POTENTIAL FOR POLLUTION OF THE UPPER FLORIDAN AQUIFER FROM FIVE SINKHOLES AND AN INTERNALLY DRAINED BASIN IN WEST-CENTRAL FLORIDA

By John T. Trommer

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ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to metric units and abbreviation of units, are as follows:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
foot (ft)	0.3048	meter (m)
foot per hour (ft/h)	0.3048	meter per hour (m/h)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09294	square meter (m^2)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.00006309	cubic meter per second (m^3/s)
gallon per minute per foot [(gal/min)/ft]	0.0000207	cubic meter per second per meter [(m^3/s)/m]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$^{\circ}F = 1.8\ ^{\circ}C + 32$$

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Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD 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 "Mean Sea Level of 1929."

POTENTIAL FOR POLLUTION OF THE UPPER FLORIDAN AQUIFER FROM FIVE SINKHOLES AND AN INTERNALLY DRAINED BASIN, WEST-CENTRAL FLORIDA

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ABSTRACT

Sinkholes are natural and common geologic features in west-central Florida, which is underlain by water-soluble limestone deposits. Dissolution of these deposits is the fundamental cause of sinkhole development. Sinkholes and other karst features are more pronounced in the northern part of the study area, but sinkhole activity has occurred throughout the area.

Fifty-eight sinkholes with known or suspected connection to the Upper Floridan aquifer are located in the study area. An internally drained basin near the city of Brandon and five sinkholes in Hillsborough, Pasco, and Hernando Counties were selected for detailed investigation. At all sites, chemical or biological constituents were detected that indicate pollutants had entered the aquifer.

A generalized classification, based on the potential to pollute, was applied to the selected sites. Four of the sites have high potential and two have moderate potential to pollute the Upper Floridan aquifer. All of the sites investigated are capable of recharging large volumes of water to the Upper Floridan aquifer in short periods of time. Continued monitoring of the quality of water entering the sinkholes and of wells downgradient to the sinks is needed to assess the future impacts on the aquifer.

INTRODUCTION

Sinkholes are natural and common geologic features in west-central Florida, which is underlain by soluble limestone deposits. Dissolution of these soluble deposits is the fundamental cause of all sinkhole development. Dissolution of near-surface limestone causes slow subsidence activity, whereas the rapidly developing type of sinkhole is caused by the collapse of near-surface materials into underlying solution cavities. Both subsidence and collapse type sinkholes occur throughout west-central Florida but are most common in the northern part.

Limestone crops out in parts of the area and in other parts it is covered by surficial deposits that range in thickness from a few feet to several hundred feet. The study area (fig. 1) is marked by numerous sinkholes, and the northern part has little surficial drainage. The few streams that are present generally originate as springs and receive very little direct runoff or are intermittent and terminate at sinkholes or in closed, internally drained basins. In the southern part of the study area, the streams receive substantial quantities of water from runoff and originate in swampy areas.

The increasing demand for water and the dependence on ground water has led to a growing awareness of the potential for pollution of the Upper Floridan aquifer from sinkholes and internal drainage. Recognizing this potential for pollution and the need to effectively manage the ground-water system, the U.S. Geological Survey and the Southwest Florida Water Management District began a cooperative study to define and classify these possible sources of pollution, to identify land uses that may be related to the potential for pollution, and to estimate drainage areas and quantities and quality of water discharging into selected sinkholes and closed basins. Information obtained from this study will be useful to water management and regulatory agencies in protecting the water supply in rapidly developing areas of west-central Florida.

Purpose and Scope

The purpose of this report is (1) to estimate drainage and recharge rates, describe the hydrogeology and land use, and determine the quality of stormwater runoff at selected sites; and (2) to evaluate and apply a general classification to selected sites based on their potential to pollute the Upper Floridan aquifer.

The study area includes Citrus, Hernando, Pasco, Pinellas, and Hillsborough Counties (fig. 1). The area was selected because it has numerous sinkholes, relies heavily on ground water for municipal supplies, and is one of the fastest growing areas in west-central Florida. Although the location of many sinkholes is known, little specific data are available on their characteristics.

Fifty-eight sinkholes were identified and visited. Five sinkholes and the internally drained area were selected for detailed study. The selected sites include a wide range of physical characteristics and land use. Information in this report is based on data collected during the study period (October 1984-September 1985), historical data from the files of the U.S. Geological Survey and the Southwest Florida Water Management District, and from previously published reports. Results should have transfer value to other similar sites in the area.

Acknowledgments

The author gratefully acknowledges the many individuals who gave their assistance and cooperation in conjunction with this study. The Southwest Florida Water Management District personnel were helpful in providing aerial

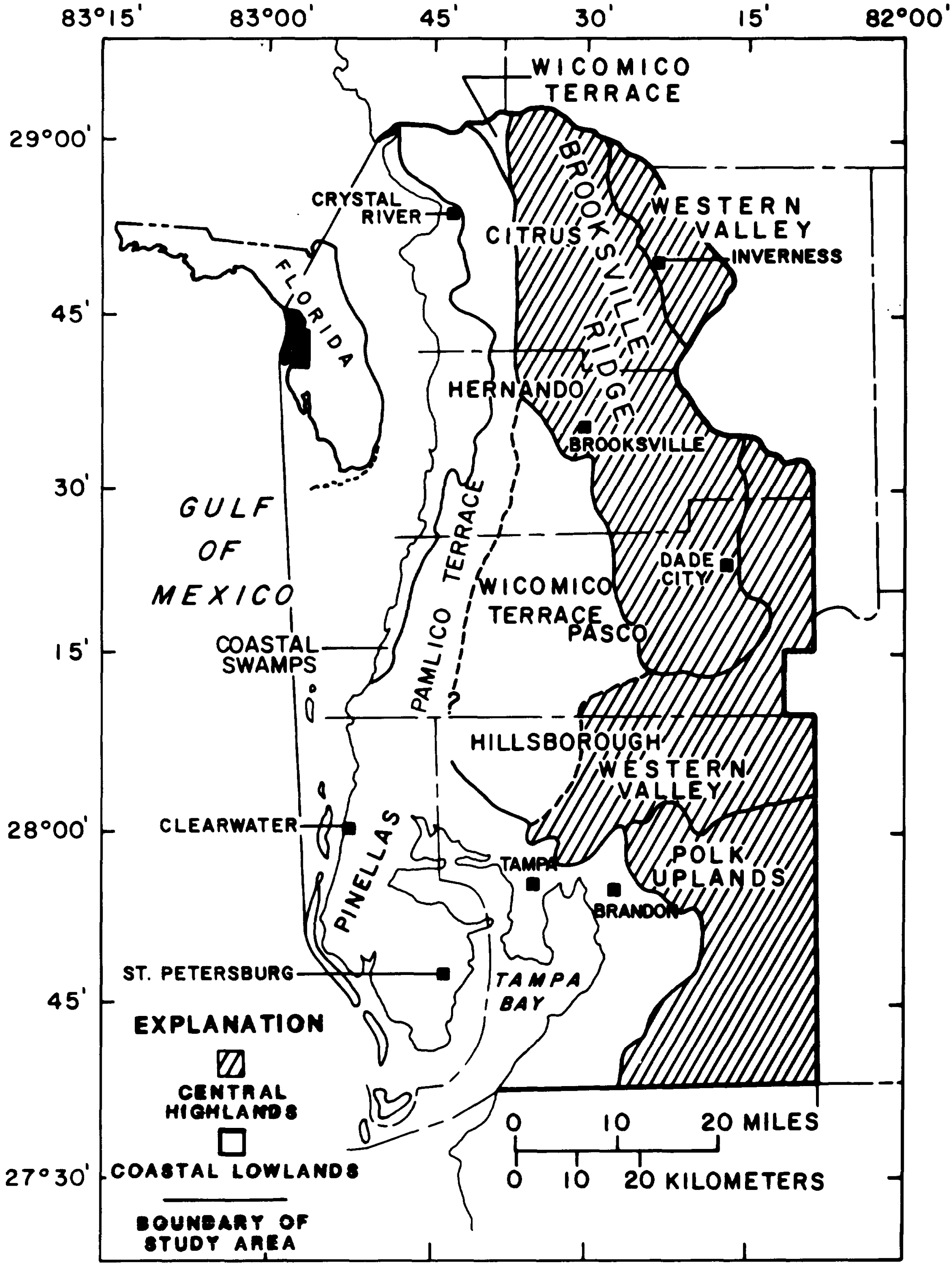

Figure 1.--Location and physiography of the study area. (Modified from White, 1970.)

maps and other information, particularly David Moore and his staff. Valuable information was provided by Vaughan Maxwell and Steven Stratsma, scuba divers who are exploring and mapping the solution conduits that connect numerous sinkholes in western Pasco County. The author extends his thanks to the property owners who allowed access to the sinkholes and wells used in this study, and to Dr. Flora Mae Wellings and her staff of the Florida Epidemiology Research Center for their cooperation in collecting and analyzing water samples for possible viral contamination. Special thanks are extended to Colonel David Wagner, Commander of the 56th Combat Support Group, and to Sergeant George Kramer, Sergeant Ronald Passmore, and Airman Ronald Weldon of the Explosive Ordinance Disposal Squadron at MacDill Air Force Base for their cooperation and assistance in handling the explosives that were used in conducting the seismic surveys.

PREVIOUS INVESTIGATIONS

Little data are available on the quantity and quality of surface-water and shallow ground-water flow into sinkholes, the capacity of sinkholes to take water, or the effects of flow into sinkholes on the aquifer system. Several hydrologic and geologic reports contain general information about sinkholes and internally drained areas. Vernon (1951) described the geology of Citrus County. Heath and Smith (1954) investigated the ground-water resources of Pinellas County, and Menke and others (1961) described the water resources of Hillsborough County. Wetterhall (1964) made a geohydrologic reconnaissance of Pasco and southern Hernando Counties and a reconnaissance of springs and sinks in west-central Florida (1965). Cherry and others (1970) described the general hydrology of the Middle Gulf area of Florida. Stewart and others (1978) investigated the availability and quality of ground water in northern Hillsborough County. Sinclair (1982) described sinkhole development resulting from ground-water withdrawals in Tampa. Ryder (1982) simulated predevelopment flow in the Floridan aquifer system in west-central Florida. Fretwell (1983) described the ground-water resources of coastal Citrus, Hernando, and southwestern Levy Counties and described the water resources and effects of development in Hernando County (1985). Sinclair and Stewart (1985) described sinkhole types, development, and distribution in Florida, and Sinclair and others (1985) discussed sinkholes in the covered karst of west-central Florida.

DESCRIPTION OF THE STUDY AREA

The study area covers about 3,200 mi^2 in west-central Florida and includes all of the five coastal counties of Citrus, Hernando, Pasco, Pinellas, and Hillsborough. The principal cities and towns are Tampa, Brandon, St. Petersburg, Clearwater, Dade City, Brooksville, Crystal River, and Inverness (fig. 1).

Topography and Drainage

Land-surface altitude ranges from sea level at the coast to more than 250 feet above sea level along the Brooksville Ridge. A few hills near Brooksville in Hernando County and Dade City in Pasco County have altitudes of about 300 feet above sea level.

The study area is in the Gulf Coastal Lowlands and the Central Highlands physiographic units described by White (1970) and shown in figure 1. The lowlands consist of a series of relatively flat plains bounded by erosional escarpments forming the Pamlico and Wicomico Terraces (Vernon, 1951). The terraces generally parallel the coast and have apparently been formed by seas that once stood at higher levels than at present. The Pamlico Terrace rises gently from the coast, where it is submerged, to an altitude of 25 feet above sea level. There are two minor escarpments located in the terrace. At an altitude of approximately 4 feet above sea level, the first escarpment forms the landward boundary of the coastal swamps (Wetterhall, 1965). The second escarpment is comprised of a sand dune complex that rises sharply to an altitude of approximately 10 feet above sea level and forms the boundary between the oak and pine forests to the east and the cypress hammocks to the west. The Wicomico Terrace overlooks the Pamlico Terrace and rises gently toward the east where it is bounded by the Brooksville Ridge. The Wicomico Terrace is absent in nearly all of Citrus County and pinches out in the central part of Hernando County. In these areas, the Brooksville Ridge forms the eastern boundary of the Pamlico Terrace.

The Brooksville Ridge constitutes the major part of the Central Highlands that lies within the study area and consists of a series of eroded ridges that generally trend in a northwest-southeast direction. The 100-foot topographic contour generally delineates the base of the Brooksville Ridge. Land-surface altitude rises sharply from this point. Much of the local relief in the ridge area is a result of numerous sinkholes and depressions characteristic of karst topography. The Western Valley and the Polk Uplands lie to the east and south of the ridge and constitute the remainder of the Central Highlands.

A large part of the water that falls on the study area as rainfall is returned to the atmosphere by evaporation and vegetative transpiration (evapotranspiration). Evapotranspiration losses are least in the barren, sandy areas and greatest in the dense swamps and forests located throughout the study area. Dohrenwend (1977) calculated that evapotranspiration averages 37 in/yr throughout Florida. Therefore, an average of about 18 to 20 in/yr of precipitation (Fretwell, 1983, p. 11) drains from the area through surface streams or percolates downward.

In the southern part of the study area, 90 percent of the drainage is direct surface runoff (Cherry and others, 1970, p. 17) through well-defined stream channels that usually originate in swampy areas and flow to the Gulf of Mexico. A small amount of surface runoff can be attributed to seepage from the ground-water system (Cherry and others, 1970, p. 17). This seepage occurs in areas where water levels are near land surface. In general, the surficial deposits in this part of the study area are relatively thick and continuous (fig. 2) and are sufficiently low in permeability to retard downward movement.

The northern part of the study area is nearly devoid of well-defined surface-water streams, and direct runoff is rare. Streams that do occur are usually near the coast and originate as springs or seeps, or they are intermittent and terminate in sinkholes or closed basins. The Withlacoochee River, and its tributaries, is the exception. It is the only perennial stream inland from the coast. It drains the area east of the Brooksville Ridge. In the upper reaches of the Withlacoochee River, part of the flow is derived from the Upper Floridan aquifer through numerous springs and seeps (Fretwell, 1983, p. 7). Downstream, the river recharges the Upper Floridan aquifer by downward percolation through exposed limestone along the river bed.

Materials that overlie the limestone in the northern part of the study area are generally thinner (fig. 2) and more discontinuous than in the southern part. In some areas, the limestone outcrops at the surface or is covered by highly permeable surficial deposits. Throughout most of the northern part of the study area, the Upper Floridan aquifer is unconfined, and ground-water levels are lower than land surface. Downward percolation, and subsequent movement through the aquifer toward the coast and coastal spring complexes, is the predominant form of drainage.

Figure 3 shows the location of 58 sinkholes inventoried during this study that have a known or suspected connection to the Upper Floridan aquifer (table 1). Where the sinkholes are open to the underlying limestone, large quantities of water can drain quickly into the aquifer.

Climate

West-central Florida is characterized by short mild winters and long humid summers. During the winter months, temperatures range from 55 °F to 75 °F. Temperatures occasionally drop into the 20's and 30's as cold fronts move through the area. Summer temperatures range between 72 and 90 °F. The average annual temperature is 72 °F.

Average annual rainfall ranges from 47 inches at Tampa to 56 inches at Brooksville. About 60 percent of the rainfall occurs from June to September as thundershowers or infrequent tropical storms (fig. 4). In the study area, rainfall for 1985 was below average for the period of January to mid-June. The 1985 rainy season started in mid-June and lasted to mid-September. Most of the rain occurred as thundershowers, but about 5 inches of rain can be attributed to Hurricane Elena, which moved through the study area in late August. Rainfall during the rainy season was above average in 1985 and helped compensate for below average rainfall experienced earlier in the year. Throughout the study area, rainfall was below average for 1984.

Population, Development, and Land Use

Florida has experienced rapid population growth during the last decade, increasing from 6.8 million in 1970 to 9.7 million in 1980 (University of

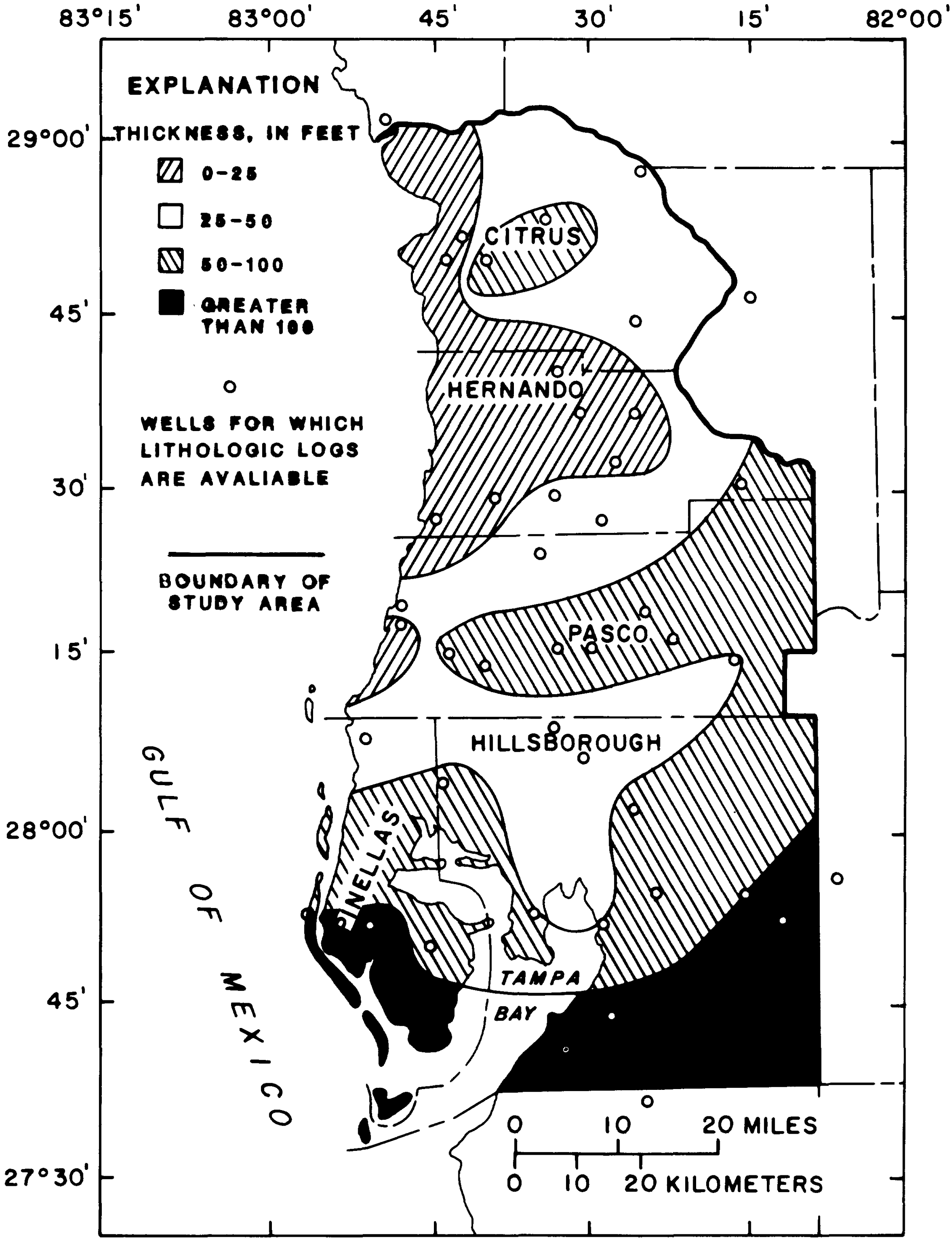

Figure 2.--Generalized thickness of the sand and clay unit that overlies the Upper Floridan aquifer in the study area. (Based on lithologic logs from the files of the Southwest Florida Water Management District and the Florida Bureau of Geology.)

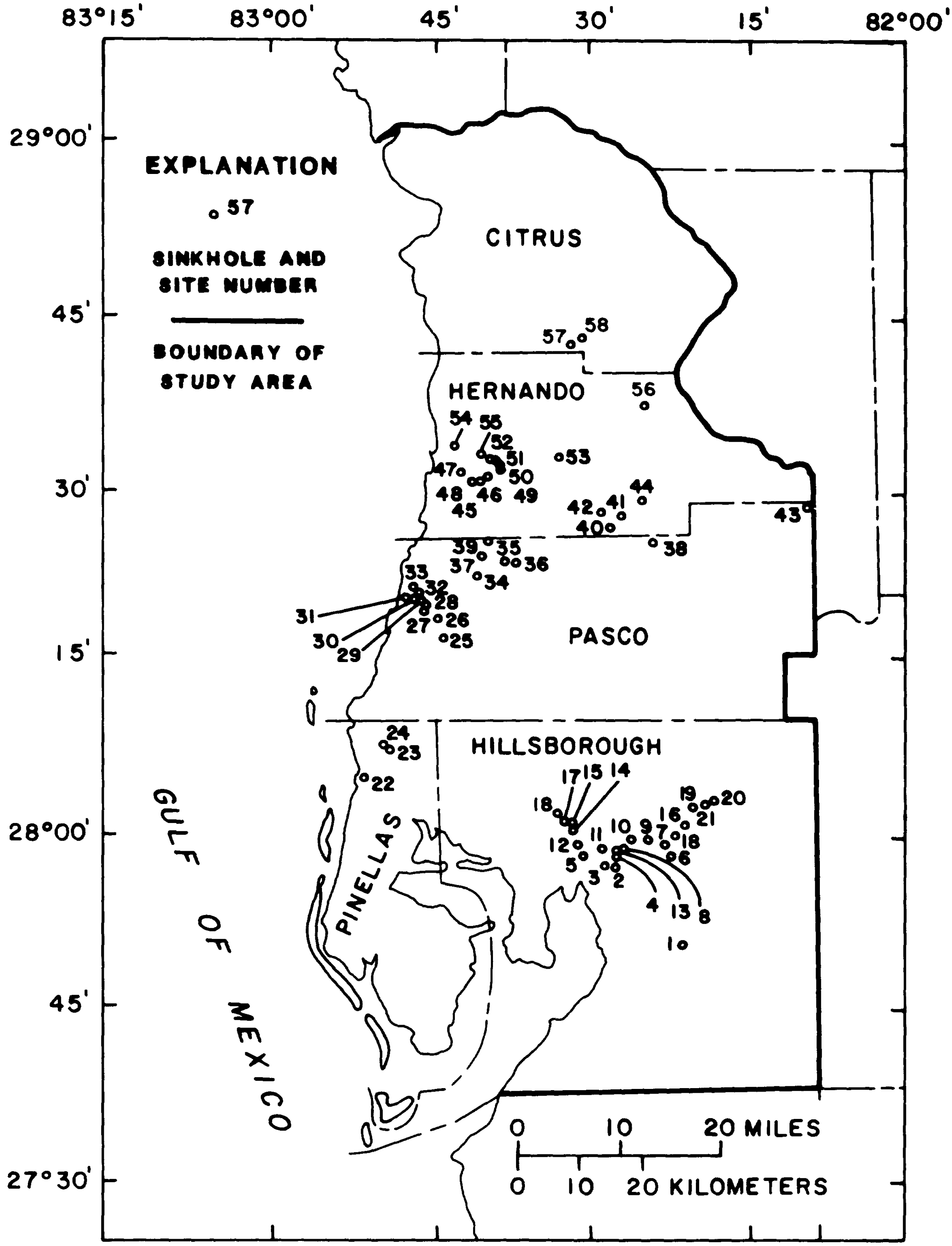

Figure 3.--Location of sinkholes with known or suspected connection to the Upper Floridan aquifer. (Site identification number and name are given in table 1.)

Table 1.--Sinkholes with known or suspected connection to the Upper Floridan aquifer

	Latitude, longitude	Name	Section-township-range	County
1	2757510821840	Limona Park Sinks	16-29-20	Hillsborough
2	2800350822453	Hillsborough River Sink[1/]	33-28-19	Hillsborough
3	2800370822515	Hillsborough River Sink[1/]	32-28-19	Hillsborough
4	2800410822450	Hillsborough River Sink[1/]	28-28-19	Hillsborough
5	2800480822629	Hannah's Swirl[2/]	30-28-19	Hillsborough
6	2800550822225	Harney Sink	26-28-19	Hillsborough
7	2801020822235	Hillsborough River Sink[1/]	26-28-19	Hillsborough
8	2801020822437	Hillsborough River Sink[1/]	28-28-19	Hillsborough
9	2801140822323	Hillsborough River Sink[1/]	27-28-19	Hillsborough
10	2801150822426	Hillsborough River Sink[1/]	28-28-19	Hillsborough
11	2801250822513	Hillsborough River Sink[1/]	29-28-19	Hillsborough
12	2801310822658	Tenth Street Sink	19-28-19	Hillsborough
13	2801520822249	Hillsborough River Sink[1/]	23-28-19	Hillsborough
14	2802200822740	Orchid Street Sink	19-28-19	Hillsborough
15	2802320822700	Poinsettia Street Sink	18-28-19	Hillsborough
16	2802460822236	Greco Sink	14-28-19	Hillsborough
17	2803000822740	Blue Sink Complex	13-28-18	Hillsborough
18	2803120822742	Curiosity Sink	13-28-18	Hillsborough
19	2804150822114	Weatherington Sink	01-28-19	Hillsborough
20	2804320822002	Nursery Sink	06-28-20	Hillsborough
21	2804400822009	Morris Bridge Sink	06-28-20	Hillsborough
22	2805200824604	Blue Sink	35-27-15	Pinellas
23	2807350824415	Tarpon Lake Sink	19-27-16	Pinellas
24	2807350824418	Knights Sink	19-27-16	Pinellas
25	2816440823959	Rocky Sink	26-25-16	Pasco
26	2819380824021	Bear Sink complex	11-25-16	Pasco
27	2820020824059	Round Sink	03-25-16	Pasco
28	2820100824107	Nexus Sink	03-25-16	Pasco
29	2820250824119	Stratomax Sink	03-25-16	Pasco
30	2820350824120	Briar Sink	03-25-16	Pasco
31	2820410824205	Hazel Sink	04-25-16	Pasco
32	2820420824122	Golf Ball Sink	03-25-16	Pasco
33	2820500824125	Smokehouse Pond	34-24-16	Pasco
34	2823250823437	Coffee Sink	14-24-17	Pasco
35	2824010823028	Unnamed sink near Crews Lake	16-24-20	Pasco

Table 1.--Sinkholes with known or suspected connection to the Upper Floridan aquifer--Continued

	Latitude, longitude	Name	Section-township-range	County
36	2824040823013	Hernasco Sink	16-24-20	Pasco
37	2824050823440	Rock Sink	14-24-17	Pasco
38	2825590821940	Lake Hancock Sink	05-24-20	Pasco
39	2826000823301	Unnamed sink	06-24-18	Pasco
40	2826010822324	Unnamed sink	34-23-29	Hernando
41	2826190822311	Rock Sink	35-23-29	Hernando
42	2827250822416	Squirrel Prairie Sinks	28-23-29	Hernando
43	2828380820408	Clay Sink	24-23-22	Pasco
44	2828440821914	Neff Lake Sink	20-23-20	Hernando
45	2829300823342	Cresent Lake Sink	12-23-17	Hernando
46	2829550823303	Wolf Sink	07-23-18	Hernando
47	2830280823542	Section 3 Lake	03-22-17	Hernando
48	2830400823610	Weeki Wachee Woodlands Lake	11-22-17	Hernando
49	2831040823144	Diepolder 3	05-23-18	Hernando
50	2831200823143	Diepolder 2	05-23-18	Hernando
51	2831400823223	Diepolder 1	31-22-18	Hernando
52	2831460823255	Joes Double Sink	36-22-17	Hernando
53	2832120822559	Pecks Sink Complex	29-22-19	Hernando
54	2832180823634	Eagles Nest Sink	21-22-17	Hernando
55	2832200823300	Lost 50	25-22-17	Hernando
56	2837380822027	Blue Sink	31-21-19	Hernando
57	2842090822633	Lizzie Hart Sink	31-20-18	Citrus
58	2842150822603	Brush Sink	32-20-18	Citrus

1/ Located in the Hillsborough River and are 5 to 28 feet deeper than the river bottom (Stewart and Mills, 1984).

2/ Located in the Hillsborough River and reported to be 20 feet deeper than the river bottom. May be a deep scour rather than a sinkhole (Stewart and Mills, 1984).

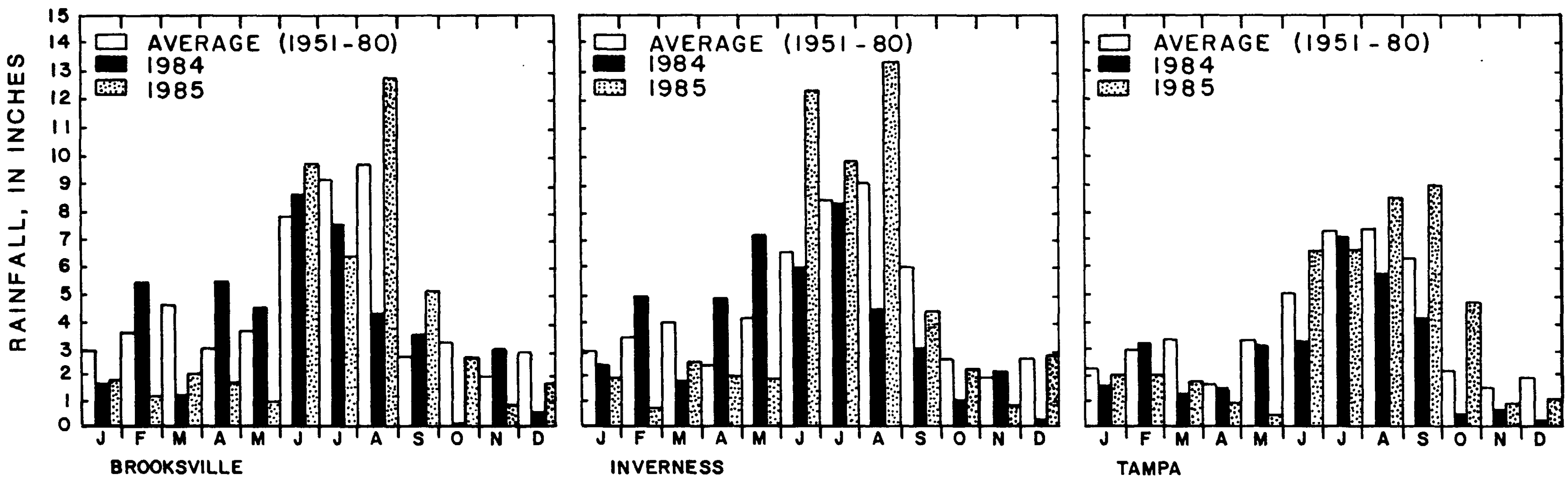

Figure 4.--Average monthly and actual monthly rainfall for Brooksville, Inverness, and Tampa, 1984-85.

Florida, 1981). The population of west-central Florida has experienced similar growth, increasing from 1.6 million in 1980 to 1.9 million in 1985 (Southwest Florida Water Management District, 1984). Over 50 percent of the current population of the study area lives in incorporated areas. Population projections by the University of Florida (1981) and the Southwest Florida Water Management District (1984) indicate that rapid growth will continue. By the year 2000, the population of Hillsborough and Pinellas Counties is projected to increase by 78 percent over 1980 levels. Pasco County population will increase by 62 percent, Citrus County by 58 percent, and Hernando County by 53 percent (Southwest Florida Water Management District, 1984).

Growth has generally been from the high density, urbanized centers of Tampa and St. Petersburg northward along the coast. As expansion continues, relatively undeveloped land is becoming moderate to high density urban and suburban areas that consist of housing subdivisions, shopping centers, restaurants, and other related industries.

About 72 percent of the land in the study area is presently (1985) undeveloped and can accommodate future development. The area consists of wetlands, agricultural land, forests, and barren lands primarily in the northern and eastern parts of the study area. Pinellas County has the highest degree of development, about 80 percent. Forty percent of Hillsborough County is developed. Most of the undeveloped areas are in the eastern and southeastern parts of the county. About 20 percent of Pasco County is developed. Hernando and Citrus Counties are the least developed counties with about 85 percent of the counties remaining undeveloped. Projections by the Southwest Florida Water Management District for the year 2035 indicate continued land-use change as a result of population growth. Residential and related commercial activities will account for most of the changing land use. These projected changes will occur northward along the coast, inland toward Brooksville, and along the Withlacoochee River to the north and east.

Water Use

Freshwater use in the study area totaled 551 Mgal/d in 1984. Of this, about 89 percent, or 492 Mgal/d, was from ground-water sources. Public supply and rural water use accounted for more than 50 percent, or 278 Mgal/d, in 1984 and was used to supply the domestic and other related needs of 1.8 million people (Stieglitz, 1985). Therefore, average per capita use was 154 gal/d. Based on projections of the Southwest Florida Water Management District (1984), by the year 2000, population in this area will have grown to 2.6 million people. This will create a demand for more than 401 Mgal/d of freshwater for public supply and rural water use, most of it from ground-water sources.

HYDROGEOLOGY

The hydrogeologic system in the study area consists principally of thick carbonate rock sequences overlain by thin clastic deposits (table 2). The system generally consists of an unconfined surficial aquifer system and an

Table 2.--Hydrogeologic framework

Series	Stratigraphic unit	Hydrogeologic unit[1]	Approximate thickness (feet)	Hydrogeologic characteristics
Holocene Pleistocene Pliocene	Undifferentiated sand and clay	Surficial aquifer system	0-100	Marine and nonmarine unconsolidated quartz sand, clay, and shells. Wells yield less than 20 gal/min. Excellent water quality.
Miocene	Hawthorn Formation	Upper confining unit	0-100	Clay with traces of limestone, sand, and silt. Retards movement of water between the surficial aquifer system and the Upper Floridan aquifer.
	Tampa Limestone			
		Upper Floridan aquifer	900	Limestone and dolomite. Production wells yield up to 3,000 gal/min. Water quality is good.
Oligocene	Suwannee Limestone			
Eocene	Ocala Limestone			
	Avon Park Formation[1]			
		Middle confining unit	300	Limestone and dolomite with intergranular gypsum and anhydrite. Extremely low permeability. Water quality is poor.

[1] Based on nomenclature defined by Miller (1986).

underlying mostly carbonate rock aquifer, which in the past was termed the Floridan aquifer. Miller (1986) redefined the Floridan aquifer to be the Floridan aquifer system, comprising the Upper Floridan aquifer, the middle confining unit, and the Lower Floridan aquifer. In the study area, freshwater occurs only in the surficial aquifer system and the Upper Floridan aquifer. Further discussion will be limited to these aquifers.

Surficial Aquifer System

Where present, the surficial aquifer system is unconfined. It consists of undifferentiated soil, sands, and clays of Pliocene and Holocene age. Water levels in this aquifer are usually less than 10 feet below land surface and reflect a subdued replica of the surface topography. The aquifer is recharged almost entirely from local precipitation, and water levels usually respond rapidly to rainfall.

In many areas, water moves downward from the surficial aquifer system and recharges the Upper Floridan aquifer. In some areas, the surficial aquifer system contains water only during the wet season. In these areas, the rapid change in water levels and temporary nature of the aquifer suggest a good hydraulic connection to the underlying limestone and leakage through clay layers if present. A continuous surficial aquifer system does not exist in the northern part of the study area because confining Miocene age deposits that separate the surficial aquifer system from the Upper Floridan aquifer become thin and discontinuous, or they pinch out completely. To the south, the Miocene thickens and is continuous (figs. 5, 6, and 7).

Because the Upper Floridan aquifer is confined in the southern part of the study area, water-level fluctuations in the surficial aquifer system do not closely parallel those in the Upper Floridan aquifer and the surficial aquifer system contains water perennially. In some low-lying areas and along the coast, the potentiometric surface of the Upper Floridan aquifer is equal to or higher than the water table in the surficial aquifer system. This results in upward flow from the Upper Floridan aquifer into the surficial aquifer system and keeps water levels relatively stable. The surficial aquifer system does not yield enough water to supply large industrial or municipal users. The most extensive use of this aquifer system is for lawn irrigation and livestock watering.

Upper Floridan Aquifer

In the study area, most ground water used is from the Upper Floridan aquifer. This highly transmissive aquifer is one of the most productive in the world and underlies the entire study area. It is composed of a continuous carbonate sequence of permeable limestone and dolomite of Tertiary age that more or less acts as a single hydrologic unit. The stratigraphic units that constitute the Upper Floridan aquifer, in ascending order, are the Avon Park Formation, the Ocala Limestone, and where present, the Suwannee and Tampa Limestones (table 2).

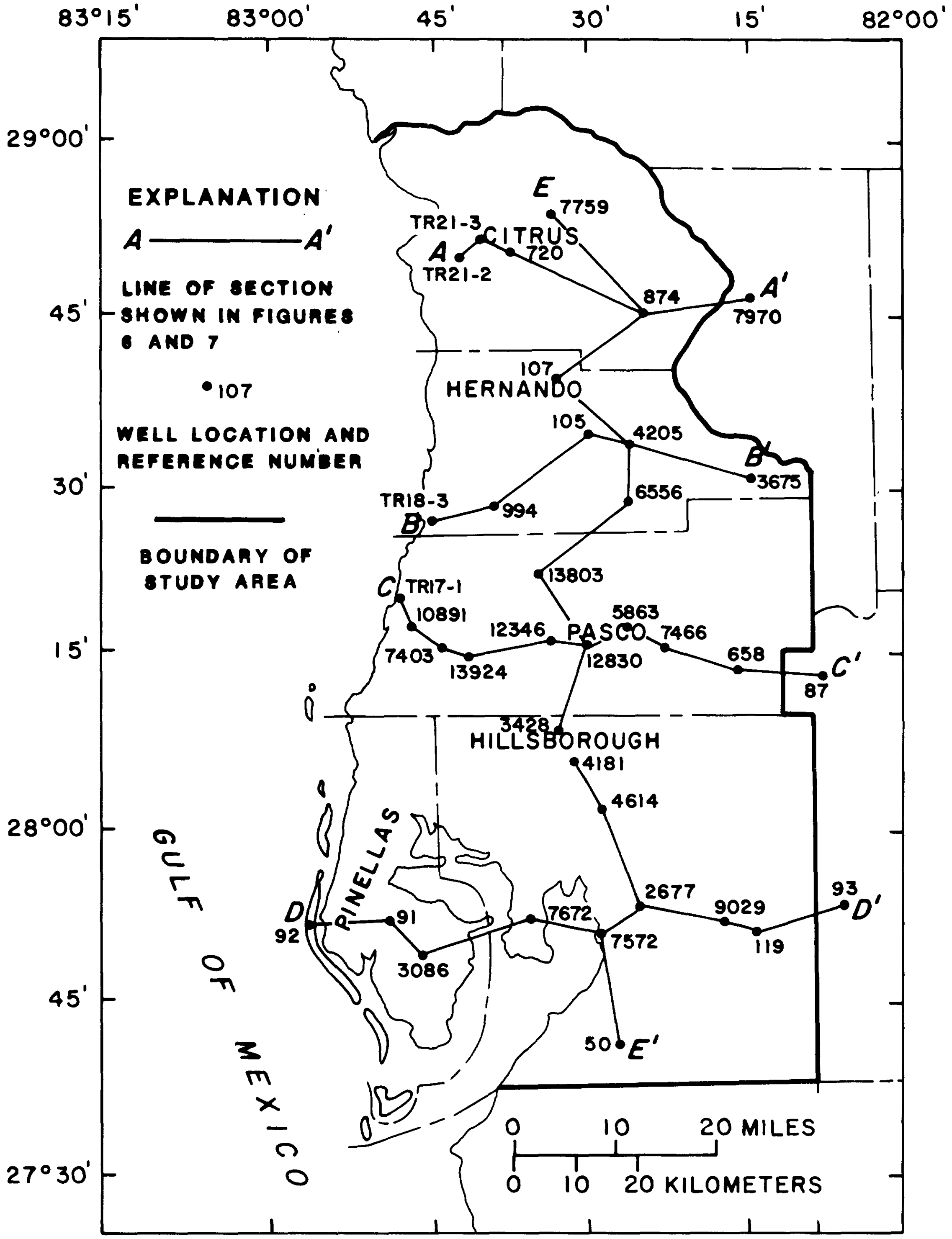

Figure 5.--Location of geologic sections. (Modified from Gilboy, 1982.)

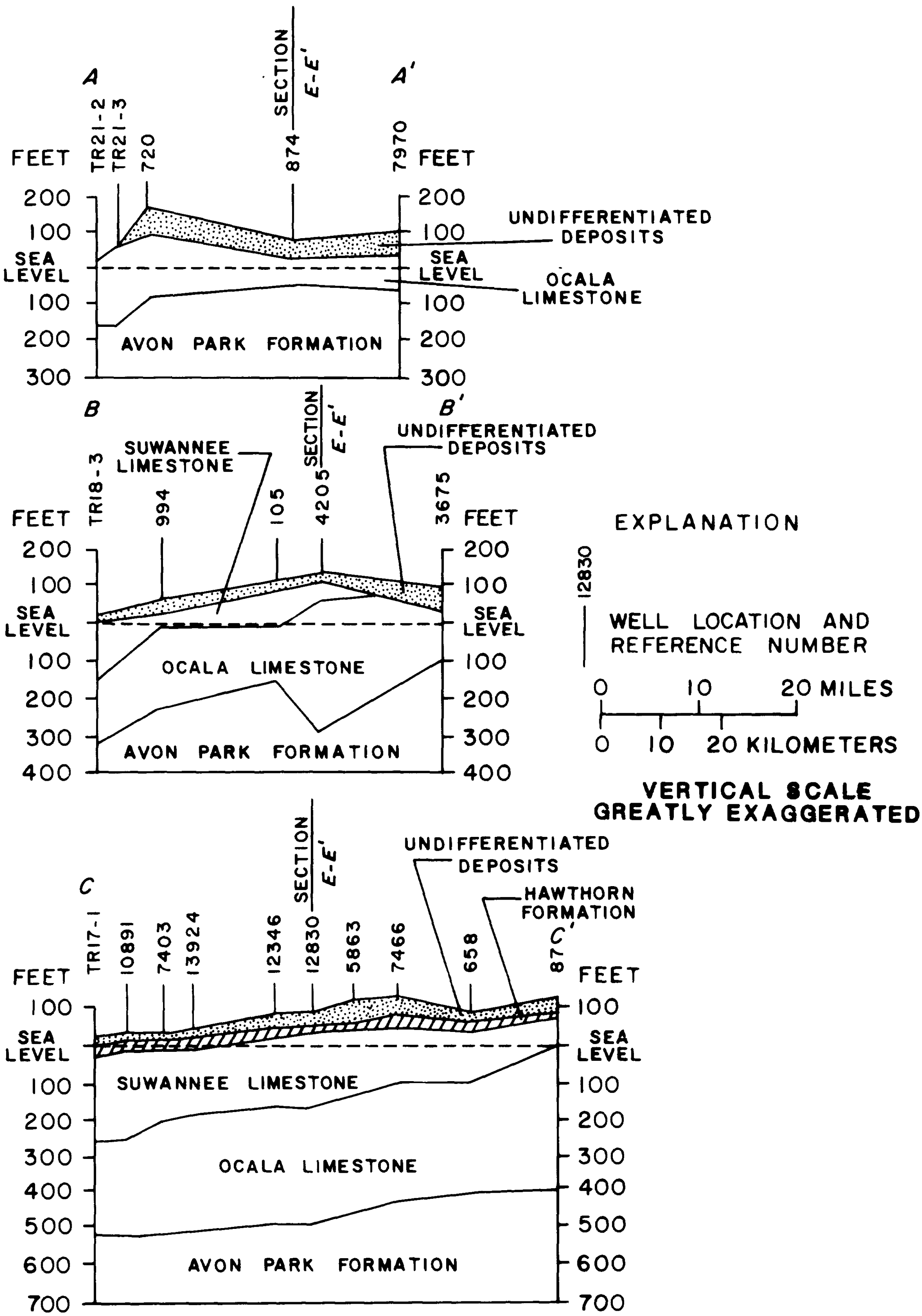

Figure 6.--Geologic sections A-A', B-B', and C-C'. (Locations of sections are shown in figure 5. Modified from Gilboy, 1982.)

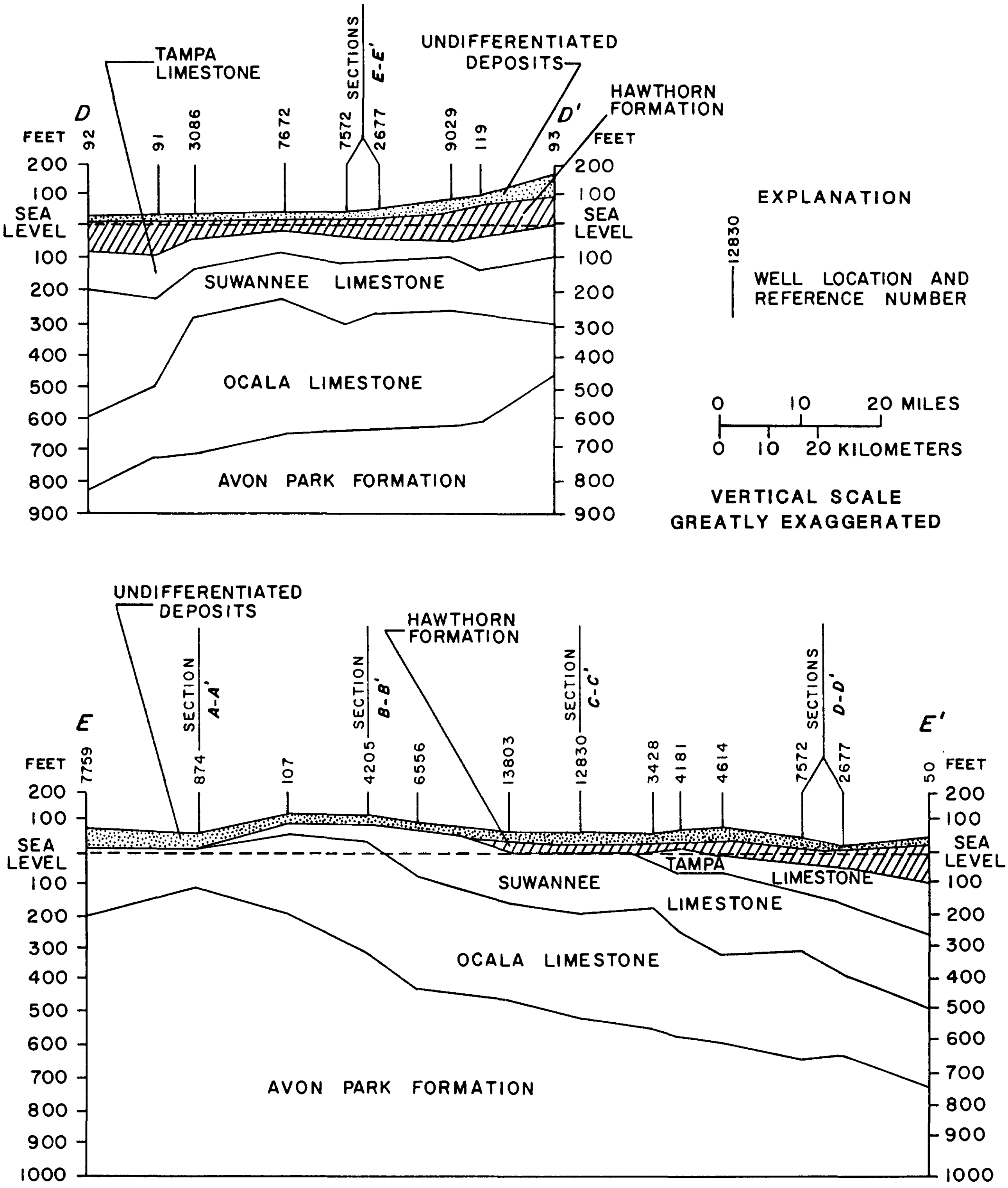

Figure 7.--Geologic sections D-D' and E-E'. (Locations of sections are shown in figure 5. Modified from Gilboy, 1982.)

Recharge to the Upper Floridan aquifer is from lakes, streams, and through the overlying permeable and semipermeable material of the surficial aquifer system. Recharge rates are low to moderate. In areas where sands are in contact with the permeable limestone, where limestone outcrops at the surface, or where sinkholes penetrate directly to the limestone, recharge rates to the Upper Floridan aquifer can be very high.

Some discharge occurs where the potentiometric surface of the Upper Floridan aquifer is above that of the surficial aquifer system, resulting in upward leakage of water. When the potentiometric surface is at or above land surface, discharge can occur as stream base flow, as springs, as seeps, or from flowing wells, usually in coastal or low-lying areas. Most discharge from the Upper Floridan aquifer is well pumpage.

Water moves through the Upper Floridan aquifer from points of high head to low head. Flow is generally at right angles to potentiometric contours (fig. 8). The potentiometric surface is defined by the levels to which water will rise in tightly cased wells open to the aquifer. In the study area, the direction of flow generally is from east to west in the northern part and from northeast to southwest in the southern part.

SINKHOLE DEVELOPMENT AND TYPES

Many of the geomorphic features of the west-central Florida landscape are due to dissolution of the underlying limestone, forming karst topography. Dissolution of limestone occurs when slightly acidic freshwater moves through porous rock, or along bedding planes, joints, or faults that provide avenues for rapid ground-water circulation. Dissolution activity tends to concentrate in areas of rapid circulation, forming conduits and cavities. Precipitation throughout west-central Florida exceeds evapotranspiration and provides the freshwater recharge necessary for dissolution activity.

Where clastic sediments have been removed by erosion and the limestone is near land surface, ground-water recharge and subsequent dissolution activity can be rapid. In these areas, the unconnected hollows or closed depressions, sinkholes, and internal drainage, which are dominant features of karst terrain, become obvious. These features are common along the Brooksville Ridge in the northern part of the study area. Most of the study area, however, is covered by sand and clay of varying thickness, generally thickening to the south. The karst is mantled and is less apparent at land surface, except when the overburden collapses or subsides into a solution cavity.

Sinclair and others (1985, p. 43) classified sinkholes into four major types based on their mode of formation. These are: (1) limestone-solution sinkholes, (2) limestone-collapse sinkholes, (3) cover-subsidence sinkholes, and (4) cover-collapse sinkholes. The type of sinkhole that develops is largely controlled by the geology and hydrology of an area. Four generalized sinkhole development type areas have been delineated across the State of Florida (Sinclair and Stewart, 1985) and are referred to as areas I, II, III, and IV. Area I consists of bare to thinly covered limestone. Solution type sinkholes and land subsidence occur in these areas. Area II consists of an

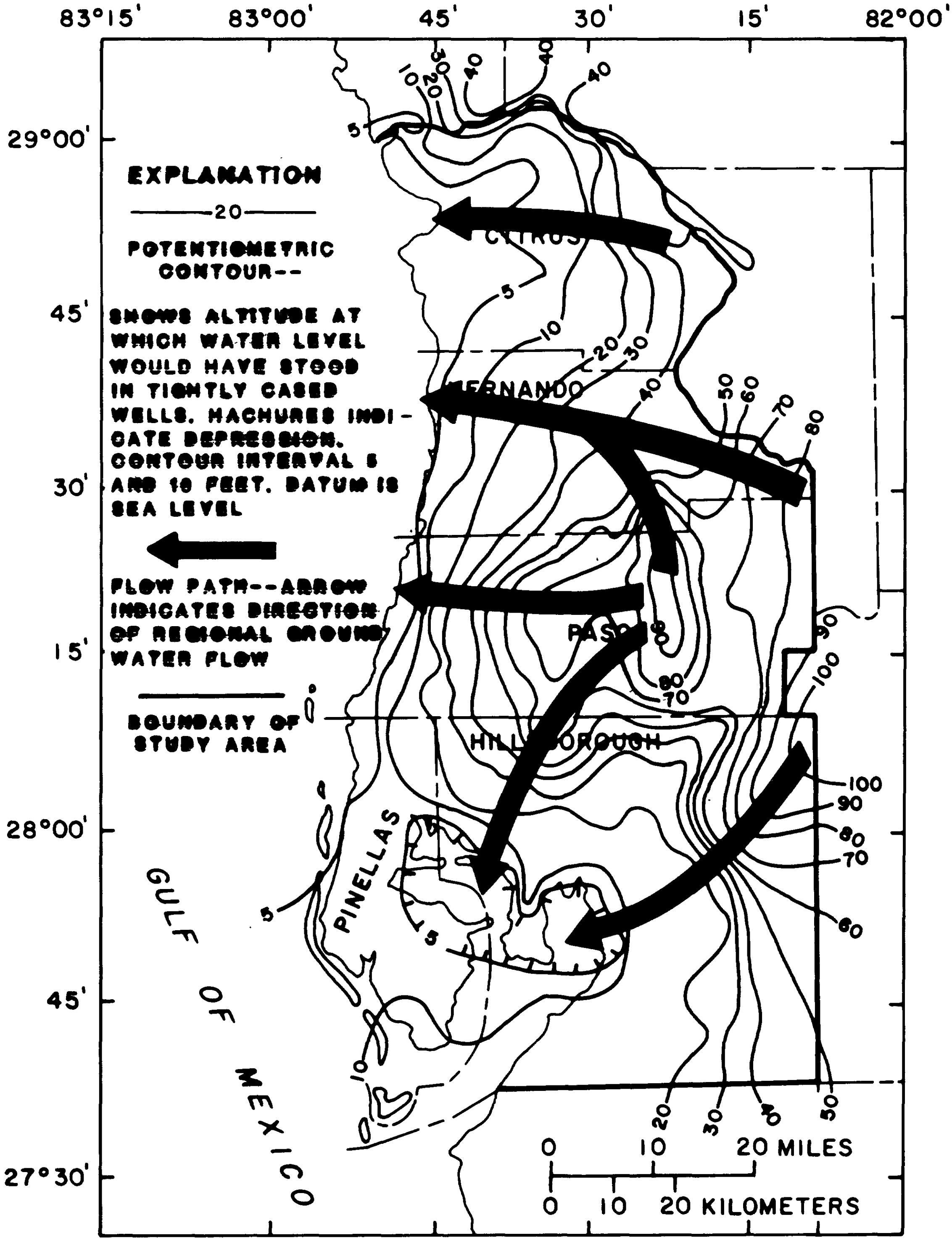

Figure 8.--Potentiometric surface and regional direction of flow in the Upper Floridan aquifer, west-central Florida, September 1985. (Modified from Barr, 1985b.)

incohesive, permeable cover that is 30 to 200 feet thick. Subsidence is the dominant activity in these areas. Area III consists of a cohesive, relatively impermeable cover that is 30 to 200 feet thick. Cover-collapse sinkholes dominate the karst activity in these areas. Area IV consists of a cohesive, relatively impermeable cover over 200 feet thick. Sinkhole occurrence is rare in these areas, but when they do occur, they are large and deep and are cover-collapse type sinkholes. The study area contains all four types of sinkhole development.

POTENTIAL FOR POLLUTION

Sinkholes and closed, internally drained basins provide natural drainage of surface runoff and shallow ground water from the land, much the same as streams provide runoff from areas not internally drained. Sinkholes and closed basins act as depositories and sometimes retention areas for large quantities of water. Where sinkholes and closed basins are open to or in direct hydraulic connection with the underlying limestone, large quantities of water can recharge the Upper Floridan aquifer in a relatively short time. Recharge to the aquifer occurs before natural purification, sorption, and filtration through sands and soils can occur.

The potential for pollution of the Upper Floridan aquifer from sinkholes and internally drained basins exists throughout most of west-central Florida. The degree to which this potential for pollution exists is influenced by many factors. The size of the drainage basin influences the amount of water available for recharge. The presence or absence, continuity, and thickness of overlying sediments influence infiltration or runoff to points of recharge, such as sinkholes and lakes that are connected to the aquifer. The hydraulic characteristics of the underlying limestone will control the rate water will move away from the point of recharge. The degree of pollution is related to the quality of the recharge water, which, in turn, is related to the land use within each drainage basin.

Classification

Drainage area, hydrogeology, land use, water quality, and volume of water recharging each sinkhole or closed basin will have to be evaluated individually to accurately assess its potential to pollute the Upper Floridan aquifer. However, a generalized classification based on their potential to pollute can be applied. Sinkholes and internally drained basins can be divided into those having a high, moderate, or low potential hazard.

Sinkholes that have a high potential for pollution of the Upper Floridan aquifer are those that are open directly to the aquifer and that receive large quantities of recharge water. Recharge may be introduced to the aquifer from large, intermittent storm surges that are relatively short in duration, or as steady, almost continuous streamflows. Some closed, internally drained basins that do not have sinkholes as recharge points may also have a high potential hazard if the limestone were covered with thin, permeable deposits that would allow large volumes of water to percolate directly into the aquifer. The potential hazard of closed basins, even though they may be hydraulically connected to the aquifer and capable of introducing large volumes of water, may not be as great as sinkholes with comparable recharge rates. The downward percolation through sediments may allow some purification through filtration of suspended solids and sorption of ionic constituents before the recharge water reaches the aquifer.

A moderate potential hazard exists at sinkholes with poor or restricted connection to the Upper Floridan aquifer. They may slow the infiltration of water and act as retention areas or lakes. Some degree of purification through settling and biological or chemical activity could occur before the water enters the aquifer. Sinkholes that are directly connected to the aquifer, but that have small drainage areas or no direct surface runoff to them, may also have a moderate potential hazard. Although these types of sinkholes may be virtually windows to the aquifer and not major points of recharge, they are susceptible to direct introduction of effluents, either intentionally or unintentionally (fig. 9). Most internally drained basins that do not have a direct recharge point (such as a sinkhole) would probably also have a moderate potential to pollute the aquifer if the surficial sediments are well drained and there is at least a semiconfining bed separating the surficial aquifer system from the Upper Floridan aquifer.

Sinkholes and very small internally drained basins that are not directly connected to the aquifer and that collect and pond rainfall rather than infiltrate water quickly would probably have a low potential hazard. These areas may reflect a perched or a temporary body of ground water that slowly percolates down to the Upper Floridan aquifer or depressions that intersect the surficial aquifer system that is separated from the Upper Floridan aquifer by a confining layer.

METHOD OF STUDY

Site Selection

Five sinkholes and one internally drained area in Pasco, Hernando, and Hillsborough Counties were selected for detailed investigation on the basis of physical characteristics and the availability of historical data (fig. 10). Although many small sinkhole-like depressions occur in Pinellas County, only a few are directly connected to the underlying limestone. These sinkholes were not selected for investigation because they are located near the coast where the Upper Floridan aquifer contains saline water, and any effects on the aquifer would be minimal. Sinkholes in Citrus County were not selected for study because the large expanse of generally inaccessible rural and forested lands made it difficult to locate sinkholes directly connected to the Upper Floridan aquifer.

A. Garbage dumped in small sink near Crews Lake.

B. Drainage culvert emptying into Briar Sink.

Figure 9.--Direct introduction of pollutants into sinkholes.

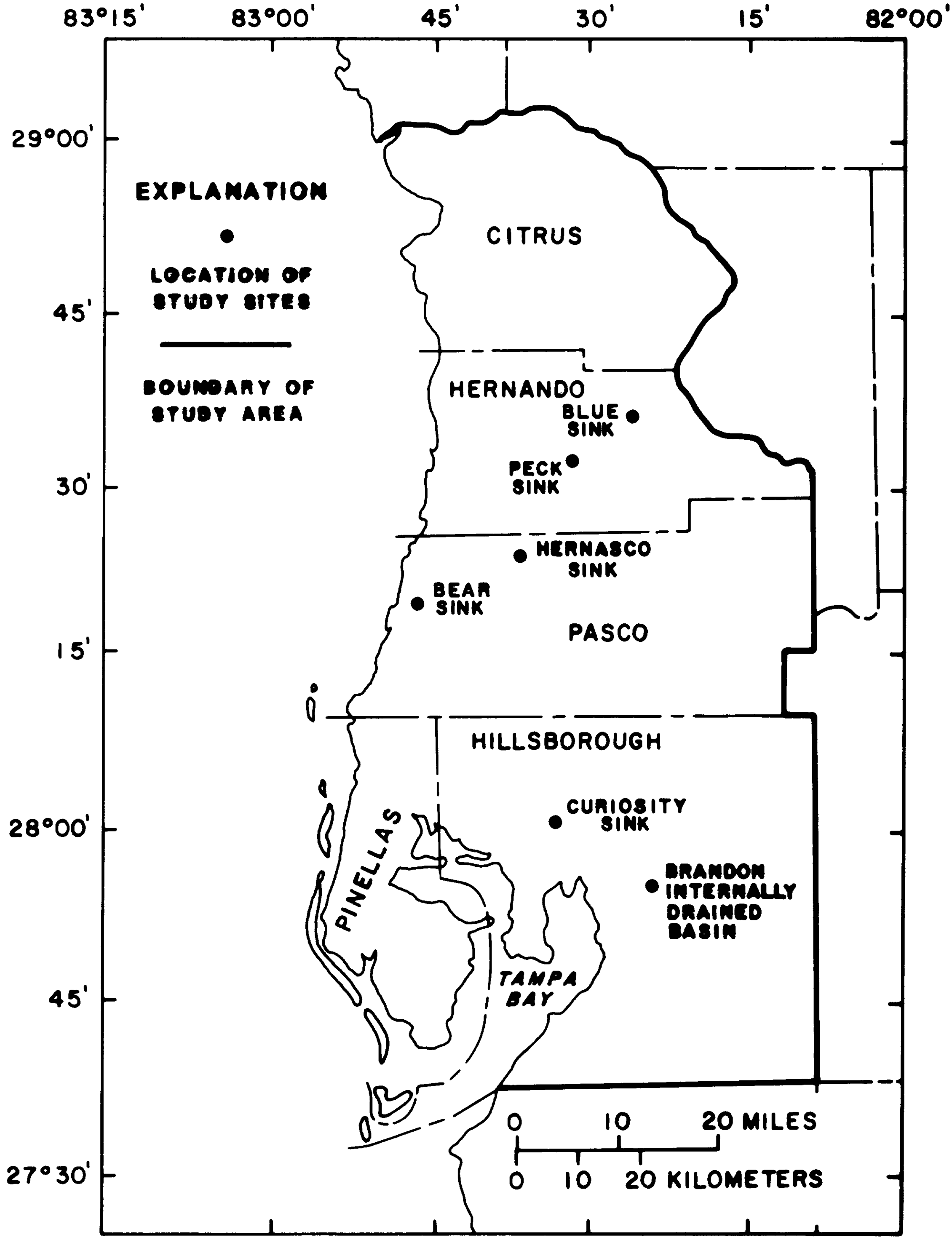

Figure 10.--Location of selected study sites.

Data Collection

Stage, discharge, and water-level data, as well as water-quality samples, were collected periodically at selected sites. Data obtained from drillers' logs were used to construct maps of the thickness of the confining unit, top of the confining unit, and top of the Upper Floridan aquifer for selected sites. The maps are generalized and some deviation can be expected.

Water-quality samples were collected from five sinkholes, six wells, and one lake. The water samples were analyzed for herbicides, pesticides, including ethylene dibromide (EDB), metals, nutrients, and other common constituents, including chlorides, sulfates, dissolved solids, and coliform bacteria. Bacteria samples were analyzed for total and fecal coliform and fecal streptococci bacteria. Coliform counts are used primarily as an indicator of sanitary pollution.

The ratio of fecal coliform to fecal streptococci (fc:fs) is used to suggest a source of pollution. Fc:fs ratios greater than 4.4 suggest the source is human domestic waste, whereas ratios less than 0.6 suggest the source is livestock, poultry, and storm runoff (Geldriech, 1966). Because of the natural variability and different survival rates for these two bacteria types (Elder, 1986, p. 15), the fc:fs ratio is used only to suggest the pollution source.

Water from the selected sites was also sampled for enterovirus content. These viruses enter and travel through the alimentary tract of man (Flora Mae Wellings, Epidemiology Research Center, written commun., 1985) and are also used to suggest the pollution source. The State of Florida Epidemiology Research Center, a division of the Florida Department of Health and Rehabilitative Services, collected and analyzed the viral samples.

BEAR SINK COMPLEX

The Bear Sink complex is in northwest Pasco County, approximately 1,500 feet south of State Highway 52, 1.7 miles east of U.S. Highway 19, and 10.3 miles west of U.S. Highway 41 at Gowers Corner (fig. 11). The complex consists of 2 major sinkholes and at least 11 smaller sinkholes that lie on the northeast side of a small northwest trending, sandy ridge. The ridge is nearly 50 feet above sea level at its highest point (fig. 12) and is surrounded on all sides by a low-lying area with altitudes that average about 20 feet above sea level. This complex forms the terminus of Bear Creek, which has a total drainage area of about 27 mi^2.

Consistent with other parts of the study area, development in the Bear Sink drainage basin has been rapid in recent years. Low density rural and agricultural land use has been replaced with high density residential and related commercial land use. Development in the drainage basin started along the western edge and proceeded rapidly eastward. Almost the entire western half of the basin has undergone some form of urbanization. The eastern half of the basin remains mostly agricultural and has a small rural population.

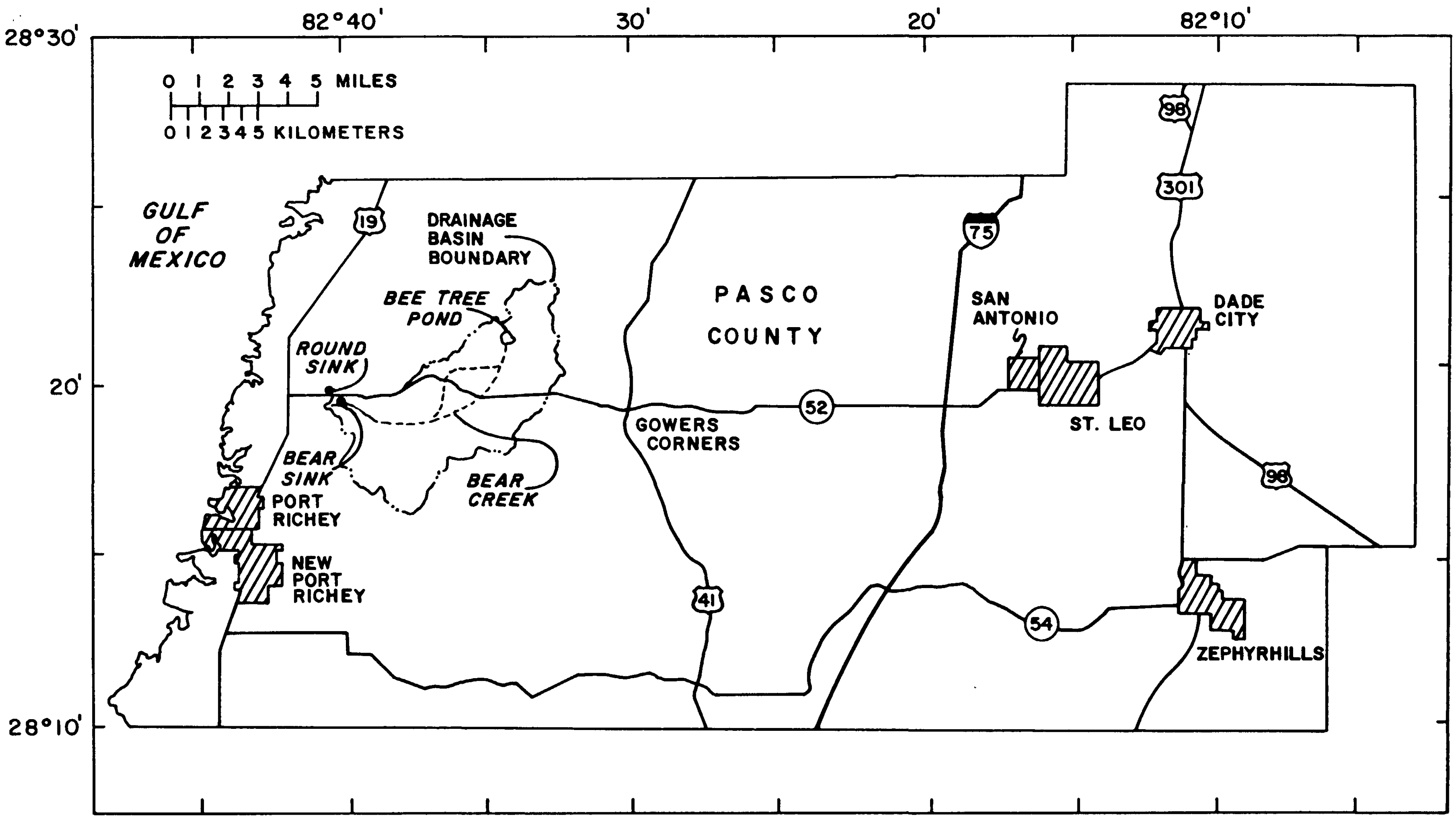

Figure 11.--Location of Bear Sink drainage basin, Pasco County.

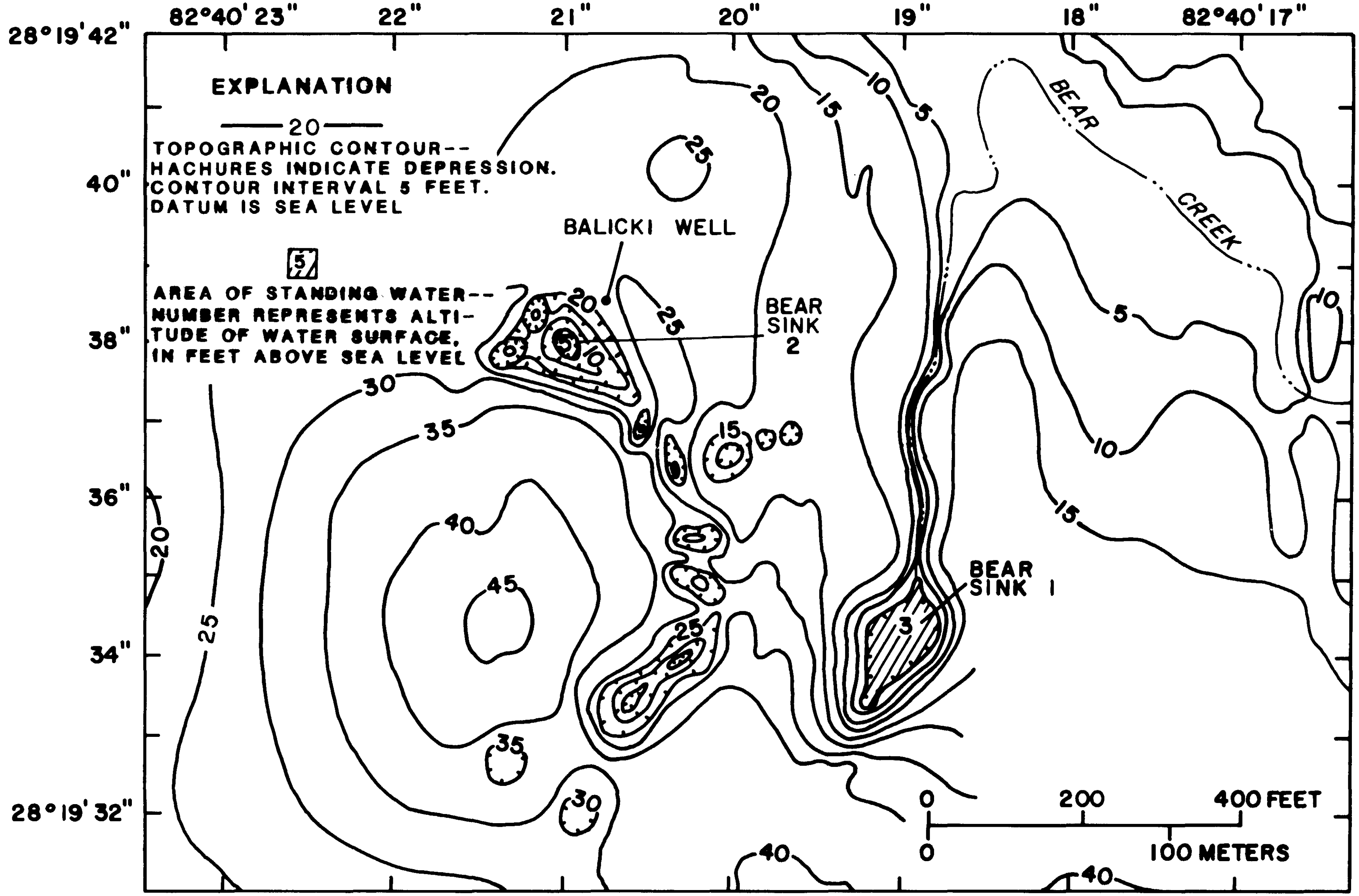

Figure 12.--Topography of the Bear Sink complex and location of sinkholes.

Bear Creek originates and flows mostly through the lightly developed parts of the drainage basin. This probably accounts for the relatively good quality of the water flowing to Bear Sink 1. State Highway 52 extends through the entire drainage basin and provides a link between Interstate Highway 75 and the coastal communities along U.S. Highway 19. As a result, it is heavily traveled by both passenger and commercial vehicles. Any spills along this road could allow potentially hazardous pollutants to enter Bear Creek and eventually the Upper Floridan aquifer. Numerous outfalls and surface-water impoundment sites in the drainage basin that are used for storage, disposal, or treatment of raw or partially treated sewage or stormwater (Moore and others, 1985) also represent a potential pollution hazard to both the surficial aquifer system and the Upper Floridan aquifer in the basin.

Most of the water withdrawn in the drainage basin is from the Upper Floridan aquifer. Rural water use, including livestock watering and lawn irrigation, accounts for most of the water withdrawn in the basin. Most of the water used for public supply is from outside the basin. As a result, less than 0.2 Mgal/d was withdrawn in the basin for public supply (Stieglitz, 1985).

Hydrogeologic Setting

The two major sinkholes in the Bear Sink complex are both open to the Upper Floridan aquifer. Drillers' logs show that, in nearby wells, the top of the Upper Floridan aquifer is located about 10 feet below sea level. One major sink is at the southeastern end of the complex and is the terminus for Bear Creek. In this report, this sink will be referred to as Bear Sink 1. The second major sinkhole is at the northwestern end of the complex and will be referred to as Bear Sink 2. The remaining 11 or more smaller sinks are located in a line between the 2 major sinkholes. These sinks apparently are not open to the Upper Floridan aquifer, but field observations indicate they have a good hydraulic connection to it.

Bear Sink 1 contains an elongated pool about 100 feet wide and 150 feet long and averages 15 feet in depth. A maximum depth of 30 feet (27.5 feet below sea level) was measured about 40 feet south of the point were Bear Creek enters the sink. Another area, which is about 15 feet from the south wall, is 26 feet deep (23.5 feet below sea level).

Bear Sink 1 is surrounded on three sides by sandy, very steep walls that rise to altitudes of 15 feet above sea level on the north side and over 35 feet above sea level on the south side (fig. 12). Bear Creek enters the sink from the north side through a cypress hammock in a well-defined stream channel that averages less than 5 feet in altitude. The sink is the terminus for Bear Creek under normal and low-flow conditions. During periods of high flow, the discharge of the creek exceeds the recharge capacity of the sink and overflows to another series of sinkholes to the northwest.

Bear Sink 2 is approximately 600 feet northwest of Bear Sink 1. The sink is circular (about 50 feet in diameter) and is surrounded on all sides by land surfaces between 20 and 25 feet above the surface of the water. The sink walls drop nearly vertically to the water surface. A maximum depth of 19.5 feet (16.9 feet below sea level) was measured on the south side of the sink. During the study period, water levels ranged from 2.5 feet to 6.7 feet above sea level.

Two small sinkholes immediately west of Bear Sink 2 showed very active side wall slumping and subsidence. The floor of one subsided over 3 feet between February and September 1985. Bear Sink 2 and the two small sinks are enclosed by higher ground and do not have a creek or other external source of recharge except limited local runoff.

The sinkholes in the Bear Sink complex are aligned in a northwesterly direction. This alignment may indicate a fault or joint along which solution activities have concentrated to produce an underground conduit system that possibly is a subsurface continuation of Bear Creek. Scuba divers have found that a conduit system exists between a series of sinkholes about 1 mile to the northwest of Bear Sink 1. They have observed a dark, tannin-colored layer of water at 60 feet below land surface that is similar to the water flowing into Bear Sink 1.

Bear Creek and the many cypress hammocks and lakes in this drainage basin are maintained by runoff and base flow from the surficial aquifer system overlying a fairly continuous clay layer. The average depth to the clay layer is 30 feet below land surface and is less than 25 feet thick throughout most of the basin (fig. 13). The clay layer in the immediate Bear Sink area is less than 10 feet thick. Drillers' logs for the area indicate that this confining layer is breached in places by sand-filled depressions that may be relict sinkholes. These depressions are probably hydraulically connected to the Upper Floridan aquifer.

Drainage, Stage, and Streamflow

Most of the surface drainage in this drainage basin is to Bear Creek. The creek originates in a swampy area in the northeastern part of the basin and flows through numerous small swamps and cypress hammocks for about 7 miles before it empties into Bear Sink 1. For most of its length, the stream channel is poorly defined and flows between cypress hammocks. In the lower reaches of Bear Creek, the stream channel is well defined, except during periods of high water.

Streamflow in Bear Creek during the study period ranged from no flow to over 230 ft^3/s. No flow was observed for a 6-week period in May and early June 1985 during an abnormally dry period. During low and normal stages, Bear Creek flows through a cypress hammock and empties into Bear Sink 1. During periods of high stage, the recharge capacity of Bear Sink 1 is exceeded. Water backs up into the cypress hammock, eventually overflowing this natural retention basin, and travels northwesterly to Round Sink (fig. 11). Round Sink is the first sink in the series of sinks about 1 mile northwest of Bear Sink 1.

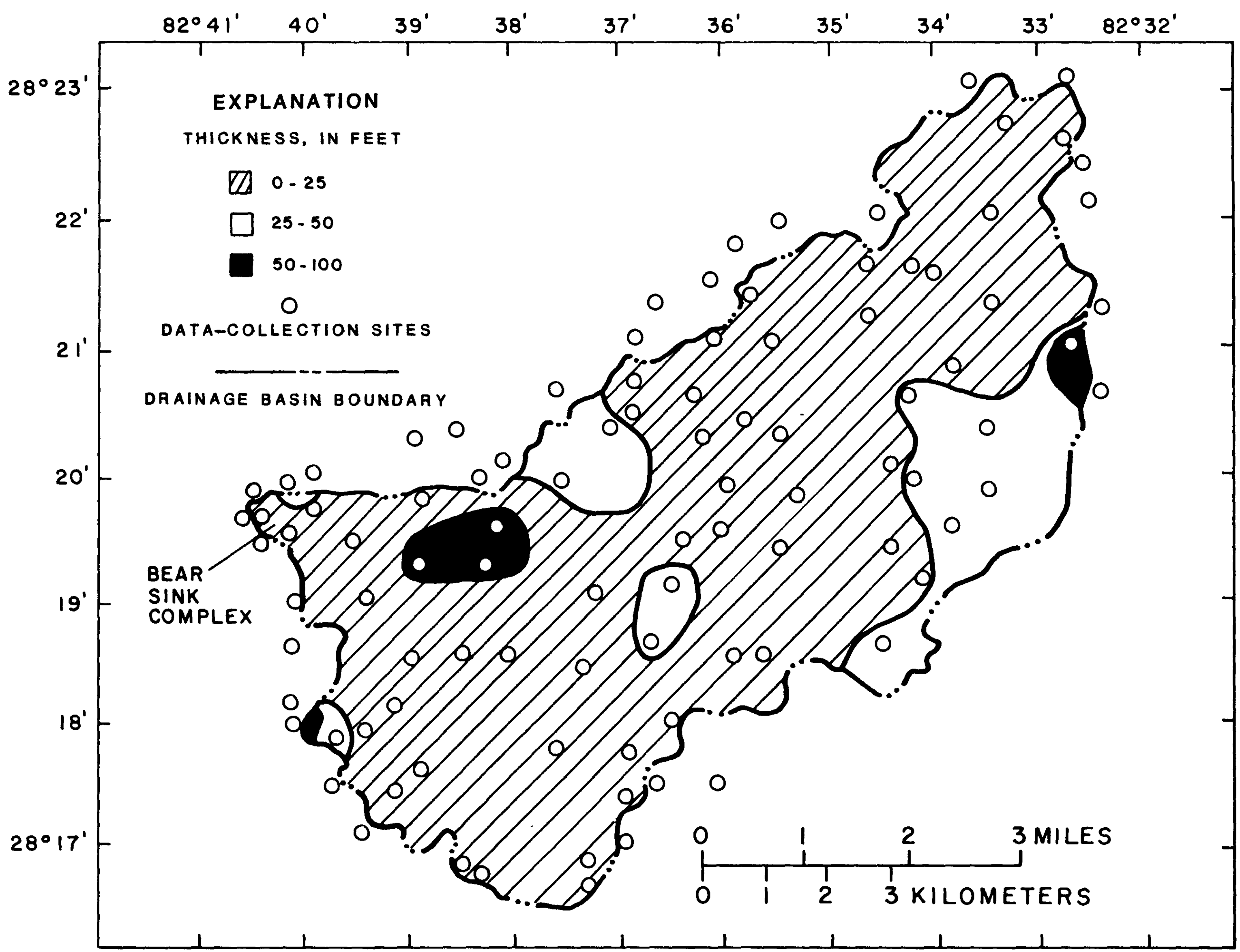

Figure 13.--Generalized thickness of the upper confining unit overlying the Upper Floridan aquifer in the Bear Sink drainage basin. (Based on drillers' completion reports from the files of the Southwest Florida Water Management District.)

To determine the capacity of Bear Sink 1, two sets of flow measurements were made during overflow conditions. On August 27, 1985, a flow of 85 ft^3/s was measured at a bridge about 1,600 feet upstream from the sinkhole. A flow of 41 ft^3/s was measured in the overflow channel about 1,500 feet downstream from the sinkhole. Most of the difference, 44 ft^3/s, was probably recharged to the Upper Floridan aquifer. The second measurement was made on September 2, 1985, following the passage of Hurricane Elena. Flow upstream from the sink was 227 ft^3/s. Flow in the overflow channel was 191 ft^3/s. At this time, about 36 ft^3/s recharged the Upper Floridan aquifer. The second measurement was made on a rising stage. The upstream measurement was completed approximately 1 hour before the completion of the downstream measurement. As a result, the actual recharge was probably slightly higher than was indicated by the measurement.

From December 27, 1984, to September 18, 1985, about 1,450 Mgal (194.0 million ft^3) of water recharged the Upper Floridan aquifer through Bear Sink 1. For the 24-day period between August 10 and September 18, 1985, approximately 25.8 Mgal/d, or 1,030 Mgal (138.2 million ft^3), recharged the aquifer. This accounts for more than 70 percent of the total recharge to the Upper Floridan aquifer during the study period.

Ground Water

Water levels in the surficial aquifer system generally reflect the topography in the basin and average about 10 feet below land surface. The surficial aquifer system extends throughout the basin and overlies a relatively continuous clay layer that separates this aquifer from the underlying Upper Floridan aquifer. However, relict sinkholes probably breach the clay layer in places and provide some degree of hydraulic connection to the Upper Floridan aquifer. The head difference between the surficial aquifer system and the Upper Floridan aquifer is less than 1 foot, and the heads appear to respond similarly during the year. This suggests that these two aquifers are also hydraulically connected through a leaky confining bed.

In most of the Bear Sink drainage basin, the top of the Upper Floridan aquifer ranges about 30 to 70 feet below land surface. The Upper Floridan aquifer apparently has a highly developed secondary porosity in the vicinity of the Bear Sink complex. Dissolution of the limestone has produced conduits that allow large volumes of water to move very rapidly through the aquifer.

During the study period, the potentiometric surface of the Upper Floridan aquifer in the Bear Creek drainage basin showed an average fluctuation of 4 feet and averaged about 50 feet above sea level at the eastern edge of the basin and about sea level at the western edge. Ground-water flow is generally from east to west (fig. 14). Water-level fluctuations in the two major sinkholes correspond to fluctuations in nearby wells open to the Upper Floridan aquifer. These sinkholes also show tidal fluctuations.

Transmissivity is the measure of an aquifer's ability to transmit water. Using a digital model, Ryder (1982) estimated transmissivity of the Upper Floridan aquifer to be 1.3×10^5 ft^2/d for the study area. Because of the

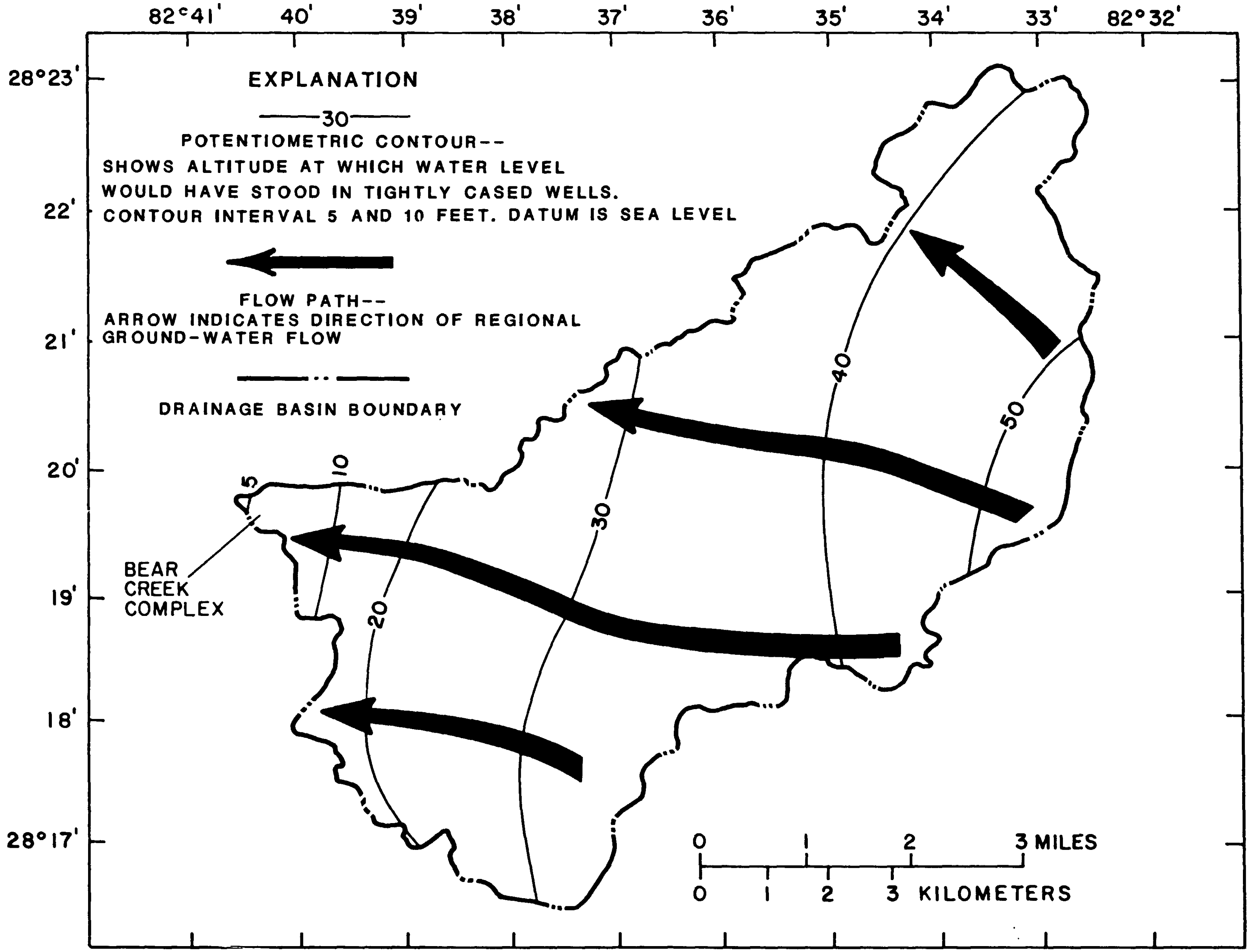

Figure 14.--Potentiometric surface and regional direction of flow in the Upper Floridan aquifer in the Bear Sink drainage basin, September 1985. (Modified from Barr, 1985b.)

highly developed secondary porosity in the sink complex, local transmissivity values may be slightly higher. However, Ryder's estimate of transmissivity should be representative of the total drainage area.

Water Quality

Water-quality samples were collected from both Bear Sinks 1 and 2 and from a nearby well that penetrates the Upper Floridan aquifer. Bear Sink 1 was sampled three times during the study period at the point where Bear Creek enters the sink. Bear Sink 2 and the Balicki well, a 70-foot deep well about 20 feet east of Bear Sink 2, were sampled once at the beginning of the study period. Specific conductance and pH were determined for all samples, and all samples were analyzed for trace elements, nutrients, and coliform bacteria. Additional analyses for organic substances, including EDB, and viruses were run on samples from Bear Sink 1.

Results of the chemical analyses are given in table 3. All parameters sampled for were within the ranges expected for natural waters in Florida (Hem, 1970). The herbicides, pesticides (including EDB), and trace elements were all below allowable (Florida Department of Environmental Regulation, 1985) or detectable levels. Coliform counts showed increases proportional to the inflow at Bear Sink 1. A sample collected when inflow was 3.1 ft^3/s showed total coliform counts about three times higher than a sample collected when inflow was 0.8 ft^3/s. Nutrient content also increased with corresponding increased inflow to the sink. These increases are small and do not suggest pollution problems.

The sample collected from Bear Sink 1 on March 21, 1985, during a rainstorm, contained coliform bacteria counts in excess of the Florida Department of Environmental Regulation (1985) limits. All other samples were within prescribed limits.

At Bear Sink 1, the fecal coliform to fecal streptococci ratios (fc:fs) ranged from 0.34 to 0.95. The low ratio suggests that warm-blooded animal wastes, other than man, are the source of the bacteria. This sample was collected when rainfall was below normal and inflow to Bear Sink 1 was less than 1 ft^3/s. The 0.95 ratio was in a sample that was collected when inflow to the sink was slightly higher than 3 ft^3/s.

Bear Creek originates and flows through an area that depends on septic tanks to dispose of domestic wastes. Septic tanks are more apt to release effluents to Bear Creek when water levels in the surficial aquifer system are high and the water in Bear Creek is mostly base flow from the surficial aquifer system rather than from surface runoff. Both samples analyzed for bacteria were collected when little base flow contributed to Bear Creek, so most flow was surface runoff.

Three samples collected from Bear Sink 1 were analyzed for viral contamination. Evidence of viral contamination was not detected; however, this does not indicate that contamination had not occurred. Two of the samples were collected during March 1985 when extremely low levels of viral activity were

Table 3.--Water-quality data for the Bear Sink complex

[Concentrations are in milligrams per liter, except as noted. µS/cm--microsiemens per centimeter, µg/L--micrograms per liter, col/100 mL--colonies per 100 milliliters]

Water-quality parameters	Bear Sink 1			Bear Sink 2	Balicki well
	1-03-85	3-13-85	3-21-85	1-03-85	1-03-85
Temperature (°C)	19.0	21.0	18.0	18.0	24.0
Specific conductance (µS/cm)	298	302	295	355	290
pH (units)	7.1	7.0	6.8	7.0	7.3
Alkalinity (as $CaSO_3$)	112	125	88	163	95
Color (platinum-cobalt units)	40	--	--	35	10
Nitrogen (as NO_2+NO_3)	0.03	0.03	0.11	0.01	1.60
Nitrogen, ammonia (as N)	--	.05	.06	--	--
Phosphorus (as P)	--	.02	.10	--	--
Total organic carbon	--	18.0	7.0	--	--
Chloride (as Cl)	15	15	18	14	19
Sulfate (as SO_4)	10	14	22	5	13
Potassium (as K)	.8	.6	1.4	1.3	0.9
Sodium (as Na)	7.5	9.1	7.2	7.8	11.0
Arsenic (µg/L as As)	--	1	2	--	--
Cadmium (µg/L as Cd)	--	<10	<10	--	--
Chromium (µg/L as Cr)	<10	<10	<10	10	10
Copper (µg/L as Cu)	--	10	<10	--	--
Iron (µg/L as Fe)	120	--	--	130	9
Lead (µg/L as Pb)	<10	<100	<100	<10	<10
Zinc (µg/L as Zn)	3	10	10	12	8

Table 3.--Water-quality data for the Bear Sink complex--Continued

Water-quality parameter	Bear Sink 1			Bear Sink 2	Balicki well
	1-03-85	3-13-85	3-21-85	1-03-85	1-03-85
Mercury (μg/L as Hg)	--	<0.1	<0.1	--	--
Total coliform (col/100 mL)	650	230	3,600	850	<1
Fecal coliform (col/100 mL)	200	47	1,900	230	<1
Fecal strep (col/100 mL)	210	140	--	77	<1
Fc:fs ratio	.95	.33	--	2.99	--
Lindane (μg/L)	--	<.01	<.01	--	--
Napthalene, polychlorinated (μg/L)	--	<.1	<.1	--	--
Aldrin (μg/L)	--	<.01	<.01	--	--
Chlordane (μg/L)	--	<.1	<.1	--	--
EDB (μg/L)	--	<.02	<.02	--	--
DDE (μg/L)	--	<.01	<.01	--	--
DDT (μg/L)	--	<.01	<.01	--	--
Dieldrin (μg/L)	--	<.01	<.01	--	--
Endosulfan (μ/L)	--	<.01	<.01	--	--
Endrin (μg/L)	--	<.01	<.01	--	--
Toxaphene (μg/L)	--	<1	<1	--	--
Heptachlor (μg/L)	--	<.01	<.01	--	--
PCB (μg/L)	--	<.1	<.1	--	--
Heptachlorepoxide (μg/L)	--	<.01	<.01	--	--
Methoxychlor (μg/L)	--	<.01	<.01	--	--
Mirex (μg/L)	--	<.01	<.01	--	--
Silvex (μg/L)	--	<.01	<.01	--	--
2,4-D (μg/L)	--	<.01	<.01	--	--
2,4,5-D (μg/L)	--	<.01	<.01	--	--
2,4-DP (μg/L)	--	<.01	<.01	--	--
Solids, residue at 180°C	170	188	160	198	160
Streamflow, instantaneous (ft^3/s)	3.09	1.21	7.76	--	--

being monitored (Flora Mae Wellings, Epidemiology Research Center, written commun., 1985). The third sample was collected in September 1985 following the passage of Hurricane Elena when water levels in Bear Creek and the surficial aquifer system were rising. Viruses, unlike bacteria, tend to adsorb to soil particles and do not wash off during periods of heavy rains and high water levels. However, changes in water to soil ratios and pH caused by high water levels cause these viruses to mobilize and travel as a plume entrained in the ground water as levels recede. Therefore, a continuous sampling program after heavy rains is necessary to detect a plume.

A sample collected from Bear Sink 2 had a fc:fs ratio of 2.99, suggesting a mixing of pollution sources, some of which may be human waste. Because no septic tanks are in this part of the drainage basin and surface water does not flow into this sinkhole, the source of the pollution is unknown.

The Balicki well was sampled at the same time as Bear Sink 2 because of its proximity to the sinkhole and because the well was reported to pump brown colored water during periods of high flow to Bear Sink 1. Coliform bacteria were not detected in this sample. During the study period, brown water was not observed coming from the well. A nitrogen concentration of 1.6 mg/L (milligrams per liter) was detected in the Balicki well. The highest nitrogen concentrations from Bear Sinks 1 and 2 were 0.11 and 0.01 mg/L, respectively.

CURIOSITY SINK

Curiosity Sink is in northwestern Hillsborough County. It is 400 feet south of Country Club Boulevard (Fowler Avenue), 0.5 mile west of Interstate Highway 275, and 1.9 miles north of the Hillsborough River, within the Tampa city limits (fig. 15). Curiosity Sink is the terminus for Curiosity Creek, which drains an area of 3.48 mi^2.

The Curiosity Sink drainage basin is highly developed, having high density residential and related commercial development. Although recent development in the basin has been centered in the northernmost part, the entire basin has undergone development. The population density of the entire basin has increased and can be attributed to the building of many new multifamily housing units. Commercial land use also has increased to accommodate the increased population density. There is no industrial development in the basin. Florida Avenue, Nebraska Avenue, and Interstate Highway 275 extend through the basin east of Curiosity Creek. Traffic, including commercial trucking that carries industrial products, is very heavy on these major north-south routes. Stormwater runoff from these routes is to Curiosity Creek. In the event of a major spill, potentially hazardous pollutants could be discharged to Curiosity Creek and, subsequently, reach the Upper Floridan aquifer.

A few domestic supply wells are found in the northernmost part of the basin. Most of the water used in the basin, however, is for public supply and is pumped from sources outside the basin. Some relatively shallow wells are located in the basin and are used for lawn irrigation.

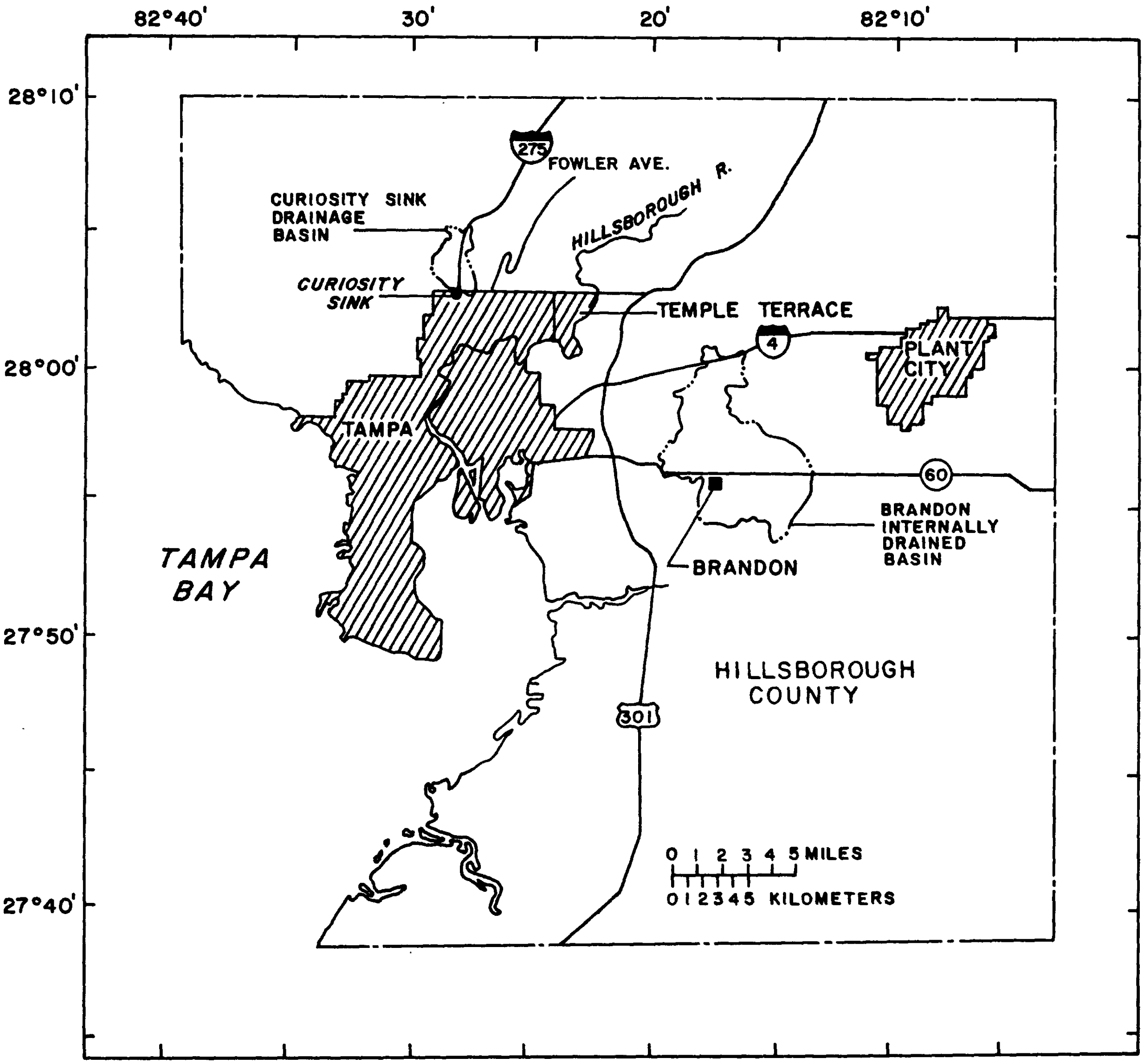

Figure 15.--Location of the Curiosity Sink drainage basin and the Brandon internally drained basin, Hillsborough County.

Hydrogeologic Setting

The ponded area of Curiosity Sink is about 500 feet long and 100 feet wide. The actual sinkhole is reported to be about 40 feet in diameter and 25 feet deep (Stewart and Mills, 1984). The depth of the sinkhole below the water surface averages 6 to 8 feet in the northern part and 12 feet in the southern part. The water level in the sink averages 20 feet above sea level. Curiosity Creek enters the sink from the north through a shallow, fairly well-developed stream channel. Land-surface altitudes range from 30 feet above sea level in the immediate sink area to slightly more than 50 feet above sea level in the north and northwest part of the drainage basin.

Curiosity Sink is one of a number of sinkholes located in a line that parallels Interstate Highway 275. This line of sinks extends northward from the Hillsborough River for about 4 miles (fig. 16). Dye studies conducted by the city of Tampa established a connection between Curiosity Sink and Blue Sink, Poinsettia Street Sink, Orchid Street Sink, and Sulphur Springs to the south. The connection appears to be through a well-developed cavity system (Stewart and Mills, 1984). Sulphur Springs provides a supplemental source of drinking water for the city of Tampa.

Dye injected into Curiosity Sink took 25.4 hours to travel the 5,400-foot distance to the Poinsettia Street Sink. The velocity of the water was 210 ft/h. The dye reached the Orchid Street Sink 2.5 hours later (27.9 hours after being injected into Curiosity Sink). The Orchid Street Sink is 900 feet from the Poinsettia Street Sink. Velocity between these two sinks was 360 ft/h. The dye reached Sulphur Springs 40 hours after the start of the test (12.1 hours after reaching the Orchid Street Sink). The dye traveled the 7,300 feet between the Orchid Street Sink and Sulphur Springs at a velocity of 603 ft/h. The average velocity of the water moving from Curiosity Sink to Sulphur Springs was 320 ft/h (Stewart and Mills, 1984).

In the Curiosity Sink drainage basin, the Upper Floridan aquifer is overlain by a fairly uniform confining layer that is generally less than 25 feet thick (fig. 17). The top of this clay layer is about 20 feet below land surface in the southern part of the basin and about 70 feet below land surface in the northern part. An extensive cavity system occurs at the top of the Upper Floridan aquifer inside the basin and in areas just south and east of the drainage basin (Stewart and Mills, 1984). The Tampa Limestone forms the top of the Upper Floridan aquifer in the Curiosity Sink drainage basin and ranges from sea level to 20 feet above sea level.

Drainage, Stage, and Streamflow

Curiosity Creek is an intermittent stream that originates in a swampy area southwest of Lake Gass. It travels through a well-defined stream channel for approximately 3 miles before terminating at Curiosity Sink. The creek has no flow for extended periods of time. Streamflow occurs only during wet periods and, for the most part, represents stormwater runoff. Stewart and Mills (1984) reported a maximum flow of 28 ft^3/s for calendar years 1979-80.

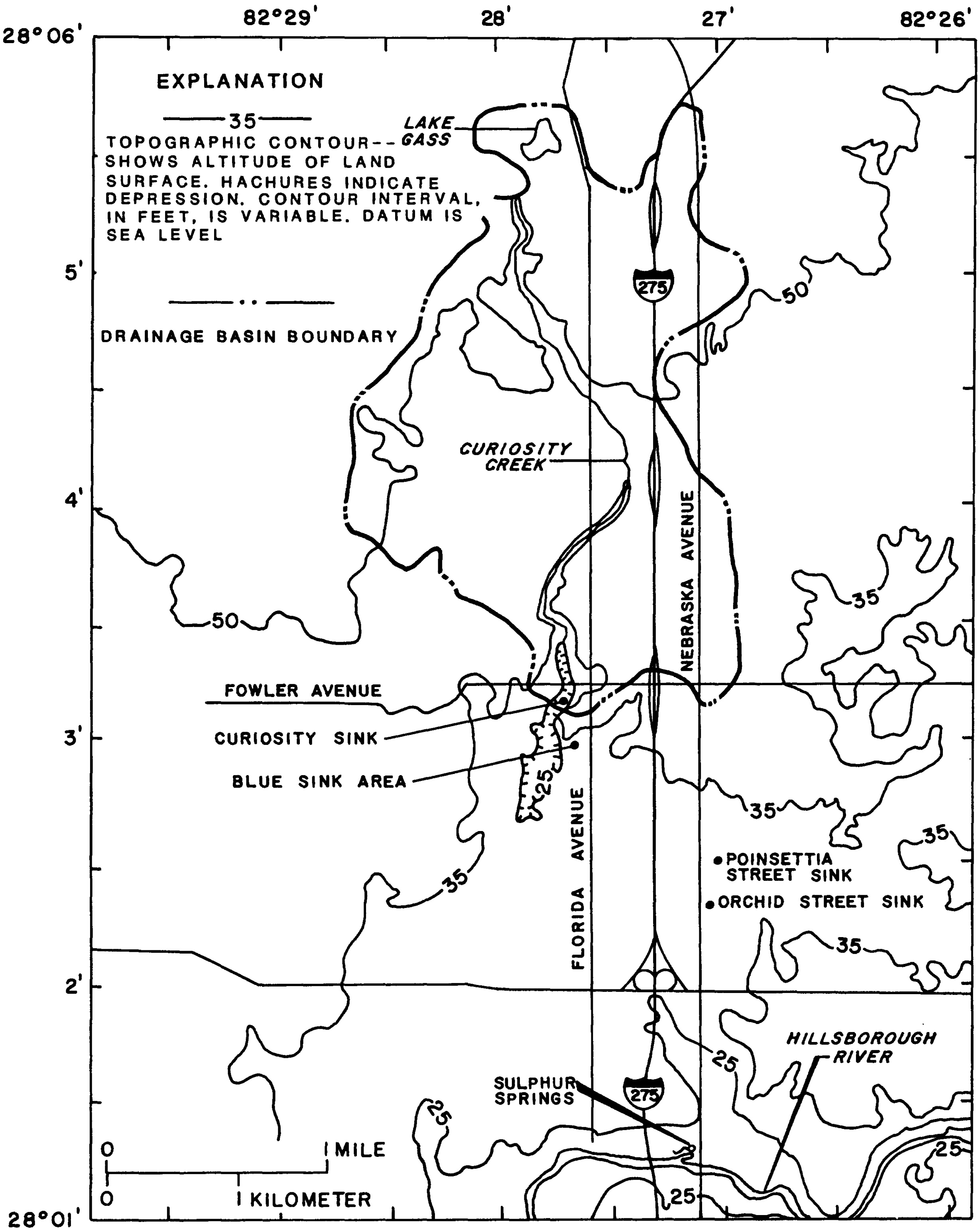

Figure 16.--Topography of the Curiosity Sink drainage basin and nearby areas and location of springs and sinks. (Modified from Stewart and Mills, 1984.)

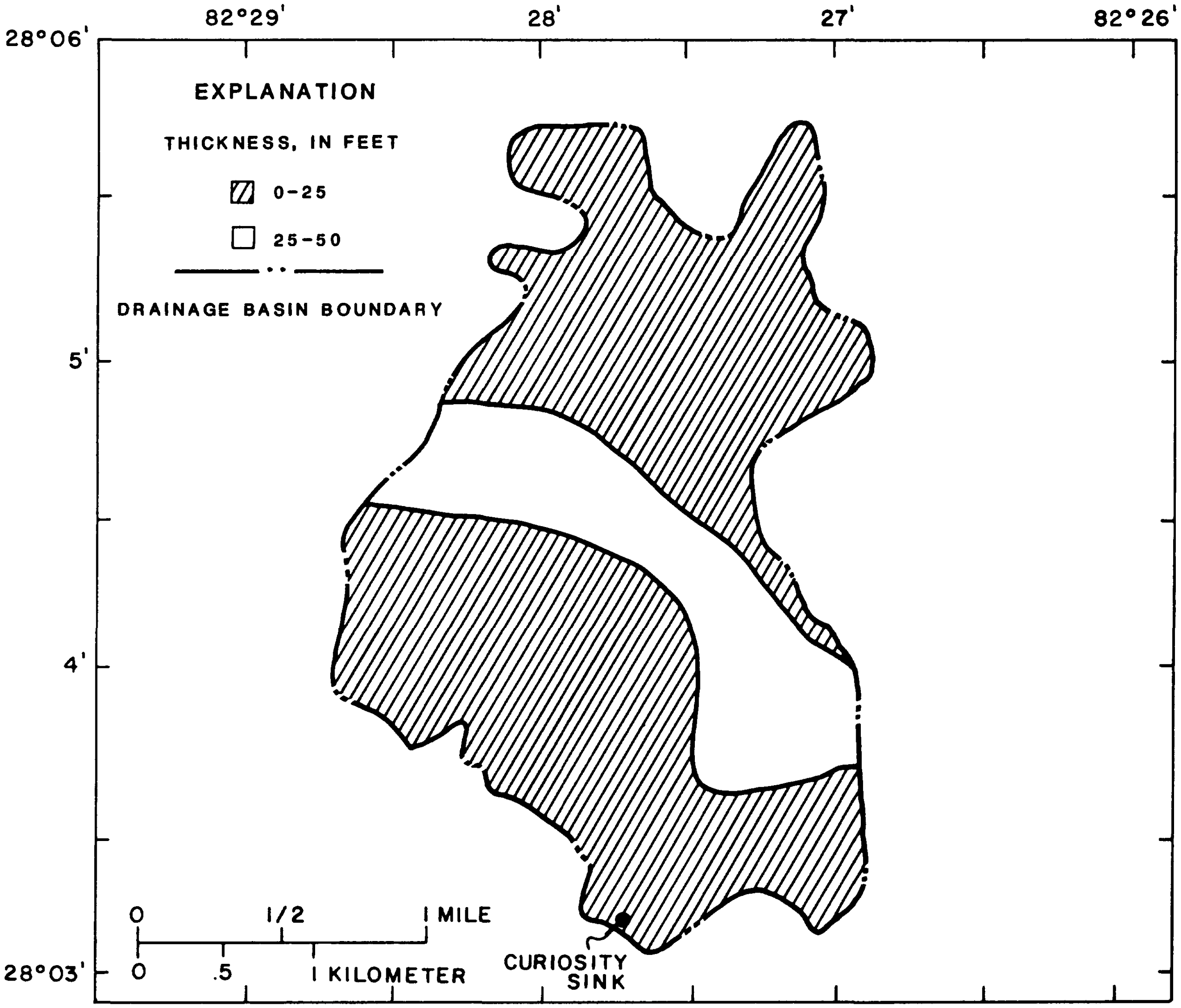

Figure 17.--Generalized thickness of the upper confining unit overlying the Upper Floridan aquifer in the Curiosity Sink drainage basin. (Modified from Stewart and Mills, 1984.)

Periodic streamflow measurements were made from 1981 to 1984 and ranged from 0.1 to 6.6 ft^3/s. From January to September 1985, flow was observed on August 9 during a major thunderstorm and on September 2 following the passage of Hurricane Elena. Measured streamflow near the peak runoff on August 9 was 8.6 ft^3/s. Less than 30 minutes after the end of this storm, streamflow had declined to less than 2 ft^3/s.

On occasion, the inflow from Curiosity Creek has exceeded the capacity of the sink to recharge water to the Upper Floridan aquifer, resulting in water overflowing the sink into the surrounding residential area. In 1980, the city of Tampa installed a pumping station on the southern end of the sink to keep water levels below flood stage. The water is pumped to the Hillsborough River. As a result of the pumping, the capacity of the sink to conduct water to the aquifer could not be measured directly. Based on pump tests conducted at the sink, however, a specific capacity of 2,500 (gal/min)/ft of drawdown was found (Stewart and Mills, 1984). Therefore, the sink should be able to recharge similar quantities of water to the aquifer.

Ground Water

The water-table in the surficial aquifer system ranges from 25 feet above sea level in the southern part of the drainage basin to 50 feet above sea level in the northern part. The average depth to water is less than 10 feet below land surface throughout most of the basin, and water-level fluctuations are generally less than 3 feet. Water levels are generally more than 10 feet below land surface in the southern part of the basin, along the stream channel, and around the sink area, indicating recharge to the Upper Floridan aquifer in those areas.

Between May and September 1985, the potentiometric surface of the Upper Floridan aquifer in the Curiosity Sink drainage basin fluctuated more than 10 feet. The potentiometric surface ranged from 20 to 30 feet above sea level in the southern part and 30 to 40 feet above sea level in the northern part. The general direction of ground-water movement in the basin is from north to south (fig. 18).

A hydraulic conductivity (the ability of an aquifer to transmit water through a unit area of the aquifer) of 1.9×10^6 ft/d was obtained from dye tests conducted between Curiosity Sink and Sulphur Springs. Transmissivity for the Upper Floridan aquifer is generally high but variable in this area (Stewart and Mills, 1984). Stewart (1968) reported transmissivity values for the areas north and west of the sinks to be on the order of 7.3×10^4 ft^2/d. Because of the highly developed cavity system, Stewart and Mills (1984) reported transmissivity values for the area just south of the drainage basin to be on the order of 2×10^6 ft^2/d. Ryder (1982) estimated transmissivity to be between 5×10^4 and 1×10^5 ft^2/d in this area. Transmissivity values of this order are probably representative of the Upper Floridan aquifer throughout most of the basin except in the immediate vicinity of conduits associated with the sinkhole.

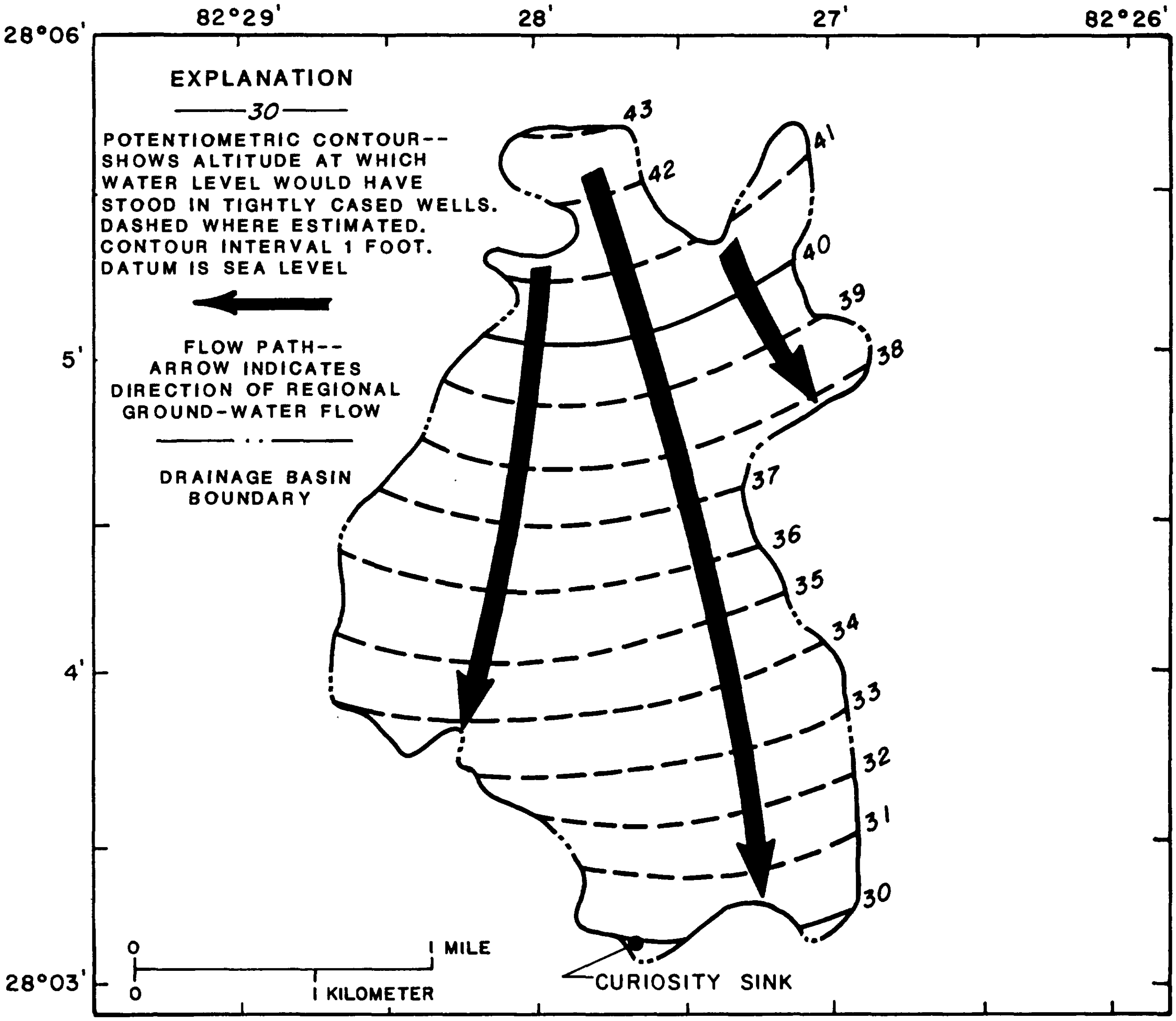

Figure 18.--Potentiometric surface and regional direction of flow in the Upper Floridan aquifer in the Curiosity Sink drainage basin, September 1985. (Modified from Barr, 1985b.)

Water Quality

A water-quality sample was collected from Curiosity Sink during a storm on August 9, 1985. Field determinations were made for pH, temperature, and specific conductance, and the sample was analyzed for trace elements, nutrients, coliform bacteria, viruses, and organic substances, including EDB. The results of these analyses and historical data are given in table 4.

Most parameters sampled for were within the ranges expected for natural waters (Hem, 1970). Trace elements, herbicides, pesticides, and EDB were below allowable or detectable levels, with the exception of small amounts of the herbicide, 2,4-D. Samples collected in June and December 1981 and in June 1983 showed 2,4-D present in quantities slightly higher than detection levels (table 4). These small amounts probably originated from home and garden use in this predominantly residential community. Some samples indicated that levels of mercury and zinc were at the maximum allowable limits set for drinking water (Florida Department of Environmental Regulation, 1985). Nutrient content generally showed fluctuations that corresponded to flow rates in Curiosity Creek. The nutrient concentrations were small and did not indicate pollution problems. Evidence of viral contamination was not observed in Curiosity Sink.

The ratio of fecal coliform to fecal streptococci (fc:fs) ranged from 0.16 to 1.30 in samples collected from October 1980 to August 1985. The sample collected August 9, 1985, had a ratio of 0.22. The low ratios suggest that the coliform bacteria is from nonhuman sources. Most samples collected from the basin contained coliform bacteria counts in excess of the limits for drinking water (Florida Department of Environmental Regulation, 1985).

BRANDON INTERNALLY DRAINED BASIN

The internally drained area near Brandon is in the central part of Hillsborough County, about 6 miles east of the city of Tampa and about 8 miles west of Plant City (fig. 15). Approximately one-third of the basin lies south of State Highway 60, the main east-west road in the study area, and the remaining two-thirds lie between State Highway 60 and Interstate Highway 4. The drainage basin covers about 35 mi^2.

In recent years, the Brandon area has undergone intense development. With the exception of small areas in the northern and eastern part of the basin, most of the land has been developed for moderate to high density residential and commercial purposes. Most, but not all, commercial development has been along State Highway 60. Major shopping centers and commercial buildings are being developed throughout the basin. A few major citrus groves remain in the central part of the drainage basin, but most of the basin is being urbanized. Little industrial development is present in the basin, but there are industrial areas nearby, and a large quantity of material that is potentially hazardous to ground-water moves through the area along the railroad lines and major roads (fig. 19).

Table 4.--Water-quality data for Curiosity Sink

[Concentrations are in milligrams per liter, except where noted. µS/cm--microsiemens per centimeter, µg/L--micrograms per liter, col/100 mL--colonies per 100 milliliters]

Water-quality parameter	Curiosity Creek					Curiosity Sink
	6-25-81	12-29-81	12-01-82	6-09-83	9-06-84	8-09-85
Temperature (°C)	27.0	18.5	22.5	25.5	25.0	25.0
Specific conductance (µS/cm)	255	213	229	180	170	198
pH (units)	6.8	7.4	6.9	6.8	6.2	7.0
Alkalinity (as $CaSO_3$)	169	164	58	154	55	94
Color (platinum-cobalt units)	--	--	--	--	--	--
Nitrogen (as NO_2+NO_3)	0.43	<0.10	1.52	<0.10	0.42	0.16
Nitrogen, ammonia (as N)	.12	.02	0.13	.07	.17	.09
Phosphorus (as P)	.50	.31	.42	.25	.45	.23
Total organic carbon	9.4	5.0	10.0	18.0	9.2	--
Chloride (as Cl)	15	13	13	12	12	5
Sulfate (as SO_4)	20	27	21	12	14	7
Potassium (as K)	3.8	5.0	4.1	3.4	4.6	4.2
Sodium (as Na)	7.5	7.8	11.0	6.9	5.3	2.6
Arsenic (µg/L as As)	--	--	--	--	--	1
Cadmium (µg/L as Cd)	--	--	--	<10	<10	10
Chromium (µg/L as Cr)	--	--	--	--	--	10
Copper (µg/L as Cu)	--	--	--	--	--	<10
Iron (µg/L as Fe)	--	--	--	280	250	--
Lead (µg/L as Pb)	--	--	--	<100	<100	100
Zinc (µg/L as Zn)	--	--	--	30	10	10
Mercury (µg/L as Hg)	--	--	--	--	--	.2
Total coliform (col/100 mL)	1,800	3,300	2,600	3,700	2,900	8,900
Fecal coliform (col/100 mL)	440	1,400	130	480	240	1,300
Fecal strep (col/100 mL)	970	1,700	100	720	370	5,800
Fc:fs ratio	.45	.82	1.30	.67	.65	.22

Table 4.--Water-quality data for Curiosity Sink--Continued

Water-quality parameter	Curiosity Creek 6-25-81	Curiosity Creek 12-29-81	Curiosity Creek 12-01-82	Curiosity Creek 6-09-83	Curiosity Creek 9-06-84	Curiosity Sink 8-09-85
Lindane (µg/L)	--	--	--	--	--	<0.01
Napthalene, polychlorinated (µg/L)	--	--	--	--	--	<.1
Aldrin (µg/L)	--	--	--	--	--	<.01
Chlordane (µg/L)	--	--	--	--	--	<.1
EDB (µg/L)	--	--	--	--	--	<3.0
DDE (µg/L)	--	--	--	--	--	<.01
DDT (µg/L)	--	--	--	--	--	<.01
Dieldrin (µg/L)	--	--	--	--	--	<.01
Endosulfan (µg/L)	--	--	--	--	--	<.01
Endrin (µg/L)	--	--	--	--	--	<.01
Toxaphene (µg/L)	--	--	--	--	--	<1
Heptachlor (µg/L)	--	--	--	--	--	<.01
PCB (µg/L)	--	--	--	--	--	<.1
Heptachlorepoxide (µg/L)	--	--	--	--	--	<.01
Methoxychlor (µg/L)	--	--	--	--	--	<.01
Mirex (µg/L)	--	--	--	--	--	<.01
Silvex (µg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<.01
2,4-D (µg/L)	.11	.07	<.01	.02	<.01	<.01
2,4,5-D (µg/L)	<.01	<.01	<.01	<.01	<.01	<.01
2,4-DP (µg/L)	<.01	<.01	<.01	<.01	<.01	<.01
Solids, residue at 180°C	157	150	151	104	120	107
Streamflow, instantaneous (ft^3/s)	.69	--	.64	6.60	--	8.60

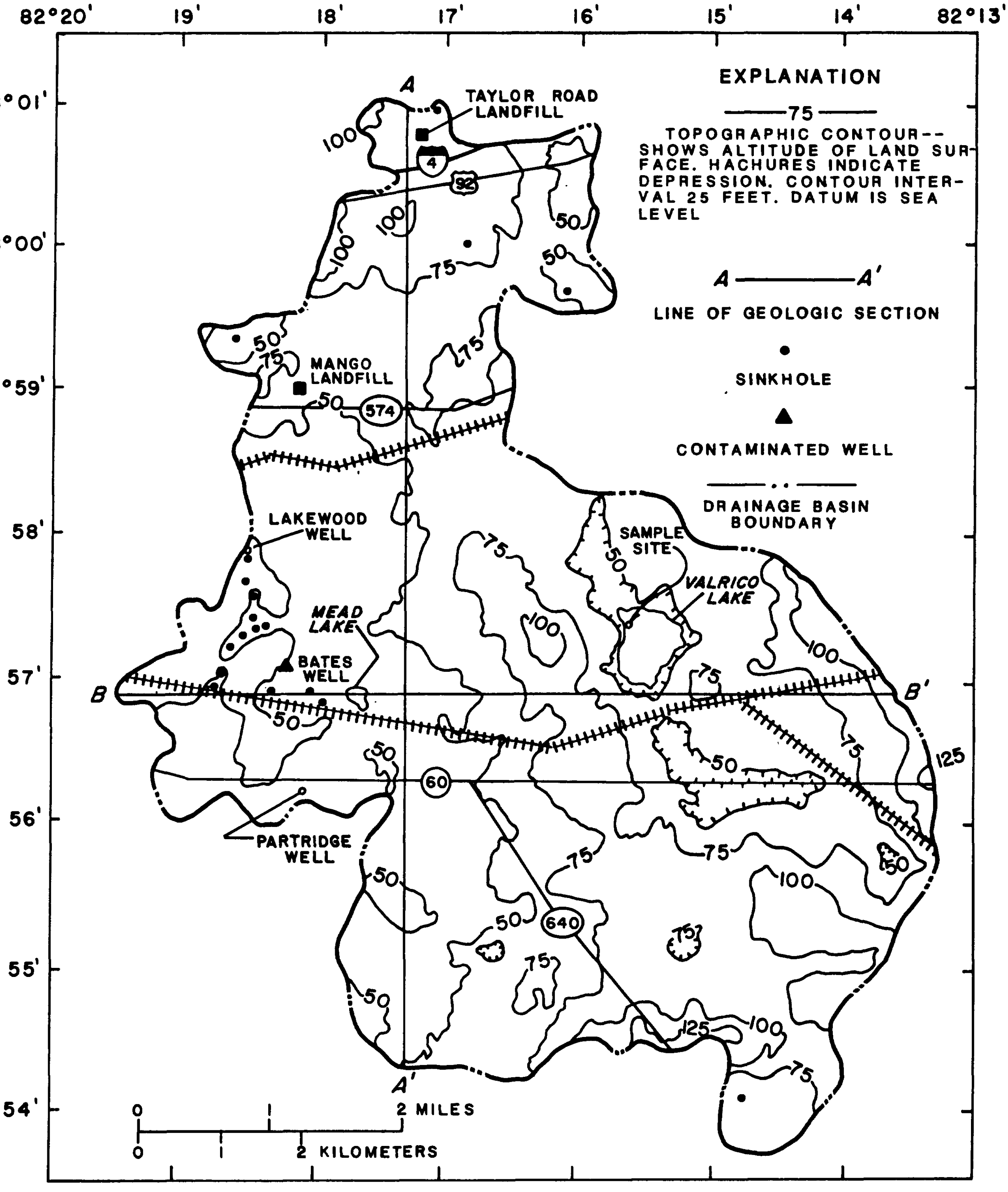

Figure 19.--Topography of the Brandon basin and locations of sampling sites, sinkholes, documented pollution sites, and geologic sections A-A' and B-B'.

In 1984, about 7.8 Mgal/d of water was withdrawn for public supply from the Upper Floridan aquifer in the Brandon area (Stieglitz, 1985). This accounted for most of the water withdrawn in the basin. Many areas in the basin are self-supplied. Based on the Brandon Chamber of Commerce 1985 population estimates, total water use in the basin was approximately 11.9 Mgal/d. Residential self-supplied water use accounts for slightly more than 4 Mgal/d. Due to the small amount of agricultural land remaining in the drainage basin, agricultural irrigation was probably very small. Many small diameter wells throughout the basin are used for lawn irrigation.

Hydrogeologic Setting

Land-surface altitude in the basin ranges from 35 to 125 feet above sea level. Generally, the lower altitudes are in the west-central part of the basin. The land rises through a series of rolling hills to higher altitudes along the southeastern edge of the basin (fig. 19). A number of sinkholes and small, shallow depressions typical of karst terrain occur throughout the basin.

Surficial deposits consisting of sands, sandy clay, and clay 40 to 140 feet thick overlie the Upper Floridan aquifer in the Brandon area. Generalized geologic sections through the drainage basin are shown in figure 20, and locations of the sections are shown in figure 19. A fairly continuous clay layer apparently extends throughout the drainage basin. The thickness of the clay layer varies widely over short distances, ranging from 15 to 125 feet in thickness (fig. 21). The top of the clay is between 1 foot and 70 feet below land surface, or between 10 feet below and 80 feet above sea level (fig. 22).

A persistent limestone at or near the top of the Tampa Limestone marks the top of the Upper Floridan aquifer in the area. Generally, the top of the limestone in the Brandon drainage basin is between 60 feet below and 60 feet above sea level (fig. 23). Drillers' logs indicate the presence of solution cavities at depths of about 100 feet below land surface in the eastern part of the basin.

Drainage and Recharge

In the Brandon area, surface drainage is poorly developed, and the basin is devoid of streams. Drainage is internal through sinkholes and small depressions, or by direct percolation through surficial deposits. The many small depressions in the basin collect and retain any surface runoff and release it to the ground-water system. Subsurface drainage is adequate during periods of normal rainfall, but during very wet periods, some closed depressions overflow and flood surrounding areas.

Recharge to the surficial aquifer system and the Upper Floridan aquifer in the Brandon basin is almost entirely from local precipitation. A small amount of recharge is from irrigation water and effluents from septic tanks and outfalls. In 1985, approximately 45 inches of rain fell in the basin.

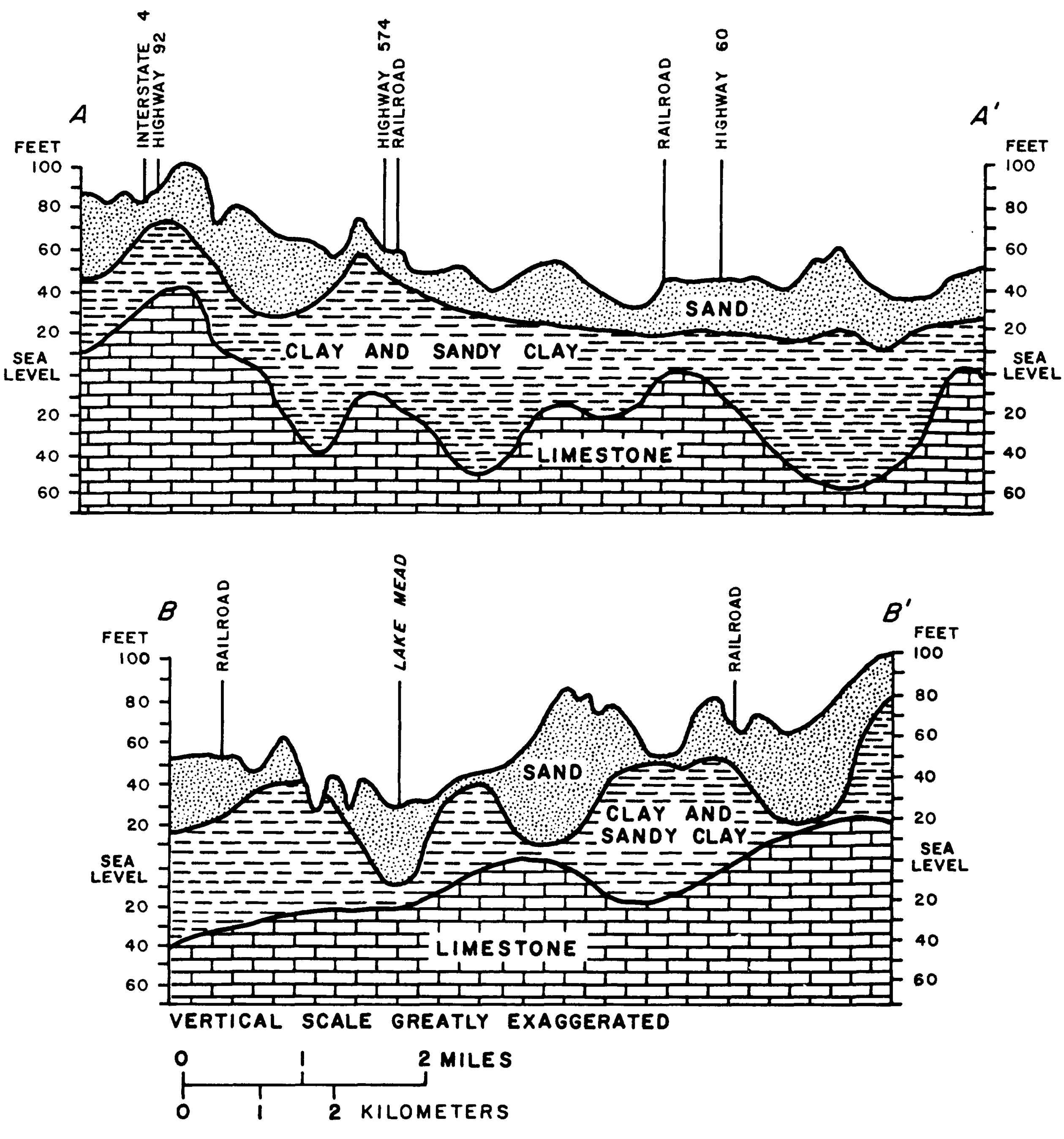

Figure 20.--Generalized geologic sections A-A' and B-B' through the internally drained Brandon basin. (Locations of sections are shown in figure 23.)

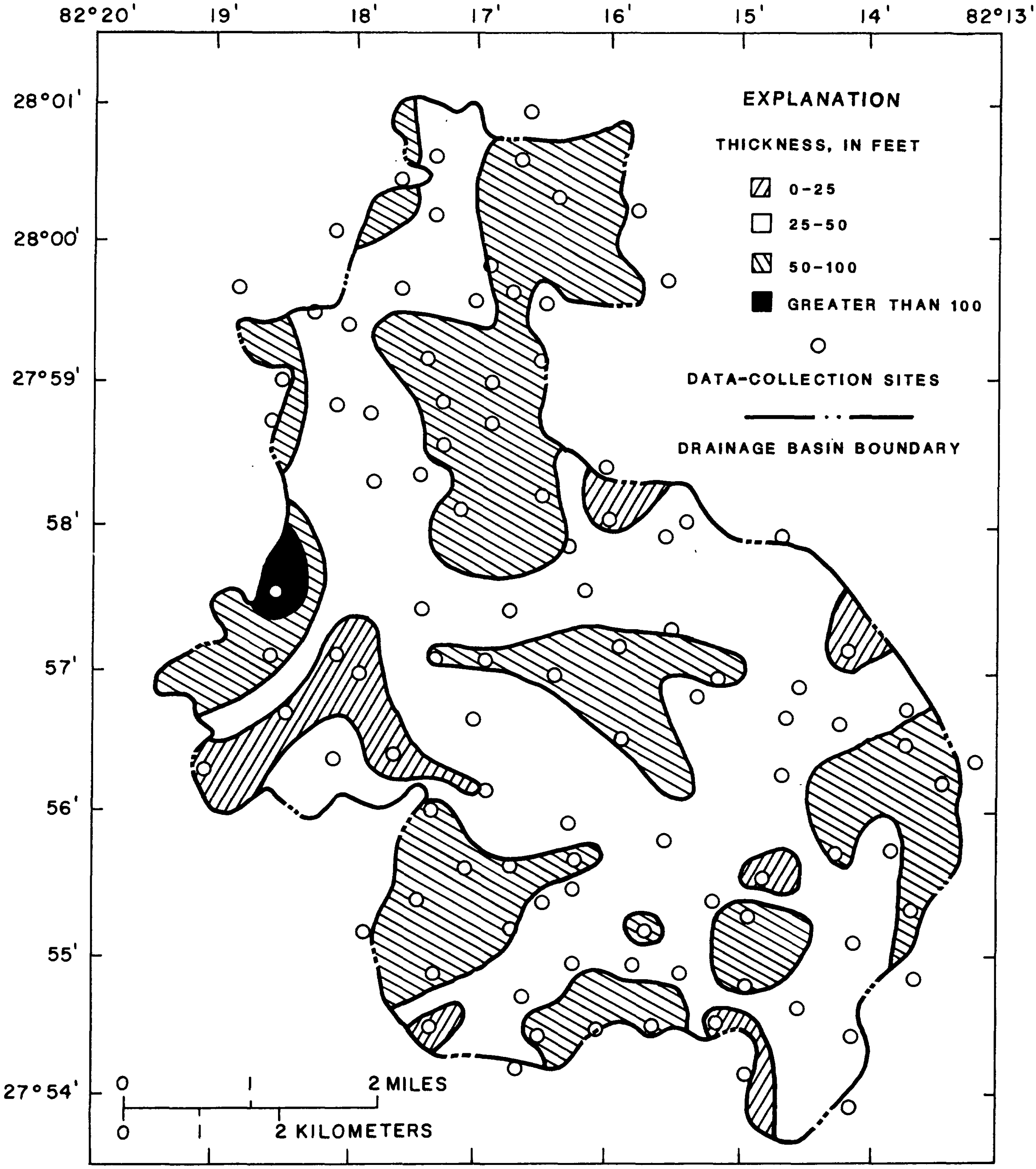

Figure 21.--Generalized thickness of the upper confining unit overlying the Upper Floridan aquifer in the Brandon basin. (Based on drillers' completion reports from the files of the Southwest Florida Water Management District.)

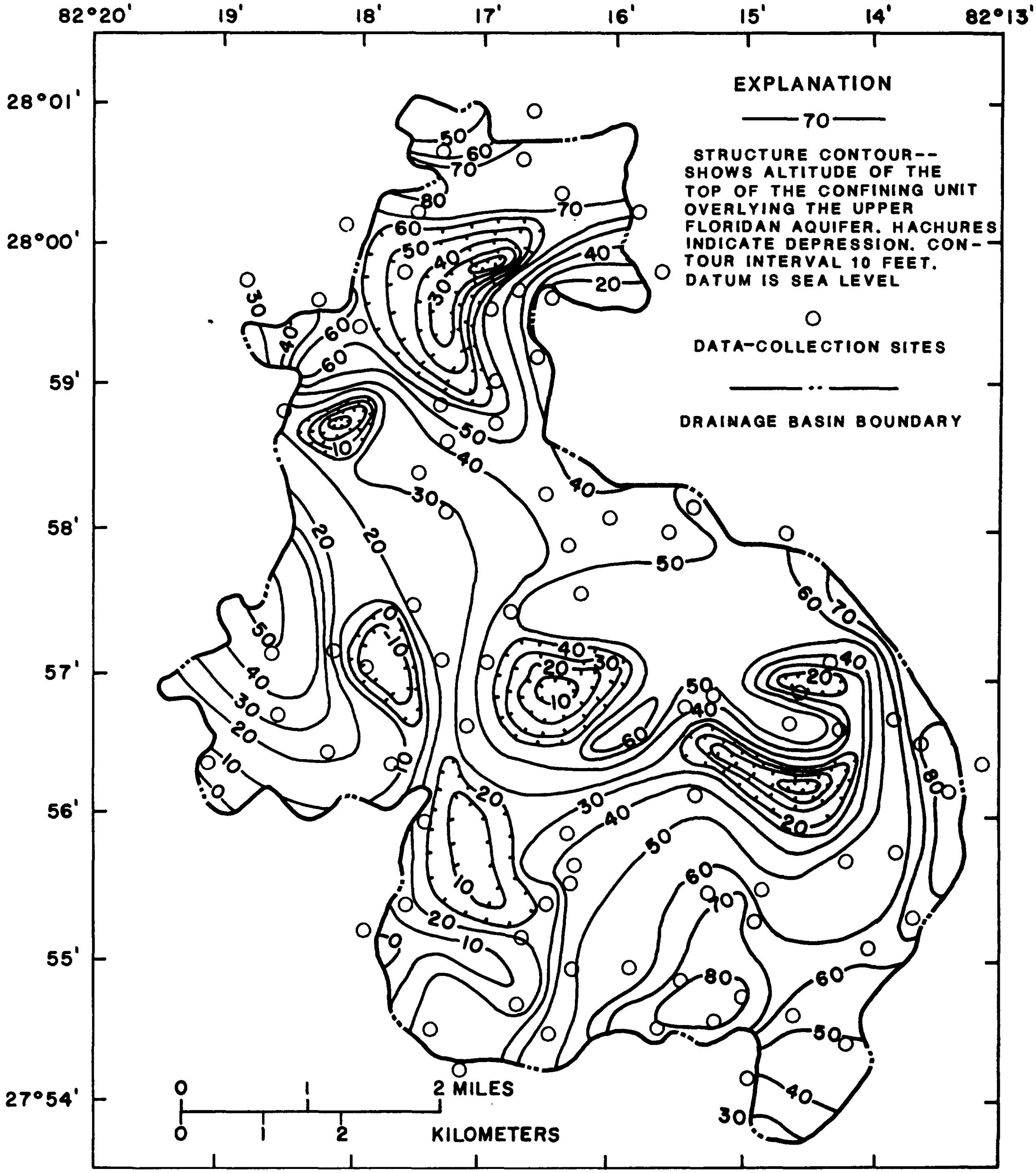

Figure 22.--Top of the upper confining unit that overlies the Upper Floridan aquifer in the Brandon basin. (Based on drillers' completion reports from the files of the Southwest Florida Water Management District.)

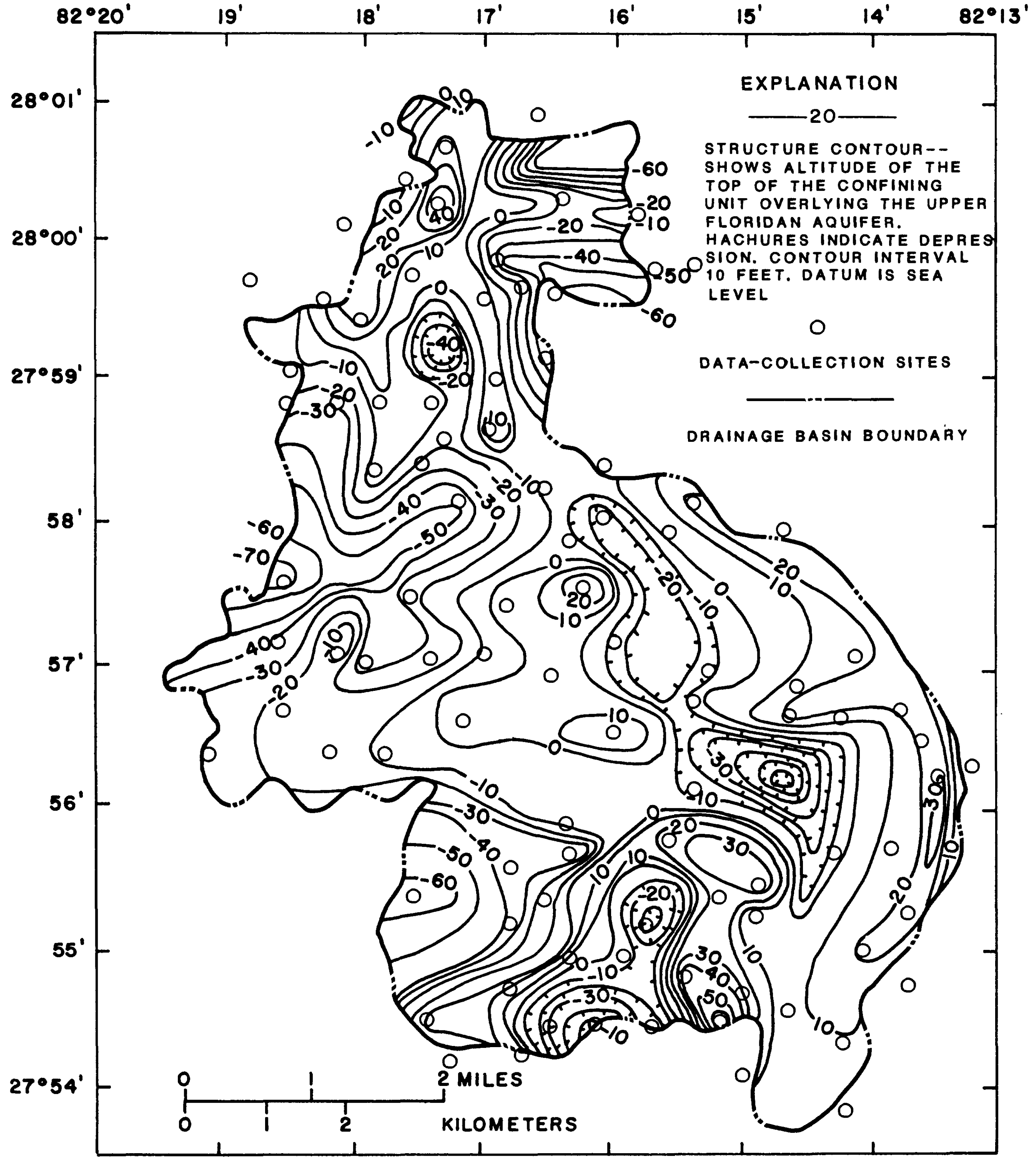

Figure 23.--Top of the Upper Floridan aquifer in the Brandon basin. (Based on drillers' completion reports from the files of the Southwest Florida Water Management District.)

Based on Dohrenwend's (1977) average for evapotranspiration, a total of 8 inches of rainfall was available for recharge throughout the basin in 1985 (about 4,900 Mgal or 650 million ft^3 of water).

Ground Water

The water table in the surficial aquifer system generally parallels the topography in the basin, except for two small areas in the southeast and north. Test drilling was conducted in 1979 in these areas. In the southeastern area, water was not found within 75 feet of land surface. Seismic surveys conducted in May and October 1985 also indicated no water in the surficial deposits in this area. However, a seismic survey conducted in January 1986 detected water at depths ranging from 21 to 40 feet above sea level. The survey was conducted approximately 1 week after a rainfall. Previous surveys were conducted during relatively dry periods when rainfall was 0.5 inch or less in the previous 30 days. In the northern area, investigations conducted by Hillsborough County indicated that a permanent water table is absent in the vicinity of the Taylor Road landfill (Hall and Metcalfe, 1979).

Water is apparently present only temporarily in the surficial deposits in these areas (fig. 24), indicating a good hydraulic connection to and a possible recharge point for the Upper Floridan aquifer. Water levels in the surficial aquifer system in the remainder of the basin ranged from 6 to 52 feet below land surface in May 1985 and from 3 to 33 feet below land surface in September 1985. Fluctuations in surficial water levels between May and September varied throughout the basin and ranged from 2 feet to nearly 30 feet. The largest fluctuations occurred in the northern part of the drainage basin.

The potentiometric surface of the Upper Floridan aquifer ranged from 20 to 30 feet above sea level in the northwestern part of the Brandon basin and from 9 to 15 feet in the southern part. Fluctuations of 6 to 10 feet occurred between May and September 1985. Ground-water flow in the Upper Floridan aquifer in the basin is generally from northeast to southwest (fig. 25).

Transmissivity of the Upper Floridan aquifer at a site just outside the western boundary of the drainage basin was determined in 1972. A transmissivity value of 8.6×10^4 ft^2/d was determined for the Tampa Limestone (Wolansky and Corral, 1985, p. 33). In 1982, Ryder, using a digital model, simulated transmissivity values between 5×10^4 and 1×10^5 ft^2/d for an area that includes the drainage basin.

Water Quality

Water-quality samples were collected from two wells and from Valrico Lake on September 5, 1985, following the passage of Hurricane Elena. The Lakewood well, a public-supply well owned by Hillsborough County, is 360 feet deep and cased to 134 feet. Most of the water from this well comes from the Suwannee Limestone. The Partridge well, a privately owned domestic well, is 125 feet

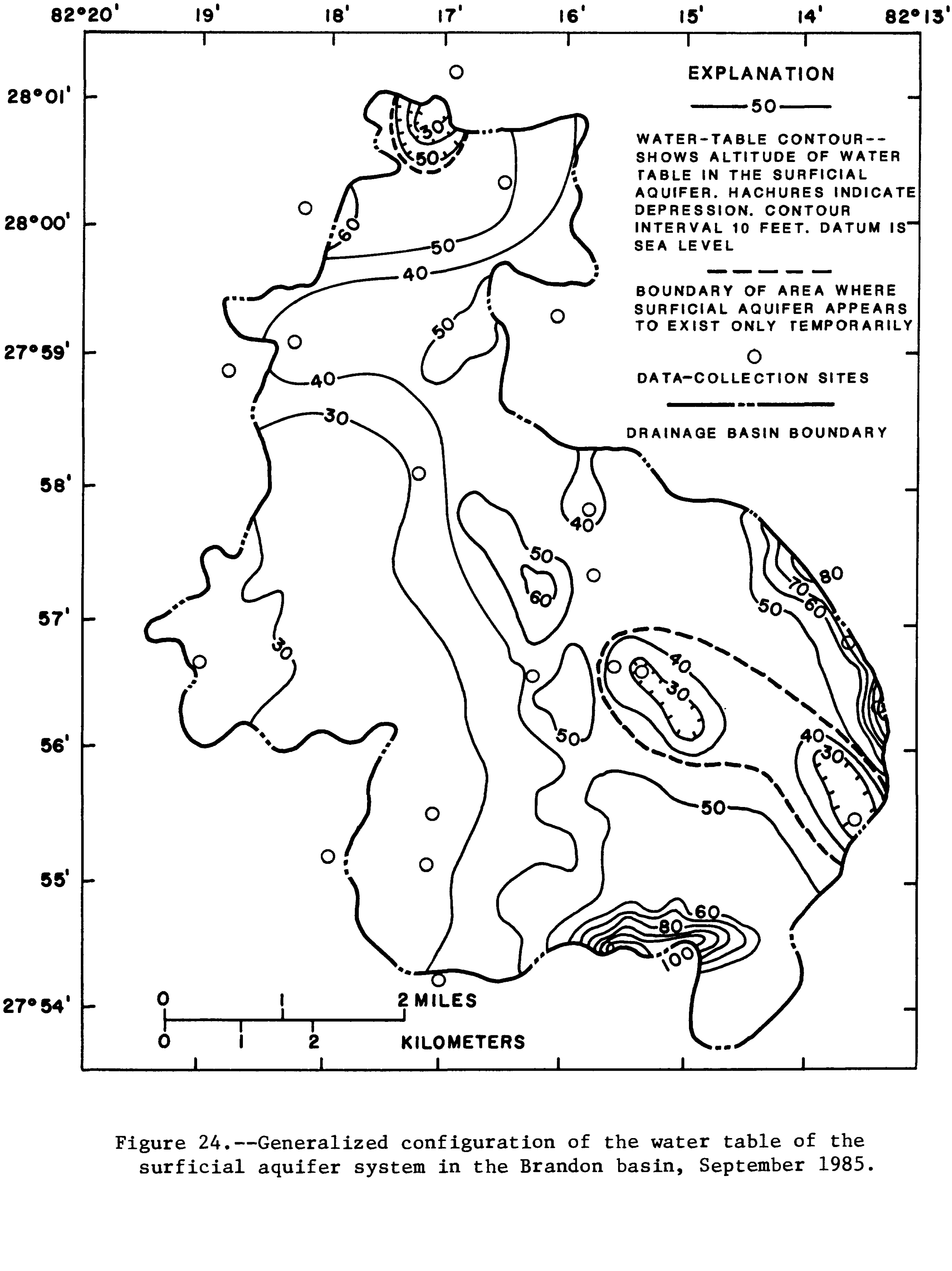

Figure 24.--Generalized configuration of the water table of the surficial aquifer system in the Brandon basin, September 1985.

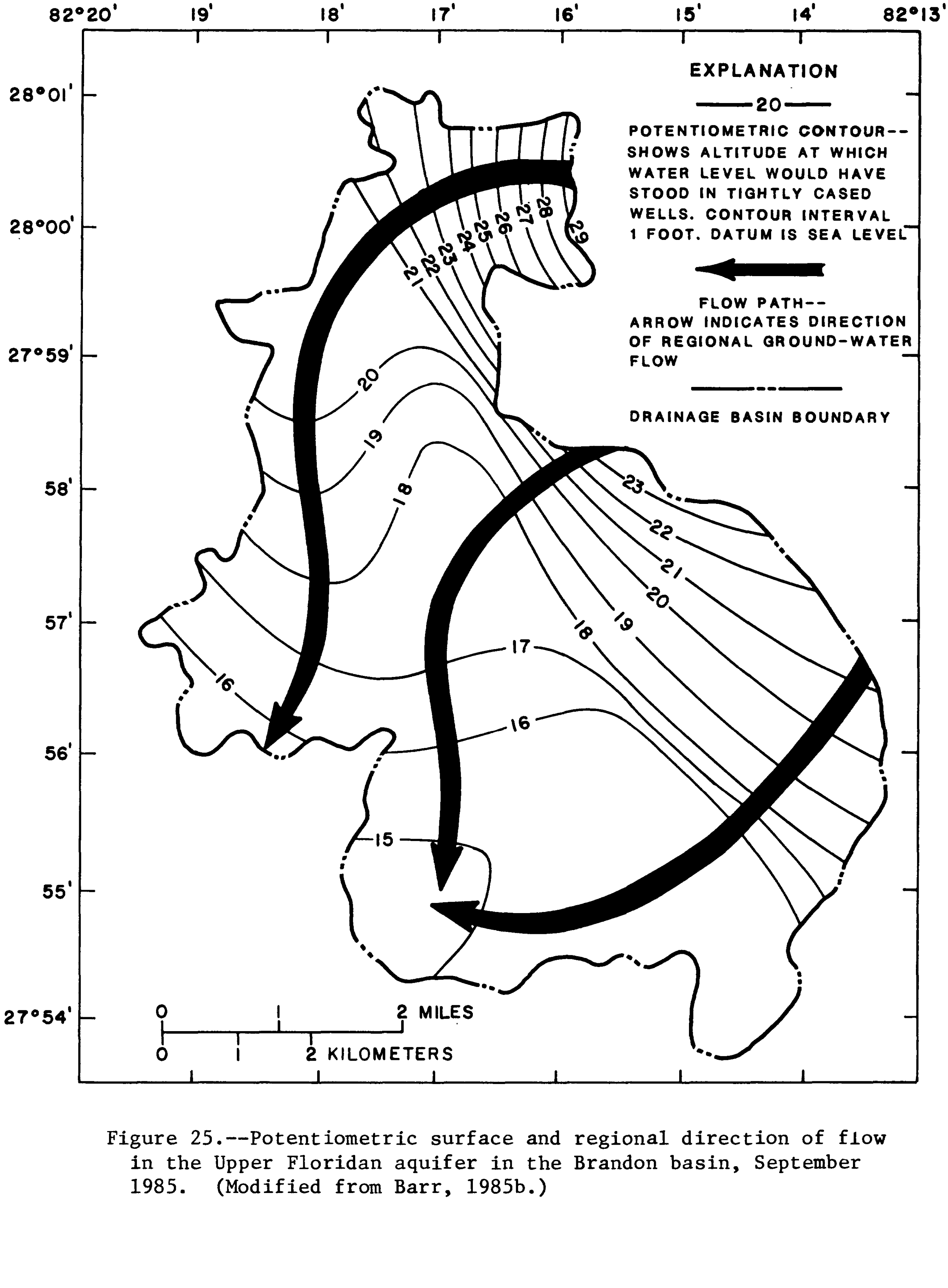

Figure 25.--Potentiometric surface and regional direction of flow in the Upper Floridan aquifer in the Brandon basin, September 1985. (Modified from Barr, 1985b.)

deep and cased to 60 feet. The water supplied by this well is from the Tampa Limestone.

The results of recent chemical analyses and some historical data are given in table 5. Most constituents were within the ranges expected. Trace elements, herbicides, and pesticides, including EDB, were below allowable or detectable levels, with the exception of zinc and 2,4-D. Viral contamination was not observed in any sample collected during the study period.

Concentrations of zinc were higher in samples from the Lakewood and Partridge wells than from Valrico Lake and may be attributed to galvanized pipes and storage tanks. The concentration of zinc in the sample collected from Valrico Lake on September 5, 1985, was 30 μg/L (micrograms per liter) and is at the maximum permissible level set by the Florida Department of Environmental Regulation (1985) for class III (recreational use) surface water. High zinc levels have been associated with stormwater runoff (Lopez and Giovannelli, 1984, p. 38).

Samples collected from Valrico Lake showed 2,4-D to be present in small quantities. The small amounts probably originated from home and garden use and can be expected in predominantly residential areas such as Brandon.

Samples collected from the Lakewood and Partridge wells contained no coliform bacteria, but the sample from Valrico Lake was positive. Coliform counts for the sample from the lake were below maximum limits set by the Florida Department of Environmental Regulation (1985) for class III (recreational) surface water; however, the fecal coliform to fecal streptococci (fc:fs) ratio for this sample was 11.85. The high ratio suggests a source of pollution associated with domestic wastes of man. There are no known septic tanks in the immediate area of Valrico Lake. The lake, however, is a local depression and receives surface runoff and discharge from the surficial aquifer system (fig. 19).

The September 1985 samples showed higher nitrogen concentrations than samples collected in 1979 (table 5); however, they are within normal ranges (Hem, 1970). These concentrations may reflect effects of fertilizers used in the basin when agricultural activities were more widespread than at present, or they may indicate the presence of effluents from septic tanks or sewage outfalls. Further monitoring would be necessary to determine the source of these nutrients.

Water quality in the northern part of the Brandon basin has been affected by the Hillsborough Heights (Taylor Road) and the Mango Clay Pit landfills (fig. 19); both landfills are presently inactive. The Taylor Road landfill is at the extreme north end of the drainage basin in an area of documented karst activity. Test borings indicate that, in some parts of the landfill site, the surficial deposits are hydraulically connected to the Upper Floridan aquifer through solution sinkholes (Hall and Metcalfe, 1979). Geraghty and Miller, Inc. (1981), observed no persistent water table at the landfill site, further indication of good hydraulic connection to the Upper Floridan aquifer. Contamination from volatile organics and oil and grease in some nearby wells has been linked to the landfill. A plume of contaminants from the landfill site has spread to the south (Geraghty and Miller, Inc., 1981), causing one county

Table 5.--Water-quality data for the Brandon internally drained basin

[Concentrations are in milligrams per liter, except as noted. µS/cm--microsiemens per centimeter, µg/L--micrograms per liter, col/100 mL--colonies per 100 milliliters]

Water-quality parameter	Valrico Lake		Lakewood well		Partridge well	
	8-07-79	9-05-85	8-06-79	9-05-85	8-07-79	9-05-85
Temperature (°C)	--	27.5	24.0	24.5	24.0	25.0
Specific conductance (µS/cm)	--	145	355	435	910	179
pH (units)	--	6.6	--	7.1	--	7.3
Alkalinity (as $CaSO_3$)	10	35	--	--	--	47
Color (platinum-cobalt units)	--	--	--	--	--	--
Nitrogen (as NO_2+NO_3)	0.02	0.03	1.62	2.25	2.51	2.85
Nitrogen, ammonia (as N)	.09	.04	--	0.02	--	0.02
Phosphorus (as P)	.07	.06	--	.02	--	.03
Total organic carbon	17.0	11.0	--	5.2	--	4.0
Chloride (as Cl)	10	14	--	11	--	8
Sulfate (as SO_4)	3	1	--	26	--	7
Potassium (as K)	.6	1.0	--	.5	--	.2
Sodium (as Na)	4.8	6.2	--	5.2	--	3.3
Arsenic (µg/L as As)	4	2	--	1	--	<1
Cadmium (µg/L as Cd)	<10	20	--	<10	--	<10
Chromium (µg/L as Cr)	<10	20	--	--	--	10
Copper (µg/L as Cu)	<10	<10	--	10	--	<10
Iron (µg/L as Fe)	170	--	--	--	--	--
Lead (µg/L as Pb)	<100	<100	--	<100	--	<100
Zinc (µg/L as Zn)	5	30	--	50	--	130
Mercury (µg/L as Hg)	--	<.1	--	<.1	--	<.1
Total coliform (col/100 mL)	--	1,260	<1	<1	<1	<1
Fecal coliform (col/100 mL)	--	320	<1	<1	<1	<1
Fecal strep (col/100 mL)	--	27	<1	<1	<1	<1
Fc:fs ratio	--	11.85	--	--	--	--

Table 5.--Water-quality data for the Brandon internally drained basin--Continued

Water-quality parameter	Valrico Lake 8-07-79	Valrico Lake 9-05-85	Lakewood well 8-06-79	Lakewood well 9-05-85	Partridge well 8-07-79	Partridge well 9-05-85
Lindane (µg/L)	<0.01	<0.01	--	<0.01	--	<0.01
Napthalene, polychlorinated (µg/L)	--	<.1	--	<.1	--	<.1
Aldrin (µg/L)	<.01	<.01	--	<.01	--	<.01
Chlordane (µg/L)	<.1	<.1	--	<.1	--	<.1
EDB (µg/L)	--	<3.0	--	<3.0	--	<3.0
DDE (µg/L)	<.01	<.01	--	<.01	--	<.01
DDT (µg/L)	<.01	<.01	--	<.01	--	<.01
Dieldrin (µg/L)	<.01	<.01	--	<.01	--	<.01
Endosulfan (µg/L)	<.01	<.01	--	<.01	--	<.01
Endrin (µg/L)	<.01	<.01	--	<.01	--	<.01
Toxaphene (µg/L)	<1	<1	--	<1	--	<1
Heptachlor (µg/L)	<.01	<.01	--	<.01	--	<.01
PCB (µg/L)	<.1	<.1	--	<.1	--	<.1
Heptachlorepoxide (µg/L)	<.01	<.01	--	<.01	--	<.01
Methoxychlor (µg/L)	<.01	<.01	--	<.01	--	<.01
Mirex (µg/L)	<.01	<.01	--	<.01	--	<.01
Silvex (µg/L)	<.01	<.01	--	<.01	--	<.01
2,4-D (µg/L)	.17	.05	--	<.01	--	<.01
2,4,5-D (µg/L)	<.01	<.01	--	<.01	--	<.01
2,4-DP (µg/L)	<.01	<.01	--	<.01	--	<.01
Solids, residue at 180°C	--	74	--	204	--	100

supply well to be abandoned and necessitated the installation of a county water system in an area previously supplied by private domestic wells. The Taylor Road landfill is included on the U.S. Environmental Protection Agency's priority pollution list and is targeted as a Superfund site.

The Mango Clay Pit landfill is about 2 miles southeast of the Taylor Road landfill. The landfill has been inactive since 1959 and has since been converted to a county park. Recent water-quality samples collected by the Florida Department of Environmental Regulation have shown low levels of volatile organic contaminants in two private wells to the south of the site (Dianne Trommer, Florida Department of Environmental Regulation, oral commun., 1986).

In 1983, the Bates well, a county public-supply well in the west-central part of the basin (fig. 19), was observed to contain EDB. The well is near a large citrus grove in an area dominated by sinkholes and small depressions. EDB was found in other private wells in the immediate area. Recent testing indicated that the well still contains a low concentration of EDB and is not being used by the county (R. Schnaare, Hillsborough County Utilities, oral commun., 1986).

HERNASCO SINK

Hernasco Sink is in the Crews Lake drainage basin and lies on the northwest shore of Crews Lake about 3.9 miles southwest of Masaryktown and 5.4 miles north of Gowers Corner in Pasco County (fig. 26).

Development in the Crews Lake drainage basin has not been as rapid as in other parts of the study area. Agricultural and forested land, with a low density rural population, is still predominant. Some residential and commercial development has occurred in the western part of the basin along U.S. Highway 41. There are surface-water impoundments, a land-application site, and outfalls used in the storage, treatment, and disposal of raw or partially treated sewage throughout the basin. The primary method of sewage disposal is through domestic septic tanks. A landfill at the Hernando County airport is also within the drainage basin. U.S. Highway 41 passes through the basin and is heavily traveled by commercial trucks. Mishaps along this major transportation route could cause spills of potentially hazardous materials. An undeveloped, heavily wooded area immediately to the west of Crews Lake is being used as a dumping site for refuse. Some small sinks are being filled with old tires, construction rubble, and a variety of trash (fig. 9). All of these represent potential sources for pollution.

Water used in the drainage basin is from the Upper Floridan aquifer and is primarily self-supplied by private wells. The Cross Bar Ranch well field lies within the basin and withdrew 12.9 Mgal/d from the Upper Floridan aquifer in 1984 (Stieglitz, 1985). Water withdrawn from the well field is distributed by the West Coast Regional Water Supply Authority for public supply outside the basin. Any water withdrawn from the surficial aquifer system, including lakes and ponds, is used for livestock watering and lawn and garden irrigation.

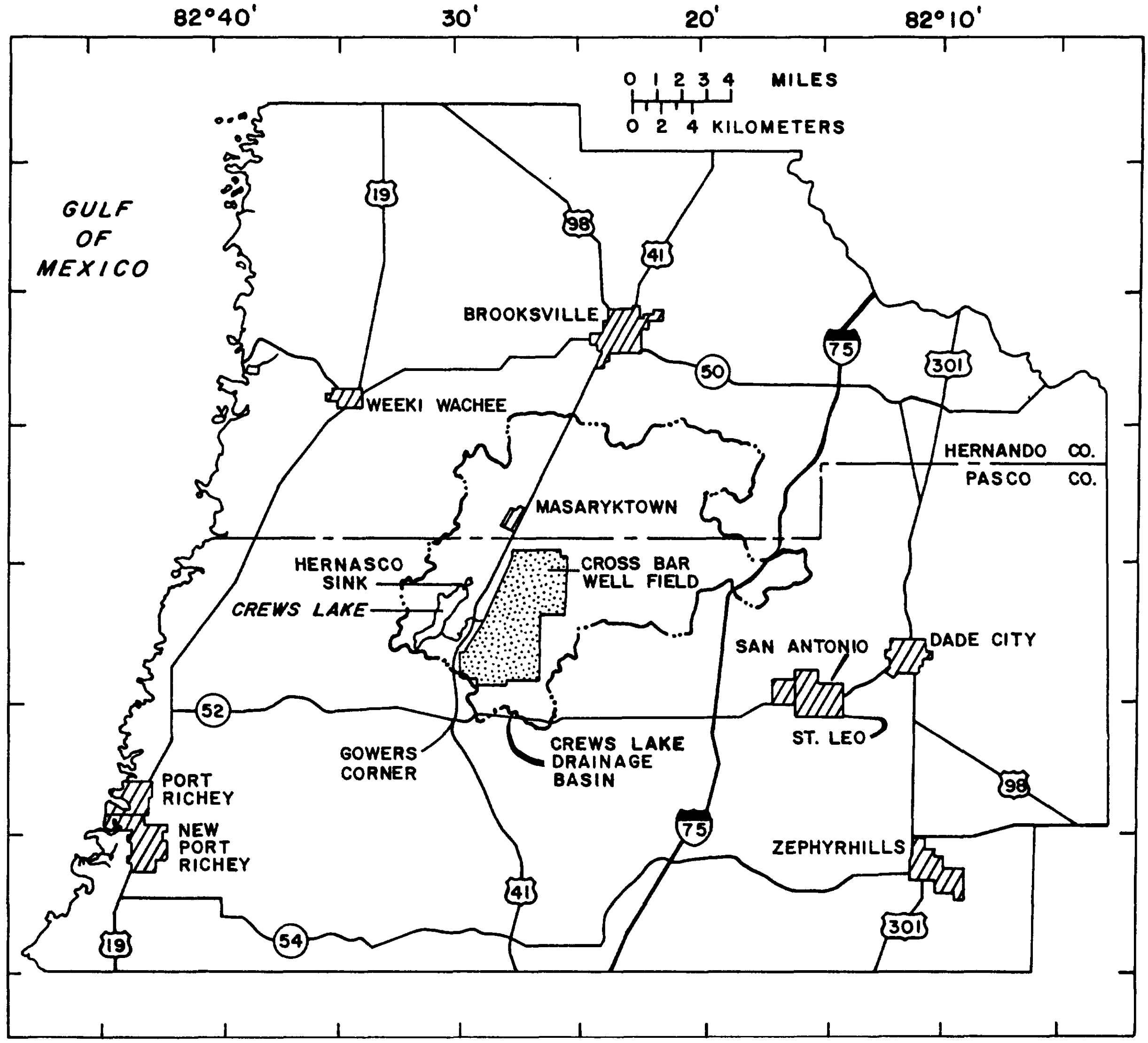

Figure 26.--Location of Crews Lake drainage basin, Hernando and Pasco Counties.

Hydrogeologic Setting

Land-surface altitudes in the basin range from 50 feet above sea level in the vicinity of Crews Lake, in the southwestern part, to more than 250 feet above sea level in the eastern part of the basin. The drainage basin is poorly drained and contains many sinkholes, sinkhole lakes, and closed depressions typical of karst terrain. Streams are generally small and flow is intermittent, usually during the wet season. Several streams terminate at sinkholes. Jumping Gully, a major stream in the basin, terminates at Crews Lake and is the major source of water for the lake. The Masaryktown Canal provides flood drainage to the lake from the Masaryktown and Squirrel Prairie areas (fig. 27). The canal was constructed along the general thalweg of the Pithlachascotee River above the lake and flows only during periods of very heavy rainfall. During wet periods, flow backs up the canal from Crews Lake. Water was observed flowing upstream and into a sinkhole in the canal bottom, about 1 mile north of U.S. Highway 41, following heavy rains in the fall of 1979 (T.H. Thompson, U.S. Geological Survey, oral commun., 1985).

Hernasco Sink is one of many sinkholes and shallow depressions that mark the lake bottom and surrounding area. The sinkhole is isolated from the lake during periods when the northern part of the lake is dry. The sinkhole is either underwater when the lake level is high, or connected to the lake by a shallow stream when levels are low. The actual sinkhole is about 10 feet in diameter, and the ponded area around the sink varies with water levels. When the water level in the sink was 42 feet above sea level, the ponded area was about 200 feet long and 50 feet wide. The northern and western sink walls drop steeply from about 55 feet above sea level to the water surface, the southern wall is not as steep, and the eastern side rises gently to the lake bed (fig. 28). Drillers' logs indicate that the top of the Upper Floridan aquifer is between 20 and 30 feet above sea level. The bottom of the sink was measured as 25 feet above sea level. The Hernasco Sink is open directly to the Upper Floridan aquifer.

There are two other large sinkholes near the Hernasco Sink. One is in a wooded area about 800 feet west of Hernasco Sink and, in this report, will be referred to as Sinkhole A. It is round in shape and about 150 feet in diameter. Sinkhole A contained water during the entire study period (October 1984 through September 1985), and water-level changes matched those in Hernasco Sink, except in September 1985 when there was inflow of water to Hernasco Sink from Crews Lake. Sinkhole A is surrounded on all sides by land that is about 60 feet above sea level. It has no external source of recharge, except for very limited local runoff.

The second large sinkhole is in the lake bed about 800 feet southwest of Hernasco Sink (fig. 28) and will be referred to as Sinkhole B. It is about 250 feet in diameter. During most of the study period, the northern part of the lake was dry, but Sinkhole B contained water during the entire period. Sinkhole B is connected to Hernasco Sink by a shallow stream channel that was dry for most of the study period. Water-level fluctuations in Sinkhole B did not correspond to those in Hernasco Sink or Sinkhole A. During the dry period, the water level remained fairly constant, while water levels continued to drop in the other sinks. The water level in Sinkhole B reacted rapidly to

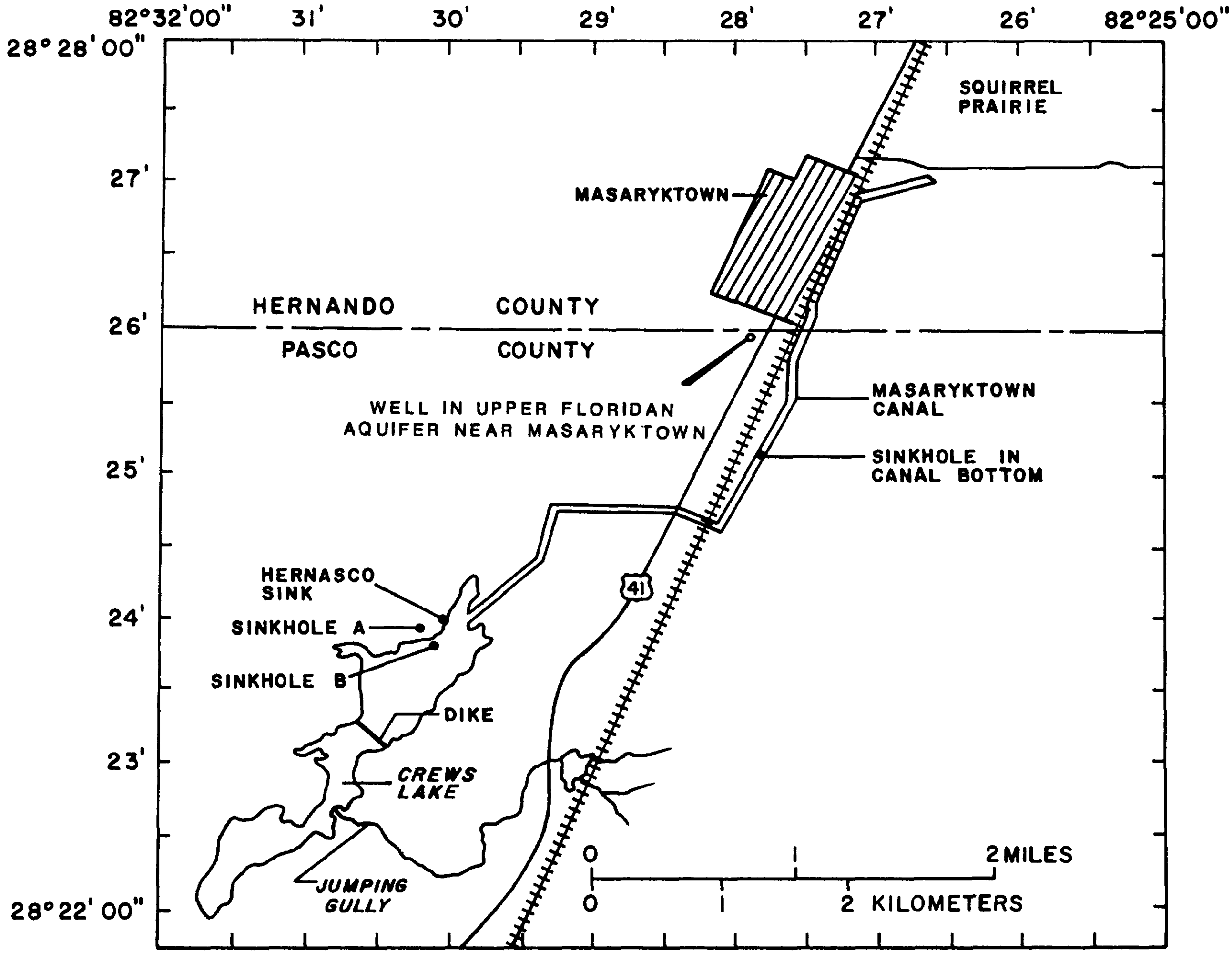

Figure 27.--Location of Crews Lake, sinkholes, Jumping Gully, Masaryktown Canal, and the Squirrel Prairie area.

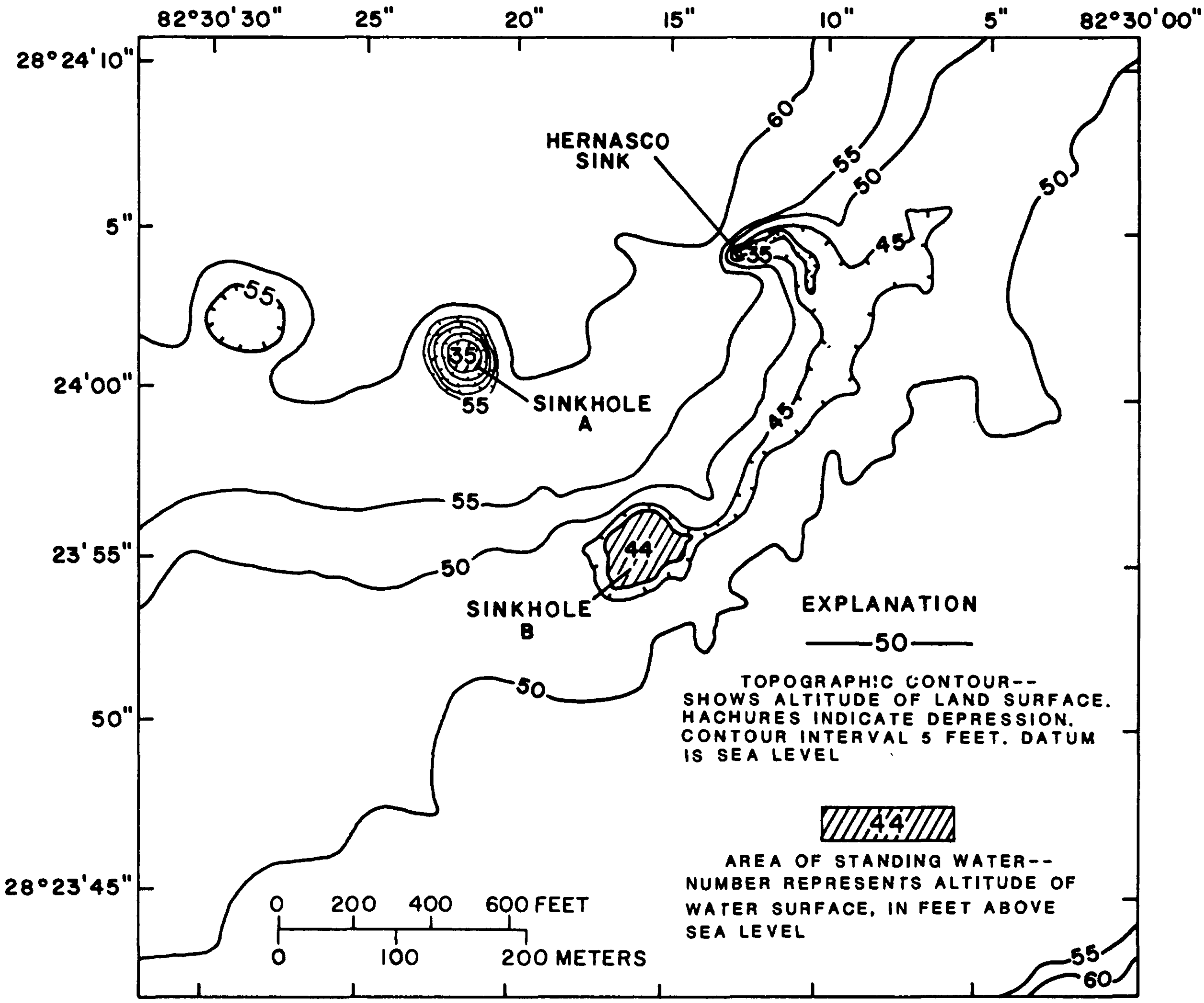

Figure 28.--Topography and location of sinkholes in the Hernasco Sink area.

rainfall in the immediate area. On March 22, 1985, after 2.5 inches of rainfall, the sink was overflowing to the stream leading to Hernasco Sink, although there was no visible inflow. Flow in the stream was less than 0.5 ft^3/s and had no effect on the water level in Hernasco Sink. Between late March and early July 1985, Sinkhole B reacted similarly on a number of occasions following rainfall. Surface inflow to Sinkhole B was observed periodically in July and August 1985 until rising water levels flooded the lake bed. The inflow came from an area of the lake bed located to the southwest that had remained swampy when the rest of the lake bed was dry. Sinkhole B appears to be recharged from the surficial aquifer system and probably has little or no direct connection to the Upper Floridan aquifer.

Crews Lake has a surface area of 1.17 mi^2. It is divided into two parts by an earthen dike (fig. 27), and a culvert connects the two parts. Most of the water in the northern part of the lake flows from the south through the culvert. This flow occurs when lake stage in the southern part is greater than 53 feet above sea level. The northern part of the lake is dry, or extremely shallow and swampy, except during the rainy season. The southern part of the lake contains water throughout the year.

The area adjacent to Crews Lake and the southwestern part of the drainage basin is underlain by a thin, but mostly continuous, clay layer, and a continuous surficial aquifer system appears to exist. The clay layer is present throughout the basin and thickens toward the Brooksville Ridge in the east (fig. 29). Drillers' logs, however, indicate that the clay layer is breached by relict sinks in many places, particularly in the northern and eastern parts of the basin. As a result, the surficial aquifer system does not extend throughout the basin. In some areas, the surficial deposits may contain water only during wet periods, or may be locally perched where confining layers of low permeability retard downward percolation.

Drainage, Stage, and Streamflow

Hernasco Sink drains about half the inflow to Crews Lake (Cherry and others, 1970, p. 11), which has a drainage area of approximately 138 mi^2. Under normal conditions, a large part of the drainage basin does not contribute water to Crews Lake. Drainage in those areas is internal and highly localized. The lakes, and the many sinkholes and depressions common in the basin, collect surface runoff and recharge the Upper Floridan aquifer.

Jumping Gully drains into the southern part of Crews lake and contributes most of the runoff to the lake. Flow rates of Jumping Gully at the gage at U.S. Highway 41 during the study period ranged from no flow during the dry season to 59 ft^3/s following the passage of Hurricane Elena. The Masaryktown Canal empties into the northern part of the lake (fig. 27). It was constructed as a flood control to drain stormwater from the Masaryktown and Squirrel Prairie areas. The canal drops from an altitude of 54 feet above sea level at Squirrel Prairie to 45 feet above sea level at Crews Lake, 6 miles to the south. At this point, however, the lake bottom is 50 feet above sea level. Consequently, water from the canal enters the lake only after water levels in the canal exceed 50 feet above sea level. For most of the study period, the

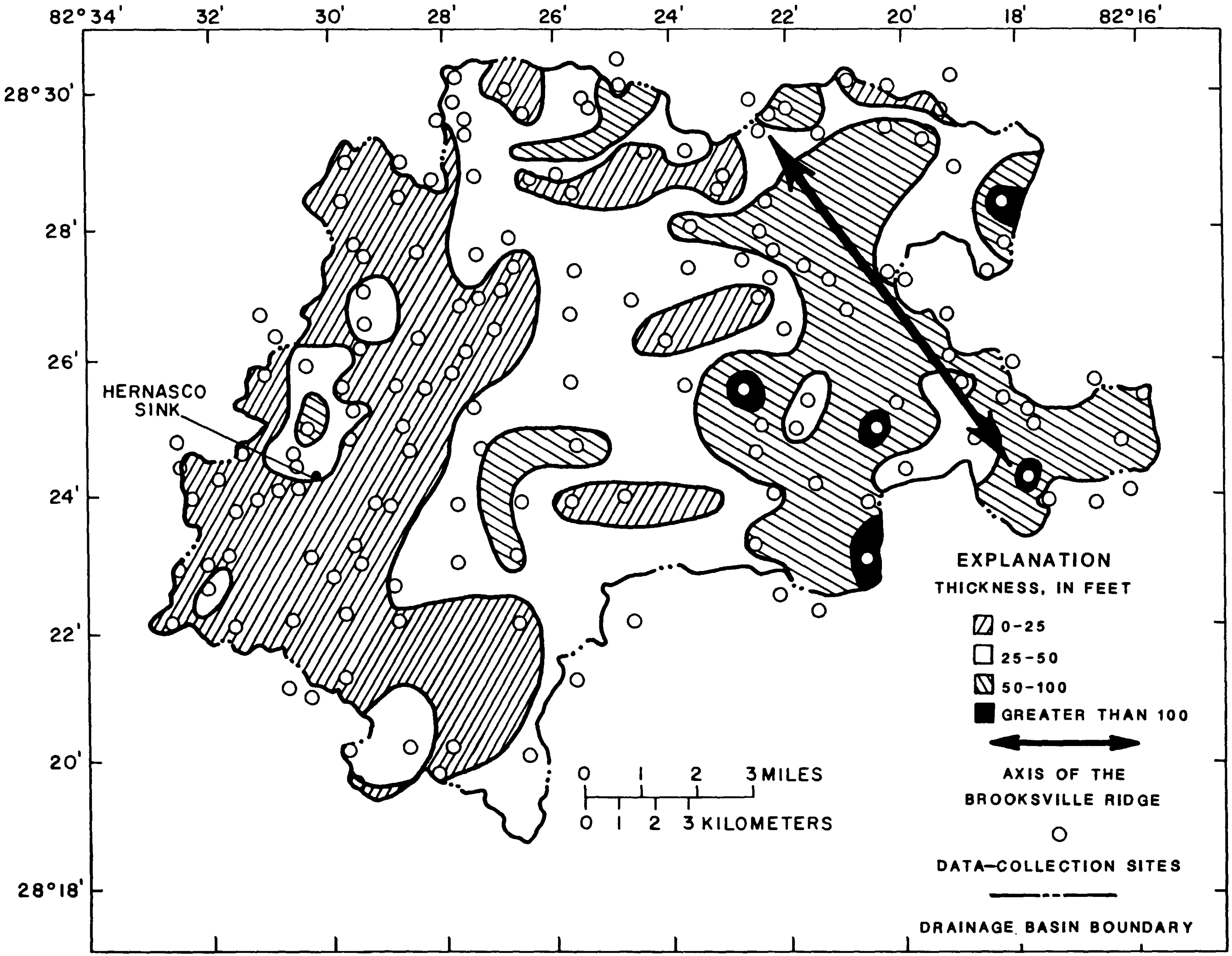

Figure 29.--Generalized thickness of the upper confining unit overlying the Upper Floridan aquifer in the Crews Lake drainage basin. (Based on drillers' completion reports from the files of the Southwest Florida Water Management District.)

canal was dry. Water was observed in the canal only after rising lake levels flooded the northern part of the lake. Flow toward the lake was not observed in the canal and most of the water in the canal probably originated from the lake. No major stream channels enter the northern part of the lake.

When the stage of Crews Lake drops below the culvert, the water level in the northern part of the lake declines faster than water levels in the southern part (Cherry and others, 1970, p. 27), which indicates water is draining to the Upper Floridan aquifer through Hernasco Sink. Water was observed flowing into Hernasco Sink on many occasions. Most observed flows were less than 0.5 ft^3/s. On August 27, 1985, flow entering Hernasco Sink was measured at 2.4 ft^3/s. Observed water levels appeared to be constant in Hernasco Sink during flow periods, indicating the recharge capacity of the sink had not been exceeded.

To estimate the capacity of Hernasco Sink, inflow measurements at Jumping Gully and outflow measurements made south of the outlet from Crews Lake were compared. On September 14, 1985, after the effects of Hurricane Elena had subsided, the difference between inflow and outflow was 12 ft^3/s. Assuming little infiltration through the surficial deposits or karst features in the lake bed, most of this difference was recharged to the Upper Floridan aquifer through Hernasco Sink.

Ground Water

Where the surficial aquifer system is present, the water table in the basin ranges from near land surface in the south to about 20 feet below land surface near the northern boundary of the Cross Bar Ranch well field. Head differences between the surficial aquifer system and the potentiometric surface of the Upper Floridan aquifer are small, and water-level fluctuations parallel one another closely, suggesting a hydraulic connection through a leaky confining bed. The surficial aquifer system is affected by pumping from the Cross Bar Ranch well field (Hutchinson, 1985).

The potentiometric surface of the Upper Floridan aquifer in the drainage basin fluctuated about 10 feet between May and September 1985. In September 1985, the potentiometric surface ranged from about 30 feet above sea level in the northwest to 80 feet above sea level in the vicinity of the Brooksville Ridge. The direction of ground-water flow in the Upper Floridan aquifer is from southeast to northwest (fig. 30). Hydrographs indicate that water-level fluctuations in Hernasco Sink and Sinkhole A correspond to water-level fluctuations in the Upper Floridan aquifer in a well near Masaryktown (fig. 31).

Transmissivity of the Upper Floridan aquifer at the Cross Bar Ranch well field was determined from aquifer tests conducted in 1978 and ranged from $5x10^4$ ft^2/d in the southern part of the well field to $1x10^5$ ft^2/d in the northeastern part (Hutchinson, 1985, p. 12).

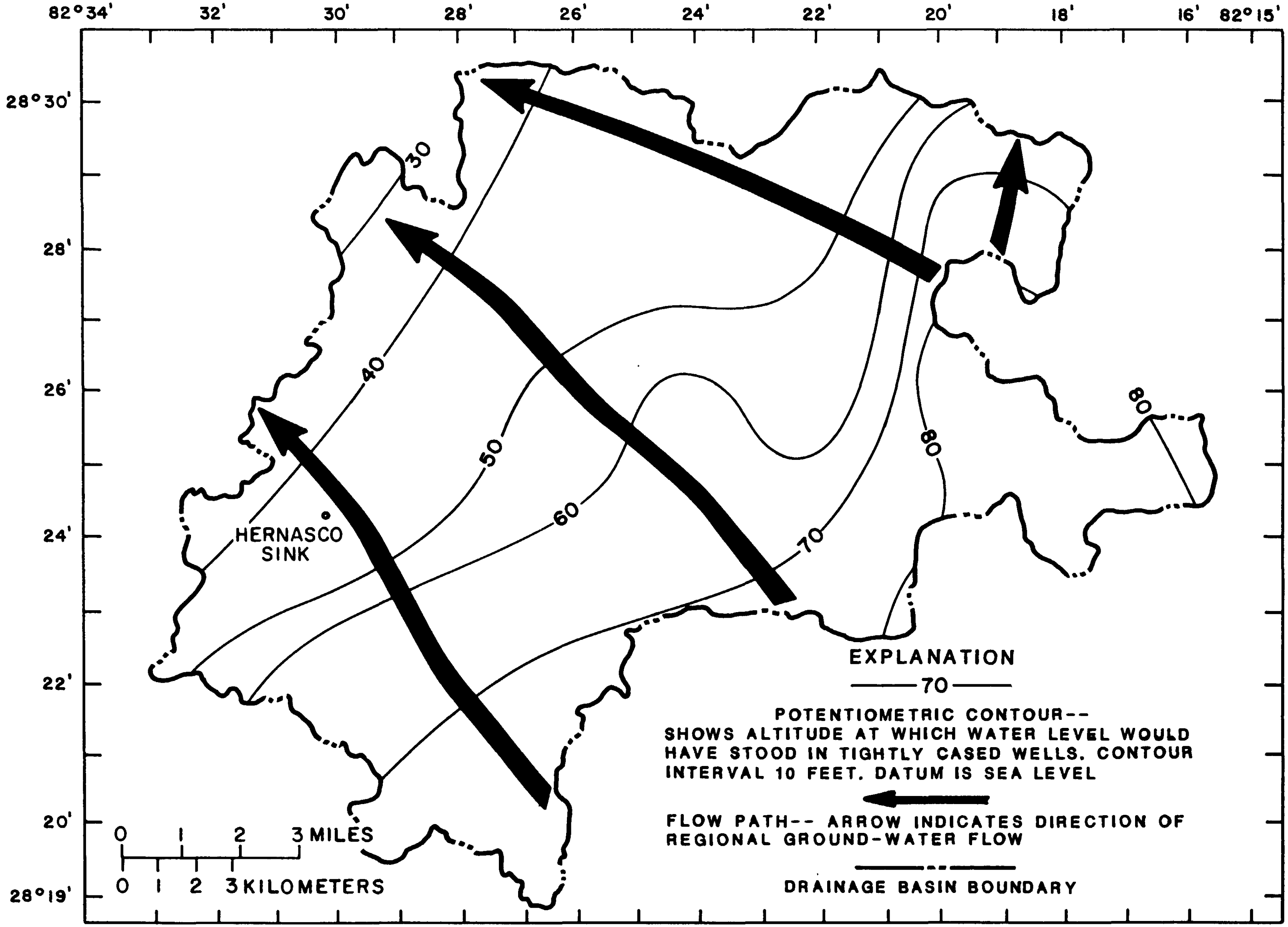

Figure 30.--Potentiometric surface and regional direction of flow in the Upper Floridan aquifer in Crews Lake drainage basin, September 1985. (Modified from Barr, 1985b.)

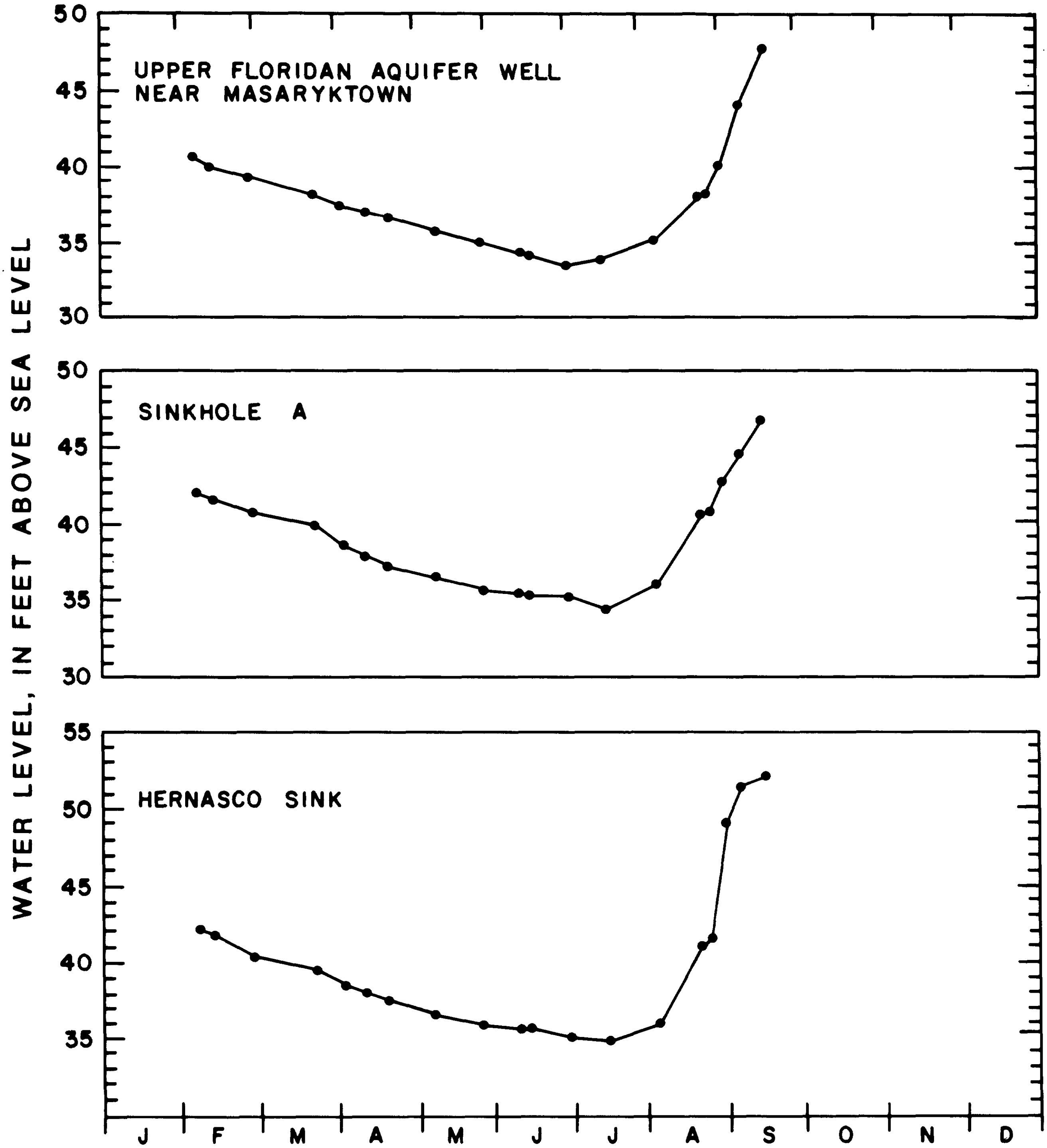

Figure 31.--Water levels of Hernasco Sink, Sinkhole A, and a well in the Upper Floridan aquifer near Masaryktown, February through September 1985. (Locations are shown in figure 30.)

Water Quality

Water-quality samples were collected from Hernasco Sink and Sinkhole A in February 1985 to coincide with low water levels and no-flow conditions. A sample also was collected from Hernasco Sink in September 1985 when the northern part of Crews Lake was flooded and recharge to the underlying aquifer was occurring. Field determinations were made for pH, temperature, and specific conductance. All samples were analyzed for trace elements, nutrients, and bacteria. Additional analyses for viruses and organic substances, including EDB, were run on the September 1985 sample.

Results of recent chemical analyses and some historical data are summarized in table 6. Herbicides and pesticides, including EDB, were below detectable levels. Samples collected on February 2, 1985, from Hernasco Sink and Sinkhole A contained 300 and 200 µg/L of lead, respectively. Both samples contained only 20 µg/L of zinc. The source of the high concentration of lead is unknown but may be related to the dumping of refuse in the nearby wooded area. The sample collected from Hernasco Sink on September 6, 1985, contained 50 µg/L of zinc but did not contain detectable levels of lead. The permissible limit set by the Florida Department of Environmental Regulation (1985) for lead and zinc in surface water is 30 µg/L. All other trace elements were within allowable limits. With the exception of samples collected in 1967 and 1968, nitrogen concentrations were low, only slightly above detectable levels. The high nitrogen concentrations in the 1967 and 1968 samples were in excess of limits set by the Florida Department of Environmental Regulation (1985) for drinking and recreational surface waters and may have been a result of agricultural activities in the basin at that time. Recent sampling detected only trace amounts of nutrients. Evidence of virus was not observed in the sample collected on September 4, 1985. This sample was collected at a time when water levels in the surficial aquifer system and the Upper Floridan aquifer were still rising.

Total coliform counts of water in Hernasco Sink were slightly higher in samples collected during low water conditions than in samples collected during high water conditions. The fecal coliform to fecal streptococci (fc:fs) ratios were 1.20 and 1.58 respectively, possibly suggesting more than one source of pollution.

Stormwater runoff does not enter Hernasco Sink directly. It first enters Crews Lake where settlation and biological processes occur, thereby providing some degree of purification before the runoff enters the sink.

PECK SINK COMPLEX

Peck Sink complex is in central Hernando County, approximately 1,800 feet south of State Highway 50, 8.6 miles east of U.S. Highway 19, and 2.9 miles southwest of Brooksville (fig. 32). The sinkhole complex is along the edge of the Brooksville Ridge, and except for the southwestern side, the Ridge delineates the basin boundary. Land-surface altitudes are in excess of 200 feet above sea level on the ridge but drop steeply to a relatively flat plain at 70

Table 6.--Water-quality data for Hernasco Sink

[Concentrations are in milligrams per liter, except as noted. µS/cm--microsiemens per centimeter, µg/L--micrograms per liter, col/100 mL--colonies per 100 milliliters]

Water-quality parameter	Hernasco Sink					Sinkhole A
	5-23-66	5-19-67	5-22-68	2-12-85	9-06-85	9-06-85
Temperature (°C)	--	30.0	35.0	17.0	28.0	15.0
Specific conductance (µS/cm)	65	190	246	210	46	122
pH (units)	6.6	6.6	6.5	7.1	6.8	7.2
Alkalinity (as $CaSO_3$)	15	64	71	98	49	52
Color (platinum-cobalt units)	30	30	35	<5	--	30
Nitrogen (as NO_2+NO_3)	0.40	17.00	14.07	0.18	<0.10	0.20
Nitrogen, ammonia (as N)	--	--	--	--	.02	--
Phosphorus (as P)	--	0.61	0.23	--	.03	--
Total organic carbon	--	--	--	--	13.0	--
Chloride (as Cl)	8	12	20	7	5	5
Sulfate (SO_4)	1.6	.4	.2	1.0	2.0	.4
Potassium (as K)	.3	1.6	2.8	.9	.4	.8
Sodium (as Na)	4.6	6.4	12.0	3.5	2.4	2.4
Arsenic (µg/L as As)	--	--	--	--	--	<1
Cadmium (µg/L as Cd)	--	--	--	--	<10	--
Chromium (µg/L as Cr)	--	--	--	10	10	<10
Copper (µg/L as Cu)	--	--	--	--	<10	--
Iron (µg/L as Fe)	50	30	180	130	--	50
Lead (µg/L as Pb)	--	--	--	200	<100	300
Zinc (µg/L as Zn)	--	--	--	20	50	20
Mercury (µg/L as Hg)	--	--	--	--	<.1	--
Total coliform (col/100 mL)	--	--	--	1,500	356	110
Fecal coliform (col/100 mL)	--	--	--	420	153	17
Fecal strep (col/100 mL)	--	--	--	350	97	13
Fc:fs ratio	--	--	--	1.20	1.58	1.31

Table 6.--Water-quality data for Hernasco Sink--Continued

Water-quality parameter	Hernasco Sink					Sinkhole A
	5-23-66	5-19-67	5-22-68	2-12-85	9-06-85	9-06-85
Lindane (µg/L)	--	--	--	--	<0.01	--
Napthalene, polychlorinated (µg/L)	--	--	--	--	<.1	--
Aldrin (µg/L)	--	--	--	--	<.01	--
Chlordane (µg/L)	--	--	--	--	<.1	--
EDB (µg/L)	--	--	--	--	<3.0	--
DDE (µg/L)	--	--	--	--	<.01	--
DDT (µg/L)	--	--	--	--	<.01	--
Dieldrin (µg/L)	--	--	--	--	<.01	--
Endosulfan (µg/L)	--	--	--	--	<.01	--
Endrin (µg/L)	--	--	--	--	<.01	--
Toxaphene (µg/L)	--	--	--	--	<1	--
Heptachlor (µg/L)	--	--	--	--	<.01	--
PCB (µg/L)	--	--	--	--	<.1	--
Heptachlorepoxide (µg/L)	--	--	--	--	<.01	--
Methoxychlor (µg/L)	--	--	--	--	<.01	--
Mirex (µg/L)	--	--	--	--	<.01	--
Silvex (µg/L)	--	--	--	--	<.01	--
2,4-D (µg/L)	--	--	--	--	<.01	--
2,4,5-D (µg/L)	--	--	--	--	<.01	--
2,4-DP (µg/L)	--	--	--	--	<.01	--
Solids, residue at 180°C	31	100	130	134	39	74

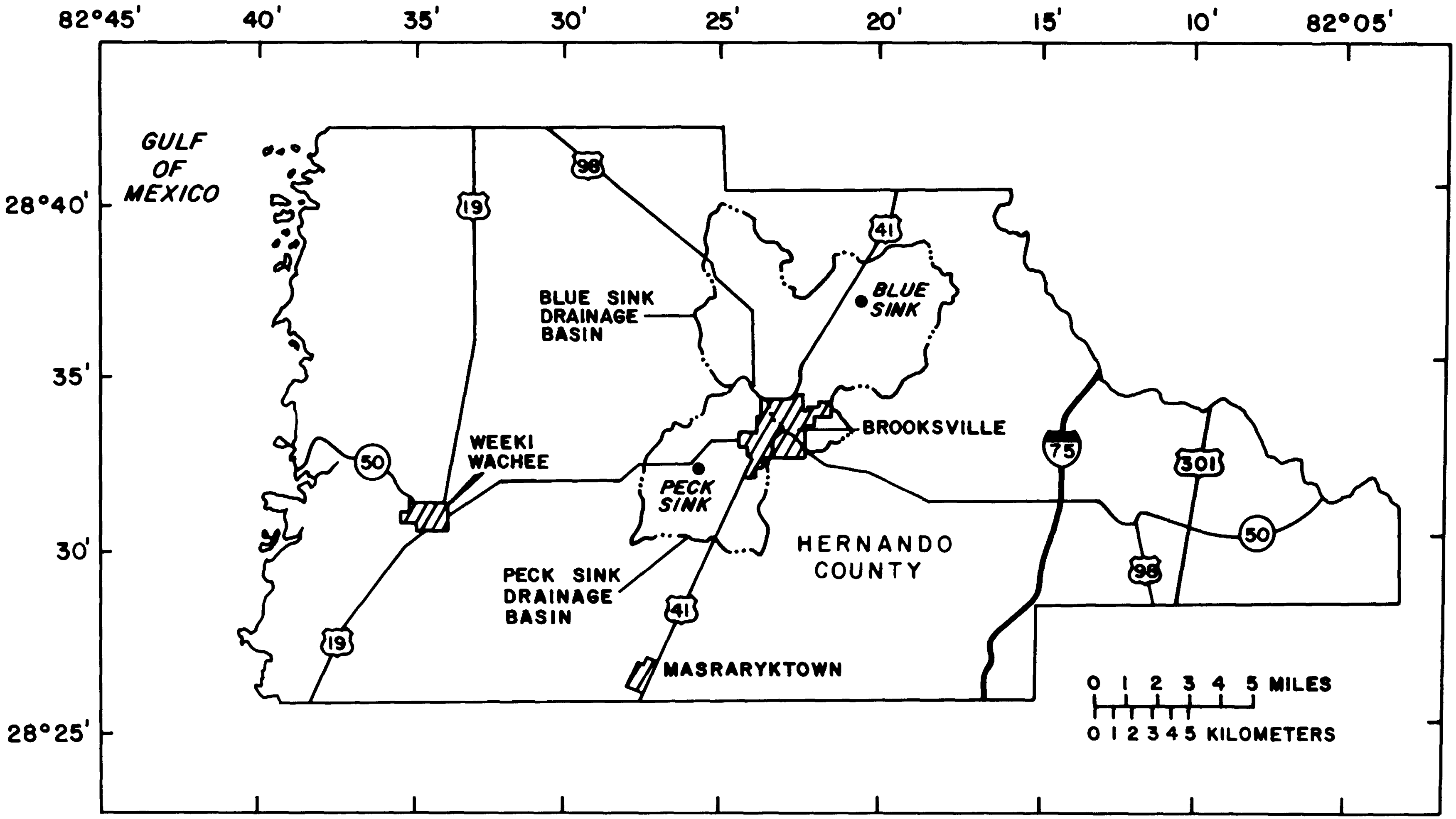

Figure 32.--Location of Peck Sink and Blue Sink drainage basins, Hernando County.

feet above sea level (fig. 33). Altitudes drop to near 30 feet above sea level at the base of the sink.

About 10 percent of the land area in the Peck Sink drainage basin lies within the city limits of Brooksville, the most urbanized part of the basin. A large part of the remaining land area is agricultural or forested. Development in the basin, however, has been increasing rapidly in recent years. Most of the development has occurred around Brooksville, to the west along State Highway 50, and to the south along U.S. Highway 41. Development has mainly been in the form of moderate to high density residential communities and related commercial centers. Some surface-water impoundments and spray-effluent sites used in the storage, treatment, and disposal of raw or partially treated sewage and other wastewater are located in the basin. Sewage disposal, however, is primarily through septic tanks. Two major, heavily traveled transportation routes pass through the basin. All of these represent a potential for pollution of the Upper Floridan aquifer.

Water for irrigation and rural supply within the basin is withdrawn from the Upper Floridan aquifer and is primarily self-supplied. All water used for public supply is pumped from wells outside the basin.

Hydrogeologic Setting

Peck Sink is a complex of at least five sinkholes (fig. 34), two of which form vertical shafts that are directly connected to the Upper Floridan aquifer. A deep, well-defined stream channel enters the first and smaller sinkhole. In this report, this sinkhole will be referred to as the first sink and the larger sinkhole will be referred to as the main sink. When inflow exceeds recharge capacity of the first sink, water ponds in a small area and overflows into the channel leading to the main sink. The first sink contains water only during the rainy season when there is runoff, and the main sink contains water perennially.

The first sink is about 15 feet in diameter and appears to be a flat, sandy, circular area at the end of the stream channel. It does not have a permanent pool and does not form a depression when dry. This sink is connected to the underlying limestone by a vertical shaft, or shafts, through openings at the base of the southern and western walls. These walls are comprised of sandy clay and rise nearly vertically for about 10 feet. When dry, the altitude of the sink floor is about 36 feet above sea level. The northern wall is not as steep as the southern and western walls. The stream channel enters the sink from the east, and the overflow channel exits from the sink through a cut in the northwestern wall. The altitude of the floor of the overflow channel, at the divide between sinks, is about 42 feet above sea level and drops steeply from this point to about 30 feet above sea level where it enters the main sink.

The main sink is about 500 feet southwest of the first sink and is approximately 50 feet in diameter. It is surrounded on three sides by steep, clayey walls that rise to an altitude of 65 feet above sea level on the south

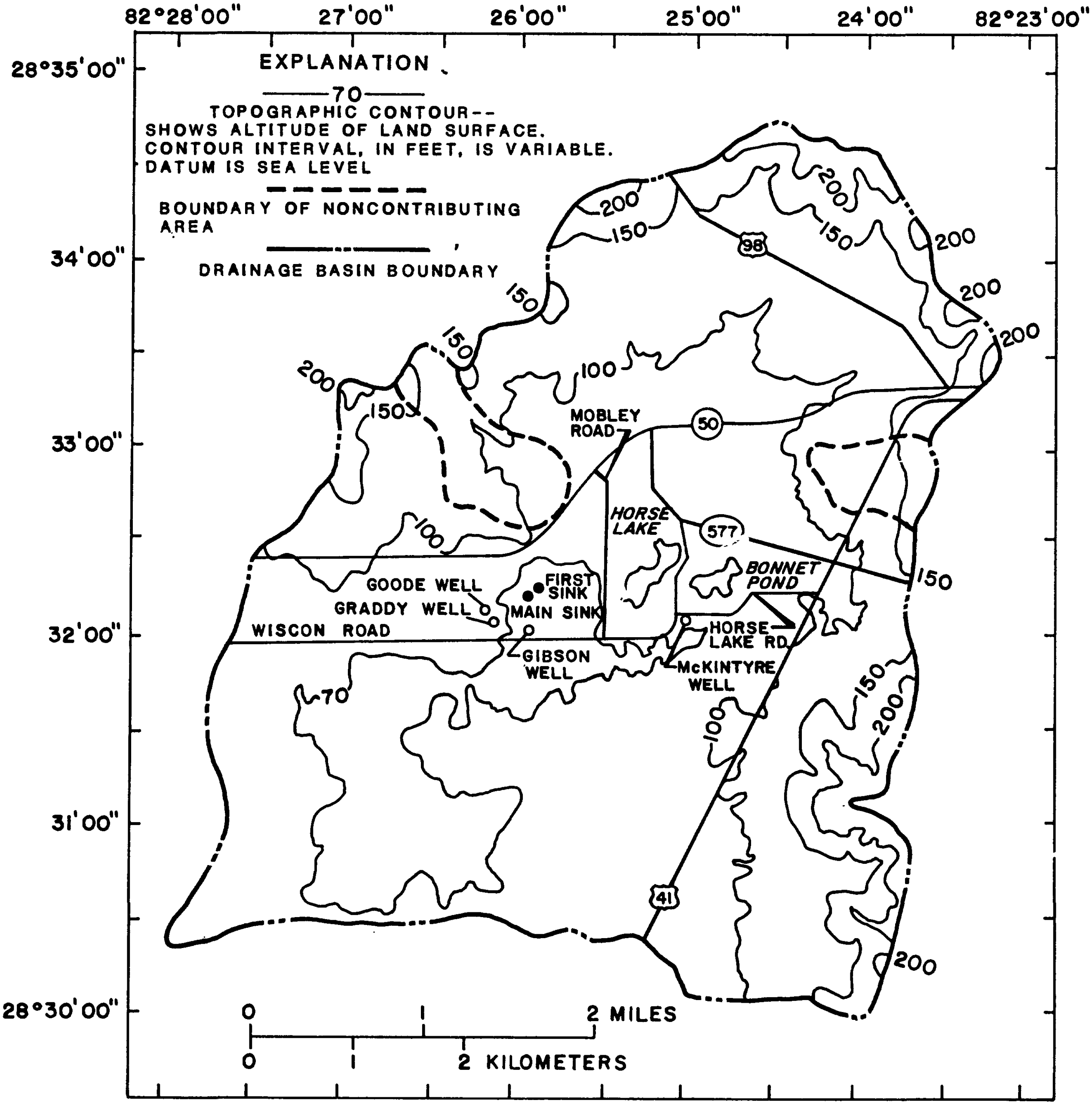

Figure 33.--Topography and location of sinkholes and wells in the Peck Sink drianage basin.

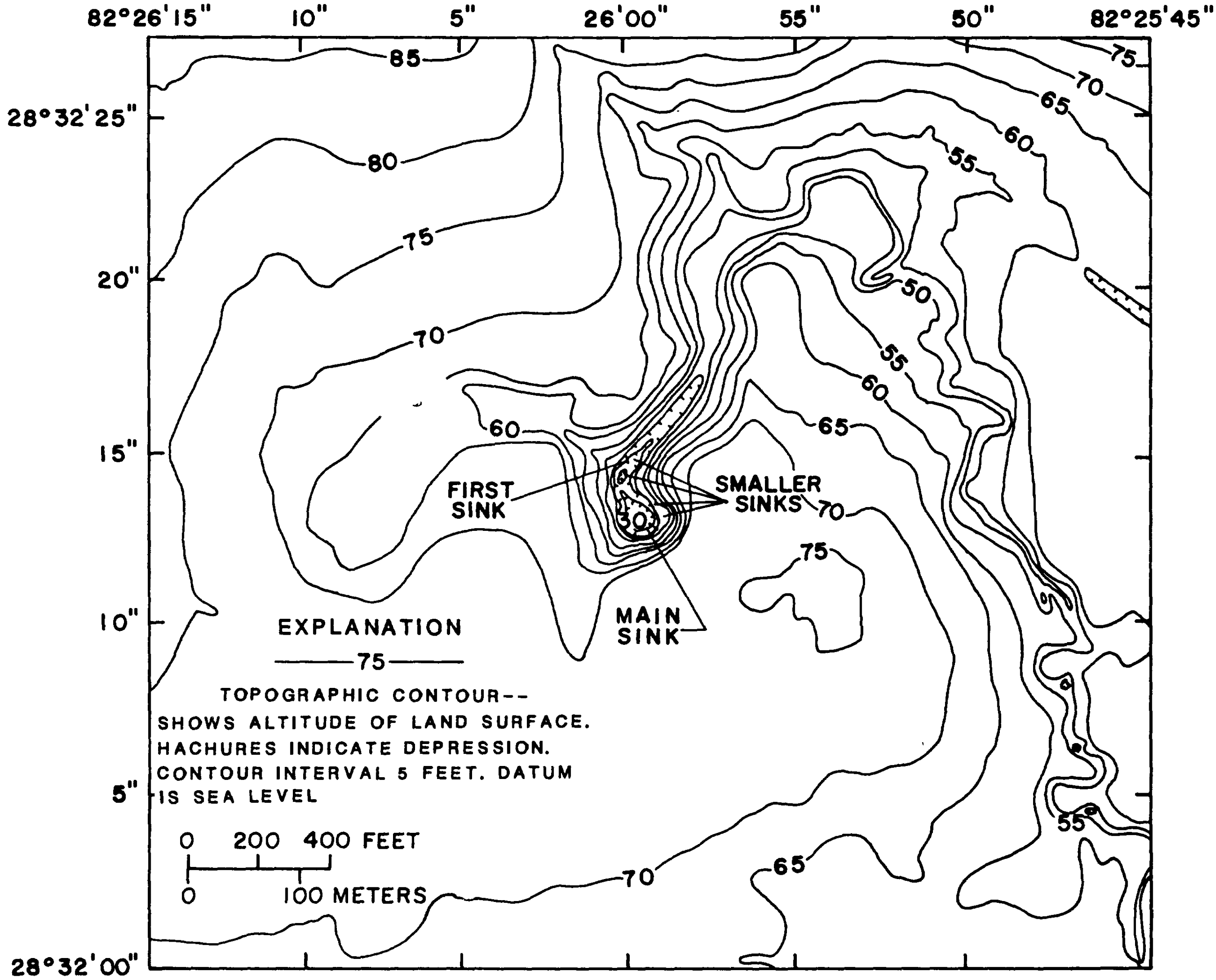

Figure 34.--Topography and location of sinkholes in the Peck Sink area.

and west sides. The eastern wall rises to a terrace at an altitude of about 55 feet above sea level where two smaller sinkholes are located. The stream channel enters the sink from the north. The deepest observed point in the main sink is about 12 feet above sea level, measured on the south side of the sink.

In the sink area, the top of the Suwannee Limestone occurs at about 10 to 15 feet above sea level. The Suwannee Limestone marks the top of the Upper Floridan aquifer in the Peck Sink basin. Drillers' logs for wells throughout the basin indicate that the top of the limestone is an unconformable erosional surface that is between 60 feet below and 120 feet above sea level (fig. 35).

A fairly continuous clay layer overlies the limestone and ranges from 20 to 130 feet thick (fig. 36). The clay outcrops, or is very near land surface, in some parts of the basin, whereas in other parts, it lies at depths greater than 50 feet. Throughout most of the basin, however, the depth to clay averages less than 20 feet. In this basin, the top of the clay lies between 60 feet above sea level at Peck Sink and 220 feet above sea level on the Brooksville Ridge (fig. 37).

Drainage, Stage, and Streamflow

Although the basin is devoid of perennial streams, drainage is fairly well developed. Many small stream channels and ditches converge and eventually flow into one main channel that leads to Peck Sink. There are many small shallow depressions in the basin that collect and retain surface runoff and slowly release it to the ground-water system. During periods of heavy rainfall, most of these depressions fill and overflow to the streams. Most of the stream channels draining the northern part of the basin lead to Horse Lake and Bonnet Pond. Bonnet Pond receives most of the stormwater runoff from that part of the city of Brooksville that lies in the basin. During wet periods, these surface-water bodies overflow to the main channel that leads to Peck Sink. The sinkhole complex drains an area of 16.2 mi^2.

There are two areas in the basin that do not contribute surface-water inflow to Peck Sink (fig. 33). The first is an area of about 0.25 mi^2 within the Brooksville city limits. Drainage has been modified to channel stormwater runoff into an old limerock mine. The second area is in the northwest part of the basin where a small sinkhole drains an area of approximately 0.5 mi^2 in much the same manner as Peck Sink (Southwest Florida Water Management District, 1979).

Many of the stream channels, including the main channel, are steep sided and undercut, which indicates high velocity streamflows. During the study period, a number of flow velocities in excess of 2 ft/s were measured in the main channel. Low infiltration rates and stream channels with relatively steep gradients (more than 170 feet in 3 miles from the Brooksville Ridge to the base of the sink) account for the rapid movement of stormwater to the sink area. During the study period, increases in flow rates and water levels in the sinks were observed less than 1 hour after storms. On July 14, 1985, a storm produced 3 inches of rain in less than an hour in Brooksville. Result-

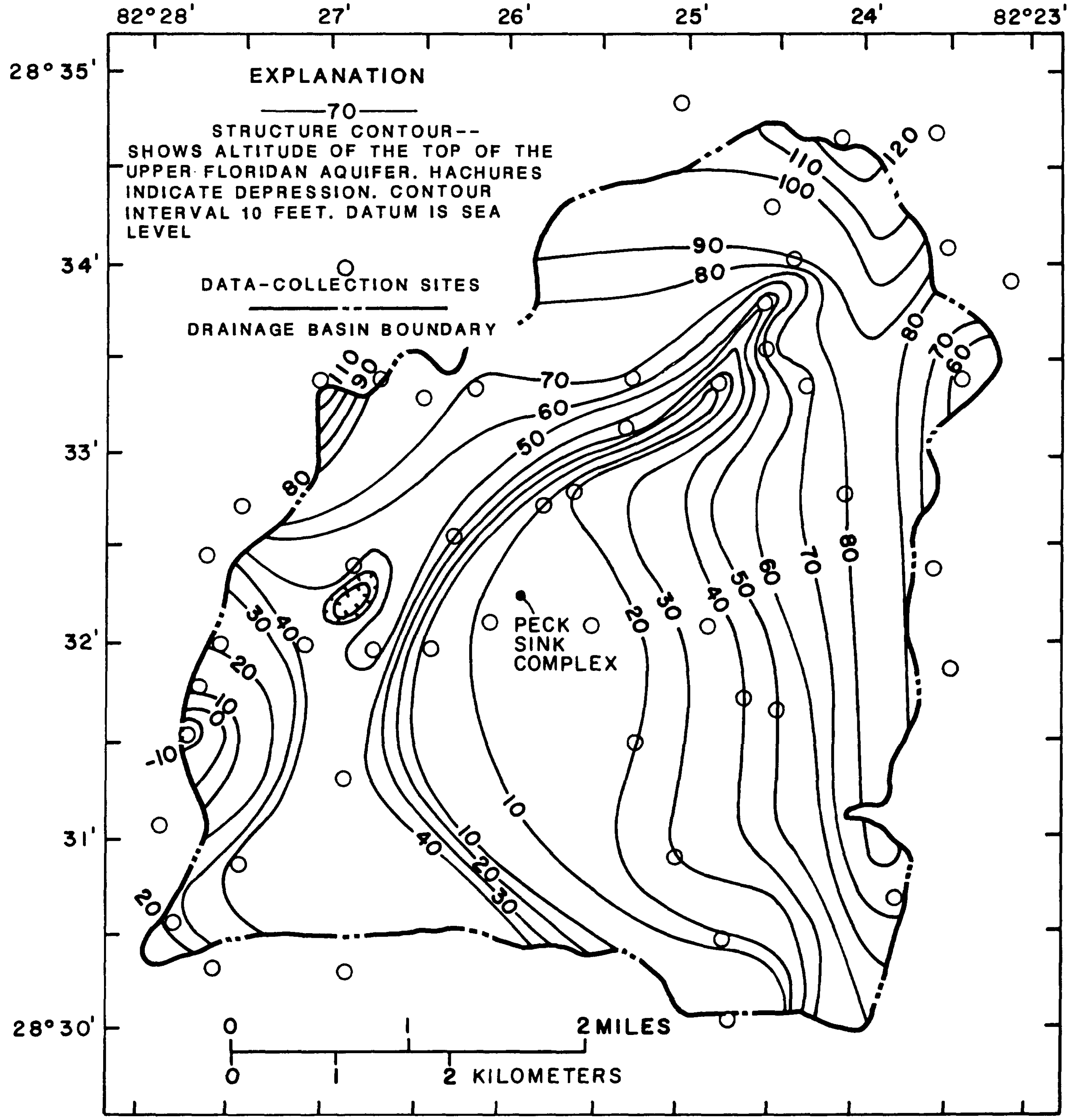

Figure 35.--Top of the Upper Floridan aquifer in the Peck Sink drainage basin.

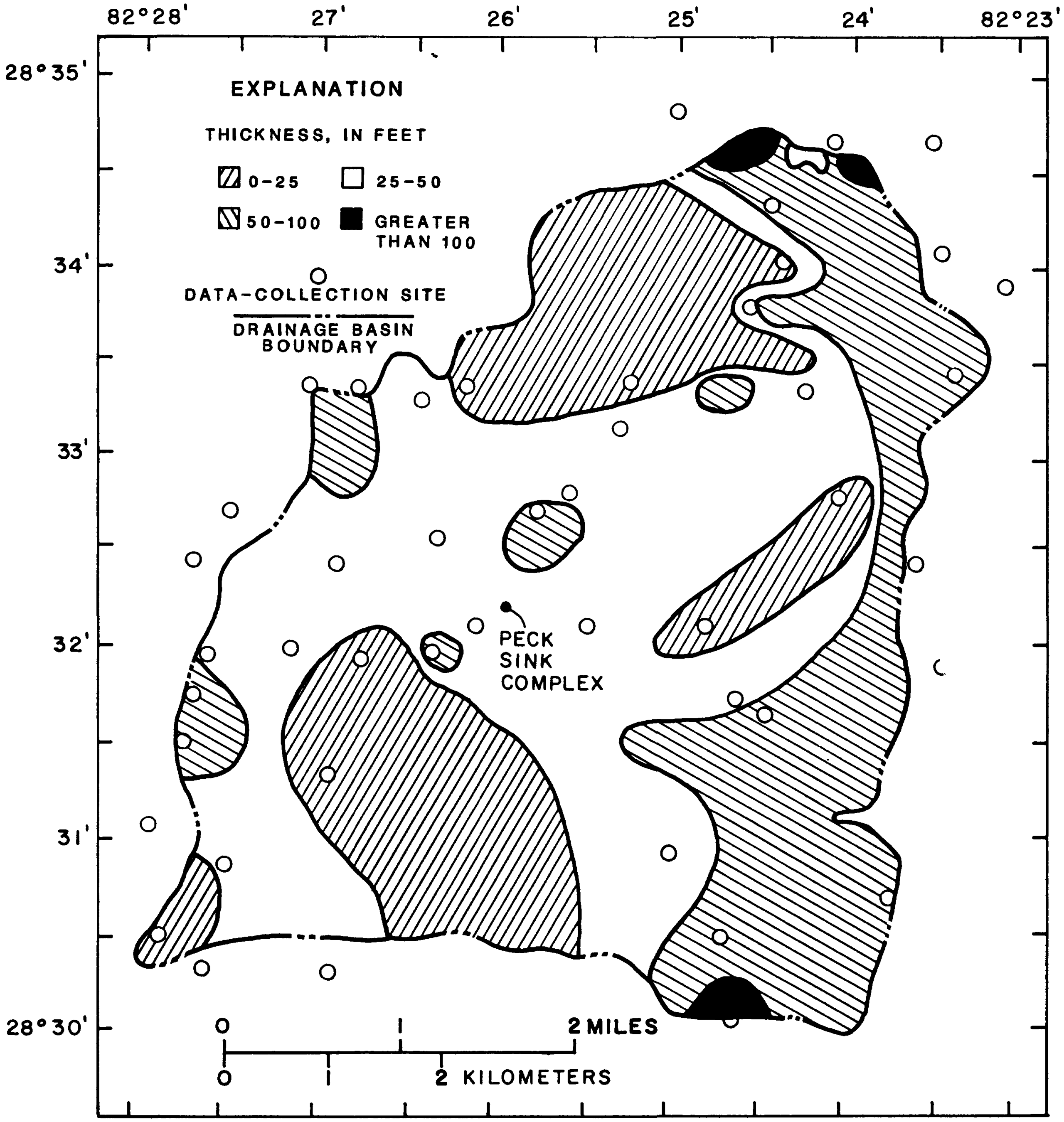

Figure 36.--Generalized thickness of the upper confining unit overlying the Upper Floridan aquifer in the Peck Sink drainage basin.

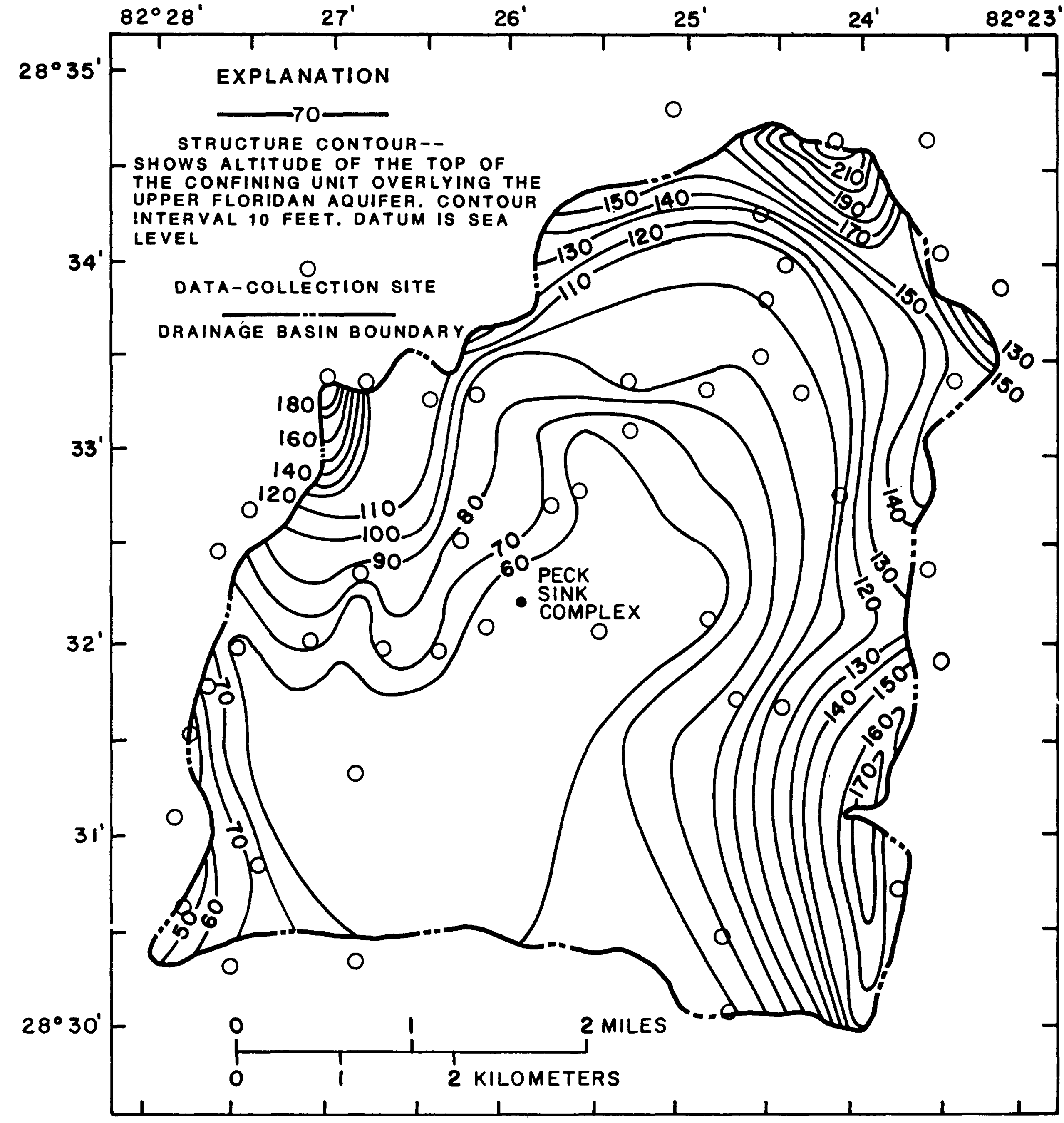

Figure 37.--Top of the upper confining unit that overlies the Upper Floridan aquifer in the Peck Sink drainage basin.

ing streamflows exceeded the recharge capacity of the sinks and caused water levels to rise over 30 feet (to approximately 60 feet above sea level) in less than 3 hours (Colonel Gibson, property owner, oral commun., 1985). Similar storms occurred between July and September 1985. Streamflows observed in the main channel from mid-June to late September 1985 ranged from about 2 to 44 ft^3/s (table 7).

The recharge capacity of the first sink was determined by the difference between inflow to the sink and outflow to the main sink. On three occasions, recharge averaged 4 ft^3/s. On June 14, 1985, an inflow to the main sink of 37.9 ft^3/s produced a 6.8-foot water-level rise (table 8), indicating that, under existing conditions, the recharge capacity of this sink was about 6 ft^3/s (2,700 gal/min) per foot of rise in the water level of the sink. The recharge capacity of the sinks under flood conditions could not be measured directly and was estimated by calculating the change in volume of flood water over a period of time and measuring inflow to the system at a point upstream from the flooded area. Over a 44-hour period during and following Hurricane Elena, the volume changed by 105 Mgal (14 million ft^3). Assuming little infiltration through surficial deposits or karst features and evaporation losses of 3 Mgal (Farnsworth and Thompson, 1982), approximately 100 Mgal (13 million ft^3) would have entered the sinks. During this time period, an average inflow of 30 ft^3/s was occurring to the flood area. Under these conditions, as much as 110 ft^3/s (49,300 gal/min) recharged the Upper Floridan aquifer through Peck Sink. As much as 1,100 Mgal (143 million ft^3) of water recharged the aquifer from June to October 1985.

Table 7.--Miscellaneous discharge measurements and recharge rates to the Upper Floridan aquifer at the Peck Sink complex, 1985

[All values are in cubic feet per second]

Date	Discharge at Wiscon Road	Total discharge from Horse Lake and Bonnet Pond	Recharge at the first sink	Recharge at the main sink
6-13-85	3.2	--	2.3	0.0
6-14-85	43.2	--	5.5	37.9
7-17-85	--	--	4.3	0.0
8-08-85	8.2	--	4.2	4.0
8-28-85	10.2	--	2.7	7.5
1/ 9-02-85	--	38.5	--	--
1/ 9-04-85	--	20.8	--	--
1/ 9-06-85	--	37.8	--	--
9-19-85	--	--	2.4	0.0

1/ Water was backed up in the sink complex and across Wiscon Road from August 31 to September 9, 1985, as a result of rainfall associated with Hurricane Elena.

Table 8.--Miscellaneous stage and water-level measurements in the vicinity of Peck Sink, 1985

[Values are in feet above sea level]

Date	Peck Sink	Gibson well	Goode well	McKintyre well
1-15-85	32.74	32.68	33.75	--
3-01-85	31.63	31.38	32.09	--
4-04-85	30.51	30.28	30.94	--
4-11-85	30.15	30.09	30.74	36.99
5-09-85	29.35	29.38	29.91	36.66
5-30-85	28.67	28.53	29.16	36.26
6-13-85	1/28.55	28.39	28.93	35.29
6-14-85	1/35.36	28.50	29.11	35.27
6-17-85	29.37	29.43	29.81	35.28
7-02-85	29.30	29.05	29.47	35.12
7-17-85	31.60	31.08	31.59	35.55
8-05-85	34.23	34.38	33.99	37.91
8-28-85	37.43	37.68	37.96	39.91
9-02-85	2/67.60	55.38	46.41	41.62
9-04-85	2/65.90	56.98	49.03	41.92
9-06-85	2/67.50	59.08	52.48	42.84
9-19-85	39.90	39.23	40.54	42.71
10-02-85	37.93	38.08	38.44	41.86

1/Measured while creek was discharging 37.9 ft^3/s into the sink.
2/Water level is estimated from height water rose over Wiscon Road.

Ground Water

Although there appears to be a fairly continuous clay layer in the basin, a continuous surficial aquifer system does not exist. The karst surface features and drillers' logs for wells in the area indicate that the confining bed is breached in many places. In 1982, the U.S. Geological Survey, during a previous study, drilled a number of wells into the surficial deposits in Hernando County. Some of these wells are near the Peck Sink drainage basin and no water table was observed. A few wells contained water only during wet periods (J.D. Fretwell, U.S. Geological Survey, oral commun., 1986).

Fluctuation in the potentiometric surface of the Upper Floridan aquifer in the Peck Sink drainage basin is variable. In the eastern part of the basin, the potentiometric surface was 38 feet above sea level in May 1985 and 39 feet above sea level in September 1985 (Barr, 1985a; 1985b). Water levels in the main sink and in nearby wells (less than 0.25 mile away) showed fluctuations of nearly 10 feet, averaging about 28 feet above sea level in May 1985 and about 37 feet above sea level in September 1985. Water levels in the McKintyre well, about 1 mile east of the main sink, ranged from 36 feet above sea level in May 1985 to 42 feet above sea level in September 1985. Figure 38 shows water-level changes in Peck Sink and nearby wells, including the effects of inflow to the sink that resulted from Hurricane Elena. The general direction of ground-water flow in the basin is to the northwest (fig. 39).

The closed-contour method (Lohman, 1972, p. 47) for calculating transmissivities when two or more closed contours surround a point of discharge-recharge was used to estimate transmissivity in the drainage basin (fig. 40). Calculated surface-water recharge to the aquifer from Peck Sink on September 2, 1985, was about 110 ft^3/s ($9.5x10^6$ ft^3/d).

The following equation was used:

$$T = \frac{2Q}{(L_1+L_2)\ \Delta h/\Delta r}$$

where L_1 = the perimeter of the outer (55-foot) contour, in feet;

L_2 = the perimeter of the inner (60-foot) contour, in feet;

Δh = head difference between contours, in feet; and

Δr = the average difference between contours, in feet.

Thus,

$$T = \frac{2\ (9.5x10^6\ ft^3/d)}{(5{,}118\ ft + 9{,}020\ ft)(5/552)} = 1.5x10^5\ ft^2/d.$$

Using a digital model, Ryder (1982) simulated transmissivity values for the area that were generally of the same magnitude, ranging from $2.5x10^5$ to $1.0x10^6$ ft^2/d.

Water Quality

Two sets of water-quality samples were collected from Peck Sink and three nearby wells that penetrate the Upper Floridan aquifer. All sites were sampled in January 1985. The main sink and the Goode and Graddy wells were

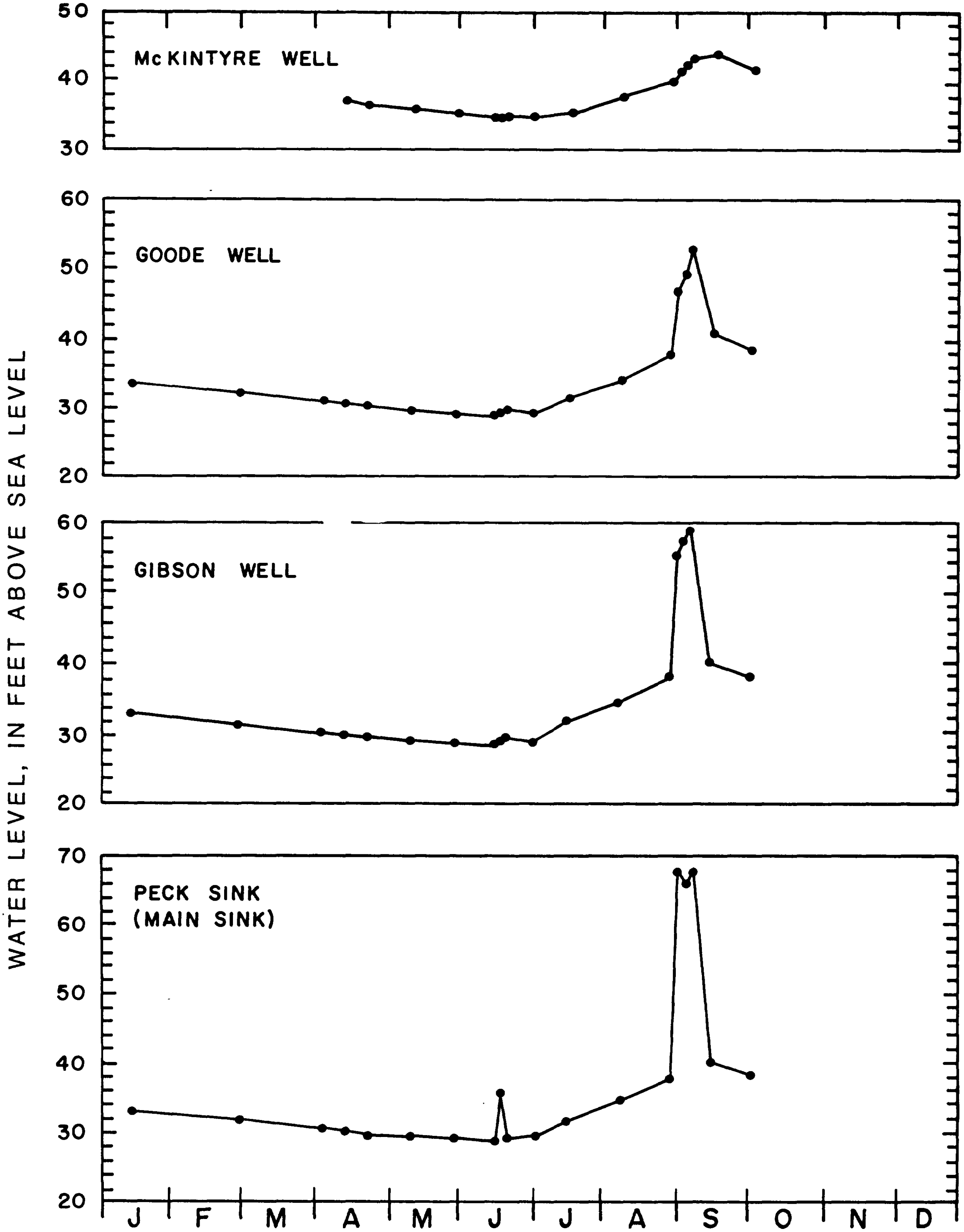

Figure 38.--Water levels in Peck Sink and the Gibson, Goode, and McKintyre wells, January through October 1985. (Water-level data are given in table 8.)

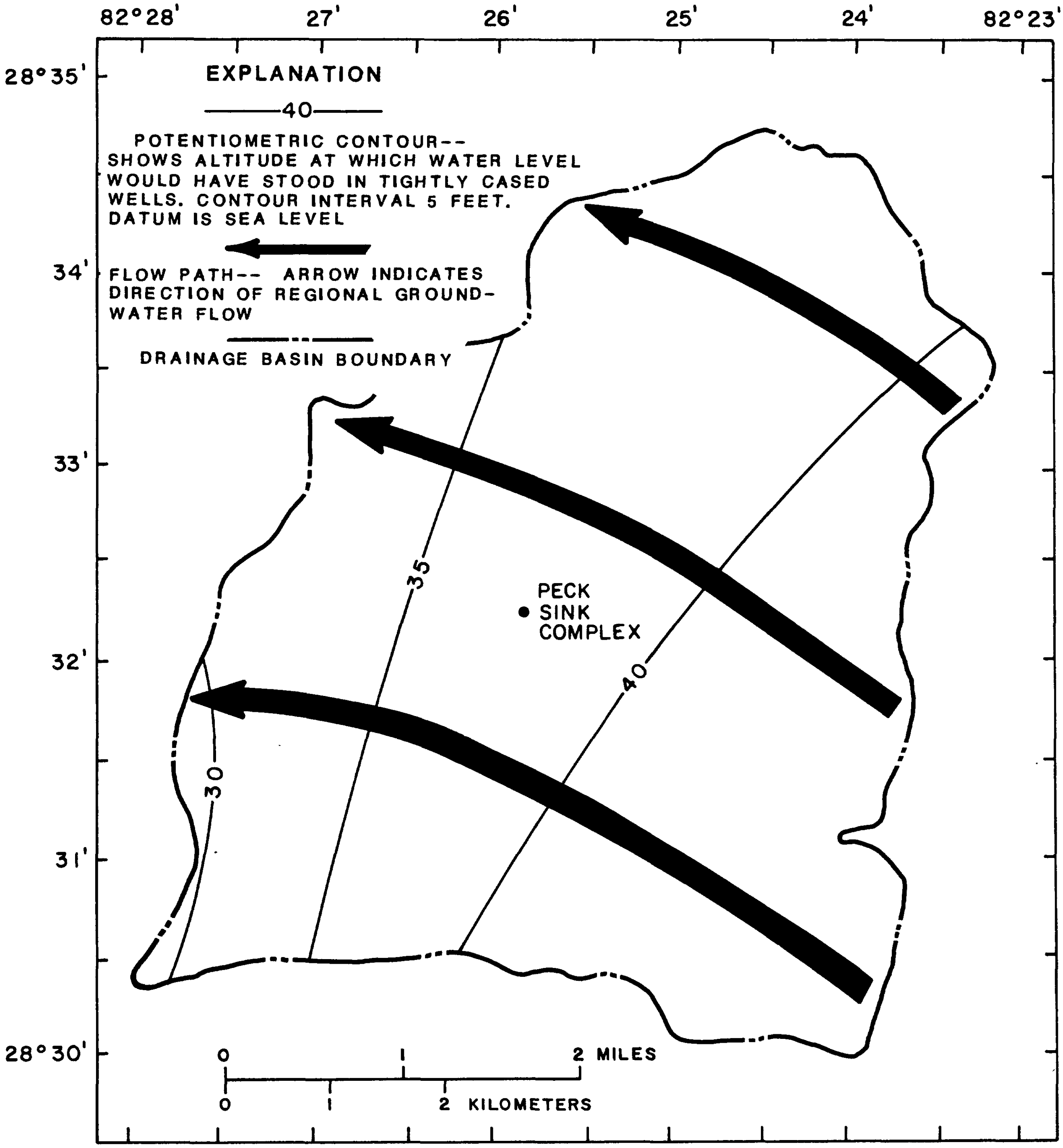

Figure 39.--Potentiometric surface and regional direction of flow in the Upper Floridan aquifer in the Peck Sink drainage basin, September 1985. (Modified from Barr, 1985b.)

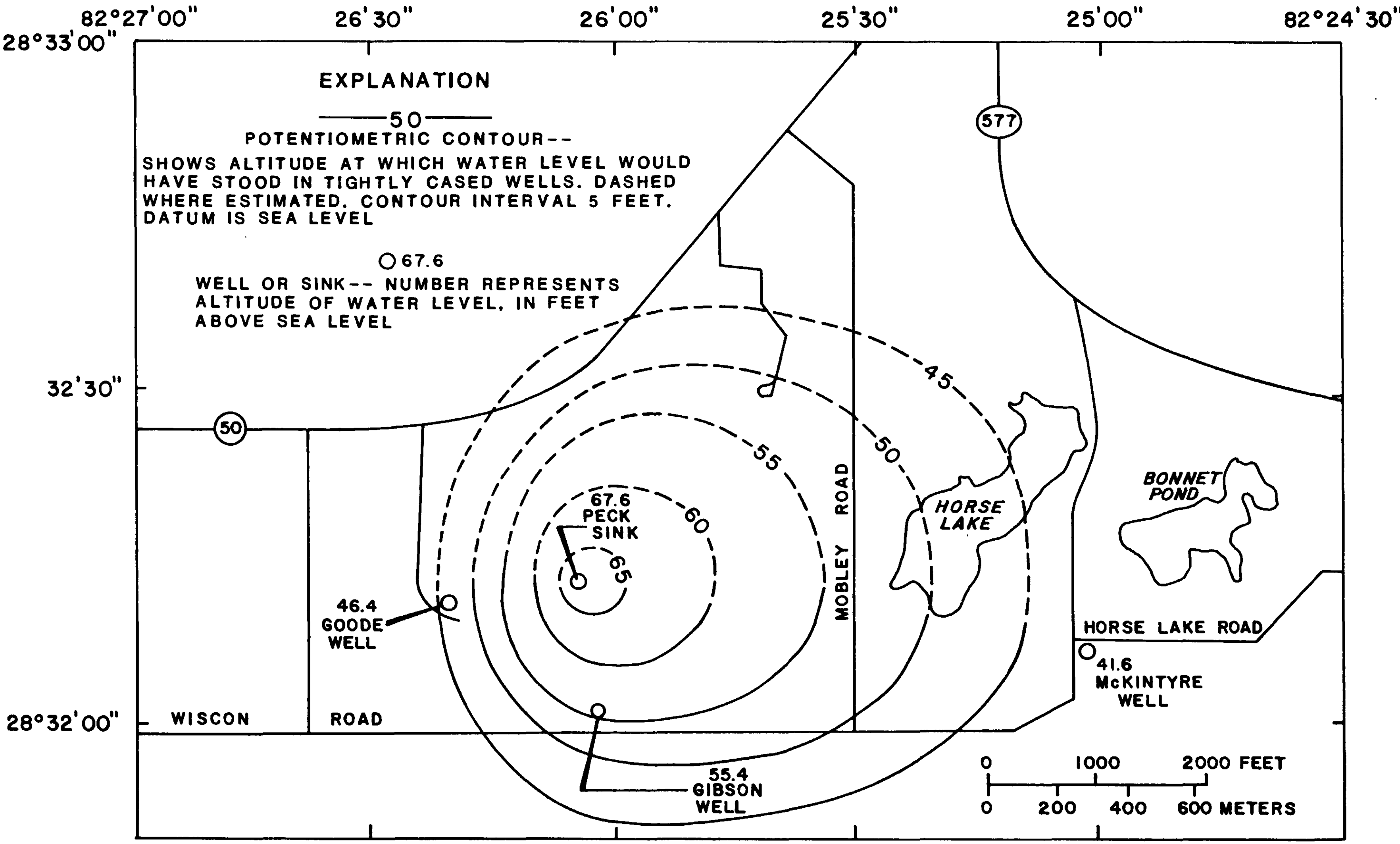

Figure 40.--Potentiometric surface of the Upper Floridan aquifer in the vicinity of Peck Sink, September 2, 1985.

sampled again to coincide with a major storm in June 1985. The Gibson well was sampled in September 1985 after this well showed more response to inflow to Peck Sink than anticipated. The first set of samples was analyzed for trace elements, nutrients, and coliform bacteria. Additional analyses for organic substances (including EDB) and viruses were conducted on the second set of samples. Field determinations for specific conductance and pH were made for all samples.

Results of the chemical analyses are summarized in table 9. Herbicides and pesticides (including EDB) were below detectable levels in all samples. With the exception of zinc, only small amounts of trace elements were detected in the samples.

All samples collected from the wells contained high amounts of zinc, probably derived from galvanized casings and storage tanks. The sample collected from the main sink on June 14, 1985, contained levels of zinc that exceeded the Florida Department of Environmental Regulation (1985) standards for drinking water. The major part of the stormwater runoff entering the sink at this time was from that part of the city of Brooksville that lies within the drainage basin.

Bacteria counts were much higher in the samples collected at Peck Sink during a major storm in June 1985 than at low water (January 1985). The June sample contained coliform bacteria counts higher than the maximum levels set by the Florida Department of Environmental Regulation (1985) for class I (drinking) and class III (recreational) surface waters. The fecal coliform to fecal streptococci (fc:fs) ratio, however, was higher in the sample collected at low water than in the sample collected during the storm. The fc:fs ratio in January was 1.7, whereas in June, it was 0.65. The higher ratio may suggest some mixing of human domestic waste with other sources of pollution. The 0.65 fc:fs ratio suggests that the source of bacteria is from warm-blooded animals other than man. The primary source of human domestic wastes in the basin is from septic tanks. Coliform bacteria were not detected in samples collected from the wells, and viral contamination was not detected in samples collected during the study period. The viral sample was collected after the flood waters that resulted from Hurricane Elena had receded to normal levels.

Samples collected from the Graddy and Goode wells following the June 14 storm contained the same silty, clayey material that was present in the sample collected from the main sink during the storm. Values for specific conductance, pH, alkalinity, nutrients, and total organic carbon were very similar. The water in the sink and the wells appears to be the same, which indicates a connection between the wells and the sink. The degree of connection or travel time between the sink and the wells could not be determined because water entering the sink did not contain specific chemical constituents in high enough concentrations to use as tracers.

BLUE SINK

Blue Sink is in the northeast part of Hernando County, approximately 1 mile east of U.S. Highway 41 and 4.9 miles northeast of Brooksville

Table 9.--Water-quality data for the Peck Sink complex

[Concentrations are in milligrams per liter, except as noted. µS/cm--microsiemens per centimeter, µg/L--micrograms per liter, col/100 mL--colonies per 100 milliliters]

Water-quality parameter	Peck Sink 1-15-85	Graddy well 1-15-85	Goode well 1-15-85	Gibson well 1-15-85
Temperature (°C)	19.0	19.0	20.0	18.0
Specific conductance (µS/cm)	430	450	400	348
pH (units)	7.6	7.1	7.5	7.6
Alkalinity (as $CaSO_3$)	210	--	216	165
Color (platinum-cobalt units)	5	--	--	5
Nitrogen (as NO_2+NO_3)	0.23	0.01	0.02	0.07
Nitrogen, ammonia (as N)	--	--	--	--
Phosphorus (as P)	--	--	--	--
Total organic carbon	--	--	--	--
Chloride (as Cl)	1	7	8	4
Sulfate (as SO_4)	4	7	6	4
Potassium (as K)	2.0	.3	.3	.3
Sodium (as Na)	4.2	4.0	3.9	3.5
Arsenic (µg/L as As)	<1	<1	<1	<1
Cadmium (µg/L as Cd)	--	--	--	--
Chromium (µg/L as Cr)	<10	<10	<10	<10
Copper (µg/L as Cu)	--	--	--	--
Iron (µg/L as Fe)	50	510	44	8
Lead (µg/L as Pb)	<10	<10	<10	<10
Zinc (µg/L as Zn)	6	420	550	670
Mercury (µg/L as Hg)	--	--	--	--
Total coliform (col/100 mL)	60	<1	<1	<1
Fecal coliform (col/100 mL)	17	<1	<1	<1
Fecal strep (col/100 mL)	10	<1	<1	<1
Fc:fs ratio	1.70	--	--	--

Table 9.--Water-quality data for the Peck Sink complex--Continued

Water-quality parameter	Peck Sink 1-15-85	Graddy well 1-15-85	Goode well 1-15-85	Gibson well 1-15-85
Lindane (µg/L)	--	--	--	--
Napthalene, polychlorinated (µg/L)	--	--	--	--
Aldrin (µg/L)	--	--	--	--
Chlordane (µg/L)	--	--	--	--
EDB (µg/L)	--	--	--	--
DDE (µg/L)	--	--	--	--
DDT (µg/L)	--	--	--	--
Dieldrin (µg/L)	--	--	--	--
Endosulfan (µg/L)	--	--	--	--
Endrin (µg/L)	--	--	--	--
Toxaphene (µg/L)	--	--	--	--
Heptachlor (µg/L)	--	--	--	--
PCB (µg/L)	--	--	--	--
Heptachlorepoxide (µg/L)	--	--	--	--
Methoxychlor (µg/L)	--	--	--	--
Mirex (µg/L)	--	--	--	--
Silvex (µg/L)	--	--	--	--
2,4-D (µg/L)	--	--	--	--
2,4,5-D (µg/L)	--	--	--	--
2,4-DP (µg/L)	--	--	--	--
Solids, residue at 180 ^{0}C	238	254	242	204
Streamflow, instantaneous (ft^3/s)	--	--	--	--

Table 9.--Water-quality data for the Peck Sink complex--Continued

Water-quality parameter	Peck Sink 6-14-85	Graddy well 6-17-85	Goode well 6-17-85	Gibson well 9-06-85
Temperature (°C)	24.5	24.0	24.0	24.5
Specific conductance (µS/cm)	320	433	413	322
pH (units)	6.8	7.6	--	7.4
Alkalinity (as $CaSO_3$)	--	224	--	--
Color (platinum-cobalt units)	--	--	--	--
Nitrogen (as NO_2+NO_3)	.14	.02	.04	.14
Nitrogen, ammonia (as N)	.04	.02	.07	.02
Phosphorus (as P)	.23	.08	.03	.03
Total organic carbon	10.0	3.5	2.5	7.5
Chloride (as Cl)	5	11	--	4
Sulfate (SO_4)	3	7	5	3
Potassium (as K)	1.6	.2	.2	--
Sodium (as Na)	2.7	3.3	--	3.5
Arsenic (µg/L as As)	<1	<1	<1	<1
Cadmium (µg/L as Cd)	10	10	<10	20
Chromium (µg/L as Cr)	20	10	10	10
Copper (µg/L as Cu)	<10	<10	10	20
Iron (µg/L as Fe)	--	--	--	--
Lead (µg/L as Pb)	<100	<100	<100	<100
Zinc (µg/L as Zn)	40	370	170	340
Mercury (µg/L as Hg)	.1	<.1	<.1	<.1
Total coliform (col/100 mL)	19,700	<1	<1	<1
Fecal coliform (col/100 mL)	5,500	<1	<1	<1
Fecal strep (col/100 mL)	8,500	<1	<1	<1
Fc:fs ratio	.65	--	--	--

Table 9.--Water-quality data for the Peck Sink complex--Continued

Water-quality parameter	Peck Sink 6-14-85	Graddy well 6-17-85	Goode well 6-17-85	Gibson well 9-06-85
Lindane (µg/L)	<0.01	<0.01	<0.01	<0.10
Napthalene, polychlorinated (µg/L)	<.1	<.1	<.1	<.1
Aldrin (µg/L)	<.01	<.01	<.01	<.01
Chlordane (µg/L)	<.1	<.1	<.1	<.1
EDB (µg/L)	<.02	<.02	<.02	<3.0
DDE (µg/L)	<.01	<.01	<.01	<.01
DDT (µg/L)	<.01	<.01	<.01	<.01
Dieldrin (µg/L)	<.01	<.01	<.01	<.01
Endosulfan (µg/L)	<.01	<.01	<.01	<.01
Endrin (µg/L)	<.01	<.01	<.01	<.01
Toxaphene (µg/L)	<1	<1	<1	<1
Heptachlor (µg/L)	<.01	<.01	<.01	<.01
PCB (µg/L)	<.1	<.1	<.1	<.1
Heptachlorepoxide (µg/L)	<.01	<.01	<.01	<.01
Methoxychlor (µg/L)	<.01	<.01	<.01	<.01
Mirex (µg/L)	<.01	<.01	<.01	<.01
Silvex (µg/L)	<.01	<.01	<.01	<.01
2,4-D (µg/L)	<.01	<.01	<.01	<.01
2,4,5-D (µg/L)	<.01	<.01	<.01	<.01
2,4-DP (µg/L)	<.01	<.01	<.01	<.01
Solids, residue at 180°C	--	256	242	191
Streamflow, instantaneous (ft^3/s)	38.94	--	--	--

(figs. 32 and 41). Blue Sink is in an area of rolling hills near the top of the Brooksville Ridge. Land-surface altitudes in the basin range from more than 200 feet above sea level on some of the peaks to 35 feet above sea level at the base of the sink (fig. 41).

A small part of the land area in the Blue Sink drainage basin lies within the city limits of Brooksville. Some small areas of moderate density residential and commercial development are scattered throughout the basin but are generally concentrated near Brooksville. Agricultural and forested lands with rural populations predominate throughout the remainder of the basin. The basin contains major transportation routes; some surface-water impoundment sites used in the storage, treatment, and disposal of raw or partially treated sewage; and private septic tanks, the primary means of sewage disposal in the basin. A large commercial dairy is also located in the basin. All of these activities represent some degree of potential for pollution of the Upper Floridan aquifer.

All ground water withdrawn in the basin is from the Upper Floridan aquifer. There are three public-supply wells in the basin (in Brooksville) that withdraw approximately 0.6 Mgal. This water is used primarily in the immediate Brooksville area (Stieglitz, 1985). Most water pumped in the basin is rural self-supplied.

Hydrogeologic Setting

The ponded area of Blue Sink is about 300 feet long, 150 feet wide on the south end, and 100 feet wide on the north end. The actual sink is at the south end and has a diameter of 150 feet. A pond, approximately 350 feet long and 200 feet wide, is located immediately to the north and is separated from the sink by a small concrete dam. The dam maintains water levels in the pond when the water level in the sink is less than 40 feet above sea level. Most of the sink is surrounded by steep, very sandy side walls. The south wall is nearly vertical. A well-developed stream channel enters the sink area from the west and empties into the pond (fig. 42).

During wet periods, the capacity of the sink to recharge water to the aquifer can be exceeded, causing flooding of adjacent low-lying areas. This occurred in September 1985 during Hurricane Elena. Backwater is retained in the undeveloped areas adjacent to the sink forming temporary retention basins. The maximum recharge capacity of the sink was not determined during the study.

There appears to be a fairly continuous clay layer throughout the drainage basin. The thickness is variable, ranging from over 100 feet thick on some of the higher hills to less than 25 feet thick at other points (fig. 43). In the immediate sink area, the clay layer is less than 25 feet thick and is about 60 feet below land surface. Drillers' logs indicate the presence of sand-filled depressions and breaches in the clay that are probably relict sinks.

In the Blue Sink drainage basin, the Suwannee Limestone is the first persistent limestone and represents the top of the Upper Floridan aquifer.

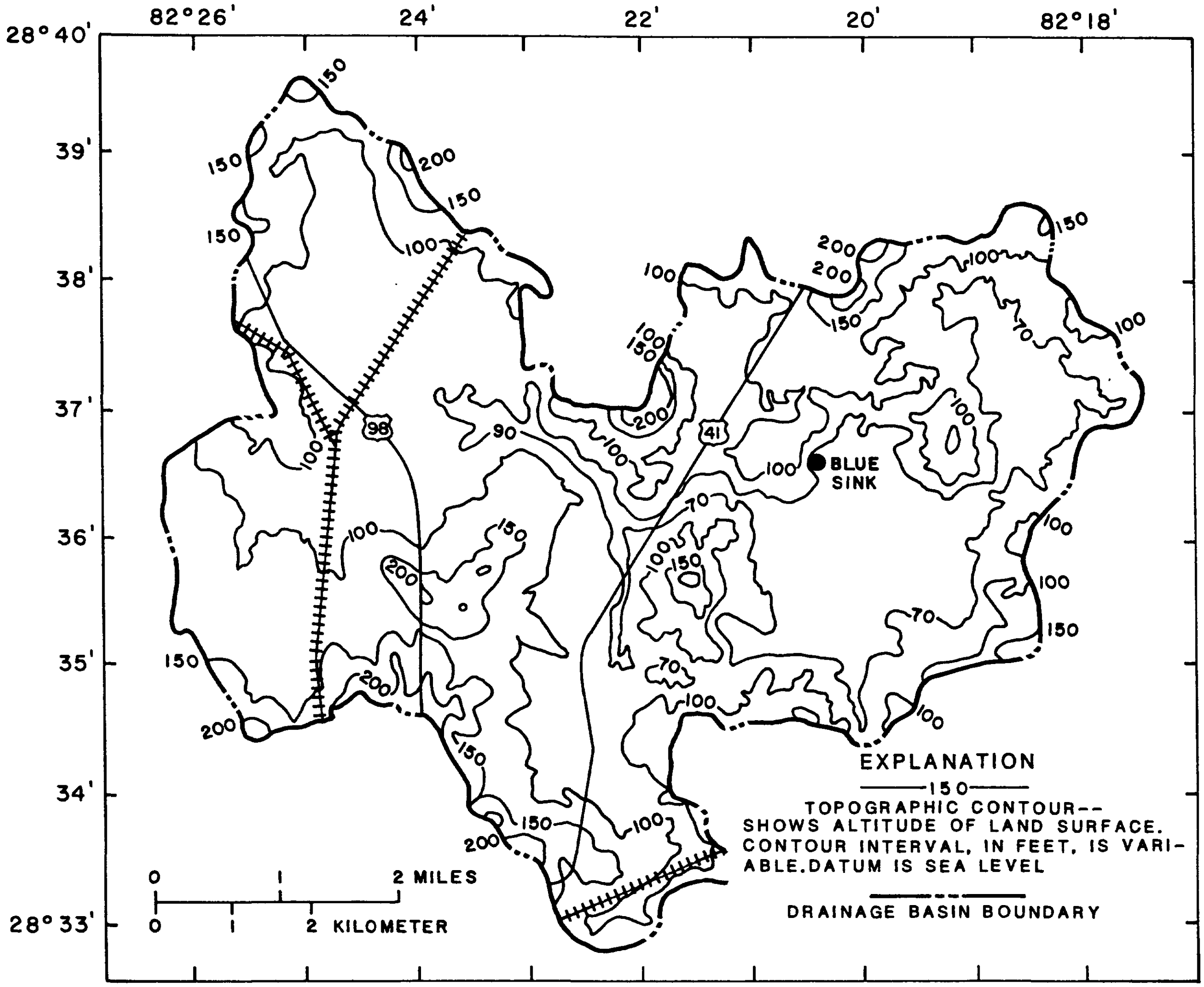

Figure 41.--Topography of the Blue Sink drainage basin and location of Blue Sink.

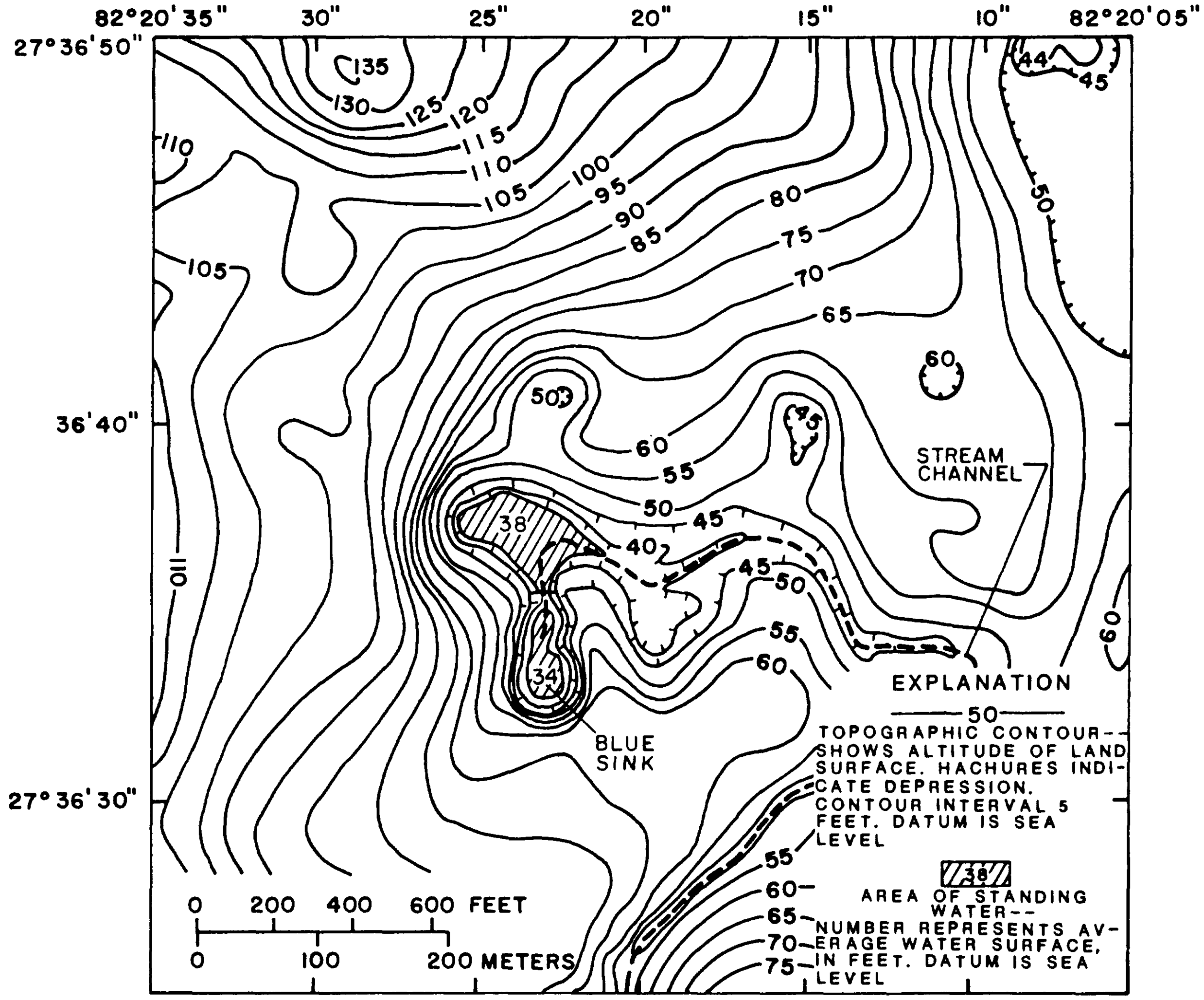

Figure 42.--Topography of the Blue Sink area and location of Blue Sink.

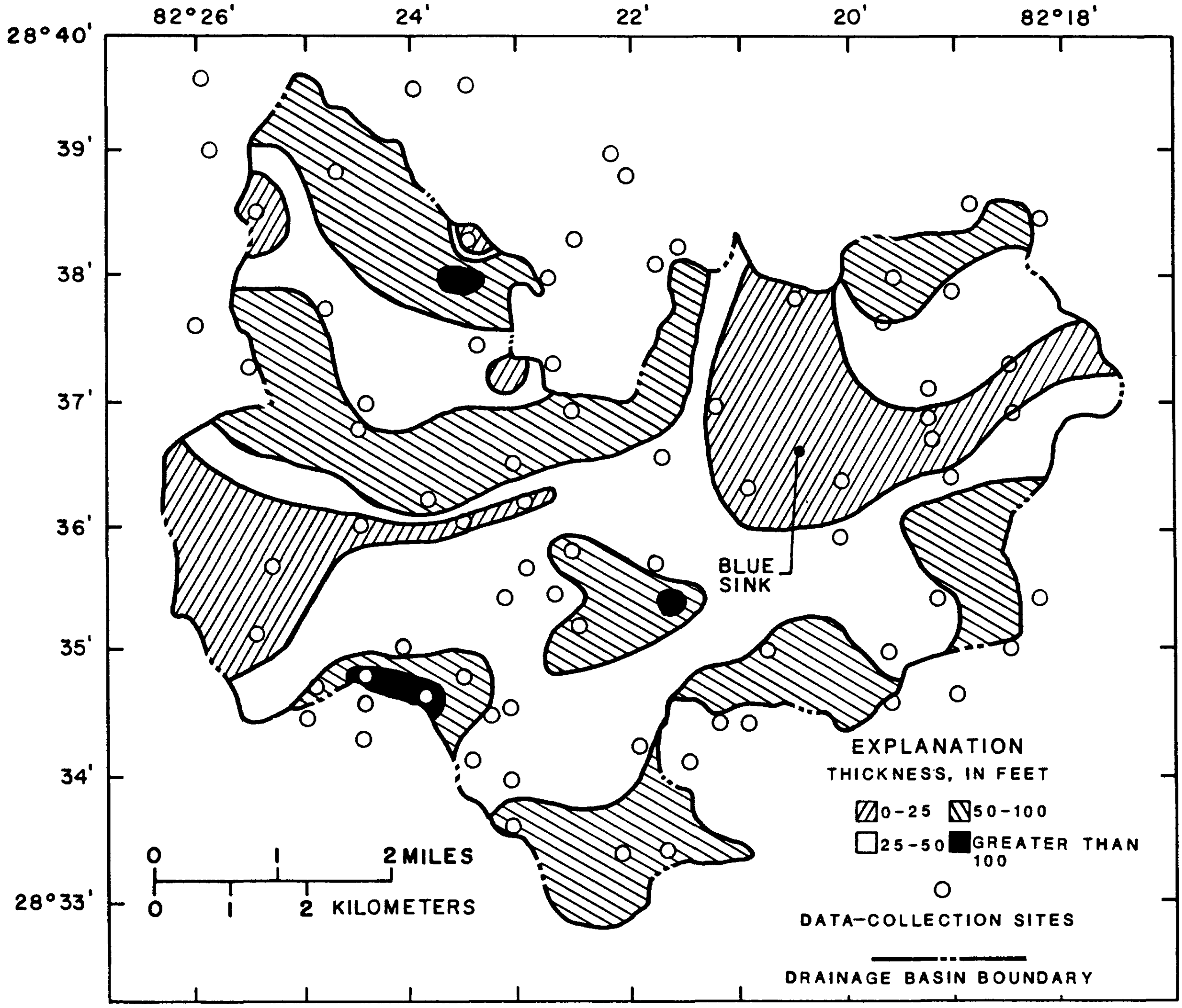

Figure 43.--Generalized thickness of the upper confining unit overlying the Upper Floridan aquifer in the Blue Sink drainage basin.

The top of the limestone ranges from 140 feet above sea level to more than 100 feet below sea level. Well drillers have noted solution cavities in the top of the limestone throughout the basin.

Drainage, Stage, and Streamflow

The basin is devoid of perennial streams, and drainage is internal. Drainage, however, is well developed. Stream channels direct stormwater runoff toward depressions in low-lying areas. During wet periods, the depressions overflow into stream channels that converge into one main channel that leads to Blue Sink. The effective area of the Blue Sink drainage basin is 36 mi^2.

Some of these streams are deep, steep sided, and undercut, which indicates high velocity streamflows. In September 1985, streamflow velocities in excess of 4 ft/s were observed in a channel approximately 1 mile upstream from the sink. High relief in the basin (fig. 41) accounts for the velocity. Flow into the sink was not observed until early August, even though rainfall had been occurring regularly since mid-June. Because the clay layer is thin and lies 60 feet below land surface in the sink area, a large part of the rainfall infiltrates directly into the surficial deposits and percolates downward to the underlying aquifer. As these deposits become sufficiently saturated and the surface depressions become full, larger amounts of rainfall are available to enter the stream channels as surface runoff.

Flows of 3.2, 19.5, and 3.0 ft^3/s entering the sink were measured and resulted in less than a 1-foot rise in water level in the sink. During Hurricane Elena, the volume of stormwater runoff exceeded the capacity of the sink, and the water level in the sink rose 16 feet. High water levels prevented accessibility to measuring sites upstream, and inflow to the sink was not measured. Water levels were reported to have dropped very rapidly after the September 3 measurement (Mrs. Bronson, property owner, oral commun., 1986).

Ground Water

During a previous study, the U.S. Geological Survey drilled a number of wells into the surficial deposits in Hernando County. Two of these wells are in the Blue Sink drainage basin. Both contained water only during the wet season (J.D. Fretwell, U.S. Geological Survey, oral commun., 1986). Drillers' logs indicate that the clay layer in the basin is breached in places. These data indicate that the surficial deposits are hydraulically connected to the limestone and allow water to quickly enter the Upper Floridan aquifer.

Between May and September 1985, the potentiometric surface of the Upper Floridan aquifer in the Blue Sink drainage basin fluctuated about 4 feet. In September, the potentiometric surface ranged from about 40 feet above sea level in the eastern part of the basin to 30 feet above sea level in the northwestern part (Barr, 1985b). The direction of flow in the Upper Floridan aquifer is from southeast to northwest (fig. 44). Except during periods of inflow to the sink, water levels in the sink closely corresponded to levels in the Bronson well, a nearby domestic supply well open to the Upper Floridan aquifer. Water levels in the well ranged from a low of 34.8 feet above sea level to a high of 41.4 feet above sea level, whereas the water level in the sink ranged from 34.8 to 54.6 feet above sea level (fig. 45).

Hydraulic characteristics of the Upper Floridan aquifer have been determined for an area just north and west of the drainage basin. Transmissivity values ranged between 9.0×10^4 and 9.4×10^5 ft^2/d (Fretwell, 1985). Using a digital model, Ryder (1982) estimated transmissivity values to be between 5×10^5 and 1×10^6 ft^2/d for an area that includes the Blue Sink drainage basin.

Water Quality

Flow to Blue Sink is intermittent. A water-quality sample was collected from the sink on August 8, 1985, during a period of flow. This sample was analyzed for trace elements, nutrients, coliform bacteria, herbicides, and pesticides (including EDB). Determinations for temperature, pH, and specific conductance were made in the field at the time the sample was collected. An additional sample was collected on September 3, 1985, by the Epidemiology Research Center and analyzed for viral content. At the time this sample was collected, the water level in the sink was at flood stage due to the passage of Hurricane Elena. Evidence of viral contamination was not detected. Results of the chemical analyses and historical data are summarized in table 10. Most constituents were within allowable or detectable limits.

Coliform bacteria counts were below the limits set by the Florida Department of Environmental Regulation (1985) for class III surface water (recreation). The fecal coliform to fecal streptococci (fc:fs) ratio was 1.9, which may suggest that water entering the sink contains some pollution from human domestic sources as well as other sources. The primary means of disposal for human domestic wastes in this basin is through septic tanks. During wet periods, septic tanks could release effluents to the streams leading to Blue Sink.

With the exception of toxaphene, all herbicides and pesticides were below detectable levels. The amount of toxaphene (table 10) exceeds the Florida Department of Environmental Regulation (1985) limits for drinking water. This pollutant probably originates from home and garden use in those residential areas around Brooksville that lie within the basin.

SUMMARY AND CONCLUSIONS

The potential for pollution of the Upper Floridan aquifer from five sinkholes and one large internally drained basin in west-central Florida was investigated during the study period (October 1984-September 1985). Land-surface altitudes at the study sites range from near sea level at Bear Sink to over 200 feet above sea level in the Peck Sink and Blue Sink drainage basins.

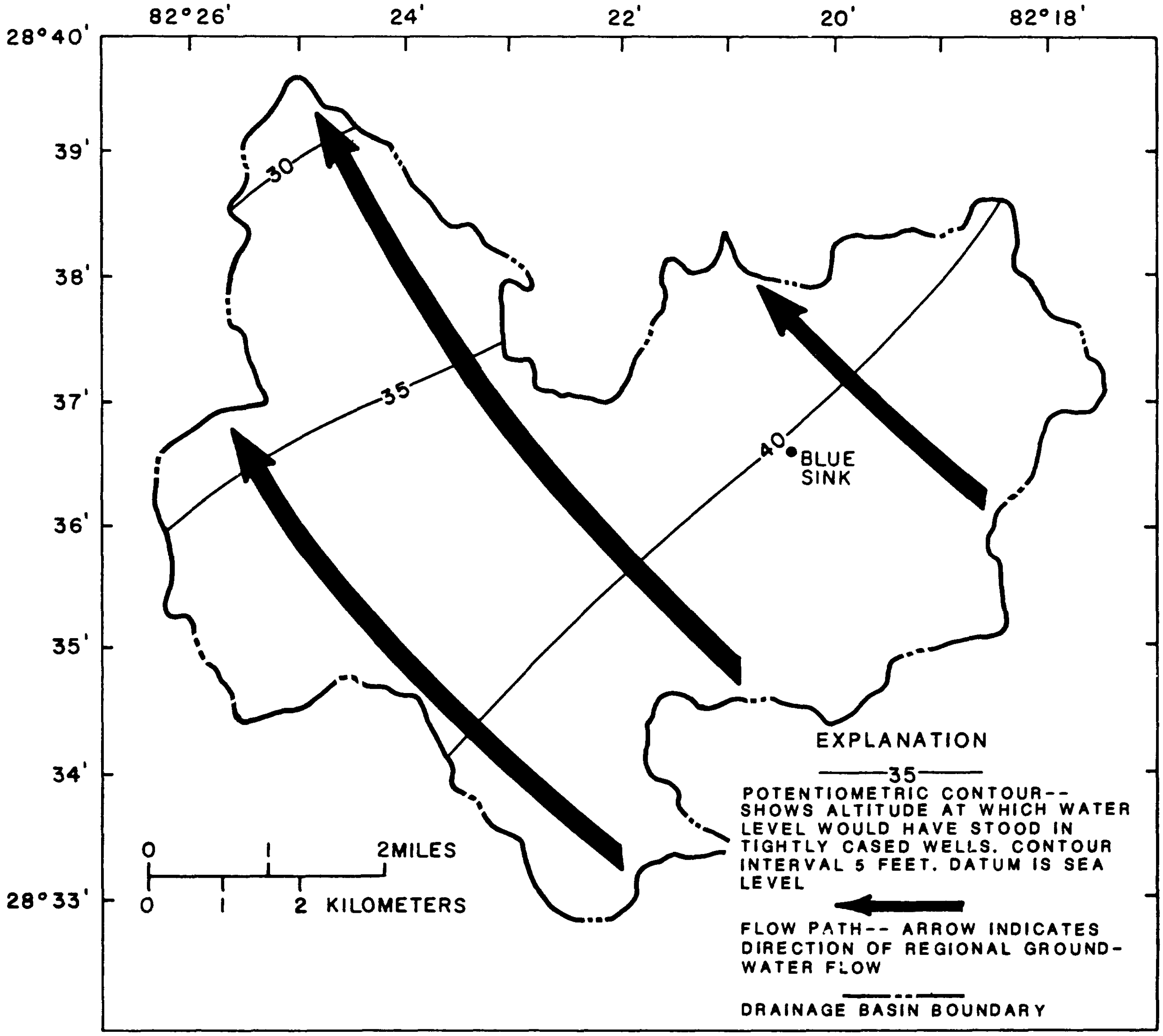

Figure 44.--Potentiometric surface and regional direction of flow in the Upper Floridan aquifer in the Blue Sink drainage basin, September 1985. (Modified from Barr, 1985b.)

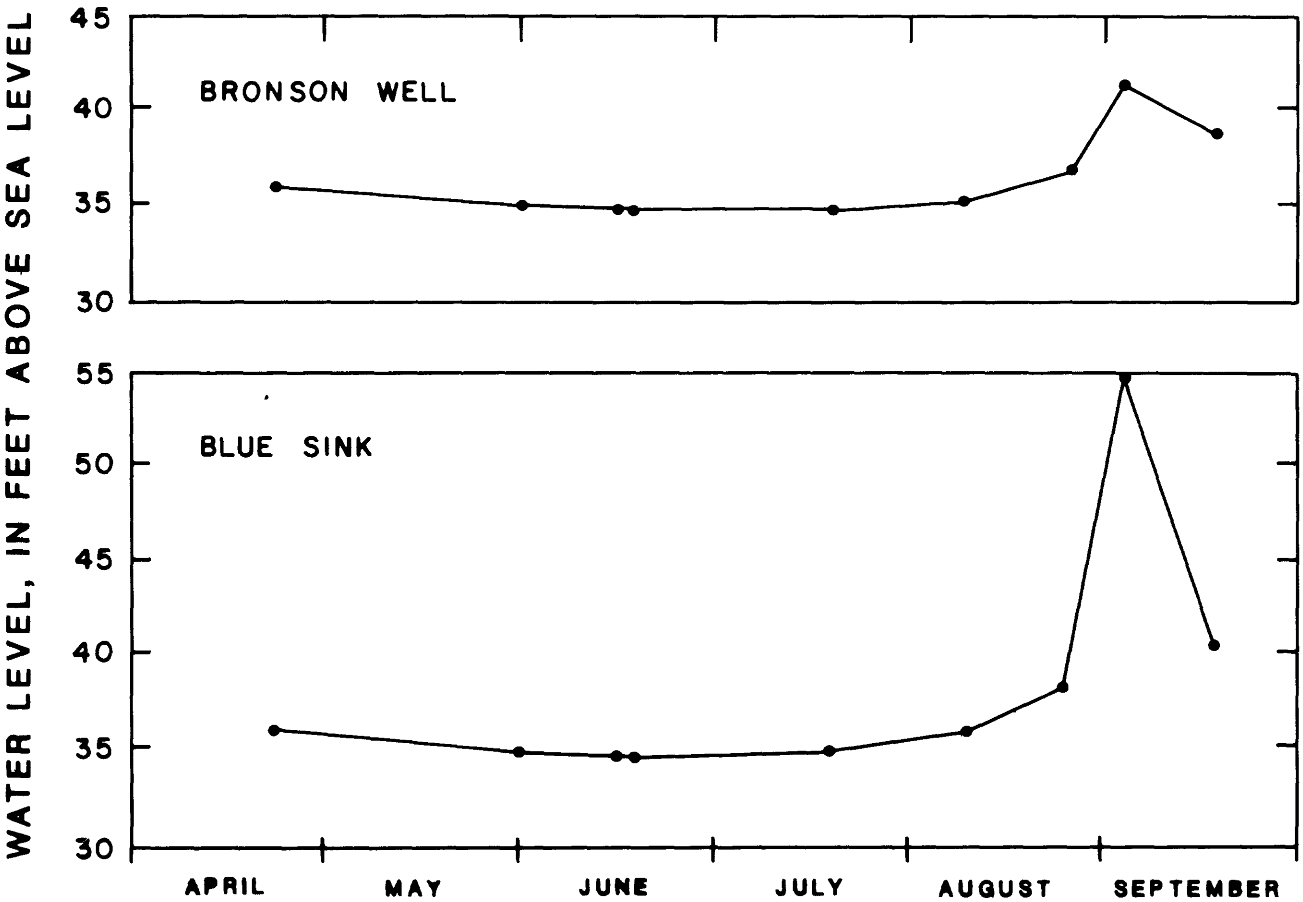

Figure 45.--Water levels of Blue Sink and the Bronson well, April through September 1985.

Table 10.--Water-quality data for Blue Sink

[Concentrations are in milligrams per liter, except as noted. µS/cm--microsiemens per centimeter, µg/L--micrograms per liter, col/100 mL--colonies per 100 milliliters]

Water-quality parameters	5-10-68	5-09-69	5-01-70	5-13-78	5-17-71	8-08-85
Temperature (°C)	24.0	26.0	26.5	25.0	28.0	29.9
Specific conductance (µS/cm)	192	160	135	165	142	120
pH (units)	7.2	7.4	7.0	--	--	7.5
Alkalinity (as $CaSO_3$)	92	71	52	--	--	--
Color (platinum-cobalt units)	--	20	45	--	--	--
Nitrogen (as NO_2+NO_3)	0.80	1.70	0.62	0.09	--	0.03
Nitrogen, ammonia (as N)	--	--	.08	.08	--	.07
Phosphorus (as P)	.24	0.35	.96	.10	--	.62
Total organic carbon	--	--	--	--	7.0	23.0
Chloride (as Cl)	6	8	8	--	--	6
Sulfate (as SO_4)	3	3	1	--	--	<1
Potassium (as K)	--	2.4	2.9	.5	--	.8
Sodium (as Na)	2.8	4.3	4.3	--	--	3.1
Arsenic (µg/L as As)	--	--	--	--	--	<1
Cadmium (µg/L as Cd)	--	--	--	--	--	10
Chromium (µg/L as Cr)	--	--	--	--	--	<10
Copper (µg/L as Cu)	--	--	--	--	--	<10
Iron (µg/L as Fe)	40	20	--	--	--	--
Lead (µg/L as Pb)	--	--	--	--	--	<100
Zinc (µg/L as Zn)	--	--	--	--	--	30
Mercury (µg/L as Hg)	--	--	--	--	--	.7
Total coliform (col/100 mL)	--	--	--	--	--	1,400
Fecal coliform (col/100 mL)	--	--	--	--	--	410
Fecal streptococci (col/100 mL)	--	--	--	--	--	220

Table 10.--Water-quality data for Blue Sink--Continued

Water-quality parameter	5-10-68	5-09-69	5-01-70	5-13-71	5-17-71	8-08-85
Fc:fs ratio	--	--	--	--	--	1.86
Lindane (µg/L)	--	--	--	--	--	<.01
Napthalene, polychlorinated (µg/L)	--	--	--	--	--	<.1
Aldrin (µg/L)	--	--	--	--	--	<.01
Chlordane (µg/L)	--	--	--	--	--	<.1
EDB (µg/L)	--	--	--	--	--	<3.0
DDE (µg/L)	--	--	--	--	--	<.01
DDT (µg/L)	--	--	--	--	--	<.01
Dieldrin (µg/L)	--	--	--	--	--	<.01
Endosulfan (µg/L)	--	--	--	--	--	<.01
Endrin (µg/L)	--	--	--	--	--	<.01
Toxaphene (µg/L)	--	--	--	--	--	1
Heptachlor (µg/L)	--	--	--	--	--	<.01
PCB (µg/L)	--	--	--	--	--	<.1
Heptachlorepoxide (µg/L)	--	--	--	--	--	<.01
Methoxychlor (µg/L)	--	--	--	--	--	<.01
Mirex (µg/L)	--	--	--	--	--	<.01
Silvex (µg/L)	--	--	--	--	--	<.01
2,4-D (µg/L)	--	--	--	--	--	<.01
2,4,5-D (µg/L)	--	--	--	--	--	<.01
2,4-DP (µg/L)	--	--	--	--	--	<.01
Solids, residue at 180°C	105	97	86	--	--	76
Streamflow, instantaneous (ft^3/s)	--	--	--	--	--	3.20

Drainage basin size for the study sites ranges from about 3.5 mi^2 at Curiosity Sink to 138 mi^2 at Crews Lake. At most of the selected sites, drainage is directly into a sinkhole, usually through a stream channel. At Hernasco Sink, drainage is to Crews Lake and then, during periods of high lake stage, to the sinkhole. The Brandon basin contains many sinkholes and other features typical of karst development but differs from the other study sites in that there is no single recharge point. Drainage is to sinkholes and small depressions, or by direct percolation through surficial deposits. Where determined, total volume of water recharged to the Upper Floridan aquifer during the 1-year study period ranged from 1,100 Mgal at Peck Sink to 4,900 Mgal in the Brandon basin.

The hydrogeology varies considerably between the study sites. Blue Sink, Curiosity Sink, and Hernasco Sink are single sinkholes that are open directly to the underlying Upper Floridan aquifer. Peck Sink and Bear Sink not only have at least one sinkhole open directly to the limestone but are complexes of sinkholes, each having varying degrees of hydraulic connection to the aquifer. With the exception of Hernasco Sink, which lies in the lake bottom on the north end of Crews Lake, all the sinkholes are the terminus of temporary streams.

A clay layer, ranging from about 1 foot to 100 feet in thickness, is often discontinuous, or breached by relict sinks in many places at all the sites. The depth to the top of the clay layer ranges from near land surface to more than 150 feet below land surface. Bear Sink and Curiosity Sink have well-developed conduit systems associated with them that allow large volumes of water to move rapidly through the aquifer.

The Bear Sink and Curiosity Sink drainage basins and part of the Crews Lake and Brandon basins contain a permanent surficial aquifer system. The Peck Sink and Blue Sink drainage basins do not contain a permanent or continuous surficial aquifer system. In the Bear Sink basin and where the surficial aquifer system is present in the Crews Lake drainage basin, the head difference between the surficial aquifer system and the Upper Floridan aquifer is very small. Water-level changes parallel one another very closely during the year, which indicates good hydraulic connection between these aquifers. Surficial water levels in the Curiosity Sink drainage basin are at greater depths below land surface in the areas around the sinkhole and along the stream channel than in the remaining part of the basin, indicating an area of recharge to the Upper Floridan aquifer. With the exception of two areas, a permanent surficial aquifer system is present in the Brandon basin. In these two areas, water in the surficial deposits is apparently present only temporarily, indicating possible recharge points to the Upper Floridan aquifer. At all the selected sinkhole sites, water-level changes in the sinkholes closely match water-level changes in nearby wells in the Upper Floridan aquifer. Transmissivity estimates at the selected sites range from 3.7×10^4 ft^2/d to 2.5×10^6 ft^2/d. The lowest estimates are for the Brandon basin, and the highest estimates are for the areas around Peck and Curiosity Sinks where channelized flow occurs through solution conduits.

Though many of the sites are located in rapidly developing, high density areas, the water that recharges the Upper Floridan aquifer is generally of good quality. Some pollutants, however, are entering the aquifer. Higher than normal concentrations of zinc and mercury were detected at Peck Sink and Blue Sink. Toxaphene in excess of maximum allowable limits was also detected at Blue Sink. Samples collected from Valrico Lake in Brandon and from Curiosity Sink contained low levels of 2,4-D. Two landfill sites (presently inactive), in the northern part of the Brandon basin, have been linked to water-quality degradation in a nearby public-supply well and in nearby private domestic wells. Coliform bacteria counts at Valrico Lake indicate a source associated with human domestic wastes, possibly septic tanks. Coliform counts at all other sites indicate that varying degrees of sanitary pollution from man and warm-blooded animals are occurring. Analysis for viral contamination, also an indicator of sanitary pollution, was negative for all sites. This does not indicate that viral contamination has not occurred. Because only one sample was collected from most sites, and because virus tend to travel as a plume, any evidence of contamination could have passed undetected. Frequent sampling after periods of heavy rain is necessary to detect any plume traveling through the basin or into the sinkholes.

Bear Sink is in a large, rapidly developing drainage basin and recharges large quantities of water to the Upper Floridan aquifer. The sink is near the coast where saltwater is relatively close to land surface. Well-developed solution channels appear to recharge runoff very rapidly downward and toward the Gulf of Mexico. As a result, the potential for pollution from this sinkhole is moderate.

In the Curiosity Sink drainage basin, transportation routes lie close to the sink. Because of the small size of the basin, any serious contaminant spills could rapidly drain to the sink during periods of runoff. This may be the greatest threat to the quality of water entering Curiosity Sink. The sink is connected directly to Sulphur Springs through solution cavities that provide rapid movement of water to the springs. Sulphur Springs is a supplementary source of water for the city of Tampa, and serious problems could occur if water were pumped from the springs to the Tampa Reservoir following a major spill or other conditions where pollutants might enter the sink. As a result of the direct connection to a public-supply source, this sinkhole has a high potential for pollution.

The Brandon basin is a large, internally drained basin. As a result, a large volume of water is available for recharge to the Upper Floridan aquifer. This volume of water could provide a means by which pollutants could enter the aquifer, especially in those areas where good hydraulic conductivity is suspected. Surface water, and possibly surficial ground water, has been affected by both sanitary pollution and pollution associated with stormwater runoff. Most of the water used for public supply and domestic needs in the basin is withdrawn from within the basin. Because of the rapid, high density development and the documented ground-water pollution sites, the potential for pollution of the Upper Floridan aquifer in this basin is high.

At present (1985), the water recharging the Upper Floridan aquifer through Hernasco Sink is of relatively good quality. Because development has been relatively slow in the drainage basin and because of the physical setting of the sinkhole within Crews Lake, the present potential for pollution of the Upper Floridan aquifer through this sinkhole is moderate.

To date (1985), the quality of water entering Peck Sink has not caused any known pollution problems. However, the sink serves as a drain for stormwater runoff from the city of Brooksville. Because of rapid runoff times and high recharge capacity, Peck Sink should be considered as having a high potential for pollution of the Upper Floridan aquifer.

Development in the Blue Sink drainage basin has not been as rapid as in other parts of west-central Florida, except for the part of the basin near the city of Brooksville. However, indications of sanitary pollution and pollution associated with stormwater runoff were detected in the sink during a period of inflow. Because flow patterns and time-of-travel in the Upper Floridan aquifer around Blue Sink are unknown and because of the apparent high recharge capacity of the sinkhole, the potential for pollution to reach the aquifer is high.

Recharge rates, flow patterns, time-of-travel, and long-term trends in the quality of recharge water are poorly defined at most of the sites. More intense sampling schedules over a wider range of conditions and further hydrologic investigation will be necessary for future management of the groundwater resources as the basins continue to be developed.

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