, chloride, and background data. Of particular interest are wells located at the fault east of Baton Rouge in the "1,200-foot" sand in and near an area where chloride concentrations indicate possible saltwater encroachment (well EB-621, Westminster station; and well EB-990, Aubin Lane station). Additional test drilling and installation of monitor wells in the "600-foot" sand would be helpful locating possible present-day (1992) saltwater encroachment. Although not documented during this study, the possibility exists that saltwater may be leaking undetected from the "600-foot" sand vertically into the underlying "800-foot" sand or moving horizontally along the base of the "600-foot" sand. Test drilling in areas where the "600-foot" and "800-foot" sands may be interconnected and in areas of structurally low elevations in the base of the "600-foot" sand may delineate areas of saltwater previously undefined.

If additional wells are not installed in the "1,500-foot" and "2,000-foot" sands, a more frequent (possibly quarterly) sampling program may be useful to detect saltwater. Intensive sampling at key wells expected to increase in chloride concentrations would give the earliest detection of saltwater encroachment and allow additional time for implementation of an alternative water supply or remedial action.

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